APPENDIX 1

MARINE IMPACTS ASSOCIATED WITH THE CONSTRUCTION OF A DESALINATION PLANT IN PERTH'S COASTAL WATERS

Prepared by

DAL Science & Engineering Pty Ltd 2002

MARINE IMPACTS ASSOCIATED WITH THE CONSTRUCTION OF A DESALINATION PLANT IN PERTH'S COASTAL WATERS

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SEPTEMBER 2002

REPORT NO. 02/258/1

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EXECUTIVE SUMMARY

The Water Corporation of Western Australia (Water Corporation) is developing a strategy to increase the supply of potable water to Perth. The strategy includes consideration of the uses of terrestrial sources of water as well as the desalination of seawater.

Originally, four separate sites were considered for the desalination plant of marine water:

1. The Cooperative Bulk Handling (CBH) Jetty at the southern end of Cockburn Sound.
2. The Kwinana Power Station (KPS) site, Cockburn Sound.
3. Woodman Point site at the northern end of Cockburn Sound.
4. The northern end of Comet Bay near Becher Point.

Presently, the sites being considered for the location of the desalination plant are the CBH Jetty and the KPS sites, only.

It is proposed that desalination will be undertaken using reverse osmosis, with an estimated intake to the desalination plant of 250 ML d^{-1}, and an outlet flow of 120 ML d^{-1}, at a salinity higher than receiving waters. Anti-scalant chemicals are added to the process waters. Anticipated intake and outlet characteristics are shown below.

PARAMETER		INTAKE	DISCHARGE
Flow	ML d^{-1}	250	120
	$m^3\ s^{-1}$	2.89	1.85
Physico-Chemical	Salinity	35–37	65
	Temperature (^oC)	17–22	<2 above ambient
Additives	Anti-Scalant (mg L^{-1})	0	6–9

This report considers the potential environmental impacts that may be incurred as a result of the construction and operation of the desalination plant at the CBH Jetty and KPS sites only. Included in this evaluation was numerical modelling used to predict the dilution and dispersion of the discharge of higher density saline waters in the receiving environment.

The environmental impacts that may be incurred during the construction and operation of the desalination plant are:

- Disturbance of the seafloor and associated benthic environment during construction;
- Potential effects of added chemicals, such as anti-scalants;
- Impacts of the intake system on resident marine flora and fauna, such as fish;
- Impacts of subsea structures on processes such as shoreline sediment transport; and
- Potential socio-economic impacts.

The primary potential impact of the project on the marine environment at the proposed sites will be to slightly increase the ambient salinity of the receiving waters. Results of the numerical modelling showed that the desalination discharge via a diffuser will only influence the salinity in the immediate vicinity of the desalination discharge, with changes from ambient salinity to be less than 1 within a radius of 25 m from the discharge point when discharged through a diffuser. Beyond the mixing zone, salinity of marine waters will not be measurably different to background, and the stringent environmental guideline criteria for the region will be met.

The adoption of trigger criteria for salinity introduces a mechanism under which further investigation of environmental impacts will be undertaken if the trigger criteria are exceeded outside the mixing zone. The ANZECC/ARMCANZ (2000) guideline adopted for salinity increase in the environment is that the post-impact median salinity should be below the 80^{th} percentile of background values at the edge of the mixing zone.

Small changes in salinity over a small spatial scale are not in themselves going to be harmful to the marine environment as greater changes in salinity occur over larger areas in the region naturally with temporal variability. Thus, it was concluded that there will be no detrimental impacts on the nearby environment as a result of the increases in salinity expected in receiving waters that will be associated with the desalination operation.

In summary, the proposed marine sites at the CBH Jetty and the KPS were found to be suitable for the construction and operation of the desalination plant without significant impact to the surrounding marine environment. Summary information drawn from the main report has been provided in the table below.

The dilution and dispersion (as calculated by numerical modelling) of anti-scalants and biocides will be such that levels in the receiving environment will not be measurable at the edge of the mixing zone. Disturbances to sediment transport and the seabed will occur during construction of the pipelines. However, these impacts will be removed after construction of the desalination plant has been completed. The potential impact of filtering large volumes of water on pelagic organisms (e.g. fishes) will be minimised by constructing fine-meshed cages around the intake pipe such that the current at the edge of the cage is <1 cm s^{-1}, enabling motile organisms to move away from the intake pipe.

It can be concluded from this information that the desalination plant will have a number of short-term environmental impacts during the construction phase however, these problems can be managed/mitigated to ensure no long-term environmental impacts. In addition, a number of environmental impacts are anticipated from the operation of the desalination plant although the majority of these impacts are minor and will not significantly affect the marine environment at any of the proposed sites.

Proposed marine environmental impacts for each site (with submarine diffuser at discharge point)

ISSUE	CBH	KPS
Disturbance of seabed and associated marine flora and fauna	Some disturbance of the seabed will occur during construction. It is expected the area will be recolonised and ecological function will return post-construction.	Some disturbance of the seabed will occur during construction. It is expected the area will be recolonised and ecological function will return post-construction.
Ambient Mixing Energy	Deep, sheltered embayment; relatively low mixing energy.	Deep, sheltered embayment; relatively low mixing energy.
Increased salinity in receiving waters	Slightly elevated plume (0.4–0.8 above ambient 95% of the time) heading north from the jetty. No resulting environmental impacts expected.	Slightly elevated plume (up to 0.8 above ambient 95% of the time) spreading along the coast from the discharge point. No resulting environmental impacts expected.
Interruption of shoreline sediment transport	No impact on shoreline sediment transport if intake and outlet structures buried under seabed surface.	No impact on shoreline sediment transport if intake and outlet structures buried under seabed surface.
Impact of intake structure on resident fish larvae (and other zooplankton)	Fish screens can be constructed around the intake pipeline such that currents at the surface of the screens are less than 1 cm s^{-1}.	Fish screens can be constructed around the intake pipeline such that currents at the surface of the screens are less than 1 cm s^{-1}.
Effects of added anti-scalants and biocides	No bioaccumulation of anti-scalants/biocides in sediments due to their volatile nature. In combination with the high initial dilution estimated at the diffuser, no acute or chronic toxicological effects on resident biota within the water column.	No bioaccumulation of anti-scalants/biocides due to their volatile nature. In combination with the high initial dilution estimated at the diffuser, no acute or chronic toxicological effects on resident biota within the water column.
Socio-economic	Construction and operation of the desalination plant will take place in a restricted public access zone of Cockburn Sound. Therefore, it is not expected that the public will be impacted by this activity at this site.	Construction and operation of the desalination plant will take place in a restricted public access zone of Cockburn Sound. Therefore, it is not expected that the public will be impacted by this activity at this site.

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1. INTRODUCTION

The Water Corporation is developing a drought emergency response plan to ensure the supply of potable water to Perth during low rainfall periods. The plan includes consideration of the uses of terrestrial sources of water as well as the desalination of seawater. DAL Science and Engineering Pty Ltd (DALSE) was requested to provide appropriate information for inclusion into an assessment of the impacts on the marine environment of the construction and operation of a desalination plant at a select number of sites.

Four separate sites were originally given consideration for hosting the desalination plant:

1. The Cooperative Bulk Handling (CBH) Jetty, south end of Cockburn Sound.
2. The Kwinana Power Station (KPS) site, Cockburn Sound.
3. Woodman Point site, northern end of Cockburn Sound.
4. The northern end of Comet Bay near Becher Point.

DALSE investigated and described the marine environment at each of the sites, and assessed the potential impacts of construction and operational activities on the marine environment at the CBH Jetty and KPS sites – the only two sites currently being considered for placement of the operation. Perceived impacts have been listed, recommendations have been made as to the management and mitigation of potential impacts, and any additional information required to support these recommendations has been identified.

1.1 NATURE OF THE ACTIVITY

The maximum intake at the desalination plant has been set at 250 ML d^{-1}, and the flow at the outlet will be 120 ML d^{-1}, resulting in an effluent discharge salinity of 65[1]. There will be a small increase in temperature ($\pm$ 1°C) at the outlet as a result of the water pumps within the reverse osmosis desalination process.

It is expected that the desalination discharge characteristics will not vary significantly between seasons, and will have the properties as shown in Table 1.

Table 1 Typical characteristics of the desalination plant discharge

PARAMETER		INTAKE	DISCHARGE
Flow	ML d^{-1}	250	120
	$m^3\ s^{-1}$	2.89	1.85
Physico-Chemical	Salinity	35–37	65
	Temperature (°C)	17–22	<2 above ambient
Additives	Anti-Scalant (mg L^{-1})	0	6–9

Within this report, the marine environment in the vicinity of the proposed desalination plant intake and outlet pipelines, and any socio-economic interests associated with the region, have been described for each of the sites: Cooperative Bulk Handling Jetty (Section 2), Kwinana Power Station (Section 3), and Woodman Point (Section 4), Cockburn Sound, and Comet Bay (Section 5). Potential impacts of the desalination plant construction and operation on the marine environment at the CBH Jetty and KPS sites only, are raised and discussed including presentation of the results of the numerical modelling that was undertaken for each of the proposed sites (Section 6).

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[1] Salinity throughout this report is referred to without units according to the Practical Salinity Scale. On this scale salinity is defined as a ratio of conductivities and therefore cannot have units. Seawater typically has a salinity in the range of 34–36.

2. SITE 1: COOPERATIVE BULK HANDLING JETTY, COCKBURN SOUND

2.1 LOCATION

The following description for the Cooperative Bulk Handling (CBH) jetty has been compiled with the understanding that the plant intake and discharge pipelines will be constructed along the existing CBH jetty (Figure 1, Figure 2). Seawater intake and desalination discharge are to be transported via subsurface pipelines to and from the plant. The diffuser is approximately 160 m long, 1 m above the seabed, oriented at 60^{o} to horizontal and located in a water column depth of 10 m.

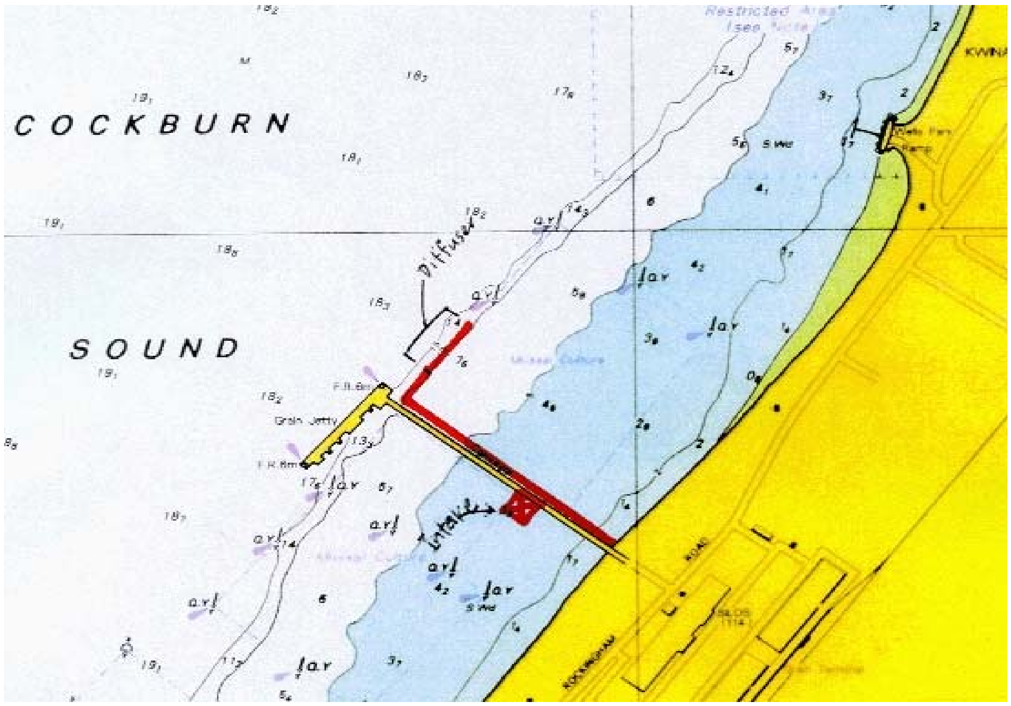

Figure 1 Proposed site location for the desalination plant intake and discharge pipelines in Cockburn Sound from the Cooperative Bulk Handling jetty

Figure 2 Aerial view of the Cooperative Bulk Handling jetty, Cockburn Sound

2.2 COASTAL PROCESSES

2.2.1 Wave Climate

The wave climate of Cockburn Sound is characterised by low wave energy, with winter storms contributing the most significant wave energy. The wave climate is dominated by short period (<8 s) wind waves. Garden Island provides a considerable barrier to incident swell waves, and as little as 5% of the swell wave energy penetrates into southern Cockburn Sound (DEP 1996). However, the degree of shelter is highly dependent on the incident wave direction and the location within Cockburn Sound. At the Cockburn Sound site, the attenuation of the prevailing south-westerly swell is considerably greater than the attenuation of north-westerly waves.

Numerical modelling of wave transformation into Cockburn Sound suggests that 95% of the south-westerly swell energy is attenuated prior to arriving at James Point, while approximately 80% of the north-westerly swell energy is attenuated (JPPL 1998). A non-directional wave recorder has been located at the entrance to Stirling Channel for several years. Data from 1996–1997 indicates that typical summer conditions are dominated by wind waves with a significant wave height and period (height and period of the highest one-third of waves) of <0.7 m and 2–3 s, respectively. During winter storm events the significant wave height approaches 1.25 m and the significant wave period ranges from 2–7 s. Similar conditions are expected at the CBH jetty site.

2.2.2 Beach Stability

Prior to 1953, the coastline near James Point was in a natural state, however, significant shoreline modifications have occurred since this time as a result of industrial growth at Kwinana. Construction of the BP Oil Refinery began in 1953 and these works included a large trestle jetty, a small boat haven, a solid cooling water intake jetty which extended 200 m beyond the shore and a cooling water outlet north of James Point. The cooling water intake jetty intercepted the predominantly southward longshore sediment transport (see below), and from 1963–1973 the beach immediately north of the intake prograded at a rate of approximately 6 m y^{-1}. By the mid-1970s the shoreline progradation to the north of the intake was of sufficient concern to BP that they constructed three breakwaters to north of the cooling water intake.

Examination of aerial photographs indicates that the shoreline immediately north and south of James Point has remained relatively stable. BHP constructed two open jetties to the north of James Point (the northern jetty between 1953 and 1963 and the southern jetty between 1963 and 1973). These jetties have had minimal impact on the shoreline position. Immediately south of James Point, the shoreline has been stabilised by the intake jetty and the BP small boat haven. During the late-1980s/early-1990s a small groyne was constructed south of the boat haven to stabilise the shoreline between the boat haven and the CBH jetty site.

2.2.3 Longshore Sediment Transport

Longshore sediment transport occurs due to the development of a longshore drift by obliquely incident waves. Along the Perth metropolitan coast the longshore transport direction is typically northwards, particularly in summer under the influence of swell and sea breeze generated waves (Masselink 1996). Occasional storms in winter result in southward longshore sediment transport. Along the eastern shore of Cockburn Sound, and particularly in the vicinity of James Point, it appears that combined effects of Garden Island and the causeway results in a net southward longshore sediment transport. The magnitude of southward sediment transport is low (1000-2000 m3 y^{-1} immediately to the north of James Point) and expected to be lower at the CBH jetty site due to the stabilising influence of the small groyne to the north of the CBH jetty site.

2.3 CIRCULATION AND MIXING IN COCKBURN SOUND

Comprehensive reviews of the hydrodynamics of Cockburn Sound are provided by Hearn (1991), D'Adamo (1992) and DEP (1996). These studies examine the hydrodynamics of Cockburn Sound and much of the information is relevant to processes in the vicinity of James Point. An understanding of these processes is important in determining the anticipated level of impact of the brine discharge within Cockburn Sound.

Currents in Cockburn Sound are primarily a result of wind forcing (DEP 1996). The synoptic wind climate of Perth is controlled by the annual variation in the location of the mid-latitude anticyclonic belt. The influence of local-scale effects are also of considerable importance, in particular the diurnal sea breeze cycle which occurs during summer. During summer the winds are typically quite persistent and 50% of winds occur in the 5–9 ms^{-1} range. In winter, winds are more variable with occasional calms and strong storm winds, and 50% of winds have a velocity of 2–7 ms^{-1}. During summer the dominant wind direction is south to south-west, whereas in winter the dominant wind direction is westerly, though northerly winds frequently occur.

The tidal range in the vicinity of Cockburn Sound is between 0.1 and 0.9 m but is typically around 0.5 m and the tides are predominantly diurnal. Sea level is also influenced by the passage of anticyclonic pressure systems, storm surges and other long period forcings, including seiching and continental shelf waves (DEP 1996).

Density effects are important in the main basin of Cockburn Sound (depth ca. 20 m) where lateral density differences can typically be up to 1 kg m^{-3}, and in the absence of strong vertical mixing (typically driven by winds), vertical density differences can be up to 0.5 kgm^{-3}.

Three distinct hydrodynamic regimes have been identified in Cockburn Sound (DEP 1996): 'winter-spring', 'summer' and 'autumn'.

During the winter-spring period, the dynamics of the Sound are strongly influenced by the passage of storm systems and buoyant discharge from the Swan River. Using available wind data, D'Adamo (1992) suggested that vertical stratification could occur in the deep central basin 85% of the time during the 'winter-spring' period. During the winter storm events the wind magnitudes are sufficient to fully mix the water column in the main basin of Cockburn Sound. During the winter, water temperatures in Cockburn Sound are typically around 16–18^{o}C and salinities are around 34–35 (DEP 1996).

During summer, wind is the dominant mechanism governing circulation within Cockburn Sound and waters are generally well mixed and the net flow direction in the Sound is northwards. Modelling of Cockburn Sound indicated that the strongest wind driven currents occur on the shallow bank immediately offshore of James Point (DEP 1996). During the summer, water temperatures in Cockburn Sound are typically around 23–25^{o}C and salinities are around 36–37 (DEP 1996).

During the autumn period the waters are less well mixed vertically due to the reduced energy input from winds. During this period the waters of Cockburn Sound are typically denser than the adjacent coastal waters and are therefore confined by the presence of bathymetric barriers.

In the vicinity of the CBH jetty site, the net drift is northward during summer in response to south to south-westerly winds that prevail. Current velocities are up to 0.2 ms^{-1} during average conditions. During winter, and periods of calm the current velocities drop to below 0.1 $m\,s^{-1}$. The shallow inshore region (depth < 10 m) is expected to have strong depth-averaged wind-driven flows however, the increased influence of bottom friction would result in a relatively rapid reduction in flows after the onset of calm conditions (Hearn 1991).

2.4 WATER QUALITY

Average water temperature in the Sound varies from about 16^{o}C in winter to 24^{o}C in summer (the shallows are 2–3^{o}C cooler in winter and 2–3^{o}C warmer in summer). Water salinity varies slightly from that of the open ocean (approximately 35), typically declining to about 34 in winter (due to outflow from the Swan River) and reaching 36 in autumn (due to evaporation during the summer months).

The waters of the Sound are generally well oxygenated, although if calm weather persists for more than a week the deep waters at the southern end of the Sound may become low in oxygen, as a result of increased sediment oxygen demand. Oxygen levels in the bottom waters may become so low at times that nutrient pulses from the sediments to the water column increases.

To date, water quality monitoring in Cockburn Sound has focussed on nutrients and nutrient-related effects (e.g. increases in phytoplankton/chlorophyll *a* concentrations). Monitoring of contaminants (e.g. metals, pesticides) in water is not conducted routinely, as levels are generally too low to detect. Sediments accumulate contaminants and so are a better means of detecting long-term, low-level inputs.

2.5 SEDIMENT QUALITY

Shallow areas of Cockburn Sound have sandy sediments, while the deeper areas accumulate fine organic particles (e.g. dead plankton, faecal material), and so are naturally more organically enriched and finer. The proportion of fine particles (the silt and clay fractions) influence the amount of naturally present metals: the more silt/clay, the higher contaminant levels.

Levels of contaminants in sediments surveyed near the CBH jetty are shown in Table 2. The information was collected in a sediment survey conducted by D.A. Lord & Associates Pty Ltd in 1999 (DAL 2000).

Table 2 Sediment contaminant levels recorded in a 1999 sediment survey (DAL 2000) near the CBH jetty; interim sediment quality guideline (SQG) low values provided

CONTAMINANT	1999	SQG-LOW
Arsenic	3.8	20
Cadmium	0.32	1.5
Chromium	27.0	80
Copper	12.0	65
Mercury	0.12	0.15
Nickel	12.0	21
Lead	11.0	50
Zinc	35.0	200
Tributyltin	<1	5

NOTE: all data in ppm; ppm of TBT present as tin.

The survey results show that contaminant concentrations at the CBH jetty were well below the national sediment quality low guidelines (SQG-low) for the protection of marine ecosystems (ANZECC/ARMCANZ 2000). The SQGs are largely based on guidelines originally developed by Long and Morgan (1991) and subsequently refined by Long *et al*. (1995), from data on estuarine and coastal sediments in the USA. Long and his co-workers derived an effects range low (ERL; 10th percentile of effects range data) and effects range median (ERM; 50th percentile of effects range data) value for each contaminant. The SQG lows equate to ERLs, values below which toxicity effects are highly unlikely.

2.6 MARINE FLORA

The marine flora of Cockburn Sound includes seagrasses, seagrass epiphytes, macroalgae and phytoplankton. The distributions of seagrass, sand, reef and silt habitats were accurately mapped in 1999 (DAL *et al.* 2000) (Table 3).

Table 3 Areas of main habitat types in Cockburn Sound (DAL et al. 2000)

BENTHIC HABITAT	AREA (ha)	AREA (%)
Silt	6,940	60
Fine sand and silt	2	<1
Sand (including sparse seagrass)	3,725	32
Seagrass	750	7
Subtidal reef	68	<1

2.6.1 Seagrasses

Extensive seagrass cover has been recorded along the eastern margin of Garden Island, and along the western margin of the shallow eastern flats of Cockburn Sound. These seagrass meadows include the species *Posidonia australis* and *P. sinuosa*. No seagrass cover was recorded along the south east margin of Cockburn Sound near the CBH jetty.

2.6.2 Reefs

There are patches of reef along the eastern shore of the Sound between Challenger Beach and the Jervoise Bay northern harbour, and isolated hummocks on the eastern flats, mainly along the western fringe. The shoreline reefs carry mainly brown algae (kelps and *Sargassum*) while on the reefs further offshore red algae are more common. Green algae (*Ulva, Cladophora*) are also common, and some of the reefs have patches of coral, including the reef-building species *Flavites* (HGM 1997). There are also macroalgae on small patches of reef in the Sound, while an unknown amount of drift algae from reefs outside the Sound enters via tidal currents through the Causeway, and via north-west storms at the north end of the Sound, and accumulates in the deep basin.

2.6.3 Phytoplankton

The species of phytoplankton present in Cockburn Sound were studied in 1978 by Chaney (1978), and between 1992 and 1994 as part of the SMCWS (Helleren and John 1995). There are over 300 species present in the Sound, the four main groups being diatoms (Bacillariophyta), dinoflagellates (Dinophyta), silicoflagellates (Chrysophyta) and blue-green algae (Cyanophyta).

Quantitative estimates of phytoplankton assemblages within Cockburn Sound have been regularly measured as concentration of chlorophyll *a* in the water. Chlorophyll *a* concentrations have been found to be highest in the summer months, with median values between 0.7 and 2.1 $\mu g\ L^{-1}$ recorded between 1978 and 2001.

2.7 MARINE FAUNA

2.7.1 Benthic Infauna

The benthic invertebrate fauna of the deep basin have been studied in 1978 (as part of the 1976–79 Cockburn Sound Environmental Study) and 1993 (as part of the SMCWS). The deep basins of Cockburn Sound, Warnbro Sound and Owen Anchorage contain fine organic-rich silts due to accumulation of detritus from surrounding areas, and have species of flora (Wilson, Kendrick et al. 1978).

The 1993 survey of benthic invertebrates found that more species were present, and in greater numbers, in the northern half of the Sound compared to the southern half. More species were found in the northern half of the Sound in 1993 compared to 1978, yet the reverse was found for the southern half of the Sound. In 1993, the bivalve *Solemya*—which prefers low oxygen conditions—was also found in the southern half of the Sound.

Two acknowledged marine pests have also been found in the benthic fauna of Cockburn Sound: the European fan worm *Sabella* cf. *Spallanzanii*, and the Asian date mussel *Musculista senhousia*.

2.7.2 Fish

Dybdahl (1979) estimated that there were about 130 species of fish and 14 large crustacean and mollusc species in Cockburn Sound. Fisheries WA[2] have provided the following list that indicates (but is not limited to) the commercially/recreationally important species known to frequent various habitats in the Sound:

- Open (deep) water. Snapper, pilchards, bonito (also dolphins, seals and penguins);
- Shallow water with sandy seabed. Whiting, juvenile King prawns, anchovies, blue sprat, and whitebait;
- Seagrass meadows. Leatherjackets, wrasse, crabs, herring; and
- Jetties and groynes. Herring, yellow tail, scad, trevally, sampson fish, mussels.

Earlier work by Penn (1977) also suggests that the deep basin is an important habitat for whiting, squid, cuttlefish, butterfish, sampson fish, sand skipjack, crabs and snapper.

There is a lack of detailed studies on fish nursery areas within the Sound. Larval fish communities in seagrass meadows were studied as part of the SMCWS (Jonker 1993), but there is little information on other habitats. It was found that meadows in Mangles Bay had similar species but significantly greater numbers of larvae than meadows off eastern Garden Island. This was attributed to greater food supply (i.e. higher phytoplankton levels), increased shelter due to the higher epiphyte loads, and greater retention of larvae due to the calmer waters of Mangles Bay compared to the Garden island site.

Although there is little information on fish nursery areas within the Sound, the breeding success of the species listed above would be affected by adverse impacts on their feeding grounds. The opinion of Fisheries WA is that both feeding areas and nursery areas are important in affecting fish populations, and that the whole of Cockburn Sound is significant as a fish nursery/habitat.

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[2] Provided by Eve Bunbury, Fisheries WA, after discussions with Fisheries WA personnel.

2.7.3 Zooplankton

Zooplankton in Cockburn and Warnbro Sounds were studied from 1992 to 1994 as part of the SMCWS, and were found to be typical of temperate coastal regions, apart from large blooms of radiolarians during late winter and early spring (DEP 1996). Zooplankton in Cockburn Sound from 1992 to 1994 were about twice as abundant as zooplankton in Warnbro Sound, presumably in response to the greater food supply (phytoplankton).

2.7.4 Marine Mammals, Reptiles and Seabirds

A resident population of bottlenose dolphins (*Tursiops sp.*) lives in Cockburn Sound, and has become a popular tourist attraction. About 180 animals have been identified as using Cockburn Sound, and approximately a quarter of these are adult females with calves, which is unusually high for dolphin populations (Donaldson[3], unpublished data).

Loggerhead, Leatherback and Green turtles sometimes stray as far south as Cockburn Sound, but this is rare.

At least 12 species of seabirds are found in the Cockburn Sound/Warnbro Sound area, but as the eastern shores of Cockburn Sound are heavily developed, they are of far lesser importance as a nesting, feeding and roosting area than the Shoalwater Islands Marine Park and Garden Island.

A small colony of Little Penguins *Eudyptula minor* (maximum 50 adults) has been established in limestone walling at Careening Bay since at least 1986. Regular migratory birds utilising Cockburn Sound include the Fairy Tern *Sterna nereis* and the Bar-tailed Godwit *Limosa lapponica*. Migratory birds that may utilise Cockburn Sound on a transitory basis include the Great Egret *Egretta alba*, the Eastern Reef Egret *Egretta sacra*, White-bellied Sea Eagle *Haliaeetus leucogaster*, the Ruddy Turnstone *Arenaria interpres*, the Caspian Tern *Sterna caspia* and the Crested Tern *Sterna bergii*. Young Australasian gannets also tend to feed in the Sound until mature and then return to New Zealand (Bob Goodall *pers. com*.).

2.8 SOCIO-ECONOMIC USES

2.8.1 Social and Cultural

Cockburn Sound is an extremely popular area for social uses including:

- Recreational fishing;
- Water sports (swimming, boating, yachting, diving, windsurfing, skiing); and
- Coastal use (beach activities, use of boat ramps).

In addition, Cockburn Sound is important for aesthetics and heritage, which are not so much social uses as values that are held.

In the waters adjacent to the CBH Jetty specifically, recorded social uses include water skiing, recreational fishing, beach access and boat launching facilities (DAL 2001c).

[3] Rebecca Donaldson, Ph. D. researcher at the School of Biological Sciences, Murdoch University.

2.8.2 Fisheries and Aquaculture

There are three main commercial fisheries in the Cockburn Sound region: crabbing, beach bait fish netting and wild catch mussel harvesting. Crabbing is the largest commercial fishery in Cockburn Sound and catches have been growing since the late 1970's. The beach bait fish netting principally targets three species of bait fish: pilchards (*Sardinops sagax neopilchardus*), anchovies (*Engraulis australis fraseri*) and white bait (*Hyperlophus vittatus*). At present, there are two commercial mussel farms located in the vicinity of the CBH jetty (Figure 3). In addition to the mussel aquaculture farms, there are three wild catch commercial licences for the collection of mussels (*Mytilus edulis*) within Cockburn Sound.

Figure 3 Aerial view of the mussel farms around the Cooperative Bulk Handling jetty, Cockburn Sound

2.8.3 Other Industrial Activity

There are two industrial process water outlets in the vicinity of the proposed Water Corporation desalination discharge outlet: the TiWest outlet and the CSBP outlet. Characteristics of the process waters from these outlets are provided in Table 4. The effluent at both outfalls is less dense than receiving water densities and form buoyant plumes, unlike the desalination effluent plume that will be denser than receiving waters and will sink toward the seafloor.

Table 4 Characteristics of TiWest and CSBP process water effluent

PARAMETER	TiWEST	CSBP
Flow Rate ($m^3 s^{-1}$)	0.07	0.579
Effluent Density (kg m^{-3})	1,013	1,021
Ambient Density (kg m^{-3})	1,025.5	1,025.5

Source: DAL 2001

3. SITE 2: KWINANA POWER STATION, COCKBURN SOUND

3.1 LOCATION

The following description for the Kwinana Power Station (KPS), Cockburn Sound has been compiled with the understanding that the plant intake pipelines will be new constructions with end points as indicated in Figure 4. The desalination discharge pipelines will either utilise the existing discharge pipeline presently operational at the KPS (Figure 4), or will be a new subsea pipeline constructed in the region with a terminal diffuser.

Figure 4 Aerial view of the intake and outlet structures at the Kwinana Power Station, Cockburn Sound

3.2 COASTAL PROCESSES

3.2.1 Wave Climate

The wave climate in Cockburn Sound is dominated by short period (<8s), wind generated waves. Garden Island provides a barrier to incident swell waves from the south-west, and as little as 5% of the swell energy penetrates to southern Cockburn Sound (DEP 1996). However, the degree of shelter is dependent on the incident wave direction and location within Cockburn Sound. The gap between Carnac Island and Garden Island allows some west and north-west swell to reach the KPS while the Southern Flats and the Causeway combine to impede most south-west swell. Numerical modelling of the transformation of wave energy into Cockburn Sound suggests that 95% of south-west swell energy is attenuated prior to arriving at the coastline near the KPS, while approximately 80% of north-west swell energy is attenuated (DAL 1998).

3.2.2 Beach Stability and Longshore Sediment Transport

The beaches in this region are narrow and there is historical evidence to suggest that significant erosion can occur, causing loss of beaches.

Analysis of aerial photographs between 1973 and 1999 has shown that there is relatively large seasonal sedimentation around the KPS intake and outfall infrastructure with net sediment transport to the south. During conditions when northward transport is dominant (summer months) the sedimentation is to the north of the outfalls and intakes and to the south of this infrastructure during the winter months.

An analysis of sediment movement in the region was recently undertaken. The modelling suggested that southerly sediment transport rates were 25,000–32,000 $m^3 y^{-1}$ in the region of the KPS. This range represents estimates for a range of year types (calm, typical, energetic).

Significant sedimentation around the KPS intake and outlet infrastructure occurs due to the cooling water discharge canals forcing offshore movement of sand travelling alongshore. As the longshore current moves offshore into relatively deeper water beyond the wave breaking and swash zone, wave action is unable to keep the sediment load suspended. The sediment load in the offshore region is deposited until the depth is shallow enough for wave action to keep the sediment load suspended.

3.3 CIRCULATION AND MIXING IN COCKBURN SOUND

In the vicinity of the KPS, the net water movement is northward during summer in response to the prevailing south to south-westerly winds. Current velocities range up to 0.2 $m s^{-1}$ under average conditions and are strongest offshore. During winter, and periods of calm the current velocities drop to below 0.1 $m s^{-1}$. The shallow inshore region is expected to have strong depth-averaged wind-driven flows however, the increased influence of bottom friction would result in relatively rapid reduction in flows after the onset of calm conditions (Hearn 1991). These decay times are estimated to be around 12–24 hours and are an important consideration when assessing circulatory response due to the onset of calm conditions.

3.4 WATER QUALITY

A detailed description of water quality in Cockburn Sound can be found in Section 2.4 that is also applicable to the KPS site.

3.5 SEDIMENT QUALITY

Levels of contaminants in sediments surveyed in the vicinity of the KPS are shown in Table 5. The information was collected in a sediment survey conducted by Burt *et al.* in 1994 (1995).

Table 5 Sediment contaminant levels recorded in a 1994 sediment survey (Burt et al., 1995) near the Kwinana Power Station; interim sediment quality guideline low values provided

CONTAMINANT	1995	SQG-LOW
Arsenic	74.0	20
Cadmium	0.3	1.5
Chromium	11.0	80
Copper	7.1	65
Mercury	0.05	0.15
Nickel	5.6	21
Lead	11.0	50
Zinc	16.0	200
Tributyltin	83.0	5

NOTE: all data in ppm; ppm of TBT present as tin.

The survey results show that contaminant concentrations near the KPS were well below the national sediment quality low guidelines (SQG-low) for the protection of marine ecosystems (ANZECC/ARMCANZ 2000), with the exception of arsenic and tributyltin. As the survey was conducted close to a neighbouring jetty, it is possible elevated levels of these contaminants in this area are due to the associated shipping activity.

3.6 MARINE FLORA

3.6.1 Seagrasses

No seagrass cover has recently been observed along the eastern margin of Cockburn Sound near the KPS. The region in the vicinity of the KPS used to support extensive seagrass meadows until the early 1970s.

3.6.2 Reefs

There are no exposed patches of pavement or low relief reef in waters adjacent to the KPS.

3.6.3 Phytoplankton

A detailed description of phytoplankton assemblages in Cockburn Sound can be found in Section 2.6.3 that is also applicable to the KPS site.

3.7 MARINE FAUNA

3.7.1 Benthic Infauna

A detailed description of the benthic infaunal assemblages of Cockburn Sound can be found in Section 2.7.1 that is also applicable to the KPS site.

3.7.2 Fish

A detailed description of the fish assemblages in Cockburn Sound can be found in Section 2.7.2 that is also applicable to the KPS site.

3.7.3 Zooplankton

A detailed description of the zooplankton assemblages in Cockburn Sound can be found in Section 2.7.3 that is also applicable to the KPS site.

3.7.4 Marine Mammals, Reptiles and Seabirds

A detailed description of other marine fauna residing in or utilising Cockburn Sound can be found in Section 2.7.4 that is also applicable to the KPS site.

3.8 SOCIO-ECONOMIC USES

3.8.1 Social and Cultural

Cockburn Sound is an extremely popular area for social uses, which include:

- Recreational fishing;
- Water sports (swimming, boating, yachting, diving, windsurfing, skiing); and
- Coastal use (beach activities, use of boat ramps).

In addition, Cockburn Sound is important for aesthetics and heritage, which are not so much social uses as values that are held.

The waters surrounding the KPS are encompassed by an industrial exclusion zone, precluding recreational use of the region (DAL 2001c).

3.8.2 Fisheries and Aquaculture

A detailed description of fisheries and aquaculture activity within Cockburn Sound can be found in Section 2.8.2 that is also applicable to the KPS site.

3.8.3 KPS's Industrial Activity

The KPS is a 'mid-merit' power station supplying electricity to the Perth metropolitan area during shoulder demand periods, thus augmenting base load supply from the Muja and Collie power plants. Because the KPS supplies electricity according to demand on the grid, demand for cooling waters abstracted from nearshore marine waters, and return water discharge back to Cockburn Sound, also varies.

There are two separate intake pipelines, and two discharge pipes. The discharge pipes are separated by approximately 100 m, and warm return cooling waters are discharged to nearshore surface waters. Characteristics of the cooling waters from the KPS are provided in Table 6. The discharged waters are warm and therefore positively buoyant, unlike the desalination effluent plume that will be denser than receiving waters and will sink toward the seafloor.

Table 6 Characteristics of the Kwinana Power Station (KPS) discharged cooling waters

PARAMETER	KPS
Peak Flow Rate ($m^3 s^{-1}$)	17–19
Peak Temperature (^oC) above Receiving Waters	7.5–8.5
Effluent Density ($kg m^{-3}$)	1023*
Ambient Density ($kg m^{-3}$)	1025.5

**Density of the effluent is dependant on the temperature – warm effluent will be less dense.*
Source: DAL (2001)

4. SITE 3: WOODMAN POINT

4.1 LOCATION

The following description for Woodman Point, Cockburn Sound has been compiled with the understanding that the plant intake and discharge pipelines have been proposed for construction at the south-western end of the Point (Figure 5). However, final routing of the pipelines will be confirmed following groundtruthing of seagrass habitat in the region, if necessary.

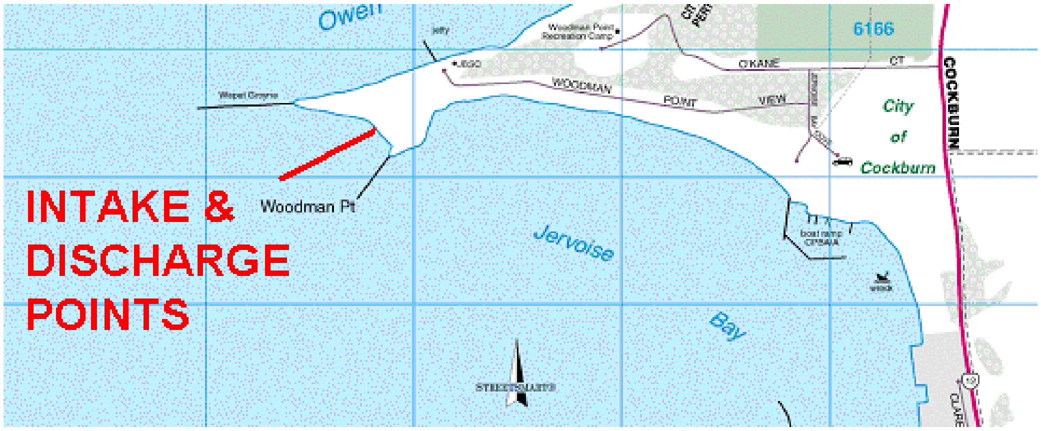


Figure 5 Proposed site location for the desalination plant intake and discharge pipelines at Woodman Point, Cockburn Sound

Figure 6 Aerial view of Woodman Point, Cockburn Sound

4.2 COASTAL PROCESSES

4.2.1 Wave Climate

The wave climate in the Owen Anchorage area (adjacent to the north of Cockburn Sound) is less energetic than offshore conditions. To reach Owen Anchorage, offshore waves must pass through the reefs and islands of the Garden Island Ridge, where they are considerably diminished by the effects of turbulence, reflection, refraction and diffraction. For example, offshore waves of 4–5 m in height are reduced to about 1.5–2 m by the time they reach the western portion of Owen Anchorage. The reduction in wave energy is even greater in adjacent Cockburn Sound, which is protected along its entire western side by Garden Island.

Swell energy is focussed by the effects of refraction onto Success and Parmelia Banks, located in Owen Anchorage (MRA 1997). Swell energy arrives from two distinct directions: the north to north-west and the west to south-west (MRA 1997). The resultant waves that are focussed on the Banks have a strong influence on the movement of sand along the Banks and towards the shore at Catherine and Woodman Points.

4.2.2 Beach Stability

Woodman Point is a sedimentary salient which has formed at the point of shore attachment of Parmelia Bank (which itself is an unconsolidated sediment body extending westward to Carnac Island). Woodman Point has formed through the development of a beach ridge plain and has a pronounced and extended morphology. The shape of Woodman Point effectively separates the nearshore sediment cells of Owen Anchorage and Cockburn Sound. This effect has been further enhanced by significant modifications, including the naval seawall and groyne (constructed in 1913 to 1918) and the Western Australian Petroleum (WAPET) groyne which extends westward from Woodman Point and was constructed in 1967 for the purposes of exploration drilling.

Examination of historical aerial photography from 1942, 1976, 1980, 1987 and 1994 shows the area of Woodman Point has generally accreted over this period (MRA 1995). The shoreline between the WAPET and Woodman Point groynes has demonstrated a very rapid accretion of approximately 7 m y^{-1} between 1976 and 1994. The shoreline of Woodman Point immediately south of the Cockburn Cement washplant has remained relatively stable during the period from 1942 to 1994. Between this point and the Cockburn Power Boat Club the shoreline of Woodman Point has accreted between 1942 and 1994 at an average rate of approximately 1 m y^{-1}.

It is considered that the accretionary trend at Woodman Point is largely due to the onshore movement of sediment from Parmelia Bank, which has been estimated to be in the order of 20,000 m^3 y^{-1} (MRA 1995).

4.2.3 Longshore Sediment Transport

The southern flank of Woodman Point is well sheltered from the effects of swell wave energy; however, this area will experience significant wind wave energy, particularly during southerly seabreezes which predominant in summer. The presence of series of groynes and breakwaters in this area has significantly reduced the potential for large volumes of longshore sediment transport. The net longshore sediment transport along this shoreline has been estimated to be relatively minor (less than 1,000 m^3 y^{-1}) and directed in an easterly direction (MRA 1995).

4.3 CIRCULATION AND MIXING IN COCKBURN SOUND

Regionally, nearshore currents generally run parallel to shore, but are modified by local bathymetry. The currents in the Owen Anchorage area are dominated by wind-driven circulation and, to a lesser extent, astronomical tides, density gradient effects and continental shelf influences (CCL 1994). The dominance of southerly winds in the area generally results in northerly flowing currents; however, periods of reversal may occur during winter storm events, which typically arrive from the north-west

(CCL 1994). Estimated speed ranges of the currents in Owen Anchorage and in the vicinity of the shipping channels are shown in Table 7.

Table 7 Estimated ranges of current speeds in Owen Anchorage

TYPE OF CURRENT	CURRENT SPEEDS (cm s^{-1})	
	TYPICAL	STRONG
Wind driven	0–20	35
Astronomical tide	0–2	3
Density effects	0–5	10
Continental Shelf	0–5	5

As can be seen in Table 7, the wind driven currents are usually of speeds less than 35 cm s^{-1}. The magnitude of these nearshore currents is such that they have a minor effect on the movement of sand on the Banks and adjacent beaches, except when acting in concert with waves.

4.4 WATER QUALITY

A detailed description of water quality in Cockburn Sound can be found in Section 2.4 that is also applicable to the Woodman Point site.

4.5 SEDIMENT QUALITY

Levels of contaminants in sediments surveyed in the vicinity of the proposed Woodman Point site are shown in Table 5. The information was collected in a sediment survey conducted by Burt *et al.* in 1994 (1995).

Table 8 Sediment contaminant levels recorded in a 1994 sediment survey (Burt et al., 1995) near the Woodman Point proposed site; interim sediment quality guideline low values provided

CONTAMINANT	1995	SQG-LOW
Arsenic	12.0	20
Cadmium	<0.2	1.5
Chromium	33.0	80
Copper	2.0	65
Mercury	0.56	0.15
Nickel	3.1	21
Lead	5.4	50
Zinc	7.8	200
Tributyltin	53.7	5

NOTE: all data in ppm; ppm of TBT present as tin.

The survey results show that contaminant concentrations near the proposed Woodman Point site were well below the national sediment quality low guidelines when surveyed, with the exception of mercury and tributyltin. As the survey was conducted within the deep basin of Cockburn Sound, it is possible that the elevated levels of these contaminants were due to the accumulation of fine sediments in this region, with high associated contaminant levels.

4.6 MARINE FLORA

4.6.1 Seagrasses

Extensive seagrass cover has been observed in shallow waters (approximately 2–5 m) around Woodman Point (Figure 7). A study to the north of the Point found dense meadows dominated by *Posidonia angustifolia*. Seagrass mapping of Owen Anchorage and Cockburn Sound (DAL *et al.* 2000) identified the seagrass cover to the south of Woodman Point as *P. australis/P. sinuosa* mixed assemblage.

Figure 7 The dark patches in waters to the north and the south of Woodman Point are seagrass meadows

4.6.2 Reefs

There are no platform or pavement reefs in the vicinity of the proposed activity. However, there are patches of reef along the shoreline, and along the western fringe of the eastern flats, both located to the east of the site.

4.6.3 Phytoplankton

A detailed description of phytoplankton assemblages in Cockburn Sound can be found in Section 2.6.3 that is also applicable to the Woodman Point site.

4.7 MARINE FAUNA

4.7.1 Benthic Infauna

A detailed description of the benthic infaunal assemblages of Cockburn Sound can be found in Section 2.7.1 that is also applicable to the Woodman Point site.

4.7.2 Fish

A detailed description of the fish assemblages in Cockburn Sound can be found in Section 2.7.2 that is also applicable to the Woodman Point site.

4.7.3 Zooplankton

A detailed description of the zooplankton assemblages in Cockburn Sound can be found in Section 2.7.3 that is also applicable to the Woodman Point site.

4.7.4 Marine Mammals, Reptiles and Seabirds

A detailed description of other marine fauna residing in or utilising Cockburn Sound can be found in Section 2.7.4 that is also applicable to the Woodman Point site.

4.8 SOCIO-ECONOMIC USES

4.8.1 Social and Cultural

Cockburn Sound is an extremely popular area for social uses, which include:

- Recreational fishing;
- Water sports (swimming, boating, yachting, diving, windsurfing, skiing); and
- Coastal use (beach activities, use of boat ramps).

In addition, Cockburn Sound is important for aesthetics and heritage, which are not so much social uses as values that are held.

The waters adjacent to Woodman Point are used by the public for recreational fishing and scuba diving. In addition, a ship wreck site is located to the north of the point (DAL 2001c).

4.8.2 Fisheries and Aquaculture

A detailed description of fisheries and aquaculture activity within Cockburn Sound can be found in Section 2.8.2 that is also applicable to the Woodman Point site.

4.8.3 Other Industrial Activity

Cockburn Cement Limited manufactures cement and lime at its works in Munster. After dredging shellsand from Parmelia and Success Banks in Owen Anchorage, the shellsand is then dumped and retrieved at a facility located on the northern side of Woodman Point, before being transported to the nearby washplant. This activity results in some turbidity in the nearshore marine waters on the northern side of the Point, however, little turbidity extends around the Point to the southern side where the proposed desalination intake pipelines are to be located.

The Water Corporation has an emergency wastewater outlet that extends 1.8 km southwest from Woodman Point. The emergency outlet is necessary in the event of a power failure. In such an event, secondary treated wastewater would be discharged from the pipeline into the deep basin of Cockburn Sound. Being freshwater, the effluent would form a buoyant plume under such circumstances. Given the desalination intake pipelines would be at the seabed in shallower waters, it is not expected that in the event of an emergency overflow, the resultant effluent plume would influence intake water quality for the desalination plant.

5. SITE 4: COMET BAY

5.1 LOCATION

The following description for site 4 has been compiled with the understanding that the plant intake and discharge pipelines would be constructed in the deeper basin of the region (Figure 8). As for previous sites, seawater intake and desalination discharges would be transported via subsurface pipelines. The diffuser design is approximately 160 m long, 1 m above the seabed, oriented at 60° to horizontal and located in a water column depth of 8 m.

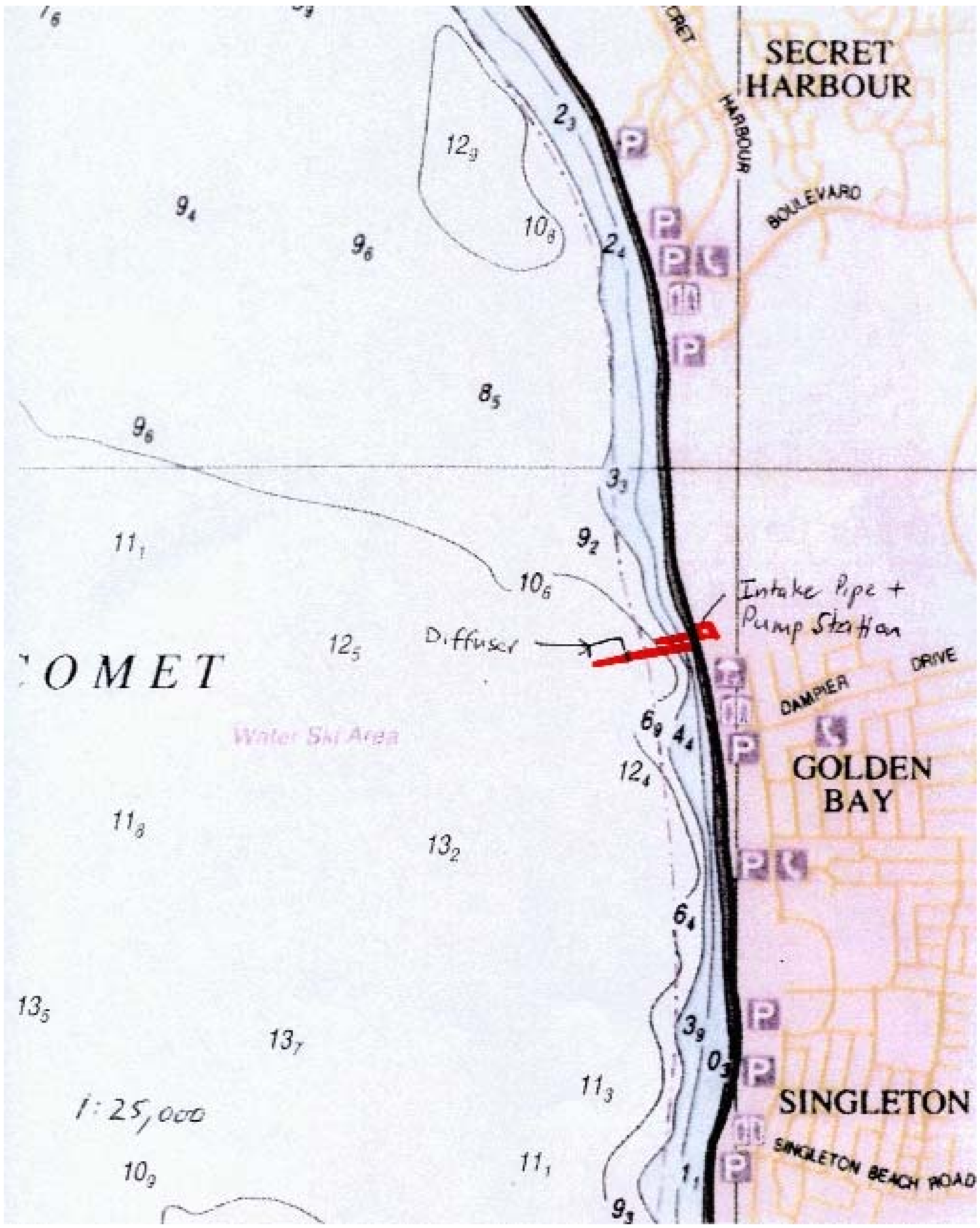


Figure 8 Proposed site location for the desalination plant intake and discharge pipelines in Comet Bay

5.2 COASTAL PROCESSES

5.2.1 Wave Climate

Comet Bay experiences a higher wave climate than that of Cockburn Sound due to gaps in the Murray Reefs which allow swell waves through in places.

One year of wave measurements were undertaken in Comet Bay between the 18th of June 1979 and the 31st of July 1980. The measurements were made with a wave rider buoy moored approximately 2,000 m off Secret Harbour (HGM 1979a). A 17 minute sample of wave data (period and amplitude) was transmitted from the buoy every 4 hours. The wave rider buoy was not equipped to provide information on wave direction. Although the wave measurement site was further south than the proposed brine discharge point, the wave climatology is representative of what may be expected 3 to 5 km north of Secret Harbour.

The wave climate is defined by the distribution of measured wave heights and periods. Statistical analyses of the data were undertaken to determine the wave climate. A summary of the results is shown in Figure 9 which also compares wave climate in Comet Bay with other sites along the metropolitan coastline.

The comparison shows that the wave climate offshore from Secret Harbour and along the coastline of Comet Bay is not as severe as the open ocean conditions offshore from Garden Island due to the protection afforded by the Murray Reef system.

5.2.2 Cross shore Sediment Transport

Cross-shore sediment transport occurs due to changing water levels, wave conditions and other nearshore hydrodynamic forces. In terms of net annual sediment transport on stable coastlines, cross shore transport is often negligible.

Erosion along the metropolitan coastline is often the result of winter storms moving sediment offshore due to a combination of larger waves and higher water levels acting over a greater proportion of the shoreline. Outside storm periods, the beach recovers from its eroded state by moving sediments shorewards and acting to restore the beach.

5.2.3 Beach Stability

Becher Point located on the northern boundary of Comet Bay, is a dynamic and actively changing coastal landform with a steadily eroding and retreating south western shoreline and a prograding northerly shoreline. Its present morphology is the product of the offshore energy regime and the way this is influenced by offshore features, particularly the limestone reefs. Much of the sediment movement north of Becher Point is deposited on the shallow sand banks adjacent to Warnbro Sound (CALM 1995).

Beach stability analyses were undertaken as part of the Environmental Review and Management Plan for Secret Harbour (HGM 1979b). Shorelines were mapped between 1924 and 1979 for the years 1924, 1942, 1955, 1965 and 1979. The shoreline plots showed that along the coastline between Secret Harbour and Becher Point the coastline has been both accreting and eroding.

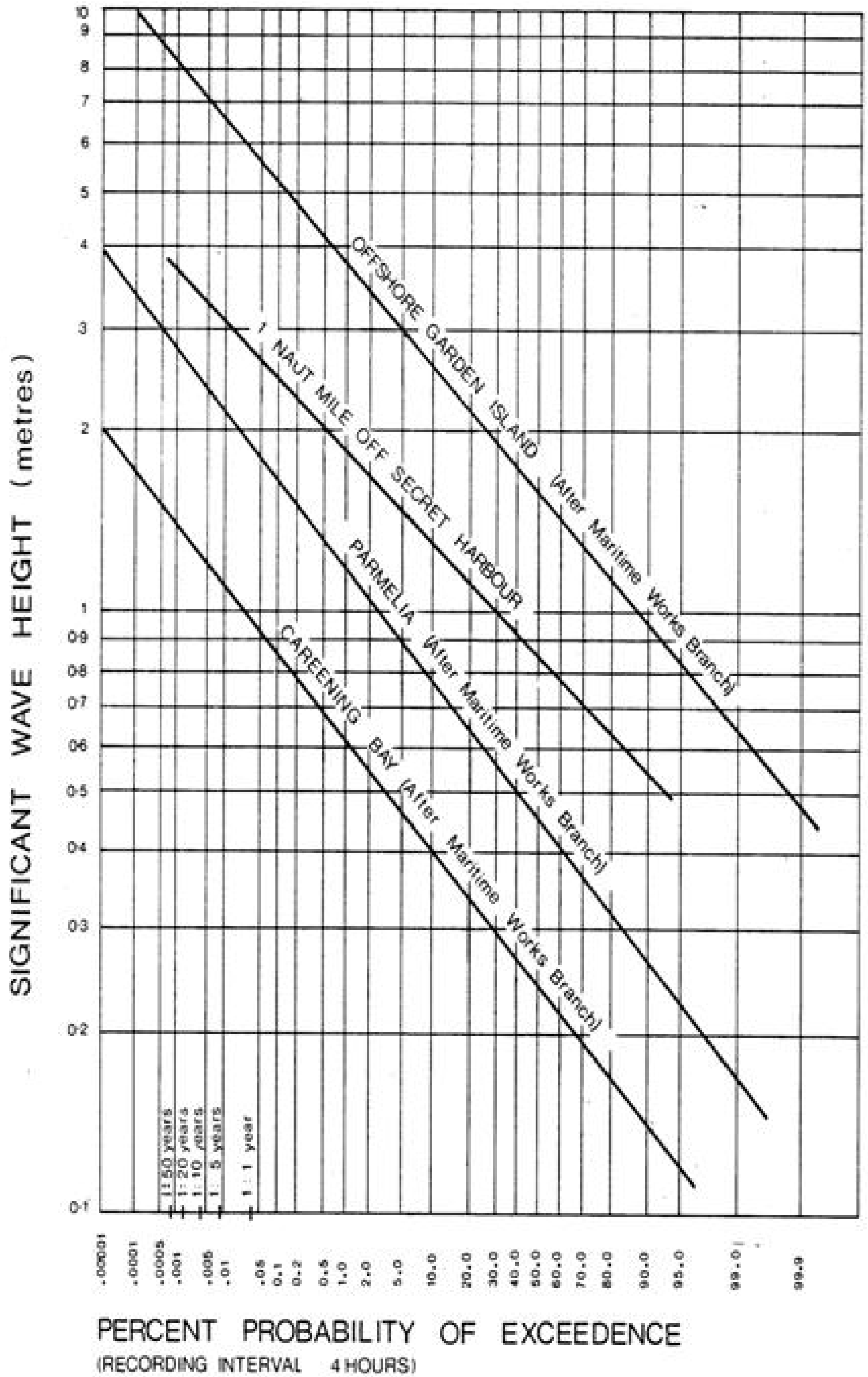


Figure 9 Comparative wave exceedence plots offshore of Garden Island, Parmelia Bank area and Careening Bay; return period wave height one nautical mile off Secret Harbour between August 1979 and July 1980 (HGM 1979a)

A stationary node (point at which the coastline has neither eroded nor accreted) was identified on the coastline, located at approximately 6415000N and 381000E (AMG coordinates). To the north of the node, towards Becher Point, the coastline has eroded between 1924 and 1979. The coastline erosion rate in this region has been estimated to be as high as 6 m y^{-1} (HGM 1979b).

To the south of the node coastline accretion rates were estimated and were generally bounded by a range of 2 to 5 m y^{-1}. Within 500 m of the node, coastline accretion rates were lower, ranging between 0 to 2 m y^{-1}.

5.2.4 Longshore Sediment Transport

Longshore sediment transport occurs due to the development of a longshore drift by obliquely incident waves, resulting in typically northwards longshore transport along Perth's coastline, particularly in summer under the influence of swell and sea breeze generated waves. Occasional storms in winter result in southward longshore sediment transport.

Analysis of littoral drift along Comet Bay indicated that there were regions of both net southerly (north of Secret Harbour) and net northerly (south of Secret Harbour) sediment transport. Based upon the conservative assumption that the mean littoral drift is northwards throughout Comet Bay, the littoral drift was estimated by a variety of methods (Foster and Wallace 1983) to be an average 60,000 m^3 y^{-1} northwards. This corresponds to between 55,000 and 115,000 m^3 y^{-1} around Becher Point. The brine discharge outlet will be to the north of Secret Harbour and it would therefore be expected that the mean northward littoral transport would range between the estimates for sediment transport around Becher Point.

5.3 CIRCULATION AND MIXING IN COMET BAY

An understanding of the hydrodynamic processes is important in determining the anticipated level of impact the Water Corporation Desalination plant discharge would have within Comet Bay.

The hydrodynamics of Perth's coastal waters is a complex combination of wind-forced waves and currents, tides, large-scale currents (the Leeuwin and Capes Currents) and localised currents due to density differences in the water column, and long period waves (Pattiaratchi, Imberger et al. 1995). The complexity is due to variations in the relative strength of each of these factors according to the weather and season.

The Murray Reef system partially separates the circulation within Comet Bay from large scale circulation processes (such as the Leeuwin and Capes Currents) over the continental shelf (Figure 10). The direct influence of the Leeuwin Current such as elevated water temperature and strong southward flowing currents are diminished. An alongshore pressure gradient in the nearshore region is generally present (possibly related to the Leeuwin Current) and will drive flow to the south in the absence of other significant forcing mechanisms such as wind.

Figure 10 Comet Bay and the adjacent Murray Reef system

Of greater importance to the circulation in Comet Bay are the direct influences of wind, tide, outflow from the Peel-Harvey Estuary, continental shelf waves and possibly density driven currents from differential heating and cooling. Generally, wind is the dominant forcing. It is only during periods of weak wind speed or in regions of constricted flow that other circulation mechanisms become important.

During summer and spring the circulation and mixing in Comet Bay will be primarily driven by wind, although there are periods when hypersaline pulses from the Peel-Harvey estuary have been identified (DEP 1996). During periods of no wind it is expected that tides, changes in atmospheric pressure and possibly alongshore pressure gradients and continental shelf waves will drive circulation processes. During summer wind mixing and night time cooling are strong enough to keep at least 10 m of water vertically mixed even in the presence of hypersaline pulses from the Peel-Harvey estuary.

During autumn there are longer periods of little or no wind. During these periods the circulation may be influenced by the outflow from the Peel-Harvey estuary, tides, continental shelf waves and changes in atmospheric pressure. Although Comet Bay is separated to some extent from the continental shelf, it is not sheltered or enclosed to the same extent as Warnbro and Cockburn Sounds. The influence of density driven currents caused by seasonal heating and cooling is expected to be minimal.

The circulation during this period may be complex as no single mechanism may be driving circulation and mixing with Comet Bay. During periods of little wind there may be limited vertical mixing and weak stratification. If outflow from the Peel-Harvey estuary is present (either as hyper- or hypo-saline outflow) vertical mixing will also be reduced and stratification will be enhanced.

During winter it is expected that the circulation will be dominated by wind during storms and Peel-Harvey outflow, tides, continental shelf waves and changes in atmospheric pressure during periods of little wind. Low salinity outflow from the Peel-Harvey estuary occurs mainly from June to September with considerable loadings of nitrogen and phosphorus. A study was undertaken to track the extent of these plumes over a 10 day period in winter (DEP 1996). The results of the field study showed that under south-westerly winds of 5–10 m s^{-1}, the outflow plume travelled from Mandurah to Warnbro Sound via Comet Bay in 1–2 days. A combination of satellite imagery, current meter data and nutrient data provided additional evidence for the path of the plume.

The oceanographic conditions at Comet Bay are more energetic than those of Cockburn Sound and consequently mixing and dispersion of the desalination discharge is expected to be rapid.

5.4 WATER QUALITY

Summer water quality surveys of Comet Bay were conducted by Buckee *et al.* (1994) in early February 1994. Average water temperatures and salinities of 22^{o}C and 36.5, respectively were recorded. Waters throughout the water column at the time of the survey were well oxygenated (7.1–7.5 mg L^{-1}).

Winter water quality surveys were conducted by Cary *et al.* (1995) in August 1991. Average water temperatures and salinities of 16.6^{o}C and 33, respectively were recorded.

5.5 SEDIMENT QUALITY

Contaminant concentrations and characteristics of sediments in Comet Bay were surveyed in 1994 as part of the Southern Metropolitan Coastal Waters study (Burt, McCafferty et al. 1995). Results are provided in Table 9.

Table 9 Contaminant concentrations in Comet Bay sediments as measured in 1994 (Burt et al. 1995)

SITE*	% Particle Size 1000–600µm	% Organic Content	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
CB 1	9.3	1.9	5.0	0.7	6.7	1.5	0.05	6.2	3.6	9.2
CB 2	3.5	3.8	16.0	0.8	7.1	1.3	<0.05	5.2	7.9	1.9
CB 3	14.4	2.6	<0.5	<0.2	<0.2	0.2	<0.05	0.6	1.2	0.2
CB 4	0.3	3.7	<0.5	<0.2	<0.2	<0.2	0.11	0.7	1.5	0.3
CB 5	7.6	2.9	<0.5	<0.2	<0.2	0.3	<0.05	0.7	1.4	0.3
CB 6	10.3	3.8	18.0	1.1	17.0	1.4	<0.05	6.1	7.0	1.7
CB 7	8.6	3.2	14.0	1.0	9.9	1.2	<0.05	5.6	7.5	1.6
CB 8	0.4	3.6	<0.5	<0.2	<0.2	0.2	<0.05	0.6	1.2	0.2
CB 9	57.6	2.9	1.0	<0.2	6.9	0.3	<0.05	<0.2	<0.2	1.4
CB 10	42.6	1.1	7.5	<0.2	16.0	0.8	<0.05	<0.2	<0.2	3.4
CB 11	5.2	2.5	14.0	0.8	14.0	1.3	0.05	5.4	7.0	1.8
CB 12	29.2	3.3	<0.5	<0.2	14.0	0.9	0.08	0.7	0.2	1.6
CB 13	33.1	3.4	14.0	0.3	20.0	0.9	<0.05	2.3	3.0	1.6
SQG-Low	-	-	20	1.5	80	65	0.15	21	50	200

**Site descriptions and locations provided in Burt* et al. *(1995); unless indicated, all results are in µg g^{-1} on a dry weight basis.*

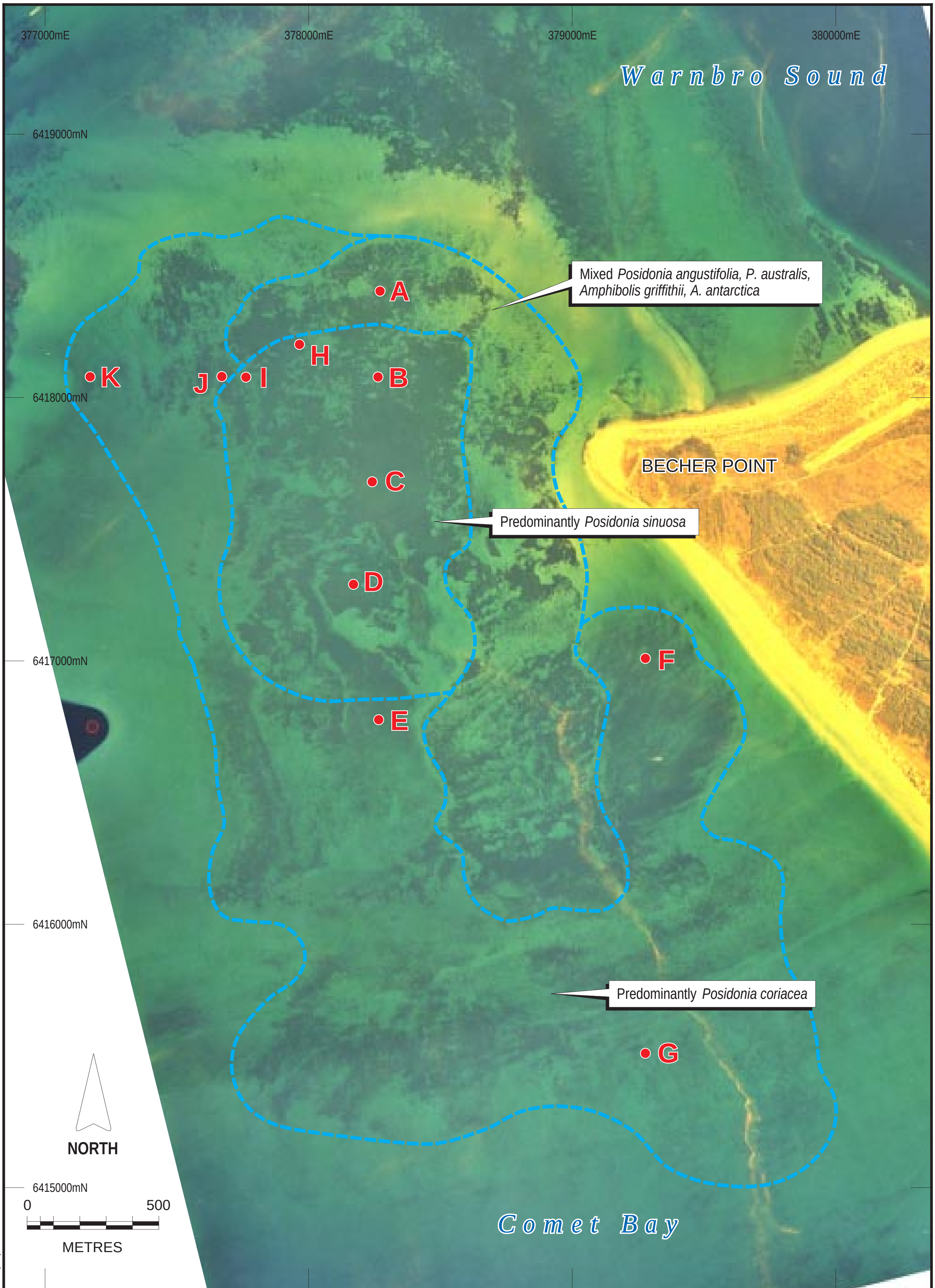
The survey results show that contaminant concentrations in the Comet Bay region were all below the national sediment quality low guidelines (SQG-low) for the protection of marine ecosystems. The particle size information shows that a considerable proportion of the sediments surveyed were composed of approximately 10–50% coarse sand fraction, reflecting the energetic nature of the region.

5.6 MARINE FLORA

5.6.1 Seagrasses

Extensive seagrass cover was observed in shallow waters (2–6 m) wrapping around Becher Point from the north-eastern aspect to the south-west. Seagrass meadows in this region were composed of three generic species assemblages (Figure 11). The nearshore assemblage was dense and multi-specific, including the species *Posidonia australis*, *P. angustifolia*, *Amphibolis antarctica* and *A. griffithii*. The second assemblage was typically mono-specific *P. sinuosa* meadows, also present in very dense cover, while the third, outer assemblage was generally mono-specific, patchy *P. coriacea* meadows.

The progression of species assemblages with distance offshore reflects wave energy and sand movement patterns in the region, consistent with previous surveys in other hydrodynamically energetic coastlines (Sheperd and Robertson 1989). The seagrass species observed in assemblage 1 defined during this survey, are considered to be tolerant of both water and sand movement, both characteristics of nearshore waters around Becher Point. *P. sinuosa*, found to dominate the second assemblage, is often found growing in quieter, less turbid waters than species of assemblage 1. Finally, *P. coriacea* is considered to be tolerant of strong water movement and greater water column depths (e.g. 20–30 m; Sheperd and Robertson 1989), and was found to be the species dominating the outer, deeper, more exposed regions around Becher Point during this survey.



Thu 11 Apr

ENVIRONMENTAL DRAFTING (08) 9278 8211

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Water Corporation of Western Australia

MARINE IMPACTS OF DESALINATION

SEAGRASS ASSEMBLAGES AT THE NORTHERN END OF COMET BAY

Figure **11**

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Table 10 Seagrass species recorded in the region surrounding Becher Point

SITE/TRANSECT	EASTING	NORTHING	DOMINANT SPECIES	DEPTH
A	0378271	6418404	*Posidonia angustifolia* *Posidonia australis* *Amphibolis griffithii* *Amphibolis antarctica*	2–3 m
Mid-Point A-T Transect	0377965	6418202	*Posidonia sinuosa*	4 m
T	0377671	6418080	*Posidonia sinuosa* *Posidonia coriacea*	5 m
500 m Transect west of T	0377171	6418079	*Posidonia sinuosa*, becoming *Posidonia coriacea* then bare sand.	7–8 m
B	0378263	6418078	*Posidonia australis* *Posidonia sinuosa*	3 m
500 m Transect west of B	0377762	6418077	Continuous *Posidonia sinuosa*	7–8 m
C	0378241	6417680	*Posidonia sinuosa* *Amphibolis antarctica*	2–3 m
Transect C to D	-	-	*Posidonia sinuosa* *Amphibolis antarctica*	2–3 m
D	0378170	6417291	*Posidonia sinuosa*	2–3 m
Transect D to E	-	-	*Posidonia coriacea*	2–3 m
E	0378266	6416777	*Posidonia coriacea*	2–3 m
Transect E to F	-	-	*Posidonia coriacea*	2–3 m
F	0379278	6417010	*Posidonia coriacea*	2–3 m
1.5 km south of F	0379278	6415510	*Posidonia coriacea*	5–6 m
1.9 km south of C	0378241	6415780	*Ecklonia radiata*	4 m

5.6.2 Reefs

The Murray Reef system runs parallel to the coast, approximately 2 km west of Comet Bay's shoreline. The limestone reef is mostly subtidal platform and pavement reef, although patches of intertidal reef may be found within the system, particularly to the north associated with several small islands. The reefs carry a high biomass of mainly brown algae (kelps and *Sargassum*), that is often shed from the reef in the winter months and deposited as extensive wrack accumulations on the shoreward side of the reef system. Underlying the brown algal canopy are predominantly coralline and non-calcareous red algal species (BBG 1988).

5.6.3 Phytoplankton

Information describing phytoplankton species in the Comet Bay region was not publicly available at the time of reporting. However, phytoplankton assemblage information was collected at a site just north of Becher Point in Warnbro Sound as part of the SCMWS (DEP 1996). The information showed that in general, diatoms predominate at this location, although silicoflagellates were also in abundance (Helleren and John 1995).

Phytoplankton biomass measurements as chlorophyll *a* concentration had been made in both summer (Buckee, Rosich et al. 1994) and winter (Cary, Masini et al. 1995), with mean values of 0.2 and 7 $\mu g\ L^{-1}$, recorded respectively. The relatively higher chlorophyll *a* concentrations measured in winter may have been due to outflow from the Peel-Harvey Estuary via the Mandurah Channel located at the southern end of Comet Bay.

5.7 MARINE FAUNA

5.7.1 Benthic Infauna

No benthic infauna assemblage information for the Comet Bay region was available for public review at the time of writing. It would be expected however, that benthic macro-invertebrates in the Comet Bay region would have relatively low species abundance due to the wave energy and mobile nature of the coarse sandy sediments (F. Wells[4] *pers comm.*).

5.7.2 Fish

The Comet Bay region is known to support a large whitebait nursery. Previous studies (Gaughan, Fletcher et al. 1996a; Gaughan, Fletcher et al. 1996b) suggest that the nursery areas are restricted to protected inshore marine areas, predominantly in the shallow waters of Warnbro Sound, to the north of Becher Point.

Earlier work by Laurenson *et al*. (1993) also suggests that Comet Bay is an important habitat for Blue Manna Crabs and Southern School Whiting. This is supported by recreational fishing surveys (information provided by Neil Sumner[5]), with 36% of boats surveyed targeting Blue Manna Crabs.

Other species common to the region have been identified via both recreational fishing surveys and commercial catch and by-catch (provided by Suzy Ayvazian[6]) information. A species list is provided in Table 11.

Table 11 Fish species found in the Comet Bay region

COMMON NAME	INFORMATION SOURCE
Bream, Silver (Tarwhine)	Recreational Survey
Bronze Whaler	Commercial By-Catch
Bullseye, Striped	Recreational Survey
Crab, Blue Manna	Recreational Survey
Cuttlefish	Recreational Survey
Flatheads, General	Recreational Survey
Flatheads, Southern Blue-Spotted	Recreational Survey
Flounders, General	Recreational Survey
Garfish, Southern Sea	Recreational Survey
Herring, Australian	Recreational Survey
Leatherjackets, General	Recreational Survey
Mackerel, Blue	Recreational Survey
Mackerel, Scaly	Recreational Survey/Commercial By-Catch
Octopus, General	Recreational Survey
Pilchard	Commercial By-Catch
Snook	Recreational Survey
Squids, General	Recreational Survey
Tailor	Recreational Survey
Trumpeters/Grunters, General	Recreational Survey
Western Rock Lobster	Commercial By-Catch
Whitebait	Commercial By-Catch
Whiting, General/Sand	Recreational Survey
Whiting, King George	Recreational Survey
Whiting, Western School	Recreational Survey
Whiting, School Southern/Silver	Recreational Survey
Wrasse/Gropers, General	Recreational Survey

[4] Fred Wells, Senior Curator, Department of Aquatic Zoology, Western Australian Museum.
[5] Neil Sumner, Senior Research Scientist, WA Marine Research Laboratories, Fisheries WA.
[6] Suzy Ayvazian, Research Scientist, Estuarine and Coastal Finfish Section, Fisheries WA.

5.7.3 Zooplankton

Information describing zooplankton species in the Comet Bay region was not publicly available at the time of reporting. However, zooplankton assemblage information was collected at a site just north of Becher Point in Warnbro Sound as part of the SCMWS (DEP 1996). The information showed that the zooplankton assemblages observed were typical of assemblages found in temperate coastal regions.

5.7.4 Marine Mammals, Reptiles and Seabirds

The largest (500–1,000) population of Little Penguins (*Eudyptula minor*) in Western Australia resides on Penguin Island to the north of Comet Bay (approximately 5 km north-north west), between March and December/January (Cannell 2001). In the 2–3 month interim, they leave the island, destination unknown. The penguins forage at sea during the day, departing just before dawn and returning after dusk. The breeding season extends from April to December (Nicholson 1994). During this time, penguins are found foraging mostly in Comet Bay, although their foraging range decreases whilst they are rearing chicks (approximately August to October) (Wooller, Bradley et al. in prep). The penguins' diet is predominantly sandy sprat (60%), pilchards and garfish, with sandy sprat known to be caught from the nursery at Becher Point (Bastow, Lenanton et al. in prep). It is for this reason that the management and protection of the sandy sprat nursery at Becher Point is also a key management recommendation for the penguins at Penguin Island (Cannell 2001).

Besides the Little Penguin, a number of other seabirds utilise the island chain just to the north of Comet Bay, the majority of which are listed under the Migratory Bird Agreements between Australia and Japan, and Australia and China (CALM 1995). Species included in these agreements are: the Caspian Tern (*Hydroprogne caspia*), the Bridled Tern (*Sterna anaethetus*), Ruddy Turnstone (*Arenaria interpres*), the Whimbrel *(Numenius phaeopus*) and the Bar-tailed Godwit (*Limosa lapponica*). In addition, the Little Shearwater (*Puffinis assimilis*) and the Pied Cormorant (*Phalacrocorax varius*) also utilise the islands, with the latter species breeding on Third Rocks and The Sisters (DCE 1986).

A colony of male Australian sea-lions (*Neophoca cinerea*) is found at Seal Island, also located to the north of Comet Bay (approximately 5.5 km north-north west). Australian sea-lions prefer the sheltered side of islands and avoid exposed rocky headlands (Shaughnessy 1999). The male population at Seal Island uses the island as a rest area between migrations to breeding colonies located at islands outside of the Perth Metropolitan region (CALM 1995).

The Southern Right Whale (*Eubalaena australis*) has been sighted in the waters of Warnbro Sound and the Shoalwater Islands Marine Park during its annual migration to the south and west coasts of Western Australia during the winter months (CALM 1995; Chris Burton[7] and Douglas Cochran[8] *pers comm.*). In addition, the Humpback Whale (*Megaptera novaeangliae*) has also been sighted in waters to the west of the Murray Reef system during its migration to Antarctic waters from the north-west coast of Western Australia (CALM 1995). Bottlenose dolphins (*Tursiops truncatus*) have been observed in the region, however at the time of reporting no known surveys of dolphins in the region had been conducted (Hugh Finn[9] and Douglas Coughran

[7] Whale Consultant with Western Whale Research.

[8] Supervising Wildlife Officer, Marine Wildlife Operations, Department of Conservation and Land Management.

[9] Researcher at Murdoch University.

pers comm.). Douglas Coughran also advised DALSE that no CALM research permits for dolphins in the Comet Bay region have been applied for, or granted, to his knowledge.

5.8 SOCIO-ECONOMIC USES

5.8.1 Social and Cultural

Comet Bay is utilised by nearby residents at Secret Harbour for swimming and beach walking. In addition, waters opposite Secret Harbour are popular for surfing and horse exercising. Recently, the City of Rockingham Council resolved to cease horse exercising activities in April 2002 due to conflict of user interests.

Four wheel drive access is prohibited within the Bay, and is tightly regulated due to an 'A' class CALM nature reserve located to the north of Secret Harbour, encompassing Becher Point.

5.8.2 Fisheries and Aquaculture

There are only two commercial crab operators in Comet Bay. In addition, there is one purse seine net operator targeting whitebait. Other commercial species of focus include pilchards, Southern Sea Garfish, Western Rock Lobster and benthic species caught by trawling (e.g. scallops and Western King Prawns). Fisheries WA has provided the following information (Table 12) indicating (but not limited to) the commercial catches in Comet Bay.

Table 12 Commercial catch information for the period 19962000

YEAR	CATCH	CRUSTACEA	FISH	MOLLUSCS	TOTAL
1996	Weight (kg)	471,285	3,194,383	32,424	3698092
	# Boats	86	70	47	
1997	Weight (kg)	625,778	2,136,718	30,134	2792630
	# Boats	86	71	53	
1998	Weight (kg)	734,395	1,693,592	28,198	2456185
	# Boats	83	67	45	
1999	Weight (kg)	1,092,959	1,340,622	31,416	2464997
	# Boats	87	66	56	
2000	Weight (kg)	1,393,435	709,739	45,672	2148846
	# Boats	89	66	66	

At the time of writing, no aquaculture licenses were held for Comet Bay.

6. IMPACTS ON THE MARINE ENVIRONMENT

6.1 INTRODUCTION

The proposed desalination facility for Cockburn Sound is designed with a capacity of producing 30 GL/year (or 82 ML/d) of potable water from seawater using the process of reverse osmosis, and then discharging approximately 120 ML/d of "concentrated" higher salinity effluent back into the marine environment.

There are currently two sites being considered for location of the intake and outlet for the desalination plant, these being: adjacent to the CBH jetty, and the Kwinana Power Station (KPS). Potential impacts on the marine environment at these two sites will be considered in this section.

The matters of concern and their potential impacts on the marine environment that would occur from the construction and operation of the desalination plant, at either of the two proposed sites include:

- Discharge of high salinity waters (approximately 65), which are of higher density than normal seawater, and which if undiluted would have an increased osmotic pressure effect on resident marine organisms, particularly those present as sedentary or sessile benthos in the area surrounding the outlet;
- Depending on the nature of the hydrodynamics of the site, an increase in salinity in the bottom waters at the site resulting from high salinities in the negatively buoyant desalination discharge may cause an increase in the strength of stratification in the water column, potentially causing secondary effects such as reduced dissolved oxygen in bottom waters;
- Structures through the nearshore zone, unless submerged, may affect coastal processes including long-shore and cross-shore sediment transport, and beach profile; and
- Contaminants (descaling, antifouling) applied to waters during the desalination process and present in low concentrations in the effluent may affect marine organisms, particularly those present as sedentary or sessile benthos in the receiving environment surrounding the outlet.

The first two of these matters can be addressed by selecting the appropriate site for the discharge and designing a discharge system for the higher salinity effluent that would ensure a rapid and sufficient dilution of the higher saline discharge. The third of these matters can be addressed by the appropriate location, design, and construction of any structures in the zone of active sediment transport. The fourth matter can be addressed by the use of suitable chemical agents that upon discharge to the marine environment have no known chronic toxic effects.

Finally a number of indirect impacts of the desalination plant may also arise including:

- Loss of public amenity (marine); and
- Influence on Marine Parks and conservation areas.

These potential impacts are relevant to both sites under consideration, and will be dealt with in turn.

6.2 DETERMINING ACCEPTABLE LEVELS OF SALINITY INCREASE IN COCKBURN SOUND

6.2.1 Water Quality Criteria Used for Reference

There is at present, no criterion (or criteria) for salinity excursions in WA coastal waters. However, reference is made to the ANZECC/ARMCANZ (2000) national water quality guidelines to provide guidance on this matter.

These guidelines provide the following advice on deriving trigger values for physical and chemical stressors in marine waters (pages 3.1-5, volume 4):

'For physical and chemical stressors and toxicants in water and sediment, the preferred approach to deriving trigger values follows the order: use of biological effects data, then local reference data (mainly physical and chemical stressors), and finally (least preferred) the tables of default values provided in the Guidelines. (While the default values are the least preferred method of deriving trigger values, it is conceded that these will be most commonly sought and applied until users have acquired local information).'

6.2.2 Setting Salinity Criteria Using Biological Effects Information

When discharged to coastal waters, hypersaline waters can have two main effects. The first is to raise the osmotic pressure of seawater, in some instances to the detriment of resident marine organisms. The second is to create a blanket of higher salinity water on the seafloor which may inhibit benthic-pelagic exchange processes, in particular oxygen transfer, resulting from denser hypersaline waters sinking through less dense ambient seawater.

Hypersaline effluents contain the same elements and compounds found in natural seawater, yet at higher concentrations. Hence, managing the effects of hypersaline effluents generally involves diluting the effluent as rapidly as possibly using both artificial means (i.e. diffusers) or by making the best use of natural processes such as water column mixing induced by regional hydrodynamics (i.e. waves, wind and currents).

There is little information available in Western Australia on the behaviour of hypersaline effluents from desalination plants, and the associated environmental impacts, hence caution is warranted. However, there is a wealth of information available internationally on the behaviour of desalination discharges and the environmental impacts and their management. In Western Australia there is a substantial base of information on the discharge and environmental impacts of bitterns [very high saline waters (in excess of 300) that are the end-product of solar salt production] (DAL 2002). Bitterns discharge of similar salinities has also been documented in Swan Alley Creek, South Australia (DAL 1996). The very high salinities of bitterns do have an adverse impact on resident biota via osmotic shock. In contrast naturally occurring hypersaline environments such as Shark Bay, where the salinity can exceed 40, diverse and well-established benthic communities exist and are well documented (Walker 1989). In comparison to these hypersaline environments, ambient seawater has a salinity of around 35, while the proposed discharge from the desalination plant will have a salinity of 65 prior to dispersion and dilution in the receiving environment.

Walker (1989) reviewed available information on seagrass communities found at Shark Bay, a sheltered embayment with salinities naturally higher than those of ambient seawater. Two seagrass species common to Perth's Coastal Waters are also found at Shark Bay: *Posidonia australis* and *Amphibolis antarctica*. Physiological investigations of *A. antarctica* found maximum growth rates at a salinity of 42.5. Densest covers of seagrass meadow found in the region occurred at salinities between 40 and 50.

The issue associated with this desalination proposal is to manage and maintain the biodiversity and ecological health of the waters surrounding the proposed discharge outlet which will be subjected to increases in marine salinities. As the desalination discharge is a negatively buoyant plume, benthic habitats within the vicinity of the outlet are of primary concern. For the sites being considered in this proposal, bare sediments are found in the vicinity of the discharge outlets, offering habitat to sedentary/sessile invertebrates. Therefore, for appropriate protection it is necessary to understand the tolerance of these communities to changes in salinity in the marine environment.

The ideal manner for setting protective water quality criteria is to have sufficient information on the chronic (long-term) effects of exposure of organisms, select values for which no (or a statistically acceptable low level of) effects have been observed, and then apply a further safety factor.

To date, this procedure has not been undertaken for salinity in WA coastal waters; consequently a brief literature review of the effects of changes in salinity to benthic marine organisms is provided below.

In general, marine invertebrates are in osmotic equilibrium with the surrounding sea water (Robertson 1949). However, most marine animals are unable to maintain their normal vigour in sea water salinities much below a salinity of 30 (Lange 1972).

All marine invertebrates possess a capability of ionic regulation (Lange 1972). In homoiosmotic animals, the body fluids of the animal are maintained at an almost constant level and are therefore little influenced by the salinity of the surrounding seawater. Regulation of the body fluids is achieved by active processes in specialised organs or cells and is generally referred to as **osmoregulation**. In isosmotic animals, osmotic equilibrium of body fluids is with the surrounding sea water. These animals are generally referred to as **osmoconformers**. Usually, some kind of ionic regulation in the extracellular fluid occurs in these animals.

When an osmoconforming cell (i.e. no regulation of the osmolarity of the internal fluids) is exposed to a change in the ionic concentration (osmolarity) of the surrounding fluid, osmosis will occur (Lange 1972). When the surrounding fluid has a lower osmolarity, the cell will swell due to the influx of water from the surrounding fluid. Conversely, when the surrounding fluid has a higher osmolarity, water will leave the cell and it will shrink.

The biological effects of salinity have long been a research interest, with many extensive studies undertaken over the years (Beadle 1931). However, the main interest with physiological responses of marine organisms to changes in salinity have been on decreases in salinity rather than increases (Beadle 1937; Ellis 1939; Smith 1939; Fletcher 1974).

For example, decreased salinities can be cause for concern for nereid polychaete worms. They swell up when salinities are reduced, and there is evidence to suggest that larval development is interrupted at lowered salinities (McShane 1981). The physiological impacts of lowered salinities has been found to affect the distribution of polychaetes in the sediment column: euryhaline species which are more tolerant of salinity changes are found near the sediment surface, while stenohaline species that are more sensitive to changes in salinities are found deeper within the sediments. Polychaetes are known to burrow into the sediments and irrigate their burrows with water drawn from the sediment surface. When the overlying water salinity decreases, worms have been observed to temporarily cease irrigation of their burrows (McShane 1981).

A summary of some of the more recently obtained information on the physiological responses of marine organisms to changes in sea water salinities is provided below in Table 13.

Table 13 Salinity tolerances of marine organisms

COMMON NAME	SPECIES NAME	SALINITY TOLERANCE	COMMENTS	REFERENCE
Not given	*Palaemon affinis*	5–43	High survival (>75%).	(Kirkpatrick and Jones 1985)
Scallop	*Pecten fumatus*	25–40	Australian species.	(Nell and Gibbs 1986)
Pipi (clam)	*Plebidonax deltoides*	20–45		
Flat oyster	*Ostrea angasi*	20–45		
Blue mussel	*Mytilus edulis*	15–45		
Sydney cockle	*Anadara trapezia*	15–45		
Crab larva	*Pagurus criniticornis*	15–55	Salinity influenced temperature tolerance with thermal limits being wider at 25 and 35 than at 45.	(Blaszkowski and Moreira 1986)
Spotted Seatrout Larvae	*Cynoscion nebulosus*	6.4–42.5	This is a minimum tolerance range for marine spawned larvae.	(Banks, Holt et al. 1991)
Florida Stone Crabs	*Menippe mercenaria*	25–40	Juvenile survival at these salinities was 100%.	(Brown, Bert et al. 1992)
Lesser blue crab (juveniles)	*Callinectes similis*	5–45	21 day LC-50 values were 2.6 and 60.8 at low and high salinities, respectively.	(Guerin and Stickle 1997)
Reef-building corals	*Porites lutea* *P. asutraliensis* *Galaxea fascicularis* *Goniastrea pectinata*	35–39	Growth was significantly lower at salinities higher than 40, although zooxanthella density among corals did not differ between salinities.	(Nakano, Yamazato et al. 1997)
Green mussel	*Perna viridis*	0–64	Venezuela.	(Segnini de Bravo, Chung et al. 1998)
Brown mussel	*Perna perna*	8–54		
Juvenile penaeid shrimps	*Metapenaeus stebbingi*	10–50	Salinities of 5, 55 and 60 were lethal (100% mortality within 24 hours of exposure).	(Ahmed and Ayub 1999)

As is evident in Table 13, marine species of benthic invertebrates have been found to be little affected by slight (<5) increases in sea water salinity (i.e. up to approximately 40), both at adult and larval stages of their life cycles.

6.2.3 Setting Salinity Criteria Using Local Reference Data

ANZECC/ARMCANZ (2000) recommend deriving low-risk trigger guidelines by measuring the statistical distribution of water quality indicators either at a specific site, or alternatively at an appropriate reference system. An appropriate statistical distribution to derive trigger values would require data collected over two years of monthly sampling. Ideally, trigger values for water quality indicators would be developed for each month (i.e. a total of 12 low-risk trigger values). Trigger values for providing a high level of protection for physical and chemical stressors should be defined in terms of the 80th percentile of values obtained from an appropriate reference system.

Provided in Table 14 are monthly low-risk trigger values for salinity that have been derived from data collected at a reference site in the north of Cockburn Sound close to the KPS. The site has been monitored with varying temporal resolution over the past five years, with surveys including comprehensive salinity profiles.

Table 14 Low-risk trigger values for salinity for a long-term monitoring site within Cockburn Sound

MONTH	MEDIAN	LOW-RISK TRIGGER VALUE (80TH PERCENTILE)	Δ SALINITY
January	34.92	35.24	0.32
February	36.48	36.49	0.01
March	36.80	36.80	0
April	36.6	36.6	0
May	35.28	35.35	0.07
June	34.75	34.8	0.05
July	-	-	-
August	33.7	34.65	0.95
September	-	-	-
October	35.09	35.1	0.1
November	35.33	35.39	0.06
December	35.65	35.68	0.03
Annual Period	**35.15**	**35.95**	**0.8**

Compared to other physical and chemical stressors that are present within the marine environment, salinity is a relatively stable parameter. This is supported by the information provided above: there is very little variation between the median and 80th percentile values.

In the derivation of guidelines for physical and chemical stressors, the ANZECC/ARMCANZ guidelines provide the following advice (pages 3.3–5, volume 4):

'The guideline trigger values are the concentrations (or loads) of the key performance indicators, below which there is a low risk that adverse biological effects will occur. The physical and chemical trigger values are not designed to be used as 'magic numbers' or threshold values at which an environmental problem is inferred if they are exceeded. Rather they are designed to be used in conjunction with professional judgement, to provide an initial assessment of the state of a water body regarding the issue in question.'

The Draft Environmental Protection (Cockburn Sound) Policy (EPP) (2001) and associated technical supporting documents define a series of levels of protection in the waters of Cockburn Sound, including:

E2: High protection
E3: Moderate protection

The Draft EPP has translated the low-risk criteria for salinity for the E2 level of protection to be within the 80th percentile of deviation from the median. This implies that a maximum ΔS for E2 zones in Cockburn Sound (see Table 14) is 0.8. Similarly, for moderate levels of protection (E3 zones) it has been considered that the 95th percentile of deviation from the mean should be the trigger level, which for Cockburn Sound is a ΔS value of 1.5.

The discharge from the desalination plant has a nominal salinity of 65, while the median salinity of the surrounding seawater is 35.15. The discharge requires dilution before it meets proposed E3 criteria of ΔS = 1.5 (i.e. S = 36.65), and further dilution before it meets proposed E2 criteria of ΔS = 0.8 (i.e. S = 35.95).

The dilutions that will be required of the discharge from the desalination plant when applying these arbitrary and statistically derived trigger levels are provided below in Table 15.

Table 15 Initial dilutions required to achieve proposed salinity criteria

LEVEL OF PROTECTION	MAX ΔS	NUMBER OF DILUTIONS
E2 – High	0.8	37
E3 – Moderate	1.5	19

6.2.4 Default Values in the Guidelines

The following default trigger values for conductivity (i.e. salinity; Table 16) have been extracted from the ANZECC/ARMCANZ (2000) guidelines (pages 3.3–15, volume 4).

Table 16 Range of default ANZECC/ARMCANZ (2000) trigger values for conductivity (EC, salinity) in south-west Australia

ECOSYSTEM TYPE	SALINITY (µS cm^{-1})	EXPLANATORY NOTES
Upland & Lowland Rivers	120–300	Conductivity in upland streams will vary depending upon catchment geology. Values at the lower end of the range are typically found in upland rivers, with higher values found in lowland rivers. Lower conductivity values are often observed following seasonal rainfall.
Lakes, Reservoirs & Wetlands	300–1,500	Values at the lower end of the range are observed during seasonal rainfall events. Values even higher than 1,500 µS cm^{-1} are often found in saltwater lakes and marshes. Wetlands typically have conductivity values in the range 500–1,500 µS cm^{-1} over winter. Higher values (>3,000 µS cm^{-1}) are often measured in wetlands in summer due to evaporative water loss.

Trigger values for salinity in the marine environment have not been provided in these guidelines (ANZECC/ARMCANZ 2000) and consequently are not of value for this assessment.

6.3 NUMERICAL MODELLING

6.3.1 Introduction

Numerical modelling was undertaken to provide a detailed understanding of the dilution and dispersion of discharge waters in the receiving environment at the two sites under consideration, namely:

- CBH, Cockburn Sound;
- KPS, Cockburn Sound;

The models represent the fluid dynamics of the system and determine the effects on the dynamics caused by changing any component (e.g. ambient salinity, temperature) of the system. The accurate representation of the dynamics provides information on the likely spatial and temporal scale and degree of any changes. This allows conclusions to be drawn about the likely extent and degree of any increased salinity and the corresponding impact on the receiving ecosystem.

The specific aim of the numerical modelling was to simulate the likely behaviour of the desalination plume under the range of meteorological and seasonal conditions that occur at the two sites; and to depict salinity distributions around each of the discharge sites.

6.3.2 Modelling Strategy

There are generally three regions of dilution which can be used to characterise a plume:

- The near-field—within which the momentum of the plume is arrested while rapid initial dilution is achieved and the plume becomes advected by the receiving waters;
- The mid-field—within which the plume is mixed vertically and further dilution occurs; and
- The far-field—within which the plume spreads laterally with even further, but generally slower rates of dilution.

The prediction of near-field and mid-field dilution and advection of the discharge at these two sites was undertaken using analytical techniques and the far-field dispersion of the plume was modelled using a three dimensional hydrodynamic model.

6.3.3 Setting Initial Dilution Requirements and Discharge Design

Based on the requirements of meeting proposed salinity ‘trigger’ levels for high protection areas (E2 zones) and moderate protection areas (E3 zones), of salinity excursions of 0.8 and 1.5, respectively; recognising that an initial dilution for 37 or more of a 65 salinity discharge by ambient seawater of 35.15 will allow E2 ‘trigger’ levels to be met; and recognising the limited size of the proposed E3 zone in eastern Cockburn Sound, a design criterion of achieving an initial dilution of a minimum of 37 in the near-field was proposed. This is a highly conservative criterion, with no reliance placed on further dilution that is known to occur in the mid-field area. This criterion can be interpreted as meaning that the requirement is for the design of a discharge and diffuser system that can provide an average initial dilution of 37 under still water conditions. Even with moderate ambient currents, the average initial dilution would be higher.

At the proposed KPS site, it is also recognised that the proximity of shipping channels would enable any waters of density greater than ambient to move down the dredge slopes and into the deeper channels. This would inhibit further mixing and dilution. Therefore, to achieve any preset dilution that may be required, it is necessary to ensure that these levels of dilution are achieved within the initial near-field mixing zone.

This criterion was applied to both the CBH Jetty and KPS sites. At the CBH Jetty site, discharge of the high saline effluent through a submerged diffuser was the only option considered. At the KPS site, an identical diffuser design was considered. However, the option of combining the high saline effluent with the cooling water discharge from the KPS discharge was also considered.

6.3.4 Diffuser Layout and Estimated Dilutions

The following design parameters were set for a submarine outlet and diffuser:

- The discharge shall be submerged at all times;
- The discharge shall be from a subsea pipeline, terminating in a diffuser array located in a suitable area;
- The magnitude of the flow requires a multi-port system. This should be designed such that the discharge from each port is uniform. Furthermore, the ports shall be spaced to maximise the dilution of the discharge;
- The subsea pipeline shall be buried, with adequate protection against exposure and impact. Each port shall be connected to the subsea pipeline via a riser, extending approximately 1 m above the seabed; and
- The ports shall be oriented at 60^{o} to the horizontal.

By applying the design discharge characteristics, a conceptual design was derived that includes the following components:

- A 1,000 mm nominal diameter (DN) subsea pipeline from the onshore pump station terminating at a minimum depth of 8 m; and
- A 160m long diffuser structure composed of a 1,000 mm DN pipeline, with 16 risers at 10 m spacings terminating in ports of 200 mm DN. The diffuser should be in a minimum depth of 8 m.

Applying models based on experimental data with dense discharges (Roberts, Ferrier et al. 1997), the following dilution and mixing zone characteristics are predicted:

- Maximum height of discharge plume from the diffuser: 6 m;
- Initial dilution of 1:37 under stagnant water conditions, higher dilutions normally occur; and
- Length of initial mixing zone: 25 m.

Therefore, at the edge of the initial mixing zone (25 m from the discharge), given a discharge salinity of 65, the salinity outside of the plume is predicted to be less than 0.8 above ambient levels. Further dilution will then occur in the far-field, albeit at a reduced rate.

The lowest values for initial dilution at the proposed sites were found to be under autumn conditions rather than summer conditions, when the frequency of calm periods is greatest and therefore vertical mixing of the water column due to wind is reduced.

It is concluded from this initial assessment that a properly designed and located subsea discharge using a diffuser system will allow sufficient initial dilution to be achieved to meet water quality trigger levels for E2: High Protection Zones at the edge of the mixing zone, at either the CBH Jetty or KPS sites.

It is recognised that should the construction of a desalination plant proceed at either site, and discharge be via a submerged outlet with diffuser, a significant amount of detailed investigation and design would be undertaken to optimise the diffuser performance.

6.3.5 Mid-Field and Far-Field Dilution and Dispersion

Modelling of the dispersion fields in the mid- and far-fields was conducted using the Environmental Fluid Dynamics Code (EFDC) model of Cockburn Sound. This model has been used for several recent submissions to the Environmental Protection Authority (EPA) as well as by the Department of Environmental Protection (DEP) for the assessment of industrial discharges. The model was provided by the owners' consortium of James Point Pty Ltd, Western Power and BP for use by Water Corporation. Furthermore, recent amendments to the meteorological data made on behalf of the DEP were made available for use in this project.

The existing model grid was refined for this application, providing a higher resolution in the vicinity of the discharge. The model grid sizes are approximately 100 m x 100 m in this region. Tidal forcing was applied as a lagged time-series along the offshore model boundary, derived from measurements at Rottnest Island and Mandurah. The vertical resolution of the model was also enhanced, to better capture the predominantly bottom attached flow. The model had a total of 14 layers, with 4 layers each of 5% of the depth at the bottom and surface, with 6 layers of 10% of the depth between.

Simulations were conducted for 30 day periods representative of autumn (generally calm conditions) and summer (stronger winds, seabreeze cycling), for the KPS and CBH Jetty sites. The discharge was applied to a single model cell at the discharge location.

Table 17 summarises the data sources for the forcing conditions:

Table 17 Data sources for the forcing conditions used in the EFDC modelling of Cockburn Sound

DATA	SOURCE	LOCATION
Atmospheric Pressure	Bureau of Met.	Rottnest Island
Air Temperature	Bureau of Met.	Swanbourne
Relative Humidity	Bureau of Met.	Swanbourne
Wind	DEP	Naval Base
Shortwave Radiation	Dept. of Agriculture	Medina
Cloud Cover	Bureau of Met.	Perth Airport

Figure 12 and Figure 13 show the modelled bottom salinity (average over bottom 20% of water column, which is approximately 1.6 m in depth at the point of discharge of water column) for the desalination effluent discharge via a submarine outlet with a diffuser at the CBH Jetty and KPS sites, for summer and autumn. Salinity excursions are presented in blue (0–<4), green (4–<8) and orange (0.8–<1.2). The values of ΔS of 0.8 and ΔS of 1.5 represent the notional 'trigger' levels for the protection of E2: High Protection and E3: Moderate Protection zones, respectively. The designated 'boundary' between the E2 and E3 zones, as provided in the draft EPP for Cockburn Sound, is also shown. From Figure 12 and Figure 13, it can be clearly seen that the high initial dilution achieved in the cases where a proper diffuser is installed, will allow water quality criteria 'trigger' levels for salinity to be readily achieved under summer and autumn conditions.

Figure 14 indicates the salinity field that is predicted if the desalination discharge of 120 ML/day at a salinity of 65 is mixed with the existing flow from outfall C of the KPS (continuous flow of 10.2 m^3/s), providing an initial dilution of approximately 7. Salinity excursions are presented in blue (0–<4), green (4–<8), orange (0.8–<1.2), red (1.2–<1.6) and pink (1.6–<2). Figure 14 shows the wider area of dispersion of the higher saline effluent and its tendency to move down slopes and into the deeper dredged channels.

In practice, there are options for combining the desalination effluent with flows from the A and B cooling water streams from the KPS, to achieve a minimal initial dilution of approximately 13. However the A and B streams do not run continuously; hence Figure 14 provides an indication of the 'worst case' of salinity excursion using this option of combining discharges.

6.3.6 Mixing Zones in Cockburn Sound

The Draft Environmental Protection (Cockburn Sound) Policy (EPP) (2001) describes a mixing zone as a clearly defined area around an effluent discharge where the effluent is actively diluted with waters in the receiving environment. Within the mixing zone (distinguished as an E4 zone), no water quality criteria are defined for physical and chemical stressors, with the exception of a select few contaminants that may potentially bioaccumulate. It is at the boundary of the E4 mixing zone and the surrounding E3 zone that water quality criteria ('trigger values') are defined and need to be met to ensure the quality of nearby waters does not deteriorate as a result of effluent discharge.

With regard to the allocation of mixing zones in Cockburn Sound, the Draft EPP states:

'This maximum cumulative water surface area will be expressed as a percentage of the total water *surface area east of the boundary between the High protection area and the Moderate protection area on the eastern side of Cockburn Sound. At this stage the EPA anticipates this figure would not exceed 5%.*'

The total mixing zone area allocated within the EPP for Cockburn Sound will be arbitrary, based on the results of numerical modelling work for the region. Ecological significance of the total area of the mixing zone will not be given consideration in the process.

At present the total area allocated as a low protection area in Cockburn Sound is 1,252 ha, encompassing 52.54 ha (or 4.12% of the area) of mixing zones from existing industry. If a mixing zone of 100 m in radius were provided for the proposed desalination discharge, this would add a further 3.14 ha of mixing zone to the region, increasing the total area occupied by mixing zones to 4.45% of the region.

The EPP is currently a draft, having recently gone out for public comment (closing date: 31st of March 2002).

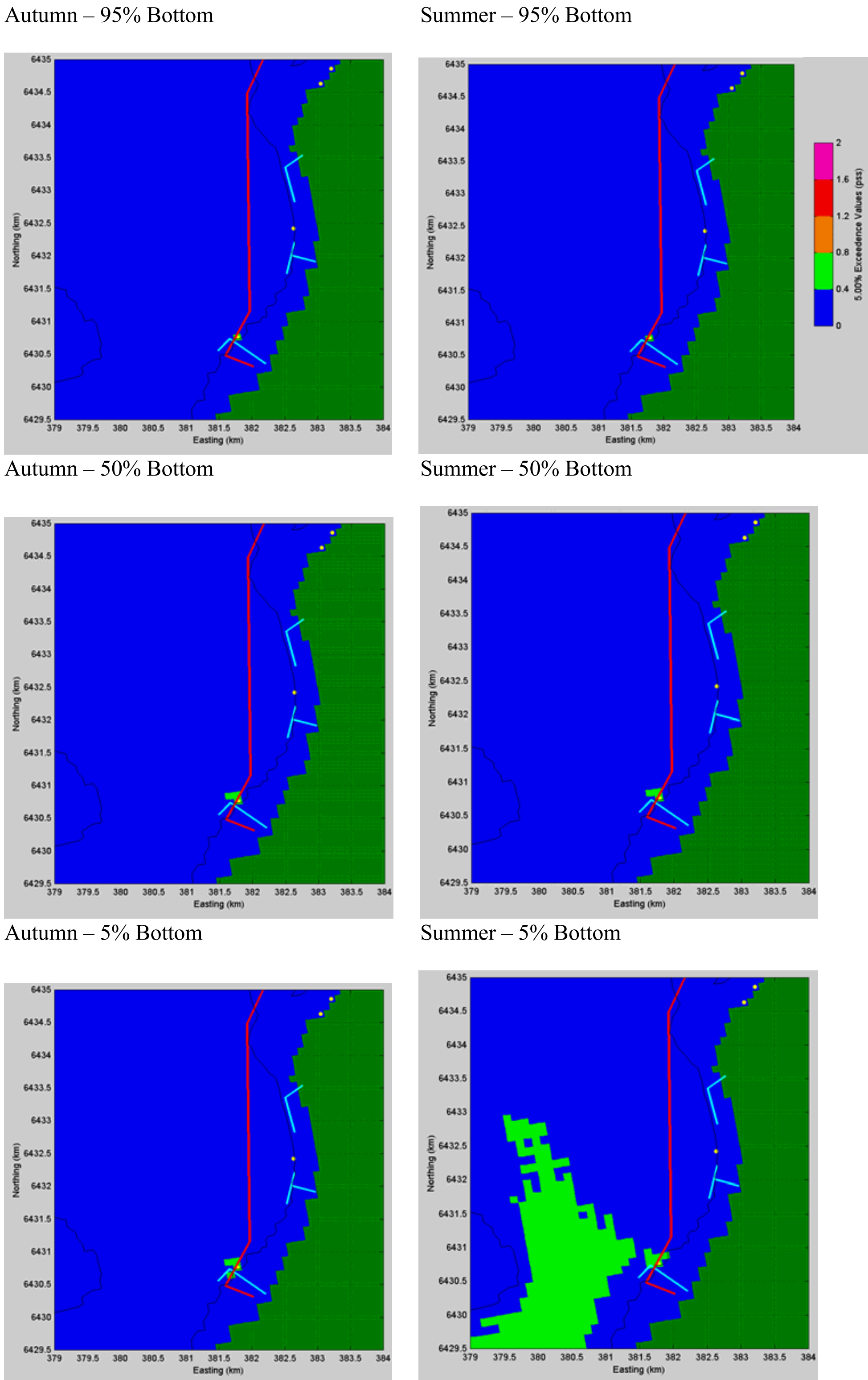
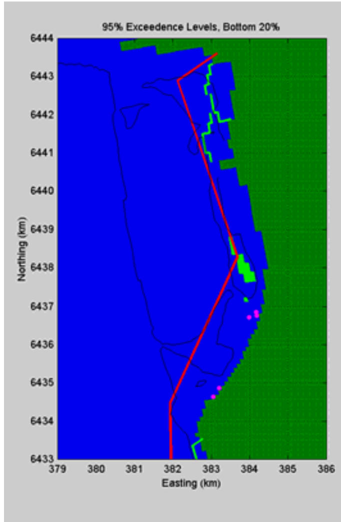
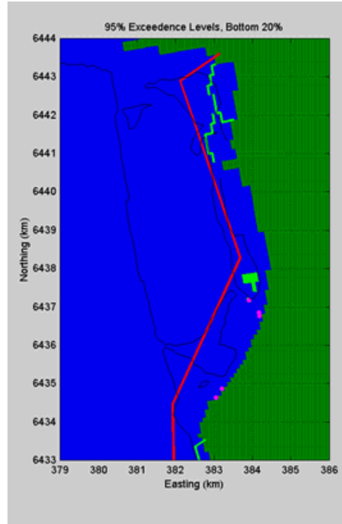


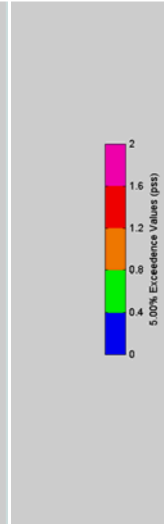
Figure 12 Dilution fields for a desalination plume discharged from a submerged diffuser at CBH Jetty, Cockburn Sound

Autumn – 95% Bottom

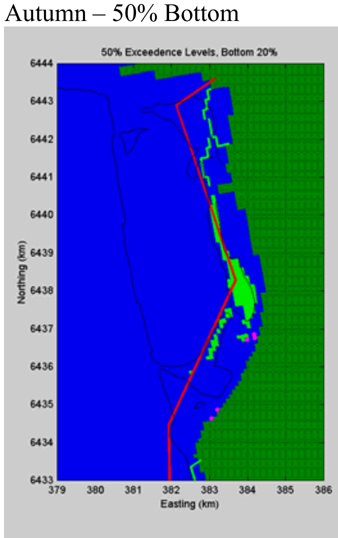


Summer – 95% Bottom

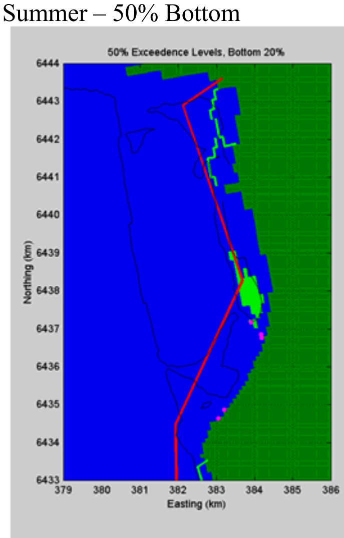




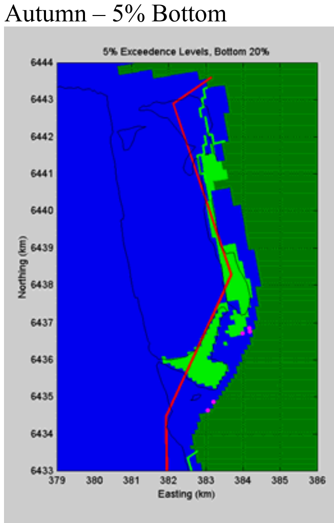
Autumn – 50% Bottom



Summer – 50% Bottom



Autumn – 5% Bottom



Summer – 5% Bottom

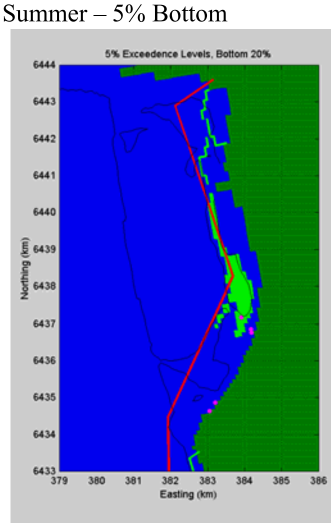


Figure 13 Dilution fields for a desalination plume discharged via a submarine outlet with diffuser at KPS, Cockburn Sound

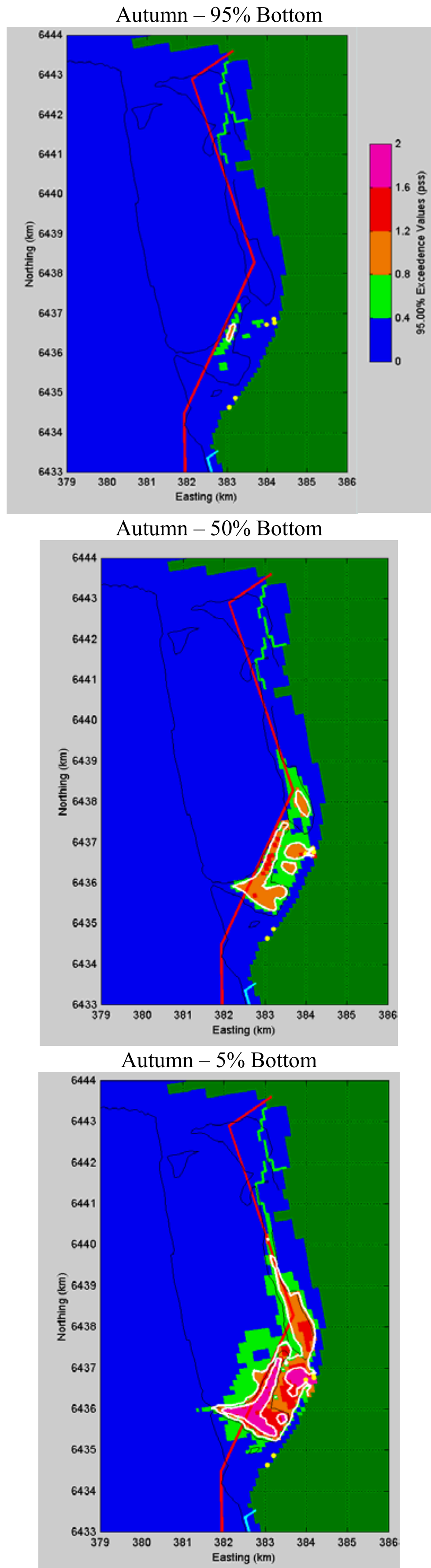


Figure 14 Dilution fields for a desalination plume discharged in combination with cooling water at KPS, Cockburn Sound

6.3.7 Proposed Mixing Zone for the Desalination Plant

Results of the numerical modelling of the desalination discharge indicate that a mixing zone of 100 m in radius would allow background environmental criteria to be met at the edge of the mixing zone at both the proposed CBH Jetty and at the KPS sites, when a submarine outlet and diffuser is used.

The indication of mixing zone size discussed above has been derived from numerical modelling results generated using the EFDC model. This model has an inherent grid cell size of 100 m by a 100 m. Therefore, these results are coarse, and as such the estimate of the mixing zone discussed here should also be considered as conservative (overestimated). Future refinement of the mixing zone for the Water Corporation desalination discharge could be gained using additional tools to provide more detailed information of the near-field discharge plume, including the use of procedures as CORMIX modelling and water quality measurements in the vicinity of the discharge point once the plant is operational.

6.4 BIOCIDES, ANTI-SCALANTS AND HEAVY METALS

6.4.1 Biocides and Anti-Scalants

Nutrient enrichment is not an issue with the Water Corporation desalination proposal as the development will not release nitrogen to the marine environment, nor alter the hydrodynamics.

A number of chemicals will be required for efficient operation of the desalination plant. These include anti-scalant that will be continuously dosed to the reverse osmosis (RO) feed line, and those required on an intermittent basis for cleaning of the ultrafiltration (UF) (e.g. biocide, sodium hypochlorite) and RO (e.g. acidic detergent) membranes.

The UF system will be backwashed every 15–20 minutes with 12% w/w sodium hypochlorite solution, while chemically enhanced cleaning of both UF and RO membranes (with acidic detergent) will occur about four times a year.

Anti-scalant must be added to the RO feed water to control the precipitation of soluble salts that would affect membrane efficiency. As the anti-scalant will be discharged to the marine environment with the reject water, it must not have toxic or bioaccumulation effects. The anti-scalant proposed for use in the RO system is Occtech product "OEC-AS-1000", a multi-functional anti-scalant for carbonate, sulphate and other less common scales, that will be added to the RO feed water at the controlled rate of 4–6 mg L^{-1}. The absolute concentration at which the anti-scalant will be added to the RO feedwater will be finalised upon determination of the quality of intake waters. OEC-AS-1000 is a proprietary blended product. The active ingredient in this anti-scalant product is phosphinocarboxylic acid. OEC-AS-300 contains no heavy metals or designated hazardous substances; it does not bioaccumulate and ultimately degrades to harmless natural by-products (carbon dioxide and phosphorus oxides).

Biocide is required to control microbiological growth that may impair membrane efficiency. The biocide proposed for use in the RO system is Occtech "OE-BIO-2000", a non-oxidising, broad-spectrum (i.e. it kills bacteria, fungi, yeast, blue-green algae and true algae) fast-acting biocide that contains the active ingredient 2,2-dibromo-3-nitrilopropionamide (DBNPA). It will be added to the UF and RO systems whilst inoperational, at approximately weekly intervals. The product contains no heavy metals, and rapidly (in less than a day under neutral pH and normal plant operating temperatures) decomposes to harmless natural by-products (carbon dioxide, ammonium and bromide) in aquatic environments, principally through its mode of action with organic contaminants and pH dependant hydrolysis. DBNPA has been registered with the US EPA for use in 'once through' cooling systems at given dosage ranges because of its environmental profile.

The acid detergent proposed for use in cleaning UF and RO membranes is "OEC-MT-3000", a general purpose acidic detergent designed for removal of hardness scales on UF and RO membranes during off-line 'Clean in Place' procedures. It comprises a powder blend of organic acids, low foam surfactants and wetting agents. The active ingredient is sulphamic acid, which is relatively benign compared to mineral acids (e.g. sulphuric acid and hydrochloric acid) and hydrolyses to ammonium bisulphate in aquatic environments. After the cleaning operation the solution will be neutralised by the addition of sodium hydroxide, and the neutralised solution discharged back into the marine environment.

The presence of anti-scalant in the discharge at between 6 and 9 mg L^{-1} will not be harmful given the low toxicity and low initial concentration. Given an initial dilution of 1:37, anti-scalant concentrations will be approximately 0.16–0.24 mg L^{-1} in the mixing zone. There is unlikely to be a discernible impact on the water quality of Cockburn Sound due to the use of anti-scalant in the proportions proposed by the Water Corporation. However, the Water Corporation will undertake whole effluent eco-toxicological testing of the discharge on marine organisms common to the area to establish the level of toxicity of the discharge. Whole effluent toxicity testing is preferred to testing of individual contaminants of concern, as whole effluent testing allows an examination of multiple stressors (e.g. increased salinity in combination with added anti-scalant) acting concurrently.

6.4.2 Heavy Metals

Naturally, marine waters have background metal concentrations. Metal concentrations in the desalination discharge are expected to increase by approximately 1.85 times, due to the extraction of freshwater and the subsequent concentration of other physico-chemical parameters naturally found in marine waters. Background concentration ranges of a number of metals as measured in Australian marine waters are provided in Table 18 (ANZECC/ARMCANZ 2000). In addition, the metal concentrations anticipated in the desalination brine prior to discharge (i.e. before initial dilution upon mixing with receiving waters), are shown and compared to the ANZECC/ARMCANZ (2000) recommended water quality guidelines for, 95% protection of species (a high level of protection as expected for the greater area of Cockburn Sound), and for 80% protection (the level of protection as expected for mixing zones). Possible exceedences in the desalination brine *prior* to discharge are in bold.

As can be seen from the information provided, cadmium concentrations slightly exceed the criterion for mixing zones as recommended by ANZECC/ARMCANZ (2000). However, after initial dilution of the desalination brine upon discharge (dilution of approximately 1:37), cadmium concentrations are expected to be less than 0.03 µg/L, and therefore within the recommended guideline for 95% species protection as required for Cockburn Sound waters.

Table 18 Background metal concentrations (in μg/L) measured in Australian waters (ANZECC/ARMCANZ 2000) compared to concentrations expected in the desalination effluent

METAL	BACKGROUND CONCENTRATION	DESALINATION DISCHARGE CONCENTRATION	ANZECC/ARMCANZ	
			95% Protection	80% Protection
Arsenic (AsIV)	1.0–1.6	1.86–2.9	13	140
Cadmium	0.002–0.7	0.004–1.3	**0.2**	**0.8**
Copper	0.025–0.38	0.04–0.7	1.4	2.5
Chromium (CrVI)	0.062–0.1	0.12–0.18	1.0	40
Iron	No Information	No Information	No Guideline	No Guideline
Lead	<0.006–0.03	<0.01–0.06	3.4	9.4
Manganese	No Information	No Information	1,900	3,600
Mercury (Inorganic)	No Information	No Information	0.6	5.4
Nickel	0.13–0.5	0.24–0.93	11	17
Silver	<0.0005	<0.0009	0.05	0.2
Zinc	<0.022–0.1	<0.04–0.18	8.0	31

6.5 SEDIMENTS AND SEDIMENT TRANSPORT

6.5.1 Contaminants

Given the volatile nature of the active ingredients of the anti-scalant and biocide present in the desalination effluent, this precludes the potential for bioaccumulation of contaminants of concern in nearby sediments. Therefore, deterioration in the quality of sediments in the vicinity of the outlet is not predicted from this proposal.

6.5.2 Coastal Processes

The proposal will not impact on the littoral transport in the region if intake and discharge outlet pipelines are submerged.

6.6 IMPACTS OF INTAKE FLOWS

The water velocity at the entrance to the intake pipe will be approximately 2 m s^{-1}. For environmental, operational and human safety reasons, the entrance to the pipeline will need to be screened to prevent marine life and debris being drawn into the plant and to allow safe underwater inspection of the intake. If water velocities are kept below typical natural velocities in the region then entrainment of marine species should not be a significant issue. Wind driven currents along the coast are in the range of 1–10 cm s^{-1} and therefore it is suggested that if velocities at the screen surface are kept to 1 cm s^{-1} or less then small fish will be able to swim away from the intake.

There are a number of techniques used to keep velocities down to acceptable levels; the simplest is to place fixed screens around the intake. However, issues with bio-fouling of such screens means that more complex systems involving travelling screens or self cleaning screens are often deployed. Another technique is to have only a coarse screen at the end of the pipe (for human safety) and have a stilling tank area upstream where velocities are lower and fish are excluded from the region leading to the plant and can swim out of the system. These systems are used where fish screens cannot be economically maintained at the point where water is initially extracted. Travelling screens may then be placed between the tank and the plant.

The methodology employed for screening will be dependent on the location for extraction. The proponent commits to having a suitable screening system in place which will meet current best practise for screening in marine ecosystems. The final design of the screening system and the maximum intake velocities will be submitted to the DEP for approval prior to construction as part of the Construction EMP.

6.7 SOCIO-ECONOMIC IMPACTS

The proposal will not result in any impacts on the recreational amenity of sites proposed in Cockburn Sound waters as the region which is proposed for a limited quality zone is within an area of restricted boating and public access.

6.8 CONCLUSIONS

1. The numerical modelling shows desalination discharge at both the CBH and KPS sites will influence salinity only in the immediate vicinity of the discharge. Changes from ambient salinity using a submarine outlet and diffuser will be restricted to less than 0.8 after initial dilution. This will readily meet the proposed criteria for the protection of E2: High Protection zones and, E3: Moderate Protection zones. These small changes in salinity over a relatively small spatial scale (mixing zone <100 m radius) will not be detrimental to the water quality in Cockburn Sound where greater changes in salinity occur over larger areas naturally, on a daily and seasonal basis. Therefore, it is concluded that desalination brine may be discharged with no detrimental impacts on the water quality of Cockburn Sound due to the difference between the salinity of the discharge and that of the Sound, and that the Water Corporation will be able to meet the E2/E3 water quality criteria as defined by the draft Environmental Protection Policy for Cockburn Sound.

2. The presence of anti-scalant in the discharge at between 6 and 9 mg L^{-1} will not be harmful given the low toxicity and low initial concentration. Any dissolved metals in the desalination discharge will not be an environmental concern. The concentration of these contaminants following initial dilution will be approximately 37 times less again.

3. Disturbances to sediment transport, the seabed and public access to the shore (where relevant) will occur during construction of the pipelines. However, these impacts will be absent after construction of the desalination plant has been completed.

4. The potential impact of filtering large volumes of water on pelagic organisms (e.g. fishes) can be minimised by constructing fine-meshed cages around the intake pipe such that the current at the edge of the cage is <1 cm s^{-1}, enabling motile organisms to move away from the intake pipe.

7. ACKNOWLEDGEMENTS

This report was prepared by **Helen Astill** (DALSE) with the assistance of **Guy Gersbach, Bruce Hegge, Mark Bailey, Des Lord** and **Karen Hillman**, (DALSE), and **Murray Burling** (Port & Harbour Consultants). Comments were provided by **Andrew Bath** (Water Corporation). Report formatting was undertaken by Katy **Rawlings** and **Christine Mellersh** (DALSE).

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APPENDIX 2

DESCRIPTION OF VEGETATION ALONG PROPOSED PIPELINE ROUTES

Prepared by

Bennett Environmental Consulting Pty Ltd

Appendix 2 Description of vegetation along proposed pipeline routes.

Condition rating scale of Bush Forever (Government of Western Australia, 2000)

Rating	Description	Explanation
1	Pristine	Pristine or nearly so, no obvious signs of disturbance.
2	Excellent	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.
3	Very Good	Vegetation structure altered, obvious signs of disturbance.
4	Good	Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it.
5	Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management.
6	Completely degraded	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species.

East Rockingham pipeline routes

This route traversed an area from Tamworth Hill Reservoir (end of product line), along Mandurah Road to the proposed plant at Office Road, then south along Patterson Road, then west to the coast along Ward Road (at termination of discharge line).

DISTANCE	VERGE WIDTH	VERGE DESCRIPTION
0 (at reservoir, Tamworth Hill)	10m from road edge cleared to fence line of Bush Forever Site 356.	Scattered small trees of Banksia attenuata, Allocasuarina fraseriana, Eucalyptus gomphocephala with scattered Conostylis aculeata and Acacia pulchella. Vegetation condition 5-6.
0.5 km	Cut across cleared paddock.	Avoid Eucalyptus gomphocephala trees. Vegetation condition 6.
0.7 km	Verge degraded to fence then firebreak inside.	Vegetation condition 6.
0.85 km	About 5m; fence at 10m. Close to Lake Cooloongup.	Banksia littoralis, Eucalyptus gomphocephala, Acacia saligna and Gahnia trifida on verge side of fence. Numerous weeds. Vegetation condition 4 beside fence.
1.35 km	About 10m.	Eucalyptus gomphocephala trees within 10m. Vegetation condition 5.
1.45 km	About 10m.	For about 50m on a dune higher than the road: Banksia attenuata with scattered Eucalyptus gomphocephala over Grevillea vestita and Hakea prostrata. However many weeds including lupins for more than 15m from the road. Vegetation condition 4-5.
1.5 km	About 10m.	Scattered Banksia attenuata and Xanthorrhoea preissii with occasional Banksia grandis over weeds including *Eragrostis curvula. Vegetation condition 4-5.
2.15 km	About 5m.	Melaleuca rhaphiophylla over weeds with many *Conyza sp., *Euphorbia terracina and Muehlenbeckia adpressa. Vegetation condition 4-5.
2.25 km	About 5m.	Regenerating Acacia rostellifera Scrub. Regrowth dense as the area was burnt within the last 12 months. Vegetation condition 4-5.
2.35 km	Over 5m.	Scattered Eucalyptus gomphocephala over weeds. Vegetation condition 5.
2.4 km	About 5m.	Scattered Eucalyptus gomphocephala over weeds.
2.45 km	About 5m.	Very scattered Eucalyptus gomphocephala and Banksia littoralis.
2.5 km	Road edge built up above the surrounding ground. 5m wide. If needed to make road wider would need to extend the road edge into the lakeside vegetation.	Eucalyptus gomphocephala trees burnt, but regenerating. Nearer to lake edge is regenerating Acacia rostellifera and Acacia saligna. Vegetation condition 4-5.

DISTANCE	VERGE WIDTH	VERGE DESCRIPTION
3.15 km	About 5m. This should not be widened.	The road verge immediately beside Lepidosperma effusum sedgeland. Occasional Eucalyptus gomphocephala and Banksia littoralis the only trees. Vegetation condition 3.
3.7 km Kerosene Lane turn off		
3.85 km	About 5m.	Eucalyptus gomphocephala over Lepidosperma effusum, below the level of the road. This vegetation must not be degraded. Vegetation condition 2-3.
4.6 km	About 5m.	Several trees of Melaleuca rhaphiophylla. Vegetation condition 4-5.
4.75 km	About 5m.	Area severely burnt less than 12 month ago. Large number of weeds. Eucalyptus gomphocephala trees are dense through the whole area, including the road verge. Vegetation condition 5.
4.85 km	Millar Road Turn off. Verge about 5m.	Area severely burnt less than 12 months ago. Eucalyptus gomphocephala, Acacia rostellifera, Melaleuca rhaphiophylla over Gahnia trifida, Isolepis nodosa and Lepidosperma effusum. Vegetation condition 4-5.
5.25 km	About 5m.	Dense Eucalyptus gomphocephala, some on the verge. Also burnt. Vegetation condition 5.
5.55 km	About 10m	Few large trees of Eucalyptus gomphocephala, scattered Hakea prostrata over weeds. Vegetation condition 5. End of Bush Forever Site 356.
6.15 km	Dixon Road, Gilmore Rd intersection.	Between this point and Day Road is Dense to Open Eucalyptus gomphocephala Woodland over Tall Shrubland of Acacia rostellifera. Several Xanthorrhoea preissii. More than 5m of the verge is cleared. Vegetation condition 6.
7.5 km Day Road		As above
7.55 km	More than 10m.	Dense clumps of Acacia rostellifera. Then become planted trees more than 10m from the road edge, with occasional Eucalyptus gomphocephala on verge. Vegetation condition 6.
8.3 km	Greater than 10m. Gas pipeline included in verge.	As above. Vegetation condition 6.
9.45 km	Varies, mostly greater than 10m.	Groups of Acacia rostellifera close to the road. Eucalyptus gomphocephala on the verge. Vegetation condition 6.
9.7 km	Office Road.	In front of factories scattered Eucalyptus gomphocephala, Acacia rostellifera, large Agonis flexuosa and *Schinus mollis. Vegetation condition 6.
10.05 km	About 10m.	Trees planted. Vegetation condition 6.
Patterson Road – short distance between Office and Ward Roads.	About 5m on western side, over 15m on eastern side.	Several trees planted along the western side of Patterson Road, but there is a cleared verge on the eastern side. Consideration should be giving to placing pipeline on eastern road verge.
0 at Ward Road	About 10m.	Acacia saligna with scattered Eucalyptus gomphocephala over weeds. Vegetation condition 5-6.
0.15 km	About 10m.	Grassed area with scattered trees of Acacia rostellifera, A. saligna and Xanthorrhoea preissii. Vegetation condition 6.
Ward Road to coast	No man made road or track through this area.	Open Eucalyptus gomphocephala over Open to Dense Shrubland of Acacia rostellifera over Dense Grassland of weed species. Scattered Melaleuca huegelii subsp. huegelii tall shrubs, occasional Acacia cyclops and Hakea prostrata. Vegetation condition 4.
Coast side of Rockingham Beach Road opposite Ward Road	Less than 5m	Shrubland of Acacia cyclops over Sedgeland of Lepidosperma gladiatum. Several *Leptospermum laevigatum. Coast edge is a Grassland of Spinifex longifolius. Vegetation condition 3-4.
Along coast		Pipeline will be below low water mark.

KPS site pipeline routes

This proposed alignment traversed a route from the reservoir on Henderson Road, along Hope Valley Road, then along Holmes Road to the railway line which was followed to Beard Street Kwinana

Beach, then along Leath Road to the Kwinana Power Station and through the area in front of the power station and refinery to the beach south of the Alcoa wharf. The section beside the railway line could not be accessed. Power lines and the gas pipeline are already on the side proposed for the pipeline route. Where it was possible to access the railway it was degraded and cleared for the placement of other infrastructures.

DISTANCE	VERGE WIDTH	VERGE DESCRIPTION
0.0 km Leath Road – entrance to Kwinana Power Station	About 7.5m to fence line	Grass only. Vegetation condition 6.
0.3 km Turn into Beard Road	About 7.5m.	Weeds including *Nicotiana glauca and *Ricinus communis and several different grasses. Vegetation condition 6.
0.4 km	About 7.5m.	Very Open Shrubland of Acacia saligna and Spyridium globulosum over weeds. Vegetation condition 4.
0.5 km	About 7.5m.	Scattered Acacia saligna and Spyridium globulosum over weeds to the road edge. Vegetation condition 5.
0.9 km - cross Rockingham Road	Built up to go over road. More than 10m.	Same as above but a large number of *Ricinus communis. Vegetation condition 5-6.
Along the railway near Lee Road cleared along the length for about 10m. There were occasional areas of dense Acacia rostellifera and occasional Acacia lasiocarpa where there was limestone. The understorey consisted of weeds. Vegetation condition 5.		
Hope Valley Road crossing, there is power and gas laid beside the railway on the east side. South of this area is cleared as far as can be seen. North of this area the track is narrow and down in a cutting, so if this were the chosen route the pipeline would need to be placed on the cleared higher ground. Vegetation condition 6.		
Wattleup Road crossing. Cleared to the north. Vegetation condition 6.		
Stamford Road crossing. On the higher ground above the railway line it is cleared to 15m. All degraded with occasional Acacia rostellifera shrubs. Vegetation condition 6.		
0.0 km at Moylan Road, which runs on the east side of the railway line.	More than 15m.	Completely degraded. Vegetation condition 6.
0.4 km Dallison Ave.	Road verge about 5m. Inside railway reserve fence greater than 10m. Pipeline alignment is to be within the railway reserve.	Shrubland of Calothamnus quadrifidus, Jacksonia furcellata and Hakea prostrata over Xanthorrhoea preissii and Hibbertia hypericoides over grass weeds. Vegetation condition 5.
0.8 km.		Weeds on railway reserve. Vegetation condition 6.
1.2 km.		Beside the railway line there are a lot of Xanthorrhoea preissii, weeds in remainder of railway reserve. Vegetation condition 6.
1.4 km		Dense Xanthorrhoea preissii, Macrozamia riedlei and Jacksonia furcellata over weeds. Vegetation condition 5.
1.6 km		Scattered Xanthorrhoea preissii and Macrozamia riedlei over weeds. Vegetation condition 5-6.
1.75		Scattered Jacksonia furcellata and Acacia saligna over weeds. Vegetation condition 5-6.
1.8 km		Several Xanthorrhoea preissii along the edge of the railway. Mainly weeds over the cleared gas pipe. Vegetation condition 6.
2.75 km cross Russell Road.		
2.8 km Turn into Holmes Road		
2.85 km	About 5m.	Weeds only along verge except in front of private properties where scattered endemic and exotic plants occur. Vegetation condition 6.
3.5 km	About 5m.	Scattered plants of Xanthorrhoea preissii and Jacksonia furcellata over weeds. Vegetation condition 5-6.
3.6 km	About 5m.	Planted, non-endemic Eucalyptus species. Vegetation condition 6.

DISTANCE	VERGE WIDTH	VERGE DESCRIPTION
3.75 km	About 10m.	Scattered native species. Vegetation condition 6.
3.85 km - Henderson Road	About 5m on west side, 15m on east side.	On the west side there are several shrubs planted in front of the houses. On the east side it has been cleared to at least 15m. Vegetation condition 6.

Woodman Point pipeline routes

This alignment traversed the same route as the Kwinana Power Station from the water tower in Henderson Road to the junction of Russell Road with Moylan Road. The alignment then follows Russell Road to Lake Coogee where it enters the Water Corporation land at Woodman Point, emerging at Cockburn Road before going along O'Kane Crt, Jervoise Bay Cove and Woodman Point View to enter the sea at the western end of the point.

As agreed, the Water Corporation land was not entered during the current survey. From the aerial photographs provided and knowledge of the vegetation of the area, the proposed alignment is predominantly through weeds with possibly a short section through a stand of *Eucalyptus gomphocephala*.

DISTANCE	VERGE WIDTH	VERGE DESCRIPTION
0.0 – Russell Road	At least 10m	Cleared land. Vegetation condition 6.
0.2 km	About 10m.	Scattered Eucalyptus gomphocephala and planted non-native shrubs and trees. Vegetation condition 6.
0.35 km	10-15m	Open Shrubland of Acacia saligna over a Dense Low Shrubland of Grevillea vestita over weeds. Also scattered Xanthorrhoea preissii and Eucalyptus gomphocephala. Vegetation condition 4-5.
0.6 km	Verge cleared for 15m.	Lot of planted Eucalyptus species. Scattered Acacia saligna and Xanthorrhoea preissii. Vegetation condition 5-6.
0.95 km	No verge.	Many Xanthorrhoea preissii up to road edge. Vegetation condition 4-5.
1.1 km – Cross over Rockingham Road		
1.35 km	5-10m.	Reserve on the north side, very degraded on the south side. Vegetation condition 6. Between this point and where the alignment enters the Water Corporation land both sides have a vegetation condition of 6.
2.55 km – where enters into water Corporation land.		
Enter onto Cockburn Road	5-10m	Scattered Acacia rostellifera over weeds. Vegetation condition 5-6.
0.0 Turn off into O'Kane Crt.	The vegetation is often at the road edge. However it varies as it can be up to 5m away. The Cockburn Cement pipeline is aligned on the north side of the road. This alignment is already degraded. Vegetation condition on south side of road 3-4.	Vegetation condition 6 on north. Dense Acacia cyclops on south – vegetation condition 4-5.
0.15 km		Regenerating Acacia cyclops on the south. Vegetation condition 4-5.
0.35 km		Vegetation condition 4-5 on north, 5 on south as dense infestation of *Asparagus asparagoides.
0.45 km – Turn off into Woodman Point View		
1.2 km		Open Grassland of Spinifex longifolius beside Open Shrubland of Acacia cyclops on south. Vegetation condition 3-4.
2.5 km – end of track	Cleared of all vegetation.	Currently this area is being developed. Vegetation condition 6.

APPENDIX 3

ASSESSMENT FRAMEWORK AND POLICY CONTEXT FOR FLORA AND FAUNA

Appendix 3 Assessment framework and policy context for Flora and Fauna

Assessment framework or policy context for vegetation and flora

National Strategy for Conservation of Australia Biodiversity

The State and Commonwealth Governments have endorsed the National Strategy for Conservation of Australia Biodiversity and the National Strategy for Ecologically Sustainable Development that protects biodiversity. The strategies address the conservation of Australia's biological diversity through:

- identification of ecosystems, species and subspecific variation;
- bioregional planning and management;
- management for conservation;
- establishing and managing a comprehensive, adequate and representative system of protected areas;
- improving biological diversity conservation outside conservation reserves;
- recognising the contribution of ethno-biological knowledge of indigenous peoples to the conservation of biodiversity;
- integration of biological diversity conservation and natural resource management;
- management of threatening processes such as clearing, alien species, fire, pollution and climate change through effective rehabilitation;
- improvement of knowledge and understanding of biological diversity;
- enhancement of community involvement and awareness; and
- using Australia's international role to promote biological diversity conservation.

The principles adopted by the strategies are described below:

1. Biological diversity is best preserved in-situ.
2. Although all levels of government have clear responsibility, the cooperation of conservation groups, resource users, indigenous peoples, and the community in general is critical to the conservation of biological diversity.
3. It is vital to anticipate, prevent and attack at source the causes of significant reduction or loss of biological diversity.
4. Processes for and decisions about the allocation of Australia's resources should be efficient, equitable and transparent.
5. Lack of full knowledge should not be an excuse for postponing action to conserve biological diversity.
6. The conservation of Australia's biological diversity is affected by international activities and requires actions extending beyond Australia's national jurisdiction.
7. Australians operating beyond our national jurisdiction should respect the principles of conservation and sustainable use of biological diversity and act in accordance with any relevant national or international laws.
8. Central to the conservation of Australia's biological diversity is the establishment of a comprehensive and adequate system of ecologically viable protected areas integrated into

sympathetic management of all areas, including agricultural and other resource production systems.

9. The close, traditional association of Australia's indigenous peoples with components of biological diversity should be recognised, as should the desirability of sharing equitably benefits arising from the innovative use of traditional knowledge of biological diversity.

EPA position statement No 2

The EPA regards biological diversity as being a key environmental factor in the State (EPA 1999). The EPA will focus on the principles (see above) and the related objectives and actions of the National Strategy for Conservation of Australia's Biological Diversity. The EPA, in assessing a clearing proposal outside the Agricultural Region will include the following basic elements in its consideration of biological diversity:

- comparison of development scenarios or options to evaluate protection of biodiversity at the species and ecosystem levels;
- no known species of plant or animal is caused to become extinct as a consequence of the development and the risks to threatened species are considered to be acceptable;
- no association or community of indigenous plants or animals ceases to exist as a result of the project;
- there is comprehensive, adequate and secure representation of scarce or endangered habitats within the project area and/or in areas which are biologically comparable to the project area, protected in secure reserves;
- if the project is large (in the order of 10 ha to 100 ha or greater, depending on where in the State) the project area itself should include a comprehensive and adequate network of conservation areas and linking corridors whose integrity and biodiversity are secure and protected; and
- the on-site and off-site impacts of the project are identified and the proponent demonstrates that these impacts can be managed.

Biodiversity has two key aspects:

- its functional value at the ecosystem level; and
- its intrinsic value at the individual species, species assemblages and genetic levels.

Significance of vegetation

The significance of vegetation lost or disturbed by the proposal was determined by considering the following:

- any special ecological functions of the vegetation;
- regional and local abundance and function of the vegetation communities;
- representation in existing or proposed conservation reserves and State Forest;
- condition of the vegetation;
- presence of Priority or Declared Rare Flora species;
- important fauna habitat functions;
- presence of threatening processes (for example, weeds, dieback); and
- presence of Threatened Ecological Communities (TECs) as listed by the Department of Conservation and Land Management and under the EPBS Act.

In the Perth Metropolitan Region, the presence of a vegetation complex, as mapped by Heddle *et al*. 1980, of which less than 10% remains in the region, is also of high significance. There is a general presumption against clearing such bushland under the Bush Forever policy (Government of Western Australia 2000).

Significant flora

The preservation and conservation of flora is covered primarily by the following three Western Australian and one Commonwealth statutes:

- *Wildlife Conservation Act* 1950;
- *Conservation and Land Management Act* 1984;
- *Environmental Protection Act* 1986; and
- *Environmental Protection and Biodiversity Conservation Act* 1999 (Commonwealth).

CALM also lists flora species on Priority lists (CALM 1998) as follows:

- **Priority 1** taxa are defined as taxa which are known from one or a few (generally <5) populations which are under threat, either due to small population size, or being on lands under immediate threat.
- **Priority 2** taxa are defined as taxa which are known from one or a few (generally <5) populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered).
- **Priority 3** taxa are defined as being Poorly Known Taxa- taxa which are known from several populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered).
- **Priority 4** taxa are defined as being taxa which are considered to have been adequately surveyed and which, whilst being rare (in Australia), are not currently threatened by any identifiable factors.

Assessment framework or policy context for fauna

The conservation status of fauna species is assessed under Federal and State Acts such as the:

- Commonwealth EPBC Act; and the
- WA Wildlife Conservation Act.

These use levels of significance recommended by the International Union for the Conservation of Nature and Natural Resources (IUCN) and reviewed by Mace and Stuart (1994), although the WA Act also has a category of “Other Specially Protected Fauna” that has no equivalent IUCN level.

In addition, Environment Australia has supported the publication of reports on the conservation status of reptiles (Cogger *et al.* 1993) and birds (Garnett and Crowley 2000), while the Threatened Species and Communities Section of Environment Australia has produced a list of Threatened Australian Fauna (Environment Australia 1999), although this list is effectively a precursor to list produced under the EPBC Act. These publications also use the IUCN categories, although those used by Cogger e*t al.* (1993) differ in some respects as this report pre-dates Mace and Stuart’s review.

In Western Australia, the Department of Conservation and Land Management has produced a supplementary list of Priority Fauna, being species that are not considered Threatened under the IUCN categories but which the Department feels there is cause for concern. Levels of Priority are described below:

- Priority 1 – taxa with few, poorly known populations on threatened lands.
- Priority 2 – taxa with few, poorly known populations on conservation lands.
- Priority 3 – taxa with several, poorly known populations, some on conservation lands.
- Priority 4 – taxa in need of monitoring.

In addition to the assessment of fauna under the CALM Priority list and the IUCN categories, some fauna are recognised under international treaties such as the China Australia Migratory Bird Agreement (CAMBA) and the Japan Australia Migratory Bird Agreement (JAMBA). Species listed under these agreements are mostly migrants that spend part of the year in each country, although some of the species are non-migrants but occur in both countries.

Fauna species included under Commonwealth conservation acts and/or agreements and of national significance, while those listed as Priority Species, can be considered of regional significance, and possibly of national significance. Those for the Perth region are summarised in Bush Forever (Government of Western Australia 2000). Species that are not listed under any of the above categories can be considered of Regional Conservation Significance if they are at the limit of their distribution or are common but within a very restricted range.

APPENDIX 4

MODELLED GROUND LEVEL CONCENTRATIONS OF NOx OVER 1 HOUR AND ANNUAL AVERAGING TIMES AT THE EAST ROCKINGHAM SITE FOR POTENTIAL GAS ENGINE AND GAS TURBINE POWER STATIONS

Prepared by

Environmental Alliances

Appendix 4 Modelled ground level concentrations of NOx over 1 hour and annual averaging times at the East Rockingham Site for potential Gas Engine and Gas turbine power stations

The dispersion of nitrogen oxides (NOx) emissions for the gas engine and gas turbine power supply options was modelled using the TAPM model (Hurley 1999) and meteorological data for the 1999 year.

The stack emission parameters used for the modelling are shown in Table 1. At this stage, potential building wake effects have not been considered.

The modelling of both options assumes no heat recovery from the emissions.

Table 1 Gas turbine stack emission parameters

Parameter	Gas engine	Gas turbine
Stack height above ground (m)	20	20
Emission temperature (C)	425	472
Emission volume flow (Nm^3/s)	29.5	73.4
NOx emission rate (g/s)	6.6	4.4
Nitrogen dioxide emission rate (g/s) [a]	3.3	2.2

[a] Based on assumption that 50% of NOx is NO_2. This should be conservative.

Nitrogen dioxide is a potential respiratory irritant. Standards for nitrogen dioxide are contained in the National Environment Protection Measure (NEPM) for Ambient Air Quality (NEPC 1998), shown in Table 2.

Table 2 Nitrogen dioxide Standards in the NEPM for Ambient Air Quality

Nitrogen dioxide concentration	Averaging time	Maximum allowable exceedences
0.12 ppm (≈246 $\mu g/m^3$)	1 hour	1 day a year
0.03 ppm (≈62 $\mu g/m^3$)	1 year	none

The maximum 1-hour and annual average nitrogen dioxide concentrations predicted by the modelling for the gas engine option are shown in Figures 1 and 2 respectively. The maximum 1-hour and annual average nitrogen dioxide concentrations predicted by the modelling for the gas turbine option are shown in Figures 3 and 4 respectively.

A summary of the predicted maximum nitrogen dioxide concentrations compared to the NEPM Standards is shown in Table 3. For both power options, the maximum predicted concentrations are well below the Standards. The predicted concentrations from the gas turbine option are nearly half that of the gas engine option. This is due to a combination of a lower NOx emission rate and a greater emission buoyancy.

Table 3 Maximum predicted nitrogen dioxide levels for gas engine and gas turbine options

Averaging time	NEPM Standard	Gas engine	Gas turbine
1 hour	0.12 ppm (≈246 μg/m^3)	11	6
1 year	0.03 ppm (≈62 μg/m^3)	2.2	1.2

The greatest nitrogen dioxide impact is the gas engine option compared to the 1-hour average Standard. In this case, the maximum predicted concentration is still less than 5% of the Standard. It is therefore considered that nitrogen dioxide emissions from the proposal would be an insignificant contribution to levels within the air-shed, irrespective of the power option chosen.

Hurley, P.J., 1999, "The Air Pollution Model (TAPM) Version 1: Technical Description and Examples", CSIRO Atmospheric Research Technical Paper No 43.

National Environment Protection Council (NEPC), 1998, "National Environment Protection Measure for Ambient Air Quality", 26 June 1998.

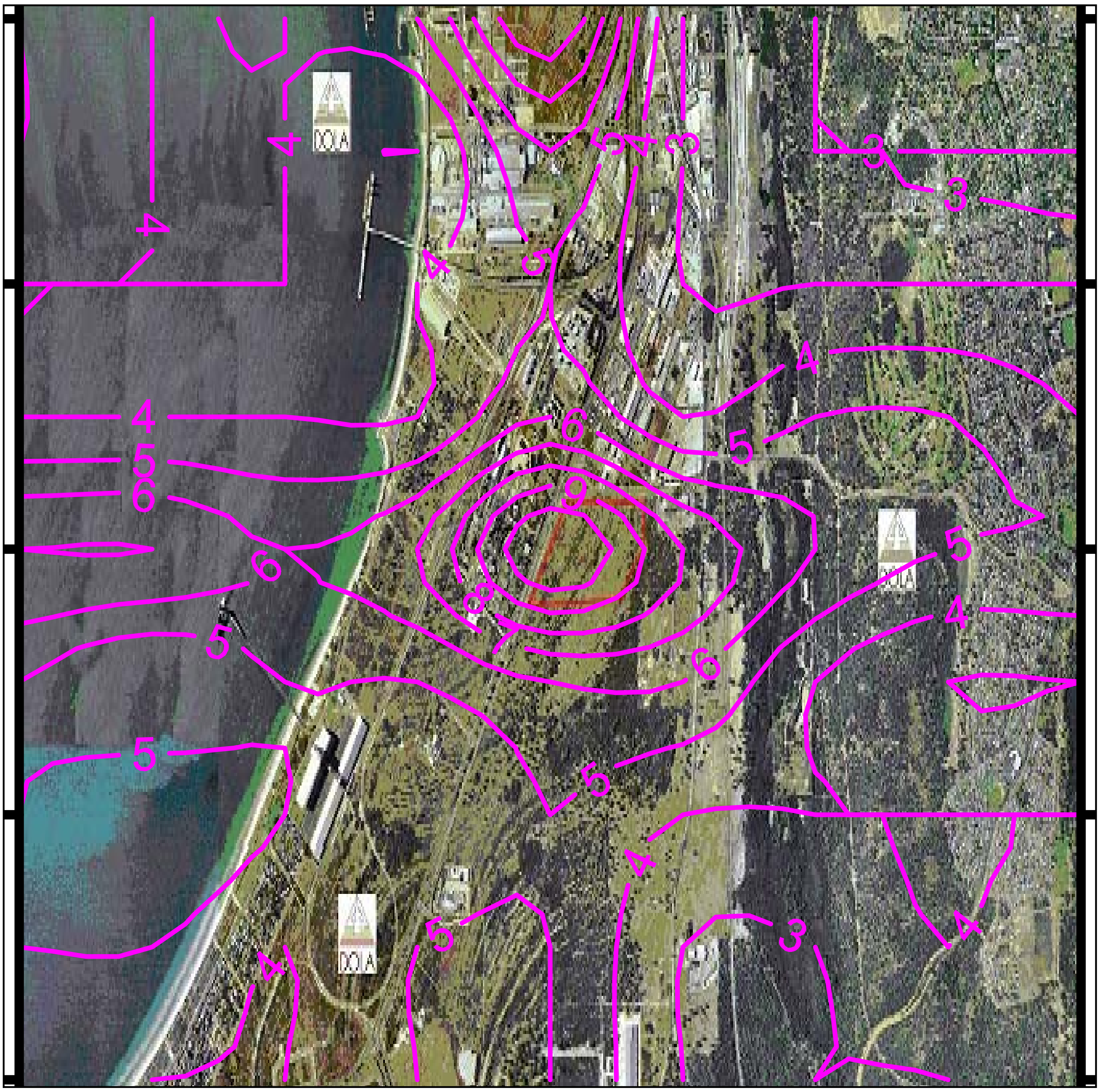

Figure 1 Predicted maximum 1-hour average nitrogen dioxide concentrations ($\mu g/m^3$) from proposed desalination plant gas engine

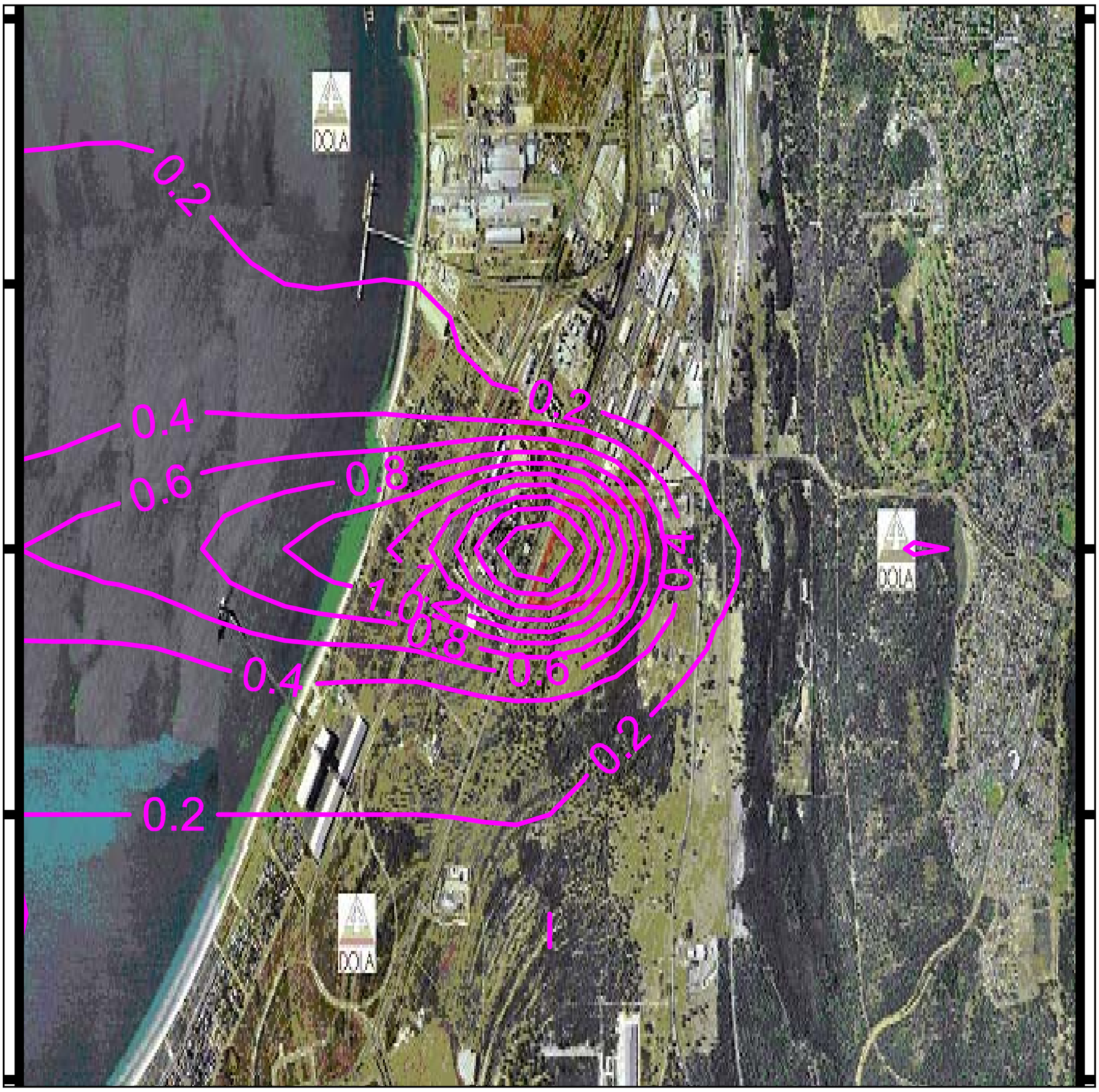

Figure 2 Predicted annual average nitrogen dioxide concentrations ($\mu g/m^3$) from proposed desalination plant gas engine

Figure 3 Predicted maximum 1-hour average nitrogen dioxide concentrations ($\mu g/m^3$) from proposed desalination plant gas turbine

Figure 4 Predicted annual average nitrogen dioxide concentrations (μg/m^3) from proposed desalination plant gas turbine