Local Water Management Strategy

Ocean Reef Marina

Prepared for
Development WA
By JBS&G Australia Pty Ltd T/A Strategen-JBS&G

21 November 2019

56956-124706 (Rev E)

www.jbsg.com.au

Table of Contents

List of Tables

List of Figures

Appendices

Executive Summary

DevelopmentWA (the proponent) proposes to develop a world class recreational, residential, boating and tourist development, referred to as the Ocean Reef Marina Development (the Development) located at Ocean Reef, Western Australia. The preferred Concept Plan for the entire Development includes 64 ha of land and sea. The terrestrial portion of the development (the site) has an area of approximately 42.27 ha.

The Development is in the Ocean Reef locality, approximately 6 km west of the Joondalup City Centre, 29 km from the Perth central business district and 9 km north of Hillarys Boat Harbour. The Development will involve the redevelopment of the existing Ocean Reef Boat Harbour into a mixed-use working marina including:

- a) a mixed use 'working marina' including club, service commercial and marine industrial uses, and boating precinct including ramps, coastal amenities and parking in the south
- b) a central retail, tourist and mixed-use precinct
- c) a northern residential precinct
- d) capacity for up to 550 boat pens and 200 boat stackers
- e) civic and community uses, including Public Open Space (POS).

This Local Water Management Strategy (LWMS) has been prepared to support the proposed Improvement Scheme.

The Site has the following environmental attributes with respect to water management:

- the Site is underlain by Tamala Limestone and Safety Bay Sands, both of which have a high hydraulic conductivity of between 1 m/day and 1000 m/day
- because of the high permeability of these soils, all rainfall is considered to be infiltrated on site in events up to the 1% AEP event
- the Site is not within the flood way or flood fringe of any waterways
- maximum groundwater level is considered to be at approximately 2.2 mAHD. Depth to groundwater is consequently not considered to be a constraint to development on the Site
- there are no wetlands within 1000 m of the Site.

The Site will be developed to include:

- public open space designed to have a low water use
- small lot sizes and the use of design guidelines to reduce household and commercial water use
- infiltration of all non-roof stormwater on Site up to the 1 in 1 year event
- use of a range of measures including basins, swales, underground storage cells and open bottom manholes to treat and infiltrate stormwater
- fill requirements will be managed through cut to fill within the Development itself, without the need for groundwater control.

The Site will comply with relevant design objectives for stormwater management, groundwater management and water conservation as outlined in Table ES 1.

Table ES 1 Compliance with design objectives

Category	Design and management objective	Methods for achievement
Water conservation and efficiency	WC1: If possible, achieve a total water consumption target of 110 kL/person/year.	Compact lot sizes with limited garden area. Promotion of water conservation measures through the IS Rating Scheme (ISRS) for best practice and design guidelines.
	WC2: Minimise the use of potable water where drinking water quality is not essential, particularly for outside uses.	Encouragement of use of rainwater tanks and other forms of alternative supply under the design guidelines. Alternative water sources are being investigated for irrigation (Section 5.3).
Water quantity management	WQ1: For the critical one-year average recurrence interval (ARI) event, the pre-development peak flow rates and volumes shall be maintained.	Pre-development flow rates off the Site will be maintained in events up to and including the 1 in 1-year event (Section 7.2.1).
Water quality management	WM1: Maintain surface water (marine) and groundwater quality.	Surface and groundwater quality will be maintained by water treatment prior to infiltration or discharge to the marina. High density of development means small private gardens. Nutrient loads for the Development are consequently anticipated to be low.
	WM2: Ensure that all runoff contained in the drainage infrastructure network receives treatment prior to discharge to a receiving environment consistent with the Stormwater Management Manual for Western Australia (DoW 2007).	Runoff will receive treatment via gross pollutant traps, swales and infiltration cells to remove sediment, rubbish and nutrients (Section 7.5).
Disease vector and nuisance insect management	DV1: To reduce health risks from mosquitoes, retention and detention treatments should be designed to ensure that between the months of November and May, detained immobile stormwater is fully infiltrated in a time period not exceeding 96 hours.	All detained immobile stormwater will be infiltrated within 96 hours.
	DV2: Permanent water bodies are discouraged, but where accepted by the Department of Water and Environment Regulation (DWER) must be designed to maximise predation of mosquito larvae by native fauna to the satisfaction of the local government on advice of the DWER and Department of Health (DoH).	Permanent terrestrial water bodies are not proposed on the Site. The marina will be a fully marine water body and thus is not suitable for mosquito breeding.

1. Introduction

1.1 Background

The potential expansion of the Ocean Reef Boat Harbour to form the Ocean Reef Marina was identified over 30 years ago, as planning for urban development in the northern Perth suburbs increased.

DevelopmentWA (the proponent) is proposing to develop a marina within a 64 ha development envelope of land and sea, in Ocean Reef, 29 km north of Perth (the Site, Figure 1-1). The Western Australian Planning Commission (WAPC) has recommended to the Minister that the area be dealt with through Improvement Plan No. 51: Ocean Reef Marina, and recommended the preparation of an Improvement Scheme. This Local Water Management Strategy (LWMS) has been prepared to support the Improvement Scheme under *Planning Bulletin 92: Better Urban Water Management (*WAPC 2008).

This LWMS has been prepared in accordance with *Better Urban Water Management* guidelines (WAPC and DPI 2008) on advice from DWER. The document is consistent with regional and district scale urban water management planning, including the *State Water Plan* (DPC 2007) as well as *State Planning Policy 2.9 Water Resources* (WAPC 2006). The document aims to meet the principles and objectives of stormwater management in Western Australia, as detailed in the *Stormwater Management Manual for Western Australia* (DoW 2004 – 2007).

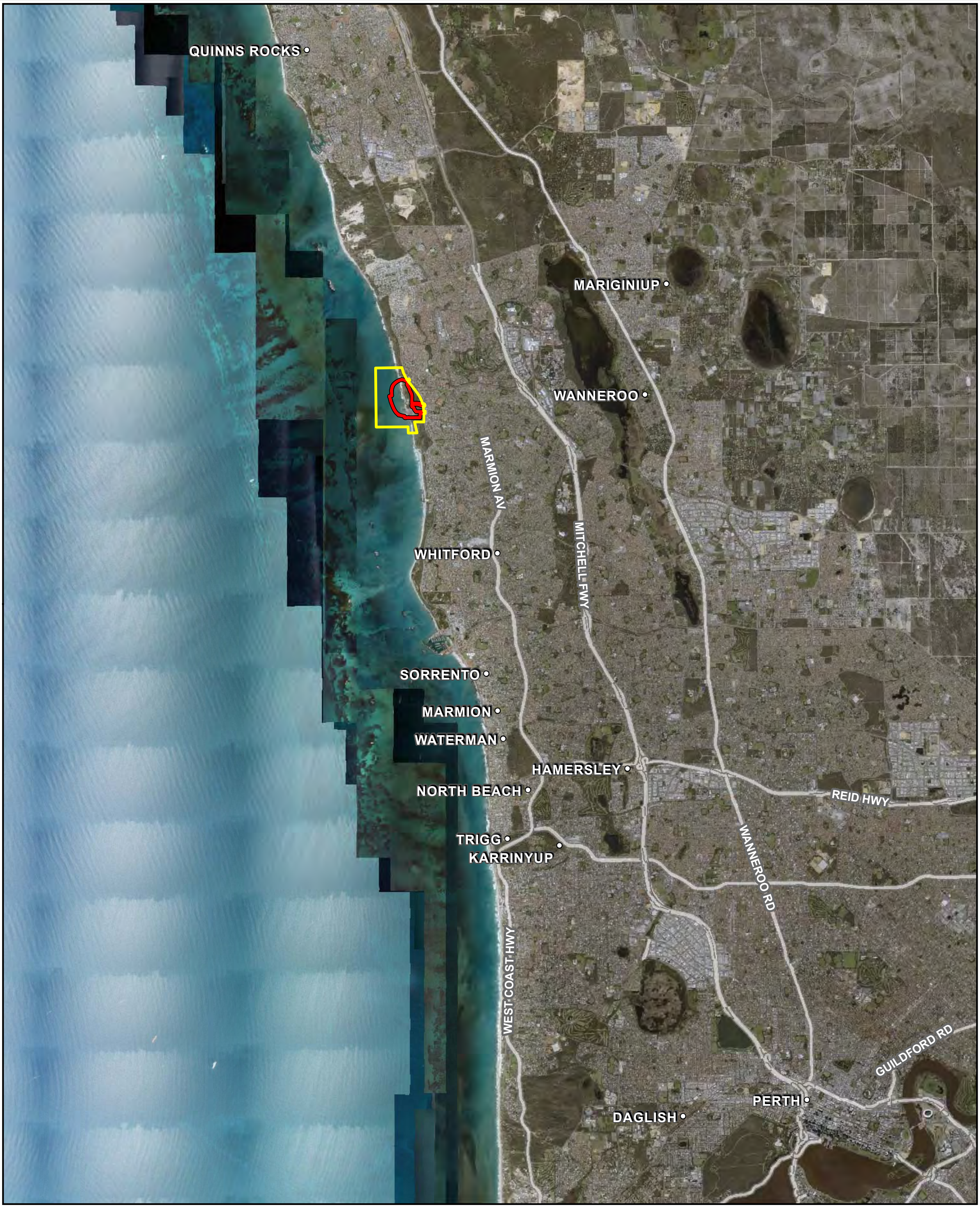
The LWMS has also been prepared to be consistent with the approved *Ocean Reef Marina District Water Management Strategy* (DMWS) (Strategen 2014).

1.2 Total water cycle management

The Ocean Reef Marina LWMS identifies and describes a range of design elements and management measures being considered for the proposed Development. The principal objective of this LWMS is to achieve better urban water management outcomes by specifying a development that manages the total water cycle in a sustainable manner and meets objectives for water sensitive urban design. This includes consideration of:

- water conservation and efficiency (water use)
- water quantity management (groundwater levels and surface water flows)
- water quality management (groundwater and surface water quality)
- disease vector and nuisance insect management.

A completed copy of the LWMS checklist (DoW 2008) addressing the above, is presented in Appendix A.



Legend:

- Improvement scheme boundary
- Site boundary
- Main roads (MRWA)

Scale 1:150,000 at A4

0 1 2
Kilometers

Coord. Sys. GDA 1994 MGA Zone 50

Job No: 56956

Client: Development WA

Version: 1

Date: 19-Nov-2019

Drawn By: hsullivan

Checked By: CT

SITE LOCATION

FIGURE 1-1

strategen JBS&G

File Name: \\008PMPMR004V001.jbsg.aust\JBS Perth\Projects\1)Open\LandCorp\56956 Ocean Reef Marina LWMS 2019\GIS\Maps\R01 Rev A\56956_01_1_SiteLocation.mxd
Image Reference: SLIP Public Services Locate Imagery 2019

		Ocean Reef Marina
Concept plan source: Taylor Burrell Barnett Town Planning and Design		**PREFERRED CONCEPT PLAN**
Job No: 56956		
Client: Development WA		**FIGURE 1-2**
Version: 1	Date: 23-Sep-2019	strategen JBS&G
Drawn By: hsullivan	Checked By: CT	

File Name: \\008PMPMR004V001.jbsg.aust\JBS Perth\Projects\1)Open\LandCorp\56956 Ocean Reef Marina LWMS 2019\GIS\Maps\R01 Rev A\56956_01_2_PreferredConceptPlan.mxd

1.3 Planning and environmental approvals background

1.3.1 State

In April 2014, a Metropolitan Region Scheme (MRS) amendment (1270/41) was initiated by the WAPC to enable the appropriate MRS zonings to be established to enable the Development. The MRS amendment was referred to the Environmental Protection Authority (EPA) under s 48A of the *Environmental Protection Act 1986* (EP Act) in May 2014. The EPA determined that the amendment did not require formal assessment as it was considered that the terrestrial aspects could be adequately managed through the relevant planning processes and the marine component would be assessed under s 38 of the EP Act. The EPA provided a 'Statement of reasons and public advice' for this decision in June 2014. The MRS amendment was published in the Government Gazette on 11 October 2019.

The marine component of the Development was separately referred to the EPA under s 38 of the EP Act in May 2014. In June 2014 the EPA determined that the marine component (including coastal processes) of the Development would be assessed at a Public Environmental Review (PER) level of assessment with an eight-week public comment period. The marine portion of the Development has now been approved subject to conditions set in Ministerial Statement 1107.

To ensure that both the marine and terrestrial aspects of the Development are appropriately addressed, the PER and MRS amendment were developed and assessed in parallel as far as possible.

The Improvement Scheme for the Development will require referral to the EPA under s 48A of the EP Act for a decision on whether it requires formal environmental impact assessment.

1.3.2 Commonwealth

At a Commonwealth level, the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) protects Matters of National Environmental Significance (MNES), including threatened and endangered species. The EPBC Act requires an assessment as to whether a proposed action is likely to have a significant impact on a MNES, and referral to the Department of the Environment and Energy (DoEE) where significant impacts to MNES are anticipated.

The Development was referred to DoEE under the EPBC Act. DoEE determined on 4th July 2014 that the proposed action is not a controlled action and therefore does not require assessment under the EPBC Act.

2. Proposed development

2.1 Preferred Concept Plan

DevelopmentWA's vision for the Development is articulated as:

- a world class recreation, residential, boating and tourism development
- a sustainable community amenity
- a social and economic benefit to all residents
- a balance of public, residential and commercial amenities
- an equitable facility for all visitors and residents
- the social and economic maximisation of land use.

The PCP presents:

- a mixed use 'working marina' including club, service commercial and marine industrial uses, boating precinct including ramps, coastal amenities and parking in the south
- a central retail, tourist and high-density residential precinct
- a northern low to medium density residential precinct
- capacity for up to 550 boat pens and 200 boat stackers
- civic and community uses, including Public Open Space (POS).

2.2 Development timeframe and staging

Development of the breakwaters for the marina are expected to begin in late 2020 followed by the construction of the marine services, boat ramps and carpark areas in the south of the Site. The remainder of the development of the Site is anticipated to occur in a staged manner with timing affected by market demand. This may represent a period of five to fifteen years.

2.3 Landscaping

The landscape concept responds in an integrated and complementary manner to the existing natural features and characteristics of the Site. The retention of significant landforms, such as ridgelines, ridge slopes and high points, has been achieved by minimising the extent of the development area and preventing encroachment into the adjoining Bush Forever Site 325.

The overall approach to the open space design is to minimise areas of irrigated grass and to retain extensive areas of coastal heath and bushland. POS is provided in a variety of forms with public beaches, water play, active land-based play, boardwalk for passive enjoyment, amphitheatre and incidental garden environments. The landscape plan is presented in Figure 2-1.

KEY

A Northern Entry Road POS &

B Southern Entry Road POS

Small POS with opportunity for interpretation nodes, access to path network, viewing platforms, respite points and infrastructure such as bike repair stations and drink fountains.

C Northern Linear POS &

D Southern Linear POS

Creating a green entry to the site these POS create significant recreational opportunities for residents and draw the dune vegetation through to the water front.

E Central POS

The central residential POS will provide recreational and social opportunity that focuses on local community needs. This will include infrastructure such as play equipment, gathering spaces, informal sport facilities and passive recreation opportunities to support the health and well-being of users.

F Promenade North POS (both)

POS situated around proposed cafe/restaurant, providing an activation to the northern promenade, services the residential community and activities that may not be easily accommodated in larger POS, such as a dog park or community garden.

G Triangle POS

The promenade allows for significant recreation opportunities, along with a connection to the water front and boats. This POS will facilitate more popular events and activities along the promenade.

H Plaza POS

A highly functional urban plaza that will address the retail and commercial hubs providing infrastructure for markets, alfresco dining and events.

I Beach POS

The beach park will be the 'jewel in the crown' of the site, a central recreational hub that will be a regional destination.

J Bush Forever

A reality of the development will be the removal of bush-forever vegetation, the retained elements will be carefully considered to protect and enhance ecological value and social value of the 'low-impact' recreational opportunities of the retained bushland.

K Breakwater

Breakwaters will present opportunity for increased, improved public realm through design approaches with the engineering team to include vegetation, seating nodes, recreational opportunities and art elements, where possible.

Significant Infrastructure

- Playground
- Youth Space
- Fishing Platform
- Lookout / Viewing Deck
- Entry Statement
- Water Slides
- Beach
- Pool

Key Themes and Approaches

1. Northern Arrival + Southern Arrival - 'Settled into the Dunes'

The dunes are fundamental to the identity of this site and as such the approach to the development from the dunes, and this interface is extremely important to the Marinas sense of place. The north/south 'arrival' zones will bookend the site and will be connected through a green spine dunal interface.

2. Central Residential - 'A Marina Community'

The residential zone of the Marina is both literally (for a majority of the site) and thematically the transition between the dune system and the water edge. Streetscapes and POS utilise an east west orientation to create visual and physical connections from water to dune.

3. Commercial Waterfront Precinct - 'Celebrating WA Marine Culture and Heritage'

The Ocean Reef Marina will be a celebration of WA maritime culture and heritage, with a central activated heart connecting out into the water through the breakwaters. This highly activated zone is to be an aspirational public realm that draws inspiration from the local vernacular, stories and memories of WA boating, fishing, diving, surfing and maritime culture.

More detail on the Precincts and Overall Landscape Masterplan development and approach is available in the Public Realm Masterplan Document, UDLA, 2019.

OCEAN REEF MARINA
PUBLIC REALM MASTERPLAN

udla

0m 100m 200m 400m

N

PROJECT NAME:	CLIENT:	DRAWN:	SCALE:	DRAWING:	ISSUE DATE:	REVISION:
Ocean Reef Marina	Landcorp	SH	1:2000 @A1	MP - 01	JULY 2019	B

	Ocean Reef Marina
Concept plan source: Udla	**LANDSCAPE CONCEPT PLAN**
Job No: 56956	
Client: Development WA	**FIGURE 2-1**
Version: 1 Date: 23-Sep-2019	
Drawn By: hsullivan Checked By: CT	

File Name: \\008PMPMR004V001.jbsg.aust\JBS Perth\Projects\1)Open\LandCorp\56956 Ocean Reef Marina LWMS 2019\GIS\Maps\R01 Rev A\56956_02_1_LandscapeCeonceptPlan.mxd

3. Design criteria

The design and management objectives of this LWMS were developed through the DWMS process and agreed by DWER and the City. These objectives are outlined in Table 3.1.

Table 3.1: Design and management objectives

Category	Design and management objective
Water conservation and efficiency	**WC1:** If possible, achieve a total water consumption target of 110 kL/person/year.
	WC2: Minimise the use of potable water where drinking water quality is not essential, particularly for outside uses.
Water quantity management	**WQ1:** For the critical 1-year event, the pre-development peak flow rates and volumes shall be maintained.
Water quality management	**WM1:** Maintain surface water (marine) and groundwater quality.
	WM2: Ensure that all runoff contained in the drainage infrastructure network receives treatment prior to discharge to a receiving environment consistent with the Stormwater Management Manual for Western Australia (DWER 2007).
Disease vector and nuisance insect management	**DV1:** To reduce health risks from mosquitoes, retention and detention treatments should be designed to ensure that between the months of November and May, detained immobile stormwater is fully infiltrated in a time period not exceeding 96 hours.
	DV2: Permanent water bodies are discouraged, but where accepted by DWER must be designed to maximise predation of mosquito larvae by native fauna to the satisfaction of the local government on advice of the DWER and DoH.

3.1 Water Resources Statement of Planning Policy 2.9 and Liveable Neighbourhoods

The LWMS has been developed in accordance with regional and local principles and objectives of Integrated Urban Water Management (IUWM).

State Planning Policy 2.9 (WAPC 2004) defines IUWM (also known as total water cycle management) as promoting *'management of the urban water cycle as a single system in which all urban water flows are recognised as a potential resource and where the interconnectedness of water supply, stormwater, wastewater, flooding, water quality, waterways, estuaries and coastal waters is recognised'*.

IUWM should also promote water conservation measures, reuse and recycling of water and best practice in stormwater management (WAPC 2004). These objectives are consistent with Liveable Neighbourhoods (WAPC and DPI 2009).

3.2 Stormwater Management Manual for Western Australia

The DWER position on Urban Stormwater Management in Western Australia is outlined in Chapter 2: Understanding the Context of the *Stormwater Management Manual for Western Australia* (DoW 2004 – 2007), which details the management objectives, principles, and a stormwater delivery approach for WA. Principal objectives for managing urban water in WA are stated as:

- Water Quality: to maintain or improve the surface and groundwater quality within development areas relative to pre-development conditions
- Water Quantity: to maintain the total water cycle balance within development areas relative to the pre-development conditions
- Water Conservation: to maximise the reuse of stormwater
- Ecosystem Health: to retain natural drainage systems and protect ecosystem health
- Economic Viability: to implement stormwater systems that are economically viable in the long term
- Public Health: to minimise the public risk, including risk of injury or loss of life to the community

- Protection of Property: to protect the built environment from flooding and water-logging
- Social Values: to ensure that social aesthetic and cultural values are recognised and maintained when managing stormwater
- Development: to ensure the delivery of best practice stormwater management through planning and development of high-quality developed areas in accordance with sustainability and precautionary principles (DoW 2004-2007).

3.3 State Coastal Planning Policy State Planning Policy 2.6

State Coastal Planning Policy State Planning Policy 2.6 (SPP 2.6) was gazetted in 2013 by WAPC to address issues associated with coastal planning in WA. With relation to water resources, SPP 2.6 states that:

- coastal development should manage water resources in accordance with the principles of water sensitive urban design and integrated water cycle management
- development on or near the coast should maintain or restore pre-existing or desirable environmental flows and hydrological cycles
- development on or near the coast should not discharge any waste or stormwater that could significantly degrade the coastal environment
- stormwater flows from development areas that comply with the *Stormwater Management Manual for Western Australia* may be incorporated into foreshore reserves (WAPC 2013).

4. Pre-development environment

4.1 Current condition

The Site is located along a coastal foreshore consisting of a range of developed and undeveloped open space and recreation reserves. It lies within the Swan Coastal Plain which forms part of a deep linear trough of sedimentary rocks known as the Perth Basin. The Perth Basin extends north-south parallel to the coastline with sediments of marine, alluvial and aeolian origin (McPherson & Jones 2005).

Existing land uses include extensive car and boat trailer parking, boat ramps, coastal recreation and public amenities, Whitfords Volunteer Sea Rescue Group and the Ocean Reef Sea Sports Club together with extensive vegetated coastal reserves (Figure 4-1). The surrounding development is predominantly residential featuring a mix of single and double storey dwellings.

The Site currently includes the Ocean Reef Boat Harbour comprising:

- one large and one small limestone groyne protecting the boat launching facilities and small beach
- eight boat launching ramps
- 153 trailer parking spaces
- public toilets
- facilities for the Whitfords Volunteer Sea Rescue Group
- facilities for the Ocean Reef Sea Sports Club.

Outside the clearly developed areas, the Site largely consists of native vegetation crossed by an informal network of pedestrian tracks.

Water Corporation holds land in the southern part of the Site as part of the Ocean Reef Ocean Outfall Landline (OROOL) (Figure 4-1). The OROOL pumps up to 135 ML/day of treated wastewater from Beenyup Wastewater Treatment Plant (WWTP) into the Indian Ocean. The WWTP discharges wastewater through a series of outlet pipes located 1.6 to 1.8 km offshore.

Water Corporation advises that the majority of its landholding is required for regular maintenance uses. However, Water Corporation has agreed to the marina development in principle as the Development will not adversely affect the functionality of OROOL. Any land uses within the Water Corporation site such as temporary parking will be subject to a licence agreement between The City and Water Corporation.

4.2 Adjacent land uses

Adjacent land uses to the Site include:

- to the north and south: bushland, forming a coastal reserve (Bush Forever Site 325)
- to the east: residential development
- to the west: Marmion Marine Park (Figure 4-1).

Legend:

- Improvement scheme boundary
- Site boundary
- Bush Forever site (DOP)

Legislated Lands and Waters (DBCA)

- Marine park

Scale 1:8,500 at A4

0 150 metres

Coord. Sys. GDA 1994 MGA Zone 50

Job No: 56956

Client: Development WA

Version: 1

Date: 26-Sep-2019

Drawn By: hsullivan

Checked By: CT

Ocean reef marina

SITE CONTEXT

FIGURE 4-1

strategen JBS&G

File Name: \\008PMPMR004V001.jbsg.aust\JBS Perth\Projects\1)Open\LandCorp\56956 Ocean Reef Marina LWMS 2019\GIS\Maps\R01 Rev A\56956_04_1_SiteContext.mxd
Image Reference: www.nearmap.com© - Imagery Date: 13 July 2019

4.3 Climate

The Site has a Mediterranean climate, characterised by hot dry summers and mild wet winters, typical of coastal areas in the Perth metropolitan region. Temperatures range from a mean maximum of 29.5°C in February to a mean minimum of 10°C in July and September, as recorded from 2013 to 2019 at Hillarys Boat Harbour NTC AWS Station (Bureau of Meteorology 2019a). The mean annual rainfall at Tamala Park (Mindarie) Station, recorded between 2004 and 2019, is 605.2 mm (Bureau of Meteorology 2019b).

A summary of climatic data for the nearest meteorological stations (Hillarys Boat Harbour NTC AWS Station and Tamala Park (Mindarie) Station) is presented in Figure 4-2.

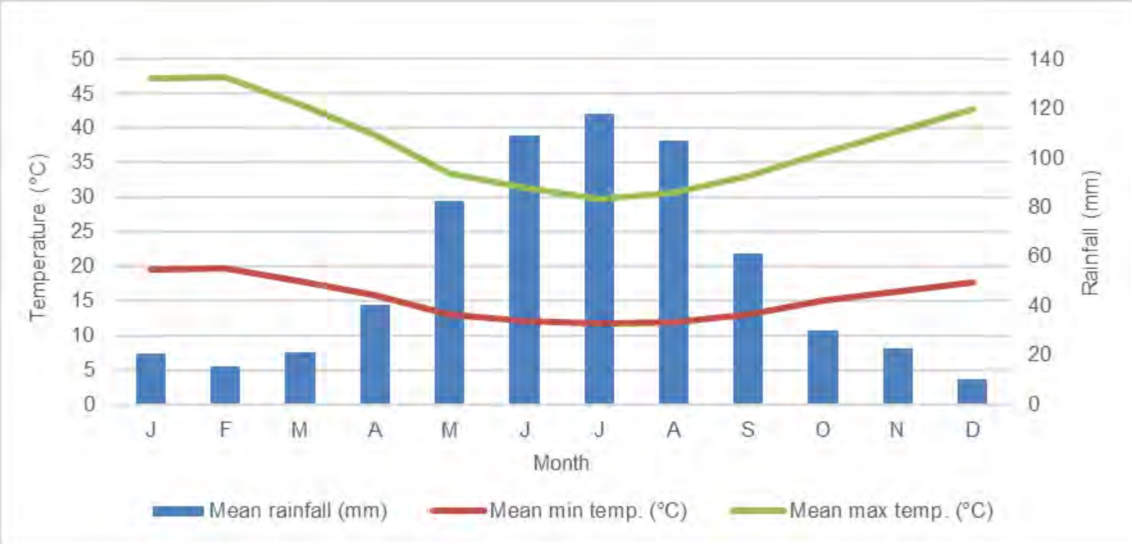


Figure 4-2: Climate data for Hillarys Boat Harbour and Mindarie

Winds are an important feature of coastal environmental settings as they are a major determinant of landwards sand migration, landforms and landscape. During summer, winds blow from the south-east in the morning and from the southwest in the afternoon with the local sea breeze. Winter is characterised by north-westerly storm winds that back around to the west and southwest, interspersed with calmer periods.

4.4 Topography

Ground elevations on the Site vary from approximately 25 mAHD in the eastern portion of the Site to 0 mAHD (sea level) along the coast to the west (Figure 4-3).

The majority of the Site is dominated by undulating topography formed by dune systems that vary in height by up to approximately 12 m (Figure 4-3). The dunes are bound to the west by limestone cliffs that vary in height from 2 to 4 mAHD. The top of the cliffs represent the gently undulating surface of old cemented dunes of the Tamala Limestone (Worley Parsons 2007).

Modifications to the topography within the Site have occurred as a result of construction of the breakwater, boat launching facilities and car park. The car park area required the use of fill material from a portion of Lot 1033 to ensure that a flat, stable area was created (Figure 4-3). As a result, the car park facility is approximately 10 m higher than the boat launching facilities and playground (Worley Parsons 2007) (Figure 4-3).

Legend:

Site boundary

Surface elevation (mAHD)

Scale 1:6,000 at A4 (0 – 150 metres)	**Ocean Reef Marina**
Coord. Sys. GDA 1994 MGA Zone 50	**SITE CONDITION PLAN**
Job No: 56956	
Client: Development WA	**FIGURE 4-3**
Version: 1 / Date: 24-Sep-2019	strategen JBS&G
Drawn By: hsullivan / Checked By: CT	

File Name: \\008PMPMR004V001.jbsg.aust\JBS Perth\Projects\1)Open\LandCorp\56956 Ocean Reef Marina LWMS 2019\GIS\Maps\R01 Rev A\56956_04_3_SiteConditionPlan.mxd
Image Reference: www.nearmap.com© - Imagery Date: 13 July 2019

4.5 Soils and geology

Two dune systems fringe the Perth coastline, the Spearwood and Quindalup Dune Systems. The Spearwood Dune System is the more easterly and consists of slightly calcareous aeolian sand remnant from leaching of the underlying Pleistocene Tamala limestone. The Site is within the Quindalup Dune System which consist of "windblown lime and quartz beach sand forming dunes or ridges that are generally oriented parallel to the present coast, but which may also occupy blowouts within the Spearwood Dune System" (McPherson & Jones 2005).

Department of Mines, Industrial Regulation and Safety (DMIRS) geomorphology mapping (Figure 4-4) provides the following description of the surficial geological units expected to occur within the Site:

- Spearwood Dune system calcarenite (limestone)
- Quindalup Dune System, which consists of unconsolidated sands, sometimes over limestone.

Geological logging undertaken by Strategen to install bores for the groundwater monitoring and Detailed Site Investigation (DSI) (Strategen 2016) and geotechnical work by Golder (2015) confirms that the Site consists of Safety Bay Sand and Tamala Limestone. These units can be described as:

- Safety Bay Sand: white, fine to medium grained, sub-rounded quartz and shell debris, of eolian origin, associated with the Quindalup Dune System
- Tamala Limestone: white to light brown, fine to coarse grained, subangular to well-rounded quartz shell debris, variably lithified, often overlain by a variable thickness of residual sandy gravel residual soil (Gozzard 1982).

Some fill is present in the area surrounding the existing car park. This appears to be Safety Bay Sand containing fragments of Tamala Limestone, as is thought to have been historically cut from the Site or the area immediately to the south (SMEC 2008).

Hydraulic conductivities were estimated by Golder (2015) as part of the geotechnical work on the Site. Golder advised that a hydraulic conductivity of 1×10^{-5} m/s (0.86 m/day) be used where limestone is present.

4.5.1 Acid sulphate soils

A review of the WAPC *Planning Bulletin No. 64 - Acid Sulphate Soils* (2003) and the Landgate WA Atlas (2013), has identified that the terrestrial portion of the Site does not contain geology consistent with the presence of actual acid sulphate soils (AASS) or potential acid sulphate soil (PASS) occurring at depths greater than 3 m.

Soil and rock materials indicative of the presence of acid sulphate soils were not observed during geological investigations by Strategen (2015a) or Golder Associates (2015).

4.5.2 Contamination

A Preliminary Site Investigation (PSI) was carried out by SMEC in 2008. A DSI including soil and groundwater sampling has been undertaken by Strategen (2016). The terrestrial portion of the Site was identified as having very limited contamination associated with illegal dumping of Potentially Asbestos Containing Materials and limited exceedances of metals guidelines in groundwater (Strategen 2016). Groundwater metals exceedances are further discussed in Section 4.7.2.

These matters are not anticipated to affect the development of the Site.

Legend:

Site boundary

Surface geology (DMP) - Perth

Cps - PEATY CLAY - dark grey and black, soft, variable organic content, some quartz sand in places, of lacustrine origin

S2 - CALCAREOUS SAND - white, fine to medium-grained, sub-rounded quartz and shell debris, of eolian origin

LS1 - LIMESTONE - light, yellowish brown, fine to coarse-grained, sub-angular to well rounded, quartz, trace of feldspar, shell debris, variably lithified, surface kankar, of eolian origin

Scale 1:6,000 at A4

0 150 metres

Coord. Sys. GDA 1994 MGA Zone 50

Job No: 56956

Client: Development WA

Version: 1

Date: 24-Sep-2019

Drawn By: hsullivan

Checked By: CT

Ocean Reef Marina

GEOLOGY AND SOILS

FIGURE 4-4

strategen JBS&G

File Name: \\008PMPMR004V001.jbsg.aust\JBS Perth\Projects\1)Open\LandCorp\56956 Ocean Reef Marina LWMS 2019\GIS\Maps\R01 Rev A\56956_04_4_GeologySoils.mxd
Image Reference: www.nearmap.com© - Imagery Date: 13 July 2019

4.6 Surface water

There are no naturally occurring permanent surface water bodies, wetlands or ephemeral streams within the Site. Two artificial storm water infiltration ponds were identified by Worley Parsons (2007). There are no existing stormwater outfalls in the vicinity of the Site.

A search of The Department of Biodiversity, Conservation and Attractions (DBCA) Western Australian Wetlands Database, and the *Environmental Protection (Swan Coastal Plain Wetlands)* indicated that the closest wetland is located approximately five kilometres to the east of the Site (Government of Western Australia 2014). As discussed in the following section, groundwater flow gradients in the locale are westerly, indicating that the Development will not have any effect on that wetland.

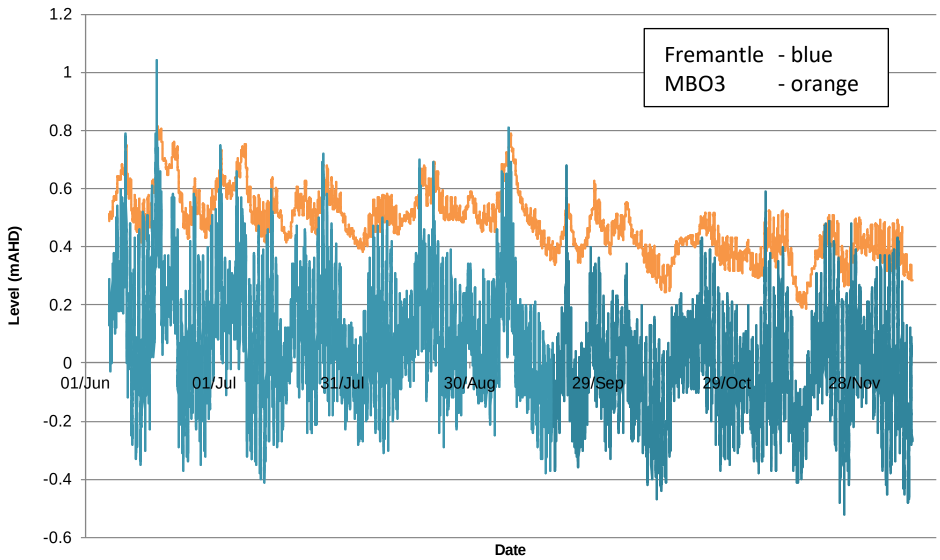
Surface water is not considered a constraint to water management on the Site.

4.7 Groundwater

The Site is located on the western side of the Gnangara Mound (South), with groundwater flow in a westerly direction towards the coast (Figure 4-7). Groundwater levels on the Site were monitored between 6 June to 10 December 2014 at the bore locations shown on Figure 4 7.

Groundwater at the coast is affected by changes in sea level including tides and storm surge[1] events as well as rainfall. As a result, groundwater levels in the Site tend to peak as a result of storm events (Figure 4-5). In extreme events, the peak sea level may exceed peak groundwater level for a short period of time (Figure 4-5).

Figure 4-5: Observed sea level at Fremantle and groundwater level at MB03



A groundwater monitoring program for the Site was developed and agreed with DWER as part of the DWMS process. The objectives of the program were to:

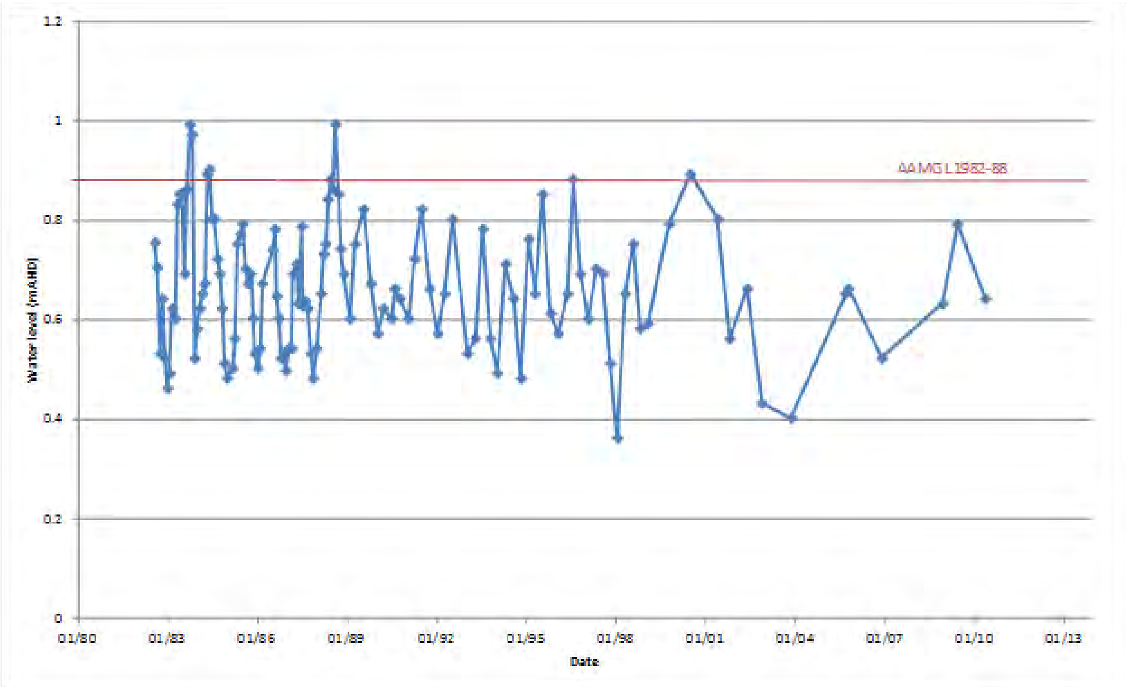
- develop a design groundwater level (DGL) based on a maximum groundwater level (MGL) to set finished surface levels for the Site
- establish baseline water quality (including nutrients)
- confirm the water quality assumptions of the previously undertaken marina flushing studies, which used data available at the time.

[1] The rising of the sea as a result of wind and atmospheric pressure changes associated with a storm.

The groundwater monitoring program included the use of data loggers in four bores over six months to determine the effects of sea level and rainfall on groundwater levels. These six months corresponded to the period of large storm events over winter and spring. The data loggers recorded groundwater levels every five minutes over a six-month period between 6 June and 10 December 2014. This included the monitoring of three new bores on the Site (MB01 to MB03) and a DWER monitoring bore to the south of the Site (Figure 4-7). Water quality monitoring was also undertaken.

The water levels obtained through the groundwater monitoring program were compared to the historic water levels at the DWER Bore 4931 located to the south of the Site (Figure 4-7). Groundwater levels had been recorded in the DWER bore from 1982 to 2011 (Figure 4-6). This historical data was used to provide context for the groundwater levels recorded during the monitoring program.

Figure 4-6: Historical water levels at DWER Bore 4931, 1982-2011



4.7.1 Maximum groundwater level

Consistent with DWER procedure for extreme surface water level events, the MGL has been based on a 1 in 100-year Average Return Interval sea level event (i.e. highest sea level anticipated to occur once in every 100 years on average) as groundwater peaks in the Site have been found to approximately correspond with sea level peaks (Figure 4-5). This corresponds to a peak sea level of 1.32 mAHD. The results of the study and methodology for determining the MGL are outlined in Appendix B.

Legend:

- Site boundary
- Design groundwater level contour (mAHD)
- Groundwater flow direction
- WIN Site bore
- Monitoring bores

Scale 1:6,000 at A4 (0 – 150 metres)		**Ocean Reef Marina**
Coord. Sys. GDA 1994 MGA Zone 50		**MAXIMUM GROUNDWATER LEVEL**
Job No: 56956		
Client: Development WA		**FIGURE 4-7**
Version: 1	Date: 24-Sep-2019	strategen JBS&G
Drawn By: hsullivan	Checked By: CT	

File Name: \\008PMPMR004V001.jbsg.aust\JBS Perth\Projects\1)Open\LandCorp\56956 Ocean Reef Marina LWMS 2019\GIS\Maps\R01 Rev A\56956_04_7_MaxGroundwaterLevel.mxd
Image Reference: www.nearmap.com© - Imagery Date: 13 July 2019

Based on this methodology, the estimated peak groundwater levels at MB03 without allowing for climate change are:

- 0.93 mAHD in a 1 in 1-year ARI storm surge event
- 0.96 mAHD in a 1 in 10-year ARI storm surge event
- 0.99 mAHD in a 1 in 100-year ARI storm surge event.

An estimated peak groundwater levels at MB02 without allowing for climate change are:

- 1.14 mAHD in a 1 in 1-year ARI storm surge event
- 1.16 mAHD in a 1 in 10-year ARI storm surge event
- 1.19 mAHD in a 1 in 100-year ARI storm surge event.

The maximum groundwater level at MB02 is considered to be equivalent the MGL at MB01 and the DWER bore because of the similar behaviour and groundwater levels within these bores.

4.7.1.1 Climate change and groundwater levels

Climate change is estimated to cause a rise in mean sea level of 0.3 m by 2060 and 0.9 m by 2110 (DoT 2010). In near coastal areas, groundwater levels are expected to rise as a consequence of the rise in sea levels. In the immediate coastal area, the rise in sea level as a result of climate change is anticipated to result in an equivalent rise in groundwater levels. Further from the land directly adjacent to the coast, other factors affecting groundwater flow and levels (such as rainfall patterns) will have a greater effect on groundwater levels.

Due to the location of the Site on the coast, a rise in sea level as a result of climate change is anticipated to result in an equivalent rise in groundwater levels. This results in an estimated MGL for the year 2110 of:

- 1.89 mAHD at MB03
- 2.09 mAHD at MB01, MB02 and DWER bore (Figure 4-7).

4.7.2 Groundwater quality

As part of the LWMS monitoring, water quality was monitored three times over the monitoring period from June to December 2014, when groundwater recharge to the ocean (and consequently groundwater inputs to the proposed marina) is greatest.

Groundwater quality monitoring was considered important to determine the pre-development water quality of the Site. Bores MB01, MB02, MB03 and the DWER bore were monitored. Parameters monitored included:

- field measurements of pH, electrical conductivity (EC), total dissolved solids (TDS) and redox potential
- laboratory analysis of water samples for total nitrogen, total phosphorus, phosphate, nitrate/nitrite, ammonia, Kjeldahl nitrogen
- laboratory analysis for the standard eight heavy metals (As, Cd, Cu, Cr, Pb, Ni, Zn, Hg).

Full results of the water quality monitoring program are presented in Appendix B.

4.7.2.1 Physicochemical results

Average pH in the four bores varied between 7.45 at MB01 and 8.0 at MB03 (Appendix B). This is slightly below the ANZECC and ARMCANZ (2000) guidelines for slightly disturbed marine inshore ecosystems of 8.0 to 8.4. Marine ecosystems tend to have higher pH values than inland waters because of a relatively high carbonate concentration compared to fresh waters. Groundwater at this

Site, although very close to the ocean, is still part of a freshwater system expected to have physiochemical parameters closer to a fresh water wetland, where ANZECC and ARMCANZ (2000) would indicate an acceptable pH range of 7.0 to 8.5. The pH at the bores was within this range. As a result, pH values observed are considered to reflect the natural water quality regime.

Electrical conductivities varied from an average of 1082 µS/cm at MB02 to 1797 µS/cm at MB03, which is closest to the coast. This indicates that the groundwater present was fresh to brackish. No seasonal trend in electrical conductivity was noted.

Nutrients

The average groundwater concentrations of total nitrogen (TN) and total phosphorus (TP) were above the ANZECC and ARMCANZ (2000) guidelines for slightly disturbed marine inshore ecosystems, as shown in Table 4.1. Average TN concentrations varied from 3 mg/L at MB03 to 12.7 mg/L at MB01, compared to a guideline of 0.23 mg/L (Table 4.1). Average TP varied from <0.05 mg/L at MB01 to 0.29 mg/L at the DWER bore, compared to a guideline value of 0.02 mg/L. These exceedances are considered to reflect the effect of fertiliser use and other nutrient inputs from the residential areas to the east of the Site.

Table 4.1: Nutrients results

Ocean Reef groundwater quality		Nutrients							
		Ammonia as N	NOx as N	Nitrite as N	Nitrate as N	Total Kjeldahl Nitrogen as N	Total N	Total P	Reactive Phosphorus as P
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PQL		0.005	0.005	0.005	0.005	0.1	0.1	0.05	0.005
ANZECC & ARMCANZ (2000) guidelines		0.005	0.005	0.005	0.005	NV	0.23	0.02	0.005
Sample ID	Sample Date								
MB01	10/06/2014	<0.005	11	<0.005	11	1.9	13	<0.05	0.01
	18/09/2014	<0.005	11	<0.005	11	2.1	13	0.08	0.015
	11/12/2014	<0.005	11	<0.005	11	1.3	12	<0.05	0.014
	Average	<0.005	11	<0.005	11	1.8	12.7	<0.05	0.013
MB02	10/06/2014	<0.005	7.4	<0.005	7.4	1.4	8.8	<0.05	0.019
	18/09/2014	<0.005	7.7	<0.005	7.7	1.9	9.6	0.05	0.028
	11/12/2014	<0.005	8	<0.005	8	<0.5	8.2	0.11	0.038
	Average	<0.005	7.7	<0.005	7.9	0.7	8.9	0.1	0.011
MB03	10/06/2014	<0.005	3.2	<0.005	3.2	0.4	3.7	<0.05	0.006
	18/09/2014	0.01	3.4	<0.005	3.4	<0.2	3.4	0.1	<0.005
	11/12/2014	<0.005	1.8	<0.005	1.8	<0.1	1.9	0.06	<0.005
	Average	0.005	2.8	<0.005	2.80	0.18	3.00	0.05	<0.005
DoW	10/06/2014	<0.005	0.073	0.018	0.055	0.6	0.6	<0.05	0.007
	18/09/2014	<0.005	11	<0.005	11	1.7	13	0.07	0.012
	11/12/2014	<0.005	0.18	<0.005	0.18	0.5	0.7	0.76	0.79
	Average	<0.005	0.18	0.008	3.75	0.93	4.77	0.29	0.27

Metals

Average metals concentrations were generally below the ANZECC and ARMCANZ (2000) 95% trigger values for marine environments, except for:

- zinc at the DoW bore, MB01 and MB02 (maximum of 0.127 mg/L compared to the 95% trigger value of 0.015 mg/L). The assessment level for long term irrigation water for zinc is 2 mg/L
- nickel in MB01, MB02 and MB03 (maximum of 0.046 mg/L compared to the 95% trigger of 0.007 mg/L for marine waters). The assessment level for long term irrigation water for nickel is 0.2 mg/L
- copper in all bores (maximum of 0.057 mg/L compared to the 95% trigger of 0.0013 mg/L). The assessment level for long term irrigation water for copper is 0.2 mg/L.

Elevated concentrations of zinc are common in groundwater in the Perth northern suburbs (Bekele 2006), probably as a result of naturally high levels of zinc in soils. Therefore, the reported zinc levels are not considered to be of concern.

Elevated concentrations of copper are also common in groundwater in the northern suburbs (Bekele 2006) and may be a result of naturally high concentrations in soils or the use of copper pipes for water supply, which can result in elevated levels of copper in soils where such water is used for irrigation.

Slightly elevated concentrations of nickel were noted in groundwater. Bekele (2006) does not address nickel concentrations in groundwater. Given the wide distribution of elevated nickel concentrations, this is possibly due to natural nickel concentrations in the area. This issue is further addressed in the DSI (Strategen 2016).

One exceedance of the lead guideline was noted within the DWER bore (Appendix 2). This exceedance is slight (0.005 mg/L compared to a guideline of 0.0044 mg/L) and the DoW bore is outside the Site (Figure 4-7). This is not considered to be of concern.

4.7.3 Groundwater availability

The Site lies within the Whitfords Groundwater Subarea (WGS), which is part of the Perth Groundwater Area (DoW 2009). Groundwater resources in the WGS consist of:

- superficial aquifer (Gnangara Mound)
- the shallow, semi-confined Mirrabooka Aquifer
- the partially confined Leederville Aquifer (DoW 2009).

The superficial aquifer in the WGS is currently over-allocated. Within the Perth Groundwater Area, the DWER Water Register indicates that groundwater is not available for allocation in this subarea. The City has two groundwater licences within the WGS with a total volume of 3 829 550 kL/yr. This water is predominantly used for the irrigation of open space within the City.

4.8 Vegetation and flora

The Site is located in the South Western Botanical Province of Western Australia, in the Darling Botanical District and the Swan Coastal Plain subregion of the Drummond Botanical District (Mattiske 2013). Vegetation types on the Site are dominated by the Quindalup vegetation complex, with some influence from the Cottesloe Vegetation Complex: Central and South, and Karrakatta vegetation complex: Central and South (Mattiske 2013). The Site also contains a portion of Bush Forever Site 325 (Figure 4-1).

Some vegetation will be cleared for the construction of the marina. No Site stormwater runoff will be allowed to enter the Bush Forever area outside of the Site.

4.9 Fauna

The Site can be divided into two broad fauna habitats:

- coastal shrubland – relatively dense vegetation dissected by numerous tracks with degraded areas along tracks
- sandy and rocky shoreline – the shoreline has been modified by existing development and is therefore largely disturbed (Western Wildlife 2008).

Four species of frog, 45 reptile species, 89 bird species, 19 mammal species and five species of introduced mammals were identified as having the potential to occur on the Site in a desktop assessment (Western Wildlife 2008). Following the desktop assessment, a survey of the Site was undertaken. Four potentially conservation dependent species are considered likely to occur within the Site based on available habitats (Western Wildlife 2008). These are Carnaby's Black-Cockatoo, Rainbow Bee-eater, Black-Striped Snake and Quenda (Western Wildlife 2008). None of these species are dependent on groundwater or surface water on the Site. Impacts on these species have been addressed through a Negotiated Planning Outcome for the Development and the appropriate processes with the Australian Government Department of the Environment and Energy (DoEE).

Because of the lack of wetlands and remnant vegetation within the Site, fauna is not considered to be a constraint for water management of the Site.

4.10 Marine environment

The existing Ocean Reef Boat Harbour is outside of the Marmion Marine Park, however a portion of the proposed development will encroach into the marine Park. This portion of the development area will be excised from the marine park. The marine environment is sensitive to changes in marine water quality, including nutrients. From the perspective of users of the Ocean Reef Marina, the aesthetic water quality of marina waterbody, including the absence of grease/oil and debris will be important. These factors have been considered in the design criteria and water management of the Development.

Impacts of development on the marine environment have been assessed by the Environmental Protection Authority (EPA), as described in Section 1.3. This assessment required studies into the flushing of the marina and water quality in the marina and surrounding waters to be undertaken.

5. Water sources and conservation

This section addresses the sources of water for the Development and how water will be conserved within the Site.

5.1 Servicing

5.1.1 Scheme water

Potable water supply will be provided from the Water Corporation reticulated water supply scheme. The Water Corporation have advised that potable water servicing to the site is planned to be achieved by connection to the existing DN200S water main located in Ocean Reef Road and by connecting to the existing DN200AC water main located in Resolute Drive at the corner of The Gap (WGE 2019).

5.1.2 Wastewater

Wastewater services at the Site will be provided by Water Corporation through a connection to the broader reticulated sewerage system. The Water Corporation has undertaken a review of their wastewater planning for the locality to include the Ocean Reef Marina Project. The Water Corporation has confirmed that a permanent single Type 40 wastewater pump station (WWPS) will be required to be constructed within the project site, to serve the proposed development. This will discharge via a DN150 pressure main constructed along Resolute Way, Constellation Drive and Beaumaris Boulevard discharging to a DN225 gravity sewer to be constructed across Santiago Park to outfall to the existing DN900 Burns Beach Main Sewer located in Santiago Parkway (WGE 2019).

5.2 Fit for purpose water use and water conservation

The DWMS set targets for water conservation to:

- if possible, achieve a total scheme water consumption of 106 kL/person/year (i.e. per resident)
- minimise the use of potable water where drinking water quality is not essential, particularly for outside uses.

The 106 kL/person/year target for residential water demand was based on the State Water Plan (DPC, 2007) and then as a target for development under BUWM (WAPC and DPI 2008). A new target of 110 kL/person/year has been established in the WaterWise Perth Action Plan (DWER, 2019).

The use of fit for purpose water sources will be encouraged to minimise the use of potable scheme water where this is not required. Analysis using the Water Corporation Water Balance tool indicates that approximately 40% of the water demand at the Development will be from commercial and industrial users. As a consequence, water conservation measures for the Development have been designed to reduce water use in both residential and commercial land uses.

Commercial and industrial development will include marine based industries (e.g. boat refitting), a hotel, food and shopping outlets. The industrial component is anticipated to be relatively small and so has been included in the commercial sector for the purposes of water demand assessment and management.

The volume of water use in commercial applications varies with land use, as does the purpose (e.g. washing dishes or boat cleaning). Consequently, water efficiency measures for the commercial sector need to be tailored to suit the land use. One water efficiency solution is considered unlikely to fit all land uses on the Site.

5.2.1 IS Rating Scheme (ISRS)

The ISRS is Australia and New Zealand's only comprehensive rating system for evaluating sustainability across the planning, design, construction and operational phases of infrastructure programs, projects, networks and assets. ISRS evaluates the sustainability performance of the quadruple bottom line (Governance, Economic, Environmental and Social) of infrastructure development.

DevelopmentWA intends to apply certification for the public realm land and marine infrastructure ensuring water is well managed at the Site. ISRS does not include the buildings. These will be covered by design guidelines to ensure water efficiency is achieved.

5.2.2 Residential lots

The Development is anticipated to consist of a range of approximately 160 residential lots. The ISRS shows density codes ranging from R80 to R160.

Construction is anticipated to be a mix of single houses and semi-detached townhouses/grouped dwellings for the lower density lots and multi-residential development for the higher density lots. Single houses are likely to be freehold, whereas the multi residential lots are likely to be strata. The proponent may wish to develop the higher density lots or sell the lots to a third party for development.

External water use of all lots is likely to be less than the WaterWise Perth Action Plan (DWER, 2019) target of 110 kL/person/year due to having less outdoor space than average lots. Water efficiency of internal uses will be guided by the design guidelines produced by the proponent.

5.3 Non-potable water use

The Site currently contains a small area of turfed POS. The City advises that the area currently utilises approximately 1500 kL/year of groundwater for irrigation.

The boat washdown bay is a small area of hardstand where boat owners can use groundwater to wash down their boats. Boat owners are required to bring their own hoses to connect to the system. It is assumed that a boat washdown facility will be provided in some form as part of the Development however the water source and expected usage is yet to be confirmed. The City advises that in the financial year 2018-19 approximately 5400 kL/year was used for boat washdown purposes.

These current groundwater uses (irrigation and boat washdown (6900kL/a)) will not be required after development is complete in their current form. This water will then be reallocated either to POS irrigation in the Development or other uses.

Approximately 4.6 ha of POS is proposed for the Development, some of which will be unirrigated beach areas. In addition to these areas, some irrigation may be required for streetscapes, tree pits, biofiltration and dune management. Preliminary estimates of total non-potable water demand for these purposes is expected to be approximately 35, 000 kL/a (UDLA 2019). This is calculated at application rates of 6750 kL/ha/a and 4500 kL/ha/a for traditional and low water use irrigable areas respectively.

Table 5.1: Preliminary estimate of landscape water use

Use	Ha	kL/a
Public open space (traditional)	2.60	17557
Parks and recreation (low water use)	1.93	7080
Streetscape		820
Car park (WSUD)		9800
Total	4.63	35257

As discussed in Section 4.7.3, the aquifers in the area are fully allocated. The City has existing groundwater allocations in the area for existing POS in the broader Whitfords groundwater sub-area (WGS), however, this water has been allocated to existing uses and the City has stated that it is not available for use within the Development.

A range of options are being considered to obtain water for the above water demands as detailed in Table 5.2. Each of these options are being investigated in detail to determine the most viable source or combination of sources.

Table 5.2: Non-potable water supply options

No	Option	Advantages	Disadvantages
1	Scheme water use	Reliable source, high quality water, low initial costs. Does not require approval from DoH and DWER.	High operating costs. Not considered an appropriate use of scheme water.
2	Purchase of groundwater allocations	Reliable source, low operating cost. Does not require approval from DoH and DWER.	Adequate allocations not anticipated to be available as the area is fully urbanised. Moderate to high capital cost.
3	Supply of wastewater from nearby Water Corporation Ocean Reef Ocean Outfall Landline (OROOL), which disposes of excess effluent from Beenyup Wastewater Treatment Plant	Reliable source volumetrically	High construction and operating costs. Regulatory approval required from DoH and possibly Economic Regulation Authority (ERA). Potential to negatively impact on marina water quality due to high nutrient concentrations. May result in algal blooms. Water Corporation advises that their wastewater stream for OROOL will become more concentrated (lower volumes, higher concentrations of salts) as a result of the expansion of the Groundwater Replenishment program. Variable water quality makes design of WWTP complex and expensive.
4	Supply of wastewater from on-site	Reliable source Warm season volume is similar to warm season demand Potentially low ongoing costs compared to other options	Require additional infrastructure for disposal of excess volume particularly in winter. High construction cost. Regulatory approval required from DoH, DWER and possibly ERA.
5	Reduction of water use at other areas irrigated by the City within WGS	Reliable source, low operating cost. Does not require approval from DoH and DER.	City irrigation allocation for both licences within WGS is already stretched– irrigation rates are being lowered as a consequence. The City is intending to use this water for other projects, including irrigation of up to 55 ha of currently dry parks within WGS.
6	Transfer of water from the City licence in the Quinns Groundwater Subarea (QGS).	Reliable source, low operating cost. Does not require approval from DoH and DWER. City irrigation allocation within QGS is less stretched than WGS. The City is not currently planning to expand the irrigation scheme in the QGS.	Option not supported by DWER. May require piping of groundwater from QGS to WGS, with associated capital costs. Requirement to transfer licence between two fully allocated Groundwater Subareas.
7	Obtain additional allocation to take groundwater that flows into the ocean from the site	Large volume available. No expected negative downstream impacts as the water flows into the ocean and extracted volume would be a small percentage of total flow (between 3% to 5%).	Environmental impacts on marine environment have not been assessed and would require investigation. Not supported by DWER due to allocation restrictions.

A search of existing licenses in the WGS (Option 2) has not identified any that do not appear to be suitably allocated for their site. It is therefore highly unlikely that this option will yield any results.

The variability of the OROOL water quality (Option 3) and the protracted and extensive regulatory approval processes involved in this option make it highly unlikely to be cost effective.

The City has confirmed that they are unable to provide groundwater within their current allocation to meet the requirements of the Development (Option 5) while meeting their current groundwater commitments.

DWER has expressed opposition to Option 6 of transferring groundwater between groundwater subareas. Likewise, DWER has expressed that they do not support Option 7 as they are currently proposing to reduce the allocations of licensees in the area and does not wish to increase an allocation.

The remaining probable options for non-potable use in the Development are using scheme water (Option 1) and the treatment of the Development's wastewater (Option 4). The use of scheme water is illogical given that its source in this area is groundwater (refer Option 7) and it undergoes a cost and energy expensive treatment process to treat it to potable standards. Using scheme water for the purpose of irrigation does not therefore tie in with the objectives of water sensitive urban design (BMT WBM 2009).

Option 4 is currently being investigated. This option will require a lengthy approvals process and the appointment of a suitable water service provider to manage the system. This is unlikely if the system is not commercially viable. If option 4 is not viable, revisiting of Options 5 and 7 should be undertaken before opting for the use of scheme water (Option 1). These options will however require DWER and/or the City to change their existing position.

The proposed landscape design will, as part of sustainable design, be low water use and will therefore aim to minimise water demand. However, if required, further, more extreme demand management may also be considered as part of the solution. This will involve the further reduction of irrigable areas and/or application rates.

5.4 Water conservation and efficiency compliance

The water conservation and efficiency criteria for the Site are anticipated to be met based on the methods described in Table 5.3. Design guidelines will be developed by the Proponent to ensure minimum standards for water efficiency.

Table 5.3 Compliance with water conservation and efficiency design and management objectives

Design and management objective	Methods for achievement
WC1: If possible, achieve a total water consumption target of 110 kL/person/year.	Compact lot sizes with limited garden area. Promotion of water conservation measures through the requirement ISRS and design guidelines.
WC2: Minimise the use of potable water where drinking water quality is not essential, particularly for outside uses.	Encouragement of use of rainwater tanks and other forms of alternative supply. Irrigation of POS areas is yet to be resolved.

6. Groundwater management strategy

6.1 Design groundwater level

Design groundwater levels (DGLs) are used in the design process to ensure adequate vertical separation between groundwater and buildings or stormwater infiltration structures. The DGL for the Site has been set at the MGL discussed in Section 4.7.1. The DGL for the Development considered the following factors:

- existing groundwater levels, which are affected by tides and storm surge
- mean sea level rise by 2110 of 0.9 m (WAPC 2013)
- potential changes to groundwater levels caused by alteration of the coastline during marina construction (Section 4.7.1).

As groundwater levels on the Site are influenced by sea level, changing the location of the coastline may affect groundwater levels. The impact of marina construction on groundwater levels in the current onshore area is considered to be marginal as the marina walls are located approximately along the current coastline. The offshore marina facility and will not bring the effect of sea levels further inland. Therefore, the marina construction itself is not considered likely to influence groundwater levels.

The MGL varies from approximately 1.89 mAHD to 2.09 mAHD over the Site based on the above factors and sea levels likely to be experienced during extreme events (Section 4.7.1) use of subsoil drainage to control groundwater is not proposed at the Ocean Reef Marina Development.

6.2 Earthworks and finished levels

Finished floor levels for the Site and building floor levels will be developed based on the need to maintain continuity of level with the existing landforms and ensure that finished levels allow appropriate separation to the DGL.

To allow 1.2 m separation from finished floor levels and groundwater, as required by The City, buildings will be required to have a minimum floor level of 3.1 to 3.3 mAHD.

The *State Coastal Planning Policy 2.6* (WAPC 2013) is used to set minimum finished levels in coastal developments based on sea levels during storm events. Under the *State Coastal Planning Policy 2.6* (WAPC 2013), coastal development is required to consider the 1 in 500-year ARI sea level, with an allowance for a sea level rise of 0.9 m over a 100-year planning horizon. The Ocean Reef Marina Coastal Hazard and Risk Management Adaptation Plan (CHRMAP) (MP Rogers 2016) uses the State Coastal Planning Policy 2.6 to determine the finished levels specific to the Development for a 100-year planning horizon.

The CHRMAP proposed a minimum finished floor level for the onshore portion of the Site required to prevent sea level inundation of +2.7 mAHD. Calculation of this level is shown in Table 6.1.

Table 6.1: 500-year ARI Water Level Inside Marina

Description	Height (m)
500-year ARI Steady Water Level in 5 m of Water (mAHD)	1.44 mAHD
Sea level rise (100-year timeframe)	0.9
Local Wind & Wave Setup & Run-up Inside Marina (m)	0.3
Freeboard/factor of safety*	n/a
Total^	**2.7 mAHD**

* The SPP2.6 does not require a freeboard to be included in the S4 inundation assessment.
^ Value has been rounded up.

The 2.7 mAHD (Table 6.1) minimum level required to prevent sea level inundation is lower than the 3.1 to 3.3 mAHD required for separation to groundwater. Consequently, the minimum finished levels for buildings will be based on the higher of the two, being separation to groundwater.
In areas of public open space, boardwalks, beaches and boat ramps, which require access to or close interface with the seawater, some inundation during storm events may be acceptable. For these areas, levels below 2.7 mAHD may be used as appropriate.

6.2.1 Basements

Developers will be permitted to install basement levels if required, on the understanding that deeper basements may be below the MGL and/or sea level. If the basements are below this level, these will be required to be waterproofed or 'tanked' to prevent water ingress. Tanking of basements is common in high-density areas such as the Perth Central Business District, where basement levels may be located below groundwater. To avoid stormwater entering the basements from the street, road surfaces will be designed to prevent water ingress (e.g. with a speed hump or similar) without stopping traffic flow.

6.2.2 Earthworks

Finished levels on the Site are anticipated to vary from 23.5 mAHD at the corner of Ocean Reef Road and Hodges Drive to 1.5 mAHD in the reclamation area at the edge of the marine industrial zone, where access to the water is required (Figure 6-1). The majority of the Development will be between 3 and 11 mAHD (Figure 6-1).

Earthworks on the Site will be undertaken using 'cut to fill', with fill from the Site and marina dredging used to construct the reclaimed portion of the Site and to level out the onshore portion as required. No fill is anticipated to be required to be imported to support the Development. Depending on the finished levels, the Development may potentially be a source of fill for other projects. The preliminary contour plan is presented in Figure 6-1.

6.3 Groundwater quality management

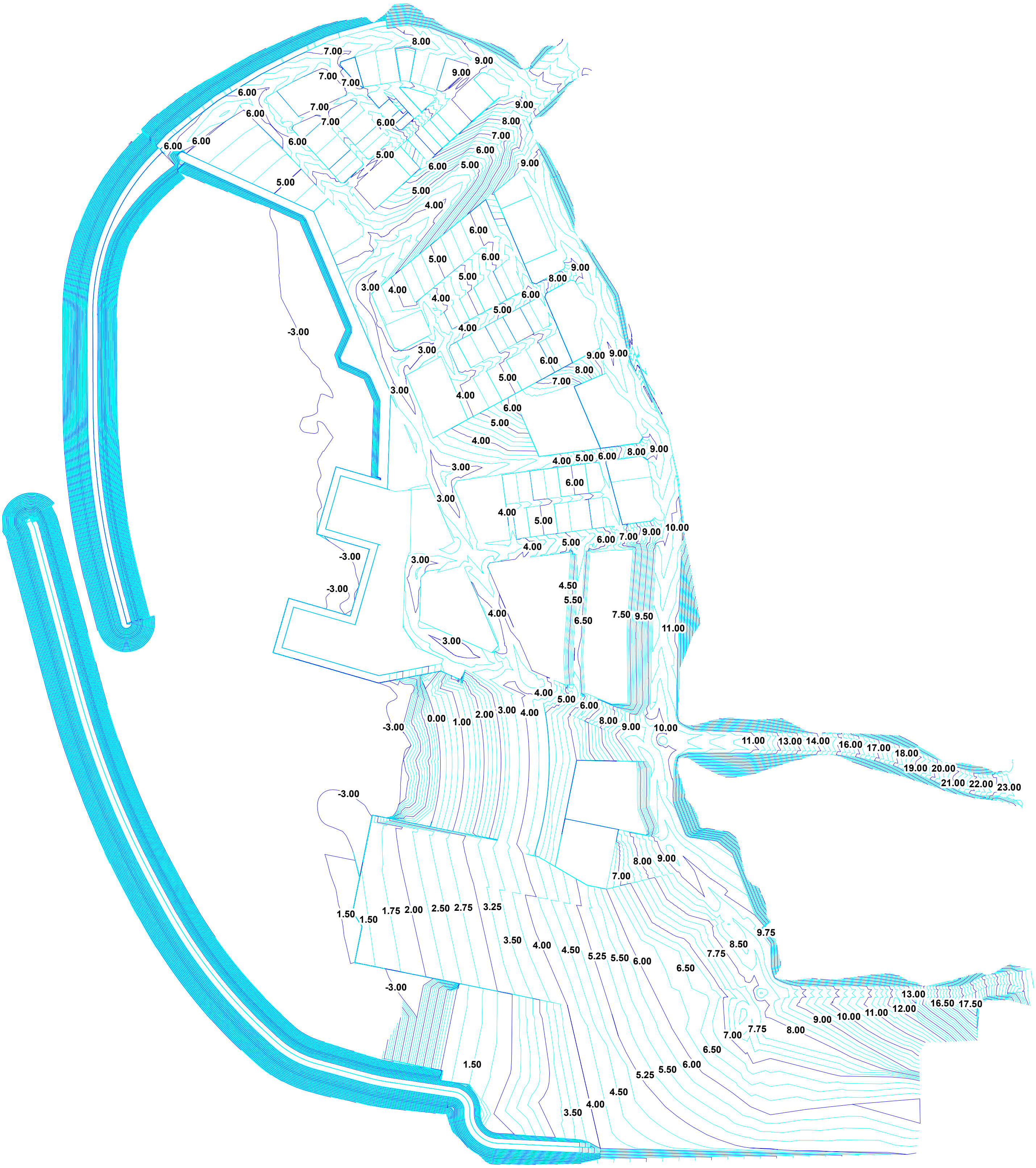
The comparatively small areas of POS and private gardens anticipated in the Development area mean that nutrient loads from the Development are anticipated to be low. The key pollutants to be removed are anticipated to include grease, oil and sediment from roads and car parks. These pollutants will be removed from stormwater through the use of the Best Management Practices described in Section 7.5.

6.4 Groundwater management compliance

The water conservation and efficiency criteria for the Site are anticipated to be met based on the methods described in Table 6.2

Table 6.2 Compliance with groundwater management design and management objectives

Design and management objective	Methods for achievement
WM1: Maintain surface water (marine) and groundwater quality.	Treatment of stormwater prior to infiltration to remove contaminants. High density of development means small private gardens. Nutrient loads for the development are consequently anticipated to be low.



		EARTHWORKS PLAN
	Job No: 56956	
	Client: Development WA	**FIGURE 6.1**
	Version: 1 / Date: 26-Sep-2019	strategen JBS&G
	Drawn By: hsullivan / Checked By: CT	

File Name: \\008PMPMR004V001.jbsg.aust\JBS Perth\Projects\1)Open\LandCorp\56956 Ocean Reef Marina LWMS 2019\GIS\Maps\R01 Rev A\56956_06_1_EarthworksPlan.mxd

7. Stormwater management strategy

7.1 Design context

The DWMS outlines the stormwater management requirements based on land use (Strategen 2014).

7.1.1 Drainage philosophy

A high density, high amenity development such as Ocean Reef Marina, places constraints on the areas for stormwater management as well as the expected aesthetic of stormwater infrastructure. In particular, the waterfront areas will be constrained in this way. These constraints will therefore influence the design of the infrastructure.

The requirement to minimise stormwater infrastructure at the water front (the lowest part of the catchment) necessitates stormwater management higher in the catchment. This will be achieved primarily through roadside and median biofiltration swales, and UGS although other WSUD devices are likely to be employed such as tree pits and raingardens. As a result, the Development will require additional stormwater infrastructure compared to many other developments.

A range of stormwater treatment and disposal approaches have been used in response to the different land use types shown in the PCP (Figure 1-2). These are detailed in Table 7.1.

Roof waters are considered clean and are not anticipated to require treatment prior to discharge or infiltration. Roof water will therefore be permitted to be discharged directly to the marina without treatment. If roof water cannot be directly discharged to the marina, it must be treated on lot up to the 1 in 1-year event. The reuse of roof water will be managed within the design guidelines.

All lots will be required to manage the 1 in 1-year event on lot (excluding roof water), minimising the area required for drainage infrastructure, particularly in the high amenity areas such as the waterfront POS.

The hard stand areas at the south of the Site, such as Marine Services and the car and trailer parking areas, will infiltrate stormwater for the 1-year event within those areas. Where this is not practical, such as due to the proximity of the water front, stormwater will runoff into the marina. Where practical, hydrocarbons must be managed to prevent them entering the marina waters.

Stormwater from events larger than the critical 1-year event will be permitted to discharge to the marina according to the requirements detailed in Table 7.1.

Catchment areas, runoff details and storage sizing are detailed in Table 7.2.

Table 7.1: Stormwater management for various land use types

Land use type	Location	Lot connection pits	Events up to critical 1- year	Events up to 18% AEP	Events up to 1% AEP
Residential	Water front	No	Roof areas - direct discharge to marina permissible else on-site treatment and infiltration or reuse by lot owners Non-roof areas – on-site treatment and infiltration or reuse by lot owners	Discharged to marina via GPTs*	Discharge to marina via local drainage system
Residential	Non water front	Yes	Roof areas - direct discharge to marina permissible else on-site treatment and infiltration or reuse by lot owners Non-roof areas – on-site treatment and infiltration or reuse by lot owners	Discharge to marina via local drainage system	
Mixed Use	Water front	No	Roof areas - direct discharge to marina permissible else on-site treatment and infiltration or reuse by lot owners Non-roof areas – on-site treatment and infiltration or reuse by lot owners	Discharged to marina via GPTs	
Mixed Use	Non water front	Yes	Roof areas - direct discharge to marina permissible else on-site treatment and infiltration or reuse by lot owners Non-roof areas – on-site treatment and infiltration or reuse by lot owners	Discharge to marina via local drainage system	
Commercial/ Retail	Water front	No	Roof areas - discharge to marina Non-roof areas - treatment and infiltration within road reserve and POS (swales and UGS)	Discharged to marina via GPTs	
Road Reserve		n/a	Treatment and infiltration within road reserve and POS (basins, swales and UGS)	Discharge to marina via GPTs and local drainage system	
Carparks		n/a	On-site treatment and infiltration via bioretention swales in landscaped areas between car bays or UGS		

* Gross pollutant trap

7.2 Stormwater system design

7.2.1 1 in 1-year ARI event

Design of the stormwater management system is constrained by the high-density nature of development, the expected amenity, the depth to groundwater and the slope of the site. There is limited POS available for above-ground storage structures and large portions of the area will be paved, increasing runoff volumes. Water management solutions have been selected to function in this environment, with a minimal land take and high aesthetic value while maintaining water quality and clearance to groundwater. Therefore, the 1-year ARI event (excepting roof water) will be treated and infiltrated on the Site through a mixture of the following WSUD devices:

- open bottomed manholes and side entry pits
- underground storage (UGS) (e.g. Stormtech or Atlantis cells)
- biofiltration swales, raingardens and tree pits
- biofiltration basins.

UGSs, open bottomed manholes and side entry pits are all below ground structures. The land above these structures may be paved or landscaped to minimise the land take.

UGSs normally require a depth from the finished surface to groundwater of 1.5 m to allow adequate separation to groundwater for infiltration. Biofiltration swales in comparison may be installed with groundwater as little as 0.6 m below the surrounding finished surface, depending on swale depth. In areas immediately adjacent to the marina, the depth to groundwater is anticipated to be less than that required to install UGSs. As a consequence, USGs are not proposed to be used immediately adjacent to the marina (Figure 7-2).

WSUD devices will be used high in the catchment (away from the marina) to minimise the volume of stormwater to be treated lower in the catchment along the water front. This may include biofiltration swales, raingardens, tree pits and UGS. Ocean Reef Marina access roads are anticipated to have bioretention swales within the median strip.

Figure 7-2 shows the preliminary locations and sizes of the stormwater infrastructure for the 1-year event. The details of the stormwater management plan are yet to be finalised and therefore the 1-year event plan will change once further information becomes available. The premise of the Figure 7-2 is to demonstrate under a worst-case scenario that the PCP is capable of managing stormwater within the basins in the POS and UGS areas shown on the plan. No infiltration devices higher in the catchment were modelled in this scenario apart from Catchment A areas. Once further detail is available, these infiltration devices will be added to the model and will reduce the volume, and therefore areas of the basins within the water-front POS areas.

7.2.2 Lot connections

All lot connections will include a sediment trap for removal of pollutants. Where separation distances are adequate, lot connection pits will have an open base to infiltrate stormwater.

7.2.3 Marine Services, car and trailer parking areas

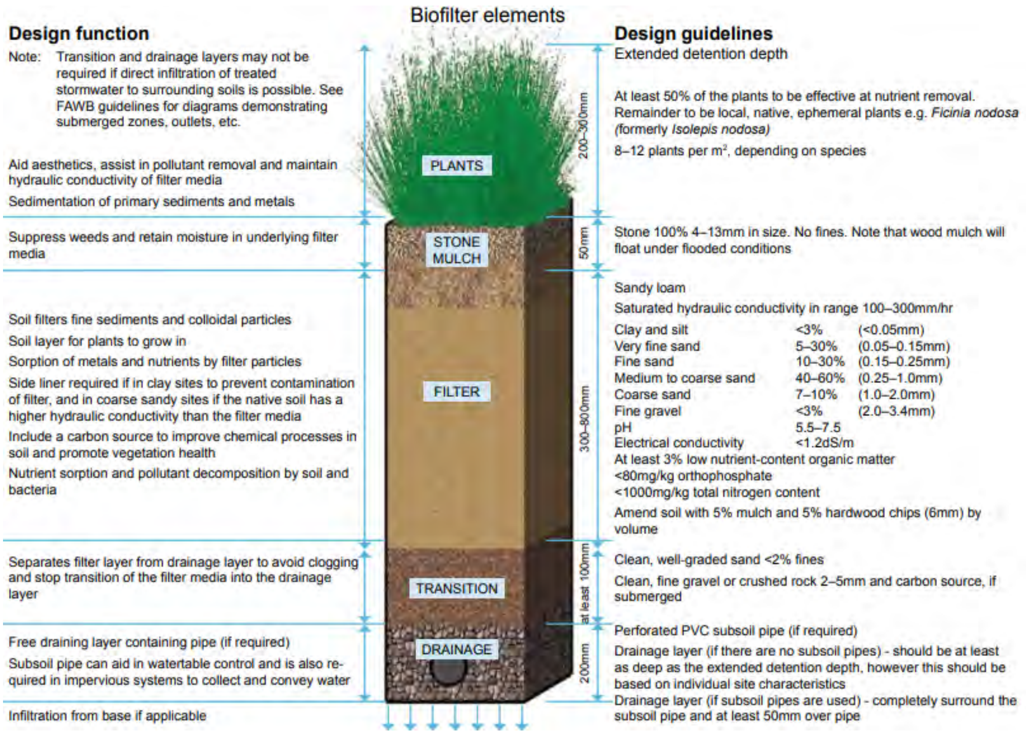
In car parking areas, biofiltration swales are anticipated to be used between bays, as shown in Plate 7-1. These structures provide an aesthetic benefit and increase the volume of water available to shade trees planted within the car park. Given the constraints to provision of irrigation water in the Site, this is a positive outcome. Some car parking areas may utilise permeable paving to minimise runoff.

Plate 7-1: Car park bioretention area

All biofiltration swales will be designed based on the guidelines outlined in *Water Sensitive Urban Design: Biofilters* (DoW 2007) and shown in Figure 7-1. A filter layer with a minimum depth of 300 mm will be placed under biofilters, consisting of a sandy loam with phosphorus retention index (PRI) greater than 15 and particle size distribution consistent with DoW (2007). Where subsoil drainage is not considered to be required due to the high infiltration rate of the underlying material, the transition and drainage layers described in Figure 7-1 may be removed.

Marine Services will be responsible for spill management of hydrocarbons and other pollutants within their sites.

Figure 7-1: Infiltration and biofiltration system design



Source: DoW 2007

Vegetation selection for biofiltration swales will be consistent with Vegetation Guidelines for Biofilters in South West Western Australia (Monash University 2014), which emphasises the use of native vegetation with the ability to uptake nutrients in a biofilter setting. Biofiltration swales will be designed depth of 0.5 m.

Legend:

- Site boundary
- Catchment areas
- Basin
- UGS
- Potential roadside swale locations
- Flow path

Scale 1:6,500 at A4 — 0 — 150 metres

Coord. Sys. GDA 1994 MGA Zone 50

Job No: 56956

Client: Development WA

Version: 1 | Date: 25-Sep-2019

Drawn By: hsullivan | Checked By: CT

Ocean Reef Marina

PRELIMINARY 1-YEAR EVENT PLAN

FIGURE 7-2

strategen JBS&G

File Name: W:\Projects\1)Open\LandCorp\56956 Ocean Reef Marina LWMS 2019\GIS\Maps\R01 Rev A\56956_07_2_1yrEventPlan.mxd
Image Reference: www.nearmap.com© - Imagery Date: 13 July 2019

7.2.4 Events greater than the 1-year ARI event

For events greater than the 1-year, 1-hour event ARI event up to the 18% AEP events, overflow from the UGSs and swales will enter the marina via a series of outflow pipes, to be constructed during marina construction. Pipes will be discharged through piped outfalls to reduce the risk of marine erosion. Discharge is predominantly within the marina. The outer walls of the marina will be made of considerably larger sized rocks than the inner walls because the outer walls are subject to greater wave heights and energy. Placing outfalls through these walls is consequently considerably more difficult and costly than placing outfalls in the inner walls. The inner portion of the marina is also closer to the Development than the outer edge.

The presence of litter and debris within the marina waterbody is considered highly undesirable. Therefore, Gross Pollutant Traps (GPTs) will be installed on all outlets prior to discharge to the marina and any external outlets.

All intersections and major roads will have piped drainage, designed to convey 18% AEP events.

For events up to the 1% AEP, finished levels will be designed so that stormwater overflows to the marina via controlled overland flood routes. Adequate clearance (or freeboard) from 1% AEP flood levels to properties levels will be required to minimise the risk of flooding.

Table 7.2: Catchment areas and storage sizing

Catchment	Storage Type	Road reserve connected area (m2)	Carpark/ hardstand connected area (m2)	Total connected catchment area (m2)	Prelim design UGS volume (m3)	Prelim design UGS area (m2)	Prelim design basin volume (m3)	Prelim design basin TWL area (m2)
Catchment A	Swale	47771	-	47771	-	-	315	2250
Catchment B	Basin	12833	-	12833	-	-	100	324
Catchment C	UGS	6576	1227	7803	50	57	-	-
Catchment D	Basin	10606	-	10606	-	-	79	289
Catchment E	Basin	11425	-	11425	-	-	86	306
Catchment F	UGS	17041	-	17041	152	173	-	-
Catchment G	Swale	-	9103	9103	-	-	79	330
Catchment H	Swale	-	45476	45476	-	-	308	2100
Catchment I	Swale	-	12265	12265	-	-	105	462
Catchment J	Swale	-	13301	13301	-	-	112	506
Catchment K	Swale	-	41611	41611	-	-	280	1935

7.3 Stormwater modelling

Detailed drainage planning for the Site has not yet been completed due to insufficient design detail being available at the time of writing. Preliminary stormwater modelling was undertaken by Strategen-JBS&G to determine estimates of the stormwater quantities and infiltration areas required to ensure the PCP can adequately manage stormwater. Detailed modelling and design will be provided in subsequent Urban Water Management Plans. The following assumptions have been made during drainage modelling:

- a hydraulic conductivity of 5 x 10^{-5} m/s (4.3 m/day) for areas located in filled areas as these areas are likely to use clean, permeable fill
- a hydraulic conductivity of 1 x 10^{-5} m/s (0.86 m/day) has been used in areas located in cut areas as these are likely to have underlying limestone
- all lots will infiltrate the 1 in 1-year ARI event or discharge directly to the marina and therefore, no allowance has been made for runoff from these areas in the modelling
- 1 year-ARI runoff coefficients are:
  - road reserves - 0.8
  - POS - 0.0
  - carparks - 1.0
  - Lots - 0.9
- underground storage cell volume calculations are based on the following assumptions:
  - Stormtech SC-740 underground storage cells (1.9 m^3 of storage per 2.3 m long cell)
  - hydraulic conductivity of 1 x 10^{-5} m/s (0.86 m/day) assuming the base of the swales are in limestone
  - one side entry pit (with open base and soakwell liner) per 30 linear metres of road reserve.

The stormwater design represents the best understanding of the project team at the Improvement Scheme stage. The stormwater design will be reviewed at the subdivision stage as part of detailed earthworks and civil design. The final stormwater system design will be presented in the Urban Water Management Plan(s) (UWMPs).

7.3.1 Post-development hydraulic conductivity

This low value is recommended because of the presence of a thin low hydraulic conductivity caprock at the top of the limestone. The limestone below the caprock layer has a higher hydraulic conductivity. If this caprock can be broken or removed during earthworks, the hydraulic conductivity of the profile will increase (Kain D [Golder], 2015 pers. comm. 9 November). Golder advised that the following hydraulic conductivities may be used where limestone is not present above the water table or the caprock has been broken or removed:

- 1 x 10^{-4} m/s (8.6 m/day)– for sand not heavily compacted (e.g. drainage swale areas that have not been earthworked)
- 5 x 10^{-5} m/s (4.3 m/day) – for compacted sand and sandy fill (Kain D [Golder], 2015 pers. comm. 9 November).

For post development modelling the conservative limestone rate of 0.86 m/day has been used for road reserves and non-reclaimed land, which is the majority of the Site. The compacted sand fill rate of 4.3 m/day has been used for POS, which is located on reclaimed land. This is considered to be a conservative approach and may be refined at later planning stages.

7.4 Nuisance insect control

To reduce health risks from mosquitoes, all retention and detention treatments will be designed to ensure that between the months of November and May, detained immobile stormwater is fully infiltrated in a time period not exceeding 96 hours. No new permanent water bodies are proposed on the Site.

7.5 Stormwater quality management

Stormwater quality will be managed through the use of biofiltration cells, UGSs, open bottomed manholes and GPTs.

The high-density nature of the Development means that there will be little vegetated landscaping and turf requiring the use of fertiliser. Most domestic dwellings will have limited garden area. POS will include hardstand and native species requiring little fertiliser, as well as lawns for amenity purposes (Figure 1-2). The use of fertiliser in POS will consequently be limited. Nutrient inputs from the Development are therefore considered likely to be low.

7.6 Stormwater quality and quantity compliance

The water quality and quantity management and disease and nuisance insect management criteria for the Site are anticipated to be met based on the methods described in Table 7.3.

Table 7.3: Compliance with stormwater management design and management objectives

Category	Design and management objective	Compliance
Water quantity management	**WQ1:** For the critical one-year average recurrence interval (ARI) event, the pre-development peak flow rates and volumes shall be maintained.	Pre-development flow rates will be maintained off the Site in events up to and including the 1 in 1-year ARI event (Section 7.2.1).
Water quality management	**WM1:** Maintain surface water (marine) and groundwater quality.	Surface and groundwater quality will be maintained by water treatment prior to infiltration or discharge to the marina.
	WM2: Ensure that all runoff contained in the drainage infrastructure network receives treatment prior to discharge to a receiving environment consistent with the Stormwater Management Manual for Western Australia (DoW 2007).	Runoff will receive treatment via gross pollutant traps, swales and infiltration areas to remove sediment, rubbish and nutrients (Section 7.5).
Disease vector and nuisance insect management	**DV1:** To reduce health risks from mosquitoes, retention and detention treatments should be designed to ensure that between the months of November and May, detained immobile stormwater is fully infiltrated in a time period not exceeding 96 hours.	All detained immobile stormwater will be infiltrated within 96 hours.
	DV2: Permanent water bodies are discouraged, but where accepted by DWER, must be designed to maximise predation of mosquito larvae by native fauna to the satisfaction of the local government on advice of the DWER and DoH.	Permanent terrestrial water bodies are not proposed on the Site. The marina will be a fully marine water body and thus is not suitable for mosquito breeding.

8. Implementation and monitoring

8.1 Governance and management framework

DevelopmentWA is the nominated proponent for the marine component of the Development and is ultimately responsible for implementing the assessed Proposal in accordance with Ministerial Statement 1107.

The governance and management framework for the Development is not yet established. The ownership and management responsibilities for the marina waterbody, groynes, POS, roads and areas zoned Parks and Recreation are to be discussed between the Proponent, the City, the Department of Planning, Lands and Heritage (DPLH) and Department of Transport (DoT). The waterbody of the marina will most likely be vested in DoT. Development of the land components may be undertaken by the Proponent as a joint venture with a future partner or independently by a third-party developer and may involve the State Government. For the purpose of this report, this party is referred to as 'the Developer'.

POS, gazetted roads and areas zoned for parks and recreation (Figure 1-2) are likely to be ceded to the City. The club facilities are likely to owned by the City, DoT or the clubs. Governance structures and responsibilities will be resolved prior to the subdivision stage of development, so that ownership and responsibilities for drainage and irrigation infrastructure can be confirmed.

Residential and commercial land within the precinct will be sold to private landowners. Water Corporation lands that are zoned public purpose will remain vested with the Water Corporation.

Long-term responsibility for management and maintenance of stormwater management and irrigation infrastructure may sit with the City or DoT. This will depend on the agreed governance and management framework proposed. For the purpose of this report, the party with long-term responsibility for the stormwater and irrigation systems is referred to as 'the Operator'.

8.2 Roles and responsibilities

The LWMS has been prepared to support the Improvement Scheme for the Site. The LWMS provides a structure in which development can occur in a water sensitive manner. The LWMS provides guidance for the future UWMP documents.

The development of the Site is anticipated to occur in a staged manner with timing affected by the size of the area, capital requirements for marina construction and market demand. The Developer will be required to prepare the subdivision designs and UWMP documents at the subdivision stage. The UWMP shall demonstrate that the requirements and criteria of the LWMS can be met and include the matters discussed in Section 8.5.

The UWMP and associated estate scale drainage and earthwork design will be prepared by the Developer in consultation with The City and DWER and in reference to other relevant guidelines and policies. The Developer will be responsible for the construction of the drainage and earthworks and the monitoring outlined in Section 8.4.

Lot connections, connections to private outfalls and any on-lot treatment shall be the responsibility of the lot purchaser. The City will approve designs for connections and treatment mechanisms through the building application and approval process.

The Development does not require connection to external drainage infrastructure. As such, there is no requirement for agreement with external parties.

8.3 Review

The surface runoff calculations presented in the LWMS (Section 7.3) are not anticipated to require revision unless the PCP undergoes significant change subsequent to approval. In these situations, an addendum to the LWMS or a revised LWMS may be prepared to address these changes.

8.4 Monitoring

The objective of this section is to provide guidance on the future post-development monitoring based on the pre-development monitoring for the Site. The monitoring will focus on comparing post-development conditions to baseline conditions, as well as monitoring the BMPs to assess their effectiveness and that these structures are fulfilling their function. Prior to handover to the Operator, the BMPs will be assessed to confirm that these are in satisfactory condition and functioning appropriately. Details of BMP monitoring will be detailed at the UWMP(s).

The monitoring undertaken for the LWMS is considered adequate to provide baseline monitoring data for the Site and for the purposes of subdivisional design.

8.4.1 Post-development trigger values

Post-development water quality monitoring trigger values have been based on:

- water quality data gathered during the monitoring period
- ANZECC & ARMCANZ guidelines (Table 8.1).

The trigger value for each parameter will be the highest of the values for that parameter provided in Table 8.1.

Table 8.1 Post-development trigger values

Parameter	Ammonia as N (mg/L)	Nitrate and nitrite as N (mg/L)	Total N (mg/L)	Total P (mg/L)	Reactive phosphorus as P (mg/L)	pH	Electrical conductivity (mS/cm)
ANZECC and ARMCANZ (2000) guidelines for marine systems	0.005	0.005	0.23	0.02	0.005	8.0 - 8.4	NA
Site water quality data	0.01	11	13	0.76	0.79	7.14-8.4	2000

8.4.2 Monitoring program

Given that there will be no surface discharge from the Site in a 1 in 1-year ARI event and that discharge of surface water will be to the marina, collecting a sample of treated surface runoff from the Site will not be practical. The post-development monitoring program will consequently focus on groundwater quality. Water quality monitoring will occur at:

- MB01, MB02 and MB03 or equivalent groundwater monitoring locations to be established during development
- one monitoring location upgradient and one location downgradient of a selected biofiltration swale, with location to be confirmed.

These locations will be confirmed at the UWMP stage to ensure that locations are representative of conditions upgradient and downgradient of the infiltration basin, while recognising issues associated with bores near the marina walls, where seawater incursion is likely to occur and affect results and the presence of sea walls may make bore installation difficult.

Monitoring will be undertaken for water levels and the water quality parameters described in Table 8.1 on a quarterly basis for two years, to commence when the Development is 80% complete.

8.4.3 Contingency plan

Contingency actions may be implemented if the trigger criteria outlined in Table 8.1 are exceeded during the post-development water quality monitoring. Actions shall be:

1. Repeat the groundwater monitoring within four weeks of the exceedance reading to confirm the exceedance is not a result of sampling error.
2. Compare upgradient and downgradient results to assess the potential source of the exceedance. If the upgradient concentrations are consistently greater than 20% higher than the upstream concentrations (i.e. on both the original and repeat round), undertake one or more contingency action as outlined below.

This approach recognises the natural variability in water quality results.

8.4.3.1 Contingency actions

1. Review the surrounding subdivision area to identify the source if possible.
2. Review POS nutrient application practices and reduce application rates if possible.
3. Remove plant material from biofilters and/or infiltration areas to increase nutrient uptake.
4. Remove sediment build up in infiltration areas and/or biofilters to remove nutrient sources.
5. Conduct a leaflet drop to remind residents of the potential impacts of excessive fertiliser use.

8.4.4 Reporting

A post-development monitoring report will be provided to the Operator, The City and DWER at the completion of the two-year monitoring period. Interim results may be provided to the Operator, The City and DWER prior to this upon request.

8.5 Matters to be addressed at the subdivision stage

More detailed water management planning is usually required at subdivision through the preparation of an Urban Water Management Plan (UWMP). Depending on the timeframe and form of the Development, multiple UWMPs may be prepared. UWMP documents will follow the guidance provided in *Urban Water Management Plans* (DoW 2008). The UWMP(s) will provide more detail on the management strategies described in the LWMS. The main areas to be addressed in the UWMP(s) are anticipated to be:

- discussion of non-potable water source
- detailed drainage design including: basin designs and local road drainage systems, including all BMPs
- implementation of water conservation strategies
- non-structural water quality improvement measures
- water requirements for POS
- management and maintenance requirements
- management of sediment and other pollutants during the construction period
- monitoring and evaluation program
- demonstration of compliance with the LWMS.

9. References

ANZECC (Australian and New Zealand Environment and Conservation Council) and ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand) 2000, *Australian Guidelines for Water Quality Monitoring and Reporting*, National Water Quality Management Strategy Paper No. 7, Canberra.

BMT WBM 2009, *Evaluating options for water sensitive urban design – a national guide*, Prepared by the Joint Steering Committee for Water Sensitive Cities, Canberra.

Bureau of Meteorology (2019a) *Climate Data Online- Hillarys Boat Harbour NTC AWS Station*, Commonwealth of Australia, Available from <http://www.bom.gov.au/climate/data. [20 November 2019].

Bureau of Meteorology (2019b) *Climate Data Online- Tamala Park (Mindarie) Station*, Commonwealth of Australia, Available from <http://www.bom.gov.au/climate/data. [20 November 2019].

Bekele E 2006 *Compilation and Assessment of Groundwater Quality Data for the Superficial Aquifer, Gnangara Mound, Western Australia,* CSIRO, Perth.

City of Joondalup (The City) undated a, *Stormwater Management Policy,* The City, Joondalup.

Davidson WA 1995, *Hydrogeology and Groundwater Resources of the Perth Region, Western Australia*, *Geological Survey, Bulletin 14,* Geological Survey of Western Australia, Perth.

Department of Environment and Conservation (DEC) 2006, '*Acid Sulfate Soil Risk Map, Swan Coastal Plain*', DEC. In *WA Atlas* [online], Landgate, Perth, Western Australia, Available from: https://www2.landgate.wa.gov.au/bmvf/app/waatlas/ [Accessed 6 March 2014].

Department of Premier and Cabinet 2007, *State Water Plan,* Western Australian Government, Perth, Western Australia.

Department of Transport 2010, *Sea Level Change in Western Australia: Application to Coastal Planning*, Department of Transport, Perth.

Department of Water 2004-2007, *Stormwater Management Manual for Western Australia*, Western Australian Government, Perth, Western Australia.

Department of Water 2007, *Water Sensitive Urban Design: Biofilters,* Western Australian Government, Perth, Western Australia.

Department of Water 2008, *Interim: Developing a Local Water Management Strategy,* Western Australian Government, Perth, Western Australia.

Department of Water (DoW) 2014, *Water Information Reporting*, [Online], State Government, available from <http://kumina.water.wa.gov.au/waterinformation/WIR/Reports/Publish/61610590/gwl01.html>, [28 February 2014].

Department of Water and Environment regulation (DWER) 2019, WaterWise Perth Action Plan, Western Australian Government, Perth, Western Australia.

Golder 2015, *Preliminary Geotechnical Investigation, Ocean Reef Marina,* unpublished report to City of Joondalup, September 2015.

Gozzard JR 1982, *Yanchep Sheet 2034 IV, Perth Metropolitan Region Environmental Geology Series,* Geological Survey of Western Australia, Perth.

Government of Western Australia 2014, Western Australian Land Information Search (WALIS), [Online], Landgate, Available from: < https://www2.landgate.wa.gov.au/bmvf/app/waatlas/ > [19 January 2015].

Landgate 2014, *Map Viewer* [Online], Western Australian Land Information Authority, Available from: https://www.landgate.wa.gov.au/bmvf/app/mapviewer/ [8 Jan 2015].

Mattiske Consulting 2013, *Level 2 Flora and Vegetation Survey of the Proposed Ocean Reef Marina Survey Area*, report prepared for Strategen.

Monash University 2014, *Vegetation Guidelines for Biofilters in South West Western Australia,* Monash University.

McPherson A & Jones A 2005, 'Appendix D: Perth Basin geology review and site class assessment'. In Jones T, Middelmann M & Corby N, *Natural hazard risk in Perth, Western Australia: comprehensive report,* Geoscience Australia, 313–44.

Natural Area Management Services 2008, *Vegetation Condition, Ecological Community and Flora Search Report, Ocean Reef Marina*, unpublished report prepared for the City of Joondalup.

MP Rogers 2016, *Ocean Reef Marina Coastal Hazard and Risk Management Adaptation Plan R608 Rev 2*, prepared for the City of Joondalup, Perth.

Rockwater 2011, *Ocean Reef Marina: Groundwater Modelling to Assess Nutrient Loads to the Ocean and Marina,* unpublished report to MP Rogers & Associates.

SMEC Australia Limited (SMEC) 2008, *Ocean Reef Marina Preliminary Site Investigation (Contamination),* unpublished report prepared for City of Joondalup.

Strategen 2014, *Ocean Reef Marina District Water Management Strategy,* unpublished report prepared for City of Joondalup, April 2014.

Strategen 2016, *Ocean Reef Marina Detailed Site Investigation,* unpublished report prepared for City of Joondalup, February 2015.

State Government 2014, *Western Australian Land Information Search (WALIS),* [Online], Landgate, Available from: < https://www2.landgate.wa.gov.au/bmvf/app/waatlas/ > [28 February 2014].

UDLA 2019, *Public Realm Masterplan Supporting Document,* unpublished report prepared for City of Joondalup, June 2019.

Western Wildlife 2008, *Ocean Reef Marina Redevelopment: Level 1 Fauna Assessment 2008*, unpublished report for City of Joondalup.

Water Corporation undated *Perth Residential Water Use Survey 2008/9*, Water Corporation, Leederville, Western Australia.

Western Australian Planning Commission (WAPC) 2003, *Planning Bulletin No. 64 - Acid Sulphate Soils.*

Western Australian Planning Commission (WAPC) 2006, *State Planning Policy 2.9: Water Resources*, Western Australian Government, Perth, Western Australia.

Western Australian Planning Commission (WAPC) 2008, *Acid Sulfate Soils Planning Guidelines*, Government of Western Australia, Perth.

Western Australian Planning Commission (WAPC) 2008, *Planning Bulletin 92: Urban Water Management*, Western Australian Government, Perth, Western Australia.

Western Australian Planning Commission (WAPC) 2013, *State Planning Policy 2.6:State Coastal Planning Policy,* Western Australian Government, Perth, Western Australia.

Western Australian Planning Commission (WAPC) and Department of Planning and Infrastructure 2008, *Better Urban Water Management,* Western Australian Government, Perth, Western Australia.

Western Australian Planning Commission and Department for Planning and Infrastructure (WAPC & DPI) 2009, Liveable Neighbourhoods (January 2009, Update 2), Western Australian Planning Commission, Perth.

Wood & Grieve Engineers (WGE) 2019, *Ocean Reef Marina Civil Engineering Utility Services Report,* unpublished report prepared for City of Joondalup, September 2019.

Worley Parsons 2007, *Ocean Reef Marina – Geological Desktop Study and Site Walkover*, prepared for the City of Joondalup.

10. Limitations

Scope of services

This report ("the report") has been prepared by Strategen-JBS&G in accordance with the scope of services set out in the contract, or as otherwise agreed, between the Client and Strategen-JBS&G. In some circumstances, a range of factors such as time, budget, access and/or site disturbance constraints may have limited the scope of services. This report is strictly limited to the matters stated in it and is not to be read as extending, by implication, to any other matter in connection with the matters addressed in it.

Reliance on data

In preparing the report, Strategen-JBS&G has relied upon data and other information provided by the Client and other individuals and organisations, most of which are referred to in the report ("the data"). Except as otherwise expressly stated in the report, Strategen-JBS&G has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report ("conclusions") are based in whole or part on the data, those conclusions are contingent upon the accuracy and completeness of the data. Strategen-JBS&G has also not attempted to determine whether any material matter has been omitted from the data. Strategen-JBS&G will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to Strategen-JBS&G. The making of any assumption does not imply that Strategen-JBS&G has made any enquiry to verify the correctness of that assumption.

The report is based on conditions encountered and information received at the time of preparation of this report or the time that site investigations were carried out. Strategen-JBS&G disclaims responsibility for any changes that may have occurred after this time. This report and any legal issues arising from it are governed by and construed in accordance with the law of Western Australia as at the date of this report.

Environmental conclusions

Within the limitations imposed by the scope of services, the preparation of this report has been undertaken and performed in a professional manner, in accordance with generally accepted environmental consulting practices. No other warranty, whether express or implied, is made.

The advice herein relates only to this project and all results conclusions and recommendations made should be reviewed by a competent person with experience in environmental investigations, before being used for any other purpose.

Strategen-JBS&G accepts no liability for use or interpretation by any person or body other than the client who commissioned the works. This report should not be reproduced without prior approval by the client, or amended in any way without prior approval by Strategen-JBS&G, and should not be relied upon by other parties, who should make their own enquiries.

Appendix A Local Water Management Strategy checklist

Checklist for assessment of local structure plan or local planning scheme amendment

1. Tick the status column for items for which information is provided.
2. Enter N/A in the status column if the item is not appropriate and enter the reason in the comments column.
3. Provide brief comments on any relevant issues.
4. Provide a brief description of any proposed best management practices, e.g. multi-use corridors, community based-social marketing, water re-use proposals.

LWMS item	Deliverable	Included?	Location in text
Executive summary			
Summary of the development design strategy, outlining how the design objectives are proposed to be met	Table 1: Design elements and requirements for BMPs and critical control points	✓	Table ES-1
Introduction			
Total water cycle management – principles & objectives Planning background Previous studies		✓	Sections 1 and 2
Proposed development			
Structure plan, zoning and land use. Key landscape features Previous land use	Site context plan Structure plan	✓ ✓	Section 2.1-2.2, 4.1, Figure 4.1
Landscape - proposed POS areas, POS credits, water source, bore(s), lake details, irrigation areas (if applicable)	Landscape Plan	✓	Section 2.3, Figure 2-3, Section 5.3
Design criteria			
Agreed design objectives and source of objectives		✓	Section 3
Pre-development environment			
Existing information and more detailed assessments (monitoring). How do the site characteristics affect the design?		✓	Section 4, 5
Site Conditions - existing topography/ contours, aerial photo underlay, major physical features	Site condition plan	✓	Figure 4-3
Geotechnical - topography, soils including acid sulfate soils and infiltration capacity, test pit locations	Geotechnical plan	✓	Section 4.5, Figure 4-4
Environmental - areas of significant flora and fauna, wetlands and buffers, waterways and buffers, contaminated sites	Environmental Plan plus supporting data where appropriate	✓	Section 4.8 -4.10, Figure 4-3.
Surface Water – topography, 100 year floodways and flood fringe areas, water quality of flows entering and leaving (if applicable)		✓	Section 4.6
Groundwater – topography, pre development groundwater levels and water quality, test bore locations	Groundwater Plan plus site investigation	✓	Section 4.7, Figure 4-7.
Water sustainability initiatives			
Water efficiency measures – private and public open spaces including method of enforcement		✓	Section 5.2
Water supply (fit-for-purpose), agreed actions and implementation		✓	Sections 5.1 -5.4
Wastewater management		✓	Section 5.1.2

LWMS item	Deliverable	Included?	Location in text
Stormwater management strategy			
Flood protection - peak flow rates, volumes and top water levels at control points,100 year flow paths and 100 year detention storage areas	100yr event plan Long section of critical points	n/a n/a	Section 7.1, 7.2
Manage serviceability - storage and retention required for the critical 5 year ARI storm events Minor roads should be passable in the 5 year ARI event	5 yr event plan	n/a	Section 7.1, 7.2
Protect ecology – detention areas for the 1 yr 1 hr ARI event, areas for water quality treatment and types of agreed structural and non-structural best management practices and treatment trains (including indicative locations). Protection of waterways, wetlands (and their buffers), remnant vegetation and ecological linkages	1yr event plan Typical cross sections	✓ n/a	Section 7.1, 7.2 Figure 7-1
Groundwater management strategy			
Post development groundwater levels, existing and likely final surface levels, outlet controls, and subsoils areas/exclusion zones	Groundwater/subsoil plan	✓	Section 6 Figure 4-7
Actions to address acid sulfate soils or contamination		✓	Section 4.5
The next stage – subdivision and urban water management plans			
Content and coverage of future urban water management plans to be completed at subdivision. Include areas where further investigations are required before to detailed design.		✓	Section 8.5
Monitoring			
Recommended future monitoring plan including timing, frequency, locations and parameters, together with arrangements for ongoing actions		✓	Section 8.4
Implementation			
Developer commitments		✓	Section 8.2
Roles, responsibilities, funding for implementation		✓	Section 8.1 – 8.2
Review		✓	Section 8.3

Appendix B Design groundwater levels and water quality results

Level 2, 322 Hay Street Subiaco WA 6008 PO Box 243 Subiaco WA 6904
Phone (08) 9380 3100 Fax (08) 9380 4606
177 Spencer Street Bunbury WA 6230 PO Box 287 Bunbury WA 6231
Phone (08) 9792 4797 Fax (08) 9792 4708

To: Genevieve Hunter

Company: City of Joondalup

Fax/email: Genevieve.hunter@joondalup.wa.gov.au

Date: 5 February 2015

Project No: COJ14134.01

Inquiries: L Adams/ M Dunlop

Ocean Reef Marina Development
Design groundwater levels and water quality results

Introduction

The District Water Management Strategy (DWMS) for the Ocean Reef Marina Site (ORM) identified that groundwater monitoring was required:

- to develop a design groundwater level (DGL) to set finished surface levels for the site
- establish baseline water quality (including nutrients)
- confirm the water quality assumptions of the previously undertaken marina flushing studies, which used data available at the time.

A monitoring program was developed in parallel with the DWMS and approved by Department of Water (DoW). The aim of this program was to assess groundwater quality, and to estimate the maximum groundwater levels (MGL) on the site, to be used in setting the design groundwater levels (DGL) as required in the DWMS (Strategen 2014). A design groundwater level (DGL) is the water level used as input into design of the development surface contours. Where subsoil drainage is used to control groundwater levels, the DGL may vary from the MGL. Subsoil drainage is expensive and is generally only used at sites that experience seasonal inundation or waterlogging. The use of subsoil drainage is not proposed at the ORM (Strategen 2014).

Consistent with DoW procedure for extreme surface water level events, the MGL has been based on a 1 in 100-year Average Return Interval sea level event (i.e. highest sea level anticipated to occur once in every 100 years on average) to reflect the anticipated maximum groundwater level. The MGL also takes the anticipated effects of sea level rise on groundwater levels on the Site into account.

This report outlines the findings of the approved groundwater monitoring program and groundwater level assessment at ORM.

Groundwater level monitoring

The monitoring program involved use of data loggers in four bores over six months to confirm the understanding of groundwater levels developed above (Figure 1). This included three new bores on the site and a Department of Water monitoring bore to the south of the site. The loggers recorded groundwater levels every five minutes over a six-month period between 6 June and 10 December 2014.

Groundwater quality monitoring

Three groundwater quality monitoring events were undertaken. Parameters monitored included:

- field measurements of pH, electrical conductivity (EC), total dissolved solids (TDS), redox
- laboratory analysis of water samples for total nitrogen, total phosphorus, phosphate, nitrate/nitrite, ammonia, Kjeldahl nitrogen
- laboratory analysis for the standard eight heavy metals (As, Cd, Cu, Cr, Pb, Ni, Zn, Hg).

Figure 1 Bore Locations

Scale 1:6,500 at A4

0 40 80 120 160 200 m

Coordinate System: GDA 1994 MGA Zone 50
Note that positional errors may occur in some areas
Date: 13/01/2015
Author: JCrute
Source: Aerial image: Landgate 09/2012. Proposal Area: CAD Resources 2013.
Path: Q:\Consult\2014\COJ\CJO14134\ArcMap_documents\M001\RevA\COJ14134_01_M001_RevA_F001.mxd

Legend

- WIN Site bore
- Monitoring bores
- MRS Amendment Boundary

STRATEGEN
info@strategen.com.au
www.strategen.com.au

Groundwater levels

<u>Background</u>

Groundwater levels in coastal areas such as Ocean Reef are influenced by:

- seasonal recharge (i.e. rainfall)
- groundwater abstractions
- sea level variation caused by seasonal patterns, tidal influences and storm surge.

As distance from the coast increases, the impact of sea level variation on groundwater levels will decrease. Because of the high hydraulic conductivity of the Tamala Limestone and limited groundwater abstraction in the project area, the key factors anticipated to impact on water levels at ORM were considered to be seasonal recharge and sea level variation.

Data from data loggers on the Site over the monitoring period recording has been compared to the five minute interval sea level data obtained from the Department of Transport (DoT) tide gauge at Fremantle Fishing Boat Harbour. The Fremantle site has been used for determination of sea level and storm impacts on ORM by MP Rogers and is consequently considered the most appropriate site for this purpose. The groundwater monitoring program included a data logger in a long-term DoW monitoring bore 4931 located approximately 200 m south of the site (Figure 1). Groundwater level had been recorded in this bore from 1982 to 2011 (Figure 2).

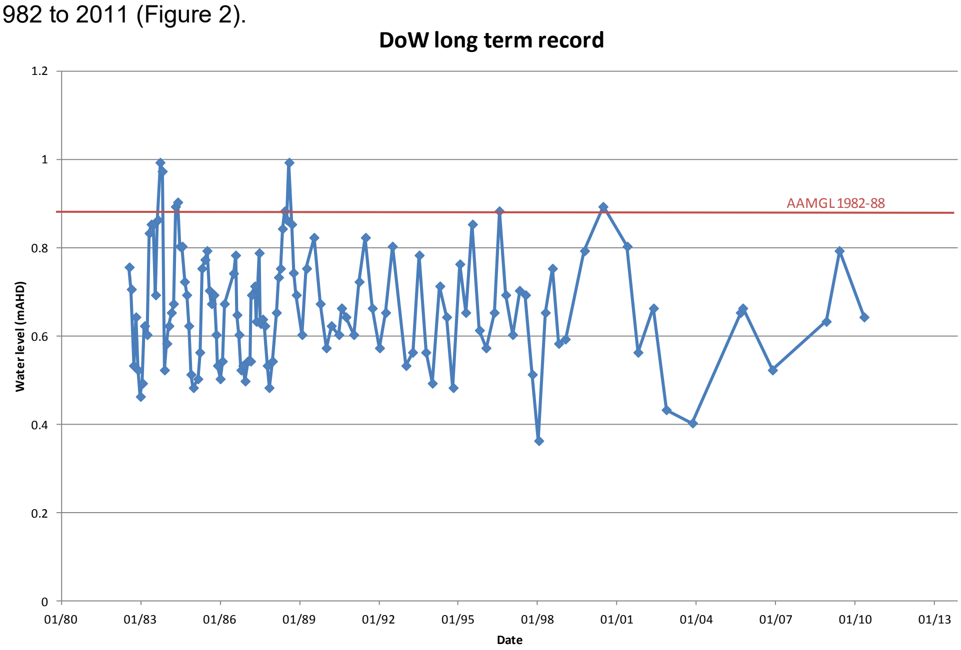


Figure 2: Historical water levels at DoW Bore 4931, 1982-2011

Source: DoW

Sea level variation can be divided into three components:

- seasonal variations due to variations in the Earth's orbit
- tidal variations
- storm surge.

Seasonal and tidal variations are well understood and can be predicted (Figure 3). At Fremantle, the DoT predicted sea levels to vary between approximately -0.3 and 0.6 mAHD over the monitoring period of 6 June to 31 November 2014, with a generally decreasing trend due to seasonal effects (Figure 3). The actual sea levels follow a similar trend, although the water levels diverge during storm events (Figure 3). The observed sea level over this period varied from -0.52 to 1.04 mAHD (blue line in Figure 4). The majority of storm events occurred between June and September (Figure 4). Storm events after September generally resulted in less extreme sea levels (Figure 4).

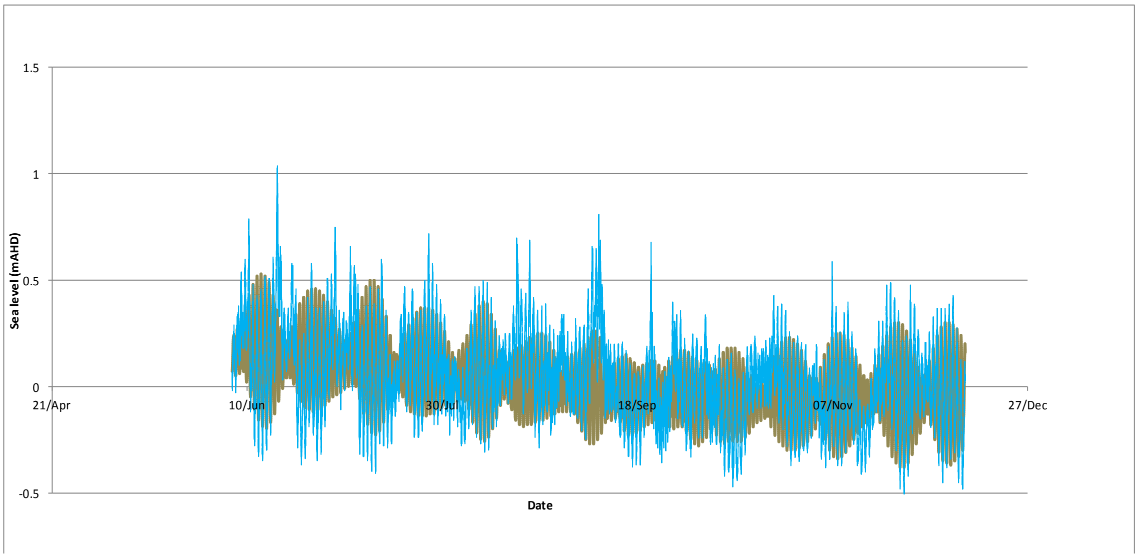


Figure 3: Predicted (brown) and actual (blue) sea level at Fremantle.

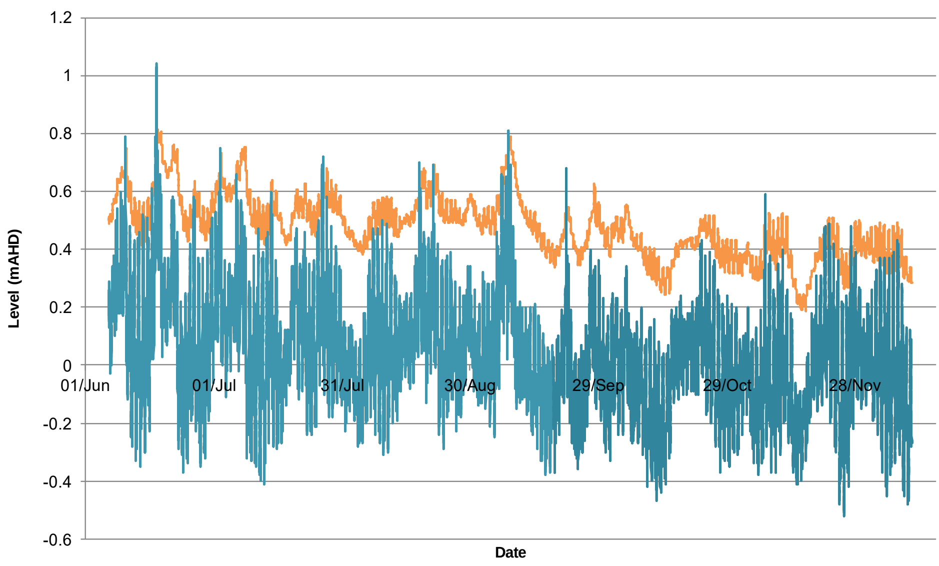


Figure 4: Observed sea level at Fremantle (blue) and groundwater level at MB03 (orange).

The highest sea level recorded during the monitoring period was 1.04 mAHD on 17 June 2014, equivalent to 181 cm Chart Datum (cm CD) using the Fremantle chart datum[1]. This corresponds to a 1 in 2 to 1 in 3-year average return interval (ARI) storm (Figure 5 [source: MP Rogers & Associates 2014]). All other storm events during the monitoring period were less than the 1 in 1-year ARI event. In a 1 in 100-year storm event, a sea level of 209 cmCD (1.32 mAHD) is anticipated (Figure 5).

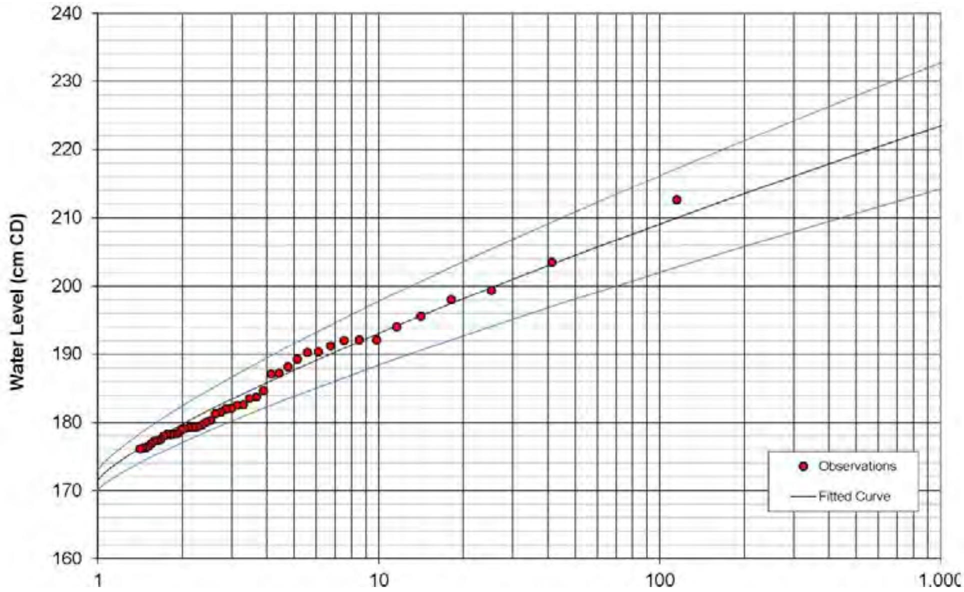


Figure 5 Extreme sea levels at Fremantle for different Average Return Intervals (ARI)

Monitored groundwater levels

Review of the groundwater data from all bores indicated that sea level, rather than recharge from rainfall was the key factor driving groundwater levels at ORM (Figure 6, Figure 8). If groundwater were driven by rainfall, groundwater levels would be expected to peak around October, as is common in the metropolitan area. Instead, high groundwater levels occurred between June and early September, when sea levels were higher and the larger storms occurred. Variations in groundwater levels up to 0.25 m occurred as a result of storm events (Figure 4, Figure 6 to Figure 8).

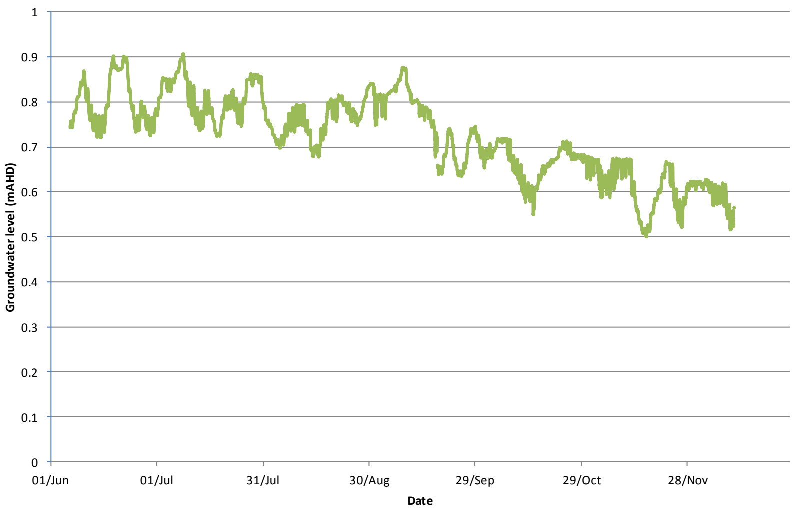


Figure 6: Groundwater levels at MB01 over monitoring period

[1] 0 cmCD (chart datum) is equivalent to 0.77 mAHD at Fremantle.

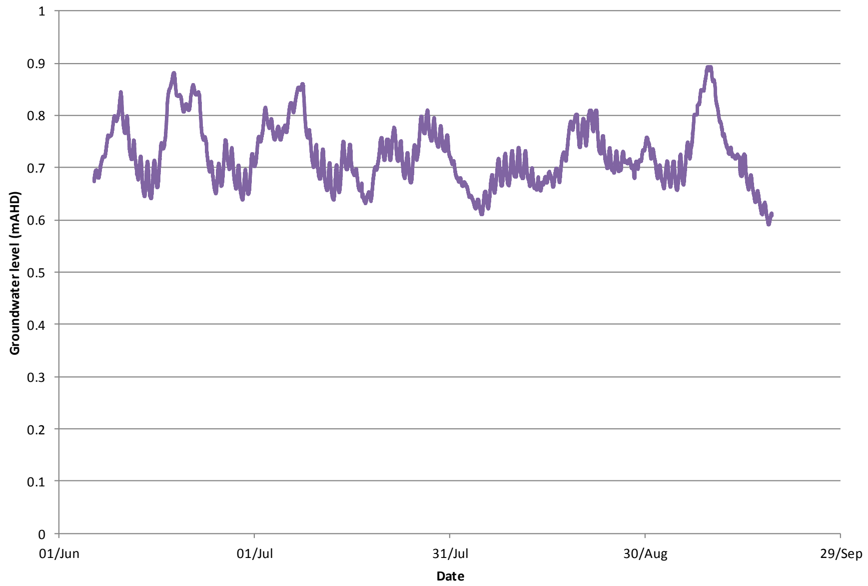


Figure 7: Groundwater levels at MB02.

The data logger in MB02 experienced problems with growth of bacteria on the logger after the 18 September monitoring event, which affected reading accuracy. Attempts were made resolve this issue by recalibration and regular cleaning but the accuracy issue was not resolved. As all but one of the major storm events occurred prior to this date, this was not a concern in using the logger data to calculate groundwater levels.

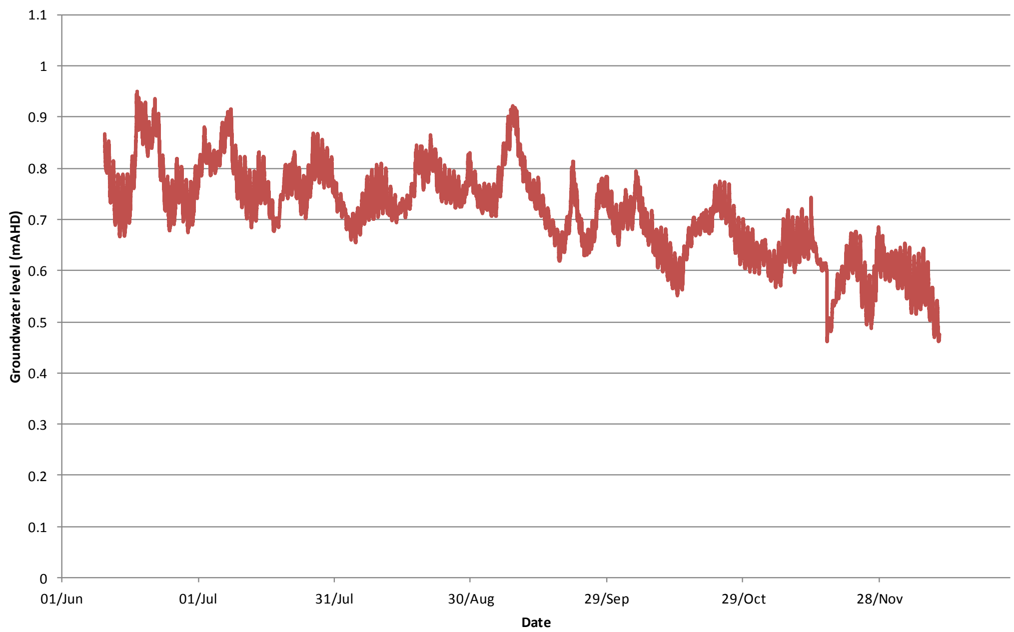


Figure 8: Groundwater levels at DoW over the monitoring period

Groundwater levels at MB03, approximately 100 m from the coast, were approximately 0.2 m lower than observed in the other three bores, which were located 200 to 300 m from the coast (Figure 4, Figure 6 to Figure 8). Groundwater levels in MB01, MB02 and MB03 were relatively similar, with peak groundwater levels in the order of 0.95 m in all bores (Figure 4, Figure 7,and Figure 8).

On this basis, the likely groundwater level to occur as a result of a 1 in 100 year ARI storm event was adopted as the maximum groundwater level. This required first determining the relationship between changes in sea level and changes in groundwater level in the bore, based on change in sea level and change in groundwater level for the largest nine storm events during the monitoring period (sea level greater than 0.63 mAHD or 140 cmCD). To determine the groundwater level, baseline sea levels and baseline groundwater levels were set.

Impact of sea level changes on groundwater levels during the monitoring period

The impact of sea level changes on groundwater levels under normal conditions were investigated using the monitoring data. For each bore, this was estimated by:

- measuring the variation between maximum and minimum sea levels over each tide cycle (sea level variation)
- measuring the corresponding variation between maximum and minimum groundwater levels over the equivalent tidal cycle in groundwater (noting that groundwater levels lagged behind tide levels) (groundwater variation)
- establishing a correlation between changes in sea levels and groundwater levels.

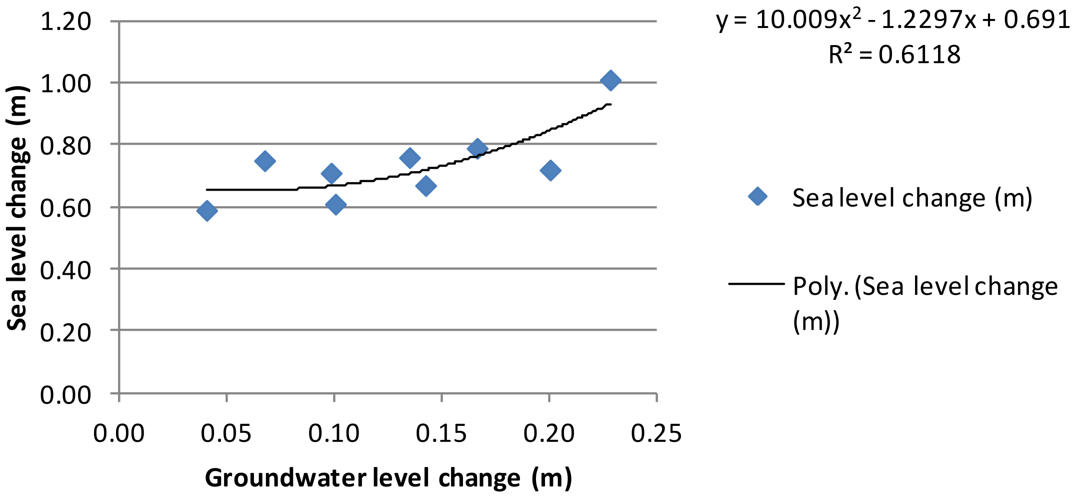
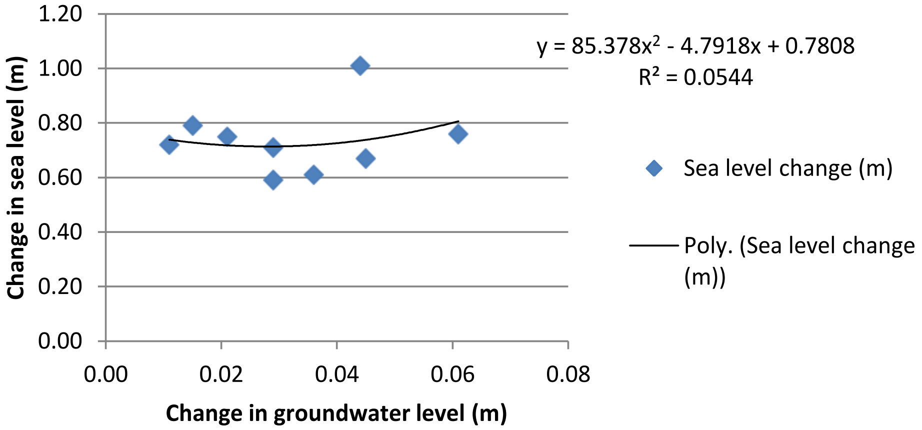


Figure 9: Groundwater level variation correlated against sea level variation for bore MB03

This process worked reasonably effectively for MB03, with an R^2 value (coefficient of determination) of 0.61 using a quadratic function (Figure 9). Results for MB01 showed a coefficient of determination of less than 0.1 (Figure 10). In MB01, the groundwater variation was 0.01 to 0.06 m (Figure 10), compared to 0.04 to 0.17 m in MB03 (Figure 9). Changes in groundwater levels at MB02 and DoW were also in the order of 0.1 to 0.2 m.

When MB01 was drilled, a vug or cavern was encountered from approximately 1.5 m above the groundwater table to 0.5 m below the groundwater table. The presence of this vug could affect the way in which the groundwater table changes, as a considerable volume of water may be required to fill the vug making groundwater levels less responsive to sea level changes than would otherwise be the case.



ore MB01

Groundwater level variations of up to 0.21 m were noted as a possible result of sea level effects in the DoW bore (Figure 11). This bore also showed a relatively low correlation (R^2 value of less than 0.2) between sea level and groundwater level. The reason for this low correlation value is not as clear as it indicates that the water level observations have been influenced by factors other than variations in sea level.

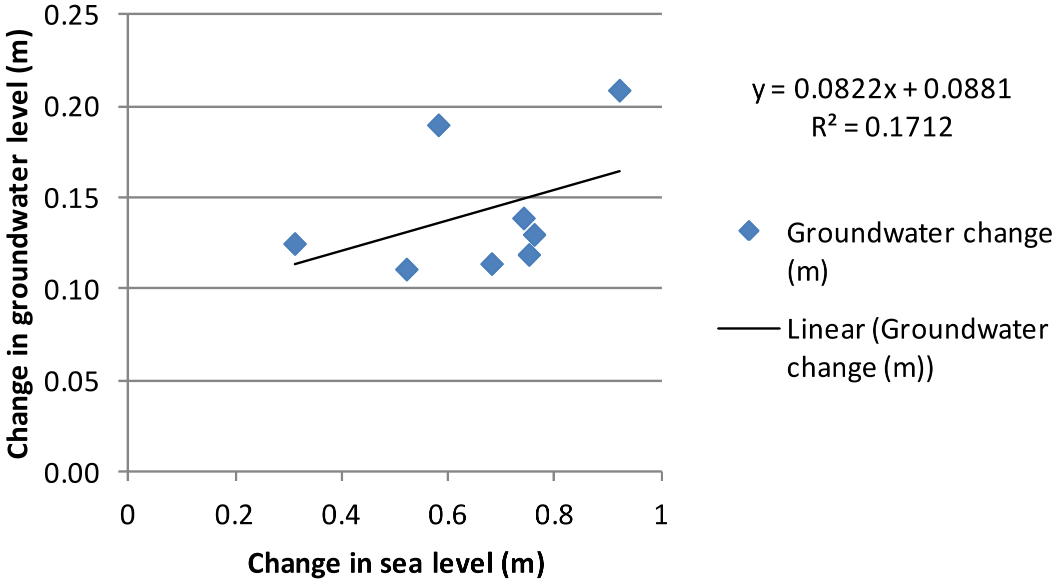


Figure 11: Groundwater level variation correlated against sea level variation for bore DoW

Good correlation between changes in sea level and groundwater level were also observed at MB02, with a coefficient of determination of 0.49 (Figure 12).

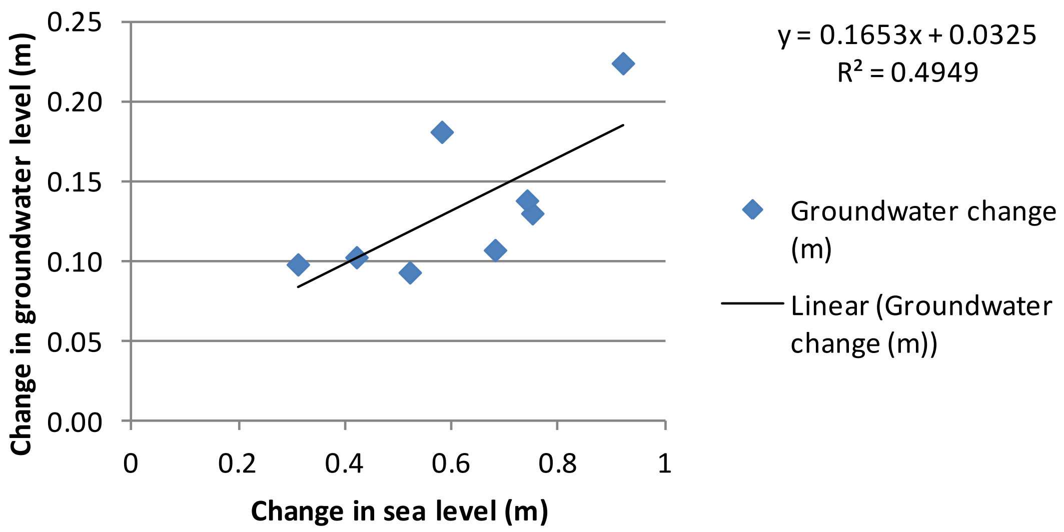


Figure 12: Groundwater level variation correlated against sea level variation for bore MB02

The coefficient of determination for MB02 and MB03 were considered sufficient for these relationships to be used to predict the impact of sea level variation due to storm surge on groundwater data. As DoW, MB01 and MB02 were a similar distance from the coast and were considered to behave similarly, use of the same equation and starting water levels for all three bores was considered appropriate.

__Groundwater levels in extreme events__

To use the equations to determine groundwater levels as a result of an event, a starting sea level and starting groundwater level must be set.

The method used by Strategen in determining changes in groundwater levels considered the change in water level over a storm event from the previous tidal low. The starting sea level; therefore, needs to represent a likely low tide level.

Sea levels at Fremantle vary significantly, with the lowest predicted astronomical tide (LAT) being -20 cmCD (-0.97 mAHD) and the highest predicted astronomical tide (HAT) being 134 cmCD (0.57 mAHD) (Figure 13 [source: Department of Transport 2004]). Events above HAT and below LAT do occur (Figure 13); however, these are the result of specific climatic events such as storm surge.

A low tide sea level of -0.18 mAHD or 59 cmCD was adopted to assess changes in sea level as a result of any storm event. This corresponds to the average of mean high low water [MHLW] and mean low low water [MLLW]). Water levels at Fremantle lower than this starting water level occur 35% of the time (Figure 13).

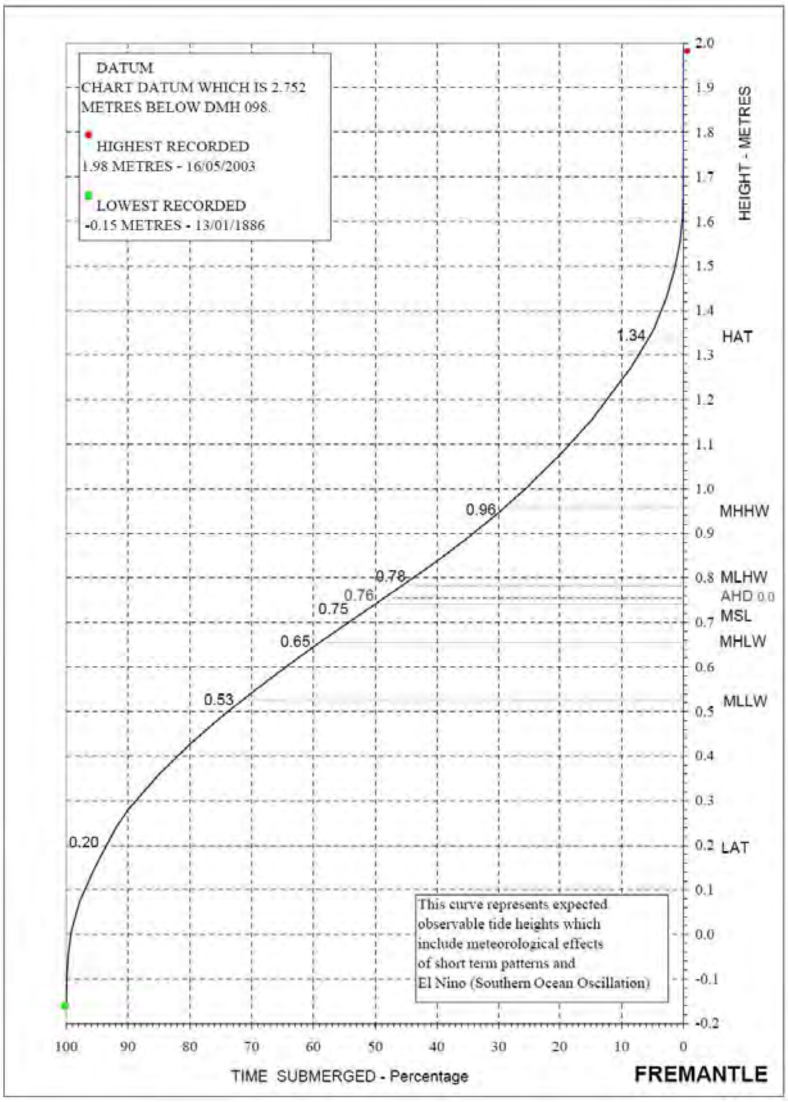


Figure 13: Submergence curve for Fremantle

Data from the DoW bore from 1982 to 1988 was used to set the baseline groundwater level at MB02. As the readings were taken monthly during this period[2], the coincidence of monitoring events with storm events was effectively random. As such, there was the possibility that some of the higher readings were taken during storm events. Given the frequency of monitoring, not all high water levels would be related to storm events. An initial water level of 0.876 mAHD was set for MB02 based on the review of the groundwater level recorded at the DoW bore from the period of monthly monitoring between 1982 and 1988 (Figure 2). This represents the average of the maximum water levels between 1982 and 1988. This level was exceeded at DoW several times during the Strategen monitoring period (Figure 8).

Long-term groundwater level data was not available at MB03. An initial groundwater level of 0.6 mAHD was set at MB03 based on review of the median water level over the period when larger storms occurred (i.e. June to August 2014) (Figure 4).

The rise in groundwater levels at MB03 was calculated using the equation shown in Figure 9 with the following results:

- 0.33 mAHD in a 1 in 1 year ARI storm surge event

[2] Readings are less frequent after 1988, reducing to every two months in 1989 and quarterly from 1991.

- 0.36 mAHD in a 1 in 10 year ARI storm surge event
- 0.39 mAHD in a 1 in 100 year ARI storm surge event.

Assuming starting water level without storm surge occurring of 0.6 mAHD results in estimated peak groundwater levels at MB03 of:

- 0.93 mAHD in a 1 in 1 year ARI storm surge event
- 0.96 mAHD in a 1 in 10 year ARI storm surge event
- 0.99 mAHD in a 1 in 100 year ARI storm surge event.

The rise in groundwater levels at MB02 was calculated using the equation shown in Figure 12 with the following results:

- 0.27 m in a 1 in 1 year ARI storm surge event
- 0.29 m in a 1 in 10 year ARI storm surge event
- 0.32 m in a 1 in 100 year ARI storm surge event.

Estimated changes in groundwater level at MB02 in extreme events are less than at MB03. This is to be expected, as MB03 is closer to the coast. Assuming a starting water level without storm surge of 0.876 mAHD results in estimated peak groundwater levels at MB02 of:

- 1.14 mAHD in a 1 in 1 year ARI storm surge event
- 1.16 mAHD in a 1 in 10 year ARI storm surge event
- 1.19 mAHD in a 1 in 100 year ARI storm surge event.

For the reasons outlined above, the maximum groundwater level at MB02 is considered to be equivalent the MGL at MB01 and DoW.

These levels do not take into account sea level rise due to climate change.

Maximum and design groundwater level

Climate change is estimated to result in a rise in sea level of 0.3 m by 2060 and 0.9 m by 2110 (DoT 2010). Rises in sea level due to climate change are not cyclical like tides or storm surge and are not impacted by tidal or storm surge influences. Due to the location of ORM on the coast, a rise in sea level as a result of climate change is anticipated to result in an equivalent rise in groundwater levels on the assumption that the other factors affecting groundwater flow and levels will remain constant. This assumption results in an estimated MGL for 2110 of:

- 1.89 mAHD at MB03
- 2.19 mAHD at the other bores (Figure 14).

This MGL will be used as the DGL at ORM.

Water quality results

Physicochemical results

Average pH in the four bores varied between 7.45 at MB01 and 8.0 at MB03 (Attachment A). This is slightly below the ANZECC and ARMCANZ (2000) guidelines for slightly disturbed marine inshore ecosystems of 8.0 to 8.4. Marine ecosystems tend to have higher pH values than inland waters because of a relatively higher carbonate concentration than fresh waters. Groundwater at this site, although very close to the ocean, is still part of a freshwater system expected to have physiochemical parameters closer to a fresh water lake. As a result, pH values observed are considered to reflect the natural water quality regime.

Electrical conductivities varied from an average of 1082 µS/cm at MB02 to 1797 µS/cm at MB03, which was closest to the coast. This indicates that the groundwater present was fresh to brackish.

Figure 14 Design Groundwater Level

Scale 1:6,500 at A4

0 40 80 120 160 200 m

Coordinate System: GDA 1994 MGA Zone 50

Note that positional errors may occur in some areas

Date: 13/01/2015

Author: JCrute

Source: Aerial image: Landgate 09/2012. Proposal Area: CAD Resources 2013. Groundwater contours: DoW 2001.

Legend

- WIN Site bore
- Monitoring bores
- Design groundwater level contour (mAHD)
- MRS Amendment Boundary
- 2.09 Design groundwater level (mAHD)

STRATEGEN
info@strategen.com.au
www.strategen.com.au

Path: Q:\Consult\2014\COJ\CJO14134\ArcMap_documents\M001\RevA\COJ14134_01_M001_RevA_F014.mxd

Nutrients

The average groundwater concentrations of total nitrogen (TN) and total phosphorus (TP) were above the ANZECC and ARMCANZ (2000) guidelines for slightly disturbed marine inshore ecosystems, as shown in Table 1. Average TN concentrations varied from 3 mg/L at MB03 to 12.7 mg/L at MB01, compared to a guideline of 0.23 mg/L (Table 1). Average TP varied from <0.05 mg/L at MB01 to 0.29 mg/L at DoW, compared to a guideline value of 0.02 mg/L. These exceedances are considered to reflect impacts from fertiliser and other nutrient sources in the residential areas to the east of the Site.

Table 1: Nutrients results

Ocean Reef groundwater quality		Nutrients							
		Ammonia as N	NOx as N	Nitrite as N	Nitrate as N	Total Kjeldahl Nitrogen as N	Total N	Total P	Reactive Phosphorus as P
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PQL		0.005	0.005	0.005	0.005	0.1	0.1	0.05	0.005
ANZECC & ARMCANZ (2000) guidelines		0.005	0.005	0.005	0.005	NV	0.23	0.02	0.005
Sample ID	**Sample Date**								
MB01	10/06/2014	<0.005	11	<0.005	11	1.9	13	<0.05	0.01
	18/09/2014	<0.005	11	<0.005	11	2.1	13	0.08	0.015
	11/12/2014	<0.005	11	<0.005	11	1.3	12	<0.05	0.014
	Average	<0.005	11	<0.005	11	1.8	12.7	<0.05	0.013
MB02	10/06/2014	<0.005	7.4	<0.005	7.4	1.4	8.8	<0.05	0.019
	18/09/2014	<0.005	7.7	<0.005	7.7	1.9	9.6	0.05	0.028
	11/12/2014	<0.005	8	<0.005	8	<0.5	8.2	0.11	0.038
	Average	<0.005	7.7	<0.005	7.9	0.7	8.9	0.1	0.011
MB03	10/06/2014	<0.005	3.2	<0.005	3.2	0.4	3.7	<0.05	0.006
	18/09/2014	0.01	3.4	<0.005	3.4	<0.2	3.4	0.1	<0.005
	11/12/2014	<0.005	1.8	<0.005	1.8	<0.1	1.9	0.06	<0.005
	Average	0.005	2.8	<0.005	2.80	0.18	3.00	0.05	<0.005
DoW	10/06/2014	<0.005	0.073	0.018	0.055	0.6	0.6	<0.05	0.007
	18/09/2014	<0.005	11	<0.005	11	1.7	13	0.07	0.012
	11/12/2014	<0.005	0.18	<0.005	0.18	0.5	0.7	0.76	0.79
	Average	<0.005	0.18	0.008	3.75	0.93	4.77	0.29	0.27

As previously identified, these results are slightly different from the historic values quoted in the Rockwater (2011) groundwater modelling report and used by MP Rogers to model nutrient inputs from groundwater into the marina. Rockwater (2011) indicates a TN range of 0.5–7.1 mg/L and a TP range of <0.01–0.5 mg/L. This means the nutrient concentrations were not constant over the model domain. From the data in the Rockwater (2011) report, it appears that the model used:

- 1–5 mg/L for TN near the marina, compared to 3–12.7 mg/L as identified from the current Strategen sampling
- a value of <0.1 mg/L for TP, compared to <0.05–0.29 mg/L as identified by Strategen.

These discrepancies may result in the Rockwater model underestimating the nutrient loads entering the marina via groundwater. As previously discussed with MP Rogers, the groundwater model may need to be revised to reflect these increases in nutrient concentrations. Potential reasons for this include:

1. The age of the results. The DoW results used by Rockwater (2011) are from the 1970s to early 1990s. Since this time, the Ocean Reef area has become increasingly urbanised, leading to an increase in nutrient loads compared to the former state of native bush. The surrounding area appears to have been mostly developed in the late 1970s and early 1980s.
2. Depths of the bores. The bores used by Strategen are screened in the top few metres of the aquifer, as is common for bores used to determine groundwater levels and quality for a LWMS. DoW bores are often deeper than this (as implied by having a WF8 and WF8 shallow as listed in Rockwater [2011]). Water quality in shallower bores often shows more elevated concentrations of pollutants than deeper bores as these are more affected by inputs of contaminants at the surface.

The marina water quality modelling is being undertaken by MP Rogers, which is responsible for the accuracy of the inputs to the model. Strategen can assist MP Rogers if additional monitoring is required to support this model.

Metals

Average metals concentrations were generally below the ANZECC and ARMCANZ (2000) 95% trigger values for marine environments, except for:

- zinc at the DoW bore
- nickel in MB01 and MB03
- copper in MB01 and the DoW bore (Table 2, Attachment A).

Elevated concentrations of zinc are common in groundwater in the northern suburbs (Bekele 2006), probably as a result of naturally high levels of zinc in soils. This is consequently not considered to be of concern.

Elevated concentrations of copper are also common in groundwater in the northern suburbs (Bekele 2006), and may be a result of naturally high concentrations in soils or the use of copper pipes for water supply, which can result in elevated levels of copper in soils where such water is used for irrigation.

Slightly elevated concentrations of nickel were noted in groundwater. Bekele (2006) does not address nickel concentrations in groundwater. Given the wide distribution of elevated nickel concentrations, this is possibly due to natural nickel concentrations in the area.

One exceedance of the lead guideline was noted within the DoW bore (Table 2, Attachment A). This exceedance is slight (0.005 mg/L compared to a guideline of 0.0044 mg/L) and the DoW bore is outside the project area (Figure 1), so this is not considered to be of concern.

Table 2: Metals concentrations

Ocean Reef groundwater quality		Metals							Phy
		Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PQL		0.001	0.0001	0.001	0.001	0.001	0.00005	0.001	0.001
ANZECC & ARMCANZ (2000) guidelines		NV	0.0007	0.0274 for Cr(III), 0.0044 for Cr(IV)	0.0013	0.0044	0.0001	0.007	0.015
Sample ID	**Sample Date**								
MB01	10/06/2014	0.001	<0.0001	0.002	0.002	<0.001	<0.00005	0.006	0.01
	18/09/2014	<0.001	<0.0001	0.002	0.002	<0.001	<0.00005	0.002	0.019
	11/12/2014	<0.001	<0.0001	0.002	<0.001	<0.001	<0.00005	0.015	0.004
	Average	0.0007	<0.0001	0.002	0.0015	<0.001	<0.00005	0.0077	0.011
MB02	10/06/2014	0.002	<0.0001	0.001	0.003	<0.001	<0.00005	0.005	0.017
	18/09/2014	0.002	<0.0001	0.001	0.001	<0.001	<0.00005	0.003	0.016
	11/12/2014	0.002	<0.0001	0.001		<0.001	<0.00005	0.009	0.001
	Average	0.002	<0.0001	0.001	0.001	<0.001	<0.0005	0.006	0.0085
MB03	10/06/2014	0.002	<0.0001	0.001	<0.001	<0.001	<0.00005	0.003	0.008
	18/09/2014	0.002	<0.0001	0.001	0.004	<0.001	<0.00005	0.007	0.012
	11/12/2014	0.002	<0.0001	0.001	0.011	<0.001	<0.00005	0.046	0.011
	Average	0.002	<0.0001	0.001	0.0075	<0.001	<0.0005	0.019	0.010
DoW	10/06/2014	0.002	<0.0001	<0.001	0.005	0.003	<0.00005	0.004	0.058
	18/09/2014	<0.001	<0.0001	0.002	<0.001	<0.001	<0.00005	0.002	0.013
	11/12/2014	0.001	<0.0001	<0.001	0.057	0.005	<0.00005	0.007	0.31
	Average	0.00	<0.0001	0.001	0.021	0.003	<0.00005	0.004	0.127

Additional discussion of metals results for soils and groundwater will be provided in the Detailed Site Investigation (DSI). The DSI also includes metals results for other bores installed on the site specifically for that purpose.

References

ANZECC (Australian and New Zealand Environment and Conservation Council) and ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand) 2000, *Australian Guidelines for Water Quality Monitoring and Reporting*, National Water Quality Management Strategy Paper No. 7, Canberra.

Bekele E 2006 *Compilation and Assessment of Groundwater Quality Data for the Superficial Aquifer, Gnangara Mound, Western Australia,* CSIRO, Perth.

Department of Transport 2004, *Fremantle Submergence Curve,* Department of Transport, Perth.

Rockwater 2011, *Ocean Reef Marina, Groundwater Modelling to Assess Nutrient Loads to the Ocean and Marina,* unpublished report to MP Rogers, June 2011.

Ocean Reef groundwater quality

		Metals								Physico-chemical					
		Arsenic	**Cadmium**	**Chromium**	**Copper**	**Lead**	**Mercury**	**Nickel**	**Zinc**	**pH**	**Electrical Conductivity**	**Temp**	**Dissolved Oxygen**	**Dissolved Oxygen**	**Redox**
Units		*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	pH Unit	*µs/cm*	oC	ppm	%	mV
PQL		0.001	0.0001	0.001	0.001	0.001	0.00005	0.001	0.001	-	-	-	-	-	-
ANZECC & ARMCANZ (2000) guidelines		NV	0.0007	0.0274 for Cr(III), 0.0044 for Cr(IV)	0.0013	0.0044	0.0001	0.007	0.015	8.0-8.4	NV	NV	NV	NV	NV
Sample ID	**Sample Date**														
MB01	10/06/2014	0.001	<0.0001	0.002	0.002	<0.001	<0.00005	0.006	0.01	7.14	1233	20.8	7.7	86.3	85.7
	18/09/2014	<0.001	<0.0001	0.002	0.002	<0.001	<0.00005	0.002	0.019	7.2	1171	20.8	4.76	NT	128
	11/12/2014	<0.001	<0.0001	0.002	<0.001	<0.001	<0.00005	0.015	0.004	7.7	1200	22.1	NT	65.9	111.3
	Average	0.0007	<0.0001	0.002	0.0015	<0.001	<0.00005	0.0077	0.011	7.45	1185.5	21.45	4.76	65.9	119.65
MB02	10/06/2014	0.002	<0.0001	0.001	0.003	<0.001	<0.00005	0.005	0.017	7.3	1129	20.6	8.17	91.5	90.4
	18/09/2014	0.002	<0.0001	0.001	0.001	<0.001	<0.00005	0.003	0.016	7.42	1065	20.6	5.44	NT	112
	11/12/2014	0.002	<0.0001	0.001		<0.001	<0.00005	0.009	0.001	7.9	1100	22.9	NT	79.1	95.1
	Average	0.002	<0.0001	0.001	0.001	<0.001	<0.0005	0.006	0.0085	7.66	1082.5	21.75	5.44	79.1	103.55
MB03	10/06/2014	0.002	<0.0001	0.001	<0.001	<0.001	<0.00005	0.003	0.008	7.87	1543	21.4	7.82	90.8	80.4
	18/09/2014	0.002	<0.0001	0.001	0.004	<0.001	<0.00005	0.007	0.012	7.97	1847	21.9	5.8	NT	85
	11/12/2014	0.002	<0.0001	0.001	0.011	<0.001	<0.00005	0.046	0.011	8.2	2000	35.6	NT	78.0	132.2
	Average	0.002	<0.0001	0.001	0.0075	<0.001	<0.0005	0.019	0.010	8.0	1797	26.3	6.81	84.4	99.2
DoW	10/06/2014	0.002	<0.0001	<0.001	0.005	0.003	<0.00005	0.004	0.058	7.48	1216	20.1	3.85	40.2	71.4
	18/09/2014	<0.001	<0.0001	0.002	<0.001	<0.001	<0.00005	0.002	0.013	7.22	1171	20.9	4.75	NT	129
	11/12/2014	0.001	<0.0001	<0.001	0.057	0.005	<0.00005	0.007	0.31	8.4	1200	22	NT	103.6	112.8
	Average	0.00	<0.0001	0.001	0.021	0.003	<0.00005	0.004	0.127	7.70	1195.67	21.00	4.30	71.90	104.40

Quality Control	
MB03	10/06/2014
DUP	10/06/2014
PQLx5	
Relative Percent Difference	

Quality Control											
MB02	11/12/2014	0.002	<0.0001	0.001	0	<0.001	<0.00005	0.009	0.001	7.9	1100
DUP	11/12/2014	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.00005	<0.001	<0.001	7.9	1100
PQLx5		0.005	0.0005	0.005	0.005	0.005	0.00025	0.005	0.005	-	-
Relative Percent Difference		*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*0%*	*0%*

Document Distribution

Rev No.	Copies	Recipient	Date
E	Electronic	DevelopmentWA, TBB	22 November 2019

Document Status

Rev No.	Author	Reviewer	Approved for Issue		
		Name	Name	Signature	Date
E	J. Hunt	D. Newsome	D. Newsome		22 November 2019

www.jbsg.com.au