Appendix N

Report:
"Stormwater Management Plan"

71 Ash Street (PO Box 191)

BARCALDINE QLD 4725

Barcaldine Regional Council
Yellow Jack Drive Waste Disposal Facility

Stormwater Management Plan

AUGUST 2017

Document Control

Date	Name	Position	Endorse/Approve
19/07/2017	William Green	Environmental Engineer	Draft
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16/08/2017	William Green	Environmental Engineer	Approve

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1. INTRODUCTION

This Stormwater Management Plan (SMP) has been developed on behalf of Barcaldine Regional Council (BRC) for the management of storm water on the operational waste disposal facility. This document focuses on the design and operational aspects associated with managing the risk of contamination to the surrounding environment caused by stormwater releases.

The SMP has been prepared for the approval of a proposed new municipal Waste Management Facility (WMF) for the town of Barcaldine in response to the communities existing waste disposal site nearing its capacity. The SMP has been prepared in accordance with current best management practice relating to stormwater management for waste management activities.

Management and control of stormwater will be essential in the operation of Barcaldine's new WMF due to the potential for pollution to the surrounding environment and subsequent detriment to surrounding environmental values. Under QLD state legislation is an offence under the Environmental Protection Act 1994 to cause environmental harm and is a requirement under ERA 60 Conditions that the quality of water released from the site does not cause environmental harm.

The purpose of the SMP is to provide guidance to BRC for the management of stormwater at their proposed WMF in accordance with State Government Regulation.

2. SURFACE WATER RELEASE

2.1. Release Water Characteristics

It is the intention of BRC to manage stormwater in a responsible manner in accordance with current best management practice, avoiding contamination to the receiving environment. The implementation of storm water management strategies will optimise the quality of site stormwater generated and limit the release of stormwater offsite.

The implementation of a range of stormwater management practices will avoid the mobilisation of contaminants in stormwater or contain contaminants in designated areas in an inert state. Management strategies implemented to minimise contamination are discussed in more detail in section 4 of this document. In the event of a large rainfall event which exceeds the capacity of the sediment basin the discharge water quality should not contain concentrations of contaminants capable of causing environmental harm, stormwater released from site will be sourced from areas of the site not likely to be contaminated with waste materials.

2.2. Stormwater release events

The storm water that is generated onsite is to be managed appropriately in accordance with current best management practice. In accordance with DEHP Model operating conditions ERA 60 activities, a Sediment basin capable of containing a 1 in 10 year event over a 24hr period event will be constructed. Therefore the release of stormwater will be limited to large rainfall events with no dry weather releases.

The stormwater release will be released to land via an outlet structure within the landfill site in accordance with DEHP's guideline on storm water management for Environmentally Relevant activities the outlet structure will be capable of withstanding a 50 year ARI event. The area surrounding the outlet structure within the waste management site boundary is to be retained as remnant vegetation until such time as the site expands to the West (approx. 20 yrs). Therefore the area of discharge will be well vegetated and resilient to erosion. Following the construction of a firebreak adjacent to the discharge area a small rill approximately 300mm will be maintained to direct discharge water in a westerly direction within the site boundary.

3. RECEIVING ENVIRONMENT, ENVIRONMENTAL VALUES

In order to assess the potential impact of the proposed activity on the surrounding environment it is important to identify the unique environmental values of the receiving environment and the appropriate management measures tailored to avoid or minimise impacts to those identified values specific to the area. This section aims to identify these values and establish a basis for the implementation of management practices required to avoid adverse impacts to the receiving environment.

3.1. Terrestrial Environment

The point of release for the proposed activity will be directly to land. The release point will be approximately 1.5km from the nearest watercourse and approximately 750m from wetlands identified as 1-50% wetland mosaic units. In this instance reference should be made to the terrestrial ecology adjacent to the site, as releases will be directly to land in an area identified as remnant vegetation.

3.1.1 Vegetation

The proposed development is located adjacent to category B Remnant Vegetation, least concern Regional Ecosystem 10.5.12 and 10.5.2a in accordance with The DNRM Mapping Database.

Regional Ecosystem 10.5.12 is described in the Regional Ecosystem Description database as; Eucalyptus populnea open woodland on sand plains where Eucalyptus Populnea dominates a sparse tree layer with a sparse ground layer of Triodia pungens and other Tussock grasses. A sparse low tree layer often consists of Archidendropsis basaltica and/or Eremophila mitchellii species and Lysiphyllum carronii, Acacia excelsa, Ventilago viminalis, Geijera parviflora, Grevillea striata and Acacia sericophylla are frequently present.

Regional Ecosystem 10.5.2a is described as Corymbia dominant woodland with C. dallachiana and C. plena dominating a sparse canopy forming open woodland on sand plains. A lower tree or shrub layer of scattered plants is often present, including Acacia sericophylla and Petalostigma pubescens.

3.1.2 Fauna

Despite significant anthropogenic disturbances occurring at the proposed development site and surrounding area the area potentially contains significant ecological features, including EVNT lissted fauna species and habitat. As part of a biological assessment conducted an EPBC Protected Matters Report on-line database search including a 1km buffer area indicated that there is the potential for endangered and vulnerable species to be present in the area. Due to the possibility of these rare fauna species residing in the area the potential exists for native fauna to be adversely impacted by released contaminants.

3.2. Aquatic Environment

Environmental value (EV) is a variably defined term, in the context of water quality management environmental values are defined in the Environmental Protection (Water) Policy 2009, the principle legislative framework for water quality management in the state of QLD and provides a process for determining the EV’s of surface waters and determining corresponding water quality objectives. The table below Provides a list of EV’s relevant to the activity identified in the Queensland Water Quality Guideline.

Table 1 Surface Water Environmental Values

EV	DEFINITION FROM QWQG (DERM 2009A)	RELEVANCE TO SITE RELEASE
Aquatic Ecosystems	Level 2: Slightly–Moderately Disturbed Ecosystems. *As described in ADWG 2000 - rural streams receiving runoff from land disturbed to varying degrees by grazing or pastoralism, or marine ecosystems lying immediately adjacent to metropolitan areas."* (AWQG 2000; 3.1-10)	Potential for contaminants released from site to adversely impact on biodiversity and ecosystem health
Primary Industries	Stock Water Drinking water for stock	Local waterways including Lagoon Creek and Alice River are utilised by livestock as a water supply
	Farm Water Supply Water used for laundry and produce preparation	Water is sourced from locations such as the Barcaldine Weir, and Omar waterhole Isisford for domestic water supply.
Recreation and Aesthetics	Primary Recreation recreation which involves direct contact and a high probability of water being swallowed - for example, swimming	Particularly relevant at points such as the Barcaldine Weir, and Omar waterhole Isisford.
	Secondary Recreation Health of humans during recreation which involves indirect contact and a low probability of water being swallowed – for example, wading, boating, rowing and fishing.	
	Visual Recreation Amenity of waterways for recreation which does not involve any contact with water - for example, walking and picnicking adjacent to a waterway.	
Drinking Water	Raw Drinking Water Supply Suitability of raw drinking water supply.	Particularly relevant points such as the Isisford Waterhole.
Cultural and Spiritual Values	Indigenous and Non-Indigenous Cultural Heritage	Particularly relevant at points such as the Barcaldine Weir, and Omar waterhole Isisford.

3.2.1 Aquatic ecosystems

The site is located between two watercourses, the Alice River to the South and Lagoon Creek to the North West, these two systems meet approximately 10 km downstream from the Landfill site. The Alice River is the main drainage channel in the Barcaldine District. It flows in a south-westerly direction past the proposed landfill activity. The Alice River does not flow permanently and is a relatively large episodic river where flows are associated with significant rainfall events in the catchment, natural ephemeral flow patterns in this part of the river have been permanently altered with the installation of a weir approximately 8.5km downstream from the site.

Lagoon Creek is an ephemeral waterway with a relatively small catchment with head water originating approximately 30km to the north-east of Barcaldine. Lagoon Creeks flow events are irregular, associated with heavy localised rainfall events. Lagoon Creek’s natural hydrological system is subject to disturbance, receiving treated water from the of Barcaldine’s sewerage treatment plant upstream from the proposed landfill site.

Upstream from the junction of the adjacent waterways are a series of flood channels forming a wetland habitat, mapped as RE 1-50% wetland (mosaic units), the landfill site will be approximately 750m from the edge of the mapped wetland areas. A map of wetland habitats is provided in appendix A.

3.2.2 Primary Industries

The primary land use in the vicinity and downstream locations of the proposed landfill location is agriculture in the form of grazing. Surface waters downstream from the proposed activity are accessible by livestock and generally utilised by landholders as stock watering points.

Surface waters from the area may be utilised for farm water supplies, these areas would be restricted to permanent water sources along the Alice River and Barcoo River further downstream.

3.2.3 Recreational Use

Although significant surface waters downstream from the proposed landfill activity are limited, surface waters may be utilised for primary and secondary recreational use. Usage for primary and secondary purposes is relatively limited due to the low population density of the area and dry climate. Examples of areas utilised for swimming, boating and fishing would include the Barcaldine weir, Isisford water Hole and Omar Waterhole Isisford.

Many of the surface waterholes in the Alice River and Barcoo River catchments are utilised for tertiary recreation sites, primarily utilised as camping sites for traveling tourists. Areas such as the Barcaldine Weir, Isisford Caravan Park on the Isisford Waterhole and Omar waterhole Isisford are extensively utilised for tertiary recreational activities in the dry season by traveling tourists.

3.2.4 Drinking Water

Surface waters downstream from the proposed landfilling activity utilised for drinking water include Isisford’s treated drinking water scheme from the Isisford waterhole approximately 45 km from the Junction of the Alice River and the Barcoo River. Windorah also utilise surface waters for drinking water, Windorah’s water supply is from the lower reaches of the catchment extracted from Cooper Creek over 300km from the proposed landfilling activity.

3.2.5 Cultural and Spiritual Values

The natural and manmade surface water supplies in the area are of significant importance to the residents of the area, for aboriginal people the rivers were an essential part of life for their survival. The river systems in the area play a vital role in the local economy’s providing drinking water for stock and attractions for tourists in the area.

4. STORM WATER MANAGEMENT CONTROLS

As identified in the previous section it has been determined that contaminants will be processed within the confines of the facility and that EV's are present in the surrounding area. The identification of these values justifies the requirement to mitigate potential risks associated with the operation of the WMF. This section discusses how the activity will be managed to mitigate the risk of contaminants having an adverse impact on the receiving environment.

4.1 Stormwater Control Devices

In accordance with DEHP's Model Operating Conditions, it is a requirement that stormwater runoff from operational areas must be retained onsite or managed to remove contaminants before release. To achieve this, storm water controls will be designed to meet the recommended standards for rainfall intensity requirements, set out in the QLD government Model Operating Conditions and Stormwater Guidelines for Environmentally Relevant Activities.

The primary objectives of the storm water management design will be to:

- Divert clean water around the operational site.
- Retain storm water from the operational area onsite.
- Segregate stormwater runoff from areas where stormwater contamination is imminent or possible (leachate) and manage separately to uncontaminated stormwater.

A description of the storm water management controls are described below. An Erosion and Sediment Control Design Plan is provided in Appendix B.

4.1.1 Bunding

Areas within the WMF with the potential to leach contaminants will be bunded, these areas include the storage areas within the waste transfer station where recoverable waste streams will be temporarily stored. These areas are the:

- Battery and Chemical Shelter: Covered structure 3mx6m for temporary storage of batteries will be constructed with impervious concrete bund.
- Green waste and Mulch stockpiles: these areas have the potential to produce organic contaminants with the potential to increase nutrient loads and biological oxygen demand in runoff; an earthen bund approximately 300mm high x 1m wide will be constructed on the down slope side of these storage areas to reduce runoff volumes from these areas.
- Construction waste, Scrap Steel and Tyre stockpiles: these areas have the potential to contain industry related contaminants and subsequently contaminate stormwater runoff, therefore an earthen bund approximately 300mm high x 1m wide will be constructed on the down slope side of these storage areas to reduce runoff volumes from these areas.

The earth bunds down slope of the transfer station stockpiles will retain storm water following rainfall events, the detention of water in these areas could become a source of contamination. Following rainfall where ponding of water has occurred the ponded water will be required to be removed. Extracted water will be utilised as a dust suppressant on the landfill working face. As an alternative management option the water may be discharged to the leachate evaporation pond.

4.1.2 Clean Water Diversion

The installation of clean water diversion earth banks on the high side of the operational site will be required to divert flows of uncontaminated clean water around the site, expelling these waters from the site. In accordance with IECA and QLD Government Storm Water guidelines the diversion banks should be constructed so that they are trapezoidal in shape and have a hydraulic free board of no less than 150mm for a 1 in 10 year event over a 24hr period.

4.1.3 Catch Drains

On the low sides of the operational area catch drains will be required to retain site stormwater from the operational area and direct the water into the sediment basin. For the effective retention of water, drains must be constructed at the appropriate levels to convey water for specified rainfall events. If the potential for high flow velocities in the catch drain are identified rock check dams should be integrated into the design to reduce water flow velocities and the erosion of the catch drain banks. These devices should also be trapezoidal in shape and have a hydraulic freeboard of no less than 150mm for a 1 in 10 year event over a 24hr period.

4.1.4 Sediment Basin

A sediment basin will be required for the retention of stormwater generated from the site operational area and must be designed to retain site runoff for events up to a 24 hr storm event with an ARI of 1 in 10 years. The sediment basin should also be designed with a sediment storage zone equal to 50% of the total storage volume required. The sediment basin design will be required to incorporate a spillway to allow for large flow events. The spillway will require a well-defined channel that can fully contain and is effectively armoured to withstand a 50 year ARI critical event.

4.1.5 Waste Transfer Station First Flush Stormwater Treatment

The waste transfer station is the receiving point for recyclable waste streams and general waste dropped off by members of the community. The transfer station is a point of segregation for different waste streams; temporary storage of waste streams at the transfer station will provide a potential source of contamination onsite due to the potential for contaminants to be incorporated amongst stockpiled wastes.

Stormwater runoff from the transfer station is to be managed in isolation from other areas of the WMF due to the potential for contaminants to be present in the stormwater. A first flush collection system is proposed to contain stormwater from this site, the first flush collection facility will be designed to capture rainfall from a minimum 20mm rainfall event. Management practices implemented to avoid contaminant releases beyond the transfer facility include:

- Appropriate Design – the first flush retention system will be designed by an RPEQ engineer with appropriate qualifications in hydraulic analysis and design. The pond will be lined with a poly liner suitable for industrial containment purposes.

- Maintain sufficient freeboard – after rainfall events sufficient to trigger the flow of water into the collection system stormwater may be extracted from the pond to a level sufficient to ensure the required capacity is available for forecast rainfall events. Extracted water will be utilised as a dust suppressant on the landfill working face. As an alternative management option the water may be discharged to the leachate evaporation pond.

- Clean water runoff exceeding of a 20mm rainfall event will be diverted into the site stormwater catchment via the clean water bypass channel once the first flush collection pond is full.

- The intake of the first flush retention pond will be sloped inward towards the retention pond and be lower than the clean water bypass channel to avoid the ingress of first flush water into the bypass system.

5. STORM WATER MANAGEMENT OPERATIONAL PRACTICES

5.1 Site Delineation and Planning

Prior to the installation of stormwater control devices, the required operational area for the facilities first stage should be clearly delineated identifying designated operational areas such as green waste, scrap steel and clean fill etc. and should minimise land disturbance without compromising safe work distances.

5.2 Routine Inspection and Management of Waste

The BRC WMF will be managed to avoid the unnecessary migration of contaminants on site or to the surrounding environment. Council will delegate staff to the management of the facility ensuring that waste is deposited and stored in the correct locations. Regular inspections of the site, particularly the waste transfer station will aim to identify any potential contaminants deposited in incorrect locations with potential to contaminate site stormwater. These potential contaminants will be appropriately disposed of to landfill or if they are regulated waste materials unauthorised for disposal at the facility they will be appropriately stored and transported offsite by a regulated waste transporter.

5.3 Segregation of Contaminated Runoff

In order to avoid the release of contaminants offsite, storm water will be partitioned on site based on the likelihood of contamination from sources of contaminants located onsite. The stormwater management system has been designed to capture and treat stormwater which comes in contact with waste streams stored or deposited onsite. Two areas where the potential for the contamination of stormwater is possible include the waste transfer station and the areas containing municipal general waste; management of runoff from general waste areas are discussed below.

5.3.1 Municipal General Waste Runoff

Municipal general waste has been characterised and documented in a number of waste management resource documents, the characterisation of this waste has identified a number of contaminants present in Australian municipal general waste facilities, as such stormwater which comes in contact with this material has the potential to absorb and transport contaminants across its flow path and is considered “leachate”. The stormwater design of Barcaldine’s WMF separates leachate material from site stormwater to avoid contaminant releases, the separation of leachate material is achieved by:

- Bunding around landfill cells to divert stormwater around the landfill cells.
- Containment of general waste at the transfer station in water tight skip bins, containing liquids which have come in contact with the general waste.
- Maintaining a high level of organisation and segregation of materials at the site; conducting routine inspections across the site and correctly storing or disposing of potential contaminants if out of place.

5.5 Sediment Basin Storage Capacity

After significant rainfall events the storage capacity of the sediment basin will be decreased. In accordance with best management practice the sediment basin must be managed in a way that within 120hrs of the most recent rainfall event, the required design capacity of the sediment basin (a 24 hr storm event with an ARI of 1 in 10 years) is available for capture and storage of stormwater from another runoff event.

5.4 Monitoring

Following large rainfall events which exceed the storage capacity of control devices, releases of storm water will occur, controlled releases of stormwater will be conducted in order to maintain sufficient storage capacity of the sediment basin for future runoff events. Prior to the release of stormwater following large rainfall events water samples will be taken for analysis, to identify if the water quality is suitable for release in accordance with the release parameter identified in table 2 below.

Water monitoring techniques must be in accordance with the methods prescribed in the current edition of the DEHP's Water Quality Sampling Manual. In accordance with the manual, all samples taken must be representative samples and a minimum of three grab samples shall be taken at 10cm below the water surface.

Surface water will be sampled from the lower end of the sediment basin adjacent to the sediment basin outlet structure. Each sample will be used to test for the specified contaminants in Table 2

Table 2 Surface Water Monitoring Program

Compositional Analysis			
Analyte	**Limit Type**	**Frequency**	**Units**
pH	Range	6-8	pH
Dissolved Oxygen	Min	6.5	mg/l
Suspended Solids	Max	50	mg/l
Electrical Conductivity	Max	1000	uS/cm
Visual Inspection			
Inspect water prior to discharge for evidence of hydrocarbons such as oil sheen, visible floating grease, scum, litter or other contaminants.			

5.6 Correct Soil Handling and Storage

To avoid unnecessary erosion and sedimentation occurring onsite, specific requirements for the handling and storage of soils should be adhered to. Topsoil material should be kept separate form any subsoil stored onsite and stockpiled no higher than 2m. Any stockpiled materials should be protected from erosion; topsoil material should be seeded with a seed mix approved by Councils Rural Lands Officer to provide stabilisation through vegetative cover. Any stockpiled subsoils that are unsuitable for vegetative growth should be covered with a suitable material such as mulch, woodchip, soil binder or geo fabric to avoid erosion.

6. MAINTENANCE REQUIREMENTS

6.1 Diversion Banks and Catch Drains

Diversion banks and catch drains should be maintained to ensure effective stormwater management. Routine monitoring particularly after significant rainfall events should aim to identify and repair any defects. Maintenance works should aim to:

- Ensure diversion banks are maintained and any degraded areas are repaired.
- Identify if water is pooling against diversion banks or catch drains and improve flow through these areas.

- Install velocity controls such as check dams if high velocity flows are causing damage to banks.
- Any build-up of sediment impeding flows should be removed.

6.2 Leachate Collection and Sediment Basins

Routine monitoring and maintenance of the sediment basin and leachate dam will be required to ensure structural integrity is not compromised. A maintenance program should include the following tasks:

- Erosion to containment banks should be monitored and repaired if required.
- If sediment or sludge build up is determined to be significantly reducing the storage capacity to the point where desired settlement volumes cannot be achieved desilting will be required. Desilted material is to be utilised as cover material in the disposal cell.
- After desilting liner integrity should be assessed and repaired if required.
- Sediment basin spillway should be assessed after large flows to check for overtopping or damage and make necessary improvements.

7. EMERGENCY CONDITIONS AND RESPONSE

All surface water onsite will be contained in either the leachate pond or the sediment basin to minimise the risk of uncontrolled release to the surrounding environment.

The following situations have been identified requiring emergency response:

- Stormwater dam has been contaminated with either leachate or sediment and stored water is unable to be released to the downstream environment.
- Freeboard capacity of the leachate bund is exceeded with the potential to overtop the spillway.

7.1 Contamination of Stormwater

If the sediment basin has been contaminated with leachate and stored water is unable to be released to the downstream environment, the following emergency response actions shall be implemented:

- Contaminated water shall be pumped to the leachate storage dam for temporary storage; and
- Irrigated over the waste mass.

7.2 Leachate Evaporation Pond Freeboard Capacity Exceeded

During and immediately after periods of high rainfall, the storage capacity of the leachate dam must be inspected and excess leachate transferred to the landfill waste cell.

The following emergency response actions need to be implemented:

- Irrigation back into the landfill if there is sufficient storage available within landfill waste mass; or
- Leachate is to be recirculated through the leachate collection and storage systems until evaporation has reduced levels to the desired freeboard capacity.

7.3 Downstream Surface Water Contamination

If surface water pollution has been reported in the downstream catchment, an investigation must be undertaken. Surface water monitoring at upstream and downstream locations will be required and subsequent analysis to determine if contaminants can be linked to the WDF.

In a situation where contamination to the surrounding environment has or is likely to have occurred the following steps will be undertaken:

- Take immediate action to contain the pollution.
- Notify the regulating body detailing:
  - The nature and source of contamination/spill
  - Actions taken
  - Future corrective actions to prevent recurrence.
- Implementation of approved actions.

8. IMPACTS ON IDENTIFIED ENVIRONMENTAL VALUES

The release to ground of stormwater originating from within the confines of the proposed WMF is not expected to adversely impact on the environmental values identified in the downstream environment. The potential for contaminant release to the receiving environment has been mitigated primary through planning/siting the activity in a location where site water can be effectively managed, in a location where a suitable proximity from aquatic ecosystems is achieved. Also the implementation of best management practice stormwater management systems will mitigate the risk of contaminants being released offsite.

Management practices implemented to avoid contaminant releases identified in this report include:

- Segregation of leachate material avoiding contaminants associated with general waste from entering stormwater
- Identifying sources of potential contaminants and implementing management measures to contain these contaminants in an inert capacity
- Minimising the operational catchment area, diverting clean water around the operational area to reduce site generated stormwater volumes.
- Erosion and sediment controls designed in accordance with current best management practice, optimising stormwater quality and reducing releases.

Environmental values have been identified downstream from the proposed activity including aquatic ecosystems and potential social impacts. A major consideration in assessing the potential for impacts to the surrounding environment is the nature of the releases and the distance from aquatic values. The release of stormwater from the facility will correspond with large rainfall events and will therefore not impact on the ephemeral nature of the associated waterways.

The proposed releases from the waste management facility are only expected to contain trace amounts contaminants from site, therefore any water released to the surrounding environment should not have any detrimental effects on the health of the aquatic ecosystems or water quality if release water were to reach the adjacent waterways.

9. REFERENCES

Australian Government National Health and Medical Research Council
Australian Drinking water Guidelines 2016

Australian Government Department of the Environment, Water, Heritage and the Arts
Emission estimation technique manual for Municipal Solid Waste (MSW) Landfills 2010

Australia and New Zealand Environment and Conservation Council
Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000

Queensland Government Environmental Protection
(Water) Policy 2009

Queensland Government Department of Environmental and Heritage Protection
Environmental values and water quality objectives

Queensland Government Department of Environmental and Heritage Protection
Healthy water for Queensland: Environmental values, management goals and water quality objectives

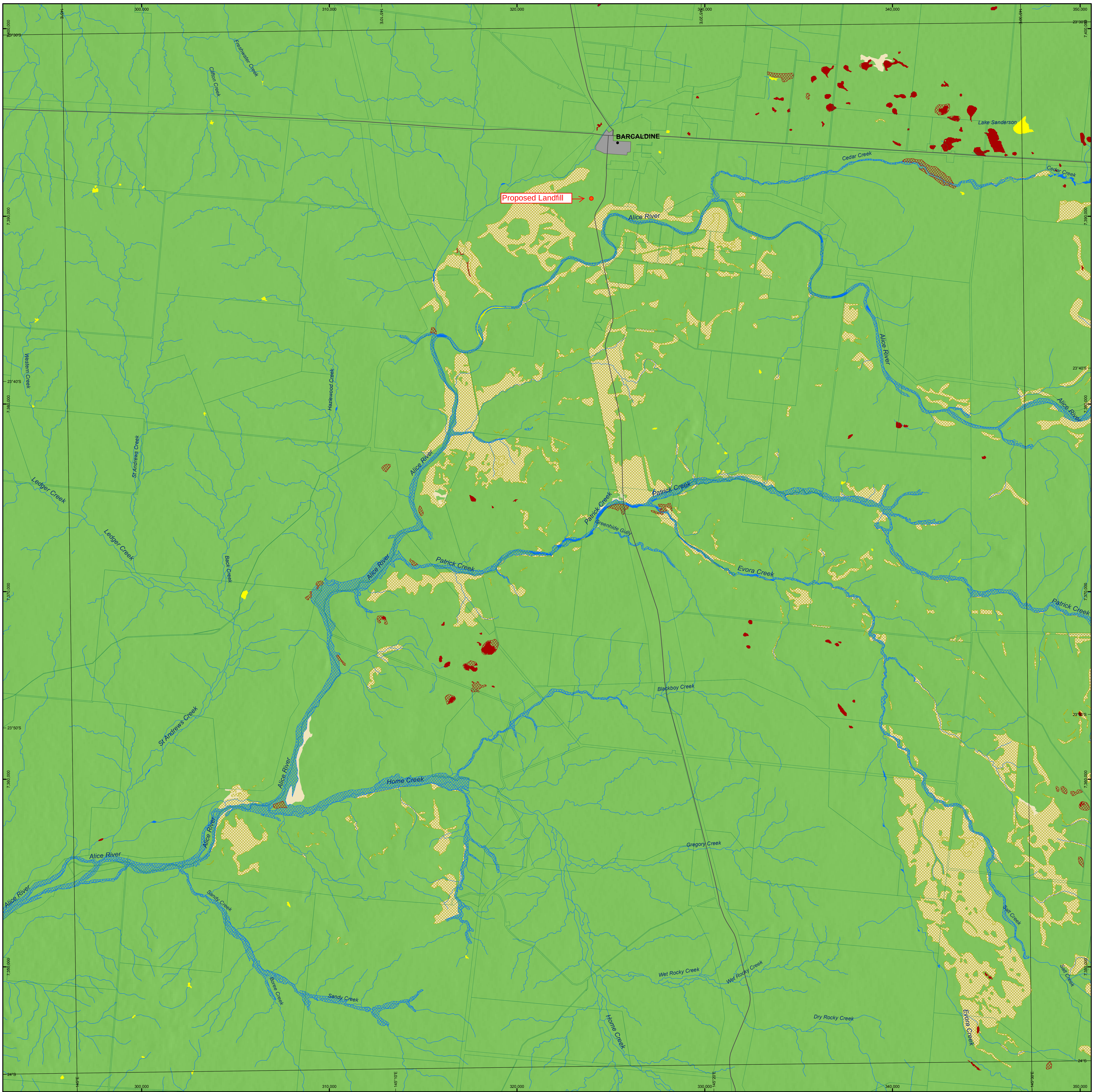
Queensland Government Department of Environment and Heritage Protection
Stormwater and environmentally relevant activities

Queensland Government Department of Environment and Heritage Protection
Technical Guide – Wastewater release to Queensland waters

Queensland Government Department of Environment and Heritage Protection
Queensland Water Quality Guidelines 2009

Appendix A

Wetland Ecology Map



Water bodies and wetland regional ecosystems

Water bodies	Wetland regional ecosystem	
		Marine system (e.g. open ocean) Open ocean extending to the Queensland 3nm coastal limit. Includes shallow coastal indentations or bays without appreciable freshwater inflows, and coasts that are exposed to oceanic waves and currents. Water regimes are determined primarily by oceanic tides.
		Estuarine system (e.g. mangroves, salt flats and estuaries) Includes wetlands with oceanic water that are significantly diluted with freshwater derived from land drainage.
		Riverine system (e.g. river and creek channels) Wetlands and deepwater habitats contained within a channel. Due to scale constraints these areas may include fringing palustrine vegetation.
		Lacustrine system (e.g. lakes) Wetlands and deepwater habitats situated in a topographic depression or a dammed river channel. Includes areas where emergent perennial vegetation has less than 30% areal coverage and total waterbody area exceeds 8ha.
		Palustrine system (e.g. vegetated swamps) Wetlands dominated by persistent emergent vegetation or where water in deepest part of the basin is less than 2m, active wave formed shores or bedrock features are lacking.

Wetland point features (e.g. springs, rockholes)

Riverine system (drainage lines)

Areas that may include wetlands

Remnant regional ecosystem 51–80% wetland (mosaic units)

Remnant regional ecosystem 1–50% wetland (mosaic units)

The above descriptions are an abbreviated version of the full descriptions in the Wetland Mapping and Classification Methodology www.wetlandinfo.ehp.qld.gov.au

Wetlands

For the purposes of mapping and classification, wetlands are:

areas of permanent or periodic/intermittent inundation, with water that is static or flowing , fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 m. To be a wetland the area must have one or more of the following attributes:

i. *at least periodically the land supports plants or animals that are adapted to and dependent on living in wet conditions for at least part of their life cycle, or*
ii. *the substratum is predominantly undrained soils that are saturated, flooded or ponded long enough to develop anaerobic conditions in the upper layers, or*
iii. *the substratum is not soil and is saturated with water, or covered by water at some time.*

Other Feature

- Towns
- Roads
- Cadastral boundaries (>0.5km² area)
- Built-up areas of Queensland
- Ocean outside 3nm limit
- Land at least 1km outside of Queensland

Queensland Wetlands 2013

MAP SERIES VERSION 4.0

BARCALDINE
7950

N

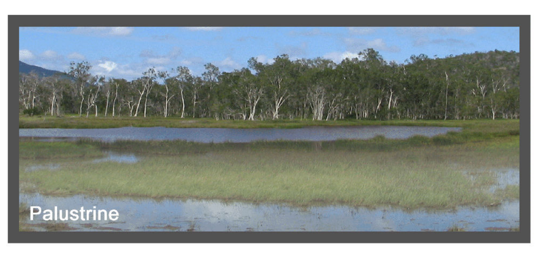
Horizontal Datum: GDA 1994

Projection: Map Grid of Australia 1994 (MGA94 Zone 55)

0 2 4 6 8 10

Kilometres

Scale 1:100,000 at A1 size

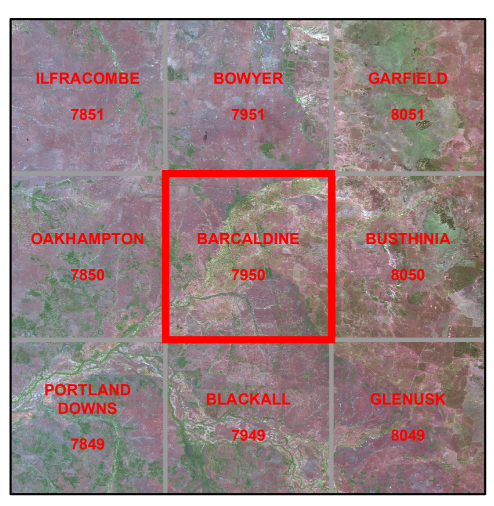


Further information on wetland mapping (including methodology and digital data) is available from www.wetlandinfo.ehp.qld.gov.au

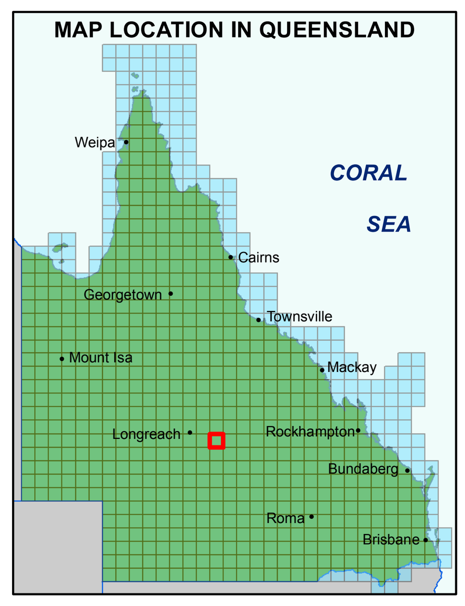
Accuracy information: The positional accuracy of wetland data mapped at a scale of 1:100,000 is +/-100m with a minimum polygon size of 5ha or 75m wide for linear features, except for areas along the east coast which are mapped at the 1:50,000 scale with a positional accuracy of +/-50m, with a minimum polygon size of 1ha or 35m wide for linear features. Wetlands smaller than 1ha are not delineated on the wetland data. Consideration of the effects of mapped scale is necessary when interpreting data at a larger scale, e.g. 1:25,000. For property assessment, digital linework should be used as a guide only. The extent of wetlands depicted on this map is based on rectified 2013 Landsat ETM+ imagery supplied by Statewide Landcover and Trees Study (SLATS), Department of Science, Information Technology and Innovation (DSITI). The extent of water bodies is based on the maximum extent of inundation derived from available Landsat imagery up to and including the 2013 imagery.

Data sources: Water body mapping derived from satellite imagery, DSITI; regional ecosystem mapping, DSITI; drainage mapping, Geoscience Australia (GA), Department of Defence and DSITI; Roads, MapInfo Australia Pty Ltd, 2006; Towns and Built-up areas, GA, 2003; Coastline, GA, 2004; Queensland 3NM Limit, Australian Maritime Boundaries Information System (AMBIS), GA, 2001; Digital Cadastral Database (DCDB), Department of Natural Resources and Mines, July 2015; Queensland springs database, Queensland Herbarium, 2015; SRTM 90m DEM, USGS/NASA, 2006. Landsat ETM+ imagery supplied by the Australian Centre for Remote Sensing (ACRES), Australian Surveying and Land Information Group (AUSLIG), Canberra. The satellite imagery used in this product has been pre-processed by SLATS, DSITI.

ADJOINING MAPS



MAP LOCATION IN QUEENSLAND



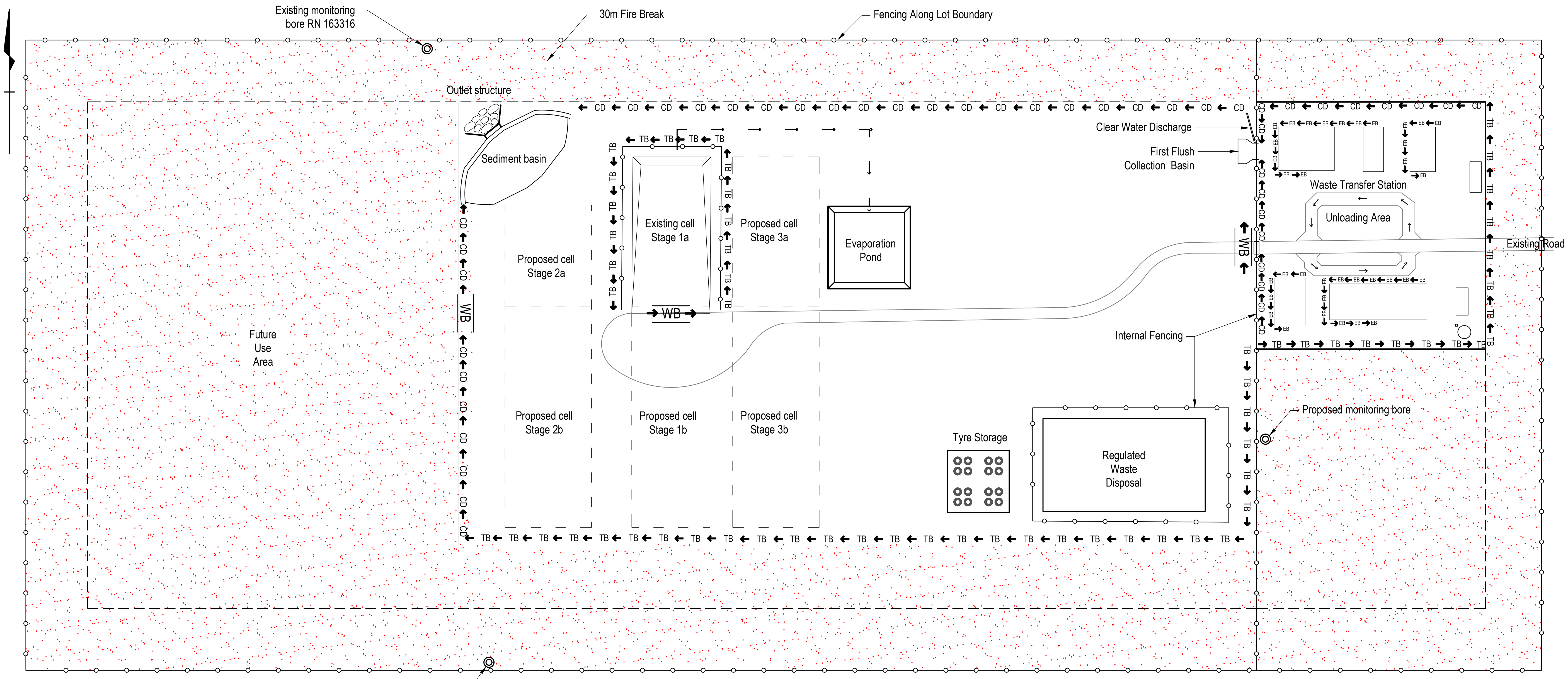
Australian Government

Queensland Government

Queensland Wetlands Program

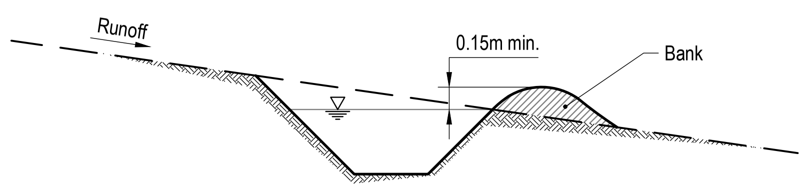
Appendix B

Waste Management Facility Site Erosion and Sediment Control Drawing

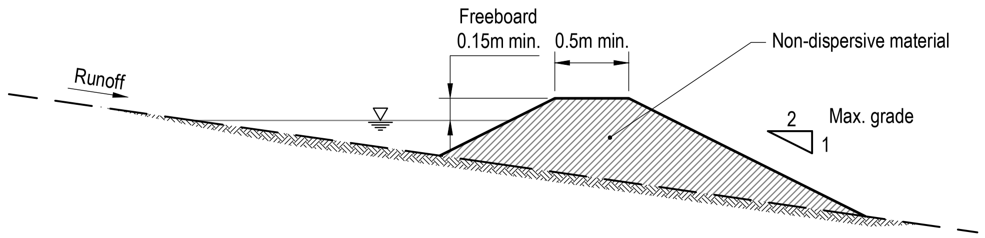


Plan View
Scale 1:2000

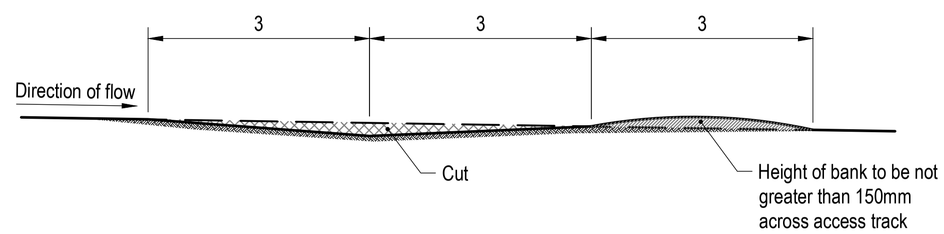
Legend	
WB	Woa-boy / Rollover Bank
TB	Topsoil Bank
CD	Catch Drain
EB	Earth Bank



Catch Drain with Bank
Scale 1:50



Topsoil Bank
Scale 1:50



Whoa-boy / Rollover bank
Scale 1:100

Rev.	Revision Description	By	Date
D	Site Erosion and Sediment Control Modifications	GC	20/07/2017
C	Modified fire break and added battery disposal shelter design	BD	04/04/2017
B	Added 30m perimeter fire break to drawing	BD	07/03/2017
A	Original Issue	JC	26/09/2016

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All dimensions shown in metres unless otherwise specified.

Drawn: GC	Approved:	
Checked: SB	SLJ Bourne (RPEQ 1513)	

Client: BARCALDINE REGIONAL COUNCIL
Project: WASTE MANAGEMENT FACILITY
Title: SITE EROSION AND SEDIMENT CONTROL

Category: STORM WATER
Drawing No. 140010-2/04
Rev. D
Scale: AS SHOWN
Size: A3

Date Printed: 21/07/2017 11:26:00

Appendix O

Report:
"Groundwater Management Plan"

71 Ash Street (PO Box 191)

BARCALDINE QLD 4725

Barcaldine Regional Council
Yellow Jack Drive Waste Disposal Facility

Groundwater Management Plan

AUGUST 2017

Document Control

Date	Name	Position	Endorse/Approve
28/07/2017	William Green	Environmental Engineer	Draft
14/08/2017	William Green	Environmental Engineer	Revision
18/08/2017	William Green	Environmental Engineer	Approval

Prepared by William Green
Title Environmental Engineer, George Bourne & Associates
Location 67 Elm Street, Barcaldine Qld
GBA File/Doc No 140010/197782

Contact for enquiries and proposed changes

If you have any questions regarding this document or if you have a suggestion for improvements, please contact:

Project Manager William Green

Phone 07 4651 5177

Table of Contents

1. INTRODUCTION

This Groundwater Management Plan (GMP) has been developed on behalf of Barcaldine Regional Council, (BRC) it assess the potential of the activity to adversely affect groundwater and related values. The document also identifies the design and operational aspects associated with managing the risk of contamination to groundwater.

The GMP has been prepared for the approval of a proposed municipal Waste Disposal Facility (WDF) for the town of Barcaldine due to the communities existing waste disposal site nearing its capacity. The GMP has been prepared in accordance with current QLD regulation and guidelines relating to groundwater management for waste management facilities.

Avoiding adverse effects to groundwater from the waste disposal facility and subsequent detriment to surrounding environmental values will be essential to ensure environmental compliance. Under QLD state legislation is an offence under the Environmental Protection Act 1994 to cause environmental harm and is a requirement under ERA 60 Conditions that the quality of water released from the site does not cause environmental harm.

2. BACKGROUND

The landfilling of waste at municipal waste facilities has the potential to adversely affect the groundwater resources through the migration of contaminants through the underlying geology. The composition of waste from municipal landfills and associated chemicals have been documented in a number of studies, which confirm the presence of potential contaminants within municipal general waste. Barcaldine's proposed WMF will receive predominantly municipal general waste to be deposed of to landfill, and therefore has the potential to contaminate groundwater.

The proposed facility is located within the Great Artesian Basin Resource Area which is the largest and deepest basin in the world, it is a vitally important water resource in inland Queensland, providing the primary source of potable water in many communities. As well as providing potable water supplies artesian groundwater is an important source of water for agriculture and mining industries. Due to the potential risk of the proposed landfill to contaminate groundwater; a vitally important resource in the area and further afield, it is a requirement for BRC as the authorised operators of the activity to manage the facility to avoid adverse impacts on groundwater values in accordance with QLD government environmental regulation.

The identified groundwater values and subsequent risks to these values relating to the proposed waste management facility are discussed in this document along with management practices to be implemented to avoid adverse impacts to the identified values.

3. RECEIVING ENVIRONMENT ENVIRONMENTAL VALUES

In order to assess the potential impact of the proposed activity on the surrounding environment it is important to identify the unique environmental values of the receiving environment and the appropriate management measures tailored to avoid or minimise impacts to those identified values specific to the area. This section aims to identify these values and establish a basis for the implementation of management practices required to avoid adverse impacts to these values.

3.1. Identified Environmental Values

Environmental values are defined in the Environmental Protection (Water) Policy 2009, the principle legislative framework for water quality management in the state of QLD and provides a process for determining the EV's of surface waters, this model has been adopted for the purpose of determining environmental values for groundwater values. This model is appropriate given the direct linkage between ground and surface waters.

The Table 1 below Provides a list of EV's relevant to the activity identified in the Queensland Water Quality Guideline.

Table 1 Environmental Values - Groundwater

EV	DEFINITION FROM QWQG (DERM 2009A)	RELEVANCE TO SITE RELEASE
Aquatic Ecosystems	Level 2: Slightly–Moderately Disturbed Ecosystems. *As described in ADWG 2000 - rural streams receiving runoff from land disturbed to varying degrees by grazing or pastoralism,."* (AWQG 2000; 3.1-10) This level of protection has been adopted due to the direct linkage between ground and surface water and disturbance levels associated with land usage in the surrounding areas.	Potential for contaminants released from site to adversely impact on biodiversity and ecosystems reliant on groundwater discharge, such ecosystems may include artesian springs.
Primary Industries	Stock Water Drinking water for stock	Groundwater is commonly used in the region for stock drinking water and domestic supply.
	Farm Water Supply Water used for laundry and produce preparation	
Recreation and Aesthetics	Primary Recreation recreation which involves direct contact and a high probability of water being swallowed - for example, swimming	Groundwater may be used as a water source for municipal and private swimming pools.
	Secondary Recreation Health of humans during recreation which involves indirect contact and a low probability of water being swallowed – for example, wading, boating, rowing and fishing.	
	Visual Recreation Amenity of waterways for recreation which does not involve any contact with water - for example, walking and picnicking adjacent to a waterway.	
Drinking Water	Raw Drinking Water Supply Suitability of raw drinking water supply.	Groundwater is utilised as a raw drinking water supply in many communities and residences.
Cultural and Spiritual Values	Indigenous and Non-Indigenous Cultural Heritage	Bore water is culturally important to areas dependant on the resource, groundwater discharge areas have significant historical importance.

3.2. Aquatic Ecosystems

Identified aquatic ecosystems in the vicinity of the site include wetland ecosystems associated with lagoon Creek and the Alice River, these wetland areas are unlikely to be affected by groundwater as they have formed in flood plain areas and are a function of surface water ecology rather than ground water.

The Barcaldine region is a significant area for artesian springs and lies within one of the eight artesian spring super groups within Queensland. The artesian springs within the great artesian basin are fragile and susceptible to groundwater interference, these wetlands environments have formed in isolation of other aquatic environments which over time has led to the evolution of unique species endemic to these environments. Changes to the composition of water in these springs could have detrimental effects on the ecology of these environments. It is however unlikely that the proposed activity will adversely impact on the ecology of the artesian springs, QLD DEHP wetland info mapping identifies the closest artesian springs to be approximately 30km to the NE of Barcaldine.

3.3. Primary Industries

The primary land use in the vicinity and of the proposed landfill location is agriculture in the form of grazing. Groundwater in the local area is extensively utilised for livestock drinking water.
Ground water is also commonly used as a domestic water supply.

3.2.3 Recreational Use

The use of groundwater for primary recreational use includes the use of groundwater in swimming pools, an example of this type of activity is the Barcaldine's swimming pool, where water is sourced from the municipal water supply, consisting of untreated artesian water. Private swimming pools in Barcaldine as well as further afield also source water from groundwater supplies.

3.2.4 Drinking Water

In inland communities bore water is often used as a drinking water supply, where groundwater is accessible and is of a reasonable quality it is often preferred as a water source over surface water supplies, due to its confined origins it can be provided with minimal treatment as the risk of pathogenic infection is low. Barcaldine's municipal water supply is sourced from an artesian aquifer which provides high quality drinking water. Artesian bores on rural properties in the district are also utilised for drinking water, the artesian source in the district can provide water of a relatively high quality suitable for drinking independent of climatic conditions.

3.2.5 Cultural and Spiritual Values

The Aboriginal peoples of inland Queensland have strong cultural associations with GAB spring dating back thousands of years. Artesian springs have been critical to the survival of Aboriginal peoples of the arid interior, providing a source of water, food and other material resources, as well as having ceremonial and spiritual values.
Artesian springs also provide non indigenous heritage as evidence of their past and present use by the pastoral industry, including stock camps, watering points for cattle and sheep grazing, and for horse, bullock and camel teams. GAB springs may also have historic heritage values associated with early exploration, surveying, land transport and agriculture.
The utilisation of groundwater in many inland areas has significant historical value, the utilisation of groundwater had a significant impact on development, providing increased water resources for pastoral activities and settlement.

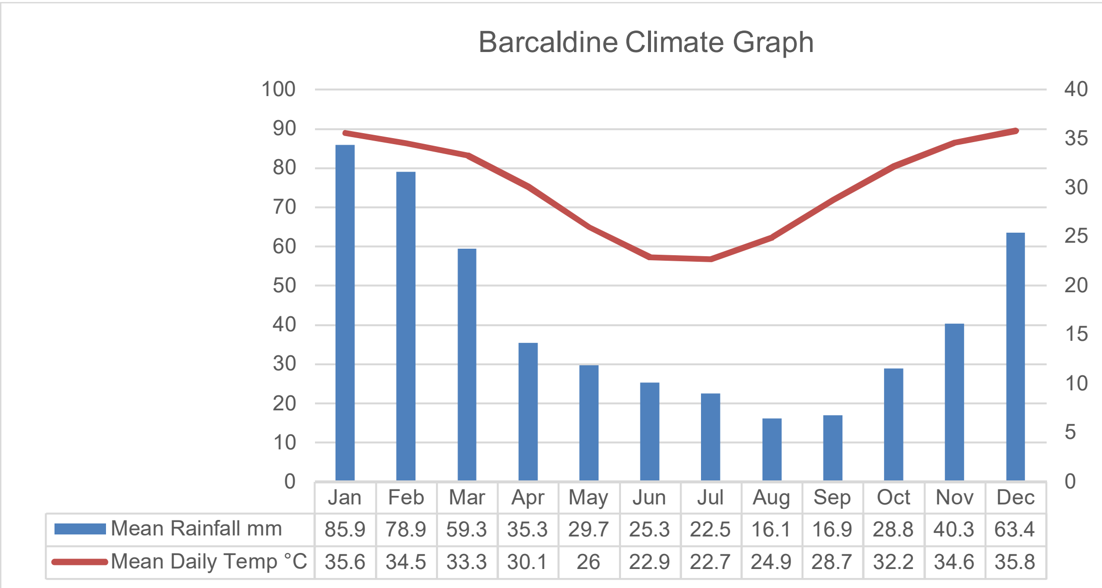
4. RISK FACTORS

4.1. Climate

Barcaldine has a sub-tropical continental climate dominated by generally dry conditions with an average annual rainfall of approximately 500mm. In general winter days are warm and sunny and nights are cold. During summer days tend to be hot and nights warm. Summer weather is influenced by a semi-permanent trough that lies roughly north-south through the interior of the state. The trough is normally the boundary between relatively moist air to the east and dry air to the west. It is best developed and generates most weather during spring and summer months. The trough often triggers convection with showers and thunderstorms, these wetter months coincide with high evaporation rates.

Average maximum temperatures are 35-36 degrees during summer and 23-26 degrees during winter. Minimum overnight temperatures are 22-23 degrees during the summer months and 8-10 degrees during winter. Maximum temperatures can reach the low to mid 40's from mid-spring through summer into autumn. Minimum overnight temperatures below freezing are relatively common during winter.

Figure 1 Barcaldine Climate Graph



5. GROUND WATER CHARACTERISTICS

5.1. Assessment of Local Groundwater Bores

An assessment of groundwater bores was conducted to assess the potential risk that the proposed activity may have on users of groundwater in the area, data was sourced from DNRM groundwater database (data summary attached in Appendix A) for registered bores. An assessment of all bore locations within a 10 km radius of the landfill site was conducted, this assessment identified 21 active bores within this area, a large proportion of these are located near or within residential areas of Barcaldine, associated with historical activities in the town, a map of bore location and status is provided in Appendix B. There are two bores in Barcaldine RN 69904 and RN313 dedicated for municipal water supply, the remaining bores are primarily used for stock watering, however due to the generally high quality of water found in the area it is possible that bore water will be used for drinking water on rural properties.

5.2. Proximity to Landfill Site

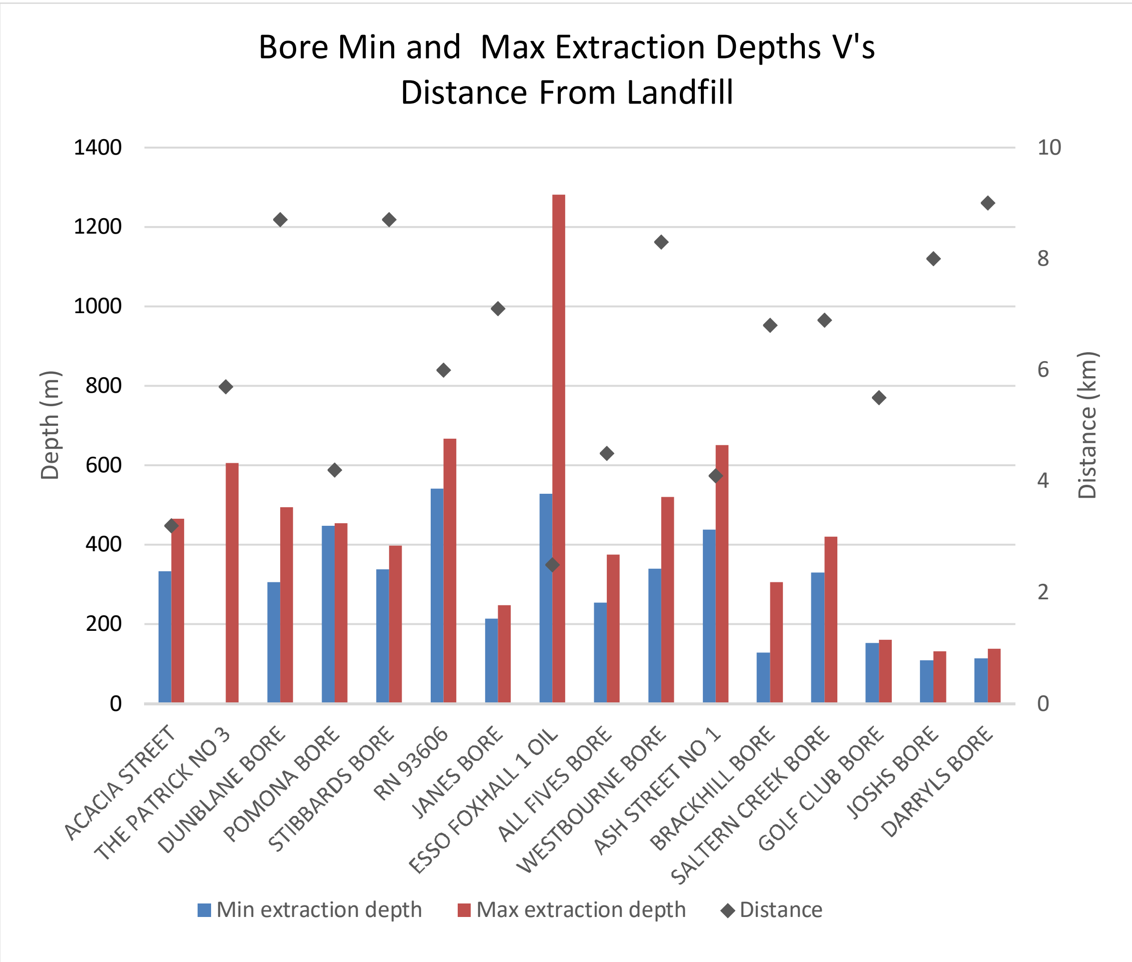
Planning of the activity has allowed for the site to be located in low density population area, as such there is not a high demand on groundwater resources in the immediate area, with the closet bore located approximately 2.5km from landfill site. The next closest Bore is the closer of Barcaldine's two drinking water supply bores located approximately 3.3km from the landfill cells. Figure 2 below details bore distance data, for bores with information on extraction depth.

5.3. Assessment of Groundwater Depths

An assessment of groundwater depths for the registered bores in the study area was conducted, extraction depth was determined based on log descriptions, specifically depth of installation of perforated slotted pipe, in some instances data was not available to determine the depths of extraction, particularly in some of the older bores. Figure 2 below identifies the water extraction depths for bores within 10km of the waste management facility, the chart also indicates the distance from the bore as an additional risk indicator when assessing the depths of water utilised in the area.

The data indicates as described above in Section 5.2, that the proximity of the bores is in excess of 2.5km. The minimum extraction depth is 108m, three other bores in the study area draw water from depths less than 154m, which are greater than 5km from the waste management facility. All other bores in the study have a minimum extraction depth of between 213 and 528m.

Figure 2 Extraction Depth v's Distance from Landfill



5.4. Groundwater Composition and Quality

Water quality data for bores located within the study area has been extracted from DNRM groundwater database, the data extracted from the database is attached in Appendix A. The data indicated that the majority of bores have targeted artesian aquifers and water quality is generally high, meeting ADWG health guidelines in most cases.

6. RISK MANAGEMENT

As identified in the previous sections it has been determined that contaminants will be present in waste material within the confines of the facility and that environmental values are present in the surrounding environment. The identification of these values justifies the requirement to mitigate potential risks associated with the operation of the facility. This section discusses how the activity will be managed to mitigate the risk of contaminant migration and subsequent impact on groundwater resources.

6.1. Cells Design and Capping

Cells sizes have been designed to provide the optimum size for the operation of the facility. The cells have been designed for 3-4 years use and to be extended in a forward direction to allow for another 3-4 years use in the second stage, providing a manageable are for operational activities such as managing the tipping face and interim waste covering. The relatively short lifespan of cells allows for operational efficiency but also reduces the potential for leachate generation and migration through the underlying geology by limiting the catchment area and subsequent volumes generated.

Capping of landfill cells with a final capping layer is to be conducted immediately following cell closure. Capping in to be constructed in accordance with best practice management with a minimum 500mm of cover. The Capping design will incorporate a minimum 200mm of impermeable clay capping overlayed with subsoil material and vegetated topsoil. The immediate capping of landfill cells will limit the potential for leachate to permeate through the underlying geology by sealing the surface and restricting the flow of water into the landfill cell.

6.2. Natural Leachate Barrier

A Hydrogeological Investigation Report has been conducted for the site, which details the geological properties of the site and should be referred to for a more detailed explanation of the sites geology.

6.2.1 Groundwater Separation Depth

Four test holes were drilled at 2 locations in 2014; a southern and a northern location. The southern location is mid-way along the southern boundary of the facility and the northern location is adjacent to the southern test hole location on the northern boundary. Table 2 below provides a summary of the test hole locations and depths.

Table 2 Test Hole Locations and Depths

Test Hole ID		Location - Lat	Location - Lon	Depth (m)
001	Southern Site	-23.587602	145.265333	04.0
002		-23.587584	145.265333	18.0
003	Northern Site	-23.585134	145.265131	11.2
004		-23.585116	145.265131	04.0

The drilling of test holes at two locations with maximum drilling depths of 18 and 11m at the Southern and Northern sites respectfully was conducted without the detection of groundwater.

Inspections following the drilling of the bores has failed to identify any water at theses depths even following substantial rainfall events. Table 3 below provides the results of recorded inspection dates from diary records of Council employees test hole inspections. Several inspections of the test holes were conducted prior to the recorded inspections detailed below, however records of these inspections could not be attained, BRC staff have verified that these inspections failed to locate ground water.

Table 3 Test Hole Inspection Results

<table>
<tr><th colspan="2">Test Hole ID</th><th>Inspection Date</th><th>Groundwater Present</th></tr>
<tr><td>1</td><td rowspan="2">Southern Site</td><td rowspan="4">14/12/2015</td><td>no</td></tr>
<tr><td>2</td><td>no</td></tr>
<tr><td>3</td><td rowspan="2">Northern Site</td><td>no</td></tr>
<tr><td>4</td><td>no</td></tr>
<tr><td>1</td><td rowspan="2">Southern Site</td><td rowspan="4">21/07/2016</td><td>no</td></tr>
<tr><td>2</td><td>no</td></tr>
<tr><td>3</td><td rowspan="2">Northern Site</td><td>no</td></tr>
<tr><td>4</td><td>no</td></tr>
<tr><td>1</td><td rowspan="2">Southern Site</td><td rowspan="4">06/07/2017</td><td>no</td></tr>
<tr><td>2</td><td>no</td></tr>
<tr><td>3</td><td rowspan="2">Northern Site</td><td>no</td></tr>
<tr><td>4</td><td>no</td></tr>
</table>

The inspections conducted in 2015 and 2016 were undertaken in response to significant rainfall events, on the 31st Nov 2015 105mm of rain was recorded in Barcaldine, this corresponds with an average rainfall reoccurrence frequency of 1 in 5 years over a 24hr period, this was followed up in early December with 25.2mm prior to the inspection. In June and July 2016 unseasonal rainfall patterns were experienced with 202mm occurring in the first half of winter, 159.4mm was recorded in June 2016, Barcaldine's wettest June on record with records from the Barcaldine Post office dating back to 1887. These records indicate that there is a significant separation depth between the landfill cell base and the highest water table.

6.2.2 Geotechnical Properties

The test hole strata descriptions identify a uniform strata formation across the site. Materials testing from the deepest of the test holes (Test Hole 002) provides Atterberg limits and Particle Size Distributions for core samples between the depths of 8-17m. The materials testing values for the core samples demonstrates fine grained material is present at these depths; plasticity and linear shrinkage values indicate a high level of plasticity consistent with clay material. These clay materials prevailing to significant depths below the landfill cell identify the absence of porous or fractured material.

Material testing below the landfill cell sampled at 0.5 and 1.5 depth in four locations provided values for Atterberg Limits, Moisture Density and Permeability. This material was characterised as a Sandy Clay. The Atterberg Limit values identify these soils to be slightly – medium plastic, in correlation with the plasticity values linear shrinkage values were low and ranged from 2.4-3.8%. These plasticity values identify a low susceptibility to desiccation cracking, a desirable characteristic for landfill cell base material. Permeability results indicate low permeability values for these soils ranging from $6x10^{-9}$ – $8x10^{-10}$, although these results show some variation they indicate the capacity to greatly restrict the leaching of contaminants from the landfill cell.

6.3. Double Lined Landfill liner

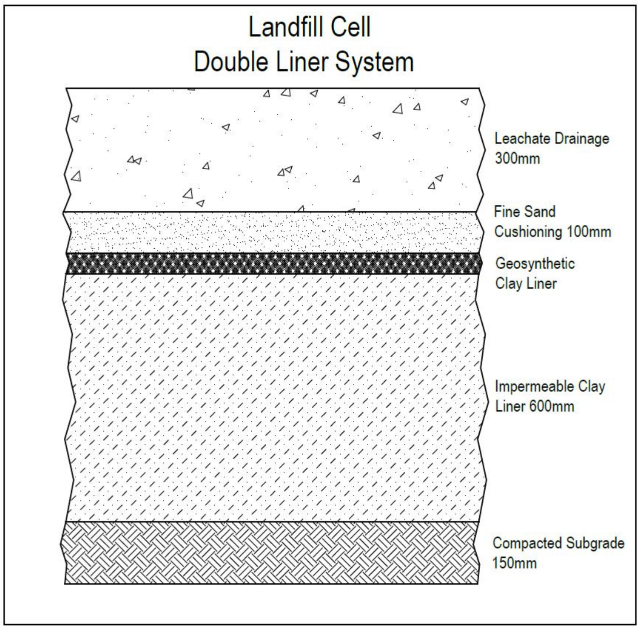
6.3.1 Discussion: Alternate Design

The prevention of contaminant releases to groundwater and subsequent adverse impacts to linked environmental values cannot be guaranteed through the implementation of operational management strategies or favourable geological properties. As such, as a precautionary measure to prevent adverse impacts to groundwater a double lined landfill liner will be constructed.

The system will be designed to align with the DEHP's risk based approach for the conditioning of environmental protection measures. Within the waste management industry the prescribed level of protection cannot be determined on a uniform basis due to differing extents of risks posed on environmental values. Due to the limited risk factors and operational management strategies implemented resulting in a relatively low residual risk level to environmental values an alternate design has been proposed for the lining system of the BRC WMF landfill cells. As an alternative to the "Double Liner" system defined in DEHP's Model Operating Conditions for waste disposal activities, which defines a "double liner" system utilising a High Density Polyethylene (HDPE) liner. The Alternate design will utilise a high grade Geosynthetic Clay Liner (GCL) in preference to a HDPE liner system. The alternate design will be capable of achieving a high level of protection comparable with a HDPE liner system with the aim to reduce logistical complexity and financial burden associated with a small scale HDPE system in a remote area. The alternate system will also reduce some of the risks associated with using a HDPE system.

The protective liner to be installed is comprised of five separate layers of material, figure 3 below provides an outline of the components of the liner system.

Figure 3 Landfill liner design



The design of the alternate lining system has been based primarily on a GCL and compacted clay liner system identified in the SA EPA guideline for Environmental management of landfill facilities, as a suggested liner system for small landfill facilities utilising geosynthetic materials for leachate management. The BRC landfill liner design does not follow the SA EPA suggested design entirely, but provides additional protection by maintaining a 600mm clay liner, where most GCL systems specify a shallow clay liner of approximately 200mm depth, a 600mm clay liner has been prescribed to ensure an increased level of protection from contaminant migration.

The installation of a HDPE lining system is not the most practical means of achieving a high level of protection in BRC's circumstances due to the logistical complexities of installing a HDPE lining system. One of the main disadvantages of HDPE in comparison to a comparable GCL system are installation costs, HDPE liners require specialist welding contractors for the installation of the product. Due to the relatively small scale of the project and the remote location, establishment costs and other expenses associated with the deployment of installation teams are unavoidably going to reduce the economic efficiency of the installation. In addition to high costs associated with a HDPE liner there are additional risks associated with the use of a high density product, namely punctures, which can be reduced through the utilisation of an alternate system. The advantages of an alternate system in comparison to a HDPE system are identified below in Table 4.

A GCL and compacted clay liner will have a number of benefits over a HDPE membrane and compacted clay liner system. In addition to reduced costs associated with installation, the use of a GCL reduces the risk of puncturing, HDPE products are frequently accidently punctured, which can result in high leakage rates. GCL products have self-healing capabilities offering a level of puncture resistance for small punctures due to their self-healing characteristics. GCL products are capable of withstanding differential settlement allowing them to mould to the underlying strata avoiding wrinkling affects and associated air pockets which can cause desiccation of underlying clays. A comparison table below provided by *Global Synthetics* provides a summary of advantages that the GCL lining system will provide.

Table 4 HDPE Geomembrane & GCL Products

HDPE Geomembrane (GM)	**GCL Products**
Very Susceptible to damage	Less Susceptible to damage
Slower installation (GM+Welding+ Geotextile(GT)+Welding Tests)	Faster installation (No need for welding, GT and testing)
More expensive installation (GM+Welding+GT+Welding Tests+Surface preparation)	Cheaper installation (No need for welding, GT, testing and Surface preparation)
Difficult to repair (Hot air welding + Extrude welding)	Easy repair with Bentofix patch and bentonite paste
Exact formation level necessary	No need for exactly flat formation level (Flexible material)
Limited ability to absorb settlement forces	Absorbs settlement forces
Special equipment required for welding overlaps	No welding
Needs contractor for installation	No special contractor or specialist for installation
No self-healing capability	Self-healing for small holes
Additional protection layer (Geotextile) required	No damage protection required
More difficult installation of cover material in slope areas (low interface friction angles)	Less difficult installation of cover material (higher interface friction available)
Wrinkles in the geomembrane will cause performance and durability problems and higher risk for installation damages	No wrinkle

Disadvantages associated with the use of GCL products have been identified in a number of circumstances. A potential problem associated with the use of GCL can be associated with the type of bentonite in the GCL, where chemical components of leachate can increase the hydraulic conductivity of the bentonite. It is therefore important to utilise high quality benotnite products formulated for landfill applications. The bentonite products utilised for GCL products are selected will be required to meet industry recommended compositional characteristics. A table is provided below identifying the characteristics of recommended bentonite characteristics for GCL products utilised in landfill liners.

Table 5 Characteristics of suitable GCL bentonite products

Property	Industry Standard Range or value*
Montmorillonite content	70 wt%
Carbonate content*	1 to 2 wt%
Bentonite form	Natural Na-bentonite or >80 % sodium as activated bentonite
Particle size	Powdered (e.g. 80% passing 75-micron sieve) or Granulated (e.g <1% passing 75-micron sieve)
Cation exchange capacity	≥70 meq/100 g (or cmol/kg)
Free swell index	≥ 24cm3/2g

*Industry standard extracted from EPA Vic BPEM landfills, Appendix E3

Hydraulic conductivity values for HDPE products are extremely low to the point where the permeation through HDPE membranes are difficult to quantify. Although GCL's are not able to achieve hydraulic conductivity values as low as HDPE liners, they are able to provide very low values, <$5x10^{-11}$m/s for GCL products currently on the market meeting Geosynthetic Research Institute GRI-GCL5* specifications. A high quality GCL product will be utilised for the double lining system utilised for BRC's WMF a product with a low hydraulic conductivity <$3x10^{-11}$m/s will be utilised and meet industry standards identified below for utilisation in landfills.

Although the lining system designed to be utilised at the BRC WMF is not a standard design for general waste landfills it has been designed to provide a high level of protection in a relatively low risk environment and reduce the economic burdens to BRC associated with the installation of a HDPE liner in a remote area.

6.3.1 Liner Specifications

Subgrade

The correct preparation of the subgrade material will provide a platform for the installation of a clay capping layer and ensure the system drains effectively throughout the life of the landfill cells.

Subgrade preparation must achieve:

- A smooth surface sloping towards the leachate sump
- Compaction to a minimum dry density ratio of 95% relative of standard compaction to a minimum depth of .15m
- Provide a sound platform for subsequent liner construction.

Clay liner

The clay liner is to be constructed from low permeability clay material with a minimum thickness of 600mm. To achieve the required in situ hydraulic conductivity of less than 1 x 10^{-9}m/s, the clay will have high plasticity and a suitable particle-size distribution, with no particles greater than 50mm in any dimension.

The construction methodologies must ensure:

- Uniform compaction in layers of less than 200mm compacted thickness using a padfoot roller.
- Effective bonding between layers.
- Constructed with suitable slope towards the leachate sump to effectively drain leachate.

Poly lined Geosynthetic Clay Liner:

The geosynthetic clay liner is to be installed to limit landfill gas and leachate migration. Properties of the GCL must include:

- Aadequate strength, flexibility and durability to maintain performance over the entire life of the landfill, including the operating and post-closure periods.
- Be reinforced, bonded by needle punching or stitching to enhance the internal shear strength of the geosynthetic clay liner.
- Be made from bentonite that is stable in slightly acidic conditions.

The product suggested for use is to be developed in accordance with industry standards for the production and use of geosynthetic materials, including, Geosynthetic Research Institute quality assurance specifications:

- GRI-GCL3: Test Methods, Required Properties and Testing Frequencies of Geosynthetic Clay Liners and
- GRI-GCL5: Design Considerations for Geosynthetic Clay Liners.

Cushioning layer

A cushioning layer is to be laid on top of the GCL layer to protect the GCL from puncturing. It is important that the application of this material utilises a small rubber wheeled machine such as a small to medium sized positrack machine with a mass of <2 tonne to limit the forces applied during the application of the cushioning layer. This material will meet the following specifications:

- No material >2mm diameter.
- > 50% of the material <.25mm.
- Physical properties of the material require that the material forms a cast when wet, will crumble easily and will not form a ribbon.

Leachate Drainage Layer

The gravel drainage material should:

- Consist of hard, strong, durable and clean gravel that will maintain the required performance under the maximum loads likely to be imposed on it in service.
- Be a pervious material and have a saturated hydraulic conductivity greater than 1x10^{-5} cm/s when tested in accordance with Australian Standard AS 1289.6.7.1.
- Be non-reactive in mildly acidic conditions and chemically resistant to the leachate in the landfill.
- Not have a shape and angularity that will damage the underlying geomembrane liner.

- Be installed in a continuous layer at least 300 millimetres thick across the entire base of the landfill cell, sloped with at least a 1% longitudinal gradient and 3% transverse gradient.

6.4. Minimisation of Leachate Generation

Waste identified as having potential for releasing potentially harmful contaminants will be managed to minimise leachate generation. The largest potential source of leachate is from general waste sources. General waste received from municipal waste collection is to be disposed of directly to landfill cells. The active landfill cell is to be constructed with stormwater controls to divert stormwater around the landfill cells thus minimising leachate volumes.

6.5. Screening of Waste

The BRC WMF will be managed to avoid the unnecessary generation of leachate. Council will delegate staff to the management of the facility ensuring that waste is correctly stored and disposed of or if necessary taken offsite. Regular inspections of the site, particularly the waste transfer station and municipal loads from council pick up will be conducted to identify any unauthorised waste types such as liquid hydrocarbons or lead acid batteries have not been added to general waste streams. These potential contaminants will be appropriately stored and transported offsite by a regulated waste transporter.

6.6. Leachate Collection and Treatment

A leachate collection system has been designed to drain, collect and pump leachate from the landfill cell. The pumping system will be designed to maintain the leachate to a maximum level of 300mm above the landfill cell base. Once leachate is collected and pumped from the landfill cell it is transferred to a purpose built leachate evaporation pond. The pond is to provide the primary treatment process through evaporation. A water balance has been conducted for modelled leachate generation rates allowing for sufficient storage to evaporate leachate from a wet year receiving rainfall from a 1 in 20yr ARI event over a 24hr period followed by average rainfall over a 1 year period (refer to Appendix C for water balance).

6.5.1 Leachate Evaporation Pond Design

The design of the pond is quite shallow to provide a large surface area to volume ration therefore optimising evaporation rates to completely evaporate stored leachate in the majority of years. The optimum size has been determined through the development of a water balance which is attached in appendix C.

The liner of the leachate evaporation pond will be a double lined liner system constructed in accordance with the landfill cell liner described in section 6.3 above.

6.5.2 Leachate Evaporation Pond Freeboard Exceedance

Pond capacity must allow for a freeboard that can accept rainfall directly on the dam from a 24 hour rainfall event with a 1-in-25 year average recurrence interval without overflowing (freeboard = 160mm). In circumstances where the leachate collection pond has exceeded freeboard levels alternate methods of treatment will be utilised in order to manage excess leachate. In these situations irrigation of leachate over the waste mass will be conducted, this will aid the decomposition of the waste and reduce the leachate volume through evaporation. Irrigation should be conducted at a sustainable rate, enabling the waste to absorb the leachate. Reinjection should not create excessive leachate levels over cell base, leachate in excess of the wastes holding capacity should be continuously withdrawn from the cell to ensure that the depth of leachate over the liner does not exceed 300mm.

7. MONITORING

A groundwater monitoring system will be implemented at the BRC WMF to monitor groundwater from depths sufficient to identify contamination to the underlying aquifers. Bores will be located to monitor from hydraulically up-gradient and down-gradient locations. BRC have installed monitoring bores at two locations at the landfill site to a maximum depth of 18m, these monitoring bores have not reached water aquifers. BRC in July 2017 have requested quotations from suitably qualified professionals with hydrogeological experience to review the current monitoring bore design and provide guidance in the implementation of a groundwater monitoring system to detect the migration of contaminants from the waste management facility.

7.1. Water Quality

Due to back ground water quality data not being available in the vicinity of the site from upper level aquifers, as a default Australian and New Zealand Water Quality Monitoring Guidelines (ANZECC and ARMCANZ 2000) have been used to assess the water quality.

The ANZECC guidelines are written to assess surface water quality, and not specifically groundwater quality. However, because groundwater and surface water are often linked systems, and because groundwater is an essential water source for many water uses, the guidelines are applied to groundwater in such a way that when it comes to the surface, it will not affect the quality of surface water systems or compromise the EVs. Therefore, ANZECC trigger values for surface water quality are used as an initial assessment of groundwater quality criteria. Where ANZECC trigger values could not be ascertained ADWG aesthetic threshold values have been utilised as well, these trigger levels are indicated in the monitoring program summary below in Table 6.

The surrounding area in and around the landfill is predominantly used for agriculture and residential land use. Over the years, these practices have modified the landscape, affecting the volume and rate of runoff, the flow characteristics of creeks and the recharge of groundwater. As such, the aquatic ecosystems of the area have been modified. Because of historical use, the regional aquifers in the area surrounding the site can be classified as *slightly - moderately disturbed*. It has therefore been proposed that groundwater samples are to be assessed against ANZECC and ARMCANZ (2000) protection of slightly-moderately disturbed ecosystem criteria where possible.

7.2. Monitoring Frequency

Monitoring events should be undertaken on a six month frequency (April and November). These events should be scheduled at the same time each year (i.e. within 30 days of the previous year's event) to provide consistency in comparing results due to any possible seasonality effects that can occur in groundwater systems. These events are designed to monitor for post-wet season period (April) and post-dry season period (November). The two events should form the data set for the annual groundwater monitoring summary.

7.3. Monitoring Protocol

Low-flow groundwater sampling is recommended for all bores, unless the recharge capacity of bores exceeds the conditions for low-flow sampling procedure (i.e. >10cm decrease in SWL during constant rate purging). If this condition is exceeded, the bore volume purging method can be used in substitute.

Sampling methodologies should be conducted in accordance with Queensland Department of Environment and Resource Management's Monitoring and Sampling Manual 2009 (Version 2);

All samples must be submitted to a NATA (National Association of Testing Authorities) accredited laboratory for all of the analytical parameters. All samples need to be transported to laboratories under industry standard chain of custody procedures.

7.4. Trigger Levels

Trigger levels for the groundwater monitoring program are given in Table 6. It is important to note that not all analytes are contaminants of groundwater; but are important as identifiers of landfill leachates. Those analytes that do not have trigger levels under ANZECC or ADWG guidelines are still important as indicators of landfill impact. Therefore, those analytes should be used for interpretational purposes of groundwater.

Table 6 Monitoring Program Summary

Analyte	Unit	Trigger Level	Source
pH	pH Units	6 Min – 8 Max	ANZECC
EC	µS/cm	For interpretational purposes	
Sodium	mg/L	180mg/L	ADWG - Aesthetic
Magnesium	mg/L	For interpretational purposes	
Potassium	mg/L	For interpretational purposes	
Calcium	mg/L	For interpretational purposes	
Chloride	mg/L	250mg/L	ADWG - Aesthetic
Sulphate	mg/L	250mg/L	ADWG - Aesthetic
Cadmium	mg/L	0.0002mg/l	ANZECC
Chromium	mg/L	0.001mg/L	ANZECC
Iron	mg/L	For interpretational purposes	ANZECC
Lead	mg/L	0.0034mg/L	ANZECC
Manganese	mg/L	1.9mg/L	ANZECC
Zinc	mg/L	0.008	ANZECC
Nitrate	mg/L	0.7	ANZECC
Ammonia	mg/L	0.9	ANZECC
Total nitrogen	mg/L	0.3	ANZECC
Disolved Oxygen	mg/L	6.8	ANZECC
Dissolved Organic Carbon	mg/L	For interpretational purposes	

7.5. Data Management and Analysis

Following the implementation of monitoring data analysis will be conducted, the following data analysis is required to assess if any impact on groundwater is being caused by landfill operations:

- Analysis of groundwater levels to assess groundwater flow direction
- Checking laboratory reports for data integrity (i.e. analytes measured within holding times, relative percentile differences of duplicate samples are within appropriate ranges).
- Comparison of groundwater quality data against relevant trigger levels presented in Table 6.
- Analysis of individual groundwater quality constituents for trends that may assist in explaining ongoing impact from landfill operations.

If results indicate that trigger levels have been exceeded, then data analysis should aim to determine the reason for threshold exceedance and weather it has occurred as a result of contaminant leaching from the landfill or is occurring independent of the landfilling activity. In the occurrence that back ground water data indicated anolyte values in exceedance of trigger values a review of the monitoring program trigger values should be implemented.

7.6. Reporting

As a minimum water testing data is to be kept on record for a minimum of five years. Regular reporting of groundwater data to the regulator will be conducted in line with licence conditions. If results indicate that contamination of groundwater is occurring these results must be reported to the DEHP within 24 hours of receiving the information.
In a situation where contamination to the surrounding environment has or is likely to have occurred the following steps will be undertaken:

- Take immediate action to contain the pollution;
- Notify the regulating body detailing:
  - The nature and source of contamination/spill;
  - Actions taken;
  - Future corrective actions to prevent recurrence; and
- Implementation of approved actions.

8. RESIDUAL RISKS TO ENVIRONMENTAL VALUES

This plan has identified environmental values relating to groundwater, the associated risks to these values and risk management practices implemented to mitigate the risk of contaminant migration causing adverse impacts to the groundwater resource. This section discusses the perceived residual risk to the identified environmental values following the implementation of risk management practices.

Section 3 of this plan documented environmental values associated with groundwater and identified how the proposed waste management facility could adversely impact on these environmental values, the identified values are summarised below:

Environmental Value	Relevance
Aquatic Ecosystems	Including groundwater discharge areas forming artesian springs
Primary Industry	Stock drinking water and domestic use
Primary Recreation	Groundwater utilised in swimming pools
Drinking Water	Groundwater utilised for human consumption from municipal and private supplies
Cultural and Spiritual Values	Indigenous cultural heritage in the form of artesian springs providing a vitally important resource
	Non indigenous cultural value relating to reliance of artesian springs for early settlers and groundwater in inland communities

The expected level of residual risk relating to the waste management facility and its effect on the environmental values are discussed below.

8.1. Aquatic Ecosystems

From the assessment of environmental values in Section 3 it was identified that the greatest risk to aquatic ecosystems is associated with groundwater discharge areas forming artesian springs. These artesian springs are significant environmental features due to the isolated nature of these systems and the adaptation of species dependant on them. Many species endemic to these systems are EVNT listed species due to the unique susceptibility from anthropogenic influences such as grazing and groundwater use which can degrade these environments and reduce groundwater discharge volumes. Despite the high level of susceptibility it is unlikely that the activity will have an impact on these systems. An assessment of the location of artesian springs has identified that the proximity of the landfilling activity is greater than 30km from any springs and the potential for contamination to surrounding environments is mitigated through operational strategies.

8.2. Cultural and Spiritual Values

Groundwater plays an extremely important role in dry inland environments. Historically groundwater discharge areas provided a water source for indigenous people, early explorers and settlers, as such these areas where imperative for survival and have significant heritage values. The drilling of bores and its rapid expansion in the late 1800's provided greater opportunities for industry expansion in inland areas, particularly within the great artesian basin. The township of Barcaldine is a great example of this, where high quality artesian bore water provides the only source of municipal water supply from two high yielding bores; it is therefore evident groundwater has significant cultural value.

8.3. Groundwater Users

From the assessment of environmental values, it is evident that the greatest risk the posed by the waste management facility is the release of contaminants causing a reduction in groundwater quality. The release of contaminants to groundwater could potentially have implications through increased health risk from the contamination of drinking water, contamination of recreational use water such as swimming pools and implications to primary industry from the contamination of stock water.

In this report risk factors were assessed and risk management practices were described. An investigation of site characteristics have assessed potential risk factors associated with ground water usage in the surrounding area. This assessment identified that there are 21 registered existing bores in a 10km radius of the landfill site, the closest groundwater extraction site is greater than 2.5 km from the site with the next closest 3.2km from the site. The assessment of groundwater bores in the area identified that the majority of bores are drawing water from deep depths targeting artesian aquifers with an average minimum extraction depth of 304m. There are three bores in the area extracting water from shallower depths between 108-162m these bores are located greater than 5km from the site. Based on this analysis it would appear that if contaminants were to migrate from the landfill site due to the lateral and vertical travel path required the risk of contaminating bore water is very low.

Risk management practices have been proposed to mitigate the risk of contaminant migration form the site. The siting of the facility has located the facility on a site with geological features conducive to restrict the migration of contaminants. Geotechnical investigations of the site have provided data which identifies the material immediately below the landfill cell to have low permeability rates. Drilling logs to a depth of 18m indicate clay material to be present to a depth of 18m below ground level.

The design of the land fill cells will incorporate a liner system, the liner is to be constructed with a double liner consisting of a poly coated GCL layer as well as a clay liner constructed in accordance with industry best management practice. The installation of the clay and geosynthetic liner system will provide a leachate barrier that will greatly restrict the migration of contaminants to groundwater, slowing the flow of leachate to an extremely low rate.

A leachate management system will be an integral risk management strategy to avoid contaminant leaching from occurring at the facility, under wet conditions where leachate is produced leachate is to be pumped from the landfill maintaining a maximum depth of 300mm, the water is then to be treated in a leachate evaporation pond with an impermeable double liner system.

Avoidance of leachate generation is integral to the minimisation of leachate migration and contaminant loads generated from the facility. Reducing leachate volumes and contaminant levels will be achieved in a number of ways, Including:

- Waste Screening, a high level of presence from trained council staff will be maintained onsite to segregate waste and screen for unauthorised materials deposited to the landfill
- Storm water management, segregating storm water from leachate to reduce leachate volumes generated
- Optimising landfill cell size, reducing the catchment size for leachate generation

A groundwater monitoring program is to be implemented to detect if contamination of the groundwater is occurring as a result of the activity. The detection of contaminants migrating from the site provides a mechanism for the evaluation of the performance of the sites environmental management objectives relating to groundwater quality.

9. REFERENCES

ANZECC and ARMCANZ 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environmental and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Department of Environment and Resource Management
Queensland Water Quality Guidelines, Version 3, DERM 2009.

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Environmental Management of Landfill Facilities 2007.

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Queensland Government Department of Environment and Heritage Protection
Guideline – Landfill Siting, Design, Operation and Rehabilitation 2013.

Appendix A

A1 Bore Details

A2 Bore Water Quality Data

A1 Bore Details Study Area

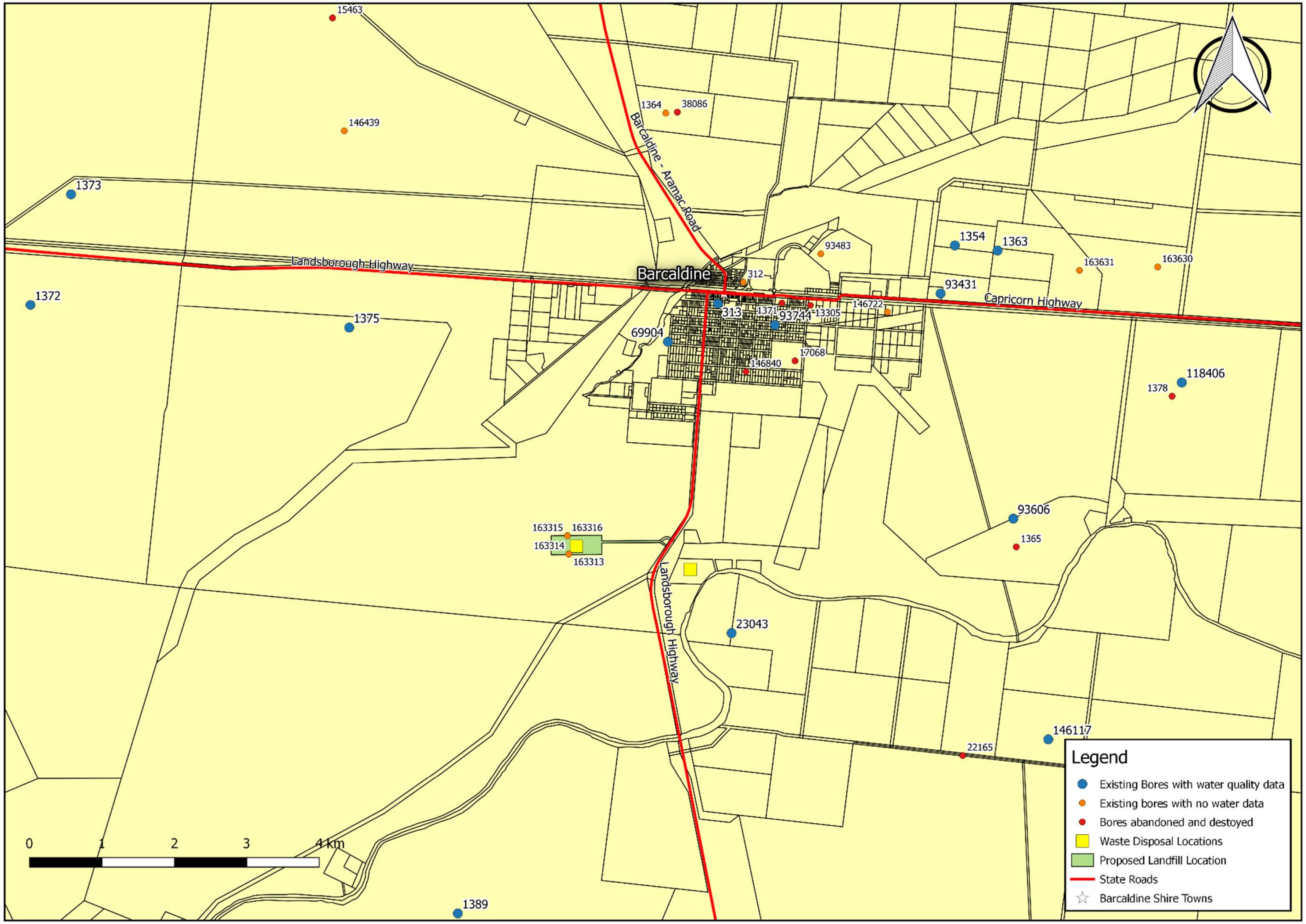
Bore Number	Bore Name	Easting	Northing	Distance from BRC WMF	Bore Depth	Perforated Slot Depth	
						Top	Bottom
69904	Acacia Street	324320	7393555	3.2km	464.45	332	464.45
1389	The Patrick No 3	321521	7384955	5.7km	640.08	N/A	605.3
1373	Dunblane Bore	316044	7395667	8.7km	493.8	304.8*	493.8*
93744	New Pomona Bore Yew St	325795	7393824	4.2km	462	447	453
93431	Power Station Bore	328078	7394327	6.2km	460	N/A	N/A
1363	Lexington Bore	328858	7394980	7.3km	303.7	N/A	N/A
118406	Stibbards Bore	331426	7393031	8.7km	408.6	337	397
93606	93606	329122	7390962	6km	666	540	666
146117	Janes Bore	329644	7387661	7.1km	252.4	213	247
23043	Esso Foxhall 1 Oil	325251	7389197	2.5km	1280	528*	1280*
1375	All Fives Bore	319913	7393714	4.5km	374.9	253.9*	374.9*
1372	Westbourne Bore	315504	7394001	8.3km	548.03	340	520
313	Ash Street No 1	325002	7394136	4.1km	625	437	651
1354	Brackhill Bore	328267	7395050	6.8km	305.41	128*	305.4*
146439	Saltern Creek Bore	319808	7396669	6.9km	422	330	420
1364	Prospect Bore	324249	7396989	6.5km		N/A	N/A
312	Baths Bore	325350	7394465	4.5km	210.9	N/A	N/A
93483	Barcaldine Golf Club Bore	326415	7394902	5.5km	162	153	161
146722	Slaughteryard Bore	327348	7394035	5.5km		N/A	N/A
163631	Joshs Bore	329991	7394696	8km	138	108	132
163630	Darryls Bore	331072	7394760	9km	144	113	138

A2 Bore Water Quality Data

Bore Number	A2 - Bore Study Area Water Quality																								
	Bore Name	DATE	DEPTH (m)	RMK	COND (uS/cm)	pH	Si (mg/L)	TOTAL IONS (mg/L)	TOTAL SOLIDS (mg/L)	Na	K	Ca	Mg	Mn	HC03	Fe	CO3	Cl	F	NO3	SO4	Zn	Al	B	Cu
69904	ACACIA STREET	07/08/1997			860	8.9		707.51	494.02	203	1.4	3.3	0.1		420	0.01	0	75	1.5	0.3	2.9				
1389	THE PATRICK NO 3	01/01/1965			387	8.2		347.8	257.93	87.5		32	0.9		176.8		14.4	36	0.2						
		01/01/1966		PU	387	8.2		294.1	224.56	87.5		3.2	1		136.8		14.4	36	0.2		15				
		20/03/1974	641	PU	460	8.1		318.78	224.24	85	2	3.8	0.2		186	0.24	104	40	0.14						
		09/07/1986	640		370	8.4	26	287.99	230.12	79	1.9	3.2	0	<0.001	165	0.04	2.5	30	0.2	<0.5	5.5	<0.01	<0.10	0.02	<0.01
		25/03/2004		PU	358	8.5	29	293.97	237.17	83.1	1.9	1.9	0	0	169.4	0.01	3.1	29.5	0.26	0	4.8	0	0	0.1	0
1373	DUNBLANE BORE	14/12/1993			357	8.5	24	290.21	228.97	83	1.5	2.1	0.1	<0.02	167.7	0.03	3.3	26.4	0.23	1	4.5	0.13	<0.05	<0.10	<0.05
		30/10/2002	493.8	MA	365	8.4	23	289.66	226.25	82	1.6	1.8		<0.03	170	<0.01	2.3	26.5	0.2	<0.5	4.6	<0.01	<0.05	0.03	<0.03
93744	NEW POMONA BORE YEW ST	29/05/2003			370	8.2	24	295.26	235.39	79	3.3	3.7	0.3	0.03	165	0.02	1.5	38	0.2	<0.5	3.6	<0.01	<0.05	<0.02	<0.03
93431	POWER STATION BORE	26/10/1998	460		395	10	3	225.88	196.86	78	3.3	0.8	0.1	0.02	63	0.07	40.5	33	0.3	0.5	6	0.02	0.12	0.14	0.05
1363	LEXINGTON BORE	29/10/2002		MA	356	8.5	22	278.99	220.48	79.5	1.4	2.5	0.1	<0.03	158.4	<0.01	2.6	29.2	0.22	<0.5	4.4	<0.01	<0.05	0.04	<0.03
118406	STIBBARDS BORE	10/12/2003	408	PU	345	8.4	23	277.92	219.59	78	1.4	2.5	0.1	<0.03	160	0.08	2.2	28.5	0.2	<0.5	4.2	<0.01	<0.05	0.12	<0.03
93606	93606	13/08/1999	462	MA	360	8.7	22	287.24	227.91	81	1.7	301	0.1	0.2	160	0.45	4	30.5	0.2	<0.5	4.8	<0.02	0.7	<0.10	<0.05
		24/01/2008	666	PU	439	8.1	22	330	259	69	20	9.4	1.7	0.09	182	<0.01	1	43	0.37	<0.5	3.2	<0.01	<0.05	0.06	<0.03
146117	JANES BORE	28/01/2009		PU	1510	8.4	23	1260	905	371	1.6	3.3	0.2	<0.01	738	<0.01	11	130	2.5	<0.5	<1.0	<0.01	<0.05	1.1	<0.03
23043	ESSO FOXHALL 1 OIL	26/02/1982		PU	560	7.8	39	434.5	351.51	82	23	22	2		240		0.9	60	1	3					
		15/11/1988	528	PU	440	8.1	24	356	283.42	70	23	12	2	<0.01	190	0.01	1.6	54	0.7	<0.5	<2.0	<0.01	0.1	0.06	<0.01
		23/11/1990		PU	484	8.3	24	368.09	295.26	77.7	24.1	13.3	2.2	<0.01	190.5	<0.01	2.3	54.6	0.7	<0.5	<2.0	<0.01	<0.05	0.07	0.04
		27/03/2003	1280	MA	469	7.4	25	361.06	288.52	73.9	23.4	12.5	2.2	0.03	191.9	0.02	0.3	53.6	0.65	<0.5	<2.0	<0.00	<0.00	0.06	<0.00
1375	ALL FIVES BORE	21/04/1972	375	PU	1380	8.2		1166.25	847.04	345		5	3	<0.03	628	0.03		175	3.6	<1.0	4	<0.01	<0.05	1.5	<0.03
		30/10/2002	374.9	MA	1390	8.6	20	1096.15	828.47	342	1.5	2.8	0.1	0	565.6	0.03	16	164.1	3.91	0	0.5	0	0	1.49	0.01
1372	WESTBOURNE BORE	21/04/1972	548	PU	390	8.3		326.3	228.2	86		6	2		193		5	30	0.3		4				
		05/12/1985	548		360	8.2	22	290.67	223.72	78	1.7	2.4	0	<0.01	175	<0.01	1.5	27	0.2	0.5	4.2	0.02	<0.10	0.02	<0.01
		14/12/1993			362	8.4	24	289.83	229.91	81.1	1.4	2	0	<0.01	175	<0.01	1.5	27	0.2	0.5	4.2	0.02	<0.10	0.02	<0.05
		14/12/2011	547.5	PU	371	8.2	24	280	221	80	1.4	2	0.1	<0.01	164	0.05	1.7	26	0.19	<0.5	4.4	<0.01	<0.05	0.03	<0.03
		01/10/1967		PU	828	7.7		559.95	443.04	149		25	3		230			134	0.95		18				
		13/10/1969		PU	790	7.9		589.85	465.82	170		20	0		244			155	0.85		0				
		15/12/1993	20	PU	1150	8.2	21	745.13	654.96	198	21.6	33.4	2	0.08	218.7	<0.02	2.2	255	1.53	9.7	2.1	0.1	<0.05	0.3	<0.05
313	ASH STREET NO 1	06/12/2003	624.9	MA	854	7.6	22	568.18	479.71	142	19.5	22.6	1.7	0.03	217.5	0	0.5	162.5	1.25	0	0.5	0.01	0.01	0.45	0.01
		10/04/1965	306	PU	0			223.45	168.2	64.4		2.9	1.4		108.7		4.3	37.2	0.25		4.3				
1354	BRACKHILL BORE	29/10/2002	305.4	MA	357	8.4	22	280.13	221.56	79.8	1.5	2.7	0.1	<0.03	158.5	<0.01	2	30.3	0.24	0.5	4.3	<0.01	<0.05	0.06	<0.03

Appendix B

Bore Locations and Status Study Area


15463
146439
1364
38086
Barcaldine - Aramac Road
1373
Landsborough Highway
1372
1375
Barcaldine
312
93483
1354
1363
163631
163630
93431
Capricorn Highway
313
1371
93744
13305
146722
69904
17068
146840
118406
1378
93606
1365
163315
163316
163314
163313
Landsborough Highway
23043
146117
22165
0
1
2
3
4 km
1389
Legend
Existing Bores with water quality data
Existing bores with no water data
Bores abandoned and destoyed
Waste Disposal Locations
Proposed Landfill Location
State Roads
Barcaldine Shire Towns

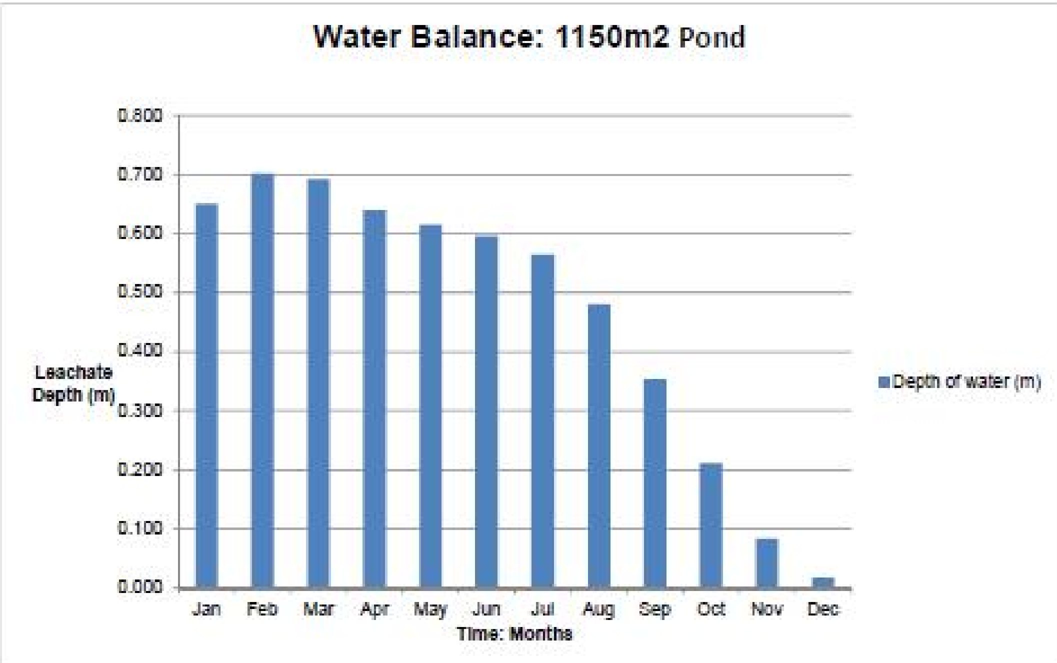
Appendix C

Water Balance

Barcaldine Waste Management Facility: Water Balance

	Leachate Pond Size	
Pond Size	**1150**	m2
Volume of water		
1 in 25 yr event for 24 hr =	155	mm
Rubbish Pit Catchment Size m2=	2500	m2
Total m3=	775	m3
Waste absorption 7%, remaining	**720.75**	m3

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average rainfall (m)	0.09	0.08	0.06	0.04	0.03	0.02	0.02	0.02	0.02	0.03	0.04	0.06
Rainfall Volume (m3)	300.24	274.53	208.15	124.41	104.60	83.75	77.49	55.25	54.91	100.08	140.04	221.01
Septic Waste (m3)	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
Evaporation (m)	0.34	0.27	0.28	0.23	0.17	0.14	0.15	0.19	0.26	0.33	0.36	0.37
Evaporation @ 70% (m)	0.24	0.19	0.19	0.16	0.12	0.09	0.10	0.13	0.18	0.23	0.25	0.26
Evaporation volume (m3)	276.92	218.16	222.18	188.37	136.85	108.68	116.73	154.56	205.28	266.46	289.80	299.46
Previous volume (m3)	720.75	747.37	807.04	796.31	735.65	706.70	685.07	649.14	553.13	406.06	242.98	96.53
Residual (m3)	747.37	807.04	796.31	735.65	706.70	685.07	649.14	553.13	406.06	242.98	96.53	21.38
Depth of water (m)	0.650	0.702	0.692	0.640	0.615	0.596	0.564	0.481	0.353	0.211	0.084	0.019



Appendix P

Report:
"Landfill Gas Management Plan"

71 Ash Street (PO Box 191)

BARCALDINE QLD 4725

Barcaldine Regional Council
Yellowjack Drive Waste Management Facility

Landfill Gas Management Plan

AUGUST 2017

Document History

Date	Name	Position	Endorse/Approve
21/07/2017	William Green	Environmental Engineer	Draft
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1.0 INTRODUCTION

This Landfill Gas Management Plan has been developed for the Barcaldine Regional Council BRC to support a Development Application for the proposed landfill Located on Yellowjack Drive, Barcaldine. This report presents the results of our assessment and proposed management practices to mitigate the risks associated with landfill gas emissions.

2.0 SCOPE

The proposed activity will be categorized as ERA 60 1(a) municipal waste landfill with a small contingent of regulated waste including septic waste from semi-rural dwellings; accordingly landfill gas (LFG) production is expected. The scope of this LFG Management Plan is to ensure that air quality objectives are met in accordance with relevant regulatory guidelines including EHP guideline – Landfill siting, design, operation and rehabilitation and Model operating conditions for ERA 60 waste disposal.

The objective of identifying and managing landfill gas at the site are to:

- Prevent impacts to human health, safety and the environment;
- Prevent off site nuisance odours; and
- Meet regulatory requirements.

The Plan provides a summary of potential hazards and expected risk levels and addresses management of LFG for the proposed facility. The management options were evaluated in accordance with the estimated LFG generation rates projected for the site.

3.0 SITE OVERVIEW

The Barcaldine landfill Facility is Located off the Landsborough Highway approximately 4km south of Barcaldine on 1/SP223525 in Central Western Queensland. A locality plan of the site is provided in Figure 1 below, the site covers an area of approximately 20ha. Access to the site is Yellow Jack Drive which can be accessed when traveling in a north or south direction along the Landsborough Highway.

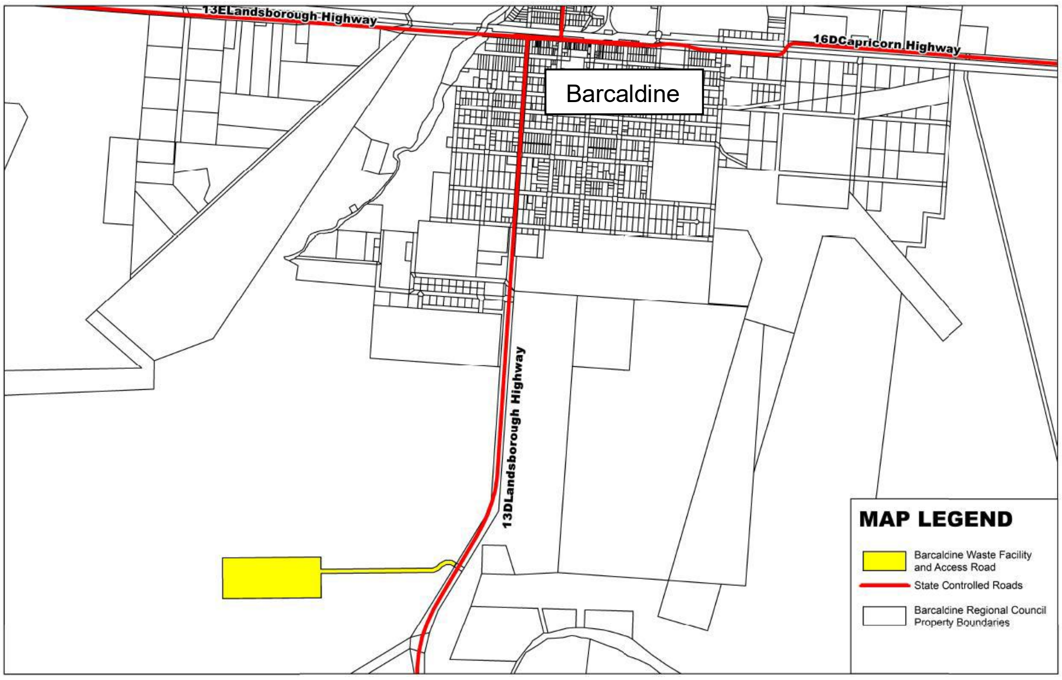


Figure 1 Landfill location map

3.1 Surrounding Land Use

The surrounding land uses in the area are predominantly agriculture with state reserve land surrounding the site in all directions for a minimum distance of approximately 700m, utilised as town common for cattle grazing.

- To the North approximately 2km, the nearest residents of Barcaldine are located where the predominant land use is residential
- To the East of the site are 2 semi-rural allotments located a minimum distance of approximately 1.2 km from the site, beyond these premises land is utilized for grazing with predominantly remnant vegetation
- To The west and south of the site the land use is utilized for grazing with predominantly remnant vegetation
- A rest area is located approximately 700m, to the east on the Landsborough Hwy

3.2 Final Land Use

Following the closure and final rehabilitation of the landfill site, the area of past waste placement will be revegetated with pasture species selected based on their suitability for rehabilitation purposes. It is proposed that after the site has been closed for a sustained period and rehabilitated areas have stabilised that the land will be utilised for grazing purposes in accordance with the surrounding council reserve area utilised for town common grazing purposes.

4.0 ESTIMATION OF LFG GENERATION

4.1 Methodology

A landfill gas simulation model, LandGEM V3.02 has been used to model the potential LFG generation for the site. LandGEM is a freely available LFG resource assessment and risk assessment model developed by the US EPA. LandGEM is based on a first-order decomposition rate equation for quantifying emissions from the decomposition of landfilled waste in municipal solid waste landfills. The software provides a relatively simple approach to estimating landfill gas emissions. Model defaults are based on empirical data from U.S. landfills.

Waste tonnages, operating time frame and annual waste acceptance rates are input into the model to estimate the gas generation capability of the waste facility. Waste acceptance volumes were estimated on current waste generation rates and extrapolated using an estimated population growth of 0.1% (sourced from Queensland Governments Statisticians Office) with an estimated lifespan of 50 years. LandGEM follows a decay model that estimates landfill gas generation. Default values are provided for anaerobic decomposition of landfilled waste.

The LandGEM model was used to estimate potential landfill gas generation from the proposed landfill. The estimation of LFG generation contributes to the development of the landfill gas risk assessment discussed below.

4.2 Uncertainty

It is noted the LandGEM model is a predictive tool and should not be relied upon for exact landfill gas generation rates, rather its purpose in this application is to provide an indicative order of magnitude estimate of landfill gas generation from the facility. Variations to the estimate of landfill gas generated may be influenced by complex site conditions not addressed in the model, hence the results should be considered as estimates for the purpose of this Development Approval.

4.3 Model Results

The LandGEM model estimates LFG generation from estimated commencement of the proposed Landfill in 2017 with an estimated lifespan of 50 years. Based on the assumptions and future predictions stated above, the results of the LandGEM modelling suggests that peak LFG generation, in the order of 93 m³/hour, occurs in 2067 at estimated completion of the facility. The predicted indicative gas generation curve is shown in Figure 2 below.

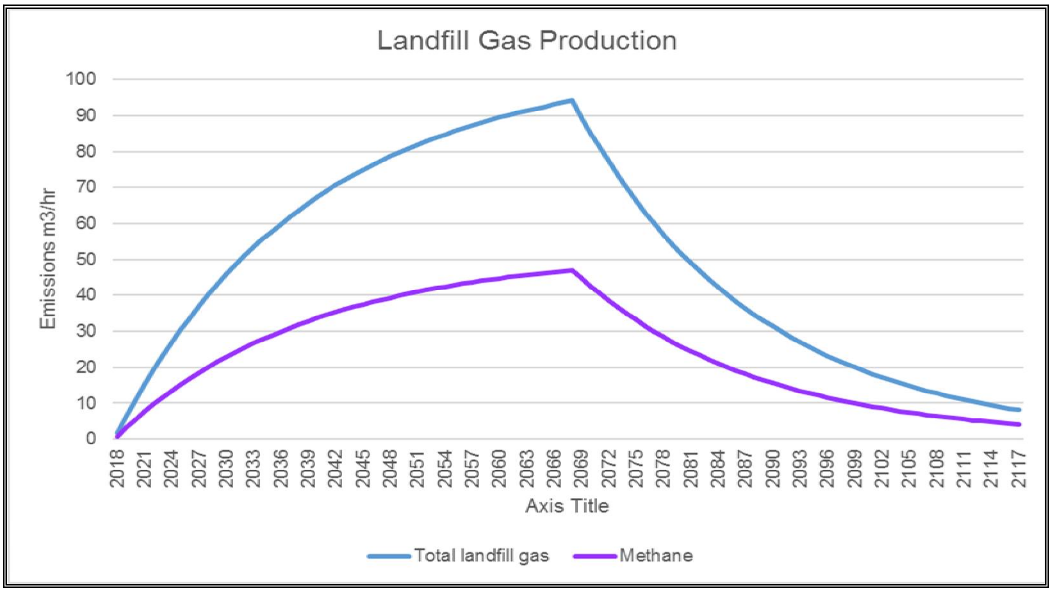


Figure 2 Total Bulk Landfill Gas Produced

5.0 LANDFILL GAS RISK ASSESSMENT

5.1 Objectives and Methodology

The objective of the LFG risk assessment is to address the potential hazards and risks associated with LFG generation at the proposed landfill facility. This LFG risk assessment has been undertaken in accordance with the following guidelines;

- The DEHP Guideline – Landfill siting, design, operation and rehabilitation dated December 2013.
- The DEHP Model operating conditions, dated 1st July 2016.
- Queensland Environmental Protection (Air) Policy 2008, dated 8 July 2008.

The proposed design for the proposed facility were used to form the basis of this LFG risk assessment. The following steps were taken to assess the site specific risks associated with LFG generation;

- Evaluate the interaction between risk sources, pathways and receptors and potential consequences.
- Hazards were identified and risk screening undertaken.
- The level of risk was assessed using a qualitative matrix by considering the likelihood of a risk occurring and the magnitude of an adverse consequence.

It is anticipated this LFG risk assessment would undergo periodic review as part of the operation of the landfill and would be progressively updated to include cell capping, landfill activities, monitoring results, and rehabilitation works or changes to surrounding land uses.

5.2 Potential Sources of LFG

As a municipal waste landfill, the activity is expected to produce a moderate quantity of LFG, as described above. LFG may be generated via three processes;

- Bacterial decomposition: the majority of LFG is produced when naturally occurring bacteria within the waste breaks down the organic material.
- Volatilization: organic compounds present in the waste may change from a liquid or solid into a vapour contributing to the generation of LFG.
- Chemical reactions: certain chemicals within the waste may react to generate LFG.

The rate, volume and quality of LFG is dependent on the waste composition, age of the waste, moisture content, presence of oxygen and temperature of the landfill.

5.3 Potential Pathways

The natural tendency of LFG is to diffuse and flow out of the landfill to the surrounding areas with lower gas concentrations. LFG will tend to migrate from areas of higher pressure to lower pressure such as from the landfill pressure to atmospheric pressure. The ability of LFG to migrate is restricted by the permeability of the surrounding media. Gases that are lighter than air, such as the methane component of landfill gas, tend to move upwards. However, where compacted or saturated waste layers and/or landfill caps are present to impeded flow, the gas can migrate horizontally (lateral migration) as pressure driven flow until it can resume the upward path. LFG that is heavier than air, such as the carbon dioxide component of landfill gas, tends to accumulate at the bottom of subsurface structures such as services trenches or basements.

The potential pathways for LFG migration for the proposed site include:

- Direct release to atmosphere from surface emissions and leachate storages
- Subsurface migration via subsurface trenches, pipes and pits;
- Subsurface migration via side wall and geological strata; and
- Migration of dissolved LFG in leachate or groundwater.

5.4 Potential Receptors

Potential receptors include;

- Employees, contractors and site visitors;
- Residential properties near the site;
- Ecology of surrounding remnant bushland and waterways
- Rest area users

6.0 HAZARD IDENTIFICATION AND SCREENING

The LFG risk assessment assessed potential sources of risk, associated pathways and receptors. The following process was undertaken to identify hazards and evaluate their severity;

- Hazard assessment: this considers the emission source and potential contaminants as well as events or accidents associated with other landfills in the shire.
- Pathway assessment: the surrounding geology, hydrogeology, subsurface infrastructure, atmospheric conditions are assessed to evaluated exposure to receptors.
- Receptor assessment: The sensitivity of receptors was assessed including residents, surface water and land of environmental significance.

6.1 Assessment of Hazard

The main source of the hazard is identified as the degradation of waste deposited at the landfill. The modelling results indicate that LFG generation is worthy of consideration at the site.

The hazards associated with LFG include;

- Impacts to humans;
- Risk of explosion and or fire damage to persons, buildings and structures;
- Impacts on groundwater;
- Impacts on local habitat and human amenity; and
- Potential for asphyxiation in confined spaces.

6.2 Assessment of Pathways

The following were identified as potential pathways of migration and release of LFG;

- Gas migration through the sub-surface geology.
- Direct release to atmosphere.

6.3 Assessment of Receptors

The key potential receptors for exposure to LFG at the site are considered to include;

- Onsite:
  - Employees, maintenance workers and Contractors;
  - Site huts and buildings where employees congregate;
  - Visitors to the site; and
- Offsite:
  - Members of the public and residents;
  - Travelers using rest area to east of the facility; and
  - Offsite personnel and workers

The closest receptors or sensitive land uses to the site are shown in (APPENDIX B) and summarised as follows:

- Sensitive residential receptors are to the east of the site, the closest being approximately 1.3 km from the proposed landfill.
- The rest area located approximately 750metres to the east of the site.
- Flora and fauna including: Remnant vegetation communities; including least concern and of concern RE identified as areas of state environmental significance approximately 1km from the site and potential for EVNT species presence within remnant vegetation areas.
- Waterways: The site is located between two local waterways , Lagoon Creek to the NW and the Alice river to the SE both approximately 1.5km form the site
- Wetlands: wetland habitat, mapped as RE 1-50% wetland (mosaic units), the landfill site will be approximately 750m from the edge of the mapped wetland areas located to SW of the site.

6.4 Risk Assessment

Our qualitative risk assessment rates the proposed activity as an overall ‘Acceptable’ risk as described below.

The qualitative risk assessment was adapted from the UK Environment Agency Guidance on the management of landfill gas (2004). The likelihood categories, severity categories, severity likelihood matrix and Risk evaluation scores are provided in Tables 1 and 2.

Table 1 Likelihood Categories

	Category	**Range**
1	Extremely unlikely	Conditions are theoretically possible, but are unheard of in the landfill
2	Very unlikely	Conditions are rarely encountered in the landfill industry
3	Unlikely	Conditions are encountered several times in the landfill industry, however it is reasonable to assume that these conditions will not
4	Somewhat unlikely	Conditions are assumed to present themselves onsite during the lifetime of the landfill
5	Fairly probable	Conditions are assumed to present themselves onsite several times during the lifetime of the landfill
6	Probable	Conditions are assumed to present themselves onsite

Table 2 Severity Categories

	Category	**Definition**
1	Minor	No health impacts Nuisance on site only No off site complaint
2	Noticeable	Noticeable nuisance off-site .e.g. discernible odours, loose rubbish Minor breach of permitted emission limits, but no environmental harm One or two complaints from the public
3	Significant	Sustained nuisance, .e.g. strong offensive odours First aid required Numerous public complaints
4	Severe	Large environmental release or incident which directly affects offsite receptors Hospital treatment required Public warning and off-site emergency plan invoked
5	Major	Major evacuation of local population (residents) Permanent disabling injuries sustained or fatality Serious toxic effect on beneficial or protected species Widespread but not persistent damage to land
6	Catastrophic	Substantial offsite impacts to broader environment, long-term environmental damage, extensive clean-up required Complete failure of environmental protection controls Site shutdown

Table 3 Severity Likelihood Matrix

Likelihood	**Severity of consequence**					
	Minor	**Noticeable**	**Significant**	**Severe**	**Major**	**Catastrophic**
Extremely unlikely	1	2	3	4	5	6
Very unlikely	2	4	6	8	10	12
Unlikely	3	6	9	12	15	18
Somewhat unlikely	4	8	12	16	20	24
Fairly probable	5	10	15	20	25	30
Probable	6	12	18	24	30	36

Table 4 Risk Evaluation

Magnitude of risk	**Score**
Insignificant	6 or less
Acceptable	8 to 12
Unacceptable	15 or more

The risk levels identified in Table 5 are described;

- Insignificant: the risk is negligible or low impact to receptors, perhaps reported by the public as a nuisance.
- Acceptable: the risk to the receptors is considered to be acceptable due to control measures and available monitoring data.
- Unacceptable: the risk to receptors is considered high due to lack of data, or control actions.

Assessment of potential risks is based on the sensitivity of receptors and potential impacts. Due to the proportion of putrescible waste estimated to be received at the site, the associated LFG generation is unavoidable, as discussed in Section 5. Potential hazards include; fire, explosion, asphyxiation, toxicity to humans, flora and fauna, odour, corrosive gases and emission of greenhouse gases. However due to the location of the site, the scale of production and large buffer zones, the risks are considered to be low.

The mitigation measures listed identify strategies to reduce the risk of LFG to the health and safety of persons potentially affected and the environment.

- The landfill cells have been designed with a minimum one kilometre buffer zone to permanent residents and approximately 700m from the rest area on the Landsborough Hwy.
- The proposed capping systems are designed to BPEM standards to minimise the uncontrolled migration of generated LFG.
- Regular monitoring of sub surface LFG at the perimeter of the site detect if LFG is migrating outside the landfill footprint in high concentrations.
- Regular monitoring of surface emissions detects LFG emissions identifying if levels are within safe working guidelines.

Table 5 presents the results of the Risk Assessment

Table 5 Assessment of Risk

Location	Hazard or Environmental Element/Aspect	Receptors	Potential Impact	Pathways for risk	Existing Controls	Likelihood	Consequence	Level of Risk
Within the site boundary	Lateral migration of LFG generated within the waste deposited at the site	Employees, Contractors, and public users.	Asphyxiation through accumulation of LFG in confined spaces.	Migration of LFG from the landfill through the rock/soil profile.	Monitoring wells adjacent to Landfill, to be monitored quarterly. Confined space entry work will unlikely be required on site Limited landfilling of general waste generated from community (Approx. population of 1600 people)	1 Extremely Unlikely	5 Major	5 Insignificant
			Explosion or fire of LFG in confined spaces.			1 Extremely Unlikely	5 Major	5 Insignificant
Within the site boundary	Residual LFG venting through trenches or excavations	Employees, Contractors, and public users.	Asphyxiation through accumulation of LFG in confined spaces such as pits or drains.	Migration of LFG from the landfill through the soil/rock profile and underground services to trenches or excavations.	The risk posed by LFG migration within trenches will be addressed prior to excavations commencing. A works procedure is required that documents health and safety requirements prior to commencing works. Confined space entry work will unlikely be required on site Monitoring wells adjacent to Landfill, to be monitored quarterly. All ignition sources are removed from the affected area.	1 Extremely Unlikely	5 Major	5 Insignificant
			Explosion of fire of accumulated gas in confined spaces, such as pits or drains.			1 Extremely Unlikely	5 Major	5 Insignificant

Location	Hazard or Environmental Element/Aspect	Receptors	Potential Impact	Pathways for risk	Existing Controls	Likelihood	Consequence	Level of Risk
Within the site boundary	Risk of odour, and impact to human health.	Employees, Contractors, and public users.	Odour caused by ineffective cap, damage to cap, stagnation of leachate evaporation pond.	Direct release of LFG to the atmosphere through uncapped waste and or stagnant leachate evaporation pond.	Monitoring to be carried out across the surface of the landfill on a biannual basis. Periodic inspections of the integrity of the landfill cap during routine operations. Regular use of interim cover during waste filling operations. Compliant landfill cap. Recirculation of leachate material through landfill and use of deodorising products when required.	4 Somewhat Unlikely	2 Noticeable	8 Acceptable
Within the site boundary	Risk of explosion	Employees, Contractors, and public users.	Explosion caused by buildup of gas concentration levels and presence of ignition sources.	Direct release of LFG to the atmosphere through uncapped waste or leachate evaporation pond.	Compliant landfill cap. Quarterly monitoring of subsurface gas. All ignition sources are removed from the affected area, machinery maintained in good repair.	1 Extremely Unlikely	5 Major	5 Insignificant

Location	Hazard or Environmental Element/Aspect	Receptors	Potential Impact	Pathways for risk	Existing Controls	Likelihood	Consequence	Level of Risk
Outside the site Boundary to the North, South, West and East of the site	Lateral migration of LFG through the sub surface geology	Offsite persons	Asphyxiation through accumulation of LFG in confined spaces such as basements or voids under buildings.	Migration of LFG from the site through the surrounding geology and underground services to residential properties and other buildings.	Potential receptors are located a considerable distance from the landfill closest residents >1km from the landfill and built up areas approximately 3.5km from the site which are considered extremely unlikely to be affected by LFG. Sub surface gas level monitoring adjacent to the landfill will be monitored quarterly to provide early warning of offsite migration of landfill gas. Methane and carbon dioxide emitted indirectly to the atmosphere through the soil or rock are likely to be dissipated and diluted shortly after release. The pathway to basements or voids is considered incomplete due to considerable distance to subsurface structures.	1 Extremely Unlikely	5 Major	5 Insignificant
			Explosion or fire of LFG accumulated in confined spaces such as basements or voids under buildings.			1 Extremely Unlikely	5 Major	5 Insignificant

Location	Hazard or Environmental Element/Aspect	Receptors	Potential Impact	Pathways for risk	Existing Controls	Likelihood	Consequence	Level of Risk
		Offsite workers in trenches or excavations	Asphyxiation through accumulation of LFG in confined spaces such as utility trenches, pits, manholes or drains.		Potential receptors are located a considerable distance from the landfill closest residents >1km from the landfill and built up areas approximately 3.5km from the site which are considered extremely unlikely to be affected by the landfill The migration of gas to utility structures is highly unlikely due to the distance to residential areas, subsurface migration to confines space areas is extremely unlikely Sub surface gas level monitoring adjacent to the landfill will be monitored quarterly to provide early warning of offsite migration of landfill gas.	1 Extremely Unlikely	5 Major	5 Insignificant
			Explosion or fire of LFG accumulated in confined spaces, such as utility trenches, pits, manholes or drains.			1 Extremely Unlikely	5 Major	5 Insignificant

Location	Hazard or Environmental Element/Aspect	Receptors	Potential Impact	Pathways for risk	Existing Controls	Likelihood	Consequence	Level of Risk
	Migration of dissolved methane in leachate or groundwater.	Offsite workers in trenches or excavations, offsite residents and workers.	Impact to human health and contamination of groundwater.	Migration of LFG from the site through the surrounding geology and dissolving into the groundwater system.	Monitoring of groundwater dissolved methane will be undertaken on an as needs basis. The pathway is considered to be incomplete as there is >5m vertical separation between the landfill cell waste and the groundwater level. All groundwater sources are located > 2.5km from the site and are drawn from a depth of > 100m, high concentrations of dissolved LFG are very unlikely.	2 Very Unlikely	5 Major	10 Acceptable

7.0 MONITORING PROGRAM

Based on the results of the risk assessment for the proposed development a monitoring program is proposed to undertake periodic monitoring of landfill gas emissions from the facility.

The monitoring program performance is based on ERA 60 model operating conditions action levels provided in Table 6.

Table 6 Landfill Gas Action Levels

Location	Parameter(s)	Action level and unit	Monitoring Frequency
Subsurface geology at or beyond the landfill site boundary	Methane concentration in air	50,0000 ppm	Quarterly
50mm above the final and intermediate cover surface including the batter slopes of the landfill unit	Methane concentration in air	500 ppm	Quarterly
The landfill site boundary when measured in facility structures	Methane concentration in air	12,500 ppm	Quarterly

7.1 Landfill Subsurface Emissions Monitoring

The proposed subsurface monitoring locations for LFG are the test hole sites drilled in the initial hydrogeological investigation of the site located on the northern and southern boundaries of the site. These have been constructed with perforated casings between the depths of approximately 2-11m. Each well has been constructed with adequate security cover to prevent damage by vandals, animals, natural processes and operational machinery.

Sampling at each well will be undertaken on a quarterly basis using a calibrated gas monitor, monitored in accordance with the current industry safe work practices. The ERA 60 Model Operating action levels for subsurface geology at the landfill boundary are provided in Table 6.

7.2 Landfill Gas Surface Emissions Monitoring

The objective of surface gas emission monitoring is to demonstrate that dangerous levels of LFG are not flowing freely into the atmosphere in high concentrations. Surface emission monitoring is proposed to be carried out on a quarterly basis. Surface emissions monitoring will involve a 15m grid site walkover of landfill cells with a calibrated gas monitor in accordance with the current industry safe work practices to detect methane concentrations in parts per million (ppm). The site walkover will help to identify any point sources or fissures that may be emitting LFG.

7.3 Landfill Gas Accumulation Monitoring

Buildings or structures at the facility will be monitored for the accumulation of LFG. The objective of monitoring of methane build up in buildings and structures is to protect human health. Monitoring is to be undertaken on a quarterly basis for all site buildings. Emissions monitoring, will be conducted with a calibrated gas monitor, in accordance with the current industry safe work practices to detect methane concentrations in parts per million (ppm).

8.0 CONTINGENCY PLANNING

If action levels are exceeded, the DEHP will be notified within 24 hours unless rectified beforehand. Remedial action will take place and further monitoring will be undertaken to demonstrate the effectiveness of the remedial works. A landfill gas remediation action plan may be required to be prepared and forwarded to the DEHP that details additional control measures required to be undertaken.

The following remediation strategies are proposed as contingency measures in the event of a detection of LFG exceeding action levels.

8.1 Subsurface Gas Emissions

If uncontrolled lateral LFG emissions that exceed LFG Action levels are detected the extent of the lateral migration will be established through increased monitoring frequency and installation of additional monitoring wells if required. If subsurface action levels are exceeded; remediation of uncontrolled LFG emissions is likely to be required. Remedial actions may include and are not limited to;

- Increased frequency of monitoring;
- Investigation into the source of the LFG;
- Notify neighbor properties, workers, and DEHP;
- Subsurface extraction drains.

8.2 Surface Gas Emissions

Corrective action for the exceedance of surface gas emission action levels may include;

- Investigation into the source of the LFG surface emission;
- Review of waste screening processes to ensure unacceptable waste is not being accepted at the Site;
- Providing thicker cover material or changing the cover material to an alternative material;
- Repairing or replacing cover material or landfill cap materials and surface erosion control methods such as vegetation establishment;
- Repairing or replacing surfaces around cap penetrations.

8.3 Accumulation of LFG in Facility Structures

Where there is an exceedance of 12500 ppm methane inside a building or structure, evacuation and immediate notification of emergency services is required. DEHP and other relevant regulatory bodies will also be notified. Daily testing will be undertaken until implemented control measures are proved effective.
These control measures include;

- Improvement to ventilation within the building or structure;
- Increased frequency of monitoring; and/or
- Identification and remediation of nearby LFG sources.

8.4 Odour

For off-site odour complaints, the following remedial actions will be implemented;

- Record complaint details in register;
- Investigate the source of the odour;
- Confirm if odour is caused by landfilling activities;
- Undertake remedial actions at source of odour if required, i.e implement leachate odour management operations procedures identified in the LEMP; and
- Notify the complainant that investigation was undertaken and remedial actions taken.

9.0 CONCLUSIONS

This LFG Management Plan has been developed to address the requirements for LFG management for the proposed Barcaldine waste management facility in accordance with current regulations. This Landfill Gas Management Plan was prepared to support the Development Approval and may be subject to change during the future operation of the facility.

The facility will be categorized as a general waste landfill with the acceptance of select regulated waste streams; accordingly LFG production is expected. The proposed site conditions were simulated to estimate the expected LFG generation, modelling results indicate a relatively low flow of LFG is expected from the facility, with a peak flow in the order of 94 m^3/hour of landfill gas will be produced during the operational life of the landfill and reducing markedly into the post closure period.

Based on this rate, LFG management monitoring strategies are proposed. The proposed LFG Monitoring system is designed to ensure LFG concentrations remain below safe limits within and beyond the facility, ongoing monitoring of the site will provide qualitative data for determining the concentration levels at the prescribed locations of the site and;

- Prevent impacts to health, safety and the environment;
- Prevent off site nuisance odours; and
- Meet regulatory requirements.

The Plan provides a summary of existing site conditions and LFG monitoring systems and addresses the management of LFG for the proposed development. A LFG risk assessment has been prepared as a basis for the LFG monitoring strategy. Based on our risk assessment it is concluded that potential risks are considered to be Acceptable.

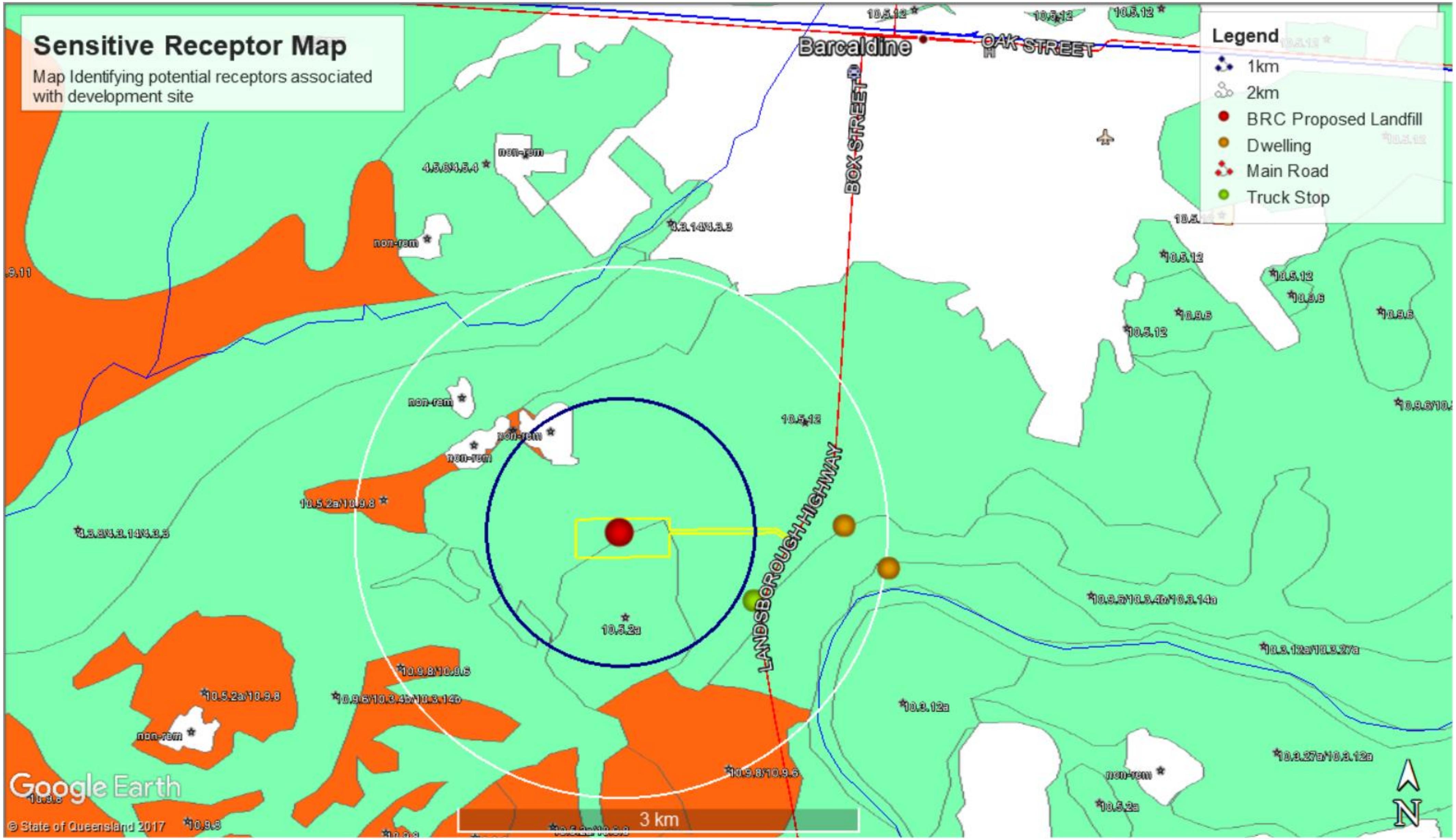
Appendix A
LandGem Model Output

Year	Total landfill gas		Methane	
	(m3/year)	(m3/hr)	(m3/year)	(m3/hr)
2017	0		0	
2018	14080.09197	1.607316435	7040.045984	0.803658217
2019	55675.91396	6.355697941	27837.95698	3.17784897
2020	95285.36629	10.87732492	47642.68315	5.43866246
2021	133005.3676	15.18326115	66502.68382	7.591630573
2022	168928.1099	19.28403081	84464.05497	9.642015407
2023	203141.2889	23.18964485	101570.6445	11.59482243
2024	235728.3233	26.90962595	117864.1617	13.45481298
2025	266768.5637	30.45303239	133384.2819	15.22651619
2026	296337.4905	33.82848066	148168.7453	16.91424033
2027	324506.9032	37.04416703	162253.4516	18.52208352
2028	351345.0993	40.10788805	175672.5497	20.05394402
2029	376917.0458	43.02706002	188458.5229	21.51353001
2030	401284.5409	45.80873755	200642.2705	22.90436877
2031	424506.3693	48.45963119	212253.1846	24.2298156
2032	446638.4484	50.98612424	223319.2242	25.49306212
2033	467733.9688	53.39428867	233866.9844	26.69714434
2034	487843.5268	55.68990032	243921.7634	27.84495016
2035	507015.2513	57.87845335	253507.6257	28.93922668
2036	525294.924	59.96517397	262647.462	29.98258699
2037	542726.0936	61.95503351	271363.0468	30.97751676
2038	559350.1851	63.85276085	279675.0925	31.92638043
2039	575206.6032	65.66285425	287603.3016	32.83142713
2040	590332.831	67.38959258	295166.4155	33.69479629
2041	604764.5233	69.03704604	302382.2617	34.51852302
2042	618535.5963	70.60908633	309267.7981	35.30454317
2043	631678.3118	72.10939633	315839.1559	36.05469816
2044	644223.3587	73.5414793	322111.6793	36.77073965
2045	656199.9287	74.90866766	328099.9644	37.45433383
2046	667635.7902	76.21413131	333817.8951	38.10706565
2047	678557.3573	77.46088554	339278.6787	38.73044277
2048	688989.7559	78.65179862	344494.8779	39.32589931
2049	698956.8864	79.7895989	349478.4432	39.89479945
2050	708481.4837	80.8768817	354240.7419	40.43844085
2051	717585.1741	81.91611577	358792.5871	40.95805788
2052	726288.529	82.90964943	363144.2645	41.45482472
2053	734611.1167	83.85971652	367305.5583	41.92985826
2054	742571.5511	84.7684419	371285.7755	42.38422095
2055	750187.5383	85.63784684	375093.7692	42.81892342
2056	757475.9211	86.46985401	378737.9606	43.23492701
2057	764452.7208	87.26629233	382226.3604	43.63314616
2058	771133.1772	88.02890151	385566.5886	44.01445075
2059	777531.7872	88.75933644	388765.8936	44.37966822
2060	783662.3405	89.45917129	391831.1703	44.72958565
2061	789537.9545	90.12990348	394768.9772	45.06495174

Year	Total landfill gas		Methane	
	(m3/year)	(m3/hr)	(m3/year)	(m3/hr)
2062	795171.1066	90.77295738	397585.5533	45.38647869
2063	800573.666	91.38968791	400286.833	45.69484395
2064	805756.9231	91.98138391	402878.4615	45.99069196
2065	810731.6174	92.54927139	405365.8087	46.27463569
2066	815507.9649	93.09451654	407753.9824	46.54725827
2067	820095.6833	93.61822869	410047.8417	46.80911435
2068	824504.0167	94.12146309	412252.0083	47.06073155
2069	784292.4813	89.53110517	392146.2406	44.76555258
2070	746042.0856	85.16462164	373021.0428	42.58231082
2071	709657.1837	81.01109403	354828.5919	40.50554702
2072	675046.7945	77.06013636	337523.3972	38.53006818
2073	642124.3738	73.30186916	321062.1869	36.65093458
2074	610807.5986	69.72689481	305403.7993	34.86344741
2075	581018.1605	66.32627403	290509.0802	33.16313701
2076	552681.5704	63.09150347	276340.7852	31.54575174
2077	525726.9722	60.01449454	262863.4861	30.00724727
2078	500086.9652	57.0875531	250043.4826	28.54377655
2079	475697.4361	54.30336028	237848.718	27.15168014
2080	452497.3984	51.65495415	226248.6992	25.82747707
2081	430428.8398	49.13571231	215214.4199	24.56785615
2082	409436.5776	46.73933534	204718.2888	23.36966767
2083	389468.1201	44.45983106	194734.06	22.22991553
2084	370473.5357	42.29149951	185236.7679	21.14574976
2085	352405.3282	40.22891874	176202.6641	20.11445937
2086	335218.3175	38.26693122	167609.1588	19.13346561
2087	318869.5272	36.40063096	159434.7636	18.20031548
2088	303318.0769	34.62535124	151659.0384	17.31267562
2089	288525.0797	32.93665294	144262.5399	16.46832647
2090	274453.5455	31.33031342	137226.7728	15.66515671
2091	261068.2882	29.802316	130534.1441	14.901158
2092	248335.8375	28.3488399	124167.9188	14.17441995
2093	236224.3558	26.96625066	118112.1779	13.48312533
2094	224703.558	25.6510911	112351.779	12.82554555
2095	213744.6362	24.40007262	106872.3181	12.20003631
2096	203320.1873	23.21006704	101660.0936	11.60503352
2097	193404.1447	22.07809871	96702.07236	11.03904936
2098	183971.7133	21.00133713	91985.85664	10.50066857
2099	174999.3069	19.97708983	87499.65347	9.988544917
2100	166464.49	19.00279567	83232.24502	9.501397833
2101	158345.9211	18.07601839	79172.96053	9.038009193
2102	150623.2994	17.19444057	75311.64968	8.597220283
2103	143277.3144	16.3558578	71638.65718	8.177928902
2104	136289.5973	15.55817321	68144.79864	7.779086603
2105	129642.6752	14.79939215	64821.3376	7.399696073

Year	Total landfill gas (m3/year)	Total landfill gas (m3/hr)	Methane (m3/year)	Methane (m3/hr)
2106	123319.9273	14.07761727	61659.96366	7.038808637
2107	117305.5435	13.39104378	58652.77175	6.695521889
2108	111584.4846	12.73795487	55792.24231	6.368977433
2109	106142.4451	12.11671748	53071.22255	6.058358738
2110	100965.817	11.52577819	50482.90848	5.762889096
2111	96041.65596	10.96365936	48020.82798	5.481829678
2112	91357.64913	10.42895538	45678.82456	5.21447769
2113	86902.08401	9.920329224	43451.042	4.960164612
2114	82663.81936	9.436509059	41331.90968	4.718254529
2115	78632.25731	8.976285081	39316.12866	4.488142541
2116	74797.31687	8.538506492	37398.65844	4.269253246
2117	71149.40868	8.122078617	35574.70434	4.061039308

Appendix B
Sensitive Receptor Map


Sensitive Receptor Map
Map Identifying potential receptors associated with development site
Legend
1km
2km
BRC Proposed Landfill
Dwelling
Main Road
Truck Stop
Barcaldine
OAK STREET
BOX STREET
LANDSBOROUGH HIGHWAY
non-rem
10.5.12
10.5.2a
10.3.12a
3 km
Google Earth
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