2025 Environmental Risk Assessment - Maningrida Wastewater Treatment Plant WDL 203-04

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PowerWater

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Abbreviations and Glossary

Abbreviation	Definition
ANZECC	Australian Water Quality Guidelines for Fresh and Marine Waters
ARMCANZ	Agriculture and Resources Management Council of Australia and New Zealand
Assessment endpoints	The explicit expressions of the actual environmental value that is to be protected, operationally defined by an ecological entity and its attributes.
BOD	Biochemical oxygen demand
BUD	Beneficial Use Declaration – the uses of water specified in subsection 3 of the *Water Act* (1992)
BOM	Bureau of Meteorology
CSM	Conceptual site model
Cultural values	To provide water to meet aesthetic, recreational and cultural needs.
DLPE	Department of Lands, Planning and Environment (NT)
DO	Dissolved oxygen
E. coli	*Escherichia coli*
Ebb tide	A falling tide - the phase of the tide between high water and the succeeding low water.
Environmental Values	To provide water to maintain the health of aquatic ecosystems.
EPBC	Environment Protection and Biodiversity Conservation Act
ERA	Environmental risk assessment
ET	Equivalent Tenement – an average residential dwelling or house. Other developments are converted to an ET value by relating their average water demand (or sewage flow) to demand from one average house.
Flood tide	A rising tide - the phase of the tide between low water and the next high tide.
ICEGs	Indigenous Community Engineering Guidelines
kL	Kilolitre
Km	Kilometre
L	Litre
m	Metre
m^2	Square metre
Macrotidal estuary	Estuaries where the tidal range is in excess of 4 metres.
mg	Milligram
mL	Millilitre
NOx	Nitrogen oxides – the sum of nitrate and nitrite ionic species.
NT	Northern Territory

NTU	Nephelometric turbidity units
NT EPA	Northern Territory Environmental Protection Authority
PL	Primary lagoon
Risk characterisation	The culmination of the planning, problem formulation and analysis of predicted or observed adverse ecological effects related to the assessment endpoints.
Risk hypothesis	Assumptions made in order to evaluate logical or empirical consequences, or suppositions tentatively accepted to provide a basis for evaluation. They are used to test if an activity (e.g. contaminant discharges) has adverse effects on an assessment endpoint.
SL	Secondary lagoon
SOCs	Site of conservation significance
SPS(s)	Sewage pump station(s)
SS / TSS	Suspended solids / total suspended solids
TDS	Total dissolved solids – the portion of solids in wastewater that passes through a 2.0 micron filter.
TN	Total nitrogen
TP	Total phosphorous
TPWC	Territory Parks and Wildlife Conservation Act
WDL	Waste discharge licence
WwTP	Wastewater treatment plant. All facilities that treat wastewater disposed of to the sewerage system consisting primarily of sewage as well as stormwater inflow and infiltration. These facilities may include a range of different types of treatment technologies e.g. waste stabilisation ponds.
WSP(s)	Waste stabilisation pond(s)

Executive Summary

This desktop environmental risk assessment (ERA) provides an assessment of the risks associated with the discharge of secondary treated effluent from the Maningrida wastewater treatment plant (WwTP) to the Liverpool River (Arafura Sea).

Based on this ERA and water quality data, there is limited evidence to suggest deleterious impacts on the environmental values identified for this receiving environment.

Risks to the assessment end-points, associated with the source, were assessed as having low to high risk rankings. These rankings were associated with the low discharge volumes into a tidal marine environment, while higher risk rankings were associated with impacts to cultural values including human health risks through primary and secondary contact and aquatic food safety.

The risk rankings may change as uncertainties associated with current assessments are addressed. A range of recommendations have been made in this risk assessment to address knowledge gaps and identify opportunities for improvement.

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1. Introduction

Power and Water operate the Maningrida WwTP pursuant to Waste Discharge Licence (WDL) 203-04 issued on 11 July 2028. This WDL allows for continuous discharge of secondary treated sewage effluent from an authorised discharge point to the Liverpool River (Arafura Sea).

Maningrida is located on the Central Arnhem coast at the mouth of the Liverpool River. It is 352 km east of Darwin (Figure 1). Based on ABS 2021 Census, Maningrida has an estimated population of 2,956 (BushTel 2025). The Wastewater Treatment Plant (WwTP) is located approximately 1.3 km south of the Maningrida township (Figure 2).

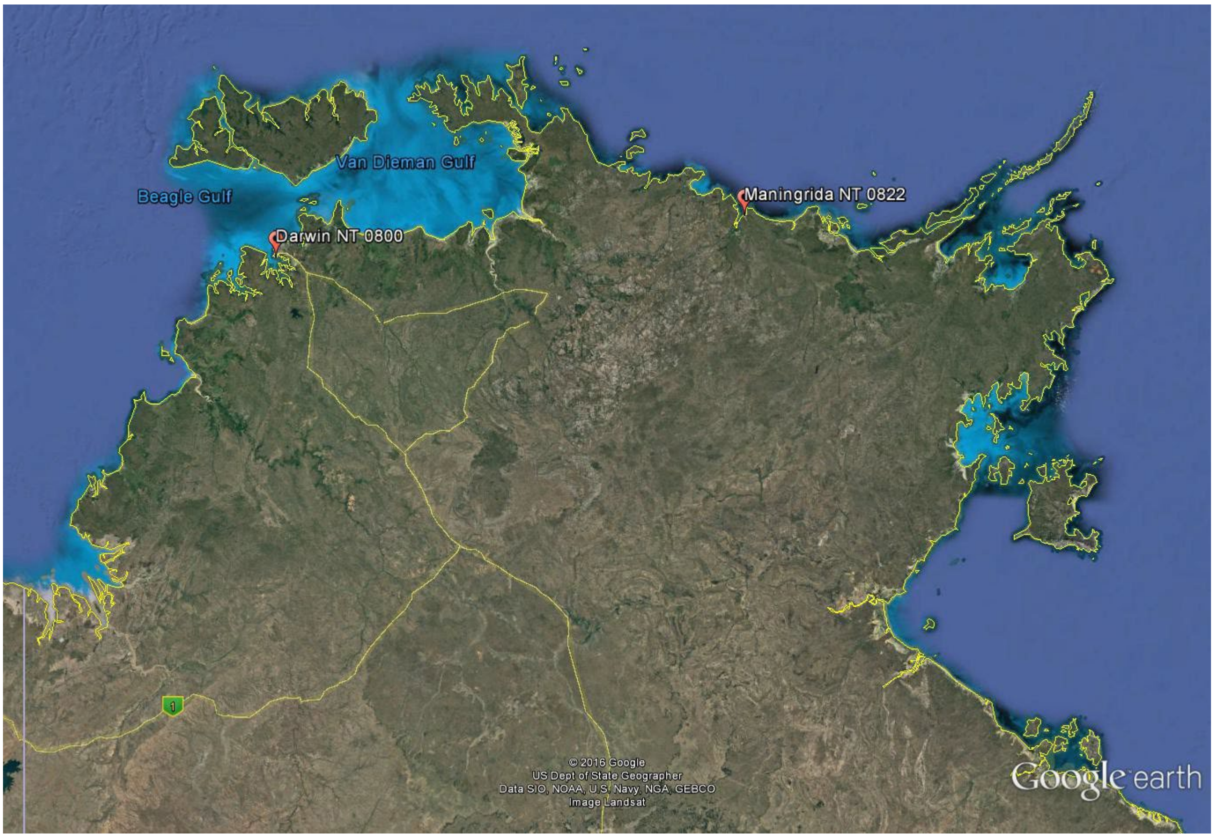

Figure 1: Maningrida location (Google Earth, 2024)

Figure 2: Maningrida site layout including WwTP and Outfall (NT ILIS 2016)

1.1 Background

Condition 43 (Item 15) of this WDL requires Power and Water to submit to the Northern Territory Environment Protection Authority (NT EPA) an updated ERA for the Licenced Activity by 1 February 2025.

The ERA must:

i. be conducted with reference to a Conceptual Site Model;

ii. characterise the impacts of discharge on the relevant Environmental Values; and

iii. inform the development of a Performance Improvement Plan.

2. Risk Assessment Methodology

The purpose of the desktop ERA is to:

- identify assessment endpoints;
- characterise environmental risks associated with the facility; and
- initiate an ongoing iterative environmental risk process associated with ongoing operation of the facility.

The methodology employed has been adapted from ERAs completed by the Power and Water's Assurance Team and the Victorian EPA *Guidance for Environmental and Human Health Risk Assessment of Wastewater Discharges to Surface Waters* (VIC EPA 2023). The guidelines utilise a framework (Figure 3) consistent with current nationally and internationally accepted risk assessment approaches.

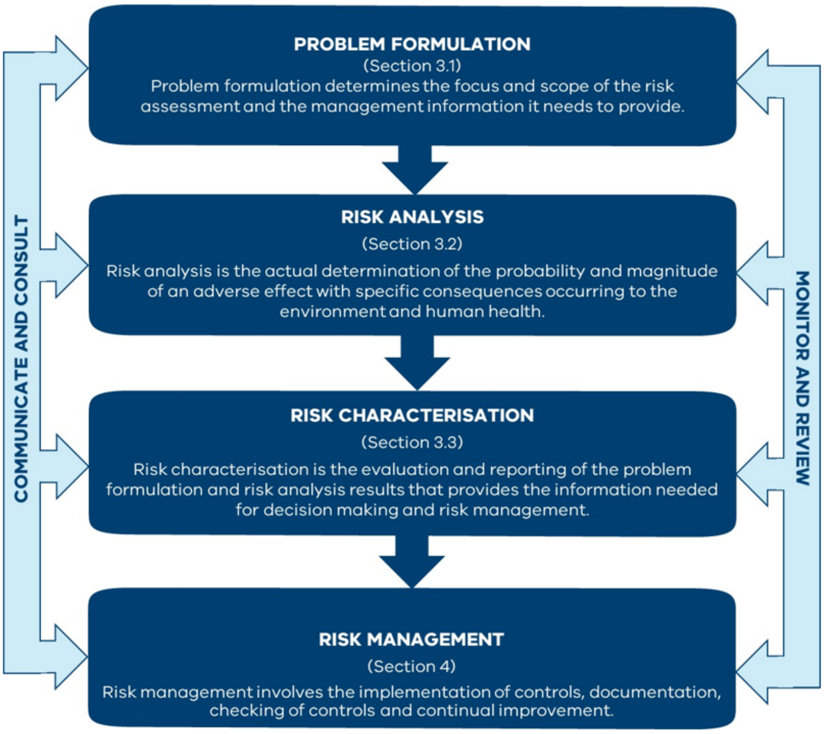

Figure 3: Risk Assessment framework for wastewater discharges to waterways (Victoria EPA, 2023)

2.1 Limitations

The following items have been identified as limitations associated with the preparation of this ERA:

- limited availability of inflow/outflow data;
- remoteness of communities impacting on the ability to understand systems due to costs, logistics and available expertise; and
- limited access to pond discharge points and surrounding environment due to climatic, safety and geographic factors.

3. Problem Formulation

The purpose of this ERA is to characterise the impacts of discharge on the relevant values and has been prepared with reference to section 1.1.

This problem is explored through the following:

- characterisation of the treated effluent discharged to the receiving environment;
- characterisation of the treated effluent discharge regime and subsequent dilution of treated effluent within receiving water; and
- identified values of receiving water and assessment endpoints representative of those values.

3.1 Maningrida Wastewater Treatment Plant

The community utilises a gravity and pressure fed sewer reticulation system which drains raw sewage from the community to the WwTP (Figure 4). The Maningrida WwTP utilises waste stabilisation pond technology and natural ultraviolet disinfection to achieve secondary level treatment of sewage effluent. Based on current circumstances, the raw sewage is almost entirely domestic in nature with no chemicals added during the treatment process. The original WwTP was constructed in 1971 (Power and Water 2021b). In May 2015, the ponds were upgraded to include the addition of a new primary pond and extension of existing outfall. The ponds consist of a primary facultative pond which gravity feeds into two secondary maturation ponds. The pond outlet contains a float arrangement and inline pump to prevent ingress of marine water into the system during periods of high tide (Power and Water 2014).

There is no gross pollutant screening, grit removal, maceration or storm flow separation located on the inlet to the pond system. The majority of the removal process for gross pollutants and other entrained materials is via sedimentation to sludge layers or entrapment in concentrated surface scums that can be physically removed. A floating boom is installed on the pond 1 surface to enhance entrapment and the pond 3 outlet contains a physical screen. Desludging of the WSPs is conducted periodically to remove accumulated solids and increase hydraulic performance, which may result in improved treatment performance.

Desludging was most recently completed in the second maturation pond during the 2015 pond upgrades.

Samples of the tertiary pond outlet are currently collected on a monthly basis. Monitoring results are included in the *Power and Water Annual Monitoring Report – Remote Community Waste Discharge Licences,* a summary is provided in Appendix 4 (Table 7).

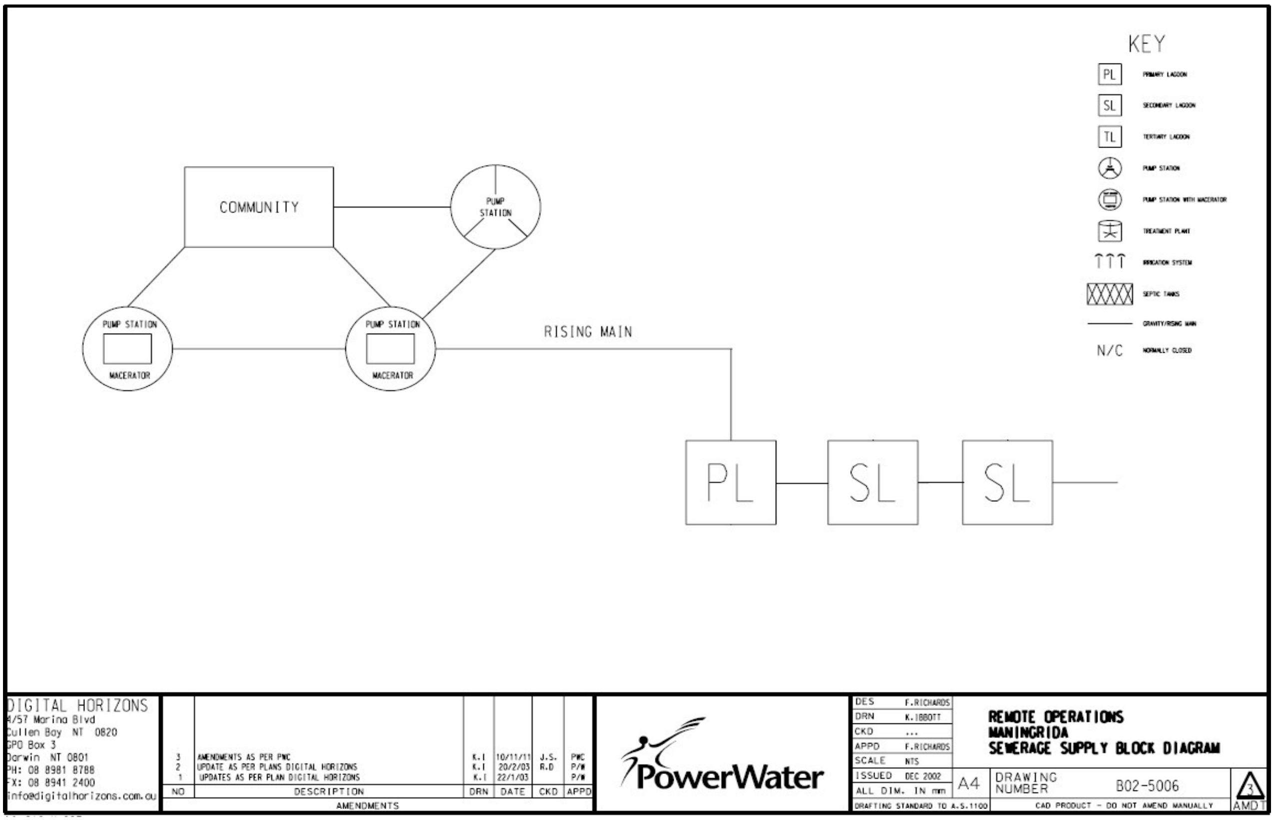

Figure 4: Maningrida wastewater collection and treatment configuration.

3.2 Discharge Regime

Discharge from the facility occurs from an outfall located in the tertiary maturation pond to the ocean. Discharge is continuous on an as-required basis (discharge is all year round) and occurs directly into the Liverpool River (Arafura Sea). The discharge outfall is approximately 135 m in length from the coastline (260 m total length from ponds) and is attached to anchor blocks along a natural rock platform. The outlet is located below the low-level tide point in close proximity to the deep water channel which extends along the coast line past the waste stabilisation ponds (Power and Water 2014).

A flow meter is installed at the Maningrida discharge point. However, currently this data set contains inconsistencies, reducing confidence in the data statistics. Further data collation and assessment is required over a longer-term to provide more accurate measurements. Inflow data from flow meters is also not currently available, estimations have been utilised based on forecast sewage Equivalent Tenement (ET) flow, which may not accurately represent the inflow to outflow ratio on site.

- The estimated mean outflow from Maningrida WwTP is **815.4 kL/day**

Note that the volume of treated wastewater discharged to the environment varies seasonally with changes in evaporation and rainfall, with maximum flow experienced during the wet season. It is probable that this is due to high ingress to the Maningrida sewer system due to age and condition of the sewer and condition of house drains and overflow relief gullies. The majority of this maximum flow is expected to be stormwater (Power and Water, 2014) and therefore the pollutant load is likely to be negligible.

3.3 Pond Performance

WSPs offer a low input, cost effective form of wastewater treatment that is particularly applicable in higher temperature environments with sufficient available land area. While the inputs are low, because it is largely driven by solar energy, the processes are no less complex and are largely controlled by the appropriate design and maintenance of the pond system to achieve the treatment performance required.

The ponds ultimately provide a centralised treatment barrier that prevents direct contamination of the receiving environment and have an important role in the protection of both environmental and public health.

Wastewater monitoring at the Maningrida primary pond inlet commenced in June 2012. This data should provide an accurate characterisation of the raw effluent entering the waste stabilisation pond system, and an indication of treatment performance.

Pond treatment performance can be measured at remote community sites utilising mean biochemical oxygen demand (BOD) removal performance and mean predicted *E.coli* disinfection performance. The results are a reduction in concentration levels from the primary pond inlet to the final pond outlet.

The mean removal percentage at the Maningrida WSPs has been calculated using data collected after the previous Environmental Risk Assessment – from August 2022 to January 2025:

- Biochemical Oxygen Demand (BOD): **63%**
- Free Ammonia (NH_3-N): **65%**
- Total Nitrogen (TN): **43%**
- Total Phosphorus (TP): **12%**

The average log reduction for the pathogens indicator is:

- *E. coli:* **2.7 log reduction**

For the scope of this risk assessment, wastewater quality monitoring data collected at the final pond discharge point to the receiving environment are illustrated on the conceptual site model (CSM) Appendix 1 (Figure 8), and water quality table Appendix 4 (Table 7).

3.4 Receiving Environment

The Liverpool River is a tide-dominated barrier estuary that discharges to the Arafura Sea. The river is 39.8 km in length and the wastewater discharge enters at the river mouth which is approximately 3.91 km wide (Geoscience Australia 2016) (Figure 5,Figure 6). Liverpool River tides are semi-diurnal and have a mean spring and neap tidal range of 2.8 m (BOM 2025).

The receiving environment consists of a weathered rock platform that slopes away from the land towards a sandy beach area. The area adjacent to the outfall is moderately vegetated with eucalyptus and seaward mangrove assemblages (Power and Water 2014) (Figure 7).

Figure 5: Maningrida Outfall (Power and Water 2016)

Figure 6: Maningrida Outfall (Power and Water 2016)

Figure 7: Mangrove habitat along coastline at Maningrida WwTP discharge point (Power and Water 2016).

The Liverpool River is located within the boundaries of the Maningrida Coastal site of conservation significance (SOCS) number 17 and contains 13 threatened marine and near shore species. The conservation status for these species listed under the Territory Parks and Wildlife Conservation Act 2000 (TPWC) and the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC) are summarised below in Table 1.

Table 1: Conservation status of species at risk from the Maningrida WwTP.

Common name	Species name	National Status (EPBC)	NT Status (TPWC)
Flora			
Australian Arenga Palm	*Arenga australasica*	VU	DD
Fauna			
Australian Bustard	Ardeotis australis	-	VU
Emu	Dromaius novaehollandiae	-	VU
Gouldian Finch	Erythrura gouldiae	EN	VU
Crested shrike-tit (northern)	Falcunculus (frontatus) whitei	VU	VU
Partridge Pigeon	Geophaps smithii	VU	VU
White-throated Grasswren	Amytornis woodwardi	VU	VU
False Water-rat	Xeromys myoides	VU	VU
Merten's Water Monitor	Varanus mertensi	EN	VU
Yellow-spotted Monitor	Varanus panoptes	-	VU
Flatback Turtle	Natator depressus	VU	DD
Leatherback Turtle	Dermochelys coriacea	EN	CR
Olive Ridley Turtle	Lepidochelys olivacea	EN	VU

CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, DD – Data Deficient

3.5 Screening Level Risk Assessment

A screening level risk assessment is used to determine if a risk to the assessment end-point exists that should be further investigated. It is a method for prioritising risks and minimising effort in assessing low risks. Table 3 provides a summary of the screening level risk assessment.

Risk hypotheses for the stressors identified in the conceptual site model (CSM) (Appendix A, Figure 11) are defined with respect to their potential effects on the identified values of the receiving environment.

The identified values of the receiving environment are summarised below in Table 2.

Table 2: Identified values of receiving environment at risk from the Maningrida WwTP

Values	Receptors	
Cultural/ Human Health	Humans	Fishing (lines, nets and spears) Shellfish harvesting Cooking Swimming/wading/diving Visible water quality Sacred sites
Environment	Marine	Fish Dugongs Dolphins Turtles Mud Crabs Crocodiles
	Terrestrial	Shorebirds Seabirds
	Plants	Mangroves Eucalyptus

Table 3. Screening level risk assessment for key indicator and stressors associated with Maningrida WwTP discharge.

Indicator (water quality parameter)	Stressor (change to indicator)	Risk Hypothesis		Assessment end-points		Scope of this desktop ERA	Further investigation required?
		ENVIRONMENTAL	CULTURAL	ENVIRONMENTAL	CULTURAL		
Gross pollutants	Presence and accumulation of gross pollutants from influent carried through to effluent	That gross and micro-scale pollutants are ingested by biota resulting in death of animals and environmental degradation.	That gross pollutants are resulting in the reduction of visual amenity in the receiving environment.	To maintain the presence of biota in the environment.	To maintain the visual amenity of the environment.	The WwTP is considered a relatively effective barrier to gross pollutant entry to the receiving environment. This is due to the settling out to sludge layers and accumulation on pond surface where gross pollutants are physically removed as required. No evidence of gross pollutant accumulation during visual monitoring of discharge site (qualitative discharge criteria). No further investigation necessary at this stage.	No
Electrical conductivity	Decrease in salinity from freshwater input to marine environment	That freshwater inputs are leading to impacts on biota less tolerant of lower salinities resulting in loss of biodiversity.		To maintain biodiversity in the environment.		Significance of freshwater inputs considered low with respect to discharge volumes and natural freshwater inputs within region (Geoscience Australia 2016). Mangroves are also at the interface of terrestrial and marine environments and can tolerate freshwater inputs (Power and Water 2015a, Power and Water 2015b). No further investigation necessary at this stage.	No
Organic matter	Increase in BOD, decrease in DO	That BOD is leading to oxygen depletion in the environment resulting in loss of biota (e.g. fish kills) and changes to ecosystem structure.	That BOD is leading to odours resulting in the reduction of amenity in the receiving environment.	To maintain the presence of biota in the environment.	To maintain oxygen levels in the environment sufficient to prevent production of odours.	The median concentration of BOD in the discharge of Maningrida WwTP is 30.0 mg/L. As BOD is present in the discharge, it is determined at a screening level that a risk is present and further investigation is necessary.	Yes
Nutrients (nitrogen and phosphorus)	Increase in nutrient concentrations	That nutrients are leading to nuisance plant growth (e.g. phytoplankton blooms) resulting in oxygen depletion; displacement of endemic species; diminished light availability; release of toxins; and changes to ecosystem structure.	That nutrients are resulting in the reduction of amenity of receiving environment through reduction in water clarity, objectionable discoloration and odours; toxic blooms that are a public health risk; and blooms of toxin producing species whereby the toxins bio-accumulate in shellfish and fish ingested by humans.	To maintain nutrient levels so that the levels of primary production do not have an adverse impact on ecosystem structure.	To maintain the amenity of the environment.	As nutrients are present in the discharge, it is determined at a screening level that a risk is present and further investigation is necessary.	Yes
Toxicants	Increase in free ammonia concentration	That free ammonia is resulting in toxicity to aquatic organisms in water and sediments.		To maintain the presence of biota in the environment.		The median concentration of free ammonia in the discharge of Maningrida WwTP is 12 mg/L. At a screening level it is determined that a risk is present and further investigation is necessary.	Yes

Pathogens	Presence of *E. coli*		That pathogens are leading to the contamination of water resulting in primary and secondary contact recreation a public health risk; and accumulation in shellfish resulting in the consumption of shellfish a public health risk.		To maintain that pathogens from municipal wastewater are not increasing the risk of illness via primary and secondary contact recreation and consumption of shellfish.	The median pathogen concentration in the discharge of Maningrida WwTP is 13,905/100mL. At a screening level it is determined that a risk is present and further investigation is necessary.	Yes

4. Risk Analysis and characterisation

4.1 Power and Water Risk Management Framework

Power and Water has adopted a qualitative risk assessment methodology aligned to the Australia/New Zealand Standard *"AS/NZ 4360: Risk Management".* This process is used to assess and manage activities that have potential to cause environmental harm.

The first step in the ERA process is to identify the aspects (problem formulation i.e. discharge of treated wastewater) (section 2.0) and corresponding potential impacts associated with each assessment endpoint identified in the screening level risk assessment as seen in Table 3.

This methodology is based on knowledge of the existing environment and incorporates site specific environmental factors into the analysis of the potential impacts. An assessment of each impact is analysed for likelihood and consequence.

The categories and associated rankings for environmental impact consequences are shown in Appendix 3 (Table 5). The likelihood of an event occurring and a risk score for each potential impact is determined by combining likelihood with consequence results as seen in Appendix 3 (11).

Low to medium risks can typically be managed by routine procedures and integration into management plans, while high to extreme risks require senior management attention, immediate action or more detailed research and management planning.

3.1.1 Risk assessment for key indicators and stressors identified in screening level assessment.

Table 4: Risk assessment for key environmental and cultural assessment endpoints associated with Yirrkala WwTP discharge.

Hypothesis	Consequence		Likelihood	Inherent Risk Ranking	
Environmental					
BOD is leading to oxygen depletion in the environment resulting in **loss of biota** and **changes to ecosystem structure**.	Dilution and dispersion are valuable processes for reducing the impacts of non-accumulative pollutants such as BOD (Agriculture and Resource Management Council of Australia and New Zealand and the Australian and New Zealand Environment and Conservation Council (ANZECC) 1997). The estimated preliminary dilution ratio between the effluent and receiving environment is 1:4 in the direct vicinity of the discharge point with further subsequent dilution (see Appendix 4) suggesting any observed oxygen demand would be absorbed by the environment.	Minor	Stressor not typically observed with such small discharge volumes, rapid dilution, large surface area available for reaeration and efficient coastal flushing (Fernando, 2012). Likelihood greater during low tide where there are short-term flushing constraints however unlikely to be sustained. PWC considers that the likelihood of oxygen depletion in the receiving environment is unlikely. Ongoing sampling will assist to characterise discharge quality.	Unlikely	Low
Free ammonia is resulting in **toxicity to aquatic organisms** in water and sediments.	One of the most visible means by which toxicity presents in an aquatic ecosystem is through the occurrence of fish kills. No fish kills reported to date. A study by Padovan, Muksgaard and Gibb (2015) found that the ammonia concentration at the outfall was below the ANZECC (2000) trigger value for ammonia in seawater. Sediment nitrogen concentrations near the outfall were also comparable to those found from Darwin Harbour (Padovan, Muksgaard and Gibb 2015).	Minor	Stressor not typically observed with such small discharge volumes, rapid dilution, and efficient coastal flushing (Fernando, 2012). Power and Water considers that the likelihood of toxicity to aquatic organisms in water and sediments is unlikely.	Unlikely	Low
Nutrients are leading to **nuisance plant growth** resulting in oxygen depletion; displacement of endemic species; diminished light availability; release of toxins; and changes to ecosystem structure.	Based on the most recent sampling results, Maningrida WwTP contributes 6.5 and 1.0 tonnes/year of total nitrogen and phosphorus respectively. A study by Padovan, Muksgaard and Gibb (2015) found that effluent nutrient concentrations from the Maningrida outfall in seawater returned to background levels within 40 m from the end of the outfall pipe as a result of rapid dilution.	Moderate	Based on the study conducted by Padovan, Muksgaard and Gibb (2015) and sampling results to date, Power and Water considers that the likelihood of nuisance plant growth in the receiving environment is unlikely.	Unlikely	Medium
Cultural/ Human Health					
BOD is leading to odours resulting in the **reduction of amenity** in the receiving environment.	The coastline is identified as having cultural beneficial uses for primary and secondary recreation. The immediate discharge site is located below the low-level tide point (Power and Water 2014) and is only accessible by the public during extreme low tide or by boat.	Moderate	Stressor not typically observed with rapid dilution and efficient coastal flushing. Likelihood greater during extreme low tide where there are short-term flushing constraints, however unlikely to be sustained. No evidence of odours during monitoring of discharge location at final pond (qualitative discharge criteria). Power and Water considers that the likelihood of reduction in amenity from BOD is unlikely.	Unlikely	Medium
Nutrients are resulting in **toxic blooms** that are a public health risk; and **blooms of toxin producing species** whereby the toxins bio-accumulate in shellfish and fish ingested by humans.	The coastline is identified as having cultural beneficial uses for primary and secondary recreation including exposure through swimming and exploratory wading. Collection and consumption of marine species such as shellfish, crabs, oysters, turtles, stingray and other fish are known to occur within the area (Michels Warren Munday 2012). Health warning signs in local language are present adjacent to the pond boundary and at the beach location regarding swimming and diving.	Moderate	Based on the primary and secondary contact recreation and cultural uses of the coastline, Power and Water considers that the likelihood of toxicant exposure is possible.	Possible	Medium
Nutrients are resulting in the **reduction of amenity** of receiving environment through **reduction in water clarity**, objectionable **discolouration** and **odours**.	The coastline is identified as having cultural beneficial uses for primary and secondary recreation. The immediate discharge site is located below the low level tide point (Power and Water 2014) and is only accessible by the public during extreme low tide or by boat.	Moderate	Stressor not typically observed with rapid dilution and efficient coastal flushing. No evidence of reduction in water clarity, objectionable discolouration of receiving water or odours during monitoring of discharge site (qualitative discharge criteria). Power and Water considers that the likelihood of reduction in amenity from nutrients is unlikely.	Unlikely	Medium
Pathogens are leading to the **contamination of water** resulting in a public health risk through primary and secondary contact recreation.	The coastline is identified as having cultural beneficial uses for primary and secondary recreation including exposure through swimming and exploratory wading. Power and Water have installed health warning signs in local language adjacent to the pond boundary and at the beach location regarding collection of shellfish, swimming and diving. A study by Padovan, Muksgaard and Gibb (2015) detected E. coli, total coliforms and Enterococci at the outfall at levels that indicate rapid dilution. These pathogens were also found at the reference sites in very low concentrations which may be a result of naturally occurring pathogens and/or dilution (Padovan, Muksgaard and Gibb 2015). Their study also found pond effluent	Moderate	Based on the secondary contact recreation and cultural uses of the coastline, Power and Water considers that the likelihood of the illness from pathogen exposure is possible.	Possible	Medium

	samples were positive for the human faecal marker *Bacteroides thetaiotamicron* but negative in the environmental samples, supporting rapid pathogen dilution once discharged (Padovan, Muksgaard and Gibb 2015).				
Pathogens are leading to **accumulation in shellfish** resulting in a public health risk through the consumption of shellfish.	Collection and consumption of shellfish are known to occur within the area (Michels Warren Munday 2012). Health warning signs in local language are present adjacent to the pond boundary and at the beach location regarding collection and consumption of shellfish and crabs. Through community consultation, it is understood that the community are well aware that they are required to cook fish caught near the outfall zone (Power and Water 2012).	Moderate	Based on the cultural uses of the coastline, Power and Water considers that the likelihood of the illness from pathogen exposure through the consumption of shellfish is possible.	Possible	Medium

5. Summary

The ERA found that the identified values of the Liverpool River (Arafura Sea) at risk from the Maningrida WwTP discharge were environmental and cultural.

The key stressors that posed a risk to these values were the presence and accumulation of gross pollutants from influent carried through to effluent; decrease in salinity; increase in BOD; increase in nutrient concentrations; increase in free ammonia concentration and the presence of *E. coli*.

The ERA process has determined that the discharge from the Maningrida WwTP poses a low to medium risk to the identified values of the receiving waterway. The influence of the discharge on the receiving environment is considered sustainable given the low discharge volumes and rapid dilution of nutrients and pathogens at the outfall. Based on this ERA and water quality data, there is limited evidence to suggest deleterious impacts to the receiving environment.

All risk rankings have considerable uncertainties attached to the assessments. The risk rankings may change as uncertainties associated with current assessments are addressed.

Based on the ERA process and outcomes, Power and Water make the following recommendations:

- continue monitoring quality of wastewater discharged to the environment;
- assess monitoring data against modelled pond performance;
- incorporate recommendations into future Performance Improvements Plans;
- implement options to accurately quantify the volume of treated wastewater discharged to the environment; and
- update the ERA and CSM based on new information and additional wastewater quality data.

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Appendices

Number	Title
Appendix 1	Maningrida Conceptual Site Model
Appendix 2	Maningrida site of conservation significance
Appendix 3	Power and Water Risk Matrix
Appendix 4	Water quality and estimated dilution Ratio for Maningrida WwTP

Appendix 1 – Maningrida Conceptual Site Model

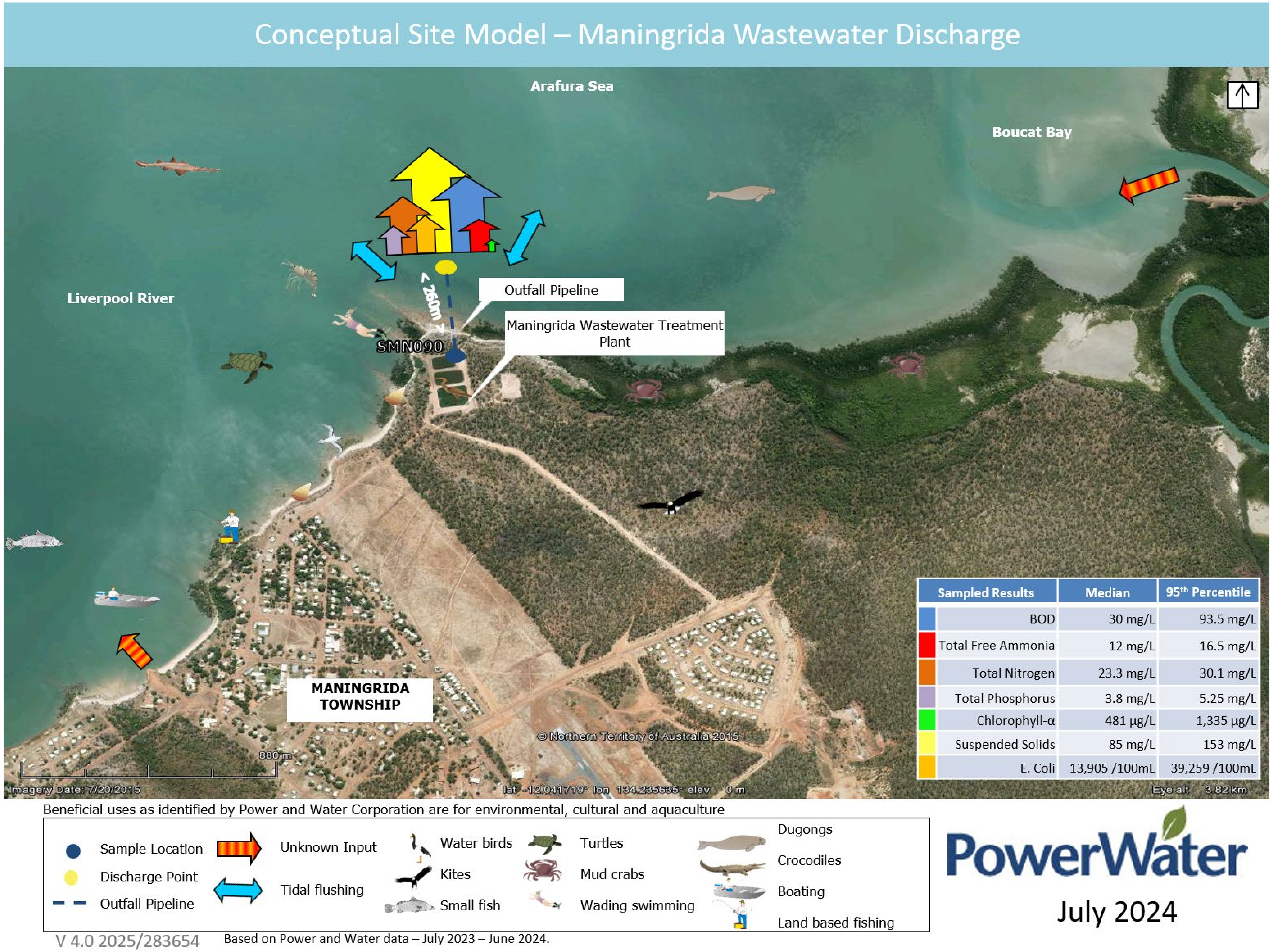

Figure 8: Conceptual site model for the Maningrida WwTP.

PowerWater

Appendix 2 – Maningrida site of conservation significance

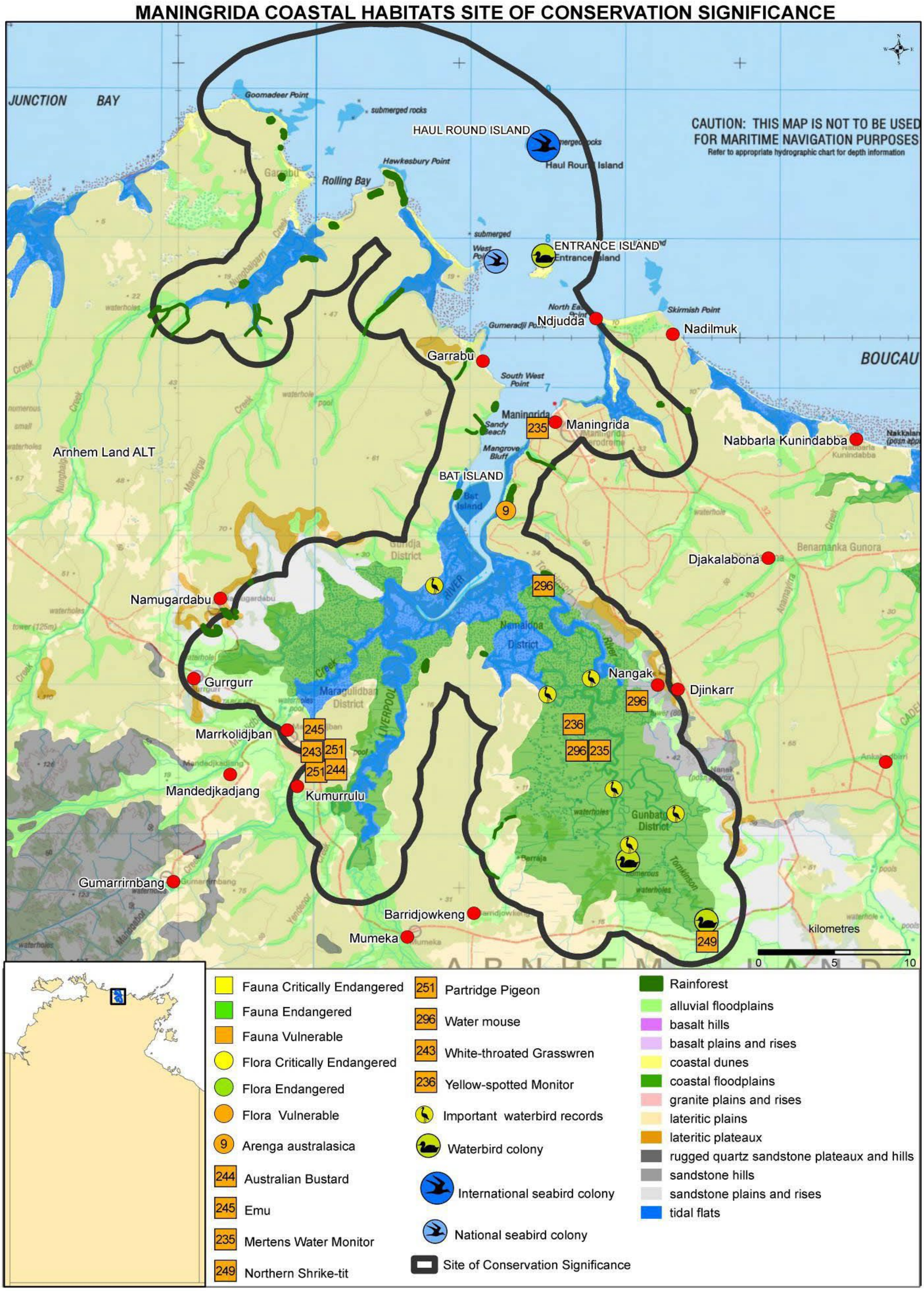

Figure 9: Maningrida coastal site of significance map (NRETAS 2008).

Appendix 3 – Power and Water Risk Matrix

Table 5: Power and Water risk consequence table.

CONSEQUENCES

The consequence (impact or outcome) associated with a risk is assessed using the following criteria:

RISK CONSEQUENCE TABLE					
Category	**Insignificant**	**Minor**	**Moderate**	**Major**	**Severe**
Health and safety	**Physical**: A near miss incident without injury or illness. **Psychosocial*:** No treatment needed from a health professional. *Notes: Psychosocial harm relates to the factors in the design or management of work that increases the risk of work-related stress and can lead to psychological or physical harm.	**Physical:** An incident resulting in a minor injury or illness, and first-aid treatment applied. **Psychosocial**: Reduced ability to perform tasks, no professional treatment needed.	**Physical:** An incident resulting in an injury or illness requiring medical treatment*. **Psychosocial:** Reduced ability to perform tasks, likely needs ongoing support from a health professional. *Notes: Medical treatment relates to treatment by a medical professional at a medical facility. Treatment at a worksite by a paramedic is a first aid injury, unless they are transported to a medical facility.	**Physical:** A serious incident: ▪ Requiring hospitalisation (24hrs); and/or ▪ Resulting in long-term permanent disabling; or ▪ Exceeding of chemical exposure with acute health impacts. **Psychosocial:** Serious psychological treatment needed, reduced ability to perform tasks.	**Physical:** A serious incident resulting in any one or more of the following: ▪ One or more fatalities; ▪ One or more persons seriously injured (includes long-term disabling effect); ▪ Widespread hospitalisation of members of the public or Power and Water's workforce. **Psychosocial**: Inability to perform tasks, ongoing extensive psychological treatment.
Financial **(Impact on EBITDA)**	Loss less than $500K.	Impact between $500K and $5M.	Impact between $5m and $25m.	Impact between $25m and $50m.	Impact greater than $50m.
Legal/ regulation	▪ Individual breach of obligation, procedure or policy. ▪ Civil action, fines and/or civil penalties (refer to Financial definition)	▪ Notification to regulator required. ▪ Regulator/external auditor non-conformance or request for further explanation ▪ Functional breach of obligation, procedure or policy. ▪ Civil action, fines and/or civil penalties (refer to Financial definition)	▪ Regulator/ external auditor issues improvement notice, multiple non-conformances or provisional improvement notice. ▪ Systemic breach of obligation, procedure or policy. ▪ Civil action, fines and/or civil penalties (refer to Financial definition)	▪ Regulator issues notices, corrective action order and/or penalties ▪ Order to stop work ▪ Multiple provisional improvement notices, prohibition notice. ▪ Civil action, fines and/or civil penalties (refer to Financial definition)	▪ Successful criminal prosecution imprisonment of Power and Water director and/or officer. ▪ Royal Commission, parliamentary or other government inquiry, ▪ Loss of licence to operate. ▪ Civil action, fines and/or civil penalties (refer to Financial definition)
Environmental	Localised low level damage controlled but no remedial action required.	Localised low level damage controlled and remedied with minimal resources.	Widespread temporary damage with extended resources to remedy.	Long-term detrimental effect on environment and once controlled results in minor permanent damage.	Substantial permanent damage to widespread and sensitive areas.
Reputation	▪ No media attention; and/or ▪ Isolated community or individual issue-based concern; and/or ▪ Localised employees dissatisfaction which is managed by normal business processes;	▪ Occasional once-off negative media attention; and/or ▪ Localised community impacts and customer concerns; and/or ▪ Localised employees dissatisfaction which requires human resources in resolution;	▪ Brief adverse media attention and/or ▪ Community/customer condemnation; and/or ▪ Limited, localised loss of confidence by the community; and/or ▪ Reduced confidence of key stakeholders ▪ Localised employees dissatisfaction with localised impacts to service delivery	▪ Prolonged adverse media attention and/or ▪ Community/ customer condemnation; and/or ▪ Prolonged, widespread community/ customer loss of confidence; and/or ▪ Confidence of key stakeholders damaged ▪ Widespread dissatisfaction and loss of confidence by employees resulting in temporary service delivery	▪ Sustained adverse media attention and/or ▪ Community/customer condemnation; and/or ▪ Sustained community/ customer loss of confidence; and/or ▪ Loss of stakeholder confidence in Board and/or ▪ Management; and/or ▪ Widespread dissatisfaction by employees resulting in sustained service delivery and industrial action
Customer **(Impact due to disruption to services)**	▪ No loss of supply. Issues rectified with corrective action. ▪ Loss of water supply <= 2 hours in any urban or remote community	▪ An event resulting in loss of a single residential feeder for 15 to 30 minutes ▪ Loss of water supply >2 hrs and <= 6 hours in any remote community ▪ Loss of water supply in urban area, restored within expected timeframes (<=4 hours)	▪ An event resulting in loss of a single to multiple zone substations for up to 3 hours ▪ Loss of water supply >6 and <=12 hours in any remote community ▪ Loss of water supply in urban area outside of expected timeframes (> 4 hours and <=12 hours).	▪ An event resulting in loss of a single to multiple zone substations affecting CBD, town centres, commercial, and emergency services lasting up to 6 hours ▪ Loss of water supply >12 hours < =24 hours in any urban area or remote community.	▪ An event resulting in loss of a single to multiple zone substations affecting CBD, town centres, commercial, and emergency services lasting > 6 hours ▪ Complete loss of water supply (>24 hours) in any urban or remote community.

LIKELIHOOD

The likelihood of a risk occurring is assessed using the following scale:

(E) Almost certain	Event is expected to occur on a regular basis. One or more times per annum.	Not applicable
(D) Likely	An event is expected to occur from time to time. Once every 1 – 3 years	Probability of occurring is greater than 33%
(C) Possible	An event should occur at some time. Once every 4 – 10 years.	Probability of occurring is greater than 10% and up to and including 33%
(B) Unlikely	An event could occur at some time. Once every 11 to 30 years	Probability of occurring is greater than 3% and up to and including 10%
(A) Rare	An event not expected but possible. Less than once in 30 years	Probability of occurring is up to and including 3%

RISK RATING

Consequences and Likelihood

Likelihood \ Consequence	Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Severe (5)
Almost certain (E)	Medium	High	Very High	Extreme	Extreme
Likely (D)	Low	Medium	High	Very High	Extreme
Possible (C)	Low	Low	Medium	High	Very High
Unlikely (B)	Low	Low	Medium	High	High
Rare (A)	Low	Low	Low	Medium	Medium

ACTIONS AND REPORTING

	Low	Medium	High	Very High	Extreme
Escalation (new risk or reassessment)	Reported through risk review process.	Reported through risk review process.	Reported to executive general manager	Reported to CEO / Executive Leadership Team as soon as practicable.	Reported to Board Chair as soon as practicable.
Reporting to ARMC	Not applicable.	Not applicable.	To be reported to Audit and Risk Management Committee on a quarterly basis.	To be reported to Audit and Risk Management Committee on a quarterly basis.	Exception reporting as soon as practicable.
Tolerance	Tolerable unless otherwise determined by management.	Tolerable unless otherwise determined by management.	Tolerance to be determined by executive general manager.	Tolerance to be determined by CEO / Executive Leadership Team.	Tolerance to be determined by Board.
Risk monitoring	Reporting frequency to be annual.	Reporting frequency as per related business process.	Status to be reported to executive general manager at each business unit management meeting. Reporting frequency to be quarterly.	Status to be reported to each ELT. Reporting frequency to be quarterly	Status reported to each Board meeting. Reporting frequency to be quarterly

Note: "Escalation" refers to the escalation of **risks** (i.e. events that could happen in future) not **incidents** (events that have happened). Escalation of incidents is covered by the *HSE Incident and Investigation Management Procedure (CONTROL0070).*

Figure 10: Power and Water likelihood, risk ranking, actions and reporting matrix.

Appendix 4 – Water quality and estimated dilution Ratio for Yirrkala WwTP

A model-based prediction of Maningrida outfall dilution was undertaken based on the method outlined by Wood, Bell and Wilkinson (1993). The model utilises site parameters such as outfall flowrate, water and wastewater temperature, outfall diameter and depth of ocean above outfall to predict the outfall plume dilution in the vicinity of the discharge point due to buoyancy led mixing.

The following parameter values were used:

Table 6: Basis for estimating outfall dilution

Parameters		Minimum	Maximum	Unit
Depth of Ocean Above Outfall[1]	z	1.5	4.5	m
Outfall Flowrate[2]	Q	0.005	0.01	m^3/s
Wastewater Temperature[3]	T_{wwater}	22	32	ºC
Ocean Temperature[4]	T_{ocean}	23.6	33.1	ºC
Outfall Diameter	d_p	0.219		m

[1] No definitive information of tide heights above outfall pipe are available; limits chosen are considered to be conservative assumptions.

[2] As per estimated average annual flows.

[3] Based on average air temperatures at site.

[4] Based on monthly average sea temperatures provided by Australian Bureau of Meteorology.

As variability occurs in the boundary conditions, a Monte Carlo analysis was used to generate 10,000 sets of random input variables to give the median "most probable" dilution for site (Sweeney 2016). The median dilution ratio calculated for the outfall and receiving environment was 1:4 (Figure 11).

Note that dilution calculated using this method is worst-case scenario. Any tidal flows or currents will increase degree of mixing and dilution. The value of dilution calculated is the dilution that occurs between the outfall and the sea surface.

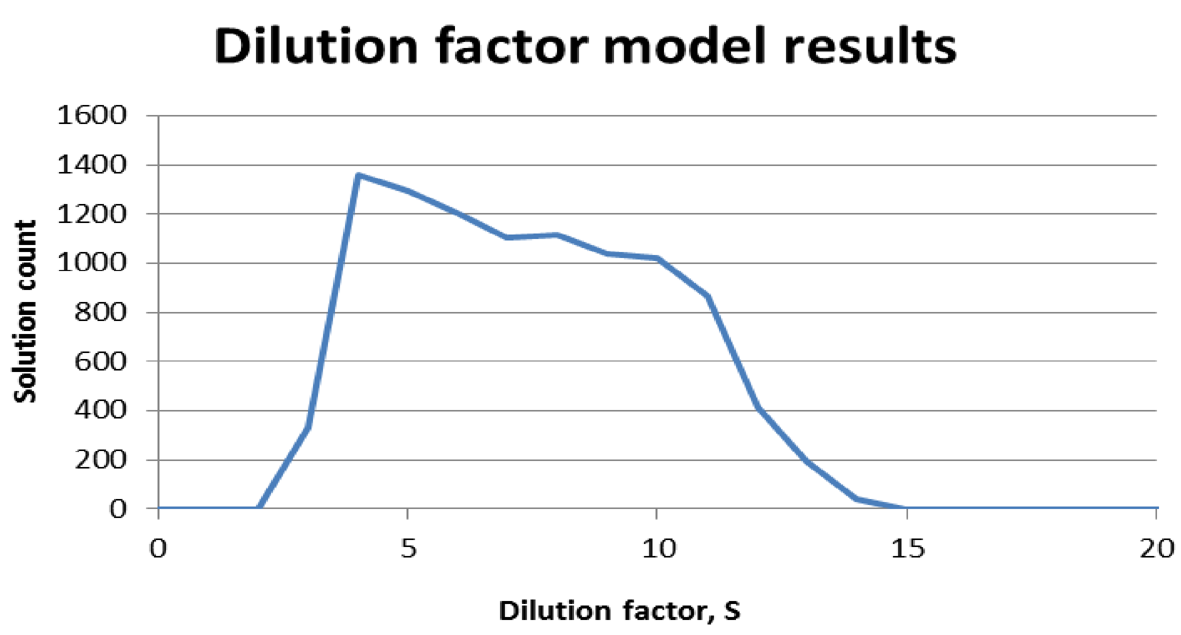

Figure 11: Monte Carlo dilution factor distribution results for Maningrida WwTP and Arafura Sea.

Table 7: Summary of 2023-2024 Maningrida water quality results

Sample Location/Asset: SYI090 (Pond 2 Outlet)	
Indicator	**Median**
Physio-chemical Parameters	
pH (pH units)	7.44
Electrical Conductivity (uS/cm)	330
Dissolved Oxygen (% Saturation)	10
Turbidity (NTU)	3.8
Total Suspended Solids (mg/L)	85
Biological Parameters	
Biochemical Oxygen Demand (mg/L)	30
Chlorophyll-a (ug/L)	481
Nutrient Parameters	
Ammonia (Total as N – NH3-N) (mg/L)	12
Total Nitrogen (mg/L)	23.3
Oxidised Nitrogen (NOx) (mg/L)	0.1
Total Phosphorus (mg/L)	3.8
Pathogen Indicators	
Escherichia coli (CFU/100mL)	13,905
Enterococci (CFU/100mL)	2,720

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