further investigation into potential environmental impact and phytotoxicity issues.

As the NEPM guidelines for TPH's are not specific to the various TPH fractions and there are no guidelines for BTEX, guidelines for TPH's were adopted from the NSW EPA *Guidelines for Assessing Service Station Sites* (Table 3).

A summary of the Soil Investigation Levels is provided in Table 3.3.1.

3.3.2 Soil analytical results

The analytical results of recovered soil samples are shown in results tabled numbered 3.1 to 3.3 (at the end of this section). Results exceeding the HIL-A and EILs are highlighted. The certificates of analysis, quality control report and chain of custody documentation are attached as Appendix 7.

Staining was witnessed directly under the cradle housing the above ground storage tank (AST) containing diesel fuel. Staining was confined to the footprint of the AST cradle. No odours or visible evidence of contamination were identified within the two locations adjacent to historical banana plantations, surrounding the former nursery shed or within the former orchard area.

The analytical results for soils indicate that there is no contamination in any of the samples analysed, with the exception of the following:

- Surface samples BH37 (0-0.15m), BH39 (0-0.15m) and BH42(0-0.15m) contained Arsenic (25, 31, and 33mg/kg), marginally exceeding the EIL and phytotoxicity-based IL (for As, 20mg/kg)).
- BH4 (0-0.15m) and BH4 (0.2-0.3m) contained TPH C_{10}-C_{14} (640mg/kg and 2400mg/kg) exceeding the NSW EPA guideline (100mg/kg).
- BH4 (0-0.15m) and BH4 (0.2-0.3m) contained TPH C_{15}-C_{28} (5,610mg/kg and 14,100mg/kg), exceeding the NSW EPA guideline (1,000mg/kg).
- BH3 (0-0.15m) contained TPH C29-C36 (1,260mg/kg), exceeding the NSW EPA guideline (1,000mg/kg).

The identified arsenic contamination adjacent to the southern banana plantation is only marginally above the EIL and consistent with background arsenic concentrations. These concentrations do not represent a health risk and therefore are not a constraint to the proposed development of the site for residential and ancillary purposes.

Table 3.3.1 Health Based Soil Investigation levels for land use exposure setting A (Residential) and the Environmental Investigation Levels

Analyte	Health-based Investigation levels(A) (mg/kg)	Environmental Investigation Levels (mg/kg)
Metals/Metalloids		
Arsenic	100	20
Cadmium	20	3
Chromium (VI)	100	-
Copper	1000	60
Lead	300	300
Nickel	600	60
Zinc	7000	200
Mercury (Inorganic)	15	1
Total Petroleum Hydrocarbons (TPH)		
C6 - C9 Fraction	100	-
C10 – C14 Fraction	100	-
C15 – C28 Fraction	1000	-
C29 – C36 Fraction	1000	-
BTEX		
Benzene	1	-
Toluene	1.4	-
Ethyl benzene	3.1	-
Total Xylenes	14	-
Polycyclic Aromatic Hydrocarbons (PAH)		
Total	100	-
Organics (Organo-chlorine and organo-phosphorus pesticides)		
Aldrin + Dieldrin	10	0.2
Chlordane	50	-
DDT+DDD+DDE	200	0.2
Heptachlor	10	-
Other		
Asbestos	No discoverable fibres	

The TPH concentrations displayed within shallow samples extracted directly below the diesel AST (which was still in use at the time of this assessment) indicate that over a period of continual use diesel fuel has been spilt onto the soil surface and penetrated it to a depth at least 0.3mBGS. The presence of TPH fractions exceeding the HIL at this location could readily be remediated and therefore do not present a constraint to the proposed project application. Soils beneath the AST would be removed and validation samples collected from the base and walls of the removed AST footprint. The analytical results presented are sufficient enough to make and informed planning decision against the DGR's.

3.4 Quality assurance and control

3.4.1 Field quality assurance (QA)

All sampling was undertaken by appropriately qualified and trained environmental scientists in accordance with AS4482.1-2005.

Quality assurance (QA) samples were collected during the investigation for quality control purposes. This included the collection of 3 duplicate soil samples, all of which were split into triplicate samples.

All duplicate samples were analysed by ALS Brisbane and all triplicate samples were sent to SGS, a third party NATA accredited laboratory.

Two (2) rinsate samples were collected following the decontamination of the Jarrett head hand auger during each day of soil sampling and from the bailer used during the groundwater sampling process. One (1) trip blank sample was added to the first sample batch prior to the transport of chilled eskies to the laboratory. This first sample batch contained samples extracted from directly under and surrounding the AST and were the only samples analysed for volatile fuel constituents.

The sampling tools (split spoon sampler and Jarrett head hand auger) were decontaminated between sampling events in accordance with standard procedures. This involved the removal of soil followed by cleaning of the implements with a phosphate-free detergent and rinsing with clean water.

The implements used for crushing and mixing of interlaboratory split (3 in total) and blind intralaboratory duplicate (3 in total) samples, were rinsed in phosphate-free detergent between samples followed by a clean water rinse.

All split and duplicate samples were homogenised in the field. No samples analysed for VOC's were duplicated or homogenised in the field as this practice may dilute the presence of VOC's.

All samples were stored in laboratory supplied glass jars or bottles, sealed with Teflon-lined lids and stored in a chilled esky. Samples were submitted to ALS and/or SGS Laboratories with appropriate chain-of-custody documentation.

Chain-of-custody and laboratory quality control documentation is supplied with the analytical results in Appendix 7.

Two (2) rinsate blanks were collected from the common soil sampling equipment which was utilised across the site following cleaning with a phosphate-free detergent. These samples were used to evaluate the efficacy of the field decontamination procedure and the risk of cross contamination.

Table 3.4.1 shows the sampling equipment rinsate results against arsenic (a key COPC for this investigation).

Table 3.4.1 Equipment rinsate results

Rinsate sample	Date	Equipment	Arsenic (mg/L)
Rinsate 1	27.01.11	Hand auger	<0.001
QC4	01.02.11	Hand auger	<0.001

The rinsate results were all below ALS LOR (<0.001mg/L) and indicates the decontamination process was adequate to negate the potential effects of cross contamination between sampling locations.

3.4.2 Internal quality control

The results of the original and duplicate samples were compared via the relative percentage difference (RPD) method as shown in tables 3.1-3.4 included at the end of Section 3.

Generally the RPD is expected to be in the range of 30% – 50% (as per AS4482.1 2005) however

greater variation may occur due to numerous factors, including:

- very low analyte concentrations
- organic analysis (which generally contains greater variation than inorganic analysis)
- sample heterogeneity.

Where measured analytes returned levels below the respective laboratory's limits of reporting the RPD could not be calculated. Where concentrations of the specified analytes were detected, the quality control duplicate RPD results ranged from 0% to 36%.

All calculated RPD values were below the 50% acceptable limit for all duplicates and triplicate samples.

On the basis of the RPD comparisons, the duplicate results demonstrate that the field QA processes generally were adequate and that the laboratory results are precise. The split sample results indicate a satisfactory correlation between the laboratories.

3.4.3 Laboratory quality control

Laboratory quality control (QC) included duplicate analysis of 10% of the samples and analysis of Laboratory Control Samples (LCS), Method Blanks and Matrix Spikes at a rate of 5% for each batch.

Laboratory QC data is also presented in the certified laboratory reports and is included in Appendix 1. Laboratory QC analytical results are summarised below.

- For all matrices, no Method Blank value outliers occurred.
- For all matrices, no Duplicate outliers occurred with the exception of;
- Sample BH24 0.0-0.15 shows poor matrix spike recovery due to matrix interference. Poor matrix recovery was confirmed by re-extraction and re-analysis.
- Sample BH2 shows poor matrix spike recovery due to matrix interference. Confirmed by re-extraction and re-analysis.
- Sample BH31 shows poor matrix spike recovery due to matrix interference
- For all regular sample matrices, no surrogate recovery outliers occurred.
- No Analysis Holding Time Outliers existed.
- Results for Demeton-S-methyl should be scrutinised as QC data indicates abnormally low recovery.

In summary we consider that the laboratory QC results are acceptable and that the data can be relied upon for the purposes of this investigation.

3.5 Dip site

Previous investigations surrounding the dip site were completed to a level where the identified contamination associated with dipping operations is fully delineated.

A Remediation Action Plan (RAP) was prepared in support of a previous Development Application in 2001. Whilst contamination has been identified and delineated in previous studies it will be necessary to further delineate prior to its remediation. This could be deferred until prior to operational works.

Previous investigations and the proposed remedial strategy for the dip site are adequate to address the DGR 6.1 for the Stage 1 Project Application.

The RAP is based on the findings of the investigation conducted by SKM in 1992 and outlines the proposed remediation strategy and validation procedure.

The proposed remediation strategy involves a combination of on-site containment, treatment and off-site disposal relative to the concentration of the contaminants in various locations.

3.6 Conclusion

The identified arsenic contamination in the vicinity of the southern banana plantation does not represent a health risk and therefore is not a constraint to the proposed development of the site for residential and ancillary purposes.

TPH results displayed within shallow soil samples extracted from beneath the diesel AST indicate minor contamination of shallow soils has occurred as a result from the use of the AST for refueling

machinery over a period of time. TPH contamination is readily manageable using standard remediation and bioremediation techniques and as such, we do not consider that these results represent a development constraint.

Remediation and validation of contaminated soils would be required prior to the site being rendered suitable for residential development.

Table 3.1
METALS RESULTS

Kings Forest Site investigation results

Parameter					Arsenic	Cadmium	Chromium	Chromium (III)	Chromium(VI)	Copper	Lead	Nickel	Zinc	Mercury
Units					mg/kg	mg/kg	mg/kg			mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Limit of reporting (ALS)					5	1	2	2	<0.5	5	5	2	5	0.1
HIL(a)					100	20	100	12,000	100	1000	300	600	7000	15
Lab	**Lab batch #**	**Sample date:**	**Sample# / Depth (m)**	**EIL**	20	3	50	50	-	100	300	60	200	1
ALS	EB1101638	27/01/11	BH1/0-0.15m		<5	<1	6	--	--	12	11	3	77	<0.1
ALS	EB1101638	27/01/11	BH2/0-0.15m		--	--	--	--	--	--	9	--	--	<0.1
ALS	EB1101638	27/01/11	BH2/0.2-0.3m		--	--	--	--	--	--	<5	--	--	<0.1
ALS	EB1101638	27/01/11	BH3/0-0.15m		--	--	--	--	--	--	9	--	--	--
ALS	EB1101638	27/01/11	BH3/0.2-0.3m		--	--	--	--	--	--	<5	--	--	--
ALS	EB1101638	27/01/11	BH4/0-0.15m		--	--	--	--	--	--	6	--	--	--
ALS	EB1101638	27/01/11	BH4/0.2-0.3m		--	--	--	--	--	--	<5	--	--	--
ALS	EB1101638	24/01/11	BH5/0-0.15m		--	--	--	--	--	--	<5	--	--	--
ALS	EB1101638	24/01/11	BH5/0.2-0.3m		--	--	--	--	--	--	<5	--	--	--
ALS	EB1101638	24/01/11	BH6/0-0.15m		--	--	--	--	--	--	<5	--	--	--
ALS	EB1101638	24/01/11	BH6/0.2-0.3m		--	--	--	--	--	--	<5	--	--	--
ALS	EB1101638	24/01/11	BH7/0-0.15m		<5	<1	13	--	--	16	13	9	80	<0.1
ALS	EB1101638	24/01/11	BH8/0-0.15m		<5	<1	15	--	--	10	8	12	83	<0.1
ALS	EB1101638	24/01/11	BH9/0-0.15m		<5	<1	11	--	--	12	7	8	72	<0.1
ALS	EB1101638	24/01/11	BH10/0-0.15m		<5	<1	12	--	--	10	6	9	64	<0.1
ALS	EB1101638	27/01/11	BH11/0-0.15m		<5	<1	10	--	--	6	<5	8	55	<0.1
ALS	EB1101638	27/01/11	BH12/0-0.15m		<5	<1	8	--	--	81	<5	6	48	<0.1
ALS	EB1101638	27/01/11	BH13/0-0.15m		<5	<1	16	--	--	20	<5	22	60	0.1
ALS	EB1101638	27/01/11	BH14/0-0.15m		<5	<1	22	--	--	15	<5	14	52	<0.1
ALS	EB1101638	27/01/11	QC1	Duplicate of BH14/0-0.15m	<5	<1	21	--	--	16	<5	16	55	<0.1
Relative Percentage Difference (RPD) between BH14/0-0.15m & QC1					--	--	5%	--	--	6%	--	13%	6%	--
SGS	ME105304	18/10/10	QC1A	Triplicate of BH14/0-0.15m	<3	1.8	17	--	--	13	7	11	58	<0.05
Relative Percentage Difference (RPD) between BH14/0-0.15m & QC1A					--	--	26%	--	--	14%	--	24%	11%	--
ALS	EB1101638	27/01/11	BH15/0-0.15m		<5	<1	28	--	--	19	<5	24	92	0.1
ALS	EB1102915	27/01/11	BH16/0-0.15m		<5	<1	27	--	--	12	<5	17	63	0.1
ALS	EB1101638	27/01/11	BH17/0-0.15m		<5	<1	32	--	--	12	<5	19	71	0.1
ALS	EB1101638	27/01/11	BH18/0-0.15m		<5	<1	18	--	--	14	<5	19	58	0.1
ALS	EB1101638	27/01/11	BH19/0-0.15m		<5	<1	26	--	--	19	<5	21	74	0.2
ALS	EB1101638	27/01/11	BH20/0-0.15m		<5	<1	26	--	--	15	<5	21	64	0.1
ALS	EB1101638	27/01/11	BH21/0-0.15m		<5	<1	31	--	--	15	<5	20	78	0.1
ALS	EB1101638	27/01/11	BH22/0-0.15m		<5	<1	22	--	--	28	<5	25	101	<0.1
ALS	EB1101858	1/02/11	BH23/0-0.15m		<5	<1	28	--	--	17	<5	24	90	0.1
ALS	EB1101858	1/02/11	BH24/0-0.15m		<5	<1	25	--	--	18	5	22	88	0.1
ALS	EB1101858	1/02/11	BH25/0-0.15m		<5	<1	24	--	--	16	<5	20	75	0.1
ALS	EB1101858	1/02/11	BH26/0-0.15m		<5	<1	29	--	--	18	<5	23	114	0.1
ALS	EB1101858	1/02/11	BH27/0-0.15m		<5	<1	12	--	--	<5	<5	6	25	<0.1
ALS	EB1101638	27/01/11	BH28/0-0.15m		<5	<1	21	--	--	16	<5	18	77	0.2
ALS	EB1101638	27/01/11	BH29/0-0.15m		<5	<1	11	--	--	7	<5	10	42	0.1
ALS	EB1101638	27/01/11	BH30/0-0.15m		<5	<1	25	--	--	18	<5	21	82	<0.1
ALS	EB1101638	27/01/11	BH31/0-0.15m		<5	<1	15	--	--	12	5	10	52	<0.1
ALS	EB1101638	27/01/11	BH32/0-0.15m		<5	<1	18	--	--	15	10	16	89	0.1
ALS	EB1101858	1/02/11	BH33/0-0.15m		<5	<1	2	--	--	<5	<5	<2	<5	<0.1
ALS	EB1101858	1/02/11	QC2	Duplicate of BH33/0-0.15m	<5	--	--	--	--	--	<5	--	--	--
Relative Percentage Difference (RPD) between BH33/0-0.15m & QC2					--	--	--	--	--	--	--	--	--	--
SGS	ME105304	1/02/11	QC2A	Triplicate of BH33/0-0.15m	<3	--	--	--	--	--	1	--	--	--
Relative Percentage Difference (RPD) between BH33/0-0.15m & QC2A					--	--	--	--	--	--	--	--	--	--
ALS	EB1101858	1/02/11	BH34/0-0.15m		<5	--	--	--	--	--	<5	--	--	--
ALS	EB1101858	1/02/11	BH35/0-0.15m		<5	--	--	--	--	--	9	--	--	--
ALS	EB1101858	1/02/11	BH36/0-0.15m		<5	--	--	--	--	--	<5	--	--	--
ALS	EB1101858	1/02/11	BH37/0-0.15m		25	--	--	--	--	--	28	--	--	--
ALS	EB1101858	1/02/11	BH38/0-0.15m		17	--	--	--	--	--	10	--	--	--
ALS	EB1101858	1/02/11	BH39/0-0.15m		31	--	--	--	--	--	9	--	--	--
ALS	EB1101858	1/02/11	BH40/0-0.15m		8	--	--	--	--	--	13	--	--	--
ALS	EB1101858	1/02/11	BH41/0-0.15m		6	--	--	--	--	--	13	--	--	--
ALS	EB1101858	1/02/11	BH42/0-0.15m		33	--	--	--	--	--	37	--	--	--
ALS	EB1101858	1/02/11	QC3	Duplicate of BH42/0-0.15m	31	--	--	--	--	--	35	--	--	--
Relative Percentage Difference (RPD) between BH42/0-0.15m & QC3					6%	--	--	--	--	--	6%	--	--	--
SGS	ME105304	1/02/11	QC3A	Triplicate of BH42/0-0.15m	23	--	--	--	--	--	30	--	--	--
Relative Percentage Difference (RPD) between BH42/0-0.15m & QC3A					36%	--	--	--	--	--	21%	--	--	--
ALS	EB1101858	1/02/11	BH43/0-0.15m		<5	--	--	--	--	--	<5	--	--	--

Notes:

-- Not analysed
(QC) Interlab split
(QCA) Blind intralab duplicate
N/A No guideline available

Exceeds health-based investigation level (HIL) for standard residential setting (A) of the *DRAFT Guidelines for the Assessment and Management of Contaminated Lands in Queensland, May 1998.*

Exceeds environmental investigation level (EIL) of the *DRAFT Guidelines for the Assessment and Management of Contaminated Lands in Queensland, May 1998.*

* Derived from the *Unpublished Department of Environment, Queensland, Guidelines for Service Station Assessments (TPH/BTEX guideline limits.*

Table 3.2
OC/OP PESTICIDE RESULTS

Kings Forest Site investigation results

Lab	Lab batch #	Sample date:	Sample# / Depth (m)		Heptachlor	Chlordane	Aldrin	Dieldrin	DDD +DDE	Endosulfan Sulfate and beta endosulfan	DDT	Other OC Pesticides	Ethion	Monocrotophos	Parathion	Bromophos-ethyl	Other OP Pesticides
			Units		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
			Limit of reporting (ALS)		0.05	0.05	0.05	0.05	0.05	0.05	0.2	0.05	0.05	0.2	0.2	0.05	0.05
			HIL(a)		10	50	10	10	200	380	200	N/A	N/A	N/A	N/A	N/A	N/A
			EIL		N/A	N/A	0.2	0.2	0.2	NA	0.2	N/A	N/A	N/A	N/A	N/A	N/A
ALS	EB1101638	27/01/11	BH1/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH2/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH2/0.2-0.3m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH3/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH3/0.2-0.3m		---	---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH4/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH4/0.2-0.3m		---	---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	24/01/11	BH5/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	24/01/11	BH5/0.2-0.3m		---	---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	24/01/11	BH6/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	24/01/11	BH6/0.2-0.3m		---	---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	24/01/11	BH7/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	24/01/11	BH8/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	24/01/11	BH9/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	24/01/11	BH10/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH11/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH12/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH13/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH14/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	QC1	Duplicate of BH14/0-0.15m	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
Relative Percentage Difference (RPD) between BH14/0-0.15m & QC1					---	---	---	---	---	---	---	---	---	---	---	---	---
SGS	ME105304	18/10/10	QC1A	Triplicate of BH14/0-0.15m	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	---	<0.05	<0.05	<0.05
Relative Percentage Difference (RPD) between BH14/0-0.15m & QC1A					---	---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH15/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1102915	27/01/11	BH16/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH17/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH18/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH19/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH20/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH21/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH22/0-0.15m		<0.05	<0.05	<0.05	<0.05	**0.07**	**0.33**	<0.2	**0.09**	<0.05	<0.2	<0.2	<0.05	**0.08**
ALS	EB1101858	1/02/11	BH23/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101858	1/02/11	BH24/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101858	1/02/11	BH25/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101858	1/02/11	BH26/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101858	1/02/11	BH27/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH28/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH29/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH30/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH31/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101638	27/01/11	BH32/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101858	1/02/11	BH33/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101858	1/02/11	QC2	Duplicate of BH33/0-0.15m	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
Relative Percentage Difference (RPD) between BH33/0-0.15m & QC2					---	---	---	---	---	---	---	---	---	---	---	---	---
SGS	ME105304	1/02/11	QC2A	Triplicate of BH33/0-0.15m	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	---	<0.05	<0.05	<0.05
Relative Percentage Difference (RPD) between BH33/0-0.15m & QC2A					---	---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH34/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101858	1/02/11	BH35/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101858	1/02/11	BH36/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101858	1/02/11	BH37/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101858	1/02/11	BH38/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101858	1/02/11	BH39/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101858	1/02/11	BH40/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101858	1/02/11	BH41/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101858	1/02/11	BH42/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
ALS	EB1101858	1/02/11	QC3	Duplicate of BH42/0-0.15m	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05
Relative Percentage Difference (RPD) between BH42/0-0.15m & QC3					---	---	---	---	---	---	---	---	---	---	---	---	---
SGS	ME105304	1/02/11	QC3A	Triplicate of BH42/0-0.15m	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	---	<0.05	<0.05	<0.05
Relative Percentage Difference (RPD) between BH42/0-0.15m & QC3A					---	---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH43/0-0.15m		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.2	<0.2	<0.05	<0.05

Notes:

-- Not analysed
(S) Interlab split
(D) Blind intralab duplicate
N/A No guideline available

Exceeds health-based investigation level (HIL) for standard residential setting (A) of the *DRAFT Guidelines for the Assessment and Management of Contaminated Lands in Queensland, May 1998.*

Exceeds environmental investigation level (EIL) of the *DRAFT Guidelines for the Assessment and Management of Contaminated Lands in Queensland, May 1998.*

* Derived from the *Unpublished Department of Environment, Queensland, Guidelines for Service Station Assessments (TPH/BTEX guideline limits.*

Table 3.3
TPH/BTEX/TOTAL PAH RESULTS

Kings Forest Site investigation results

Parameter	Benzene	Ethylbenzene	Toluene	Total Xylene	Napthalene	Benzo(a)pyrene	PAH total	C6 - C9 Fraction	C10-C14 Fraction	C15-C28 Fraction	C29-C36 Fraction	C10 - C36 Fraction
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Limit of reporting (ALS)	0.2	0.5	0.5	0.5	0.5	0.5	0.5	10	50	100	100	50
HIL(a)	14	14	14	14	N/A	N/A	N/A	100*	100*	1000*	1000*	1000*
EIL	N/A	N/A	N/A	N/A	N/A	1	100	N/A	N/A	N/A	N/A	N/A

Lab	Lab batch #	Sample date:	Sample# / Depth (m)												
ALS	EB1101638	27/01/11	BH1/0-0.15m		---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH2/0-0.15m		<0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<10	<50	<100	<100	<50
ALS	EB1101638	27/01/11	BH2/0.2-0.3m		<0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<10	<50	<100	<100	<50
ALS	EB1101638	27/01/11	BH3/0-0.15m		<0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<10	90	920	<100	**1010**
ALS	EB1101638	27/01/11	BH3/0.2-0.3m		<0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<10	12	250	**1260**	**1510**
ALS	EB1101638	27/01/11	BH4/0-0.15m		<0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<10	**640**	**5610**	180	**6430**
ALS	EB1101638	27/01/11	BH4/0.2-0.3m		<0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	18	**2500**	**14100**	120	**16700**
ALS	EB1101638	24/01/11	BH5/0-0.15m		<0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<10	<50	<100	160	160
ALS	EB1101638	24/01/11	BH5/0.2-0.3m		<0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<10	<50	<100	<100	<50
ALS	EB1101638	24/01/11	BH6/0-0.15m		<0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<10	<50	<100	<100	<50
ALS	EB1101638	24/01/11	BH6/0.2-0.3m		<0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<10	<50	<100	<100	<50
ALS	EB1101638	24/01/11	BH7/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	24/01/11	BH8/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	24/01/11	BH9/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	24/01/11	BH10/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH11/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH12/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH13/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH14/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	QC1	Duplicate of BH14/0-0.15m	---	---	---	---	---	---	---	---	---	---	---	---
Relative Percentage Difference (RPD) between BH14/0-0.15m & QC1					---	---	---	---	---	---	---	---	---	---	---	---
SGS	ME105304	18/10/10	QC1A	Triplicate of BH14/0-0.15m	---	---	---	---	---	---	---	---	---	---	---	---
Relative Percentage Difference (RPD) between BH14/0-0.15m & QC1A					---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH15/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH16/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH17/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH18/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH19/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH20/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH21/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH22/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH23/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH24/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH25/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH26/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH27/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH28/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH29/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH30/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH31/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101638	27/01/11	BH32/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH33/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	QC2	Duplicate of BH33/0-0.15m	---	---	---	---	---	---	---	---	---	---	---	---
Relative Percentage Difference (RPD) between BH33/0-0.15m & QC2					---	---	---	---	---	---	---	---	---	---	---	---
SGS	ME105304	1/02/11	QC2A	Triplicate of BH33/0-0.15m	---	---	---	---	---	---	---	---	---	---	---	---
Relative Percentage Difference (RPD) between BH33/0-0.15m & QC2A					---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH34/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH35/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH36/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH37/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH38/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH39/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH40/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH41/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH42/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	QC3	Duplicate of BH42/0-0.15m	---	---	---	---	---	---	---	---	---	---	---	---
Relative Percentage Difference (RPD) between BH42/0-0.15m & QC3					---	---	---	---	---	---	---	---	---	---	---	---
SGS	ME105304	1/02/11	QC3A	Triplicate of BH42/0-0.15m	---	---	---	---	---	---	---	---	---	---	---	---
Relative Percentage Difference (RPD) between BH42/0-0.15m & QC3A					---	---	---	---	---	---	---	---	---	---	---	---
ALS	EB1101858	1/02/11	BH43/0-0.15m		---	---	---	---	---	---	---	---	---	---	---	---

Notes:

-- Not analysed
(S) Interlab split
(D) Blind intralab duplicate
N/A No guideline available

Exceeds health-based investigation level (HIL) for standard residential setting (A) of the *DRAFT Guidelines for the Assessment and Management of Contaminated Lands in Queensland, May 1998.*

Exceeds environmental investigation level (EIL) of the *DRAFT Guidelines for the Assessment and Management of Contaminated Lands in Queensland, May 1998.*

* Derived from the *Unpublished Department of Environment, Queensland, Guidelines for Service Station Assessments (TPH/BTEX) guideline limits.*

4 Radiation assessment

Gilbert & Sutherland Pty Ltd (G&S) conducted a preliminary investigation of surface radiation levels and constructed boreholes to enable radiation profiling of the sub soils within portions of the site potentially affected by sand mining activities.

The purpose of the preliminary investigation was to address DGR 6.9 and to characterise the site's radiological profile and propose site management and/or remediation techniques (if required) for the Kings Forest development.

4.1 Surface radiation level survey

A site inspection and surface radiation survey was conducted on 4 November 2009 and a subsurface investigation (drilling program) was completed on 10 November 2009, by suitably qualified G&S environmental scientists. The drilling program was conducted by MazLab under the supervision of a G&S scientist.

4.1.1 Methodology

A walkover survey strategy was employed for the site. This involved the measurement of surface radiation levels in a 25m x 25m grid pattern across four (4) separate areas (shown on Drawing No. 10468.7.3) to characterise the site and to aid comparison with guideline radiation level limits.

The four (4) investigation areas surveyed were identified as possibly being affected by historical mineral sand mining within Aspect North's assessment of disturbance within the Kings Forest area. Size estimates of the four (4) survey areas are as follows.

- Area 1 approximately 134,000 m^2
- Area 2 approximately 63,000 m^2
- Area 3 approximately 10,800 m^2
- Area 4 approximately 11,400 m^2.

A Ludlum 2241-3/HP270 survey meter (serial number 248102/604064) was used to measure the surface radiation levels at a distance of one (1) metre Above the Ground Surface (AGS). The instrument was calibrated by the Government of Western Australia Department of Health, utilising a range of ambient equivalent dose rates emitted from Caesium (Cs-137) and traceable to national standards via the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). All traceable calibration levels were recorded in microGray's per hour (μGy.h-1), which is the unit of measurement specified for environmental exposure rates. Calibration records are presented in Appendix 5.

4.1.2 Results

The surface radiation level survey results are presented in Appendix 1 (Section 6.1 tables 1 to 4). The survey transects are shown on Drawing No. 10468.7.4.

Survey results were recorded in micro Sieverts per hour ($\mu Sv.h^{-1}$), which for effective dose rates for gamma and beta rays is equivalent to microGray per hour ($\mu Gy.h^{-1}$) at a ratio of 1:1. For the purposes of this assessment all results were recorded in μSv.h-1 and all guideline comparisons utilise the same dose rate reading at a 1:1 ratio to the guideline unit (microGray per hour).

Effective dose rates, (gamma rates) recorded within Appendix 1 (Section 7.1 tables 1 to 4) were compared to radiation level limits adopted by the Radiation Control Section, New South Wales Environmental Protection Authority (EPA) in its guideline, Radiation Safety Information Series No. 12 – Clean Up and Disposal of Radioactive Residues from Commercial Operations involving Mineral Sands, (RSIS No 12). This guideline is utilised for specific remediation trigger levels associated with former mineral sands mining operations occurring within areas proposed for residential use.

The surface radiation results are summarised as follows:

- No surface radiation levels recorded across the four survey areas exceeded the remediation trigger guideline limit of 0.7 $\mu Sv.h^{-1}$ (equivalent to 0.7 $\mu Gy.h^{-1}$) for 'dwellings, schools, businesses and industries where occupancies by the same people occurs on a day to day basis'.
- No surface radiation level results across the four survey areas were recorded above 0.2 $\mu Sv.h^{-1}$,

which is consistent with the survey meter's background level readings and is generally considered representative of natural background radiation level.

A copy of the NSW Radiation Safety Policy (RSIS No. 12) is presented in Appendix 3.

4.2 Subsurface soil survey

4.2.1 Methodology

A total of 24 boreholes were drilled across the four surveyed areas to a minimum depth of 2.0 metres below ground surface (mBGS).

Borehole locations were chosen (where possible) to broadly reflect a grid pattern, over the four areas identified as potentially being affected by sand mining activities. The target depth for each borehole was 2.0 mBGS to account for residential dwelling footing depths and possible excavation of materials for the installation of services and/or swimming pools. A select number of boreholes were extended to refusal depths with a solid flight auger drill rig.

Measurements of gross radioactivity, recorded in $\mu Sv.h^{-1}$, were logged at 100mm depth intervals using a custom HP 270 extendable probe assembly mated to the Ludlum 2241-3 survey meter. The gross radioactivity results were used to derive empirical radiation exposure levels for each 100mm interval of sub soil.

This derived exposure reading is representative of the radiation levels that would be expected if the sub soils were exposed to the surface and surveyed as per the methodology described in Section 3.1.1 above. Therefore the derived sub soil radiation level results can be directly compared with the NSW policy document remediation trigger value of 0.7 $\mu Sv.h^{-1}$ (equivalent to 0.7 $\mu Gy.h^{-1}$) for dwellings, schools, businesses and industries where occupancies by the same people occurs on a day-to-day basis.

The borehole logging method provides an estimate of the likely exposure to be recorded should thin sand lenses be bulked to a thickness greater than 300mm by site works or erosion.

Attributable errors associated with borehole logging of radiation exposures arise from the material densities and counting geometry variations. The method used may overestimate derived sub soil radiation levels where contaminant material is less than 100mm thick. Errors for this method should be considered as + 30% of reported values.

4.2.2 Results

Results of radiation levels in boreholes are presented in Appendix 1 (Section 7.2, tables 5 to 10). Borehole locations are shown on Drawing No. 10468.7.5 and the soil profiles are recorded within bore logs presented in Appendix 4.

Vertical soil strata recorded in borehole logs revealed the site is characterised by grey, brown and white, fine sands with shallow groundwater existing across the assessed area at an average depth ranging from 1.1m to 1.4 mBGS. The presence of indurated black sands was recorded within the 24 boreholes at an approximate depth range of between 1.2m and 1.9 mBGS. The maximum depth of logged gross radiation levels was 2.1 mBGS within borehole BH24 located within Survey Area 1.

Derived gross radiation levels recorded within each borehole were compared to the DECCW NSIS No. 12 guideline. The subsurface-derived gross radiation results are summarised as follows:

- No subsurface-derived gross radiation level results across the four survey areas exceeded the remediation trigger guideline limit of 0.7 $\mu Sv.h^{-1}$ (equivalent to 0.7 $\mu Gy.h^{-1}$) for dwellings, schools, businesses and industries where occupancies by the same people occurs on a day-to-day basis.
- All subsurface-derived gross radiation level results across the four survey areas were below 0.2 $\mu Sv.h^{-1}$ (which is consistent with background radiation levels for the survey meter and natural background levels) except for the following two results.
- BH11, located within Survey Area 4 at 0.100 mBGS, recorded 0.217 $\mu Sv.h^{-1}$ which is slightly above natural background levels (0.2 $\mu Sv.h^{-1}$).
- BH12, located within Survey Area 4 at 0.000 and 0.500 mBGS recorded 0.204 and 0.225 μ

Sv.h^{-1} respectively, each of which are slightly above natural background levels (0.2 μSv.h^{-1}).

4.3 Conclusion

All areas potentially disturbed by sand mining exploration or extraction have been identified and no radioactivity was identified at levels that would create a health risk. Therefore no further investigation is necessary.

5 Landfill impact assessment

The following site investigations have been undertaken of the capped Bogangar Landfill since 2001:

- Detailed Site Contamination Assessment (Stage 2) – Proposed Methodology for Bogangar Road Landfill Site – March 2001.[10]
- Depot Road Landfill – Assessment of Remediation Options and Remediation Action Plan – June 2003.[11]
- Report on Bogangar Landfill – analysis of monitoring results – GHD, March 2008.[12]

The assessment of the probable impact of the landfill on the proposed development is based on these reports.

Groundwater level monitoring was undertaken by Tweed Shire Council (TSC) and the data analysed by Coffey Geosciences Pty Ltd (Coffey Geosciences) to determine the groundwater flow conditions. The TSC data as analysed by Coffey Geosciences[13] indicates the groundwater flows in a west north-westerly direction from the proposed Stage 1 Project Application development area towards the landfill. The groundwater continues to flow westwards from the landfill. The gradient of the groundwater is low – in the order of 0.35% (0.035 m/m). The Coffey Geosciences groundwater contours are attached in Appendix 6.

TSC has undertaken monitoring of the groundwater adjacent to the landfill for the period from 2001 to Dec 2007. The monitoring program collected data on the groundwater height, major ions, nitrogen compounds, phosphate and a range of metals. GHD's review of the data indicated that the landfill leachate[14] might be having some influence on the groundwater bores numbered 10 (GW10) and 16 (GW16).[15] These bores are within the proposed development area but adjacent to the boundary (within 6m) of the landfill.

The GHD report concludes that the nature of the impact is marginal. GHD's assessment of the other bores within the monitoring bore field showed no evidence of landfill contamination within the surrounding environment.

GW10 and GW16 exhibited elevated ammonia N, total N and Total Kjeldahl N concentrations. The total N concentrations were directly connected to the increased ammonia N.[16] The form of ammonia is dependent on pH and water temperature. The impact of pH and temperature on the proportions of ammonia and ammonium are shown in Table 4.1 (following page).

GW16 showed ammonia ranging from 2-3.5 mgL^{-1} and an acid pH (ranging from 3.0-5.0). At these pH levels the dominant ion in solution is ammonium (NH_4^+). The expected concentrations of un-ionised ammonia (NH_3) are less than 0.001 mg L^{-1} (see Table 4.1) for all the detected ammonia levels during the monitoring period.

GW10 showed ammonia concentrations ranging from 0.5-4.0mg L^{-1} with pH ranging from 6.0-8.0. The higher pH associated with this bore increases the proportion of un-ionised ammonia in the solution (see Table 4.1).

For the high pH event (8.0) between March 2006 and September 2006 the ammonia was 1.0mgL^{-1} and suggests an NH_3 concentration between 0.03 and 0.08mgL^{-1} (depending on the water temperature). The high Ammonia concentration of approximately 4.0mg L^{-1} corresponded to a pH of 6 and a non-ionised ammonia of between 0.001 and 0.003mg L^{-1} (depending on the water temperature).

[10] Philip Bell and Partners Pty Ltd (March 19, 2001) Detailed Site Contamination Assessment (Stage 2) – *Proposed Methodology for Old Bogangar Road Landfill Site (Issue 2) - Kings Forest Development Cudgen, New South Wales*. Prepared for Narui Gold Coast Pty Ltd.

[11] Coffey Geosciences (June 30, 2003) *Depot Road Landfill, Cudgen – Assessment of Remediation Options and Remediation Action Plan.* Prepared for Tweed Shire Council.

[12] GHD 2008 *Tweed Shire Council - Report on Bogangar Landfill, Analysis of monitoring results*. Report No. 41/19476/3328 March 2008.

[13] Coffey Geosciences Pty Ltd 2003 *Depot road landfill Assessment of remediation options and remediation action plan*, September 2003.

[14] GHD 2008 Tweed Shire Council - Report on Bogangar Landfill, Analysis of monitoring results. Report No. 41/19476/3328 March 2008.

[15] Locations of bores GW 10 and 16 are shown in the Coffey Geosciences groundwater contour plan, attached to this report as Appendix 6.

[16] GHD 2008 Tweed Shire Council - Report on Bogangar Landfill, Analysis of monitoring results. Report No. 41/19476/3328 March 2008. Pages 8-9.

Table 4.1 Concentration of un-ionised ammonia (mg L^{-1}) as a proportion[17] of total ammonia in relation to pH and temperature (^{o}C)

	Total ammonia 0.5 mg L^{-1}					
Temp (^{o}C)	pH 3	pH 4	pH 5	pH 6	pH 7	pH 8
15	0.000	0.000	0.000	0.000	0.001	0.014
20	0.000	0.000	0.000	0.000	0.002	0.020
25	0.000	0.000	0.000	0.000	0.003	0.029
30	0.000	0.000	0.000	0.000	0.004	0.040
	Total ammonia 1.0 mg L^{-1}					
Temp (^{o}C)	pH 3	pH 4	pH 5	pH 6	pH 7	pH 8
15	0.000	0.000	0.000	0.000	0.003	0.028
20	0.000	0.000	0.000	0.000	0.004	0.041
25	0.000	0.000	0.000	0.001	0.006	0.057
30	0.000	0.000	0.000	0.001	0.009 *	0.079
	Total ammonia 2.0 mg L^{-1}					
Temp (^{o}C)	pH 3	pH 4	pH 5	pH 6	pH 7	pH 8
15	0.000	0.000	0.000	0.001	0.006	0.057
20	0.000	0.000	0.000	0.001	0.008	0.082
25	0.000	0.000	0.000	0.001	0.012	0.115
30	0.000	0.000	0.000	0.002	0.017	0.159
	Total ammonia 4.0 mg L^{-1}					
Temp (^{o}C)	pH 3	pH 4	pH 5	pH 6	pH 7	pH 8
15	0.000	0.000	0.000	0.001	0.012	0.114
20	0.000	0.000	0.000	0.002	0.017	0.163
25	0.000	0.000	0.000	0.002	0.024	0.230
30	0.000	0.000	0.000	0.003	0.034	0.318

Notes: * = LC50 aquarium fish at 30^{o}C and pH 7 for a 4 day exposure - 0.006 mg L^{-1} [18]

The Australian Drinking Water Guidelines indicate an aesthetic limit for NH_3^- ammonia of 0.5mgL^{-1}.[19] None of the calculated values in Table 4.1 exceed this value. There are no health criteria for ammonia in the drinking water guidelines.

The dominant NH^4 is a non-toxic form of ammonia and poses an insignificant risk to human health and a minor risk in terms of environmental impact, given that the water is contained within the groundwater. The main hazard associated with this material is its nutrient impacts.

GW16 also showed elevated conductivity (and the associated major ions) and iron and manganese. The concentrations of these analytes were assessed by the GHD report as indicating the influence of landfill leachate. GW9, located within the Kings Forest Stage 1 Project Application area, ~50m from the landfill boundary, showed initial elevated N, P and iron levels that have (since March 2007 sampling) reduced to below average concentrations (for that bore). GW19, located in the Stage 1 Project Application area ~100m from the boundary, shows no evidence of leachate. [20]

Whilst the direction of groundwater flow is likely to change to south westerly to westerly, the proposed landuse to the south is community

[17] Un-ionised NH_3 = total Ammonia/{1+10 $^{((0.0902\text{-pH})+(2730/(273.2+T)))}$}

[18] US Environmental Protection Authority. *Ambient Water Quality Criteria for Ammonia*, (EPA 440/5-85-001). January 1985.

[19] Australian Government 2004 *National Water Quality Management Strategy. Australian Drinking Water Guidelines 6 2004.* Endorsed by NHMRC 10-11 April 2003 Australian Government table 10.10 page 10-22.

[20] GHD 2008 *Tweed Shire Council - Report on Bogangar Landfill, Analysis of monitoring results*. Report No. 41/19476/3328 March 2008. Pages 9-10.

infrastructure. Such land use suggests that there would be no groundwater extraction for private use and the condition of the groundwater will pose no threat to the residential area. Similarly, any leachate transport to the west would pose no human health risk as there is no residential development to the west of the landfill. In addition, TSC intends to extend the surface drainage of the landfill site to connect the existing drain on the boundary with the flow line to the west of the landfill.[21] This will direct any excess runoff from the landfill away from the site and towards open space.

The investigations indicate that the groundwater associated with the capped landfill will have no significant impact on the development proposed under the Kings Forest Stage 1 Project Application development area.

[21] Tweed Shire Council (Dec 2008): Depot road, Chinderah Sports fields and Amenities: Concept plan RC08008/01-07.

6 Conclusions

6.1 Site contamination assessment

Based on the review of previous environmental assessments undertaken in support of the Concept Plan application, no new potentially contaminating activities have occurred in the Stage 1 Project Application area. Based on a site inspection conducted on 4 November 2009, G&S did not identify any further potentially contaminating activities within the area of the Kings Forest Stage 1 Project Application.

6.2 Surface radiation survey

Based on the results of the surface radiation survey conducted across four (4) areas identified as potentially affected by historical sand mining activities, no effective dose radiation levels were recorded above the Ludlum survey meter's background level of 0.2μSv.h^{-1} (generally consistent with natural background levels). G&S concludes that the site's surface radiation levels are compliant with the EPA guideline limit of 0.7 μGy.h^{-1} and therefore pose no constraint to the proposed development.

6.3 Sub surface radiation survey

No sub surface gross radiation levels existed above the NSW EPA radiation trigger value of 0.7μGy.h^{-1}. Based on these results no further assessment and/or remediation of sub surface soils within the Stage 1 Project Application development area is required.

G&S considers the risk of mineralised sands radiation levels to be low for the purposes of the site works and intended site use.

6.4 Contamination assessment of potentially contaminated areas

Based on the findings of this quantitative shallow soil assessment of areas previously identified to have had potentially contaminating activities occurring on or adjacent to them G&S considers neither the identified TPH concentrations (in excess of the HILs) nor the elevated arsenic concentrations (in excess of the EIL), constitute a development constraint. This is because, the identified arsenic contamination is only marginally above the EIL and consistent with background concentrations, whilst the TPH contamination can be readily remediated using standard techniques.

The shallow soil material below the diesel AST will require excavation and validation prior to the commencement of bulk earthworks in this area. This could occur in concurrence with the remediation of the former livestock dip.

6.5 Adjacent capped Bogangar Road landfill

The investigations of the impact of the capped landfill adjacent to the proposed development indicate that the groundwater associated with capped landfill will have no significant impact on the proposed development due the following considerations.

Groundwater flows in a westerly direction from the proposed development towards the landfill and through to the western side of the landfill.

The land use adjacent to the landfill will be community infrastructure and the likelihood of private or residential and exposure to the leachate will be avoided.

7 Appendix 1 – Results tables

7.1 Tables 1 to 4: Surface radiation survey results

Table 1: Area 1 survey results (transects 1 to 8). Approximate survey area 134,000 m^2

Transect No.	Sample No.	Reading (uSv/hr)	Clicks	Comments
1	1	0.075	3	GPS start: 554635N 6869520E
1	2	0.074	3	
1	3	0.028	2	
1	4	0.105	6	
1	5	0.083	3	
1	6	0.091	7	
1	7	0.126	9	Drainage line encountered
1	8	0.13	7	
1	9	0.123	8	
1	10	0.077	2	
1	11	0.118	7	
1	12	0.106	5	
1	13	0.087	3	
1	14	0.102	5	
1	15	0.102	8	
1	16	0.112	5	
1	17	0.064	3	
1	18	0.083	5	
1	19	0.112	4	
1	20	0.156	8	
1	21	0.195	9	
1	22	0.13	8	GPS finish: 554140N 6869602E
Transect 2				
2	1	0.068	3	GPS start: 554171N 6869631E
2	2	0.073	4	
2	3	0.081	5	
2	4	0.05	4	
2	5	0.072	4	
2	6	0.071	6	
2	7	0.073	4	
2	8	0.078	3	
2	9	0.045	1	
2	10	0.032	1	
2	11	0.093	5	
2	12	0.086	2	
2	13	0.146	6	Drainage line encountered
2	14	0.081	4	
2	15	0.075	1	
2	16	0.147	5	
2	17	0.114	2	

2	18	0.087	1	
2	19	0.072	1	
2	20	0.054	1	GPS finish: 554641N 6869533E
Transect 3				
3	1	0.066	1	GPS start: 554658N 6869565E
3	2	0.084	2	
3	3	0.082	1	
3	4	0.034	0	
3	5	0.053	1	
3	6	0.073	1	
3	7	0.134	6	Drainage line encountered
3	8	0.042	1	
3	9	0.058	1	
3	10	0.083	2	
3	11	0.055	1	
3	12	0.081	2	
3	13	0.077	1	
3	14	0.083	2	
3	15	0.058	1	
3	16	0.083	2	
3	17	0.078	1	
3	18	0.061	1	
3	19	0.103	4	GPS finish: 554210N 6869685E
Transect 4				
4	1	0.083	3	GPS start: 554217N 6869707E
4	2	0.094	3	
4	3	0.072	1	
4	4	0.124	5	
4	5	0.089	2	
4	6	0.107	4	
4	7	0.092	3	
4	8	0.061	1	
4	9	0.092	2	
4	10	0.045	1	
4	11	0.068	1	
4	12	0.058	1	
4	13	0.051	1	Drainage line encountered
4	14	0.062	0	
4	15	0.083	1	
4	16	0.091	2	
4	17	0.084	1	
4	18	0.107	3	
4	19	0.064	1	GPS finish: 554682N 6869685E
Transect 5				
5	1	0.038	0	GPS start: 554683N 6869619E
5	2	0.062	0	
5	3	0.094	2	
5	4	0.098	2	
5	5	0.105	3	

5	6	0.098	2	
5	7	0.062	2	Drainage line encountered
5	8	0.062	1	
5	9	0.072	1	
5	10	0.054	0	
5	11	0.042	0	
5	12	0.072	1	
5	13	0.074	1	
5	14	0.082	2	
5	15	0.082	1	
5	16	0.086	1	
5	17	0.077	1	
5	18	0.042	0	
5	19	0.036	0	GPS finish: 554260N 6869788E
Transect 6				
6	1	0.092	2	GPS start: 554268N 6869810E
6	2	0.076	1	
6	3	0.068	1	
6	4	0.086	1	
6	5	0.041	0	
6	6	0.061	1	
6	7	0.092	4	
6	8	0.126	5	
6	9	0.083	1	
6	10	0.042	0	
6	11	0.079	2	
6	12	0.103	3	
6	13	0.068	1	Drainage line encountered
6	14	0.066	1	
6	15	0.083	1	
6	16	0.066	0	
6	17	0.087	0	GPS finish: 554665N 6869645E
Transect 7				
7	1	0.074	1	GPS start: 554710N 6869671E
7	2	0.074	0	
7	3	0.068	1	
7	4	0.048	0	
7	5	0.103	2	
7	6	0.073	0	
7	7	0.103	4	Drainage line encountered
7	8	0.06	0	
7	9	0.053	2	
7	10	0.069	1	
7	11	0.051	1	
7	12	0.096	2	
7	13	0.023	0	
7	14	0.075	2	
7	15	0.055	0	
7	16	0.075	1	
7	17	0.074	1	
7	18	0.083	2	GPS finish: 554275N 6869853 E

Transect 8				
8	1	0.077	2	GPS start: 554282N 6869881E
8	2	0.064	1	
8	3	0.092	2	
8	4	0.075	1	
8	5	0.068	1	
8	6	0.094	2	
8	7	0.083	1	
8	8	0.076	1	
8	9	0.042	0	
8	10	0.051	1	
8	11	0.093	3	
8	12	0.086	1	
8	13	0.055	0	Drainage line encountered
8	14	0.058	1	
8	15	0.096	2	
8	16	0.083	0	
8	17	0.106	2	
8	18	0.094	2	GPS finish: 554694N 6869704E

Table 2: Area 2 survey results (transects 1 to 4). Approximate survey area 63,000 m^2

Transect No.	Sample No.	Reading (uSv/hr)	Clicks	Comments
1	1	0.104	3	GPS start: 554789N 6869814E
1	2	0.102	3	
1	3	0.09	1	
1	4	0.089	2	
1	5	0.089	1	
1	6	0.101	2	
1	7	0.107	3	
1	8	0.052	0	
1	9	0.019	0	
1	10	0.084	1	
1	11	0.058	0	
1	12	0.077	2	
1	13	0.088	1	GPS finish: 554515N E6869950
Transect 2				
2	1	0.088	2	GPS start: 554521N 6869978E
2	2	0.064	0	
2	3	0.077	1	
2	4	0.068	1	
2	5	0.068	1	
2	6	0.058	1	
2	7	0.121	3	
2	8	0.083	1	
2	9	0.055	0	
2	10	0.051	1	
2	11	0.066	1	GPS finish: 554787N 6869903E

Transect 3				
3	1	0.06	1	GPS start: 554799N 6869934E
3	2	0.073	2	
3	3	0.051	1	
3	4	0.072	0	
3	5	0.086	1	
3	6	0.104	3	
3	7	0.062	0	
3	8	0.032	0	
3	9	0.03	1	
3	10	0.06	0	
3	11	0.036	0	GPS finish:554549N 6870039E
Transect 4				
4	1	0.077	2	GPS start: 554552N 6870064E
4	2	0.068	0	
4	3	0.096	2	
4	4	0.068	0	
4	5	0.077	1	
4	6	0.034	0	
4	7	0.058	0	
4	8	0.073	1	
4	9	0.072	1	
4	10	0.048	0	
4	11	0.065	1	GPS finish:554774N 686997E

Table 3: Area 3 survey results. Approximate survey area 10,800 m^2

Transect No.	Sample No.	Reading (uSv/hr)	Clicks	Comments
1	1	0.04	2	GPS start: 554399N 6870452E
1	2	0.064	2	
1	3	0.11	6	
1	4	0.092	4	
1	5	0.128	5	
1	6	0.131	5	
1	7	0.076	5	
1	8	0.021	0	
1	9	0.048	3	
1	10	0.073	3	
1	11	0.06	5	
1	12	0.128	6	GPS finish: 554345N 6870165E

Table 4: Area 4 survey results. Approximate survey area 11,400 m^2

Transect No.	Sample No.	Reading (uSv/hr)	Clicks	Comments
1	1	0.103	5	GPS start: 554359N 6870258E
1	2	0.144	6	
1	3	0.042	4	
1	4	0.086	6	
1	5	0.114	7	
1	6	0.063	4	
1	7	0.094	6	
1	8	0.075	4	
1	9	0.116	5	
1	10	0.076	5	
1	11	0.132	8	
1	12	0.152	8	
1	13	0.141	10	
1	14	0.09	5	
1	15	0.107	8	GPS finish: 554021N 6870312E

7.2 Tables 5 to 10: Subsurface (borehole) gross radiation results

Table 5: Subsurface gross radiation results BH1 – BH4

Borehole Depth (m)	BH1			BH2			BH3			BH4		
	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks
0		0.040	0		0.071	3		0.112	4		0.085	2
0.1	Top Soil	0.032	1	Top Soil	0.051	2	Top Soil	0.074	4	Top Soil	0.074	2
0.2	LGS	0.019	1	GS	0.066	2	LGS	0.067	2	LGS	0.081	3
0.3	LGS	0.050	2	GS	0.073	2	LGS	0.062	2	LGS	0.062	2
0.4	LBS	0.065	3	GS	0.065	2	LGS	0.045	2	LGS	0.051	1
0.5	LBS	0.120	5	GS	0.036	3	DBS	0.032	1	BS	0.053	1
0.6	BS	0.104	4	BS	0.02	2	DBS	0.019	0	BS	0.042	1
0.7	BS	0.091	3	BS	0.038	1	DBS	0.025	0	DBS	0.038	1
0.8	BS	0.099	3	BS	0.08	2	DBS	0.031	0	DBS	0.042	1
0.9	BS	0.163	4	BS	0.068	2	DBS	0.048	1	DBS	0.032	0
1.0	BS	0.103	4	BS	0.058	2	BIS	0.04	4	DBS	0.04	0
1.1	BS	0.069	3							DBS	0.051	2
1.2										BIS	0.068	2
1.3										BIS	0.066	2
1.4										BIS	0.07	3

Notes:

BS	Brown Sands
BIS	Black Indurated Sands
DBS	Dark Brown Sands
GS	Grey Sand
LBS	Light Brown Sands
LGS	Light Grey Sands
WS	White Siliceous Sands

Bold Radiation levels above background 0.2 $\mu Sv.h^{-1}$

Table 6: Subsurface gross radiation results BH5 – BH8

	BH5			BH6			BH7			BH8		
Borehole Depth (m)	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks
0		0.083	3		0.12	4		0.102	5		0.071	6
0.1	Top Soil	0.062	2	LGS	0.093	3	LGS	0.089	3	LGS	0.051	6
0.2	LGS	0.081	3	DBS	0.082	3	LGS	0.071	2	GS	0.066	2
0.3	LGS	0.06	1	DBS	0.045	2	DBS	0.088	2	BS	0.073	2
0.4	LGS	0.047	1	DBS	0.058	2	DBS	0.094	2	BS	0.065	3
0.5	LGS	0.062	1	DBS	0.051	1	DBS	0.074	3	DBS	0.036	1
0.6	LGS	0.056	1	DBS	0.038	0	DBS	0.092	2	DBS	0.02	2
0.7	LGS	0.068	1	DBS	0.042	1	DBS	0.071	2	DBS	0.038	3
0.8	LGS	0.066	1	DBS	0.055	1	DBS	0.087	2			
0.9	LGS	0.058	1	DBS	0.071	2						
1.0	DBS	0.062	2	LGS & WS	0.092	3						
1.1				LGS & WS	0.081	3						
1.2				LGS & WS	0.094	4						

Notes:

BS	Brown Sands
BIS	Black Indurated Sands
DBS	Dark Brown Sands
GS	Grey Sand
LBS	Light Brown Sands
LGS	Light Grey Sands
WS	White Siliceous Sands

Black Radiation levels above background 0.2 $\mu Sv.h^{-1}$

Table 7: Subsurface gross radiation results BH9 – BH12

	BH9			BH10			BH11			BH12		
Borehole Depth (m)	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks
0		0.101	3		0.097	3		0.186	7		**0.204**	7
0.1	LGS	0.133	4	Top Soil	0.105	4	Rocky Fill	**0.217**	8	Top Soil	0.195	6
0.2	LGS	0.107	3	LGS	0.094	3	DBS	0.198	7	LGS	0.186	5
0.3	LGS & Rocky Fill	0.095	4	LGS	0.097	3	DBS	0.161	8	LGS	0.197	6
0.4	LGS	0.031	0	LGS	0.103	4	DBS	0.126	4	LGS	0.186	5
0.5	WS & LGS	0.042	1	WS & LGS	0.096	3	GS	0.092	3	LGS	**0.225**	6
0.6	WS & LGS	0.066	1	WS & LGS	0.112	4	GS	0.096	4	LGS & WS	0.109	4
0.7	WS & LGS	0.062	1	WS & LGS	0.058	1	GS	0.058	1	LGS & WS	0.125	5
0.8	WS & LGS	0.068	2	WS & LGS	0.065	2	GS	0.062	1	LGS & WS	0.084	2
0.9	WS & LGS	0.063	2	WS & LGS	0.06	1	GS	0.056	1	LGS & WS	0.097	3
1.0	WS & LGS	0.101	3	WS & LGS	0.04	1	GS	0.065	2	LGS & WS	0.107	4
1.1	WS & LGS	0.058	1	WS & LGS	0.038	1	LGS	0.068	2	LGS & WS	0.077	3
1.2	WS & LGS	0.045	1	WS & LGS	0.087	3	LGS	0.062	2	LGS & WS	0.058	2
1.3	WS & LGS	0.062	1	WS & LGS	0.091	4	LGS	0.059	2	LGS & WS	0.072	2
1.4	WS & LGS	0.086	2				LGS	0.068	3	LGS & WS	0.065	1
1.5	WS & LGS	0.114	3				LGS	0.079	2	BIS	0.061	1
1.6							LGS	0.075	2	BIS	0.083	2
1.7							LGS	0.086	3			

Notes:

BS	Brown Sands
BIS	Black Indurated Sands
DBS	Dark Brown Sands
GS	Grey Sand
LBS	Light Brown Sands
LGS	Light Grey Sands
WS	White Siliceous Sands

Bold Radiation levels above background 0.2 $\mu Sv.h^{-1}$

Table 8: Subsurface gross radiation results BH13 – BH16

	BH13			BH14			BH15			BH16		
Borehole Depth (m)	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks
0		0.022	0		0.061	2		0.068	2		0.087	3
0.1	DBS	0.049	2	GS	0.054	2	LGS	0.042	1	Top Soil	0.092	4
0.2	DBS	0.051	2	GS	0.06	2	LGS	0.059	2	LGS	0.081	3
0.3	LGS	0.063	1	GS	0.045	1	LGS	0.055	2	LGS	0.073	3
0.4	LGS	0.083	3	GS	0.036	2	LGS	0.06	2	LGS	0.059	2
0.5	DBS	0.071	2	GS	0.061	4	LGS	0.079	2	WS	0.048	1
0.6	DBS	0.081	2	GS	0.058	3	LGS	0.088	3	WS	0.057	1
0.7	LGS & WS	0.079	2	GS	0.047	2	LGS	0.064	2	WS	0.064	2
0.8	LGS & WS	0.067	1	LGS & WS	0.042	1	LGS	0.049	2	WS	0.077	3
0.9	LGS & WS	0.062	1				LGS	0.045	3	WS	0.048	2
1.0	DGS	0.074	2				LGS	0.027	2	WS	0.051	2
1.1	DGS	0.092	3							WS	0.034	1
1.2	DGS	0.072	2							WS	0.052	2

Notes:

BS	Brown Sands
BIS	Black Indurated Sands
DBS	Dark Brown Sands
GS	Grey Sand
LBS	Light Brown Sands
LGS	Light Grey Sands
WS	White Siliceous Sands

Bold Radiation levels above background 0.2 $\mu Sv.h^{-1}$

Table 9: Subsurface gross radiation results BH17 – BH20

	BH17			BH18			BH19			BH20		
Borehole Depth (m)	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks
0		0.057	2		0.072	2		0.068	2		0.084	3
0.1	Top Soil	0.048	1	Top Soil	0.051	2	WS & LGS	0.048	1	Top Soil	0.079	3
0.2	GS	0.052	2	GS	0.062	3	WS & LGS	0.053	1	LGS & WS	0.064	2
0.3	GS	0.051	2	GS	0.074	3	WS	0.070	2	LGS & WS	0.025	0
0.4	GS	0.019	0	GS	0.052	2	WS	0.064	2	LGS & WS	0.029	0
0.5	GS	0.028	0	GS	0.044	1	WS	0.079	3	LGS & WS	0.038	1
0.6	GS	0.03	1	GS	0.062	2	WS	0.075	2	LGS & WS	0.042	2
0.7	WS	0.038	2	GS	0.051	1	WS	0.042	1	LGS & WS	0.055	2
0.8	WS	0.058	2	GS	0.062	2	WS	0.070	3	LGS & WS	0.047	2
0.9	WS	0.047	1				WS	0.094	2	LGS & WS	0.084	3
1.0	WS	0.049	2							WS	0.052	2
1.1										WS	0.062	2
1.2										WS	0.071	3
1.3										WS	0.064	2
1.4										WS	0.075	3
1.5										WS	0.069	2
1.6										WS	0.075	3
1.7										WS	0.036	1

Notes:

BS	Brown Sands
BIS	Black Indurated Sands
DBS	Dark Brown Sands
GS	Grey Sand
LBS	Light Brown Sands
LGS	Light Grey Sands
WS	White Siliceous Sands

Bold Radiation levels above background 0.2 $\mu Sv.h^{-1}$

Table 10: Subsurface gross radiation results BH21 – BH24

	BH21			BH22			BH23			BH24		
Borehole Depth (m)	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks	Soil Description	Reading (uSv/hr)	Clicks
0		0.098	6		0.087	3		0.079	2		0.114	6
0.1	WS	0.137	7	LBS	0.073	2	LGS	0.08	2	Top Soil	0.102	6
0.2	WS	0.112	6	LBS	0.092	3	LGS	0.091	3	LGS	0.097	5
0.3	WS	0.092	4	LBS	0.102	4	LGS	0.081	2	LGS	0.091	5
0.4	WS	0.087	2	LBS	0.042	1	LGS	0.092	2	LGS	0.076	3
0.5	WS	0.077	3	LGS	0.031	1	LGS	0.091	2	LGS	0.081	3
0.6	WS	0.032	1	LGS	0.056	2	LGS	0.082	3	LGS	0.053	2
0.7	WS	0.038	1	LGS	0.032	1	LGS	0.071	3	LGS	0.052	2
0.8	WS	0.047	2	LGS	0.096	3	LGS	0.063	2	LGS	0.047	1
0.9	WS	0.051	2	LGS	0.072	2	LGS	0.042	1	LGS	0.068	2
1.0				BIS	0.068	1	LGS	0.051	2	LGS	0.074	3
1.1							LGS	0.062	1	LGS	0.084	3
1.2							LGS	0.079	2	LGS	0.081	3
1.3							LGS	0.064	3	LGS	0.067	2
1.4							LGS	0.078	2	LGS	0.077	2
1.5							LGS	0.069	2	LGS	0.075	3
1.6							BIS & LGS Seams	0.073	1	BS	0.091	4
1.7							BIS & LGS Seams	0.046	1	BS	0.084	4
1.8							BIS & LGS Seams	0.049	1	BS	0.069	2
1.9							BIS & LGS Seams	0.058	2	BIS	0.077	3
2.0											0.071	2
2.1											0.064	2

Notes:

BS	Brown Sands
BIS	Black Indurated Sands
DBS	Dark Brown Sands
GS	Grey Sand
LBS	Light Brown Sands
LGS	Light Grey Sands
WS	White Siliceous Sands

Bold Radiation levels above background 0.2 $\mu Sv.h^{-1}$

8 Appendix 2 – 1962 Aerial photograph of Kings Forest

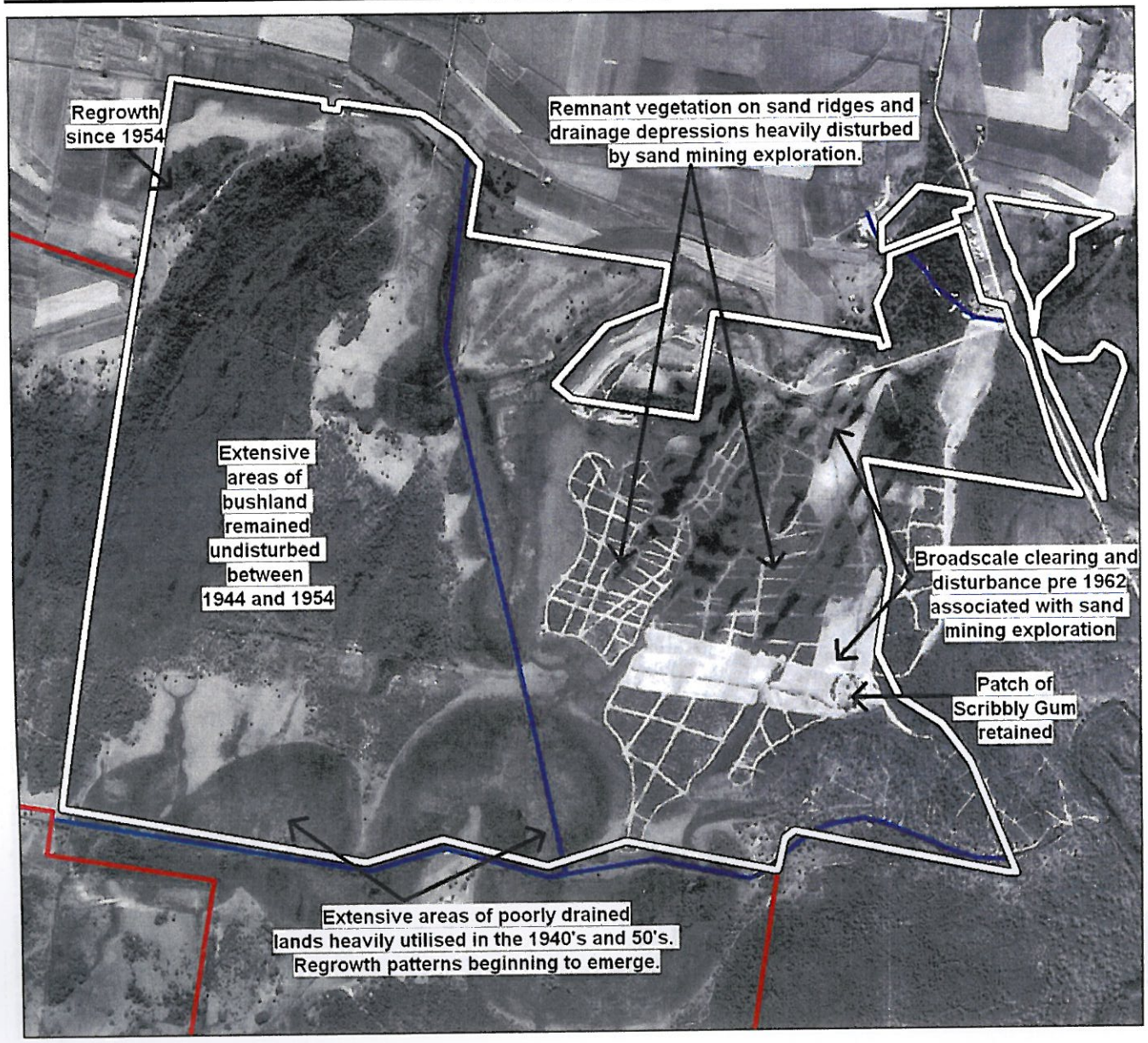

Plate 3. 1962 Aerial. Extensive disturbance associated with sand mining has occurred in the eastern part of the area.

9 Appendix 3 – NSW Radiation Safety Guideline (RSIS No.12)

RADIATION SAFETY INFORMATION SERIES No 12

CLEAN-UP AND DISPOSAL OF RADIOACTIVE RESIDUES FROM COMMERCIAL OPERATIONS INVOLVING MINERAL SANDS

The National Health and Medical Research Council (N.H.M.R.C.) has adopted a set of standards relating to the clean-up and disposal of radioactive residues from commercial operations (5.1) involving sands. These standards cover the areas of:

1. action level criteria;
2. remedial action criteria;
3. disposal area criteria;
4. protection of disposal sites;

and the recommendations made by the N.H.M.R.C. are as set out below

1. Action Level Criteria

1.1 For dwellings, schools (Including playground) businesses, factories, etc. where occupancies by the same individuals occur regularly on a day by day basis, the remedial action level should be 0.7 $\mu Gy\ h^{-1}$ (or 70 $\mu R\ h^{-1}$) for all points at 1 metre above the area of concern on the property.

1.2 For other areas, where occupancies are for a few hours per week by the same individuals or by differing individuals and for garden areas, the remedial action level should be 1.0 $\mu Gy\ h^{-1}$ (100 $\mu R\ h^{-1}$) for all points at 1 metre above the lowest surface of the area.

1.3 For roads, paths, and other areas with intermittent occupancy, the remedial action level should be 2.5 $\mu Gy\ h^{-1}$ (250 $\mu R\ h^{-1}$) for all points at 1 metre above the surface of the areas.

1.4 All values quoted above should include a value for normal natural background of 0.1 $\mu Gy\ h^{-1}$ (10 $\mu R\ h^{-1}$)

2. Remedial Action Criteria

2.1 The remedial action required will depend on the particular situation, but it is only in rare cases that prompt action will be necessary. In many cases, exposures could have been going on for some time, so that a small extension of that time would have minimal effects.

2.2 Remedial action, when being considered, should take into account potential uses of an area as well as present uses. This will cover the fact that occupancy of an area can change dramatically following changes of use of that area. An example would be a house being extended so that a new room is now located over what was previously a garden area giving elevated radiation readings. However, realism will need to be applied in considering such matters.

2.3 Complete removal of contaminated soils will not always be necessary or desirable. Once commenced, removal of contaminated soil should continue until the radiation levels are as low as reasonably achievable below the action levels. Major undertakings, such as the removal of parts of, or all of, buildings should not be necessary but, if old or unsatisfactory, their removal may assist in remedial action.

2.4 The use of concrete for shielding purposes should be avoided if possible because, although of value in some cases, it could create problems in the future following the modification or removal of buildings.

2.5 Whilst remedial action may not seem necessary or urgent for particular circumstances, there remains the possibility that such action may be necessary in the distant future. Decisions must be made in these cases to carry out remedial action either as the need arises or in the immediate future. If the choice to carry out remedial action as the need arises is taken, it would be important to place some restrictions on the future use of the property. For public areas, such as roads and paths, the relevant authority should be informed so that roads, for example, cannot be opened in designated areas without advice from the health authorities.

2.6 Whenever remedial action is to be undertaken, it will be necessary for an assessment to be made of the likely doses to persons undertaking the action. This assessment should taken into account the radiation likely to be received from external x-rays and from inhalation or ingestion of radioactive contaminants in dust or soil. Proper work procedures should be instituted and the workers advised of these and of appropriate personal hygiene. To date these levels have been shown to be low.

3. Disposal Area Criteria

The procedures for disposal of the recovered residues should follow those given in the Radioactive Waste Management (Mining and Milling) Code (1982) (5.2). Ideally, the residues should be returned to the area they came from, but if that area is not available, alternative sites should be used. Such sites should be in areas which are geologically sound and should not be subject to wind and water erosion.

4. Protection of Disposal Sites

Procedures should be instituted to prevent trespassing on and damage by vandalism at disposal sites. Following completion of disposal, rehabilitation and revegetation of the site should be carried out. Disposal sites should be subject to some restriction on their long-term use, but the extent of restriction would be dependent on each site and its characteristics.

5. References

5.1 National Health and Medical Research Council, report of the ninety-seventh session, June 1984; Australian Government Publishing Service (A.G.P.S.), Canberra.

5.2 Commonwealth of Australia. Code of practice on the management of radioactive wastes from the milling and milling of radioactive ores, 1982. A.G.P.S., Canberra

10 Appendix 4 – Borelogs

Borehole: BH1

Project: GJ0873

Client: Project 28

Northing: _____

Easting: _____

RL(m): _____

GILBERT+SUTHERLAND
agriculture - water - environment

Depth (m): 3

Logged by: NG

Drilled by: Mazlab

Start date: 10/11/09

Drilling Method: Solid Auger

Depth NSL(m)	Drilling: Depth (RL) m	Drilling: Method	Drilling: Graphic log	Soil Description (as per McDonald et.al1990)	Aust. Soil Class.	Revised Standard Colour	Accessories	Additional Comments	Depth NSL(m)
				SAND , Light grey, fine grained, moist, gradual change to;					
				SAND , Light brown, fine grained, moist, gradual change to;					
				SAND , Brown/light brown, fine grained, moist, gradual change to;					
1				SAND , Brown/light brown, fine grained, very moist, gradual change to;				Water table @ 1.25	1
2				SAND , Brown/light brown, fine grained, wet.					2
3									3
4									4
5									5
6									6
7									7

Borehole: BH2

Project: GJ0873

Client: Project 28

Northing: _____

Easting: _____

RL(m): _____

GILBERT+SUTHERLAND
agriculture - water - environment

Depth (m): 3

Logged by: NG

Drilled by: Mazlab

Start date: 10/11/09

Drilling Method: Solid Auger

Depth NSL(m)	Drilling: Depth (RL) m	Drilling: Method	Drilling: Graphic log	Soil Description (as per McDonald et.al1990)	Aust. Soil Class.	Revised Standard Colour	Accessories	Additional Comments	Depth NSL(m)
				SAND , Grey/dark grey, fine grained, gradual change to;					
				SAND , Brown/light brown, fine grained, moist, gradual change to;					
1									1
				SAND , Brown/light brown, fine grained, wet.				Water table @ 1.1	
2									2
3									3
4									4
5									5
6									6
7									7

Borehole: BH3

Project: GJ0873

Client: Project 28

Northing: _____

Easting: _____

RL(m): _____

GILBERT+SUTHERLAND
agriculture - water - environment

Depth (m): 2

Logged by: NG

Drilled by: Mazlab

Start date: 10/11/09

Drilling Method: Solid Auger

Depth NSL(m)	Drilling: Depth (RL) m	Drilling: Method	Drilling: Graphic log	Soil Description (as per McDonald et.al1990)	Aust. Soil Class.	Revised Standard Colour	Accessories	Additional Comments	Depth NSL(m)
				SAND , Light grey, fine grained, gradual change to;					
				SAND , Brown/dark brown, fine grained, moist, gradual change to;					
1				SAND , Brown/dark brown, fine grained, wet, gradual change to;				Water table @ 1.1	1
				SAND , Dark brown/black indurated fill.					
2									2
3									3
4									4
5									5
6									6
7									7

Borehole: BH4

Project: GJ0873

Client: Project 28

Northing: _____

Easting: _____

RL(m): _____

GILBERT+SUTHERLAND
agriculture - water - environment

Depth (m): 2

Logged by: NG

Drilled by: Mazlab

Start date: 10/11/09

Drilling Method: Solid Auger

Depth NSL(m)	Drilling: Depth (RL) m	Drilling: Method	Drilling: Graphic log	Soil Description (as per McDonald et.al1990)	Aust. Soil Class.	Revised Standard Colour	Accessories	Additional Comments	Depth NSL(m)
				SAND , Light grey, fine grained, moist, gradual change to;					
				SAND , Brown, fine grained, moist, gradual change to;					
				SAND , Dark brown, fine grained, moist, gradual change to,					
				SAND , Black indurated, fine grained				Water table @ 1.2	

1 2 3 4 5 6 7

Borehole: BH5

Project: GJ0873

Client: Project 28

Northing: _____

Easting: _____

RL(m): _____

GILBERT+SUTHERLAND
agriculture - water - environment

Depth (m): 2

Logged by: NG

Drilled by: Mazlab

Start date: 10/11/09

Drilling Method: Solid Auger

Depth NSL(m)	Drilling: Depth (RL) m	Drilling: Method	Drilling: Graphic log	Soil Description (as per McDonald et.al1990)	Aust. Soil Class.	Revised Standard Colour	Accessories	Additional Comments	Depth NSL(m)
0				SANDY LOAM , Black fine grained, gradual change to;					0
				SAND , Grey/light grey, fine grained, gradual change to;					
				SAND , Black, fine grained, moist, gradual change to;					
1									1
				SAND , Black, fine grained, wet.				Water table @ 1.2	
2									2
3									3
4									4
5									5
6									6
7									7

Borehole: BH6

Project: GJ0873

Client: Project 28

Northing: _____

Easting: _____

RL(m): _____

GILBERT+SUTHERLAND
agriculture - water - environment

Depth (m): 6.2

Logged by: NG

Drilled by: Mazlab

Start date: 10/11/09

Drilling Method: Solid Auger

Depth NSL(m)	Drilling: Depth (RL) m	Drilling: Method	Drilling: Graphic log	Soil Description (as per McDonald et.al1990)	Aust. Soil Class.	Revised Standard Colour	Accessories	Additional Comments	Depth NSL(m)
				SAND , Light grey, fine, dry, gradual change to;					
				SAND , Black, moist, in-fills, gradual change to;					
1				SAND , Light grey/white, fine grained, moist, gradual change to;					1
2									2
3									3
4				SAND , Black, fine grained, wet.				Water table @ 1.5	4
5									5
6									6
7									7

Borehole: BH7

Project: GJ0873

Client: Project 28

Northing: _____

Easting: _____

RL(m): _____

GILBERT+SUTHERLAND
agriculture - water - environment

Depth (m): 2

Logged by: NG

Drilled by: Mazlab

Start date: 10/11/09

Drilling Method: Solid Auger

Depth NSL(m)	Drilling: Depth (RL) m	Drilling: Method	Drilling: Graphic log	Soil Description (as per McDonald et.al1990)	Aust. Soil Class.	Revised Standard Colour	Accessories	Additional Comments	Depth NSL(m)
				SAND , Light grey, fine grained, gradual change to;					
				SAND , Brown/dark brown, fine grained, moist, gradual change to;					
				SAND , Light grey, fine grained, gradual change to;					
1				SAND , Brown/black, fine grained, wet.				Water table @ 1.2	1
2									2
3									3
4									4
5									5
6									6
7									7

Borehole: BH8

Project: GJ0873

Client: Project 28

Northing: _____

Easting: _____

RL(m): ____

GILBERT+SUTHERLAND
agriculture - water - environment

Depth (m): 2

Logged by: NG

Drilled by: Mazlab

Start date: 10/11/09

Drilling Method: Solid Auger

Depth NSL(m)	Drilling: Depth (RL) m	Drilling: Method	Drilling: Graphic log	Soil Description (as per McDonald et.al1990)	Aust. Soil Class.	Revised Standard Colour	Accessories	Additional Comments	Depth NSL(m)
				SAND , Light grey, fine grained, gradual change to;					
1				SAND , Brown/black, fine grained, moist, gradual change to;				Water table @ 1.1	1
2				SAND , Black, fine grained, wet.					2
3									3
4									4
5									5
6									6
7									7

Borehole: BH9

Project: GJ0873

Client: Project 28

Northing: _____

Easting: _____

RL(m): _____

GILBERT+SUTHERLAND
agriculture - water - environment

Depth (m): 2

Logged by: NG

Drilled by: Mazlab

Start date: 10/11/09

Drilling Method: Solid Auger

Depth NSL(m)	Drilling: Depth (RL) m	Drilling: Method	Drilling: Graphic log	Soil Description (as per McDonald et.al1990)	Aust. Soil Class.	Revised Standard Colour	Accessories	Additional Comments	Depth NSL(m)
				SAND , Light grey/grey, fine grained, dry, gradual change to;					
				SAND , Light grey/grey, rocky seams, fine grained, dry, gradual change to;					
1				SAND , White/grey, fine grained, moist.				Water table @ 1.4	1
2									2
3									3
4									4
5									5
6									6
7									7

Borehole: BH10

Project: GJ0873

Client: Project 28

Northing: _____

Easting: _____

RL(m): _____

GILBERT+SUTHERLAND
agriculture - water - environment

Depth (m): 2

Logged by: NG

Drilled by: Mazlab

Start date: 10/11/09

Drilling Method: Solid Auger

Depth NSL(m)	Drilling: Depth (RL) m	Drilling: Method	Drilling: Graphic log	Soil Description (as per McDonald et.al1990)	Aust. Soil Class.	Revised Standard Colour	Accessories	Additional Comments	Depth NSL(m)
				SANDY LOAM , Grey/brown, fine grained, gradual change to;					
				SAND , Light grey, fine grained, moist, gradual change to;					
1				SAND , Light grey/white, fine grained, moist, gradual change to;					1
				SAND , Light grey/white, fine grained, wet.				Water table @ 1.4	
2									2
3									3
4									4
5									5
6									6
7									7

Borehole: BH11

Project: GJ0873

Client: Project 28

Northing: _____

Easting: _____

RL(m): _____

GILBERT+SUTHERLAND
agriculture - water - environment

Depth (m): 2

Logged by: NG

Drilled by: Mazlab

Start date: 10/11/09

Drilling Method: Solid Auger

Depth NSL(m)	Drilling: Depth (RL) m	Drilling: Method	Drilling: Graphic log	Soil Description (as per McDonald et.al1990)	Aust. Soil Class.	Revised Standard Colour	Accessories	Additional Comments	Depth NSL(m)
				SAND , Black, dry, gradual change to;					
				SAND , Grey/light grey, moist, gradual change to;					
				SAND , Grey/light grey, wet.				Water table @ 1.6	

1 2 3 4 5 6 7

Borehole: BH12

Project: GJ0873

Client: Project 28

Northing: _____

Easting: _____

RL(m): _____

GILBERT+SUTHERLAND
agriculture - water - environment

Depth (m): 7.5

Logged by: NG

Drilled by: Mazlab

Start date: 10/11/09

Drilling Method: Solid Auger

Depth NSL(m)	Drilling: Depth (RL) m	Drilling: Method	Drilling: Graphic log	Soil Description (as per McDonald et.al1990)	Aust. Soil Class.	Revised Standard Colour	Accessories	Additional Comments	Depth NSL(m)
				SANDY LOAM , Brown, fine grained, dry, gradual change to;					
				SAND , Grey/light grey, fine grained, dry, gradual change to;					
				SAND , Grey/light grey, fine grained, dmoist, gradual change to;					
1				SAND , Brown/dark brown, moist, gradual change to,					1
				SAND , Brown/dark brown, wet, gradual change to,				Water table @ 1.9	
2									2
3				SAND , Brown, black seams, gradual change to;					3
4									4
5									5
6				SAND , Orange/brown, wet, gradual change to;					6
7									7
				SAND , Black, indurated sand.					

Borehole: BH13

Project: GJ0873

Client: Project 28

Northing: _____

Easting: _____

RL(m): _____

GILBERT+SUTHERLAND
agriculture - water - environment

Depth (m): 5.6

Logged by: NG

Drilled by: Mazlab

Start date: 10/11/09

Drilling Method: Solid Auger

Depth NSL(m)	Drilling: Depth (RL) m	Drilling: Method	Drilling: Graphic log	Soil Description (as per McDonald et.al1990)	Aust. Soil Class.	Revised Standard Colour	Accessories	Additional Comments	Depth NSL(m)
				SAND , Brown, fine grained, gradual change to;					
				SAND , Light grey/white, fine grained, gradual change to;					
				SAND , Brown, fine grained, moist, gradual change to;					
				SAND , Light grey/white, fine grained, moist, gradual change to;					
1				SAND , Brown/dark grey, fine grained, gradual change to;				Water table @ 1.5	1
2				SAND , Brown/dark grey, fine grained, wet, gradual change to;					2
3				SAND , Orange/brown, fine grained, wet, gradual change to;					3
4				SAND , Light brown, fine grained, wet, gradual change to;					4
5				SAND , Light brown, grey seams, fine grained, wet, gradual change to;					5
				SAND , Indurated sands, bore hole terminated					
6									6
7									7