City of Greater Geraldton

Point Moore

Residential Onsite Effluent Treatment and Disposal Study

November 2016

Executive Summary

Point Moore accommodates approximately 200 residential dwellings that were built in the 1960s and 1970s on leasehold land within reserves vested with the City of Greater Geraldton. All dwellings use onsite systems (septic tanks with wastewater disposed of via leach drains or soak wells) for wastewater treatment and disposal. Whilst originally established as holiday cottages, many of the Point Moore lessees are now retirees and beach lifestyle enthusiasts that occupy the residences year-round.

The *Point Moore Inundation & Coastal Processes Study* completed in 2015 has highlighted that the area could be severely impacted by coastal inundation and erosion in the future. Given the small size of the residential properties (in the order of 300 m^2), the low elevation of the area (existing ground levels in the order of two metres above current sea levels) and predictions that sea levels will rise significantly in the future, the continued viability of onsite wastewater disposal systems in the area has also come into question.

The City of Greater Geraldton (CGG) commissioned GHD Pty Ltd (GHD) to complete a study to review available information and to conduct a series of investigations to assess the performance of the existing onsite systems, their potential impacts on the local environment, and the degree to which they comply with current legislation and guidelines. The fieldwork to locate and to assess the onsite systems at a selection of properties was completed by Sun City Plumbing (SCP).

The following conclusions have resulted from this study:

1. Observations made during the field investigation indicate that a significant number of the existing septic tanks and leach drains/soak wells are in a poor condition and require remedial works and in some cases replacement.
2. The properties in the study area are significantly smaller than the minimum lot size currently permitted for onsite wastewater disposal (typically 2,000 m^2), and many of the onsite systems do not comply with current standards in a number of respects (e.g. sizing, configuration, horizontal setbacks, vertical separation distance to groundwater). For many properties it would not be possible to upgrade the existing onsite systems to meet current standards, or install alternative onsite systems that comply with current standards.
3. Though local groundwater is not used for irrigation or any other purpose, it does discharge to the nearby ocean, and residents or others could come into contact with groundwater when undertaking a range of land-based activities. In relation to public health risks:
   - The potential for contact with groundwater when undertaking land based sub-surface activities such as excavation or trenching works is considered to represent a potential health risk to residents and others undertaking such activities in the study area. This risk will increase over time as local groundwater levels increase as a direct consequence of sea level rise.
   - It is considered unlikely that elevated levels of pathogens in groundwater flowing from the study area would pose a significant health risk to persons engaging in primary contact recreation in the ocean near Point Moore given natural purification processes in the aquifer and the high levels of dilution that would typically occur where the groundwater discharges into the ocean. However, under conditions of calm winds and low wave climate, rates of dilution may be greatly reduced, thereby increasing the potential health risk. These conditions typically occur late in the bathing season from March-May.

- It is not possible to discount the possibility that onsite disposal of effluent from the Point Moore residential properties is at least partly responsible for the observed seasonal spikes in *Enterococci* levels at the CGG's local marine water quality monitoring sites.

4. In the long term local groundwater levels will rise as sea levels rise, and the magnitude of the rise will severely constrain the potential to dispose of wastewater generated in the study area with the existing conventional onsite septic tank and leach drain/soak well systems approach.

5. If residential properties are to remain at Point Moore for the long term then a reticulated wastewater collection system will need to be installed that routs wastewater to the Water Corporation's Geraldton wastewater scheme.

6. An indicative cost estimate to design and to construct a conventional reticulated gravity sewer type collection system to serve all properties in the study area is $6 to 10M. At a unit cost of approximately $35,000 to $55,000 per property, this is likely to be prohibitively expensive. Whilst alternative wastewater collection technologies exist that may be able to be implemented at a significantly lower capital cost, ongoing costs for these systems would be higher.

7. Whilst nutrient levels in sampled groundwater indicated elevated wastewater-induced contamination above the adopted assessment criteria for all monitoring rounds, given the high levels of dilution that typically occur where groundwater discharges into the ocean it is considered unlikely that elevated levels of nutrients in groundwater flowing from the study area are having any measurable impact on near shore marine ecosystems.

This report is subject to, and must be read in conjunction with, the limitations set out in Section 1.3 and the assumptions and qualifications contained throughout the Report.

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1. Introduction

Point Moore is located in the City of Greater Geraldton (CGG) and is a prominent sandy foreland protected by the Point Moore reefs. There are approximately 200 residential dwellings near the coast built in the 1960s and 1970s on leasehold land within reserves vested in CGG. All dwellings use onsite systems (septic tanks with effluent disposed of via leach drains or soak wells) for wastewater treatment and disposal. Whilst originally established as holiday cottages, many of the Point Moore lessees are now retirees and beach lifestyle enthusiasts that occupy the residences year-round.

Given their age, many of the original septic tanks and soak wells/leach drains may have reached or be approaching their serviceable life and some may have been replaced or upgraded. Due to the low ground levels in the area there is limited vertical separation distance between the soak wells/leach drains and the water table. This separation distance will likely reduce in the future due to rise in sea levels.

M P Rogers & Associates completed the *Point Moore Inundation & Coastal Processes Study*, hereafter termed the Coastal Inundation Study, in 2015 (m p rogers, 2015). The study identified areas of Point Moore which could be impacted by coastal inundation and erosion. Further discussion with regards to this study is provided in Section 3 and the summary report from this m p rogers study is provided in Appendix A.

The CGG commissioned GHD Pty Ltd (GHD) to complete a study to review available information and to conduct a series of investigations to assess the performance of the existing onsite systems and their potential impacts on the local environment and the degree to which they comply with current legislation and guidelines. The fieldwork completed to locate and assess the onsite systems at a selection of properties was completed by Sun City Plumbing (SCP).

1.1 Study Objective

The overall objective of the study is to provide the Point Moore stakeholders with data and documentation on the performance and compliance of the existing onsite wastewater treatment and disposal systems and to assist the CGG in their decision-making process relating to the future status of and potential obligation to Point Moore lessees beyond the current lease expiry dates of 2025 and 2028.

1.2 Scope of Work

The study was completed in two stages, with the key tasks in each stage listed in Table 1.

Table 1 Scope of Work

Phase/Task	Description
Stage 1	
Task 1	Desktop review of available information.
Task 2	Soil and groundwater investigations, including installation of three new monitoring wells.
Task 3	Groundwater level and quality monitoring program (three-month program).
Stage 2	

Phase/Task	Description
Task 4	Onsite wastewater system field inspections.
Task 5	Technical assessment and reporting.

This report documents the findings from all five tasks undertaken to complete this study.

1.3 Limitations and Assumptions

This report has been prepared by GHD for the City of Greater Geraldton and may only be used and relied on by the City of Greater Geraldton for the purpose agreed between GHD and the City of Greater Geraldton as set out in Section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than the City of Greater Geraldton arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by the City of Greater Geraldton and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report. At the time of preparing this report, the nature of the proposed redevelopment (and as such the likely magnitude of disturbance across the site) remained unconfirmed.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

GHD has prepared indicative cost estimates using information reasonably available to GHD; and based on assumptions and judgments made by GHD.

The indicative cost estimates have been prepared to provide an order of magnitude indication of the costs to upgrade the existing onsite systems or install new reticulated wastewater infrastructure. They must not be used for any other purpose.

The cost estimates are indicative estimates only. Actual prices, costs and other variables may be different to those used to prepare the cost estimates and may change. Unless as otherwise specified in this report, no detailed quotation has been obtained for actions identified in this report. GHD does not represent, warrant or guarantee that upgrade of the existing onsite systems or installation of new reticulated wastewater infrastructure could be completed at costs which are the same or less than the estimated indicative costs.

Where estimates of potential costs are provided with an indicated level of confidence, notwithstanding the conservatism of the level of confidence selected as the planning level, there remains a chance that the cost will be greater than the planning estimate and any funding would not be adequate. The confidence level considered to be most appropriate for planning purposes will vary depending on the conservatism of the user and the nature of the project. The user should therefore select appropriate confidence levels to suit their particular risk profile.

2. Site Identification and Physical Characteristics

2.1 Site Description

Point Moore is located approximately two kilometres (km) south of the Geraldton business district, and forms the western extremity of the Geraldton tombolo (CGG, 2016). The study area is bounded by the Indian Ocean to the south, east and west, and John Willcock Link to the north. The subject land comprises several land parcels:

- Reserves vested in the City of Greater Geraldton:
  - Reserve R29729 — Public Recreation (Pages Beach Coastal Reserve);
  - Reserve R2562 — Esplanade and Recreation (Greys Beach, Point Moore and Explosives Coastal Reserve);
  - Reserve R29173 — Caravan Park and Tourist Accommodation;
  - Reserve R25459 — Recreation and Leasing of Cottages; and
  - Reserve R31658 — Parklands.
- Reserves vested in the Australian Maritime Safety Authority:
  - Reserve R44687 — Navigation, Communication, Meteorology and Survey (Point Moore Lighthouse).
- Other land:
  - Private land holding — 481 Marine Terrace (land and property around Point Moore lighthouse);
  - Vacant Crown Land — Part of Point Moore and Greys Beach.

The focus of this study is the residential dwellings located within Reserve R25459. There are approximately 200 residential dwellings in this reserve, typically two to three bedroom dwellings, each on approximately 300 m^2 of land area. A locality plan is included as Figure 1.

2.2 Geology and Soil

2.2.1 Geology

Regional geological mapping indicates that the surface geology of the study area is dune and beach sand, which is comprised of white calcareous and quartzose sand (Geological Survey WA, 1995).

2.2.2 Soil Landscapes

DAFWA (2016) mapping of the South-West of Western Australia was used to characterise the soil-landscapes present within the study area. The study area is covered by the Quindalup Central 1 urban phase, which is described as follows:

- Urban development on Quindalup 1 coastal dune subsystem on Aeolian calcareous sands and minor limestone in the North Coastal Plain, adjacent to the coast from Jurien Bay to Bluff Point. Man-made, disturbed soils; originally Calcareous deep sand.

2.2.3 Preliminary Acid Sulphate Soil Assessment

A review of the WA Atlas for Department of Environment Regulation (DER) Acid Sulphate Soil risk mapping (Landgate, 2016), indicated that potential ASS has not been mapped within the study area. A search of the CSIRO (2016) database indicated that there was an extremely low probably of ASS occurring with very low confidence.

2.3 Hydrogeology

2.3.1 Aquifers and Groundwater Flow

The Perth Groundwater Atlas indicates that the Site is located above a Superficial (unconfined) Aquifer, Perth – Superficial Swan (DoW, 2016a).

The atlas indicates that groundwater beneath the study area is at approximately three metres below ground level. Groundwater was identified to flow towards the Indian Ocean.

2.3.2 Local Bores

General

Based on advice from CGG, groundwater from the Point Moore area is not used for irrigation or any other purposes in the study area, and the nearest production bores are the CGG bores located approximately 600 m east to north east of the study area near Ocean and Point Streets. These bores are up-gradient of the study area and supply irrigation water for open space areas near the Geraldton city business district.

Department of Water WIN Bore Search

A search of the Department of Water's (DoW) water information reporting (WIN) bore database indicates that three bores are registered within a 2.5 km radius of the study area. The bores are located approximately 2 km north-east and 1.5 km south-east from the study area. No other registered bores occur down-gradient or up gradient of the study area within 1 km during the search.

Figure 1 Locality Plan

2.3.3 Local Groundwater Levels and Quality

Prior to this study there was one groundwater monitoring well (GMW – SHP8) located in the study area, more specifically within Coxswain Park as shown on Figure 11.

Groundwater Quality Data

No data was provided by CGG that could be used to characterise the quality of groundwater in the study area.

Groundwater Depth

The CGG is required under its groundwater licence to report to the DoW the standing water levels in GMW – SHP8 twice a year (Pers. comm. Michael DuFour, 28 July 2016). The standing water levels over the period February 2013 to August 2015 are depicted in Figure 2. There are some data gaps over this period, and no data was provided for the period beyond August 2015.

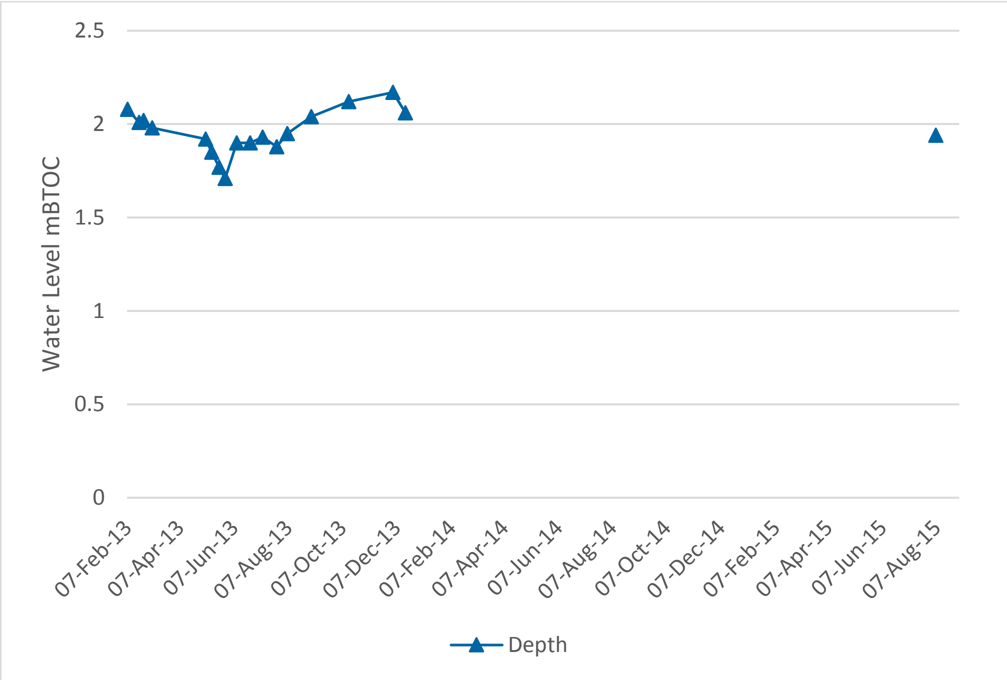

Figure 2 Standing Groundwater Levels at SHP8

2.4 Nearshore Marine Environment

2.4.1 General

The nearshore bathymetry ranges from 0 to 10 m in depth and comprises a complex system of exposed reefs and deeper channels. Beaches are sandy, and where sheltered they are wide and flat. In exposed areas the beaches are narrower and subject to erosion (CGG, 2016).

2.4.2 Water Quality

The CGG undertakes marine surface water monitoring at designated beach locations within Geraldton and Greenough at sampling locations depicted in Figure 3. GHD has reviewed the laboratory water quality data supplied by CGG for the period November 2012 to April 2016.

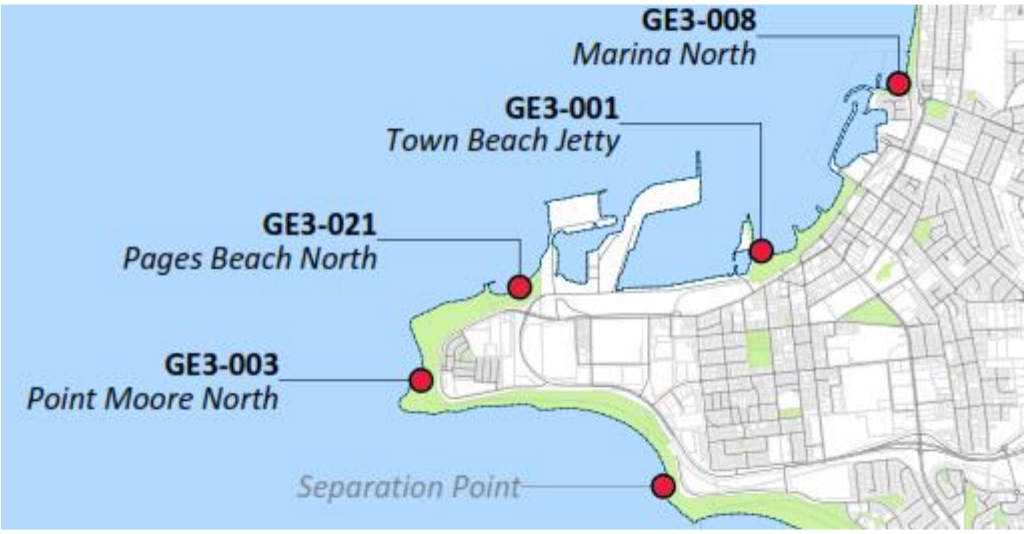

Figure 3 Near Shore Marine Sampling Points (CGG, 2016)

Two monitoring locations, Point Moore North (GE3-003) and Pages Beach North (GE3-021), are located close to the study area. The *Enterococci* data at these two locations, and at one location remote from Point Moore (Town Beach Jetty, GE3-001), was assessed in this study. As shown in Figure 4, the *Enterococci* data was compared against the ANZECC (2000) water quality guidelines for primary and secondary contact recreation which are:

- Primary contact: Median of 35 *Enterococci*/100 mL during bathing season with maximum in one sample being 60 to 100 *Enterococcoi*/100 mL;
- Secondary Contact: Median of 230 *Enterococcoi/*100 mL and maximum number in any one sample being 450 to 700 organisms/100 mL.

Based on these water quality guidelines, some reported *Enterococci* results were above the primary contact and in some instances above the secondary contact guideline values. The reported results thus indicate that persons engaging in both primary contact (e.g. swimming, skin diving) and secondary contact (e.g. boating and fishing) recreational activities in the area are exposing themselves to health risks. Of note, as shown Figure 4 there were no exceedances of the ANZECC (2000) guideline values at the Town Beach Jetty monitoring location over the same period.

The *Enterococci* data was also compared against the NHMRC (2008) percentile values for determining water-quality assessment categories for the protection of healthy adult bathers (refer to Appendix A) which are:

- Category A: <40 *Enterococci*/100 mL (no observed-adverse-effect-level (NOAEL);
- Category B: 41-200 *Enterococci*/100 mL (threshold of illness transmission in most epidemiological studies attempted to define a NOAEL);
- Category C: 200-500 *Enterococci*/100 mL (represents substantial elevation in the probability of all adverse health outcomes); and
- Category D: >500 *Enterococci*/100 mL (above this level may be a significant risk of high levels of illness transmission of *Enterococci*/).

As depicted in Figure 5, one reported *Enterococci* result was in Category C, and one result was in Category D, i.e. at levels that pose a significant risk of illness transmission of *Enterococci* and considered to warrant further investigation.

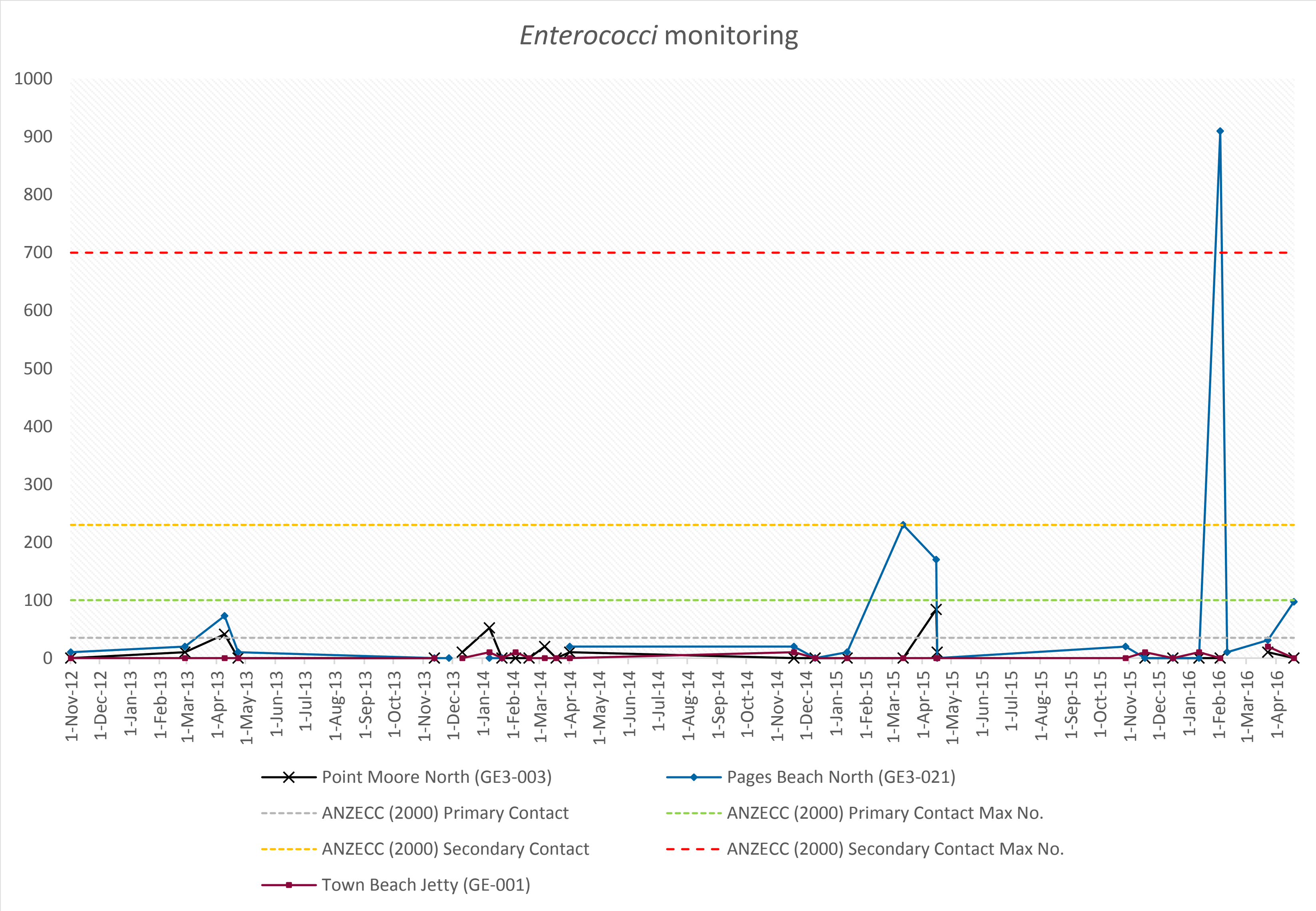

Figure 4 Comparison of Nearshore Marine *Enterococci* Levels with ANZECC (2000) Recreational Water Quality Guidelines

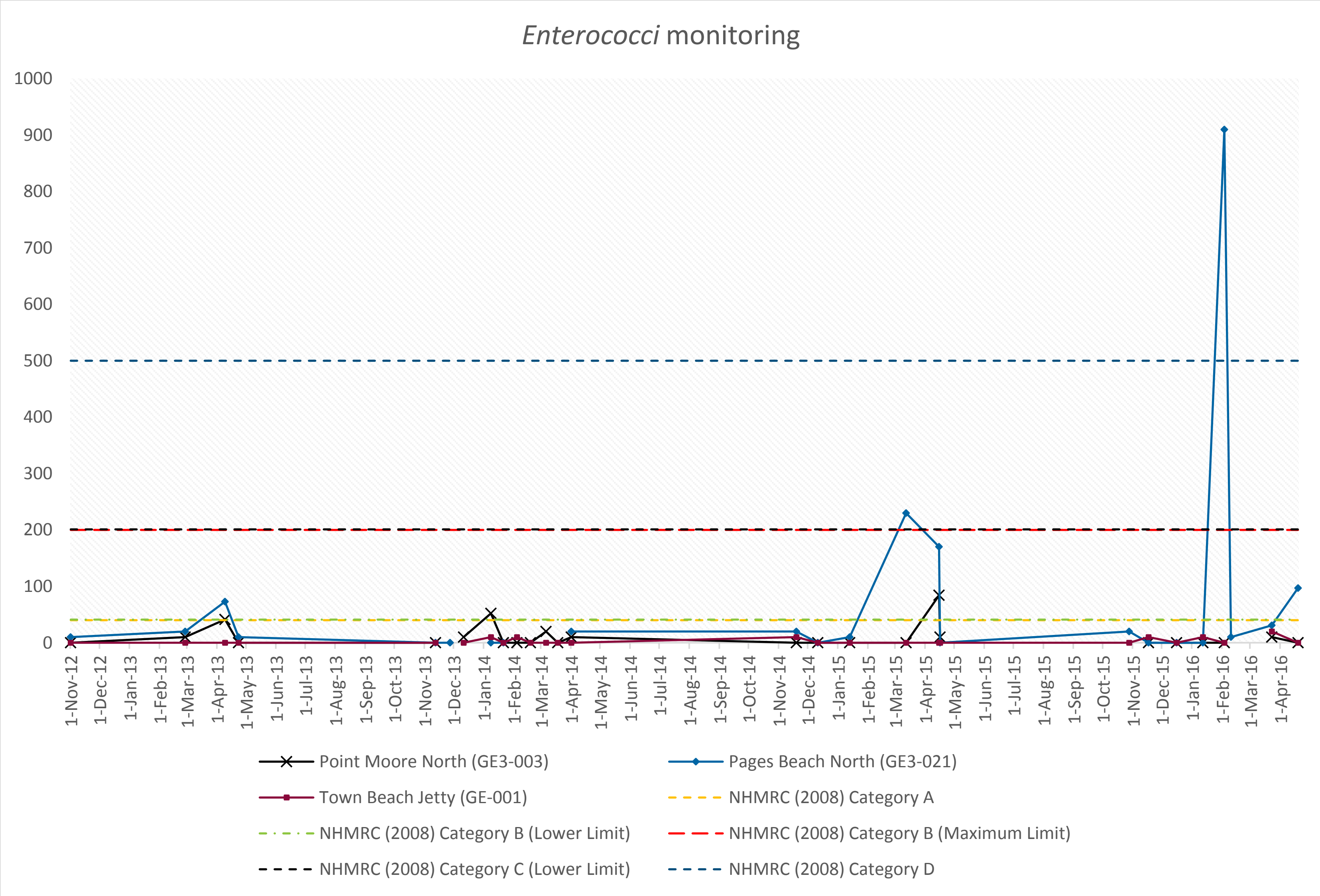

Figure 5 Comparison of Nearshore Marine *Enterococci* Levels with NHMRC (2008) Recreational Water Quality Categories

3. Coastal Inundation Study

3.1 Study Overview

The Coastal Inundation Study (m p rogers, 2015) identified areas of Point Moore which could be impacted by coastal inundation and erosion. As part of the study the following were completed:

- Cyclone storm surge modelling to determine the potential inundation of these extreme events;
- Analysis of available water level records to determine the potential inundation caused by non-cyclonic events;
- Modelling the potential beach and dune erosion caused by severe events;
- Assessment of historical and potential future shoreline movement caused by natural coastal processes; and
- Assessment of the effects of potential sea level rise (assuming 0.9 metres of sea level rise by year 2110 as required by State Planning Policy No. 2.6 (SPP 2.6)) on the coastal inundation and erosion.

The Coastal Inundation Study Summary Report is provided in Appendix B.

3.2 Maps Depicting Study Results

The Coastal Inundation Study (m p rogers, 2015) included a series of maps to depict the study results and recommendations. Some of the key maps are shown and briefly described next.

Coastal Processes Allowance Plan

The coastal processes allowance plan relates to the extent of coastal erosion over 'planning horizons' including present day, 2030, 2070 and 2110. The recommended present day, 2030, 2070 and 2110 coastal setbacks are shown in Figure 6.

Inundation Mapping Plans

The inundation map (Figure 7) depicts the areas of inundation that could occur in the present, with colours to represent different severity events. The purple shading represents those areas that are predicted to be inundated during a 20-year average recurrence interval (ARI) event, the blue shading demonstrates the additional area that would be inundated during a 100 year ARI event, and the green shading the additional area inundated during a 500 year ARI event. Inundation maps used to establish the 2030, 2070 and 2110 coastal setback are provided in Appendix B.

Inundation Depth Plans

The inundation depth plan provided in Figure 8 shows the potential depth of inundation that is predicted to occur in 2030 under a 20 year average recurrence interval (ARI) event. Other inundation depths maps produced by m p rogers (2015) are included in Appendix B.

Combined Coastal Vulnerability Mapping Plans

The combined coastal vulnerability map provided in Figure 9 depicts the area that would be impacted by inundation or coastal erosion (based on present day setbacks) in a 500 year ARI event. Similar plans generated for the recommended 2030, 2070 and 2110 setbacks (500 year ARI events) are provided in Appendix B.

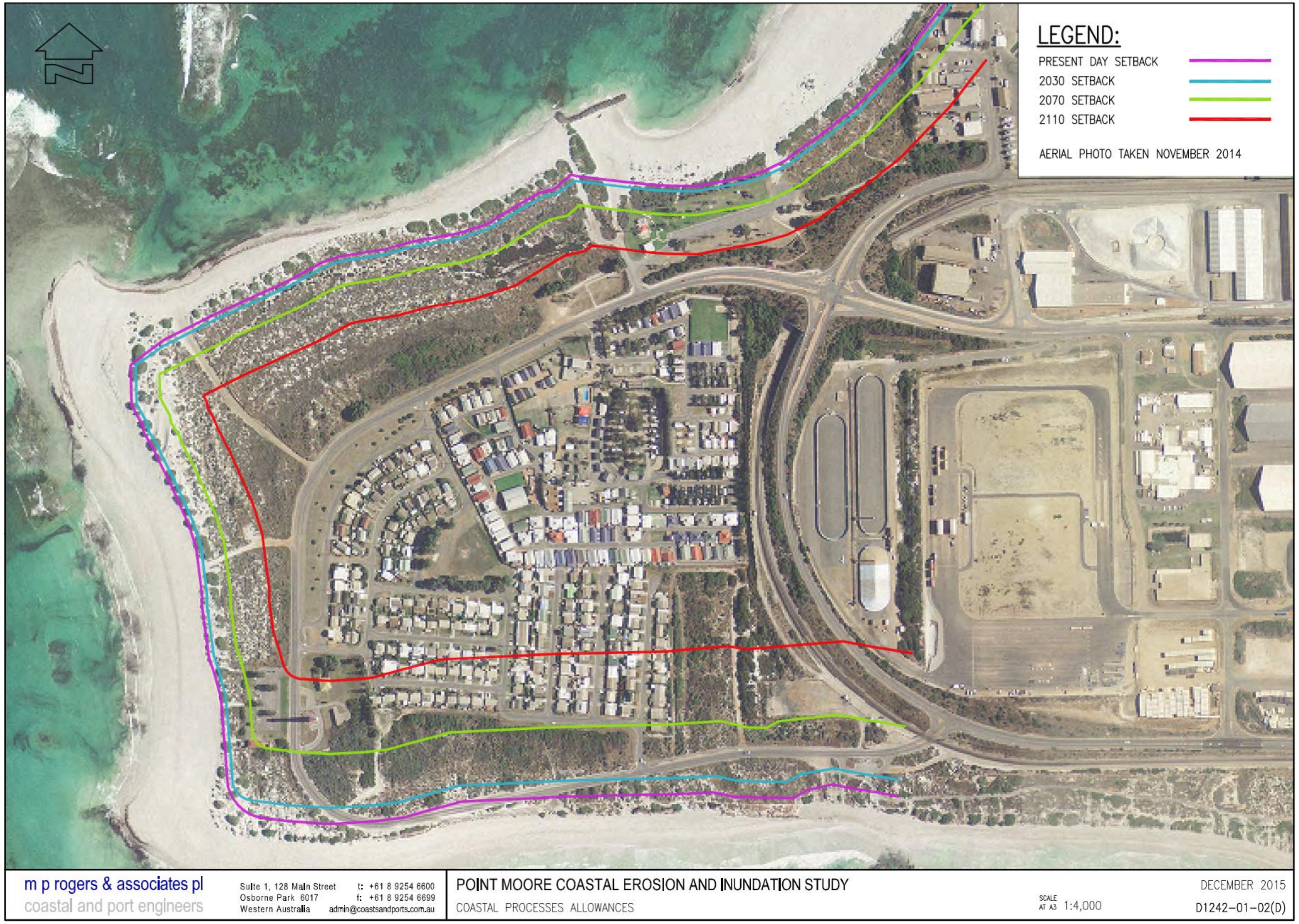

Figure 6 Coastal Processes Allowance Map (m p rogers, 2015)

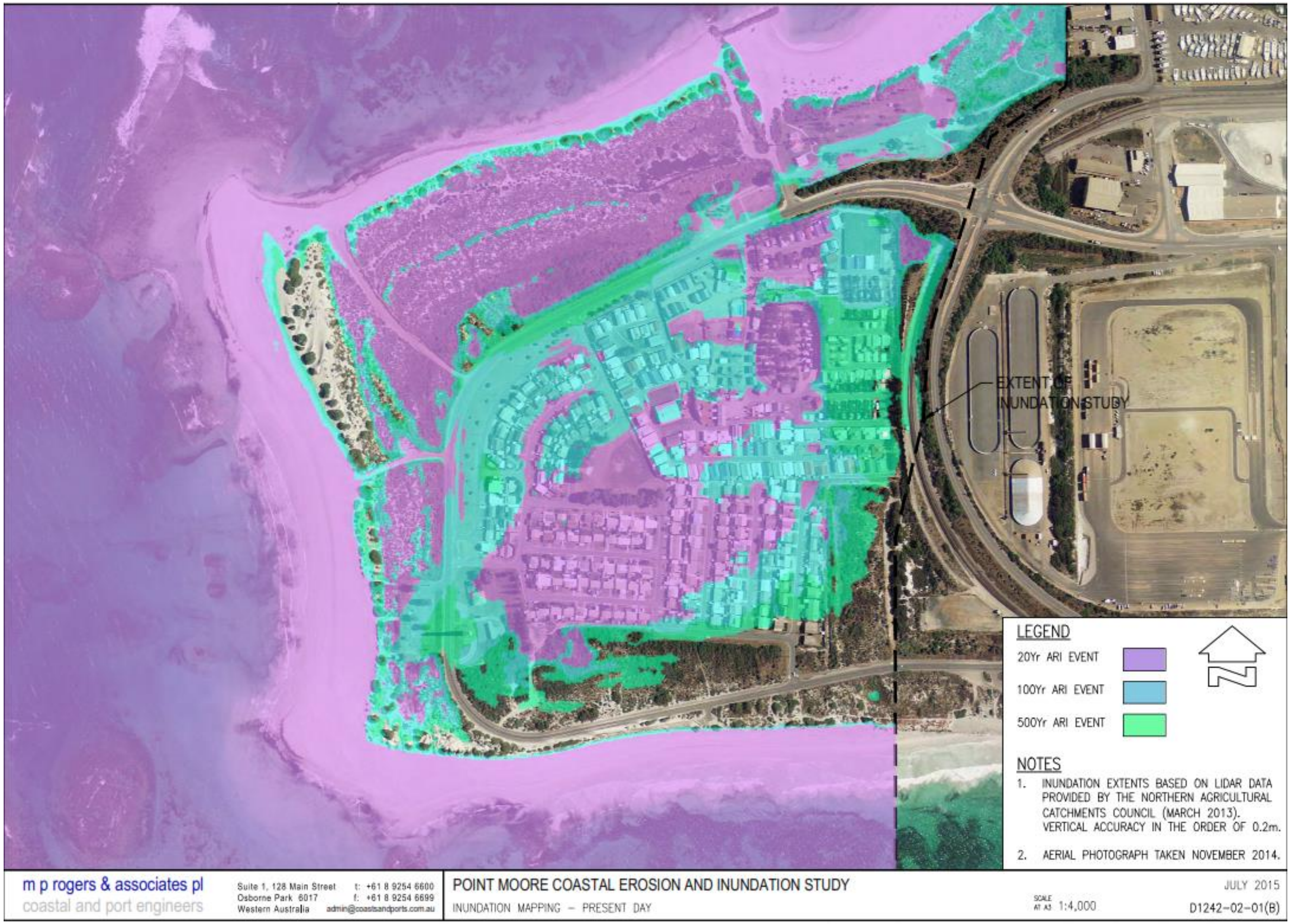

Figure 7 Inundation Mapping - Present Day Setback (m p rogers, 2015)

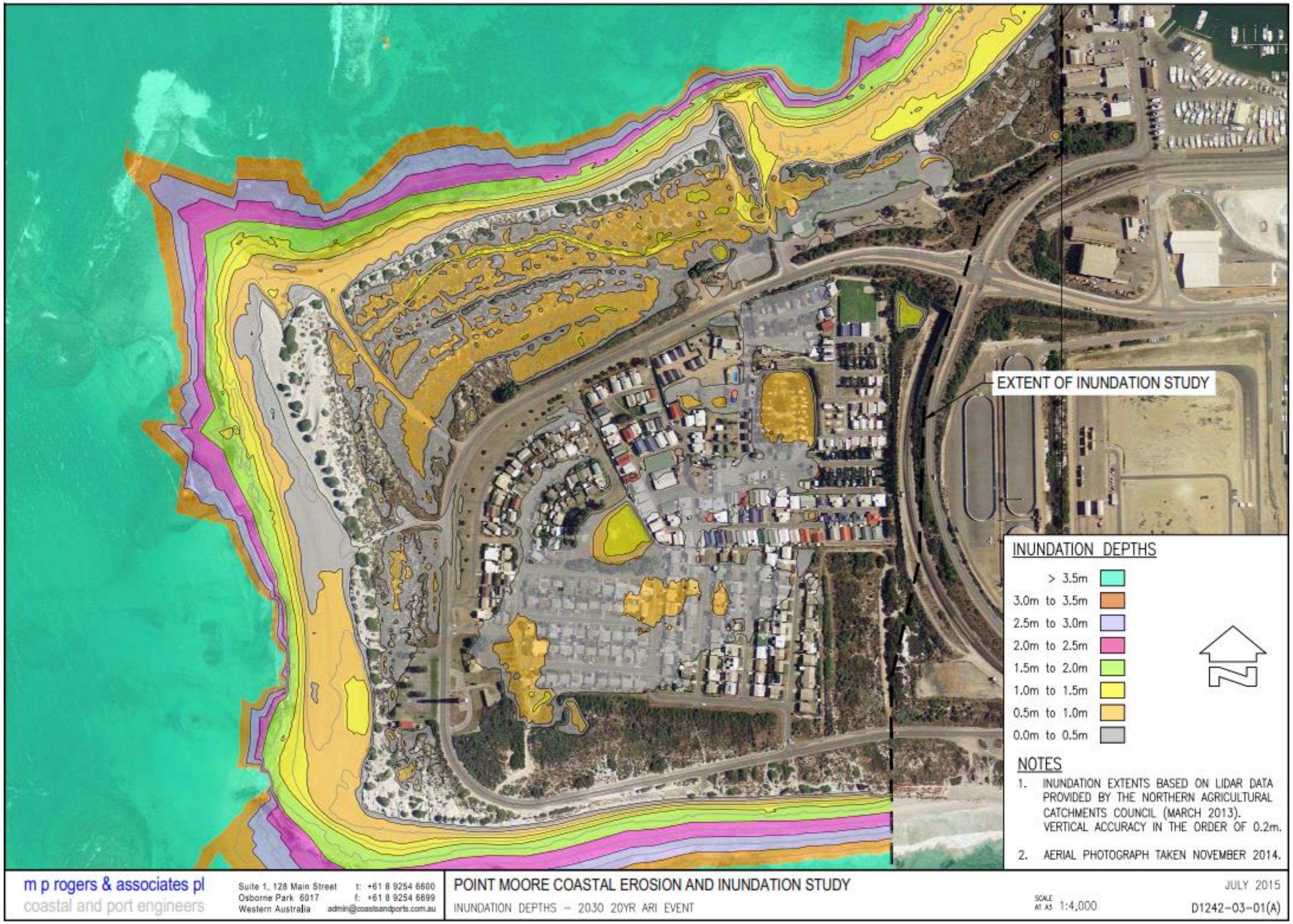

Figure 8 Inundation Depth – 2030 Setback (20 year ARI Event) (m p rogers, 2015)

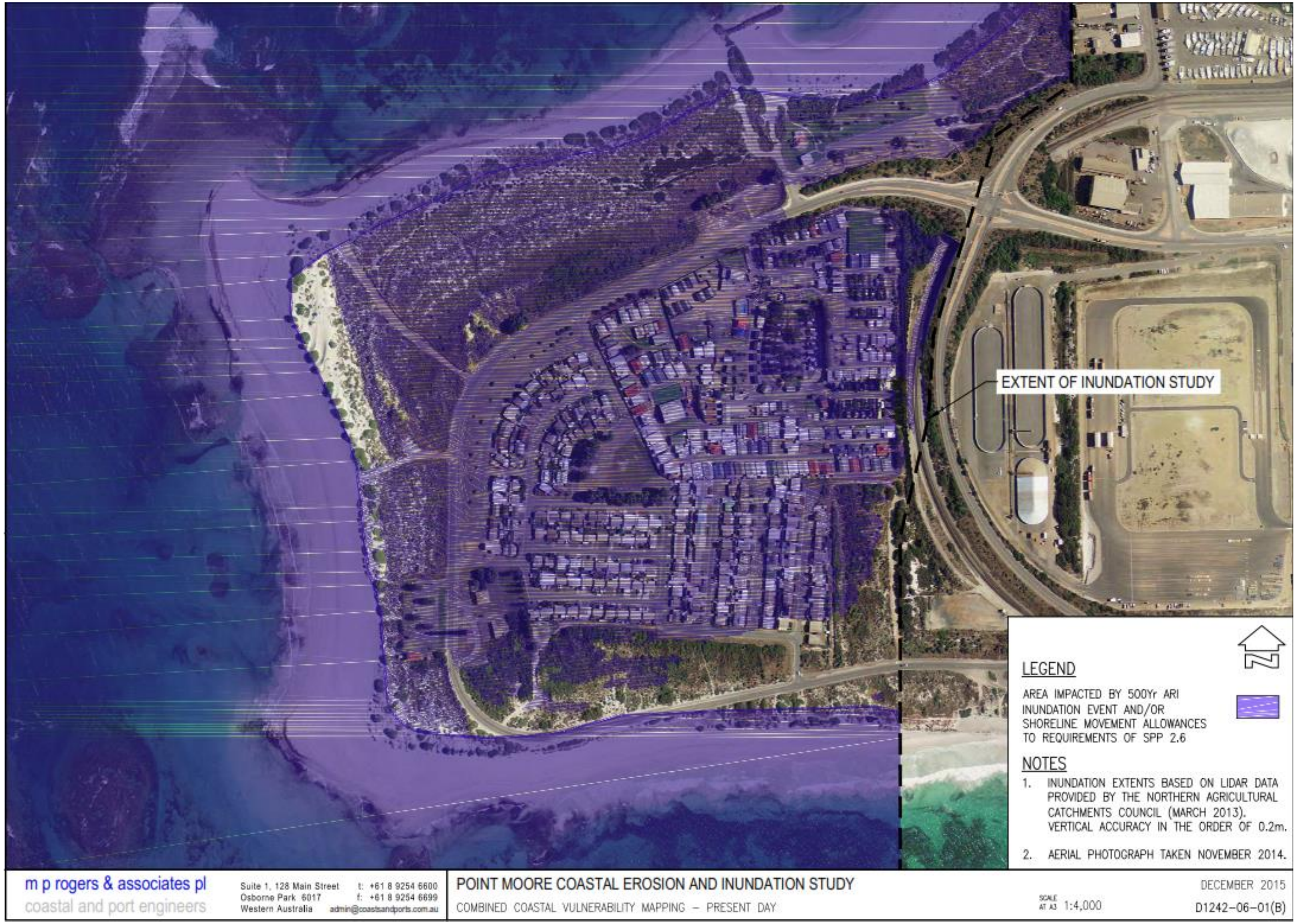

Figure 9 Combine Coastal Vulnerability Mapping - Present Day (Setback) (m p rogers, 2015)

3.3 Consultation with Regulatory and Planning Bodies

Advice and comments on the Coastal Inundation Study (m p rogers, 2015) provided to CGG by the Department of Health (DoH), Department of Lands (DoL) and Department of Planning (DoP) are summarised next. Note that CGG sought a response from the Department of Environment Regulation (DER), no comment was provided.

3.3.1 Department of Health

In a correspondence letter the DoH advised:

> *When developing strategies based upon the findings in the report you may consider a risk assessment of each of the respective areas. Such strategies should incorporate issues such as disaster preparedness, emergency shelters and recovery* (DoH, 2016a).

3.3.2 Department of Lands

In a correspondence letter the DoL advised:

> *As indicated at that meeting, the findings of the report indicated that the reserve is at risk from coastal hazards and that the risk is increasing both in extent and depth. The report provides impetus for further discussion with the City on the long term land use planning for the area post the expiry of the current leases on Point Moore Reserve 25459* (DoL, 2016).

3.3.3 Department of Planning

In email correspondence the DoP advised:

> *The WAPC / DoP position on the West End is contained in the Greater Geraldton Structure Plan June 2011 which identifies it as an area of State Government owned land that provides facilities for tourism, visitor activity. It is severely constrained due to its proximity to the port, a lack of wastewater and vulnerability to storm surges, inundation and long term coastal recession (erosion). I believe the City has just updated its Local Planning Strategy and Scheme, this was the best place to include its intentions for the West End, you should discuss this with your colleague, Murray Connell, the City's Manager Urban and Regional Development. In the LPS on the Geraldton Area Strategy Plan the West End is identified as Strategic Tourism. The LPS also includes at section 4.11 page 27 an action to "ensure land use decision making is based on the best available science regarding coastal processes and the need for adequate setbacks"* (DoP, 2016a).

In a correspondence letter the DoP further advised:

> *DoP.... consider the study to be adequate in demonstrating that much of the current development footprint is already at risk from coastal hazards and that the risk is increasing both in extent and depth. Hence there is sufficient basis and detail in the study to conclude against extension of the current leases when they expire in 2028. It is unlikely that the City or the Department of Lands would wish to fund and maintain coastal protection works for this Crown Reserve and hence leaseholders should not be under any hope of such action (DoP, 2016b).*

4. Wastewater Management

4.1 General

Many of the residential properties established on the Point Moore leases were built in the 1960s and 1970s. Originally established as holiday cottages, they have been commonly acquired by retirees and beach lifestyle enthusiasts. Onsite wastewater treatment and disposal systems that were approved by DoH at that time consisted of either:

- combined systems, comprising two concrete septic tanks (1500 mm and 1200 mm diameter) and two standard size (1200 mm diameter) concrete soak wells or one 9 m leach drain; or
- separate systems comprising one tank and one soak well each for toilet waste and another tank and soak well receiving wastewater from separate sewer lines, with the tanks and soak wells typically located on opposite sides of the dwelling (CGG, 2016a).

Having land areas of approximately 300 m^2, the residential properties are significantly smaller than the minimum lot area currently recommended for houses reliant on onsite wastewater systems. For instance, in its discretionary provisions the Draft Country Sewerage Policy (DoH, 2003) states that lot sizes down to 1,000 m^2 can be considered under certain conditions (e.g. residential subdivisions in remote areas or towns without sewerage that do not create more than 25 lots). Given that the Point Moore area is within the Geraldton townsite, and that Geraldton is a sewered town, the discretionary provisions of this policy do not apply to Point Moore.

The City's internal health database established in 2003 has two reported cases of failing septic systems; one at Zodiac Lane and another at Bosons Crescent. This compares with 44 other enquiries received from various other locations across the City outside the Point Moore site in relation to poorly functioning septic systems (CGG, 2016).

In 2006 the City received advice from the DoH stating that it "*objects to the creation of any new lots and is unsupportive of the extension of the leases, without adequate provision being made for effluent disposal*". Accordingly, the City has since issued standard advice on settlement enquires regarding Point Moore properties because of the potential interest at the time from building owners to apply for building extensions; the advice stated;

> "*The future owner is advised that existing lease lot size may restrict / constrain the available area for future upgrade to onsite effluent disposal system as a result of functional failure or redevelopment in future*" (CGG, 2016).

4.2 Review of Available Information on Existing On-site Systems

CGG provided GHD with a copy of as-constructed records (stamped block plans) and correspondence that provides information on the existing onsite wastewater treatment and disposal systems for approximately 50% of the houses (dated from 1972 to 2001). GHD's review of this information found that:

- Of the nominal 80 houses for which information was available on the effluent disposal system, approximately 20% of the houses use soak wells (typically two soak wells per house), with the remainder using leach drains (typically 1 x 9 m leach drain).
- In July 1983 the Town of Geraldton's Senior Health Surveyor reported that approximately 59 beach cottage leases were due to expire in 1986, and that of these 30 have septic or disposal systems that do not conform to Health Act legislation. The majority of the non-conformances related to instances where wastewater from adjoining cottages was directed to a single septic tank/soak well installation. These landowners were advised to

effect plumbing amendments to achieve compliance with regulations, and that these amendments need to be completed prior to renewal of the lease agreements.

Since 1989, most household septic tank systems have been installed with either two leach drains or two sets of soak wells (DoH, 2011). These systems are known as alternating systems as they have a diverter box to enable flow to be switched from one leach drain or train of soak wells to the other, which allows the effluent disposal systems to be operated on a cyclic duty:resting regime. Such an operating regime is beneficial (if implemented), as periodic resting of leach drains and soak wells rejuvenates the soil's ability to receive effluent.

4.3 Current Regulatory Requirements

The current requirements for onsite treatment and disposal of wastewater in WA are set out in the Health (Treatment of Sewage and Disposal of Effluent and Liquid Waste) Regulations 1974. In addition to these regulations, the Draft Country Sewerage Policy (Draft from 22 September SOCWM Meeting Amended September 2003) and the Australian Standard AS1547:2012 (On-site domestic wastewater management) provide guidance that is relevant to the onsite wastewater systems at Point Moore. Some of the key requirements relevant to the performance of the existing onsite systems at Point Moore (sand conditions assumed) are summarised in Table 2.

Table 2 Key regulatory requirements

Item	Requirement/ Guideline	Regulation	Policy or Guideline	Reference (1)
Wastewater disposal area inundation/flooding risk	Probability of such to be less than once every 10 years.		✓	B
Soak Well Sizing				A
– 2 bedroom dwelling	3 x soak wells(2)	✓		
– 3 bedroom dwelling	4 x soak wells(2)	✓		
Leach Drain Sizing				A
– 2 bedroom dwelling	2 x 6 m leach drains(3)	✓		
– 3 bedroom dwelling	2 x 8 m leach drains(3)	✓		
Minimum Vertical Separation Distance to Groundwater (4)	1.2 m (5)		✓	B
	0.6 - >1.5 m (6)		✓	C

Table Notes:

1. References:
   A. Health Regulations 1974
   B. Draft Country Sewerage Policy
   C. AS1547:2012
2. Each soak well shall have a minimum diameter of 1.2 m and a minimum effective depth of 1.5 m, unless otherwise approved by DoH.
3. Assuming standard dimensions of 0.6 m effective depth and 0.4 m internal width.
4. Minimum vertical distance between invert of septic tank receptacle (in this case soak well or leach drain) and the highest seasonal water table.
5. The policy states that "*for existing developed areas or infill areas a depth to highest known groundwater level may be a minimum of 1.2 m from ground level*".
6. The recommended separation distance is a function of the groundwater pollution hazard

Available as-constructed records (Section 4.2) indicate that existing effluent disposal systems are under-sized with respect to current requirements (Table 2).

In addition to the 'performance requirements' detailed in Table 2, current regulations and guidelines include minimum horizontal clearances that must (unless otherwise approved) be maintained between septic tanks/soak wells//leach drains and buildings, property boundaries etc. The purpose of these clearances is to ensure that septic tanks/leach drains/soak wells can be maintained or replaced without affecting the stability or structural integrity of nearby buildings and the like, and that loadings from buildings do not affect the structural integrity of the wastewater infrastructure. This is further discussed in Section 5.3.

4.4 Estimated Vertical Separation Distance to Groundwater

As shown in Figure 1, although there are some small areas of higher and lower land, the natural surface level across most of the study area is approximately RL 2.0 m. Adopting RL 2.0 m as the typical natural surface level on the residential lots and assuming that the upstream end of the drainage pipework is installed at a depth (to invert) of 0.5 m, and that the typical length and grade of the drain from this point to the septic tank is 10-20 m and 1 in 60, respectively, the typical invert level of the septic tank inlet pipes is estimated to be approximately 0.7-0.9 m below ground level, or RL 1.1 m to RL 1.3 m. Adopting this level, and assuming that soak wells and leach drains have effective depths of 1.5 m and 0.5 m, respectively, the typical invert level of the soak wells are estimated to be approximately RL -0.2 m to RL -0.4 m, and the typical invert level of the leach drains are estimated to be approximately RL 0.6 m to RL 0.8 m.

Noting that the groundwater level currently ranges from approximately RL 0.2-0.5 m (refer to Section 6.3.5), the vertical separation distance between the invert of the leach drains and the water table is estimated to be approximately 0.1 to 0.6 m, and the invert of the soak wells (assuming 1.5 m effective depth as above) is likely to be below water table.

With reference to the current guidelines summarised in Table 2, it is evident that most of the soak wells and many of the leach drains in the study area are unlikely to comply with current vertical separation distance guidelines.

5. Property Assessments

5.1 General

SCP completed field investigations over the week commencing 17 October 2016 to assess the existing wastewater treatment and disposal systems at seventeen properties at Point Moore selected by CGG. Of these fifteen properties had non-invasive investigations undertaken, and two properties had more detailed invasive investigations undertaken.

The scope for the investigations, and the main findings from the investigations, are summarised next. Further detail is provided in SCP's full report.

5.2 Scope of Investigations

The scope of the investigations was to:

- Review available as-constructed information on the existing wastewater systems;
- Liaise with owner/occupiers to gain access to works area, and obtain general advice relevant to this study (e.g. comment on system performance, recent upgrade/maintenance works etc.);
- Take photos of entire property, and measure exterior of house;
- Run a drain camera down the drain (where possible);
- Locate septic tanks by visual inspection or probing, determine if single or dual septic systems, and mark on plan;
- Locate soakwell/leach drains by visual inspection or probing, and mark on plan; and
- Excavate & take photos of the septic tanks and leach drains/soak wells, and then reinstate properties to similar condition to how they were found for the two properties selected for invasive investigations.

5.3 Assessment Findings and Conclusions

The key findings from the investigations were:

- All properties where septic tanks were located had two septic tanks (first tank 1.5 m diameter, second tank 1.2 m diameter). Whilst no markings or stamps were visible stating that the tanks are DoH approved products, they appeared to be proprietary products.
- None of the located septic tanks met all of the standard horizontal separation distance requirements detailed in current regulations. Specifically, the clearance between the tanks (required minimum clearance = 1.2 m), the separation distance between the tanks and buildings (1.8 m required) or property boundaries (1.8 m required) did not comply with current requirements. The same issue applies for the located leach drains.
- Without excavation, the leach drains were difficult to locate. Of those that were located, a number were in poor condition, with some having at least several collapsed segments.
- No twin (alternating) leach drain systems with diverter valves were located, the longest leach drain was 8 m in length, and it was not possible to determine if they are DoH approved products.
- Soil types encountered during the investigations were typically fine grained sands below a topsoil layer, and are expected to have good drainage properties.

Based on the above findings SCP concluded that:

1. For the sites where the septic tanks and leach drains were located, none of the homes inspected had onsite systems that comply with relevant Australian Standards or the current DoH regulations.
2. Because of the small block sizes at Point Moore, it is not possible to install septic tank and leach drain systems that are fully compliant with current DoH regulations on many of the properties.

6. Soil and Groundwater Investigations

6.1 Guideline Framework for Contamination Assessment

This section of the report summarises the assessment criteria adopted to evaluate the human health and ecological risks posed by the existing septic systems within the study area. Consideration has been given to potential off-site impacts.

The legislation and guidelines that outline the appropriate framework for the investigation include the:

- Contaminated Sites Act 2003 and Contaminated Sites Regulations 2006;
- DER Contaminated Sites Management Series guidelines;
- DER Assessment and management of contaminated sites guideline (DER 2014); and
- National Environmental Protection Council (1999), National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1).

The overarching reference in this assessment was the National Environment Protection (Assessment of Site Contamination) Measure 1999, as amended by the *National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1)*, herein referred to as the NEPM. NEPM Schedule B1 "Guidelines on investigation levels for soil and groundwater" contains investigation and screening levels suitable for the assessment of the chemicals of potential concern in soil and groundwater at the site.

As defined in the NEPM, investigation levels are the concentrations of a contaminant above which further appropriate investigation and evaluation will be required.

6.1.1 Soil assessment criteria

Ecological Assessment Criteria

As defined in the NEPM (NEPC 1999), ecological investigation levels (EILs) have been developed for selected organic substances and are applicable for assessing risk to terrestrial ecosystems. EILs depend on specific soil physicochemical properties and land use scenarios and generally apply to the top 2 metres of soil. The NEPM advises that in arid regions, where the predominant species may have greater root penetration depth, specific consideration may result in their application to 3 m depth. Two metres depth is considered appropriate in this case for the site circumstances.

The following assessment criteria was adopted for a pragmatic consideration of risk to the environment:

- NEPC (2013) EIL for Public Open Space.

6.1.2 Groundwater Assessment Guidelines

The DER has provided criteria for use in the assessment of water (DEC, 2010), which are based upon the "*Australian and New Zealand Guidelines for Fresh and Marine Water Quality*" (ANZECC, 2000), the "*Australian Drinking Water Guidelines*" (NHMRC, 2004) and the "*Contaminated study areas Reporting Guideline for Chemicals in Groundwater*" (DoH, 2006).

Groundwater is likely to discharge into the Indian Ocean, which is located immediately adjacent to Point Moore. This part of the Indian Ocean is generally used for swimming, surfing, windsurfing, kite surfing, diving, fishing and boating.

No abstraction of groundwater takes place at Point Moore (refer to Section 2.3.2). The legislation and guidelines that outline the appropriate framework for the groundwater investigations is summarised next.

Ecological Assessment Criteria

A search was undertaken on the Bureau of Meteorology's (BoM) (2016) Atlas of Groundwater Dependent Ecosystems database. The BoM (2016) reported one groundwater dependent ecosystem reliant on surface expression of groundwater in the vicinity of the study area, which has a low potential for groundwater interaction. This GDE type is *Acacia ligulata*, an open scrub that is situated to north of the study area and is unlikely to interact with groundwater from the study area, and therefore is not considered further in the context of potential impacts from existing Point Moore wastewater practices.

The study area's groundwater is anticipated to flow towards the Indian Ocean. To assess the potential risk to the coastal marine environment and human health of coastal users, the ANZECC (2000) marine inshore default trigger values for South West Australia for physical and chemical stressors and primary recreational contact were adopted, respectively.

Health Assessment Criteria

As noted previously, the groundwater at Point Moore is not used for drinking water or irrigation in the study area, rather all such needs are met with scheme water. The groundwater beneath the study area flows towards the Indian Ocean, where a number of recreational activities are carried out. As a conservative measure the ANZECC (2000) guideline values for primary contact recreation (microbiological water quality limits only) were adopted.

6.2 Methodology

6.2.1 Field Work Preparation

Monitoring Bore Locations

Water Corporation and Telstra assets were identified in the vicinity of the original proposed location for MW1. Consequently, MW1 was relocated beyond these assets and to the western side of Marine Terrace. The rationale for the groundwater monitoring well locations is provided in Table 3, and the GMWs locations are depicted in Figure 11.

Table 3 Rationale of GMW Locations

Well ID	Location	Rationale
MW1	West side of Marine Terrace, south of Pages Beach carpark	Down-gradient of existing residential properties targeting groundwater flowing in a westerly direction towards the Indian Ocean.
MW2	South side of Captains Crescent, opposite of Helm Way	Down-gradient and south of all residential properties, intersecting groundwater flowing in a southerly direction towards the Indian Ocean.
MW3	Corner of Sextant and Astrolab Lane.	Down-gradient and east of all residential properties, intersecting groundwater flowing in a easterly direction towards the Indian Ocean
SHP8 (previously installed by CGG)	Coxswain Park, situated along Coxswain Crescent	Down-gradient and south of Belair Lifestyle Village, Belair Gardens Caravan Park and small number of residential properties. Up-gradient from older residential properties.

6.2.2 Soil Investigation

During the drilling program soils were logged and representative soil samples were collected during the installation of the new GMWs. The soil sampling activities were undertaken with reference to section 7, Schedule B2 of the *NEPM*, and Australian Standard AS 4482.1-2005 *Guide to the Sampling and Investigation of Potentially Contaminated Soil* (Standards, Australia, 2005).

Soil Sampling Methodology

To enable soil sample collection during the drilling program the drilling contractor utilised an air core drilling method for GMW installation. The following was undertaken at the GMW locations:

- Soil samples were collected at 0.5 metre intervals;
- Field observations, including olfactory and visual inspection of the soil, soil lithology, samples, QA samples were recorded on field sheets.

All soil samples were visually inspected and all field observations and subsurface conditions were recorded on field lithological logs. Soil from the borehole was obtained from a collection point on the drill rig and placed on clean sheeting, and samples were subsequently collected from this material.

Soil samples were placed into laboratory prepared containers provided by the primary laboratory and filled to the top to eliminate headspace. Each sample was identified by means of a label showing sample location, depth, date and job number. All soil samples were also identified by the depth at which they have been collected (MW1_0.5). The samples were then transferred to a chilled esky for sample preservation prior to and during shipment to the testing laboratory.

Sample details were entered onto a chain of custody form that accompanied the samples to the laboratory. All samples were transported and handled following chain of custody procedures. A chain of custody form was used for every batch of samples submitted to the laboratory. Delivery of the samples to the laboratory complied with analytical extraction holding times.

All field work was undertaken in the presence of an environmental scientist trained in sampling of contaminated sites. The environmental scientist was present during the services location, supervised the sub-contractors, sampled and completed lithological logs of the soil profile. Field activities were conducted in accordance with accepted industry protocols for environmental sampling.

The study area conditions were photographed during soil sampling and incorporated into the report.

6.2.3 Groundwater Investigation

Groundwater wells were sampled with reference to section 8, Schedule B2 of the *NEPM* and Australian Standard AS5667-11-1998 *Guidance on sampling of groundwaters* (Standards Australia, 1998).

Groundwater well locations were determined based on anticipated hydrogeological characteristics (from the desktop review) including reported depths to groundwater and apparent groundwater flow direction. The locations were confirmed following consultation with the CGG.

Three GMWs were installed in the study area on 16 August 2016 The locations of these GMWs were selected to complement the existing GMW SHP8 located in Coxswain Park (refer to Table 3 for rationale of GMW locations).

Groundwater Monitoring Well Installation

Monitoring wells were drilled to a minimum depth of three metres below the groundwater table and were installed with the following general characteristics:

- 50 mm polyvinyl chloride (PVC) class 18 blank and screened casings;
- Screened casing comprised of machine slotted apertures of approximately 0.5 mm;
- Screened casing extended the full length of the GMWs as the groundwater levels are influenced by tides and may significantly fluctuate. A screen sock extended the full length of the screen casing, to prevent the infiltration of gravel into the GMW;
- Blank and screened PVC casing was attached to each other using flush mounted factory-threaded joints;
- Primary filter pack material used was chemically inert, well rounded material with a high coefficient of uniformity and extend from the base of the borehole annulus to the ground surface;
- Bentonite/cement grout was placed at the ground surface to minimise surface water ingress; and
- Monitoring wells were equipped with flush mounted head-works to protect the wells.

The GMWs logs are provided in Appendix C.

Groundwater Monitoring Well Development

The groundwater monitoring wells were developed immediately following installation with air lifting techniques by the drilling contractor. Monitoring wells were developed until:

- No further noticeable sand or silt is recovered.
- The water was relatively clear when pumped from the well.
- A minimum of four well volumes removed.

Monitoring well development optimises the well efficiency, specific capacity, stabilisation of aquifer material and control of suspended solids.

The newly installed groundwater monitoring wells were allowed to stabilise for a minimum of seven days prior to purging and sampling. The groundwater field sheets are provided in Appendix D.

Groundwater Loggers

Groundwater loggers were deployed from the 16 August 2016 until 30 September 2016 to gauge the depth to groundwater and how this depth varies over time. The loggers were deployed in three GMWs across the network, i.e. MW1, MW2 and MW3. The findings are provided in Section 6.3.5.

Groundwater Sampling Program

The 2016 groundwater sampling program comprised three monitoring rounds across the current groundwater monitoring network within Point Moore.

- GMWs were gauged to determine the standing water level.
- Following gauging, GMWs were purged and samples collected with a low flow pump (less than 1 L/minute) (with reference to the methodology outlined in USEPA 540/5-95/504).

The wells were purged and sampled with low-density poly-ethylene tubing coupled to a Sample-Pro Micro purge ('low flow') pump system. The low flow pump provided an appropriate method for collection of representative samples for the required analytes and is recognised as best practice for groundwater sampling.

Field parameters measured during purging included temperature, pH, conductivity, dissolved oxygen and redox potential. Field parameters were recorded on field data sheets. Wells were purged until field parameters stabilised.

The variance associated with the above mentioned parameters required to establish chemical stabilisation are as follows:

- pH: 0.1 unit
- Temperature: 0.2^{o}C
- Eh (ORP): 10%
- DO: 10%
- SC: 10%

Samples at each bore were collected with new disposable gloves and placed directly into laboratory provided sample bottles. Each sample was identified by a label with the sample location, date, job number and depth. The samples were placed on ice in an insulated container, and kept cold during storage and transportation to the laboratory.

Decontamination Procedure

To ensure samples were collected without the potential presence of cross contamination, all reusable sampling equipment was decontaminated in accordance with the procedure and methods described in AS 4482.1 - 2005. In addition, all samples were handled by field staff with disposable nitrile gloves, which were replaced between each GMW.

Groundwater sampling equipment was decontaminated as follows:

- Washed and scrubbed in tap water;
- Washed and scrubbed in laboratory grade detergent (Decon90); and
- Rinsed in distilled or deionised (Grade 3) water.

Survey

Following installation, the monitoring wells were accurately surveyed to AHD and Geocentric Datum of Australia (GDA94), Map Grid Australia (MGA), Zone 50. As the reduced levels of the GMWs (top of casing levels) were accurately determined, measuring the depth to groundwater in the wells enabled groundwater flow directions beneath the study area to be determined.

6.2.4 Groundwater Laboratory Analysis Program

During each groundwater monitoring event (GME) four primary groundwater samples were submitted for analysis to National Association of Testing Authorities (NATA) accredited laboratories including the Australian Laboratory Services (ALS), SGS Australia (SGS) and mpl Laboratories (mpl). Analyses were selected to ascertain data pertaining the current status of groundwater contamination at Point Moore.

The four primary groundwater samples collected during each GME were submitted for laboratory determination of the following parameters:

- Microbiological quality: Total coliforms, *E. coli*, faecal coliforms and total plate count;
- Nutrients levels: Total phosphorus, ammonia-N, nitrate+nitrite-N, TKN and total nitrogen; and
- Other: Biological oxygen demand and total dissolved solids.

6.3 Results

6.3.1 Soil Investigation

Field Observations

Based on the information gathered during the establishment of the GMWs, the underlying geology is calcareous medium to coarse grained sand. A summary of the geology encountered at MW1 is provided in Table 4, which is typical of the three new monitoring wells. The field logs for all new GMW are provided in Appendix C and the relevant photographs from the works are provided in Appendix I.

Table 4 Summary of Geology Encountered at MW1

Depth (m bgl)	Lithological Description
0 – 2.0	Fine sand, brown with minor loam
2.0 – 6.0	Calcareous coarse sand, grey to white, minor quartz

During the field logging of soil samples (i.e. visually inspection and sampling), there were no olfactory signs (i.e. odours or staining) of contamination that warranted further investigation, so no laboratory analyses of soil samples were undertaken.

6.3.2 Groundwater Investigation: August 2016

The first round of groundwater monitoring at MW1, MW2, MW3 and SHP8 occurred on 24 August 2016.

Field Observations

GMW locations are illustrated in Figure 11, and groundwater monitoring field forms are provided in Appendix D.

To determine groundwater flow direction, groundwater elevations from the newly installed GMWs and the existing GMW SHP8 were calculated from depth to groundwater and survey data. Survey data, depth to groundwater and groundwater elevations are presented in Table 5. Groundwater contours derived from this data are depicted in Figure 11.

Table 5 Groundwater Well Survey Data

ID	Easting	Northing	TOC elevation (m AHD)	Depth to water (m bTOC)	Groundwater Elevation (m AHD)
MW1	263938	6814127	2.608	2.36	0.248
MW2	263709	6813860	2.151	1.78	0.371
MW3	263934	6813674	3.009	2.67	0.339
SHP8	263885	6813915	2.427	2.1	0.327

Groundwater Quality Field Parameters

During purging of the groundwater wells, groundwater quality field parameters were measured with a multi-parameter water quality meter (temperature, pH, specific conductivity (SC), salinity, dissolved oxygen (DO), and oxidation-reduction potential (ORP)). This equipment was calibrated by the equipment supplier (Thermofisher Scientific) prior to use on-site and did not require adjusting for redox measurements. A calibration certificate for the water quality meter is presented in Appendix H. Completed groundwater field sheets including a summary of groundwater quality field parameters can be found in Appendix D.

Groundwater samples were described as follows:

- MW1: Colourless, minor particulate, slight H_2S odour;
- MW2: Colourless, slight H_2S odour;
- MW3: Colourless, minor particulates, slight H_2S odour; and
- SHP8: Colourless, slight H_2S odour.

Field parameters indicate that groundwater beneath the study area is generally brackish to saline, and is alkaline. Groundwater is aerobic and with a reducing condition. No indicators of contamination were noted during the sampling with the exception of organic odour noted in the wells.

Groundwater Analytical Results

The groundwater analytical results are tabulated in Table G1, Appendix G and the Laboratory certificates of analysis are presented in Appendix F. Review of quality control and assurance data completed as part of this GME is provided in Appendix E. Exceedances of the adopted criteria during this monitoring round are discussed next.

Reported Exceedances

The following exceedances were reported during the August 2016 GME:

- Ammonia exceeded the adopted EIL (0.91 mg/L) at MW1 (2.68 mg/L);

- Total nitrogen and total phosphorus exceeds the ANZECC (2000) marine inshore default trigger values in all GMWs;
- Nitrate was reported above the ANZECC (2000) Marine Inshore trigger value in MW1 and MW2; and
- Faecal coliforms and *E. coli* results were reported to have exceeded the ANZECC (2000) guideline values for primary contact recreation (150 cfu/100mL) at MW1, MW2 and MW3.

Whilst not an exceedance as ANZECC (2000) does not include guideline values for total coliforms, coliform results (coliforms by membrane filtration) reported in MW1 (250,000 cfu/100 mL) were two orders of magnitude higher than results for up-gradient GMWs including MW2 (1000 cfu/100mL), MW3 (3000 cfu/100mL) and SHP8 (200 cfu/100mL).

6.3.3 Groundwater Investigation: September 2016

The second round of groundwater monitoring at MW1, MW2, MW3 and SHP8 occurred on 22 September 2016.

Field Observations

The depth to groundwater and groundwater elevations are shown in Table 6.

Table 6 Groundwater Well Survey Data

ID	Easting	Northing	TOC elevation (m AHD)	Depth to water (m bTOC)	Groundwater Elevation (m AHD)
MW1	263938	6814127	2.608	2.43	0.178
MW2	263709	6813860	2.151	1.83	0.321
MW3	263934	6813674	3.009	2.68	0.329
SHP8	263885	6813915	2.427	2.08	0.347

Groundwater Quality Field Parameters

During purging of the groundwater wells, groundwater quality field parameters were measured with a multi-parameter water quality meter. A calibration certificate for the water quality meter is presented in Appendix H. The completed groundwater field sheets are reproduced in Appendix D.

Groundwater samples were described as follows:

- MW1: Colourless, particulate, H_2S odour;
- MW2: Colourless, H_2S odour;
- MW3: Colourless, particulates, H_2S odour; and
- SHP8: Colourless, slight H_2S odour.

Field parameters indicate that groundwater beneath the study area is generally brackish to saline, and is acidic to slightly alkaline. The low dissolved oxygen concentrations are indicative of an anaerobic environment with reducing conditions. A hydrogen sulphide odour and high level of particulates was noted during the sampling at all GMW locations. The reported temperatures in the GMWs are likely due to a faulty temperature sensor.

Groundwater Analytical Results

The groundwater analytical results are tabulated in Table G1, Appendix G and the Laboratory certificates of analysis are presented in Appendix F. Review of quality control and assurance data completed as part of this GME is provided in Appendix E. Exceedances of the adopted criteria are discussed next.

Reported Exceedances

The following exceedances were reported during the 22 September 2016 GME:

- Ammonia exceeded the ANZECC (2000) Marine Water 95% (0.91 mg/L) at MW1 and SHP8 (6.28 mg/L and 2.54 mg/L, respectively);
- Total nitrogen and total phosphorus exceeds the ANZECC (2000) default marine inshore trigger values for these parameters in all GMWs;
- Nitrate was reported above the ANZECC (2000) Marine Inshore trigger value in MW1 and 2; and
- Whilst faecal coliforms and *E. coli* were reported above the LOR at two GMWs, i.e. MW2 (1 cfu/100 mL) and MW3 (1 cfu/100 mL), no exceedances occurred.

6.3.4 Groundwater Investigation: October 2016

Field Observations

The third round of groundwater monitoring at MW1, MW2, MW3 and SHP8 occurred on 18 October 2016. The depth to groundwater and groundwater elevations are presented in Table 7.

Table 7 Groundwater Well Survey Data

ID	Easting	Northing	TOC elevation (m AHD)	Depth to water (m bTOC)	Groundwater Elevation (m AHD)
MW1	263938	6814127	2.608	2.41	0.198
MW2	263709	6813860	2.151	1.90	0.251
MW3	263934	6813674	3.009	2.71	0.299
SHP8	263885	6813915	2.427	2.17	0.257

Groundwater Quality Field Parameters

During purging of the groundwater wells, groundwater quality field parameters were measured with a multi-parameter water quality meter. A calibration certificate for the water quality meter is presented in Appendix H. The completed groundwater field sheets are reproduced in Appendix D.

Groundwater samples were described as follows:

- MW1: Colourless, minor suspended solids, H_2S odour;
- MW2: Colourless, H_2S odour, minor suspended solids;
- MW3: Colourless, minor suspended solids, no odour; and
- SHP8: Colourless, slight H_2S odour, minor suspended solids.

Field parameters indicate that groundwater beneath the study area is generally brackish to saline, and is alkaline. Though groundwater had reasonable oxygen levels, it also had reducing conditions. There were no indicators of contamination during sampling with the exception of organic odours. The temperature in MW1 was 0.6 ^{o}C higher than other GMWs.

Groundwater Analytical Results

The groundwater analytical results are tabulated in Table G1, Appendix G and the laboratory certificates of analysis are provided in Appendix F. The quality control and assurance report for this GME is provided in Appendix E. Exceedances of the adopted criteria are discussed next.

Reported Exceedances

The following exceedances were reported during the October 2016 GME:

- Ammonia exceeded the ANZECC (2000) Marine Water 95% (0.91 mg/L) at MW1 and MW2 (3.95 mg/L and 1.48 mg/L, respectively);
- Total nitrogen and total phosphorus exceeds the ANZECC (2000) Marine Inshore trigger values for these parameters in all GMWs;
- Nitrate was reported above the ANZECC (2000) Marine Inshore trigger value in MW1 and 2; and
- Whilst not an exceedance, faecal coliforms and *E. coli* were reported above the LOR at all GMWs (all samples reported a count of 1 cfu/mL).

6.3.5 Groundwater Data Loggers

Data loggers were deployed at MW1, MW2 and MW3 for 38 days (16 August to 22 September). This groundwater level data is presented in Figure 10 with the following key findings :

- Water levels of the three MGWs co-varied throughout the 38 day deployment. Hence, groundwater flow directions are seemingly uni-directional as depicted below in Figure 11.
- Groundwater levels across the groundwater network are influenced by coastal tidal variations to varying degrees as follows:
  - MW2 seemingly undergoes daily tidal-induced level variations of 0.05 m during spring tides and 0.01-0.02 m during neap tides. This suggests that connectivity to the marine waters is relatively rapid with concomitant relatively short travel times from the GMW to the marine environment;
  - In contrast, MW3 has much more muted tidal-induced level variations of 0.01-0.02 m during spring tides and no level variations during neap tides. This suggests that connectivity to the marine waters is substantially slower than MW2 with concomitant relatively long travel times from this GMW to the marine environment; and
  - Over the short measurement record of MW1 (only 16-24 August due to subsequent instrument failure), this GWM responds to tidal variations more akin to MW3 in a muted manner.

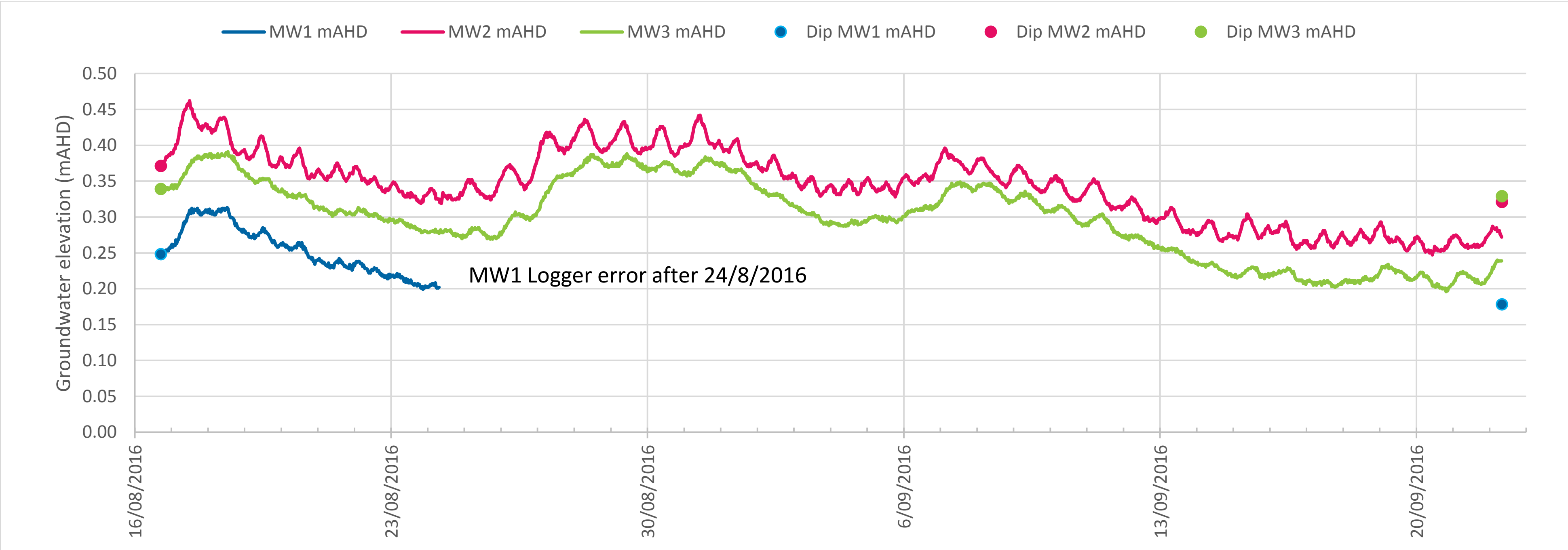

Figure 10 Groundwater Levels Logger Data for MW1, MW2 and MW3

Calculated Groundwater Flow

The groundwater contours depicted in Figure 11 indicate that groundwater beneath the study area flows towards the Indian Ocean, with groundwater in northern, western and southern portions of the study area flowing to the north, west and south, respectively. The lowest groundwater levels were reported in MW1.

Figure 11 Groundwater Contours, August 2016

6.4 Review of Laboratory Groundwater Quality Data

6.4.1 Summary of Data

A statistical summary of laboratory groundwater quality data obtained over the course of the monitoring program completed as part of this study is presented in Table 8. Trends apparent in the data are discussed in Section 6.4.2.

Table 8 Summary of Laboratory Groundwater Quality Data

Parameter	Unit	Water Quality Guidelines: ANZECC 2000 MW 95%	Water Quality Guidelines: ANZECC 2000 Marine Inshore	Water Quality Guidelines: ANZECC 2000 Primary Contact Recreation	Water Quality Guidelines: ANZECC 2000 Secondary Contact Recreation	Statistical Summary: Number of Results	Concentration: Minimum	Concentration: Maximum	Concentration: Mean	Concentration: Median
Ammonia as N	mg/L	**0.91**	-	-	-	12	0.13	**6.28**	**1.7**	0.675
BOD	mg/L	-	-	-	-	12	3	57	15	5.5
Coliform	cfu/100 mL	-	-	-	-	12	<1	250,000	21,185	5.5
Plate Count (36°C)	CFU/mL	-	-	-	-	12	17	68,000	13,140	4,950
Plate Count (22°C)	CFU/mL	-	-	-	-	12	12	70,000	13,483	3,300
Nitrate (as N)	mg/L	-	**0.05**	-	-	12	<0.01	**13.8**	**2.6**	0.04
Nitrite + Nitrate (as N)	mg/L	-	-	-	-	12	<0.01	14	2.7	0.04
Nitrite (as N)	mg/L	-	-	-	-	12	<0.01	1.85	0.2	0.005
Faecal Coliforms	CFU/100mL	-	-	150	1000	12	<1	400	92	1
E. Coli	cfu/100 mL	-	-	150	1000	12	<1	400	92	1
Total Dissolved Solids	mg/L	-	-			4	1,090	8,890	3,695	2,400
Total Dissolved Solids (Filtered)	mg/L	-	-	-	-	8	1,320	22,300	6,766	2,205
Total Kjeldahl Nitrogen (as N)	mg/L	-	-	-	-	12	0.6	6.7	2.5	2.3
Nitrogen (Total)	mg/L	-	**0.23**	-	-	12	**0.6**	**17.1**	**5.2**	**3.25**
Phosphorus (Total)	mg/L	-	**0.005**	-	-	12	**0.06**	**0.81**	**0.27**	**0.245**

Legend

ANZECC 2000 MW 95%	Indicates a level is equal to or above the ANZECC (2000) marine waters 95% species protection trigger value
ANZECC 2000 Marine Inshore	Indicates a level is equal to or above the ANZECC (2000) marine inshore trigger value
ANZECC 2000 Primary Contact Recreation	Indicates a level is equal to or above the ANZECC (2000) guideline value for primary contact recreation (e.g. swimming)
ANZECC 2000 Secondary Contact Recreation	Indicates a level is equal to or above the ANZECC (2000) guideline value for secondary contact recreation (e.g. boating, fishing)

6.4.2 Trends

GHD reviewed laboratory water quality data from the three surveys and the following trends were determined:

- Faecal coliforms and *E. coli* results were reported to have exceeded the ANZECC (2000) guideline valves for primary contact recreation (150 cfu/100mL) at MW1, MW2 and MW3 during the August GME. Follow up GMEs September and October reported faecal coliforms and *E. coli* results had declined (1 cfu/100 mL) across the groundwater network, with no exceedances recorded during these two rounds;
- Coliforms (coliform by membrane filter) were highest in the August survey (MW1 -250,000 CFU/mL, MW2 – 1000 CFU/mL, MW3 – 3000 CFU/mL and SHP8 – 200 CFU/mL), whereas the September survey had coliforms ranging from below the LOR (<1) to 10 CFU/mL (MW2, MW3); and the September GME reported that pH levels across the monitoring well network had largely declined from the August GME, however, in the October GME, pH levels inclined;
- In each monitoring round ammonia was reported above the adopted EIL in at least one GMW. Ammonia in MW1 increased from 2.68 mg/L in August to 6.28 mg/L in September, and subsequently declined in October. Ammonia in MW3 and SHP8 also exhibited a similar trend. A single exceedance of the adopted Ammonia EIL was reported at SHP8 during the September GME. Ammonia in MW2 declined between August and September then increased in October. There was a single exceedance of the adopted EIL in October at MW2;
- Nitrate was above the ANZECC (2000) default marine inshore trigger value at MW1 and MW2 for all three surveys. MW1 exhibited an increasing trend over the three surveys, while MW2 exhibited a decreasing trend; and
- Total nitrogen and total phosphorus were reported to have exceeded the ANZECC (2000) default marine inshore trigger values in the three GMEs and at all GMWs. Concentrations were relatively consistent in all GMEs.

With respect to the nutrient exceedances discussed above, Ammonia is the only nutrient species considered a toxicant in marine waters, and as a nutrient may stimulate algal growth and contribute toward eutrophication (Trefey et. Al, 2006). The other nutrients discussed above, whilst not directly toxic to marine life, may also act to stimulate plant growth and contribute towards eutrophication. Phosphorus will adsorb readily onto some mineral phases in soils, and is heavily retarded in some soil types such as the calcareous sands and limestones in the Point Moore area.

The cause of the significantly higher faecal coliform and *E. coli* levels recorded during the August 2016 GME is not clear. Whilst this GME was preceded by more rainfall than was the case for the other GMEs (5.6 mm was recorded at the Bureau of Meteorology's Geraldton Town weather station two days prior to the September GME, 1.6 mm was recorded three days prior to the September 2016 GME and no rainfall was recorded eight days prior to the October GME), it is unlikely that the increased levels would have been caused by the resultant higher rate of infiltration to groundwater. It is also considered unlikely that tidal variations caused this.

7. Discussion

7.1 Asset Condition

As many of the existing onsite systems were installed between 30 and 50 years ago, a significant number of the septic tanks and associated leach drains/soak wells are likely to have reached the end of their serviceable life. Information from the field investigation program verified this, with a number of the septic tanks observed to be in a "fair" condition, one septic tank system with covers that were on the verge of collapse, and several leach drains partially collapsed. During the field investigation there was not any evidence of saturated ground conditions above the leach drains.

An indicative estimate of the cost to construct new septic tanks and 2 x 6 m long leach drains sized for a two-bedroom dwelling, inclusive of the cost of the required plumbing modifications, is $10,000 per property.

7.2 Compliance with Current Standards

The properties in the study area are significantly smaller than the minimum lot size currently permitted for onsite wastewater disposal (typically 2,000 m^2). In addition, based on review of available information and the field investigation for this study:

- Many of the effluent disposal systems are undersized by current standards and are not configured as alternating systems;
- Many of the septic tanks and leach drains/soak wells do not comply with current horizontal setback requirements; and
- The inverts of the leach drains are estimated to be approximately 0.1 to 0.6 m above the water table, and the invert of the soak wells (assuming 1.5 m effective depth as above) is likely to be below water table (nil separation), hence current guidelines on the required vertical separation distance are not met. As natural purification processes are most effective in the aerobic unsaturated zone rather than in the soils below water table (Washington State Department of Health, 1990), the quality of effluent infiltrating to groundwater will be worse than would be the case if there was greater vertical separation between the leach drains/soak wells and groundwater. This situation will worsen as groundwater levels rise in the future (refer to discussion below).

7.3 Health Risks

7.3.1 Current Situation

Local groundwater is not used for irrigation or any other purpose, but does discharge to the nearby ocean. There is also a potential human health risk with regards to residents or others that could come into direct contact with groundwater when undertaking land-based activities. Conservative water quality assessment criteria based on default guideline values for primary contact recreation were used to assess the health risks posed by contact with groundwater. Elevated microorganism levels in sampled groundwater indicated wastewater-induced contamination above the adopted assessment criteria for one of the three monitoring rounds.

The current health risks posted by contact with groundwater are discussed below.

Risks Associated with Recreational Activities in Ocean

Based on studies done elsewhere at locations with similar hydrogeological conditions, e.g. detailed investigations completed at Halls Head (Mandurah) as reported in Toze et.al. (2010), groundwater quality will improve significantly over time as it flows (sub-surface) to the ocean. With respect to die-off of pathogenic microorganisms:

- The travel time for Point Moore groundwater to reach the inshore marine waters off the coast is uncertain. The groundwater level measurements and seemingly high connectivity to the ocean via tidal variations at GMW MW2 suggests that there are preferential flow paths to rapidly transport groundwater to the ocean for some portions of the study area, with travel times perhaps being in the order of days. In contrast, the muted tidal-induced variations at GMWs MW1 and MW3 suggest that transport times of groundwater to the ocean are likely to be substantially longer. As a conservative measure it has been assumed that the range of transport times from leach drains and soak wells across the Point Moore study area ranges from 2 days (e.g. MW2) to 20 days (e.g. perhaps from the centre of Point Moore). These travel times are likely to be more rapid than actually occurs, which is conservative as it reduces the time for die-off of bacteria and other pathogenic microorganisms (e.g. viruses and protozoa). For example, on the basis of other studies with similar hydrogeological settings, the minimum groundwater travel time from the Point Moore residential properties to the ocean would be estimated to be in the order of 40 days;
- The aquifer residence time for 1 log removal (90% reduction) of bacteria is approximately 2 days (Toze et al, 2010). In the case of bacteria, for every 2 days of aquifer residence time the level of bacteria would reduce by 90%;
- Hence, on the basis of the conservative superficial aquifer residence times adopted in this study (2 days to 20 days), the bacteria will be expected to undergo, from onsite effluent disposal systems to the point of groundwater discharge to the ocean, log reductions ranging between a 1 log (90% reduction in 2 days) and a 15 log ($1x10^{-13}$ % remaining) reduction. In short, for those septic systems that are located in preferential flow paths with relatively rapid transport times to the ocean, there is a risk of relatively direct pathways to deliver to the ocean groundwater with elevated pathogens that may pose a risk to human health.

Clearly, one ameliorating factor of the risk of high pathogen levels introduced into the marine environment via preferential groundwater pathways are the high levels of dilution that would typically occur where the groundwater discharges into the ocean. Hence, for the most part, it is considered unlikely that elevated levels of pathogens in groundwater flowing from the study area would pose a significant health risk in terms of primary contact recreation in the ocean near Point Moore. However, under conditions of calm winds and low wave climate, rates of dilution may be greatly reduced, thereby increasing the potential health risk. These conditions typically occur late in the bathing season from March-May.

Based on the above discussion it is not possible to discount the possibility that onsite disposal of effluent from the Point Moore residential properties is at least partly responsible for the observed seasonal spikes in *Enterococci* levels at the CGG's marine water quality monitoring sites near Point Moore (Section 2.4.2).

Other Risks

In addition to the health risk associated with recreational activities in the ocean near Point Moore, there is a risk that residents or others could come into direct contact with groundwater when completing excavation or trenching works, or undertaking dewatering operations, for:

- construction of foundations for new buildings or other structures,
- construction of installation of swimming pools;
- installation of new services, or maintenance of existing services; or

- landscaping/gardening projects.

The risk of such direct contact is a function of several factors, including the depth to groundwater. Whilst the depth to groundwater is currently approximately 1.5m or more across much of the study area, there are some areas (e.g. park north of Sailors Lane which includes land with a surface level below RL1.0m [Figure 1], some residential lots on the south side of Gunners Lane where the surface level is only marginally above RL1.0m [topographic data from CGG Inframaps]) where this depth may be in the order of 0.5m only. The risk of direct contact with groundwater is obviously greatest in such areas.

Whilst elevated faecal coliform and *E. coli* levels above adopted trigger values were only measured at the monitoring bores in one of the three monitoring rounds, it must be noted that testing for viruses and other pathogenic microorganisms (e.g. protozoa such as cryptosporidium and giardia) was not undertaken as part of this study, and that the rate of die-off of these other pathogens in groundwater is significantly slower than faecal coliforms, *E. coli* and other bacteria. In addition, the levels of pathogens in effluent infiltrating to groundwater is likely to be higher than is typically the case because of the limited (or non-existent in the case of soak wells) vertical separation distance between effluent disposal facilities and the water table (refer to Section 7.2). Given this, contact with groundwater in the study area is considered to present a health risk to residents and others in the study area. Whilst for works undertaken by CGG and service utilities it would be possible to mitigate these risks to an acceptable level through use of appropriate personal protective equipment and control measures, it would not be realistic to rely upon such measures to safeguard the health of local residents and others engaging in activities where they come into contact with groundwater.

7.3.2 Long term Future

In the long term, local groundwater levels will rise as sea levels rise. If sea levels rise by 0.9 m in 2110 as predicted, the groundwater levels at that time could be within approximately 0.6 m of the natural surface level at many properties. In some areas groundwater levels could rise above the natural surface level, in which case some areas could become permanently inundated with water containing elevated levels of pathogenic microorganisms.

As groundwater levels rise in the future the likelihood that residents or others could come into direct contact with groundwater will increase, which will in turn increase the public health risks posed by the onsite wastewater systems.

7.4 Environmental Risks

Conservative water quality assessment criteria based on inshore marine default trigger values for nutrients were adopted for the groundwater sampled from the GMWs (three rounds of sampling over two months). Nutrient levels in sampled groundwater indicated elevated wastewater-induced contamination above the adopted assessment criteria for all monitoring rounds.

As discussed in Section 7.3.1, high levels of dilution typically occur where groundwater discharges into the ocean. Given this dilution it is considered unlikely that elevated levels of nutrients in groundwater flowing from the study area are having any measurable impact on near shore marine ecosystems.

7.5 Long Term Wastewater Management

In the long term local groundwater levels will rise as sea levels rise, and the magnitude of the rise will severely constrain the potential to dispose of effluent generated in the study area using conventional onsite septic tank and leach drain/soak well systems. That is:

- If sea levels rise by 0.9 m in 2110 as predicted, the groundwater levels at that time could be within approximately 0.6 m of the natural surface level at many properties.
- If house and ground levels remain as-is, this groundwater level will be too high to enable the onsite disposal systems to function effectively, with potential for odour problems or saturated ground conditions in the vicinity of the onsite disposal systems, and an increased risk of residents or others coming into contact with effluent or contaminated groundwater.

Whilst alternative onsite systems may be able to be used in the long term, the small size of the lots would severely constrain the options are available for effluent disposal (e.g. aerobic treatment units with dedicated irrigation disposal areas could not be installed as insufficient area is available for the irrigation areas). Rather, if residential properties are to remain at Point Moore for the long term it is considered that a reticulated wastewater collection system would need to be installed that discharges wastewater to the Water Corporation's Geraldton wastewater scheme.

Design and construction of a reticulated wastewater collection system to serve properties in the study area would be constrained by the small size of the lots and limited room available to construct sewers along property rear and side boundaries, the relatively flat topography of the area and the shallow depth to groundwater.

An indicative estimate of the cost to design and construct a conventional reticulated gravity sewer type wastewater collection system to serve all properties in the study area, inclusive of the cost of the house connections, as well as pump stations and pressure mains to discharge this wastewater to the Geraldton wastewater system, is $6M to $10M. This estimate, which assumes that the collection and conveyance infrastructure is constructed to Water Corporation design standards, equates to a cost of approximately $35,000 to $55,000 per property. Additional costs may also apply if the Water Corporation's sewerage scheme needs to be upgraded to cope with the flows from Point Moore.

It would also be possible to serve the properties with a vacuum sewerage system, similar to that operated by the Geraldton Port Authority, or a pressure sewer type collection system. For both alternatives the required depth of the collection pipework would be significantly less than would be the case for a conventional gravity sewer type collection network, which is one of their main advantages. In the case of a vacuum sewerage scheme, wastewater from several properties would gravitate to local pits equipped with proprietary vacuum valves, and from these pits would be conveyed to a single vacuum pump station via vacuum sewers. Conventional wastewater pumps and a pressure main would then deliver the wastewater to the Water Corporation's wastewater scheme. In the case of a pressure sewer system, wastewater from each property would gravitate to small proprietary pump stations equipped with high-head pumps (one pump station per property), and these pumps stations would pump wastewater into a small-diameter interconnected pressure main network that conveys the wastewater direct to the Water Corporation's wastewater scheme, or more likely via a conventional wastewater pump station and pressure main. Whilst the capital cost of installing a vacuum sewerage system or pressure sewer type collection system to serve Point Moore residents may be significantly lower than the cost to install a conventional gravity sewer type collection system, ongoing operations and maintenance costs would be significantly higher for these alternative systems.

8. Conclusions

The overall objective of the study is to provide CGG and Point Moore stakeholders with data and documentation on the performance and compliance of the existing onsite wastewater treatment and disposal systems that assists CGG in the decision-making process relating to the future beyond the current lease expiry dates of 2025 and 2028 and potential obligations it has in relation to Point Moore lessees. Based on work completed in undertaking this study the following conclusions are made:

1. Observations made during the field investigation indicate that a significant number of the existing septic tanks and leach drains/soak wells are in a poor condition and require remedial works and in some cases replacement.
2. The properties in the study area are significantly smaller than the minimum lot size currently permitted for onsite wastewater disposal (typically 2,000 m^2), and many of the onsite systems do not comply with current standards in a number of respects (sizing, configuration, horizontal setbacks, vertical separation distance to groundwater). For many properties it would not be possible to upgrade the existing onsite systems to meet current standards, or install alternative onsite systems that comply with current standards.
3. Though local groundwater is not used for irrigation or any other purpose, it does discharge to the nearby ocean, and residents or others could come into contact with groundwater when undertaking a range of land based sub-surface activities. In relation to public health risks:
   - The potential for contact with groundwater when undertaking land based sub-surface activities such as excavation or trenching works is considered to represent a significant public health risk to residents and others undertaking such activities in the study area. This risk will increase over time as groundwater levels increase as a direct consequence of sea level rise.
   - Whilst data from the monitoring program indicates that for some portions of the study area groundwater travel times to the ocean may be short due to preferential groundwater pathways, it is considered unlikely that elevated levels of pathogens in groundwater flowing from the study area would pose a significant health risk to persons engaging in primary contact recreation in the ocean near Point Moore given natural purification processes in the aquifer and the high levels of dilution that would typically occur where the groundwater discharges into the ocean. However, under conditions of calm winds and low wave climate, rates of dilution may be greatly reduced, thereby increasing the potential health risk. These conditions typically occur late in the bathing season from March-May.
   - It is not possible to discount the possibility that onsite disposal of effluent from the Point Moore residential properties is at least partly responsible for the observed seasonal spikes in *Enterococci* levels at the CGG's marine water quality monitoring sites near Point Moore.
4. In the long term local groundwater levels will rise as sea levels rise, and the magnitude of the rise will severely constrain the potential to dispose of wastewater generated in the study area with the existing conventional onsite septic tank and leach drain/soak well systems approach.
5. If residential properties are to remain at Point Moore for the long term it is considered that a reticulated wastewater collection system would need to be installed that discharges wastewater to the Water Corporation's Geraldton wastewater scheme. An indicative estimate of the cost to design and construct a conventional gravity sewer type wastewater

collection system to serve all properties in the study area, inclusive of the cost of the house connections, as well as the pump stations and pressure mains to discharge this wastewater to the Geraldton wastewater system, is $6M to $10M. This equates to a cost of approximately $35,000 to $55,000 per property, which is likely to be prohibitively expensive. Whilst alternative wastewater collection technologies exist that may be able to be implemented at a significantly lower capital cost, ongoing costs for these systems would be higher than the ongoing costs associated with a conventional gravity sewer type collection system.

6. Whilst nutrient levels in sampled groundwater indicated elevated wastewater-induced contamination above the adopted assessment criteria for all monitoring rounds, given the high levels of dilution typically occur where groundwater discharges into the ocean it is considered unlikely that elevated levels of nutrients in groundwater flowing from the study area are having any measurable impact on near shore marine ecosystems.

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