Environmental Risk Assessment

Numbulwar Waste Stabilisation Ponds 2023

PowerWater

Document History

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Executive Summary

This desktop Environmental Risk Assessment (ERA) provides an assessment of the risks associated with the discharge of secondary treated effluent from the Numbulwar Wastewater Treatment Plant (WwTP) to estuary waters within Rose River (Gulf of Carpentaria).

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 medium risk rankings. The environmental impacts associated with the very low discharge volumes into a tidal estuary 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 Numbulwar WwTP pursuant to Waste Discharge Licence (WDL) 218-01 issued on 9 July 2019. This WDL allows for continuous discharge of secondary treated sewage effluent from an authorised discharge point to estuary waters within Rose River (Gulf of Carpentaria).

Numbulwar is located along the eastern coast of the Northern Territory, south-west of Groote Island, approximately 783 km south-east of Darwin (Figure 1). Numbulwar has an estimated population of 884 in 2021 (DHCD 2017). The Wastewater Treatment Plant (WwTP) is located approximately 1.3 km south-west of the Numbulwar Township (Figure 2).

Figure 1. Numbulwar locality map (Google Earth 2017)

Figure 2. Numbulwar site layout including WwTP and outfall location (NT ILIS 2017)

Background

Condition 34 of this WDL requires PWC to update the environmental risk assessment for the Licenced Activity. This condition specifies the ERA 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 Administering Agency at least 60 days prior to the end date of this licence with the understanding that the Administering Agency may require the licensee to revise amend and/or resubmit the proposed assessment.

Objectives

The objectives of this ERA are to:

1. Characterise environmental risks associated with the activity
2. Identify potential risks
3. Determine if risks are changing due to improvements/reduction of discharge quality
4. Use the results to identify opportunities for improvement, if warranted

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).

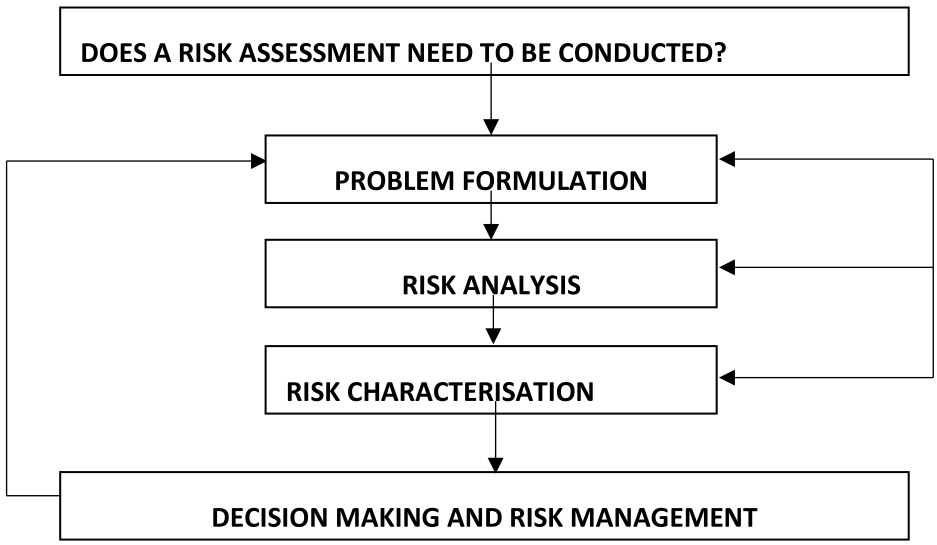

Figure 3. Risk assessment framework for wastewater discharges to waterways (Victoria EPA 2009)

Limitations

The following variables have been identified as limitations associate with the preparation of this ERA:

- Limited availability of inflow & outflow data,
- Use of estimated inputs in pond performance modelling,
- Remoteness of communities impacting on the ability to understand systems due to costs, logistics and locally available expertise; and
- Limited access to pond discharge points and surrounding environment due to climatic, safety and geographic factors

Problem Identification

Numbulwar Wastewater Treatment Plant

The community utilises a pressure fed sewer reticulation system which pumps raw sewage from the community to the WwTP (**Error! Reference source not found.**). The Numbulwar WwTP utilises waste stabilisation pond technology 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 1981 (PWC 2021a), and consist of a primary facultative pond which gravity feeds into a secondary maturation pond before being discharged offsite.

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 the WSPs is conducted where required to remove accumulated solids and increase hydraulic performance, which may result in improved treatment performance. Desludging was most recently completed at Numbulwar in 2017.

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 218. Samples of the secondary maturation 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, **Error! Reference source not found.**.

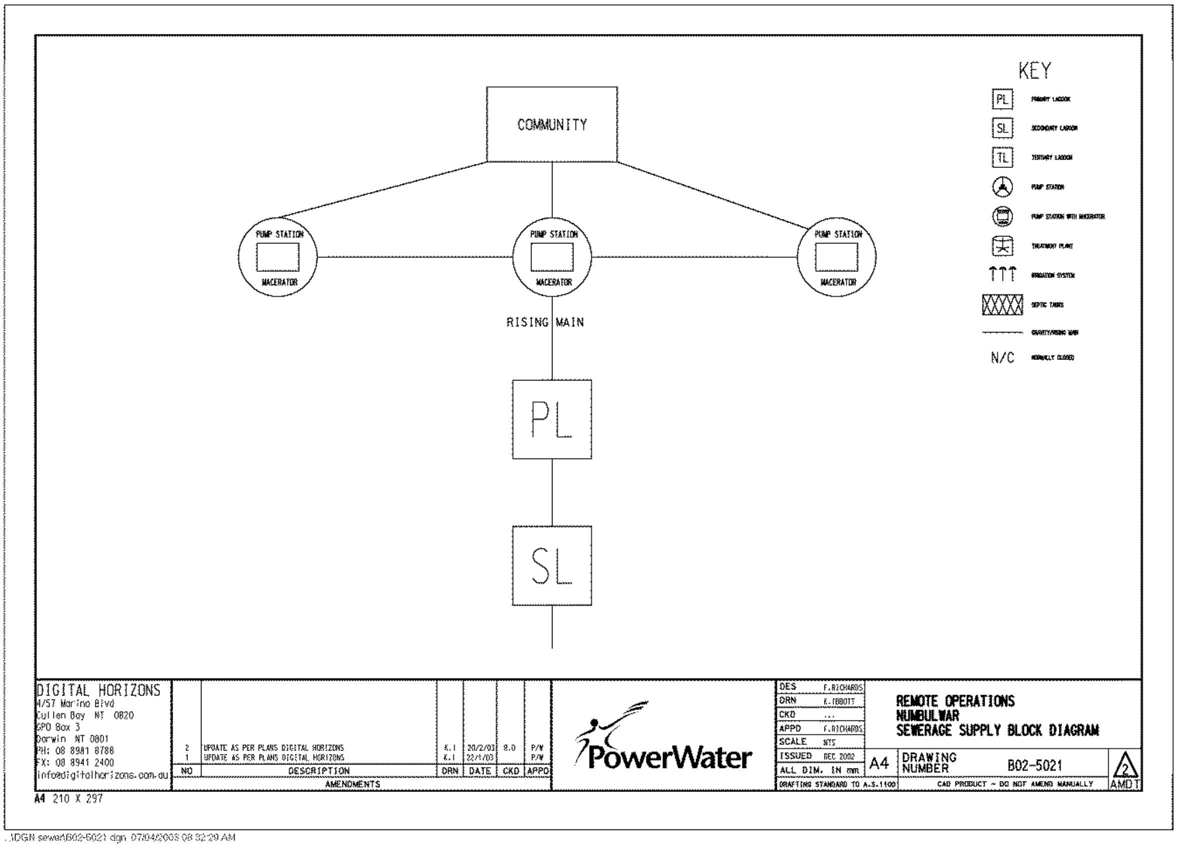

Figure 4: Numbulwar wastewater collection and treatment configuration including modelled flow rates (blue)

Discharge Regime

Discharge from the facility occurs from a gravity fed discharge pipe located in the secondary maturation pond (**Error! Reference source not found.**). Discharge is continuous on an as-required basis (discharge is all year round) and occurs onto land within a low-lying tidal mangrove area before draining to the Rose River, approximately 50m away. The discharge outfall pipe from the secondary maturation pond is approximately 600 m in length, north-west of the ponds (**Error! Reference source not found.**).

The annual water balance is estimated based on forecast sewage Equivalent Tenement (ET) flow, estimated total sewer ET, rainfall, evaporation and pond area (Appendix B, Table 8). It is estimated that the mean daily inflow of untreated wastewater into the WwTP is 194 kL/day. This is supplemented by an approximate rainfall contribution of 27 kL/d and reduction due to evaporation of 39 kL/d to give the mean measured outflow of 182 kL/day. Due to the small community population (884), Numbulwar has relatively low discharge volume in comparison to other NT wastewater facilities in major centres (PWC 2015b).

Note that the volume of treated wastewater discharged to the environment varies seasonally with changes in evaporation and rainfall.

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.

In the past, a model based prediction of the Numbulwar 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 93.2 mg/L (53% removal) and 30,689/100 mL (2.3 log removal) respectively (modelled data used as pond performance indicator only).

In 2016, Power and Water implemented regular biannual wastewater monitoring of the WwTP discharge, which provides a characterisation of the treated effluent discharged to the receiving environment. Monitoring is now being conducted on a quarterly basis as per the conditions specified in the licence (sampling results are included in Appendix D, **Error! Reference source not found.**).

The median *in-situ* water quality results for BOD and *E. coli* were 31.5 mg/L and 17,825 cfu/100mL respectively; which are relatively consistent with modelled water quality results utilised to assess pond performance.

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 in this context.

Power and Water have increased wastewater monitoring at a number of remote communities in 2020, however inlet monitoring has yet to be conducted at Numbulwar WwTP due to restricted funding under Indigenous Essential Services (IES). For the purpose of this risk assessment, both sets of data are illustrated on the conceptual site model (CSM) (Appendix A, **Error! Reference source not found.**).

Receiving Environment

The receiving environment consists of a tidal mangrove forest community that covers most sections of the Rose River banks (Figure 5); the receiving area drains into a tidal estuary channel about 50 m from the discharge pipe (Figure 6) (PWC 2017). The outer section of the estuary is approximately 2 km downstream from the discharge point area in the river. Mangrove vegetation is dominated by *Sonneratia alba* (Mangrove apple) and *Rhizophora stylosa* (Stilt rooted mangrove) species. Shellfish were observed within the discharge waters during an inspection (PWC 2017).

Visual observations during a recent site visit in 2021 at the Numbulwar WwTP discharge point indicate no significant changes to mangrove vegetation over time (PWC 2021b) Figure 7, Figure 8). Water clarity within the discharge area was green consistent with pond water, however recent tidal flushing was apparent, with aquatic macroinvertebrates and fish species observed within the deeper sections near the outlet.

The receiving environment is considered to have experienced minor disturbance due to the lack of vehicle tracks and recreational use of the area (PWC 2017, 2010). During the ERA inspection a track to the outfall location was difficult to determine through vegetation, however a track to the site can easily be seen on Google Earth images. This is not an area which is commonly used by local community members for recreation (PWC 2021b).

Figure 5: Final discharge point (PWC 2017)

Figure 6: Tidal estuary channel into Rose River (PWC 2017)

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Figure 7: Final discharge point (PWC 2021)

Figure 8: Healthy mangroves observed at immediate discharge point (PWC 2021)

Receptor identification

The receiving environment is located within the South-East Arnhem Land Aboriginal Protected Area. The area contains 17 threatened animal 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 at risk species in the Numbulwar WwTP recieving environment

Common Name	Species Name	National Status (EPBC)	NT Status (TWPC)
Vertebrates			
Partridge Pigeon	*Geophaps smithii*	VU	Vulnerable
Gouldian Finch	*Erythrura gouldiae*	Endangered	Vulnerable
Lesser Sand Plover	*Charadrius mongolus*	Endangered	Vulnerable
Greater Sand Plover	*Charadrius leschenaultia*	Vulnerable	Vulnerable
Bar-tailed Godwit	*Limosa lapponica*	-	VU
Eastern Curlew	*Numenius madagascariensis*	DD	VU

Great Knot	*Calidris tenuirostris*	DD	VU
Red Knot	*Calidrus canutus*	EN	VU
Curlew Sandpiper	*Calidris ferruginea*	DD	VU
Masked Owl (northern mainland)	*Tyto novaehollandiae kimberli*	VU	VU
Bare-rumped Sheathtailed Bat	*Saccolaimus saccolaimus*	CR	-
Northern Hoppingmouse	*Notomys aquilo*	VU	VU
Pale Field-rat	*Rattus tunneyi*	-	VU
Flatback Turtle	*Natator depressus*	VU	DD
Green Turtle	*Chelonia mydas*	VU	LC
Hawksbill Turtle	*Eretmochelys imbricata*	VU	DD
Olive Ridley Turtle	*Lepidochelys olivacea*	EN	DD

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. **Error! Reference source not found.** provides a summary of the screening level risk assessment.

Risk hypotheses for the stressors identified in the conceptual site model (CSM) (Appendix A, **Error! Reference source not found.**) are defined with respect to their potential effects on the identified beneficial uses of the receiving environment.

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

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

Values	Receptors	
Cultural (Recreational Water Quality)	Humans	Fishing (offshore)
Cultural (Aesthetics)	Humans	Visible water quality Sacred sites
Environment (Aquatic Ecosystem Protection)	Aquatic	Fish Turtles

		Dugongs Dolphins Macro-invertebrates (mud crabs) Crocodiles
	Terrestrial	Wading Birds Shorebirds Seabirds Invertebrates (water insects) Mammals Reptiles
	Plant	Native vegetation • Mangroves

Table 3: Screening level risk assessment from key indicators and stressors associated with Numbulwar 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 accumulation during monitoring of discharge site (qualitative discharge criteria). 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 average concentration of BOD in the discharge of Numbulwar WwTP is 31.5 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 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 the 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 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 sediments.		To maintain the presence of biota in the environment		The average concentration of free ammonia in the discharge of Numbulwar WwTP is 4.3 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 Numbulwar WwTP is 17,825 mpn /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 Table 3: Screening level risk assessment from key indicators and stressors associated with Numbulwar WwTP discharge.

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: PWC corporate risk ranking consequence table and the likelihood of an event occurring are shown in Table 5: PWC corporate risk ranking likelihood table. A risk score for each potential impact is determined by combining likelihood with consequence results as seen in Table 6: PWC corporate risk matrix.

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

Likelihood		
(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%

Table 6: PWC corporate risk matrix

Likelihood	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

Risk Assessment for key indicators and stressors identified in screening level assessment

Table 7: Risk assessment for key environmental and cultural assessment end points associated with Numbulwar WwTP discharge using corporate risk ranking methodology

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 of the wastewater would be tidal (daily) within the mangrove forest area and then substantial dilution and mixing would occur within the Rose River estuary. The estimated dilution volume ratio between the effluent and receiving environment is >1:10,000 (Appendix C), suggesting significant dilution due to the width of Rose River estuary, any observed oxygen demand would be absorbed by the environment.	Minor	Based on sampling data to date, Numbulwar WwTP BOD discharge water quality is 31.5 mg/L. These BOD concentrations are elevated in comparison to concentrations at other remote communities; these values are considered to be classified as low effluent strength (>40 mg/L, <1,500 mg/L) (PWC 2020). Based on the dilution ratio between effluent and receiving environment and the nature of the receiving environment (large width of estuary and therefore significant flushing), PWC considers that the likelihood of oxygen depletion in receiving environmental waters may be unlikely. Ongoing sampling will assist to characterise discharge quality.	Unlikely	Low
Free ammonia is resulting in **toxicity to aquatic organisms** in water and sediments.	Toxicity to aquatic organisms may only be applicable to localised invertebrate populations and sediment dwelling organisms at immediate discharge point. 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.	Minor	Numbulwar WwTP free ammonia discharge quality is 4.3 mg/L. These ammonia concentrations are relatively low in comparison to concentrations at other remote communities (PWC 2020). Low pH may also be an indicator of increased ammonia toxicity (ANZECC 2000); a mean pH of 7.91 at Numbulwar 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, Numbulwar WwTP contributes very low levels of total nitrogen and phosphorus 1.1 and 0.18 tonnes/year respectively. The effects of these levels of discharges into an estuary are statistically insignificant when compared to total loads in the ocean (ARMCANZ and ANZECC, 2000).	Minor	Total nitrogen (16.15 mg/L) and total phosphorus (2.7 mg/L) concentrations are slightly elevated in comparison to concentrations at other remote communities; and is considered to be classified as low effluent strength (<50mg/L;<10mg/L) (PWC 2022). No nuisance plant growth observed during site inspections (PWC 2021b). Stressor not typically observed with such small discharge volumes, initial high dilution, and efficient coastal flushing (Fernando 2012). Mangroves within the immediate discharge point may absorb excess nutrients. PWC considers that the likelihood of nuisance plant growth is unlikely.	Unlikely	Low
Cultural					
BOD is leading to odours resulting in the **reduction of amenity** in the receiving environment.	Access to the discharge point is limited to foot and a rough 4wd vehicle track. Observations during ERA inspections suggest track isn't used very often/ not well known – difficult to see from main road and difficult to access (PWC 2021b; PWC 2017). Minimal cultural beneficial uses of the receiving environment observed. Recreation activities occur in water around other side of the estuary, closer to the Numbulwar community (PWC 2017).	Minor	Stressor not typically observed with rapid dilution and efficient coastal flushing. Likelihood greater during Dry Season where there are flushing constraints. However no evidence of odours during monitoring of discharge area (qualitative discharge criteria), and recreational use of the receiving area is minimal. Odours would be limited to immediate discharge site in mangrove forest area. PWC considers that the likelihood of reduction in amenity from BOD is unlikely.	Unlikely	Low

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Nutrients are resulting in the **reduction of amenity** of receiving environment through **reduction in water clarity**, objectionable **discolouration** and **odours**.	Minimal cultural beneficial uses of the receiving environment observed. Unlikely the public access the immediate discharge site. Recreational use unlikely due to saltwater crocodiles in the area. Some boat-based fishing may occur occasionally in Rose River but would be within the estuary mouth where substantial flushing and tidal mixing occurs (PWC 2017).	Minor	Stressor not typically observed with rapid dilution and efficient coastal flushing. During monitoring of discharge site some evidence of reduction in water clarity, objectionable discolouration of receiving water or odours was observed through the discharge being bright green colour (high algal count is normal) at the immediate discharge point during low tide. However tidal flushing at high tide would result in mixing of treated effluent with tidal waters. PWC considers that the likelihood of reduction in amenity from nutrients is apparent at the immediate receiving environment (zone of influence) but unlikely in the receiving waters of Rose River. Risk is still considered low due to lack of recreational use within the immediate area.	Unlikely	Low
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.	Minimal cultural beneficial uses of the receiving environment observed. Unlikely the public access the immediate discharge site. Some boat-based fishing may occur occasionally in Rose River.	Minor	Stressor not typically observed with rapid dilution and efficient coastal flushing. Based on the minimal primary and secondary contact recreation and cultural uses of the Rose River, PWC considers that the likelihood of toxicant exposure is unlikely.	Unlikely	Low
Pathogens are leading to the **contamination of water** resulting in primary and secondary contact recreational a public health risk.	Rose River is identified as having minimal cultural beneficial uses for primary and secondary recreation. Pathogens likely to filter out once reaching areas known for recreational use south-east of the discharge site that are a considerable distance away (>2km).	Moderate	Median pathogen concentrations of 17,825 mpn/100mL *E. coli* within the Numbulwar WwTP discharge are slightly elevated in comparison to concentrations at other remote communities (PWC 2022). Based on the minimal secondary contact recreation and cultural uses of the Rose River and nearby coastline, PWC considers that the likelihood of the illness from pathogen exposure is unlikely.	Unlikely	Medium
Pathogens are leading to **accumulation in shellfish** resulting in the consumption of shellfish a public health risk.	Collection and consumption of shellfish known to occur along the coastline, closer to the Numbulwar community (>2km away), however effluent volumes are anticipated to be filtered out before reaching any shellfish harvesting areas. However signs of shellfish and crabs at the immediate discharge area were observed during an ERA inspection.	Moderate	Based on the minimal secondary contact recreation and cultural uses of the Rose River and immediate mangrove forest is considered unlikely. However the fact that shellfish consumption does occur downstream, and may be some recreational fishing in the river, (i.e. crabbing), PWC considers that the likelihood of the illness from pathogen exposure through the consumption of shellfish is possible.	Possible	Medium

Summary and Recommendations

The ERA found that the identified values of the nearby mangrove forest and Rose River estuary at risk from the Numbulwar 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; 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 Numbulwar WwTP poses a low to medium risk to the identified values of the receiving area. The influence of the discharge on the receiving environment is considered sustainable given the very low discharge volumes and high dilution that would occur in the nearby estuary. Based on this ERA and modelled 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;
- assess 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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Appendix A: Numbulwar Conceptual Site Model

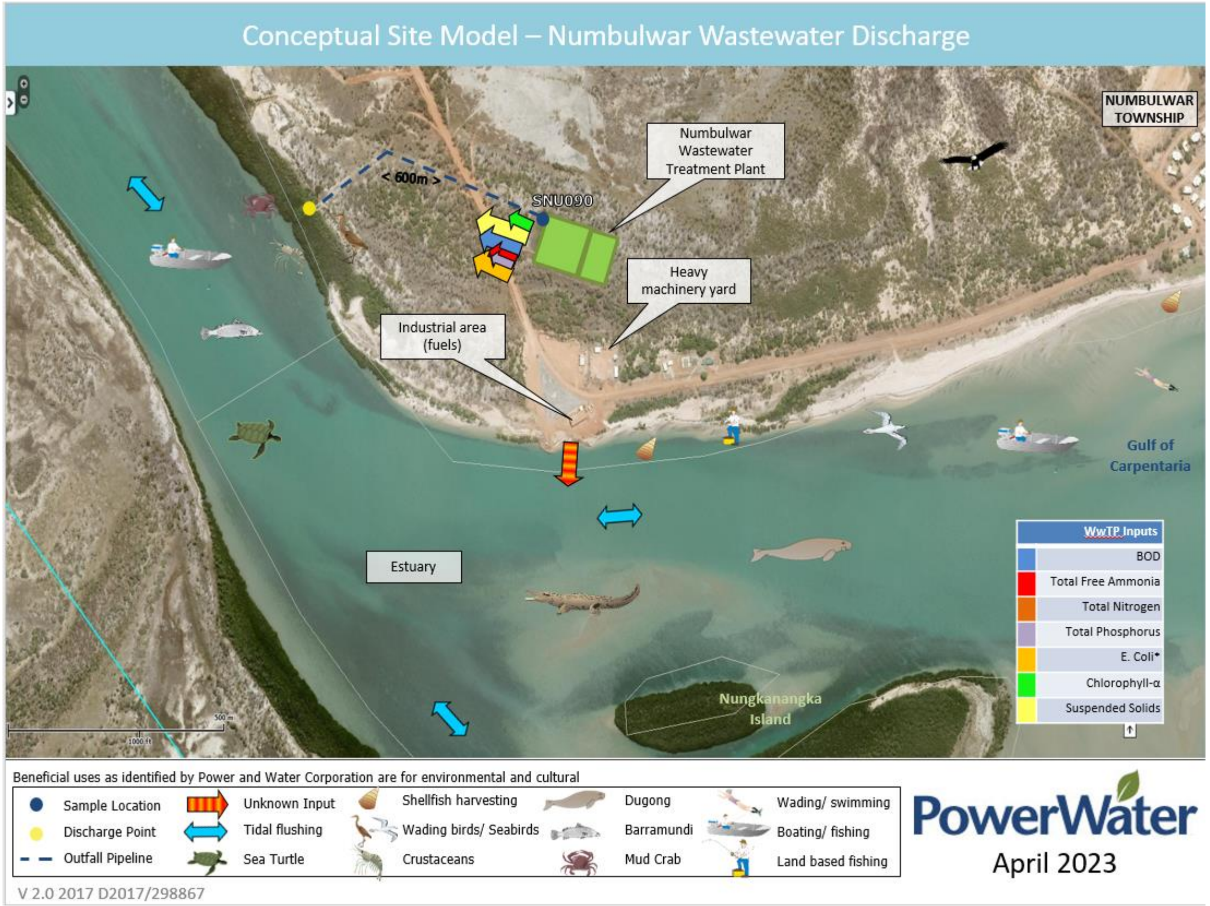

Figure 9: Conceptual site model for Nubulwar WwTP discharge receiving environment

Appendix B: Estimated Flowrates for Numbulwar WwTP

Assumptions:

Raw wastewater flow rate based on ICEG (2017) forecast sewage ET flow of 850 L/day and estimated total sewer ET for Numbulwar of 228 (PWC 2021a).

Rainfall catchment estimates based on mean monthly rainfall for all available years from Bureau of Meteorology (BOM) and total pond surface area (6,572 m^2) (PWC 2021a). Rainfall data was obtained using the Groote Eylandt Airport weather station (station number 014518) located approximately 85 km away.

Rainfall and evaporation estimates are based on mean monthly values for all available years from BOM and total pond surface.

Table 8. Estimated average annual flows

Month	Actual Inflow kL/d	Rainfall kL/d	Evaporation kL/d	Total outflow kL/d
January	194	62	39	217
February	194	75	39	230
March	194	24	39	179
April	194	56	39	211
May	194	2	39	157
June	194	0	39	155
July	194	1	39	156
August	194	0	39	155
September	194	7	39	162
October	194	2	39	157
November	194	60	39	215
December	194	33	39	188
Mean	**194**	**27**	**39**	**182**

Appendix C: Dilution Ratio for Numbulwar WwTP

Treated wastewater is discharged into a tidal mangrove area, which then drains into the Rose River estuary. Prior to entering the estuary, limited dilution of the treated wastewater would occur during the dry season. Dilution within the unnamed creek has been calculated using the method for estimating diffusion mixing in continuous discharge to a river outlined by Metcalf and Eddy (1991).

Due to the tidal nature of the estuary, a time-averaged approximation has been calculated assuming that the net advective velocity in the estuary is equal to the volumetric flowrate of the treated wastewater entering the estuary. This would be the case in the conservative scenario when no other dilution is occurring from runoff in the catchment. A typical diffusion mixing decay constant of 0.3 d^{-1} has been assumed. The locations for which dilution ration have been calculated are shown in Figure 10. Calculated dilution ratios are tabulated in Table 9: Discharge volume and dilution ratio calculation Table 9.

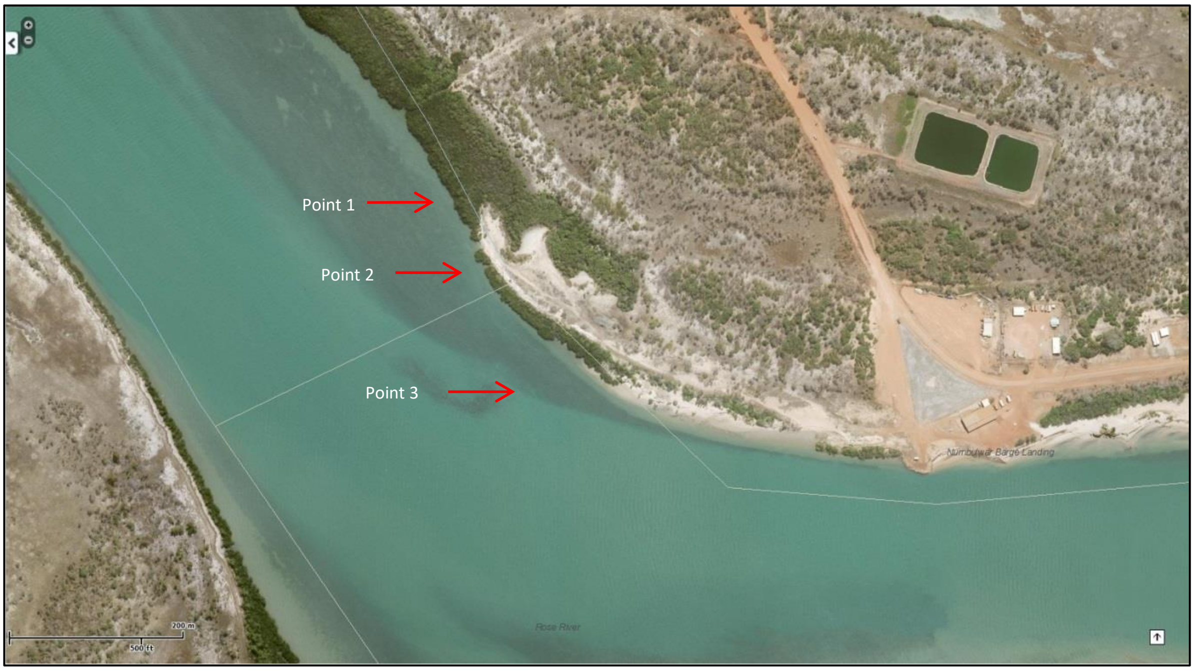

Figure 10: Numbulwar wastewater discharge surface watercourse showing at 100, 200 and 400m from discharge point (NT ILIS 2017)

Table 9: Discharge volume and dilution ratio calculation

Distance from discharge point (m)	Point 1 (100)	Point 2 (200)	Point 3 (400)
Width of estuary channel (m)	400	396	455
Estimated mean depth of channel (m)	0.5	0.75	1.0

Maximum treated wastewater flow (kL/d)[1]	210		
Net advective velocity (m/s)	1.24×10^{-5}	5.90×10^{-5}	5.44×10^{-6}
Ratio[2]	>1:10,000	>1:10,000	>1:10,000

[1] See appendix B for discharge volume calculations

[2]Due to the receiving environment being calculated across Rose River rather than a creek into an estuary, width and cross sectional areas are very large

Appendix D: Wastewater Quality Monitoring Results

Sample Location/Asset: SNU090 (Pond 2 Outlet)			
Indicator	**Reporting Value**		
	Median Wet Season	**Median Dry Season**	**Median**
Physio-chemical Parameters			
pH	8.1	7.82	7.91
Electrical Conductivity (uS/cm)	880	970	895
Dissolved Oxygen (% Saturation)	10	5	10
Turbidity (NTU)	130	95	130
Total Suspended Solids (mg/L)	124	88	95
Biological Parameters			
Biochemical Oxygen Demand (mg/L)	30	36	31.5
Chlorophyll-a (ug/L)	608	443	482
Nutrient Parameters			
Ammonia (Total[1] as N – NH3-N) (mg/L)	2.6	6.3	4.3
Total Nitrogen[2] (mg/L)	15.7	16.85	16.15
Oxidised Nitrogen (NOx) (mg/L)	0.05	0.05	0.05
Total Phosphorus (mg/L)	2.7	2.7	2.7
Pathogen Indicators			
Escherichia coli (E. coli/100mL)	17,825	20,140	17,825
Enterococci (Enterococci/100mL)	100	200	149

[1] Calculated as NH_3-N

[2] Calculated NH_3-N Organic + NH_3-N Free + NO_x

Appendix E: Additional Site Inspection Images

Figure 11: Numbulwar WwTP (PWC 2017)

Figure 12: Pond drained to be desludged (PWC 2017)

Figure 13:Aerial photo of Numbulwar Ponds (PWC 2017)

Figure 14: Shellfish (Longbums) observed at Numbulwar discharge outfall during inspection – June 2017 (PWC 2017)

Figure 15: Numbulwar pond 1 - Wet Season 2021

Figure 16: Numbulwar pond 1 water quality - Wet Season 2021 (PWC 2021)

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