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Bluey's Estate Water Sensitive Development Strategy

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Bluey's Estate
Water Sensitive Development Strategy

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Synopsis : *Great Lakes Council is co-ordinating background studies associated with a Planning Proposal for Lots 110 and 112 DP 1091944 The Lakes Way, Pacific Palms. The background studies required for the site include the investigation of stormwater, flooding and groundwater characteristics and future development impacts. This report describes the outcomes of these initial investigations.*

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

WORKING DRAFT SUMMARY

This working draft report outlines the results of preliminary investigations completed to assist with identifying a potential developable area footprint for the Bluey's Estate development investigation area. A potential developable area footprint based specifically on preliminary flooding and riparian corridor assessments for the site is shown in Figure 6-3. It is envisaged that other relevant studies for the site considering ecology, terrain, transport, bushfire and other urban design criteria will be completed to refine the potential development footprint. Following integrated consideration of all these urban design elements, we understand that a potential development footprint and development characteristics will be confirmed to enable MUSIC modelling of water quality/quantity to be completed (along with other urban design elements) to confirm the development feasibility.

In advance of completing MUSIC modelling based on the potential development footprint, a review of background data and Council policies has been completed by BMT WBM to confirm existing site conditions and objectives/targets for the future development. Additional groundwater and geotechnical data has been gathered for the site to assist with progressing the Water Sensitive Development Strategy. Preliminary MUSIC modelling has been completed based on the existing land uses within the site and available water quality data. A preliminary developed condition model has also been prepared to indicate the approximate magnitude of pollutant reductions required to achieve Council's targets. These initial results indicate that provision of a standard development within the site will require a significant coverage of Water Sensitive Urban Design measures to achieve Council's objectives.

The preliminary investigation and outcomes are summarised in the following sections.

1 INTRODUCTION

Great Lakes Council is co-ordinating background studies associated with a Planning Proposal for Lots 110 and 112 DP 1091944 The Lakes Way, Pacific Palms ("the site"). The site comprises approximately 338 hectares of primarily forested land. The site also includes areas that have been cleared for rural uses and development of a golf course.

The Planning Proposal seeks to evaluate the potential for rezoning the site for the purposes of residential and commercial development, and conservation purposes. The areas being evaluated for development are referred to within this report as the 'development investigation areas'. The development investigations areas have been identified for the site based on Council's current appreciation of the site features and these areas are shown in Figure 1-1.

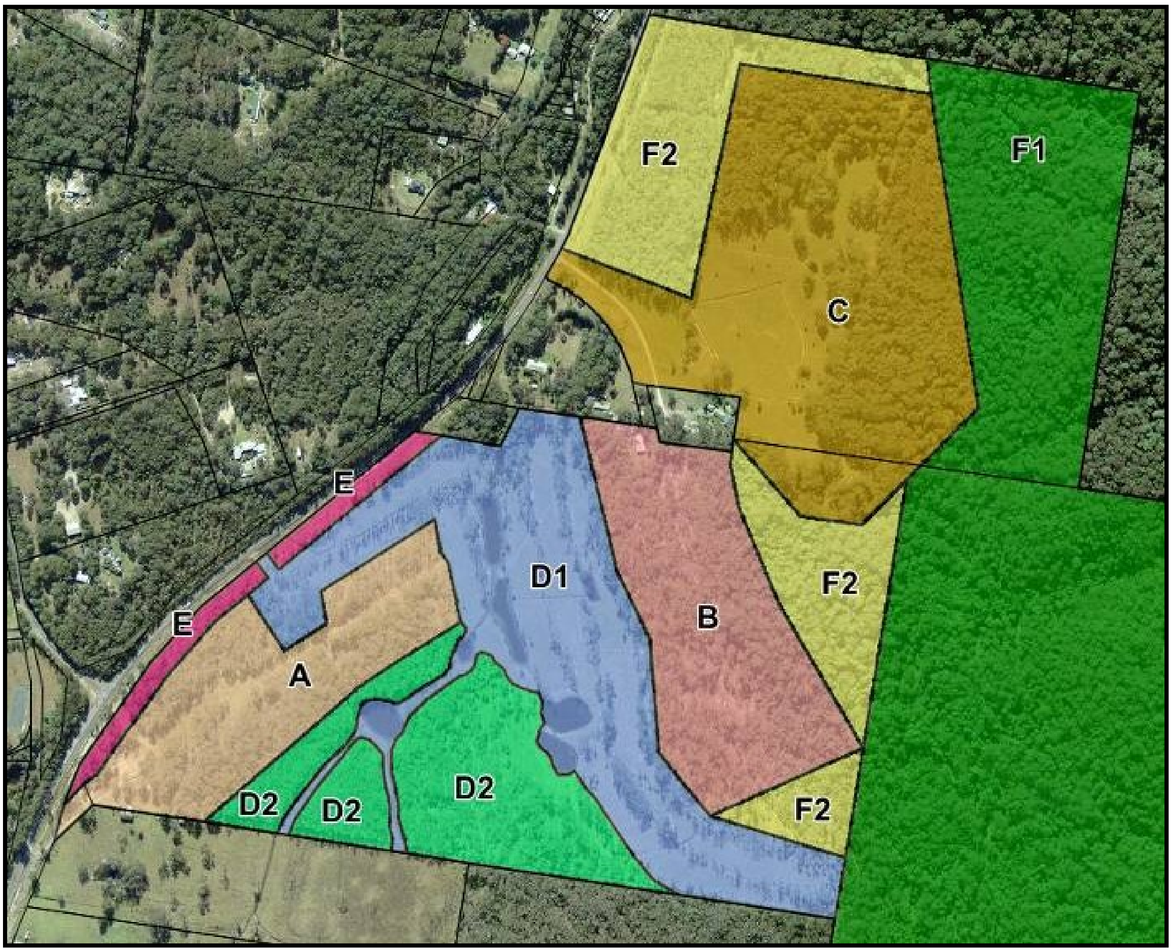


Figure 1-1 Development Investigation Areas (extract) (Great Lakes Council, 2012)

The development investigation area shown in Figure 1-1 includes:

- Areas A, B and C that comprise land being investigated for development;
- Area D1 that comprises land within the approved golf course area (including access, carparks and ponds);
- Area D2 that comprises land being investigated for recreational development or conservation;

- Area E that comprises land to potentially be applied as a buffer to The Lakes Way;
- Area F1 that comprises potential conservation dedication land; and
- Area F2 that comprises potential private or public conservation land.

This study focuses on all the development investigation areas summarised above, with the exception of Area F1. It is assumed that Area F1 would be zoned for environmental conservation if development within the site were to proceed.

The background studies required for the site include the investigation of stormwater, flooding and groundwater characteristics and future development impacts. This report describes the outcomes of these initial investigations.

2 POLICIES AND GUIDELINES

2.1 Overview

There are a number of water management planning policies, instruments and guidelines that are relevant to future water management within the development investigation area. These policies and guidelines outline key objectives and targets for managing water within catchments to assist with protecting sensitive receiving environments.

The key local planning instrument for the water management within development in the Great Lakes Council LGA is DCP 54 – Water Sensitive Development. This planning instrument outlines Council's requirements for managing water conservation, stormwater quality and stormwater quantity within development sites.

DCP 54 was prepared considering a number of other regional, state and national policies and guidelines relevant to the protection of catchments, waterways and natural ecosystems. Some of the key policies and guidelines that are also relevant to development within this site are discussed below including:

- National Strategy for Ecologically Sustainable Development;
- National Urban Water Planning Principles;
- Natural Resources Commission Targets; and
- NSW Water Quality and River Flow Objectives.

2.2 DCP 54 – Water Sensitive Development

DCP 54 outlines objectives, principles and targets for water conservation, stormwater quality and stormwater quantity management. DCP 54 outlines controls for 'small' and 'large' scale development. The DCP large scale development controls would be most applicable for the development investigation area.

The key objective of DCP 54 is to facilitate the application of the following principles of Water Sensitive Development in the Great Lakes Council local government area:

- protection and enhancement of natural water systems (creeks, rivers, wetlands, estuaries, lakes, lagoons, groundwater systems);
- protection and enhancement of water quality, by improving or maintaining the quality of stormwater runoff;
- minimisation of harmful impacts of development upon surface and groundwater flow regimes;
- integration of stormwater management systems into the landscape in a manner that provides multiple benefits, including water quality protection, stormwater retention and detention, ecological enhancement, public open space and recreational and visual amenity; and
- reduction in potable water demand/use by taking a whole of water cycle approach.

Proposed amendments to DCP 54 have recently (November, 2012) been placed on public exhibition, and Council is seeking comments in response to the proposed amendments. It is assumed for development of this WSD Strategy that the proposed changes will proceed with only minor amendments. The specific DCP 54 requirements are discussed further in Section 3.

2.3 Water Quality Improvement Plans

Through the application of the National Water Quality Management Strategy (NWQMS) the Australian Government is working in collaboration with States and Territories to develop Water Quality Improvement Plans (WQIP) to reduce pollution being released into aquatic ecosystems with established ecological, social and/or recreational values.

Water Quality Improvement Plans (WQIPs), prepared consistent with the Framework for Marine and Estuarine Water Quality Protection, amongst other matters identify the most cost-effective and timely projects for investment by all parties including the Australian Government, State and Local Governments, and community and environment groups.

WQIPs seek to deliver significant reductions in the discharge of pollutants to agreed high value receiving environments through:

- identification of the environmental values of water;
- determination of water quality objectives and load targets for pollutants of concern;
- development of environmental flow objectives and environmental water provisions;
- implementation of catchment based management actions, including control of point and diffuse sources, market-based instruments and adaptive management; and
- the application of predictive models and ambient monitoring programs.

The Great Lakes Water Quality Improvement Plan (GLWQIP) was developed in 2009 for Wallis, Smiths and Myall Lakes. The outcomes of this plan assisted with developing Council’s DCP 54 which aims to protect water quality in these receiving environments. The GLWQIP is particularly relevant to this site which drains into the ecologically sensitive southern part of Wallis Lake. Further discussion on this area of Wallis Lake is provided in Section 4.5.4.

2.4 National Strategy for Ecologically Sustainable Development

The overarching principles for Water Sensitive Urban Design (WSUD) relevant to all development in Australia are outlined in the *National Strategy for Ecologically Sustainable Development (*Ecologically Sustainable Development Steering Committee, 1992) which sets out the broad strategic and policy framework under which governments co-operatively make decisions and take actions to pursue Ecologically Sustainable Development (ESD) in Australia. The strategy plays the critical role of setting the scene for the broad changes in direction and approach that governments will take to ensure that Australia's future development is ecologically sustainable. Encouraging the principles of ESD is a specific objective of the *Environmental Planning and Assessment Act, 1979* (EP&A Act) which governs the planning process in NSW.

The *National Strategy for Ecologically Sustainable Development* includes the following key objectives to promote the principles of ESD:

"To develop and manage in an integrated way, the quality and quantity of surface and groundwater resources, and to develop mechanisms for water resource management which aim to maintain ecological systems while meeting economic, social and community needs."

Ecologically sustainable development requires the effective integration of economic and environmental considerations in decision making processes. Ecologically sustainable development is achieved through the implementation of the following principles and mechanisms:

(a) the precautionary principle, i.e. lack of full scientific certainty should not be used as a reason for postponing controls to prevent environmental degradation where there are threats of serious environmental damage;

(b) inter-generational equity, i.e. the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations;

(c) conservation of biological diversity and ecological integrity, i.e. conservation of biological diversity and ecological integrity should be a fundamental consideration; and

(d) improved valuation, pricing and incentive mechanisms, i.e. environmental factors should be included in the valuation of assets and services.

Governments work towards ensuring that development decisions which impact on water resources are based on acceptable water quality and quantity criteria, and management requirements to meet those criteria on a sustainable basis are recognised. Efforts should be focussed on using water more efficiently; allocating water for stream flow and other environmental uses; and minimising pollution. It is also important that the efforts to improve water management can be funded and are in the community's interests.

As part of a Council's charter to properly manage, develop, protect, restore, enhance and conserve the environment, these principles must be considered when:

- undertaking strategic planning for proposed or existing urban areas;
- undertaking regulatory functions, such as approving development applications;
- undertaking service functions, such as roads and stormwater drainage;
- setting rates and charges; and
- managing community land, such as parks and reserves.

2.5 National Urban Water Planning Principles

COAG has adopted the National Urban Water Planning Principles (Department of Sustainability, Environment, Water, Population and Communities, 2012). These principles assist Australian governments and water utilities with planning the development of urban water and wastewater service delivery in a sustainable and economically efficient manner. Whilst primarily applicable to water supply and wastewater systems, the eight principles are also relevant to stormwater management where this can be utilised to supplement conventional water supply sources. Principles 4 and 5 outlined below are particularly relevant to stormwater management.

Principle 4 - Manage water in the urban context on a whole-of-water-cycle basis.

The management of potable water supplies should be integrated with other aspects of the urban water cycle, including stormwater management, wastewater treatment and re-use, groundwater management and the protection of public and waterway health.

Water quality of potable supplies should be protected through appropriate catchment management practices and management of wastewater. This will involve a range of activities, from land use planning and management that protects the quality of natural water resources, through to addressing the disposal, treatment and reuse phases of the water cycle.

Principle 5 - Consider the full portfolio of water supply and demand options.

Selection of options for the portfolio should be made through a robust and transparent comparison of all demand and supply options, examining the social, environmental and economic costs and benefits and taking into account the specific water system characteristics. By considering the full range of options, access to a range of sources should be able to be optimised dynamically (even on a short term basis) through the availability of diverse infrastructures that may include both centralised and decentralised water supply schemes.

2.6 Natural Resources Commission Targets

The Natural Resources Commission (NRC) is an independent body that provides the NSW Government with advice on natural resource management in the environmental, economic, social and cultural interests of the state. The NRC's primary areas of responsibility are to independently review Catchment Action Plans (CAPs) prepared by the Catchment Management Authorities (CMAs), audit their implementation and provide recommendations to the NSW Government based on the review/audit findings. The NRC also has specific roles under environmental planning legislation to review and advise the Minister on development master plans, or consider requests to waive the need for a master plan.

The NRC was tasked with recommending state-wide standards and targets for natural resources management to the NSW Government in 2005. The NRC identified 13 state-wide targets for natural resource management, including 5 specific water management targets:

- Target 5: By 2015 there is an improvement in the condition of riverine ecosystems.
- Target 6: By 2015 there is an improvement in the ability of groundwater systems to support groundwater dependent ecosystems and designated beneficial uses.
- Target 7: By 2015 there is no decline in the condition of marine waters and ecosystems.
- Target 8: By 2015 there is an improvement in the condition of important wetlands, and the extent of those wetlands is maintained.
- Target 9: By 2015 there is an improvement in the condition of estuaries and coastal lake ecosystems.

The state-wide targets are promoted through the Catchment Action Plans, but are also relevant for future development planning.

2.7 NSW Water Quality and River Flow Objectives

The NSW Government provides guidelines on water quality and river flow objectives for waterways in NSW (refer http://www.environment.nsw.gov.au/ieo/). These guidelines are intended for local Councils, Catchment Management Authorities and state agencies to consider and include in strategic, catchment and land use planning processes.

NSW Water Quality and River Flow Objectives were established by the NSW Government in 1999 for the majority of NSW catchments. Objectives were established for the Karuah River / Great Lakes catchments and these are particularly relevant to the development investigation area.

The guidelines provide an overview of specific water quality and river flow objectives for the Karuah River / Great Lakes catchments. The guidelines outline the following water quality objectives for these receiving environments:

- aquatic ecosystems
- visual amenity
- secondary contact recreation
- primary contact recreation
- aquatic foods.

In terms of river flow objectives, the guidelines outline the following objectives:

- maintain wetland and floodplain inundation
- maintain natural flow variability
- manage groundwater for ecosystems
- minimise effects of weirs and other structures
- maintain or rehabilitate estuarine processes and habitats.

Public consultation completed to establish the water quality and river flow objectives identified the following specific issues for the Karuah River and Great Lakes receiving environments:

- Control bacterial contamination in estuarine areas. This was seen as an important issue, given the potential implications for the oyster-growing industry, recreation and tourism in the catchments.
- Minimise the impact of tourism and recreational activities on water quality and flows, particularly during peak tourism periods.
- Improve management of the estuary and lower floodplain areas. There were numerous issues of concern in particular, water quality, acid sulfate soils (associated with flood mitigation and drainage) and increased nutrient levels (from both point sources and stormwater runoff from farms and towns).

- Control diffuse-source pollution from urban development, dairy farms and various agricultural practices.
- Provide more community information on managing aquatic environments and water resources. In particular, people wanted the information base on water quality, flow monitoring and biological health to be further developed.
- Protect existing riparian vegetation and restore it where necessary. Associated land-based issues included protecting the habitat of native animals, revegetating where necessary, and reducing erosion, sedimentation, weeds and land degradation.
- Monitor and account for all uses of the water resource. Increasing use of water under riparian access rights, as well as groundwater use, was a cause for concern.
- Reduce stress in river systems where this has been identified as an issue.
- Protect rivers with high conservation value. As a guide, such rivers should not be allowed to further degrade in water quality or flow regime, and may require restoration where water quality is poor, the flow regime has changed, or habitat has been lost or degraded.
- Improve strategic planning for land development. This was seen as an important issue, and natural resource capability assessments were identified as a useful tool in facilitating such an approach.
- Respect Aboriginal spiritual and cultural values associated with rivers, creeks, wetlands and lakes; and traditional Aboriginal management roles in, and uses for, these areas-including as a source of traditional foods that are safe to eat.

3 WSD OBJECTIVES, TARGETS, PRINCIPLES AND CONTROLS

3.1 Summary

Great Lakes Council has identified specific Water Sensitive Development (WSD) objectives, targets, principles and controls relevant to proposed developments in their LGA and these are outlined in DCP 54. These objectives, targets, principles and controls are specifically relevant to future development within the site and are summarised below for the following water management elements:

- Water conservation;
- Stormwater quality; and
- Stormwater quantity.

3.2 Water Conservation

3.2.1 Objectives

- To reduce the consumption of potable water;
- To reduce wastewater discharges into the receiving environment;
- To harvest wastewater where appropriate; and
- To harvest rainwater and urban stormwater runoff for use where appropriate.

3.2.1 Targets

Any BASIX affected development is to demonstrate compliance with State Environmental Planning Policy - Building Sustainability Index (BASIX). Developments not subject to the provisions and requirements of BASIX must demonstrate that consideration has been given to the interaction of all elements of the water cycle (stormwater, wastewater, potable water) through an integrated water management plan. This plan should identify how each water source is appropriate for its end use and that demands on potable water supplies are minimised.

3.2.2 Principles and Controls

- Wherever possible, the water source used for a particular end use should reflect the quality required for that end use (fit for purpose);
- Integrate stormwater quantity management with quality management to optimise treatment performance and improve opportunities for re-use and groundwater management;
- Management of stormwater shall be considered along with the full range of other water fluxes;
- Reduce hydrological impacts of development as far as possible by preserving interactions between surface and groundwater - delivering appropriate water to the right places for the right times;
- Manage quality and quantity across the frequency spectrum from quarterly (0.25 year ARI) treatment flows up to the safe control of 100 year ARI discharges to ensure appropriate levels of risk (probability of damage);

- Opportunities for multiple use of stormwater infrastructure should be investigated e.g. water quality benefits of modified detention basins and unlined, vegetated channels;
- The roof area directed to a rainwater tank should be maximised, to both increase the effectiveness and reliability of the reuse system, and reduce the degree of stormwater treatment required for those areas not draining to the rainwater tank;
- Source control rainwater capture and reuse should be considered for all developments prior to large scale infrastructure; and
- Dual reticulation should be provided for all greenfield and infill redevelopments which are located in existing or planned recycled water reticulation zones.

The following controls apply to development that is not subject to the provisions and requirements of BASIX:

- Ensure any water use fittings demonstrate minimum standards defined by the Water Efficiency Labelling and Standards (WELS) Scheme;
- Water efficient washing machines and dishwashers are to be used wherever possible;
- Incorporate dual reticulation for toilet flushing, laundry, irrigation and potentially cooling towers in infill redevelopment and greenfield areas that are within existing or planned recycled water reticulation zones, in accordance with the integrated water management plan;
- Install rainwater tanks to meet a portion of supply such as outdoor use, toilets, laundry or hot water in accordance with the integrated water management plan. Where potable water is available, rain water is not to be connected to the kitchen tap;
- Ensure that any cooling towers proposed:
    - are connected to a conductivity meter to ensure optimum circulation before discharge;
    - include a water meter connected to a building energy and water metering system to
    - monitor water usage;
    - employ alternative water sources for cooling towers where practical; and
    - use alternative sources (e.g. rainwater, stormwater, recycled water, grey water) to meet at least 80 per cent of demand for external water use (e.g. irrigation of landscaped areas, pools, water features etc.).

3.3 Stormwater Quality

3.3.1 Objective

- To safeguard the environment by improving the quality of stormwater run-off.

3.3.2 Targets

The site is located within an area defined in DCP 54 as a ‘water quality improvement catchment’, and the development would be categorised as a ‘greenfield’ development since the existing site imperviousness is less than 10%. Greenfield development within catchments defined as ‘water quality improvement catchment’’ is required to demonstrate compliance with the following stormwater quality objectives:

- Gross pollutants – 90% reduction relative to the developed condition without treatment;
- Total Suspended Solids (TSS) – TSS load discharged from the future development site not to exceed load from the existing site;
- Total Phosphorus (TP) – TP load discharged from the future development site not to exceed load from the existing site; and
- Total Nitrogen (TN) – TN load discharged from the future development site not to exceed load from the existing site.

3.3.3 Principles and Controls

- WSD elements should be integrated into landscaped areas to fit into the built environment of the development;
- WSD elements should be located and configured to maximise the impervious area that is treated;
- Consideration should be given to incorporation of multiple uses of WSD infrastructure (e.g. stormwater detention and treatment) where possible;
- WSD elements should be incorporated to enhance ecological outcomes;
- The proposed treatments are required to address the entire development when fully operational;
- Where WSD elements are within areas of shallow groundwater tables, all assets are to be lined to prevent contamination of local groundwater sources unless it can be demonstrated that unlined systems will sufficiently protect groundwater quality;
- Where WSD elements are constructed in sand, all raingardens should have the sides lined to avoid exfiltration; and
- On lot treatments (apart from rainwater tanks) are to be avoided due to uncertainty around long term maintenance of WSD on private property.

3.4 Stormwater Quantity

3.4.1 Objectives

- To control the impacts of development on receiving ecosystems including but not limited to groundwater, wetlands and bushland by controlling the frequency, magnitude and duration of flows;
- To reduce the hydrological effects of development by seeking to preserve as far as practicable pre-development groundwater and surface water regimes and interactions;
- Appropriate water in the right places for the right times;
- To control the impacts of development on channel bed and bank erosion by controlling the magnitude, nature and duration of sediment-transporting flows; and
- To promote disconnection of impervious areas by introducing appropriate measures to minimise the rate, frequency and volume of urban runoff events in order to improve WSD performance.

3.4.2 Targets

All development covered by DCP 54 are to achieve the targets listed below:

- Streams – Take all reasonable management actions to reduce the impervious areas that are directly connected to the stormwater system (except in high soil salinity areas where the only reasonable management action available is infiltration);
- Natural bushland – Take all reasonable management actions to reduce the potential for erosion within downstream bushland areas; and
- Natural wetlands – No change to hydrologic indices (within natural variation) identified as critical for the specific wetland type.

These requirements are in addition to any hydrologic management requirements needed to address flooding and stormwater drainage for developments as set out in the Great Lakes Council Flood Policy and other relevant Development Control Plans.

3.4.3 Principles and Controls

- Disconnection of impervious areas from the drainage system can include directing runoff from downpipes, rainwater tank overflows and impervious areas onto stormwater harvesting devices, infiltration measures and grassed or other landscaped areas designed to accept these flows
- The physical nature of flows into receiving environments needs to be preserved. In particular, where the receiving environment naturally receives dispersed flows, concentration of flows should be avoided.
- If practicable, on-site stormwater flow modification measures such as detention and infiltration could address management of low level, high frequency flows to avoid short-circuiting and pollutant export. These flows carry the greater part of the pollutant load. This approach might also include extended detention allowances within bio-retention and use of larger ephemeral wetlands to retain, treat and infiltrate larger runoff events where possible.

4 BACKGROUND REVIEW

4.1 Existing Land Uses

A development comprising an 18 hole golf course, water storage dams, access roads, parking areas, pro shop, club house and tourist villas was approved by Council and has been partially completed within the development investigation area. Currently, fairways and tees for a portion of the holes have been partially completed and eight water storages have been constructed. The cleared fairway and tee areas are currently grazed by cattle. No construction for the approved access road, parking area, pro shop, club house or tourist villas has commenced.

The currently cleared golf course areas rise slightly to the south to a low ridge where the club house was proposed. To the east of the partially constructed fairways, the ground rises steeply at gradients of approximately 20% to a ridge that separates southern and northern parts of the investigation area.

The northern part of the investigation area comprises steep forested slopes falling towards a central cleared relatively level area that is currently used for cattle grazing. The northern part drains into a downstream forested area prior to discharging under The Lakes Way.

The eastern part of the site is planned for environmental conservation and is primarily in a relatively natural forested condition. Vehicle access tracks have being formed through this area, water storages formed and some areas partially cleared of vegetation possibly to support cattle grazing in this area.

4.2 Drainage

The site is drained through two distinct sub-catchments separated by a ridge that runs north-west / south-east through the development investigation area. The southern catchment drains a relatively large upstream catchment area, whilst the northern catchment is signficantly smaller.

The southern catchment drains to a triple cell box culvert (3 x 3m x 2.4m) (3 x 3.3m x 2.1m ??) (refer to Figure 4-1) under The Lakes Way prior to discharge into Wallis Creek which flows into Wallis Lake.

Figure 4-1 Southern Catchment Culvert

A number of swales have been constructed within this part of the development investigation area to divert overland flow from upstream catchment areas to the south and east away from fairways to constructed water storages. Other swales have been formed adjacent to the golf course fairways to control local runoff and reduce the extent of boggy areas to improve trafficability (refer typical example in Figure 4-2).

Figure 4-2 Typical Drainage Swale

There are currently eight water storages of varying sizes distributed throughout the development investigation area. These water storages appear to intercept the natural groundwater table (refer to examples in Figure 4-3).

Figure 4-3 Southern Catchment - Existing Water Storages

The northern catchment drains to a seven cell box culvert (7 x 2.4m x 1.2m) under The Lakes Way (refer Figure 4-4). A number of natural steep gullies drain runoff from the eastern parts of this catchment into the development investigation area. These gullies connect to drainage swales that have been constructed in the lower parts of this catchment to control and direct runoff to the culvert. The drainage swales ensure that existing pasture areas are relatively dry for grazing.

Figure 4-4 Northern Catchment Culvert (source: Great Lakes Council)

4.3 Groundwater Quality

Groundwater quality has previously been sampled from three boreholes (BH1, BH2 and BH3) established across the southern portion of the investigation area in 1997 (Coffey, 1997). Groundwater quality samples were taken from BH1 and BH3 in both 1997 and 2002, whilst only one sample was taken from BH3 in 2002 (Coffey, 2002). The samples taken in 1997 were prior to commencement of development of the golf course, whilst the 2002 samples were taken after the current development occurred. The samples were extracted from three boreholes located in the current golf course area within the southern part of the development investigation area. The previous monitoring results are summarised in Table 4-1. These results are compared with the 2012 groundwater sampling in Section 7.4.1.

Table 4-1 Previous Groundwater Quality Monitoring Results (Coffey, 2002)

	BH1		**BH3**		**BH2**
Parameter	**1997**	**2002**	**1997**	**2002**	**2002**
NO_2 (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01
NO_3 (mg/L)	0.07	0.02	0.02	0.06	0.01
TKN (mg/L)	0.4	0.3	<0.1	0.6	<0.1
TN[1] (mg/L)	0.48	0.33	0.13	0.67	0.12
TP (mg/L)	0.14	0.14	0.15	0.11	0.06
Potassium (mg/L)	11	26	17	24	39
Copper (µg/L)	9	41	3	52	42
Lead (µg/L)	106	121	92	88	168
Zinc (µg/L)	114	104	65	159	60

1. Calculated based on concentration for individual nitrogen species.

Soil testing was completed to identify the suitability of the insitu soils for growing turf on the golf course (Richland Laboratories, 1992). The testing identified that the insitu soils has low nutrient levels and soil had low dispersion levels. A nitrogen/phosphorus/potassium fertiliser was recommended to be spread to a depth of 100mm at a rate of 500kg/ha for turfed areas. We understand that fertilised turfed areas have not been established to date.

4.4 Surface Water Quality

We understand that there is currently no surface water quality data available for the development investigation area. Future planning and investigations would benefit from establishing background water quality conditions in the existing water storages and drainage channels during wet weather.

4.5 Receiving Environments

4.5.1 Groundwater

Groundwater aquifers are layers of permeable soils or rock through which water is able to flow. Groundwater is typically the initial receiving environments for infiltrated stormwater. Contaminants that enter groundwater can persist for timescales that are orders of magnitudes higher than surface water environments, and therefore protection of groundwater from contamination should be a high priority. Where infiltrated stormwater is relatively uncontaminated, attenuation and biological treatment of the infiltrated stormwater can occur prior to the groundwater flow intersecting a creek, wetland or other receiving environment. In these situations the slower flow assists with treatment and reducing potential pollution. Groundwater typically will be the source of most flow to wetlands in coastal areas. Changes to the quality and quantity of water entering groundwater can have significant impacts on the wetland habitats

Developments proposed within the zone of influence of sensitive groundwater dependent ecosystems (particularly groundwater recharge areas) typically must prepare an environmental assessment of the risks of the development to the ecosystem (DLWC, 2002).

4.5.2 Freshwater Creeks

Surface runoff from development within the site will initially discharge into watercourses from piped or otherwise constructed drainage systems. Watercourses are often the receiving environment where development impacts are first observed. Watercourses may be impacted by point discharge of stormwater into the watercourses resulting in localised scouring of banks. More frequent and elevated discharge from impervious surfaces in the development can also increase erosion of watercourse banks and beds. Stormwater also conveys pollutants into the watercourse impacting on water quality and smothering of bed sediments that support aquatic fauna.

Increased imperviousness resulting from development is known to increase the peak discharge and volume of runoff following development with a related increase in sediment transport capacity and erosion potential. The impacts of development on hydrology are not specifically related to the total impervious area, but are primarily related to the degree of connectivity of the impervious areas to the watercourses.

Initially catchment development is known to increase sediment loads to watercourses. However, the coarse sediment load to watercourses may also drop below natural levels following maturation of urban catchments (particularly when measures are provided to filter the catchment runoff). A decreased coarse sediment supply to a watercourse can lead to increased bed erosion as watercourse energy is expended on erosion.

For many watercourses receiving development runoff, deposition of sediment along the watercourse bed during frequent smaller events is also a significant issue impacting on watercourse geomorphology and watercourse health.

4.5.3 SEPP 14 Coastal Wetland No. 638

Wetlands are areas of land that are wet by surface water and/or groundwater for long enough periods that the plants and animals in them are adapted to, and depend on, moist conditions for at least part of their lifecycle. They include areas that are inundated cyclically, intermittently or permanently with fresh, brackish or saline water. Hydrology is often the most significant issue for the management of wetlands. All wetlands are integral to landscape processes such as nutrient cycling, detention of flood water and sediment trapping (DECCW, 2010).

SEPP 14 Coastal Wetlands aims to preserve and protect coastal wetlands in the environmental and economic interests of NSW. The areas covered by SEPP 14 are delineated on a series of maps prepared by the Department of Planning and Infrastructure. SEPP 14 requires that a person must not clear land, construct a levee, drain land or fill land which is covered by the SEPP except with the consent of the local council and the concurrence of the Director General of Planning.

The SEPP 14 maps indicate that Coastal Wetland No 638 is located downstream of the site. Although the development would not be located within the mapped boundaries of Coastal Wetland No. 638, runoff from development will discharge to a watercourse that flows through the wetland prior to discharging into Charlotte Bay.

Many coastal wetlands are ephemeral, that is, they are not permanently wet. The hydrology for estuarine lakes and saltmarsh is primarily influenced by tides. Ephemeral coastal wetlands are particularly threatened by development within the catchment. Development may indirectly impact on the hydrology, morphology and vegetation characteristics of wetlands, in addition to direct impacts from excavation, filling, over drainage and exposure of acid sulfate soils.

4.5.4 Wallis Lake

The southern bays of Wallis Lake have limited tidal exchange and mixing with the northern parts of Wallis Lake and the lower estuary (Great Lakes Council, 2009). Therefore, pollutants from the catchments draining to the southern bays of Wallis Lake would tend to accumulate in these bays. This system is therefore highly susceptible to impacts from increased catchment inflows and associated increased pollutant loads. Increasing pollutant loads from development within the catchments can potentially result in increasing and chronic impacts on these environments.

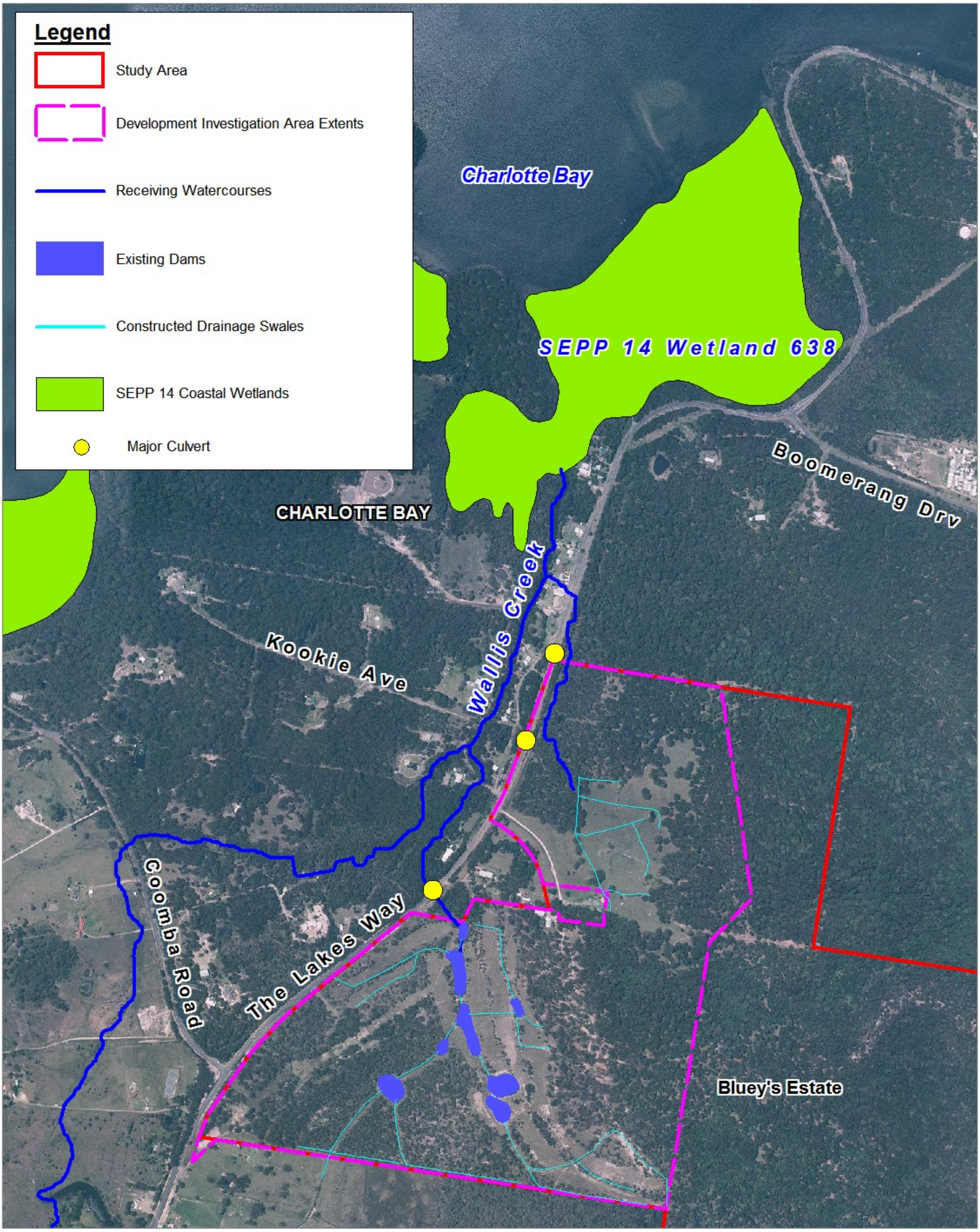
Seagrasses, macrophytes, sponges and other bottom-dwelling plants and animals are extremely important components of estuarine ecosystems that exist in Wallis Lake. They provide food and shelter to a wide range of fish and importantly threatened seahorses and pipe fishes. Water clarity is important for establishing the depth that seagrasses can grow to and subsequently the area that sea grasses can cover within a lake or lagoon. Water clarity is also important for the diverse range of sponges that exist in southern Wallis Lake. Suspended sediments washed into Wallis Lake in excessive levels would increase water turbidity and results in light penetrating to a lower depth. In addition to suspended sediments, coarse sediments discharged into lakes can directly cover and smother sea grasses. If seagrasses do not receive adequate light due to increased turbidity or smothering by sediment they are unable to survive and this subsequently impacts on the availability of suitable habitats for the aquatic animals reliant on the seagrass cover (Great Lakes Council, 2009).

Light penetration can also be reduced by excessive algal growth, as a result of nutrients discharged into Wallis Lake being taken up by algae. Direct growth of algae on seagrasses can also significantly reduce the amount of light reaching the sea grasses. Whilst the growth and death of algae occurs in cycles, nutrients absorbed by algae in the growth phase sink to the lake bed with the dead algae cells, and over time the concentration of nutrients in the sediments increases. Under particular environmental conditions the nutrients are able to be released from the sediments and recycled by algae. As the concentration of nutrients increases, more frequent and longer lasting elevated algal levels can be sustained between rainfall events that provide additional nutrients. This is particularly relevant for areas of Wallis Lake with limited tidal exchange.

The southern bays of Wallis Lake are in near-pristine condition. The average chlorophyll-a concentration is less than 1 µg/L, turbidity is less than 2 NTU and water clarity exceeds 3m. The near-pristine water quality conditions support ecologically important seagrasses, macrophytes and estuarine sponges. Many of the estuarine sponges are unique to Wallis Lake and have not been formally named (Great Lakes Council, 2009). Maintaining near-pristine water quality in these bays, including Charlotte Bay which the site eventually drains to, is therefore highly important for protection of the ecology.

4.5.5 External Catchments

In addition to direct impacts within the catchment of a development, there are other potential impacts on external catchments that form a water supply source for the development and for the assimilation of treated sewage discharges. WSD should also consider impacts on these external environments, particularly during initial planning stages when the potential for implementing an integrated water cycle management system to manage stormwater, flooding, water supply and wastewater is being considered.



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Blueys Estate
Locality Plan

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Figure 4-5

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5 PRELIMINARY FLOODING INVESTIGATION

5.1 Introduction

A preliminary flooding investigation was completed to assist with evaluating the development potential of development investigation areas with the site. The approach followed to complete this preliminary investigation and associated results are outlined below.

5.2 Model Setup

A TUFLOW flood model of the area was established to investigate the 1% AEP flooding behaviour across the site. A 10m grid ground surface model covering 14.75 km^2 was prepared using LiDAR data provided by Great Lakes Council. The ground surface model was adopted as a base for developing the hydraulic model, and a direct rainfall approach was applied for hydrologic modelling within the site and the contributing external catchments.

The model hydrology used the direct rainfall approach in which rain is applied to each grid cell. A range of storm durations were modelled for the 1% AEP. Results indicated that a 2 hour duration design storm was the critical event for flooding within the site. Based on BoM (2012), the 1% AEP, 2 hour duration design rainfall total depth was determined to be 104.2 mm. The 2 hour rainfall hyetograph used in the model is based on Australian Rainfall and Runoff 1987 (AR&R). Initial and continuing losses of 10 mm and 2.5 mm/hr respectively were adopted for the site based on guidance provided in AR&R.

Two bridges and a triple pipe culvert were included in the model as summarised in Table 5-1. The dimensions of each culvert were adopted from data provided by Great Lakes Council. Adopted culvert inverts are based on road crest levels estimated from LiDAR data, and assume 600 mm cover to culvert obverts. Whilst these assumed levels are considered reasonable for initial investigations, additional detailed ground survey of the culverts is recommended prior to finalising development layouts. The road crest elevations are also key hydraulic controls and further survey of the road crest levels at each culvert is recommended to confirm levels.

Table 5-1 Summary of Bridges and Culvert Data

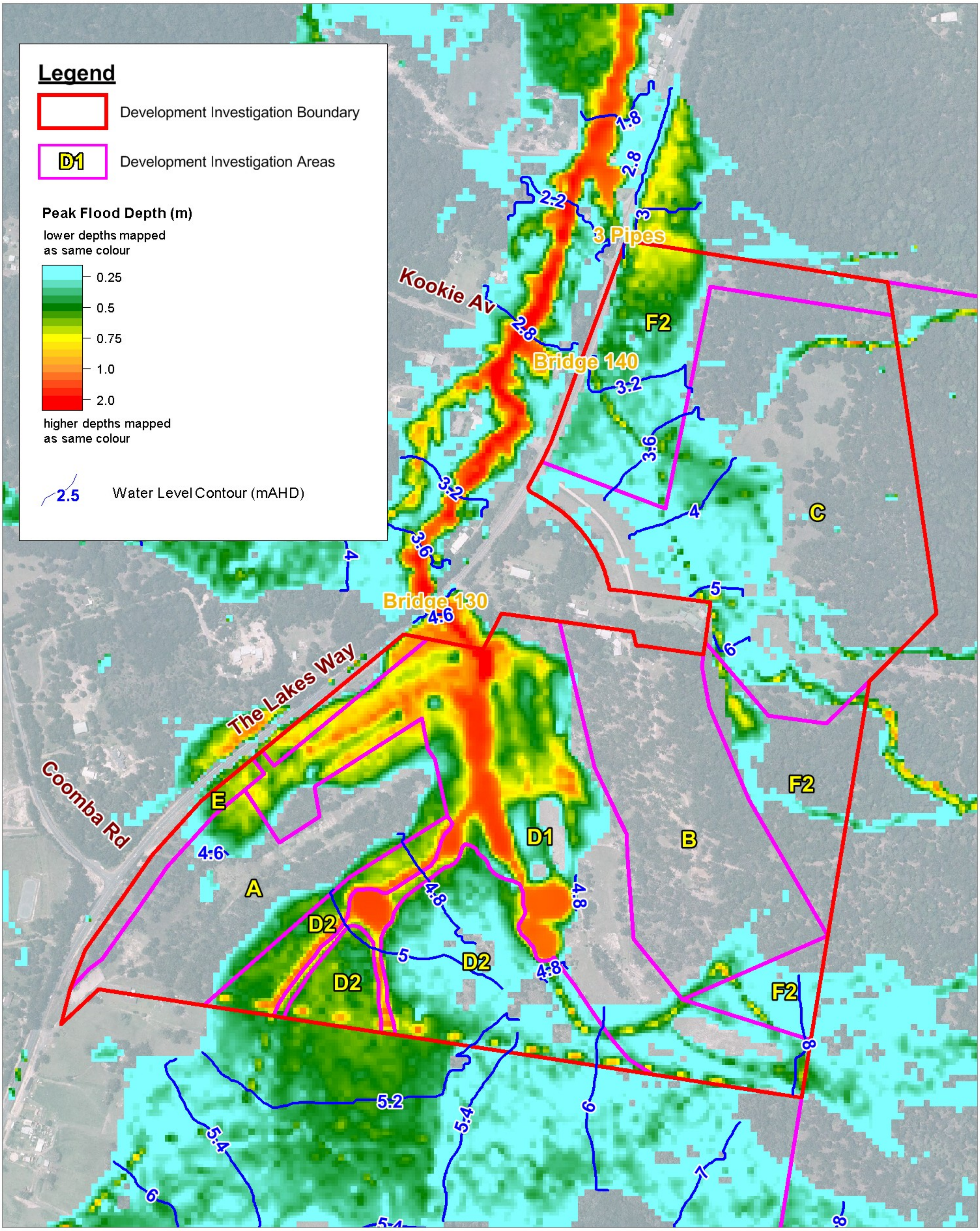
Structure	Dimensions	Estimated Invert	Comment
3 Pipes	3 x 0.9 m diameter pipes	1.8m AHD	Significant drainage from northern catchment. Estimated invert only.
Bridge 0111B140	7 x 2.4 x 1.2 box culverts	2.1m AHD	Significant drainage from northern catchment. Estimated invert only.
Bridge 0111B130	3 x 3.0 x 2.4 box culverts	1.5m AHD	Major drainage from southern catchment. Estimated invert only.
Culvert 0111C272	0.6 m pipe diameter	4.2m AHD	Small pipe culvert not included in model. Estimated invert only.

5.3 Predicted 1% AEP Flood Behaviour

Peak flood depths and flood level contours across the site are presented in Figure 5-1 for the 1% AEP flood event. Flooding within the site is influenced by runoff from a major southern catchment and minor northern catchment which are separated by a ridge that runs centrally through the development investigation areas.

The southern catchment drains under The Lakes Way through Bridge 111B130 (Bridge 130 on Figure 5-1) which forms a major flow constriction. During the modelled 1% AEP flood event, estimated flood levels immediately upstream of this culvert are approximately 4.6 m AHD. Floodplain levels in this area are typically 4 to 4.5 m AHD resulting in flood depths above 0.5 m being common on the floodplain, and flood depths exceeding 1 m common along watercourses.

The smaller northern catchment drains under The Lakes Way through Bridge 111B140 (noted as Bridge 140 on Figure 5-1) and a triple 0.9m diameter pipe culvert (noted as 3 Pipes on Figure 5-1). During the modelled 1% AEP flood event, the capacity of the culverts would be exceeded resulting in significant overtopping of The Lakes Way to the north of the development investigation area. During the modelled 1% AEP flood event, flood levels immediately upstream of the Bridge 140 culvert would be approximately 3.0 m AHD, resulting in predicted flood depths up to approximately 0.8m.



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Existing 1% AEP Peak Flood Depths and Levels

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6 RIPARIAN CORRIDORS

6.1 Riparian Corridor Functions

Riparian corridors form a transition zone between terrestrial and aquatic environments and perform a range of important environmental functions including:

- protecting the watercourse bed and banks from erosion;
- protecting water quality by trapping pollutants;
- providing habitat diversity for a range of terrestrial and aquatic flora and fauna species;
- providing connections between wildlife habitats;
- providing for conveyance of catchment runoff and flood flows; and
- providing a buffer between developments and watercourse.

The protection or restoration of vegetated riparian areas is important for maintaining or improving the geomorphic form and ecological functions of watercourses. Riparian lands should be protected by excluding urban infrastructure (including WSUD measures). In addition, the quality and quantity of stormwater discharged from a development should be managed to avoid directly impacting on the stability of the watercourse bed and banks.

6.2 Legislation, Policies and Guidelines

Controlled activities carried out in, on or under waterfront land are now regulated by the *Water Management Act 2000* (WM Act). The WM Act includes many provisions which were previously under the *Rivers and Foreshores Improvement Act 1948* (RFI Act) prior to its repeal, including those provisions regarding licences and approvals. The object of the WM Act is the *“sustainable and integrated management of the State's water for the benefit of both present and future generations”* and in particular:

> *“(a) to apply the principles of ecologically sustainable development, and*
>
> *(b) to protect, enhance and restore water sources, their associated ecosystems, ecological processes and biological diversity and their water quality”.*

Part 3 of Chapter 3 of the WM Act relates to Approvals and Section 91(2) requires a ‘controlled activity approval’ for works at a specified location in, on or under ‘waterfront land’. ‘Controlled activity’ and ‘waterfront land’ are defined by the WMA as follows:

> *“**controlled activity** means:*
>
> *(a) the erection of a building or the carrying out of a work (within the meaning of the Environmental Planning and Assessment Act 1979), or*
>
> *(b) the removal of material (whether or not extractive material) or vegetation from land, whether by way of excavation or otherwise, or*
>
> *(c) the deposition of material (whether or not extractive material) on land, whether by way of landfill operations or otherwise, or*
>
> *(d) the carrying out of any other activity that affects the quantity or flow of water in a water source.*

> …
>
> ***waterfront land** means:*
>
> *(a) the bed of any river, together with any land lying between the bed of the river and a line drawn parallel to, and the prescribed distance inland of, the highest bank of the river, or*
>
> *(a1) the bed of any lake, together with any land lying between the bed of the lake and a line drawn parallel to, and the prescribed distance inland of, the shore of the lake, or*
>
> *(a2) the bed of any estuary, together with any land lying between the bed of the estuary and a line drawn parallel to, and the prescribed distance inland of, the mean high water mark of the estuary, or*
>
> *(b) if the regulations so provide, the bed of the coastal waters of the State, and any land lying between the shoreline of the coastal waters and a line drawn parallel to, and the prescribed distance inland of, the mean high water mark of the coastal waters,*
>
> *where the prescribed distance is 40 metres or (if the regulations prescribe a lesser distance, either generally or in relation to a particular location or class of locations) that lesser distance. Land that falls into 2 or more of the categories referred to in paragraphs (a), (a1) and (a2) may be waterfront land by virtue of any of the paragraphs relevant to that land."*

Development requiring such an approval is designated under Section 91 of the EP&A Act as 'Integrated Development' and the consent authority (e.g. Council) is required to refer the development application to the relevant 'approval body' which is currently the NSW Office of Water (NoW). The approval body is required to inform the consent authority whether it would be prepared to grant approval and if so, the general terms of that approval. The consent authority cannot grant development consent if the approval body advises that it is not prepared to grant approval.

Minimum riparian corridors widths are defined within the *Guidelines for Riparian Corridors on Waterfront Land* (NoW, 2012). The riparian corridor (RC) includes the watercourse channel and adjacent vegetated riparian zone (VRZ) as shown in Figure 6-1.

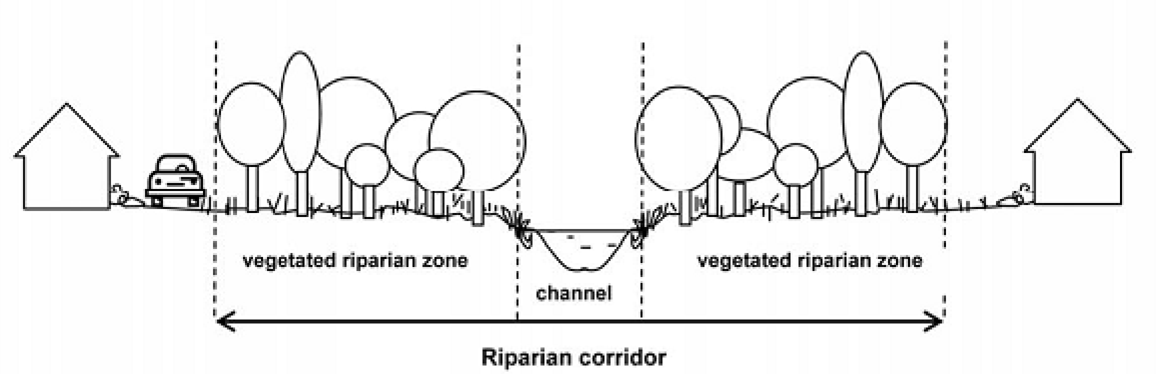
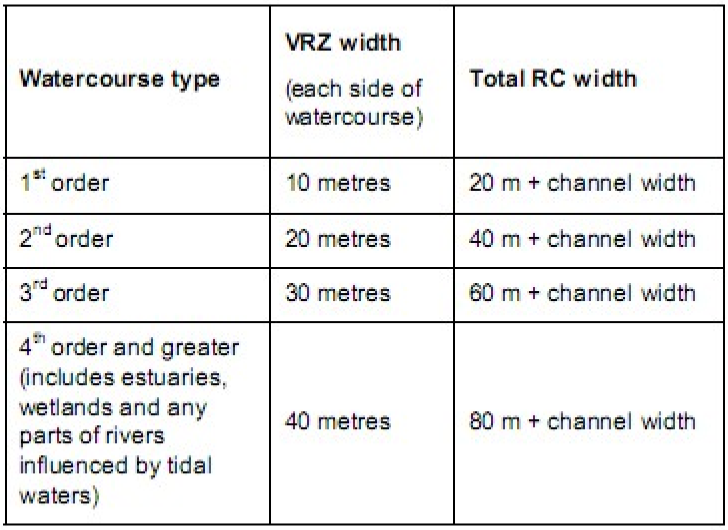


Figure 6-1 Riparian Corridor (NoW, 2012)

NoW recommends that RC and VRZ widths are based on the watercourse order classified under the Strahler System using current 1:25,000 topographic maps. The recommended RC and VRZ widths for watercourses are summarised in Table 6-1.

Table 6-1 RC and VRZ widths (NoW, 2012)

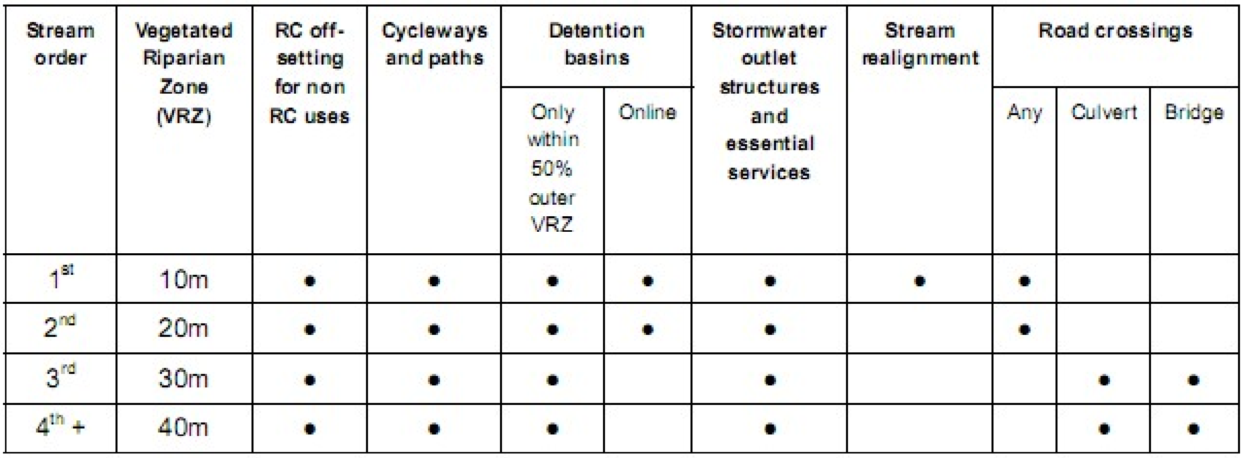


Watercourse type	VRZ width (each side of watercourse)	Total RC width
1st order	10 metres	20 m + channel width
2nd order	20 metres	40 m + channel width
3rd order	30 metres	60 m + channel width
4th order and greater (includes estuaries, wetlands and any parts of rivers influenced by tidal waters)	40 metres	80 m + channel width

The channel comprises the bed and banks of the watercourse to its highest banks. The VRZ adjoins the channel and combines the core riparian zone and vegetated buffer that were defined in earlier NoW guidelines (NoW, 2011). NoW typically seeks to ensure that the VRZ remains, or becomes vegetated, with fully structured native vegetation (including groundcovers, shrubs and trees). The VRZ also functions to protect the environmental integrity of the watercourse from weed invasion, micro-climate changes, litter, trampling and pollution.

NoW currently allows the positioning of certain infrastructure within riparian corridors. Allowable infrastructure are summarised in Table 6-2. NoW allows dry flood detention basins and APZs to be located within the outer 50% of the VRZ provided an equivalent offset area is available on the opposite bank to compensate for any encroachment. Stormwater quality management measures are required to be positioned outside the RC.

Table 6-2 Riparian Corridor Matrix (NoW, 2012)



Stream order	Vegetated Riparian Zone (VRZ)	RC off-setting for non RC uses	Cycleways and paths	Detention basins		Stormwater outlet structures and essential services	Stream realignment	Road crossings		
				Only within 50% outer VRZ	Online			Any	Culvert	Bridge
1st	10m	●	●	●	●	●	●	●		
2nd	20m	●	●	●	●	●		●		
3rd	30m	●	●	●		●			●	●
4th +	40m	●	●	●		●			●	●

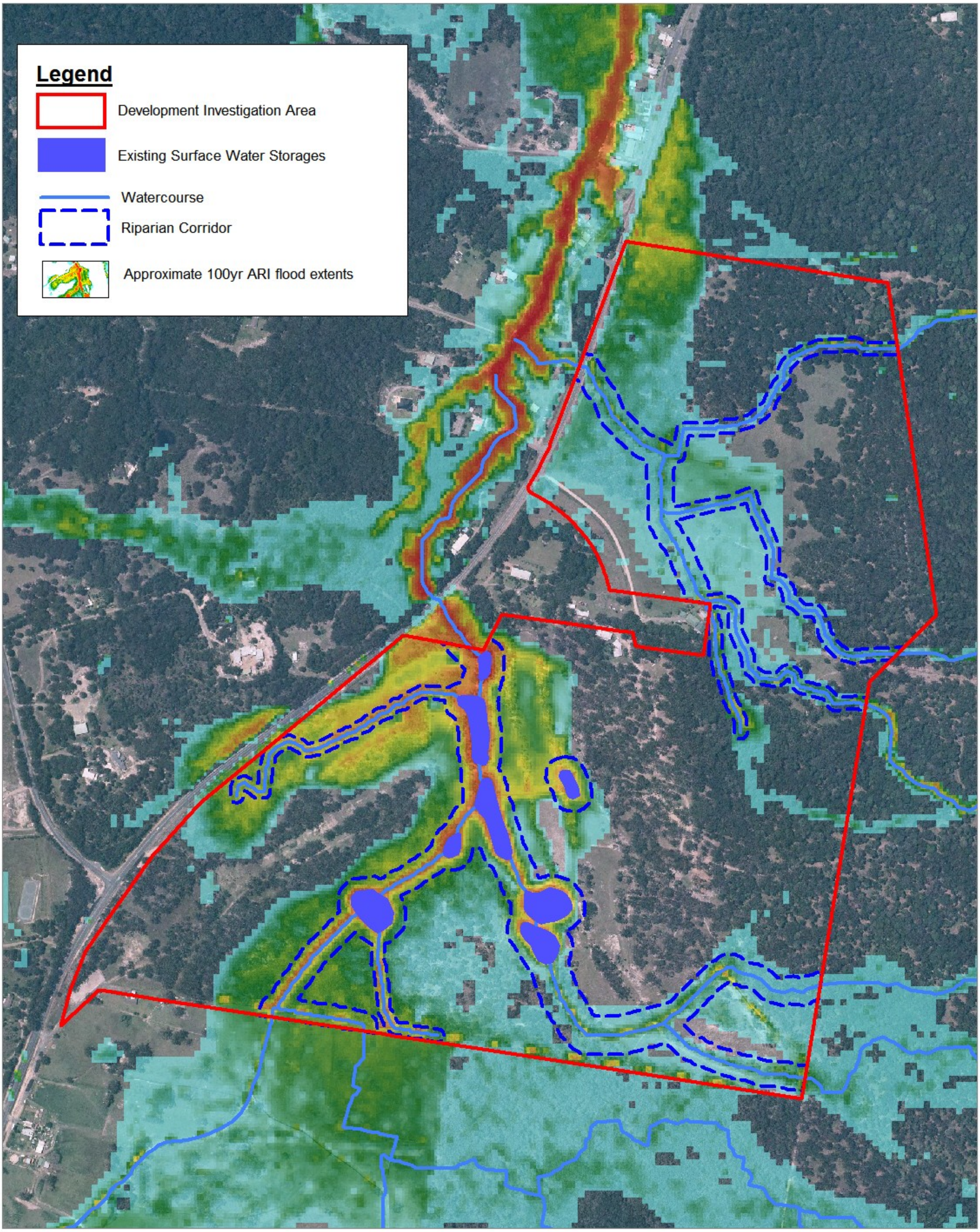
Asset Protection Zones (APZ) are a requirement of the NSW Rural Fire Service and are designed to protect assets (house, buildings etc.) from potential bushfire damage. The APZ should contain cleared land adjacent to the VRZ. WSUD measures can typically be located within the APZ provided the NSW Rural Fire Service requirements outlined in the guideline document *Planning for Bushfire Protection, 2006* are met.

6.3 Analysis

Watercourse ordering has been completed for the watercourses that flow through the development investigation areas. First order watercourses were defined following consideration of the 1:25,000 topographic map available for the site and more detailed CatchmentSim software analysis utilising LiDAR data available for the catchment. Determination of first-order watercourse locations was based on CatchmentSim analysis considering minimum catchment areas of 5ha and 10ha. The watercourse ordering analysis identified the presence of first, second and third order watercourses within the development site.

Previous development within the site has resulted in many natural drainage pathways being modified to suit the existing land uses. The watercourse ordering analysis and definition of riparian corridors was based upon the current location of the watercourses (i.e. either natural or constructed locations).

Riparian corridors often correspond with floodways. In many circumstances, the requirements of the NSW Flood Prone Lands Policy result in development being excluded from riparian corridors due to the associated flood risk. The riparian corridors in most parts of the development investigation area were found to lie within the estimated 1% AEP flooding extents (refer to Figure 6-2).



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Blueys Estate
Riparian Corridors

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6.4 Potential Developable Areas

A preliminary flooding investigation and assessment of riparian corridors was completed and the potential developable areas based on these hydrologic considerations are summarised in Table 6-3 and shown on Figure 6-3. The initial hydrologic investigations indicate that development within a relatively large proportion of the existing site would be constrained by flooding. Some additional minor areas (parts of D1, D2 and C) lie above the estimated 1% AEP flood levels, but would be isolated during a 1%AEP flood and would therefore also be unsuitable for most development purposes.

Table 6-3 Potential Developable Areas

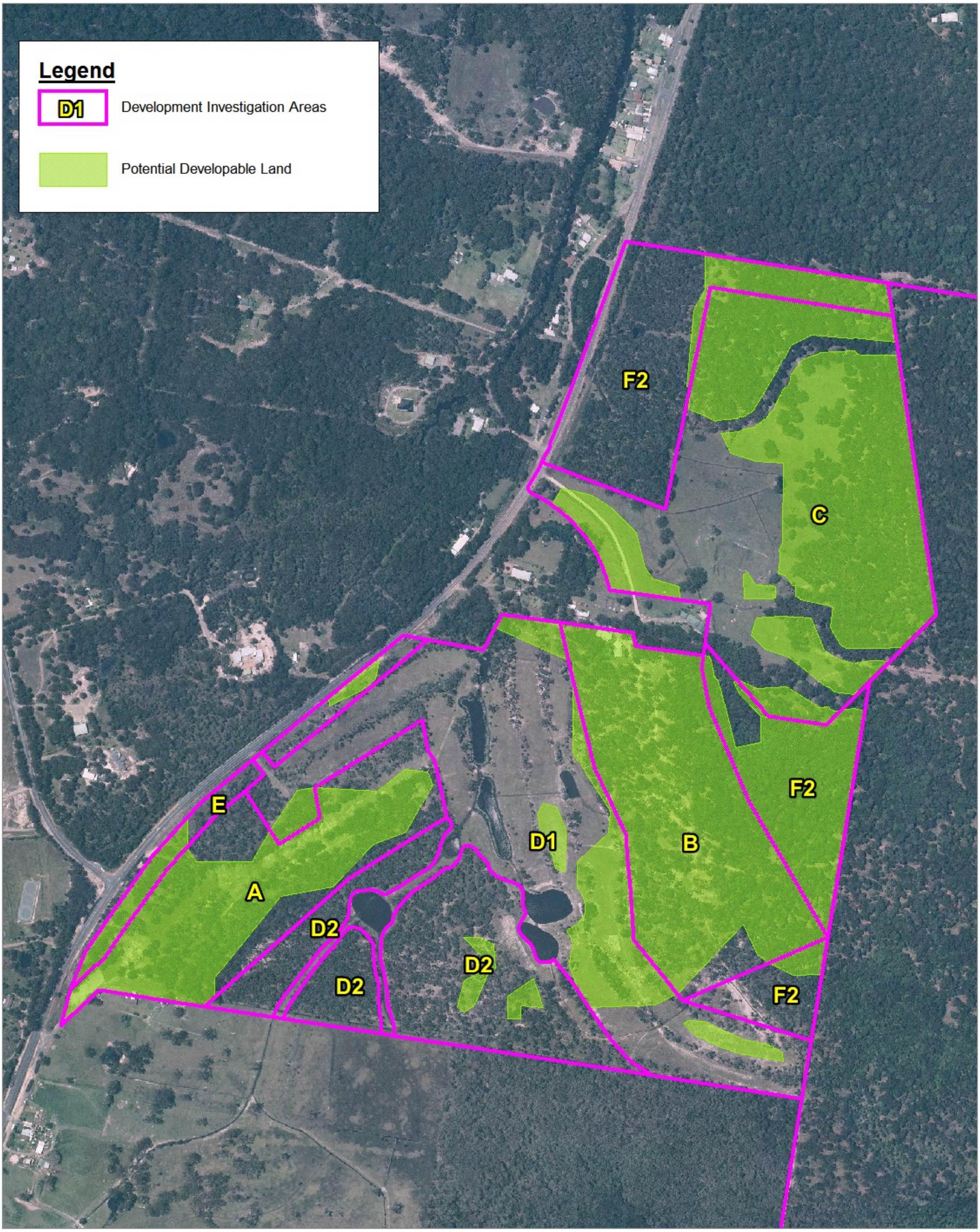
Investigation Area	Total Area (ha)	Potential Developable Area (ha)	% Potential Developable Area
A	10.11	7.00	69%
B	12.31	11.73	95%
C	24.11	15.87	66%
D1	20.14	4.01	20%
D2	11.41	0.9	8%
E	2.17	1.02	47%
F2	14.8	6.21	42%

The potential developable land is based upon preliminary flooding investigations that warrant further consideration prior to finalisation of a development layout for the site. Some of the key assumptions and recommendations for further consideration are outlined below.

The 1% AEP flood assessment completed to evaluate the potential developable area shown in Figure 6-3 is a preliminary assessment only and was undertaken to broadly determine if the development investigation areas are significantly constrained by flooding. The flooding assessment concluded that flooding is a key constraint for development within the site and it is recommended that a more detailed flooding assessment be completed to confirm the development potential of land that is close to the flooding extents predicted by the preliminary assessment.

The potential developable land shown on Figure 6-3 assumes that no regrading or filling would be undertaken within the site to raise ground levels above the 1% AEP level. It was also assumed that any future building/dwelling development would be at least 0.5m above the estimated flood levels and that any future development upstream and within the development investigation area would be required to have detention to ensure that 1% AEP discharges through the site are not increased above existing conditions.

In addition to further consideration of hydrology/flooding; ecology, terrain, slope stability, bushfire and other urban design criteria require consideration prior to confirming a potential development footprint.



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Blueys Estate
Potential Developable Land (considering hydrology)

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7 GEOTECHNICAL INVESTIGATIONS

7.1 Objectives

Geotechnical investigations were completed within the site to achieve the following study objectives:

- An assessment of the capability / suitability of soils and groundwater conditions for infiltration, swale drainage, etc.;
- A description of the groundwater characteristics based on the results of the field investigation and laboratory testing, including groundwater levels at each of the borehole and test pit locations (where encountered) and an assessment of the groundwater quality; and
- Preparation of a preliminary map based on the initial groundwater measurements showing indicative groundwater contours (AHD) across the site based on water level measurements.

The methodology and outcomes of these investigations are summarised in the following sections and detailed in the geotechnical report in APPENDIX A:

7.2 Fieldwork

Field work for the assessment included:

- A site walkover to provide a preliminary ground assessment to verify the results of the preliminary soil and groundwater models developed during the desktop review;
- The excavation of 12 test pits to establish a typical soil profile in each of the nominated terrain units;
- Infiltration (falling head) testing at four of the test pit locations; and
- The installation of six groundwater wells at depths of between 4.7 and 5.0m.

7.3 Soil Capability for WSD

The geotechnical investigations have identified three distinct terrain zones throughout the development investigation areas, Terrain Zones A, B and C. These terrain zones are discussed below and shown spatially in APPENDIX A:

7.3.1 Terrain Zone A

Terrain Zone A includes low-lying flat to gentle sloping land that typically corresponds with the floodplain. Soils in this zone typically comprise 0.3m of topsoil overlying deep alluvial and residual sandy/ clay layers which grade to weathered rock at depths exceeding 5m below the existing surface.

Falling head permeability testing was completed at a depth of 1m within four test pits in Terrain Zone A. The measured permeability range across the four test pits was 0.4 to 1.5mm/hr. The testing results confirm that soil permeability is consistent across the four test pits and very low across Terrain Zone A.

The soils in this terrain zone are therefore unlikely to be suitable for WSUD measures that rely on infiltration due to the low permeability of the insitu soils. WSUD measures that rely on sub-surface filtration (e.g. biofiltration) would need to be positioned at locations where sufficient clearance to seasonal high groundwater table could be achieved. It is considered that locations where this could be achieved would be limited within this terrain zone. WSUD measures including swales, vegetated ponds and constructed wetlands are likely to be the most appropriate measures in this terrain zone.

7.3.2 Terrain Zone B

Terrain Zone B includes gentle sloping areas on the lower slopes adjacent to floodplain areas. Soils in this zone typically comprise 0.15m of topsoil overlying colluvial and residual clay layers to depths of 1.8 to 4.5m. The clay layers are underlain by bedrock.

Similarly to Terrain Zone A, Terrain Zone B is expected to incorporate low permeability soils that would be unsuitable for infiltration of stormwater. Groundwater was not observed in the test pits excavated in Terrain Zone B Whilst the soils are unlikely to be suitable for infiltration of stormwater, the depth to bedrock is considered sufficient for sub-surface filtration of stormwater to be achieved.

7.3.3 Terrain Zone C

Terrain Zone C includes land on the mid to upper slopes. Slopes are primarily steep except along ridge lines. Soils in this zone typically comprise 0.1m of topsoil overlying shallow colluvial and residual clay layers. Weathered bedrock is typically found at shallow depths of 0.5m to 1m below the existing surface.

The shallow soils and steep topography in Terrain Zone C will provide a considerable constraint to the provision of WSUD measures in this zone. The steep topography limits the application of many vegetated systems due to the potential for scouring unless the development layout is configured to convey stormwater along the contours. The shallow soils limit the application of infiltration measures and sub-surface filtration measures. In addition, concentrated infiltration of stormwater in the elevated areas has a high potential to seep out further down the hillslopes and consequently impact on downslope development.

Ideally, runoff from development in Terrain Zone C should either be harvested and used close to the source, or directed to areas within Terrain Zone B that are not as steep and have soil depths that are more conducive to the provision of a range of WSUD measures.

7.4 Groundwater Characteristics

7.4.1 Groundwater Quality

Six groundwater samples were recovered from each of the groundwater wells on 29 November 2012, one week after the installation of the wells. The six samples were sent to a NATA registered laboratory for testing and were assessed for pH, electrical conductivity, total dissolved salts, total suspended solids, nitrate, nitrite, phosphate, ammonium, total nitrogen and total phosphorus. The results of the testing are presented in APPENDIX A:. Observed concentrations for key water quality parameters are presented in Table 7-1 along with the results from previous snapshot sampling completed within the site.

Table 7-1 Groundwater Quality Monitoring Results (1997 to 2012)

	Observed Groundwater Concentration Ranges			Typical Dry Weather Concentrations (Fletcher et al, 2005)		
Parameter	**1997[1]**	**2002[2]**	**2012[3]**	**Forest**	**Rural**	**Agriculture**
NO_2 (mg/L)	<0.01	<0.01	0.001 – 0.014	-	-	-
NO_3 (mg/L)	0.02 - 0.07	0.01 – 0.06	0.005 – 0.111	-	-	-
TKN (mg/L)	<0.01 - 0.4	<0.01 - 0.6	0.16 – 0.44	-	-	-
TN (mg/L)	0.13 - 0.48	0.12 – 0.67	0.17 – 0.51	0.08 – 1	0.4 - 2	0.4 – 3
TP (mg/L)	0.14 – 0.15	0.06 - 0.14	0.02 – 0.08	0.01 – 0.09	0.02 – 0.2	0.03 – 0.3
TSS (mg/L)	-	-	32 – 110[5]	2 - 20	5 - 40	8 – 50
Potassium (mg/L)	11 – 17	24 – 39	-	-	-	-
Copper (µg/L)	3 - 9	42 – 52	-	-	20 – 300[4]	-
Lead (µg/L)	92 - 106	88 – 168	-	-	10 – 200[4]	10 – 200[4]
Zinc (µg/L)	65 - 114	60 - 159	-	-	70 – 700[4]	-

1. Two samples; 2. Three samples; 3. Six samples; 4. Wet weather concentration ranges (dry weather ranges unavailable); 5. Outlier of 1008 mg/L removed.

The 2012 testing results indicate that observed nitrogen concentrations are similar to earlier monitoring for all nitrogen species sampled. Total phosphorus concentrations are lower than previous monitoring results which suggest that phosphorus concentrations have progressively improved (reduced) since the initial sampling in 1997.

The 2012 testing results indicate that the observed TP concentrations are in the typical dry weather range for forested catchments. The TN concentrations also lie within the forested range, although some higher observed concentrations may be more representative of some deterioration in natural water quality due to the influence of the current rural land uses. TSS concentrations are elevated above typical dry weather ranges for similar land uses, and are likely to reflect the natural fine-grained clay soils within the site.

7.4.2 Groundwater Flow

Depth to groundwater was measured at six groundwater wells in Terrain Zone A one week after drilling of the wells. The groundwater table was observed 0.7 to 1.6m below the existing surface across the six wells. An extract from the interpolated groundwater contour plan is shown in Figure 7-1 and the complete plan is shown in the geotechnical report in APPENDIX A:

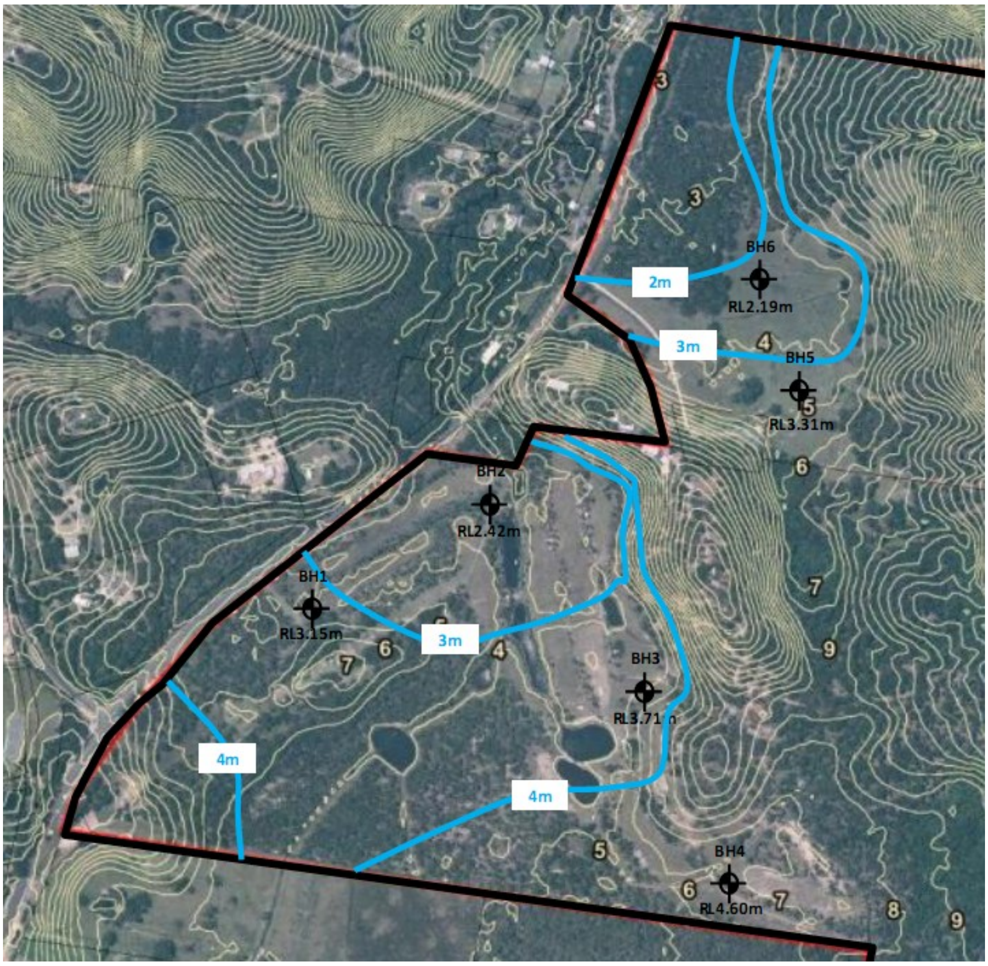


Figure 7-1 Interpolated Groundwater Contours (Regional Geotechnical Solutions, 2013)

The groundwater depths were observed after an extended dry period and therefore the interpolated groundwater contours shown in Figure 7-1 are more likely to represent typical dry weather conditions. It is expected that the groundwater levels would rise closer to the surface following wet weather. Whilst the water levels may rise following wet weather and the groundwater gradient may increase, it is considered that the groundwater flow directions shown in Figure 7-1 are likely to be similar for wet weather. The interpolated groundwater contours indicate that groundwater generally flows towards the central watercourses and culverts that drain the northern and southern sections of the site either side of the central ridge.

8 MUSIC MODELLING

8.1 Modelling Approach

The performance of the proposed Water Sensitive Development Strategy was assessed using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) software (Version 5.1) developed by eWater. The software has been specifically designed to allow for comparisons to be made between different stormwater management systems and thereby function as a decision support tool. The key model inputs and MUSIC modelling approach are described in the following sections.

8.2 Meteorological Template

The meteorological template includes the rainfall and areal potential evapotranspiration data. It forms the basis for the hydrologic calculations within MUSIC.

To simulate the performance of stormwater quality treatment measures, MUSIC requires the input of data from a representative continuously recording rainfall station (pluviograph). The nearest long-term Bureau of Meteorology (BoM) continuously recording rainfall stations are located at Taree (Stations 60030 Taree - Robertson St and 60141 Taree - Airport AWS) approximately 49km north of the site and Williamtown (Station 61078 Williamtown RAAF) approximately 81km south of the site. A long-term daily rainfall station is located at Forster (Station 60013 Forster-Tuncurry Marine Rescue) approximately 17km north of the site.

Pluviograph data were available at Taree from Station 60030 for the 1964 to 2005 period, and Station 60141 after 2005 when Station 60030 was closed and Station 60141 opened. Pluviograph data were available at Williamtown from Station 61078 for the 1952 to 2011 period. Daily rainfall data were also available for these rainfall stations for a longer period. Daily rainfall data were available from Station 60013 at Forster for the 1896 to 2013 period.

Mean annual rainfall based on daily rainfall records for the Forster, Taree and Williamtown stations is presented in Table 8-1 for the entire record at each station, and a recent common period (1981 to 2010). Based on the 1981 to 2010 period, mean annual rainfall for Forster is similar to Taree, whilst mean annual rainfall at Williamtown is approximately 5% lower.

Table 8-1 Mean Annual Rainfall Comparison

Daily Rainfall Station	Total Period	Mean Annual Rainfall	
		Total Period	1981 - 2010
Stn 60013 Forster Tuncurry Marine Rescue	1896 - 2013	1220mm	1190mm
Stn 60030 Taree – Robertson Street	1881 - 2010	1179mm	1183mm
Stn 61078 Williamtown RAAF	1942 – 2013	1122mm	1127mm

Pluviograph data from Taree and Williamtown were reviewed along with daily rainfall data for the closer Forster station to identify an average data period from the pluviographs that is representative of local conditions. Whilst the Taree station is closer to the site, the available rainfall record includes a number of data gaps and periods of accumulated rainfall data that are not ideal for continuous simulation modelling. The Williamtown record was observed to be more complete with a lower number of accumulated data periods. Pluviograph rainfall data were sourced for Williamtown and reviewed for the 1952 to 2011 period to identify a continuous period of good quality data with an average annual rainfall similar to long term conditions at Forster.

Review of the Williamtown rainfall data indicates that the 1998 to 2007 period is relatively free of data gaps and accumulated rainfall data. The mean annual rainfall for this period is 1125mm which is approximately 8% lower than the long term mean annual rainfall for Forster and 5% lower than the 1981 to 2010 average. Whilst the mean annual rainfall is lower than average, for the purposes of continuous simulation modelling, it is considered that the better quality data available from the Williamtown station is more critical. Rainfall data for the 1998 to 2007 period from Station 61078 Williamtown RAAF were adopted for MUSIC modelling at the site.

Comparison of mean annual rainfall for the Forster and Williamtown sites over the selected period is shown in Figure 8-1. The comparison indicates that the annual rainfall totals at Williamtown are similar to the Forster annual totals over this period except for 2003 and 2005 when recorded rainfall at Forster was considerably higher.

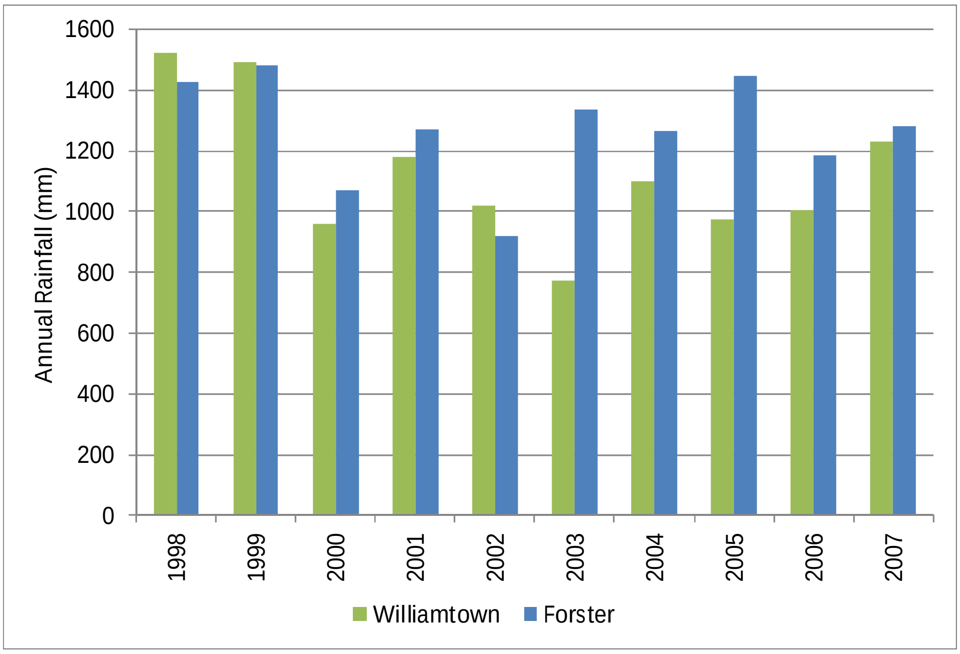


Figure 8-1 Stn. 61078 Williamtown RAAF and Stn. 60013 Forster Tuncurry Marine Rescue

Average monthly areal potential evapotranspiration (PET) rates adopted for the MUSIC modelling are summarised in Table 8-2. These values were obtained from BOM gridded data derived from data for the 1960 to 1991 period.

Table 8-2 Adopted Average Monthly Areal PET Rates

Month	Mean monthly areal PET (mm)
January	184
February	148
March	142
April	93
May	65
June	53
July	55
August	73
September	102
October	139
November	154
December	175

8.3 Rainfall-Runoff Parameters

Modelling of the rainfall-runoff process in MUSIC requires the definition of one impervious surface parameter and eight pervious surface parameters. The parameters can be estimated through a calibration and validation exercise for a particular site. The impervious surface parameter (rainfall threshold) was adopted considering industry accepted defaults. Preliminary modelling was undertaken to confirm appropriate pervious surface parameters based on the soil types and hydrological conditions typical of catchments similar to site.

The average annual rainfall fraction (ARF) was estimated for the proposed development applying methods derived by Fletcher et al. (2005) for NSW catchments. The work by Fletcher et al. (2005) assists with estimating the surface runoff proportion for 100% pervious NSW catchments/sites based upon the local mean annual rainfall. It represents the proportion of rainfall that is typically converted to runoff for a particular catchment/site. Based on a MAR of 1125mm for the adopted modelling period, it is estimated that the ARF would be 26% for the site.

Runoff modelled within MUSIC includes surface runoff and base flow components. For this study, a base flow index (BFI) of 0.2 was adopted as being representative of the ephemeral catchment conditions that are likely to prevail in the site. This assumes that 80% of runoff observed in the watercourses is typically sourced from surface runoff, with the remaining 20% contributed by base flow during dry weather periods. Appropriate soil storage capacity and field capacity parameters were estimated based on the adopted ARF and assumed BFI. Other pervious parameters including infiltration capacity, daily recharge, daily baseflow and daily seepage parameters were derived from BMT WBM (2010) based on clay type soils that prevail throughout the site. The MUSIC hydrologic parameters estimated based on these assumptions are summarised in Table 8-3. The rainfall-runoff parameters were adopted for modelling all existing and future land uses within the site.

Table 8-3 Adopted MUSIC Rainfall-Runoff Parameters

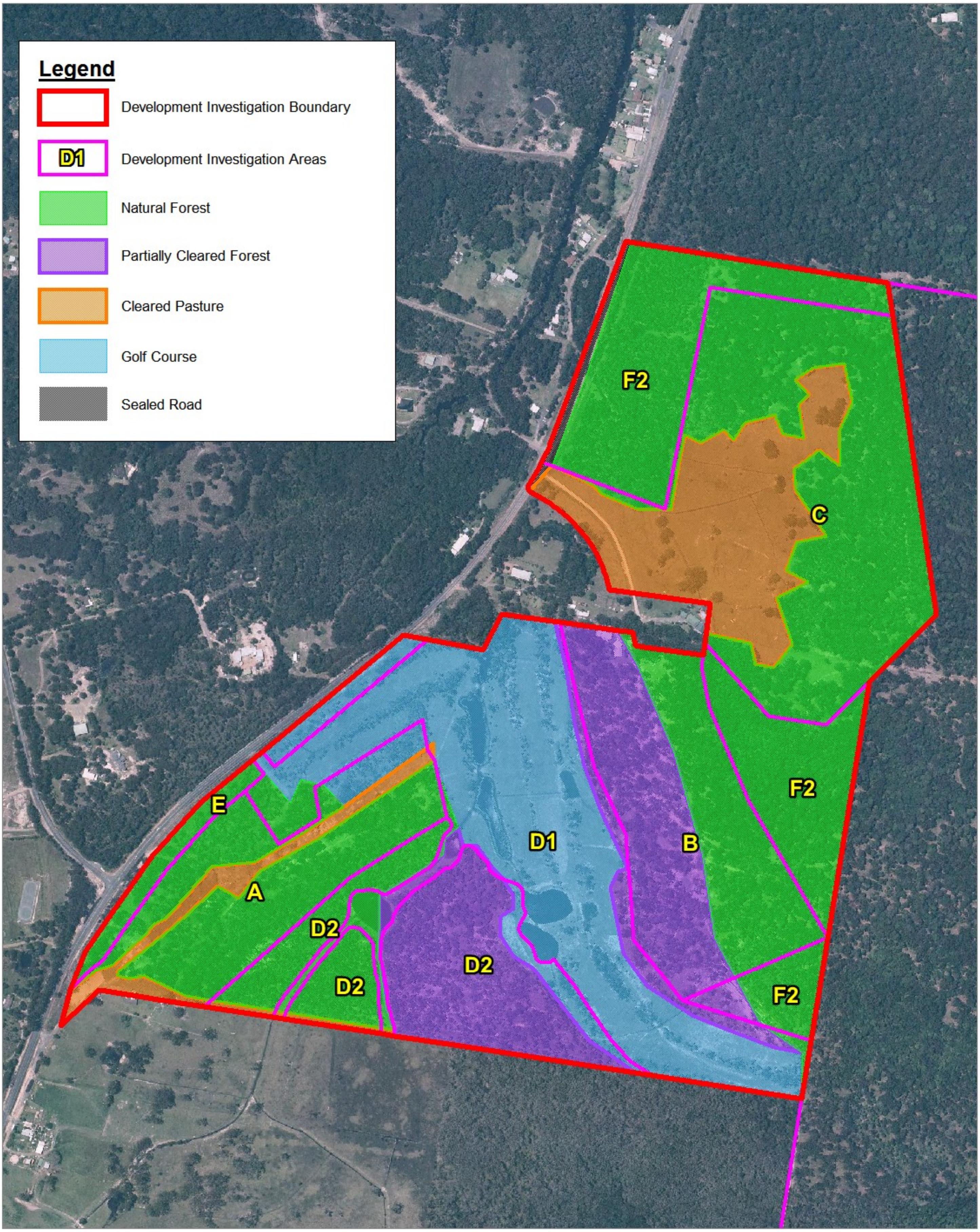
Impervious Area Parameters	Value
Rainfall Threshold (mixed urban surfaces, mm)	1.5
Pervious Area Parameters	
Soil Storage Capacity (mm)	88
Initial Storage (% of capacity)	30
Field Capacity (mm)	60
Infiltration Capacity Coefficient – a	150
Infiltration Capacity Exponent - b	3.5
Groundwater Properties	
Initial Depth (mm)	10
Daily Recharge Rate (%)	25
Daily Baseflow Rate (%)	10
Daily Deep Seepage Rate (%)	0

8.4 Existing Land Uses

The existing land uses within the development investigation areas are summarised in Table 8-4 and the distribution of these land uses across the site is shown on Figure 8-2. The existing land use distribution was utilised as a basis for estimating pollutant concentrations from the existing site for comparison with future developed conditions.

Table 8-4 Existing Land Use Distribution

	Land Use Area (ha)				
Investigation Area	Natural Forest	Partially Cleared Forest	Cleared Pasture	Golf Course	Sealed Road
A	7.43	0	1.88	0.80	0
B	5.62	6.69	0	0	0
C	14.81	0	9.30	0	0
D1	1.59	1.98	0.05	16.52	0
D2	3.63	6.55	0.26	0.97	0
E	1.27	0	0	0.90	0
F2	13.91	0.39	0	0	0.50



Title:

Blueys Estate
Existing Land Uses

Figure:

Figure 8-2

Rev:

A

N

0 200 400m

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N2441_BlueysEstate_WaterManagementStrategy\MapInfo\Workspaces\DRG_xxx_Existing_Land_Uses.wor

8.5 Pollutant Concentrations

There are limited water quality data available for runoff quality within the Great Lakes Council LGA. For this site, typical base flow and storm flow concentrations for common stormwater pollutants were adopted from the Draft NSW MUSIC Modelling Guidelines (BMT WBM, 2010). The mean adopted pollutant concentrations (normalised) are summarised in Table 8-5. MUSIC requires the concentrations to be input as log_{10} concentrations and these inputs for TSS, TP and TN are summarised in Table 8-6 and Table 8-7.

Table 8-5 Mean Adopted Concentration Parameters (mg/L)

Land Use Category	Event Flow			Base Flow		
	TSS	TP	TN	TSS	TP	TN
Urban	140	0.25	2.0	16	0.14	1.3
Forest	40	0.08	0.9	6	0.03	0.3
Rural	90	0.22	2.0	14	0.06	0.9
Unsealed Tracks	1000	0.50	2.2	16	0.14	1.3
Agricultural	140	0.60	3.0	20	0.09	1.1

Table 8-6 Storm flow concentrations for MUSIC modelling in NSW (log_{10})

Land Use Category	TSS		TP		TN	
	mean	std. dev	mean	std. dev	mean	std. dev
Urban	2.15	0.32	-0.60	0.25	0.30	0.19
Forest	1.60	0.20	-1.10	0.22	-0.05	0.24
Rural	1.95	0.32	-0.66	0.25	0.30	0.19
Unsealed Tracks	3.00	0.32	-0.30	0.25	0.34	0.19

Table 8-7 Base flow concentrations for NSW MUSIC modelling in NSW (log_{10})

Land Use Category	TSS		TP		TN	
	mean	std. dev	mean	std. dev	mean	std. dev
Urban	1.20	0.17	-0.85	0.19	0.11	0.12
Forest	0.78	0.13	-1.52	0.13	-0.52	0.13
Rural	1.15	0.17	-1.22	0.19	-0.05	0.12
Unsealed Tracks	1.20	0.17	-0.85	0.19	0.11	0.12

Considering the land use categories summarised in Table 8-6 and Table 8-7 the following parameters were adopted to represent the existing land uses shown in Figure 8-2.

- Relatively undisturbed **Natural Forest** areas – adopted **Forest** parameters;
- **Partially Cleared Forest**, regenerated or vehicle accessible forested areas – adopted **Forest** parameters for 90% of the area and **Unsealed Tracks** parameters for 10% of the area;
- **Cleared Pasture** areas used for cattle grazing - adopted the **Rural** parameters;
- Existing **Golf Course** tees, fairways and rough – adopted the **Rural** parameters; and
- **Sealed Roads** – adopted the **Urban** parameters.

A MUSIC model was prepared adopting the existing land use distribution summarised in Table 8-4 and shown in Figure 8-2, rainfall-runoff parameters summarised in Table 8-3 and applicable runoff concentration parameters in Table 8-6 and Table 8-7. The MUSIC modeling results are summarised in Section 8.6.

8.6 Modelling Results

Preliminary MUSIC models have been prepared based on the existing condition of the development investigation areas, and a developed condition where each investigation area is fully developed. Based on the potential developable area shown in Figure 6-3 it is envisaged that less development will occur and therefore the magnitude of the developed loads is likely to be lower. However, the relative increase in pollutant load for the proportion of each investigation area developed compared to the existing is likely to be similar. The modeling results outlined below are preliminary only, and will be updated in further detail following confirmation of potential developable areas.

8.6.1 Existing and Developed

MUSIC modeling results for the existing site conditions are summarised in Table 8-8 for TN. Indicative TN loads for a developed scenario where 50% of the investigation area is impervious are provided for comparative purposes. The preliminary results indicate that development of the investigations areas would require TN loads to be reduced by approximately 70% to 85% from the developed condition to achieve the existing loads. The increase in TN load is estimated to be lowest for the C and D1 investigation areas.

Table 8-8 TN loads (kg/yr)

Investigation Area	Existing		Developed	
	Source	Residual[1]	Source	% increase[2]
A	36	29	140	79%
B	35	28	170	84%
C	93	93	337	72%
D1	109	88	281	69%
D2	37	30	158	81%
E	88	7.1	30	76%
F2	44	44	206	79%

1. Residual loads represent the remaining load after runoff passes through the existing water storage dams.

2. % increase relative to the existing residual load.

8.6.2 Developed (with WSD)

TO BE COMPLETED

We have allowed for evaluating one potential developable land configuration based upon the outcomes of the preliminary studies. It is assumed that the potential developable area would be confirmed by Council after consideration of constraints identified for the site.

9 WSUD OPPORTUNITIES (PRELIMINARY)

9.1 Integrated Water Management

The Planning Proposal is seeking to evaluate the potential for rezoning the site to provide residential development, eco-tourist development, a golf course and dedicated conservation land.

A key objective for this development will be to manage water within the site in an integrated manner to minimise impacts on the receiving environments (due to increased stormwater discharges, stormwater pollutant loads, wastewater discharges) and water supply catchments (due to increased demand for potable water).

Integrated water management requires joint consideration of water conservation, stormwater quality, stormwater quantity and wastewater elements to determine the optimum water management solution for the development.

9.2 Water Conservation

Preliminary ideas for consideration to improve water conservation include:

- Rainwater harvesting from roofs for toilet flushing, laundry and irrigation;
- Stormwater harvesting for golf course and landscaping irrigation; and

9.3 Stormwater Quality

Preliminary ideas for consideration to manage stormwater quality include:

- Stabilisation of existing eroding areas within the catchment and along streams;
- Reduce unsealed trafficable areas;
- Regrading and stabilisation of unsealed road to reduce scouring and soil erosion;
- Re-vegetation of cleared areas;
- Rainwater and stormwater harvesting systems to reduce the volume of stormwater;
- Dry retention basins to manage eroded sediment during construction and post development phases;
- Ephemeral biofiltration systems to filter stormwater to capture pollutant loads;
- Floating reed beds within existing storage ponds to manage nutrients; and
- Constructed wetlands to manage stormwater quality in low lying areas.

9.4 Stormwater Quantity

Preliminary ideas for consideration to manage stormwater quantity include:

- Disconnection of impervious surfaces from receiving environments;
- Re-vegetation of cleared areas to improve rainfall retention, increase evapotranspiration and re-establish natural groundwater recharge conditions;

- Encourage infiltration and evapotranspiration where soil and ecological conditions are appropriate;
- Rainwater and stormwater harvesting systems to reduce the volume of stormwater;
- Dedicated detention storage in stormwater quality measures to manage stream forming flows; and
- Diversion of additional stormwater runoff volumes from sensitive vegetated receiving environments.

10 REFERENCES

ANZECC, 2000, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Environment Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), Canberra.

BMT WBM, 2009, *Evaluating Options for Water Sensitive Urban Design – A National Guide*, Prepared by the Joint Steering Committee for Water Sensitive Cities to achieve Clause 92(ii) of the National Water Initiative, downloaded May 2010 from www.nwc.gov.au

BMT WBM, 2010, *Draft NSW MUSIC Modelling Guidelines*. Prepared for the Sydney Metropolitan Catchment Management Authority.

Brookes, K. and Wong, T.H.F. (2009) The adequacy of the Stream Erosion Index as an alternative indicator of geomorphic stability in urban waterways. WSUD09 proceedings.

Department of Sustainability, Environment, Water, Population and Communities, 2012, National Urban Water Planning Principles, available from http://www.environment.gov.au/water/policy-programs/urban-reform/nuw-planning-principles.html

Ecological Engineering, 2005, Water Sensitive Urban Design Solutions for Catchments Above Wetlands, Report prepared for Hunter Councils.

Ecologically Sustainable Development Steering Committee, 1992, *National Strategy for Ecologically Sustainable Development* Endorsed by the Council of Australian Governments, December, 1992, http://www.environment.gov.au/about/esd/publications/strategy/intro.html.

Great Lakes Council, 2009, Great Lakes Water Quality Improvement Plan: Wallis, Smiths and Myall Lakes, Forster, NSW.

Great Lakes Council, 2011, Water Sensitive Design Development Control Plan No. 54, December 2011.

Institution of Engineers, Australia (1987) *Australian Rainfall and Runoff: A Guide to Flood Estimation* , Vol. 1, Editor-in-chief D.H. Pilgrim, Revised Edition 1987 (Reprinted edition 1998), Barton, ACT

Landcom, 2004, *Managing Urban Stormwater: Soils and Construction, 4th Edition*, NSW Government.

Macleod, A, 2008, MUSIC calibration based on soil conditions. Proceedings of Stormwater 2008, Stormwater Industry Assocation Regional Conference, Gold Coast, 2008.

National Water Quality Management Strategy Guidelines (available at http://www.environment.gov.au/water/policy-programs/nwqms/)

Natural Resources Commission, 2005, Recommendations - State-wide Standards and Targets, prepared for the NSW Government, September 2005.

NSW DECCW, 2010, NSW Wetlands Policy, NSW Department of Environment, Climate Change and Water.

NSW Department of Environment and Conservation, 2006, *Managing Urban Stormwater – Harvesting and Reuse*

NSW DLWC, 1998, The NSW Groundwater Quality Protection Policy, NSW Department of Land and Water Conservation.

NSW DLWC, 2002, The NSW State Groundwater Dependent Ecosystems Policy, NSW Department of Land and Water Conservation.

NSW Government, 1999, NSW Water Quality and River Flow Objectives, sourced from www.environment.nsw.gov.au/ieo web-site.

NSW Government, 2005, Floodplain Development Manual – the management of flood liable land, April 2005.

NSW Office of Water (NoW), 2012, Controlled Activities on Waterfront Land - Guidelines for riparian corridors on waterfront land.

APPENDIX A: GEOTECHNICAL REPORT

BMT WBM Pty Ltd

Geotechnical Assessment

Proposed Land Rezoning

Lots 110 & 112 DP1091944, The Lakes Way, Charlotte Bay

Report No. RGS00460.1-AC
15 January 2013

REGIONAL
GEOTECHNICAL SOLUTIONS

REGIONAL
GEOTECHNICAL SOLUTIONS

Manning-Great Lakes

Port Macquarie

Coffs Harbour

RGS00460.1-AC

15 January 2013

BMT WBM Pty Ltd
126 Belford Street
NEWCASTLE NSW 2292

Attention: Mr Mark Wainwright

Dear Mark

RE: Geotechnical Assessment
Proposed Land Rezoning
Lots 110 & 112 DP1091944, The Lakes Way, Charlotte Bay

As requested, Regional Geotechnical Solutions Pty Ltd (RGS) has undertaken a geotechnical assessment for the proposed land rezoning at the above lots near Pacific Palms, NSW.

The work includes an assessment of the soil capability and an assessment of the groundwater characteristics at the site.

If you have any questions regarding this project, or require any additional consultations, please contact the undersigned.

For and on behalf of

Regional Geotechnical Solutions Pty Ltd

Simon Keen

Geotechnical Engineer

Regional Geotechnical Solutions Pty Ltd
ABN 51141848820

44 Bent Street
Wingham NSW 2429
Ph. (02) 6553 5641

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Web: www.regionalgeotech.com.au

Table of Contents

Figures

Appendices

1 INTRODUCTION

As requested, Regional Geotechnical Solutions Pty Ltd (RGS) has undertaken a geotechnical assessment for the proposed rezoning of Lots 110 and 112 DP1091944 to the east of The Lakes Way in Charlotte Bay, near Pacific Palms.

The assessment is one part of the studies associated with the development of a Planning Proposal for the land which seeks to evaluate the appropriateness and reasonableness of rezoning the land for residential / commercial development and conservation purposes. The assessment has been limited to the areas that have been nominated in the Consultancy Brief as possible development footprints (areas A, B and C), to the approved golf course (area D1) and to areas D2 and F2.

The purpose of the work described herein was to provide the following:

- An assessment on the capability / suitability of soils and groundwater conditions for infiltration, swale drainage, etc.;
- A description of the groundwater characteristics based on the results of the field investigation and laboratory testing, including groundwater levels at each of the borehole and test pit locations (where encountered) and an assessment of the groundwater quality; and
- The preparation of a preliminary map based on the initial groundwater measurements showing indicative groundwater contours (AHD) across the site based on water level measurements.

The site was the subject to five geotechnical and groundwater assessments by Coffey Partners International Pty Ltd & Coffey Geosciences Pty Ltd between 1992 and 2002 with copies of the reports being provided to RGS as part of the preliminary desktop study. The reports, which were undertaken for the proposed golf course and associated structures on Lot 110 included:

- An initial geotechnical assessment (report no. N4816/1-AC, dated 7 January 1992)
- An acid sulfate soil survey (report no. N4816/1-AD, dated 13 November 1992),
- An assessment of the effects on groundwater due to the proposed golf course (report no. N4816/2-AF, dated 6 November 1997), and
- A subsequent round of groundwater testing (report no. TA0136/01-AA, dated 10 July 2002).

2 ASSESSMENT PROCEDURE

Field work for the assessment included:

- A site walkover to provide a preliminary ground assessment to verify the results of the preliminary soil and groundwater models developed during the desktop review;
- The excavation of 12 test pits to establish a typical soil profile in each of the nominated terrain units;
- Infiltration (falling head) testing at four of the test pit locations; and
- The installation of six groundwater wells at depths of between 4.7 and 5.0m.

Field work was undertaken on 22, 23 and 28 November 2012 by a geotechnical engineer and a geotechnician. Engineering logs of the test pits and boreholes, and the results of the infiltration testing are presented in Appendix A. The test locations are shown on Figure 1 and were recorded with a hand held GPS. Reduced levels at the test locations were estimated from contours shown on drawings provided by BMT WBM based on the positions recorded by GPS. The levels are shown on the logs.

3 LABORATORY TESTING

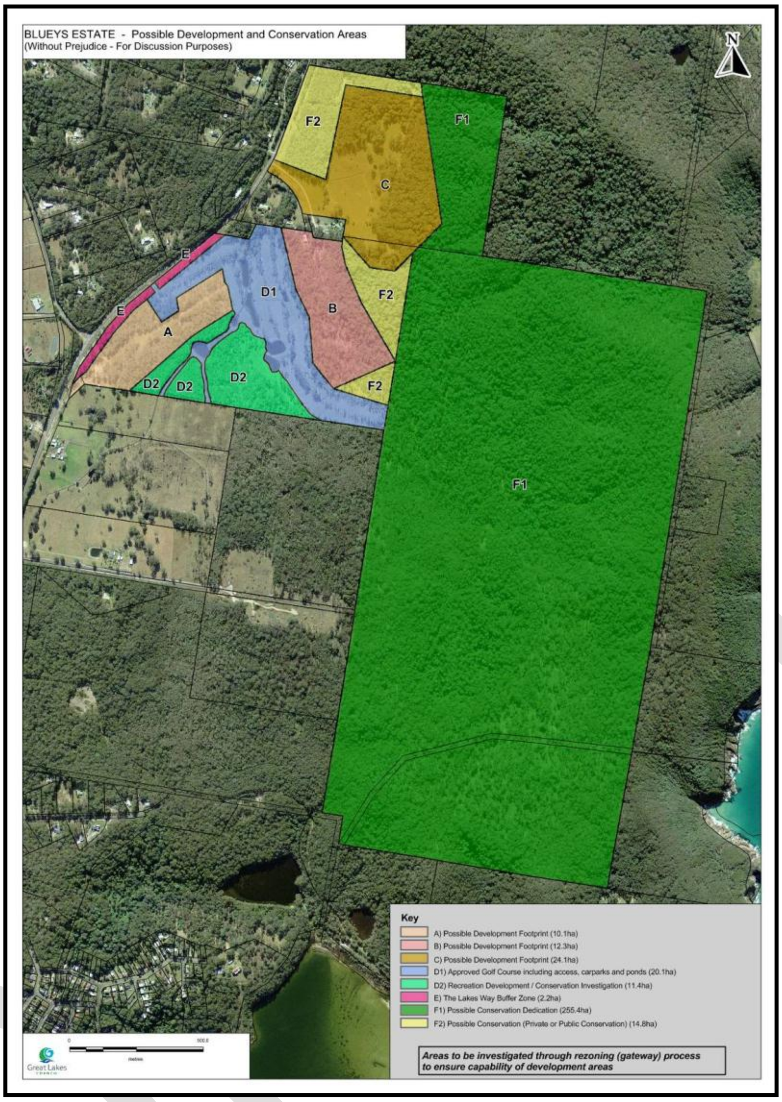
Groundwater samples were recovered from each of the six groundwater wells on 29 November 2012, one week after the installation of the wells which were installed without the use of water or drilling fluids.

The six samples were sent to an external chemical laboratory and were assessed for pH, electrical conductivity, total dissolved salts, total suspended solids, nitrate, nitrite, phosphate, ammonium, total nitrogen and total phosphorus. The results of the testing are summarised in Section 6.2, while test result sheets are presented in Appendix B.

4 SITE CONDITIONS

4.1 Surface Conditions

The site is located to the east of The Lakes Way in Charlotte Bay, near Pacific Palms. Topographically it comprises of two low lying flat to gently undulating areas separated by a north-westerly trending ridgeline, and a westerly facing hillside in the north east corner of the site. A site image that was provided within the tender package is reproduced below.



Site area to the east of The Lakes Way. The assessment area was limited to areas A, B, C, D1, D2 and F2. which are dominated by low lying generally flat terrain and by a north-westerly trending ridgeline through the area nominated as Area B.

4.2 Subsurface Conditions

Published geology maps (Bulahdelah 1:100,000 Sheet 9333, Edition 1 1993) indicates that the site is underlain by the late Carboniferous aged Koolanock Sandstone member that typically comprises interbedded sandstone and siltstone, and undifferentiated alluvium. The Smiths Lake 1:25,000 Quaternary Geology map indicates that the alluvial areas are quaternary alluvial and colluvial fan comprising fluvial sand, silt, clay and gravel.

The test pits and boreholes encountered distinctly different soil profiles on the elevated parts of the site, compared with the low-lying lakeside areas. On the basis of the conditions observed the site has been divided into three geotechnical terrain zones:

- Zone A – lower lying flat to gently sloping areas with alluvial/colluvial clay and sand deposits overlying residual clay soils which grade into weathered rock at depth;
- Zone B – gently sloping areas underlain by colluvial and residual soil profiles grading into weathered sandstone and mudstone at depth;
- Zone C – elevated sloping areas underlain by colluvial and residual clay soil profiles with weathered sandstone and mudstone at shallow depths.

The material profiles encountered in Terrain Zones A, B and C are summarised in Tables 1 to 3 respectively. Further details are provided in the Engineering Logs.

Table 1: Summary of Subsurface Profile Encountered in the Test Pits and Boreholes in Terrain Unit A

Material Name	**Material Description**	**Depth to Base of Material Layer (m)**								
		BH102	**BH103**	**BH104**	**BH105**	**BH106**	**TP3**	**TP4**	**TP9**	**TP10**
Topsoil	Silty CLAY, Sandy Silty CLAY, Silty SAND, Clayey SILT, ranging from low to high plasticity, fine grained, pale grey, grey-brown and dark brown	0.05	0.40	0.60	--	0.70	0.50	0.30	0.10	--
Alluvial Soil	CLAY, Silty CLAY, Sandy CLAY, Clayey SAND, ranging from low to high plasticity and fine to medium grained, ranging from firm to very stiff and medium dense	≥5.0	3.70	4.60	3.70	4.50	≥2.7	1.50	≥2.8	≥3.0
Residual Soil	CLAY, Clayey SAND, Sandy CLAY, high plasticity, fine to coarse grained, stiff to hard and medium dense	--	4.70	--	4.70	4.50	--	≥2.7	--	--
Extremely Weathered Rock	Recovered as CLAY, Clayey SAND, Silty CLAY, medium to high plasticity and fine to coarse grained, very stiff to hard and friable, medium dense	--	≥5.0	≥5.0	--	≥5.0	--	--	--	--

Notes:	--	indicates that the material was not encountered at the test location
	≥	indicates that the base of the material layer was not encountered

Table 2: Summary of Subsurface Profile Encountered in the Test Pits and Boreholes in Terrain Unit B

Material Name	Material Description	Depth to Base of Material Layer (m)			
		BH101	TP2	TP5	TP8
Topsoil	Silty CLAY, Sandy Silty CLAY, Silty SAND, Clayey SILT, ranging from low to high plasticity, fine grained, pale grey, grey-brown and dark brown	0.10	0.20	0.15	0.10
Colluvial Soil	Sandy CLAY, Clayey GRAVEL and CLAY, medium to high plasticity and fine to coarse grained, ranging from stiff to hard, dense	--	--	--	1.70
Residual Soil	CLAY, Clayey SAND, Sandy CLAY, high plasticity, fine to coarse grained, stiff to hard and medium dense	1.70	0.80	0.90	2.00
Extremely Weathered Rock	Recovered as CLAY, Clayey SAND, Silty CLAY, medium to high plasticity and fine to coarse grained, very stiff to hard and friable, medium dense	4.50	≥2.7	1.80	--
Bedrock	MUDSTONE and SANDSTONE, highly to moderately weathered, high strength, fine to coarse grained,	≥5.0	--	1.9	≥2.1

Notes: -- indicates that the material was not encountered at the test location
≥ indicates that the base of the material layer was not encountered

Table 3: Summary of Subsurface Profile Encountered in the Test Pits in Terrain Unit C

Material Name	Material Description	Depth to Base of Material Layer (m)				
		TP1	TP6	TP7	TP11	TP12
Topsoil	Silty CLAY, Silty SAND, low plasticity, fine grained, dark brown and dark grey	0.10	0.20	0.10	--	0.10
Colluvial Soil	CLAY, Sandy Silty CLAY and Sandy CLAY, ranging from low to high plasticity, friable, grey	0.35	--	--	0.40	0.60
Residual Soil	SAND, fine to medium grained, dense, some sandstone gravel and cobbles	--	--	0.40	--	--
Extremely Weathered Rock	Recovered as Gravelly CLAY, high plasticity, friable	0.50	--	--	--	--
Bedrock	MUDSTONE and SANDSTONE, highly to moderately weathered, ranging from low to very high strength	≥0.80	≥0.50	≥0.50	≥1.00	≥1.40

Notes: -- indicates that the material was not encountered at the test location
≥ indicates that the base of the material layer was not encountered

Groundwater levels were recorded in all six of the groundwater wells and the results are provided in Section 5. Groundwater inflows were not encountered in any of the test pits.

5 GROUNDWATER CONDITIONS

5.1 Groundwater Levels

Groundwater levels in monitoring wells were recorded at one week after the completion of the drilling and are summarised below in Table 4. Groundwater inflows were not encountered in the test pits.

Table 4: Summary of Groundwater Measurements

Borehole Number	Depth to Groundwater from Ground Level (m)	Approx. RL Ground Level (m AHD)	Approx. Groundwater RL (m AHD)
BH101	0.81	3.96	3.15
BH102	1.31	3.73	2.42
BH103	0.66	4.37	3.71
BH104	1.62	6.22	4.60
BH105	1.38	4.69	3.31
BH106	1.40	3.59	2.19

Groundwater contours have been interpolated and are shown on Figure 2. The contours indicate the presence of a groundwater divide along the central ridgeline around TP6 and TP7. Groundwater north of the ridgeline appears to flow to the west-northwest, while groundwater to the south of the ridgeline appears to flow to the northwest.

A data logger (measuring absolute pressure and temperature) was installed in BH103 which recorded data at 10 minute intervals between 29 November 2012 and ***PENDING***. The absolute pressure measurements were converted to groundwater levels by subtracting the atmospheric pressure reduced to mean sea level (Press MSL) from observations at RAAF Williamtown and Taree Airport, and cross checked against the measured groundwater levels when installing and uninstalling the logger. A graph showing the calculated groundwater level over time is shown below, while the recorded data is produced in Appendix A.

FIGURE PENDING

The logger collected data over a ***XX*** day period that was not subjected to periods of high rainfall. The highest rainfall recorded at Forster over the assessed period was 19.6mm on both 11 and 26 December 2012 ***(PENDING CONFORMATION).***

5.2 Groundwater Quality

Groundwater samples were obtained from the six groundwater wells seven days after installation using industry protocols and sent to Environmental Analysis Laboratory (EAL) for testing. A summary of the groundwater test results from the current investigation are provided in Table 5.

Table 5: Summary of Groundwater Test Results

Parameter	BH101	BH102	BH103	BH104	BH105	BH106
pH	6.92	6.27	5.82	5.64	6.53	6.60
Electrical Conductivity (dS/m)	6.92	15.78	3.91	6.16	2.20	4.45
Total Dissolved Salts (mg/L)	4,706	10,730	2,659	4,189	1,496	3,026
Total Suspended Solids (mg/L)	1,008	92	32	75	76	110
Total Phosphorous (mg/L P)	0.08	0.05	0.02	0.04	0.07	0.06
Orthophosphate (mg/L P)	0.006	0.009	<0.005	<0.005	<0.005	0.019
Total Nitrogen (mg/L N)	0.44	0.51	0.17	0.23	0.43	0.46
Nitrate (mg/L N)	0.005	0.111	0.009	0.018	0.015	0.015
Nitrite (mg/L N)	0.002	0.014	0.001	0.001	0.002	0.005
Ammonia (mg/L N)	0.146	0.042	0.007	0.001	0.218	0.051

Previous groundwater monitoring undertaken by Coffey in 1997 and 2002 indicated that samples collected from monitoring wells installed in the southern portion of Terrain Zone A had:

- Phosphorous levels of between 0.06 and 0.15mg/L P; and
- Nitrate levels of between 0.01 and 0.07mg/L N;
- Nitrite levels of less than 0.01mg/L N; and
- Ammonia values of between <0.01 and 0.05mg/L N.

6 SOIL CAPABILITY

6.1 Extents of Unsuitable Foundation Materials

Terrain Zone A comprises of firm to stiff alluvial and medium dense sand deposits which overly residual clay soils which grade into weathered rock at depth. Topsoil depths within Terrain Zone A varied, with an average thickness of 300mm and a maximum thickness of 700mm being encountered. Whilst the majority of the alluvial clays were of stiff consistency, firm clay was encountered on the northern section of Zone A in boreholes BH105 and BH106 to a depth of 2m. Drainage in the southern section of Terrain Zone A has been improved by the construction of a number of dams and swales during earthworks for the proposed golf course. Swales have also been excavated within the paddocks of the northern section of Terrain Zone A.

Unsuitable foundation material in the southern portion of Terrain Zone A is expected to comprise of approximately 300mm of topsoil with isolated areas of lower strength clays likely to be identified during earthworks. Unsuitable material in the northern portion of Zone A is expected to include approximately 250mm of topsoil, however, during adverse weather the area is likely to contain wet, low strength clay layers underlying the topsoil to depths of at least 1m and a rock drainage blanket may be required.

Terrain Zone B comprises about 150mm of topsoil overlying colluvial and residual clays (and extremely weathered rock) which grade into bedrock at depths of between 1.8 and 4.5m. The residual clays were of stiff consistency or stronger, however isolated low strength clay layers may be encountered. Unsuitable material within Zone B is expected to be limited to stripping of topsoil.

Terrain Zone C comprises about 100mm of topsoil overlying colluvial and residual clays which grade into weathered rock at depths as shallow as 0.5m. Unsuitable material within Terrain Zone C is expected to be limited to stripping of topsoil.

6.2 Excavation Conditions

Excavation of the soils within Terrain Zone A will be achievable with small to medium sized excavators or a backhoe to at least the maximum depths of this investigation. Excavation of soil strength material within Terrain Zone B will be achievable with medium to large size excavators/

The test pits excavated within Terrain Zone C were terminated due to refusal of the backhoe at depths as shallow as 0.5m and based on experience with other earthworks projects in the area, higher strength and less fractured material would be expected to be encountered below the base of the test pits. Consequently, in Terrain Zone C and where bedrock is encountered in Terrain Zone B excavation conditions are likely to be difficult, requiring heavy ripping and potentially the use of rock breakers depending on required bulk excavation depths. Developments should be designed to minimise requirements for bulk excavation. Service trenches will require the use of single tyned rippers and rock buckets, depending on required depths, and a hydraulic rock breaker may be required where localised high strength bands are encountered.

6.3 Infiltration Testing

Falling head permeability testing was undertaken adjacent to four of the test pits in Terrain Zone A using the Porchet method summarised in Kessler & Oosterbaan (1974). The results are summarised in Table 6, while test result sheets are presented in Appendix A.

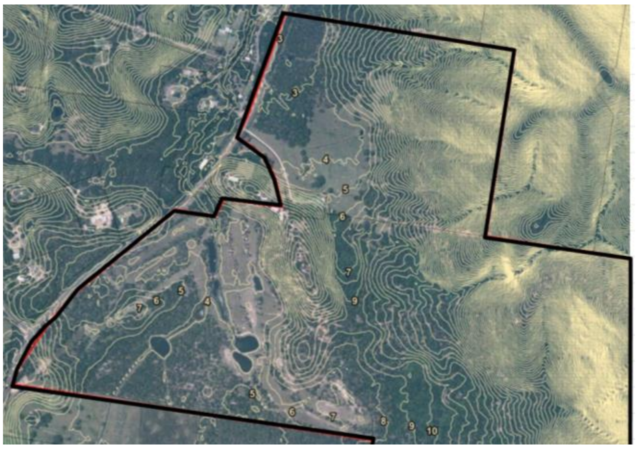
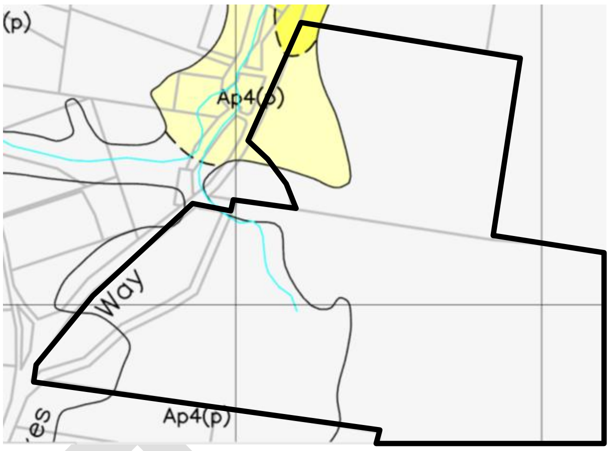
Table 6: Summary of Subsurface Profile Encountered in the Test Pits in Terrain Unit B

Test Location	Test Depth (m)	Permeability (m/s)
TP3	1.0	1.07×10^{-7}
TP4	1.0	1.83×10^{-7}
TP9	1.0	8.50×10^{-7}
TP10	1.0	2.17×10^{-7}

6.4 Acid Sulfate Soils

Acid Sulfate Soils (ASS) produce sulphuric acid when exposed to oxygen due to the presence of iron sulphides in the form of pyrite within the soil matrix. These soils form when iron-rich sediments are deposited in saltwater or brackish water environments. Prior to oxidation, these pyritic soils are referred to as Potential ASS. ASS that have produced acid as a result of oxidation are referred to as Actual ASS. They typically occur in natural, low-lying coastal depositional environments below approximately 5m AHD. In the field ASS are generally identified as saline sediments such as alluvial or estuarine soils or bottom sediments in creeks and estuaries.

Reference to the Pacific Palms 1:25,000 Acid Sulfate Soil Risk Map indicates that most of the site is in an area of no known occurrence of ASS, while part of the northern alluvial plan of Terrain Zone A is in an area of low probability of occurrence of ASS materials within the soil profile greater than 3m beneath the ground surface. An area of low occurrence of ASS between 1 and 3m beneath the ground surface is shown on the northwest corner of the site in an area of the site that has been identified as a potential conservation area where the soil is not expected to be disturbed.

	
Location of the site as indicated by a provided survey.	*Extract from Pacific Palms 1:25,000 ASS Risk Map indicates that a portion of the northern section of Terrain Zone 1 is in an area of low occurrence of ASS.*

ASS testing on the southern section of Terrain Zone A (now mapped as an area of no known occurrence) was undertaken by Coffey and Partners in 1992, using the screening procedure developed by Brinkman and Pons. The results indicated that the soils were not acidic and had a very low to negligible acid sulfate potential. The areas have since been excavated for the dams that currently exist. Distinct hydrogen sulphide odours (i.e. 'rotten egg') were observed in BH102 and BH103 at a depth of about 1m.

ASS testing was not undertaken as part of the current assessment. It is recommended that an ASS assessment be undertaken on the northern portion of the site that has been identified as being in an area of low occurrence of ASS and the low lying area around BH102 and BH103, if earthworks are to be undertaken in this area.

6.5 Limitations for Stormwater Management & Water Quality

Comments are provided below for each terrain zone outlining some of the factors that are likely to influence stormwater management and water quality, and that impact on the suitability of each terrain type for the infiltration of stormwater.

Terrain Zone A - Lower Lying Flat to Gently Sloping Areas

- Characterised by low lying to gently sloping areas with slopes of up to about 3°;
- Infiltration testing indicates that the alluvial soils within the terrain zone are of low permeability (typically 10^{-7}m/s);
- Excavation depths will exceed 3m and bedrock is at greater than 5m depth. The groundwater level was measured during the investigation to be between 0.8 and 1.6m

below the existing ground surface (as outlined in Section 5) and would be expected to rise during and after prolonged periods of high rainfall;

- Whilst laboratory testing to assess the dispersive nature of the soils was not undertaken during the investigation, previous experience in the area and site observations indicate that the soils in Terrain Zone A are not dispersive. The soils are not expected to be highly erodible provided good vegetation cover is maintained, except when subjected to high velocity flows or concentrated water flows; and
- Seepage in Terrain Zone A is likely to be governed by the combined effects of the low permeability clay soils and the shallow water table. Sand lenses were encountered within the alluvial profile and the flow of groundwater and infiltrated waters would be expected to follow these sand lenses. Downslope seepage is not anticipated to be an issue.

Terrain Zone B – Gently Sloping Areas

- Characterised by undulating slopes in the range of approximately 3 to 8°;
- The residual soil, colluvial soil and extremely weathered rock materials are of low permeability;
- Excavation depths for stormwater systems will be limited to about 1.5 to 1.8m, with bedrock being encountered within the test pits as shallow as 1.8m. Groundwater was not encountered within Terrain Zone B during the investigation, however during and after extended periods of high rainfall groundwater may be encountered at the top of bedrock;
- Whilst laboratory testing to assess the dispersive nature of the soils was not undertaken during the investigation, previous experience in the area and site observations indicate that the soils in Terrain Zone B are not dispersive. The soils are not expected to be highly erodible provided good vegetation cover is maintained, except when subjected to high velocity flows or concentrated water flows; and
- Seepage in Terrain Zone B is likely to be governed by the combined effects of the low permeability clay soils and the bedrock depth. While clayey sand was encountered within the test pits, the density of the material and the presence of clay within the soil matrix indicate that the material would not provide a flow path for groundwater or infiltrated waters. Downslope seepage is not anticipated to be an issue.

Terrain Zone C – Elevated Sloping Areas

- Characterised by moderately steep slopes of between about 8 and 15°;
- The residual soil, colluvial soil and extremely weathered rock materials are of low permeability;
- Bedrock was encountered in the test pits at depths as shallow as 0.5m, limiting potential excavations for stormwater systems and limiting the effectiveness of subsurface infiltration systems. Groundwater was not encountered within Terrain Zone C during the investigation,

however during and after extended periods of high rainfall groundwater may be encountered at the top of bedrock;

- Whilst laboratory testing to assess the dispersive nature of the soils was not undertaken during the investigation, previous experience in the area and site observations indicate that the soils in Terrain Zone C are not dispersive. The soils are not expected to be highly erodible provided good vegetation cover is maintained, except when subjected to high velocity flows or concentrated water flows; and
- Seepage in Terrain Zone C is likely to be governed by the combined effects of the low permeability of the residual/colluvial soils and the shallow bedrock depth. Infiltrated waters would be expected to follow the interface between bedrock and the overlying soil materials. Site observations indicate that where upslope infiltration occurs waters may exit further down gradient.

7 LIMITATIONS

The findings presented in the report and used as the basis for recommendations presented herein were obtained using normal, industry accepted geotechnical practises and standards. To our knowledge, they represent a reasonable interpretation of the general condition of the site. Under no circumstances, however, can it be considered that these findings represent the actual state of the site at all points. If site conditions encountered during construction vary significantly from those discussed in this report, Regional Geotechnical Solutions Pty Ltd should be contacted for further advice.

This report alone should not be used by contractors as the basis for preparation of tender documents or project estimates. Contractors using this report as a basis for preparation of tender documents should avail themselves of all relevant background information regarding the site before deciding on selection of construction materials and equipment.

If you have any questions regarding this project, or require any additional consultations, please contact the undersigned.

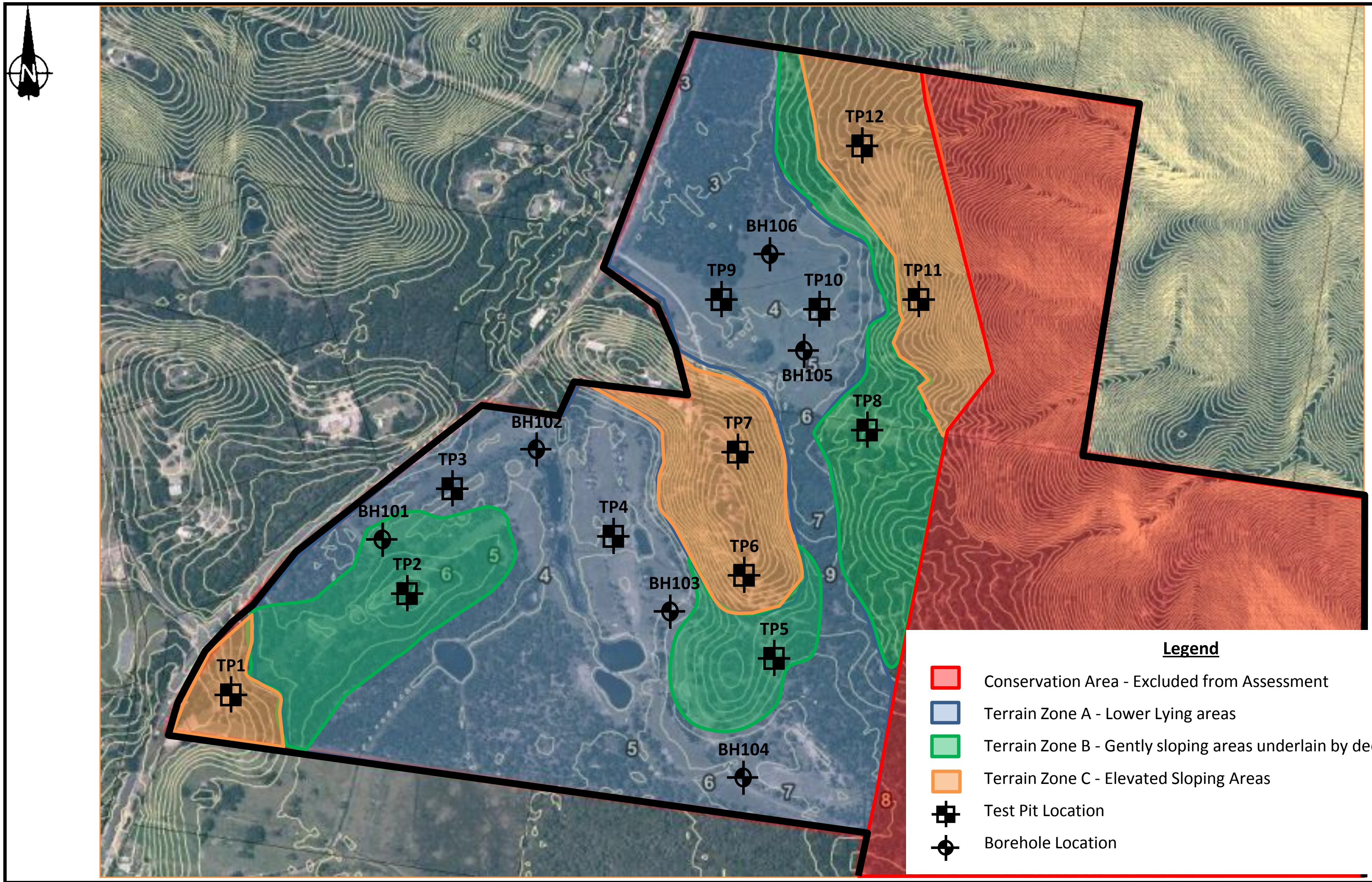
For and on behalf of

Regional Geotechnical Solutions Pty Ltd

Simon Keen

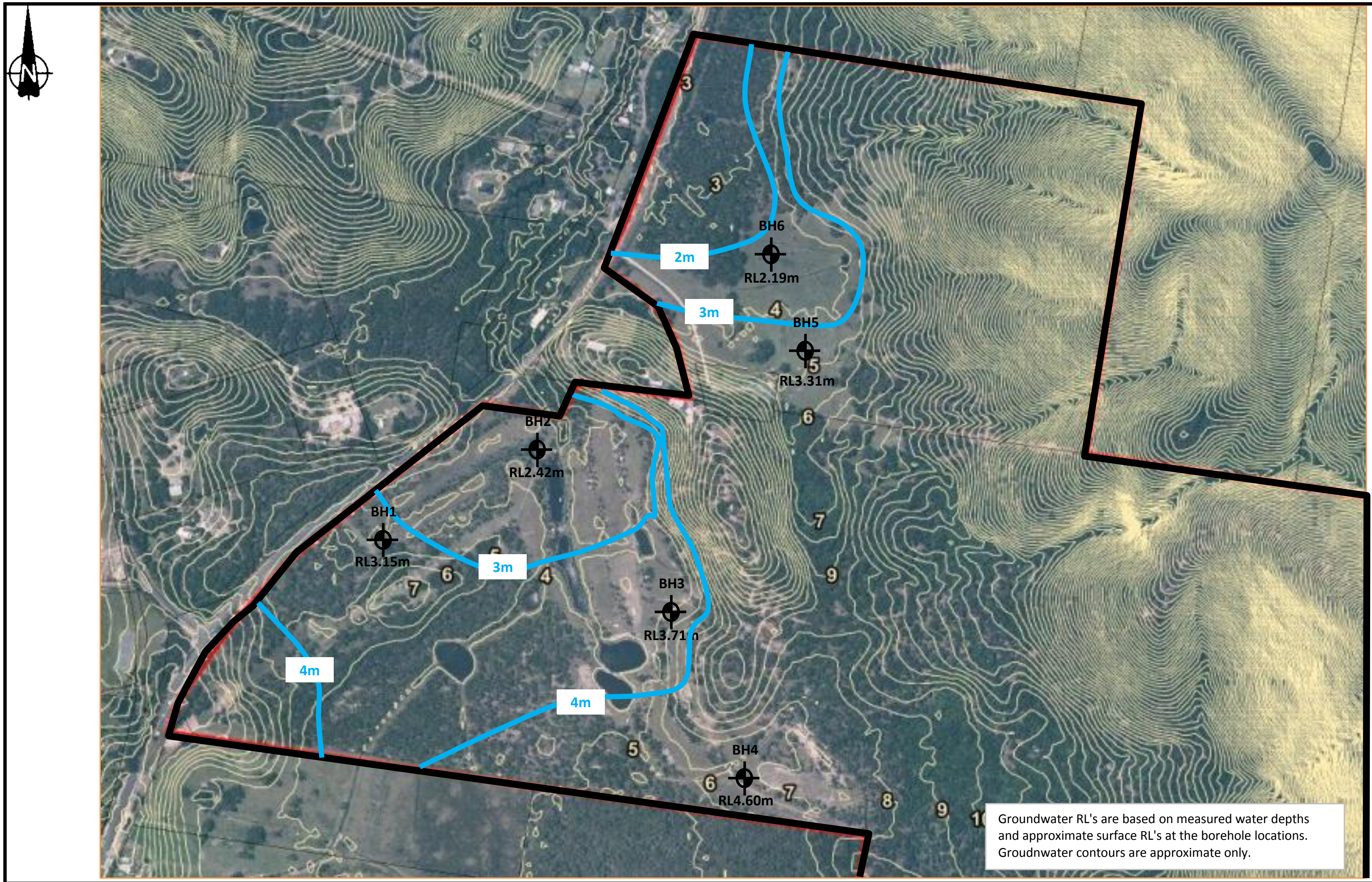
Geotechnical Engineer

Figures



REGIONAL
GEOTECHNICAL SOLUTIONS

Client	BMT WBM	Job No.	RGS00460.1
Project:	Proposed Land Rezoning Lots 110 & 112 DP1091944, The Lakes Way, Charlotte Bay	Drawn By:	Simon Keen
		Date:	15-Jan-13
Title:	Test Location Plan	Drawing No.	**Figure 1**



Groundwater RL's are based on measured water depths and approximate surface RL's at the borehole locations. Groudnwater contours are approximate only.

REGIONAL
GEOTECHNICAL SOLUTIONS

Client	BMT WBM	Job No.	RGS00460.1
Project:	Proposed Land Rezoning	Drawn By:	Simon Keen
	Lots 110 & 112 DP1091944, The Lakes Way, Charlotte Bay	Date:	8-Jan-13
Title:	Interpreted Grondwater Contour Map	Drawing No.	**Figure 2**

Appendix A

Results of Field Investigations

ENGINEERING LOG - BOREHOLE

CLIENT:	BMT WBM Pty Ltd	**BOREHOLE NO:**	**BH101**
PROJECT NAME:	Proposed Land Rezoning	**PAGE:**	1 OF 1
		JOB NO:	RGS00460.1
		LOGGED BY:	SK
LOCATION:	The Lakesway Charlotte Bay - Refer to figure 1	**DATE:**	22/11/12

DRILL TYPE:	Nissan Patrol Mounted Rig	**SURFACE RL:**	4.0 m
BOREHOLE DIAMETER:	100 mm	**DATUM:**	AHD

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
			4.0	0.00			0.10m TOPSOIL: Clayey Silt, low plasticity, dark brown	M < W_P				TOPSOIL
				0.10		CH	CLAY: high plasticity, pale grey, mottled brown	M < W_P				RESIDUAL SOIL
			3.5	0.5					St			
	▶—		3.0	1.0		CH		M > W_P				
			2.5	1.5					VSt			
				1.70			1.70m CLAY: medium to high plasticity, orange, trace to with some fine grained Sand					EXTREMELY WEATHERED MUDSTONE
			2.0	2.0								
Solid Flight - V Bit			1.5	2.5			becoming pale grey to pale brown mottled orange					
			1.0	3.0		CH						
			0.5	3.5			trace of highly to moderately weathered MUDSTONE gravel recovered	M < W_P	Fb			
Solid Flight - TC Claw			0.0	4.0								V BIT REFUSAL GROUNDWATER INFLOW BETWEEN 4.0M AND 4.5M
			-0.5	4.5			4.50m MUDSTONE: dark grey, interbedded extremely to high material recovered as high plasticity clay					MODERATELY WEATHERED MUDSTONE, HIGH STRENGTH
			-1.0	5.0			5.00m Hole Terminated at 5.00 m					
			-1.5									

LEGEND:

Water

- Water Level (Date and time shown)
- ▶— Water Inflow
- —◀ Water Outflow

Strata Changes

- — — Gradational or transitional strata
- —— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - BOREHOLE

CLIENT:	BMT WBM Pty Ltd	**BOREHOLE NO:**	**BH102**
PROJECT NAME:	Proposed Land Rezoning	**PAGE:**	1 OF 1
		JOB NO:	RGS00460.1
		LOGGED BY:	SK
LOCATION:	The Lakesway Charlotte Bay - Refer to figure 1	**DATE:**	22/11/12

DRILL TYPE:	Nissan Patrol Mounted Rig	**SURFACE RL:**	3.7 m
BOREHOLE DIAMETER:	100 mm	**DATUM:**	AHD

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
Solid Flight - V Bit				0.05m			TOPSOIL: Silty CLAY, medium plasticity, dark brown	M > w_P				TOPSOIL
			3.5 3.0 2.5	0.5 1.0 1.20m			CLAY: high plasticity, dark brown becoming grey brown, slight rotten egg odor		St			ALLUVIAL SOIL
	►		2.0 1.5	1.5 2.0 2.20m		CH	CLAY: high plasticity, grey discretely mottled orange		St - VSt			ALLUVIAL SOIL
			1.0	2.5 3.0 3.00m			Silty CLAY: medium plasticity, pale grey, discretely mottled orange, trace to some fine grained Sand		VSt			
			0.5	3.30m		CH	Sandy CLAY: high plasticity, pale grey, fine grained Sand, trace of medium to coarse grained Sand		St			GROUNDWATER INFLOW BETWEEN 3.5M AND 4.0M
			0.0 -0.5	3.5 4.0 4.20m			Clayey SAND: fine to medium grained, pale grey mottled orange, high plasticity fines	W	MD			MATERIAL CAN BE REMOULDED
			-1.0	4.5 5.0 5.00m			CLAY: high plasticity, grey mottled orange brown, with some fine to coarse grained Sand	M > w_P	VSt			
			-1.5				Hole Terminated at 5.00 m					

LEGEND:

Water

- Water Level (Date and time shown)
- ► Water Inflow
- ◄ Water Outflow

Strata Changes

- — — Gradational or transitional strata
- —— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - BOREHOLE

CLIENT:	BMT WBM Pty Ltd	**BOREHOLE NO:**	**BH103**
PROJECT NAME:	Proposed Land Rezoning	**PAGE:**	1 OF 1
		JOB NO:	RGS00460.1
		LOGGED BY:	SK
LOCATION:	The Lakesway Charlotte Bay - Refer to figure 1	**DATE:**	22/11/12

DRILL TYPE:	Nissan Patrol Mounted Rig	**SURFACE RL:**	4.4 m
BOREHOLE DIAMETER:	100 mm	**DATUM:**	AHD

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
Solid Flight Auger - V Bit			4.0				TOPSOIL: Silty CLAY, low plasticity, dark brown	M > W_P				TOPSOIL
	▶—			0.5		CL	0.40m Silty CLAY: medium plasticity, brown, with some fine to coarse grained Sand		St			ALLUVIAL SOIL
			3.5 3.0 2.5	1.0 1.5 2.0		CH	0.80m Sandy CLAY: high plasticity, pale grey, fine to medium grained Sand, with some coarse grained Sand, distinct "rotten egg odor"					RESIDUAL SOIL
			2.0 1.5 1.0	2.5 3.0 3.5		SC	2.00m Clayey SAND: fine to coarse grained, pale grey to white, high plasticity fines, with some Silt traces of subrounded gravel	M	MD			GROUNDWATER INFLOW AT 3.2M
			0.5	4.0		CH	3.70m Sandy CLAY: high plasticity, pale grey to white, fine to coarse grained Sand, with some silt	M > W_P	St			
			0.0 -0.5	4.5 5.0		SC	4.20m Clayey SAND: fine to coarse grained, grey mottled orange, high plasticity fines, with some silt	W	MD			POSSIBLE EXTREMELY WEATHERED SANDSTONE
			-1.0				5.00m Hole Terminated at 5.00 m					

LEGEND:

Water

▼	Water Level (Date and time shown)
▶—	Water Inflow
—◀	Water Outflow

Strata Changes

— — —	Gradational or transitional strata
———	Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition

D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

REGIONAL GEOTECHNICAL SOLUTIONS

ENGINEERING LOG - BOREHOLE

CLIENT:	BMT WBM Pty Ltd	**BOREHOLE NO:**	**BH104**
PROJECT NAME:	Proposed Land Rezoning	**PAGE:**	1 OF 1
		JOB NO:	RGS00460.1
		LOGGED BY:	SK
LOCATION:	The Lakesway Charlotte Bay - Refer to figure 1	**DATE:**	22/11/12

DRILL TYPE:	Nissan Patrol Mounted Rig	**SURFACE RL:**	6.2 m
BOREHOLE DIAMETER:	100 mm	**DATUM:**	AHD

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
Solid Flight Auger - V Bit			6.0	0.5	▨	CL	Silty CLAY: medium plasticity, brown	M < W_P				ALLUVIAL SOIL/POSSIBLE FILL
	▶—		5.5 5.0 4.5	0.60m 1.0 1.5	▨	CL	CLAY: medium plasticity, brown mottled orange grey becoming grey-brown mottled orange	M > W_P	St			ALLUVIAL SOIL
			4.0	1.70m 2.0	▨	CH	CLAY: high plasticity, grey, trace of fine grained sand					ALLUVIAL SOIL
			3.5	2.20m 2.5 3.0	▨	CH	Sandy CLAY: high plasticity, yellow mottled orange, fine to coarse grained sand					
			3.0	3.00m 3.5	▨	SC	Clayey SAND: fine to medium grained, grey mottled orange, high plasticity fines, trace of coarse grained Sand	M	MD			
			2.5	3.50m 4.0	▨	CH	Sandy CLAY: high plasticity, pale grey mottled orange, fine to medium grained sand	M > W_P	VSt			
			2.0	4.00m 4.5	▨	CL	CLAY: high plasticity, pale grey discretely mottled orange with a trace to some fine to medium grained sand					
			1.5	4.60m 5.0	▨	CL	Silty CLAY: medium plasticity, pale grey, trace of fine grained subangular mudstone gravel	M < W_P	Fb			EXTREMELY WEATHERED MUDSTONE
			1.0	5.00m			Hole Terminated at 5.00 m					

LEGEND:

Water

- ▼ Water Level (Date and time shown)
- ▶— Water Inflow
- —◀ Water Outflow

Strata Changes

- — — Gradational or transitional strata
- —— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - BOREHOLE

CLIENT:	BMT WBM Pty Ltd	**BOREHOLE NO:**	**BH105**
		PAGE:	1 OF 1
PROJECT NAME:	Proposed Land Rezoning	**JOB NO:**	RGS00460.1
		LOGGED BY:	SK
LOCATION:	The Lakesway Charlotte Bay - Refer to figure 1	**DATE:**	22/11/12

DRILL TYPE:	Nissan Patrol Mounted Rig	**SURFACE RL:**	4.7 m
BOREHOLE DIAMETER:	100 mm	**DATUM:**	AHD

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
SolidStem Auger - V Bit			4.5		▨		Silty CLAY: medium plasticity, brown	M ~ w_P	F - St			ALLUVIAL SOIL
				0.5								
			4.0									
				1.0			becoming pale brown mottled orange					
			3.5									
					▨		1.20m CLAY: high plasticity, grey with some fine to medium grained Sand and silt					ALLUVIAL SOIL
	▶—			1.5								
			3.0									
				2.0		CH						
			2.5				Sand becoming fine to coarse grained, trace of fine grained subangular gravel		St			
				2.5	▨		2.50m Sandy CLAY: high plasticity, grey, fine to coarse grained sand, with a trace of subangular gravel, some silt					
			2.0			CH						
				3.0								
			1.5		▨		3.20m CLAY: high plasticity, grey, some silt		St - VSt			
				3.5								
			1.0				becoming grey mottled orange		VSt			
				4.0		CH						
			0.5									
				4.5								
			0.0				4.70m Hole Terminated at 4.70 m					V BIT - REFUSAL
				5.0								
			-0.5									

LEGEND:

Water

- Water Level (Date and time shown)
- ▶— Water Inflow
- —◀ Water Outflow

Strata Changes

- — — Gradational or transitional strata
- —— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - BOREHOLE

CLIENT:	BMT WBM Pty Ltd	**BOREHOLE NO:**	**BH106**
PROJECT NAME:	Proposed Land Rezoning	**PAGE:**	1 OF 1
		JOB NO:	RGS00460.1
		LOGGED BY:	SK
LOCATION:	The Lakesway Charlotte Bay - Refer to figure 1	**DATE:**	22/11/12

DRILL TYPE:	Nissan Patrol Mounted Rig	**SURFACE RL:**	3.6 m
BOREHOLE DIAMETER:	100 mm	**DATUM:**	AHD

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
Solid Stem Auger - V Bit			3.5 3.0	0.5			TOPSOIL: Silty CLAY, low plasticity, brown	$M < W_P$				TOPSOIL
	►—		2.5 2.0	0.70m 1.0 1.5 2.0		CL	CLAY: medium plasticity, grey-brown mottled orange with some silt and a trace of fine to coarse grained sand and fine grained subangular gravel	$M \sim W_P$	F			ALLUVIAL SOIL
			1.5 1.0	2.00m 2.5		CH	CLAY: high plasticity, pale grey with discrete orange mottle, with some to a trace of fine to coarse grained and silt		St			
			0.5 0.0 -0.5	3.0 3.5 4.0			with some fine grained sand					
				4.5				$M \sim W_P$	St - VSt			
			-1.0	4.50m 5.0		CH	Sandy CLAY: high plasticity, fine to medium grained sand, some silt					
			-1.5	5.00m			Hole Terminated at 5.00 m					

LEGEND:

Water

- ▼ Water Level (Date and time shown)
- ►— Water Inflow
- —◄ Water Outflow

Strata Changes

- — — Gradational or transitional strata
- ——— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - TEST PIT

CLIENT:	BMT WBM Pty Ltd	**TEST PIT NO:**	**TP1**
PROJECT NAME:	Proposed Land Rezoning	**PAGE:**	1 OF 1
		JOB NO:	RGS00460.1
		LOGGED BY:	SK
LOCATION:	The Lakes Way Charlotte Bay - Refer to figure 1	**DATE:**	28/11/12

EQUIPMENT TYPE:	Case 580 K Backhoe	**SURFACE RL:**	9.6 m
TEST PIT LENGTH:	**WIDTH:**	**DATUM:**	AHD

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
600mm Rock Tooth Bucket	(None encountered)		9.5	0.10m			TOPSOIL: Silty CLAY, low plasticity, dark brown, trace fine grained Sand					TOPSOIL
				0.35m		CH	CLAY: high plasticity, grey	M < w_P	Fb			COLLUVIAL SOIL
				0.50m		CH	Gravelly CLAY: high plasticity, grey brown mottled yellow orange, fine to coarse grained, highly weathered mudstone gravel					EXTREMELY WEATHERED MUDSTONE
			9.0	0.80m			MUDSTONE: highly to moderately weathered with intermixed extremely to highly weathered material, low to very high strength pale grey to pale brown and dark grey with orange-yellow staining, fractured becoming medium to very high strength					HIGHLY WEATHERED MUDSTONE SLIGHTLY WEATHERED MUDSTONE, MEDIUM TO VERY HIGH STRENGTH
							Hole Terminated at 0.80 m Refusal					

RL (m)	DEPTH (m)
9.5	
	0.5
9.0	
	1.0
8.5	
	1.5
8.0	
	2.0
7.5	
	2.5
7.0	
	3.0
6.5	

LEGEND:

Water

- Water Level (Date and time shown)
- ▶— Water Inflow
- —◀ Water Outflow

Strata Changes

- — — Gradational or transitional strata
- —— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

REGIONAL
GEOTECHNICAL SOLUTIONS

ENGINEERING LOG - TEST PIT

CLIENT: BMT WBM Pty Ltd
PROJECT NAME: Proposed Land Rezoning
LOCATION: The Lakes Way Charlotte Bay

TEST PIT NO: TP2
PAGE: 1 OF 1
JOB NO: RGS00460.1
LOGGED BY: SK
DATE: 28/11/12

EQUIPMENT TYPE: Case 580 K Backhoe
TEST PIT LENGTH:
WIDTH:
SURFACE RL: 7.1 m
DATUM: AHD

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
600mm Rock Tooth Bucket	(None encountered)		7.0				TOPSOIL: Silty CLAY, high plasticity, pale grey	$M < w_P$				TOPSOIL
				0.20m		CH	CLAY: high plasticity, pale yellow to pale brown		H			RESIDUAL SOIL
			6.5	0.5			with grey mottle from 0.5m, relic fabric					
				0.80m		CH	Silty CLAY: medium to high plasticity, pale grey with discrete yellow-orange-red mottle, relic fabric					EXTREMELY WEATHERED MUDSTONE
			6.0	1.0								
		1.30m D 1.40m										
			5.5	1.5						HP	=450	
							slight increase in moisture content from 1.8m					
			5.0	2.0								
		2.40m D 2.50m		2.5								
			4.5	2.70m			becoming pale grey to pale brown with dark red staining and white calate veins					
							Hole Terminated at 2.70 m					
				3.0								

LEGEND:

Water

▼	Water Level (Date and time shown)
►—	Water Inflow
—◄	Water Outflow

Strata Changes

— —	Gradational or transitional strata
——	Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		UCS (kPa)
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - TEST PIT

CLIENT:	BMT WBM Pty Ltd	**TEST PIT NO:**	**TP3**
PROJECT NAME:	Proposed Land Rezoning	**PAGE:**	1 OF 1
		JOB NO:	RGS00460.1
		LOGGED BY:	SK
LOCATION:	The Lakes Way Charlotte Bay	**DATE:**	28/11/12

EQUIPMENT TYPE:	Case 580 K Backhoe	**SURFACE RL:**	3.8 m
TEST PIT LENGTH:	**WIDTH:**	**DATUM:**	AHD

Drilling and Sampling					Material description and profile information					Field Test		Structure and additional observations
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	
600mm Rock Tooth Bucket	(None encountered)						TOPSOIL: Silty CLAY, medium plasticity, dark brown	M < w_P				TOPSOIL
			3.5							HP	=450	
				0.5			0.50m CLAY: high plasticity, dark grey to grey mottled orange, traces of fine grained Sand in orange mottle, slight 'rotten egg' odour in upper 15.m	M > w_P		HP HP	=220 =250	ALLUVIAL SOIL
			3.0									
				1.0								
									VSt			
			2.5									
				1.5								
						CH						
			2.0							HP	=450	
							some fissures from 1.8m					
				2.0								
									H			
			1.5									
				2.5								
							2.70m					
							Hole Terminated at 2.70 m					
			1.0									
				3.0								

LEGEND:

Water

- ▼ Water Level (Date and time shown)
- ▶— Water Inflow
- —◀ Water Outflow

Strata Changes

- — — Gradational or transitional strata
- —— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - TEST PIT

CLIENT:	BMT WBM Pty Ltd	**TEST PIT NO:**	**TP4**
PROJECT NAME:	Proposed Land Rezoning	**PAGE:**	1 OF 1
		JOB NO:	RGS00460.1
		LOGGED BY:	SK
LOCATION:	The Lakes Way Charlotte Bay	**DATE:**	28/11/12

EQUIPMENT TYPE:	Case 580 K Backhoe	**SURFACE RL:**	4.0 m
TEST PIT LENGTH:	**WIDTH:**	**DATUM:**	AHD

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
600mm Rock Tooth Bucket	(None encountered)		4.0				TOPSOIL: Silty CLAY, medium plasticity, dark brown	$M < w_P$	Fb			TOPSOIL
			3.5	0.30m 0.5		CH	CLAY: high plasticity, dark grey to dark brown mottled orange	$M > w_P$	St	HP HP HP HP HP	=150 =120 =180 =240 =250	ALLUVIAL SOIL
			3.0	0.70m 1.0		CL	CLAY: medium plasticity, pale grey to grey with discrete orange mottle		VSt			
			2.5 2.0 1.5	1.50m 1.5 2.0 2.5		CH	CLAY: high plasticity, grey with discrete orange mottle with some extremely weathered claystone inclusions up to about 100mm in size					RESIDUAL SOIL
			1.0	2.70m 3.0			Hole Terminated at 2.70 m					

LEGEND:

Water

▼ Water Level (Date and time shown)

►— Water Inflow

—◄ Water Outflow

Strata Changes

— — Gradational or transitional strata

—— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

REGIONAL GEOTECHNICAL SOLUTIONS

ENGINEERING LOG - TEST PIT

CLIENT:	BMT WBM Pty Ltd	**TEST PIT NO:**	**TP5**
PROJECT NAME:	Proposed Land Rezoning	**PAGE:**	1 OF 1
		JOB NO:	RGS00460.1
		LOGGED BY:	SK
LOCATION:	The Lakes Way Charlotte Bay	**DATE:**	28/11/12

EQUIPMENT TYPE:	Case 580 K Backhoe	**SURFACE RL:**	10.4 m
TEST PIT LENGTH:	**WIDTH:**	**DATUM:**	AHD

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
600mm Rock Tooth Bucket	(None encountered)			0.15m			TOPSOIL: Sandy Silt CLAY, medium plasticity, grey-brown, fine grained Sand	M < W_P	Fb			TOPSOIL
			10.0	0.5 0.60m		CH	CLAY: high plasticity, brown mottled yellow-orange with some fine grained Sand	M > W_P	H	HP HP HP HP	>600 >600 >600 >600	RESIDUAL SOIL
			9.5	0.90m		CH	CLAY: high plasticity, grey-brown mottled orange with some fine grained Sand					
			9.0	1.0 1.5 1.80m		CH	CLAY: high plasticity, grey mottled orange with some fine to coarse grained Sand		VSt - H			EXTREMELY WEATHERED SANDSTONE
			8.5	1.90m			SANDSTONE: fine to coarse grained, orange					MODERATELY WEATHERED SANDSTONE
			8.0 7.5	2.0 2.5 3.0			Hole Terminated at 1.90 m Refusal					

LEGEND:

Water

- Water Level (Date and time shown)
- Water Inflow
- Water Outflow

Strata Changes

- Gradational or transitional strata
- Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

REGIONAL GEOTECHNICAL SOLUTIONS

ENGINEERING LOG - TEST PIT

CLIENT:	BMT WBM Pty Ltd	**TEST PIT NO:**	**TP6**
PROJECT NAME:	Proposed Land Rezoning	**PAGE:**	1 OF 1
		JOB NO:	RGS00460.1
		LOGGED BY:	SK
LOCATION:	The Lakes Way Charlotte Bay	**DATE:**	28/11/12

EQUIPMENT TYPE:	Case 580 K Backhoe		**SURFACE RL:**	19.9 m
TEST PIT LENGTH:		**WIDTH:**	**DATUM:**	AHD

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
600mm Rock Tooth Bucket	(None encountered)						TOPSOIL: Silty SAND: fine to medium grained, dark brown					TOPSOIL
						0.20m	SANDSTONE: moderately weathered, very high strength, fine to medium grained, pale brown and orange and dark grey, Sandstone cobbles and boulders to atleast 600mm in size in a grey sandy matrix					MODERATELY WEATHERED SANDSTONE
			19.5	0.5		0.50m						
							Hole Terminated at 0.50 m Refusal					
			19.0	1.0								
			18.5	1.5								
			18.0	2.0								
			17.5	2.5								
			17.0	3.0								

LEGEND:

Water

▼ Water Level (Date and time shown)

▶— Water Inflow

—◀ Water Outflow

Strata Changes

— — Gradational or transitional strata

—— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition

D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density			
	V	Very Loose	Density Index <15%
	L	Loose	Density Index 15 - 35%
	MD	Medium Dense	Density Index 35 - 65%
	D	Dense	Density Index 65 - 85%
	VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - TEST PIT

CLIENT:	BMT WBM Pty Ltd	**TEST PIT NO:**	**TP7**
PROJECT NAME:	Proposed Land Rezoning	**PAGE:**	1 OF 1
		JOB NO:	RGS00460.1
		LOGGED BY:	SK
LOCATION:	The Lakes Way Charlotte Bay	**DATE:**	28/11/12

EQUIPMENT TYPE:	Case 580 K Backhoe	**SURFACE RL:**	18.1 m
TEST PIT LENGTH:	**WIDTH:**	**DATUM:**	AHD

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
60mm Rock Tooth Bucket	(None encountered)		18.0	0.10m			TOPSOIL: Silty SAND, fine to medium grained, dark grey					TOPSOIL
				0.40m		SC	SAND: fine to medium grained, pale grey, high plasticity fines, some highly to moderately weathered SANDSTONE gravel and cobbles					RESIDUAL SOIL
				0.5 0.50m			SANDSTONE: moderately weathered, high strength, medium to coarse grained, yellow-brown, subangular and subrounded SANDSTONE cobbles and boulders in a pale grey clayey sand matrix					MODERATELY WEATHERED SANDSTONE
			17.5				Hole Terminated at 0.50 m Refusal					
			17.0	1.0								
			16.5	1.5								
			16.0	2.0								
			15.5	2.5								
			15.0	3.0								

LEGEND:

Water

- ▼ Water Level (Date and time shown)
- ▶— Water Inflow
- —◀ Water Outflow

Strata Changes

- — — Gradational or transitional strata
- —— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - TEST PIT

CLIENT:	BMT WBM Pty Ltd	**TEST PIT NO:**	**TP8**
PROJECT NAME:	Proposed Land Rezoning	**PAGE:**	1 OF 1
		JOB NO:	RGS00460.1
		LOGGED BY:	SK
LOCATION:	The Lakes Way Charlotte Bay	**DATE:**	28/11/12

EQUIPMENT TYPE:	Case 580 K Backhoe	**SURFACE RL:**	9.8 m
TEST PIT LENGTH:	**WIDTH:**	**DATUM:**	AHD

Drilling and Sampling — METHOD: 600mm Rock Tooth Bucket; WATER: (None encountered); SAMPLES; RL (m); DEPTH (m)

DEPTH (m)	RL (m)	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
0.10m			TOPSOIL: Silty SAND, fine grained, grey-brown	M < W_P				TOPSOIL
0.60m	9.5	CH	Sandy CLAY: medium to high plasticity, brown, fine grained sand	M < W_P	H	HP	=600	COLLUVIAL SOIL
0.90m	9.0	GC	Clayey GRAVEL: fine to coarse grained angular to rounded moderately weathered SANDSTONE gravel, yellow-orange gravel and grey highly plasticity clay	M < W_P	D			
1.70m	8.5	CH	CLAY: high plasticity, grey mottled red with some fine to coarse grained subrounded and rounded gravel	M > W_P	St - VSt			COLLUVIAL/RESIDUAL SOIL
2.00m	8.0	CH	CLAY: high plasticity, pale grey mottled orange	M < W_P M > W_P	H St			RESIDUAL SOIL
2.10m			SANDSTONE: highly to moderately weathered, fine to medium grained, orange-brown, intermixed extremely weathered material	M > W_P	St			HIGHLY TO MODERATELY WEATHERED SANDSTONE

Hole Terminated at 2.10 m
Refusal

LEGEND:

Water

- ▼ Water Level (Date and time shown)
- ►— Water Inflow
- —◄ Water Outflow

Strata Changes

- — — Gradational or transitional strata
- —— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - TEST PIT

TEST PIT NO: TP9
PAGE: 1 OF 1
CLIENT: BMT WBM Pty Ltd
JOB NO: RGS00460.1
PROJECT NAME: Proposed Land Rezoning
LOGGED BY: SK
LOCATION: The Lakes Way Charlotte Bay
DATE: 28/11/12

EQUIPMENT TYPE: Case 580 K Backhoe
SURFACE RL: 4.0 m
TEST PIT LENGTH:
WIDTH:
DATUM: AHD

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
600mm Rock Tooth Bucket	(None encountered)						TOPSOIL: Silty CLAY, low plasticity, dark brown	M < w$_P$	VSt			TOPSOIL
				0.10m		CL	CLAY: medium plasticity, grey-brown with discrete orange mottle					ALLUVIAL SOIL
			3.5	0.5				M > w$_P$				
										HP	=250	
										HP	=150	
									St	HP	=80	
										HP	=30	
									F	HP	=30	
			3.0	1.0					S			
		1.30m		1.30m		CL	Silty CLAY: medium plasticity, grey, intermixed zones of orange-brown iron oxide stained extremely weathered mudstone intermixed + soft to firm layers	M > w$_P$	St			
			2.5	1.5								
		D	2.0	2.0					H			
			1.5	2.5								
		2.60m		2.60m		CL	Silty CLAY: low to medium plasticity, pale grey	M < w$_P$				
		D 2.80m		2.80m			Hole Terminated at 2.80 m					
			1.0	3.0								

LEGEND:

Water

- Water Level (Date and time shown)
- ▶— Water Inflow
- —◀ Water Outflow

Strata Changes

- — — Gradational or transitional strata
- —— Definitive or distict strata change

Notes, Samples and Tests

U$_{50}$	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W$_p$	Plastic Limit
W$_L$	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

REGIONAL GEOTECHNICAL SOLUTIONS

ENGINEERING LOG - TEST PIT

CLIENT:	BMT WBM Pty Ltd	**TEST PIT NO:**	**TP10**
PROJECT NAME:	Proposed Land Rezoning	**PAGE:**	1 OF 1
		JOB NO:	RGS00460.1
		LOGGED BY:	SK
LOCATION:	The Lakes Way Charlotte Bay	**DATE:**	28/11/12

EQUIPMENT TYPE:	Case 580 K Backhoe	**SURFACE RL:**	4.0 m
TEST PIT LENGTH:	**WIDTH:**	**DATUM:**	AHD

Drilling and Sampling					Material description and profile information					Field Test		Structure and additional observations
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	
600mm Rock Tooth Bucket			3.5	0.5		CL	Silty CLAY: medium plasticity, pale brown	$M < w_P$ $M > w_P$	H VSt	HP HP HP HP	=450 =250 =250 =200	ALLUVIAL SOIL
						CL	0.70m Silty CLAY: medium plasticity, pale grey mottled orange					
		1.30m D 1.50m	3.0 2.5 2.0	1.0 1.5 2.0		CH	0.90m CLAY: high plasticity, pale grey mottled orange, some Silt		St - VSt			
	►—		1.5	2.5		SC	2.10m Clayey SAND: fine to medium grained, pale grey, high plasticity Clay	M	MD			
			1.0	3.0		CH	2.80m CLAY: high plasticity, orange mottled pale grey, with some fine to medium grained red gravel	$M > w_P$				
							3.00m Hole Terminated at 3.00 m					

LEGEND:

Water

- Water Level (Date and time shown)
- ►— Water Inflow
- —◄ Water Outflow

Strata Changes

- — — Gradational or transitional strata
- ——— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

REGIONAL
GEOTECHNICAL SOLUTIONS

ENGINEERING LOG - TEST PIT

CLIENT:	BMT WBM Pty Ltd	**TEST PIT NO:**	**TP11**
PROJECT NAME:	Proposed Land Rezoning	**PAGE:**	1 OF 1
		JOB NO:	RGS00460.1
		LOGGED BY:	SK
LOCATION:	The Lakes Way Charlotte Bay	**DATE:**	28/11/12

EQUIPMENT TYPE:	Case 580 K Backhoe			**SURFACE RL:**	11.6 m
TEST PIT LENGTH:		**WIDTH:**		**DATUM:**	AHD

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
600mm Rock Tooth Bucket	(None encountered)		11.5		▨	CL	Sandy Silty CLAY: low plasticity, dark brown, fine grained Sand	M < W_P	Fb			COLLUVIAL SOIL
			11.0	0.40m 0.5			MUDSTONE: highly to moderately weathered, low to high strength, pale grey and orange-brown intermixed extremely weathered material, excavates as clayey Sandy GRAVEL up to 100mm					HIGHLY TO MODERATELY WEATHERED MUDSTONE
			10.5 10.0 9.5 9.0	1.00m 1.0 1.5 2.0 2.5 3.0			Hole Terminated at 1.00 m Practical Refusal					

LEGEND:

Water

- Water Level (Date and time shown)
- ▶— Water Inflow
- —◀ Water Outflow

Strata Changes

- — — Gradational or transitional strata
- —— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition	
D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density		
V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

ENGINEERING LOG - TEST PIT

TEST PIT NO: TP12
CLIENT: BMT WBM Pty Ltd
PAGE: 1 OF 1
PROJECT NAME: Proposed Land Rezoning
JOB NO: RGS00460.1
LOGGED BY: SK
LOCATION: The Lakes Way Charlotte Bay
DATE: 28/11/12

EQUIPMENT TYPE: Case 580 K Backhoe
SURFACE RL: 15.2 m
TEST PIT LENGTH:
WIDTH:
DATUM: AHD

Drilling and Sampling					Material description and profile information					Field Test		
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics,colour,minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	Structure and additional observations
600mm Rock Tooth Bucket	(None encountered)						TOPSOIL: Silty CLAY, low plasticity, dark brown					TOPSOIL
			15.0	0.5		CL	0.10m Sandy CLAY: medium plasticity, grey, fine grained Sand	M < w_P	Fb			COLLUVIAL SOIL
			14.5 14.0	1.0			0.60m MUDSTONE and SANDSTONE: highly to moderately weathered, medium to high strength, fine to medium grained, orange-brown excavates as high plasticity clayey gravel up to 100mm in size					HIGHLY TO MODERATELY WEATHERED MUDSTONE AND SANDSTONE
			13.5 13.0 12.5	1.5 2.0 2.5 3.0			1.40m Hole Terminated at 1.40 m Refusal					

LEGEND:

Water

- ▼ Water Level (Date and time shown)
- ▶— Water Inflow
- —◀ Water Outflow

Strata Changes

- — — Gradational or transitional strata
- —— Definitive or distict strata change

Notes, Samples and Tests

U_{50}	50mm Diameter tube sample
CBR	Bulk sample for CBR testing
E	Environmental sample (Glass jar, sealed and chilled on site)
ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
B	Bulk Sample

Field Tests

PID	Photoionisation detector reading (ppm)
DCP(x-y)	Dynamic penetrometer test (test depth interval shown)
HP	Hand Penetrometer test (UCS kPa)

Consistency		**UCS (kPa)**
VS	Very Soft	<25
S	Soft	25 - 50
F	Firm	50 - 100
St	Stiff	100 - 200
VSt	Very Stiff	200 - 400
H	Hard	>400
Fb	Friable	

Moisture Condition

D	Dry
M	Moist
W	Wet
W_p	Plastic Limit
W_L	Liquid Limit

Density

V	Very Loose	Density Index <15%
L	Loose	Density Index 15 - 35%
MD	Medium Dense	Density Index 35 - 65%
D	Dense	Density Index 65 - 85%
VD	Very Dense	Density Index 85 - 100%

Appendix B

Laboratory Test results

RESULTS OF WATER ANALYSIS (Page 1 of 1)

6 samples supplied by Regional Geotechnical Solutions Pty Ltd on the 6th December, 2012 - Lab. Job No. C3618

Analysis requested by Simon Keen - **Your Project: P# RGS004601**

(44 Bent Street, WINGHAM NSW 2429)

PARAMETER	METHODS REFERENCE	Sample 1 BH101	Sample 2 BH102	Sample 3 BH103	Sample 4 BH104	Sample 5 BH105	Sample 6 BH106
	Job No.	*C3618/1*	*C3618/2*	*C3618/3*	*C3618/4*	*C3618/5*	*C3618/6*
pH	APHA 4500-H^+-B	6.92	6.27	5.82	5.64	6.53	6.60
CONDUCTIVITY (EC) (dS/m)	APHA 2510-B	6.92	15.78	3.91	6.16	2.20	4.45
TOTAL DISSOLVED SALTS (mg/L)	calculation using EC x 680	4,706	10,730	2,659	4,189	1,496	3,026
TOTAL SUSPENDED SOLIDS (mg/L)	GFC equiv. filter - APHA 2540-D	1,008	92	32	75	76	110
TOTAL PHOSPHORUS (mg/L P)	APHA 4500 P-H	0.08	0.05	0.02	0.04	0.07	0.06
ORTHOPHOSPHATE (mg/L P)	APHA 4500 P-G	0.006	0.009	<0.005	<0.005	<0.005	0.019
TOTAL NITROGEN (mg/L N)	APHA 4500 N-C	0.44	0.51	0.17	0.23	0.43	0.46
NITRATE (mg/L N)	APHA 4500 NO_3^--F	0.005	0.111	0.009	0.018	0.015	0.015
NITRITE (mg/L N)	APHA 4500 $NO3^-$-I	0.002	0.014	0.001	0.001	0.002	0.005
AMMONIA (mg/L N)	APHA 4500 NH_3-H	0.146	0.042	0.007	0.001	0.218	0.051

Notes:

1. 1 mg/L (milligram per litre) = 1 ppm (part per million) = 1000 µg/L (micrograms per litre)= 1000 ppb (part per billion)
2. For conductivity - 1 dS/m = 1 mS/cm = 1000 µS/cm
3. Analysis performed according to APHA, 2005, “Standard Methods for the Examination of Water & Wastewater”, 21st Edition, except where stated otherwise.
4. Analysis conducted between sample arrival date and Report provision date

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checked: ....
Graham Lancaster (Nata signatory)
Laboratory Manager

FALLING HEAD INFILTRATION TEST - UNCASED HOLE

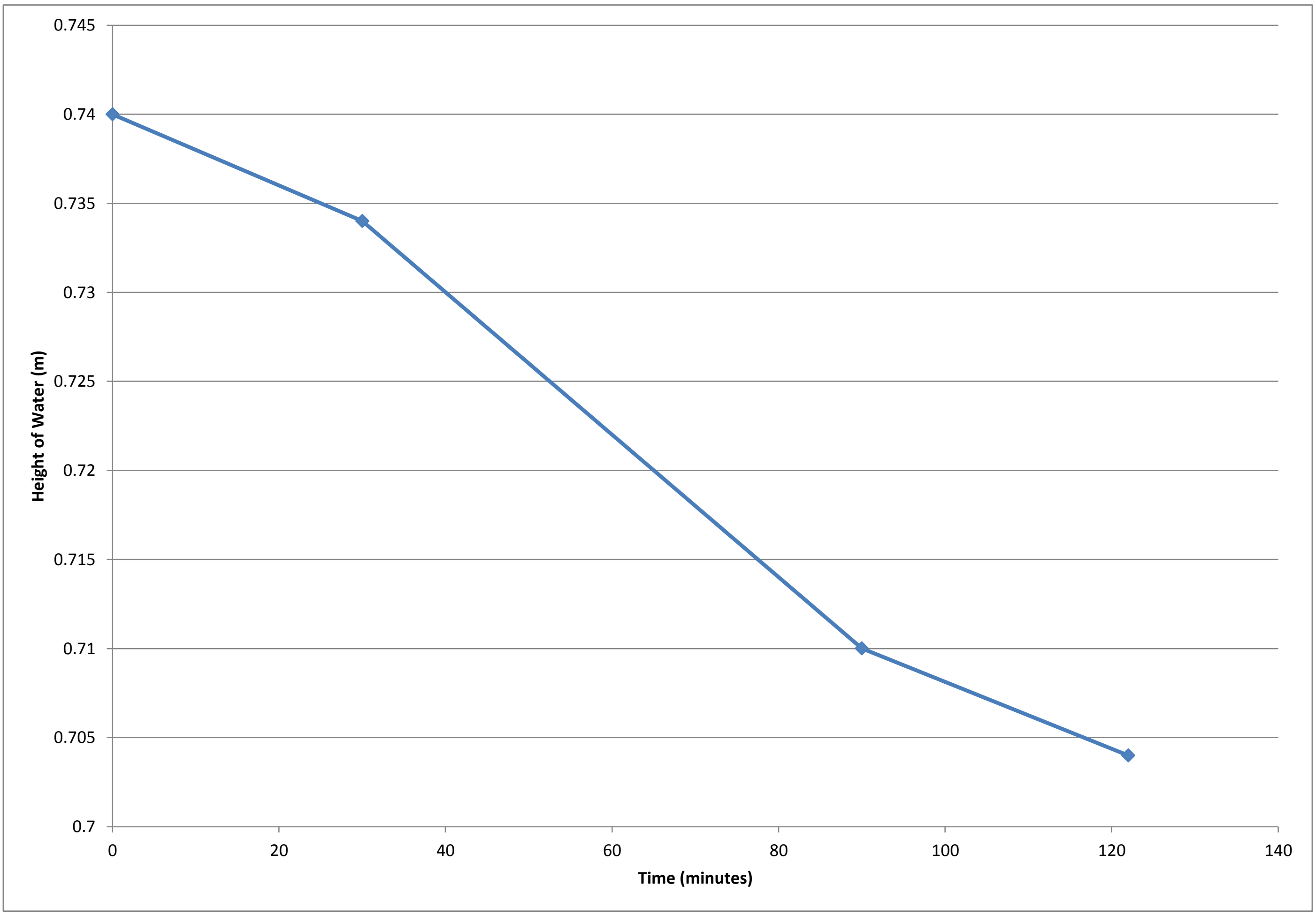
CLIENT: BMT WBM Pty Ltd
Job No.: RGS00460.1
PROJECT: Geotechnical Assessment for Proposed Land Rezoning
By: SK
LOCATION: Lots 110 & 112 DP1091944, The Lakes Way, Charlotte Bay

Date: 26-Nov-12

Test number: TP3
Hole radius (m): 0.05
Hole depth(m): 1
Depth to water table(m): Not Encontered

Test Location: See Figure 1
Surface RL: 3.81m AHD
Water table RL(m) Not Encountered
(Porchet, page 292 in Kessler & Oosterbaan 1974)

Reading	Time elapsed (min)	Depth to water (m)	Height of Water (m)	Head loss (m)	Cum. head loss (m)	Volume loss (L)	Cum. Volume loss (L)	Calculations
1	0	0.26	0.74					Constant loss time period:
2	30	0.266	0.734	0.006	0.006	4.7E-05	4.7E-05	Time 1: 90 Height of Water: 0.71
3	90	0.29	0.71	0.024	0.03	1.9E-04	2.4E-04	Time 2: 122 Height of Water: 0.704
4	122	0.296	0.704	0.006	0.036	4.7E-05	2.8E-04	Total time (min): 32
5								Total head loss (m): 0.006
6								Volume of water lost (L): 0.0471
7								Flow rate (L/sec): 2.45E-05
8								
9								In situ Permeability:
10								
11								1.07E-07 m/sec
12								(x 10m/sec)



FALLING HEAD INFILTRATION TEST - UNCASED HOLE

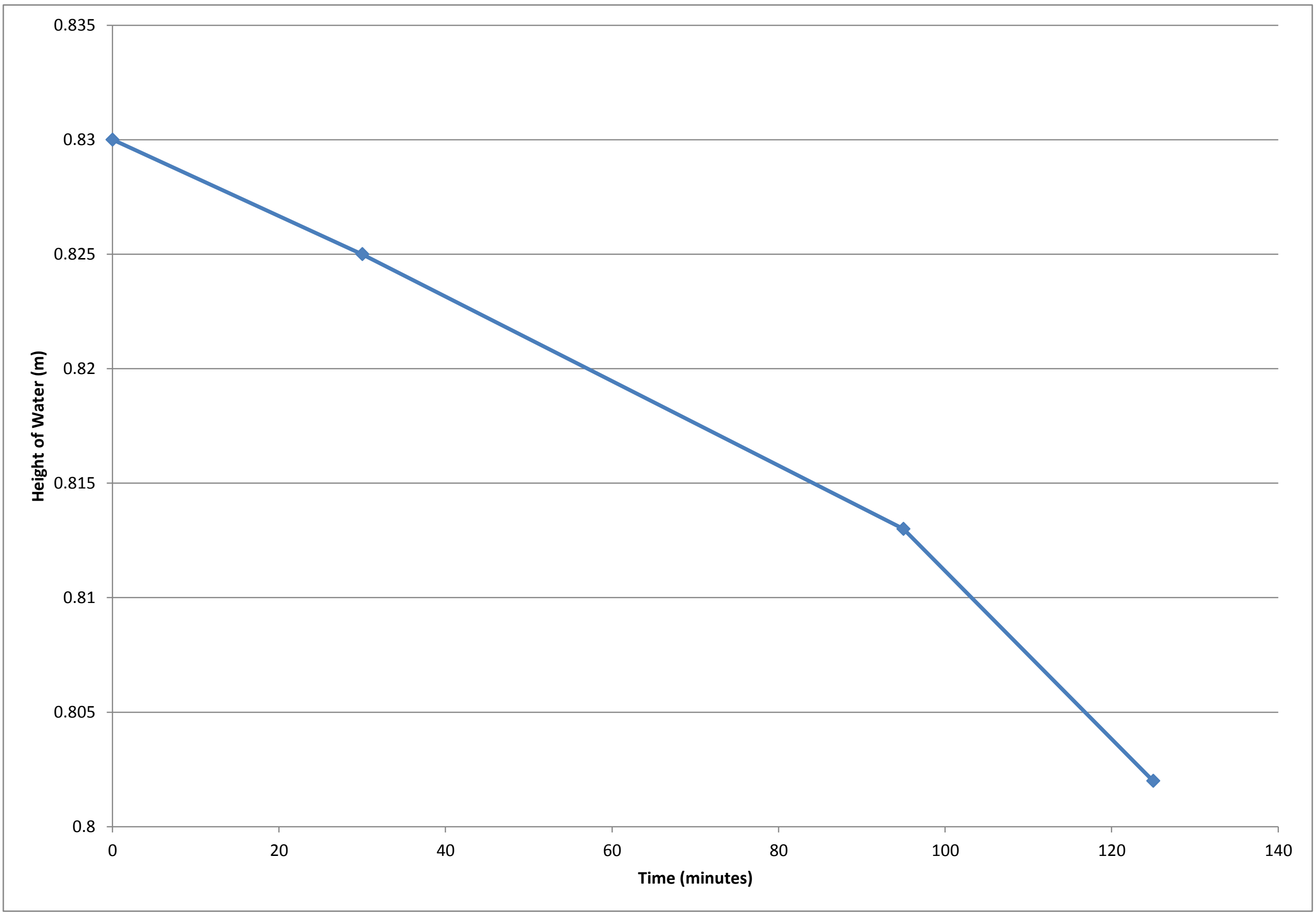
CLIENT: BMT WBM Pty Ltd
Job No.: RGS00460.1
PROJECT: Geotechnical Assessment for Proposed Land Rezoning
By: SK
LOCATION: Lots 110 & 112 DP1091944, The Lakes Way, Charlotte Bay

Date: 26-Nov-12

Test number: TP4
Hole radius (m): 0.05
Hole depth(m): 1
Depth to water table(m): Not Encountered

Test Location: See Figure 1
Surface RL: 4.04m AHD
Water table RL(m) Not Encountered
(Porchet, page 292 in Kessler & Oosterbaan 1974)

Reading	Time elapsed (min)	Depth to water (m)	Height of Water (m)	Head loss (m)	Cum. head loss (m)	Volume loss (L)	Cum. Volume loss (L)	Calculations			
1	0	0.17	0.83					Constant loss time period:			
2	30	0.175	0.825	0.005	0.005	3.9E-05	3.9E-05	Time 1:	95	Height of Water:	0.813
3	95	0.187	0.813	0.012	0.017	9.4E-05	1.3E-04	Time 2:	125	Height of Water:	0.802
4	125	0.198	0.802	0.011	0.028	8.6E-05	2.2E-04	Total time (min):			30
5								Total head loss (m):			0.011
6								Volume of water lost (L):			0.0864
7								Flow rate (L/sec):			4.8E-05
8											
9								In situ Permeability:			
10											
11								1.83E-07			m/sec
12								(x 10m/sec)			



FALLING HEAD INFILTRATION TEST - UNCASED HOLE

CLIENT: BMT WBM Pty Ltd

PROJECT: Geotechnical Assessment for Proposed Land Rezoning

LOCATION: Lots 110 & 112 DP1091944, The Lakes Way, Charlotte Bay

Job No.: RGS00460.1

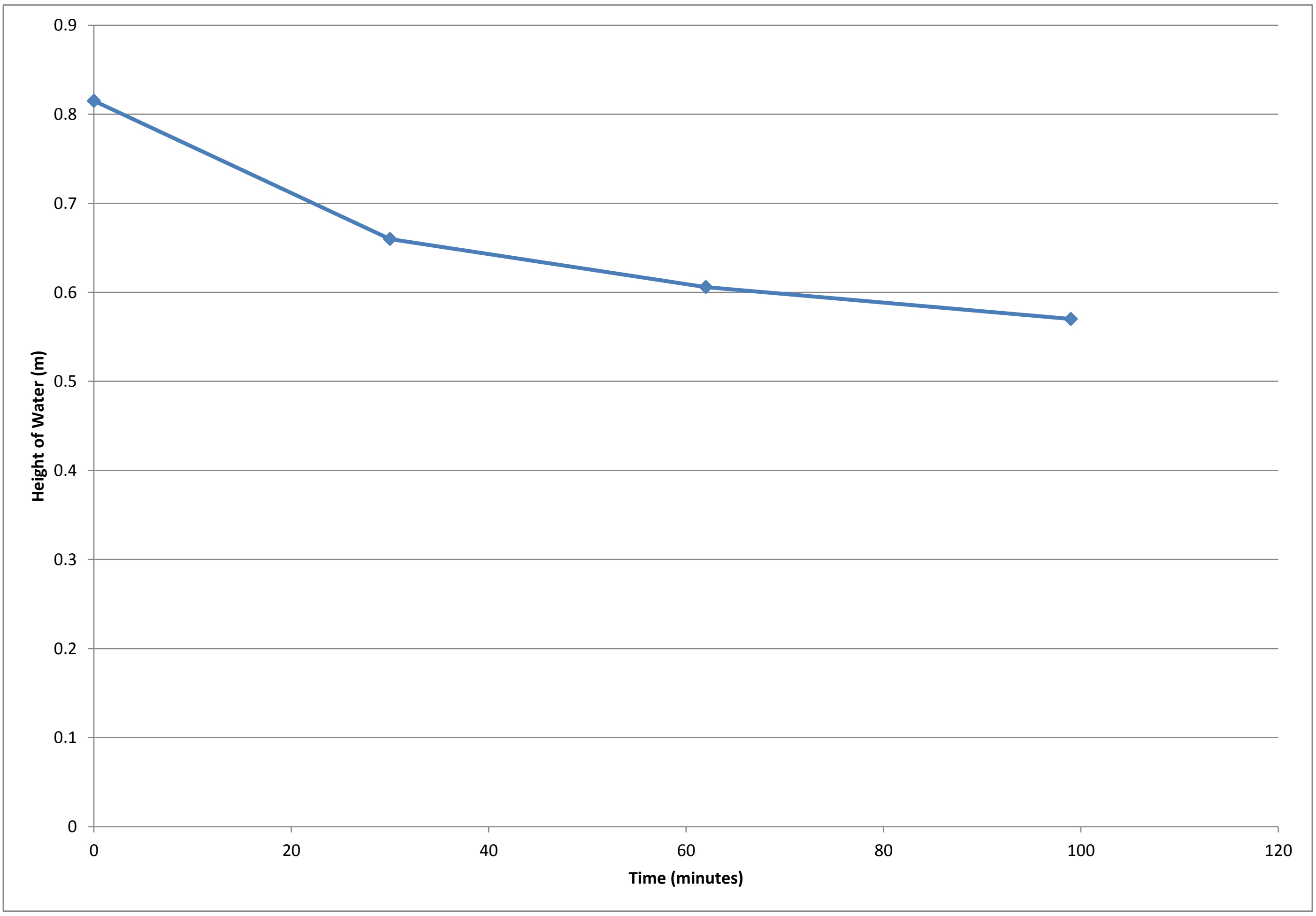
By: SK

REGIONAL GEOTECHNICAL SOLUTIONS

Date: 26-Nov-12

Test number:	TP9	Test Location:	See Figure 1
Hole radius (m):	0.05	Surface RL:	3.99m AHD
Hole depth(m):	1	Water table RL(m)	Not Encountered
Depth to water table(m):	Not Encountered	(Porchet, page 292 in Kessler & Oosterbaan 1974)	

Reading	Time elapsed (min)	Depth to water (m)	Height of Water (m)	Head loss (m)	Cum. head loss (m)	Volume loss (L)	Cum. Volume loss (L)	Calculations			
1	0	0.185	0.815					Constant loss time period:			
2	30	0.34	0.66	0.155	0.155	1.2E-03	1.2E-03	Time 1:	30	Height of Water:	0.66
3	62	0.394	0.606	0.054	0.209	4.2E-04	1.6E-03	Time 2:	99	Height of Water:	0.57
4	99	0.43	0.57	0.036	0.245	2.8E-04	1.9E-03	Total time (min):			69
5								Total head loss (m):			0.09
6								Volume of water lost (L):			0.7069
7								Flow rate (L/sec):			0.000171
8											
9								In situ Permeability:			
10											
11								8.50E-07			m/sec
12								(x 10m/sec)			



FALLING HEAD INFILTRATION TEST - UNCASED HOLE

REGIONAL GEOTECHNICAL SOLUTIONS

CLIENT: BMT WBM Pty Ltd

PROJECT: Geotechnical Assessment for Proposed Land Rezoning

LOCATION: Lots 110 & 112 DP1091944, The Lakes Way, Charlotte Bay

Job No.: RGS00460.1

By: SK

Date: 26-Nov-12

Test number:	TP9	Test Location:	See Figure 1
Hole radius (m):	0.05	Surface RL:	3.99m AHD
Hole depth(m):	1	Water table RL(m)	Not Encountered
Depth to water table(m):	Not Encountered	(Porchet, page 292 in Kessler & Oosterbaan 1974)	

Reading	Time elapsed (min)	Depth to water (m)	Height of Water (m)	Head loss (m)	Cum. head loss (m)	Volume loss (L)	Cum. Volume loss (L)
1	0	0.24	0.76				
2	30	0.254	0.746	0.014	0.014	1.1E-04	1.1E-04
3	59	0.267	0.733	0.013	0.027	1.0E-04	2.1E-04
4	101	0.282	0.718	0.015	0.042	1.2E-04	3.3E-04
5							
6							
7							
8							
9							
10							
11							
12							

Calculations

Constant loss time period:

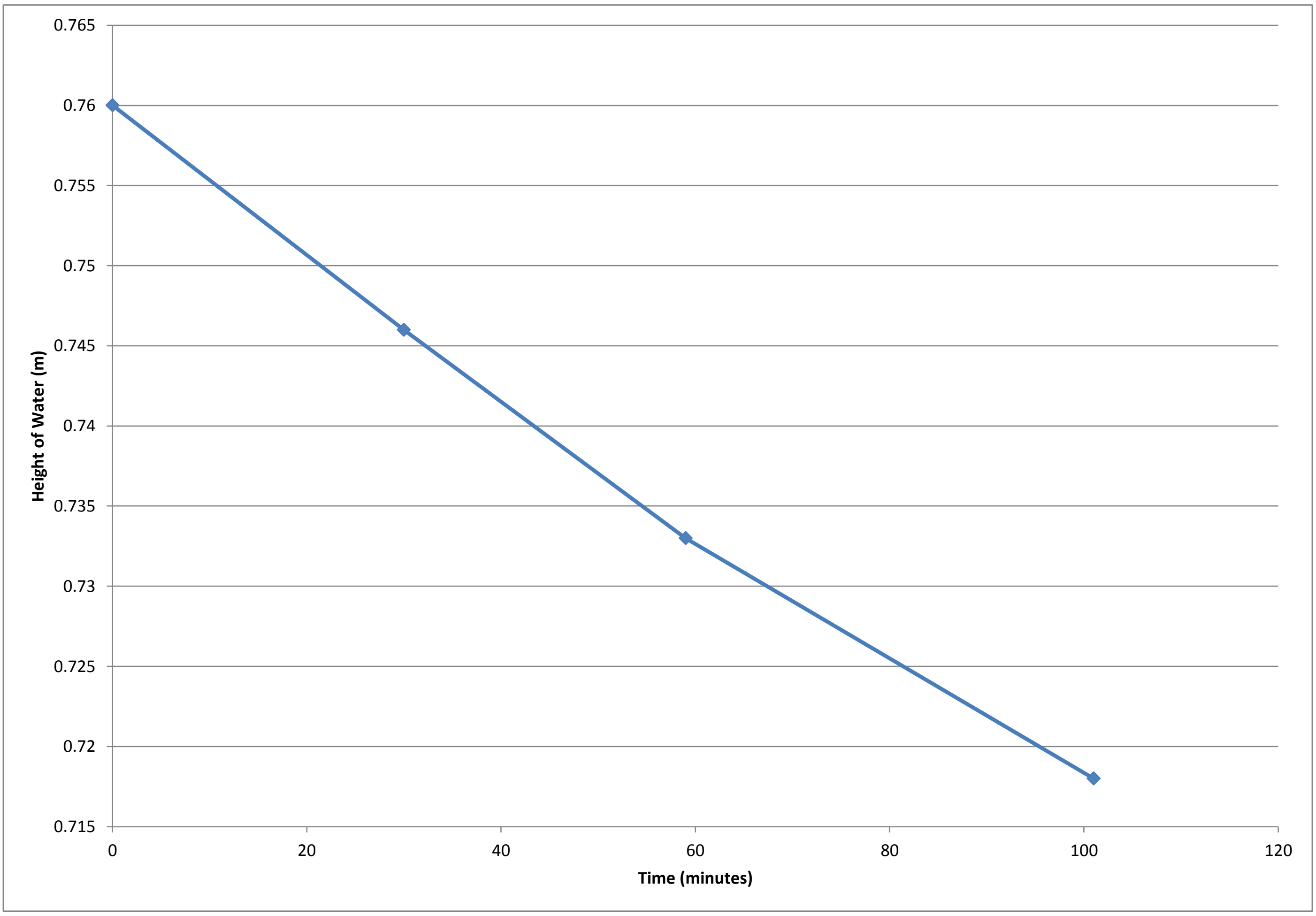
Time 1:	30	Height of Water:	0.746
Time 2:	101	Height of Water:	0.718

Total time (min):	71
Total head loss (m):	0.028
Volume of water lost (L):	0.2199
Flow rate (L/sec):	5.16E-05

In situ Permeability:

2.17E-07 m/sec

(x 10m/sec)



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