

Logan Greyhound Facility



CONTAMINATED SITE INVESTIGATION

Draft

March 2010



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1. Introduction

Greyhounds Queensland Limited (GQL) is planning the development of the Logan Greyhound Facility (“the Project”) at Cronulla Park, Slacks Creek (“the site”). Cronulla Park was formerly used a landfill (“the Landfill”) between the 1970s and 1980s. A plan showing the location of the site is provided in **Figure 1, Appendix A**.

The proposed development includes:

- main facilities building with an open air viewing stand;
- kennel block;
- maintenance shed;
- greyhound racing track;
- car park with 70 spaces;
- trailer park for trainers with 50 spaces; and
- internal access roads with connections to Kingston Road and Compton Road.

Plans of the proposed development are provided in **Appendix B**.

GQL has engaged Sinclair Knight Merz (SKM) to undertake a Contaminated Site Investigation (“the Investigation”) of the site. The aims of the Investigation were to establish:

- whether the site in its current condition poses an unacceptable risk to human health and/or the receiving environment; and
- whether remediation will be required to enable the site to be used for a commercial land use (greyhound racing facility), and if so, the required remedial measures.

The primary objectives of the Investigation were:

- to investigate the quality of groundwater entering and exiting the site, and whether the groundwater exiting the site poses an unacceptable risk to the receiving environment;
- to investigate the presence of groundwater underlying the site, and whether the site is likely to pose an unacceptable risk to this aquifer;
- to investigate the risk to human health from the material used in the capping of the site, and the permeability of this material;
- to investigate the concentration of landfill gas in shallow ground deposits on the periphery of the Landfill; and
- to investigate the risk to human health from shallow ground conditions (<0.3 m below ground level or bgl).

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This report provides a summary of the findings of the Investigation and should be read in conjunction with the limitations described in **Appendix I**.

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2. Background Information

2.1. Site Description

The site comprises 10.24 hectares of Crown Land located at the corner of Compton Road and Kingston Road, Slacks Creek, Queensland. The land is described as Lot 658 on Plan SL12298. Current title records show that the site is held in trust by Logan City Council (LCC), as gazetted on the 25 June 1988. The designated purpose of the site is local government (entertainment and recreation). A copy of the current certificate of title and registered plan is provided in **Appendix H**.

2.2. Surrounding Land Uses

Light industrial and commercial properties are located on the northern, eastern, and southern boundaries of the site. Kingston Road bounds the western portion of the site, and light industrial and commercial properties are located to the west of Kingston Road.

Land uses within the vicinity of the site with the potential to cause contamination include the following:

- Up-gradient:
 - service station across Kingston Road
 - two car service centres across Kingston Road
 - two car yards and a car rental agency across Kingston Road¹
- Cross-gradient:
 - smash repairs adjacent to the northern boundary
 - two car body repairs workshops adjacent to the southern boundary
 - air conditioning repairs workshop adjacent to the southern boundary
- Down-gradient:
 - exhaust repair workshop
 - panel beater workshop
 - suspension workshop
 - commercial bakery and truck parking facility
 - radiator repair workshop.

¹ These land uses have the potential for petroleum product storage.



2.3. Environmental Management Register

The site is listed on the Environmental Management Register (EMR) for the notifiable activity “Landfill”. The Queensland Department of Environment and Resource Management (DERM) has advised that the site is not managed under a Site Management Plan (SMP).

The site is not listed on the Contaminated Land Register (CLR).

A copy of the EMR search result is provided in **Appendix H**.

2.4. Topography and Drainage

The site and surrounding land slopes in an easterly direction towards Slacks Creek. Surface water discharges to Slacks Creek which is located approximately 320 m east of the site.

The topography and overland flow drainage of the site is shown in **Figure 3, Appendix A**.

The highest point of the site is approximately 34.5 m Australian Height Datum (AHD) close to Kingston Road and falls to approximately 22.2 m AHD close to the north east corner industrial lots. The average gradients on the site are relatively flat ranging from 0.8 % to 2.0 %. The main form of drainage is a combination of overland sheet flows and open channel flows. The north east corner is steeper than the majority of the site with grades up to a maximum of 12.5 % towards the east.

Several low bunds have been placed across the predominant gradient of the site (in a north-south configuration) which intercept and divert the overland flow towards the north and south into existing open channel drains.

An open channel drain to the south and east separates the site from the adjoining industrial lots. The open channel drain conveys surface runoff from Kingston Road, cross-catchment flows from across Kingston Road, and from several culverts from the south. The open channel eventually discharges into a large open chamber with its invert level (base) well below the level of the open channel base of 20.4 m AHD.

The north eastern portion of the site falls to the north and north east into an earth drain alongside Compton Road and into existing stormwater gully pits along Cronulla Court.

Water quality in Slacks Creek is not monitored by LCC or DERM. The Healthy Waterways initiative of the Queensland Government provides a long-term data set for Logan River (Slacks Creek is a tributary of the Logan River) (South-east Queensland Healthy Waterways Partnership 2007). The overall Waterway Report Card indicates that Logan Catchment is generally in a poor condition. Both nutrient cycling and physico-chemical indicators suggest that there is some level of degradation to the ecosystem, and has resulted in a rating of “D” (South-east Queensland Healthy



Waterways Partnership 2009). This rating has been relatively consistent since monitoring of the Catchment began in 1999, and has been based on high nutrient loading in the Catchment. High nutrient loads have historically been attributed to a range of factors such as urban (residential, commercial, and industrial) and rural land uses, and discharges from sewage treatment plants.

2.5. Regional Geology

The regional geology of the site is described in the Beenleigh area (1:100,000 series) as: alluvium soils, mainly clay, silt and gravel overlaying shale, siltstone and sandstone (with possible coal seams). The regional geology is part of the tertiary Oxley Group, a subset of the early tertiary continental basins of the area (Moreton Regional Geology Map 1980) (CMPS&F Environmental, May 1995. *Preliminary Site Investigation and Management Plan for The Former Compton Road Landfill Site* ("the CMPS&F Report")).

The geology encountered on the site during the investigation is described in **Section 6.1**. A cross-section showing the conceptual geology on the site is provided in **Figure 5, Appendix A**.

2.6. Regional Hydrogeology

A review of the Groundwater Resources Map of Queensland (1987) indicates that regional groundwater yield is hosted in sedimentary strata and is expected to be less than 5 L/sec. The total dissolved solids (TDS) in groundwater is generally within the range of 500-1500 mg/L, and is suitable for domestic applications (e.g. potable water, recreation, irrigation) and stock watering. Further information on groundwater encountered in sedimentary on the site is provided in **Section 6.2**.

Based on topography groundwater flow direction across the site is expected to be northeast towards Slacks Creek.

A search of the DERM groundwater bore records indicates that there are no registered operational bores (groundwater users) in the vicinity of the site. The closest operational registered bore is approximately 0.7 km north of the site (registration number – 134259). This bore is sub-artesian and although registered as a potable water source, notes on the bore card indicate that it supplies water for garden irrigation only. The screened interval of this bore is between 8 m bgl and 30 m bgl.

2.7. Historical Land Use

The CMPS&F Report states that the site was used as a municipal landfill from the 1970s to 1983. This is consistent with historical aerial photography which shows the site in use as a landfill during this time period. Further information regarding the operation and closure of the Landfill is provided in **Section 2.8**.



Following closure of the Landfill, the site has been used for open space recreational purposes by the general public, such as bike riding, and dog walking. The current configuration of the site does not provide park facilities such as seating, cooking, and playgrounds which would facilitate more frequent recreational use of the site.

Prior to the use of the site as a landfill in the 1970s, the site was vegetated and undeveloped. Further information on the history of the site based on a review of the historical aerial photography is provided in **Table 2-1**. A copy of the historical aerial photographs reviewed is provided in **Appendix H**.

■ **Table 2-1 Historical Aerial Photography**

Year	Site Description
1955	The site is covered in trees and other vegetative cover. A small valley can be seen running to the east toward Slacks Creek. This is presumed to be the tributary aforementioned.
1968	The site is predominantly covered in trees. A dirt track runs west to east across the site, and there is a small clearing present in the middle.
1973	Distinct zones of activity (areas of disturbed land) can be seen across the site, however the nature of activity (e.g. type of waste material being disposed) within each zone cannot be determined. These zones generally align with the known differing disposal areas. There are several buildings visible in the south western corner of the site, consistent with the area used for washdown. There is a heavily vegetated strip to the south and west of the site.
1983	The site is bare soil, with few areas of what appears to be weed and grass growth. A small area of concrete or roofing is present in the south western corner, consistent with the area used for washdown. Tree cover to the south and west of the site has thinned. The date of this photo coincides with the closure of the facility.
1993	The site is grassed, and several dirt access roads pass across the property. No buildings are visible on-site. No vegetative cover exists along the southern border of the site.
1997	The entire surface of the site has been cleared and appears to have been re-capped.
2002	As per the 1993 aerial photography. The general location of access roads has changed across the site.

2.8. Landfill Operation and Closure

The following provides a summary of the operation and closure of the Landfill, and is based on the CMPS&F Report.

2.8.1. Landfill Operation

A tributary of Slacks Creek historically ran through site. Prior to the commencement of the construction of the Landfill, the tributary was diverted around the site in an open drain located on



the southern and eastern boundary of the site. The location of the former tributary is shown as Area 7 in **Figure 4, Appendix A**.

The Landfill was operated by Albert Shire Council (now LCC), and JJ Richards & Sons Pty Ltd. The Landfill was formed using a method which involved the excavation of trenches, and then the placement and compaction of wastes within each trench. The quantity of waste received at the site is not known. The maximum depth of waste was said to be 4 m in the CMPS&F Report. The Investigation however found the depth of waste to be up to approximately 10 m bgl, and waste has been placed directly over natural ground strata including weathered sandstone, and sandstone (refer to **Section 6.1**).

Based on the CMPS&F Report it is understood that the construction of the Landfill did not include the installation of a liner, or leachate and landfill gas collection system. This was confirmed during the undertaking of the Investigation.

Waste Acceptance

Based on the CMPS&F Report, wastes which were accepted at the Landfill included:

- domestic waste;
- commercial and light industrial solid waste;
- sanitary solid waste; and
- construction and demolition waste.

The Landfill may have also received asbestos, and hazardous domestic wastes (e.g. paints and pesticides). The Landfill received approximately 2,000 to 3,000 animal carcasses including dogs, cats, cows and horses; these were placed in Area 3 and Area 4 (refer to **Figure 4, Appendix A**).

Wastes which were not accepted at the Landfill included:

- heavy industrial waste;
- hazardous solid waste;
- medical waste; and
- liquid waste (hazardous and non-hazardous).

Landfill Layout

The layout of the Landfill can be divided into 10 areas based on the type of waste received, and when the areas was utilised. These areas are shown in **Figure 4, Appendix A**, and are summarised in **Table 2-2**.



■ **Table 2-2 Landfill Layout**

Area No.	Wastes Received	Comments
1	Domestic refuse	Wastes were placed in north-south aligned trenches
2	Domestic refuse	Wastes were placed in east-west aligned trenches
3	Sanitary waste and animal remains	Wastes were placed in east-west aligned trenches
4	Sanitary waste and animal remains	Wastes were placed in small trenches located between existing trees
5	Steel and tyres	None
6	None	None
7	Domestic refuse and light industrial	Historical creek alignment which was filled with wastes
8	None	Workshop and washdown area
9	General waste	None
10	None	None

Other Infrastructure

Infrastructure located at the site which was decommissioned following closure of the Landfill included a sewerage line and sewage holding tank, site buildings, hardstanding, and the washdown area.

2.8.2. Landfill Closure

The Landfill was capped using a clay based soil. After the closure of the Landfill in 1983, Albert Shire Council used the site for the stockpiling of soil and concrete demolition wastes. These wastes were subsequently removed.

In 1991 a new sewerage line was installed at the northern boundary of the site. The installation of the sewer line required trenches to be cut into the northern and southern embankments of the Landfill. It was stated in the CMPS&F Report that geofabric was laid over the trenches to contain exposed waste and act as a drainage medium for leachate collection into the sewerage line.

The CMPS&F Report made a number of recommendations for the retrofitting of the Landfill post closure. **Table 2-3** provides a summary of these measures, and whether they were implemented based on discussions with LCC (B. Lee, 2009), and site observations.

■ **Table 2-3 CMPS&F Recommended Landfill Retrofit Measures**

CMPS&F Recommendation	Implementation
1. Install a landfill gas venting system	LCC has installed four landfill gas vents. LCC however does not have records on how and when the vents were installed. A review of the aerial photography suggests that they may have been installed between 1997 and 2003.



CMPS&F Recommendation	Implementation
2. Install a leachate collection system to collect leachate seeping from embankments	The CMPS&F Report states that sewer lines installed on the northern boundary of the site included a mechanism to enable the collection of leachate in the line. It is not known whether the system installed is effective; however, seepage from the eastern embankment of the landfill was observed during the Investigation.
3. Install a surface water drainage system to direct rainfall runoff off the surface layer	LCC has installed diversion drains over the surface to assist with the shedding of rainfall runoff off the surface layer. Additional surface material is said to have been placed over the Landfill in 1998 ² however LCC has no records to confirm whether this occurred.
4. Remove the stockpiled soil and concrete demolition waste	LCC has removed the stockpiled material.
5. Remove the remaining landfill infrastructure including hardstanding and a building	LCC has removed the remaining infrastructure.
6. Place additional surface material over the eastern and northern embankment to cover over exposed waste, and vegetate embankments	LCC has placed additional surface material over a majority of the embankments; exposed waste is no longer visible. The embankments have been revegetated.
7. Remove the underground fuel tank located in Area 3	LCC has advised that the tank has been removed, however no record of its removal is available. Verification of this is discussed in Section 9.

2.9. Historical Analytical Data

This section provides a summary of the soil, groundwater and landfill gas data for the site. This includes data collected by CMPS&F in 1995, and data collected by LCC from July 2000 to August 2008.

2.9.1. Soil Data

Six samples of the Landfill surface material were collected by CMPS&F in 1995. The location of the soil samples is shown in **Figure 2, Appendix A**.

The samples were analysed for metals, asbestos, and organochlorine pesticides. All samples had metal analytes with concentrations which were below the health-based NEPM³ HIL-F guidelines for a commercial/industrial land use. Asbestos and organochlorine pesticides were not detected in any soil samples analysed.

² CPR Group. 2004. Regional Trail Bike Site Survey Site Assessment, Cronulla Park, Kingston Road and Compton Road, Slacks Creek

³ the National Environment Protection (Assessment of Site Contamination) Measure 1999 ("the NEPM")



2.9.2. Groundwater Data

LCC has monitored groundwater quality from three monitoring wells (CR13, CR14 and CR15, “the LCC Wells”) since July 2000. The location of the LCC wells is shown in **Figure 2, Appendix A**. LCC has advised that records of how the wells were installed are not available. The depths of these wells are approximately 4.4, 8.4, and 5.0 m bgl respectively. Based on the location of the wells either on the other side of the drainage channel or within the remnant vegetated area to the west of the site, it is considered likely that the monitoring wells targeted groundwater in the weathered sandstone.

Data has been compared to a combination of the following guidelines:

- Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters (“ANZECC Guideline”).
- The Netherlands Ministry of Housing, Spatial Planning and Environment's *Circular on target values and intervention values for soil remediation* (2000) (“the Dutch Guidelines”) which consider both the risk to human health and the environment;
- The National Health and Medical Research Council (2004) *Australian Drinking Water Guidelines* (“the Australian Drinking Water Guidelines”); and
- *United States Environmental Protection Agency (2009) Region 9 Preliminary Remediation Goals* (“the USEPA guidelines”).

A full description of the Human Health Assessment Criteria and Environmental Assessment Criteria adopted in this investigation has been included in **Sections 4.3.1** and **4.3.2** respectively.

The following provides a summary of the analytical data for the LCC wells, and a comparison of these with the Human Health Assessment Criteria and Environmental Assessment Criteria. A full tabulation of the analytical results is provided in **Appendix D.2.1**.



Monitoring Well CR13

Monitoring well CR13 is located down gradient and east of the Landfill. **Table 2-4** provides a summary of the groundwater monitoring results for CR13. The analytes copper, lead, zinc, ammonia, total phosphorus, and TPH exceeded the Environmental Assessment Criteria in some of the samples analysed. Ammonia exceeded the Human Health Assessment Criteria in all of the samples analysed. TPH exceeded the Human Health Assessment Criteria in some of the samples analysed.

■ **Table 2-4 CR13 Groundwater Results 2000 to 2008**

Analyte	No. of Samples	Minimum Value	Maximum Value	Quartile Range	Average $\pm$ Standard Deviation	Environmental Assessment Criteria	No. of Samples Exceeding Environmental Assessment Criteria	Human Health Assessment Criteria	No. of Samples Exceeding Human Health Assessment Criteria
Inorganics (mg/L)									
pH (pH units)	30	4.82	6.21	5.48 - 5.6	5.47 ± 0.27	6.5-8.0	-		-
Aluminium	1	0.05	0.05	0.05 - 0.05	n/a $\pm$ n/a		-		-
Iron	30	<0.01	8.3	1.42 - 3	1.84 ± 1.86		-		-
Copper	6	<0.001	0.012	0.001 - 0.008	0.004 ± 0.005	0.0025	1	1	-
Manganese	30	0.03	0.08	0.04 - 0.05	0.05 ± 0.01	3.6	-	0.5	-
Nickel	6	0.003	0.006	0.005 - 0.006	0.005 ± 0.001	0.017	-	0.1	-
Lead	6	<0.001	0.03	0.001 - 0.002	0.006 ± 0.012	0.0094	1	0.05	-
Zinc	30	<0.003	0.069	0.01 - 0.015	0.014 ± 0.013	0.031	2	5	-
Ammonia	30	6.5	39.3	13 - 15.7	13.8 ± 6.3	2.3	30	0.5	30
Nitrate	30	<0.002	1.9	0.02 - 0.095	0.181 ± 0.418	17	-	10000	-
Phosphate	17	<0.1	0.1	n/a	n/a		-		-
Total Phosphorus	6	0.03	1.21	0.4 - 0.7	0.48 ± 0.46	0.05	5		-
Organics (μg/L)									
TPH (C6-C9)	6	<20	<20		n/a		-		-
TPH (C10-C14)	6	<50	293		131 ± 95		-		-
TPH (C15-C28)	6	<100	1230		437 ± 435		-		-
TPH (C29-C36)	6	<50	265		97 ± 85		-		-
TPH (C10-C36)	6	<220	1788		663 ± 609	600	3	600	3



Monitoring Well CR14

Monitoring well CR14 is located in the south western corner (up-gradient) of the Landfill. **Table 2-5** provides a summary of the groundwater monitoring results for CR14. The analytes copper, nickel, lead, zinc, and total phosphorus exceeded the Environmental Assessment Criteria in some of the samples analysed.

■ **Table 2-5 CR14 Groundwater Results 2000 to 2008**

Analyte	No. of Samples	Minimum Value	Maximum Value	Quartile Range	Average $\pm$ Standard Deviation	Environmental Assessment Criteria	No. of Samples Exceeding Environmental Assessment Criteria	Human Health Assessment Criteria	No. of Samples Exceeding Human Health Assessment Criteria
Inorganics (mg/L)									
pH (pH units)	28	3.35	6.86	4.44 - 4.73	4.54 $\pm$ 0.65	6.5-8.0	-		-
Aluminium	1	0.08	0.08	0.08 - 0.08	n/a $\pm$ n/a		-		-
Iron	28	<0.002	41	0.071 - 0.133	1.59 $\pm$ 7.726		-		-
Copper	6	0.003	0.089	0.008 - 0.015	0.021 $\pm$ 0.034	0.0025	6	1	-
Manganese	28	<0.003	0.21	0.026 - 0.031	0.034 $\pm$ 0.036	3.6	-	0.5	-
Nickel	6	0.002	0.027	0.003 - 0.004	0.007 $\pm$ 0.01	0.017	1	0.1	-
Lead	6	<0.001	0.017	0.001 - 0.001	0.004 $\pm$ 0.007	0.0094	1	0.05	-
Zinc	28	<0.003	0.031	0.011 - 0.019	0.013 $\pm$ 0.007	0.031	1	5	-
Ammonia	28	<0.01	0.12	0.1 - 0.1	0.07 $\pm$ 0.04	2.3	-	0.5	-
Nitrate	28	<0.004	0.06	0.02 - 0.033	0.029 $\pm$ 0.024	17	-	10000	-
Phosphate	15	<0.1	<0.1	n/a	n/a		-		-
Total Phosphorus	6	0.28	1.02	0.6 - 0.83	0.62 $\pm$ 0.29	0.05	6		-
Organics (μg/L)									
TPH (C6-C9)	6	<20	<20		n/a		-		-
TPH (C10-C14)	6	<50	<50		n/a		-		-
TPH (C15-C28)	6	<100	105		101 $\pm$ 2		-		-
TPH (C29-C36)	6	<20	55		46 $\pm$ 13		-		-
TPH (C10-C36)	6	<160	160		210 $\pm$ 24	600	-	600	-



Monitoring Well CR15

Monitoring well CR15 is located along the southern boundary of the Landfill. **Table 2-6** provides a summary of the groundwater monitoring results for CR15. Total phosphorus exceeded the Environmental Assessment Criteria in some of the samples analysed. Ammonia exceeded the Human Health Assessment Criteria in the majority of the samples analysed.

■ **Table 2-6 CR15 Groundwater Results 2000 – 2008**

Analyte	No. of Samples	Minimum Value	Maximum Value	Quartile Range	Average $\pm$ Standard Deviation	Environmental Assessment Criteria	No. of Samples Exceeding Environmental Assessment Criteria	Human Health Assessment Criteria	No. of Samples Exceeding Human Health Assessment Criteria
Inorganics (mg/L)									
pH (pH units)	28	5.31	6.77	5.92 - 6.13	5.97 $\pm$ 0.36	6.5-8.0	-		-
Aluminium	1	0.2	0.2	0.2 - 0.2	n/a $\pm$ n/a		-		-
Iron	28	<0.02	78	9.3 - 14	10.99 $\pm$ 14.55		-		-
Copper	4	<0.001	0.001	0.001 - 0.003	n/a $\pm$ n/a	0.0025	-	1	-
Manganese	28	0.022	0.08	0.039 - 0.045	0.039 $\pm$ 0.011	3.6	-	0.5	-
Nickel	4	<0.001	0.009	0.002 - 0.004	n/a $\pm$ n/a	0.017	-	0.1	-
Lead	4	<0.001	0.002	0.001 - 0.001	n/a $\pm$ n/a	0.0094	-	0.05	-
Zinc	28	<0.001	0.025	0.007 - 0.01	0.007 $\pm$ 0.005	0.031	-	5	-
Ammonia	28	0.06	0.8	0.6 - 0.7	0.58 $\pm$ 0.16	2.3	-	0.5	23
Nitrate	28	<0.01	0.16	0.02 - 0.03	0.03 $\pm$ 0.03	17	-	10000	-
Total Phosphorus	4	<0.01	0.7	0.13 - 0.31	n/a $\pm$ n/a	0.05	3		-
Organics (μg/L)									
TPH (C6-C9)	4	<20	<20		n/a		-		-
TPH (C10-C14)	4	<50	89		n/a $\pm$ n/a		-		-
TPH (C15-C28)	4	<100	165		n/a $\pm$ n/a		-		-
TPH (C29-C36)	4	<50	99		n/a $\pm$ n/a		-		-
TPH (C10-C36)	4	<55	353		n/a $\pm$ n/a	600	-	600	-

Summary of Groundwater Data

pH

Although there was some variation in pH between July 2000 and August 2008 (particularly in CR14), the overall change in pH has been small in all three wells (-0.08 in CR13, -0.3 in CR14 and +0.34 in CR15). All wells consistently reported pH levels which were mildly acidic and below the Environmental Assessment Criteria range of 6.5 to 8.0.



Metals

The concentration of zinc exceeded the Environmental Assessment Criteria of 0.008 mg/L in samples from all three groundwater monitoring wells. There are generally no trends in zinc concentration over time.

Copper exceeded the Environmental Assessment Criteria in all samples from CR14. The concentration of copper in samples from CR13 and CR15 were generally below the LOR and/or the Environmental Assessment Criteria.

In general, no other metals analytes regularly exceeded the Environmental Assessment Criteria.

Ammonia

Ammonia concentrations were reported above the Environmental Assessment Criteria of 2.3 mg/L in CR13 (down-gradient of the Landfill). The concentrations of ammonia in CR13 were consistently higher than the samples from CR14 and CR15. The monitoring data indicates that the concentration of ammonia in CR13 has decreased over time, from 39.9 mg/L in October 2000 to 12 mg/L in August 2008.

Ammonia concentrations exceeded the Human Health Assessment Criteria (0.01 mg/L) in all of the samples from CR13 and CR15, and approximately half the samples in CR14.

Nitrate

Nitrate concentrations were below the Environmental Assessment Criteria in all samples from CR13, CR14, and CR15. Although variable over time, higher concentrations of nitrate have generally been found in the samples from CR13 in comparison to the other groundwater samples.

Total Phosphorus and Phosphate

The majority of samples analysed from CR13, CR14, and CR15 had concentrations of total phosphorus which exceeded the Environmental Assessment Criteria in monitoring events in 2002. Total phosphorus has not been monitored since 2002. Phosphate was included in the monitoring program from 2004-2008 and was found to be below laboratory detection limits in all monitoring wells.

Total Petroleum Hydrocarbons (TPH)

TPH was included in the monitoring program from July 2000 to January 2002. During this time period TPH was reported in the samples from CR13 at concentrations which exceeded the Environmental Assessment Criteria (600 µg/L). TPH was detected in some of the samples from CR14 and CR15 with concentrations which were below the Environmental Assessment Criteria.

Additional testing to confirm the nature or species of the hydrocarbons was not undertaken as part of the LCC monitoring program. However it should be noted that the TPH measured may be



comprised of non-polar based organic substances present in landfill leachate which were being generated through the decomposition of putrescible waste materials rather petroleum products, for reasons outlined in **Section 7.2.3**.

2.9.3. Groundwater Levels

Groundwater levels were monitored in 2003 and 2004. Based on this data the inferred groundwater flow direction is to the north east towards Slacks Creek.

2.9.4. Landfill Gas Data

A landfill gas assessment was undertaken by CMPS&F in 1995. The investigation included the sampling and analysis of landfill gas from the monitoring wells G1, G2, G3, G5, G6, G7 and GW3. The CMPS&F Report indicates that these wells were constructed to allow gas monitoring, and included measures such as appropriately screened intervals and specialised free-venting well caps. The gas assessment detected elevated concentrations of methane from monitoring wells within the Landfill with concentrations which exceeded the lower explosive limit (LEL) for methane (5%⁴). However the concentrations of methane in the monitoring wells located around the boundary of the Landfill were below the LEL.

LCC has monitored landfill gas concentrations from monitoring wells located around the boundary of the site since July 2000. The monitoring wells which have been monitored include GW1, G2, G3, CR13, CR14 and CR15. The location of the monitoring wells is show in **Figure 2, Appendix A**. Since monitoring commenced in July 2000, the concentrations of methane in all boundary monitoring wells have been found to be less than the LEL.

The monitoring data is summarised in **Appendix D.3.1**.

⁴ ERA 75 – Waste Disposal, Landfill siting, design, operation and rehabilitation.



3. Conceptual Site Model

3.1. Contaminants of Concern

Based on the site history described in **Section 2.8** and previous investigations of the site (refer to **Section 2.9**), potential contaminants of concern include the following:

- A broad range of metals (including arsenic, cadmium, chromium, nickel, lead, and zinc) associated with a range of materials potentially disposed at the site.
- Ammonia and other landfill leachate products formed during the decomposition of organic materials (e.g. fatty acids).
- Organochlorine/organophosphate pesticides (OCP/OPP) discarded as agricultural wastes.
- Volatile or semi-volatile organic compounds (VOCs/SVOCs), including polycyclic aromatic hydrocarbons (PAHs), associated with the disposal of lubricants, paints, oils and fumigants; and the burning of various wastes.
- Total petroleum hydrocarbons (TPH) and benzene, toluene, ethylbenzene and xylenes (BTEX compounds) associated with the disposal of fuels, lubricants and oils.
- Polychlorinated biphenyls (PCBs) associated with transformers, refrigerants and fluorescent lighting.
- Asbestos containing materials (ACM) such as fibrous sheeting.

3.2. Potential Pathways

Potential pathways for which contamination may cause a risk to specific receptors include:

- Human health:
 - inhalation of soil through dust;
 - ingestion of soil through handling;
 - dermal absorption from soils through handling; and
 - inhalation of vapours and landfill gases.
- Environmental:
 - migration of potential contaminants in surface water runoff; and
 - migration of potential contaminants in groundwater.

3.3. Receptors

The current potential on and off-site receptors include:



- On-site:
 - members of the public; and
 - future users of the site (including construction workers, staff, and patrons).
- Off-site:
 - down gradient properties;
 - groundwater which is expected to provide to provide a base flow to Slacks Creek; and
 - surface water (Slacks Creek).

Slacks Creek is a highly disturbed system which has been heavily modified from its natural state. Slacks Creek is not a recreational water body or used as a source of potable water.

Groundwater within the region is generally not used as a potable resource. The closest operational registered bore is approximately 0.7 km to the north of the site. This bore is sub-artesian and although registered as a potable water source, notes on the bore card indicate that it supplies water for garden irrigation only.

3.4. Potential Pollutant Linkages

Table 3-1 provides a summary of the potential source-pathway-receptor (pollutant) linkages with respect to human health.

■ **Table 3-1 Potential Pollutant Linkages With Respect to Human Health**

Source	Pathways	Receptors
Potential contaminants in soil, landfill leachate	Ingestion of soil through handling	1) Members of the public accessing the site
	Dermal absorption through skin through handling	2) Future site workers
	Inhalation of airborne dust and vapours, and build up landfill gases in confined spaces	3) Users of down gradient Properties

Table 3-2 provides a summary of the potential source-pathway-receptor (pollutant) linkages with respect to the environment.



■ **Table 3-2 Potential Pollutant Linkages With Respect to the Environment**

Source	Pathways	Receptors
Potential contaminants in soil	Migration of landfill leachate to shallow groundwater and Slacks Creek	1)Surface Water
	Migration of potential contaminants as sediment in rainfall runoff	2)Shallow Groundwater

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4. Regulatory Framework

This Section highlights the key elements employed from the relevant regulatory framework in preparing and implementing the investigation methodologies, assessing the data gathered and recommending remediation / management approaches.

4.1. Commonwealth Legislation

4.1.1. National Environmental Protection Measure

The National Environment Protection Council, in co-operation with environmental health agencies, prepared national guidelines for contaminated land matters in the National Environment Protection (Assessment of Site Contamination) Measure 1999 ("the NEPM").

The purpose of the NEPM is to establish a nationally consistent approach to the assessment of site contamination to ensure sound environmental management practices by the community which includes regulators, site assessors, contaminated land auditors, land owners, developers and industry.

The NEPM contains two schedules:

- Schedule A which identifies the recommended process for the Assessment of Site Contamination, indicating guiding principles to be applied to preliminary and detailed site investigations; and
- Schedule B which comprises 10 general guidelines for the Assessment of Site Contamination, including outlines for assessment criteria, field activities and health and ecological risk assessments.

The key element applicable from the NEPM is the nomination of investigation levels (HILs) for contaminant concentrations above which potential health or environmental risks may occur and require further investigation. The HILs adopted for the investigation are discussed further in **Section 4.3.**

4.2. State Legislation

4.2.1. Environmental Protection Act 1994

In Queensland, the Environmental Protection Agency (EPA) administers the *Environmental Protection Act 1994* (EP Act). The EP Act's emphasis is on managing Queensland's environment within the principles of ecologically sustainable development. Chapter 7, Part 8 of the EP Act details matters relating to the investigation and management of contaminated land. Further, current



Queensland guidelines for contaminated land include the *Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland* (DoE, 1998) (“the Draft Guidelines”).

The key elements applicable from the EP Act and the Draft Guidelines include:

- **Environmental Management Register (EMR):** land that has been or is being used for a Notifiable Activity or has been contaminated by a hazardous contaminant, and about which the EPA is notified, is recorded on the EMR. Sites recorded on the EMR pose a potential risk to human health and the environment under the current land use. Entry on the EMR does not mean the land must be cleaned up or that the current land use must cease.
- **Disposal Permit:** Section 424 of the EP Act states that a Disposal Permit must be obtained for soil that is contaminated and originates at a site listed on the EMR prior to removal of that soil from the subject site. If the chosen remediation option includes the removal of contaminated soil from the subject site to an EPA-licensed landfill, then appropriate sampling and analysis results must be forwarded to the EPA, together with supporting documentation and the appropriate application form, to obtain a Disposal Permit. In the case where the subject site is not listed on the EMR, the EPA may exercise its discretion to issue an ‘approval letter’ or similar document to acknowledge that the appropriate contaminated soil management approach is being taken in the soil removal.

4.2.2. Environmental Relevant Activity Guidelines (ERA)

Regulations governing aspects of proposed, operational and decommissioned landfills (incorporating landfills) are outlined in the *Qld EPA Guidelines ERA 75 (Waste Disposal) – Landfill Siting, Design, Operation and Rehabilitation* (ERA 75). The Guidelines are designed to create a unified approach to landfill management in Queensland.

Specific to this Project, relevant stipulations on the management and rehabilitation of landfills have been discussed below.

- **Landfill Gas Criteria:** The guideline defines a Lower Explosive Limit (LEL) of 5% and Upper Explosive Limit (UEL) of 15% for methane based on safety requirements.
- **Site Management Plan (SMP):** The ERA 75 outlines triggers for long-term management of decommissioned landfills through an SMP (pursuant to Chapter 7, Part 8, Division 5 of the EP Act). This also includes future land use planning and ongoing environmental monitoring constraints.



4.2.3. Waste Regulations

The *Environmental Protection (Waste Management) Policy 2000* and the *Environmental Protection (Waste Management) Regulation 2000* clarify waste management practices in Queensland and provide improved environmental safeguards. Developed in conjunction with local government and industry, the legislation benefits Queensland communities through safer disposal practices and cost savings from improved planning and management of waste services.

In relation to the identification and evaluation of remediation options for this Project, the key elements considered from this legislation are:

- The waste management hierarchy of reduce, reuse, recycle also applies to contaminated land management, the management options (in order of decreasing preference) being:
 - Treatment of contaminated soil on-site, followed by on-site reuse;
 - Management of contaminated soil on-site with appropriate mitigation measures to protect human health and the environment;
 - Off-site treatment; and
 - Off-site disposal.
- The setting of Waste Acceptance Criteria specific to individual landfill sites and differentiation between contaminated soil and regulated wastes.

4.3. Assessment Criteria

4.3.1. Risk to Human Health

Potential Contaminants in Soils

The HILs in *National Environment Protection (Assessment of Site Contamination) Measure (NEPM) 1999* (“the NEPM”) ‘HIL-F for Commercial/Industrial Land’ have been adopted as the assessment criteria (“the Human Health Assessment Criteria”) for the Investigation. These guidelines are considered appropriate on the basis that the proposed use of the site is commercial.

The soil Human Health Assessment Criteria adopted for the Investigation are summarised in **Table 4-1**.

■ Table 4-1 Human Health Assessment Criteria (Soil)

Analyte	Assessment Criteria (mg/kg)	Assessment Criteria Source
Lead	1500	NEPM HIL-F
Arsenic	500	
Cadmium	100	
Chromium (III+VI)	500	

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Analyte	Assessment Criteria (mg/kg)	Assessment Criteria Source
Copper	5000	
Mercury	75	
Nickel	3000	
Zinc	35000	

Potential Contaminants in Groundwater

As discussed in **Section 2.6** there are no registered operational bores (groundwater users) in the vicinity of the site. This is likely to be due to the low yield of groundwater, which occurs in the vicinity of the site and the presence of other reliable and higher quality water sources (i.e. reticulated water). The nearest registered bore is located 700 m north of the site and north of Slacks Creek. Accordingly the site would not influence groundwater at the location of this bore.

Groundwater is not planned to be used on the site post development (e.g. for irrigation) due to the low yield and presence of landfill leachate (refer to **Section 8.2**). Whilst the majority of leachate from the landfill is discharged into groundwater via sub-surface flow, a small portion of leachate from the landfill seeps from the eastern embankment into the drain. Post development access to the eastern embankment will be controlled by fencing and is not expected to be accessed by human receptors (e.g. for recreational use).

Landfill leachate from the site discharges to Slacks Creek located 320 m east of the site via seepages into the drain, and groundwater migration. Parts of Slacks Creek down-gradient of the site are within parks and accessible by the public for recreational purposes. Accordingly the analytical results have been compared to the Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, *Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters* ("ANZECC Guideline") for secondary contact recreational use.

A number of potential contaminants were detected for which there is no ANZECC Guideline. In the absence of an ANZECC Guideline in order of decreasing preference the following Assessment Criteria have been applied.

- The Netherlands Ministry of Housing, Spatial Planning and Environment's *Circular on target values and intervention values for soil remediation* (2000) ("the Dutch Guidelines") which consider both the risk to human health and the environment;
- The National Health and Medical Research Council (2004) *Australian Drinking Water Guidelines* ("the Australian Drinking Water Guidelines"); and



- *United States Environmental Protection Agency (2009) Region 9 Preliminary Remediation Goals* (“the USEPA guidelines”)

In summary, the Human Health Assessment Criteria adopted for this Investigation and their source are summarised in **Table 4-4**.

■ **Table 4-2 Human Health Assessment Criteria (Water)**

Analyte (µg/L unless stated)	Assessment Criteria	Assessment Criteria Source
Ammonia as N (mg/L)	0.5	Australian Drinking Water Guidelines 2004
Arsenic (mg/L)	0.05	ANZECC 2000 Recreational Water Quality
Cadmium (mg/L)	0.005	ANZECC 2000 Recreational Water Quality
Chromium (mg/L)	0.05	ANZECC 2000 Recreational Water Quality
Copper (mg/L)	1	ANZECC 2000 Recreational Water Quality
Lead (mg/L)	0.05	ANZECC 2000 Recreational Water Quality
Nickel (mg/L)	0.1	ANZECC 2000 Recreational Water Quality
Zinc (mg/L)	5	ANZECC 2000 Recreational Water Quality
TPH C10-C40	600	Dutch Guidelines
Benzene	10	ANZECC 2000 Recreational Water Quality
Toluene	1000	Dutch Guidelines
Ethylbenzene	150	Australian Drinking Water Guidelines 2004
meta- & para-Xylene	200	USEPA 2009 Region 9 Tap Water
ortho-Xylene	1400	USEPA 2009 Region 9 Tap Water
Isopropylbenzene	150	Dutch Guidelines (aromatic solvents)
n-Propylbenzene	150	Dutch Guidelines (aromatic solvents)
1,2,4-Trimethylbenzene	15	USEPA 2009 Region 9 Tap Water
p-Isopropyltoluene	-	-
Dichlorodifluoromethane	390	USEPA 2009 Region 9 Tap Water
Chlorobenzene	300	Australian Drinking Water Guidelines 2004
1,4-Dichlorobenzene	40	Australian Drinking Water Guidelines 2004
1,2-Dichlorobenzene	1500	Australian Drinking Water Guidelines 2004
Naphthalene	70	Dutch Guidelines
Phenanthrene	-	-
2-Methylphenol	200	Dutch Guidelines (Cresols)
3- & 4-Methylphenol	200	Dutch Guidelines (Cresols)
2,4-Dimethylphenol	730	USEPA 2009 Region 9 Tap Water
2,4-Dichlorophenol	200	Australian Drinking Water Guidelines 2004
4-Chloro-3-methylphenol	350	Dutch Guidelines
2,4,5-Trichlorophenol	1	ANZECC 2000 Recreational Water Quality



Landfill Gases

Volatile organic gas data has been compared to the *National Occupational Health and Safety Commission (NOHSC) 1995, Exposure Standards for Atmospheric Contaminants in the Occupational Environment* (“the NOHSC Guidelines”). Guideline values provide both a time weighted average (TWA) and short-term exposure limit (STEL) for human exposure to ambient gas concentrations within an enclosed building or space, assuming a standard workplace scenario.

The NOHSC Guidelines do not include methane which is a volatile gas produced during the degradation of putrescible wastes in landfills. Methane is an asphyxiant, and is highly flammable. As an asphyxiant in an unventilated enclosed space, methane at 7 % concentration can displace normal air and reduce oxygen concentrations to levels below the US Occupational Safety & Health Administration (OSHA) allowable level (19.5 % O₂) (Doyle, 2001). At 5 % concentration in air (the LEL, refer to **Section 4.2.2**) methane is flammable. Accordingly a Human Health Assessment Criteria of 5 % concentration of methane in air has been used on the basis that it considers both safety (LEL) and health (asphyxiant) concerns.

The NOHSC Guidelines are summarised in **Table 4-3**.

■ **Table 4-3 NOHSC Guidelines**

Analyte	NOHSC Guideline	
	TWA (mg/m ³)	STEL (mg/m ³)
n-pentane	1770	2210
n-hexane	176	-
cyclohexane	1035	-
methylcyclohexane	1610	-
n-heptane	1640	2050
n-octane	1400	1750
n-nonane	1050	-
chlorobenzene	46	-
benzene	16	-
ethylbenzene	434	543
1,2,3-trimethylbenzene	123	-
1,2,4-trimethylbenzene		
1,3,5-trimethylbenzene		
p/m-xylene	350	655
o-xylene		
acetone	1185	2375



4.3.2. Risk to the Environment

Potential Contaminants in Soils

Soil guidelines for the protection of ecological health, such as the NEPM ecological-based investigation levels (EILs) are not recommended for application at this site on the basis that the ecological sensitivity of the site is considered to be low (i.e. the site does not support ecosystems with high ecological value), and the site in its current condition does not appear to be impairing plant growth. It should also be noted that the NEPM acknowledges in Schedule B(1) Section 3.2 that the EILs for an urban setting “*have not been derived to protect nominated ecological values and are somewhat arbitrary*”. For these reasons the use of the EILs is not recommended. It should be noted that the CSIRO is currently working on a methodology to give more scientifically robust and ecologically relevant EILs⁵.

Potential Contaminants in Groundwater

A qualitative assessment of groundwater receptors at the site indicates that the nearest receiving water body is Slacks Creek. As Slacks Creek is a freshwater system, the appropriate primary screening criteria are the Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, *Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters* (“ANZECC Guideline”).

On the basis that the current ecological condition of Slacks Creek is a highly disturbed and heavily modified system, the 80% trigger value for freshwater ecosystems has been used.

A number of potential contaminants were detected for which there is no ANZECC Guideline. In the absence of an ANZECC Guideline, the following Assessment Criteria have been applied.

- *United States Environmental Protection Agency (2004) Region 9 Preliminary Remediation Goals* (“the USEPA Guidelines”); and
- the Dutch Guidelines.

The Dutch Guideline for hydrocarbon in groundwater has been derived for mineral-based (petroleum) hydrocarbons. The guideline value was used to compare samples of Total Petroleum Hydrocarbons (TPH) where the source of the hydrocarbons was petroleum based. This applied to TPH analytes which had been prepared using a silica gel clean-up to remove interference from polar organics⁶.

⁵ CSIRO, 2008, *Draft Proposal for an Australian Methodology to Derive Ecological Investigation Levels in Contaminated Soils*. Report 18/08

⁶ Polar organics such as lipids, proteins, sugars etc. are removed by running the sample extract over a charged



It should be noted that the NEPM includes Groundwater Investigation Levels (GILs) for freshwater ecosystems. These however are based on the *Australian Water Quality Guidelines for Fresh and Marine Waters* (ANZECC, 1992) for the protection of freshwater ecosystems which have now been withdrawn. Accordingly the NEPM GILs have not been used.

The extraction of groundwater for use (e.g. irrigation) is considered unlikely for reasons outlined in **Section 4.3.1**. Accordingly ecological risks associated with extractive uses are considered to be low and do not require further consideration.

In summary, the Environmental Assessment Criteria adopted for this Investigation and their source are summarised in **Table 4-4**.

■ **Table 4-4 Environmental Assessment Criteria**

Analyte (µg/L unless stated)	Assessment Criteria	Assessment Criteria Source
Ammonia as N (mg/L)	2.3	ANZECC 2000 Freshwater Ecosystems (80%)
Arsenic (mg/L)	0.36	ANZECC 2000 Freshwater Ecosystems (80%)
Cadmium (mg/L)	0.0008	ANZECC 2000 Freshwater Ecosystems (80%)
Chromium (mg/L)	0.04	ANZECC 2000 Freshwater Ecosystems (80%)
Copper (mg/L)	0.0025	ANZECC 2000 Freshwater Ecosystems (80%)
Lead (mg/L)	0.0094	ANZECC 2000 Freshwater Ecosystems (80%)
Nickel (mg/L)	0.017	ANZECC 2000 Freshwater Ecosystems (80%)
Zinc (mg/L)	0.031	ANZECC 2000 Freshwater Ecosystems (80%)
TPH C10-C40	600	Dutch Guidelines
Benzene	2000	ANZECC 2000 Freshwater Ecosystems (80%)
Toluene	180	ANZECC 2000 Trigger Value for Freshwater Slightly-Moderately Disturbed Systems
Ethylbenzene	80	ANZECC 2000 Trigger Value for Freshwater Slightly-Moderately Disturbed Systems
meta- & para-Xylene	340	ANZECC 2000 Freshwater Ecosystems (80%)
ortho-Xylene	640	ANZECC 2000 Freshwater Ecosystems (80%)
Isopropylbenzene	30	ANZECC 2000 Trigger Value for Freshwater Slightly-Moderately Disturbed Systems
n-Propylbenzene	128	USEPA Ecological Risk Assessment Freshwater Screening Benchmarks
1,2,4-Trimethylbenzene	33	USEPA Ecological Risk Assessment Freshwater Screening Benchmarks
p-Isopropyltoluene	85	USEPA Ecological Risk Assessment Freshwater Screening Benchmarks
Dichlorodifluorometh-ane	390	USEPA 2009 Region 9 Tap Water
Chlorobenzene	55	ANZECC 2000 Trigger Value for Freshwater Slightly-Moderately Disturbed Systems
1,4-Dichlorobenzene	60	ANZECC 2000 Trigger Value for Freshwater Slightly-Moderately Disturbed Systems
1,2-Dichlorobenzene	160	ANZECC 2000 Trigger Value for Freshwater Slightly-Moderately Disturbed Systems
Naphthalene	85	ANZECC 2000 Freshwater Ecosystems (80%)

silica gel. Non-polar petroleum components then remain in the sample extract for analysis.

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Analyte (µg/L unless stated)	Assessment Criteria	Assessment Criteria Source
Phenanthrene	2	ANZECC 2000 Trigger Value Freshwater/Marine (95% protection)
2-Methylphenol	13	USEPA Ecological Risk Assessment Freshwater Screening Benchmarks
3- & 4-Methylphenol	543	USEPA Ecological Risk Assessment Freshwater Screening Benchmarks
2,4-Dimethylphenol	2	ANZECC 2000 Trigger Value Freshwater/Marine (95% protection)
2,4-Dichlorophenol	120	ANZECC 2000 Trigger Value for Freshwater Slightly-Moderately Disturbed Systems
4-Chloro-3-methylphenol	350	Dutch Guidelines
2,4,5-Trichlorophenol	0.5	ANZECC 2000 Trigger Value for Freshwater Slightly-Moderately Disturbed Systems

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5. Investigation Methodology

5.1. Scope of Investigation

The scope of the Investigation comprised:

- 1) a site inspection.
- 2) the review of historical aerial photography obtained from the Department of Environment and Resource Management (DERM).
- 3) the review data provided by Logan City Council (LCC) including:
 - CMPS&F Environmental, May 1995. *Preliminary Site Investigation and Management Plan for The Former Compton Road Landfill Site*. Prepared for the Logan City Council (“the CMPS&F Report”).
 - groundwater and landfill gas monitoring data from July 2000 to August 2008 (“LCC Environmental Data”) including an assessment of historical groundwater trends within three previously installed monitoring wells (“the LCC wells”).
- 4) the undertaking of a groundwater monitoring event from monitoring wells present at the site, and the collection of a water sample from the drain exiting the site.
- 5) the preparation of a Sampling and Analysis Plan (SAP) based on the findings of 1) to 3) above for the undertaking of further intrusive ground investigation to establish whether the site in its current condition poses an unacceptable risk to human health and/or the receiving environment.
- 6) the undertaking of the intrusive ground investigation which comprised:
 - a review of the “Dial Before You Dig Records” of the site and confirmation of service locations by a Telstra Accredited Underground Service Locator;
 - the installation and development of nine groundwater monitoring wells around the periphery of the site, including:
 - a total of five combined shallow groundwater/landfill gas wells intersecting the perched leachate water (“the perched wells”) within materials contained within the Landfill (“the waste material”).
 - A total of four deeper groundwater wells intersecting the natural groundwater table below the Landfill (“the groundwater wells”).
 - the excavation of ten shallow test pits within the surface material and sampling of shallow surface soils for contamination testing at a National Association of Testing Laboratories (NATA) Accredited Laboratory;
 - the undertaking of four Talsma-Hallam Permeameter (permeability) tests from four of the shallow test pits.



- 7) the undertaking of two rounds of landfill gas and groundwater monitoring comprising:
 - landfill gas monitoring from the perched wells and the Landfill vents; and
 - groundwater monitoring and sampling from the four groundwater wells and five perched wells (collectively referred to as “the monitoring wells”) and from the discharge point of the drainage channel and the testing of the samples collected at a NATA Accredited Laboratory.
- 8) the preparation of an Interim Report on the findings of the intrusive ground investigation following completion of the two monitoring rounds referred to in 6) above.
- 9) the undertaking of a further four rounds of landfill gas monitoring and two rounds of groundwater monitoring comprising:
 - landfill gas monitoring from the perched wells and the Landfill vents; and
 - one round of volatile gas sampling from the perched wells by SIMTARS, and the testing of the samples collected for a range of volatile organic contaminants; and
 - groundwater monitoring and sampling from the four groundwater wells and five perched wells (collectively referred to as “the monitoring wells”) and from the discharge point of the drainage channel and the testing of the samples collected at a NATA Accredited Laboratory.
- 10) the preparation of an interpretative report (this report) on the findings of the Investigation.

A Preliminary Geotechnical Investigation was undertaken in October 2009 which comprised the drilling of 10 boreholes over the site to provided preliminary characterisation of ground conditions in the vicinity of the proposed buildings, the car/trailer park, and racing track. Ground conditions encountered during the Preliminary Geotechnical Investigation have been summarised in this report.

5.2. Installation of Monitoring Wells

A total of nine monitoring wells were installed as part of the Investigation. All monitoring wells were installed based on the requirements of the *Minimum Construction Requirements for Water Bores in Australia (2003)*. Bore logs of the groundwater wells installed as part of the investigation have been presented in **Appendix C**.

Perched Wells

The perched wells only intersected the waste material and not the natural materials beneath the Landfill. The five perched wells were screened across the static water level and into the waste material above to intersect phase separated hydrocarbons and allow for landfill gas monitoring.



A bentonite plug⁷ was used to seal the perched wells through the surface material.

A summary of the perched well construction details is provided in **Table 5-1**.

■ **Table 5-1 Perched Well Installation Details**

Monitoring Well	Total Depth (m bgl)	Screened Interval (m bgl)
MW03	2.0	1.0-2.0
MW04	5.0	2.0-5.0
MW05	6.0	1.0-6.0
MW07	5.0	1.0-5.0
MW08	3.0	1.0-3.0

Groundwater Wells

The four groundwater wells were installed through the waste material, and screened within natural ground below the waste materials.

Where the groundwater wells intersected loose or wet waste material, the hole was advanced to the base of the waste material. The hole was then cased with a concrete-bentonite slurry and allowed to cure overnight. Following this, a second augur was advanced through the concrete casing and into the natural material below.

The groundwater wells were screened through the natural material only. A bentonite plug⁸ was installed at the base of the concrete casing to ensure that an adequate seal between the waste material and natural material was achieved.

A summary of the groundwater well construction details is provided in **Table 5-1**.

■ **Table 5-2 Groundwater Well Installation Details**

Monitoring Well	Total Depth (m bgl)	Screened Interval (m bgl)
MW01	7.0	5.0-7.0
MW02	7.5	4.5-7.5
MW06	9.0	8.0-9.0
MW09	8.0	5.0-8.0

Well Development

All monitoring wells at the site were developed by removing a minimum of three well volumes of water (or until well purged dry), until groundwater parameters stabilised.

⁷ of a minimum thickness of 1 m

⁸ of a minimum thickness of 1 m.



5.3. Soil Sampling

During the installation of monitoring wells, samples of surface soils were collected incrementally until the intersection of the waste material, and from trial pits excavated over the capping layer.

Soil samples were screened using a photo-ionisation detector (PID)⁹ for the presence of volatile hydrocarbons. No detects were noted in any sample across the site.

Samples were immediately placed in appropriately preserved containers and placed on ice for transportation to the laboratory.

Selected soil samples from within the shallow soil profile¹⁰ were submitted for analysis of a broad range of potential contaminants including:

- Inorganic analytes:
 - Metals (arsenic, cadmium, chromium, copper, lead, nickel, zinc and mercury);
 - pH;
 - Asbestos;
- Organic analytes:
 - Total petroleum hydrocarbon (TPH);
 - Volatile Organic Compounds (VOC) including BTEX (benzene, toluene, ethylbenzene and xylenes);
 - Semi-volatile Organic Compounds including:
 - Polycyclic Aromatic Hydrocarbons (PAH);
 - Phenols;
 - Polychlorinated Biphenyls (PCB);
 - Organochlorine Pesticides (OCP); and
 - Organophosphate Pesticides (OPP).

5.4. Landfill Gas Monitoring and Analytical Testing

Perched wells were fitted with gas monitoring well caps to allow for landfill gas¹¹ monitoring.

⁹ Calibration certificates are included in Appendix D.

¹⁰ Depths less than 0.3 m bgl.

¹¹ Including methane, oxygen, carbon dioxide, carbon monoxide and hydrogen sulphide



Wells were sealed for a minimum of 48 hours prior to monitoring. A landfill gas meter (GA2000 or similar)¹² was used to monitor gas concentrations from within the monitoring wells for three consecutive minutes. Peak and average landfill gas readings were recorded.

Four existing landfill vents at the site were also monitored for three consecutive minutes from sampling ports at the base of the vent.

5.5. Groundwater Sampling

Groundwater levels were recorded using a Solonist Oil-Water Interface Probe¹³. Wells were then purged until groundwater parameters stabilised, or until the well was dry. Post purge groundwater physico-chemical parameters¹⁴ of recharging water were recorded.

Samples were collected using a disposable bailer. Samples were placed into appropriately preserved sample containers and placed on ice for transportation to the laboratory.

Samples for metals analysis were filtered to 0.45 µm prior to placing in a sample container.

Groundwater samples were submitted for analysis of a broad range of potential contaminants including:

- Inorganic analytes:
 - Metals (arsenic, cadmium, chromium, copper, lead, nickel, zinc and mercury);
 - pH;
- Organic analytes:
 - Total petroleum hydrocarbon (TPH) fractions;
 - Volatile Organic Compounds (VOC) including BTEX (benzene, toluene, ethylbenzene and xylenes);
 - Semi-volatile Organic Compounds including:
 - Polycyclic Aromatic Hydrocarbons (PAH);
 - Phenols;
 - Polychlorinated Biphenyls (PCB);
 - Organochlorine Pesticides (OCP); and
 - Organophosphate Pesticides (OPP).

¹² Calibration certificates are included in Appendix D.

¹³ Calibration certificates are included in Appendix D.

¹⁴ Including pH, dissolved oxygen (DO), reduction potential, total dissolved solids (TDS) and temperature



6. Site Conditions

6.1. Ground Conditions

A conceptualisation of the ground conditions at the site is provided in **Figure 5, Appendix A**. Exploratory bore logs, including the logs from the Preliminary Geotechnical Investigation are included in **Appendix B**.

Surface Material

For the majority of the Landfill, the surface material was found to be comprised of a layer of silty sand (0-0.1 m thickness) and an underlying clay based material comprised of sandy clay to clayey sand (0.2-0.8 m thickness).

The surface material layer of the eastern embankment of the Landfill was found to be comprised of well compacted clayey sand (0.2-0.5 m thickness).

Waste Materials

The thickness of waste materials encountered varied from 1.2 m to 10.5 m. Where encountered, waste materials (30-90%) were found to be mixed in a damp to saturated grey unconsolidated clay or sandy clay matrix (10-70%). The waste intersected in the investigation was domestic in origin, and appeared to contain infrequent residual putrescible materials. Common items noted in the waste materials included plastic packaging, plastic bags, metal fragments and glass bottles. No regulated wastes were noted in the waste material intersected.

The waste materials have been placed directly over natural materials in the majority of exploratory boreholes.

Natural Material

The natural material was generally a sandy or silty clay of weathered sandstone. This was underlain by the coarse grained red and white low strength sandstone. The sandstone was incised with a medium strength siltstone in several locations across the site.

In background locations across the site (including in locations within the wooded area along the western portion of the site), the soil profile was a silty sandy clay material consistent with the weathered sandstone.

6.2. Groundwater

Two groundwater systems have been observed on the site. These include:

- groundwater within the weathered sandstone beneath the Landfill; and
- perched water within the Landfill.



Perched water within the Landfill is expected to be recharged from the lateral migration of groundwater entering the Landfill and the vertical migration of rainwater through the surface material.

The CMPS&F Report describes the Landfill as being constructed using a method which involved the excavation of trenches, and the placement and compacting of waste within the trench. The report does not describe the construction of a liner system.

The absence of an engineered liner was confirmed during the Preliminary Geotechnical Investigation which involved the drilling of 10 boreholes over the former landfill site. The Preliminary Geotechnical Investigation confirmed that waste materials have been placed directly over natural materials. This was found to be the sandy clay strata (weathered sandstone) in the majority of boreholes. In BH4 waste materials were found to have been placed directly over the sandstone. Consequently it is considered highly likely that the perched water within the Landfill is in connection with groundwater in the weathered sandstone.

Evidence of a connection between the two groundwater systems within the site can be drawn from the presence of organic contaminants and ammonia from groundwater samples taken from MW06 and MW09. MW06 and MW09 are monitoring wells which target groundwater in the weathered sandstone beneath and at the eastern (down-gradient) boundary of the Landfill (refer to **Appendix D.2.2**). If there was not a connection between the perched water within the Landfill and the groundwater in the weathered sandstone, elevated concentrations of organics and ammonia would not have been expected to be found in the samples from MW06 and MW09.

Figure 6, Appendix A provides a summary of the groundwater levels monitored during the investigation. Both the groundwater within the weathered sandstone and perched groundwater within the Landfill flow in a north easterly direction towards Slacks Creek. The perched groundwater within the Landfill is expected to combine with the groundwater in the weathered sandstone down gradient of the site. This is evident from ammonia and organic contaminants detected in CR13 which is a groundwater monitoring well installed by LCC down gradient of the Landfill.

Perched water within the Landfill potentially seeps into the drain on the eastern boundary of the site, as the elevation of the drain is below perched water levels within the Landfill. In addition seepages from the eastern embankment of the Landfill were observed in the north eastern corner of the site.

Appendix 0 provides a summary of groundwater observations made during the undertaking of the investigation. Odours and sheens were observed in some of the monitoring wells within the site.



Further discussion on the quality of the perched water within the Landfill and groundwater within the weathered sandstone is provided in **Section 7.2**.

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7. Analytical Results

This Section provides a summary of the analytical results of the investigation. A complete tabulation of the analytical results and a comparison of these with the Human Health and Environmental Assessment Criteria are provided in **Appendix D**. A copy of the laboratory analytical reports is provided in **Appendix E**. An assessment of the quality of the data is provided in **Appendix F**. A discussion of implications of the analytical results in regard to the risk to the environment and human health is provided in **Section 8**, and the remedial requirements in **Section 9**.

7.1. Soil Analytical Results

Seventeen samples of capping material (0-0.1 m or 0.2-0.3m) were analysed for a range of potential contaminants including metals¹⁵, asbestos, and/or organic analytes¹⁶. **Table 7-1** provides a summary of the analytical results for metals.

■ **Table 7-1 Metals, Surface Material**

Analyte (mg/kg)	Assessment Criteria	Minimum Value	Maximum Value
Arsenic	500	<5	<5
Cadmium	100	<1	<1
Chromium	500	2	28
Copper	5000	<5	16
Lead	1500	<5	18
Nickel	3000	<2	10
Zinc	35000	<5	31
Mercury	75	<0.1	<0.1

Metals (chromium, copper, lead, nickel and zinc) were found in some of the samples analysed in low concentrations which were well below the Human Health Assessment Criteria.

Asbestos fibres were not detected in any of the samples analysed.

All organic analytes were below laboratory detection limits in the samples analysed.

¹⁵ metals included arsenic, cadmium, chromium, copper, lead, nickel, zinc, and mercury

¹⁶ organics included total petroleum hydrocarbons (TPH); BTEX – benzene, toluene, xylene isomers, and ethyl benzene; polycyclic aromatic hydrocarbons (PAH); phenolic compounds; total polychlorinated biphenyls (PCBs); and organochlorine / organophosphate pesticides (OCPs/OPPs).



Permeability and Drainage of Surface Material

In-situ Talsma-Hallam Permeameter tests of the clay based material within the surface material indicates that the permeability of this material varies between 10^{-6} and 10^{-8} m/s. The test results, and an estimated permeability of the clay based material based on particle size analysis are summarised in **Table 7-2**.

■ **Table 7-2 Permeability Test Results**

Exploratory Location	Depth to Clay Based Material (m bgl)	Thickness of Clay Based Material (m)	Talsma-Hallam Permeameter Result of Clay Based Material	Estimated Permeability Based on Particle Size Distribution Testing
TP2	0.2	0.4	$k = 4.0 \times 10^{-7}$ m/s	$(k = 10^{-8}$ m/s) Estimate only
TP3	0.1	0.8	$k = 1.1 \times 10^{-6}$ m/s	
TP4	0.1	0.5	$k = 1.4 \times 10^{-7}$ m/s	
TP5	0.1	0.5	$(k = 4.4 \times 10^{-8})$ m/s	
TP9	0.15	0.2	Not measured	-

Low bunds have been constructed over parts of the site to assist with the shedding of rainfall runoff off the surface material into the drains on the northern and southern boundaries of the site (refer to **Section 2.4**). These surface water drainage measures and the low permeability of the clay based surface material will assist with limiting the infiltration of rainfall into the Landfill. The temporary ponding of water has been observed on the site in some locations following rainfall in capping areas which have formed depressions following ground subsidence.

7.2. Groundwater Analytical Results

Five rounds of groundwater monitoring have been undertaken at the site. Groundwater samples collected were tested for a range of inorganic¹⁷ and organic¹⁸ analytes.

¹⁷ inorganic analytes included metals (arsenic, cadmium, chromium, copper, lead, nickel, zinc, and mercury) and ammonia

¹⁸ organic analytes included:

- total petroleum hydrocarbons (TPH)
- volatile organic compounds: BTEX – benzene, toluene, xylene isomers, and ethyl benzene; monocyclic aromatic hydrocarbons; oxygenated compounds, fumigants, halogenated aliphatic/aromatic compounds; trihalomethanes; naphthalene)
- semi-volatile organic compounds: polycyclic aromatic hydrocarbons (PAH); phenolic compounds; total polychlorinated biphenyls (PCBs); and organochlorine / organophosphate pesticides (OCs/OPs).



7.2.1. Physico-Chemical Parameters and Ammonia

Table 7-3 provides a summary of the physico-chemical parameters and ammonia analytical results for the on-site monitoring wells.

■ **Table 7-3 Physico-Chemical Parameters and Ammonia, On-site Locations**

Analyte	Environmental Assessment Criteria	Human Health Assessment Criteria	Groundwater Beneath Former Landfill				Perched Water Within Former Landfill			
			Cross-gradient (MW02)		Down-gradient (MW06, MW09)		Cross-gradient (MW03, MW04, MW08)		Down-gradient (MW05, MW07)	
			Min	Max	Min	Max	Min	Max	Min	Max
Dissolved Oxygen (mg/L)			1.1	5.8	1.1	5.0	0.1	7.1	0.1	1.9
Total Dissolved Solids (ppK)			2.9	4.9	0.3	2.4	0.4	2.2	1.1	3.2
pH			3.4	4.1	3.8	6.4	4.4	7.7	6.8	7.6
Reduction Potential (eH)			279	458	-44	275	-197	262	-150	-87
Temperature (°C)			22.4	23.7	19.5	24.1	19.4	25.3	20.3	23.7
Ammonia as N (mg/L)	2.3	0.01	0.02	0.12	0.5	50.4	<0.01	228	43.4	120

Perched water within the Landfill generally tended to contain low salt content, low dissolved oxygen (DO), and acidic to slightly alkaline pH.

In general, groundwater in the weathered sandstone was generally acidic and saline, as observed in samples from the cross-gradient, and down-gradient monitoring wells.

Elevated concentrations of ammonia which exceed the Environmental and Human Health Assessment Criteria were found in groundwater samples from down-gradient monitoring wells which targeted perched water within the Landfill (MW05 and MW07), and groundwater monitoring wells in the weathered sandstone (MW06). The results show that the Landfill is producing elevated concentrations of ammonia in leachate, which is impacting on both the perched groundwater and the underlying aquifer.

Table 7-4 provides a summary of the physico-chemical parameters and ammonia analytical results for the off-site monitoring wells and the surface water drain.



■ **Table 7-4 Physico-Chemical Parameters and Ammonia, Off-site Locations**

Analyte	Environmental Assessment Criteria	Human Health Assessment Criteria	Off-site Wells						Drain	
			Up-gradient (CR14, MW01)		Cross-gradient (CR15)		Down-gradient (CR13)			
			Min	Max	Min	Max	Min	Max	Min	Max
Dissolved Oxygen (mg/L)			1.9	5.9	2.4	4.6	2.9	4.0	4.0	6.6
Total Dissolved Solids (ppK)			0.2	7.3	0.1	0.9	0.2	0.4	0.2	0.3
pH			3.8	4.3	5.0	6.0	5.0	5.7	7.0	7.5
Reduction Potential (eH)			148	407	18	100	2	111	-16	68
Temperature (°C)			21.2	22.6	19.7	21.2	21.6	22.4	19.4	25.7
Ammonia as N (mg/L)	2.3	0.01	0.14	0.06	-	-	9.79	9.79	4.21	4.21

Table 7-4 shows that the physico-chemical parameters for the up-gradient and cross-gradient off-site monitoring wells were similar to the results from groundwater samples taken from up-gradient and cross-gradient monitoring wells beneath the Landfill in the weathered sandstone.

Elevated concentrations of ammonia which exceeded the Environmental and Human Health Assessment Criteria were found in the monitoring well down-gradient of the Landfill (CR13) and the drain. The maximum concentration of ammonia detected in CR13 (9.79 mg/L) was lower than the maximum concentrations detected in the perched water within the Landfill (228 mg/L). This may be partly attributed to the dilution of ammonia as the perched groundwater within the Landfill mixes with the groundwater within the weathered sandstone, and further attenuation in the aquifer as groundwater moves beneath the site to CR13.

Perched groundwater within the Landfill potentially seeps into the drain on the eastern boundary of the site on the basis that the elevation of the drain is below perched water levels within the Landfill. The elevated concentration of ammonia found in the drain is likely to be attributed to seepage of perched groundwater from the Landfill and possibly other off-site commercial/industrial sources (refer to **Section 2.4**).

7.2.2. Metals

The analytical results for metals are summarised in **Table 7-5** for the on-site monitoring wells, and **Table 7-6** for the off-site monitoring wells.



■ **Table 7-5 Metals, On-site Locations**

Analyte (mg/L)	Environmental Assessment Criteria	Human Health Assessment Criteria	Groundwater Beneath Former Landfill				Perched Water Within Former Landfill			
			Cross-gradient (MW02)		Down-gradient (MW06, MW09)		Cross-gradient (MW03, MW04, MW08)		Down-gradient (MW05, MW07)	
			Min	Max	Min	Max	Min	Max	Min	Max
Arsenic	0.36	0.05	<0.001	0.001	<0.001	0.025	<0.001	0.018	0.002	0.008
Cadmium	0.0008	0.005	0.0003	0.0006	<0.0001	0.0002	<0.0001	0.0007	<0.0001	0.0006
Chromium	0.04	0.05	0.001	0.009	<0.001	0.001	<0.001	0.012	<0.001	0.019
Copper	0.0025	1	0.003	0.018	<0.001	0.006	<0.001	0.02	<0.001	0.009
Lead	0.0094	0.05	0.001	0.043	<0.001	0.003	<0.001	0.048	<0.001	0.002
Nickel	0.017	0.1	0.002	0.1	<0.001	0.019	0.003	0.124	0.012	0.122
Zinc	0.031	5	0.06	0.359	0.021	0.042	<0.005	0.463	<0.005	0.043
Mercury	0.0054		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

■ **Table 7-6 Metals, Off-site Locations**

Analyte (mg/l)	Environment al Assessment Criteria	Human Health Assessment Criteria	Off-site Wells						Drain	
			Up-gradient (CR14, MW01)		Cross-gradient (CR15)		Down-gradient (CR13)			
			Min	Max	Min	Max	Min	Max	Min	Max
Arsenic	0.36	0.05	<0.001	0.002	<0.001	0.002	0.016	0.022	<0.001	0.001
Cadmium	0.0008	0.005	<0.0001	0.0003	<0.0001	0.0003	<0.0001	0.0004	<0.0001	0.0011
Chromium	0.04	0.05	0.001	0.021	<0.001	<0.001	<0.001	<0.001	<0.001	0.007
Copper	0.0025	1	0.014	0.028	<0.001	0.002	<0.001	0.007	0.002	0.02
Lead	0.0094	0.05	0.026	0.115	<0.001	0.002	<0.001	<0.001	<0.001	0.013
Nickel	0.017	0.1	0.028	0.038	<0.001	0.003	0.001	0.001	0.001	0.005
Zinc	0.031	5	0.072	0.154	0.014	0.07	0.016	0.042	0.09	0.173
Mercury	0.0054		<0.0001	<0.0001	<0.0001	<0.001	<0.0001	<0.001	<0.0001	<0.0001

Elevated concentrations of copper, lead, nickel and zinc with concentrations above the Environmental Assessment Criteria were found in MW01 (refer to **Table 7-6**) which is a monitoring well located up-gradient of the Landfill in the weathered sandstone.

Elevated concentrations of copper and zinc with concentrations which exceed the Environmental Assessment Criteria were also found in CR14 which is an off-site monitoring well located up-gradient of the Landfill. Lead was found with concentrations which exceeded the Human Health Assessment Criteria in groundwater samples from off-site well MW01.

MW01 and CR14 are considered to be up-gradient of the Landfill on the basis that: these monitoring wells are located on the western boundary on the known extent of the Landfill (refer to **Section 2.8**); elevated concentrations of ammonia (which is an indicator of the presence of landfill leachate) have not been detected in groundwater samples from these wells (refer to **Table 7-4**); and



the absence of waste materials encountered when drilling the monitoring well in MW01¹⁹ (refer to **Appendix B**).

Table 7-5 shows that the majority of samples from the on-site monitoring wells had concentrations of copper, lead, nickel and zinc with concentrations above the Environmental Assessment Criteria. The maximum concentrations detected, however, were lower than those found in MW01. The findings indicate that elevated concentrations of metals occur in the vicinity (and up-gradient) of the site. The source of these metals is unknown, and are potentially derived from industrial sources in the vicinity of the site, or naturally occurring within groundwater. Notwithstanding this, leachate from the Landfill is unlikely to be having a deleterious effect on groundwater with respect to metals.

An elevated concentration of cadmium which exceeded the Environmental Assessment Criteria was detected in the drain on the eastern boundary of the site in one of the sampling rounds. All other samples from the drain and groundwater had concentrations of cadmium which were below the Environmental Assessment Criteria.

7.2.3. Hydrocarbons

The analytical results for Total Petroleum Hydrocarbons (TPH) are summarised in **Table 7-7** for the on-site monitoring wells, and **Table 7-8** for the off-site monitoring wells.

■ **Table 7-7 Total Petroleum Hydrocarbons, On-site Locations**

Analyte (µg/L)	Environmental Assessment Criteria	Groundwater Beneath Former Landfill				Perched Water Within Former Landfill			
		Cross-gradient (MW02)		Down-gradient (MW06, MW09)		Cross-gradient (MW03, MW04, MW08)		Down-gradient (MW05, MW07)	
		Min	Max	Min	Max	Min	Max	Min	Max
C6 - C9		<20	<20	<20	50	<20	50	30	60
C10 - C14		<50	<50	<50	840	<50	580	90	800
C15 - C28		<100	<100	<100	2500	<100	1700	300	1900
C29 - C36		<50	<50	<50	710	<50	710	<50	680
C10 - C36		<50	<50	<50	4050	<50	2990	440	3170

¹⁹ Note LCC has been unable to provide the exploratory logs and well construction records for CR13, CR14, and CR15.



■ **Table 7-8 Total Petroleum Hydrocarbons, Off-site Locations**

Analyte (µg/L)	Environmental Assessment Criteria	Off-site Wells						Drain	
		Up-gradient (CR14, MW01)		Cross-gradient (CR15)		Down-gradient (CR13)			
		Min	Max	Min	Max	Min	Max	Min	Max
C6 - C9		<20	<20	<20	<20	<20	<20	<20	<20
C10 - C14		<50	60	<50	<50	<50	110	<50	80
C15 - C28		<100	400	<100	160	200	500	<100	350
C29 - C36		<50	240	<50	100	<50	530	<50	130
C10 - C36		<50	690	<50	260	200	1100	<50	560

Concentrations of TPH were generally higher in samples from down-gradient groundwater monitoring wells when compared to samples of perched water from monitoring wells located around the boundary of the Landfill. Whilst not directly sampled in this investigation, high concentrations of TPH would also be expected to be found in perched water within the central parts of the Landfill.

Due to the presence of elevated concentrations of TPH in the first monitoring round, aliphatic/aromatic hydrocarbons were included the laboratory analysis in addition to TPH in the second and third monitoring rounds for selected samples. The analytical results for aliphatic/aromatic hydrocarbons are summarised in **Table 7-9**.

■ **Table 7-9 Aromatic/Aliphatic Hydrocarbons, On-site Locations**

Analyte (µg/L)	Human Health/ Environmental Assessment Criteria	Groundwater Beneath Former Landfill				Perched Water Within Former Landfill			
		Cross-gradient (MW02)		Down-gradient (MW06, MW09)		Cross-gradient (MW03, MW04, MW08)		Down-gradient (MW05, MW07)	
		Min	Max	Min	Max	Min	Max	Min	Max
Aliphatic C10-C14		-	-	<50	<50	<50	<50	<50	<50
Aliphatic C15-C28		-	-	<100	<100	<100	<100	<100	400
Aliphatic C29-C36		-	-	<50	<50	<50	<50	<50	150
Aliphatic C10 - C36		-	-	<50	<50	<50	<50	<50	550
Aromatic C10-C14		-	-	<50	<50	60	70	60	180
Aromatic C15-C28		-	-	<100	<100	<100	<100	<100	<100
Aromatic C29-C36		-	-	<50	<50	<50	<50	<50	<50
Aromatic C10 - C36		-	-	<50	<50	60	70	60	180
Aliphatic/Aromatic C10 - C36	600	-	-	<50	<50	60	70	60	730



An elevated concentration of aliphatic/aromatic hydrocarbons which exceeded the Environmental and Human Health Assessment Criteria was detected in the sample from MW05 (730 µg/L C₁₀-C₃₆) in the second monitoring round. All other samples tested however had concentrations of aliphatic/aromatic hydrocarbons (C₁₀-C₃₆) which were below the Environmental Assessment Criteria.

With the exception of the sample from MW05 in the second monitoring round, the concentrations of aliphatic/aromatic hydrocarbons (C₁₀-C₃₆) were lower than concentrations of TPH (C₁₀-C₃₆) in the samples analysed (refer to **Appendix D.2.2**). For example, in the third monitoring round, the sample from MW04 had a TPH (C₁₀-C₃₆) concentration of 1420 µg/L, and an aliphatic/aromatic hydrocarbon (C₁₀-C₃₆) concentration of 60 µg/L. The difference between these results is attributed to the removal of polar based organics²⁰ via silica gel clean up which is a standard procedure for the analysis of aliphatic/aromatic hydrocarbons. The aliphatic/aromatic hydrocarbons remaining in the sample following silica gel clean up are largely petroleum derived non-polar hydrocarbons. Conversely it should be noted that TPH analysis includes all recoverable hydrocarbons (polar and non-polar) and includes non-petroleum based hydrocarbons.

In the fourth monitoring round samples were analysed for TPH, and TPH 'with silica gel clean up'. The analytical results for the on-site monitoring wells are shown in **Table 7-10**, and the off-site monitoring wells in **Table 7-11**.

■ **Table 7-10 Total Petroleum Hydrocarbons, 7 October 2009, On-site Locations**

Analyte (µg/L)	Human Health/ Environmental Assessment Criteria	Groundwater Beneath Former Landfill			Perched Water Within Former Landfill				
		Cross- gradient	Down-gradient		Cross-gradient			Down-gradient	
			MW02	MW06	MW09	MW03	MW04	MW08	MW05
Total Petroleum Hydrocarbons									
C6 - C9		<20	30	<20	<20	50	50	50	50
C10 - C14		<50	350	60	70	410		370	590
C15 - C28		<100	960	180	120	880		1190	1300
C29 - C36		<50	220	60	60	290		410	270
C10 - C36		<50	1530	310	250	1580		1970	2160
Total Petroleum Hydrocarbons (Silica Gel Clean Up)									
C10 - C14		<50	<50	<50	<50	<50		<50	<50
C15 - C28		<100	<100	<100	<100	<100		<100	<100
C29 - C36		<50	<50	<50	<50	<50		<50	<50
C10 - C36	600	<50	<50	<50	<50	<50		<50	<50

²⁰ Such as fatty acids, lipids, proteins, sugars etc.



■ **Table 7-11 Total Petroleum Hydrocarbons, 7 October 2009, Off-site Locations**

Analyte (µg/L)	Human Health/ Environmental Assessment Criteria	Off-site Wells				Drain
		Up-gradient	Up-gradient	Cross-gradient	Down-gradient	Down-gradient
		MW01	CR14	CR15	CR13	
Total Petroleum Hydrocarbons						
C6 - C9		<20	<20	<20	<20	<20
C10 - C14		60	<50	<50	110	80
C15 - C28		130	<100	160	330	350
C29 - C36		60	<50	100	80	130
C10 - C36		250	<50	260	520	560
Total Petroleum Hydrocarbons (Silica Gel Clean Up)						
C10 - C14		<50	<50	<50	<50	<50
C15 - C28		<100	<100	<100	<100	<100
C29 - C36		<50	<50	<50	<50	<50
C10 - C36	600	<50	<50	<50	<50	<50

Table 7-10 and **Table 7-11** show that whilst elevated concentrations of TPH were detected, the concentrations of TPH with silica-gel clean up were below laboratory detection limits in the majority of samples analysed. In regard to the TPH detected in the fourth monitoring round, the laboratory advised that the main source of hydrocarbons found were not petroleum based, however the source of the hydrocarbons could not be confirmed.

These findings, and those for the analysis of aliphatic/aromatic hydrocarbons (with the exception of the aliphatic/aromatic sample result from MW05 in the second monitoring round) show that the elevated concentrations of TPH detected in groundwater, are likely to be comprised of mainly non-polar and non-petroleum based organic substances present in landfill leachate which are being generated through the decomposition of putrescible materials.

7.2.4. Volatile Organic Compounds

The analytical results for the volatile organic compounds (VOC) found in samples with concentrations above laboratory detection limits are summarised in **Table 7-12** for the on-site monitoring wells, and **Table 7-13** for the off-site monitoring wells.



■ Table 7-12 Volatile Organic Compounds, On-site Locations

Analyte (µg/L)	Environmental Assessment Criteria	Human Health Assessment Criteria	Groundwater Beneath Former Landfill				Perched Water Within Former Landfill			
			Cross-gradient (MW02)		Down-gradient (MW06, MW09)		Cross-gradient (MW03, MW04, MW08)		Down-gradient (MW05, MW07)	
			Min	Max	Min	Max	Min	Max	Min	Max
Monocyclic Aromatic Hydrocarbons										
Benzene	2000	10	<1	<1	<1	2	<1	6	3	5
Toluene	180	1000	<2	<2	<2	10	<2	<2	<2	10
Ethylbenzene	80	150	<2	<2	<2	2	<2	11	<2	5
meta- & para-Xylene	340	200	<2	<2	<2	2	<2	10	<2	9
ortho-Xylene	640	1400	<2	<2	<2	<2	<2	4	<2	3
Isopropylbenzene	30	150	-	-	<5	<5	<5	5	<5	<5
n-Propylbenzene	128		-	-	<5	<5	<5	8	<5	<5
1,2,4-Trimethylbenzene	33		-	-	<5	<5	<5	24	<5	14
p-Isopropyltoluene	85		-	-	<5	<5	<5	29	<5	18
Halogenated Aliphatic Compounds										
Dichlorodifluoromethane	390	390	-	-	<50	<50	<50	60	<50	<50
Halogenated Aromatic Compounds										
Chlorobenzene	55	300	-	-	<5	7	<5	8	7	26
1,4-Dichlorobenzene	60	40	-	-	<5	11	<5	6	<5	47
1,2-Dichlorobenzene	160	1500	-	-	<5	<5	<5	<5	<5	8
Polycyclic Aromatic Hydrocarbons										
Naphthalene	85	70	-	-	<7	20	<7	20	10	24



■ **Table 7-13 Volatile Organic Compounds, Off-site Locations**

Analyte (µg/L)	Environmental Assessment Criteria	Environmental Assessment Criteria	Off-site Wells						Drain	
			Up-gradient (CR14, MW01)		Cross-gradient (CR15)		Down-gradient (CR13)			
			Min	Max	Min	Max	Min	Max	Min	Max
Monocyclic Aromatic Hydrocarbons										
Benzene	2000	10	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	180	1000	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	80	150	<2	<2	<2	<2	<2	<2	<2	<2
meta- & para-Xylene	340	200	<2	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene	640	1400	<2	<2	<2	<2	<2	<2	<2	<2
Isopropylbenzene	30	150	<5	<5	<5	<5	<5	<5	<5	<5
n-Propylbenzene	128		<5	<5	<5	<5	<5	<5	<5	<5
1,2,4-Trimethylbenzene	33		<5	<5	<5	<5	<5	<5	<5	<5
p-Isopropyltoluene	85		<5	<5	<5	<5	<5	<5	<5	<5
Halogenated Aliphatic Compounds										
Dichlorodifluoromethane	390	390	<50	<50	<50	<50	<50	<50	<50	<50
Halogenated Aromatic Compounds										
Chlorobenzene	55	300	<5	<5	<5	<5	<5	<5	<5	<5
1,4-Dichlorobenzene	60	40	<5	<5	<5	<5	<5	<5	<5	<5
1,2-Dichlorobenzene	160	1500	<5	<5	<5	<5	<5	<5	<5	<5
Polycyclic Aromatic Hydrocarbons										
Naphthalene	85	70	<1	<1	<7	<7	<1	<1	<1	<1

VOCs were detected in samples from the perched water within the Landfill, and from groundwater samples from down-gradient monitoring wells within the Landfill. The concentrations of VOCs detected did not exceed the Environmental Assessment Criteria.

1,4-Dichlorobenzene was detected in a sample of perched water from MW05 in the second monitoring round with a concentration which exceeded the Human Health Assessment Criteria. All other samples of perched water from MW05, the other groundwater monitoring wells and the drain, had concentrations of 1,4-Dichlorobenzene which were below the Human Health Assessment Criteria.

VOCs were not detected in any off-site groundwater samples, or in water samples from the drain.



7.2.5. Semi-Volatile Organic Compounds

The analytical results for semi-volatile organic compounds (SVOC) found in samples with concentrations above laboratory detection limits are summarised in **Table 7-14** for the on-site monitoring wells, and **Table 7-15** for the off-site monitoring wells.

■ **Table 7-14 Semi-Volatile Organic Hydrocarbons, On-site Locations**

Analyte (µg/L)	Environm ental Assessme nt Criteria	Human Health Assessme nt Criteria	Groundwater Beneath Former Landfill						Perched Water Within Former Landfill			
			Up-gradient (MW01)		Cross-gradient (MW02)		Down-gradient (MW06, MW09)		Cross-gradient (MW03, MW04, MW08)		Down-gradient (MW05, MW07)	
			Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Polycyclic Aromatic Hydrocarbons												
Phenanthrene	2	-	-	-	-	-	<1	1.8	<1	1.1	<1	<1
Phenolic Compounds												
2-Methylphenol	13	200	-	-	-	-	<1	2	<1	<3.8	<1	225
3- & 4-Methylphenol	543		-	-	-	-	<2	<2	<2	<7.7	<2	49
2,4-Dimethylphenol	2	730	-	-	-	-	<1	1.2	<1	<3.8	<1	4.6
2,4-Dichlorophenol	120	200	-	-	-	-	<1	<1	<1	<3.8	<1	1.3
4-Chloro-3-methylphenol	350	350	-	-	-	-	<1	<1	<1	<3.8	<1	36.4
2,4,5-Trichlorophenol	0.5	1	-	-	-	-	<1	<1	<1	<3.8	<1	1

■ **Table 7-15 Semi-Volatile Organic Compounds, Off-site Locations**

Analyte (µg/L)	Environmental Assessment Criteria	Human Health Assessment Criteria	Off-site Wells						Drain	
			Up-gradient (CR14, MW01)		Cross-gradient (CR15)		Down-gradient (CR13)			
			Min	Max	Min	Max	Min	Max	Min	Max
Polycyclic Aromatic Hydrocarbons										
Phenanthrene	2	-	<1	<1	-	-	<1	<1	<1	<1
Phenolic Compounds										
2-Methylphenol	13	200	<1	<1	-	-	<1	<1	<1	<1
3- & 4-Methylphenol	543		<2	<2	-	-	<2	<2	<2	<2
2,4-Dimethylphenol	2	730	<1	<1	-	-	<1	<1	<1	<1
2,4-Dichlorophenol	120	200	<1	<1	-	-	<1	<1	<1	<1
4-Chloro-3-methylphenol	350	350	<1	<1	-	-	<1	<1	<1	<1
2,4,5-Trichlorophenol	0.5	1	<1	<1	-	-	<1	<1	<1	<1

As shown **Appendix D.2.2**, elevated concentrations of phenolic compounds which exceeded the Environmental and Human Health Assessment Criteria were found in a sample of perched water from MW05 in the second monitoring round. All other samples of perched water from MW05, the other groundwater monitoring wells and the drain, had concentrations of phenolic compounds which were below the Environmental and Human Health Assessment Criteria.



All other SVOC analytes were below the Environmental Assessment Criteria in the samples analysed. Organo-pesticides, oxygenated compounds, fumigants, and PCB were not detected in any of the groundwater samples tested. SVOCs were not detected in groundwater sampled from off-site wells, or in water sampled from the drain.

7.3. Landfill Gas Monitoring

Historical Monitoring

LCC has undertaken an ongoing landfill gas monitoring program (2000 to 2008) from monitoring wells fitted with free-venting gas well caps installed around the boundary of the site. The monitoring program has detected low levels of methane gas over this time period with concentrations which were well below the LEL for methane (5%). These findings indicate that gas from the Landfill is unlikely to pose an unacceptable risk to off-site receptors (refer to **Section 2.9.4**).

Concentrations of methane ranged between 0% and 1.7% along the eastern boundary of the site, 0% and 0.3% along the northern, southern and western boundaries.

Concentrations of CO₂ ranged between 0% and 11.2% along the eastern boundary of the site, 0% to 6.3% along the northern boundary, 0% and 7.3% along the western boundary and 0% to 10.1% along the southern boundary.

Full copies of the gas monitoring data have been included in **Appendix D.3.1**.

Landfill Gas Monitoring

As part of the Investigation landfill gas monitoring wells were installed within the Landfill, as described in **Section 5.2**. Five rounds of landfill gas monitoring have been undertaken, the results of which are summarised in **Appendix D.3.2**. Six rounds of landfill gas monitoring were undertaken by SKM for the Investigation. The methodology used for landfill gas monitoring is summarised in **Section 5.4**.

Concentrations of methane which exceeded the LEL were detected in monitoring wells MW04, MW05, MW08 and MW09 in the majority of monitoring rounds undertaken during the Investigation at a maximum concentration range of between 49.7% (MW07) and 99.3% (MW08).

Elevated concentrations of carbon dioxide have also been detected in these wells at a maximum concentration range of between 9.5% (MW07) and 15.5% (MW04).

It should be noted that portable landfill gas analysers report hydrocarbon vapours in addition to methane. Consequently a methane reading from the analyser can be comprised of methane and other hydrocarbon vapours.



Gas samples from the monitoring wells MW03, MW04, MW05, MW07, and MW08 were collected by Simtars on the 29 October 2009 and analysed for 73 volatile organic compounds (VOC). A copy of the report prepared by Simtars on the gas analysis is provided in **Appendix F**. The analytical results from the VOC gas analysis are summarised in **Table 7-16**. It should be noted that the VOC analytical methodology used by Simtars does not include methane. Simtars advised that there were unable to test for methane in the VOC gas analysis.

■ **Table 7-16 Volatile Organic Compound Gas Analysis**

Analyte	NOHSC Guideline		MW03	MW04	MW05	MW07	MW08
	TWA (mg/m ³)	STEL (mg/m ³)					
Rate of Flow (L/min)			<0.005	<0.3	<0.03	<0.03	<0.05
Aliphatic Hydrocarbons							
2-methylbutane			<0.2	1.1	0.2	0.6	2.1
n-pentane	1770	2210	<0.2	1.5	<0.2	0.6	1.3
2-methylpentane			<0.2	0.9	<0.2	0.5	1.9
3-methylpentane			<0.2	0.7	<0.2	0.3	1.3
methylcyclopentane			<0.2	0.3	<0.2	0.3	1
n-hexane	176	-	<0.2	1.1	0.3	0.6	2.3
3-methylhexane			<0.2	0.9	<0.2	0.4	1.6
cyclohexane	1035		<0.2	0.6	<0.2	0.4	1.6
methylcyclohexane	1610		<0.2	2.7	0.6	0.7	4.1
2,2,4-trimethylpentane			<0.2	0.6	<0.2	0.3	1.8
n-heptane	1640	2050	<0.2	0.7	<0.2	0.4	1.7
n-octane	1400	1750	<0.2	0.2		0.4	1.5
n-nonane	1050	-	<0.2	<0.2	2	2.5	7.7
n-decane			<0.2	<0.2	5.1	1.7	14.7
n-undecane			<0.2	<0.2	1.8	<0.2	7.8
n-dodecane			<0.2	<0.2	<0.2	<0.2	0.3
alpha-pinene			<0.2	<0.2	<0.2	<0.2	2.4
D-limonene			<0.2	<0.2	<0.2	<0.2	1.2
Chlorinated Hydrocarbons							
chlorobenzene	46	-	<0.2	0.8	0.7	<0.2	<0.2
1,4-dichlorobenzene			<0.2	0.8	2.1	1.1	<0.2
Aromatic Hydrocarbons							
benzene	16	-	<0.2	0.6	0.3	0.7	0.7
ethylbenzene	434	543	<0.2	0.1	1.1	0.2	6.6
isopropylbenzene			<0.2	2.1	1.5	1.5	1.9
1,2,3-trimethylbenzene			<0.1	0.2	<0.1	0.4	<0.1
1,2,4-trimethylbenzene	123	-	<0.2	0.5	3.5	0.6	6.2
1,3,5-trimethylbenzene			<0.2	<0.1	1.7	0.2	1.8
p/m-xylene	350	655	<0.2	<0.1	2.7	0.8	5.2
o-xylene			<0.2	0.1	0.7	<0.1	0.7
Ketones							
acetone	1185	2375	<0.2	<0.2	0.6	<0.2	<0.2
Alcohols							
2-ethyl hexanol			<1.0	<1.0	3.8	4.9	<1.0
Total VOC			<2.0	374	342	481	666



Table 7-16 shows that a range of VOCs were detected in the gas samples collected with concentrations which were below the NOHSC Guideline. Simtars interpretation of the results indicated the profile of gases in the four perched wells was consistent with a mineral turpentine solvent mixture.

The rate of flow was measured using a portable flow meter by Simtars prior to sampling at each location. The rate of flow varied within each perched well, and ranged between <0.005 L/min and 0.3 L/min.

Landfill Vent Monitoring

In the majority of monitoring rounds, low or non-detectable concentrations of methane and carbon dioxide were detected from the monitoring ports attached to the landfill vents (refer to **Appendix D.3.2**). This may be attributed to atmospheric dilution in the vents, as evident from measured oxygen concentrations at approximately 21%. In the monitoring round on 4 November 2009, an elevated detection of methane which exceeded the LEL was found in Vent 2; all other vents however had concentrations of methane which were below the LEL or below detection limits.



8. Qualitative Risk Assessment

8.1. Risk to Human Health

8.1.1. Capping Materials

The findings of the soil sampling of the capping material indicate that potential contaminants are at concentrations which would not pose an unacceptable risk to future site users.

The capping layer of the eastern embankment of the Landfill was found to be comprised of poorly structured clayey sand (0.2-0.5 m thickness). The thickness of the surface material at this location does not provide an adequate barrier between the surface and the waste material below. It is recommended that the capping layer of the eastern embankment be built up to provide a minimum thickness of 0.5 m.

8.1.2. Landfill Gases

Monitoring of landfill gases from the perched wells indicates that the waste materials are generating methane at concentrations well above the LEL. Landfill gas which includes methane, is considered to pose a risk to future site users as an asphyxiant and flammable gas (refer to **Section 4.2.2**). The primary risk to future site users will be the migration of gases along pathways created by foundations (including piles) and underground services or service trenches into buildings located on the site, or other confined spaces (e.g. service pits). Controls will need to be put in place to mitigate potential risks to future site users; these are summarised in **Section 9**. It is expected that the control of gas accumulation in buildings will also mitigate any potential odour issues associated with landfill gases. Note no ambient odours were noticed at the site. Odours were only noted in monitoring wells installed within the Landfill.

A range of volatile organic compounds have been detected in landfill gases at concentrations which were below the NOHSC Guidelines, and accordingly are unlikely to pose an unacceptable risk to future uses of the site.

8.2. Risk to the Environment

Two groundwater systems have been observed on the site. These include:

- groundwater within the weathered sandstone beneath the Landfill; and
- perched groundwater within the Landfill.

It is considered highly likely that the perched water is in connection with the groundwater in the weathered sandstone, and these systems combine down-gradient of the Landfill for reasons outlined **Section 6.2**. These groundwater systems flow in a north-easterly direction towards Slacks



Creek. Slacks Creek is located approximately 320 m east of the site, and is considered to be the main environmental receptor of groundwater from the site. Accordingly, the potential risks to ecosystems in the creek are assessed by comparison of contaminant concentrations in site groundwater to ecosystem-based Environmental Assessment Criteria, and Human Health Assessment Criteria associated with recreational contact.

Metals

Elevated concentrations of copper, lead, nickel and zinc with concentrations above the Environmental Assessment Criteria have been found in groundwater samples from monitoring wells up-gradient of the Landfill, and within the Landfill. Lead was found in a monitoring well up-gradient of the Landfill with a concentration which exceeded the Human Health Assessment Criteria. The highest concentrations detected were from the up-gradient monitoring well (MW01). An increase in the concentration of metals was not observed in the monitoring wells down-gradient of the Landfill. These findings indicate that elevated concentrations of metals occur in the vicinity (and up-gradient) of the site, however it is unknown whether the elevated concentrations are associated with surrounding industrial land use, naturally occurring background conditions, or a combination of both these factors. Leachate from the Landfill is unlikely to be having a deleterious effect on groundwater with respect to metals.

Ammonia

Ammonia was detected at concentrations which exceed the Environmental and Human Health Assessment Criteria in groundwater samples from monitoring wells within and down-gradient of the Landfill. Ammonia is widely recognised as one of the most prevalent and continuous contaminants sourced from former landfills (Kjeldsen et al 2002). The site investigation data for CR13 which is a monitoring well located down-gradient of the Landfill shows that the concentrations of ammonia have attenuated from 39.9 mg/L in 2000 (refer to **Section 2.9.2**) to approximately 10 mg/L in 2008-09. Notwithstanding this, elevated concentrations of ammonia were detected in other monitoring wells along the eastern boundary of the Landfill.

A review of the Australian Drinking Water Guidelines (2004) and the World Health Organisation Guidelines for Drinking-water Quality²¹ was undertaken to determine the human health implications of high concentrations of ammonia in water. Conclusions from these guidelines indicate that ammonia is not of direct importance for health (via ingestion) in concentrations to be expected in drinking water. The Australian Drinking Water Guideline value derived is instead based on other considerations such as attacking copper pipes and fittings, or nuisance growths of micro-organisms which may lead to skin irritation. Accordingly the risk to human health through ingestion from ammonia in groundwater is considered to be low. It is noted, however, that

²¹ WHO, 1996, Ammonia in Drinking-water. World Health Organisation, Geneva.



ammonia can have a toxic effect on humans only if the intake becomes higher than the detoxification capacity of the body. In studies with animals, high doses of ammonia (over 100 mg/kg body weight per day) have generally not produced any significant toxic effects.

Ammonia is a known toxicant to fish and can have a deleterious effect on aquatic ecosystem health. However factors such as dilution would lower the concentration of ammonia prior to discharge to the nearest receiving watercourse (Slacks Creek, 320 m east of the site).

Nitrate

Nitrate concentrations in samples from CR13 which is a monitoring well located down-gradient of the Landfill consistently exceeded the Environmental Assessment Criteria between November 2004 and May 2006. However since July 2006, the concentrations of nitrate in samples from CR13 have been below the Environmental Assessment Criteria (refer to **Section 2.9.2**).

Total Phosphorus and Phosphate

Total phosphorus was found in groundwater samples with concentrations which exceeded the Environmental Assessment Criteria in 2002. Total phosphorus has not been monitored since 2002, however phosphate was included in the monitoring program from 2004-2008 and was found to be below laboratory detection limits (refer to **Section 2.9.2**).

Hydrocarbons

Elevated concentrations of hydrocarbons have been consistently detected in groundwater. The analytical results and interpretation of the source hydrocarbons by the laboratory indicate that the elevated concentrations of hydrocarbons found in groundwater samples are predominately organic substances being produced by the Landfill through the decomposition of putrescible materials rather than petroleum based hydrocarbons (e.g. oils).

An elevated concentration of petroleum based aliphatic hydrocarbons was detected in one groundwater sample in the second monitoring round with a concentration which exceeded the Environmental and Human Health Assessment Criteria. However, no other exceedances of the Environmental and Human Health Assessment Criteria for petroleum based hydrocarbons was found.

Volatile Organic Compounds

A range of VOCs were detected in groundwater samples with concentrations which were below the Environmental Assessment Criteria.

An elevated concentration of 1,4-Dichlorobenzene which exceeded the Human Health Assessment Criteria was found in a perched water sample from one of the monitoring wells (MW05) in the second monitoring round. On the basis that elevated concentrations of 1,4-Dichlorobenzene which exceed the Human Health Assessment Criteria were not consistently found and dilution factors in



the receiving environment, the risk to human health from 1,4-Dichlorobenzene is considered to be low. All other samples from MW05 and samples from the other groundwater monitoring wells had concentrations of phenolic compounds which were below detection limits or below the Human Health Assessment Criteria.

Semi-Volatile Organic Compounds

The majority of SVOCs including PAH (with the exception phenanthrene), pesticides, oxygenated compounds, fumigants, and PCB were not detected in any of the groundwater samples tested. Phenanthrene was detected in some of the samples analysed with concentrations below the Environmental Assessment Criteria.

An elevated concentration of phenolic compounds which exceeded the Environmental Assessment Criteria was found in a perched water sample from one of the monitoring wells (MW05) in the second monitoring round. All other samples from MW05 and samples from the other groundwater monitoring wells had concentrations of phenolic compounds which were below detection limits or below the Environmental Assessment Criteria. On the basis that elevated concentrations of phenolic compounds which exceed the Environmental Assessment Criteria were not consistently found, the risk to the receiving environment from phenolic compounds is considered to be low.

Summary of Findings

Slacks Creek is a highly disturbed system which has been heavily modified from its natural state.

It is considered likely that landfill leachate from the site which contains elevated concentrations of ammonia and organics is potentially having some deleterious impact on Slacks Creek. It should be noted that the site is located within a large urban catchment with residential and commercial/industrial areas which would also be contributing to the degradation of Slacks Creek.

Landfill leachate is discharged from the site via seepages into the drain, and groundwater migration. Leachate discharged from the site will be diluted via other sources of surface water discharged to the drain, groundwater occurring in the vicinity of the site, and water present in Slacks Creek.

As the Landfill has not been constructed with an engineered liner or leachate collection system it is not considered feasible to modify the Landfill to effectively capture and treat landfill leachate. The concentration of contaminants in leachate from the Landfill will decrease with time, as the putrescible material in the Landfill degrades. This is evident from the decrease in ammonia concentrations in monitoring well CR13 from 2000 to 2008-09. Accordingly the most appropriate approach for the ongoing management of the site is considered to be the continuation of the monitoring program currently being undertaken to confirm that attenuation of contaminants is occurring over time. The proposed development will also need to be constructed in a way which minimises percolation of rainfall into the landfill (by contouring and surface drainage design) and

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which does not exacerbate potential pathways (e.g. through uncontrolled breaches in the capping layer) on the site. Construction methods for the proposed development are discussed further in **Section 9**.

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9. Remediation Strategy

This section provides a summary of the remediation strategy proposed for the development of the site. The key remedial measures required for the redevelopment of the site include:

- the building up of the capping layer in the eastern embankment of the site;
- the inclusion of gas protection measures in buildings;
- the re-construction of gas vents closed during the construction phase for the proposed development;
- the location of services above the capping material where practicable;
- the use of sensitive construction and piling measures to minimise disturbance to the capping material;
- the use of low permeability materials or membranes for proposed water storage areas on the site;
- the undertaking of an ongoing monitoring program during and post development of the site; and
- the confirmation that former underground tank on the site has been removed.

These measures are summarised as follows and described in further detail in the Remediation Plan prepared for the Project.

9.1. Capping Layer

The capping layer of the eastern embankment of the Landfill was found to vary from 0.2-0.5 m in thickness. The capping layer of the eastern embankment will be built up to provide a minimum thickness of 0.5 m using uncontaminated fill material. As the embankment may be acting as a pathway for the venting of landfill gases, it is not recommended that a low permeability material be used to build up the embankment. Such a material could potentially change the landfill gas migration and venting regime along the embankment.

9.2. Gas Protection

Three buildings have been proposed on the site including:

- main facilities building with an open air viewing stand;
- kennel block; and
- maintenance shed.

The proposed location of these buildings is shown in **Figure 2, Appendix A**.



Main Facilities Building

The boreholes drilled for the Preliminary Geotechnical Investigation shows that eastern half of the Main Facilities Building is likely to be located over soil/waste materials, and the western half over soil materials. Further ground characterisation during the detailed design phase will confirm the ground conditions beneath this building.

It is proposed that the Main Facilities Building will be founded on piles and a slab suspended off-the-ground. An open void will be located between the slab and the ground to allow for the free venting of air beneath the building.

Kennel Block and Maintenance Shed

The boreholes drilled for the Preliminary Geotechnical Investigation show that ground beneath the Kennel Block and Maintenance Shed is unlikely to contain waste materials. Further ground characterisation during the detailed design phase will confirm this. Slab-on-ground foundations are proposed for these buildings. Gas protection measures proposed for these buildings include:

- well-constructed ground slab located above the capping layer;
- low-permeability gas/vapour membrane;
- the location of services above the capping layer and entering buildings from the side (rather than through floor slabs); and
- passive in-ground venting, with the venting system being located above the capping layer and beneath the floor slab to allow for the venting of landfill gases.

During the detailed design phase of the Project, monitoring will be undertaken at the location of these proposed buildings to characterise the Landfill gas regime at these locations. Should the findings of landfill gas monitoring indicate that the gas regime at these locations is of low risk, the protection measures proposed may be amended in consultation with DERM.

9.3. Landfill Gas Vents

The proposed development will involve the removal of two of the existing landfill gas vents. It is proposed that two additional vents will be constructed in the vicinity of the vents being removed during the construction process.

The height of the vents will be reduced to allow for improved viewing and the functioning of the site as a greyhound racing facility. A reduction in the height of the vents is not expected to impair their functionality.



9.4. Services

All services will either run above or within the capping material. Where services are located within the capping material, they will be exposed to the atmosphere to vent potential landfill gases prior to a worker entering any confined spaces. Services will not be located beneath the capping layer.

9.5. Construction Methods

Piling Methods

Piling will be required for the construction of the Main Facilities Building. The piles will be founded on the sandstone strata beneath the site. Piling will require disturbance to the capping material. The capping material surrounding the piles will be resealed with a low permeability clay based material.

Racing Track

Preloading will be undertaken over the racing area to accelerate the settlement process and stabilise the surrounding ground. Groundwater mounding may occur as a result of preloading however it is not expected to result in any further risk to human health or the environment. Pad foundations are to be used for the running rail around the racing track and lighting following preloading. This will negate the need to pile through the Landfill cap for the running rail.

9.6. Stormwater and Surface Drainage

Surface drainage and stormwater management features of the proposed development are described in the *Infrastructure Servicing and Site Based Stormwater Management Plan* (SKM, 2009). The main features of the proposed stormwater management system are shown in **Appendix B**.

Stormwater collected from the surface of the site will be diverted to vegetated swales to capture litter, suspended solids and other matter prior to discharging into the drainage system. The installation of swales minimises the need to excavate through the surface material and into the waste material below.

During periods of heavy rainfall, surface water is to be captured and temporarily held within retention basins on-site. The retention basin will be lined high density poly-ethylene (HDPE) liners or equivalent to prevent vertical seepage into the Landfill.

The drain skirting the south and east of the site is to be managed by LCC as an easement. It is proposed that some restoration of this drain be undertaken by LCC as part of the redevelopment. The level of restoration to be undertaken will be confirmed during the detailed design phase. It is not anticipated that the restoration work will involve disturbance to the Landfill.



9.7. Monitoring

Monitoring of groundwater quality and landfill gases will be undertaken during the construction of the Project.

Post development the site will be managed under a Site Management Plan (SMP). The SMP will be prepared during the detailed design phase and held on record with DERM.

The SMP will provide a framework for ongoing environmental monitoring as well as stipulate any ongoing operational controls for the site.

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10. Conclusions and Recommendations

10.1. Project Overview

Greyhounds Queensland Limited (GQL) is planning the development of the Logan Greyhound Facility (“the Project”) at Cronulla Park, Slacks Creek (“the site”). Cronulla Park was formerly used a landfill (“the Landfill”) between the 1970s and 1980s.

GQL engaged Sinclair Knight Merz (SKM) to undertake a Stage 1 and Stage 2 Contaminated Site Investigation (“the Investigation”) of the site. The aims of the Investigation were to establish:

- whether the site in its current condition poses an unacceptable risk to human health and/or the receiving environment; and
- whether remediation will be required to enable the site to be used for a commercial land use (greyhound racing facility), and if so, the required remedial measures.

10.2. Site Conditions

Surface Material

For the majority of the Landfill, the surface material was found to be comprised of a layer of silty sand (0-0.1 m thickness) and an underlying clay based material comprised of sandy clay to clayey sand (0.2-0.8 m thickness).

The surface layer of the eastern embankment of the Landfill was found to be comprised of poorly structured clayey sand (0.2-0.5 m thickness).

Waste Material

Where encountered, waste materials varied in thickness from 1.2 to 10.5 metres in thickness. An engineered liner was not found beneath the Waste Material.

Natural Material

The natural material was generally a sandy or silty clay of weathered sandstone. This was underlain by the coarse grained sandstone.

Groundwater

Two groundwater systems have been observed on the site. These include:

- groundwater within the weathered sandstone beneath the Landfill; and
- perched water within the Landfill.

The perched water is likely to be in connection with the groundwater in the weathered sandstone beneath the Landfill. These two systems also combine together down-gradient of the Landfill.

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These groundwater systems flow in a north-easterly direction to Slacks Creek which is located approximately 320 m east of the site.

Slacks Creek is the main environmental receptor of both groundwater and surface water from the site.

10.3. Analytical Results

Capping Material

Shallow soils in the capping material at the site were found to contain contaminant concentrations which were below the Human Health Assessment Criteria. Shallow soils at the site would subsequently not pose an unacceptable risk to human health.

Landfill Gases

Monitoring of landfill gases from the perched wells indicates that the waste materials are generating methane at concentrations well above the LEL. Landfill gas which is primarily methane, is considered to pose a risk to future site users as an asphyxiant and flammable gas. Volatile organic compounds have been detected in landfill gases at concentrations which were below the NOHSC Guidelines, and accordingly are unlikely to pose an unacceptable risk to future uses of the site.

Groundwater

Slacks Creek is a highly disturbed system which has been heavily modified from its natural state. It is considered likely that landfill leachate from the site which contains elevated concentrations of ammonia and organics is potentially having some deleterious impact on water quality in Slacks Creek. Residential and commercial/industrial areas located within the catchment will also contributing to the degradation of Slacks Creek.

On the basis that the Landfill has not been constructed with an engineered liner or leachate collection system it is not considered feasible to modify the Landfill to effectively capture and treat landfill leachate. The concentration of contaminants in leachate from the Landfill will decrease with time as the putrescible material in the Landfill degrades. This process is occurring as evident from the decrease in ammonia concentrations in groundwater from 2000 to 2008-09. The most appropriate approach for the ongoing management of the site in regard to groundwater is considered to be the continuation of the monitoring program currently being undertaken to confirm that attenuation of contaminants is occurring over time.

10.4. Suitability of Site for Proposed Development

Based on the findings of the Investigation the site is considered to be suitable for the proposed development and use provided that potential risks relating to landfill gas and contaminated groundwater are addressed in the design, construction, and future management stages of the site. It

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is intended the site will be constructed in accordance with a Remediation Plan (RP), and managed post-construction under a Site Management Plan (SMP). The SMP will provide a framework for ongoing environmental monitoring as well as stipulate any ongoing operational controls for the site, and will be administered by LCC. The SMP will include groundwater and landfill gas monitoring at the site.

The key remedial measures required for the redevelopment of the site include:

- the building up of the capping layer in the eastern embankment of the site;
- the inclusion of gas protection measures in buildings;
- the re-construction of gas vents closed for the proposed development;
- the location of services above the capping material where practicable;
- the use of sensitive construction and piling measures to minimise disturbance to the capping material;
- the use of low permeability materials or membranes for proposed water storage areas on the site;
- the undertaking of an ongoing monitoring program during and post development of the site; and
- the confirmation that former underground tank on the site has been removed.

Further detail regarding the proposed remediation strategy are to be provided in the Remediation Plan which is being prepared for the redevelopment of the site.



11. References

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Appendix A Figures

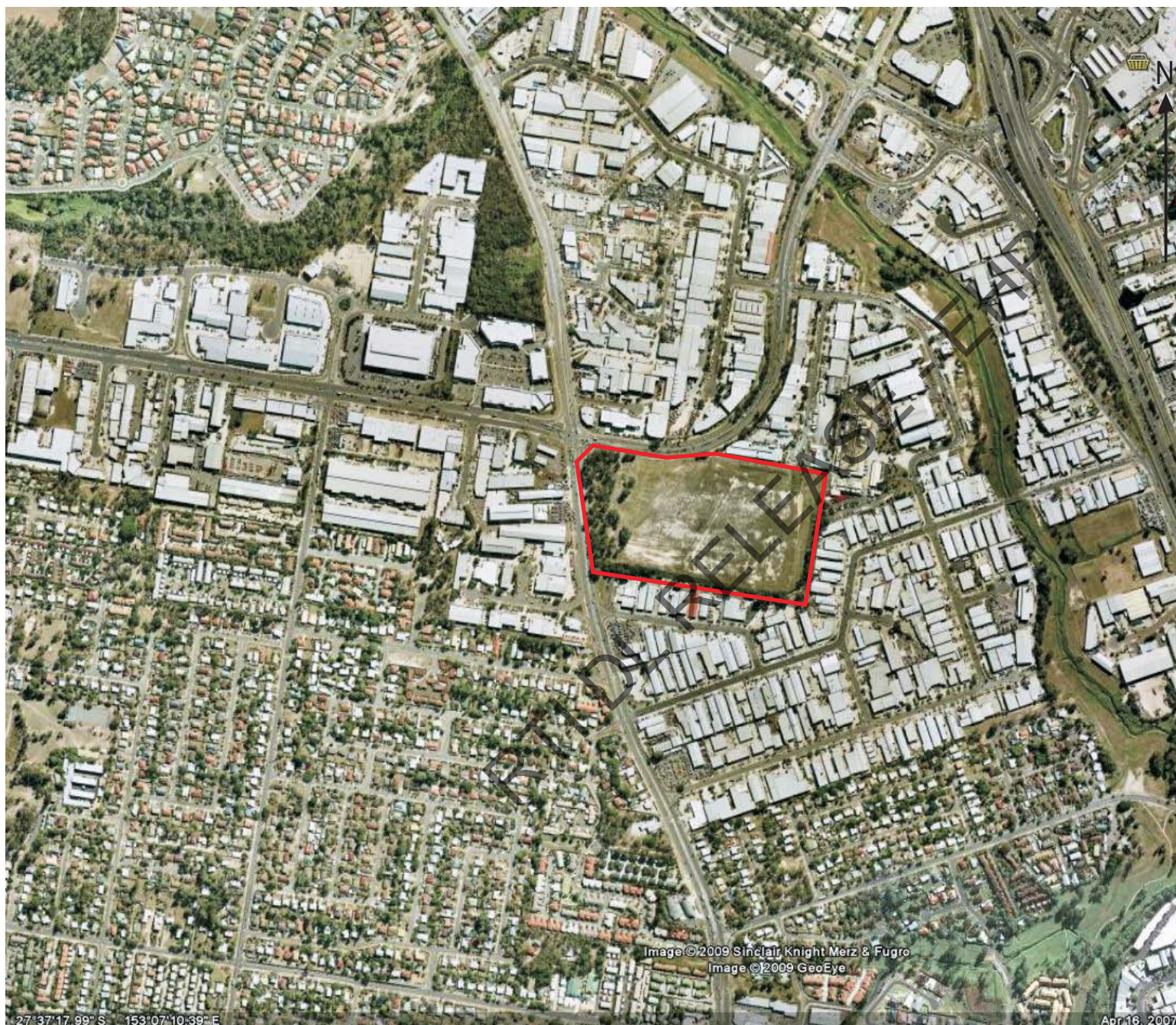
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Logan Greyhound Facility Supplementary Site Investigation

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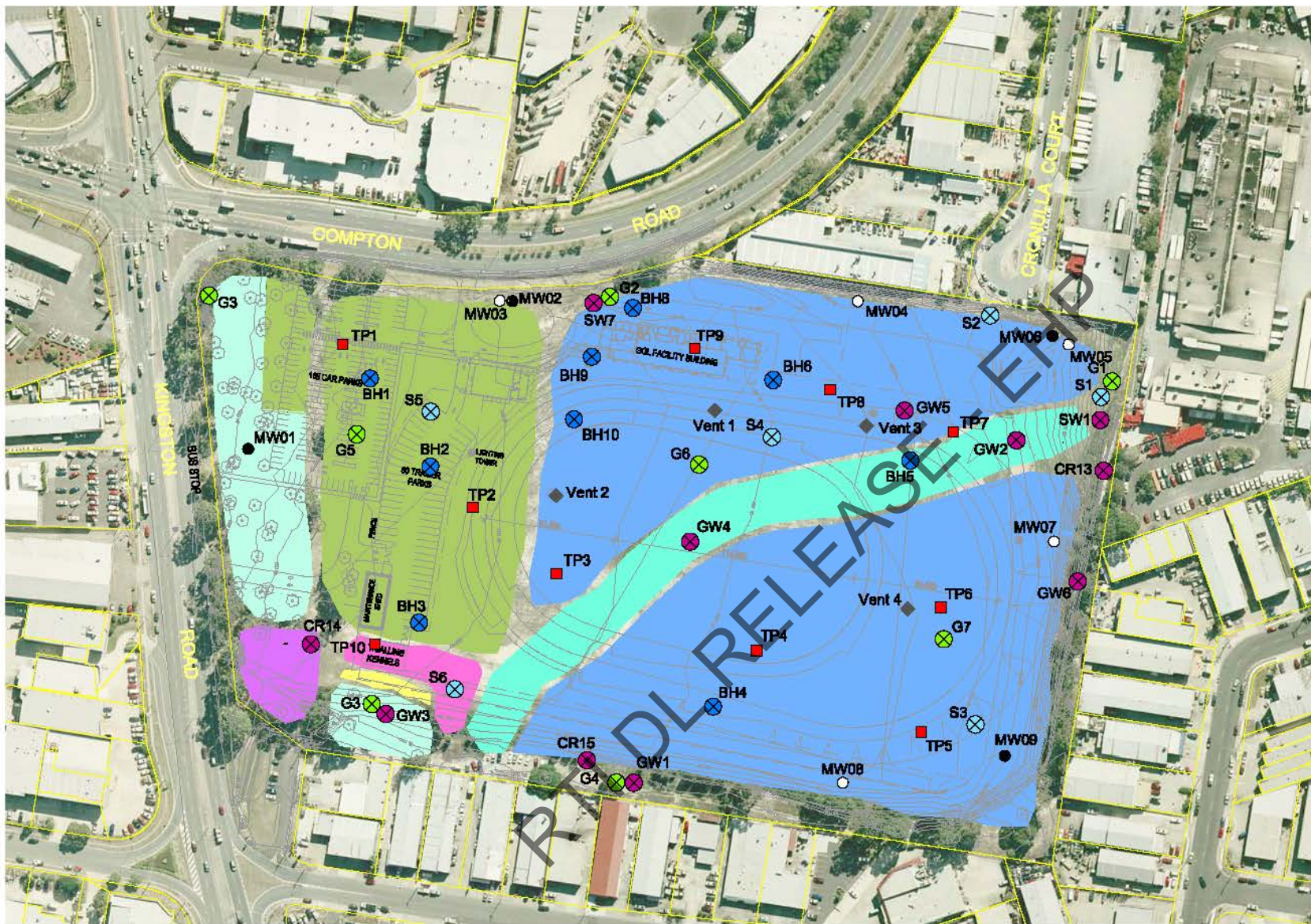
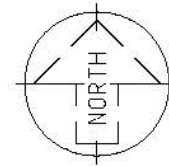
Site Boundary



Notes:

1. Aerial Photograph - Google Earth Pro, 2008
2. Scale and features shown are approximate locations only

Figure 1
Site Location Plan



LEGEND

- ◆ Landfill Vent
- BOREHOLES**
 - 2009 Shallow Monitoring Bore
 - 2009 Deep Monitoring Bore
 - 2009 Shallow Soil Sampling Location
 - ⊗ Geotechnical Borehole
 - ⊗ Historical Gas Sampling Well
 - ⊗ Historical Soil Bore
 - ⊗ Historical Groundwater Well
- LANDFILL**
 - Municipal and Light Industrial Waste
 - Municipal Waste-Domestic
 - Animal and Sanitary Waste
 - Tyre and Steel Waste
 - No Waste Disposal (Treed Area)
 - Workshop Washdown Area
 - General Waste

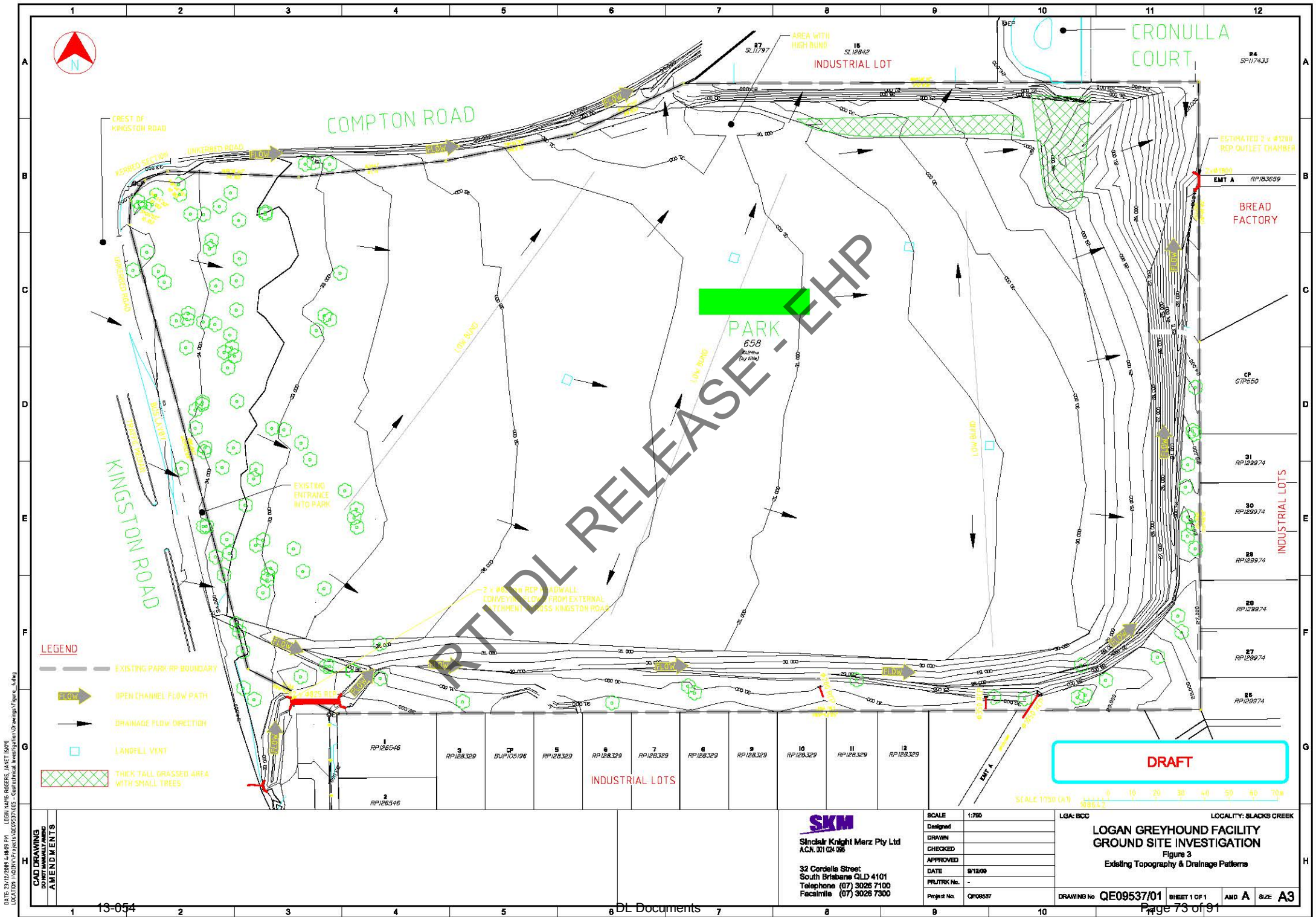
PLAN
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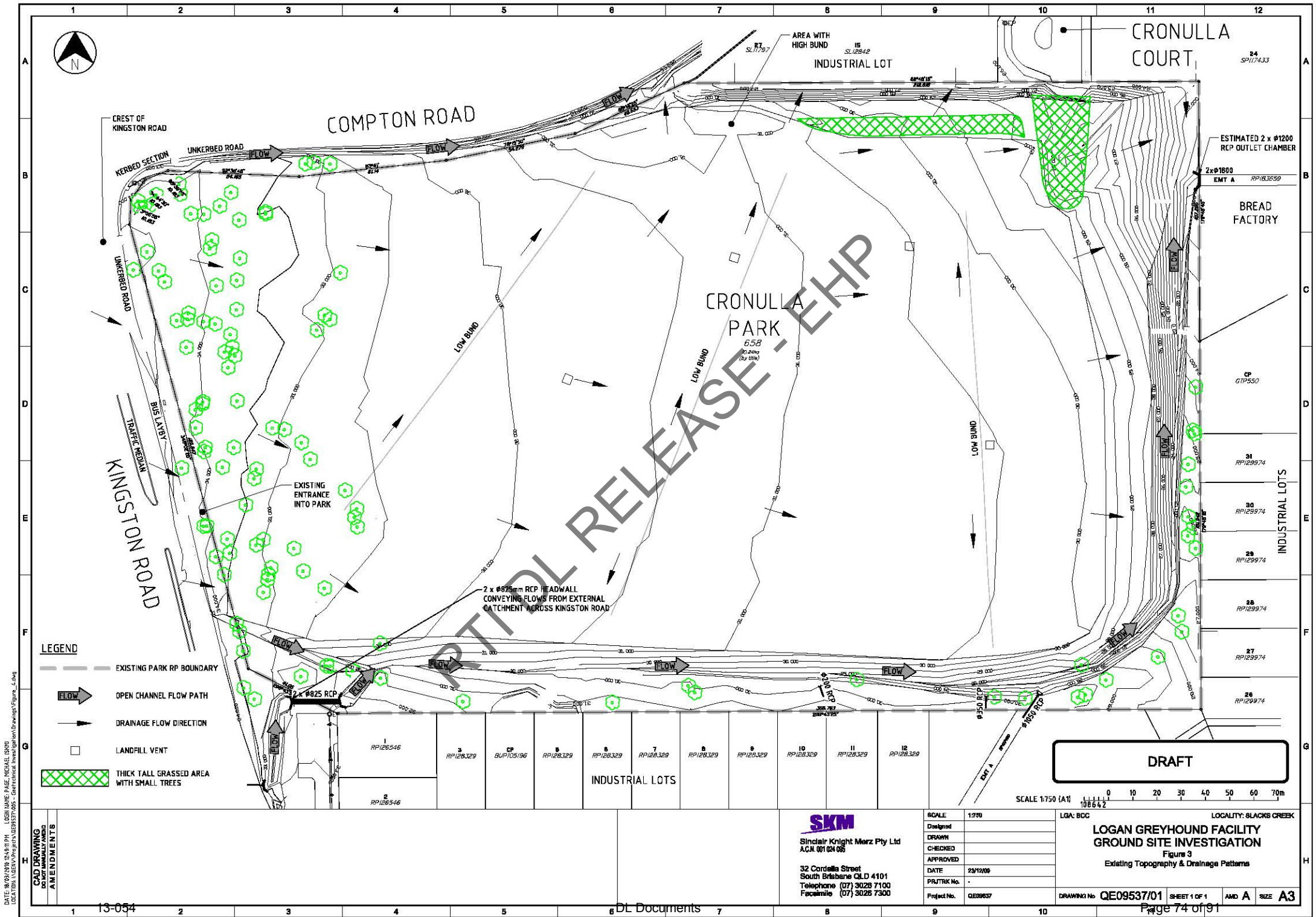
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LOCALITY: SLACKS CREEK
LOGAN GREYHOUND FACILITY
GROUND SITE INVESTIGATION
Figure 3
Existing Topography & Drainage Patterns
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- LEGEND**
- EXISTING PARK RP BOUNDARY
 - OPEN CHANNEL FLOW PATH
 - DRAINAGE FLOW DIRECTION
 - LANDFILL VENT
 - THICK TALL GRASSED AREA WITH SMALL TREES

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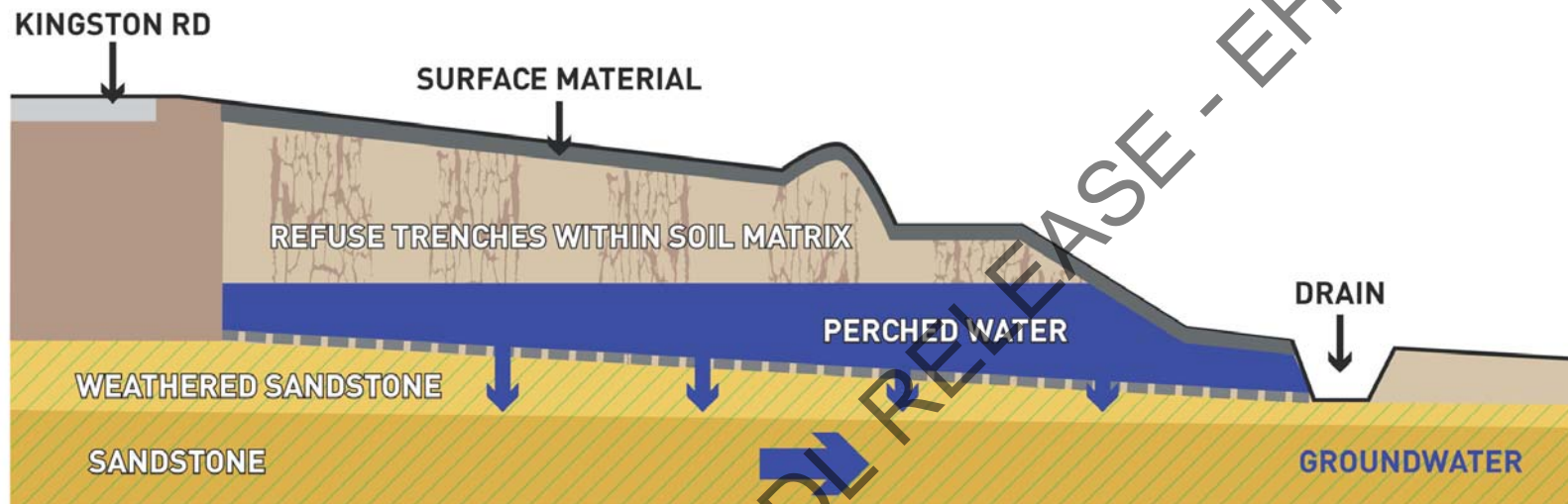
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Logan Greyhound Facility Supplementary Site Investigation

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Notes:
1. Figure not to scale.

Figure 5
Conceptual Site Geology

Logan Greyhound Facility

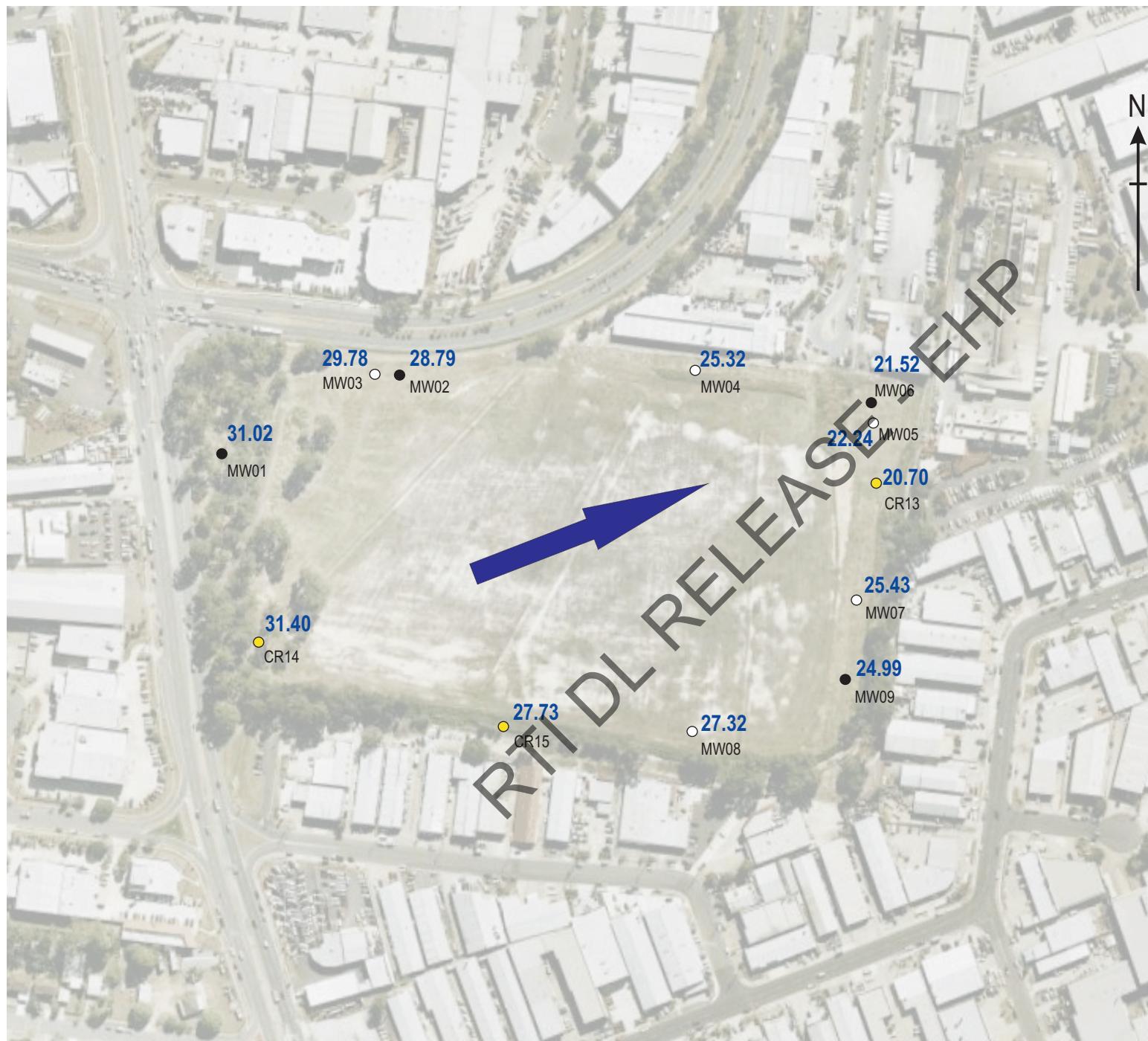
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- 2009 Shallow Monitoring Bore
- 2002 Shallow Monitoring Bore
- 2009 Deep Monitoring Bore
- 22.24 Average Groundwater Level over monitoring period (m AHD)
- Approximate Groundwater Flow Direction

Notes:

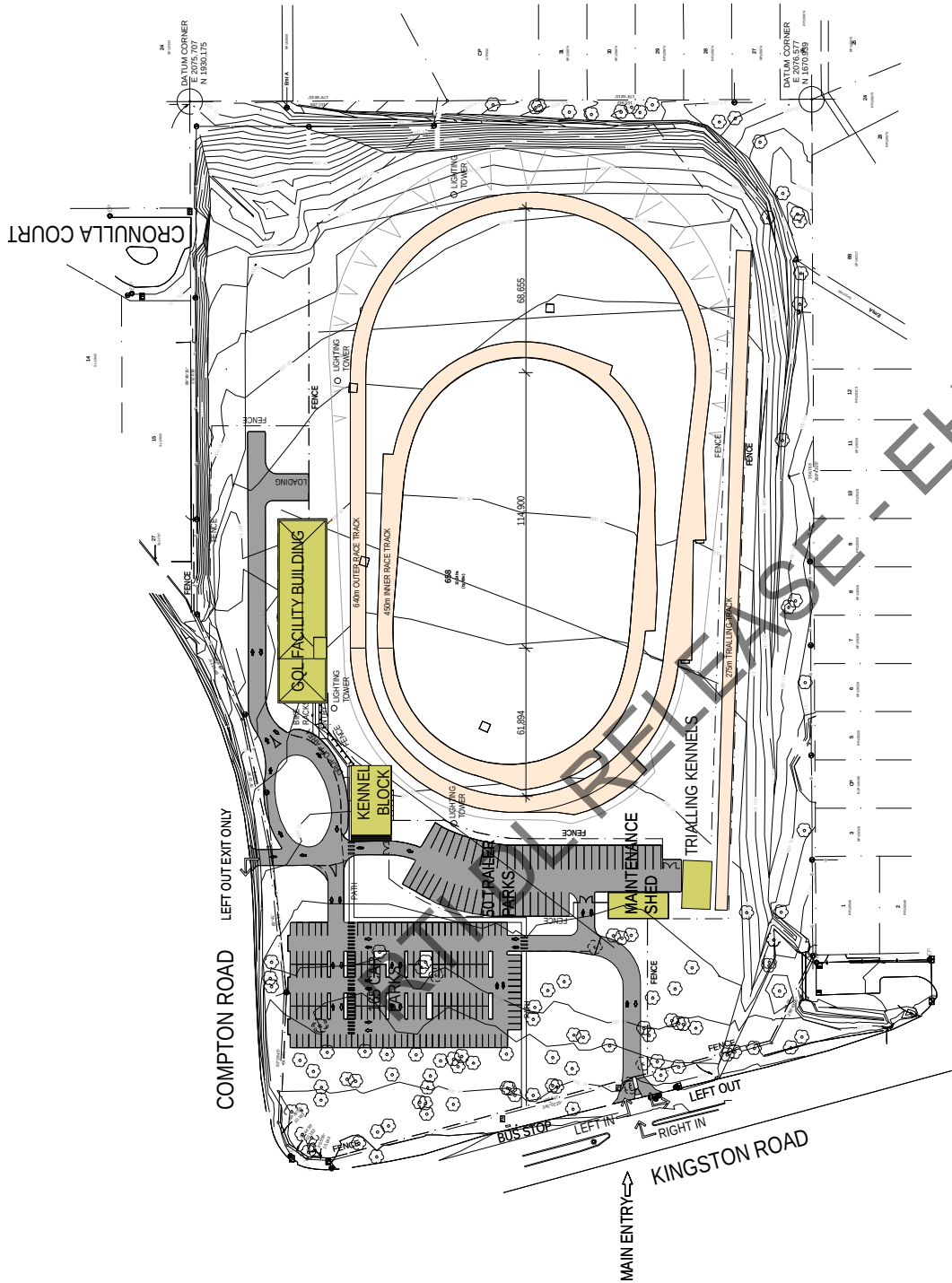
1. Aerial Photograph - Google Earth Pro, 2008
2. Scale and features shown are approximate locations only

Figure 6
Average Groundwater Levels



Appendix B Development Application Plans

RTI DL RELEASE - EHP



1 Site Plan 1:2000

FACILITY BUILDING GFA: 2400m²
 KENNEL BLOCK GFA: 363m²
 TRIALLING KENNELS GFA: 170m²
 MAINTENANCE SHED GFA: 270m²
TOTAL SITE GFA: 3203m²

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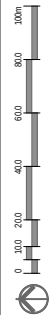
LOGAN GREYHOUND FACILITY
 GREYHOUNDS QUEENSLAND



architecture | master planning | urban design | interior design

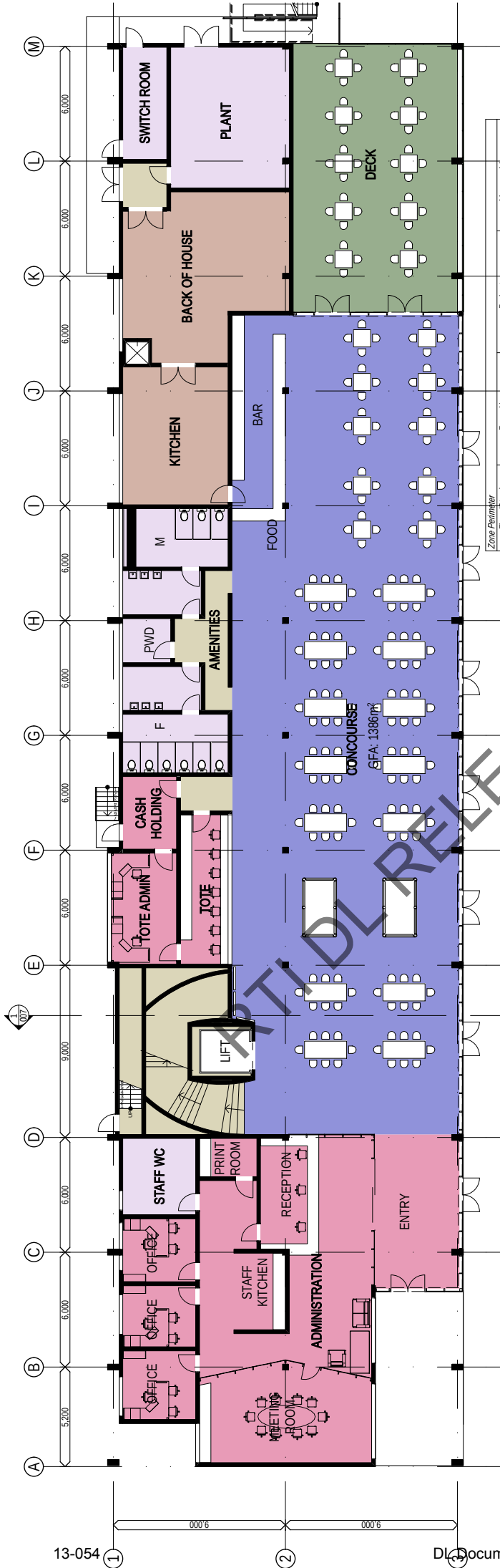
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1 GROUND FLOOR PLAN 1:200

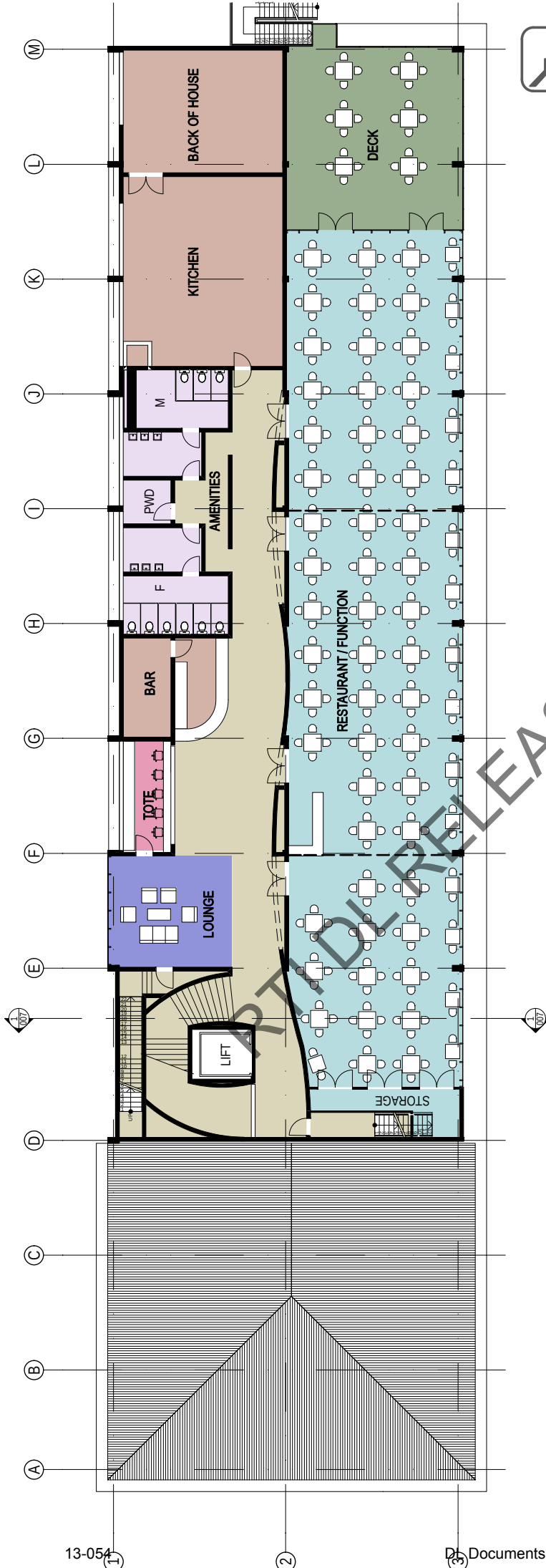
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Zone	Perimeter	Room Name	Measured Area
Zone 1	9.00		4.96
	9.22		5.32
	21.00		15.36
	31.29		56.38
	69.81	ADMINISTRATION	232.12
	44.60	AMENITIES	60.80
	35.39	BACK OF HOUSE	65.14
	13.21	CASH	10.65
	110.23	CONCOURSE	503.78
	45.80	DECK	124.60
	25.39	KITCHEN	39.57
	27.13	PLANT	45.65
	15.60	STAFF WC	15.20
	16.33	SWITCH ROOM	13.49
	20.61	TOTE	19.51
Zone 2	18.40	TOTE ADMIN	19.72
	13.10		6.82
	123.41	RESTAURANT / FUNCTION	192.50
	113.48	AMENITIES	418.81
	44.60	BACK OF HOUSE	60.80
	29.60	BAR	53.86
	20.87	DECK	28.14
	39.95	KITCHEN	89.85
	38.50	LOUNGE	82.68
	24.60	TOTE	37.70
	18.40		14.25
	23.11	STAIR	24.82
	21.30		19.09
	22.60		22.98
	104.45 m		2,265.58 m²

LOGAN GREYHOUND FACILITY

GREYHOUNDS QUEENSLAND

FLOOR PLANS - GQL FACILITY BUILDING

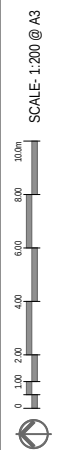


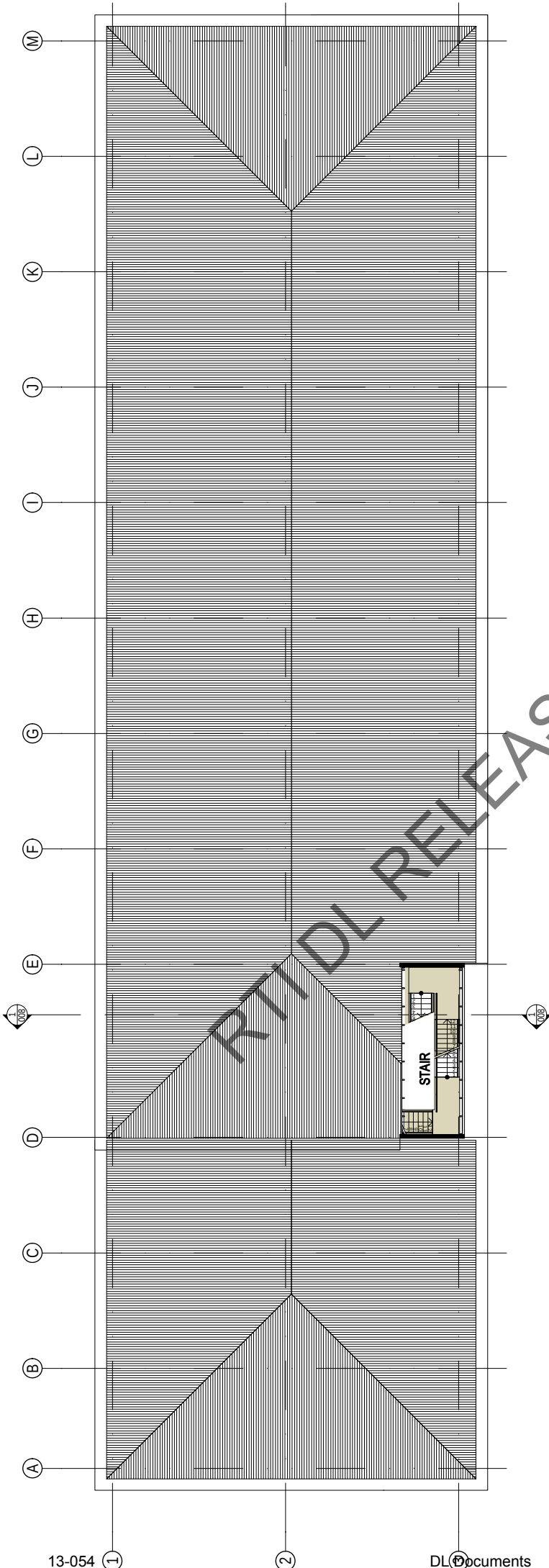
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GREYHOUNDS QUEENSLAND



FLOOR PLANS - GQL FACILITY BUILDING





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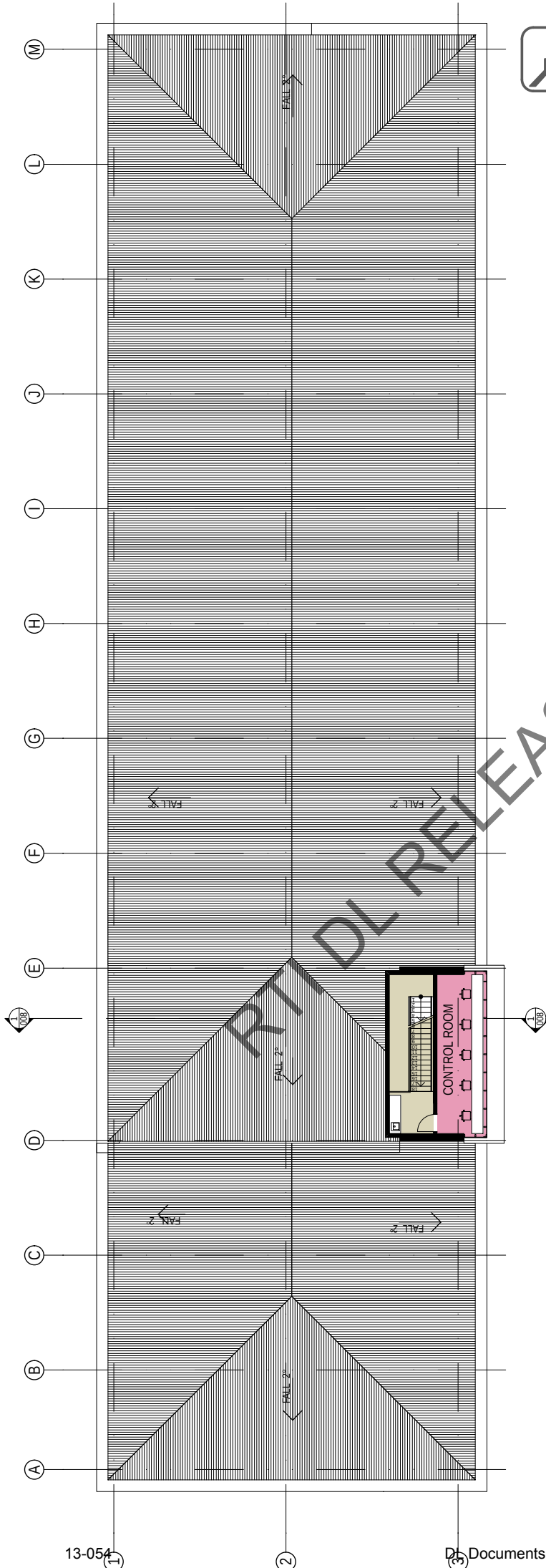
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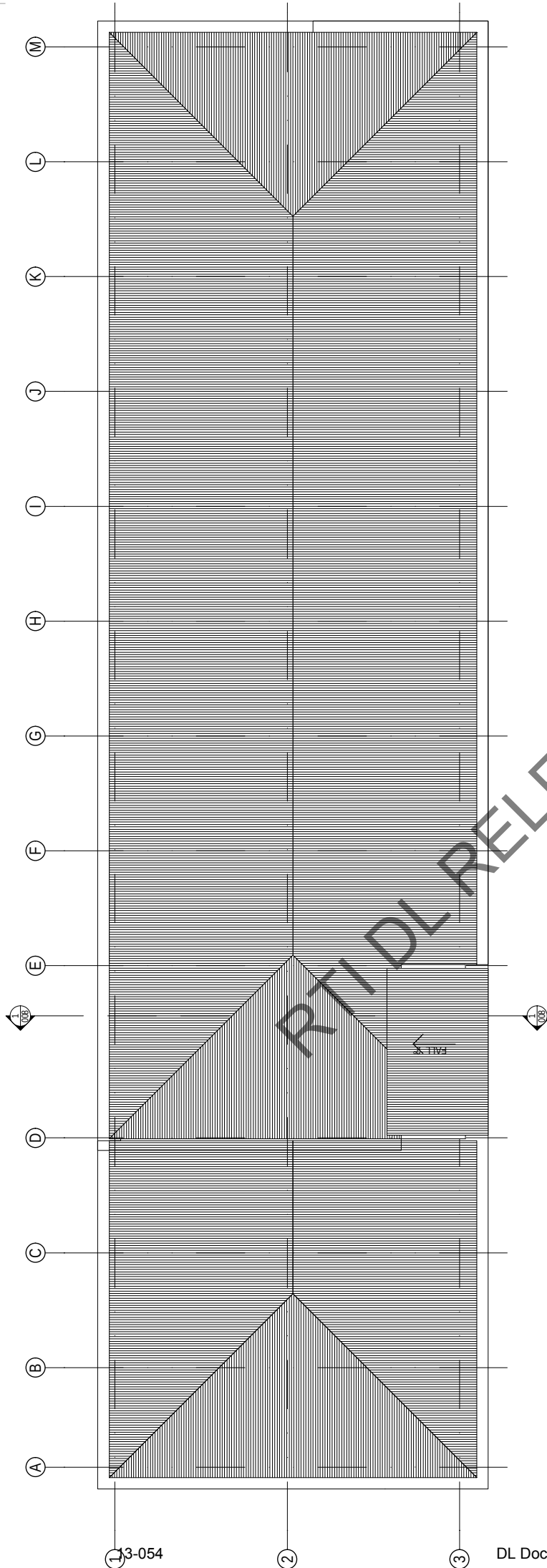
1 LEVEL 2 PLAN 1:200

LOGAN GREYHOUND FACILITY

GREYHOUNDS QUEENSLAND

FLOOR PLANS - GQL FACILITY BUILDING





1 ROOF PLAN 1:200

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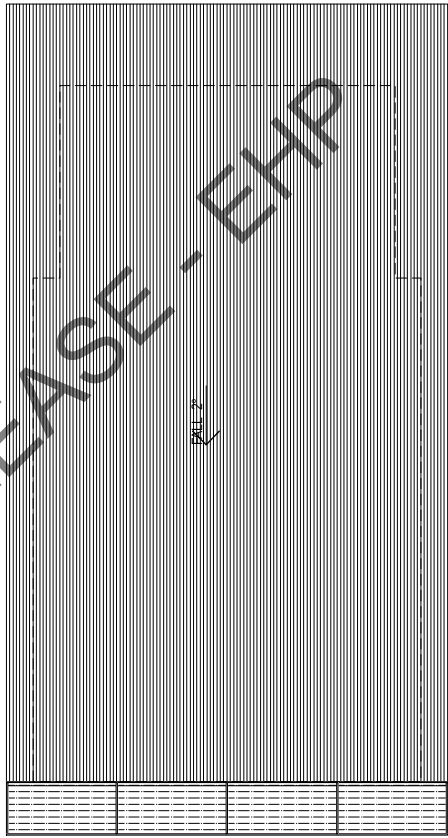
GREYHOUNDS QUEENSLAND

ROOF PLANS - GQL FACILITY BUILDING



1 GROUND FLOOR PLAN 1:200

Zone Perimeter	Floor (Story)	Room Name	Perimeter	Measured Area
Ground		KENNELS	65.05	259.79
		STEWARDS	16.60	16.60
		VET	15.60	14.40
		WEIGHT ROOM	38.68	52.92
			135.93 m	343.91 m²



2 ROOF PLAN 1:200

FLOOR PLANS - KENNEL BLOCK

LOGAN GREYHOUND FACILITY
GREYHOUNDS QUEENSLAND

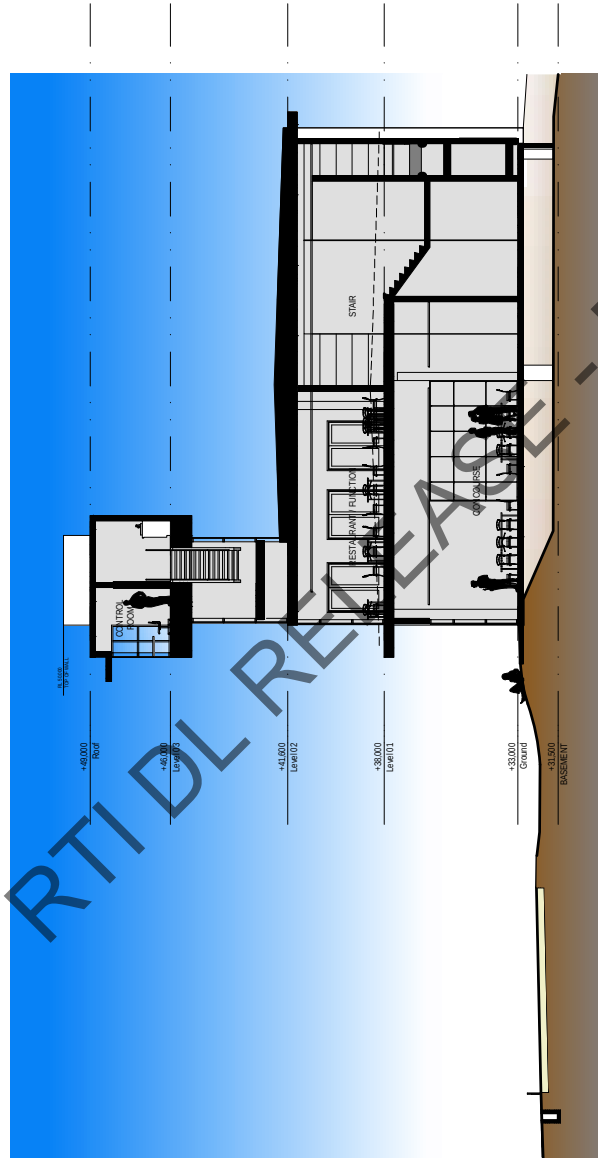


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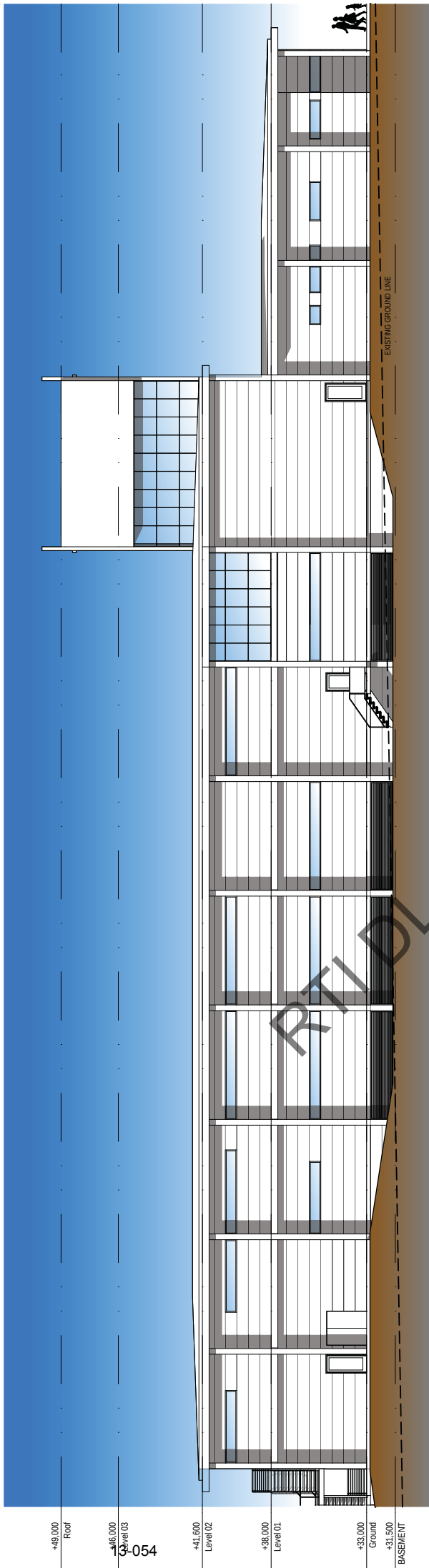
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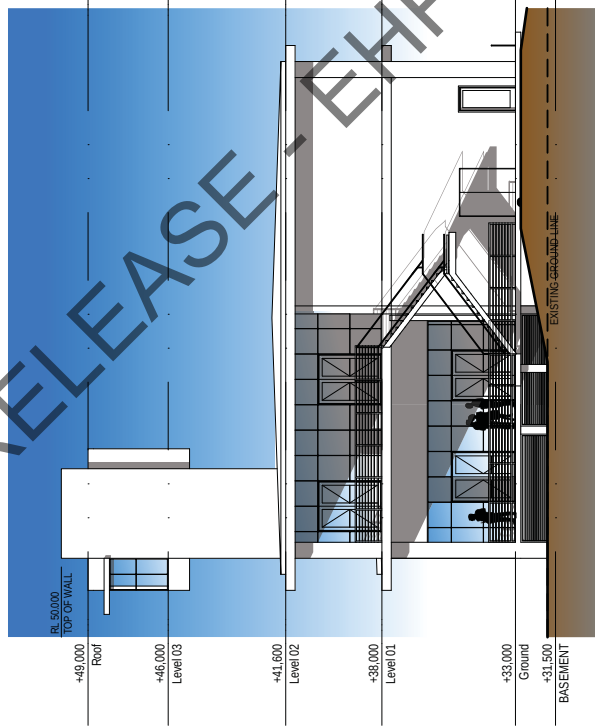
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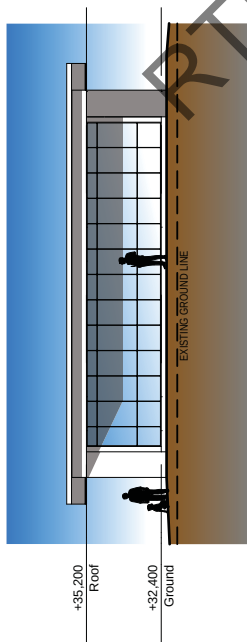


B EAST ELEVATION 1:200

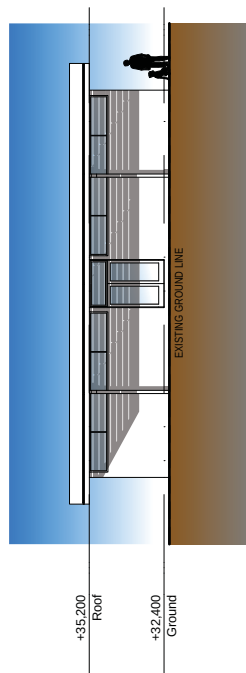
ELEVATIONS - GQL FACILITY BUILDING

LOGAN GREYHOUND FACILITY

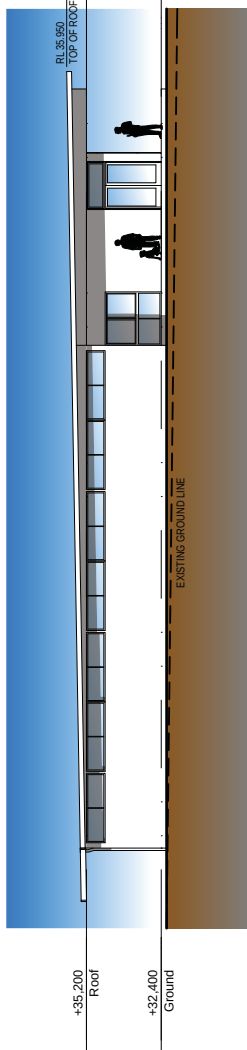
GREYHOUNDS QUEENSLAND



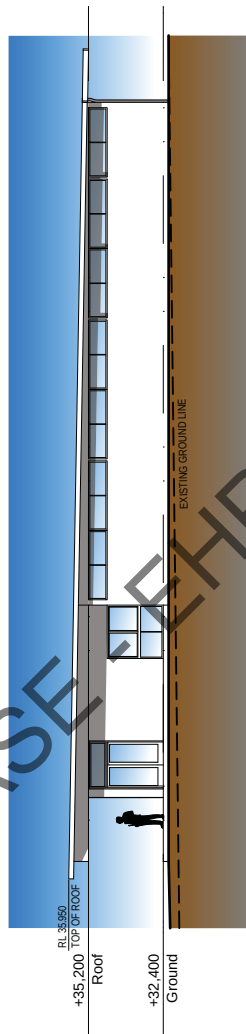
A EAST ELEVATION 1:200



C WEST ELEVATION 1:200



B SOUTH ELEVATION 1:200



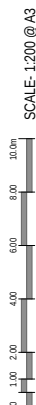
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LOGAN GREYHOUND FACILITY
GREYHOUNDS QUEENSLAND



ELEVATIONS - KENNEL BLOCK

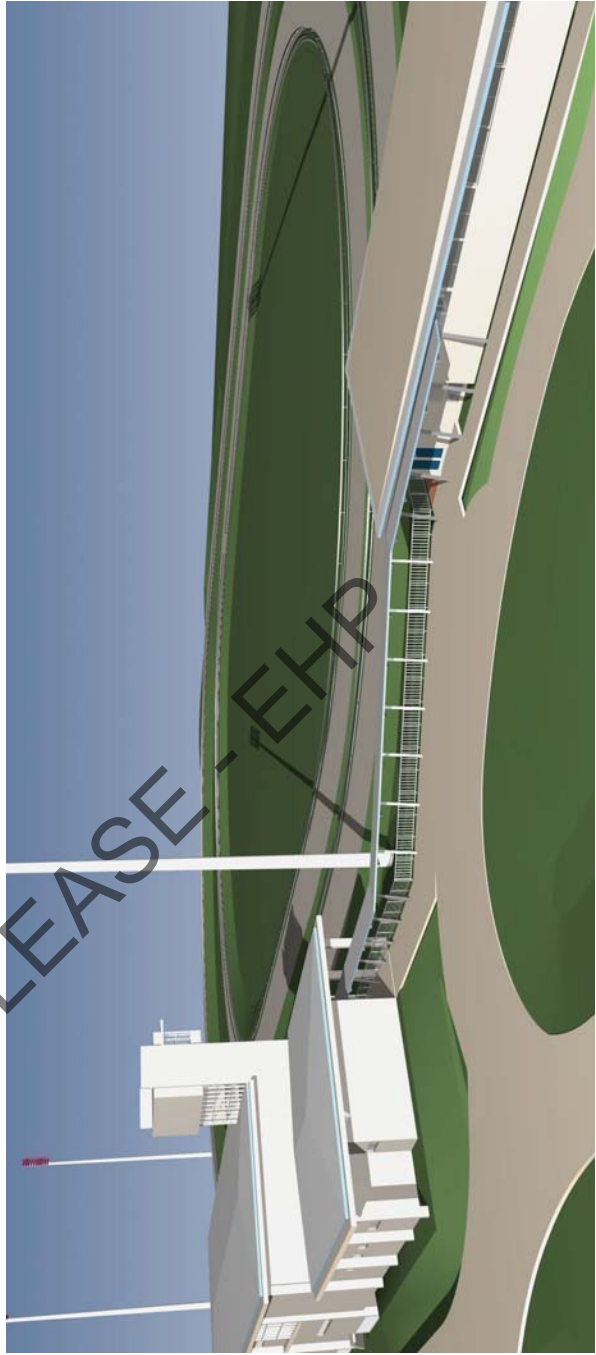




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PERSPECTIVES -

