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RTA Weipa
02-Nov-2018

Sampling Analysis and Quality Plan

PFAS Detailed Site Investigation, Weipa

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PFAS Detailed Site Investigation, Weipa

Client: RTA Weipa

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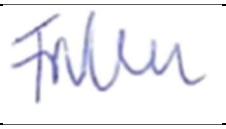
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1.0 Introduction

AECOM Australia Pty Ltd (AECOM) was engaged by RTA Weipa Pty Ltd (RTAW) to deliver a Detailed Site Investigation (DSI) and associated studies, specifically targeting Per- and Poly- fluoroalkyl Substances (PFAS) in the Weipa and Andoom mining areas on Western Cape York Peninsula in Queensland (the 'site'). Historical environmental investigations at the site have identified the presence of PFAS at concentrations exceeding current environmental guidelines (Golder, 2018a).

1.1 Objective

AECOM understands that RTAW's overall objective is to understand the nature and extent of the identified PFAS impact and to address Requirements 7 and 8 of the Department of Environment and Science (DES) *Notice to conduct or commission an environmental evaluation*, dated 7 September 2018 (the 'Notice') Reference 101/0008738, CR84931, STAT1304, which are:

"Prior to commencing requirement 8, submit to the department for review and comment, a draft Sampling Analysis and Quality Plan (SAQP) designed to characterise the nature and extent of PFAS contamination impacts at all the locations to which this notice relates. Comments provided to you by the department in relation to the SAQP, must be considered before commencing monitoring; and

By 30 April 2019, submit to the department a Detailed Site Investigation (DSI) report prepared in accordance with ASC NEPM. Notwithstanding ASC NEPM, the report must:

a) Delineate the lateral and vertical extent of contamination at the premises and adjoining impacted land;

b) Include an updated CSM; and

c) Where environmental harm has been identified, include remediation and management options to address the harm."

1.2 Scope of Work

This Sampling and Analysis Quality Plan (SAQP) is designed to guide AECOM field staff in undertaking the fieldwork required to inform the DSI and is based on the requirements outlined in the Notice.

This SAQP sets out the:

- Proposed investigation design, investigation matrix (soil, sediment, surface water and groundwater);
- Proposed sample location, depths and rationale;
- Proposed sample methodologies and monitoring;
- Proposed Quality Assurance / Quality Control (QA/QC) regime; and
- Reporting requirements.

1.3 Guidance and regulatory documents

This SAQP has been developed in general accordance with the following regulatory and guidance documents:

- Notice to conduct or commission an environmental evaluation (DES, 7 September 2018);
- National Environment Protection (Assessment of Site Contamination) Measure (NEPM), 1999 as amended 2013, National Environment Protection Council (NEPC);
- AS4482.1-2005 Australian Standard Guide to the investigation and sampling of sites with potentially contaminated soil, Part 1: Non-volatile and semi-volatile compounds, Standards Australia;

- AS4482.2-1999 Australian Standard Guide to the investigation and sampling of sites with potentially contaminated soil, Part 2: Volatile substances, Standards Australia; and
- PFAS *National Environmental Management Plan (NEMP)*, January 2018, Heads of Environmental Protection Agencies (HEPA), Australia and New Zealand.
- While the DSI report will not be prepared as a Contaminated Land Investigation Document (CLID), reference will also be made to the requirements as presented in *Handbook for Contaminated Land, Module 6: Content requirements for contaminated land investigation documents, certifications and audit reports* (DES, July 2018).
- All works would be carried out by a Suitably Qualified Person as defined in s.564 of the *Environmental Protection Act, 1994*.

1.4 Project Background

RTAW owns and operates the Weipa bauxite mine on Western Cape York Peninsula in Queensland. Since 1961, RTAW has extracted bauxite from mining lease ML 7024 on the Weipa Peninsula and lease ML 7031 north of Weipa. Detailed environmental setting information has been previously reported (Golder, 2018a) and is therefore not repeated here.

RTAW's activities comprise a range of mining and associated activities including minerals processing, ore haulage (by road and rail) and product shipping. These activities are supported by a range of infrastructure including, power generation, transport facilities including an airport and, water supply and other municipal services. Groundwater is the source for drinking water supply for the mining area and the township of Weipa and is the responsibility of RTAW. It was reported in Golder (2018a) that PFAS concentrations in water samples from potable wells were below the adopted drinking water screening values.

RTAW has been investigating the source of the PFAS in groundwater. In 2018, a Preliminary Site Investigation (PSI) was completed (Golder, 2018a). The PSI identified primary, secondary and potential source areas and developed a preliminary conceptual site model. The source of the PFAS impacts was considered to be the historical use of aqueous film forming foam (AFFF) products as part of fire suppression systems installed at one location within the Mission River catchment (Andoom Heavy Equipment Workshop) and five locations within the Embley River catchment (Weipa Operations – Evans Landing Industrial Precinct, Railway Workshop, Fire and Rescue (F&R) at Lorim Point, Weipa Airport and East Weipa Heavy Equipment Workshop). Collectively, these six areas are referred to as the 'investigation area'. The location and extent of the investigation area is shown in the figures in **Appendix A**.

The planned DSI builds on the findings of the PSI. The investigation is focused on the six primary source areas, as identified in the PSI and has been designed to investigate and assess PFAS in soil, groundwater, surface water and soil at these locations. There is the potential for other contaminants (such as hydrocarbons) potentially associated with activities undertaken in the primary source areas. For the purposes of clarity, this SAQP excludes the investigation of contaminants other than PFAS.

2.0 General Site Overview

2.1 Location

The investigation area is located on the western side of the Cape York Peninsula. The investigation area is spilt into two key areas – Andoom and East Weipa operations area, which are located north and south of the Mission River respectively. The site location is presented in **Figure 1**, **Appendix A**.

2.1.1 Surrounding land use

Land uses in the surrounding areas are provided in **Table 1**.

Table 1 Surrounding Land Use

Direction	Land Use
North / northwest	Undeveloped land of the Mission River and Wenlock River catchments. The residential community of Mapoon is located on the northern banks of the Embley River, an estuarine inlet of the Wenlock River 36 km north of the Investigation Area.
South	Embley River and undeveloped land of the Embley River catchment. Development activities have commenced south of the Embley River for bauxite mining as part of the Amrun Project.
East	Royal Australian Air Force (RAAF) Base Scherger is located on the northern side of the Peninsula Development Road, to the east of the Weipa mining area. The Base covers approximately 5,500 ha and has been present since 1998. The facility is identified as a non-operational “bare base”, staffed by limited personnel but with capacity to accommodate up to 1,400 personnel.
West	Albatross Bay and the Gulf of Carpentaria

2.2 Environmental Setting

2.2.1 Climate

The climate of the Weipa area is described as typical of tropical monsoon conditions with distinct wet (during summer and early autumn) and dry seasons (late autumn to spring). The average annual rainfall is reported as 1918 mm (Bureau of Meteorology, 2018 for Weipa Aero Station No 027045).

2.2.2 Topography and Surface Water Drainage

The Andoom and Weipa investigation areas are located on the western side of the Cape York Peninsula. The area is characterised by flat coastal plains with a series of freshwater and estuarine creeks and two major Rivers, namely the Mission River and Embley River to the south and Mission River to the north of Weipa Township. The major rivers in the Andoom area include Andoome Creek on the western side of the Andoom Area and the Pine River to the north. The northern end of the Great Dividing Range is located to east and includes hills up to 800 m above sea level (Golder, 2018b).

2.2.3 Geology and Soils

The investigation area is underlain by:

- Quaternary age mud, silt and sand along the coastal flats associated with the Embley River, Mission River, Pine River and Andoom Creek
- Late Tertiary to Quaternary aluminous laterite, including bauxite with sandy “A” horizon and deeply weathered Aurunkun surface over the majority of the Andoom and Weipa mining areas. This is the predominant geological unit across the investigation area; and
- Eocene age Bulimba Formation including sandstone, pebble conglomerate and sandy claystone along incised sections of Pappan Creek and Mission River Creek to the east of the Weipa mining area and to the west and east of the Andoom mining area (Golder, 2018b).

The predominant soil description across the investigation area is Red Massive Earths described as gently undulating plains with only occasional very shallow drainage depressions comprising gradational red massive soil with aluminous concretions, A2 horizon nonbleached, neutral massive earth with limited suitability for agriculture (QLD Globe, 2018).

2.2.4 Hydrogeology

The Weipa and Andoom areas which form the investigation area of this SAQP are located within the Mesozoic Carpentaria Basin with the rocks of the Normanton Formation (in the Rolling Downs Group) being representative of the regional aquifer. The deep regional aquifer is overlain by younger rocks of the Karumba Basin and Bulimba Formation (Golder, 2018b).

Previous hydrogeological investigations divide the shallow subsurface into a superficial Kaolinite Unit and a shallow sandstone aquifer of the Bulimba Formation. Studies of the unconfined Kaolinite Unit have indicated that the formation is mainly unsaturated and discontinuous (Golder, 2018b).

Previous hydrochemical studies of groundwater in the regional aquifer system suggest a vertical connection between the Karumba Basin and the underlying aquifer, however, vertical connectivity between these units has not been assessed on a local scale. Conceptually the connectivity between the Karumba Basin and underlying formations suggest the aquifers and partial aquifers of the Karumba basin directly overly aquifers of the Carpentaria Sequence, however vertical interaction of groundwater between these different layers is not well understood (Golder, 2018b).

The sandstone of the Bulimba Formation generally represents a high yielding shallow aquifer, which is an important groundwater resource over the Weipa Peninsula. The potentiometric surface of the shallow aquifer generally follows surface topography and groundwater flow is predominantly east to west, although at the margins of the Weipa Peninsula flow is radially outward towards the surrounding bays. Recharge to the sandstone of the Bulimba Formation occurs via rainfall infiltration and by leakage from overlying surficial aquifers. Groundwater quality in the shallow aquifer is relatively fresh due to the high annual rainfall and recharge to the Karumba Basin (Golder, 2018b).

Drinking water for the township of Weipa and surrounding areas is sourced from the potable water supply bores. RTAW supplies drinking water to the Weipa airport and Andoom and Weipa mining areas. The Weipa Town Authority operates the drinking water supply scheme for the Weipa township, Evans Landing and Lorim Point. All residential areas (including supporting functions such as recreational areas, schools and accommodation facilities) are connected to these domestic water supplies (Golder, 2018b).

Some unregistered groundwater bores are known to be in operation on the Weipa Peninsula for non-potable uses such as garden watering and filling swimming pools (Golder, 2018b).

3.0 Conceptual Site Model Summary

The primary source areas are those which have been identified as having PFAS in groundwater and soils at concentrations exceeding the PFAS NEMP (2018). Where linkages are complete or potentially complete, further investigation is proposed to better understand the impact of primary source areas to the identified receptors.

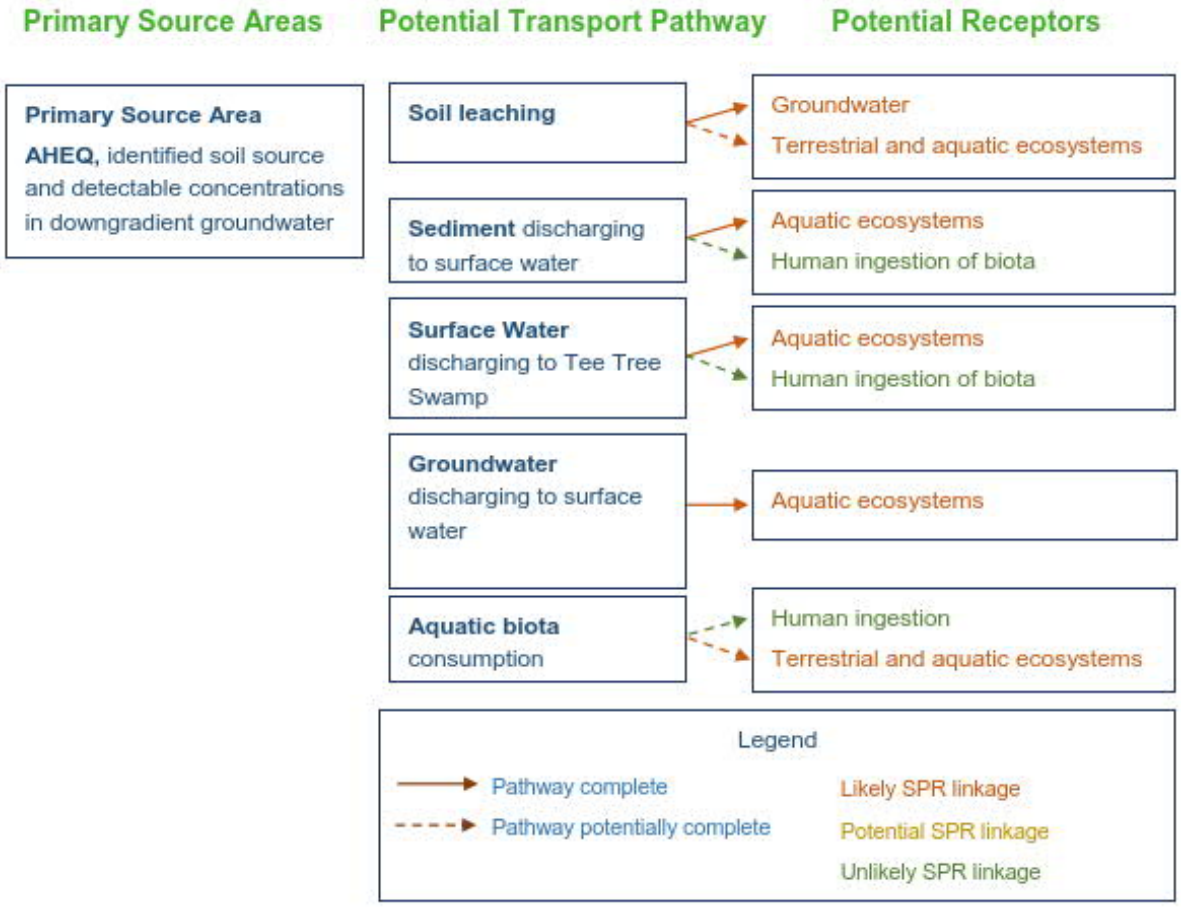


Plate 1 Conceptual Site Model Summary for Andoom Heavy Equipment Workshop, Mission River Catchment (from DSI SAQP Golder, 2018b)

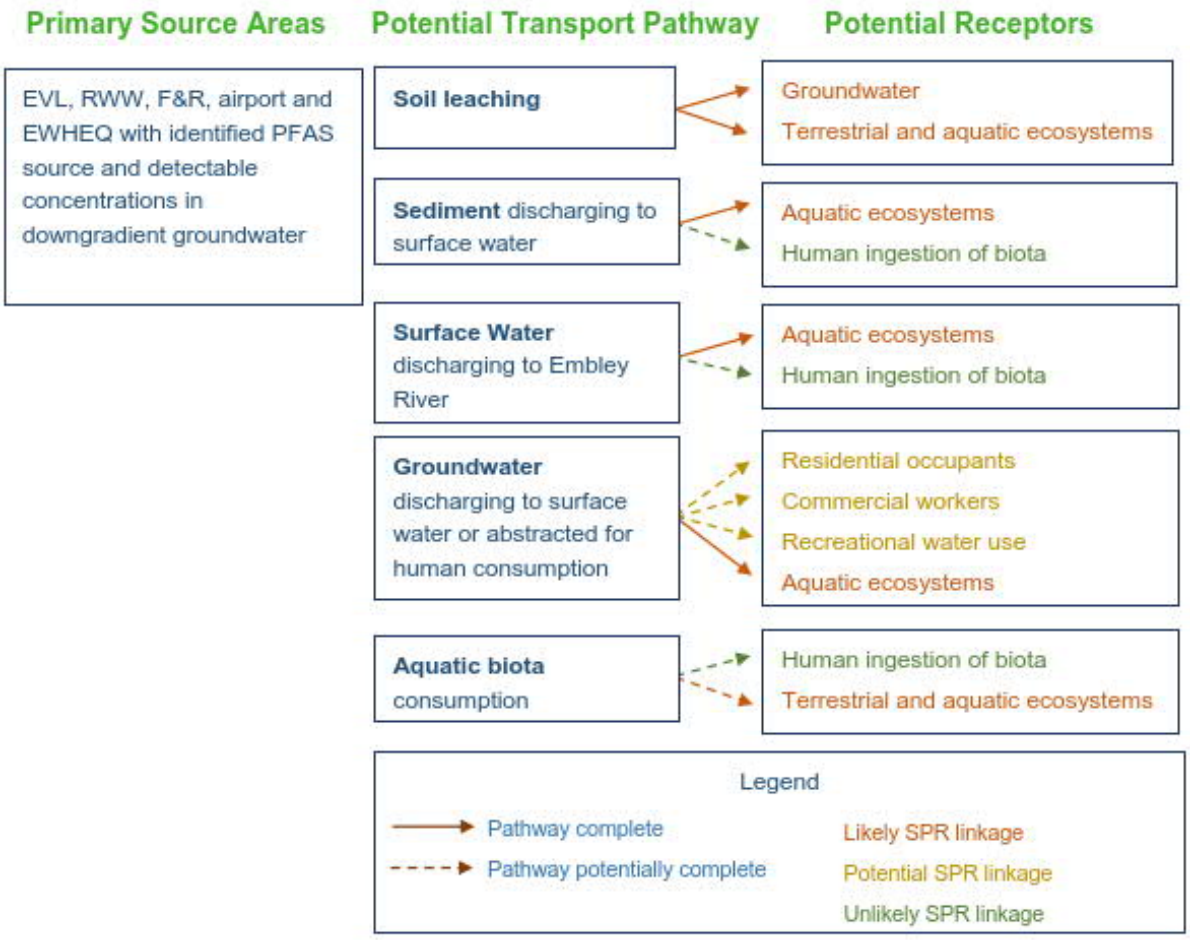


Plate 2 Conceptual Site Model Summary for Primary Source Areas in Embley River Catchment (from DSI SAQP Golder, 2018b)

4.0 Data Quality Objectives

4.1 Data Quality Objectives Steps

The amended National Environmental Protection Measure (NEPM, Schedule B [2]) Guideline on Site Characterisation (2013) specifies that the nature and quality of the data produced in an investigation will be determined by the data quality objectives (DQOs). As referenced by the NEPM, the DQO process is detailed in the United States Environmental Protection Agency (US EPA) *Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA QA/G-4 : EPA/240/B-06/001), February 2006.*

The US EPA defines the process as *'a strategic planning approach based on the Scientific Method that is used to prepare for a data collection activity. It provides a systematic procedure for defining the criteria that a data collection design should satisfy, including when to collect samples, where to collect samples, the tolerable level of decision errors for the study, and how many samples to collect'.*

The process of establishing appropriate DQOs is defined by the US EPA (2006) according to the following seven steps:

Table 2 The seven steps in defining DQOs

Step	Data Quality Objective Step
1	***State the problem*** – Define the problem that necessitates the study; identify the planning team, examine budget, schedule.
2	***Identify the goal of the study –*** State how environmental data will be used in meeting objectives and solving the problem, identify study questions, define alternative outcomes.
3	***Identify information inputs*** – Identify data & information needed to answer study questions.
4	***Define the boundaries of the study*** – Specify the target population & characteristics of interest, define spatial & temporal limits, scale of inference.
5	***Develop the analytic approach*** – Define the parameter of interest, specify the type of inference, and develop the logic for drawing conclusions from findings.
6	***Specify performance or acceptance criteria*** – Develop performance criteria for new data being collected or acceptable criteria for existing data being considered for use.
7	***Develop the plan for obtaining data*** – Select the resource-effective sampling and analysis plan that meets the performance criteria.

The approach adopted relative to the seven steps presented above is summarised in **Table 3** below.

Table 3 Data Quality Objectives

DQO	Outcome
1 - Define the problem.	During preliminary investigation works in the investigation area, PFAS concentrations have been identified in soil, surface water, groundwater and potable water samples. The conceptual site model identified a number of complete and potentially complete source – pathway - receptor linkages for the six primary source areas which are the subject of this DSI SAQP. The concentrations reported may represent an unacceptable risk to human health and/or the surrounding environment. The concentrations and extent of contamination require further characterisation to enable an assessment of these risks to be made to better define which pathways are complete, followed by development of strategies to remove, manage, or mitigate unacceptable risks. The works will need to be undertaken in accordance with the regulatory framework outlined in **Section 1.3**. A further eight secondary source areas and three potential source areas were identified during the PSI. These are not being considered as part of the DSI SAQP and have not been discussed further.

DQO	Outcome
2 – Identify the goal of the study	The goal of the study is to collect the data required to characterise the extent of the identified PFAS contamination within the primary source areas for input into a risk assessment and revise the CSM. Based on the identified data gaps the goal of the study is to answer the following principal study questions: **Investigation Area** 1) What are the concentrations of PFAS in soil in the primary source areas and what is the lateral and vertical extent of impact? 2) What are the concentrations of PFAS in surface water and sediment at locations upstream and downstream of the key discharge points within the investigation area? 3) What are the concentrations of PFAS in groundwater across the investigation area and how far does the contamination extend from the primary source area? **Groundwater beneficial use** 4) Is PFAS present (if so, at what concentrations) in groundwater used for drinking? **Contaminant Migration & Pathways** 5) What is the PFAS mobility in site soils under normal environmental conditions? 6) What are the characteristics of the aquifer beneath the site? 7) Are there preferential pathways for PFAS impacted groundwater to surface water receptors? 8) What are the key source – pathway – receptor linkages between the primary source areas and the identified receptors? 9) What is the risk to human health and the environment in the vicinity of the site?
3 – Identify Inputs to the Decision	The inputs required to address the goal of the study are as follows: • Detailed review of previous investigations completed within the study area • Regulatory guidance as outlined in Section 1.2 and any further correspondence from DES • Tier 1 health and ecological investigation and screening levels of each protected beneficial use applicable within the boundary of the study area. • Quantitative site characterisation data including visual observations and field measurements made during intrusive investigations, laboratory analytical data from field samples (soil, sediment, groundwater and surface water), analytical data comparisons with screening criteria appropriate for the land use. • Hydrogeological and hydrological data across the Site including gradient and flow direction. • Publicly available information including aerial photographs, topographical and geological and soils maps (i.e QLD Globe inputs) • Review of environmental receptors (EPBC) • Any additional relevant information provided by RTAW.
4 – Define the boundaries for the study	The lateral extent of the study area is identified as the Property boundary, presented in **Figure 2, Appendix A**. The investigation locations are shown on **Figure 4** series in **Appendix A**. The vertical extent of the investigation will be the depth to the shallow aquifer system beneath the Site. The temporal boundary of the study is the current conditions at the time of the proposed fieldwork timeframes, which is considered to be during November 2018.

DQO	Outcome
5 – Develop the analytical approach	The analytical approach is outlined in **Appendix B**. The approach includes: • Samples of soil, groundwater, surface water and sediment will be analysed for PFAS. • Results of the DSI will initially be compared against Tier 1 screening criteria outline in **Section 1.2** and a preliminary Tier 1 risk assessment will be undertaken. • If the concentrations of COPC samples exceed the Tier 1 investigation or screening levels (**Section1.2**), further discussions with DES and RTAW will be undertaken to determine any further actions to be undertaken. • Selected samples will be analysed for Australian Standard Leaching Procedure (ASLP) and PFAS with Total Oxidisable Precursor Assay (TOPA) analysis based on the results of the initial analysis results. ASLP will be conducted to assess the leachability of PFAS under natural rainfall conditions. TOPA analysis will be undertaken to investigate the potential presence of precursor compounds at each source area investigated. ASLP and TOPA analysis will be scheduled based on the review of the results. The decision on the acceptance of the analytical data will be made on the basis of the Data Quality Indicators (DQIs) as follows: • **Precision:** A quantitative measure of the variability (or reproducibility) of data. • **Accuracy**: A quantitative measure of the closeness of reported data to the “true” value. • **Representativeness**: The confidence (expressed qualitatively) that data are representative of each media present on Site. • **Completeness**: A measure of the amount of useable data from a data collection activity. • **Comparability**: The confidence (expressed qualitatively) that data may be considered to be equivalent for each sampling and analytical event.
6 – Specify Limits on Decision Errors	Specific limits for this project are in accordance with the appropriate guidance made or endorsed by state and national regulations, appropriate indicators of data quality, and standard procedures for field sampling and handling. This step also examines the certainty of conclusive statements based on the available new site data collected. This should include the following points to quantify tolerable limits: • A decision can be made based on a certainty assumption of 95% confidence in any given data set. A limit on the decision error will be 5% that a conclusive statement may be a false positive or false negative. • A decision error in the context of the decision rule presented above would lead to either underestimation or overestimation of the risk level associated with a particular sampling area. Sampling errors may occur when the sampling program does not adequately detect the variability of a contaminant from point to point across the site. To address this, the SAQP outlines minimum numbers of samples proposed to be collected from each media. • As such, there may be limitations in the data if aspects of the SAQP cannot be implemented. Some examples of this scenario include but are not limited to: - Proposed surface water sample locations may be dry at the time of sampling; and - Proposed samples are not collected due to access being restricted to a given location. • Limitations in ability to acquire useful and representative information from the data collected. The data are proposed to be collected from multiple locations

DQO	Outcome
	and sample media. Some examples of this scenario include: - Inability to collect surface water and sediment samples at the same location; - Measurement errors can occur during sample collection, handling, preparation, analysis and data reduction. To address this the following measures are proposed: ▪ Collection of sufficient sample mass to facilitate analysis reported to standard laboratory detections limits. Collection of insufficient sample mass may result in raised detection limits. ▪ Field staff to follow a standard procedure when collecting samples, including decontamination of tools, removal of adhered soil to avoid false positives in results, and use of appropriate sample containers and preservation methods. ▪ Laboratories to follow a standard procedure when preparing samples for analysis and undertaking analysis. • Laboratories to report quality assurance/ quality control data for comparison with the DQIs established for the project.
7 – Develop the plan for obtaining data	The methodology presented in this SAQP is designed to meet the objectives described in **Section 1.2** and to achieve the nominated DQOs. Optimisation of the data collection process will be achieved by: • Working closely with the analytical laboratories and sampling equipment suppliers to ensure that appropriate procedures and processes are developed and implemented prior to and during the fieldwork, to ensure that sample handling, and transport to and processing by the analytical laboratories is as smooth as possible; and • Conducting sampling according to AECOM SOPs for the type of sampling being conducted. SOPs are present in **Appendix C**. This SAQP presents a framework for the DSI which has been designed to perform a Tier 1 assessment of the risk due to identified potentially complete SPR linkages identified in the PSI. Targeted investigations have been designed to characterise the lateral extent of groundwater contamination around each primary source area and to characterise soil quality in the source areas to identify the location of PFAS impacts. Where possible, the lateral and vertical extent of PFAS impacts in soil will be characterised to the extent possible at the time of the fieldwork. The scope of works will be carried out to a level of accuracy and confidence presented in the NEPM (NEPC, 2013).

4.2 Quality Assurance

A QA/QC program will be implemented to ensure that data collected is sufficiently accurate and reproducible for the purposes of the investigation. The objective of the QA/QC program is to provide an assessment of the reliability of the data presented for interpretation in terms of the DQOs.

4.3 Summary of QA/QC Program

The objective of the QA/QC program is to provide an assessment of the reliability of the data presented for interpretation. All work completed will be conducted in accordance with standard AECOM environmental sampling protocols as presented in Table 4 below.

Table 4 Essential Elements of the Field QA/QC Program

Aspect	Description
Use of experienced personnel	Field work will be undertaken by trained AECOM personnel with previous experience in contaminated site assessment. Field personnel will be familiar with: • Identification of potential contamination sources. • Field sampling techniques. • AECOM and site-specific health and safety protocols.
Record keeping	Date, field personnel details, observations and findings of field activities Recording of sample description and collection details on standard AECOM field sheets.
Sample collection	Samples will be collected with reference to applicable industry guidelines.
Quality control sampling	Quality control field duplicates and triplicates for soil and groundwater will be collected. In addition, rinsate and trip blanks will be collected during sampling.
Sample labelling	A unique sample identification number will be used for each sample to specify the sample origin (sample location ID and date), preservation standards and analytical requirements.
Chain of custody	Standard AECOM CoC procedures will be adopted for sample transfers. CoC documentation includes sample numbers; date of sampling/collection; analyses required; and release and receipt of parties accepting sample custody.
Sample storage	Samples will be collected in appropriate sample containers supplied by the analytical laboratory. Where required, sample containers will be prepared with preservation solutions based on the analyte of interest. Samples will be placed in cool storage on ice prior to transfer to the laboratory.
Equipment decontamination	All non-dedicated field equipment used in the sampling process will be subject to appropriate decontamination procedures.

4.4 Laboratory Selection

The laboratory selected to conduct the analysis of groundwater will be:

- Accredited by the National Association of Testing Authorities (NATA);
- Certified by NATA to conduct the specific tests required, unless NATA does not certify a particular analysis or method specified in this SAQP; and
- Able to demonstrate that it can achieve the required analytical limits of reporting (typically an order of magnitude below the respective assessment criteria for the matrix and parameter).

In this instance, AECOM will use ALS Environmental (ALS) (based in Brisbane) as the primary laboratory and the National Measurement Institute (NMI) in Sydney, as the secondary laboratory. Laboratory reporting for each laboratory including data management information will be provided in the report.

5.0 Regulatory Overview and Screening Criteria

The assessment will be performed consistent with State, Territory and local government environmental legislation and requirements to the extent that these do not conflict with Commonwealth legislative obligations.

5.1 Screening Criteria

The principal legislative basis for water quality management in Queensland is the *Environmental Protection (Water) Policy (EPP), 2009*, which identifies a process for identifying environmental values of waterways and establishing corresponding water quality objectives to protect identified environmental values.

Tier 1 screening assessment criteria have been selected with consideration of the Site conditions and the current and future land use. The criteria presented below are generic Tier 1 risk based criteria. Where concentrations of a contaminant of potential concern exceed the generic Tier 1 assessment criteria, then further consideration of the specific exposure pathway is required which may warrant further investigation, assessment or the development of a strategy to mitigate the potential risks identified.

5.1.1 Soil

5.1.1.1 Human Health

The primary reference for PFAS in soils is the NEMP (HEPA, 2018) for commercial / industrial and open space land uses.

5.1.1.2 Waste Management

Excavated soil will be left in situ and covered, pending analytical results to assess disposal options. Based on the results, a suitable disposal route will be selected.

5.1.1.3 Ecological

The primary reference for PFAS in soils is the NEMP (HEPA, 2018) for industrial land use.

5.1.2 Groundwater and Surface Water

The primary reference for PFAS in groundwater is the NEMP (HEPA, 2018). Human health guidelines are available for drinking water and recreational use and ecological guidelines are available for the protection of freshwater and marine ecosystems.

6.0 Site Investigation

This section provides a summary of the tasks and types of data needed to be collected for this DSI. A detailed sampling plan including details such as sampling locations, analytical suite, etc. is presented in **Appendix B** with proposed sampling locations shown in **Figures in Appendix A**.

Shallow soil boring is planned in preference to test pitting as based on the conceptual understanding of release of AFFF to ground surface, it is considered that the PFAS impacts are likely to be mainly present in near surface soils. If required, characterisation of deeper vertical extent of soil contamination could be completed as a later phase of the investigation.

Groundwater bores are proposed to be installed in the shallow aquifer, generally between 10-12m depth below surface.

Up to ten rising/falling head tests will be performed on new wells across the investigation area with a minimum of one test per investigation area, to support the groundwater modelling and contaminant migration assessments.

The sampling rationale applied to the six primary source areas is outlined in **Table 5** below.

Table 5 Sampling Rationale Applied to Primary Source Areas

Source Area	Description	Data Gaps / Identified Risks	Sampling* and analysis rationale
Andoom Heavy Equipment Workshop and Andoom Service Bay	PFAS impacts are present in groundwater around the workshop. Groundwater quality to the south of workshop has relatively higher PFAS concentrations compared with concentrations in groundwater in bores to the north and east. The contaminant distribution suggests PFAS is migrating with groundwater flow to the south and southwest of the workshop.	• There are no monitoring bores located to the west of the workshop so the lateral extent of the PFAS plume is not delineated in this direction • The leading edge of the PFAS plume has not been delineated and the extent of the plume to the south and southwest is not understood. • The extent of any PFAS impacts remains unknown. May extend a considerable distance from this potential source area. • No soil characterisation has been undertaken.	• Installation of two additional groundwater monitoring bores (identified as AHEQ MW-07 and AHEQ MW-08) to the south west and west of AHEQ-03, which is likely to be close to the potential source area. Locations shown in purple circles on **Figure 4A**. • Installation of three additional groundwater monitoring bores (identified as AHEQ MW-09, AHEQ MW-10 and AHEQ MW-11) to the south of the potential source area (nominally 300-400 m from the source area). Locations shown in purple circles on **Figure 4A**. • Groundwater sampling of 13 monitoring bores (eight existing [AHEQ MW-01, AHEQ MW-03 to MW-06, ASB MW-08, ASB MW-21, ASB MW23], and five new monitoring bores [AHEQ MW-07 to MW-11]) to characterise the extent of PFAS in this source area. Locations shown in purple and yellow circles on **Figure 4A**. • Advancement of shallow soil bores to 0.5 mbgs at seven locations in the operational area immediately north and south of the workshop to characterise soil for residual PFAS impacts. Soil samples to be collected from two horizons, at 0.1-0.2 and 0.3-0.5 mbgs). Locations shown as red and white locations on **Figure 4A**. • Collection of three surface water and sediment samples from local surface water bodies (PR/AND/WS, PR/AND/DOS, PR/AND/LF, where surface water is present or known to accumulate. Locations shown in green circles on **Figure 4A**. • Complete rising/falling head tests on up to two newly installed groundwater wells. • Collection of water sample from potable regional well ASA092 to assess drinking water quality. Refer **Figure 4A**, **Appendix A** (adapted from Golder, 2018b).

Source Area	Description	Data Gaps / Identified Risks	Sampling* and analysis rationale
Evans Landing	PFAS has been identified in groundwater in a number of monitoring bores within this operational area. Due to the proximity of the estuary to the south and southeast, groundwater is expected to express to receiving surface waters in this area.	• The lateral extent of the PFAS in groundwater is not characterised to the north and northeast of the area with the highest PFAS concentrations (ELS MW-18). • The location of a PFAS source area within this area is not known and no soil characterisation has been undertaken to date.	• Installation of four additional groundwater monitoring bores (ELS MW-28, ELS MW-29 to the east and northeast of ELS MW-18 and ELN MW-09 and ELN MW-10 to the north) to characterise the lateral extent of PFAS groundwater contamination. • Groundwater sampling of 14 monitoring bores (ten existing [identified in yellow circles in **Figure 4B**] and four new bores [identified in purple circles in **Figure 4B**]) to characterise the extent of PFAS in groundwater within this potential source area. • Advancement of shallow soil bores to 0.5 mbgs at eight nominated locations across Evans Landing investigation area – three at Evans Landing South and five to the north east. Soil samples to be collected from two horizons, at 0.1-0.2 and 0.3-0.5 mbgs). Locations are shown as red/white boxes on **Figure 4B**. • Collection of three surface water and sediment samples from along the foreshore (EMB/EV/NSA, EMB/EV/NSB and EMB/EV/NSC, shown in green circles on **Figure 4B**) – one round of surface water at high tide and one round at low tide. • Collection of three surface water samples offshore (EMB/EV/OSA, EMB/EV/OSB and EMB/EV/OSC, shown in green circles on **Figure 4B**) - one round at high tide and one round at low tide. • Complete rising/falling head tests on up to two newly installed groundwater wells. Refer **Figure 4B Appendix A** (adapted from Golder, 2018b).

Source Area	Description	Data Gaps / Identified Risks	Sampling* and analysis rationale
Railway Workshop	PFAS impacts are present in groundwater in one monitoring bore adjacent to the railway workshop area. Due to the presence of the estuary to the south and southwest, groundwater flow is expected to be directed towards this surface water area.	• The lateral extent of the PFAS in groundwater is not characterised to the northwest, west and southeast of the area with the highest PFAS concentrations (RWW-MW07). • The location of a PFAS source area is not known and no soil characterisation has been undertaken to date.	• Installation of three additional groundwater monitoring bores (RWW MW06 to RWW MW008) to the northwest, west and southeast of RWW MW-01 to characterise the lateral extent of PFAS groundwater contamination. • Groundwater sampling of eight monitoring bores (five existing [identified in yellow circles in **Figure 4C**] and three new bores [identified in purple circles in **Figure 4C**) to characterise the extent of PFAS in groundwater within this potential source area. • Advancement of shallow soil bores to 0.5 mbgs at four locations in the vicinity of RWW MW-01 to the south and south west of the workshop to characterise soil for residual PFAS impacts. Soil samples to be collected from two horizons, at 0.1-0.2 and 0.3-0.5 mbgs). Locations are shown as red/white boxes on **Figure 4C**. • Due to the distance to the nearest surface water body, sediment and surface water sampling is not proposed. If standing or flowing surface water is observed during the fieldwork, surface water and sediment samples will be collected. • Complete rising/falling head tests on one newly installed groundwater well. Refer **Figure 4C, Appendix A** (adapted from Golder, 2018b).
Lorim Point	PFAS impacts are present in a number of monitoring bores in this area. Leachate PFAS analysis on a near-surface soil sample (TP-12) has identified high concentrations of PFAS (153 ug/L) in the leachate.	• Groundwater quality close to and up-gradient of the potential source area (fire and rescue training area) is not known. Soils in the area exceed the interim ecological criteria but are below the NEMP human health screening values. • The lateral extent of the PFAS in groundwater is not characterised to the west and southeast of the area	• Installation of one groundwater monitoring bore (LPI MW-24) up-gradient (to the north) of the source area to characterise the extent of PFAS impacts to the north. • Installation of three additional groundwater monitoring bores (LPI MW-25, LPI MW-26 and LPI MW-27) in the potential source area (Lorim Point fire and rescue area) to understand distribution of PFAS impacts in groundwater around TP-12. • Installation of three groundwater monitoring bores (LPI MW-28, LPI MW-29 and LPI MW-30) to the west and southwest of the source area to understand the lateral extent of impacts to

Source Area	Description	Data Gaps / Identified Risks	Sampling* and analysis rationale
		with the higher PFAS concentrations. • The location of a PFAS source area is not known and no soil characterisation has been undertaken to date.	the west. • Installation of one groundwater monitoring bore to the south (LPI MW-31) to understand the distribution of PFAS in groundwater to the south. • Groundwater sampling of 16 monitoring bores (eight existing [identified in yellow circles in **Figure 4D**) and eight new bores [identified in purple circles in **Figure 4D**) to characterise the extent of PFAS in groundwater within this potential source area. • Sampling of potable water bores SA012, SA014 and SA015 to assess potential PFAS concentrations, also in yellow circles on **Figure 4D**. • Advancement of shallow soil bores to 0.5 mbgs at eight locations in the vicinity of the fire and rescue station to characterise soil for residual PFAS impacts. Soil samples to be collected from two horizons, at 0.1-0.2 and 0.3-0.5 mbgs). Locations are shown as red/white boxes on **Figure 4D**. • Collection of three surface water and sediment samples from along the foreshore (shown in green circles on **Figure 4D**) - one round of surface water at high tide and one round at low tide. • Collection of three surface water samples offshore (shown in green circles on **Figure 4D**) - one round at high tide and one round at low tide. • Complete rising/falling head tests on up to two newly installed groundwater wells. Refer **Figure 4D** in **Appendix A** (adapted from Golder, 2018b).

Source Area	Description	Data Gaps / Identified Risks	Sampling* and analysis rationale
Weipa Airport	PFAS impacts are present in groundwater along the southern side of the airstrip. The groundwater flow direction is likely to be towards the south and southwest.	• The lateral extent of the PFAS in groundwater is not characterised to the south and southwest area with the higher PFAS concentrations. • Anecdotal evidence of fire training areas was identified (Golder, 2018a) and further investigation at the north western and south eastern ends of the runway appears to be warranted based on this information. • Additional sampling between the landfill and runway is not proposed as the receiving environment is to the south and there are deemed to be sufficient current and proposed locations in this area to assess the risks to groundwater from this source area.	• Installation of three additional groundwater monitoring bores (ALF MW-06, ALF MW-07 and AFD MW-37) down-gradient of the detected PFAS impacts to understand distribution of PFAS in groundwater. • Installation of two groundwater bores at either end of the runway (AP MW-01 and AP MW-02) • Groundwater sampling of 13 monitoring bores (eight existing [shown in yellow circles on **Figure 4E**] and five new bores [shown in purple circles on **Figure 4E**]) to characterise the extent of PFAS in groundwater within this potential source area. • Advancement of shallow soil bores to 0.5 mbgs at eight locations (four at each end of the runway) to characterise surface soil for residual PFAS impacts. Soil samples to be collected from two horizons, at 0.1-0.2 and 0.3-0.5 mbgs). Locations are shown as red/white boxes on **Figure 4E**. • Collection of three surface water and sediment samples from Beening Creek (two existing locations – SW/BEN/DOS and SW/BEN/UPS and one proposed location SW/BEN/MID). Locations are circled in green on **Figure 4E**. • Complete rising/falling head tests on one newly installed groundwater well. • Sampling of potable water bores SA009 and SA026, to assess potential PFAS concentrations. • Collection of water sample from potable regional well SA005 to assess drinking water. Refer **Figure 4E**,**Appendix A** (adapted from Golder, 2018b).

Source Area	Description	Data Gaps / Identified Risks	Sampling* and analysis rationale
East Weipa Heavy Equipment Workshop Focus Area	PFAS impacts are present in groundwater close to, and to the southwest of the workshop.	• The lateral extent of the PFAS in groundwater is not characterised to the northeast (expected to be upgradient), northwest, southwest and south of the workshop. • The location of a PFAS source area is not known and no soil characterisation has been undertaken.	• Installation of four additional groundwater monitoring bores (EWHEQ MW-06 to MW-09) to understand distribution of PFAS in groundwater including upgradient and downgradient of primary source area. • Groundwater sampling of eight monitoring bores (four existing [shown in yellow circles on **Figure 4F**] and four new bores [shown in purple circles on **Figure 4F**]) to characterise the extent of PFAS in groundwater within this potential source area. • In addition, two registered bores (RN78251 and RN109710) will be included in the groundwater sampling regime. • Advancement of shallow soil bores to 0.5 mbgs at eight locations in the operational area immediately south west of the workshop to characterise soil for residual PFAS impacts. Soil samples to be collected from two horizons, at 0.1-0.2 and 0.3-0.5 mbgs). Locations are shown as red/white boxes on **Figure 4F**. • Up to four surface water / sediment locations are proposed at the EWHEQ (2 existing locations – PR/EWM/WP and PR/EWM/WP/DOS and 2 new - PR/EWM/01 and PR/EWM/WP/02) along the drainage line to the SW of the facility. Locations are circled in green on **Figure 4F**. • Complete rising/falling head tests on up to two newly installed groundwater wells. Refer **Figure 4F**, **Appendix A** (adapted from Golder, 2018b).

* Individual sampling locations may be moved in the field based on site observations, accessibility to location, topography and presence of underground services or for operational reasons. Where possible the locations will be placed as close as practical to the planned locations.

7.0 Field Methodology

Guidance on PFAS groundwater sampling is provided in the NEMP (HEPA 2018). The guidance includes the following:

- Quality control samples (duplicates and triplicates) should be sampled at a frequency of 1 in 10, which is greater than the 1 in 20 samples identified in AS4482.1-2005 and ASC NEPM.
- Rinsate samples should be collected to verify decontamination or if there is doubt about whether materials are PFAS free. Field and trip blank samples should be collected to verify the integrity of the sampling and decontamination procedures. Rinsate and blank samples should use PFAS-free water that has been certified by the laboratory.
- Precautions should be taken to limit cross contamination of samples. Materials and products that should not be worn or used during any stage of sampling at the Site or during transport include new clothing (fabric treatments), stain and water resistant products, sunscreen, cosmetics, fast food wrappers, Teflon, sampling containers with Teflon lined lids, foil, sticky notes, waterproof papers, drilling fluids, decontamination solutions and reusable freezer blocks.
- The general order of sampling in the field is important to reduce the chance of sample contamination. Sampling should proceed from areas of likely low concentration of PFAS contamination to areas of likely higher concentration.
- For each groundwater sample collected, the required minimum volume is 250 mL as per USEPA (2009). Polypropylene or HDPE sample containers should be used. Glass containers with lined lids are not suitable for PFAS analysis.
- Decontamination of sampling equipment should not use detergents unless they have been confirmed to be PFAS-free. Deionised water (which is certified to be PFAS-free) should be used.
- Equipment (e.g. pumping equipment, water quality meter, interface probe) containing Teflon parts or LDPE tubing should not be used. The equipment recommended for collecting groundwater samples includes low flow peristaltic pumps using silicone or HDPE tubing. Consumable sampling equipment should not be reused.
- Larger sample volumes may be necessary if the required limit of reporting are ultra-trace and /or if a TOPA or TOA analysis is to be performed on the same sample.

Further information on sampling requirements were presented in interim guidance on the assessment and management of PFAS published by Western Australia's Department of Environmental Regulation (January 2017) identified the following potential sources of environmental sample contamination during PFAS investigations and recommended mitigation practices and alternatives.

These requirements will be implemented during the sampling program.

Product	Mitigation practice	Alternative product or practice when PFAS sampling is to be undertaken
Clothing and food		
New clothing	Not to be used/consumed by sampling personnel[1]	Wash all field clothing a minimum of six times after purchase to remove surface coatings before using at the site.
Clothing with stain-resistant, rain-resistant, or waterproof coatings/ treated fabric (for example GORE-TEX®)		Avoid sampling during rain if possible; polyethylene rain gear (for example disposable LDPE), vinyl or polyvinyl chloride (PVC) clothing are acceptable.
Tyvek® clothing		None
Fast food wrappers and containers		Use rigid plastic containers or bags or stainless steel containers for all food brought to site.
Pre-wrapped foods and snacks (for example chocolate bars, energy bars, granola bars and potato chips		Use plastic (rigid containers or bags) or stainless steel containers to bring food to site.
Sampling equipment and containers		
Teflon® containing or coated field equipment (tubing, bailers, tape and plumbing paste)	Do not use at site[2]	High Density Polyethylene (HDPE) or silicone tubing, and HDPE or polypropylene field equipment recommended. Concawe (2016) reports that although high purity Teflon tubing does not cause 'blank contamination' in contrast to common Teflon tubing, some researchers have found that Teflon could adsorb PFAS.
Teflon® lined lids on containers (for example sample containers, rinsate water storage containers)	Do not use at site[2]	Polypropylene lids[3] for sample containers and polypropylene or HDPE containers for rinsate.
Glass sample containers with lined lids	Do not use	Use polypropylene or HDPE for sample containers[3] (PFAS adsorb strongly to glass).
Other products		
Aluminium foil	Do not use[1]	Thin HDPE sheeting (commonly used as drop cloths for painting or home improvement) can be used.
Self-sticking notes and similar office products (for example 3M Post-It notes)	Do not use at site[2]	Avoid the use of these products at the site.
Waterproof paper, notebooks, and labels	Do not use at site[2]	Standard paper and paper labels.
Drilling fluid containing PFAS	Do not use at site[2]	PFAS-free drilling fluids or use alternative techniques (for example sonic drilling) which do not require drilling fluids.
Detergents and decontamination solutions (for example Decon 90® Decontamination Solution)	Do not use	Follow water-only decontamination approach.
Reusable chemical or gel ice packs (for example BlueIce®)	Do not use	Ice contained in plastic (polyethylene) bags (double bagged).

Notes

[1] Sampling personnel includes all personnel who:

- are directly involved in the collection, handling and/or processing of samples prior to the samples leaving the site;
- handle any part of well development equipment that directly contacts bore water being sampled;
- handle any part of equipment that directly contacts surface water or aquatic sediment;
- are within 2–3m of the borehole during soil sampling; or
- are within 2–3m of the collection and processing area on aquatic vessels during sediment or surface water sampling.

Personnel are not included as sampling personnel if they remain at least 2–3m away from sample collection areas prior to and during sampling.

[2] Entire sample collection and processing area, including vehicles used by sampling personnel.

[3] USEPA and ASTM method for the analysis of PFAS in solid and liquids specify polypropylene or HDPE with polypropylene lids. Check with the laboratory with regards to preference for polypropylene or HPDE.

7.1 Drilling

The soil bores and the shallow groundwater monitoring wells for the DSI will be installed by a combination of non-destructive digging, hand augering and rig-mounted drilling using push tube, solid or hollow stem auger, rotary coring and air/or hammer techniques pending the lithology of the well locations.

The groundwater monitoring wells will be installed to evaluate the nature and extent of PFAS impact in shallow soils and groundwater. The groundwater monitoring wells will be installed to a depth that will be determined based on field observations. Each well will be constructed with 50-mm slotted uPVC to the target depth with a sand pack with lengths varying on location, site and well conditions. The

screened interval depth will be determined based on site conditions. Proposed well construction diagrams are provided in **Appendix C**.

RTW are directly subcontracting the drilling work to a licensed Queensland drilling company. The groundwater monitoring wells will be constructed in accordance with the Minimum Construction Requirements for Water Bores in Australia (Edition 3, February 2012). The drilling program will be directed by an experienced AECOM field technician who will be present throughout the drilling program. The field technician will co-ordinate logistics in collaboration with our Brisbane office, log the intersected geology and collect soil samples for laboratory analysis.

7.2 Logging of Soil Bores

To support subsequent data interpretation, soil bores will have the geological strata logged in the field in general accordance with the Unified Soil Classification System (USCS) and AECOM SOP (**Appendix C**).

For each soil bore the following details will be clearly presented on the logs:

- Name of the field technician supervising the investigation and the rig/equipment type and the sampling method.
- Date of sampling, unique sampling location number, depth of sampling, sample type and unique sample number.
- All field records will be rigorously documented and comprise field observations of colour, odour, field-screening results and details of any unusual material encountered.
- Completed graphic logs will be presented with surface elevations (to accuracy ±10 mm) with depth scale in metres.

7.3 Soil Sampling

Soil samples shall be collected and handled in a manner that ensures field personnel safety, and the integrity of the sample itself.

Field personnel will describe the nature of each sediment sample (soil type, colour, staining, etc.). Further information on the correct techniques to be employed when using a hand auger to collect samples is presented in the AECOM Manual Tasks Procedure (**Appendix C**).

Soil samples beyond 1.5 mbgs will be collected from plastic sleeves recovered from the push tube on the drilling rig or drill cuttings recovered from solid stem auger or air hammer drill as part of the monitoring well installations.

Soil samples for laboratory analysis are to be collected in 250 mL unpreserved lab supplied containers. One PFAS specific sample container will be required for each sample.

The soil sample volume required by the laboratory is dependent upon the number of analytes requested to be analysed. AECOM will work with the laboratories to ensure that appropriate sample volumes are collected for the number of analytes requested.

7.4 Surveying and Groundwater Gauging

All the newly installed monitoring wells will be surveyed by an accredited surveyor for MGA horizontal co-ordinates and Australian Height Datum levels for ground level and top of casing.

Groundwater levels will be gauged using a calibrated interface probe to the TOC with depths to non-aqueous phase liquid (NAPL) (if encountered) and groundwater recorded. Recordings will be utilised to establish NAPL thickness (if present) and the standing water level elevation.

7.5 Well Development

Following completion of the bore to the target depth and installation of a monitoring well screen, the bore will be developed to remove particulate matter that may be present from well drilling and

construction. The development reduces sample turbidity by removing fine particulate matter from the filter pack and the geologic formation near the well.

7.6 Groundwater Sampling

Groundwater samples will be collected by low flow sampling consistent with current best practice for PFAS assessment. All sampling will be undertaken by an appropriately qualified AECOM Environmental technician and samples shall be collected and handled in a manner that ensures field personnel safety, and the integrity of the sample itself.

7.6.1 Monitoring Wells

Groundwater samples will be collected in accordance with the AECOM SOP (**Appendix C**) so that they are representative of groundwater sampled up until the time of their analysis.

Groundwater monitoring wells (where there is no dedicated pump) will be gauged prior to sampling with an oil/water interface probe to measure depth to groundwater, total depth of the wells, and to detect the presence of NAPL (if encountered). Each well will be sampled using a low flow pump. Before and between sampling each well, the interface probe and all other equipment which will be placed down well will be decontaminated using demineralised water (deionised (DI) water) to reduce the risks of cross contamination. The low flow sampling will use new sample tubing at each well. Waste tubing will be collected by AECOM and disposed appropriately.

7.6.2 Sample Collection Methods

Groundwater quality parameters (temperature, pH, electrical conductivity (EC), dissolved oxygen (DO) and redox potential (ORP)) will be measured in the field prior to sample collection to demonstrate conditions of the groundwater in the well. Groundwater used for the measurement of water quality parameters will be collected in a new laboratory-supplied plastic bottle at each location.

Groundwater collected for sample analysis will be collected in the appropriate laboratory supplied sample containers for the specific analysis to be conducted (as recommended by the laboratories).

For intra-laboratory and inter-laboratory samples (duplicate and triplicate sampling), AECOM personnel will attempt to reduce potential heterogeneity in the water collected by alternating between primary and intra/inter-laboratory bottles during sampling to allow mixing. All groundwater samples will be placed in eskies containing ice in double bags in polyethylene immediately after sampling.

Sample containers shall be placed in a cooler with ice and kept, if possible, at approximately 4°C during transit to the laboratory. Prior to sampling, assessment of the analytical holding times shall be made and the sampling planned accordingly to ensure that holding times are not breached or minimised. Samples will be transported directly to the laboratory for analytical testing under standard chain of custody procedures.

Primary and duplicate samples for all media types and their associate QA/QC samples will be analysed by ALS Laboratory Group (ALS), a NATA accredited laboratory for the analytes being investigated.

Triplicate (inter-laboratory) samples will be analysed by National Measurement Institute Laboratories (trading as NMI) also a NATA accredited laboratory for the analytes being investigated.

Further information on groundwater monitoring well sampling methodologies is presented in the SOP (**Appendix C**).

7.6.3 Surface Water Sampling

The surface water sample collection method employed is dependent on the nature of the location. A copy of the SOP is provided in **Appendix E** and is in accordance with Australian Standard for Water Quality Sampling (AS5567: 1998).

At creek locations, surface water samples are to be collected using a sampling pole to retrieve water from near the water surface, and towards the centre of the creek (where possible with consideration to hazards associated with working near a water body). If the creek location is a shallow ephemeral pool and the creek bank gradient allows easy access, the sample can be collected into the sample bottle by

a gloved hand. Care should be taken to ensure the water column at the sampling location is not agitated during sampling.

At each sample location, field personnel will note the creek/water body morphology, soil type and nature of surface water flow. Surface water samples are to be collected in appropriate sample bottles.

7.6.4 Sediment Sampling

Sediment samples shall be collected and handled in a manner that ensures field personnel safety, and the integrity of the sample itself.

Sediment samples collected from near the ground surface (no greater than 0.2 mbgs) are to be collected by a gloved hand or clean trowel.

Field personnel will describe the nature of each sediment sample (soil type, colour, staining, etc.). Further information on the correct techniques to be employed when using a hand auger to collect samples is presented in the AECOM Manual Tasks Procedure (**Appendix C**).

Sediment samples for analysis are to be collected in 250 mL plastic containers for PFAS. The sediment sample volume required by the laboratory is dependent upon the number of analytes requested to be analysed.

7.6.5 Sample Handling and Transport to Laboratory

All samples shall be placed in a cooler containing ice and kept, if possible, at approximately 4°C during transit to the laboratory. Prior to sampling, assessment of the analytical holding times shall be made and the sampling planned accordingly to ensure that holding times are not breached or minimised.

Samples will be transported directly to the laboratory for analytical testing under standard chain of custody procedures. Primary and associated duplicate and other QA/QC samples will be analysed by NMI. Triplicate (inter-laboratory) samples will be analysed by ALS.

QA/QC sampling is discussed in **Section 4.2**.

7.7 Equipment Required for Sampling

The equipment identified in **Table 6** will be used by AECOM and its subcontractors during the fieldwork.

Table 6 Sampling Equipment

Equipment Item	Reason for Equipment Use
Utility Location Equipment	Identification of underground surfaces (e.g. electrical, gas) so that suitable locations can be nominated for the groundwater wells.
Non-Destructive Drilling (NDD) Rig	Clear each borehole to confirm they are clear of utilities.
Drill Rig - push tube and solid stem auger, etc.	Required to drill boreholes, collect soil samples and install on-site groundwater wells.
Hand Auger	Collection of samples from near to the ground surface during NDD.
Crowbar	Collection of sediment samples from near to the ground surface. A crowbar is used as an alternative to a hand auger, where the ground surface may be difficult to penetrate.
Sampling Pole, Waders	Collection of surface water samples.
Brush, Bucket and Deionised Water	Decontaminate of the hand auger and shovel between sample collections.
Interface Probe	To measure the stabilised water level in the monitoring wells.
Water Quality Meter	Collection of field water quality parameters for each water sample. Parameters include: temperature, pH, EC, DO, ORP.
Submersible low-flow bladder pump	Collection of groundwater samples from locations where there is no dedicated pump.
Surveying Equipment	Surveying of the location, surface elevation and top of casing of each groundwater well to infer groundwater flow and direction.

7.8 Calibration

The water quality meter will be calibrated at the commencement of field activities by the supplier prior to the sampling program. The calibration will be in accordance with manufacturers' instructions or NATA publication "General Requirements for Registration: Supplementary Requirement: Chemical Testing (NATA 1993) and Technical Note No. 19 (NATA 1994)".

7.9 Analytical Suite and Laboratory Analysis Methods

All media sampled shall be analysed for the standard PFAS suite identified in **Table 7** below.

Table 7 Sample Analytical Suite for PFAS

PFAS Group	Compound	CAS No.
Perfluoroalkyl Sulfonic Acids	Perfluorobutane sulfonic acid (PFBS)	375-73-5
	Perfluoropentane sulfonic acid (PFPeS)	2706-91-4
	Perfluorohexane sulfonic acid (PFHxS)	355-46-4
	Perfluoroheptane sulfonic acid (PFHpS)	375-92-8
	Perfluorooctane sulfonic acid (PFOS)	1763-23-1
	Perfluorodecane sulfonic acid (PFDS)	335-77-3
Perfluoroalkyl Carboxylic Acids	Perfluorobutanoic acid (PFBA)	375-22-4
	Perfluoropentanoic acid (PFPeA)	2706-90-3
	Perfluorohexanoic acid (PFHxA)	307-24-4
	Perfluoroheptanoic acid (PFHpA)	375-85-9
	Perfluorooctanoic acid (PFOA)	335-67-1

PFAS Group	Compound	CAS No.
	Perfluorononanoic acid (PFNA)	375-95-1
	Perfluorodecanoic acid (PFDA)	335-76-2
	Perfluoroundecanoic acid (PFUnDA)	2058-94-8
	Perfluorododecanoic acid (PFDoDA)	307-55-1
	Perfluorotridecanoic acid (PFTrDA)	72629-94-8
	Perfluorotetradecanoic acid (PFTeDA)	376-06-7
Perfluoroalkyl Sulfonamides	Perfluorooctane sulphonamide (FOSA)	754-94-6
	N-Methyl perfluorooctane sulfonamide (MeFOSA)	31506-32-8
	N-Ethyl perfluorooctane sulfonamide (EtFOSA)	4151-50-2
	N-Methyl perfluorooctane sulfonamidoethanol (MeFOSE)	2448-09-7
	N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	1691-99-2
	N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	2355-31-9
	N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	2991-50-6
(n:2) Fluorotelomer Sulfonic Acids	4:2 Fluorotelomer sulfonic acid (4:2 FTS)	757124-72-4
	6:2 Fluorotelomer sulfonic acid (6:2 FTS)	27619-97-2
	8:2 Fluorotelomer sulfonic acid (8:2 FTS)	39108-34-4
	10:2 Fluorotelomer sulfonic acid (10:2 FTS)	120226-60-0

The current standard laboratory LOR are identified in **Table 8** below.

Table 8 Laboratory Limits of Reporting

Sample Media	Parameter	Technique/Method Reference	LOR*
Groundwater	Super trace PFAS Suite	LC/MS-MS	0.0003 – 0.001 µg/L
Surface water samples	Super trace PFAS Suite	LC/MS-MS	0.0003 – 0.001 µg/L
Soil and sediment	Standard PFAS Suite	LC/MS-MS	0.0002 – 0.001 mg/kg

Notes: LC/MS-MS = Liquid chromatography–mass spectrometry, GC = Gas chromatography
*LOR for NMI

7.10 Waste Management

7.10.1 Soil

Excess soil cuttings generated from soil boring activities will be covered and left in situ while awaiting laboratory analysis results. Where contamination is identified, the soils will be collected and disposed of accordingly. The location of the soils will be recorded in the field notes for the project to enable future identification of these areas.

7.10.2 Waste Water from Well Development

Waste water generated during development of the wells will be diverted to a 205 L waste drum, which will be labelled accordingly with details such as location, date, contact details of the field technician or project manager and number of drums for that location. Drums are expected to be stored at the site and will be managed or disposed of appropriately upon receipt of laboratory results in accordance with the requirements of the Environmental Protection Act, 1994.

7.10.3 Quality Assurance/Quality Control Sampling

As detailed below, quality control samples must be collected to reduce the extent of uncertainty in the data and to comply in full with the NEPM (NEPC 2013) and the relevant Australian Standards. The types of quality control samples to be collected are listed in **Table 9**.

Table 9 Quality Control Sample Definitions

Quality Sample	Description
Duplicate	Used to document the precision of the sampling process. Independent samples which are sampled as close as possible to the primary sample in space and time. They are separate samples taken from the same source and stored in separate containers and analysed independently. Duplicate samples will be collected at a rate of one per 10 primary samples.
Triplicate	Used to document inter-laboratory precision. Independent samples which are sampled as close as possible to the primary sample in space and time. They are separate samples taken from the same source and stored in separate containers and analysed at the secondary laboratory. Triplicate samples will be collected at a rate of one per 10 primary samples.
Rinsate blank	Used to assess the adequacy of the decontamination of the sampling equipment. A sample of analyte free water will be poured over the decontaminated equipment (e.g. augers, interface probe) prior to the collection of the next sample. The sample will be analysed for the same suite as the primary samples and collected at a rate of one per sampling day.

7.10.4 Reporting QC Data

To provide defensible laboratory data, AECOM considers that QA/QC sampling; analysis and reporting should be rigorous and comprehensive.

Analytical data validation is the process of assessing whether data are in compliance with method requirements and project specifications. The primary objectives of this process are to ensure that data of known quality is reported, and to identify if the data can be used to fulfil the overall project objectives.

The data validation guidelines adopted is based upon data validation guidance documents published by the United States Environmental Protection Agency (US EPA). These include the US EPA Contract Laboratory Program for Organic Data Review, October 1999; US EPA Contract Laboratory Program for Inorganic Data Review, July 2002; and the US EPA Guidance on Environmental Data Verification and Data Validation, November 2002. The process involves the checking of analytical procedure compliance and an assessment of the accuracy and precision of analytical data from a range of quality control measurements, generated from both the field sampling and analytical programs.

The report will include summary tables which assess:

- Holding time compliance tables;
- Field QC sample results;
- Duplicate relative percentage difference compliance tables; and
- Laboratory QC compliance tables.

In addition, the data would be reviewed as part of the ESdat database system for conformity with QA/QC principles and methodologies. Any inconsistencies or inadequacies would be presented within PSI report findings.

7.11 Fieldwork Documentation

7.11.1 Field Notes

Field notes shall be maintained to record all field sampling events and include observations made at each sample location. Field notes should include information specific to the sample media as follows:

7.11.1.1 Field Records – Soil and Sediment Sampling

At each sampling point the field records will include, as a minimum, the following information:

- The sampling time, date and the name of the sampler.
- A description of the sampling rig, company and names of drillers/drivers, if applicable.
- Weather conditions.
- The geo-coordinates for each sample location and location of quality control (e.g. duplicate and triplicate) sample collection points (where needed).
- A description of the sampling locations.
- Observations of contamination or the absence of contamination.
- Evidence of visual or odorous contamination.
- A description of the soil and geological profile in accordance with the USCS protocol. Records of field observations must be recorded and maintained to support subsequent interpretation and conceptualisation of site conditions.
- The potential for an off-site source of the contamination based on the surrounding land-use and immediate area topography, drainage features etc.
- The sample collection method and the equipment decontamination method.

7.11.1.2 Field Records – Surface Water Sampling

At each sampling location for groundwater the field records will include the minimum of the following information:

- Sampling time, date and the name of the sampler.
- Weather conditions.
- Sample collection method.
- Presence of light non-aqueous phase liquid.
- Field screening (turbidity, colour, odour etc.).
- The geo-coordinates for each sample location and location of quality control (e.g. duplicate and triplicate) sample collection points (where needed).
- Water quality meter calibration records and parameters.
- Sample equipment decontamination procedures where non-disposable sampling equipment is utilised.

7.11.1.3 Field Records – Groundwater Sampling

At each sampling location for groundwater the field records will include the minimum of the following information:

- Sampling time, date and the name of the sampler;
- Weather conditions;
- Sample collection method;
- Presence of light non-aqueous phase liquid;

- Field screening (turbidity, colour, odour etc.);
- The geo-coordinates for each sample location and location of quality control (e.g. duplicate and triplicate) sample collection points (where needed);
- Purging records including water quality meter calibration records;
- Sample equipment decontamination procedures where non-disposable sampling equipment is utilised.

7.11.2 Sample Labels

Sample containers will be labelled, as a minimum, with the following information:

- AECOM project number;
- Name of sampler;
- Sample ID;
- Date of sample collection;
- Filtered vs non-filtered (for water samples only).

A ball point pen shall be used for labelling, to ensure that the lettering is not erased during transit to the laboratory.

7.11.3 Chain of Custody Forms

A chain of custody form shall be completed, documenting the sample identification number and analytes. The chain of custody documents the chain of events from sample collection to delivery at the laboratory and provides a traceable account of sample handling. The chain of custody form shall be signed by both the sample collector and the receiving laboratory.

The chain of custody form shall include the following information:

- Job number (Note: Name of site is not listed for confidentiality of project);
- Date of sample collection;
- Sample ID;
- Type of containers;
- Name of sampler;
- Laboratory to be used;
- Analyses required;
- Any comments;
- Signatures of the sampler and laboratory receiver.

Upon receipt of the original documents accompanying the samples at the laboratory, the laboratory shall provide a sample receipt document (noting temperature of samples upon receipt, analyses required and any non-conformances) and return the signed chain of custody form to confirm analyses to be performed.

7.11.3.1 Sampling Documentation

Field sampling sheets will be completed for each location and will include the following information (as appropriate for the media being sampled):

- Name of sampler;
- Sample location;
- Date /time of monitoring/ sampling;
- Sampling method; and

- Observations of the sampled media.

7.11.4 Calibration Records

Records of all equipment calibration shall be included in the PSI report.

7.11.5 Laboratory Reports

Laboratory reports should be issued in accordance with the requirements of NATA endorsement and will include the following information appended within the baseline report:

- The sample receipt notifications (detailing samples have been received in adequate condition and within the maximum hold times).
- The test results for the samples.
- The test results for the laboratory's in-house duplicates.
- The test results for the laboratory's in-house surrogate and matrix spike recovery determination.
- The extraction (where applicable) and analysis dates which would be used to determine compliance with the permitted holding times.

8.0 References

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Golder Associates Pty Ltd (2018b), Draft Detailed Site Investigation Sampling Analysis Quality Plan.

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Standards Australia, 1998a. *Water quality – Sampling. Part 11: Guidance on sampling of groundwaters. Australian Standards*, AS5667.11, 5 April 1998.

US EPA (2006) *Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4* (EPA 240/B-06/001).

Appendix A

Figures (adapted from Golder, 2018b)



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DATUM GDA 1994, PROJECTION MGA ZONE 56

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metres

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LEGEND

Mineral Exploration Permit

Mining Lease

Data sources:
Golder, 2013b – DSI SAQP provided by RTAW.
Qspatial: Mining Lease spatial layers

Weipa

REGIONAL LOCALITY MAP AND MINING LEASE AREAS

PROJECT ID	60588844
CREATED BY	JB
LAST MODIFIED	JB - 01 Nov 2018
VERSION:	1

Figure 1

Filename: T:\JRB\Tasks\Carina J - Weipa\Weipa_F3_MiningLease_20181031.mxd

A3 size



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LEGEND
Study Area
Receiving Environment Study Area

Data sources:
Golder, 2013b – DSI SAQP provided by RTAW.

Weipa

LOCAL FEATURES AND PRIMARY SOURCE AREAS

PROJECT ID	60588844
CREATED BY	JB
LAST MODIFIED	JB - 01 Nov 2018
VERSION:	1

Figure 2

Filename: T:\JRB\Tasks\Carina J - Weipa\Weipa_F2_LocalityFeatures_20181031.mxd

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LEGEND

Catchment:

- Embley River
- Mission River
- Wenlock River
- Pine River

Data sources:
Golder, 2013b – DSI SAQP provided by RTAW.

Weipa

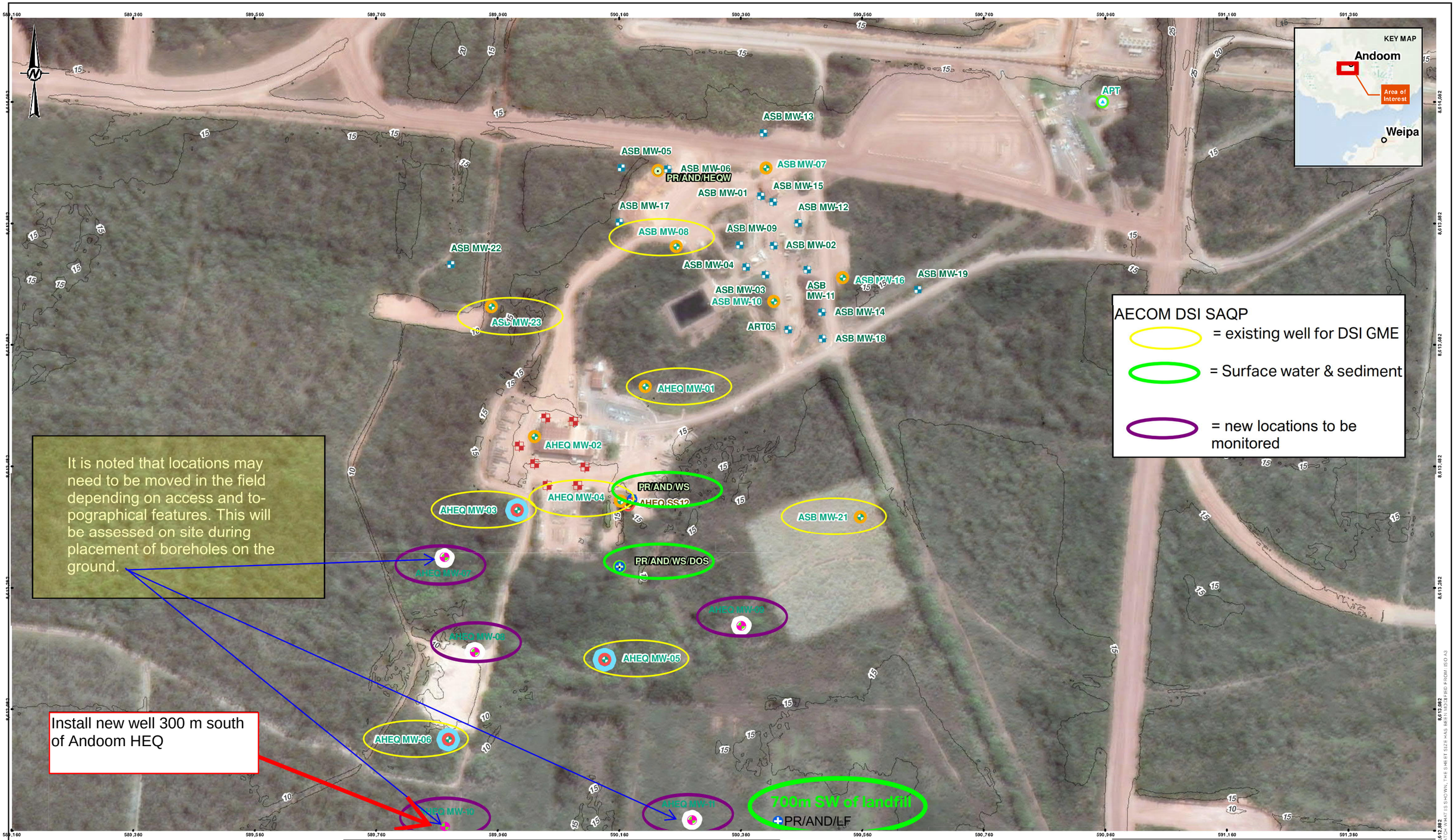
CATCHMENT BOUNDARIES

PROJECT ID	60588844
CREATED BY	JB
LAST MODIFIED	JB - 01 Nov 2018
VERSION:	1

Figure 3

Filename: T:\JRB\Tasks\Carina J - Weipa\Weipa_CatchmentMap_20181031.mxd

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LEGEND

Location Type (Existing)

- Accumulation Points (TWD)
- Groundwater Monitoring Well (BH101)
- Potable Water Bore (SA017)
- Soil Leachate Samples (SS012, TP012)
- Surface Water (PR/AND/WS)

Regional Wells *(Not Sampled)*

- Monitoring
- Potable
- Non-Potable Processing

AECOM Proposed **DSI Test Locations**

- New Monitoring Well
- Existing Monitoring Well
- Surface Water
- Shallow soil sample
- 5 metre contour

Screening Criteria	Halo Colour
Concentration > 2 orders of magnitude above 99% Species Protection	
Concentration > 99% Species Protection	
Concentration < LOR	

Guideline Value	PFOS µg/L
Aquatic Ecosystem – Freshwater - 99% species protection *(NEMP 2018)*	0.00023

Confidential and Privileged

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

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1:6,000 @ A3 METRES

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CONSULTANT: AECOM www.aecom.com

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REVIEWED	EC
APPROVED	GW

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Contour Data recieved form client June 2018

PROJECT: Weipa

TITLE: **APPROXIMATE POSITION OF PROPOSED DETAILED SITE INVESTIGATION (DSI) LOCATIONS**

Andoom Focus Area

PROJECT NO.	CONTROL	REV.	FIGURE
60588844		A	4A

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AECOM DSI SAQP

= existing well for DSI GME

= Surface water & sediment
3 new, 3 existing

= new locations to be monitored

KEY MAP

Weipa

Area of Interest

ELN MW-30
ELN MW-01
ELN MW-10
ELN MW-04
ELN MW-02
ELN MW-09
ELS MW-29
ELN MW-03
ELN MW-06
ELN MW-05
ELN MW-07
ELS MW-18
ELS MW-28
ELN MW-08
ELL MW-29
ELL MW-32
ELS MW-02
ELS MW-27
ELS MW-20
ELS MW-21
ELS MW-02a
ELS MW-17
ELS RW-04
ELS MW-31
ELS MW-03a
ELS RW-01
ELS MW-26
ELS RW-03
ELS MW-19
ELL MW-28
EMB/EV/NSA
ELS MW-25
ELS MW-23
ELS MW-22
ELS MW-24
EMB/EV/NSB
EMB/EV/OSA
EMB/EV/OSB
EMB/EV/NSC
EMB/EV/OSC

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8,600,224 8,600,124 8,600,024 8,599,924 8,599,724

LEGEND

Location Type

- Accumulation Points (TWD)
- Groundwater Monitoring Well (BH101)
- Potable Water Bore (SA017)
- Soil Leachate Samples (SS012, TP012)
- Surface Water (EMB/EV/NSA)

Regional Wells *(Not Sampled)*

- Monitoring
- Potable
- Non-Potable Processing

DSI Test Locations

- New Monitoring Well
- Existing Monitoring Well
- Surface water
- Shallow Soil Sample
- 5 metre contour

Screening Criteria	Halo Colour
Concentration > 2 orders of magnitude above 99% Species Protection	
Concentration > 99% Species Protection	
Concentration < LOR	

Guideline Value	PFOS µg/L
Aquatic Ecosystem – Freshwater - 99% species protection *(NEMP 2018)*	0.00023

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Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

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PREPARED	DC
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APPROVED	GW

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PROJECT
Weipa

TITLE
APPROXIMATE POSITION OF PROPOSED DETAILED SITE INVESTIGATION (DSI) LOCATIONS

Evans Landing Focus Area

PROJECT NO.	CONTROL	REV.	FIGURE
60588844		A	4B

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AECOM DSI SAQP

= existing well for DSI GME

= Surface water & sediment
3 new, 3 existing

= new locations to be monitored

KEY MAP

Weipa

Area of Interest

ELN MW-30
ELN MW-01
ELN MW-10
ELN MW-04
ELN MW-02
ELN MW-09
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EMB/EV/NSB
EMB/EV/OSA
EMB/EV/OSB
EMB/EV/NSC
EMB/EV/OSC

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8,600,224 8,600,124 8,600,024 8,599,924 8,599,724

LEGEND

Location Type

- Accumulation Points (TWD)
- Groundwater Monitoring Well (BH101)
- Potable Water Bore (SA017)
- Soil Leachate Samples (SS012, TP012)
- Surface Water (EMB/EV/NSA)

Regional Wells *(Not Sampled)*

- Monitoring
- Potable
- Non-Potable Processing

DSI Test Locations

- New Monitoring Well
- Existing Monitoring Well
- Surface water
- Shallow Soil Sample
- 5 metre contour

Screening Criteria	Halo Colour
Concentration > 2 orders of magnitude above 99% Species Protection	
Concentration > 99% Species Protection	
Concentration < LOR	

Guideline Value	PFOS µg/L
Aquatic Ecosystem – Freshwater - 99% species protection *(NEMP 2018)*	0.00023

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Projection: Transverse Mercator
Datum: GDA 1994

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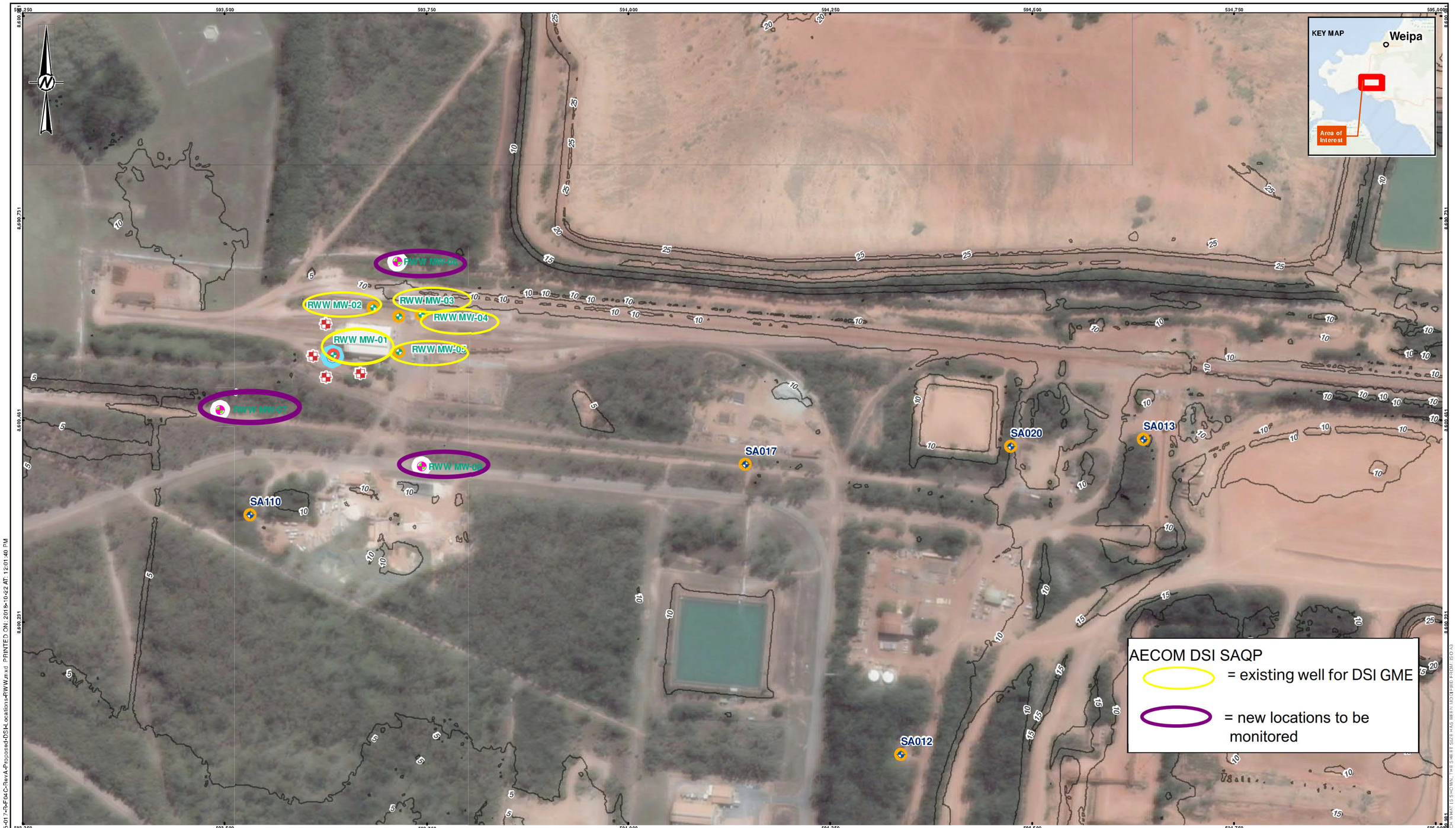
APPROXIMATE POSITION OF PROPOSED DETAILED SITE INVESTIGATION (DSI) LOCATIONS

Evans Landing Focus Area

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LEGEND

Location Type

- Accumulation Points (TWD)
- Groundwater Monitoring Well (BH101)
- Potable Water Bore (SA017)
- Soil Leachate Samples (SS012, TP012)

Regional Wells ***(Not Sampled)***

- Monitoring
- Potable
- Non-Potable Processing

DSI Test Locations

- New Monitoring Well
- Existing Monitoring Well
- Shallow Soil Sample
- 5 metre contour

Screening Criteria	Halo Colour
Concentration > 2 orders of magnitude above 99% Species Protection	
Concentration > 99% Species Protection	
Concentration < LOR	

Guideline Value	PFOS µg/L
Aquatic Ecosystem – Freshwater - 99% species protection *(NEMP 2018)*	0.00023

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Datum: GDA 1994

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PROJECT: Weipa

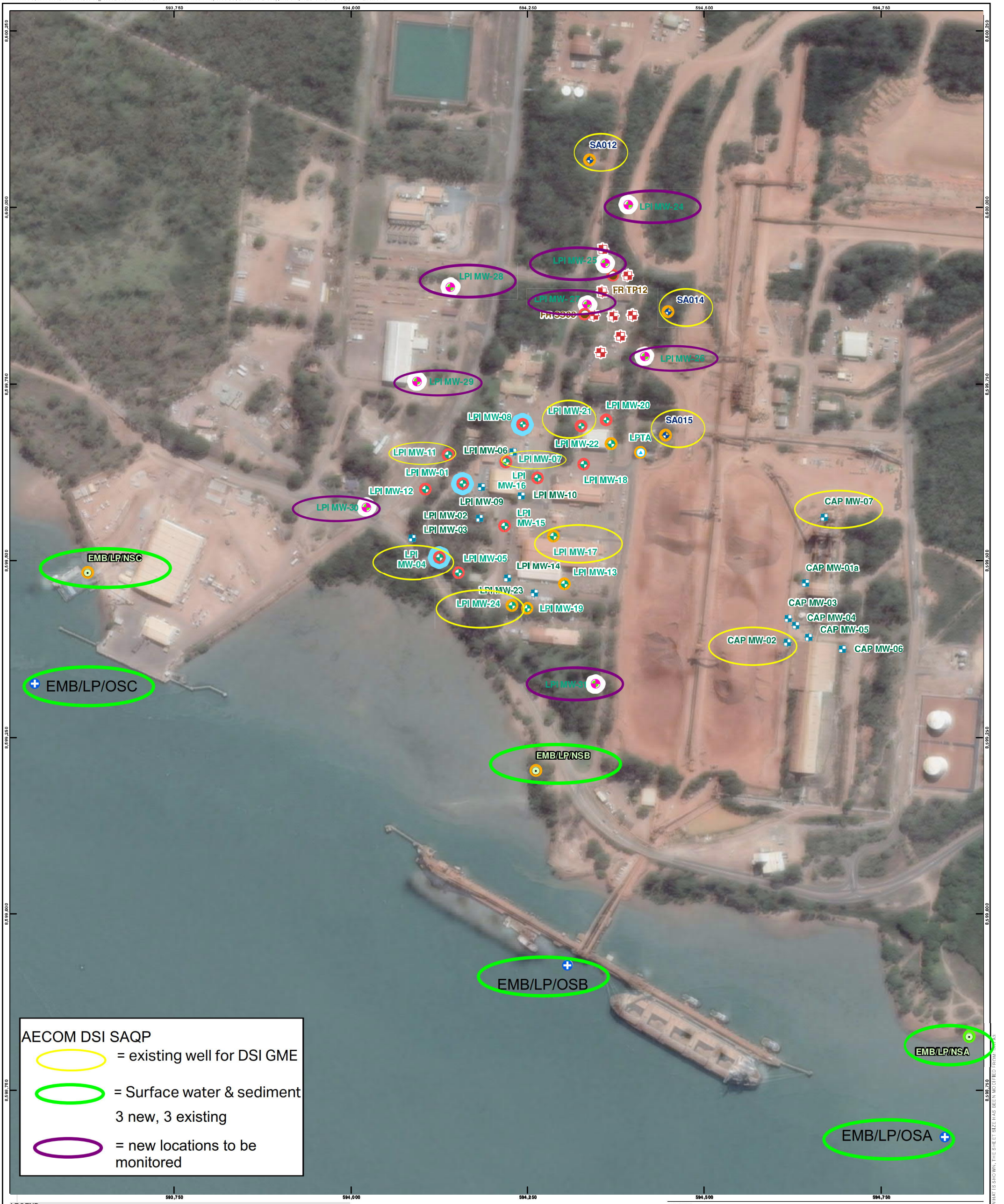
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Railway Workshop Focus Area

PROJECT NO.	CONTROL	REV.	FIGURE
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LEGEND

Location Type

- Accumulation Points (TWD)
- Groundwater Monitoring Well (BH101)
- Potable Water Bore (SA017)
- Soil Leachate Samples (SS012, TP012)
- Surface Water (PR AND WS)

Regional Wells *(Not Sampled)*

- Monitoring
- Potable
- Non-Potable Processing

DSI Test Locations

- New Monitoring Well
- Existing Monitoring Well
- Surface water
- Shallow Soil Sample
- 5 metre contour

Confidential and Privileged

Coordinate System:
GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

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PROJECT
Weipa

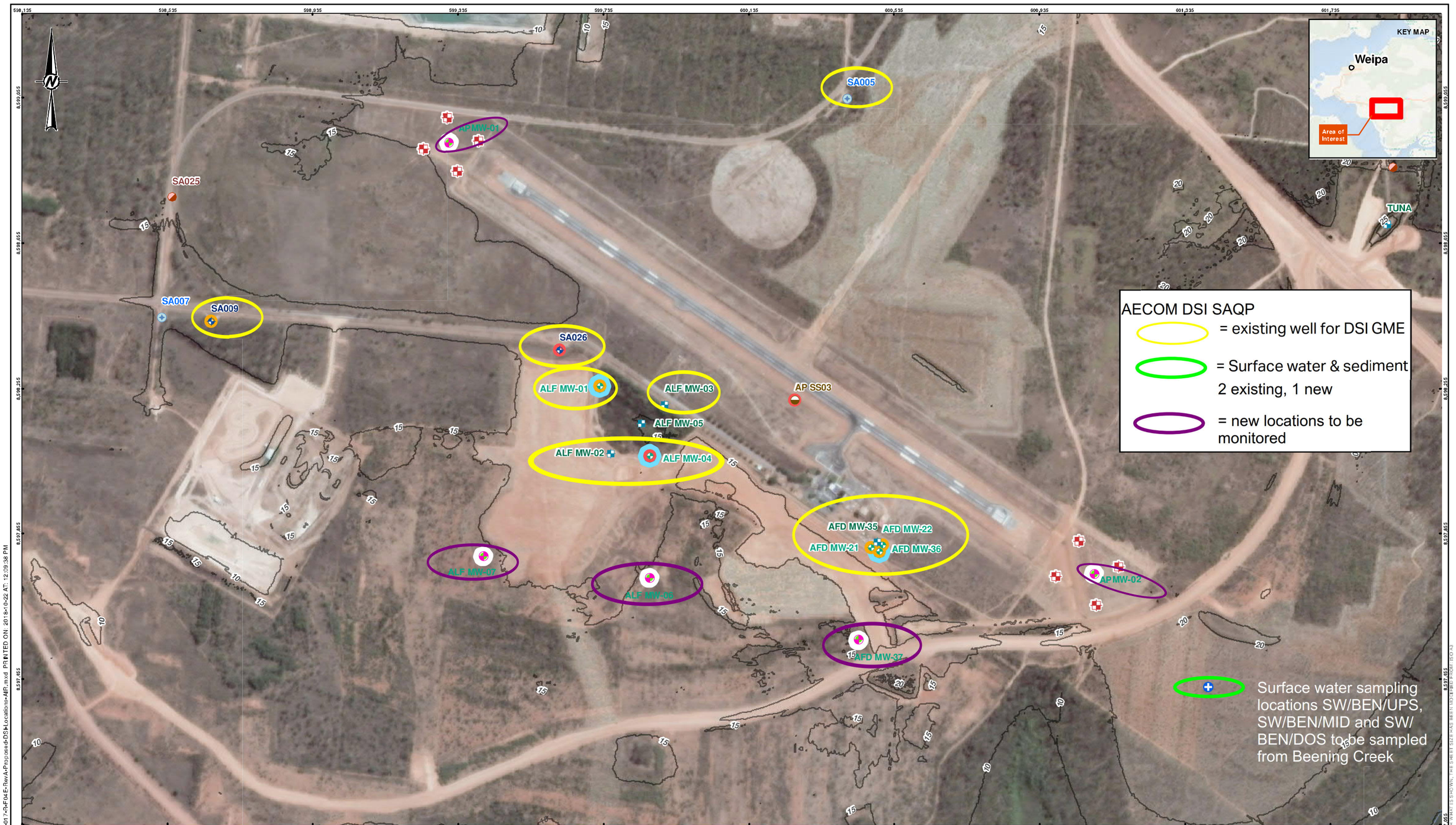
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Lorim Point Jetty Focus Area

CONSULTANT

YYYY-MM-DD	2018-10-22
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PROJECT NO. 60588844 | CONTROL | REV. A | FIGURE 4D

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LEGEND

Location Type

- Accumulation Points (TWD)
- Groundwater Monitoring Well (BH101)
- Potable Water Bore (SA017)
- Soil Leachate Samples (SS012, TP012)
- Surface Water (PRIVATE WB)

Regional Wells *(Not Sampled)*

- Monitoring
- Potable
- Non-Potable Processing

DSI Test Locations

- New Monitoring Well
- Existing Monitoring Well
- Surface water
- Shallow Soil Sample
- 5 metre contour

Screening Criteria	Halo Colour
Concentration > 2 orders of magnitude above 99% Species Protection	
Concentration > 99% Species Protection	
Concentration < LOR	

Guideline Value	PFOS µg/L
Aquatic Ecosystem – Freshwater - 99% species protection *(NEMP 2018)*	0.00023

Confidential and Privileged

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

0 100 200 300 400
1:10,000 @ A3 METRES

CLIENT
RTA Weipa Pty Ltd

CONSULTANT
AECOM
www.aecom.com

YYYY-MM-DD	2018-10-22
DESIGNED	DC
PREPARED	DC
REVIEWED	EC
APPROVED	GW

NOTE(S)
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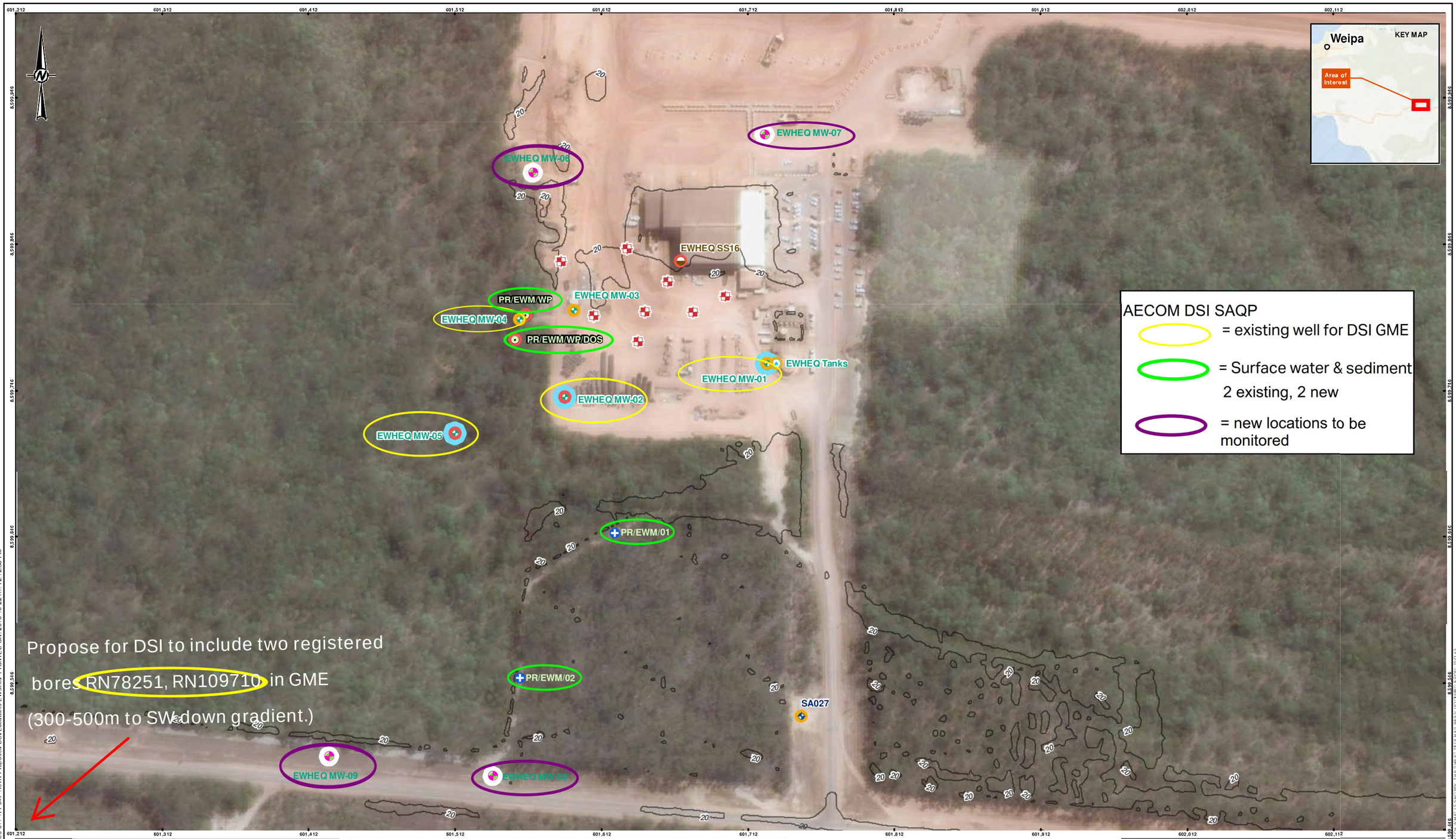
REFERENCE(S)
Gazetter: © State of Queensland (Department of Natural Resources, Mines and Energy) 2018
Watercourse: © Geoscience Australia. Data received from Client 04/10/2017.
Contour Data recieved form client June 2018

PROJECT
Weipa

TITLE
APPROXIMATE POSITION OF PROPOSED DETAILED SITE INVESTIGATION (DSI) LOCATIONS
Airport Focus Area

PROJECT NO.	CONTROL	REV.	FIGURE
60588844		A	4E

PATH: R:\01 Client\181\10235\181002359_PROJECTS\01\7\181002359-017-PrjF04E-RevA-Proposed-DSILocations-AIP.mxd PRINTED ON: 2018-10-22 AT: 12:09:38 PM



LEGEND

Location Type

- Accumulation Points (TWD)
- Groundwater Monitoring Well (BH101)
- Potable Water Bore (SA017)
- Soil Leachate Samples (SS012, TP012)
- Surface Water (WS-SW01/02)

DSI Test Locations

- New Monitoring Well
- Existing Monitoring Well
- Surface water
- Shallow Soil Sample
- 5 metre contour

Screening Criteria	Halo Colour
Concentration > 2 orders of magnitude above 99% Species Protection	
Concentration > 99% Species Protection	
Concentration < LOR	

Guideline Value	PFOS µg/L
Aquatic Ecosystem – Freshwater - 99% species protection *(NEMP 2018)*	0.00023

Confidential and Privileged

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

0 20 40 60 80 100
1:2,500 @ A3 METRES

CLIENT: RTA Weipa Pty Ltd

CONSULTANT: AECOM www.aecom.com

YYYY-MM-DD	2018-10-22
DESIGNED	DC
PREPARED	DC
REVIEWED	EC
APPROVED	GW

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REFERENCE(S)

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Contour Data recieved form client June 2018

PROJECT: Weipa

TITLE: **APPROXIMATE POSITION OF PROPOSED DETAILED SITE INVESTIGATION (DSI) LOCATIONS**
East Weipa Heavy Equipment Workshop Focus Area

PROJECT NO.	CONTROL	REV.	FIGURE
60588844		A	4F

PATH: R:\01 Cli\en\181002351810023599_PROJECTS\01718100235\01-7-Fb-F04-F-NavA-Proposed-DSH_locations-EW.mxd PRINTED ON: 2018-10-22 AT: 12:12:56 PM
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN INCORRECTLY REPRODUCED
25mm
0

PATH: R:\01 Client\18100235\18100235\99_PROJECTS\017\18100235-017-R-F005-RevA-Sample-Locations-Potable-Water-Supply.mxd PRINTED ON: 2018-10-17 AT: 1:37:30 PM

590,000 592,500 595,000 597,500 600,000 602,500

8,612,500 8,610,000 8,607,500 8,605,000 8,602,500 8,600,000

Andoom

Andoom Potable Tank (APT)

ASA093

ASA091

ASA092

KEY MAP

Area of Interest

Weipa

Mission River

Town Water Dam (TWD)

Weipa

SA038

SA041

SA350

SA039

SA037

SA036

SA351

AECOM DSI SAQP

= existing well for DSI GME

SA349

SA107

SA017

SA020

SA013

Evans Landing

SA110

SA012

SA014

Lorim Point

SA015

Lorim Point Tanks (LPTA)

SA027

SA009

SA026

Napranum

590,000 592,500 595,000 597,500 600,000 602,500

LEGEND

- Potable Water Bore
- Accumulation Point

Confidential and Privileged

0 500 1,000 1,500 2,000 2,500

Scale: 1:50,000 @ A3 METRES

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

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Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Basemap: Pan-sharpened Landsat 8 OLI Image Service, 31/07/2017

CLIENT
RTA Weipa Pty Ltd

PROJECT
Weipa

TITLE
POTABLE WATER SUPPLY AND ACCUMULATION POINTS

CONSULTANT
AECOM
www.aecom.com

YYYY-MM-DD	2018-10-17
DESIGNED	DC
PREPARED	DC
REVIEWED	EC
APPROVED	EC

PROJECT NO. 60588844 | CONTROL | REV. A | FIGURE 5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ISO A0
0 25mm

Appendix B

Sampling & Analysis Summary

Sampling and Analysis Schedule for RTAW DSI SAQP

	Water				Water Analysis			QA/QC			Soils			Soil/Sediment Analysis			Other		
					PFAS standard suite analysis Supertrace Analysis			PFAS standard suite analysis						PFAS standard suite analysis				Supertrace analysis	
	New wells	Existing monitoring wells	Potable/ regional wells	Surface water	Primary (inlcudes 2 rounds of potable wells)	QAQC Duplicate	QAQC Triplicate	Rinsates	Field blank	Trip blank	Shallow Soil Locations (1/location)	Borehole Soils (2/hole)	Sediment	Primary	QAQC Duplicate	QAQC Triplicate	TOPA on highest concentrations from initial screening	ASLP and PFAS Ex	Waste classification TCLP with TOPA
						10%	10%								10%	10%	Soil/water		
AHEQ/ASB	5	8	1	3	18	2	2	1	1	1	7	10	3	20	2	2	1/1	1	1
EVL	4	10	0	12	26	3	3	1	1	1	8	8	3	19	2	2	1/1	1	1
RWW	3	5	0	0	8	1	1	1	1	1	4	6	0	10	2	2	1/1	1	1
LP	8	8	3	12	34	4	4	1	1	1	8	16	3	27	3	3	1/1	1	1
WAP	5	8	3	3	22	3	3	1	1	1	8	10	3	21	2	2	1/1	1	1
EWHEQ	4	6	0	4	14	2	2	1	1	1	8	8	4	20	2	2	1/1	1	1

Appendix C

Standard Operating Procedures and Documentation

Groundwater Monitoring and Sampling with Low Flow Pump

1.0 Purpose and Scope

This procedure provides guidance on the use of collection of low flow groundwater sampling methods to collect representative groundwater samples. The low flow sampling technique is designed to minimise the hydraulic stress on the aquifer during purging and sampling.

Low flow groundwater sampling entails the use of an adjustable rate pump to purge then sample groundwater specifically in the screened interval of a well to minimise the drawdown of the water level in the well. Samples are collected after parameters stabilise, indicating groundwater purging is complete and sampling will be representative of the aquifer intersected by the well.

Typically less purge water is required than in volume-based purge methods, thereby generating less waste to be physically managed and disposed of.

If performed carefully, sample turbidity is reduced, and the potential for mixing of water and volatilisation ('degassing') of dissolved chemicals is also reduced compared to more turbulent methods.

Limitations include requirements for specific training and use of powered equipment requiring additional set-up and with additional scope for failure.

Other sampling methods may be preferred for very low recharge wells, and for collection of non-aqueous liquids (e.g. to visually assess product thickness).

The following procedures are standard and typically may be varied depending on site conditions, equipment, client preferences, and/or other limitations. The actual procedure employed at each well should be documented in the field and reported.

2.0 Health and Safety

2.1 Health and Safety Plan and Site Specific Safe Work Method Statements (SWMS) should be prepared prior to field work in accordance with the SWMS Development Procedure and in the Project Specific Health and Safety Plan Template.

2.2 Any subsurface excavation requires a Dial before You Dig search and surveyed by a licensed utilities surveyor and the Underground Utilities Checklist Form must be followed.

3.0 References

3.1 SWMS Development Procedure S4AN-701-PR1

3.2 Project Specific Health and Safety Plan Template S4AN-702-TP1

3.3 Water Quality Meter Calibration Form Q4AN(EV)-336-FM23

3.4 Safe Work Method Statement – Accessed via the SWMS tool on myAECOM.

3.5 ASTM (2002). Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations, ASTM D 6771-02.

3.6 Puls, R.W. and Barcelona, M. J. (1996). Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures. United States Environmental Protection Agency Ground Water Issue. EPA/540/S-95/504.

4.0 Equipment

Equipment required for low flow groundwater sampling:

- peristaltic or bladder sampling pump
- silicone tubing – 1 roll
- air tubing (¼ inch LDPE)
- interface probe
- water quality meter and calibration fluids
- flow cell or unpreserved 0.5 L plastic bottle
- measuring cups - for measuring flow rates
- hand pump – for metals samples
- buckets (about 5, some with lids)
- tape measure
- tubing cutter
- field records sheets including sample records sheets, well gauging sheet, QA/QC sample register available on myAECOM.
- sample bottles and supplies including coolers, ice, chain of custody forms, trip blank/trip spike
- Personal Protective Equipment (PPE) including nitrile gloves, safety glasses, safety boots, high visibility vest, hat or hard hat (as required by site management), respirator and ABEK1filter (new)
- approved site specific HASP including SWMS
- sampling, analysis and quality plan (SAQP)
- site plan showing wells and well construction details
- tools – including 8 mm Allen key, hammer, screwdrivers (2 x)
- DECON 90
- traffic cones
- permanent markers, mechanical pencils
- garbage bags
- paper towels

5.0 Procedure

5.1 Preparation

5.1.1 Pack all the equipment needed.

5.1.2 Confirm that the pump selected is appropriate for use with low-flow sampling techniques, the expected sample depths (reference well construction logs) and the analytes to be analysed. Suitable pumps for low-flow sampling are currently:

- o peristaltic pumps (adjustable rate): Peristaltic pumps are typically suitable to a maximum depth of approximately 7-8 metres. Potential for volatilisation should be minimised through use of low purge rates, and noting and eliminating any bubble production in the discharge tubing, e.g. through smooth tubing cuts. Peristaltic pumps create a vacuum on the sampling line, which may cause loss of volatile organic compounds (VOCs).
- o bladder pumps (adjustable rate). These are a technically preferred option but entail more complicated operation (hence more training), and longer set-up and take-down times, hence slower sampling. Bladder pumps may be used at depths greater than 7-8 metres, and for high volatility target analytes. Bailers are not suitable for low-flow sampling.

5.2 Setting Up at a Monitoring Well

5.2.1 Calibrate water quality meter probe using calibration solutions.

5.2.2 Review SAQP and locate well to be sampled.

5.2.3 Prepare new sample record sheets.

5.2.4 Decontaminate dip-meter/interface probe and all other equipment which will be placed down monitoring well.

5.2.5 Open well cover and install dip-meter/interface probe in well.

5.2.6 Measure standing water level (SWL) below the top of casing (TOC).

5.2.7 Measure total depth (TD) to base of well.

5.2.8 Measure the well inner diameter (ID).

5.2.9 Measure and cut new LDPE down-well tubing to position pump intake within screen interval. Record the depth of the pump intake on the sample record sheet. Mark a point on the down-well tubing at the well casing so that the position of the pump intake can be checked during sampling.

The down-well tubing may be positioned according to site specific requirements, including:

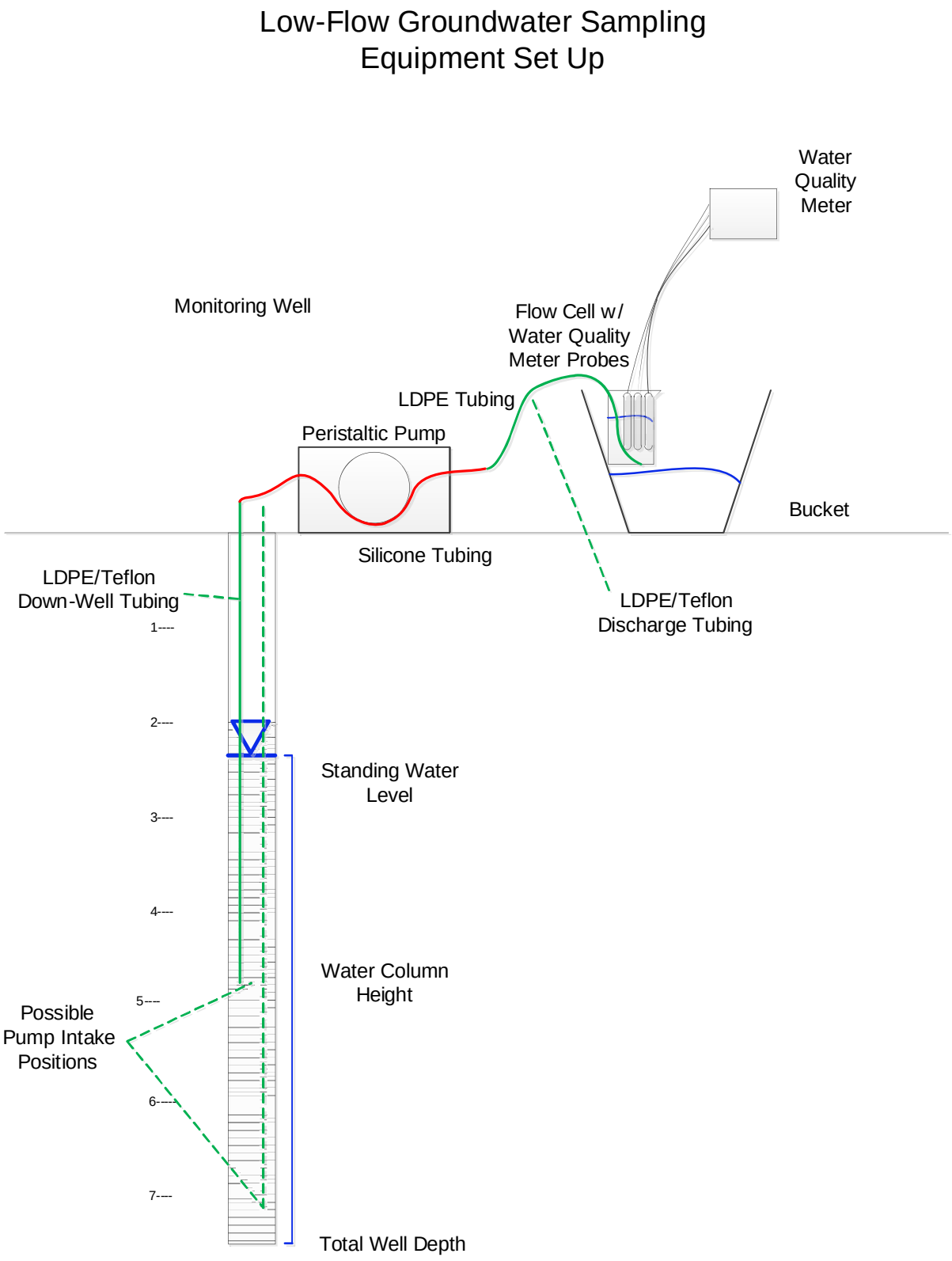
- o at the midpoint of the screen interval;
- o towards the base of the screened interval (e.g. 0.3 metres above the base of the well for DNAPL); or
- o at another point to be determined by the PM.

5.2.10 Fit new flexible silicone tubing to peristaltic pump head (less than 20 cm length);

5.2.11 Cut another length of new LDPE tubing (approximately 40 cm in length) to run from pump discharge to flow-cell.

5.2.12 Connect pump to power source.

- Equipment Schematic for low flow purging using a peristaltic pump.



5.3 Purging

5.3.1 Start the pump at its lowest speed setting and slowly increase the speed until water begins flowing into the bucket. A purge rate of 100 - 500 mL per minute is typically used for low flow sampling (use the maximum rate around this range at which drawdown is minimised or zero).

5.3.2 Fill the flow cell / container from the base allowing overflow from the top into a larger bucket. Position tubing outlet at base of flow cell/container so that newly purged water flows first past probe tips, and is not in direct contact with atmosphere.

5.3.3 Measure the flow rate from the pump – at low flow rates the flow rate can be measured with a stopwatch and graduated container (small bucket, measuring jug, cooking cups or similar) measuring the time required to fill a certain volume.

5.3.4 Take parameter readings (pH, temperature, conductivity, oxidation-reduction potential (ORP), dissolved oxygen (DO) and turbidity) at frequent intervals.

Measure SWLs frequently with the dip meter.

Monitor and record:

- well drawdown (via SWLs);
- any recharge (via SWLs);
- water quality parameters;
- turbidity, odour, sheen; and
- flow rates.

Slow the pump rate if significant drawdown or turbidity is observed.

Drawdown should generally not exceed 25 % of the distance between the top of the well screen and the pump intake (so that water in the casing pre-purging is not drawn down to the pump intake and sampled).

Copies of Groundwater Sampling and Well Gauging Record Sheets are included in Attachment 1.

5.4 Sampling

5.4.1 When to Sample after purging

Typically sampling may occur if

- 3 consecutive readings stabilise – i.e. readings within ± 10% or within the ranges specified below (ASTM, 2002):

Table 1 ASTM Parameter Stabilisation Criteria

Parameter	Stabilisation Criteria
pH	± 0.2 pH units
Conductivity	± 3 % of reading
DO	± 10 % of reading or ± 0.2 mg/L whichever is greater
ORP	± 20 mV

- Recharge or laminar flow is noted (minimal or zero drawdown).
- Parameters peak, then fluctuate around a reading.
- Often it is appropriate to sample after purging approximately one well volume if the above conditions are met.

5.4.2 Sampling Technique

- Record the final set of purge water quality parameters.
- Prepare and label all sample vials and bottles.

- Put on a fresh pair of nitrile gloves.
- Remove the free end of the discharge tubing from the flow cell apparatus. Confirm that discharge is steady and laminar.
- Place the end of the discharge tubing at the mouth of the sample vials and bottles and carefully decant groundwater into each sample bottle, directing the stream down the side of the glass. Begin sampling by filling VOC vials first, followed by other analyte bottles.
    a) Immediately cap each bottle tightly after filling.
    b) Ensure no headspace remains in volatile VOC vials by inverting and examining for bubbles. If bubbles are present in a VOC vial, discard vial (due to potential volatilisation and/or loss of preservation) and replace with a new vial.
- Immediately place samples in a cooler with cooling media (ice, or freezer blocks).
- Remove the pump and tubing after collecting samples. Discard disposable tubing appropriately.
- Close and lock well.

5.4.3 Extremely Low recharge Conditions

Extremely low recharge conditions exist if any of the following occur:

- drawdown exceeds 25 % of the distance between the top of the well screen and the pump intake; or
- failure of parameters to stabilise within a reasonable period (e.g. less than one hour).

Should extremely low recharge conditions be encountered, consult with the PM to determine a course of action. For example:

- immediately collect a ‘pre-purge grab sample’ (recorded as such on the sample record sheet);
- sample using another purge method;
- purge one well volume slowly (stopping and starting the pump if needed) under minimal disturbance (laminar flow) conditions, then collect the sample. This is a slower and less efficient method, but may be appropriate for some sample programmes; or
- purge well dry then relocate, returning to collect an immediate sample at a later time. Allow sufficient time for well to recharge and stabilise. Purging dry may temporarily result in high dissolved oxygen or other chemical changes that may not represent in-situ conditions, and should be avoided if practicable.

ATTACHMENT 1 - Wetted Volume Calculation

wetted well volume (m^3) = $\pi r^2 h$

For a 50 mm well, 7.49 m deep with standing water level 2.35m BTOC:

TD = 7.49 m

SWL = 2.35 m

R = 0.025 m

wetted well volume ≈3.14 x (0.025)2 x (7.49 – 2.349)

= 3.14 x 0.000625 x 5.14

= 0.01089 m^3

= 10.9 L (round up to 11 L)

Manual Tasks Procedure

1.0 Purpose and Scope

1.1 The purpose of this procedure is to ensure that manual tasks are eliminated or minimised so far as is reasonably practicable. If the manual task is required then it should be conducted in a manner that prevents injury or adverse health effects to employees and subcontractors.

1.2 This procedure is applicable for all Australia New Zealand (ANZ) employees and subcontractors, and covers the requirements associated with the identification, assessment and control of risks arising from manual tasks.

2.0 Terms and Definitions

2.1 Hazardous Manual Task - Any task in which forces are exerted, loads handled, repetitive movement, awkward postures, sustained postures and equipment and tools that expose workers to vibration.

2.2 Manual Handling - Defined as any activity requiring a person to use force to lift, lower, push, carry, hold or restrain an animate or inanimate object.

2.3 Musculoskeletal Disorders (MSD) - Include a wide range of inflammatory and degenerative conditions affecting the muscles, tendons, ligaments, joints, peripheral nerves, and supporting blood vessels. Examples of disorders arising out of work include carpal tunnel syndrome, vibration white finger, sciatica as well as musculo-ligamentous strains, sprains and tears. Musculoskeletal disorders may result from an acute one off event or exposure over a period of time to physical and psychosocial factors that are present in the work environment or are otherwise encountered in the course of conducting work.

2.4 Whole Body Vibration - Shaking of the body as a whole unit in the vertical plane (up & down), transverse plane (side to side) or the linear plane (back & forth).

2.5 Hand-arm vibration - The oscillation of the hand and arm by the operation of hand-held equipment that has either oscillating parts or unbalanced rotating parts.

2.6 Vibration White Finger - This is a condition in which the smallest arteries that bring blood to the fingers or toes constrict (go into spasm) when exposed to cold and/or working with vibrating machinery. The result is that the fingers become pale, cold and numb. The potential for this type of disorder is increased when working at reduced temperatures.

3.0 References

3.1 Hazard Recognition and Risk Assessment S3AN-700-PR1

4.0 Procedure

4.1 Hazard Identification - Managers will identify and assess all manual tasks of a hazardous nature performed in the work environments using the Hazardous Manual Tasks Checklist S4AN-761-FM1. Where a manual handling risk is assessed as posing a significant risk, specific controls must be implemented to eliminate or minimise the associated risks. The Manager/Supervisor in conjunction with workplace employees shall record manual handling tasks using the hazard identification process.

4.2 Load Weight for Manual Handling Tasks

4.2.1 Figure 1, below, shows 9 lifting zones in relation to the human body with the risk varying from extreme and high to moderate. The illustration assumes that the object can be carried close to the body. Any object which is held away from the body should be considered an extreme risk and the maximum weight reduced accordingly.

4.2.2 Personnel are not to lift objects beyond their physical capacity. Manual handling tasks should be carried out while operating within the moderate risk area as shown below. Higher

risks will be experienced if moving the object into the other zones or moving across multiple zones as outlined in the diagram. If manual handling of an object is required from the high and extreme zones, the weight must be reduced at least by ½ and a ¾ respectively as compared to an acceptable load within the moderate zone.

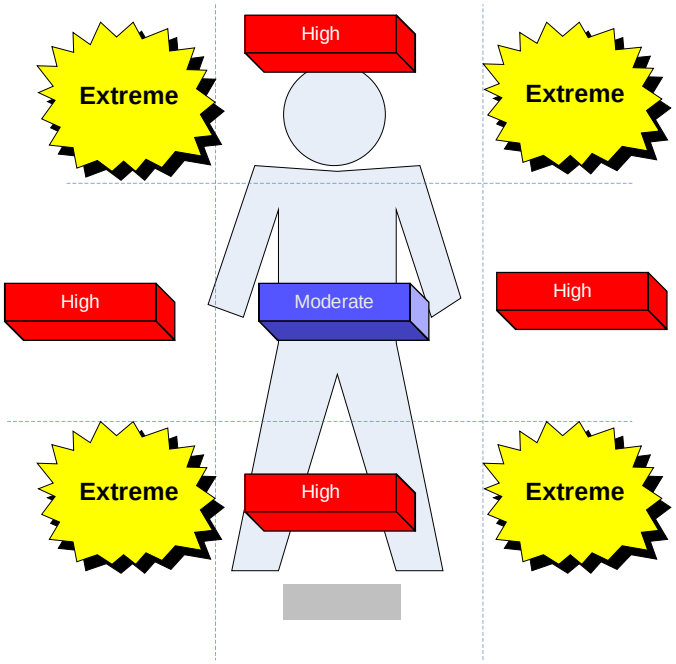


Figure 1 Load Weight

4.3 Heavy Load Marking

Loads which are above 20kg should be marked with “Heavy Load” tag or sticker. Standard loads should have their weight marked in a visible location, wherever possible.

4.4 Vibration – Hand-arm vibration

- Wear suitable vibration dampening gloves where possible or applicable
- Maintain body warmth
- Limit the amount of time (hours per day and days per week) vibrating tools are used.
- Take a 10 minute break for every hour spent working with a vibrating tool
- Alternate work with vibrating and non-vibrating tools.
- Let the tool do the work. Use as light a grip as possible to keep the tool under control. A tight grip restricts blood flow in the hands and fingers and allows more vibration to pass from the tool to the body.
- Maintain tools in accordance with manufacturers’ direction. Tools that are worn, blunt or misaligned vibrate more.
- Limit cigarettes as nicotine reduces the peripheral blood flow.

4.5 Health impacts and monitoring of vibration - Medical examinations shall be conducted where persons are considered for segmental vibration exposures (where the person is expected to encounter exposure of the upper limbs to vibratory motion within the frequencies of 5Hz to 1500 Hz at suspected weighted at or above 2.9 m/s^2.

5.0 Training

5.1 Training will be provided on the correct use of equipment that presents a risk of vibration based on the outcomes of the associated risk assessment.

6.0 Records

6.1 Hazardous Manual Tasks Checklist S4AN-761-FM1

6.2 Associated Medical Examination Results: Maintain for 30 years after date of last entry.

Groundwater Monitoring - Water Level Measurements

1.0 Purpose and Scope

This procedure defines the methods to be used for measuring the depth to groundwater, NAPL thickness and total depth of groundwater monitoring wells to the nearest 0.001m using an electronic water level meter. The depths within wells will be measured from the top of casing (typically the inner casing) at the surveyed elevation measuring point. The measuring point should be clearly marked on the well casing so that water level measurements are consistently taken from the same point.

2.0 Health and Safety

2.1 Health and Safety Plan and Site Specific Safe Work Method Statements (SWMS) should be prepared prior to field work in accordance with the SWMS Development Procedure and in the Project Specific Health and Safety Plan Template.

2.2 Any subsurface excavation requires a Dial before You Dig search and surveyed by a licensed utilities surveyor and the Underground Utilities Checklist Form must be followed.

3.0 References

3.1 SWMS Development Procedure S4AN-701-PR1

3.2 Project Specific Health and Safety Plan Template S4AN-702-TP1

3.3 Site Contamination Analysis Water Level Data Sheet Q4AN(EV)-336-FM9

4.0 Equipment

- Electronic water level meter/interface probe;
- equipment decontamination materials;
- plastic sheeting or bucket for resting instrument off the ground;
- water level data field form;
- well construction records;
- approved plans (e.g., Sampling Analysis and Quality Plan (SAQP), HASP);
- field project logbook/waterproof pen;
- appropriate hand tools and keys to access monitoring wells; and
- personal protective equipment (PPE) including nitrile gloves, safety glasses, safety boots, high visibility vest, hat or hard hat (as required by site management).

5.0 Procedure

5.1 Preparation

- Review well records to determine well construction characteristics, including the location of the measuring point and the total depth of the well. Historic static water level measurements and survey information may also be reviewed.
- Identify the necessary procedures and equipment to access the wellhead prior to entering the site.
- Check that the appropriate equipment is used based on well construction details (e.g., well diameter, anticipated depth to water, anticipated presence of NAPL, total well depth, etc.). The specific equipment to be used should be inspected before use. Equipment should be checked to

ensure it is in proper working order and the measurement increment marks are legible. The type of power supply (e.g., type of batteries) should be determined so that an appropriate back-up supply can be obtained prior to mobilisation.

- Calibrate water level meter following manufacturer's instructions, if any.
- Decontaminate all equipment placed in the monitoring well prior to and after use, and between well locations in accordance with project-specific requirements.

  For some projects, there may be a specific order in which measurements are to be collected. For example, best practise is to make measurements from the least to most contaminated well at sites were historical sampling data is available.
- Prior to accessing the well, the wellhead should be cleared of debris and/or standing water. Once the wellhead is clear, open the well.

  In some cases, it may be necessary to allow the water level to equilibrate after opening the well cover and prior to measurement. This is particularly true for wells with fully submerged screens and a well cap that is fully sealed not allowing the well to vent to changes in atmospheric pressure.

5.2 Measurement

- Determine the location of the surveyed elevation mark/measuring point at the monitoring well location.

  Markings may include either a notch or other permanent mark on top of the well casing. Some projects may specify a consistent measuring point for all wells. The reference point must be specified if not marked and the project manager must be notified to arrange for the elevation of the new reference point to be surveyed.

5.2.1 Water Level Measurement

- Lower the decontaminated probe of the water level meter down into the well until the audible sound of the unit is detected or the light on an electronic sounder illuminates indicating it is in water. The water level probe should be lowered slowly into the well to avoid disruption of formation water and creation of turbulent water within the well.

  The precise water level measurement should be determined (to the nearest 0.001 m) by raising and lowering the tape into and out of the water to converge on the exact measurement. Obtain the reading from the marked cable where it crosses the surveyed measuring point. If the cable is not marked to the nearest 0.001 m, a manual rule may be used to interpolate a reading between marked measurements.
- Record the water level measurement as well as the location identification number, measuring point (surveyed elevation point), date, time, and weather conditions in the field logbook and/or field form.

5.2.2 NAPL Thickness/Level Measurement

- Sample the headspace in the wellhead immediately after the well is opened for organic vapors using either a photoionization detector (PID) or an organic vapour analyser, and record the measurements.
- Lower an interface probe into the well to determine the existence of any immiscible layer(s), LNAPL and/or DNAPL, and record the measurements.
- Confirm the presence or absence of an immiscible phase by slowly lowering a clear bailer to the appropriate depth, then visually observing the results after sample recovery.

  If the well contains an immiscible phase, it may be desirable to sample this phase separately. It may not be meaningful to conduct water sample analysis of water obtained from a well containing LNAPL or DNAPLs.

5.2.3 Total Well Depth Measurement

- Lower the probe (turn down signal as appropriate) slowly to the bottom of the well.

  For deep wells or wells with a soft or silty base, the depth may be difficult to determine. It may be helpful to lower the probe until there is slack in the tape, and gently pull up until it feels as if there is a weight at the end of the tape.

- Obtain the depth reading (to the nearest 0.001 m) from the cable where it crosses the surveyed measuring point. If the cable is not marked to the nearest 0.001 m, a manual rule may be used to interpolate between marked measurements.
- Record the total well depth in the field logbook and field form.

5.2.4 Decontamination

- Following the measurement, the meter shall be decontaminated in accordance with appropriate project-specific requirements and equipment use and care requirements.

  If the probe was in contact with separate-phase liquids, the potential for cross-contamination is greater, so appropriate care should be taken during decontamination, as specified in project-specific requirements.

  It is important to avoid placing the measuring tape and probe directly on the ground surface (to minimize potential cross-contamination) or allowing the cable to become kinked (which affects the accuracy of the measured depths). Clean plastic sheeting should be placed on the ground surface for placing equipment.

5.3 Special conditions

It may be difficult to lower the water level meter probe into wells containing pumps or other equipment. There may not be sufficient space within the well for the water level meter probe, or the water level meter cable may become bound up in the tubing, cables, or other equipment in the well rendering it impossible to remove. It is preferable to remove down-hole equipment when feasible. Another option is to insert a guide tube of slotted PVC into the well through which to lower the probe. This guide tube should be of a diameter sufficient to allow the probe to pass, but small enough to fit past well obstructions.

If removal of the equipment or installation of a guide tube is not feasible and there is a reasonable chance of getting the water level meter probe and cable caught in the well and not being able to remove it, it may be preferable to avoid collecting water level data and discuss this issue with the Project Manager.

5.4 Quality assurance / quality control

Field personnel shall follow site-specific quality assurance guidelines. Where measured depths are not consistent with well records or previously measurements, the depths should be re-measured, verified, and documented in the field records.

Field duplicates of the depth-to-water measurements will be obtained if required by and at the frequency specified in project-specific requirements. To collect a field duplicate measurement, the water level probe will be fully withdrawn from the well after making a measurement, then re-lowered to obtain a second measurement of the depth to water. No more than a few minutes should elapse between the two measurements. Field duplicates will not be obtained if water levels are changing rapidly, for example, during pumping tests.

Manufacturer's instructions, if any, for calibrating or maintaining the accuracy of the instrument shall be followed.

Groundwater Monitoring Well Installation and Development

Q4AN(EV)-336-PR5

1.0 Purpose

This procedure provides guidance for installing groundwater monitoring wells and subsequent well development.

Monitoring wells are installed to monitor the depth to groundwater, to measure aquifer properties and to obtain samples of groundwater for chemical analysis.

Monitoring well development and/or redevelopment is necessary for several reasons:

- to improve/restore hydraulic conductivity of the surrounding formations as they have likely been disturbed during the drilling process, or may have become partially plugged with silt
- to remove drilling fluids (water, mud), when used, from the borehole and surrounding formations
- to remove residual fines from well filter materials and reduce turbidity of groundwater, therefore, reducing the chance of chemical alteration of groundwater samples caused by suspended sediments.

Monitoring wells need to be constructed to a high standard to ensure ongoing and reliable data is obtained over the life of the well. A monitoring well should be constructed in accordance with the document *Minimum Construction requirements for water bores in Australia* (National Uniform Drillers Licensing Committee 2011).

Deviations from this procedure to accommodate other regulatory requirements should be reviewed in advance of the field program, should be explained in the sampling and analysis plan (SAP), and must be documented in the field project notebook when they occur.

2.0 Scope

The scope of this procedure covers the installation of groundwater monitoring wells (monitoring bores) and subsequent well development following the drilling of a borehole. For the drilling of boreholes reference should be made to the project SAP.

This procedure is applicable to installation of single monitoring wells within a borehole. The construction and installation of nested, multilevel or other special well designs is not covered within this procedure. This procedure applies to both overburden and bedrock monitoring wells.

3.0 Health and Safety

3.1 Health and Safety Plan and Site Specific Safe Work Method Statements (SWMS) should be prepared prior to field work in accordance with the SWMS Development Procedure and in the Project Specific Health and Safety Plan Template.

3.2 Any subsurface excavation requires a Dial before You Dig search and surveyed by a licensed utilities surveyor and the Underground Utilities Checklist Form must be followed.

4.0 References

4.1 SWMS Development Procedure S4AN-701-PR1

4.2 Project Specific Health and Safety Plan Template S4AN-702-TP1

4.3 Groundwater Monitoring Well Construction Detail form Q4AN(ENV)-336-FM27

4.4 Soil Bore Log Q4AN(EV)-336-FM20

4.5 Site Contamination Analysis Well Development Form Q4AN(EV)-336-FM11

5.0 Equipment

5.1 Well Construction

Well construction materials are usually provided by the drilling subcontractor and most often consist of the following commercially available materials. The length of the screen and the size of the screen slots should be specified in the project work plan and be considerate of the Conceptual Site Model (CSM) and specifically the geology into which the well is being installed.

Common well construction and completion materials		
Flush-threaded well screen with a minimum 50 mm inside diameter (PVC or stainless steel).	Riser pipe (PVC or stainless steel)	Protective casings
Blank casing with a minimum 50 mm inside diameter (PVC or stainless steel)	Centralisers	Well plugs
Filter pack (often inert silica sand)	Cement	Protective casings
Bentonite (pellets, powder)		Locks

Other materials and equipment that may be required are detailed below. A number of these items will need to be provided by the consultant or arranged with the drilling contractor should the consultant not have items available.

Common well construction and completion materials and equipment – miscellaneous		
Potable water supply	Waterproof marker and paint (to label wells)	Water containment equipment (Intermediate bulk containers, buckets)
Fibreglass or steel measuring tape	Equipment decontamination materials	Environmental incident response supplies (spill kits, drip trays, silt fencing)
Water level indicator (dip meter)	Camera	Health and safety supplies
Well construction diagrams	Field notebook and pen	Traffic control signage and barriers

5.2 Well Development

Well development can be performed using a variety of methods and equipment. The specific method chosen for development of any given well is governed by the purpose of the well, well diameter and materials, depth, accessibility, geologic conditions, static water levels in the well and type of contaminants present, if any. Containment and proper disposal of contaminated well development water needs to be planned.

The following list of equipment, each with their own particular application, may be used to develop and/or purge monitoring wells. Note the equipment required for well development will depend on the preferred development technique and should be confirmed as part of the SAP. Well drillers usually can conduct well development if requested.

Well Development Method	**Detail**	**Note**
Bailer	A bailer is used to purge silt-laden water from wells after using other devices such as a surge block. In some situations, the bailer can be used to develop a well by bailing and surging.	Used for purging in situations where the depth to static water is greater than 8 m and/or where insufficient hydraulic head is available for use of other development methods. Additional equipment: Bailer rope
Surge Block	Surge blocks are commercially available for use with Waterra™-type pumping systems or may be manufactured using a rubber or teflon "plunger" attached to a rod or pipe of sufficient length to reach the bottom of the well.	For use with foot-valve type pumping systems. Additional equipment: tubing, foot valves, filters

Well Development Method	Detail	Note
Pump	In some situations, the pump alone can be used to develop the well and remove the fines by over-pumping. Pumping may not be successful in low-yielding aquifer materials or in wells with insufficient hydraulic head.	12 V submersible pumps applicable for generally 1 to 40 m depth. Centrifugal pumps applicable for less than 8 m depth. Additional equipment: power, tubing
Compressed Gas	Also known as 'Air-lifting'. Can be used to both surge and develop a monitoring well. Compressed gas can also be used for "jetting" where gas is directed at the slots in the well screen to cause turbulence (thereby disturbing fine materials in the adjacent filter pack).	Compressed gas is not limited by any depth range. May be used by the drilling contractor with addition of dispersants and detergents. Additional equipment: power source, tubing
Well development – other recommended equipment and materials		
Oil water interface probe	Field project notebook and pen.	Equipment decontamination materials
Well development records	Health and safety equipment	Water quality instrumentation: turbidity meter, pH, temperature, specific conductance meters, as required
	Plastic disposable bailers	Bailer rope

6.0 Procedure

6.1 Monitoring Well Construction

- All well construction data will be recorded on the Groundwater Monitoring Well Construction Detail Form.
- All well locations will be referenced onto the appropriate site map.
- A field notebook and/or Soil Bore Log will be used as additional means of recording data.
- In no case will the notebook or boring log alone take the place of the Groundwater Monitoring Well Construction Detail Form.

6.1.1 General Preparation

- Borehole Construction

  If water or other drilling fluids have been introduced into the boring during drilling or well installation, samples of these fluids should be obtained and analysed for chemical constituents that may be of interest at the site. In addition, an attempt should be made to recover the quantity of fluid or water that was introduced, either by flushing the borehole prior to well installation and/or by overpumping the well during development (refer to well development procedure below).

- Well Material Decontamination

  Well materials should be inspected by the project geologist/engineer upon delivery to check cleanliness. If the well materials appear dirty, or if local or regional regulatory guidance requires decontamination, then well material decontamination should be performed by the drilling subcontractor in accordance with the project SAP.

6.1.2 Installation - Procedure

- Depth Measurement

  Once the target drilling depth has been reached, the drilling subcontractor will measure the total open depth of the borehole with a weighted, calibrated tape measure. Adjustments of borehole depth can be made at this time by drilling further or installing a small amount of sand filter material to achieve the desired depth. If drilling fluids were used during the drilling process, the borehole should be flushed at this time using potable water.

- Centralizers

  In order to install a well which is centered within the borehole, it is recommended that centralizers be used. Centralizers are especially helpful for deep well installations where it may be difficult to position the well by hand. Centralizers may not be necessary on shallow water table well installations where the well completion depth is within 8 m of the ground surface.

- Well Construction

  The well screen and riser pipe generally are assembled by hand as they are lowered into the borehole. Before the well screen is inserted into the borehole, the full length of the slotted portion of the well screen as well as the unslotted portion of the bottom of the screen should be measured with the measuring tape. These measurements should be recorded on the well construction diagram (Figure 1).

  After the above measurement has been taken, the drilling subcontractor may begin assembling the well. As the assembled well is lowered, care should be taken to ensure that it is centered in the hole if centralizers are not used. The well should be temporarily capped before filter sand and other annular materials are installed.

- Filter Sand Installation

  The drilling subcontractor should fill the annular space surrounding the screened section of the monitoring well to at least 0.5 m above the top of the screen with appropriately graded, clean sand or fine gravel. In general, the filter pack should not extend more than 1.0 m above the top of the screen to limit the thickness of the monitoring zone. If coarse filter materials are used, an additional 0.3 m thick layer of fine sand should be placed immediately above the filter pack to prevent the infiltration of sealing components (bentonite or grout) into the filter pack. As the filter pack is placed, a weighted tape should be lowered in the annular space to verify the depth to the top of the layer. Depending upon depth, some time may be required for these materials to settle. If necessary, to eliminate possible bridging or creation of voids, placement of the sand pack may require the use of a tremie pipe. Tremie pipe sandpack installations are generally suggested for deep water table wells and for wells which are screened some distance beneath the water table.

- Bentonite Seal Installation

  A minimum 0.5 m thick layer of bentonite pellets or slurry seal will be installed by the drilling subcontractor immediately above the well screen filter pack in all monitoring wells. The purpose of the seal is to provide a barrier to vertical flow of water in the annular space between the borehole and the well casing. Bentonite is used because it swells significantly upon contact with water. Pellets generally can be installed in shallow boreholes by pouring them very slowly from the surface. If they are poured too quickly, they may bridge at some shallow, undesired depth. As an option, powdered bentonite may be mixed with water into a very thick slurry and a tremie pipe used to inject the seal to the desired depth.

- Annular Grout Seal Installation

  The grout seal (where required) should consist of a bentonite/cement mix with a ratio of bentonite to cement of between 1:5 and 1:20. The grout ratio should be chosen based on site conditions with a higher percentage of bentonite generally used for formations with higher porosity. A mud balance should be used if a specific mud density is required at a particular site. Grout slurry should be pumped into the annular space using a side-discharging tremie pipe located about 0.5m above the sand pack. Side discharge will help preserve the integrity of the sand pack.

  In situations where the monitoring well screen straddles the water table, the seal will be in the unsaturated zone and pure bentonite (pellets or powder) will not work effectively as seals without hydration. Dry bentonite may be used if sufficient time to hydrate the seal is allowed. Seal hydration requires the periodic addition of clean water. Optionally, seals in this situation may be a cement/bentonite mixture containing up to 10 percent bentonite by weight. This type of mixture shall be tremied to the desired depth in the borehole.

  The borehole annulus will be grouted with seal materials to within 1 m of the ground surface. Drill cuttings, even those known not to be contaminated, will not be used as backfill material.

- Well Completion

  The drilling subcontractor will cut the top of the well to the desired height and install a vented (if possible) locking cap. The upper portion of the well casing can optionally be drilled to allow venting. Well casings are usually cut to be a certain height above ground surface (typically 0.75m to 1m) or are cut to be flush with or just below the ground surface.

- Protective Casing

  Where monitoring wells have been located in areas that may become overgrown or difficult to identify, there may be a need to install steel risers to enable easy identification during subsequent visits. The suitability for installation of steel risers will be site specific and judgement for the need of one should be made during the development of the SAP.

  Where steel risers are used, the drilling subcontractor will install a steel guard pipe on the well as a protective casing. The borehole around the guard pipe will be dug out to an approximate 0.5 m to 0.75 m radius to a minimum depth of 0.3 m at the centre and 0.15 m at the edges. After installing the protective casing, the excavation will be filled with a concrete/sand mix. The surface of the concrete pad will be sloped so that drainage occurs away from the well.

  Flush mounted covers, where considered most suitable, should be completed such that they are slightly mounded above the surrounding surface to prevent surface water from running over or ponding on top of the casing. It may be necessary to ensure these are installed in accordance with transportation authority requirements if installed in areas of high vehicular traffic.

  Above-ground protective casings should also be vented or should have non-air tight caps. Road box installations should not be vented due to possible accumulation and entry of surface water into the well. Installation of protective guard pipes (or bollards) may be necessary around above-ground well completions in traffic areas. Protective casings should be lockable to prevent unauthorized access.

- Well Numbering

  The project geologist/engineer will number each well casing with an indelible marker or paint to identify the well. This is particularly important with nested or paired wells to distinguish between shallow and deep wells. The well should be labelled on both the outside of the protective casing and inside beneath the protective casing lid.

- Measuring Point Identification

  The measuring point is the point which will require surveying during the well elevation survey task. The project geologist/engineer will mark the measuring point from which water level measurements will be made at a specific location along the upper edge of the well casing. PVC wells can easily be notched with a pocket knife or saw. Stainless steel wells (or PVC wells) can be marked with a waterproof marker on the outside of the well casing with an arrow pointing to the measuring point location.

- Well Measurements

  Upon completion, the following well measurements should be taken by the project geologist/engineer and recorded on the Groundwater Monitoring Well Construction Detail Form.Depth to static water level if water level has stabilised.

  - Total length of well measured from top-of-well casing.
  - Height of well casing above ground surface.
  - Depth of bottom of protective casing below ground surface (may be estimated).

  Well screen filter pack, bentonite seal and annular seal thicknesses and depths should also be recorded on the well construction diagram.

- Disposal of Drilling Wastes

  Drill cuttings and other investigation-derived wastes such as drilling mud or well development/purge water must be properly contained and disposed. Site-specific requirements for collection and removal of these waste materials should be outlined within the project work plan. Containment of these materials should be performed by the drilling

subcontractor; however, the final disposal of drilling wastes may need to be managed by the project team.

- Well Elevation Survey

  At the completion of the well installation program, all monitoring wells are usually surveyed to provide, at a minimum, the top-of-casing measuring point elevation for water level monitoring purposes. Other surveyed points which may be required by the project work plan include: ground surface elevation, top of protective casing elevation, and well coordinate position. Well elevation surveys are usually conducted by a surveying subcontractor.

6.2 Well Development

6.2.1 General Preparation

The Site Contamination Analysis Well Development Form will be completed by the site engineer conducting the development.

In addition, a field project notebook should be maintained detailing any problems or unusual conditions which may have occurred during the development process.

A number of considerations are provided below prior to developing a newly installed well:

- **Well Records Review**: Well completion diagrams should be reviewed to determine well construction characteristics. Formation characteristics should also be determined from review of available boring logs.
- **Site Preparation**: Well development, similar to groundwater sampling, should be conducted in as clean an environment as possible. This usually requires, at a minimum, placing sheet plastic on the ground to provide a clean working area for placing decontaminated well development equipment.
- **IDW Containment**: Provisions should be in place for collection and management of investigation-derived wastes (IDW), specifically well development water and miscellaneous expendable materials generated during the development process. The collection of IDW in drums or tanks may be required depending on project-specific requirements.
- **Water Level/Well Depth Measurement**: The water level and well depth should be measured with a water level indicator and written on the well development record. This information is used to calculate the volume of standing water (i.e., the well volume) within the well.
- **Equipment Decontamination**: All down-well equipment should be decontaminated prior to use in accordance with the projects SAP.
- **Removal of Drilling Fluids**: Drilling fluids such as mud or water, if used during the drilling and well installation process, should be removed during the well development procedure. It is recommended that a minimum of 1.5 times the volume of added fluid be removed from the well during development. Drilling muds should initially have been flushed from the drilling casing during the well installation procedure with water added during the flushing process. If the quantity of added fluid is not known or could not be reasonably estimated, removal of a ***minimum of 10 well volumes*** of water is recommended during the development procedure.

6.2.2 Well Development – Procedure

- Development Method Selection

  The construction details of each well shall be used to define the most suitable method of well development. Some consideration should be given to the potential degree of contamination in each well as this will impact IDW containment and disposal requirements.

  The criteria for selecting a well development method include well diameter, total well depth, static water depth, screen length, the likelihood and level of contamination, and characteristics of the geologic formation adjacent to the screened interval.

  The limitations, if any, of a specific procedure are discussed within each of the following procedures.

- General Water Quality Measurements

  Measure and record water temperature, pH, specific conductance, and turbidity periodically during development using the available water quality instruments. These measurements will aid in determining whether well development is proceeding efficiently, will assist in identifying when well development is complete, will help determine whether the development process is effective or not with any given well and, potentially, may identify well construction irregularities (i.e. grout in well, poor well screen slot size selection). Water quality parameters should be checked a minimum of 3 to 5 times during the development process.

- Bailer Procedure
  - When using a bailer to purge well water, select the appropriate bailer, then securely tie a length of bailer cord onto the end of the bailer.
  - Lower the bailer into the screened section of the monitoring well to the bottom of the well. Silt, if present, will generally accumulate within the lower portions of the well screen.
  - In some cases, enough silt may be accumulated in the bottom of the well to prevent the bailer from reaching the bottom. The bailer may be raised and lowered repeatedly in the bottom of the well to remove accumulated silts, until the bottom of the well is reached.
  - The bailer may then be raised and lowered repeatedly in the screened internal to further simulate the action of a surge block and pull silt through the well screen.
  - Remove the bailer from the well and empty the contents into an appropriate storage container.
  - Continue surging/bailing the well until sediment free water is obtained. If moderate to heavy siltation is still present, the surge block procedure should be repeated and followed again with bailing.
  - Check water quality parameters periodically.
- Surge Block Procedure
  - A surge block effectively develops most monitoring wells. This device first forces water within the well through the well screen and out into the formation, and then pulls water back through the screen into the well along with fine soil particles. Surge blocks may be manufactured to meet the design criteria or may be purchased as an adaptor to fit commercially available well purging systems such as the Waterra system.
  - A surge block is typically used only after silt accumulation in the bottom of the well has been removed and the produced water has started to become less turbid.
  - Insert the surge block into the well and lower it slowly to the level of static water. Start the surge action slowly and gently above the well screen using the water column to transmit the surge action to the screened interval. A slow initial surging, using plunger strokes of approximately 1m, will allow material which is blocking the screen to separate and become suspended.
  - After 5 to 10 plunger strokes, remove the surge block and purge the well using a pump or bailer. The returned water should be heavily laden with suspended silt and clay particles. Discharge the purged water into the appropriate storage container.
  - Repeat the process. As development continues, slowly increase the depth of surging to the bottom of the well screen. For monitoring wells with long screens (greater than 3m) surging should be undertaken along the entire screen length in short intervals (0.5m to 1m) at a time. Continue this cycle of surging and purging until the water yielded by the well is free of visible suspended material.
  - Check water quality parameters periodically.

- Pump Procedure
    - Well development using only a pump is most effective in monitoring wells that will yield water continuously. When using a submersible pump or surface pump, set the intake of the pump or intake line in the centre of the screened interval of the monitoring well.
    - Pump a minimum of three well volumes of water from the well and raise and lower the pump line through the screened interval to remove any silt/laden water.
    - Continue pumping water from the well until sediment-free water is obtained. This method may be combined with the manual surge block method if well yield is not rapid enough to extract silt from the surrounding formations.
    - Check water quality parameters periodically.
- Compressed Gas Procedure
    - Caution must be exercised in highly permeable formations not to inject gas into the formation. Drilling subcontractors will often provide the necessary materials as well as perform this method, if requested. When using a compressor, an oil-less compressor should be used, or an oil trap/filter should be placed on the air discharge line which enters the well.
    - Lower the gas line into the well, setting it near the bottom of the screened interval. Install the discharge control equipment (i.e., tee fitting) at the well head.
    - Set the gas flow rate to allow continuous discharge of water from the well.
    - At intervals during gas-lifting, especially when the discharge begins to contain less suspended material , shut off the air flow and allow the water in the well to backflush through the screened interval to disturb any bridging that may have occurred. Re-establish the gas flow when the water level in the well has returned to the pre-development level.
    - Continue gas-lifting and/or jetting until the discharged water is free from suspended material.
    - Check water quality parameters periodically.

ANZ

Standard Operating Procedure S3AZ-202-PR2 Aquifer Characterisation - Slug Tests

IMS reference number TBC

1.0 Purpose and Scope

1.1 This Standard Operating Procedure (SOP) provides guidance for conducting **slug tests**, also referred to as **rising head** or **falling head tests**.

1.2 The purpose of slug tests is to provide an estimate of the hydraulic conductivity of an aquifer, a measure of the aquifer water transmitting properties. Pump tests can provide more detailed information about aquifer characteristics including the hydraulic conductivity, however pump tests are more expensive and more involved than slug tests. The hydraulic conductivity is a key aquifer parameter that is required for a number of purposes including the development of conceptual models, remediation system design and fate and transport calculations.

1.3 Slug tests are so called as a 'slug' of water is introduced to a monitoring well (falling head test) or removed from the monitoring well (rising head test) and the resultant response from the water column is a function of the aquifer hydraulic conductivity. The water level decline or rise is measured and plotted and the resultant curve (along with some monitoring well parameters) is analysed to calculate a value of hydraulic conductivity. There are many analytical methods available but the *Bouwer and Rice* and *Hvorslev* methods are among the most commonly used.

1.4 Historically the groundwater level response was measured using an electronic water level meter, however this is only suitable for aquifers with a low hydraulic conductivity such as shale or siltstone due to the longer response times. Nowadays, pressure transducers connected to dataloggers are used to accurately record groundwater level fluctuations, allowing high hydraulic conductivity aquifers to be quantified.

1.5 This SOP outlines how to conduct a slug test and what data to collect. The analysis process is outlined, however this relies on having an understanding of the monitoring well and aquifer/s intersected.

2.0 Health and Safety

2.1 A Health and Safety Plan (HASP) and Site Specific Safe Work Method Statements (SWMS) should be prepared prior to field work in accordance with the AECOM Procedures.

2.2 For the drilling of boreholes and installation of monitoring wells, reference should be made to the project Sampling and Analysis and Quality Plan (SAQP), and also AECOM SOP for Subsurface Soil Sampling using Borehole and Auger Techniques Q4AN(EV)-336-PR7.

3.0 References

3.1 Project Specific Health and Safety Plan Template S4AN-702-TP1

3.2 SWMS Development Procedure S4AN-701-PR1

3.3 Safe Work Method Statement – Accessed via the SWMS tool on myAECOM

3.4 SOP for Subsurface Soil Sampling using Borehole and Auger Techniques Q4AN(EV)-336-PR7.

3.5 Analysis can be undertaken using spreadsheet methods or specialist software such as AQUIFERTEST or AQTESOLV.

4.0 Equipment

4.1 The following equipment is required to undertake a slug test.

4.1.1 **Properly constructed monitoring well**;

4.1.2 **Monitoring well construction records**;

4.1.3 **Electronic water level meter**;

4.1.4 **Data logger** and **pressure transducer assembly**, **laptop** and **download cable**;

4.1.5 **String, wire** or **rope** to suspend the datalogger;

4.1.6 **Well cap** with a hole in it to suspend the datalogger;

4.1.7 **Bucket** and **water** (falling head test);

4.1.8 **Pump** or **displacement tube** such as a bailer (rising head test);

4.1.9 **Stopwatch** (if manual measurements are to be conducted);

4.1.10 **Appropriate tools to access the monitoring wells**;

4.1.11 Approved plans e.g. **SAQP**, **HASP**;

4.1.12 **Field project logbook/notebook**; and

4.1.13 **Personal protective equipment** (PPE) such as nitrile gloves, safety glasses, safety boots, high visibility vest, hat or hard hat (as required by site management).

5.0 Procedure

The choice to use a falling head test or rising head test is dependent on the monitoring well design. Falling head tests can only be undertaken when the monitoring well screen is completely saturated, that is the standing water level is above the screen. For many environmental monitoring wells the well screen is designed to straddle the watertable and is thus unsuitable for falling head tests. In these cases, rising head tests should be performed.

In designing a field program it is recommended that falling head tests are conducted after water sampling is undertaken so introduced water will not impact the measured groundwater quality. Rising head tests could be combined with groundwater sampling as long as the aquifer has recovered sufficiently after groundwater purging. In conducting multiple slug tests, it is best practise to commence with the least contaminated wells and progress to the most contaminated to minimise the likelihood of cross contamination.

The methodology for conducting a slug test (rising head or falling head) is as follows:

5.1 Review monitoring well construction details to determine the borehole diameter, screen interval and borehole depth.

5.2 Review site operations to ensure the aquifer is at equilibrium and is not impacted by recent drilling or localised pumping or the water is not impacted by drilling muds.

5.3 Identify the necessary tools required to remove the well cap.

5.4 Use the electronic dip meter to measure the standing water level.

5.5 In contaminated wells ensure all equipment to enter the borehole has been cleaned appropriately with Decon solution.

5.6 Assess if the standing water level is above the screened interval and determine if a falling head or rising head test can be undertaken. If the standing water level is within the screened interval, only a rising head test can be conducted.

5.7 Suspend the pressure transducer within the monitoring well, position it towards the base of the hole and check that the data logger is monitoring.

5.8 Set the monitoring time interval of the data logger depending on the lithology intersected. For high permeability aquifers such as clean sand, the interval should be set at seconds whereas for lower permeability aquifers such as shale the monitoring interval can be set at one minute.

5.9 For a **falling head test** pour potable water into the borehole with a bucket as quickly as possible and monitor the water level response automatically with the data logger. Try and fill the whole monitoring

well with water so when analysing the data, the water level decline is obvious. If the standing water level is deep and it is not practical to fill the whole water column, usually a maximum of 20 litres of water is sufficient to induce a suitable response in a 50 mm diameter well.

5.10 For a **rising head test** remove a slug of water by either inserting a bailer or similar device to displace a slug of water. Alternatively a pump can be used to remove a larger volume of water. If using a pump to remove water, the pump must be installed so the electrical cables do not interfere with the pressure transducer. In addition, a non-return valve should be fitted to the pump so when the pump is switched off the water in the pump column cannot return to the borehole and cause a water level rise. Alternatively, the pump can be pulled quickly out of the monitoring well to prevent the water in the water column from returning to the borehole.

5.11 At the completion of the test, manually monitor the water level in the monitoring well to compare with the datalogger water levels.

5.12 For aquifers that recover quickly, it is good practise to conduct multiple tests (up to three) and average the results.

5.13 Once the test is complete, data from the data loggers should be viewed and plotted (most data logger software automatically plots data) to ensure that appropriate water decline/rise curves have been produced and each file is correctly labelled.

6.0 Data Analysis

A detailed data analysis procedure is beyond the scope of this procedure, however the following points should be noted;

6.1 The following information is required for the analysis procedure:

- 6.1.1 Borehole diameter;
- 6.1.2 Casing diameter;
- 6.1.3 Screen interval;
- 6.1.4 Standing water level (before and after the test); and
- 6.1.5 Water level response derived in the field.

6.2 Some experience is required in selecting the correct part of the curve to analyse the slope. For a falling head test, typically the first part of the curve is due to the water being dispersed into the gravel pack in the borehole annulus and it is the second part of the curve that represents the aquifer properties.

6.3 In high permeability aquifers, it may not be possible to measure the hydraulic conductivity using slug tests because the aquifer is more permeable than the well screen. Typically, the highest values of hydraulic conductivity obtained in 50 mm diameter machine slotted well screen are 1 to 5 m/day, which appears to be related to the properties of the casing and gravel pack.

6.4 There are a variety of methods of analysing slug test data, although the Horvslev and Bouwer and Rice methods are the most common. The method selected is dependent on the properties of the aquifer being tested. Spreadsheet methods or specialised software can be used to analyse the data to calculate the hydraulic conductivity of the aquifer intersected.

7.0 Document Approval and Revision History

Revision	Revision Date	Prepared By	Reviewed By	Authorised	
				Name	Signature
0	31-Jan-2013	Graham Hawkes	Ainslie Sumner	Jason Clay	Jason Clay

Soil and Rock Logging Procedure

Q4AN(EV)-336-PR2

1.0 Purpose and Scope

1.1 The purpose of this procedure is to provide a standard method of soil and rock description of soil, rock and fill materials encountered during an investigation. The system uses a list of standard descriptions in a set sequence. The description of materials should be consistent throughout AECOM Australia New Zealand.

2.0 Health and Safety

2.1 Health and Safety Plan and Site Specific Safe Work Method Statements (SWMS) should be prepared prior to field work in accordance with the SWMS Development Procedure and in the Project Specific Health and Safety Plan Template.

2.2 Any subsurface excavation requires a Dial before You Dig search and surveyed by a licensed utilities surveyor and the Underground Utilities Checklist Form must be followed.

3.0 References

3.1 SWMS Development Procedure S4AN-701-PR1

3.2 Project Specific Health and Safety Plan Template S4AN-702-TP1

3.3 Underground Utilities Checklist Form S4AN-721-FM1

3.4 Soil Bore Log Q4AN(EV)-336-FM20

3.5 ASTM 2009. ASTM D2488- Rev A. Standard Practice for Description and Identification of Soils (Visual Manual Procedure). Designation D2488-09a. 15 June 2009.

3.6 ASTM 2011. ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System). Designation D2487 – 11. ASTM International. 1 May 2011.

3.7 ASTM 2012. ASTM 5434 Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock. 1 February 2012.

3.8 Caltrans, 2010. Soil and Rock Logging, Classification and Presentation Manual. 2010 Edition.. State of California Department of Transportation.

4.0 Equipment

Field equipment required for soil logging may include:

- **Pocket penetrometer** to measure the unconfined compressive strength of clays and silts.;
- **Photoionisation Detector** (PID);
- **Sampling Trowel** for extruding the soil sample from the auger head once recovered from the sub-surface field pen knife
- **Tape measure** for measuring depths within the excavation
- **Level D equipment or PPE**; upgrades as warranted by HASP and site conditions;
- **USCS classification guides**;
- **logging sheets, pen and pencil**;
- **Camera and photoboard** for documenting the lithology.

5.0 Procedure

The basis for this systematic classification is the Unified Soil Classification System (USCS). It is intended as a guideline as such, only that its general principles need be adopted.

5.1 Logging of Sands, Silts and Clays

5.1.1 Step 1 – Define Soil Type

Refer to the USCS Chart for describing soil type based on grain sizes ranging from clays to gravels.

The primary soil component is to be referred to in capital letters, for instance, '**sandy CLAY'**, describes a soil where clay is the primary component, and sand is the secondary component. As an exception, if the sample is defined as fill, then the soil should be referred to as 'FILL,' followed by soil description e.g. '**FILL, sandy clay**'.

Cobbles (63 – 200 mm grain size), **Gravels** (2 – 63 mm grain size) and **Sand** (0.2 to 2.36 mm grain size) comprise rock fragments of various sizes and shapes that may be either rock fragments or single minerals.

Silt (0.002 – 0.075 mm grain size) is intermediate between clay and fine sand. Silt is less plastic and more permeable than clay, and displays '*dilatant*' and '*quick*' behavior. A simple test of patting a saturated soil sample in the hand can be undertaken to assess these properties and distinguish silt from clay.

Clay (>0.002 mm) consists of very small particles and exhibits the properties of '*cohesion*' and '*plasticity*', which are not found in sand or gravel.

The relevant USCS symbol may follow the soil type in brackets e.g: '**FILL, sandy clay (CLS)**', or '**silty GRAVEL (GM)'** and are shown on **Table 1**.

Table 1 USCS Chart

Major divisions			Group symbol	Group name
Coarse grained soils more than 50% retained on No.200 (0.075 mm) sieve	gravel > 50% of coarse fraction retained on No.4 (4.75 mm) sieve	clean gravel <5% smaller than #200 Sieve	**GW**	well graded gravel, fine to coarse gravel
			GP	poorly graded gravel
		gravel with >12% fines	**GM**	silty gravel
			GC	clayey gravel
	sand ≥ 50% of coarse fraction passes No.4 sieve	clean sand	**SW**	well graded sand, fine to coarse sand
			SP	poorly-graded sand
		sand with >12% fines	**SM**	silty sand
			SC	clayey sand
Fine grained soils more than 50% passes No.200 sieve	silt and clay liquid limit < 50	inorganic	**ML**	silt
			CL	clay
		organic	**OL**	organic silt, organic clay
	silt and clay liquid limit ≥ 50	inorganic	**MH**	silt of high plasticity, elastic silt
			CH	clay of high plasticity, fat clay
		organic	**OH**	organic clay, organic silt
Highly organic soils			**Pt**	peat

5.1.2 Step 2 – Describe Colour

The colour given should be the overall colour and not that of individual constituents. If appropriate, the distribution of colour may be described using the terms *mottled* or *banded*. Where used, such terms should be written after the main colour e.g. '**dark brown, mottled yellow'**. Clear colour terms should be used, avoiding the use of ambiguous terms such as 'peach', 'buff', 'tan' or 'coffee'.

Table 2 Soil Colours

Prefix descriptive	Common colours	Rarer Colours
Dark	Brown	Black
Light	Yellow	White
	Red	Purple
	Orange	Green
	Grey	Pink

5.1.3 Step 3 – Describe Moisture Condition

- Dry: looks and feels dry, runs freely through hands, hard, powdery or friable.
- Moist: feels cool, darkened in colour, tends to cohere. Weakened by moisture, but no free water on hands when remoulding.

- Wet: weakened by moisture, free water forms on hands when handling. Feels cool, darkened in colour and free water is present on the sample.

5.1.4 Step 4a – If soil is mostly Sands or Gravels, then describe Particle Size "Grading"

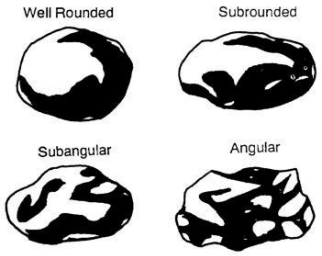
Gravels and Sands should next be described in terms of grain size (Table 3). Gravels and sands may also be described as *well graded* (a good representation of all particle sizes from largest to smallest), or *poorly graded* (a limited representation of grain sizes).

Table 3 Grain Size

Term	Size
Boulder	>200 mm
Cobble	63 – 200 mm
Coarse Gravel	20 – 63 mm
Medium Gravel	6 – 20 mm
Fine Gravel	2 – 6 mm
Coarse Sand	0.6 – 2.36 mm
Medium Sand	0.2 – 0.6 mm
Fine Sand	0.075 – 0.2 mm
Silt	0.002 – 0.0075 mm
Clay	< 0.002 mm

5.1.5 Step 4b – If soil is mostly Sands or Gravels, then describe particle shape

Particle shape can be expressed in terms of *roundness* or *angularity.*



5.1.6 Step 4c – If soil is mostly Clay, describe Plasticity in terms of low to high plasticity

A *highly plastic* soil is one that can be moulded or deformed over a wide moisture content range, without cracking or showing any tendency to volume change. It also shows no trace of "quick" or dilatant behavior. *Highly plastic* clays will become 'rock hard' when dry, while those of *low plasticity* can be crumbled in the fingers.

Soils should be wetted if possible and fashioned into a ribbon of material to work in the palm (Table 4).

Table 4 Soil Plasticity Test

Description	Criteria
Non plastic, or low plasticity	Non: a 3 mm thread cannot be rolled at any water content. Low: the thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium plasticity	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High plasticity	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

5.1.7 Step 5 – If soil is mostly Gravel or Sand, then describe density

Relative density refers to the "denseness", or degree of compactness of a coarse soil in the ground, and is expressed as the *density index*. The terms very loose through to very dense are used to describe this property as based on Standard Penetration Test (SPT) results. When SPTs are not executed in the field, then the density should be described in commas and indicate these derived on basis of visual field observation only.

Table 5 Density

Density (Granular Soils)
Very Loose (VL)
Loose (L)
Medium Dense (MD)
Dense (D)
Very Dense (VD)

5.1.8 Step 6 – If soil is mostly clay, then describe soil consistency

Table 6below provides a guide to the terms used to designate soil strength and related properties in clay rich soils.

Table 6 Consistency of fine soils

Consistency	
Very Soft (VS)	Easily exudes between fingers when squeezed
Soft (S)	Easily indented by finger pressure
Firm (F)	Indented by strong finger pressure and can be indented by thumb pressure
Stiff (S)	Difficult to indent by thumb pressure
Very Stiff (Vst)	Can be indented by thumbnail but not thumb pressure
Hard (H)	Difficult to indent by thumbnail

5.1.9 Step 7 – Describe Secondary Components

Secondary soil components if present are to be described based on estimated proportion in the total sample, using recommended terms in the table below.

The consistency or density and moisture of secondary components do not require as comprehensive a description as the primary component, or may need very little description at all.

Table 7 Describing proportion of secondary soil components

Proportion of Secondary Components	
Term	**Proportion**
Trace of	0-5 %
Few	5-10%
With	15-25 %
Some	30-45%

5.1.10 Step 8 – Describe Inclusions

Other material such as pieces of coal, shell, or traces of oils should be described. Strong odours should also be noted.

5.1.11 Step 9 - Describe presence or lack of any odours or anthropogenic materials.

Especially important in fill material to state with asbestos containing materials (ACM) were observed.

5.2 Logging of Rock

The order of terms used for describing rock is similar to that given for soils, however the description gives greater attention to the presence of discontinuities in the rock mass (fractures or defects) and the effects of weathering.

5.2.1 Step 1 – Describe Rock type followed by Rock Name

Rock type and rock name (in brackets) are to be described in capital letters, and require some prior understanding of site geology, e.g. SEDIMENTARY ROCK (SHALE), IGNEOUS ROCK (GRANITE), METAMORPHIC ROCK (SCHIST). For sandstones and conglomerates, follow by describing rock and inclusions grain size. For Igneous and Metamorphic rocks, describe crystal size.

5.2.2 Step 2 – Describe Colour

Colour should be described using the terms described previously for soil description.

5.2.3 Step 3 - Describe bedding, foliation, banding or flow texture

The term bedded indicates the presence of layers. The latter can be qualified with terms to describe how visible the bedding is, such as indistinctly bedded, or distinctly bedded. Bedding thickness should be included using terms defined below:

Table 8 Describing bedding inclination and thickness

Term	Bed Thickness/ Spacing
Thinly laminated	< 2 mm
Laminated	2 mm – 6 mm
Very thin	6 mm – 20 mm
Thin	20 mm – 60 mm
Moderately	60 mm – 200 mm
Thin	0.2 m – 0.6 m
Thick	0.6 m – 2 m
Very thick	> 2 m

Describe inter-bedded rock by bedding thicknesses of the components using the terms provided, and the rock name of the secondary layers. This is followed by the complete individual descriptions of the layers e.g., for a sample consisting of moderate beds of sandstone interbedded with thin beds of siltstone:

- SEDIMENTARY ROCK (SANDSTONE), fine grained, moderately bedded with thin interbeds of SILTSTONE. SANDSTONE; fine grained; grey; fresh; hard; slightly fractured; SILTSTONE; gray; slightly weathered; moderately hard; moderately fracture

5.2.4 Step 4 – Describe Degrees of Rock Weathering

There are several degrees to which rock weathers with time. These are:

- Unweathered (fresh): rock mass shows no loss of strength, discolouration or other effects due to weathering.
- Slightly Weathered: the rock mass is not significantly weaker than when unweathered. Rock may be discoloured along defects, some of which may have been opened slightly.
- Moderately Weathered: the rock mass is significantly weaker than the fresh rock. Rock material may be discoloured.
- Highly Weathered: most of the original rock mass strength is lost. Material is discoloured.
- Extremely Weathered: Original rock strength is lost and the rock mass changed to a soil either by chemical decomposition or by physical disintegration. Fabric generally remains intact, e.g. bedding layers.
- Residual Soil: Rock is completely changed to a soil with the original fabric destroyed.

5.2.5 Step 5 - Describe Fracture Density

If possible, describe fracture density based on recovered cores, excluding mechanical breaks, along the core axis. More complex fracture condition descriptions lie outside the scope of this procedure.

Table 9 Fracture Density Descriptions

Description	Observed Fracture Density
Unfractured	No fractures.
Very Slightly Fractured	Core lengths greater than 0.9 m (3 ft).
Slightly Fractured	Core lengths mostly from 0.3 to 0.9 m (1 to 3 ft).
Moderately Fractured	Core lengths mostly from 10 cm to 0.3 m (4 in. to 1 ft)
Intensely Fractured	Core lengths mostly from (2.5 to 10 cm) 1 to 4 in.
Very Intensely Fractured	Mostly chips and fragments.

5.2.6 Step 6 - Describe presence or lack of any odours or anthropogenic materials.

As for soil logging (5.1.11).

5.3 Summary and Examples

The whole sequence is written in the lower case except for the soil name, or rock type and rock name. Terms in the sequence are separated by commas. Examples as follows:

- silty CLAY (CL), Light brown mottled red and yellow, slightly moist, medium plasticity, very stiff, trace of fine grained ironstone gravels. Minor hydrocarbon odour observed.
- gravelly SAND (SPG), Light yellow brown, very moist, poorly sorted, fine to medium grained, sub rounded, medium dense, with fine grained gravels. Minor hydrocarbon odour observed.
- FILL, sandy gravel (GWS), dark brown, saturated, coarse grained, medium dense, with medium grained sand, a trace of fine glass, metal, and bricks fragments. No odour, ACM or staining observed.
- SEDIMENTARY ROCK (SANDSTONE), coarse grained, high quartz content, dark brown, slightly weathered, very hard, no observed bedding. No odour observed.
- IGNEOUS ROCK (BASALT); very thickly bedded; black; fresh; hard; slightly fractured.

ANZ

Subsurface Soil Sampling Using Borehole and Auger Techniques

Q4AN(EV)-336-PR7

1.0 Purpose

This procedure describes the specific methods and procedures used in obtaining subsurface soil samples through borehole sampling (auger drilling, push tube and standard penetration test [SPT] sampling) and shallow subsurface sampling (hand auger). Sampling in accordance with this procedure will promote consistency in sampling and provide a basis for sample representativeness. Deviations from this procedure should be reviewed in advance of the field program, should be explained in the project work plan, and must be documented in the field project notebook when they occur.

2.0 Scope

The purpose of a typical soil sampling program is to locate the extent, depth and concentrations of contaminants, and/or to characterise the physical and mechanical properties of the soils. Therefore, no universal sampling procedure and methodology can be recommended. Choosing a sampling method should be based on physical properties of the soil (grain size, cohesiveness, moisture), site characteristics (depth to bedrock, water table) and sampling depth required to reach the horizon of interest. It is noted that the preferred drilling methodology will dictate whether a disturbed or an undisturbed sample is required. Disturbed samples are generally used for chemical analysis, visual classification, water content, grain size analysis, Atterberg limit tests, specific gravity, and compaction tests. Undisturbed samples are required for shear, consolidation and permeability testing.

This procedure does not include sampling through rotary core barrel drilling for rock or soils that employs a drilling fluid or air to bring cuttings to the surface. The method of sampling soil cuttings directly as they are removed from the borehole or directly from the auger is not recommended.

3.0 Health and Safety

3.1 Health and Safety Plan and Site Specific Safe Work Method Statements (SWMS) should be prepared prior to field work in accordance with the SWMS Development Procedure and in the Project Specific Health and Safety Plan Template.

3.2 Any subsurface excavation requires a Dial before You Dig search and surveyed by a licensed utilities surveyor and the Underground Utilities Checklist Form must be followed.

3.3 Subsurface soil sampling may involve chemical hazards associated with the types of contaminants potentially encountered and will always involve potential physical hazards associated with use of drilling equipment. Sufficient time should be allowed to identify and mark locations of any utilities that may be buried on site prior to commencing drilling or augering activities.

3.4 When sampling is performed in materials which may contain hazardous constituents, adequate Health and Safety measures must be taken to protect sampling personnel. These measures must be addressed in the project HASP.

3.5 In addition to any other safety considerations outlined in the Site specific HASP, the following safety procedures should be employed when using drilling equipment:

- Always use safety cages when present on drill rigs.
- Never place hands or fingers under the bottom of an auger section when hoisting the auger over the top of the auger section in the ground or other hard surfaces such as the drill rig platform.
- Never allow feet to get under the auger section being hoisted.
- When rotating augers, stay clear of the rotating auger and other rotating components of the drill rig. Never stand in the vicinity of a rotating auger for any reason.
- Never use your hands or feet to move cuttings away from the auger, use a long-handled shovel.
- Do not attempt to remove earth from rotating augers. Augers should be cleaned only when the drill rig is in neutral and the augers are stopped from rotating.

- Only use the auger for the purposes they are intended and designed and do not attempt to exceed the manufacturers ratings or speed, force, torque, pressure etc.

4.0 Terms and Definitions

4.1 **Disturbed and undisturbed samples:** A disturbed sample is one in which the structure of the soil has been changed sufficiently such that tests of structural properties of the soil will not be representative of *in-situ* conditions; only the properties of the soil grains can be accurately determined.

An undisturbed sample is one where the condition of the soil in the sample is close enough to the conditions of the soil *in-situ* to allow tests of structural properties of the soil.

4.2 **Subsurface Soil**: Unconsolidated material which may consist of one or a mixture of the following materials: sand, gravel, silt, clay, peat (or other organic soils) and fill material.

4.3 **Hand Auger**: equipment used for the manual excavation of shallow boreholes. The equipment consists of a horizontal handle connected perpendicular to a metal shaft. At the base of the metal shaft is the auger cutting head used to penetrate the subsurface and retrieve shallow disturbed soil samples. Hand augers are regularly used to clear a borehole of underground services prior to the commencement of mechanical drilling.

4.4 **Push Tube Sampling**: is the collection of continuous samples using a hydraulically powered percussion drill rig (e.g. Geoprobe) which hammers a hollow steel rod and cutting shoe into the ground. The rod is lined with a core samplers (liner) from which soil samples are collected.

4.5 Mechanical Auger Sampling: is the collection of disturbed soil samples from the cutting head of a solid flight auger. This method is the least preferred method of soil sampling.

4.6 **SPT Sampling**: is the collection of undisturbed soil samples through the use of standard penetration test (SPT) equipment. The split-barrel equipment consists of a tubular body with two halves that split apart lengthwise, a drive head on the upper end with a ball-check valve for venting, and a hardened steel cutting shoe at the bottom

4.7 Geoprobe™: A manufacturer of hydraulically powered drill rigs that are typically mounted on small track, ute or truck vehicles.

4.8 **Liners (core samplers):** the liner placed inside the hollow drill rod which is typically made of plastic (PVC), although Teflon or Polyethylene Terephtalate Glycol (PETG), stainless steel or brass are also available, but less commonly used. A catcher is placed at the bottom end of the Sample Core to prevent material falling out the bottom end when pulled up out of the borehole.

4.9 **Core Catcher**: a dome shaped plug device placed at the end of the liner to prevent unconsolidated material falling out of the liner when it is retrieved from the borehole.

4.10 **Dual Tube (DT45):** Push tube sampling where two sets of rods are used. An outer casing of rods are driven down to keep the borehole open. The smaller diameter sampling rods are driven through the centre of the outer rods with lead rod containing the liner for sampling. This method of push tube drilling is required for unconsolidated soils (such as sandy or silty soils) that will collapse into the borehole when rods are pulled out.

5.0 References

5.1 Soil Bore Log Q4AN(EV)-336-FM20

5.2 Site Contamination Analysis: Field Investigation Daily Report Q4AN(EV)-336-FM7

5.3 PID Calibration Form Q4AN(EV)-336-FM12

5.4 Soil and Rock Logging Q4AN(EV)-336-PR2

6.0 Equipment

Equipment	
Disturbed Soil Samplers:	**Undisturbed Soil Samplers:**
• Mechanical Augers o Typically 110 mm diameter solid flight augers • Hand Operated Augers o Hand bucket augers o Small-diameter helical or screw type augers o Spiral augers o "T" handle & drill rods/extensions	• Split-Barrel Sampler (also known as standard penetration test [SPT] sampler) o Sampler shoe and head o Sample catchers • Push Tube • Geoprobe® drill rig or equivalent • Drill rods and cutting shoe • Macro Core Push Tube: PVC or Polyethylene Terephtalate Glycol (PETG) liners available in 0.6 m, 0.9 m, 1.2 m and 1.5 m lengths • Dual Tube (DT45): PVC or PETG liners available in 1 m, 1.2 m, 1.5 m and 1.8 m lengths • Catchers • Liner cutter (specialised product; no open bladed knives to be used) • Hydraulic Liner Extruder (for when sample cores get stuck in the drill rod) • Pitcher Tube (via rotary drilling) • Outer core barrel • Inner stationary, spring-loaded sampling tube
Other equipment includes Fluorescent flagging tape/caution tape, Field records: boring log, Field logbook/pen, Sample kit (i.e., bottles/labels, custody records, cooler, ice, etc.), Measuring tape, Project plans (HASP, Sampling Plan), Compass (optional), Decontamination materials and solutions, Camera, Stakes, Disposable nitrile gloves, Spatula, Drums for storage of drill cuttings and Housekeeping items (shovel/broom)	

7.0 Planning and Sampling Considerations

Project specific requirements for soil/fill sampling shall be stated in the site-specific sampling or work plan. The criteria for choosing the specific soil/fill samples to be tested are dependent on the objectives of the investigation. In some cases, the required sampling depths are dictated by regulatory requirements. More frequently, the objectives of chemical testing are to assess the horizontal and vertical extent of soil contamination. In this situation, it is most effective to select a series of samples within the zone of contamination, and sample outside the limits of contamination to assist with delineation. The data collected can then be used to demonstrate zonation of the contaminant away from the source. Field indicators such as discolouration, headspace measurements, or odour often provide a guide to sample selection. In other cases, the objective may be to collect "worst case" samples for remedial planning or hazardous waste characterisation testing. When physical tests are to be performed, sample locations and depths will most likely be determined by observed changes in soil properties such as texture, grain size or moisture content. Samples are often collected at each observed change in strata. Because the choice of samples to be tested is usually dependent on decisions made in the field, it is particularly important to record all field observations on the borehole log or other form for future reference.

In most contaminated land investigations, compositing samples should not be used because it does not provide information on the vertical or horizontal extent of contamination, or on the variability between samples. Mixing of soils is also not recommended when analysis of volatile compounds is required.

7.1 Disturbed Samples

7.1.1 Mechanical Auger Sample

A simple method of obtaining bulk samples of large volume is to sample the soil cuttings directly from the auger as they are removed from the borehole. Because this method results in a completely disturbed sample and likely loss of volatiles, it is not recommended for most applications. However, it can be used to obtain samples for visual classification, or where large volumes are needed for testing.

An important disadvantage of this technique is that a measure of the source depth can only be estimated on the basis of soil type, depth and drilling method. For example, with the hollow-stem auger drilling method, sandy cuttings are quickly brought to the surface on the auger flights, while clay cuttings may remain in the augers for a longer duration. With percussion drilling, the cuttings are blown to the surface almost instantaneously.

7.1.2 Hand Operated Auger

Hand auger borings are a simple, inexpensive method of obtaining soil samples from relatively shallow depths above the water table. Several types of augers are available:

- **Hand bucket augers** - suitable for sampling all types of soil except loose saturated materials and hard or cemented soils
- **Small-diameter helical or screw type augers** – With continuous flights, most useful for sampling cohesive soils using a thin walled tube sampler.
- **Spiral augers** - used for loose or gravelly soils.

Hand operated augers typically consist of a bucket auger or thin-walled tube sampler composed of stainless steel, a series of rods, and a "T" handle. The drill hole is advanced by manually rotating the auger while applying downward pressure. The procedure for sampling with a bucket auger or screw auger with a thin-walled tube sampler is as follows:

- Ensure clearance of underground utilities has taken place prior to commencement of subsurface drilling activities in accordance with the Site specific HASP.
- Attach the auger to a series of drill rod extensions (as required) and the "T" handle to the drill rod.
- Clean the area to be sampled of any surface debris (twigs, rocks, litter).
- Advance the pre-cleaned and decontaminated hand auger into the soil by twisting the "T" handle under pressure.
- When the sample barrel is full, withdraw the auger and remove the soil from the barrel using a pre-cleaned stainless steel extruder. After the soil has been removed, carefully place the auger back in the borehole and continue advancing the sample barrel.
- When the desired sampling depth is achieved, remove the auger from the borehole, extrude the soil from the core barrel, and decontaminate the equipment. Decontaminate the auger prior to taking the sample then carefully place the auger back in the borehole and collect the sample by advancing the sample barrel. If collecting the sample with a Thin-Walled Tube Sampler, proceed with the following:
  a) Remove the auger tip from the drill rods and replace with a pre-cleaned thin-walled tube sampler.
  b) Gradually force the corer into the soil. Care should be taken to avoid scraping the borehole sides. Hammering of the drill rods to facilitate coring should be avoided as the vibrations may cause the boring walls to collapse.
  c) Remove the corer and unscrew the drill rods
  d) Remove the cutting tip and remove the core from the device
  e) Discard the top of the core (approximately 2.5 cm), which represents any material collected by the core before penetration of the layer in question. Place the remaining core into the sample container.
- After collecting the sample, withdraw the auger and extrude the soil into an appropriate sample container.
- Decontaminate equipment between sample locations and sampling intervals to minimize the potential for cross contamination.

7.2 Undisturbed Samples

There are many types of samplers for collecting undisturbed samples, including SPT samples, thin-walled tube samples (Shelby tube), piston samples (thin-walled, stationary, Lowe-Acker, Osterberg and McClelland, Swedish foil), double-tube core barrel samples (Denison, TAMS, Pitcher) and push tube

samples. Only the SPT samplers, Shelby tube, and push tube samplers, which are most commonly used during environmental drilling works in Australia, are described here. Most of the other samplers are of complex design and require extensive decontamination when used for waste investigations.

7.2.1 SPT Sampler

The SPT sampler, also known as split-barrel sampler, is the most commonly used soil sampling device and can be used with hollow-stem auger, rotary, and percussion hammer drilling equipment. Split-barrel sampling can be used in most soils to obtain representative driven samples for chemical analysis, visual identification, and density. The use of a split-barrel sampler can also provide a measure of the resistance to sampler penetration (blow count), to be used in characterizing soil density, commonly referred to as Standard Penetration Tests.

The split-barrel consists of a tubular body with two halves that split apart lengthwise, a drive head on the upper end with a ball-check valve for venting, and a hardened steel cutting shoe at the bottom. The soil sample enters the split-barrel through the cutting shoe as the device is driven into the ground. Samples collected from soil below the water table or in very loose soils may require the use of split barrels equipped with retainers or “sample catchers”. The sample catcher is made with flexible prongs that close over the end of the tube as the sampler is retraced from the soil. The sample catcher is placed between the sampler shoe and barrel, with the prongs facing in toward the barrel. Once the sampler is retrieved, the drive head and cutting shoes are removed and the split-spoon halves are then separated, revealing the sample.

Subsurface soil sampling is usually accomplished as part of a drilling program where a soil boring is advanced with drilling equipment to the designated depth prior to collection of a representative sample. The general procedures outlined briefly in the following section provide requirements for advancing drill casing/augers in preparation for sampling.

Procedure:

Soil borings that are completed for soil sampling purposes are typically advanced using hollow-stem augers and sometimes drive-and-wash or other casing methods. The casing/augers must be of sufficient diameter to allow for soil sampling at a minimum. The casing/augers are advanced according to project requirements to the required depth for sampling. If hollow-stem augers are used, a temporary plug should be used in the lead auger to prevent the auger from becoming filled with drill cuttings while drilling is in progress.

Each split-barrel must be decontaminated prior to its initial use and following collection of each soil sample. Site-specific requirements for equipment decontamination should be outlined within the Project Sampling Plan.

For those borings which encounter obstructions, the casing/augers will be advanced past or through the obstruction if possible. Caution should be exercised when obstructions are encountered and an effort made to identify the obstruction before drilling is continued. If the obstruction is not easily drilled through or removed, the boring should be relocated to an adjacent location.

Sample Recovery

The split-spoon will be immediately opened upon removal from the casing/auger. The open sampler shall then be screened for volatile organics with a photoionization device (PID) if required by the project-specific plan. If the Sampling Plan also requires individual soil sample headspace screening for volatile organic compounds, then a small portion of the split-spoon sample shall be removed and properly contained for that purpose.

Sample recovery will be determined by the project geologist/sampling engineer who will examine the soil core once the sampler is opened. The length of sample shall then be measured with a folding rule or tape measure. Any portion of the split-spoon contents which are not considered part of the true sample (i.e., heaved soils) will be discarded. If the sample recovery is considered inadequate for sample characterization or analytical testing purposes, another sample should be collected from the next vertical interval if possible before drilling is reinitiated.

Adequate sample recovery for stratigraphic logging purposes and/or headspace organic vapor testing purposes should be approximately 15 centimetres. Adequate sample recovery

for analytical testing purposes is dependent on the type of analytical testing required. In some cases, continuous sampling over a short interval, and compositing of the sample, may be required to satisfy analytical testing requirements. Larger diameter samplers may be used if large volumes of soil are required for analytical testing.

Sample Containment - General

Once retrieved, the sample will be removed from the split-spoon and placed into the appropriate sample container. The sample will be split if necessary to meet sampling program requirements. Sample splitting may be necessary to provide individual samples for headspace testing, visual characterization, physical testing, analytical testing, or simply for archiving purposes. In general, most sampling programs are structured around environmental characterization needs; therefore, sample portions required for analytical testing should be collected first. The project-specific plan provides specific sample container requirements for each type of sample and should be referred to for guidance.

Sample Containment - Volatile Organic Analyses

Collection of subsurface soil samples for volatile organic analysis (VOA) is slightly more complex than collection of samples for other routine chemical or physical testing primarily because of the concern for the potential loss of volatiles during the sample collection procedure. To limit the potential for loss of volatiles, the soil sample needs to be obtained as quickly and as directly as possible from the split-spoon. This generally means that the VOA sample is to be collected and placed into the appropriate sample container first. The VOA sample should also be obtained from a discrete portion of the entire sample interval and not composited or homogenized. The remainder of the recovered sample can then be composited, homogenized or split to meet the other testing requirements. The boring log and/or sample logbook should be filled out to indicate actual sample collection depths for both VOA samples and other portions of the sample which may have been composited over a larger vertical interval.

7.2.2 Push tube sampling

Push tube sampling is the collection of continuous samples using a hydraulically powered percussion drill rig which hammers a hollow steel rod and cutting shoe into the ground. The rod is lined with a core sampler (liner), from which soil samples are collected. The liner placed inside the hollow drill rod which is typically made of either Teflon or Polyethylene Terephtalate Glycol (PETG), although stainless steel, brass or plastic (PVC) are also available, but less commonly used. A catcher is placed at the bottom end of the liner to prevent material falling out the bottom end when pulled up out of the borehole.

There are two types of drilling methodologies for push tube sampling:

Dual Tube (DT45): push tube sampling where two sets of rods are used. An outer casing of rods are driven down to keep the borehole open. The smaller diameter sampling rods are driven down the centre of the outer rods with lead rod containing the liner for sampling. This method of push tube drilling is required for unstable soils (such as sandy or silty soils) that will collapse into the borehole when rods are pulled out.

Macro Core Push Tube (MC): push tube sampling is where one set of rods are used for continuous push tube sampling. When used in stable soils (soils that won't collapse into the open uncased borehole such as clays) the sampling rod with lining is retrieved from the open hole and then placed back down the hole. When used in unstable soils a 3.2cm centre rod closed point assembly is added to the end of the rod to prevent collapsed soils entering the liner so the sample can be collected from the desired depth.

Procedure

- Drilling rods and cutting shoe are decontaminated prior to commencing drilling be scrubbing with diluted Decon 90 and rinsing in potable water.
- Driller places a new disposable liner with catcher placed inside lead sample rod and screws on the cutting shoe to the end of the rod.
- Driller assembles outer casing and the lead sample rod is driven into the ground to collect first sample depth interval.

- The lead rod is retrieved from borehole and the liner is removed by the driller. A hydraulic liner extruder may be used when the liner becomes stuck in the rod. Water is not to be used to remove a stuck liner (unless the material is not going to be sampled).
- Driller cuts open the liner using liner cutter. The top and bottom depth are marked on the liner by the driller with a permanent marker (the end with catcher is the bottom depth of the liner).
- Samples are collected from the required sampling interval wearing a new pair of nitrile gloves to collect each discrete sample from the liner (wearing cut resistant gloves beneath as the cut liner can have sharp edges). Use a decontaminated spatula/ trowel or gloved hand if the material is soft/loose to collect sample from liner as needed. Decontaminate the spatula/trowel between samples. Fill laboratory supplied soil jars in accordance with the sample containment procedure in **Section 7.2.1** above.
- When sampling for VOCs or dye testing ensure samples are collected immediately from the liner (log the cores after samples are collected). To reduce loss of volatiles don't cut open the liners until ready for sample collection or slow down the drilling process so the collection of samples keeps pace with drilling.
- Log recovered core in the liner in accordance with AECOM procedure for Soil and Rock Logging.
- Decontaminate the push tube shoe between push tubes with diluted Decon 90 and rinse with potable water.
- A new disposable liner is placed inside the lead rod and driven down to the next interval and then retrieved.

The above steps are repeated until target depth or push tube refusal is reached. Refusal will depend on the type and power of drill rig used, however will typically occur on bedrock, hard/dense fill or very stiff clays. (The maximum depth for push tube sampling is typically 12 - 15 m subject to lithology).

ANZ

Surface and shallow soil sampling via hand auger

Q4AN(EV)-336-PR1

1.0 Purpose and Scope

1.1 The purpose of this procedure is to provide a standardised method and equipment list for surface soil sampling. Use of hand augers provides quick, economic data in disturbed samples and is often utilised in areas that may be inaccessible to drilling rigs and excavators.

2.0 Health and Safety

2.1 Health and Safety Plan and Site Specific Safe Work Method Statements (SWMS) should be prepared prior to field work in accordance with the SWMS Development Procedure and in the Project Specific Health and Safety Plan Template.

2.2 Any subsurface excavation requires a Dial before You Dig search and surveyed by a licensed utilities surveyor and the Underground Utilities Checklist Form must be followed.

3.0 References

3.1 SWMS Development Procedure S4AN-701-PR1

3.2 Project Specific Health and Safety Plan Template S4AN-702-TP1

3.3 Underground Utilities Checklist Form S4AN-721-FM1

3.4 Soil Bore Log Q4AN(EV)-336-FM20

3.5 Mason, B.J. (1992) Preparation of soil sampling protocols: sampling techniques and strategies, United States Environmental Protection Agency, published July 1992.

4.0 Equipment

Equipment required to comply with this procedure includes:

- **Project plan and site plan** for proposed locations, depths and sampling procedure.
- **Soil augers** various models of soil augers are acceptable in obtaining environmental samples with the main difference being the type of head for specific soil types. Essentially a hand auger is made up of a T-bar handle, a shaft and a head, most often constructed from stainless steel. See plate 1 below.



Plate 1 Auger Heads

Head 1 is for small soil particles (<0.08 mm diameter) *i.e.* clays and silts; head 2 is for fine to coarse sands (<4.8 mm diameter); and head 3 is designed for fine gravels (<19 mm diameter). *NB*, most brand and makes of hand augers will not be able to recover any material greater than 20 mm diameter. Coarse gravels, cobbles and boulders will need to be removed by hand and scissor shovel.

Brands and makes of hand augers vary in shaft and handle materials and design. If you are expecting to encounter stiff clays/silts or dense granular material thinner shafts and ratcheted handles are not advised.

- **Trowel** for extruding the soil sample from the auger head once recovered from the sub-surface.
- **Plastic sheeting** for laying the material as it is recovered from the subsurface, in order to build a picture of the lithology.
- **Tape measure** for measuring depths within the excavation.
- **Cut-resistant gloves** for use during the manual handling element of the procedure.
- **Nitrile gloves** to be used when taking environmental soil samples.
- **Pocket penetrometer** to measure the unconfined compressive strength of clays and silts. OPTIONAL.
- **Sampling flags** to be placed after moving from location for visibility. OPTIONAL.
- **Field notebook** for logging soil lithology.
- **Camera and photoboard** for documenting the lithology.
- **Decon 90 or similar non-ionic type detergent and water** for decontamination between locations.
- **Rubbish bags or drums** for waste cuttings.

5.0 Procedure

5.1 **STEP BACK**. Do one final check of local utilities. Are you happy that, based on the information provided, it is not likely that subsurface utilities are beneath your location? Remember surface and shallow soils are the danger area for utilities! Stay alert to sharp contacts in fill material strata (especially dry, loose engineering sands), plastics/metal objects and allow the rotary action of auger head do its work; hitting objects within a pit using percussive force is discouraged, especially when visibility is low at depth!

5.2 Surface and shallow soil samples will be collected from each of the locations and depths identified in the project plan. A pair of cut-resistant gloves is to be worn next to the skin, overlain by a new pair of nitrile gloves that will be replaced between locations. Each sampling location must be recorded on a site plan prior to collecting the sample.

5.3 Place the plastic sheeting adjacent to the location, weighing it down with nearby heavy objects at the corners. With the trowel, cut a square of turf and remove to the side of the location NOT on the plastic sheeting. This will be used later to reinstate the location.

5.4 Based on initial site walkover, select the appropriate auger head and place the hand auger head on the ground, positioning vertically with the T-bar handle at the top. Holding the tool with hands either side of the bar, apply downwards pressure sufficient enough to drive the auger the length of the head into the subsurface whilst applying a twisting force. *NB*, at this point, during stiff or dense ground conditions, significant stress can be placed across the skeletal muscles around the spine; take care not to overexert pressure to the twist.

5.5 Remove the tool from the ground by pulling up on the handle whilst applying a twisting force; again, correct posture should be a straight back and bent knees, with force coming from the quadriceps and biceps, not the back muscles. If the sample was retrieved successfully, a plug of soil will be within the auger head.

5.6 Hold the hand auger horizontally or place it on the ground. Using a clean pair of nitrile gloves over the cut-resistant ones, use the trowel to extrude the soil from the auger head, placing soil directly into a sample container if a sample is needed. If a sample is not need, place the cuttings from the auger head onto the plastic sheeting in a manner that will allow a top to bottom, right to left construction of lithology from the cuttings as per plate 2 below.

5.7 Decontaminate the trowel using decon-90 or similar and take a rinsate sample if necessary.



Plate 2 Lithology Construction

5.8 After reaching the target depth of the location and taking appropriate samples as per the project plan, the lithology should be logged as per the approved AECOM procedure for Soil and Rock Logging and photographed with a photo board. All locations will require a photo for future queries once the site works have been completed.

5.9 The cuttings should then be disposed of as per the project plan and the hand auger head removed and decontaminated. The plastic sheeting and nitrile gloves are dedicated to each location and should then be thrown away.

Surface Water Sampling

1.0 Purpose

This procedure describes the methods for collecting direct or representative surface water samples from streams, rivers, lakes, ponds, lagoons, and surface impoundments. It includes samples collected from depth, as well as samples collected from the surface. If followed properly, use of this procedure will promote consistency in each of the above areas and ensure regulatory compliance across Australia and New Zealand where best practice guidelines have been developed.

2.0 Scope

The following samplers and sampling techniques result in the collection of representative samples from the majority of surface waters and impoundments encountered.

- Kemmerer bottle
- Van Dorn sampler
- Bacon bomb sampler
- Dip Sampler
- Direct method

3.0 Health and Safety

3.1 Health and Safety Plan and Site Specific Safe Work Method Statements (SWMS) should be prepared prior to field work in accordance with the SWMS Development Procedure and in the Project Specific Health and Safety Plan Template.

3.2 When sampling from water bodies, physical hazards must be identified and adequate precautions must be taken to ensure the safety of the sampling team. The team member collecting the samples should stay away from the edge of the water body, where bank failure may cause loss of balance. When collecting samples near the edge of water bodies, personnel should wear a lifeline or use a buddy system for added safety. All sampling personnel must wear personal flotation devices (life vests). If sampling from a boat, appropriate protective measures must be identified and implemented in accordance with reviewed and approved Health and Safety Plans and Site Specific Safe Work Method Statements (SWMS).

4.0 Terms and Definitions

Morphometry: The measurement of the form characteristics, including area depth, length, width, volume, bottom gradients, of a surface water body.

Impoundments: A body of water formed by the collection or confinement of water, as if in a reservoir.

Boat wake: The visible track of turbulence left by a boat moving through water.

Substrate: Stream substrate (sediment) is the material that rests at the bottom of a stream, including mud (silt and clay), sand, granules, pebbles, cobbles and boulders.

5.0 References

5.1 SWMS Development Procedure S4AN-701-PR1

5.2 Project Specific Health and Safety Plan Template S4AN-702-TP1

6.0 Equipment

Equipment needed for collection of surface water samples may include (depending on the chosen technique):

Table 1 Surface Water Sampling Equipment

Equipment	
Kemmerer bottles	Field data sheets
Van Dorn sampler	Decontamination equipment / supplies
Bacon bomb sampler	Maps / plot plan
Dip sampler	Safety equipment
Line and messengers	GPS
Peristaltic pump	Tape measurer
Tygon tubing	Camera
0.45 micron filters	Logbook
Sample bottles / preservatives	Personal protective equipment (including personal flotation devices, as needed)
Water quality meter including calibration fluids	Ice
Chain of custody records, custody seals	Eskies, packing material
Long water quality cables may be required if stratification is being measured	

7.0 Best Practice Guidelines

A number of guidelines have been developed across the ANZ region outlining best practice methods for surface water sampling. Consideration of these must be made when designing and implementing surface water sampling within the ANZ region. Key documents noted include those detailed in Table 2 below:

Table 2 Best Practice Guideline References

Level	Reference
National / Federal	ANZ Standard 5667.1:1998 Part 1: *Guidance on the design of sampling programmes, sampling techniques and the preservation and handling of samples*
	ANZ Standard 5667.4.1998 Part 4: *Guidance on sampling from lakes, natural and man-made.*
	ANZ Standard 5667.6.1998 Part 6: *Guidance on sampling rivers and streams*
	ANZ Standard 5667.9.1998 Part 9; *Guidance on sampling marine waters*
State – Western Australia	Government of Western Australia Department of Water: *Surface Water Sampling Methods and analysis – Technical Approaches. Standard operating procedures for water sampling – methods and analysis. January 2009.*

It should also be noted that specific guidance documents or advisory notes for surface water sampling may also exist across ANZ and state to state for specific industries. For instance in the Northern Territories (NT) the Department of Mines and Energy have provided an advisory note outlining good practice for sampling of surface waters at mine sites in the NT.

8.0 Procedure

8.1 Planning

The extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies needed should be outlines in the project-specific sampling plan. Sampling and monitoring equipment should be properly decontaminated prior to initial use, between sampling locations, and following completion of the sampling event. General locations for sampling should be marked or identified on a site map with a geo-reference to landmarks/topography, GPS coordinates or measured from a fixed feature. If required, the proposed locations may be adjusted based on site

access, property boundaries, and obstructions. Final sample locations should be documented using topographic maps/ site plans or a GPS unit to identify and record sample location coordinates.

8.2 Sampling Considerations

In order to collect a representative sample, the hydrology and morphometry of a stream, river, pond, lake or impoundment should be determined prior to sampling. This will aid in determining the presence of phases or layers in lagoons or impoundments, flow patterns in streams, and appropriate sample locations and depths. Water quality data should be collected in ponds, lakes and impoundments to determine if stratification is present. Measurements of dissolved oxygen, pH, conductivity, oxidation-potential, temperature and turbidity can indicate if strata exist that would affect analytical results. Measurements should be collected at one-meter intervals from the surface to the bottom using the appropriate instrument.

These water quality measurements can assist in the interpretation of analytical data, and the selection of sampling sites and depths when surface water samples are collected. Factors that contribute to the selection of a sampling device used for sampling surface waters in streams, rivers, lakes, ponds, lagoons, and surface impoundments include:

- width, depth, flow and accessibility of the location being sampled; and,
- whether the sample will be collected onshore or offshore.

The appropriate sampling device must be of a proper composition. Selection of samplers constructed of glass, stainless steel, polyvinyl chloride (PVC) or PTFE (Teflon®) should be based upon the suspected contaminants and the analyses to be performed.

8.3 Sample Collection

8.3.1 Direct Method

For streams, rivers, lakes, and other surface waters, the direct method may be utilized to collect water samples directly into the sample container(s). Health and safety considerations must be addressed when sampling lagoons or other impoundments where specific conditions may exist that warrant the use of additional safety equipment. Using adequate protective clothing, access the sampling station by appropriate means.

For shallow stream stations, collect the sample under the water surface while pointing the sample container upstream; the container must be upstream of the collector. When possible, collect samples in a downstream to upstream direction and avoid disturbing the substrate beneath the water.

For lakes and other impoundments, collect the sample under the water surface (10 to 20 cm) while avoiding surface debris or boat wake.

When using the direct method, do not use pre-preserved sample bottles as the collection method may dilute the concentration of preservative necessary for proper sample preservation. Use a non preserved bottle, rinse it three times with the surface water, collect the sample, then transfer the surface water to the appropriately preserved bottles. Details of suitable preservatives and bottles

8.3.2 Kemmerer Bottles

A Kemmerer bottle may be used in most situations where site access is from a boat or structure, such as a bridge or pier, and where samples at specific depths are required. Sampling procedures are as follows:



a) Use a properly decontaminated Kemmerer bottle. Set the sampling device so that the upper and lower stoppers are pulled away from the body, allowing the surface water to enter tube.
b) Lower the pre-set sampling device to the predetermined depth. Avoid disturbance of the bottom.
c) When the Kemmerer bottle is at the required depth, send the weighted messenger down the suspension line, closing the sampling device.
d) Retrieve the sampler and discharge the first 10-20 milliliters (mL) from the drain to clear potential contamination from the valve. This procedure may be repeated if additional sample volume is needed to fulfil analytical requirements. Subsequent grabs may be composited or transferred directly to appropriate sample containers.

8.3.3 Van Dorn Sampler

A Van Dorn sampler is used to collect a surface water sample from a specific sampling depth or from a shallow water body. Since the sampler is suspended horizontally, the depth interval sampled is the diameter of the sampling tube. The sampling procedure is as follows:

a) Use a properly decontaminated Van Dorn sampler. Set the device so that the end stoppers are pulled away from the body allowing surface water to enter the tube.
b) Lower the pre-set sampling device to the predetermined depth. Avoid disturbance of the bottom.
c) When the Van Dorn is at the required depth, send the weighted messenger down the suspension line, closing the sampling device.
d) Retrieve the sampler and discharge the first 10-20 mL from the drain to clear potential contamination from the valve. This procedure may be repeated if additional sample volume is needed to fulfil analytical requirements. Subsequent grabs may be composited or transferred directly to appropriate sample containers.

8.3.4 Bacon Bomb Sampler

A bacon bomb sampler may be used in situations similar to those outlined for the Kemmerer bottle. Sampling procedures are as follows:



a) Lower the bacon bomb sampler carefully to the desired depth, allowing the line for the trigger to remain slack at all times. When the desired depth is reached, pull the trigger line until taut. This will allow the sampler to fill.
b) Release the trigger line and retrieve the sampler.
c) Discharge the first 10-20 mL from the drain to clear potential contamination from the valve. This procedure may be repeated if additional sample volume is needed to fulfil analytical requirements.

8.3.5 Dip Sampler

A dip sampler is useful in situations where a sample is to be recovered from an outfall pipe or along a lagoon bank where direct access is limited. The long handle on such a device allows access from a discrete location. Sampling procedures are as follows:



a) Assemble the device following manufacturer's instructions.
b) Collect the sample by dipping the sampler into the water.
c) Transfer the sample to the appropriate sample container(s).

8.4 Sample Preservation, Containers, Handling and Storage

Once samples have been collected, the following procedures should be followed:

- Transfer the sample(s) into suitable, labelled sample containers specific for the analyses to be performed.
- Measure field parameters with a calibrated water quality meter.
- Filter the sample on site if required (for example, as is required for dissolved metals analysis).
- Preserve the sample, if appropriate. Do not overfill bottles if they are pre-preserved.
- Cap the container securely, place in a resealable plastic bag, and cool to 4°C.
- Record all pertinent data in the site logbook and/or on field data sheets.
- Complete the Chain of Custody record.
- Attach custody seals to esky prior to shipment.
- Decontaminate all non-dedicated sampling equipment prior to the collection of additional samples.

9.0 Records

The following records will be maintained:

9.1 sample collection records, including a record of the surface water sampling locations on a site map with a geo-reference to landmarks/topography, GPS coordinates, or measured from a fixed feature;

9.2 field notebook;

9.3 chain-of-custody forms; and,

9.4 shipping receipts.

All documentation will be placed in the project files and retained following completion of the project

CHAIN OF COUSTODY

Submitted to: Australian Laboratory Services (Brisbane)
2 Byth St, Stafford 4053. (Corner of Byth & Shand Streets). Phone: 07 3243 7222

CLIENT: AECOM (Brisbane Office)

OFFICE: Brisbane Level 8 - 540 Wickham Street Fortitiude Valley QLD 4006

PROJECT:

ORDER NUMBER: 605XXXXX Task: X.X

PROJECT MANAGER: First Name, Last Name | **CONTACT PH: 3553 2000**

SAMPLER: First Name, Last Name | **SAMPLER MOBILE:** XXXX XXX XXX

COC emailed to ALS? Circle (YES / NO) | **EDD FORMAT (or default):**

Email Reports to: sampler@aecom.com, project.manager@aecom.com

Email Invoice to: project.manager@aecom.com

TURNAROUND REQUIREMENTS : (Standard TAT may be longer for some tests e.g.. Ultra Trace Organics)

☐ Standard TAT **(List due date):** Non Standard TAT:

ALS QUOTE NO.: **EN/004/16**

COC SEQUENCE NUMBER (Circle)

COC:	**1**	**2**	**3**	**4**	**5**	**6**	**7**
OF:	**1**	**2**	**3**	**4**	**5**	**6**	**7**

FOR LABORATORY USE ONLY (Circle)

Custody Seal Intact?	Yes	No	N/A
Free ice / frozen ice bricks present upon receipt?	Yes	No	N/A
Random Sample Temperature on Receipt:		˚C	
Other comment:			

RELINQUISHED BY:	**RECEIVED BY:**	**RELINQUISHED BY:**	**RECEIVED BY:**
Sample Signature			
DATE/TIME:	DATE/TIME:	DATE/TIME:	DATE/TIME:

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

ALS USE ONLY	**SAMPLE DETAILS** MATRIX: Solid(S) Water(W)			**CONTAINER INFORMATION**		**ANALYSIS REQUIRED including SUITES** (NB. Suite Codes must be listed to attract suite price) Where **Metals** are required, specify **Total** (unfiltered bottle required) or **Dissolved** (field filtered bottle required).								**Additional Information**
LAB ID	**SAMPLE ID**	**DATE / TIME**	**MATRIX**	**TYPE & PRESERVATIVE** *(refer to codes below)*	**TOTAL BOTTLES**	**EP231X - (PFAS – Full Suite - (28 analytes))**	**EP231X (TOPA) (PFAS – Full Suite TOPA (28 analytes))**		**HOLD**					
TOTAL														

ANZ

FQM - Daily Activity Report

Q4AN(EV)-002-FM1

Project Name:		**Project Number:**	
Project Location:		**Client:**	
Date of Fieldwork:		**PM Name:**	
Time Arrive:		**Time Depart:**	

Administration

Personnel On-Site:	
Contractors (Inducted, Downtime):	

Tasks Undertaken

Describe tasks and time of activities undertaken, observations, communications with PM, clients and subcontractors etc.

☐Cross out unused portions of the site notes ☐ Indicate QAQC samples collected & note on tracking sheet

☐ Record number waste drums transported on & off-site ☐ Indicate observations of on-Site environmental receptors

Indicate Weather Conditions:

HSE Actions

Describe any HSE actions or oberservations or additional information that is not recorded in the HSEP

Approval and Distribution

Fieldwork Staff Signature **Date**

Distribution: Project Central File

FQM - Borehole\ Monitoring Bore Field Log

Project Name:		**Project Number:**		**Borehole No.:**
Project Location:		**Client:**		
PM Name:		**Date Commenced:**		
Bore Location:		**Date Completed:**		**Sheet** **of**
Drill Contractor:		**Fieldwork Staff:**		

Drill Model: Hole Angle: deg. Bore Size: RL:

Drilling Fluid: Orientation: deg. Co-ords: Permit No.:

Field Data

Material Description									Field Notes	Well Construction			
Method	Casing	Penetration	Depth	Graphic Log	USCS Classification	Type, colour/mottling, plasticity/particle size,secondary/minor components, soil origin	Moisture	Consistency/Rel Density	PID (ppm)	Sampling	Odour, staining, groundwater observations/regime, additional information	Gatic: Standpipe: Well Cap: Surface Seal: Backfill: Seal: Filterpack:			
												Depth	Anulus	Casing	Anulus

ANZ

FQM - Gas Monitoring Calibration Record

Q4AN(EV)-003-FM1

Project Name:		**Project Number:**	
Project Location:		**Client:**	
PM Name:		**Fieldwork Staff Name:**	

This calibration record is intended to prompt fieldwork staff to calibrate various gas instruments (PID, LEL, Landfill gas meters) daily before the start of fieldworks.

INSTRUMENT DETAILS

Supplier:	
Make and Model:	
Serial Number:	
For PID - Lamp Photon Energy (eV):	

CALIBRATION

Calibration (Span) Gas:	
Batch Number:	
Expiry Date:	
Concentration (ppm or % v/v):	

CALIBRATE WITH SPAN GAS

Calibration Date:					
Calibration Time:					
Fresh Air Calibration Reading (ppm or % v/v):					
Calibration Reading (ppm or % v/v):					

CORRECTION FACTOR

The project HSEP provides the target compound/s of interest and should include the appropriate correction factor to be used for the PID.

Target Compound/s:	
Correction Factor:	

BUMP TEST WITH SPAN GAS

Time:					
Bump Test Reading (ppm):					

ALARM LEVELS

The project HSEP provides actions levels for the target compound/s of interest and the instrument should be set up with high and low level alarms based on the action level concentrations where required.

High Level Alarm (ppm or % v/v):	
Low Level Alarm (ppm or % v/v):	

TEST ALARMS BY BUMP TEST

Time:					
Alarms Activated at Low Level (Y/N):					

COMMENTS

Detail any equipment faults, minor maintenance performed, change of batteries or technical support provided.

Approval and Distribution

Fieldwork Staff Signature _____ **Date** _____

Distribution: Project Central File

ANZ

FQM - NAPL and Groundwater Level Gauging Record

Project Name:		**Project Location:**		**PM Name:**	
Project Number:		**Client:**		**Fieldwork Staff Name:**	

Confirm NAPL and groundwater levels by repeat measurements. All columns must be completed. If NAPL is not present in a well write 'ND' (Not Detected) in the relevant column.

Field Data

Well ID	Date (dd/mm/yy)	Time (24hr:mm)	PID Reading (ppm)	Depth to LNAPL (mBTOC)	Depth to Groundwater (mBTOC)	LNAPL Thickness (m)	Depth to DNAPL (mBTOC)	Total Well Depth (mBTOC)	DNAPL Thickness (m)	Comments (well condition, odour, NAPL colour and viscosity)

Measurement Equipment

Make & Model:		**Supplier:**	
Serial No.:		**Calibration Report Provided?**	

Notes/Comments

(PID) - photo ionisation detector; (ppm) - parts per million; (LNAPL) - light non-aqueous phase liquids; (DNAPL) - dense light non-aqueous phase liquid; (mBTOC) - metres below top of casing

Approval and Distribution

Fieldwork Staff Signature Date

Project Manager Signature Date

Distribution: Project Central File

ANZ

FQM - Groundwater Sampling and Purging Record

Q4AN(EV)-405-FM1

						Bore ID:	
Project Name:		**Project Number:**		**PM Name:**		**Sample Date:**	
Client:		**Project Location:**		**Fieldwork Staff:**		**Well Development or Well Sampling Event? (circle)**	

General Bore Information		**Parameter Info.**	**Decontamination**	**Sampling Method**	**Hydrasleeve info.**	
Date of GW Level:	Bore Radius (mm):	Chem Kit Serial No.:	☐ Decontaminated	☐ **Low Flow** Pump rate:	Hydrasleeve Size:	**Monitoring sequence followed (number in order):**
Depth to GW (m-pvc):	Screen Interval (m):	Chem Kit Model:	☐ Dedicated	Intake depth:	Hydrasleeve Type:	
Bore Depth (m-pvc):	Casing Radius (mm):	**Corrected Redox:** Y / N	☐ Disposable	☐ Bailer ☐ Hydrasleeve	Sampling Depth (m-pvc):	Gauging
Depth to Product (m-pvc):	Cover Type (gatic/stick up):	(The correction to apply is probe dependent)	☐ Other (specify)	☐ Peristaltic Pump ☐ Waterra	Hydrasleeve Install time:	Hydrasleeve in
Product Thickness (m):	Bore Locked (YES/NO):	**Parameter method:** ☐ Downhole		☐ Other (specify)	Sampling Start Time:	Hydrasleeve out
	Key Type (if applicable):	☐ Retrieved				Parameters

Calculated bore volume (L):	Includes/ excludes bore annulus (circle)	# purge volumes removed:	Total purged volume (L):

Water Quality Parameters

Time	Cumulative Vol. Removed (L)	SWL (m-pvc)	Pump Rate	DO (ppm or mg/L)	E.C. (mS/cm or µS/cm)	pH	Redox (mV)	Temp °C	Odour, Colour, Turbidity
Acceptable Parameter Range:				± 10%	± 3%	± 0.05	± 10 mV	± 0.2 °C	± 10% turbidity (if using a turbidity meter)

Analytes Sampled for:		**Bottles Collected**						**QA/QC Information**	**Field Commets**
Field Filtered:	**Unfiltered:**		x 40 mL Vial (HCl)		x 60 mL Ferrous		x 60 mL metals (HNO_3)		Bore volume calculation, bore condition, fate of tubing, redox correction etc.
			x 40 mL Vial (H_2SO_4)		x 100 mL Amber		x 250 mL Plastic		

Approval and Distribution

Fieldwork Staff Signature	**Date**	**Checker Name and Signature**	**Date**
Project Manager Signature	**Date**	**Distribution:** Project Central File	

AECOM

ANZ

FQM - Sample QAQC Tracking Sheet

Q4AN(EV)-011-FM1

Project Name:		**Project Number:**	
Project Location:		**Client:**	
PM Name:		**Fieldwork Staff:**	

QAQC Information

QAQC ID	Primary Sample ID	Sample Type	Batch Number

QA\QC Project Requirements

QAQC	Required		Frequency		Method Used
Field Duplicates	☐ Yes	☐ No	☐ 1 in 10	☐ 1 in 20	
Field Triplicates	☐ Yes	☐ No	☐ 1 in 10	☐ 1 in 20	
Rinsate Blanks	☐ Yes	☐ No	☐ 1 per matrix/equipment/day		
Field Blanks	☐ Yes	☐ No	☐ 1 per day		
Trip Blanks	☐ Yes	☐ No	☐ 1 per ice chest		
Trip Spikes	☐ Yes	☐ No	☐ 1 per ice chest		

Approval and Distribution

______________________________ **Fieldwork Staff Signature** ______________________ Date

______________________________ **Project Manager Signature** ______________________ Date

Distribution: Project Central File

16;#Australia New Zealand|a541b326-6e42-45fc-a7d5-d797f3cb72ce

Groundwater Monitoring Well Construction Detail Form

Q4AN(EV)-336-FM27

Project Details

Client			Well ID
Project Number			
Site Location			Date Installed
Well Location	Coords - Easting	Northing	Inspector
Method			Contractor

Delete or add monitoring well detail where appropriate.

