Water Quality

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Chapter 17 - Table of Contents

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17.1 Introduction

The proposed resort has been designed to protect and enhance the chemical and physical characteristics of surface waters of the island and the Great Barrier Reef Marine Park. This chapter of the EIS provides an assessment of water quality objectives applicable to the site and proposed stormwater management strategies to mitigate potential impacts of any discharges from the proposed resort on sensitive receiving waters. It details the chemical and physical characteristics of surface waters within the area that may be affected by the project, including a description of water quality variability associated with climatic and seasonal factors.

The geotechnical assessment undertaken for the project found that the geology of the island is not one that is conducive to the formation of aquifers and if groundwater does occur, it will be limited to areas of intense fracturing of the rock (refer to **Appendix F - Geotechnical Assessment**). A review of historical data regarding bore water extraction confirms this assessment and indicates that any groundwater resource is limited and usually limited to short period of time following a rainfall event. Due to the unreliability and limited nature of this resource, no extraction of groundwater resources is proposed.

The stormwater and water management strategy for the Lindeman Great Barrier Reef Resort Project aims to reduce the pollutant load being discharged to streams that drain to the Great Barrier Reef Marine Park. Specifically, stormwater and water management strategies will be adopted that:

- Re-uses rainwater, reducing potable water demand and stormwater pollutant loads;
- Treats and re-uses wastewater for non-potable uses on site;
- Minimises the potential sources of stormwater pollutants;
- Treats stormwater runoff to remove sediment and nutrient load;
- Replicates existing flow patterns;
- Reduces potential for scour and erosion; and
- Integrates open space with stormwater drainage corridors and treatment areas to maximise public access and recreation and preserve waterway habitats and wildlife corridors.

This section provides a summary of the technical assessment undertaken by Cardno as provided in **Appendix P – Stormwater Management Plan and Water Balance Modelling**. Further information regarding water and sewage treatment infrastructure is included in **Chapter 24 - Infrastructure**.

Addendum: *This EIS was initially prepared assuming that the safe harbour was to be part of the Lindeman Great Barrier Reef Resort Project. With the commencement of the Great Barrier Reef Marine Park Authority's (GBRMPA) Dredging Coral Reef Habitat Policy (2016), further impacts on Great Barrier Reef coral reef habitats from yet more bleaching, and the recent impacts from Tropical Cyclone Debbie, the proponent no longer seeks assessment and approval to construct a safe harbour at Lindeman Island. Instead the proponent seeks assessment and approval for upgrades to the existing jetty and additional moorings in sheltered locations around the island to enable the resort's marine craft to obtain safe shelter under a range of wind and wave conditions. Accordingly, remaining references to, and images of, a safe harbour on various figures and maps in the EIS are no longer current.*

17.2 Statutory Framework and Standards

17.2.1 Environmental Protection Act 1994

The Environmental Protection Act (EP Act) provides the legislative framework by which Queensland's environment is protected while allowing for development that improves the total quality of life, both now and in the future. Specifically, the EP Act seeks to maintain a range of environmental values including:

(a) *a quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety; or*

(b) *another quality of the environment identified and declared to be an environmental value under an environmental protection policy or regulation.*

For the purposes of the environmental impact statement, reference is made to the environmental values provided in the *Environmental Protection (Water) Policy 2009* (EPP Water) established under the EP Act. The following sections provide an overview of the environmental values identified in this policy along with the objectives established achieve their protection.

17.2.2 Environmental Protection (Water) Policy 2009

The EPP (Water) provides that the environmental values (section 6(2)(a)) to be enhanced or protected under this policy are:

(a) *for high ecological value waters—the biological integrity of an aquatic ecosystem that is effectively unmodified or highly valued;*

(b) *for slightly disturbed waters—the biological integrity of an aquatic ecosystem that has effectively unmodified biological indicators, but slightly modified physical, chemical or other indicators;*

(c) *for moderately disturbed waters—the biological integrity of an aquatic ecosystem that is adversely affected by human activity to a relatively small but measurable degree;*

…

(h) *for waters that may be used for recreation or aesthetic purposes, the suitability of the water for—*

(i) primary recreational use; or

(ii) secondary recreational use; or

(iii) visual recreational use;

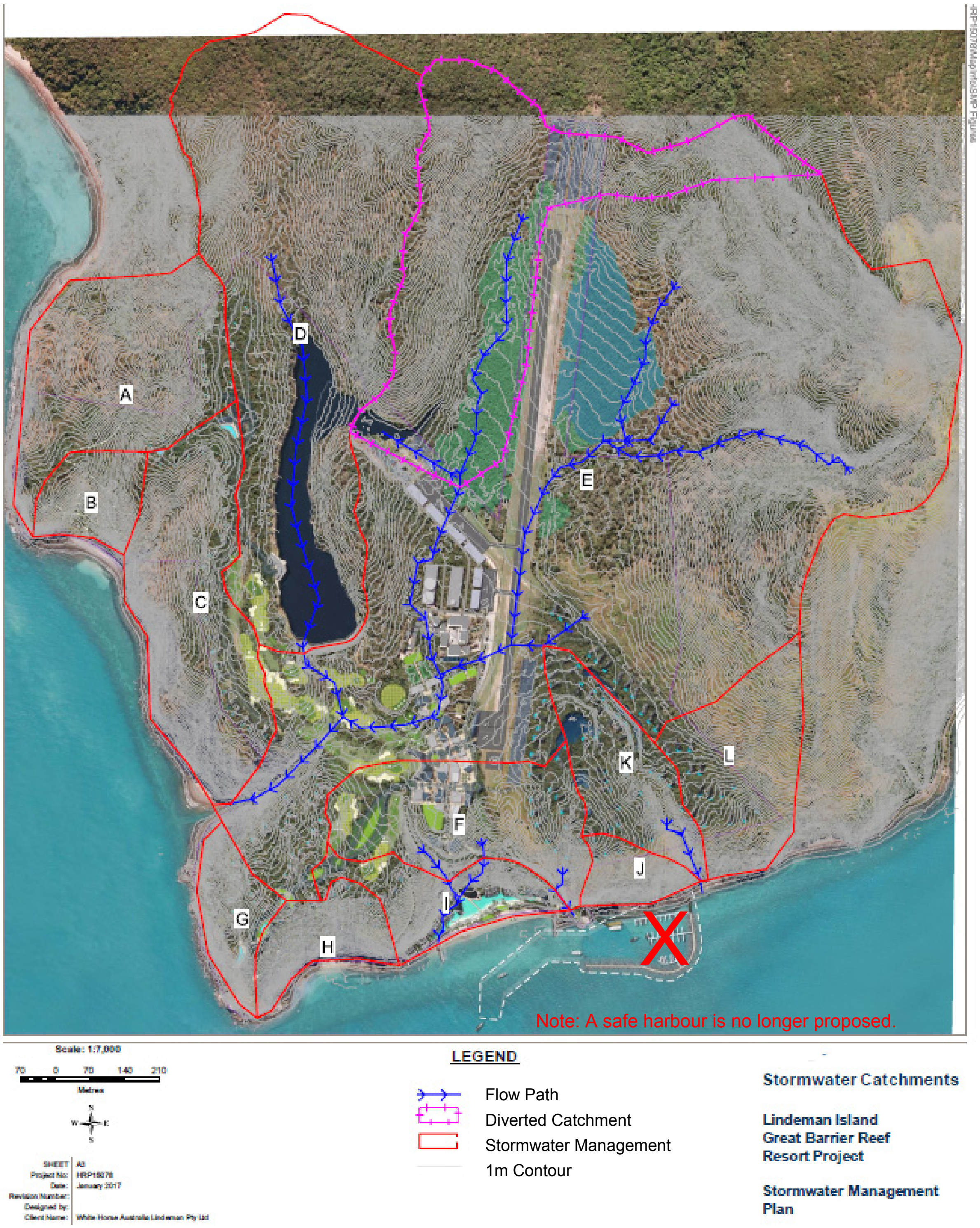
(i) *for waters that may be used for drinking water—the suitability of the water for supply as drinking water.*

17.3 Water Quality Objectives

17.3.1 Site Description

The site has an existing resort, golf course, maintenance facilities and a dam, which supplies all water requirements for the resort. Gap Creek and several other small ephemeral freshwater streams traverse the site and discharge to the ocean, as shown in **Figure 17-1.** Due to the steepness of the island these freshwater streams have negligible interaction with tidal waters, as the tidal zone on the island is limited in area. The extent of development is mostly contained to cleared or previously developed areas. Eco villas are proposed to be constructed in previous golf course and densely vegetated areas around the perimeter of the site.

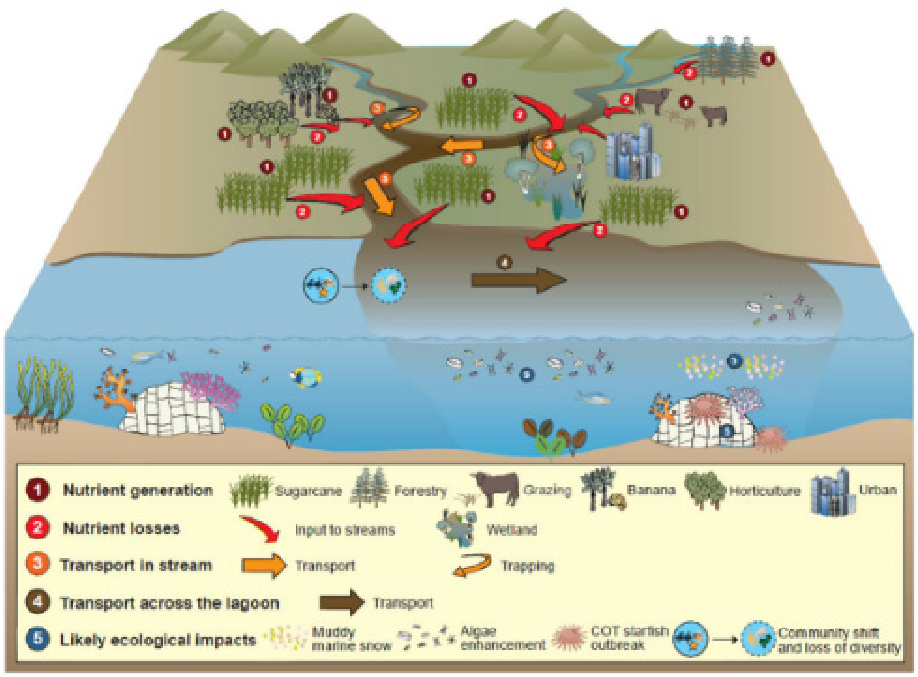
Figure 17-1. Stormwater Catchments.



17.3.2 Existing Water Quality

The water quality of the Mackay Whitsundays is under pressure from land uses such as agriculture, forestry, grazing and urban. Increased nutrients, sediment and herbicide loads resulting from development have impacted negatively on the health of the Great Barrier Reef (GBR). Urban and other intensive uses (including sewage treatment plants) account for just over 10% of the total regional particulate nutrient load, and 4% of the regional dissolved organic load (Mackay Whitsundays Water Quality Improvement Plan 2014-2021 (WQIP)). The schematic from the Mackay Whitsundays WQIP demonstrating the different pressures and impacts is shown in **Figure 17-2**.

Figure 17-2. Conceptual Diagram of Nutrient Pollutant Generation and Transport and Effects on the Marine Environment.



The Healthy Rivers to Reef Partnership 2014 Pilot Report Card gave the Inshore Marine Whitsunday waterways a rating of C/ Moderate. This was based on a moderate score for water quality and coral and a poor score for seagrass. The moderate condition of the existing water quality highlights the need for the development to ensure that the potential for additional nutrients, sediments, pesticides and herbicides to be discharged from the site is limited. Water quality is naturally variable, and is dependent on numerous factors such as land use, catchment management practices, antecedent conditions, soil types, climatic and seasonal factors and in-stream processes. Tropical rivers and creeks are characterised by minimal flows in the winter dry season, which generally have low dissolved oxygen, low nitrogen and phosphorous levels, and low turbidity levels. During the summer wet seasons, “first flush” run-off can be acidic with elevated levels of suspended solids, nutrients, sulphates and heavy metals. During extreme events there is potential for high levels of pollutants to be discharged to the marine receiving environment if catchment areas are not appropriately managed.

Two rounds of event based testing were able to be conducted at the site within the waterways for sites LIND01 – LIND06 (refer to **Figure 17-3**). The results are provided in **section 17.3.4** and **Appendix P - Stormwater**

Management Plan and Water Balance Modelling. Based on the event based WQOs the current water quality meets objectives, with one elevated recording for suspended solids.

17.3.3 Water Quality Objectives

The water quality objectives were sourced from the *Environmental Protection (Water) Policy 2009 (EPP (Water) 2009)* Proserpine River, Whitsunday Island and O'Connell River Basins Environmental Values and Water Quality Objectives and associated plans. The *Water Quality Guidelines for the Great Barrier Reef Marine Park 2010* were also referenced.

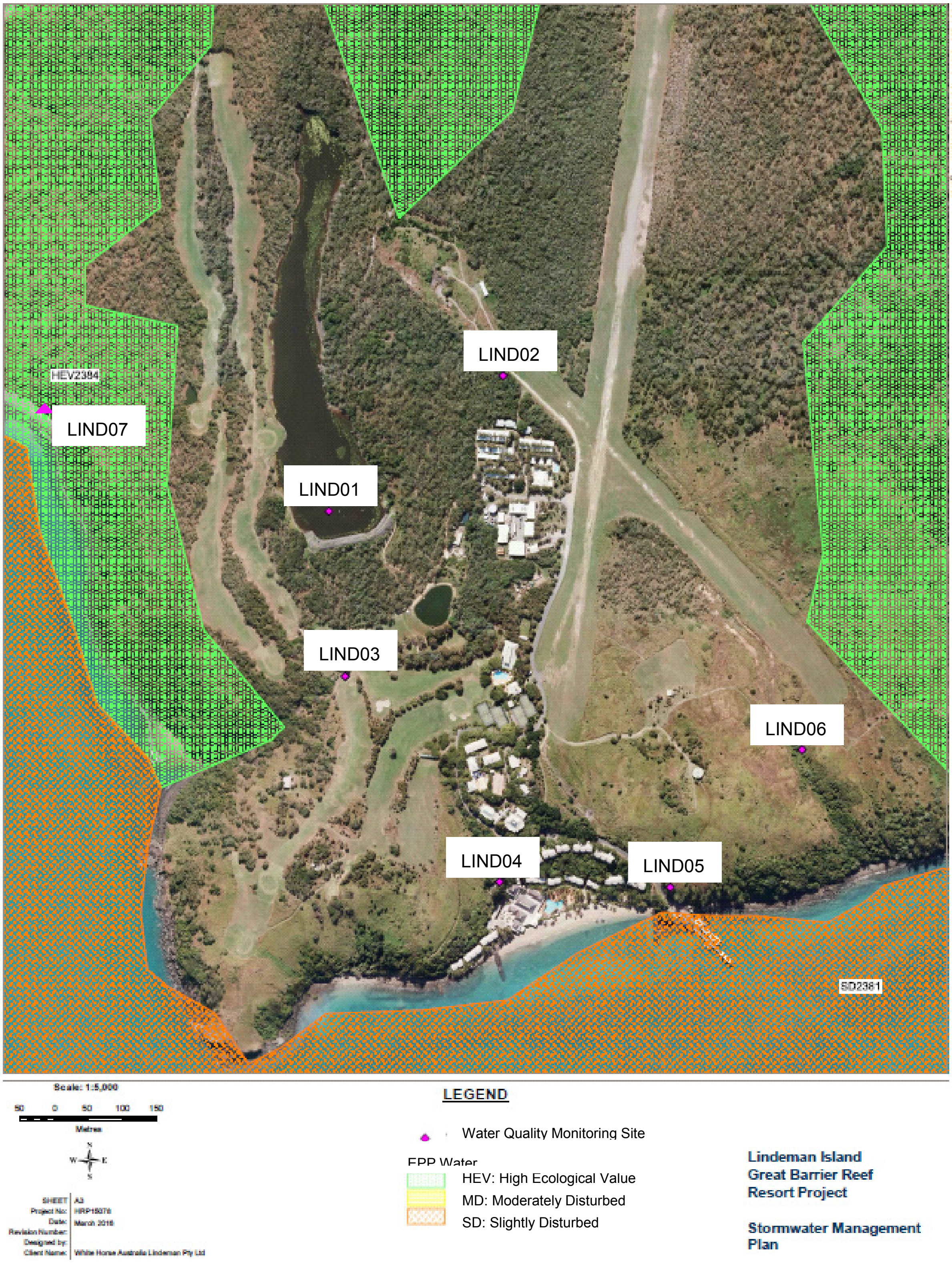
17.3.3.1 Freshwater

Based on Table 1 of *EPP (Water) 2009*, the relevant environmental values for Lindeman Island's fresh waters (i.e. Whitsunday Islands fresh waters) include:

- Aquatic Ecosystems;
- Irrigation;
- Secondary Recreation;
- Visual Recreation;
- Drinking Water; and
- Cultural and Spiritual Values.

The majority of Lindeman Island is classified as Whitsunday Island freshwater with High Ecological Value (HEV) for Aquatic Ecosystems (HEV2384) (refer to **Figure 17-3**). However, the existing and proposed developed area of Lindeman Island (with the exception of glamping area on the western coast) is not included in this area and is therefore classified as Moderately Disturbed Freshwater.

Figure 17-3. Stormwater Management Plan.



The water quality objectives for this area are:

Aquatic Ecosystem – moderately disturbed (MD)

Ambient (baseflow). In the absence of more locally applicable information, WQOs for Whitsunday Islands fresh waters at the moderately disturbed level of protection are based on the 20th/80th percentile of WQOs for Repulse Creek subcatchment (mainland):

- *Dissolved inorganic nitrogen: <31 µg/L*
- *Particulate N: <52 µg/L*
- *Filterable reactive phosphorus (FRP): <15 µg/L*
- *Particulate phosphorus: <17 µg/L*
- *Dissolved oxygen:*
    - i. *No-flow 20th and 80th percentile: 50 to 120% saturation*
    - ii. *Flow 20th and 80th percentile: 90 to 105% saturation*
- *Suspended solids: <3 mg/L*
- *pH: 7.2-7.6*
- *Electrical conductivity (EC): <780 µS/cm*
- *Ametryn: <LOD*
- *Atrazine: <LOD*
- *Diuron: <LOD*
- *Hexazinone: <LOD*
- *Tebuthiuron: <LOD*

As the freshwater streams on Lindeman Island are ephemeral limited opportunity exists to undertake baseflow monitoring. No specific water quality objectives are provided for events in EPP (Water) 2009. However, Table 31 of the Mackay Whitsundays WQIP has the following event-based WQOs for moderately disturbed freshwater streams in Repulse Creek (which is used to define WQOs for Whitsunday Islands):

- *Dissolved inorganic nitrogen: <256 µg/L*
- *Particulate N: <261 µg/L*
- *Filterable reactive phosphorus (FRP): <27 µg/L*
- *Particulate phosphorus: <31 µg/L*
- *Suspended solids: <8 mg/L*

Secondary Contact Recreation

Objectives as per NHMRC (2008), including:

- *intestinal enterococci: 95th percentile ≤ 40 organisms per 100mL (for healthy adults) (NHMRC, 2008; Table 5.7)*
- *cyanobacteria/algae—refer objectives for primary recreation, NHMRC (2008), i.e.:*
    - *Level 1: ≥ 10 µg/L total microcystins; or ≥ 50 000 cells/mL toxic Microcystis aeruginosa; or biovolume equivalent of ≥ 4 mm^3/L for the combined total of all*

cyanobacteria where a known toxin producer is dominant in the total biovolume or

- *Level 2: ≥ 10 mm^3/L for total biovolume of all cyanobacterial material where known toxins are not present*
- *cyanobacterial scums consistently present.*

Visual Recreation

- Recreational water bodies should be aesthetically acceptable to recreational users. The water should be free from visible materials that may settle to form objectionable deposits; floating debris, oil, scum and other matter; substances producing objectionable colour, odour, taste or turbidity; and substances and conditions that produce undesirable aquatic life.

Drinking Water

The drinking water quality objectives for the dam, before treatment are:

- *Giardia: 0 cysts (Queensland Water Supply Regulator). If Giardia is detected in drinking water then the health authorities should be notified immediately and an investigation of the likely sources of contamination undertaken.*
- *Cryptosporidium: 0 cysts (Queensland Water Supply Regulator). If Cryptosporidium is detected in drinking water then the health authorities should be notified immediately and an investigation of the likely sources of contamination undertaken.*
- *E. coli: <100 cfu/100mL*
- *Enterococci: <100 cfu/100mL*
- *Blue green algae (cyanobacteria): <10000 cells/mL*
- *Algal toxin: <1 µg/L Microcystin*
- *Turbidity: <30 NTU*
- *Colour: <35 TCU*
- *pH: 6.5-8.0*
- *Total hardness: <115mg/L*
- *Conductivity: <300 µS/cm*
- *Total dissolved solids: ADWG 2011 aesthetic guideline: <600 mg/L*
- *Total organic carbon: <2 mg/L*
- *Sodium: <25 mg/L*
- *Sulfate: <4 mg/L*
- *Dissolved oxygen: >80% saturation*
- *Pesticides: <0.1 µg/L for individual compound, <1.0 µg/L combined total for all compounds*

Visual Recreation

> Recreational water bodies should be aesthetically acceptable to recreational users. The water should be free from visible materials that may settle to form objectionable deposits; floating debris, oil, scum and other matter; substances producing objectionable colour, odour, taste or turbidity; and substances and conditions that produce undesirable aquatic life.

Cultural and Spiritual Values

> Protect or restore indigenous and non-indigenous cultural heritage consistent with relevant policies and plans.

17.3.3.2 Coastal and Marine Waters

The *Water Quality Guidelines for the Great Barrier Reef Marine Park* (2010) describe the concentrations and trigger values for sediment, nutrients and pesticides that have been established as necessary for the protection and maintenance of marine species and ecosystem health of the Great Barrier Reef. Parameters that are not listed default to the Queensland Water Quality Guidelines, which in turn default to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Gap Creek and several other small ephemeral freshwater streams traverse the site and discharge to the ocean, as shown in **Figure 17-1**. Due to the steepness of the island these freshwater streams have negligible interaction with tidal waters, because the tidal zone on the island is limited to the shoreline area.

The stormwater and water management strategy for the Lindeman Great Barrier Reef Resort Project aims to reduce the pollutant load being discharged to streams that drain to the Great Barrier Reef Marine Park. Specifically, stormwater and water management strategies will be adopted that:

- Re-use rainwater, reducing potable and irrigation water demand and stormwater pollutant loads;
- Treat and re-use wastewater for non-potable uses on site;
- Minimise the potential sources of stormwater pollutants;
- Treat storm water runoff to remove sediment and nutrient load;
- Replicate existing flow patterns;
- Reduce potential for scour and erosion; and
- Integrate open space with stormwater drainage corridors and treatment areas to maximise public access and recreation and preserve waterway habitats and wildlife corridors

17.3.4 Water Quality Testing

17.3.4.1 Existing Conditions and Monitoring

As the freshwater streams on Lindeman Island are ephemeral limited opportunity exists to undertake baseflow monitoring. Despite this, two rounds of event based testing were able to be conducted at the site within the waterways. For the March 2016 event, there were two rounds of sampling were conducted for sites LIND 1 - 6 for the same event due to issues with transporting samples from the island. Given the recommended holding times, only the later results have been referenced. For the June 2016 event it was not possible to undertake sampling at LIND05. The results are provided in **Appendix P – Stormwater Management Plan and Water Balance Modelling,** with the median and range of results summarised below in **Table 17-1**.

Table 17-1. Existing water quality test results.

Parameter	Median Concentration (mg/L)		
	Mar-16	Jun-16	Event Based WQO
Suspended Solids	<5	5	8
Total Nitrogen	0.35	0.70	n/a
Dissolved Inorganic Nitrogen	0.035	0.049	0.256
Total Phosphorus	0.03	0.04	n/a
Filterable Reactive Phosphorus	0.01	0.006	0.027
Parameter	**Range of Results**		
	Mar-16	**Jun-16**	**Event Based WQO**
Suspended Solids	<5	<5 to 14	8
Total Nitrogen	0.2 to 0.6	0.55 to 0.98	n/a
Dissolved Inorganic Nitrogen	0.02 to 0.06	0.034 to 0.09	0.256
Total Phosphorus	0.02 to 0.05	0.02 to 0.06	n/a
Filterable Reactive Phosphorus	<0.01 to 0.02	<0.005 to 0.019	0.027

In terms of the monitoring points LIND01 is located within the existing dam and LIND02 – LIND06 is normally dry and as such sampling can only take place immediately after a rainfall event. LIND07 is a new proposed monitoring point located over at the proposed glamping facility.

Based on the event based WQOs listed in **section 17.3.3**, the current water quality meets the specified objectives. In June, at site LIND06 there was an elevated level of TSS.

Further additional water quality testing is proposed at the terrestrial sites prior to the commencement of construction in accordance with the following proposed sampling schedule. Additionally, the proponent has made a commitment to completing a baseline marine water quality sampling program. The objective of the program would be to identify the environmental values of receiving waters and set objectives and indicators relevant to the protection of those values.

Table 17-2. Sampling Schedule.

TEST PARAMETER	HOLDING TIMES
Total Suspended Solids	7 days
Nitrogen Compounds	TN, TKN and NH3 – 28 days Nitrate and Nitrites – 2 days
Phosphorous Compounds	Reactive – 2 days Total – 28 days
Chlorophyll A	2 days

17.3.4.2 Construction

Undertake water quality testing as close as possible to each month (noting that as the streams are ephemeral this will be determined by rainfall events) during construction at locations indicated in **Figure 17-3**. The WQOs will be determined based on the results of the water quality monitoring, with the purpose of carrying out the 12 months of monitoring is to set these WQOs.

17.3.4.3 Operation

If the proposed stormwater treatment devices are modelled using MUSIC, detailed based on Healthy Waterways guidelines and constructed as detailed, then regular water quality monitoring during operation is not required. However, to confirm compliance, event based freshwater quality testing is to be conducted at least once a year at locations shown in **Figure 17-3**. Regular water quality monitoring of the dam and at the WTP will be required for drinking water purposes. Regular water quality monitoring at the STP will be required to ensure suitability for irrigation and re-use.

17.4 Stormwater Quality Objectives

17.4.1 Construction Phase

During the construction phase, the potential exists for significant increases in the amount of pollutants, particularly sediment, to be exported from the site. An Erosion and Sediment Control Program (ESCP) will be required to be prepared for the site prior to construction in accordance with the **Environmental Management Plan (EMP)** refer to chapter 28 of the EIS. The ESCP must:

- Be consistent with current best management practice guidelines such as the IECA Best Practice Erosion and Sediment Control;
- Prescribe non-structural controls where applicable, such as minimising the extent and duration of soil exposure, diversion of upstream catchments around disturbed areas, staging the works, identifying areas for protection and delaying clearing until construction works are imminent;
- Include a maintenance schedule for ensuring ESC and stormwater infrastructure is maintained in effective working order;
- Include an adaptive management program to identify and rectify non compliances and deficiencies in environmental performance;
- Include contingency management measure for the site, for example to ensure ESC measures are effective at all times, particularly just prior to, during and after wet weather;
- For each phase of works detail the types, location, sequence and timing of measures and actions to effectively minimise erosion, manage flows and capture sediment;
- Be consistent with current best management practice standards, taking into account all environmental constraints including erosion hazard, season, climate, soil and proximity to waterways;
- Be prepared to a sufficient standard and level of detail with supporting documentation;
- Include an effective monitoring and assessment program to identify, measure, record and report on the effectiveness of ESCs and the lawfulness of releases; and

- Be prepared by a suitably qualified and experienced professional.

The release limits for stormwater captured in a sediment basin are not to exceed the following limits:

- *Total Suspended Solids (TSS): 50 mg/L;*
- *Turbidity (NTU): less than 10% above background; and*
- *pH: 6.5 – 8.5.*

No development, besides glamping on the western beach, is proposed within HEV areas.

17.4.2 Operational Phase

Stormwater Quality

The water quality objectives for the stormwater quality treatment measures proposed throughout the development were sourced from State Planning Policy, July 2014, for the Central Queensland (north) climatic region. They specify a minimum reduction in mean annual pollutant loads, when compared to an unmitigated catchment. The water quality objectives for the post construction phase are:

- *75% reduction in Total Suspended Solids (TSS);*
- *60% reduction in Total Phosphorus (TP);*
- *35% reduction in Total Nitrogen (TN); and*
- *90% reduction in Gross Pollutants (>5mm).*

It should be noted that Mackay Regional Council has adopted a lower target of 35% removal of TN than required by other Councils in this climatic region. A sensitivity analysis was conducted to determine the impact on sizing of treatment devices if a higher TN removal objective was targeted.

Waterway stability management

This objective is applicable if runoff from a site drains to or passes through natural channels, non-tidal waterways or wetlands. As parts of the development is draining to a non-tidal waterway it is required to provide attenuation of peak discharges to match the existing case for the 63% Annual Exceedance Probability (AEP) event. It is considered that this objective will be satisfied by the Water Sensitive Urban Design (WSUD) measures proposed throughout the development, which will provide some attenuation of peak flows in minor storm events. The upstream dam diversion will also reduce flows during minor events. Outlets from WSUD devices will be designed to evenly disperse flow or will be provided with appropriate scour protection, so as to reduce the potential for scour of downstream waterways.

17.5 Stormwater Quality Management

17.5.1 Existing Stormwater Management

Vegetated swales located around the site currently provide some polishing of stormwater before it is discharged off site. No other stormwater treatment measures, such as Gross Pollutant Traps (GPTs) are currently provided.

17.5.2 Proposed Stormwater Management

17.5.2.1 Suitable Stormwater Treatment Devices

Rainwater Harvesting

The development is required to provide its own water supply via the existing dam. In order to increase the reliability of this supply a number of measures are proposed to be implemented. One of these measures is to use rainwater harvesting for pool top up and toilet flushing for villas, and provide a priority source of water at the WTP. Rainwater harvesting has the added benefit of reducing the stormwater and associated pollutant load being discharged downstream, and improving waterway stability. The estimated reduction in potable water demand from rainwater harvesting is 21.2 ML/year. The following minimum tank volumes and contributing catchment areas will be provided:

- 10kL for each villa, draining a minimum roof area of 100m^2, with a pool surface area of 25m^2.
- 500kL for resort pools, draining a minimum roof area of 3500m^2, with a pool surface area of 3000m^2.
- 350kL for additional rainwater harvesting near Water Treatment Plant (WTP), draining a minimum roof area of 6300m^2.

In order to further improve the reliability of the water supply as much roof area as practical should be directed to rainwater tanks.

Revegetation/Buffer Areas

A large proportion of the existing development footprint is cleared for use as a golf course. The majority of the proposed new development area will be located within these cleared areas and the golf course will be reduced in size. Revegetation around the proposed site with native vegetation will reduce the runoff and associated pollutant load. Vegetated buffer areas between waterways and development areas will be provided. The paths around the development will be allowed to sheet flow to these buffer areas, avoiding the concentration of runoff.

Vegetated Swales

The continued use of vegetated swales throughout the site will reduce pollutant loads by slowing flow velocities and filtering pollutants.

Bio-retention Gardens and Basins

Bio-retention gardens treat stormwater runoff "at-source", before it is discharged to the stormwater pipes. They treat stormwater by allowing it to slowly percolate through the vegetated filtration media, where filtration, adsorption and some biological uptake occurs. They are particularly suited to the removal of nutrients. They are effective treatment devices in areas where the location of an end-of-line basin is impractical as they do not need as much vertical differentiation and can be integrated into the landscape design. Bio-retention gardens can be accommodated "on-line", i.e. with field inlets located within the garden area, or "off-line", i.e. excess stormwater overflows to standard gully inlets located downstream of gardens. If located "on-line" then additional depth above the field inlet is required so that ponding external to the garden area is minimised. Appropriate batters or edge treatments are required for safety purposes. Alternatively, raised bio-retention gardens can be provided to treat excess runoff from roof water not directed to rainwater tanks. If the filter media depth is increased to a minimum of 0.8 metres then they can also be planted with trees. The extended detention depth (EDD) provided in bio-retention gardens is generally less than provided for bio-retention basins so as to allow for their integration into landscape areas at street level. An EDD of 0.1m was assumed in the MUSIC modelling. Bio-retention basins are similar to bio-retention gardens except that they are located end-of-line, are larger in area and have increased EDD (0.3m assumed in MUSIC modelling). Coarse sediment forebays are required on the inlets, and measures to avoid damage to vegetation and filter media during high flows should be accommodated in the design. Bio-retention basins require less overall area than bio-retention gardens due to their increased EDD and their reduced batter extents. Bio-retention gardens and basins should be planted with vegetation that is proven to be effective at reducing nutrients and tolerating periods of inundation. During prolonged dry periods it may be necessary to irrigate with treated wastewater.

Figure 17-4. Bio-retention Garden in Central Median.

Constructed Wetlands

Constructed wetlands are shallow, densely vegetated waterbodies that use sedimentation, filtration and biological uptake processes to treat stormwater. Outlets are sized so that water is released slowly over a few days. They require a variety of water depths and vegetation zones. They provide habitat and potential storage of water for re-use. They typically require areas significantly larger than needed for bio-retention systems, but can be installed end-of-line in vertically constrained areas. A GPT or sedimentation basin is often used to provide pre-treatment of flows entering the wetland and high flow bypasses are required so that damage to the wetland is avoided in major storm events. Due to the presence of rock at shallow depths the use of constructed wetlands for treatment of stormwater runoff may be more practical in relatively flat areas of the site, if excavation can be minimised.

Litter Baskets

Litter baskets are installed within field and gully inlets, capturing gross pollutants and sediment before they are discharged to the stormwater network. Although not included in the MUSIC treatment train they should be considered in areas where high litter levels are likely. They can be cleaned manually or by vacuum truck.

Figure 17-5. Litter Basket.

Proprietary Treatment Devices

There are numerous proprietary stormwater treatment devices available that can provide primary, secondary or tertiary treatment of stormwater using either mechanical or biological methods. Some are able to treat stormwater to a high enough level to meet all stormwater pollutant removal targets. They require less area than standard stormwater treatment devices and can be located at end-of-line without the need for significant vertical differentiation. However, the cost and practicality of ongoing maintenance should be considered. They might be appropriate for use in areas when standard bio-retention gardens or basins cannot be accommodated, or areas with specific pollutant loads, such as re-fuelling areas. Proprietary devices have not been included in the MUSIC treatment train.

Porous Pavement

Due to the presence of rock at shallow depths and the steepness of the majority of the site the use of porous pavement is not considered to be practical at this site. However, it should be considered for use in low traffic, relatively flat areas where adequate underdrainage can be accommodated.

17.5.2.2 Proposed Stormwater Treatment Devices

MUSIC modelling has been conducted to determine the stormwater quality treatment devices required to meet pollutant load objectives. The proposed stormwater treatment devices include:

> Rainwater Harvesting:
  - 10kL for each villa, draining a minimum roof area of 100m^2, with a pool surface area of 25m^2.
  - 500kL for resort pools, draining a minimum roof area of 3500m^2, with a pool surface area of 3000m^2.
  - 350kL for additional rainwater harvesting near Water Treatment Plant (WTP), draining a minimum roof area of 6300m^2.

> Vegetated Buffers for Paths to Villas;

> Vegetated Swales maintained throughout site;

> Treatment of runoff from remaining impervious areas (not directed to rainwater tanks) from Resort units, communal facilities and maintenance and service areas to following requirements:

  - Bio-retention Gardens within landscape areas with a minimum filter surface area equivalent to 0.9% of the contributing catchment area. Minimum filter depth of 0.4m and EDD of 0.1m assumed;
  - Raised Bio-retention Gardens treating roof runoff not directed to tanks with a minimum filter surface area equivalent to 0.6% of the contributing catchment area. Minimum filter depth of 0.4m and EDD of 0.3m assumed;
  - End-of-line Bio-retention Basins with a minimum filter surface area equivalent to 0.6% of the contributing catchment area. Minimum filter depth of 0.4m and EDD of 0.3m assumed; OR
  - Constructed Wetlands with a surface area equivalent to 5% of the contributing catchment area. Minimum detention time of 48 hours and EDD of 0.5m assumed. Constructed wetlands will be provided with GPTs or sedimentation basins for pre-treatment.

> Litter baskets or GPTs for areas with high levels of litter expected.

> Proprietary Treatment devices where the use of standard Water Sensitive Urban Design (WSUD) is not suitable.

Point and Diffuse Sources

Diffuse sources of pollution potentially include run-off from urban areas such as roads, runway, footpaths and other sealed surfaces, while the point sources include the areas in the services infrastructure precinct such as the diesel storage tanks. The runoff from the runway and surrounding hardstand areas will be directed via grassed swales to stormwater treatment areas. Underground spill containment storage be provided upstream of these treatment areas. The MUSIC modelling assumed that villa roof area not directed to rainwater tanks would be treated by buffer areas and grassed swales. However, it is recommended that raised bio-retention gardens be provided for roofwater runoff not connected to tanks, particularly for villas located near waterways. This option was not included in the MUSIC modelling. The outlets of all rainwater tanks and stormwater treatment devices will be designed to disperse flow to avoid scour and erosion.

Point sources will be managed through the enclosure and bunding of areas to be used for the storage of hazardous materials, including roofing of such areas to minimise the potential for overflow. Any stormwater captured within bunded areas used for the storage and/handling of wastes or other hazardous materials shall be pumped-out and disposed of at an appropriately licensed facility on the mainland. Refer to **Chapter 23 – Contamination** and **Chapter 24 – Infrastructure.**

17.5.2.3 Stormwater Quality Management Strategies

The prevention of pollution is the most effective means of reducing pollutant loads. The following management strategies will be adopted on site:

(a) Use of pesticides, herbicides or fertilisers throughout the development is to be avoided. Appropriate landscaping will be used to minimise their requirements. If necessary they are not to be applied during the wet season months of January to March and a buffer of at least 20 metres to all waterways is to be maintained. Organic pesticide alternatives should be used if possible;

(b) Application of irrigation water will occur in areas with appropriate buffers;

(c) All potentially hazardous materials and waste (e.g. waste oils, batteries, fuels and chemical wastes etc.) shall be stored in separate containers located within a bunded and roofed hardstand area;

(d) Refuelling areas will be bunded with a stormwater containment system to prevent discharge to soil or waterways.

(e) A spill response procedure shall be established and implemented, and appropriate clean up equipment and materials shall be provided where any construction activities or waste storage activities are undertaken to prevent the contamination of stormwater;

(f) Any stormwater captured within bunded areas used for the storage, refuelling or handling of fuels, waste or other hazardous materials shall be pumped out and disposed of at an appropriately licensed facility on the mainland;

(g) Regular inspections and maintenance will be undertaken for stormwater drainage and treatment systems;

(h) Runoff from golf course areas will be managed in accordance with the Golf Course Management Plan and the Irrigation Management Plan (refer to **Chapter 28 – Environmental Management Plan**) with any runoff directed towards vegetated buffer areas. In accordance with point (a) use of pesticides, herbicides or fertilisers will be avoided where possible but if required they are not to be applied during the wet season months of January to March and a buffer of at least 20 metres to all waterways is to be maintained. Organic pesticide alternatives should be used if possible. Any nutrients will be taken up by the vegetation;

(i) Monitoring of soil nutrient levels to prevent leaching of nitrogen and phosphates;

(j) Monitoring of water quality throughout the development to identify potential non-compliances;

(k) Bins will be provided around the development for the collection of litter and these will be regularly emptied;

(l) Landscape maintenance measures will include collection of all garden litter for composting in controlled areas. No disposal to waterways is to be allowed;

(m) Staff training will include awareness of environmental issues; and

(n) Issues relating to stormwater quality will be recorded in the Environmental Incident Register, and appropriate actions will be taken.

The catchment which discharges to the existing dam on the island is generally undisturbed, with some existing golf course area. Consequently, the quality of the water in the dam is very good. A restaurant and several villas are proposed within the dam catchment. These will be provided with a high level of stormwater quality treatment. Regular monitoring of the dam water quality will be carried out as part of the project to ensure appropriate quality is maintained. Best practice water quality treatment measures will be implemented and maintained at all times through the construction and operational phases. A detailed Environmental Management Plan (EMP) will be prepared prior to any construction work commencing, detailing the proposed techniques to be employed around the study area.

17.6 Stormwater Quality Modelling

The proposed development was modelled in MUSIC Version 6.1.0 based on 10 years of 6 minute rainfall data at Mackay M.O Station 33119 (1/1/1990 to 31/12/1999) was used for the analysis. The MUSIC source nodes were based on the values for urban, rural residential, forest and commercial land uses, as outlined in the Mackay Regional Council MUSIC Guidelines – Version 1.1 2008 (Mackay Regional Council, 2008). The adopted source nodes are summarised in **Table 17-3** and **Table 17-4**. The upland soil typology node was used to define the rainfall-runoff characteristics, as this was considered to be characteristic of the soils encountered at the site. The urban source nodes were used for the majority of the developed areas as these are recommended for use in residential developments with small areas of commercial use.

Table 17-3. MUSIC Rainfall Runoff Parameters.

Parameter	Value
Soil Typology	Upland
Rainfall threshold (mm)	1
Soil storage capacity (mm)	200
Initial storage (% capacity)	30
Field capacity (mm)	80
Infiltration capacity coefficient a	200
Infiltration capacity exponent b	1
Initial depth (mm)	10
Daily recharge rate (%)	0.5
Daily baseflow rate (%)	0.16
Daily deep seepage rate (%)	2

Table 17-4. Mackay Pollutant Export Parameters.

Parameter	Surface Type	TSS Log^{10} Values		TP Log^{10} Values		TN Log^{10} Values	
		Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Urban							
Baseflow	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	1.00	0.34	-0.97	0.31	0.20	0.20
	Ground	1.00	0.34	-0.97	0.31	0.20	0.20
	Combined	1.00	0.34	-0.97	0.31	0.20	0.20
Stormflow	Roof	1.30	0.39	-0.89	0.31	0.26	0.23
	Roads	2.43	0.39	-0.30	0.31	0.26	0.23
	Ground	2.18	0.39	-0.47	0.31	0.26	0.23
	Combined	2.18	0.39	-0.47	0.32	0.26	0.23
Commercial							
Baseflow	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	0.78	0.39	-0.60	0.50	0.32	0.30
	Ground	0.78	0.39	-0.60	0.50	0.32	0.30
	Combined	0.78	0.39	-0.60	0.50	0.32	0.30

Parameter	Surface Type	TSS Log^{10} Values		TP Log^{10} Values		TN Log^{10} Values	
		Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Stormflow	Roof	1.30	0.38	-0.89	0.34	0.25	0.34
	Roads	2.43	0.38	-0.30	0.34	0.37	0.34
	Ground	2.16	0.38	-0.39	0.34	0.37	0.34
	Combined	2.16	0.38	-0.39	0.34	0.37	0.34
Rural Residential							
Baseflow	Combined	0.53	0.24	-1.54	0.38	-0.52	0.39
Stormflow	Combined	2.26	0.51	-0.56	0.28	0.32	0.30
Forest							
Baseflow	Combined	0.51	0.28	-1.79	0.28	-0.59	0.22
Stormflow	Combined	1.90	0.20	-1.10	0.22	-0.075	0.24

17.6.1 Catchment Areas

The site was broken down into different land use areas as shown in **Figure 17-6**. The catchment parameters used in the MUSIC analysis are summarised in **Table 17-5** and **Table 17-6**. Two MUSIC models were set up: one that included only developed mainly impervious areas of the site for compliance with stormwater quality objectives (refer **Table 17-5**) and another that included the full extent of development, including bushland and golf course areas (refer **Table 17-6**). The second model was set up to allow comparison to the existing pollutant loads.

Figure 17-6. MUSIC Land Use Areas.

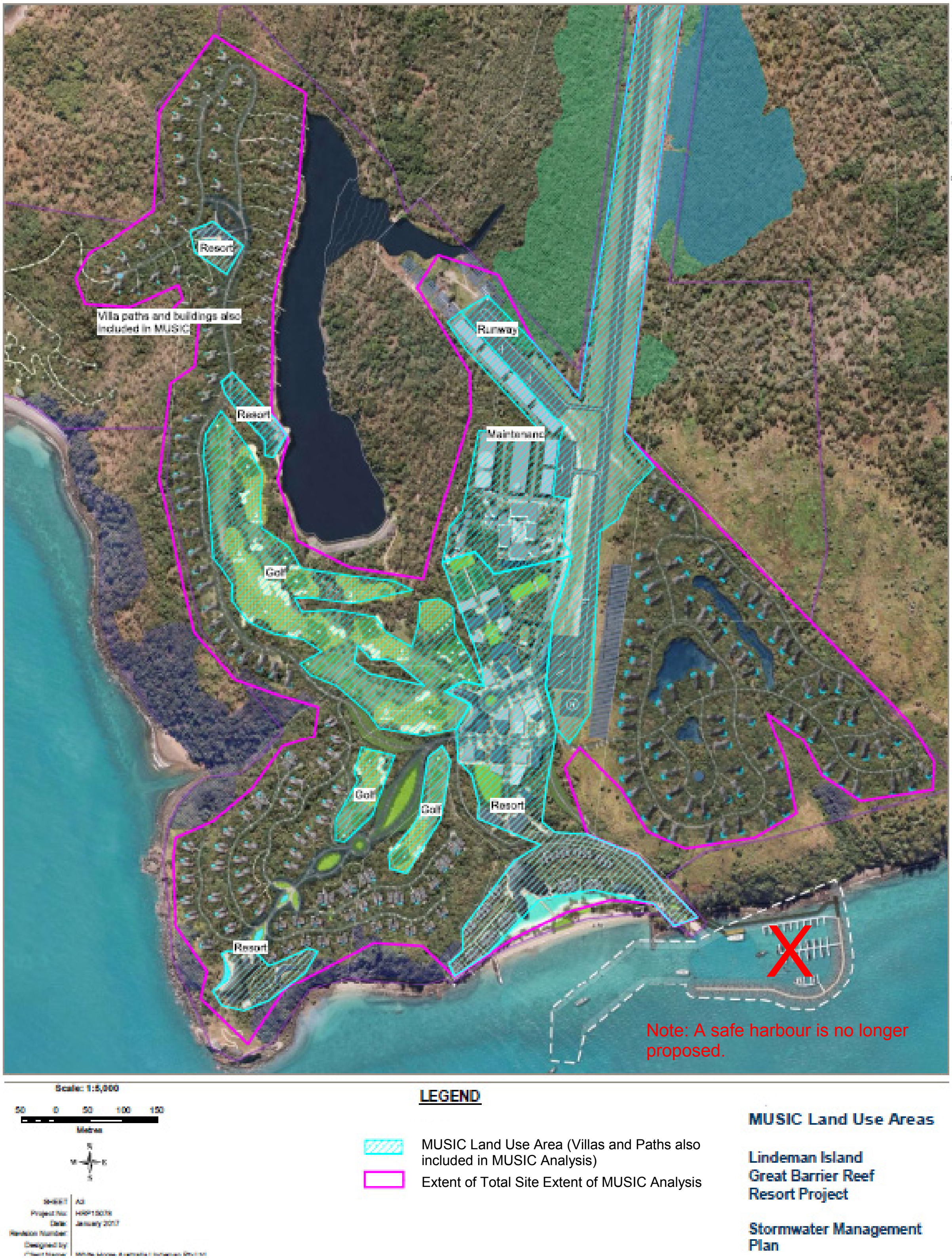


Table 17-5. Proposed Developed Areas MUSIC Catchments.

Catchment Name	Source Type	Area (ha)	Fraction Impervious
Resort Roof to Tank	Urban Roof	0.350	1.0
Maintenance Roof to Tank	Urban Roof	0.630	1.0
Villa Roof to Tank	Urban Roof	0.945	1.0
Villa Roof	Urban Roof	0.945	1.0
Villa Paths	Urban Road	2.500	0.8
Resort	Urban Combined	5.910	0.6
Resort d/s of Swale	Urban Combined	2.810	0.6
Maintenance Facilities	Urban Combined	2.820	0.8
Runway Pavement	Commercial Road	4.665	1.0

Table 17-6. Entire Site Existing and Developed Case MUSIC Catchments.

Catchment Name	Source Type	Area (ha)	Fraction Impervious
Entire Developed Site			
Resort Roof to Tank	Urban Roof	0.350	1.0
Maintenance Roof to Tank	Urban Roof	0.630	1.0
Villa Roof to Tank	Urban Roof	0.945	1.0
Villa Roof	Urban Roof	0.945	1.0
Villa Paths	Urban Road	2.500	0.8
Resort	Urban Combined	5.910	0.6
Resort d/s of Swale	Urban Combined	2.810	0.6
Maintenance Facilities	Urban Combined	2.820	0.8
Runway Pavement	Commercial Road	4.665	1.0
Runway Grass	Rural Residential	4.665	0.0
Golf Course Grassed Area	Rural Residential	7.440	0.0
Forest	Forest	42.740	0.0
Entire Existing Site			
Resort	Urban Combined	3.150	0.6
Resort d/s of Swale	Urban Combined	2.810	0.6
Maintenance	Urban Combined	3.450	0.7
Runway Pavement	Commercial Road	3.387	1.0
Runway Grass	Rural Residential	7.903	0.0
Golf Course	Rural Residential	14.960	0.0
Caretaker	Rural Residential	1.840	0.15
Forest	Forest	38.920	0.0

17.6.2 Treatment Devices

Rainwater Tanks

The rainwater tank demands were taken from the results of the GoldSim modelling. The villa rainwater tanks are to be used for toilet flushing and pool top up; the resort tanks are to be used for pool top and the maintenance area tanks are be used as a source of water at the WTP. The rainwater demands were:

> 14.0 ML/year, scaled on PET-rain for 189 10kL (total storage of 1890kL) villa rainwater tanks.

> 6.3 ML/year, scaled on PET-rain for a 500kL resort rainwater tank. This rainwater tank is to be divided proportionally between communal resort pools.

> 21.2 kL/day (7.7ML/year) for additional rainwater harvesting from 350kL maintenance area tank.

Buffer Areas

Buffer areas were used to treat runoff from villa rooves and paths, as revegetation of cleared areas is proposed. It was assumed that they treated 100% of the upstream catchment and were equivalent to 50% of the upstream impervious area.

Vegetated Swale

A 10 metre wide swale with 1 metre wide base, depth of 0.5m and a bed slope of 3 percent was used to represent the numerous grassed swales located throughout the development.

Option 1 - Bio-retention Gardens

Bio-retention gardens were modelled as being 0.9% of the contributing catchment with an EDD of 0.1m and a minimum filter depth of 0.4m. The filter media and surface area were assumed to be equal. The filter media was assumed to be sandy loam, with a saturated hydraulic conductivity of 200mm/hr, a TN content of 300 mg/kg and an orthophosphate content of 20 mg/L. The gardens were assumed to be vegetated with effective nutrient removal plants and the overflow weir width was assumed to be one tenth of the filter media area.

Option 2 - Bio-retention Basins

Bio-retention basins were modelled as being 0.6% of the contributing catchment with an EDD of 0.3m and a filter depth of 0.4m. The filter media and surface area were assumed to be equal. The filter media was assumed to be sandy loam, with a saturated hydraulic conductivity of 200mm/hr, a TN content of 300 mg/kg and an orthophosphate content of 20 mg/L. The basins were assumed to be vegetated with effective nutrient removal plants and the overflow weir width was assumed to be one tenth of the filter media area.

Option 3 - Constructed Wetland

Constructed wetlands were modelled as being 5% of the contributing catchment with an EDD of 0.5m, a permanent pool volume equivalent to an average depth of 0.3m and an outlet sized to provide 48 hours of detention time. GPTs or sedimentation basins should be provided on the inlets.

Litter Baskets and GPTs

No litter baskets, GPTs or proprietary devices were included in the MUSIC modelling. However these should be considered for use in some areas.

17.6.3 MUSIC Results

Pollutant Load Removal

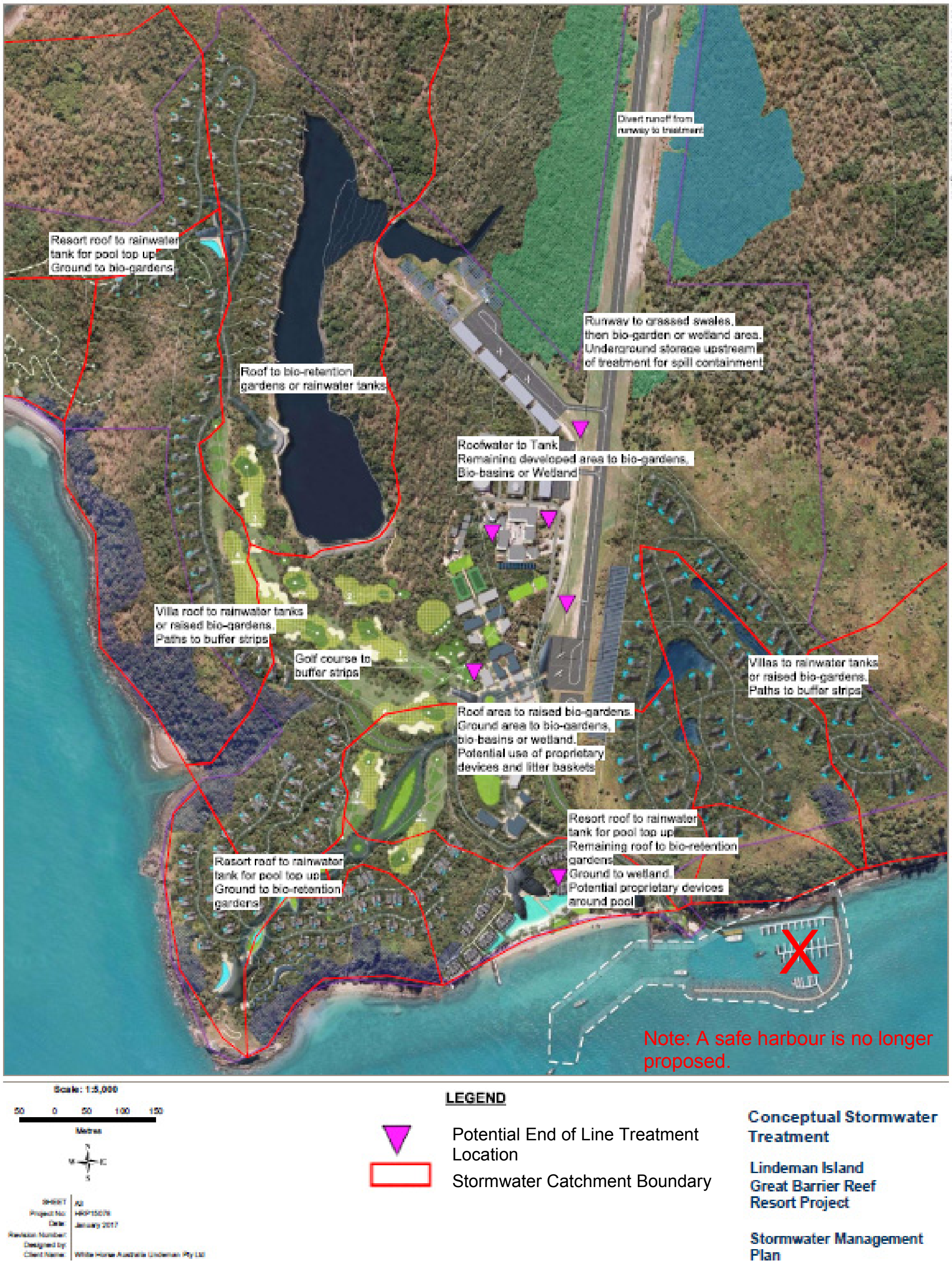
The results of MUSIC for the pollutant load analysis for the developed areas of the site are summarised in **Table 17-7. MUSIC Results – Developed Areas**. As demonstrated by this table, all treatment options meet the required pollutant load reduction targets. The limiting pollutant is TN for all treatment options.

Table 17-7. MUSIC Results – Developed Areas.

Pollutant	Pollutant Load (kg/year)		% Pollutant Load Removed			
	IN	Option 1 OUT	Option 1	Option 2	Option 3	Water Quality Objective
Flow (ML/year)	287	265	7.8	7.3	13.1	n/a
Total Suspended Solids	71,300	11,200	84.3	83.6	90.1	75
Total Phosphorus	134	45.3	66.1	65.5	70.1	60
Total Nitrogen	711	454	36.2	36.4	36.1	35
Gross Pollutants	5,740	0	100	100	100	90

The concept stormwater management plan for the site, identifying the most appropriate options for various areas, is shown in **Figure 17-7**. If a higher TN removal rate of 40% is targeted then the treatment area is significantly increased. For example, the bio-retention garden area for Option 1 increases from 0.9% to 1.3% of the contributing catchment areas. Larger bio-retention areas should be considered where possible on site.

Figure 17-7. Conceptual Stormwater Treatment.



17.6.3.1 Comparison to Existing Case

A comparison to the existing case stormwater pollutant loads and flows was conducted. The results are shown in **Table 17-8**. As demonstrated by this table, due to the stormwater re-use, stormwater treatment and proposed revegetation around the site the developed case pollutant loads are less than the existing case for all pollutants despite likely increases in impermeable surfaces.

Table 17-8. MUSIC Results – Comparison to Existing Case Pollutant Loads.

Pollutant	Pollutant Load (kg/year)			
	Existing Case		Developed Case	
	IN	OUT	IN	OUT
Flow (ML/year)	454	454	542	520
Total Suspended Solids	101,000	51,300	109,000	36,900
Total Phosphorus	134	91.5	171	85
Total Nitrogen	860	812	1,050	804
Gross Pollutants	3,310	633	5,740	0

17.6.3.2 Average Annual Flow Comparison

The MUSIC modelling predicted an increase in average annual flow of 88 ML/year due to the increased impervious area. This reduced to 66 ML/year once rainwater tank demands were excluded. The average annual results of GoldSim modelling for the existing and developed scenarios were added to the flow outputs. The results are summarised in **Table 17-9**. Due to increased evaporation losses (due to diversion of additional runoff into the dam), the increase in runoff is further reduced to 58 ML/year.

Table 17-9. Average Annual Flows.

Pollutant	Average Annual Flow (ML/year)				
	Dam Overflow	STP Overflow	Diversion Catchment	MUSIC Outflow	TOTAL
Existing Case	139.2	48.2	163.1	454	804.5
Developed Case No Dam Diversion	156.6	32.9	163.1	520	872.6
Developed Case With Diversion (Diversion Threshold 6ML/day)	219.5	31.5	91.5	520	862.5
Developed Case With Diversion (No Diversion Threshold)	309.5	31.5	0	520	861.0

The same STP storages and irrigation rates were assumed for the existing and developed cases. The GoldSim modelling had increased water demands, reduced irrigation demands and storage volumes than assumed in the MEDLI modelling, which showed that no STP overflows would be likely. The following observations are made in relation to **Table 17-9**:

- Due to a reduction in water demand from the dam the average annual overflows are increased.
- Due to reduced water demands and increased use of recycled water the volume of predicted overflow from the STP is significantly reduced. This will have significant impacts on the potential nutrient loads discharged downstream.
- Diverting the additional catchment area to the dam reduces downstream flows by around 10 ML/year due to increased evaporation losses.

17.7 Stormwater Quantity Modelling - Preliminary Detention Basin Sizing

Preliminary detention basin sizing was conducted in accordance with the Queensland Urban Drainage Manual (QUDM, 2008). The existing and developed case 63% and 1% AEP peak flows were calculated based on the Rational Method to determine the volume of storage required for each catchment shown in **Figure 17-1**. To simplify the analysis the dam diversion was not included. This will reduce the volume of detention storage required for catchment E. The results are summarised in **Table 17-10** and **Table 17-11.**

Table 17-10. Rational Method Calculations.

Catchment	Time of Con-centration (min)	Fraction Impervious		1% AEP Peak Flow (m^3/s)		63% AEP Peak Flow (m^3/s)	
		Existing Case	Developed Case	Existing Case	Developed Case	Existing Case	Developed Case
A	16.7	0.00	0.02	7.79	7.84	1.80	1.81
B	10.5	0.00	0.00	2.29	2.29	0.53	0.53
C	15.6	0.00	0.07	8.40	8.57	1.95	1.99
D	34.9	0.14	0.16	16.96	17.06	3.93	3.95
E	41.6	0.05	0.09	46.03	46.55	10.61	10.73
F	14.2	0.12	0.16	6.57	6.64	1.51	1.53
G	12.2	0.00	0.28	2.19	2.36	0.51	0.55
H	9.3	0.00	0.24	2.78	2.97	0.64	0.68
I	13.1	0.31	0.36	3.51	3.55	0.81	0.82
J	12.2	0.00	0.05	1.40	1.42	0.32	0.33
K	14.4	0.00	0.14	3.99	4.15	0.92	0.96
L	11.8	0.00	0.05	5.55	5.63	1.28	1.30

Table 17-11. Preliminary Detention Basin Sizing.

Catchment	Detention Storage Required (m^3) 1% AEP	Detention Storage Required (m^3) 63% AEP	Approximate Total Rainwater Tank Storage (m^3)	Likely Additional Stormwater Treatment
A	60	14	110	Buffer strips and some bio-retention gardens
B	0	0	0	n/a – camping sites
C	210	49	350	Buffer strips and some bio-retention gardens
D	260	60	180	Buffer strips and some bio-retention gardens
E	1726	398	700	Mix of bio-retention gardens, bio-retention basins, grassed swales and wetland areas.
F	82	19	130	Mix of bio-retention gardens, bio-retention basins, grassed swales and wetland areas
G	170	39	260	Buffer strips and remaining roof and ground to bio-retention gardens
H	141	32	180	Buffer strips and some bio-retention gardens
I	48	11	360	Mix of bio-retention gardens and wetland areas.
J	20	5	40	Buffer strips and some bio-retention gardens
K	184	42	310	Buffer strips and some bio-retention gardens
L	75	17	120	Buffer strips and some bio-retention gardens

The results from **Table 17-11** show that the amount of rainwater tank storage being provided is significantly greater than the 63% AEP detention storage required for all catchments. However, as the rainwater tanks may be full prior to the storm event occurring, it is recommended that an additional 20 percent storage be provided above the rainwater tank outlet, i.e. each 10kL tank for the villas should have a minimum size of 12kL, with 2kL above the outlet, for catchments where bio-retention or wetland devices are not being provided. Additional detention storage will also be provided by the bio-retention and wetland stormwater quality treatment devices provided throughout the site. The greatest volume of detention storage is required for catchment E. However, as 27 hectares from this catchment will be diverted towards the dam, the flows from this catchment will be significantly reduced in the developed case.

17.8 Impacts associated with Climate Change

The potential impacts of climate change in the Mackay Whitsunday region are summarised in the 2014-2021 WQIP. The climate change trends for the Mackay Whitsunday region include:

- Increased atmospheric CO2;
- Increases in average air temperatures, more hot days and fewer cold days. On a national basis, Australia's climate has warmed by 0.9ºC, with more extreme heat and fewer cool extremes (Bureau of Meteorology and CSIRO 2014). Projections for the Mackay Whitsunday region show that average maximum temperatures may increase by 1ºC by 2030 and 2ºC by 2070 (RPS 2014);
- Annual rainfall is not expected to change, however the intensity of extreme events is expected to increase (Hilbert et al. 2014). Projections for the Mackay Whitsunday region indicate baseline (1995) 1 in 100 year rainfall events may occur every 70 years by 2030 and every 60 years by 2050 (RPS 2014);
- The intensity (not frequency) of tropical cyclones is expected to increase (Hilbert et al. 2014);

- Evapotranspiration is expected to increase in all seasons (Hilbert et al. 2014);
- Wind speeds are expected to increase across eastern Australia (Hilbert et al. 2014); and
- Sea levels will continue to rise, and the frequency and height of storm surges are expected to increase (Hilbert et al. 2014).

Although the average annual rainfall is not expected to change, the increases in rainfall intensity during the wet season, likely reductions in rainfall intensity in dry seasons and increases in evapotranspiration indicate that an overall reduction in runoff is likely. The implications of climate change on the island's water resources are addressed in **Chapter 18 – Water Resources**.

17.9 Potential Impacts and Mitigation Measures

The following table provides an assessment of potential impacts and mitigation measures relating to water quality.

Table 17-12. Risk assessment matrix – water quality.

Potential Impact	Significance of Impact: Unmitigated	Mitigation Measure			Significance of Impact: Mitigated
		Design	Construction	Operation	
Acid Sulfate Soil (ASS) Disturbance during construction activities	High (15)	-	• ASS management practices shall adhere to the requirements of the Queensland Acid Sulfate Soil Technical Manual Soil Management Guidelines including testing and monitoring during construction • Implementation of a Construction Environmental Management Plan	• Excavation of areas less than 5 metres AHD is to be undertaken in accordance with the Acid Sulfate Soils Management Plan.	Low (5)
Increases in the amount of sediments that may be exported from the site.	High (15)	-	• Prepare and comply with an Erosion and Sediment Control Program (ESCP).	• Regular inspections and maintenance will be undertaken for stormwater drainage and treatment systems.	Low (5)
Pollution arising from site activities.	High (15)	-	• Install stormwater treatment devices (e.g. litter traps/vegetated swales and buffers). • Monitoring of soil nutrient levels to prevent leaching of nitrogen and phosphates at monitoring points identified on **Figure 17-3**.	• Regular inspections and maintenance will be undertaken for stormwater drainage and treatment systems; • Use of pesticides, herbicides is avoided or limited to the dry season.	Low (5)

Potential Impact	Significance of Impact: Unmitigated	Mitigation Measure			Significance of Impact: Mitigated
		Design	Construction	Operation	
Pollution arising from the storage or use of hazardous materials.	High (15)	-	• All potentially hazardous materials and waste (e.g. waste oils, batteries, fuels and chemical wastes etc.) shall be stored in separate containers located within a bunded and roofed hardstand area; • Any stormwater captured within bunded areas used for the storage, refuelling or handling of fuels, waste or other hazardous materials shall be pumped out and disposed of at an appropriately licensed facility; • Refuelling areas will be bunded with a stormwater containment system to prevent discharge to soil or waterways. • Establish a spill response procedure.	• All potentially hazardous materials and waste (e.g. waste oils, batteries, fuels and chemical wastes etc.) shall be stored in separate containers located within a bunded and roofed hardstand area; • Any stormwater captured within bunded areas used for the storage, refuelling or handling of fuels, waste or other hazardous materials shall be pumped out and disposed of at an appropriately licensed facility on the mainland; • Refuelling areas will be bunded with a stormwater containment system to prevent discharge to soil or waterways. • Establish a spill response procedure.	Low (5)
Pollution from liquid waste (sewage) in the event of overloading, electrical failure, structural failure or mechanical failure	High (15)	• Waste water treatment infrastructure shall be located outside of the water supply dam catchment • Redundancy in key aspects of the treatment train e.g. duty/standby pumps	• All critical infrastructure shall be bunded	• The wastewater treatment plant will be managed in accordance with conditions of an environmental authority for its operation. • Temporary bunding and wet weather storage requirements shall be utilised to mitigate the risk of overflow with any water collected to be pumped out and disposed of at an appropriately licensed facility on the mainland. • Back-up generators shall be provided for use during power failures	Low (5)

Potential Impact	Significance of Impact: Unmitigated	Mitigation Measure			Significance of Impact: Mitigated
		Design	Construction	Operation	
Recycled water discharged to surface water	Medium (9)	-	• 12 ML wet weather storage to be constructed to contain flows during occasions when irrigation is unavailable due to wet weather	• All wastewater will be treated through an appropriately sized plant with effluent quality suitable for public irrigation (Class A+) with nutrient removal • Where discharge of recycled water is required, monitoring of quality of all discharges shall be conducted	Low (2)
Mismanagement of irrigation activities	Medium (9)	• Areas for irrigation are to be located outside of the Dam catchment area	-	• Recycled water shall be treated through an appropriately sized plant with effluent quality suitable for public irrigation (Class A+) with nutrient removal • Irrigation activities shall be conducted in accordance with an Irrigation Management Plan	Low (2)

17.10 Summary

Water quality is naturally variable, and is dependent on numerous factors such as land use, catchment management practices, antecedent conditions, soil types, climatic and seasonal factors and in-stream processes. The water quality objectives for the assessment were sourced from the *Environmental Protection (Water) Policy 2009 - Proserpine River, Whitsunday Island and O'Connell River Basins Environmental Values and Water Quality Objectives*, and associated plans. The *Water Quality Guidelines for the Great Barrier Reef Marine Park 2010* were also referenced. The majority of Lindeman Island is classified as Whitsunday Island freshwater with High Ecological Value (HEV) for Aquatic Ecosystems, however the existing and proposed developed area of Lindeman Island (with the exception of glamping area on the western coast) is not included in this area and is therefore classified as Moderately Disturbed Freshwater.

As the freshwater streams on Lindeman Island are ephemeral limited opportunity exists to undertake baseflow monitoring, however despite this two rounds of event based water quality testing were able to be conducted at the site within the waterways. The water quality testing identified that that current water quality meets the specified objectives. In June, at site LIND06 there was an elevated level of TSS. Further additional water quality testing is proposed prior to construction, with the inclusion of an additional monitoring point LIND07 near the proposed glamping facilities. The proponent has also made a commitment to completing a baseline marine water quality sampling program. The objective of the program would be to identify the environmental values of receiving waters and set objectives and indicators relevant to the protection of those values.

MUSIC modelling undertaken as part of the EIS has identified that despite marginal increases in impermeable surfaces, stormwater quality across all measures (Total Suspended Solids, Phosphorus, Nitrogen and Gross Pollutants) is predicted to improve as a consequence of proposed stormwater treatment devices and measures. These measures include rainwater tanks, vegetated buffer strips, bio-retention gardens, bio-retention basins, constructed wetlands, Gross Pollutant Traps and revegetation of cleared areas. Further the proposed golf course will be managed in accordance with the Golf Course Management Plan and Irrigation Plan to ensure any nutrients will be taken up by the existing vegetation.

The stormwater and water management strategy for the Lindeman Great Barrier Reef Resort aims to reduce the pollutant load being discharged to streams that drain to the Great Barrier Reef Marine Park. Specifically, stormwater and water management strategies will be adopted that:

- Re-uses rainwater, reducing potable water demand and stormwater pollutant loads;
- Treats and re-uses wastewater for non-potable uses on site;
- Minimises the potential sources of stormwater pollutants;
- Treats stormwater runoff to remove sediment and nutrient load;
- Replicates existing flow patterns;
- Reduces potential for scour and erosion; and
- Integrates open space with stormwater drainage corridors and treatment areas to maximise public access and recreation and preserve waterway habitats and wildlife corridors.

Accordingly, no long term irreversible water quality impacts, both terrestrial or marine, are likely to arise from the development.