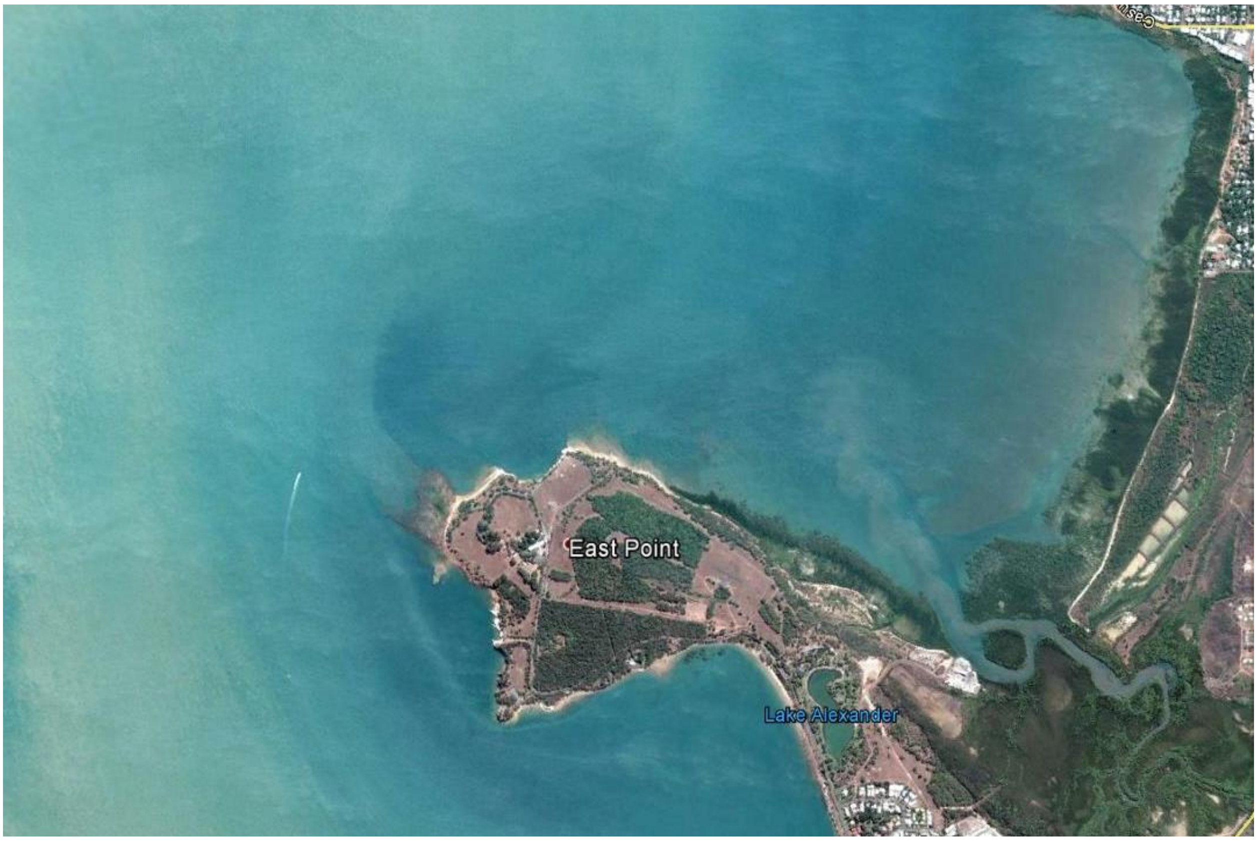
POWER AND WATER CORPORATION



East Point Outfall - Benthic Infauna Monitoring and Management Plan

May 2016

PowerWater

Executive Summary

Ludmilla Wastewater Treatment Plant is located close to Ludmilla Creek on Dick Ward Drive between Fannie Bay and Coconut Grove, north of the Darwin central business district. Advanced primary treated wastewater from the plant that is not reused is discharged to Darwin Harbour via an intertidal outfall located north of East Point in the bay between East Point and Nightcliff, several hundred metres offshore.

The closure of the Larrakeyah macerator and outfall in late May 2012 resulted in an increase in the inflow to the Ludmilla WWTP from Larrakeyah and Darwin sewage catchments and consequent increased flow of effluent from the plant to the outlet require the duplication of the rising main from the treatment plant to the marine outfall to minimise diversion of high flows to Ludmilla Creek.

The Commonwealth Department of the Environment approval and Northern Territory Environment Protection Authority assessment for the construction and operation of the duplicate rising main both included the requirement for a Benthic Infauna Monitoring and Management Plan (BIMMP) to document the extent of the impact of the existing discharge arrangement on ecosystem indicator species, and to protect the foraging areas of inshore dolphins, turtles and dugongs. Commissioning of the duplicate main cannot commence until the BIMMP is approved by the Commonwealth Minister.

This document presents the background and design of an effluent exposure gradient-based benthic infauna monitoring program. The program includes management triggers and a response plan to protect ecosystem values more than 200 m from the existing outlet. The gradient-based benthic infauna monitoring program was designed on a demonstrated understanding of effluent dispersion and environmental exposure processes, experience with benthic monitoring programs at other municipal outfalls, use of the results of infauna surveys at East Point outlet in 2013/14 and review of the requirements of the regulatory authorities.

The monitoring program includes seasonal surveys of benthic infauna along transects radiating from the existing outfall and seasonal surveys of seagrass beds up to 2 km from the existing outfall. The sampling sites, sampling methods, data analysis and reporting requirements are described for both the benthic infauna monitoring component and the seagrass bed monitoring component of the Plan.

Marine ecosystem triggers are specified for three tiers of management response, which are described from lowest to highest response:

Level 1 Identify and Monitor

Level 2 Alert and Prepare

Level 3 Act and Manage

The importance of integrating the Benthic Infauna Monitoring and Management Plan with other marine environmental regulatory and monitoring tools to manage the effluent discharge at East Point outfall is discussed.

A reporting protocol for reporting in response to ecosystem triggers and general environmental assessment is discussed.

This report was prepared by Consulting Environmental Engineers (CEE) for the exclusive use of Power and Water Corporation.

FIGURES

TABLES

1 Background

Power and Water Corporation of the Northern Territory (PWC) is responsible for collection, treatment, reuse and disposal of municipal wastewaters in Darwin and elsewhere in the Northern Territory.

Ludmilla Wastewater Treatment Plant (WwTP), constructed in 1975, is located close to Ludmilla Creek on Dick Ward Drive between Fannie Bay and Coconut Grove, north of the Darwin CBD. Advanced primary treated wastewater from the plant is discharged to Darwin Harbour via an intertidal outfall located several hundred metres off shore to the north of East Point in the bay between East Point and Nightcliff.

On 31 May 2012 the Larrakeyah macerator and outfall were closed and sewage from the Larrakeyah catchment redirected to Ludmilla wastewater treatment plant, this represented the completion of Stage 1 of the Larrakeyah closure plan. The Larrakeyah closure plan is a key component of PWC's commitment to improve the performance of the Darwin Region's wastewater treatment and disposal facilities and reduce the potential impacts on the environment from sewerage operations. The closure of the Larrakeyah outfall resulted in an increase in the average dry weather inflow (ADWF) to Ludmilla WwTP from 9.5ML/day before to 12.5 ML/day after the closure with the current ADWF of 13.7 ML/day or 158 L/second.

Stage 2 of the closure plan involved the upgrading of the Ludmilla Wastewater Treatment Plant (WwTP) to cater for the diverted load from the Larrakeyah and Darwin CBD areas following the closure of the Larrakeyah outfall. The upgrade provided additional capacity to provide for the immediate increased load and for future population growth. The treatment plant upgrade was completed in April 2013.

The upgrade has improved the discharge water quality. In 2011-12, prior to the closure the East Point Outfall (EPO) discharged 23 tonnes of total phosphorus (TP) and 180 tonnes of total nitrogen (TN); in 2013-14 despite the increased wastewater discharge the loads were 13 tonnes TP and 186 tonnes of TN respectively. This represents an overall decrease in all contaminants to Darwin Harbour but an increase in TN discharged via the EPO.

The East Point rising main (EPRM) carries treated wastewater from the Ludmilla WwTP to the EPO. The EPRM is currently restricted to 300 L/second. The increased inflow to Ludmilla WwTP has resulted in an increase in the volume of treated wastewater discharged to Ludmilla Creek, particularly in the wet season. Stage 3 of the Larrakeyah Closure plan, the construction of an augmented (duplicated) rising main to East Point will increase the capacity from 300 L/second to 1000 L/second. The construction works for the duplicated EPRM were completed in late 2014 with commissioning to be conducted during 2015.

1.1 Need for Benthic Infauna Monitoring and Management Plan

The increased inflows to the Ludmilla WwTP from Larrakeyah and Darwin CBD sewage catchments due to the closure of the Larrakeyah outfall have increased the flow of effluent from the Ludmilla WwTP. The duplication of the EPRM from the treatment plant to the EPO will minimise the discharge of treated wastewater Ludmilla Creek and result in an increase in wet season discharges at the EPO. The increased wet season discharge is not expected to increase the impact zone however benthic infauna monitoring is a valuable tool to identify changes in the zone of influence of the current outfall and will inform decision relating to Stage 4 of the Larrakeyah closure plan which is to assess options for the relocation of the outfall from the current intertidal site to an outfall in deeper water further offshore.

2 Background to BIMMP

The Northern Territory Environment Protection Authority assessment recommendation (NT EPA 2012) and the Commonwealth Department of the Environment approval (Ward 2013) for the construction and operation of the augmented (duplicated) rising main both included the requirement for a Benthic Infauna Monitoring and Management Plan (BIMMP) to document the extent of the existing discharge's impact on ecosystem values, to demonstrate protection of dolphin, turtle and dugong habitat in the vicinity of the current outfall and to inform decisions on potential relocation of the outfall further offshore.

Commissioning of the duplicate main cannot commence until the BIMMP is approved by the Commonwealth Minister. PWC contracted CEE Consultants to develop a suitable Benthic Infauna Monitoring and Management Plan to satisfy the requirements of the NT EPA recommendation and Commonwealth Approval. This report reviews recent information on marine ecological conditions at the outfall, presents a rationale for the design of a monitoring program and describes the recommended monitoring program for review by the Commonwealth and NT regulators.

2.1 Regulators Requirements

Northern Territory environmental assessment recommendations and Commonwealth regulatory approval for the project both included requirements for a marine ecological monitoring program focused on benthic infauna.

2.1.1NT EPA Requirements

Northern Territory EPA assessment recommends benthic infauna monitoring to inform amendments to the discharge licence applicable for the Ludmilla Wastewater Treatment Plant. The NT EPA assessment of the rising main project recommends that PWC undertake benthic infauna monitoring along a gradient away from the outfall to 'verify levels of impact relating to the current outfall mixing zone'. Sediment particle size analysis must be conducted at monitoring sites in addition to collecting data on the infauna community.

The NT EPA assessment (NT EPA 2012) of the works included the two recommendations.

> *Recommendation 6: Benthic Infauna Survey*
>
> The Proponent is required to undertake a Benthic Infauna Survey along a gradient away from the current EPO to verify levels of impact relating to the current outfall mixing zones. Survey design may require inclusion of sediment particle size analysis, and should be developed in consultation with NT EPA. Interpreted results should be submitted to NT EPA within 12 months of this Report and will inform conditions on the Waste Discharge Licence.
>
> *Recommendation 8: Benthic Infauna Monitoring Program*
>
> The Proponent is to design and implement an annual Benthic Infauna Monitoring Program to the satisfaction of the NT EPA (Informed by outcomes of Recommendation 6). Monitoring should be conducted and reported annually to NT EPA until the East Point Outfall extension is completed.

2.1.2Commonwealth Requirements

Approval from the Commonwealth Department of Environment (DoE) was required under the Environment Protection and Biodiversity Conservation Act due to the perception that the project may impact on Matters of National Environmental Significance including threatened and migratory marine species. DoE was particularly concerned that the 'foraging habitat for marine turtles, inshore dolphins and dugong (Dugong dugong)' remained protected. DoE reiterated the requirements of the NT EPA, adding that the monitoring plan must be reviewed by the independent technical advisor prior to being submitted to the Commonwealth Minister for approval.

The Commonwealth approval of the East Point Rising Main augmentation works (Ward 2013) includes specific requirement for a Benthic Infauna Monitoring and Management Plan.

Condition 14: Benthic Infauna Monitoring and Management Plan (BIMMP)

> *'The person taking the action must submit a BIMMP for the Minister's approval to protect the foraging habitat for marine turtles, inshore dolphins and dugong (Dugong dugong). The duplicated rising main cannot be commissioned until the Minister has approved the BIMMP. The BIMMP must:*
>
> *a) be informed by a benthic infauna survey of all benthic habitats within a 1000 m radius of the existing outfall to verify levels of impact relating to the existing outfall mixing zones. Survey design must include sediment particle size analysis.*
>
> *b) include ongoing monitoring of benthic infauna within a 1000 m radius of the existing outfall (as shown in Appendix B) until the existing outfall becomes non-operational.*
>
> *c) include defined threshold trigger levels for sensitive receptors, mitigation/management responses for actions when thresholds are reached and reporting requirements for exceedances of trigger levels.*
>
> *d) monitoring must be conducted once every six calendar months and results reported to the department annually until the existing outfall (as shown in Appendix B) becomes non-operational.'*

The Commonwealth Approval makes it clear that the benthic infauna monitoring and management plan is to follow the principles of adaptive management and Condition 15 states:

> *'Management plans must be reviewed annually, from the date of approval, by the independent technical reviewer to enable continuous improvement and adaptive management of water quality and benthic infauna. The person taking the action must provide to the Minister a copy of all advice and recommendations made by the independent technical reviewer and an explanation of how the advice and recommendations will be implemented within the management plan(s) or an explanation of why the person taking the action does not propose to implement certain recommendations. This information must be provided to the Minister when the management plan(s) are submitted for approval.'*

The key species listed in the Commonwealth approval, turtles, dolphins and dugong are not directly reliant on infauna. Turtles and dugong in the Darwin coastal region feed on seagrasses and some other marine plants. A benthic infauna monitoring program is unlikely to inform the effect of the outfall on priority habitat for turtles or dugongs. Hence, the recommended monitoring program includes monitoring of seagrass extent, composition and density in the vicinity of the outfall. Inshore dolphins range along the coast and feed on fish and cephalopods (squid and octopus). Seagrasses may provide some useful habitat for fish and cephalopods and hence benefit inshore dolphins. Fish and cephalopods may also forage over the intertidal mudflats at high tide, thereby indirectly benefiting from the infauna community.

2.2 Independent Reviewer

As required by Condition 11 of the Commonwealth Approval, PWC has contracted an independent technical reviewer to provide advice, scope of works (GHD 2013) and review of the BIMMP prior to approval of the BIMMP by the Commonwealth Minister.

The independent reviewers' Scope of Works informed the initiation of a preliminary survey of sediment and infauna to document conditions in the region of the East Point outfall (EOP) during the 2013-14 wet and dry seasons (Jacobs 2014).

As required by the NT EPA recommendations and Commonwealth Government approval for the augmentation of the East Point Rising Main the outcomes of the 2013-14 has been used to inform the design of the ongoing BIMMP. The recommended design will be reviewed by the independent reviewer prior to being submitted to the regulators from approval.

3 Effluent Exposure Gradient

Wastewater outfalls discharge water constituents (freshwater, nutrients, toxicants) at concentrations that are generally substantially higher than the concentrations in the water body receiving the wastewater. The concentrations of constituents in the marine environment decrease with distance from the outfall at a rate depending on the volume of the discharge and the mixing characteristics of the discharge and receiving environment.

The response of biological communities to wastewater depends on their degree of exposure to the dispersing effluent (Appendix A). Exposure of biological communities to the dispersing effluent depends on their distance from the outfall:

- Plant and animal assemblages close to the discharge can be expected to show a stronger response compared to those further away;
- The magnitude of response shown by a biological indicator, such as individual species abundances, species richness or composition, will decrease with distance from an outfall.

The understanding of ecological changes along effluent exposure gradients has been understood for at least decades (Appendix A). The need for simple techniques to document ecological changes along effluent exposure gradients to determine the extent and magnitude of ecological effect of discharges in the marine environment in Australia is recognised but not widely used (Carey 2002, ANZECC & ARMCANZ 2000).

3.1 Ecological Monitoring along Effluent Exposure Gradients

CEE has applied the gradient monitoring approach to a wide range of wastewater discharges in Australia, ranging from intertidal discharges on soft seabeds and reef platforms to subtidal discharges through open-ended pipes or through diffusers designed to produce specific minimum effluent dilutions (Table 9). Discharge volumes range from less than 0.1 ML/d to 400 ML/d and include intertidal open ended pipe discharges, submerged open ended pipe discharge and submerged outfall diffusers designed to produce specific near-field initial dilution. The results of the studies are available as technical reports to the various water authorities, examples are discussed in Appendix A.

The gradient monitoring approach requires establishing monitoring sites along exposure gradients around an outfall and documenting the patterns of distribution of biota along the exposure gradients. In rivers, streams and estuaries, the response of biota to a downstream effluent exposure gradient may be overlapped by other natural gradients (salinity, seabed composition, nutrient gradients, and turbulence) and so interpretation of changes in the ecological community due to effluent exposure alone along a downstream gradient (Figure 10) is confounded by these other overlapping factors. This is a recognised complication in the interpretation of effects using not only the gradient approach (Downes et al. 2002), but also BACI-style programs including MBACI(p) (McGuiness 2003). Further discussion of the gradient approach and 'BACI' are included in Appendix A.

Dispersion in the open marine environment is usually greater than in relatively one dimensional river and river-estuary environments. The maximum exposure gradient in an open marine environment corresponds to the pathway or pathways along which the effluent most commonly travels. The most common pathways are the result of winds and ambient currents and conform to the laws of physics. Hence, they are usually parallel to shore, with the average concentration of effluent decreasing with distance from the outfall along the dispersion pathway. The abundance of numerous species at sites can simply be plotted along the dispersion pathway (distance from discharge point) to provide transparent evidence of spatial patterns that are consistent with likely effects of the effluent. Absent or inconsistent patterns are indicative of very sparse abundances, small effects of wastewater exposure or effects of factors other than wastewater exposure.

The value of the effluent gradient approach is that exposure gradient studies can be designed to represent plausible dispersion gradients; multiple contaminant and stressor sources; variable contaminant or stressor strengths; and variation in the nature of ecosystem effects. Such studies give the impression of a simple dose-response assessment (Downes et al 2002), however the interaction of multiple species in the real environment with the potential for multiple contaminant sources can result in successional replacement of tolerant or hardy species (positive indicators) or replacement by more sensitive species (negative indicators) as distance along the gradient increases (Figure 10, Figure 14).

Assessment of the monitoring can require a more flexible approach to the interpretation of the dosage response than simple univariate analysis and the gradient approach is of benefit in data interpretation.

Gradient approaches to impact assessment also benefit from ‘before’ or baseline surveys, multiple surveys over time and documentation of characteristics at ‘control’ or reference sites, for the same reasons as the BACI approach. The detection of a spatial gradient radiating from the discharge point without ‘before’ data must be conservatively interpreted as an effect. Further evidence, such as wider spatial ecological sampling, water quality surveys, presence of known positive or negative indicator species and toxicity tests are required to address the possibility that the pattern naturally occurred in the area without the effluent discharge (a ‘false positive’). In rivers and estuaries this can result in the need for elaborate, complex and expensive sampling programs (McGuiness 2003). Temporary gradients or changes in the ‘strength’ of gradients (change in distance of effect or proportional change in abundance between surveys) may also occur either as a ‘coincidence’ or due to combinations of real factors over time (Underwood 1992, Downes et al 2002). Hence, the understanding and definition of impacts and their spatial extent in the context of natural variations and perturbations (Bender et al. 1984) become clearer as the period of monitoring increases, and preferably with the benefit of ‘before’ data or descriptions.

In the marine environment, it is possible to measure gradients radiating from a point source. The use of multiple transects radiating from the outlet is a way of providing multiple tests of consistency with the interpretation that the pattern in biota is consistent with a effluent exposure gradient radiating from point of discharge without having to replicate the discharge. This does not require exactly the same pattern to occur along all transects because there is no assumption that the exposure gradient is symmetrical around the discharge. In fact we are trying to determine the pattern and compare it with other factors. The pattern does not have to represent a ‘bull’s-eye’ if currents transporting the effluent are stronger in particular directions, when an elongate pattern is likely. The detection of high abundances of probable positive indicators close to the discharge and increasing numbers of sensitive or negative indicators at distance along multiple transects provides good evidence of the presence of an impact and its extent (Fairweather 1993). Data that showed the patterns were absent ‘before’ the discharge commenced would, of course, make the conclusion of impact causation considerably stronger (Downes et al 2002, Gray and Pearson 1982).

3.2 Considerations for Gradient Approach at East Point Outfall

Infauna populations in open water environments are usually highly variable at small and large spatial scales. They also vary over periods of months, seasonally and inter-annually (Carey 2002, Hewitt & Thrush 2007). It is likely that the East Point Outfall discharge impacts on infauna communities (if detectable) will vary over time and may be evident on different species at different times (seasons and years). Small spatial scale (metres) variations in distribution at individual sites will require sampling at different spatial scales along the effluent exposure gradient.

Sediment particle size can be another natural influence on infauna characteristics if there is sufficient variation in the substratum between sites or along the effluent exposure gradient. Sediment characteristics (particle size distribution) at each site will require documentation.

It is considered that there is sufficient load of suspended material in the EPO primary effluent (median suspended solids concentration 33.5 mg/L, daily average effluent flow 15.6 ML/day) to result in a localised increase in infauna abundance: suspended solids provide food for many filter-feeding and deposit feeding invertebrates.

3.2.1Effluent Dispersion

The position of sites for gradient-style assessments and monitoring programs should be arranged along likely dispersion pathways, on seabed with similar characteristics (in this case, particle size) and at similar water depths. The actual positions also need to consider other factors that may affect the distribution of the chosen ecological indicators such as other inputs (creeks and stormwater drains) and boundaries (marine parks and special use areas).

East Point Outfall is located on intertidal mudflat extending to a mangrove shoreline to the east, with rocky outcrops to the south and west, down-sloping seabed to the northwest and extensive intertidal mudflat to the north. While tides are large in the Darwin region (tidal range of up to 6-7 m at the outfall) and currents through the main channels and offshore are substantial, tidal currents across the mudflats around the outfall are not strong due to the flat, shallow seabed and the open-nature of the bay. Net near shore water currents in the bay at most times are likely to be parallel to shore, and follow the bend of the coastline. Large variations in shoreline topography due to tidal changes in water depth and shoreline position will influence dispersion pathways on a daily and fortnightly cycle.

The freshwater effluent from the outfall will form a layer across the surface of the seawater and will disperse with ambient currents and wind shear on the water surface. Most water movement and effluent dispersion, particularly at the surface, is likely to be wind driven and wind-wave mixed.

Winds at the site are strongly seasonal and diurnal (Figure 1). Winds are reliably from the west and northwest (onshore) during the wet season and southeast to east (offshore) during the dry season. Onshore sea breezes in afternoons strengthen the onshore component during the wet season and weaken the offshore component in the dry season. Hence, effluent dispersal will be strongly influenced by opposite wind directions during the two seasons.

The net outcome of these factors is that effluent from the existing intertidal East Point outfall disperses along a range of different pathways, though wind driven dispersion will be mostly offshore in the dry season and onshore during the wet. There may be stronger influences close to the outfall where effluent discharge at low tide erodes sediments and results in an effluent ‘pool’ and drainage channel within metres of the discharge point.

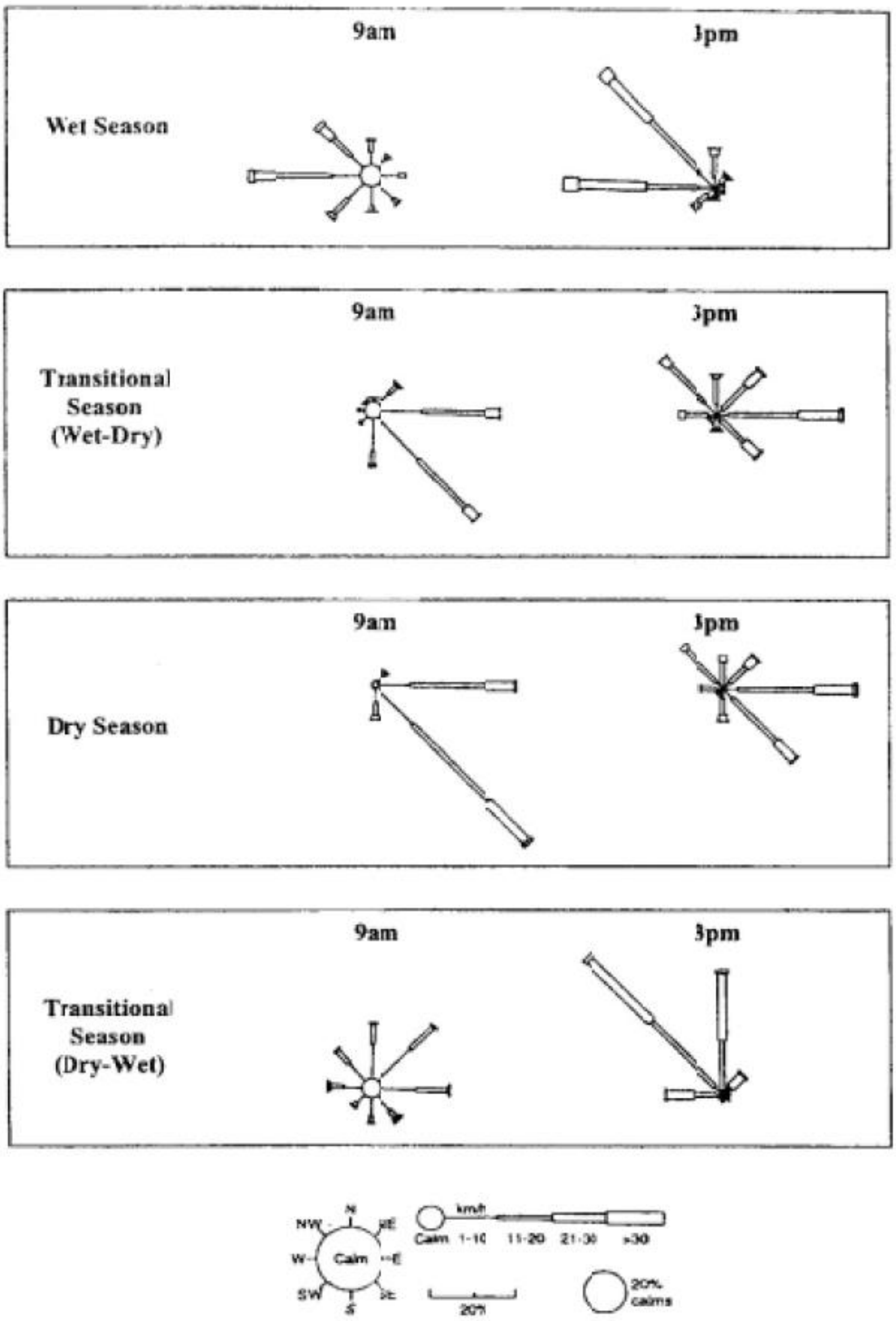


Figure 1 - Wind roses for Darwin airport

3.2.2Spatial Extent of Effect

The spatial extent of effect will be influenced by the variation in effluent dispersion direction over time, the degree of mixing over the water column and the effluent composition.

As effluent disperses over a range of directions depending on the time of year and time of day, the duration of effluent exposure at distance from the outfall is highly intermittent.

The depth of water above the discharge ranges from 0 m to 7 m over a spring tide cycle. This variation has a strong influence on the natural environmental factors affecting infauna (mobility and transport of mobile species, desiccation, temperature, predation, sediment resuspension and sedimentation), but also affects (1) the potential for benthic animals and plants to be in direct contact with the surface layer of effluent and (2) the physical mixing and dilution of the effluent as it rises through the water column from the discharge pipe. At low tide mixing and dilution of effluent with seawater will be minimal, at high tide mixing and dilution will be high. Therefore the concentration of effluent in close proximity to the outfall will range from very high (low tides) to very low (high tides). Benthic biota at a distance from the outfall will seldom be in contact with concentrated effluent at low tide and only intermittently be exposed to highly dilute effluent at high tide.

The net result of these considerations is that the extent of effect of the discharge on benthic infauna is likely to rapidly reduce as distance from the outfall increases. The greatest effect is likely to be detected within 25 m of the outfall, with effects due to the discharge unlikely to be detectable at 200 m from the outfall.

3.2.3Previous Monitoring

Previous monitoring by Jacobs in 2013/14 (Appendix B) provides evidence of a likely gradient of effect and information that will inform the design of the ongoing monitoring program. The results of the 2013/14 infauna surveys by Jacobs are discussed in the next section and the full report is included as Appendix B to this monitoring and management plan.

4 Previous infauna monitoring at East Point Outfall

Benthic infauna were monitored over the 2013 dry and 2014 wet seasons by Jacobs Group to document the possible impacts of licensed discharges from the Ludmilla WWTP on sediments and infauna in the vicinity of East Point outfall (Jacobs 2014 see Appendix B). The program followed the general requirements of the Independent Reviewers initial requirements and was guided by the NT EPA requirement to focus on subtidal rather than intertidal environments. The results of the 2013/2014 surveys provide useful information to design the on-going gradient-style monitoring program. A summary of the 2013/2014 surveys follow. Details of the 2013/14 monitoring sites, methods and data analysis can be found in Jacobs 2014. The infauna monitoring sites are shown in Table 1 and Figure 2 (below).

Figure 2 samples were collected predominantly from shallow subtidal mud flats, along transects oriented perpendicular to shore, with some samples collected in deeper subtidal areas. The dry season survey (September 2013) sampled at 18 sites along three transects – at the existing outfall and along two reference transects to the north (off Nightcliff and Rapid Creek respectively). The wet season survey (April 2014) sampled at 16 sites along two transects – at the existing outfall and off Rapid Creek.

Three replicate Van-Veen grabs were collected at each site. Grabs were sieved through 1 mm mesh and retained infauna sorted and identified to lowest possible taxonomic level – occasionally to species but often to order or higher taxonomic levels.

Infauna data was analysed by Jacobs Group using non-metric Multidimensional Scaling (nMDS) and Similarity Percentage (SIMPER) to determine spatial trends in relation to the outfall according to the recommendations of the independent adviser to PWC. Further details of the assessment methodology can be found in Jacobs 2014.

In addition to benthic infauna samples were collected and analysed for Total Organic Carbon (TOC) and sediment particle size determination to more effectively quantify impacts related to the outfall compared to variation due to environmental differences.(Jacobs 2014, included as Appendix B) In accordance with the requirements of the NT EPA the focus of the assessment was for impacts in the sub-tidal zone rather than the inter-tidal zone however sites to 250 metres were all exposed under varying tidal conditions.

Table 1 - Sites sampled by Jacobs 2014, September 2013 and April 2014

Location	Site	Distance (m)	Season Sampled	
			Dry	Wet
Existing outfall	Outfall	0	✓	✓
	EO12	25	✓	✓
Outfall Transect (near shore to offshore)	50NW	50	✓	✓
	125NW	125	✓	✓
	250NW	250	✓	✓
	500NW	500	✓	✓
	1000NW	1000	✓	✓
	Offshore OS7	~2000	✓	✓
Primary reference (near shore to offshore)	RE/NWR	na		✓
	25NWR	na	✓	✓
	50NWR	na		✓
	125NWR	na	✓	✓
	250NWR	na	✓	✓
	500NWR	na	✓	✓
	1000NWR	na	✓	✓
	2000NWR	na	✓	✓

Secondary	RE/NWR2	na	✓
reference	25NWR2	na	✓
(near shore to	50NWR2	na	✓
offshore)	125NWR2	na	✓

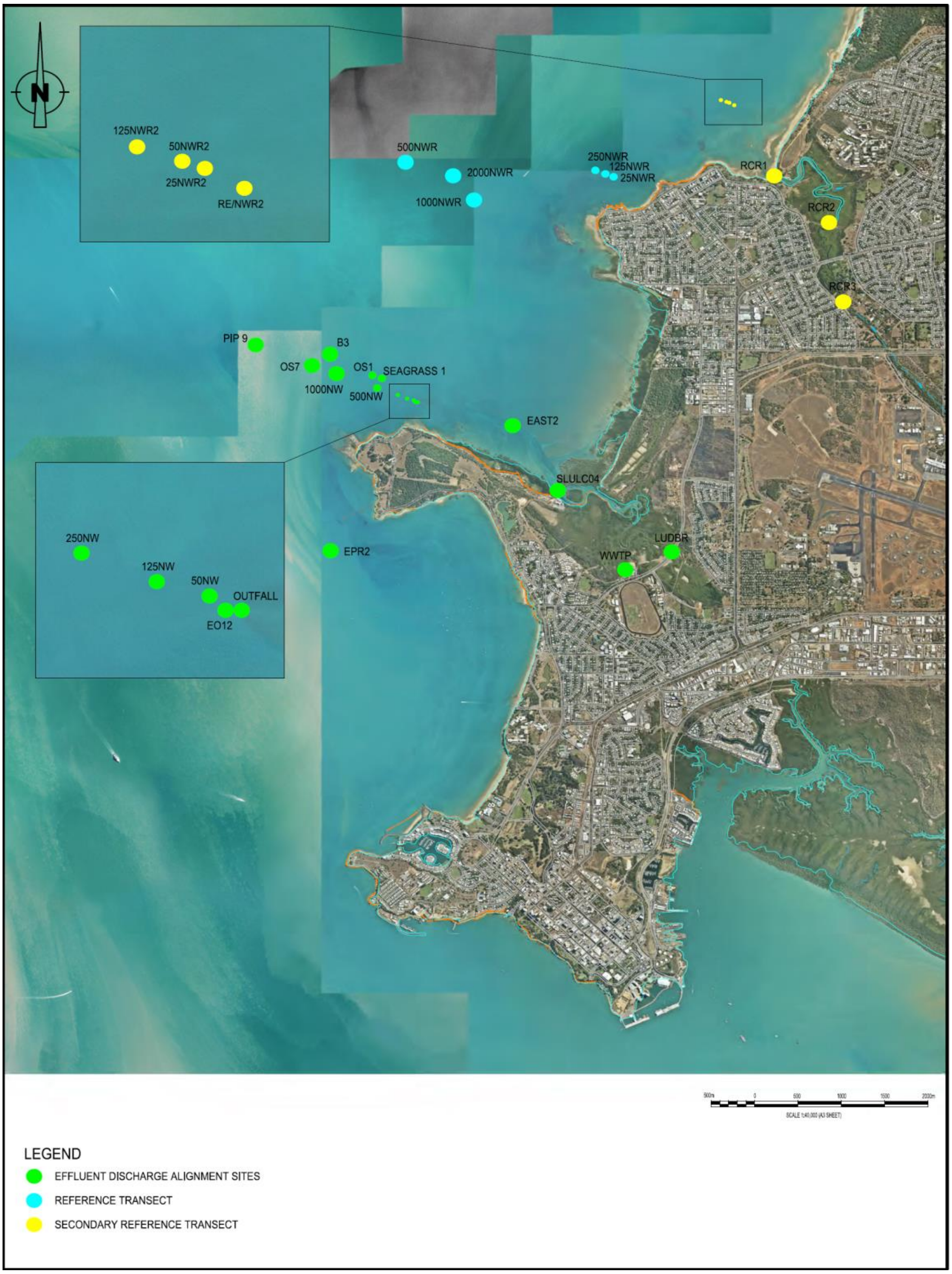
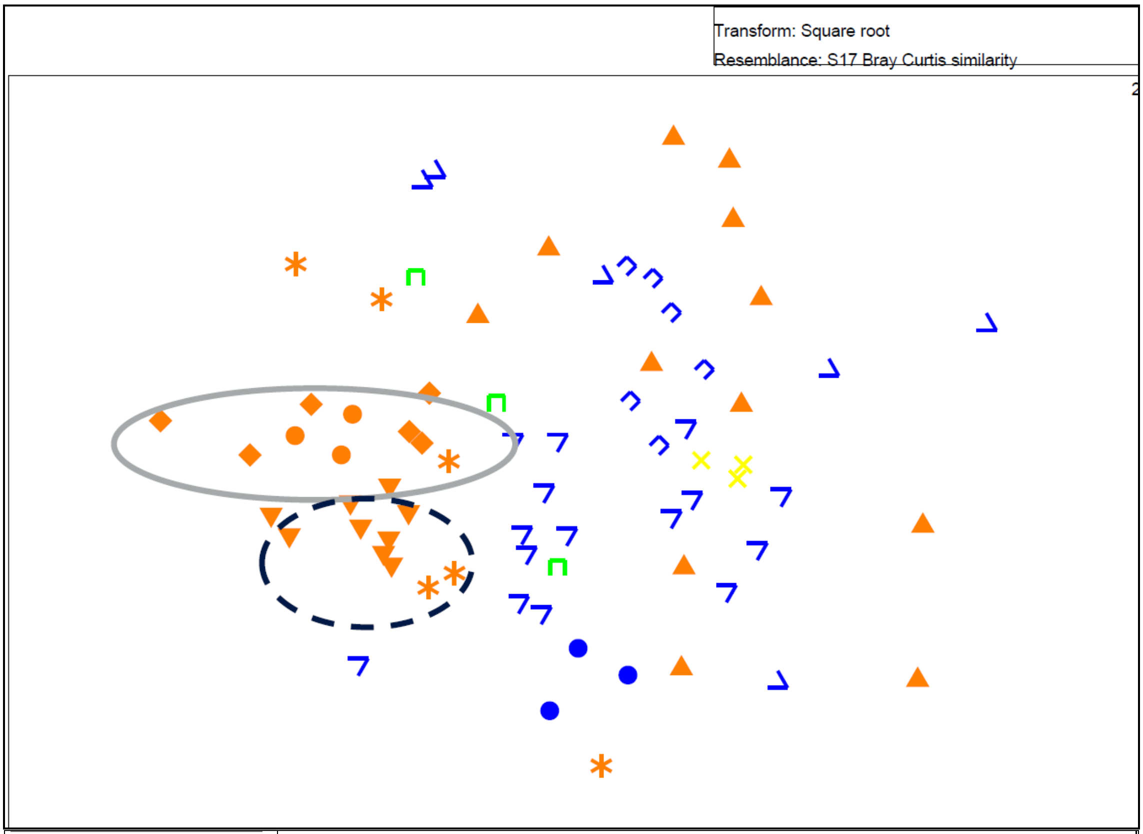


Figure 2 - Layout of sites sampled by Jacobs Group in 2013/14 dry season (Jacobs 2014)

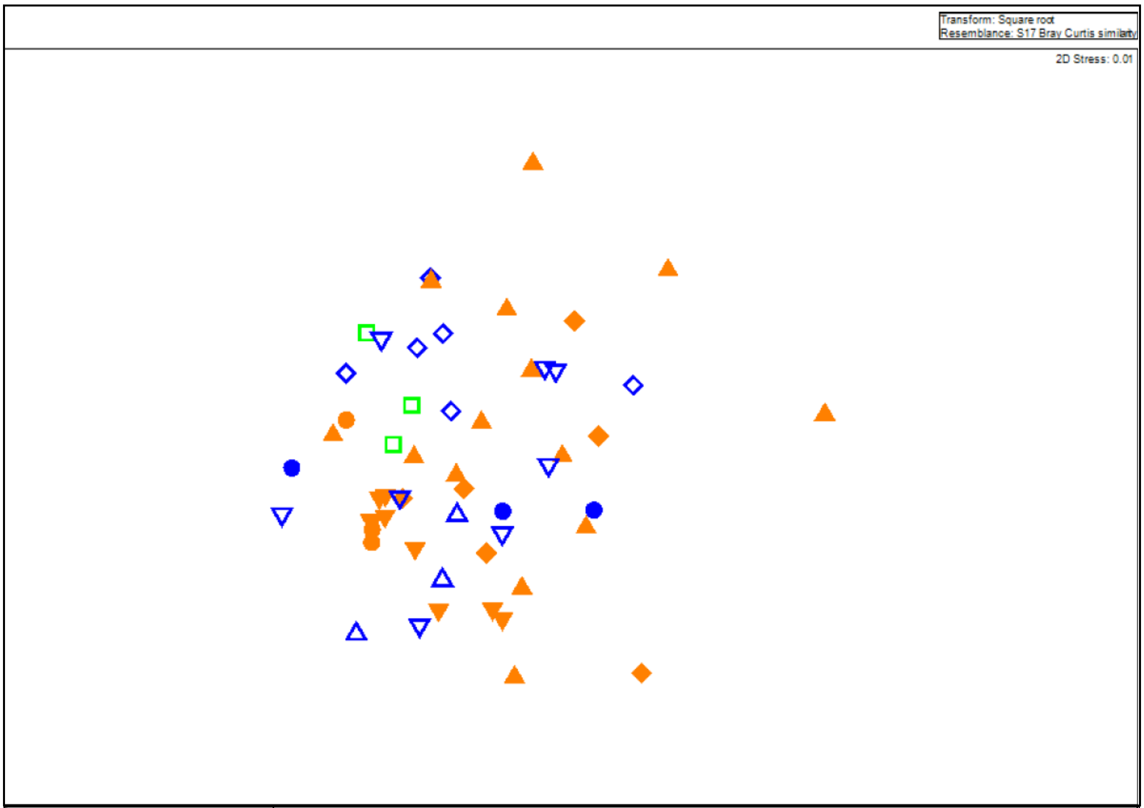
4.1 Results of Jacobs 2013/14 Infauna Surveys

The results of the 2013 dry and 2014 wet season surveys were presented as a series of non-metric multi-dimensional scaling (MDS) plots of Bray Curtis dissimilarity matrices assembled from the complete data set in Jacobs 2014 are reproduced below in Figure 3 and Figure 4.



Distn	Dry Season Site descriptions
Shore	Shoreline sample
OF inshore	Inshore of East Point Outfall
OF	East Point Outfall
OF <125	Less than 125 metres from East Point Outfall
OF <500	Less than 500 metres from East Point Outfall
OF >500	Greater than 500 metres from East Point Outfall
Sg	Seagrass monitoring site (B3)
NWR	North West Rapid Creek reference site
NWR <125	North West Rapid Creek less than 125 metres from reference site
NWR <500	North West Rapid Creek less than 500 metres from reference site
NWR >500	North West Rapid Creek greater than 500 metres from reference site

Figure 3 - MDS Plot of Infauna Community Structure – Dry Season 2013 (Jacobs 2014)



Distribution	Wet Season Site descriptions
OF	East Point Outfall
OF <125	Less than 125 metres from East Point Outfall
OF <500	Less than 500 metres from East Point Outfall
OF >500	Greater than 500 metres from East Point Outfall
Sg	Seagrass monitoring site (B3)
NWR	North West Rapid Creek reference site
NWR <125	North West Rapid Creek less than 125 metres from reference site
NWR <500	North West Rapid Creek less than 500 metres from reference site
NWR >500	North West Rapid Creek greater than 500 metres from reference site

Figure 4 - MDS Plot of Infauna Community Structure – Wet Season 2014 (Jacobs 2014)

The data were further analysed to determine the species responsible for the patterns observed in the MDS plots (typically only a small number of species are responsible). Species abundance data were not summarised or plotted in the report. The principal findings stated in the Jacobs Group report were:

- There was a large difference in the number of infauna sampled in the 2013 dry season compared with the 2014 wet season, with very low numbers of infauna in the wet season

survey.
- “Increased abundance of the deposit-feeding worm Cirratulidae at 25 m to 125 m from the outfall” were apparent in the dry season survey
- “Minor increase in abundance of the burrowing anemone Edwardsiidae at 25 m to 125 m from the outfall’ were apparent in the dry season survey
- “Infauna assemblages at sites > 500 m were more similar to those at the reference sites’
- “These patterns were driven by Cirratulid worms”,
- “No obvious spatial pattern in sediment particle size or TOC concentration relating to the outfall”.

4.1.1Conclusions to 2013/14 Surveys

From these findings, Jacobs suggested that there were two distinct zones of impact; a primary impact zone from 25 m to 125 m where the discharge has a positive influence on Cirratulid abundance and burrowing anemone abundance (*Edwardsia sp*.), and a secondary impact zone at the outfall, and from 125 m to 500 m where the discharge has a small positive influence on Cirratulid abundance. Both are deposit feeders and therefore are likely to respond to organic enrichment.

Jacobs identified potential indicators of effluent impacts that could be used as triggers for management action:

- Uniform species composition at impacted sites
- Higher infauna numbers at impacted sites
- Low species diversity as indicated by diversity indices at impacted sites
- Elevated abundance of Cirratulidae and/or Edwardsia sp. at impacted sites

4.2 Limitations on Interpreting 2013/2014 Data

The 2013/14 data provide useful data on infaunal species abundance and distribution (also see following Section 0). However, the interpretation of effect along the transects may be confounded by the orientation of the transects in the 2013/14 design.

The orientation of the transects in the Jacobs design was across the mudflat, perpendicular to the Kulaluk coast and parallel to the shoreline of the East Point headland. This orientation of the transects corresponds to the tidal exposure or depth gradient – another important environmental gradient. For example, biota at 250 m from the outfall are submerged for longer durations than those within 125 m of the outfall and while bathymetry in the area is not precise, it is likely that the infauna at 500 m from the outfall are located in a subtidal environment; an environment with entirely different environmental conditions from those close to the outfall.

The orientation of the transects means that the tidal exposure gradient may explain some or all of the pattern in infauna abundance that is interpreted as the effect of effluent exposure. The ongoing, gradient style monitoring program must ensure that this factor is addressed in the placement of sampling sites. This may be addressed by sampling along several transects radiating from the point source as discussed in Section 3.1.

4.3 Further Analysis of 2013/14 Infauna Data

PWC provided CEE with the raw data from the 2013/14 infauna surveys. The general abundance data are presented in Table 2. The five most abundant infauna in the wet and dry season surveys are listed in Table 3. The abundances of the five most common species in the dry season dry season survey are plotted in Figure 5.

Table 2 shows that the average abundance of infauna was almost seven times greater in the dry season compared to the wet season (data are for outfall transect only). The dry season infauna survey collected 830 individuals from 98 taxa. Only a few taxa were numerous, most were present in very low abundance. In the wet season survey there were only 153 individual infauna collected from just 41 taxa.

Table 3 shows that Cirratulid worms were the most common infauna group in wet and dry season surveys. Edwardsiid anemones were also common in both wet and dry season surveys. The remaining three 'top five' infauna taxa were different between dry and wet season surveys. The population abundances and the community composition appear to change between the wet and dry seasons. The period over which this change occurs (weeks or months) is not known.

Table 2 -Summary of Infauna Data East Point Outfall Transect, 2013/14

Distance from outfall (m)	Total infauna per site		Total taxa per site		Shannon's diversity index	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
Intertidal						
0	67	13	15	6	1.6	1.2
25	207	38	20	8	1.0	1.0
50	202	27	18	10	1.2	1.3
125	182	27	17	7	0.9	0.8
Subtidal						
250	23	14	7	9	1.0	1.0
500	48	15	17	13	2.1	1.9
1000	72	19	34	13	2.5	1.6
2000	29	0	25	0	2.1	
	830	153	98	41		

Table 3 - Most common infauna species

Season	5 Most Abundant Families
Dry	*Cirratulidae*
	Tellinidae
	Edwardsiidae
	Glyceridae
	Lumberineridae
Wet	*Cirratulidae*
	Nephtyidae
	unidentified bivalve
	Edwardsiidae
	Spionidae

Plots of the abundance of the five most common infauna in Figure 5 reveal some clear patterns in the infauna community along the transect at the outfall and the reference transect off Nightcliff. The plots show that the abundance of Cirratulidae and Edwardsiidae is clearly highest from 25 m to 125 m of the outfall, very few were seen at other sites or at comparable reference sites (i.e.

sites at a similar shore level). Tellinidae numbers were higher than reference at 0, 50 and 125 m from the outfall, but were also high at one site on the reference transect. No other species show patterns in their abundance relating to effluent exposure.

In the April 2014 (wet season) survey infauna numbers were markedly lower, however Cirratulidae numbers were still higher than at all other sites up to 250 m from the outfall. Edwardsiidae was seen 50 m from the outfall but at no other sites. These two groups appear to be the best invertebrate effluent exposure indicators in the vicinity of the East Point Outfall, but, as discussed in Section 4.2, tidal zonation may also result in the spatial pattern at the outfall transect.

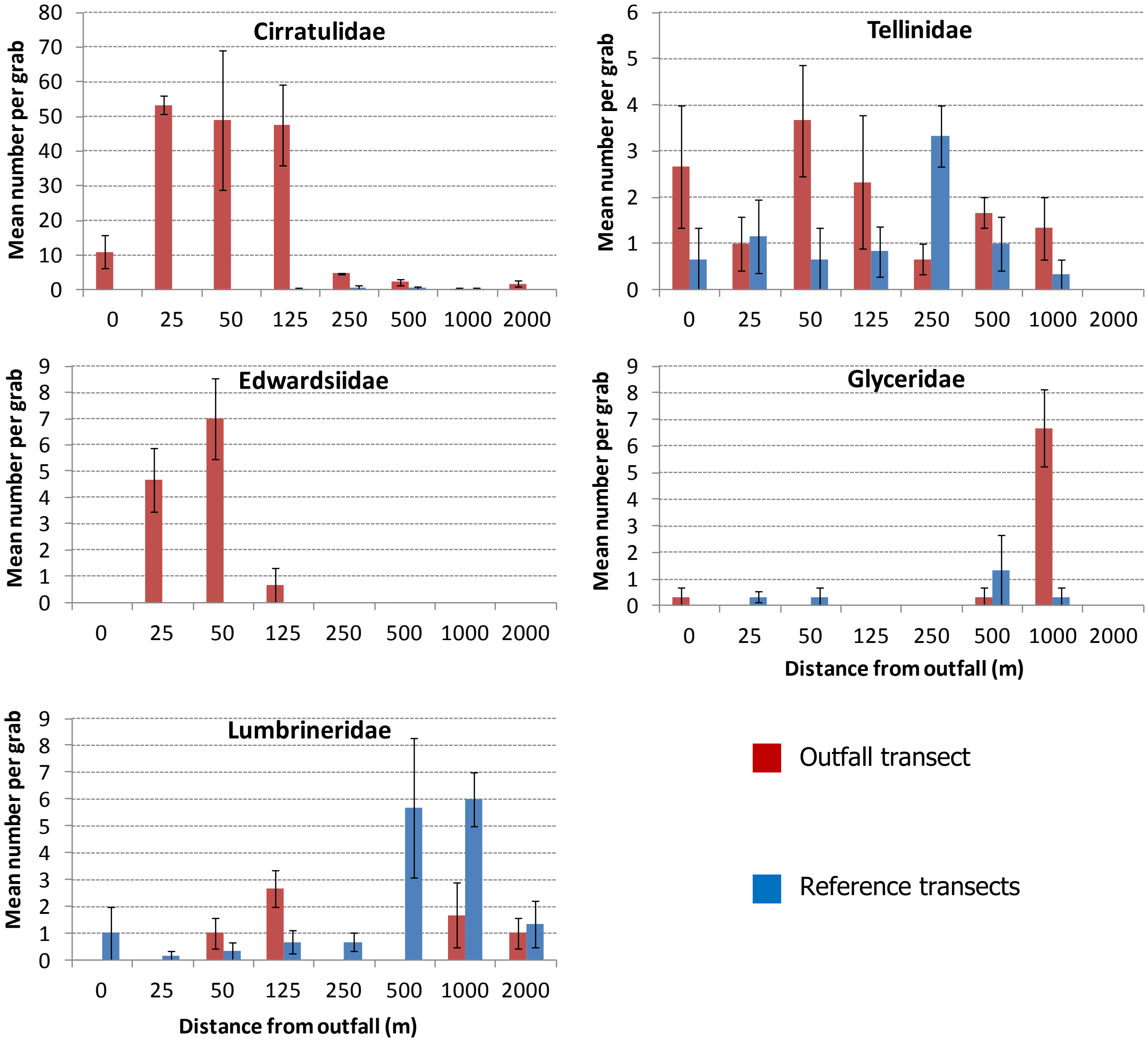


Figure 5 - Abundance of most Abundant Taxa along Outfall Transect – Dry Season

4.3.1 Implications for Next Phase Design

The pilot sampling surveys provide valuable information that can be used to design an ongoing program. The pilot sampling showed that:

- Infauna numbers are relatively low in the intertidal sediments around the outfall
- The effect of the outfall is likely to be small and localised
- The characteristics of the infauna are strongly seasonal and numbers are very low in the wet season
- The infauna community is numerically dominated by a relatively low number of taxa, which may provide a focus as indicator species in the ongoing program.
- The existing discharge may affect the abundance of some taxa (e.g. Cirratulidae, Tellinidae and Edwardsiidae) to between 50 and 125 m from the outlet during the dry season.

Outcomes of the pilot sampling that should be considered in developing the on-going program include:

- The number of sites close to the outfall was low relative to the distant sites. Highest effluent exposure will occur close the outfall, hence greatest impact is expected close to the outfall, and there should be greater sampling effort close to the outfall to document the near-field exposure gradient.
- Sites close to the outfall were distributed along only one possible dispersion pathway. Multiple transects will improve the ability to identify impacts radiating in several directions from the point source.
- Sites were distributed over a range of environmental conditions – depth, particle size, region – so the effluent effects were not readily distinguishable from other factors. Site should be stratified as far as possible to minimise the effects of variation in other factors, or to allow their influence to be identified.
- Sites at greater distance from the outfall were affected by different environmental factors and characterised. Reference sites should be located within similar environmental conditions within 1000 m of the point source.
- MDS plots included all sites and therefore patterns in sites were confounded.

5 Indicators, Receptors, Triggers and Responses

The DoE Condition 14 states that the Infauna Monitoring Program should:

"Include defined threshold trigger levels for sensitive receptors, mitigation/management responses for actions when thresholds are reached and reporting requirements for exceedances of trigger levels."

This section examines the information specific to the existing, intertidal East Point outfall and presents a framework to address the DoE Environmental Approval condition. The DoE environmental approval requires that the BIMMP is designed to assess the impact of the existing outfall and current discharge quality and quantity on benthic infauna and sensitive receptors within 1000 metres of the current outfall's intertidal location. The approval requires that the monitoring program continue until the outfall ceases to operate.

The BIMMP relates to the augmentation of the EPRM which will increase the discharge capacity of the EPO to accommodate flows greater than 300 L/second. The current ADWF into Ludmilla is less than 160 L/second indicating that in dry weather the majority of the discharge is via the EPRM and EPO.

The increase in effluent volumes treated at Ludmilla WwTP occurred as of 31 May 2012 and the influence will be evident in the current monitoring, the main focus of the augmentation of the EPRM is in the ability of the treatment plant to treat and discharge via the East Point Outfall the wet weather inflows at volumes up to 1000 litres per second. In 2013-14 period 87% of the discharge from Ludmilla WwTP was via the EPO. Of the 13% of the treated wastewater discharged via the overflow weir to Ludmilla Creek 97.85% of the total discharge to the creek occurred during the wet season during high inflow events, increases in flow via the East Point Outfall will primarily (>97%) occur during the monsoonal wet inflows.

The relocation of the outfall (Stage 4 of the Larrakeyah Outfall Closure Plan) is the subject of a current environmental impact assessment. The proposed BIMMP includes the collection of benthic infauna along a transect adjacent to the proposed outfall relocation site to provide baseline data for the operation of a future relocated outfall.

5.1 Indicator Species

As discussed in Section 3 and Appendix A, species that indicate a positive or negative response to effluent exposure may be peculiar to the discharge characteristics and location. Section 4.3 showed that there were relatively few taxa that were sufficiently common or uniformly distributed to use as possible positive indicator species. However, the data on several species in the 2013 dry season (Cirratulidae, Edwardsiidae and Tellinidae) indicated that the effect of the discharge may have extended to 125 m from the outlet, but not as far as 250 m. Taxa collected in the 2013/14 surveys that may be candidate indicator species are listed together with their trophic character in Table 4.

Table 4 - Common infauna for potential use as effluent exposure indicators

Taxon	Description	Potential as indicator species
Cirratulidae	Deposit/filter feeding polychaete worm	Yes – Positive
Tellinidae	Filter feeding clam (bivalve mollusc)	Yes – Positive
Edwardsiidae	Filter feeding anemone	Yes – Positive
Glyceridae	Predatory polychaete worm	Possible - Negative
Lumbrineridae	Predatory polychaete worm	Possible - Negative

While the data collected in 2013/14 cannot be used to definitively assign species as indicators of effluent effects Table 4 provides a guide to taxa at East Point outfall that may be candidate indicator species. Further surveys will provide increasing understanding of the abundance, distribution, variation and response of particular taxa to effluent exposure at East Point Outfall.

5.2 Sensitive receptors

Key sensitive marine ecological receptors in the area include:

- Inshore dolphins - mobile species that have wide geographic range, generally not found in intertidal area, unlikely to be found frequently near East Point Outfall.
- Turtles and dugongs - mobile species that have wide geographic range, generally not found in intertidal area except at high tide if intertidal seagrasses are present.
- Seagrass beds – the nearest seagrass is approximately 300 northwest of East Point Outfall.
- East Point Aquatic Life Reserve - boundary approximately 350 m west of East Point Outfall.

5.3 Management Triggers and Response

It is recommended that management triggers to protect the listed key marine ecological receptors should be defined in terms of likely extent of effect of the discharge from the existing outfall location on the infauna community as the ecological indicator. It is proposed that the key marine ecological receptors in the East Point region beyond 200 m from the existing outfall will be protected from ecological effects if:

- All common infauna taxa at 200 m from the outlet are present in abundances expected of negligible exposure to effluent; and
- A range of taxa at 200 m from the outlet are present in proportions expected of negligible exposure to effluent.

Infauna conditions “expected of negligible exposure to effluent” will guided by:

- the interpretation of spatial patterns that correspond with effluent exposure using data from individual surveys and that accumulated from previous surveys; and
- the distribution and abundance of positive and negative indicator species that may be identified from individual surveys and accumulated data from previous surveys.

Infauna data from future surveys should be examined with experienced attention to the consistency of the correspondence of distribution and abundance patterns to effluent exposure, feeding guilds of abundant taxa and possible successional patterns of taxa along the effluent exposure gradient or its surrogate, increasing distance from the discharge point. Potential positive and negative indicators should be identified.

It is expected that infaunal species composition will change naturally from time to time. The magnitude of variation in infauna abundance or species richness between sites and between surveys will influence the triggers. Studies of variation in infauna populations demonstrate that effect sizes of 50% to 200% may be required as trigger values due to the ambient natural spatial variation in infauna abundance at some locations, but may be trivial in the context of the range of natural variation (Carey 2002). It has been suggested that changes within the range of natural variation are not cause for concern (Underwood 1992, 1994). Hence a knowledgeable and flexible approach to the interpretation of effluent exposure effect from the data is required.

ANZECC & ARMCANZ 2000 advocates the use of 20 and 80 percentile values of reference sites for judging divergence of the median values of physico-chemical parameters at a test site from local natural conditions. We suggest that this approach be used to judge “substantial” increases or reduction in indicator species abundance at management distances along each of the monitoring transects.

Population numbers for marine ecosystem indicator species naturally occupy a range of values. The range in natural variation is often specific to species and may be large or small and vary on a small, medium or large scale, or over short periods, seasons or years.

The infauna that occupies the East Point and Ludmilla Bay are, like mud-flat infauna elsewhere, short-lived, seasonal and patchily distributed.

A 'threshold value' to represent an impact needs to take into account potential increases and decreases in population numbers that may occur due to the effluent discharge in addition to the natural variation.

Threshold values of the 20th percentile and 80th percentile range represents an allowance of 30% natural variation either side of the median population number. This variation is similar in magnitude to the one standard deviation (34.1%) used in parametric statistics but does not require assumptions of normality of the data. Using the 20th and 80th percentile values provides a simple, yet conservative management threshold and is based upon actual population data reflecting reference environmental conditions. The approach uses a consistent form of control charting that applies to chemical and physical indicators that are not only 'stressors' they are also components of the marine environment that are also natural constituents and are, in many cases, required for life.

Once the initial assessment of the variation from reference has been made a qualitative or quantitative lines-of-evidence approach should then be used to assess the strength and extent of the effect of the discharge on the benthic infauna community around the East Point Outfall.

The monitoring and management plan is designed to provide early warning of potential impacts on the sensitive receptor organisms (inshore dolphins, marine turtles and dugong). Potential ecological events that may precipitate the decline or death of sensitive receptor organisms can include persistent algal blooms, eutrophication of the water or sediments and decline in important food or habitat requirements. While algal blooms and eutrophic events are not likely to result from the routine operation of the LWwTP or from progressive changes in the discharge the monitoring and management plan has been designed to include triggers at earlier alert levels that are designed to warn of potential impacts to enable remedial actions to be implemented prior to the occurrence of deaths or declines in the population of sensitive receptor organisms or of species or habitats of importance to the sensitive receptor species.

The LWwTP has discharged to Darwin Harbour via the East Point Outfall for over 30 years without the occurrence of algal blooms or eutrophication being identified as occurring due to the LWwTP discharge and the increase in wet season discharges is considered unlikely to change this, however assessment criteria have been included to ensure any increase in environmental impact is identified and mitigated.

Seagrass is an important food and habitat resource for the sensitive receptor species, however within Ludmilla Bay it is ephemeral and patchily distributed resulting in the area not being considered as significant habitat for sensitive receptor organism and no decline in numbers of species has been observed and no deaths of sensitive receptor animals recorded in the area. While no evidence of the death or decline of sensitive receptor organisms has been identified, field monitoring procedures for the benthic infauna and water quality monitoring programs has been modified to include a record of algal blooms and sensitive receptor organism numbers.

The BIMMP and the WQMMP have been designed to detect at earlier levels any characteristic of the discharge that may result in the decline of key habitat requirements for sensitive receptor organisms or the decline or deathly of sensitive receptor organisms. Three distance-based levels of trigger are proposed to manage potential degradation of marine environmental quality beyond

200 m from the outlet as indicated by infauna community characteristics along possible effluent exposure gradients. The assessment are informed by changes in species numbers both within the near field, mid field and far field zones. From lowest to highest level of response the levels are:

Level 1	Identify and monitor
Level 2	Alert and manage
Level 3	Action

Trigger levels and management response for each level are presented in Section 5.3.1 to 5.3.3 below.

5.3.1 Level 1 - Identify Trend and Monitor

Triggers

- Median abundance of individual indicator species to 50 m from existing outlet is outside the 20 to 80 percentile range of reference sites.
- Number of species within 50 m of outlet is less than the 80 percentile value of the reference sites.
- Persistent or toxic algal blooms recorded within 50 metres of the outfall.
- Dissolved Oxygen levels in water or sediment within 50 metres of outfall indicate eutrophication.
- Decline in food species or key ecosystem requirement for sensitive receptor species identified within 200 metres of the outfall.
- Evidence of decline in number or condition of sensitive receptor organisms identified within 200 metres of outfall.

Response

- PWC to examine data in more detail to determine likely causes of ecological variation.
- PWC to review water quality and sediment data from WQMMP to identify causal factors.
- PWC to identify major changes in influent and remedy.
- PWC to identify changes in treatment process that may cause variation.
- PWC to identify likelihood of effluent or natural cause.
- PWC to consider increased level of monitoring.
- PWC to consider developing a management plan if appropriate.
- PWC to advise regulator if further expansion of effect is predicted.

5.3.2 Level 2 - Alert and Prepare

Triggers

- Median abundance of individual indicator species to 100 m from existing outfall is outside the 20 to 80 percentile range of reference sites.
- Number of species within 100 m of outfall is less than the 80 percentile value of the reference.
- Persistent or toxic algal blooms identified within 100 metres of the outfall.
- Anoxic sediments identified within 100 metres of outfall indicate eutrophication.
- Dissolved Oxygen levels in water or sediment within 100 metres of outfall indicate eutrophication. .
- Anoxic sediments identified within 100 metres of outfall.
- Evidence of the decline in numbers of sensitive receptor organisms or important habitat or food requirements for sensitive receptor organisms within 500 metres of outfall.

Response

- PWC to investigate changes in effluent flows or quality that may be resulting in effect.
- PWC to data from WQMMP to identify trends in water quality that may have resulted in toxic or persistent algal blooms.
- PWC to identify whether the East Point Outfall discharge is the probable cause of the event.
- PWC to identify source of major change in influent and remedy.
- PWC to identify change to treatment process that may result in effect and correct.
- PWC to develop management plan appropriate to cause of effect.
- PWC to consider increased level of monitoring.
- PWC to advise regulator if further expansion of effect is predicted.

5.3.3 Level 3 - Act and Manage

Triggers

- Median abundance of individual indicator species to 200 m from existing outfall is outside the 20 to 80 percentile range of reference sites.
- Number of species within 200 m of outfall is less than the 80 percentile value of the reference.
- Chlorophyll-a or algal counts indicate persistent or toxic algal blooms within 200 metres of the outfall.
- Anoxic sediments identified within 200 metres of outfall indicate eutrophication.
- Evidence of death or decline of sensitive receptors identified within 1000 in the vicinity of the outfall.
- Evidence of decline in important food or habitat species for sensitive receptor species identified within 1000 metres of outfall.

Response

- PWC to immediately advise regulators of potential non-compliance (within 48 hours of identifying impact).
- In the event of death or decline of sensitive receptors PWC to initiate program to directly monitor presence and health of key environmental receptors in the East Point area.
- PWC to review WQMMP data to identify potential causes of identified trigger event.
- PWC to investigate inflow characteristics and changes in effluent flows or quality that may have caused effect.
- PWC to initiate ‘sensitive receptor’ rehabilitation program
- PWC to ensure correction to process if ‘incident’ was due to failure in existing process.
- PWC to contribute to identification and solutions if incident was due to process outside PWC’s systems.
- PWC to liaise with regulators and take immediate action appropriate to cause of environmental degradation.
- PWC to provide incident report to regulator following conclusion of the investigation.

6 Recommended Infauna Monitoring Program

The benthic infauna monitoring program required to inform the management responses proposed in Section 5.3 is described below.

6.1 Objectives

The benthic infauna monitoring program aims to document the characteristics of benthic infauna communities in the vicinity of East Point outfall to determine the extent and nature of effect of the effluent discharge on infauna, to compare this information against management trigger levels and to use the information to determine appropriate management response to further protect sensitive marine ecological receptors in the region.

6.2 Infauna Sampling Strategy

The Jacobs 2013/2014 benthic infauna study identified a 125 metre impact zone adjacent to the East Point Outfall and a further zone of influence where population differences were evident to a distance of 500 metres from the outfall (Jacobs 2014). A review of the Jacobs data set found that the relatively low number of sites assessed within the 500 metre zone resulted in difficulties in differentiating between effects resulting from exposure to effluent discharged via the East Point Outfall, catchment influences due to freshwater from Ludmilla Creek and differences in exposure to the air caused by the tidal gradient in the vicinity of the outfall. The Jacobs study assumed all differences resulted from exposure to effluent. To more effectively differentiate between the range of factors it is proposed to increase the number of transects and the number of sites within the 125 metre impact zone and the 500 metre zone of influence identified in the Jacobs study and to include transects both up and down stream of the plume path (PWC 2011).

As required by Condition 14 of the environmental approval, where feasible all transects extend to 1000 metres across the intertidal and subtidal zone however sites beyond 500 metres will be less intensive with one site at 750 metres and one at 1000 metres. The monitoring plan includes eight intertidal reference sites in the 800 to 1000 metre zone to the north east of the outfall and eight background sites along the boundary of the subtidal zone which will provide reference data for future monitoring once the outfall is relocated to a subtidal location. The sampling design for the intertidal and subtidal BIMMP is shown in Figure 6, the map provides an indicative orientation for the transects which may require minor adjustments to address particular bathometric or ecological features identified in field investigations, exact site locations will be reported.

6.2.1 Intertidal Community

The existing outfall is located in the intertidal zone; approximately 350 metres off shore, effluent from the outfall will disperse from the outfall due to the local effects of wind, waves and tide (which vary on daily, weekly, monthly and seasonal scales). Infauna will be monitored along seven transects radiating up to 1000 m from the existing outfall between East Point and Nightcliff, and at eight intertidal reference sites between 800 m and 1000 m from the outlet (Figure 6).

The Jacobs study showed that the infauna in the Ludmilla Bay and East Point area were different from those in other areas, hence other areas do not provide an ideal reference. The inclusion of the eight sites, beyond the outfall's the zone of influence identified by Jacobs 2014 and outside the plume trajectory monitored and modelled for the outfall (PWC 2011) but within the Ludmilla Bay provide a useful reference that remove any potential for autocorrelation along a natural gradient or linear feature within the Ludmilla Bay/ Kulaluk wetlands.

This design not only allows the scale of the effect of the effluent (if any) to be identified but also avoids the difficulty involved in selecting distant reference or control sites (Ellis et al. 2000). The array also recognises other possible environmental factors including the position of rocky outcrops, tidal air exposure gradient and location of the East Point Aquatic Life Reserve boundary.

The infauna sampling distances along transects is divided into zones that are likely to be most useful for management considerations of the extent of effect with the near-field and mid-field. Individual samples will be collected at increasing spacing along each transect with each zone to detect potential changes corresponding to distance along the exposure gradient (Figure 6).

- Near-field zone to 25 m, where effluent exposure will be greatest and the likelihood of effects will be most obvious
  - Samples will be collected at 5 m, 15 m and 25 m from the outlet along each transect to detect potential changes in effect and to document potential small spatial scale variation toward the outer boundary of the near-field zone
- Mid-field zone to 200 m where effluent exposure will rapidly reduce and effects may also show substantial reduction
  - Samples will be collected at 40 m 50 m and 60 m from the outlet along each transect to detect potential changes in effect and to document potential spatial variation over the first third of mid-field zone
  - Samples will be collected at 70 m, 85 m and 100 m from the outlet along each transect to detect potential changes in effect and to document potential spatial variation over the middle of the mid-field zone
  - Samples will be collected at 130 m, 160 m and 200 m from the outlet along each transect to detect potential changes in effect and to document potential spatial variation towards the outer boundary of the mid-field
- Far-field zone beyond 200 m where effluent exposure will be low to very low and effects may be very low and indistinguishable from background variation
  - Samples will be collected at 350 m, 500 m, 750 and 1000 along transects where this is possible, the SSW and SSE transects will be positioned to maximise the number of sites; and
  - At 8 random intertidal sites 800 m to 1000 m from the outlet.

6.2.2 Subtidal Community

Monitoring also includes 10 offshore sites immediately below the subtidal contour line that divides the intertidal and subtidal zones; this is the depth contour of the proposed location for the future extended outfall. These sites are in the immediate vicinity of the proposed outfall relocation site and will be used to collect baseline data for the proposed extended outfall. The proposed extended outfall will discharge within 100 m offshore from the low tide mark. Infauna will be sampled to document baseline conditions at 10 sites along the same depth contour. The data collected from the subtidal transect will inform the impact assessment and monitoring program for the outfall relocation.

Comparison with the intertidal transects is inappropriate as variation in depth and/or sediment particle size may support markedly different communities.

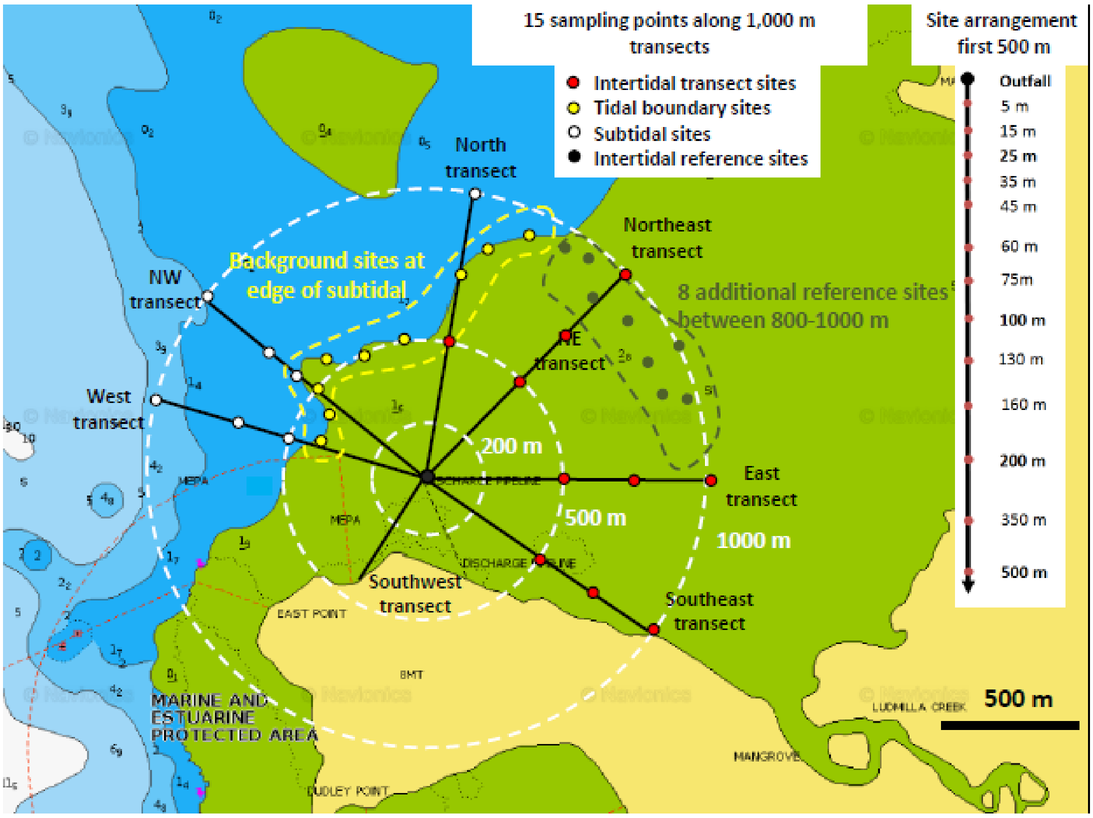


Figure 6 - Infauna sampling site layout

6.3 Monitoring Frequency

Water quality in Darwin Harbour is distinctly different in wet and dry seasons. High rainfall in the wet season leads to large freshwater flows with associated nutrient and sediment runoff leading to low water clarity. The 2013/14 infauna monitoring program found very low infauna numbers in the wet season compared with the dry. The wet season occurs from November to March with a transitional period around April and the dry season from May to September with a transitional period around October. These regular seasonal differences have to be accounted for in the monitoring program.

Samples will be collected once during the wet season and once during the dry season for each year of the program.

6.4 Sampling Method

Sediment samples for infauna analysis will be collected at each site using a Ponar grab. Samples will also be collected for analysis of sediment particle size, total organic carbon and pH. These measures and the observations recorded during collection will be sufficient to identify sediment conditions that could affect infauna composition. Details of infauna sample numbers are shown in Table 5.

The grab method will involve:

- Collect known volumes of sediment using Ponar grab from vessel (gape size approximately 24 cm by 30 cm = 0.07 m2) with penetration to approximately 5 cm;
- collect grab at each site for infauna analysis
- sieve sample through 1 mm mesh transferring the retained sieve samples to labelled bags;

- preserve samples in 5 percent formalin in seawater solution prior to sorting in the laboratory.
- additional grab for at each site for particle size and total organic carbon analysis
- sample labelled in appropriate container and refrigerated for transport to laboratory.

Table 5 - Infauna sampling details

Location	Distances	Sites	Total samples
Existing intertidal outfall monitoring			
Near-field (≤ 25 m)	3	7 x 3	21
Mid-field (40 m to 200 m)	9	7 x 9	56
Far-field (>200m)	3	6x3	18
Sub Total			97
Intertidal reference monitoring sites			8
Baseline subtidal monitoring sites			10
TOTAL SITE SAMPLES			113

6.4.1 Field documentation, quality control on collection of samples, quality assurance of data

Field sheets and sample labels will be prepared so that the condition of each sample is collected and stored is documented. The information will be sufficient to ensure quality control in the collection process: (1) sampling procedure is consistent with methods, (2) individual samples are comparable with other samples and (3) sample volume and characteristics can be checked for confirmation during subsequent data analysis.

Field sheets will include (for example Table 6):

- Project
- Personnel
- Date
- Time
- GPS position
- Sample unique position code
- Water depth
- Photograph
- Presence of sensitive receptor
- Behaviour / condition of sensitive receptors observed in area
- Recovery volume
- Number of grabs in sample
- Sample composition and general description
- Sample odour
- Sample colour
- pH (e.g. 1:5 aqueous mix)
- Sieve size

Waterproof labels for each sample will be prepared prior to sampling and will include:

- Project
- Date
- Time
- GPS position or waypoint number
- Sample unique position code
- Sampling person

Table 6 - Example of infauna sampling field sheet

CEE Consultants

PWC East Point Outfall Infauna monitoring				
Site:	**Date:**	**Time:**	**Weather:**	Operator:
GPS waypoint:		Water depth:	Photograph:	
Method: Ponar grab		No. of grabs required:	Vol. recovered:	Sieve size:
Sample ID (Infauna):			Sample ID (Physical):	
General notes				
Sediment description				
Composition				
Colour				
Odour				
Biota				
pH				

6.4.2 Sample analysis

Infauna will be identified to family taxonomic level by infauna taxonomy specialist consultant Numbers of each identified taxon will be counted and standardised to numbers per m2. Infauna analysis data reports will include the project, sampling date and sample unique position code for every sample, a full taxonomic list, and abundance data for every taxon on the list for every site (zero for taxon absent from site).

Sediment from all sites will be analysed for grain size distribution (approximate fractions 0.0625 mm, 0.125 mm and 0.250 mm based on Jacobs 2014). Representative samples from each location will be analysed for total organic carbon.

6.4.3 Data analysis and quality assurance

Data from the BIMMP will be analysed to identify:

- Spatial trends in abundance of individual taxa that may reflect a positive or negative effect of the outfall on taxa abundances and;
- Spatial trends in assemblage composition at each site that indicate a pattern as a function of distance from the outfall (effluent exposure).; and
- Relationships between these patterns and sediment characteristics of the habitat.

Infauna community structure parameters will be determined for each site. Summary statistics will include total abundance, number of taxa, species richness and species diversity (Shannon's index).

The arrangement of the sites will allow assessment of spatial patterns in relation to the outfall or other geographic features (or the lack of meaningful patterns) over approximately 1 km2 of intertidal flats in the study area. A large number of samples (75) will be collected from a range of spatial scales (near field, mid field and far field). The data can be analysed for patterns along individual transects, patterns between distances from outfall, locations or sediment character by simple, transparent graphical and spatial presentation as shown in Section 3.1.

Results for individual sites that are inconsistent with surrounding sites will be identified for quality assessment. Sample collection documentation and sediment character will be checked for consistency with standard procedure. Possible causes of any inconsistency will be identified and documented in the quality assessment section of the report.

The extent of likely effect on infauna will be determined according to a lines-of-evidence approach based on understanding of the exposure gradient and the likely responses of positive and negative indicators to effluent exposure.

6.5 Reporting

Specialist contractors will conduct the sampling and data analysis and provide a report to Power and Water for submission to the Independent Technical Review. The report will be prepared following each survey which:

- Describes the methods used
- Provides a table containing the dates, sites and positions of the survey and previous surveys
- Presents a table of summary infauna statistics for the present survey
- Presents summary tables and plots of individual taxon abundances that provide key evidence of spatial distribution consistent with effluent exposure
- Lists possible positive and negative indicators
- Identifies possible extent of effect of discharge based on evidence presented
- Assesses outcomes against management triggers
- Assesses actions taken in response to management triggers
- Recommendations of modification to monitoring design that will improve detection of effects (where relevant)
- The survey report will include a compliance reports detailing any non-compliance incidents in relation to:
- Compliance with sampling procedures;
- Analytical results that:
    - Trigger a Level 1 Alerts:
    - Trigger a Level 2 Alerts:
    - Trigger a Level 3 Alerts;
        - the outcome of any investigation or the proposed investigation to be undertaken.
        - actions taken to mitigate risks to sensitive receptors.
- Any breaches of Level 1 or Level 2 Alert triggers will be investigated and if the impact is identified as being related to the outfall, and likely to further expand, the Water Quality Office will advise the regulator of the exceedance and what mitigation measures have

been implemented.

- The Water Quality Officer will immediately (within 48 hours of becoming aware of the exceedance) report any potential exceedance of a Level 3 triggers to the regulatory authorities as a potential non-compliance
- The Senior Water Quality and Treatments Officer will be responsible for reporting on management actions taken to mitigate risks to sensitive receptors due to the exceedance of Level 3 triggers.
- A summary of all exceedances, investigation outcomes, mitigation actions implemented will be included in the annual report for the program.

The annual report will include recommendations for variations to the monitoring program and will be reviewed by the Independent Technical Reviewer. A comprehensive review will occur after 3 years.

7 Seagrasses

Seagrasses are a vital marine ecosystem component in the Darwin region. They are an important food source for several protected marine animals such as marine turtles and dugongs and provide nursery and feeding habitats for many commercial and recreation fish species.

Several species of marine turtles and dugongs are frequently sighted in the Darwin Harbour region from Fanny Bay to the upper tributaries of the Harbour. They are primarily herbivores and feed on *Halodule uninervis* and *Halophila spp.* Distinctive feeding trails are left behind when dugongs uproot entire seagrass plants to access the nutritious rhizomes – if they are accessible. When the rhizomes are deeply buried in the sediment, dugongs feed by cropping the seagrass leaves; similar feeding behaviour to marine turtles.

Seagrasses are sensitive to changes in a range of environmental factors including water quality. Many species show natural seasonal variation in presence, productivity or abundance. Inter-annual variation in abundance and distribution is also common.

Seagrasses are susceptible to the effects of reduced light, smothering by algae and sedimentation. Intertidal species of seagrass are also susceptible to desiccation. High levels of nutrients can cause excessive epiphytic growth on the surface of leaves limiting the amount of light reaching the seagrass leaves for photosynthesis. This process can result in decreased seagrass biomass or even seagrass loss. Common sources of nutrients include runoff from agricultural or developed catchments and wastewater discharges. Reduction in seagrass may result in flow-on effects to sensitive receptor animals such as marine turtles and dugongs that rely directly on seagrass for food.

7.1 Seagrass Near East Point

Surveys in the East Point area indicate that *Halodule spp* and *Halophila spp* are the most common seagrass species (Cardno 2014, Geo-Oceans 2014, Jacobs 2014). *Halodule spp* dominates lower intertidal area, while *Halophila* dominates the shallow subtidal area. They generally form mono-specific patches but also occur as mixed communities. The available information showed that seagrass was present on deeper seabed (lower intertidal and subtidal areas) than the outfall and just over 300 m northwest of the outfall. Information from the Jacobs and Geo-oceans monitoring programs was used to map the likely extent of seagrasses between East Point and Nightcliff (Figure 7).

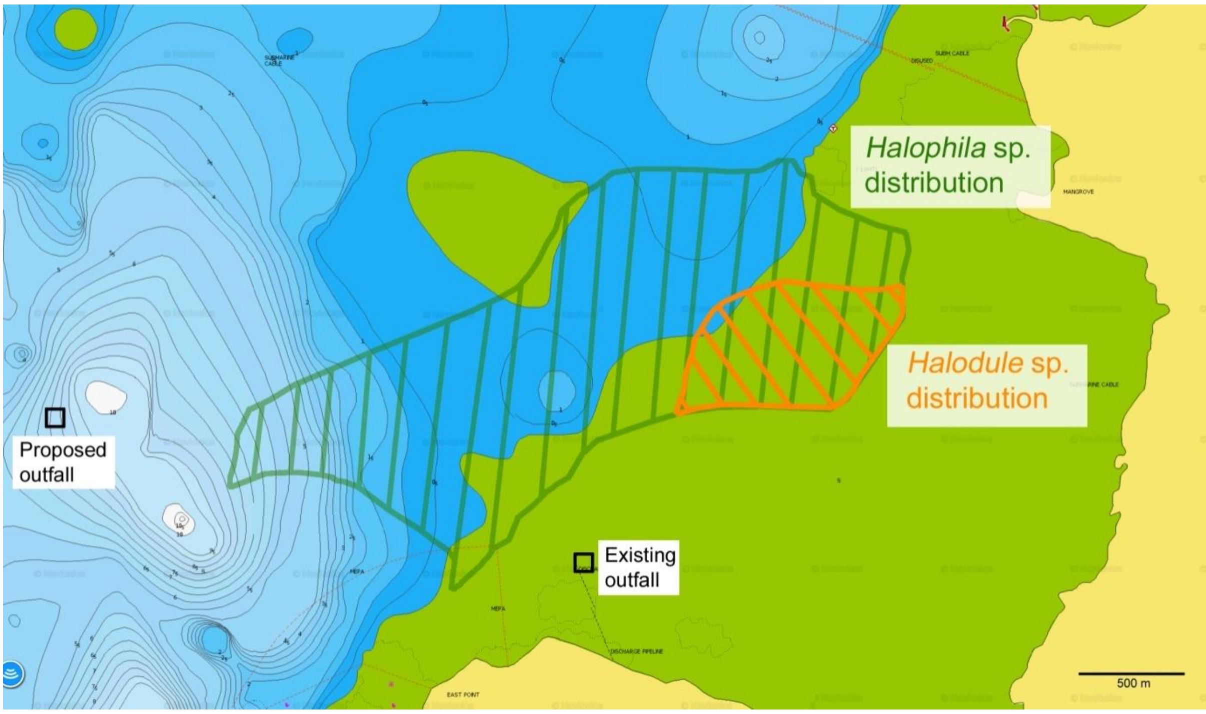


Figure 7 - Derived extent of seagrass beds in East Point area

Table 7 - Depth and per cent cover of seagrass at East Point seagrass beds
(from Geo-oceans, 2014)

Depth (m, LAT)	Approximate seagrass percent cover							
	Dry (May 2013)		Dry (Aug 2013)		Wet (Nov 2013)		Dry (May 2014)	
	Halophila	*Halodule*	*Halophila*	*Halodule*	*Halophila*	*Halodule*	*Halophila*	*Halodule*
0	0	8	18	13	0	7	0	2
-0.5	0	0	20	5	0	0	0	0
-1	0	0	2	0	8	0	0	0
-1.5	0	0	0	0	0	0	0	0
-2	0	0	5	0	6	0	0	0
-2.5	0	0	0	0	0	0	0	0

Monitoring data (Table 7 and Figure 8) shows that seagrass in East Point seagrass beds is highly seasonal. Seagrass distribution and density in the region fluctuates \between the wet and dry seasons. *Halophila* is present over a larger area than *Halodule* over the dry season, but disappears over the wet season while *Halodule* persists. *Halophila* appears to recover in subsequent dry season.

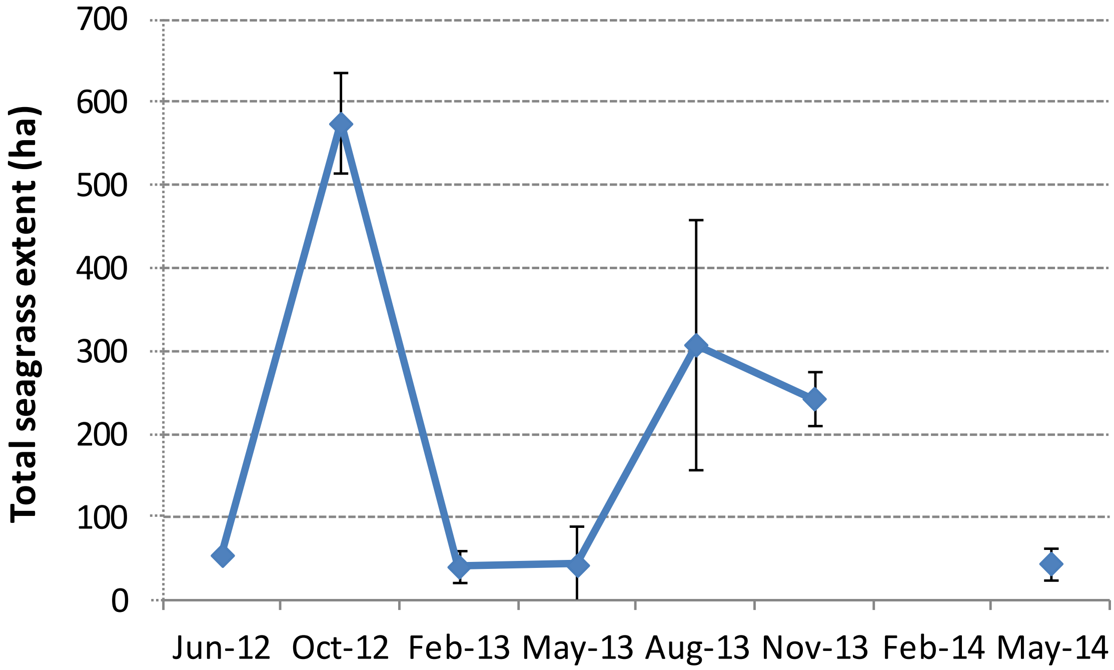


Figure 8 - Total seagrass extent (ha) at East Point seagrass beds

Error bars show reliability estimates (from Geo Oceans 2014)

Seagrasses were identified as a key marine environmental receptor in Section 5.2. The Commonwealth approval of works includes the condition that:

> *"The person taking the action must submit a BIMMP* (Benthic Infauna Monitoring and Management Plan) *for the Minister's approval to protect the foraging habitat for marine turtles, inshore dolphins and dugong (Dugong dugong)."*

7.2 Need for Seagrass Monitoring

Seagrasses are an important foraging habitat for many turtle species and the dugong. The requirement for infauna monitoring is not a direct measure of seagrass condition, hence seagrass monitoring is added here as a supplement to the benthic infauna monitoring program.

7.3 Objectives

The objective of the seagrass monitoring program is to monitor and report potential impacts on seagrass communities in the vicinity of the Ludmilla WWTP by taking into account seagrass distribution extent and per cent cover.

7.4 Monitoring Frequency

Sampling will be conducted twice a year, once during the wet season and once during the dry season (in concert with infauna monitoring) to allow seasonal differences in the seagrass community as well as any effects from the effluent.

7.5 Sampling Strategy

The sampling strategy is shown in Figure 8 . The sampling effort is targeted at known seagrass beds in the vicinity of the outfall. There is an element of uncertainty in relation to the precise locations of seagrass beds between East Point and Nightcliff, so transects are systematically arranged in the areas where seagrasses may be found.

The dominant seagrasses, *Halodule* and *Halophila*, around East Point are structurally small and sparsely distributed; they can be easily obscured when visibility is low. Under these conditions numerous small-area photo quadrats are more effective than towed video, although a combination of methods may be used depending on ambient conditions.

Sampling using photo quadrats along transects positioned using GPS will enable the detection of small-scale changes in seagrass per cent cover and species composition. Seagrass will be sampled from high-resolution photo-quadrat images taken at intervals along each transect. The abundance of seagrass and other visual categories (macroalgae, invertebrates, sediment) in each image will be quantified using point intercept methods to estimate percent cover. This will provide an accurate record of seagrass per cent cover, species composition and presence of other biota at a location (transect) at a particular time, and provide the capability to detect changes.

The aim of the design is to:

- collect information on the presence and condition of seagrass that can be quantitatively presented, compared and assessed
- sample along transects at the same positions repeatedly over time in the area that seagrass beds have been known to be located; and
- use non-destructive techniques that can efficiently collect information over relatively large areas in short time periods.

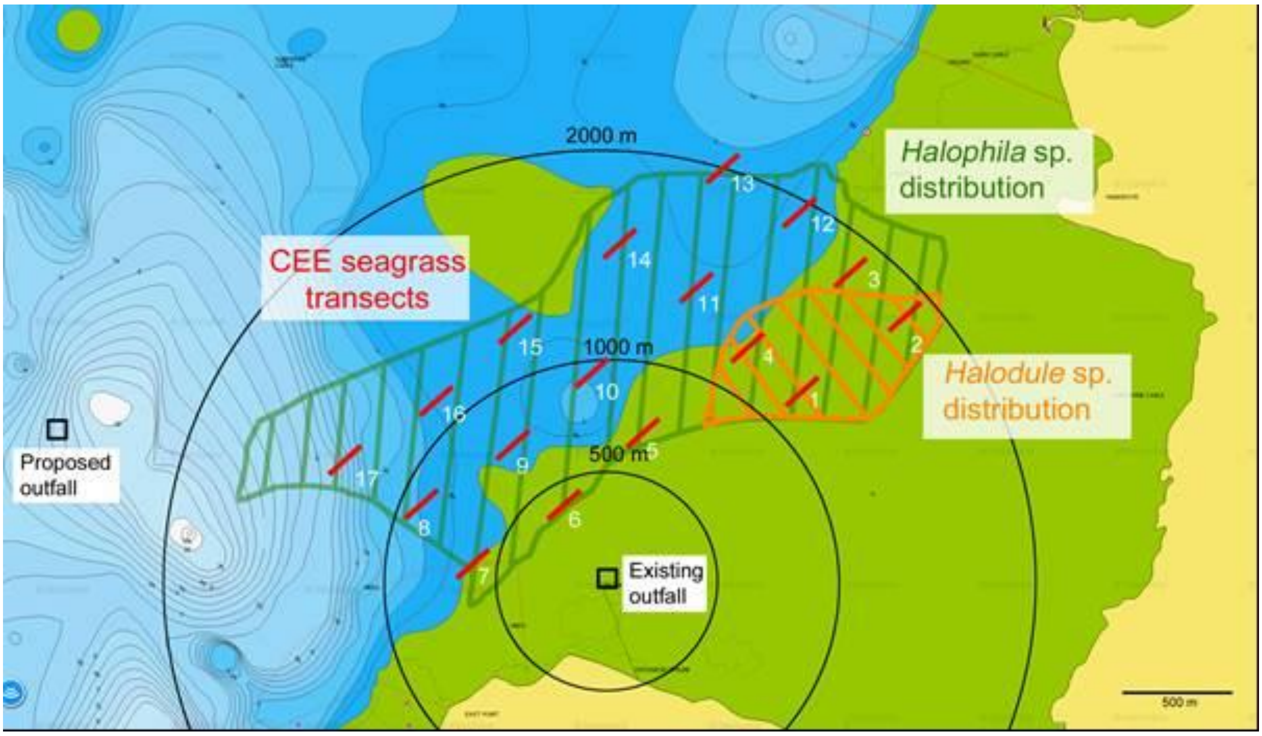


Figure 8 - Seagrass sampling fixed transects

7.6 Sampling Method

A total of twenty 200 m long transects will be positioned across the study area where seagrass has previously been documented. The transects will be marked by GPS coordinates to provide permanent reference points. Sampling will be conducted during high tide conditions.

Photo quadrats will be taken at regular intervals along each transect, with a target of 50 photographs per transect. A time-lapse camera mounted with a 30 cm x 40 cm quadrat will be lowered from the boat to the seabed carefully to minimise sediment disturbance. The camera rig will be bounced over the seabed. A real time video camera with surface monitor will be used by scientists on the surface to control the orientation of the camera rig.

The presence of seagrass along the infauna monitoring transects will also be recorded (i.e. whether they are present in the sediment cores/grabs).

7.7 Image Analysis

The seagrass abundance will be quantified using Coral Point Count (CPCe 3.5) to process the images from each transect. Each image will be superimposed with 25 randomly positioned points and percent cover of seagrass and other biological (e.g. macroalgae, corals etc.) and non-biological categories will be determined for each photo quadrat.

The condition of the seagrass in each frame will also be ranked according to colour (bright green, pale green, yellow, brown) and presence of epiphytes.

7.8 Data Presentation and Assessment

All abundance data will be compiled into a database and presented in data tables. The mean abundance and variance measure for each common or unusual category will be plotted for each site and depth. Subsequent surveys will be added to the database, tables and plots. The plots and data will be assessed for possible seasonal and longer term trends. Years of data will be required to numerically assess the strength of temporal patterns or inter annual trends or to determine management triggers.

7.9 Reporting

Existing information indicates that the presence of seagrasses in the East Point area is highly variable between seasons and from year to year. The data will be compiled and presented to show:

- The extent of seagrass beds in the study area, and (progressively) its seasonal and inter-annual variation
- The average density and patchiness of seagrass and (progressively) its seasonal and inter-annual variation
- The condition of seagrass and (progressively) its seasonal and inter-annual variation
- The information will be used to inform development of triggers and targets for management of seagrass as an important foraging resource for turtles and dugongs and as a vital environmental component in its own right.

8 Effluent dispersion studies and integrated Assessment

As discussed above, the presence of biological distributional patterns may correlate with effluent exposure. The dilution and dispersion of effluent under different tidal and seasonal conditions should be documented through a series of effluent dispersion studies.

The studies proposed under the Benthic Infauna Monitoring and Management Plan are summarised below in Table 8.

Table 8 - Benthic Infauna Monitoring and Management Plan Monitoring Program Summary

Monitoring	Zone			
	Near field	Mid field	Far field	Reference sites
Description	Outfall to 25 metres	>25 m to 200 m	> 200 to 1000 m	
Rationale	• Greatest likelihood of impact; • Detect small scale variations towards outer boundary.	• Effluent exposure rapidly reduces; • Effects may show substantial reduction. • Zone divided into thirds to better define spatial variation and detect potential effects.	• Effluent exposure low to very low; • Effects may be low to very low, indistinguishable from background.	Intertidal reference: • 800 to 1000 m • Beyond identified impact zone. Subtidal reference: • Variable distances; • Boundary to intertidal and subtidal to provide background for future monitoring.
Sampling regime	5; 15 and 25 m from outfall	Inner zone: 40; 50; and 60 m from outfall. Mid zone: 70; 85; and 100 m from outfall. Outer zone: 130; 160; and 200 m from outfall.	350; 500; 750; and 1000 m The SSW and SSE transects will be positioned to maximise the number of sampling points before reaching the shore or the marine reserve	Intertidal reference: There will be 8 randomly selected intertidal sites to the north east outside the discharge plume trajectory. Subtidal reference: There are 10 offshore sites immediately below the subtidal contour; the sites are to the north, north west and west of the outfall.
Transects	7	7	7	Contour not transect
Benthic infauna	Yes	Yes	Yes	Yes
Sediment characteristics	Yes	Yes	Yes	Yes
Seagrass	No	Possible	Yes	Yes
Sensitive receptor field observations	Yes	Yes	Yes	Yes
Algal bloom and anoxia observation	Yes	Yes	Yes	Yes
Relevant Water Quality sites	Yes	Yes	Yes	Yes

Effluent dispersion studies can involve:

- systematic sampling of ambient seawater over a radial grid centred on the outfall to determine dispersion characteristics and average seawater and effluent dilution at distance from the outlet over time; and
- specific effluent plume tracking and sampling surveys to determine the “worst case” dilution of effluent along the centreline of the dispersing effluent

Both of these approaches provide valuable information on water quality conditions that, together with biological monitoring information, ecotoxicological data and effluent flows and concentrations, can provide an integrated understanding of the impact of the effluent discharge on marine environmental conditions in the region of the outlet. The integrated information can inform assessment of the need and extent of a regulatory mixing zone and the management and planning of future effluent treatment options and discharge arrangements.

The Commonwealth Approval requires a separate Water Quality Monitoring and Management Plan to be developed and implemented in relation to the EPO discharge. While the two programs will inform each other they are separate plans.

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APPENDIX A - EFFLUENT EXPOSURE CONCEPT FOR MEASURING ECOLOGICAL IMPACTS

APPENDIX B - PRELIMINARY BENTHIC INFAUNA INVESTIGATION