Environmental Risk Assessment

Warruwi Waste Stabilisation Ponds 2023

PowerWater

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Glossary

Abbreviation	Explanation
ANZECC	Australian Water Quality Guidelines for Fresh and Marine Waters
ARMCANZ	Agriculture and Resources Management Council of Australia and New Zealand
Assessment end-points	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.
d	Day
DEPWS	Department of Environment, Parks and Water Security (NT)
DO	Dissolved oxygen
E. coli	*Escherichia coli*
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.
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
N/A	Not applicable
N/C	Normally closed
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
PWC	Power and Water Corporation previously Power and Water Authority (PAWA)
%	Per cent
Risk characterisation	The culmination of the planning, problem formulation and analysis of predicted or observed adverse ecological effects related to the assessment end-points.

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 end-point.
s	Second
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(s)	Waste discharge licence(s)
WwTP(s)	**Wastewater treatment plant(s). 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.**

Note: All abbreviations may not be used in this document

Executive Summary

This environmental risk assessment (ERA) provides an assessment of the risks associated with the discharge of secondary treated effluent from the Warruwi wastewater treatment plant (WwTP) to the 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 ranging from low to high risk. The environmental impacts associated with the very low discharge volumes into a marine environment were rated as low risk, 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.

Introduction

PWC operate the Warruwi WwTP pursuant to Waste Discharge Licence (WDL) 222-02 issued on 14 July 2023. This WDL allows for continuous discharge of secondary treated sewage effluent from an authorised discharge point to Mardbal Bay in the Arafura Sea.

Warruwi is located on South Goulburn Island 3 km north off the West Arnhem Land coast (Figures 2 and 3). Warruwi has a population of 507 in 2021 (BushTel 2023).

Figure 1. Warruwi locality map (Google Earth 2016)

Figure 2. Warruwi site layout including WwTP and outfall location (NT ILIS 2016)

Background

Condition 34 of this WDL requires PWC to update the environmental risk assessment for the Licenced Activity.

Condition 34 of the WDLs specifies that the Environmental Risk Assessment must:

34.1 be conducted in reference to a conceptual site model;
34.2 characterise the impacts of discharge(s) on the relevant Environmental Values;
34.3 inform the development of the Performance Improvement Plan; and
34.4 be submitted to the Administrating Agency at least 60 business days prior to the end date of this licence, with the understanding that the Administrating Agency may require the licensee to revise, amend and/or resubmit the proposed assessment.

Purpose of the ERA

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

Risk Assessment Methodology

The methodology employed has been adapted from ERAs completed by the PWC Water Quality team and the Victorian EPA *Guidelines for Risk Assessment of Wastewater Discharges to Waterways* ('the guidelines') (VIC EPA 2009). The guidelines utilise a framework (Figure 3) consistent with nationally and internationally accepted risk assessment frameworks by the Australian and New Zealand Environment and Conservation Council and Agriculture and Resources Management Council of Australia and New Zealand (2000).

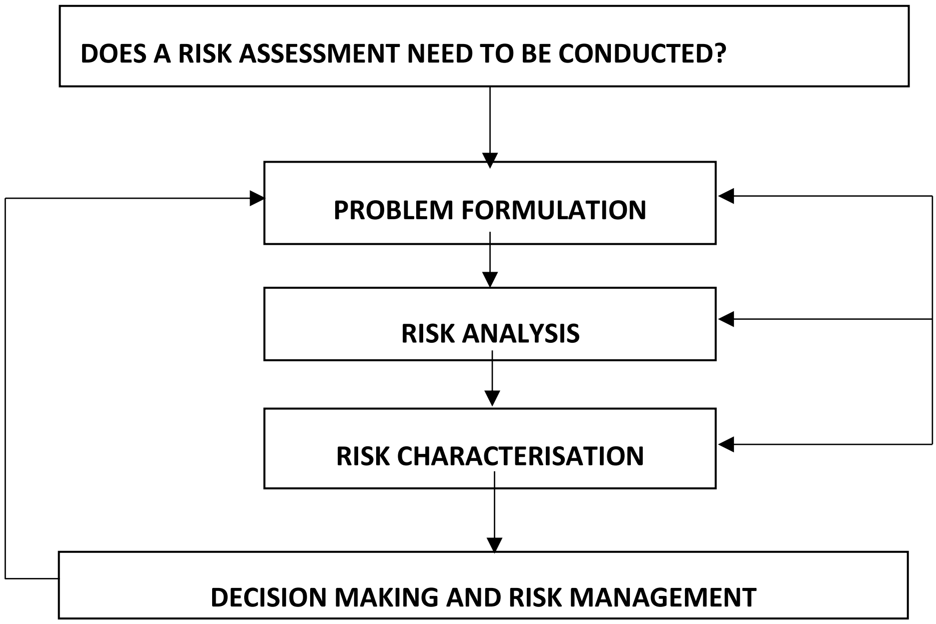

Figure 3: Risk assessment framework for wastewater discharges to waterways (Victoria EPA 2009)

Limitations

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

- limited availability of inflow/outflow data;
- use of estimated inputs used in pond performance modelling;
- 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.

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 end-points representative of those values.

Warruwi 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 Warruwi WwTP utilises waste stabilisation pond technology and 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 WwTP was constructed in 1991 (PWC 2021a) and consists of a primary facultative pond which gravity feeds into a secondary maturation pond.

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. Desludging of remote community ponds is conducted periodically where required to remove accumulated solids and increase hydraulic performance. There are no records available for desludging works conducted at Warruwi; a sludge survey was conducted in 2019.

Prior to 2016, no regular wastewater monitoring was undertaken at the site, with no WDL in place. Regular wastewater monitoring commenced in March 2016, consistent with WDL 222. Samples of the secondary pond outlet are currently collected on a quarterly basis. Monitoring results are included in the *PWC Annual Monitoring Report – Remote Community Waste Discharge Licences,* a summary is provided in Appendix D, Table 8.

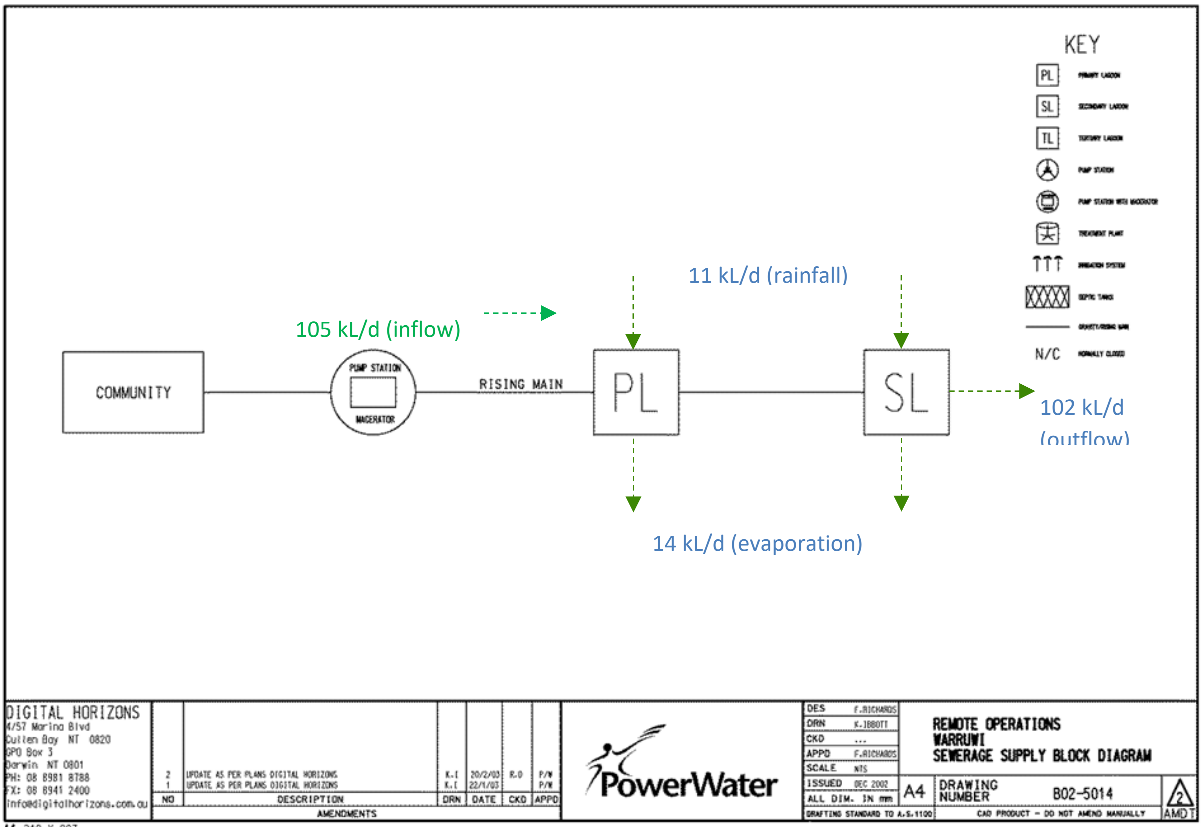

Figure 4. Warruwi wastewater collection and treatment configuration, including logged mean flow (green) and modelled flow (blue) rates.

Discharge Regime

Discharge from the facility occurs from a gravity fed outfall located in the secondary maturation pond to the coastline. Discharge is continuous on an as-required basis (discharge is all year round) and occurs daily directly to the coast (Mardbal Bay). The outfall is approximately 30 m in length from the coastline (135 m total length from ponds) and becomes partially inundated during high tides.

There is currently no flow meter data available at the Warruwi discharge point to determine discharge volumes to the receiving environment. An annual water balance is therefore utilised below.

The annual water balance is estimated based on average inflow, rainfall, evaporation and pond area (**Error! Reference source not found.**, Table 6). Wastewater flow data is measured at the sewer pump station using telemetry with a mean daily inflow of untreated wastewater into the WwTP of 105 kL/day. This is supplemented by an average daily rainfall contribution of 11 kL/d and reduction due to evaporation of 14 kL/d giving the total mean outflow of 102 kL/day.

Note that the volume of treated wastewater discharged to the environment varies seasonally with fluctuations in evaporation and rainfall. During the wet season, it is believed that infiltration of water into the gravity sewer network may occur, however due to the constraints of quantifying this volume and a negligible associated pollutant load it is not included within the flow rate calculations (PWC 2017). Further investigations are required to understand potential for infiltration into the sewer main.

Pond Performance

In the past, a model based prediction of the Warruwi WwTP performance was undertaken by Louey-Gung (2011) utilising industry standard design models. The model utilised various pond parameters to predict treated wastewater quality using mean biochemical oxygen demand (BOD) removal performance and mean predicted *E.coli* disinfection performance. This model was utilised in absence of *in-situ* wastewater monitoring data.

The modelled water quality results at the pond outlet for mean BOD removal and *E.coli* disinfection were 76.8 mg/L (62% removal) and 37,420/100 mL (2.2 log removal) respectively (modelled data used as pond performance indicator only).

Since 2020, Power and Water implemented monthly wastewater monitoring of the WwTP discharge, which provides a characterisation of the treated effluent discharged to the receiving environment. To date, the mean *in-situ* water quality results for BOD and *E. coli* were 24 mg/L and 17,650/100mL respectively; which are relatively consistent with modelled water quality results utilised to assess pond performance. Additional monitoring at the primary pond inlet is required to verify pond performance.

Power and Water have increased wastewater monitoring at a number of remote communities in 2020, however inlet monitoring has yet to be conducted at Warruwi WwTP due to restricted funding under Indigenous Essential Services (IES). For the purpose of this risk assessment, *in-situ* monitoring data is illustrated on the conceptual site model (CSM) (Appendix A, Figure 10).

Receiving Environment

Mardbal Bay is a bay of the Arafura Sea and is situated along the east coast of South Goulburn Island. The receiving environment consists of weathered rock and is moderately vegetated with seaward mangrove assemblages. Mardbal Bay tides are semi-diurnal and have a mean spring and neap tidal range of 4.91 m (BOM 2016). Images of the receiving environment are below (Figure 5, Figure 6, Figure 7).

The environment is considered to have experienced minor disturbance (PWC 2010) due to fishing, shellfish harvesting and middens known to the area. The bay also has a number of non-point sources including various creek inlets and run off from a nearby waste facility and market garden (**Error! Reference source not found.**). A warning sign has been erected at the discharge point to notify the community of risks from effluent disposal within the area (Figure 8).

There is also an increasing interest in aquaculture activities on the island with research and farm trials in progress for the growing and harvesting of seafood and aquarium species for local enterprises within the community as well as commercial export (Fleming *et. al.* 2015). The species of interest include tropical blacklip (*Saccostrea mytiloides*) and milky (*Saccostrea ordax*) oysters, trepang (sea cucumbers) and giant clams (*Tridacna squamosal*) (Petheram *et. al*. 2013).

Figure 5. Warruwi WwTP ocean outfall at low tide (PWC 2016)

Figure 6. Warruwi WwTP ocean outfall at high tide (PWC 2016)

Figure 7. Warruwi WwTP ocean outfall (PWC 2021)

Figure 8. Discharge point warning signage installed by ESO (PWC 2020)

The receiving environment contains 20 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 within South Goulburn Island.

Common name	Species name	National Status (EPBC)	NT Status (TPWC)
Red Goshawk	*Erythrotriorchis radiatus*	VU	VU
Lesser Sand Plover	*Charadrius mongolus*	EN	VU
Greater Sand Plover	*Charadrius leschenaultii*	VU	VU
Bar-tailed Godwit	*Limosa lapponica*	-	VU
Eastern Curlew	*Numenius madagascariensis*	-	VU
Great Knot	*Calidris tenuirostris*	-	VU
Red Knot	*Calidris canutus*	EN	VU
Curlew Sandpiper	*Calidris ferruginea*	-	VU
Water Mouse	*Xeromys myoides*	VU	-
Merten's Water Monitor	*Varanus mertensi*	-	VU
Yellow-spotted Monitor	*Varanus panoptes*	-	VU
Flatback Turtle	*Natator depressus*	VU	-
Loggerhead Turtle	*Caretta caretta*	EN	-
Green Turtle	*Chelonia mydas*	VU	-
Hawksbill Turtle	*Eretmochelys imbricata*	VU	-
Olive Ridley Turtle	*Lepidochelys olivacea*	EN	VU
Leatherback Turtle	*Dermochelys coriacea*	EN	-
Dwarf Sawfish	*Pristis clavata*	VU	-
Largetooth Sawfish	*Pristis pristis*	VU	-
Whale Shark	*Rhincodon typus*	VU	-
CR – Critically Endangered, EN – Endangered, VU – Vulnerable			

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 3provides a summary of the screening level risk assessment.

Risk hypotheses for the stressors identified in the conceptual site model (CSM) (**Error! Reference source not found.**, Figure 10) 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 Warruwi WwTP

Values	Receptors	
Cultural	Humans	Fishing Shellfish farming/harvesting Swimming/wading Camping Visible water quality
Aquaculture	Marine	Giant clam Shellfish Sea cucumber
Environment	Marine	Fish Dugongs Turtles Mud crabs Crocodiles
	Terrestrial	Shore birds Horses
	Plants	Mangroves Eucalyptus

Table 3: Screening level risk assessment for key indicators and stressors associated with Warruwi 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[1]	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.		Mangroves are at the interface of terrestrial and marine environments and can tolerate freshwater inputs (PWC 2015a, PWC 2015b). While the impact on less tolerant species is considered possible, the significance of this is considered low with respect to discharge volumes and other stressors. No further investigation necessary at this stage.	No
Organic matter	Increase in BOD, decrease in DO[1]	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 Warruwi WwTP is 24 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[1]	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 discolouration 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[1]	That free ammonia is resulting in toxicity to aquatic organisms in water and sediments.		To maintain the presence of biota in the environment.		The average concentration of free ammonia in the discharge of Warruwi WwTP is 7 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*[1]		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 including activities associated with aquaculture and consumption of shellfish.	The median pathogen concentration in the discharge of Warruwi WwTP is 17,650/100mL. At a screening level it is determined that a risk is present and further investigation is necessary.	Yes

Risk Analysis and Characterisation

Power and Water Risk Management Framework

PWC has adopted a qualitative risk assessment methodology aligned to the Australia/New Zealand Standard *“AS/NZ 4360: Risk Management”* (PWC 2009). 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 end-point identified in the screening level risk assessment as seen in **Error! Reference source not found.**.

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 Table 4. and the likelihood of an event occurring are shown in Table 5. A risk score for each potential impact is determined by combining likelihood with consequence results as seen in Figure 9.

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

Table 4. PWC corporate risk ranking consequence table

	Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Severe (5)
Health & Safety	Minor event with or without injury; and/or No on-going impact to health.	Injuries requiring first aid treatment; and/or Minor short term inconvenience.	Medical Treated injury; and/or Short term reversible disabling effect to human health; and/or Lost Time Injury <1 week lost.	Hospitalisation; and/or Injuries resulting in Lost Time Injury > 1 week lost; and/or Long term (chronic) chemical health exceedance or short term chemical exceedance of chemical with acute health impacts; and/or Long term aesthetic exceedance with health impact on supply.	One or more fatalities; and/or One or more persons seriously injured (includes long term disabling effect); and/or Widespread release of untreated water (eg due to disinfection failure).
Financial **(impact on EBITDA)**	Loss less than $500K.	Impact between $500K and $2M.	Impact between $2m and $10m.	Impact between $10m and $40m.	Impact greater than $40m.
Legal/ Regulation	Legal issues managed by corporate procedures or practices; and/or Breach of internal policies or procedures without the need for formal investigation.	Matter requires legal advice to address issues; and/or Internal breach of policies or procedures requiring a formal investigation.	Required to operate under limited regulatory restrictions or orders; and/or Incident which requires legal representation resulting in court proceeding.	Required to operate under significant regulatory restrictions or orders; and/or Government inquiry/ intervention.	Criminal charges / civil litigation against the Corporation and/or Officers; and/or Operating licences revoked.
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.
Service Delivery (external customers only)	Category 1 loss of service (refer to Appendix C of this document)	Category 2 loss of service (refer to Appendix C of this document)	Category 3 loss of service (refer to Appendix C of this document)	Category 4 loss of service (refer to Appendix C of this document)	Category 5 loss of service (refer to Appendix C of this document)
Reputation	No media attention; and/or Isolated community or individual issue-based concern; and/or Localised dissatisfaction which is managed by normal business processes; and/or Short term aesthetic exceedance.	Occasional once-off negative media attention; and/or Localised community impacts and customer concerns; and/or Localised staff dissatisfaction which requires Human Resources in resolution; and/or Long term aesthetic exceedance.	Brief adverse media attention and/or community/customer condemnation (days); and/or Limited, localized loss of confidence by the community; and/or Localised staff dissatisfaction with localised impacts to service deliver and/or Short term chemical health exceedance.	Prolonged adverse media attention and/or community/ customer condemnation (weeks); and/or Prolonged, widespread community/ customer loss of confidence (weeks); and/or Widespread dissatisfaction and loss of confidence by staff resulting in temporary service delivery issues.	Sustained adverse media attention and/or community/customer condemnation (months); and/or Irreconcilable community/ customer loss of confidence; and/or Loss of stakeholder confidence in Board and/or Management; and/or Widespread dissatisfaction by staff resulting in sustained service delivery issues.

Table 5. PWC corporate risk ranking likelihood table

(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%

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

Figure 9. Corporate risk matrix

Hypothesis	Consequence		Likelihood		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 (ANZECC 2000). The estimated dilution volume ratio between the effluent and receiving environment is 1:2 (Appendix C). Based on the receiving environment being a tidal ocean environment, dilution and tidal mixing within the immediate discharge point suggests oxygen demand would be absorbed by the environment.	Minor	Based on sampling data to date, Warruwi WwTP BOD discharge water quality is 24 mg/L. These BOD concentrations are relatively consistent in comparison to concentrations at other remote communities, these values are considered to be classified as low effluent strength (<40mg/L) (PWC 2022). Stressor not typically observed with such small discharge volumes, initial high dilution, and large surface area available for reaeration and 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 (PWC 2015a). No fish kills reported to date.	Minor	Warruwi WwTP free ammonia discharge quality is 9.9 mg/L. These ammonia concentrations are low in comparison to concentrations at other remote communities (PWC 2022). Low pH may also be an indicator of increased ammonia toxicity (ANZECC 2000); a mean pH of 7.43 at Warruwi suggests the risk of ammonia toxicity to be low Stressor not typically observed with such small discharge volumes, initial high dilution, and efficient coastal flushing (Fernando 2012). PWC 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 **WDL sampling to date, Warruwi WwTP contributes 0.685 and 0.15 tonnes/year of total nitrogen and phosphorus respectively.** The effects of most ocean discharges are statistically insignificant when compared to total loads in the ocean (ARMCANZ and ANZECC, 2000). **Naturally occurring bloom events of predominately *Trichodesmium erythraeum*** are known to occur in **the region every year between September and November due to increased water temperatures,** so presumably biota are exposed to this naturally. It is not known whether this source may contribute to the naturally occurring phytoplankton biomass either through direct inputs of phytoplankton contained in the effluent or through nutrient stimulation of in-situ biomass (PWC 2015a).	Minor	Total nitrogen (18.4 mg/L) and total phosphorus (4 mg/L) concentrations are relatively consistent in comparison to concentrations at other remote communities, and is considered to be classified as low effluent strength (<50mg/L;<10mg/L) (PWC 2022). PWC considers that the likelihood of nuisance plant growth in the receiving environment is unlikely due to low levels of TN and TP and ocean flushing. However due to observations of naturally occurring bloom events the likelihood is possible. Ongoing sampling and inspections will assist to characterise discharge quality.	Possible	Low
Cultural					
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 with the immediate discharge site readily accessible by the public during low tide.	Minor	No odours have been observed or reported at the ocean outfall (PWC 2021b), with any odours being limited to immediate discharge point. Stressor not typically observed with initial high dilution and efficient coastal flushing. Likelihood greater during low tide where there are short-term flushing constraints however unlikely to be sustained long term; discharge pipe is considerable distance out from the shoreline. PWC considers that the likelihood of reduction in amenity from BOD is unlikely.	Unlikely	Low
Nutrients are resulting in **toxic blooms** that are a public health	The coastline is identified as having cultural beneficial uses for primary and secondary recreation including exposure of children through exploratory wading. Ingestion of marine	Moderate	Based on the primary and secondary contact recreation and cultural uses of the coastline, and observed algal blooms within the localised area, PWC considers that the likelihood of toxicant	Possible	Medium

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risk; and **blooms of toxin producing species** whereby the toxins bio-accumulate in shellfish and fish ingested by humans.	species such as oysters, mud crab, turtle, dugong, crayfish, stingray, mud mussels, pipis, giant clams, barramundi and other fish are known to occur within the area (Petheram *et al*. 2013).		exposure is possible. Ongoing sampling will assist to characterise discharge quality. Further investigations are required to determine extent.		
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 with the immediate discharge site readily accessible by the public during low tide.	Minor	Recently no indicators have been present that suggest reduction of amenity as a result of the discharge - water clarity is clear, no odours present, healthy aquatic organisms and native vegetation present surrounding the receiving waters (PWC 2021b). PWC considers that the likelihood of reduction in amenity from nutrients is possible during low tide.	Possible	Medium
Pathogens are leading to the **contamination of water** resulting in primary and secondary contact recreational a public health risk.	The coastline is identified as having cultural beneficial uses for primary and secondary recreation including exposure of children through exploratory wading. Immediate discharge site is readily accessible by the public during low tide.	Major	Median pathogen concentrations of 17,650 mpn/100mL *E. coli* within the Warruwi WwTP discharge are medium in comparison to concentrations at other remote communities (PWC 2022). Based on the secondary contact recreation and cultural uses of the coastline, PWC considers that the likelihood of the illness from pathogen exposure is possible. Assigned likelihood is worst-case scenario based on exposure to humans and limited localised pathogen data.	Possible	High
Pathogens are leading to **accumulation in shellfish** resulting in the consumption of shellfish a public health risk.	Collection and consumption of shellfish such as oysters, mud mussels, pipis and giant clams are known to occur within the area (PWC 2021b; *Petheram et al*. 2013).	Major	Based on the cultural uses of the coastline, PWC considers that the likelihood of the illness from pathogen exposure through the consumption of shellfish is possible. Assigned likelihood is worst-case scenario based on exposure to humans and limited localised pathogen data.	Possible	High

Summary and recommendations

The ERA found that the identified values of the Woods Inlet at risk from the Warruwi 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 Warruwi WwTP poses a low to high risk to the identified values of the receiving waterway. The influence of the discharge on the receiving environment is considered sustainable. 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, PWC make the following recommendations:

- continue monitoring quality of wastewater discharged to the environment;
- 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.

References

BushTel (2023), BushTel - Warruwi Profile, accessed 18/04/2023, <https://bushtel.nt.gov.au/profile/429>

Department of Housing and Community Development (DHCD). (2017). (Adjusted figures for 2021 – D2020/567238). Indigenous Community Engineering Guidelines. Northern Territory Government, Darwin.

EPA Victoria. (2009). Guidelines for Risk Assessment of Wastewater Discharges to Waterways, Publication Number 1287, Environment Protection Authority, Melbourne.

Fernando, H.J. (2013). Handbook of Environmental Fluid Dynamics, Volume Two: Systems, Pollution, Modelling and Measurements.

Fleming, A., Gibb, K, Campbell, D., Munksgaard, N., Fortune, J., Kaestli M. and Birch, A. (2015), *Assessment of heavy metals in tropical rock oysters (blacklip and milky) and implications for placement into the Australian seafood market and for Indigenous enterprise development in the NT*. FRDC Project No. 2013/223, Canberra, Australia, CC BY 3.0

Louey-Gung, J. (2011). Remote Operations Waste Stabilisation Pond Performance Evaluation Modelling (D2011/73466). Power and Water Corporation, Darwin.

Petheram, L., Fleming, A., Stacey, N & Perry, A. (2013). Indigenous women's preferences for climate change adaptation and aquaculture development to build capacity in the Northern Territory, National Climate Change Adaptation Research Facility, Gold Coast.

PWC (2022), WDL Monitoring Report for Remote Communities (D2022/99769), Power and Water Corporation, Darwin

PWC. (2021a). Sewage Treatment Summary. (D2018/352304). Power and Water Corporation, Darwin.

PWC. (2021b). Observations from Site Inspection by Essential Service Operator, conducted 07 April 2021.

PWC. (2020). Monitoring Report 2020 – Remote Community Waste Discharge Licences. (D2020/268887). Power and Water Corporation, Darwin.

PWC. (2015a). Desktop environmental risk assessment for the discharge of treated effluent from the Berrimah wastewater treatment plant to Bleesers Creek (D2013/331809). Power and Water Corporation, Darwin.

PWC. (2015b). Desktop environmental risk assessment for the discharge of treated effluent from the Palmerston wastewater treatment plant to Myrmidon Creek (D2013/476393). Power and Water Corporation, Darwin.

PWC. (2010). PWC Sewer Pond Discharge Assessment. (D2010/49573). Power and Water Corporation, Darwin.

PWC. (2009). Risk Management Foundation Document – Risk Management Guidelines. (QDOC2009/191). Power and Water Corporation, Darwin.

Sweeney, D. (2016). Remote Operations WDL Risk Assessment Outfall Dilution Model. (D2016/341702). Power and Water Corporation, Darwin.

Wood, I., Bell, R. & Wilkinson, D. (1993). Ocean Disposal of Wastewater. World Scientific Publishing, Singapore.

Appendix A: Warruwi conceptual site model

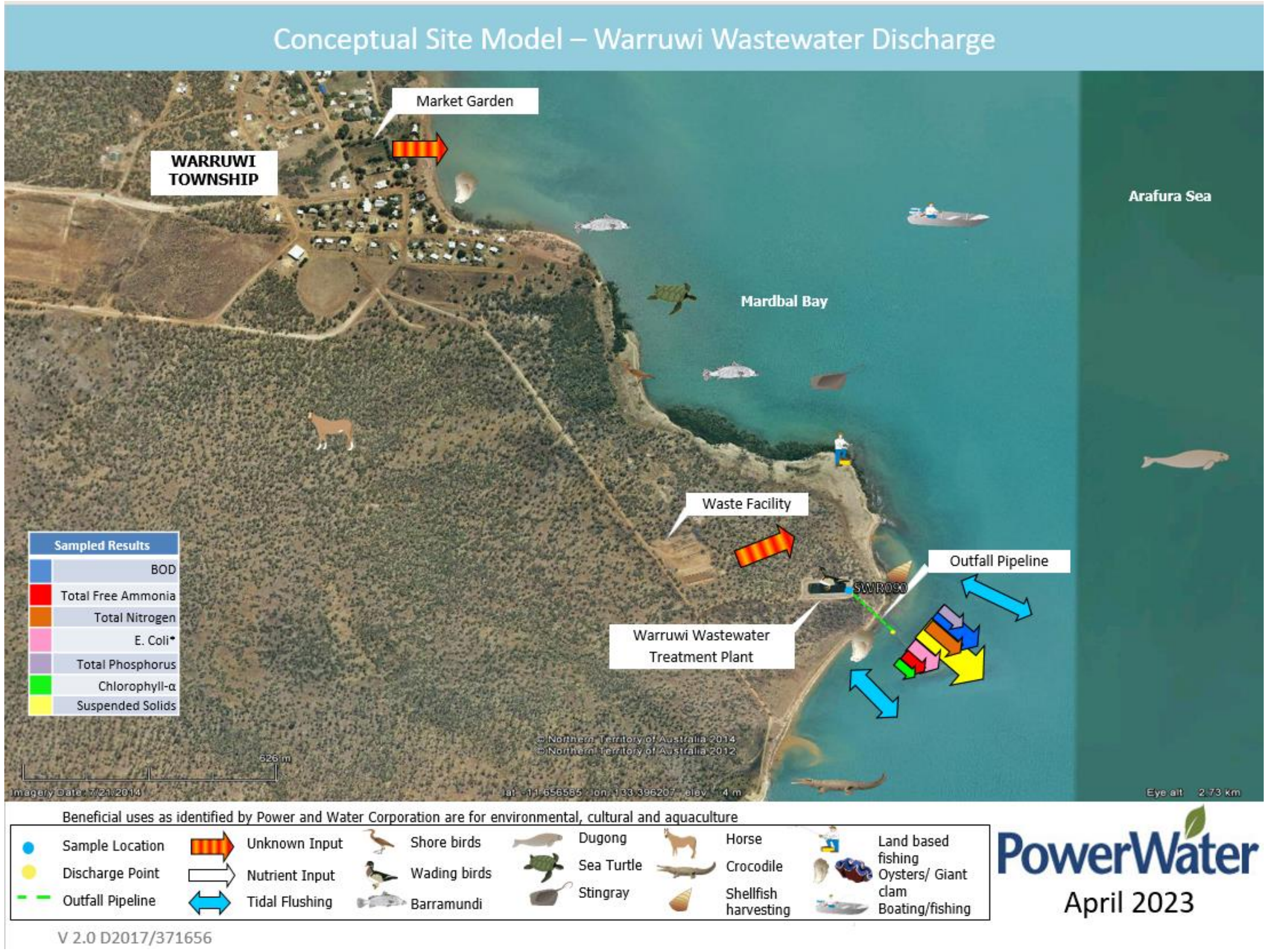

Figure 10: Conceptual site model for the Warruwi WwTP

Appendix B – Estimated flowrates for Warruwi WwTP

Assumptions:

Using the IGEC value of 850L/s/ET to estimate the inflow at an estimated ET of 124.

Rainfall catchment estimates are based on mean monthly rainfall for all available years from Bureau of Meteorology (BOM) and total pond surface area (2,351 m^2) (PWC 2021a). Rainfall data was obtained using the Warruwi Airport weather station (station number 014238) located 2.5 km away.

Evaporation estimates are based on mean monthly evaporation for all available years from BOM and total pond surface. Evaporation data was not available from the Warruwi Airport weather station therefore data modelled data was used (Louey-Gung 2011).

Flow rates are summarised in the table below (Table 7).

Table 6. Estimated average annual flows

Month	Inflow kL/d	Rainfall kL/d	Evaporation kL/d	Total outflow kL/d
January	105	22	14	113
February	105	35	14	126
March	105	14	14	105
April	105	8	14	99
May	105	0	14	91
June	105	0	14	91
July	105	1	14	92
August	105	0	14	91
September	105	7	14	98
October	105	5	14	96
November	105	10	14	101
December	105	32	14	123
Mean	**105**	**11**	**14**	**102**

Appendix A: Estimated minimum dilution ratio for Warruwi WwTP and Arafura Sea

A model based prediction of Warruwi outfall dilution was undertaken based on the method outlined by Wood, Robert, Wilkinson (1993). The model utilises various pond parameters such as outfall flowrate, water and wastewater temperature, outfall diameter and depth of ocean above outfall to predict the outfall dilution values.

The following parameter values were used:

Table 7: Parameters used for Warruwi WwTP discharge dilution ratio

Parameters		Minimum	Maximum	Unit
Depth of Ocean Above Outfall	z	0	3	m
Outfall Flowrate	Q	0.0024	0.0027	m^3/s
Wastewater Temperature	T_{wwater}	25	35	ºC
Ocean Temperature	T_{ocean}	23.6	33.1	ºC
Outfall Diameter	d_p	0.15		m

As boundary conditions for the site vary throughout the range, 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 modelled dilution result for the outfall and receiving environment was 1:2.

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.

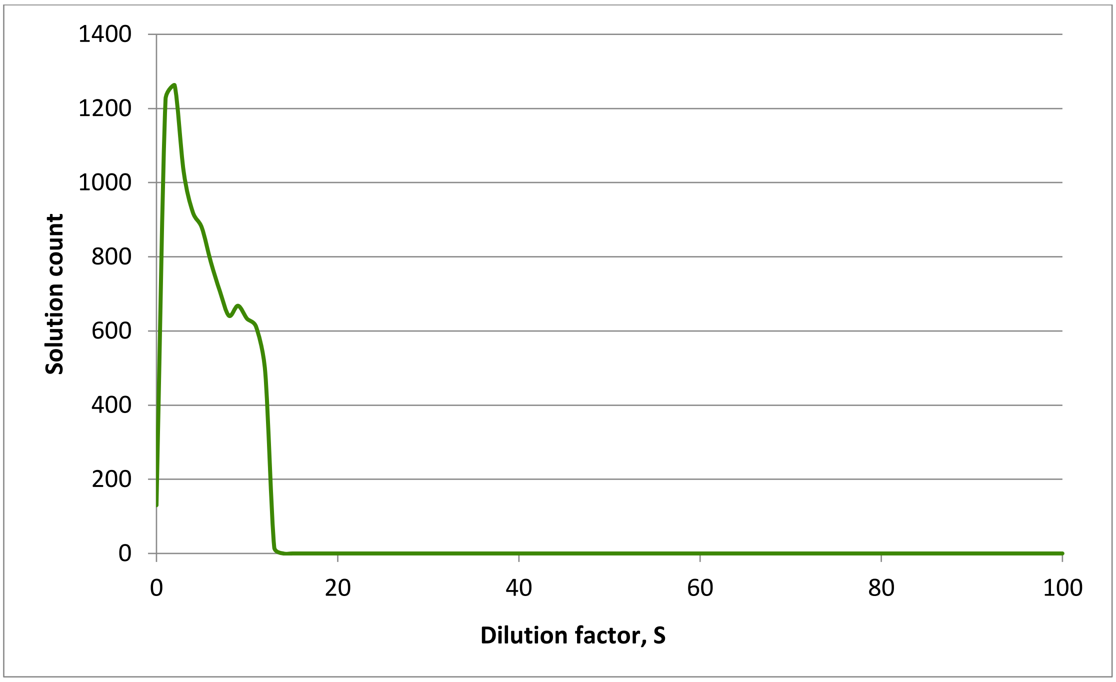

Figure 11. Monte Carlo analysis for Warruwi WwTP and Arafura Sea dilution ratio distribution

Appendix B: Wastewater Quality Monitoring Results

Table 8: Summary of PWC wastewater quality results for Warruwi WwTP 2020-2023

Sample Location/Asset: SWR090 (Pond 2 Outlet)			
Indicator	**Reporting Value**		
	Median Wet Season	**Median Dry Season**	**Median**
Physio-chemical Parameters			
pH	7.37	7.46	7.43
Electrical Conductivity (uS/cm)	645	670	670
Dissolved Oxygen (% Saturation)	11.5	5	11
Turbidity (NTU)	42	81	47
Total Suspended Solids (mg/L)	53	95	70
Biological Parameters			
Biochemical Oxygen Demand (mg/L)	17.5	28	24
Chlorophyll-a (ug/L)	493	1170	864
Nutrient Parameters			
Ammonia (Total[1] as N – NH3-N) (mg/L)	6.65	12	7
Total Nitrogen[2] (mg/L)	15.65	23.8	18.4
Oxidised Nitrogen (NOx)	0.05	0.05	0.05
Total Phosphorus (mg/L)	3.4	5	4
Pathogen Indicators			
Escherichia coli (E. coli/100mL)	10,460	29,090	17,650
Enterococci (Enterococci/100mL)	310	310	310

[1]Calculated as NH3-N Free

[2]Calculated NH3-N Organic + NH3-N Free + NOx

Appendix E: Additional Site Inspection Images

Figure 12. Warruwi WwTP Pond 1 (PWC 2021)

Figure 13. Warruwi WwTP Pond 1 (left) and Pond 2 (right) (PWC 2021)

Figure 14. Wastewater sampling conducted by the ESO (PWC 2021)

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