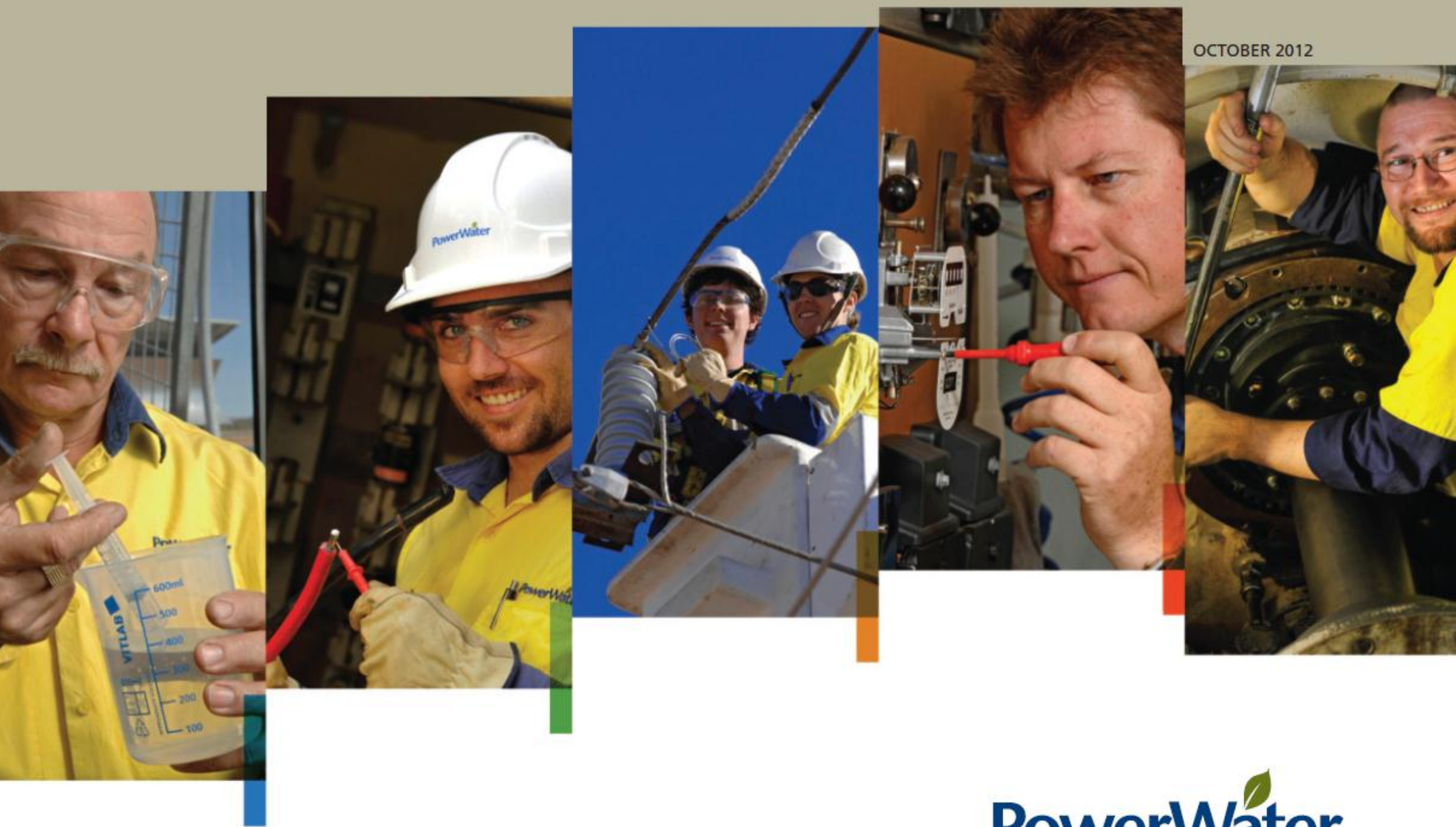
POWER AND WATER CORPORATION

# PUBLIC ENVIRONMENT REPORT

# RESPONSE TO NRETAS' REQUEST FOR ADDITIONAL INFORMATION

OCTOBER 2012



PowerWater

WE VALUE SAFETY INTEGRITY TEAMWORK COMMITMENT COMMUNICATION

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## Abbreviations

| Abbreviation | Description |
|---|---|
| % | Percentage |
| °C | Degrees centigrade |
| AASS | Actual Acid Sulphate Soils |
| ADWF | Average Dry Weather Flow |
| AHD | Australian Height Datum |
| AHU | Aquatic Health Unit |
| ANZECC | Australia and New Zealand Environment Conservation Council |
| API | Aerial Photo Interpretation |
| ASS | Acid Sulphate Soils |
| ASSMP | Acid Sulphate Soils Management Plan |
| BOD | Biochemical Oxygen Demand |
| CAS | Chemical Assisted Sedimentation |
| CDU | Charles Darwin University |
| CEMP | Construction Environmental Management Plan |
| DCC | Darwin City Council |
| DH | NT Department of Health |
| DHAC | Darwin Harbour Advisory Committee |
| EIA | Environmental Impact Assessment |
| EPBC Act | *Environment Protection and Biodiversity Conservation Act 1999* |
| EPO | East Point Outfall |
| ERM | Effluent Rising Main |
| EQO | Environmental Quality Objectives. |
| GPS | Global Positioning System |
| IMS | Integrated Management System |
| ISO | International Standards Organisation |
| kL | Kilo-litre |
| Km | Kilometre |
| Km/h | Kilometres per hour |
| L/s | Litre per Second |
| LAT | Lowest Astronomical Tide |
| LOCP | Larrakeyah Outfall Closure Program |
| m | Meter |
| m2 | Square Meter |
| mL | Millilitre |
| mm | Millimetre |
| NEPM | National Environment Protection Measure |
| NOI | Notice of Intent |
| NRETAS | NT Department Natural Resources, Environment, the Arts and Sport |
| NT | Northern Territory |
| NT Minister | The NT Minister for Natural Resources, Environment and Heritage |
| NTG | Northern Territory Government |
| OH&S | Occupational Health and Safety |
| PASS | Potential Acid Sulphate Soils |
| PER | Public Environmental Report |
| PWC | Power and Water Corporation |
| SEWPAC | Commonwealth Department of Sustainability, Environment, Water, Population and Communities |
| The Final PER | The Draft PER together with the Supplement |

# Abbreviations

| Abbreviation | Description |
|---|---|
| The Guidelines | Guidelines for the Preparation of a Public Report, Duplication of the East Point Effluent Rising Main and Extension of the EPO, February 2010 |
| TN | Total Nitrogen |
| TP | Total Phosphorous |
| TSS | Total Suspended Solids |
| WQO | Water Quality Objectives |

# 1 Introduction

NRETAS has identified concern about the impacts caused by additional effluent discharge at the existing East Point outfall. Power and Water Corporation states that the proposed discharges through the existing outfall will be temporary; however, until the outfall is extended, there will be increased contaminant loads discharging from the existing outfall with associated impacts. Information about these potential impacts is required to inform the current environmental impact assessment.

The current assessment is based on the Effluent Rising Main duplication delivering additional effluent volumes compared to those proposed in 2009 when the project was determined to require formal assessment and also updated data presented in the 2011 draft Public Environmental Report.

The format of this information request is designed to give background context for the reader. The information requirements are arranged topically, and presented in tabular form specifying, where relevant, the level of information required, and potential data sources that are known to the Environment and Heritage Division (EHD).

This response by PWC is designed to address NRETAS' request for additional information on the impacts associated with ongoing discharge of treated wastewater from the existing East Point Outfall (EPO) for an unspecified period, i.e. until such time as the outfall extension is operational. During this period it is anticipated that the volume of wastewater discharged from the EPO will increase due to combining the discharge of the Larrakeyah Waste Water Treatment Plant (WWTP) with that of the Ludmilla WWTP, but that subsequently the quality of wastewater discharged will improve as a result of the planned upgrade to the Ludmilla WWTP, which is currently in progress. The assessment has been extended beyond these initial stages to consider the long-term (20 year) combined wastewater discharge scenario, however it is intended that the EPO extension will be completed by 2014.

The information requested by NRETAS is presented under the major section headings used in the request for additional information:

- Contaminants
- Modelling of mixing zones
- Potential impacts
  (Note that the habitat survey referred to the potential impacts section is presented at Appendix A)
- Impacts to EPBC listed species
- Monitoring Plans
  The Draft Water, Sediment and Biota Monitoring Plan (presented as Appendix Q of the PER incorporating revisions to address an extended period of discharge from the EPO is provided at Appendix B.

The response is presented as a stand-alone document with each topic fully addressed, however, where appropriate, cross referencing is made to tables presented elsewhere in the document and to technical data previously presented in the PER and Supplement in order to minimise duplication.

# 2 Contaminants and Stressors

Information is required on contaminants/stressors that may potentially be present in sewage treated at Ludmilla Waste Water Treatment Plant (LWWTP) that has not yet been presented in the PER or Supplement. Table 3.4.1 of the ANZECC Guidelines for Fresh and Marine Water Quality lists a range of toxicants that should be presented at a minimum (and include those already presented). Of these, information is required on the levels/loads being discharged from the Ludmilla WWTP. Toxicants in particular should be discussed in terms of load, as well as concentration, because some may be at or below concentrations of Darwin Harbour water quality objectives of ANZECC Guidelines for Fresh and Marine Water Quality, but accumulate and bio-accumulate in the environment. Please also discuss the capacity of the Ludmilla WWTP to remove toxicants. The proposed development caters for the projected growth anticipated in the Darwin City Centre, Darwin Centre Inner Suburbs and Darwin Northern Suburbs precincts for the next 20 years. Using the projected growth figures, discuss the future loads of key contaminants expected over the next 20 years.

## 2.1 Influent and effluent stressor/contaminant concentrations

In accordance with the conditions of the Waste Discharge Licence for the LWWTP, PWC undertakes regular analysis of the water entering the treatment plant (influent) and water discharged following treatment (effluent).

In addition to monitoring undertaken in response to licence conditions, which focusses on physical parameters, nutrients and bacteria, PWC undertakes monthly monitoring of the plant effluent (at site SLu080), the ocean outfall (site SLUEP01) and a series of impact/reference sites (SLUEP02 to SLUEP11) as part of its ongoing performance assessment and investigations into the East Point Outfall upgrade. This program, which includes monitoring of a number of potential metal and metalloid contaminants in addition to physico-chemical stressors, has previously been discussed in the East Point Outfall PER Supplement (PWC 2011). The nutrient concentration median values for the LWWTP effluent monitoring site (SLu080) over the period 2004 – 2011 are presented in Table 2-1.

**Table 2-1 LWWTP stressors (nutrients), monthly survey median concentrations**

| LWWTP Effluent Quality | Default Trigger Value : Estuaries (ANZECC & ARMCANZ 2000) | Darwin Harbour Water Quality Objective (Outer Estuary) | LWWTP Effluent SLU080 (median value) (n = 14) |
|---|---|---|---|
| Analyte | µg/L | µg/L | µg/L |
| **Stressor (nutrient)** | | | |
| Oxides of nitrogen | 30 | 10 | 100 |
| Ammonia (ionised) | NG | 20 | 29 000 |
| Total nitrogen | 250 | 440 | 34 200 |
| Filterable reactive phosphorus | 5 | 10 | 3400 |
| Total phosphorus | 20 | 16 | 4900 |

NG No guideline

## 2 Contaminants and Stressors

The contaminant data for site SLu080 has been updated to include additional data since submission of the PER Supplement. The median values for the 14 month period February 2011 to May 2012 are presented in Table 2-2.

**Table 2-2 LWWTP effluent contaminants, monthly survey median concentrations**

| POWER WATER NT<br>LWWTP and EPO | Trigger Value: Marine Water<br>99% Species Protection Level | Trigger Value: Marine Water<br>95% Species Protection Level | Low reliability guideline<br>(Presented here for indicative purposes only) | LWWTP Effluent<br>SLU080<br>(median value)<br>(n = 14) |
|---|---|---|---|---|
| Analyte | µg/L | µg/L | µg/L | µg/L |
| **Metals and Metalloids** | | | | |
| Aluminium | ID | ID | 0.5 | 278 |
| Arsenic | ID | ID | 2.3 (AsIII)<br>4.5 (AsV) | 0.9 |
| Cadmium | 0.7 | 5.5 | | 0.1 |
| Chromium | CrIII 7.7<br>CrV 0.14 | CrIII 27.4<br>CrV 4.4 | | 1.3 |
| Copper | 0.3 | 1.3 | | 124 |
| Iron | ID | ID | 300 | 733 |
| Lead | 2.2 | 4.4 | | 1.5 |
| Mercury | Inorganic 0.1<br>Methyl ID | Inorganic 0.4<br>Methyl ID | | 0.1 |
| Magnesium | NG | NG | NG | 7710 |
| Manganese | ID | ID | 80 | 68 |
| Molybdenum | ID | ID | 23 | 0.7 |
| Nickel | 7 | 70 | | 2.1 |
| Selenium (Total) | ID | ID | 3 | 0.3 |
| Silver | 0.8 | 1.4 | | 0.2 |
| Tin | ID | ID | 10 | 2 |
| Uranium | ID | ID | ID | 0.1 |
| Zinc | 7 | 15 | | 48.5 |

ID Insufficient data to establish a reliable guideline
NG No guideline
Values shaded in grey are the trigger values applying to slightly to moderately disturbed ecosystems
Values highlighted in yellow in the right hand column identify exceedance of the slightly-moderately system trigger value

## 2 Contaminants and Stressors

During the course of the monthly monitoring program the stressors nitrogen and phosphorus (Total N and Total P) have been identified as consistently exceeding the Darwin Harbour Water Quality Objectives (NRETAS 2010) while the contaminants copper and zinc have consistently exceeded the ANZECC & ARMCANZ (2000) trigger values for slightly to moderately disturbed systems, as applicable to the Darwin Harbour outer estuary (NRETAS 2010). Two further metals, aluminium and iron, for which no reliable trigger values are available, exceeded the interim low reliability guideline values. Subsequent analysis of influent and effluent water samples, from which both unfiltered and filtered samples were analysed, shows both aluminium and iron to be generally present in the influent at higher concentrations than in the effluent, and also to be present predominantly in particulate (unfiltered) form (refer to Table 2-4, below).

The median concentrations of other metals for which testing has been undertaken did not exceed the ANZECC & ARMCANZ (2000) slightly-moderately disturbed system trigger values or interim guideline values (Table 2-2).

In addition to the monthly sampling program, on 2 May 2012 (early dry season period) influent and effluent water samples were collected by PWC from the LWWTP for contaminant analysis. These samples were analysed for a more extensive suite of analytes comprising metals, petroleum hydrocarbons, polycyclic aromatic hydrocarbons, BTEX, phenols, pesticides and industrial solvents. Results of the analyses are presented in Table 2-3.

It is noted that many of the substances tested do not have marine water quality trigger values set under the ANZACC & ARMCANZ (2000) water quality guidelines. Accordingly, where they exist, the low reliability guidelines discussed in ANZACC & ARMCANZ (2000) have been quoted as a guide to the significance of the data presented.

In the one-off survey undertaken in May 2012, three of the substances analysed exceeded the trigger values for slightly-moderately disturbed systems. These were the metals copper and zinc and the non-metallic inorganic compound cyanide.

The monthly median concentration of nitrogen (TN) exceeded the Darwin Harbour WQO by a factor of 77 and the concentration of phosphorus (TP) by a factor of 245.

In both surveys the concentration of zinc present in the discharge exceeded the slightly-moderately disturbed system trigger value by a factor of 3.5 and the concentration of copper by a factor of 92. The concentration of cyanide exceeded the slightly-moderately disturbed system trigger value by a factor of <2.

All of the other substances tested, including the remaining metals and a range of hydrocarbons and pesticides, were present at concentrations below the ANZECC & ARMCANZ (2000) trigger values for slightly-moderately disturbed systems and interim guidelines and/or were present at concentrations too low to be detected in the testing undertaken.

# 2 Contaminants and Stressors

### Table 2-3 LWWTP Influent and Effluent Contaminant Concentrations (May 2012)

| POWER WATER NT Ludmilla Waste Water Treatment Plant | Trigger value Marine water 99% Species Protection Level | Trigger value Marine water 95% Species Protection Level | Low reliability guideline (Presented here for indicative purposes only) | LWWTP Influent SLU010 | LWWTP Effluent SLU080 |
|---|---|---|---|---|---|
| ANALYTE | µg/L | µg/L | | µg/L | µg/L |
| **Metals and Metalloids** | | | | | |
| Antimony | ID | ID | 270 | < 5 | < 5 |
| Arsenic | ID | ID | 2.3 (AsIII)<br>4.5 (AsV) | < 1 | < 1 |
| Beryllium | ID | ID | | < 1 | < 1 |
| Boron | ID | ID | 5100 | < 50 | < 50 |
| Cadmium | 0.7 | 5.5 | | < 0.2 | < 0.2 |
| Chromium | Cr(III) 7.7<br>Cr (VI) 0.14 | Cr(III) 27.4<br>Cr (VI) 4.4 | | 1 | 2 |
| Cobalt | 0.005 | 1 | | < 1 | < 1 |
| Copper | 0.3 | 1.3 | | 200 | 120 |
| Lead | 2.2 | 4.4 | | 3 | 2 |
| Manganese | ID | ID | 80 | 81 | 87 |
| Mercury | Inorganic 0.1<br>Methyl ID | Inorganic 0.4<br>Methyl ID | | < 0.1 | < 0.1 |
| Molybdenum | ID | ID | 23 | < 5 | < 5 |
| Nickel | 7 | 70 | | 3 | 2 |
| Selenium | (Total) ID | (Total) ID | 3 (Tot) | < 1 | < 1 |
| Silver | 0.8 | 1.4 | | < 5 | < 5 |
| Tin | ID | ID | 10 | < 5 | < 5 |
| Zinc | 7 | 15 | | 110 | 53 |
| | | | | | |
| **Non-Metallic Inorganics** | | | | | |
| Cyanide (total) | 2 | 4 | | < 5 | 6.7 |
| | | | | | |
| **Chlorinated Hydrocarbons** | | | | | |
| 1.2.3.4-Tetrachlorobenzene | ID | ID | 4 | < 0.1 | < 0.1 |
| 1.2.3.5-Tetrachlorobenzene | ID | ID | 5 | < 0.1 | < 0.1 |
| 1.2.3-Trichlorobenzene | ID | ID | 3 | < 1 | < 1 |
| 1.2.4.5-Tetrachlorobenzene | ID | ID | 5 | < 0.1 | < 0.1 |
| 1.2.4-Trichlorobenzene | 20 | 80 | | < 1 | < 1 |
| 1.2-Dichlorobenzene | ID | ID | 160 | < 1 | < 1 |
| 1.3.5-Trichlorobenzene | ID | ID | 8 | < 0.1 | < 0.1 |
| 1.3-Dichlorobenzene | ID | ID | 260 | < 1 | < 1 |
| 1.4-Dichlorobenzene | ID | ID | 60 | 3 | 1 |
| Benzal chloride | ID | ID | | < 0.1 | < 0.1 |
| Benzotrichloride | ID | ID | | < 0.1 | < 0.1 |
| Benzyl chloride | ID | ID | | < 1 | < 1 |
| Hexachlorobenzene | ID | ID | 0.1 | < 0.1 | < 0.1 |
| Hexachlorobutadiene | ID | ID | | < 0.1 | < 0.1 |
| Hexachlorocyclopentadiene | ID | ID | | < 0.1 | < 0.1 |
| Hexachloroethane | ID | ID | 0.05 | < 0.1 | < 0.1 |
| Pentachlorobenzene | ID | ID | 1.5 | < 0.1 | < 0.1 |
| | | | | | |
| **BTEX** | | | | | |
| Benzene | 500 | 700 | | < 1 | < 1 |
| Ethylbenzene | ID | ID | 5 | < 1 | 1 |
| o-Xylene | ID | ID | 350 | < 1 | < 1 |
| Toluene | ID | ID | 180 | 5 | 7 |
| Total m+p-Xylenes | ID | ID | | < 2 | < 2 |
| Xylenes (ortho, meta and para) | ID | ID | | < 3 | < 3 |

# 2 Contaminants and Stressors

| POWER WATER NT Ludmilla Waste Water Treatment Plant | Trigger value Marine water 99% Species Protection Level | Trigger value Marine water 95% Species Protection Level | Low reliability guideline (Presented here for indicative purposes only) | LWWTP Influent SLU010 | LWWTP Effluent SLU080 |
|---|---|---|---|---|---|
| **ANALYTE** | µg/L | µg/L | | µg/L | µg/L |
| **Polycyclic Aromatic Hydrocarbons** | | | | | |
| Acenaphthene | ID | ID | | < 1 | < 1 |
| Acenaphthylene | ID | ID | | < 1 | < 1 |
| Anthracene | ID | ID | 0.01 | < 1 | < 1 |
| Benzo(a)anthracene | ID | ID | | < 1 | < 1 |
| Benzo(a)pyrene | ID | ID | 0.2 | < 1 | < 1 |
| Benzo(b)fluoranthene | ID | ID | | < 1 | < 1 |
| Benzo(g.h.i)perylene | ID | ID | | < 1 | < 1 |
| Benzo(k)fluoranthene | ID | ID | | < 1 | < 1 |
| Chrysene | ID | ID | | < 1 | < 1 |
| Dibenz(a.h)anthracene | ID | ID | | < 1 | < 1 |
| Fluoranthene | ID | ID | 1.4 | < 1 | < 1 |
| Fluorene | ID | ID | | < 1 | < 1 |
| Indeno(1.2.3-cd)pyrene | ID | ID | | < 1 | < 1 |
| Naphthalene | 50 | 70 | | < 1 | < 1 |
| Phenanthrene | ID | ID | 0.6 | < 1 | < 1 |
| Pyrene | ID | ID | | < 1 | < 1 |
| Total PAH | ID | ID | | < 1 | < 1 |
| | | | | | |
| **Phenols (non-Halogenated)** | | | | | |
| 2.4-Dimethylphenol | ID | ID | 2 | < 3 | < 3 |
| 2.4-Dinitrophenol | ID | ID | 45 | < 30 | <30 |
| 2-Cyclohexyl-4.6-dinitrophenol | ID | ID | | < 100 | < 100 |
| 2-Methyl-4.6-dinitrophenol | ID | ID | | < 30 | < 30 |
| 2-Methylphenol (o-Cresol) | ID | ID | | < 3 | < 3 |
| 2-Nitrophenol | ID | ID | 2 | < 10 | < 10 |
| 3&4-Methylphenol (m&p-Cresol) | ID | ID | | 110 | 14 |
| 4-Nitrophenol | ID | ID | 58 | < 30 | < 30 |
| Dinoseb | ID | ID | | < 100 | < 100 |
| Phenol | 270 | 400 | | 14 | < 3 |
| Total Non-Halogenated Phenol | ID | ID | | 100 | < 100 |
| | | | | | |
| **Phenols (Halogenated)** | | | | | |
| 2.4.5-Trichlorophenol | ID | ID | 4 | < 10 | < 10 |
| 2.4.6-Trichlorophenol | ID | ID | 3 | < 10 | < 10 |
| 2.4-Dichlorophenol | ID | ID | 120 | < 3 | < 3 |
| 2.6-Dichlorophenol | ID | ID | 34 | < 3 | < 3 |
| 2-Chlorophenol | ID | ID | 340 | < 3 | < 3 |
| 4-Chloro-3-methylphenol | ID | ID | | < 10 | < 10 |
| Pentachlorophenol | 11 | 22 | | < 10 | < 10 |
| Tetrachlorophenols - Total | ID | ID | | < 30 | < 30 |
| Total Halogenated Phenol | ID | ID | | < 10 | < 10 |
| | | | | | |
| **Polychlorinated Biphenyls** | | | | | |
| Aroclor-1016 | ID | ID | 0.009 | < 1 | < 1 |
| Aroclor-1221 | ID | ID | 1 | < 1 | < 1 |
| Aroclor-1232 | ID | ID | 0.3 | < 1 | < 1 |
| Aroclor-1242 | ID | ID | 0.3 | < 1 | < 1 |
| Aroclor-1248 | ID | ID | 0.03 | < 1 | < 1 |
| Aroclor-1254 | ID | ID | 0.01 | < 1 | < 1 |
| Aroclor-1260 | ID | ID | | < 1 | < 1 |
| Total PCB | ID | ID | | < 1 | < 1 |

# 2 Contaminants and Stressors

| POWER WATER NT Ludmilla Waste Water Treatment Plant | Trigger value Marine water 99% Species Protection Level | Trigger value Marine water 95% Species Protection Level | Low reliability guideline (Presented here for indicative purposes only) | LWWTP Influent SLU010 | LWWTP Effluent SLU080 |
|---|---|---|---|---|---|
| **ANALYTE** | **µg/L** | **µg/L** | | **µg/L** | **µg/L** |
| **Organochlorine Pesticides** | | | | | |
| 4.4'-DDD | ID | ID | | < 0.1 | < 0.1 |
| 4.4'-DDE | ID | ID | 0.0005 | < 0.1 | < 0.1 |
| 4.4'-DDT | ID | ID | 0.0004 | < 0.1 | < 0.1 |
| a-BHC | ID | ID | | < 0.1 | < 0.1 |
| Aldrin | ID | ID | 0.003 | < 0.1 | < 0.1 |
| b-BHC | ID | ID | | < 0.1 | < 0.1 |
| Chlordane | ID | ID | 0.001 | < 1 | < 1 |
| d-BHC | ID | ID | | < 0.1 | < 0.1 |
| Dieldrin | ID | ID | 0.00001 | < 0.1 | < 0.1 |
| Endosulfan I | ID | ID | 0.0002 | < 0.1 | < 0.1 |
| Endosulfan II | ID | ID | 0.007 | < 0.1 | < 0.1 |
| Endosulfan sulphate | ID | ID | | < 0.1 | < 0.1 |
| Endrin | 0.004 | 0.008 | | < 0.1 | < 0.1 |
| Endrin aldehyde | ID | ID | | < 0.1 | < 0.1 |
| Endrin ketone | ID | ID | | < 0.1 | < 0.1 |
| g-BHC (Lindane) | ID | ID | 0.007 | < 0.1 | < 0.1 |
| Heptachlor | ID | ID | 0.0004 | < 0.1 | < 0.1 |
| Heptachlor epoxide | ID | ID | | < 0.1 | < 0.1 |
| Hexachlorobenzene | ID | ID | 0.05 | < 0.1 | < 0.1 |
| Methoxychlor | ID | ID | 0.04 | < 0.1 | < 0.1 |
| Toxaphene | ID | ID | | < 1 | < 1 |
| | | | | | |
| **Total Recoverable Hydrocarbons - 1999 NEPM Fractions** | | | | | |
| TRH C6-C9 | NG | NG | | 0.04 | 0.07 |
| TRH C10-C14 | NG | NG | | 0.33 | < 0.05 |
| TRH C15-C28 | NG | NG | | 1.3 | 0.4 |
| TRH C29-C36 | NG | NG | | 1.1 | 0.4 |
| TRH C10-36 (Total) | NG | NG | | 2.7 | 0.8 |
| | | | | | |
| **Total Recoverable Hydrocarbons - Draft 2010 NEPM Fractions *** | | | | | |
| Naphthalene | 50 | 70 | | < 0.02 | < 0.02 |
| TRH C6-C10 | NG | NG | | 0.26 | 0.09 |
| TRH C6-C10 less BTEX | NG | NG | | 0.26 | 0.08 |
| TRH >C10-C16 | NG | NG | | 0.43 | 0.07 |
| TRH >C10-C16 less Naphthalene | NG | NG | | 0.43 | 0.07 |
| TRH >C16-C34 | NG | NG | | 2.1 | 0.6 |
| TRH >C34-C40 | NG | NG | | 0.5 | 0.2 |

* values shaded in grey are the trigger values applying to slightly to moderately disturbed systems

Following identification of the presence of some metallic contaminants at elevated concentration in the monthly surveys, additional analysis was undertaken of samples collected over a two week period in June 2012. Samples were collected twice daily over two, three day periods and both filtered and unfiltered samples were analysed.

The results generally indicate some reduction in the unfiltered metal concentrations as occurring within the treatment plant, with either no change or a small increase in filtered metal concentrations.

The median concentrations for the twelve sampling events are presented in Table 2-4.

# 2 Contaminants and Stressors

**Table 2-4 LWWTP Influent and Effluent Filtered and Unfiltered Metal Concentrations (June 2012)**

| Analyte (Concentrations in µg/L) | Trigger value Marine water 99% Species Protection Level | Trigger value Marine water 95% Species Protection Level | Low reliability guideline (Presented here for indicative purposes only) | LWWTP Influent SLu010 | LWWTP Effluent SLu080 |
|---|---|---|---|---|---|
| Aluminium | ID | ID | 0.5 | 1230 | 510 |
| Aluminium (filtered) | ID | ID | 0.5 | 60 | 85 |
| Copper | 0.3 | 1.3 | | 170 | 140 |
| Copper (filtered) | 0.3 | 1.3 | | 102 | 98 |
| Iron | ID | ID | 300 | 645 | 460 |
| Iron (filtered) | ID | ID | 300 | 75 | 105 |
| Zinc | 7 | 15 | | 101 | 95 |
| Zinc (filtered) | 7 | 15 | | 20 | 28 |

As previously noted, the one-off contaminant survey samples were collected on a single day and thus represent a snapshot of treatment plant water quality. In order to ascertain the representativeness of the data, analytes common to both programs have been compared against the monthly medians for the period February 2011 to May 2012 and against the data for the 9 May 2011 sample. This sample matches the season from which the snapshot sample was collected. The comparative data presented in Table 2-5 show a good match between the data sets, suggesting that the one-off contaminant survey samples are representative of normal operating conditions.

# 2 Contaminants and Stressors

**Table 2-5 Comparative analysis – SLU080 monthly and one-off survey results**

| POWER WATER NT<br>LWWTP and EPO | LWWTP Effluent<br>Monthly Program<br>SLU080<br>(median value)<br>(n = 14) | LWWTP Effluent<br>Monthly Program<br>SLU080<br>9 May 2011 | LWWTP Effluent<br>One-off Survey<br>SLU080<br>2 May 2012 |
|---|---|---|---|
| Analyte | µg/L | µg/L | µg/L |
| **Metals and Metalloids** | | | |
| Arsenic | 0.9 | 0.9 | < 1 |
| Cadmium | 0.1 | < 0.1 | < 0.2 |
| Chromium | 1.3 | 1.1 | 2 |
| Copper | 124 | 124 | 120 |
| Lead | 1.5 | 1 | 2 |
| Mercury | 0.1 | <0.03 | < 0.1 |
| Manganese | 68 | 73 | 87 |
| Molybdenum | 0.7 | 0.4 | < 5 |
| Nickel | 2.1 | 1.4 | 2 |
| Selenium (Total) | 0.3 | 0.1 | < 1 |
| Silver | 0.2 | 0.08 | < 5 |
| Tin | 2 | 2.1 | < 5 |
| Zinc | 48.5 | 43.4 | 53 |

# 2 Contaminants and Stressors

## 2.2 Key stressors and contaminants – current and future loadings

The 2011 Average Dry Weather Flow (ADWF) for the Ludmilla WWTP discharge through the East Point Outfall was 9.5 megalitres per day (ML/d), or 3467.5 ML/annum.

Predicted future flows for the combined Ludmilla and Larrakeyah catchments are based on the population predictions shown in Table 2-6.

**Table 2-6 Population predictions Ludmilla and Larrakeyah catchments to 2030**

| Catchment Population | 2011 | 2016 | 2021 | 2026 | 2030 |
|---|---|---|---|---|---|
| Ludmilla catchment population | 33 300 | 35 900 | 38 700 | 41 700 | 44 200 |
| Larrakeyah catchment population | 9 400 | 10 100 | 10 900 | 11 700 | 12 400 |
| **Total catchment population** | **42 700** | **46 000** | **49 600** | **53 400** | **56 600** |

Predicted ADWFs for the population predictions in presented in Table 2-6 are as shown in Table 2-7.

**Table 2-7 ADWFs for Ludmilla and Larrakeyah catchments to 2030**

| ADWF (ML/day) | 2011 | 2016 | 2021 | 2026 | 2030 |
|---|---|---|---|---|---|
| Ludmilla | 9.5 | 10.8 | 11.6 | 12.5 | 13.3 |
| Larrakeyah | 3 | 3.2 | 3.5 | 3.8 | 4 |
| **Combined catchment flow** | **12.5** | **14** | **15.1** | **16.3** | **17.3** |

The current and predicted future ADWFs for the Ludmilla WWTP and the combined Ludmilla WWTP and Larrakeyah catchments which PWC have adopted for planning purposes are set out in Table 2-8.

**Table 2-8 Current and predicted ADWFs from the East Point Outfall**

| Year | Flow Scenarios | Flow rate ML/day | Flow rate ML/annum |
|---|---|---|---|
| 2011 | Existing flow (Ludmilla WWTP only) | 9.5 | 3467.5 |
| 2012 | Combined flow (Ludmilla WWTP plus Larrakeyah WWTP) | 12.5 | 4562.5 |
| 2016 | Combined flow (Ludmilla WWTP plus Larrakeyah WWTP) | 14 | 5110 |
| 2030 | Combined flow (Based on predicted population growth) | 17.5 | 6387.5 |

Nutrients, which are essential for plant and animal growth, are regarded as environmental stressors when present in high concentrations. Both nitrogen and phosphorus have been identified as present in the LWWTP discharge at concentrations exceeding the default trigger values applicable to northern

# 2 Contaminants and Stressors

Queensland, the Northern Territory and north-west Western Australia (ANZECC & ARMCANZ 2000) and the water quality objectives for Darwin Harbour (outer estuary) (NRETAS 2010).

In presenting load predictions for future nutrient discharge, it is noted that while the volume of the discharge is predicted to increase over time (Table 2-8) as a result of population growth, it is also planned that the concentration of nutrients will decrease as a result of improvements in wastewater treatment achieved by the plant upgrade presently being implemented. Present and predicted nutrient concentrations in the LWWTP discharge are presented in Table 2-9.

**Table 2-9 Predicted annual nutrient concentrations discharged from the LWWTP to 2030**

| Stressor | Concentration (µg/L) | | | | |
|---|---|---|---|---|---|
| | Ludmilla WWTP 2011 | Combined effluent (pre-upgrade) 2012 | Combined effluent (post-upgrade) 2012 | Combined effluent (post-upgrade) 2016 | Combined effluent (post-upgrade) 2030 |
| Total nitrogen | 34 200 | 34 200 | 30 000 | 30 000 | 30 000 |
| Total Phosphorus | 4 900 | 4 900 | 2740 | 2740 | 2740 |

Table 2-10 presents the predicted loads for nutrients (TN and TP) discharged from the LWWTP up to the year 2030. The nutrient loads are calculated from the predicted flow rates presented in Table 2-8 and the concentrations presented in Table 2-9.

The load of both nitrogen and phosphorus discharged via the EPO will increase when the two effluent streams are combined, followed by a reduction in the combined load once the plant upgrade is completed. Subsequently the annual load of both nutrients will increase in line with predicted population increases however the phosphorus load is not predicted to reach the pre-existing LWWTP load until post 2016.

**Table 2-10 Predicted annual nutrient loads discharged from the LWWTP to 2030**

| Stressor | | Load (t/a) | | | |
|---|---|---|---|---|---|
| | Ludmilla WWTP 2011 | Combined effluent (pre-upgrade) 2012 | Combined effluent (post-upgrade) 2012 | Combined effluent (post-upgrade) 2016 | Combined effluent (post-upgrade) 2030 |
| Total nitrogen | 119 | 156 | 137 | 154 | 190 |
| Total Phosphorus | 17 | 22 | 13 | 15 | 18 |

## 2 Contaminants and Stressors

The key contaminants discharged from the EPO have been identified in previous investigations as copper and zinc, both of which are essential micronutrients but potentially toxic when present at high concentrations.

Aluminium and iron were also identified as contaminants of interest, based on exceedances of the ANZECC & ARMCANZ (2000) low reliability guidelines for these metals however iron was subsequently discounted as being predominantly present in particulate form. Cyanide has also been identified as a contaminant of interest as a result of the one off survey, exceeding the ANZECC & ARMCANZ (2000) 95% species protection trigger value.

Manganese was identified as exceeding the ANZECC & ARMCANZ (2000) low reliability guideline value in the one-off survey, but not the long term median of the monthly survey data.

No other toxicant exceeded the slightly-moderately disturbed system trigger values or the low reliability guideline values.

Table 2-11 presents the predicted loads for key contaminants discharged from the LWWTP up to the year 2030. It has been assumed that while the volume of the discharge will increase over time, the concentration of metallic contaminants will remain the same. Figures in brackets represent the values used previously in modelling and load calculations. In all cases these are higher than the most recent data.

**Table 2-11 Predicted annual contaminant loads discharged from the LWWTP to 2030**

| Contaminant/Stressor | Concentration (µg/L | Load (kg/a) | | | |
|---|---|---|---|---|---|
| | | 2011 | 2012 | 2016 | 2030 |
| Copper | 124 (139) | 430 (482) | 566 (634) | 634 | 792 (888) |
| Zinc | 53 (80) | 184 (277) | 242 (364) | 271 | 258 (510) |
| Aluminium | 278 | 964 | 1268 | 1420 | 1776 |
| Cyanide | 6.7 | 23 | 30 | 34 | 42 |
| Hydrocarbons (oil and grease) | 800 | 2774 | 3650 | 4088 | 5110 |

Note that the presence of hydrocarbons should not be taken to indicate the presence of petroleum products. Most of the hydrocarbons present are longer chain hydrocarbons and likely to comprise predominantly vegetable oils and animal fats.

# 2 Contaminants and Stressors

## 2.3 LWWTP toxicant removal capacity

The Ludmilla WWTP is specifically designed for solids removal rather than toxicant removal. However review of existing (pre-upgrade, Ludmilla catchment only) influent and effluent data for the plant (Tables 2-3 and 2-4) indicates that as a consequence of solids removal there may be some limited contaminant removal from the waste water stream.

Using the influent and effluent data as a guide, it would appear that:

- Hydrocarbon concentrations may be reduced by 60 - 70%
- Unfiltered concentrations of aluminium, iron, copper and zinc may be reduced, presumably by removal of solids, as concentrations of soluble forms remain relatively unchanged.

In presenting the above assessment it should be noted that the effluent water quality data shown in Tables 2-3 and 2-4 does not necessarily represent post-treatment water quality for influent of the same composition as that presented in those tables, and thus contaminant removal may be over or under estimated.

The CAS treatment approach utilising coagulation and flocculation primarily targets effective removal of particulate matter in the raw sewage and has very limited influence on dissolved matter such as soluble BOD and ammonia nitrogen and heavy metals. Upgrading of the plant does however afford the opportunity for significant improvement in the physico-chemical properties of the effluent. Table 2-12 shows the raw sewage concentrations adopted for the plant upgrade, while Table 2-13 shows the indicative post-upgrade treatment targets. These show significant reductions in BOD, TSS, Total Nitrogen, Free Ammonia and Total Phosphorus.

TSS reduction offers some potential for reduction in metals present in solid form as micro-particulates and colloidal complexes, as identified above.

**Table 2-12 Raw Sewage Concentrations Adopted for the Ludmilla WWTP Upgrade Design**

| Parameter | Average (mg/L) | Median (mg/L) | 90%ile (mg/L) |
|---|---|---|---|
| pH | 7.1 | 7.1 | 7.4 |
| BOD | 165 | 150 | 290 |
| TSS | 265 | 165 | 640 |
| Total Nitrogen | 45 | 45 | 65 |
| Free Ammonia | 30 | 35 | 40 |
| Total Phosphorus | 7.5 | 7.0 | 11.5 |

Chemical conditioning at the Ludmilla WWTP will consist of dosing with lime, a coagulant and settling aid polymer.

The objective of the settling process is to remove both discrete particulates and non-discrete colloidal particles. Significant fluctuations in both the raw sewage characteristics and flows entering the

# 2 Contaminants and Stressors

Ludmilla WWTP mean that accurate predictions for the treated effluent quality from the upgraded treatment plant are difficult. Indicative treated effluent quality targets are presented in Table 2-13. These targets were derived based on the raw sewage characteristics as shown in Table 2-12 and PWC's assessment of the historical effluent quality data available from the plant operations record and recent plant flocculation trials. The targets set in Table 2-13 are based on the plant being operated as per design with lime, ferric and polymer dosing. If the correct chemical combination is not used, it is unlikely that these effluent quality targets will be achieved. However the proposed process of coagulation and flocculation provides the greatest opportunity to achieve the effluent quality targets suggested in Table 2-13.

The targets set in Table 2-13 are based on the plant being operated as per design with lime, ferric and polymer dosing.

**Table 2-13 Indicative Treated Effluent Quality Targets for the Upgraded Ludmilla WWTP**

| Assessable Parameter | Median (mg/L) | 90%ile (mg/L) |
|---|---|---|
| pH | - | >6 |
| BOD | 90 | 165 |
| TSS | 65 | 90 |
| Total Nitrogen | 39 | 45 |
| Free Ammonia | 2.5 | 4.5 |
| Total Phosphorus | - | >6 |

Disinfection capability has also been included in the existing and upgraded plant design to reduce bacterial levels (*E. coli* and Enterococci) to meet NHMRC marine recreational guidelines at the point of discharge under normal operating conditions.

# 3 Modelling of Mixing Zones

Improved bathymetric data (LIDAR) was available to improve the modelling yet no discussion was provided on why this was not used.

Bathymetric information provided suggested that sand waves have created a sedimentary basin in which the current outfall discharges. It is possible that this will affect how effluent from the current outfall will impact on the local marine environment, the sedimentary basin may trap fine sediments and flocculated particulate matter and may not be well flushed. The Supplement state that "effects of the current and proposed discharge on sediment toxicity and nutrient accumulation/cycling have yet to be evaluated, and that further testing will be conducted for the outfall extension proposal. Information was requested on the potential for impacts at the current outfall, and this should include the most recent information. Consideration should be given to ecotoxicological testing within the mixing zone at the current outfall to demonstrate level of impacts. This will be a future requirement prior to consideration of a mixing zone for new or modified outfalls.

Water quality monitoring from 2011 (provided at Appendix M of the Supplement) indicates that several parameters were detected above Darwin harbour Water Quality Objectives at sampling locations beyond the modelled mixing zones. This occurred with nearly all samples for total phosphorus and a majority of samples for filterable reactive phosphorus, and also occasional samples of total nitrogen and other parameters not modelled, even at a reference site. This indicates that either there may be significant departure of the model from reality, effluent does not disperse adequately, contaminants do not decay as predicted or that background levels are already high. Please explain how the results of modelling of mixing zones can be relied on in light of this monitoring data. Evidence may be required to substantiate any assertions, such as isotope analysis, that would distinguish whether or not contaminants detected outside mixing zones are derived from effluent discharges or are background derived. Discuss the appropriateness of the reference monitoring site.

To demonstrate extent of impact on marine habitats, please provide model graphics with size (i.e. hectares or other meaningful units) of initial and subsequent scenarios. Please include effluent mixing zone models overlain with lowest astronomical tide and mean tide lines, the boundary of the East Point Aquatic Life Reserve, significant benthic habitats (e.g. seagrass, sponge beds, coral reefs, etc.) and sampling points. Please also describe habitats that occur within the widest combined boundaries of mixing zones as well as nearby habitats important to listed species (seagrass has already been provided but please include an outline on the model graphics. Benthic habitat descriptions derived from video mapping are not considered a reliable method of determining  benthic habitat as they do not provide baseline data used to assess impacts on sediments and the consequential health of infaunal and epibenthic communities. Benthic habitats within mixing zoned should be provided.

## 3.1 Bathymetric data used in modelling

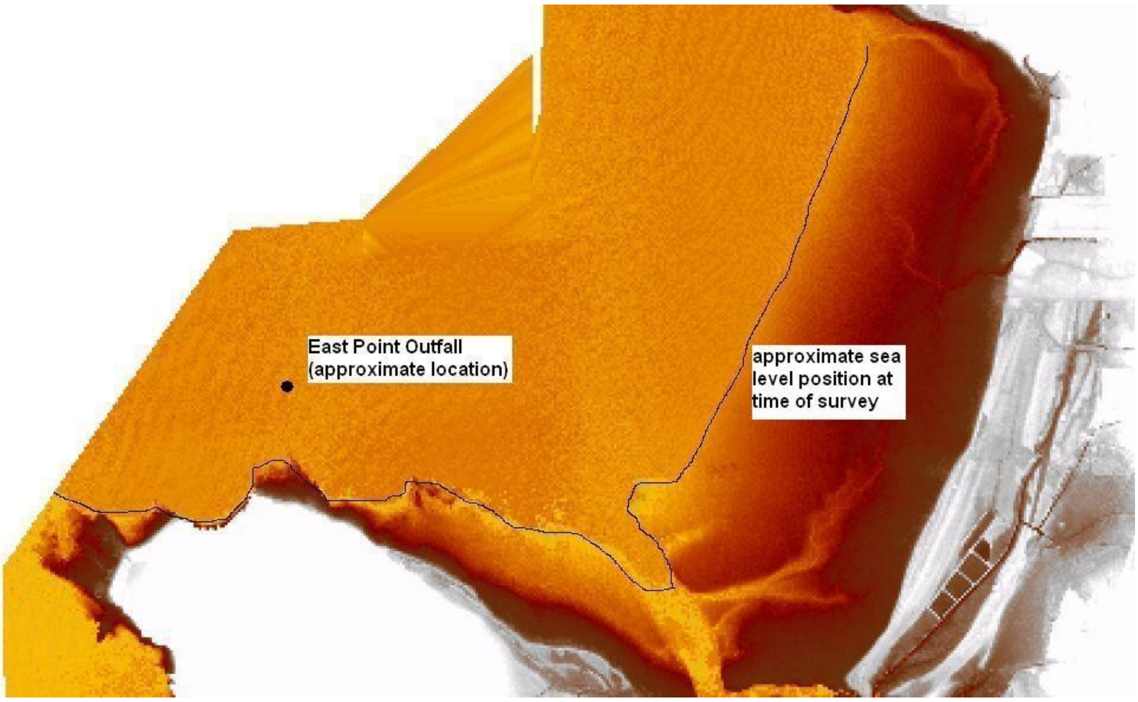
The LiDAR dataset is a digital elevation model (DEM) covering the coastal region between Dundee Beach and Glyde Point. Commissioned by the CRC for Spatial Information (CRCSI), the DEM was captured using Airborne LiDAR flown on the 4th and 5th of July 2009. The vertical accuracy of the dataset is stated as being 0.15 m where captured in open ground areas and the horizontal accuracy 0.21 m. All airborne LiDAR acquisition was required to be done within 2 hours of the low tide. It should be noted that this technique does not penetrate below sea level and therefore elevation data is only provided for areas above the water level at the time of survey.

# 3 Modelling of Mixing Zones

The tidal cycle at the time of the survey was not optimal for capturing low-intertidal areas, being between the neap and spring cycles. The exact time of the survey in the East Point area is not available, but processing and review of the data suggests that it did not coincide with low-tide conditions in this area.

Figure 3-1 shows LiDAR data for the East Point area. The data has been processed to highlight the approximate sea level at the time of survey, which is indicated by the black line. The outfall was not exposed and the survey provides no useful bathymetric data around the East Point Outfall area for the mixing zone model used for this study.

**Figure 3-1 LIDAR data for the East Point area**




## 3.2 Potential for impacts at the current outfall location

### 3.2.1 Habitat distribution about the outfall

The mapping of intertidal and subtidal habitats in the region around the outfall by Geo Oceans in May 2012 shows the outfall to be located in an area where no marine macroalgae or seagrasses were identified and macrofaunal productivity (as evidenced by the absence of epibenthic fauna, and low level of infaunal activity, using the absence of burrows as an indicator) at the time of survey was below the criteria used in the mapping (Refer to Appendix A, Figure 15). The absence of seagrass around the outfall location is consistent with the findings of previous surveys (e.g. (GHD 2009, NRETAS 2011, Geo Oceans 2011), however the absence of seagrass from areas further to the north where it has previously been observed (Appendix A, Figure 16) may be related to seasonal of inter-annual variability. The absence of epibenthic fauna on the soft sediments about the outfall location is consistent with previous observations (e.g. GHD 2009). Sediment sampling and the presence of contaminants in the sediments is described in Section 4.1.2.

# 3 Modelling of Mixing Zones

### 3.2.2 Water quality

Water quality data indicate that only one contaminant, copper, was routinely present in the discharged wastewater at Site SLUEP01 at a concentration exceeding the ANZECC & ARMCANZ (2000) 95% species protection trigger value. From the monthly water quality data (Table 4-1), the median[1] concentration of copper at the outfall monitoring site of 7 µg/L exceeded the guideline value of 1.3 ug/L by a factor of <6, i.e. six further dilutions would be required to bring it below the trigger value.

Considering the 95th percentile values (Table 4-2), expands the number of contaminants and sites for which exceedance of the guidelines was recorded, to include nickel and zinc in addition to copper.

The inorganic compound cyanide was detected at a concentration 1.5 times the ANZACC & ARMCANZ (2000) low reliability trigger value at Site SLU080 in the more extensive, one-off sampling program. Based on the findings of the marine water quality survey program it can be concluded that this compound would be below the guideline concentration as a result of initial dilution if measured at the outfall monitoring site (SLUEP01).

One further substance, aluminium, occurred in concentrations around the outfall exceeding the values recorded at the reference sites. The form in which the aluminium is present has not been determined, however it is noted that the majority of the aluminium discharged from the plant is in particulate form (refer to Table 2-4).

Nutrients are discharged at elevated concentrations but the majority are present in forms (organic nitrogen and non-reactive phosphorus) which require chemical transformation before becoming available to plants. As a result of tidal dispersion it is unlikely that significant stimulation of growth will occur in the immediate vicinity of the outfall.

While the nutrients discharged from the EPO may give rise to some stimulation of plant growth beyond the outfall, the area over which this may occur and level of stimulation is uncertain.

### 3.2.3 Sediments

#### *3.2.3.1 Sediment metals*

Reference to the sediment test data (refer to Table 4-3) shows metal concentrations to be within guidelines for all metals other than arsenic, which is known to be naturally elevated within the sediments of Darwin Harbour. In particular, copper and zinc, which occur in the discharge stream at concentrations exceeding the water quality trigger value, were not found at appreciable concentrations either in the sediments about the outfall or at the more distant locations sampled. Further there is no evidence of a gradient in metal concentrations in any direction about the outfall.

Sediment sampling reported by Fortune (2006) in the area between East Point and Lee Point across a range of intertidal and subtidal sampling sites similarly shows no evidence of significant metal accumulation which might be attributed to the discharge from the Ludmilla WWTP.

Given that the discharge salinity is low, this outcome is not unexpected as the plume will initially rise to, and be dispersed and diluted, at the surface before becoming mixed throughout the water column and potentially being deposited onto the sediment surface.

[1] Note that when calculating median and 95th percentiles, other than when all values were below the level of reporting (LOR),

# 3 Modelling of Mixing Zones

#### 3.2.3.2 Sediment nutrients

Nitrogen has not been found to be elevated in the sediments about the EPO however phosphorus concentrations are elevated at the outfall location (SED01) and immediately adjacent sites. The form in which the phosphorus is present, and thus its availability and ability to stimulate plant growth, is uncertain.

## 3.3 Differences between modelling and data provided in PER Supplement Appendix M

Appendix M (of the Supplement) provides water quality results from 11 marine water quality monitoring sites around East Point (refer to Figure 3-1 in PER Appendix Q for map of locations). Water quality is sampled at these locations on a monthly basis.

Most of the locations are considered to be outside of the effluent mixing zone. SLUEP10 and SLUEP11 in particular are located approximately 2 km from the existing outfall and are considered to be monitoring background/ambient water quality. Metal concentration data for the Ludmilla WWTP marine monitoring sites presented in Section 4.1.1 (Tables 4-1 and 4-2) shows no discernible influence on Sites SLUEP10 and SlUEP11 of the wastewater discharge.

However monitoring sites, including those considered to be well outside the mixing zone, display several parameters at levels above the Darwin Harbour Water Quality Objectives (WQO). In particular, Total Phosphorous levels are generally reported to be above the WQO for almost all samples. PWC considers that the majority of results provided in Appendix M are representative of background levels in the East Point area. Additional supporting information is presented in Section 3.4.

As described in the Supplement (Appendix B), the hydrodynamic and water quality model is a development of the original NRETAS model, and has been calibrated in the East Point area using tracer studies.

The model is used to generate a 2-D concentration plume for contaminants discharged at the outfall location (refer PER Supplement Appendix B). The model does not take into account the background water quality, calculating the parameter concentration due only to discharge at the outfall (i.e. the contribution to parameter concentration due to effluent discharge at the EPO).

To generate Mixing Zones, the model is run for a 30-day tidal cycle for each parameter and essentially derives the maximum concentration reached in each model cell during that period. These results are compared to the appropriate trigger level (i.e. the WQO) to generate a mixing zone for each parameter, which therefore represents parameter concentration above the WQO, not the absolute concentration.

## 3.4 Source(s) of high levels of contaminants outside mixing zones

A review of water quality data for the mid and outer estuary areas shows that levels of Total Phosphorous (TP) can significantly exceed the WQO of 0.02 mg/L (20 µg/L) in areas remote from treatment plant discharges. TP concentrations are for samples obtained near the surface of the water column and can be influenced by floating organic material (leaf litter etc.). Such material may originate from a wide range of sources including urban runoff, riverine inputs, seaweed (in particular the seasonal onset of *Sargassum* sp.) or floating material associated with the formation of oceanic Langmuir circulation cells (Stewart, Robert H., Introduction To Physical Oceanography, 2002). Thus, elevated TP concentrations will inevitably occur at sites far removed from any effluent mixing zones.

# 3 Modelling of Mixing Zones

For example, representative samples taken by NRETAS for development of the Darwin Harbour Report Cards showed TP levels consistently above 0.04 mg/L (40 µg/L) during sampling in August 2010. Refer to Figure 3-2 for the distribution and levels of TP for August 2010.

PWC is not aware of any specific sampling or analysis that has been carried out in Darwin Harbour to determine the origin of nutrients in individual samples. Techniques for distinguishing between contaminants originating from treated effluent and other sources have not previously been applied to Darwin Harbour water quality.

Recent studies by CDU (Karen Gibb) used genetic fingerprinting to investigate the source of bacteria in the waters around Darwin’s beaches and concluded that there are multiple sources of contamination from land or water-based activities.

Stable isotope analysis may provide a useful tool in the future for distinguishing between contaminants derived from WWTP effluent and other sources. Baseline assessments and detailed datasets will be required before any determinations can be made and stable isotope analysis is not proposed at this time.

## 3.5 Reference monitoring site

PWC is of the view that the elevated TP levels recorded at the monitoring sites, including SLUEP10 and SLUEP11, are reflective of the background/ambient water quality in the East Point region.

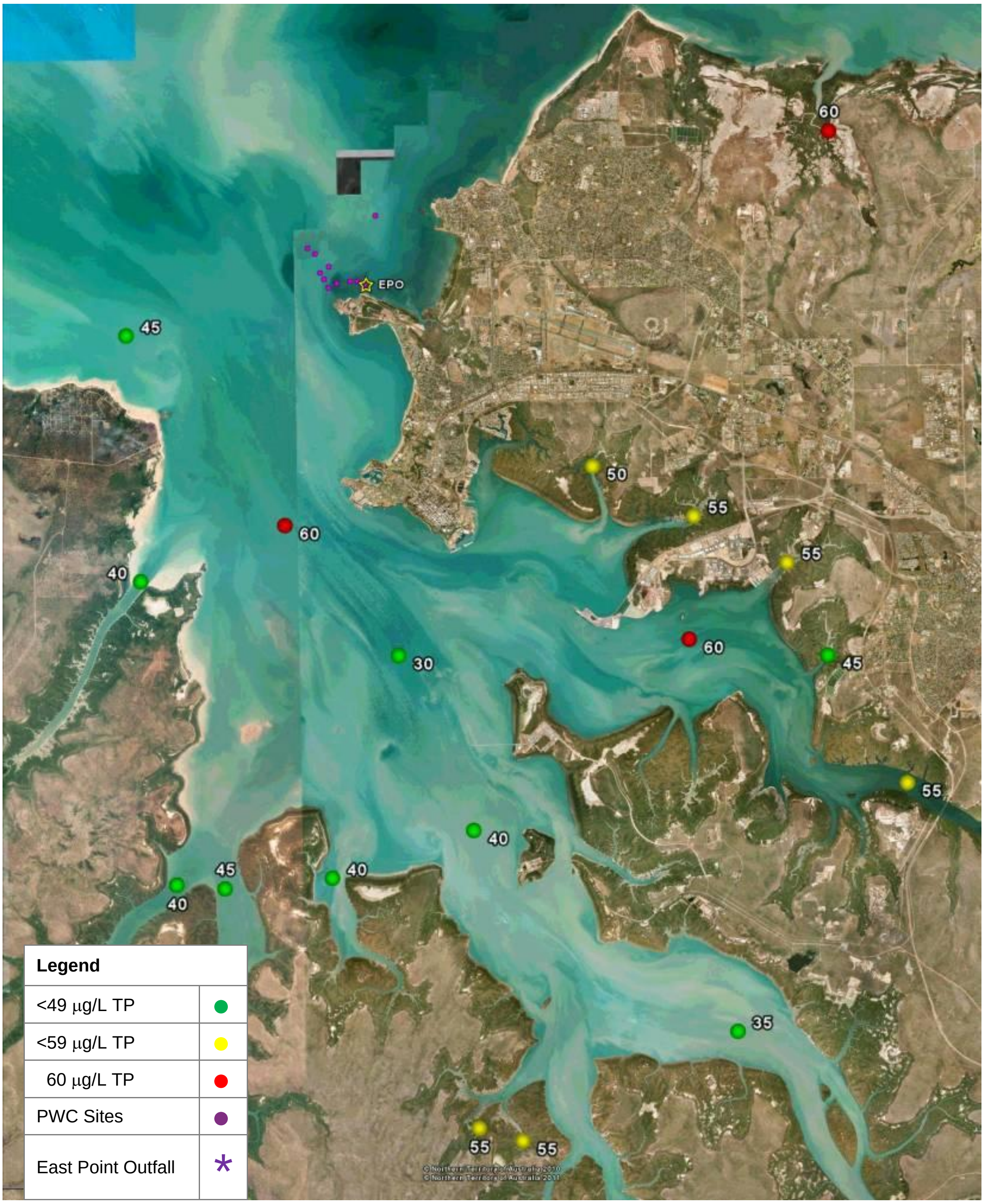
Metal concentrations at these sites are consistently within the background range, indicating that the elevated levels of phosphorus detected at these sites are derived from sources other than the EPO.

The site locations are considered to be appropriate for an ongoing monitoring program in relation to the current outfall and proposed outfall extension.

CDU and PWC believe that the model can be used confidently in decision making for managing wastewater discharges in Darwin Harbour.

# 3 Modelling of Mixing Zones

**Figure 3-2 NRETAS Darwin Harbour results for Total Phosphorus August 2010**




## 3.6 Mapping of mixing zones in relation to habitat

The following figures (Figures 3-3 and 3-4) show the extent of the plume from the combined discharge of the Ludmilla and Larrakeyah facilities (12.5 ML/d ADWF) from the upgraded plant for the median (typical) and 90$^{th}$ percentile (atypical) discharge conditions.

# 3 Modelling of Mixing Zones

It is noted that removal of metals is not an assumed outcome of the proposed treatment plant upgrade and consequently that the discharge concentrations are not predicted to change following the upgrade.

In Figures 3-3 and 3-4 the concentrations of copper from the point of discharge have been overlain on the habitat map prepared by Geo Oceans (Appendix A Figure 15).

In both cases most of the dilution is shown as occurring over the habitat mapped as bare sand with no bioturbation.

Under the typical (median) discharge condition, no mangrove, hard coral, filter feeder of macroalgal habitat is contacted by the plume at above background concentration. Smaller areas of bare intertidal reef, intertidal reef with oysters and intertidal reef with turf algae will be exposed to copper concentrations within the plume of 3 µg/L or less (the guideline concentration is 1.3 µg/L).

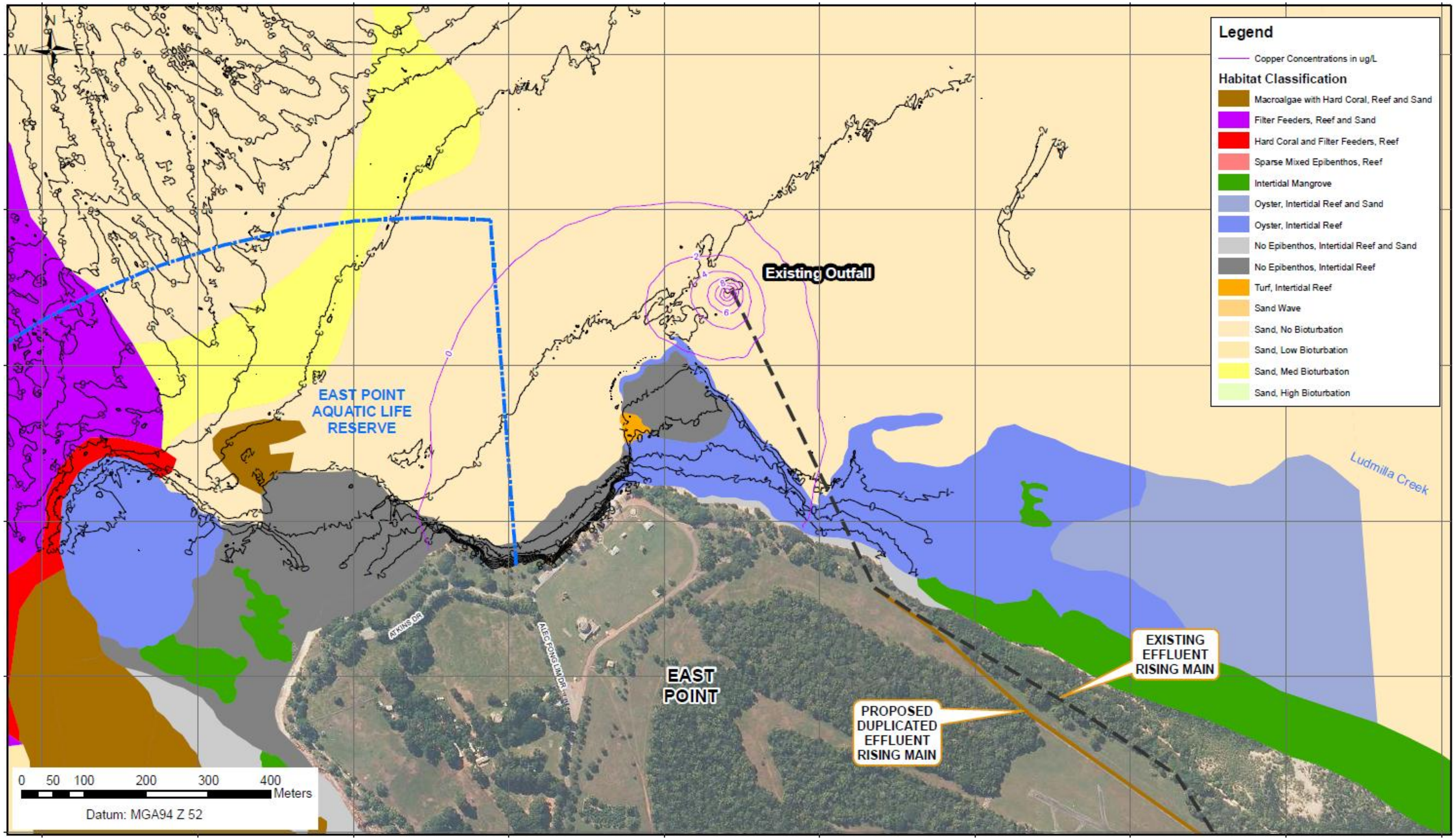
Under atypical ($90^{th}$ percentile) conditions the area impacted by the plume is greater, and includes some areas of mangrove and macroalgal habitat which could be expected to be exposed to concentrations of copper of between 0 and 2 µg/L in addition to further areas of bare intertidal reef, intertidal reef with oysters and intertidal reef with turf algae habitat, which may be intermittently exposed to copper concentrations between 0 and 5 µg/L.

Although not present in sufficient density to be recognised as a habitat in the Geo Oceans classification system, the copper plume under atypical conditions (combined $90^{th}$ percentile ADWF) does not extend to the areas in which seagrass was mapped in previous studies (Appendix A Figure 16).

As previously noted, the discharge concentration for all other metals tested, relevant to the applicable ANZECC & ARMCANZ (2000) trigger value, is lower than for copper, and hence the areas of exposure to these metals at above guideline concentration will be less than that for copper.

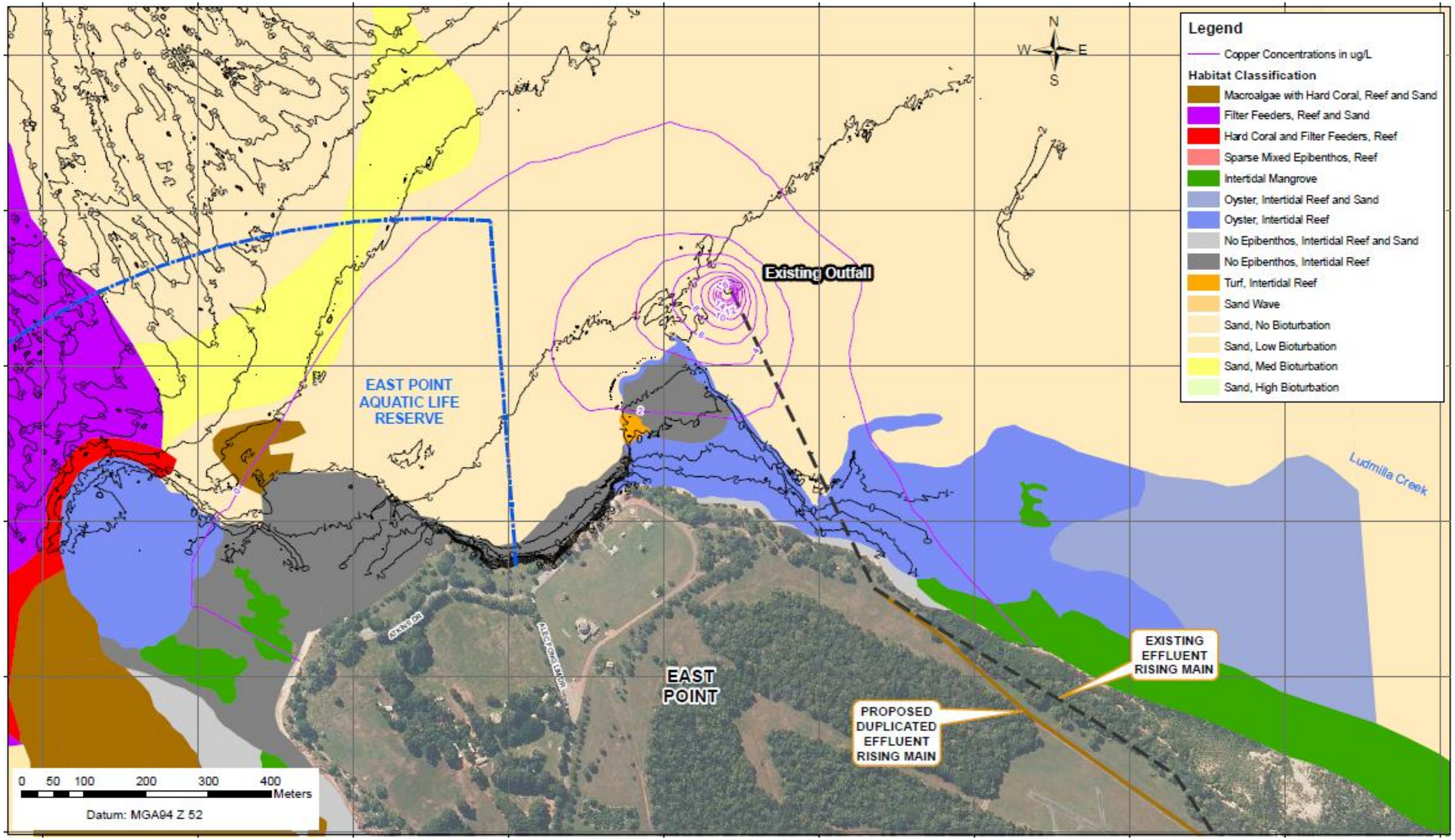
# 3 Modelling of Mixing Zones

**Figure 3-3 Typical (median) effluent quality from upgraded plant – combined Ludmilla and Larrakeyah ADWF**



# 3 Modelling of Mixing Zones

**Figure 3-4 Atypical (90th percentile) effluent quality from upgraded plant – combined Ludmilla and Larrakeyah ADWF**



# 3 Modelling of Mixing Zones

# 4 Potential Impacts

Concerns have been raised, and remain, on the adequacy of information on impacts to marine flora and fauna presented in the draft PER and Supplement. This includes demonstrating the likely presence of EPBC listed species that could be impacted by contaminants in treated effluent. It is acknowledged that the boundary of the mixing zones is where water quality objectives are met, but what remains unknown is the fate of toxicants and nutrients beyond the mixing zone and how they can impact on marine species and habitats.

A discussion is required on the known (or unknown) fate (decay or longevity and accumulation) of contaminants in marine water and sediments, preferably in tropical marine environments, the expected pathways that describe the fate of nutrients and toxicants, and their potential impacts to habitats, species or key taxonomic groups known or expected to occur in the area within and beyond the mixing zones. Discussion could group contaminants by their known fate and should include those contaminants identified above or through a risk assessment process, and/or contaminants listed in the ANZECC Guidelines for Fresh and Marine Water Quality.

## 4.1 Fate of identified effluent constituents in water and sediments

### 4.1.1 Effluent constituents in the water column

In addition to the monitoring of effluent composition at the Ludmilla WWTP effluent monitoring point, PWC has been monitoring surface water quality at the outfall (SLUEP01) and four surrounding locations (SLUEP02 - SLUEP05) since August 2010. This program was subsequently expanded to ten surrounding sites (SLUEP02 - SLUEP011) in February 2011 (Figure 4-1). The median concentration for each of the heavy metals analysed is presented in Table 4-1 and the 95$^{th}$ percentile value in Table 4-2. 95$^{th}$ percentiles were calculated using the Microsoft Excel percentile function.

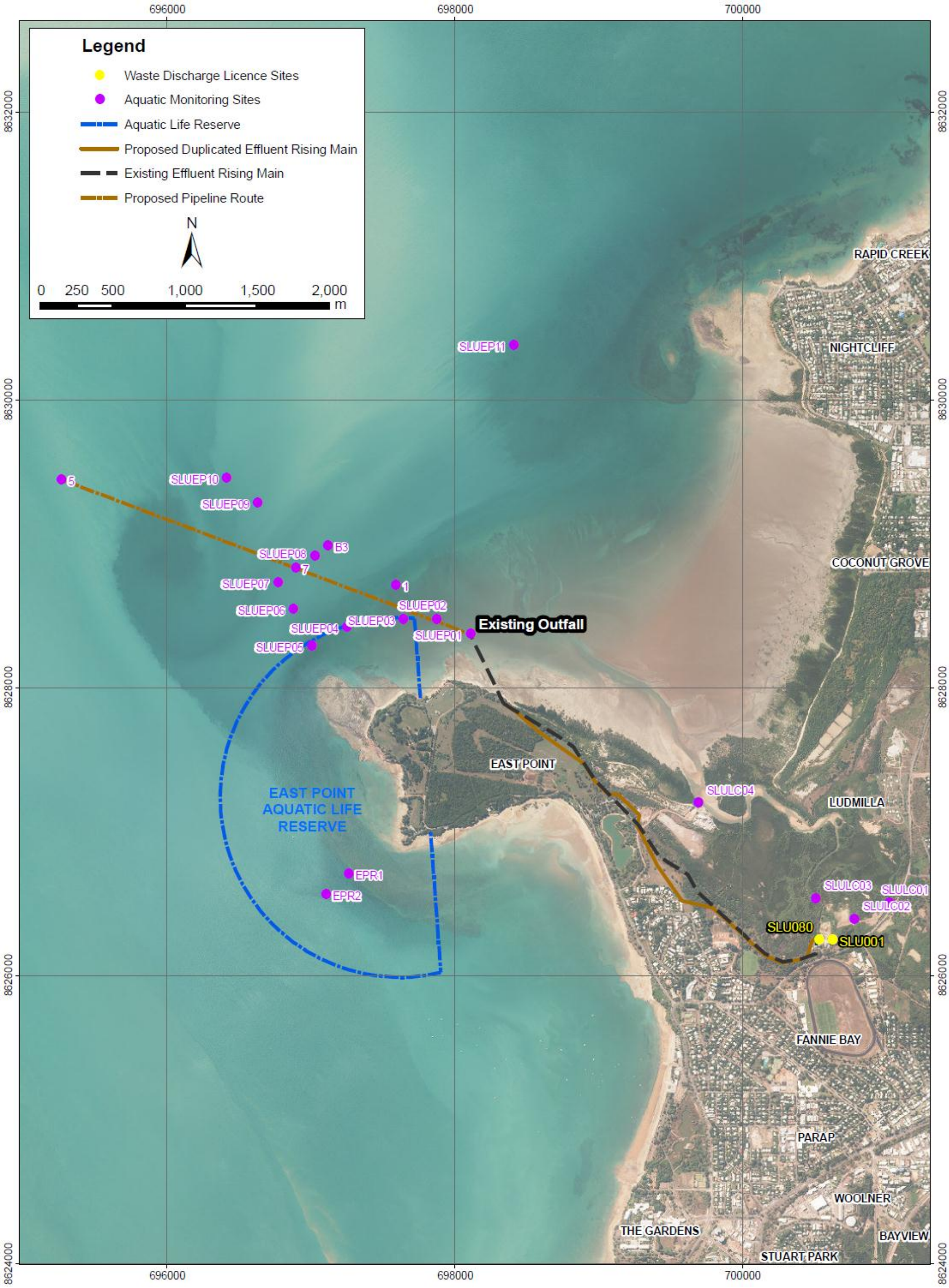
It is noted that a number of metals typically return values below the limit of reporting (LOR), e.g. mercury. Other than where values below the LOR have been returned on every sampling occasion, values below the LOR have been rounded up to the LOR in order to generate a (conservative) median or 95$^{th}$ percentile value. In the case of 95%iles the value generated is typically due to the presence of only one value reported at or marginally above the LOR for the dataset and the value may not be a reliable indicator.

Examination of median values (Table 4-1) shows only one contaminant, copper, at the outfall location (SLUEP01) as routinely exceeding the ANZECC & ARMCANZ (2000) trigger value for slightly-moderately disturbed systems.

Examination of 95$^{th}$ percentile values (Table 4-2) shows that copper, nickel and zinc exceed the guidelines at the outfall monitoring site and a number of the impact/reference monitoring locations. The calculation of the 95$^{th}$ percentile values is influenced by the small sample numbers and occasional high sample values such that guideline exceedances are typically driven by only one or two high values at each site. This is a reflection of the variable quality of the effluent and consistent with the expectation that the discharge plume would not impact on all sites on all occasions.

# 4 Potential Impacts

**Figure 4-1 EPO water quality sampling sites**



# 4 Potential Impacts

**Table 4-1 Median metal concentrations: East Point Outfall water quality monitoring sites**

| | | | | | | | Site | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample** | **Trigger Value*** | **SLUEP01** | **SLUEP02** | **SLUEP03** | **SLUEP04** | **SLUEP05** | **SLUEP06** | **SLUEP07** | **SLUEP08** | **SLUEP09** | **SLUEP10** | **SLUEP11** |
| **Metal Analyte** | | | | | | | **µg/L** | | | | | |
| Aluminium | ID | 37.5 | 10 | 10 | 10 | 14.5 | 10 | 12 | 10 | 32 | 37 | 20.5 |
| Arsenic | ID | <3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 |
| Cadmium | 0.7 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Chromium | 27.4 (CrIII) 4.4 (CrV) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Copper | 1.3 | 7 | 1 | 1 | 1 | 1 | 1 | <1 | 1 | <1 | <1 | 1 |
| Iron | ID | 133 | 68 | 63.5 | 51 | 70 | 68.5 | 87 | 103 | 101 | 118 | 96.5 |
| Lead | 2.2 | 1 | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Magnesium | NG | 1040000 | 1180000 | 1130000 | 1140000 | 1180000 | 1170000 | 1150000 | 1180000 | 1140000 | 1160000 | 1150000 |
| Manganese | ID | 5.5 | 3 | 3 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| Mercury | 0.1 (inorg.) ID (methyl) | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 |
| Molybdenum | ID | 9 | 9.5 | 9 | 9.5 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |

# 4 Potential Impacts

| | | | | | | Site | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample** | **Trigger Value*** | **SLUEP01** | **SLUEP02** | **SLUEP03** | **SLUEP04** | **SLUEP05** | **SLUEP06** | **SLUEP07** | **SLUEP08** | **SLUEP09** | **SLUEP10** | **SLUEP11** |
| **Metal Analyte** | | | | | | | **µg/L** | | | | | |
| Nickel | 7 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Selenium | ID | 1 | 1.5 | 3 | 2.5 | 2.5 | 3 | 3 | 2 | 3 | 3 | 3.5 |
| Silver | 0.8 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 |
| Tin | ID | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Uranium | ID | 3 | 3 | 2.5 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 2 |
| Zinc | 15 | 6.5 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |

* Trigger values for slightly to moderately disturbed systems (ANZECC & ARMCANZ 2000)

# 4 Potential Impacts

**Table 4-2 95th percentile metal concentrations: East Point Outfall water quality monitoring sites**

| | | | | | | | Site | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample** | **Trigger Value*** | **SLUEP01** | **SLUEP02** | **SLUEP03** | **SLUEP04** | **SLUEP05** | **SLUEP06** | **SLUEP07** | **SLUEP08** | **SLUEP09** | **SLUEP10** | **SLUEP11** |
| **Metal Analyte** | | | | | | | µg/L | | | | | |
| Aluminium | ID | 454 | 303 | 271 | 251 | 145 | 133 | 167 | 93 | 225 | 207 | 162 |
| Arsenic | ID | <3 | 3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 |
| Cadmium | 0.7 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Chromium | 27.4 (CrIII)<br>4.4 (CrV) | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 35 |
| Copper | 1.3 | 43 | 3 | 55 | 8 | 25 | 4 | <1 | 3 | <1 | 1 | 1 |
| Iron | ID | 796 | 529 | 564 | 456 | 280 | 227 | 259 | 204 | 469 | 316 | 361 |
| Lead | 2.2 | 2 | 1 | 2 | 2 | 2 | <1 | <1 | <1 | <1 | <1 | <1 |
| Magnesium | NG | 1196000 | 1303000 | 1283000 | 1256000 | 1255000 | 1286000 | 1306000 | 1303000 | 1342000 | 1282000 | 1303000 |
| Manganese | ID | 21 | 6 | 8 | 7 | 13 | 4 | 4 | 4 | 6 | 5 | 7 |
| Mercury | 0.2 (inorg.)<br>ID (methyl) | <0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 | 0.5 | 0.3 | 0.3 | 0.3 | <0.3 |
| Molybdenum | ID | 11 | 11 | 11 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |

# 4 Potential Impacts

| | | | | | | | Site | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample** | **Trigger Value*** | **SLUEP01** | **SLUEP02** | **SLUEP03** | **SLUEP04** | **SLUEP05** | **SLUEP06** | **SLUEP07** | **SLUEP08** | **SLUEP09** | **SLUEP10** | **SLUEP11** |
| **Metal Analyte** | | | | | | | **µg/L** | | | | | |
| Nickel | 7 | 35 | 21 | 65 | 29 | 56 | 19 | 10 | 16 | 67 | 7 | 7 |
| Selenium | ID | 12 | 7.9 | 16 | 10 | 9 | 12 | 7 | 10 | 9 | 8 | 10 |
| Silver | 1.4 | 0.3 | <0.3 | 0.3 | <0.3 | 0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 |
| Tin | ID | <5 | <5 | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Uranium | ID | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Zinc | 15 | 251 | 83 | 351 | 195 | 195 | 13 | 4 | 7 | 4 | 11 | 10 |

* Trigger values for slightly to moderately disturbed systems (ANZECC & ARMCANZ 2000)

# 4 Potential Impacts

### 4.1.2 Effluent constituents in the sediments

As part of its ongoing program of investigations, PWC undertook monitoring of the surface sediments at nine locations about the outfall in November 2011 (six sites) and January 2012 (three sites) (Figure 4-2 and Table 4-3).

**Figure 4-2 EPO sediment sampling locations**


Metal concentrations exceeding the Interim Sediment Quality Guidelines (ISQG-Low) (ANZECC & ARMCANZ 2000) trigger values were reported only for arsenic. Arsenic concentrations exceeded the ISQG-Low value typically by a factor of ~2 apart from at the two nearshore sites (SED06 and SED07), which were at or below the guideline value.

Overall, there were no clear trends in metal concentrations with respect to either distance or direction from the outfall location.

To relate the results to surface sediment metal concentrations in Darwin Harbour, comparison has been made to results from two studies: a pre-construction survey of Darwin Harbour for the Ichthys gas export pipeline (URS 2009); and an earlier sediment and grain size study of Darwin Harbour, one area of which is a study of sediments between East Point and Lee Point (Fortune 2006).

# 4 Potential Impacts

The INPEX Ichthys nearshore sediment survey follows approximately the line of the proposed export pipeline from Middle Arm to beyond the Harbour mouth and is considered to reflect relatively un-impacted conditions. A comparison of those metals which were analysed in both surveys is shown in Table 4-3. Median values for all metals were comparable or lower at the East Point area than for the pipeline route, with the exception of manganese, the concentration of which was higher but still within the range measured along the pipeline route. The measured concentrations of arsenic, which is known to be naturally elevated in the sediments of Darwin Harbour, were similar in both surveys.

Notably, the average and median values for copper, zinc and iron, which have been identified at elevated concentrations within the effluent, were lower than those calculated from the pipeline survey results.

The comparison with the East Point - Lee Point survey results (Table 4-4) again shows elevated levels of arsenic and manganese in the East Point outfall area. Copper and iron concentrations were similar and the concentration of zinc lower in the EPO survey area than in the broader East Point - Lee Point survey area.

The above comparisons would suggest that there is no evidence of accumulation of those metals which are present at elevated concentration in the effluent in the sediments in the vicinity of the EPO.

Nutrient levels in the sediment of the East Point area showed different responses for nitrogen and phosphorus. Nitrogen in the sediments is present almost entirely in organic form (Kjeldahl nitrogen) with low levels of nitrate and nitrite (soluble inorganic forms). Overall, there were no clear trends in either inorganic or organic nitrogen concentrations with respect to either distance or direction from the outfall location (SED01).

Phosphorus concentrations were higher at the outfall location (SED01) and the two nearest sites (SED02, SED03) than the other sites sampled, potentially indicating a decreasing gradient in concentration from the outfall. However this relationship becomes less clear at the more distant sites.

There are no guideline concentrations for nutrients in sediments. Accordingly nutrient concentrations in the sediments at East Point have been compared to those found during the Ichthys pipeline survey (Table 4-5). The comparison shows that while total nitrogen levels are lower in the East Point survey area than along the pipeline route, total phosphorus levels in all cases are higher.

Polynuclear aromatic hydrocarbons were not detected at any of the East Point sediment sites.

Hydrocarbons were reported at only one site (SED08), which is one of the more distant locations from the outfall. The hydrocarbon detected was a short (C6-C9) carbon chain compound(s) likely to be indicative of localised contamination, possibly by petrol in the water column rather than the sediments.

# 4 Potential Impacts

**Table 4-3 Nutrients and contaminants in the sediments**

| Sample | | | SED01 | SED02 | SED03 | SED04 | SED05 | SED06 | SED07 | SED08 | SED09 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Analyte** | **LOR** | **ISQG Low** | | | | | **mg/kg** | | | | |
| Major Cations | | | | | | | | | | | |
| Calcium | 10 | N/G | 224000 | 230000 | 224000 | 249000 | 252000 | 239000 | 232000 | 256000 | 228000 |
| Magnesium | 10 | N/G | 19300 | 19300 | 19500 | 20700 | 19800 | 16600 | 14600 | 18200 | 16200 |
| Metals | | | | | | | | | | | |
| Aluminium | 50 | N/G | 1440 | 1470 | 1420 | 1540 | 1600 | 1320 | 1830 | 1840 | 1710 |
| Arsenic | 5 | 20 | 41 | 37 | 42 | 36 | 34 | 18 | 20 | 42 | 35 |
| Chromium | 2 | 80 | 8 | 8 | 8 | 8 | 8 | 6 | 8 | 9 | 8 |
| Copper | 5 | 65 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Iron | 50 | N/G | 11900 | 10700 | 11900 | 10100 | 10300 | 6720 | 8170 | 12800 | 11400 |
| Lead | 5 | 50 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | 6 | <5 |
| Manganese | 5 | N/G | 665 | 625 | 682 | 640 | 624 | 434 | 466 | 734 | 646 |
| Mercury | 0.1 | 0.15 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Nickel | 2 | 21 | 2 | <2 | <2 | <2 | <2 | <2 | 3 | 3 | 3 |
| Silver | 2 | 1 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |

# 4 Potential Impacts

| Sample | | | SED01 | SED02 | SED03 | SED04 | SED05 | SED06 | SED07 | SED08 | SED09 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Analyte** | **LOR** | **ISQG Low** | | | | | **mg/kg** | | | | |
| Tin | 5 | N/G | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Uranium | 0.1 | N/G | 1.3 | 1.2 | 1.3 | 1.2 | 1.2 | 0.9 | 1.1 | 1.3 | 1.2 |
| Vanadium | 5 | N/G | 26 | 22 | 25 | 21 | 21 | 13 | N/S | N/S | N/S |
| Zinc | 5 | 200 | 6 | 6 | 5 | 6 | 7 | 6 | 8 | 7 | 7 |
| Nutrients | | | | | | | | | | | |
| NOx and N (sol.) | 0.1 | N/G | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 | 0.2 | <0.1 | <0.1 | <0.1 |
| TKN | 20 | N/G | 340 | 270 | 260 | 350 | 390 | 500 | 230 | 170 | 170 |
| Total N | 20 | N/G | 340 | 270 | 260 | 350 | 390 | 500 | 230 | 170 | 170 |
| Total P | 2 | N/G | 858 | 812 | 759 | 686 | 778 | 559 | 515 | 653 | 656 |
| PAHs | | | | | | | | | | | |
| Napthalene | 0.5 | 0.16 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | N/S | N/S | N/S |
| Acenapthylene | 0.5 | 0.044 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | N/S | N/S | N/S |
| Acenapthene | 0.5 | 0.016 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | N/S | N/S | N/S |
| Fluorene | 0.5 | 0.019 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | N/S | N/S | N/S |
| Phenanthrene | 0.5 | 0.24 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | N/S | N/S | N/S |

# 4 Potential Impacts

| Sample | | | SED01 | SED02 | SED03 | SED04 | SED05 | SED06 | SED07 | SED08 | SED09 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | LOR | ISQG Low | | | | | mg/kg | | | | |
| Anthracene | 0.5 | 0.085 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | N/S | N/S | N/S |
| Fluoranthene | 0.5 | 0.6 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | N/S | N/S | N/S |
| Pyrene | 0.5 | 0.665 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | N/S | N/S | N/S |
| Benz(a)anthracene | 0.5 | 0.261 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | N/S | N/S | N/S |
| Chrysene | 0.5 | 0.384 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | N/S | N/S | N/S |
| Benz(b)fluoranthene | 0.5 | N/G | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | N/S | N/S | N/S |
| Benz(k)fluoranthene | 0.5 | N/G | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | N/S | N/S | N/S |
| Benzo(a)pyrene | 0.5 | 0.43 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | N/S | N/S | N/S |
| Indeno(1.2.3.cd)pyrene | 0.5 | N/G | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | N/S | N/S | N/S |
| Dibenz(a.h)anthracene | 0.5 | 0.63 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | N/S | N/S | N/S |
| Benzo(g.h.i)perylene | 0.5 | N/G | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | N/S | N/S | N/S |
| Sum of PAHs | 0.5 | 4 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | N/S | N/S | N/S |
| Total Petroleum Hydrocarbons | | | | | | | | | | | |
| C6 – C9 Fraction | 10 | N/G | <10 | <10 | <10 | <10 | <10 | <10 | <10 | 4390 | <10 |

# 4 Potential Impacts

| Sample | | | SED01 | SED02 | SED03 | SED04 | SED05 | SED06 | SED07 | SED08 | SED09 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Analyte** | **LOR** | **ISQG Low** | | | | | **mg/kg** | | | | |
| C10 – C14 Fraction | 50 | N/G | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 |
| C15 – C28 Fraction | 100 | N/G | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 |
| C29 – C36 Fraction | 100 | N/G | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 |
| C10 – C36 Fraction (sum) | 50 | 550 (NAGD) | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 |
| Total Recoverable Hydrocarbons (NEPM 2010) | | | | | | | | | | | |
| C6 – C10 Fraction | 10 | N/G | <10 | <10 | <10 | <10 | <10 | <10 | <10 | 7100 | <10 |
| >C10 – C16 Fraction | 50 | N/G | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 |
| >C16 – C34 Fraction | 100 | N/G | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 |
| >C34 – C40 Fraction | 100 | N/G | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 |
| >C10 – C40 Fraction (sum) | 50 | 550 (NAGD) | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 |

LOR Limit of Reporting

ISQG-Low Interim Sediment Quality Guideline (ANZECC & ARMCANZ 2000) trigger value

N/G No guideline

(NAGD) National Assessment Guidelines for Dredging (2009) Screening Level

# 4 Potential Impacts

**Table 4-4 Heavy metals in sediments: Darwin Harbour survey and East Point Outfall survey**

| | Darwin Harbour (Ichthys Pipeline)* | | | East Point Outfall area** | | |
|---|---|---|---|---|---|---|
| Analyte | Range (mg/kg) | Average (mg/kg) | Median (mg/kg) | Range (mg/kg) | Average (mg/kg) | Median (mg/kg) |
| Arsenic | 9 – 87 | 42 | 33 | 18 - 42 | 33.9 | 36 |
| Chromium | 9 - 201 | 44.1 | 39 | 6 - 9 | 7.9 | 8 |
| Copper | <5 - 19 | 6.6 | 6.9 | <5 | <5 | <5 |
| Iron | 8220 - 67700 | 31249 | 28600 | 6720 - 12800 | 10443 | 10700 |
| Lead | <5 – 37 | 11.7 | 11 | <5 - 6 | <5 | <5 |
| Manganese | 135 - 734 | 325.1 | 309 | 434 - 734 | 613 | 646 |
| Nickel | <2 – 13.5 | 7.2 | 7.5 | <2 - 3 | <2 | <2 |
| Silver | <0.1 - <2 | <2 | <0.1 | <2 | <2 | <2 |
| Zinc | <5 - 28 | 12.8 | 13.2 | 5 - 7 | 6.4 | 6 |

* URS 2009, Report: Ichthys Gas Field Development Project, Nearshore marine water quality and sediment study.

** From PWC 2012 data presented in Table 4-3.

**Table 4-5 Heavy metals in sediments: East Point to Lee Point and East Point Outfall survey**

| | East Point to Lee Point* | | | East Point Outfall area** | | |
|---|---|---|---|---|---|---|
| Analyte | Range (mg/kg) | Average (mg/kg) | Median (mg/kg) | Range (mg/kg) | Average (mg/kg) | Median (mg/kg) |
| Arsenic | 10.6 – 78.1 | 28.7 | 16.4 | 18 - 42 | 33.9 | 36 |
| Copper | 1.9 – 8.8 | 3.9 | 2.6 | <5 | <5 | <5 |
| Iron | 8600 - 40900 | 14700 | 11000 | 6720 - 12800 | 10443 | 10700 |
| Lead | 10.3 – 10.8 | 10.6 | <5.6 | <5 - 6 | <5 | <5 |
| Manganese | 215 - 929 | 468 | 386 | 434 - 734 | 613 | 646 |
| Nickel | 4.9 – 13.3 | 7.5 | 6 | <2 - 3 | <2 | <2 |
| Zinc | 13 - 36 | 24.1 | 25 | 5 - 7 | 6.4 | 6 |

* Fortune 2006, Report: The grain size and heavy metal content of sediment in Darwin Harbour.

** From PWC 2012 data presented in Table 4-3.

# 4 Potential Impacts

**Table 4-6 Nutrients in sediments: Darwin Harbour survey and East Point Outfall survey**

| | Darwin Harbour (Ichthys Pipeline)* | | | East Point Outfall area** | | |
|---|---|---|---|---|---|---|
| **Analyte** | **Range (mg/kg)** | **Average (mg/kg)** | **Median (mg/kg)** | **Range (mg/kg)** | **Average (mg/kg)** | **Median (mg/kg)** |
| Nitrite + Nitrate (soluble, as N) | <0.1 – 1.07 | 0.28 | <0.10 | <0.1 | 0.14 | 0.1 |
| Total Kjeldahl Nitrogen (as N) | 140 – 1100 | 581 | 510 | 170 - 500 | 298 | 270 |
| Total Nitrogen (as N) | 160 – 1100 | 581 | 510 | 170 - 500 | 298 | 270 |
| Total Phosphorus (as P) | 66 – 513 | 314 | 301 | 515 - 858 | 697 | 686 |

* URS 2009, Report: Ichthys Gas Field Development Project, Nearshore marine water quality and sediment study.

** From PWC 2012 data presented in Table 4-3.

### 4.1.3 Fate of metals in water and sediments

#### *4.1.3.1 Fate in water*

Water quality sampling of the plant effluent (at Site SLu080) shows that copper, the metal present in highest concentration with reference to the guideline concentration, is present at a median concentration at the treatment plant of 124 µg/L.

Water quality sampling at the outfall location (SLUEP01) has returned a median concentration of 7 µg/L, demonstrating the effect of initial dilution, while all surrounding sites had median concentrations of 1 or less than 1 µg/L, less than the guideline value of 1.3 µg/L.

A more conservative assessment is indicated by the plume modelling (Figures 3-1 and 3-2).

Based on monitoring to date there is no evidence of persistent accumulation of copper in the water column in nearshore waters about the outfall and this is consistent with the exposed location of the outfall, strong tidal currents (up to 2.3 m/s [8 km/hr]) which occur in the area, and exchange rates for Darwin Harbour (estimated at 33 x $10^8$ $m^3$ between a spring high and low tide (PER Supplement Appendix B). The latter would indicate it is likely a significant portion of the copper present in solution or suspended the water column could be transported out of the Harbour.

Copper in the marine environment is rapidly complexed and bound to organic and inorganic colloids and particulates where it is less toxic than if present in solution in ion form. The present US EPA National Water Quality Criteria for Aquatic Life for exposure to dissolved copper (continuous concentration) is 3.1 µg/L (US EPA 2012).

Copper attached to particulate matter may subsequently be deposited on accreting (typically mangrove) shorelines either within or outside of the Harbour (refer to Section 4.1.3.2).

# 4 Potential Impacts

A similar fate is predicted for zinc, however it is noted that the median concentration of zinc at the outfall is below the ANZECC & ARMCANZ (2000) guideline concentration.

In plants and animals both copper and zinc are essential micronutrients but can have adverse effects when present in excess (refer to Section 4.2), i.e. for the purpose of this assessment at greater than ANZECC & ARMCANZ (2000) guideline concentrations.

#### *4.1.3.2 Fate in sediments*

As identified in section 4.1.2 there is no evidence of accumulation of metals or other toxicants in the sediments about the EPO or further offshore the discharge location.

This would likely mean that any deposition, either in this area or more broadly, is occurring at a scale that is within the natural range for metal cycling between the sediments and water column.

Based on the tidal currents and exchange rates for Darwin Harbour it is likely that a significant portion of any deposited contaminants could be transported out of the harbour, with a smaller portion potentially deposited on sedimentary (typically mangrove) shorelines in low concentration over a wide area, again at concentrations that are within the natural range.

No specific site of deposition has been identified.

## 4.2 Pathways describing the fate in relation to EPO

### 4.2.1 Discharge into the water column

As previously noted, effluent from the EPO is discharged into the water column at tide levels above neap low tide level and onto the sediments at tide levels below low neaps.

On higher tides the plume, comprised largely of fresh water, will be buoyant and rise to the surface, mixing and diluting as it does so, before further dispersing at the surface and finally mixing through the water column.

Modelling of the combined effluent (post-upgrade) shows for the worst case metallic contaminant (copper) dilution to water quality guideline values (1.3 µg/L) will occur within ~200 m under typical (median ADWF combined flow) conditions and ~500 m under atypical ($90^{th}$% ADWF combined flow) conditions (Figures 3-1 and 3-2). Beyond the initial mixing zone dilution will continue to the point where background concentrations are achieved. Based on modelled dilution, dilution to background will be achieved within the near vicinity of East Point under all conditions (refer to PER Supplement Appendix B).

As is the case in natural waters, there is expected to be some uptake of metals from the water column by biota – seagrasses, corals, other epibenthic species, pelagic and demersal fishes, turtles and cetaceans.

Pathways describing the fate of the three metals identified in the monitoring results (Tables 4-1 and 4-2) as occurring at elevated concentrations under typical and atypical discharge conditions are described below.

# 4 Potential Impacts

#### *4.2.1.1 Copper*

Copper exists in natural waters, either in the dissolved form as the cupric ($Cu^{++}$) ion or complexed with inorganic anions or organic ligands or as suspended particles when present as a precipitate or absorbed to organic matter (Mance et al 1984). It can also be adsorbed to bottom sediments or exist as settled precipitates. The concentration of each of these forms depends on the complex interaction of variables, including the concentration of copper and the hardness, alkalinity, salinity, pH and concentration of bicarbonate, carbonate, sulphide, phosphate, organic ligands and other metal ions in the water. It is noted that some of the variables are more relevant to freshwaters (e.g. hardness, alkalinity and pH) than for saltwaters. Complexes formed by copper with natural organic compounds are generally more stable than other metals such as cadmium, lead and zinc (Cole et al 1999).

The high concentrations of particulate matter in estuaries facilitates the removal of copper from solution by adsorption to suspended particles which in turn may be deposited and accumulate in sediments. The copper concentrations measured in the sediments around East Point (<5 mg/kg at all sites) are well below the ANZECC & ARMCANZ (2000) ISQG-Low trigger value of 65 mg/kg.

The remaining dissolved copper in the water column is likely to be present either as an organic complex or as the cupric ion. The cupric ion is the most bioavailable form of copper.

Copper is readily accumulated by plants and animals however whole-body concentrations tend to decrease with increasing trophic level. It is believed copper is regulated or immobilised in many species and is not biomagnified in food chains to any significant extent (CCREM 1987).

#### *4.2.1.2 Zinc*

Zinc is found in natural waters in both dissolved forms and associated with suspended particles (Mance and Yates 1984). In estuaries, where concentrations of suspended particles are greater, a greater proportion of the zinc is adsorbed to suspended particles (CCREM 1987). In highly turbid conditions zinc associated with suspended sediment will be deposited with flocculated particles where it can accumulate particularly in anaerobic sediments. In seawater, much of the zinc is found in dissolved form as inorganic and organic complexes.

Zinc accumulates in sediments and can pose a hazard to sediment dwelling organisms at concentrations above 124 mg/kg, according to Canadian interim marine sediment quality guidelines (CCREM 1987). The maximum concentration found in the study of East Point sediments (Table 4-3) was 8 mg/kg.

Zinc is an essential element for many marine organisms and, as such, is readily bioaccumulated. Several species of crustacean are able to regulate the uptake of zinc but, at higher concentrations, this process appears to break down leading to an influx of zinc. This complicates the calculation of bioconcentration factors (BCF), and can be misleading. Organisms can take up zinc which is reflected in the BCF but the concentrations in the tissues are of no toxicological significance (Cole et al 1999).

#### *4.2.1.3 Nickel*

Nickel occurs in aquatic systems as soluble salts adsorbed on clay particles or organic matter (detritus, algae, bacteria), or associated with organic particles, such as humic and fulvic acids and proteins. Nickel is known to accumulate in sediments (WHO 1991) but was not found in the sediments about East Point at concentrations greater than 3 mg/kg, considerably below the ISQG of 21 mg/kg.

# 4 Potential Impacts

The fate of nickel in freshwater and sea water is affected by several factors including pH/pE, ionic strength, type and concentration of organic and inorganic ligands, and the presence of solid surfaces for adsorption (Cole et al 1999).

Cole et al (1999) report that laboratory studies have shown that nickel had little capacity for accumulation in all of the fish species studied. In uncontaminated waters, the range of concentrations reported in whole fish (on a wet-weight basis) ranged from 0.02 to 2 mg/kg. These values could be up to 10 times higher in fish from contaminated waters. In wildlife, nickel is found in many organs and tissues due to dietary uptake by herbivorous animals and their carnivorous predators. However, accumulation factors in different trophic levels of aquatic food chains suggest that biomagnification of nickel along the food chain, at least in aquatic ecosystems, does not occur (WHO 1991).

### 4.2.2 Discharge onto the sediments

The movement (run-off, infiltration) of metals and other contaminants discharged onto the sediments during low tidal periods is unclear, however existing data (Table 4-3) show no evidence of contaminant accumulation.

From this it may be concluded that any metals deposited on the sediments during low tide periods are mobilised and transported away from the discharge area on subsequent high tides.

## 4.3 Impacts of contaminants in water and sediments

### 4.3.1 Impacts of contaminants in water

The discharge of wastewater from the EPO has been associated with concentrations of copper at above guideline concentrations at the outlet under typical discharge conditions (refer to Table 4-1), and copper, nickel and zinc at above guideline concentrations at a number of sites under atypical discharge conditions (refer to Table 4-2).

This will result in organisms present in the water column at the time either avoiding the area of the plume or being exposed to elevated contaminant levels for the period that they remain within the plume or until the plume breaks down as a result of tidal current reversal and/or reversion to normal discharge conditions, or the outlet becomes isolated by the low tide and no further exposure to organisms within the water column is possible.

The tidal sequence of wetting and drying also means that above guideline concentrations will not be continuous in the water column about the discharge location.

Comparison of habitat distribution about the outfall location (Geo Oceans 2012) with atypical discharge concentrations (PER Supplement Appendix B), as shown for copper in Figure 3-2, gives no visual indication of habitat response to the wastewater discharge, with little or no elevation of contaminant levels in high value mangrove, coral, filter feeder or macroalgal habitats.

### 4.3.2 Impacts of contaminants in sediments

As previously identified, sediment data collected by PWC in 2012 do not indicate the presence of Ludmilla WWTP derived contaminants for any parameter at any of the sites monitored. Moreover the potential contaminants present in the sediments about East Point were at concentrations consistent with those found at non-contaminated sites within Darwin Harbour (i.e. are naturally present).

# 4 Potential Impacts

While it is likely that some of the metals present in the effluent will eventually be incorporated into marine sediment, it is anticipated that they will first be widely dispersed (within and outside of the Harbour) in the water column by currents and not settle in one location in high concentration. As such it is not possible to determine impacts of the Ludmilla WWTP against other anthropogenic sources or natural occurring metal levels.

# 5 Impacts to EPBC Act Listed Species

A major concern of any development is the impact to listed species or their habitats. To satisfy the impact assessment process an understanding of likely impacts to listed species is required. This could be achieved by using the information gathered for the above potential impacts to marine flora and fauna by contaminants and the knowledge of the location of the impact (i.e. mixing zones), demonstrating that no listed species or their habitats would be significantly impacted. Surveys are usually conducted that substantiate the presence or absence of species at risk, so information provided will require reasonable reliability for assessment.

The PER or Supplement has not addressed issues concerning discharge times the EPO will be exposed during low tides. In this situation, nutrients will be absorbed by the sediments. These nutrients will be broken down by bacteria in the sediments and may cause an anoxic layer to be formed, greatly reducing the carrying capacity of infauna within these sediments. Migratory and wader birds rely on these infauna for food. It is critical to assess the effect of discharge on sediment toxicity and nutrient accumulation / cycling before the impact to significant habitats like wader bird feeding areas, seagrass and reefal habitats can be assessed and monitoring programs can be developed.

## 5.1 Impacts to listed species or their habitats

### 5.1.1 Listed marine species and habitats

Existing habitat condition and any impacts on listed marine species reflect the current condition which includes the discharge of 9.5 ML/day (ADWF) of treated effluent. As no detailed pre-discharge habitat mapping or habitat condition assessment is available, it is not possible to determine the present condition relative to the pre-impact condition, i.e. to determine existing impacts.

The mapping of marine habitats by Geo Oceans (2012) (Appendix A, Figure 15) indicates that substrate and water depth are the key factors in habitat distribution, with no discernible relationship with proximity to the outfall.

Increasing the effluent volume to 12.5 ML ADWF while retaining the present contaminant concentrations (Ludmilla WWTP + Larrakeyah WWTP, pre-upgrade) will not change the concentration of contaminants present in the effluent but will slightly increase the area required for initial dispersion. This is anticipated to minimally expand the area in which potential exceedances of the ANZECC & ARMCANZ (2000) 95% species protection levels will occur (Refer to PER Supplement, Appendix B). Following the 2012 upgrade of the Ludmilla WWTP there is expected to be a reduction in the concentrations of suspended solids, nitrogen and phosphorus, with phosphorus falling below present discharge concentrations and loading.

No evidence has been found of increasing sediment metal levels associated with discharge from the Ludmilla WWTP, either in the intertidal zone (PWC data) or further offshore (Fortune 2006).

As noted in Section 4.5.1 of the PER Supplement, the listed threatened and migratory marine species identified by an EPBC Protected Matters Search of the East Point area comprise cetaceans, sea turtles, dugong, estuarine crocodiles, whale sharks and sawfish. The first four groups are reported as highly mobile within the Harbour and consequently may on occasion pass through the plume; there are no records in the MAGNT database of the sawfish species in Darwin Harbour (refer to PER Supplement, Section 4.5.1 for additional description on the occurrence and habits of these species within Darwin Harbour).

# 5 Impacts to EPBC Act Listed Species

Continuous exposure to contaminants at the discharge concentration is not possible, as most of the dispersal area is intertidal (see also PER Supplement sections 4.5.1 and 6.9). Furthermore, at the time of the marine habitat survey (Appendix A) there were no significant feeding resources within the area potentially impacted by the plume which might lead to benthic feeders such as turtles and dugong spending significant periods in the outfall area feeding or in search of food.

### 5.1.2 Listed migratory shorebirds

A number of EPBC listed migratory shorebirds have been recorded in the vicinity of the EPO location during counts conducted for the Shorebirds 2020 program. This includes species with varying foraging strategies. Species recorded in the vicinity of the discharge site in significant numbers include the:

- Lesser Sand Plover (*Charadrius mongolus*)
- Greater Sand Plover (*Charadrius leschenaultia*)
- Whimbrel (*Numenius phaeopus*)
- Grey-tailed Tattler (*Tringa brevipes*)
- Great Knot (*Calidris tenuirostris*)
- Ruddy Turnstone (*Arenia interpres*).

Issues relevant to impacts on migratory shorebirds include potential exposure to discharged metals that may occur at higher concentrations near the EPO discharge point, and indirect impacts relating to changes in shallow water environmental conditions due to nutrient enrichment (phosphorus). The latter may have implications for epibenthos and infauna which form prey items for shorebirds.

Potential impacts on shorebirds through direct ingestion during foraging are likely to be minimised by a number of factors, including the reduced period of time when substrates surrounding the discharge point are likely to be exposed or accessible to feeding birds (with the longest period on low spring tides). Shorebird foraging in the vicinity of the discharge point is also likely to be low or absent, based on data on the epibenthos and infauna in this area (Appendix A). Tidal flats and reef in the vicinity of the EPO discharge point are likely to be of low importance as foraging sites, and high concentrations of shorebirds have been observed at high tide roosts in the East Point area rather than foraging on the tidal flats. These factors reduce potential exposure of shorebirds to contaminants. However the extent of use of the area immediately surrounding the EPO discharge point and adjacent areas by foraging shorebirds has not been assessed by formal surveys, and further specific monitoring of shorebirds would be required to clarify these issues.

Copper is the only metal found to be present at levels exceeding recommend standards during regular monitoring. Copper is an essential micronutrient with a range of important biological functions and in vertebrates internal copper levels are generally well regulated (Hargreaves et al. 2011). Shorebirds may ingest pollutants (including metals) from the tissues of prey. During foraging shorebirds may also ingest significant amounts of sediment which may contain contaminants, either directly or from sediments contained in the digestive tract of prey items (Hui & Beyer 1998). Sediment ingestion is thought to be significant and widespread in a range of shorebird species (Hui & Beyer 1998).

Studies have indicated that copper does not bio-accumulate from invertebrate prey to shorebirds (Hargreaves et al. 2011). Shorebirds only retain a small percentage of the copper ingested from invertebrate prey and many species are able to cope with high levels of hepatic copper (Bryan & Langston 1992). The most toxic and bio-available form of dissolved Cu (cupric ion) represents a minor percentage of total copper and this form of copper becomes less bio-available at increased salinity levels (Bryan & Langston 1992). These factors, combined with the probable low suitability of foraging

habitat for shorebirds in the vicinity of the EPO discharge point and limited tidal exposure, suggest that risks to migratory shorebirds are reduced.

Phosphorus levels in the immediate vicinity of the outfall location have been identified as higher than those observed in other studies in the Darwin area. Shorebird responses to nutrient (phosphorous) enrichment are potentially related to benthic and pelagic anoxia, changes in marine plant and macro-algae growth and associated impacts on invertebrate prey. Some studies have shown that feeding opportunities for shorebirds can increase under some moderate nutrient enrichment in the short term, but excessive nutrient loadings lead to a deteriorating shallow-water habitat quality (Raffaelli 1999). Impacts on shorebirds are likely to vary depending on foraging strategies and prey type.

It is expected that the potential impacts of nutrient enrichment on shallow water and tidal environments in the vicinity of the EPO discharge would be reduced by tidal mixing of the water column on high tides. Tidal mixing and exposure of the sediment to the atmosphere at low tides may also mitigate benthic and pelagic anoxia. As the areas surrounding the EPO discharge point are not thought to support important shorebird foraging habitats, impacts on migratory birds are not expected to change significantly. Impacts on foraging areas away from the immediate discharge area will depend on the location and extent of shorebird foraging sites in relation to the mixing zones.

Upgrades to the sewage treatment facilities to be completed in 2012 are expected to reduce and stabilise nutrient inflows.

## 5.2 Impacts of EPO discharge at low tides

The EPO is located at an elevation of approximately low neap tide. As a result the outfall is exposed for varying times on most low tides, with the longest period of exposure occurring on low spring tides. During periods of exposure the surrounding intertidal sediments and the flora/fauna that they support may be exposed to effluent at the concentration at which it is discharged from the plant, while avifauna may have direct access to the effluent.

### 5.2.1 Infauna

As noted in Section 4.1.2, there is no evidence of a relationship between nitrogen levels in the sediment and the EPO wastewater discharge. Moreover nitrogen levels in the sediment at East Point are generally lower than in other studies of the sediments in Darwin Harbour, possibly a reflection of the outer harbour location of the site. Phosphorus levels have been identified as higher than those observed in other studies and notably are higher in the immediate vicinity of the outfall location.

Anoxia is possible within the sediments, as is frequently the case with estuarine sediments, however it is unlikely to occur at the sediment - water column interface about the EPO location due to exposure of the sediment to the atmosphere on low tides and efficient tidal mixing of the water column on high tides. The depth at which anoxia (if present) occurs within the sediments about the outfall has not been determined.

Geo Oceans (Appendix B) describes the intertidal sediments of the area in which the EPO is located as not supporting epibenthos (plants or animals living on the sediment surface). The Geo Oceans report maps the broad area around the existing outfall as sand with low bioturbation (indicating low presence of infauna) bisected by a band of medium bioturbation running from north to south to the west of the outfall location.

# 5 Impacts to EPBC Act Listed Species

The survey results do not give any indication of gradients in biological activity associated with the location of the outfall.

No evidence was found for contaminant toxicity of wastewater origin in the sediments.

### 5.2.2 Seagrass habitat

The detailed habitat survey of the East Point area undertaken by Geo Oceans (Appendix B) concluded that seagrass habitat was not present in the discharge area, including within the intertidal zone, at >1% seagrass cover, although very sparse (<1% cover) seagrass (*Halodule* sp.) was found on one (subtidal) transect to the north of East Point. This is the general area where seagrass had been identified in previous studies (NRETAS 2011, Geo Oceans 2011). These studies identified seagrass of up to 3% cover and mapped areas of greater than 1% cover.

The apparent reduction in seagrass is likely a result of seasonal conditions and the ephemeral nature of the species concerned.

There is no evidence that the pattern of distribution or density of seagrass surveyed in 2012 has been influenced by discharge at the existing outfall location.

### 5.2.3 Reefal habitat

As a result of combining the Larrakeyah and Ludmilla WWTP effluent flows, the species present on the seabed on the north east side of East Point may be exposed to higher concentrations of copper during atypical discharge conditions. No impact on the reef area was anticipated during normal discharge conditions (Appendix A and PER Supplement Appendix B).

Figures 3-1 and 3-2 show the reefal habitat which will be exposed to occasionally higher levels of copper (exceeding the 95% species protection level) comprises intertidal reef with no visible epibiota, intertidal reef with oysters and intertidal reef with turf algae. Subtidal reef with corals, other filter feeders and macroalgae was not subject to above guideline concentrations.

Modelling showed no significant change in the distribution of lead or zinc, both of which have a very small dispersal area over sandy intertidal flat habitat, from the combined effluents (PER Supplement Appendix B), with no impact on reefal habitat.

### 5.2.4 Migratory and wading birds

The results of the habitat survey (Appendix A) suggest that the intertidal sediments about the EPO have low biological productivity as indicated by the absence of epibiota (seagrasses and marine fauna) and absence/very low numbers of burrows. Monitoring data from the local area do not document the extent of foraging of shorebirds in the vicinity of the EPO. Shorebirds would potentially have access to the area surrounding the EPO during periods of low water, and could potentially forage there. However studies (Appendix A) have indicated the intertidal sediments of the area in which the EPO is located do not support abundant epibenthos and infauna, suggesting that the area would not be a significant shorebird foraging site. Further monitoring would be required to assess the extent of shorebird foraging in the local area.

Shorebirds may be exposed to pollutants while foraging in a number of ways, including direct contact with contaminants, ingestion of pollutants contained in the tissues of prey, direct consumption of sediment and consumption of sediment in the intestinal tracts of prey (Hui & Beyer 1998). Some

# 5 Impacts to EPBC Act Listed Species

shorebirds also drink while foraging on tidal flats (Blakey et al. 2006). In the absence of specific guidelines, the effect on waterbirds of drinking low salinity Ludmilla WWTP effluent during neap tide periods, when the outfall is exposed and effluent ponds around the outfall, has been examined by comparing the undiluted effluent to the Australian Drinking Water Guidelines (NHMRC 2011) (human drinking water) and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Section 4.3: Livestock drinking water quality (ANZECC & ARMCANZ 2000) (Table 5-1).

Only one substance has been detected in the undiluted wastewater at a concentration exceeding a guideline value: aluminium which exceeds the Australian (human) drinking water guideline for acid soluble aluminium, but not the livestock drinking water guideline (total aluminium). It is not known if the aluminium is present in acid soluble form at the point of discharge.

The risk from chemical contaminants to waterbirds or other species drinking water from the outlet or consuming food which may have been in direct contact with the effluent is considered low for the metallic elements tested. No assessment of the risks from consuming other substances or pathogens (bacteria and viruses) present in the effluent has been undertaken however disinfection of the effluent will significantly reduce risk from the latter source.

# 5 Impacts to EPBC Act Listed Species

**Table 5-1 Comparison of LWWTP effluent to drinking water guidelines**

| Analyte<br><br>Concentrations in µg/L | Australian Drinking Water Guideline<br><br>NHMRC 2011 | Recommended low risk trigger value - Livestock drinking water<br><br>ANZECC & ARMCANZ 2000 | LWWTP Effluent<br><br>SLU080<br>(median value)<br>(n = 14) | LWWTP Effluent<br><br>SLU080<br>(May 2012 survey) |
|---|---|---|---|---|
| Nitrate (as N)<br>Nitrite (as N) | 11 287 – 22 573<br>912 | 90 000<br>9120 | 0.7<br>($NO_2$ + $NO_3$ as N) | – |
| Aluminium* | (acid soluble) 200 | 5000 | 278 | – |
| Antimony | 3 | ND | _ | <5 |
| Arsenic | 10 | 500 | 0.9 | <1 |
| Beryllium | 60 | ND | _ | <1 |
| Boron | 4000 | 5000 | _ | <50 |
| Cadmium | 2 | 10 | 0.1 | <0.2 |
| Chromium | 50 | 1000 | 1.3 | 2 |
| Cobalt | ND | 1000 | _ | <1 |
| Copper | 2000 | (poultry) 5000 | 124 | 120 |
| Iron | 300* | ND | 733 | _ |
| Lead | 10 | 100 | 1.5 | 2 |
| Magnesium | ND | > 2000 | 7710 | _ |
| Manganese | 500 | NG | 68 | 87 |
| Mercury | 1 | 2 | 0.1 | <0.1 |
| Molybdenum | 50 | 150 | 0.7 | <5 |
| Nickel | 20 | 1000 | 2.1 | 2 |
| Selenium | 10 | 20 | 0.3 | <1 |
| Silver | 100 | ND | 0.2 | <5 |
| Tin | ND | ND | 2 | _ |
| Uranium | 17 | 200 | 0.1 | _ |
| Vanadium | ND | ND | _ | _ |
| Zinc | 3000* | 20 000 | 48.5 | 53 |
| Cyanide | 80 | ND | _ | 6.7 |

* Guideline based on aesthetic considerations (taste). No health based guideline determined

\- Not analysed

ND No guideline determined/required.

# 6 Monitoring Programme

Please review the Draft Water, Sediment and Biota Monitoring Plan provided at Appendix Q of the PER in light of any impacts that have arisen through the provision of the above information request.

Given that the period over which effluent will continue to be discharged from the existing EPO is presently undefined, the monitoring program designed for the pre-construction baseline, construction and operations phases (provided as Appendix Q of the PER) has been reviewed to ensure that the scope is sufficiently comprehensive to address the continued operation of the EPO at its present location

In developing the East Point monitoring plan, additional monitoring at the EPO location and adjacent areas was included to obtain additional information on marine impacts from the existing EPO. This included water, sediment and biota monitoring locations. Due to uncertainties in the timing of construction of the extended outfall no cut-off date for this monitoring was specified in the monitoring plan, rather it was proposed that any addition or deletion of monitoring sites or changes to monitoring frequency would be considered as part of the annual review of the plan.

No requirement for additional monitoring sites or additional frequency of monitoring has arisen through the studies that have been undertaken since the submission of the plan.

In the subsequently issued Waste Discharge Licence (WDL150-01) a requirement was included for the monitoring of a number of endocrine disrupting compounds at monitoring sites SLu080 (plant) and SLUEP01 (outfall). Since site SLUEP01 is also included in the marine monitoring program, for completeness the required analyses will be documented in the annual revision of the Water, Sediment and Biota Monitoring Plan, due at the end of 2012. This update will include any additional monitoring requirements identified in the next Waste Discharge Licence (due to take effect on 1 November 2012).

As a result of current uncertainty regarding the location and timing for construction of the extended outfall, annual review of the construction schedule and marine monitoring programs is considered the most effective mechanism for determining the relevance of current sites to the ongoing monitoring program, the monitoring parameters and frequency of monitoring.

The frequency of reviews may also be reconsidered once the location of the new outfall and/or timing of construction are known and subsequently when operational discharges from the new outfall commence.

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# 8 Limitations

Power and Water Corporation has prepared this report in accordance with its usual care and thoroughness. Only those third parties who have been authorised in writing by Power and Water Corporation can rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the advice included in this report.

The methodology adopted and sources of information used by Power and Water Corporation are outlined in this report. Power and Water Corporation has made no independent verification of this information and Power and Water Corporation assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to Power and Water Corporation was false.

This report was prepared between 10 April and 5 October 2012 and is based on the conditions encountered and information reviewed at the time of preparation. Power and Water Corporation disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full with the draft Public Environmental Report and Supplement (PWC 2011). No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

# Appendix A Towed camera marine habitat mapping survey NT Power and Water Corporation – East Point Aquatic Life Reserve

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