



Orica Australia Pty Ltd

Conceptual Site Model

Yarwun Manufacturing Facility
30 Reid Road, Yarwun, QLD

5 December 2017

52877 110916 R002 Rev 0

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Executive Summary

JBS&G Australia Pty Ltd (JBS&G) was engaged by Orica Australia Pty Ltd (the client) to prepare a revised Conceptual Site Model (CSM) for the land identified as Lot 138 on CTN2123, located at 30 Reid Road, Yarwun, Queensland (the site).

A site location map is presented as **Figure 1**. A site features plan which shows the site boundaries is provided as **Figure 2**.

Orica was issued a notice to conduct or commission an environmental evaluation from the Queensland Department of Environment and Heritage Protection (EHP) on 21 July 2017. The notice was issued on the grounds that “...under section 326B of the *Environmental Protection Act 1994* the administering authority is satisfied on reasonable grounds that an activity or proposed activity is causing, or is likely to cause environmental harm”, with the environmental harm relating to increasing concentrations of free cyanide (on site), total ammonia and nitrate (on site, at the site boundary and off site) in groundwater.

The notice listed a number of requirements for Orica to implement. The first requirement was to engage a Suitable Qualified Person (SQP) to conduct a Detailed Site Investigation (DSI). The DSI was completed by JBS&G in August 2017 (*Orica Australia Pty Ltd Yarwun Manufacturing Facility Detailed Site Investigation, 30 Reid Road, Yarwun QLD*, JBS&G Australia Pty Ltd, 31 August 2017). The main findings of the DSI are presented in **Section 4.1.16**.

The second requirement was to engage a SQP to produce a revised CSM (this report).

The third requirement was to engage a SQP to prepare a Contamination Action Plan (CAP).

The objective of the investigation is to prepare a revised CSM as per the National Environmental Protection (Assessment of Site Contamination) Measure as amended 2013 (ASC NEPM), which includes the following:

- An assessment of the adequacy of the investigation works completed to date to determine if they meet the requirements of the ASC NEPM;
- The incorporation of any relevant findings as a result of the DSI conducted in accordance with requirement 1 of the notice;
- A review of groundwater monitoring data collected from wells within the source zone to determine the source of the increases in concentration of free cyanide, ammonia and nitrate;
- An assessment of the adequacy and appropriateness of the characterisation and delineation completed to date of the groundwater contamination on and emerging from the site;
- The identification of the relevant environmental values;
- An assessment of the risk to environmental values that includes modelling of contaminant concentrations and migration pathways in groundwater and an estimate of the rate of lateral and vertical movement of contaminants in groundwater; and
- A map delineating the extent and distribution of the ammonia, nitrate and free cyanide groundwater plume(s).

The objectives of this report have been taken directly from requirement 2 of the notice.

Subject to the limitations in **Section 7** and with respect to the objectives stated in **Section 1.2** JBS&G conclude that:

- The investigation works completed to date by JBS&G and others adequately meet the requirements of the ASC NEPM;
- The findings of the DSI prepared by JBS&G have been incorporated into this report;
- Historical groundwater monitoring data was assessed to determine the source of increases in concentration of free cyanide, ammonia and nitrate in groundwater. The groundwater contamination plume maps indicate AN Plant No 1 and the AN Solutions Tank are the primary sources of ammonia and nitrate contamination in groundwater. The groundwater contaminant plume maps indicate the CN manufacturing area is the primary source of cyanide contamination in groundwater.
- Based on the review of the environmental values for the Gladstone State Development Area waters (mainland) the key environmental values that need to be protected are the aquatic ecosystems of the receiving environment (Flying Fox Creek/Port Curtis).
- Following a detailed review of the distribution of contamination and migration pathways in groundwater, an assessment of the risk to environmental values was undertaken with the following conclusions:
 - The current site data indicates that the presence of free cyanide in groundwater on the site poses no risk to environmental values;
 - Ammonia and nitrate are present in groundwater on the site, at the site boundary and in offsite areas at concentrations that exceed the relevant criteria for the receiving environment;
 - Groundwater from the site discharges to the drainage systems along Reid Road and to the low lying area to the east of Reid Road and south of Gladstone Mount Larcom Road. Significant direct discharge of groundwater to the north of Gladstone Mount Larcom Road is considered unlikely;
 - Calculations of mass flux of nitrate (and ammonia) across the site boundary (assuming no operation of the remediation system) indicates the potential for substantial migration of contaminants from the site to the low lying area east of Reid Road;
 - Given the reported ammonia and nitrate concentrations at the site boundary and in offsite areas, the calculated mass flux of contaminants and the period of time that flow has occurred from the site, it is concluded that a substantial mass of ammonia and nitrate has migrated from the site; and
 - While it is noted that operation of a remediation system (**Section 4.7.2**) has recently been improved and data¹ for ammonia and nitrate at the discharge point to the receiving environment beneath Gladstone Mount Larcom Road indicates general compliance with the ANZECC/ARMANZ (2000) toxicant trigger values, the concentrations of contaminants offsite and the mass flux estimates indicate that ammonia and nitrate in groundwater pose a potential risk to the identified environmental values (aquatic ecosystems of Flying Fox Creek/Port Curtis)
- A Contamination Action Plan (CAP)² has been prepared (separate to this CSM) that provides recommendations to expand the existing ammonia and nitrate remediation system to address the potential risk associated with discharge of groundwater to the receiving environment.

¹ JBS&G (2017) Receiving Environmental Monitoring Program Preliminary Interpretative Report, dated 26 June 2017.

² JBS&G (2017) Contamination Action Plan, dated 5 December 2017.

- This report has been structured based upon the essential elements of a CSM defined in Schedule B1 of the National Environmental Protection (Assessment of Site Contamination) Measure as amended 2013, to assess potential risks to environmental values. The CSM provides a suitable basis for development of a CAP.

1. Introduction

1.1 Background

JBS&G Australia Pty Ltd (JBS&G) was engaged by Orica Australia Pty Ltd (the client) to prepare a revised Conceptual Site Model (CSM) for the land identified as Lot 138 on CTN2123, located at 30 Reid Road, Yarwun, Queensland (the site).

A site location map is presented as **Figure 1**. A site features plan which shows the site boundaries is provided as **Figure 2**.

Orica was issued a notice to conduct or commission an environmental evaluation from the Queensland Department of Environment and Heritage Protection (EHP) on 21 July 2017. The notice was issued on the grounds that “...under section 326B of the *Environmental Protection Act 1994* the administering authority is satisfied on reasonable grounds that an activity or proposed activity is causing, or is likely to cause environmental harm”, with the environmental harm relating to increasing concentrations of free cyanide (on site), total ammonia and nitrate (on site, at the site boundary and off site) in groundwater.

The notice listed a number of requirements for Orica to implement. The first requirement was to engage a Suitable Qualified Person (SQP) to conduct a Detailed Site Investigation (DSI). The DSI was completed by JBS&G in August 2017 (*Orica Australia Pty Ltd Yarwun Manufacturing Facility Detailed Site Investigation, 30 Reid Road, Yarwun QLD*, JBS&G Australia Pty Ltd, 31 August 2017). The main findings of the DSI are presented in **Section 4.1.16**.

The second requirement was to engage a SQP to produce a revised CSM (this report).

The third requirement was to engage a SQP to prepare a Contamination Action Plan (CAP).

1.2 Objectives

The objective of the investigation is to prepare a revised CSM as per the National Environmental Protection (Assessment of Site Contamination) Measure as amended 2013 (ASC NEPM), which includes the following:

- An assessment of the adequacy of the investigation works completed to date to determine if they meet the requirements of the ASC NEPM;
- The incorporation of any relevant findings as a result of the DSI conducted in accordance with requirement 1 of the notice;
- A review of groundwater monitoring data collected from wells within the source zone to determine the source of the increases in concentration of free cyanide, ammonia and nitrate;
- An assessment of the adequacy and appropriateness of the characterisation and delineation completed to date of the groundwater contamination on and emerging from the site;
- The identification of the relevant environmental values;
- An assessment of the risk to environmental values that includes modelling of contaminant concentrations and migration pathways in groundwater and an estimate of the rate of lateral and vertical movement of contaminants in groundwater; and
- A map delineating the extent and distribution of the ammonia, nitrate and free cyanide groundwater plume(s).

The objectives of this report have been taken directly from requirement 2 of the notice.

1.3 Scope of Works

The scope of works comprised:

- Review of previous environmental reports made available to JBS&G (see **Section 4**); and
- Preparation of a report in accordance with guidance made or approved by EHP, including the ASC NEPM.

On the basis of the notice (i.e. groundwater focused), the properties of the site contaminants and the fact that it is an operating site and not subject to divestment or change in land use, this report has not considered historical soil results. It is also noted that the highest concentrations of soil contamination would be at entry points (source areas) and these areas are not effectively accessible due to site infrastructure.

The scope of works completed in this CSM report was conducted by a SQP in accordance with the EHP *Guideline for Assessing a Suitably Qualified Person* (EHP, 2016) and the *Environmental Protection Act 1994*.

1.4 National Environmental Protection (Assessment of Site Contamination) Measure 1999, as amended 2013

This report has been structured based upon the essential elements of a CSM defined in Schedule B1 of the National Environmental Protection (Assessment of Site Contamination) Measure as amended 2013 (ASC NEPM), as shown in the table below:

Table 1.1: Summary of Report Contents - NEPM Requirements

ASC NEPM Requirement	Section in this CSM
Known and potential sources of contamination and contaminants of concern including the mechanism(s) of concern	Section 5.1 and 5.2
Potentially affected media	Section 5.3
Human and ecological receptors	Section 5.4
Potential and complete exposure pathways	Section 5.5
Data gap identification and uncertainty assessment	Section 5.6

2. Site Condition and Surrounding Land Use

2.1 Site Identification

The site is located in the Yarwun Industrial Estate at 30 Reid Road, Yarwun, Queensland. The site location is shown on **Figure 1**. A site features plan which shows the site boundaries is provided as **Figure 2**. The site details are summarised in **Table 2.1** and described in detail in the following sections.

Table 2.1: Summary Site Details

Lot/Plan	Lot 138 on CTN2123
Address	Yarwun Industrial Estate, 30 Reid Road, Yarwun
Local Government Authority	Gladstone Regional Council
Site Zoning	Special Purpose
Current Use	Industrial – Chemical manufacturing facility
Previous Use	Prior to Orica's occupation of the site, the site was undeveloped
Proposed Use	The site is to remain Industrial – Chemical manufacturing facility
Site Area	50.44 ha

2.2 Site Description

The site occupies an area of approximately 50 ha, of which 20 ha is currently developed. Based on information provided by Orica (URS, 2009), the site manufactures sodium cyanide, nitric acid (as an intermediate product), ammonium nitrate (AN), and, until recently, chlorine.

Development of the greenfield site began in 1990, with the construction of the cyanide and chlorine plants. The first acid plant and the first AN plant were constructed in 1993. The second acid plant was subsequently installed, with the third acid plant and second ammonium nitrate (AN) plant constructed in 2005 and 2006.

The developed portion of the site is divided into three broad zones:

- Chemicals Complex (CC);
- AN Plant; and
- The administration area and visitor carpark.

Additional site infrastructure includes an administration building, two control rooms, workshop, store, various storage areas and a container loading and laydown area. The site has two liquid effluent treatment areas, the AN effluent ponds, located north side of the AN tank farm, and the CC effluent ponds, located east of the chlorine processing plant. The site also includes an expanded polystyrene (EPS) plant, which is located on the western boundary of the site.

2.3 Environmental Protection Licensing and Approvals

Information provided by Orica indicates that the site is subject to Environmental Authority (EA) EPPR00872013 (current version of the EA was issued on 6 March 2017), which authorises chemical manufacturing at both the AN and CC facilities. The following Environmentally Relevant Activities (ERAs) are listed on the permit for Lot 138:

- 12 (2) Plastic product manufacturing – Manufacturing, in a year, a total of 5t or more of foam, composite plastics or rigid fibre-reinforced plastics;
- 33 Crushing, milling, grinding or screening – Crushing, grinding, milling or screening more than 5000t of material in a year;
- 7 (4b) Chemical manufacturing – Manufacturing, in a year, the following quantities of fertilizer – more than 5000t; and

- 7 (6d) Chemical manufacturing - Manufacturing, in a year, the following quantities of inorganic chemicals, other than inorganic chemicals to which items 1 to 4 apply – more than 100,000t.

2.4 Identified Sources of Contamination

JBS&G completed a Detailed Site Investigation (JBS&G, 2017), the following primary source areas (**Figure 2**) were identified based a detailed site inspection and review of current and historical groundwater monitoring trends:

- AN Plant No. 1;
- The AN Solutions Storage;
- The AN Bulk Store; and
- The Cyanide Plant and Warehouse.

It is noted that that Orica has completed a number of projects to reduce groundwater impacts and manage source control including:

- Installation of a groundwater interception trench and treatment system;
- Installation of an extensive groundwater monitoring network;
- Installation of new concrete laydown areas;
- Recoating Cyanide Plant ground flooring;
- Repaired floors in NA1 tank and AN1;
- Repair Bulk Store 1 floor;
- Lined the AN Solutions bund;
- Installation of the CC1 stormwater basin; and
- Replacement of effluent treatment tanks, sales liquid tank and Cyanide effluent drain.

2.5 Surrounding Land Use

Table 2.2 presents a summary of the land use immediately surrounding the site.

The Gladstone Area Water Board (GAWB) water treatment plant and Gladstone Regional Council sewage treatment plant are located on the eastern side of Reid Road. A cleared area between these two facilities designates the former site of the Australian Magnesium Corporation's pilot processing plant. To the north of the GAWB water treatment plant (on the corner of Gladstone Mount Larcom Road and Reid Roads) are tidal mud flats of Port Curtis.

South of the site is undulating forested land, and a railway easement. West of the site is forested land, and Rio Tinto's alumina refinery (approximately 1 km west of the site). A high voltage transmission line easement runs east-west along the southern border of the site, and a low voltage transmission line easement runs adjacent to the site's northern boundary. An electrical substation is located on the north side of Gladstone Mount Larcom Road.

Table 2.2: Surrounding Land Use

Location	Detail
North	Gladstone Mount Larcom Road, electrical substation, tidal mud flats of Port Curtis
East	Reid Road, GAWB water treatment plant, Gladstone Regional Council sewage treatment plant
South	Forested land
West	Forested land

3. Environmental Setting

3.1 Regional Hydrogeology

Areas of the site are underlain by up to three groundwater units including: perched; shallow; and deep aquifers. The deep aquifer is present in the rock beneath the site and is characterised by low hydraulic conductivity. Historical investigation of the deeper lithological units have confirmed that groundwater contamination from the site is confined to the perched / shallow aquifer(s).

3.1.1 Perched Aquifer/Groundwater

A perched groundwater unit has been identified in the reworked gravelly clay fill materials and the upper portion of the residual gravelly clays. The inferred groundwater flow direction in the perched aquifer during both the wet and dry seasons is in a northeast direction towards Port Curtis, generally following the filled natural drainage pathway, at a hydraulic gradient ranging between 0.005 and 0.01.

There does not appear to be a continuous perched groundwater unit in the vicinity of the Cyanide Plant.

Significant variation (three orders of magnitude) in hydraulic conductivity and calculated groundwater flux has been observed in the perched aquifer. The large variation in groundwater flux at different locations is related to the lithology of the perched aquifer (fill; reworked gravelly clay) and the presence of preferential groundwater flow pathways:

- Overall, preferential flow occurs through the natural drainage pathway backfilled for site construction, towards the north east. Downgradient of the Cyanide Plant the plume has two branches, one migrating to the north beneath Cyanide Alley (P12 had a hydraulic conductivity of 10 m/day, though P13 has a very low K) and one migrating east beneath Rankin Road;
- Preferential flow is inferred to occur in backfilled sub-surface utility trenches, in particular in the vicinity of P13 in Cyanide Alley, and P73 and P75 at Heron Drive; and
- Identified preferential pathways at the AN Plant include those associated with a former cutoff drain and reworked fill in the area near P50 as well as associated with the area near P71.

The following table presents a summary of the hydrogeological characteristics of the perched aquifer at the site (URS, 2009).

Table 3.1: Perched Aquifer Hydrogeological Characteristics

Depth (m bgl)	Geology	Gradient	Hydraulic Conductivity (m/day)	Horizontal Seepage Velocity (m/year)***
0.5 to 4.0	Fill, including reworked gravelly clay and upper residual gravelly clay	0.007 to 0.01 (Dry Season) 0.008 to 0.02 (Wet Season)	0.06 to 95 <i>0.12* - 13**</i>	0.2 to 2000 <i>2.2* - 237**</i>

Notes: *Geomean of low flow (<1m per day) conditions

**Geomean of high flow (>1 m per day) conditions

***Calculation is based on an average gradient of 0.01 and an effective porosity of 0.2

Groundwater elevations vary seasonally, with higher elevations in the wet season compared to the dry season. Water level hydrographs (in the vicinity of Reid Road) for the wet season indicate that the perched aquifer responds very rapidly to rainfall events (JBS&G, 2014). Peak water levels are observed soon after a rainfall event followed by a relatively rapid decline (although the resulting water level remains higher than that before the rainfall). In paved areas (the manufacturing areas of

CC and AN) the rainfall response may be less. Recharge of the perched aquifer in the plant area will be limited to unpaved areas upgradient of the plant, through cracks in roads and potentially leaks from subsurface pipes and sections of stormwater drains above the water table.

3.1.2 Shallow Aquifer/Groundwater

A shallow groundwater unit is present within the residual gravelly clays at depths between approximately 2 and 12 m. The inferred shallow groundwater flow direction is in a north-east direction towards Port Curtis. Water level hydrographs (in the vicinity of Reid Road) for the wet season indicate that the shallow aquifer responds slowly to rainfall and is more affected by seasonal variations than individual events.

The hydraulic conductivity calculated for the shallow groundwater is likely to be representative of the natural gravelly clay soils encountered beneath the site. The significantly lower hydraulic conductivity of the shallow aquifer (0.02 m/day) suggests the majority of groundwater flux occurs in the overlying perched aquifer (hydraulic conductivity of 0.1 to 100 m/day). However, since there are no aquitard features between aquifer units, some vertical hydraulic connection between perched and shallow aquifers is likely.

The following table presents a summary of the hydrogeological characteristics of the shallow aquifer (URS, 2009).

Table 3.2: Shallow Aquifer Hydrogeological Characteristics

Depth (m bgl)	Geology	Gradient	Hydraulic Conductivity (m/day)	Horizontal Seepage Velocity (m/year)**
2.0 to 8.0	Residual gravelly clay and reworked gravelly clay fill	0.008 to 0.015 (Dry Season) 0.004 to 0.02 (Wet Season)	0.004 to 0.2 0.02*	0.05 to 10 0.39*

Notes: *Geomean conditions

**Calculation is based on the average gradient and an effective porosity of 0.2

3.2 Stormwater

Natural drainage surrounding the site is poorly defined, reflecting low surface runoff conditions and high infiltration rates within the surface soil layers. Down-slope accumulation and sub-surface outflow zones, reflected by more abundant *Melaleuca* species, occur in the area surrounding the tidal mud flats to the northeast of the site (near the junction of Gladstone Mount Larcom Road and Reid Roads). The construction of the Gladstone Mount Larcom Road appears to have altered the natural drainage pathways and subsequently effected the diversity of the ecosystem within the receiving environment. There appears to have been a gradual change in the composition of the community, which has adapted to the longer periods of water logging. On the northern side of the Gladstone Mount Larcom Road, expansive mud flats extend more than 1.5 km to the mangrove lined shore of the Port Curtis estuary.

Stormwater at the CC is collected via a network of pits and conveyed by underground concrete pipes (invert of approximately 2 m bgl) following local topography to the Stormwater Retention System (SWRS) and licensed stormwater discharge point, CC1 in the northeast. Stormwater from CC and the surrounding area also drains into the CC1 SWRS via aboveground drainage.

Stormwater from the administration area and carpark discharges from the site. The administration area drains via underground pipes to the eastern side of Reid Road near the weighbridge entrance to the site. The carpark drains via a shallow swale drain to the table drain on the western side of Reid Road.

Stormwater at AN is collected via a network of pits and conveyed by underground concrete pipes (invert of approximately 2 m bgl) following local topography to Dam 1, Dam 2 and the licensed discharge point ANP1/ANP2.

A "first flush" system has been installed at the CC and AN discharge points which is designed to capture the initial rainfall off plant areas and hold stormwater in retention basins prior to testing/discharge from the site.

4. Data Review

4.1 Previous Reports

A series of environmental investigations and groundwater monitoring rounds have been conducted in relation to the site over the past 17 years. Orica engaged Environmental Ground, Water and Air Consultants Pty Ltd (EGC) to undertake investigations from 2000 to 2007. Groundwater monitoring rounds were completed by CCI Laboratories (CCI) in July 2007 and January 2008. Between August 2007 and March 2010 a significant number of investigations were undertaken by URS Australia Pty Ltd (URS) including development of a detailed CSM (URS, 2009). Since 2010, regular groundwater monitoring has been undertaken at the site by Golder Associates Pty Ltd (Golder). Detailed analysis of the results of historical monitoring data (up to January 2017) is presented in the Annual Groundwater Monitoring Report³ (JBS&G, 2017). The most recent groundwater monitoring undertaken by Golder in July 2017 has also been referenced in this report.

The following documents were made available for completion of the CSM:

- o *Review of Potential Inputs of Contamination into Stormwater Orica Yarwun*, URS Australia, 8 May 2008;
- o *Preliminary Offsite Surface Water Assessment Orica Yarwun*, URS Australia, 9 May 2008;
- o *Soil and Groundwater Investigation, Orica Yarwun*, URS Australia, 8 May 2008;
- o *Off-site Surface Water and Sediment Quality Assessment – Dry Season, Orica Yarwun*, URS Australia, 27 November 2008;
- o *Stage 3 Soil and Groundwater Investigation, Orica Yarwun*, URS Australia, 27 November 2008;
- o *Revised Conceptual Site Model, Orica Yarwun*, URS Australia, February 2009;
- o *Orica Yarwun – Status Report Nutrients in Groundwater and Surface Water*, URS Australia, 29 September 2009;
- o *Orica Yarwun – July 2009 Groundwater Monitoring and Cyanide Delineation Investigation*, URS Australia, 12 January 2010;
- o *Remediation of Nutrients in Groundwater, Orica Yarwun – Preferred Remedial Strategy*, Golder Associates Pty Ltd, 13 May 2011;
- o *Cyanide Groundwater Remediation Options*, Golder Associates Pty Ltd, 15 September 2011;
- o *Yarwun Manufacturing Facility Groundwater Remediation Action Plan*, JBS&G Australia Pty Ltd, 30 June 2014;
- o *Orica Australia Pty Ltd Yarwun Manufacturing Facility Groundwater Monitoring Plan Reid Road, Yarwun Queensland*, JBS&G Australia Pty Ltd, 25 October 2016;
- o *Orica Australia Pty Ltd Yarwun Manufacturing Facility Annual Groundwater Monitoring Report Reid Road, Yarwun Queensland*, JBS&G Australia Pty Ltd, 29 June 2017; and
- o *Orica Australia Pty Ltd Yarwun Manufacturing Facility Receiving Environmental Monitoring Program Preliminary Interpretive Report, Reid Road, Yarwun Queensland*, JBS&G Australia Pty Ltd, 26 June 2017.

³ *Orica Australia Pty Ltd Yarwun Manufacturing Facility Annual Groundwater Monitoring Report Reid Road, Yarwun Queensland*, JBS&G Australia Pty Ltd, 29 June 2017

JBS&G note that other reports have been prepared in relation to the site, however, based upon information provided by the client the reports listed above provide the best understanding of current contamination conditions at the site.

JBS&G note that other reports have been prepared by various consultants in response to site requirements. These include biannual groundwater monitoring reports, annual reporting requirements of the EA and stormwater and surface water interaction reports to support strategies to mitigate ingress of groundwater to the stormwater system. However, the above listed reports provide the most pertinent information with respect to characterisation and understanding of the groundwater contamination concerns

Material from the reports listed above has been used in this report to detail the existing understanding of the site. Each report has been summarised in the following section including an assessment of the adequacy of the investigation works to determine if they adequately meet the requirements of the ASC NEPM. The summaries provided have focused on the objectives, scope and a high level summary of the overall findings. The groundwater data presented in each report has been considered in detail as part of historical groundwater monitoring reports. Groundwater monitoring locations are shown on **Figure 3**.

4.1.1 Review of Potential Inputs of Contamination into Stormwater URS 2008

URS prepared a document titled 'Review of Potential Inputs of Contamination into Stormwater' in May 2008. The aim of the report was to review the condition of the stormwater system, review previous soil and groundwater investigations, undertake a detailed site inspection, and describe potential high risk sources of contamination at the site.

The following potential sources of soil and/or groundwater contamination were identified by URS:

Cyanide Plant

- Cyanide Plant Effluent Pit;
- Cyanide Plant Solids Dissolving Tank;
- Cyanide Plant grated floor drains and wastewater pits;
- Cyanide Plant floor area; and
- Cyanide Plant Sparge Loading Area.

Nitric Acid Storage Tank 1, Pumps and Pit

- Bulk Nitric Acid Storage Tank No. 1;
- Nitric Acid Pump Station; and
- Acid Neutralisation Pit.

No. 1 AN Plant

- No. 1 AN Plant Prill Tower Scrubber;
- No. 1 AN Plant floor area and floor drains; and
- No. 1 AN Plant Solids Dissolving Pit.

AN Solution Storage Tanks

- AN Concentrator Tank Farm and AN Concentrator Fan Unit.

Former Outdoor AN Storage Area

- Former Outdoor AN Storage – South End of AN Bulk Store 1.

The areas shown above are presented in **Figure 2**.

The report concluded that there were a number of potential historical and current sources of ammonia, nitrate and cyanide compound inputs to the stormwater and groundwater systems at the site. There were also a number of pathways for movement of contaminants through the stormwater system and interaction between stormwater and groundwater systems. Further stormwater and groundwater investigations would be required to assess the relative contribution of each of the sources to the stormwater and groundwater contamination and to identify the specific pathways for movement of contamination from the site.

4.1.2 Preliminary Offsite Surface Water Assessment URS 2008

URS prepared a document titled 'Preliminary Off-site Surface Water Quality Assessment' in May 2008. The aim of the investigation was to:

- Conduct a desktop review of existing relevant information regarding the discharge of stormwater from the site; and
- Conduct a screening level assessment of water quality in offsite surface water bodies.

The desktop study revealed very few sources of existing data on freshwater environments in the Yarwun area.

The investigation included the collection of 19 surface water samples (**Appendix A**) from potentially impacted drains/streams (located along the sites northern and eastern boundary) and four background surface water samples (located south west of the site) which were collected in February 2008.

Concentrations of ammonia, nitrate and total cyanide were elevated in surface waters collected from drainage pathways in the immediate vicinity of the site. In particular, concentrations of total cyanide exceeded the Environmental Protection Authority (now EHP) licence conditions, and concentrations of ammonia and nitrate exceeded ANZECC/ARMCANZ (2000)⁴ trigger values for the protection of 95% of freshwater aquatic species for more than 120m downstream of the licenced discharge (CC).

Total cyanide concentrations exceeded licence limits for more than 200m downstream of the unlicensed discharge point at the north-west corner of the site, and nitrate concentrations exceeded ANZECC/ARMCANZ (2000) trigger values for the protection of 95% of aquatic species for more than 70m downstream of the licenced discharge. It is noted that since this report was prepared the regulated contaminant has changed from Total to Free Cyanide, and an improved stormwater management system has been installed in the Chemical Complex.

Concentrations of nitrate exceeded the licence limits for up to 180m downstream of the ANP1 adjacent to Reid Road. Ammonia exceeded ANZECC/ARMCANZ (2000) trigger values for the protection of 95% of aquatic species for a distance greater than 320m downstream of the pond, and nitrate concentrations exceeded the ANZECC/ARMCANZ (2000) trigger values for the protection of 95% of aquatic species for 480m, downstream of the pond. It is noted that since this report was prepared an improved stormwater management system has been installed in the AN Plants.

The report identified that the interaction between surface water and groundwater in offsite locations was currently unknown, and therefore the relative contribution of surface water and groundwater to any conditions evident in offsite surface waters could not be confirmed.

⁴ Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand 2000, Australian Water Quality Guidelines for Fresh and Marine Waters, National Water Quality Management Strategy, Australian and New Zealand Environment and Conservation Council, Canberra

The report concluded that elevated concentrations of ammonia, nitrate and total cyanide were measured in surface water in the receiving environment adjacent to the site. URS considered that the source of offsite surface water contamination was likely to be stormwater being discharged from the site. URS considered that sources that may be contributing to the contamination of the site stormwater included both above ground sources and / or the ingress of contaminated groundwater into the stormwater system.

4.1.3 Soil and Groundwater Investigation URS 2008

URS prepared a document titled 'Soil and Groundwater Investigation' in May 2008. The aim of the investigation was to:

- Determine the extent nitrate, ammonia and cyanide impacted groundwater;
- Develop an understanding of the geology and hydrology of the shallow aquifer;
- Assess the soil quality in potential source areas of the site and along the eastern boundary of the site;
- Determine the hydraulic parameters of the shallow aquifer along the eastern boundary of the site where a groundwater interception system was proposed;
- Estimate the contamination (nitrate, ammonia and cyanide) flux potentially crossing the eastern site boundary;
- Reduce the potential for cross contamination of the deep aquifer; and
- Assess the adequacy and effectiveness of the current groundwater extraction system operating at the cyanide plant on the site.

The first stage of the investigation (undertaken in August and October 2007) included (**Appendix A**):

- Drilling 28 boreholes;
- Decommissioning of selected deep monitoring wells (to reduce potential for cross contamination of the deep aquifer);
- Installation of groundwater monitoring wells in 18 of the boreholes;
- Collection of groundwater samples from each of the new monitoring wells; and
- Recovery testing on selected new and existing monitoring wells.

The second stage of the investigation (undertaken in January 2008) included sampling all available monitoring wells across the site.

The third stage (undertaken in February 2008) included the inspection and assessment of groundwater extraction wells, gauging of monitoring wells surrounding the extraction bores, and recovery testing of the extraction bores.

The groundwater velocities encountered by URS are summarised in the table below.

Table 4.1: Ranges of Average Linear Groundwater Velocity (1)

Aquifer	Range for Average Linear Velocities (m/year)
Perched	0.1 to 138
Shallow	0.05 to 1.1

The report made the following conclusions (paraphrased):

- The site is underlain by three groundwater units: a perched, shallow and deep aquifer;

- The perched and shallow aquifers have been impacted by ammonia, nitrate and cyanide, released from various sources across the site;
- The presence of contamination within the deep aquifer appears to be limited based on the data available;
- The major sources of ammonia and nitrate impacts to groundwater appear to be AN Plant 1, the AN AST farm and the AN Bulk Store Area, although based on the distribution of contaminants in the groundwater other sources are contributing to the groundwater contamination;
- The major sources of cyanide impacts to groundwater appears to be the Cyanide Plant;
- The extent of perched groundwater (and associated contamination) beneath the site has not been delineated;
- Nitrate and ammonia impacts in perched groundwater appear to have migrated north east beyond the site, however the extent of impacts have not been delineated beyond the eastern edge of Reid Road;
- Shallow groundwater impacted with nitrate and ammonia has migrated north east and off the site boundary. Nitrate impacts are not expected to extend far beyond the eastern edge of Reid Road and ammonia impacts do not appear to extend beyond the eastern edge of Reid Road;
- The lateral extent of cyanide contamination in the perched and shallow aquifers have not been delineated south and east of S54, whilst the downgradient (north and north east) extent of the cyanide impacted groundwater has not been delineated between R24, S46 and S2. Concentrations of total cyanide have been detected at the site boundary in monitoring wells S47 and historically S2, however further monitoring and investigation into the form of cyanide is considered necessary to confirm the water quality and potential toxicity at these locations;
- At the time of the report, it was considered that there were insufficient monitoring wells surrounding the extraction bores to determine the extent of influence of the groundwater extraction, but the extent of influence was expected to be limited based on the relatively low hydraulic conductivity of the aquifer;
- The groundwater flow volume per unit length is approximately 0.12 m³/day/m for the perched groundwater and 0.0008 m³/day/m for the shallow groundwater; and
- The largest portion of the ammonia (97 %) and nitrate (93 %) flux across the eastern boundary of the site in groundwater is associated with the perched groundwater in the vicinity of P50 (*this was based on available information at the time of publishing the report in 2008 although it should be noted that circumstances have now changed as is discussed in Section 4.6*).

4.1.4 Off-site Surface Water and Sediment Quality Assessment – Dry Season URS 2008

URS prepared a document titled 'Off-site Surface Water and Sediment Quality Assessment' in November 2008. The aim of the investigation was to collect additional surface water and sediment data in the dry season in addition to the preliminary surface water assessment completed in February 2008 (URS, May 2008).

The dry season sampling (August 2008) of off-site aquatic environments was timed to coincide with the driest months of the year (typically July to August) to allow comparison with 'wet season' results (February 2008). The main scope of work was to revisit locations sampled in February 2008 and sample surface water wherever possible. In addition, sediments were collected from within the

water courses at all locations to assess the extent of Chemicals of Potential Concern (COPCs) accumulation within the receiving environment (**Appendix A**).

The report found that despite the absence of water at many of the locations in August 2008, contamination patterns were broadly similar to those in the wet season, with the exception that ammonia was less prevalent and nitrate concentrations tended to be higher. URS considered that these trends were likely to be related to the presence of suitable conditions for ammonia nitrification during the dry season.

The report made the following comparison between wet season and dry season results:

- Within the discharge pathway associated with the licensed release point CC, nitrate concentrations in sediment during the dry season, and total cyanide concentrations in water (wet season) and sediment (dry season) exceeded twice mean background concentrations;
- At the northwest fence line, concentrations of all COPCs in wet season surface runoff was low, whereas the sediment contained high levels of nitrate (dry season);
- Within the discharge pathway associated with the unlicensed release point at the northwest corner of the site, nitrate in water (at the fence during the wet season) and total cyanide in water up to 200 m downstream of the discharge (wet season) and in water at 200 m from the discharge (dry season) exceeded the assumed licence discharge limits. COPCs were low in sediment at all distances from the release point (dry season);
- Within the containment pond (associated with licensed release points ANP1 and ANP2) and 180 m downstream nitrate in water (wet and dry seasons) exceeded licence limits. Nitrate was high in sediment in the containment pond during the dry season and total cyanide in water (dry season) exceeded the assumed licence limits; and
- Within the roadside drainage channels downstream of the Reid Road culvert (among the bulrushes), nitrate and total cyanide in water (dry season only) at all locations exceeded licence discharge limits. Nitrate and total cyanide in sediment (only at 60 m downstream of the culvert in the dry season) exceeded twice mean background concentrations.

The report concluded that the interaction between surface water and groundwater at off-site locations had not yet been adequately defined however groundwater was the likely source of a flowing discharge on the eastern side of Reid Road. The presence of a large pool of water adjacent to the Mt Larcom-Gladstone Road during both the wet and dry seasons also indicated surfacing of groundwater. Despite extensive ground investigation, surfacing of groundwater was not identified in the forested land.

4.1.5 Stage 3 Soil and Groundwater Investigation URS 2008

URS prepared a document titled 'Stage 3 Soil and Groundwater Investigation' in November 2008. The aim of the investigation was to:

- Identify the source areas of contamination, particularly in the vicinity of the cyanide plant, the nitric acid plants and within the AN processing areas; and
- Delineate the extent of groundwater contamination in the perched and shallow aquifers on- and off-site.

The investigation was undertaken in July and August 2008 and included (**Appendix A**):

- Drilling an additional 79 boreholes to allow collection of soil samples and installation of monitoring wells in the perched and shallow aquifers;
- Measurement of water levels and collection of representative groundwater samples from 129 new and existing monitoring wells; and

- Completion of recovery testing on 34 new monitoring wells.
- The groundwater velocities encountered by URS are summarised in the table below.

Table 4.2: Ranges of Average Linear Groundwater Velocity (2)

Aquifer	Range for Average Linear Velocities (m/year)
Perched	0.2 to 2000
Shallow	0.05 to 10

The report made the following conclusions (paraphrased):

- The extent of perched groundwater beneath the site was more extensive than previously identified and may be continuous in certain areas of the site, particularly areas that have been filled and/or have former natural features such as infilled drainage lines;
- The major sources of ammonia and nitrate contamination to groundwater appear to be the Nitric Acid Plants, AN Plant 1, the AN AST farm and the northern portion of the AN Bulk Storage Area (including the southern portion of the EP plant), although based on the distribution of contaminants in groundwater other sources are contributing to the contamination;
- The major source of cyanide contamination to groundwater appears to be the Cyanide Plant;
- Nitrate and ammonia contamination in the perched groundwater appear to have migrated north east beyond the site boundary, however the extent of contamination have not been delineated beyond the eastern edge of Reid Road due to the presence of the dense forest.;
- Nitrate and ammonia contamination in perched groundwater appear to be migrating offsite via two preferential pathways, one in the vicinity of P71 (in the car park area) and one in the vicinity of P50 (near stormwater discharge point ANP1, approximately 60m south of the car park entrance). Several other preferential pathways were identified in the perched groundwater across the site and are associated with existing or former underground service utility trenches, areas which were filled during the construction of the site and areas where former natural drainage paths existed;
- Shallow groundwater contaminated with nitrate and ammonia has migrated north east and off the site boundary. Nitrate and ammonia contamination is not expected to extend far beyond the eastern edge of Reid Road;
- In the vicinity of the Cyanide Plant there does not appear to be a continuous perched groundwater unit, two of the new perched monitoring wells were dry and one was nearly dry. In contradiction to the dry wells, one of the new perched monitoring wells reported high measured hydraulic conductivity of approximately 10 m/day;
- The cyanide plume in perched groundwater appears to have two branches, one migrating north east beneath the north eastern corner of the site and one migrating east beneath Rankin Road, indicative of a heterogeneous nature of the perched groundwater system. The branch of the cyanide plume migrating north east appears to extend towards the north eastern boundary of the site, however, does not appear to have migrated offsite in a north east direction. The second branch of the cyanide plume appears to extend beneath Rankin Drive, however does not appear to extend far beyond Rankin Drive;
- The extent of cyanide contamination in shallow groundwater generally follows the same pattern as the perched groundwater, however the contamination appears to have migrated further east and south east. Total cyanide in shallow groundwater does not appear to extend beyond the north east perimeter fence and appears to extend east beneath Larcom Road (onsite), however does not extend to the eastern boundary of the site. The free cyanide plume

in the shallow groundwater does not appear to extend beyond the immediate vicinity of the plant and the down gradient extraction wells; and

- Cyanide contamination detected in monitoring wells located near the AN processing area of the site are unlikely to be sourced from the Cyanide Plant. The source of this contamination is not known, however may be associated with cyanic acid which can potentially form in the ammonium nitrate effluent. The source of these contaminants is unclear and further monitoring of these locations is recommended to confirm the reported cyanide concentrations.

4.1.6 Revised Conceptual Site Model URS 2009

URS prepared a document titled 'Revised Conceptual Site Model' in February 2009.

Based on the finding of previous investigation works the CSM provided a summary of:

- Contamination sources;
- Distribution of contamination in groundwater, sediment and surface water; and
- Mechanisms for exposure by human and environmental receptors.

Based on the results of the investigations completed, URS concluded that the reported contaminant concentrations in groundwater and surface water at the site have not resulted in measured adverse effects to the receiving environment.

The CSM recommended further delineation of cyanide impacted groundwater and additional groundwater, surface water and stormwater monitoring.

4.1.7 Status Report Nutrients in Groundwater and Surface Water URS 2009

URS prepared a document titled 'Status Report Nutrients in Groundwater and Surface Water' in September 2009.

The letter provides a summary of the investigations undertaken between August 2007 and August 2009

4.1.8 Groundwater Monitoring and Cyanide Delineation Investigation URS 2010

URS prepared a document titled 'Groundwater Monitoring and Cyanide Delineation Investigation' in March 2010. The aim of the investigation was to:

- Carry out a groundwater monitoring event to collect temporal concentration data for ammonia, nitrate and cyanide in groundwater; and
- Conduct additional cyanide delineation works to address data gaps identified in the Stage 3 Investigation.

The groundwater monitoring event and investigation works were undertaken in May and June 2009 and included:

- Installation of 18 new perched and shallow groundwater monitoring wells to the north of the Cyanide Plant; and
- Collection of groundwater samples from 106 groundwater wells.

The report made the following conclusions (paraphrased):

- Analyses of samples utilising the weak acid dissociable (WAD) technique demonstrated that in cases where the total cyanide concentration exceeds the free cyanide concentration the difference is a result of the presence of relatively stable cyanide complexes (e.g. iron form). This observation confirms the assessment of groundwater contamination at the site should be based on free cyanide concentrations;

- In addition to the above, it is important to note that the fate and transport of free cyanide in groundwater is influenced significantly by the presence of minerals containing iron in the subsurface. These minerals are widely distributed and not only result in the conversion of free cyanide to complex cyanide species (reported as total cyanide) which is less toxic to aquatic organisms but also the permanent retardation and removal of cyanide from flowing groundwater;
- The major source of cyanide contamination to groundwater at the site is the Cyanide Plant and in particular the solids dissolving tank. Extensive remediation work has been undertaken by Orica on this tank and it is not considered to be an ongoing source of cyanide contamination to groundwater;
- The free cyanide plume in perched groundwater appears to migrate in a north and north easterly direction from the source. The plume has migrated north under the Cyanide Control Building but has not continued further north under the Chlorine Plant. The northern edge of the free cyanide plume has been delineated and is located entirely on the site;
- The total cyanide plume extends from the Cyanide Plant to the north east boundary of the site.
- The extent of cyanide contamination in shallow groundwater generally follows the same pattern as in perched groundwater;
- The major historical source of ammonia and nitrate contamination to groundwater were the Nitric Acid Plants, AN Plant 1, the AN AST farm and the northern portion of the AN Bulk Storage Area (including the southern portion of the EP plant);
- Ammonia concentrations and distribution in perched groundwater across the site were similar to the previous investigations while concentrations of nitrate reported significant decreases in several wells;
- The concentration of nitrate in a number of offsite wells exceeded the adopted guidelines. The concentrations of ammonia in one offsite well slightly exceeded the guideline;
- Dense vegetation in the forested land limited the delineation of nitrate concentration in groundwater beyond the eastern edge of Reid Road; and
- The extent of ammonia and nitrate concentration in shallow groundwater generally follows the same pattern as in perched groundwater.

4.1.9 Remediation of Nutrients in Groundwater, Orica Yarwun – Preferred Remedial Strategy in Groundwater Golder Associates 2011

Golder prepared a document titled 'Remediation of Nutrients in Groundwater – Preferred Remedial Strategy' in May 2011.

The aim of the strategy was to recommend a preferred remediation option to reduce the mass flux of ammonia and nitrate migrating from the site in groundwater and to establish remediation objectives/criteria.

The remediation options considered included:

- Groundwater extraction and treatment;
- Permeable reactive barriers;
- Bioremediation;
- Phytoremediation; and
- Monitored natural attenuation.

The preferred remedial strategy was groundwater extraction using a capture trench with ex-situ water treatment to provide a reduction of ammonia nitrate migrating offsite in the short-term until primary sources are controlled and stable decreasing ammonia nitrate concentrations in groundwater are observed on the site.

It was also recommended to assess the feasibility of in-situ bioremediation as a potential long-term solution for plume-wide aquifer restoration.

4.1.10 Remediation of Nutrients in Groundwater: Groundwater Extraction and Treatment Preliminary Design Tasks Golder Associates 2011

Golder prepared a document titled 'Remediation of Nutrients in Groundwater – Groundwater Extraction and Treatment Preliminary Design Tasks' in September 2011.

The aim of the report was to provide a preliminary design for the groundwater extraction system and summarise information relevant to the design of the groundwater treatment system.

The report included a summary of the site description, environmental setting, sources of contamination and distribution of nutrient contamination in groundwater.

The design description included two trenches (P71 and P50). The location of the proposed trenches was described as 'cross the northern preferential flow path centred around P71 and extending to intercept backfill around the carpark stormwater system and across the southern preferential flow path intersecting P85 and P50 and the stormwater pipes at ANP1.

The P71 trench was described as 50m long, 0.3m nominal width, an average of approximately 2.7m deep, with a pumping location at the centre. The P50 trench was described as 50m long, 0.3m nominal width, an average of approximately 2.5m deep, with a pumping location at the northern end.

The as built drawing for the two trenches have been included in **Appendix C**.

4.1.11 Cyanide Groundwater Remediation Options Golder Associates 2011

Golder prepared a document titled 'Cyanide Groundwater Remediation Options' in September 2011.

The aim of the study was to identify a preferred remediation approach the two remediation scenarios: remediation of plume-wide cyanide impacts in groundwater and migration of ingress of cyanide impacted groundwater to stormwater drains.

The remediation options considered included:

- Ex-Situ Approached:
 - Source area excavation and offsite disposal and treatment;
 - Groundwater extraction and management of groundwater.
- In-Situ Approaches:
 - Chemical oxidation;
 - Bioremediation;
 - Geochemical fixation;
 - Permeable reactive barrier;
 - Phytoremediation;
 - Monitoring natural attenuation;
 - Thermal;
 - Hydraulic isolation.

Golder concluded that primary source control should continue to be the focus for management of cyanide impacts to groundwater. Golder also concluded that although the major historical cyanide sources have been mitigated/controlled (such as the solids dissolving tank), fugitive emissions of very low concentrations of cyanide may still prove an ongoing source to groundwater.

Golder considered the preferred overall cyanide groundwater strategy could include:

1. Migration of groundwater ingress to stormwater:
 - a. Groundwater extraction in the backfill of stormwater drains and perched aquifer at Cyanide Alley to lower water levels below drain inverts and achieve cyanide mass reduction. Treatment of extracted groundwater using existing chemical complex effluent treatment system.
 - b. Groundwater extraction in the backfill of stormwater drains to the south of the chemical complex effluent ponds in the vicinity of P73 and P75 to lower water levels below drain inverts.
2. Source zone and plume-wide groundwater remediation:
 - a. Groundwater extraction from the perched aquifer in the source zone and Cyanide Alley to achieve mass reduction over a short timeframe until concentrations decrease to the order of 10mg/L total cyanide or less. Treatment of extracted groundwater using the existing chemical complex effluent treatment systems.
 - b. Assess feasibility of a granular ZVI PRB installed in the perched aquifer at appropriate locations (e.g. downgradient of the Cyanide Plant, at the toe end of the free cyanide plume, or adjacent to stormwater drains) to mitigate further migration (if any) of cyanide in groundwater. Implement if feasible.
 - c. Assess feasibility of enhanced in-situ bioremediation, potentially using additional of super-aerated water and rate limiting constituents (possibly phosphate and alkalinity) in the source area and plume to further reduce cyanide concentrations in the aquifer over the long term. Implement if feasible.

4.1.12 Groundwater Remediation Action Plan JBS&G 2014

JBS&G prepared a document titled 'Groundwater Remediation Action Plan' in June 2014. The plan prepared in response to a requirement of the EA for the site.

The plan included the review of monitoring data, review of potential remediation options and selection of the preferred remediation option.

The preferred remedial strategy for the remediation of nutrients referred to the reports compiled by Golder in 2011. The JBS&G RAP included a review of remediation options for the cyanide plume and the proposed remediation strategy was monitoring natural attenuation. However, it is noted that free cyanide concentrations had increased at some locations and as a result it was also recommended that further assessment of other remediation options (e.g. in-situ bioremediation) are progressed in parallel with monitored natural attenuation.

4.1.13 Groundwater Monitoring Plan JBS&G 2016

JBS&G prepared a document titled 'Groundwater Monitoring Plan' in October 2016. The report was originally drafted during the revision on the EA. The aim of the Groundwater Monitoring Plan was to provide a program of groundwater quality and hydraulic monitoring suitable for assessing the distribution of contaminants and effectiveness of remediation works at the site.

The plan details the groundwater monitoring program from the Yarwun and Fisherman's Landings sites.

4.1.14 Annual Groundwater Monitoring Report JBS&G 2017

JBS&G prepared a document titled 'Annual Groundwater Monitoring Report' in June 2017. The aim of the Annual Groundwater Monitoring Report was to satisfy the requirement of the EA. Annual reports were also completed by JBS&G in 2014, 2015 and 2016.

The report included the statistical analyses of groundwater monitoring results collect by Golder from 99 monitoring wells collected in July 2016 and January 2017 and a review of groundwater remediation progress.

The Annual Groundwater Monitoring Report provided the following summary:

- Statistical review of groundwater monitoring data indicates:
 - Cyanide:
 - The majority of wells reported stable or decreasing free cyanide concentrations. An increasing trend (based on the last five years of data) was present for a number of locations immediately downgradient or adjacent to the source zone. However, review of data for these locations also indicated that the trend was generally dominated by increases prior to 2014 with concentrations relatively stable in recent years.
 - Ammonia and Nitrate:
 - The majority of source area wells reported concentrations of ammonia and nitrate exceeding the trigger values. However, it is considered that ammonia and nitrate concentrations in the source zones have been relatively consistent since completion of the 2014 annual groundwater monitoring report;
 - The majority of boundary wells reported concentrations of ammonia and nitrate exceeding the trigger values;
 - Decreasing trends were observed at six boundary wells while increasing trends were reported at thirteen wells. Overall, it is considered that concentrations of ammonia and nitrate were generally stable at the Site boundary during 2016/2017; and
 - While reported concentrations of ammonia and nitrate exceeded the trigger values at a number of offsite wells the most significant contaminant at most locations was nitrate. Elevated ammonia concentrations (greater than ten times the trigger value) were observed at P61/S61, P80, P88 and P89/S89.
- Review of operation of the nutrient in groundwater remediation system (comprising two 50 m interception trenches and a water treatment plant) indicates that the remediation system has had no significant effect on groundwater flow rates across the site boundary and considering that ammonia and nitrate concentrations have increased it is considered likely that contaminant mass flux from the Site is now higher than that prior to the commencement of remediation works; and
- The free cyanide plume is considered to be stable and Monitored Natural Attenuation (MNA) continues to be an appropriate remediation strategy for free cyanide at the Site.

4.1.15 Receiving Environmental Monitoring Program Preliminary Interpretive Report JBS&G 2017

JBS&G prepared a document titled 'Receiving Environmental Monitoring Program (REMP) Preliminary Interpretive Report' in June 2017. The aim of the REMP is to detail a program that monitors the potential effects of stormwater discharge from the site to the receiving environment.

The report included the REMP monitoring undertaken by Orica between July 2016 and June 2017. Three monitoring events were undertaken during the reporting period at two stormwater discharge locations and eight REMP locations.

REMP samples were collected from the locations presented in **Table 4.3 (Appendix A)**.

Table 4.3: REMP Sample Location Rationale

Location	Description	Purpose
ANP1/ANP2 and CC	Licensed Stormwater Discharges	Assess concentrations discharging from the Site.
REMP1	Culvert at Mount Larcom Road (northern or southern side)	Assess concentrations discharging from the mixing zone to the upper portion of the salt pan. This location is considered a suitable screening level location for assessing concentrations of contaminants discharging to the receiving environment.
REMP2	Western side of culvert under Reid Road	Assess concentrations after dilution from flows sourced from the table drain on the southern side of Mount Larcom Road.
REMP3 and REM4	Pipes under fence line	Assess attenuation of contaminants by dilution from the table drain on the eastern side of Reid Road and attenuation through the Gladstone Area Water Board property. Also assess concentrations entering the mixing zone.
REMP5	Drain at northern edge of carpark	Assess concentrations discharging from the Site via "Reid Road East" and assess potential influences of groundwater discharge.
REMP6	Drain under fence line at southern edge of carpark	Assess concentrations after dilution from flows sourced from the table drain on the western side of Reid Road. Also, relevant to assessing potential influence of groundwater discharge on contaminant concentrations.
REMP7 and REM8	Within diversion drains	Assess concentrations for areas up hydraulic gradient of the Site.

The report provided the following preliminary interpretation of REMP monitoring data:

- Reported concentrations of ammonia and nitrate at ANP1/ANP2 ranged between 0.78 to 0.89 mg/L and 3.68 and 5.70 mg/L respectively during the sampling events. Concentrations at upgradient sampling locations (REMP7 and REM8) were approximately one order of magnitude lower than those reported at ANP1/ANP2;
- Sampling locations in the mixing zone downgradient of ANP1/ANP2 (REMP3, REM4 and REM6) reported concentrations of ammonia and nitrate approximately one order of magnitude higher than those at ANP1/ANP2;
- The cause of the increase in nitrogen concentrations in the mixing zone compared to those discharged at ANP1/ANP2 may be related to a number of factors including degradation of biological material/vegetation present and/or discharge of groundwater with elevated concentrations of ammonia and nitrate in the mixing zone;
- The concentrations of ammonia and nitrate were approximately one order of magnitude higher in REM6 compared to ANP1/ANP2. Given the significant increases in concentrations between ANP1/ANP2 and REM6 and the very low likelihood that degradation of biological material could contribute significantly over this flow path it is concluded that groundwater discharge is the primary cause of the reported concentrations at REM6;
- All sampling events reported concentrations of ammonia and nitrate had decreased significantly between the mixing zone sample locations and REM1 (discharge point to the receiving environment);

- Free and WAD cyanide was less than the laboratory limit of reporting and the toxicant trigger values at all sample locations for all sampling events; and
- Total cyanide was detected in locations CC (0.007 mg/L on 17 March 2017 and 0.590 mg/L on 22 March 2017) and REMP2 (0.006 mg/L on 17 March 2017).

4.1.16 Detailed Site Investigation JBS&G 2017

JBS&G prepared a document titled 'Detailed Site Investigation' in August 2017. The aim of the DSI was to assess the potential for groundwater contaminated based on the current and historical site activities and address the requirements of the EHP notice.

The DSI included the review of site conditions, environmental setting and site history. The DSI included a detailed site inspection to identify possible sources of onsite contamination. The report included the review of potential pathways for groundwater contamination and identified the locations of potential and actual contamination based on the July 2017 groundwater monitoring event and 2016-2017 REMP monitoring events.

Based on the concentrations of contaminants identified in perched and shallow groundwater beneath the site, the primary source areas identified were:

- AN Plant No. 1 located in the centre of the AN processing area of the site. High nitrate and ammonia concentrations have been detected at monitoring well P55 located adjacent to AN Plant No. 1. Elevated concentrations were also detected in monitoring well P93, which is also located adjacent to AN Plant No. 1;
- The AN Solutions Storage, located in the northern portion of the AN processing area and north of AN Plant No. 1 was also identified as a potential source area. Elevated nitrate and ammonia concentrations were detected in the monitoring wells P35, located immediately adjacent to the tank farm and monitoring well P94, which is located north east of P35;
- The AN Bulk Store, located in the eastern portion of the AN processing area appears to be source area. Elevated nitrate and ammonia concentrations were detected in monitoring well P33, which is located east of the AN Bulk Store, and P95, which is located north of the AN Bulk Store and north east of AN Plant No. 1; and
- The Cyanide Plant and Warehouse appears to be the major cyanide source on the site. High total and free cyanide concentrations were reported in monitoring well P12 located immediately north of the Cyanide Plant and Warehouse. Elevated concentrations were also reported in P14 and P16 located east of the Cyanide Plant and Warehouse.

The DSI included the following conclusions:

- A number of potential or actual sources of contamination have been identified. The primary concerns relate to the AN and CC Plants;
- Historical groundwater (perched water and shallow aquifer) and surface water investigations have identified that actual contamination exists. The primary concerns relate to cyanide, nitrate and ammonia at concentrations exceeding adopted criteria;
- Potential pathways for groundwater contaminant migration include stormwater and perched water, with perched water likely to represent the primary concern; and
- The potential ecological receptors of site originated contamination which are of greatest concern represent ecosystems dependent upon the tidal mud flats and the broader Port Curtis area.

4.1.17 ASC NEPM Compliance

JBS&G completed a review of each of the reports (listed above) to assess the adequacy of the investigation works to determine if they meet the requirements of the ASC NEPM.

The key aspects of each report that were assessed included:

- Completeness: Is the report complete (i.e. text, figures, tables and all appendices)?
- Site Identification: Was the site (i.e. area of investigation) adequately defined?
- Site Condition: Is the site condition at the time of the assessment adequately defined?
- Environmental Setting: Has the environmental setting been adequately defined?
- Quality Assurance and Quality Control: Does the report include sufficient evidence of a well documented quality assurance and quality control program?
- Data Reliability Assessment: Does the report highlight any potential data reliability issues and is the overall data reliability assessment defensible?
- Results: Are the results provided consistent (i.e. laboratory report vs. summary tables vs. text)?
- Conclusions and Recommendations: Are the conclusions and recommendations provided defensible on the basis of the results?

Table 4.4 provides a summary of the NEPM compliance review.

Based on **Table 4.4**, JBS&G consider that the historical reports cited in **Section 4.1** are adequately compliant with the requirements of the ASC NEPM and provide a suitable basis for preparing a CSM.

Table 4.4: Assessment of Compliance of Historical Reports with ASC NEPM Requirements

Report	Completeness	Site Identification	Site Condition	Environmental Setting	Quality Assurance and Quality Control	Data Reliability Assessment	Results	Conclusions and Recommendations
Review of Potential Inputs of Contamination into Stormwater (URS, 2008)	Yes	Yes (limited)	Yes (limited)	No	NA – no data collected	NA – no data collected	NA – no data collected	Yes (limited)
Preliminary Offsite Surface Water Assessment Orica Yarwun (URS, 2008)	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Soil and Groundwater Investigation, Orica Yarwun (URS, 2008)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Off-site Surface Water and Sediment Quality Assessment – Dry Season (URS, 2008)	Yes	Yes	Yes	No*	Yes	Yes	Yes	Yes
Stage 3 Soil and Groundwater Investigation, Orica Yarwun (URS, 2008)	Yes	Yes	Yes	Yes	Yes	Yes ¹	Yes	Yes
Revised Conceptual Site Model (URS, 2009)	Yes	Yes	Yes	Yes	NA – no data collected	NA – no data collected	NA – no data collected	Yes
Status Report Nutrients in Groundwater and Surface Water (URS, 2009)	Yes	Yes (limited)*	Yes (limited)*	No*	NA – no data collected	NA – no data collected	NA – no data collected	Yes
July 2009 Groundwater Monitoring and Cyanide Delineation Investigation (URS, 2010)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Remediation of Nutrients in Groundwater (Golder, 2011)	Yes	Yes (limited)*	Yes (limited)*	No*	NA – no data collected	NA – no data collected	NA – no data collected	Yes
Remediation of Nutrients in Groundwater: Groundwater Extraction and Treatment	Yes	Yes	Yes	Yes	NA – no data collected	NA – no data collected	NA – no data collected	Yes

Report	Completeness	Site Identification	Site Condition	Environmental Setting	Quality Assurance and Quality Control	Data Reliability Assessment	Results	Conclusions and Recommendations
Preliminary Design Tasks (Golder, 2011)								
Cyanide Groundwater Remediation Options (Golder, 2011)	Yes	Yes	Yes	Yes	NA – no data collected	NA – no data collected	NA – no data collected	Yes
Groundwater Remediation Action Plan (JBS&G, 2011)	Yes	Yes	Yes	Yes	NA – no data collected	NA – no data collected	NA – no data collected	Yes
Groundwater Monitoring Plan (JBS&G, 2016)	Yes	Yes	Yes (limited)*	Yes (limited)*	NA – no data collected	NA – no data collected	NA – no data collected	Yes
Annual Groundwater Monitoring Report (JBS&G, 2017)	Yes	Yes	Yes	Yes (limited)*	Yes	Yes	Yes	Yes
Receiving Environmental Monitoring Program Preliminary Interpretive Report (JBS&G, 2017)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Detailed Site Investigation (JBS&G, 2017)	Yes	Yes	Yes	Yes	NA – no data collected	NA – no data collected	NA – no data collected	Yes

*Site identification, site condition and environmental setting were not included in all reports as some reports had specialised scopes. These details were also adequately defined in previous reports.

¹ Groundwater monitoring undertaken by URS in 2009 detected cyanide in offsite groundwater monitoring wells. This event has been the only time cyanide was detected in these monitoring wells and is therefore considered to be associated with cross contamination.

4.2 Source Review

4.2.1 Ammonia and Nitrate

Statistical analyses undertaken in the Annual Groundwater Monitoring Report (JBS&G, 2017) identified increasing trends (analysed independently of the actual contaminant concentration and site assessment criteria) for ammonia and nitrate at:

AN Source Areas

- P93/S93 (ammonia and nitrate), P95/S95 (ammonia and nitrate), S53 (ammonia), S81 (nitrate) and S94 (ammonia).

Site Boundary

- P48 (nitrate and ammonia), P50 (ammonia), P66 (ammonia), P69/S69 (nitrate (S69 only) and ammonia), P70 (nitrate and ammonia), P70/S71 (nitrate and ammonia), P86/S86 (nitrate), S4 (ammonia), S46 (nitrate and ammonia), S47 (nitrate and ammonia), S68 (nitrate) and S70 (ammonia).

Offsite

- P61/S61 (nitrate and ammonia), P62/S62 (nitrate), P80/S80 (nitrate and ammonia (P80 only)), P87 (ammonia), P88/S88 (nitrate and ammonia (P88 only)) and P89/S89 (nitrate and ammonia (S89 only)).

CN Source Areas

- P76 (ammonia), S12 (nitrate) and S14 (nitrate).

All other wells reported decreasing, stable or no trends for ammonia and nitrate concentrations in groundwater.

Interpreted plume maps for contaminants in groundwater have been included in **Appendix B**.

Table 4.5 provides a summary of ammonia and nitrate plume migration in the perched and shallow aquifer between 2008 and 2017.

Table 4.5: Ammonia and Nitrate Plume Migration Summary

Contaminant/Aquifer	Year	Potential Source	Distribution ¹
Ammonia (perched aquifer)	Aug 2008	The highest concentration detected was at P55 (257mg/l) northeast of AN Plant No 1.	Exceedances of the site assessment criteria extended from the Bulk Store in the south to the administration building in the north and cyanide plant in the west to eastern site boundary in the east. Offsite wells east of Reid Road did not exceed the site assessment criteria.
Ammonia (perched aquifer)	Jun 2009	The highest concentration detected was at P94 (734mg/l) northeast of AN Solutions Storage Tanks.	The extent of the plume is similar to 2008.
Ammonia (perched aquifer)	Jun 2010	The highest concentration detected was at P55 (3,440mg/l) northeast of AN Plant No 1.	Exceedances of the site assessment criteria have extended to P88 (eastern side of Reid Road), with evidence the plume is migrating to the northeast.
Ammonia (perched aquifer)	Oct 2011	The highest concentration detected was at P55 (404mg/l) northeast of AN Plant No 1.	The extent of the plume is similar to 2010.
Ammonia (perched aquifer)	Jun 2012	The highest concentration detected was at P55 (902mg/l) northeast of AN Plant No 1.	The extent of the plume is similar to 2011.
Ammonia (perched aquifer)	Jun 2013	The highest concentration detected was at P95 (984mg/l) northeast of AN Solutions Storage Tanks.	The extent of the plume is similar to 2012.
Ammonia (perched aquifer)	Jun 2014	The highest concentration detected was at P55 (2,490mg/l) northeast of AN Plant No 1.	The extent of the plume is migrating to the northeast (between the two extraction trenches). With concentrations of ammonia over 1,000mg/l at P55, P33, P95 and P48. Exceedances of the site assessment criteria have extended to P61 (eastern side of Reid Road). Ammonia was detected at 341mg/l at P12 (within the Cyanide Plant).
Ammonia (perched aquifer)	Jul 2015	The highest concentration detected was at P93 (1,940mg/l) east of AN Plant No 1.	The extent of the plume is migrating to the northeast (between the two extraction trenches). Exceedances of the site assessment criteria have extended to P89 and P61 (eastern side of Reid Road).
Ammonia (perched aquifer)	Jul 2016	The highest concentration detected was at P55 (1,560mg/l) northeast of AN Plant No 1.	The extent of the plume is similar to 2015.
Ammonia (perched aquifer)	Jul 2017	The highest concentration detected was at P48 (845mg/l) east of the carpark.	Concentrations have reduced; however, the extent of the plume is similar to 2015.

Contaminant/Aquifer	Year	Potential Source	Distribution ¹
Ammonia (shallow aquifer)	Aug 2008	The highest concentration detected was at S92 (173mg/l) northeast of Bulk Store.	Exceedances of the site assessment criteria extended from AN Plant No 2 in the south to the former chloride plant in the north and cyanide plant in the west to S87 (offsite east of Reid Road) in the east.
Ammonia (shallow aquifer)	Jun 2009	The highest concentration detected was at S92 (67.7mg/l) north of the Bulk Store	The extent of the plume is similar to 2008.
Ammonia (shallow aquifer)	Jun 2010	The highest concentration detected was at S55 (3,430mg/l) northeast of AN Plant No 1.	The extent of the plume is migrating to the northeast, with concentrations of ammonia over 1,000mg/l at S55 and S95. Offsite wells east of Reid Road did not exceed the site assessment criteria.
Ammonia (shallow aquifer)	Oct 2011	The highest concentration detected was at S55 (194mg/l) northeast of AN Plant No 1.	Concentrations have reduced; however, the extent of the plume is similar to 2010.
Ammonia (shallow aquifer)	Jun 2012	The highest concentration detected was at S55 (283mg/l) northeast of AN Plant No 1.	The extent of the plume is similar to 2011.
Ammonia (shallow aquifer)	Jun 2013	The highest concentration detected was at S48 (265mg/l) east of the carpark.	The extent of the plume is similar to 2012.
Ammonia (shallow aquifer)	Jul 2014	The highest concentration detected was at S48 (1,160mg/l) east of the carpark.	The extent of the plume is similar to 2013. Ammonia was detected at 90.1mg/l at S12 (within the Cyanide Plant).
Ammonia (shallow aquifer)	Jul 2015	The highest concentration detected was at S3 (811mg/l) east of the carpark.	Exceedances of the site assessment criteria have extended to S61 and S89 (eastern side of Reid Road).
Ammonia (shallow aquifer)	Jul 2016	The highest concentration detected was at S3 (668mg/l) east of the carpark.	The extent of the plume is similar to 2015.
Ammonia (shallow aquifer)	Jul 2017	The highest concentration detected was at S3 (615mg/l) east of the carpark.	The extent of the plume is similar to 2016.
Nitrate (perched aquifer)	Aug 2008	The highest concentration detected was at P55 (476mg/l) northeast of AN Plant No 1.	Exceedances of the site assessment criteria extended from Bulk Store in the south to the stormwater retention tank in the north and gas enhancement plant in the west to P89 (offsite east of Reid Road) in the east.
Nitrate (perched aquifer)	Jun 2009	The highest concentration detected was at P70 (432mg/l) within the Carpark.	The extent of the plume is similar to 2008, with concentrations of nitrate over 300mg/l at P80 (offsite east of Reid Road).

Contaminant/Aquifer	Year	Potential Source	Distribution ¹
Nitrate (perched aquifer)	Jun 2010	The highest concentration detected was at P55 (5,240mg/l) northeast of AN Plant No 1.	Concentrations of nitrate over 500mg/l are migrating to the northeast at P48 (east of the carpark) and P88 (offsite east of Reid Road).
Nitrate (perched aquifer)	Oct 2011	The highest concentration detected was at P55 (451mg/l) northeast of AN Plant No 1.	Concentrations have reduced; however, the extent of the plume is similar to 2010.
Nitrate (perched aquifer)	Jun 2012	The highest concentration detected was at P55 (1,080mg/l) northeast of AN Plant No 1.	The extent of the plume is similar to 2011.
Nitrate (perched aquifer)	Jun 2013	The highest concentration detected was at P95 (1,150mg/l) northeast of AN Solutions Storage Tanks.	The extent of the plume is similar to 2012.
Nitrate (perched aquifer)	Jul 2014	The highest concentration detected was at P55 (2,750mg/l) northeast of AN Plant No 1.	The extent of the plume is migrating to the northeast (between the two extraction trenches), with concentrations of nitrate over 1,000mg/l at P93, P55, P95, P69, P48 and P88.
Nitrate (perched aquifer)	Jul 2015	The highest concentration detected was at P95 (1,990mg/l) northeast of AN Solutions Storage Tanks.	The extent of the plume is similar to 2014.
Nitrate (perched aquifer)	Jul 2016	The highest concentration detected was at P55 (2,010mg/l) northeast of AN Plant No 1.	The extent of the plume is similar to 2015.
Nitrate (perched aquifer)	Jul 2017	The highest concentration detected was at P55 (1,370mg/l) northeast of AN Plant No 1.	The extent of the plume is similar to 2016.
Nitrate (shallow aquifer)	Aug 2008	The highest concentration detected was at S55 (336mg/l) northeast of AN Plant No 1.	Exceedances of the site assessment criteria extended from Bulk Store in the south to the former chlorine plant in the north and hardstand laydown area in the west to P61 (offsite east of Reid Road) in the east.
Nitrate (shallow aquifer)	Jun 2009	The highest concentration detected was at S92 (245mg/l) northeast of Bulk Store.	The extent of the plume is similar to 2008.
Nitrate (shallow aquifer)	Jun 2010	The highest concentration detected was at S55 (2,180mg/l) northeast of AN Plant No 1.	The extent of the plume is migrating to the northeast, with concentrations of nitrate over 1,000mg/l at S55 and S95 and above 500mg/l at S48.
Nitrate (shallow aquifer)	Oct 2011	The highest concentration detected was at S55 (444mg/l) northeast of AN Plant No 1.	Concentrations have reduced; however, the extent of the plume is similar to 2010.
Nitrate (shallow aquifer)	Jun 2012	The highest concentration detected was at S55 (537mg/l) northeast of AN Plant No 1.	The extent of the plume is similar to 2011.

Contaminant/Aquifer	Year	Potential Source	Distribution ¹
Nitrate (shallow aquifer)	Jun 2013	The highest concentration detected was at S48 (579mg/l) east of the carpark.	The extent of the plume is similar to 2012.
Nitrate (shallow aquifer)	Jul 2014	The highest concentration detected was at S48 (1,760mg/l) east of the carpark.	Concentrations have increased; however, the extent of the plume is similar to 2013.
Nitrate (shallow aquifer)	Jul 2015	The highest concentration detected was at S3 (1,240mg/l) east of the carpark.	The extent of the plume is similar to 2014.
Nitrate (shallow aquifer)	Jul 2016	The highest concentration detected was at S48 (623mg/l) east of the carpark.	The extent of the plume is similar to 2015.
Nitrate (shallow aquifer)	Jul 2017	The highest concentration detected was at S3 (823mg/l) east of the carpark.	The extent of the plume is similar to 2016.

¹ The site assessment criteria for ammonia is 1.43mg/l and 3.8mg/l for nitrate (Groundwater Monitoring Plan JBS&G 2016)

The groundwater contamination plume maps indicate the highest concentrations of ammonia and nitrate in groundwater were located downgradient of AN Plant No 1, the AN Solutions Tank, indicating these areas are the primary sources of ammonia and nitrate contamination in groundwater. The distribution of contaminants in groundwater also indicates that the Cyanide Plant may be a potential source of ammonia contamination.

4.2.2 Cyanide

Statistical analyses undertaken in the Annual Groundwater Monitoring Report (JBS&G, 2017) identified increasing trends for cyanide:

Free Cyanide

- P14, P75, S16 and S25.

Total Cyanide

- P14, P66, P73, P75, P76, S16, S25, S54 and S67.

All other wells reported decreasing, stable or no trends for cyanide concentrations in groundwater.

Review of the monitoring data indicates that the increasing trends are largely the result of an increase in concentration prior to 2014 (the statistical trend is based on the previous 5 years of data). Concentrations have been relatively stable between 2014 and 2017.

Groundwater contamination plume maps have been included in **Appendix B**.

Table 4.6 provides a summary of free cyanide and total cyanide plume migration in the perched and shallow aquifer between 2008 and 2017.

Due to the toxicity in the environment, Free Cyanide is the primary contaminant of concern, however, routine analyses includes Free, Total and WAD Cyanide.

Table 4.6: Cyanide Plume Migration Summary

Contaminant/Aquifer	Year	Potential Source	Distribution ¹
Free Cyanide (perched aquifer)	Aug 2008	The highest concentration detected was at P11 (363mg/l) within the Cyanide Plant.	Limited sampling was undertaken. However, cyanide was not detected along the eastern boundary of the site.
Free Cyanide (perched aquifer)	Jun 2009	The highest concentration detected was at P11 (238mg/l) within the Cyanide Plant.	Cyanide was detected in monitoring wells within the Cyanide Plant. Cyanide was also detected in P67 and P65 (northeast of the Cyanide Plant).
Free Cyanide (perched aquifer)	Jun 2010	NA	Only offsite monitoring wells were sampled and cyanide was not detected.
Free Cyanide (perched aquifer)	Jun 2011	The highest concentration detected was at P12 (0.023mg/l) within the Cyanide Plant.	The extent of the plume is migrating to the northeast to P73 and P67 (north of the administration building). Cyanide was also detected in P65.
Free Cyanide (perched aquifer)	Jun 2012	Source area not sampled.	Cyanide was only detected in P75 (north of the workshop).
Free Cyanide (perched aquifer)	Jun 2013	The highest concentration detected was at P12 (360mg/l) within the Cyanide Plant.	The extent of the plume is migrating to the northeast to P75 (north of the workshop).
Free Cyanide (perched aquifer)	Jul 2014	The highest concentration detected was at P12 (53.6mg/l) within the Cyanide Plant.	Cyanide was only detected in P12.
Free Cyanide (perched aquifer)	Jul 2015	The highest concentration detected was at P12 (9.47mg/l) within the Cyanide Plant.	The extent of the plume is migrating to the northeast to P75 (north of the workshop).
Free Cyanide (perched aquifer)	Jul 2016	The highest concentration detected was at P14 (0.091mg/l) within the Cyanide Plant.	The extent of the plume is similar to 2015. However, cyanide was detected in P16 (Cyanide Plant eastern boundary).
Free Cyanide (perched aquifer)	Jul 2017	The highest concentration detected was at P12 (1.48mg/l) within the Cyanide Plant.	The extent of the plume is similar to 2016.
Free Cyanide (shallow aquifer)	Aug 2008	The highest concentration detected was at S23 (0.95mg/l) within the Cyanide Plant.	Cyanide was only detected in P23.
Free Cyanide (shallow aquifer)	Jun 2009	The highest concentration detected was at S23 (154mg/l) within the Cyanide Plant.	Cyanide was detected in monitoring wells within the Cyanide Plant. Cyanide was also detected in S25 (north of the workshop).
Free Cyanide (shallow aquifer)	Jun 2010	NA	Only offsite monitoring wells were sampled and cyanide was not detected.

Contaminant/Aquifer	Year	Potential Source	Distribution ¹
Free Cyanide (shallow aquifer)	Jun 2011	The highest concentration detected was at S14 (0.167mg/l) within the Cyanide Plant.	The extent of the plume is migrating to the northeast to S25 (north of the workshop).
Free Cyanide (shallow aquifer)	Jun 2012	Source area not sampled.	Cyanide was only detected in S25 (north of the workshop).
Free Cyanide (shallow aquifer)	Jun 2013	The highest concentration detected was at S12 (13.8mg/l) within the Cyanide Plant.	The extent of the plume is migrating to the northeast to S25 (north of the workshop). Cyanide was also detected S18 (east of the former Chloride Plant).
Free Cyanide (shallow aquifer)	Jul 2014	The highest concentration detected was at S12 (11mg/l) within the Cyanide Plant.	Cyanide was only detected in S12.
Free Cyanide (shallow aquifer)	Jul 2015	The highest concentration detected was at S14 (0.049mg/l) within the Cyanide Plant.	The extent of the plume is migrating to the northeast to S25 (north of the workshop).
Free Cyanide (shallow aquifer)	Jul 2016	The highest concentration detected was at S16 (0.128mg/l) within the Cyanide Plant.	The extent of the plume is similar to 2015. However, cyanide was detected in S16 (Cyanide Plant eastern boundary).
Free Cyanide (shallow aquifer)	Jul 2017	The highest concentration detected was at S25 (north of the workshop).	The extent of the plume is similar to 2016.
Total Cyanide (perched aquifer)	Aug 2008	The highest concentration detected was at P11 (890mg/l) within the Cyanide Plant.	Limited sampling was undertaken. However, cyanide was not detected along the eastern boundary of the site.
Total Cyanide (perched aquifer)	Jun 2009	The highest concentration detected was at P11 (3820mg/l) within the Cyanide Plant.	Cyanide was detected in monitoring wells within the Cyanide Plant. Cyanide was also detected in P76, P73, P67, P66, P65 and P64 (northeast of the Cyanide Plant); P77 (west of the workshop); P82 (southeast boundary); and offsite at P87 and P89. ²
Total Cyanide (perched aquifer)	Jun 2010	NA	Only offsite monitoring wells were sampled and cyanide was not detected.
Total Cyanide (perched aquifer)	Jun 2011	The highest concentration detected was at P12 (6.02mg/l) within the Cyanide Plant.	The extent of the plume is migrating to the northeast to P76 (north of the administration building) and P66 and P65 (northeast fence line).
Total Cyanide (perched aquifer)	Jun 2012	Source area not sampled.	Cyanide was only detected in (P73, P67, P75 and P76 east of the Cyanide Plant) and P65 (northeast of the Cyanide Plant).
Total Cyanide (perched aquifer)	Jun 2013	The highest concentration detected was at P12 (484mg/l) within the Cyanide Plant.	The extent of the plume is similar to 2012.

Contaminant/Aquifer	Year	Potential Source	Distribution ¹
Total Cyanide (perched aquifer)	Jul 2014	The highest concentration detected was at P12 (180mg/l) within the Cyanide Plant.	The extent of the plume is similar to 2013.
Total Cyanide (perched aquifer)	Jul 2015	The highest concentration detected was at P12 (30.9mg/l) within the Cyanide Plant.	The extent of the plume is similar to 2014.
Total Cyanide (perched aquifer)	Jul 2016	The highest concentration detected was at P12 (14.1mg/l) within the Cyanide Plant.	The extent of the plume is similar to 2015.
Total Cyanide (perched aquifer)	Jul 2017	The highest concentration detected was at P12 (7.64mg/l) within the Cyanide Plant.	The extent of the plume is similar to 2016.
Total Cyanide (shallow aquifer)	Aug 2008	The highest concentration detected was at S19 (27mg/l) east of the cyanide effluent tanks.	Cyanide was detected in monitoring wells within the Cyanide Plant. Cyanide was also detected in S19 (northeast of the Cyanide Plant); S54, S47 and S48 (east of the Cyanide Plant); and offsite at S61. ²
Total Cyanide (shallow aquifer)	Jun 2009	The highest concentration detected was at S23 (637mg/l) within the Cyanide Plant.	Cyanide was detected in monitoring wells within the Cyanide Plant. Cyanide was also detected in S54, S25, S73, S5 and S19 (northeast of the Cyanide Plant); S77 and S81 (west of the workshop); P94 (south of the workshop); S71 (carpark); and offsite at S79, S89 and S87. ²
Total Cyanide (shallow aquifer)	Jun 2010	NA	Only offsite monitoring wells were sampled and cyanide was not detected.
Total Cyanide (shallow aquifer)	Jun 2011	The highest concentration detected was at S12 (15.5mg/l) within the Cyanide Plant.	The extent of the plume is migrating to the northeast to S54 and S25 (north of the workshop).
Total Cyanide (shallow aquifer)	Jun 2012	Source area not sampled.	The extent of the plume is similar to 2011.
Total Cyanide (shallow aquifer)	Jun 2013	The highest concentration detected was at S12 (75.1mg/l) within the Cyanide Plant.	The extent of the plume is similar to 2012. However, cyanide was also detected at S67 and S18.
Total Cyanide (shallow aquifer)	Jul 2014	The highest concentration detected was at S12 (59.3mg/l) within the Cyanide Plant.	The extent of the plume is similar to 2013.
Total Cyanide (shallow aquifer)	Jul 2015	The highest concentration detected was at S12 (28.5mg/l) within the Cyanide Plant.	The extent of the plume is similar to 2014.
Total Cyanide (shallow aquifer)	Jul 2016	The highest concentration detected was at S12 (12.6mg/l) within the Cyanide Plant.	The extent of the plume is similar to 2015.

Contaminant/Aquifer	Year	Potential Source	Distribution ¹
Total Cyanide (shallow aquifer)	Jul 2017	The highest concentration detected was at S14 (4.55mg/l) within the Cyanide Plant.	The extent of the plume is similar to 2016.

¹ The site assessment criteria for free cyanide is 0.011mg/l (Groundwater Monitoring Plan JBS&G 2016)

² Groundwater monitoring undertaken by URS in 2008 and 2009 detected cyanide in offsite groundwater monitoring wells. These events have been the only time cyanide was detected in these monitoring wells and is therefore considered to be associated with cross contamination.

The groundwater contaminant plume maps indicate the highest concentrations of free and total cyanide in groundwater were located downgradient to the Cyanide Plant. This indicates the CN manufacturing area is the primary source of cyanide contamination in groundwater.

4.3 Groundwater Contamination Characterisation and Delineation

Since 2009, routine groundwater monitoring has been undertaken at the site by Golder. Monitoring programs have focussed on the two operating areas of the site:

- AN - the main constituents of interest consist of ammonia, nitrate and nitrite (since nitrite represents a small portion of total nitrogen relative to nitrate, total oxidised nitrogen (NOx) has been analysed since February 2011). 93 monitoring wells are included in the nutrient monitoring program, with monitoring undertaken on a biannual basis; and
- CC - the main constituents of interest consist of total cyanide, WAD cyanide and free cyanide. 35 monitoring wells are included in the cyanide monitoring program, with monitoring undertaken on a biannual basis.

Groundwater contaminant plume maps (**Appendix B**) have characterised plume migration between 2008 and 2017.

The extensive historical monitoring program has adequately characterised the cyanide, ammonia and nitrate groundwater plumes including assessment of seasonal variability in both the perched and shallow aquifers. Statistical analyses on the monitoring results is undertaken on an annual basis and reported to EHP. The monitoring program has been undertaken in accordance with the site Groundwater Monitoring Plan (JBS&G, 2016).

The cyanide plume has been delineated within the site boundary with no detected concentrations of cyanide in the downgradient monitoring wells on the east side of Reid Road (with the exception of the 2008 and 2009 monitoring events that are considered to be influenced by cross contamination). Recent monitoring data indicates the potential for a data gap in the vicinity of the carpark (east of the Cyanide Plant). The significance of this is discussed further in **Section 5.6**.

Ammonia and nitrate have been detected in the downgradient monitoring wells on the east side of Reid Road, however, the installation of further monitoring wells in this area is limited due to the thick vegetation present in the forested land east of Reid Road. Recent monitoring data indicates the potential for a data gap in the vicinity of the Cyanide Plant and AN Plant 2. The significance of this is discussed further in **Section 5.6**.

4.4 Environmental Values

The site is within the Calliope River Basin, therefore the *Environmental Protection (Water) Policy 2009* Curtis Island, Calliope River and Boyne River Basins *environmental values and water quality objectives (November 2014)* apply to the site. The environmental values for the Gladstone State Development Area waters (mainland) includes:

- Aquatic ecosystems;
- Irrigation;
- Farm supply/use;
- Stock water;
- Aquaculture;
- Human consumption;
- Visual recreation;
- Industrial use;

- Cultural and spiritual values; and
- Environmental values prescribed for groundwater.

The receiving environment for stormwater discharged from the site is Flying Fox Creek/Port Curtis.

Surface water flow from the site to Port Curtis may potentially occur via two flow paths. The first is via a culvert under Gladstone Mount Larcom Road that represents the flow path for Flying Fox Creek (**Figure 4**). The second is via drains along the southern edge of Gladstone Mount Larcom Road that discharge to an anabranch of the Calliope River. Due to construction of the Wiggins Island Coal Export Terminal (WICET) flow towards the anabranch has been restricted. It is therefore anticipated that the majority of flows from the site will enter Port Curtis via Flying Fox Creek.

The WICET Environmental Impact Statement (EIS) provides a detailed description of the receiving environment and the area to the north of the culvert under Gladstone Mount Larcom Road is described as:

- o An intertidal wetland;
- o The higher levels are covered by extensive salt pans;
- o As Flying Fox Creek becomes more defined it is lined by mangroves (e.g. *Avicennia/Aegicaras/Rhisporoa/Cerriops*);
- o Further north (lower levels of the intertidal zone) aggregated patches of *Zostera* sp. seagrass are present in areas of exposed banks (mud and sand); and
- o The open waters of Port Curtis are then encountered.

The receiving environment is a low-gradient, intertidal area that extends from Gladstone Mount Larcom Road to the foreshores of Port Curtis. The sediment substrate is comprised of mud and sand. Sparse salt marsh vegetation is present near the discharge point, but is largely barren for 1.0 km to the uppermost reaches of the mangrove stands. The mud/sand flats are dissected by the drainage system (Flying Fox Creek) from the culvert, but elsewhere drainage patterns are indistinct.

Saline waters cover parts of the flats at high tide and during Spring tides waters flood through the culvert. Stormwater discharged through the culvert or other low lying point is expected to mix with fully saline waters over the flats at high tides, but at low tides stormwater would be channelled predominantly down rivulets in the flats.

Beyond the predominantly barren flats, the north-easterly trending rivulet becomes a larger meandering (serpentine) drainage (Flying Fox Creek) that enters an extensive area of mangroves. The meandering drainage continues beyond the mangroves in intertidal and subtidal elevations in a channel that is navigable by small craft.

Based on the review of the environmental values for the Gladstone State Development Area waters (mainland) the key environmental values that need to be protected are the aquatic ecosystems of the receiving environment (Flying Fox Creek/Port Curtis).

4.5 Chemistry of Contaminants of Concern in the Environment

The following section provides a summary of the chemistry of COPCs in the environment and was sourced directly from the Revised Conceptual Site Model (URS, 2009).

4.5.1 Nitrogen in the Environment

Ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-) are the most common ionic (reactive) forms of dissolved inorganic nitrogen in aquatic ecosystems.

The process for the degradation of ammonia in natural environments typically involves oxidation of ammonia to produce nitrite, which in turn is oxidised to nitrate. The oxidation process is called nitrification and is a common aerobic process mediated by two types of naturally occurring bacteria.

The first type of bacteria (*Nitrosomonas spp.*) converts the nitrogen in ammonia to nitrate, whilst the second type of bacteria (*Nitrobacter spp.*) converts nitrite to nitrate. Factors affecting nitrification include temperature, pH, dissolved oxygen concentration, and the presence of dissolved organic matter. Nitrite is readily oxidised to nitrate, and oxidation of ammonia tends to result in the accumulation of nitrate in water rather than nitrite. In anaerobic conditions (unlikely in surface waters at the Yarwun site), nitrate may be converted to nitrogen gas (N₂) through the process of denitrification involving organisms such as fungi and the bacteria *Pseudomonas spp.*

Ammonia tends to be oxidized to nitrate in a two-step process ($\text{NH}_4^+ \rightarrow \text{NO}_2^- \rightarrow \text{NO}_3^-$) by aerobic chemoautotrophic bacteria. NH_4^+ , NO_2^- and NO_3^- may be removed from water by macrophytes, algae and bacteria, which assimilate them as sources of nitrogen, which is an essential nutrient for plant growth.

Excess inorganic nitrogen can impair the ability of aquatic animals to survive, grow or reproduce as a result of direct toxicity. However, aside from toxic effects, excess inorganic nitrogen can also stimulate or enhance the development, maintenance and proliferation of primary producers, e.g. algae, resulting in eutrophication of freshwater, estuarine, and coastal marine systems.

Carmargo and Alonso (2006) concluded that levels of total nitrogen (TN) lower than 0.5 –1.0 mg TN/L could prevent aquatic ecosystems (excluding those ecosystems with naturally high N levels) from developing acidification and eutrophication, at least by inorganic nitrogen pollution. These relatively low TN levels could also protect aquatic animals against the toxicity of inorganic nitrogenous compounds since, in the absence of eutrophication, surface waters usually present relatively high concentrations of dissolved oxygen and most inorganic reactive nitrogen will be in the form of nitrate.

4.5.2 Cyanide in the Environment

At 25°C cyanide exists in various states including free, simple and complex cyanide species. In aqueous solutions, the form is dependant upon the pH and redox conditions of the solution and the presence of suitable molecules for binding. CN^- is the predominant stable form of free cyanide in waters above a pH of 9.0 to 9.5. With a lowering in pH increasing amounts of CN^- converting to HCN until 99.5% of cyanide exists as HCN at pH 7.0 (Moran, 2004). Most free cyanide in natural waters (pH 6.0 to 8.5) is therefore in the form of HCN. Free cyanide readily reacts within a few hours to a few days with almost any other chemicals it contacts, producing either simple or complex compounds. Simple cyanide compounds such as NaCN, KCN and $\text{Ca}(\text{CN})_2$ are readily soluble whereas $\text{Zn}(\text{CN})_2$, CuCN, $\text{Ni}(\text{CN})_2$ and AgCN are insoluble. Complex cyanide compounds form when CN^- binds with numerous organic and inorganic molecules, creating a wide variety of compounds of varying toxicity.

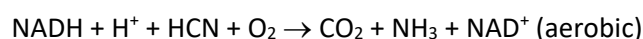
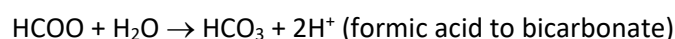
The persistence of cyanide in groundwater is dependent on groundwater chemistry, aquifer composition and groundwater microbiology. There are eight principal processes that affect the fate of cyanide in groundwater: complexation, precipitation, adsorption, oxidation, volatilisation, formation of thiocyanate, photolytic degradation and biodegradation (Meehan, 2000).

Complexation reactions typically occur when free cyanide reacts with transition metals present in the groundwater, often resulting in the formation of ferro- and ferri-cyanide complexes that precipitate in a range of pH and redox conditions. If sulphur is present, the reaction forms thiocyanate (SCN^-) which typically combines with metals to form metal-thiocyanate complexes (Meehan, 2000). Cyanide complexes (but not free cyanide) may adsorb onto soils depending on the anion exchange capacity of the soil.

The breakdown of cyanide and cyanide complexes results in the formation of nitrate and ammonia. Some of the strong cyanide complexes (e.g. $\text{Fe}(\text{CN})_6^{4-}$, $\text{Co}(\text{CN})_6^{4-}$) do not break down in the presence of strong acids but will decompose (releasing free cyanide) when exposed to various wavelengths of light (Moran, 2004). Decomposition rates are also affected by water temperature,

pH, total dissolved solids and the concentration of the cyanide complex. Some complexes degrade more rapidly when exposed to sunlight, atmospheric CO₂, and air, whereas others degrade more rapidly when they percolate through soils, are agitated and mixed by wind or streams, or are metabolised by bacteria (Moran, 2004).

Cyanide can be degraded by micro-organisms in both aerobic and anaerobic conditions. In aerobic conditions, cyanide is converted to formate then to carbon dioxide and in anaerobic conditions cyanide is degraded in methanogenic conditions to ammonia and formate, with the formate rapidly transformed to bicarbonate (Meehan, 2000). The degradation of cyanide can be expressed as follows:



Note: NAD = nicotinamide adenine dinucleotide, coenzyme 1, is a derivative of nicotinic acid which is required in small amounts for redox reactions where oxidoreductase enzyme transfer hydrogen.

4.5.3 Water Quality Guidelines

The relevant water quality guidelines for Port Curtis are the Curtis Island, Calliope River and Boyne River Basins Environmental Values and Water Quality Objectives (WQO) (EHP 2014). Where contaminants are not specified in the WQO, such as free cyanide, then the default guidelines are the marine water TVs presented in ANZECC/ARMCANZ (2000). For Port Curtis an ANZECC/ARMCANZ (2000) level of protection (95%) is considered appropriate to maintain the existing ecosystem condition for contaminants not specified in the WQO.

It is noted that water quality data from the Port Curtis Integrated Monitoring Program (PCIMP) November 2012 Field Report (EnvironMine 2013) indicates that ambient concentrations of ammonia and nitrate exceed the water quality objectives presented in the WQO (EHP 2014). This data is summarised in **Table 4.7** below.

Table 4.7: PCIMP Data and Relevant Water Quality Guidelines

	Ammonia (as N) mg/L	Nitrate (as N) mg/L	Free Cyanide mg/L
Western Basin WQO ⁵	0.008 ⁶	0.016 ⁷	NA
PCIMP Northern Sites Mean (2012)	0.02	0.045	NA
PCIMP Southern Sites Mean (2012)	0.021	0.049	NA
ANZECC/ARMCANZ (2000) TTV 95% Marine	0.91	0.7 ⁸	0.004
ANZECC/ARMCANZ (2000) TTV 90% Fresh	1.43	3.8 ⁹	0.011

Based on a review of the Environmental Values presented in **Section 4.4** the appropriate criteria for groundwater is ANZECC/ARMCANZ (2000) 90% trigger values for the protection of Fresh Water ecosystems. However, the guideline criteria presented in **Table 4.7** would be more appropriate for the receiving environment (Flying Fox Creek/Port Curtis).

⁵ Gladstone Harbour, the Narrows, adjacent coastal waters and estuaries: Water quality objectives to protect aquatic ecosystem environmental values under baseload conditions

⁶ 80th percentiles

⁷ Oxidised nitrogen

⁸ low reliability trigger value

⁹ refer *Updating nitrate toxicity effects on freshwater species* (Hickey January 2013)

4.6 Risk to the Environment

The assessment of risk to environmental values from site contaminants has been undertaken as follows:

- Assessment of migration pathways;
- Numerical assessment of groundwater/contaminant migration rates and mass flux; and
- Review of contaminant concentrations with respect to criteria relevant to the key environmental values.

4.6.1 Assessment of Groundwater Migration Pathways

Previous detailed assessments of groundwater flow at the site (URS 2009) concluded that groundwater occurs in three units:

- A perched groundwater unit (thickness varying from 0 to 3 m) in the reworked gravelly clay fill materials and the upper portion of the residual gravelly clays;
- A shallow groundwater unit is present within the residual gravelly clays at depths between approximately 2 and 12 m; and
- A deep groundwater unit present in the rock.

Investigations undertaken in the rock have not identified significant contamination and therefore migration within this unit is not considered further in this section.

As discussed in **Section 3** the properties (notably hydraulic conductivity) of the perched groundwater unit are highly variable and preferential pathways have been identified as being present at a number of locations. The presence of these preferential pathways (particularly those along the site boundary with Reid Road) is clearly shown on the plume maps presented in **Appendix B** and is most apparent for nitrate prior to 2010. The most significant preferential pathways are those at P71 (inferred to be a former drainage area that was backfilled during site development) as well as near P50/P85 (inferred to be associated with former stormwater drainage in this area). However, more recent data (nitrate concentrations in July 2017) indicates that plume migration is occurring across a more extensive portion of the site boundary than that identified prior to 2010.

Given the above, it is concluded that while contaminant migration in the perched groundwater unit is influenced by the presence of preferential flow paths, significant migration also occurs in the perched unit more generally.

Groundwater flow in the perched aquifer is interpreted to occur from the site towards the north-east. Based on survey data for the drainage system located to the east of Reid Road (adjacent to P88) and for the low lying area near P87, perched groundwater will generally discharge to the drainage systems and low-lying areas to the east of Reid Road. During periods of low rainfall groundwater discharge from the perched system is also low and will primarily occur to the low-lying area immediately south of Gladstone Mount Larcom Road. Review of groundwater levels in the perched and shallow units indicates that it is highly unlikely that significant groundwater discharge occurs directly to the mud flat/tidal areas north of Gladstone Mount Larcom Road.

The shallow groundwater unit is characterised by relatively low (of the order of 0.02 m/day) and consistent hydraulic conductivity compared to that of the perched unit. While groundwater migration rates in the shallow aquifer are relatively low the distribution of contamination in the aquifer is similar to that of the perched aquifer. This is attributed to the lack of a defined aquitard between the two layers allowing some vertical hydraulic connection (see below) to exist between the units. Consistent with the perched unit, groundwater from the shallow unit will discharge to the low lying area to the east of Reid Road and south of Gladstone Mount Larcom Road although the discharge rate is likely to be significantly lower (refer **Section 4.6.2**).

While differences in water level between adjacent piezometers installed in the perched and shallow units cannot be used to directly calculate flow/flux rates, they can be used to provide comment on flow direction. For locations with nested piezometers, **Appendix E** shows the head difference (positive indicating a downward flow potential and negative an upward potential) in July 2017. In general, the data indicates that for areas on the site there is only a relatively small vertical head difference with flow potential upward from the shallow to perched unit. Conversely, in areas near the site boundary and to the east of Reid Road there is a strong downward head difference. This downward trend decreases/reverses to the north and north east of Reid Road (with the exception of P78) where discharge of groundwater to the low lying areas occurs. It is noted that review of long term data at P78 indicates that the head difference varies with rainfall (during the wet season there is a downward gradient and for dry periods there is a very low difference).

The downward head difference at the site boundary and along Reid Road will result in downward migration of contamination into the shallow unit. However, as the shallow unit is characterised by relatively low horizontal hydraulic conductivity, migration rates will be slow and therefore the dominant migration pathway from the site to the receiving environment is via the perched groundwater unit.

4.6.2 Migration Rates

Numerical assessment/modelling of groundwater/contaminant migration rates and mass flux for ammonia and nitrate at the Reid Road site boundary is presented below in **Table 4.8**. It should be noted that these migration rates do not take in to account the interception and treatment of groundwater and therefore actual flows will be less than that in **Table 4.8**. While similar calculations can be performed for cyanide in groundwater, the cyanide plumes are not migrating from the site (refer **Appendix B**) and do not pose a risk to offsite environmental values. As a result, assessment of migration rates of cyanide has not been undertaken.

Table 4.8: Assessment of Migration Rates

Boundary Monitoring Well	Measured Hydraulic Conductivity (m/day)	Groundwater Velocity (m/year)	Representative Width (m)	Groundwater Flow Rate (m ³ /day)	July 2017 Nitrate (as N) Concentration (mg/L)	Estimated Nitrate (as N) Mass (kg/year)
Perched Unit						
P68	0.12	2.7	42	0.19	2.3	0.2
P71	60.94	1334	64	141	275	14 172
P48	0.01	0.22	37	0.01	861	4.3
P69	0.09	2.0	38	0.12	410	18.2
P84	0.73	16	38	1.00	9.5	3.5
P50	8.97	196	27	8.66	201	635
P85	0.06	1.3	37	0.08	101	2.9
P86	1.75	38	26	1.63	540	322
					Total	15 158
Shallow Unit						
S46	0.003	0.05	0	0.00	8.6	0.0
S47	0.015	0.27	51	0.03	56	0.6
S71	0.004	0.08	42	0.01	266	0.7
S48	0.005	0.09	37	0.01	515	1.5
S69	0.014	0.26	28	0.02	263	1.5

Boundary Monitoring Well	Measured Hydraulic Conductivity (m/day)	Groundwater Velocity (m/year)	Representative Width (m)	Groundwater Flow Rate (m ³ /day)	July 2017 Nitrate (as N) Concentration (mg/L)	Estimated Nitrate (as N) Mass (kg/year)
S49	0.014	0.26	39	0.02	1.2	0.0
S50	0.020	0.37	37	0.03	0.06	0.0
S85	0.182	3.32	51	0.37	76	10
S51	0.044	0.80	40	0.07	6.1	0.2
					Total	15

Notes: Calculations assume a perched unit thickness of 3 m and hydraulic gradient of 0.012 (4 m shallow unit thickness and 0.01 gradient) and porosity of 0.2.

The assessment of migration rates is summarised as follows:

- Groundwater seepage velocities, flow rates and mass flux are highly variable in the perched aquifer. Very large variations in rates occur over relatively small distances and as a result the rate estimates are subject to significant uncertainty;
- The velocity estimates for the perched aquifer imply that site derived contamination would migrate from the boundary to the low-lying areas to the east of Reid Road in relatively short periods (<5 years). Reported concentrations of ammonia and nitrate in offsite areas confirms that this has occurred;
- Groundwater seepage velocities, flow rates and mass flux are relatively consistent at each measurement location in the shallow aquifer;
- Velocity estimates for the shallow aquifer imply that site derived contamination would slowly migrate (>10 years) from the boundary to the low-lying areas to the east of Reid Road. Based on this it is concluded that the identified concentrations of ammonia and nitrate in the shallow aquifer at the boundary and in offsite areas is most likely due to vertical flow from the perched aquifer;
- The calculated mass flux discharge across the site boundary for nitrate is of the order of 15,000 kg/year. While the flux is dominated by the area around P71 it is important to note that current mass removal rates at the groundwater treatment system are approximately 8,000 kg/year (refer **Section 4.7.2**) and as a result it is clear that flow through preferential pathways dictate mass flux at the site boundary; and
- While it is considered that the mass flux values presented in **Table 4.8** are subject to uncertainty they provide significant information with respect to the potential for small scale features to be the dominant risk factor to environmental values.

4.6.3 Risk to Environmental Values

An assessment of the risk to environmental values is presented below with consideration of the information regarding migration pathways and rates presented in **Sections 4.6.1** and **4.6.2** as well as the distribution of contamination discussed in **Section 4.3** and presented in the plume maps in **Appendix B**:

- The current site data indicates that the presence of free cyanide in groundwater on the site poses no risk to environmental values;
- Ammonia and nitrate are present in groundwater on the site, at the site boundary and in offsite areas at concentrations that exceed the relevant criteria for the receiving environment by more than two orders of magnitude;

- Groundwater from the site discharges to the drainage systems along Reid Road and to the low lying area to the east of Reid Road and south of Gladstone Mount Larcom Road. Direct discharge of groundwater to the north of Gladstone Mount Larcom Road is considered unlikely;
- Calculations of mass flux of nitrate (and ammonia) across the site boundary (assuming no operation of the remediation system) indicates the potential for substantial migration of contaminants (>10,000 kg/year of nitrate and a similar mass of ammonia) from the site to the low lying area east of Reid Road;
- Given the reported ammonia and nitrate concentrations at the site boundary and in offsite areas, the calculated mass flux of contaminants and the period of time that flow has occurred from the site, it is concluded that a substantial mass of ammonia and nitrate has migrated from the site; and
- While it is noted that operation of a remediation system (**Section 4.7.2**) has recently been improved and data¹⁰ for ammonia and nitrate at the discharge point to the receiving environment beneath Gladstone Mount Larcom Road indicates general compliance with the ANZECC/ARMANZ (2000) toxicant trigger values, the concentrations of contaminants offsite and the mass flux estimates indicate that ammonia and nitrate in groundwater pose a potential risk to the identified environmental values (aquatic ecosystems of Flying Fox Creek/Port Curtis).
- A Contamination Action Plan (CAP)¹¹ has been prepared (separate to this CSM) that provides recommendations to expand the existing ammonia and nitrate remediation system to address the potential risk to the environment.

4.7 Evaluation of Current Controls

4.7.1 Source Control

Orica has completed a number of preventative source control works at the site including:

- Installation of new concrete laydown areas (installed in 2012/2013);
- Recoating Cyanide Plant ground flooring (2008);
- Repaired floors in NA tank No.1 (2005) and AN Plant No.1 (2012);
- Repair Bulk Store 1 floor (2010/2011)
- Lined the AN Solutions bund (2008); and
- Replacement of Cyanide Plant effluent treatment tanks (2008/2009), sales liquor tank (2011) and Cyanide effluent drain (2010).

These control works have focused on the primary source areas identified in **Section 2.4**.

Statistical analyses undertaken in the Annual Groundwater Monitoring Report (JBS&G, 2017) identified increasing trends for ammonia and nitrate in AN source areas including P93/S93 (ammonia and nitrate), P95/S95 (ammonia and nitrate), S53 (ammonia), S81 (nitrate) and S94 (ammonia). Statistical analyses have also identified increasing trends for cyanide in cyanide source areas including P14 (free and total cyanide) and S16 (free and total cyanide). Review of the monitoring data indicates that the increasing cyanide trends are largely the result of an increase in concentration prior to 2014 and since this time concentrations have been relatively stable.

¹⁰ JBS&G (2017) Receiving Environmental Monitoring Program Preliminary Interpretative Report, dated 26 June 2017.

¹¹ JBS&G (2017) Contamination Action Plan, dated 5 December 2017.

4.7.2 Groundwater Interception and Treatment System

The groundwater interception trench and treatment system corresponds to that presented in Remediation of Nutrients in Groundwater (Golder, 2011). The trenches were constructed on the site in early-2012 and commissioned by the end of 2012. Extraction and treatment commenced in mid-2013.

The location of the remediation system is illustrated on **Figure 3**. As built drawings for the interception trenches are provided in **Appendix C**.

The system is summarised as follows (Golder, 2011):

- *Design basis – to achieve a decrease in mass flux from the site.*
- *Description – P71 trench 50 m long, 0.3 m nominal width, an average of approximately 2.7 m deep, with a pumping location (0.5 m width) at the centre. P50 trench 50 m long, 0.3 m nominal width, an average of approximately 2.5 m deep, with a pumping location at the northern end.*
- *Locations – Across the northern preferential centred around P71 and extending to intercept backfill around the carpark stormwater system. Across the southern preferential flow path intersecting P85 and P50 and the stormwater pipes at ANP1.*
- *Flow rate – maximum 25/60 kL/day or sufficient to achieve a water level of 3.8 mAHD in the capture trench.*
- *Monitoring – water level monitoring at a minimum of eight perched monitoring wells and two wells installed in the backfill of the stormwater system at each trench location.*

As detailed in Golder (2011) the installed system was deemed to be pilot scale and intended to initially operate to allow collection of data suitable for determining long term remediation requirements. The data was required due to the variability in ground conditions at the site and their influence on contaminant concentration and required pumping rates. Estimates of groundwater flow rates across the eastern boundary of the site indicated potential flows of up to 200 kL/day. Most of this flow was expected to occur at the preferential flow paths and in particular the northern (P71) trench area.

Groundwater pumped from the interception trenches (location presented on the plume maps in **Appendix B**) is directed to a purpose built water treatment plant. Treated water is discharged to the Trade Waste Facility (TWF), via the AN effluent management system, in accordance with the Environmental Authority.

The treatment plant has recently been uprated with the result that significantly increased flow rates have been achieved since June 2017 (refer plots presented in **Appendix B**). Current flow rates to the plant are approximately 50 and 25 kL/day from the northern and southern trenches respectively. At these flows the mass of ammonia and nitrate being removed from groundwater is of the order of 6,700 and 8,700 kg/year respectively. Prior to the uprate of the treatment plant mass removal rates were substantially lower.

It is noted that trench flows have been observed to vary based on climatic conditions with significant increases occurring immediately following heavy rain. Insufficient data is currently available to determine whether the changes in inflows to the trenches are associated with changes in contaminant concentrations.

Water level maps for February 2016, January 2017 and July 2017 are presented in **Appendix D**. Review of the water level maps presented indicates that groundwater levels (and therefore flow paths) in areas not directly adjacent to the trenches have not been significantly altered by their

operation. While only one data set (July 2017) is available for the period when the treatment plant was operating at the increased rates, review of water level hydrographs (**Appendix D**) for piezometers located close to the trenches indicates that water level drawdown during pumping is relatively minor (i.e. the water level change in the trench pump pit(s) is very large (1.5 m) while changes to levels immediately outside the trench are small (0.5 m)). While this observation is typical of low permeability aquifers it may also be due to poor hydraulic connection between the trench and aquifer.

While early operation of the system did not achieve significant mass removal rates the recent operation of the system has resulted in mass removal rates of a similar magnitude to the calculated mass flux rates at the site boundary and is therefore clearly consistent with the goal of decreasing mass flux from the site. However, the lack of significant water level drawdown near the trenches and the observed increase in contaminant concentrations at locations between the trenches implies that additional extraction is required. Whether the increased extraction is achieved by improving operation of the existing trenches and/or installation of additional trenches in the area between the southern and northern trenches should be made based on detailed consideration of the site hydrogeology. As concluded in **Section 4.6.1** risk to environmental values are dominated by small scale features (preferential flow paths) and as these features are not easily identified by site investigations, the installation of additional trenched portions along the site boundary is likely to be the preferred option to ensure that risks to environmental values can be appropriately managed.

5. Conceptual Site Model

The following CSM has been updated and revised based on *Revised Conceptual Site Model, Orica Yarwun*, URS Australia, February 2009.

5.1 Contaminants of Potential Concern

A detailed review of contaminants of potential concern was undertaken as part of the investigation of potential sources (JBS&G 2017 and URS 2008). Based on the results of the review contaminants of potential concern have been grouped into two categories (URS 2008):

1. Major Contaminants of Concern – these contaminants are considered to be the “contaminants of concern” for this site based on their extensive use/storage on site in both extent and quantity and/or being considered to present a high risk of causing contamination; or
2. Minor Contaminants of Concern – these contaminants are both minor in the quantity of use and storage on site and were considered to have a low to moderate potential risk of causing contamination. For these reasons, the minor contaminants of potential concern are considered to not pose a significant risk of contamination and therefore are not considered in the CSM but are presented below for completeness.

The identified contaminants of potential concern are summarised in **Table 5.1** and **Table 5.2**.

Table 5.1: Summary of Major Contaminants of Concern

Contaminant	Primary Chemicals
Cyanide	Sodium Cyanide Cyanide Residues
Ammonia	Ammonia Ammonium nitrate Cyanide
Nitrate (nitrite)	Nitric acid Ammonia nitrate

Table 5.2: Summary of Minor Contaminants of Concern

Contaminant	Primary Chemicals
Acids (low pH)	Hydrochloric acid Sulphuric acid
Alkaline (high pH)	Sodium hydroxide Soda ash
Salts	Sodium chloride
Petroleum Hydrocarbons	Oil Diesel Lilamin Paraffin Oil

5.2 Sources of Contamination

5.2.1 Potential Sources of Contamination

The DSI (JBS&G, 2017) identified the following potential sources (**Figure 2**):

AN Complex

- Nitric Acid Plant No. 1;
- Nitric Acid Plant No. 2;
- Nitric Acid Plant No. 3;

- Acid Neutralisation Pit;
- Nitric Acid Storage Tanks;
- AN Plant No 1;
- AN Plant No. 2;
- Groundwater Treatment Plant;
- AN Solutions Storage;
- Effluent Ponds;
- Hardstand Laydown;
- Bulk Store;
- Emulsion Phase Plant;
- Stormwater Retention Tank;
- Ammonia Bullets; and
- Cooling Towers.

CN Complex

- CN Plant;
- CN Warehouse.;
- CN Effluent and Stormwater Retention;
- CN Isotainer Storage; and
- Cooling Towers.

Diffuse Sources

- CN Complex Stacks;
- AN Complex Stacks; and
- Truck Movements.

5.2.2 Identified Sources of Contamination

Based on the concentrations of contaminants identified in perched and shallow groundwater beneath the site, the primary source areas on the site are the following:

- AN Plant No. 1 located in the centre of the AN processing area of the site. High nitrate and ammonia concentrations have been detected at monitoring well P55 located adjacent to AN Plant No. 1. Elevated concentrations have also been detected in monitoring well P93, which is also located adjacent to AN Plant No. 1;
- The AN Solutions Storage, located in the northern portion of the AN processing area and north of AN Plant No. 1 was also identified as a potential source area. Elevated nitrate and ammonia concentrations have been detected in the monitoring wells P35, located immediately adjacent to the tank farm and monitoring well P94, which is located north east of P35;
- The AN Bulk Store, located in the eastern portion of the AN processing area appears to be source area. Elevated nitrate and ammonia concentrations have been detected in

monitoring well P33, which is located east of the AN Bulk Store, and P95, which is located north of the AN Bulk Store and north east of AN Plant No. 1; and

- The Cyanide Plant and Warehouse appears to be the major cyanide source on the site. High total and free cyanide concentrations have been reported in monitoring well P12 located immediately north of the Cyanide Plant and Warehouse. Elevated concentrations have also been reported in P14 and P16 located east of the Cyanide Plant and Warehouse.

5.2.3 Potential Offsite Sources of Contamination

The site is located in a rural setting within the Gladstone State Development Area, which is a designated industrial precinct. The nearest industrial neighbours are located on the eastern side of Reid Road and include the Gladstone Area Water Board (GAWB) Water Treatment Plant (cross gradient) and Calliope Shire's Sewage Treatment Plant (STP) (cross/upgradient). It is noted that the STP disposes of its treated effluent by onsite irrigation and is therefore a potential offsite source of nitrates (and ammonia) to the receiving environment (URS, 2009). A cleared area between these two facilities designates the former site of the Australian Magnesium Corporation's pilot processing plant. The Rio Tinto Aluminium alumina refinery is located 1 km west and upgradient of the site.

It is considered that the offsite potential sources of contamination are unlikely to represent sources of significant contamination contributing to the ammonia, nitrate or cyanide plumes.

5.3 Affected Media

5.3.1 Groundwater

The following sections provide a discussion of the most recent groundwater monitoring results as these results are considered to best approximate contamination conditions at the time of this report. Historical results are assessed on an annual basis as part of the annual groundwater monitoring reports.

5.3.1.1 Nitrate and Ammonia Groundwater Plume

Perched Groundwater

Nutrients in the perched groundwater unit were noted at the following concentrations in July 2017:

- NO_x (as N): <0.01 mg/l to 1,000 mg/l (P95); and
- Ammonia (as N): <0.01 mg/l to 845 mg/l (P48).

NO_x concentrations at the perched groundwater wells sampled exceeded the Groundwater Monitoring Plan (GWP) (JBS&G, 2016) Assessment Criteria in July 2017, except wells P19, P64, P66, P73, P78, P79 and P87.

The nature and extent of nitrate/NO_x in the perched aquifer is similar to that described in the Revised Conceptual Site Model (URS, 2009). The distribution of NO_x in groundwater appears to be migrating within the two preferential pathways:

- From the ANP1 area towards the north and then north-east as indicated by concentrations generally greater than 100 mg/l in the plant area (P55 and P95), car park and offsite between P88 and P80 along Reid Road in the east. Nitrate/NO_x concentrations were less than Groundwater Monitoring Plan (GMP) Assessment Criteria in perched groundwater well P87 in the forested woodland east of Reid Road and P78 and P79 along Reid Road to the north; and
- From the ANP1 towards the east in the vicinity of P50 to P86 and offsite in the vicinity of P62.

Ammonia concentrations at P12, P33, P48, P50, P55, P61, P69, P70, P71, P80, P88, P89, P94, P95, P103, P104 and P105 exceeded the GMP Assessment Criteria (JBS&G, 2016) in July 2017.

The nature and extent of ammonia in the perched aquifer is similar to that described in the Revised Conceptual Site Model (URS 2009). In general, the distributions of ammonia and nitrate¹² in groundwater at the site are similar. Historically, monitoring locations in offsite areas were characterised by significantly lower ammonia concentrations than nitrate concentrations, though the relative proportion of ammonia has increased since the Revised Conceptual Site Model was prepared within the preferential flow pathway at the car park and offsite at P88.

Ammonia concentrations exceeding 100 mg/l have been reported in a zone extending from the ANP1 area (P55 and P95) towards the north-east to the car park and along the eastern site boundary at P88.

Shallow Groundwater

The distribution of nutrients in the shallow aquifer is of a similar pattern to that observed in the perched aquifer. However, this is not attributed to horizontal migration but is likely the result of vertical migration from the perched groundwater (URS 2009).

Nutrients in the shallow groundwater unit were noted at the following concentrations in July 2017:

- NOx (as N): <0.01 mg/l to 823 mg/l (S3¹³); and
- Ammonia (as N): <0.01 mg/l to 625 mg/l (S3).

Elevated concentrations (exceeding 100 mg/L) of NOx within shallow groundwater were reported in the vicinity of ANP1 (S55), the car park (S48 and S71), east of the AN processing area (S33, S4, S53) and offsite at S61. NOx concentrations at S3, S4, S12, S14, S16, S25, S33, S35, S46, S47, S48, S51, S53, S54, S55, S61, S62, S69, S70, S71, S80, S85, S86, S88, S89, S93, S94, S95, S103 and S105 exceeded the GMP Assessment Criteria (JBS&G, 2016) in July 2017.

Elevated concentrations (exceeding 50 mg/L) of ammonia within shallow groundwater were reported in the vicinity of ANP1 (S55) and the car park (S48 and S71). Ammonia concentrations at S3, S4, S12, S14, S16, S33, S35, S46, S47, S48, S53, S55, S61, S69, S71, S89, S93, S94, S95, S103 and S104 exceeded the GMP Assessment Criteria (JBS&G, 2016) in July 2017.

5.3.1.2 Cyanide Groundwater Plume

Perched Groundwater

Cyanide in the perched groundwater unit was noted at the following concentrations in July 2017:

- Total cyanide: <0.004 mg/l to 7.64 mg/l (P12);
- WAD cyanide: <0.004 mg/l to 2.02 mg/l (P12); and
- Free cyanide: <0.004 mg/l to 1.48 mg/l (P12).

Free cyanide concentrations at P12 and P75 exceeded the GMP Assessment Criteria (JBS&G, 2016) in July 2017.

Based on the current and historical analytical data, the primary source of cyanide contamination in the perched aquifer is considered to be the Cyanide Plant area. Maximum total, WAD and free cyanide concentrations have historically been reported in monitoring well P11 located in backfill around the solids dissolving tank in the centre of the Cyanide Plant (Note: P11 was not sampled during July 2017 as this well is not included in the Groundwater Monitoring Plan (JBS&G, 2016) due to access issues). Monitoring well P12 located immediately north of the Cyanide Plant, has also

¹² Or NOx (nitrate and nitrite), which has been analysed since 2011. Since nitrite has been shown to represent a very small portion of NOx, NOx concentrations in groundwater are considered equivalent to nitrate concentrations.

¹³ S3 is potentially screened across both the perched and shallow groundwater unit.

reported significant total cyanide concentrations (exceeding 400 mg/L in June 2013, however, following source control work concentrations of total cyanide in P12 reduced by more than one order of magnitude by June 2015, and have reduced further since).

Downgradient of the Cyanide Plant, a zone of elevated total cyanide extends in the perched aquifer to the east across Rankin Drive (located within the site) and to the north-east towards the site boundary, with total cyanide historically detected above the laboratory reporting limit (LOR) at P64, P65 and P66. The zone of elevated WAD and free cyanide concentrations in the perched aquifer is less extensive than for total cyanide, with distribution in the vicinity of the Cyanide Plant and P75 in the north-east.

Shallow Groundwater

Cyanide in the shallow groundwater unit was noted at the following concentrations in July 2017:

- Total cyanide <0.004 mg/l to 4.55 mg/l (S14);
- WAD cyanide <0.004 mg/l to 0.043 mg/l (S25); and
- Free cyanide <0.004 mg/l to 0.048 mg/l (S25).

Free cyanide concentrations at S12, S14, S16, and S25 exceeded the GMP Assessment Criteria (JBS&G, 2016) in July 2017.

The distribution of cyanide compounds in the shallow groundwater generally follows the same pattern as the perched aquifer, although cyanide compounds appear to have a limited extent towards the north-east (cyanide compounds are less than the LOR at S65/S66 at the production plant boundary), and total cyanide may have migrated further east and south-east (as indicated by elevated total cyanide concentration at S54, adjacent to the administration office).

5.3.2 Surface Water

The site Environmental Authority EPPR00872013 (current version of the EA was issued on 6 March 2017) includes several conditions related to monitoring of stormwater discharge. The monitoring includes a Receiving Environment Monitoring Program (REMP) that requires annual monitoring and reporting of offsite surface water.

REMP samples are collected from the locations presented in **Table 4.3**.

Analytical results from the July 2016 to June 2017 period are summarised as follows:

- Reported concentrations of ammonia and nitrate at ANP1/ANP2 ranged between 0.78 to 0.89 mg/L and 3.68 and 5.70 mg/L respectively during the sampling events. Concentrations at upgradient sampling locations (REMP7 and REMF8) were approximately one order of magnitude lower than those reported at ANP1/ANP2;
- Sampling locations in the mixing zone downgradient of ANP1/ANP2 (REMP3, REMF4 and REMF6) reported concentrations of ammonia and nitrate approximately one order of magnitude higher than those at ANP1/ANP2;
- The cause of the increase in nitrogen concentrations in the mixing zone compared to those discharged at ANP1/ANP2 may be related to a number of factors including degradation of biological material/vegetation present and/or discharge of groundwater with elevated concentrations of ammonia and nitrate in the mixing zone;
- The concentrations of ammonia and nitrate were approximately one order of magnitude higher at REMF6 compared to ANP1/ANP2. Given the significant increases in concentrations between ANP1/ANP2 and REMF6 and the very low likelihood that degradation of biological

material could contribute significantly over this flow path it is concluded that groundwater discharge is the primary cause of the reported concentrations at REMP6;

- All sampling events reported that concentrations of ammonia and nitrate had decreased significantly between the mixing zone sample locations and REMP1 (discharge point to the receiving environment);
- Free and WAD cyanide was less than the laboratory limit of reporting and the toxicant trigger values at all sample locations for all sampling events; and
- Total cyanide was detected in locations CC (0.007 mg/L on 17 March 2017 and 0.590 mg/L on 22 March 2017) and REMP2 (0.006 mg/L on 17 March 2017).

5.4 Receptors

Surface water and groundwater from the site discharge into the forested land located approximately 300 metres from the site to the north east and east. After entering this mixing zone water ultimately discharges to the intertidal waters of Port Curtis. Because of the location of the site and the nature of the receiving aquatic environment it is considered unlikely that direct human exposure would occur.

The potential key receptors of ammonia, nitrate and/or cyanide in the receiving environment include:

- Aquatic fauna such as macroinvertebrates (e.g. insect larvae) and fish (likely to only be present in permanent water bodies);
- Semi-aquatic fauna such as frogs and wading waterbirds;
- Terrestrial fauna (e.g. birds, reptiles and mammals) that utilise the water for drinking and/or bathing;
- Aquatic plants (e.g. bulrush); and
- Terrestrial plants that utilise the water (e.g. *Eucalyptus* spp. and *Melaleuca* spp.).

URS (2009) completed ecological surveys of the mixing zone that identified the following receptors.

Aquatic insect larvae are present in the mixing zone and likely to be exposed to aqueous COPCs; yabbies are known to inhabit the containment pond (onsite) and are also likely to be present in the intertidal area. Fish are unlikely to inhabit the drainage channels and intertidal area due to the seasonal variability of the water levels.

Semi-aquatic species such as frogs are known to inhabit the drainage channels and are likely to be present in the intertidal area. Frogs are recognised as a good indicator of water quality. At times of suitable water levels, wading waterbirds are also likely to utilise the drainage channels and intertidal area for foraging.

The vegetation surrounding the site would provide shelter and food for a large variety of birds, mammals and reptiles. Although no targeted fauna survey was completed any fauna that was opportunistically observed during the flora surveys was recorded. A total of 27 birds were observed during the survey period, as were three amphibian species (including the feral Cane Toad *Bufo marinus*), one native reptile and one native mammal species. Terrestrial fauna could be expected to utilise any free standing water as a source for drinking and bathing (e.g. birds), particularly during the drier winter periods.

The flora survey found that the vegetation present in the mixing zone was composed of communities of *Melaleuca viridiflora* and *Eucalyptus tereticornis* Open Woodland and *Eucalyptus tereticornis*, *Lophostemon suaveolens* and *Melaleuca* sp. Woodland. Understorey species recorded in the mixing

zone have been affected by the proximity to roadside verges and other 'edges' with many weed species concentrated around the edges of the vegetation stands.

Several weed species within tracts of vegetation appeared to be as a result of 'bird drop', where droppings of bird species utilising roosting spots cause the spread of weeds (e.g. *Lantana camara*) within bushland of otherwise good condition. Many of the weed species observed within the receiving environment were also present at reference sites.

Typha sp. (bulrush) is adapted to living in aquatic environments and is found in the drainage channel near the junction of Reid and Mt. Larcom-Gladstone Roads, and within the entrance to the (onsite) containment pond adjacent to Reid Road. This species is often planted in wetlands established to biologically treat contaminated water. As such, the *Typha* sp. habitat in the mixing zone adjacent to the Orica Yarwun site is likely to be assisting with the natural attenuation of COPCs (particularly ammonia and nitrate) in surface waters. In addition, the vegetation (mainly grasses) within the drainage channels elsewhere near the site, and within the intertidal area are also likely to be utilising these COPCs.

The receiving environment for stormwater discharged from the site, after passing through the mixing zone, is Flying Fox Creek/Port Curtis.

Surface water flow from the site to Port Curtis may potentially occur via two flow paths. The first is via a culvert under Gladstone Mount Larcom Road that represents the flow path for Flying Fox Creek (**Figure 4**). The second is via drains along the southern edge of Gladstone Mount Larcom Road that discharge to an anabranch of the Calliope River. Due to construction of the WICET flow towards the anabranch has been restricted. It is therefore anticipated that the majority of flows from the site will enter Port Curtis via Flying Fox Creek.

5.5 Potential and Complete Exposure Pathways

The extensive data set collected during site investigations and historical monitoring programs has adequately characterised the cyanide, ammonia and nitrate groundwater plumes including assessment of seasonal variability in both the perched and shallow aquifers. The cyanide plume has been delineated within the site boundary with no detected concentrations of cyanide in the downgradient monitoring wells on the east side of Reid Road. Therefore, this indicates that cyanide in groundwater has not migrated to the receiving environment. The results of groundwater monitoring do not indicate that the cyanide plume is expanding and future risk to the environment from cyanide in groundwater are considered to be low. Ammonia and nitrate have been detected in monitoring wells on the east side of Reid Road and are therefore considered to be migrating into the mixing zone of the receiving environment. Concentrations of ammonia and nitrate in offsite monitoring wells and in surface water in the mixing zone significantly exceeds the relevant ANZECC/ARMCANZ (2000) trigger values for the protection of Fresh Water ecosystems. While it is noted that operation of a remediation system (**Section 4.7.2**) has recently been improved and the data for ammonia and nitrate at the discharge point to the receiving environment beneath Gladstone Mount Larcom Road indicates general compliance with the ANZECC/ARMANZ (2000) toxicant trigger values, the reported concentrations of contaminants offsite and calculated estimate of site boundary mass flux is considered to pose a potential risk to the identified environmental values (aquatic ecosystems of Flying Fox Creek/Port Curtis).

5.6 Data Gaps

The historical monitoring program has gathered sufficient data to complete the Contamination Action Plan which is required under requirement 3 of the EHP notice (dated 21 July 2017).

However, it is noted that during review of the available data a number of data gaps were identified that warrant the collection of additional water quality data during the next round of monitoring. Cyanide analyses should be included for existing monitoring wells located in the carpark east of the

Cyanide plant and ammonia and nitrate analyses should be included for existing monitoring wells in the vicinity of the Cyanide Plant and AN Plant 2 to further assess potential for cyanide migration and confirm previous historical results remain valid (i.e. extensive historical monitoring in these areas have shown that the plume was previously delineated and/or source areas were defined).

6. Conclusions

Subject to the limitations in **Section 7** and with respect to the objectives stated in **Section 1.2** JBS&G conclude that:

- The investigation works completed to date by JBS&G and others adequately meet the requirements of the ASC NEPM;
- The findings of the DSI prepared by JBS&G have been incorporated into this report;
- Historical groundwater monitoring data was assessed to determine the source of increases in concentration of free cyanide, ammonia and nitrate in groundwater. The groundwater contamination plume maps indicate AN Plant No 1 and the AN Solutions Tank are the primary sources of ammonia and nitrate contamination in groundwater. The groundwater contaminant plume maps indicate the CN manufacturing area is the primary source of cyanide contamination in groundwater.
- Based on the review of the environmental values for the Gladstone State Development Area waters (mainland) the key environmental values that need to be protected are the aquatic ecosystems of the receiving environment (Flying Fox Creek/Port Curtis).
- Following a detailed review of the distribution of contamination and migration pathways in groundwater, an assessment of the risk to environmental values was undertaken with the following conclusions:
 - The current site data indicates that the presence of free cyanide in groundwater on the site poses no risk to environmental values;
 - Ammonia and nitrate are present in groundwater on the site, at the site boundary and in offsite areas at concentrations that exceed the relevant criteria for the receiving environment;
 - Groundwater from the site discharges to the drainage systems along Reid Road and to the low lying area to the east of Reid Road and south of Gladstone Mount Larcom Road. Significant direct discharge of groundwater to the north of Gladstone Mount Larcom Road is considered unlikely;
 - Calculations of mass flux of nitrate (and ammonia) across the site boundary (assuming no operation of the remediation system) indicates the potential for substantial migration of contaminants from the site to the low lying area east of Reid Road;
 - Given the reported ammonia and nitrate concentrations at the site boundary and in offsite areas, the calculated mass flux of contaminants and the period of time that flow has occurred from the site, it is concluded that a substantial mass of ammonia and nitrate has migrated from the site; and
 - While it is noted that operation of a remediation system (**Section 4.7.2**) has recently been improved and data¹⁴ for ammonia and nitrate at the discharge point to the receiving environment beneath Gladstone Mount Larcom Road indicates general compliance with the ANZECC/ARMANZ (2000) toxicant trigger values, the concentrations of contaminants offsite and the mass flux estimates indicate that ammonia and nitrate in groundwater pose a potential risk to the identified environmental values (aquatic ecosystems of Flying Fox Creek/Port Curtis)

¹⁴ JBS&G (2017) Receiving Environmental Monitoring Program Preliminary Interpretative Report, dated 26 June 2017.

- A Contamination Action Plan (CAP)¹⁵ has been prepared (separate to this CSM) that provides recommendations to expand the existing ammonia and nitrate remediation system to address the potential risk associated with discharge of groundwater to the receiving environment.
- This report has been structured based upon the essential elements of a CSM defined in Schedule B1 of the National Environmental Protection (Assessment of Site Contamination) Measure as amended 2013, to assess potential risks to environmental values. The CSM provides a suitable basis for development of a CAP.

¹⁵ JBS&G (2017) Contamination Action Plan, dated 5 December 2017.

7. 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 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.

JBS&G accepts no liability for use or interpretation by any person or body other than the client who commissioned the works. This report should not be reproduced without prior approval by the client, or amended in any way without prior approval by JBS&G, and should not be relied upon by other parties, who should make their own enquires.

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.

Limited sampling and laboratory analyses were undertaken as part of the investigations undertaken, as described herein. Ground 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 subsurface 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.

Figures



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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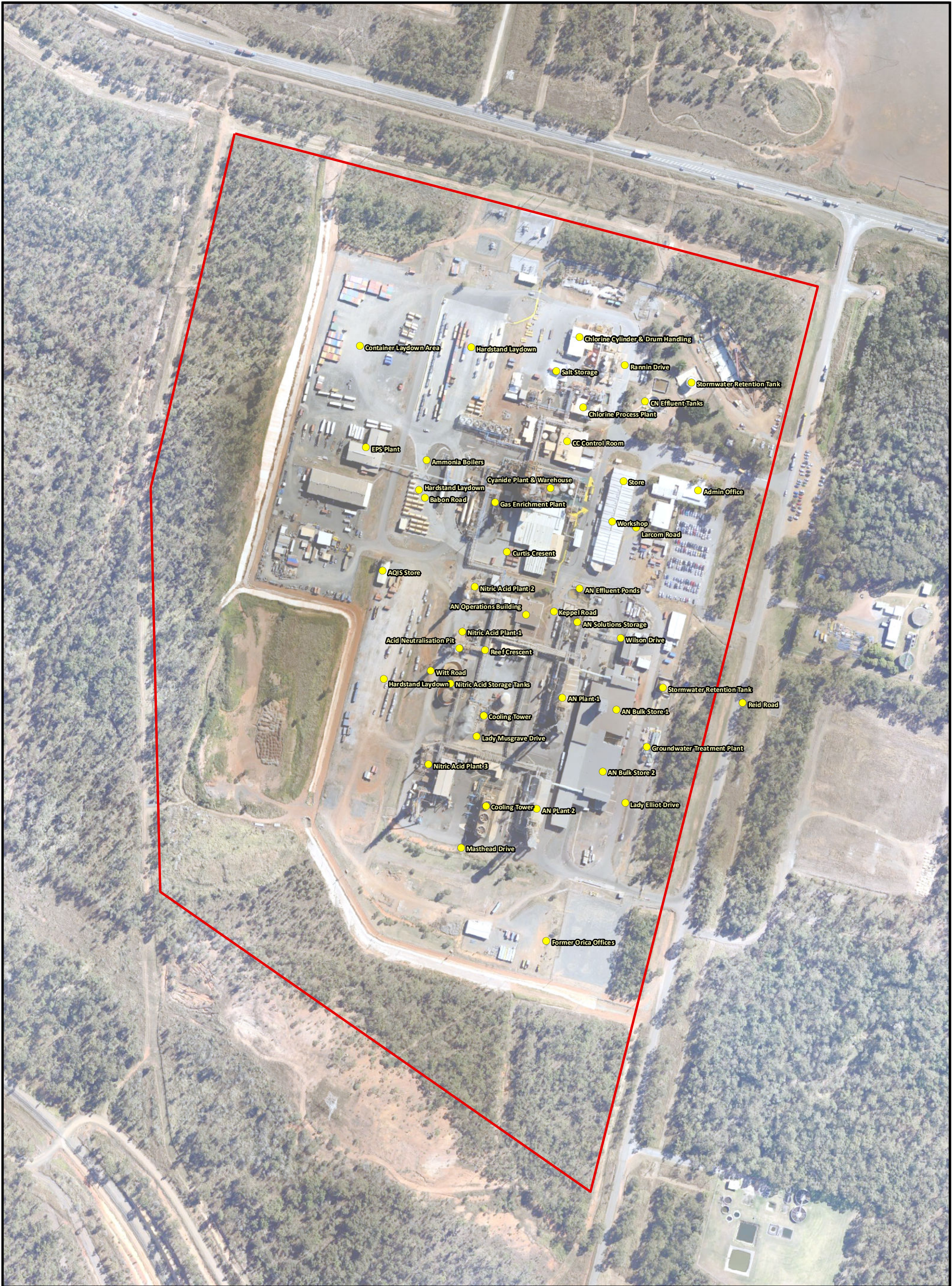
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A3			
B	Original Issue - R02	RF	17-11-2017
Rev	Description	Drn.	Date

Legend:
— Approximate Boundary - Lot 138 CTN2123

JBS&G Figure 1: Site Location

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877
File Name: 52877_01





Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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Datum: MGA94 Zone 56 - AHD		
A3		
B	Original Issue - R02	RF 17-11-2017
Rev	Description	Drn. Date

Legend:
— Approximate Boundary - Lot 138 CTN2123
● Site Features

JBS&G Figure 2: Site Features

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877
File Name: 52877_02





Port Curtis

Flying Fox
Creek

Wiggins Island
Coal Export
Terminal

Orca
Yarwun

Gladstone

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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0 310 620 1,240
m

Scale: 1:32,255

Datum: MGA94 Zone 56 - AHD

A3			
A	Original Issue - R02	RF	16-06-2014
Rev	Description	Drn.	Date

Legend:

JBS&G Figure 4: Receiving Environment

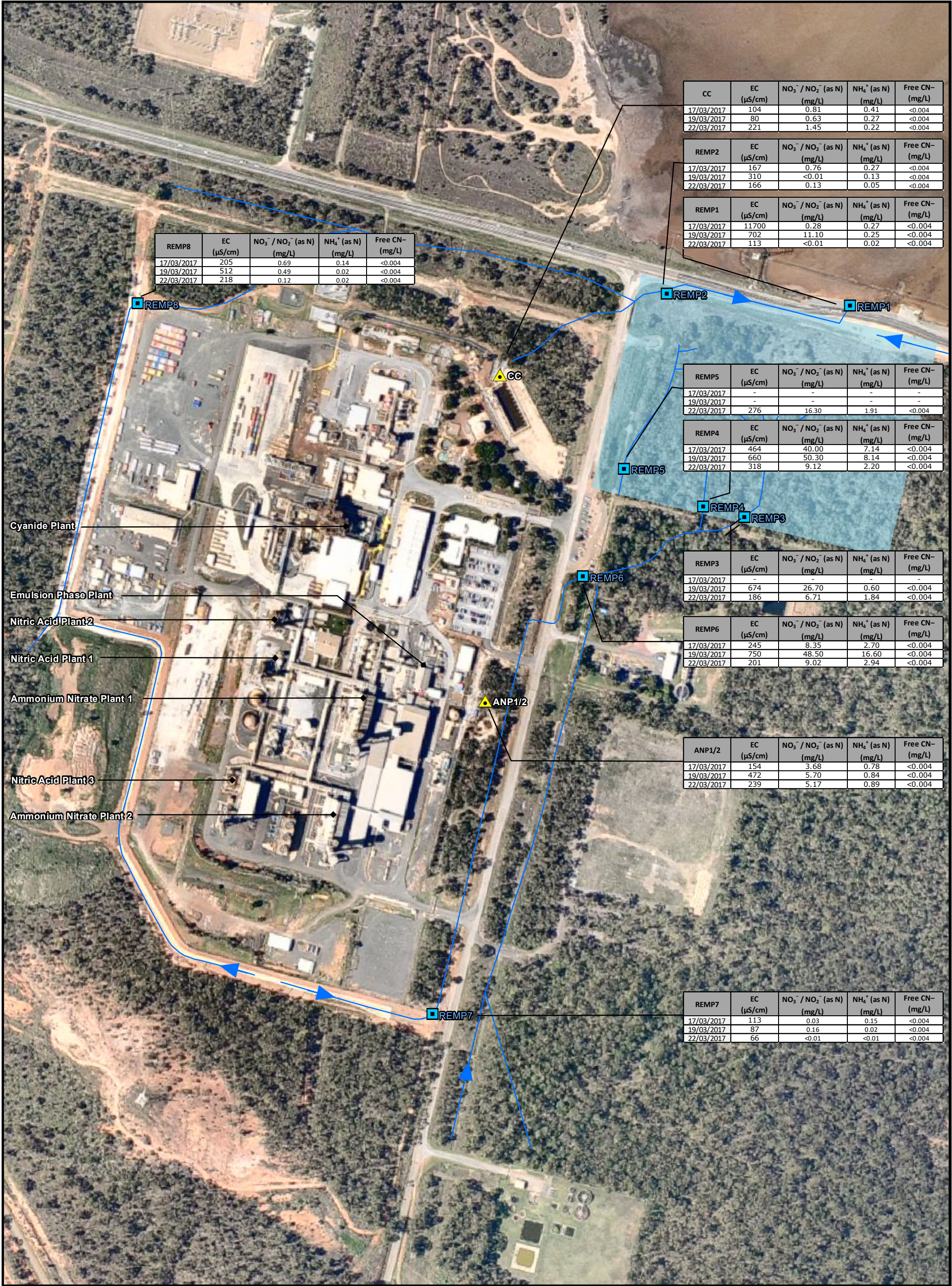
Client: Orca Australia Pty Ltd

Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)

Job No: 52877

File Name: 452877_04

Appendix A Historical Sample Locations



Source: Base Image www.nearmap.com - Imagery Date Dec 2014.

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Rev	Description	Dm.	Date

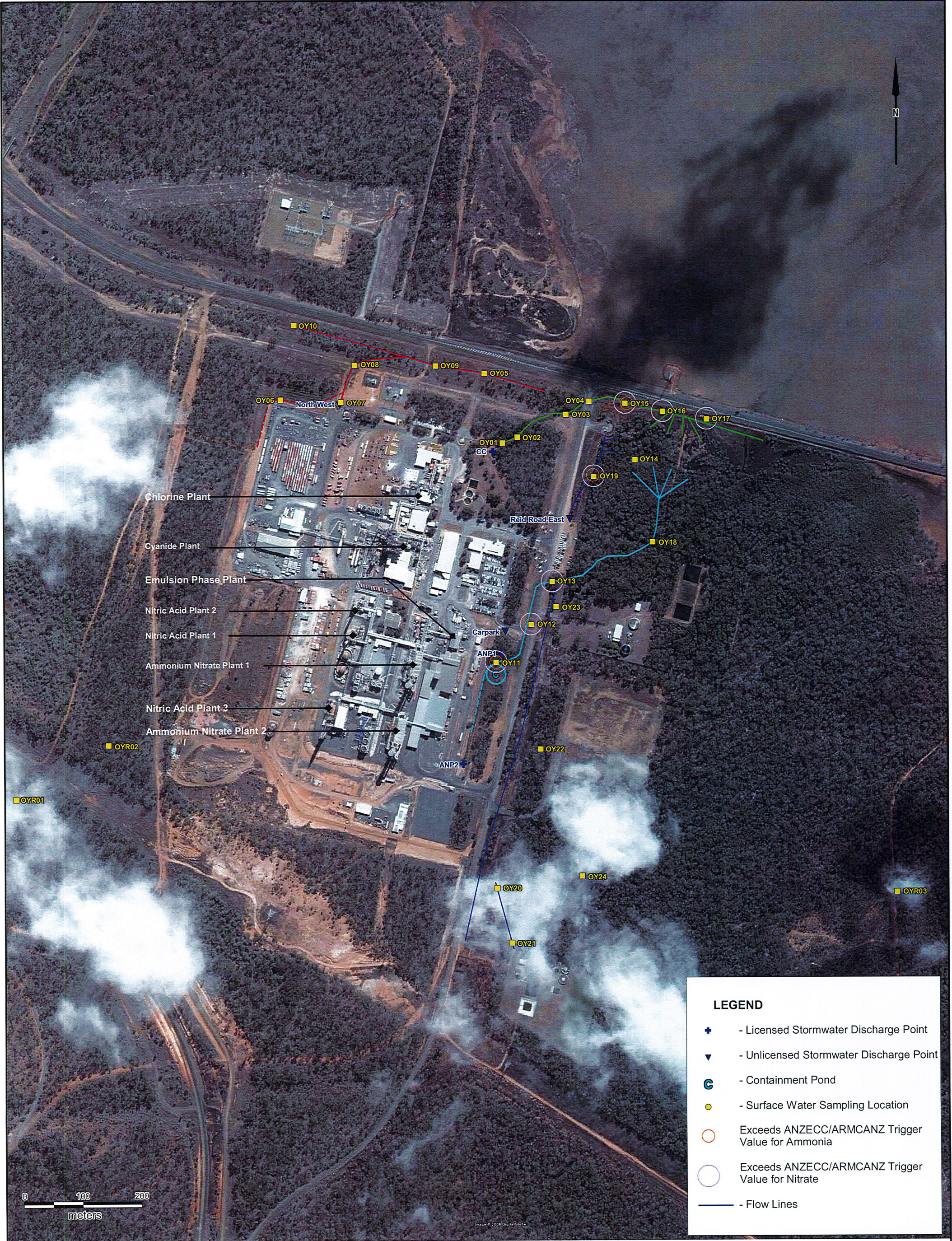
- Legend:
- Licensed Stormwater Discharge Point
 - Surface Water Sample Locations
 - Drainage Line
 - Mixing Zone

Location	Electrical Conductivity (µS/cm)	Nitrate / Nitrite (as N) (mg/L)	Ammonia (as N) (mg/L)	Free Cyanide (mg/L)
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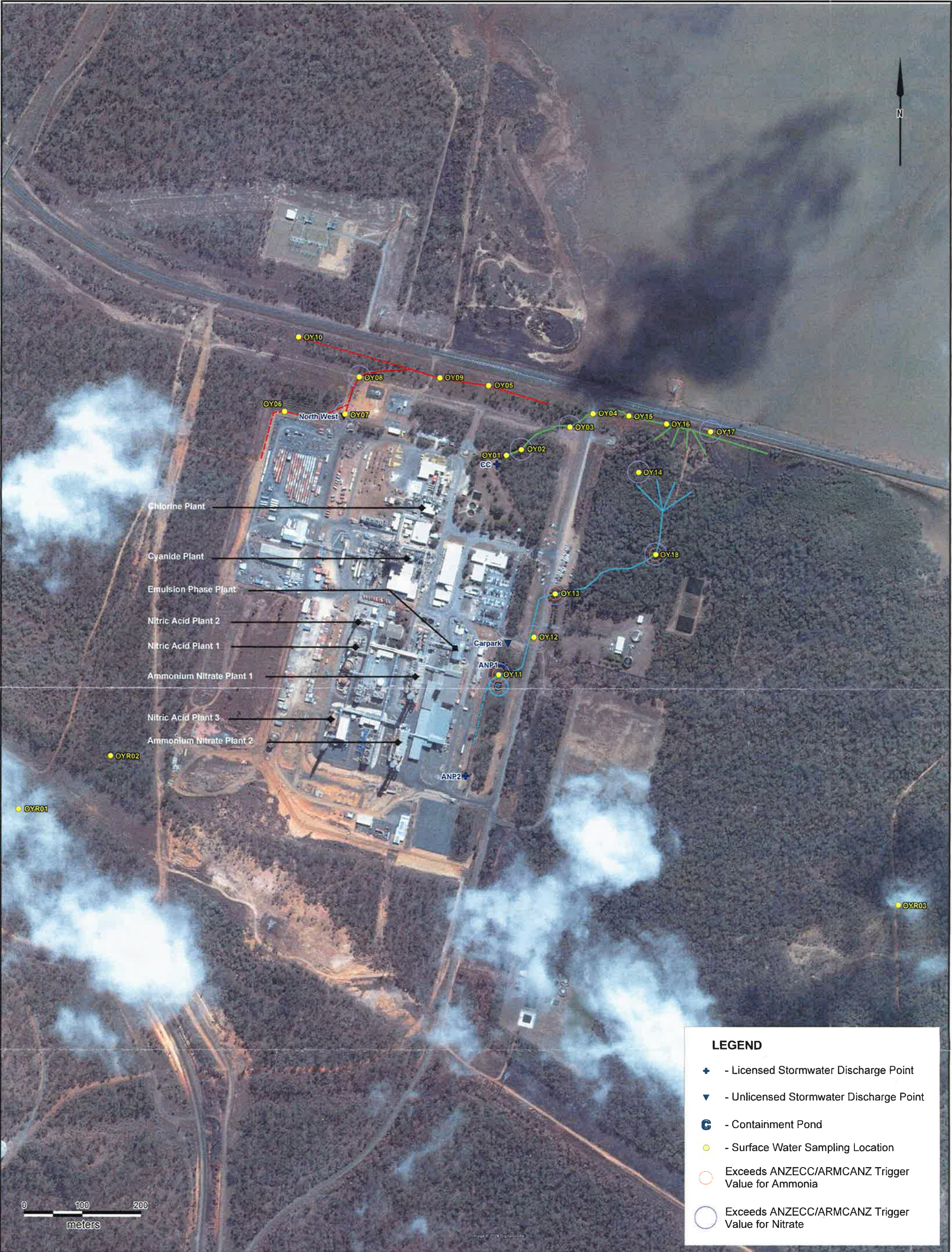
Figure 8: REMP Monitoring Locations and Sampling Results

Client: Orica Australia Pty Ltd	
Project: Yarwun REMP Interpretive Report	
Job No: 52877	File Name: 52877_08



SOURCE: IMAGE FROM GOOGLE EARTH

Client ORICA AUSTRALIA PTY LTD	Project PRELIMINARY OFFSITE SURFACE WATER ASSESSMENT YARWUN PRODUCTION FACILITY, GLADSTONE QUEENSLAND	Title SURFACE WATER SAMPLING LOCATIONS
URS	Drawn: AJW Job No: 43217778 Approved: PMG File No: 43217778.017.wor Date: 26/11/2008	Figure: 2



SOURCE: IMAGE FROM GOOGLE EARTH

Client ORICA AUSTRALIA PTY LTD	Project PRELIMINARY OFFSITE SURFACE WATER ASSESSMENT YARWUN PRODUCTION FACILITY, GLADSTONE QUEENSLAND	Title SURFACE WATER SAMPLING LOCATIONS
URS	Drawn: AJW Approved: PMG Date: 01/05/2008 Job No: 43217778 File No: 43217778.017.wor	Figure: 2



Source: Google Earth

Client
ORICA AUSTRALIA PTY LTD

Project
SOIL AND GROUNDWATER INVESTIGATION
YARWUN PRODUCTION FACILITY,
GLADSTONE QUEENSLAND

Title
SITE LAYOUT, BOREHOLE AND GROUNDWATER
MONITORING WELL LOCATIONS

URS

Drawn: AJW
Approved: GVS
Date: 01/05/2008
Job No: 43217716
File No: 43217716-001.wor

Figure: 2

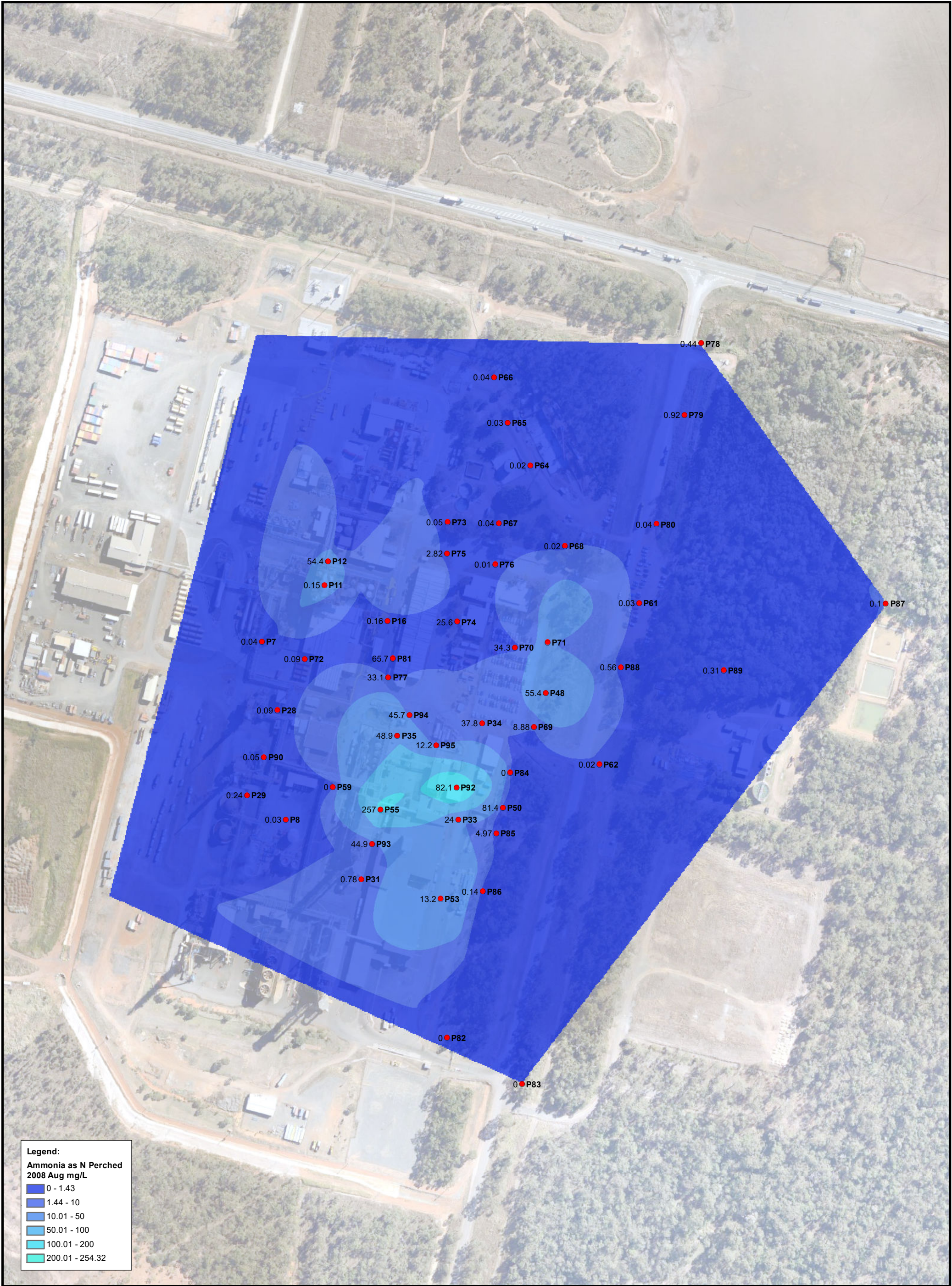


Source: Google Earth

Client ORICA AUSTRALIA PTY LTD	Project STAGE 3 SOIL AND GROUNDWATER INVESTIGATION YARWUN PRODUCTION FACILITY, GLADSTONE QUEENSLAND			Title SITE LAYOUT, BOREHOLE AND GROUNDWATER MONITORING WELL LOCATIONS	
	Drawn: AJW Job No: 43217845			Approved: GVS File No: 43217716-068.wor	
			Date: 05/11/2008		Figure: 2



Appendix B Groundwater Contamination Plume Maps



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

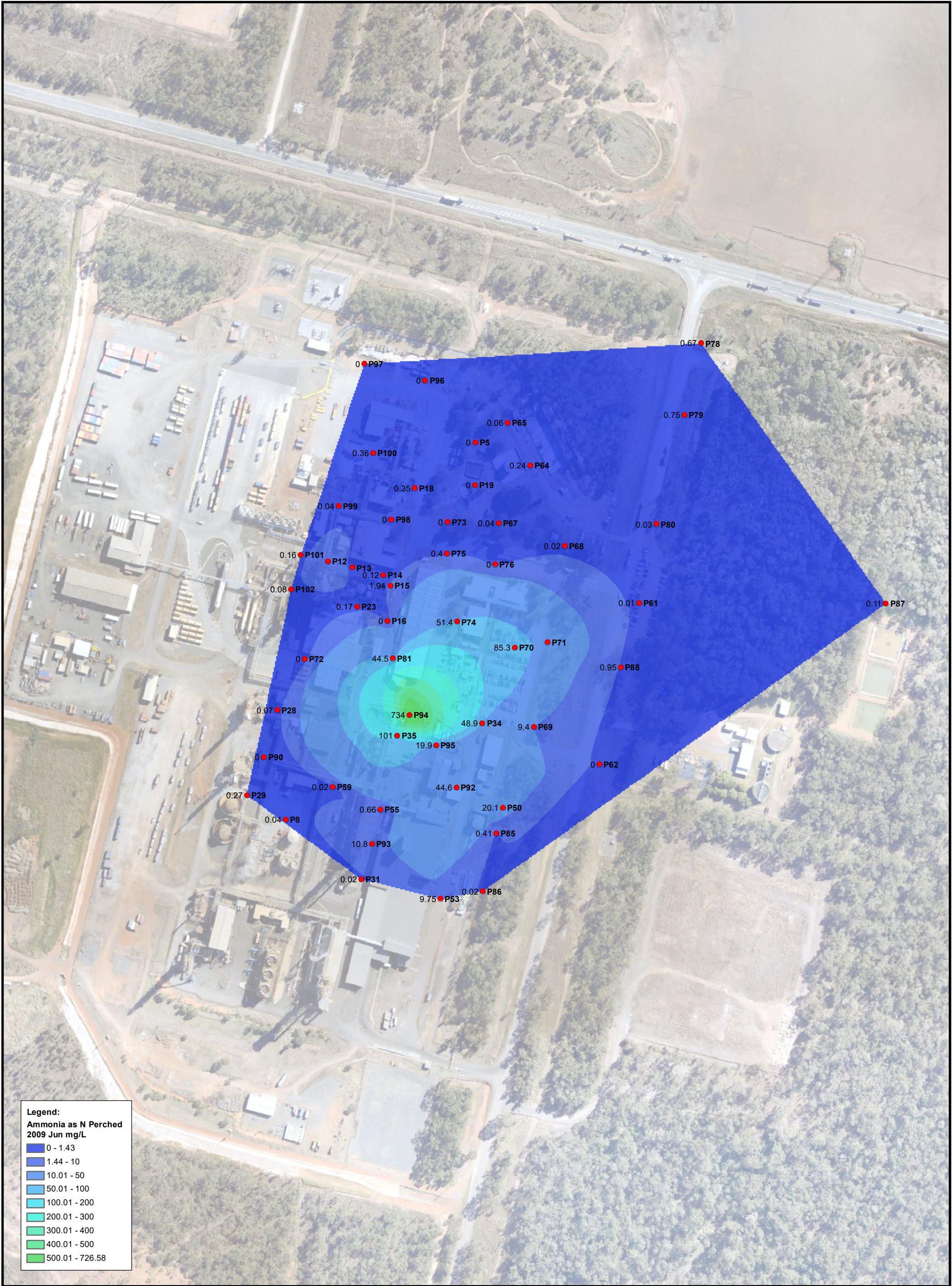
© 2017 JBS&G

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Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R01	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● Ammonia Perched

JBS&G Figure: Ammonia as N Perched
2008 Aug mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_AmmPd_2008Aug



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

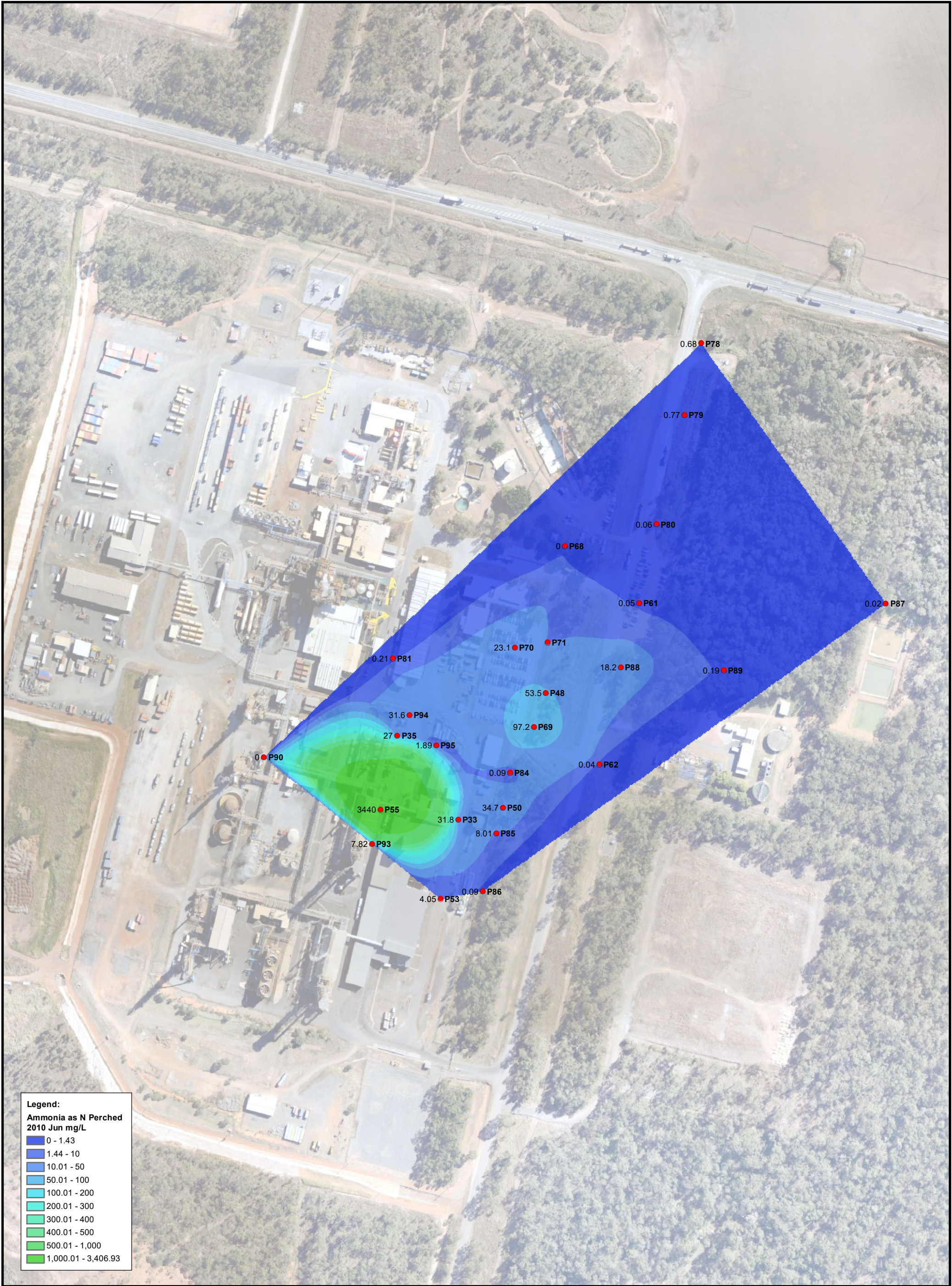
© 2017 JBS&G

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Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● Ammonia Perched

JBS&G Figure: Ammonia as N Perched
2009 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_AmmPd_2009Jun



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

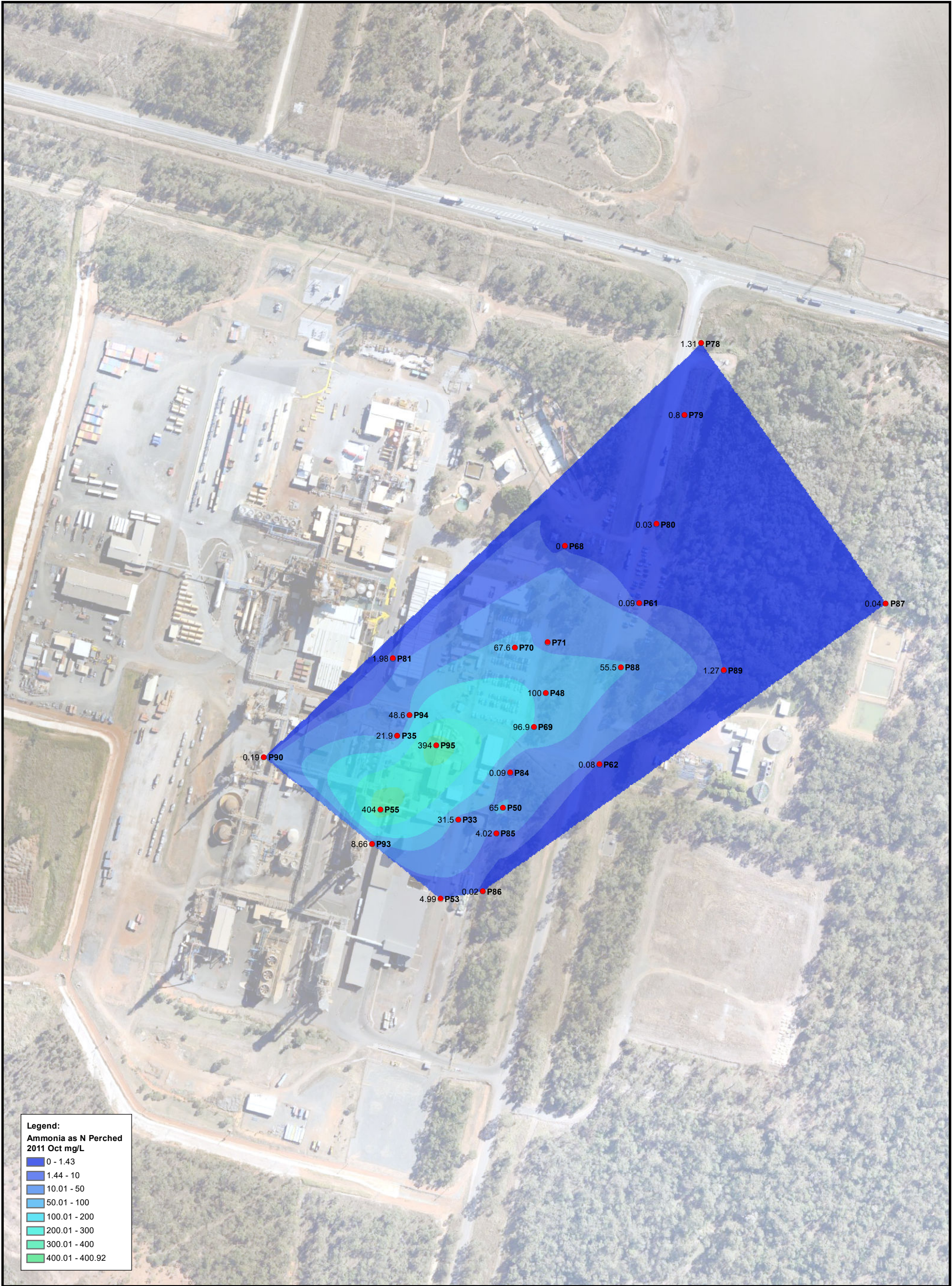
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A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● Ammonia Perched

JBS&G Figure: Ammonia as N Perched
2010 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_AmmPd_2010Jun



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

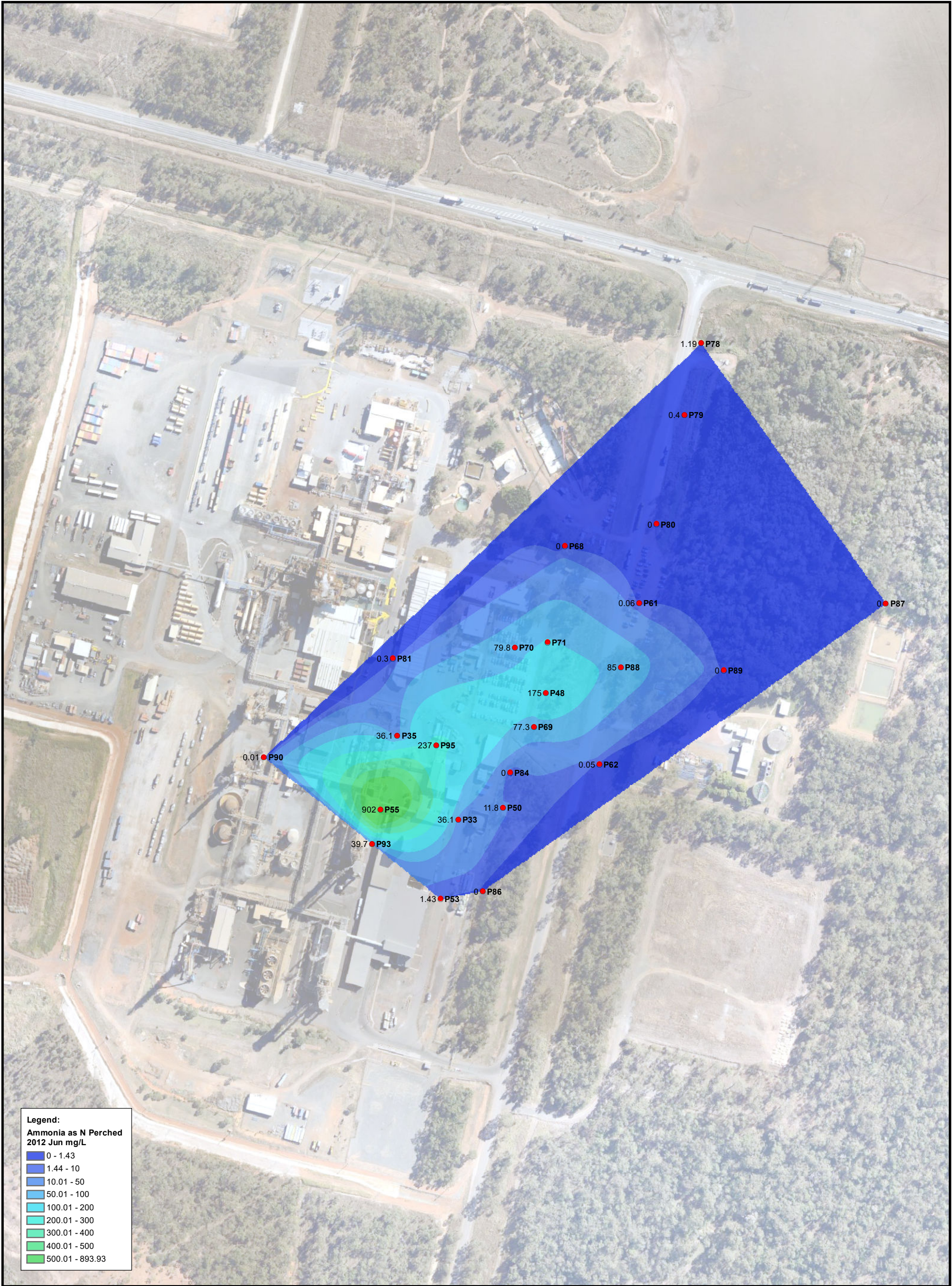
© 2017 JBS&G

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Rev	Description	Drn.	Date

Legend:
● Ammonia Perched

JBS&G Figure: Ammonia as N Perched
2011 Oct mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_AmmPd_2011Oct



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

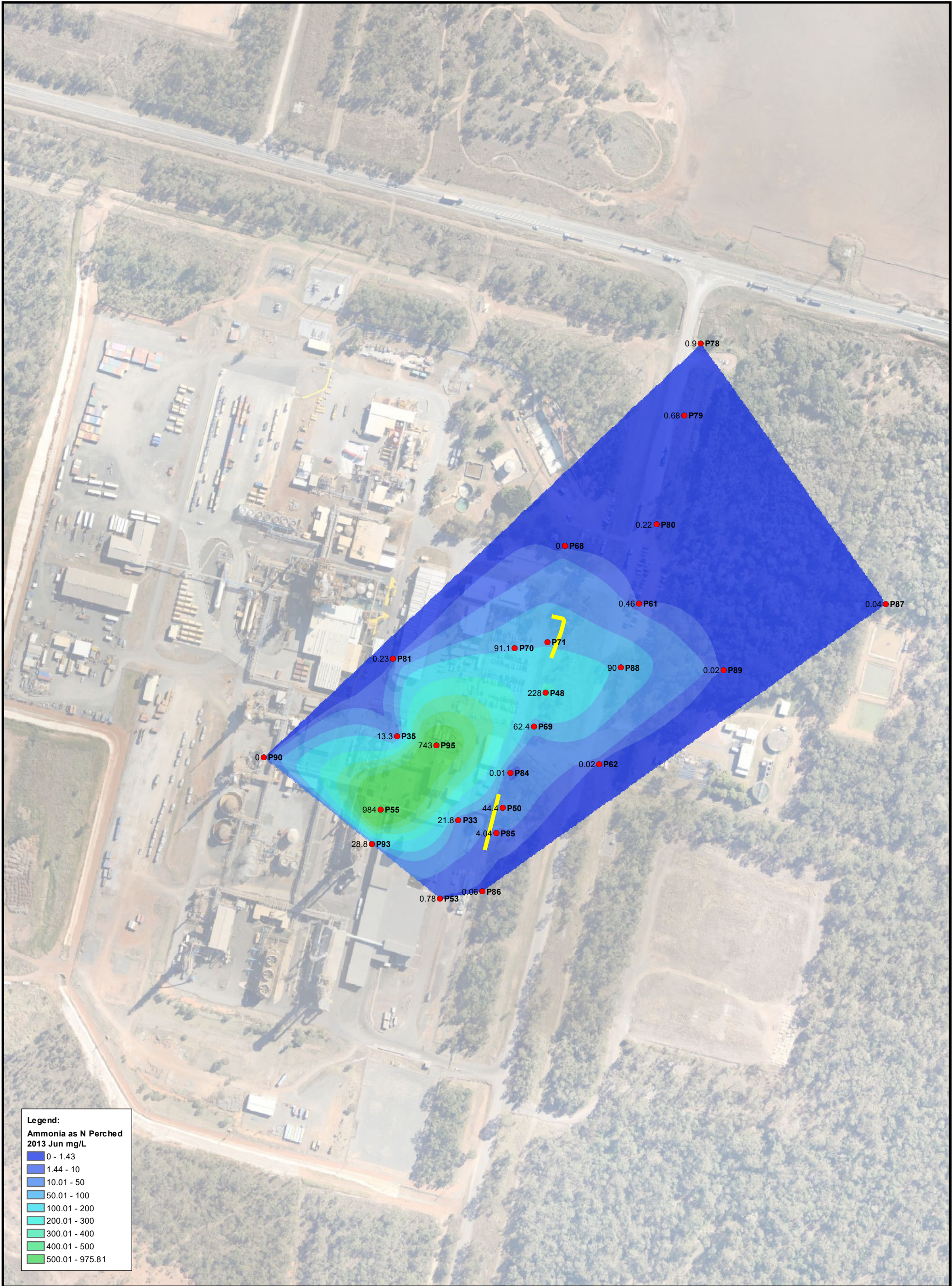
© 2017 JBS&G

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A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● Ammonia Perched

JBS&G Figure: Ammonia as N Perched
2012 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_AmmPd_2012Jun



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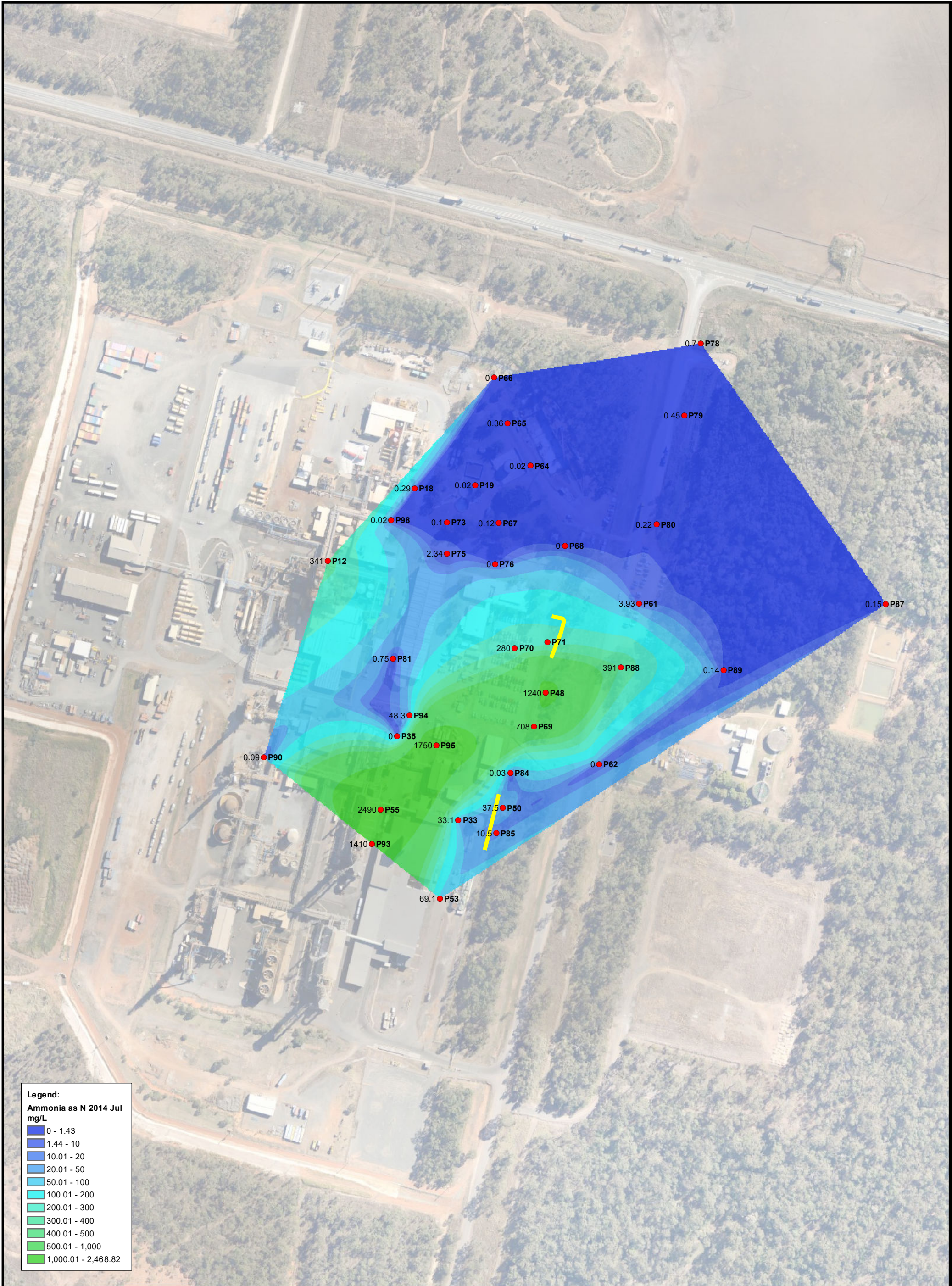
© 2017 JBS&G

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Rev	Description	Drn.	Date

Legend:
● Ammonia Perched
— Trench Locations

JBS&G Figure: Ammonia as N Perched
2013 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_AmmPd_2013Jun



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

© 2017 JBS&G

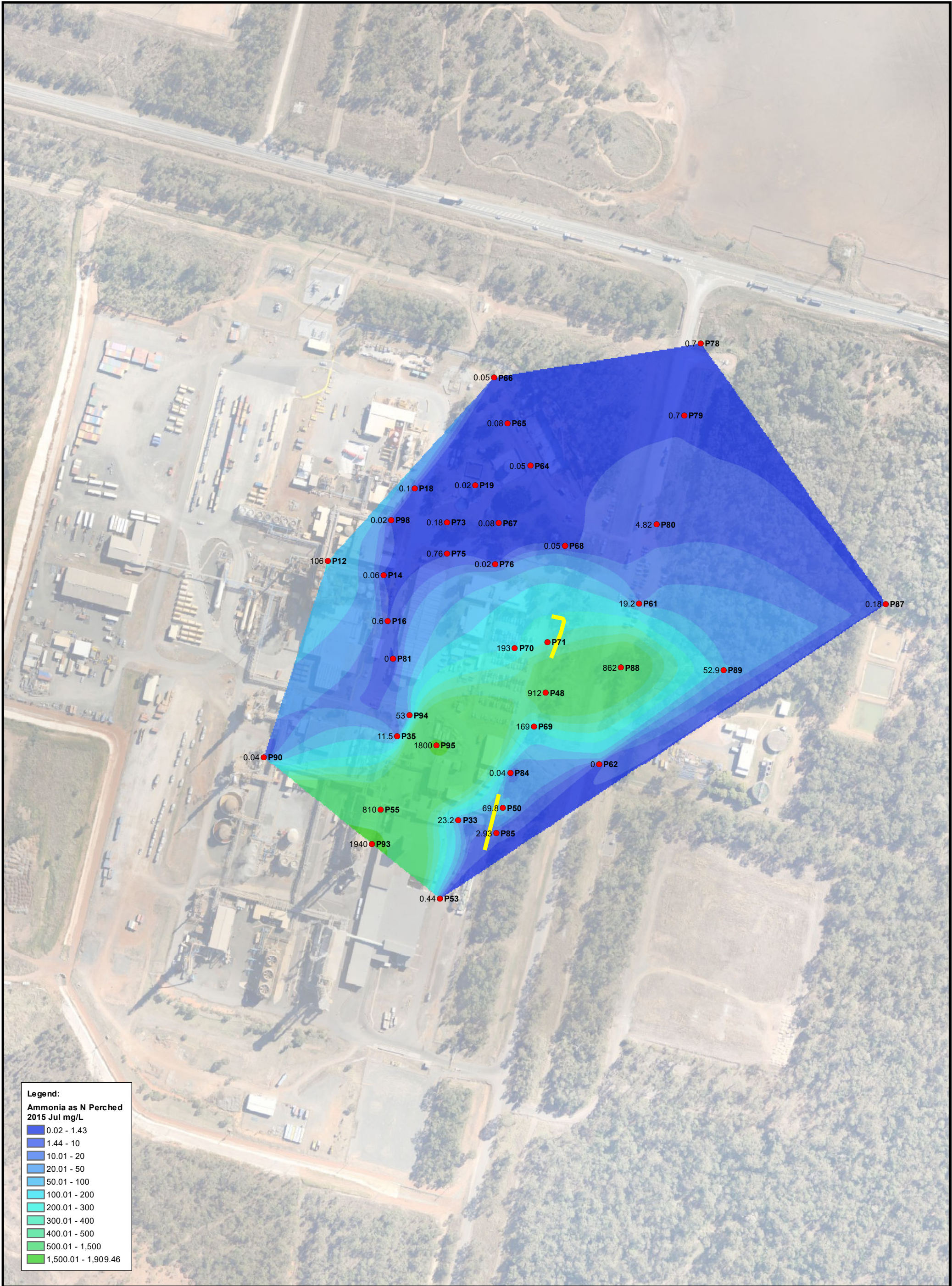
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Rev	Description	Dm. Date

Legend:

- Ammonia Perched
- Trench Locations

JBS&G Figure: Ammonia as N Perched
2014 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_AmmPd_2014Jul



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

© 2017 JBS&G

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Rev	Description	Dmn.	Date

Legend:
● Ammonia Perched
— Trench Locations

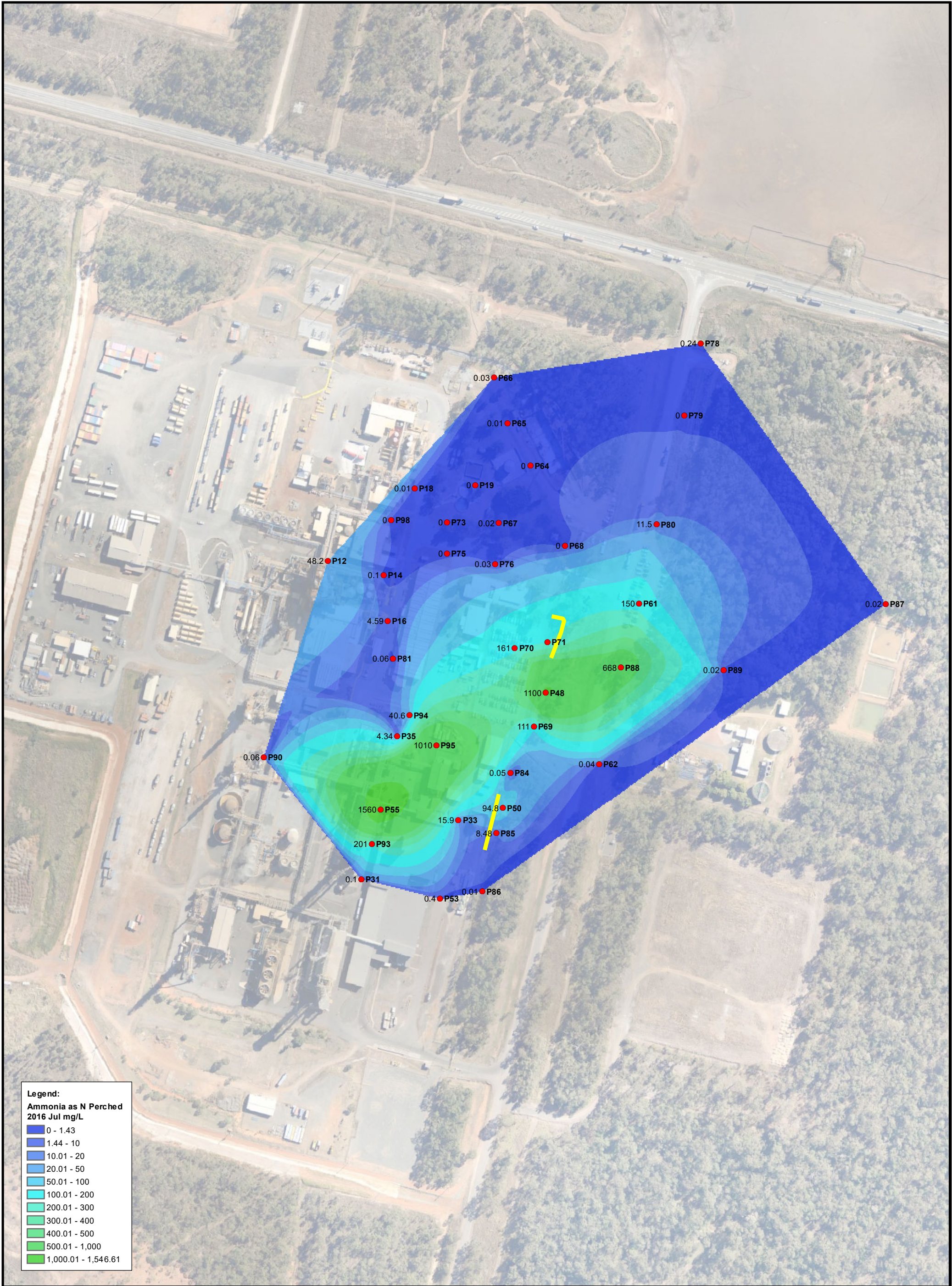
JBS&G Figure: Ammonia as N Perched 2015 Jul mg/L

Client: Orica Australia Pty Ltd

Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)

Job No: 52877

File Name: 52877_nn_AmmPd_2015Jul

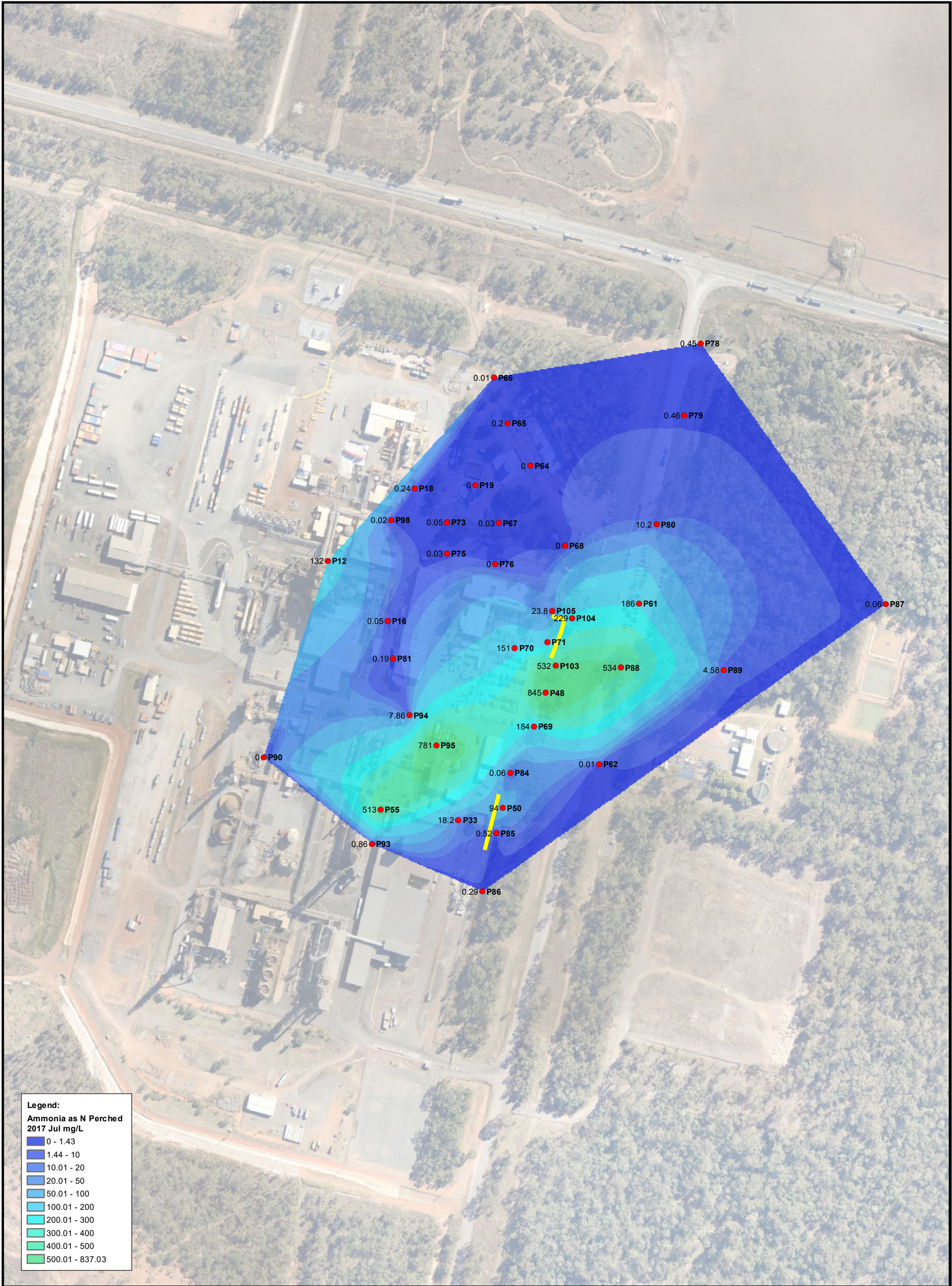


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m			
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A3			
A	Original Issue - R02	RF	14-10-2017
Rev	Description	Dmn.	Date

Legend:
● Ammonia Perched
— Trench Locations

JBS&G Figure: Ammonia as N Perched 2016 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_AmmPd_2016Jul



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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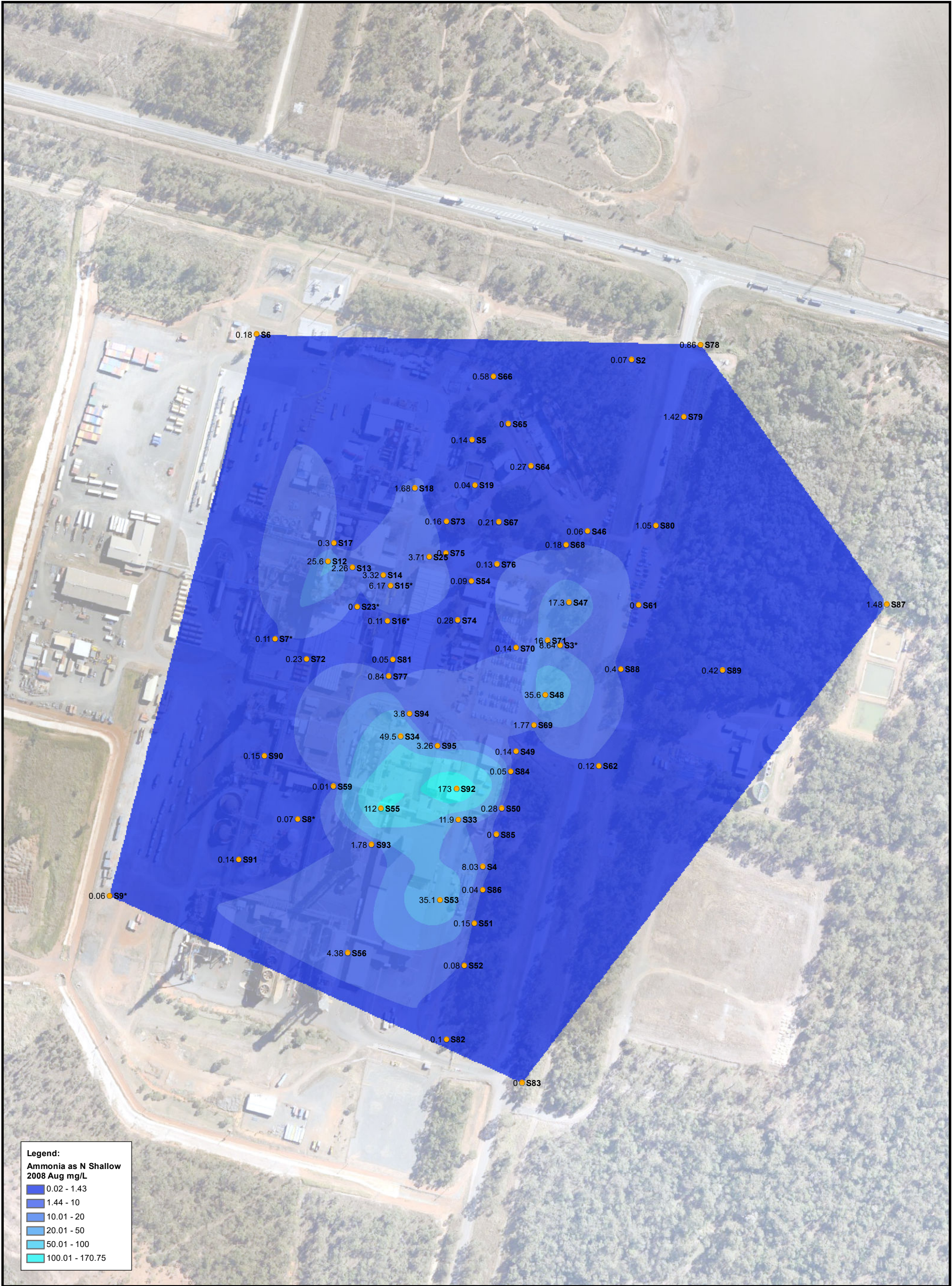
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A	Original Issue - R02	RF	17-10-2017
Rev	Description	Drn.	Date

Legend:

- Ammonia Perched
- Trench Locations

JBS&G Figure: Ammonia as N Perched
2017 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_AmmPd_2017Jul



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

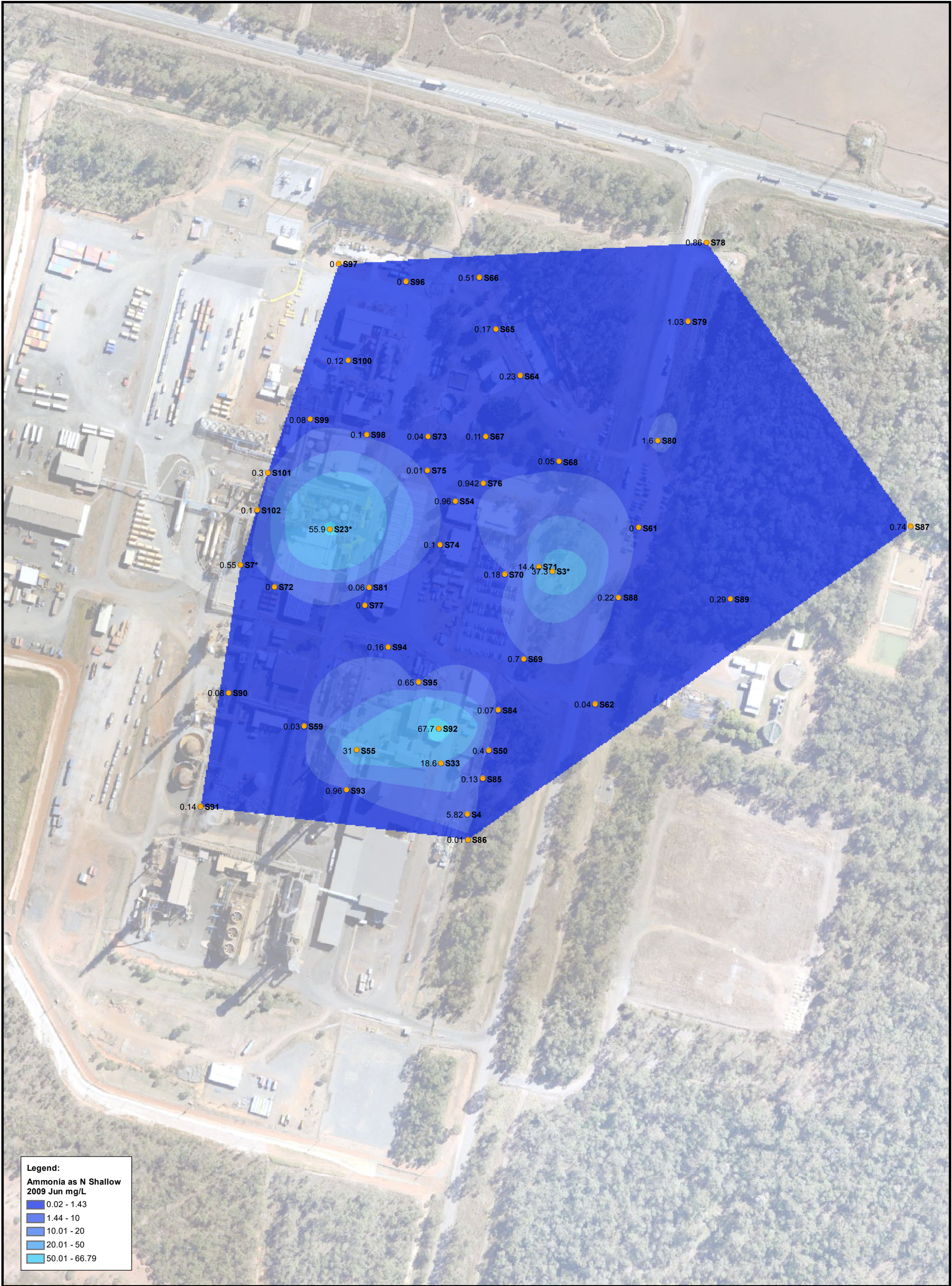
© 2017 JBS&G

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Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R01	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● Ammonia Shallow

JBS&G Figure: Ammonia as N Shallow
2008 Aug mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_AmmSh_2008Aug



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

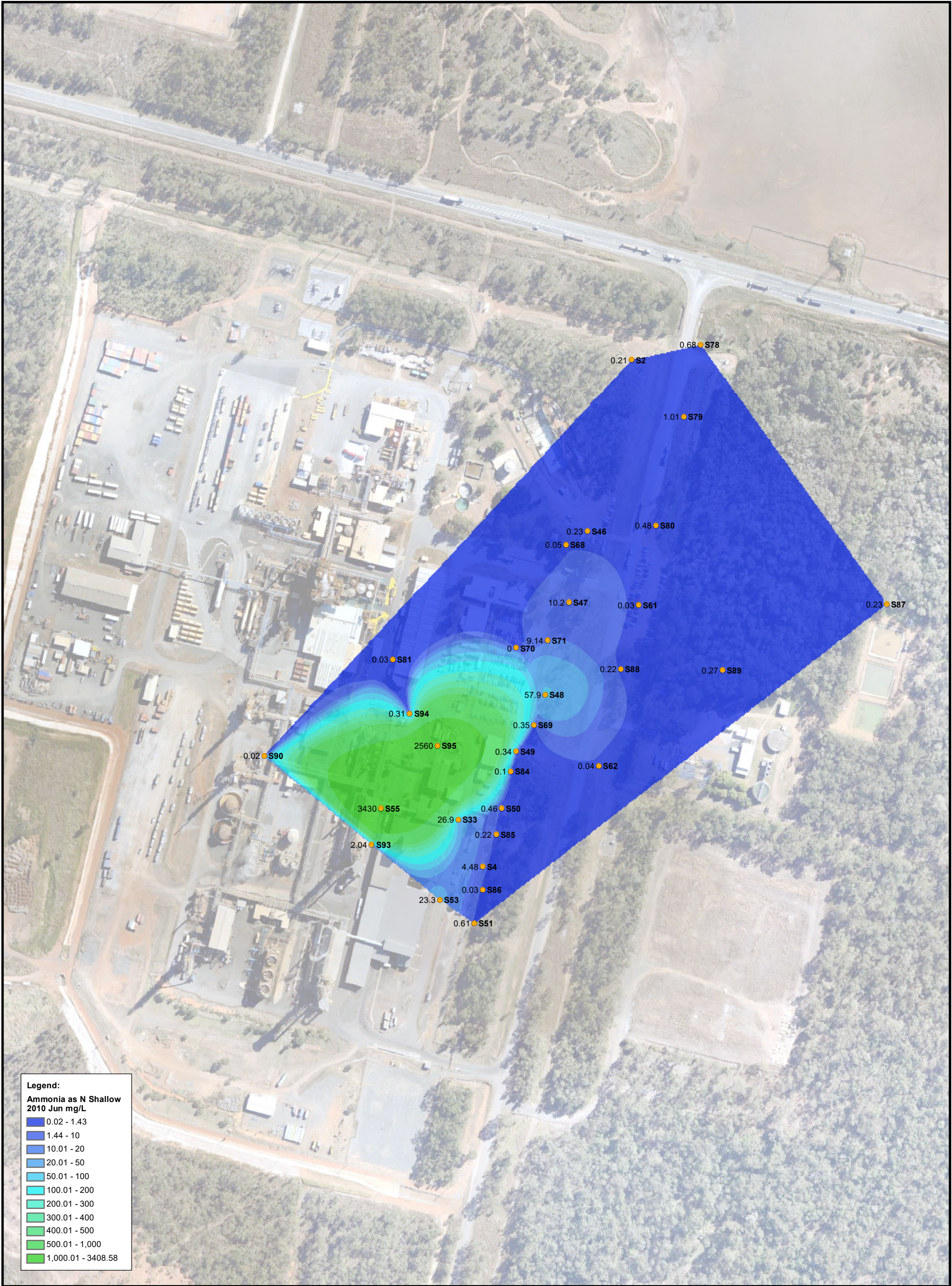
© 2017 JBS&G

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A3			
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Rev	Description	Drn.	Date

Legend:
● Ammonia Shallow

JBS&G Figure: Ammonia as N Shallow
2009 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_AmmSh_2009Jun



Legend:
Ammonia as N Shallow
2010 Jun mg/L

0.02 - 1.43
1.44 - 10
10.01 - 20
20.01 - 50
50.01 - 100
100.01 - 200
200.01 - 300
300.01 - 400
400.01 - 500
500.01 - 1,000
1,000.01 - 3408.58

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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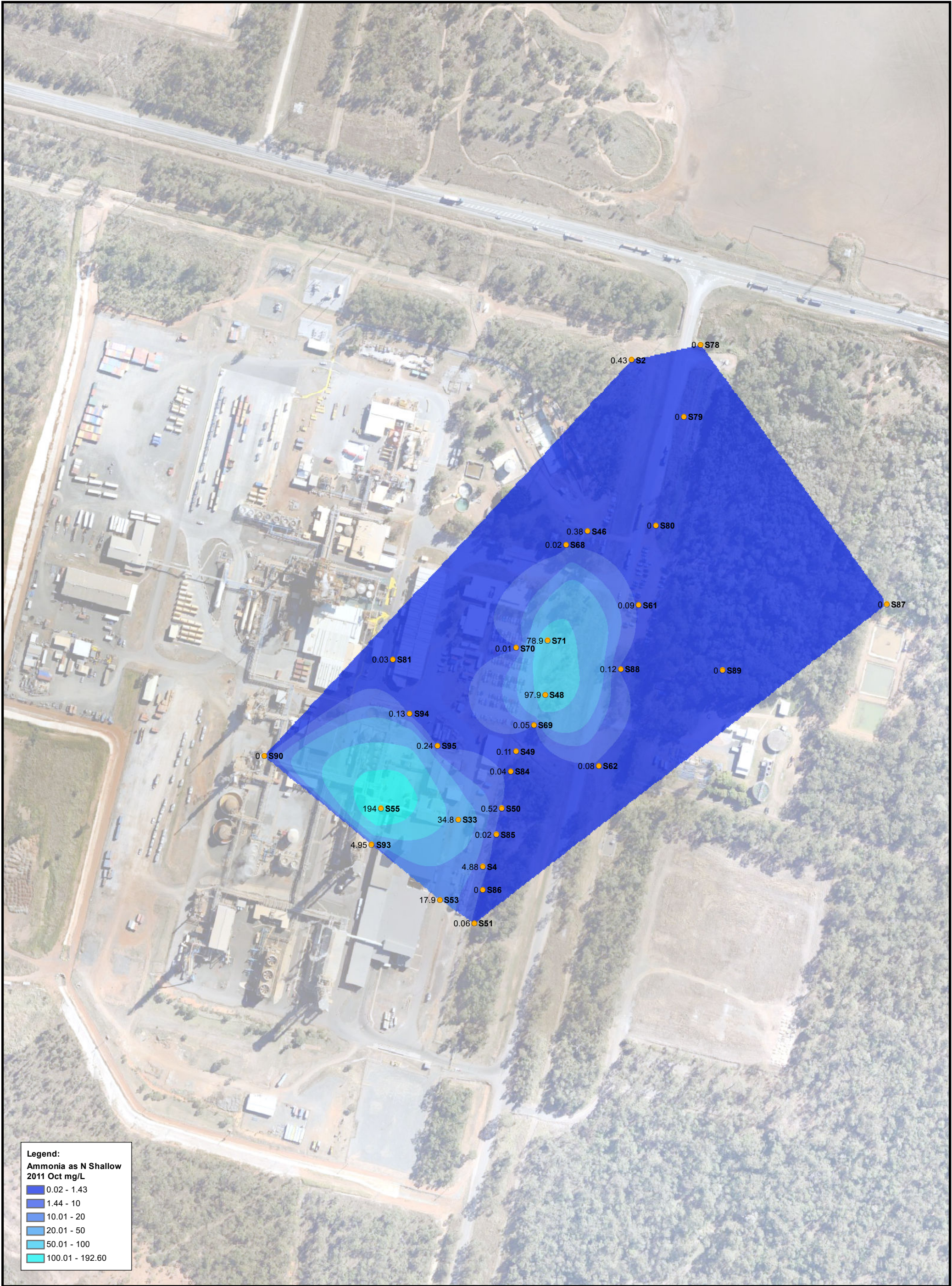
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A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● Ammonia Shallow

**Figure: Ammonia as N Shallow**
2010 Jun mg/L

Client: Orica Australia Pty Ltd	
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)	
Job No: 52877	File Name: 52877_nn_AmmSh_2010Jun





Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

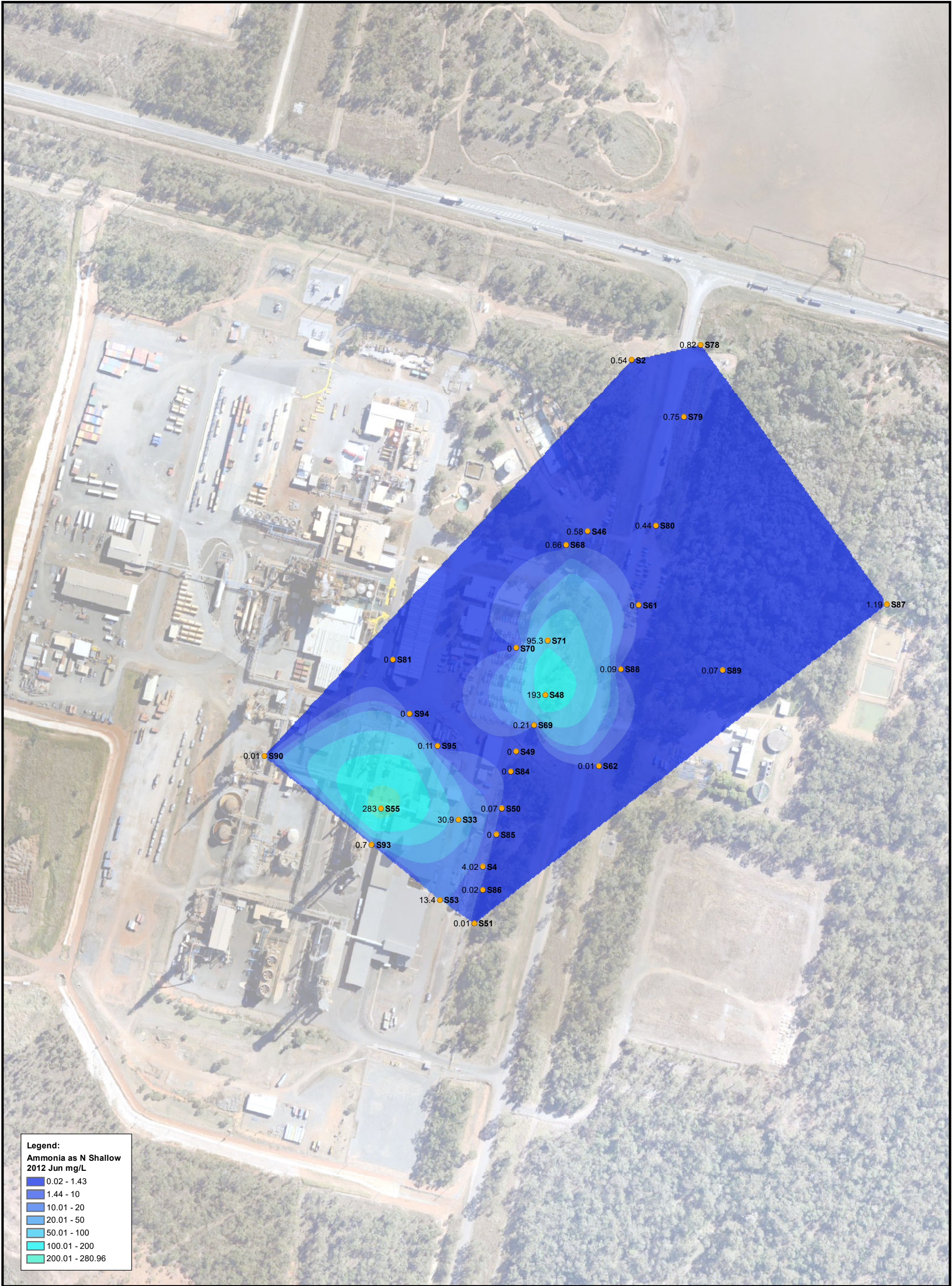
© 2017 JBS&G

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Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● Ammonia Shallow

JBS&G Figure: Ammonia as N Shallow
2011 Oct mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_AmmSh_2011Oct



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

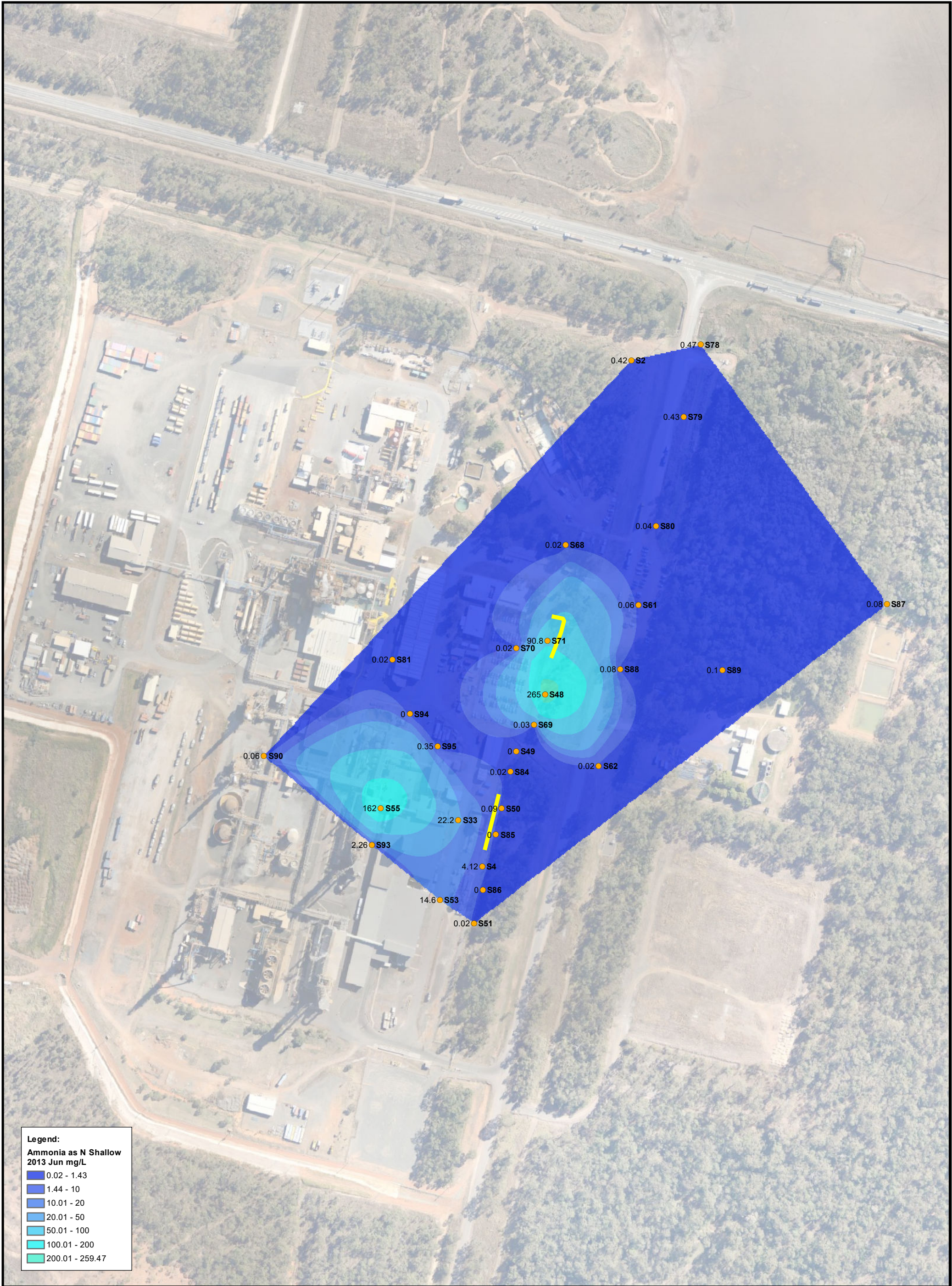
© 2017 JBS&G

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Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● Ammonia Shallow

JBS&G Figure: Ammonia as N Shallow
2012 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_AmmSh_2012Jun



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

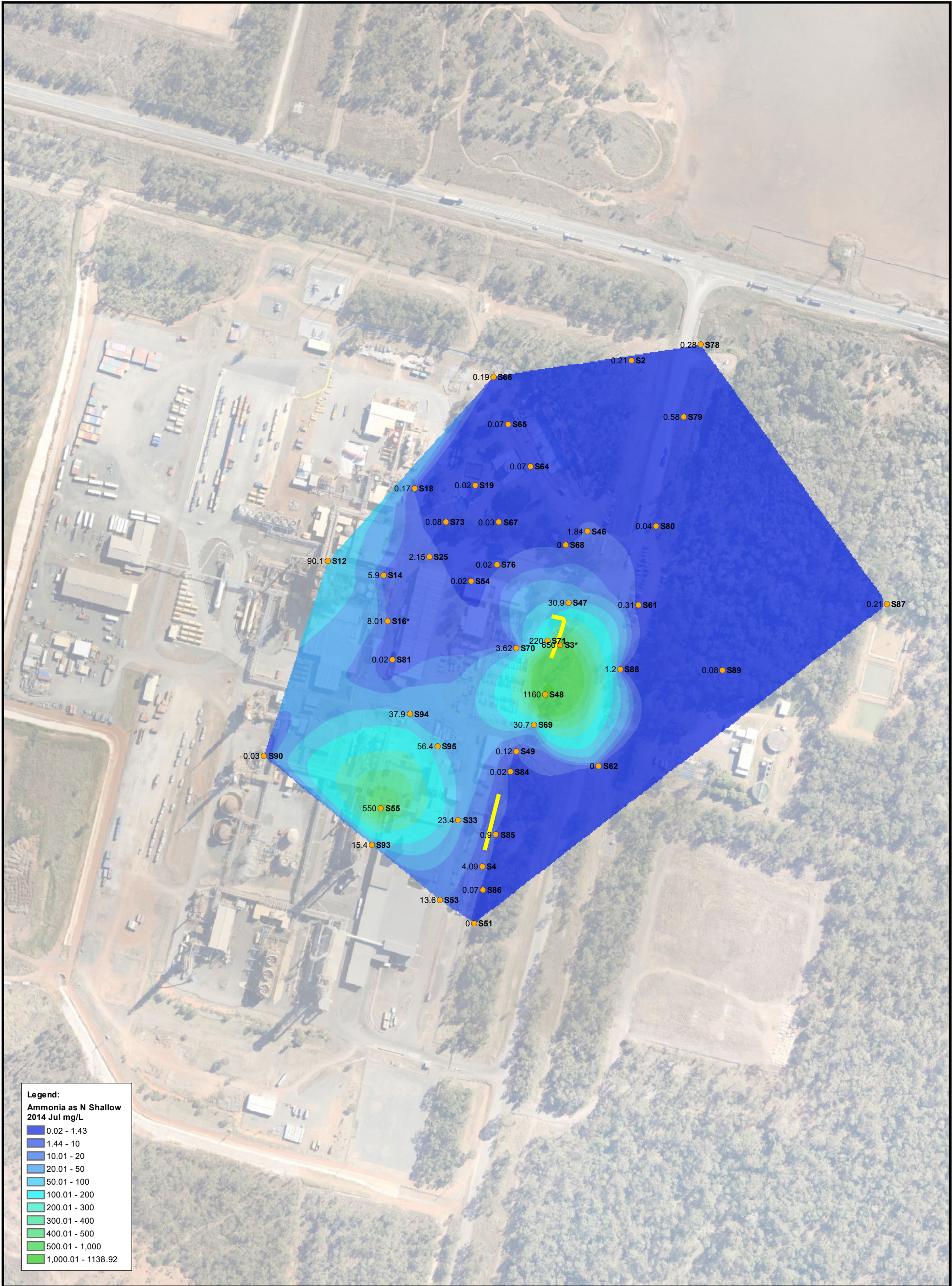
© 2017 JBS&G

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m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	18-10-2017
Rev	Description	Drm.	Date

Legend:
● Ammonia Shallow
— Trench Locations

JBS&G Figure: Ammonia as N Shallow
2013 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_AmmSh_2013Jun



Legend:
Ammonia as N Shallow
2014 Jul mg/L

0.02 - 1.43
1.44 - 10
10.01 - 20
20.01 - 50
50.01 - 100
100.01 - 200
200.01 - 300
300.01 - 400
400.01 - 500
500.01 - 1,000
1,000.01 - 1138.92

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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0 25 50 100 m			
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Rev	Description	Drn.	Date

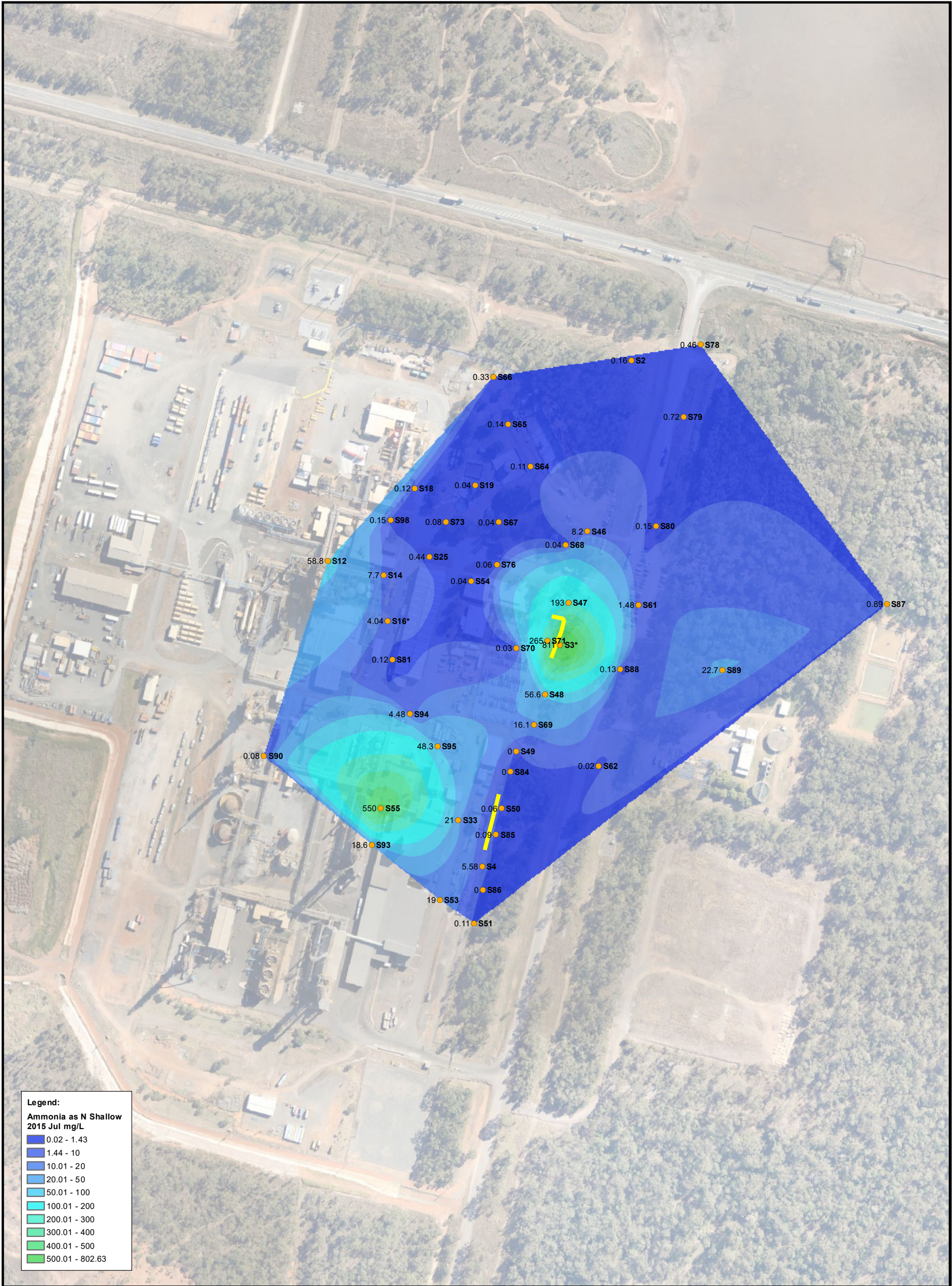
Legend:

- Ammonia Shallow
- Trench Locations

Figure: Ammonia as N Shallow
2014 Jul mg/L

Client: Orica Australia Pty Ltd	
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)	
Job No: 52877	File Name: 52877_nn_AmmSh_2014Jul





Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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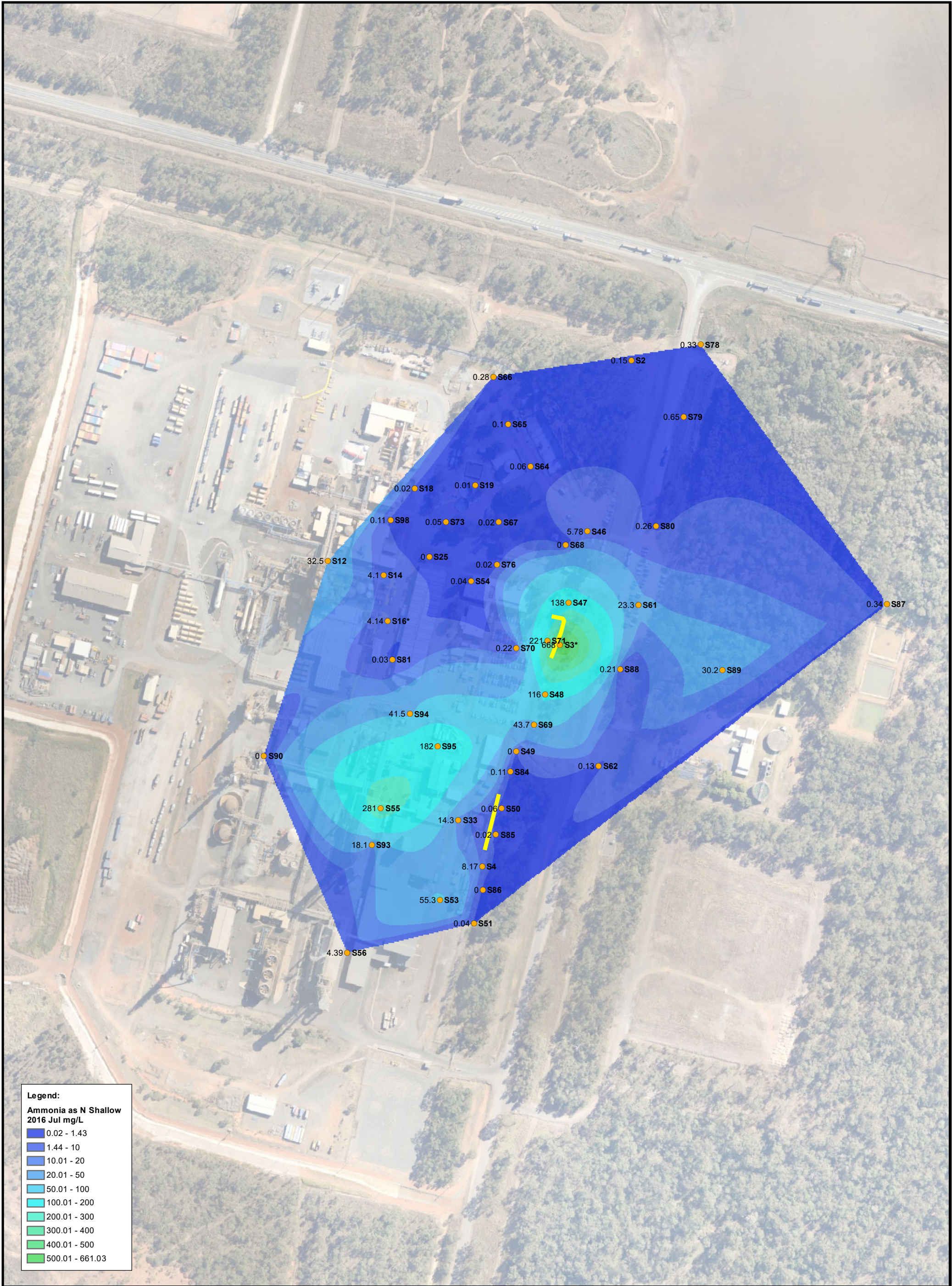
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Rev	Description	Drn.	Date

Legend:

- Ammonia Shallow
- Trench Locations

JBS&G Figure: Ammonia as N Shallow
2015 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_AmmSh_2015Jul



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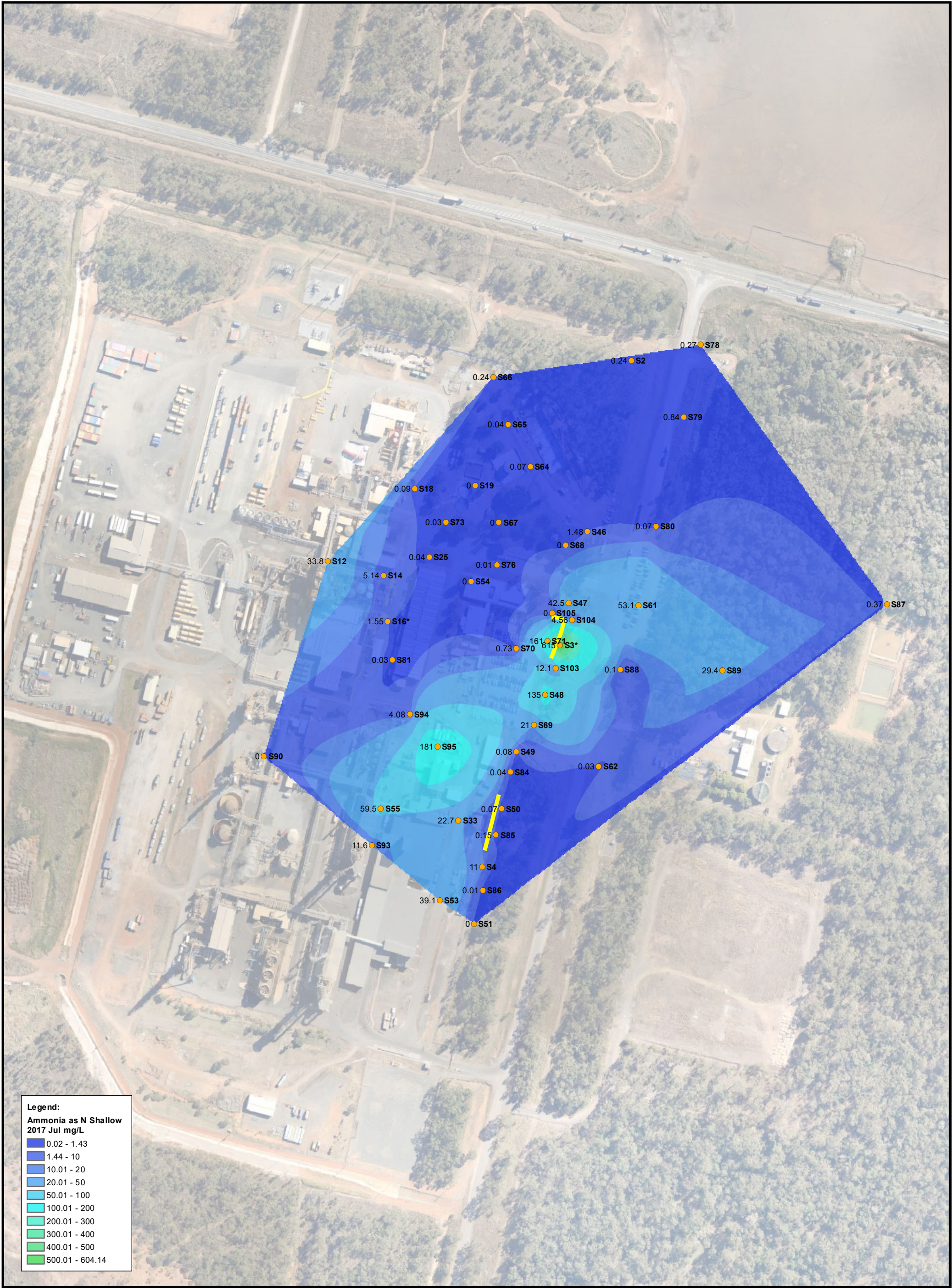
© 2017 JBS&G

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Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	18-10-2017
Rev	Description	Drm.	Date

Legend:
● Ammonia Shallow
— Trench Locations

JBS&G Figure: Ammonia as N Shallow
2016 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_AmmSh_2016Jul



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

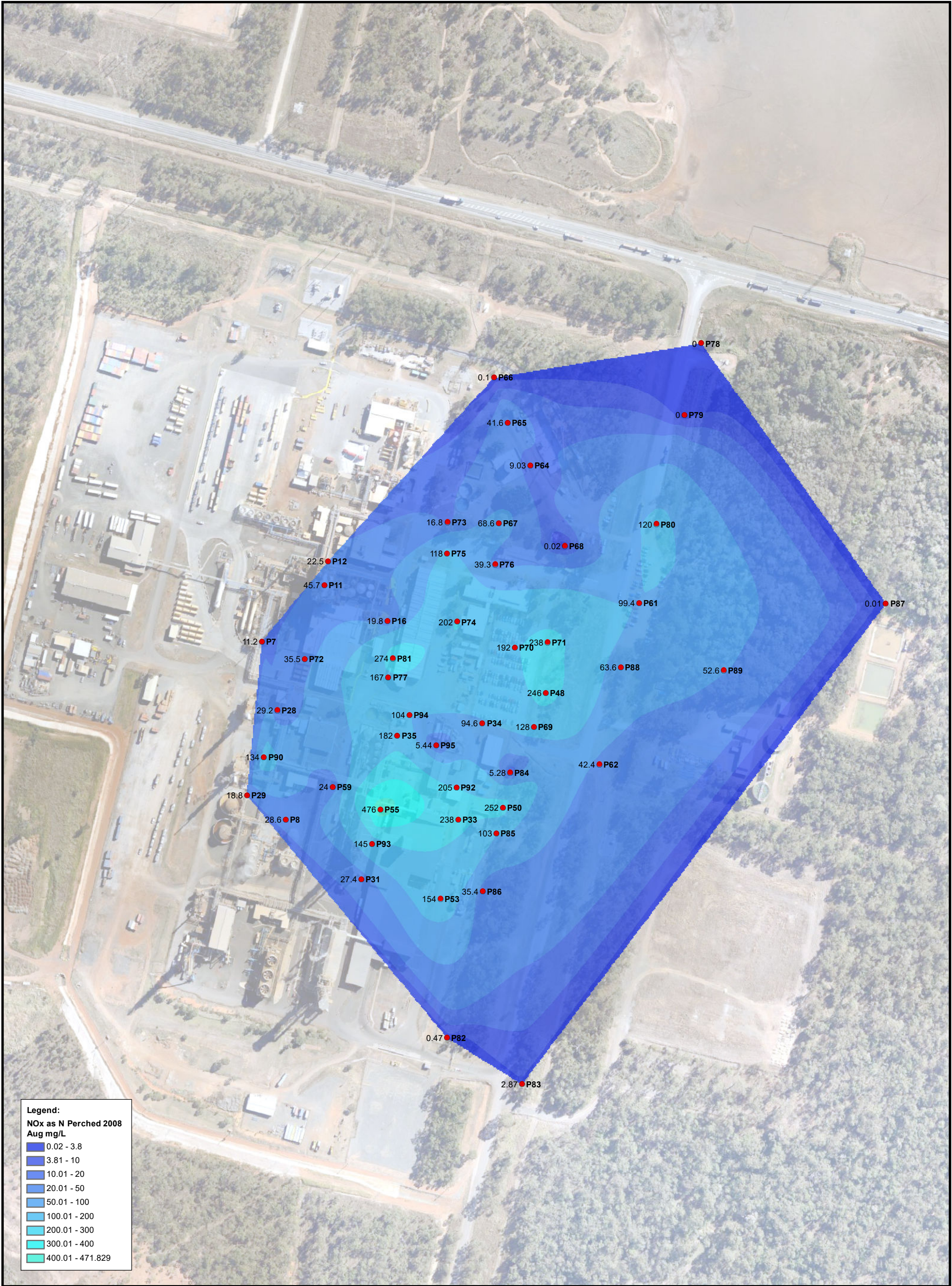
© 2017 JBS&G

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A3			
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Rev	Description	Drn.	Date

Legend:
● Ammonia Shallow
— Trench Locations

JBS&G Figure: Ammonia as N Shallow
2017 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_AmmSh_2017Jul



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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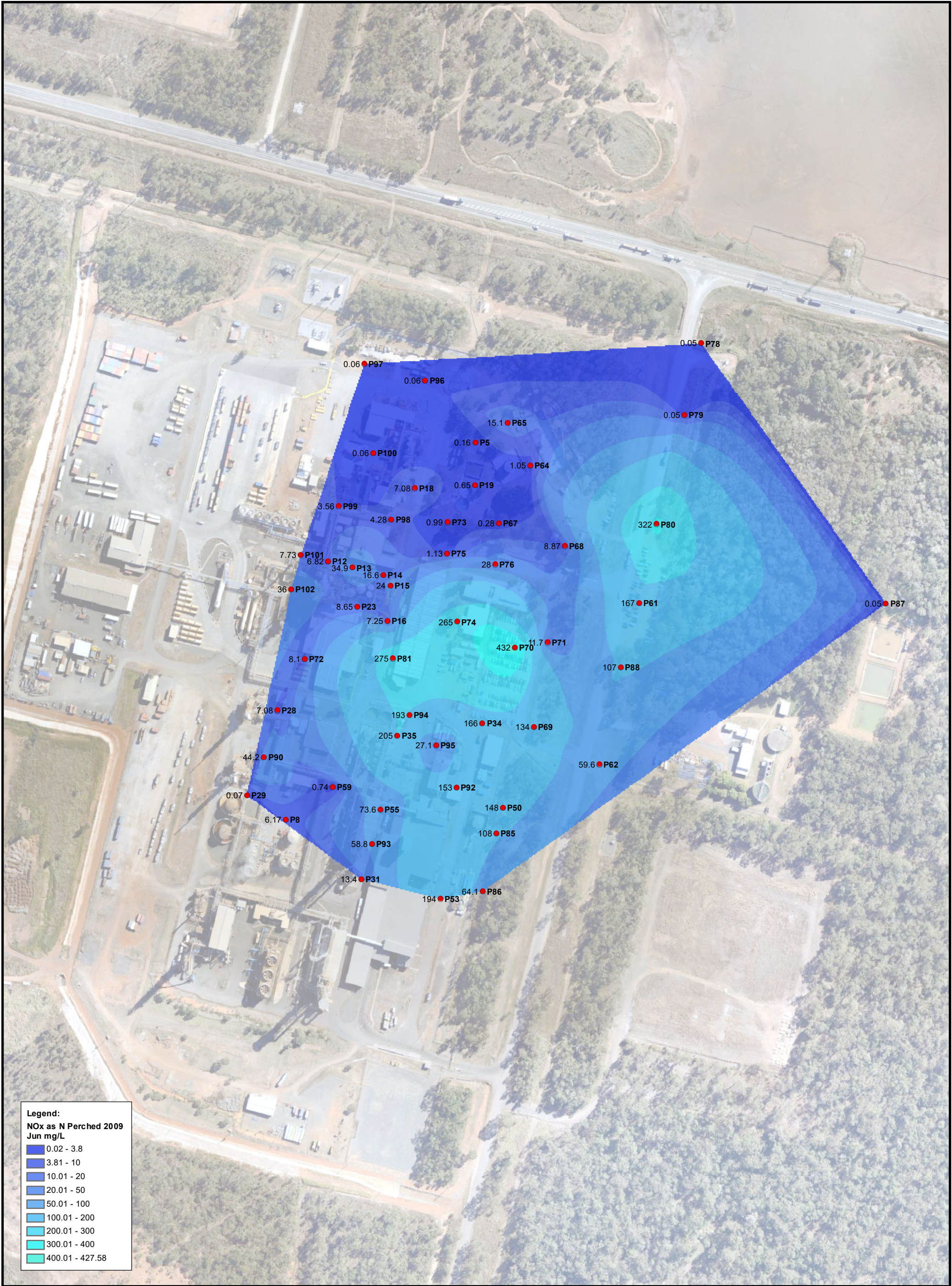
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A3			
A	Original Issue - R01	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● NOX Perched



Figure: Nitrate as N/Nitrite and Nitrate (NOx) as N Perched 2008 Aug mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_NOXPd_2008Aug



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

© 2017 JBS&G

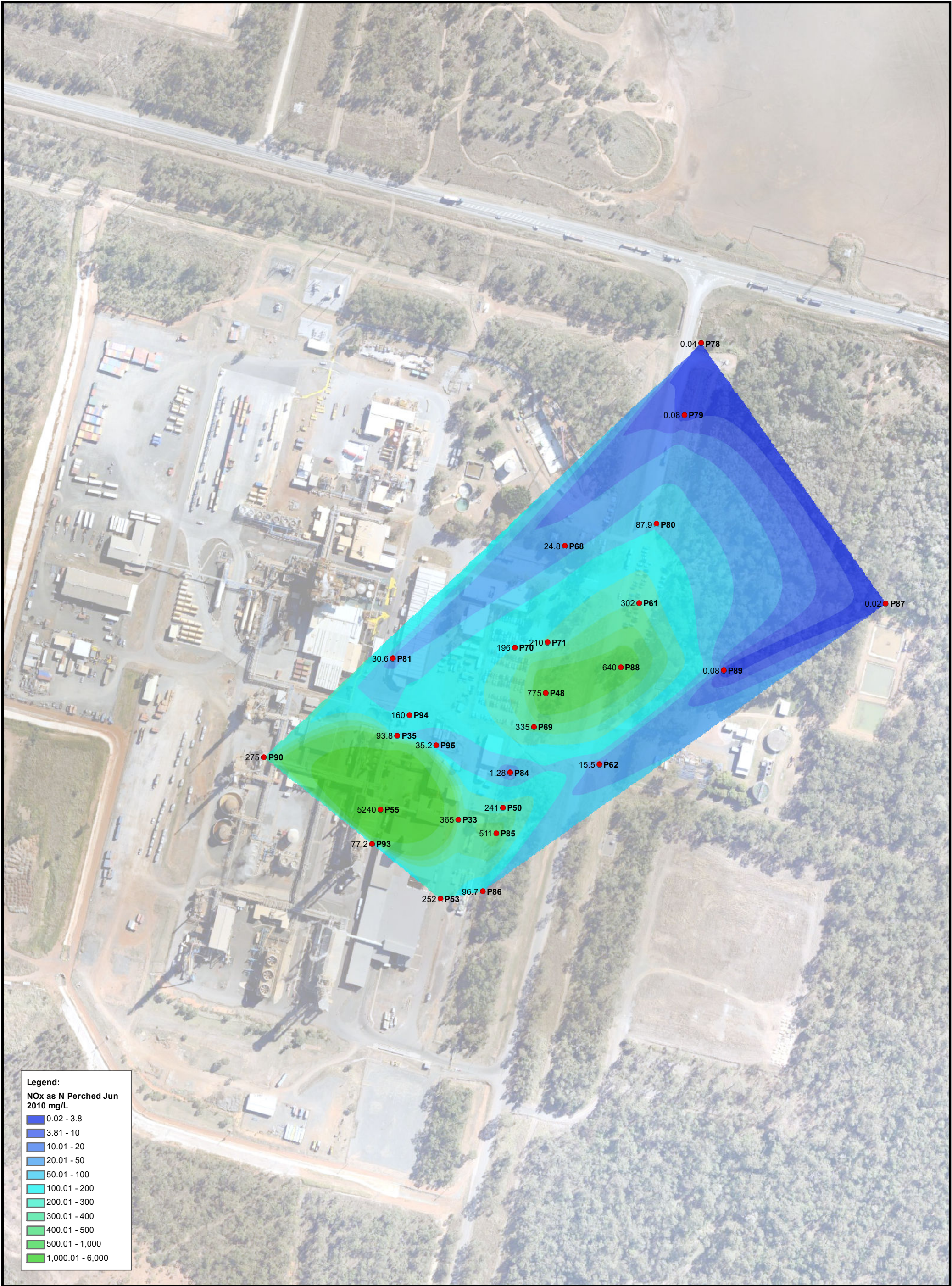
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Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● NOx Perched



Figure: Nitrate as N/Nitrite and Nitrate (NOx) as N Perched 2009 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_NOXPd_2009Jun



Legend:
NOx as N Perched Jun 2010 mg/L

0.02 - 3.8
3.81 - 10
10.01 - 20
20.01 - 50
50.01 - 100
100.01 - 200
200.01 - 300
300.01 - 400
400.01 - 500
500.01 - 1,000
1,000.01 - 6,000

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

© 2017 JBS&G

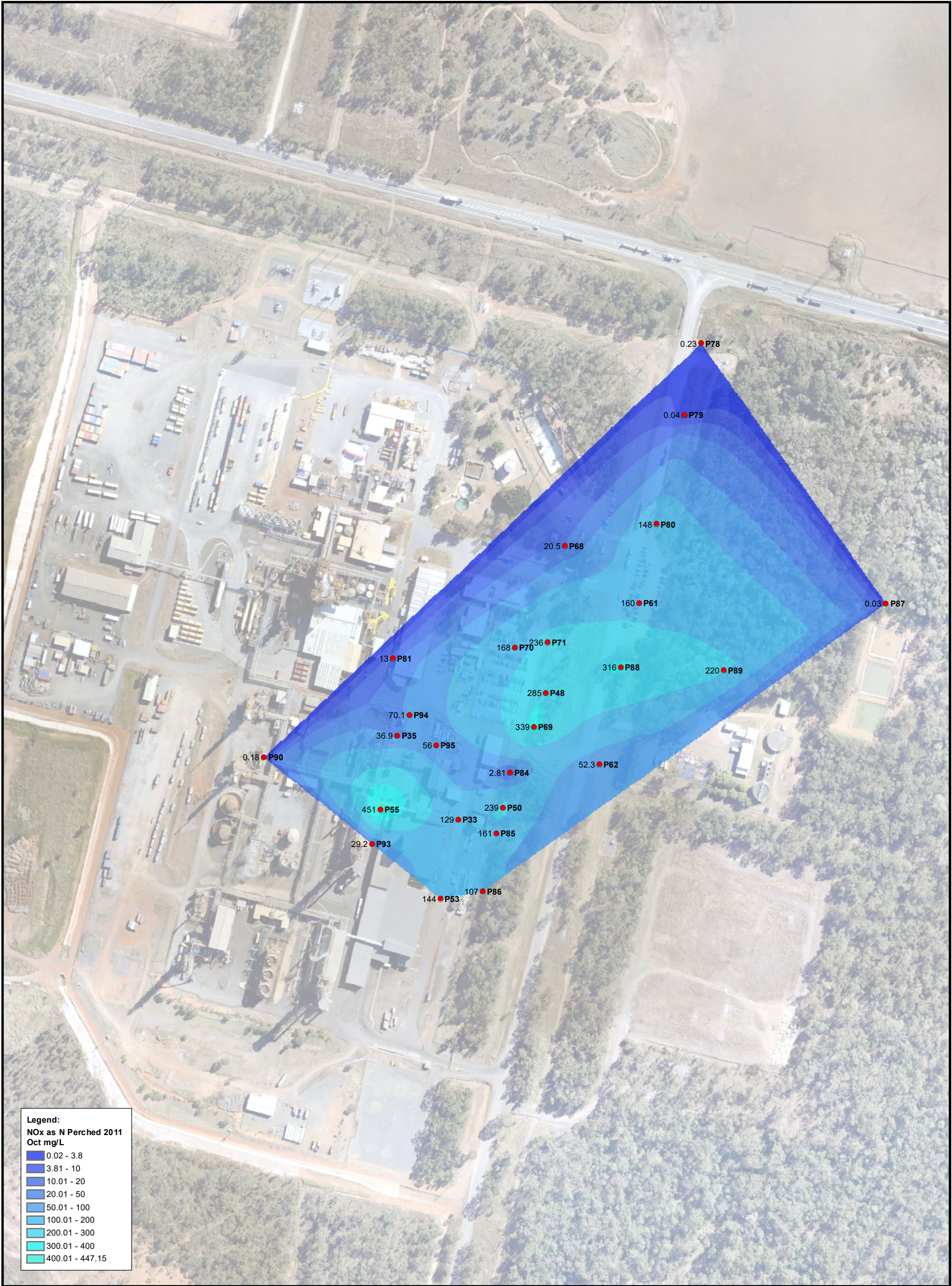
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m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● NOx Perched



Figure: Nitrate as N/Nitrite and Nitrate (NOx) as N Perched 2010 Jun mg/L

Client: Orica Australia Pty Ltd	
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)	
Job No: 52877	File Name: 52877_nn_NOXPd_2010Jun



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

© 2017 JBS&G

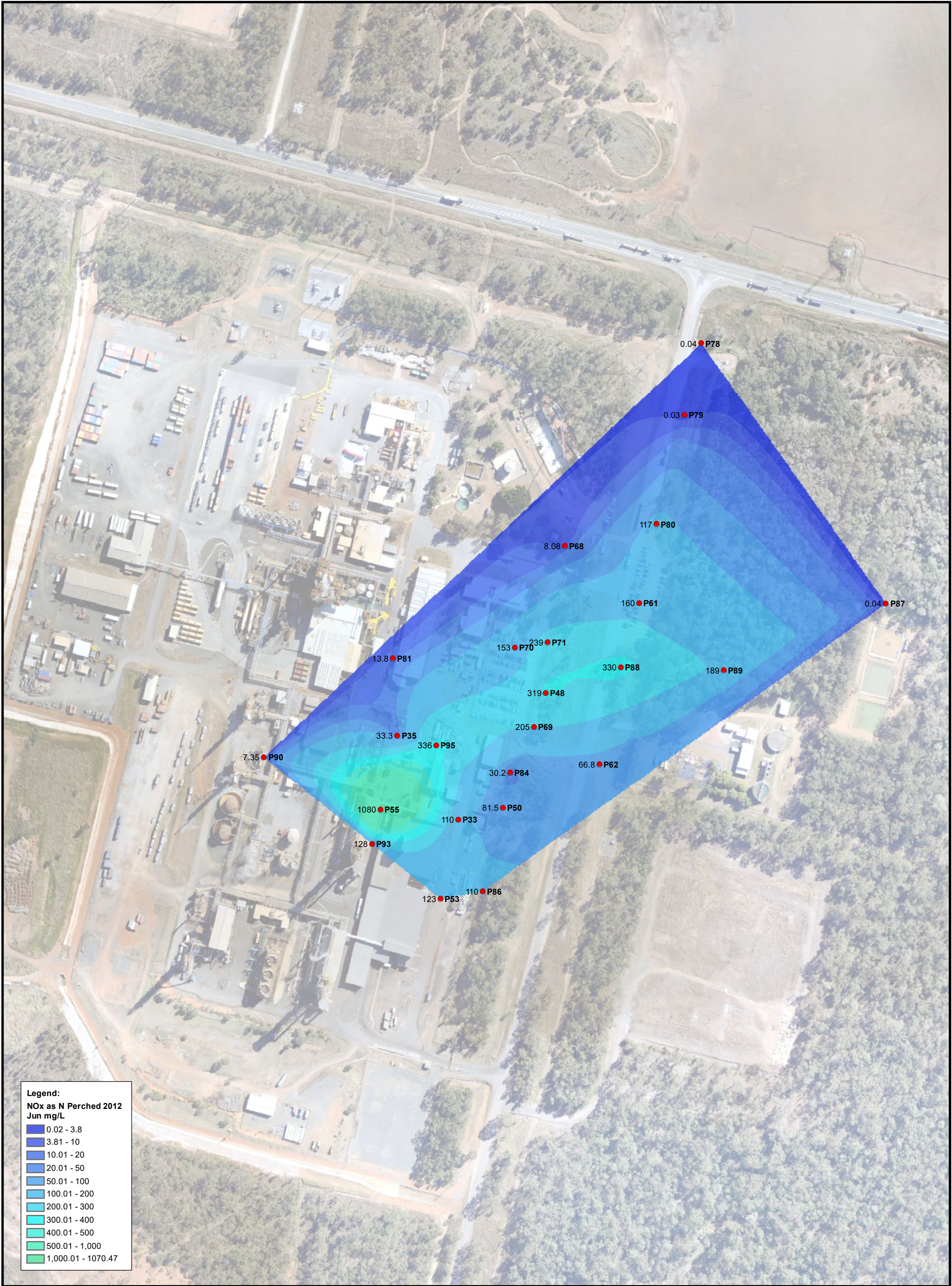
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Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● NOx Perched



Figure: Nitrate as N/Nitrite and Nitrate (NOx) as N Perched 2011 Oct mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_NOXPd_2011Oct



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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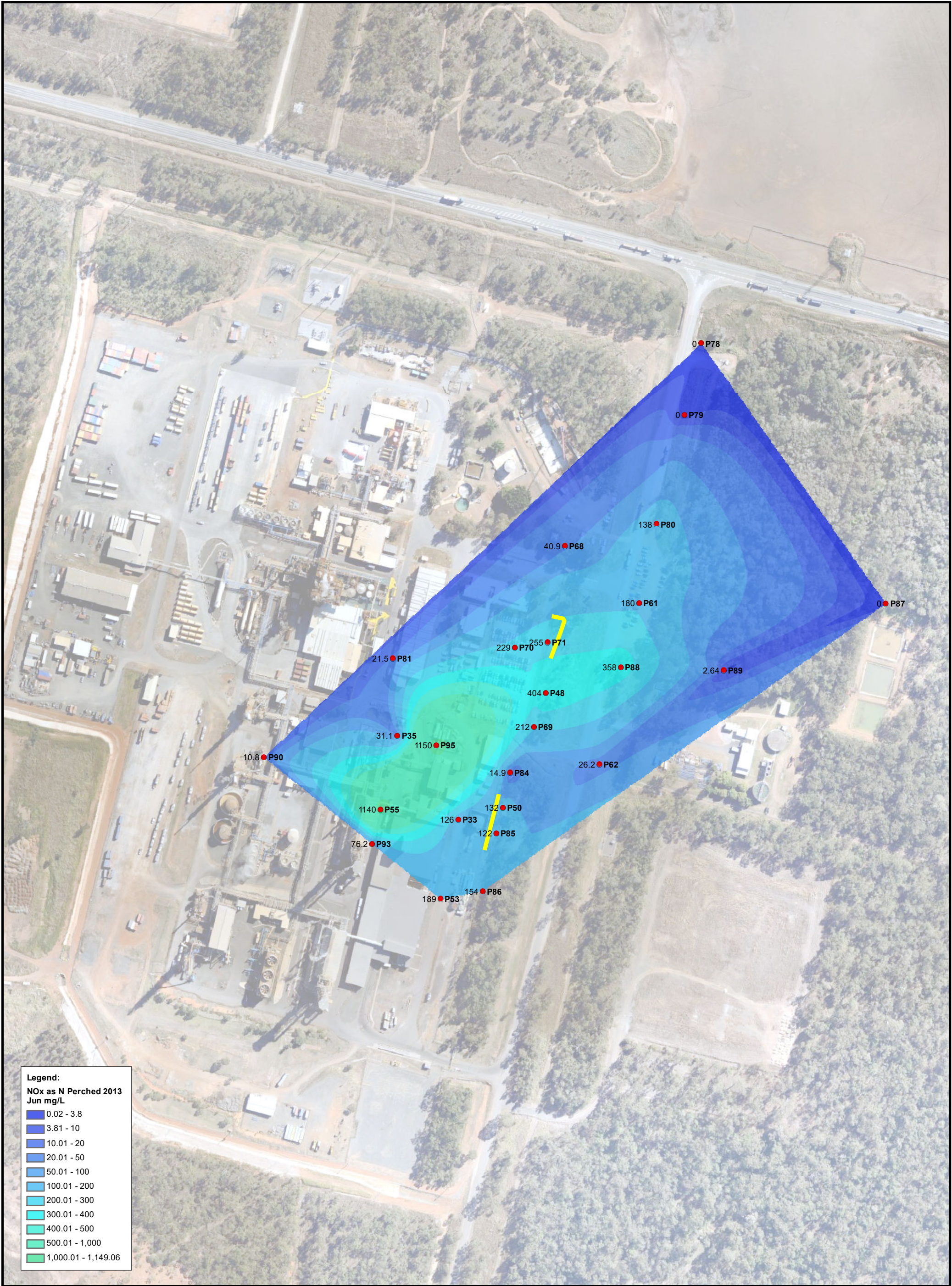
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A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● NOx Perched



Figure: Nitrate as N/Nitrite and Nitrate (NOx) as N Perched 2012 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_NOXPd_2012Jun



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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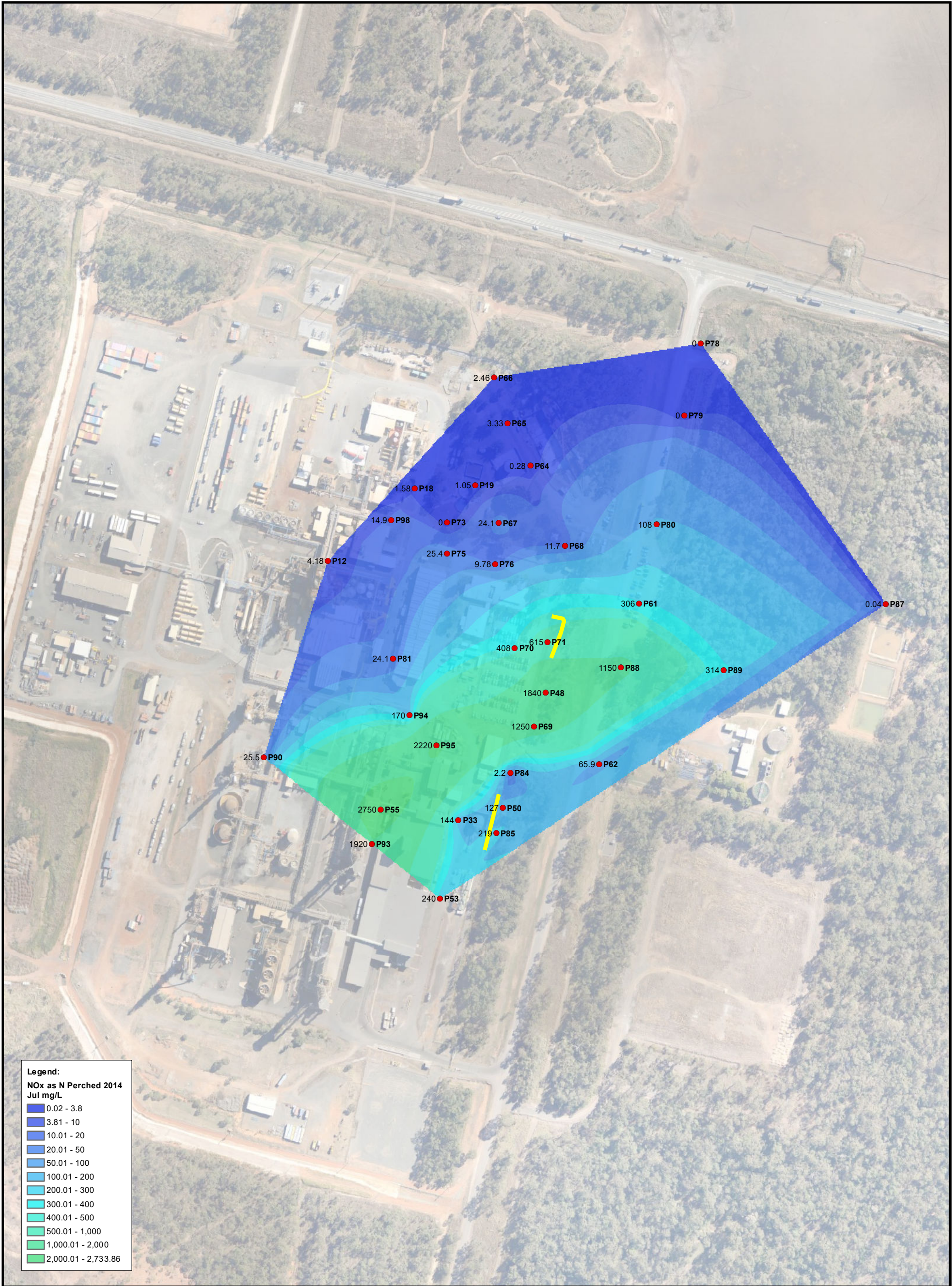
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Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● NOx Perched
— Trench Locations



Figure: Nitrate as N/Nitrite and Nitrate (NOx) as N Perched 2013 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_NOXPd_2013Jun



Legend:
NOx as N Perched 2014 Jul mg/L

0.02 - 3.8
3.81 - 10
10.01 - 20
20.01 - 50
50.01 - 100
100.01 - 200
200.01 - 300
300.01 - 400
400.01 - 500
500.01 - 1,000
1,000.01 - 2,000
2,000.01 - 2,733.86

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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0	20	40	80
m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	16-10-2017
Rev	Description	Drn.	Date

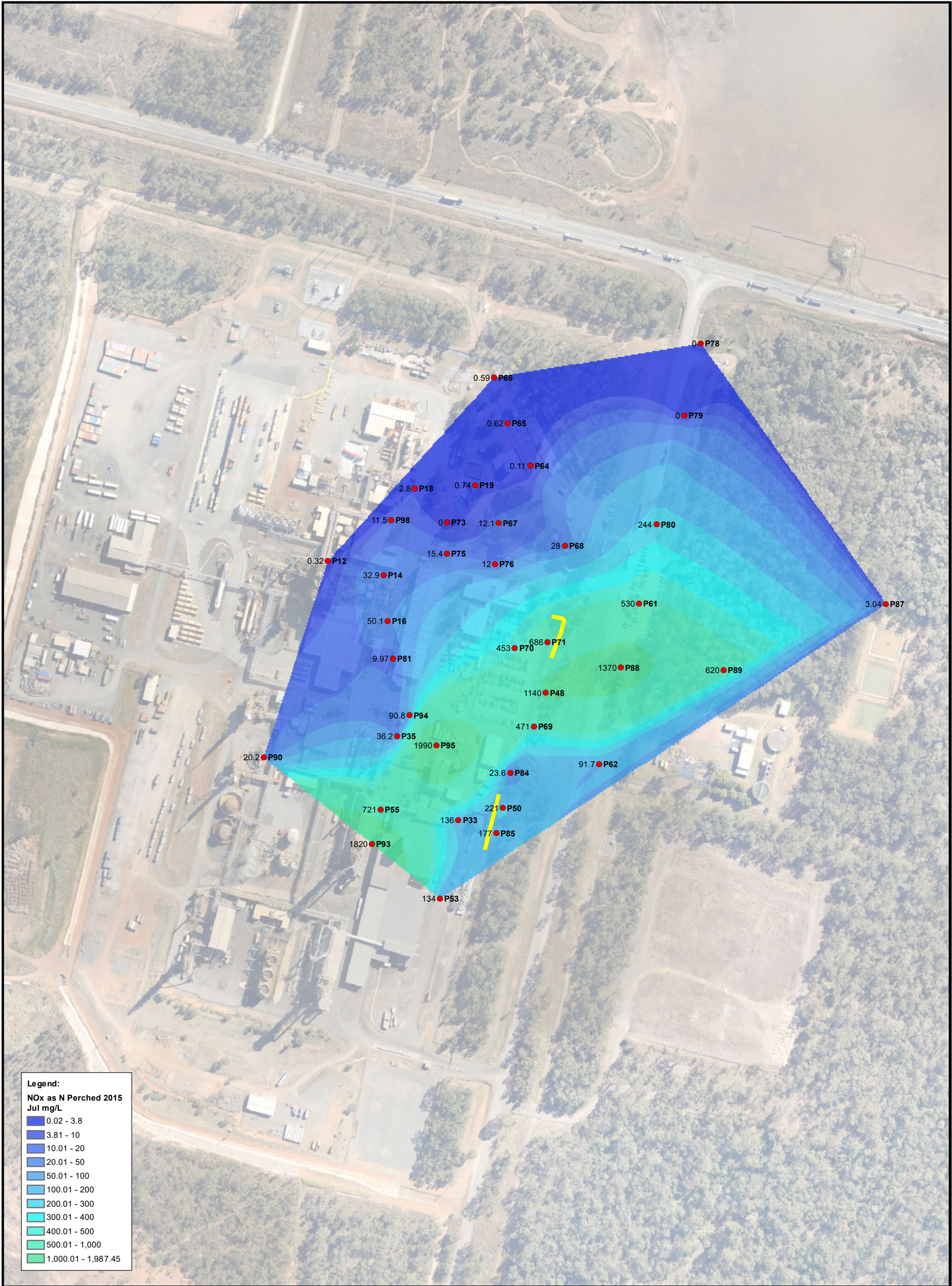
Legend:

- NOx Perched
- Trench Locations



Figure: Nitrate as N/Nitrite and Nitrate (NOx) as N Perched 2014 Jul mg/L

Client: Orica Australia Pty Ltd	
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)	
Job No: 52877	File Name: 52877_nn_NOXPd_2014Jul



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

© 2017 JBS&G

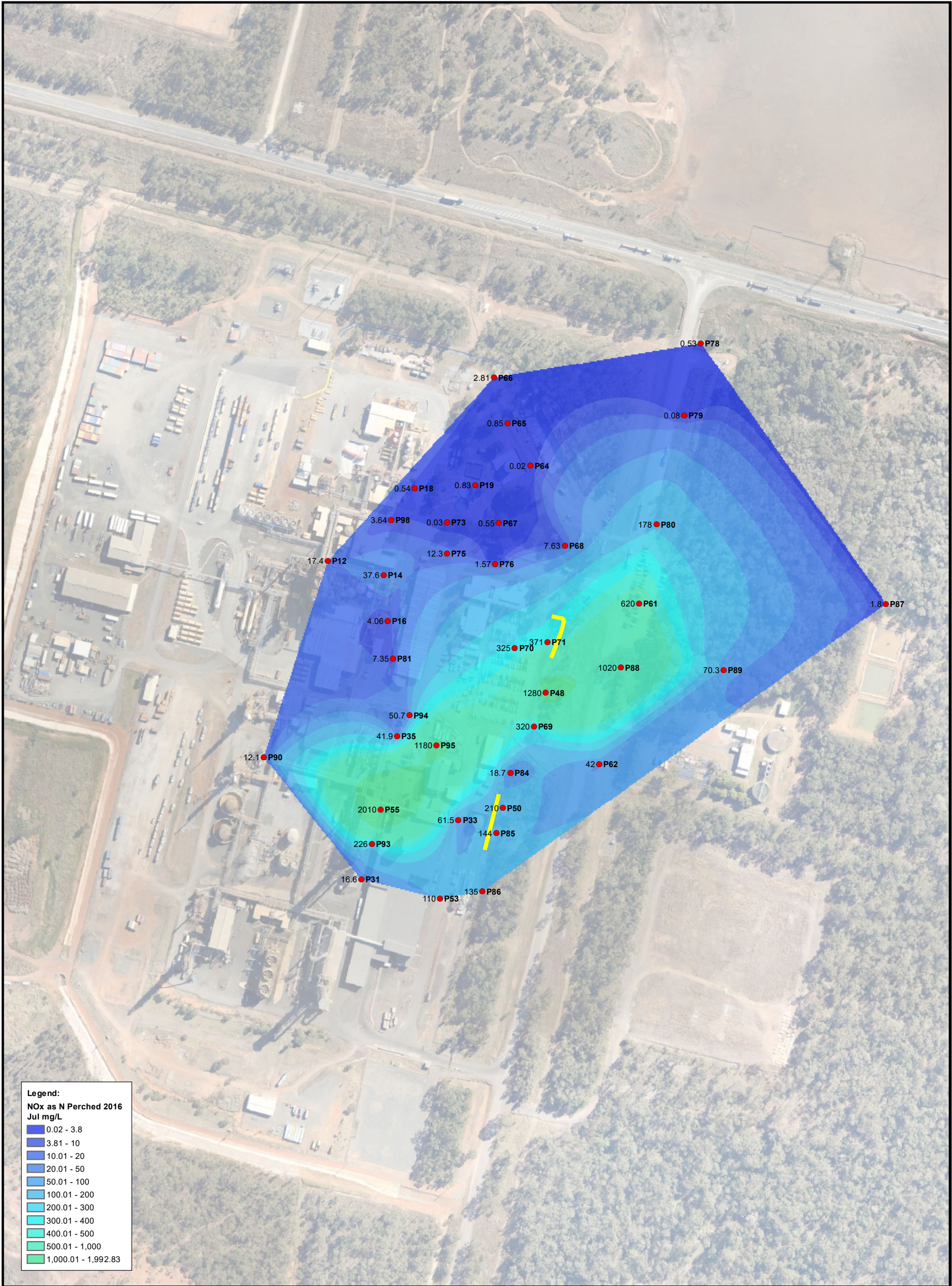
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A3			
A	Original Issue - R02	RF	16-10-2017
Rev	Description	Drn.	Date

Legend:
● NOx Perched
— Trench Locations



Figure: Nitrate as N/Nitrite and Nitrate (NOx) as N Perched 2015 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_NOXPd_2015Jul



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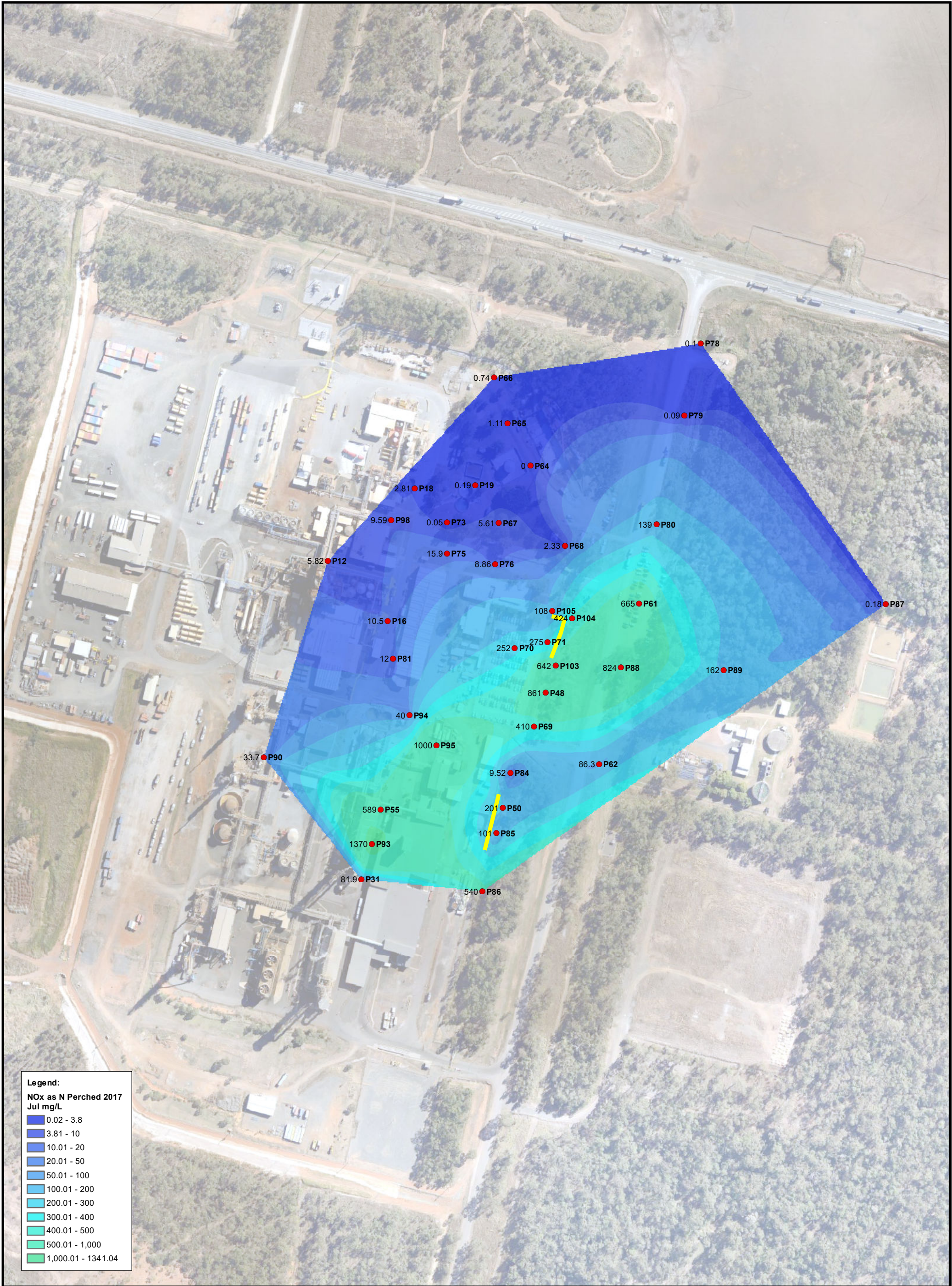
Figure: Nitrate as N/Nitrite and Nitrate (NOx) as N Perched 2016 Jul mg/L

Client: Orica Australia Pty Ltd

Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)

Job No: 52877

File Name: 52877_nn_NOXPd_2016Jul



Legend:

NOx as N Perched 2017 Jul mg/L

0.02 - 3.8
3.81 - 10
10.01 - 20
20.01 - 50
50.01 - 100
100.01 - 200
200.01 - 300
300.01 - 400
400.01 - 500
500.01 - 1,000
1,000.01 - 1341.04

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

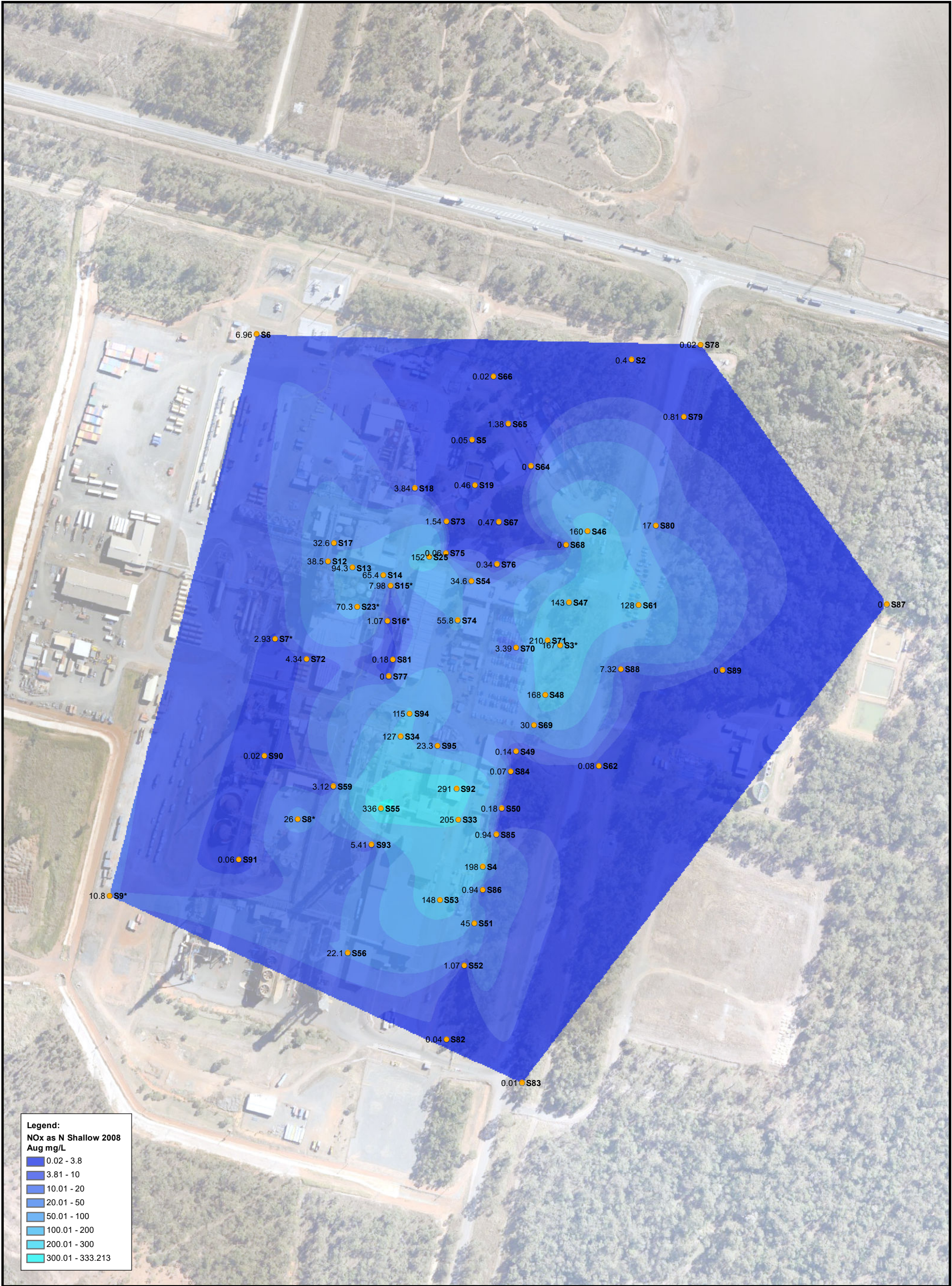
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m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	19-10-2017
Rev	Description	Dmn.	Date

Legend:

●	NOx Perched
—	Trench Locations

Figure: Nitrate as N/Nitrite and Nitrate (NOx) as N Perched 2017 Jul mg/L	
Client: Orica Australia Pty Ltd	
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)	
Job No: 52877	File Name: 52877_nn_NOXPd_2017Jul



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

© 2017 JBS&G

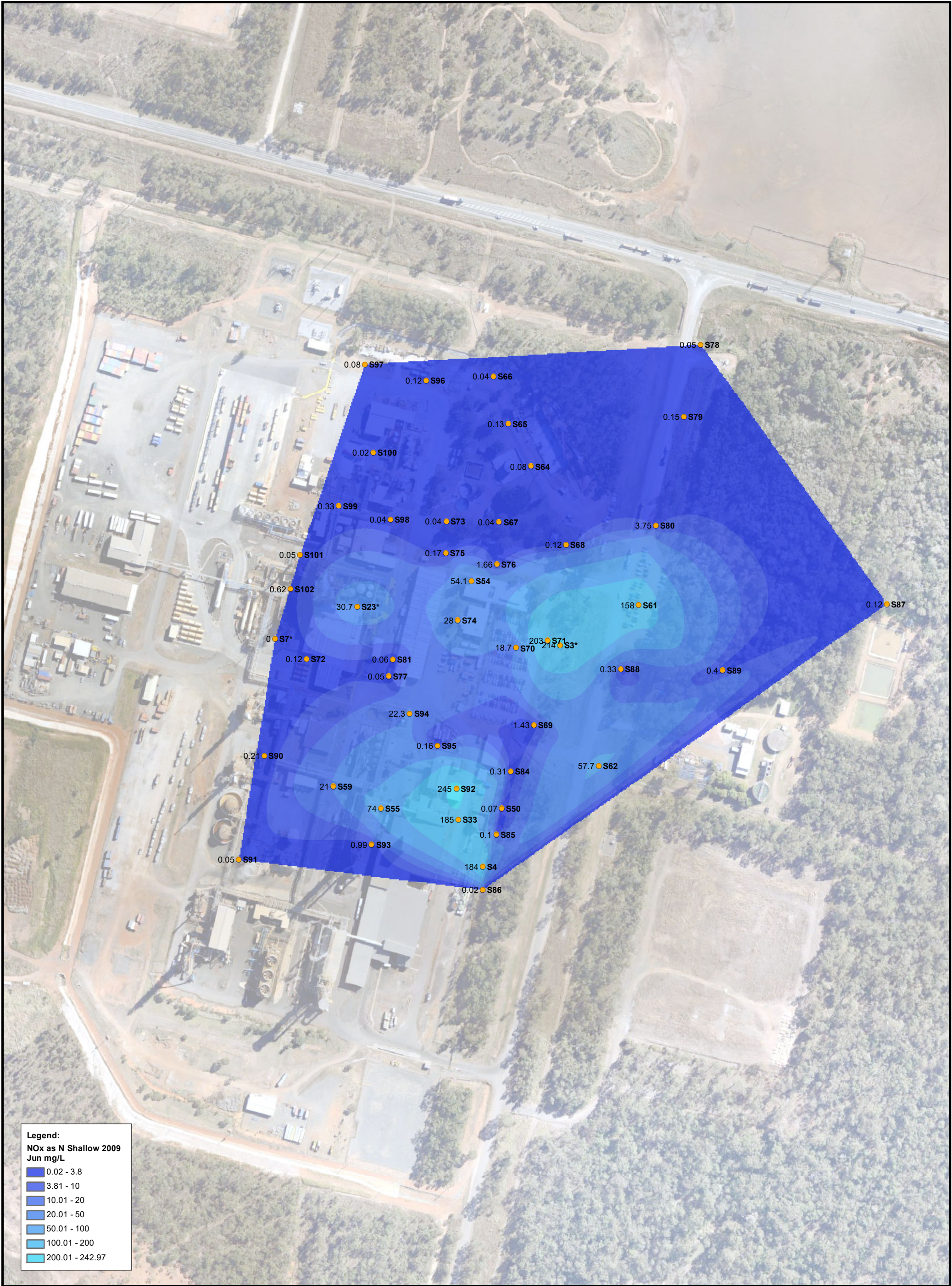
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Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R01	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● NOx Shallow



Figure: Nitrate as N/Nitrite and Nitrate (NOx) as N Shallow 2008 Aug mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_NOXSh_2008Aug



Legend:
NOx as N Shallow 2009 Jun mg/L

0.02 - 3.8
3.81 - 10
10.01 - 20
20.01 - 50
50.01 - 100
100.01 - 200
200.01 - 242.97

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

© 2017 JBS&G

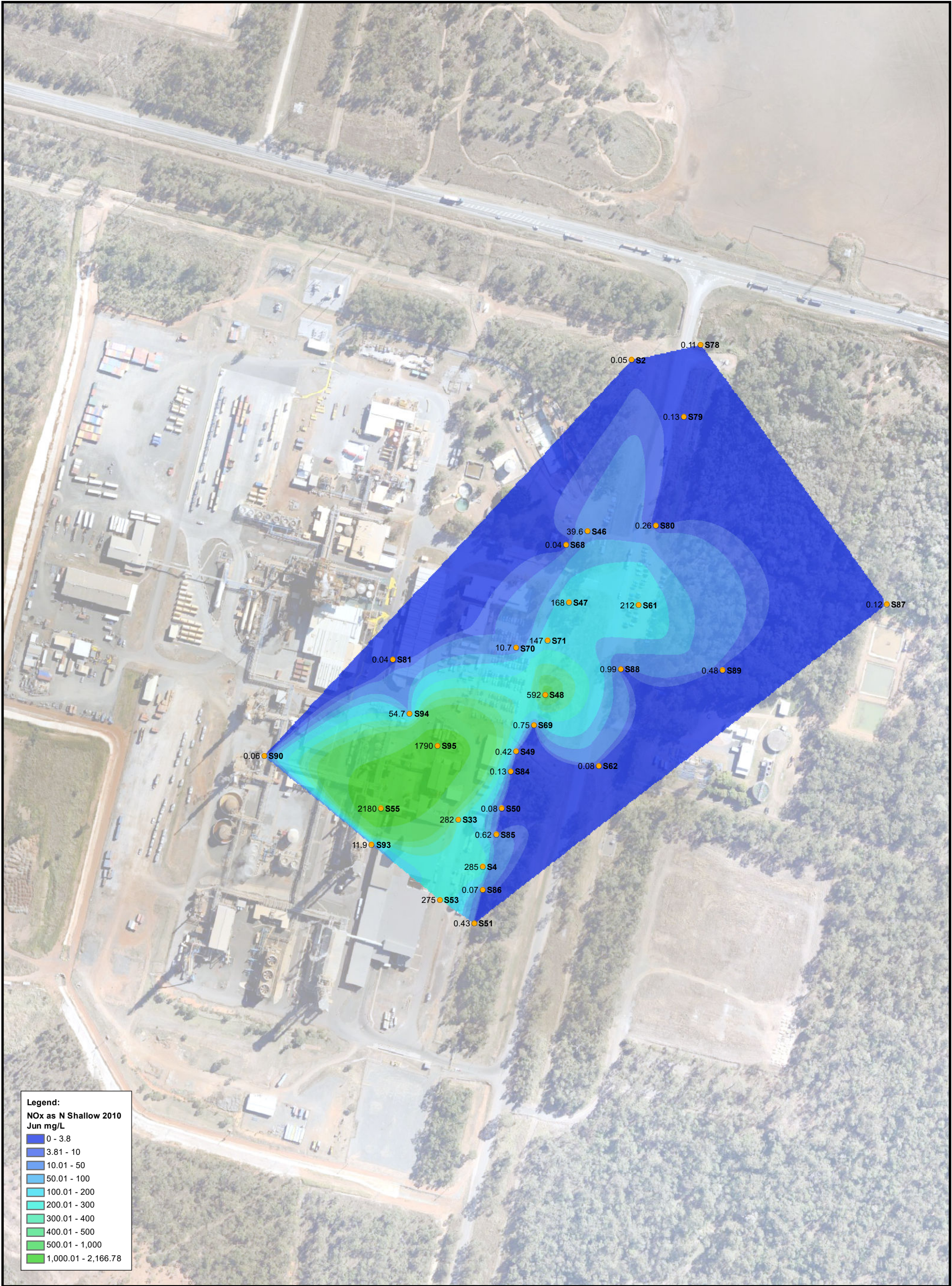
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Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● NOx Shallow



Figure: Nitrate as N/Nitrite and Nitrate (NOx) as N Shallow 2009 Jun mg/L

Client: Orica Australia Pty Ltd	
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)	
Job No: 52877	File Name: 52877_nn_NOXSh_2009Jun

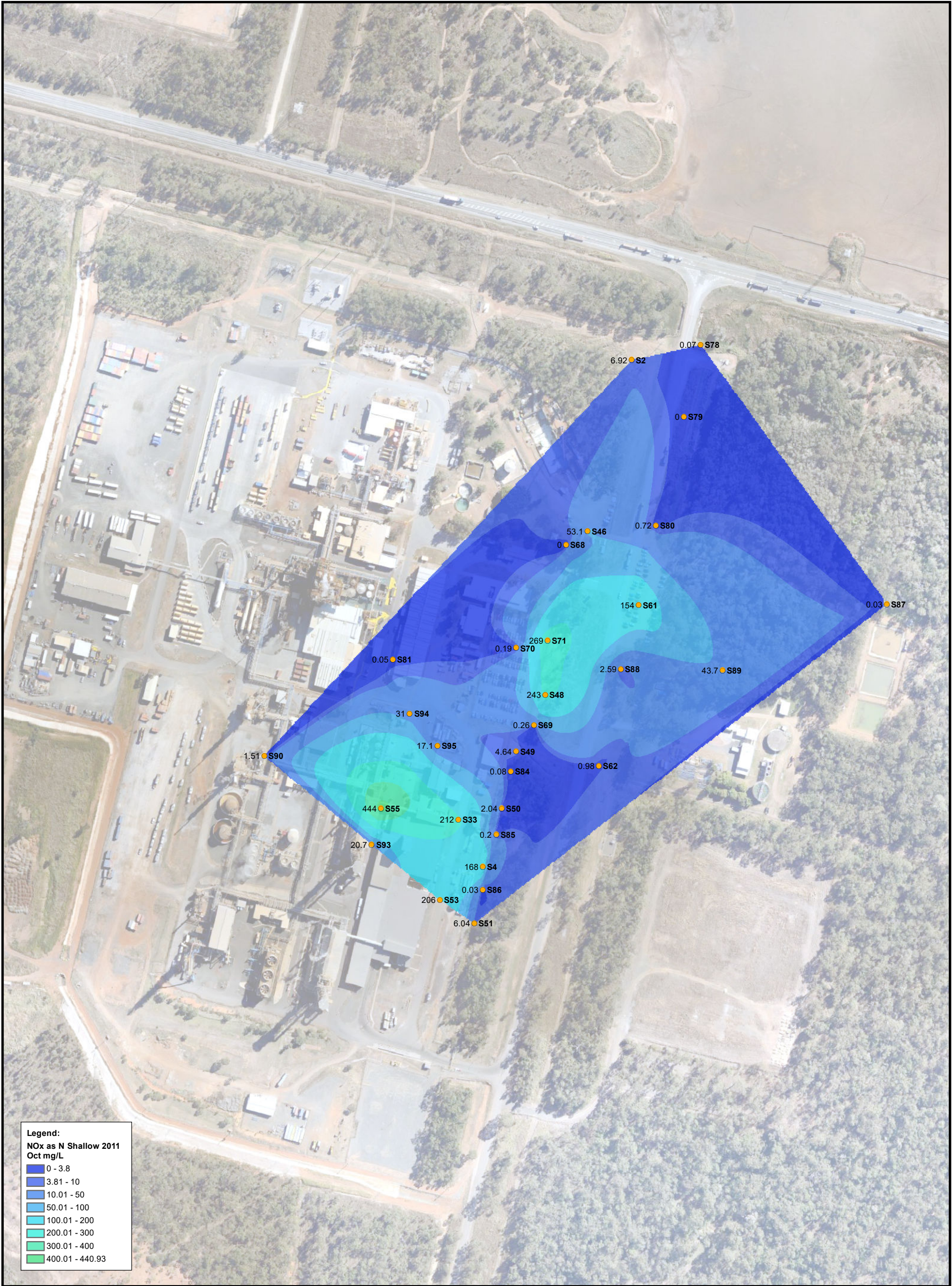


0	25	50	100
m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date



Figure: Nitrate as N/Nitrite and Nitrate (NOx) as N Shallow 2010 Jun mg/L

Client: Orica Australia Pty Ltd	
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)	
Job No: 52877	File Name: 52877_nn_NOXSh_2010Jun



Legend:
NOx as N Shallow 2011
Oct mg/L

0 - 3.8
3.81 - 10
10.01 - 50
50.01 - 100
100.01 - 200
200.01 - 300
300.01 - 400
400.01 - 440.93

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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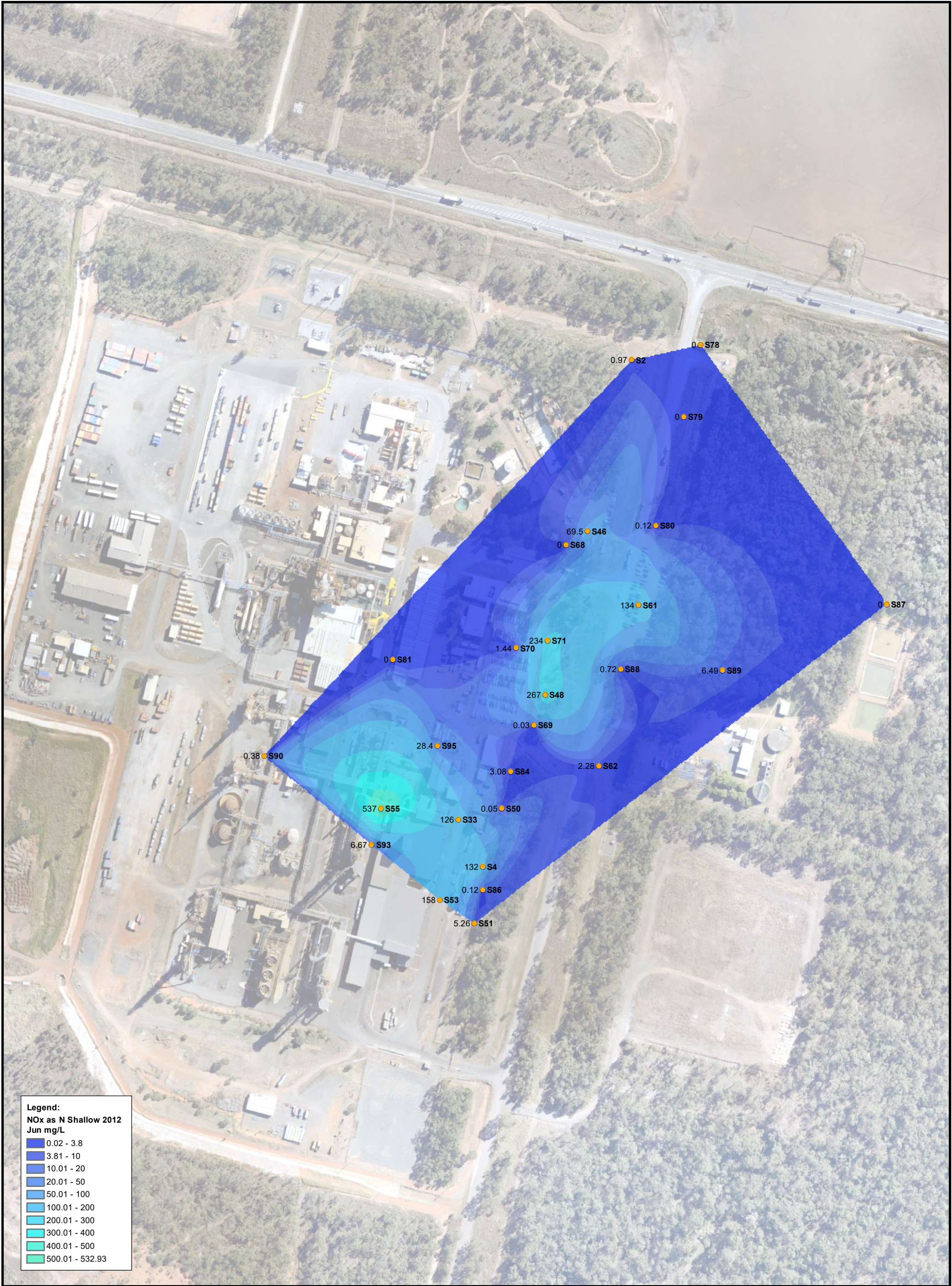
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Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● NOx Shallow



**Figure: Nitrate as N/Nitrite and
Nitrate (NOx) as N Shallow
2011 Oct mg/L**

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_NOXSh_2011Oct



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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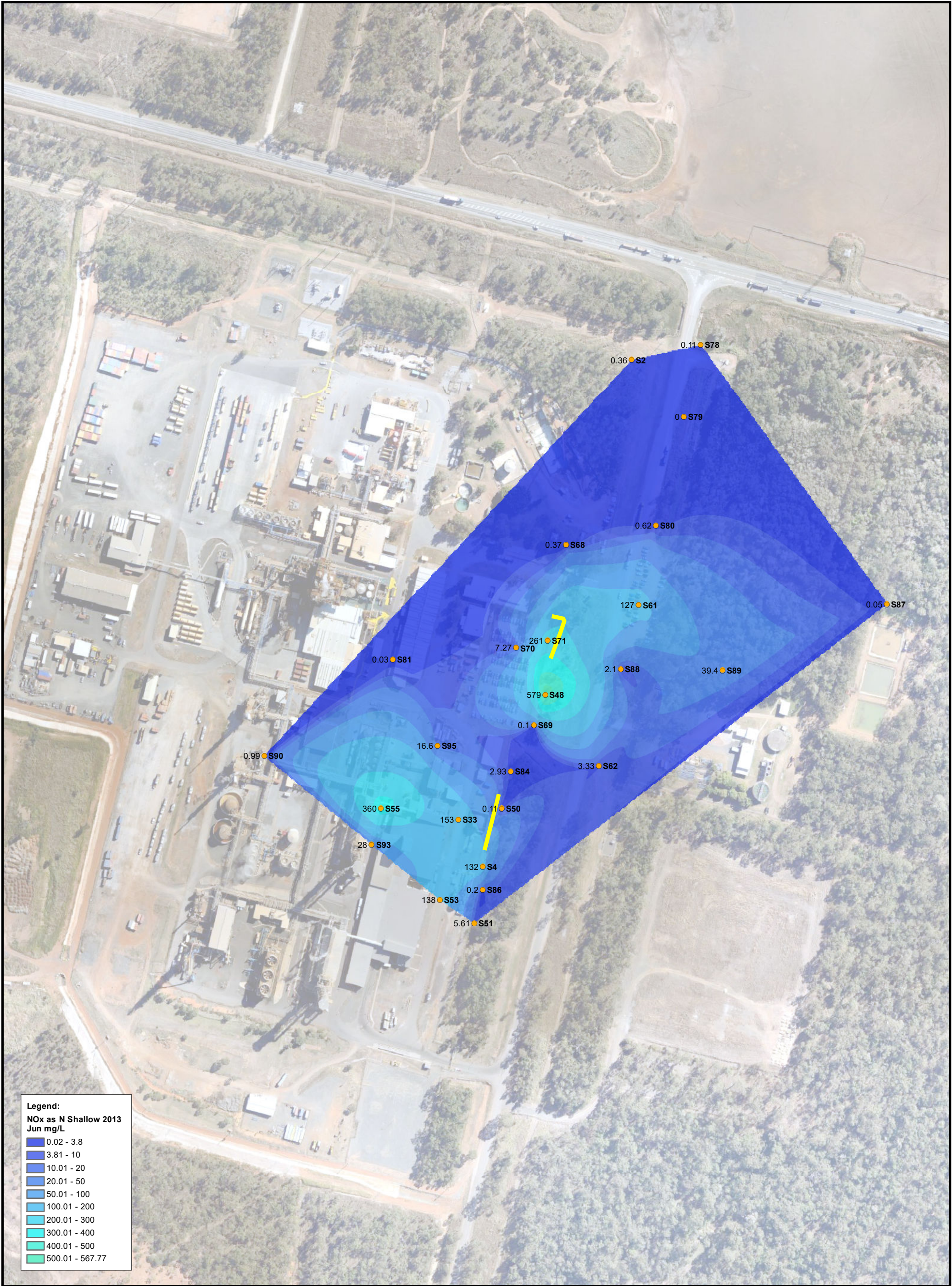
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Datum: MGA94 Zone 56 - AHD			
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A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● NOx Shallow



Figure: Nitrate as N/Nitrite and Nitrate (NOx) as N Shallow 2012 Jun mg/L

Client: Orica Australia Pty Ltd	
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)	
Job No: 52877	File Name: 52877_nn_NOXSh_2012Jun



- Legend:**
NOx as N Shallow 2013 Jun mg/L
- 0.02 - 3.8
 - 3.81 - 10
 - 10.01 - 20
 - 20.01 - 50
 - 50.01 - 100
 - 100.01 - 200
 - 200.01 - 300
 - 300.01 - 400
 - 400.01 - 500
 - 500.01 - 567.77

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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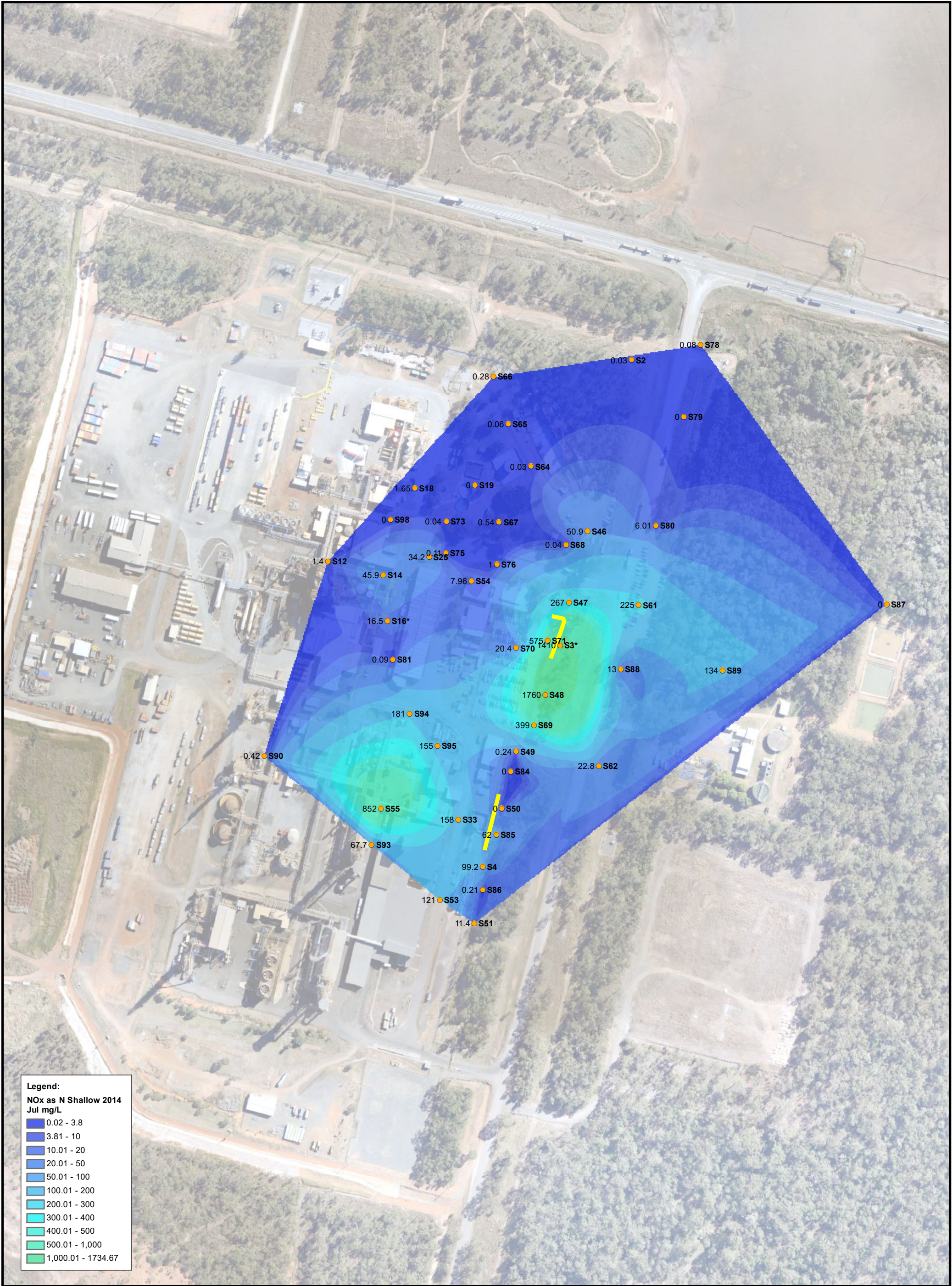
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A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

- Legend:**
- NOx Shallow
 - Trench Locations



Figure: Nitrate as N/Nitrite and Nitrate (NOx) as N Shallow 2013 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_NOXSh_2013Jun



Legend:
NOx as N Shallow 2014 Jul mg/L

0.02 - 3.8
3.81 - 10
10.01 - 20
20.01 - 50
50.01 - 100
100.01 - 200
200.01 - 300
300.01 - 400
400.01 - 500
500.01 - 1,000
1,000.01 - 1734.67

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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0	25	50	100
m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

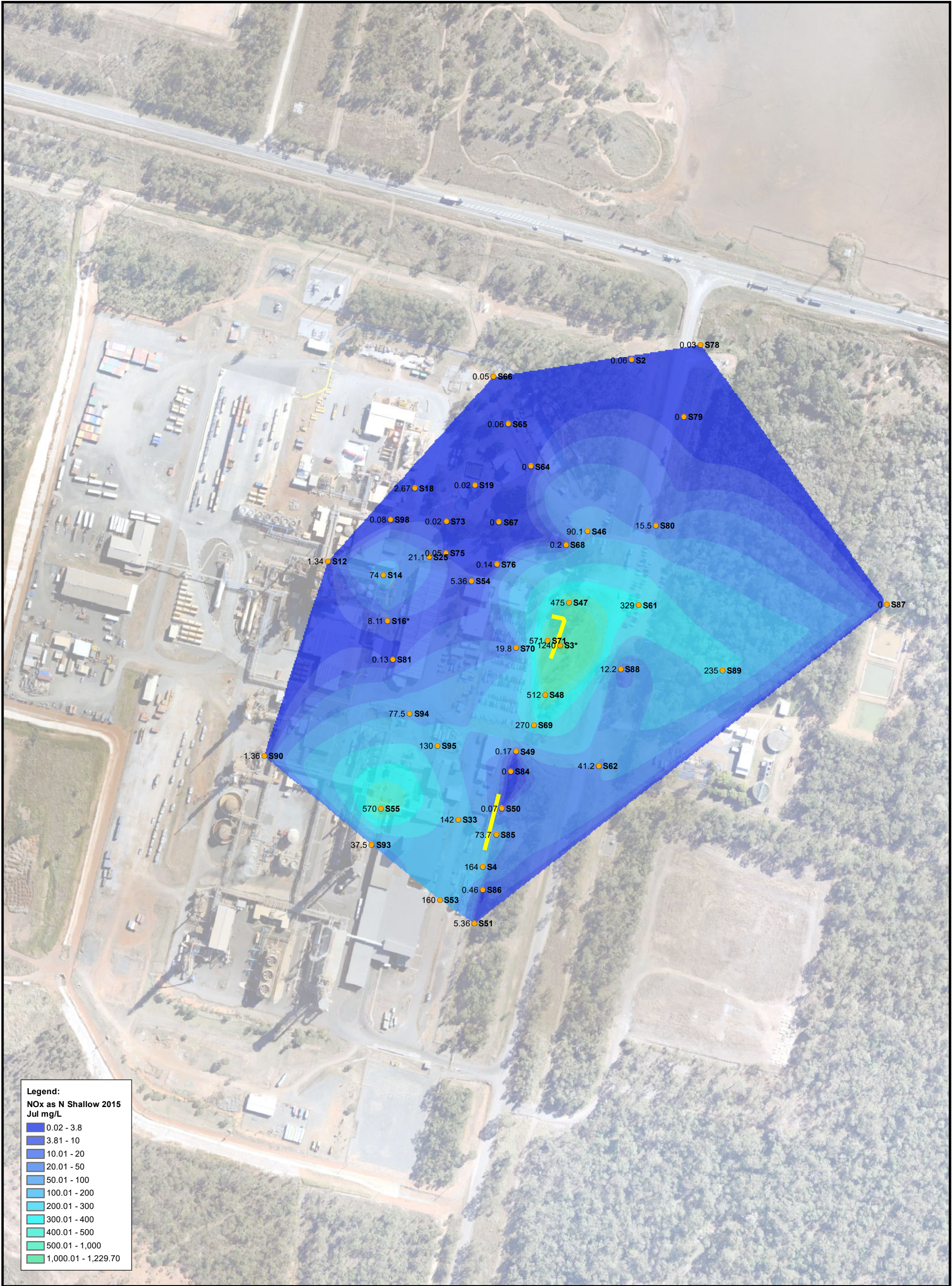
Legend:

- NOx Shallow
- Trench Locations



Figure: Nitrate as N/Nitrite and Nitrate (NOx) as N Shallow 2014 Jul mg/L

Client: Orica Australia Pty Ltd	
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)	
Job No: 52877	File Name: 52877_nn_NOXSh_2014Jul



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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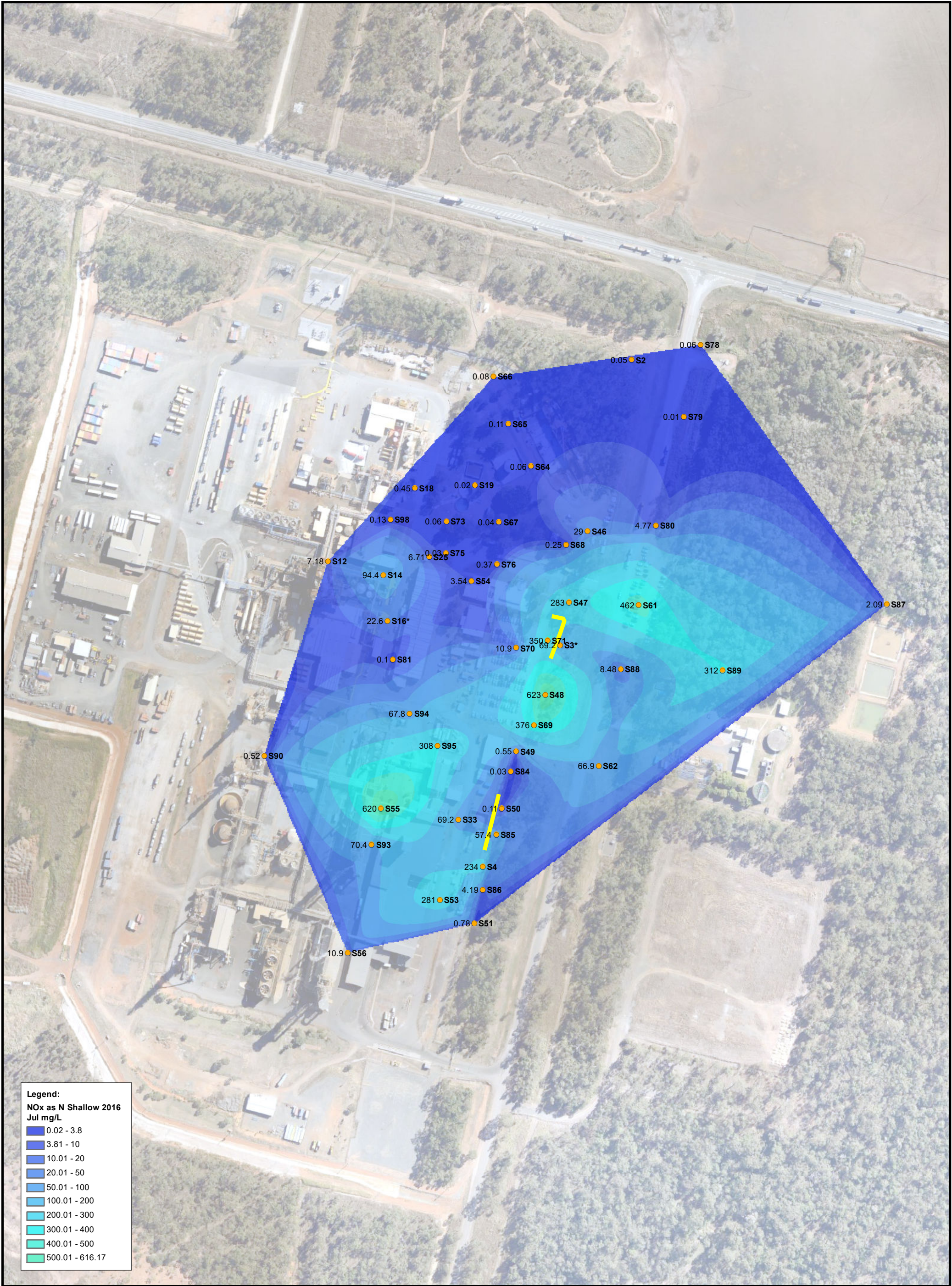
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A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

- Legend:
- NOx Shallow
 - Trench Locations



Figure: Nitrate (NOx) as N/Nitrite and Nitrate (NOx) as N Shallow 2015 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_NOXSh_2015Jul



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A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

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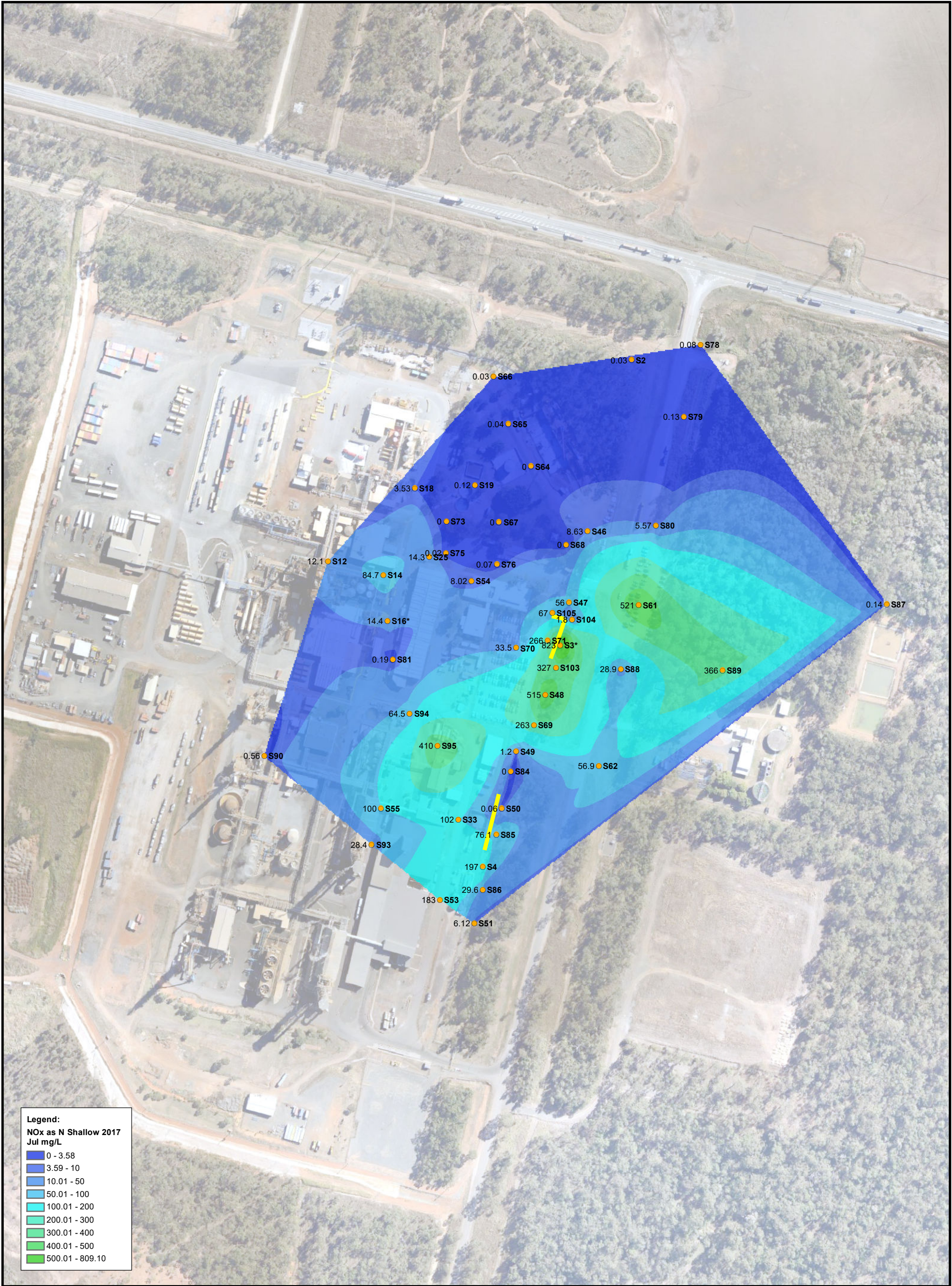
- NOx Shallow
- Trench Locations

JBS&G Figure: Nitrate as N/Nitrite and Nitrate (NOx) as N Shallow 2016 Jul mg/L

Client: Orica Australia Pty Ltd

Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)

Job No: 52877 File Name: 52877_nn_NOXSh_2016Jul



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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025100m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● NOx Shallow
— Trench Locations



Figure: Nitrate (NOx) as N/Nitrite and Nitrate (NOx) as N Shallow 2017 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_NOXSh_2017Jul



Legend:
Cyanide Free Perched
2008 Aug mg/L

0 - 0.011
0.012 - 10
10.01 - 50
50.01 - 100
100.01 - 200
200.01 - 300
300.01 - 360.98

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

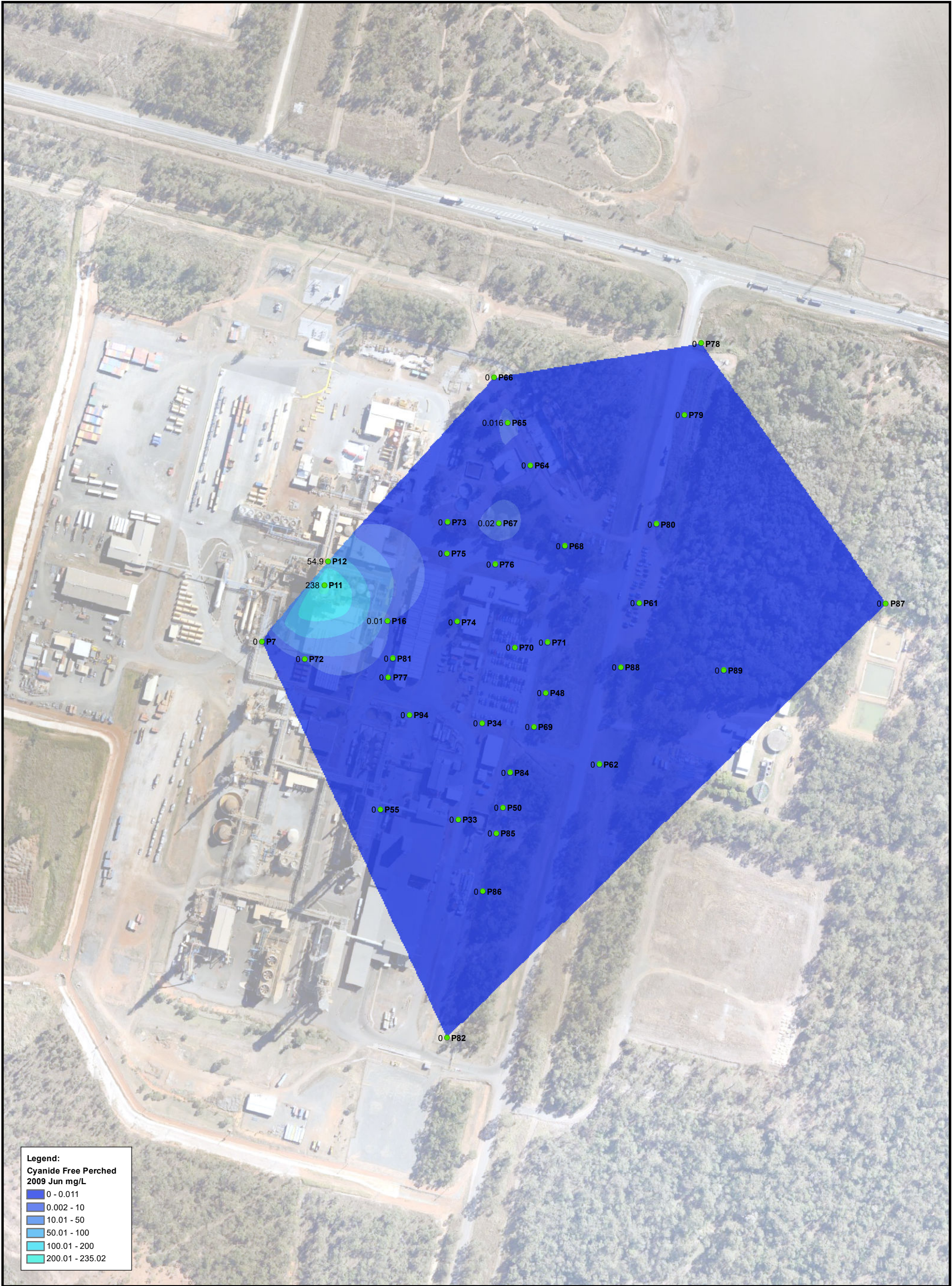
© 2017 JBS&G

0	25	50	100
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Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R01	RF	24-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Free Perched

JBS&G Figure: Cyanide Free Perched
2008 Aug mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNFreePd_2008Aug



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	24-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Free Perched

JBS&G Figure: Cyanide Free Perched
2009 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNFreePd_2009Jun



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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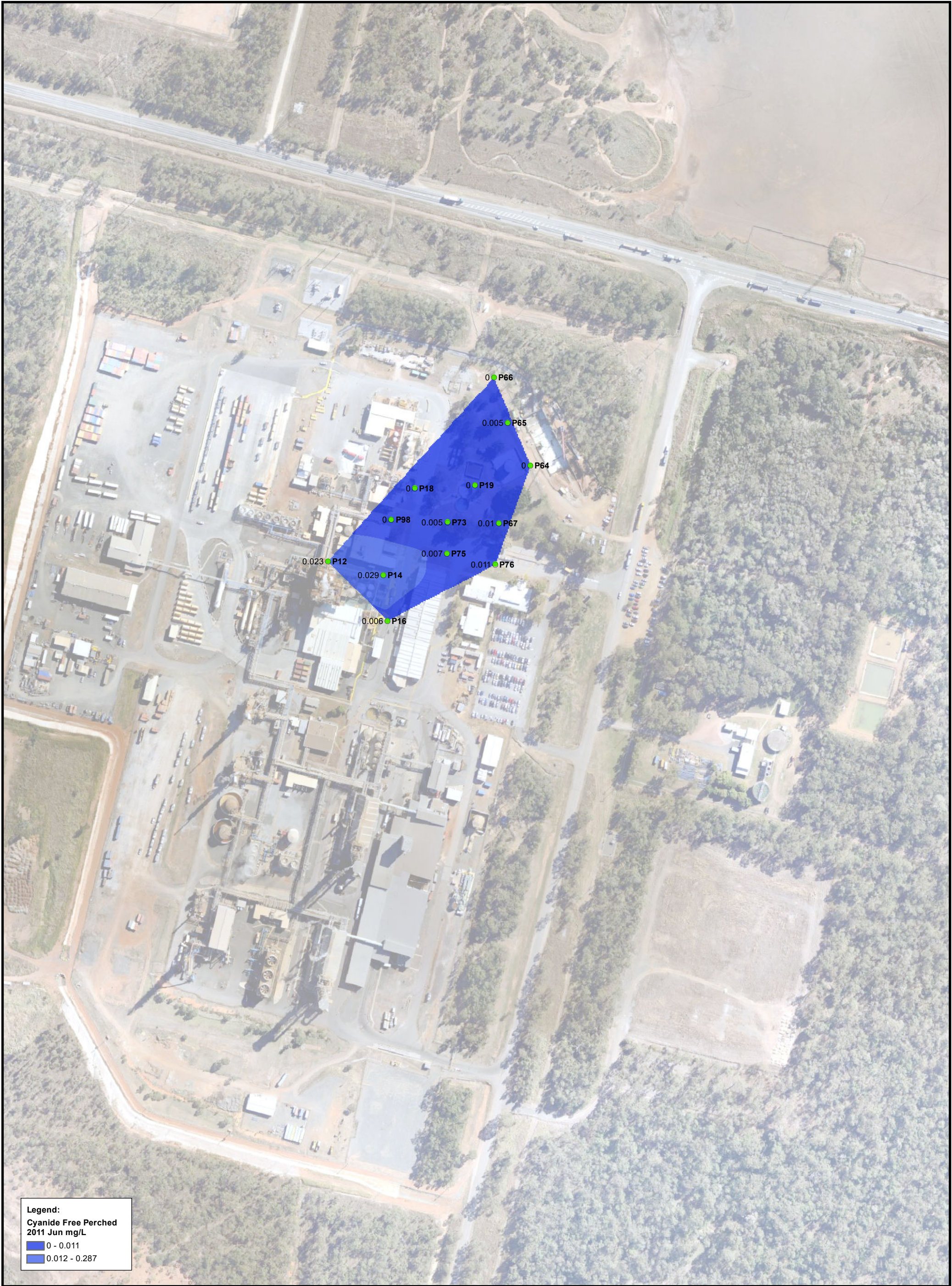
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A	Original Issue - R02	RF 24-10-2017
Rev	Description	Drn. Date

Legend:
● CN Free Perched

JBS&G Figure: Cyanide Free
Perched 2010 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNFreePd_2010Jun





Legend:
Cyanide Free Perched
2011 Jun mg/L
0 - 0.011
0.012 - 0.287

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

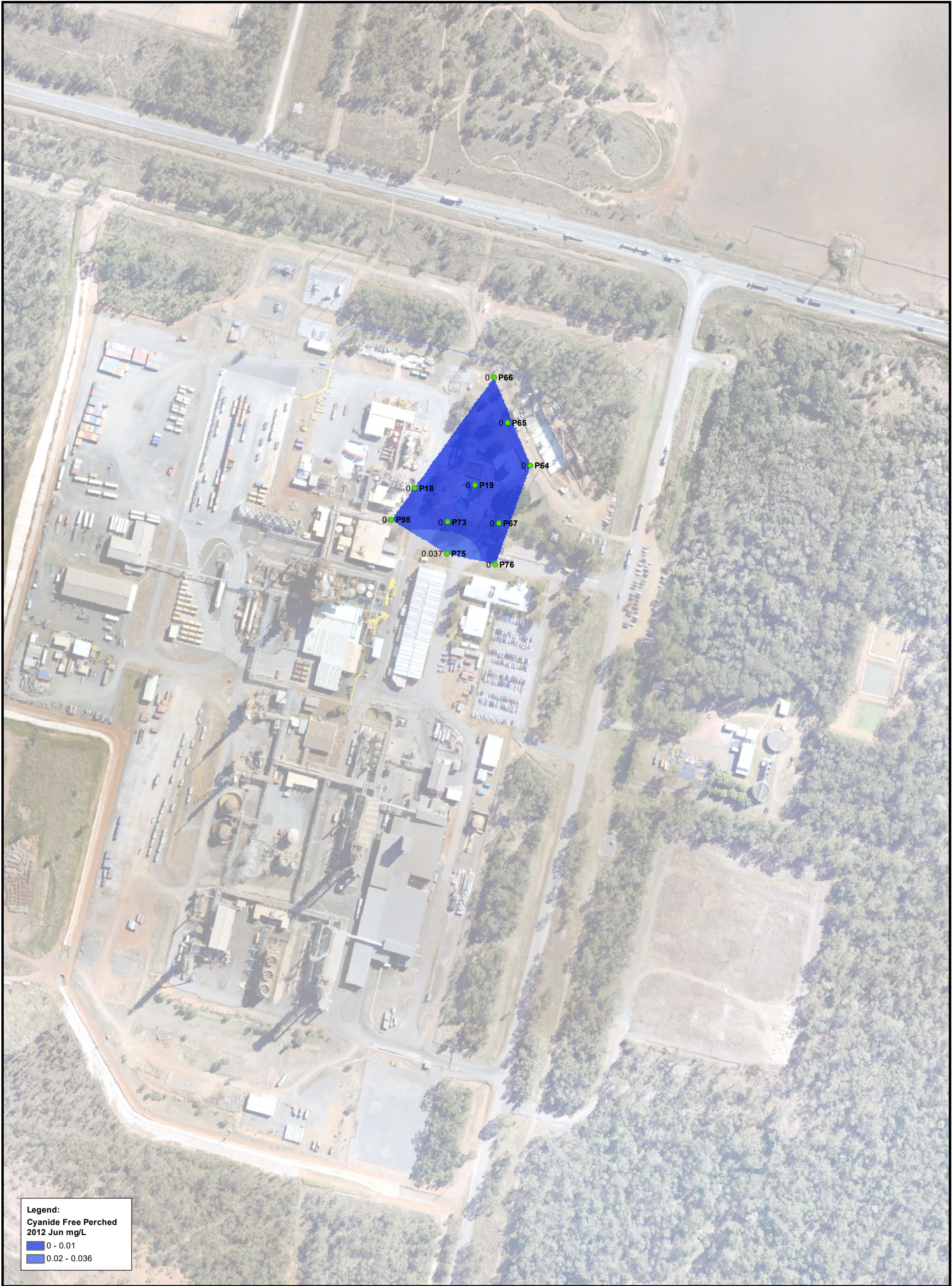
© 2017 JBS&G

0	25	50	100
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Datum: MGA94 Zone 56 - AHD			
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A	Original Issue - R02	RF	24-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Free Perched

JBS&G Figure: Cyanide Free Perched
2011 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNFreePd_2011Jun



Legend:
Cyanide Free Perched
2012 Jun mg/L
0 - 0.01
0.02 - 0.036

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

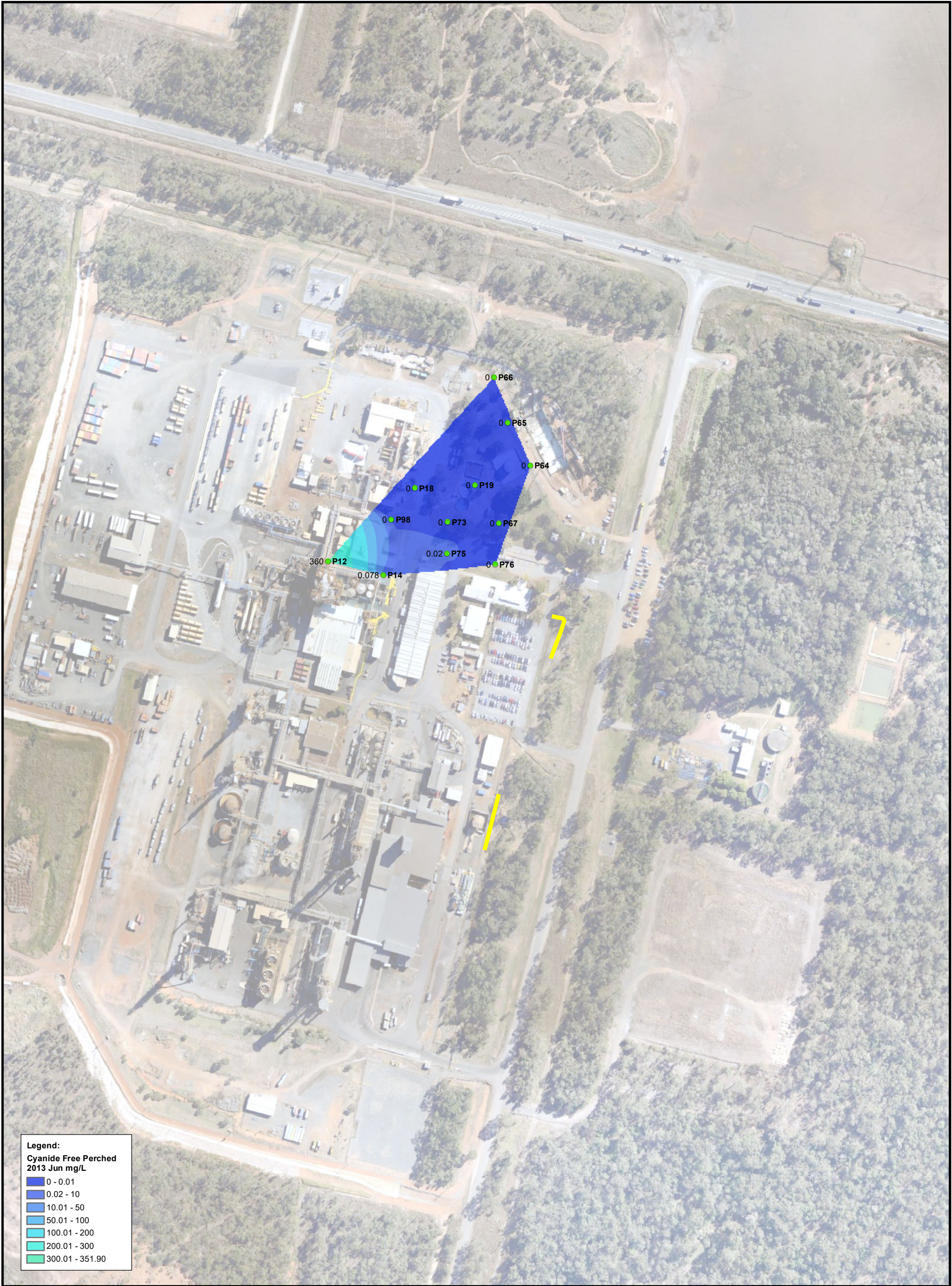
© 2017 JBS&G

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Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	24-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Free Perched

JBS&G Figure: Cyanide Free Perched
2012 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNFreePd_2012Jun



Legend:
Cyanide Free Perched
2013 Jun mg/L

0 - 0.01
0.02 - 10
10.01 - 50
50.01 - 100
100.01 - 200
200.01 - 300
300.01 - 351.90

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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0	25	50	100
m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	24-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Free Perched
— Trench Locations

JBS&G Figure: Cyanide Free Perched
2013 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNFreePd_2013Jun



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Legend:
Cyanide Free Perched
2015 Jun mg/L
0 - 0.011
0.012 - 9.27

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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0	25	50	100
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Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	24-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Free Perched
— Trench Locations

JBS&G Figure: Cyanide Free Perched
2015 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNFreePd_2015Jul





Legend:
Cyanide Free Perched
2016 Jul mg/L
0 - 0.011
0.012 - 0.090

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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0	25	50	100
m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	24-10-2017
Rev	Description	Drn.	Date

Legend:
● CNFreePerched
— Trench Locations

JBS&G Figure: Cyanide Free Perched
2016 Jul mg/L

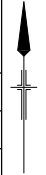
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Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNFreePd_2016Jul

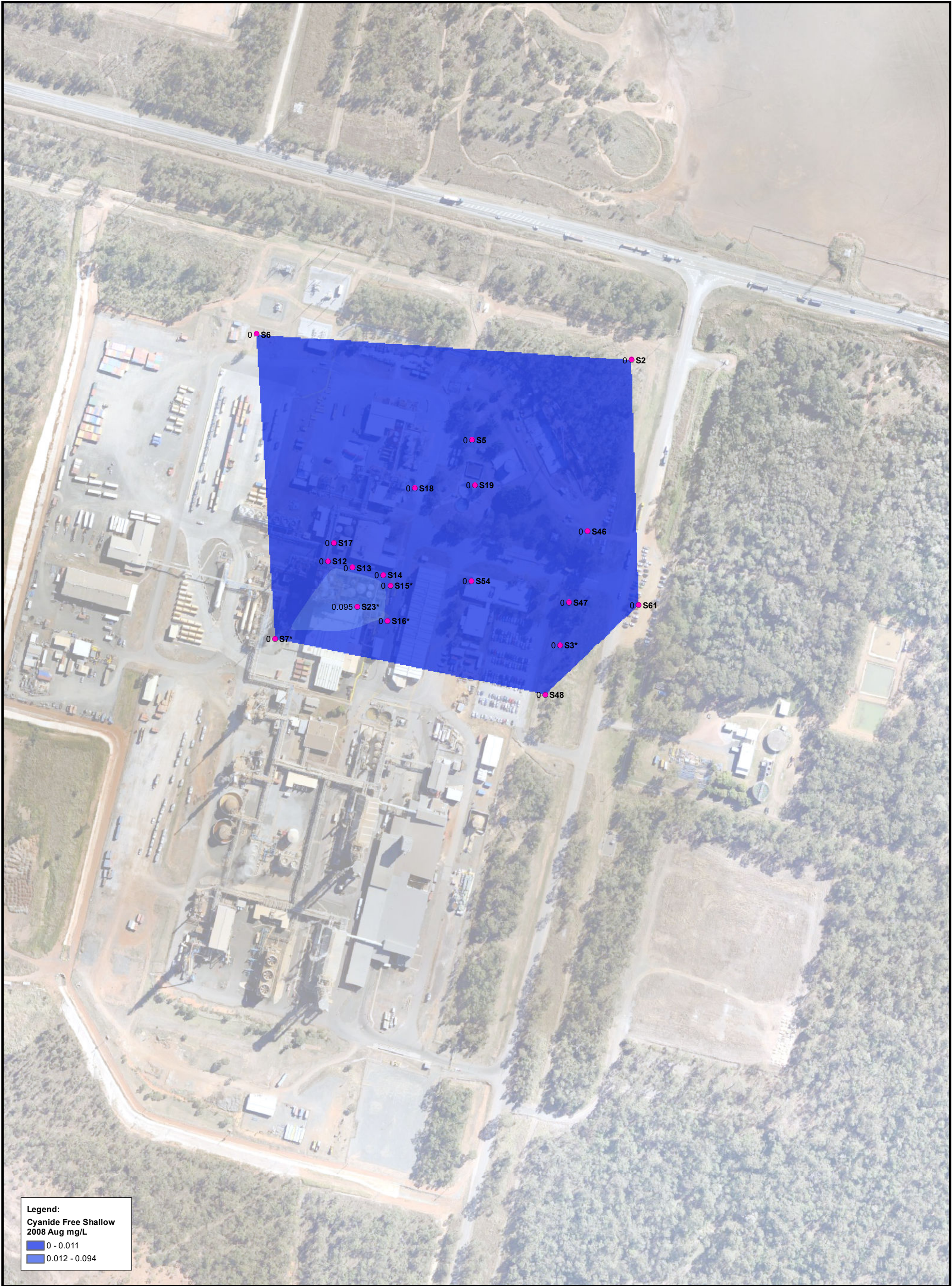


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A	Original Issue - R02	RF	24-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Free Perched
— Trench Locations

JBS&G Figure: Cyanide Free Perched
2017 Jul mg/L
Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNFreePd_2017Jul





Legend:
Cyanide Free Shallow
2008 Aug mg/L
0 - 0.011
0.012 - 0.094

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

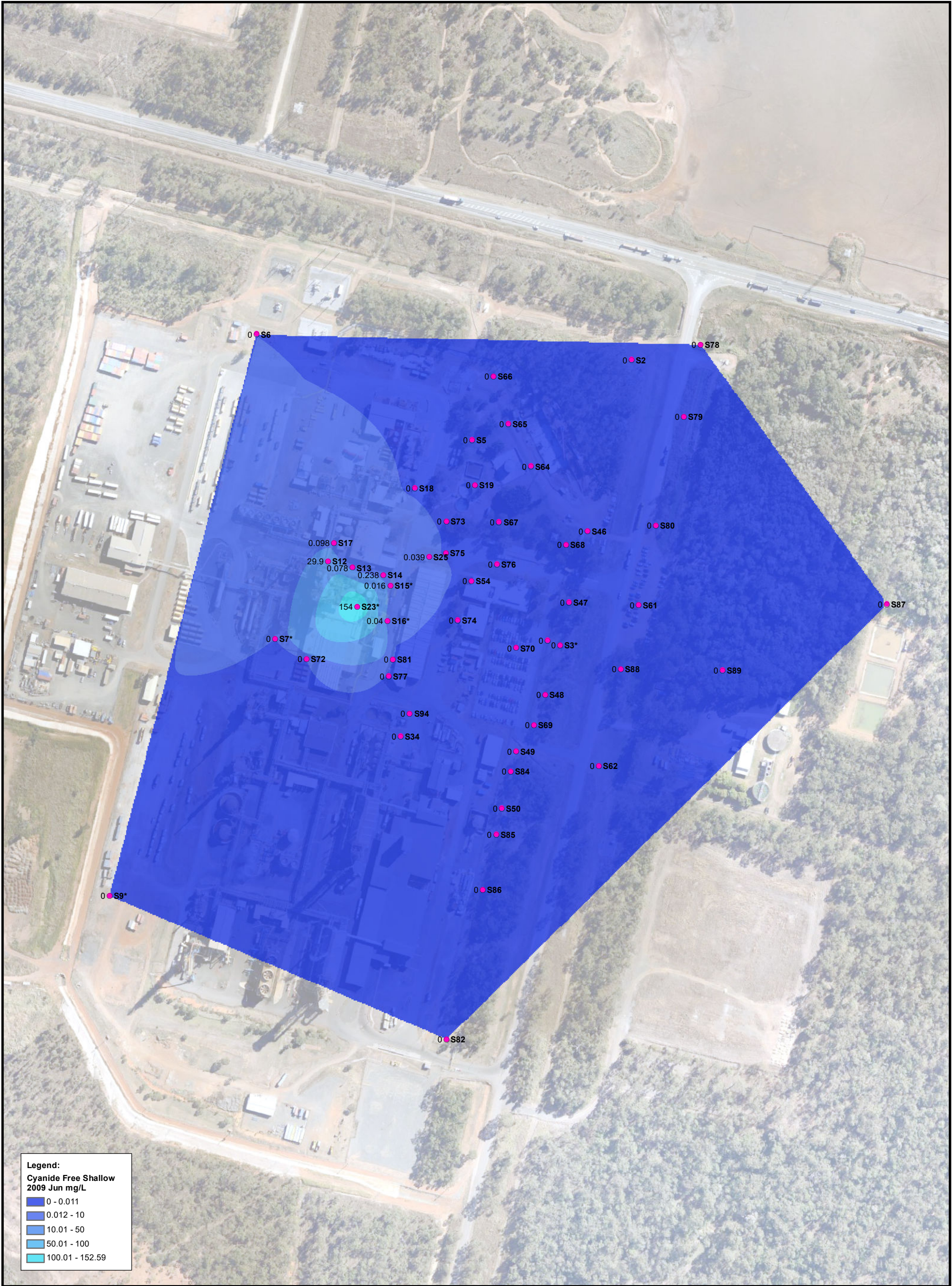
© 2017 JBS&G

0	25	50	100
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Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R01	RF	24-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Free Shallow

JBS&G Figure: Cyanide Free Shallow
2008 Aug mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNFreeSh_2008Aug



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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Scale: 1:3,000			
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A3			
A	Original Issue - R02	RF	24-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Free Shallow

JBS&G Figure: Cyanide Free Shallow
2009 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNFreeSh_2009Jun



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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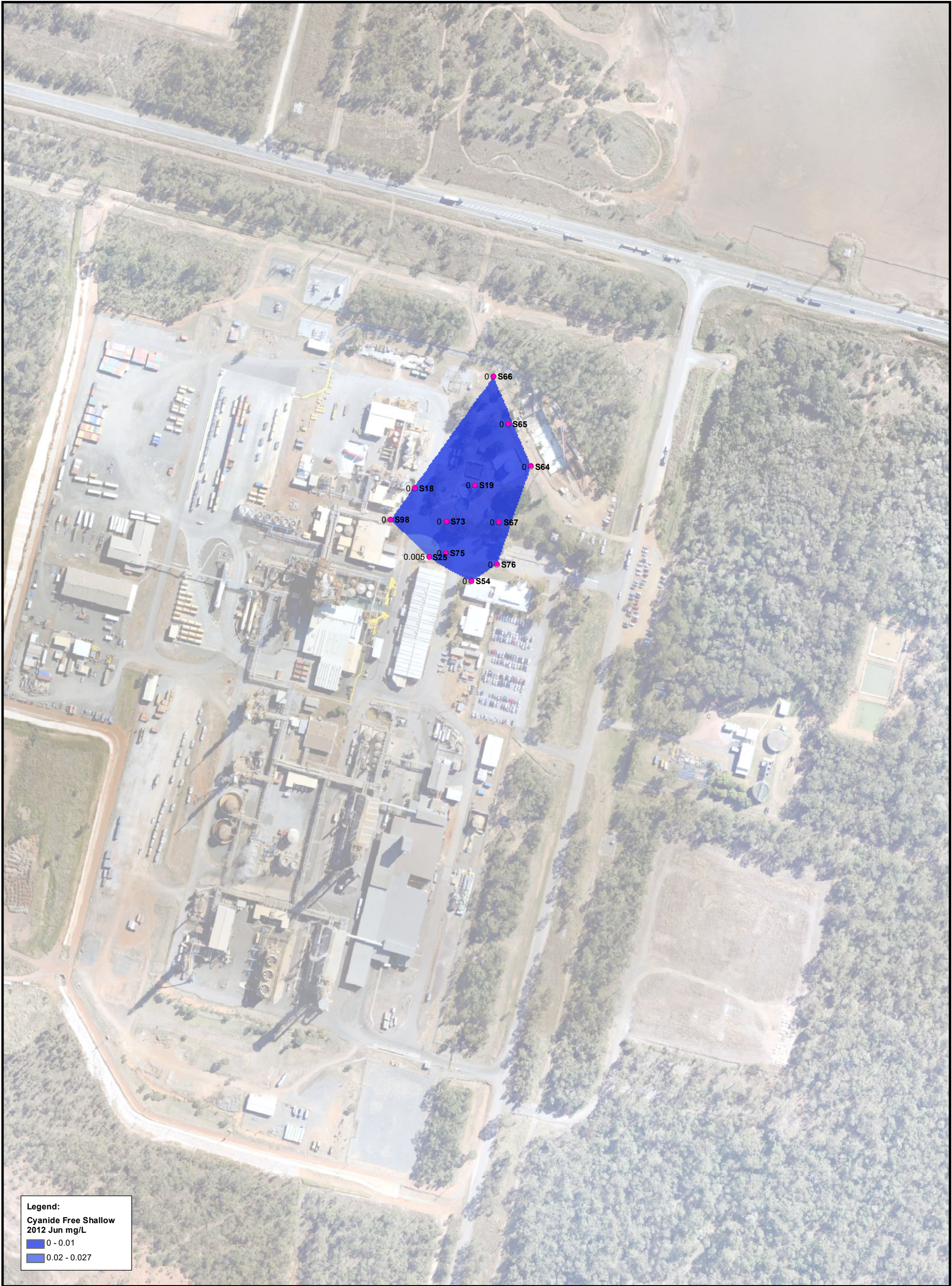
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A	Original Issue - R02	RF	24-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Free Shallow

JBS&G Figure: Cyanide Free
Shallow 2010 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNFreeSh_2010Jun





Legend:
Cyanide Free Shallow
2012 Jun mg/L
0 - 0.01
0.02 - 0.027

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

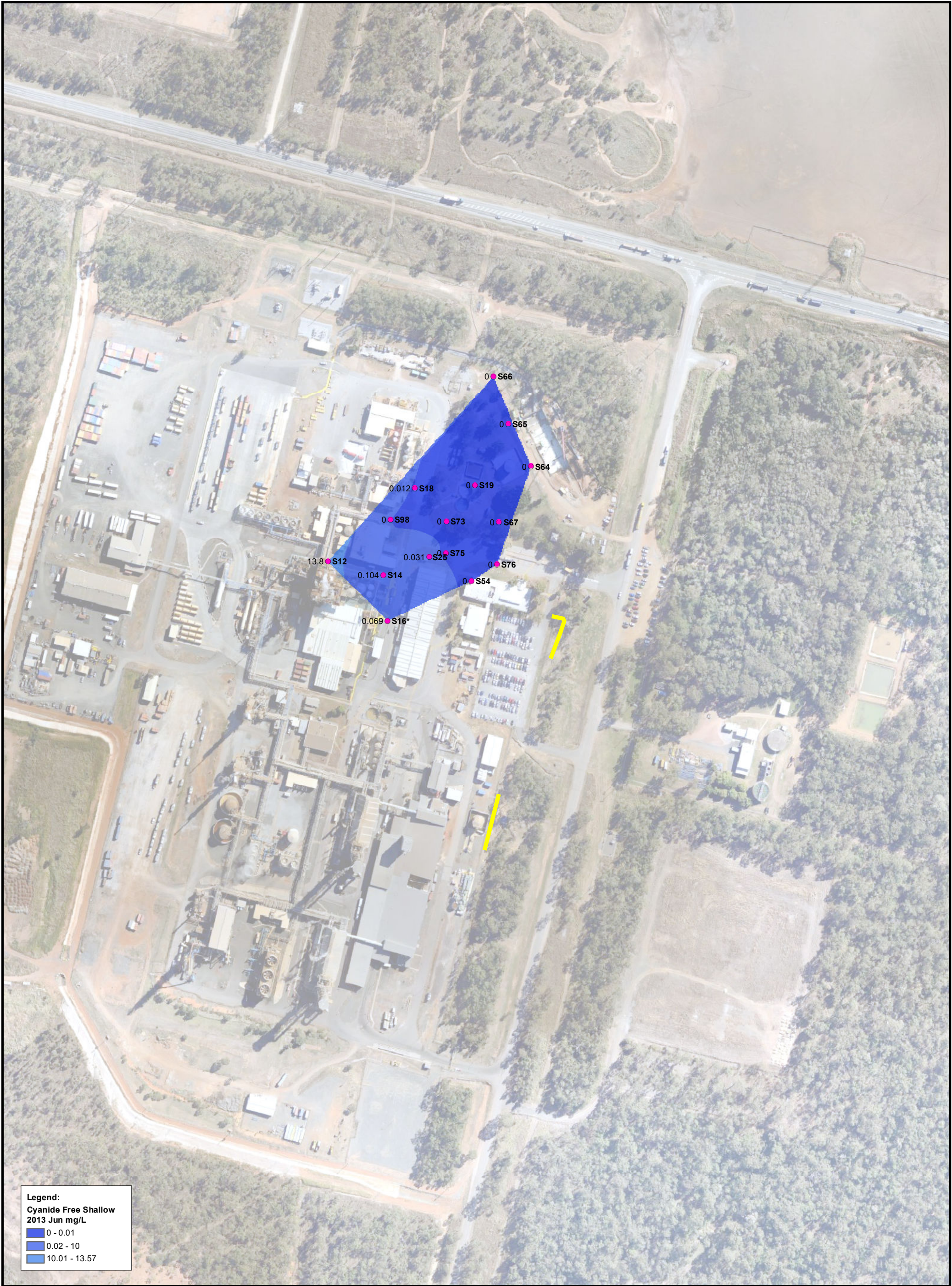
© 2017 JBS&G

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A3			
A	Original Issue - R02	RF	24-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Free Shallow

JBS&G Figure: Cyanide Free Shallow
2012 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNFreeSh_2012Jun



Legend:
Cyanide Free Shallow
2013 Jun mg/L
0 - 0.01
0.02 - 10
10.01 - 13.57

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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0	25	50	100
m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	24-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Free Shallow
— Trench Locations

JBS&G Figure: Cyanide Free Shallow
2013 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNFreeSh_2013Jun



Legend:
Cyanide Free Shallow
Jul 2014 mg/L
0 - 0.01
0.02 - 10
10.01 - 10.77

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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0	25	50	100
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Datum: MGA94 Zone 56 - AHD			
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A	Original Issue - R02	RF	24-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Free Shallow
— Trench Locations

JBS&G Figure: Cyanide Free Shallow
2014 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNFreeSh_2014Jul



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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Datum: MGA94 Zone 56 - AHD			
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A	Original Issue - R02	RF	24-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Free Shallow
— Trench Locations

JBS&G Figure: Cyanide Free Shallow
2016 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNFreeSh_2016Jul



Legend:
Cyanide Free Shallow
Jul 2017 mg/L
0 - 0.011
0.012 - 0.047

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

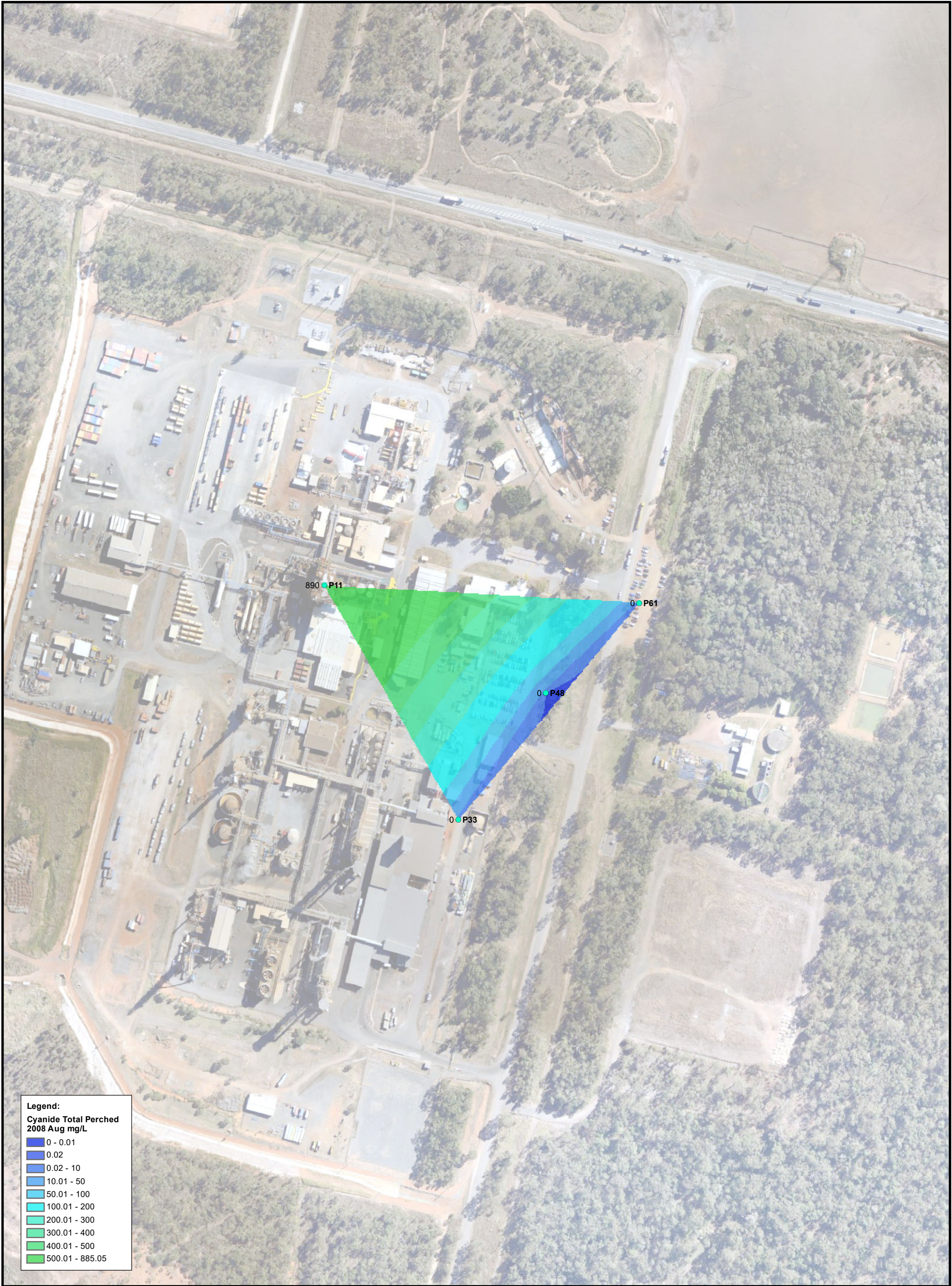
© 2017 JBS&G

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Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	24-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Free Shallow
— Trench Locations

JBS&G Figure: Cyanide Free Shallow
2017 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNFreeSh_2017Jul



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

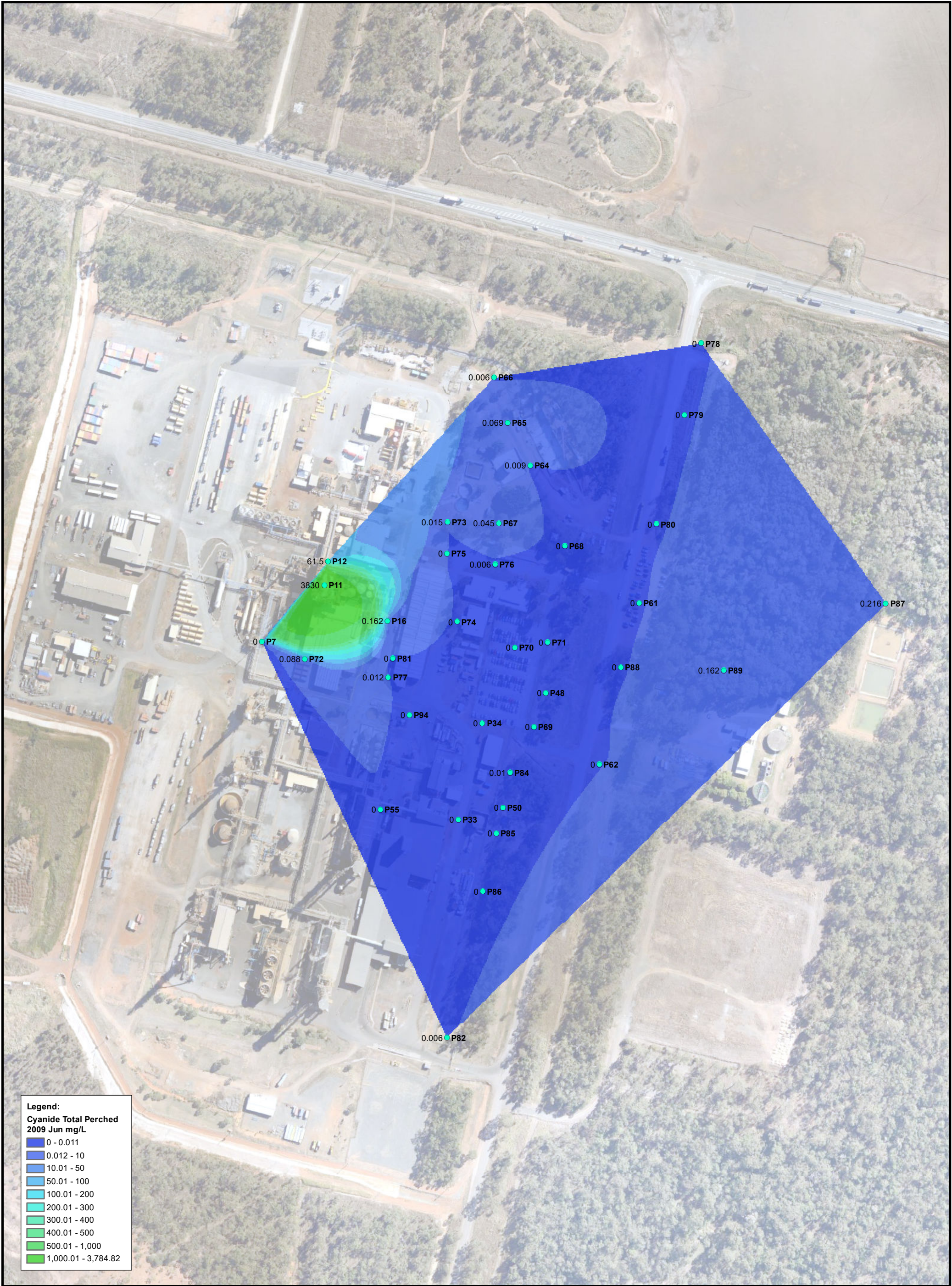
© 2017 JBS&G

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A3			
A	Original Issue - R01	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Total Perched

JBS&G Figure: Cyanide Total Perched
2008 Aug mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNTotalPd_2008Aug



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Total Perched

JBS&G Figure: Cyanide Total Perched
2009 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNTotalPd_2009Jun



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

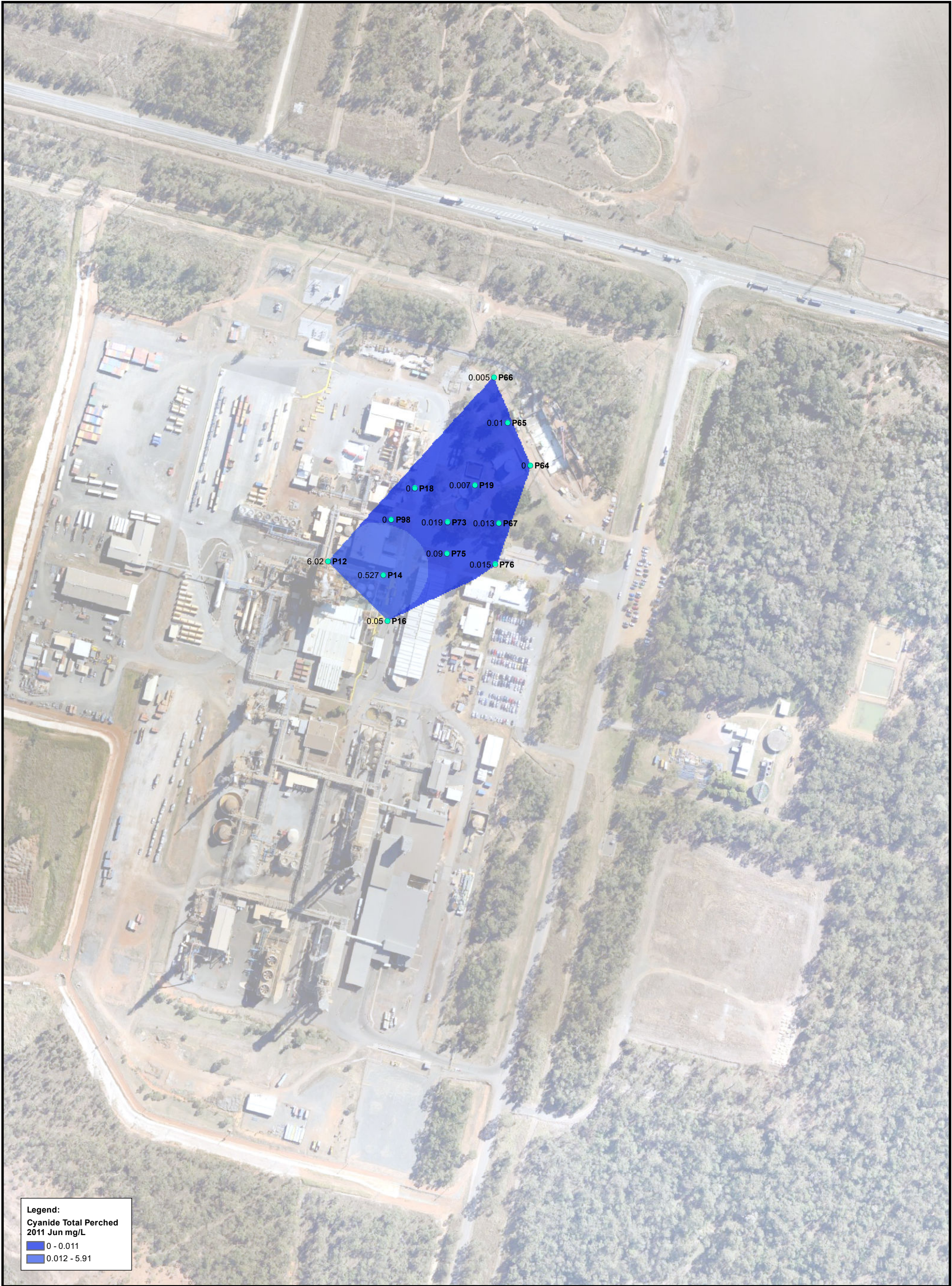
© 2017 JBS&G

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A3		
A	Original Issue - R02	RF 25-10-2017
Rev	Description	Drn. Date

Legend:
● CN Total Perched

JBS&G Figure: Cyanide Total
Perched 2010 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNTotalPd_2010Jun



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

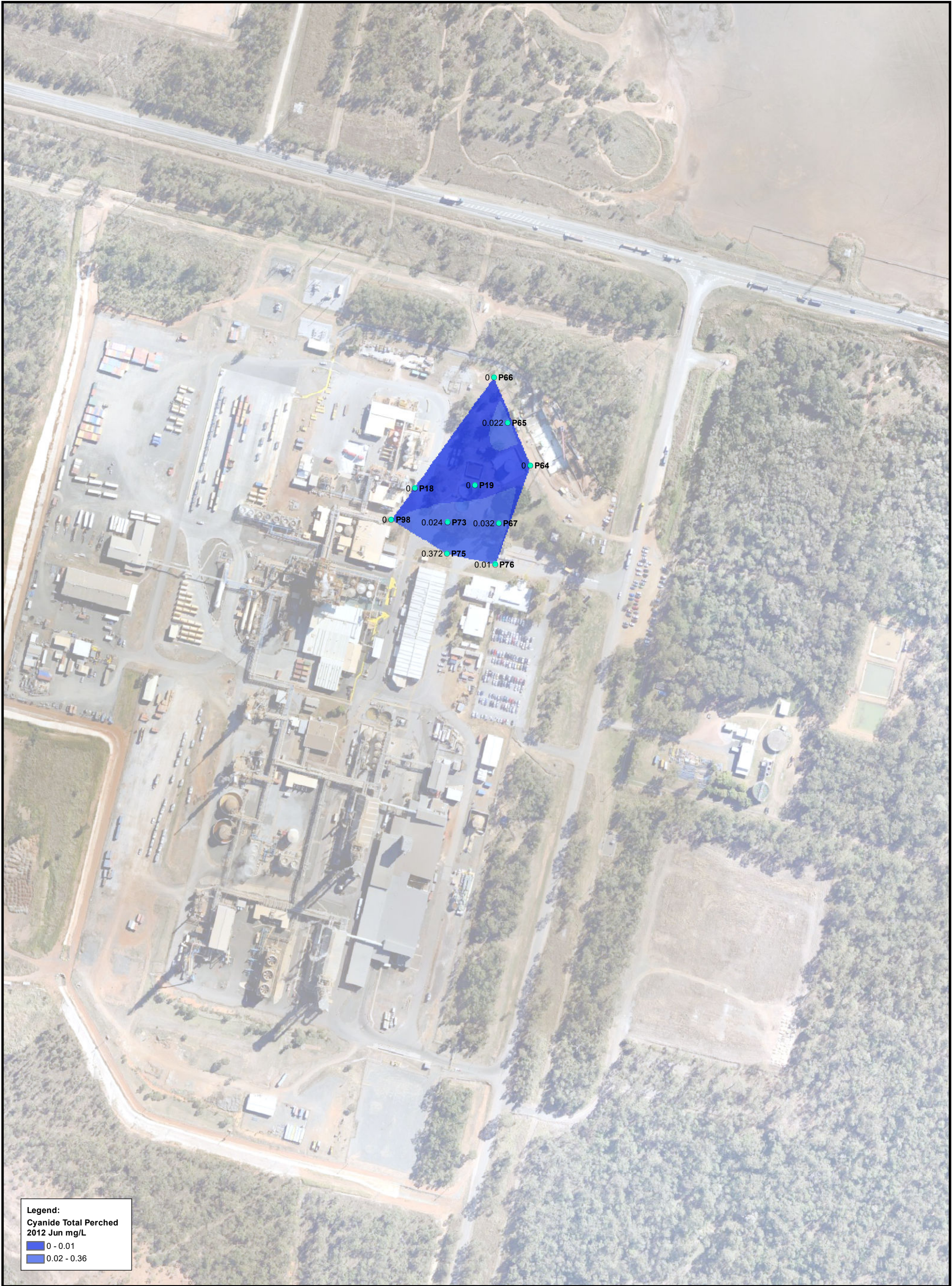
© 2017 JBS&G

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A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Total Perched

JBS&G Figure: Cyanide Total Perched
2011 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNTotalPd_2011Jun



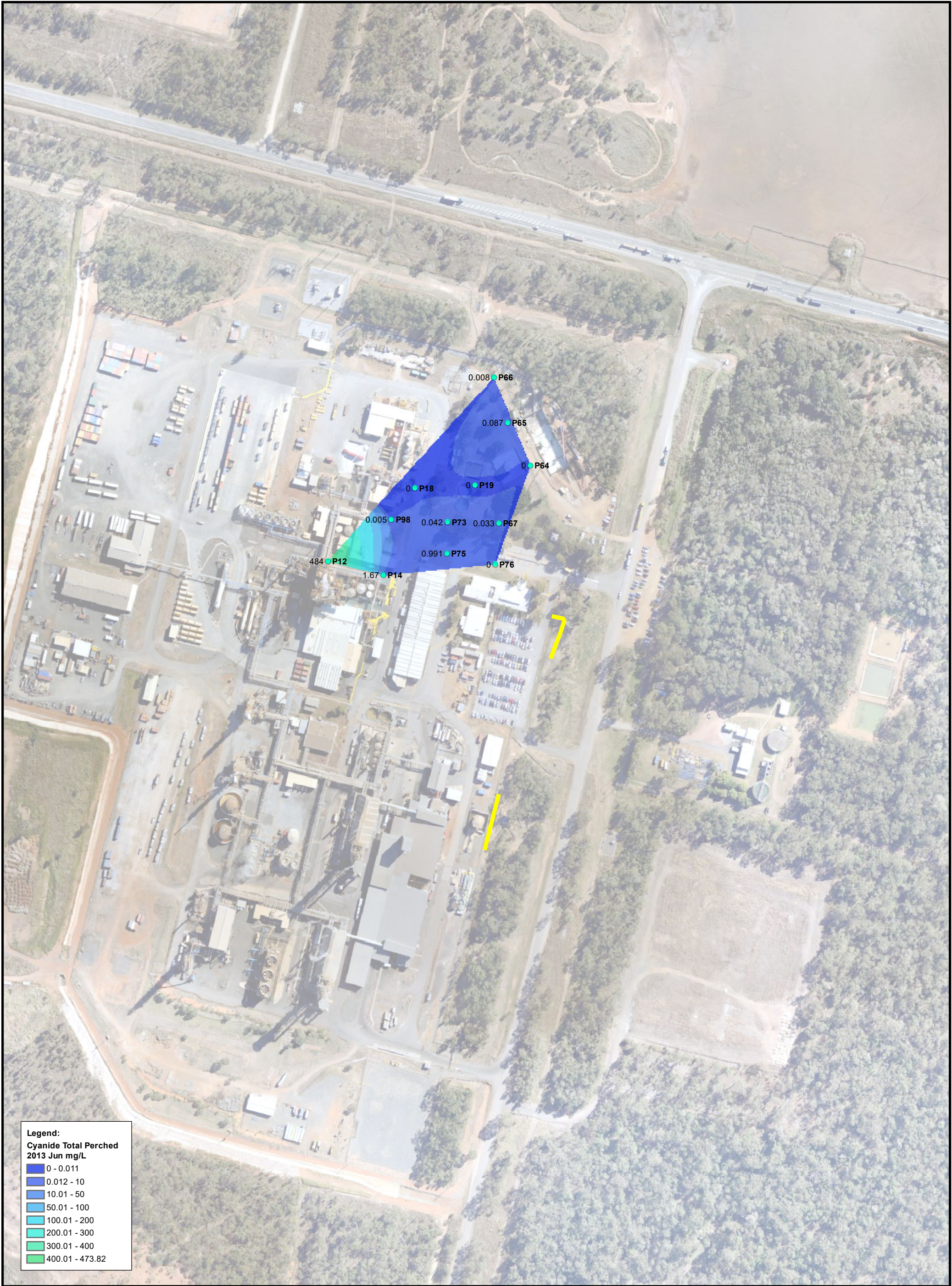
**Figure: Cyanide Total Perched
2012 Jun mg/L**

Client: Orica Australia Pty Ltd

Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)

Job No: 52877

File Name: 52877_nn_CNTotalPd_2012Jun



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

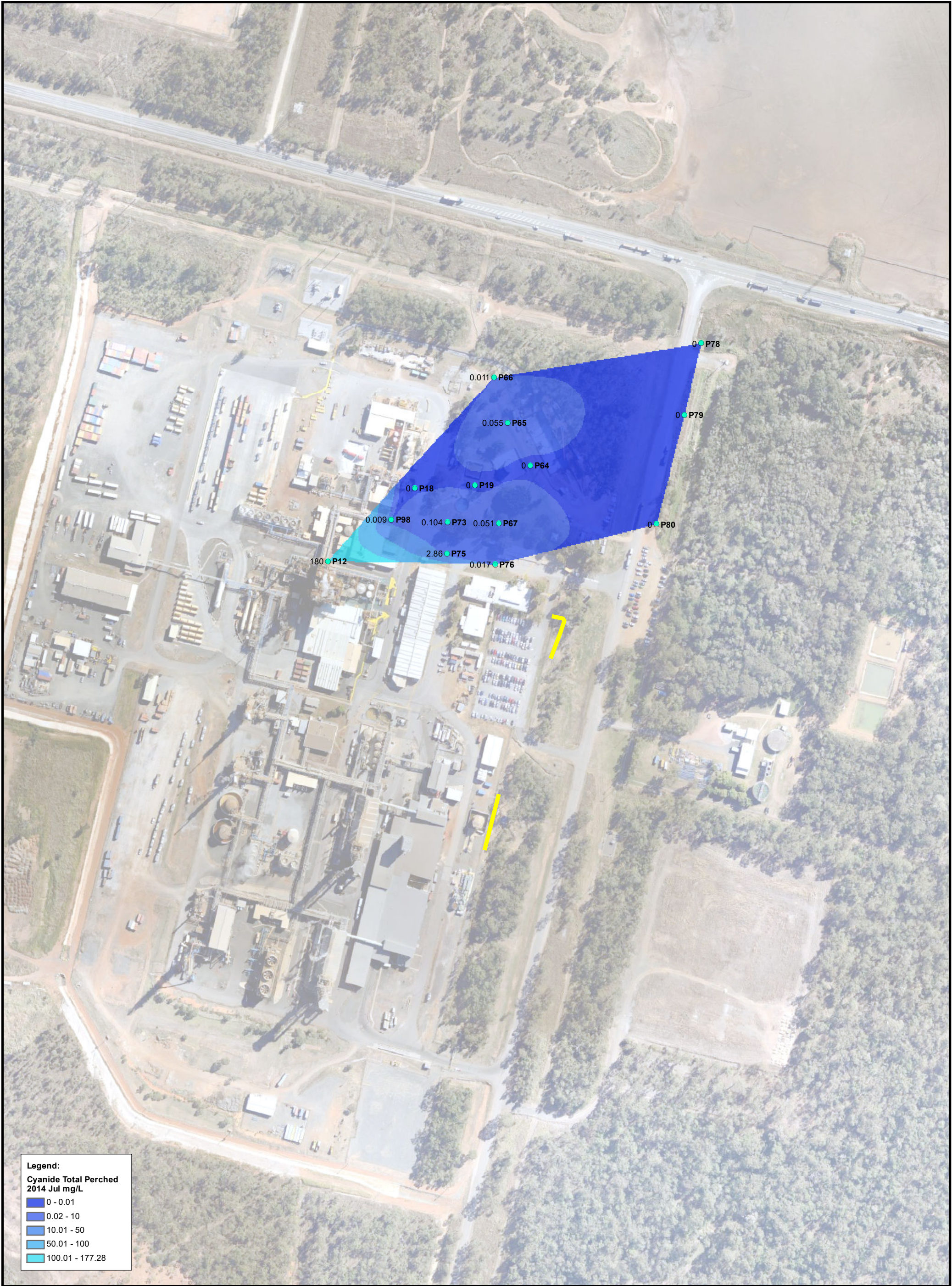
© 2017 JBS&G

0 25 50 100 m			
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A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Total Perched
— Trench Locations

JBS&G Figure: Cyanide Total Perched
2013 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNTotalPd_2013Jun



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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0 25 50 100 m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
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Rev	Description	Drn.	Date

Legend:
● CN Total Perched
— Trench Locations



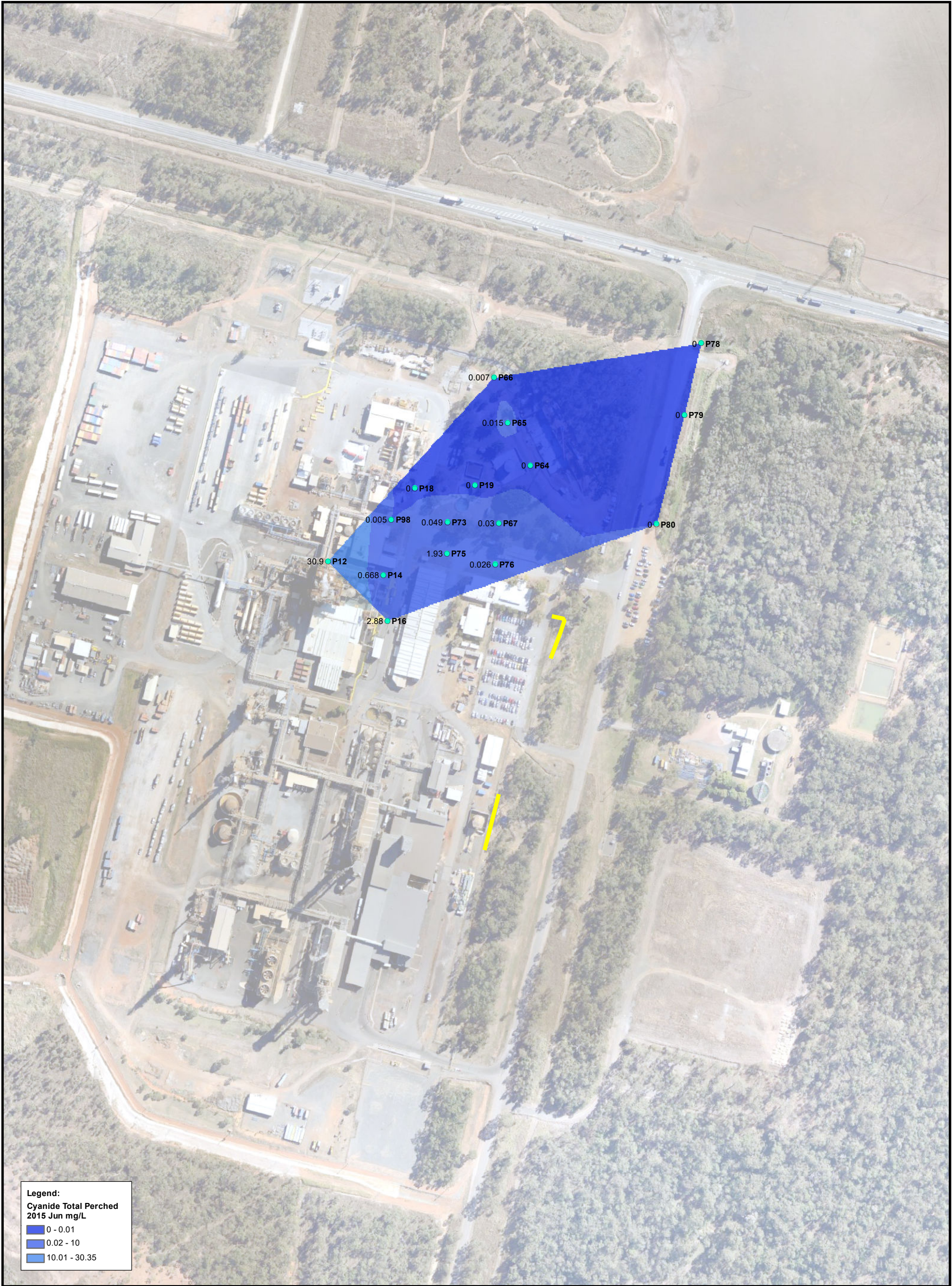
Figure: Cyanide Total Perched
2014 Jul mg/L

Client: Orica Australia Pty Ltd

Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)

Job No: 52877

File Name: 52877_nn_CNTotalPd_2014Jul



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

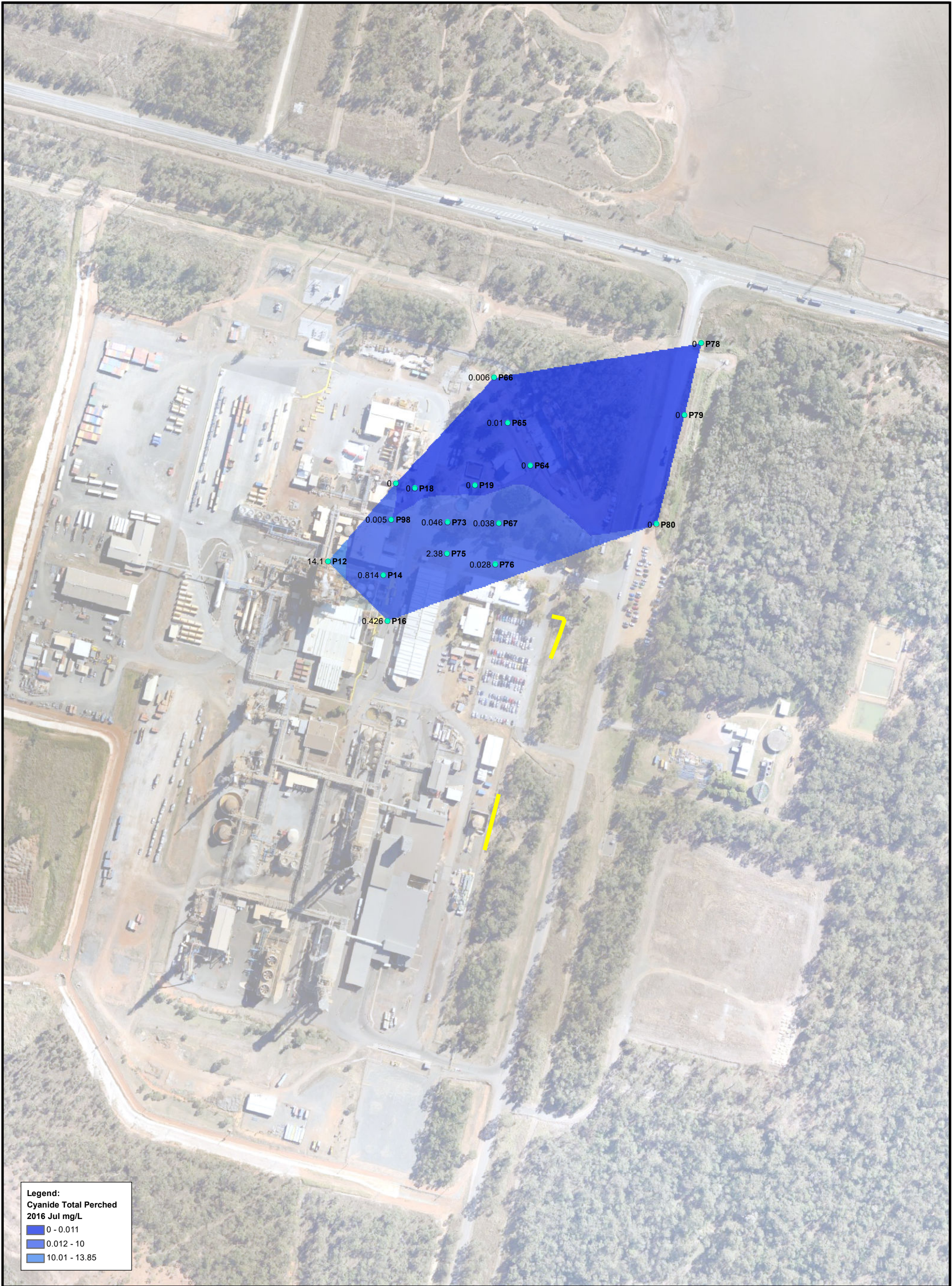
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0 25 50 100 m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● CN Total Perched
— Trench Locations

JBS&G Figure: Cyanide Total Perched
2015 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNTotalPd_2015Jul



Legend:
Cyanide Total Perched
2016 Jul mg/L

0 - 0.011
0.012 - 10
10.01 - 13.85

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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0	25	50	100
m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

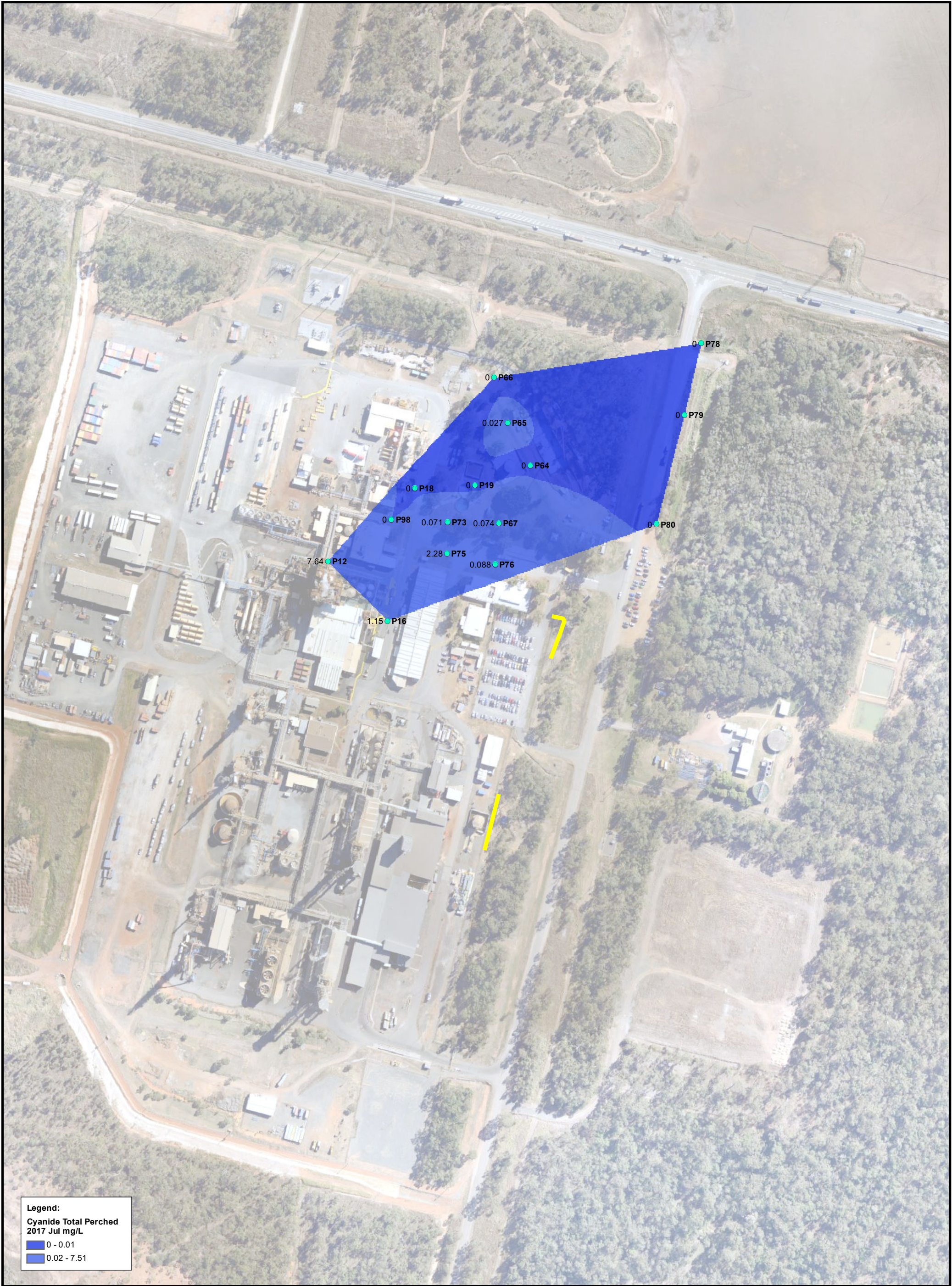
Legend:

- CN Total Perched
- Trench Locations



Figure: Cyanide Total Perched
2016 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNTotalPd_2016Jul



Legend:
Cyanide Total Perched
2017 Jul mg/L
0 - 0.01
0.02 - 7.51

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

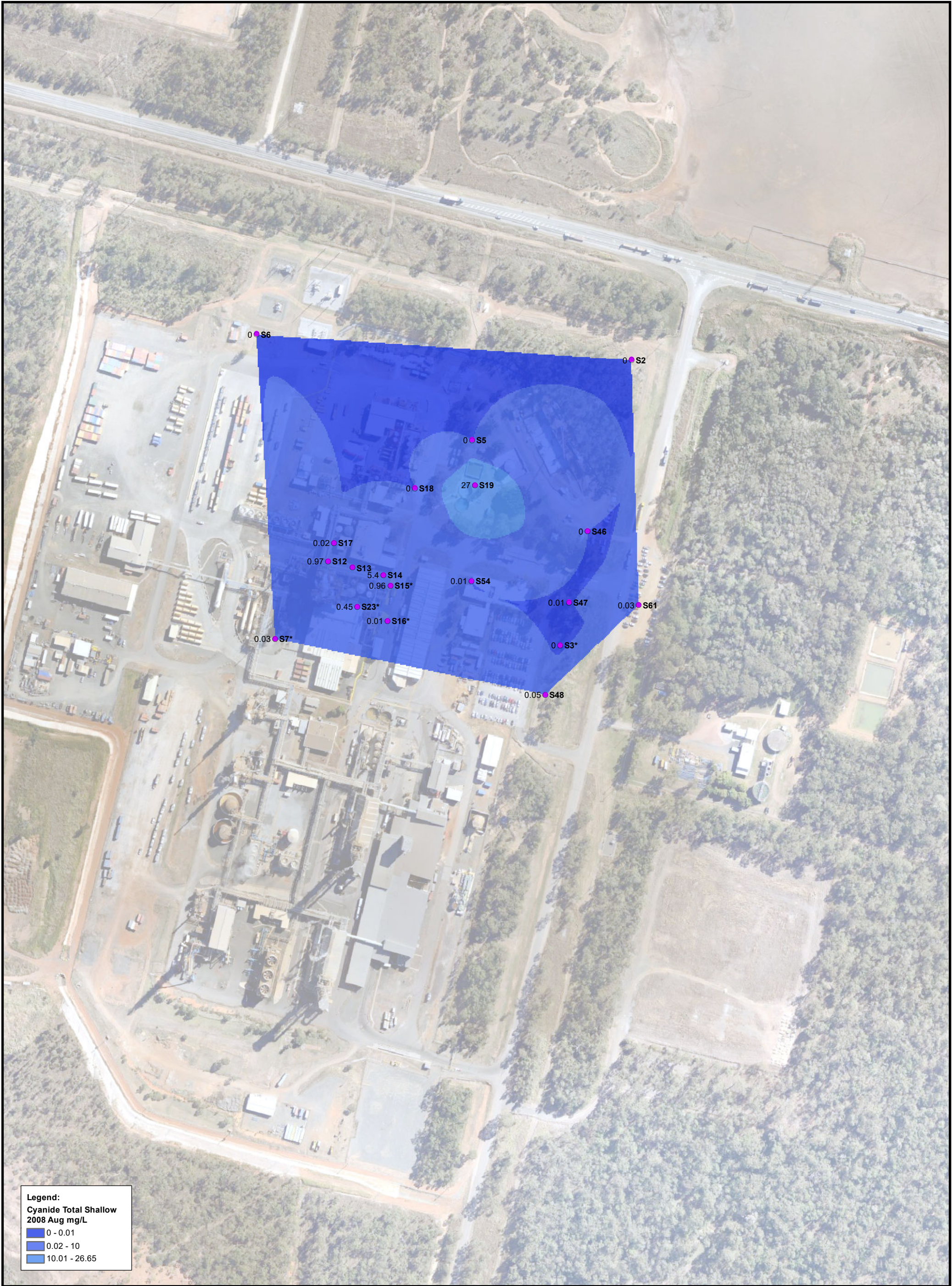
© 2017 JBS&G

0	25	50	100
m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
CN Total Perched
Trench Locations

JBS&G Figure: Cyanide Total Perched
2017 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNTotalPd_2017Jul



Legend:
Cyanide Total Shallow
2008 Aug mg/L

0 - 0.01
0.02 - 10
10.01 - 26.65

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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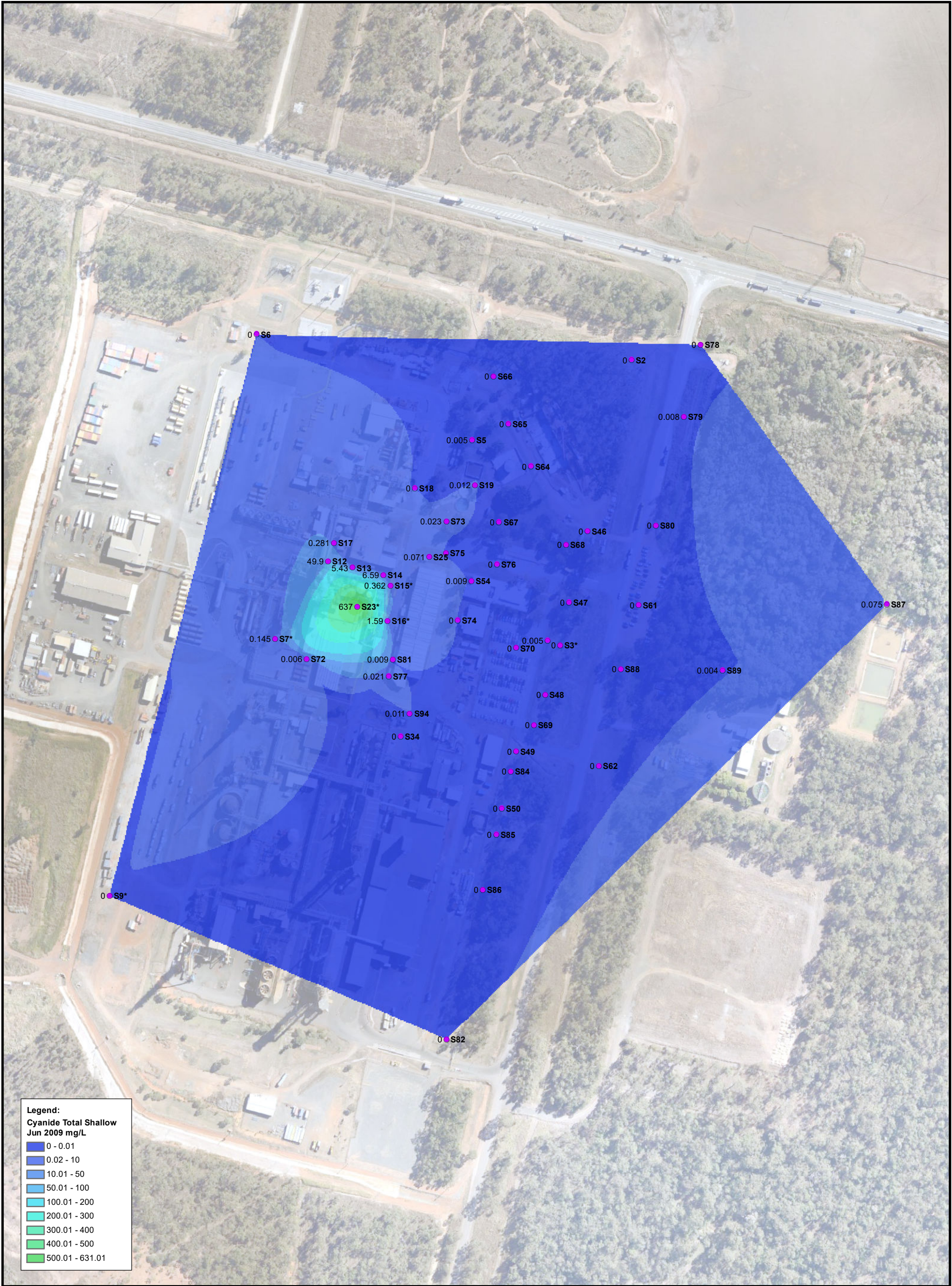
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m			
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Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R01	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● CNTotalShallow

JBS&G Figure: Cyanide Total Shallow
2008 Aug mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNTotalSh_2008Aug





Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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0 20 40 80 m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● CNTotalShallow



Figure: Cyanide Total Shallow
2009 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNTotalSh_2009Jun



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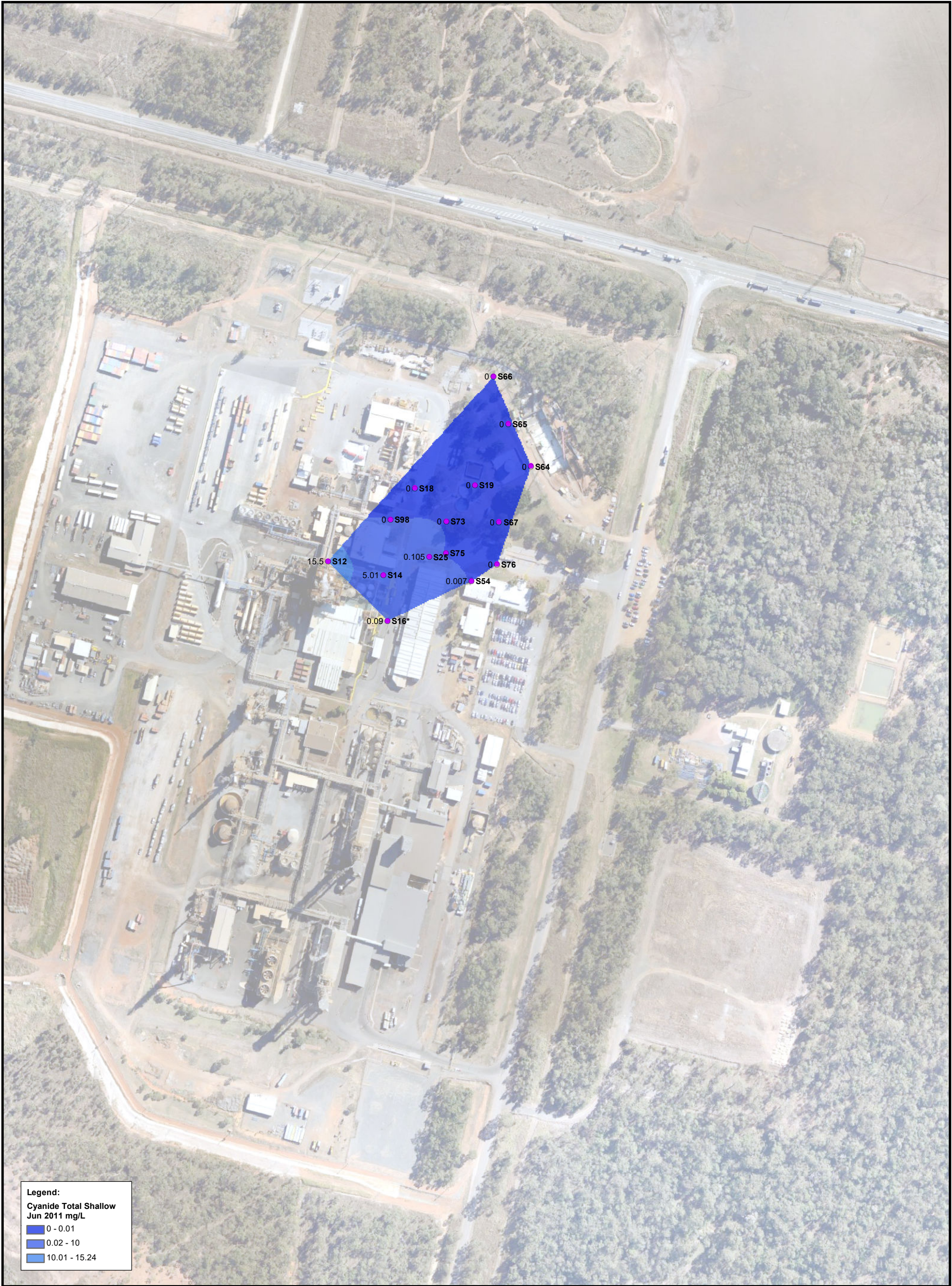
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Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● CNTotalShallow

JBS&G Figure: Cyanide Total
Shallow 2010 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNTotalSh_2010Jun





Legend:
Cyanide Total Shallow
Jun 2011 mg/L

0 - 0.01
0.02 - 10
10.01 - 15.24

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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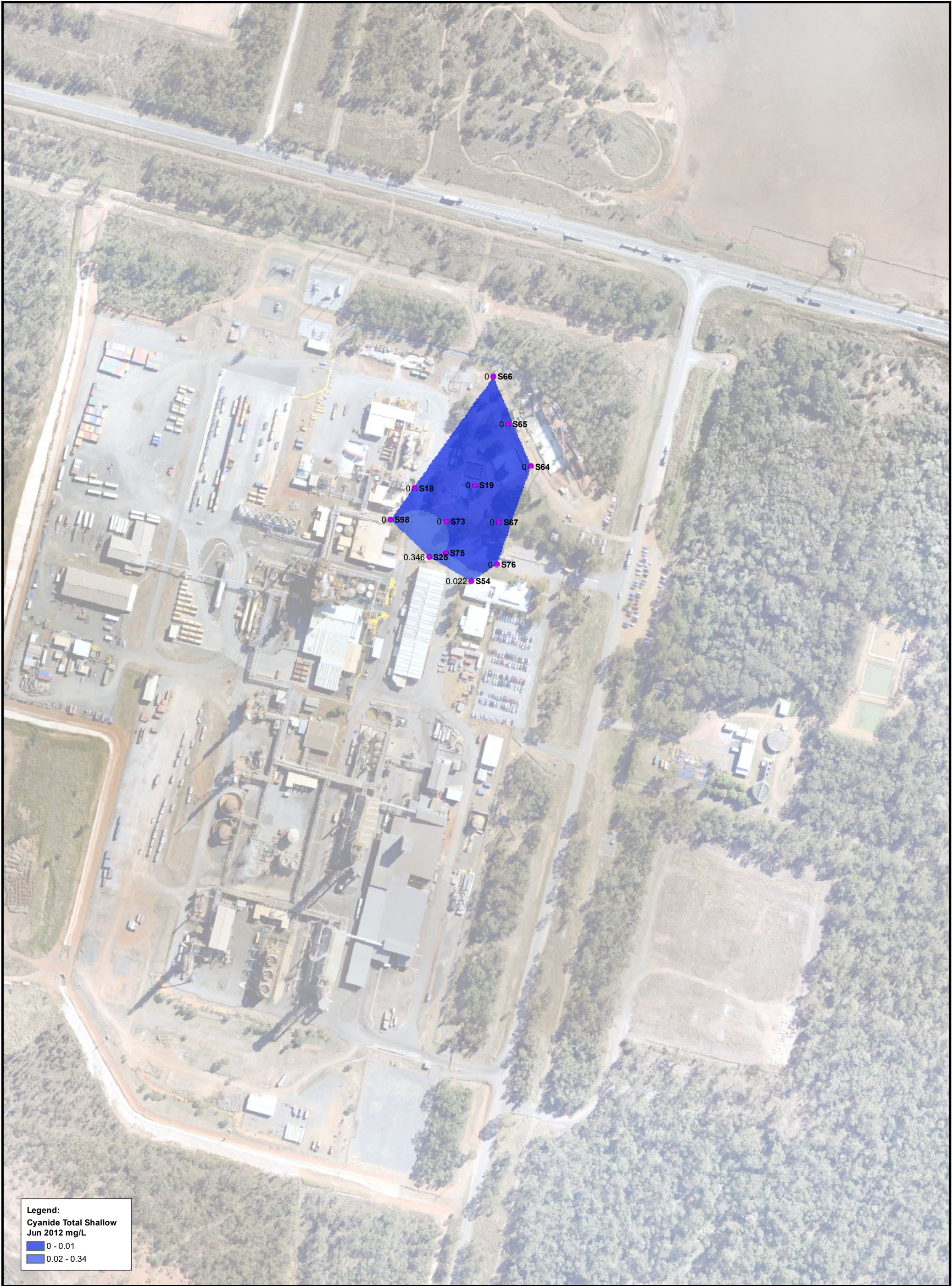
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Scale: 1:3,000			
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A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● CNTotalShallow

JBS&G Figure: Cyanide Total Shallow
2011 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNTotalSh_2011Jun





Legend:
Cyanide Total Shallow
Jun 2012 mg/L
0 - 0.01
0.02 - 0.34

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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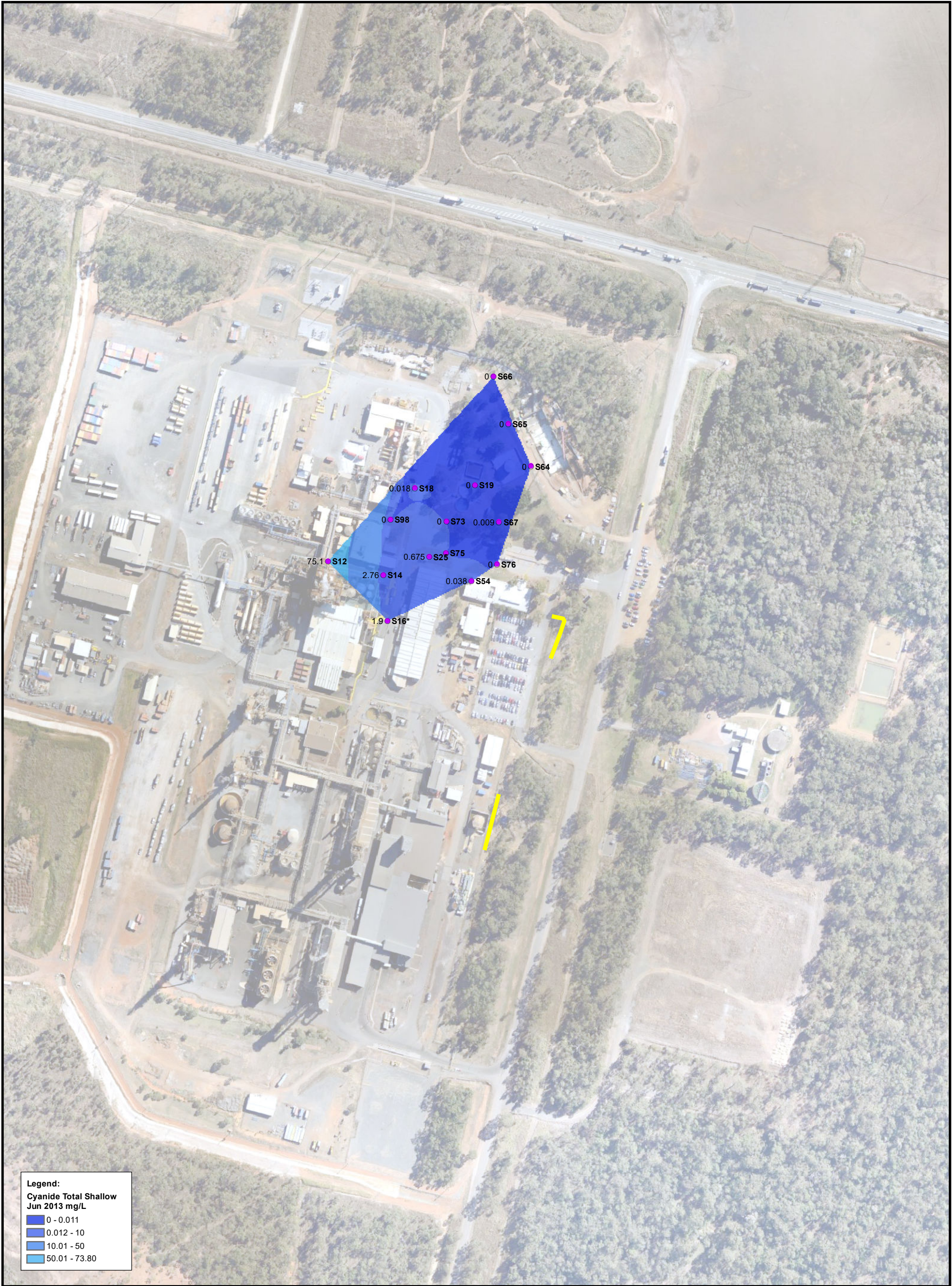
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m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● CNTotalShallow

JBS&G Figure: Cyanide Total Shallow
2012 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNTotalSh_2012Jun





Legend:
Cyanide Total Shallow
Jun 2013 mg/L

0 - 0.011
0.012 - 10
10.01 - 50
50.01 - 73.80

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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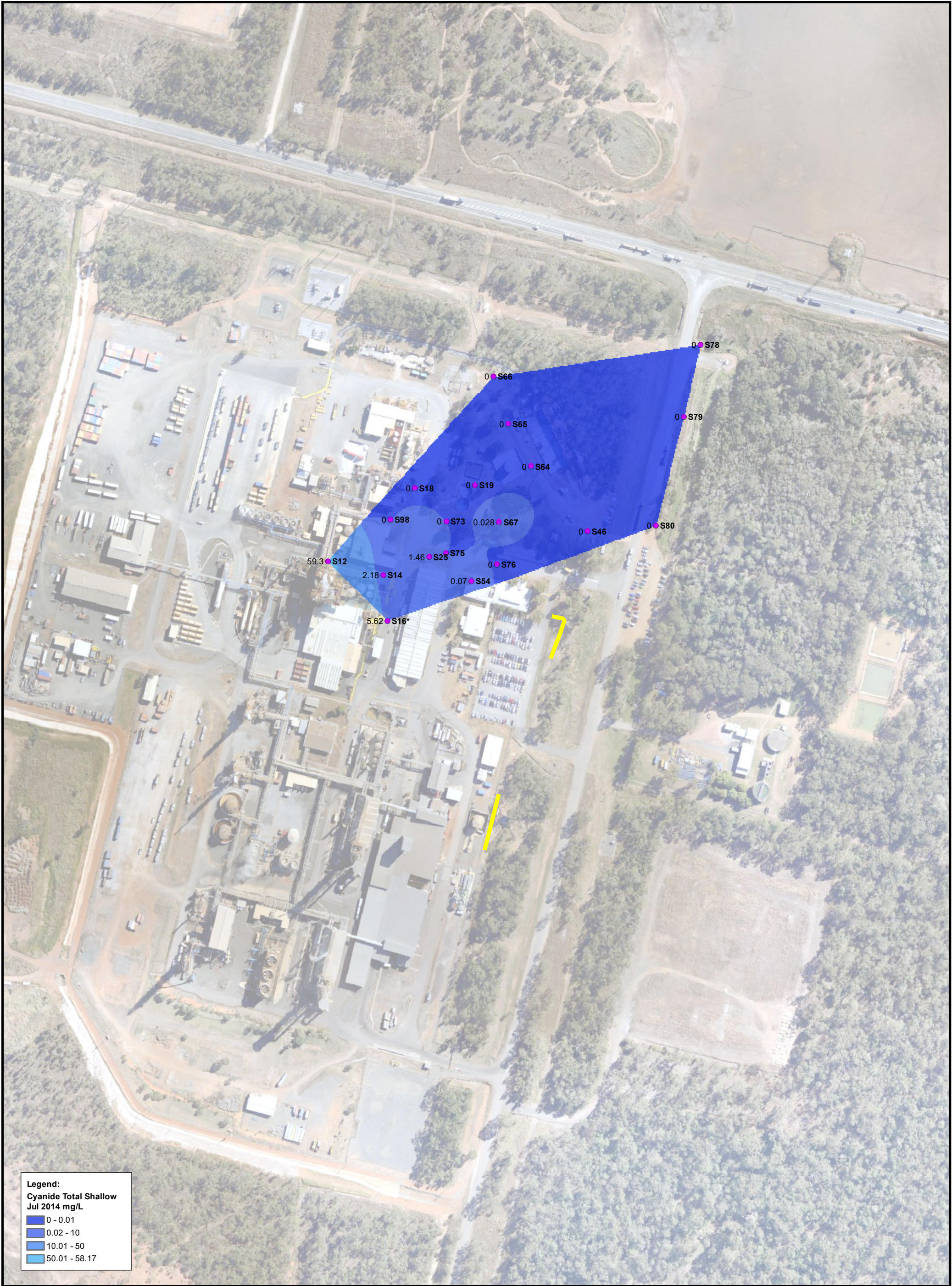
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A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:

- CNTotalShallow
- Trench Locations

JBS&G Figure: Cyanide Total Shallow
2013 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNTotalSh_2013Jun



Legend:
Cyanide Total Shallow
Jul 2014 mg/L

0 - 0.01
0.02 - 10
10.01 - 50
50.01 - 58.17

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● CNTotalShallow
— Trench Locations

JBS&G Figure: Cyanide Total Shallow
2014 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNTotalSh_2014Jul



Legend:
Cyanide Total Shallow
Jun 2015 mg/L
0 - 0.01
0.02 - 10
10.01 - 27.97

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

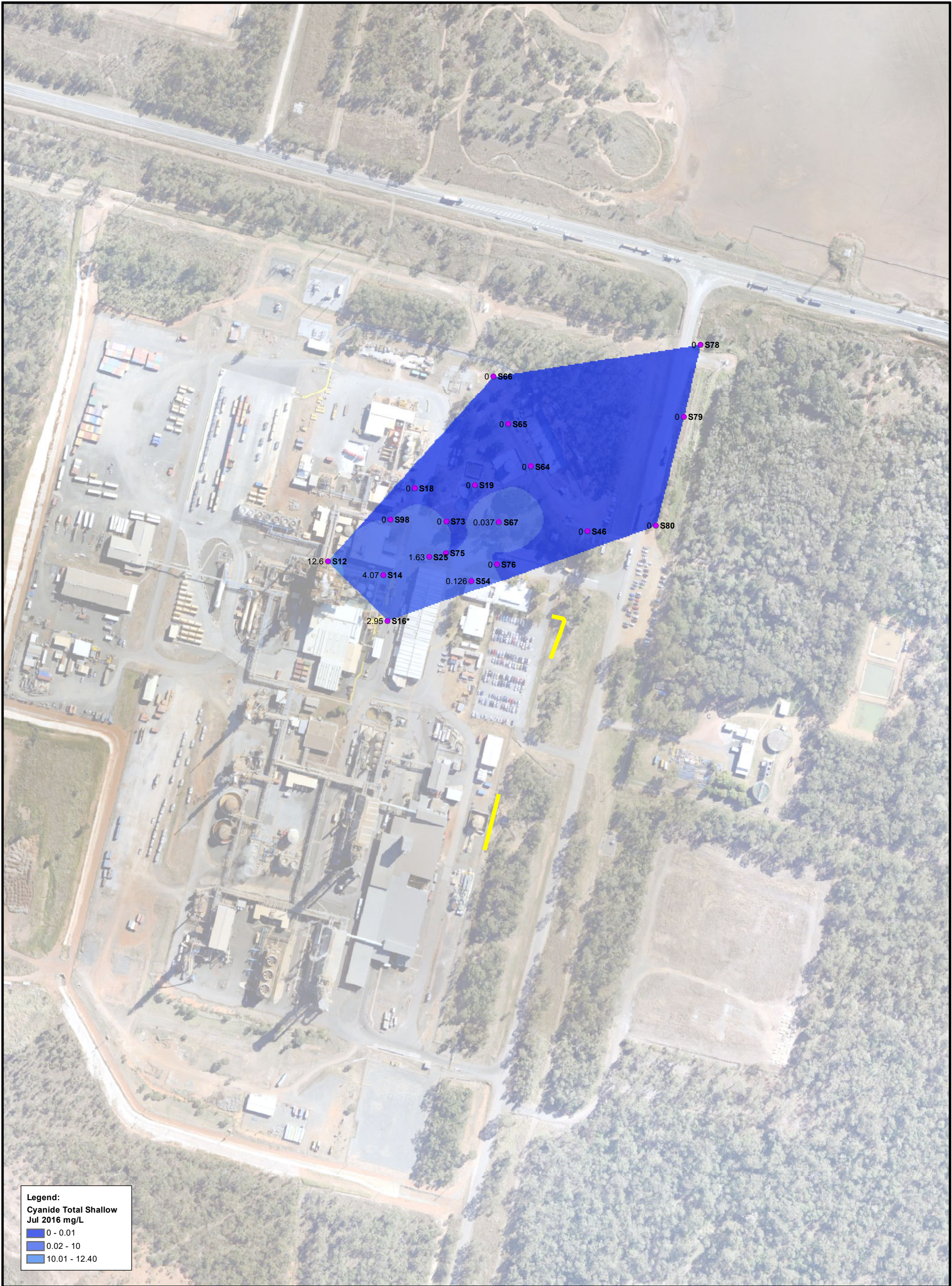
© 2017 JBS&G

0	25	50	100
m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● CNTotalShallow
— Trench Locations

JBS&G Figure: Cyanide Total Shallow
2015 Jun mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNTotalSh_2015Jul



Legend:
Cyanide Total Shallow
Jul 2016 mg/L
0 - 0.01
0.02 - 10
10.01 - 12.40

Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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0	20	40	80
m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● CNTotalShallow
— Trench Locations



Figure: Cyanide Total Shallow
2016 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877
File Name: 52877_nn_CNTotalSh_2016Jul



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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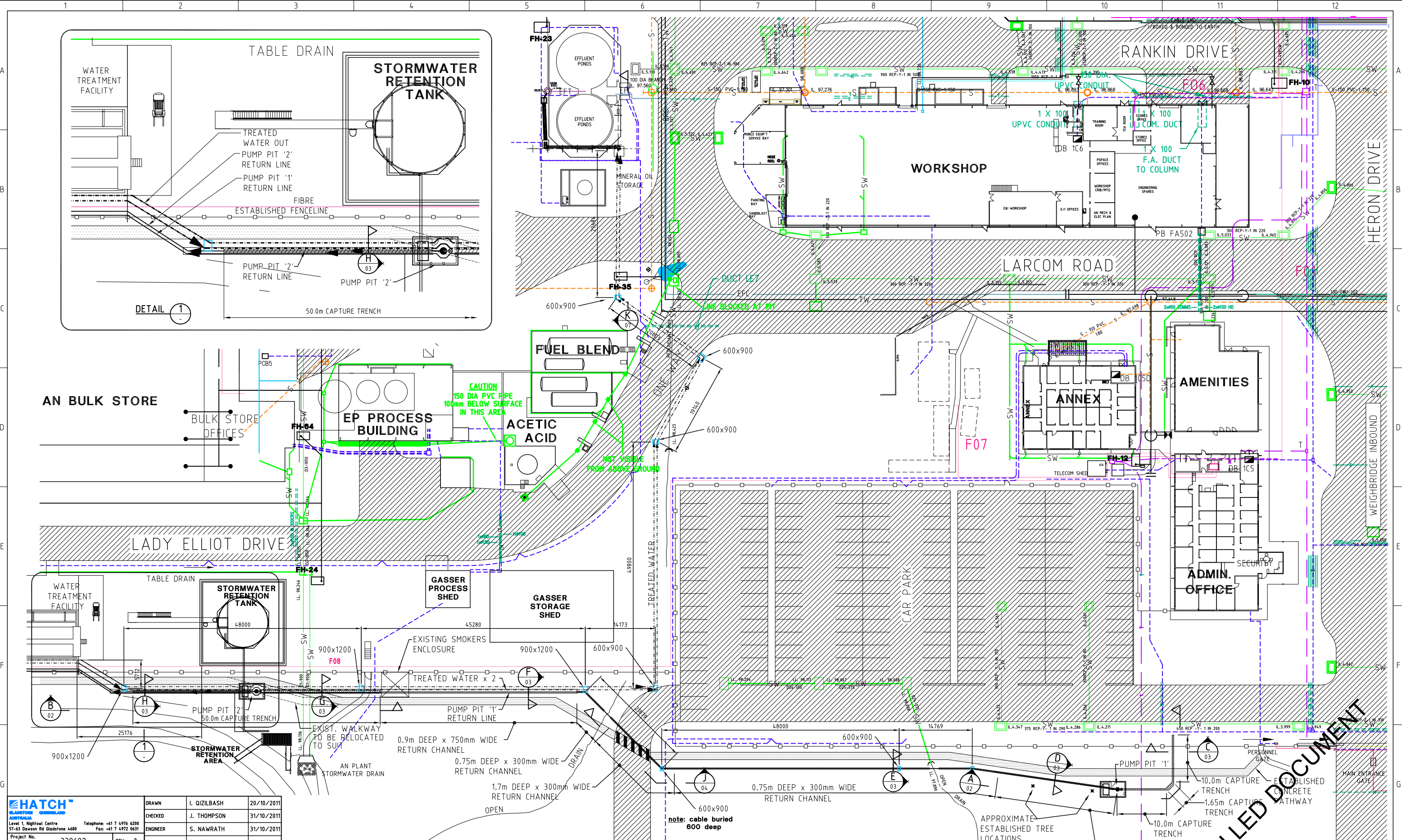
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A3			
A	Original Issue - R02	RF	25-10-2017
Rev	Description	Drn.	Date

Legend:
● CNTotalShallow
— Trench Locations

JBS&G Figure: Cyanide Total Shallow
2017 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_nn_CNTotalSh_2017Jul

Appendix C Groundwater Interception Trench as Built Drawings



HATCH GLADSTONE AUSTRALIA Level 1, Nightlow Centre 57-63 Dawson Rd Gladstone 4680 Telephone: +61 7 4976 6200 Fax: +61 7 4972 0631			
Project No.	339692	REV: 0	
DRAWN	I. QIZILBASH	20/10/2011	
CHECKED	J. THOMPSON	31/10/2011	
ENGINEER	S. NAWRATH	31/10/2011	
ENGINEER CHECK	S. HOSSAIN	14/11/2011	

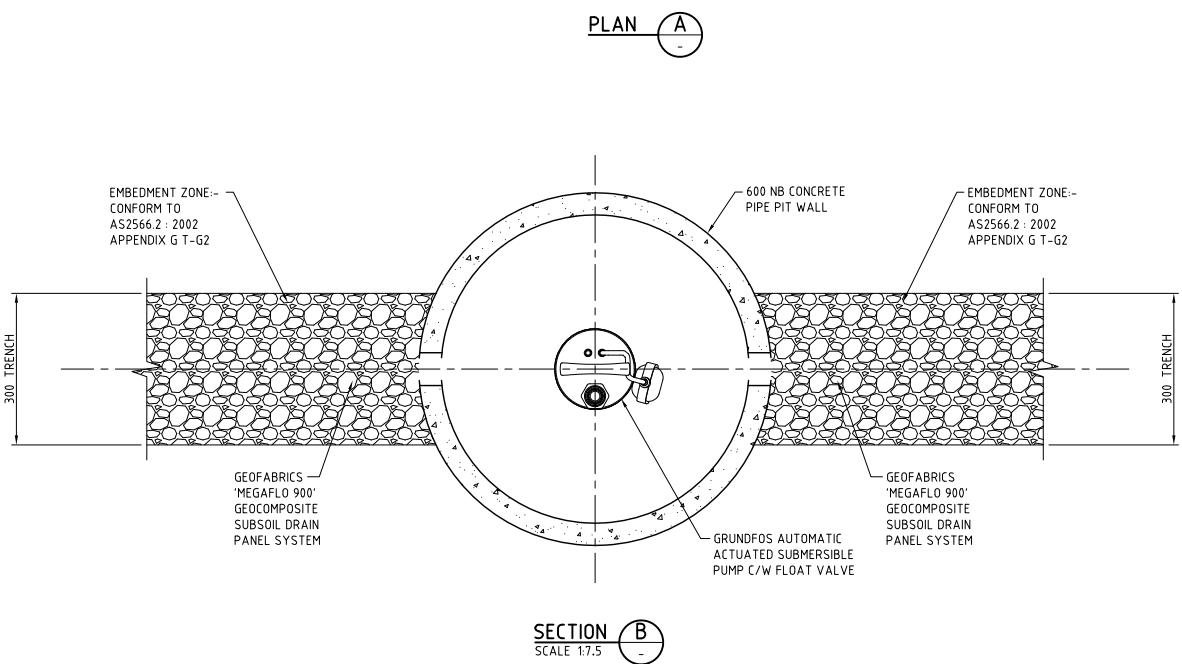
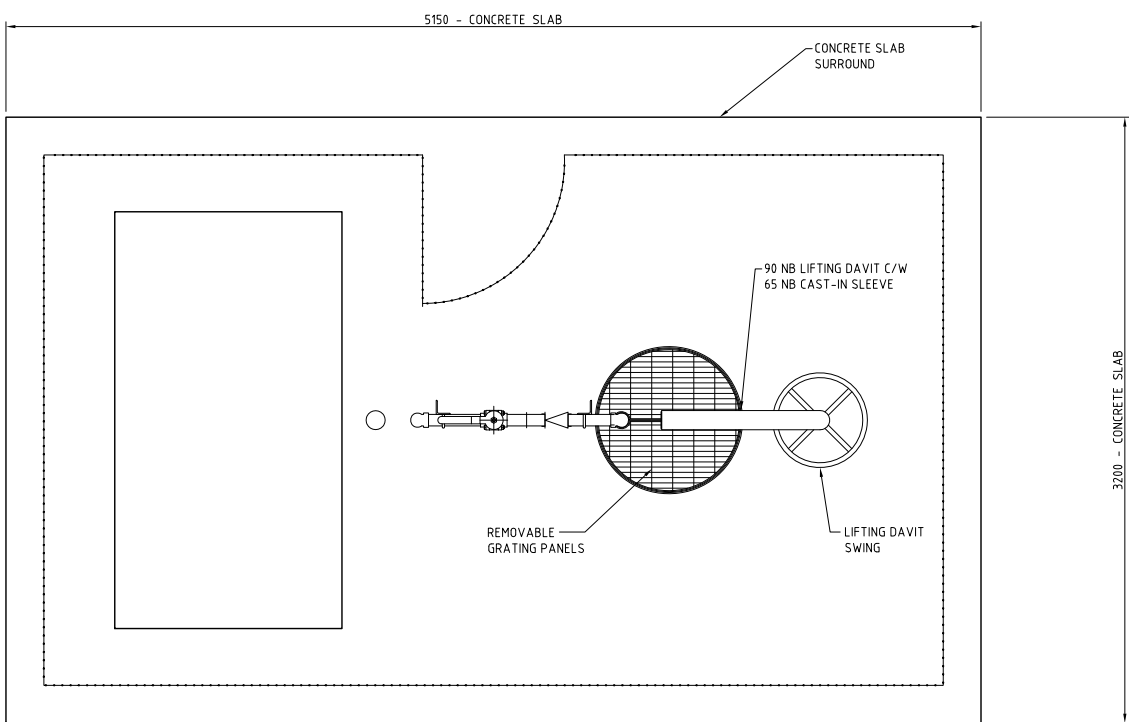
1	AS BUILT	P.B	18.5.15
0B	TREATMENT FACILITY PLAN UPDATE	P.B	26.4.12
0A	AS PER GOLDR CHANGES	P.B	24.1.12
0	ISSUED FOR CONSTRUCTION	P.B.	28/11/11
REV.	REVISION DETAILS	APP BY	DATE

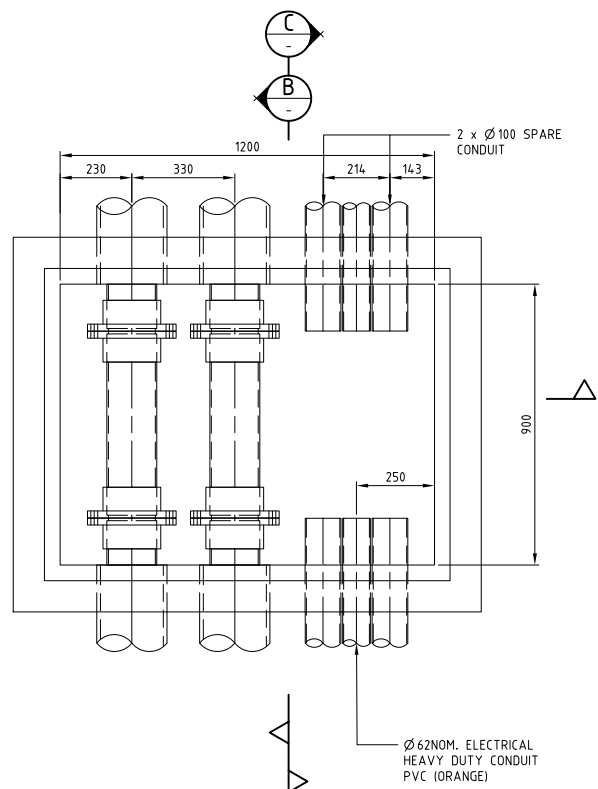
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MECH'L	NOT APPLICABLE	A	-	-
CIVIL	NOT APPLICABLE	A	-	-
ELECTRIC	NOT APPLICABLE	A	-	-
CONTROL	NOT APPLICABLE	A	-	-
PROJECT	NOT APPLICABLE	A	-	-
CONSTR'N	NOT APPLICABLE	A	-	-
INTER-DISCIPLINE REVIEW	REV	DATE		
TRENCH LONG SECTIONS			5370-11-50224	
REFERENCE DRAWINGS			DRG No.	

DO NOT SCALE
IF IN DOUBT ASK
THIS DRAWING IS A PRIVATE AND
CONFIDENTIAL COMMUNICATION AND THE
PROPERTY OF
Orica Pty. Ltd.
BEING RETURNABLE UPON REQUEST.
IT MUST NOT BE COPIED OR LOANED
WITHOUT THE CONSENT OF THE COMPANY.

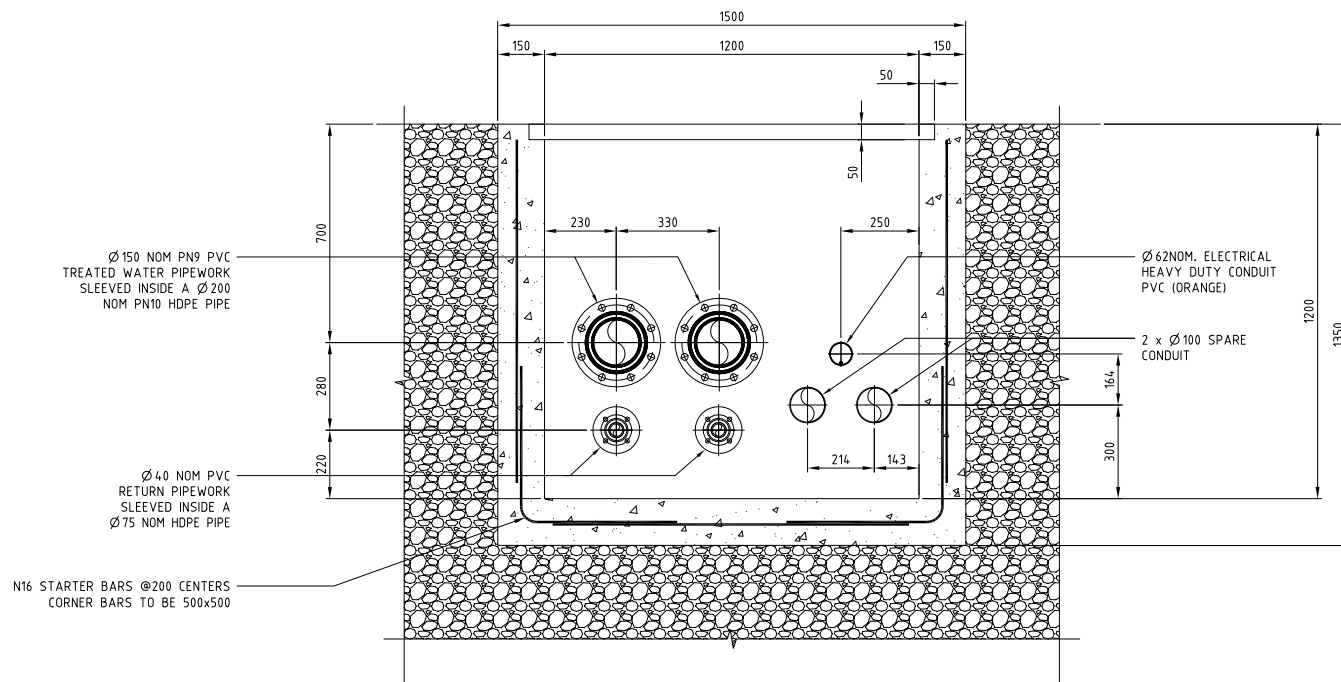
DRAWN	I.A.Q.	DATE	01/10/2011
ENGINEER	S. NAWRATH	DATE	01/10/2011
CHECKED	A. MCGREGOR	DATE	21/11/2011
PASSED	K. BRUTON	DATE	21/11/2011
AUTHORISED	P. BARLAY	DATE	21/11/2011

WORKS	YARWUN	TITLE	GROUND WATER CAPTURE AND REMEDIATION
PLANT	SITE	SECTION	---
THIRD ANGLE PROJECTION		SCALE	A1
DRAWING NUMBER	5370-11-50223	REVISION	1
YARWUN SITE		A.C.N. 004 117 828	
SHEET 1 OF 7		DRAWING	

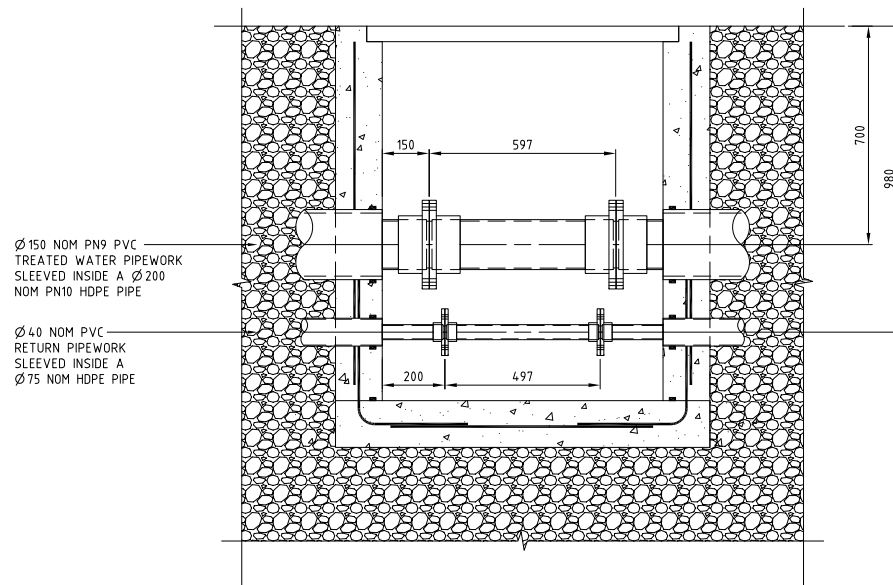
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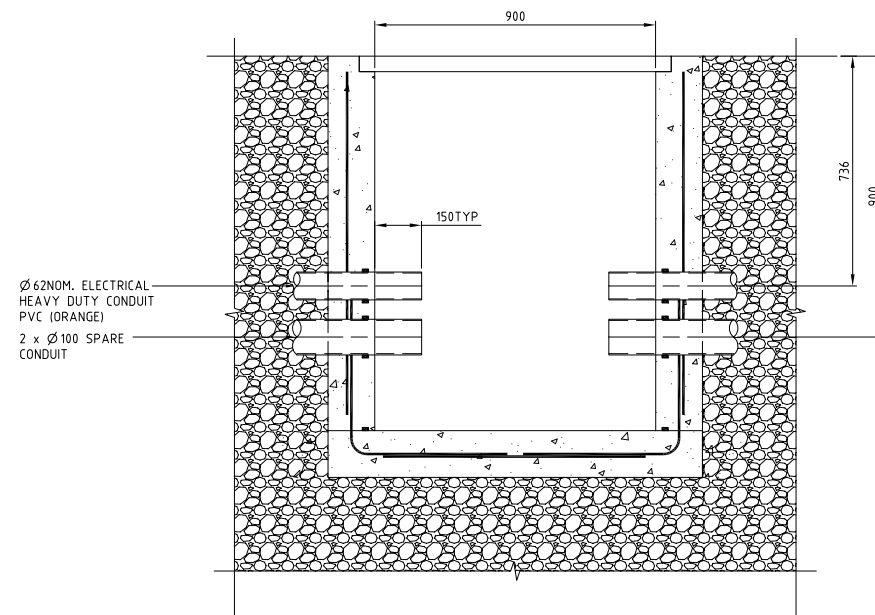
PLAN



SECTION A



SECTION B



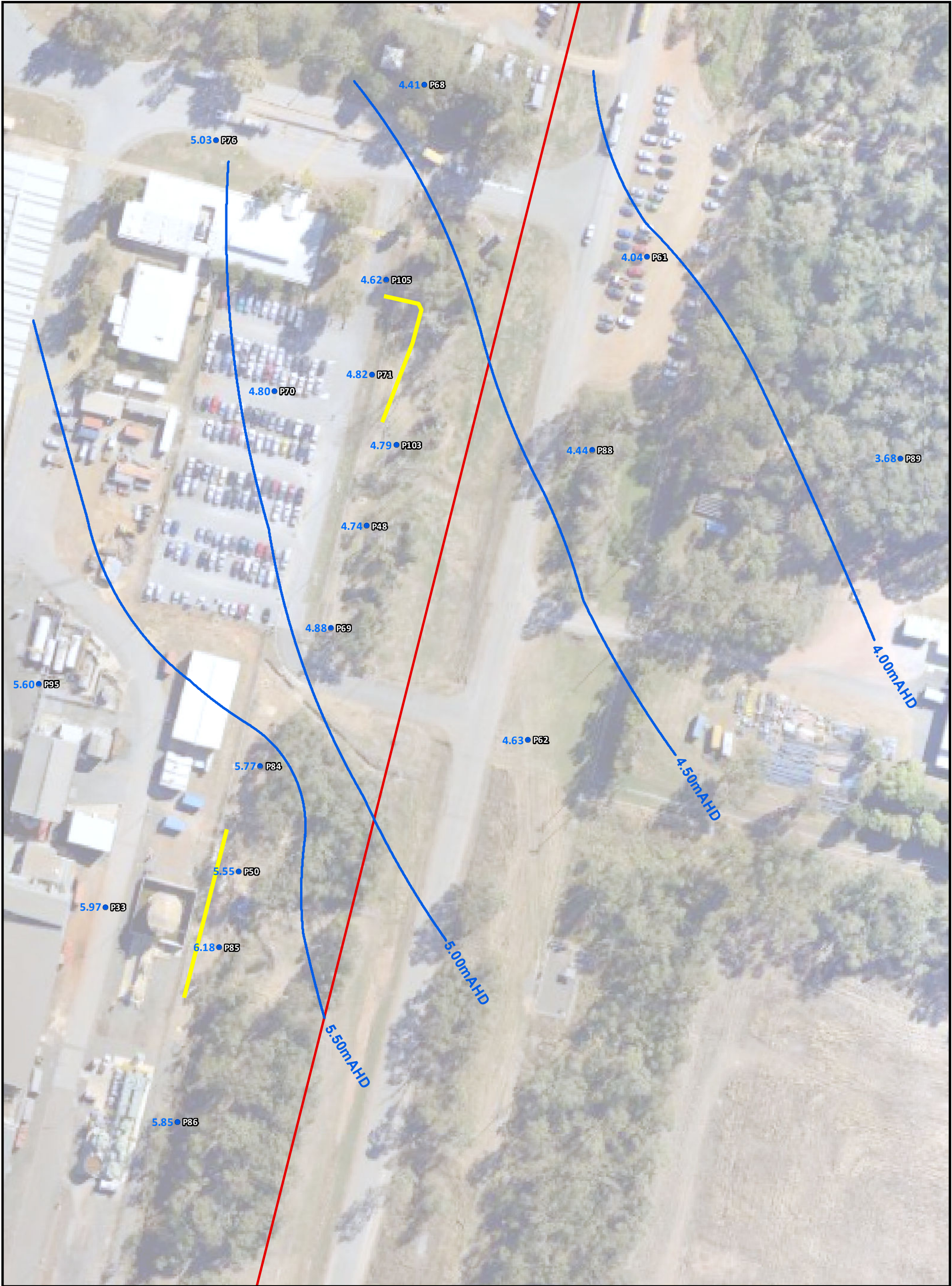
SECTION C

				DRAWN I. QIZILBASH 20/10/2011		PROCESS NOT APPLICABLE A - -				DO NOT SCALE IF IN DOUBT ASK		DRAWN I.A.Q. 01/10/2011		WORKS YARWUN		YARWUN SITE	
				CHECKED J. THOMPSON 31/10/2011		MECH'L NOT APPLICABLE A - -				THIS DRAWING IS A PRIVATE AND CONFIDENTIAL COMMUNICATION AND THE PROPERTY OF		ENGINEER S. NAWRATH 01/10/2011		PLANT SITE		A.C.N. 004 117 828	
				ENGINEER S. NAWRATH 31/10/2011		CIVIL NOT APPLICABLE A - -				Orica Pty. Ltd.		CHECKED A. MCGREGOR 21/11/2011		SECTION - -		TITLE	
				ENGINEER CHECK S. HOSSAIN 14/11/2011		ELECTRIC NOT APPLICABLE A - -				BEING RETURNABLE UPON REQUEST. IT MUST NOT BE COPIED OR LOANED WITHOUT THE CONSENT OF THE COMPANY.		DATE 21/11/2011		THIRD ANGLE PROJECTION		GROUND WATER CAPTURE AND REMEDIATION TRENCH RISER DETAILS	
						CONTROL NOT APPLICABLE A - -				SITE LOCATION PLAN		DATE 21/11/2011		SCALE 1:4		SHEET 6 OF 7	
						PROJECT NOT APPLICABLE A - -				5370-11-50223		P. BARLAY 21/11/2011		SIZE A1		DRAWING NUMBER	
						CONSTR'N NOT APPLICABLE A - -				REFERENCE DRAWINGS		P. BARLAY 21/11/2011				5370-11-50228	
						INTER-DISCIPLINE REVIEW REV DATE										REVISION 1	
																DRAWING	

HATCH
GLADSTONE QUEENSLAND
Level 1, Nighthawk Centre
57-63 Dawson Rd Gladstone 4680
Telephone: +61 7 4976 6200
Fax: +61 7 4972 0631
Project No. 339692 REV: 0

ORICA
UNCONTROLLED DOCUMENT
YARWUN SITE
A.C.N. 004 117 828
GROUND WATER CAPTURE AND REMEDIATION
TRENCH RISER DETAILS
SHEET 6 OF 7
DRAWING NUMBER
5370-11-50228
REVISION 1
DRAWING

Appendix D Groundwater Elevation Maps



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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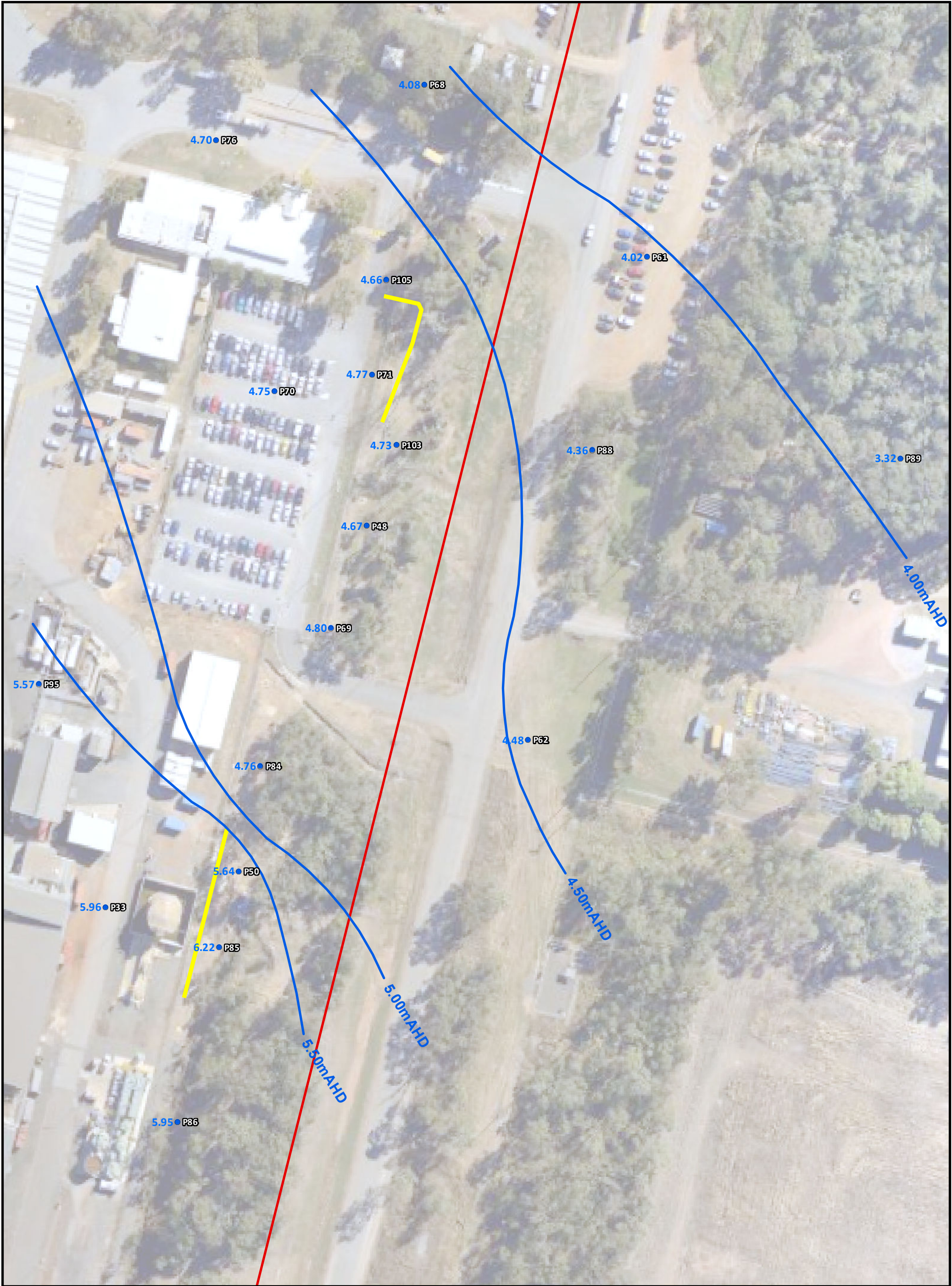
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Datum: MGA94 Zone 56 - AHD			
A3			
B	Original Issue - R02	RF	17-11-2017
Rev	Description	Drn.	Date

- Legend:
- Approximate Boundary - Lot 138 CTN2123
 - Trench Locations
 - Groundwater Elevation (mAHd)
 - Groundwater Elevation (mAHd)

JBS&G Figure: Groundwater Elevation (mAHd) - February 2016

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_February 2016





Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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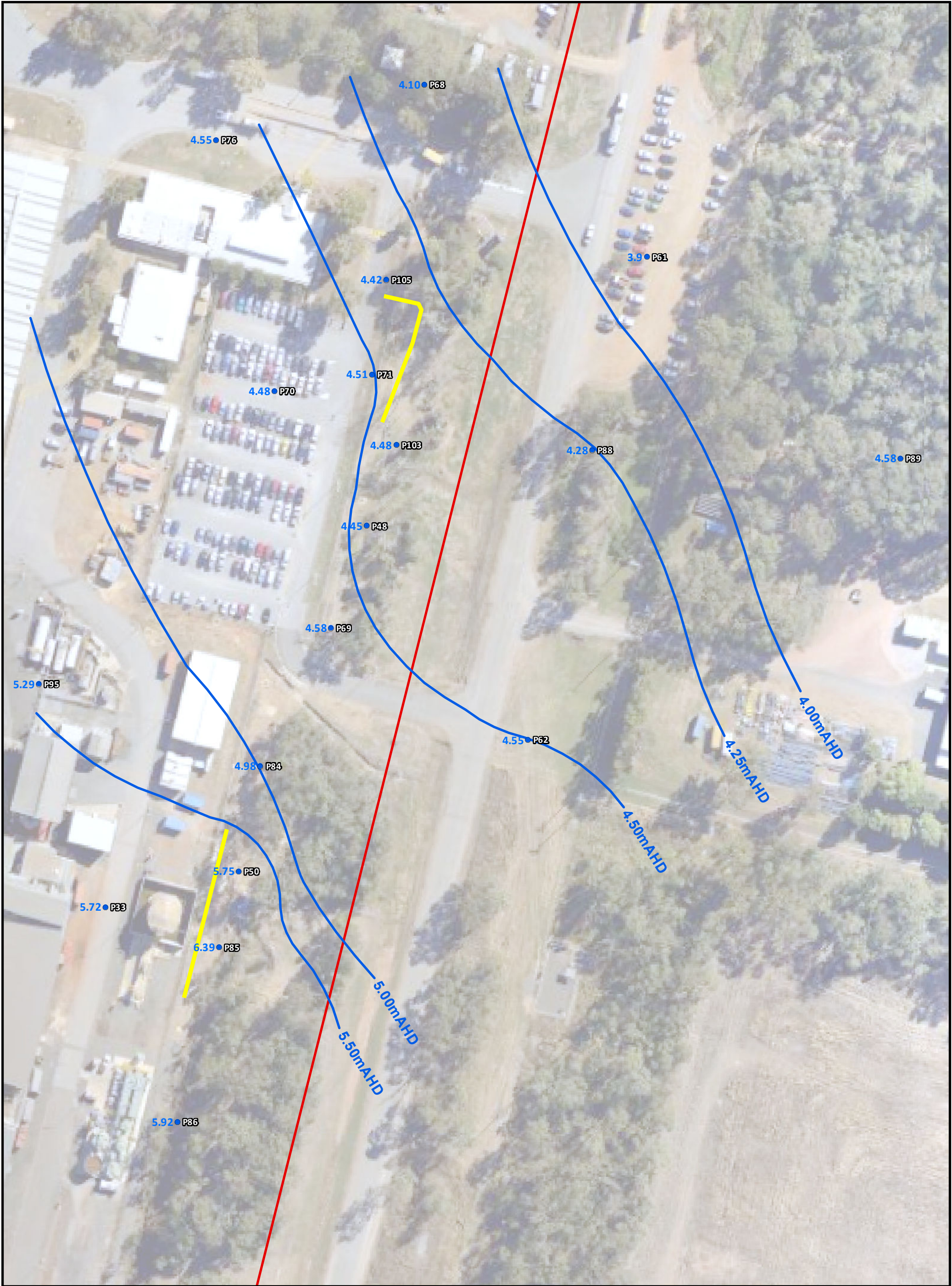
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Scale: 1:1,000			
Datum: MGA94 Zone 56 - AHD			
A3			
B	Original Issue - R02	RF	17-11-2017
Rev	Description	Drn.	Date

- Legend:
- Approximate Boundary - Lot 138 CTN2123
 - Trench Locations
 - Groundwater Elevation (mAHd)
 - Groundwater Elevation (mAHd)

JBS&G Figure: Groundwater Elevation (mAHd) - January 2017

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_January 2017





Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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0 5 10 20 m			
Scale: 1:1,000			
Datum: MGA94 Zone 56 - AHD			
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B	Original Issue - R02	RF	17-11-2017
Rev	Description	Drn.	Date

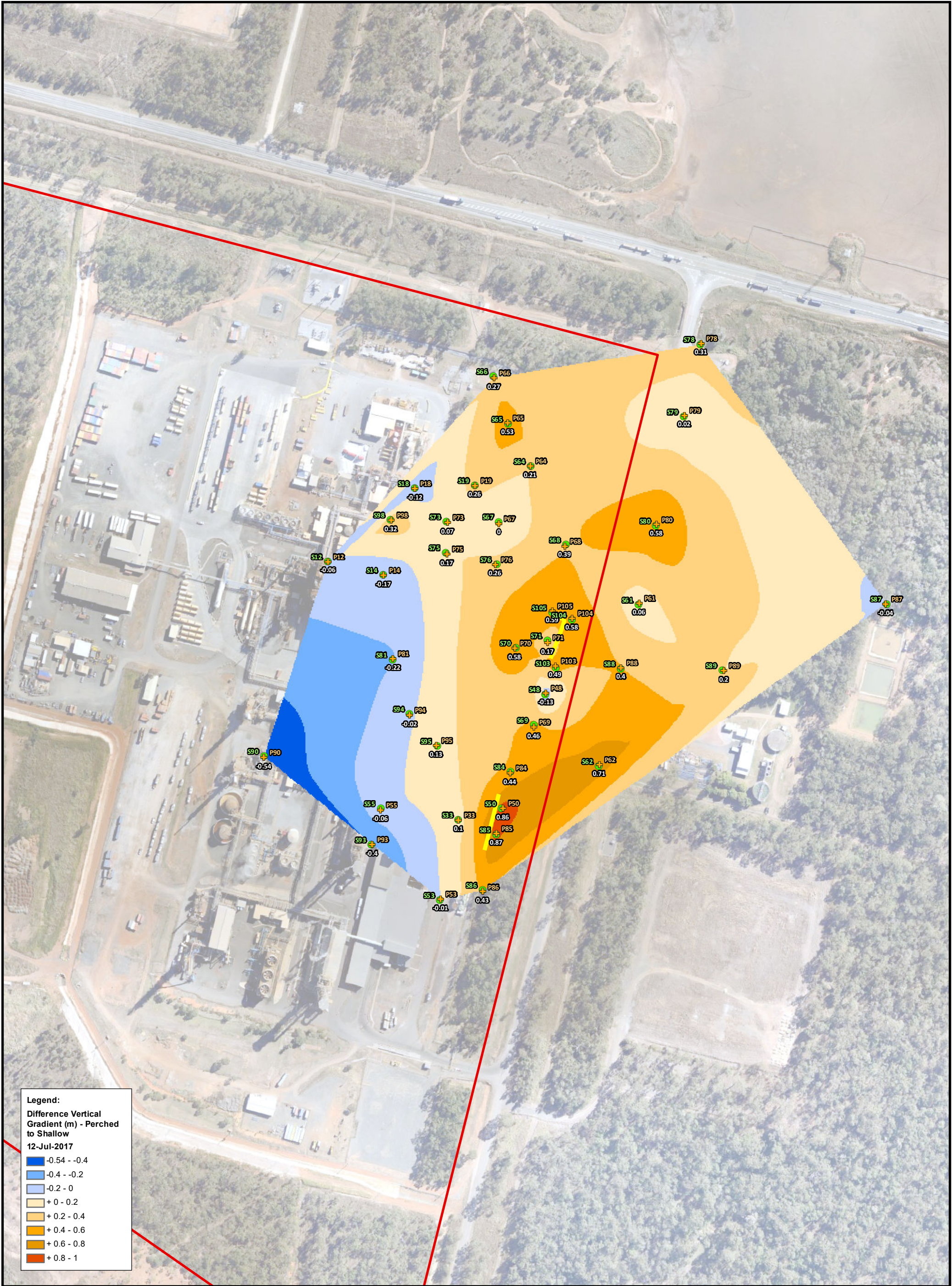
- Legend:**
- Approximate Boundary - Lot 138 CTN2123
 - Trench Locations
 - Groundwater Elevation (mAHd)
 - Groundwater Elevation (mAHd)

JBS&G Figure: Groundwater Elevation (mAHd) - July 2017

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: 52877_July 2017



Appendix E Vertical Gradient Maps



Source: Base Image www.nearmap.com - Imagery Date 7-8-2013. Accessed 29-8-2013

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02550100m			
Scale: 1:3,000			
Datum: MGA94 Zone 56 - AHD			
A3			
A	Original Issue - R02	RF	21-11-2017
Rev	Description	Drn.	Date

- Legend:
- Approximate Boundary - Lot 138 CTN2123
 - Trench Locations
 - Groundwater Elevation (mAHD) - Perched 12-Jul-2017
 - Groundwater Elevation (mAHD) - Shallow 12-Jul-2017
 - Vertical Gradient - Perched to Shallow 12-Jul-2017

JBS&G Figure: Difference Vertical Gradient Perched to Shallow 2017 Jul mg/L

Client: Orica Australia Pty Ltd
Project: 30 Reid Road, Yarwun, QLD (Lot 138 on CTN2123)
Job No: 52877 File Name: Vertical_Gradient_Pd_12-7-17

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		Name	Name	Signature	Date
A	Stuart Derham	Greg Dasey	Greg Dasey	DRAFT for client review	30 October 2017
B	Stuart Derham	Greg Dasey	Greg Dasey	DRAFT for client review	21 November 2017
0	Stuart Derham	Greg Dasey	Greg Dasey		5 December 2017

