



Sampling Analysis and Quality Plan for Hazardous Ground Gas Assessment of the Nuclear-Powered Submarine Construction Yard, Osborne, South Australia

URPS

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We acknowledge the Traditional Custodians of Country throughout Australia and their connections to land, sea and community.

We pay respect to Elders past and present and in the spirit of reconciliation, we commit to working together for our shared future.

Caring for Country The Journey of JBS&G
Artist: Patrick Caruso, Eastern Arrernte

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Abbreviations

Term	Definition
ANI	Australian Naval Infrastructure
ASA	Australian Submarine Agency
BS	British Standard
BTEXN	Benzene, toluene, ethylbenzene, xylenes and naphthalene
CEMP	Construction Environment Management Plan
CIRIA	Construction Industry Research and Information Association
COC	Chain of Custody
COPC	Chemicals of Potential Concern
CSM	Conceptual Site Model
DO	Dissolved Oxygen
DQI	Data Quality Indicator
DQO	Data Quality Objectives
EIS	Environmental Impact Statement
EPA SA	Environment Protection Authority South Australia
EPA VIC	Environment Protection Authority Victoria
GSV	Gas Screening Value
HDPE	High Density Polyethylene
HGG	Hazardous Ground Gas
HGGRA	Hazardous Ground Gas Risk Assessment
LEL	Lower Explosive Limit (<i>of CH₄</i>)
LFG	Landfill Gas
LOR	Limit of Reporting
LTEL	Long Term Exposure Limit
mAHD	Metres Australian Height Datum
mBGL	Metres below ground level
NAPL	Non-aqueous Phase Liquid
NATA	National Association of Testing Authorities
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NSW EPA	New South Wales Environmental Protection Agency
PARCCS	Precision, accuracy, representativeness, comparability, completeness and sensitivity
PCA	Potentially Contaminating Activities
PFAS	Per- and polyfluoroalkyl substances
PID	Photo Ionisation Detector
PPB	Parts per Billion
PPM	Parts per Million
PSI	Preliminary Site Investigation

Term	Definition
PQL	Practical Quantitation Limit
QA / QC	Quality Assurance/Quality Control
RPD	Relative Percent Difference
SAQP	Sampling, Analysis and Quality Plan
SCY	Submarine Construction Yard
STEL	Short Term Exposure Limit
SWL	Standing Water Level
TRH	Total Recoverable Hydrocarbons
TOC	Total Organic Carbon
UCL	Upper Confidence Limit
UEL	Upper Explosive Limit (<i>of CH₄</i>)
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compounds

1. Introduction and Background

1.1 Introduction

The Australian Submarine Agency (ASA) was established in July 2023 to safely and securely acquire, construct, deliver, technically govern, sustain and dispose of Australia's conventionally-armed nuclear-powered submarine capability for Australia.

Australian Naval Infrastructure (ANI) as the owner and manager of the existing Osborne Naval Shipyard is proposing the development of adjacent land to construct a new, purpose-built, secure, nuclear-powered Submarine Construction Yard (SCY; the subject site – see **Figure 1**, attached). The SCY will provide a facility for the construction of the submarines by a third-party ship builder, for delivery to ASA.

The Minister for Planning declared the SCY as an impact assessed development under section 108 (1)(c) of the *Planning, Development and Infrastructure Act 2016*, which requires the preparation of an Environmental Impact Statement (EIS).

JBS&G Australia Pty Ltd (JBS&G) was engaged by URPS, acting on behalf of ANI, to complete the Physical Environment chapter of the EIS (land-based portion of the subject site only).

In order to complete this chapter of the EIS, JBS&G undertook a limited preliminary site investigation (PSI), soil investigation and groundwater investigation¹. While no significant site derived contamination was identified at the subject site, methane was reported at elevated concentrations in the majority of groundwater wells across the site (likely to be naturally occurring as associated with historic swamps and mangroves). Methane is a volatile chemical and has the potential to impact the project (both construction and operation) via accumulation in enclosed spaces, and hence further assessment of the risks from methane via the vapour pathway were recommended.

This Sampling and Analysis Quality Plan (SAQP) has been prepared to detail the objectives, scope, and methodology of the Hazardous Ground Gas (HGG) assessment proposed to inform the EIS.

Note: At time of writing and parallel to this assessment, it is understood the Siting and Site Evaluation Report (SSER) was being prepared for the SCY site. The SSER documents and characterises the natural and human induced hazards that could affect the safety of the nuclear licenced activities where they occur at the site. The results of any assessment works undertaken as part of the SSER have not been shared with JBS&G, and hence have not informed the scope of the HGG assessment works outlined herein.

1.2 Background

Prior to European settlement, the north-eastern portion of the Le Fevre Peninsula consisted predominantly of swamps and mangroves. The peninsula was subject to land reclamation activities from the late 1930's, and was significantly modified by the mid 1980's when minimal swamps and mangroves remained.

The highly organic swamp and mangrove deposits underlying the site will remain below the fill and slab-on-grade building construction, and may decay slowly over many years, generating methane and carbon dioxide. Marine and estuarine deposits such as these often contain sulphides and may also release hydrogen sulphide. Dissolved methane and carbon dioxide that has degassed may reach relatively high concentrations in monitoring wells or the unsaturated zone under the slab (partitioning is reversible, so the equilibrium soil gas

¹ *Nuclear Powered Submarine Construction Yard – Site Contamination Assessment*, JBS&G Australia Pty Ltd, 11 November 2024 (JBS&G 2024).

concentration is the same as the partial pressure in the source)². However, mass transport rates of methane out of solution are a function of groundwater flow rates and other factors that are not likely to pose an unacceptable risk to the future development for JBS&G's scope of assessment work, noting that the nuclear licencing requirements will be assessed within the SSER.

Diffusive flow depends on a concentration gradient being present (i.e. methane and other HGG will move from an area of high concentration to a low concentration). The low permeability nature of the underlying soils (sands) that are inundated with sea water/groundwater are likely to result in diffusion as the dominant HGG migration mechanism (Wilson et al, 2019³).

There is some potential for advection of HGG during low-high tide events, if tidal influences are affecting the groundwater levels at the subject site (currently unknown). The diffusion migration mechanism is widely regarded as a low-risk pathway when compared to HGG migration via advection (pressure difference seen in landfill environments) – i.e. the mass flux of dissolved methane at sea level is not likely to be high enough to accumulate to dangerous levels but it may be sufficient to exceed the typical Action Levels for Landfill Gas (LFG) in sub-surface wells outside landfills⁴.

Given the above, the overall approach of the investigation will be designed to initially characterise gaseous concentrations of HGG onsite, and to determine the source of methane and carbon dioxide using a multiple lines of evidence approach.

1.3 Objective

The objective of this SAQP is to detail the proposed sampling and analysis strategy to conduct a staged HGG Risk Assessment (HGGRA), in accordance with the relevant guidelines. It is noted that the HGGRA excludes the requirements for nuclear licencing, which are being addressed within the SSER.

1.4 Guidance Documents

In the absence of guidance pertaining to HGG assessments in South Australia, the following Australian documents have been considered and referred to where relevant, including:

- NSW EPA (2020);
- *Environmental Guidelines Solid waste landfills*, Second Edition, NSW Environment Protection Authority, 2016 (NSW EPA 2016);
- EPA VIC (2015); and
- *Publication 1684: Landfill gas fugitive emissions monitoring guideline*, Environment Protection Authority Victoria, February 2018 (EPA VIC, 2018).

In addition, where appropriate, the following international guidance was also considered:

- *BS8576: 2013 Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs)*, British Standards Institution, 2013 (BSI, 2013);
- BS 8485:2015+A1:2019 Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings, British Standards Institution, 2019 (BSI, 2019); and
- *LFTGN03 Guidance on the Management of Landfill Gas*, UK Environment Agency, 2004 (UK EA, 2004).

² *Assessment and management of hazardous ground gases, Contaminated Land Guidelines*, NSW Environment Protection Authority, May 2020 (NSW EPA, 2020).

³ *Technical Paper: Risk and Reliability in Gas Protection Design – 20 years on: Part 1 and Part 2*, Geoff Card, James Lucas and Steve Wilson, 2019 (Wilson et al 2019).

⁴ *Publication 788.3: Siting, design, operation and rehabilitation of landfills*, Environment Protection Authority Victoria, August 2015 (EPA VIC, 2015).

2. Initial Conceptual Site Model for Hazardous Ground Gases

2.1 Scope of the Initial CSM for HGG

The initial CSM for HGG is a simplified representation of a complex relationship between the gas source/s, pathways and receptors. The purpose of the HGG CSM is to provide the technical basis for this HGG investigation, and assist in identification of various temporal and operational effects that could influence the source-pathway-receptor linkages and the ground gas regime.

The HGG CSM is an iterative tool that will evolve as the assessment, risk characterisation and response actions are developed during the course this investigation.

The scope of the initial HGG CSM is to address the following concepts:

- The source of gas including the origin, dimension of plume, composition, rate of generation and properties of gas. The generation and transport of HGG through the subsurface is likely to be highly variable and will be affected by atmospheric conditions such as rainfall, groundwater levels and barometric pressure fluctuations;
- Potential pathways in which HGG can move are affected by the presence of preferential pathways, geology and hydrogeology. Capping, containment, perched water, layers and types of fill and their compaction are also significant in affecting gas movement. Natural attenuation mechanisms and chemical reactions likely to occur in the sub-surface were also considered; and
- Potential receptors for future site use, including landuse, the location of future buildings, and the likely types of building construction (e.g. potential future service pits [confined spaces] or slab on grade constructions).

2.2 Potential Sources of HGG at the site

The initial HGG CSM considered the primary HGG to be predominately methane and carbon dioxide. It is considered that the primary source of these gases is from the natural swamp, mangrove clays / muds and organic fractions contained in imported fill underlying the site.

Each source of gas will typically contain a range of different compounds in different proportions and is referred to as the 'gas fingerprint'. The differences in compounds present can be used to ascertain the most likely source of the gas. Consideration of the presence of secondary gases presented in Table 1 and Table 2 in NSW EPA (2020) has been undertaken in the context of the site. These include hydrogen sulphide, a secondary gas that may be present within reclaimed wetlands and mangroves, generated from swamps, wetlands and waterlogged soils.

Methane is generated by microbial activity on carbonaceous matter, and so the total gas quantity depends on the size of the carbon reservoir (potential or actual). The total carbon reservoir in an area will influence the potential lifetime of gas generation, and may indicate that the potential exists for gas generation, even if it is not occurring at present.

Methane that migrates into the shallow soil may be oxidised to carbon dioxide and water by aerobic methanotrophic bacteria present in the soil (NSW EPA 2020). Therefore, this mode is potentially not as hazardous as deep HGG migration that could migrate through the sandy geology and up directly under a structure is a fault, fissure or preferential pathway.

Various literature sources also report that risks associated with release of methane and carbon dioxide from peat, alluvium and marine sediments are low for several reasons, as follows:

- When alluvium was initially deposited it contained organic material. Initially this would have degraded to produce gas, however only the labile (easily degradable material) would have been used up. The

reservoir of organic material that is left in the ground is non-labile or very slowly degradable – the turnover rate for this material will be many thousands of years (Couwenberg 2009⁵);

- As the gas was generated it would have been emitted from the surface of the alluvium. As more layers are deposited eventually the gas becomes trapped in the soil in various forms such as:
 - Trapped in small gas pockets that do not move because of surface tension forces;
 - Dissolved in pore water; or
 - Adsorb to organic material.

For a hazard to exist there must be enough flow of methane from the available soil gas source to cause gas concentrations greater than the Lower Explosive Limit (LEL) inside the future structure/s. ASTM (2016⁶) state that there are no known examples of methane incidents from diffusive transport alone. ASTM (2016) state that the potential for significant rates of soil gas transport can be recognised by relatively high differential pressure equivalent to greater than about 5 millibar (mb) along with high concentrations.

Where the fill is thick and is well compacted in the upper portion of the soil profile, high gas concentrations can be encountered. These conditions are not usually associated with high gas pressure or sustained flow rates, but flow forced by barometric pumping or groundwater level fluctuations may occur (NSW EPA, 2020). The tidal changes may lead to an enhanced pressure gradient between the ground and surface, and between the ground and indoor air spaces. However, fluctuations in tidal fluctuations may also initiate pressure-driven flow in an advective pressure scenario (i.e. unsaturated soil pore space).

2.3 Migration of HGG with Groundwater Flow in the Dissolved Phase

Methane can be transported as a dissolved product in groundwater (although solubility is very low around 25-35 mg/L) and when the pressure is reduced or temperature is increased, this dissolved methane can volatilise out of solution. Estimates of dissolved methane equate to 25 mg/L or 3 to 6 % v/v in a monitoring bore (Card, 1995⁷). It is possible for dissolved phase transport of methane and carbon dioxide from groundwater into soil gas above the water table, however, this is a function of groundwater flow rates.

It is unlikely that a significant risk is posed from HGG dissolved in groundwater due to the following:

- Methane gas will not easily dissolve into groundwater or leachate at, or close to, atmospheric pressures. Carbon dioxide is more likely to dissolve into ground water than methane; and
- It is unlikely that there would be a sufficient volume of HGG dissolved to present a hazard, although data has not been presented at this stage to discount this risk.

Carbon dioxide is soluble in water and will form carbonic acid in aqueous solutions where carbon dioxide gas is present. The condensate will be acidic (generally around pH 3 to 6.5) due to dissolved carbon dioxide and acidic trace compounds. This media can corrode a range of metals.

2.4 Human Receptors

The following potential human receptors of ground gases and vapours have been identified:

- Onsite workers (during site operation);
- Construction workers (during the construction program); and

⁵ *Methane emissions from peat soils (organic soils, histosols) facts, MRV-ability, emission factors*, John Couwenberg, August 2009, http://www.imcg.net/media/download_gallery/climate/couwenberg_2009b.pdf (Couwenberg, 2009).

⁶ *Standard Guide for Evaluating Potential Hazard as a Result of Methane in the Vadose Zone, ASTM E2993-16*, ASTM International, 2016 (ATSM 2016).

⁷ *Protecting Development from Methane* – CIRIA Report 149, GB Card (Card 1995)

- Sub-surface maintenance workers of any confined spaces (during site operation).

The building layouts and engineering drawings, if available, will be reviewed as part of the HGG risk assessment to characterise the source-pathway-link.

3. Data Quality Objectives

The DQO process outlined in the *National Environment Protection (Assessment of Site Contamination) Measure*⁸ has been adopted to establish the type, quantity and quality of data needed to inform the study. The following sections address the seven-step DQO process with relevant inputs seeking to address the project objectives outlined in **Section 1.3**.

3.1 State the Problem

Methane was reported at elevated concentrations in the majority of groundwater wells across the site. Methane (and other associated ground gases including carbon dioxide and hydrogen sulphide) have the potential to impact the project (both construction and operational stage) via the vapour pathway (primarily due to explosive risk and asphyxiation).

3.2 Goal of the Study

The objectives of the staged HGGRA are as follows:

- To define the likely source of the HGG;
- To assess whether there is a potential human health risk to the identified receptors due to HGG; and
- If required (subject to the outcomes of the screening HGGRA), provide mitigation measures to manage HGG.

3.3 Information Inputs

In general terms, the HGGRA is related to acute risks associated from accumulation of gross volumes of HGG (i.e. explosion and asphyxiation). A screening assessment will be carried out to assess longer term (chronic) exposure to low concentrations of trace gases and Volatile Organic Compounds (VOCs) that may be present at the site.

As staged assessment has been outlined below. The staged assessment will not need to progress pass the initial stages if Action Levels are not exceeded, and the source has been characterised.

The following scope is proposed to be undertaken:

- Augment current desk-based studies, and soil and groundwater investigation data from a HGG perspective. This includes refining the HGG CSM and articulating this on scaled plans that show aspects such as nature and dimension of potential HGG sources, distance, and potential pathways (or absence of pathways and bulk gas sources) to future receptors, depth and type of imported fill (natural or anthropogenic sources), total organic carbon results and groundwater levels/variability;
- An initial drilling program comprising drilling of 42 boreholes converted to HGG monitoring wells on the site. This density satisfies the density recommended in *Assessing Risks Posed by Hazardous Ground Gases to Buildings*⁹, which requires 25 m to 50 m spacing for a 'high sensitivity development over made ground with limited degradable material, organic clays of limited thickness'. It is noted that groundwater investigation completed in 2024 (JBS&G 2024) reported groundwater levels between about 0.5 m and 2 m below ground surface – HGG wells need to be installed above the water table to avoid conflation.

⁸ *National Environment Protection (Assessment of Site Contamination) Measure 1999*, National Environment Protection Council, 1999 as amended 2013 (NEPC, 2013).

⁹ *C665: Assessing Risks Posed by Hazardous Ground Gases to Buildings*, Construction Industry Research and Information Association, December 2007 (CIRIA, 2007).

The proposed network will assess the variability in HGG concentrations (if present) as well as assess the impact of tidal influences on groundwater levels;

- Monitoring of the 42 HGG wells at discrete intervals in all HGG wells, and production of Ternary plots to provide a simple graphical approach to examining the composition of the ground gases encountered in the targeted wells and investigating the potential for differences in the nature and source of the gas encountered at different locations and areas. Such information can help to further characterise the ground gas regime, differentiate between potential sources and provide additional lines of evidence to support the HGG CSM. The plots can also be used to identify when carbon dioxide concentrations above 5 %v/v are likely to pose a low risk and do not warrant the increase from Characteristic Situation CS1 to CS2 discussed in NSW EPA (2020);
- Additional monitoring of groundwater will be undertaken utilising 15 existing groundwater wells installed in the Q1 aquifer, including the following:
 - Groundwater monitoring event of the 15 existing wells, with analysis for dissolved carbon dioxide, methane and hydrogen sulphide); and
 - Installation of two high frequency groundwater level loggers at targeted groundwater well locations, to accurately measure groundwater levels and tidal fluctuations to assess risks from piston effect (if relevant).

3.4 Study Boundaries

The site location and physical boundaries of the subject site are shown in **Figure 1**. The HHGRA will consider the subject site only.

HGG wells are to be installed to a maximum depth of 2 m below ground level (bgl).

Existing groundwater monitoring wells included in the sampling program are installed within the Q1 aquifer (total depth of 5 mbgl).

The HGG assessment is to be staged due to use of the sediment ponds in Area 3 for dewatering effluent in the second half of 2024, which resulted in elevated groundwater levels in this portion of the site. To this end, the HGG assessment of Area 1 and 2 and the groundwater monitoring is to be completed between August and December 2024). The HGG assessment of Area 3 will be undertaken between March and June 2025.

As outlined in **Section 1**, it is noted the nuclear licensing requirements are beyond the scope of the investigation completed by JBS&G and are being assessed within the SSER.

3.5 Decision Rules

The decision rules adopted to answer the decisions identified are summarised in **Table 3.1**.

Table 3.1: Summary of Decision Rules

Decision Required to be Made	Decision Rule
1. Is data of acceptable quality for interpretive purposes?	<p>The QA/ QC program for field monitoring of LFG throughout the investigation program will be reviewed against the precision, accuracy, representativeness, comparability, completeness and sensitivity parameters and associated DQIs.</p> <p>If the criteria are satisfied, the decision is Yes.</p> <p>If the criteria are not satisfied, the decision may be No, and further assessment of the quality and reliability of the data may be required.</p>

Decision Required to be Made	Decision Rule
2. Is there an appropriate level of understanding of background concentrations to inform the investigation outcomes?	If there is sufficient data / understanding from the desktop review and data collected to characterise background concentrations, the decision is Yes. Otherwise, the decision is No and further characterisation maybe required.
3. Has sufficient environmental data been collected to address the study objectives?	If sufficient environmental data has been collected to assess HGG across the site (i.e. data collected in accordance with this SAQP), then the answer is Yes. Otherwise, the decision is No, and additional data may need to be collected.
4. Are there potentially unacceptable risks to human health receptors on-site due to HGG?	Are landfill gas concentrations/ parameters present in ground gas at concentrations exceeding the appropriate and adopted screening criteria (risk to human health based on NSW EPA [2020])? If yes, the decision is Yes. Otherwise, the decision is No.
5. Has the nature and extent of HGG been determined to the extent necessary?	If sufficient environmental data has been collected to assess HGG across the site (i.e. data collected in accordance with this SAQP), then the answer is Yes. Otherwise the decision is No.

3.6 Acceptance Criteria

This step is to establish the decision maker’s tolerable limits on decision errors, which are used to establish performance goals for limiting uncertainty in the data. Data generated during the study must be appropriate to allow decisions to be made with confidence.

Specific limits for this project have been adopted in accordance with the appropriate guidance from the NEPC (2013), appropriate indicators of data quality (DQIs used to assess quality assurance/ quality control as outlined in this section) and standard JBS&G procedures for field sampling and handling. With respect to decision errors, these may lead to either underestimation or overestimation of the risk level associated with a sample location.

Acceptance limits on field data collected for this investigation will be in accordance with ASC NEPM (NEPC, 2013).

The potential for significant decision errors will be minimised by completing a Quality Assurance/Quality Control (QA/QC) program, including adoption of appropriate data quality indicators (DQIs used to assess QA/QC performance, and implementing JBS&G Standard Operating Procedures (SOPs).

The pre-determined DQIs established for the project are discussed below in relation to precision, accuracy, representativeness, comparability, completeness and sensitivity (PARCCS parameters), and are shown in **Table 3.2**. The DQIs are based on the ASC NEPM (NEPC 2013) and the requirements of the National Association of Testing Authorities (NATA) accreditation for the nominated laboratories.

- **Precision** – measures the reproducibility of measurements under a given set of conditions. The precision of the laboratory data and sampling techniques is assessed by calculating the Relative Percent Difference (RPD) of duplicate samples.
- **Accuracy** – measures the bias in a measurement system. The accuracy of the laboratory data that are generated during this study is a measure of the closeness of the analytical results obtained by a method to the ‘true’ value. Accuracy is assessed by reference to the analytical results of laboratory control samples, laboratory spikes and analyses against reference standards.

- **Representativeness** – expresses the degree which sample data accurately and precisely represent a characteristic of a population or an environmental condition. Representativeness is achieved by collecting samples on a representative basis across a site, and by using an adequate number of sample locations to characterise a site to the required accuracy.
- **Comparability** – expresses the confidence with which one data set can be compared with another. This is achieved through maintaining a level of consistency in techniques used to collect samples; ensuring analysing laboratories use consistent analysis techniques and reporting methods.
- **Completeness** – is defined as the percentage of measurements made which are judged to be valid measurements. The completeness goal is set at there being sufficient valid data generated during the study.
- **Sensitivity** – expresses the appropriateness of the chosen laboratory methods, including the limits of reporting, in producing reliable data in relation to the adopted criteria.

If any of the DQIs are not met, further assessment will be necessary to determine whether the non-conformance will significantly affect the usefulness of the data. Corrective actions may include requesting further information from samplers and/or analytical laboratories, downgrading of the quality of the data or alternatively, re-collection of the data.

Table 3.2: Summary of QA/QC Program

Data Quality Objectives	Frequency	Data Quality Indicator
Precision		
Intra-laboratory duplicate samples	1 in 20 primary samples (5%)	<30% RPD ^{#1}
Inter-laboratory split samples	1 in 20 primary samples (5%)	<30% RPD ^{#1}
Laboratory duplicates ^{#2}	1 in 20 primary samples (5%)	<30% RPD ^{#1}
Accuracy		
Method blanks	1 per lab batch	Less than the laboratory limit of reporting (<LOR)
Laboratory control samples	1 per lab batch	70-130% or as nominated in the laboratory's QC report
Matrix spikes	1 per lab batch	70-130% or as nominated in the laboratory's QC report
Representativeness		
Sampling appropriate for media and analytes	-	_#3
Samples extracted and analysed within holding times	All samples	Samples extracted and analysed within 7 days
Rinsate samples	1 per day of site work where reusable equipment is used (drilling of soil boreholes, sampling of groundwater wells)	<LOR
Laboratory blanks	1 per lab batch	<LOR
Comparability		
Standard operating procedures for sample collection and handling	All samples	Samples collected in accordance with relevant procedure ^{#3}
Standard analytical methods used for all analyses	All samples	All samples analysed by a laboratory that is NATA accredited for the analyses performed

Data Quality Objectives	Frequency	Data Quality Indicator
		Primary laboratory to be consistent for all samples with the exception of inter-laboratory split samples
Consistent field conditions, sampling staff and laboratory analysis	All samples	_#3
Limits of reporting appropriate and consistent	All samples	Laboratory LOR is below adopted guideline values and allows relevant comparability between results where more than one laboratory is used (i.e. for analysis of inter-laboratory split samples)
Completeness		
Sample description and COCs completed and appropriate	All samples	_#3
Appropriate documentation	All samples	_#3
Satisfactory frequency and result for QC samples	All QA/QC samples	As detailed above
Data from critical samples is considered valid	-	Critical samples valid
Sensitivity		
Analytical methods and limits of recovery appropriate for media and adopted site assessment criteria	All samples	Laboratory LOR is below adopted guideline values
<p>Notes:</p> <p>#1: If the RPD between primary and duplicate / split sample is greater than the pre-determined data quality indicator, a judgment will be made as to whether the excess is critical in relation to the validation of the data set or unacceptable sampling error is occurring in the field.</p> <p>#2: Duplicate sample analysis performed by the laboratory as part of their internal QA/QC program for the data.</p> <p>#3: A qualitative assessment of compliance with standard procedures and appropriate sample collection methods will be completed during the DQI compliance assessment.</p>		

3.7 Plan for Obtaining Data

A detailed description of the HGG investigation methodology is provided in **Section 4**.

4. Methodology

4.1 HGG Wells

Soil Sampling and Installation of HGG Wells

A total of 42 HGG wells are to be installed at the locations in **Figure 2**. The following describes the soil sampling and installation of HGG well methodology:

- Professional service location following review of dial before you dig plans will be undertaken for all HGG well locations;
- All drilling equipment will be decontaminated using a suitable detergent (Liquinox) prior to the start of drilling at each investigation location to minimise the potential for cross contamination between drilling locations. A rinsate sample will be collected on each day of drilling to validate decontamination procedures;
- Soil boreholes will be advanced using solid augers (minimum of 100 mm diameter) to a target depth to intercept the surface to the Q1 aquifer, noting this varied across the site. Soils encountered during drilling will be logged by an experienced field scientist in accordance with the procedures described in the ASC NEPM (NEPC 2013). Soil samples will be collected from the top of each lithological layer encountered with a maximum of 0.3 m between samples. Measurements of total VOCs will be recorded in the borehole/well headspace in addition to duplicate soil samples from all sampling depths using a photoionisation detector (PID);
- Samples will be collected into laboratory supplied sample containers and transported to NATA accredited laboratories under Chain of Custody Documentation (COC) in chilled cool boxes. The analytical program is outlined in **Section 5**. Eurofins MGT will be adopted as the primary laboratory and Envirolab will be adopted as the secondary laboratory (for QC purposes); and
- Following completion of drilling, HGG wells will be installed, as follows:
 - HGG wells will be constructed using 50 mm Class 18 uPVC screen and casing;
 - A screen length of 500 mm (with end cap) will be installed to the base of the borehole;
 - A graded washed gravel pack will be installed from the bottom of the drilled borehole to approximately 500 mm above the screened interval;
 - An activated bentonite seal of approximately 500 mm will be installed above the gravel annulus , with a concrete slurry/ grout mix added to fill the remaining annulus; and
 - HGG wells will be completed with flush mounted gatic covers.
- HGG wells will then be left for a minimum of one week to allow for stabilisation following which time they will be gauged to ensure they are above the groundwater table, and then brass Excap gas cap (or equivalent) will be installed to allow sampling; and
- Leak testing will then be completed on all HGG wells using an isopropanol (isopropyl alcohol) leak test method in general accordance with the leak testing methodology stated in *EPA 600/R-18/225: Leak, Purge, and Gas Permeability Testing to Support Active Soil Gas Sampling*¹⁰. The leak test enables confirmation of the integrity of the gastight bentonite seal installed in the construction of each bore, which in turn confirms the validity of the monitoring results. The following leak testing procedure will be undertaken:

¹⁰ EPA 600/R-18/225: *Leak, Purge, and Gas Permeability Testing to Support Active Soil Gas Sampling*, United States Environment Protection Agency, October 2018 (US EPA, 2018).

- Prior to leak testing, a background reading will be taken from the monitoring bore using a landfill gas meter with a ppm-level PID inlet attached to the exhaust of the GA5000, with a 5-minute pumping duration or until stabilisation of gas concentrations;
- A sealed plastic container or bag with airtight fittings will then be placed over the HGG well and the tracer (isopropanol) applied to a cloth and placed inside the container with the top of the tap exposed for connection of the gas sample line. The volatiles will be allowed to accumulate for 2 minutes, and a reading taken from inside the container. The container will then be sealed to atmosphere;
- A reading of volatile vapours will then be taken from the wellhead/ gas sample tap and compared to readings subsequently taken from the monitoring bore. Soil gas monitoring bores are considered to have failed leak detection if PID readings are measured above 10% of the background vapour concentrations measured in the well prior to commencement of the leak test. In the event of a failed leak detection test, the installation of the monitoring bore will be checked, remedial measures implemented and recorded prior to retesting the monitoring well;
- A complete purge of the bore headspace is not considered necessary as the tracer is sufficiently volatile to be detected as it is drawn through holes/ joins in the PVC as the headspace gas is drawn over it; and
- The leak test will be performed in conjunction with a QA/ QC check of the well installation and visual checks of the bentonite seal around the monument or gatic well cover.

Monitoring of HGG Wells

The following monitoring will be completed twice weekly over a 6-week period. It is noted that this frequency may be optimised following review of data during the monitoring program. The following monitoring methodology will be undertaken:

- In field monitoring using a calibrated GA5000 HGG analyser and PID (for methane, carbon dioxide, oxygen, carbon monoxide, hydrogen sulphide, balance, atmospheric and relative well pressure, gas well flow and VOCs [via PID]), under conditions likely to represent worst case, if possible (i.e. falling barometric pressure and dry ground conditions). Ambient air readings will also be collected from adjacent to each HGG well location for comparison with HGG well results, the following is noted:
 - HGG analyser measurement in HGG wells will occur over a minimum of 3 minutes. If the monitored gas concentrations have not reached a stabilised concentration after three minutes of continuous sampling, the gas concentrations at three minutes will be recorded along with the direction and rate of change in concentration (increase or decrease in % v/v over a regular time period such as 30 seconds), with these noted as the non-stabilised final readings. If very high landfill gas concentrations are recorded on the instrument (>30% v/v methane and/or 30% v/v carbon dioxide), then monitoring of the bore should be extended beyond three minutes (up to 10 minutes) to try to further assess the persistence of the gas detected within the bore;
 - Following monitoring using the landfill gas meter, the PID (ppm-range) will then be used to measure the VOCs over a minimum period of three minutes; and
 - Any field observations will be noted (e.g. moisture in sampling tubes).
- If the adopted Action Levels are exceeded (refer to **Section 6**), continuous in-situ gas analysers will be installed for up to 6 weeks (the well[s] for the Gasflux installation will be confirmed after the initial monitoring rounds). This will improve the resolution of data and prevent potential design or risk characterisation errors resultant from spot monitoring. It is envisaged that data representative of worst-case conditions can be collected (following stabilisation of the wells after installation) from this 6-week period; and
- If Action Levels are not exceeded after 6 weeks, monitoring will cease.

The minimum requirements to assess a Gas Screening Value (GSV) and CS are measured flow rates and HGG concentrations from an appropriate number of monitoring locations over an appropriate number of monitoring rounds, which should include measurements taken during falling atmospheric pressure (as per NSW EPA (2020)).

This monitoring frequency described above is based on professional judgement and the current understanding of the HGG CSM. JBS&G will consider the forecasted and actual meteorological conditions during the continuous monitoring period, with scope to extend the monitoring period beyond 6 weeks should relatively stable pressure and weather conditions be encountered. That is, should “worst case” falling barometric pressure and a large differential pressure not be encountered, an extension to the monitoring program may be required.

4.2 Groundwater Sampling

A total of 15 existing groundwater wells be sampled using low flow methods – the groundwater well locations are shown in **Figure 2**. The following describes the groundwater sampling methodology:

- All sampling equipment (interface probe, low flow pump, water quality meter) will be decontaminated using a suitable detergent (Liquinox) prior to the start of sampling at each well location to minimise the potential for cross contamination. A rinsate sample will be collected on all days of groundwater sampling to validate decontamination procedures;
- The wells will be gauged within a 4-hour period prior to commencement of sampling. Groundwater well gauging will be undertaken using an electronic interface probe to measure the depth to water, depth to non-aqueous phase liquid (NAPL) (if present) and total depth of each well;
- Groundwater sampling will be completed via low flow methods, as follows:
 - Dedicated tubing (High Density Polyethylene [HDPE]) will be used for each groundwater well;
 - The HDPE tubing will be lowered into the well so that the intake point is set approximately 500 mm below the standing water level. The depth of the intake point will be recorded on the field sampling sheets;
 - The peristaltic pump will then be used to purge the well at a rate to establish a stabilised pumping rate while minimising drawdown. A maximum drawdown of 100 mm is proposed for the investigation;
 - Following the establishment of the flow rate, indicator parameters (including DO, EC, redox potential, pH and temperature) will be measured to determine when purging has been completed (i.e. when indicator parameters are considered stable in accordance with EPA SA [2019]), with a minimum of one bore volume required to be removed prior to sampling. The presence or absence of visual and/or olfactory evidence of contamination will also be noted on the field sampling sheets; and
 - Following removal of a minimum of one bore volume and stabilisation of indicator parameters, a groundwater sample will be collected in appropriately preserved sample bottles for the chemicals of interest (provided by the laboratory).
- Samples will be collected into laboratory supplied sample bottles and transported to NATA accredited laboratories under COC documentation in chilled eskies. The groundwater analytical program is outlined in **Section 5**. Eurofins MGT will be adopted as the primary laboratory and Envirolab will be adopted as the secondary laboratory (for QC purposes);
- Following completion of groundwater sampling, two high frequency groundwater level loggers will be installed at targeted groundwater well locations to accurately measure groundwater levels and tidal fluctuations to assess risks from piston effect. These loggers will remain insitu for 3-6 weeks; and
- All groundwater purge water will be placed in 205 L drums, and then stored in a designated area on the subject site. Groundwater results will be provided for the water drums to facilitate offsite disposal.

Drums will be collected by a contractor licenced to transport and receive contaminated water at the end of the site works program.

5. Laboratory Analytical Program

5.1 Soil

Two samples from each HGG well location (42 locations) will be analysed for total organic carbon (TOC). The quality control (QC) sample program is outlined in **Table 5.1**.

Table 5.1: Soil Investigation – QC Sample Program

Samples	Detail	Analysis
Intra-laboratory duplicates	5 (1 per 20 primary samples)	<ul style="list-style-type: none"> • TOC: 5
Inter-laboratory splits	5 (1 per 20 primary samples)	<ul style="list-style-type: none"> • TOC: 5
Rinsates	4 (one per day of soil borehole / HGG well drilling)	<ul style="list-style-type: none"> • TOC: 4

Abbreviations:
TOC – total organic carbon.

5.2 Groundwater

A sample from each of the nominated 15 groundwater wells will analysed for methane, carbon dioxide and hydrogen sulphide. The Quality Control (QC) sample program is outlined in **Table 5.2**.

Table 5.2: Groundwater Investigation – QC Sample Program

Sample Type	Proposed Number of Samples for Analysis	Proposed Analytical Program
Intra-laboratory duplicate samples	1 (1 per 20 primary samples)	<ul style="list-style-type: none"> • HGG^{#1}: 1
Inter-laboratory split samples	1 (1 per 20 primary samples)	<ul style="list-style-type: none"> • HGG^{#1}: 1
Rinsate samples	2 (one per day of groundwater sampling)	<ul style="list-style-type: none"> • HGG^{#1}: 2

Notes:
#1: HGG includes methane, carbon dioxide and hydrogen sulphide.

6. Assessment Criteria

6.1 Soil and Groundwater

The data obtained from the soil and groundwater sampling will be used as inputs into the HGGRA to assess the risks from HGG, rather compared to soil and groundwater criteria.

6.2 HGG

In the absence of objectives and indicators to assess risk from HGG in SA, reference has been made to the EPA Publication 788.3 (EPA VIC 2015) – the Action Levels are summarised in **Table 6.1**Table 6.1.

Table 6.1: Landfill Gas Action Levels (HGG Wells)

Ground gas parameter	Unit of measurement	Action Level
Methane (CH ₄)	%v/v	1.0
Carbon dioxide (CO ₂)	%v/v	1.5 or above established background concentrations
Oxygen (O ₂)	%v/v	For reference
Carbon monoxide ^{#1} (CO)	Ppm	10 (±2% of full scale 500 ppm cell)
Hydrogen sulphide ^{#2} (H ₂ S)	Ppm	10 (±2% of full scale 500 ppm cell)
VOCs	Ppm	Above background outside air
Borehole differential pressure	Millibar (mb)	±4.0
Barometric pressure	mb/hPa	±4.0
Well flow	l/h	±0.3 ^{#3}

Notes:

#1: Reference to workplace exposure limit for carbon monoxide of 8 hr at 30 ppm (*National Exposure Standards for Atmospheric Contaminants in the Occupational Environment*, National Occupational Health and Safety Commission, 1995 [NOHSC, 1995]). The lower accuracy level of the GA5000 is 10 ppm.

#2: Reference to workplace exposure limit of hydrogen sulphide of 8 hr at 10 ppm (NOHSC, 1995). The lower accuracy level of the GA5000 is 10 ppm..

#3: Lower accuracy range of instrument to be used for calculating gas screening value (GSV).

7. Naming Conventions

The HGG wells will be labelled HGGW01-HGGW42.

The existing groundwater well IDs will be adopted.

8. Reporting

Upon completion of field works program, a HGGRA report in accordance with NSW EPA (2020) will be prepared. The HGGRA report will include the following:

- Introduction and objectives;
- Site identification details;
- Scope of work undertaken;
- Methodology;
- Summary of the Action Levels;
- Data quality assessment;
- Results and discussion, including:
 - Field observations;
 - Results data; and
 - Calculations (where required).
- Discussion of results;
- Summary of outcomes;
- Refining of the HGG CSM;
- Conclusions and recommendations.

9. Limitations

This report has been prepared for use by the client who has commissioned the works in accordance with the project brief only, and has been based in part on information obtained from the client and other parties. The report has been prepared specifically for the client for the purposes of the commission, and no warranties, express or implied, are offered to any third parties and no liability will be accepted for use or interpretation of this report by any third party.

The advice herein relates only to this project and all results conclusions and recommendations made should be reviewed by a competent person with experience in environmental investigations, before being used for any other purpose. This report should not be amended in any way without prior approval by JBS&G, or reproduced other than in full including all attachments as originally provided to the client by JBS&G.

Sampling and chemical analysis of environmental media is based on appropriate guidance documents made and approved by the relevant regulatory authorities. Conclusions arising from the review and assessment of environmental data are based on the sampling and analysis considered appropriate based on the regulatory requirements or agreed scope of work.

Limited sampling and laboratory analyses were undertaken as part of the investigations undertaken, as described herein. Conditions between sampling locations and media may vary, and this should be considered when extrapolating between sampling points. Chemical analytes are based on the information detailed in the site history. Further chemicals or categories of chemicals may exist at the site, which were not identified in the site history and which may not be expected at the site.

Changes to the conditions may occur subsequent to the investigations described herein, through natural processes or through the intentional or accidental addition of contaminants. The conclusions and recommendations reached in this report are based on the information obtained at the time of the investigations.

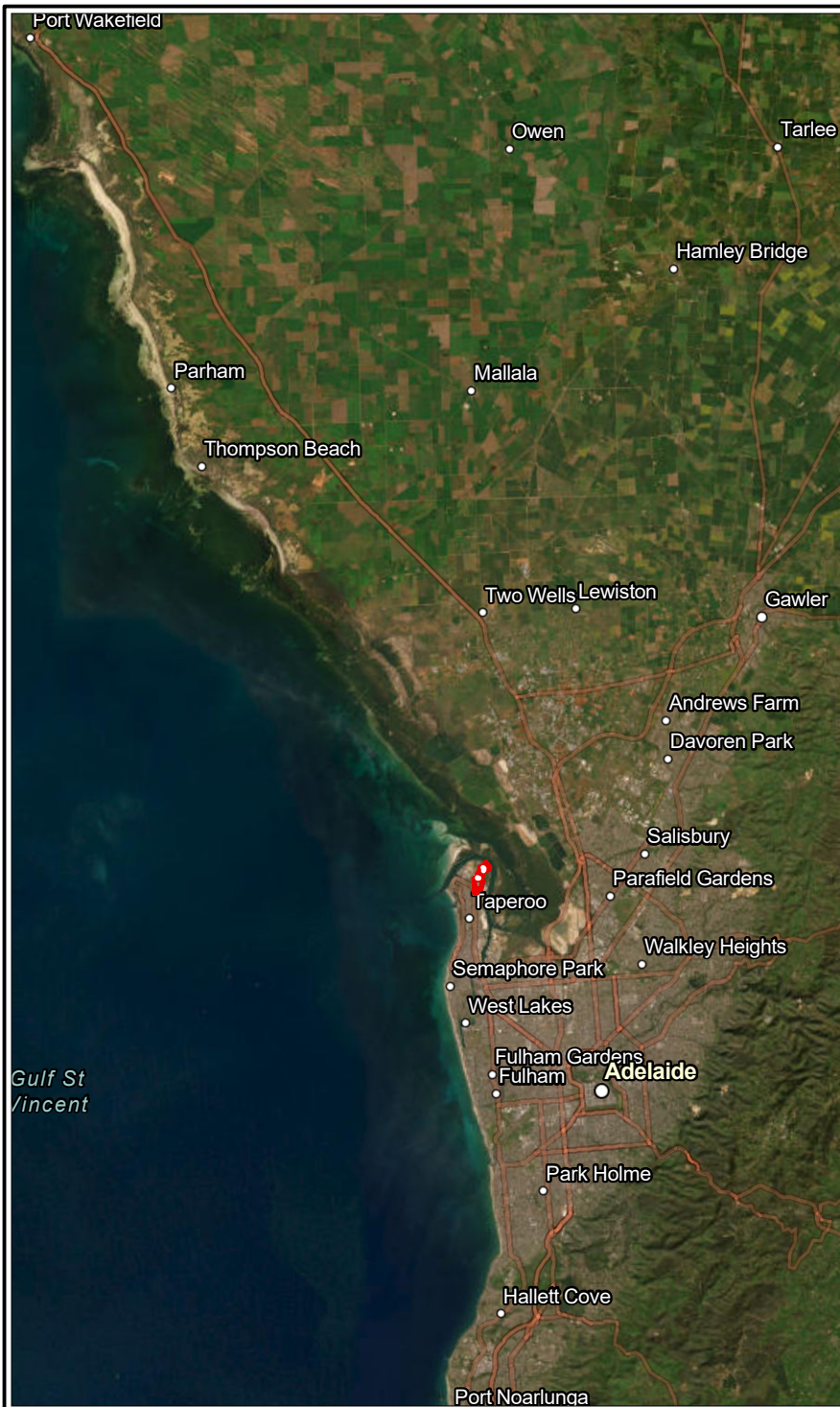
This report does not provide a complete assessment of the environmental status of the site, and it is limited to the scope defined herein. Should information become available regarding conditions at the site including previously unknown sources of contamination, JBS&G reserves the right to review the report in the context of the additional information.



Nuclear licensing requirements are beyond the scope of the investigation completed by JBS&G and are being assessed within the Siting and Site Evaluation Report (SSER).

10. References

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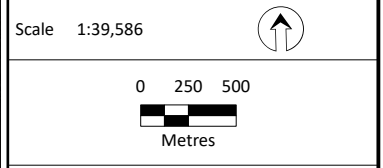
Figures



- Legend**
-  Site Boundary
 -  Not Subject to Site Contamination Investigation - Not Included in EIS



Job No: 67064
 Client: URPS
 Version: FINAL Date: 04-Nov-2024
 Drawn By: FF Checked By: KL

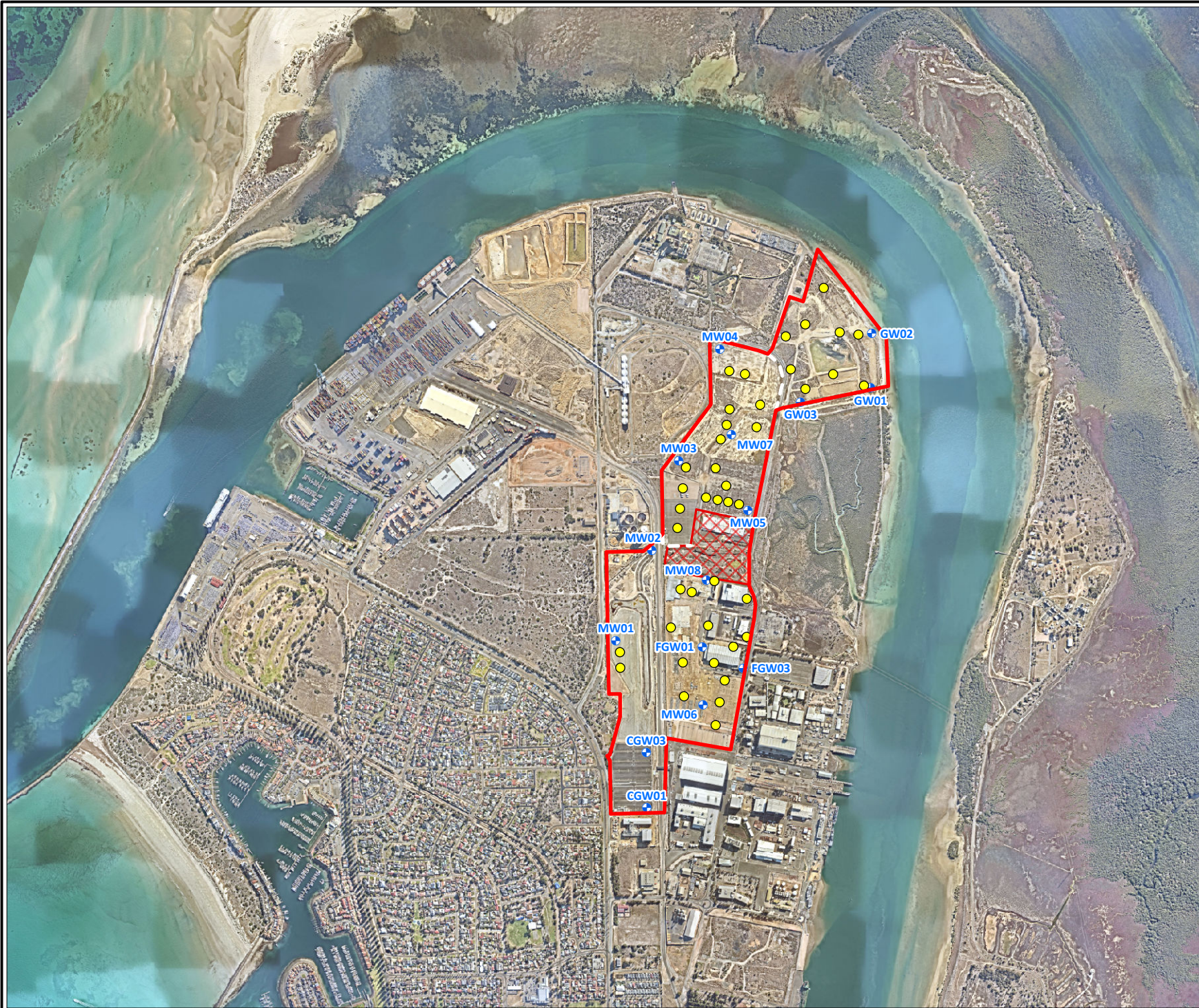


Coord. Sys. GDA2020 MGA Zone 54

Osborne, South Australia

LOCATION OF THE NUCLEAR-POWERED SUBMARINE CONSTRUCTION YARD (OSBORNE)

FIGURE 1



- Legend**
- ▭ Site Boundary
 - ▭ Not Subject to Site Contamination Investigation - Not Included in EIS
 - + Groundwater Wells
 - Proposed Soil Boreholes/HGG Wells



Job No: 67831

Client: URPS

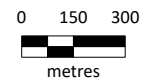
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Osborne, South Australia

**SOIL BOREHOLES, HGG WELLS AND
GROUNDWATER SAMPLING LOCATIONS**

FIGURE 2

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