Riverview Projects (ACT) Pty Ltd

Proposed Re-zoning of West Belconnen Land, ACT

West Belconnen Landfill Site - Landfill Related Advice

June 2014

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Executive summary

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

GHD Pty Ltd (GHD) was engaged by Riverview Projects (ACT) Pty Ltd (Riverview) project managers for and on behalf of the ACT Government Land Development Agency and the NSW land owners to provide advice on potential issues associated with future residential development in the vicinity of the West Belconnen Landfill Site (WBLS). This advice was required as:

- Substantial areas of land adjacent to the WBLS are proposed to be re-zoned for future residential development; and
- Riverview wishes to re-develop and incorporate the WBLS as the centre piece of the proposed future development.

Scope of Works

This scope of works essentially required the identification and consideration of a number of potential opportunities and constraints associated with the WBLS, specifically as they related to the proposed overarching development project. Specifically, GHD was required to provide advice on:

- Existing conditions that may be relevant to the future use and development of the WBLS as part of the proposed land re-zoning;
- The potential for landfill mining and heat recovery from landfilled waste at the WBLS;
- Impacts of existing surface water quality in Spring Creek and whether it provides some constraints to potential uses of the watercourse
- The potential suitability of the WBLS for selected possible future land uses;
- Additional investigative or monitoring works that may be required to assist future decision making regarding the future use of the WBLS;
- Additional investigative or monitoring works that may be required to support the proposed land re-zoning of land adjacent to the WBLS for future development; and
- Potentially appropriate buffer distances that should be applied to development in the vicinity of the WBLS.

The principal conclusions of this report in relation to the above are as follows:

Site Analysis and Testing

Existing information about the WBLC is contained in a number of different documents and drawings. Following the review of the available documentation identified in Appendix C, GHD prepared consolidated drawings of the WBLS.

Existing Uses and Suitability

The WBLS is still used for resource recovery activities, as well as landfilling of asbestos, which will continue until the specific area of the site is filled. It has also been designated as an emergency landfill for the ACT, should the other facilities serving the ACT become unavailable for a short period. Continuation of these current activities is not compatible with future residential development adjacent to the WBLS boundaries. A suitable buffer zone needs to be established to provide proper separation of these activities from an amenity perspective. Currently a minimum buffer zone of 500m applies to the WBLS.

A decision has not been made by the ACT Government about whether the WBLS should continue to be the designated emergency landfill, as this use is most incompatible with future residential development in the vicinity of the WBLS. The future of existing resource recovery activities, within the main site and in the Parkwood Estate adjoining the main site is uncertain. Some types of resource recovery activities may be compatible and indeed complementary to the future residential development, in providing services needed for the development eg waste transfer facilities. Excessively noisy, dusty and potentially odorous activities are not compatible with such uses.

The WBLS therefore presents a mixture of opportunities and constraints in relation to both on-site and off-site future development. A number of these opportunities and constraints are not currently fully understood / defined at a detailed level. Further investigations / assessments are required to further understand the identified opportunities and constraints.

Future Uses and Suitability

Future land uses of the WBLS have not yet been determined. It is critical to decide which areas of the WBLS would be used for the individual future land uses to enable additional investigative works identified within this report to be further refined (and subsequently undertaken). Completion of these works would allow further understanding of the opportunities and constraints presented by the WBLS as they relate to the proposed future on-site and off-site developments.

All of the uses of the WBLS listed in Table 6-2 could occur in the medium to long term, once settlement of landfilled waste is well advanced. However the level and type of access to the site would affect the risk profile of the different uses.

For example, recycling activities are compatible with the current uses of the site and public access to the site would be restricted to certain areas. As such, this type of use would require less investigation and on-going management than other “new” uses, such as community gardens or equestrian activity where public access is uncontrolled.

Uses involving buildings such as indoor resource recovery or education/administration facilities should ideally only be considered for areas that have not been previously landfilled. For any buildings and underground pipes, allowance for ongoing settlement needs to be part of the design. Gas prevention and ongoing detection measures would be needed for any buildings placed on the site, and any buried infrastructure such as pipes and electrical pits.

Passive recreational uses would be most applicable over the various areas of the site. Forestry would be possible but ideally not in previously landfilled areas, due to potential disturbance of the cap. Mountain bike trails may be possible in the medium to long term provided the cap is not disturbed. Solar farms would normally be considered for non-landfilled areas due to settlement and the possible risks associated with the combination of landfill gas and potential sparking from power generation equipment.

Additional activities considered

Landfill mining and recovery of heat from landfill sources have been considered in conjunction with some of the future uses outlined above.

In relation to landfill mining, the potential costs and impacts associated with waste disturbance would seem to outweigh the potential benefits of recovering resources and/or creating additional land for redevelopment in most areas of the site. In specific areas such as the tyre disposal area, detailed investigations including a cost benefit analysis would be necessary to make a definitive assessment of the opportunities available. Even if such areas are remediated through this process, they would likely lie within the buffer zone and not be able to be utilised for future residential development. However, if appropriate gas protection is provided for buildings, some commercial activities may be possible.

The assessment of potential heat recovery opportunities has indicated that the landfill gas engine would provide a compact source of high grade heat, due to the high temperatures associated with jacket water and exhaust gases. Utilisation of this heat source may be technically and economically feasible, depending upon the envisaged end use for the heat. However the potential life of the engine on site may be less than 5 years, after which a flare would be used on site. A heat recovery system that can initially use the engine as the heat main source, but can be adapted to extracting heat from the flare exhaust may be a possibility.

Whilst it is technically feasible to recover heat from the landfilled waste and from leachate, this is less likely to be economically viable as it is a dispersed source of low grade heat (relatively low temperature) and therefore may be costly to install and operate the pipework and associated equipment needed to extract the heat over a large area. Heat losses may be a major issue in beneficial usage of the extracted heat, depending upon the end uses. If the site generates a relatively small amount of leachate (which is thought to be the case), the overall amount of heat that could be extracted from this source may be relatively small.

The identified heat recovery projects may not initially be economically viable, but they may be able to be set up as sustainability projects on a demonstration scale to provide improved data. This would provide an opportunity to demonstrate their feasibility to potential users and attract investment for larger scale systems.

Surface Water Impacts

Surface water quality downstream of the WBLS does not appear to be adversely impacted by WBLS activities, and could potentially be harnessed for potential uses. Existing tributaries and drainage lines could be retained or enhanced as water features within the proposed residential development. There is a risk that leachate and / or sediment laden water derived from the WBLS could impact upon off-site surface water in the future if the WBLS is retained as an emergency landfill.

Further Investigation Works (offsite)

A range of investigative works have been suggested to provide greater certainty about certain aspects of the site. The key issue that needs to be investigated prior to redevelopment of the areas adjacent to the WBLS is the potential for off-site migration of landfill gas. This will inform the determination of appropriate buffer zones around the WBLS.

If the future development involves some related activities eg community gardens, commercial plant nurseries being conducted within the WBLS, additional investigative works would be required, focussing on landfill gas emissions. Potential offsite impacts on groundwater are important, however current data indicates that groundwater within the site is largely unaffected by past activities. Landfill gas and settlement would be the principal areas of focus.

Further Investigation Works (onsite)

There is some uncertainty around current sub-surface conditions, which warrants further investigation (the level of which depends on the ultimate proposed future uses of the WBLS). As a minimum, this would involve further cross checking of information sources. However, significant subsurface investigations in relation to landfill gas are needed before any rezoning is contemplated. Other investigations such as settlement potential, or capping thickness investigations would be needed in areas of the WBLC that would be redeveloped.

Buffer Distances

Appropriate buffer distances for surrounding residential development will be dependent upon the future activities to be conducted at the WBLC. The greater the likelihood of dust, odour or noise emissions, the greater would be the buffer distances required. If the WBLS remains as the designated emergency landfill for the ACT, a greater buffer distance will be required than if another site is nominated. Potential issues with subsurface emission of landfill gas also need to be taken into consideration in establishing suitable buffer distances. This issue is likely to become less of a problem in the longer term, as the amount of gas produced by the site diminishes.

It may be possible to reduce the current mandated buffer distance if appropriate investigations are undertaken and reduced buffer distances are approved by an ACT accredited contaminated land auditor.

Recommendations

Recommendations arising from the above are as follows:

- For Riverview to discuss and agree with the relevant stakeholders precisely what the future land uses of the WBLS will be in the future (short, medium and long term) and locations of these land uses at the WBLS;
- Following determination of the above, for Riverview to subsequently refine and undertake the relevant additional investigative works referred to in this report (both on and off-site). Completion of these works would allow further understanding of the opportunities and constraints presented by the WBLS as they relate to the proposed future on-site and off-site developments;
- Finalise the Master Plan design on the basis of new information that has arisen from the additional investigation works; and
- Develop guidelines for future development of specific areas in the vicinity of the WBLS.

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1. Introduction

1.1 Overview

GHD Pty Ltd (GHD) was engaged by Riverview Projects (ACT) Pty Ltd (Riverview) project managers for and on behalf of the ACT Government Land Development Agency and the NSW land owners to provide advice on potential issues associated with future residential development in the vicinity of the West Belconnen Landfill Site (WBLS). This advice was required as:

- Substantial areas of land adjacent to the WBLS are proposed to be re-zoned for future residential development; and
- Riverview wishes to re-develop and incorporate the WBLS as the centre piece of the proposed future development.

This report summarises the works undertaken by GHD to investigate specific issues that may affect, or be affected by the proposed development work, and provides overall conclusions and recommendations in relation to the relevance of each issue.

1.2 Objectives

A further over-arching objective of this report was to undertake the identified tasks with consideration of the Vision for the project, which is "*Creating a sustainable community of international significance in the Nation's capital".*

1.3 Scope of works

GHD undertook the following scope of works as requested by Riverview (with consideration of the Vision as relevant):

- Obtained and reviewed relevant data and information and prepared a description of the WBLS (Section 3)
- Prepared drawings identifying known surface and subsurface conditions at the WBLS (Section 4);
- Assessed the potential for landfill mining of historically landfilled waste materials at the WBLS (Appendix G);
- Assessed potential sources of heat at the WBLS (Appendix H);
- Assessed existing off-site surface water monitoring data (Appendix I);
- Assessed the physical suitability of selected potential future land uses at the WBLS (Section 5 and Section 6);
- Identified additional landfill related investigative and monitoring works that are required to assist future decision making for the WBLS (Section 7);
- Identified additional landfill related investigative and monitoring works that are required to support the proposed re-zoning of land adjacent to the WBLS (Section 8);
- Provided recommendations on potentially appropriate buffer distances that may be required for development in the vicinity of the WBLS (Section 9); and
- Prepared a report summarising the works (i.e. this report).

The scope of works above essentially required the identification and consideration of a number of potential opportunities and constraints associated with the WBLS, specifically as they related to the proposed overarching development project.

1.4 Assumptions

A number of assumptions have been made for the purposes of this report. These include the following (in addition to those noted within the main body of the report):

- The information /data provided to GHD is accurate and representative of the WBLS and its environs;
- All cost estimates contained in the document are indicative only; and
- Where site specific information was not available, GHD have used publically available information (as far as possible).

1.5 Reliance

A large number of documents were obtained, reviewed and relied upon for the purposes of preparation of this report. A comprehensive list of these documents is contained in Appendix C.

2. Project description

2.1 Background

Following a number of years of discussions and negotiations, Corkhill Bros Pty Ltd (Corkhill Group), Reid & Stevens Pty Ltd (Reid & Stevens – part of the Corkhill Group) and the ACT Government signed a Heads of Agreement during May 2013. This Heads of Agreement relates to the proposed re-zoning and subsequent development of substantial areas of land for urban uses in the ACT and NSW. This agreement is understood to outline (amongst other things) that:

- The three parties have agreed to develop land in accordance with agreed project objectives;
- Reid & Stevens can develop NSW into residential and / or commercial lots at a prescribed time; and
- Riverview Projects (ACT) Pty Ltd (Riverview) will act as Development / Project Managers on behalf of the ACT Government through their Land Development Agency (LDA) to develop ACT land for residential uses (specifically Blocks 1605 & 1606).

The parcels of land that are currently under consideration for re-zoning and future development are known as the West Belconnen Study Area (Study Area).

The central portion of the Study Area is occupied by the West Belconnen Landfill Site (WBLS). Due to the potential impacts (amenity, environmental, health & safety etc.) that the WBLS could have on a community built in close proximity, the future use and development of the WBLS is key to the overall land re-zoning and future development.

The illustrative master plan showing how the WBLS may integrate into the proposed future development is contained in Appendix A.

2.2 Project approach

2.2.1 Overview

The approach to the development project was created in consultation with a large number of stakeholders. The project approach is detailed within the *Belconnen Project Sustainability Vision* (the Vision). The Vision contains:

- A project specific vision;
- Project specific objectives; and
- Project specific guiding principles.

A copy of the Vision is contained in Appendix B.

2.2.2 Project vision

The Vision for the overarching project is as follows:

Creating a sustainable community of international significance in the Nation's capital

The overarching project has been conceived and is intended to be delivered on a fully integrated and audited triple bottom line.

2.2.3 Project objectives

The over-arching project objectives are that the project will:

- Be sustainable over time, socially, economically and ecologically (with low and reducing ecological footprint);
- Respond to the local and global environment;
- Provide for future beneficial change to occur in design, infrastructure and regulatory mechanisms;
- Be cost effective, replicable and measurable; and
- Act as a new model that others can follow.

2.2.4 Guiding principles

The Vision contains thirty-one (31) individual Guiding Principles for Sustainable Results (Guiding Principles) that all project management, sub-consultants and referral agencies were expected to use to direct decision making relating to the delivery and development of the overall project. The individual Guiding Principles are based around the five key areas of:

- Partnering;
- Evaluation;
- Ecological;
- Social and Cultural; and
- Economic.

3. Description of the WBLS

3.1 Overview

GHD reviewed the available documentation contained in Appendix C and subsequently prepared this description of the WBLS. GHD notes that much of the information contained in this section of the report has been derived (and updated as relevant / possible from more recently obtained data) from the discussion paper titled *Risks posed by adjacent landfill (GHD, 2012b)*.

3.2 General

ACT NOWaste is the current leaseholder of the WBLS (Block 1586, Belconnen) and is currently responsible for all operations, activities and maintenance aspects that occur there. The WBLS includes the Parkwood Road Recycling Estate (Estate). However, management responsibility for the Estate lies with ACT Department of Land and Property Services.

A number of other commercial resource recycling / recovery operations currently operate at the WBLS, including Canberra Sand and Gravel (green waste recycling facility) and Energy Developments Limited (landfill gas fuelled electricity generation facility), under direct leases with ACT NOWaste. The time periods of these leases are not known.

The Territory Plan 2008 prepared by the Act Government dated 2008[1] (Territory Plan) is the key statutory planning document in the ACT, providing the policy framework for the administration of planning in the ACT. The Territory Plan identifies land use zoning in all areas of the ACT. It also identifies the objectives of each zone and lists development types that are permissible and prohibited in each of the zones.

The WBLS is situated on land that is currently zoned NUZ3 - Hills, Ridges and Buffer. Under the Territory Plan, ancillary land uses such as a landfill site, recycling facility and recycling materials collection are permissible on the WBLS (on a site specific basis) subject to assessment under the ACT “Merit Track”.

3.3 Site location and layout

The WBLS is situated approximately 15 km north west from the centre of Canberra, ACT as shown on Figure 1 below.

[1] GHD notes that the Territory Plan is currently being reviewed by the ACT Government.

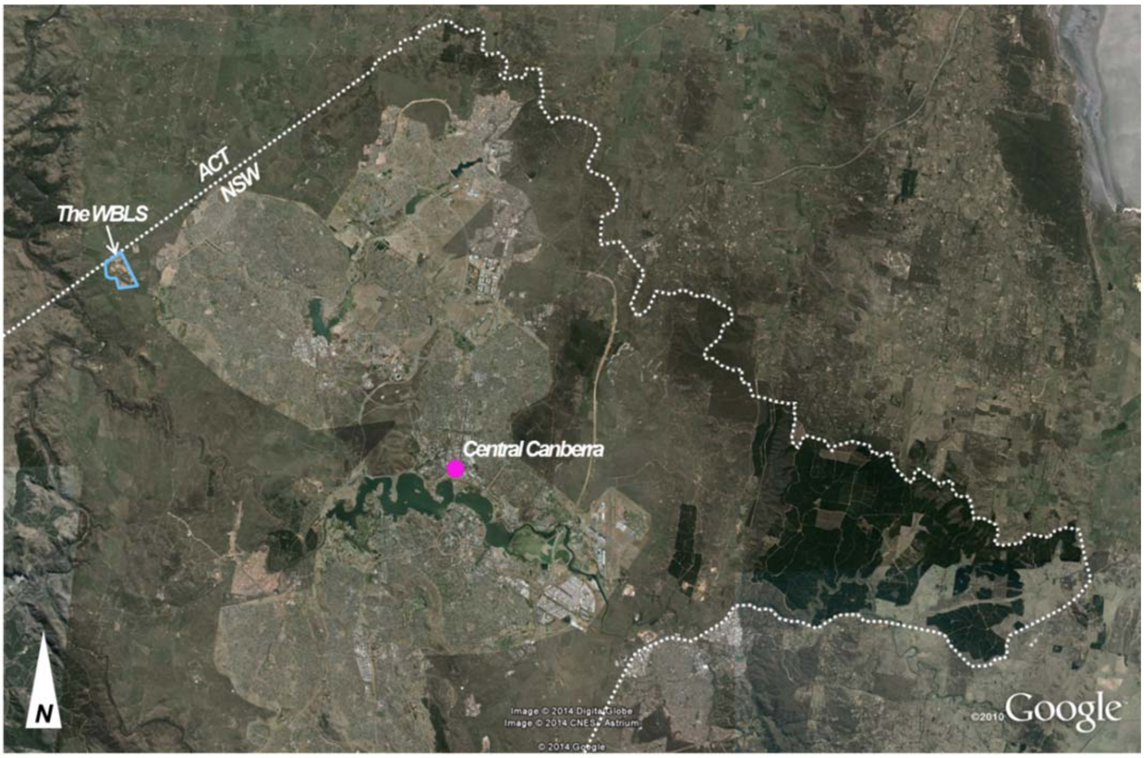

Figure 1 Location of the WBLS in the ACT

The WBLS is located approximately 2 km west of the residential suburbs of Macgregor, Holt and Higgins and is abutted by the NSW/ACT border to the immediate north, Parkwood Road to the east, and open fields to the south and west. The existing access road to the WBLS is located in the site's south eastern corner. Figure 2 below shows the WBLS and its local environmental setting.

Figure 2 Local environmental setting of the WBLS

The WBLS covers an area of approximately 105 hectares, although not all of the land has had waste deposited across / within it. An internal buffer zone of variable width is currently in existence between the waste footprint and the boundary of the WBLS. In some western locations, this buffer may be as much as 300 metres wide, in other locations (notably the north and east of the WBLS) it may be as little as 10 metres wide (or less). The WBLS has a number of features including:

- A green waste recycling facility;
- A weighbridge;
- A public drop-off / recycling facility;
- Historical landfill areas;
- Operational landfill areas (asbestos wastes and cover materials only);
- A number of stormwater collection ponds;
- A landfill gas fuelled electricity generation facility; and
- The Parkwood Estate.

These are illustrated in Figure 3. The Parkwood Estate has an area of approximately 11 ha and is located in the north eastern corner of the WBLS. A number of materials recycling facilities have historically and / or currently operate in this Estate. The Parkwood Estate also contains a pesticide storeroom, a laboratory and a chemical depot.

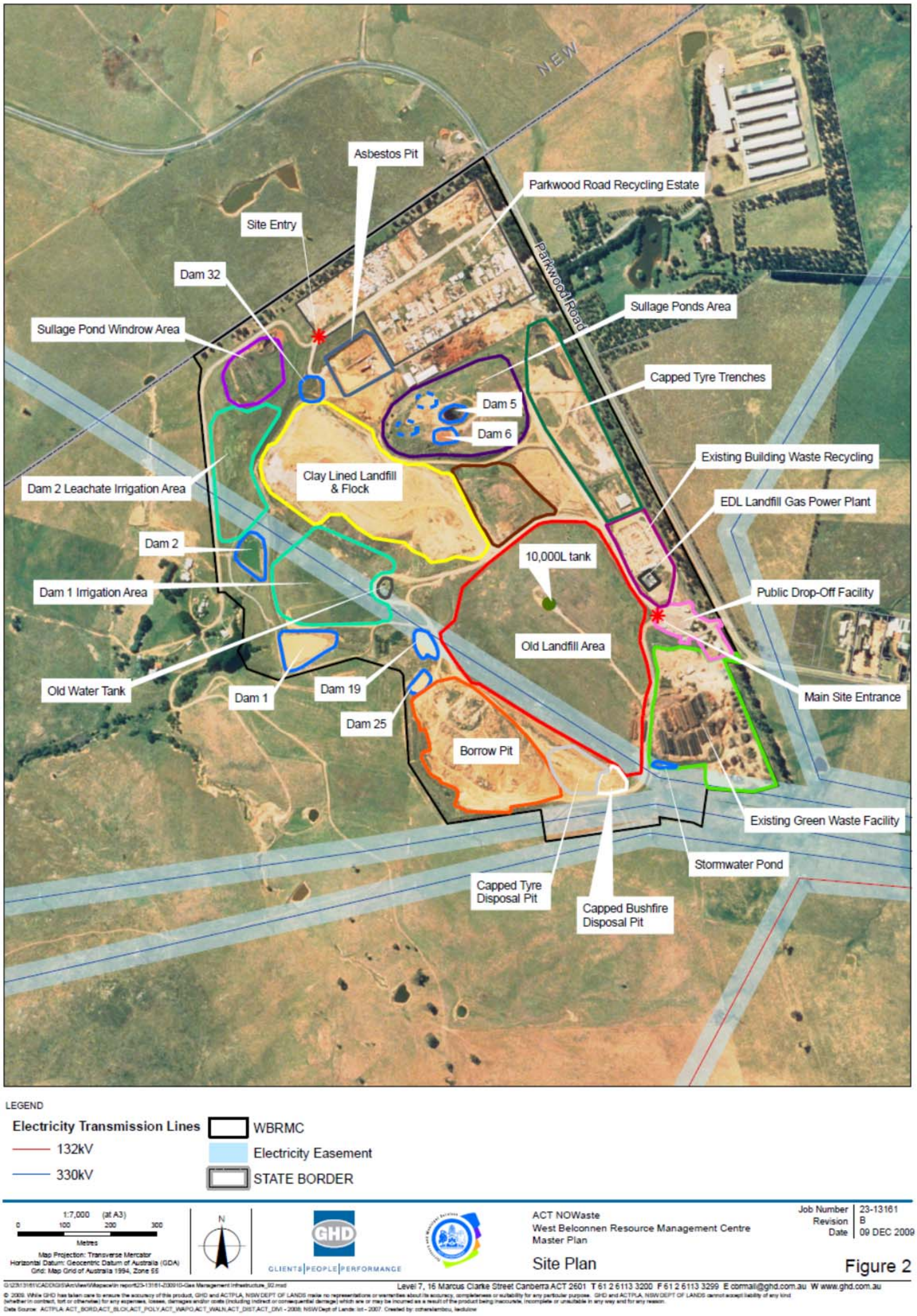

Figure 3 Existing site operations

3.4 Site history

The following description of the history of the WBLS is based on the documentation contained in Appendix C and the aerial photographs contained in Appendix E.

Waste disposal operations at the WBLS are understood to have begun in approximately 1970. Initial operations are understood to have consisted of the excavation and landfilling of a series of trenches across the landfill footprint (commencing in the south eastern corner of the WBLS – beneath the current green waste recycling facility). Following completion of these trenches, the landfilling approach is understood to have altered to an “area fill” method occurring directly across a number of the historically landfilled trenches.

The WBLS was used to landfill predominantly municipal solid waste (MSW), although it is understood that smaller quantities of commercial & industrial, construction & demolition and other wastes have also been disposed of at the site. Use of the WBLS for general waste disposal purposes is understood to have occurred up to 2002. Between 2002 and 2006, only relatively small quantities of special wastes and tyres are understood to have been accepted for disposal at the WBLS.

From 2006 to present, only relatively small quantities of asbestos contaminated materials (and associated cover materials) are understood to have been landfilled at the WBLS. Landfilling of these materials during this period is understood to have been confined to the “Borrow Pit” and the “Asbestos Pit” areas (refer to Appendix D).

It is understood that these materials are sourced on an ad-hoc basis from various development sites within the ACT. The aerial photographs contained in Appendix E suggest that these areas were excavated during the early to mid-1990s and subsequent landfilling commenced soon afterwards.

According to ACT NOWaste, the timing for final filling of these areas depends upon the rate at which waste containing asbestos is produced in the ACT, as this is the only site in the ACT for disposal of such material. Completion of filling may take five to ten years (from the present), which would be followed by remediation (in the form of capping the filled areas).

The Parkwood Estate appears to have commenced operating at around the same time as the landfilling operations (circa 1970) and to have slowly expanded in size to the present.

A number of waste management / resource recovery operations are currently in operation at the WBLS including:

- A green waste recycling facility;
- A public drop-off / recycling facility; and
- Various facilities located in the Estate.

Precise dates for the commencement of these operations are not known by GHD. However, some facilities within the Parkwood Estate may have commenced operation during the early 1970s. Other operations appear to have commenced operation sometime in the mid to late 1990s / early 2000s. It is currently unclear how long some of these operations may continue for as this may change depending on the proposed future development.

The WBLS is currently identified (GHD, 2010d) as the emergency landfill site for the ACT. As such, the WBLS would be used as Canberra’s main landfill site should a situation arise where waste cannot be accepted at the Mugga Lane Resource Management Centre and transporting of waste to another landfill site in NSW is considered prohibitively expensive.

3.5 Waste composition and quantity

No detailed information is available on the composition and quantity of the waste landfilled at the WBLS. Available information suggests that the WBLS accepted predominantly MSW between 1970 and 2002. From 2002 to 2006, the WBLS appears to have only accepted relatively small quantities of special wastes (including asbestos) and tyres. The Borrow Pit and Asbestos Pit areas have accepted asbestos contaminated materials for landfilling since at least 2006 at an approximate combined annual rate of 50,000 tonnes per annum.

A preliminary estimate made by GHD (2010d) suggested a total possible volume of existing landfilled material at the WBLS of circa 5,000,000 m^3. This estimate included (as was perceived at the time) all deposited waste materials[2], all engineering materials (including the final landfill cover layer and daily cover materials) and assumed that the original waste disposal trenches extended across the entire landfilled footprint (as perceived at the time) to a depth of 3 metres below prevailing ground levels.

Since this estimate was prepared, additional survey information and drawings have been provided to GHD which identifies that the landfilled waste mass is likely to be more extensive than previously thought. As such, GHD has revised its earlier estimate and now considers that a total possible volume of landfilled materials of circa 6,500,000 m^3 may be present at the WBLS[3]. GHD further estimates that in addition to the 6,500,000 m^3 of landfilled material noted above, that there may be:

- Circa 1,000,000 m^3 of asbestos contaminated materials (once Asbestos Pit and Borrow Pit are completed); and
- Circa 250,000 m^3 of trenched waste tyres at the WBLS.

The calculations supporting the figures above are further detailed in Appendix G.

It is noted that there is considerable uncertainty in relation to the actual composition and quantity of waste that was landfilled at the WBLS.

No waste is known to have been landfilled below ground level in the Parkwood Estate, although some landfilling does appear to have occurred beneath part of the former ACT NOWaste Woodbusters site.

3.6 Geology

According to a geological evaluation of the site by the Department of National Development Bureau of Mineral Resources, Geology and Geophysics (Broek, 1971), the site is a mildly eroded, perched basin. It is underlain by Silurian Soils from the Mount Painter Porphyry group. The site's geology specifically consists of highly weathered to fresh volcanic and sedimentary rocks, which were mostly covered by a thick layer of soil (Broek, 1971).

The site is shown as being located in an area of Moderate to Moderately High groundwater vulnerability on the NSW Natural Resources Atlas (http://www.nratlas.nsw.gov.au).

The pre-filling soil profile consisted of a thin top soil layer (0.3 m to 0.6 m), underlain by a thick layer of clay (CL to CH in the Unified Soil Classification) (1.5 m to 3 m) and then completely weathered volcanic rock or moderately weathered sedimentary rock (Broek, 1971).

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[2] This estimate excluded the Asbestos Pit Area, Borrow Pit Areas and Tyre Trench Areas.

[3] This estimate excludes the asbestos disposal areas and Tyre Trench Areas.

3.7 Hydrogeology

Hydrogeological information collected at the WBLS prior to its development and operation as a landfill revealed groundwater is present within both confined and unconfined aquifers in the lower portions of the site (Broek, 1971). Seepage after heavy rainfall within the unconfined aquifer, and springs from the confined aquifer through the overlying impermeable layer was observed during geological investigations undertaken prior to the site's development (Broek, 1971).

The permeability of the completely weathered volcanic rock (the confined aquifer) was investigated and estimated at 8.7×10^{-7} cm/sec (Broek, 1971). These geological investigations determined that the site was not hydrologically safe and that lining of trenches with clay was required.

Maximum groundwater levels are generally observed in October-November and minimum levels in February-April (Jacobson, 1978). According to groundwater monitoring data collected by Scientists Engineers Managers & Facilitators (SEMF) in 2013, the water table at the site ranges from approximately 3.5 m below ground level (bgl) (Bore 13) at the south western perimeter to 16.5 m bgl (Bore WBBH5) at the eastern perimeter of the site. Groundwater flow within the confined fractured rock aquifer is generally to the southwest (Jacobson, 1978).

The monitoring results indicate that there have been some exceedences of the ammonia guideline levels (ANZECC freshwater criteria and ACT Environment Protection Regulation levels) in two groundwater bores. There was an unusually high ammonia concentration in Bore 12 in May 2011, but this bore has now returned to a normal situation (groundwater ammonia levels well below criteria). This once off exceedence in Bore 12 suggests that it may have been contaminated by surface water runoff from the leachate irrigation area.

The historical records show that ammonia guideline levels are exceeded in bore WBBH2. This bore is located at the toe of the landfill and the presence and concentrations of ammonia in the water samples from this bore suggests that leachate is entering the groundwater in this area. More investigation of the reasons for elevated ammonia levels in WBBH2 is warranted, as the results indicate a rising trend since 2005.

3.8 Topography and Landform

The main landfill area at the WBLS is a small dome-shaped hillock that rises above the natural ground levels. Prior to filling the site was described as rolling to undulating terrain that was used for grazing (Broek, 1971).

The topography surrounding the WBLS consists of relatively flat plains with small undulating hills to the east of the site. The highest peak reaches circa 600 metres Australian Height Datum (AHD).

The Estate area is generally flat, ranging between approximately 580 and 600 m (AHD) and sloping slightly to the south west (ERM, 2012).

3.9 Hydrology

The Hydrological Report from SEMF (2011) indicates that there are six small dams on the WBLS which act as storage for both clean surface water (Dams 19 and 24), sediments (Dam 1, Dam 25 and Dam 32) and leachate (Dam 2). Each dam is linked to create 3 separate sub-systems (clean water, sediment retention and a leachate treatment system).

The WBLS also has a number of stormwater drains constructed on / across the site and Ginninderra Creek runs to the east of the site. These drains and creek all ultimately drain to the west of the site through part of the proposed development land and finally into the

Murrumbidgee River. (Main drainage from the site is via Spring Creek west directly to the Murrumbidgee River)

Data provided to GHD for some of these surface water locations indicate that there are elevated concentrations of copper and iron present in surface water at a number of locations (dams) across the WBLS. Lead, faecal coliforms and ammonia were also occasionally detected in slightly elevated concentrations at some locations.

There are no known surface water features on the Estate area.

There are a number of small agricultural dams located within the proposed development area adjacent to the WBLS (a number of which are believed to not be currently sampled). Furthermore, there are understood to be at least six tributaries / drainage lines that convey surface water across the proposed development area (all of which ultimately feed into the Murrumbidgee River). Only one of these tributaries / drainage lines is currently believed to be sampled for surface water quality.

Surface water sampled within the monitored tributary located beyond the WBLS boundary (western boundary of the WBLS) was regularly found to have elevated faecal coliform concentrations. This is thought to be attributed to the presence of grazing cattle in the area, as it faecal coliforms are not commonly associated with landfill leachate. Slightly elevated concentrations of mercury and lead have also been detected in this tributary on occasions. These results are not currently considered to indicate significant off-site impacts from the landfill. Water quality beyond the WBLS boundary is further discussed in Appendix I.

3.10 Climate

Rainfall data from the Bureau of Meteorology's weather station at Canberra Airport (site number 070014), taken over a period of over seventy years (1939 – 2010, station ceased operation in 2010), indicate that the annual average rainfall is 616.4 mm. Monthly averages range from the highest in November (64.6 mm) to the lowest in June (40.4 mm), as shown in Figure 4. Average annual evaporation is 1715.5 mm (mean daily average is 4.7 mm), with average daily evaporation data presented in Figure 5.

The mean maximum daily temperatures recorded at Canberra ranged from 28.0°C in January to 11.4°C in July.

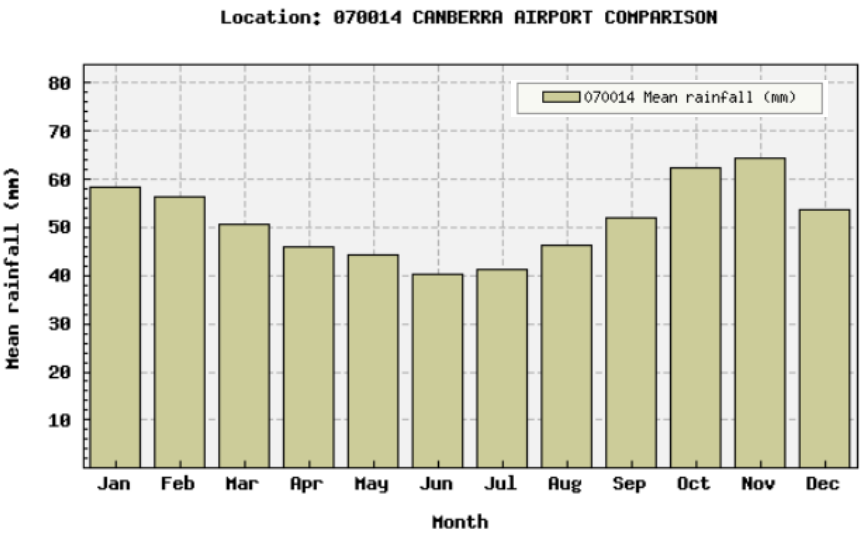


Figure 4 Average monthly rainfall (BOM, 1939 - 2010)

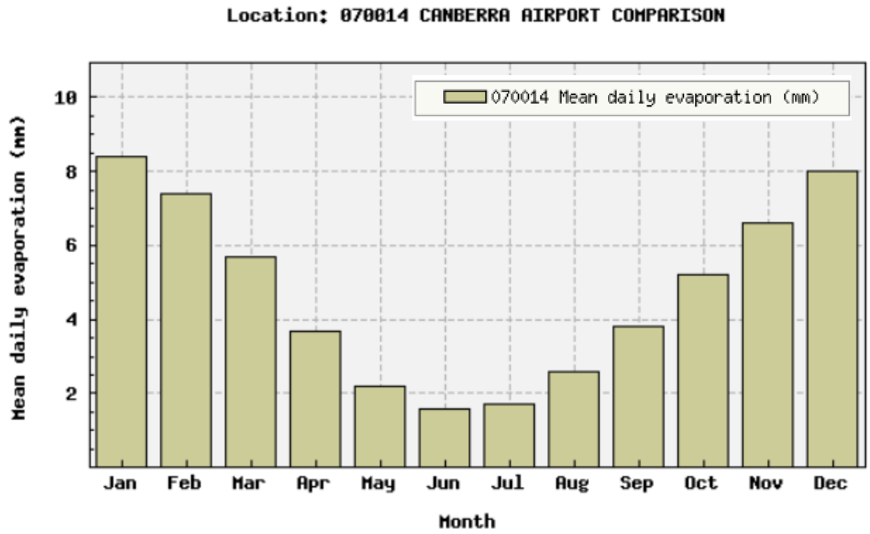


Figure 5 Average daily evaporation (BOM, 1939 - 2010)

3.11 Landfilling operations

Landfilling is understood to have initially been undertaken on a balanced cut and fill trench approach, with soil excavated as part of trenching and utilised as cover material in the landfilling operation. Review of documentations (LT Frazer & Associates, 1973) suggests that the landfill trenches were lined with approximately 300 mm of on-site sourced clay material. The degree of compaction (if any) on the clay is unknown. The trench excavation batter walls are understood to have been approximately 2(H): 1(V), while a pseudo-leachate collection system was provided by a “layer of permeable” (LT Frazer & Associates, 1973) material placed on top of the clay liner.

Based on the local geological profile and the likely operational equipment available for trenching, it was previously (GHD, 2012b) inferred that the depth of the initial trenches was probably limited to the upper clay layer, approximately 1.5 m below ground level (bgl) to 3 m bgl. It was therefore considered unlikely that trenches extend into the underlying weathered volcanic and sedimentary rock.

It is understood that the landfilling style progressed to an area filling practice once landfilling moved above the historical landfilled trenches.

It is understood that the following waste filling and segregation procedures were adopted during the initial landfilling operations (LT Frazer & Associates, 1973):

- Fluffy, elastic, or lightweight materials spread at the bottom of the fill;
- Large bulky objects confined to a separate area of the site;
- Waste placed and compacted in layers no greater than 600 mm;
- Compaction to a target density of 700 kg/m^3;
- Cell height (above natural ground level) from 2 m to 9 m, with the first lift limited to 2 m; and
- Cover material of a minimum 150 mm thick was placed over each cell at the end of each day.

It is noted that landfilling practices at the WBLS will have evolved with time. It is further noted that there is some uncertainty around the precise locations and depths of the landfilled waste mass at the WBLS. This is illustrated on the drawings contained in Appendix D.

Generally no waste is known to have been landfilled below ground level in the Estate, although some landfilling does appear to have occurred beneath part of the former ACT NOWaste Woodbusters site.

3.12 Final landfill cover layer

Geotechnical investigation (GHD, 2009b) identified that the certain locations across the existing final landfill cover layer at that time did not meet the requirements outlined in EPA Victoria's landfill guidelines (selected by ACT NOWaste for assessment purposes). The existing final landfill cover layer across the WBLS consists of clayey sand / sandy clay with occasional gravel / cobble inclusions. It is of a variable thickness ranging between approximately 0.3 m and 1.3 m across the landfill footprint of the WBLS.

Consequently, ACT NOWaste has been upgrading / improving the final cover layer in the required locations to achieve the relevant requirements over recent years. The following works were recommended by GHD in the Landfill Cell Remediation Plan (GHD, 2012e):

- Applying an additional layer of low permeability clay, as shown on drawing 21-18515-C004 in the Landfill Cell Remediation Plan (GHD, 2012e), to achieve a minimum 500mm of compacted clay across the whole of the landfilled waste;
- Fill and shape the surface of the landfilled areas to promote surface water runoff and prevent waterponding. This is to ensure that the surface water management system continues to perform adequately;
- Reshape the steep landfill batter above the Dam 1 leachate irrigation area (on the south western edge of landfill area A) to achieve a slope less than 20%, to ensure the long term stability of the landfill;
- Regrade the steep landfill slopes around to a slope < 20% to ensure longer term stability;
- Revegetate all filled, reshaped, and thickened areas of the landfill, as well as revegetation of any other area where current grassing is poor. The revegetation process should include application of an appropriate layer of topsoil, mulch / compost, or other soil suitable for revegetation, to achieve a total revegetation / protection layer thickness of 300mm.

Anecdotal evidence in the Landfill Cell Remediation Plan (GHD, 2012e) suggests that the current final landfill cover is providing an effective barrier against surface water infiltration (and therefore preventing significant leachate generation). The extent of progress made by ACT NOWaste on upgrading the existing final cover layer and upgrading of the monitoring infrastructure is not known but should be investigated.

Additional investigations into landfill cover thickness and gas emissions through the existing cover are recommended prior to redevelopment of the surrounding area.

3.13 Leachate generation and management

No information is currently available regarding the rate of leachate generation for the WBLS or details for the leachate collection system within the landfill trenches. However, it is understood that leachate generation has reduced in recent years since the majority of waste disposal ceased (2006). This is likely due to the:

- The high net evaporation at the WBLS (evaporation is approximately 1100 mm higher than rainfall);
- The placement of the final landfill cover layer over the landfilled waste; and
- The upgrade / improvement works to the final landfill cover layer.

Based on the available leachate monitoring results, the following key points are noted:

- The leachate pH is typically neutral to moderately alkaline; and
- The leachate quality data in general represents low level concentration of contaminants and therefore suggests some level of dilution with surface waters.

Leachate within the landfilled waste is collected via basic-leachate collection system that comprises a “layer of permeable” (LT Frazer & Associates, 1973) material placed on top of the clay liners within the excavated trenches. It is understood that the trenches were lined with approximately 300 mm of clay to provide a rudimentary leachate containment system.

Leachate generated by the landfill is collected by the leachate collection system and gravity feeds to Dam 2 which acts as both a retention and evaporation pond. As per schedule 2 of the site’s Environmental Authorisation (No. 0374), leachate cannot be discharged offsite through the site’s surface water management system. Therefore all leachate is retained within Dam 2 and can only be disposed of via evaporation or through irrigation over a defined leachate irrigation area.

Perimeter drains constructed along the boundaries of the leachate irrigation areas collect any potential leachate run-off and direct the waters back towards the leachate storage dam (Dam 2), thereby preventing any leachate from being discharged offsite.

The environmental effects of leachate irrigation over the designated irrigation area(s) are unknown, with little information available to GHD in regard to soil contamination. Additional investigations are recommended prior to redevelopment of the surrounding area.

3.14 Landfill gas generation and management

No landfill gas generation / emission model has been provided for the WBLS. However, a previous GHD preliminary estimate (GHD, 2012b) suggests that the WBLS was likely to be generating landfill gas in significant quantities as of 2010 (possibly between 750 and 1250 m^3/hr during 2010). It is uncertain how valid this estimate may now be as a substantial quantity of additional landfilled waste materials have now been identified at the WBLS which were not included within the limited modelling work previously undertaken.

Based on GHD’s experience, it is considered that the WBLS is still likely to be generating landfill gas in significant quantities as of 2014 (and possibly within a similar range as indicated during 2010). It is likely that the WBLS will continue to generate landfill gas for a considerable period from 2014 (>30 years).

There are understood to be two landfill gas collection systems operating at the WBLS. The first is a passive landfill gas collection system consisting of a gravel filled trench located along the toe of the waste batters constructed during the initial landfilling (trenching) operations. The Development Report (LT Frazer & Associates, 1975) describes the gas collection trenches as approximately 600 mm deep and installed to the east of the landfill trenches primarily fronting Parkwood Road.

In addition to the passive system, an active landfill gas collection and treatment system has been installed within the site by Energy Developments Pty Ltd (EDL). The system is operated and maintained by EDL and consists of a series of vertical gas extraction wells installed throughout the landfill waste mass. The wells are linked by an underground pipe network to a series of central gas collection points (manifolds). Landfill gas collected at these manifolds is directed via gas header lines to the landfill gas treatment facility (a landfill gas fuelled engine). The collected landfill gas is combusted in a gas engine which drives a generator, with the green electricity created exported to the electricity grid.

The entire active gas collection system is maintained under a vacuum (or negative pressure) to assist the extraction of landfill gas to the treatment facility. Prior to combustion in the gas engine, the collected landfill gas is processed to remove excess moisture levels and large particles. The active landfill gas collection and treatment system appears to have a reasonable coverage over the main landfilled mound, although it is noted that the gas wells do not extend to the boundary of this area or across certain areas considered likely to contain MSW (e.g. the beneath the current green waste recycling facility). This system is shown on the plan contained in Appendix F.

The available data suggests that the total quantity of landfill gas extracted from the WBLS has reduced from 2003 to 2009 (the most recent data supplied). The most recent data for the system (FYE 2009) suggests that an average of circa 200 – 300 m^3/hr of landfill gas was extracted from the site during that year. This is significantly lower than the preliminary estimate made by GHD of landfill gas generation during 2010 (possibly between 750 and 1250 m^3/hr).

The precise reasons for the reduction in total quantity of landfill gas extracted from the WBLS and the discrepancy between EDL's figures and GHD's estimates are not currently known but should be investigated further and confirmed. Possible reasons could include local climatic conditions (quite dry) and / or the condition / operation of the current landfill gas management system. It is almost certain that the total quantity of landfill gas extracted from the WBLS has further decreased between 2009 and present (although, by how much is not known by GHD).

In the landfill cell rehabilitation plan (GHD, 2012) it was recommended that ACT NOWaste undertook the following:

- Monitoring of surface gas emissions, as per NSW EPA guidelines to assess the performance of landfill cap in terms of gas containment. This will be undertaken before and after completing works to improve the existing landfill capping layer (see Section 5.2);
- Monitoring of surface gas emissions to the east of the old landfill trenches, adjacent to Parkwood Road, where a gas interception trench was installed, to identify if landfill gas emissions are occurring;
- Landfill gas accumulation monitoring across the site, including all above and below ground building and structures within 250m of the landfilled waste; and
- Evaluation of the risk of offsite subsurface landfill gas migration and implementation of an appropriate monitoring program, including installation of subsurface landfill gas monitoring wells if found to be necessary.

Limited landfill gas monitoring was undertaken by GHD during March 2011 to provide information as to the presence or extent of any landfill gas sub-surface migration and / or accumulation off-site. No significant impacts were observed during any of the three monitoring rounds.

No information on any landfill gas monitoring completed by ACT NOWaste or on emissions managed by the landfill gas engine has been provided to GHD. Additional investigations relating to landfill gas emissions from the site are recommended prior to redevelopment of the surrounding area.

3.15 Environmental monitoring

The existing Environmental Authorisation (No. 0374) requires environmental monitoring to be undertaken at a number of locations for various parameters. This includes monitoring of:

- Groundwater;
- Stormwater;

- Leachate; and
- Soil (leachate irrigation area only).

3.15.1 Monitoring locations

The existing Environmental Authorisation (Authorisation) requires monitoring of 10 groundwater monitoring bores located on site (however, it is understood that additional bores are present and monitored voluntarily by ACT NOWaste). Seven bores are located near the western boundary of the WBLS. Two bores are located near the centre of the WBLS, hydrogeologically downstream of the main landfilled mound. An upstream monitoring bore is located near the site entrance.

- Stormwater monitoring is undertaken at Dam 1 and downstream of the WBLS at Tip Creek.
- Leachate monitoring is undertaken at Dam 2 only.
- Soil sampling is undertaken across the leachate irrigation area only.

3.15.2 Monitoring parameters and frequencies

The following paragraphs provide an outline of the mandatory monitoring program as required by the Authorisation. Further details are provided in the Authorisation and the Landfill Cell Remediation Plan (GHD, 2010e).

- The groundwater monitoring bores are to be monitored quarterly for a range of typical groundwater parameters.
- The stormwater monitoring locations are to be monitored quarterly (or six-monthly depending on the precise location) for a range of typical stormwater parameters.
- Leachate quality is to be monitored (at Dam 2) every 6 months, for a range of typical leachate parameters.
- Soil sampling is to be undertaken across the leachate irrigation area, on a random basis, annually. The soil is required to be tested for a range of parameters.

A detailed analysis of surface water sampling results is provided in Appendix I.

3.16 Post closure management, monitoring and maintenance

The Landfill Cell Remediation Plan (GHD, 2012e) outlines the post closure management, monitoring and maintenance requirements of the WBLS, which are based on the assumption that the existing landfill gas extraction system will continue to be operated until such time as monitoring demonstrates that the system is no longer required.

This will include monitoring the following:

- The quantity and composition of landfill gas collected;
- Emissions of landfill gas from the surface of the landfill;
- Subsurface emissions of landfill gas; and
- Accumulation of landfill gas in all above and below ground structures within 250m of the landfilled waste.

Electricity generation will continue at the site until no longer financially viable. Indications are that a smaller generator (or gas flare) will eventually be need to be installed and may provide an additional 15 year life for the electricity generation project. After that time the collected landfill gas may be combusted in a flare.

As mentioned in the Landfill Cell Remediation Plan (GHD, 2012e), the following works would be carried out by ACT NOWaste as part of site closure and aftercare:

- Additional monitoring of leachate management measures to confirm the adequacy of the existing disposal system, particularly during high rainfall events;
- Ongoing monitoring of surface water quality and the performance of existing stormwater management measures, particularly during the proposed remedial works;
- Rationalising the existing surface water management system and ultimately eliminating the need for Greywater dams on the site through revegetation works;
- Improved landfill gas emissions monitoring;
- Upgrading the groundwater monitoring system and investigating the sources of elevated ammonia levels in bore WBBH2;
- Removing plant, equipment and infrastructure no longer required for landfilling operations at the site;
- Upgrading signage.

4. Site classification for future use

4.1 Existing information

Existing information about the WBLC is contained in a number of different documents and drawings. Following the review of the available documentation identified in Appendix C, GHD prepared consolidated drawings of the WBLS as follows:

- One drawing showing the current surface layout of the WBLS (as far as GHD was able to establish);
- Three drawings showing the current subsurface conditions of the WBLS (as far as GHD was able to establish); and
- Two drawings grouping identified individual areas of the WBLS into larger consolidated groups with similar sub-surface characteristics (as far as GHD was able to establish). Further information on this is provided in Section 4.2 below.

These drawings are contained in Appendix D.

There is some uncertainty around certain aspects of these drawings, particularly the current sub-surface conditions. Further investigation (the scope of which depends on the ultimate proposed future uses of the WBLS) is recommended. This would involve further cross checking of information sources, and subsurface investigations in areas that are proposed to be redeveloped.

GHD notes that these drawings are also only valid at one point in time and need to be updated regularly as conditions alter at the WBLS or are further understood and defined.

4.2 Grouping of similar areas

To assist GHD with the completion of the landfill mining task (Appendix G) and future land use options task (Section 6), GHD grouped various individual areas of the WBLS according to their known or perceived sub-surface characteristics (principally whether they had or had not been landfilled, then if landfilled, with what).

The existing area names (as shown on Drawing 21-23237-C001 in Appendix D) and their assigned assessment group names are provided in Table 4-1 below:

Table 4-1 Existing areas names and assigned assessment group names

Existing area name (refer to Drawing 21-23237-C001 in Appendix D)	Assessment group name (colour shown below matches that on Drawing 21-23237-C006 in Appendix D)	Area (approximate)
Old landfill area	MSW landfill areas	51. 3 ha
Clay lined landfill & flock		
Existing green waste facility		
Old street sweeping compost yard		
Dam 3, Dam 4, Dam 6		
Dam 5 sullage		
Clean fill		
Capped bushfire disposal pit		
EDL landfill gas power plant		

Existing area name (refer to Drawing 21-23237-C001 in Appendix D)	Assessment group name (colour shown below matches that on Drawing 21-23237-C006 in Appendix D)	Area (approximate)
Existing green waste facility		
Building waste recycling		
Capped tyre trench	Tyre trench areas	2.4 ha
Capped tyre disposal pit		
Dam 1 Irrigation Area	Stormwater management areas	5.5 ha
Dam 1		
Dam 19		
Dam 24		
Dam 25		
Dam 30		
Dam 32		
Electrical easement (part of)		
Dam 2 Leachate Irrigation Area	Leachate management areas	2. 2 ha
Dam 2		
Electrical easement (part of)		
Asbestos Pit	Asbestos disposal areas	8.3 ha
Borrow Pit		
Former ACT NOWaste Woodbusters Site (part)		
Parkwood Road Recycling Estate (various recycling activities)	Estate area	11.3 ha
Pesticide storeroom		
Laboratory		
Chemical depot		
Former ACT NOWaste Woodbusters site (part)		
Weighbridge, amenities and office area	Weighbridge and recycling area	12.6 ha
Public drop off facility		
Electrical easement (part of)	Electrical easement area	6.9 ha
Tree buffer	Less disturbed areas	7.1 ha
Former landfarming area		
Other unnamed areas		

Drawing 21-23237-C005 contained in Appendix D shows how the existing areas were consolidated into these larger assessment group areas. Drawing 21-23237-C006 in Appendix D shows the final assessment group areas. It is noted that there are some uncertainties in relation to the actual individual boundaries between certain individual areas (and precisely what materials may have been landfilled in certain areas). As such, Drawings 21-23237-C005 and 2123237-C006 are indicative only and give an approximation of the areas.

The issue of uncertainty in relation to sub-surface conditions (i.e. landfilled waste types, depths and boundaries) is one of significance in relation to further understanding the potential to undertake landfill mining at the WBLS. Landfill mining is further discussed in Section 6.7.1 and Appendix G.

The WBLS represents a number of potential opportunities in relation to future on-site land uses for facilities that may be required / compatible with the proposed adjacent development (e.g. future recreational areas, future employment areas, future food growth areas etc.).

However, the WBLS also has a number of constraints that are likely to make development of the WBLS challenging, particularly in certain areas (e.g. large quantities of waste present over large areas, landfill gas issues, settlement issues etc.). Furthermore, the WBLS also presents certain constraints that will warrant further studies and possible remedial action if development on adjacent areas is to proceed (e.g. landfill gas issues, leachate issues etc.).

5. Future development of the WBLS site and surrounds

5.1 Overview

Riverview intends to develop a sustainable community of international significance in Canberra, the nation’s capital, adjacent to the WBLS, and with the WBLS at the centre of the development area. At this stage, it is not clear what role the WBLS would play in the future development. A range of uses/roles have been suggested but the constraints associated with its former use as a landfill, and the potential opportunities it presents, through being a large area of potentially otherwise undevelopable land, need to be explored.

It will be necessary to have appropriate distances and buffer zones between the former landfilling areas and any future residential areas. Currently, the Territory Plan 2008 (Territory Plan) requires a 500 metre wide ‘Clearance Zone’ (buffer distance) around the WBLS within the ACT.

However this is based on the current and former uses of the WBLS as a putrescible waste landfill. What buffer distance is appropriate for the long term is still to be determined, as future operations of the WBLS may include an emergency landfill, which would involve a buffer, or it may entail rehabilitated landfill and low environmental impact activities, which would enable the buffer distance to be reassessed and potentially reduced in some areas, using a risk management approach.

A detailed assessment of potential buffer zones is provided in Section 9.

5.2 Previously considered future uses for the WBLS

ACT NOWaste has previously considered a number of possible future uses for the WBLS once landfilling operations cease. These are detailed in the Master Plan (GHD, 2012).

In summary, ACT NOWaste considered that the most practical future uses of the WBLS was for certain areas to be used for resource recovery and recycling operations and the previously landfilled areas to be converted to low maintenance grassed areas).ACT NOWaste also considered that some use of the WBLS for solar energy generation may be appropriate. The WBLS would also act as the Emergency Landfill Site for the ACT.

GHD notes that these future uses were developed prior to the signing of the Heads of Agreement between the Corkhill group, Reid & Stevens and the ACT Government previously discussed.

Depending upon the types of resource recovery operations undertaken on site, this may not pose a constraint to surrounding residential development. Suitable buffer zones would need to be provided for noisy, odorous or dusty operations.

As such, there is currently some uncertainty around the long term future uses of the WBLS. As part of this project’s scope of works, GHD was requested by Riverview to assess the physical feasibility of a number of potential future land uses (as proposed by Riverview). Further information on these works is provided in Section 6.

The existing physical conditions at certain parts of the WBLS (both at the ground’s surface and in the sub-surface) influence the physical suitability of these areas for a number of these identified future land uses.

Section 4 provides a brief discussion of the plans / cross-sections created by GHD that illustrate the current surface and subsurface conditions at the WBLS (as far as GHD has been able to establish). These have a significant bearing on the types of future uses contemplated for the site.

5.3 Opportunities and constraints

The presence of the WBLS represents a number of potential opportunities in relation to future on-site land uses for facilities that may be required / compatible with the proposed adjacent development (e.g. future recreational areas, future employment areas, future food growth areas etc.).

However, the WBLS also has a number of constraints that are likely to make development of the WBLS challenging (e.g. landfill gas issues, leachate issues, settlement issues etc.).

WBLS Furthermore, the WBLS also presents certain constraints that will warrant further studies and possible remedial action if development on adjacent areas is to proceed (e.g. landfill gas issues, leachate issues, existing buffer distance issues).

Section 6 discusses potential future uses for the site, and activities that could be conducted on site, in the context of the proposed Riverview development surrounding the site.

6. Potential future land uses of the WBLS

6.1 Overview

As previously mentioned,

- Substantial areas of land adjacent to the WBLS are proposed to be re-zoned for future development; and
- Riverview wish to re-develop and incorporate the WBLS as the centre piece of the proposed future development.

As such, GHD has undertaken a high level preliminary assessment of the physical suitability (only) of eleven (11) potential future land uses of the WBLS (as selected by Riverview), both in the short term (< 10 years from April 2014 and in the Medium Term (> 10 years but < 20 years).

The aim of this assessment was to identify potentially physically suitable future land uses of the WBLS to feed into a Master Plan (to be prepared by others) for the redevelopment of the WBLS.

The following sections detail the assessment and GHD's findings and recommendations arising from it.

It is noted that this assessment is highly subjective in nature and as such should be treated as indicative only.

6.2 Potential future land uses

The potential future land uses identified by Riverview and subsequently assessed by GHD were as follows:

- Resource recovery (both with buildings and without buildings);
- Green waste recycling (both with buildings and without buildings);
- Solar farm;
- Light industry;
- Commercial plant nursery;
- Community gardens;
- Mountain bike trails;
- Equestrian activity;
- Passive recreation;
- Forestry / tree planting; and
- Administrative / education facilities (related to on-site activities).

6.3 Surface and subsurface conditions at the WBLS

As identified on the plans in Appendix D, surface and sub-surface conditions are not homogenous across the WBLS. This is a result of the numerous waste management / resource recovery related activities that have occurred (and evolved) across the WBLS since circa 1970.

As such, the present day WBLS is a "patchwork" formed from a number of individual areas, each with specific characteristics. Furthermore, the specific characteristics of one area of the WBLS are sometimes quite different to the specific characteristics of adjacent or nearby areas.

The specific characteristics of these individual areas represent both opportunities and constraints in relation to the physical suitability of individual areas for the potential future land uses identified in Section 6.2.

6.4 Assumptions for assessment

GHD has grouped various areas of the WBLS for the purposes of this assessment, as described in Section 4. These grouped areas are shown on Drawing 21-23237-C006, contained in Appendix D. Following the grouping of the areas for assessment, GHD undertook the assessment of the physical suitability (only) of eleven (11) potential future land uses of the WBLS.

A number of assumptions were made for the assessment, including:

- The electricity easement would remain in existence / use both in the short term and the medium term (hence this area was not considered in the assessment);
- That all existing waste management / resource recovery activities (e.g. asbestos disposal, green waste processing etc.) had ceased and the relevant assessment group areas had been cleared (e.g. of stockpiles), vacated and / or appropriately capped (as relevant);
- That major land / soil contamination issues of the assessment group areas surface (top metre below ground level) were not in existence or could be readily managed if required;
- That existing topographical gradients would remain;
- The integrity of the existing and future landfill capping systems would need to be maintained;
- That no landfill mining would have occurred in any area;
- That if required, it would be possible to relocate / adapt:
  - Leachate management infrastructure;
  - Landfill gas collection and treatment infrastructure;
  - Stormwater management infrastructure; and / or
  - Weighbridge and recycling area; and / or
  - Existing services excluding the existing electricity easement (e.g. on-site electrical cables).
- That only the following potential future land uses would require buildings and / or significant amounts of infrastructure (e.g. underground services etc.) to be constructed:
  - Resource recovery;
  - Green waste recycling;
  - Solar farm;
  - Light industry; and
  - Administrative / education facilities (related to on-site activities).
- Consolidation and biodegradation of waste are likely to make certain areas more suitable for certain uses in the medium term than they may be in the short term;
- Hardstand areas in the Weighbridge and Recycling Area and Estate Area would remain in the short term but could be removed in the medium term if required;
- Future land uses would not use on-site groundwater, surface water or leachate for drinking, irrigation purposes etc.;

- That community gardens and forestry / tree planting would require planting of trees in existing soil profiles (including above the landfill cap);
- Existing tree buffer land along Parkwood Road could be developed if desired;
- No protected / endangered flora and / or fauna species exist in / on any areas;
- The assessment relates to physical suitability. It does not consider potential legal, economic, community and social issues etc.; and
- No consideration has been given to ACT NOWaste's potential requirements for the WBLS.

6.5 Assessment methodology

6.5.1 Constraints identification

To complete the assessment, GHD has identified key physical constraints of the identified assessment groups in relation to the identified potential future land uses. A summary of the identified key physical constraints is contained in Table 6-1 below.

Table 6-1 Existing key physical constraints of assessment group areas

Assessment group name	Existing key physical constraints
MSW Landfill Areas	Landfilled mixed waste, landfill environmental control systems landfill gas, leachate, barriers etc.), settlement, leachate, landfill gas, settlement, topography (often sloping), slope stability, unknown landfill capping specification in places, unknown characteristics / contamination status of soil, shallow revegetation layer / cover soils, potential future landfill fires, geotechnically "weak (i.e. non-load bearing)
Tyre Trench Areas	Landfilled tyre waste (and possibly other waste types), landfill environmental control systems (barriers etc.), settlement, unknown landfill capping specification in places, unknown characteristics / contamination status of soil, likely shallow revegetation layer / cover soils, potential future landfill fires, geotechnically "weak" / spongy (i.e. non-load bearing), unlikely to generate significant quantities of leachate or landfill gas in their own right, but are adjacent to MSW landfill areas, so could be impacted by leachate or landfill gas moving from these areas.
Stormwater Management Areas	Widely dispersed and often of relatively small size (apart from consolidated area on western side of WBLS), existing use for stormwater management purposes, topography sloping in places, unknown characteristics / contamination status of soil, unknown thickness of cover soils, are adjacent to MSW landfill areas, so could be impacted by leachate or landfill gas moving from these areas, would most need to be filled in with suitable clean fill to allow future development for certain purposes
Leachate Management Areas	Existing use for leachate management purposes, topography generally sloping, unknown characteristics / contamination status of soil, unknown thickness of cover soils, are adjacent to MSW landfill areas, so could be impacted by leachate or landfill gas moving from

Assessment group name	Existing key physical constraints
	these areas, Dam 2 would most likely need to be filled in with suitable clean fill to allow future development for certain purposes.
Asbestos Disposal Areas	Landfilled asbestos contaminated waste (and possibly other waste types), landfill environmental control systems (landfill capping etc.), settlement, unknown landfill capping specification in places (ACT NOWaste Woodbusters Area), unknown characteristics / contamination status of soil, likely shallow revegetation layer / cover soils, geotechnically challenging but likely better than MSW landfill and Tyre Trench areas, unlikely to generate significant quantities of leachate or landfill gas in their own right, but are adjacent to MSW landfill areas, so could be impacted by leachate or landfill gas moving from these areas.
Estate Area	Unknown characteristics / contamination status of soil, unknown thickness of cover soils, are in close proximity to MSW landfill areas, so could be impacted by leachate or landfill gas moving from these areas.
Weighbridge and Recycling Area	Unknown characteristics / contamination status of soil, unknown thickness of cover soils, are in close proximity to MSW landfill areas, so could be impacted by leachate or landfill gas moving from these areas.
Less Disturbed Areas	Topography sloping in a number of areas, heavily vegetated along Parkwood Road (Tree Buffer Area), are widely dispersed and unusual sized apart from along Parkwood Road (Tree Buffer Area) and western part of the WBLS, unknown characteristics / contamination status of soil, unknown thickness of cover soils, are in close proximity to MSW landfill areas, so could be impacted by leachate or landfill gas moving from these areas.

6.5.2 Discussions with relevant disciplines

Following identification of the key constraints to potential future land development at the WBLS, GHD consulted internally with personnel working in a number of relevant discipline areas to:

- Discuss the separate areas of the WBLS and their individual characteristics (as far as known); and
- Seek views on the likely physical suitability of the identified assessment group areas for the selected potential future land uses.

This included consultation with personnel working in the areas of:

- Geotechnical engineering;
- Soil / agricultural science;
- Waste management / landfill engineering / science;
- Contaminated land assessment.

6.6 Opportunities and constraints

The WBLS presents a number of potential opportunities in relation to using some or all of the available land for a variety of land uses that may be required by / compatible with, the proposed adjacent development. That said, there are a number of physical constraints to potential development of the WBLS including potential issues relating to landfill gas, leachate, settlement, slope stability soil characteristics and depth, landfill capping systems etc.

Following the consultation exercise, GHD has prepared:

- The table contained in Appendix J. This table visually identifies and consolidates the views of GHD's specialists. It summarises the perceived physical suitability of the assessment group areas for the identified potential future land uses based on available information and GHD knowledge / experience; and
- The two drawings contained in Appendix K. These drawings visually display the combined views of GHD's specialists. They show the perceived combined physical suitability of the assessment group areas for the identified potential future land uses based on available information and GHD knowledge / experience (in both the short term and medium term).
- In addition, other considerations relating to the suitability of various future uses include the type of access (controlled versus uncontrolled, and public versus private access), and the potential for damage to the capping layer from specific activities. These would affect the level of additional investigation works needed to justify the use, and the level of ongoing management required ie the overall risk profile of different end uses. This is summarised in Table 6-2.

Table 6-2 Risk profile of potential end uses

Future use	Access type	Risk to capping	Investigation level and on-going management needed (risk profile)
Resource recovery activities	Controlled public	Low	Low
Green waste recycling	Controlled public	Low	Low
Solar farm	Controlled private	Low	Medium
Light industry	Controlled public	Low	Medium
Commercial plant nursery	Controlled public	Medium	Medium
Community gardens	Uncontrolled public	High	High
Mountain bike trails	Uncontrolled public	Medium	High
Equestrian activity	Uncontrolled public	High	High
Passive recreation	Uncontrolled public	Low	Low
Forestry/tree planting	Controlled private	High	High
Admin/education facilities	Controlled public	Low	High

All of the uses of the WBLS listed in Table 6-2 could occur in the medium to long term, once settlement of landfilled waste is well advanced. However the level and type of access to the site would affect the risk profile of the different uses.

For example, recycling activities are compatible with the current uses of the site and public access to the site would be restricted to certain areas. As such, this type of use would require less investigation and on-going management than other “new” uses, such as community gardens or equestrian activity where public access is uncontrolled.

Potential impacts to people from high level exposure to landfill gas (leading to explosion, asphyxiation in extreme situations) and potential adverse impacts to infrastructure (pipes, roads, pathways, buildings) from settlement are the key issues for old landfill sites.

As such, uses involving buildings such as indoor resource recovery or education/administration facilities should ideally only be considered for areas that have not been previously landfilled. For any buildings and underground pipes, allowance for ongoing settlement needs to be part of the design. Gas prevention and ongoing detection measures would be needed for any buildings placed on the site, and any buried infrastructure such as pipes and electrical pits.

For these reasons, passive recreational uses would be most applicable over the various areas of the site. Forestry would be possible but ideally not in previously landfilled areas, due to potential disturbance of the cap. Mountain bike trails may be possible in the medium to long term provided the cap is not disturbed. Solar farms would normally be considered for non-landfilled areas due to settlement and the possible risks associated with the combination of landfill gas and potential sparking from power generation equipment.

6.7 Additional activities considered

6.7.1 Landfill mining

GHD has undertaken an assessment of the potential for landfill mining at the WBLS, as it was thought that it may be possible to reclaim airspace for future filling, potentially with soils / construction waste derived from the adjacent development project or to reclaim land for development and/or reclaim some buried wastes for re-use / recycling (or some combination of these). The assessment report is contained in Appendix G.

This assessment has concluded that there are a number of potential risks are associated with undertaking a landfill mining project at the WBLS. These include environmental, WH&S and economic risks. The hazardous nature of the waste material landfilled in certain areas of the WBLS (i.e. asbestos contaminated materials) is likely to preclude landfill mining in those areas.

The nature of materials that may be recovered from certain areas is likely to be highly variable / difficult to work with (e.g. MSW areas). Materials from other areas may be more uniform in nature / easier to work with (e.g. the tyre trenches).

There is currently a considerable uncertainty around the potential viability of undertaking a landfill mining project at the WBLS (whether for the whole site or just selected areas in part or the whole site). The economic returns from sale of recovered materials are likely to be quite low, and it is likely to generate a significant amount of waste (materials that cannot be re-used or sold) that will require landfill disposal either at the WBLS or another landfill site. So the costs of excavation, processing and resource recovery, and landfill disposal of the residuals combined may exceed the revenue obtainable for the recovered materials.

Landfill mining may have other disadvantages. It may preclude heat recovery from the WBLS if it were to occur in certain areas (see Section 6.7.1), and associated odour and noise impacts have the potential to adversely affect both on-site and off-site receptors due to. Therefore it may affect the potential for potentially amending the existing buffer distance in place around the WBLS (see Section 9 for further discussion of buffer distances around the WBLS).

Overall, the potential costs and impacts associated with waste disturbance would seem to outweigh the potential benefits of recovering resources and/or creating additional land for redevelopment in most areas of the site. In specific areas such as the tyre disposal area, detailed investigations including a cost benefit analysis would be necessary to make a definitive assessment of the opportunities available. Even if such areas are remediated through this process, they would likely lie within the buffer zone and not be able to be utilised for future residential development. However, if appropriate gas protection is provided for buildings, some commercial activities may be possible.

6.7.2 Heat recovery from landfill

One benefit from locating the Riverview development in close proximity to the WBLC is that it may be possible to recover heat from certain locations at the WBLS for subsequent use by on and / or off-site users. GHD has undertaken a technical assessment of the feasibility of recovering heat for beneficial uses. A detailed report is provided in Appendix H.

There are three potential heat recovery sources at the WBLS, i.e. the MSW landfill, the leachate collection and management system and the landfill gas engine. While suitable technologies exist to potentially recover heat from these heat sources, which are evidenced from various successful heat recovery projects undertaken internationally (some on trial basis), there is a large amount of uncertainty at present in relation to the economic feasibility of collecting heat from these three sources.

Available data indicates that the technical feasibility of recovering heat from the reviewed heat sources is likely to be as follows (in the order of most likely first):

- landfill gas engine jacket water (estimated 1,900 MJ per hour)
- landfill gas engine exhaust (estimated 1,450 MJ per hour)
- MSW landfill (estimated 1,200 MJ to 4,000 MJ per hour)
- Leachate collection and management system (unknown amount of heat but much less than the other possibilities).

Recovery of heat from the gas engine jacket water is more standardised technology than recovery of heat from engine exhaust gases, or recovery of heat from a landfill or leachate, and the heat source is relatively compact. The higher the temperatures involved, the wider are the applications for such heat. This makes heat recovery from the gas engines more likely to be technically and economically feasible than the other options where the heat is in a low temperature form.

Recovering heat from the landfill or leachate would involve much larger amounts of pipework and associated pumps and/or fans to transfer the same heated liquids or gases as the available heat is dispersed over a much larger area. Lower temperature differences between the landfilled waste and leachate, and the ambient air combined with significant pipework distances mean that the heat losses between the sources and users of heat may be significant.

There are also significant uncertainties in relation to the actual quantity and longevity of heat that could be recovered from the WBLS because the waste was placed a long time ago in some areas, and it may be reaching the end of its most active decomposition period. Available data suggests that the total quantity of landfill gas extracted from the WBLS has reduced from 2003 and 2009. From past experience, GHD estimates that the existing landfill gas engine may continue to operate at the WBLS for less than 5 years, after which a flare would be used on site.

A heat recovery system that can initially use the engine as the heat main source, but can be adapted to extracting heat from the flare exhaust may be a possibility.

It is unclear and how much the heat recovery system(s) associated with the landfill and leachate may cost to install and operate, as this depends on the actual temperatures involved, and the locations and heating requirements of potential future users of any recovered heat. If the site generates a relatively small amount of leachate (which is thought to be the case), the overall amount of heat that could be extracted from this source may be relatively small.

In summary, a lot more investigation work would need to be done to be more conclusive about the feasibility of heat recovery at WBLS, but the fact that the landfill gas engines may cease operating within a relatively short period suggests that it may not be viable to base a heat recovery system on this source alone. The other sources provide much less certain outcomes than the gas engines.

The identified heat recovery projects may not initially be economically viable, but they may be able to be set up as sustainability projects on a demonstration scale to provide improved data. This would provide an opportunity to demonstrate their feasibility to potential users and attract investment for larger scale systems.

6.7.3 Surface water quality impacts

GHD has undertaken an assessment of surface water quality in the vicinity of the WBLC.

The purpose of this assessment was to investigate whether the surface water flowing from the WBLS could potentially be harnessed for potential uses or the existing tributaries / drainage lines could be retained or enhanced as water features within the proposed residential development. Alternatively, if the water quality was deemed unsuitable for this purpose, the assessment was to determine what limitations (if any) should be placed on the watercourses to ensure that they did not affect the health of future residents.

Spring Creek appears to be fed, at least in part, by Dam 1 at the WBLS, flows from north-east to south-west before discharging into the Murrumbidgee River approximately 1200 m from the WBLS. The creek flows into a second, unnamed dam approximately 325 m down gradient of the discharge valve before discharging into the Murrumbidgee River.

GHD reviewed and assessed 16 sets of surface water monitoring data (and the associated quality assurance/quality control - QA/QC -information) as provided by Australian Laboratory Services (ALS) on behalf of Riverview in order to comment on potential surface water quality issues adjacent to the WBLS.

The assessment report, which is provided in Appendix I suggests that surface water adjacent to the WBLS could potentially be harnessed for potential uses and that the existing tributaries / drainage lines could be retained / enhanced as water features within the proposed residential development.

That said, the limited available data suggests that there may be some limitations in relation to what the water could actually be used for. Assuming acceptable data quality control processes have been employed by ALS during sampling and laboratory analysis, assessment of the data relative to six selected guidelines / standards suggests no obvious, regular, significant impact from the WBLS at the monitored locations.

There is a risk that sediment laden water derived from the WBLS could impact upon off-site surface water in the future, should the site be used as an emergency landfill in future. There is always a possibility that leachate from the existing landfill could enter the watercourse, but the current monitoring data suggests that it is unlikely.

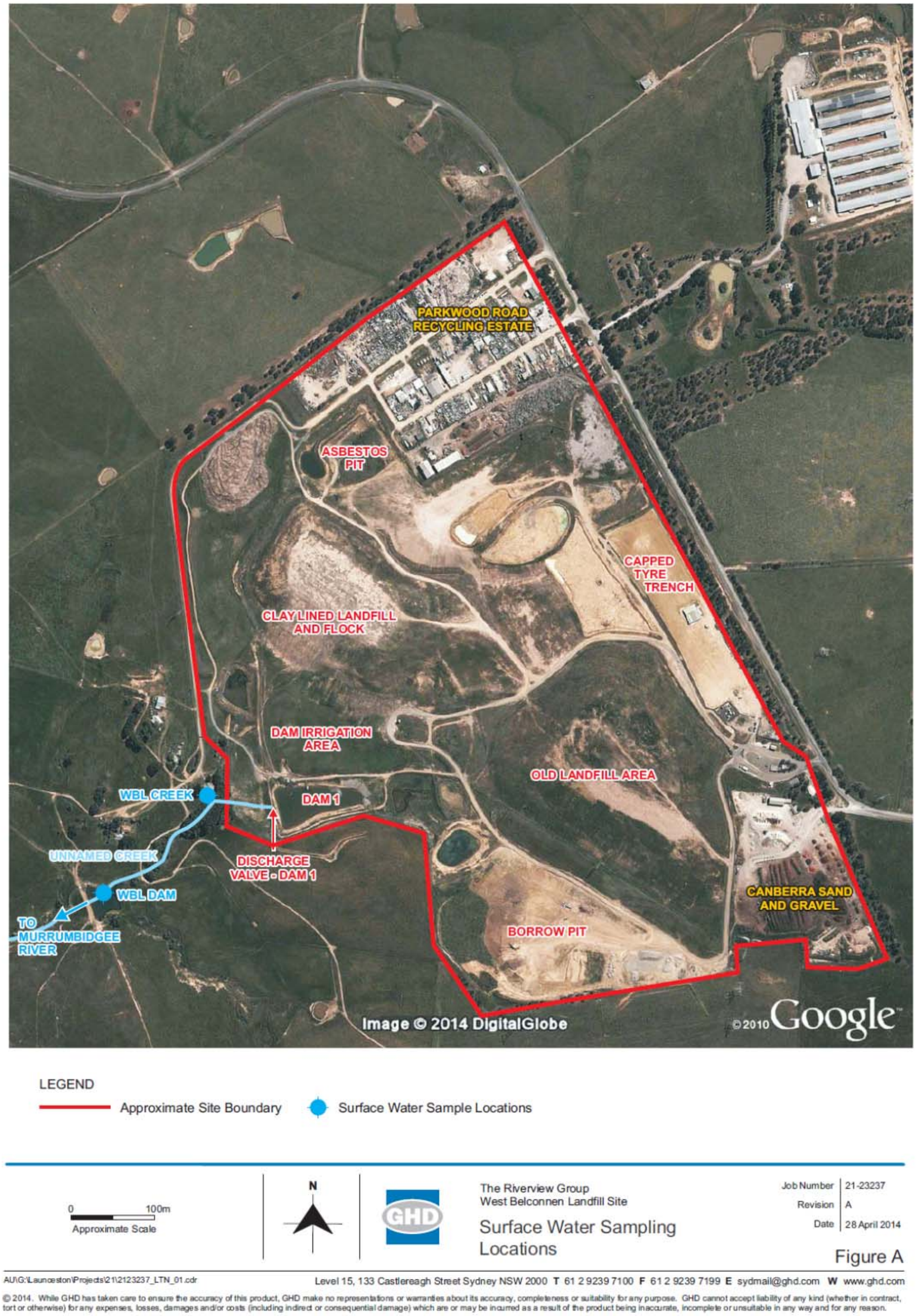


Figure 6 Surface water sampling locations

6.8 Conclusions

In relation to this section, GHD makes the following key conclusions:

- There are a number of physical conditions at the WBLS that present constraints to development including:

  - Landfill gas;
  - Leachate;
  - Settlement;
  - Slope stability;
  - Soil characteristics and depth; and
  - Landfill capping systems.
- It is considered by GHD that all of the potential future land uses identified by Riverview are likely to be possible at all of the assessment group areas at the WBLS. However, some assessment group areas are likely to be more suitable for certain uses than others (and therefore to likely require less confirmatory investigative works and / or engineering controls);
- All of the proposed land uses would require at least limited physical investigation and assessment of the relevant assessment group areas prior to the land use altering / commencing. GHD notes that there are also likely to be other requirements that need to be fulfilled before land uses at the WBLS could change (e.g. land use planning requirements, potential contaminated land audits etc.); and
- The physical suitability of certain assessment group areas (principally the landfilled areas) for certain potential future land uses is likely to increase with time. This is principally because as the landfilled waste degrades and / or consolidates over time, the potential significance of landfill gas and / or settlement issues is likely to reduce.

6.9 Recommendations

Based on the key conclusions provided above, GHD makes the following recommendations (made with consideration of the Vision – see Table 6-3 below):

1. Engage in discussions with the relevant stakeholders including ACT EPA, planning authority, ACT NOWaste and the community to discuss their views on the potential future land uses;
2. Based on the findings from 1. above, select preferred land uses for the identified assessment group areas at the WBLS in the short and medium term;
3. Identify appropriate investigations required for the preferred land uses in both the short and medium term (and potentially also for adjacent areas if they have the potential to adversely impact upon the proposed land uses); and
4. Use the information obtained during 3. above to prepare a detailed cost benefit analysis of the preferred land uses in both the short and medium term.
5. On the basis of the above, preparation of Master Plan to guide the ongoing development and use of the site

Table 6-3 identifies how the recommendations above were developed with consideration of the overarching project Vision (Appendix B).

Table 6-3 Recommendations and relevant guiding principles (as contained in the Vision)

Recommendation	Relevant guiding principles
1	Ptnr 1., Ptnr 2., Ptnr 4.
2	Eva 1., Eco 2., Eco 5., Eco 6., Soc 6., Econ 1., Econ 3., Econ 6., Econ 7.
3	Eva 1., Eco 2.,
4	Eva 1., Econ 1.

7. Risk identification and potential additional works (on-site only)

7.1 Overview

GHD undertook a preliminary risk assessment exercise to identify any additional landfill related (physical only) investigative and / or monitoring works that may be required to assist future decision making regarding the potential future use(s) of the WBLS. In order to do this, GHD:

- Identified the likely landfill related hazards (physical only) associated with the WBLS;
- Undertook a preliminary risk assessment of the likelihood and consequences of the identified hazards impacting upon newly introduced on-site receptors at the WBLS; and
- Based on the findings of the preliminary risk assessment, GHD identified potential additional investigative and / or monitoring works (landfill related only) that are required to assist future decision making regarding the potential future use(s) of the WBLS.

GHD notes that the risk assessment is preliminary in nature (as is the table of associated potential additional works). Only key landfill related physical hazards have been identified and assessed (as relevant). All indications provided of potential costs, frequencies, timing etc. are indicative in nature only.

Further details on this exercise are provided in the following sections.

7.2 Assumptions

The following assumptions were made for the purposes of this assessment:

- The existing landfill gas engine and leachate management system would continue to operate at the WBLS; and
- That it is understood that risk assessment is a subjective task. Risk ratings specifically relate to the risk tolerance of the individual who undertook the risk assessment. In this case, Mr. Matthew Welsh of GHD assessed the risks from his perspective as an experienced landfill gas specialist .

7.3 Preliminary hazard identification

7.3.1 Landfill related hazards

A number of landfill related physical hazards are inherently associated with former landfill sites like the WBLS including:

- Landfill gas;
- Leachate;
- Noise;
- Odour;
- Sediment laden surface water;
- Settlement;
- Exposed waste / ground contamination; and
- Slope stability.

These hazards present risks of potential impact upon on-site receptors (people, buildings, plants etc.) at the WBLS.

7.4 Risk assessment

Following identification of the likely landfill related physical hazards associated with the WBLS, GHD undertook a preliminary risk assessment of the likelihood and consequences of these hazards impacting upon future on-site receptors.

This risk assessment was undertaken broadly in line with the recommendations of AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines. The adopted risk assessment matrix and associated risk assessment tables (including risk ratings) are contained in Appendix L.

It is noted that no consideration was given to potential on-site impacts that may be caused by future on-site land uses (e.g. noise associated with future resource recovery operations). This is because the actual future land uses at the WBLS are highly uncertain at present.

7.5 Investigative and / or monitoring works at the WBLS (on-site)

Following completion of the preliminary risk assessment, GHD identified potential additional investigative and / or monitoring works that may be required on-site to assist future decision making regarding the future use of the WBLS. These additional works are summarised in the tables contained in Appendix L.

7.6 Opportunities and constraints

The WBLS presents a number of potential opportunities in relation to using some or all of the available land for a variety of land uses that may be required by / compatible with, the proposed adjacent development. That said, there are a number of physical constraints to potential on-site development of the WBLS including potential issues relating to landfill gas, leachate, settlement, slope stability soil characteristics and depth, landfill capping systems etc.

7.7 Conclusions

In relation to this Section, GHD makes the following key conclusions:

- There are a number of physical hazards (landfill related) inherently associated with the WBLS that have the potential to impact upon future on-site receptors;
- The key potential risks to future on-site receptors appear to be associated with the hazards of landfill gas, leachate, settlement, exposed waste / ground contamination land and slope failure; and
- There are a number of identified potential additional investigative and / or monitoring works that are recommended on-site to assist future decision making regarding the future use of the WBLS.

7.8 Recommendations

Based on the findings of the preliminary risk assessment GHD has made a number of recommendations for potential additional investigative and / or monitoring works. (made with consideration of the Vision). These additional works are summarised in the tables contained in Appendix L.

8. Risk identification and potential additional works (off-site only)

8.1 Overview

GHD undertook a preliminary risk assessment exercise to identify any additional landfill related (physical only) investigative and / or monitoring works that may be required to support the proposed residential redevelopment adjacent to the WBLS site boundary. In order to do this, GHD:

- Identified the likely landfill related hazards (physical only) associated with the WBLS;
- Undertook a preliminary risk assessment of the likelihood and consequences of the identified hazards impacting upon newly introduced off-site receptors adjacent to the WBLS site boundary; and
- Based on the findings of the preliminary risk assessment, identified potential landfill related additional investigative and / or monitoring works that are recommended to support the proposed residential redevelopment adjacent to the WBLS site boundary.

GHD notes that the risk assessment is preliminary in nature (as is the table of associated potential additional works). Only key landfill related physical hazards have been identified and assessed (as relevant). All indications provided of potential costs, frequencies, timing etc. are indicative in nature only.

Further details on this exercise are provided in the following Sections.

8.2 Assumptions

The following assumptions were made for the purposes of this assessment:

- The existing landfill gas and leachate management systems would continue to operate at the WBLS; and
- That it is understood that risk assessment is a subjective task. Risk ratings specifically relate to the risk tolerance of the individual who undertook the risk assessment. In this case, Mr. Matthew Welsh of GHD.

8.3 Preliminary hazard identification

8.3.1 Landfill related hazards

A number of landfill related physical hazards are inherently associated with former MSW landfill sites like the WBLS. Several of these hazards can result in off-site impacts. These hazards include:

- Landfill gas;
- Leachate;
- Noise;
- Odour;
- Sediment laden surface water;
- Exposed waste / ground contamination; and
- Slope stability.

These hazards present risks of potential impact upon off-site receptors (people, buildings, plants etc.) adjacent to the WBLS.

8.4 Risk assessment

Following identification of the likely landfill related physical hazards associated with the WBLS, GHD undertook a preliminary risk assessment of the likelihood and consequences of these hazards impacting upon future off-site receptors.

This risk assessment was undertaken broadly in line with the recommendations AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines. The adopted risk assessment matrix and associated risk assessment tables (including risk ratings) are contained in Appendix M.

It is noted that no consideration was given to potential off-site impacts that may be caused by future on-site land uses (e.g. noise associated with future resource recovery operations). This is because the actual future land uses at the WBLS are highly uncertain at present.

8.5 Investigative and / or monitoring works at the WBLS

Following completion of the preliminary risk assessment, GHD identified potential additional investigative and / or monitoring works that are recommended at the boundary of the WBLS to support the proposed residential redevelopment adjacent to the WBLS site boundary. These additional works are summarised in the tables contained in Appendix M.

8.6 Opportunities and constraints

The WBLS presents a number of potential opportunities in relation to using some or all of the available land for a variety of land uses that may be required by / compatible with, the proposed adjacent development. That said, there are a number of potential constraints that the WBLS presents to potential off-site development adjacent to the WBLS. These include potential issues relating to landfill gas, leachate, slope stability etc.

8.7 Conclusions

In relation to this section, GHD makes the following key conclusions:

- There are a number of physical hazards (landfill related) inherently associated with the WBLS that have the potential to impact upon future off-site receptors;
- The key potential risks to future off-site receptors appear to be associated with the hazards of landfill gas, leachate, exposed waste / ground contamination and slope failure; and
- There are a number of identified potential additional investigative and / or monitoring works that are recommended to support the proposed residential redevelopment adjacent to the WBLS site boundary.

8.8 Recommendations

Based on the findings of the preliminary risk assessment GHD has made a number of recommendations for potential additional investigative and / or monitoring works. (made with consideration of the Vision). These additional works are summarised in the tables contained in Appendix M.

9. Buffer distances

9.1 Overview

Appropriate buffer distances (separation distances) are often required between industrial activities (including landfill sites) and sensitive nearby land uses such as residential properties (receptors). These buffer distances serve to protect the receptors from any impacts resulting from a failure of facility design or management, or abnormal weather conditions. Buffer distances are not an alternative to providing appropriate management practices, but provide for contingencies that may arise with typical management practices.

For landfill sites, buffer distances are primarily set to manage:

- Odour, which is of most concern during the operational phase; and
- Landfill gas impacts, including the risk of explosion and / or asphyxiation, which can continue up to 30 years after landfill closure (and is therefore relevant in the operational and post-closure phases).

For other industrial land uses, buffer distances are primarily set to manage:

- Odour; and
- Dust; and
- Noise.

It is noted that there is considerable uncertainty at present in relation to potential future land uses at the WBLS (as discussed in Section 6). As such, GHD have limited consideration of other industrial uses in this Section to:

- Resource recovery operations; and
- Green waste recycling facilities.

These two land uses have been selected as they are most likely to be the ones that would require potentially significant (large) buffer distance requirements in comparison to the other proposed land uses presented in Section 6. Any reference from this point on in this Section to other industrial land uses is a reference only to resource recovery operations and / or green waste recycling facilities.

The WBLS currently has a mandated buffer distance of 500 metres (as measured from its boundary) within the ACT. GHD understands that there is no currently no mandated buffer distance associated with the WBLS within NSW.

Substantial areas of land adjacent to the WBLS (potentially up to the site's boundary) are proposed to be re-zoned for subsequent future development as part of the overarching project (see Section 1). As such, GHD was asked to review and comment upon the potential buffer distance that may be required around the WBLS in the future (with consideration of the overarching project).

It is noted that GHD has previously prepared several documents that consider buffer distances that may be required around the WBLS in the future. The two most recent documents are:

- Proposed West Belconnen Development and the WBBRMC Buffer Zone (GHD, 2012a)
- Report for West Belconnen Residential Development, Risks Posed by Adjacent Landfill Discussion Paper (GHD, 2012b)

GHD has reviewed these documents and subsequently developed the updated advice provided in the following sections.

9.2 Assumptions

A number of assumptions were made for the purposes of commenting upon the potential buffer distance that may be required around the WBLS in the future (with consideration of the overarching project). The key assumptions were as follows:

- That all existing waste management / resource recovery activities (e.g. asbestos disposal, green waste processing etc.) had ceased and the WBLS had been cleared, vacated and / or appropriately capped (if a landfill area); and
- That the land immediately adjacent to the WBLS is likely to generally be physically suitable for residential development. It is noted that land adjacent to the WBLS may have been impacted to an unknown degree by the operations at the WBLS, but that further works are required to assess this possibility (as discussed in Sections 8).

9.3 Existing buffer distance

Currently, the Territory Plan 2008 (Territory Plan) requires a 500 metre wide 'Clearance Zone' (buffer distance) around the WBLS within the ACT. This Clearance Zone is shown on the figure contained in Appendix N.

The Territory Plan further specifies that (within this Clearance Zone):

- *Development of the following uses is not permitted:*
  - *A) Community use*
  - *B) Residential use*

and:

- *Development for Residential use or community use in this area will be restricted to prevent the environmental impacts of existing land uses, such as the spread of odours and wind-blown particulates, conflicting with more sensitive land uses.*

The existing buffer distance is formally required around the WBLS within the ACT (although not on the NSW side of the border, where different legislation prevails). There is currently no mandated buffer distance on the NSW side of the ACT / NSW border.

The existing buffer distance is set from the boundary of the WBLS and does not differentiate between activities (e.g. landfilling, green waste recycling etc.) occurring on the WBLS.

9.4 Approaches to buffer distances in other Australian states and territories (landfill sites)

9.4.1 Overview

All states and territories of Australia typically require buffer distances to be maintained around landfill sites. Examples of buffer distances recommended in a number of Australian jurisdictions are provided in Table 9-1**.**

Table 9-1 Recommended buffer distances from landfill sites

Reference	Buffer distance			Conditions if development is within recommended buffer distances	Where is buffer distance measured from?
	Measure	Type of facility	Recommended buffer distance		
VIC EPA[1]	Siting buffer distance required for landfill gas migration, safety and amenity impacts from a building or structures	Type 2 landfill (Municipal waste landfill)	500 m	Where an application for land development occurs within the recommended buffer, EPA currently recommends that the planning authority require an environmental audit to be conducted to assess the risk of harm to the environment posed by the potential offsite migration of landfill gas and the amenity impacts resulting from the landfill on the proposed development.	Buffer distance measured from the sensitive land use to the edge of the closest landfill cell. All cells, including closed cells, need to be considered in calculating buffers. For sites where there is uncertainty in the location of landfill cells, the boundary of the landfill premises is the point of measurement.
		Type 3 landfill (Solid inert waste landfill)	200 m		
	Post closure buffer distance required for landfill gas migration from a building or structures	Type 2 landfill (Municipal waste landfill)	500 m	Where an application for land development occurs within the recommended buffer, EPA currently recommends that the planning authority require an environmental audit to be conducted to assess the risk of harm to the environment posed by the potential offsite migration of landfill gas and the amenity impacts resulting from the landfill on the proposed development.	
		Type 3 landfill (Solid inert waste landfill)	200 m		
QLD DEHP[2]	Indicative buffer distance from a noise, dust or odour sensitive place	Landfill	500 m (indicative only)	A risk assessment should be undertaken to determine the appropriate buffer distances. The risk assessment should be reviewed if encroachment is proposed or has occurred. Where additional design and management practices are identified through the risk assessment as being required to provide the same level of protection to sensitive land uses, these should be implemented.	Buffer distance measured from the sensitive land use to the edge of the closest landfill cell. All cells, including closed cells, need to be considered in calculating buffers. For sites where there is uncertainty in the location of landfill cells, the boundary of the landfill premises is the point of measurement.
NSW EPA[3]	The location of inappropriate areas for NEW landfills	Distance between landfill sites and residential areas	250 m	A detailed assessment is required if the proposed landfill is within 250 m of a residential zone or dwelling not associated with the development.	Unspecified within document
NSW DUAP[4]	The location of inappropriate areas for NEW landfills	Distance between landfill sites and residential areas	250 m	A detailed assessment is required if the proposed landfill is within 250 m of a residential zone or dwelling not associated with the development.	Unspecified within document
WA DEC[5]	Minimum buffer distances recommended by the DEC from activities capable of causing a nuisance to the nearest sensitive land use.	Class I landfill (inert landfill)	150 m	Subject to completion of a risk assessment, additional design or operational measures may be required to ameliorate the risks associated with a reduction in the identified buffer distances.	Measured from the activities capable of causing a nuisance to the nearest sensitive land use
		Class II or III landfill (putrescible landfill)	500 m (or 150 m from a single dwelling)		
TAS DPI[6]	Suggested minimum distances between landfills and sensitive receptors	Inert landfills	300 m	The buffer distance to residences for landfills can be reduced where a detailed assessment, including noise, particulate (dust) and odour modelling, indicates that the amenity of the residences will not be reduced.	Unspecified within document
		Putrescible landfills	500 m		
SA EPA[7]	Recommended separation distance for protection of air quality	Landfills	500 m	If site specific circumstances appear to indicate a reason for departing from the recommended separation distance (e.g. scale of operation, local topography, state of the art technology etc.), a separation distance different from the recommended distances may be able to be justified.	Unspecified within document
		'Other'	300 m		
NT EPA[8]	To protect sensitive areas from impacts associated with landfill operations	Landfills	None	The requirement for and extent of buffer areas should be determined on a site-specific basis.	Unspecified within document

Sources:

1. EPA Victoria (2010) *Best Practice Environmental Management: Siting, Design, Operation and Rehabilitation of Landfills,* Publication No. 788.1
2. Queensland Government Department of Environment and Heritage Protection (2013) *Guideline –Landfill siting, design, operation and rehabilitation Version:2*
3. NSW EPA (1996) *Environmental Guidelines: Solid Waste Landfills*
4. NSW Department of Urban Affairs and Planning (1996) *Landfilling EIS Guideline*
5. Western Australian Government Department of Environment (2005) *Best Practice Environmental Management, Draft: Siting, Design, Operation and Rehabilitation of Landfills*
6. Department of Primary Industries Tasmania (2004) *Landfill Sustainability Guide*
7. Environment Protection Authority, South Australia (2007) *Guidelines for Separation Distances*
8. Northern Territory Environment Protection Authority (2013) *Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites In the Northern Territory January 2013*

Table 9-1 shows that the maximum recommended buffer distance from an operating landfill to a sensitive receptor is 500 metres. Buffers distances of between 200 and 300 metres are typically recommended for operating landfills that accept inert wastes only (in most jurisdictions). Some jurisdictions (e.g. Queensland and the Northern Territory) do not recommend specific buffer distances, and instead recommend that appropriate buffer distances should be established by undertaking a site specific assessment.

Table 9-1 also shows that in the majority of jurisdictions if the recommended buffer distance is not afforded, there is a requirement to undertake site specific assessments to determine the risks posed by the landfill. This highlights that buffer distances need to reflect the actual risks posed by the landfill in question.

A buffer distance of up to 500 metres is generally considered appropriate for an operating putrescible waste landfill. However, a reduced buffer distance could be appropriate at a landfill site where site specific factors reduce the risks of off-site impact e.g. active putrescible landfilling no longer occurs; high quality and extensive environmental management and monitoring measures are undertaken etc.

9.4.2 Relevance to the WBLS

GHD understands that ACT EPA currently refers to Best Practice Environmental Management Siting, Location, Design, Operation and Rehabilitation of Landfills (EPA Victoria, 2010) (BPEM) in relation to landfill operations and management. As such, GHD has considered the potential implications of the required buffer distances around the WBLS if the requirements contained within the BPEM were applied rather than the requirements within the Territory Plan.

The BPEM would classify the WBLS as a type 2 (municipal) landfill site. As such a site (and assuming the WBLS had been fully capped / rehabilitated), a buffer distance of 500 metres from buildings and structures would need to be maintained. This buffer distance would be required to be measured from the edge of the closest waste disposal cell (where known) or the site boundary where the edge of the closest waste disposal cell is not known.

Where this buffer distance is proposed to be reduced or encroached upon, the BPEM requires an environmental audit to be conducted. The audit must assess the risk of harm to the proposed development posed by the potential offsite migration of landfill gas and amenity impacts resulting from the landfill.

The approach contained in the BPEM allows consideration of site specific conditions such as the operational status of the landfill, the installed environmental control technology and / or existing internal buffer distances in relation to determining the required buffer distance. The WBLS currently has variable internal buffer distances of between approximately 10 and 300 metres.

If the mandatory approach required by the Territory Plan were amended to allow the approach outlined in the BPEM to be applied (i.e. site specific audit), it may be possible to decrease the required landfill buffer distance with no significant increase in potential risks to the proposed future development (if supported by the findings of the audit). Previous GHD work completed during 2012 assessed the potential extent of buffer distances that may ultimately be required around the WBLS under a number of future scenarios. Plans showing these potential buffer distances are contained in Appendix N.

GHD notes that ACT EPA is currently developing its own guidance on the determination of buffer distances (likely to be available for consultation later in 2014).

9.5 Approaches to buffer distances in other Australian states and territories (other industrial uses)

9.5.1 Overview

All states and territories of Australia typically require buffer distances to be maintained around industrial areas (including resource recovery operations, green waste recycling operations, agriculture, chemical production, food processing etc.). Examples of buffer distances recommended in a number of Australian jurisdictions are provided in Table 9-2.

Table 9-2 Recommended buffer distances from other industrial uses

Ref	Buffer distance – Measure	Buffer distance – Type of facility	Buffer distance – Buffer distance recommended	Requirement if development occurs within recommended buffer distances	Where is buffer distance measured from?
VIC EPA[1, 2, 3]	Separation distances between sensitive land uses and various waste or recycling depots.	A - Materials recovery and recycling facility B - Transfer station C - Green waste facility	Case by case basis 250 m 800 - 2000 m+* *to be determined by site specific data	If site specific circumstances appear to indicate a reason for departing from the recommended buffer distances (e.g. implementation of best available technology), a separation distance different from the recommended distances may be able to be justified. Advice from the EPA should be obtained.	A & B - Measured from activity boundary within site (not site boundary) to property boundary of sensitive receptor. C - Measured from site boundary to property boundary of sensitive receptor
QLD EHP[1,2, 3, 4]	Separation distances between sensitive land uses and odorous industrial developments	A - Materials recovery and recycling facility B - Transfer station C - Green waste facility	Case by case basis 250 m 800 - 2000 m+* *to be determined by site specific data	QLD EHP guidance recommends that the approach outlined in EPA Victoria document number 1518 be followed. If site specific circumstances appear to indicate a reason for departing from the recommended buffer distances (e.g. implementation of best available technology), a separation distance different from the recommended distances may be able to be justified. Advice from the EPA should be obtained.	A & B - Measured from activity boundary within site (not site boundary) to property boundary of sensitive receptor. C - Measured from site boundary to property boundary of sensitive receptor
NSW EPA[5]	Separation distances between sensitive land uses and composting and related facilities	Composting and related organics processing facilities	Site specific assessment only. No suggested distance.	Unspecified within document	Unspecified within document
NSW EPA[6]	Separation distances between sensitive land uses and waste transfer stations	Waste transfer stations	More than 250 metres from the nearest residence or sensitive receptor not associated with the facility	Unspecified within document	Unspecified within document
NSW DUAP[7]	Separation distances between sensitive land uses and composting and related facilities	Composting and related facilities	Site specific assessment only. No suggested distance.	Unspecified within document	Unspecified within document
WA EP[8]	Buffer distance between industrial and sensitive land uses	Composting facility (outdoor, uncovered) Composting facility (enclosed windrows with odour control) Scrap metal recycling works Wreckers (automotive) Used tyre storage Waste depot Waste – resource recovery plant	150 m for green waste 1, 000 m for manures and food wastes *No minimum distance specified for green waste* 250 m for manures and food wastes 300 – 500 m 300 m 100 – 200 m 200 m Case by case	A sound site-specific technical analysis will provide the most appropriate guide to the separation distance that should be maintained between a particular industry and sensitive land uses, or between industrial precincts and sensitive land uses, to avoid or minimise land use conflicts. Where a site-specific study is carried out, it should generally include a technical analysis and report on the nature and level of the possible emissions from the industry, the site context, predicted impacts, acceptable criteria, and proposed management. Where the separation distance is less than the generic distance, a scientific study based on site- and industry-specific information must be presented to demonstrate that a lesser distance will not result in unacceptable impacts.	Unspecified within document
WA DER[9]	Separation distance to residential dwelling	Household hazardous waste storage facility	At least 300 m from nearest residential receptor	Unspecified within document	Unspecified within document
No relevant guidance was found regarding suggested or recommended buffer distances from resource recovery operations of green waste recycling facilities within Tasmania.					
SA EPA[10]	Separation distances between sensitive land uses and various waste or recycling depots.	Waste or recycling depot - other Compost works (between 20 and 200 tonnes per year) Compost works (greater than 200 tonnes per year)	300 m 300 m 1, 000 m	If site specific circumstances appear to indicate a reason for departing from the recommended separation distance (e.g. scale of operation, local topography, state of the art technology etc.), a separation distance different from the recommended distances may be able to be justified based on site specific information and assessment. .	Measured from activity boundary (not site boundary) to property boundary of sensitive receptor
No relevant guidance was found regarding suggested or recommended buffer distances from resource recovery operations of green waste recycling facilities within the Northern Territory.					

Source:

1. EPA Victoria (2013) *Recommended separation distances for industrial residual air emissions.* Publication No. 1518.
2. EPA Victoria (2012) *Separation distances for large composting facilities.* Publication No. 1495
3. EPA Victoria (2012) *Draft guidelines for separation distances for composting facilities.* Publication No. 1445
4. Department of Environment and Heritage Protection (2013) *Guideline Odour Impact Assessment from Developments*
5. NSW EPA (2004) *Environmental Guidelines Composting and Related Organics Processing Facilities*
6. Department of Environment and Conservation NSW (2006) *Handbook for Design and Operation of Rural and Regional Transfer Stations*
7. NSW Department of Urban Affairs and Planning (1996) *EIS Practice Guidelines: Composting and Related Facilities.*
8. Western Australian Environmental Protection Authority (2005) *Guidance for the Assessment of Environmental Factors (in accordance with the Environmental Protection Act 1986) No. 3, Separation Distances between Industrial and Sensitive Land Uses*
9. Government of Western Australia Department of Environmental Regulation (2013) *Guidelines for the operation and management of facilities for the acceptance and storage of household hazardous waste s*
10. Environment Protection Authority, South Australia (2007) *Guidelines for Separation Distances*

Table 9-2 provides the requirements of the individual guidelines. These are variable depending on the nature and size of the operation. That said, a number of guidelines recommend / require site specific scientific studies to be undertaken to:

- Identify the required buffer distance; or
- Identify the appropriate buffer distance if a reduction in the recommended buffer distance is proposed.

9.5.2 Relevance to the WBLS

Recent correspondence between GHD and ACT EPA has identified that ACT EPA is developing a separation guideline for determining required buffer distances within the ACT. It is understood that this guideline will be based on the Environment Protection Authority, South Australia (2007) *Guidelines for Separation Distances* (Separation Guideline) and will be available for consultation later in 2014.

As such, GHD has considered the potential implications of the required buffer distances around the WBLS if the requirements contained within the Separation Guideline were applied rather than the requirements of the Territory Plan.

The Separation Guideline would classify the current (and potential future) resource recovery operations and green waste recycling facilities at the WBLS as shown in Table 9-3.

Table 9-3 Buffer distances for other industrial facilities

Industrial operation	Separation Guideline classification	Recommended buffer distance	Where measured from?
Resource recovery operations (with or without buildings)	Waste or recycling depot - other	300 m	Measured from activity boundary (not site boundary) to property boundary of sensitive receptor
Green waste composting operations (with or without buildings)	Compost works	300 m to 1,000 m (input dependent)	Measured from activity boundary (not site boundary) to property boundary of sensitive receptor

Where site specific circumstances appear to indicate a reason for departing from the recommended separation distances shown in Table 9-3 above (e.g. scale of operation, local topography, state of the art technology etc.), the Separation Guideline notes that separation distances different from the recommended distances may be able to be justified based on site specific information and assessment.

The approach contained in the Separation Guideline allows consideration of site specific conditions such as the operational status of the industrial facility, the installed environmental control technology and / or existing internal buffer distances in relation to determining the required buffer distance. The WBLS currently has variable internal buffer distances of between approximately 10 and 300 metres.

If the mandatory approach required by the Territory Plan were amended to allow the approach outlined in the Separation Guideline to be applied (i.e. site specific assessment), it may be possible to decrease the required buffer distance for other industrial uses with no significant increase in potential risks to the proposed future development (if supported by the findings of the assessment). Previous GHD work completed during 2012 assessed the potential extent of buffer distances that may ultimately be required around the WBLS under a number of future scenarios. Plans showing these potential buffer distances are contained in Appendix N.

9.6 Additional relevant uncertainties

There are a number of additional uncertainties that are relevant for consideration in relation to potential future buffer distances required around the WBLS. These include:

- Uncertainty around the actual future land uses to which the WBLS will be put (as discussed in Section 6) and their compatibility (e.g. will they need buffer distances themselves and potentially between each other?); and
- Uncertainty around whether the existing waste management / resource recovery land uses will remain, be altered in scale / nature or be removed from the WBLS.

9.7 Opportunities and constraints

Agreeing on a suitable alternative approach to determining the required buffer distances around the WBLS would potentially release significant areas of land for development (depending on the outcomes of the required assessments). The current mandated landfill buffer distance around the WBLS represents a significant constraint to potential land development for residences and supporting infrastructure.

9.8 Conclusions

In relation to this section, GHD makes the following key conclusions:

9.8.1 General

- There is currently a high level of uncertainty around the actual future land uses to which the WBLS will be put (as discussed in Section 6) and their compatibility (e.g. will they need buffer distances themselves and potentially between each other?); and
- There is currently a high level of uncertainty around whether the existing waste management / resource recovery land uses will remain, be altered in scale / nature or be removed from the WBLS.

9.8.2 Landfill sites

- Most published Australian guidelines of recommended buffer distances between sensitive land uses and landfill sites state that a default distance of 500 metres is needed to protect sensitive receptors from odour, dust, noise and landfill gas impacts. The buffer distance required around the WBLS within the Territory Plan is consistent with this distance;
- Most published Australian guidelines state that the required buffer distance can be reduced if an appropriate site specific assessment is completed (and shows that any such reduction will not cause adverse impacts upon the newly introduced receptors). The Territory Plan does not currently allow this approach to be adopted;
- A number of the Australian guidelines specify that the buffer distance is to be measured from the activity / landfill cell boundary rather than the landfill boundary itself (if activity boundary is not known, then the site boundary is to be used as the point of measurement in most cases); and
- If the mandatory approach required by the Territory Plan were amended to allow the approach outlined in the BPEM to be applied (i.e. site specific audit), it may be possible to decrease the required landfill buffer distance with no significant increase in potential risks to the proposed future development (if supported by the findings of the audit).

9.8.3 Industrial operations

- The buffer distances required by industrial facilities within the published Australian guidelines are variable depending on nature and size of the operations;
- A number of Australian guidelines recommend / require site specific scientific studies to be undertaken to:
  - Identify the required buffer distance; or
  - Identify the appropriate buffer distance if a reduction in the recommended buffer distance is proposed.
- A number of the Australian guidelines specify that the buffer distance is to be measured from the activity boundary rather than the facility boundary itself;
- If the mandatory approach required by the Territory Plan were amended to allow the approach outlined in the Separation Guidelines to be applied (i.e. site specific assessment), it may be possible to decrease the required industrial facilities buffer distance with no significant increase in potential risks to the proposed future development (if supported by the findings of the assessment).

9.9 Recommendations

Based on the key conclusions provided above, GHD makes the following recommendations (made with consideration of the Vision – see Table 9-4 below):

- As identified in Section 6, discuss and determine with relevant stakeholders short, medium and long term future land uses at the WBLS and locations of these land uses at the WBLS;
- Following agreement of future land uses, undertake consultation with relevant stakeholders in relation to altering the mandatory Territory Plan approach to buffer distance determination around the WBLS to a site specific assessment approach (inclusive of the landfill and existing / potential future land uses);and
- Agree with the relevant stakeholders what appropriate investigations / actions / process is / are required to further assess the required buffer distances (potentially considering the additional works identified in Sections 7 and 8 of this report) with a view to potentially reducing it if the required works indicate that this would cause no significant additional impacts to a new off-site receptor.

Table 9-4 identifies how the recommendations above were developed with consideration of the overarching project Vision (Appendix B).

Table 9-4 Recommendations and relevant guiding principles (as contained in the Vision)

Recommendation	Relevant guiding principles
1	Ptnr 1., Ptnr 2., Ptnr 4., Eva 1., Eco 2., Eco 4., Eco 5., Eco 6., Eco 7., Soc 3., Soc 5., Soc 6., Econ 1., Econ 3., Econ 6., Econ 7.
2	Ptnr 1., Ptnr 2., Ptnr 4., Eva 1., Eco 2., Eco 4., Eco 5., Eco 6., Eco 7., Soc 5., Soc 6., Econ 1., Econ 3., Econ 6., Econ 7.
3	Ptnr 1., Ptnr 2., Ptnr 4., Eva 1., Eco 2., Eco 4., Eco 5., Eco 6., Eco 7., Soc 5., Soc 6., Econ 1., Econ 3., Econ 6., Econ 7.

10. Conclusions

10.1 Overview

Sections 6 to 9 of this report contain individual conclusions and recommendations as relevant to each Section. As such, the reader is directed to the individual Sections for detailed conclusions and recommendations.

However, due to the complex nature of the WBLS and its potential implications for the proposed future development (both on and off-site), it is considered appropriate to provide a brief summary of the over-arching conclusions and recommendations. These are provided below.

10.2 Summary of conclusions

The principal conclusions of this report in relation to the above are as follows:

- The WBLS is still used for resource recovery activities, as well as landfilling of asbestos, which will continue until the specific area of the site is filled. It has also been designated as an emergency landfill for the ACT, should the other facilities serving the ACT become unavailable for a short period. Continuation of these current activities is not compatible with future residential development adjacent to the WBLS boundaries. A suitable buffer zone needs to be established to provide proper separation of these activities from an amenity perspective. Currently a minimum buffer zone of 500m applies to the WBLS.
- A decision has not been made by the ACT Government about whether the WBLS should continue to be the designated emergency landfill, as this use is most incompatible with future residential development in the vicinity of the WBLS. The future of existing resource recovery activities, within the main site and in the Parkwood Estate adjoining the main site is uncertain. Some types of resource recovery activities may be compatible and indeed complementary to the future residential development, in providing services needed for the development eg waste transfer facilities. Excessively noisy, dusty and potentially odorous activities are not compatible with such uses.
- The WBLS therefore presents a mixture of opportunities and constraints in relation to both on-site and off-site future development. A number of these opportunities and constraints are not currently fully understood / defined at a detailed level. Further investigations / assessments are required to further understand the identified opportunities and constraints;
- Future land uses of the WBLS have not yet been determined. It is critical to decide which areas of the WBLS would be used for the individual future land uses to enable additional investigative works identified within this report to be further refined (and subsequently undertaken). Completion of these works would allow further understanding of the opportunities and constraints presented by the WBLS as they relate to the proposed future on-site and off-site developments.
- All of the uses of the WBLS listed in Table 6-2 could occur in the medium to long term, once settlement of landfilled waste is well advanced. However the level and type of access to the site would affect the risk profile of the different uses.
- For example, recycling activities are compatible with the current uses of the site and public access to the site would be restricted to certain areas. As such, this type of use would require less investigation and on-going management than other “new” uses, such as community gardens or equestrian activity where public access is uncontrolled.

- Uses involving buildings such as indoor resource recovery or education/administration facilities should ideally only be considered for areas that have not been previously landfilled. For any buildings and underground pipes, allowance for ongoing settlement needs to be part of the design. Gas prevention and ongoing detection measures would be needed for any buildings placed on the site, and any buried infrastructure such as pipes and electrical pits.
- Passive recreational uses would be most applicable over the various areas of the site. Forestry would be possible but ideally not in previously landfilled areas, due to potential disturbance of the cap. Mountain bike trails may be possible in the medium to long term provided the cap is not disturbed. Solar farms would normally be considered for non-landfilled areas due to settlement and the possible risks associated with the combination of landfill gas and potential sparking from power generation equipment.
- In relation to landfill mining, the potential costs and impacts associated with waste disturbance would seem to outweigh the potential benefits of recovering resources and/or creating additional land for redevelopment in most areas of the site. In specific areas such as the tyre disposal area, detailed investigations including a cost benefit analysis would be necessary to make a definitive assessment of the opportunities available. Even if such areas are remediated through this process, they would likely lie within the buffer zone and not be able to be utilised for future residential development. However, if appropriate gas protection is provided for buildings, some commercial activities may be possible.
- The assessment of potential heat recovery opportunities has indicated that the landfill gas engine would provide a compact source of high grade heat, due to the high temperatures associated with jacket water and exhaust gases. Utilisation of this heat source may be technically and economically feasible, depending upon the envisaged end use for the heat. However the potential life of the engine on site may be less than 5 years, after which a flare would be used on site. A heat recovery system that can initially use the engine as the heat main source, but can be adapted to extracting heat from the flare exhaust may be a possibility.
- Whilst it is technically feasible to recover heat from the landfilled waste and from leachate, this is less likely to be economically viable as it is a dispersed source of low grade heat (relatively low temperature) and therefore may be costly to install and operate the pipework and associated equipment needed to extract the heat over a large area. Heat losses may be a major issue in beneficial usage of the extracted heat, depending upon the end uses. If the site generates a relatively small amount of leachate (which is thought to be the case), the overall amount of heat that could be extracted from this source may be relatively small.
- The identified heat recovery projects may not initially be economically viable, but they may be able to be set up as sustainability projects on a demonstration scale to provide improved data. This would provide an opportunity to demonstrate their feasibility to potential users and attract investment for larger scale systems.
- Surface water quality downstream of the WBLS does not appear to be adversely impacted by WBLS activites, and could potentially be harnessed for potential uses. Existing tributaries and drainage lines could be retained or enhanced as water features within the proposed residential development. There is a risk that leachate and / or sediment laden water derived from the WBLS could impact upon off-site surface water in the future if the WBLS is retained as an emergency landfill.
- A range of potential land uses have been examined. Most of the uses investigated could occur in the medium to long term, once degradation and associated settlement of landfilled waste is well advanced. Uses involving buildings such as indoor resource

recovery would typically only be considered for areas that have not been previously landfilled. Passive recreation uses would be most applicable for most various areas of the site. Activities such as forestry would ideally not be conducted in previously landfilled areas, due to potential disturbance of the cap. Commercial plant nursery activities and mountain bike trails may be possible uses in the medium to long term provided the cap is not disturbed. Solar farms would be most practical in non-landfilled areas where settlement is not an issue.

- A range of investigative works have been suggested to provide greater certainty about certain aspects of the site. The key issue that needs to be investigated prior to redevelopment of the areas adjacent to the WBLS is the potential for off-site migration of landfill gas. This will inform the determination of appropriate buffer zones around the WBLS. If the future development involves some related activities eg community gardens, commercial plant nurseries being conducted within the WBLS, additional investigative works would be required, focussing on landfill gas emissions. Potential offsite impacts on groundwater are important, however current data indicates that groundwater within the site is largely unaffected by past activities. Landfill gas and settlement would be the principal areas of focus.
- Appropriate buffer distances for surrounding residential development will be dependent upon the future activities to be conducted at the WBLC. The greater the likelihood of dust, odour or noise emissions, the greater would be the buffer distances required. If the WBLS remains as the designated emergency landfill for the ACT, a greater buffer distance will be required than if another site is nominated. Potential issues with subsurface emission of landfill gas also need to be taken into consideration in establishing suitable buffer distances. This issue is likely to become less of a problem in the longer term, as the amount of gas produced by the site diminishes.
- It may be possible to reduce the current mandated buffer distance if appropriate investigations are undertaken and reduced buffer distances are approved by an ACT accredited contaminated land auditor

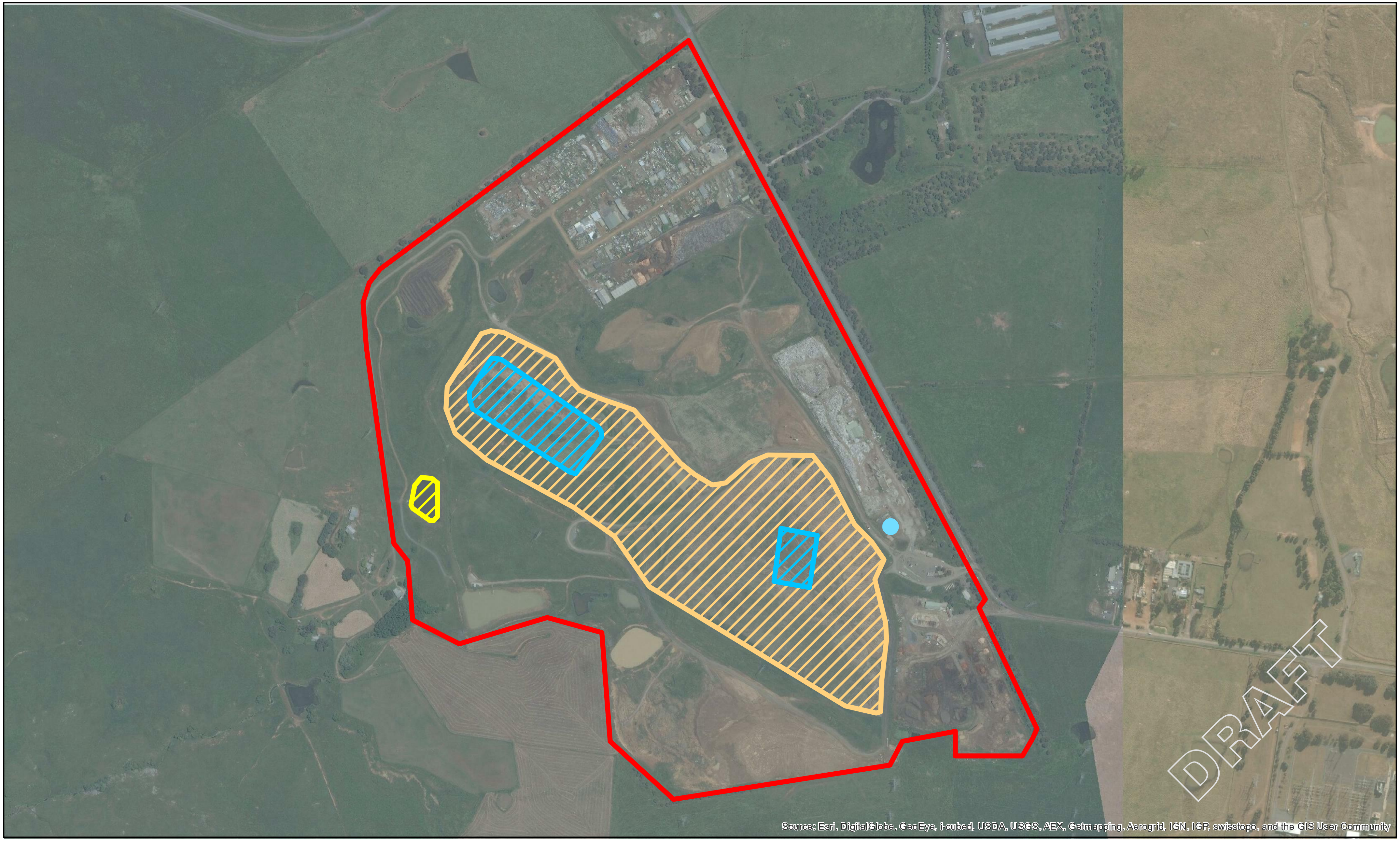
11. Recommendations

Recommendations arising from the above are as follows:

- For Riverview to discuss and agree with the relevant stakeholders precisely what the future land uses of the WBLS will be in the future (short, medium and long term) and locations of these land uses at the WBLS;
- Following determination of the above, for Riverview to subsequently refine and undertake the relevant additional investigative works referred to in this report (both on and off-site). Completion of these works would allow further understanding of the opportunities and constraints presented by the WBLS as they relate to the proposed future on-site and off-site developments;
- Finalise the Master Plan design on the basis of new information that has arisen from the additional investigation works; and
- Develop guidelines for future development of specific areas in the vicinity of the WBLS.

Appendices

Appendix A - Plans showing areas relevant to heat assessment



Paper Size A3

0 0.05 0.1 0.2 0.3

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: Australian 1966
Grid: AGD 1966 ACT Grid AGC Zone

N

Landfill Gas Engine
Site Boundary (Approximate)
Closed Loop Heat Exchange Areas
Leachate Collection and Management System
MSW Landfill

GHD

The Riverview Group
West Belconnen Landfill Advice

Job Number	21-23237
Revision	A
Date	28 Apr 2014

Heat Exchange Areas

Figure A

G:\21\23237\GIS\Maps\MXD\2123237_Z00X_HeatExchangeAreas.mxd

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:mlfaint

Appendix B – Vision documentation

The Belconnen Project Sustainability Vision

"Creating a sustainable community of international significance in the Nation's capital."

The Riverview Group, working with the ACT and NSW Governments, will develop the site at Belconnen to achieve a vision of inspiring sustainable living, development practice and awareness. Achieving a high quality of life for the people living at Belconnen is at the heart of our project planning and design.

We will create a community that exemplifies World's Best Practice in its design, construction and long-term liveability. As a model of sustainable community living it will be a place and community that can be showcased throughout Australia and internationally.

Project objectives:

To achieve our Vision we will challenge conventional industry thinking. We will employ practices, processes and systems that embody innovation and design excellence.

This project has been conceived and will be delivered on a fully integrated and audited triple bottom line basis.

Our project will:

- » Be sustainable over time, socially, economically and ecologically (with a low and reducing ecological footprint)
- » Respond to the local and global environment
- » Provide for future beneficial change to occur in design, infrastructure and regulatory mechanisms
- » Be cost effective, replicable and measurable
- » Act as a new model that others can follow.

Guiding Principles for Sustainable Results

The principles below will direct decision-making by all project management, sub-consultants and referral agencies in the delivery and development of the Belconnen site. They reflect national priorities and Federal, State and Territory Government policies on housing affordability, climate change and environmental protection.

PARTNERING PRINCIPLES

Ptnr 1. Partnering is essential to this project and the scale and timeframe will allow for positive partnerships to grow and thrive

Ptnr 2. Partnering with public agencies is a cornerstone of our approach

Ptnr 3. Engaging the community in design and governance is fundamental to the delivery of the project.

Ptnr 4. Designing the project for community ownership and ultimate community control

Ptnr 5. Supporting community housing through public and private partnering arrangements

Ptnr 6. Collaborating with research and educational institutions to drive innovation.

EVALUATION PRINCIPLES

Eva 1. Identifying and delivering realistic and costed initiatives

Eva 2. Providing independent peer review of project proposals and project outcomes

Eva 3. Using recognised international and national benchmarks for sustainability performance to publicly report and raise awareness of project outcomes

Eva 4. Empowering resident and community monitoring and management of sustainability performance

Eva 5. Encouraging a culture of continuous improvement.

ECOLOGICAL PRINCIPLES

Eco 1. Acknowledging the intrinsic value of all species and the special role and regional significance of the Murrumbidgee river corridor and Gininnderra Creek

Eco 2. Respecting and supporting the ecosystem functions of air, soil and water, recognising the importance of living and non-living environmental resources

Eco 3. Reducing greenhouse gas emissions through innovative products and place design, material selection and service provision

Eco 4. Recognising our natural ecological limits and minimising our resource, water and energy consumption

Eco 5. Using existing local infrastructure to deliver efficient renewable services and reusable resources

Eco 6. Enhancing local opportunities for food production and production of materials

Eco 7. Fostering a deep sense of respect for and connection to the land, flora and fauna.

SOCIAL AND CULTURAL PRINCIPLES

Soc 1. Respecting and honouring Aboriginal and non-Aboriginal cultural, historical and spiritual values, including integrating with the existing rich, social fabric of Belconnen

Soc 2. Designing for social equity, affordability, diversity and interdependence, honouring differences and catering for the needs of individuals through all stages of life

Soc 3. Maximising health, safety and comfort of the built environment to provide enduring quality of life

Soc 4. Instilling awareness and supporting education of sustainability values, technology and lifestyles

Soc 5. Using creative and robust design solutions to create a continuing sense of place and beauty that inspires, affirms and ennobles

Soc 6. Designing neighbourhoods that support and encourage community interactions through imaginative, functional and enjoyable public spaces

ECONOMIC PRINCIPLES

Econ 1. Delivering a financial return to the ACT Government recognising their sovereign interest in the land

Econ 2. Recognising the opportunities provided by the project's scale and low capital base to achieve high-level sustainability outcomes while delivering profitability to joint venture partners

Econ 3. Building on existing local infrastructure

Econ 4. Ensuring long-term economic viability through design excellence and community building

Econ 5. Minimising obsolescence through design of enduring component life cycle, allowing for disassembly and change

Econ 6. Integrating with the Belconnen commercial, retail and employment networks

Econ 7. Growing a formal and informal green economy that fosters local jobs and builds regional learning around green innovation and technology

Appendix C - Document reference list

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23. Van Vossen and Prent 2011, *Feasibility Study Sustainable Material and Energy Recovery from Landfills in Europe*, Proceedings Sardinia 2011, Thirteenth International Waste Management and Landfill Symposium

24. WMW 2011, *Landfill Mining and Energy Recovery Planned in Taiwan*, Waste Management World

25. WMW 2010, *Environmental Group Comments on Waste to Energy Plans in Cayman Islands*, Waste Management World

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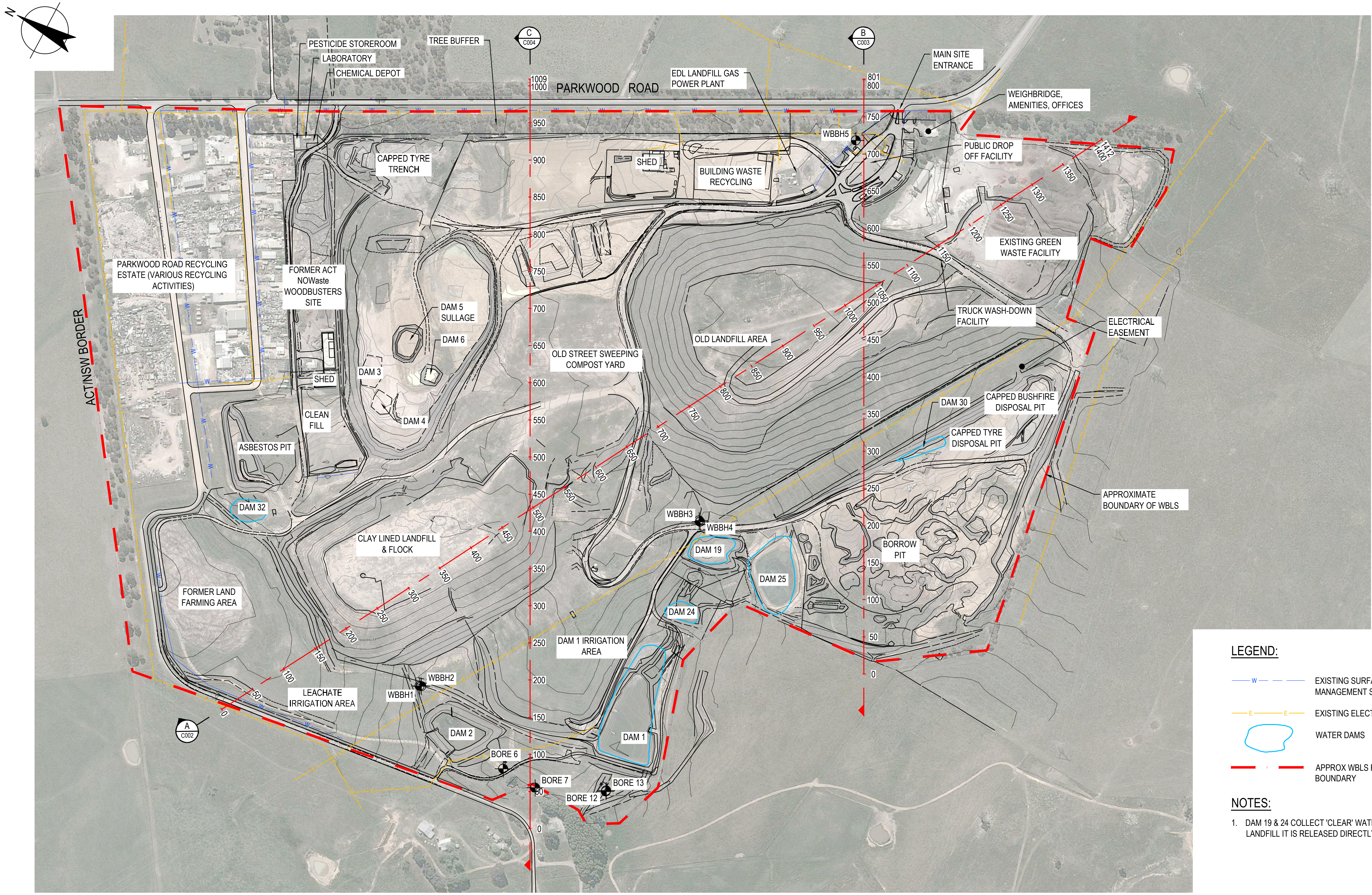
Appendix D – Drawings of WBLS



LEGEND:

- EXISTING SURFACE WATER MANAGEMENT SYSTEM
- EXISTING ELECTRICAL SERVICE
- WATER DAMS
- APPROX WBLS PROPERTY BOUNDARY

NOTES:

1. DAM 19 & 24 COLLECT 'CLEAR' WATER FROM CLOSED LANDFILL IT IS RELEASED DIRECTLY OFF SITE

EXISTING SITE PLAN

SCALE 1:2500

PRELIMINARY

No	Revision	Drawn	Job Manager	Project Director	Date
A	DRAFT FOR REVIEW	MF	MW	DG	14.04.14

Note: * indicates signatures on original issue of drawing or last revision of drawing

0 25 50 75 100 125m
SCALE 1:2500 AT ORIGINAL SIZE

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E sydmail@ghd.com W www.ghd.com

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Drawn M. FORTU
Designer
Drafting Check
Design Check
Approved (Project Director)
Date
Scale 1:2500
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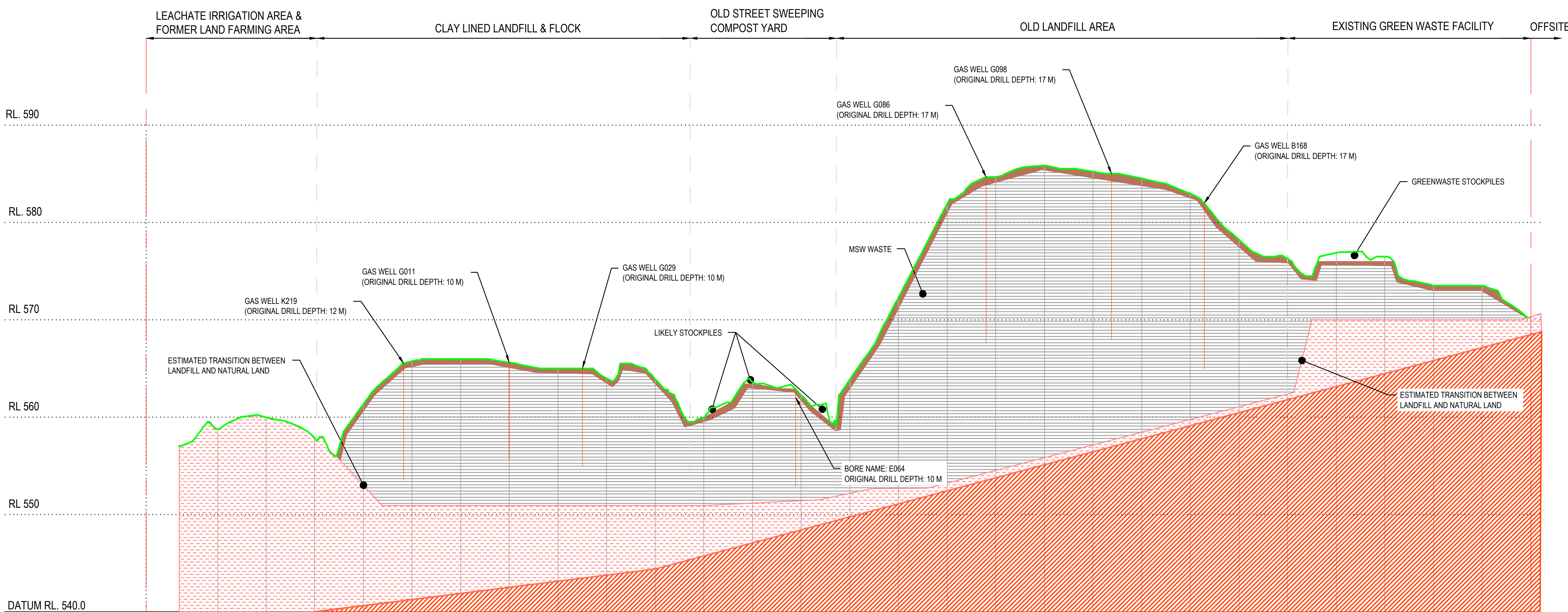
Client THE RIVERVIEW GROUP
Project WEST BELCONNEN LANDFILL SITE
Title INDICATIVE SITE LAYOUT BASED ON 2010 SURVEY
Original Size A1
Drawing No: 21-23237-C001
Rev: A

Plot Date: 7 May 2014 - 9:17 AM Plotted by: Carol Ng Cad File No: G:\21\23237\CADD\Drawings\21-23237-C001.dwg



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CHAINAGE	0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1411.56

LONGITUDINAL SECTION LS-REF 1

HORIZONTAL SCALE 1:2500 VERTICAL SCALE 1:250

A / C001 SECTION
SCALE 1 : 2500

VERTICAL SCALE EXAGGERATED 10 TIMES

LEGEND:

- APPROX WBLS BOUNDARY
- 2010 LANDFORM SURFACE
- EDL VERTICAL GAS WELLS
- GROUNDWATER BORES
- APPROX LANDFILL CAP
- MUDSTONE
- VOLCANIC ROCK
- SOIL LAYER (MOSTLY CLAY)
- MSW WASTE
- ASBESTOS WASTE

NOTES:

1. PLAN SHOWS ESTIMATED BASAL PROFILE POST EXCAVATION BASED ON GHD'S REVIEW OF AVAILABLE INFORMATION
2. REVIEW OF LANDFILL DEVELOPMENT REPORT (1973) SUGGESTS A CLAY LAYER, 0.3 M MINIMUM THICKNESS, BE LEFT IN-SITU TO PROVIDE BARRIER
3. REVIEW OF LANDFILL DEVELOPMENT REPORT (1973) SUGGESTS A LAYER OF 0.3 M THICK BE PLACED ABOVE THE CLAY FOR LEACHATE COLLECTION
4. NOT ALL EDL GAS WELLS ON SECTION SHOWN

PRELIMINARY

No	Revision	Drawn	Job Manager	Project Director	Date
A	DRAFT FOR REVIEW	MF	MW	DG	

Note: * indicates signatures on original issue of drawing or last revision of drawing

VERTICAL 1:500 AT ORIGINAL SIZE 0 5 10 15 20 25m
HORIZONTAL 1:2500 AT ORIGINAL SIZE 0 25 50 75 100 125m

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Drawn M. FORTU | Designer
Drafting Check | Design Check
Approved (Project Director)
Date
Scale 1:2500

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Client **THE RIVERVIEW GROUP**
Project **WEST BELCONNEN LANDFILL SITE**
Title **INDICATIVE LONG SECTIONS SHEET 1 OF 3**

Original Size **A1** **Drawing No: 21-23237-C002** **Rev: A**

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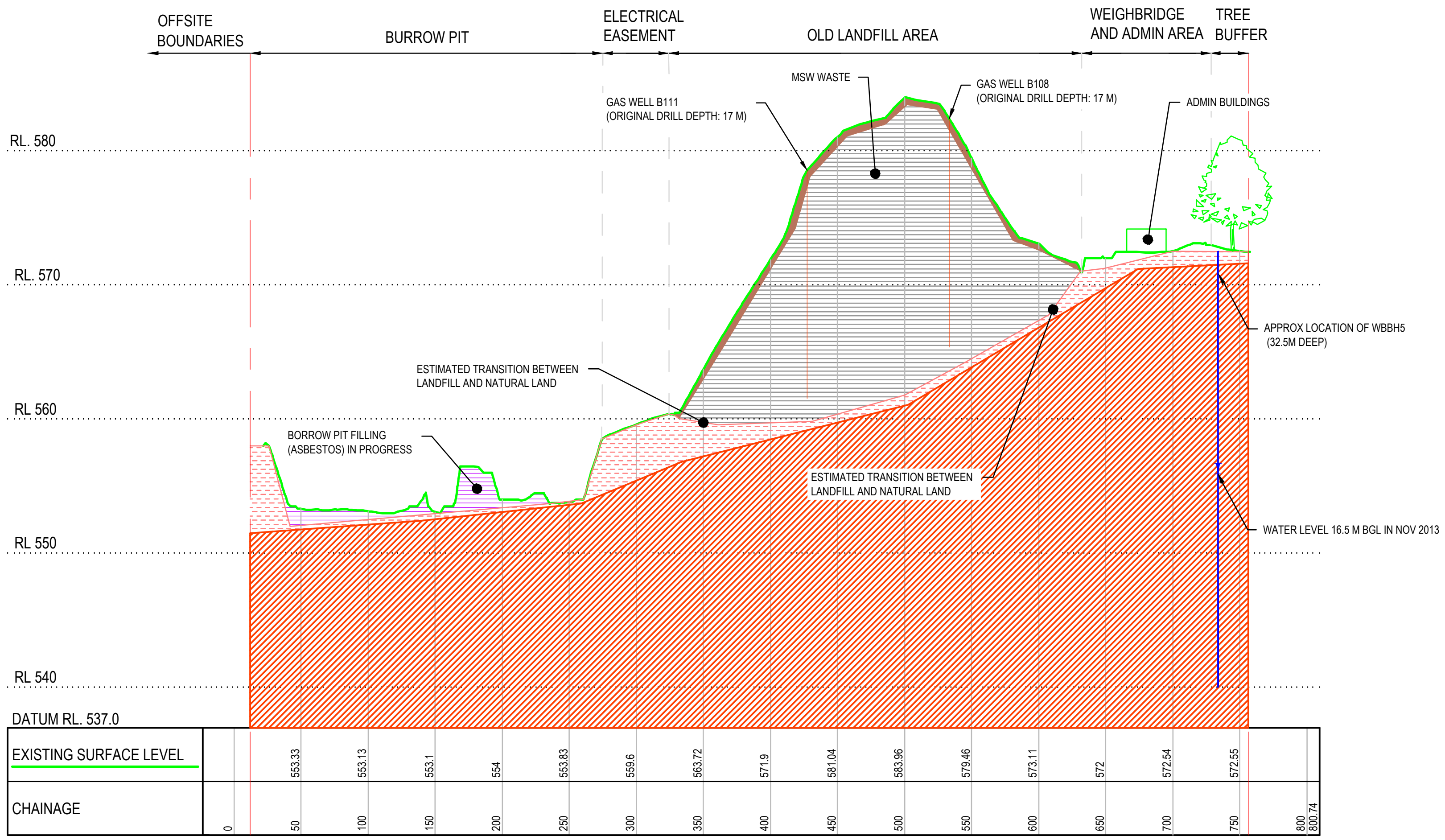

LONGITUDINAL SECTION LS-REF 3

HORIZONTAL SCALE 1:2500 VERTICAL SCALE 1:250

B SECTION
C001 SCALE 1 : 2500

VERTICAL SCALE EXAGGERATED 10 TIMES

LEGEND:

- APPROX WBLS BOUNDARY
- 2010 LANDFORM SURFACE
- EDL VERTICAL GAS WELLS
- GROUNDWATER BORES
- APPROX LANDFILL CAP
- MUDSTONE
- VOLCANIC ROCK
- SOIL LAYER (MOSTLY CLAY)
- MSW WASTE
- ASBESTOS WASTE

NOTES:

1. PLAN SHOWS ESTIMATED BASAL PROFILE POST EXCAVATION BASED ON GHD'S REVIEW OF AVAILABLE INFORMATION
2. REVIEW OF LANDFILL DEVELOPMENT REPORT (1973) SUGGESTS A CLAY LAYER, 0.3 M MINIMUM THICKNESS, BE LEFT IN-SITU TO PROVIDE BARRIER
3. REVIEW OF LANDFILL DEVELOPMENT REPORT (1973) SUGGESTS A LAYER OF 0.3 M THICK BE PLACED ABOVE THE CLAY FOR LEACHATE COLLECTION
4. NOT ALL EDL GAS WELLS ON SECTION SHOWN

PRELIMINARY

No	Revision	Drawn	Job Manager	Project Director	Date
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Note: * indicates signatures on original issue of drawing or last revision of drawing

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HORIZONTAL 1:2500 AT ORIGINAL SIZE 0 25 50 75 100 125m

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Client **THE RIVERVIEW GROUP**
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Title **INDICATIVE LONG SECTIONS SHEET 2 OF 3**

Original Size **A1** Drawing No: **21-23237-C003** Rev: **A**

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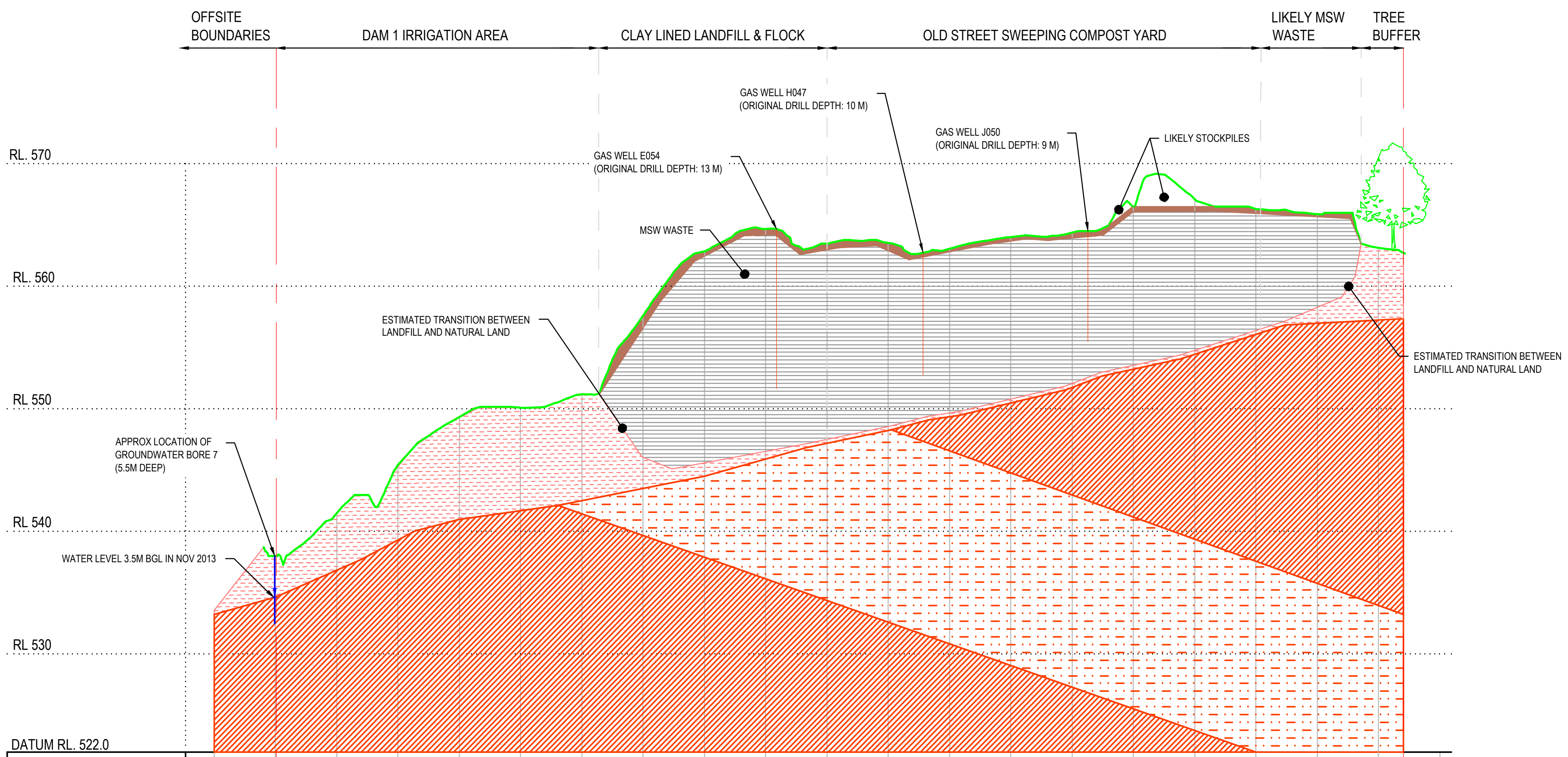

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CHAINAGE	0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000 1008.8

LONGITUDINAL SECTION LS-REF 2

HORIZONTAL SCALE 1:2500 VERTICAL SCALE 1:250

VERTICAL SCALE EXAGGERATED 10 TIMES

C / C001 SECTION
SCALE 1 : 2500

LEGEND:

- APPROX WBLS BOUNDARY
- 2010 LANDFORM SURFACE
- EDL VERTICAL GAS WELLS
- GROUNDWATER BORES
- APPROX LANDFILL CAP
- MUDSTONE
- VOLCANIC ROCK
- SOIL LAYER (MOSTLY CLAY)
- MSW WASTE
- ASBESTOS WASTE

NOTES:

1. PLAN SHOWS ESTIMATED BASAL PROFILE POST EXCAVATION BASED ON GHD'S REVIEW OF AVAILABLE INFORMATION
2. REVIEW OF LANDFILL DEVELOPMENT REPORT (1973) SUGGESTS A CLAY LAYER, 0.3 M MINIMUM THICKNESS, BE LEFT IN-SITU TO PROVIDE BARRIER
3. REVIEW OF LANDFILL DEVELOPMENT REPORT (1973) SUGGESTS A LAYER OF 0.3 M THICK BE PLACED ABOVE THE CLAY FOR LEACHATE COLLECTION
4. NOT ALL EDL GAS WELLS ON SECTION SHOWN

PRELIMINARY

No	Revision	Drawn	Job Manager	Project Director	Date
A	DRAFT FOR REVIEW	MF	MW	DG	

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HORIZONTAL 1:2500 AT ORIGINAL SIZE 0 25 50 75 100 125m

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Project **WEST BELCONNEN LANDFILL SITE**
Title **INDICATIVE LONG SECTIONS SHEET 3 OF 3**

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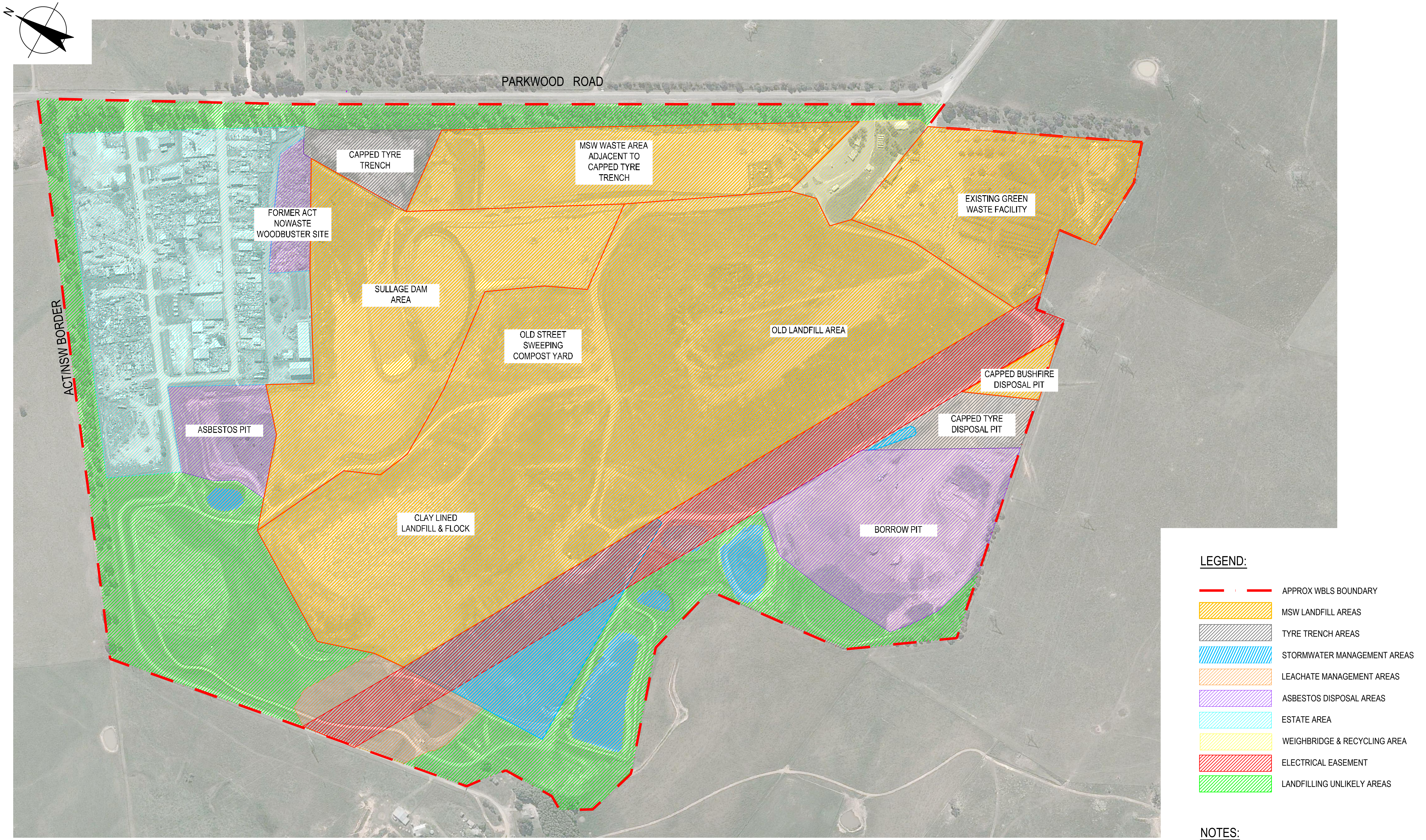

NOTES:

1. BOUNDARIES ARE INDICATIVE ONLY

SITE AREAS

SCALE 1:2500

PRELIMINARY

No	Revision	Drawn	Job Manager	Project Director	Date
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Client **THE RIVERVIEW GROUP**
Project **WEST BELCONNEN LANDFILL SITE**
Title **CONSOLIDATION OF INDIVIDUAL AREAS INTO ASSESSMENT GROUP AREAS**

Original Size A1 Drawing No: **21-23237-C005** Rev: A

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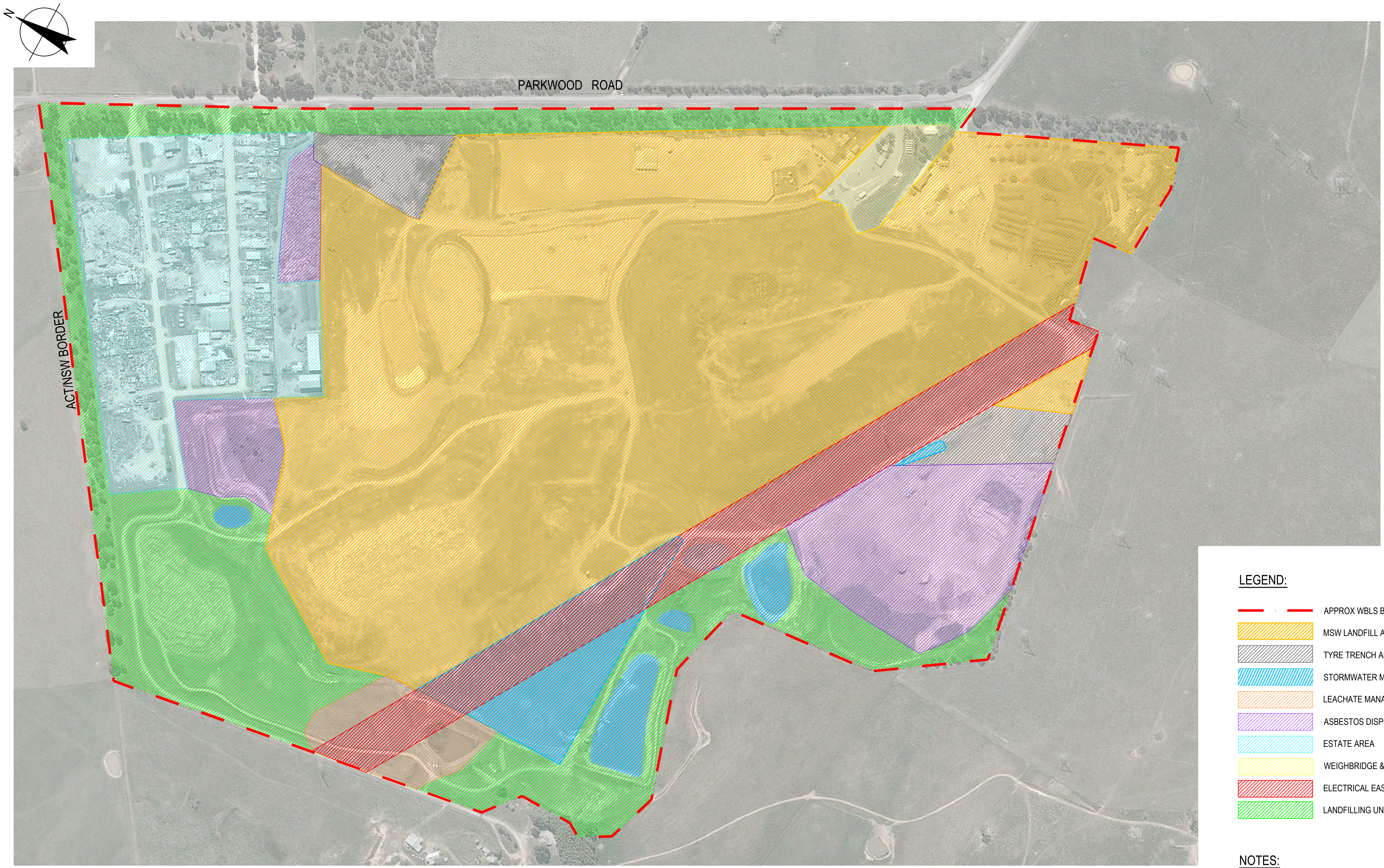

LEGEND:

- APPROX WBLS BOUNDARY
- MSW LANDFILL AREAS
- TYRE TRENCH AREAS
- STORMWATER MANAGEMENT AREAS
- LEACHATE MANAGEMENT AREAS
- ASBESTOS DISPOSAL AREAS
- ESTATE AREA
- WEIGHBRIDGE & RECYCLING AREA
- ELECTRICAL EASEMENT
- LANDFILLING UNLIKELY AREAS

NOTES:

1. BOUNDARIES ARE INDICATIVE ONLY

SITE AREAS

SCALE 1:2500

PRELIMINARY

No	Revision Note: * indicates signatures on original issue of drawing or last revision of drawing	Drawn	Job Manager	Project Director	Date
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Date	
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Client **THE RIVERVIEW GROUP**
Project **WEST BELCONNEN LANDFILL SITE**
Title **ASSESSMENT GROUP AREAS**

Original Size **A1** Drawing No: **21-23237-C006** Rev: **A**

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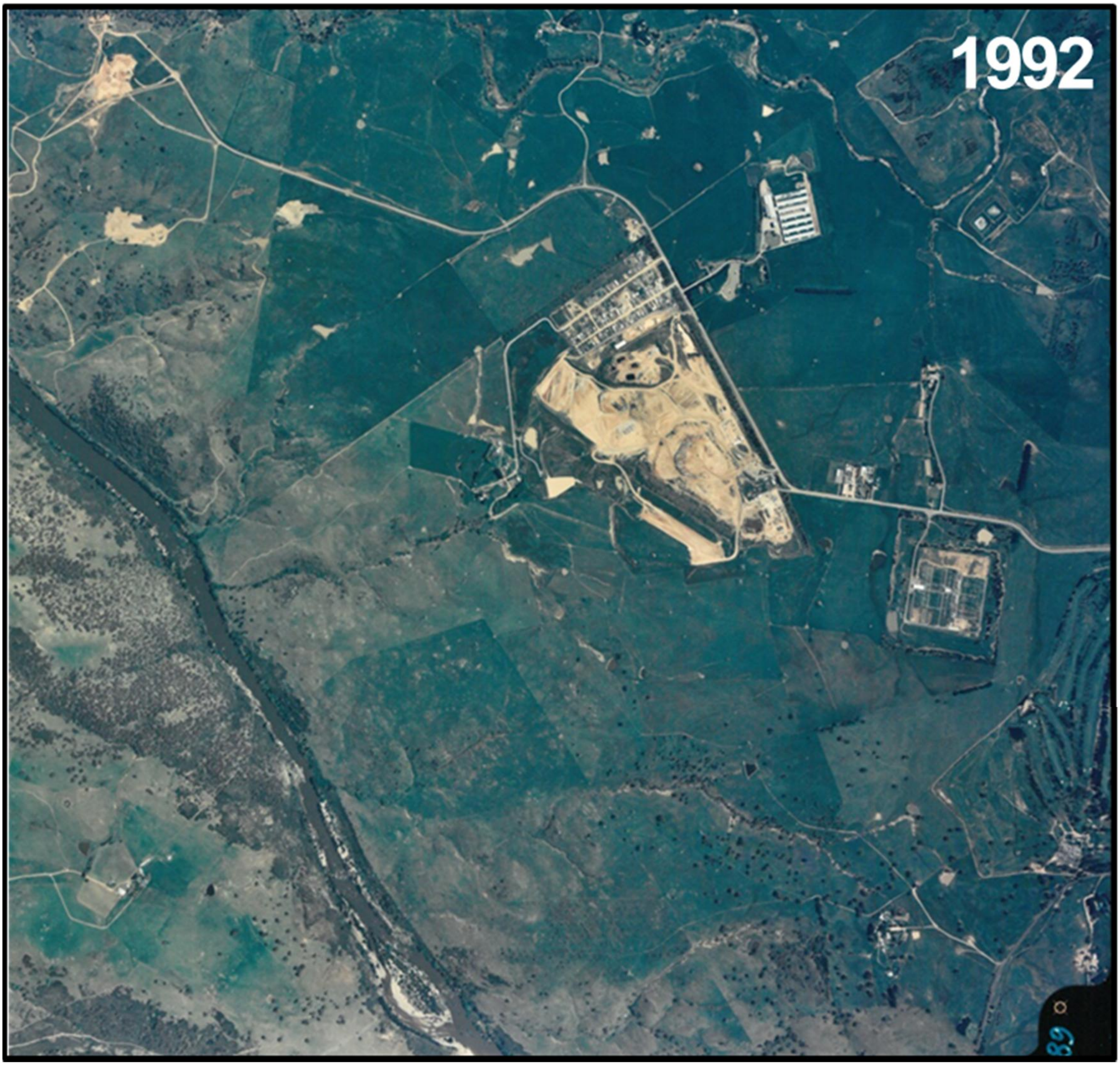
Appendix E - Available historical aerial photographs of the WBLS


1959

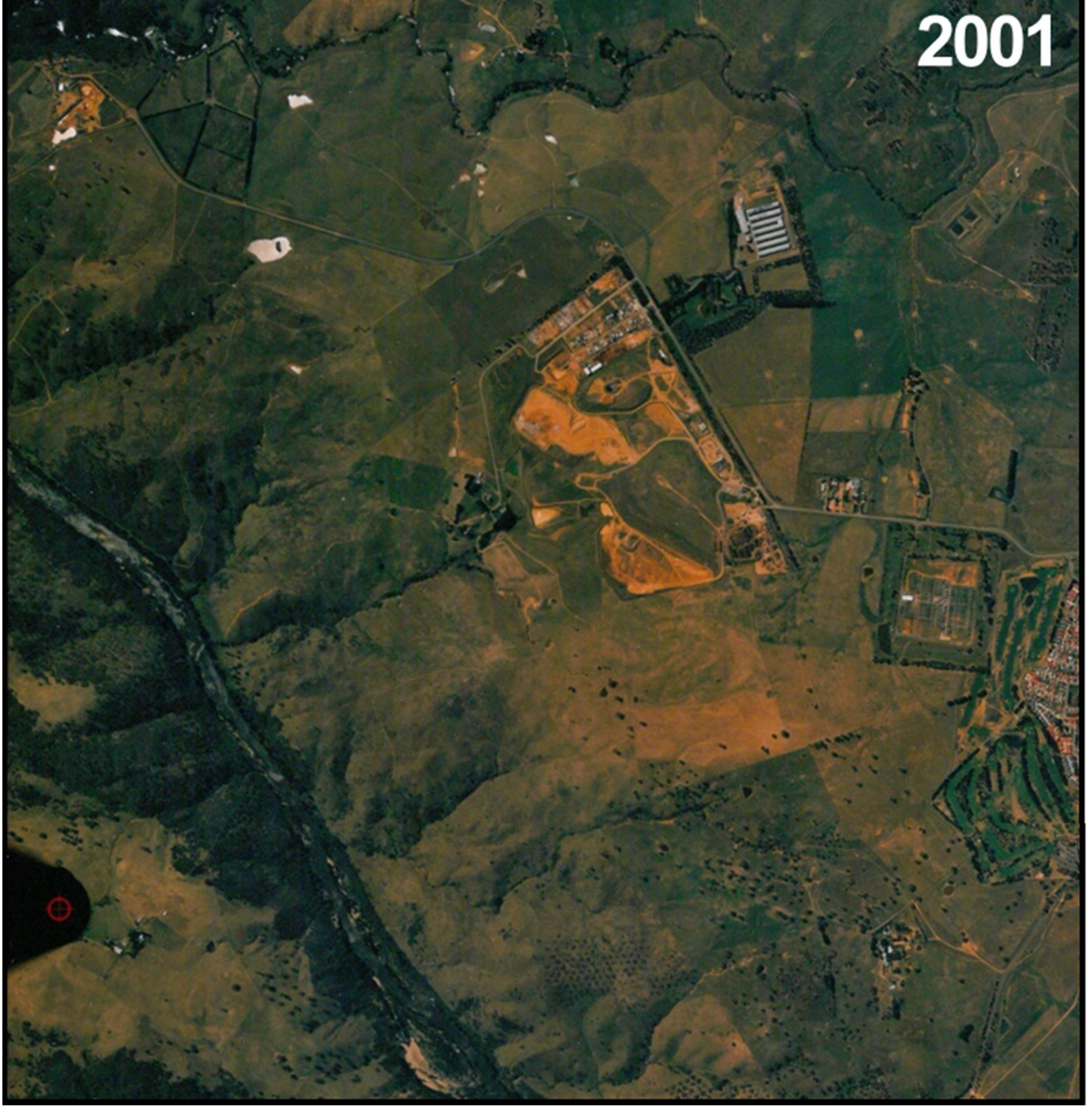

1967


1976


1985


1992

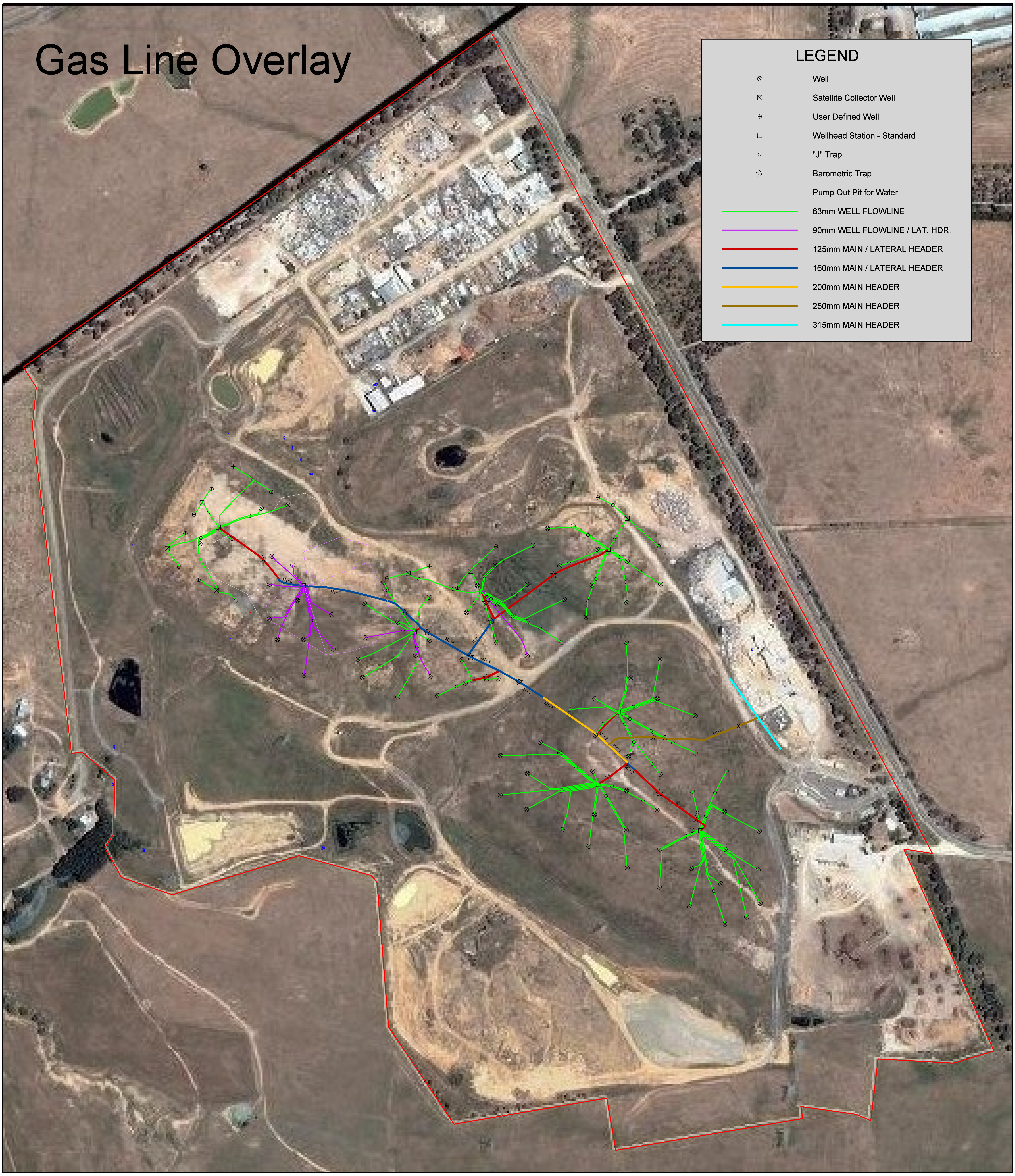

1998


2001


2005


2014

Appendix F - EDL landfill gas system plan



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Produced from: September 2008 from ACTPLA's 2008 Satellite Imagery and Energy Developments West Belconnen LFG Power Project As Built Drawing No. 867-AB-001 Dated 16/01/01

0 100 200 300 400 500

Metres

West Belconnen Landfill

Drawn by: BW FOX DRAFTING & CONSULTANT SERVICES
SEPTEMBER 2008
REFERENCE: #08091001

ACT NOWASTE

Appendix G – Landfill mining assessment

Riverview Projects (ACT) Pty Ltd

West Belconnen Landfill Site

Landfill Mining Assessment

June 2014

*This report: has been prepared by GHD for Riverview Projects (*ACT) Pty Ltd and *may only be used and relied on by Riverview Projects (*ACT) Pty Ltd *for the purpose agreed between GHD and Riverview Projects (*ACT) Pty Ltd *as set out in section 1 of this report.*

*GHD otherwise disclaims responsibility to any person other than Riverview Projects (*ACT) Pty Ltd *arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.*

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

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

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

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

GHD has prepared the preliminary cost estimates and prices contained within this report ('Cost Estimates') using information reasonably available to the GHD employee(s) who prepared this report; and based on assumptions and judgments made by GHD (described within this report).

The Cost Estimates have been prepared for the purpose of developing a preliminary understanding of the scale of potential costs associated with the relevant actions / works identified and must not be used for any other purpose.

The Cost Estimates are preliminary estimates only. Actual prices, costs and other variables may be different to those used to prepare the Cost Estimates and may change. Unless as otherwise specified in this report, no detailed quotations have been obtained for actions / work identified within this report. GHD does not represent, warrant or guarantee that the actions / works can or will be undertaken at costs which are the same or less than the Cost Estimates.

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

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

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

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Figure index

Appendices

1. Introduction

1.1 Overview

GHD has undertaken an assessment of the potential for landfill mining at the WBLS, as it was thought that it may be possible to reclaim airspace for future filling, potentially with soils / construction waste derived from the adjacent development project or to reclaim land for development and/or reclaim some buried wastes for re-use / recycling (or some combination of these).

1.2 Reliance

1. Emery 2011, *Mining of Waste from Landfill in a Developing Country for Beneficiation (Re-Use/Recycling): is it a Viable and Sustainable Opportunity? Insight to a Trial Study in South Africa*, Proceedings Sardinia 2011, Thirteenth International Waste Management and Landfill Symposium

2. Dewaele et al. 2011, *Waste Excavation and Screening for Reclamation and Re - Engineering of a Municipal Landfill Site*, Proceedings Sardinia 2011, Thirteenth International Waste Management and Landfill Symposium

3. GHD 2010, *West Belconnen Resource Management Centre Master Plan*

4. Hudgins et al. 2010, *The 'Sustainable Landfill' becomes a Reality*, Waste Management World

5. ISWA 2013, *Key Issue Paper – Landfill Mining*, International Solid Waste Association

6. Jones et al. 2012, *Enhanced Landfill Mining in view of Multiple Resource Recovery: a Critical Review*

7. Strange, Preserving Resources through Integrated Sustainable Management of Waste, Technical Brief from the World Resource Foundation, retrieved April 24, 2014 from http://www.enviroalternatives.com/landfill.html

8. Umans, 2013, *Mining of Waste from an Old Landfill for Re-Use or Recycling: is it a Viable and Sustainable Opportunity? Trial Study of the Zuienkerke Location (Flanders)*, Proceedings Sardinia 2013, Fourteenth International Waste Management and Landfill Symposium

9. Van Vossen and Prent 2011, *Feasibility Study Sustainable Material and Energy Recovery from Landfills in Europe*, Proceedings Sardinia 2011, Thirteenth International Waste Management and Landfill Symposium

10. WMW 2010, *Environmental Group Comments on Waste to Energy Plans in Cayman Islands*, Waste Management World

11. WMW 2011, *Landfill Mining and Energy Recovery Planned in Taiwan*, Waste Management World

12. Zero Waste Scotland 2013, *Feasibility and Viability of Landfill Mining and Reclamation in Scotland*

2. Assessment

2.1 Overview

Landfill mining refers to the extraction of previously deposited material from a landfill to enable component materials to be recovered for recycling or reuse and the balance redeposited. It is sometimes also referred to as 'landfill farming'.

Landfill mining in one form or another has been undertaken since as early as the 1950s in some parts of the world. According to publically available literature, landfill mining is currently being conducted at more than fifty known sites across the world (Zero Waste Scotland, 2013). Furthermore, a number of landfill mining operations are currently being planned or are under consideration (see Section 3 for case studies of some currently operational / planned ventures).

The main purpose of landfill mining is rarely for resource recovery, which is usually undertaken opportunistically if suitable materials are extracted. Typically landfill mining is conducted to:

- Increase available landfill capacity; or
- Consolidate existing landfilled waste to free areas for subsequent development.

There is often a clear financial benefit in increasing available landfill capacity or freeing up land for redevelopment. Resource recovery on its own rarely justifies the expense of excavating, sorting and re-filling the subject landfill site or another location with residual materials.

2.2 Typical processes

Figure 1 (Jones et al., 2012) summarises the typical stages involved in a landfill mining project, where the aim of the project is for future land development.

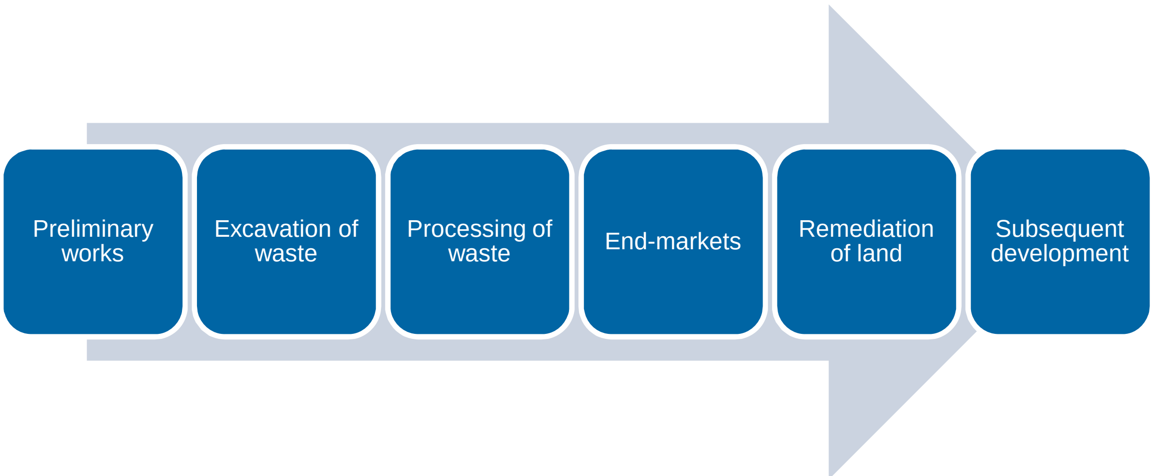


Figure 1 Typical landfill mining stages

Based on GHD's research and knowledge of the waste industry, it is anticipated that physical process of landfill mining would be conducted in general accordance with the process described in Figure 5 below.

1. WASTE EXCAVATION

Material would be excavated from the landfill using an excavator and either loaded directly into a semi-trailer or a truck & dog trailer, or stockpiled nearby. If placed in a stockpile, the material would ultimately be loaded into a semi-trailer or truck & dog trailer, by an excavator or wheeled loader.

2. WASTE TRANSPORT AND STOCKPILE

The material would be transported to a central location at which a permanent or temporary separation plant would have been set up. The material would be stockpiled here for future processing. An excavator with a grab arm would remove any large or bulky items from the material that cannot be recovered or safely processed through the equipment. These would be stockpiled and later loaded into a semi-trailer or truck & dog trailer to be disposed of (either at the subject landfill site or at an alternative location). Preliminary separation of materials contained within stockpiles may also occur manually.

3. WASTE SORTING

Material to be processed would be loaded by an excavator or wheeler loader into a hopper which feeds onto a conveyor. The conveyor would pass underneath a belt magnet which would remove any iron and steel items. The remaining material would be fed into a trommel (a rotating drum with screens of different sizes) that would separate out one or more streams of dust, soil and small items. The size of the particles in the separated streams would be determined by the size of the holes in the trommel's screens.

4. MATERIAL RECOVERY

The undersize 'soil' stream separated by the trommel would require further processing as it would contain a mixture of soil and a range of small items of numerous other materials (e.g. non-ferrous metals, timber, concrete, plastic etc.). This could be done using more sophisticated equipment such as stacked deck screens or bounce adherence separators.

5. FURTHER REFINING

This would be all that is required to separate soil and metals. However, further separation could be achieved by a variety of methods including hand picking, air classifiers (that blow air across moving steams to separate light weight particles), and eddy currents (for separating aluminium items) . In very sophisticated systems, optical separation (these separate very small particles of materials according to their colour or opacity) could also be used.

6. DISPOSAL

Material not suitable for recovery would be stockpiled, loaded by an excavator or wheeled loader into a semi-tralier or a truck & dog trailer and transported back to the subject site (or an alternative location) for disposal.

Figure 2 Indicative physical processes of landfill mining

The process described above is general and different processes may be used depending on local conditions and the material being excavated. The exact details of the process and the specifications for particular equipment that might be used would depend on a number of factors including:

- The results of trial operations (if any were conducted);
- Materials to be separated (if any);
- The preferences of the operators; and
- Cost.

2.3 Potential risks

2.3.1 Overview

There are a number of potential risks associated with a typical landfill mining project, including:

- Approval risks;
- Technical risks;
- Environmental risks;
- Work, health & safety (WH&S) risks;
- Operational risks;
- Economic risks;
- Legal risks; and
- Community & social risks.

Brief discussions of these risks are provided in the following sections.

2.3.2 Approval risks

Planning issues

Planning approval may need to be obtained for a landfill mining project. This may require preparation of a detailed environmental impact assessment (or similar document). Furthermore, planning approval may ultimately not be granted by the relevant planning authority.

Environmental agency issues

Environmental agency / licensing approval may need to be obtained for a landfill mining project. This may require preparation of detailed environmental impact assessment (or similar documents). Furthermore, an operational license may ultimately not be granted by the relevant environmental agency.

2.3.3 Technical risks

Technical issues

Technical risks for a potential landfill mining project may be numerous, and could include:

- How the project may integrate with existing and future waste networks;
- Accessibility / traversability of the project site;
- Availability of existing services and utilities required for the project;
- Size and geometry of land required for materials processing / storage etc.; and

- Security of the project site.

2.3.4 Environmental risks

Amenity issues

Landfill mining involves excavation of waste and mobilisation of plant, which may result in the amenity issues of noise, dust, odour, litter, visual impact and traffic. How significant the impacts associated with these issues would be depends on the sensitivity of the surrounding area. Concern would be higher if there were established residential or commercial areas nearby and comparatively lower if the landfill was in a remote area, or if sensitive receptors were shielded from the landfill mining operations.

Escape of leachate and / or landfill gas during landfill mining operations

Landfill mining is likely to affect existing environmental controls such as the landfill cap and landfill gas collection and treatment system. This may result in uncontrolled releases of pollutants (for example leachate and / or landfill gas) to the local environment (resulting in potential surface water, groundwater, soil or air impacts). .

Whilst it may be possible to minimise uncontrolled leachate releases by constructing and operating temporary storage and treatment facilities, potential uncontrolled releases of landfill gas are likely to be more difficult to control.

The potential significance of these issues depends on a number of factors including the age of a landfill as well as the waste types it contains. Generally speaking, leachate and landfill gas issues are likely to be less significant at older landfills (or parts of landfills) that received inert wastes (e.g. soils, sand, concrete etc.) than they may be at more recent landfills (or parts of landfills) that have received municipal solid waste (or other biodegradable wastes).

Spontaneous combustion of waste

The disturbance of landfilled waste at a landfill site is likely to introduce air into both the excavated waste materials and those that remain landfilled. The introduction of air into the waste is likely to alter the degradation conditions from anaerobic (no / low proportion of air present) to aerobic (high air proportion present) conditions.

This is likely to result in an increase in the rate of biological degradation of the organic components contained within the waste, with an associated increase in the amount of heat generated. The heat generated by this process may result in spontaneous combustion of excavated waste if stockpiles are not appropriately managed. Furthermore, if air is drawn into the waste remaining in the landfill during the landfill mining process by the landfill gas collection and treatment system, it is possible that a similar reaction would occur and a landfill fire may develop unless the process is carefully managed.

The significance of these issues depends on the age of a landfill as well as the waste types it contains. Generally speaking, spontaneous combustion issues are likely to be less significant at older landfills (or parts of landfills) that received inert wastes (e.g. soils, sand, concrete etc.) than they may be at more recent landfills (or parts of landfills) that have received municipal solid waste (or other biodegradable wastes).

2.3.5 WH&S risks

Potential for presence of hazardous materials

Landfill sites may have previously been used for the disposal of hazardous materials. It is not unusual to find that landfill operators or owners have limited information regarding waste types and quantities disposed of at their landfills. Hazardous materials including asbestos, radioactive waste, medical waste and animal carcasses may be present which, if excavated may pose WH&S to the operational personnel and potentially to adjacent land users / occupiers.

Other WH&S issues

Other WH&S risks for a potential landfill mining project may be numerous, and could include:

- Exposure to landfill gas / leachate / waste / dust / bioaerosols etc.;
- Landfill gas explosion / fire;
- Fire; and
- Collision with equipment / trucks

2.3.6 Operational risks

Operational issues

Operational risks for a potential landfill mining project may be numerous, and could include:

- Lack of appropriately qualified and trained personnel to work on project;
- Lack of appropriate operational management plan (or plan not followed); and
- Equipment breakdowns.

2.3.7 Economic risks

Economic issues

The primary purpose of landfill mining is usually to recover land (for subsequent sale or development) or to recover landfill airspace. The establishment of a landfill mining project is likely to involve significant up-front capital costs without a guaranteed return on investment. There may also be a reliance on governments to provide financial incentives and support through provision of tax breaks, levy discounts and investment support etc.

The main economic deterrent for landfill mining is the uncertainty in the return from a capital intensive investment that is often heavily reliant on a number of assumptions (e.g. how much waste is present, what types of waste are present, can the selected equipment adequately process the excavated waste etc.). It is only after conducting numerous field trials (or actual commencement of the landfill mining process) that the project operator can actually:

- Confirm the validity of the assumptions made;
- Determine actual project costs; and
- Determine the likely economic value of the reclaimed land / airspace / recovered materials (if any).

Table 1 provides a summary of the positive and negative economic aspects of landfill mining.

Table 1 Positive and negative economic aspects of landfill mining (adapted from ISWA, 2013)

Negative aspect	Positive aspect
Expenditure	Income
• Site investigation preliminaries • Excavation	• Land redevelopment • Landfill airspace

Negative aspect	Positive aspect
• Environment controls • Waste preparation and pre-treatment • Transport • Disposal charges and levies if residual waste is transferred to other landfills • Potential liabilities under carbon pricing mechanisms (due to potential uncontrolled releases of landfill methane at the landfill site during the project, potentially from any excavated waste that is it is subsequently re-landfilled)	• Sale of recovered material • Waste fuel sales (if fuel made from waste materials)
Income loss	Cost avoidance
• Landfill gas powered electricity generation and carbon offset schemes • Planned after-use income (for example rent or lease income for the duration of mining operations) • Likely loss of any income from landfill heat resource	• Future aftercare costs (e.g. likely reduced monitoring costs) • Use of recovered materials instead of new or virgin materials • Unknown legislative change • Potential tax breaks, levy discounts etc.

Materials contamination

One issue that reduces the viability of materials recovery by landfill mining is the quality and quantity of the materials recovered from the process. The quality of excavated material is substantially a function of the composition of the landfilled waste, which can include both chemical and physical contaminants (e.g. heavy metals, soil etc.).

Low quality organic materials may be recovered and these could potentially be used as a refuse derived fuel (RDF) although there is only a small specialised market for this in Australia. In addition, organic materials deposited in landfill sites undergo biodegradation process over time, which further reduces the quality of excavated materials.

This conclusion was confirmed by the results of a field test evaluation of the Collier County landfill mining system in Florida (Strange, 2014). One of the findings of this evaluation was that the ferrous and plastics fractions contained substantial levels of contamination that would probably impact their marketability. Similarly at Edinburg, New York, a landfill mining test project for energy recovery found that whilst more than 50% of material larger than 250 mm could be taken to a Materials Recycling Facility (MRF) for recycling, the excessive amount of dirt could contaminate clean source-separated recyclables. Other potentially recoverable materials, such as white goods and scrap metal, would also have to be cleaned to remove soil before the material could be baled and sold (Strange, 2014).

2.3.8 Legal risks

Legal issues

Legal risks principally revolve around the project not being compliant with all relative legislation (local, state and national).

2.3.9 Community & social risks

Community angst and social concerns

Landfill mining may result in community angst and social concerns prior to and during a potential project due to the potential environmental and WH&S issues that may be associated with a typical landfill mining project. As landfill mining is not commonly practiced in Australia, the community's reaction to a potential project (especially if in close proximity to sensitive receptors) could be quite negative.

2.4 Potential opportunities

Potential opportunities for landfill mining include:

- Reclamation of land (especially valuable urban land);
- Increase in landfill airspace (if site is continued to be used as landfill);
- Recovery of materials and generating potential income and cost savings from sale & reuse of materials;
- Mitigation of environmental impacts;
- Lower landfill aftercare costs (depending on the extent of waste excavation); and
- Improved perception of an area.

Where waste has been disposed of in uncontrolled and unlined sites, excavation of waste also provides the opportunity to install / improve existing engineering controls (for example, installation of a basal liner system) for better environmental performance. Removing and transferring waste from old uncontrolled landfills to modern, engineered landfills can allow for rehabilitation of land, potentially improving local environmental and health conditions.

Larger societal benefits may include obtaining resources of some value (e.g. recycled aggregates) instead of generating these materials through primary production processes (e.g. mining / quarrying). This contributes towards sustainable development. In the right circumstances, landfill mining may reduce local pollution risks in the long term, improve regional material autonomy and allow for conservation of strategically important materials such as metals.

3. Examples of landfill mining operations

3.1 Australia

Based on GHD research and understanding, two inert waste landfill sites located in Victoria have been known to undertake some form of landfill mining operations. Brief details on these sites are provided below. Whilst there is no specific information available on the relative successes of these operations, their continued operation supports the existence of certain financial (or other) benefits on an ongoing basis.

Din San landfill (Heatherton, Victoria)

Din San landfill has been reclaiming wastes, crushing concrete and shredding timber from its landfill for more than fifteen years and largely using it directly or selling it through its adjacent nursery business. This operation is viable because of two unique circumstances. The first is that the operators can use much of the material on-site for engineering purposes or sell it through its own retail outlet on the same property.

The second advantage is that the site is located within a sand belt area (i.e. a soft rock area), unlike certain other areas Melbourne which are located within basalt areas (i.e. hard rock areas). This means that any crushed rock sold or used in the Heatherton area has to be transported from quarries that are a significant distance from the area. This makes the quarried primary product slightly more expensive in the Heatherton area and gives Din San's locally extracted material a small financial competitive advantage in comparison. Figure 3 below shows a rehabilitated part of the Din San landfill site.

Figure 3 Rehabilitated part of Din San landfill site

Western Land Reclamation (Brooklyn, Victoria)

Perhaps the best example of landfill mining in Australia was the Western Land Reclamation site at Brooklyn operated by the Sunshine Groupe. Most activity occurred in the past but a small amount is believed to be still going on. The main purpose of the operation was to recover phosphate rock waste which had been historically landfilled at the site. The phosphate rock waste was excavated and sold, resulting in income from sales and landfill airspace being recovered. Figure 4 below shows historical landfill mining operations at the Western Land Reclamation site.

Figure 4 Western Land Reclamation site

3.2 Overseas

GHD has selected a number of overseas landfill mining case studies to illustrate some key points in relation to existing and proposed landfill mining projects. These case studies are presented in Table 2 below.

Table 2 International landfill mining case studies

Country	Description
Existing landfill mining operations	
South Africa (Emery, 2011)	The financial uncertainty of materials recovery is exemplified by a South African case study which found that very low income was obtained from the sale of extracted materials. With a recovery rate of 75% the operation made a net loss and it was found that the only way that landfill mining could be viable was if airspace was valued at more than R 1,108 per m^3, (approximately $132 per m^3).
United States (Hudgins et al., 2010)	At the Perdido Municipal Solid Waste Landfill in Escambia County, Florida, landfill mining was undertaken to enable the previously non-compliant site to be upgraded to meet waste management regulations. Recovery of previously deposited materials was only one of a number of other secondary advantages of the operation, including recovery of landfill airspace, removing a source of leachate and landfill gas and reclaiming soils for on-site reuse. In addition, high calorific materials were sent off-site to a Refuse Derived Fuel (RDF) facility or a waste-to-energy (WTE) plant.
Netherlands (Van Vossen and Prent, 2011)	Perhaps the most unique landfill mining operation is conducted in the Netherlands where Multi-Purpose Industries (MPI) operates a mobile landfill mining business. Where the composition of an existing waste site is economically viable, MPI buys the sites for as little as €1. It then removes and processes the waste at its own expense. MPI generates income from the sale of materials as end products or for energy recovery. Sites are also excavated for other reasons such as remediation of chemical contamination.

Country	Description
Canada (Dewaele et al, 2011)	The municipal solid waste landfill that services the town of Barrie, Ontario, Canada, is subject to a long term program of waste excavation, screening and re-compaction. A new engineered liner and leachate collection system is being installed and operators took advantage of the requirement to move all the waste, passing it through a screen in the process. The process was started with a pilot program to identify suitable screening and heavy equipment and provide information for phasing and costs associated with the full scale program.
Belgium (Umans, 2013)	The most recently announced landfill mining operation is planned for the Remo Milieubeheer Landfill near Limburg in Belgium. The site has been closed since the 1960s but a Belgian waste company and a British waste-to-energy company expect to recover 45% of the landfill's contents either as direct materials recovery or as electricity generated via a WTE plant.
Proposed landfill mining program	
Taiwan (WMW, 2011)	The largest planned landfill mining program is that in Taiwan where the Environment Protection Agency plans to excavate all of the country's 404 landfills and sort through the waste to recover material for use in energy production. Taiwan has 26 large-scale waste incinerators which will be transformed into bio-energy centres with increased electrical output. Glass, metal and flammables will be recovered and rocks and pebbles will be reused for road paving. A secondary aim is to reduce the adverse effects landfills have on the environment.
Grand Cayman (United Kingdom) (WMW, 2010)	Plans have also been announced to rehabilitate the George Town landfill on Grand Cayman to address a range of long standing visual, odour, air and noise issues. A waste to energy facility will convert excavated materials to electrical power.

4. Potential impacts of landfill mining operations at the WBLS

4.1 Overview

Section 2.3 previously identified a number of potential risks associated with a typical landfill mining project. It is expected that the identified issues would be relevant if such a project were to be proposed at the WBLS. As such, it is considered that if such a project were to be undertaken at the WBLS, it could have a number of adverse impacts upon the proposed future development. The potential impacts of a landfill mining project at the WBLS along with possible management / mitigation measures are described in Table 3.

Table 3 Potential impacts of a landfill mining project at the WBLS and possible management / mitigation measures

Potential impact	Possible management / mitigation measures
Approval impact (i.e. project not approved by planning authority or environmental agency)	Engage with relevant stakeholders early. Develop a good project document including how all potential environmental and WH&S impacts would be managed. Develop project in a staged way so that if significant issues are encountered, project can be ceased at the completion of a defined stage. Consider targeting certain areas only for landfill mining (possibly those with a high likelihood of containing inert / non-hazardous wastes only). Complete any landfill mining prior to development within 500 metres of the WBLS.
Technical impact (e.g. size of land, accessibility / traversability of site, security of site etc.)	Develop a good project document including how all potential technical impacts will be managed. Develop project in a staged way so that if significant issues are encountered, project can be ceased at the completion of a defined stage. Consider undertaking a trial to determine the potential significance of technical issues.
Environmental issue impact (e.g. dust, noise, odour, litter, traffic, leachate, landfill gas, fire etc.)	Engage with relevant stakeholders early. Develop a good project document including how all potential environmental and WH&S impacts would be managed. Install and operate appropriate management / monitoring measures as required. Develop project in a staged way so that if significant issues are encountered, project can be ceased at the completion of a defined stage. Consider targeting certain areas only for landfill mining (possibly those with a high likelihood of containing inert / non-hazardous wastes only). Complete any landfill mining prior to development within 500 metres of the WBLS. Consider undertaking a trial to determine the significance of potential environmental impacts associated with the project.
WH&S impacts (e.g. hazardous materials exposure, landfill gas / leachate / waste exposure, fire, collision with	Engage with relevant stakeholders early. Develop a good project document including how all potential environmental and WH&S impacts would be managed. Ensure appropriate risk assessments and WH&S method statements have been prepared for all tasks required. Install and operate appropriate management /

Potential impact	Possible management / mitigation measures
equipment / trucks etc.)	monitoring measures as required. Develop project in a staged way so that if significant issues are encountered, project can be ceased at the completion of a defined stage. Consider targeting certain areas only for landfill mining (possibly those with a high likelihood of containing inert / non-hazardous wastes only). Complete any landfill mining prior to development within 500 metres of the WBLS. Consider undertaking a trial to determine the significance of potential WH&S impacts associated with the project.
Operational impacts (e.g. lack of suitable personnel, lack of operational plan, equipment breakdowns etc.)	Engage with relevant stakeholders early. Develop a good project document including how all potential operational impacts would be managed. Ensure appropriate risk assessments and WH&S method statements have been prepared for all tasks required. Install and operate appropriate management / monitoring measures as required. Ensure project personnel are appropriately qualified and trained. Ensure that project personnel operate in accordance with an appropriate operational plan. Ensure contingencies are made in relation to equipment breakdowns / maintenance etc. Develop project in a staged way so that if significant issues are encountered, project can be ceased at the completion of a defined stage Consider targeting certain areas only for landfill mining (possibly those with a high likelihood of containing inert / non-hazardous wastes only). Complete any landfill mining prior to development within 500 metres of the WBLS. Consider undertaking a trial to determine the significance of potential operational impacts associated with the project.
Economic impacts (e.g. expenditure, revenue loss revenue, cost avoidance, materials contamination etc.)	Develop a detailed cost-benefit analysis (CBA) document for the project prior to commencement incorporating a number of financial contingencies. Do not proceed with project unless CBA strongly suggests that the project is economically feasible. Regularly review the projected cost / income during the project and continually assess economic viability of potential project through course of project. Develop project in a staged way so that if significant issues are encountered, project can be ceased at the completion of a defined stage. Consider targeting certain areas only for landfill mining (possibly those with a high likelihood of containing inert / non-hazardous wastes only). Complete any landfill mining prior to development within 500 metres of the WBLS. Consider undertaking a trial to determine the significance of potential economic impacts associated with the project.
Legal impacts (i.e. project is non-compliant with any relevant legislation)	Ensure that any project is developed and operated so as to be complaint with all relevant legislation.
Community & social	Engage with relevant stakeholders early. Develop a good project

Potential impact	Possible management / mitigation measures
impacts (i.e. community angst and social concerns)	document including how all potential environmental and WH&S impacts would be managed. Install and operate appropriate management / monitoring measures as required. Develop project in a staged way so that if significant issues are encountered, project can be ceased at the completion of a defined stage. Consider targeting certain areas only for landfill mining (possibly those with a high likelihood of containing inert / non-hazardous wastes only). Complete any landfill mining prior to development within 500 metres of the WBLS. Consider undertaking a trial to determine the significance of potential impacts associated with the project.

4.2 Potential operational parameters

If landfill mining were to be pursued at the WBLS, a number of operational parameters would need to be determined including the following key parameters:

- Potential timeframes;
- Typical plant, equipment and other resources required;
- Potential quantity and nature of materials that may be recovered; and
- Disposal of residual non re-usable / re-saleable materials.

The following sections discuss these key operational parameters.

4.2.1 Potential timeframes

If landfill mining were to be pursued at the WBLS, there would be benefit in undertaking planning works as soon as possible. Table 4 provides a "ballpark" indicative estimate of the potential timeframe of the required works if all landfilled waste areas were excavated (excluding the Asbestos Pit, the Borrow Pit, the former ACT NOWaste Woodbusters site and the Capped Bushfire Disposal Pit – all understood to contain asbestos wastes). GHD notes that this estimate is highly uncertain and has the potential to vary significantly depending on a large number of factors. Table 4 has been estimated with consideration of previous GHD experience of waste project approval timeframes and the steps identified in Figure 1 contained in Section 2.2.

Table 4 Indicative landfill mining timeframe for the WBLS

Works required	Indicative timing (approximate, likely best / shortest case scenario)	Comments
Preliminary Works		
Discussion with relevant stakeholders, receive approval	3 to 6 months (may be significantly longer if an Environmental Impact Assessment – EIA - is required)	As landfill mining is rarely practiced in Australia and does not appear to have been previously undertaken on this scale for landfills accepting general and municipal solid waste, the approval processes required are uncertain. Extraction of a significant amount of material may require planning

Works required	Indicative timing (approximate, likely best / shortest case scenario)	Comments
		approval through the preparation of an EIA and may add significantly to the timing of the project.
EIA preparation and approval (may or may not be required)	1 to 2 years	The scale of the landfill mining activity is likely to determine the need for an EIA (or not).
Project planning	3 to 6 months	Management and control plans will be required prior to project commencement.
Waste investigations	3 to 6 months	Investigation of areas to be landfill mined to confirm quantities and types of waste likely to be encountered during landfill mining.
Project set up - hiring, training, procurement and set up of machinery	3 to 6 months	The machinery may need to be procured and shipped from specialist companies.
Excavation of waste		
Landfill mining trial	3 to 6 months	Prior to undertaking a full scale landfill mining project, it would seem prudent to undertake a preliminary trial. This could potentially be undertaken at Mugga Lane landfill (instead of breaching the landfill cap at the WBLS) to identify any potential unexpected issues and subsequently refine the proposed approach. Alternatively a certain area at the WBLS could be targeted.
Full scale landfill mining (waste excavation)	5 to 15 years Dependent upon area mined	This timeframe is highly uncertain and would depend largely upon the precise areas to be landfill mined and the rate at which the waste could be excavated.
Processing of waste		
Processing of waste	5 to 15 years	Assumed to occur simultaneously with the full scale landfill mining process
End Markets		
Sale / disposal of materials	5 to 15 years	Assumed to occur simultaneously with the full scale landfill mining process and processing of waste
Remediation of land		

Works required	Indicative timing (approximate, likely best / shortest case scenario)	Comments
Decommissioning and rehabilitation	10 to 20 years	Likely to be progressive and follow the full scale landfill mining (waste excavation) step around the WBLS (i.e. one area excavated, then proven to be "clean", then backfilled with clean material to allow future development). Is dependent upon the availability of a suitable quantity of clean backfill material to place into any voids subsequently developed at the WBLS.

Table 4 above suggests that the full scale landfill mining of the WBLS (excluding the Asbestos Pit, Borrow Pit, Capped Bushfire Pit and Former ACT NOWaste Woodbusters site) may take of the order of ten to twenty five years. This assumes that such a project actually received regulatory approval. It is noted that the GHD that this estimate is highly uncertain and has the potential to vary significantly depending on a large number of factors.

It is further noted that if only certain areas were selected / targeted for landfill mining, that the timeframes may be significantly shorter (perhaps in the 5 to 10 year bracket), particularly if the areas were likely to predominantly contain materials that would not have significant impacts upon excavation (e.g. the tyre trenches).

4.2.2 Typical plant, equipment and other resources required

Plant / Equipment

Typical plant and equipment that may be required to establish a landfill mining operation at the WBLS could include:

- Excavator(s);
- Trommel(s) – cylinder used to separate materials by size;
- Conveyor belt(s);
- Magnet(s);
- Stacker(s) – machine to pile material onto a stockpile;
- Bulldozers(s);
- Prime mover(s) – to move materials i.e. semi-trailer truck;
- Trailer(s); and
- Skip bins / containers.

The quantity / numbers of plant / equipment would need to reflect the scale and complexity of the proposed landfill mining operation. The plant / equipment would also require fuel and / or electricity as power source. Specialist plant / equipment may also be required for certain tasks.

Plant / equipment would need to be maintained regularly. There may be options to hire plant / equipment (as opposed to buying outright) and/or contracting out the works.

Staff

Staff would be required to support the operations and plant / equipment. The number of staff required would need to reflect the scale and complexity of the proposed landfill mining operation (i.e. the entire WBLS or just selected areas). Specialist staff may also be required for certain tasks.

Typically, required labour may include:

- Leading hand operator(s) to operate the plant / equipment and supervise other staff;
- Pickers for the removal of certain materials from excavated material
- Operators to operate the plant / equipment

Staff will require ongoing training. There may be options to temporarily hire staff and / or contracting out the works.

4.2.3 Potential quantity and nature of materials that may be recovered

Overview

No detailed information is available on the precise quantity and composition of the waste materials landfilled at the WBLS. The available information suggests that the WBLS predominantly accepted municipal solid waste (MSW) between approximately 1970 and 2002. Between 2002 and 2006, the WBLS appears to have only accepted relatively small quantities of special wastes (including asbestos) and tyres. From 2006 to present, only relatively small quantities of asbestos contaminated materials (and associated cover materials) are understood to have been landfilled at the WBLS. Landfilling of these materials during this period is understood to have been confined to the “Borrow Pit” and the “Asbestos Pit” areas.

Quantity of waste

A preliminary estimate made by GHD (2010) suggested a total possible volume of landfilled material at the WBLS of circa 5,000,000 m^3. Since this estimate was prepared, additional information has been provided to GHD which identifies that the landfilled waste mass is likely to be more extensive than previously thought. As such, GHD has revised its earlier estimate and now considers that a larger total possible volume of landfilled materials may be present at the WBLS. This is identified in Table 5 below.

Table 5 Estimated total landfilled material volume at the WBLS

Assessment Group Area (refer to Section 4)	Estimated total area	Estimated total landfilled material volume
MSW Landfill Areas	51.3 ha (51,300 m^2)	6,500,000 m^3
Tyre Trench Areas	2.4 ha (24,000 m^2)	250,000 m^3
Asbestos Disposal Areas	8.3 ha (83,000 m^2)	1,000,000 m^3 (once Asbestos Pit and Borrow Pit are completed)

The estimates contained in Table 5 above were based on the relevant plans contained in Appendix A and the associated calculations contained in Appendix B.

It is noted that there is considerable uncertainty in relation to these estimates which would potentially need to be further refined should landfill mining be pursued at the WBLS.

Nature of waste

Depending on the area(s) proposed to be subjected to landfill mining processes, the nature of the waste materials recovered could differ significantly in a number of characteristics including:

- Type. For example some areas of the WBLS contain mixed MSW, others are believed to only contain tyres;
- Quality. For example in some areas of the WBLS, the waste materials may be of a relatively high quality (i.e. a high concentration of an individual material that is relatively clean / uncontaminated). Conversely, in other areas of the WBLS, the waste materials may be relatively low quality (i.e. diffuse / mixed wastes that are relatively dirty / contaminated). It would be anticipated that:
  - The tyre trench areas at the WBLS would be likely to contain relatively high quality materials (i.e. relatively clean, concentrated tyres); and
  - The mixed MSW areas at the WBLS would be likely to contain relatively low quality materials (i.e. relatively dirty, mixed materials).
- Hazardous characteristics. For example, in some areas of the WBLS, the waste materials may be of a relatively hazardous nature (e.g. asbestos in the asbestos Pit). Conversely, in other areas of the WBLS, the waste materials may be relatively non-hazardous in nature (e.g. tyres in the tyre trenches).

Following waste excavation, the excavated waste material could be processed or removed from site for subsequent disposal.

Any material that was processed would need to be processed to a condition that was suitable for the ultimate end user. This could be relatively cheap and simple (depending on the material, its quality and the requirements on the end user). However, is also has the potential to be relatively expensive and complex (again depending on the material, its quality and the requirements on the end user).

4.2.4 Disposal of residual non-re-usable and non re-saleable materials

It is unlikely that a landfill mining project would be able to cost-effectively excavate and reuse / sell all materials historically landfilled at the WBLS (indeed some areas of the WBLS such as the asbestos areas should be actively avoided by such a project).

This would likely result in a certain amount of waste being generated by the process that would need subsequent management.

There are two main options for the disposal of non-re-useable and re-saleable materials as follows:

- Disposal back to the WBLS; or
- Transfer to, and disposal at, another landfill.

Disposal at the WBLS

Disposal at the WBLS has the benefit of reducing transportation costs and potentially disposal fees. Nevertheless, this approach could reduce the quantity of land that may be available for future development or future disposal of construction and demolition waste generated by the proposed development. If the area that was mined did not have an engineered basal lining system, it is likely that the ACT EPA would require the installation of such a liner prior to placement of waste. Furthermore, the ACT EPA would require a suitably engineered landfill cap to be placed over the waste once the area previously mined was backfilled. Landfill lining and capping systems would constitute considerable potential costs to a landfill mining project (>$1 Million).

Transfer to, and disposal at, another landfill

Transferring the generated waste to another landfill would likely result in higher transportation costs and disposal fees, but may remove the need for an engineered landfill lining system to be provided at the WBLS in the mined area(s) (assuming these areas were backfilled with clean material). It may also reduce the need for a landfill cap to be provided at the WBLS above the mined areas ((assuming these areas were backfilled with clean material).

It is likely that a significant quantity of waste (possibly of many different types) would be generated by a landfill mining project at the WBLS. As such, an appropriate assessment should be undertaken as part of the pre-planning for any such project prior to deciding on the preferred disposal route for any non-re-usable and / or non re-saleable materials.

4.3 Opportunities and constraints

Certain areas of the WBLS may have the potential for landfill mining to reclaim airspace for future filling (potentially with soils / construction waste derived from the adjacent development project), to reclaim land for development and / or reclaim materials for re-use / recycling (or some combination of these). That said, a number of potential risks are associated with undertaking a landfill mining project at the WBLS. These include environmental, WH&S and economic risks. The hazardous nature of the waste material landfilled in certain areas of the WBLS (i.e. asbestos contaminated materials) is likely to preclude landfill mining in those areas. ,

A landfill mining project has the potential to affect both on-site and off-site receptors, and may affect the potential for potentially amending the existing buffer distance in place around the WBLS.

5. Conclusions

In relation to this section, GHD makes the following key conclusions:

General

- Landfill mining projects can be feasible and have been / are undertaken in a number of countries (including Australia);
- There are a number of potential risks and opportunities associated with such projects; and
- Most landfill mining projects are principally undertaken to recover land for future development or to reclaim airspace for landfilling.

Specific to WBLS

- A landfill mining project at the WBLS could potentially have a number of impacts upon the proposed development project. There are a number of possible mitigation / management measures that could be implemented to reduce the significance of these potential impact;
- There are a number of areas of the WBLS that are known to contain asbestos;
- A full scale landfill mining project at the WBLS (excluding the Asbestos Pit, Borrow Pit, Capped Bushfire Pit and Former ACT NOWaste Woodbusters site areas) may take of the order of ten to twenty five years. It is noted that the GHD that this estimate is highly uncertain and has the potential to vary significantly depending on a large number of factors;
- If only certain areas of the WBLS were selected / targeted for landfill mining, the timeframes may be significantly shorter (perhaps in the 5 to 10 year bracket), particularly if the areas were likely to predominantly contain materials that would not have significant impacts upon excavation (e.g. the tyre trenches);
- The tyre trench areas along Parkwood Road potentially represent the most appropriate location on the WBLS to undertake a cost-effective landfill mining project due to the likely high quality materials contained (likely concentrated tyres) and their proximity to Parkwood Road (likely high future land value);
- Appropriate plant / equipment and staff would be required for a landfill mining project;
- There may be of the order of 6,500,000 m^3 of MSW material landfilled at the WBLS (inclusive of daily cover and engineering materials);
- There may be of the order of 250,000 m^3 of waste tyres landfilled at the WBLS (including daily cover and engineering materials);
- There may be of the order of 1,000,000 m^3 of asbestos contaminated material landfilled at the WBLS (including daily cover and engineering materials)> This figure assumes that both the Asbestos Pit and Borrow Pit areas have been completely filled to ground level;
- The nature of materials that may be recovered from certain areas is likely to be highly variable / difficult to work with (e.g. MSW areas). Materials from other areas may be more uniform in nature / easier to work with (e.g. the tyre trenches);
- A landfill mining project is likely to generate a significant amount of waste (materials that cannot be re-used or sold) that will require landfill disposal either at the WBLS or another landfill site; and

- There is currently a large amount of uncertainty around the potential viability of undertaking a landfill mining project at the WBLS (whether for the whole site or just selected areas in part or the whole site)

6. Recommendations

Based on the key conclusions provided above, GHD makes the following recommendations (made with consideration of the vision – see Table 6 below):

1. Engage in discussions with the relevant stakeholders including ACT EPA, planning authority and ACT NOWaste to discuss their views on landfill mining at the WBLS and potential approvals required (specifically in relation to the capped tyre trench with a possible future view to other areas if successful);
2. Assuming responses to 1. above do not stop the potential project, prepare a preliminary cost benefit analysis of landfill mining of the capped tyre trench.
3. If 2. above suggests that a landfill mining project is likely to be financially feasible at the capped tyre trench, then undertake limited intrusive investigations of the area to further confirm this is the case (e.g. test pitting, boreholes); and
4. If 3. above suggests that the project is still likely to be financially feasible, commence works as outlined in Table 4.

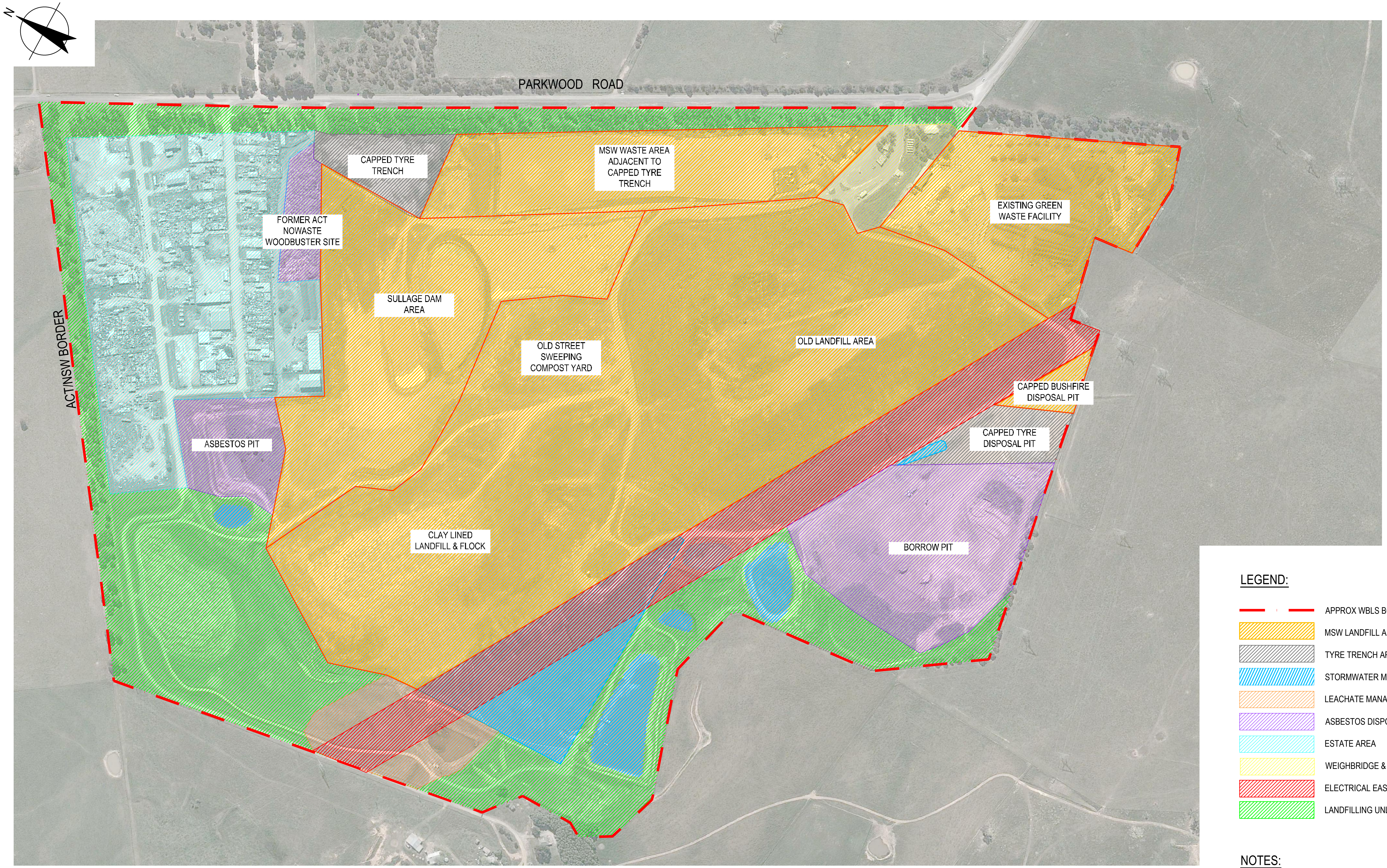
Table 6 identifies how the recommendations above were developed with consideration of the overarching project Vision (Appendix C).

Table 6 Recommendations and relevant guiding principles (as contained in the Vision)

Recommendation	Relevant guiding principles
1	Ptnr 1., Ptnr 2.
2	Eva 1., Econ 1.
3	Eva 1, Econ 1.
4	Ptnr 1., Ptnr 2., Eva 1., Eco 2., Eco 5., Eco 6., Econ 1.

Appendices

Appendix A – Plan consolidating individual areas into assessment group areas



LEGEND:

- APPROX WBLS BOUNDARY
- MSW LANDFILL AREAS
- TYRE TRENCH AREAS
- STORMWATER MANAGEMENT AREAS
- LEACHATE MANAGEMENT AREAS
- ASBESTOS DISPOSAL AREAS
- ESTATE AREA
- WEIGHBRIDGE & RECYCLING AREA
- ELECTRICAL EASEMENT
- LANDFILLING UNLIKELY AREAS

NOTES:

1. BOUNDARIES ARE INDICATIVE ONLY

SITE AREAS

SCALE 1:2500

PRELIMINARY

No	Revision	Drawn	Job Manager	Project Director	Date
A	DRAFT FOR REVIEW	MF	MW	DG	

Note: * indicates signatures on original issue of drawing or last revision of drawing

0 25 50 75m
SCALE 1:2500 AT ORIGINAL SIZE

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Drafting Check | Design Check
Approved (Project Director)
Date
Scale 1:2500
This Drawing must not be used for Construction unless signed as Approved

Client **THE RIVERVIEW GROUP**
Project **WEST BELCONNEN LANDFILL SITE**
Title **CONSOLIDATION OF INDIVIDUAL AREAS INTO ASSESSMENT GROUP AREAS**

Original Size A1 Drawing No: **21-23237-C005** Rev: A

Plot Date: 9 May 2014 - 10:00 AM Plotted by: Carol Ng Cad File No: G:\21\23237\CADD\Drawings\21-23237-C005-C006.dwg

Appendix B - Calculation sheets for landfill mining

Client:	Riverview Projects (ACT)	**Job Number:**	21-23237		
Project:	West Belconnen Landfill Site - Landfill Related Advice	**Calcs by:**	C Ng	**Date:**	8/05/2014
Subject:	WBLS - Waste quantity calculations (Main landfill area)	**Checked by:**	M Welsh	**Date:**	8/05/2014

Total material volume in main landfill area (Clay lined landfill & flock + Old landfill area + Old street sweeping compost yard)			
		Unit	**Source**
Approximate area of main landfill area	300,000	m^2	CAD, rounded
Estimated average depth	15	m	GHD estimate, based on 2010 survey and estimated basal depth
Total Material Volume	**4,500,000**	**m^3**	
Total material volume in MSW waste area adjacent to capped tyre trench			
		Unit	**Source**
Approximate area	56,000	m^2	CAD, rounded
Estimated average depth	10	m	GHD estimate, based on 2010 survey and estimated basal depth
Estimated volume	**560,000**	**m^3**	
Total material volume in sullage dam area			
		Unit	**Source**
Approximate area	104,000	m^2	CAD, rounded
Estimated average depth	10	m	GHD estimate, based on 2010 survey and estimated basal depth
Estimated volume	**1,040,000**	**m^3**	
Total material volume beneath existing green waste facility			
		Unit	**Source**
Approximate area	58,000	m^2	CAD, rounded
Estimated average depth	5	m	GHD estimate, based on 2010 survey and estimated basal depth
Estimated volume	**290,000**	**m^3**	
Total material volume in Capped bushfire disposal pit			
		Unit	**Source**
Approximate area	5,000	m^2	CAD, rounded
Estimated average depth	10	m	GHD estimate, based on 2010 survey and estimated basal depth
Estimated volume	**50,000**	**m^3**	
Total Material Volume	**6,440,000**	**m^3**	(rounded to 6,500,000 m^3)

Client:	Riverview Projects (ACT)	**Job Numbe**	21-23237		
Project:	West Belconnen Landfill Site - Landfill Related Advice	**Calcs by:**	C Ng	**Date:**	8/05/2014
Subject:	WBLS - Waste quantity calculations (Other areas)	**Checked by**	M Welsh	**Date:**	8/05/2014

Capped tyre disposal pit			
		Unit	**Source**
Approximate area	12,000	m^2	CAD, rounded
Estimated average depth	5	m	GHD estimate, based on 2010 survey and estimated basal depth
Estimated volume	**60,000**	$\mathbf{m^3}$	
Capped tyre trench			
			Source
Approximate area	13,000	m^2	CAD, rounded
Estimated average depth	10	m	GHD estimate, based on 2010 survey and available survey from 2002
Estimated volume	**195,000**	$\mathbf{m^3}$	
Total Material Volume (Tyre Trench Areas)	**255,000**	$\mathbf{m^3}$	(rounded to 250,000 m^3)

Asbestos pit			
		Unit	**Source**
Approximate area	18,000	m^2	CAD, rounded
Estimated average depth	15	m	GHD estimate based on advice from ACT NOWaste
Estimated volume	**270,000**	$\mathbf{m^3}$	
Borrow Pit			
		Unit	**Source**
Approximate area	58,000	m^2	CAD, rounded
Estimated average depth	10	m	GHD estimate, based on 2010 survey and advice from ACT NOWaste
Estimated volume	**580000**	$\mathbf{m^3}$	
Former ACT NOWaste Woodbusters Site			
			Source
Approximate area of area	9,000	m^2	CAD, rounded
Estimated average depth	10	m	GHD estimate based on survey of adjacent capped tyre trench area
Estimated volume	**90,000**	$\mathbf{m^3}$	
Total Material Volume (Asbestos disposal areas)	**940,000**	$\mathbf{m^3}$	(rounded to 1,000,000 m^3)

Appendix C – Vision document

THE RIVERVIEW GROUP

The Belconnen Project Sustainability Vision

"Creating a sustainable community of international significance in the Nation's capital."

The Riverview Group, working with the ACT and NSW Governments, will develop the site at Belconnen to achieve a vision of inspiring sustainable living, development practice and awareness. Achieving a high quality of life for the people living at Belconnen is at the heart of our project planning and design.

We will create a community that exemplifies World's Best Practice in its design, construction and long-term liveability. As a model of sustainable community living it will be a place and community that can be showcased throughout Australia and internationally.

Project objectives:

To achieve our Vision we will challenge conventional industry thinking. We will employ practices, processes and systems that embody innovation and design excellence.

This project has been conceived and will be delivered on a fully integrated and audited triple bottom line basis.

Our project will:

- Be sustainable over time, socially, economically and ecologically (with a low and reducing ecological footprint)
- Respond to the local and global environment
- Provide for future beneficial change to occur in design, infrastructure and regulatory mechanisms
- Be cost effective, replicable and measurable
- Act as a new model that others can follow.

elton consulting   Landmatters Pty Ltd   green building council australia MEMBER 2010-2011

Guiding Principles for Sustainable Results

The principles below will direct decision-making by all project management, sub-consultants and referral agencies in the delivery and development of the Belconnen site. They reflect national priorities and Federal, State and Territory Government policies on housing affordability, climate change and environmental protection.

PARTNERING PRINCIPLES

Ptnr 1. Partnering is essential to this project and the scale and timeframe will allow for positive partnerships to grow and thrive

Ptnr 2. Partnering with public agencies is a cornerstone of our approach

Ptnr 3. Engaging the community in design and governance is fundamental to the delivery of the project.

Ptnr 4. Designing the project for community ownership and ultimate community control

Ptnr 5. Supporting community housing through public and private partnering arrangements

Ptnr 6. Collaborating with research and educational institutions to drive innovation.

EVALUATION PRINCIPLES

Eva 1. Identifying and delivering realistic and costed initiatives

Eva 2. Providing independent peer review of project proposals and project outcomes

Eva 3. Using recognised international and national benchmarks for sustainability performance to publicly report and raise awareness of project outcomes

Eva 4. Empowering resident and community monitoring and management of sustainability performance

Eva 5. Encouraging a culture of continuous improvement.

ECOLOGICAL PRINCIPLES

Eco 1. Acknowledging the intrinsic value of all species and the special role and regional significance of the Murrumbidgee river corridor and Gininnderra Creek

Eco 2. Respecting and supporting the ecosystem functions of air, soil and water, recognising the importance of living and non-living environmental resources

Eco 3. Reducing greenhouse gas emissions through innovative products and place design, material selection and service provision

Eco 4. Recognising our natural ecological limits and minimising our resource, water and energy consumption

Eco 5. Using existing local infrastructure to deliver efficient renewable services and reusable resources

Eco 6. Enhancing local opportunities for food production and production of materials

Eco 7. Fostering a deep sense of respect for and connection to the land, flora and fauna.

SOCIAL AND CULTURAL PRINCIPLES

Soc 1. Respecting and honouring Aboriginal and non-Aboriginal cultural, historical and spiritual values, including integrating with the existing rich, social fabric of Belconnen

Soc 2. Designing for social equity, affordability, diversity and interdependence, honouring differences and catering for the needs of individuals through all stages of life

Soc 3. Maximising health, safety and comfort of the built environment to provide enduring quality of life

Soc 4. Instilling awareness and supporting education of sustainability values, technology and lifestyles

Soc 5. Using creative and robust design solutions to create a continuing sense of place and beauty that inspires, affirms and ennobles

Soc 6. Designing neighbourhoods that support and encourage community interactions through imaginative, functional and enjoyable public spaces

ECONOMIC PRINCIPLES

Econ 1. Delivering a financial return to the ACT Government recognising their sovereign interest in the land

Econ 2. Recognising the opportunities provided by the project’s scale and low capital base to achieve high-level sustainability outcomes while delivering profitability to joint venture partners

Econ 3. Building on existing local infrastructure

Econ 4. Ensuring long-term economic viability through design excellence and community building

Econ 5. Minimising obsolescence through design of enduring component life cycle, allowing for disassembly and change

Econ 6. Integrating with the Belconnen commercial, retail and employment networks

Econ 7. Growing a formal and informal green economy that fosters local jobs and builds regional learning around green innovation and technology

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	M Welsh	D Gamble		D Gamble		

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Appendix H – Heat recovery assessment

Riverview Projects (ACT) Pty Ltd

West Belconnen Landfill

Heat Recovery Assessment

June 2014

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Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

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

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Appendices

1. Introduction

1.1 Overview

GHD has undertaken a technical assessment of the feasibility of recovering heat for beneficial uses.

There are three potential heat recovery sources at the WBLS, i.e. the MSW landfill, the Leachate collection and management system and the Landfill gas engine. While suitable technologies exist to potentially recover heat from these heat sources, which are evidenced from various successful heat recovery projects undertaken internationally (some on trial basis), there is a large amount of uncertainty at present in relation to the economic feasibility of collecting heat from these three sources.

1.2 Reliance

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3. D. Brown and M. Preene 2014, ‘Ground Source Heat Recovery has Potential for Landfills’, *Energy & Carbon Management,* http://www.golder.com.au/en/modules.php?name=Newsletters&op=viewarticle&sp_id=172&page_id=1100&article_id=601

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8. Kjeldsen et al. 2002. *Present and Long-term Composition of MSW Landfill leachate: A review*, Environmental Science and Technology, 32(4), pp. 297-336

9. Landfill Gas Engine Output Boosted with CPT Exhaust Heat Recovery, *Waste Management World,* <http://www.waste-management-world.com/articles/2010/11/landfill-gas-engine-output-boosted-with-cpt-exhaust-heat-recovery-.html>

10. Landfill Based Geothermal Heating System, *American Academy of Environmental Engineers and Scientists,* 2013 Grand Prize - Small Projects*,<http://www.aaees.org/e3competition-winners-2013gp-smallprojects2.php>*

11. M. Preene et al. 2008, ‘Ground Source Heat Pumps in the Waste Industry’, *Proceedings Waste 2008: Waste and Resource Management*, pp. 1-12

12. N. Yesiller et al. 2005, ‘Heat Generation in Municipal Solid Waste Landfills’, *Journal of Geotechnical and Geoenvironmental Engineering*, Vol. 131, No. 11, pp. 1330-1344

13. S. O'Connell & S. F. Cassidy 2003, 'Recent large scale ground-source heat pump installations in Ireland', *Geo-Heat Center Bulletin*, vol. 24, No. 4, pp. 8-12

2. Assessment

2.1 Overview

Certain operations at the WBLS generate heat that is potentially recoverable. It is understood that the feasibility of harnessing the heat energy for beneficial uses at or adjacent to the WBLS has not been previously assessed.

This section of the report provides a high level assessment of the heat energy resources that may be present at the WBLS and the potential feasibility of harnessing them for subsequent beneficial uses.

This heat assessment is restricted to the following potential heat sources at the WBLS only:

- The main MSW landfill area (landfill area that has received the bulk of deposited MSW);
- The leachate collection and management system; and
- The landfill gas engine.

A figure showing these potential heat sources is contained in Appendix A.

2.2 Description of potential heat resources

2.2.1 MSW landfill

Studies have shown that heat generation occurs during the biodegradation of organic waste, with the greatest gain in temperature occurring during the onset of anaerobic (no / low oxygen condition) decomposition (C.J.R. Coccia et al., 2012) Temperatures between 30 and 40°C may be expected within the body of a landfill during normal operations and temperatures upwards of 60°C are not uncommon. These temperatures could be exploited as a source for heating.

Heat generation within landfills is affected by the following factors (C.J.R. Coccia et al., 2012):

- Variation of waste temperature with respect to landfill depth:
- Waste materials located relatively close to the landfill's surface (within 9 m depth) are heavily influenced by seasonal temperature variations, fluctuating with the seasonal variations. Stability of landfill temperature is typically found at depths greater than 9 m;
- Waste materials located near the edge of the landfill are more affected by seasonal temperatures than those that are located further away. Stable temperature throughout the year are maintained by wastes located further away from the landfill's edge; and
- Waste temperature increases with depth of landfill.
- Effect of waste age on heat content:
- Rapid increase in temperature of recent waste to a peak temperature after 2 to 7 years followed by a gradual decrease in temperature; and
- A previous investigation (GHD, 2012) suggests that the WBLS accepted predominantly MSW between approximately 1970 and 2002. As such, the present age of the landfilled MSW is estimated to be in the range of 12 to 44 years (as of April 2014). This suggests that waste temperatures have likely already peaked and will gradually decline into the future.
- Effect of climatic conditions on heat content of waste:

- The heat content of waste increases with the precipitation rate, with a peak value occurring at approximately 2.3 mm/day. Heat content decreases if the precipitation rate is outside this optimal value; and
- Air and earth temperatures do not influence the heat content recorded in waste after a depth of approximately 9 m (C.J.R. Coccia et al., 2012)

It is understood that the presence of commercial, industrial, and / or construction and demolition wastes may reduce the MSW's ability to generate heat.

2.2.2 Leachate collection and management system

Leachate refers to the liquid principally created by percolation of rainwater into landfilled waste. Heat transferred from the elevated temperatures in the landfilled waste mass to the leachate as it travels through the landfill provides a potential heat source that could be recovered. The temperature of leachate within a landfill is typically comparable to the temperatures of the surrounding landfilled waste (i.e. between 30°C and 60°C).

Leachate is currently collected from the WBLS and fed by gravity to a leachate dam (Dam 2) which acts as both a retention and evaporation pond.

2.2.3 Landfill gas engine

Landfill gas is currently collected at the WBLS and directed to a landfill gas engine. The landfill gas is combusted to produce electricity and subsequently exported to the electricity grid. It is understood that the existing landfill gas engine commenced operation in the late 1990s /early 2000s. GHD is not aware of the expected future operation of the engine.

In a typical internal combustion gas engine, more than 50% of the landfill gas energy content is exhausted as waste heat to the atmosphere, thereby generating substantial quantities for potential heat recovery. This heat energy is typically exhausted through the engine cooling system (e.g. engine jacket water) and exhaust gas emissions.

Typically, waste heat temperatures of the exhaust gas emissions can be expected to be in the range of 400 to 500°C (D. Gewald et al., 2012), whilst engine jacket water outlet can reach temperature close to 99°C. A plate heat exchanger could be implemented with the landfill gas engine jacket water system to allow for heat transfer between the hot jacket water and the liquid / air being heated. Typically, a flow return process of e.g. preheated 70°C incoming water and 90°C outgoing water (after exchange of heat with the jacket water) could be achieved (Clarke Energy, 2014).

Currently, neither the engine exhaust gas nor the jacket water waste heat at the WBLS is harnessed for beneficial uses. These could be exploited through the implementation of a heat recovery system.

2.3 Heat collection methods

2.3.1 Overview

Heat generated by the identified heat resources may be able to be harnessed via a number of methods, selected as appropriate for the identified resource. These methods are discussed in more detail in the following sections.

2.3.2 MSW landfill

Heat energy could potentially be extracted from the MSW landfill through the implementation of a subset of ground-source heat pumps (GSHP).

A GSHP system utilises a heat transfer system such as heat pumps to pass thermal loads between the source and load side. A heat pump is a mechanical device which uses an electrically driven refrigerant vapour compression cycle to efficiently upgrade heat from one reservoir to another. Conventionally, GSHP systems are used to provide space heating and cooling for residential and commercial buildings by exploiting natural subterranean thermal sources such as the ground, groundwater, or bodies of water in intimate contact with the ground.

It is understood that landfilling of all MSW at the WBLS ceased in 2006. As such, in order to minimise disturbance of waste and the final cover layer, the most suitable approach to extract heat energy from the MSW landfill is likely to be via the installation and operation of a closed loop vertical heat exchange configuration. This would need to be installed through the final cover layer into the deepest / thickest part of the waste mass.

Closed loop system refers to the circulation of fluid through a loop of underground pipes which is passed through a heat transfer system at the ground's surface, and is then recirculated back through the buried ground loop to exchange with the surrounding waste. Such a system would require the drilling of numerous vertical boreholes through the landfill as deep as possible, without damaging existing environmental control systems such as the basal liner, leachate and landfill gas collection system. This configuration is shown in Figure 1 (C.J.R. Coccia et al., 2012).

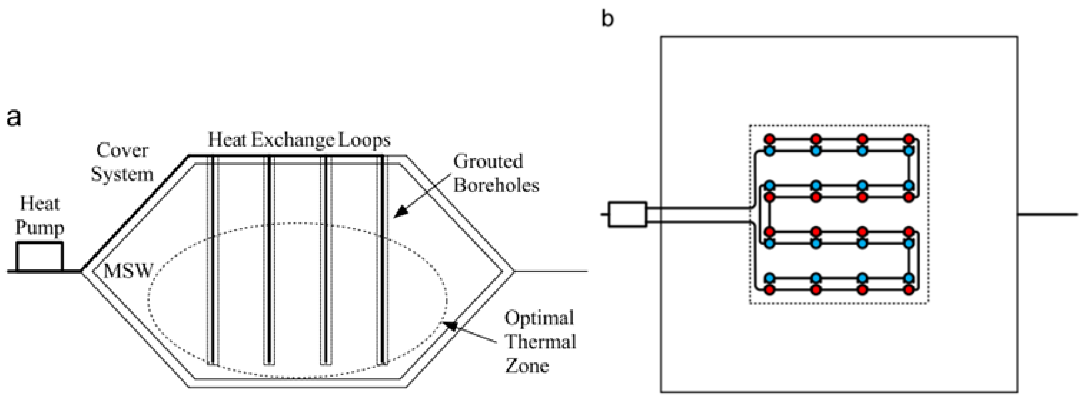


Figure 1 Vertical geothermal heat exchanger configuration for closed landfills: (a) Elevation section of vertical configuration; (b) Plan view of vertical configuration.

It is to be noted that the configuration shown on Figure 1 would require the penetration of the landfill final cover layer. Appropriate sealing methods would therefore need to be adopted at these points of penetration.

Gate valves should be installed on each heat exchange tube in order to allow for uniform flow within each individual loop. Each borehole should be directly connected to one another at the surface of the landfill final cover as a manifold connection.

GHD notes that closed loop horizontal heat exchange configurations also exist. However, this has not been considered further as GHD do not consider it to be a realistically feasible option for the WBLS due to a number of reasons including the following:

- Likely large amount of disturbance to final cover layer and waste mass to install such a system (i.e. trenching into the landfill to depths of at least 9 metres); and
- Likely significant number of risks associated with installing such a system (i.e. odour, dust, noise, landfill gas leachate, hazardous materials etc.).

2.3.3 Leachate collection and management system

Heat energy could potentially be extracted from the leachate collected from the landfill through the implementation of an open loop heat exchange system.

An open loop system operates by abstracting the leachate from a source (i.e. leachate collection sump) then pumping that leachate through heat exchangers or heat pumps to extract the heat, before being disposed of (at a lower temperature than before). This configuration is shown on Figure 2 (M. Preene et al. 2008).

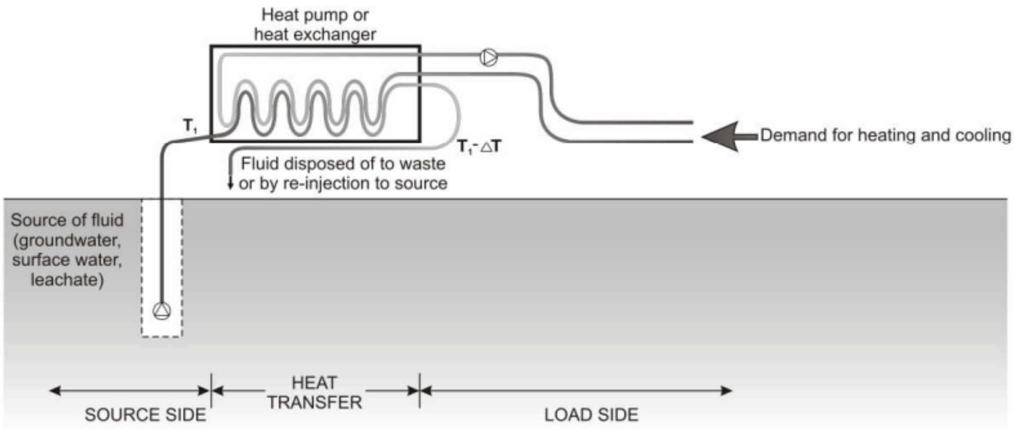


Figure 2 Open loop GSHP system

Such open loop systems may suffer operational problems due to clogging of the heat exchanger or heat pump by chemical and / or biological encrustations derived from the leachate.

2.3.4 Landfill gas engine exhaust emission

Literature (D. Gewald et al., 2012) indicates that both the Organic Rankine Cycle and Water/Steam Rankine Cycle have been considered as favourable for waste heat recovery from the exhausts of internal combustion / landfill gas engines. This is due to the exhaust gas temperatures from such engines being in the range (approximately 400 to 500°C) where both cycles may have specific advantages in terms of thermal efficiency, power generation and economic considerations.

Organic Rankine Cycle (ORC)

ORC technology is one of the most common and widely applied methods for recovering exhaust gas waste heat for the generation of additional electricity. The working fluid is compressed with a pump, preheated in a regenerator and evaporated by the landfill gas engine exhaust gas heat. The vapour is then expanded in a turbine which drives the generator producing electricity. The expanded vapour is then driven through the regenerator and finally condensed in an air cooled condenser to be recirculated. The working media can be any organic fluid with the appropriate thermal properties in order to efficiently exploit the heat provided from the landfill gas engine.

The working principle of an ORC is shown in Figure 3 (D. Gewald et al., 2012).

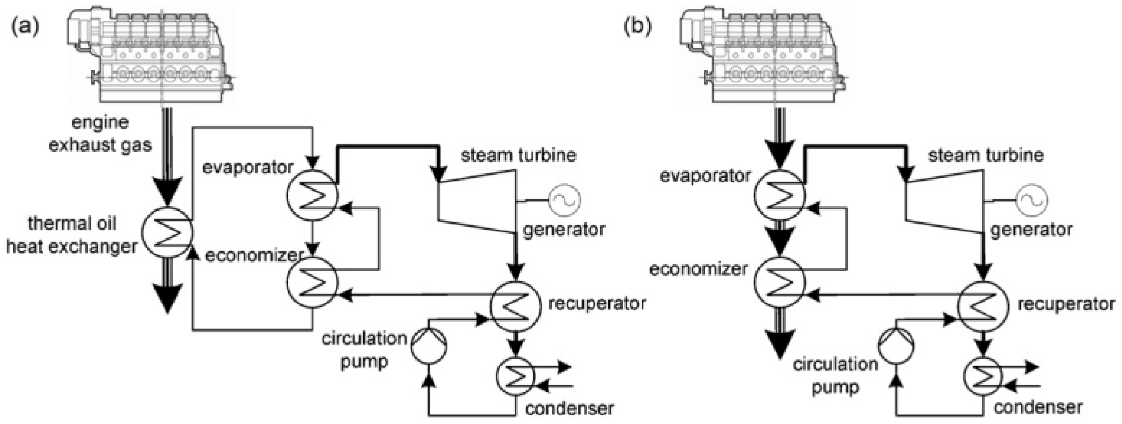


Figure 3 Schematic of ORC: (a) with thermal oil intermediate circuit and (b) direct heat exchange Open loop GSHP system

Water/Steam Rankine Cycle

This technology recovers the exhaust gases in a natural circulation heat recovery steam generator. Saturated steam is produced by the preheater for de-aeration with the low grade heat of the exhaust gases. The steam is used for both heating the feedwater tank and also as saturated low pressure steam for the low pressure stage of the steam turbine. Similar to the ORC, the steam turbine drives the generator which in turns produces electricity. A condensate preheater is installed within the exhaust gas flow to cool the exhaust gases down to about 90°C. The working principle of a Water/Steam Rankine Cycle is shown in Figure 4 (D. Gewald et al., 2012).

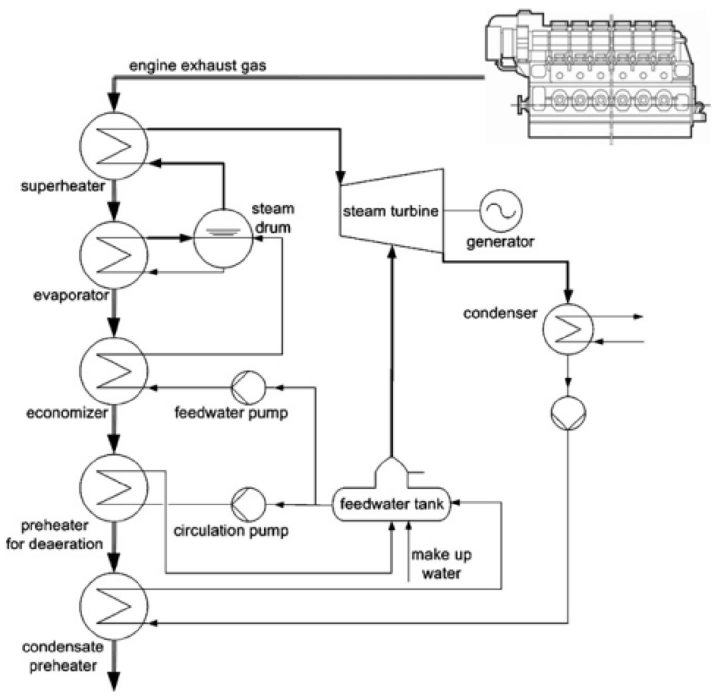


Figure 4 Schematic of Water/Steam Rankine Cycle

2.3.5 Landfill gas engine jacket water

Typically, heat from engine jacket water can be collected through the use of a plate heat exchanger. Plate type heat exchangers consist of a series of separate parallel plates. The plates are separated by gaskets and hot jacket water passes in parallel through alternative plates whilst the liquid to be heated passes in parallel between the hot plates. Typical heat recovery efficiencies for plate heat exchangers are in the order of 75 to 80% (Energy, Mines and Resources Canada).

This process is illustrated in Figure 5.

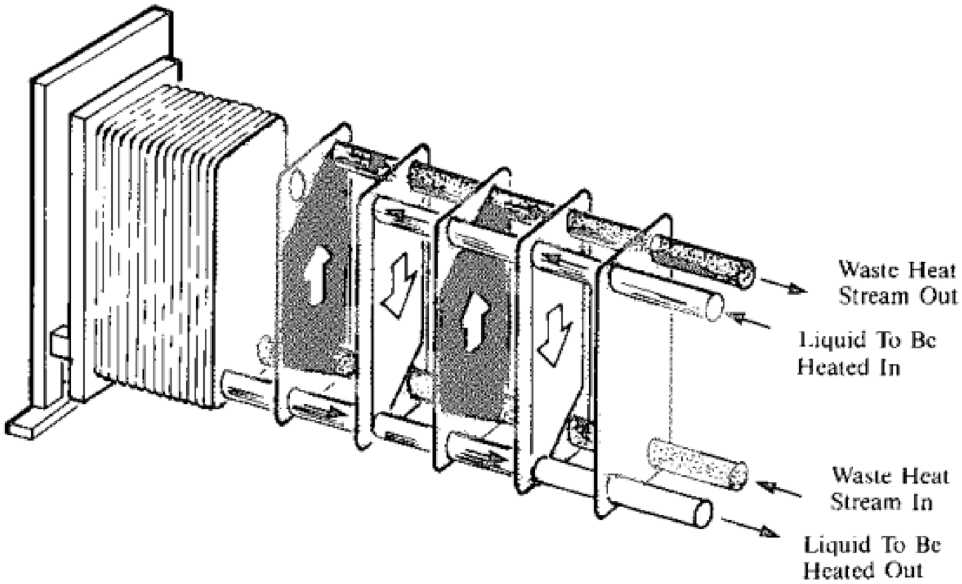


Figure 5 Plate heat exchanger (Energy, Mines and Resources Canada)

In gas engine applications, this is typically implemented in a Combined Heat and Power (CHP) system, in which the system utilises the power and heat simultaneously from the same fuel source. Heat recovery through CHP systems are widely practiced in industry.

2.4 Previous project examples of heat recovery

2.4.1 MSW landfill

GHD has identified the following previous project examples:

- A GSHP is used for heating an administration building at a landfill site at Kinsale Road, Cork (Ireland). The landfill has been operational since the 1960s and accepts MSW and non-hazardous industrial wastes for disposal. The landfill (including historical landfill areas) is approximately 72 hectares in size. Landfilling operations ceased in July 2009. The GSHP system installed in 2000 collects heat from the landfilled waste and was indicated to be a horizontal closed loop system (2,400 m of loop) of peak capacity 28 kW, operating with a coefficient of performance (COP) of 4.5 to 6 (S. O'Connell & S. F. Cassidy, 2003). The COP of a system describes the ratio of the total heat output from a heat pump to the quantity of electrical energy used to drive the heat pump. The landfill is shown in Figure 6 below.

Figure 6 (Left) Aerial image of Kinsale Road Landfill; (Right) Permanent capping outline

- CMA Engineers, Inc. undertook the design and installation of a landfill based geothermal heating system in Bethlehem, New Hampshire (USA). The project involved installing a geothermal heat exchanger at the base of a landfill expansion cell to collect landfill derived heat to be used as the heat source for an on-site garage and an ice melt system for site roads. The site is subject to severely cold winter temperatures. The design consisted of ten 152 m long loops of 31.75 mm diameter high-density polyethylene (HDPE) pipe spaced at 50 mm intervals. The loops were installed above the geomembrane landfill liner system and are protected by a 460 mm thick layer of sand. The loop is connected via a manifold to the 76.2 mm diameter supply and return lines that are routed in a trench to the facility maintenance garage. A 0.56 kW pump is used to circulate the fluid between the ground coupled heat exchanger and the storage tank. The system was installed during landfill cell construction in October 2011, shortly before waste disposal commenced. After 14 months it was observed that temperatures have climbed steadily and are expected to exceed 35°C. This project demonstrates the feasibility of recovering thermal energy from a landfill and its direct use (Landfill Based Geothermal Heating System, 2013). The landfill and part of the installed system are shown in Figure 7 below.

Figure 7 (Left) Aerial image of NCES Landfill; (Right) Supply and Return Line Manifold for the 10 GCHX Loops

2.4.2 Leachate collection and management system

GHD have identified the following previous project examples:

- Golder Associates undertook the concept design for a trial closed loop horizontal heat exchanger and the associated pipework that was subsequently installed in a leachate extraction trench in the U.K. The heat exchangers were placed approximately 5 metres below ground level and in direct contact with waste and leachate, but below the landfill final cover layer. This trial showed that there was significant heat energy available, which they thought may be sufficient to provide direct heating without an additional heat pump for the leachate treatment plant at the landfill site (D. Brown and M. Preene, 2014). Part of the installed system is shown in Figure 8 below.

Figure 8 A mobile thermal response testing unit connected to a buried ground collector loop.

2.4.3 Landfill gas engine

GHD have identified the following previous project examples:

- The Greek company Helector in association with the Australian company Energy Developments Ltd, constructed a landfill gas fuelled power plant based on internal combustion engines (ICEs) at the Ano Liosia landfill, Athens (Greece). The power station consists of 15 ICEs with a total installed capacity of 23.5 MW. One Water/Steam Rankine Cycle unit was installed, with an electricity production cost of approximately €23/MWh (or equivalent to AU$30.54/MWh in November 2012). Thermodynamic analysis shows an increase of electrical station efficiency of up to 4.8% (D. Gewald et al., 2012).

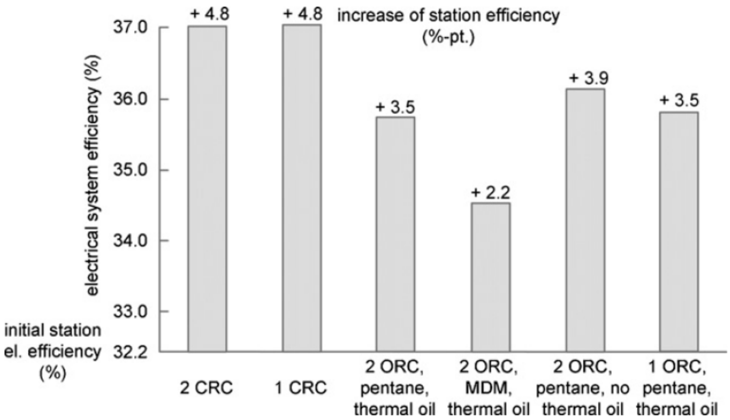


Figure 9 Increase of electrical efficiency of the station by different Rankine cycle configurations implemented

- Clean Power Technologies Inc. installed a Heat Recovery Landfill (HR-L 300) unit at a landfill site in Oxfordshire, U.K. The HR-L 300 produces electricity purely from the waste exhaust heat from an existing landfill gas fuelled engine. The unit produces electricity without additional fuel or emissions and with no back pressure or other detrimental effects to the efficiency of the existing engine upon which it is installed. The system includes a sophisticated heat exchanging device fitted into the stream of the engine exhaust pipe which coverts water to superheated steam. The superheated steam is then fed through electronic and mechanical control devices to power a compact steam engine, which in turn powers an electrical generator. The steam engine exhausts into a condenser which returns condensed water thus completing a 'closed loop' operation. The HR-L 300 produced an electrical output of 26.7 kW which equates to the unit providing an additional

10.7% increase in electrical power for export to the grid when the landfill gas engine is operating at 250 kW (Waste Management World, 2010).

Figure 10 Installed HR-L 300 unit on the existing engine

- Modern Landfill Inc. manages a 120 acre, non-hazardous solid waste landfill located in Lewsiton, New York, USA. Landfill gas collected is used as fuel for the CHP system which has been configured on seven CAT 3516, 800 kW engine-generator sets where most of the electricity is exported to the grid. The system was installed in early 2004 and has a design CHP efficiency of 70%. The waste heat (approximately 32,500 MJ/h) is recovered from the engines as hot water which is used by an adjoining hydroponic grower for space heating.

Figure 11 Landfill gas fuelled engine-generator sets

- Caterpillar is one example of a manufacturer of gas engines that has implemented CHP systems worldwide. Projects include:
  - Landfill CHP in Aix en Provence, France – Jacket water and exhaust heat recovery from a 1 MW CHP engine used for leachate drying

Figure 12 Installed CHP G3516A 1MW engine

  - Industrial CHP for Mercedes Benz in Turkey – Jacket water and exhaust heat recovery from four G3520C CHP engines

Figure 13 Installed CHP G3520C engines

  - District heating in Debrecian, Hungary – Jacket water and exhaust heat recovery from six G3520C CHP engines

Figure 14 Installed six off CHP G3520C engines

3. Potential technical feasibility of heat recovery

3.1 MSW landfill

Heat recovery from landfilled waste has been undertaken in a few locations internationally using GHSP systems and has been shown to be technically feasible. The utilisation of such system will produce heat in the form of either warm water or warm air which is less efficient to transmit over long distances, requiring insulated pipes, in comparison to electricity transmission. It is understood that there is no existing heat transmission infrastructure into which the WBLS could connect to. Thus the heat which could potentially be collected would likely be used in the immediate vicinity of the WBLS.

As the MSW landfill area is already at the post-closure stage, the most technically feasible approach for heat recovery from the MSW landfill is likely to be via the installation and operation of a closed loop vertical heat exchange configuration (C.J.R. Coccia et al., 2012). It is understood that a landfill gas collection system has been installed within the body of the MSW landfill. Boreholes required to be installed through the landfill cover for the installation of the closed loop system may potentially interfere with the existing landfill gas collection system. This may make the installation of the closed loop system difficult and expensive (and potentially impact upon the landfill gas collection system).

The age of waste in the landfill is estimated to be between 12 to 44 years old. Literature sources have suggested that the lower half of the landfill would provide a warmer and more stable heat source for heat exchange. Assuming a constant rate of waste input throughout the landfill life, the age of the lower half of the landfill is well past its peak heat generation age and the heat content of waste is therefore assumed to have declined considerably. On the other hand, the wastes located at the top half of the landfill are younger, and can still be assumed to contain and generate substantial heat which could be recovered. However, the top half of the landfill may be heavily influenced by seasonal change in temperatures which would reduce the efficiency and effectiveness of heat recovery of this landfill area.

It is also noted that there are some other uncertainties in relation to the technical feasibility of installing and operating such system which include waste type, depth, temperatures, landfill settlement or movement, physical accessibility of landfill for installation purposes (e.g. drilling rigs) and location of existing environmental control measures.

Given the existing gas and leachate collection systems in place, heat collection from the WBLS may present some implementation challenges with some uncertainties regarding the amount of heat resource and potential use of the recovered heat. Implementation of a temperature testing program involving array installation of thermocouple wire inside Polyvinyl Chloride (PVC) conduits, as well as appropriate modelling based on the age and content of the landfill may provide valuable inputs for a cost benefit analysis. This will assist in determining the viability of a heat recovery system to be implemented at the WBLS.

In summary, recovery of heat from the MSW landfill is technically feasible but also it would be challenging. The economics of setting up a system are also uncertain. .

3.2 Leachate collection and management system

Based on the available information, the most technically feasible approach for heat recovery from the leachate collection and management system at the WBLS appears to be via the installation and operation of an open loop heat exchange configuration. Implementation of such a system has been undertaken in a very limited number of locations internationally and has been shown to be technically feasible (at least on trial basis). However, the actual technical feasibility of installing and operating such a system at WBLS would depend upon the physical accessibility of leachate collection points (for installation / connection purposes).

Previous investigations undertaken by GHD in 2012 indicated that the landfill was generating a relatively minor quantity of leachate, which may have been diluted by stormwater ingress through the landfill final cover. Previous investigation (GHD, 2012) suggests leachate generation at the site is low since the cessation of the waste disposal at the landfill in 2006. It was presumed that it was due to the high net evaporation rate at the site (dry Canberra climate) and also due to the placement of the final landfill cover layer over the landfilled waste.

Aside from this, it is also understood that the majority of the landfilled area has no leachate collection system, with the exception of two drainage pipes that flow to the leachate dam (Dam 2).

Furthermore, heat extraction from the collected leachate could potentially slow the evaporation (disposal) rate of leachate in Dam 2 due to lowered temperatures, which may not be favourable.

Assuming the likely constant trend of climate at the WBLS, in conjunction with the completion of a final landfill capping layer upgrade and the site's limited leachate collection system, the rate of leachate generation and collection is likely to continue to be low. However, no substantiating data / modelling for this view has been provided to GHD.

In summary, it is considered that recovering heat from the leachate collection and management system is likely to be technically feasible but may be technically challenging. The amount of heat that may be able to be recovered from the leachate system is difficult to quantify, but is expected to be quite low, due to small volumes of leachate present, and its low temperatures.

3.3 Landfill gas engine

Industrial waste heat recovery through the use of CHP or ORC or Water/Steam Rankine Cycle technology has been practiced in the industry for a reasonable amount of time and has been shown to be technically feasible. Literatures have shown significant increase in electrical efficiency of up to 4.8% and electrical power of 2.8 MW for Ranking Cycle systems (D. Gewald et al., 2012).

Furthermore, electrical infrastructure to supply electricity generated by the landfill gas back to the electricity grid already exists. Electricity generated from the waste heat could therefore be supplied back to the electricity grid without major infrastructure works. Heat collected from the engine jacket water could be used to provide heating of site offices and workshops, as well as for water heating for site usage.

Available data suggest that the total quantity of landfill gas extracted from the WBLS has reduced from 2003 and 2009 and is currently approximately 200-300 m^3/hr. The reason for this reduction in gas collection is unknown, but is likely linked to some extent to the age of the landfilled waste. From past experience, GHD estimate that the existing landfill gas engine may continue to operate at the WBLS for less than 5 years (unless something is done to increase the quantity of gas collected).

In summary, it is considered that recovering heat from the landfill gas engine waste heat system is likely to be technically feasible as this has been widely practiced worldwide. However, the amount of heat and electricity that can be recovered and generated (respectively), are currently unknown due to the lack of available data on the existing landfill gas engine. Further investigations to confirm the actual current gas generation on site as well as prediction modelling to forecast the remaining gas generation period available and the engine operation strategy are recommended to allow for a more conclusive analysis.

4. Order of magnitude costs

4.1 MSW landfill

Little cost information is publicly available for the costs to install and operate a closed loop vertical heat exchange configuration within landfill sites. This appears to principally be due to the fact that these systems are not readily available “off the shelf”. Rather, the systems are designed and priced based on the individual requirements of the ultimate end user (this implies that use of these systems for landfill heat recovery is a relatively uncommon application).

A high level indicative cost range for the design and installation of such a system has been obtained from GeoExchange Australia (a local supplier of this technology). GeoExchange Australia estimated that designing, supplying and installing such a system at selected areas of the MSW landfill (3 ha in total size) may cost in the region of $2.5 to- $5.5 million. In addition, it was estimated that boreholes at a spacing of 4 metres would be required across the selected area.

This would result in the installation of approximately 1,850 boreholes to 15 metres depth across the selected area (and through the final landfill cover layer). This would cost approximately $3 million in drilling fees, resulting in a potential overall cost range of $5.5 to $8.5 million. This estimate was obtained based on the following assumptions:

- The area that would be accessible for installation is approximately 3 hectares in size (i.e. 30,000 m^2);
- Boreholes are drilled into the waste to 15 metres below ground level at 4 metre spacing (where applicable); and
- No allowance was made for any waste disposal costs or costs to repair any damage caused by the installation.

GeoExchange Australia has estimated that operation and maintenance costs would be relatively low as neither the heat pumps nor the ground heat exchanger require regular service. However, it is noted that there are a number of uncertainties associated with the estimates provided by the supplier and that they are only indicative in nature. Further assessment is required to confirm the validity of these estimates.

A figure showing the potential location for such a system is contained in Appendix A.

4.2 Leachate collection and management system

Similarly, little cost information is publicly available for the costs of an open loop heat exchange configuration that is to be interfaced to a leachate collection and management system. Again, this is due to the nature of the system in which it has to be designed specifically for a particular application. Furthermore, it appears that systems which interface with leachate collection and management system are less common than systems designed to interface with waste mass directly.

As such, the cost range for design, installation and operation of such a system is highly uncertain.

Also, it is to be noted that the composition of the leachate being circulated may cause operational problems following installation due to potential clogging and biological encrustations of the system. From this, the operation and maintenance costs can be expected to be higher than heat exchanger systems typically utilised for landfill heat extraction.

4.3 Landfill gas engine

Information is not readily available on the typical costs of setting up and operating gas engine waste heat recovery systems. At this stage, the cost range for design, installation and operation of such systems is highly uncertain due to the lack of data available on the existing engine on site.

Additional information regarding the existing landfill gas engine, such as flow rate, exhaust gas composition and temperature, would be required to allow for a budgetary quote to be prepared by a supplier.

5. Potential quantities of heat generated

5.1 MSW landfill

Specification and Assumptions

Due to a number of uncertainties, the potential quantity of heat that may be generated by the MSW landfill is difficult to determine. The following estimate has been prepared based on a number of assumptions derived from the available information. The specifications and assumptions of the WBLS landfill are outlined as follows:

Age of landfill

Previous investigation (GHD, 2012) by GHD indicated that the site accepted predominantly MSW between 1970 and 2002. From this it can be estimated that the landfill present age is to be in the range of 12 to 44 years (as of April 2014).

Waste composition

The composition of landfill at the WBLS is unknown; however it is believed to be predominantly MSW. Due to the lack of data, the following estimation of waste composition was undertaken based on waste audit data from Mugga Lane Landfill which is located approximately 25 km south of the WBLS. It is to be noted that the following estimation is only indicative with the assumption that both landfills received similar waste during operation and may not necessarily be representative of the waste composition at the WBLS.

Table 1 Composition of Landfilled Waste at Mugga Lane Landfill (Adapted from GHD, 2010)

Material	Including Garbage Bags
Paper and cardboard	10.7%
Organics	9.0%
Wood and timber products	5.4%
Textiles and rubber	3.9%
Glass	0.4%
Plastics	5.8%
Metals	1.1%
Building material	3.0%
Hazardous	0.0%
Bags and loose garbage	59.9%
E-waste and office equipment	0.2%
Other	0.6%

The audit found that the largest proportion of waste deposited at Mugga Lane was garbage bags, the contents of which were not known without opening them and investigating further. The bags originate from domestic and commercial sources so it is likely that the contents consist of organic materials (mainly food), paper and plastic.

Heat content

Heat content of waste mass is defined as the difference between measured waste temperatures and unheated baseline waste temperatures at equivalent depth. It quantifies the heat gain in the wastes compared to unheated baseline conditions. Peak heat content occurs at an optimal average precipitation of 2.3 mm/day, beyond which heat content decreases.

Figure 15 shows the increase and decrease of waste heat content with waste age.

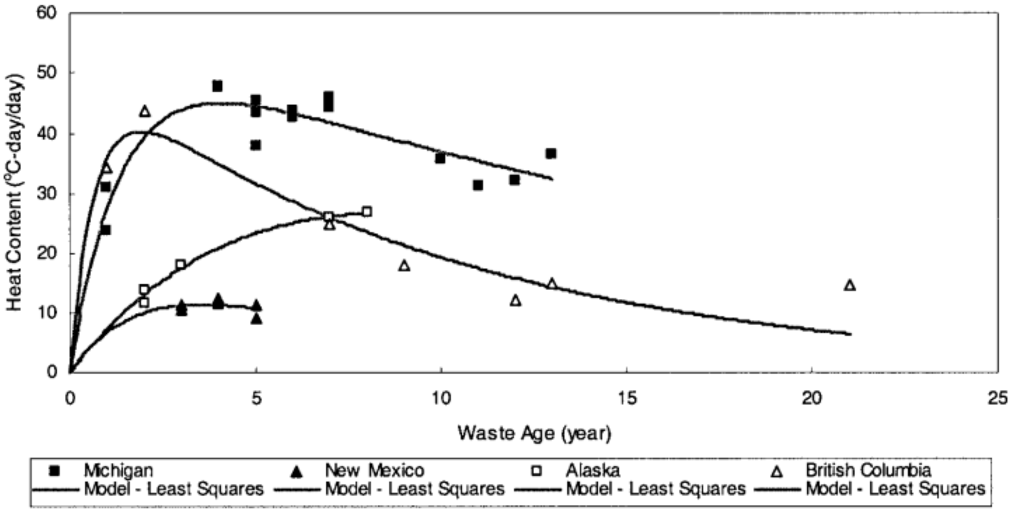


Figure 15 Variation of maximum heat content with waste age (N. Yesiller et al., 2005)

Extrapolating the heat content of the waste within the MSW landfill from the graph presented in Figure 15 suggests a heat content range for the waste within the MSW landfill of between 5°C-day/day for the older waste (> 20 years old) and 20 °C-day/day for the younger waste (~12 years old). It is to be noted that the data in Figure 15 has been derived from a number of landfill sites within USA and it can be seen that heat content can vary significantly between different landfill sites. Furthermore, there is no data available to estimate heat content for waste older than approximately 20 years. As such, it is important to note that the data may not reflect the actual heat content in the WBLS landfill. Further investigation and testing to determine heat content at the WBLS are recommended.

Landfill temperature variation

Figure 16 and Figure 17 shows the variation of waste temperature at different depths and with time. It is to be noted that available temperature variation data only exists for a period of 4 years in a landfill in the north of the USA (and therefore this data may not well represent conditions at the MSW landfill).

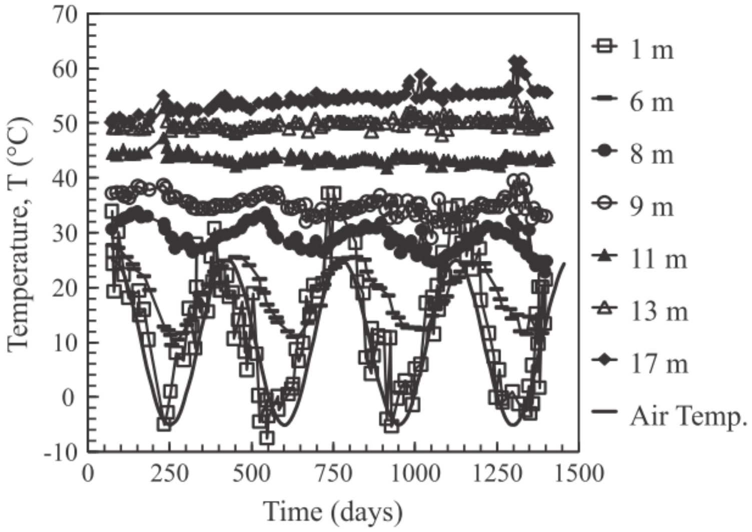


Figure 16 Variation of temperature at different depths in a Michigan landfill (C.J.R. Coccia et al., 2012)

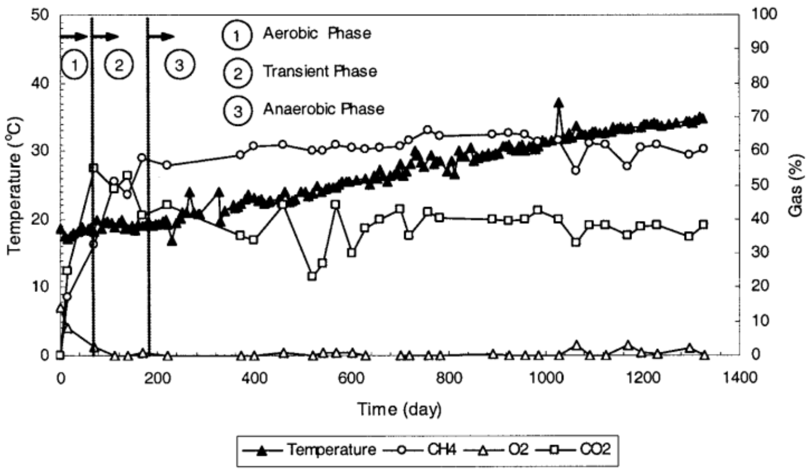


Figure 17 Variation of temperature and gas with time (N. Yesiller et al., 2005)

Extrapolation of temperatures of the MSW landfill at WBLS from the graphs presented in Figure 16 and Figure 17, would give an estimated temperature range of the waste of between 35°C and 50°C. This estimate needs to be confirmed through field measurements as waste age and composition vary within the landfill.

Estimation of heat generated

Determination of heat generation present considerable uncertainties due to the lack of data, however heat generation of typical landfill are found to be approximately 23 to 77 MJ/m^3, per annum if thermal losses (i.e. losses to the surrounding environment) are neglected (N. Yesiller et al., 2005).

For the purposes of this estimate, it has been assumed that a closed loop vertical heat exchanger configuration would be implemented. It has further been assumed that the system would cover 3 hectares (30,000 m^2) of the MSW landfill and that the vertical loop would be installed in all borehole locations to a depth of 15 metres. As such, the effective waste volume for heat recovery would be approximately 450,000 m^3.

This would translate to approximately between 10,350,000 MJ/yr (23 MJ/m^3/yr * 450,000 m^3) and 34,650,000 MJ/yr (77 MJ/m^3/yr * 450,000 m^3).

In summary, approximately 1,200 MJ to 4,000 MJ per hour of heat could potentially be recovered from the landfill[1].

As previously indicated, the actual composition of waste at the WBLS is unknown at this stage. The amount of MSW in comparison to other non-degradable waste may be much lower than estimated, which may impact the estimated temperature and heat content. As such, it is to be noted that the estimates are only indicative in nature. Further investigation and field testing are recommended to confirm the validity of these estimates and obtain a more definitive analysis.

5.2 Leachate collection and management system

There is insufficient data currently available to further assess the potential quantities of heat that may be generated or collected from the leachate collection and management system. Further investigation and field testing are required to quantify and further assess the potential of this heat source.

5.3 Landfill gas engine

Due to the lack of data and a number of uncertainties, the quantification of recoverable heat from the landfill gas engine's exhaust is difficult to estimate accurately. The following estimate has been prepared based on a number of assumptions derived from the available information and are outlined in the following sections.

Landfill gas engine specification

The specification for the existing landfill gas engine is understood to be as per Table 2.

Table 2 WBLS landfill gas engine specification (CAT G3500 Series Gas Generator Sets Catalogue)

Gas generator model	CAT 3516
Landfill gas input required	600 sm^3/hr @ 40% methane
Electrical power	1041 kW
Thermal output	1556 kW
Electrical efficiency	32.1%
Thermal efficiency	47.0%
Total efficiency	79.1%

Typical gas engine performance

Table 3 summarises performance characteristics for typical commercially available natural gas spark ignition engine combined heat and power (CHP) systems, commercially available in 2007, over a 100 kW to 5 MW size range.

[1] This is approximately equivalent to 10,350,000 MJ/yr (10,350 GJ/yr) and 34,650,000 MJ/yr (34,650 GJ/yr)

Table 3 Gas Engine CHP – typical performance parameters (Energy and Environmental Analysis, 2008)

Cost & Performance Characteristics[8]	System 1	System 2	System 3	System 4	System 5
Baseload Electric Capacity (kW)	100	300	800	3,000	5,000
Total Installed Cost (2007 $/kW)[9]	$2,210	$1,940	$1,640	$1,130	$1,130
Electric Heat Rate (Btu/kWh), HHV[10]	12,000	9,866	9,760	9,492	8,758
Electrical Efficiency (percent), HHV	28.4%	34.6%	35.0%	36.0%	39.0%
Engine Speed (rpm)	1800	1800	1800	900	720
Fuel Input (MMBtu/hr)	1.20	4.93	9.76	28.48	43.79
Required Fuel Gas Pressure (psig)	<3	<3	<3	43	65
CHP Characteristics					
Exhaust Flow (1000 lb/hr)	1.4	6.3	12.1	48.4	67.1
Exhaust Temperature (Fahrenheit)	1,060	939	909	688	698
Heat Recovered from Exhaust (MMBtu/hr)	0.28	1.03	1.85	4.94	7.01
Heat Recovered from Cooling Jacket (MMBtu/hr)	0.33	1.13	2.45	4.37	6.28
Heat Recovered from Lube System (MMBtu/hr)	0.00	0.00	0.00	1.22	1.94
Total Heat Recovered (MMBtu/hr)	0.61	2.16	4.30	10.53	15.23
Total Heat Recovered (kW)	179	632	1,260	3,084	4,463
Form of Recovered Heat	Hot H_20	Hot H_20	Hot H_20	Hot H_20	Hot H_20
Total Efficiency (percent)[11]	79%	78%	79%	73%	74%
Thermal Output/Fuel Input (percent)	51%	44%	44%	37%	35%
Power/Heat Ratio[12]	0.56	0.79	0.79	0.97	1.12
Net Heat Rate (Btus/kWh)[13]	4,383	4,470	4,385	5,107	4,950
Effective Electrical Efficiency[14]	0.78	0.76	0.78	0.67	0.69

The reference and analysis basis for the parameters in Table 3 have been tabulated in Table 4. These have been extracted directly from the Technology Characterization Reciprocating Engines literature.

Table 4 List of references and basis of analysis

Reference No.	Reference / Basis of analysis
8	Characteristics for “typical” commercially available natural gas engine gensets. Data based on: IPower ENI85 – 85 kW; GE Jenbacher JMS 312 GS-N.L – 625 kW; GE Jenbacher JMS 320 GS-N.L – 1050 kW; Caterpiller G3616 LE – 3 MW; Wartsila 5238 LN - 5 MW; Energy use and exhaust flows normalised to nominal system sizes.
9	Installed costs based on vendor quote or on CHP system producing hot water from exhaust heat recovery (138°C exhaust from heat recovery heat exchanger), and jacket and lube system cooling
10	All engine manufacturers quote heat rates in terms of the lower heating value (LHV) of the fuel. However the purchase price of fuels on an energy basis is typically measured on a higher heating value basis (HHV). For natural gas, the average heat content of natural gas is 1030 Btu/kWh on an HHV basis and 930 Btu/kWh on an LHV basis – or about a 10% difference.
11	Total CHP Efficiency = (net electric generated + net thermal energy recovered)/total engine fuel input
12	Power/Heat Ratio = (CHP electric power output (Btus))/useful thermal output (Btus)

Reference No.	Reference / Basis of analysis
13	Net Heat Rate = (Total fuel input to the CHP system - the fuel that would be normally used to generate the same amount of thermal output as the CHP system thermal output assuming an efficiency of 80%)/CHP electric output (kW).
14	Effective Electrical Efficiency = (CHP electric power output)/(Total fuel into CHP system – total heat recovered/0.8); Equivalent to 3,412 Btu/kWh/Net Heat Rate

Available landfill gas collection data

Gas extraction data provided by the operator of the landfill gas engine (Energy Developments) for the financial years 2005/2006 and 2008/2009 indicate a steady drop in methane extraction from the MSW landfill, which decreased from approximately 2.3 Mm^3/annum to 1.2 Mm^3/annum respectively. GHD used this data to estimate theoretical electrical output capacity, which appears to have dropped from approximately 0.88 MW to 0.45 MW, respectively over the two financial years.

Based on this information, GHD has assumed that the landfill gas engine has been downgraded to possibly a 0.5 MW unit.

Estimation of heat generated from landfill gas engine exhaust and jacket water

Upon conversion of unit from MMBtu/hr to MJ/hr in Table 3 (i.e. 1MMBtu/hr = 1056MJ/hr), the correlation between engine capacity and potential heat recovered can be plotted as shown in Figure 18.

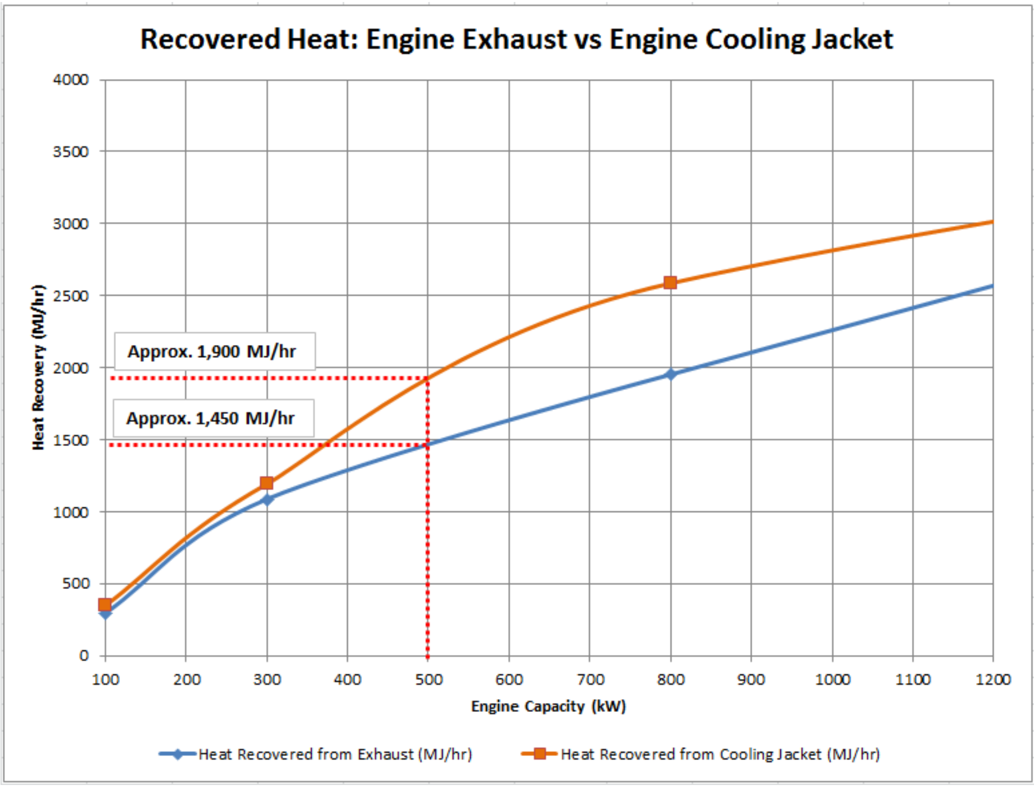


Figure 18 Plot of exhaust and cooling jacket heat recovery from System 1, 2 and 3

Interpolating the data in Table 3, as shown in Figure 18, the heat recovered from the engine exhaust for a 0.5MW gas engine could be of the order of approximately 1,450 MJ per hr.

Interpolating the data in Table 3, as shown in Figure 18, the heat recovered from the engine jacket water for a 0.5MW gas engine could be of the order of approximately 1,900 MJ per hr.

It is to be noted that the data presented Table 3 in are reasonably old and may be outdated. Furthermore, the values presented are for natural gas fuelled gas engines which may be misrepresentative for landfill gas engines. However for the purpose of this high level waste heat assessment, the estimated value provides an indication of potential heat that could be collected.

In order to obtain a proper quantification of potential waste heat available, field testing of the engine flue gas is recommended to obtain actual flow rate, composition and temperatures of the exhaust flue gas.

6. Potential uses for collected heat

6.1 MSW landfill

There is potentially a very large amount of low grade heat available from this source. GHD considers that the heat collected could potentially be put to the following (or similar) uses:

- Diversion of heat to nearby greenhouse complexes, fish farms or other proximate facilities requiring heat input; and / or
- Provision of space heating for welfare and other on-site facilities including offices and workshops.

The feasibility of both applications would be subject to the actual temperatures of the waste within the landfill mass and a number of other factors.

6.2 Leachate collection and management system

GHD considers that although the heat collected from leachate is expected to be significantly less in comparison to the MSW landfill, it could potentially be put to similar uses to those mentioned above, but at a much smaller scale eg a small demonstration facility.

6.3 Landfill gas engine

GHD considers that the heat collected could potentially be put to the following (or similar) use:

- Heat from engine exhaust
- Generation of additional electricity using ORC or Water/Steam Rankine Cycle system; or
- It is understood that there is no plan for construction of a leachate treatment plant at the WBLS. However, if further treatment is considered in the future, recovered heat could be used to heat the leachate prior to its biological treatment in winter.
- Diversion of heat to the leachate evaporation dam to assist with the disposal of collected leachate (speed up evaporation rate);
- Drying applications on site; and / or
- Generation of steam in a waste heat boiler.
- Heat from engine jacket water
- Hot water generation for domestic usage; and / or
- Provision of space heating for welfare and other on-site facilities including offices and workshops.

6.4 Potential impacts to landfill after heat collection

Net extraction of heat from the landfill or leachate is likely to result in lower temperatures within the landfill or leachate over time. The potential effects of changing the temperature of the waste are briefly discussed in the following sections.

6.4.1 Reduced methane / heat generation

- Optimum temperature for landfill methane generation is approximately 41°C. Temperatures above 41°C decreases landfill methane generation rates, with a complete cessation at around 55°C (C.J.R. Coccia et al., 2012). Extraction of heat from the landfill could potentially further decrease the methane generation rate at the WBLS; and

- The current age of the landfill suggests that the landfill has passed its peak temperature generating stage, and heat generation is likely to be declining. Extraction of heat from the landfill could potentially further decrease the heat generation rate at the WBLS.

6.4.2 Extension of landfill basal liner lifespan

- The WBLS utilises rudimentarily engineered clay as components of the primary base liners;
- Elevated liner temperatures caused by heat generated from organic waste decomposition may result in desiccation of clay liners. This may result in loss of liner performance and increased contaminant diffusion through the basal liner (S. O'Connell & S. F. Cassidy, 2003);
- Elevated temperatures at the base of the landfill could potentially create thermal gradients between the landfill base liner and the underlying groundwater regime, causing increased water flow from the landfill to the underlying subsoil, resulting in desiccation of the base liner (S. O'Connell & S. F. Cassidy, 2003); and
- Heat extraction from the base of the landfill may extend the life of the liner system.

6.4.3 Leachate collection and management systems

- Elevated temperatures have been observed to increase the rate of biologic activity within waste, which suggests a higher potential for clogging of the leachate collection layer and mounding at the base of the landfill (S. O'Connell & S. F. Cassidy, 2003); and
- Decreased temperatures within the landfill may minimise the adverse effects of increased biological activity in the leachate collection layer.

6.5 Preliminary comparison of potential collected heat and potential requirements of identified users

6.5.1 Overview

In order to compare the potential quantity of heat collected to the potential users identified in Section 6.8 above, GHD have prepared Table 5 below.

It is noted that Table 5 has been developed so as to directly compare energy that could potentially be collected from the various heat sources (in the unit of Joules) to typical <u>total energy consumption for a domestic consumer</u> in the ACT (in the unit of Joules).

Realistically, the energy collected from the available sources would mostly be in the form of hot water or air, whilst total energy consumption for a domestic consumer would be in a variety of forms including hot water, electricity, natural gas etc. As such, further investigation is required to properly define specific requirements for potential heat users local to the WBLS and to more thoroughly estimate the quantity of heat that could be collected from the identified sources. Such an investigation may identify that the collected heat could service a substantially lower number of buildings than are indicated by the preliminary estimate contained in Table 5. <u>It is noted that there are substantial uncertainties in the figures contained in Table 5 and that additional work is required to further confirm their validity.</u>

In addition, only technical feasibility of collecting these heat sources has been assessed. The feasibility of transferring the collected energy to the potential users has not been addressed. Reticulation systems for heat collected could potentially be a significant factor in the overall cost estimate of the system due to installation (e.g. insulated pipework and metering to consumers) and storage requirements associated with delivery of heat energy.

Furthermore, it is important to further define the likely consumer of energy, quantity of energy consumed, base and peak loading of energy consumption. For example, will peak energy consumption occur for short periods throughout the day (e.g. once in the morning and once at night) and very low demand for all other periods of the day? Since energy would be collected continuously from the sources identified in the report, there would be a need to either only supply users who have a constant demand or to identify means of storing the collected heat until such demand from the user(s) exists.

6.5.2 Preliminary energy comparison

Table 5 compares the amount of heat potentially recoverable from the various sources against potential user requirements.

It is noted that the estimates provided in this table are indicative only, have been done for a high level assessment and should be considered with consideration of the clarifications within Section 6.5.1. Further investigations are necessary to further refine these preliminary figures.

Table 5 Preliminary comparison of potential heat recoverable versus user requirements

Potential use	Source (available heat)		
	MSW Landfill	Leachate collection and management system	Landfill gas engine
Potential Heat Recoverable	Approximately between 10,350 to 34,650 GJ/annum (N. Yesiller et al., 2005)	Unable to estimate potential heat recoverable	Approximately 11,650 GJ/annum from jacket water (Energy and Environmental Analysis, 2008) (Note 2)[2]
On-site / nearby buildings	Yes – approximately 500 to 1,700 households (Note 1)	Yes - Not possible to estimate at this time as unable to estimate potential heat recoverable	Yes – approximately 350 households (Note 1)
Greenhouse complexes	Yes - Not possible to estimate at this time due to lack of specific information on user requirements	Yes - Not possible to estimate at this time as unable to estimate potential heat recoverable	Yes - Not possible to estimate at this time due to lack of specific information on user requirements
Fish farms	Yes - Not possible to estimate at this time due to lack of specific information on user requirements	Yes - Not possible to estimate at this time as unable to estimate potential heat recoverable	Yes - Not possible to estimate at this time due to lack of specific information on user requirements
Steam generation using waste heat boiler	No – heat from source unlikely to be hot enough for this use	No – heat from source unlikely to be hot enough for this use	Yes – some of the landfill engine exhaust gas could be redirected to a waste heat boiler for steam generation on site. It is difficult to estimate the amount of steam that could be

[2] It was assumed that any waste heat recoverable from the exhaust of the landfill gas engine would be utilised to generate more electricity (and improve efficiency of the landfill gas engine) and would be sold back to the grid. Only heat from the jacket water system would be recovered and utilised for applications within and external to the WBLS.

Potential use	Source (available heat)		
	MSW Landfill	Leachate collection and management system	Landfill gas engine
			generated at this stage due to lack of specific information on the landfill gas engine exhaust heat
Other nearby facilities needing low level heat	Yes - Not possible to estimate at this time due to lack of specific information on user requirements	Yes - Not possible to estimate at this time as unable to estimate potential heat recoverable	Yes - Not possible to estimate at this time due to lack of specific information on user requirements
Heating the leachate evaporation dam to assist with the disposal of collected leachate (speed up evaporation rate);	No – heat from source unlikely to be hot enough for this use	No – heat collected from the leachate is likely to reduce overall temperature of leachate in the dam	Yes - Not possible to estimate at this time due to lack of specific information on user requirements
Heating up on-site / nearby water if required.	Yes – warm air produced may be used for heating during winter	No – heat from source unlikely to be hot enough for this use	Yes - Not possible to estimate at this time due to lack of specific information on user requirements

Notes:

- Assumes annual energy consumption of approximately 20 GJ per household in the ACT (Australian Bureau of Statistics)
- Landfill gas engine assumed to be operating at 70% availability only. Heat from landfill gas engine exhaust is assumed to be converted into electricity and fed back to the grid, as opposed to customer usage.

6.6 Summary table

The heat resource assessment is summarised in Table 6 below.

Table 6 Heat resource assessment summary table

Potential heat source	Collection method	Heat collection technical feasibility	Indicative cost ($2014, excluding GST)	Estimated potential heat resource (MJ)	Potential use of collected heat	Relevant guiding principles	GHD comments / assumptions
MSW landfill	Vertical loop ground source heat pump	Technically feasible and widely practised in geothermal applications, however unusual for landfill.	$5.5M - $8.5M (inclusive of drilling costs)	1,200 MJ to 4,000 MJ per hour from the landfill[3]	Greenhouses, fish farms or nearby facility, building space heating.	Ptnr 2 & 6 Eva 5 Eco 2 – 5 Econ 1; 3; 5; 7.	Effective landfill area available is approximately 3 ha with a depth of 15 m. Consistent temperature at 15 metres depth is 35˚C.
Leachate collection and management system	Drainage pipe; heat pump	Technically feasible but the leachate collection system is limited and little leachate appears to be generated by the WBLS	N/A	N/A	Greenhouses, fish farms or nearby facility, building space heating.	Ptnr 2 & 6 Eva 5 Eco 2 – 5 Econ 3; 5; 7	Minor quantity of leachate is generated / collected on site. The installation of additional leachate pipework is challenging / costly as the landfill's final cover layer has

[3] This is approximately equivalent to 10,350,000 MJ/yr (10,350 GJ/yr) and 34,650,000 MJ/yr (34,650 GJ/yr)

Potential heat source	Collection method	Heat collection technical feasibility	Indicative cost ($2014, excluding GST)	Estimated potential heat resource (MJ)	Potential use of collected heat	Relevant guiding principles	GHD comments / assumptions
							been placed. closed
Landfill gas engine	Organic Rankine Cycle or Water/Stream Rankine Cycle or CHP System	Widely practised	To be confirmed	1,450 MJ per hour from landfill gas engine exhaust[4]. 1,900 MJ per hour from landfill gas engine jacket water[5].	Greenhouses, fish farms or nearby facility Improved leachate evaporation process Improve gas engine efficiency Steam generation using waste heat boiler	Ptnr 2 & 6 Eva 3 & 5 Eco 3 – 5 Econ 1; 3; 5; 7.	Gas engine may have been downgraded to 500 kW due to reduced landfill gas generation (or is not being operated at all times)

[4] This is equivalent to approximately 12,702,000 MJ/yr (12,702 GJ/yr)
[5] This is equivalent to approximately 11,650,000 MJ/yr (11,650 GJ/yr) at 70% gas engine availability

6.7 Opportunities and constraints

There may be potential to recover heat from certain locations at the WBLS for subsequent use by on and / or off-site users. That said, there are significant uncertainties in relation to the actual quantity and longevity of heat that could be recovered and how much the heat collection system(s) may cost to install and operate. Likewise there is considerable uncertainty in relation to the locations and requirements of potential future users of any collected heat.

The technical feasibility of a landfill heat recovery project has the potential to be significantly affected by a landfill mining project (which would essentially remove part of one of the available heat sources).

7. Conclusions

In relation to this section, GHD makes the following key conclusions:

- There are three potential heat recovery sources at the WBLS, i.e. the MSW landfill, the Leachate collection and management system and the Landfill gas engine;
- Suitable technologies exist to potentially recover heat from these heat sources, which are evidenced from various successful heat recovery projects undertaken internationally (some on trial basis);
- There is a large amount of uncertainty at present in relation to the actual technical and economic feasibility of collecting heat from the three identified sources at the WBLS. Notwithstanding, GHD considers that collection of heat from these sources at the WBLS is likely to be technically feasible (subject to the findings of appropriate further investigations). It is further considered that heat recovery from the identified heat sources is likely to be technically challenging;
- Available data indicates that the technical feasibility of recovering heat from the reviewed heat sources is likely to be as follows (in the order of most likely first):
- Landfill gas engine; then
- MSW landfill; then
- Leachate collection and management system.
- Due to the unique nature of heat recovery from a landfill, such systems would require to be custom designed for the individual projects. As such, there is limited cost / price information available on them in the public domain;
- Heat recovered from the heat sources could potentially be used for a number of applications (both at and adjacent to the WBLS); and
- Whilst heat recovery from the identified sources may be technically feasible, other areas of feasibility (e.g. economic) are currently unknown.

8. Recommendations

In light of the high level assessment of potential heat at the WBLS and the key conclusions provided above, GHD proposes the following recommendations and future work to be undertaken (made with consideration of the Vision – see Table 7 below):

- Engage in discussions with the relevant stakeholders including ACT Environmental Protection Authority (EPA), planning authority, ACT NOWaste and Energy Developments to discuss their views on heat recovery from the reviewed heat sources at the WBLS;
- Assuming responses to item 1 (above) do not stop the potential project, further consider the value;
- Assuming after completing item 2 (above), identify and undertake appropriate studies required to further determine the technical feasibility of undertaking heat recovery from the identified heat sources. These should include (but are not limited to):
- Further investigations into the composition of waste landfilled in the MSW landfill and the distribution of MSW areas across the WBLS;
- Conduct field testing to determine landfill diffusivity, density and conductivity of the landfill;
- Limited intrusive investigations of the MSW landfill area to further confirm waste thickness (i.e. boreholes);
- Further investigation into existing leachate and gas collection system to determine the location and extent of the installed system. This is crucial to minimise potential interference of the GSHP system, which will drive the suitable potential location and depth of the vertical heat exchangers;
- Heat monitoring at the landfill to determine the heat resource and temperature variation with respect to depth and distance from the cell edge (including seasonal variability). This modelling of heat resource over time will assist with the appropriate quantification of temperatures within the MSW landfill;
- Quantification of temperatures and quantity / flow rate of the leachate (including seasonal variability); and
- Obtain clarification into the existing gas engine operation strategy.
- Quantification of temperatures and quantity / flow rate of landfill gas engine exhaust (including seasonal variability).
- Use the information obtained from item 3 (above) to prepare a cost benefit analysis of heat recovery from the MSW landfill, leachate collection system and landfill gas engine.
- If item 4 (above) suggests that heat recovery is likely to be financially feasible from any of the heat sources, then consider undertaking limited trials.

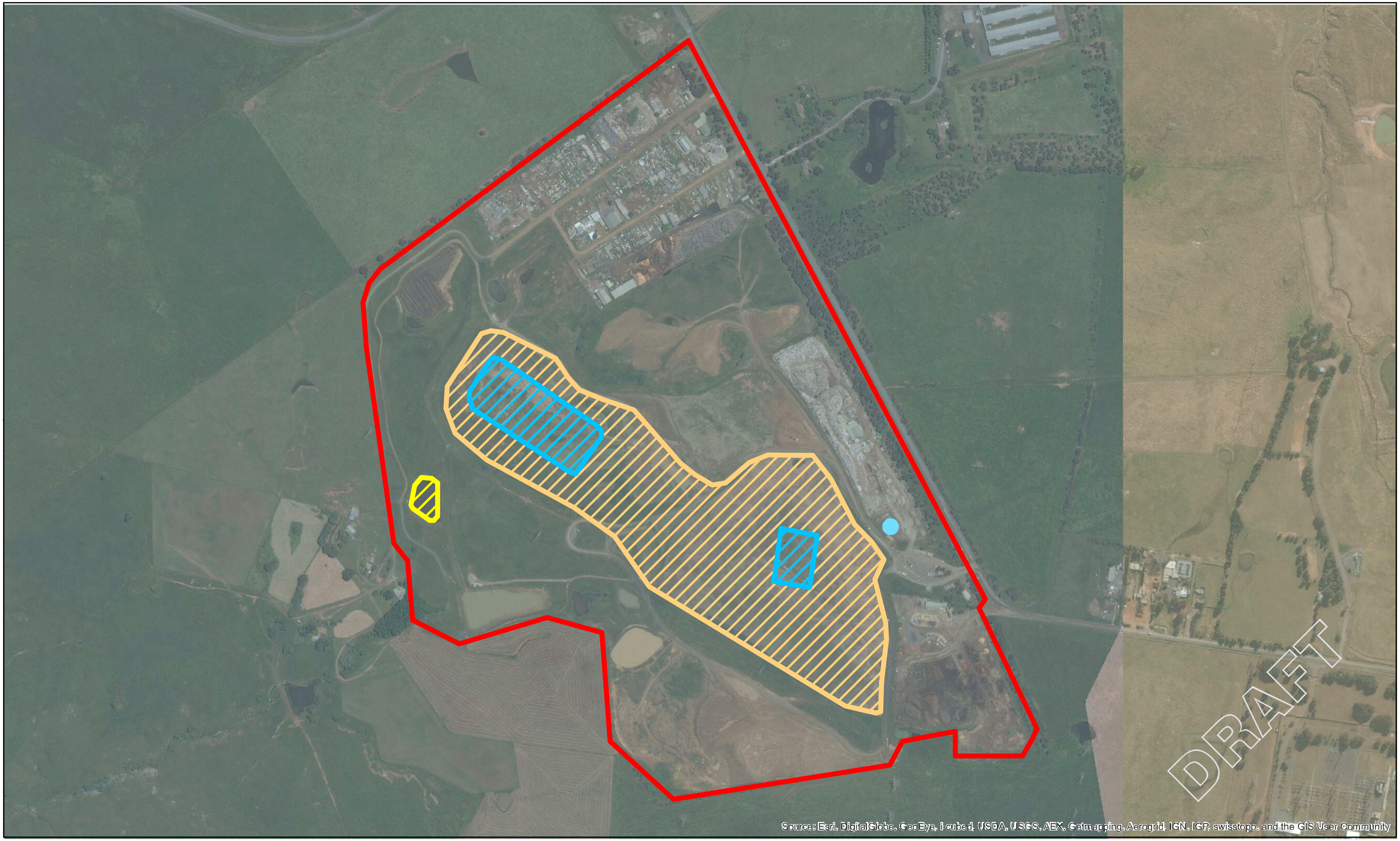
Table 7 identifies how the recommendations above were developed with consideration of the overarching project Vision (Appendix B).

Table 7 Recommendations and relevant guiding principles (as contained in the Vision)

Recommendation	Relevant guiding principles
1	Ptnr 1., Ptnr 2.
2	Eva 1., Econ 1.
3	Ptnr 1., Ptnr 2., Ptnr. 6, Eva 1., Eco 3., Eco 4.
4	Eva 1., Econ 1.
5	Ptnr 1., Ptnr 2., Ptnr 6., Eva 1., Eco 3., Eco 4., Econ 1., Econ 4., Econ 6., Econ 7.

Appendices

Appendix A - Plans showing areas relevant to heat assessment



Paper Size A3

0 0.05 0.1 0.2 0.3

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: Australian 1966
Grid: AGD 1966 ACT Grid AGC Zone

N

- Landfill Gas Engine
- Site Boundary (Approximate)
- Closed Loop Heat Exchange Areas
- Leachate Collection and Management System
- MSW Landfill

GHD

The Riverview Group
West Belconnen Landfill Advice

Job Number	21-23237
Revision	A
Date	28 Apr 2014

Heat Exchange Areas

Figure A

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Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:mlfaint

Appendix B – Vision documentation

The Belconnen Project Sustainability Vision

"Creating a sustainable community of international significance in the Nation's capital."

The Riverview Group, working with the ACT and NSW Governments, will develop the site at Belconnen to achieve a vision of inspiring sustainable living, development practice and awareness. Achieving a high quality of life for the people living at Belconnen is at the heart of our project planning and design.

We will create a community that exemplifies World's Best Practice in its design, construction and long-term liveability. As a model of sustainable community living it will be a place and community that can be showcased throughout Australia and internationally.

Project objectives:

To achieve our Vision we will challenge conventional industry thinking. We will employ practices, processes and systems that embody innovation and design excellence.

This project has been conceived and will be delivered on a fully integrated and audited triple bottom line basis.

Our project will:

- Be sustainable over time, socially, economically and ecologically (with a low and reducing ecological footprint)
- Respond to the local and global environment
- Provide for future beneficial change to occur in design, infrastructure and regulatory mechanisms
- Be cost effective, replicable and measurable
- Act as a new model that others can follow.

elton consulting Landmatters Pty Ltd green building council australia MEMBER 2010-2011

Guiding Principles for Sustainable Results

The principles below will direct decision-making by all project management, sub-consultants and referral agencies in the delivery and development of the Belconnen site. They reflect national priorities and Federal, State and Territory Government policies on housing affordability, climate change and environmental protection.

PARTNERING PRINCIPLES

- Ptnr 1. Partnering is essential to this project and the scale and timeframe will allow for positive partnerships to grow and thrive
- Ptnr 2. Partnering with public agencies is a cornerstone of our approach
- Ptnr 3. Engaging the community in design and governance is fundamental to the delivery of the project.
- Ptnr 4. Designing the project for community ownership and ultimate community control
- Ptnr 5. Supporting community housing through public and private partnering arrangements
- Ptnr 6. Collaborating with research and educational institutions to drive innovation.

EVALUATION PRINCIPLES

- Eva 1. Identifying and delivering realistic and costed initiatives
- Eva 2. Providing independent peer review of project proposals and project outcomes
- Eva 3. Using recognised international and national benchmarks for sustainability performance to publicly report and raise awareness of project outcomes
- Eva 4. Empowering resident and community monitoring and management of sustainability performance
- Eva 5. Encouraging a culture of continuous improvement.

ECOLOGICAL PRINCIPLES

- Eco 1. Acknowledging the intrinsic value of all species and the special role and regional significance of the Murrumbidgee river corridor and Gininnderra Creek
- Eco 2. Respecting and supporting the ecosystem functions of air, soil and water, recognising the importance of living and non-living environmental resources
- Eco 3. Reducing greenhouse gas emissions through innovative products and place design, material selection and service provision
- Eco 4. Recognising our natural ecological limits and minimising our resource, water and energy consumption
- Eco 5. Using existing local infrastructure to deliver efficient renewable services and reusable resources
- Eco 6. Enhancing local opportunities for food production and production of materials
- Eco 7. Fostering a deep sense of respect for and connection to the land, flora and fauna.

SOCIAL AND CULTURAL PRINCIPLES

- Soc 1. Respecting and honouring Aboriginal and non-Aboriginal cultural, historical and spiritual values, including integrating with the existing rich, social fabric of Belconnen
- Soc 2. Designing for social equity, affordability, diversity and interdependence, honouring differences and catering for the needs of individuals through all stages of life
- Soc 3. Maximising health, safety and comfort of the built environment to provide enduring quality of life
- Soc 4. Instilling awareness and supporting education of sustainability values, technology and lifestyles
- Soc 5. Using creative and robust design solutions to create a continuing sense of place and beauty that inspires, affirms and ennobles
- Soc 6. Designing neighbourhoods that support and encourage community interactions through imaginative, functional and enjoyable public spaces

ECONOMIC PRINCIPLES

- Econ 1. Delivering a financial return to the ACT Government recognising their sovereign interest in the land
- Econ 2. Recognising the opportunities provided by the project's scale and low capital base to achieve high-level sustainability outcomes while delivering profitability to joint venture partners
- Econ 3. Building on existing local infrastructure
- Econ 4. Ensuring long-term economic viability through design excellence and community building
- Econ 5. Minimising obsolescence through design of enduring component life cycle, allowing for disassembly and change
- Econ 6. Integrating with the Belconnen commercial, retail and employment networks
- Econ 7. Growing a formal and informal green economy that fosters local jobs and builds regional learning around green innovation and technology

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
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Appendix I – Surface water assessment

Riverview Projects (ACT) Pty Ltd

West Belconnen Landfill

Surface water quality assessment

June 2014

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GHD has prepared the preliminary cost estimates and prices contained within this report ('Cost Estimates') using information reasonably available to the GHD employee(s) who prepared this report; and based on assumptions and judgments made by GHD (described within this report).

The Cost Estimates have been prepared for the purpose of developing a preliminary understanding of the scale of potential costs associated with the relevant actions / works identified and must not be used for any other purpose.

The Cost Estimates are preliminary estimates only. Actual prices, costs and other variables may be different to those used to prepare the Cost Estimates and may change. Unless as otherwise specified in this report, no detailed quotations have been obtained for actions / work identified within this report. GHD does not represent, warrant or guarantee that the actions / works can or will be undertaken at costs which are the same or less than the Cost Estimates.

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

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

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

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Appendices

1. Introduction

1.1 Overview

GHD has undertaken an assessment of surface water quality in the vicinity of the WBLC. The purpose of this assessment was to investigate whether the surface water flowing from the WBLS could potentially be harnessed for potential uses or the existing tributaries / drainage lines could be retained or enhanced as water features within the proposed residential development.

Alternatively, if the water quality was deemed unsuitable for this purpose, the assessment was to determine what limitations (if any) should be placed on the watercourses to ensure that they did not affect the health of future residents.

1.2 Reliance

1. Australian and New Zealand Environment and Conservation Council, and Agriculture and Resource Management Council of Australia and New Zealand, 2000. National Water Quality Management Strategy No. 4 - Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Sydney: Australian Water Association.

2. Australian and New Zealand Environment and Conservation Council, and Agriculture and Resource Management Council of Australia and New Zealand, 2000. National Water Quality Management Strategy Guidelines, accessed [24/04/2014] http://www.environment.gov.au/topics/water/water-quality/national-water-quality-management-strategy

3. Health Canada 2012, *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Total coliforms. Water, Air and Climate Change Bureau*, Healthy Environments and consumer Safety Branch, Health Canada, Ottawa, Ontario. (Catalogue No H144-8/2013E-PDF)

2. Assessment

2.1 Overview

GHD reviewed and assessed 16 sets of surface water monitoring data (and the associated quality assurance/quality control - QA/QC -information) as provided by Australian Laboratory Services (ALS) on behalf of Riverview in order to comment on potential surface water quality issues adjacent to the WBLS. The purpose of this assessment was to investigate whether the surface water adjacent to the WBLS could potentially be harnessed for potential uses or the existing tributaries / drainage lines could be retained or enhanced as water features within the proposed residential development. Alternatively, if the water quality was deemed unsuitable for this purpose, the assessment was to determine what limitations (if any) should be placed on the watercourses to ensure that they did not affect the health of future residents.

Currently, the WBLS is surrounded by agricultural land which is predominantly used for grazing cattle. A potential impact on surface water quality was noted from this existing land use in addition to the potential impacts from the WBLS.

2.2 Sampling data

It is understood that two monitoring locations (WBL Creek and WBL Dam – shown on Figure A in Appendix A were sampled by ALS to gather data for assessing any potential impacts to surface water occurring adjacent to the WBLS. The sample dates of the 16 sets of data were:

- 4 March 2011;
- 24 June 2011;
- 19 August 2011;
- 16 September 2011;
- 30 November 2011;
- 13 December 2011;
- 2 March 2012;
- 29 June 2012;
- 11 September 2012;
- 12 October 2012;
- 12 December 2012;
- 30 January 2013;
- 22 March 2013;
- 14 June 2013;
- 17 September 2013;
- 3 December 2013; and
- 27 March 2014

The objectives of the assessment were the following:

- To assess the reliability and quality of the data with reference to sampling and analytical procedures applied; and
- To assess the data against relevant water quality guidelines to identify any potential issues with water quality or indications of landfill impact upon the monitoring locations.

To achieve this, GHD reviewed the data from ALS against the relevant water quality guidelines and the WBLS' Environmental Authorisation. QA/QC checks were also conducted to assess the validity of the data being reviewed. Findings of the assessment are outlined below with recommendations for future action.

This Section contains a number of technical terms and should be read in conjunction with the glossary contained in Appendix A.

2.3 Assessment of data quality

The data quality was assessed in terms of the sample locations used and the reliability of the data. The appropriateness of the surface water parameters measured by the laboratory is discussed in Section 2.5.1.

2.3.1 Sample location assessment

The two sample locations at which ALS collected surface water samples are shown on Figure A in Appendix A. 'WBL Creek' samples (named 'WBCREEK' in the results tables contained in Appendix A) were collected from Spring Creek which flows from north-east to south-west before discharging into the Murrumbidgee River approximately 1200 m from the WBLS.

Spring Creek appears to be fed, at least in part, by Dam 1 (refer to Figure A in Appendix A), which is located on the WBLS (flow occurs via a discharge valve). The creek flows into a second, dam (Spring Creek Dam) approximately 325 m down gradient of the discharge valve before discharging into the Murrumbidgee River. This dam is where the 'WBL Dam' (named 'WBDAM' in in the results tables contained in Appendix A) samples are understood to have been collected by ALS.

It is noted that both the WBL Creek and WBL Dam sample locations are located hydraulically down gradient of the WBLS.

The appropriateness of these sample locations has been assessed from two perspectives:

- As the two sample locations are hydraulically down-gradient of Dam 1 and the WBLS, they both have the potential to be affected by landfill discharges of water or leachate moving via local groundwater or surface water. Usually, samples are collected from both upstream and downstream of a source, such as a landfill, in order to identify any changes occurring in the water as it flows past the potential source.

  There is no up-gradient sampling location data available to be used as a comparison with these downstream samples. The absence of this data means that changes to the natural, background concentrations of the contaminants of potential concern (COPC)[1] cannot be identified. For this reason, the two sample locations are considered insufficient on their own to fully allow any landfill impacts to surface water to be identified.

  A suitable up-gradient sample location (such as the Murrumbidgee River) is considered to be required to fully demonstrate any potential impact (or lack thereof) that the WBLS may be causing on the two sample locations used. However, the data can be reviewed against

[1] COPC; chemical compounds that have the potential to be present in quantities greater than those found naturally

the assessment criteria (outlined in Section 2.4) to determine whether concentrations of the COPC at these sample locations are likely to be posing potentially unacceptable risks to the receptors identified in Section 2.4 including ecological receptors, livestock and both current and future residents of the site.

- The existing dataset only represents the dam and creek system sampled and not any other surface water features which may form part of the proposed development area. Given that the proposed future development is likely to occur over a large area surrounding the WBLS, the data set is considered to be limited in its use for an assessment of surface water quality across the entire proposed development area. Nevertheless, the data is considered valid for a preliminary assessment of the potential risks to future users in the immediate vicinity of these sample locations.

2.3.2 Data Reliance

Data quality information in respect of field and laboratory procedures was requested from ALS in conjunction with the surface water sample analysis results.

Field QA/QC

The general information provided to GHD did not contain any specific information regarding sample collection or handling practices. No chain of custody (COC) forms[2] were included in the sample records provided to GHD for any samples collected.

During sample collection, it is common to collect a series of additional samples (such as field duplicates, rinsate blanks (if applicable), trip blanks or trip spikes) which can be used to assess the accuracy of the laboratory and reliability of the samples being collected. Information provided to GHD from ALS indicated that these standard procedures are conducted by ALS. However, the sample analysis data provided does not contain the results of any field QA/QC. Therefore, there is no evidence to confirm that ALS conducted these standard field QA/QC sampling/testing procedures.

Data precision and repeatability, the potential for cross contamination or losses of volatile constituents are therefore unable to be verified. As such, no comment can be made on the appropriateness (or otherwise) of the procedures used during sample collection.

Laboratory QA/QC

ALS provided the following general information outlining procedures used in controlling laboratory data quality (provided via email from Kai Squires at 12:23 pm, 13/03/2014):

"The minimum quality control schedule adopted by ALS Environmental Division is Quality Control Schedule 2 (QCS2). This schedule includes the analysis of, and optional reporting of a Laboratory Control Sample (LCS) and method blank per analytical lot. Surrogate compounds are added to all samples requiring trace organic determinations (excluding TPH C10-C36 and selected LC/MS procedures).

The QCS3 schedule requires the analysis of a matrix spike and a pair of laboratory duplicates for each QC lot (20 samples) in addition to the QCS2 requirements. It is not mandatory that the sample(s) for a matrix spike (MS) and laboratory duplicate(s) are selected from the work order requesting the QCS3 schedule. Preference should be given to perform QC on samples from the larger batches within the process lot. The following summarises the frequency QC samples processed:

[2] COC forms: a hard copy record that shows the sample details (such as ID number, time and date collected, and the type of water sample) and which analyses should be conducted on which samples. It serves two main goals: to ensure that the sample collected is the same sample which is analysed/tested in the laboratory, and to ensure that the sample is not altered, changed, substituted, or tampered with between the field collection and submission to the laboratory for testing.

- *5% method blanks – one analysed within each process lot of 20 samples.*
- *10% laboratory duplicates – two analysed with each process lot of 20 samples.*
- *5% laboratory control samples (LCS) – one analysed within each process lot of 20 samples.*
- *5% matrix spikes (MS) – one analysed within each process lot of 20 samples.*
- *Surrogate spike on all organic determinations (excluding TPH C_{10}-C_{36} and selected LC/MS procedures).*
- *Initial calibration verification (ICV) – one analysed following the initial calibration (if quadratic best fit is used, validation of the calibration using low-level standards (<10 x LOR) is also required).*
- *Continuing calibration verification (CCV) – one analysed within each process lot of 20 samples and after the last analytical sample."*

Copies of the Quality Control Schedules (2 and 3) referred to in the above text were not provided to GHD.

From the National Association of Testing Authorities (NATA) website (www.nata.com.au), the laboratories of ALS Water Resources Group in Fyshwick (ACT) are NATA accredited (Registration No. 992). This indicates a satisfactory level of technical competence. GHD understands that final laboratory results are reviewed and approved by a NATA signatory. A search of the NATA accreditation register indicates that the ALS Water Resources Group also complies with the requirements of ISO/IEC 17025:2005 (General requirements for the competence of testing and calibration laboratories). This further supports the understanding that there is a satisfactory level of technical competence in ALS.

According to the NATA website, NATA accreditation requires that staff are appropriately qualified, the correct laboratory equipment is calibrated and maintained, adequate quality assurance procedures are used, and appropriate sampling practices should be employed. However, evidence of these standards being met (in respect of field practices and laboratory procedures) for this specific project has not been provided to GHD.

In general, given the NATA accreditation and information provided in respect of laboratory QC/QC, it is considered that the laboratory analyses were generally of sufficient quality and that the subsequent results provided are accurate.

2.3.3 Data reliance conclusion

GHD was satisfied with the likely quality and accuracy of the laboratory analysis of the sample data obtained due ALS's NATA accreditation. However, there is inadequate evidence of standard QA/QC procedures having been carried out during field procedures. As such, no comment can be made on the appropriateness (or otherwise) of the procedures used during sample collection and the subsequent data reliability.

The sample locations used are considered to be insufficient on their own to:

- Fully allow any landfill impacts to surface water to be identified; and
- Indicate the representative conditions of surface water across the entire proposed adjacent development.

The two locations used (WBL Dam and WBL Creek) can only give an indication of surface water quality in the immediate vicinity of these sample locations. As such, it is considered that there is a need for additional sampling locations up-gradient of the WBLS and from alternate surface water sources (such as the Murrumbidgee River) to be selected and monitored in future sampling rounds (in addition to the WBL Creek and WBL Dam locations).

Nevertheless, the data available is considered valid for a preliminary assessment of the potential risks to future users in the immediate vicinity of these sample locations.

2.4 Nominated assessment criteria

The current and potential future uses of the proposed development area were considered in selecting appropriate assessment criteria against which the data could be assessed. Following a review of potentially relevant guidance / standards for the assessment of water quality, GHD selected six that we consider to be suitable for assessing the existing data against and which reflect the current and likely future beneficial uses of the watercourse.

These guidelines / standards specify acceptable concentrations (depending on usage) for a number of parameters that may be detected in surface water. These concentrations are the criteria against which the sample results are compared and assessed. The specific parameters and associated concentrations are shown in the results tables contained in Appendix A. Further details on the selected guidelines / standards are provided in sections 2.4.1 to 2.4.4.

GHD notes that two "Groundwater Investigation Level" (GIL) criteria were adopted in this assessment. This term comes from the *National Environment Protection Measure (NEPM), 2013*, and is slightly misleading, as:

- The fresh water criteria are based on surface water systems from the Australia and New Zealand Environment and Conservation Council (ANZECC), 2000, and;
- The drinking water GILs apply to any water source in terms of potential consumption, whether surface or groundwater, and are therefore relevant to this assessment.

2.4.1 ANZECC (2000) irrigation criteria

According to the *National Water Quality Management Strategy Guidelines* (ANZECC and the Agriculture and Resource Management Council of Australia and New Zealand, 2000), the irrigation criteria aim to maintain the productivity of irrigated agricultural land and associated water resources in accordance with the principles of ecologically sustainable development and integrated catchment management. The focus of these principles is to adopt sustainable farming systems while minimising the off-farm movement or leaching of potential aquatic contaminants.

The criteria provided in these guidelines were considered relevant to this assessment due to the current and historical use of the proposed development area (including the sample locations used by ALS) as agricultural land.

2.4.2 ANZECC (2000) stock watering criteria

The *National Water Quality Management Strategy Guidelines* (ANZECC and the Agriculture and Resource Management Council of Australia and New Zealand, 2000) states that these are acceptable trigger values to avoid toxic effects on a range of livestock species. Downstream water quality requirements were also considered in the development of these guidelines. The criterion considers a range of water quality aspects affecting animal health such as biological and chemical water characteristics.

The criteria provided in these guidelines were considered relevant to this assessment due to the current and historical use of the proposed development area (including the sample locations used by ALS) as cattle grazing and agricultural land.

2.4.3 ANZECC (2000) primary contact recreation

According to the *National Water Quality Management Strategy Guidelines* (ANZECC and the Agriculture and Resource Management Council of Australia and New Zealand, 2000), the primary contact and recreation guidelines aim to achieve adequate water quality to maintain human health if accidentally consumed during direct contact (such as swimming) or during other recreational activities (such as sailing). The criteria are also necessary to preserve the aesthetic appeal of water bodies. A range of microbiological, physical and chemical characteristics are used in the monitoring and management of water quality to determine its suitability for recreational use.

The criteria provided in these guidelines were considered relevant to this assessment to account for the potential health effects in the context of proposed potential future use of existing surface water by potential future residents (particularly children).

2.4.4 NEPM 2013 groundwater investigation levels (GILs), drinking water

Drinking water guidelines are concerned with the safety and aesthetic quality of drinking water for consumers. They are intended to be applied at the point of use (i.e. the tap) and applicable to any water intended for consumption. The criterion covers a range of microbial, physical and chemical water quality characteristics related to both short and long term human health effects.

The criteria provided in these guidelines were considered relevant to this assessment to account for potential health effects from the consumption (e.g. children drinking it on hot days) of the sampled surface water. However, this is considered unlikely as it is assumed that the proposed development would be constructed with a reticulated (mains) water supply, and it is therefore unlikely that the sampled surface water would be considered as a drinking water supply. These criteria were therefore used to consider alternative scenario's apart from recreational use (described in section 2.5.4) that could potentially occur in the future.

2.4.5 NEPM 2013 GILs, fresh waters

The water quality guidelines in *Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000)* aim to provide water quality objectives required to sustain current, or likely future, environmental values for natural and semi-natural water resources in Australia and New Zealand.

For the purpose of this assessment, surface water quality was compared to the criteria outlined in ANZECC (2000). The WBL Creek and WBL Dam sample locations are considered to be within "a slightly modified freshwater system" (ANZECC, 2000).

The criteria provided in these guidelines were considered relevant to this assessment due to the proposed development area's close proximity to the Murrumbidgee River.

2.4.6 WBLS sediment retention dam water quality criteria

These criteria were adopted from the West Belconnen Site Environmental Authorisation (ACT EPA, 2011)(Authorisation). The Authorisation states that 'The Authorisation holder shall manage water quality in sediment retention dams with the object of being within the limits for the parameters listed in *Table 5*.' These parameters are shown in the tables contained in Appendix A).

These criteria were considered relevant to this assessment for the following reasons:

- The sample locations are directly down gradient of Sediment Retention Dam 1 (refer to Figure A in Appendix A);
- To account for any potential water quality impacts from the WBLS; and

- To assess whether the surface water is meeting the Authorisation's requirements beyond the boundary of the WBLS at the sampled locations. It is important to note, that this does not give an indication of other surface water bodies located within the proposed development area beyond the boundary of the WBLS.

2.5 Data assessment

2.5.1 General

The surface water data provided by ALS was compiled and assessed against the adopted assessment criteria outlined in Section 2.4. ALS tested samples for the following groups of compounds:

- Inorganics;
- Nutrients;
- Metals;
- Total petroleum hydrocarbons (TPH) (C6-C36);
- Organochlorine (OC) pesticides;
- Polychlorinated biphenyls (PCBs); and
- Biological (faecal coliforms).

The full list of individual contaminants analysed for as part of the above suites is tabulated in the results tables contained in Appendix A along with the sample results relative to the nominated assessment criteria. The outcome of the comparison of the results with each set of criteria is summarised below.

There is a large range of COPC which could occur at the WBLS including copper, mercury, dissolved oxygen (DO), ammonia, nitrate, and nitrite. It is noted that the adopted analytical suite did not include zinc, BOD or COD, which are also COPC and would normally be considered as important landfill leachate indicators. According to Kjeldsen et al (2002), other typical landfill leachate indicator parameters include inorganic macro-components (such as chloride, sulphate, sodium, potassium, calcium, magnesium, manganese, and silica) and other heavy metals (such as cobalt).

Lack of these COPC in the given data sets prevents a comprehensive assessment of the potential impact of the WBLS on surface water at the sample locations. These parameters should therefore be added to the existing analytical suites during future sampling events in order to detect the potential presence (or otherwise) of landfill leachate in surface water samples.

2.5.2 ANZECC (2000) irrigation criteria

There were no exceedances of these assessment criteria with the exception of iron (filtered), in both WBL Creek and WBL Dam samples collected on 2 March 2012. These results appear anomalous in the context of all other rounds of data as they are significantly higher (by approx. 0.2 mg/L on average). However, the margin of exceedances is small (0.29 mg/L compared to the iron criterion of 0.2 mg/L). Subject to the assessment of data quality, the analytical data reviewed suggests that water in the two sampling locations is likely to be suitable for irrigation purposes.

2.5.3 ANZECC (2000) stock watering criteria

There were no exceedances of these assessment criteria by the reviewed sample data, indicating that there is unlikely to be an unacceptable risk posed to livestock at either WBL Creek or WBL Dam. Subject to the assessment of data quality, the analytical data reviewed suggests that water in the two sampling locations is likely to be suitable for stock watering purposes.

2.5.4 ANZECC (2000) primary contact recreation

No exceedances were detected apart from total PCBs[3] (detection limit exceedances only). As noted below, the detection limit should be lowered to provide a more comprehensive assessment of the risk posed by PCBs. However, as PCBs are not very soluble in water and are unlikely to be present in significant concentrations in surface water in the absence of a significant source this exceedence is considered unlikely to pose a significant risk for primary contact recreational uses.

Overall, based on the available data, it is therefore considered that the potential risk posed to future recreational users in the vicinity of the sample locations from the parameters analysed is low. However, the faecal coliform content (for which there is no assessment criterion under these guidelines) was noted to be relatively high and would therefore indicate that recreational contact should be avoided without further investigation.

2.5.5 NEPM 2013 GILs, drinking water

No exceedances of these assessment criteria were detected with the exception of some isolated detection limit exceedances of heptachlor epoxide. Consistent with the discussion above, this compound is also not very soluble in water and unlikely to be regularly present in concentrations greater than the nominated assessment criteria in the absence of a significant upstream source.

It is therefore considered that based on the reported results, the potential risk posed to future drinking water users from the parameters analysed in the vicinity of the two sample locations is low, although the faecal coliform content (for which there is no criterion under these guidelines) would indicate that consumption should be avoided without further investigation Given the prevalence of faecal coliforms (detected in all samples, ranging from 4 CFU/100mL to 1,200,000 CFU/100mL), consideration should be given to carrying out specific testing for *Escherichia coli* and thermotolerant coliforms, which should not be detected in potable water supplies (Health Canada, 2012).

2.5.6 NEPM 2013 GILs, fresh waters

Exceedances of the following assessment criteria (those detectable above the laboratory instrumentation limit only) were recorded for the following:

- Copper (filtered; WBL Dam and WBL Creek) exceeded eight out of 16 occasions, recording up to 0.0034 mg/L (GIL of 0.0014 mg/L);
- Mercury (filtered, 2 exceedances in WBL Dam and one exceedance in WBL Creek), up to 0.0003 mg/L (GIL of 0.00006 mg/L for 99% level of protection); and
- TPH C10-C36 (Sum of total TPH), 1 exceedance at WBL Dam of 6.67 mg/L (GIL of 0.6 mg/L).

Given the absence of an up-gradient sampling location (and associated analytical data), it is not possible to comment on whether the detected copper concentrations are typical for surface

[3] PCBs: Polychlorinated Biphenyls (synthetic organic chemical compound)

waters in the area, as the margin of exceedances are small and generally frequent. It is also noted that the GIL for copper is hardness based and adjusting for hardness typical of the Murrumbidgee River would likely reduce the number of exceedances. The detected copper concentrations are therefore considered unlikely to pose an unacceptable risk to fresh water ecological receptors and no action is required.

The mercury concentrations detected were up to a factor of five above the adopted fresh water GIL. The exceedances in the WBL dam and WBL creek samples do not appear to be temporally related as the WBL Dam exceedances were observed before those at the WBL Creek. As the WBL Creek sample location is upstream of the WBL Dam, these results do not suggest an upgradient source (such as the WBLS). It is noted that the samples would not have failed under a 95% level of protection (GIL criteria of 0.0006 mg/L), suggesting that a significant threat to ecological systems from mercury contamination is unlikely, hence no action is required. The difference between the two levels of species protection is that 99% levels would typically apply to a “pristine” or undisturbed system, whereas 95% protection levels would apply to a slightly to moderately disturbed system. In this case, the 95% level is considered to be more appropriate.

The TPH exceedance is an anomalous result in the general context of the dataset, and may indicate a fuel spill or similar near the WBL Dam location. Given that the up-gradient location (WBL Creek) did not indicate any exceedances it appears unlikely that the WBLS is the source. Therefore, no action is required to address this exceedence.

The minimum detectable concentration in the ALS data was greater than a number of the assessment criteria contained in the NEPM 2013 GILs fresh waters. The relevant detection limit exceedances were:

- <0.0001 mg/L mercury (filtered) – all samples;
- <0.01 µg/L DDT (pesticide) – all samples;
- <0.5 µg/L Endrin (insecticide) – four samples;
- <0.5 µg/L g-BHC (Lindane) (pesticide) – four samples;
- <0.5 µg/L heptachlor (insecticide) – four samples;
- <1 µg/L Arochlor 1242 (PCB) – all samples; and
- <1 µg/L Arochlor 1254 (PCB) - all samples.

It is noted that the organic pesticide compounds and PCBs listed above are typically not very soluble in water and unless a large source was present in the WBLS, the potential for leaching and release to the aquatic environment is considered to be low. Future sampling rounds would need to specify lower minimum detection limits for the parameters listed above to allow direct comparison to be made with the adopted assessment criteria and hence comprehensively assess the potential impact posed by the WBLS on surface waters.

2.5.7 WBLS sediment retention dam water quality criteria

Exceedances of the following assessment criteria were recorded for the following:

- Total Suspended Solids (TSS), one exceedance at WBL Dam and one exceedance at WBL Creek, up to 240 mg/L (assessment criterion 60 mg/L);
- Faecal coliforms, numerous exceedances at both the WBL Dam and WBL Creek, up to 1.2 million CFU[4]/100 mL (assessment criterion 1000 CFU/100 mL)

[4] CFU: Colony Forming Units – a measure of viable bacterial or fungal cells.

It is noted that the TSS exceedances do not appear to be linked to upgradient (WBLS) sources as the value detected within the WBL Dam sample was higher than that detected within the up-gradient WBL Creek sample.

Although faecal coliform criteria are frequently being exceeded, these are likely to be linked to the presence of cattle and other fauna in the vicinity of the sample locations. There is no evidence to suggest that the results are being affected by leachate discharge or run-off.

2.6 Summary of data assessment

Samples from WBL Dam and WBL Creek were assessed against six water quality criteria, the results of which are summarised in Table 1.

Table 1 Data conformance of data results from surface water samples relative to six assessment criteria

	WBL Dam	WBL Creek
ANZECC (2000) irrigation criteria	**Conformance** No exceedances	**Conformance** No exceedances
ANZECC (2000) stock watering criteria	**Conformance** No exceedances	**Conformance** No exceedances
ANZECC (2000) primary contact recreation	**Potentially Conforming** Results complied with the assessment criteria, however high faecal coliform concentrations were noticed. This indicates that recreation should be avoided without further investigation.	**Potentially Conforming** Results complied with the assessment criteria, however high faecal coliform concentrations were noticed. This indicates that recreation should be avoided without further investigation.
NEPM 2013 GILs, drinking water	**Potentially Conforming** Results complied with the assessment criteria, however high faecal coliform concentrations were noticed. This indicates that consumption should be avoided without further investigation.	**Potentially Conforming** Results complied with the assessment criteria, however high faecal coliform concentrations were noticed. This indicates that consumption should be avoided without further investigation.
NEPM 2013 GILs, fresh waters	**Non-conforming** Numerous mercury, copper and faecal coliform exceedances as well as one TPH exceedence. However the risk posed by these exceedences was deemed to be unlikely.	**Non-conforming** Numerous mercury, copper and faecal coliform exceedances. However the risk posed by these exceedences was deemed to be unlikely.
WBLS sediment retention dam water quality criteria	**Non-conforming** Regular faecal coliform exceedances, This is likely to be caused by the current surrounding	**Non-conforming** Regular faecal coliform exceedances. This is likely to be caused by the current surrounding

	WBL Dam	WBL Creek
	land use (cattle grazing). There is no evidence to suggest that the results are being affected by leachate discharge or run-off.	land use (cattle grazing). There is no evidence to suggest that the results are being affected by leachate discharge or run-off.

2.7 Opportunities and constraints

The surface water adjacent to the WBLS could potentially be harnessed for potential uses. Alternatively the existing tributaries and drainage lines could be retained or enhanced as water features within the proposed residential development.

That said, the limited available data suggests that there may be some limitations in relation to what the water could actually be used for. Furthermore there is a risk that leachate and / or sediment laden water derived from the WBLS could impact upon off-site surface water in the future.

3. Conclusions

In relation to this section, GHD makes the following key conclusions from which recommendations were made (see section 4) :

- No up-gradient sample location (such as the Murrumbidgee River) or associated data exists to compare to the data obtained for the two down gradient sampling points (WBLS Dam and WBL Creek);
- The two sampled locations (WBL Dam and WBL Creek) do not represent all surface water features in the proposed development area;
- No field QA/QC data was provided for assessment, henceno comment on the appropriateness or otherwise of the QA / QC procedures employed by ALS during sampling was made;
- It is considered that the QA/ QC procedures employed by ALS during laboratory work are acceptable;
- A number of potential landfill leachate indicator parameters have not been analysed for in the samples taken;
- It should be noted that the reliability, accuracy and validity of the data cannot be fully verified in the absence of detail regarding sampling protocols in the field QA/QC samples. With minimal data reliance information, the assessment of the sample data is considered to have large levels of uncertainty; and
- Assuming acceptable data quality control processes have been employed by ALS during sampling and laboratory analysis, assessment of the data relative to six selected guidelines / standards suggests no obvious, regular, significant impact from the WBLS at the monitored locations.

4. Recommendations

Based on the key conclusions provided above, GHD makes the following recommendations (made with consideration of the Vision – see Table 2 below):

- Continue the current regular monitoring of surface water adjacent to the WBLS and expand it as soon as possible to:
  - Include a suitable upgradient surface water sampling point (possibly upstream of the WBLS in the Murrumbidgee River);
  - Include other potential surface water locations away from the WBLS but within the proposed development area (consideration of AECOM's contamination work should also be given here);
  - Include other potential leachate indicator parameters (as relevant).
- Ensure that both field and laboratory QA/QC information is provided by ALS for each future sampling round for each sampled location;
- Ensure that relevant hardness related adjustments are made to detected copper concentrations in accordance with ANZECC (2000) during future sampling events;
- Ensure that all future samples are analysed using equipment that can achieve the required detection limits for the appropriate assessment criteria;
- Continue to assess future surface water sampling data against the six identified guidelines / standards (unless conditions change, in which case the relevant guidelines / standards should be re-considered); and
- Retain a suitably qualified person to review and assess every future round of surface water monitoring data (it is noted that regular reviews could be quite simple / cheap and more formal annual summaries could be prepared if required).

Table 2 identifies how the recommendations above were developed with consideration of the overarching project Vision (Appendix B).

Table 2 Recommendations and relevant guiding principles (as contained in the Vision)

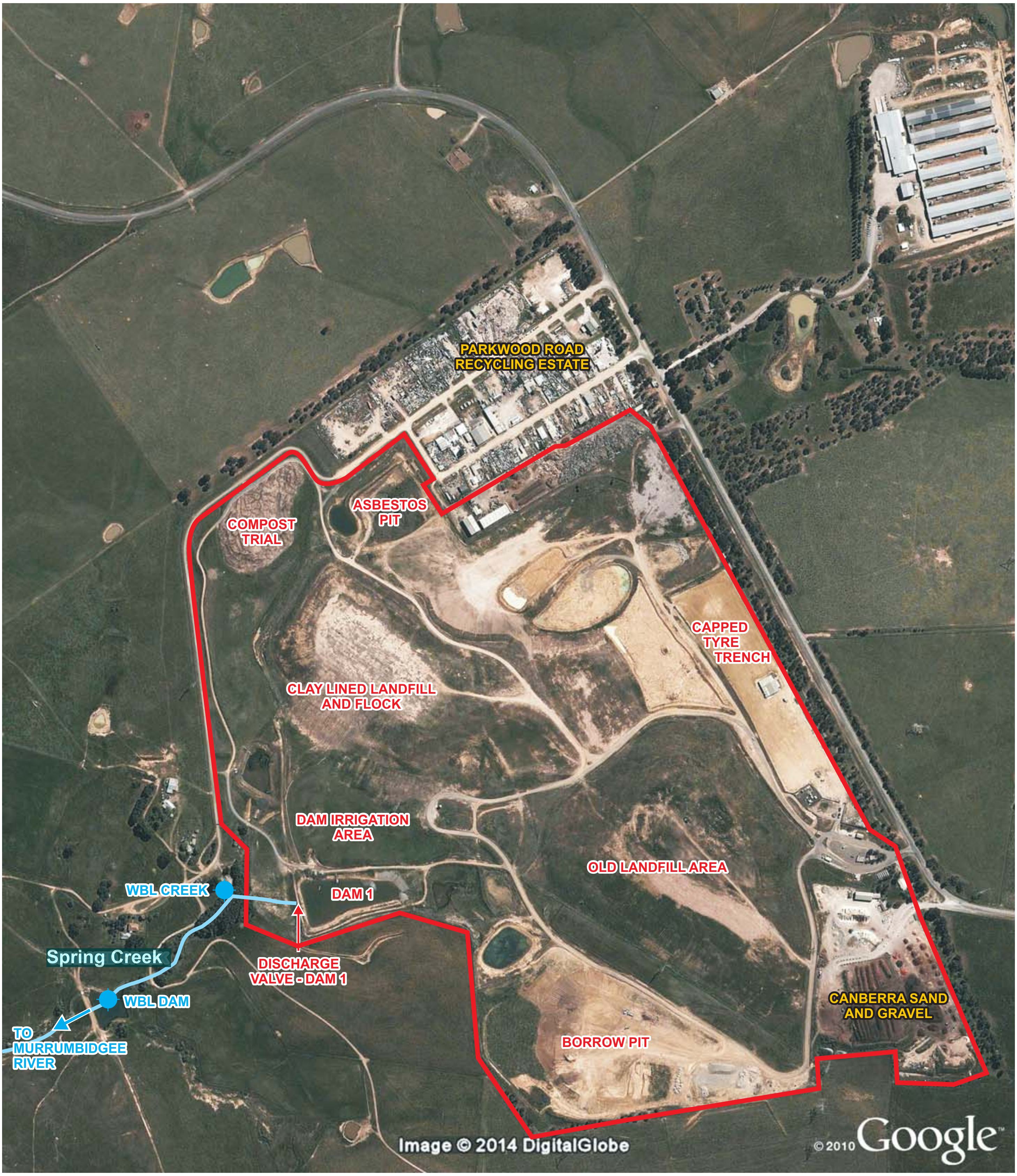
Recommendation	Relevant guiding principles
1	Eco 1., Eco 2., Eco 7.
2	Eco 1., Eco 2., Eco 7.
3	Eco 1., Eco 2., Eco 7.
4	Eco 1., Eco 2., Eco 7.
5	Eval 3., Eco 1., Eco 2., Eco 7.
6	Eval 3., Eco 1., Eco 2., Eco 7.

Appendices

Appendix A - Surface water monitoring glossary, location plan and analytical results

Glossary

Abbreviation	Details
ALS	Australian Laboratory Services (company)
ANZECC	Australia and New Zealand Environment and Conservation Council
BTEX	Benzene, toluene, ethyl benzene and xylenes
COC	Chain of custody
CoC	Chemical/Contaminant of Concern
CoPC	Chemical/Contaminant of Potential Concern
DDT	Dichlorodiphenyltrichloroethane
DO	Dissolved oxygen
EIL	Ecological investigation level
ESA	Environmental site assessment
GIL	Groundwater investigation levels
LOD	Limit of detection
LOR	Limit of reporting
mbgl	Metres below ground level
mg/kg	Milligrams per kilogram
mg/L	Milligrams per litre
mg/m3	Milligram per cubic metre
mm	Millimetres
NATA	National Association of Testing Authorities
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NSW EPA	New South Wales Environmental Protection Authority
OCP	Organo-chlorine Pesticides
OH&S	Occupational health and safety
OPP	Organo-phosphate pesticides
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated Biphenyl's
ppm	Parts per million
PQL	Practical quantitation limit
QA/QC	Quality assurance/quality control
SEPP	State Environmental Planning Policy
TCE	Trichloroethene
TPH	Total petroleum hydrocarbons
TRH	Total recoverable hydrocarbons
µg/L	Micrograms per litre
µ	Micron
µS/cm	Micro-Siemens per centimetre
VOC	Volatile organic compounds



LEGEND

Approximate Site Boundary

Surface Water Sample Locations

0 100m
Approximate Scale

N

GHD

The Riverview Group
West Belconnen Landfill Site

Surface Water Sampling Locations

Job Number 21-23237
Revision A
Date 3 April 2014

Figure ?

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Sampled_Date-Time	LocCode	Matrix_Type	Dissolved Oxygen (Field)	Dissolved Oxygen (Field) (Filtered)	Electrical Conductivity (Field)	pH (Field)	Temp (Field)	TOC	Total Dissolved Solids	Total Suspended Solids	Ammonia as N	Nitrate (as N)	Nitrite (as N)	Nitrogen (Total Oxidised)	Arsenic (Filtered)	Cadmium (Filtered)	Chromium (III+VI) (Filtered)	Copper (Filtered)	Iron (Filtered)	Lead (Filtered)	Mercury (Filtered)
			mg/L	mg/L	µS/cm	pH Units	oC	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC 2000 Irrigation - Long-term Trigger Values															0.1	0.01	0.1	0.2	0.2	0.2	0.002
ANZECC (2000) Primary Contact Recreation						6.5			1000			10	3.29		0.05	0.005	0.05	1	0.3	0.05	0.001
ANZECC 2000 - Stock Watering												*90*	*9.1*		*0.5*	*0.01*	*1*	*0.5*		*0.1*	*0.002*
NEPM 2013 GILs, Drinking Water(B)															0.01	0.002		2		0.01	0.001
NEPM 2013 GILs, Fresh Waters(A)																**0.0002**		**0.0014**		**0.0034**	**0.00006**
4/03/2011	WBCREEK	water	-	9.3	910	7.3	18.9	15	620	18	0.04	1.6	0.09	1.7	0.002	<0.00005	0.003	0.0007	0.02	<0.00005	**0.0001**
24/06/2011	WBCREEK	water	-	9.4	930	8	15.5	9	630	3	<0.01	1.3	<0.01	1.3	0.002	<0.00005	<0.002	0.0009	0.04	<0.00005	**<0.0001**
19/08/2011	WBCREEK	water	-	9.7	1100	7.2	8.3	11	750	4	0.09	2.9	0.02	2.9	<0.001	<0.00005	<0.002	0.0007	0.02	<0.00005	**<0.0001**
16/09/2011	WBCREEK	water	-	10.9	950	7.7	6.1	9	650	<2	<0.01	2.8	<0.01	2.8	<0.001	<0.00005	<0.002	0.0007	0.02	<0.00005	**<0.0001**
30/11/2011	WBCREEK	water	-	8.9	850	7.1	11.5	12	580	35	0.1	2.3	0.02	2.3	0.001	<0.00005	0.003	**0.0016**	0.04	<0.00005	**<0.0001**
13/12/2011	WBCREEK	water	-	10.4	630	7.9	10.8	12	430	20	<0.01	1.7	<0.01	1.7	<0.001	<0.00005	<0.002	**0.0015**	0.06	<0.00005	**<0.0001**
2/03/2012	WBCREEK	water	-	9.9	1000	8.2	16.7	9	680	4	<0.1	2.7	0.01	2.7	<0.001	<0.00005	<0.002	**0.0016**	0.01	<0.00005	**0.0003**
29/06/2012	WBCREEK	water	-	11.7	910	8.3	12.9	6	620	3	<0.1	2	<0.01	2	<0.001	<0.00005	<0.002	**0.0014**	0.02	<0.00005	**<0.0001**
11/09/2012	WBCREEK	water	-	8.6	430	7.4	19.1	16	290	47	<0.1	1.6	0.05	1.7	0.001	<0.00005	<0.002	**0.0021**	0.19	0.00009	**<0.0001**
12/10/2012	WBCREEK	water	-	9.2	460	7.9	19	15	310	33	<0.1	1.4	0.02	1.4	0.001	<0.00005	<0.002	**0.0019**	0.19	0.0001	**<0.0001**
12/12/2012	WBCREEK	water	-	9.5	530	7.3	19.1	20	360	59	0.4	1.7	0.14	1.8	0.002	<0.00005	<0.002	**0.003**	0.09	0.00011	**<0.0001**
30/01/2013	WBCREEK	water	-	10.2	550	8.1	17.9	17	370	29	<0.1	1.8	0.07	1.9	0.002	<0.00005	<0.002	**0.0025**	0.06	0.00006	**<0.0001**
22/03/2013	WBCREEK	water	-	9	350	7.2	17.1	23	240	240	0.2	1.6	0.05	1.6	0.002	<0.00005	<0.002	**0.0034**	0.29	0.00027	**<0.0001**
14/06/2013	WBCREEK	water	-	9.3	340	7.1	17	19	230	93	0.1	1.4	0.03	1.4	0.001	<0.00005	<0.002	**0.0024**	0.28	0.00022	**<0.0001**
14/06/2013	WBCREEK	water	-	12.1	910	8.3	8.5	7	620	<2	0.1	3.2	<0.01	3.2	<0.001	<0.00005	<0.002	0.0012	0.02	<0.00005	**<0.0001**
17/09/2013	WBCREEK	water	-	13.3	1200	7.6	11	9	820	3	<0.1	3.3	0.03	3.3	<0.001	<0.00005	<0.002	0.0011	0.04	<0.00005	**<0.0001**
3/12/2013	WBCREEK	water	-	12.8	790	8.2	13.3	9	540	3	<0.1	2.6	<0.01	2.6	<0.001	<0.00005	<0.002	<0.0005	0.02	<0.00005	**<0.0001**
27/03/2014	WBCREEK	water	-	20.2	1000	7.8	15.8	16	680	5	<0.1	3	0.04	3	<0.001	<0.00005	<0.002	**0.0015**	0.09	0.00007	**<0.0001**
4/03/2011	WBDAM	water	-	10.3	880	7.8	14.7	11	600	53	<0.1	1.4	0.04	1.4	0.001	<0.00005	<0.002	0.0009	0.08	<0.00005	**<0.0001**
24/06/2011	WBDAM	water	-	10.1	750	8.3	13.8	9	510	18	<0.1	1.1	0.01	1.1	0.001	<0.00005	<0.002	0.001	0.1	0.00007	**<0.0001**
19/08/2011	WBDAM	water	-	8.6	820	8.3	28	14	560	2	<0.1	0.21	0.01	0.22	0.003	0.00006	<0.002	0.001	0.02	<0.00005	**<0.0001**
16/09/2011	WBDAM	water	-	9.7	820	7.7	20.3	11	560	<2	<0.1	0.51	<0.01	0.51	0.002	<0.00005	<0.002	0.0013	0.02	<0.00005	**0.0001**
30/11/2011	WBDAM	water	8.5	8.5	680	8.2	24.9	25	460	20	0.3	<0.05	0.02	<0.05	0.002	<0.00005	<0.002	<0.0005	0.18	0.00014	**<0.0001**
13/12/2011	WBDAM	water	8	8	280	8.1	21.5	13	190	5	<0.1	0.96	<0.01	0.96	0.002	<0.00005	<0.002	0.001	0.07	0.00006	**<0.0001**
2/03/2012	WBDAM	water	-	8.1	1000	8	18.5	14	680	15	0.1	0.21	0.03	0.24	0.002	<0.00005	<0.002	0.0006	0.02	0.0001	**<0.0001**
29/06/2012	WBDAM	water	-	8.3	710	8.1	17.7	10	480	14	<0.1	0.69	<0.01	0.69	0.001	<0.00005	<0.002	0.0012	0.03	<0.00005	**<0.0001**
11/09/2012	WBDAM	water	10.5	10.5	1200	7.9	12.4	5	820	<2	<0.1	3	0.01	3	<0.001	<0.00005	<0.002	0.0007	0.02	<0.00005	**<0.0001**
12/10/2012	WBDAM	water	11	-	970	8.2	11.4	6	660	<2	<0.1	2.5	<0.01	2.5	-	-	-	-	-	-	-
12/12/2012	WBDAM	water	-	11	970	8.2	11.4	6	660	<2	<0.1	2.5	<0.01	2.5	<0.001	<0.00005	<0.002	0.0009	0.02	<0.00005	**<0.0001**
30/01/2013	WBDAM	water	-	9.6	740	7.7	13.4	14	500	22	<0.1	1.5	0.02	1.5	<0.001	<0.00005	<0.002	**0.0015**	0.08	0.00006	**<0.0001**
22/03/2013	WBDAM	water	-	3.7	950	7.1	14.1	20	650	56	0.2	1.7	0.04	1.8	<0.001	<0.00005	<0.002	**0.004**	0.18	0.00036	**<0.0001**
14/06/2013	WBDAM	water	14.3	14.3	900	8.2	19.3	8	610	<2	<0.1	0.37	<0.01	0.37	0.002	0.0001	<0.002	**0.0014**	0.02	<0.00005	**<0.0001**
17/09/2013	WBDAM	water	7.6	7.6	1000	7.5	23.2	11	680	12	0.2	1.6	0.04	1.6	0.002	0.00007	<0.002	**0.0019**	0.04	0.00009	**<0.0001**
3/12/2013	WBDAM	water	8.6	-	-	8.2	18	12	620	<2	-	-	-	-	0.002	<0.00005	<0.002	<0.0005	0.05	0.00006	**<0.0001**
27/03/2014	WBDAM	water	8.5	-	-	7.7	19.2	12	750	6	-	-	-	-	0.002	<0.00005	<0.002	<0.0005	<0.01	0.00019	**<0.0001**

Sampled_Date-Time	LocCode	C6 - C 9 Fraction	C10 - C14 Fraction	C15 - C28 Fraction	C29 - C36 Fraction	C10 - C36 (Sum of Total) - Lab calc	4,4-DDE	a-BHC	Aldrin	b-BHC	chlordane	Chlordane (cis)	Chlordane (trans)	d-BHC	DDD	DDE	DDT	Dieldrin	Endosulfan	Endosulfan I	Endosulfan II	Endosulfan sulphate	Endrin
		mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
ANZECC 2000 Irrigation - Long-term Trigger Values																							
ANZECC (2000) Primary Contact Recreation									1								3	1	40				1
ANZECC 2000 - Stock Watering																							
NEPM 2013 GILs, Drinking Water(B)											2						9		20				
NEPM 2013 GILs, Fresh Waters(A)											**0.03**						**0.006**		**0.03**				**0.01**
4/03/2011	WBCREEK	<0.025	<0.025	<0.1	<0.1	-	-	-	<0.01	-	<0.01	-	-	-	<0.01	<0.01	**<0.01**	<0.01	<0.01	-	-	-	<0.01
24/06/2011	WBCREEK	<0.025	<0.025	<0.1	<0.1	-	-	-	<0.01	-	<0.01	-	-	-	<0.01	<0.01	**<0.01**	<0.01	<0.01	-	-	-	<0.01
19/08/2011	WBCREEK	<0.025	<0.025	<0.1	<0.1	-	-	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
16/09/2011	WBCREEK	<0.025	<0.025	<0.1	<0.1	-	-	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
30/11/2011	WBCREEK	<0.025	<0.025	<0.1	<0.1	-	-	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
13/12/2011	WBCREEK	<0.025	<0.025	<0.1	<0.1	-	-	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
2/03/2012	WBCREEK	<0.025	<0.025	<0.1	<0.1	-	-	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
29/06/2012	WBCREEK	<0.025	<0.025	<0.1	<0.1	-	-	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
11/09/2012	WBCREEK	-	<0.05	<0.1	<0.05	<0.05	<0.5	<0.5	<0.5	<0.5	-	<0.5	<0.5	<0.5	<0.5	-	**<2**	<0.5	-	<0.5	<0.5	<0.5	**<0.5**
12/10/2012	WBCREEK	-	<0.05	<0.1	<0.05	<0.05	<0.5	<0.5	<0.5	<0.5	-	<0.5	<0.5	<0.5	<0.5	-	**<2**	<0.5	-	<0.5	<0.5	<0.5	**<0.5**
12/12/2012	WBCREEK	<0.02	<0.05	0.18	<0.05	0.18	<0.5	<0.5	<0.5	<0.5	-	<0.5	<0.5	<0.5	<0.5	-	**<2**	<0.5	-	<0.5	<0.5	<0.5	**<0.5**
30/01/2013	WBCREEK	<0.02	<0.05	0.17	<0.05	0.17	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
22/03/2013	WBCREEK	-	<0.05	<0.1	<0.05	<0.05	<0.5	<0.5	<0.5	<0.5	-	<0.5	<0.5	<0.5	<0.5	-	**<2**	<0.5	-	<0.5	<0.5	<0.5	**<0.5**
14/06/2013	WBCREEK	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
14/06/2013	WBCREEK	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
17/09/2013	WBCREEK	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
3/12/2013	WBCREEK	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
27/03/2014	WBCREEK	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
4/03/2011	WBDAM	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
24/06/2011	WBDAM	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
19/08/2011	WBDAM	<0.02	6.19	0.48	<0.05	6.67	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
16/09/2011	WBDAM	<0.02	<0.05	0.33	<0.05	0.33	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
30/11/2011	WBDAM	<0.02	0.06	0.22	0.06	0.34	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
13/12/2011	WBDAM	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
2/03/2012	WBDAM	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
29/06/2012	WBDAM	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
11/09/2012	WBDAM	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
12/10/2012	WBDAM	<0.02	<0.05	<0.1	<0.05	<0.05	-	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
12/12/2012	WBDAM	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
30/01/2013	WBDAM	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
22/03/2013	WBDAM	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
14/06/2013	WBDAM	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
17/09/2013	WBDAM	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**	<0.01	-	<0.01	<0.01	<0.01	<0.01
3/12/2013	WBDAM	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
27/03/2014	WBDAM	<0.02	<0.05	<0.1	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**<0.01**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Sampled_Date-Time	LocCode	Matrix_Type	Endrin aldehyde	Endrin ketone	g-BHC (Lindane)	Heptachlor	Heptachlor epoxide	Hexachlorobenzene	Methoxychlor	Oxychlordane	BHC_Total	Arochlor 1016	Arochlor 1221	Arochlor 1232	Arochlor 1242	Arochlor 1248	Arochlor 1254	Arochlor 1260	Aroclor 1262	PCBs (Total)	Faecal Coliform
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	CFU/100mL
ANZECC 2000 Irrigation - Long-term Trigger Values																					
ANZECC (2000) Primary Contact Recreation					10	3														0.1	
ANZECC 2000 - Stock Watering																					
NEPM 2013 GILs, Drinking Water(B)					10		0.3														
NEPM 2013 GILs, Fresh Waters(A)					**0.2**	**0.01**									**0.3**		**0.01**				
4/03/2011	WBCREEK	water	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	-	-	-	-	-	-	-	-	<0.1	960
24/06/2011	WBCREEK	water	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	-	-	-	-	-	-	-	-	<0.1	540
19/08/2011	WBCREEK	water	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	-	-	-	-	-	<0.1	6
16/09/2011	WBCREEK	water	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	-	-	-	-	-	<0.1	8
30/11/2011	WBCREEK	water	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	-	-	-	-	-	<0.1	220
13/12/2011	WBCREEK	water	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	-	-	-	-	-	<0.1	50
2/03/2012	WBCREEK	water	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	-	-	-	-	-	<0.1	30
29/06/2012	WBCREEK	water	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	-	-	-	-	-	<0.1	10
11/09/2012	WBCREEK	water	<0.5	<0.5	**<0.5**	**<0.5**	<0.5	<0.5	<2	-	-	-	-	-	-	-	-	-	-	<1	18,000
12/10/2012	WBCREEK	water	<0.5	<0.5	**<0.5**	**<0.5**	<0.5	<0.5	<2	-	-	-	-	-	-	-	-	-	-	<1	1700
12/12/2012	WBCREEK	water	<0.5	<0.5	**<0.5**	**<0.5**	<0.5	<0.5	<2	-	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	1400
30/01/2013	WBCREEK	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	240
22/03/2013	WBCREEK	water	<0.5	<0.5	**<0.5**	**<0.5**	<0.5	<0.5	<2	-	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	1,200,000
14/06/2013	WBCREEK	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	310,000
14/06/2013	WBCREEK	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	4
17/09/2013	WBCREEK	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	3
3/12/2013	WBCREEK	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	6
27/03/2014	WBCREEK	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	310
4/03/2011	WBDAM	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	8000
24/06/2011	WBDAM	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	3900
19/08/2011	WBDAM	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	390
16/09/2011	WBDAM	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	90
30/11/2011	WBDAM	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	33,000
13/12/2011	WBDAM	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	690
2/03/2012	WBDAM	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	-	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	640
29/06/2012	WBDAM	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	-	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	1100
11/09/2012	WBDAM	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	100
12/10/2012	WBDAM	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	310
12/12/2012	WBDAM	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	310
30/01/2013	WBDAM	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	1100
22/03/2013	WBDAM	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	2700
14/06/2013	WBDAM	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	16
17/09/2013	WBDAM	water	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	-	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	1200
3/12/2013	WBDAM	water	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	1400
27/03/2014	WBDAM	water	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<1	<1	<1	**<1**	<1	**<1**	<1	<1	<1	1000

Appendix B – Vision document

The Belconnen Project Sustainability Vision

"Creating a sustainable community of international significance in the Nation's capital."

The Riverview Group, working with the ACT and NSW Governments, will develop the site at Belconnen to achieve a vision of inspiring sustainable living, development practice and awareness. Achieving a high quality of life for the people living at Belconnen is at the heart of our project planning and design.

We will create a community that exemplifies World's Best Practice in its design, construction and long-term liveability. As a model of sustainable community living it will be a place and community that can be showcased throughout Australia and internationally.

Project objectives:

To achieve our Vision we will challenge conventional industry thinking. We will employ practices, processes and systems that embody innovation and design excellence.

This project has been conceived and will be delivered on a fully integrated and audited triple bottom line basis.

Our project will:

» Be sustainable over time, socially, economically and ecologically (with a low and reducing ecological footprint)

» Respond to the local and global environment

» Provide for future beneficial change to occur in design, infrastructure and regulatory mechanisms

» Be cost effective, replicable and measurable

» Act as a new model that others can follow.

elton consulting

Landmatters Pty Ltd

green building council australia
MEMBER 2010-2011

Guiding Principles for Sustainable Results

The principles below will direct decision-making by all project management, sub-consultants and referral agencies in the delivery and development of the Belconnen site. They reflect national priorities and Federal, State and Territory Government policies on housing affordability, climate change and environmental protection.

PARTNERING PRINCIPLES

- Ptnr 1. Partnering is essential to this project and the scale and timeframe will allow for positive partnerships to grow and thrive
- Ptnr 2. Partnering with public agencies is a cornerstone of our approach
- Ptnr 3. Engaging the community in design and governance is fundamental to the delivery of the project.
- Ptnr 4. Designing the project for community ownership and ultimate community control
- Ptnr 5. Supporting community housing through public and private partnering arrangements
- Ptnr 6. Collaborating with research and educational institutions to drive innovation.

EVALUATION PRINCIPLES

- Eva 1. Identifying and delivering realistic and costed initiatives
- Eva 2. Providing independent peer review of project proposals and project outcomes
- Eva 3. Using recognised international and national benchmarks for sustainability performance to publicly report and raise awareness of project outcomes
- Eva 4. Empowering resident and community monitoring and management of sustainability performance
- Eva 5. Encouraging a culture of continuous improvement.

ECOLOGICAL PRINCIPLES

- Eco 1. Acknowledging the intrinsic value of all species and the special role and regional significance of the Murrumbidgee river corridor and Gininnderra Creek
- Eco 2. Respecting and supporting the ecosystem functions of air, soil and water, recognising the importance of living and non-living environmental resources
- Eco 3. Reducing greenhouse gas emissions through innovative products and place design, material selection and service provision
- Eco 4. Recognising our natural ecological limits and minimising our resource, water and energy consumption
- Eco 5. Using existing local infrastructure to deliver efficient renewable services and reusable resources
- Eco 6. Enhancing local opportunities for food production and production of materials
- Eco 7. Fostering a deep sense of respect for and connection to the land, flora and fauna.

SOCIAL AND CULTURAL PRINCIPLES

- Soc 1. Respecting and honouring Aboriginal and non-Aboriginal cultural, historical and spiritual values, including integrating with the existing rich, social fabric of Belconnen
- Soc 2. Designing for social equity, affordability, diversity and interdependence, honouring differences and catering for the needs of individuals through all stages of life
- Soc 3. Maximising health, safety and comfort of the built environment to provide enduring quality of life
- Soc 4. Instilling awareness and supporting education of sustainability values, technology and lifestyles
- Soc 5. Using creative and robust design solutions to create a continuing sense of place and beauty that inspires, affirms and ennobles
- Soc 6. Designing neighbourhoods that support and encourage community interactions through imaginative, functional and enjoyable public spaces

ECONOMIC PRINCIPLES

- Econ 1. Delivering a financial return to the ACT Government recognising their sovereign interest in the land
- Econ 2. Recognising the opportunities provided by the project's scale and low capital base to achieve high-level sustainability outcomes while delivering profitability to joint venture partners
- Econ 3. Building on existing local infrastructure
- Econ 4. Ensuring long-term economic viability through design excellence and community building
- Econ 5. Minimising obsolescence through design of enduring component life cycle, allowing for disassembly and change
- Econ 6. Integrating with the Belconnen commercial, retail and employment networks
- Econ 7. Growing a formal and informal green economy that fosters local jobs and builds regional learning around green innovation and technology

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-
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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	A Smit	D Gamble		D Gamble		

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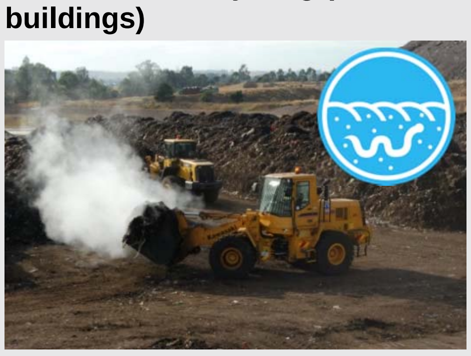
Appendix J - Table of potential future land uses (physical suitability)

Summary of findings from internal consultation exercise - physical suitability of assessment group areas for identified potential future land uses

Legend	
Blue	Physically possible, no further investigation and assessment needed
Green	Physically possible, limited further investigation and assessment needed
Orange	Physically possible, moderate further investigation and assessment needed
Red	Physically possible, significant further investigation and assessment needed
Black	Not physically possible

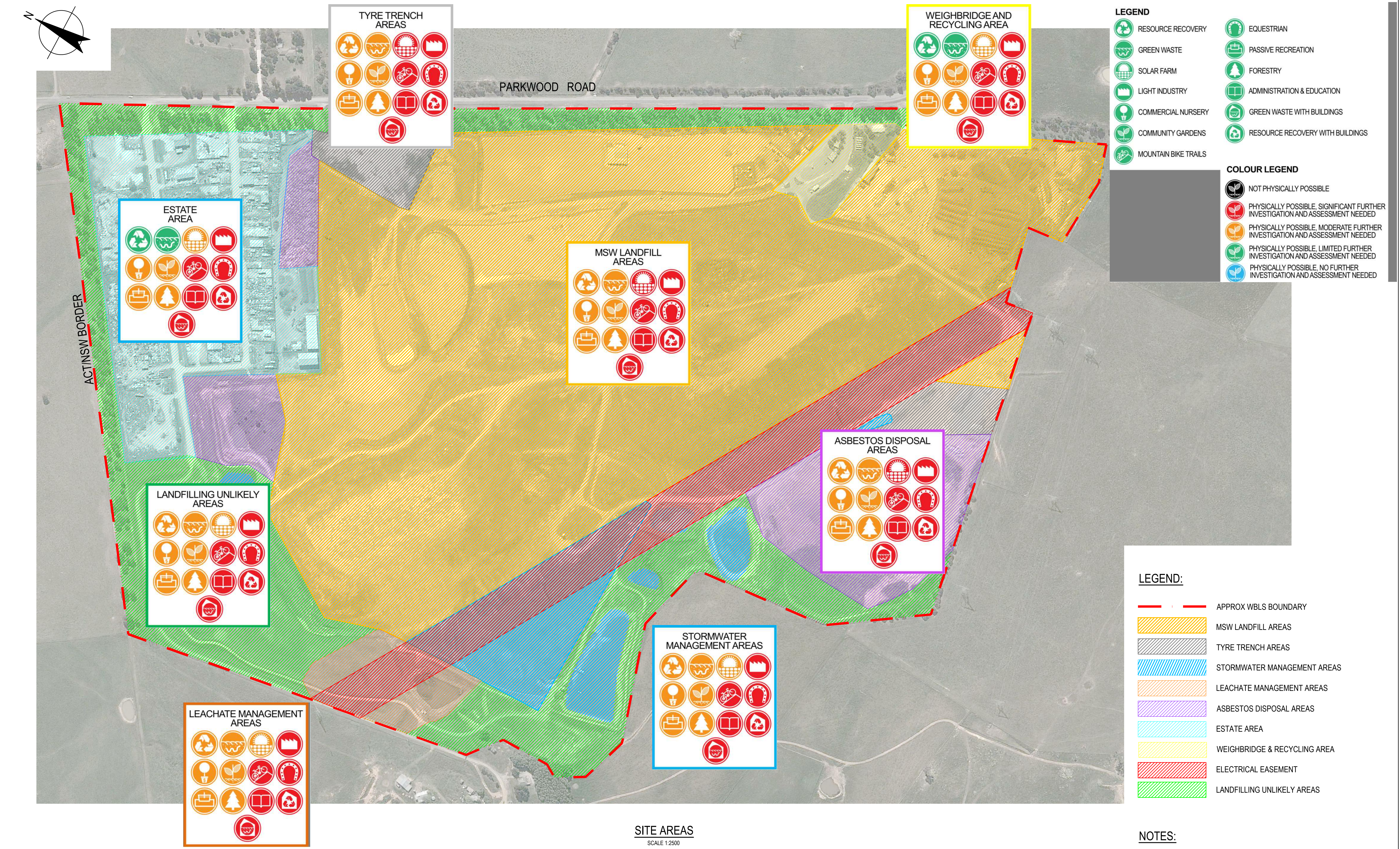
* *Short term* is defined as between 0 – 10 years and *medium term* is defined as between 10 – 20 years.

Potential future land use	Assessment group areas	GHD specialists' views / position								Justification for combined rankings
		Geotechnical (settlement)		Soils (plant growth, soil erosion)		Waste (landfill issues including integrity of cap, gas, leachate, slope stability and WH&S issues)		Combined		
		Short term*	Medium term*	Short term*	Medium term*	Short term*	Medium term*	Short term*	Medium term*	
Resource recovery (with buildings) 	MSW Landfill Areas	Red	Orange	Green	Green	Red	Orange	Red	Orange	Settlement of waste and gas accumulation makes installing a building on the site difficult in the short term. Both of these concerns will diminish in severity in the medium term.
	Tyre Trench Areas	Red	Orange	Green	Green	Red	Orange	Red	Orange	
	Stormwater Management Areas	Green	Green	Green	Green	Red	Orange	Red	Orange	
	Leachate Management Areas	Green	Green	Green	Green	Red	Orange	Red	Orange	
	Asbestos Disposal Areas	Red	Orange	Green	Green	Red	Orange	Red	Orange	
	Estate Area	Green	Green	Green	Green	Red	Orange	Red	Orange	
	Weighbridge and Recycling Area	Green	Green	Green	Green	Red	Orange	Red	Orange	
	Landfilling unlikely	Green	Green	Green	Green	Red	Orange	Red	Orange	
Resource recovery (without buildings) 	MSW Landfill Areas	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Settlement of waste and cap integrity during site activities makes this land use difficult in the short term. Cap integrity under site activity will remain in the medium term. The Estate and Weighbridge areas are largely concrete.
	Tyre Trench Areas	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	
	Stormwater Management Areas	Green	Green	Orange	Orange	Green	Green	Orange	Orange	
	Leachate Management Areas	Green	Green	Orange	Orange	Green	Green	Orange	Orange	
	Asbestos Disposal Areas	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	
	Estate Area	Green	Green	Green	Green	Green	Green	Green	Green	
	Weighbridge and Recycling Area	Green	Green	Green	Green	Green	Green	Green	Green	
	Landfilling unlikely	Green	Green	Orange	Orange	Green	Green	Orange	Orange	
Green waste recycling (with buildings) 	MSW Landfill Areas	Red	Orange	Green	Green	Red	Orange	Red	Orange	Settlement of waste and gas accumulation makes installing a building on the site difficult in the short term. Both of these concerns will diminish in severity in the medium term.
	Tyre Trench Areas	Red	Orange	Green	Green	Red	Orange	Red	Orange	
	Stormwater Management Areas	Green	Green	Green	Green	Red	Orange	Red	Orange	
	Leachate Management Areas	Green	Green	Green	Green	Red	Orange	Red	Orange	
	Asbestos Disposal Areas	Red	Orange	Green	Green	Red	Orange	Red	Orange	
	Estate Area	Green	Green	Green	Green	Red	Orange	Red	Orange	
	Weighbridge and Recycling Area	Green	Green	Green	Green	Red	Orange	Red	Orange	
	Landfilling unlikely	Green	Green	Green	Green	Red	Orange	Red	Orange	
Green waste recycling (without buildings) 	MSW Landfill Areas	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Settlement of waste and cap integrity during site activities makes this land use difficult in the short term. Cap integrity under site activity will remain in the medium term. The Estate and Weighbridge areas are largely concrete.
	Tyre Trench Areas	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	
	Stormwater Management Areas	Green	Green	Orange	Orange	Green	Green	Orange	Orange	
	Leachate Management Areas	Green	Green	Orange	Orange	Green	Green	Orange	Orange	
	Asbestos Disposal Areas	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	
	Estate Area	Green	Green	Green	Green	Green	Green	Green	Green	
	Weighbridge and Recycling Area	Green	Green	Green	Green	Green	Green	Green	Green	
	Landfilling unlikely	Green	Green	Orange	Orange	Green	Green	Orange	Orange	

Potential future land use	Assessment group areas	GHD specialists' views / position: Geotechnical (settlement) – Short term*	Geotechnical (settlement) – Medium term*	Soils (plant growth, soil erosion) – Short term*	Soils (plant growth, soil erosion) – Medium term*	Waste (landfill issues including integrity of cap, gas, leachate, slope stability and WH&S issues) – Short term*	Waste – Medium term*	Combined – Short term*	Combined – Medium term*	Justification for combined rankings
Solar farm 	MSW Landfill Areas									Landfill gas poses a risk to electrical componentry on site that may spark. Depth required for footing over waste areas may also be of concern. These will diminish into the medium term.
	Tyre Trench Areas									
	Stormwater Management Areas									
	Leachate Management Areas									
	Asbestos Disposal Areas									
	Estate Area									
	Weighbridge and Recycling Area									
	Landfilling unlikely									
Light industry 	MSW Landfill Areas									Settlement of waste and gas accumulation makes installing a building on the site difficult in the short term. Both of these concerns will diminish in severity in the medium term.
	Tyre Trench Areas									
	Stormwater Management Areas									
	Leachate Management Areas									
	Asbestos Disposal Areas									
	Estate Area									
	Weighbridge and Recycling Area									
	Landfilling unlikely									
Commercial plant nursery 	MSW Landfill Areas									Land use of this type could cause erosion and deterioration of the landfill cap. This risk will diminish over time as the cap and vegetation becomes more established.
	Tyre Trench Areas									
	Stormwater Management Areas									
	Leachate Management Areas									
	Asbestos Disposal Areas									
	Estate Area									
	Weighbridge and Recycling Area									
	Landfilling unlikely									
Community gardens 	MSW Landfill Areas									Land use of this type could cause erosion and deterioration of the landfill cap. This risk will diminish over time as the cap and vegetation becomes more established.
	Tyre Trench Areas									
	Stormwater Management Areas									
	Leachate Management Areas									
	Asbestos Disposal Areas									
	Estate Area									
	Weighbridge and Recycling Area									
	Landfilling unlikely									
Mountain bike trails 	MSW Landfill Areas									Land use of this type could cause erosion and deterioration of the landfill cap. Landfill gas could pose an OHS risk for site users in the short term. This risk will diminish over time as the cap and vegetation becomes more established.
	Tyre Trench Areas									
	Stormwater Management Areas									
	Leachate Management Areas									
	Asbestos Disposal Areas									
	Estate Area									
	Weighbridge and Recycling Area									
	Landfilling unlikely									
Equestrian activity 	MSW Landfill Areas									Land use of this type could cause erosion and deterioration of the landfill cap. Landfill gas could pose an OHS risk for site users in the short term. This risk will diminish over time as the cap and vegetation becomes more established.
	Tyre Trench Areas									
	Stormwater Management Areas									
	Leachate Management Areas									
	Asbestos Disposal Areas									
	Estate Area									
	Weighbridge and Recycling Area									
	Landfilling unlikely									

Potential future land use	Assessment group areas	GHD specialists' views / position								Justification for combined rankings
		Geotechnical (settlement)		Soils (plant growth, soil erosion)		Waste (landfill issues including integrity of cap, gas, leachate, slope stability and WH&S issues)		Combined		
		Short term*	Medium term*	Short term*	Medium term*	Short term*	Medium term*	Short term*	Medium term*	
Passive recreation 	MSW Landfill Areas									Land use of this type could cause erosion and deterioration of the landfill cap. Landfill gas could pose some OHS issues for site users.
	Tyre Trench Areas									
	Stormwater Management Areas									
	Leachate Management Areas									
	Asbestos Disposal Areas									
	Estate Area									
	Weighbridge and Recycling Area									
	Landfilling unlikely									
Forestry / tree planting 	MSW Landfill Areas									Land use of this type could cause erosion and deterioration of the landfill cap. This risk may diminish over time as the cap and vegetation becomes more established.
	Tyre Trench Areas									
	Stormwater Management Areas									
	Leachate Management Areas									
	Asbestos Disposal Areas									
	Estate Area									
	Weighbridge and Recycling Area									
	Landfilling unlikely									
Administrative / education facilities 	MSW Landfill Areas									Settlement of waste and gas accumulation makes installing a building on the site difficult in the short term. Both of these concerns will diminish in severity in the medium term.
	Tyre Trench Areas									
	Stormwater Management Areas									
	Leachate Management Areas									
	Asbestos Disposal Areas									
	Estate Area									
	Weighbridge and Recycling Area									
	Landfilling unlikely									

Appendix K – Future land use options plans (physical suitability)



SITE AREAS

SCALE 1:2500

NOTES:

1. BOUNDARIES ARE INDICATIVE ONLY

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No	Revision	Drawn	Job Manager	Project Director	Date
A	DRAFT FOR REVIEW	MF	MW	DG	

Note: * indicates signatures on original issue of drawing or last revision of drawing

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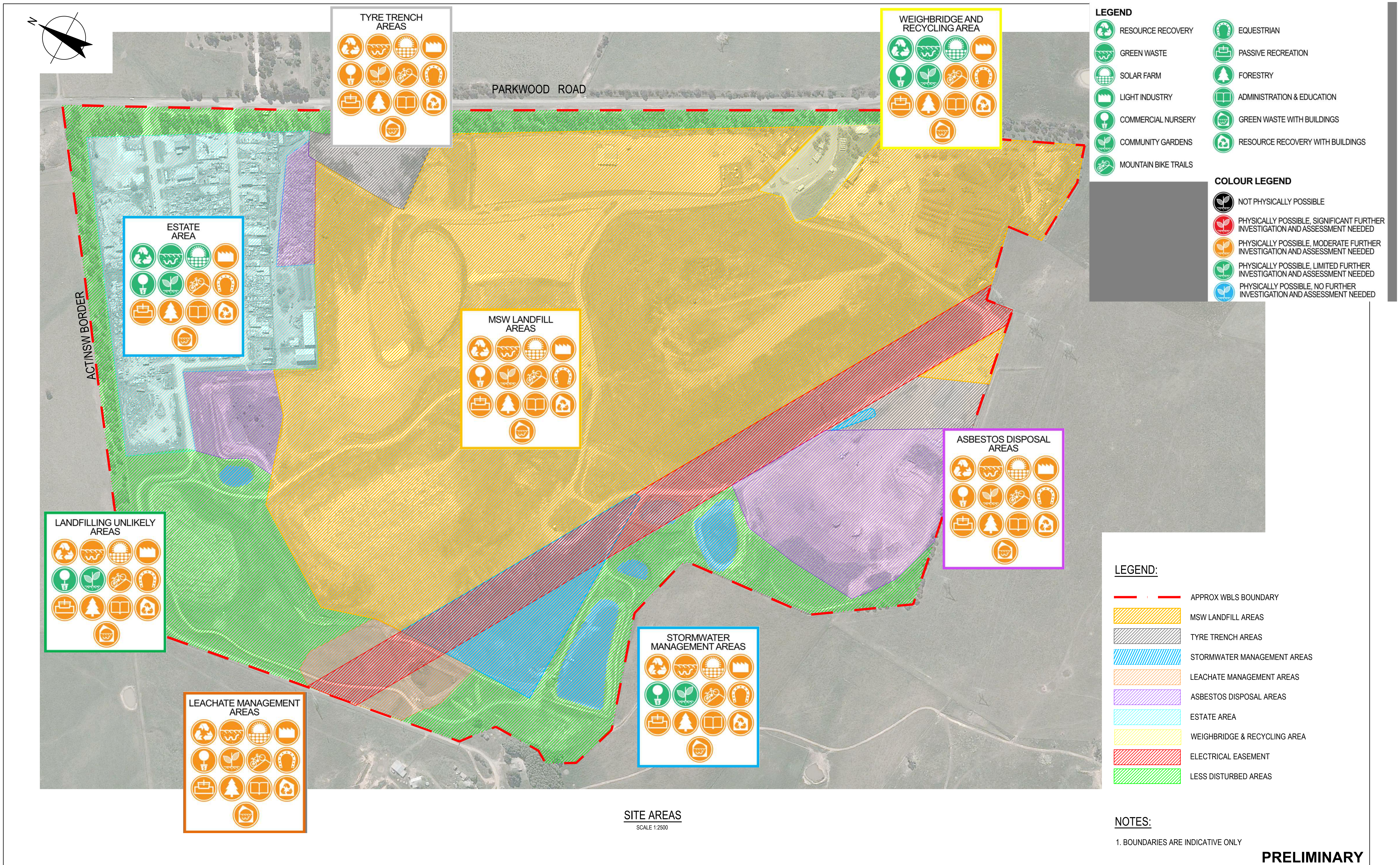
Drawn M. FORTU	Designer
Drafting Check	Design Check
Approved (Project Director) Date	
Scale 1:2500	This Drawing must not be used for Construction unless signed as Approved

Client **THE RIVERVIEW GROUP**
Project **WEST BELCONNEN LANDFILL SITE**
Title **SUITABILITY OF FUTURE LAND USES SHORT TERM (0-10 YEARS)**

Original Size **A1** Drawing No: **21-18515-C007** Rev: **A**

Plot Date: 8 May 2014 - 9:57 AM Plotted by: Carol Ng Cad File No: G:\21\23237\CADD\Drawings\21-23237-C007.dwg



PRELIMINARY

No	Revision	Drawn	Job Manager	Project Director	Date
A	DRAFT FOR REVIEW	MF	MW	DG	

Note: * indicates signatures on original issue of drawing or last revision of drawing

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Drafting Check | Design Check
Approved (Project Director)
Date
Scale 1:2500
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Client **THE RIVERVIEW GROUP**
Project **WEST BELCONNEN LANDFILL SITE**
Title **SUITABILITY OF FUTURE LAND USES MEDIUM TERM**

Original Size A1 Drawing No: **21-18515-C008** Rev: A

Plot Date: 8 May 2014 - 9:57 AM Plotted by: Carol Ng Cad File No: G:\21\23237\CADD\Drawings\21-23237-C008.dwg

Appendix L – Risk assessment and potentially required works tables (on-site)

On-site risk assessment and potential additional works

Risk matrix

The risk matrix below has been developed based on AS/NZS ISO 31000:2009 Risk Assessment (SAI Global, 2009). It has been applied to the key landfill related risks (physical only) posed by the WBLS to potential future on-site receptors. These risks have been given a risk rating based on the likelihood and consequences of individual risks.

Risk Matrix		Consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likelihood		**A**	**B**	**C**	**D**	**E**
Almost Certain	**5**	Low	Moderate	Significant	Extreme	Extreme
Likely	**4**	Low	Low	Moderate	Significant	Extreme
Possible	**3**	Negligible	Low	Moderate	Significant	Extreme
Unlikely	**2**	Negligible	Negligible	Low	Moderate	Significant
Very Unlikely	**1**	Negligible	Negligible	Low	Moderate	Moderate

Any risks that are deemed to be ‘extreme’ or ‘significant’ should be eliminated, mitigated or revised. ‘Moderate’ risks require the consideration of all practicable controls to reduce the risk. Risks scored as ‘low’ should be reviewed and risks deemed to be ‘negligible’ suggest that no further management / monitoring actions are likely to be required.

This risk matrix has been applied within Table 1 below. Receptors have been identified as relevant to the potential risk identified (i.e. not all potential on-site receptors have been assessed for all potential risks identified).

Table 1: On-site landfill related risks potentially posed to future on-site receptors at the WBLS

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Potential additional works identification number(s) (refer to Table 2)
Risk 1 – Landfill gas impact to on-site receptors							
On-site buildings / structures	Adverse impact to buildings / structures (fire and / or explosion)	Possible	Catastrophic	Extreme	Landfill gas could have an adverse impact on buildings / structures on-site. Gas accumulations could result in fires and / or explosions that could damage or destroy buildings / structures and injure or kill their occupants.	Eco 2.	1.1 to 1.5
On-site underground services	Adverse impact to underground services (fire and / or explosion)	Possible	Catastrophic	Extreme	Landfill gas could have an adverse impact on underground services on-site. Gas accumulations could result in fires and / or explosions that could damage or destroy underground services.	Eco 2.	1.1 to 1.5
On-site people	Adverse impact to people (fire, explosion, toxic exposure and / or asphyxiation)	Possible	Catastrophic	Extreme	Landfill gas could have an adverse impact on people present on-site. Gas accumulations could result in injury or death via fires, explosions, toxic exposure and / or asphyxiation.	Eco 2.	1.1 to 1.5

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Potential additional works identification number(s) (refer to Table 2)
On-site flora and / or fauna	Adverse impact to the onsite flora and / or fauna (toxic exposure and / or asphyxiation)	Possible	Minor	Low	Landfill gas could have an adverse impact on flora and / or fauna on-site. Gas accumulations could result in injury or death via toxic exposure and / or asphyxiation.	Eco 2.	1.1 to 1.5
Risk 2 - Leachate impact to on-site receptors							
On-site buildings / structures	Adverse impact to buildings / structures (corrosion / structural damage etc.)	Possible	Major	Significant	Leachate could have an adverse impact on buildings / structures on-site. Leachate could cause corrosion / structural damage to building / structure foundations that could damage or destroy buildings / structures and injure their occupants.	Eco 2.	2.1 to 2.6
On-site underground services	Adverse impact to underground services (corrosion / structural damage etc.)	Possible	Moderate	Moderate	Leachate could have an adverse impact on underground services on-site. Leachate could cause corrosion / structural damage to underground services.	Eco 2.	2.1 to 2.6

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Potential additional works identification number(s) (refer to Table 2)
On-site people	Adverse impact to people (toxic exposure)	Possible	Moderate	Moderate	Human contact with leachate could pose health issues via toxic exposure.	Eco 2.	2.1 to 2.6
On-site flora and / or fauna	Adverse impact to on-site flora and / or fauna through contact with leachate (toxic exposure)	Possible	Minor	Low	Flora and / or fauna contact with leachate could cause health issues via toxic exposure.	Eco 2.	2.1 to 2.6
On-site surface waters	Adverse impact to quality of on-site surface waters	Possible	Moderate	Moderate	Contamination of surface water by leachate may prevent use of water, require it to be disposed of as leachate and / or cause health issues for humans, flora and / or fauna who come into contact with it (e.g. via recreational contact or by drinking it).	Eco 2.	2.1 to 2.6

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Potential additional works identification number(s) (refer to Table 2)
On-site groundwater	Adverse impact to quality of on-site groundwater	Likely	Moderate	Moderate	Contamination of groundwater by leachate may prevent use of this water, require it to be disposed of as leachate and / or cause health issues for humans, flora and / or fauna who come into contact with it (e.g. via recreational contact or by drinking it).	Eco 2.	2.1 to 2.6
Risk 3 – Amenity issues associated with operation of landfill gas engine (noise and odour)							
On-site people: Noise	Operational noise may cause disturbance to on-site people	Possible	Minor	Low	Operational noise should be low.	Eco 2.	3.1
On-site people: Odour	Odour from the landfill gas engine may cause disturbance to on-site people	Unlikely	Minor	Negligible	Landfill gas engines generally emit very low levels of odour.	Eco 2.	3.1
Risk 4 – Amenity issues associated with operation of leachate treatment system (noise and odour)							
On-site people: Noise	Operational noise may cause disturbance to on-site people	Unlikely	Insignificant	Negligible	Operational noise should be low.	Eco 2.	4.1

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Potential additional works identification number(s) (refer to Table 2)
On-site people: Odour	Odour from the leachate treatment system may cause disturbance to on-site people	Possible	Minor	Low	The odour from the leachate treatment system should be relatively low.	Eco 2.	4.1
Risk 5 - Sediment laden surface water impacting upon on-site receptors							
On-site flora and / or fauna	Adverse impact to on-site flora and / or fauna through contact with sediment laden surface water	Possible	Minor	Low	Flora and / or fauna contact with sediment laden surface water could cause health issues.	Eco 2.	5.1
On-site surface waters	Adverse impact to quality of on-site surface waters	Possible	Moderate	Moderate	Contamination of surface water by sediment may prevent use of water, require it to be treated and / or cause health issues for humans, flora and / or fauna who come into contact with it (e.g. via recreational contact or by drinking it).	Eco 2.	5.1
Risk 6 – Settlement impacting upon on-site receptors							

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Potential additional works identification number(s) (refer to Table 2)
On-site buildings / structures	Adverse impact to buildings / structures due to settlement (structural damage)	Possible	Major	Significant	Settlement could have an adverse impact on buildings / structures on-site. Settlement could cause structural damage to buildings / structures that could damage or destroy buildings / structures and injure their occupants.	Eco 2.	6.1 to 6.2
On-site underground services	Adverse impact to underground services due to settlement (structural damage)	Possible	Major	Significant	Settlement could have an adverse impact on underground services on-site. Settlement could cause structural damage to underground services.	Eco 2.	6.1 to 6.2
Risk 7 – Exposed waste / ground contamination impacting upon on-site receptors							
On-site people	Adverse impact to people (toxic exposure)	Possible	Major	Significant	Human contact with exposed waste / ground contamination could pose health issues via toxic exposure (particularly if hazardous wastes such as asbestos)	Eco 2.	7.1 to 7.2

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Potential additional works identification number(s) (refer to Table 2)
On-site flora and / or fauna	Adverse impact to on-site flora and / or fauna through contact with waste / ground contamination (toxic exposure)	Possible	Minor	Low	Flora and / or fauna contact with waste / ground contamination could cause health issues via toxic exposure.	Eco 2.	7.1 to 7.2
On-site surface waters	Adverse impact to quality of on-site surface waters	Possible	Moderate	Moderate	Contamination of surface water by exposed waste / ground contamination may prevent use of water, require it to be disposed of as leachate and / or cause health issues for humans, flora and / or fauna who come into contact with it (e.g. via recreational contact or by drinking it).	Eco 2.	7.1 to 7.2
Risk 8 – Stability failure of landfill impacting upon on-site receptors							

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Potential additional works identification number(s) (refer to Table 2)
On-site buildings / structures	Adverse impact to buildings / structures (structural damage)	Unlikely	Catastrophic	Significant	Stability failure could have an adverse impact on buildings / structures on-site. Stability failure could result in landfill slumps / landslides that could damage or destroy on-site buildings / structures and injure or kill their occupants.	Eco 2.	8.1 to 8.4
On-site underground services	Adverse impact to underground services (structural damage)	Unlikely	Moderate	Moderate	Stability failure could have an adverse impact on underground services on-site. Stability failure could result in landfill slumps / landslides that that could damage or destroy on-site underground services.	Eco 2.	8.1 to 8.4
On-site people	Adverse impact to people (asphyxiation or crushing)	Unlikely	Catastrophic	Significant	Stability failure could have an adverse impact on people. Stability failure could result in landfill slumps / landslides that that could injure or kill on-site people.	Eco 2.	8.1 to 8.4

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Potential additional works identification number(s) (refer to Table 2)
On-site flora and / or fauna	Adverse impact to the onsite flora and / or fauna (asphyxiation or crushing)	Unlikely	Minor	Negligible	Stability failure could have an adverse impact upon flora and / or fauna on-site. Stability failure could result in landfill slumps / landslides that that could injure or kill on-site flora and / or fauna.	Eco 2.	8.1 to 8.4
On-site surface waters	Adverse impact to quality of on-site surface waters	Unlikely	Moderate	Low	Stability failure could result in landfill slumps / landslides that that could damage / block on-site surface water drainage lines and / or introduce sediment or waste materials into them.	Eco 2.	8.1 to 8.4

Table 2 below identifies potential additional on-site investigative and / or monitoring works that may be required to assist future decision making regarding the potential future use(s) of the WBLS and is based on the findings of Table 1.

Table 2: On-site additional investigative and / or monitoring works at the WBLS

Potential additional works identification number (refer Table 1 above)	Works	Indicative cost range ($ 2014) ex GST	Indicative frequency and length of time required for	Reason(s) for works	Relevant guiding principals
1.1	Undertake formal landfill gas risk assessment for the WBLS (to include landfill gas modelling).	Initially $15,000 to $25,000. Updates $5,000 to $10,000	Initially once (should be updated at least annually). Initial document may take 4 to 6 weeks to prepare. Updates 3 to 4 weeks.	To further understand and formally assess landfill gas risks present on and adjacent to the WBLS. To allow risk based monitoring and management measures to be developed and subsequently implemented.	Eco 2.
1.2	Develop and implement regular landfill gas monitoring program based on outcomes of landfill gas risk assessment (to include monitoring of surface emissions, sub-surface services, existing buildings / structures etc.). Regularly assess the collected data.	Development of monitoring program: $3,000 to $5,000 plus Monitoring and data assessment: $5,000 to $15,000 per round	To be confirmed by landfill gas risk assessment in 1.1 above. Ongoing.	To further confirm potential risks posed by landfill gas generated at the WBLS to potential future receptors and to provide base information upon which future land uses can be adequately designed to prevent adverse impact.	Eco 2.
1.3	Review of landfill gas collection system data	$3,000 - $5,000 per round	Quarterly. Ongoing.	To allow understanding of the quantities of landfill gas being collected from the WBLS and when.	Eco 2.
1.4	Refine existing landfill gas management measures (gas collection system, barriers etc.) as required based on outcomes of 1.1, 1.2 and 1.3 above.	Not possible to estimate until 1.1, 1.2 and 1.3 are completed	Not possible to estimate until 1.1, 1.2 and 1.3 are completed	To ensure that potential risks posed by landfill gas are appropriately managed to prevent significant on-site and / or off-site impacts.	Eco 2.

Potential additional works identification number (refer Table 1 above)	Works	Indicative cost range ($ 2014) ex GST	Indicative frequency and length of time required for	Reason(s) for works	Relevant guiding principals
1.5	Following the selection of the precise areas of land that may be developed in the future on the WBLS (and the associated land uses), develop and implement appropriate ground gas investigations and monitoring (as relevant).	Not possible to estimate at present until development areas and proposed future uses selected.	Not possible to estimate at present until development areas and proposed future uses selected.	To ensure landfill gas issues in potential future land use areas are well understood and to provide base data upon which future land uses can be adequately designed to prevent adverse impact.	Eco 2., Soc 3.
2.1	Undertake formal hydrological risk assessment for the WBLS (to include leachate generation / water balance modelling but excluding any design works).	Initially $40,000 to $70,000. Updates $5,000 to $10,000	Initially once (should be updated at least every 3 years). Initial document may take 4 to 6 weeks to prepare. Updates 3 to 4 weeks.	To further understand and formally assess leachate risks present on and adjacent to the WBLS. To allow risk based monitoring and management measures to be developed and subsequently implemented.	Eco 2.

Potential additional works identification number (refer Table 1 above)	Works	Indicative cost range ($ 2014) ex GST	Indicative frequency and length of time required for	Reason(s) for works	Relevant guiding principals
2.2	Refine existing water (leachate, groundwater and surface water) monitoring program based on outcomes of hydrological risk assessment (to include monitoring of leachate within the waste mass, expansion of on-site leachate / groundwater bore locations – as identified in 2.3 below and expansion of surface water monitoring locations). Regularly assess the collected data.	Review and refinement of monitoring program: $10,000 to $20,000 plus Monitoring and data assessment: $15,000 to $40,000 per round (inclusive of laboratory fees)	To be confirmed by hydrological risk assessment in 2.1 above. Quarterly. Ongoing.	To further confirm potential risks posed by leachate generated at the WBLS to potential future receptors and to provide base information upon which future land uses can be adequately designed to prevent adverse impact.	Eco 2.
2.3	Design and installation of additional leachate / groundwater monitoring bores on-site	Approximately $5,000 - $10,000 per bore. Approximately 6 to 7 bores may be required; hence cost may range from $30,000 to $70,000.	To be confirmed by hydrological risk assessment in 2.1 above. Ongoing.	To provide for a more thorough investigation of the groundwater and leachate issues present at the site to understand potential risks to potential future on-site receptors.	Eco 2.

Potential additional works identification number (refer Table 1 above)	Works	Indicative cost range ($ 2014) ex GST	Indicative frequency and length of time required for	Reason(s) for works	Relevant guiding principals
2.4	Review of leachate collection system data	$2,000 - $3,000 per round	Quarterly. Ongoing.	To allow understanding of the composition and quantities of leachate being collected from the WBLS and subsequently irrigated	Eco 2.
2.5	Refine existing leachate management measures (collection system, barriers etc.) as required based on outcomes of 2.1, 2.2 and 2.3 above.	Not possible to estimate until 2.1, 2.2 and 2.3 are completed	Not possible to estimate until 2.1, 2.2 and 2.3 are completed	To ensure that potential risks posed by leachate are appropriately managed to prevent significant on-site and / or off-site impacts.	Eco 2.
2.6	Following the selection of the precise areas of land that may be developed in the future on the WBLS (and the associated land uses), develop and implement appropriate water (leachate, groundwater and surface water) investigations and monitoring (as relevant).	Not possible to estimate at present until development areas and proposed future uses selected.	Not possible to estimate at present until development areas and proposed future uses selected.	To ensure water issues in potential future land use areas are well understood and to provide base data upon which future land uses can be adequately designed to prevent adverse impact.	Eco 2.,Soc 3.
3.1	Review of operational hours, noise, odour and exhaust emissions from engine and flare	$3,000 - $5,000 per round	Quarterly. Ongoing	To allow understanding of the operations of, and any associated impacts with, the engine and flare	Eco 2., Soc 3.
4.1	Review of operational hours, noise and odour from leachate collection system	$3,000 - $5,000 per round	Quarterly. Ongoing	To allow understanding of the operations of, and any associated impacts with, the leachate system	Eco 2. Soc 3.

Potential additional works identification number (refer Table 1 above)	Works	Indicative cost range ($ 2014) ex GST	Indicative frequency and length of time required for	Reason(s) for works	Relevant guiding principals
5.1	Include consideration / assessment of sediment laden water with leachate related works contained in 2.1 to 2.3 above	As detailed in 2.1 to 2.3 above	As detailed in 2.1 to 2.3 above	As detailed in 2.1 to 2.3 above	Eco 2. Soc 3.
6.1	Commence regular settlement monitoring of the WBLS (particularly potential future development areas)	$10,000 to $15,000 to set-up settlement monitoring equipment. $10,000 to $15,000 per monitoring round.	One-off set-up. Monitoring every 6 months. Ongoing	To allow understanding of settlement rates at the WBLS to be established and their likely significance in relation to potential future land use areas.	Eco 2. Soc 3.
6.2	Following the selection of the precise areas of land that may be developed in the future on the WBLS (and the associated land uses), undertake appropriate geotechnical investigations and assessment (as relevant). This should include determining cover layer type and thickness, waste depths and waste characteristics in selected areas.	Not possible to estimate at present until development areas and proposed future uses selected.	Not possible to estimate at present until development areas and proposed future uses selected.	To ensure geotechnical issues in potential future land use areas are well understood and to provide base data upon which future land uses can be adequately designed to prevent adverse impact	Eco 2. Soc 3.

Potential additional works identification number (refer Table 1 above)	Works	Indicative cost range ($ 2014) ex GST	Indicative frequency and length of time required for	Reason(s) for works	Relevant guiding principals
7.1	Following the selection of the precise areas of land that may be developed in the future on the WBLS (and the associated land uses), undertake appropriate investigations (as relevant). This should include test pitting of the landfill cover layers in the selected areas (if appropriate to do so) and sampling and testing of the surface soils (particularly for asbestos).	Not possible to estimate at present until development areas and proposed future uses selected.	Not possible to estimate at present until development areas and proposed future uses selected.	To ensure exposed waste / ground contamination issues in potential future land use areas are well understood and to provide base data upon which future land uses can be adequately designed to prevent adverse impact	Eco 2. Soc 3.
7.2	Following the selection of the precise areas of land that may be developed in the future on the WBLS (and the associated land uses), it may be appropriate to also investigate areas of land adjacent to potential future land use areas. This may be of particular importance if potential surface contaminants (e.g. asbestos fibres) may be present on adjacent land that could adversely impact upon the potential future land use areas.	Not possible to estimate at present until development areas and proposed future uses selected.	Not possible to estimate at present until development areas and proposed future uses selected.	To ensure exposed waste / ground contamination issues in areas of land adjacent to potential future land use areas are well understood and to provide base data upon which future land uses can be adequately designed to prevent adverse impact	Eco 2. Soc 3.

Potential additional works identification number (refer Table 1 above)	Works	Indicative cost range ($ 2014) ex GST	Indicative frequency and length of time required for	Reason(s) for works	Relevant guiding principals
8.1	Undertake formal slope stability risk assessment for the WBLS. This would be done principally through a desk based review of fill records and a site inspection.	Initially $15,000 to $25,000. Updates $5,000 to $10,000	Initially once (should be updated at least every 3 years). Initial document may take 4 to 6 weeks to prepare. Updates 3 to 4 weeks.	To further understand and formally assess landfill related slope stability risks present on the WBLS (and by the WBLS to adjacent land). To allow risk based monitoring and management measures to be developed and subsequently implemented.	Eco 2., Soc 3.
8.2	Develop and implement regular slope stability monitoring program based on outcomes of slope stability risk assessment (to include visual inspections of slopes). Regularly assess the collected data.	Development of monitoring program: $3,000 to $5,000 plus Monitoring and data assessment: $5,000 to $15,000 per round	To be confirmed by slope stability risk assessment in 8.2 above. Ongoing.	To monitor potential risks posed by landfill related slope stability issues at the WBLS to potential future on-site receptors and to provide base information upon which potential future land uses can be adequately designed to prevent adverse impact.	Eco 2., Soc 3.
8.3	Refine existing slope stability management measures (visual monitoring, stand-offs etc.) as required based on outcomes of 8.1 and 8.2 above.	Not possible to estimate until 8.1 and 8.2 are completed	Not possible to estimate until 8.1 and 8.2 are completed	To ensure that potential risks posed by slope stability are appropriately managed to prevent significant on-site and / or off-site impacts.	Eco 2., Soc 3.

Potential additional works identification number (refer Table 1 above)	Works	Indicative cost range ($ 2014) ex GST	Indicative frequency and length of time required for	Reason(s) for works	Relevant guiding principals
8.4	Following the selection of the precise areas of land that may be developed in the future on the WBLS (and the associated land uses), develop and implement appropriate slope stability investigations and monitoring (as relevant).	Not possible to estimate at present until development areas and proposed future uses selected.	Not possible to estimate at present until development areas and proposed future uses selected.	To ensure slope stability issues in potential future land use areas are well understood and to provide base data upon which future land uses can be adequately designed to prevent adverse impact.	Eco 2., Soc 3.

Appendix M – Risk assessment potentially required works tables (off-site)

Off-site risk assessment and potential additional works

Risk matrix

The risk matrix below has been developed based on AS/NZS ISO 31000:2009 Risk Assessment (SAI Global, 2009). It has been applied to the key landfill related risks (physical only) posed by the WBLS to potential future off-site receptors at the WBLS boundary. These risks have been given a risk rating based on the likelihood and consequences of individual risks.

Risk Matrix		**Consequence**				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likelihood		**A**	**B**	**C**	**D**	**E**
Almost Certain	**5**	Low	Moderate	Significant	Extreme	Extreme
Likely	**4**	Low	Low	Moderate	Significant	Extreme
Possible	**3**	Negligible	Low	Moderate	Significant	Extreme
Unlikely	**2**	Negligible	Negligible	Low	Moderate	Significant
Very Unlikely	**1**	Negligible	Negligible	Low	Moderate	Moderate

Any risks that are deemed to be ‘extreme’ or ‘significant’ should be eliminated, mitigated or revised. ‘Moderate’ risks require the consideration of all practicable controls to reduce the risk. Risks scored as ‘low’ should be reviewed and risks deemed to be ‘negligible’ suggest that no further management / monitoring actions are likely to be required.

This risk matrix has been applied within Table 1 below. Receptors have been identified as relevant to the potential risk identified (i.e. not all potential off-site receptors have been assessed for all potential risks identified).

Table 1: Off-site landfill related risks potentially posed to future off-site receptors at the WBLS boundary

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Recommended additional works identification number(s) (refer to Table 2)
Risk 1 – Landfill gas impact to off-site receptors							
Off-site buildings / structures	Adverse impact to buildings / structures (fire and / or explosion)	Possible	Catastrophic	Extreme	Landfill gas could have an adverse impact on buildings / structures off-site. Gas accumulations could result in fires and / or explosions that could damage or destroy buildings / structures and injure or kill their occupants.	Eco 2.	1.1 to 1.6
Off-site underground services	Adverse impact to underground services (fire and / or explosion)	Possible	Catastrophic	Extreme	Landfill gas could have an adverse impact on underground services off-site. Gas accumulations could result in fires and / or explosions that could damage or destroy underground services.	Eco 2.	1.1 to 1.6
Off-site people	Adverse impact to people (fire, explosion, toxic exposure and / or asphyxiation)	Possible	Catastrophic	Extreme	Landfill gas could have an adverse impact on people present off-site. Gas accumulations could result in injury or death via fires, explosions, toxic exposure and / or asphyxiation.	Eco 2.	1.1 to 1.6

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Recommended additional works identification number(s) (refer to Table 2)
Off-site flora and / or fauna	Adverse impact to the onsite flora and / or fauna (toxic exposure and / or asphyxiation)	Possible	Minor	Low	Landfill gas could have an adverse impact on off-site flora and / or fauna. Gas accumulations could result in injury or death via toxic exposure and / or asphyxiation.	Eco 2.	1.1 to 1.6
Risk 2 - Leachate impact to off-site receptors							
Off-site buildings / structures	Adverse impact to buildings / structures (corrosion / structural damage etc.)	Possible	Major	Significant	Leachate could have an adverse impact on buildings / structures off-site. Leachate could cause corrosion / structural damage to building / structure foundations that could damage or destroy buildings / structures and injure their occupants.	Eco 2.	2.1 to 2.6
Off-site underground services	Adverse impact to underground services (corrosion / structural damage etc.)	Possible	Moderate	Moderate	Leachate could have an adverse impact on underground services off-site. Leachate could cause corrosion / structural damage to underground services.	Eco 2.	2.1 to 2.6

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Recommended additional works identification number(s) (refer to Table 2)
Off-site people	Adverse impact to people (toxic exposure)	Possible	Moderate	Moderate	Human contact with leachate could pose health issues via toxic exposure.	Eco 2.	2.1 to 2.6
Off-site flora and / or fauna	Adverse impact to off-site flora and / or fauna through contact with leachate (toxic exposure)	Possible	Minor	Low	Flora and / or fauna contact with leachate could cause health issues via toxic exposure.	Eco 2.	2.1 to 2.6
Off-site surface waters	Adverse impact to quality of off-site surface waters	Possible	Moderate	Moderate	Contamination of surface water by leachate may prevent use of water, require it to be disposed of as leachate and / or cause health issues for humans, flora and / or fauna who come into contact with it (e.g. via recreational contact or by drinking it).	Eco 2.	2.1 to 2.6

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Recommended additional works identification number(s) (refer to Table 2)
Off-site groundwater	Adverse impact to quality of off-site groundwater	Possible	Moderate	Moderate	Contamination of groundwater by leachate may prevent use of this water, require it to be disposed of as leachate and / or cause health issues for humans, flora and / or fauna who come into contact with it (e.g. via recreational contact or by drinking it).	Eco 2.	2.1 to 2.6
Risk 3 – Amenity issues associated with operation of landfill gas engine (noise and odour)							
Off-site people: Noise	Operational noise may cause disturbance to off-site people	Unlikely	Minor	Negligible	Operational noise should be low. The nearest new off-site receptor may be at least 100 metres from the engine.	Eco 2.	3.1
Off-site people: Odour	Odour from the landfill gas engine may cause disturbance to off-site people	Unlikely	Minor	Negligible	Landfill gas engines generally emit very low levels of odour. The nearest new off-site receptor may be at least 100 metres from the engine.	Eco 2.	3.1
Risk 4 – Amenity issues associated with operation of leachate treatment system (noise and odour)							

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Recommended additional works identification number(s) (refer to Table 2)
Off-site people: Noise	Operational noise may cause disturbance to off-site people	Unlikely	Insignificant	Negligible	Operational noise should be low. The nearest new off-site receptor may be at least 100 metres from the leachate dam.	Eco 2.	4.1
Off-site people: Odour	Odour from the leachate treatment system may cause disturbance to off-site people	Unlikely	Minor	Negligible	The odour from the leachate treatment system should be relatively low. The nearest new off-site receptor may be at least 100 metres from the leachate dam.	Eco 2.	4.1
Risk 5 - Sediment laden surface water impacting upon off-site receptors							
Off-site flora and / or fauna	Adverse impact to off-site flora and / or fauna through contact with sediment laden surface water	Possible	Minor	Low	Flora and / or fauna contact with sediment laden surface water could cause health issues.	Eco 2.	5.1

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Recommended additional works identification number(s) (refer to Table 2)
Off-site surface waters	Adverse impact to quality of off-site surface waters	Possible	Moderate	Moderate	Contamination of surface water by sediment may prevent use of water, require it to be treated and / or cause health issues for humans, flora and / or fauna who come into contact with it (e.g. via recreational contact or by drinking it).	Eco 2.	5.1
Risk 6 – Exposed waste / ground contamination impacting upon off-site receptors							
Off-site people	Adverse impact to people (toxic exposure)	Possible	Major	Significant	Human contact with exposed waste / ground contamination could pose health issues via toxic exposure (particularly if hazardous waste such as asbestos)	Eco 2.	6.1
Off-site flora and / or fauna	Adverse impact to off-site flora and / or fauna through contact with waste / ground contamination	Possible	Minor	Low	Flora and / or fauna contact with waste / ground contamination could cause health issues.	Eco 2.	6.1

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Recommended additional works identification number(s) (refer to Table 2)
Off-site surface waters	Adverse impact to quality of off-site surface waters	Possible	Moderate	Moderate	Contamination of surface water by exposed waste / ground contamination may prevent use of water, require it to be disposed of as leachate and / or cause health issues for humans, flora and / or fauna who come into contact with it (e.g. via recreational contact or by drinking it).	Eco 2.	6.1
Risk 7 – Stability failure of landfill impacting upon off-site receptors							
Off-site buildings / structures	Adverse impact to buildings / structures (structural damage)	Very unlikely	Catastrophic	Moderate	Stability failure could have an adverse impact on buildings / structures off-site. Stability failure could result in landfill slumps / landslides that could damage or destroy off-site buildings / structures and injure or kill their occupants.	Eco 2.	7.1 to 7.3

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Recommended additional works identification number(s) (refer to Table 2)
Off-site underground services	Adverse impact to underground services (structural damage)	Very unlikely	Major	Moderate	Stability failure could have an adverse impact on underground services off-site. Stability failure could result in landfill slumps / landslides that that could damage or destroy off-site underground services.	Eco 2.	7.1 to 7.3
Off-site people	Adverse impact to people (asphyxiation or crushing)	Very unlikely	Catastrophic	Moderate	Stability failure could have an adverse impact on off-site people. Stability failure could result in landfill slumps / landslides that that could injure or kill off-site people.	Eco 2.	7.1 to 7.3
Off-site flora and / or fauna	Adverse impact to the onsite flora and / or fauna (asphyxiation or crushing)	Very unlikely	Minor	Negligible	Stability failure could have an adverse impact upon flora and / or fauna off-site. Stability failure could result in landfill slumps / landslides that that could injure or kill off-site flora and / or fauna.	Eco 2.	7.1 to 7.3

Receptors	Potential impact	Likelihood	Consequence	Risk rating	Justification of ranking	Relevant guiding principles	Recommended additional works identification number(s) (refer to Table 2)
Off-site surface waters	Adverse impact to quality of off-site surface waters	Very unlikely	Moderate	Low	Stability failure could result in landfill slumps / landslides that could damage / block off-site surface water drainage lines and / or introduce sediment or waste materials into them.	Eco 2.	7.1 to 7.3

Table 2 below identifies potential additional investigative and / or monitoring works that may be required at the boundary of the WBLS to support the proposed residential redevelopment adjacent to the WBLS boundary and is based on the findings of Table 1.

Table 2: Off-site additional investigative and / or monitoring works at the boundary of the WBLS

Potential additional works identification number (refer Tables 1 above)	Works	Indicative cost ($ 2014) ex GST	Indicative frequency and length of time required for	Reason(s) for works	Relevant guiding principals
1.1	Undertake formal landfill gas risk assessment for the WBLS (to include landfill gas modelling).	Initially $15,000 to $25,000. Updates $5,000 to $10,000	Initially once (should be updated at least annually). Initial document may take 4 to 6 weeks to prepare. Updates 3 to 4 weeks.	To further understand and formally assess landfill gas risks present on and adjacent to the WBLS. To allow risk based monitoring and management measures to be developed and subsequently implemented.	Eco 2.
1.2	Develop and implement regular landfill gas monitoring program based on outcomes of landfill gas risk assessment (to include monitoring of perimeter gas bores – see 1.3 below, surface emissions, sub-surface services, existing buildings / structures etc.). Regularly assess the collected data.	Development of monitoring program: $3,000 to $5,000 plus Monitoring and data assessment: $5,000 to $15,000 per round	To be confirmed by landfill gas risk assessment in 1.1 above. Ongoing.	To further confirm potential risks posed by landfill gas generated at the WBLS to potential future off-site receptors and to provide base information upon which future on-site land uses can be adequately designed to prevent adverse impact off-site.	Eco 2.

Potential additional works identification number (refer Tables 1 above)	Works	Indicative cost ($ 2014) ex GST	Indicative frequency and length of time required for	Reason(s) for works	Relevant guiding principals
1.3	Design and install a network of perimeter landfill gas monitoring wells around the entire boundary of the WBLS (potentially in stages). Additional bores may be required in sensitive locations and / or past the boundary of the WBLS depending on gas monitoring results ultimately obtained. It may be possible to "dual design" the landfill gas monitoring wells to also allow for groundwater monitoring (see 2.3 below).	Design and installation of each bore is estimated to cost approximately $3,000 to- $5,000. A number of bores is likely to be required (number and spacing initially to be based on findings of 1.1. above). If a 50 metre spacing was found to be appropriate, approximately 70 bores would be required.	Typically 2 to 3 bores can be installed per day. Based on this and 70 bores being appropriate, the total installation period may be approximately 7 weeks. Additional bores may be required in sensitive locations and / or past the boundary of the WBLS depending on gas monitoring results ultimately obtained. These bores should last approximately 15 years. Replacement bores are likely to eventually be required.	To further understand landfill gas risks adjacent to site boundary and to provide information in relation to required buffer distances.	Eco 2.
1.4	Review of landfill gas collection system data	$3,000 - $5,000 per round	Quarterly. Ongoing.	To allow understanding of the quantities of landfill gas being collected from the WBLS and when.	Eco 2.

Potential additional works identification number (refer Tables 1 above)	Works	Indicative cost ($ 2014) ex GST	Indicative frequency and length of time required for	Reason(s) for works	Relevant guiding principals
1.5	Refine existing landfill gas management measures (gas collection system, barriers etc.) as required based on outcomes of 1.1 to 1.4 above.	Not possible to estimate until 1.1 to 1.4 are completed	Not possible to estimate until 1.1 to 1.4 are completed	To ensure that potential risks posed by landfill gas are appropriately managed to prevent significant on-site and / or off-site impacts.	Eco 2.
1.6	Depending on the findings of 1.1 to 1.4 above, appropriate ground gas investigations and monitoring may be required on land adjacent to the WBLS (if proposed to be developed).	Not possible to estimate at present	Not possible to estimate at present	To ensure landfill gas issues in potential future off-site development areas are well understood and to provide base data upon which future development off-site can be adequately designed to prevent adverse impact.	Eco 2., Soc 3.
2.1	Undertake formal hydrological risk assessment for the WBLS (to include leachate generation / water balance modelling but excluding any design works).	Initially $40,000 to $70,000. Updates $5,000 to $10,000	Initially once (should be updated at least every 3 years). Initial document may take 4 to 6 weeks to prepare. Updates 3 to 4 weeks.	To further understand and formally assess leachate risks present on and adjacent to the WBLS. To allow risk based monitoring and management measures to be developed and subsequently implemented.	Eco 2.

Potential additional works identification number (refer Tables 1 above)	Works	Indicative cost ($ 2014) ex GST	Indicative frequency and length of time required for	Reason(s) for works	Relevant guiding principals
2.2	Refine existing water (leachate, groundwater and surface water) monitoring program based on outcomes of hydrological risk assessment (to include monitoring of leachate within the waste mass, expansion of groundwater bore locations, as costed below in item 2.3, and expansion of surface water monitoring locations). Regularly assess the collected data.	Review and refinement of monitoring program: $10,000 to $20,000 plus Monitoring and data assessment: $15,000 to $40,000 per round (inclusive of laboratory fees)	To be confirmed by hydrological risk assessment in 2.1 above. Quarterly. Ongoing.	To further confirm potential risks posed by leachate generated at the WBLS to potential future off-site receptors and to provide base information upon which future land uses can be adequately designed to prevent adverse impact.	Eco 2.

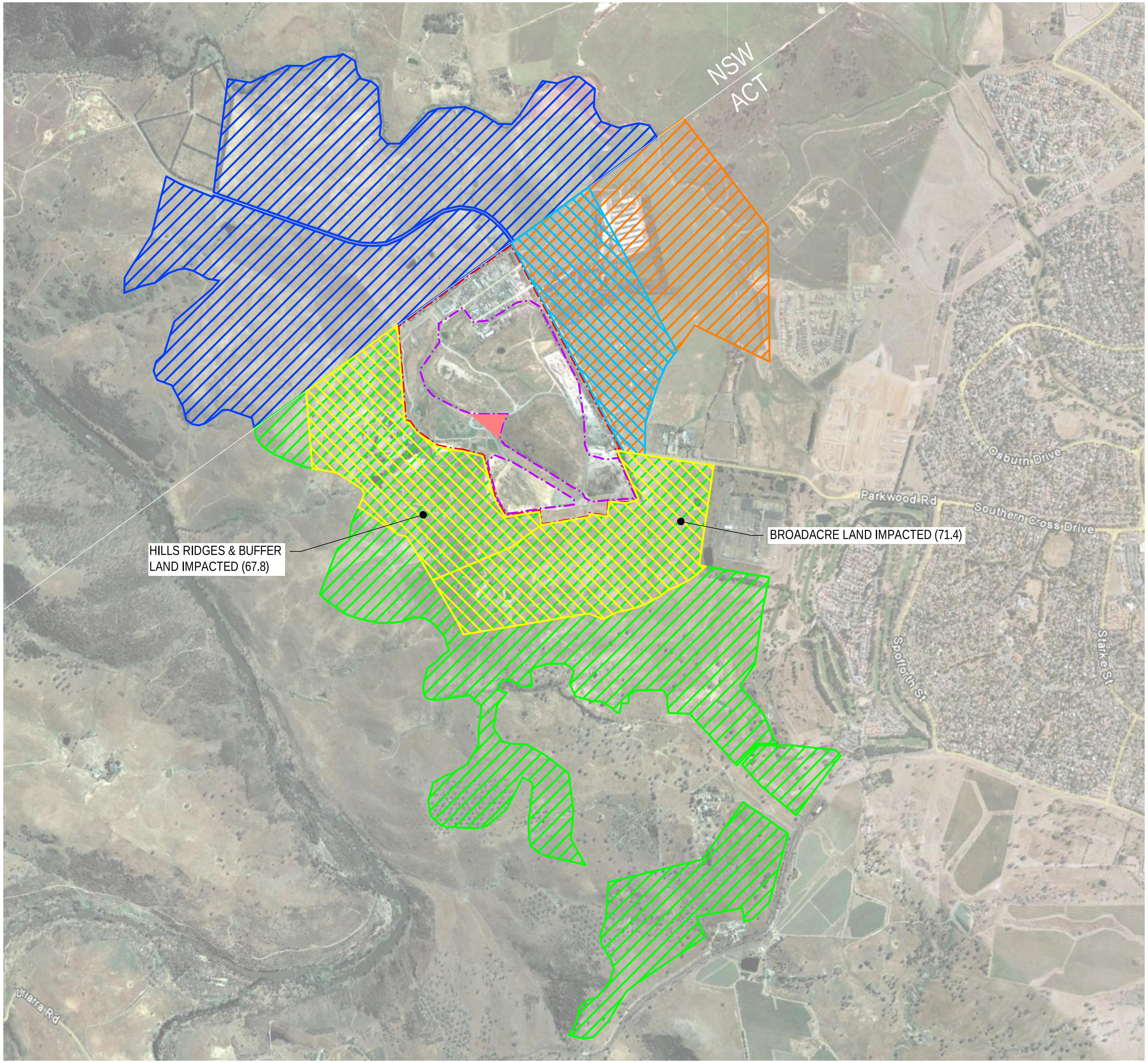
Potential additional works identification number (refer Tables 1 above)	Works	Indicative cost ($ 2014) ex GST	Indicative frequency and length of time required for	Reason(s) for works	Relevant guiding principals
2.3	Design and install additional perimeter groundwater monitoring wells around the boundary of the WBLS. Additional bores may be required in sensitive locations and / or past the boundary of the WBLS depending on groundwater monitoring results ultimately obtained. It may be possible to "dual design" the landfill gas monitoring wells to also allow for groundwater monitoring (see 1.3 above).	Design and installation of each bore is estimated to cost approximately $3,000 to- $5,000. A number of bores is likely to be required (number and spacing initially to be based on findings of 2.1. above). Could be of the order of 5 to 10 bores in total.	Typically 2 to 3 bores can be installed per day. Based on this and 10 bores being appropriate, the total installation period may be approximately 1 week. Additional bores may be required in sensitive locations and / or past the boundary of the WBLS depending on groundwater monitoring results ultimately obtained. These bores should last approximately 15 years. Replacement bores are likely to eventually be required.	To further understand leachate risks adjacent to / beyond the boundary of the WBLS and to provide information in relation to required buffer distances.	Eco 2.
2.4	Review of leachate collection system data	$2,000 - $3,000 per round	Quarterly. Ongoing.	To allow understanding of the composition and quantities of leachate being collected from the WBLS and subsequently irrigated	Eco 2.

Potential additional works identification number (refer Tables 1 above)	Works	Indicative cost ($ 2014) ex GST	Indicative frequency and length of time required for	Reason(s) for works	Relevant guiding principals
2.5	Refine existing leachate management measures (collection system, barriers etc.) as required based on outcomes of 2.1 to 2.3 above.	Not possible to estimate until 2.1, 2.2 and 2.3 are completed	Not possible to estimate until 2.1, 2.2 and 2.3 are completed	To ensure that potential risks posed by leachate are appropriately managed to prevent significant on-site and / or off-site impacts.	Eco 2.
2.6	Depending on the findings of 2.1 to 2.4 above, appropriate water (leachate, groundwater and surface water) investigations and monitoring may be required on land adjacent to the WBLS (if proposed to be developed).	Not possible to estimate at present	Not possible to estimate at present	To ensure water issues in potential future off-site development areas are well understood and to provide base data upon which future development off-site can be adequately designed to prevent adverse impact.	Eco 2., Soc 3.
3.1	Review of operational hours, noise, odour and exhaust emissions from engine and flare	$3,00 - $5,000 - per round	Quarterly. Ongoing	To allow understanding of the operations of, and any associated impacts with, the engine and flare	Eco 2., Soc 3.
4.1	Review of operational hours, noise and odour from leachate collection system	$3,00 - $5,000 - per round	Quarterly. Ongoing	To allow understanding of the operations of, and any associated impacts with, the leachate system	Eco 2.,Soc 3.
5.1	Include consideration / assessment of sediment laden water with leachate risk recommendations contained in 2.1 to 2.5 above	As detailed in 2.1 to 2.5 above	As detailed in 2.1 to 2.5 above	As detailed in 2.1 to 2.5 above	Eco 2., Soc 3.

Potential additional works identification number (refer Tables 1 above)	Works	Indicative cost ($ 2014) ex GST	Indicative frequency and length of time required for	Reason(s) for works	Relevant guiding principals
6.1	Prior to potentially developing land within the current 500 metre buffer distance from the WBLS, identify and undertake appropriate exposed waste / ground contamination investigations (as relevant). This may include test pitting and sampling and testing of the surface soils (particularly for asbestos). It is noted that AECOM have recently undertaken some limited off-site contaminated land investigations. GHD was not aware of the precise scope or outcomes form this work at the time of writing.	Not possible to estimate at present	Not possible to estimate at present	To ensure exposed waste / ground contamination issues in potential future land use areas are well understood and to provide base data upon which future land uses can be adequately designed to prevent adverse impact	Eco 2. Soc 3.
7.1	Undertake formal slope stability risk assessment for the WBLS. This would be done principally through a desk based review of fill records and a site inspection.	Initially $15,000 to $25,000. Updates $5,000 to $10,000	Initially once (should be updated at least every 3 years). Initial document may take 4 to 6 weeks to prepare. Updates 3 to 4 weeks.	To further understand and formally assess landfill related slope stability risks present on the WBLS (and by the WBLS to adjacent land). To allow risk based monitoring and management measures to be developed and subsequently implemented.	Eco 2., Soc 3.

Potential additional works identification number (refer Tables 1 above)	Works	Indicative cost ($ 2014) ex GST	Indicative frequency and length of time required for	Reason(s) for works	Relevant guiding principals
7.2	Develop and implement regular slope stability monitoring program based on outcomes of slope stability risk assessment (to include visual inspections of slopes). Regularly assess the collected data.	Development of monitoring program: $3,000 to $5,000 plus Monitoring and data assessment: $5,000 to $15,000 per round	To be confirmed by slope stability risk assessment in 8.2 above. Ongoing.	To monitor potential risks posed by landfill related slope stability issues at the WBLS to potential off-site future receptors and to provide base information upon which the potential future off-site development can be adequately designed to prevent adverse impact.	Eco 2., Soc 3.
7.3	Refine existing slope stability management measures (visual monitoring, stand-offs etc.) as required based on outcomes of 7.1 and 7.2 above.	Not possible to estimate until 7.1 and 7.2 are completed	Not possible to estimate until 7.1 and 7.2 are completed	To ensure that potential risks posed by slope stability are appropriately managed to prevent significant on-site and / or off-site impacts.	Eco 2., Soc 3.

Appendix N - Territory plan buffer distance plan for the WBLS



LEGEND

	RIVERVIEW CONTROLLED LAND (ACT)	345.0ha
	RIVERVIEW CONTROLLED LAND (NSW)	264.3ha
	ACT GOVT. CONTROLLED LAND (ACT)	126.2ha
	RIVERVIEW CONTROLLED LAND IMPACTED	139.2ha
	ACT GOVT. CONTROLLED LAND IMPACTED	55.6ha
	EMERGENCY LANDFILL AREA	1.1ha
	SITE BOUNDARY	
	APPROX. EXTENT OF EXISTING WASTE	

Nb: ALL LAND AREAS/BOUNDARIES ARE APPROXIMATE.

0 200 400 600m
SCALE 1:20,000 AT ORIGINAL SIZE

N

THE RIVERVIEW GROUP
WEST BELCONNEN LANDFILL SITE
PRELIMINARY WORKS

EXISTING 500m TERRITORY PLAN BUFFER DISTANCE

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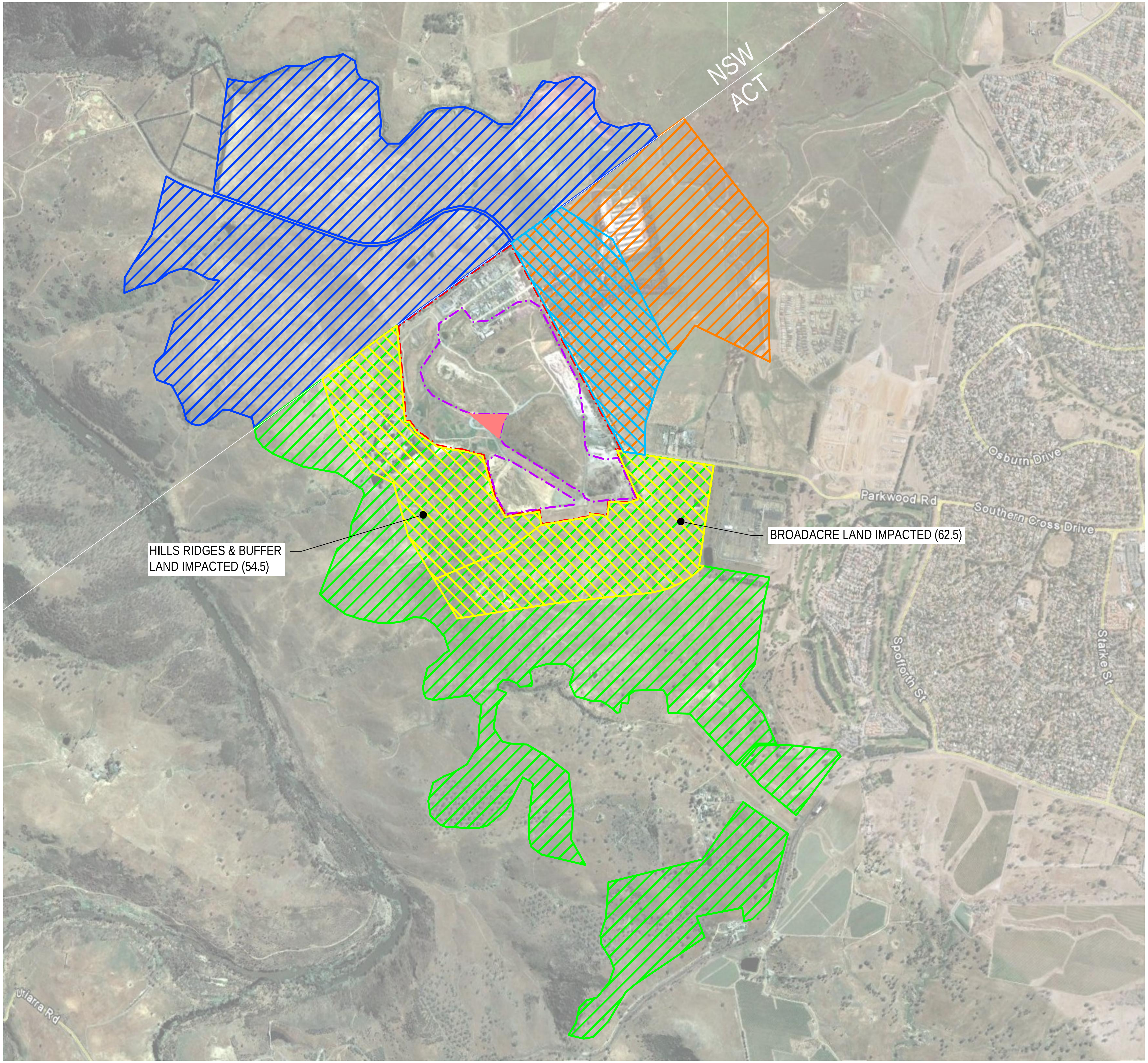
Figure 01

Plot Date: 7 February 2012 - 11:17 AM Plotted by: Adrian P Miller/Sydney/GHD/AU Cad File No: G:\21\20325\CADD\Drawings\21-20325-FIG01.dwg



LEGEND

	RIVERVIEW CONTROLLED LAND (ACT)	345.0ha
	RIVERVIEW CONTROLLED LAND (NSW)	264.3ha
	ACT GOVT. CONTROLLED LAND (ACT)	126.2ha
	RIVERVIEW CONTROLLED LAND IMPACTED	117.1ha
	ACT GOVT. CONTROLLED LAND IMPACTED	51.1ha
	EMERGENCY LANDFILL AREA	1.1ha
	SITE BOUNDARY	
	APPROX. EXTENT OF EXISTING WASTE	

Nb: ALL LAND AREAS/BOUNDARIES ARE APPROXIMATE.

0 200 400 600m
SCALE 1:20,000 AT ORIGINAL SIZE

N

THE RIVERVIEW GROUP
WEST BELCONNEN LANDFILL SITE
PRELIMINARY WORKS

EPA VIC 500m BUFFER FROM EXISTING WASTE LIMIT

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Figure 02

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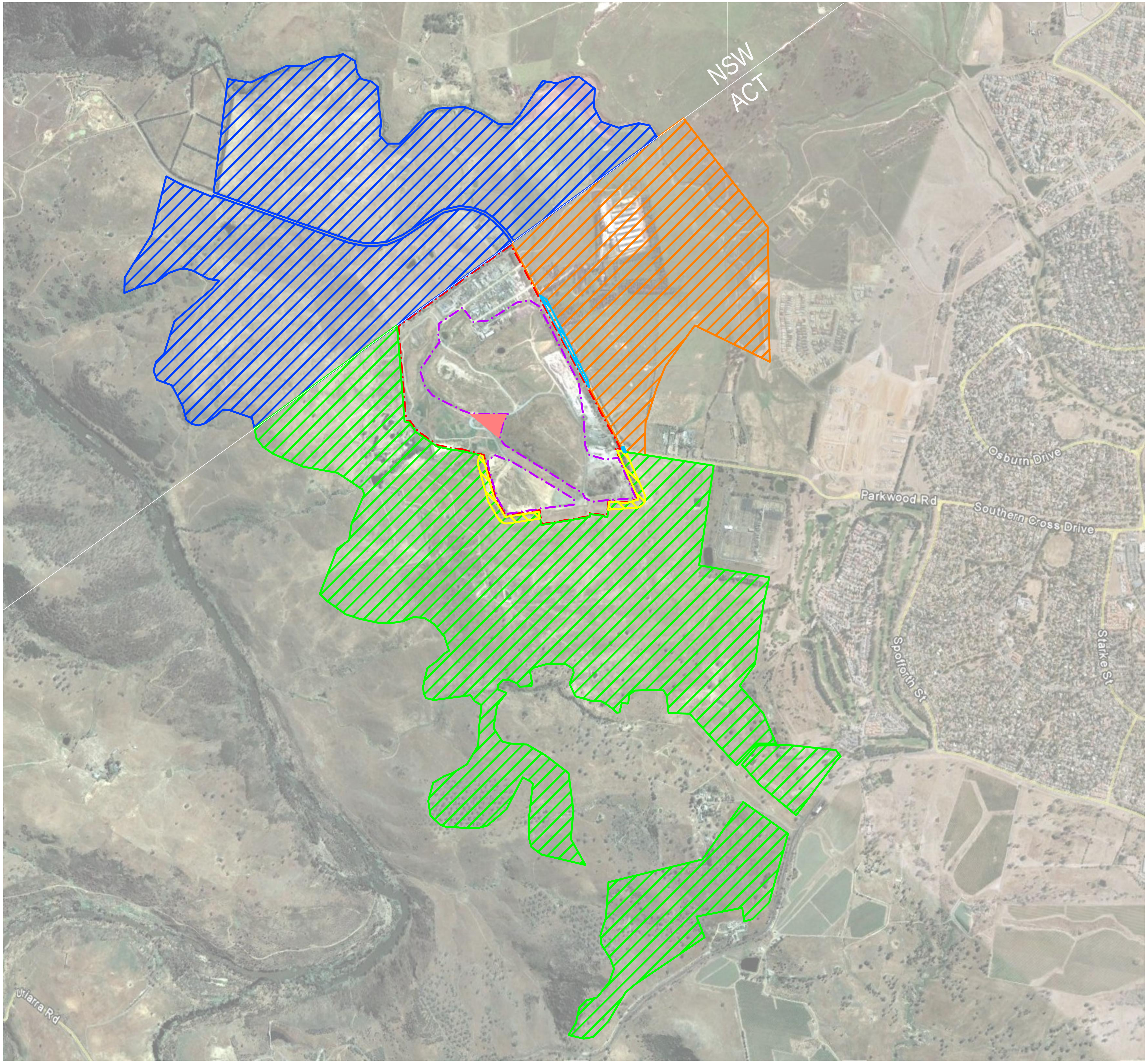

LEGEND

	RIVERVIEW CONTROLLED LAND (ACT)	345.0ha
	RIVERVIEW CONTROLLED LAND (NSW)	264.3ha
	ACT GOVT. CONTROLLED LAND (ACT)	126.2ha
	RIVERVIEW CONTROLLED LAND IMPACTED	3.6ha
	ACT GOVT. CONTROLLED LAND IMPACTED	0.9ha
	EMERGENCY LANDFILL AREA	1.1ha
	SITE BOUNDARY	
	APPROX. EXTENT OF EXISTING WASTE	

Nb: ALL LAND AREAS/BOUNDARIES ARE APPROXIMATE.

0 200 400 600m
SCALE 1:20,000 AT ORIGINAL SIZE

N

THE RIVERVIEW GROUP
WEST BELCONNEN LANDFILL SITE
PRELIMINARY WORKS

EPA VIC 50m BUFFER FROM WASTE LIMIT

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Date FEB 2012

Figure 03

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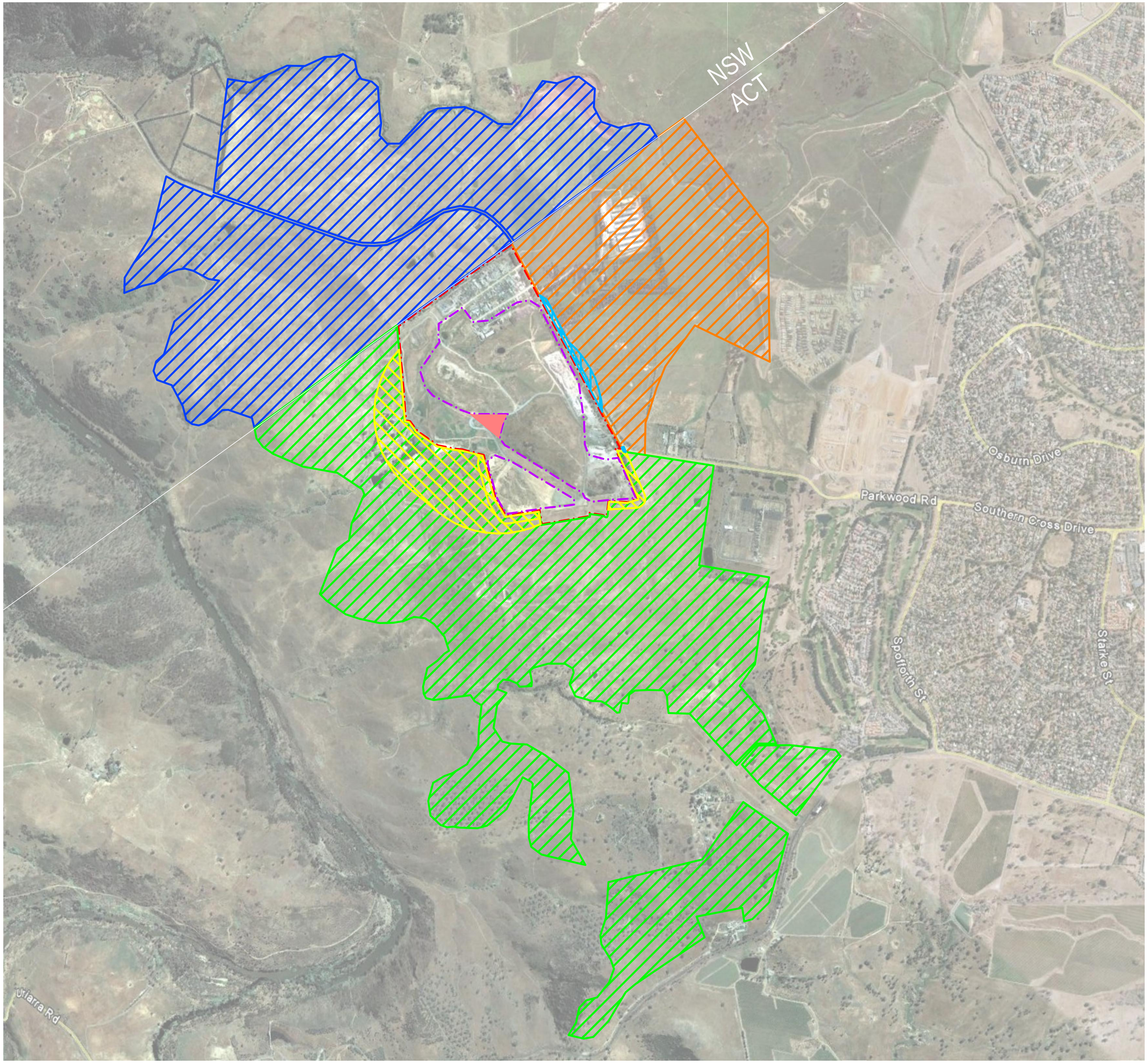

LEGEND

RIVERVIEW CONTROLLED LAND (ACT)	345.0ha
RIVERVIEW CONTROLLED LAND (NSW)	264.3ha
ACT GOVT. CONTROLLED LAND (ACT)	126.2ha
RIVERVIEW CONTROLLED LAND IMPACTED BY EMERGENCY LANDFILL AREA	26.1ha
ACT GOVT. CONTROLLED LAND IMPACTED BY EMERGENCY LANDFILL AREA	2.1ha
EMERGENCY LANDFILL AREA	1.1ha
SITE BOUNDARY	
APPROX. EXTENT OF EXISTING WASTE	

Nb: ALL LAND AREAS/BOUNDARIES ARE APPROXIMATE.

NOTE: GREEN WASTE FACILITY WOULD HAVE 200m BUFFER DISTANCE. (THIS MAY BE INSIDE SITE BOUNDARY)

0 200 400 600m
SCALE 1:20,000 AT ORIGINAL SIZE

N

THE RIVERVIEW GROUP
WEST BELCONNEN LANDFILL SITE
PRELIMINARY WORKS

EPA VIC 50m BUFFER FROM WASTE LIMIT & EPA VIC 500m BUFFER FROM EMERGENCY LANDFILL WASTE LIMIT

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Figure 04

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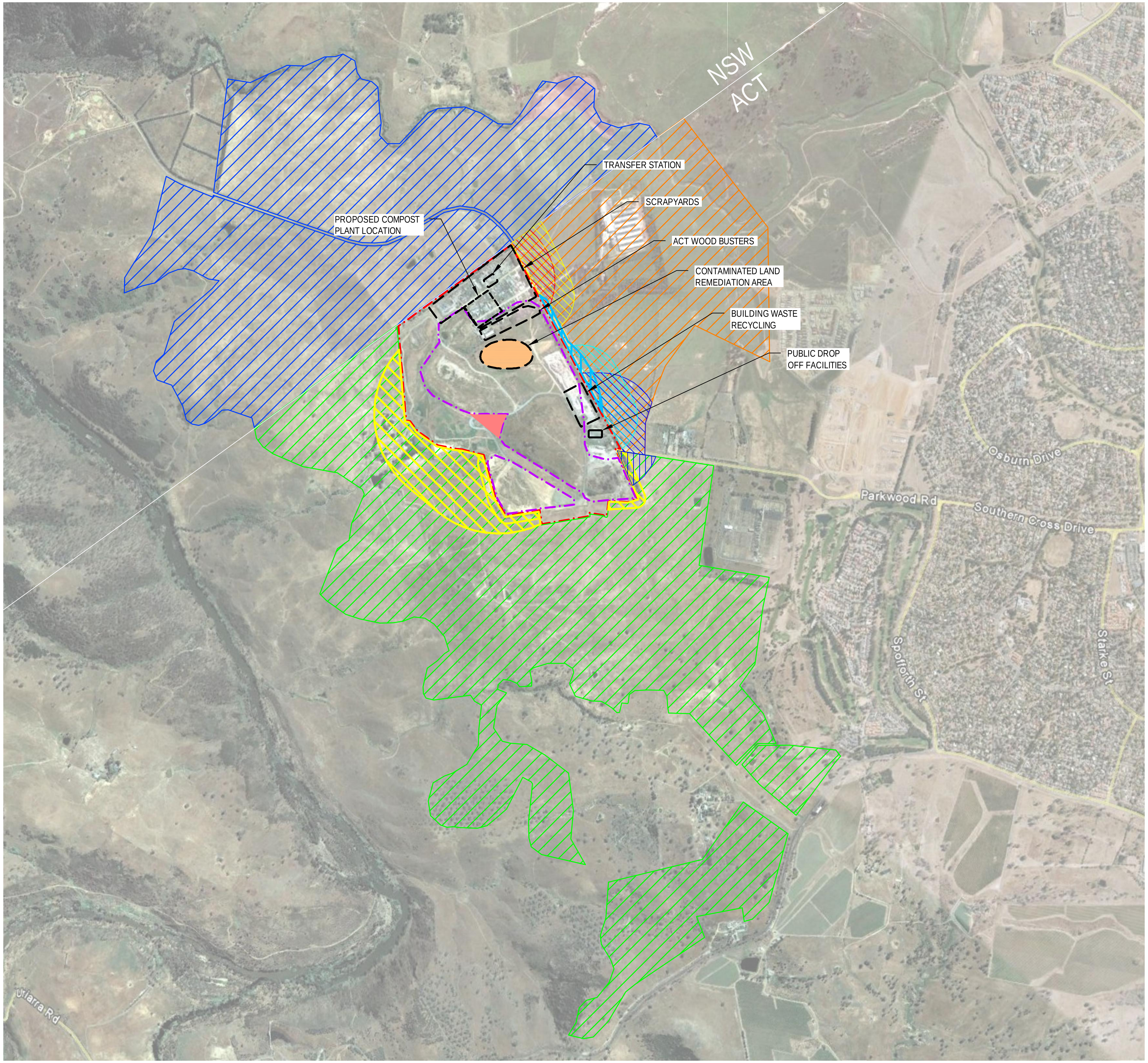

LEGEND

(green hatch)	RIVERVIEW CONTROLLED LAND (ACT)	345.0ha
(blue hatch)	RIVERVIEW CONTROLLED LAND (NSW)	264.3ha
(orange hatch)	ACT GOVT. CONTROLLED LAND (ACT)	126.2ha
(yellow hatch)	RIVERVIEW CONTROLLED LAND IMPACTED BY EMERGENCY LANDFILL AREA	26.1ha
(cyan vertical hatch)	ACT GOVT. CONTROLLED LAND IMPACTED BY EMERGENCY LANDFILL AREA	2.1ha
(blue vertical hatch)	RIVERVIEW CONTROLLED LAND IMPACTED BY PUBLIC DROP-OFF AREA BUFFER (300m)	1.9ha
(magenta vertical hatch)	RIVERVIEW CONTROLLED LAND IMPACTED BY GREEN WASTE BUFFER (1275m)	231.0ha
(dark blue hatch)	ACT GOVT. CONTROLLED LAND IMPACTED BY PUBLIC DROP-OFF AREA BUFFER (300m)	8.8ha
(magenta hatch)	ACT GOVT. CONTROLLED LAND IMPACTED BY GREEN WASTE BUFFER (1275m)	99.2ha
(red hatch)	ACT GOVT. CONTROLLED LAND IMPACTED BY TRANSFER STATION BUFFER (300m)	4.6ha
(light yellow hatch)	ACT GOVT. CONTROLLED LAND IMPACTED BY SCRAPYARDS BUFFER (200m)	8.8ha
(light cyan hatch)	ACT GOVT. CONTROLLED LAND IMPACTED BY BUILDING WASTE RECYCLING BUFFER (200m)	8.8ha
(yellow outline)	RIVERVIEW CONTROLLED LAND IMPACTED BY CONTAMINATED LAND BUFFER (200m)	0.4ha
(red fill)	EMERGENCY LANDFILL AREA	1.1ha
(red dash-dot line)	SITE BOUNDARY	
(purple dash-dot line)	APPROX. EXTENT OF EXISTING WASTE	
(black dashed line)	SITE FACILITY BOUNDARIES	
(black short-dashed line)	PROPOSED COMPOST PLANT LOCATION	

NOTES:

ALL LAND AREAS/BOUNDARIES ARE APPROXIMATE.
200m BUFFER DISTANCE FROM GREENWASTE PLANT IS ENTIRELY WITHIN SITE BOUNDARY IN ACT.
NO BUFFER REQUIRED FOR ACT WOODBUSTERS AS NON-OPERATIONAL.
TOTAL RIVERVIEW LAND IMPACTED: 29.8ha
TOTAL ACT GOVT. LAND IMPACTED: 20.6ha

0 200 400 600m
SCALE 1:20,000 AT ORIGINAL SIZE

N

THE RIVERVIEW GROUP
WEST BELCONNEN LANDFILL SITE
PRELIMINARY WORKS

EPA VICTORIA 50m BUFFER FROM EXISTING WASTE LIMIT & 500m BUFFER FROM EMERGENCY LANDFILL WASTE LIMIT

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Date | FEB 2012

Figure 05

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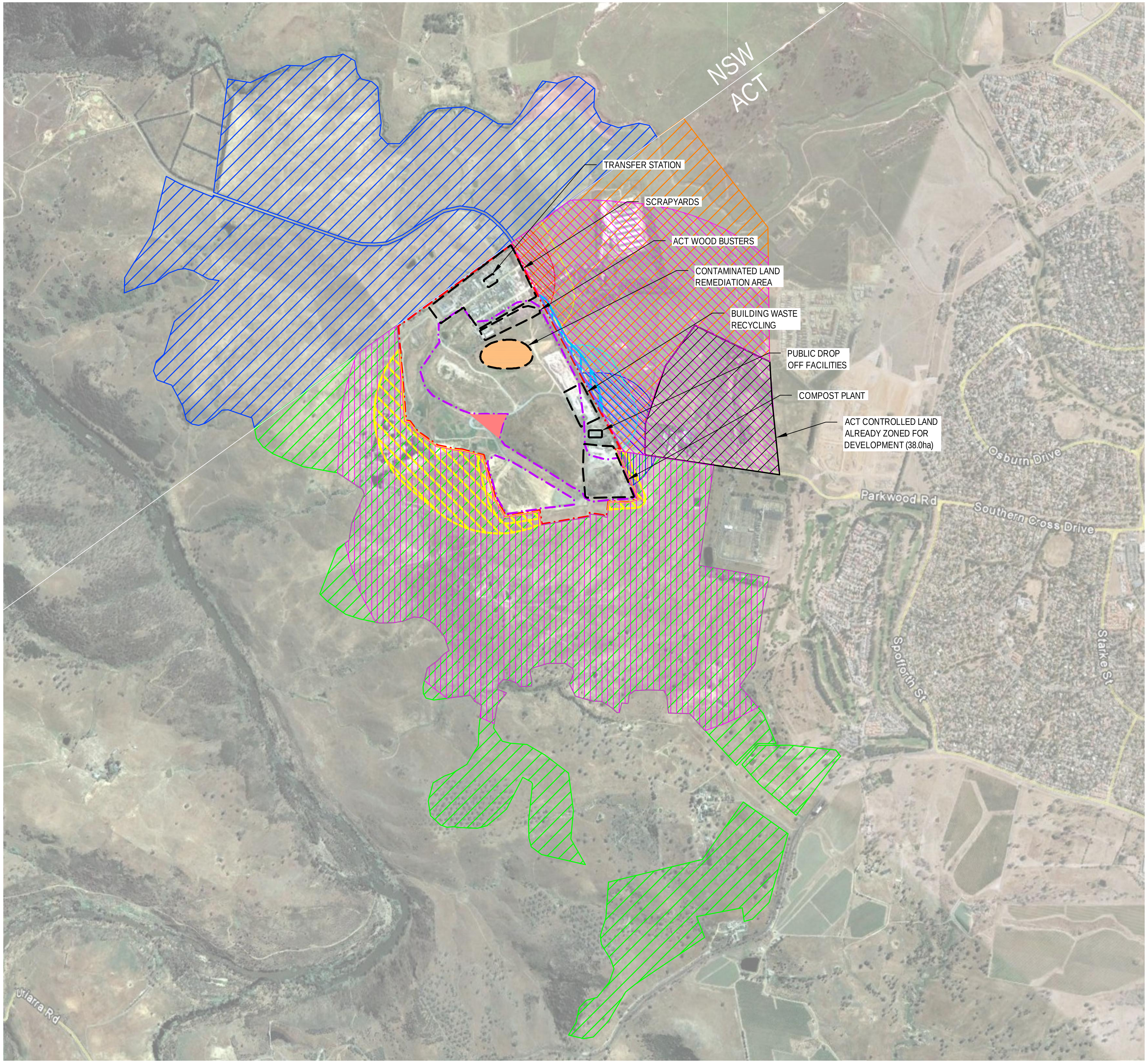

LEGEND

RIVERVIEW CONTROLLED LAND (ACT)	345.0ha
RIVERVIEW CONTROLLED LAND (NSW)	264.3ha
ACT GOVT. CONTROLLED LAND (ACT)	126.2ha
RIVERVIEW CONTROLLED LAND IMPACTED BY EMERGENCY LANDFILL AREA	26.1ha
ACT GOVT. CONTROLLED LAND IMPACTED BY EMERGENCY LANDFILL AREA	2.1ha
RIVERVIEW CONTROLLED LAND IMPACTED BY PUBLIC DROP-OFF AREA BUFFER (300m)	1.9ha
RIVERVIEW CONTROLLED LAND IMPACTED BY GREEN WASTE BUFFER (1275m)	231.0ha
ACT GOVT. CONTROLLED LAND IMPACTED BY PUBLIC DROP-OFF AREA BUFFER (300m)	8.8ha
ACT GOVT. CONTROLLED LAND IMPACTED BY GREEN WASTE BUFFER (1275m)	99.2ha
ACT GOVT. CONTROLLED LAND IMPACTED BY TRANSFER STATION BUFFER (300m)	4.6ha
ACT GOVT. CONTROLLED LAND IMPACTED BY SCRAPYARDS BUFFER (200m)	8.8ha
ACT GOVT. CONTROLLED LAND IMPACTED BY BUILDING WASTE RECYCLING BUFFER (200m)	8.8ha
RIVERVIEW CONTROLLED LAND IMPACTED BY CONTAMINATED LAND BUFFER (200m)	0.4ha
EMERGENCY LANDFILL AREA	1.1ha
SITE BOUNDARY	
APPROX. EXTENT OF EXISTING WASTE	
SITE FACILITY BOUNDARIES	

NOTES:

ALL LAND AREAS/BOUNDARIES ARE APPROXIMATE.
NO BUFFER REQUIRED FOR ACT WOODBUSTERS AS NON-OPERATIONAL.
TOTAL RIVERVIEW LAND IMPACTED: 231.0ha
TOTAL ACT GOVT. LAND IMPACTED: 99.2ha
TOTAL ACT GOVT. LAND FOR DEVELOPMENT IMPACTED: 39.2ha

0 200 400 600m
SCALE 1:20,000 AT ORIGINAL SIZE
N

THE RIVERVIEW GROUP
WEST BELCONNEN LANDFILL SITE
PRELIMINARY WORKS

EPA VIC RECYCLING/RESOURCE
RECOVERY FACILITIES BUFFER DISTANCES

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Figure 06

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
01	M Welsh	D Gamble		FINAL DRAFT		19/6/14
02	M Welsh	D Gamble		REVISED FINAL DRAFT		20/6/14
03	M Welsh	D Gamble		FINAL		25/6/14

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