Government of Western Australia
Department of Water and Environmental Regulation

Decision Report

Review of Existing Licence

Division 3, Part V *Environmental Protection Act 1986*

Licence Number	L6266/1991/10
Applicant	Water Corporation of Western Australia
File Number	DER2014/000608
Premises	Broome South sewage facility 34 Clementson Street MINYIRR WA 6725 Lot 1639 on Plan 184761 and Lot 512 on Plan 409418 As defined in Schedule 1 of the Revised Licence
Date of Report	13 December 2018
Status of Report	Final

Executive Summary

This Decision Report presents an assessment of the foreseeable Risk Events to public health, amenity, water resources and the environment from the Primary Activities currently being undertaken at the Water Corporation's Broome South sewage facility (Premises). Sewage is pumped via pipelines into the Premises and treatment occurs through a four-stage pond system with treated sewage passing through chlorination and filtration systems before being disposed of via irrigation at four treated sewage reuse facilities located within the Broome town site.

The reuse of treated sewage is not assessed in this Decision Report. The Delegated Officer has determined that the four irrigation reuse facilities are separate Prescribed Premises and the discharge of treated sewage will be considered separately under the provisions of the EP Act for each Prescribed Premises.

The Broome South sewage facility is located within 200m of the Roebuck Bay shoreline. Roebuck Bay is an area of high conservation value, with environmental values of national and international significance.

Through the risk-based assessment documented within this Decision Report the Delegated Officer has found that:

- Water Corporation implemented a number of measures during 2017 that reduced the likelihood of impact to the environmental values of Roebuck Bay from seepage originating within the Premises; and
- seepage from the Premises currently presents an Extreme risk to the values of the receiving environment due to the potential for medium to long term impacts, including the potential for nutrients within the seepage plume and associated hydraulic and biogeochemical processes to influence the occurrence of cyanobacterial blooms within Roebuck Bay.

Based on the risk assessments presented in this Decision Report the Delegated Officer has determined that the Revised Licence will be granted subject to multiple regulatory controls commensurate to the risks and necessary for administration and reporting requirements.

In consideration of the risks posed by seepage at the Premises the Delegated Officer determined that the secondary and tertiary ponds require low permeability liners installed by specified dates. These controls were consistent with the 2016 and 2018 Draft Referrals. The Delegated Officer notes the Licence Holder's preference, and will take into consideration any future applications, regarding the possible closure and decommissioning of the Premises, consolidation of sewage treatment infrastructure for the Broome town site at the Broome North sewage facility and how controls under the Revised Licence are applied. Taking a precautionary approach, the findings of the risk-based assessment do not support continued operation of the current sewage facility until 2025 at this time due to the risk from seepage.

This Decision Report presents phase one of a two-phase risk-based assessment process. The two-phase approach is considered appropriate due to a concurrent process under the *Contaminated Sites Act 2003*, being the detailed site investigation (DSI) and additional information that will become available. Findings of the DSI may inform the assumptions and uncertainties documented within this Decision Report. The DSI process is expected to be completed in 2019 which, may require additional investigations. The risk-based assessments presented within this Decision Report will be considered against the findings of the DSI and the Conditions of the Revised Licence may be amended commensurate to the outcomes of phase two of the risk-based assessment process.

Table of Contents

List of Figures

List of Tables

Definitions of terms and acronyms

In this Decision Report, the terms in Table 1 have the meanings defined.

Table 1: Definitions.

Term	Definition
Category/Categories	Categories of Prescribed Premises as set out in Schedule 1 of the EP Regulations
Condition	means a condition to which a Licence (being the Existing Licence or Revised Licence) is subject under Section 62 of the EP Act
Controlled Waste	Has the same meaning given to that term under the *Environmental Protection (Controlled Waste) Regulations 2004*
CS Act	*Contaminated Sites Act 2003* (WA)
DER	Department of Environment Regulation
Decision Report	This document
Delegated Officer	An officer under section 20 of the EP Act.
Draft Referral	the Draft Revised Licence and Draft Decision Report referred by the then DER to the Licence Holder for comment on 14 November 2016
DWER	Department of Water and Environment Regulation
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cwth)
EP Act	*Environmental Protection Act 1986* (WA)
EP Regulations	*Environmental Protection Regulations 1987* (WA)
Existing Licence	The licence issued under Part V, Division 3 of the EP Act and in force prior to the commencement of, and during completion of, this review
Licence Holder	The Water Corporation of Western Australia
Minister	the Minister responsible for the EP Act and associated regulations
Noise Regulations	*Environmental Protection (Noise) Regulations 1997* (WA)
Occupier	Defined in the EP Act to mean a person who is in occupation or control of a premises, or part of a premises, whether or not that person is the owner of the premises or part of the premises.
Premises	Broome South Wastewater Treatment Plant (BSWWTP) on Crown Reserve 37454 (Lot 1639 Clementson Street)
Primary Activities	activities which fall within the description of the category of Prescribed Premises in Schedule 1 of the EP Regulations and as defined in Schedule 2 of the Revised Licence

Term	Definition
Prescribed Premises	Premises prescribed under Schedule 1 to the EP Regulations
Review	the review of the Risk Events arising from the Primary Activities and the Existing Licence documented within this Decision Report
Risk Event	being events that involve all of the following: (a) an emission occurring; and (b) a receptor being exposed to the emission through an identified actual or likely pathway; and (c) potential adverse effects to the receptor from exposure to the emission
Sewage	The *Health Act 1911* defines sewage as any kind of sewage, nightsoil, faecal matter or urine, and any waste composed wholly or in part of liquid
TOB	Top of pond embankment level
TWL	Top water level (excluding freeboard)

1. Purpose and scope of assessment

Water Corporation of Western Australia (Licence Holder) are approved under *Environmental Protection Act 1986* (EP Act) Part V Licence L6266/1991/10 (Existing Licence) for the operation of an *Environmental Protection Regulations 1987* (EP Regulations) Schedule 1 Category 54 sewage facility and Category 61 liquid waste facility at the Broome South sewage facility located at Lot 1639 on Plan 184761 and Lot 512 on Plan 409418 Broome, Western Australia (Premises), see Figure 1 and Figure 2. Sewage accepted under Category 54 operations accounts for over 99% of the quantity of liquid waste accepted at the Premises.

In April 2015, the Chief Executive Officer of the former Department of Environment Regulation (DER) determined that a risk-based review (Review) of the Premises and Existing Licence was appropriate. The decision to undertake a risk-based review resulted from the identification of elevated concentrations of total phosphorus, total nitrogen and nitrogen species in groundwater monitoring bores located in the vicinity of the Premises and the adjacent treated sewage irrigation site, the Broome Golf Club.

This Decision Report finds that a two phase approach to the Review is appropriate and concludes phase 1 of the Review. Presented herein is an assessment of the foreseeable Risk Events to public health, amenity, water resources and the environment as a result of the Primary Activities currently being undertaken at the Premises and identified within this Review. The reuse of treated sewage at other premises, see Figure 1, is not considered in this Review (see Section 3.4 of this Decision Report). This Review has been undertaken in accordance with the DWER 2018 *Regulatory best practice principles*.

1.1 Review details

This Review has been undertaken over the period 2015 to 2018. As part of this Review process the then DER and DWER have undertaken consultation with various stakeholders, considered available literature and sought technical expert advice to inform the findings of this Review. As part of this Review process, the then DER referred a Draft Revised Licence and Draft Decision Report (2016 Draft Referral) to the Licence Holder for comment on 14 November 2016 (see Section 5.10.4 of this Decision Report). This Decision Report and the Revised Licence take into consideration consultation associated with and supersedes the 2016 Draft Referral.

In accordance with the *Contaminated Sites Act 2003* (CS Act) the Premises was classified as *Contaminated – remediation required* on 28 April 2015 (see Section 5.8 of this Decision Report). Decisions made in this Review have taken into consideration the concurrent processes under the CS Act. Where relevant, assumptions and information gaps that may be addressed through the CS Act processes are identified within this Decision Report.

Documents and reports submitted by the Licence Holder that directly consider the Risk Events arising from the Primary Activities at the Premises and inform this Review are detailed in Table 2, including identified reports relevant to the CS Act. A full list of documents, literature and technical reports considered as part of the Review are detailed in Appendix 1.

Table 2: Documents submitted by Licence Holder relevant to this Review process.

Document/ information description
URS Australia Pty Ltd October 2013, *Hydrological assessment of nutrient flux in Broome South wastewater treatment plant* (A708425).
URS Australia Pty Ltd September 2015, *Preliminary nutrient impact assessment Broome South wastewater treatment plant* (A984224).

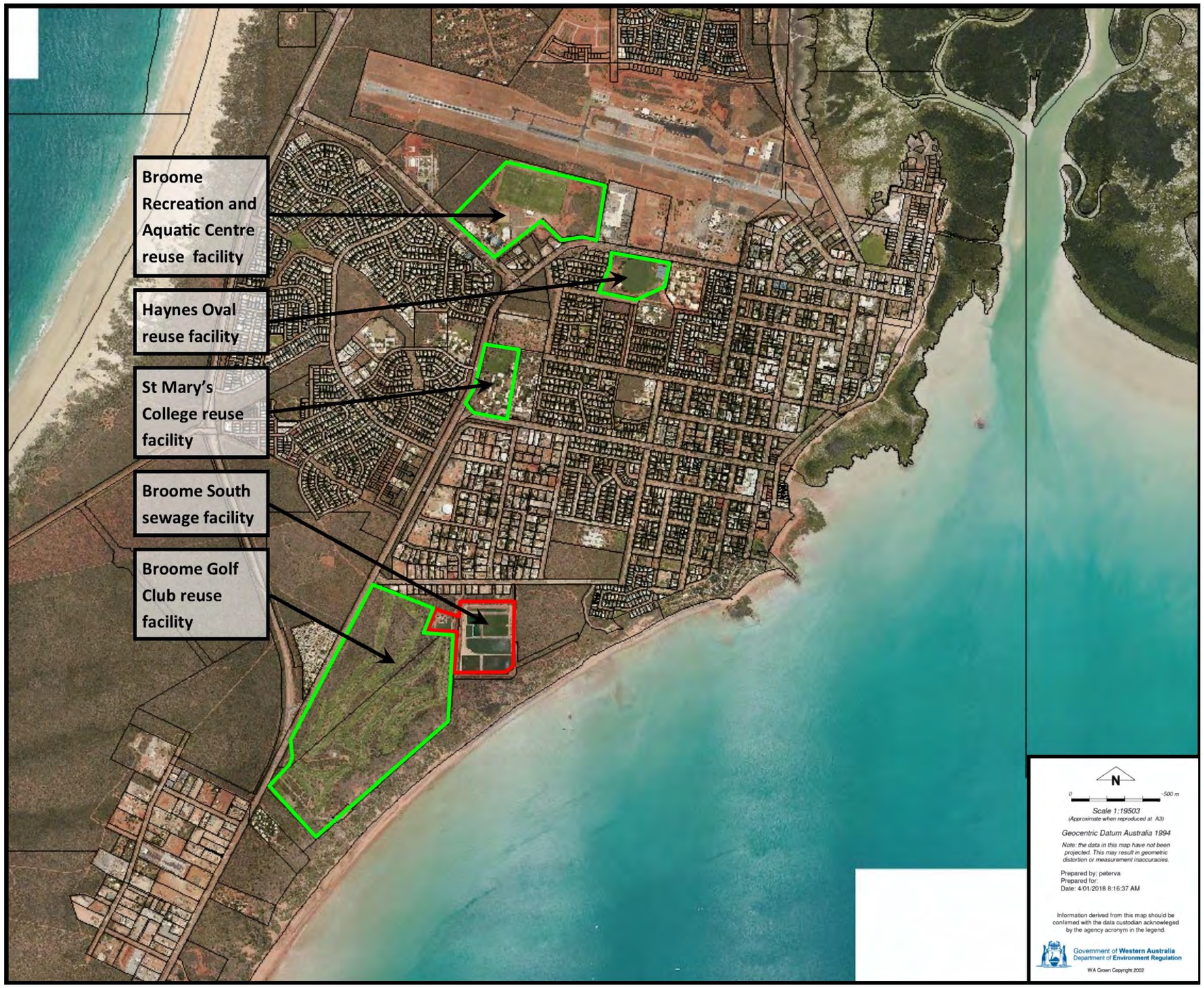
Document/ information description
RPS Environment and Planning Pty Ltd September 2015, *Literature review Broome South wastewater treatment plant and surrounding areas* (A980787).
RPS Environment and Planning Pty Ltd October 2015, *Preliminary site investigation Broome South wastewater treatment plant* (A1380441).
RPS Environment and Planning Pty Ltd 20 January 2016, *Holding Pond E3 sediment sampling and assessment findings* (A1100687).
Bowman and Associates Pty Ltd 2016, *Broome South waste water treatment facility holding pond E3 line installation – construction quality assurance report* (A1384408).
AECOM Australia Pty Ltd 19 August 2016, *Preliminary nutrient impact assessment Broome South Wastewater Treatment Plant* (A1165073).
Water Corporation email to DWER dated 31 August 2017, *Draft EP Act Licence L6266/1991/10 Broome South WWTP*, (A1516812) including the attached: • Letter dated 31 August 2017, *RE: Draft EP Act Licence L6266/1991/10 Broome South WWTP*; and • PowerPoint presentation dated 3 August 2017, *Broome Wastewater Planning presentation to DWER (Industry Regulation)*.
Golder Associates Pty Ltd 15 December 2017, *Broome South WWTP – Water balance analysis and seepage loss assessment* (A1580982).
McMahon and Dunham 2017, *Investigation into nitrogen sources for Roebuck Bay and the Yawuru Nagulagun/ Roebuck Bay Marine Park a final report for Water Corporation* (A1586244)
Water Corporation letter to DWER dated 14 January 2018 (*received 19 February 2018*), *Re: review of Broome South WWTP Licence L6266/1991/10 – request for clarification of information for risk assessment* (A1627931), including attachments (fA231569)
Senversa Pty Ltd 1 May 2018, *Mandatory Auditor's report Broome wastewater treatment plant, 34 Clementson Street, Western Australia, Broome Golf Course, 221 and 223 Port Drive Minyirr, Western Australia* (A1667251)
Water Corporation May 2018, *Broome South WWTP (L6266) Pond E3 Leakage Management Plan* (A1685101), including the correction in the email dated 27 August 2018 (DWERDT89239)
Water Corporation letter to DWER dated 31 July 2018 (received 1 August 2018), *Proposed amendment to EP Act Licence Number L6266/1991/10 (Broome South)* (DWERDT80153)
Golder Associates Pty Ltd July 2018, *Report Broome South Wastewater Treatment Plant response to draft licence decision report* (DWERDT80156)
Water Corporation email to DWER dated 27 August 2018, L6266 Broome South proposals for groundwater monitoring bore locations – clarification (DWERDT89239)

2. Background

The Premises is located in the West Kimberley region of Western Australia, directly south of the Broome town site approximately 200 m northwest of the Roebuck Bay shoreline. The Premises is the original sewage facility for the Broome town site and was commissioned in 1981, prior to the commencement of the EP Act. Disposal of treated sewage from the Premises has been undertaken by a number of irrigation disposal and reuse methods and infiltration. The Licence Holder has held approval to operate the sewage facility under the Existing Licence and previous versions since approximately 1991.

Reuse of treated sewage at the public open spaces commenced in 1996 and continues to be provided to reuse facilities under a Recycled Water Supply Agreement with the Shire of Broome (at Haynes Oval, Broome Recreation and Aquatic Centre and St Mary's College) and separately with the Broome Golf Club Incorporated under a Memorandum of Understanding. Disposal and reuse of treated sewage has occurred at various decommissioned infiltration and irrigation locations around the Premises and Broome Golf Club in the past. The reliance on infiltration and some irrigation options to dispose of treated sewage has reduced over time.

Figure 1: Premises and reuse facility location map.



In December 2002 EP Act Part V Works Approval W3685/1991/1 was granted for upgrades to the infrastructure at the Premises. A redesign of the ponds system was approved, relocating the primary and secondary ponds to the southern end of the Premises and increasing the nominal treatment capacity from 3,100 m^3/ day to 3,500 m^3/ day. Additional works and modifications undertaken to infrastructure affecting the Premises are detailed in Section 3.1 of this Decision Report.

The layout of the current infrastructure arrangement, including treated sewage reuse is detailed in Figure 2. Chlorination, filtration and reuse facility offtake pumping infrastructure are located adjacent Emergency Pond 3. One other Category 54 sewage facility services the Broome town site, also operated by the Licence Holder.

The Broome North sewage facility, located approximately 6.5 km north east of the Broome town site, was granted approval for construction on 18 June 2009 under EP Act Works Approval W4531/2009/1. Approval for operation was granted on 30 June 2011 under EP Act Licence L8556/2011/1 (now Licence L9094/2017/1). In 2012 approximately 1,200 m^3/ day of sewage inflow was diverted from the Premises for treatment at the Broome North sewage facility. The Broome North sewage facility also serves as the primary disposal site for Category 61 liquid waste activities.

The operations of the Premises are summarised in Section 3 of this Decision Report. The Prescribed Premises Categories that are granted approval in the Existing Licence are detailed in Table 3. The volume of waste accepted under Category 54, over 99% of the annual throughput, and Category 61 operations is detailed in

Table 4.

Potential receptors from discharges and emissions at the Premises are summarised in Section 4 of this Decision Report. The Premises is located 200m northwest of the shoreline to Roebuck Bay. Roebuck Bay is considered to have cultural and ecological values of regional, national and international significance including listing as a Wetland of International Importance under the Ramsar Convention, containing a Threatened Ecological Community and providing ecosystem services for a diversity of threatened and priority fauna (see Section 4.3 of this Decision Report).

Table 3: Prescribed Premises Categories approved in the Existing Licence.

Classification of Premises	Description	Approved Premises design capacity[1]
Category 54	Sewage facility: Premises — (a) on which sewage is treated (excluding septic tanks); or (b) from which treated sewage is discharged onto land or into waters.	3,500 m^3 per day
Category 61	Liquid waste facility: Premises on which liquid waste produced on other premises (other than sewerage waste) is stored, reprocessed, treated or irrigated.	1,000 m^3 per annual period

Note 1: Under the Existing Licence a design capacity of 3,500 m^3 per day was approved, a total that did not clearly include the liquid waste accepted under Category 61 activities. The approved design capacity of the Revised Licence takes into consideration the sewage acceptance volumes discussed in Section 3.2 of this Decision Report and is addressed further in Sections 8.4 and 9.1.1 of this Decision Report.

Table 4: Summary of annual waste volumes accepted at the Premises.

Year	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18
Cat. 54 kL accepted[1]	N/A	N/A	N/A	944,767	935,364	839,735	780,793	765,893	664,337	673,431
Cat. 61 kL accepted[2]	1,152.25	839.23	661.1	850.56	1,026.97	801.98	678.8	209	0	0

Note 1: Data source Water Corporation Annual Environmental Report 2011/12 through 2017/18.

Note 2: Data source DWER Controlled Waste Tracking System.

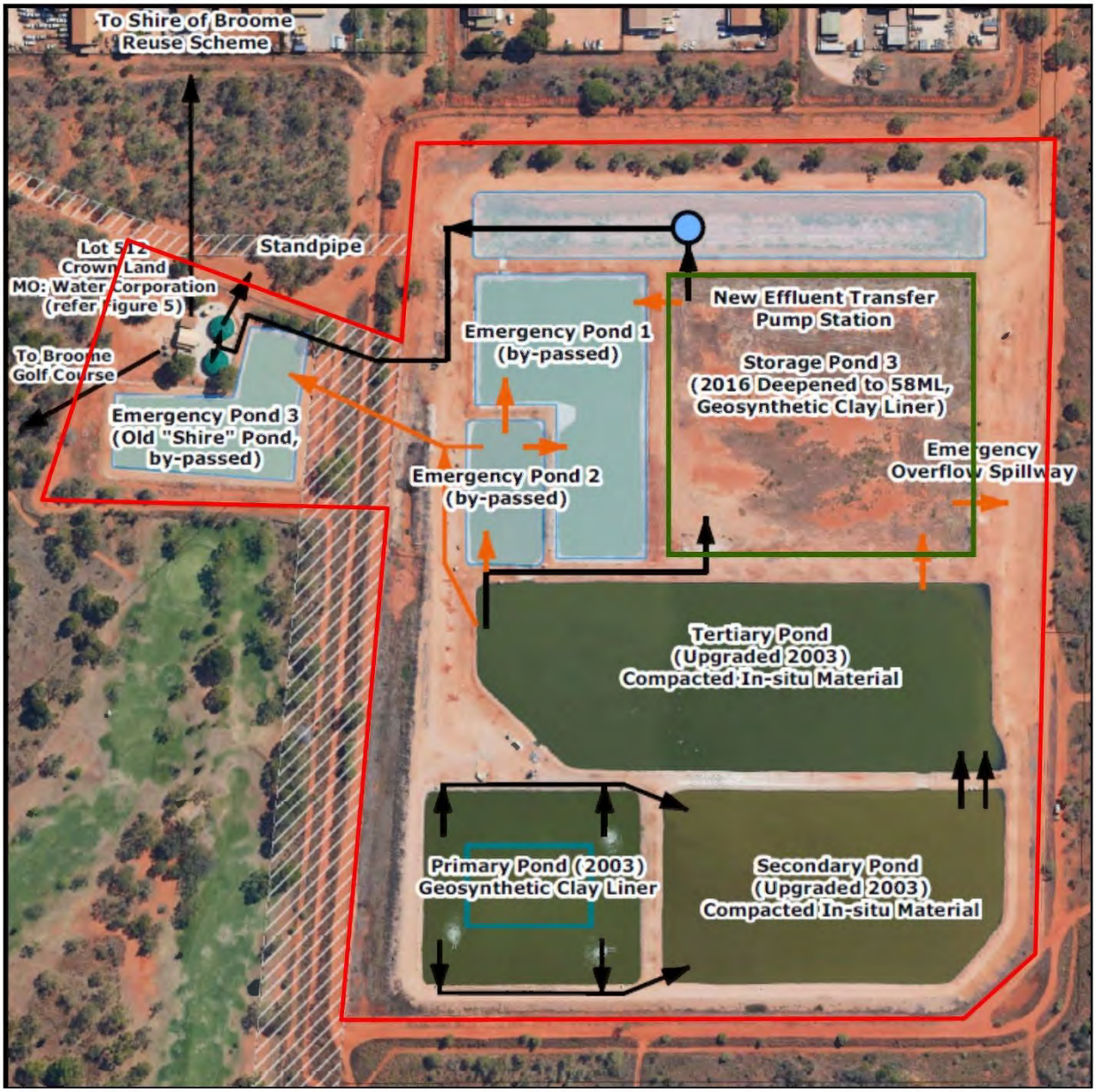


Figure 2: Infrastructure location and sewage conveyance paths for the Broome South sewage facility[1].

Note 1: lines within Figure 3 demarcate as follows:

- Red line = boundary of Prescribed Premises;
- Black lines = flow path of sewage through to treated sewage and the off-take to reuse facilities; and
- Orange lines = emergency overflow flow points and spillways.

3. Overview of Premises

3.1 Construction aspects

The Licence Holder has confirmed (Water Corporation 19 February 2018) that no short-term changes or construction works are proposed to the Primary Activities at the Premises that are relevant to this Review. A recent history of works that have effected or are expected to affect operations at the Premises is detailed in Table 5, this includes item 1 for the long-term planning of sewage treatment infrastructure.

Table 5: Recent history of construction works at and affecting the Premises.

	Date	Construction/ infrastructure works	Reference	EP Act Part V Approval
1	*N/A*	Licence Holder plans, long-term (~2025), to consolidate infrastructure and capacity at Broome North sewage facility and decommission the operations at the Premises.	Water Corporation 31 August 2017 and Water Corporation 31 July 2018	Not applicable at this time
2	April 2017 – June 2018	Investigation of installing microbiological culture pad system to improve the quality of treated sewage within the Tertiary Pond, the Storage Pond and Emergency Pond 3.	Field Capacity 2017b, page 21; Water Corporation 2018a.	None granted
3	2016 – ongoing (*commenced and partially completed*)	Sewage inflow redirections. Cable Beach sewage inflows (pump station SP5) redirected to the Broome North sewage facility, being up to 300 m^3/ day and reducing inflow for the Premises to an average 1,200 m^3/ day. Completion is expected in 2018 that will see all flows diverted to the Broome North sewage facility.	Water Corporation 31 January 2017; Water Corporation 31 August 2017; Water Corporation 2018a.	None granted
4	2016 - 2017	Emergency Pond 3 (*now Storage Pond*) capacity increase to 51,409 m^3 and relined with geosynthetic clay liner and decommissioning of the following ponds, lined with in-situ compacted Pindan soils, to be used for emergency storage only (*where available*): • Holding pond (*now emergency pond 1*) • Overflow pond (*now emergency pond 2*) • Emergency pond (*decommissioned and filled with inert waste*) • Reuse pond (*now emergency pond 3*)	Water Corporation 31 January 2017; Water Corporation 31 August 2017	Existing Licence (granted 16 June 2016)

Future works proposed at the Broome North sewage facility may include the expansion of a treated sewage reuse program, being pasture irrigation. These works may facilitate additional diversion of sewage inflows from the Premises to the Broome North sewage facility (see item 1 of Table 5). In responses to the 2016 Draft Referral by the then DER the Licence Holder has requested an extension from 2021 to 2025 to address the requirements of the 2016 Draft Revised Licence (see Section 5.10.4 of this Decision Report). Subsequently, in response to the 2018 Draft Referral the Licence Holder has committed to consolidate infrastructure and capacity at Broome North sewage facility and decommission the operations at the Premises by approximately the end of 2025, citing an ~7 year process to achieve this.

3.2 Operational aspects

Infrastructure at the Premises incorporates a pond-based sewage treatment system with a nominal design capacity of less than 2,000 m^3/ day (Water Corporation 31 August 2017). The volume of sewage inflow has been reduced since the partial diversion of sewage to the Broome North sewage facility in 2012. The Premises accepted on average 2,143 m^3/ day in 2014/15 that has reduced to 1,820-1845 m^3/ day in 2016/17 and 2017-18 (see

Table 4). Following completion of the works described in item 4 of Table 5 the sewage treatment infrastructure operates according to the plan in Figure 2.

Sewage is accepted via inflows direct to the Primary Pond. Under the Existing Licence Liquid waste, of the types detailed in Table 6, can be accepted via the liquid waste discharge point directly into the Primary Pond. The Primary ponds consists of a deeper anaerobic treatment stage and a surface facultative stage that is supported by four aerators. Sewage moves from the Primary Pond to the secondary and then tertiary pond before entering the Storage Pond.

From the Storage Pond treated sewage is directed through a chlorination and filtration system to the reuse facilities via the off-take pumping stations. Pumping station 1 directs treated sewage to the Broom Golf Club, pumping station 2 directs treated sewage to the reuse facilities Haynes Oval, the Broome Recreation and Aquatic Centre and St Mary's College; separate offtake pumps for the other three reuse facilities are not located at the Premises.

The primary, secondary, tertiary and storage ponds are operated with the levels and capacities detailed in
Table **9**. The Licence Holder has proposed to retain emergency storage capacity in the three emergency ponds that are lined with in-situ soils. The Storage Pond freeboard and Emergency Pond storage capacities provide a total capacity of 31,481 m^3 prior to overtopping into the environment east of the Storage Pond.

Table 6: Liquid waste types approved for acceptance in the Existing Licence.

Environmental Protection (Controlled Waste) Regulations 2004 **waste type**	**DER 2015, *Controlled Waste Category List* equivalent waste type**
Waste from grease traps	K110 Waste from grease traps
Sewage	K130 Sewage waste from the reticulated sewage system K210 Septage wastes
Waste oil and water, or hydrocarbons and water, mixtures or emulsions	L100 Car and truck wash waters
Not applicable	L150 Industrial wash water contaminated with a controlled waste

(1) Key Finding: The Delegated Officer finds that the sewage treatment systems is under the control of the Licence Holder, comprising of all sewage treatment infrastructure located within Lot 1639 on Plan 184761 and Lot 512 on Plan 409418, until treated sewage is pumped to the reuse facilities post-chlorination and filtration.

Sewage and liquid waste is treated at the Premises to the quality detailed in

Table **7** and has historically been directed to the reuse facilities at the hydraulic and nutrient loads detailed in Table 10. All treated sewage quality samples are collected prior to chlorination, it is assumed that all results post-chlorination for *Escherichia coli* are <1000 cfu/ 100 mL and that chlorination and filtration do not materially impact the results for other parameters.

Table 7: Summary of treated sewage quality discharged from the Premises[1].

		Biochemical oxygen demand (mg/L)	*Escherichia coli* (cfu/ 100 ml)	Total nitrogen (mg/L)	Total phosphorus (mg/L)	Total dissolved solids (mg/L)	Total suspended solids (mg/L)
2013/ 14	**Average**	**21.25**	**3097.5**	**30.25**	**7.6**	**776**	**88.75**
	Min: Max	15: 25	250: 7700	17: 38	6: 10	621: 851	*55: 140*
	SD	*4.79*	*3426*	*9.14*	*1.82*	*37*	*37.05*
2014/ 15	**Average**	**26.04**	**7183**	**34.76**	**9.6**	**732**	**105.92**
	Min: Max	18.3: 35	3750: 13000	23.3: 44.2	9.2: 10.3	707: 757	83.7: 123.3
	SD	*6.85*	*5065*	*9.36*	*0.48*	*26*	*16.66*
2015/ 16	**Average**	**28.13**	**6338**	**32.83**	**10.5**	**693**	**97.50**
	Min: Max	20: 42.5	1700: 10000	19: 58.3	9.2: 12	640: 720	65: 120
	SD	*9.87*	*3486*	*17.43*	*1.25*	*38*	*23.98*
2016/ 17	**Average**	**36.67**	**2308**	**21.14**	**7.83**	**673**	**121.25**
	Min: Max	<5: 50	130.5: 5800	14: 33	6.5: 8.8	580: 760	75: 160
	SD	*11.55*	*2439*	*8.92*	*1.12*	*76*	*35.21*
2016/ 18	**Average**	**72.5**	**2962**	**23.50**	**7.83**	**665**	**155**
	Min: Max	30: 190	10: 11000	11: 40	3.7: 11	420: 770	110: 260
	SD	*78.48*	*5369*	*12.12*	*3.14*	*165*	*71.4*
Average		***37***	***4,378***	***28.5***	***8.7***	***708***	***114***

Note 1: Data source Water Corporation Annual Environmental Reports (*averages from quarterly data collection*).

SD = Standard deviation

3.3 Infrastructure

The Premises infrastructure, as it relates to the Primary Activities is detailed in Table 8, details on the sewage facility ponds in

Table **9** and with reference to the Site Plan, see Figure 2.

Table 8: Broome South sewage facility Primary Activity infrastructure.

Infrastructure and equipment	
1	Category 61 controlled waste truck receipt bay: gravity flows into deep anaerobic section of Primary Pond.
2	Category 54 sewage inlet discharge tower: gravity flows into deep anaerobic section of Primary Pond.
3	Primary pond: comprised of a deeper anaerobic section and a stepped aerobic layer maintained via four aerators (11kW Tornado Surface Aerators), overflow to the Secondary Pond is via four outlets that gravity feed to Manholes MH4 and MH6.
4	Primary pond sludge withdrawal pipe and sump: allows removal of sludge from deep anaerobic section of Primary Pond.
5	Secondary pond (facultative): gravity feeds into the Tertiary Pond via two parallel weirs in the northeast corner.
6	Tertiary pond (facultative): gravity feeds into the Storage Pond via the outlet in the northwest corner.
7	Storage pond: stores treated sewage before transfer to the Recycled Water Storage Tanks via the Effluent Transfer Pump Station.

Infrastructure and equipment	
8	Emergency Pond 1: inflow is via a high-level overflow weir from the Tertiary Pond, provides emergency containment capacity for high flow and maintenance events, upon capacity being restored contents are returned to the sewage treatment ponds.
9	Emergency pond 2: inflow is via a high-level overflow weir from the Tertiary Pond, provides emergency containment capacity for high flow and maintenance events, upon capacity being restored contents are returned to the sewage treatment ponds.
10	Emergency pond 3: inflow is via gravity from Emergency Pond 2, provides emergency containment capacity for high flow and maintenance events, upon capacity being restored contents are returned to the sewage treatment ponds.
11	Recycled Water Storage Tanks: two 230 kL (200 kL operational volume) steel corrugated storage tanks.
12	Chlorinator: dosing at inlet and outlet point of the Recycled Water Storage Tanks from two 920 kg chlorine gas storage vessels (duty and standby).
13	Recycled Water Pump Station: two pump sets from Recycled Water Storage Tanks to filtration units.
14	Filtration units: two filter sets of two Filtomat course screen filter sets, for Broome Golf Course and Shire of Broome reuse facilities (filter backwash returned to the Primary Pond).
15	Recycled Water Supply Mains: one to Broome Golf Course (DN368 and DN250) and one to Shire of Broome reuse facilities (DN150).
16	Microbiological culture pad trial: being undertaken April 2017 to March 2018 (see Field Capacity 2017b).
17	Monitoring: operational and treated sewage quantity and quality monitoring locations and ambient groundwater monitoring bores.

Table 9: Specifications of the ponds at the Premises[1].

Pond name	Pond floor dimensions	Pond floor level	Storage capacity	Surface levels/ freeboard	Liner type (permeability)
Primary pond	7,120 m^2 (*at base*) 9,284 m^2 (*at upper stepped tier*)	4.30m AHD	35,000 m^3	Freeboard = 0.445 m TWL = 12.855 mAHD TOB = 13.30 mAHD	Geosynthetic clay liner (<1 x 10^{-9} m/s) (installed 2003)
Secondary pond	14,245 m^2	10.00 mAHD	35,484 m^3	Freeboard = 300 mm TWL = 12.515 mAHD TOB = 12.815 mAHD	In-situ compacted Pindan soils (permeability unknown)
Tertiary pond	20,493 m^2	9.00 mAHD	61,965 m^3	Freeboard = 300 mm TWL = 12.465 mAHD TOB = 12.765 mAHD	In-situ compacted Pindan soils (permeability unknown)
Storage pond	[2] 14,595 m^2	8.40 mAHD	58,409 m^3 (~68,000 m^3 at spillway)	Freeboard = 492 mm TWL = 11.9 mAHD Spillway to Emergency Pond 1 = 12.05 mAHD Spillway to Environment = 12.392 mAHD	Geosynthetic clay liner (1.2-1.4 x 10^{-10} m/s) (installed 2017)
Emergency pond 1	7,910 m^2	10.30 mAHD	~10,000 m^3	Freeboard = 300 mm TWL = ~12.20 mAHD TOB = ~12.50 mAHD	Estimated ≤4.4 x 10^{-7} m/s; (Golder Associates 1997, page 10); In-situ compacted Pindan soils
Emergency pond 2	2,287 m^2	10.30 mAHD	~3,900 m^3	Freeboard = 300 mm TWL = ~12.20 mAHD TOB = ~12.50 mAHD	

Pond name	Pond floor dimensions	Pond floor level	Storage capacity	Surface levels/ freeboard	Liner type (permeability)
Emergency pond 3	3,671 m^2	9.8 mAHD	~9,000 m^3	Freeboard = 300 mm TWL = ~11.30 mAHD TOB = ~11.60 mAHD	

Note 1: source values confirmed via Water Corporation 2018a unless specified otherwise.

Note 2: source Golder Associates 2017.

3.4 Exclusions to the Premises – reuse of treated sewage

The operations at the Premises provide treated sewage to the irrigation activities at the reuse facilities, being the Recreation and Aquatic Centre, Haynes Oval, St Mary's College and the Broome Golf Club. The Licence Holder is not the Occupier of the reuse facilities. The locations of the reuse facilities are depicted in Figure 1 and a summary of the sizes and loads of treated sewage discharged to the reuse sites is detailed in Table 10.

Table 10: Summary and assessment of reuse facility discharges of treated sewage.

Reuse facility		Irrigation area		Annual nitrogen load (kg/ ha/ year)		Annual phosphorus load (kg/ ha/ year)		Volumetric discharge (m^3)	
		Hectares	% of group	*Total nitrogen 2014/15*[1]	*Inorganic nitrogen 2015/16*[2]	*Total phosphorus 2014/15*[1]	*Filterable reactive phosphorus 2015/16*[2]	2015/16	Daily volume as % of group[3]
Group 1	Recreation and aquatic centre	8.08	55%	*520.9*	*226*	*143.0*	*60.9*	165,636 m^3/ year; 453.8 m^3/ day	249.61 m^3/ day
	Haynes Oval	3.64	25%		*251*		*68*		112.45 m^3/ day
	St Mary's College	2.97	20%		*296*		*80*		91.74 m^3/ day
Group 2	Broome Golf Club	20[4]	100%	*738.4*[4]	*424.8*[4]	*202.8*[4]	*113.8*[4]	388,338 m^3/ year	1063.94 m^3/ day

Note 1: Data source Water Corporation 2015 Annual Environmental Report (A964983).

Note 2: Data source Water Corporation 2016 Annual Environmental Report (A1157867).

Note 3: Assumes equitable hydraulic loading rates across the available irrigation areas; actual nutrient load data indicates higher volumetric discharges to Haynes Oval and St Mary's College; and daily loading rate is an underestimate based on the assumption of an equitable distribution of volume across every day of the year.

Note 4: 20 hectares as per Field Capacity Pty Ltd 2017b, corrected from previous value of 28.8 that did not account for 8.8 hectares of non-irrigated lands, all loading rates increased proportionally by 144%.

(2) The Delegated Officer notes that all four reuse facilities, being the Recreation and Aquatic Centre, Haynes Oval, St Mary's College and the Broome Golf Club are Prescribed Premises for the purpose of Part V of the EP Act, being Category 54 sewage facilities, as defined under Schedule 1 of the EP Regulations, with design capacities of 100 m^3 or more per day.

(3) The Delegated Officer considers that the operations at other prescribed premises are not Risk Events that should be assessed within the scope of this Review.

4. Location and siting

4.1 Siting context

The Premises is located south of the Broome town center, adjacent to the light industrial area and approximately 200 m northwest of the Roebuck Bay shoreline. The Broome town site has a baseline population of approximately 15,000 people that can triple during the peak tourist season, being May to September. Climatic conditions are generally warm and clear with rainfall, associated with tropical depressions that can result in cyclones, predominantly occurring during the wet season November to February.

4.2 Residential and sensitive human receptors

The distances to sensitive human receptors from the Premises are detailed in Table 11.

Table 11: Residential and public sensitive receptors distance from Premises.

Sensitive Land Uses	Distance from the Premises
Residences	Residences located approximately 470 m to the east, separated from the Premises by vacant land zoned 'Development', extending further to the east and north. Residences located approximately 600 m to the northeast, separated from the Premises by vacant land zoned 'Development', the light industrial area and extending further to the north. Broome Vacation Village Caravan Park, located approximately 720 m to the west, separated from the Premises by the Broome Golf Club.
Light industrial area	Adjacent to the north, separated from the Premises by a thin (20 m) vegetated strip and extending over 500 m to the north.
Recreational area – Broome Golf Club	Adjacent to the east, extending for approximately 500 m east and a further 2 kilometres to the southwest.
Recreation area – Roebuck Bay shoreline	200 m to the southeast, extending to 400 m to the east and south.

4.3 Environmental receptors and specified ecosystems

Specified ecosystems are areas of high conservation value and special significance that may be impacted as a result of Primary Activities at or Emissions and Discharges from the Premises. A summary of the specified ecosystems proximate to the Premises are detailed in Table 12. Table 12 also summarises the distances to other relevant ecosystem values that do not fit the definition of a specified ecosystem. The shoreline, intertidal and marine areas of Roebuck Bay are associated with high levels of biodiversity, bio-productivity and importance as nursery and foraging areas.

Table 12: Environmental receptors and specified ecosystems.

Specified ecosystems	Distance from the Premises
Roebuck Bay marine ecosystem: **(a)** Shoreline and Threatened Ecological Community – *Roebuck Bay mudflats* (vulnerable) **(b)** Yawuru Nagulagun/ Roebuck Bay Marine Park. **(c)** West Kimberley National Heritage listing (relevant under Section 15B and 15C of the *Environmental Protection and Biodiversity Conservation Act 1999*). **(d)** Ramsar wetland boundary (relevant under Section 16 and 17 of the *Environmental Protection and Biodiversity Conservation Act 1999*).	**(a)** 200 m to the southeast, extending to 400 m to the east and south. **(b)** Starts 2 km east and 9 km south, having the Port of Broome area excised. **(c)** Starts 3 km east and again approximately 3 kilometres southwest and northwest across the Broome Peninsula. Gazetted 31 August 2011, No. S132. **(d)** Starts 8.8 km east extending around to the south along the Roebuck Bay shoreline and intertidal areas.
Dampier Creek: Directory of Important Wetlands and mangrove forest (high value ecosystem)	Starts 1.5 km east, extending approximately 3 km east and 5 km north.
Yawuru Birragun Conservation Park	Starts approximately 5 km north east and extends along the eastern shoreline of Dampier Creek.

Specified ecosystems	Distance from the Premises
Keraudrenia exastia (threatened – Critically Endangered under the *Wildlife Conservation Act 1950* and *Environmental Protection and Biodiversity Conservation Act 1999*)	Closest known occurrence of *K. exastia* is 1.2 km north east of the Premises.
Biological component	**Distance from the Premises**
Priority 1 ecological communities: *Corymbia paractia* (ghost gum) within the coastal dunes, described in Coffey 2013 as '*Open Woodland of Corymbia polycarpa over open shrubland dominated by Crotalaria cunninghamii subsp. cunninghamii and Tephrosia rosea var. rosea over grassland dominated by Triodia acutispicula and Poaceae sp. 2 on orange sand on secondary dunes*' (page, 94).	Adjacent southeast and extending east and west of Premises.
Described in Coffey 2013 as '*Open Woodland of Corymbia damperi and Corymbia zygophylla over sparse Shrubland of Acacia colei var. colei and Acacia eriopoda over grassland dominated by Triodia acutispicula, Triodia microstachya or Triodia pungens on orange to red pindan soils on lower to upperslope positions*' (page, 94).	Adjacent southwest corner and adjacent east.
Roebuck Bay marine ecosystem: Threatened and priority marine ecosystem fauna (extensive list including migratory birds and marine species, turtles and marine mammals).	From 200 m to the southeast and extending from 400 m to the east and south extending throughout the Roebuck Bay marine ecosystem. See Section 5.1 of this Decision Report.

4.4 Groundwater and water sources

An unconfined aquifer extends throughout the Broome Peninsula up from the Broome sandstone into the surface Pindan soil layer (see Section 4.5 of this Decision Document). The distances to groundwater and water sources from the Premises are detailed in Table 13. A more detailed analysis of the hydrogeology at the Premises and the Broome Peninsula is provided in Section 6 of this Decision Report.

Table 13: Groundwater and water sources.

Groundwater and water sources	Distance from Premises	Value
Surface water (Roebuck Bay)	Starting from 200 m to the southeast, extending to 400 m to the east and south.	See Section 4.3 of this Decision Report.
Groundwater	Standing groundwater water levels at the Premises range from approximately 1 to 4 mAHD, being equivalent to 6 to 10 mBGL (derived from Table 15). Generally, groundwater flows from the Broome Peninsula in the north and discharges into Roebuck Bay in the south and/ or south east. See Section 6 of this Decision Report for a more detailed summary of groundwater, including groundwater quality and monitoring data. The tidal changes of Roebuck Bay have been found to influence groundwater elevation levels at the Premises in the order of 0.5 to 0.6 m.	Discharges to Roebuck Bay south of the Premises; provides a role in and influences bio-productivity and ecological assemblages.
Groundwater resources	No declared groundwater resources occur proximate to the Premises. Groundwater at the top of the unconfined superficial aquifer displays water quality characteristics consistent with non-potable beneficial uses for industry and domestic users; therefore, can be considered a groundwater resource. Groundwater abstraction and use occurs within the Broome town site.	Current and future non-potable use.

4.5 Topography and soil type

Topography at the Premises is generally flat sloping down towards Roebuck Bay with an elevated divide of coastal sand dunes separating the inland and coastline areas. Elevations at the Premises range from approximately 10 to 15 mAHD and elevations at the adjacent Broome Golf Club fall below 10 mAHD.

The surface soils type is described as Pindan soil that consists of fine to medium grained red sands with minor silt and clay. The Pindan soil extends to a depth of approximately 10-12 mBGL. Below the Pindan soil is the Broome sandstone layer that consists of fine to very coarse marine sandstone.

Table 14 details soil types and characteristics relevant to the assessment, these details have been derived from available groundwater monitoring bore logs (Field Capacity 2017b; AECOM 2016; and Water Corporation 2018a). Generally, bore logs at the Premises confirmed the existence of Pindan soils to depths over 10 mBGL. Bore logs indicate that the Broome sandstone occurs at higher elevations north of the primary dune system along the Roebuck Bay Shoreline and that higher clay levels occur in Pindan soil in eastern and northern parts of the Premises.

The Pindan soil has been used as the liner in the secondary, tertiary and emergency ponds at the Premises. Permeability tests of the Pindan soils have been recorded at 4.4×10^{-7} m/s under the then evaporation ponds located within the southern half of the Premises (Golder Associates 1997, page 10). The report URS 2013 (page 20) considered the vertical hydraulic conductivity at the Premises by calculating the horizontal hydraulic conductivity via slug tests conducted in groundwater monitoring bores. URS 2013 estimate that the hydraulic conductivity in soils beneath the ponds at the Premises range from 0.01 to 0.004 m/day, being equivalent to 1.16×10^{-7} to 4.6×10^{-8} m/s. The hydraulic conductivity of the underlying Broome sandstone is estimated to range from 1 to 10 m/day.

Clay content within the Pindan soil has been analysed for physiochemical parameters. URS 2013 undertook sampling during the installation of groundwater monitoring bores and found:

- The cation exchange capacity ranged between 0.6 to 16 meq/ 100g (URS 2013, page 12). The data is considered to indicate the potential for limited retardation of ammonia within the Pindan soil unit.
- The phosphorus retention capacity of the soil was found to be low to medium. The Phosphorus Retention Index (PRI) was assessed and ranged from 0 to 24 mL/g, the maximum concentration of phosphorus in soils was recorded at 120 mg/kg (URS 2013, pages 12 and 24). The data is considered to indicate that continuous infiltration of wastewater will result in the maximum sorption capacity of the soils being exceeded at some point.

As part of the construction works to deepen and install a liner within the Storage Pond, RPS 2016 undertook soil testing from the base of the original pond (previously Pond E3). Soil was tested to a depth of 0.5 m below the base of the original pond. Concentrations of nitrogen and phosphorus were found to decrease with depth. Maximum concentrations within the surface sediment were in the range of 1300-1570 mg/ kg total nitrogen and 1600-3300 mg/kg total phosphorus and concentrations fell to range of 160-170 mg/ kg total nitrogen and 150-570 mg/kg total phosphorus at 0.5 m depth. RPS 2016 concluded that nitrogen was leaching through the pond liners and that the Pindan soils complex strongly retained phosphorus.

Table 14: Soil and sub-soil characteristics within and adjacent Premises[1].

Bore number[1]		2/17S-D	9/17S-D	12/17S	19/17	5/17S-D	6/17S-D	7/17S-D	4/13D	3/13D
Location description		North of sewage facility.	West of sewage facility	Centre of sewage facility	Southwest corner of sewage facility	South (west) of sewage facility	South (central) of sewage facility	Southeast of sewage facility	East of sewage facility	East of sewage facility
Soil type/ profile	**Ground level (mAHD)**	13.19	11.68	12.87	10.68	10.4	10.85	10.42	9.6	9.51
	Pindan soil (mAHD)	Silty sand 13.19 to 11.09; Clayey sand 11.09 to 5.99; clayey/ sand gravel layer; silty sand with small gravel intersections 5.39 to -1.56	Silty sand 11.48 to 6.68; clayey sand 6.68 to 0.68; gravelly clayey sand 0.68 to -0.82; 1 m core loss section	Silty sand 12.87 to 9.17; clayey sand 9.17 to 0.87 (with multiple core losses).	Silty sand 10.68 to 8.68; clayey sand 8.68 to 2.18; clayey sandy gravel 2.18 to 0.18	Silty sand 10.4 to 7.2-4; clayey sand 7.2-4 to 1.5-2.1; gravelly clayey sand 1.5-2.1 to -0.7-(-)0.1	Silty sand 10.85 to 7.85; clayey sand 7.85 to -1.15 with small sand intersection;	Silty sand 10.42 to 6.82; clayey sand 6.82 to -1.78	Silty sand 9.6 to 7.0; clayey sand 7.0 to -0.2 with small gravel intersection;	Silty sand 9.51 to 7.51; clayey sand 7.51 to -2.49
	Top of Broome sandstone (mAHD)	Sandstone -1.56 to -1.76 then sand to -4.31.	Sand -1.83 to -4.33; sandy clay -4.33 to -4.83	N/A	Sandstone 0.18 to -0.32; clayey sandy gravel -0.32 to -1.82	Sandstone -0.7-(-)0.1 to -3.2; gravelly clayey sand -3.2 to -4.0; sand -4.0 to -6.1	Clayey sandy gravel -1.15 to -3.65; sand -3.65 to -5.65	Sand -1.78 to -6.08 Note: 7/17D2: sand extends to -9.28; sandstone -9.28 to -13.08 with gravelly sand intersection -9.58 to -10.58; sand -13.58 to –16.58	Sandstone -0.20 to -1.4; gravelly sand tending sand -1.4 to -5.4	Sandstone -2.49 to -4.29; sand -4.29 to -5.69; sandstone -5.69 to -6.99
Standing groundwater level (mAHD)		~2.59	~1.18	~2.37	~2.68	~1.9	~3.85	~2.42	~1.2	~2.01

Note 1: Water Corporation 2018a, *Broome South WWTP proposal to amend operational bore locations*.

As part of the investigations to install groundwater monitoring bores at the adjacent Broome Golf Club Field Capacity 2017b (page 20) found:

- Soils exhibited a phosphorus buffering index (PBI) in the range of 30 – 150 with samples at depths between 6.9 and 7.5 mBGL increasing to 170 – 200 PBI; and
- Increasing concentrations of iron within the soils at depth, correlated with higher proportions of gravel.

4.6 Meteorology

Annual evaporation exceeds rainfall at the Premises for most of the year as depicted by the data in Figure 3 and Figure 4. Rainfall and evaporation influences the volume of treated sewage that can be stored with the ponds across the year and the capacity of the reuse facilities to receive treated sewage. Winds from the southeast and east are more dominant during the morning periods, this may direct odour towards the Broome Golf Club and light industrial area (see Figure 5). Winds from the west are more dominant during the afternoon periods, this may direct odour towards and across the Roebuck Bay shoreline (see Figure 6).

The coastline of Western Australia between Exmouth to the west and Broome to the east is the most active in Australia for tropical cyclones and depressions. Tropical cyclones and depressions can result in rainfall events significantly greater than the mean values presented in Figure 3. The rainfall events can impact the storage capacity of the sewage system via direct rainfall inputs and indirectly through ingress into the sewage conveyance network and subsequent increased flows into the sewage facility.

In January and February 2018 tropical depressions resulted in significant rainfall events at Broome. Rainfall values for the months of January and February 2018 are detailed in Table 15 (Station 003003). A total of 915.6 mm of rain falling over the events. This is in comparison to an annual average rainfall total of 615.5 mm. As a result of rainfall events in early and mid-January combined with the very high rainfall events at the end of January and mid-February the containment capacity of the ponds at the Premises were compromised and an overflow events occurred (see Section 5.10.6 of this Decision Report).

Table 15: Broome rainfall January and February 2018 (source: Bureau of Meteorology).

Date range	1 – 6	7 – 11	12 – 13	14 – 15	16 – 17	18 – 26	27 – 28	29	30	31
January rainfall (mm)	3.2	83.4	108.2	2.4	43	8	102.4	97.2	439.4	58.2
February rainfall (mm)	50.2	1.2	7.6	0	402	102.8	50.2	N/A	N/A	N/A

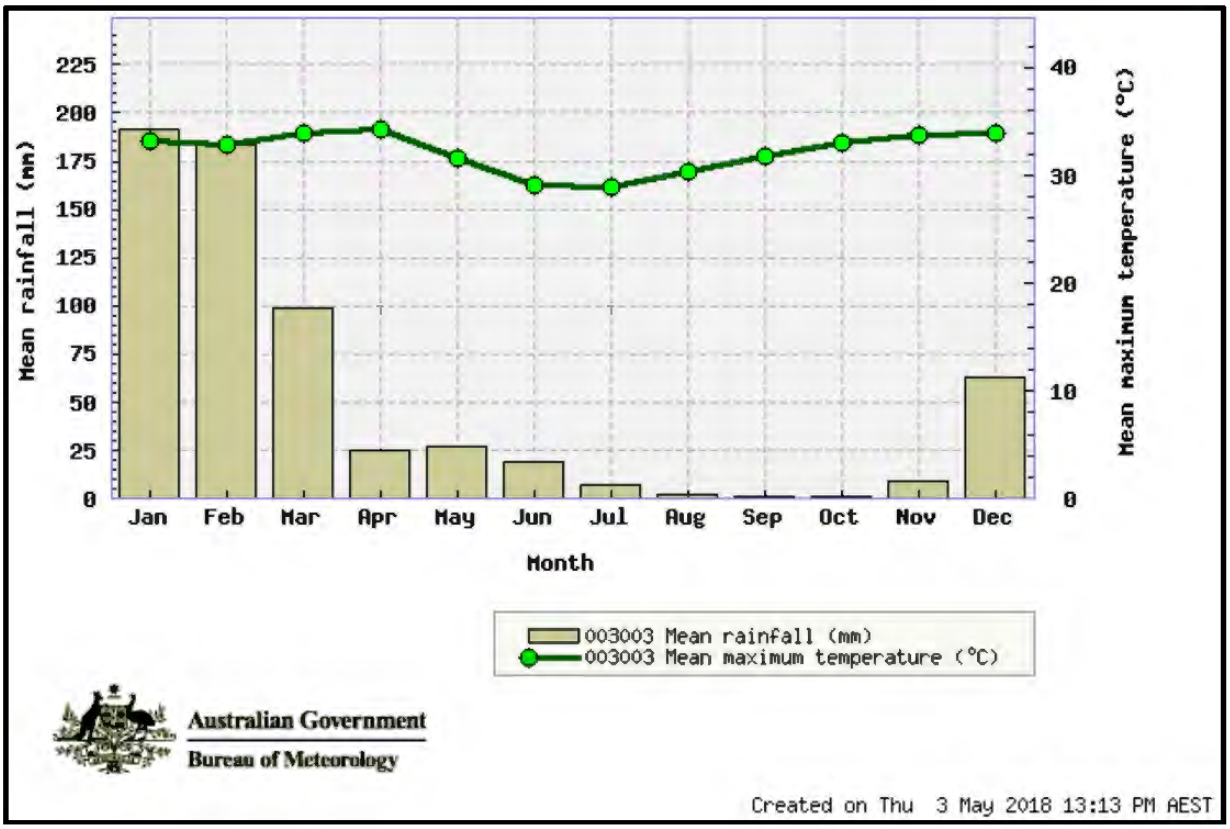


Figure 3: Mean monthly rainfall and mean maximum temperature (location 03003, Broome airport) (source: Bureau of Meteorology).

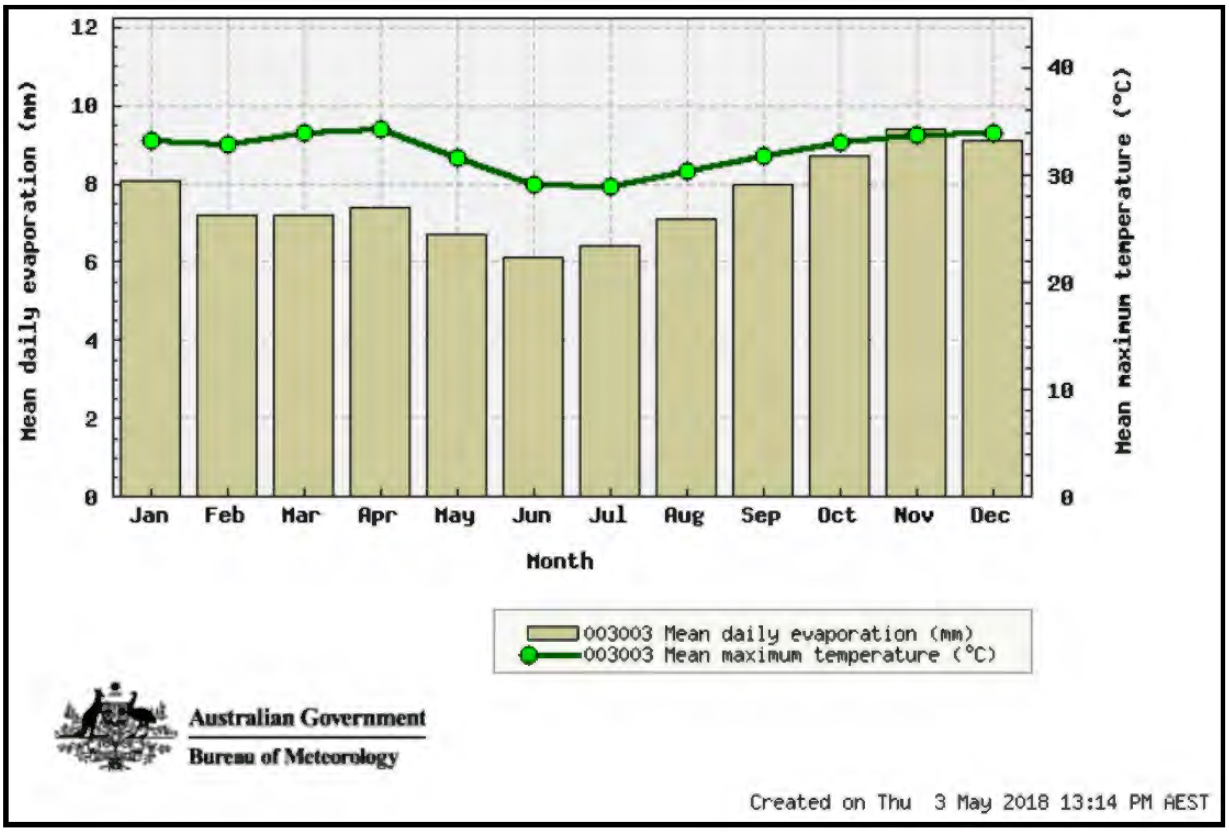


Figure 4: Mean daily pan evaporation and mean maximum temperature (location 03003, Broome airport) (source: Bureau of Meteorology).

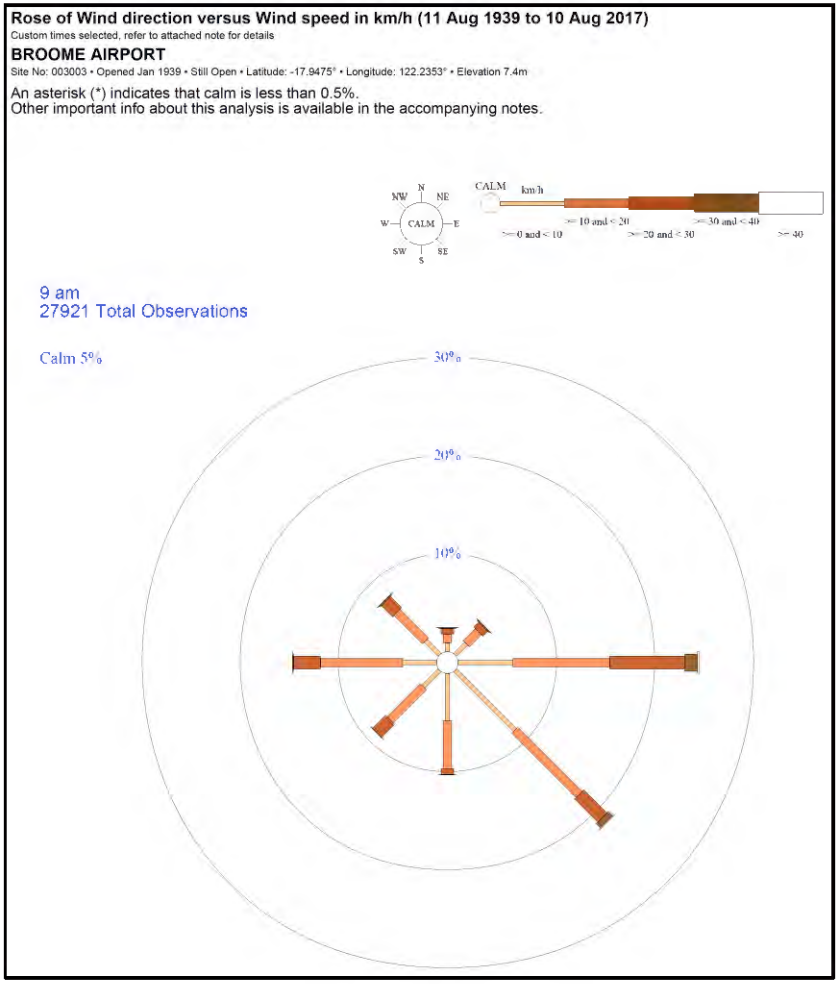


Figure 5: Annual average 9am wind plot (location 03003, Broome airport) (source: Bureau of Meteorology).

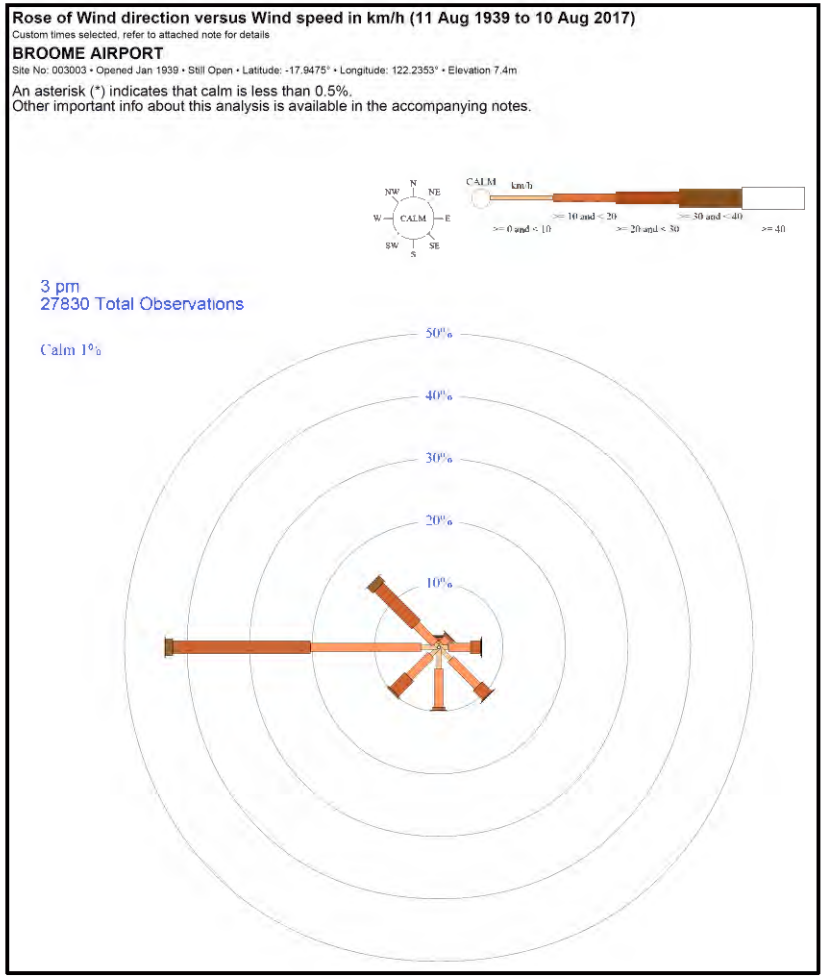


Figure 6: Annual average 3pm wind plot (location 03003, Broome airport) (source: Bureau of Meteorology).

5. Legislative context

Table 16 provides a summary of all approvals, tenure and relevant legislation that have been identified and are considered relevant to the assessment of the Review. The relevant legislation and approvals are discussed in further detail in the sections below. Any approval granted under the Revised Licence does not absolve the Licence Holder from ensuring that all other statutory approvals to operate the Primary Activities at the Premises are in place.

Table 16: Relevant approvals and tenure.

Legislation	Location/ number	Subsidiary	Approval type/ status
Environment Protection and Biodiversity Conservation Act 1999 (Cwth)	Not applicable	Not applicable	Not applicable
Land Administration Act 1997 (WA)	Management Order for Lot 1639 on Plan 184761 (Premises)	Water Corporation	Sewage facility
	Management Order for Lot 512 on Plan 409418 (Premises)	Water Corporation	Sewage facility
Planning and Development Act 2005 (WA)	Not applicable	Not applicable	Not applicable – see Section 5.3
Port Authorities Act 2005 (WA)	Not applicable	Not applicable	Not applicable
Conservation and Land Management Act 1984 (WA)	Not applicable	Not applicable	Not applicable
Dangerous Goods Safety Act 2004 (WA)	Dangerous Goods Licence DGS014024	Water Corporation	Chlorine gas storage
Health Act 1911 (WA)	(a) Not applicable	(a) Not applicable	Not applicable
Contaminated Sites Act 2004 (WA)	(a) Lot 1639 on Plan 184761 (Premises) (b) Lot 512 on Plan 409418 (Premises) (c) Lot 510 and 511 on Plan 409418 (Broome Golf Club) (d) Other adjacent lands: Lot 604 on Plan 76204, Lot 2824 on Plan 218274 and Lot 450 on Plan 72936	(a) Water Corporation (b) Water Corporation (c) Broome Golf Club (d) Unallocated Crown Land, Shire of Broome and Yawuru Native Title Holders Aboriginal Corporation	(a) Contaminated – remediation required (source site) (b) Reported (c) Reported (d) Reported
Part V of the EP Act (WA)	Lot 1639 on Plan 184761: Licence L6266/1991/10	Water Corporation of Western Australia	Category 54 sewage facility and Category 61 liquid waste facility

5.1 Environment Protection and Biodiversity Conservation Act

Under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) approval from the Australian Government Environment Minister is required for actions that do have, will have or are likely to have a significant impact on matters of national environmental significance. The following matters of national environmental significance are located proximate to the Premises within Roebuck Bay:

- Wetland of international importance: being the Roebuck Bay Ramsar site number 479.
- Migratory bird species: being those listed under the Bonn Convention, Japan-Australia Migratory Bird Agreement (JAMBA), China-Australia Migratory Bird Agreement (CAMBA) and the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA).
- Other endangered and threatened species including bird, dolphin, dugong, sawfish, whale and turtle (including endangered *Caretta caretta*, *Dermochelys coriacea* and threatened *Chelonia mydas* and *Natator depressus*) species that use the shoreline, intertidal and marine areas of Roebuck Bay.

The location of the Premises in relation to the Roebuck Bay Ramsar wetland, Dampier Creek (nationally important wetland), and the interconnecting mud flats (national heritage place) are depicted in Figure 7. Figure 7 does not detail the distribution of mobile fauna species that are matters of national environmental significance or threatened ecological communities.

Figure 7: Location of Premises (red dot) in relation to matters of national environmental significance, excluding fauna (source: http://www.environment.gov.au/epbc/protected-matters-search-tool).

(4) The Delegated Officer notes that nothing in this Decision Report limits the obligations of the Licence Holder under Section 68 of the EPBC Act.

5.2 Land Administration Act

The vesting details of lands at the Premises under the *Land Administration Act 1997* are summarised in Table 17. The Existing Licence applies to part of Lot 1639 on Plan 18476, being part of Crown Reserve 37454. The Existing Licence does not apply to Lot 512 on Plan 409418. Consistent with Key Finding (1) and the vesting of lands under the *Land Administration Act 1997*, the Revised Licence will apply to Lot 1639 on Plan 18476 and Lot 512 on Plan 409418.

Table 17: Vesting of lands under the *Land Administration Act 1997* subject to Review.

Lot/ location	Proprietor	Vested authority	Management Order	Land use purpose
Lot 1639 on Plan 184761 Broome South sewage facility	Department of Lands	Water Corporation	Management Order Registration Number (*not identified*)	Sewage treatment
Lot 512 on Plan 409418 Broome South sewage facility (reuse infrastructure)	Department of Lands	Water Corporation	Management Order Registration Number (*not identified*)	Sewage treatment

(5) The Delegated Officer notes that the vesting of lands at the Premises are consistent with the Primary Activities.

5.3 Planning and Development Act

The Premises is vested by management order with Water Corporation for the use of sewage treatment. Under Section 6 of the *Planning and Development Act 2005* the public works are exempt from development/ planning approval. This is consistent with Section 137 of the *Water Services Act 2012* that exempts the Licence Holder, in its capacity as service provider, from the requirement to obtain development approvals for Public Service Works under a Local Planning Scheme.

The location of the Premises and zoning of the surrounding lands under the *Shire of Broome Town Planning Scheme No. 6* is depicted in Figure 8. Lot 1639 on Plan 184761 is zoned for public purposes wastewater treatment plant. Part of the Premises, being Lot 512 on Plan 409418 is located within land zoned 'parks, recreation and drainage' being the Shire of Broome Golf Club. Land located directly south of the Premises is zoned 'coastal', to the north 'light and service industry' and to the east 'development'. The closest land zoned 'residential' is located approximately 400 m east of the Premises, directly adjacent the 'essential service buffer area' for the Broome South sewage facility.

(6) Key Finding: The Delegated Officer finds, consistent with the *Guidance Statement: Land use planning*, that there are no known planning decisions that limit a determination through this Review. Taking into consideration the history of operations within Lot 512 on Plan 409418, the apparent lack of alignment with the planning scheme is not considered to be materially relevant in this Review and decision to grant the Revised Licence.

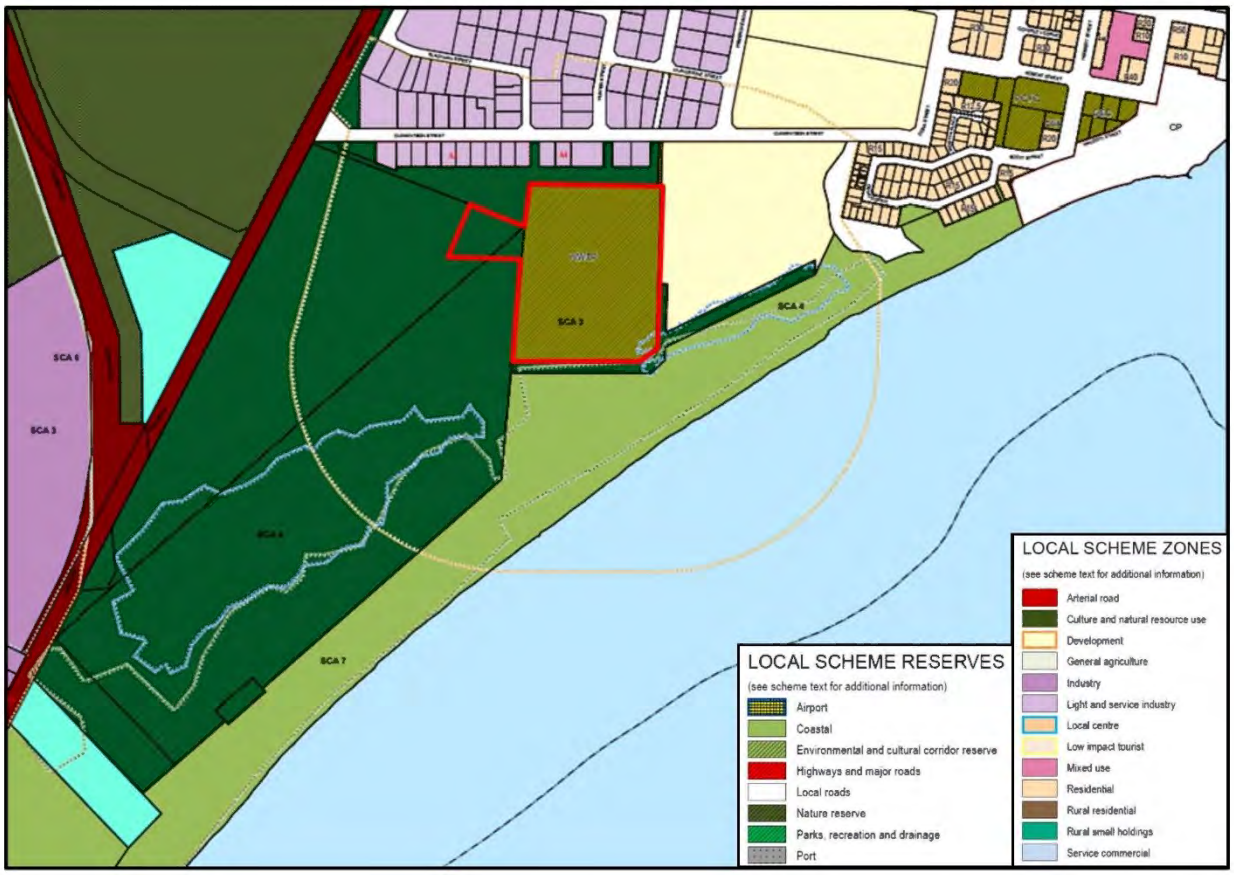


Figure 8: Premises location (red line) and zoning of adjacent lands (source: adapted from *Shire of Broome Town Planning Scheme No. 6*).

5.4 Port Authorities Act

The marine waters directly south of the Premises are located within the Port of Broome under the Kimberley Port Authority defined by Schedule 1 of the *Port Authorities Act 1999*. The provisions of The EP Act are not limited in operation under the *Port Authorities Act 1999,* Section 31(2). The boundary of the Port of Broome detailed in **Error! Reference source not ound.**.

(7) Key Finding: The Delegated Officer finds that while the area of Roebuck Bay adjacent to the Premises is within the Port of Broome boundary, the environmental values remain consistent with those of Roebuck Bay as an area of high conservation value and special significance and incorporate the Threatened Ecological Community *Roebuck Bay mudflats*, flora and fauna.

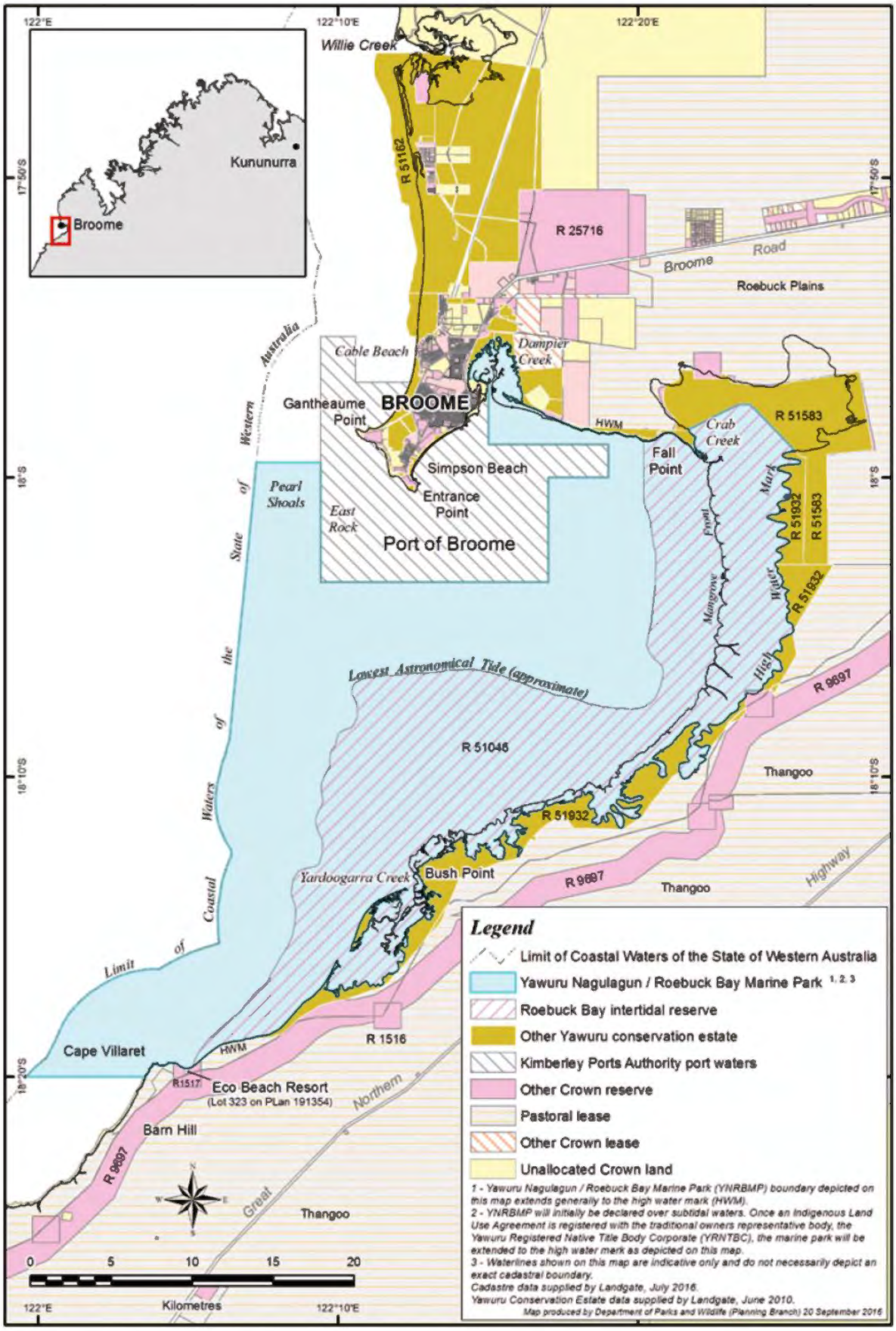


Figure 9: Tenure and conservation classification of the land and waters around Roebuck Bay (source: DPAW 2016, page 17).

5.5 Conservation and Land Management Act

The marine waters of Roebuck Bay, excluding the Port of Broome, are defined as a marine park under Section 6(6) of the *Conservation and Land Management Act 1984* (CALM Act) and are subsequently vested with the Conservation and Parks Commission (CPC) under Section 7(1)(e) of the CALM Act. The marine park waters, excluding the Port of Broome, are referred to as Yawuru Nagulagun/ Roebuck Bay Marine Park as defined within the *Yawuru Nagulagun / Roebuck Bay Marine Park Order 2016* (*Western Australian Government Gazette* No. 181, 4 October 2016, page 4246) and *Yawuru Nagulagun / Roebuck Bay Marine Park (Alteration of Boundaries) Order 2017* (*Western Australian Government Gazette* No. 41, 14 February 2017, page CO401). See Figure 9**Error! Reference source not found.** for the locations and oundaries of the Yawuru Nagulagun/ Roebuck Bay Marine Park. Section 13(B)(1) of the CALM Act defines marine parks as being reserved for:

> '*… allowing only that level of recreational and commercial activity … consistent with the proper conservation and restoration of the natural environment, the protection of indigenous flora and fauna and the preservation of any feature of archeological, historic or scientific interest'.*

The Department of Biodiversity Conservation and Attractions (DBCA) is responsible for day to day management of the Yawuru Nagulagun/ Roebuck Bay Marine Park on behalf of the CPC. With regard to the factors discussed in Section 6 of this Decision Report, the then Department of Parks and Wildlife published the '*Yawuru Nagulagun/ Roebuck Bay Marine Park Joint Management Plan 2016*' (DPAW 2016) that identifies:

- factors that contribute to the blooms of *Lyngbya majuscula* have been identified as elevated nutrient levels in the sediments and water column of Roebuck Bay, particularly sediments high in ammonia and phosphorus;
- potential sources of nutrients are identified as including seepage from the Premises and from the irrigation of treated sewage at the Broome Golf Club (Section 4.2.2, pages 33-34);
- the leakage into groundwater and surface drainage discharge from the Premises is an existing and potential pressure on filter feeding communities (Section 4.2.6, page 45);
- blooms of *Lyngbya majuscula* have the ability to impact the distribution and abundance of benthic intertidal fauna that then affects the foraging behaviour of shorebirds (Section 4.2.2, page 34);
- blooms of *Lyngbya majuscula* are identified as potentially impacting seagrass health (Section 4.2.3, page 38); and
- blooms of *Lyngbya majuscula* are identified are an existing and potential pressure on the food source of shorebirds (Section 4.2.6, page 45).

Consultation with the DBCA is detailed in Appendix 2 of this Decision Report.

(8) Key Finding: In accordance with the *Guidance Statement: Risk Assessment* the Delegated Officer interprets that the DPAW 2016 management plan finds that blooms of *Lyngbya majuscula* to foreseeably present a severe consequence to the environmental values of Roebuck Bay and that the Primary Activities at the Premises could contribute to this impact occurring.

5.6 Dangerous Goods Safety Act

The Licence Holder was granted Licence number DGS014024 under the *Dangerous Goods Safety Act 2004* by the Department of Mines, Industry Regulation and Safety, (source: RPS Environment and Planning Pty Ltd 2015b, page 193). The approval was for 1.6 kL of chlorine gas that is used for disinfection of treated sewage prior to transfer of treated sewage for irrigation at the reuse facilities.

(9) Key Finding: The Delegated Officer finds that the storage and application of chlorine gas to the sewage facility is regulated by the *Dangerous Goods Safety Act 2004* and is not a matter to be considered in this Review.

5.7 Health Act

The Department of Health (DoH) regulates recycled water schemes through approvals under the *Health Act 1911* (Health Act) for the protection of public health. Treated sewage discharged from the Premises is approved under the Health Act**Error! Reference source not ound.**. The approved reuse schemes are required to be operated in accordance with the Department of Health 2011 *Guidelines for the non-potable uses of recycled water in Western Australia* and conditions of the relevant approval. Health Act approval A49/BM000 is granted to the Shire of Broome and approval A49/GC000 is granted to the Broome Golf Club Incorporated. Health Act approval is not relevant to the assessment of Risk Events at the Premises.

5.8 Contaminated Sites Act

The then Department of Environment Regulation classified the Premises on 28 April 2015 as being *Contaminated – remediation required* under the CS Act. A Detailed Site Investigation is expected to be submitted to DWER by the Licence Holder in 2019 (see *Assessment and management of contaminated sites* for further information). Identified reports submitted to the then DER and DWER under the *Contaminated Sites Act 2003* has been, and future submissions will be, considered within the scope of this Review.

(10) Key Finding: The Delegated Officer notes that:

(a) any existing contamination of groundwater as a result of operations at the Premises will be considered under the *Contaminated Sites Act 2003*; and

(b) the risk of ongoing and future contamination of groundwater and impacts to receptors as a result of operations at the Premises will be addressed through this Review.

5.9 Part IV of the EP Act

The operations at the Premises have not been subject to a referral or approval under Part IV of the EP Act.

5.10 Part V of the EP Act

5.10.1 Applicable regulations, standards and guidelines

The overarching legislative framework of this assessment is the EP Act and EP Regulations. Guidance Statements published by the then DER that inform this assessment under Part V of the EP Act are detailed in Appendix 1 of this Decision Report.

5.10.2 Works approval and licence history

A summary of the works approval and licence history for the Premises is detailed in Table **18**.

Table 18: Works approval and licence history.

Instrument	Granted	Nature and extent of works approval, licence or amendment
L6266/1991/1-5	N/A	Historical versions of the Existing Licence.
L6266/1991/6	22 September 2003	New Licence reissued, replaced Licence L6266/1991/5.
W3685/1991/1	23 December 2002	New works approval following application by the Licence Holder to reconfigure the existing sewage facility pond system and increase the sewage treatment capacity from 3,100 m^3/ day to 3,500 m^3/ day. Works included (source A877948): • Convert the southwest pond to be the primary pond and lined with High Density Polyethylene (HDPE); • Convert the south east and middle infiltration storage ponds to be the secondary and tertiary ponds; • Convert the northern treatment ponds into storage ponds
L6266/1991/7	5 October 2004	New Licence reissued, replaced Licence L6266/1991/6.
L6266/1991/8	31 October 2007	New Licence reissued, replaced Licence L6266/1991/7.
L6266/1991/9	1 November 2011	New short term Licence reissued, replaced Licence L6266/1991/8.
L6266/1991/10	29 December 2011	New Licence reissued, replaced Licence L6266/1991/9 and incorporated amendments including: • Condition 25: submission of a hydrogeological report by June 2013; and • Condition 27: submission of a nutrient irrigation management plan by June 2012.
L6266/1991/10	4 July 2013	Amended Licence, extending the submission date for Condition 25 from 31 June 2013 to 30 October 2013 and removing the conditions regarding the nutrient loading rate calculations and nutrient irrigation management plan that were due for submission by 30 June 2012.
L6266/1991/10	10 December 2015	Amended Licence granted following application by the Licence Holder dated 23 February 2015 to approve the testing of pH in the monitoring program at the Premises and not within a NATA accredited laboratory. Administrative updates were also implemented: • Condition 25 regarding submission of a hydrogeological report by June 2013 became Condition 23.

Instrument	Granted	Nature and extent of works approval, licence or amendment
L6266/1991/10	16 June 2016	Amended Licence granted following application by the Licence Holder dated 17 May 2016 to approve works to increase the capacity of and install a new liner (permeability ≤2 x 10^{-10} m/s) within pond E3 (being the Storage Pond in the Revised Licence) and subsequently redirect the flow of sewage through the sewage treatment facility infrastructure. Conditions included: • Conditions 12 and 24-28 were added regarding seepage management and reporting, including the submission of a Leakage Management Plan by 31 May 2018, being 6 months after the operation of the Storage Pond (previously pond E3) that commenced in November 2017 (see Section 6.3 of this Decision Report). • Condition 23 regarding submission of a hydrogeological report by June 2013 became Condition 30 (see Section 0 of this Decision Report).

5.10.3 Key and recent works approvals and approved works

In 2003, an upgrade of the sewage facility was completed in accordance with Works Approval W3685/1991/1. The upgrades were in part a response to an overflow event at the Premises that occurred following Tropical Cyclone Steve in March 2000 and resulted in sewage being discharged into Roebuck Bay. The works involved the re-configuration of the sewage treatment ponds, lining the Primary Pond with HDPE and increasing the design capacity of the sewage facility from 3,100 m^3/ day to 3,500 m^3/ day. At the time all ponds other than the Primary Pond remained lined with compacted in-situ Pindan soils.

A summary of more recent works is provided in Table 5 of this Decision Report. Not all works that influence the operations at the Premises, such as works to the sewage network in the Broome town site catchment, are subject to approvals under Part V of the EP Act.

5.10.4 Key and recent licence amendments

Licence Amendment granted June 2016

The Licence Holder applied to amend Licence L6266/1991/10 on 17 May 2016 seeking approval to deepen and line the Storage Pond. The Storage Pond was previously referred to as 'Pond E3'. The works provided a storage capacity of 58,409 m^3 with a geosynthetic clay liner (GCL). The GCL provided a permeability co-efficient of ≤2 x 10^{-10} m/s. The storage pond liner configuration is depicted in Figure 10. The increased storage capacity does not include the additional 492 mm freeboard, equivalent to 9,581 m^3 storage that the Storage Pond provides during emergency events, before discharging to the environment. Emergency Ponds also provide an additional 21,900m^3 storage before discharging to the environment. Approval to install the GCL liner was granted on 16 June 2016, being the Existing Licence.

The Licence Holder submitted the construction compliance document Bowman and Associates Pty Ltd *Broome south waste water treatment facility holding pond E3 liner installation – construction quality assurance report* (Bowman and Associates 2016) in December 2016. Bowman and Associates 2016 stated that the deepening and lining of the Storage Pond were completed in accordance with the conditions of the Existing Licence. Following completion of the Storage Pond works all sewage is now redirected from the Tertiary Pond directly to the Storage Pond.

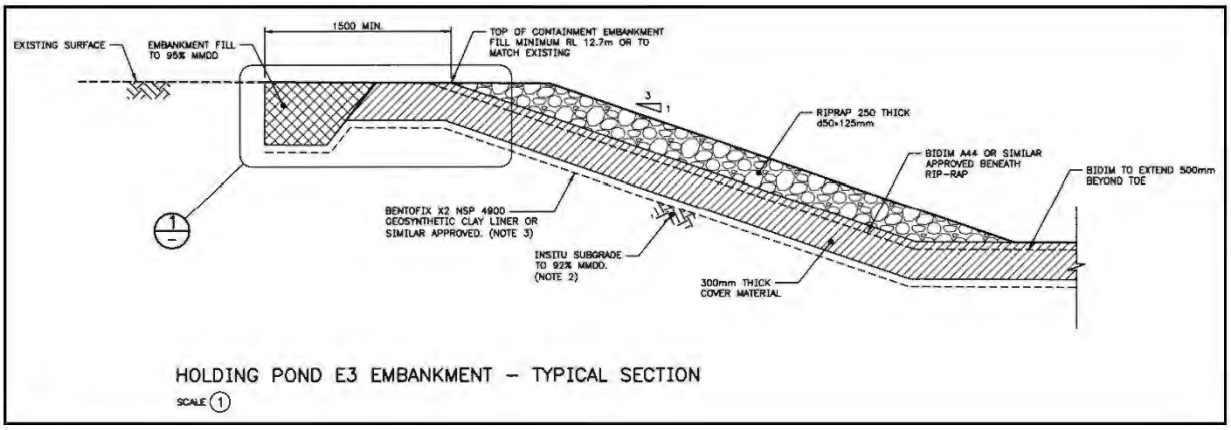


Figure 10: Storage pond approved liner configuration construction plan (adapted from Bowman and Associated 2016, page 25).

Draft Referral: draft Revised Licence and draft Decision Report 14 November 2016

On 14 November 2016, as part of the Review process, the then DER referred a Draft Revised Licence and Draft Decision Report (2016 Draft Referral) to the Licence Holder for consultation. The Draft Referral was based on the consideration that the risk of nutrients seeping into groundwater and impacting the Roebuck Bay ecosystem as a result of the Premises operations were a high-risk event, based on a major consequence and likely likelihood. Controls that were proposed in the 2016 Draft Referral included:

- the decommissioning of the 'holding pond' (*referred to as Emergency Pond 3 under the Revised Licence*) and 'emergency pond 1' (*referred to as Emergency Pond 1 under the Revised Licence*);
- the liners of all operational ponds meeting minimum specifications by specified dates; and
- limits on the nutrient load within treated sewage for discharge from the Premises to the reuse facilities by specified dates.

Since the 2016 Draft Referral the Licence Holder has provided the responses and additional information detailed in Table 19 and Table 20 that includes a summary of the items most relevant to this Review and reconsideration of the 2016 Draft Referral.

(11) Key Finding: The Delegated Officer notes that due to the additional information received and changes made to the Primary Activities at the Premises since the risk assessments for the 2016 Draft Referral were completed that it was necessary for all Risk Events arising from the Primary Activities at the Premises to be reassessed (see Section 8 of this Decision Report).

The following key elements of the 2016 Draft Referral were amended within this Decision Report and Revised Licence:

(a) The operational infrastructure at the Premises was altered and the alterations are reflected within this Decision Report and the risk assessments;

(b) The assessment of the reuse facilities was excluded from the scope of this Review (see Section 3.4 of this Decision Report).

(c) The consequence of seepage emission impacts from the Premises ponds to Roebuck Bay was Major in the Draft Referral. This has been reassessed (see Section 8.6 of this Decision Report).

(d) The likelihood of impact from seepage emissions, from the Premises ponds, to Roebuck Bay was Likely in the Draft Referral. This has been reassessed for pre-2017 and post-2017 operating conditions (see Section 8.6 of this Decision Report).

(e) Additional information submitted by the Licence Holder was considered within the Review and risk-based assessment process.

(f) Controls (draft conditions of Licence L6266/1991/10) proposed within the 2016 Draft Referral were amended to the Conditions within the Revised License following consideration of the alterations to the operational infrastructure, the additional information submitted by the Licence Holder and commensurate to the findings of the risk-based assessments present within this Decision Report (see Section 9.1 and Attachment 1 of this Decision Report).

Table 19: Submissions relevant to the Review for the 2016 Draft Referral.

	Date submitted	Submission title/ details	Consideration in this Decision Report
1	31 January 2017 (A1474510)	*Response to Draft Licence L6266/1991/10 – Environmental Protection Act 1986 ("EP Act")*: **(a)** Objection to hydrostatic leak testing of the Storage Pond. **(b)** Objection to the decommissioning timeframe, 1 June 2017, for some of the emergency ponds. **(c)** Objection to the lining of the Secondary Pond by 31 May 2020 and Tertiary Pond by 31 May 2018. **(d)** No sludge drying hardstand area is currently constructed at the Premises. **(e)** Clarification required for flow metering device requirements. **(f)** Changes to the operational configuration of the ponds assessed in the Draft Referral. **(g)** Changes to the infrastructure and equipment specifications assessed in the Draft Referral. **(h)** Objection to the nutrient loading limits for the reuse facilities and need to consider pending irrigation management documents (being Field Capacity 2017a and Field Capacity 2017b).	**(a)** See Appendix 4 (Technical Expert Report) and Condition 5 of the Revised Licence. **(b)** See Section 3.3; addressed via updated risk assessments. **(c)** See Section 8.6 and Conditions 5 and 6 of the Revised Licence. **(d)** Noted, see Condition 4 of Revised Licence. **(e)** Noted, recording of Category 61 wastes accepted via controlled waste tracking forms is adequate. **(f)** See Section 3.3; addressed via updated risk assessments. **(g)** See Section 3.3; addressed via updated risk assessments. **(h)** See Section 3.4, not addressed in this Decision Report.
		General comment: changes to the operations at the Premises are risk assessed in this Decision Report, the conditions of the Draft Referral have been updated commensurate to the risk of the operations being undertaken at the time of this report.	
2	31 August 2017 (A1516812)	*Re: Draft EP Act Licence L6266/1991/10 Broome South WWTP*: **(a)** Confirmed permanent reduction of sewage inflow to 1.88 ML/ day (< 2,000 m^3/ day). **(b)** Confirmed permanent reduction to four full-time sewage treatment ponds. **(c)** Confirmed GCL lining of the storage pond, decommissioning and emergency ponds arrangements. **(d)** Requested an extension to meeting the requirements of the Draft Referral from December 2021 to 31 December 2025. **(e)** Submission of reports Field Capacity 2017a and Field Capacity 2017b. **(f)** Identified the need to consider pending seepage assessment documents (being Golder Associates 2017). **(g)** Identified the need to consider pending Detailed Site Investigation documents required under the CS Act.	**(a)** See Section 8.4 and Condition 2 of the Revised Licence. **(b)** See Section 3.3; addressed via updated risk assessments. **(c)** See Section 3.3; addressed via updated risk assessments. **(d)** See Section 8.6 and Condition 5 and 6 of the Revised Licence. **(e)** See Section 3.4, not addressed in this Decision Report. **(f)** See Section 6.2, Section 8.6 and Conditions 5 and 6 of the Revised Licence. **(g)** See Section 5.8, information will be assessed through due process as it becomes available.
3	12 December 2017 (A1586244)	McMahon and Dunham 2017, *Investigation into nitrogen sources for Roebuck Bay and the Yawuru Nagulagun/ Roebuck Bay Marine Park a final report for Water Corporation*:	See Section 6.4.3.
4	15 December 2017 (A1580982)	Golder Associates Pty Ltd 2017, *Broome South WWTP – Water balance analysis and seepage loss assessment*.	See Section 6.2.

Table 20: Further information provided February 2018 treatment summary.

	Submitted file name	Reference	Consideration in this Decision Report
1	BM66-002-006-01B	A1627944	Maps and plans for infrastructure layout at various locations and times within the Premises. Content used to cross-reference figures and inform the risk assessment processes in Section 8.4 and Section 8.6.
2	BM66-002-007-01A	A1627932	
3	BM66-003-007-01E	A1627937	
4	BM66-003-008-01E	A1627948	
5	BM66-003-014-01A	A1627953	
6	BM66-003-015-01C	A1627947	
7	BM66-003-016_A	A1627941	
8	BM66-005-005-01E	A1627950	
9	BM66-005-006-01E	A1627933	
10	BM66-005-007-01E	A1627939	
11	BM66-005-008-01F	A1627955	
12	BM66-005-012-01C	A1627951	
13	BM66-085-016-01A	A1627957	
14	Broome Golf Club MoU_Dec 2012	A1627935	Noted, see Section 3.4.
15	Broome South WWTP L6266 – Process Description – Jan 2018	A1627952	See Section 3.
16	Broome South WWTP Process Control Table Schematic	A1627930	Plan for infrastructure layout and monitoring point locations, see Section 3.3 and informs conditions of the Revised Licence addressed under Sections 9.1.4
17	BroomeWWTP_DWER_fig1v2.1	A1627946	Maps and plans for infrastructure layout and operational arrangements at the Premises, see Section 3.3 and Figure 2.
18	BroomeWWTP_DWER_fig2v2	A1627936	
19	BroomeWWTP_DWER_fig3v2	A1627945	
20	BroomeWWTP_DWER_fig4v3	A1627943	
21	EK58-001-002-01A	A1627956	Maps and plans for reuse infrastructure pumps and filter arrangements noted and considered in Section 3.3.
22	EK58-060-002-01C	A1627954	
23	EK58-091-002-01C	A1627934	
24	EK58-091-003-01C	A1627940	
25	EK58-091-005-01B	A1627949	
26	EK58-091-009_C	A1627938	
27	Incident - Wastewater - NWR Broome - Significant Rainfall Event - Section 72 Notification	A1627921	See Section 4.6
28	Letter to DWER - Broome South L6266 - Clarification on licence amendment information	A1627931	Multiple sections referenced as Water Corporation 2018a throughout this Decision Report, data considered to supersede any relevant inconsistent information/ values sourced from older reference documents.
29	Proposal to amend monitoring bore locations	A1627942	See Section 9.1.4.
30	Recycled Water Supply Agreement Broome Shire	A1627929	Noted, see Section 3.4.

5.10.5 Compliance inspections and compliance history

No items are identified through compliance inspections and reported incidents that are considered materially significant for the Review other than overflow events. An overflow event in 2000 triggered upgrades under Works Approval W3685/1991/1 and a spill of approximately 8 kL within the Premises has also occurred. The overflow events in 2018 are addressed in section 5.10.6 of this Decision Report.

5.10.6 2018 overflow events

Section 4.6 of this Decision Report described the meteorological conditions over January 2018 that gave rise to the overflow of the sewage facility and discharge to Roebuck Bay. The January overflow incident was recorded under DWER Incident Complaint and Management System item 48214.

A notification required under Section 72 of the EP Act was received by DWER on 14 February 2018. The notification identified that:

- the Premises has a total hydraulic capacity of 213 ML of which, 23 ML are the combined total capacity of Emergency Pond 1, 2 and 3;
- the Storage Pond has a freeboard (492 mmm) designed to contain '*a 1 in 50 year rainfall event*';
- the rainfall event between 27th and 31st January 2018 resulted in '*a >1 in 100 year 24 hour ARI [average recurrence interval] event and >1 in 100 year 5 day ARI event*'; and
- approximately 20.72 ML of wastewater was discharged from the Premises, ~16.1 ML overflowing to Roebuck Bay and ~4.6 ML that was transferred to Emergency Pond 3.

The rainfall event resulted in the overflow of ~20.72 ML of wastewater of which, ~16.1 ML was discharged to the environment. The flow path of the overflow is depicted in Figure 11.

High rainfall also occurred in February 2018 and a subsequent overflow incident was recorded under DWER Incident Complaint and Management System item 48457. The incident was similar to the January 2018 event and resulted in the overflow of ~23.7 ML of wastewater that discharged to the environment.

The report Water Corporation May 2018, *Broome high rainfall events January – February 2018 water quality results sampling report* (Water Corporation 2018c) provides a summary and review of the overflow event and sampling undertaken. Water Corporation 2018c identifies that:

- during peak rainfall events an estimated 75% of the inflows to sewage facilities can be stormwater with peak inflows to the Premises; peak inflows at Broome South were recorded between 3.65 and 4.43 times average annual daily inflow;
- the overflow from the Broome South sewage facility had passed through the sewage facility treatment ponds and discharged from the storage pond spill way to the environment to the east side of the Premises;
- the volumetric contribution of the Broome South sewage facility overflow was insignificant in comparison to the total stormwater input to Roebuck Bay during the rainfall events; and

- sampling of stormwater and wastewater occurred during the events however, the meteorological conditions limited access to sample locations and services at times; six sample events occurred between the 2 and 20 February 2018, results are presented in Table 21.

Water Corporation 2018c is considered further in the risk assessment for containment failure and overtopping (see Section 8.4. of this Decision Report).

Table 21: Sampling results for *Escherichia coli* (cfu/ 100 mL) (source Water Corporation May 2018c. page 6).

Sample date	Storm water	Untreated wastewater	Treated wastewater	Storm water + treated wastewater
2/02/2018	2,400	>2.4 million	No sample	63
3/02/2018	12,000	>2.4 million	No sample	3,300
4/02/2018	2,000	>2.4 million	No sample	1,000
17/02/2018	8,700	>2,400	600	710
19/02/2018	98	10 million	610	750
20/02/2018	14,000	13 million	120	2,000

Figure 11: Path and discharge point to Roebuck Bay of 2018 overflow events.

The overflow from the Premises is depicted in Figure 12 and the subsequent point of discharge to Roebuck Bay was through the erosion of the primary dune that was caused by a combination of stormwater runoff and overflow from the Premises. The Licence Holder reported that the sand dune was observed to have been washed away at ~0400 hours and that the sewage facility began overflowing at ~0600 hours on Tuesday 30 January 2018The overflow from the Premises followed the preferential flow path into Roebuck Bay.

Figure 12: Overflow from Premises (source: Environs Kimberley Incorporated).

6. Modelling and monitoring data

An extensive body of monitoring and research has been undertaken regarding the operations at the Premises, the treated sewage reuse facilities, local hydrogeology and the Roebuck Bay ecosystem. A full list of monitoring and research reports considered in this Review are detailed in Appendix 1. The following Sections 6.1 through 6.7 of this Decision Report summarise the elements raised in the monitoring and research that are considered significant to this Review. This includes consideration of relevant reports submitted in response to the Conditions of the Existing Licence, 2016 and 2018 Draft Referrals and previous versions of Licence L6266/1991/10. Technical expert advice from within DWER has been considered in the Review and sections below, a copy of the Technical Expert Report is provided in Appendix 4. In summary:

- Section 6.1 considers the groundwater monitoring data required by Conditions of the Existing Licence.
- Section 6.2 considers the content of reports submitted by the Licence Holder in response to Condition 30 (hydrogeological report) of the Exiting Licence.
- Section 6.3 considers the content of reports submitted by the Licence Holder in response to Condition 28 (leakage management plan) of the Exiting Licence.
- Section 6.4 considers the content of reports that investigate the hydrogeology, groundwater and Roebuck Bay marine ecosystem more broadly and the report McMahon and Dunham 2017 is considered under Section 6.5.3.
- Section 6.5 considers the identified submissions made under the requirements of the *Contaminated Sites Act 2003*. This includes the Golder Associates 2018 submission made as part of the 2018 Draft Referral process.
- Section 6.6 considers submissions made by Golder Associates Pty Ltd, including the content of the Golder Associates 2017 pond seepage loss assessment and response to elements of the 2018 Draft Referral.
- Section 6.7 provides a consolidated summary of the information considered in Sections 6.1 to 6.6 and how groundwater and hydrogeological information across all sources relates to the foreseeable Risk Events that arise due to the Primary Activities at the Premises. The groundwater monitoring data that is relevant to the assessment of the Primary Activities at the Premises and irrigation of treated sewage at reuse facilities is generally not documented in a consolidated or comprehensive format; the outcomes of the DSI process will help address this issue further in phase 2 of the Review.

6.1 Monitoring of groundwater

Groundwater monitoring bores considered in the Review have been installed at the Premises and surrounding lands in four phases (1997, 2004, 2013 and 2017). Not all monitoring bores installed during 1997 and 2004 phases are captured under the Existing Licence monitoring requirements. In 2013 nine groundwater bores were installed that included bores within the Broome Golf Club irrigation area. As part of the *Contaminated Sites Act 2003* process requirements additional groundwater bores were installed in 2017. The 2013 and 2017 groundwater bores are not captured under the monitoring requirements of the Existing Licence. Bore locations are depicted in Figure 13.

The Licence Holder has been required under Conditions of the Existing Licence to submit Annual Environmental Reports (AERs) that include quarterly monitoring data for groundwater bores 1/04, 2/04, 2/97, 3/04, 3/97, 4/97 and 8/97. These bores are part of the 1997 and 2004 installation phases. Groundwater bores 2/97, 3/04 and 4/97 are nested bores and have a shallow and deep monitoring bore component.

The Existing Licence does not delineate between shallow and deep monitoring bore components. The Delegated Officer understands that only monitoring data from the shallow bores are reported by the Licence Holder within AERs.

Based on the locations of the groundwater bores reported under the AERs some assumptions can be made based on groundwater generally flowing from the north to south at the Premises. Assumptions include that bores 2/97, 2/04 and 3/97 should provide samples that are more representative of background groundwater quality, that bore 3/04 may indicate if the Storage Pond is impacting groundwater quality and that bores 1/04, 4/97 and 8/97 may indicate if seepage from the infrastructure at the Premises is impacting groundwater quality leaving the Premises.

The locations and depth of groundwater monitoring bores need to be appropriate to accurately characterise the extent to which the Primary Activities may have and may be now or in the future impacting groundwater quality. In addition, changes over time to the arrangement, use, loading and lining of different ponds at the Premises must be considered when assessing the rationale behind groundwater monitoring bore locations and monitoring requirements. The potential for mounding of groundwater below the ponds as a result of seepage must also be considered.

(12) Key Finding: The Delegated Officer finds that:

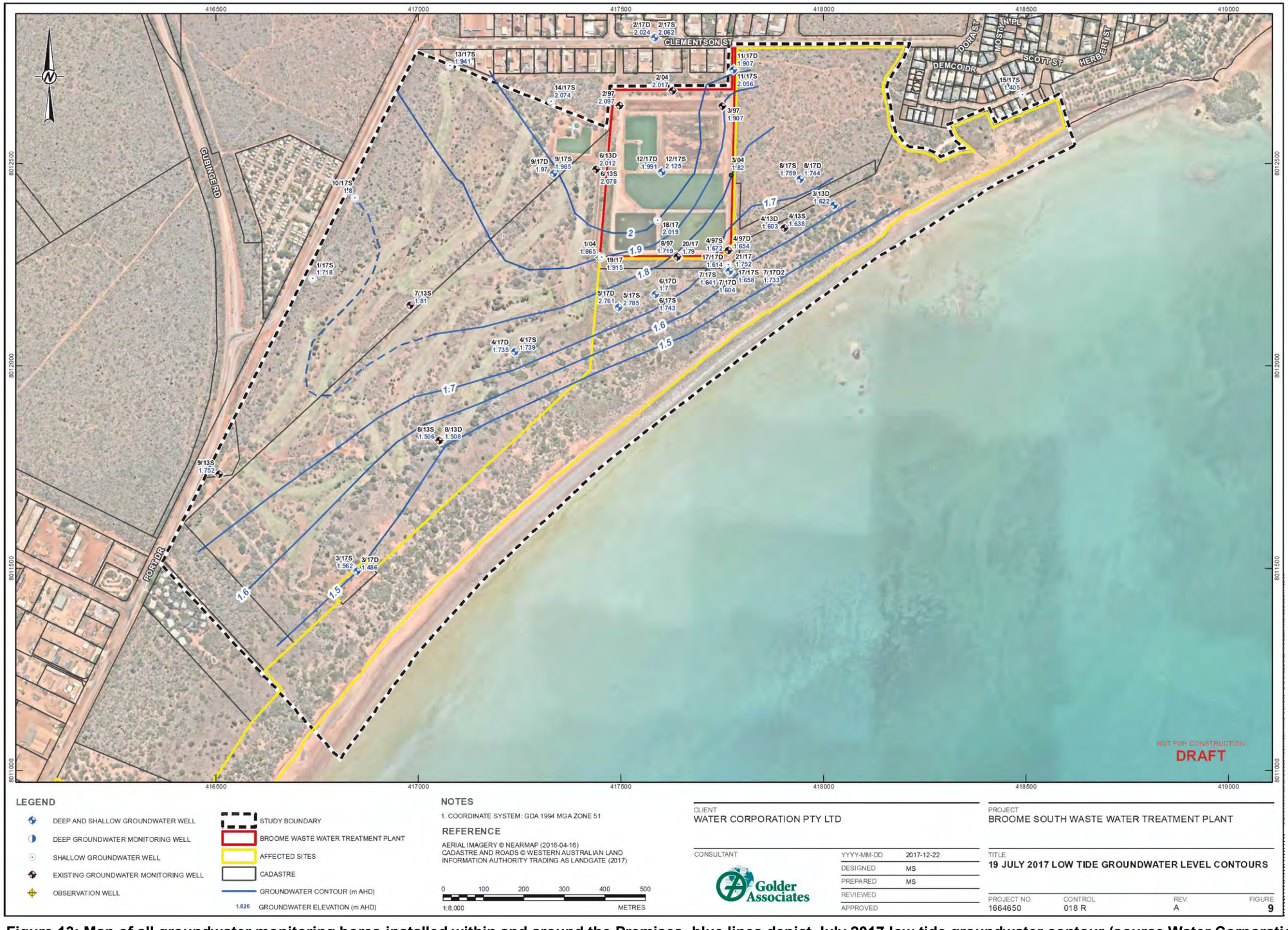
(a) the groundwater monitoring requirements specified under the Conditions of the Existing Licence are not adequately defined and are not sufficient in spatial and temporal coverage to adequately characterise local groundwater quality and the likelihood of seepage from the Primary Activities impacting groundwater quality; and

(b) all groundwater monitoring bores within the boundary of the Premises are possibly or have been influenced by groundwater mounding from seepage.

Due to the limitations identified within the existing AER reporting data set and taking into consideration the concurrent Detailed Site Investigation process (see Golder Associates 2018) a detailed analysis of the AER data has not been undertaken. Additional groundwater quality monitoring data is considered in the following sections of this Decision Report.

In addition, as part of the 2018 Draft Referral, the Licence Holder has proposed amendments to the suite groundwater bores, under the Existing Licence, as per

. The proposed amendment is addressed in Section 9.1.4 of this Decision Report.



LEGEND

- DEEP AND SHALLOW GROUNDWATER WELL
- DEEP GROUNDWATER MONITORING WELL
- SHALLOW GROUNDWATER WELL
- EXISTING GROUNDWATER MONITORING WELL
- OBSERVATION WELL
- STUDY BOUNDARY
- BROOME WASTE WATER TREATMENT PLANT
- AFFECTED SITES
- CADASTRE
- GROUNDWATER CONTOUR (m AHD)
- 1.826 GROUNDWATER ELEVATION (m AHD)

NOTES

1. COORDINATE SYSTEM: GDA 1994 MGA ZONE 51

REFERENCE

AERIAL IMAGERY © NEARMAP (2016-04-16)
CADASTRE AND ROADS © WESTERN AUSTRALIAN LAND INFORMATION AUTHORITY TRADING AS LANDGATE (2017)

0 100 200 300 400 500
1:8,000 METRES

CLIENT: WATER CORPORATION PTY LTD

CONSULTANT: Golder Associates

YYYY-MM-DD	2017-12-22
DESIGNED	MS
PREPARED	MS
REVIEWED	
APPROVED	

PROJECT: BROOME SOUTH WASTE WATER TREATMENT PLANT

TITLE: 19 JULY 2017 LOW TIDE GROUNDWATER LEVEL CONTOURS

PROJECT NO.	CONTROL	REV.	FIGURE
1664650	018 R	A	9

Figure 13: Map of all groundwater monitoring bores installed within and around the Premises, blue lines depict July 2017 low tide groundwater contour (source Water Corporation 2018a, *Broome South WWTP proposal to amend operational bore locations*, page 19).

Table 22: Amendments proposed to suite of groundwater monitoring bores.

Source	Existing Licence	Report *Broome South WWTP proposal to amend operational monitoring bores* (received 19/02/2018 – A1627942)[1]	Report: *Broome South WWTP (L6266) Pond E3 Leakage Management Plan* (received 31/05/2018 – A1685101)[2]	Report: *Broome South WWTP (L6266) Pond E3 Leakage Management Plan* (received 27/08/2018 – DWERDT89239) [2]
Monitoring bore numbers	1/04; 2/04; 2/97; 3/04; 3/97; 4/97; and 8/97	3/04; 3/13D; 4/13D; 2/17S; 6/17S; 6/17D; 7/17S; 7/17D; and 12/17S	1/04; 2/04; 2/97; 3/04; 3/97; 4/97; and 8/97	3/04; 2/17S; 6/17S; 7/17S; and 12/17S

Note 1: bores proposed with regards to entire groundwater bore monitoring suite under Part V EP Act.

Note 2: bores proposed specific to groundwater bore monitoring suite for standing water level under Part V EP Act.

6.1.1 Annual Environmental Report infiltration volumes

Estimations of volumes infiltrated from the Premises ponds, in accordance with Condition 31(c) of the Existing Licence, are provided by the Licence Holder over three years. The volumes are calculated using the method '*infiltration = (inflow + rainfall) – (evaporation + outflow)*'. Two of the three years date provided by the Licence Holder were calculated by incorporating the negative monthly infiltration values in the annual infiltration total, as summarised in Table 23. The incorporation of negative values in the total annual infiltration volume calculation results in significant error, by implying that high evaporation months may counteract infiltration, balance out infiltration during other months or that seepage rates are not subject to a minimum constant.

Table 23: Infiltration volume estimated for the Premises ponds.

Annual reporting period	**2013/14**	**2014/15**	**2015/16**
Estimated annual infiltration volume (kL)	51,207	41,607	164,262
Number of negative evaporation value months	5	4	0

6.2 Hydrogeological report

The submission of a hydrogeological report by 30 October 2013, required by Condition 30 of the Exiting Licence and previsions versions of L6266/1991/10 under different condition numbers, has been in effect since 29 December 2011. Condition 30 required:

> *The licensee shall, by 30 October 2013, submit to the CEO, a report detailing the results of a hydrogeological investigation of the groundwater movement beneath the premises. The hydrogeological investigation shall be designed to include, but not be limited to, the following:*
>
> *(a) Investigation and assessment of the hydrology of the premises and surrounding area within at least a 1km buffer;*
>
> *(b) A review of existing groundwater data against applicable standards and guidelines;*
>
> *(c) Identify the seasonal standing water levels of groundwater surrounding the premises;*
>
> *(d) A determination of seepage rates and volumes of effluent emanating from the premises treatment ponds;*
>
> *(e) Investigation into the likelihood of nutrient-rich groundwater discharging from the premises;*
>
> *(f) Application of contaminant fate and transport modelling detailing the quantity and quality of nutrient loads discharging from the premises;*
>
> *(g) Determination (if applicable) of the possible environmental impacts of any nutrient-rich discharges from the premises;*
>
> *(h) Determination, if required, of additional groundwater monitoring bores; and*

(i) *Details of proposed management measures (if applicable) including timelines, to be implemented by the licensee to reduce the risk of nutrient rich groundwater discharges from the premises impacting the surrounding environment.*

To support the requirements of Condition 30 the Licence Holder submitted the report URS Australia Pty Ltd 2013, *Hydrogeological assessment of nutrient flux from Broome south wastewater treatment plant* and the report AECOM Australia Pty Ltd 2016, *Preliminary nutrient impact assessment Broome South Wastewater Treatment Plant*. URS 2013 was also submitted in part to meet the requirements under the *Contaminated Sites Act 2003*.

6.2.1 URS 2013 Hydrogeological assessment of nutrient flux

The report URS 2013 documented the 2013 installation of 13 groundwater monitoring bores around the Premises, soil samples at the bore locations, groundwater quality monitoring and water level logging from the new bores and slug testing of the Pindan soils for hydraulic connectivity. The locations of the groundwater monitoring bores are depicted in Figure 13. The flux of nutrients towards Roebuck Bay was assessed based on a site conceptual model. URS 2013 did not address elements (g) and (i) of Condition 30 and concluded that:

- approximately 90,900 kL of water within the sewage facility seeps through the ponds based on water balance calculations and that groundwater beneath and downgradient of the Premises is dominated by seepage waters;
- approximately 3,770 kg/ year of nitrogen seeps from the ponds and of that, following nitrification, approximately 640 kg/ year of nitrogen reaches groundwater beneath the ponds and after attenuation approximately 470 kg/ year discharges into Roebuck Bay; and
- approximately 830 kg/ year of phosphorus seeps from the ponds, phosphorus is strongly retained within the soil and seepage is not considered to add to background phosphorus concentrations that discharge to Roebuck Bay.

(13) Key Finding: The Delegated Officer notes that since the URS 2013 assessment that the sewage facility pond configuration and potential seepage footprint have changed (see Section 3 of this Decision Report).

(14) Key Finding: The Delegated Officer notes that based on advice in the Technical Expert Report that the assessment undertaken by URS 2013 was based on an insufficient monitoring bore network and did not take into consideration the potential for the core of the groundwater plume to be at depth within the unconfined aquifer and not intercepted by the groundwater monitoring bore network. Subsequently, based on the Technical Expert Report the URS 2013 assessment is considered to have a significant level of uncertainty.

6.2.2 URS 2015 Preliminary nutrient impact assessment proposal Broome South wastewater treatment plant

The report URS 2015 provided a proposal for a preliminary nutrient impacts assessment for the Premises and adjacent Broome Golf Club that would contribute to the requirements of elements (e), (f) and (g) of Conditions 30 of the Existing Licence. The proposal by URS Australia Pty Ltd is not known to have been commissioned.

6.2.3 AECOM 2016 Preliminary nutrient impact assessment

The report AECOM 2016 sought to specifically address component (g) of Condition 30 in the Existing Licence:

> *'Determination (if applicable) of the possible environmental impacts of any nutrient-rich discharges from the premises'.*

AECOM 2016 considered impacts to groundwater beneath the Premises and the Broome Golf Club and developed a conceptual model describing nutrient sources across the Roebuck Bay catchment, see Figure 14. As part of the investigations the available groundwater monitoring data was used to interpret the likelihood of seepage from the ponds at the Premises occurring and impacting groundwater quality. The highest likelihood of seepage determined in AECOM 2016 was for the now decommissioned and filled northern emergency overflow pond and the Storage Pond (*prior to it being lined with low permeability geosynthetic clay liner*). A summary of the available groundwater monitoring data used in the assessment is detailed in Table 24.

Table 24: Groundwater monitoring data summary for the Premises and background (Broome Peninsula) where data was available (source AECOM 2016, page 20).

Analyte	BSWWTP				Background			
	Pindan Sand (shallow)		Broome Sandstone (deep)		Pindan Sand (shallow)		Broome Sandstone (deep)	
	Range (n)	Median	Range (n)	Median	Range (n)	Median	Range (n)	Median
Total Nitrogen (mg/L as N)	1.6 - 66 (63)	11	0.3 – 93 (245)	8.3	0.8 – 12.7 (23)	4.2	1 – 34.4 (15)	4.8
Nitrate (mg/L as N)	<0.05 – 43 (53)	6.6	<0.01 – 64.4 (229)	5.4	0.02 – 11.4 (27)	2.8	0.15 – 42.8 (27)	4.56
Ammonia (mg/L as N)	<0.05 – 33 (45)	0.14	0.007 – 13 (175)	0.1	<0.005 – 0.09 (11)	0.05	0.02 – 0.06 (3)	0.06
Total Phosphorus (mg/L)	<0.05 – 2.1 (64)	0.18	0.02- 12 (250)	0.05	<0.05 – 1.22 (23)	0.13	0.01 – 0.55 (15)	0.06
TDS (mg/L)	52.5 - 1350 (18)	337	121.6 - 995 (123)	633	84 – 6,345 (30)	529	86.4 – 15,657 (31)	2,037
Redox (mV)	75 - 361 (18)	117.1	-125 - 378 (24)	132	20 - 405 (19)	104	-142 – 514 (16)	148
Dissolved Oxygen (mg/L)	0.6 – 5.1 (18)	2.56	0.1 – 5.1 (24)	2.0	1.2 – 4.9 (11)	2.13	2.2-3.5 (3)	2.4
Dissolved Organic Carbon (mg/L)	<1- 10 (13)	1.0	<1 - 15 (14)	2.0	1 - 14 (5)	4.0	-	-
Total Organic Carbon (mg/L)	<1 - 2 (10)	1.0	<1 – 16 (16)	2.0	1 - 3 (4)	1.0	-	-
pH (pH units)	6.08 – 7.54 (18)	6.87	5.8 – 9.2 (32)	6.7	5.93 – 8.15 (27)	7.0	5.8-8.2 (28)	6.95

n = number of samples in brackets

In assessing the hydraulic and biogeochemical processes of the aquifer the report AECOM 2016 interpreted and concluded that:

(a) the unconfined aquifer and vadose zone beneath the Premises supports the nitrification of ammonia to nitrate;

(b) phosphorus is strongly retained within the soil and subsequently attenuates much slower through the groundwater and is unlikely to impact Roebuck Bay;

(c) groundwater monitoring data to the southeast for the Premises is lacking and

subsequently the understanding of the transport and fate of nutrients in the groundwater towards Roebuck Bay is limited;

(d) numerous diffuse and point source inputs of nutrients to Roebuck Bay exist and the quantification and significance of all inputs cannot be determined with the available information;

(e) surface water nutrient samples within Roebuck Bay closest to the Premises were slightly elevated compared to the other four surface water sample locations which, were all below the concentrations within Dampier Creek;

(f) groundwater is likely to discharge from the Premises to Roebuck Bay however, the degree to which nutrients within the groundwater contribute to blooms of *Lyngbya majuscula* within Roebuck Bay could not be determined; and

(g) additional groundwater monitoring bores are required to be installed to inform the hydrogeological conceptual model.

The report AECOM 2016 (pages E-4 and E-5) also considered the available data and estimated the potential annual nutrient loads going into Roebuck Bay as a result of the Primary Activities at the Premises (see Table 27 in Section 6.7 of this Decision Report).

(15) The Delegated Officer notes, consistent with the Technical Expert Report, that:

(a) the groundwater monitoring data is insufficient to determine the extent to which attenuation of nitrogen and retention of phosphorus is occurring within a possible seepage plume; and

(b) hydraulic and biogeochemical processes may be influencing a possible seepage plume (see Section 6.7 of this Decision Report).

6.3 Leakage management plan

Condition 28 in the Existing Licence required:

> *The Licensee shall submit to the CEO and implement a Leakage Management Plan within six months of pond E3 becoming operational at the Premises. The plan should include but not be limited to:*
>
> *(a) a methodology for assessing monitoring and operational data to evaluate the liner integrity of lined ponds on the Premises on an ongoing 6 monthly basis; and*
>
> *(b) a methodology, diversion options and target timeframes for rectification of any leaks identified from the lined ponds.*

The Storage Pond (pond E3) '… *was commissioned and deemed operational on November 2017* …' (Water Corporation 2018a). The Licence Holder submitted the *Broome South WWTP (L6266) Pond E3 Leakage Management Plan* on 31 May 2018 in response to Condition 28. The corrected groundwater monitoring bores proposed by the Licence Holder to monitor seepage, via changes in standing water levels around the Premises, are included in the amendment addressed in Section 9.1.4 of this Decision Report.

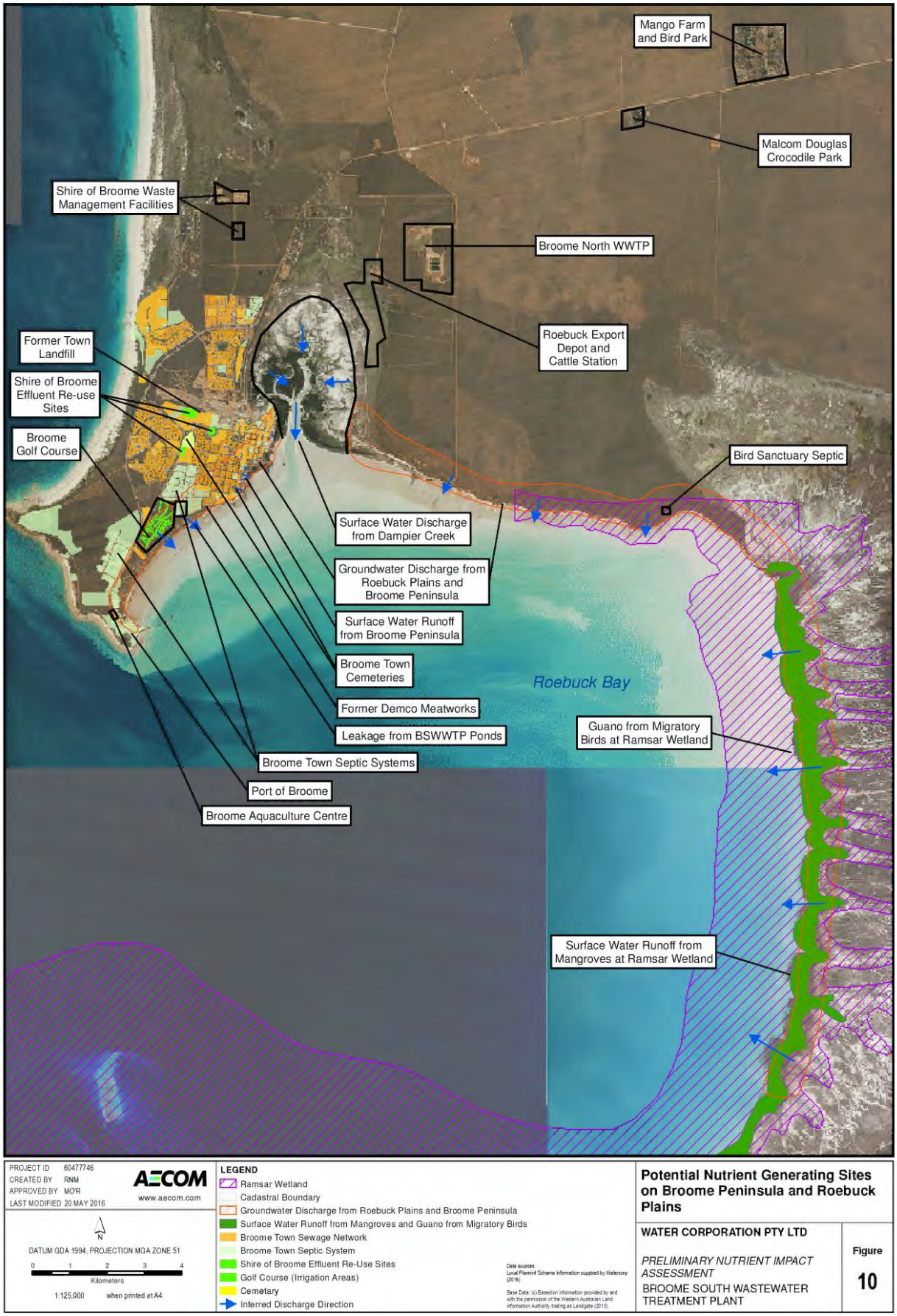


Figure 14: Roebuck Bay potential nutrient inputs (source: AECOM 2016, page 93).

6.4 Hydrogeology and monitoring of the local ecosystem

A number of studies have been undertaken regarding the hydrogeology of the Broome Peninsula, Roebuck Bay and the potential impacts inputs of groundwater and nutrients may play in the Roebuck Bay ecosystem. The consensus through the reported literature is that there is a directional divide within the unconfined aquifer of the Broome Peninsula that generally sees groundwater on the south-eastern side of the divide, including the Premises, migrate towards Roebuck Bay and groundwater on the north-western side of the divide migrate to the west, see Figure 15. Hydrogeological factors at the Premises are discussed further in Section 6.7.2 of this Decision Report.

Consensus has not been reached in the reported literature regarding the quantity of nutrients (nitrogen and phosphorus) being discharged from the unconfirmed aquifer, specifically from the Primary Activities at the Premises and reuse facilities, into Roebuck Bay and any impact on the Roebuck Bay ecosystem (see Table 27 in this Decision Report).

A series of thesis investigated the hydrogeology of the Broome Peninsula and Roebuck Bay and are discussed further in Golder Associates 2018. The reports made the following conclusions relevant for consideration in this Review:

- that nutrients seeping from the Premises and infiltrating from the Broome Golf Club are discharging via the submarine groundwater table into Roebuck Bay and that nutrients are contributing to *Lyngbya majuscula* blooms (Wright 2013);

  and

- nutrient availability is only one component that influences the abundance and distribution of *Lyngbya majuscula* blooms within Roebuck Bay and that nutrient levels within stormwater from the catchment have increased from anthropogenic sources (Gunaratne 2015).

More recent investigations (AECOM 2016) concluded that:

- nutrient levels are elevated within groundwater below the Premises;
- the soil between any seepage sources and the aquifer and hydrogeology of the aquifer support nitrification of ammonia to nitrate and in areas of low dissolved oxygen attenuation of nitrate via denitrification is likely;
- while the activities at the Premises do contribute to the nutrient load entering Roebuck Bay, a lack of groundwater monitoring bores between the Premises and Roebuck Bay limits the understanding of the transport and fate of nutrients within the groundwater; and
- hydraulic modelling of Roebuck Bay indicates that higher nutrient concentrations are predicted over northern and eastern parts of Roebuck Bay and not in the north-western areas adjacent the Premises. The modelling is consistent with water quality results reported in Estrella 2013 however, the higher nutrient levels are not consistent with the observed distribution of *Lyngbya majuscula* blooms documented in Estrella 2013, see Figure 16.

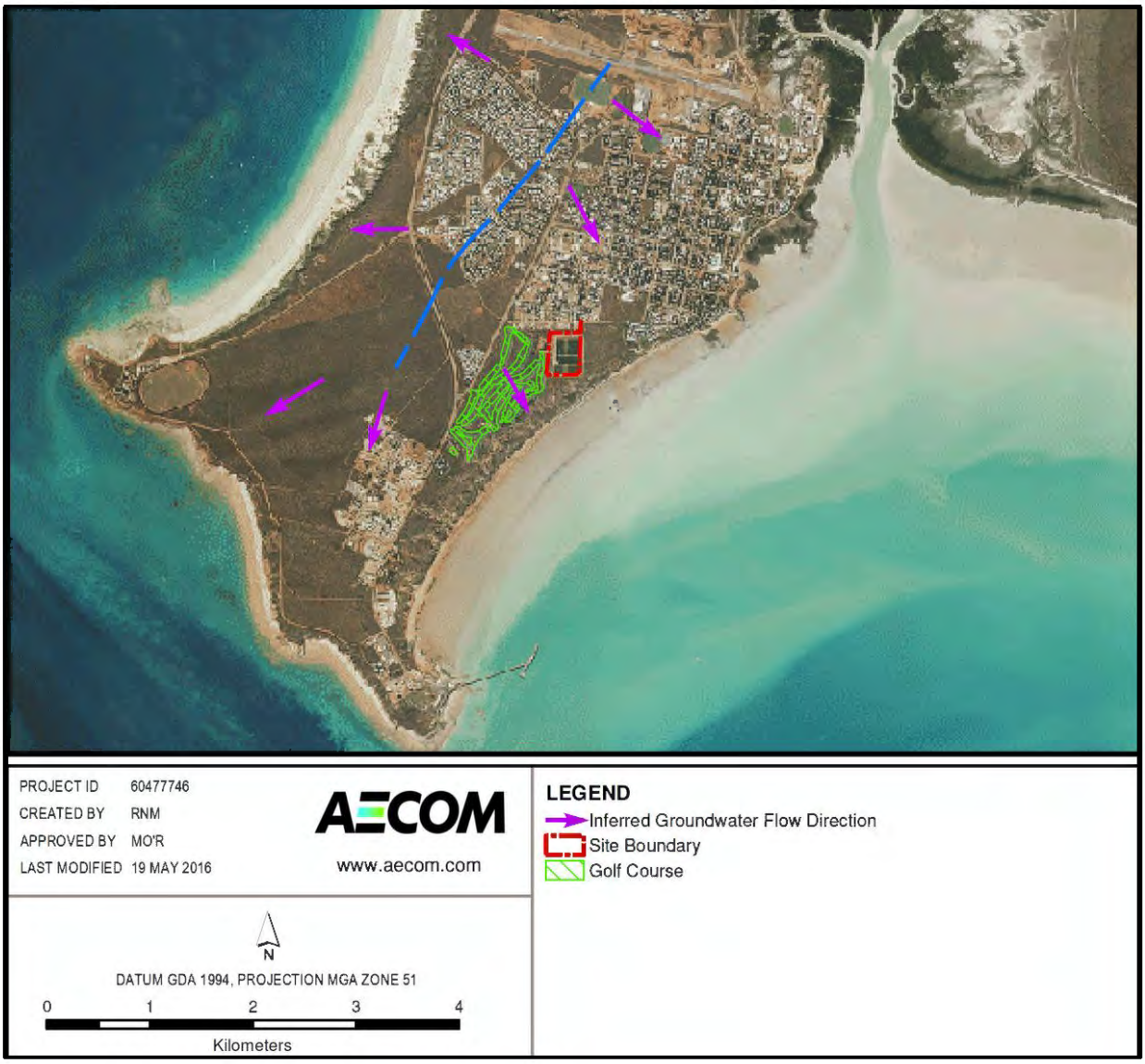


Figure 15: Inferred unconfined aquifer divide (blue line) and groundwater flow direction (purple arrows) of the Broome Peninsula (source: AECOM 2016, page 87).

The postdoctoral investigations reported in Estrella 2013 were the culmination of a three-year study. Estrella 2013 concluded that blooms of *Lyngbya majuscula* were impacting the ecology of Roebuck Bay. The blooms were found to be highly dependent on climatic conditions and benthic sediment composition. Estrella 2013 did not determine the level of influence that seepage from the Premises was having on blooms of *Lyngbya majuscula*.

6.4.2 *Lyngbya majuscula*

Blooms of the cyanobacteria *Lyngbya majuscula* were first observed in Roebuck Bay in 2000 and annually since 2005. An investigation into the occurrence of *Lyngbya majuscula* is documented in the report Estrella 2013 (see Figure 16). The increase in frequency may be attributed to an increased occurrence of blooms and/ or an increased interest and observation in the area. Blooms of *Lyngbya majuscula* in tropical marine waters are not isolated to the Roebuck Bay area. The start of the annual bloom in Roebuck Bay is usually around December and ending around March. The first high rainfall events can occur at this time and result in a flush of nutrients from the catchment into Roebuck Bay (Estrella 2013).

The blooms are of concern due to the significance of the Roebuck Bay environmental receptors, cultural values and the potential for the blooms to impact flora and fauna and the benthic intertidal habitat used for foraging by migratory birds. Estrella 2013 found that large blooms of *Lyngbya majuscula* have resulted in significant changes to the benthic invertebrate community of Roebuck Bay and subsequently affected the diet of at least one migratory bird species *Limosa lapponica* (Bar-tailed godwit). The blooms can also present a human health risk, cyanotoxins have been linked to skin, eye and respiratory irritation (Osborne et al 2001).

In Roebuck Bay *Lyngbya majuscula* was found to occur in areas with coarser sediments. The coarser sediments were inferred to result in lower suspended solids in the water column, more sunlight and provide a more solid substrate compared to areas dominated by mud and silt sediments found in eastern areas of Roebuck Bay. High periods of sunlight following periods of heavy rainfall that flush nutrients into Roebuck Bay have been correlated to the occurrence and abundance of *Lyngbya majuscula* blooms. Nutrients within benthic sediments were found to be more important to the growth of *Lyngbya majuscula* than nutrients within the water column.

Blooms of *Lyngbya majuscula* were correlated to low concentrations of ammonium and phosphorus in the benthic sediments, this is thought to result from *Lyngbya majuscula* depleting the available nutrients (Estrella 2013). Other studies have found *Lyngbya majuscula* to be nitrogen fixing however, not all strains may exhibit this ability and this has not been established within *Lyngbya majuscula* in Roebuck Bay. Bioavailable iron has also been found to be a limiting element in *Lyngbya sp.* blooms however, the role and relationship of bioavailable iron in Roebuck Bay was not established within Estrella 2013.

Cyanotoxins resulting from blooms of *Lyngbya majuscula* have also been linked to fibropapillomatosis (tumors) in marine turtles (Osborne et al 2001 and Arthur et al 2008). Additional impacts to the ecology of Roebuck Bay are likely to occur as a result of blooms of *Lyngbya majuscula*.

Figure 16: Observed distribution and abundance of *Lyngbya majuscula* in January 2012, Premises depicted by red rectangle (source: adapted from Estrella 2013, page 45).

(16) Key Finding: The Delegated Officer finds that it is reasonably foreseeable that seepage from the Primary Activities at the Premises that enters groundwater and discharges into Roebuck Bay could play a role in the blooms of *Lyngbya majuscula*. The relationship and the role that seepage from the Primary Activities at the Premises play in the occurrence and abundance of *Lyngbya majuscula* may be complex, indirect and has not been conclusively established (see Section 6.7 of this Decision Report).

(17) Key Finding: The Delegated Officer finds that the correlation of blooms of *Lyngbya majuscula* to areas with depleted concentrations of ammonium and phosphorus in the benthic sediment is significant when considering the potential role of an anoxic seepage plume in influencing the release of phosphorus and iron within the aquifer (see Section 6.7 of this Decision Report).

6.4.3 McMahon and Dunham 2017 Roebuck Bay nitrogen sources

The report McMahon and Dunham 2017, *Investigation into nitrogen sources for Roebuck Bay and the Yawuru Nagulagun/ Roebuck Bay Marine Park a final report for Water Corporation* considered the spatial variation of nitrogen isotopes ($\delta^{15}N$) within the seagrass species *Halophila ovalis* and *Halodule uninervis* across northern parts of Roebuck Bay from the Port of Broome to Crab Creek. Seagrass was used as an indicator to detect if nitrogen arising from the Premises was present within seagrass based on isotopic variations. Nitrogen available to seagrass could also be available to support blooms of *Lyngbya majuscula*. The report was supported by a media release from the Licence Holder on 14 December 2017 titled *Roebuck Bay study finds treated wastewater is not causing algal blooms*.

The investigation was conducted over an eleven-month period at eighteen sample locations and concluded that nitrogen arising from Primary Activities at the Premises were not a primary source of nitrogen for marine flora. No clear spatial distribution of nitrogen levels was found with a range of nitrogen sources being inferred from the results. Nitrogen isotope levels were found to most likely indicate inorganic fertilisers as a source of nitrogen. Increases in nitrogen content were found over the period February to March, which coincided with increases in annual rainfall. The '*study did not find any evidence of treated wastewater [sewage] contamination influencing the nutrient levels within locally growing seagrass populations, compared to other sites in Roebuck Bay*' (McMahon and Dunham 2017, page 23). The methodology and findings of McMahon and Dunham 2017 were considered within the Technical Expert Report.

(18) The Delegated Officer notes that based on the Technical Expert Report that the report McMahon and Dunham 2017:

a) indicates that the size blooms of *Lyngbya majuscula* are not limited by the availability nitrogen.

b) is not conclusive regarding the influence nitrogen seeping from the Primary Activities at the Premises may be having on the environmental values of Roebuck Bay and does not conclude that the sewage facility is not an important emission source that may contribute to triggers that influence blooms of *Lyngbya majuscula* (see Section 6.7 of this Decision Report and Appendix 4).

6.5 Reporting under the *Contaminated Sites Act 2003*

The report RPS 2015b, *Preliminary site investigation Broome South wastewater treatment plant* was received by the then DER on 9 October 2015 in response to the classification of the Premises as 'contaminated – investigation required' on 31 March 2015. The report RPS 2015b provides a desktop study of available information, previous investigations and preliminary site conceptual model. The report RPS 2015b was supported by the report RPS 2015a, *Literature review Broome South wastewater treatment plant and surrounding areas*. Investigations following the initial reports by RPS Environment and Planning Pty Ltd inform the understanding of the groundwater, hydrogeology and risk of impact to receptors from the Primary Activities at the Premises.

(19) Key Finding: The Delegated Officer notes that the outcomes of the *Contaminated Sites Act 2003* (CS Act) detailed site investigation process will be considered in conjunction the findings of the risk-based assessment process undertaken in this Review. Subsequently, this Review will take a two-phase approach:

(a) Phase 1 will assess the acceptability of risk posed to receptors from the operation of the Primary Activities on a reasonable worst-case scenario basis using the best available information to inform the consequence and likelihood of a Risk Event. Regulatory controls will be imposed commensurate to the risk rating and taking into consideration the assumptions and uncertainty affecting the risk assessment process.

(b) Phase 2 will be undertaken following the completion of the detailed site investigation process under the CS Act. The second phase will reconsider the risk-based assessments in this Decision Report based on the updated information. Amendments to regulatory controls will be considered commensurate to the outcomes of the phase two risk-based assessment process.

The findings of the risk assessments in Section 8 of this Decision Report support this two-phase approach.

The report Senversa 2018 forms part of the Detailed Site Investigation (DSI) process. The report does not provide conclusions on any impacts; however, the interim findings are that groundwater presents a potential pathway for contaminated groundwater to migrate from the Premises to Roebuck Bay and that further investigation is required.

DWER is expecting the submission of a DSI in 2019. The DSI will be considered by DWER with regards to the provision of the *Contaminated Sites Act 2003*. In addition, the outcomes of the DSI process will inform phase 2 of the Review risk-based assessments.

6.6 Golder Associates

6.6.1 Golder Associates 1997

The report Golder Associates 1997 documented the earliest known assessment of groundwater at the Premises. Seepage from the pond arrangement at the time was estimated to range between 200 – 1,000 kL/ day. Groundwater mounding at the edge of the Premises was found to be +0.3m and the water quality analysis showed seepage from the Premises within the unconfined aquifer. This is noted with regards to operations at the Premises having commenced in 1981.

6.6.2 2017 pond seepage loss assessment

The report Golder Associates 2017 documented a seepage loss assessment from the secondary and tertiary ponds. The assessment does not address '… *nutrient loading and environmental risks* …' as they are '… *to be addressed through the DSI [Detailed Site Investigation] scope*…' (Golder Associates 2017, page 2). The assessment estimated the seepage values across thirteen days (see **Error! Reference source not found.**) and found hat:

- The secondary and tertiary ponds discharge 70 – 105 m^3/ day via seepage, equivalent to 25.5 – 38.3 ML/ year.
- The primary and storage ponds discharge 0.8 m^3/ day via seepage, equivalent to 0.3 ML/ year.
- The total seepage from the primary, secondary, tertiary and storage ponds is estimated to be 1.83 – 2.79 kg/ day (668 - 1018 kg/ year) total nitrogen and 0.62 – 0.92 kg/ day (226 – 335.8 kg/ year) total phosphorus.
- Based on the assessment undertaken in URS 2013, the removal of the three emergency ponds and decommissioning of the old emergency pond is likely to have reduced the discharge to groundwater from the Premises by between 52.2 ML/ year (57%) and 64.9 - ML/ year (71%).

Golder Associates 2018 provides an updated interpretation of the seepage loss assessment, incorporating interim findings from the DSI process.

Table 25: Seepage estimate from Golder Associates 2017 water balance assessment.

Assessment day	1	*2*	3	4	5	6	7	8	*9*	10	11	12	*13*[1]
Seepage estimate (mm)	2.9	*-0.9*	0.7	1.8	2.3	2.1	0.3	3.3	*-0.8*	0.5	3.4	3.8	*-5.8*
Seepage estimate (m^3)	99	*-31.9*	24.1	63	79.4	73.5	12.0	114.6	*-26.3*	16.2	119.2	132.4	*-201.1*
Average (mm) [2]				2.11			**Average (m^3)** [2]				73.34		
Standard deviation (mm) [2]				1.27			**Standard deviation (m^3)** [2]				44.16		

Note 1: coincided with a 9.8 mm rainfall event at the Broome airport.

Note 2: calculated with negative values days 2, 9 and 13 being omitted.

(20) The Delegated Officer notes that the Golder Associates 2017 assessment of seepage rates is subject to some uncertainty:

- **(a) the data set is limited to a narrow temporal extent and displayed relatively high standard deviation of seepage rates across the assessment period;**
- **(b) the ponds were not isolated as part of the assessment;**
- **(c) sensitivity of the assessment to assumptions and uncertainty; and**
- **(d) a change in the seepage rate of ±1 mm equates to a volume change in the seepage rate of approximately ±35 m^3/ day.**

(21) The Delegated Officer notes that based on the Technical Expert Report the method used to estimate seepage is acceptable (see Technical Expert Report,

Appendix 4)

6.6.3 Response to 2018 Draft Referral – Golder Associates 2018

The report Golder Associates Pty Ltd July 2018, *Report Broome South Wastewater Treatment Plant response to draft licence decision report* has used information gathered as part of the DSI process to inform this Review and was submitted in response to the 2018 Draft Referral process. The report does not present a conclusion to the DSI process however, is the most recent assessment of data gathered as part of the DSI process that is available at the time of writing this Decision Report. Further consideration of the report is made in the Technical Expert Report (see Appendix 4) and in Section 6.7 of this Decision Report. Golder Associates 2018 provides a summary of available information regarding the potential for seepage from the sewage facility to result in contaminated groundwater discharge to Roebuck Bay based on seepage estimates documented in Golder Associates 2017 and details:

- updated information on the lateral and vertical characterisation of groundwater quality around the Premises; and
- a conceptual model and assessment of contaminant fate and transport within seepage from the Premises, including an estimate of 180 kg/ year of total nitrogen currently discharging to Roebuck Bay from the modelled 900 m length of the potentially impacted groundwater discharge plane; this estimate is based on currently available groundwater monitoring data and estimated groundwater flux within the 900 m plane of 250 m^3/ day.

Based on the available groundwater monitoring results, Golder Associates 2018 infer that:

> '*…significant nitrogen mass reduction is occurring as groundwater migrates through and away from the WWTP site [Premises], likely associated with denitrification … groundwater… is also noted to have reducing conditions, likely due to the presence of organic matter … this further supports reduction through denitrification*' (Golder Associates 2018, page 30).

Discussion on the fate and transport of contaminants present in areas of existing groundwater contamination, and within the conceptual model was limited to nutrient parameters (nitrogen and phosphorus) and some metal/metalloid elements. Based on the waste types that are able to be received at the Premises, under the Existing Licence, other constituents that may be present in wastewater at the Premises include:

- anthropogenic chemicals (e.g. per- and polyfluoroalkyl substances and , polybrominated diphenyl ethers);
- biological pathogens;
- fats and greases;
- oil and hydrocarbons;
- other chemicals received within trade waste and sewage network discharge streams;
- persistent organic and inorganic compounds present in surfactants, pharmaceuticals, personal care products, anti-microbial, disinfection products and other products; and
- plasticisers and other potential endocrine disrupting chemicals

The Technical Expert Report prepared in consideration of the updated data and assessment presented in the Golder Associates 2018 report found:

- the estimate of 180 kg/ year of total nitrogen discharging to Roebuck Bay does not adequately account for potential residual contamination within soils and groundwater and the addition of nitrogen from current Primary Activity inputs;
- further delineation of groundwater is required between the sewage facility and Roebuck Bay to more accurately define the risks posed to environmental receptors, including the vertical extent of the existing contamination plume and definition of the location of the fresh/ salt groundwater interface, which may influence groundwater discharge location into Roebuck Bay;
- the role and effectiveness of natural attenuation processes within groundwater have not been adequately demonstrated through provision and discussion of relevant soil quality data; and
- a precautionary approach is recommended to limit seepage from the Premises in order to protect against influences on contaminant mobilisation and transport, and potential future contamination of groundwater resulting from Primary Activities at the Premises.

The content of Golder Associates 2018 is considered further in Section 6.7 of this Decision Report. **Error! Reference source not found.**Figure 17 presents a cross section of the lithology through the Premises, including groundwater monitoring bore locations and screening intervals.

(22) The Delegated Officer notes that a precautionary approach is appropriate taking into consideration uncertainties and assumptions that include:

(a) adequate definition of source characteristics such as the volume of seepage from the secondary and tertiary ponds, the integrity of the primary pond liner, the form and quantity of contaminants within seepage from the ponds, the form and quantity of residual contaminants within the Pindan soils;

(b) the physical, hydraulic and biogeochemical process that influence the the attenuation, mobilisation, form and concentration of contaminants along the pathway and within the pore water and sediments of Roebuck Bay; and

(c) the scope and sensitivity of receptors (other than those examined by the previous studies), within and reliant upon the Roebuck Bay mudflat and shallow marine ecosystems, to contaminants of potential interest within potential emissions from the Premises.

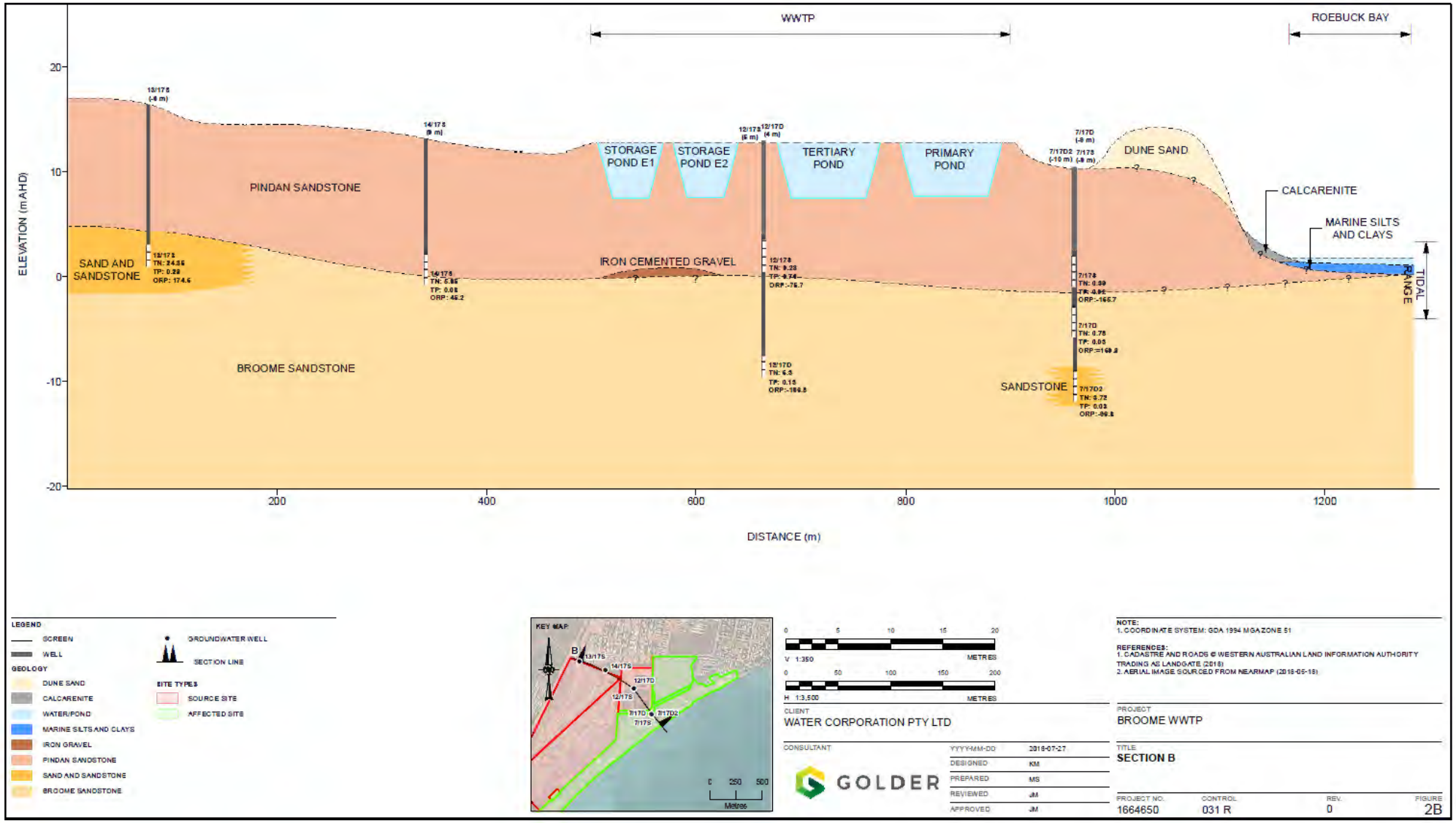


Figure 17: (Golder Associates 2018, page 66 of 85).

6.7 Modelling and monitoring data summary

Taking into consideration the available monitoring and research regarding the operations at the Premises, local hydrogeology and environmental receptors within Roebuck Bay the Delegated Officer has obtained technical expert advice from within DWER to inform the risk-based assessment process. A copy of the Technical Expert Report is provided within Appendix 4 of this Decision Report. A site conceptual source/ pathway/ receptor model is depicted in Figure 18**Error! Reference source not found.**.

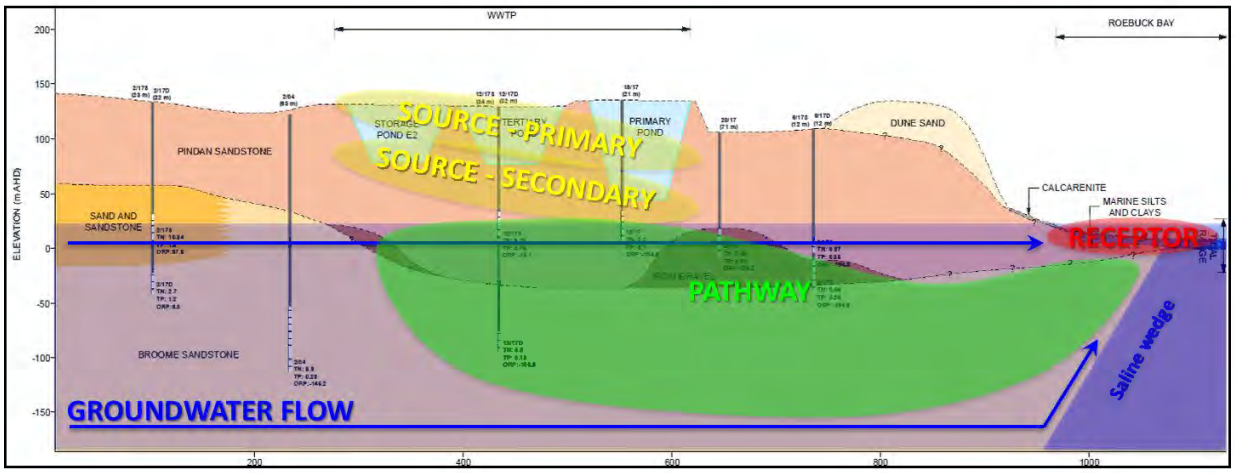


Figure 18: Conceptual source pathway receptor model summary (adapted from Golder Associates 2018).

The primary sources are contaminants from within the sewage facility, currently contained within and seeping from the treatment ponds into the local soils and then into the groundwater aquifer. Any contaminants that are retained within the unsaturated soils above the groundwater aquifer have the potential to become a secondary source of contaminants. Residual soil contamination within the Pindan soils, resulting from historical operations at the Premises are also identified as a secondary source. Physical, hydraulic and biogeochemical process within the Pindan soils will influence the mobility and characteristics of contaminants that reach the groundwater aquifer. Both primary and secondary sources need to be considered when interpreting the available groundwater data and considering the potential impacts from future seepage. Improvements that reduce the load of seepage from the ponds may not be detectable within the aquifer at the discharge point to Roebuck Bay in the order of years to decades (Golder Associates 2018, page 35). Future seepage from existing ponds, as well as stormwater infiltration within and in the vicinity of the Premises may also influence the hydraulic and biogeochemical process that effect the attenuation or mobilisation, of contaminants, and their subsequent fate and transport along the pathway (groundwater flow path) to the receptor (the Roebuck Bay mudflat ecosystem).

Key aspects of the available information regarding the sources, pathway and receptors for the site conceptual model and the assumptions and uncertainty influencing the risk-based assessment process undertaken in this Decision report are considered below.

6.7.1 Sources

Much of the information summarised in Table 26 of this Decision Report that considers the quantity of seepage from the containment infrastructure (ponds) at the Premises was documented prior to the changes identified in items 2 - 4 of Table 5 in this Decision Report. The changes include the reduction in sewage inflows, lining of the Storage Pond and the isolation of the emergency ponds for contingency containment events. Subsequently, when

considering the estimated quantity of seepage arising from the Premises (presented in Table 26), these changes have been taken into consideration.

Due to differences in the pond use configuration, including the standard of pond liner and consistency of use to hold sewage, the risks posed by the primary seepage source from the Premises infrastructure will consider:

- Low permeability lined ponds: Primary Pond and Storage Pond lined with geosynthetic clay liner (GCL);
- Temporary use ponds: Emergency Pond 1, Emergency Pond 2 and Emergency Pond 3 lined with compacted Pindan soils; and
- Operational ponds: Secondary Pond and Tertiary Pond lined with compacted Pindan soils.

The potential loss of integrity of the GCL pond liners during construction and over time are a relevant consideration to the likelihood of seepage occurring.

In addition, the unsaturated Pindan soils beneath the ponds are considered to be a secondary source, where seepage or infiltration of stormwater may mobilise residual contaminants present as a result of historical activities.

Finally, seepage from the ponds could influence the fate and transport of residual contaminants already present within the groundwater aquifer as a result of historical activities.

Assumptions and uncertainty

The effectiveness of the existing liners and compacted Pindan soils in limiting seepage from the ponds has been considered through a number of methods, the results are summarised in Table 26 and Table 27. The effectiveness of the pond liners depends on the liner type, quality of construction and performance over time. The potential for reduced performance of the low permeability liner of the Primary Pond as a result of maintenance, operations and groundwater coming into contact with the liner or through desiccation over time is a reasonable consideration.

Table 26 summarises the available data that estimates the volume of seepage discharging from the ponds at the Premises, noting that only Golder Associates 2017 and Golder Associates 2018 considers seepage from the Premises after the 2017 operational changes.

Table 27 summarises the available data that estimates the nutrient load being discharged within the seepage or being discharged to Roebuck Bay, noting that some of the estimates only consider input from the Premises, while other estimates consider inputs from the Broome Golf Club and/ or the whole Broome Peninsula. The estimates of nutrient loads being discharged within the seepage from the Premises is considered in the Technical Expert Report and the values detailed in Table 26 and Table 27 are considered further in Section 8.6 of this Decision Report.

All models and estimates of seepage volume and contaminant loads are subject to inherent assumptions and uncertainty; these include:

- accuracy in the characterisation of conditions at the Premises (for example: adequacy, homogeneity, reliability, selectivity and variability of the source soil, sewage/ wastewater, pond liner and groundwater data);
- accuracy and variability in estimating hydraulic parameters (for example: evaporation rates, hydraulic head and inflow velocity rates within ponds); and

- natural and real word variability such as the loss of integrity in pond liners and barrier layers and presence of preferential flow paths within soils; and
- how physical, hydraulic and biogeochemical processes influence seepage rates and contaminant attenuation and mobility under different conditions that may or may not be accounted for.

As demonstrated by the January 2018 rainfall event (see Section 4.6 of this Decision Report) seepage from the emergency ponds has the potential to occur when these ponds are in use and during these events, overall seepage rates from the Premises will increase. Periodic increase in seepage from the use of emergency ponds will be likely when used to contain treated sewage and/ or sewage mixed with stormwater. Seepage from the emergency ponds, in most circumstances, will likely occur when the ponds received storm water and overflow wastewater from the Tertiary Pond or Storage Pond. It is recognised that the seepage occurring under these circumstances is likely to contain lower concentrations of contaminants however, the infiltration of water has the potential to act as a mechanism for dissolution of retained contaminants within secondary source areas. Generally, anoxic conditions within a seepage plume could occur from a consistent source, these conditions are not expected to arise within the emergency ponds.

Significant uncertainty remains regarding the form and concentration of residual contaminants within the Pindan soils in secondary source areas, and how the physical, hydraulic and biogeochemical processes resulting from Primary Activities may influence the fate and transport of those contaminants.

6.7.2 Pathways

Based on the available information, all seepage from the premises (either from ponds or unsealed areas) is assumed to be directed through the Pindan soils at the Premises, into the unconfined groundwater aquifer and finally into the intertidal benthic marine sediments of Roebuck Bay. The following components of the pathway are considered to potentially have a significant impact on any seepage emissions arising from the containment infrastructure (ponds) at the Premises and discharge to Roebuck Bay:

- The hydraulic load, form and concentration of contaminants coming from the primary and secondary sources;
- The residual contamination within the aquifer;
- The hydraulic and contaminant retention properties of the Pindan soils and Broome sandstone;
- The hydraulic and biogeochemical processes within the aquifer; and
- The hydraulic and biogeochemical processes within the benthic sediments of Roebuck Bay.

The groundwater chemistry and potential persistence of anoxic groundwater conditions along the pathway are considered to have a significant influence on the attenuation, migration, form and concentration of contaminants along the pathway and within the benthic marine sediments of Roebuck Bay.

Table 26: Summary of calculated volumes of seepage discharged from the Premises.

Year	Golder Associates 1997	AER data[1]	Wright 2013	URS 2013	Hearn 2014	RPS 2015b	Kelly 2015	AECOM 2016	Golder Associates 2017 (incl. Golder Associates 2018)
2013/ 14	N/A	96,003 kL[2]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2014/ 15		76,871 kL[2]							
2015 /16		164,262 kL							
Annual average	146,000 kL/ year	112,789 kL (*average of values above*)		90,900 kL (*2011 data source*)[3]				183,000 kL[4]	25,500 – 38,300 kL (*mean 31,900 kL*) (*from the secondary and tertiary ponds only*)

Note 1: Source Licence Holder AERs, volume was estimated by inflow + rainfall – evaporation – reuse;

Note 2: Corrections were made to the Licence Holder's calculations, any monthly negative values were amended to zero resulting in an increase in the estimated volume from 51,207 kL in 2013/14 and from 41,602 kL in 2014/15. In the Licence Holder's AER 2014 the value of 51,207 kL was used to question the validity of the estimates made in URS 2013, however the Delegated Officer has found the Licence Holder's calculation to be erroneous.

Note 3: in 2012 sewage inflows to the Premises decreased with the partial diversion to the Broome north sewage facility however, the Delegated Officer considers that this is unlikely to have materially affected the rate of seepage.

Note 4: AECOM 2016, page E-5, value derived from data supplied by the Licence Holder.

Table 27: Summary of calculated loads of nutrients within seepage discharged from the Premises[0].

		Wright 2013[1]	URS 2013[2]	Hearn 2014[3]	RPS 2015b	Kelly 2015	AECOM 2016[5]	Golder Associates 2017[6]	Golder Associates 2018
Annual load seeping from Premises	**Total nitrogen**	N/A	**3,770 kg/ year** (*at 41.5 mg/L*)	N/A	*Considers that the values within URS 2013 are overestimated, not accounting for reduced seepage loads from the Premises and not accounting for soil adsorption, nitrification and denitrification.*	N/A	**8,180 kg/ year**	**668 - 996.5 kg/ year**	N/A
	Total Phosphorus	N/A	**830 kg/ year** (*at 9.1 mg/L*)	N/A		N/A	**1,867 kg/ year**	**226.3 – 335.8 kg/ year**	N/A
Annual load seeping into Roebuck Bay	**Total nitrogen**	43,000 kg/ year (*estimated range 4,300 to 179,000 kg/ year*)	**470 kg/ year** (*based on 74% of 640 kg at 7 mg/L*)	32,826 kg/ year		**500 – 1000 kg/ year[4]** (*assumes denitrification occurs at source*)	**945 kg/ year** (*based on 74% of average at 7 mg/L*)	N/A	**180 kg/ year**
	Total Phosphorus	390 kg/ year (*estimated range 0 to 1,600 kg/ year*)	N/A (*based on soil sorption capacity between ponds and groundwater estimated at 42,000 kg)*	455 kg/ year		N/A	N/A (*based on soil sorption capacity/ attenuation)*	N/A	N/A

Note 0: Bold values are estimates from the Broome South sewage facility and may include the Broome Golf Club, other values are for the discharge of groundwater from the whole of the Broome Peninsula.

Note 1: Wright 2013 values were based on total groundwater discharge annual nutrient loads to Roebuck Bay.

Note 2: URS 2013 values based on assumed infiltration volume of 90,900 m^3/ year.

Note 3: Hearn 2014 values were based on total groundwater discharge annual nutrient loads to Roebuck Bay of that the Premises and Broome Golf Club were considered to be the most significant contributors to the nutrient load.

Note 4: Kelly 2015 values are based on annual nutrient loads to Roebuck Bay from the Premises and Broome Golf Club.

Note 5: AECOM 2016 values adapted from URS 2013 and Water Corporation 2016, *Broome South wastewater treatment plant preliminary water balance assessment version 2, 4 January 2016*.

Note 6: Golder Associates 2017 assessed values are based on a reduced seepage footprint, being the secondary and tertiary ponds.

Assumptions and uncertainty

Section 4.5 of this Decision Report discusses the soil profile and properties at the Premises, including available data on the phosphorus retention capacity of the soils and rates of hydraulic conductivity. No baseline data is available on the quality of soils or groundwater prior to commencement of Primary Activities at the Premises in 1981. The earliest recorded groundwater data at the Premises is detailed within Golder Associates 1997 which, concluded that impact to the unconfined aquifer from operations at the Premises was occurring. Groundwater monitoring results from the Broome Peninsula are relevant to consider with regards to the potential impact to groundwater from the Primary Activities. Elevated nitrogen levels are known to occur in groundwater within the Broome Peninsula up hydraulic gradient of the Premises.

Different assessments have used different groups of groundwater monitoring bores to assess the quality of groundwater and inform the delineation of potential impacts from the Premises. Some bores are located at different depths and in different geological units within the unconfined aquifer. Bores were installed in separate phases, sampling may have used different methods, and different quality assurance processes may have been used to attain and analyse the samples. The monitoring network used to characterise groundwater quality prior to 2017, is not considered to be adequate enough to delineate and characterise the impact to groundwater that seepage may be having with any certainty. Potential deficiencies in the post-2017 groundwater monitoring bore network have also been identified in the Technical Expert Report (see Appendix 4 of this Decision Report).

These factors affect the ability to analyse and compare groundwater quality data across different assessments and over time. This introduces uncertainty in the assessment of risk related to the hydraulic and biogeochemical process that may influence and be influenced by the seepage within the Pindan soils, aquifer and benthic sediments of Roebuck Bay.

Hydraulic and biogeochemical processes that influence contaminants within the pathway

Based on the information currently available to inform the risk assessment process under Phase 1 of the Review uncertainty remains with regards to:

- the hydraulic and biogeochemical processes that influence the form and transport of contaminants as a result of seepage that has and may continue to occur from the Premises; and
- the quantity and quality of groundwater that is discharging, now and in the future, into the Roebuck Bay benthic marine environment and subsequently the hydraulic and biogeochemical process occurring within the benthic sediments.

The fate of contaminants when passing through the soil profile, aquifer and benthic sediments of Roebuck Bay will influence the likelihood of an impact occurring from seepage. In considering the fate of contaminants in a conceptual site model for the Premises the following processes are considered relevant:

- Nitrogen attenuation: the main processes of nitrification of ammonium and denitrification of nitrate within the seepage plume and aquifer can significantly reduce the mass of nitrogen within groundwater however, within the core of seepage plumes anoxic conditions can significantly limit the nitrification process. Subsequently, the persistence of ammonia and nitrogen species within anoxic groundwater may not have been accounted for in the discussion presented by Golder Associates 2018 on the forms of nitrogen species likely to be present in groundwater, discharging to Roebuck Bay.

- Phosphorus attenuation: absorption to iron based minerals in the local soils can result in very slow migration of phosphorus through the soil profile and into the groundwater aquifer however, the local soils will have a maximum phosphorus retention capacity that will be exceeded over time. There is currently insufficient information to determine the phosphorus retention capacity of the soils affected by seepage at the Premises and stability of the phosphorus sorption that may be occurring. However, available data does not indicate that the capacity of the Pindan soils have been exceeded to date. It is considered that phosphorus and iron can be mobilised within an anoxic seepage plume, and by other biogeochemical processes, resulting in more rapid transport of phosphorus into groundwater that discharges into Roebuck Bay.
- Release of phosphorus, iron and nitrogen within the benthic marine sediments of Roebuck Bay: the prevalence of elevated concentrations of nutrients in groundwater may have led to an increase in the mass of phosphorus, iron and nitrogen being retained in benthic marine sediments along the groundwater flow-path. Re-mobilisation of nutrients from sediments can occur when hypoxic conditions prevail in the water column due to higher temperatures and low oxygen concentration (usually following heavy rainfall followed by calm conditions). Where organic carbon is present in the sediments or aquifer, this process can be inferred to be occurring. The remobilisation of iron and phosphorus is identified in Hanington et al. 2016, cited in Golder Associates 2018. The potential contribution and footprint of seepage from the Premises to contaminant loads within the benthic marine sediments of Roebuck Bay remains uncertain and undefined at this time.

These processes are discussed in the Technical Expert Report in Appendix 4 of this Decision Report. Calculations of the load of contaminants seeping from the Premises and/ or entering Roebuck Bay are summarised in Table 27**Error! Reference source not found.**. The report older Associates 2018 is summarised in Section 6.6.1 of this Decision Report.

6.7.3 Receptors

Roebuck Bay is considered to be the receptor of impacts arising from seepage coming from the Premises. Within Roebuck Bay potential ecological systems that are considered with regards to the risk assessment are:

- direct impacts to the Roebuck Bay mudflat ecosystems and benthic flora and fauna as a result of seepage and altered hydraulic and biogeochemical processes that affect community structure and ecosystem services; and
- secondary indirect impacts to birds, turtles, other fauna and humans as a result changes to community structure, ecosystem services and from cyanotoxins within and released by *Lyngbya majuscula*.

The scope of receptors extends from the primary producers, with a focus on the Roebuck Bay mudflats Threatened Ecological Community to the top of the food chain and the environmental values described in Sections 4.3 and 5.1 of this Decision Report.

Assumptions and uncertainty

Two key assumptions are made with regards to receptors:

- that the seepage under post-2017 operational conditions is of sufficient magnitude to result in or reasonably contribute to impacts to normal ecosystem function at the receptors. As discussed in Section 6 of this Decision Report, the assumptions, uncertainty and scientific principles regarding the hydraulic and biogeochemical processes that influence seepage within the Pindan soils, aquifer and benthic sediments is sufficient to consider a precautionary approach when assessing the risks to receptors; and
- that the receptor is susceptible to the impacts from the seepage. The supporting literature is considered to demonstrate that the Roebuck Bay ecosystem, flora and fauna could be impacted by discharges of groundwater contaminated by constituents contained within sewage and wastewater effluent; directly and indirectly, including from blooms of *Lyngbya majuscula*.

(23) The Delegated Officer notes, consistent with the Technical Expert Report, that:

(a) seepage from the ponds contained on the Premises enters groundwater and discharges to the Roebuck Bay mudflat ecosystem;

(b) nutrient inputs from multiple sources within the Roebuck Bay catchment almost certainly play a cumulative role in the abundance and distribution of *Lyngbya* blooms;

(c) nitrogen is not likely the limiting factor for the appearance of *Lyngbya* blooms but may be a contributing factor, and ammonia, iron and phosphorus released from benthic sediments is likely to be a primary factor in initiating blooms.

(d) nutrients from the Premises that enter Roebuck Bay and the influence of associated hydraulic and biogeochemical process within the aquifer and benthic sediments may have a material impact on the abundance and distribution of *Lyngbya* blooms.

(e) the occurrence of anoxic conditions within a seepage plume from the Premises would increase the likelihood of impacts in Roebuck Bay.

(f) other potential contaminants of concern that are not currently delineated or discussed that may impact the Roebuck Bay ecosystem can be considered further following the DSI under phase 2 of the Review (for example per- and polyfluoroalkyl substances, surfactants, pharmaceuticals, personal care products, anti-microbial products and plasticisers and other potential endocrine disrupting chemicals)

7. Consultation

The then DER and DWER have liaised with the Licence Holder throughout the Review process. Consultation has been in regards to the submissions listed in Table 2 and the documents listed in Appendix 1 of this Decision Report and items detailed in the 2016 Draft referral. Consultation of the draft version of this Decision Report and the draft Revised Licence (2018 Draft Referral) is detailed in Appendix 3 of the Decision Report and is referred to as the 2018 Draft Referral (see Section 6.6.3 of this Decision Report).

A referral for consultation to the Department of Biodiversity, Conservation and Attractions was undertaken on 1 May 2018.

Referrals for consultation with the following stakeholders was undertaken by DWER on 31 May 2018:

- Broome Golf Club Incorporated;
- Yawuru native title holders;
- Environs Kimberley;
- Roebuck Bay Working Group; and
- Shire of Broome.

No responses were received from the five stakeholders as a result of the May 2018 correspondence.

Consultation is detailed in Appendix 2 and Appendix 3 of this Decision Report.

8. Risk assessment

8.1 Determination of emission, pathway and receptor

In undertaking its risk assessment, DER will identify all potential emissions pathways and potential receptors to establish whether there is a Risk Event which requires detailed risk assessment. To establish a Risk Event there must be an emission, a receptor that may be exposed to that emission through an identified actual or likely pathway and a potential adverse effect to the receptor from exposure to that discharge/ emission. Where there is no actual or likely pathway and/ or no receptor, the emission will be screened out and will not be considered as a Risk Event. In addition, where an emission has an actual or likely pathway and a receptor which may be adversely impacted, but that emission is regulated through other mechanisms such as Part IV of the EP Act, that emission will not be risk assessed further and will be screened out through Table 28**Error! Reference source not found.**. The identification of the sources, pathways, receptors to determine Risk Events are set out in Table 28.

Table 28: Identification of emissions, pathway and receptors during operation of Primary Activities.

Risk Events						**Continue to detailed risk assessment**	**Reasoning**
Sources/ Activities		**Potential emissions**	**Potential receptors**	**Potential pathway**	**Potential adverse impacts**		
Sewage and liquid waste acceptance, treatment and storage	Delivery, treatment and storage of sewage via sewage system to the sewage facility ponds. .	Discharge to land (containment failure/ overtopping)	Adjacent lands, being the coastal vegetated strip behind the primary dunes, includes: *Corymbia paractia* ecological communities. Groundwater discharging into Roebuck Bay marine and intertidal ecosystem (*discharge area not known at this time*). Surface water discharge to Roebuck Bay.	Direct discharge/ overland flow	Amenity and human health impacts. Ecosystem service impacts.	Yes	The risk events are considered foreseeable, noting the scale and type of the operations, having a defined pathway, receptor and potential adverse impacts to the receptor/s. *See Section 8.4: Discharge to land (containment failure)*
				Seepage through soil and within groundwater	Nutrient loading of soils and groundwater, pore water and marine waters; suppression of ecosystem services; impacts to fauna and flora; contamination of marine ecosystem.		

Risk Events						Continue to detailed risk assessment	Reasoning
Sources/ Activities		**Potential emissions**	**Potential receptors**	**Potential pathway**	**Potential adverse impacts**		
Sewage and liquid waste acceptance, treatment and storage (continued)	Delivery and treatment of sewage via sewage system to primary, secondary and tertiary ponds (continued).	Noise	Residential premises located 470 m to the east and 600 m to the northeast. Commercial premises located 50 m to the north. Users of the golf club directly west. Users of the Roebuck Bay shoreline directly south/ southeast.	Air / wind dispersion	Amenity and human health impacts	No	Distance to receptors, scale and type of operations and lack of reasonably foreseeable impact. No known significant emission sources or history of noise emission impacts. Adequately regulated by the *Environmental Protection (Noise) Regulations 1997.*
		Odour	Residential premises located 470 m to the east and 600 m to the northeast. Commercial premises located 50 m to the north. Users of the golf club directly west. Users of the Roebuck Bay shoreline directly south/ southeast.	Air / wind dispersion	Amenity and human health impacts	Yes	The risk event is considered foreseeable, noting the type of operations, having a defined pathway, receptor and potential adverse effects to the receptor/s. *See Section 8.5: Odour*
		Seepage (through base of ponds/ liners)	Groundwater discharging into Roebuck Bay marine and intertidal ecosystem (*specific discharge area not known at this time*).	Seepage through soil and within groundwater	Nutrient loading of soils and groundwater, pore water and marine waters; suppression of ecosystem services; impacts to fauna and flora; contamination of marine ecosystem.	*Yes*	The risk event is considered foreseeable, noting the scale and type of operations, having a defined pathway, receptor and potential adverse effects to the receptor/s. *See Section 8.6: Seepage.*

Risk Events						Continue to detailed risk assessment	Reasoning
Sources/Activities		**Potential emissions**	**Potential receptors**	**Potential pathway**	**Potential adverse impacts**		
Sludge storage	Dewatering and storage of sludge from ponds	Discharge to land (storage/ containment/ dewatering)	Groundwater discharging into Roebuck Bay marine and intertidal ecosystem (*specific discharge area not known at this time*).	Seepage through soil and within groundwater	Nutrient loading of soils and groundwater, pore water and marine waters; suppression of ecosystem services; impacts to fauna and flora; contamination of marine ecosystem.	Yes	The risk events are considered foreseeable, noting the scale and type of the operations, having a defined pathway, receptor and potential adverse effects to the receptor/s. *See Section 8.4: Discharge to land (containment failure)*
		Odour	Residential premises located 470 m to the east and 600 m to the northeast. Commercial premises located 50 m to the north. Users of the golf club directly west. Users of the Roebuck Bay shoreline directly south/ southeast.	Air / wind dispersion	Amenity and human health impacts	Yes	The risk event is considered foreseeable, noting the type of operations, having a defined pathway, receptor and potential adverse effects to the receptor/s. *See Section 8.5: Odour*
Management of storm water[1]	Storm water management (all)	Discharge to land (stormwater contaminated with sewage and/ or sediment)	Adjacent lands, being the coastal vegetated strip behind the primary dunes, includes: *Corymbia paractia* ecological communities. Groundwater discharging into Roebuck Bay marine and intertidal ecosystem (*specific discharge area not known at this time*). Surface water discharge to Roebuck Bay.	Direct discharge/ overland flow	Amenity and human health impacts. Ecosystem service impacts.	No	Duration, scale and type of Operations. Adequately regulated by *Environmental Protection (Unauthorised Discharge) Regulations 2004* and general provisions of the EP Act.
				Seepage through soil and within groundwater	Nutrient loading of soils and groundwater, pore water and marine waters; suppression of ecosystem services; impacts to fauna and flora; contamination of marine ecosystem.		

Risk Events						Continue to detailed risk assessment	Reasoning
Sources/Activities		**Potential emissions**	**Potential receptors**	**Potential pathway**	**Potential adverse impacts**		
Discharge of treated sewage	Treated sewage discharge to reuse facilities.	Discharge to land (irrigation	Groundwater Roebuck Bay	Through soils	Groundwater quality	No	Discharge occurs onto prescribed premises as defined under the *Environmental Protection Act 1986*. Risks of impacts to receptors from operations at other prescribed premises are the responsibility of the occupiers of those prescribed premises and will be assessed and controlled through the provisions of the *Environmental Protection Act 1986*.
			Surface water	Overland flow	Surface water quality		

Note 1: Where stormwater is relevant to a specific Risk Event within Table 28 stormwater is considered within the assessment for that Risk Event.

8.2 Consequence and likelihood of risk events

A risk rating will be determined for risk events in accordance with the risk rating matrix set out in Table 29. DER will undertake an assessment of the consequence and likelihood of the Risk Event in accordance with Table 30.

Table 29: Risk rating matrix.

Likelihood	Consequence				
	Slight	Minor	Moderate	Major	Severe
Almost certain	Medium	High	High	Extreme	Extreme
Likely	Medium	Medium	High	High	Extreme
Possible	Low	Medium	Medium	High	Extreme
Unlikely	Low	Medium	Medium	Medium	High
Rare	Low	Low	Medium	Medium	High

Table 30: Risk criteria table.

Likelihood		Consequence		
The following criteria has been used to determine the likelihood of the Risk Event occurring.		The following criteria has been used to determine the consequences of a Risk Event occurring:		
			Environment	Public health* and amenity (such as air and water quality, noise, and odour)
Almost Certain	The risk event is expected to occur in most circumstances	Severe	• **onsite impacts**: catastrophic • **offsite impacts local scale**: high level or above • **offsite impacts wider scale:** mid-level or above • Mid to long-term or permanent impact to an area of high conservation value or special significance^ • Specific Consequence Criteria (for environment) are significantly exceeded	• Loss of life • **Adverse health effects:** high level or ongoing medical treatment • Specific Consequence Criteria (for public health) are significantly exceeded • **Local scale impacts:** permanent loss of amenity
Likely	The risk event will probably occur in most circumstances	Major	• **onsite impacts**: high level • **offsite impacts local scale**: mid-level • **offsite impacts wider scale**: low level • Short-term impact to an area of high conservation value or special significance^ • Specific Consequence Criteria (for environment) are exceeded	• **Adverse health effects:** mid-level or frequent medical treatment • Specific Consequence Criteria (for public health) are exceeded • **Local scale impacts**: high level impact to amenity
Possible	The risk event could occur at some time	Moderate	• **onsite impacts**: mid-level • **offsite impacts local scale**: low level • **offsite impacts wider scale**: minimal • Specific Consequence Criteria (for environment) are at risk of not being met	• **Adverse health effects:** low level or occasional medical treatment • Specific Consequence Criteria (for public health) are at risk of not being met • **Local scale impacts:** mid-level impact to amenity
Unlikely	The risk event will probably not occur in most circumstances	Minor	• **onsite impacts**: low level • **offsite impacts local scale**: minimal • **offsite impacts wider scale**: not detectable • Specific Consequence Criteria (for environment) likely to be met	• Specific Consequence Criteria (for public health) are likely to be met • **Local scale impacts:** low level impact to amenity
Rare	The risk event may only occur in exceptional circumstances	Slight	• **onsite impact**: minimal • Specific Consequence Criteria (for environment) met	• **Local scale**: minimal to amenity • Specific Consequence Criteria (for public health) met

^ Determination of areas of high conservation value or special significance should be informed by the *Guidance Statement: Environmental Siting.*

* In applying public health criteria, DWER may have regard to the Department of Health's *Health Risk Assessment (Scoping) Guidelines.*

"onsite**"** means within the Prescribed Premises boundary.

8.3 Acceptability and treatment of Risk Event

The acceptability and treatment of Risk Events will be determined in accordance with Table 31.

Table 31: Risk treatment table.

Rating of Risk Event	Acceptability	Treatment
Extreme	Unacceptable.	Risk Event will not be tolerated. DWER may refuse application.
High	May be acceptable. Subject to multiple regulatory controls.	Risk Event may be tolerated and may be subject to multiple regulatory controls. This may include both outcome-based and management conditions.
Medium	Acceptable, generally subject to regulatory controls.	Risk Event is tolerable and is likely to be subject to some regulatory controls. A preference for outcome-based conditions where practical and appropriate will be applied.
Low	Acceptable, generally not controlled.	Risk Event is acceptable and will generally not be subject to regulatory controls.

8.3.1 Consideration of criteria for assessment

The following receptors were identified as potentially being impacted by the Risk Events identified in Table 28, the associated consequence criteria are applicable when considering the potential impact to that receptor:

- The coastal vegetation *Corymbia paractia* priority ecological communities are an area of high conservation value and special significance.
- The Roebuck Bay intertidal ecosystem is an area of high conservation value and special significance. In addition, being a marine ecosystem, the ANZECC and ARMCANZ 2000 Section 3.4, Table 3.4.1 trigger values for toxicants and Section 3.5, Table 3.5.1 sediment quality guidelines are relevant for considering specific consequence criteria.
- Public health receptors within proximate residences, light industrial area and users of the Broome Golf Club and Roebuck Bay shoreline are considered with regards to amenity and health impacts from odour emissions and with regards to the ANZECC and ARMCANZ 2000 Section 5.2, Table 5.2.2 guidelines for contact with sewage from overflow and containment failure.

All values stated within guidelines and considered as potential specific consequence criteria need to be considered with regards to the site-specific circumstances. Relevant specific consequence criteria are considered below under the assessment for each Risk Event. Section 3.1 of Golder Associates 2018 also discusses potential consequence criteria.

8.4 Risk Assessment – Discharge to land (containment failure and overtopping)

8.4.1 Description of discharge to land (containment failure and overtopping)

Discharge of raw, partially treated and/ or treated sewage may occur from the Broome South sewage facility ponds, a sludge drying hardstand and/ or pipes via overtopping or structural failure (*e.g. pipeline failure or pond wall collapse*). Overtopping is considered the most reasonably foreseeable event. Any discharges are expected to discharge from the southern end of the Premises or seep into local soils. As demonstrated by the events detailed in Section 4.6 of this Decision Report, large volume containment failure can result in direct discharge to the waters of Roebuck Bay. The discharges could contain contaminants including heavy metals, nutrients, pathogens, phenols and surfactants. Contaminants could impact the terrestrial ecosystem functions, flora and fauna of the *Corymbia paractia* priority ecological communities, enter groundwater or discharge to Roebuck Bay. Discharges to land via containment failure are considered foreseeable as one-off events within this risk assessment and will likely be coincidental with and diluted by high volumes of rainfall. Human usage of adjacent lands and/ or Roebuck Bay shoreline is considered possible and in the event of containment failure impacting human receptors is considered reasonably foreseeable.

8.4.2 Identification and general characterisation of emission

The Premises receives a continuous load of sewage subject to diurnal and seasonal fluctuations. As sewage proceeds through the treatment ponds some contaminants undergo biological treatment and some contaminants settle to the base of the ponds to form sludge. Generally, as the sewage proceeds through the treatment ponds, the concentration of contaminants decreases. The quantity and quality of sewage, raw or treated, discharge via containment failure will vary depending on the nature of the containment failure at the time, location of failure within the sewage facility, hydraulic load being placed on the sewage facility, effectiveness of the sewage facility treatment process, capacity to direct wastewater to reuse facilities, ambient meteorological conditions including potential infiltration of stormwater within the sewage conveyance network and response time to resolve the containment failure. The rainfall event documented in Section 4.6 of this Decision Report describes the nature of overflow events derived from a significant rainfall event and demonstrates that there are reasonably foreseeable limitations to the current containment capacity at the Premises.

8.4.3 Description of potential adverse impact from the emission

Under a worst-case scenario impacts could occur to:

- Roebuck Bay; and/ or.
- humans using the adjacent lands and/ or Roebuck Bay shoreline.

Impacts to ecosystem services, flora and fauna and health of the *Corymbia paractia* priority ecological communities could also occur but have been excluded on the assumption that overflow events would most likely follow preferential flow paths towards Roebuck Bay or infiltrate to groundwater as described in Figure 11. This is demonstrated by previous events, (see Sections 4.6 and 5.10.6 of this Decision Report) and the occurrence of overflow at the Premises is more foreseeable during extreme rainfall events compared to normal operating conditions.

Based on a surface water pathway to Roebuck Bay, impacts are considered with regards to water quality and potential eutrophication of the marine waters and not the hydrogeological pathway discussed in Section 6.7. Therefore, containment failure is not reasonably considered to result in impacts causing or from *Lyngbya majuscula* blooms.

8.4.4 Criteria for assessment

Environment: Roebuck Bay is an area of high conservation value and special significance.

Public health: ANZECC and ARMCANZ 2000 Section 5.2, Table 5.2.2 guidelines with regards to primary contact with sewage from overflow and containment failure, being specific consequence criteria. Impacts to public health were considered more significant than impacts to amenity values.

8.4.5 Licence Holder controls

Treated sewage is discharged to four irrigation reuse areas (see on Table 10). Following the completion of the Storage Pond and reconfiguration of the sewage treatment system in 2017 the capacity for overtopping and containment failures is controlled by emergency ponds 1, 2 and 3 and the freeboard of the Storage Pond. Emergency containment capacity equates to 31,481 m^3, being the equivalent of ~400 mm of rainfall or ~17.3 days of average sewage inflow when all other variables are excluded. No dedicated sludge drying/ containment infrastructure is located at the Premises. The Licence Holder has identified that peak sewer inflows are correlated to high rainfall events (Water Corporation 2018a).

8.4.6 Key findings

(24)	**Key Finding: The Delegated Officer considers that overtopping and/ or containment failure would only occur during upset or exceptional circumstances and that the Licence Holder must be able to demonstrate how the sewage facility infrastructure is prepared for the additional containment capacity that may be required each wet season.**

8.4.7 Consequence

If containment failure occurs beyond the boundary of the Premises, then the Delegated Officer has determined that if impacts to the environmental values of Roebuck Bay occur they will be short term to an area of high conservation significance or special significance. Therefore, the Delegated Officer considers the consequence of containment failure for environmental receptors to be **Major**.

If containment failure occurs beyond the boundary of the Premises, then the Delegated Officer has determined that if impacts to human health occur they will be specific consequence criteria (for public health) being exceeded. Therefore, the Delegated Officer considers the consequence of containment failure for human health receptors to be **Major**.

The Delegated Officer notes that the six sampling events taken over 19 days during an overflow event (see Table 19 of this Decision Report) are not considered representative of the reasonably foreseeable risk to receptors or to adequately characterise the pathogen concentrations that may overflow from the Premises or contribute to the contamination of storm water. Subsequently, a precautionary approach has been taken in considering the reasonably foreseeable consequence for human health.

8.4.8 Likelihood of Risk Event

The Delegated Officer has taken into consideration the emergency storage capacity at the Premises, potential variability of rainfall events and the likelihood of a containment failure being of sufficient scale to impact the receptors. The determination of likelihood for impacts from containment failure has assumed that irrigation outputs remain at current quantities.

The Delegated Officer has determined that the likelihood of containment failure occurring and impacting environmental and human health receptors will probably not occur in most circumstances. Therefore, the Delegated Officer considers the likelihood of impacts to environmental and human health receptors from containment failure to be **Unlikely**.

The Delegated Officer notes that prior to the 2017 works to increase the containment capacity at the Premises that a higher likelihood of impact may have been determined. The Delegated Officer has also considered the likelihood of containment failure and overtopping if irrigation were not to occur. Based on the total contingency capacity provided by the Storage Pond freeboard and the emergency ponds, being ~32,491 m^3 based on Table 9 data, and the total daily irrigation volumes, being ~1,518 m^3 based on Table 10 data, a minimum storage capacity of ~21.4 days irrigation volume is provided at the Premises. This estimate would more than half based on daily sewage inflows of ~2,000 m^3 and this estimate does not consider evaporation or seepage. Based on this very simple analysis the Delegated Officer considers that in the absence of irrigation, or alternate appropriate disposal/ reuse options, that the likelihood of impacts could increase to possible or likely.

8.4.9 Overall rating of Discharge to land (containment failure and overtopping)

The Delegated Officer has compared the consequence and likelihood ratings described above with the risk rating matrix (Table 29) and determined that the overall rating for the risk of containment failure is **Medium** for environmental receptors and for human health receptors.

8.5 Risk Assessment – Odour

8.5.1 Description of odour

Odour may be generated by the acceptance, storage and treatment of sewage wastes, removal and processing of sewage sludges. Sewage wastes can contain high loads of biochemical oxygen demand (BOD) and can also contain aromatic molecules; both can result in potentially odourous emissions. Odour emissions during the storage and treatment of sewage waste can be accentuated where pond waters undergo uncontrolled anaerobic reaction and/ or are overloaded with contaminants beyond the hydraulic and treatment capacity of the ponds; considered as foreseeable abnormal operating conditions. Odour emissions are considered based on the frequency, intensity, duration and offensiveness of the emission and locations of the emission source and receptors considering the pathway.

8.5.2 Identification and general characterisation of emission

Odour emissions that impact receptors are expected to be periodic, of low frequency and short to medium term duration. Abnormal operating conditions may give rise to higher frequency and duration odour emission events. Wind plots presented in Figure 5 and Figure 6 indicate that the pathway, via the airshed, is predominantly towards receptors in the west and north west during the morning (golf club and light industrial area) and towards the east in the afternoons (coastal reserve, vacant land and residential area).

8.5.3 Description of potential adverse impact from the emission

Odour can impact the amenity value for the receptor and can have secondary health impacts. Meteorological factors are expected to have a significant influence on the pathway for odour emissions and therefore the potential level of impact on receptors. Residential receptors are expected to be more sensitive than industrial receptors. Users of the Roebuck Bay foreshore area are also considered in this risk assessment.

8.5.4 Criteria for assessment

No specific consequence criteria are applicable. The health, welfare, convenience, comfort and amenity of receptors are relevant in determining the consequence of odour emissions. The closest recreational receptors are identified at the Broome Golf Club directly west and within coastal reserves located due south and extending a few hundred metres east. The closest residential receptors are identified at 470 m east, 600 m northeast and 720 m west from the sewage facility infrastructure. There is no documented history of odour complaints.

8.5.5 Licence Holder controls

No specific management plans or supporting documents have been provided by the Licence Holder regarding the management of odour at the sewage facility. This assessment has reviewed the controls set out in Table 32.

Table 32: Licence Holder's proposed controls for odour.

Control type	Infrastructure control	Operational control
Siting	Sewage facility siting.	Under the *Shire of Broome Town Planning Scheme No. 6* the Premises is provided an essential service buffer delegating a Special Control Area. The buffer extends in an arc around the Premises at 500 m from west through south and to the east, the buffer falls to 400 m in the west and 200 to 250 m in the north to accommodate existing residential and light industrial Premises (see Figure 8 in this Decision Report).
Sewage facility (treatment)	Treatment of sewage through the sewage facility under normal operating conditions.	The Licence Holder provides treated sewage that is required to be within the pH range of ≥ 6.5 and ≤ 8.5.
Sewage facility (sludge management)	None.	Sludge is not stored at the Premises.

8.5.6 Key findings

(25) Key Finding: The Delegated Officer has reviewed the information regarding odour and has found that maintenance of sewage through the treatment process ≥6 pH and ≤9 pH is appropriate for odour management.

8.5.7 Consequence

If impacts from emission of odour occur, then the Delegated Officer has determined that the impact of emission of odour will be will be local scale mid-level impact to amenity. Therefore, the Delegated Officer considers the consequence of emission of odour to be **Moderate**.

8.5.8 Likelihood of Risk Event

The Delegated Officer has taken into consideration the siting of the Premises, prevailing ambient meteorological conditions and lack of historical odour complaints. The Delegated Officer has determined that the likelihood of emission of odour occurring and impacting receptors will only be in exceptional circumstances. Therefore, the Delegated Officer considers the likelihood of impacts arising from the emission of odour to be **Rare**.

8.5.9 Overall rating of odour emissions

The Delegated Officer has compared the consequence and likelihood ratings described above with the risk rating matrix (Table 29) and determined that the overall rating for the risk of emission of odour is **Medium**.

8.6 Risk Assessment – Seepage

8.6.1 Description of Seepage

Seepage from the ponds at the Premises is expected to occur continuously based on historic groundwater monitoring data, seepage investigations and types of liners within the sewage facility ponds. The rate of seepage = being subject to the hydraulic load within the ponds, permeability of the pond liner and nature of the hydrogeology (Pindan soils, Broome sandstone and aquifer). The events of seepage from treated sewage reuse storage tanks, conveyance infrastructure and any sewage sludge containment are relevant to this risk assessment however, they are not considered to be of comparable significance. Section 6 of this Decision Report discusses the hydrogeological context of seepage migration in more detail and the data presented in

Table **9** and Table 14 establish approximate separation distances to groundwater from below the pond floors. Based on a groundwater level ranging between 1 to 4 mAHD, separation distances to the base of ponds range from 6 to 9 mAHD for the Emergency Ponds and Secondary Pond, 5 to 8 m for the Storage and Tertiary ponds and 0 to 3 m for the Primary Pond. Section 6.7 of this Decision Report summarises the available information that informs the Delegated Officers understanding of the sources, pathways, receptors and potential uncertainty and assumptions that inform this assessment of the risk from seepage emissions.

Sewage and sewage sludge wastes could contain contaminants that may be mobilised within seepage generated from ponds containing sewage wastes. The nature of the containments within the seepage and interaction with the soil profile and hydraulic and biogeochemical processes will affect the distribution of containments within the unsaturated soils beneath the ponds and in groundwater containing seepage.

Ponds at the Premises are considered in three groups. Ponds with low permeability liners installed are considered to present the lowest likelihood of seepage, followed by the ponds lined with in-situ compacted Pindan soils. The groups are considered as:

- Low permeability lined ponds: Primary Pond and Storage Pond lined with geosynthetic clay liners (GCL);
- Temporary use ponds: Emergency Pond 1, Emergency Pond 2 and Emergency Pond 3 lined with compacted Pindan soils; and
- Operational ponds: Secondary Pond and Tertiary Pond lined with compacted Pindan soils.

The Delegated Officer notes that while not specifically assessed herein that the proximity of the Primary Pond GCL to groundwater 0 to 3 m separation distance and the age of the liner (installed in 2003 and no documented construction quality assurance process identified at this time), are factors that could materially affect the long-term performance of the GCL. These factors may be considered further in Phase 2 of the Review.

8.6.2 Identification and general characterisation of emission

The quantity and quality of the seepage from the ponds that reaches groundwater beneath the Premises will be different to that reaching Roebuck Bay. The concentration of contaminants within the seepage will be affected by physical, hydraulic and biogeochemical processes before discharging to Roebuck Bay. Calculations of the volume of seepage arising from the Premises are summarised in Table 26. Calculations of the load of contaminants seeping from the Premises and/ or entering Roebuck Bay are summarised in Table 27. The estimates of contaminant loads applied in this risk assessment were based on the following sources and supported by the Technical Expert Report:

- total nitrogen concentrations of 41.5 mg/L and total phosphorus concentrations of 7 mg/ L within the seepage source (URS 2013, page v).
- total nitrogen concentrations of 44.7 mg/L and total phosphorus concentrations of 10.2 mg/ L within the seepage source (AECOM 2016, Table 1).
- total nitrogen concentrations of 25.8 mg/L and total phosphorus concentrations of 8.7 mg/ L within the seepage source (Golder Associates 2017, page 10 and Golder Associates 2018, page 17).

The Delegated Officer notes that all calculation methods are subject to uncertainty and assumptions, some of which are identified in individual reports and some are discussed in Section 6.7 of this Decision Report.

Golder Associates 2017 estimate that the Primary Pond and Storage Pond are contributing 0.76 % - 1.14 % of the total seepage volume from the Premises. The lined Primary Pond and Storage Pond are not considered to materially contribute to seepage on the assumption that the liners are intact and operating to manufacture specifications.

The temporary unlined emergency ponds are only used when storage capacity within the primary, secondary, tertiary and storage ponds are exceeded (see Section 8.4.5 of this Decision Document). Continued use of the ponds is considered possible and the occurrence of seepage is assumed to be almost certain when the ponds contain water for extended periods (e.g. > 24 hours) due to the lack of certified low-permeability liners.

The Secondary Pond and Tertiary Pond are considered the two main sources of seepage at the Premises. Golder Associates 2017 estimate the seepage load coming from the Primary Pond and Storage Pond only, consistent with current operating practices. Golder Associates 2018 provides an updated estimate of the seepage load based on Golder Associates 2017 and the interpretation of interim groundwater monitoring data with respect to seepage impacts, as part of the DSI process.

All estimates presented in Table 26 and Table 27, other than Golder Associates 2017 and Golder Associates 2018, are based on emergency ponds 1, 2 and 3 being operational ponds under consistent hydraulic load and the Storage Pond being lined by in-situ compacted Pindan soils. The Storage Pond now has a GCL, and the emergency ponds are not in continual use.

Based on the available information and the Technical Expert Report, the Delegated Officer has considered that:

- Concentrations at the seepage source of 37.3 mg/ L of total nitrogen and 8.6 mg/ L of total phosphorus are derived from the average of URS 2013, AECOM 2016 and Golder Associates 2017 over a total seepage source footprint of 34,738 m^2 for the secondary and tertiary pond (area calculated from
- Table **9**). The footprint of the secondary and tertiary pond is ~55% of the total pond footprint used in all assessments prior to Golder Associates 2017 (calculated from
- Table **9** excluding the Primary Pond that has had a low permeability liner installed since 2003). The ~55% value accounts for the Storage Pond now having a low permeability GCL.
- An average volume of seepage discharging from the Secondary Pond and Tertiary Pond is 65,828 kL/ year based on the annual average values in Table 26, corrected to ~55% for estimates prior to Golder Associates 2017 and Golder Associates 2018.

Volume (65,828) = [(~55% x annual average seepage estimate) + (31,900)]
5 (number of annual average seepage estimates)

- Based on the estimated concentration (37.3 mg/ L total nitrogen and 8.6 mg/L total phosphorus) and annual volume (65,828 kL), seepage is discharging 2,455 kg/ year total nitrogen and 566 kg/ year total phosphorus from the secondary and tertiary pond into the Pindan soils. Based on Golder Associates 2017 and Golder Associates 2018 seepage may be discharging an estimated 668 – 996.5 kg/ year total nitrogen and 226.3 – 335.8 kg/ year total phosphorus from the secondary and tertiary pond.
- It is assumed that the phosphorus retention capacity of the Pindan soils, that make up the unsaturated zone between the Premises and the aquifer, will become exhausted at some time and mobilisation of residual contaminant loads by seepage is considered to be foreseeable. Phosphorus concentrations within the aquifer, correlated with the release of iron in anoxic environments, are subsequently assumed to be as high as 566 kg/ year total phosphorus discharging into Roebuck Bay.
- The nitrification/ denitrification process within areas of the plume may be significantly limited by potential anoxic conditions and the total load of nitrogen as high as 2,455 kg/ year is assumed to be discharging to Roebuck Bay.
- As discussed in Section 6.7 of this Decision Report the footprint of seepage inputs was reduced by ~45% during 2017. Due to the potential nature of a seepage plume and considering historic loading the total contaminant load from the seepage discharging into Roebuck Bay will almost certainly remain elevated for a number of years regardless of improvements during 2017 or required in the Revised Licence. Groundwater flow modelling indicates that the travel time for water seeping from the Premises into Roebuck Bay is in the order of years to decades (Golder Associates 2018, page 35). Physical, hydraulic and biogeochemical processes could extend th travel time for some contaminants.

Golder Associates 2018 uses recent groundwater monitoring data to refine the Golder Associates 2017 estimate; a total of 180 kg/ year total nitrogen is estimated to be discharging into Roebuck Bay along the modelled groundwater discharge plane. Golder Associates 2018 do not estimate a load of total phosphorus to be discharging into Roebuck Bay, the attenuation of phosphorus via sorption to local soils is inferred to result in no significant impact or transport of phosphorus in groundwater. Section 6.6.3 discusses aspects of the Golder Associates 2018 estimate of 180 kg/ year total nitrogen and grounds for a precautionary approach.

(26) Key Finding: The Delegated Officer has found, consistent with the Technical Expert Report, that the likelihood of impacts to the environmental values of Roebuck Bay at the time of this assessment may be higher due to residual contaminants from larger volumes of historic seepage, still present in the soils and aquifer that almost certainly occurred during the pre-2017 operational arrangements at the Premises.

8.6.3 Description of potential adverse impact from the emission

Direct impacts from seepage include changes to community structure and the ecosystem services to parts of the Roebuck Bay benthic intertidal mudflat ecosystem. Direct impacts include altering the biogeochemical processes within the benthic sediments and abundance, diversity and health of flora and fauna. Changes to hydraulic and biogeochemical processes can support the release of phosphorus, iron and organic carbon from benthic sediments that in

turn support the growth of and increase competition from *Lyngbya majuscula*.

Known indirect/ secondary impacts, being the release of cyanotoxins by *Lyngbya majuscula* and/ or changes to ecosystem services, can impact community structure, birds, turtles, other fauna and human health. The occurrence of *Lyngbya majuscula* is noted to almost certainly be the result of multiple factors influencing the health of Roebuck Bay; seepage from the Premises is considered to potentially be a material contributor to some areas where *Lyngbya majuscula* has been observed.

Other contaminants of potential interest within the seepage that could impact the environmental impacts of Roebuck Bay include per- and polyfluoroalkyl substances, polybrominated diphenyl ethers, organic and inorganic chemicals, surfactants, pharmaceuticals, personal care products, anti-microbial and disinfection products and plasticisers and other potential endocrine disrupting chemicals. Some of these contaminants can persist in the environment, bio-accumulate and exhibit endocrine disrupting properties. It is considered that theses contaminants have the potential to be present in seepage generated from Primary Activities at the Premises at concentrations that have the potential to cause impact to susceptible environmental receptors within Roebuck Bay.

8.6.4 Criteria for assessment

The Roebuck Bay ecosystem, flora and fauna are considered an area of high conservation value and special significance. Criteria specified within ANZECC and ARMCANZ 2000 are not considered appropriate as specific consequence criteria in this risk assessment.

Human health is considered with regards to adverse health effects from cyanotoxins released by *Lyngbya majuscula*.

8.6.5 Licence Holder controls

The controls used by the Licence Holder are all source containment controls detailed in Table 33. These controls follow changes to the operation of the sewage facility in 2017.

Table 33: Licence Holder's proposed controls for seepage.

Risk Event infrastructure controls	Risk Event operational controls

Ponds:
• Hydraulic head and separation distance to groundwater.
• Liner standard/ integrity:
  ○ Primary Pond – HDPE liner
  ○ Secondary and tertiary ponds – compacted Pindan soils
  ○ Storage pond – GCL liner supported by construction quality assurance validation report.
  ○ Emergency ponds (*temporary*) – compacted Pindan soils.
	Actions summarised in Table 5 of this Decision Report.
	Groundwater monitoring:
	• Quarterly monitoring of groundwater bores 1/04, 2/04, 2/97, 3/04, 3/97, 4/97 and 8/97.
	• Additional monitoring and investigations undertaken outside the provisions of the Existing Licence.

Commitment to cease the acceptance of waste and operations at the Premises by approximately the end of 2025.	

8.6.6 Key findings

(27) Key Finding: The Delegated Officer has reviewed the information regarding the risk of seepage and found:

(a) the extent to which seepage from the Premises has and may in the future impact Roebuck Bay and influence the growth of *Lyngbya majuscula* is currently uncertain;

(b) seepage from the Premises is considered to be one of many inputs to Roebuck Bay contributing to chronic ecosystem impacts and the presence of *Lyngbya majuscula*; and

(c) due to the uncertainty and assumptions that inform the risk assessment process and the significance and sensitivity of the receptors that a precautionary approach to the risk assessment is required.

(28) Key Finding: The Delegated Officer considers that the risk of seepage should be considered for both pre and post 2017 operational situations (see Section 3.1 of this Decision Report).

8.6.7 Consequence

If seepage occurs, then the Delegated Officer has determined that the impact on the Roebuck Bay ecosystem, both pre and post 2017 operational situations, will be medium to long term to an area of high conservation significance. Therefore, the Delegated Officer considers the consequence of seepage to Roebuck Bay to be **Severe**.

8.6.8 Likelihood of Risk Event

The Delegated Officer has taken into consideration the uncertainty, assumptions, significance of the receptors, supporting reports and Technical Expert Report documented in this Decision Report. These factors have led the Delegated Officer to consider that an anoxic seepage plume was emanating from the Premises and that some contaminants contained within the groundwater impacted by the seepage are almost certainly discharging to Roebuck Bay. Data presented within Golder Associates 2018 is considered to inform a reduction in the likelihood of anoxic conditions from post-2017 operations. A precautionary approach is required and this hypothesis will be informed as additional information becomes available through the DSI and Phase 2 of this Review.

The Delegated Officer has determined that the likelihood of seepage, pre-2017 operational situation, directly impacting Roebuck Bay, supporting the growth of *Lyngbya majuscula* and secondary impacts to receptors occurring will probably be in most circumstances. Therefore, the Delegated Officer considers the likelihood of impacts from seepage occurring was **Likely**.

The Delegated Officer has determined that the likelihood of seepage, post-2017 operational situation, directly impacting Roebuck Bay, supporting the growth of *Lyngbya majuscula* and secondary impacts to receptors occurring could be at some time. Therefore, the Delegated Officer considers the likelihood of impacts from seepage occurring to be **Possible**.

8.6.9 Overall rating of seepage

The Delegated Officer has compared the consequence and likelihood ratings described above with the risk rating matrix (Table 29) and determined that the overall rating for the risk of seepage was **Extreme** (pre-2017) and remains **Extreme.**

(29) Key Finding: The Delegated Officer notes, consistent with the *Guidance Statement: Risk Assessments*, that Extreme risks are unacceptable and must be mitigated.

The Delegated Officer notes that the Licence Holder has advised DWER that the Broome South sewage facility will be closed and cease operation in approximately seven years (~end of 2025). With a Risk Rating of Extreme found under Phase 1 of this Review for emission of seepage an approval to continue to operate for that timeframe has been found unacceptable.

8.6.10 Consideration of 2016 Draft Referral

The consequence of impacts from seepage emissions to Roebuck Bay was determined as major in the 2016 Draft Referral and this has been elevated to Severe in this Decision Report. This determination was based on the following factors:

(a) the criteria for assessment applied to the Roebuck Bay environmental receptor is now a 'specified ecosystem' (see *Guidance Statement: Environmental Siting*) and not the ANZECC and ARMCANZ 2000 default trigger levels for the marine environment;

(b) the identification that phosphorus and iron may play a more significant role in triggering and supporting blooms of *Lyngbya* than nitrogen (see Technical Expert Report in Appendix 4);

(c) the consideration of the role anoxic conditions within a seepage plume may play in influencing the concentrations of iron, nitrogen, phosphorus and organic carbon within groundwater discharging to Roebuck Bay;

(d) the potential for other contaminants of potential interest that have the potential to cause impact receptors within Roebuck Bay (see Section 8.6.3 of this Decision Report); and

(e) the more accurate characterisation of impacts to benthic marine ecosystem services and fauna including from blooms of *Lyngbya* and associated impacts from cyanotoxins as being medium to long term, rather than short term impacts.

The likelihood of impacts from seepage emissions to Roebuck Bay was Likely in the Draft Referral and was reduced to Possible. The determination was based on the following factors:

(f) the changes to the consideration of consequence; and

(g) the changes that were made to the operations at the Premises in 2017 and subsequent assessment of risk in pre and post 2017 operating contexts.

8.7 Summary of acceptability and treatment of Risk Events

A summary of the risk assessment and the acceptability or unacceptability of the risk events set out above, with the appropriate treatment and control, are set out in

Table 34 below. Controls are described further in Section 9 of this Decision Report.

Table 34: Risk assessment summary

Description of Risk Event				Applicant controls	Risk rating	Acceptability with controls (conditions on instrument)
Emission		Source	Pathway/ Receptor (Impact)			
Section 8.4	Discharge to land	Containment failure/ overtopping	Direct discharge to land, seepage to groundwater, overland flow to native vegetation and Roebuck Bay	See section 8.4.5	Environmental receptors: Major Unlikely **Medium risk** Public health receptors: Major Unlikely **Medium risk**	Acceptable subject to proponent controls conditioned, outcomes based controls and management conditions
Section 8.5	Odour	Sewage acceptance, storage, treatment and sludge	Amenity impacts to the Public in the receiving airshed	See section 8.5.5	Moderate Rare **Medium risk**	Acceptable subject to proponent controls conditioned / outcomes based controls
Section 8.6	Seepage	Ponds and containment infrastructure	Discharge to groundwater and impacts to ecosystem services of and receptors within Roebuck Bay	See section 8.6.5	Pre-2017 Severe Likely **Extreme risk** Post-2017 Severe Possible **Extreme risk**	Unacceptable

9. Regulatory controls

A summary of regulatory controls determined to be appropriate for the Risk Event is set out in Table 35. The Risk Events are set out in the assessments in Section 8 of this Decision Report and the controls are detailed in this section. DWER will determine controls having regard to the adequacy of controls proposed by the Licence Holder. The Conditions of the Revised Licence will be set to give effect to the determined regulatory controls.

Table 35: Summary of regulatory controls to be applied

Risk Event emission source (see risk analysis in Section 8 of this Decision Report)	Controls (references are to sections below setting out details of controls)				
	Revised Licence				
	9.1.1 Waste classification, acceptance and throughput	9.1.2 Waste processing	9.1.3 Infrastructure and equipment	9.1.4 Monitoring requirements	9.1.5 Record keeping
1. Discharge to land (containment failure)	●		●		●
2. Odour	●	●	●		●
3. Seepage	●		●	●	●

9.1 Revised Licence L6266/1991/10 controls

All Conditions from the Existing Licence have been deleted and replaced with the following Conditions of the Revised Licence. A copy of the Existing Licence is provided in Appendix 5 of this Decision Report.

New Condition 1 of the Revised Licence has been included to set the regulatory framework for exclusion, limitations and requirements for emissions and discharges arising from the Primary Activities at the Premises in accordance with the provisions of the EP Act.

- Condition 1(a) establishes the Conditions of the Revised Licence that need to be complied with to approve seepage, being a specified discharge from the Premises. The Conditions for seepage are comprised of commitments and infrastructure specifications made by the Licence Holder and additional Conditions considered commensurate to the risk. The Conditions are considered reasonable and appropriate to mitigate the risk to environmental receptors to an acceptable level. The appropriateness of these Conditions will be considered further in Phase 2 of the Review.
- Condition 1(b) lists the regulatory controls for all other emissions and discharges for the operation of the sewage facility at the Premises; the potential emissions considered in Section 8.1, Table 28 of this Decision Report are noise, odour and storm water.

Unless a Specified Emission/ Discharge the provisions of Condition 1(b) and the EP Act apply, including for containment failures and no defence under Section 74A of the EP Act in granted or implied. A time limited approval is provided for the discharge of seepage. The transfer of treated sewage to the reuse facilities, being prescribed premises, is required to be monitored.

9.1.1 Waste classification, acceptance and throughput

The Delegated Officer considers that Condition 2 of the Revised Licence is appropriate. The controls reflect the Licence Holder's method of operation. Approved capacities are limits set to define the scope of this risk assessment process and scale of potential emissions and discharges. The provisions of Condition 2 are consistent with previous approvals under the Existing Licence and Primary Activities undertaken by the Licence Holder. Limiting the type and volume of waste accepted results in a lower likelihood of impacts from containment failure, odour and seepage and a reduced consequence from contaminants in the waste accepted and potentially discharged.

Grounds: In accordance with *Guidance Statement: Regulatory Principles* and *Guidance Statement: Setting Conditions* Condition 2:

- restricts the type of waste approved for acceptance consistent with the Existing Licence; the liquid waste type '*Industrial wash water contaminated with a controlled waste*' has been removed as '*industrial waste water*' does not clearly align to a waste type within Schedule 1 of the *Environmental Protection (Controlled Waste) Regulations 2004*.
- restricts the method of waste acceptance approved consistent with the commitments by the Licence Holder and the Existing Licence.
- restricts the volume of sewage waste approved to 2,000 m^3/ day, consistent with the commitments made by the Licence Holder (Water Corporation 31 August 2017) and is commensurate to the risk ratings for containment failure and seepage.
- restricts other liquid waste acceptance to 1,000 m^3/ annual period is consistent with historical volumes detailed in

- **Table 4**.

9.1.2 Waste processing

The Delegated Officer considers that Conditions 3 and 4 of the Revised Licence are appropriate. The provisions of the Condition are consistent with previous approvals under the Existing Licence and Primary Activities undertaken by the Licence Holder taking into consideration the changes detailed in Table 5 of this Decision Report. The controls for the sewage treatment facility address the risks from odour and contaminants in treated sewage.

Grounds: In accordance with *Guidance Statement: Regulatory Principles* and *Guidance Statement: Setting Conditions* the conditions are consistent with the Licence Holder's infrastructure commitments to treat sewage for discharge to land at other prescribed premises. Condition 3 sets out the sewage treatment system process and Condition 4 addresses the lack of dedicated sludge containment and dewatering infrastructure at the Premises.

9.1.3 Infrastructure and equipment

The Delegated Officer considers that Conditions 5 – 9 of the Revised Licence are appropriate and reasonable:

- Conditions 5 and 6 address works that are required at the Premises to adequately control the risk to receptors as a result of seepage from the Secondary Pond and the Tertiary Pond. The conditions address the design and construction specifications for the works and timeframes for completion that are considered reasonable and appropriate commensurate to the risk. Specifications have been made to address potential leakage from the new liners.
- Condition 7 addresses the operational requirements for the sewage facility and is largely consistent with previous approvals under the Existing Licence and Primary Activities undertaken by the Licence Holder taking into consideration the changes detailed in Table 5 of this Decision Report.
- Conditions 8 and 9 address the operational requirements for the sewage facility to manage extreme rainfall events and ensure and appropriate storage volume is maintained for contingency events during the higher rainfall period November through March.

Grounds: In accordance with *Guidance Statement: Regulatory Principles* and *Guidance Statement: Setting Conditions*:

- Conditions 5 and 6 specify the construction standards and timeframes for low permeability liners to be installed within the Tertiary Pond and the Secondary Pond. The requirements are commensurate to the findings of the risk-based assessment for seepage (see Section 8.4 of this Decision Report) and Section 62 of the EP Act, being the mitigation of potential environmental harm. The specifications are derived from the approval to line the Storage Pond granted 16 June 2016 and appropriate minimum standards. The Tertiary Pond was prioritised over the Secondary Pond based on potential seepage footprint size.

(30) The Delegated Officer notes that the 2020 and 2021 timeframes specified within Conditions 6(b) and 6(c) are designed to provide the Licence Holder with adequate time to undertake planning and budget considerations and then consecutive winter (dry) periods to install the low permeability liners. The timeframes also allow phase 2 of the Review to be completed.

- Condition 6(a) requires that the Licence Holder demonstrate that the specifications within Condition 5 will be met and how, with due consideration to risks that may arise from changes to operations at the Premises, to facilitate the ongoing operations of the sewage facility while Works are on-going.

(31) The Delegated Officer notes that should the specifications for the low permeability liners within Condition 5 vary in the submission specified by Condition 6(a), the submission should be accompanied by an application to amend the Revised Licence. Any alternate proposal for the installation of low permeability liners must be to an equivalent or higher standard and fit for purpose.

- Condition 6(d) provides for flexibility in the specifications of the Works through an outcomes risk-based focus.
- Condition 7 specifies infrastructure and operational requirements consistent with the commitments by the Licence Holder, relevant specifications of the existing infrastructure and required for quantitative and qualitative monitoring. In addition, the direction of stormwater to minimise the risk of overtopping and the maintenance of pH levels to minimise the risk of odour is appropriate.
- Conditions 8 and 9 specify the management requirements for extreme rainfall events, are consistent with the risk to receptors posed by containment failure and impose timeframes that align with Conditions 6(b) and 6(c) and reasonably foreseeable meteorological conditions.

9.1.4 Monitoring requirements

The Licence Holder has proposed the use of a groundwater monitoring bore network composition different to that in the Existing Licence (see Section 6.1 of this Decision Report). The Delegated Officer has approved the changes with the inclusion of additional groundwater monitoring bores. The decision takes into consideration the issues discussed in Section 6.1 of this Decision Report, Golder Associates 2018 and the critical role that groundwater monitoring data serves to interpret potential seepage, changes to groundwater quality and impacts to receptors from seepage emissions. Changes to the monitoring points specified in Condition 13, Table 7 of the Revised Licence may be considered under Phase 2 of the Review.

The Delegated Officer considers that Conditions 10 – 13 of the Revised Licence are appropriate and reasonable:

- Condition 10 sets appropriate standards for sampling, monitoring and analysis. Groundwater sampling point references in Table 7 have been amended from those detailed in the Existing Licence. Sampling point references, in addition to those proposed by the Licence Holder are:
    - 2/17D and 2/04: to provide better background water quality data from the Broome sandstone;
    - 3/97: to provide water quality data, as an indicator bore, on the northeast corner of the Premises, reasonably foreseeably showing improvement in water quality over time following the installation of a low permeability liner in the Storage Pond and tending towards a control bore;
    - 6/13S and 6/13D: to provide water quality data, as indicator bores, from

the Tertiary Pond, also potentially an indicator for the emergency pond residual contamination;

- 12/17D: to complement 12/17S and provide water quality data from the Broome sandstone, serving as an indicator bore;
- 18/17: serving as an indicator bore;
- 19/17: serving as an indicator bore for the Primary Pond and a replacement for bore 1/04;
- 20/17: serving as a replacement to 8/97 and providing as an indicator bore on the south side of the secondary pond; and
- 17/17S: serving as an indicator bore for the Secondary Pond and along the most direct route to Roebuck Bay, also serves to validate data within bore 7/17S; and
- 4/13S: to complement 4/13D and provide water quality data from the Broome sandstone, serving as an indicator bore east of the Premises.

- Condition 11 sets the volumetric monitoring committed to by the Licence Holder within the 'Process Control Table' (Water Corporation 2018a) and required to determine the hydraulic load and variability placed on the sewage facility and in accordance with Section 62 and 62A of the EP Act inform the volume of treated sewage being transferred from the Premises.
- Condition 12 sets the monitoring required to determine the quality of treated sewage being transferred from the Premises The Delegated Office notes that in accordance with the 'Process Control Table' (Water Corporation 2018a) the qualitative sampling is undertaken post chlorination and filtration; this is not consistent with the sampling location discussed in Section 3.2 of this Decision Report.
- Condition 13 sets the monitoring required to indicate the potential for seepage emissions arising at the Premises to impact groundwater and the environmental values of Roebuck Bay.

Grounds: In accordance with the *Guidance Statement: Regulatory Principles* and *Guidance Statement: Setting Conditions* the conditions are consistent with the Existing Licence, Licence Holder's commitments to treat sewage for transfer from the Premises and/ or commensurate to risks to receptors of containment failure and/ or seepage.

9.1.5 Record keeping

The Delegated Officer considers that Conditions 14 – 21 of the Revised Licence are appropriate. The Delegated Officer considers that:

- Condition 14 is reasonable and appropriate for records keeping and when / if making information available.
- Condition 15 is reasonable and appropriate should the Licence Holder receive complaints.
- Conditions 16 – 18 are reasonable and appropriate to ensure that the Works specified in Condition 5 are constructed and validated as meeting specifications that are fit for purpose.
- Condition 19 is consistent with the *Guidance Statement: Regulatory Principles* and *Guidance Statement: Publication of Annual Audit Compliance Reports*.

- Condition 20 requires annual submissions, commensurate with the findings of the risk assessments.
- Condition 21 is reasonable and appropriate should a Department Request be made.

Grounds: In accordance with DER's *Guidance Statement: Setting Conditions* the record keeping requirements are appropriate to validate assessment predictions and provide assurance of the effectiveness of Conditions for works, infrastructure and operation and for transparency.

10. Determination of Revised Licence Conditions

The Conditions in the issued Revised Licence in Attachment 1 have been determined in accordance with the *Guidance Statement: Risk Assessments, Guidance Statement: Setting Conditions* and within the provisions of Sections 62 and 62A of the EP Act. Conditions 5 and 6 of the Revised Licence for the lining of the Secondary Pond and Tertiary Pond are appropriate and commensurate to the Extreme risk rating for seepage. Delaying the requirement to line the ponds out to 2025 is not commensurate to the risk. Outcomes of the detailed site investigation and Phase 2 of the Review may find a higher, lower or equivalent risk rating for seepage. Subsequently, in consideration of the Extreme risk rating for seepage a practical, precautionary, reasonable and timely set of Works are set through Conditions 5 – 6. The completion dates provide adequate time for planning to be undertaken in parallel to the consideration of the outcomes from the detailed site investigation and Phase 2 of the Review.

The *Guidance Statement: Licence Duration* has been applied and the Revised Licence expires on 31/12/2025. The expiry date provides an extension to the expiry date of the Existing Licence, being 31 December 2021 that was granted under the Notice of Amendment dated 29 April 2016. The Delegated Officer considers that the extended expiry date is appropriate, ensures that the timeframes for all works in the Conditions of the Revised Licence can take effect and is likely an appropriate maximum timeframe to review the licence following Phase 2 of the Review.

DWER notes that it may review the appropriateness and adequacy of controls at any time and that, following a review and/ or Phase 2, DWER may initiate amendments to the Revised Licence under the EP Act.

Table 36 lists that the Licence Conditions that have been imposed beyond the commitments of the Licence Holder and that are amendments or additions to the Conditions of the Existing Licence.

Table 36: Summary of conditions applied in addition to Licence Holder commitments.

Condition Ref	New and/ or altered elements
Conditions 1(a)(i) and 1(b)(i)	As specified against the relevant conditions.
Condition 2	Approved capacities added, and waste type descriptions clarified.
Condition 3	Waste processing specifications updated and clarified
Condition 4	Lack of sewage sludge storage infrastructure addressed
Conditions 5 and 6	Works specified to install low permeability liners for the secondary and tertiary pond

Condition 7 , Table 5	Waste processing infrastructure and operational specifications updated and clarified, including: • pond levels and capacities; • pond freeboard levels; • sewage and waste transfer and treatment equipment; and • maintenance of pH range.
Condition 8 and 9	Minimum preparation for extreme rainfall events specified
Condition 10	Monitoring standards updated and clarified
Condition 11	Quantitative monitoring standards specified
Condition 12	Treat sewage qualitative monitoring requirements updated and clarified
Condition 13	Ambient groundwater qualitative monitoring requirements updated and clarified

11. Applicant's comments

The Licence Holder was provided with the draft Decision Report and draft Revised Licence on 31 May 2018 (2018 Draft Referral). The Licence Holder provided comments that are summarised, along with DWER's consideration of the items raised, in Appendix 2. The items raised by the Licence Holder resulted in the following material changes to the draft Decision Report and draft Revised Licence:

- Addition of provisions under Condition 5(b);
- Additional 1 year added to the timeframes under Conditions 6(b) and 6(c); and
- Amendment of groundwater monitoring bore locations.

12. Conclusion

This assessment of the risks of activities on the Premises has been undertaken with due consideration of a number of factors, including the documents and policies specified in this Decision Report (summarised in Appendix 1).

Based on this assessment, it has been determined that the Revised Licence will be granted subject to conditions commensurate with the determined controls and necessary for administration and reporting requirements.

Ruth Dowd
Senior Manager Waste Industries
Delegated Officer
under section 20 of the *Environmental Protection Act 1986*

Appendix 1: Key documents

	Document Title	In text ref	Availability
1	Golder Associates Pty Ltd August 1997, *Hydrogeological investigations for Broome treated wastewater re-use Broome*	Golder Associates 1997	DWER records: ref A1566675
2	URS Australia Pty Ltd 2012, *Nutrient irrigation management plan Broome (south) wastewater treatment plant*.	URS 2012	DWER records: ref A560392
3	URS Australia Pty Ltd October 2013, *Hydrological assessment of nutrient flux in Broome South wastewater treatment plant*	URS 2013	DWER records: ref A708425
4	URS Australia Pty Ltd September 2015, *Preliminary nutrient impact assessment Broome South wastewater treatment plant*	URS 2015	DWER records: ref A984224
5	RPS Environment and Planning Pty Ltd September 2015, *Literature review Broome South wastewater treatment plant and surrounding areas*	RPS 2015a	DWER records: ref A980787
6	RPS Environment and Planning Pty Ltd October 2015, *Preliminary site investigation Broome South wastewater treatment plant*	RPS 2015b	DWER records: ref A1380441
7	RPS Environment and Planning Pty Ltd 20 January 2016, *Holding Pond E3 sediment sampling and assessment findings*	RPS 2016	DWER records: ref A1100687
8	Bowman and Associates Pty Ltd 2016, *Broome South waste water treatment facility holding pond E3 line installation – construction quality assurance report*	Bowman and Associates 2016	DWER records: ref A1384408
9	AECOM Australia Pty Ltd 19 August 2016, *Preliminary nutrient impact assessment Broome South Wastewater Treatment Plant*	AECOM 2016	DWER records: ref A1165073
10	Field Capacity Pty Ltd February 2017, Broome Golf Club agronomic assessment	Field Capacity 2017a	DWER records: ref A1565826
11	Field Capacity Pty Ltd February 2017, Broome South waste water treatment plant effluent reuse scheme management strategy	Field Capacity 2017b	DWER records: ref A1565809
12	Water Corporation 2016, *Recycled water supply agreement Water Corporation and Shire of Broome*.	N/A	DWER records: ref A1627929
13	Water Corporation 2012, Memorandum of understanding recycled water supply Water Corporation and Broome Golf Club Incorporated	N/A	DWER records: ref A1627935
14	Water Corporation application to amend licence L6266/1991/10 dated 17 May 2017.	Water Corporation 17 May 2016	DWER records: ref A1100685
15	Water Corporation email to DWER dated 31 January 2017, *L6266 Broome South Wastewater Treatment Plant - response to proposed licence amendment*	Water Corporation 31 January 2017	DWER records: ref A1474510
16	Water Corporation email to DWER dated 31 August 2017, *Draft EP Act Licence L6266/1991/10 Broome South WWTP*	Water Corporation 31 August 2017	DWER records: ref A1516812

	Document Title	In text ref	Availability
17	Golder Associates Pty Ltd 15 December 2017, *Broome South WWTP – Water balance analysis and seepage loss assessment*	Golder Associates 2017	DWER records: ref A1580982
18	McMahon and Dunham 2017, *Investigation into nitrogen sources for Roebuck Bay and the Yawuru Nagulagun/ Roebuck Bay Marine Park a final report for Water Corporation*	McMahon and Dunham 2017	DWER records: ref A1586244
19	Water Corporation letter to DWER dated 14 January 2018 *Re: review of Broome South WWTP Licence L6266/1991/10 – request for clarification of information for risk assessment* (received 19 February 2018)	Water Corporation 2018a	DWER records: ref A1627931 and within folder fA231569
20	Senversa Pty Ltd 1 May 2018, *Mandatory Auditor's report Broome wastewater treatment plant, 34 Clementson Street, Western Australia, Broome Golf Course, 221 and 223 Port Drive Minyirr, Western Australia*	Senversa 2018	DWER records: ref A1667251 and A1667252
21	Water Corporation letter to DWER dated 31 July 2018 (received 1 August 2018), *Proposed amendment to EP Act Licence Number L6266/1991/10 (Broome South)*, including: • Golder Associates Pty Ltd July 2018, *Report Broome South Wastewater Treatment Plant response to draft licence decision report*.	Water Corporation 2018b • Golder Associates 2018	DWER records: ref DWERDT80153 and DWERDT80156
22	Water Corporation May 2018, *Broome high rainfall events January – February 2018 water quality results sampling report*	Water Corporation 2018c	DWER records: ref DWERDT86413
23	Coffey Environments Australia Pty Ltd 2013, *Notice requiring further information – Development of Lot 616, Lot 1221 and Port Drive Road Reserve (Ref: AC01-2013-0007)*	Coffey 2013	DWER records: ref A1670776
24	BCE Surveying, *Detail survey Broome WWTP Minyirr*, dated 2/03/2016.		DWER records: ref A1100681
25	Water Corporation, *Application form: works approval/ licence*, dated 17/05/2016.		DWER records: ref A1099381
26	Bureau of Meteorology*, Broome Airport station 003003*	Bureau of Meteorology	Commonwealth of Australia website: http://www.bom.gov.au
27	Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water*	ANZECC and ARMCANZ 2000	Commonwealth of Australia website: http://agriculture.gov.au/water/quality/nwqms
28	Commonwealth of Australia 2013, *National Environment Protection (Assessment of Site Contamination) Measure 1999*.	N/A	Commonwealth of Australia website: http://www.nepc.gov.au/nepms/assessment-site-contamination
29	Swan River Trust 2014, *Western Australian environmental guidelines for the establishment and maintenance of turf grass areas*	N/A	Department of Parks and Wildlife website: https://www.dpaw.wa.gov.au

	Document Title	In text ref	Availability
30	Department of Parks and Wildlife 2016, *Yawuru Nagulagun/Roebuck Bay Marine Park, Joint management plan 2016*	N/A	Department of Parks and Wildlife website: https://www.dpaw.wa.gov.au
31	Department of Environment and Conservation 2004, *Environmental guidelines use of effluent by irrigation*	N/A	Available from website: http://www.environment.nsw.gov.au
32	Bratton J F 2010, *The three scales of submarine groundwater flow and discharge across passive continental margins*, The Journal of Geology, vol. 10, pp. 565-567.	Bratton 2010.	DWER records: ref A1657191
33	Estrella S M 2013, *Effects of nutrient enrichment and toxic Lyngbya blooms on benthic invertebrate communities of Roebuck Bay Ramsar Site Final Report*, University of Western Australia.	Estrella 2013	DWER records: ref A880654
34	Wright N 2013, *Hydrogeology and hydrochemistry of the unconfined aquifer of the Broome Peninsula*, Honours Manuscript, Curtin University.	Wright 2013	DWER records: ref A880680
35	Hearn D 2014, *Source, fate and mobility of groundwater nutrients, metals/ metaloids and 4-nonylphenol in the unconfined Broome aquifer*, Honours Manuscript, University of Western Australia.	Hearn 2014	DWER records: ref A1565691
36	Kelly D 2015, *Groundwater flow and solute transport modelling of the unconfined Broome aquifer: Broome peninsula Western Australia*, Honours Manuscript, University of Western Australia.	Kelly 2015	DWER records: ref A1565684
37	Gunaratne G L D A 2015, *Characterising the response of inter-tidal zone ecohydrology, to coastal hydrodynamics and anthropogenic nutrient loads*, Honours Manuscript, University of Western Australia.	Gunaratne 2015	DWER records: ref A1565685
38	Hanington P, Rose A and Johnstone R 2016, *The potential of benthic iron and phosphorus fluxes to support the growth of a bloom forming toxic cyanobacterium Lyngbya majuscula, Moreton Bay, Australia*, Marine and Freshwater Research, volume 67, number 12. pp. 1918-1927.	Hanington et al 2016	N/A
39	Osborne N, Webb P and Shaw G 2001, *The toxins of Lyngbya majuscula and their human and ecological health effects*, Environment International, volume 27, pp. 381–392.	Osborne et al 2001	Available from website: https://www.elsevier.com/
40	Arthur K, Limpus C, Balazs C, Capper A, Udy J, Shaw G, Keuper-Bennett U and Bennett B 2008, *The exposure of green turtles (Chelonia mydas) to tumour promoting compounds produced by the cyanobacterium Lyngbya majuscula and their potential role in the aetiology of fibropapillomatosis*, Harmful Algae, volume 7, pp. 114–125.	Arthur et al 2008	Available from website: https://www.elsevier.com/
41	Department of Environment Regulation July 2015, *Guidance Statement: Regulatory principles.*	*Guidance Statement: Regulatory principles*	Available from website: http://www.dwer.wa.gov.au; http://www.dwer.wa.gov.au
42	Department of Environment Regulation October 2015, *Guidance Statement: Setting conditions.*	*Guidance Statement: Setting conditions*	
43	Department of Environment Regulation August 2016, *Guidance Statement: Licence duration.*	*Guidance Statement: Licence duration*	

	Document Title	In text ref	Availability
44	Department of Environment Regulation February 2017, *Guidance Statement: Risk Assessments*.	*Guidance Statement: Risk Assessments*	
45	Department of Environment Regulation February 2017, *Guidance Statement: Decision Making*.	*Guidance Statement: Decision Making*	
46	Department of Environment Regulation November 2016, *Guidance Statement: Environmental Siting*.	*Guidance Statement: Environmental Siting*	
47	Department of Environment Regulation February 2017, *Guidance Statement: Land Use Planning*.	*Guidance Statement: Land Use Planning*	
48	Department of Environment Regulation May 2016, *Publication of Annual Audit Compliance Reports*.	*Publication of Annual Audit Compliance Reports*	
49	Department of Environment Regulation July 2013, *Enforcement and prosecution policy* and Department of Water and Environmental Regulation 2017, *Compliance and enforcement policy (interim)*.	*Enforcement and prosecution policy*	
50	Department of Environment Regulation 2014, *Contaminated Sites Guidelines: Assessment and management of contaminated sites*	*Assessment and management of contaminated sites*	

Appendix 2: Summary of stakeholder consultation

Stakeholder	Comment	DWER consideration
Department of Biodiversity Conservation and Attractions	See inset below (2 pages)	Noted and considered in the determination of risk rating criteria and commensurate controls.

GOVERNMENT OF WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

Kimberley Region

PARKS AND WILDLIFE SERVICE

Your ref: DER2014/000608
Our ref: 2008/005289-1
Enquiries:
Phone:
Email:

Department of Water and Environmental Regulation
Locked Bag 33
Cloisters Square
PERTH WA 6850

Dear

***ENVIRONMENTAL PROTECTION ACT 1986* – REVIEW OF BROOME SOUTH SEWAGE FACILITY**

The Department of Biodiversity, Conservation and Attractions (DBCA) appreciates the focus and effort the Department of Water and Environmental Regulation (DWER) is putting towards this important and longstanding issue. As you are aware, Roebuck Bay is of great conservation and cultural significance and is highly valued and used for tourism and recreation. Increased nutrient loads have been recorded from the bay for over a decade and the subsequent outbreaks of *Lyngbya majuscula* represent a current and real threat to the ecological, cultural and social assets of the area. Interagency collaboration on this issue is very much welcomed.

With respect to the summary of findings from the risk-based review and Technical Expert Report, DBCA's Kimberley Region provides the following comments.

DBCA agrees that it is very likely that historic and current seepage from the Broome South Waste Water Treatment Plant (BSWWTP) is entering groundwater, discharging into Roebuck Bay and promoting periodic blooms of the noxious cyanophyte *Lyngbya majuscula*. Recent analysis of the DBCA Lyngbya abundance time-series data indicates that the highest abundances of Lyngbya along the northern shores of Roebuck Bay between the Port and Town Beach are encountered closer to the likely groundwater discharge area down gradient from the BSWWTP.

Given the capacity of Lyngbya to fix atmospheric nitrogen, DBCA agrees that nitrogen may not be a limiting factor, and it is likely that phosphorus, iron, ammonia, as well their interaction with surface-derived organic content, are primary limiting factors for bloom initiation and maintenance. However, long term increases in nutrient loads entering Roebuck Bay potentially represent a systematic departure from 'natural/background' (and acceptable) levels, with periodic blooms of Lyngbya being one of the more visible and detrimental outcomes. The spatial extent and level of environmental impacts from Lyngbya have only been partially determined (e.g. de Silva 2015, Hearn 2014, Estrella 2013 etc) and there have been no investigations into other potential environmental impacts from increased nutrient loads. A systematic departure from a more acceptable baseline (with respect to water/sediment nutrients) has potential legal ramifications under the *Environmental Protection and Biodiversity Conservation (Commonwealth) 1999 Act* via the Ramsar site and its associated 'limits of acceptable change' based management framework.

Parks and Wildlife Service
PO Box 942, Kununurra, Western Australia 6743
Lot 248 Ivanhoe Road, Kununurra, Western Australia
Phone: (08) 9168 4200
Web: pws.dbca.wa.gov.au

DBCA commends recent actions (e.g. transfer of untreated wastewater to Broome North, lining of primary pond) to reduce the risks associated with seepage from the BSWWTP and agrees that this is likely to have a material beneficial effect on the longer term ecological health of Roebuck Bay; however, DBCA also agrees that the ongoing risks associated with the limited lining of the remaining ponds are unacceptable. DBCA encourages DWER to ensure the Water Corporation are required to reduce these risks to more acceptable levels as rapidly as possible. Delaying action undermines the investments already made, extends the already longer-term time frame for the reduction of nutrient loads in groundwater and intertidal sediments, and increases the risk of systematic departure from acceptable levels of nutrient loads and associated potential legal ramifications under the EPBC Act.

DBCA strongly recommends additional research and monitoring requirements be attached to Licence L6266/1991/10, the cost of which to be borne by the Water Corporation, and that the "...environmental risks posed by seepage from the Broome South sewage facility cannot be adequately quantified until further groundwater investigations have been undertaken at the site" is considered unacceptable. At a minimum, further monitoring should be targeted to address this critical knowledge gap, as well as monitoring of intertidal sediment/water quality to begin quantifying the level of environmental impact. In conjunction with this monitoring, specific research questions should be investigated with regard to determining the potential for groundwater nutrients to create anoxic conditions that lead to an increase in bioavailable iron and phosphorus and contribute to blooms of Lyngbya. A scientifically sound literature review and risk analysis should also be undertaken to identify other potentially damaging environmental effects that long-term increases to nutrient loads may be having in Roebuck Bay, with subsequent field-based research required should significant risks be identified. DBCA strongly recommends that additional research and monitoring be required to be undertaken by an expert third party and be planned and reported on transparently and in regular consultation with DWER and DBCA. To date, Lyngbya abundance monitoring and associated data processing and analysis undertaken by DBCA since 2011 amounts to well over 1000 hours of staff time, plus operational costs and costs associated with third party research (e.g. Estrella 2013). The majority (75%) of this relates to sites at the Port slip way, Demco Beach and Town Beach – all of which are outside CALM Act estate and are very likely to have been impacted by groundwater nutrients from the BSWWTP (as per the Technical Expert Report and risk-based review). DBCA considers the additional research and monitoring requirements outlined above to represent a bare minimum to assess the return on investment by both DBCA and the Water Corporation. Without this information, it is impossible to quantify the effects that groundwater nutrients may be having on the Roebuck Bay environment and any recovery that may happen following actions by the Water Corporation to reduce groundwater-related nutrient influx.

While potentially outside the direct scope of the current review, DBCA strongly recommends a transparent, collaborative, multi-agency approach to addressing the water/sediment quality issues in Roebuck Bay.

DBCA appreciates the opportunity to comment and contribute to this review process, and is interested to work with DWER, the Water Corporation and others to further address this serious and long-standing issue. Should you require additional information on this matter please contact Yawuru Nagulagun / Roebuck Bay Marine Park Coordinator

Yours sincerely

Regional Manager, Kimberley Region
15 May 2018

Parks and Wildlife Service
PO Box 942, Kununurra, Western Australia 6743
Lot 248 Ivanhoe Road, Kununurra, Western Australia
Phone: (08) 9168 4200
Web: pws.dbca.wa.gov.au

Appendix 3: Summary of Licence Holder's comments

Condition/ Section	Summary of Licence Holder comment	DWER consideration
2016 Draft Referral		
Draft Referral – summary of consultation process 2017	Concerns were raised regarding: • Hydrostatic leak/ seepage testing of the GCL liner used in the Storage Pond. • The lining of the secondary and tertiary ponds. • The decommissioning of ponds and emergency storage requirements. • Desludging storage infrastructure. • Treated sewage irrigation at reuse facilities and loading limits. • Options and timeframes to implement measures to reduce the risk from seepage at the Premises and from the risk of treated sewage irrigation at reuse facilities.	The submissions to the then DER and DWER by the Licence Holder were considered in the Review process and have informed the controls proposed in the Revised Licence. See Section 5.10.4 of this Decision Report. Subsequent consultation is documented below.
2018 Draft Referral		
Revised Licence		
Condition 3(a)	The primary pond (Primary Pond) undergoes aerobic and anaerobic facultative treatment.	Condition amended to reflect treatment type.
Condition 3(b)	The secondary pond (Maturation Pond #1) undergoes maturation treatment.	Condition amended to reflect treatment type.
Condition 3(c)	The tertiary pond (Maturation Pond #2) undergoes maturation treatment.	Condition amended to reflect treatment type.

Condition/ Section	Summary of Licence Holder comment	DWER consideration
Condition 3(e)	Chlorine dosing only occurs at the outlet of the storage tanks and not at the inlet.	Reference to inlet chlorination removed from condition.
Condition 7	Given the proposed closure of the BSWWTP by 2025 and additional information supplied in the report *Response to Draft Licence Decision Report* (Golder 2018), the Corporation requests the requirement to line the Tertiary Pond by 31 October 2020 be removed from the licence.	The conditions to line the ponds have been maintained under Condition 5 and 6. Taking a precautionary approach, the findings of the risk-based assessment do not support continued operation of the current sewage facility until 2025 at this time due to the risk from seepage.
Condition 8	Given the proposed closure of the BSWWTP by 2025 and additional information supplied in the report *Response to Draft Licence Decision Report* (Golder 2018), the Corporation requests the requirement to line the Secondary Pond by 31 October 2021 be removed from the licence.	
Condition 5 Table 4	Given the requested removal of the requirement to line the Tertiary and Secondary ponds, the Corporation also requests that the requirement to install a leakage detection system beneath the liners be removed.	The specifications for the ponds, if they are lined, are maintained. Taking a precautionary approach, the findings of the risk-based assessment do not support continued operation of the current sewage facility until 2025 at this time due to the risk from seepage.

Condition/ Section	Summary of Licence Holder comment	DWER consideration
Condition 10 Table 5	General question: will the Corporation be required to report to DWER each and every time there is a leak and/or defect (including minor leaks and/or defects) within operational infrastructure?	The question is understood to relate to the operational requirement for conveyance pumps and pipes to be 'maintained free of leak and defect' and may also relate to the integrity of pond liners. Such incidents should be considered on a case by case basis. It is noted that: • there is no specific condition of the Revised Licence that requires leaks/ defects to be reported; • where infrastructure is not maintained free of leak or defect, this may be reportable under Condition 19, through the submission of the Annual Audit Compliance Report; and • discharges/ emissions arising from such incidents would be considered with regards to Condition 1(b).
Condition 10 Table 5	There are two pump sets at the re-use site; the Shire reuse pumps can pump up to 20 L/s and the Golf Club reuse pumps can pump up to 40 L/s.	Condition amended to refer to a minimum 20L/s capacity.
Condition 10 Table 5	Flow meters are electronic Magflow meters.	Condition amended to refer to electronic Magflow meters
Condition 11	Given the potential for a large rainfall event in late October, the Corporation requests the wording of this condition be amended to: *The Licence Holder must ensure that sufficient freeboard is maintained within the emergency ponds to cater for a significant rainfall event*.	The proposed wording is not considered to be clear or enforceable in accordance with *Guidance Statement: Condition Setting*. Condition amended to state October in place of November. The intent is to ensure that the contingency capacity of the sewage facility is prepared for each coming wet season.

Condition/ Section	Summary of Licence Holder comment	DWER consideration
Condition 14	The Corporation calculates WWTP inflows as Average Annual Daily Flow (AADF) in accordance with *Wastewater Engineering Treatment and Reuse 5th Ed.* (Metcalf and Eddy 2013). AADF is an industry standard calculation for estimating inflows. The hydraulic design of a WWTP allows for short-term peak inflows from significant rainfall events; unlike an industrial facility, inflow to a WWTP cannot be simply shut-off. Reporting of inflow as a monthly average will likely lead to an over-reporting of inflows during periods of high rainfall, even though emission limits are unlikely to be exceeded based upon the treatment design of the WWTP. Further consultation is requested prior to DWER setting the averaging period for inflow as it impacts all licenced and registered WWTP's.	Causes for variations in sewage inflow are noted. The reporting of average daily inflows in monthly intervals in designed to provide a more informed understanding of the variability that occurs to the sewage facility. This data can be considered in any events that result in use of the Emergency Overflow Ponds, overtopping of the Storage Pond or changes to the quality and quantity of treated wastewater leaving the Premises. The monthly data monitoring intervals under the Condition are not limits and are considered appropriate and reasonable for the Premises risk profile. The requirement is not implied to be applicable to any other Premises and further consultation through this instrument is not considered necessary. No comments were received against Condition 2, approved waste acceptance capacities. Defences are provided under the EP Act, for example within the provisions of Part V and under Sections 74 and 75. There are currently no emission limits proposed in the Revised Licence.
Condition 14(b)	Treated wastewater supplying the overhead standpipe does not go through the filtration unit; however the Corporation do not utilise the standpipe and will decommission it. Please remove reference to the standpipe from the licence.	Condition amended, reference to standpipe deleted.
Condition 14(c)	It is possible to transfer treated wastewater to the Broome North sewage facility via SPS No. 5 and SPS no. 6 at up to 25 L/s.	Noted, provision of Condition maintained.

Condition/ Section	Summary of Licence Holder comment	DWER consideration
Condition 23	The in-text reference to Table 9 should be Table 8.	Condition amended to consistent table numbering, being Table 8.
Decision Report		
Figure 7.	The premises is shown in the wrong location.	The red dot locating the Premises and been relocated appropriately.
Section 5.10.6	The sand dune was observed to have been washed away at ~4:00 am on Tuesday 30/01/18 while the WWTP did not begin to overflow until ~6:00 am on the same day. The Corporation requests that this statement be revised.	The text: '*The degree that overflow from the Premises contributed to the overall volume and subsequent erosion of the primary dune has not been quantified*', has been deleted and replaced with the text: '*The Licence Holder reported that the sand dune was observed to have been washed away at ~0400 hours and that the sewage facility began overflowing at ~0600 hours on Tuesday 30 January 2018*'.
Key finding 17	As noted within DWER's Technical Expert Report the Ham and Baum (2009) method requires ponds to be taken offline and is not feasible for operational sites. The Corporation requests this statement be revised.	The statement is found to be accurate, being that the Ham and Baum 2009 method is the preferred approach under the Technical Expert Report to assess seepage rates from ponds. The operational limitations of systems that cannot be taken offline are noted, as reflective in the methodology used by Golder Associates 2017. No conditions have been prescribed in the Revised Licence requiring seepage assessment using the Ham and Baum 2009 method.

Condition/ Section	Summary of Licence Holder comment	DWER consideration
Table 26	Sludge storage is included as a risk event though sludge is not stored onsite (as per Section 8.4.5)	Sludge waste will be produced at the sewage facility and therefor it is appropriate and reasonable risk assess that management of the waste. Condition 4 of the Revised Licence addresses the lack of sludge management infrastructure at the Premises and the inferred control that sludge in managed in accordance with the provisions of the EP Act off-Premises.
Section 8.4.7	The Corporation requests DWER seek DoH advice in regard to public health risks from this event.	The consequence to public health was amended from Severe to Major under Section 8.4.7 of the Decision Report following a review of the Water Corporation 2018c that was received in August 2018 and further consideration of the context in which overflows would reasonably foreseeably occur. Advice from the Department of Health was not sought on this matter. The *Guidance statement: risk assessments* is specific to risk-based assessments under Part V of the EP Act.
Section 8.4.8	Given that the ponds are designed to cater for 1:50 ARI events the likelihood of an overflow should be considered to be **Rare** (may only occur in exceptional circumstances) rather than **Unlikely** (will probably not occur in most circumstances)	Noted, see Section 8.4.8 of this Decision Report. Based on the capacity of the ponds and subsequent reliance on operational measures and annual rainfall patterns a reduction in the likelihood of impact is not considered appropriate. As a result of the amendment to consequence under Section 8.4.7 of this Decision Report both environmental and human health receptors are now considered Medium Risk Events.

Condition/ Section	Summary of Licence Holder comment	DWER consideration
Section 8.6.8	Given the additional information supplied in regard to the ongoing contaminated sites investigation, the Corporation requests DWER reconsider the likelihood of this event occurring. Based upon the updated calculation of historical nutrient loading from the facility, the Corporation considers that the likelihood of seepage, pre-2017 operational situation, directly impacting upon Roebuck Bay is **Unlikely**. Based upon the updated calculation of current loading from the facility, the Corporation considers that the likelihood of seepage, post-2017 operational situation, directly impacting upon Roebuck Bay is **Unlikely**.	The estimates provided in Golder Associates 2018 are noted and addressed within this Decision Report, including assumptions and uncertainties within the risk assessment for potential impacts from seepage to Roebuck Bay. Commentary is also provided within the Technical Expert Report. Taking a precautionary approach: • The likelihood of impacts pre-2017 has remained 'probably' and is considered Likely; and • The likelihood of impacts post-2017 has remained 'could' and is considered Possible.
Section 8.6.9	Given the reduced likelihood of seepage from the facility impacting Roebuck Bay, and the proposed closure of the BSWWTP by 2025, the Corporation request DWER consider the risk of seepage as **High** and may be acceptable.	See Section 8.6 of this Decision Report and the response to the item above.
Key finding 33	The Corporation request DWER review the Corporation's request to amend the current groundwater monitoring bore locations given the submission of *Broome South Wastewater Treatment Plant Response to Draft Licence Decision Report* (Golder 2018).	See Section 9.1.4 of this Decision Report

Appendix 4: Technical Expert Report

Government of Western Australia
Department of Water and Environmental Regulation

REPORT

Broome South sewage facility

Assessment and management of nutrient discharges to Roebuck Bay from wastewater

Version: Final

November 2018

Document control

Document version history

Date	Name	Role
20/11/18	Dr Steve Appleyard	Author
20/11/18	Andrew Miller	Reviewer

Corporate file information

File number and/or name	File owner or custodian	File location
DER2013/669	Science and Planning	Atrium

Produced and published by
Department of Water and Environmental Regulation
168 St Georges Terrace, Perth, Western Australia

November 2018

Questions regarding this report should be directed to:
Department of Water and Environmental Regulation
Locked Bag 33 Cloisters Square
PERTH WA 6850
Phone: +61 8 6364 7000
Fax: +61 8 6364 7001
Email: info@dwer.wa.gov.au
Web: www.dwer.wa.gov.au

Contents

Key Points:

- *Lyngbya* blooms in Roebuck Bay are likely to be triggered by the flux of phosphorus and iron from sediments into the water column under periodic hypoxic conditions caused by the degradation of organic carbon that is discharged to the bay in surface runoff and by groundwater discharge;
- The rate of nitrogen and phosphorus discharge from the currently used wastewater ponds at the Broome South sewage facility have been estimated using an appropriate water balance method by Golder Associates 2017. However, the current discharge estimates of about 180 kg/year of nitrogen and negligible phosphorus (Golder Associates 2018) may underestimate the actual fluxes of these nutrients in groundwater to Roebuck Bay due to the likely presence of currently unquantified soil and groundwater contamination from historical seepage from the ponds;
- The nitrogen isotope investigations undertaken by the Centre of Marine Ecosystem Research at Edith Cowan University have been undertaken in an appropriate manner and the conclusions drawn from the study are supported. It is important to note that the study does not conclude that the sewage facility is not an important source of contamination that helps trigger *Lyngbya* blooms, but rather it only indicates that these blooms are not limited by the availability of nitrogen;
- The environmental risks posed by seepage from the Broome South sewage facility cannot be adequately quantified until further groundwater investigations have been undertaken between the site and Roebuck Bay;
- Ongoing seepage from wastewater ponds at the site could cause further leaching of nitrogen and other chemical constituents from wastewater that are stored in the unsaturated zone. This risk cannot currently be assessed due to a lack of information about sediment and pore-water quality in the unsaturated zone. A precautionary approach to managing this risk would be to install liners on ponds that are currently unlined at the site; and
- Due to the slow rate of nutrient transport by groundwater flow, any measures that are taken in the short term to regulate the discharge of wastewater to the ground at the Broome South sewage facility are unlikely to show any clear benefits for the receiving environment for many years.

1. Introduction

Roebuck Bay is the most important shorebird site in Australia due to the number of species it supports in internationally significant numbers (Estrella, 2013). The importance of Roebuck Bay as a shorebird site appears to be linked to the high diversity and biomass of benthic invertebrates in its tidal mudflats which are amongst the richest such fauna assemblages in the world (Estrella, 2013).

However, the environmental values of this ecosystem are being threatened by increasing nitrogen, iron and phosphorus inputs from land-based activities which are increasing the degree to which Roebuck Bay is becoming eutrophic. These conditions are contributing to the periodic growth of blooms of the highly toxic cyanobacterium *Lyngbya majuscula* to take place on mud flats in Roebuck Bay. These blooms are a public health hazard and can lead to public beaches being closed. They also appear to be affecting the distribution and diversity of benthic macroinvertebrates on mudflats in the area (Estrella *et al*., 2011).

Although there are a number of potential sources of nutrients from land surrounding Roebuck Bay, previous work (Hearn, 2014) has suggested that historical leakage from a sewage facility pond at the Broome South sewage facility is a significant point-source contributing to the development of *Lyngbya* blooms in Roebuck Bay. As a consequence of this, Contaminated Sites has previously provided advice about the role that these sites could have in contributing to the formation of *Lyngbya* blooms.

Since that time, a number of additional studies have been commissioned by Water Corporation to provide additional information on the risk of nutrient leaching to groundwater at the sewage facility and the golf course sites, and whether *Lyngbya* blooms in Roebuck Bay are limited by the availability of nitrogen. As a consequence of this, Regulatory Services (Environment) is seeking further advice from Science and Planning about the adequacy of information provided in reports that have been prepared as a result of these studies.

On the basis of this work and published literature, this report examines the factors that are likely to be triggering *Lyngbya* blooms in Roebuck Bay and the likelihood that discharges from the sewage facility are contributing to the formation of these blooms. This report does not examine other impacts to Roebuck Bay that may result from seepage at the sewage facility. This report is an update of advice provided in previous reports prepared by Science and Planning.

2. Factors contributing to *Lyngbya* blooms in Roebuck Bay

Although nitrogen is often considered to be a limiting nutrient in the development of algal blooms in marine systems, evidence from laboratory and field studies indicates that the cyanobacterium *Lyngbya majuscula* (*Lyngbya*) is stimulated by phosphorus (Elmetri and Bell, 2004) and soluble iron (Ahern et al., 2006, Bell and Elmetri, 2007) and that blooms of this organism are mostly limited by the availability of phosphorus in shallow coastal marine systems in Australia (Wulff *et al*., 2011). An investigation using nitrogen isotopes (McMahon and Dunham, 2017) suggests that this is also the case in Roebuck Bay, where the principal source of nitrogen in *Lyngbya* appeared to be the fixation of atmospheric N rather than uptake from the water column or from sediments.

Much of the iron and phosphorus that triggers blooms of *Lyngbya* and other benthic cyanobacterial mats appears to be released from sediments during hypoxic conditions (Skoog and Arias-Esquivel, 2009; Hanington *et al*., 2016; Ford *et al*., 2018) driven by the degradation of organic carbon (Brocke *et al*., 2015), particularly in areas where sewage discharge is taking place (Ford *et al*., 2017). The principal sources of the organic carbon that drive the benthic fluxes of phosphorus and iron into the water column within Roebuck Bay are likely to be:

- The settling of suspended particles discharged in runoff during heavy rainfall events in sheltered areas where there is limited scouring of bottom sediments by wave action or currents (Brocke *et al.*, 2015; Harrington *et al.*, 2016); and
- The discharge of groundwater containing high concentrations of dissolved organic carbon and phosphorus and iron derived from the leakage of sewage or the deliberate disposal of wastewater to ground (McCobb *et al.*, 2003). High concentrations of phosphorus and iron released in the groundwater discharge zone will likely be produced as a result of both the direct discharge of these elements in the anoxic core of the plume, and the reductive dissolution of iron oxides at the intertidal sediment-water column interface by the reaction of dissolved organic carbon in the groundwater discharge with these minerals.

It is likely that both processes are taking place in Roebuck Bay, but there is insufficient information available to quantify each of these processes with any degree of confidence. In particular, *Lyngbya* blooms in Roebuck Bay commonly occur in still conditions after a heavy rainfall event suggesting that runoff is a significant source of the organic carbon that drives sediment hypoxia in the bay. Additionally, *Lyngbya* blooms often appear in shallow water near the Broome South sewage facility suggesting that the submarine groundwater discharge from leaking wastewater ponds may be a significant source of sediment hypoxia in this area (Fig. 1).

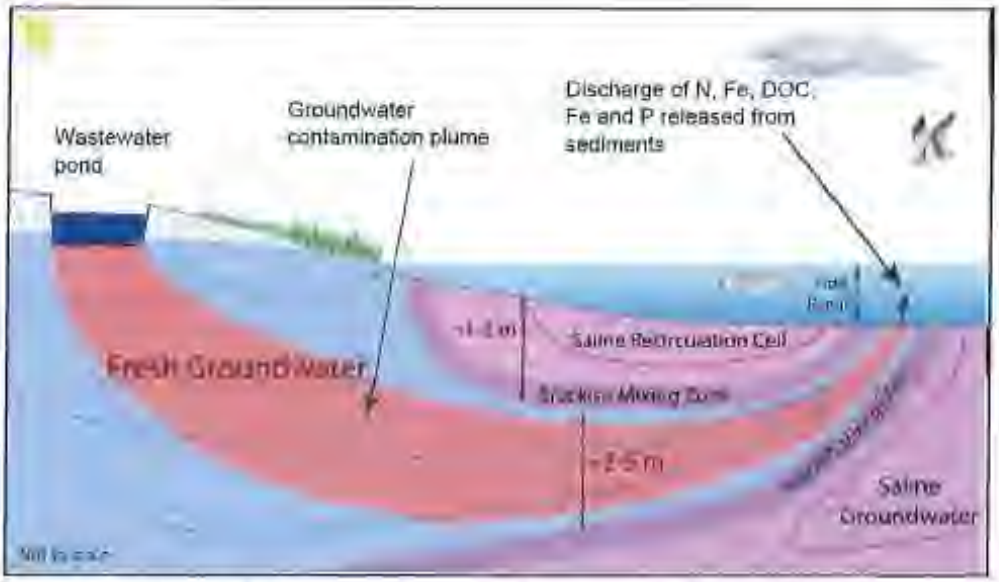


Figure 1. Discharge of nutrients from a wastewater groundwater contamination plume to a tidal nearshore marine environment.

In Roebuck Bay groundwater discharge will take place in shallow water where high temperatures and light penetration will suit the growth of cyanobacteria. The groundwater discharge will also contain elevated concentrations of iron, nitrogen, phosphorus, a combination of chemical constituents that has been shown to maximise the growth of *Lyngbya* under suitable conditions in a marine environment (Ahearn et al., 2008).

A recent study of nutrient cycling in Shark Bay (Burkholder *et al.* 2013) found that both nitrogen and phosphorus limited conditions could occur in different parts of an embayment, and the authors cautioned against drawing conclusions about which nutrients are limiting based on large-scale nutrient budgets. Additionally, controlled field experiments undertaken by Ahearn *et al.* (2008) have demonstrated that the combined addition of readily bioavailable iron, phosphorus and nitrogen to *Lyngbya* can generate 18 times as much biomass as the addition of these nutrients on an individual basis to test plots. Therefore, while phosphorus and iron remain the key elements of concern, nitrogen cannot be disregarded as a contaminant of concern.

However, investigations at a wastewater treatment plant in the USA where the infiltration of wastewater to the groundwater took place in close vicinity to a surface water body (McCobb *et al.* 2003) indicated that phosphorus concentrations in excess of 3 mg/L and iron concentrations in excess of 10 mg/L occurred in the groundwater discharge zone, concentrations that were sufficiently high to lead to widespread eutrophication and frequent algal blooms in the receiving water body. If similar conditions were to occur in groundwater at the Broome South sewage facility site, groundwater discharge from the site might trigger the formation of *Lyngbya* blooms in shallow water near the sewage facility site.

Consequently, to address these concerns, additional groundwater investigations were undertaken by Golder Associates in 2018 to assess whether seepage from wastewater ponds at the Broome South sewage facility has caused significant impacts on local groundwater quality and to determine whether groundwater discharge from the sewage facility is likely to be causing adverse impacts on Roebuck Bay. These issues are discussed in the following Section.

3. Investigations undertaken to assess wastewater discharges

Regulatory Services (Environment) has requested that Science and Planning provide advice on measures that have been undertaken by the Water Corporation to quantify the amount of wastewater that is discharged to ground by seepage from ponds. This was undertaken by firstly reviewing a report prepared by Golder Associates in December 2017 to assess the seepage rate of wastewater and nutrient from the ponds that are currently being used at the sewage facility. The report was considered with regards to previous reports (URS 2015; AECOM 2016). Secondly, a report prepared by Golder Associates in 2018 summarising additional groundwater investigations at the site was also reviewed (Golder, 2018).

3.1. Seepage from wastewater ponds

A study previously commissioned by Water Corporation (URS 2015) suffered from a number of limitations which could affect conclusions drawn from the investigations. Firstly, insufficient monitoring bores were drilled to delineate full lateral and vertical extent of groundwater contamination from the wastewater pond at the Broome South sewage facility, and therefore modelled estimates of the load of nitrogen that is being discharged in seepage from the wastewater ponds were likely to be subject to a high level of uncertainty.

As most of the monitoring bores near the site were constructed within the zone of water table fluctuation where geochemical conditions favour nitrogen removal from the aquifer through the process of denitrification, there is a risk that concentrations of nitrogen compounds measured in these bores were much lower than in the core of the groundwater plume which is likely to be present at depth in the unconfined aquifer. That is, estimates of the groundwater flux from the sewage facility to Roebuck Bay were likely to have greatly overestimated the extent to which the combined effects of nitrification and denitrification reactions attenuate the mass of

nitrogen that is discharged to Roebuck Bay. This issue could only be resolved by ensuring that sufficient monitoring bores are constructed at the site to determine the full vertical thickness of groundwater contamination at the site and its spatial extent. Additional monitoring bores were installed at the site by Golder Associates in 2018 to provide this information, and the results of these investigations are discussed in the following section.

Golder Associates has estimated seepage from the current wastewater ponds at the site using a water balance approach with a daily time-step. The assessment was undertaken without isolating the ponds and using pan evaporation data from offsite, measures that are not consistent with the approach outlined by Ham and Baum (2009) which is the preferred methodology for assessing seepage from wastewater storage ponds.

However, given the difficulties in isolating ponds in an operational sewage facility, the method used by Golder Associates is considered to be a reasonable compromise, although the degree of uncertainty in the estimates of both seepage and nutrient discharge rates from the ponds to groundwater is likely to be greater than indicated by Golder Associates 2017.

3.2 Distribution of chemical constituents of environmental concern in groundwater

The monitoring bores that were installed by Golder Associates in 2018 have been constructed in accordance with nationally recognised practices and the spatial distribution of monitoring bores is considered to be generally appropriate for delineating the lateral extent of a groundwater plume that is discharging from leaking wastewater ponds at the site. However, the current network of monitoring bores has not adequately delineated the vertical distribution of contamination at the site. This is because clusters of bores drilled on east-west transects between the sewage facility and the coast do not appear to have fully penetrated the full thickness of the contamination plume that is inferred to have emanated from the wastewater ponds at the site (Fig. 2).

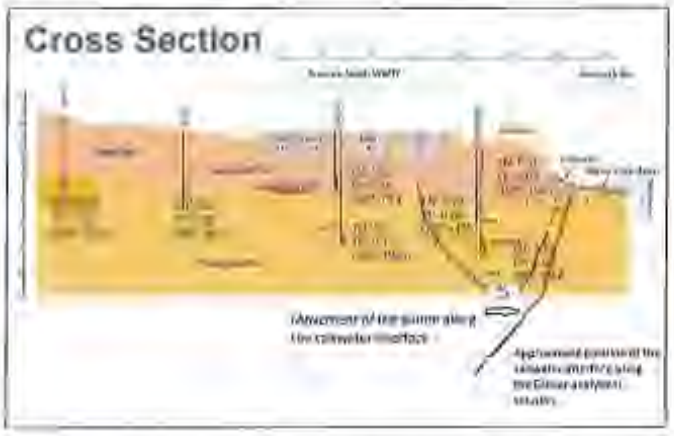


Figure 2. East-west cross-section showing the vertical distribution of nitrogen and phosphorus in groundwater between the wastewater ponds and the coast. A possible location of the 5 mg/L nitrogen concentration contour is shown in blue, and the predicted location of the freshwater-saltwater interface in the aquifer is shown in red.

Typically, contamination plumes that contain high concentrations of nutrients and dissolved organic carbon (such as those discharging from wastewater treatment plants and landfills) are denser than the surrounding groundwater and tend to sink in an aquifer with increasing distance from a source. This means that the depth at which a contamination plume is intersected by monitoring bores will also increase with distance from a contamination source. In coastal areas, these plumes will continue to sink until they reach the saltwater-freshwater interface. As contaminated groundwater in these plumes is generally less dense than seawater, contaminated groundwater will then be forced to rise near the interface until it discharges into the ocean (Figs 1 and 2).

This behaviour is observed in the cluster of monitoring bores at site 7 (Fig. 2) where the highest nitrogen concentration in groundwater downgradient of the wastewater ponds was monitored in the deepest monitoring bore at this site. Based on information provided by Golder Associates, it could be inferred that the bulk of the nitrogen contamination plume is located beneath the deepest monitoring bore at site 7 and that this plume then moves up the freshwater-saltwater interface to the discharge area (Fig. 2). Consequently, there is a risk that Golder Associates has underestimated the mass-flux of nitrogen and other dissolved constituents that are being discharged by groundwater to Roebuck Bay at the Broome South sewage facility as the position of the toe of the contamination plume has not been adequately defined by the current groundwater monitoring network at the site.

3.3 Inferred attenuation processes for groundwater contaminants

Golder Associates has inferred that nitrogen and phosphorous compounds are being removed from groundwater by a variety of biogeochemical and physical processes in both the Pindan and Broome Sandstone aquifers. However, Golder Associates has not provided sufficient lines of evidence to support these inferred removal processes to meet the internationally-recognised requirements of demonstrating natural attenuation in an aquifer. These include:

- Demonstrating that contaminants and reaction products are disappearing and appearing in groundwater in proportion to the stoichiometry of chemical reactions that are assumed to be responsible for natural attenuation;
- Demonstrating that contaminants are disappearing at a rate which is consistent with published values under chemical conditions present in an aquifer at a given site; and
- Demonstrating that a contamination plume is either stable or is shrinking over time.

These factors have not been adequately determined at the Broome South sewage facility.

There are a number of potential problems with the conceptual model proposed by Golder Associates for the attenuation of contaminants in groundwater beneath the Broome South site which are discussed below.

3.3.1 Nitrogen attenuation

Nitrogen compounds in aquatic environments can undergo a variety of chemical reactions in soil and aquatic environments that can affect their speciation and concentrations in groundwater (Fig. 3). As much of the nitrogen in treated wastewater is in the form of ammonium ions, the key microbially-assisted chemical processes that are able to remove the nitrogen from wastewater in the unsaturated zone and in shallow groundwater are:

- The combined effects of nitrification and denitrification (Fig. 3) which firstly convert ammonium to nitrite and nitrate ions which is then converted to nitrous oxide and nitrogen gases which are released from soil pore-water and groundwater; and
- The process of anammox (Fig. 3) where ammonium is directly converted to nitrogen gas which is released from soil pore-water and groundwater.

Both of these processes only take place under moderately oxidising conditions near the water table and on the fringes of wastewater plumes. Ammonium ions are highly stable in the cores of wastewater plumes and elevated concentrations of these ions may persist in wastewater plumes in groundwater for several decades (Böhlke *et al.*, 2006).

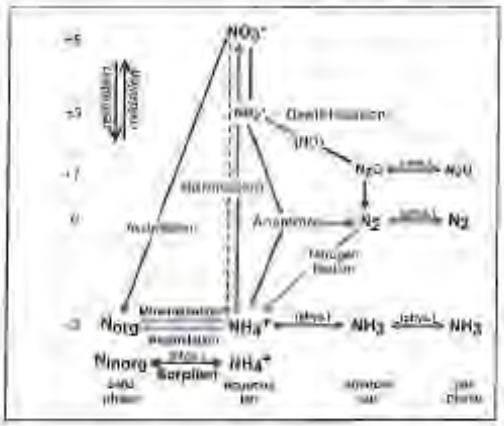


Figure 3 Physical and chemical species affecting the speciation of nitrogen in soils and aquatic systems (from Böhlke et al., 2006).

Golder Associates has assumed that the process of denitrification is the principal mechanism by which nitrogen is being removed from contaminated groundwater beneath the Broome South sewage facility.

Although chemical conditions within groundwater at the Broome South site appear to be suitable for the removal of nitrate and nitrite ions by denitrification, this is unlikely to be a suitable mechanism for the removal of ammonium ions from groundwater at depth beneath the site. This is because ammonium ions must first be oxidised to nitrate before denitrification can take place, and measured oxidation-reduction potentials (ORPs) appear to be too low at depth in aquifers beneath the site to allow ammonium oxidation to nitrate to occur (Appelo and Postma, 2005).

Under some circumstances, the direct oxidation of ammonium to nitrogen gas can take place under anaerobic conditions in an aquifer through the "anammox" process, but additional isotopic measurements or tracer tests would be required (Smith *et al.*, 2015; Wang *et al.*, 2017) to demonstrate that this is taking place at the Broome South sewage facility.

The decline of ammonium concentrations over time observed in some monitoring bores at the site suggests that anammox could be a significant process at least on the fringes of the contamination plume beneath the sewage facility. However, previous investigations on a plume at a wastewater treatment plant (Böhlke *et al.*, 2006) have suggested that anammox does not appear to be a significant process within the most concentrated core of the plume where high carbon concentrations may allow high ammonium concentrations to persist for

decades after the discharge of contaminants to an aquifer ceases (Smith *et al*., 2013, refer also to Fig. 4).

As drilling downgradient of the wastewater ponds may not have intersected the core of the plume, there is consequently a significant risk that there is negligible attenuation of ammonium concentrations taking place at depth in the Broome Sandstone aquifer and that elevated ammonium concentrations are being discharged near the saltwater-freshwater interface into Roebuck Bay. Additional drilling to the depth of the saltwater-freshwater interface would be required downgradient of the Broome South sewage facility to determine whether such a residual "slug" of contamination exists at this site that is continuing to discharge elevated nitrogen concentrations to Roebuck Bay.

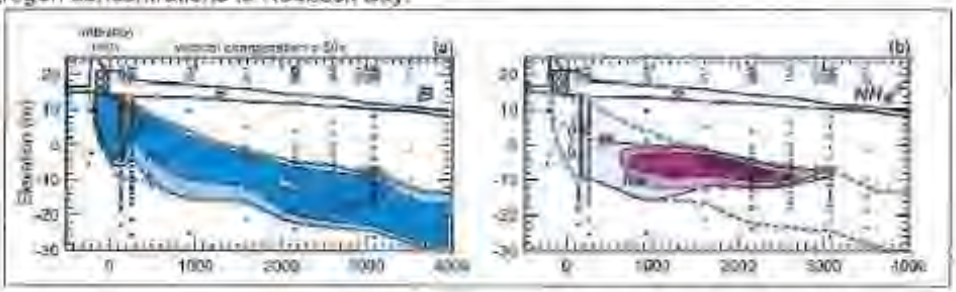


Figure 4. Vertical distribution of (a) boron and (b) ammonium ions in wastewater plume in a sandy aquifer in Massachusetts, USA. The full extent of the sinking wastewater plume is delineated by the distribution of boron concentrations in groundwater. By contrast, nitrogen concentrations in the vicinity of the contamination source are undergoing natural attenuation, but a residual "slug" of contaminated groundwater containing elevated ammonium contamination persists downgradient of the source (Figure from Böhlke et al., 2006)

There are insufficient monitoring bores between the sewage facility and Roebuck Bay to determine whether there is a residual 'slug" of nitrogen contamination in groundwater that is discharging (or has the potential to discharge) nitrogen and other chemical constituents into the nearshore marine environment in the area (Fig. 2).

3.3.2 Phosphorus attenuation

Phosphorus in the form of phosphate ions usually has a limited mobility in freshwater aquifers as this anion is usually strongly adsorbed to iron oxyhydroxide minerals that are widely distributed in the subsurface. However, this is not necessarily the case under highly reducing conditions that occur in the centre of wastewater contamination plumes (McCobb *et al*., 2003). Phosphorus concentrations in the cores of such plumes may exceed 1 mg/L and contaminated groundwater from this part of the plume may continue to discharge environmentally significant concentrations of this nutrient into environmentally sensitive surface water bodies for many decades after the source of contamination has been removed (Parkhurst *et al*., 2003).

Data provided by Golder Associates indicates that large amounts of iron hydroxide minerals are present as coatings on sand grains and in gravel units near the water table beneath the Broome South sewage facility which should be able to adsorb large amounts of phosphorus that are discharged from the sewage facility. Consequently, it is considered to be unlikely that significant amounts of phosphorus would have penetrated far below the water table in groundwater beneath the site.

However, the absence of monitoring bores that have been drilled to the saltwater-freshwater interface downgradient of the sewage facility means that there is a possibility that elevated concentrations of phosphate occur in groundwater near the interface. Additional drilling to the depth of the saltwater-freshwater interface would be required downgradient of the Broome South sewage facility to determine whether such a residual "slug" of contamination exists at this site that is continuing to discharge elevated phosphate concentrations to Roebuck Bay.

3.4 Effect of the saltwater-freshwater interface on contaminant discharge

Golder Associates has undertaken investigations at the Broome South sewage facility without considering the effects of the saltwater-freshwater interface on the distribution of wastewater-derived groundwater contaminants and without considering the important role that the position of this interface has in forcing the upward discharge of contamination of groundwater contaminants at the coast.

This can be shown schematically in Figure 5 which is output from a model showing the behaviour of a groundwater plume from a point-source of contamination near the coast (from La Licata *et al.*, 2011). As can be seen in this Figure, it would be possible to drill monitoring bores downgradient of a contamination source with a sinking plume and gain a misleading impression that the plume is shorter than it actually is if the bores have not been drilled sufficiently deep. The Figure also indicates that contaminants in groundwater from a long distance below sea-level can be brought to the surface in groundwater flow near the saltwater-freshwater interface. The only way to be sure whether a contamination plume is not discharging to the ocean from a coastal point-source of pollution is to ensure that bores on the seaward side of the pollution source intersect the saltwater-freshwater interface.

Calculations using the Glover analytical solution suggest that monitoring bores on the seaward side of the sewage facility have not intersected the saltwater-freshwater interface (refer to Figure 2), and therefore it is not possible to conclude that there is negligible groundwater discharge of contaminants to Roebuck Bay from the sewage facility based on the monitoring network that has been established at the site.

Consequently, there is a significant risk that Golder Associates has underestimated the mass flux of nitrogen that is being discharged by groundwater to Roebuck Bay from the site. Additional monitoring bores would need to be drilled to the depth of the saltwater-freshwater interface at monitoring site 7 (refer to Fig. 2) and at sites closer to the coast to determine the actual mass-flux of contaminants in groundwater from this site.

Figure 5. Modelled distribution of contamination in a coastal aquifer from a point-source in a coastal aquifer. Flow vectors (arrows showing the direction and magnitude of flow on the Figure) show that groundwater flow in the aquifer is largely horizontal until the saltwater-freshwater interface is reached. At this point, groundwater flows vertically upwards to the groundwater discharge area, transporting contaminants into the ocean (Figure from La Licata et al., 2011).

4. Residual nutrients in the unsaturated zone beneath the site

The investigations that have been undertaken by Golder Associates have not considered the possibility that nitrogen compounds and other chemical constituents are stored in the unsaturated zone beneath the sewage facility that could be flushed to groundwater by ongoing seepage from wastewater ponds.

The degree to which stored nitrogen in the unsaturated zone beneath could cause impacts on groundwater quality beneath the site will depend on the extent to which ammonium ions are converted to nitrate by the process of nitrification. This in turn depends on: the seepage rate the physical properties of sediments above the water table; on whether seepage takes place continuously or is intermittent in nature, and on the organic carbon content of wastewater. For example, in well oxygenated sediments where the water table is about 10 m thick, up to 70% of the nitrogen in wastewater that is discharged to ground may be converted from ammonium to nitrate ions in the unsaturated zone (DeSimone and Howes, 1998). In less well oxygenated sediments, a greater percentage of the nitrogen could remain in the form of ammonium ions in the unsaturated zone.

The chemical form that nitrogen occurs in the unsaturated zone is important as this factor affects the rate at which this nutrient is flushed into groundwater and timing and severity of groundwater contamination that takes place beneath the infiltration area. In situations where a large proportion of the ammonium ions are converted to nitrate, nitrogen is flushed rapidly from the unsaturated zone because nitrate ions are not really adsorbed by sediments. The infiltrating nitrate may also react with organic carbon in groundwater, allowing denitrification to take place and lowering nitrogen concentration in the aquifer immediately beneath the infiltration area.

However, the rate of transport of nitrogen to groundwater will be much slower in situations less-well oxygenated sediments where most of this nutrient is present as ammonium ions. This is because ammonium ions are strongly adsorbed to sediments and are therefore transported to groundwater at a much slower rate that the seepage rate (Bohlke et al., 2006). This means that it could take many years for the full impacts of nitrogen contamination to be experienced in groundwater.

The extent to which sediments in the unsaturated zone beneath wastewater ponds at the Broome South sewage facility is currently unknown as is the dominant chemical form of this nutrient in sediments above the water table. In the absence of this information, it is recommended that a precautionary approach is taken to limiting the infiltration of water from wastewater ponds at the site to limit the potential flushing of nitrogen to the water table. The most effective way of managing infiltration from the ponds is considered to be by ensuring the ponds are underlain by a suitable lining system.

5. Nitrogen isotope measurements in Roebuck Bay

Regulatory Services (Environment) has requested that Contaminated Sites provides advice on the nitrogen isotope investigations that were carried out by the Centre for Marine Ecosystem Research at Edith Cowan University. The report provided has been reviewed and the following comments are offered on this study:

The investigations were carried out in an appropriate manner and the conclusions that were drawn are supported. The investigations supported the hypothesis that much of the nitrogen in the *Lyngbya* blooms is being derived by the fixation of atmospheric N and that there is no clear association between the isotopic signatures of the seagrass and wastewater from the Broome South sewage facility.

It is important to note that the study does not conclude that the sewage facility is not an important source of contamination that helps trigger *Lyngbya* blooms, but rather it only indicates that these blooms are not limited by the availability of nitrogen.

6 Likelihood of impacts

Regulatory Services (Environment) has requested that Science and Planning provides advice on the likelihood of impact from discharges of chemical constituents in wastewater to environmental receptors in Roebuck Bay and to groundwater. The following comments are offered on this issue.

From a management perspective, there are two classes of "impacts" that need to be considered when assessing leakage of wastewater from ponds at the Broome South sewage facility which will be managed by DWER using different regulatory measures. These are:

- Impacts on environmental receptors in Roebuck Bay caused by the discharge of groundwater contamination from the site. These potential impacts will be mostly managed using provisions of the *Contaminated Sites Act, 2003*; and
- Impacts on local groundwater quality caused by the emission of contaminants within seepage from the sewage facility and from the unsaturated soils below the sewage facility. These potential impacts will be mostly managed using provisions under Part V of the *Environmental Protection Act, 1987*.

These issues are discussed further below.

6.1 Potential impacts on Roebuck Bay

On the basis of the conceptual model for the development of *Lyngbya* blooms that was presented in Section 2 of this report, groundwater discharge from the Broome South sewage facility is considered to be one of a number of sources of organic carbon, phosphorus and soluble iron that are likely to trigger the formation of *Lyngbya* blooms in Roebuck Bay. These discharges may also contribute of other types of environmental degradation in the bay that have yet to be adequately characterised. Additionally, the cumulative likelihood of impact occurring from by groundwater discharge from the site by comparison with the discharge or organic matter and nutrients in surface runoff is not known, but could be relatively low during heavy rainfall events in the wet season when large amounts of sediment are likely to be discharged to Roebuck Bay in surface runoff. It is also likely that the groundwater discharge of nitrogen and other chemical constituents from other sites around Roebuck Bay is contributing to the environmental problems in the nearshore marine environment in this area.

Golder Associates 2018 has undertaken investigations at the Broome South sewage facility without considering the effects of the saltwater-freshwater interface on the distribution of wastewater-derived groundwater contaminants and without considering the important role that the position of this interface has in forcing the upward discharge of contamination of groundwater contaminants at the coast (refer to Fig. 5). Additionally, the most recent groundwater investigations that have been carried out by Golder Associates have not characterised the extent and severity of groundwater contamination that may be present in the area between the sewage facility and the coast.

Consequently, it is considered that there is a risk that there is a residual "slug" of groundwater contamination (refer to Fig. 4b) sitting near the saltwater interface in the superficial aquifer that has not been detected by the drilling that has been undertaken by Golder Associates. Such residual contamination from historical leakage from the site could be discharging to Roebuck Bay without being detected by the current network of monitoring bores at the site. This means that the flux of nitrogen to Roebuck Bay in groundwater discharge from the site of 180 kg/year that has been determined by Golder Associates may be an underestimate. Additional drilling would be required to the depth of the saltwater interface between the site and the coast to determine whether this is the case.

6.2 Potential impacts on local groundwater quality

Recent groundwater investigations at the site indicate that there are locally elevated nitrogen concentrations in groundwater in the immediate vicinity of the wastewater ponds which suggests that seepage from the ponds has affected local groundwater quality. Golder Associates has argued that these impacts are historical in nature and that emissions from ponds at the site will now be negligible due to recent changes in how wastewater is managed at the site.

However, this assessment does not consider the possibility that large amounts of chemical constituents from historical seepage are stored in the unsaturated zone beneath the ponds at the site (refer to Section 4 in this report). This means that that there is a risk that nitrogen and other contaminants could be continuing to be leached to the water table by seepage from unlined ponds at the site, even if water in the ponds currently contains low levels of potential contaminants.

This risk cannot be quantified due to a lack of information about sediment and pore-water quality in the unsaturated zone near wastewater ponds at the site. Therefore it is recommended that a precautionary approach is taken to limit the rate of seepage of ponds to reduce the risk of leaching of chemical constituents from the unsaturated zone. The most effective way of doing this is considered to be by installing liners in ponds at the site that are currently unlined.

References

AECOM, 2016. *Preliminary Nutrient Impact Assessment, Broome South Wastewater Treatment Plant*. Technical produced for the Water Corporation.

Ahern, K.S., O'Neil, J.M., Udy, J.W., and Albert, S., 2006. Effects of iron additions on filament growth and productivity of the cyanobacterium *Lyngbya majuscula*. *Marine and Freshwater Research*, **57**, 167-178.

Ahearn, K.S., Ahearn, C.R. and Udy, 2008. In situ field experiment shows *Lyngbya majuscula* (cyanobacterium) growth stimulated by added iron, phosphorus and nitrogen. *Harmful Algae*, **7(4)**, 389-404.

Appelo, C.A.J. and Postma, D., 2005. *Geochemistry, Groundwater and Pollution, 2nd Edition*. Balkema publishers, the Netherlands, 649pp.

Bell, P.R.F., and Elmetri, I., 2007. Some chemical factors regulating the growth of *Lyngbya majuscula* in Moreton Bay, Australia: Importance of sewage discharges. *Hydrobiologia*, **592**, 359-371.

Böhlke, J.K., Smith, R.L. and Miller, D.N., 2006. Ammonium transport and reaction in contaminated groundwater: Application of isotope tracers and isotope fractionation studies. *Water Resources Research*, **42**, DOI:10.1029/2005WR004349.

Burkholder, D.A., Forqurean, J.W. and Heithaus, M.R., 2013. Spatial pattern in seagrass stoichiometry indicates that both N-limited and P-limited regions of an iconic P-limited subtropical bay. *Marine Ecology Progress Series*, **472**, 101-115.

DeSimone, L.A. and Howes, B.L., 1998. Nitrogen transport and transformations in a shallow aquifer receiving wastewater discharge: A mass balance approach. *Water Resources Research*, **34**, 271-285.

Elmetri, I. and Bell, P.R.F., 2004. Effects of phosphorus on the growth and nitrogen fixation rates of *Lyngbya majuscula*: implications for management in Moreton Bay, Queensland. *Marine Ecology Progress Series*, **281**, 27-35.

Estrella, S.M., 2013. *Effects of Nutrient Enrichment and Toxic Lyngbya Blooms on Benthic Invertebrates and Migratory Shorebird Communities of Roebuck Bay Ramsar Site*. University of Western Australia, School of Animal Biology Technical Report. The report is available from web site http://www.roebuckbay.org.au/wp-content/uploads/2012/01/Lyngbya-nutrients-Roebuck-Bay-Project-FINAL-REPORT.pdf

Estrella, S.M., Storey, A.W., Pearson, G. and Piersma, T., 2011. Potential effects of *Lyngbya majuscula* blooms on benthic invertebrate diversity and shorebird foraging ecology at Roebuck Bay, Western Australia: preliminary results. *Journal of the Royal Society of Western Australia*, **94**, 171-179.

Field Capacity Pty Ltd February 2017, *Broome Golf Course Agronomic Assessment: developed for discussion with Department of Environmental Regulation and Broome Golf Club*

Field Capacity Pty Ltd August 2017, *Broome South Waste Water Treatment Plant Effluent Reuse Scheme Management Strategy: prepared for Water Corporation and Broome Golf Club*

Ford, A.K., van Hoytema, N., Moore, B.R., Pandihau, L., Wild, C. and Ferse, S.C.A., 2017. High sedimentary oxygen consumption indicates that sewage input from small islands drives benthic community shifts on overfished reefs. *Environmental Conservation*, **44**, 405-411.

Ford, A.K., Bejarno, S., Nugues, M.M., Visser, P.M., Albert, S. and Ferse, S.C.A., 2018. Reefs under siege – the rise, putative drivers, and consequences of benthic cyanobacterial mats. *Frontiers in Marine Science*, **5**, doi.org/10.3389/fmars.2018.00018

Golder Associates Pty Ltd December 2017, *Broome South WWTP – Water balance analysis and seepage loss assessment*

Golder Associates Pty Ltd July 2018, *Report Broome South Wastewater Treatment Plant response to draft licence decision report*.

La Licata, I., Langevin, C.D., Dausman, A.M. and Alberti, L., 2011. Effect of tidal fluctuations on transient dispersion of simulated contaminant concentrations in coastal aquifers. *Hydrogeology Journal*, **19**, 1313-1322.

Ham, J.M. and Baum, K.A., 2009. Measuring seepage from waste lagoons and earthen basins with an overnight water balance test. *Transactions of the ASABE*, **52**, 835-844. The paper is available from web site https://elibrary.asabe.org/abstract.asp?aid=27405.

Harrington, R., Rose, A. and Johnstone, R., 2016. The potential of benthic iron and phosphorus fluxes to support the growth of a bloom forming toxic cyanobacterium Lyngbya majuscule. Moreton Bay, Australia. *Marine and Freshwater Research*, **67**, 1918-1927.

Hearn, D., 2014. *Source, Fate and Mobility of Groundwater Nutrients, Metals/Metalloids and 4-Nonylphenol in the Unconfined Broome Aquifer*. University of WA Honours Thesis.

McCobb, T.D., LeBlanc, D.R., Walter, D.A., Hess, K.M., Kent, D.B. and Smith, R.L., 2003. *Phosphorus in a Ground-Water Contaminant Plume Discharging to Ashumet Pond, Cape Cod, Massachusetts, 1999*. US Geological Survey, Water Resources Investigation Report 02-4306. The report is available from web site www.usgs.gov.

McMahon, K. and Dunham, N., 2017. *Investigation into Nitrogen Sources for Roebuck Bay and the Yawuru Nagulagun/ Roebuck Bay Marine Park*. Technical Report produced by the Centre for Marine Ecosystems Research, Edith Cowan University.

Parkhurst, D.L., Stollenwerk, K.G. and Colman, J.A., 2003. *Reactive-Transport Simulation of Phosphorus in the Sewage Plume at the Massachusetts Military Reservation, Cape Cod, Massachusetts*. US Geological Survey Water-Resources Investigation Report 03-4017.

Skoog, A.C. and Arias-Esquivel, V.A., 2009. The effect of anoxia and reoxygenation on benthic fluxes of organic carbon, phosphate, iron and manganese. *Science of the Total Environment*, **407**, 6085-6092. The paper is available from web site www.academia.edu.

Smith, R.L., Repert, D.A., Barber, L.B. and LeBlanc, D.R., 2013. Long-term groundwater contamination after source removal – The role of sorbed carbon and nitrogen on the rate of reoxygenation of a treated-wastewater plume on Cape Cod, MA, USA. *Chemical Geology*, **28**, 38-47.

Smith, R.L., Böhlke, J.K., Song, B. and Tobias, C.R., 2015. Role of anaerobic ammonium oxidation (anammox) in nitrogen removal from a freshwater aquifer. *Environmental Science and Technology*, **49(20)**, 12169-12177.

URS Australia Pty Ltd September 2015. *Preliminary nutrient impact assessment Broome South wastewater treatment plant*.

US EPA, 2006. Process Design Manual: Land Treatment of Municipal Wastewater Effluents. US EPA Technical Report No EPA/625R-06/016. The report is available from web site www.epa.gov.

Wang, S., Radny, D., Huang, S., Zhuang, L., Zhao, S., Berg, M., Jetten, M. and Zhu, G., 2017. Nitrogen loss by anaerobic ammonium oxidation in unconfined aquifer soils. *Nature*, DOI:101038/srep40173.

Wulff, F., Eyre, B.D., and Johnstone, R., 2011. Nitrogen versus phosphorus limitation in a subtropical coastal embayment (Moreton Bay, Australia): implications for management. *Ecological Modelling*, **222**, 120-130.

7. Limitations

It is assumed that information provided in the reports that were provided for review is correct as presented.

Signatures

Author Name STEVE APPLEYARD	Signature
Position PRINCIPAL HYDROGEOLOGIST	Date 20/11/2018
Reviewer Name Andrew Mullen	Signature
Position A/Director	Date 20/11/18

Appendix 5: Copy of Existing Licence

Government of Western Australia
Department of Environment Regulation

AMENDED LICENCE FOR PRESCRIBED PREMISES
Environmental Protection Act 1986

LICENCE NUMBER: L6266/1991/10 **FILE NUMBER: DER2014/000608**

LICENSEE
Water Corporation
629 Newcastle Street
LEEDERVILLE WA 6007

PREMISES
Broome Wastewater Treatment Plant
Reserve 37454 Lot 1639 Clementson Street
BROOME WA 6725
(as depicted in Attachment 1)

PRESCRIBED PREMISES CATEGORY
Schedule 1 of the *Environmental Protection Regulations 1987*

CATEGORY NUMBER	CATEGORY DESCRIPTION	CATEGORY PRODUCTION OR DESIGN CAPACITY	PREMISES PRODUCTION OR DESIGN CAPACITY
54	Sewage facility: premises on which sewage is treated (excluding septic tanks); or from which treated sewage is discharged onto land or into waters.	100 cubic metres or more per day	3,500 cubic metres per day
61	Liquid waste facility: premises on which liquid waste produced on other premises (other than sewerage waste) is stored, reprocessed, treated or irrigated.	100 tonnes or more per year	More than 100 tonnes per year

CONDITIONS OF LICENCE
Subject to the conditions of licence set out in the attached pages

Date signed: 16 June 2016

Ruth Dowe
SENIOR MANAGER LICENSING (WASTE INDUSTRIES)
Officer delegated under Section 20
of the *Environmental Protection Act 1986*

ISSUE DATE: Thursday 29 December 2011
COMMENCEMENT DATE: Sunday, 1 January 2012
EXPIRY DATE: Friday, 31 December 2021
DATE OF AMENDMENT: Thursday, 16 June 2016 Page 1 of 17

DEFINITIONS

In these conditions of works approval, unless inconsistent with the text or subject matter:

'AS/NZS' means the most recent version (unless otherwise stated) of the specified Australian and New Zealand Standard as jointly published by Standards Australia International Ltd, Sydney and Standards New Zealand, Wellington;

'AS/NZS 5667 or Australian Standard 5667' means the most recent version and the relevant parts of the Australian and New Zealand series of guidance standards on Water Quality Sampling;

'Broome Wastewater Treatment Plant' means the Water Corporation wastewater treatment plant located on Reserve 37454 Lot 1639, Clementson Street as depicted in Attachment 1;

'CEO' for the purpose of correspondence means:

> Chief Executive Officer
> Department Administering the *Environmental Protection Act 1986*
> Locked Bag 33
> CLOISTERS SQUARE WA 6850
> Email: info@der.wa.gov.au

'controlled waste' means a waste listed in Schedule 1 of the *Environmental Protection (Controlled Waste) Regulations 2004* (amended 2014);

'DER' means the Department of Environment Regulation;

'DoW' means the Department of Water;

'discernible' means capable of being seen, noticed or observed;

'GCL' means geosynthetic clay liner;

'kg/day' means kilograms per day;

'mg/L or milligrams per litre' means the concentration of an aqueous solution and is the ration of the mass of specific solute to the volume of solution (not solvent);

'NATA' means the Australian National Association of Testing Authorities;

'premises' means Broome Wastewater Treatment Plant, Reserve 37454 Lot 1639 Clementson Street as depicted in Attachment 1;

'pond E3' means the storage pond 'E3' which forms part of the Wastewater Treatment Plant premises as depicted within Attachment 1, Map of Premises;

'Septage Receival Bay' means the concrete receival facility which forms part of the Wastewater Receival Pump Station as depicted in Attachment 1; and

'Shire of Broome Effluent Re-use Scheme' means the effluent irrigation scheme whereby treated effluent from the Broome Wastewater Treatment Plant is irrigated at the Broome Golf Course, Haynes Oval, St Mary's Oval and the Broome Recreation and Aquatic Centre etc.

'Works' means the installation of a GCL in pond E3 including all associated preparatory works, site works, excavation and reuse or disposal of excavated material.

CONDITIONS OF LICENCE
Environmental Protection Act 1986

LICENCE NUMBER: L6266/1991/10 **FILE NUMBER:** DER2014/000608

GENERAL CONDITIONS

1. The licensee shall only accept the following controlled waste categories:
   (a) Category No. K210 Septage waste;
   (b) Category No. K110 Grease trap waste;
   (c) Category No. K130 Sewage waste; and
   (d) Category No. L150 and L100 Industrial wash water.

2. The licensee shall ensure that all waste permitted to be accepted at the premises as per condition 1 of this licence is disposed into the Septage Receival Bay as depicted in Attachment 1.

3. The licensee shall maintain a fence at least 1.8 m in height around the whole of the perimeter of the premises and ensure that any entrance to the premises is securely locked when the premises is unattended.

4. The licensee shall maintain a suitable metering device to measure cumulative monthly volumes (m^3 per day) of water entering the wastewater treatment plant and include this data in tabular form in the Annual Environmental Report required by condition 30 of this licence.

5. The licensee shall ensure that the installation and verification of accuracy of the flow meter required by condition 4 is performed in accordance with the Australian Technical Standards and Australian Standards specified within 'Guidelines for Water Meter Installation' (DoW, 2009) and reported in the Annual Environmental Report required by condition 30 of this licence.

6. The Licensee must ensure that the proposed Works specified in Column 1 of Table 1.2.1 are designed and constructed to meet or exceed the specifications in Column 2 of Table 1.2.1 for the infrastructure in each row of Table 1.2.1.

7. The Licensee must not depart from the specifications in Table 1.2.1 except:
   (a) where such departure is minor in nature and does not materially change or affect the infrastructure; or
   (b) where such departure improves the functionality of the infrastructure and does not increase risks to public health, public amenity or the environment;

   and all other Conditions in this Licence are still satisfied

Table 1.2.1: Column 1 Infrastructure	**Works specifications** Column 2 Specifications (design and construction)
Pond 'E3' Secondary Storage Pond (See Attachment 1. Plan of Premises)	The Licensee must ensure that : 1. pond E3 (as depicted in Schedule 1) is lined with a GCL with a permeability of ≤2 x 10^{-10} m/s; 2. any GCL stored at the premises prior to use is covered with UV resistant plastic sheeting; 3. the GCL is not installed in wet weather; 4. the sub-grade is smooth and free of debris, compacted to 92% maximum modified density and be proof-rolled with a smooth drum roller prior to GCL application; 5. the GCL is applied with the use of a spreader bar or approved equipment; 6. the GCL has a moisture content of ≤ 50% at time of installation 7. A soil cover layer of 300 mm thick is placed over the GCL and compacted as it is being laid 8. the GCL shall be covered at each laydown once installed by overlying fill; 9. the GCL is secured by dedicated anchor trenches; 10. the GCL seams are constructed by overlapping their adjacent edges; 11. a cover soil layer of 300 mm thick shall be placed and compacted over the GCL as it is being laid; 12. erosion protection included for wave action with graded rip rap placed over the GCL surface on the Secondary Storage pond E3 slopes; 13. installation of the GCL liner shall be subject to construction quality assurance processes in accordance with Level 1 of Australian Standard AS3798-2007 Guidelines on Earthworks for Commercial and Residential developments (Standards Australia Ltd 2007); and 14 the emergency overflow pond and depression located north and west (respectively) of pond E3 are vegetated or equivalent on completion of filling and compaction with soil/ sediment from pond E3 to ensure no windblown particulates.

8. The Licensee must conduct the installation and operation of the GCL in pond E3 (including all associated preparatory works, site works, excavation and reuse or disposal of excavated material) in accordance with the documents listed in Table 1.2.2, and subject to the Conditions of this Licence.

Table 1.2.2: Construction Requirements[1]

Document	Parts	Date of Document
Broome Wastewater Treatment Plant Licence Amendment – Application Form.	All, including appendices and drawings	March 2016
Holding Pond E3 Sediment Sampling and Assessment Findings – RPS Environment and Planning Pty Ltd (Att: Robin Smolarek, Water Corporation). Document: C1418604	All, including Tables, Appendices and Laboratory results	20 January 2016
Email. Broome South - Additional Information. (Liner Installation details) sent by Craig Chaudhry	All, including attachment	19 May 2016
Email: Odour emissions and Dust emissions received from Craig Chaudhry, Water Corporation	All	25 May 2016

Note 1: Where the details and commitments of the documents listed in condition 1.2.1 are inconsistent with any other condition of this Licence, the Conditions of this Licence shall prevail.

9 If Condition 8 applies, then the Licensee must provide the CEO with a list of departures which are certified as complying with Condition 8 at the same time as the certifications under Condition 11.

10. The Licensee must submit a construction compliance document to the CEO, within one month, following the construction of the Works and prior to operating the new works at Broome Wastewater Treatment Plant.

11. The Licensee must ensure the construction compliance document:
    (a) is certified by a suitably qualified professional engineer or builder that each item of infrastructure specified in Condition 8, Table 1.2.2 has been constructed in accordance with the Conditions of the Licence with no material defects, and
    (b) be signed by a person authorised to represent the Licensee and contain the printed name and position of that person within the company.

DISCHARGE TO LAND

12. The licensee shall manage the wastewater treatment ponds in a manner such that:
    (a) stormwater runoff resulting from site drainage is prevented from entering the wastewater treatment ponds or causing the erosion of any outer pond embankments;
    (b) overtopping of the wastewater treatment ponds does not occur;
    (c) there is no measurable seepage loss from the wastewater treatment ponds, and
    (d) vegetation (emergent or otherwise) is prevented from growing in the wastewater treatment ponds or on the inner pond embankments.

WASTE MINIMISATION / REMOVAL / STORAGE

13. The licensee shall conduct weekly inspections of the wastewater treatment ponds at the premises and take necessary action for the de-sludging of excessive build-up of sludge.

14. The licensee shall advise the CEO in writing no less than 72 hours prior to taking a treatment pond within the premises offline for maintenance works.

15. The licensee shall advise the CEO in writing no less than 14 days prior to the removal of sewage or septage sludge from a treatment pond.

16. Where sewage sludge is temporarily stored on the premises, the licensee shall direct sludge to a low permeability hardstand area which:
    (a) is adequately bunded to effectively contain all leachate and sludge; and
    (b) is designed to return all sludge leachate from the sludge storage area back to the treatment plant.

17. The licensee shall dispose of sludge and biosolids to a licensed landfill.

18. The licensee shall dispose of all collected grit and screenings from the wastewater treatment plant to a licensed landfill.

MONITORING CONDITIONS

19. The licensee shall conduct a monitoring program outlined in Table 1.2.3 of this licence which measures the parameters stated in column 2 of Table 1.2.3 of this licence, in the unit of measurement stated in column 3 of Table 1.2.3 of this licence, at the monitoring

locations stated in column 1 of Table 1.2.3 of this licence, at the frequency stated in column 4 of Table 1.2.3 of this licence.

Table 1.2.3: Water Quality Monitoring Requirements

Column 1	Column 2	Column 3	Column 4
Monitoring location	Parameters to be measured	Unit	Sampling frequency
Monitoring bores 1/04, 2/04, 2/97, 3/04, 3/97, 4/97, 8/97 (as depicted in Attachment 3).	(i) Total Dissolved Solids calculated from Electrical Conductivity; (ii) Total Nitrogen; (iii) Ammonium-Nitrogen; (iv) Nitrate + Nitrite-Nitrogen; (v) Total Phosphorous; (vi) Standing Water Levels; and (vii) pH[1].	mg/L mg/L mg/L mg/L mg/L AHD pH units mg/L	December; March; June; and September.
Broome Wastewater Treatment Plant Final Effluent Sample Point (as depicted in Attachment 3)	(i) Total Suspended Solids; (ii) Total Dissolved Solids calculated from Electrical Conductivity; (iii) Biochemical Oxygen Demand; (iv) Total Nitrogen; (v) Total Phosphorus; (vi) *E. coli*; (vii) pH[1]; and (viii) Oil and Grease	mg/L mg/L mg/L mg/L mg/L orgs/100ml pH units	December; March; June; and September.

Note 1: In field non-NATA accredited analysis permitted

20. The licensee shall maintain the monitoring bores referred to in column 1 of Table 1.2.3 of this licence in this licence and as depicted in Attachment 3, to allow representative water samples to be collected.

21. The licensee shall collect all samples required by condition 19 of this licence in accordance with the relevant parts of Australian Standard 5667.

22. The licensee shall submit all samples required by condition 19 of this licence to a laboratory with current NATA accreditation for the analysis of parameters specified in Table 1.2.3.

COMPLAINTS MONITORING

23. The licensee shall keep a written record of all complaints received at the premises. The record must provide the following information (if known):
    (a) date and time of complaint;
    (b) location about which the complaint was made;
    (c) general description of the nature of complaint;
    (d) wind direction, wind speed and temperature at the time of the complaint;
    (e) likely source of the reported problem; and
    (f) actions taken in response to the complaint.

REPORTING CONDITIONS

DISCHARGE REPORTING

24. The licensee shall advise the CEO in writing within 24 hours of becoming aware of any discharge of wastewater to the environment that does not comply with condition 12 (b) or 12 (c) of this licence.

25. The licensee shall ensure the written advice required by condition 24 of this licence includes, but is not limited to:
    (a) the date, time and probable reason for the discharge;
    (b) an estimate of the period over which the treated wastewater was or is likely to be discharged; and
    (c) an estimate of the extent and the total volume of the discharge and an indication of known or potential environmental impacts.

26. The licensee shall undertake an investigation into any discharge reported under condition 24 of this licence, within one (1) working day of becoming aware of the discharge.

27. The licensee shall provide to the CEO a discharge report on the investigation required by condition 26 of this licence within 21 working days of the discharge. The discharge report shall include, but not be limited to:
    (a) the date, time and reason for the discharge;
    (b) the period over which the discharge occurred;
    (c) the extent and the total volume of the discharge, estimated nutrient loads and their significance in terms of potential or known environmental impacts;
    (d) consultation taken with relevant stakeholders to determine corrective action required to mitigate emissions in the case of any discharge that has crosses the premises boundary;
    (e) corrective action undertaken within the 21 days since the discharge and the continuing planned actions taken to mitigate environmental impact; and
    (f) corrective action undertaken to prevent a recurrence of a discharge, including a timeline for implementation.

28. The licensee shall submit to the CEO and implement a Leakage Management Plan within six months of pond E3 becoming operational at the premises. The plan should include, but not be limited to:
    (a) A methodology for assessing monitoring and operational data to evaluate the liner integrity of lined ponds on the premises on an ongoing 6 monthly basis; and
    (b) A methodology, diversion options and target timeframes for rectification of any leaks identified from lined ponds.

COMPLAINTS REPORTING

29. The complaints record required by condition 23 of this licence shall be included in the Annual Environmental Report required by condition 31 of this licence and shall be made available to the CEO on request.

HYDROGEOLOGICAL REPORT

30. The licensee shall, by 30 October 2013, submit to the CEO, a report detailing the results of a hydrogeological investigation of the groundwater movement beneath the premises. The hydrogeological investigation shall be designed to include, but not be limited to, the following:

(a) Investigation and assessment of the hydrology of the premises and surrounding area within at least a 1km buffer;
(b) A review of existing groundwater data against applicable standards and guidelines;
(c) Identify the seasonal standing water levels of groundwater surrounding the premises;
(d) A determination of seepage rates and volumes of effluent emanating from the premises treatment ponds;
(e) Investigation into the likelihood of nutrient-rich groundwater discharging from the premises;
(f) Application of contaminant fate and transport modelling detailing the quantity and quality of nutrient loads discharging from the premises;
(g) Determination (if applicable) of the possible environmental impacts of any nutrient-rich discharges from the premises;
(h) Determination, if required, of additional groundwater monitoring bores; and
(i) Details of proposed management measures (if applicable) including timelines, to be implemented by the licensee to reduce the risk of nutrient rich groundwater discharges from the premises impacting the surrounding environment.

ANNUAL ENVIRONMENTAL REPORT

31. The licensee shall by 1 September in each year provide to the CEO an Annual Environmental Report containing data collected during the period 1 July the previous year and ending on 30 June in that year. The report shall contain, but not be limited to:
(a) monitoring data and other collected data required by any condition of this licence (data should be provided in tabular and in graphical format);
(b) an explanation of the monitoring data and other collected data required by any condition of this licence in comparison with past monitoring data collected over the previous three (3) years, and known relevant Australian Standards and guidelines;
(c) cumulative monthly volumes (in cubic metres) of treated effluent discharged to the Shire of Broome Effluent Re-use Scheme and the premises infiltration / evaporation ponds;
(d) any issues raised from inspections or incident responses during the reporting period together with details as to how these have been addressed or, if the required work has yet to be completed, how and when said work will be completed;
(e) any changes to site boundaries, location of groundwater monitoring bores, surface drainage channels and on-site or off-site impacts or pollution;
(f) de-sludging events and quantities of sludge removed as required by condition 15 of this licence;
(g) a summary of controlled waste dockets, including the calculation of the cumulative monthly volume of controlled waste accepted at the premises, and
(h) The assessment of the integrity of the lined ponds on the premises undertaken in accordance with the Leakage Management Plan for that annual period.

ANNUAL AUDIT COMPLIANCE REPORT

32. The licensee shall by 1 September in each year, provide to the CEO an Annual Audit Compliance Report in the form in Attachment 2 to this licence, signed and certified in the manner required by Section C of the form, indicating the extent to which the licensee has complied with the conditions of this licence, and any previous licence issued under Part V of the Act for the premises, during the period beginning 1 July the previous year and ending on 30 June in that year.

ATTACHMENT 2

ATTACHMENT 1

LICENCE NUMBER: L6266/1991/10 **FILE NUMBER: 2012/003425**

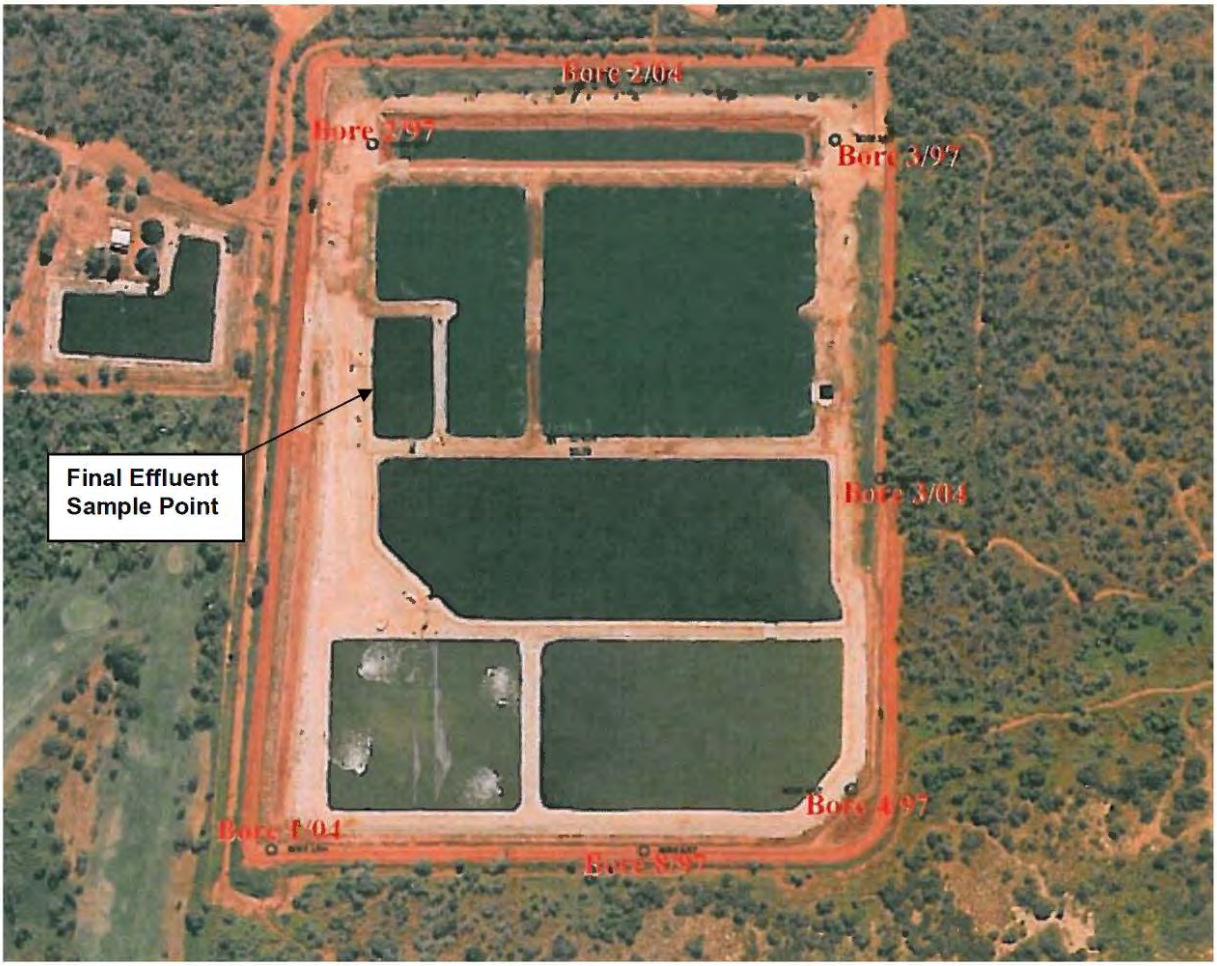
PLAN OF PREMISES

ISSUE DATE:	Thursday, 29 December 2011
COMMENCEMENT DATE:	Sunday, 1 January 2012
EXPIRY DATE:	Saturday, 31 December 2016
DATE OF AMENDMENT:	Thursday, 16 June 2016

ATTACHMENT 3

LICENCE NUMBER: L6266/1991/10 **FILE NUMBER: 2012/003425**

BROOME SOUTH WASTEWATER TREATMENT PLANT – MONITORING BORE LOCATIONS



Attachment 1: Revised Licence L6266/1991/10