Environmental Evaluation

CopperChem Ltd

Great Australia Mine

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1. Introduction

In a letter, dated 16 May 2014, the Department of Environment and Heritage Protection (DEHP) has decided to issue CopperChem Ltd (hereafter CopperChem) a notice to conduct or commission an Environmental Evaluation pursuant to Section 326B of the Environmental Protection Act 1994. This Environmental Evaluation was issued, primarily, to address groundwater contamination issues identified at the Great Australia Mine in Cloncurry.

This Environmental Evaluation Report addresses the issues raised by DEHP.

2. Scope

As specified in the DEHP Environmental Evaluation (hereafter EE); this report addresses the following relevant matters. These include:

1. Assess the actual and potential impact of the contaminants released from the site as a result of the mining activities to groundwater on the environmental values of the receiving environment. The investigation must:

    a. Identify and define the environmental values of the receiving environment in accordance with ANZECC 2000 methodology;
    b. Including an assessment of the impacts on the environmental values identified for groundwater;
    c. Include a comparison and review of previous relevant studies undertaken; and
    d. Include identification of and comparison with the groundwater quality at relevant reference sites.

2. Identify the reason for discharge and distribution of contaminants, including but not limited to sulphate, from the site in the groundwaters in the receiving environment.

3. Undertake an assessment of the site water management system and infrastructure in place at the site as it relates to groundwater quality. This assessment must include but not be limited to:-

    a. Review the water management system in terms of protection of groundwater quality from impacts of mining activities with specific reference to the heap leach operation; and
    b. Identify the following:
        i. Location and types of groundwater aquifers;
        ii. Groundwater contours and levels for contaminants which include but not limited to sulphate at the site and receiving environment;
        iii. Existing measures for mitigation of groundwater impacts;
        iv. Maintenance and replacement procedures for mining infrastructure, including but not limited to pumps, pipes and liners.

4. Include a report that details all relevant options and detailed remedial works required to address the cause of contamination and impacts on the receiving environment. Remediation options must ensure protection of the environmental values of the receiving environment.

3. Project and Site Description

The Great Australia Mine (GAM), operated by CopperChem, is located approximately 2-km south of the town of Cloncurry in North West Queensland. The site comprises inactive mining pits (i.e. GAM, Orphan Shear, Paddock Lode & Taipan), active and inactive waste rock dumps, a Run-Of-Mine (ROM) pad, a copper oxide and copper sulphide ore processing plant, a Tailings Storage Facility (TSF) and historical and active heap leach cells. The GAM operations are located on Mining Leases (ML) 90065 and 90108 (Figure 1).

The heap leach operation is located towards the south of the mining lease and comprises a Solvent Extraction (SX) plant and copper crystallisation circuit for producing copper sulphate pentahydrate. At present six Stormwater Ponds (SP) are connected in series to contain contaminated stormwater runoff from the heap leach pads, spent heap leach landform and processing areas.

A TSF has been constructed to contain tailings from the flotation circuit of the sulphide ore processing facility. The TSF is located to the north-west of the processing area and east of the GAM WRD. However, as of July 2014, the operation of CopperChem's sulphide ore processing plant has been temporarily suspended and, as a result, there has been no input into the TSF since this time.

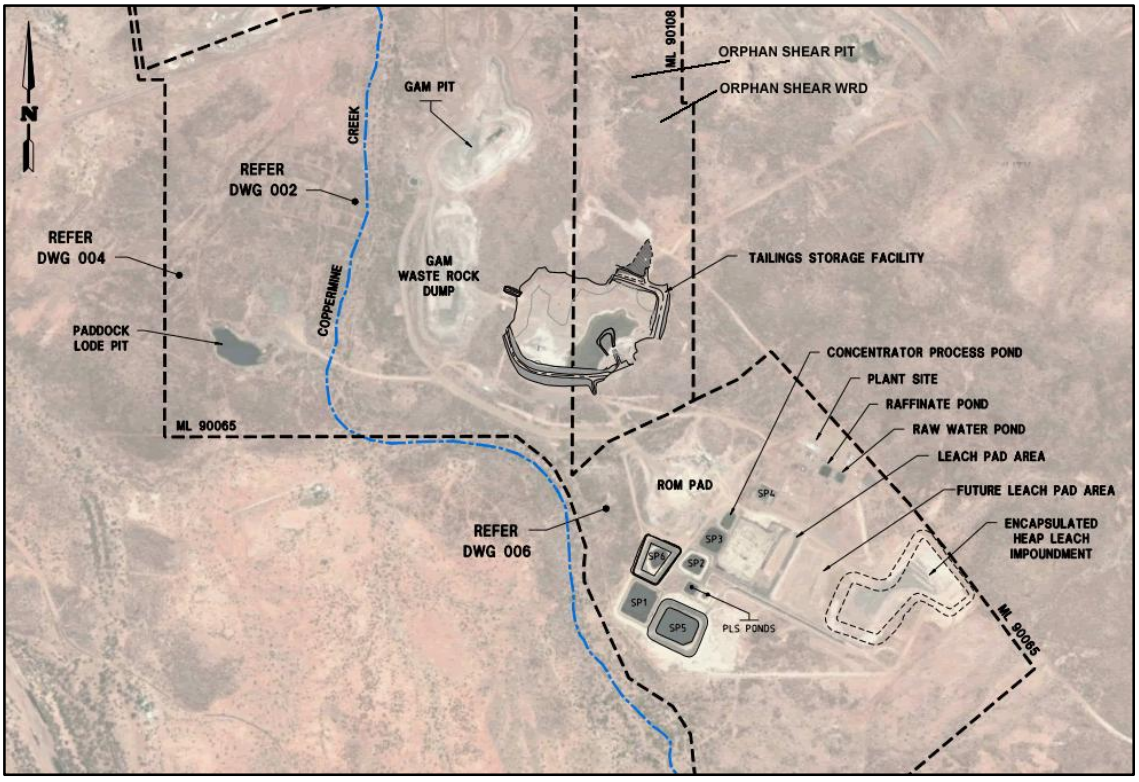

Figure 1 Configuration of Stormwater Ponds used to contain runoff from mining operations at the GAM facility (modified after ATC, 2012)

4.1 Background to hydrology, climate, geology & hydrogeology

4.1.1 Hydrology

Regionally, the GAM is located within the Flinders River Basin (Figure 2), discharging to the Gulf of Carpentaria to the north, with headwaters formed at the Selwyn Ranges, approximately 95-km south from the site. The main tributary occurring within the site is the shallowly incised Coppermine Creek, flowing in the area between the GAM Pit and WRD to the east and Paddock Lode and Taipan Pit to the west. The Coppermine Creek flows in a northerly direction to a confluence with the Cloncurry River. The natural condition of the creeks and drainages within the region are ephemeral; therefore, flow is a direct response from wet season recharge. As a result of the terrain in the area of the GAM site, surface hydraulics respond rapidly to rainfall.

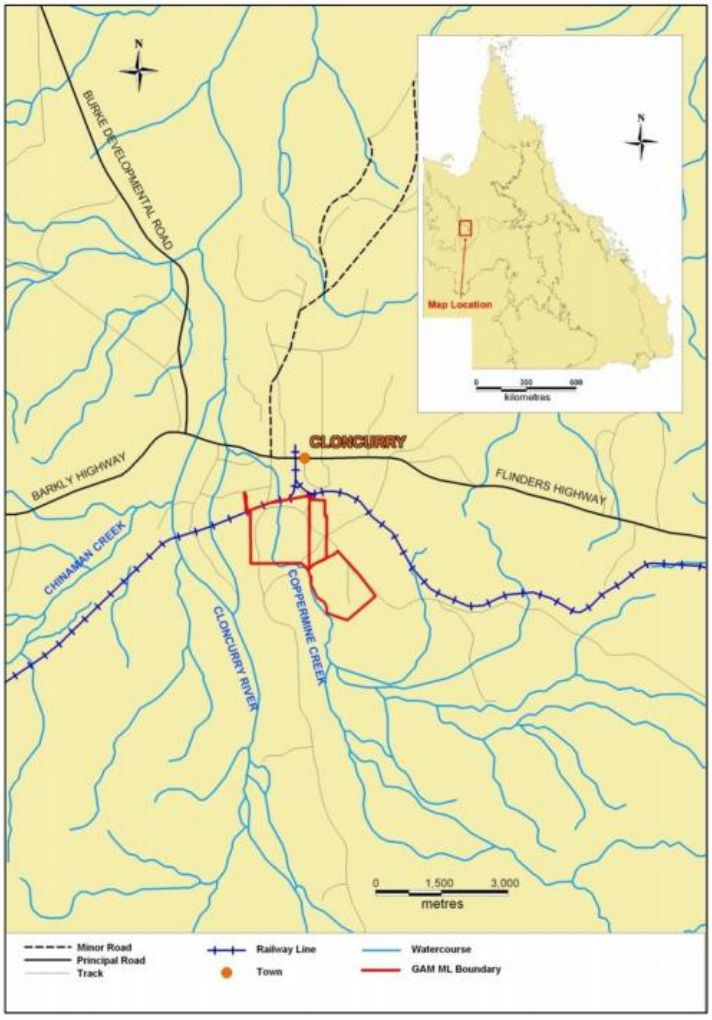

Figure 2 Site Locality Map (AARC, 2014)

Figure 3 shows the surface water courses that traverse the GAM site. These include the Coppermine Creek and other smaller ephemeral systems.

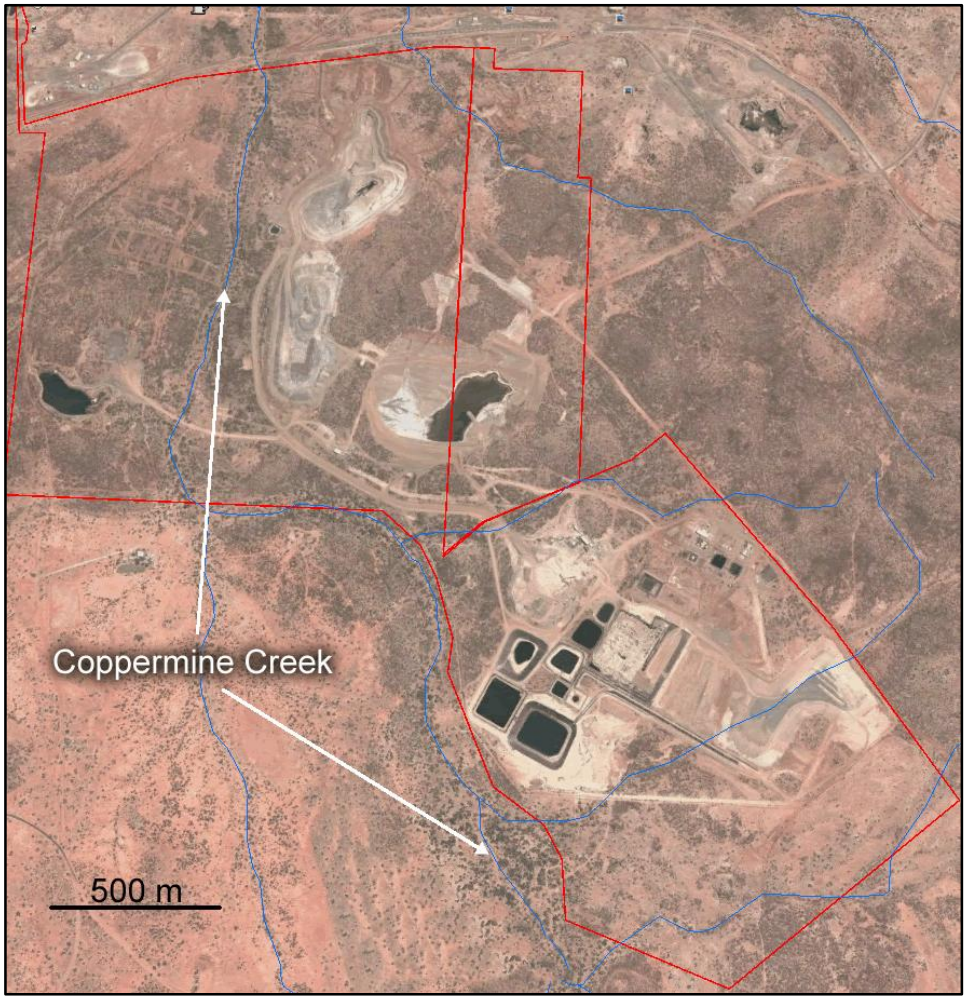

Figure 3Surface water courses (blue lines) at GAM site.
Note: flow is in the direction of Coppermine Creek

4.1.2 Regional Climate

The GAM site is located in a sub-tropical arid climate with extremely variable annual rainfall. Information acquired from the Bureau of Meteorology (BoM) website indicates that the average annual rainfall for the region[1]is approximately 520.6 millimetres (mm), with peak rainfall occurring during January and February.

[1]Based on data collected from the Cloncurry Airport

The coldest period of the year occurs in July, with an average minimum temperature of 10.3 degrees Celsius (ºC), and an average maximum of 26.1ºC. The warmest month of the year is December, with an average minimum temperature of 24.7 ºC, and an average maximum of 38.5 ºC. Moderate winds between 13.4 to 18.2 kilometres per hour (kph) from the south and south-west are predominant in the region. Mean monthly rainfall, temperature and evaporation data of the Cloncurry region is summarised in Table 1.With regards to Table 1 it is evident that mean monthly evaporation exceeds mean monthly precipitation by a factor of up to 14.

Table 1 - Mean Monthly Rainfall and Temperature Data

Month	Rainfall	Evaporation[2] (Mt Isa)	Temperature Maximum	Temperature Minimum
	mm	mm	ºC	ºC
January	174.7	297.6	36.6	24.7
February	105.6	246.4	36.1	24.1
March	75.8	272.8	35.6	22.5
April	20.1	249.0	33.5	19.9
May	7.2	198.4	29.1	15.3
June	6.4	162.0	26.2	11.2
July	2.1	170.5	26.1	10.3
August	3.1	213.9	28.8	12.1
September	6.3	267.0	33.1	16.5
October	20.2	325.5	36.2	20.2
November	33.6	330.0	37.7	23.0
December	80.7	331.7	38.5	24.7
Annual	520.6	3066	33.1	18.7

4.1.3 Site Geology

Figure 4 shows a generalised geological surface map of the GAM site. With reference to Figure 4 it can be seen that the site is underlain by metavolcanics (i.e. gabbroid), calc-silicate

[2] Mt Isa Station #: 029127 ~155km west

breccia and Quaternary colluvium (Figure 4). As reported by Australian Groundwater and Environmental (AGE) Consultants (2004), the distribution of the rock types are largely controlled by a series of fault networks that cross the site. For example, it is believed that the ore body identified in the GAM pit is associated with the large fault identified in Figure 4.

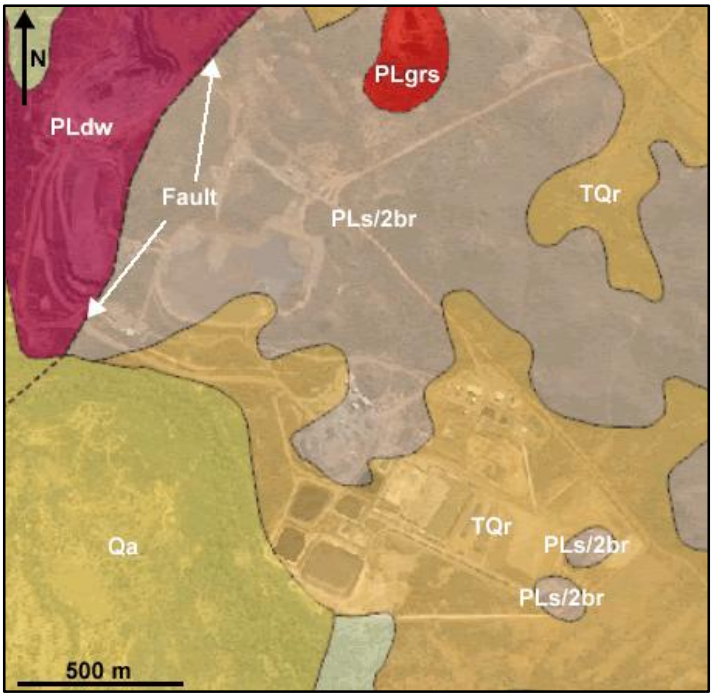

Figure 4Geological Map the GAM site (PLdw = metavolcanics, PLgrs = granitoid, PLs/2br = brecciated calc-silicate, TQr = Quaternary colluvium, Qa = Quaternary alluvium).

According to the AGE report (2004), there is some evidence supported by air photograph interpretation that geological lineations exist to the east of the TSF. This suggests the presence of a fault. This has yet to be substantiated.

4.1.4 Site Hydrogeology

Australasian Groundwater and Environmental Consultants Pty Ltd (2004)[3] provided the following conclusions regarding the hydrogeological regime at GAM. These include:

- Groundwater storage is within secondary porosity features such as fractures and joints rather than within the primary porosity of the rock (groundwater flow from such

[3]Australasian Groundwater and Environmental Consultants Pty Ltd, September 2004. Report on Hydrogeological Regime Environmental Management Overview Study Great Australia Mine. Project G1251.

geological structures (and units) at GAM is laterally discontinuous and has little to no hydraulic connection with surrounding environment);
- All open voids that are in hydraulic connection with groundwater (i.e. GAM, Paddock Lode and Taipan pits) act as a groundwater sink;
- Depths to groundwater vary from 4m below ground level in the gravels adjacent to Coppermine Creek to 17m deep adjacent to the Great Australia pit; and
- Groundwater flow is generally towards Coppermine Creek (Figure 5).

Areas where rock is near or at the surface, and with very few joints and fractures, generally have a low permeability (i.e. approximately $1x10^{-9}$ m/sec to $1x10^{-7}$); whereas areas underlain by colluvium have a permeability in the range of approximately $1x10^{-7}$m/sec to $1x10^{-4}$m/sec).

According to AGE (2004) much of the [superficial] subsurface at GAM can be divided into three distinct types. These consist of:

- Higher permeability, fractured, weathered rock, which is likely to form porous medium flow characteristics;
- Lower permeability, less weathered rock mass with few open discontinuities; and
- Discrete, open voids (typically joint planes and solution cavities) in the rock mass which will have fracture flow characteristics and have the potential to channel high water flow volumes.

As a result of the depth to groundwater, when compared to the depth of incision of the watercourses on the GAM site, it is extremely unlikely that a groundwater-surface water connectivity exists. However, it is reasonable to consider that some degree of shallow connectivity may occur in Coppermine Creek (only) during extreme flows.

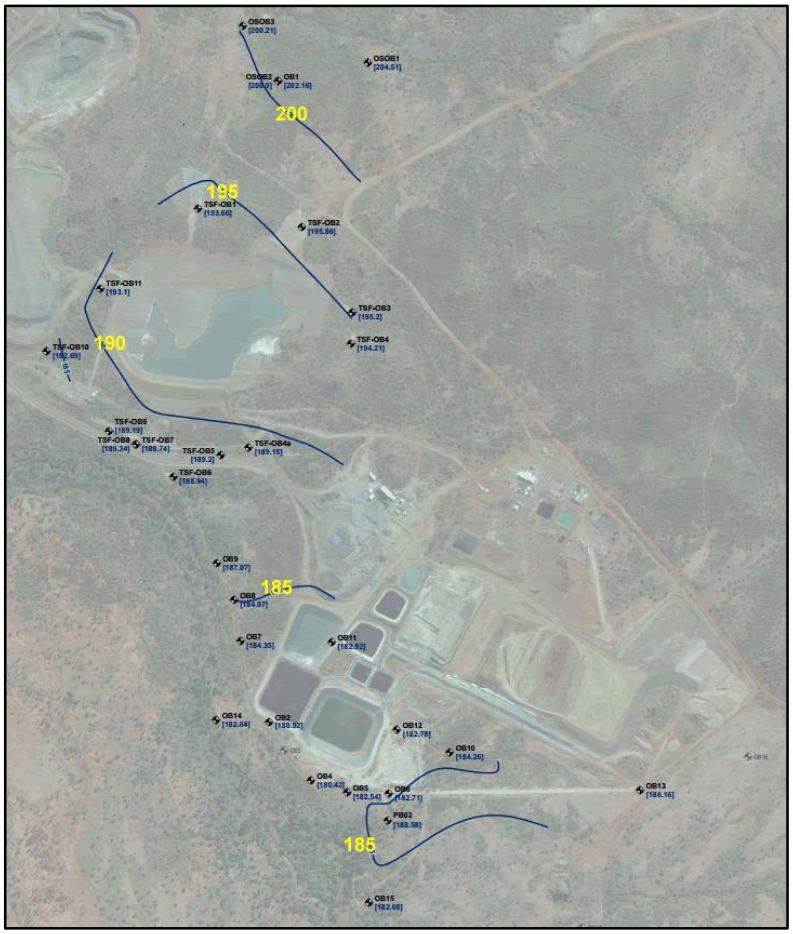

Figure 5 Generalised groundwater contours (compiled using current database) at GAM (Note: yellow numbers indicate depth to groundwater in meters Australian Height Datum (mAHD))

5 Principal Site Activities

The principal site activities at GAM, that may have the potential to negatively affect groundwater quality, are listed below.

5.1 Regulated Dams

Much of the contemporary site operations at GAM have been in operation since 1996; and since this time GAM has had several titleholders prior to CopperChem acquiring the Project in late2009. Prior to CopperChem taking over operations in 2009, the only regulated dams onsite included Stormwater Pond (SP) 1, SP2, SP3, SP4, Raffinate Pond (RAF), Raw water Pond (RAW) and Pregnant Liquor Solution (PLS) Ponds east and west(Figure 6).

Since CopperChem has taken over the GAM, the following regulated storage dams have been added. These include:

- SP5 (March, 2010);
- SP6 (June, 2011);
- The Process Water Pond (PWP) (2010); and
- The Tailings Storage Facility (TSF) (2010/2011).

The following sub-sections describe the current processing infrastructure and Water Management System (WMS) (including the function of the regulated dams), present at the GAM site. However, the 2014/2015 WMS is currently in review and is subject to minor changes. For a full appreciation of the forthcoming 2014/2015 WMS please review the URS WMS (and Design Storage Allowance) Report (Due for release 15-October, 2014).

➢ **Stormwater Ponds 1 to 6**

There are currently six High Density Poly-Ethylene (HDPE)-lined stormwater ponds (SP-series) associated with GAM operations; which contain contaminated stormwater runoff from the heap leach pads, spent heap leach landform and processing area during the wet season (Figure 6). This water is stored and then reused for processing[4]; when required.

Figure 7 shows the generalised catchment and flow of stormwater pertinent to the regulated dam network. For a full appreciation of the water balance of the GAM network, please review the URS DSA and Water Management Plan (to be released 15-October, 2014).

Table 2 shows the storage capacity of each Stormwater Pond (i.e. SP 1 to 6) at the GAM site.

CopperChem took over the GAM operations soon after the 2009 wet season. And prior to this acquisition, the only SP and Process Ponds onsite were SP1, SP2, SP3, SP4 and PLS Ponds east and west (Figure 6).The DSA for Storm Ponds 1, 2, 3 and 4 ponds is equal to the storage volume for a 1:10 year, 2-month wet season rainfall (422mm across the catchment) plus process water inputs.

- **Stormwater Pond 5**

The earthworks and lining of SP5 was completed in March 2010 and has a storage capacity of approximately 115,000 m^3. The construction of SP5 is to provide further security against another overflow event occurring from the processing facility. Combined with the existing storage facilities, SP5 will accommodate a combined DSA of a 1 in 100 year ARI, 2 month wet season rainfall event for the heap leach facility. The maximum combined available

[4]For the heap leach or flotation process

storage capacity in SPs 1, 2 and 3 is over 80,000m^3. As such, the minimum storage capacity required for Storm Pond 5 to achieve the DSA is 100,000 m^3 (AWA, 2010- Annual Hazardous Dam Safety Review Report).

Stormwater Pond 5 is located to the east of SP1 (Figure 6) and has been fully HDPE lined. Inflow into SP5 is via the spillway from SP1 or from the stormwater launder extending from the spent heap leach landform. Stormwater Pond 5 was formed by excavation with the exception of the north and eastern embankment which is buttressed with spoil from the excavation.

- **Stormwater Pond 6**

An EA Amendment was lodged in August 2010 for the construction of SP6, and in June 2011 this dam was completed. Stormwater Pond 6 has a maximum storage capacity of 46,500 m^3, total surface area of 16,950m^2, pond depth of 5.5m, external batter slope 1V:2.5H and a crest level RL of 196.0m.

Table 2 Stormwater Pond identification and corresponding storage capacities

Pond I.D	Storage Capacity (ML)
Stormwater Pond #1	54.7
Stormwater Pond #2	17.8
Stormwater Pond #3	15.8
Stormwater Pond #4	3.95
Stormwater Pond #5	115
Stormwater Pond #6	46.5

Figure 6Location and Identification of storage dams at GAM

- **Process Water Ponds**

For the purposes of this report, the process water ponds presently in use at GAM, collectively include the HDPE-lined Raffinate (RAF) Pond, Raw Water(RAW) Pond and PLS Ponds (PLS Ponds east and west). These ponds are connected through a pipeline system forming part of the function of the heap leach processing circuit.

The RAF Pond is located near to the SX plant and discharges into SP4 via a [to be installed (prior to 1-Nov 2014)] poly-lined launder (Figure 7). The RAW Pond contains clean water, sourced from Cloncurry Township, and is to be isolated from process water system ahead of 1-Nov (2014).

PLS Ponds east and west were re-lined with HDPE in 2012 and are located between Storm Pond 2 and 5 (Figure 6). There is an interconnecting spillway between the two PLS ponds. The launder from the heap leach cells discharges into PLS pond east, overflow to PLS pond west and, if needed, can be diverted into SP2, subject to stormwater flow conditions or through pumping. Otherwise PLS is stored in PLS west and/or SP2 and recirculated back to the SX plant for processing.

Figure 7 shows the generalised catchment and flow of the heap leach and PLS circuit pertinent to the process plant network. For a full appreciation of the water balance of the GAM network, please review the URS DSA and Water Management Plan (to be released October, 2014).

Table 3 shows the storage capacity of each Stormwater Pond (i.e. RAF, RAW, PLS east/west) at the GAM site.

Table 3 Pond identification and corresponding storage capacities

Pond I.D	Storage Capacity (ML)
Process Water Pond (PWP)	2.5
Raw Water Pond (RAW)	3.0
Raffinate Pond (RAF)	3.0
PLS East	6.0
PLS West	6.0

The PWPs and SPs are designated as hazardous dams and as such have a Designed Storage Allowance (DSA) and Mandatory Reporting Level (MRL) as described in the GAM EA.

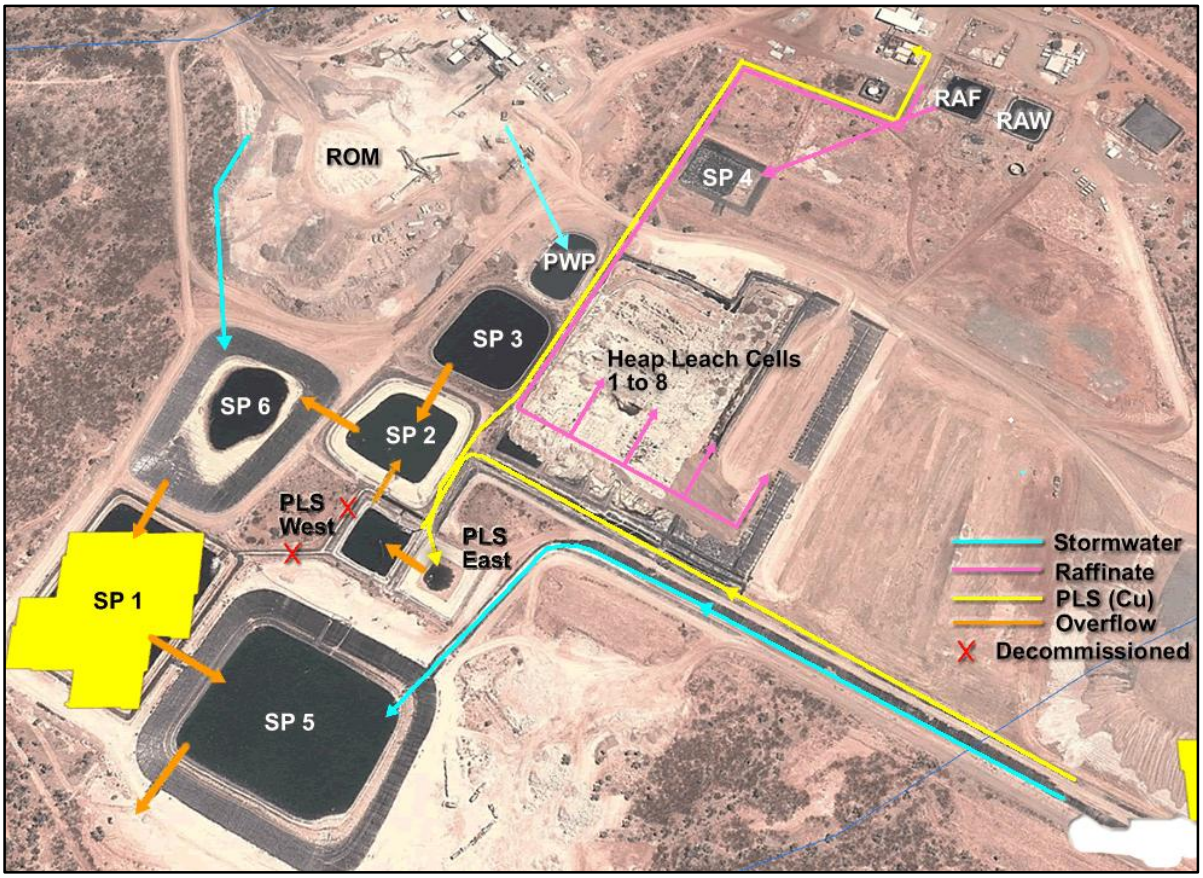

Figure 7 Generalised schematic of stormwater catchment and circuit (blue lines) and process plant catchment and circuit (pink and yellow lines). Orange lines represent and show the overflow (spillways) between the various regulated dams. Note: *Be advised this image does not represent the FINAL water balance for the GAM site. For a full appreciate of the water balance and DSA for GAM please see the URS report (Due to be released 15-Oct, 2014).*

5.2 Flotation Circuit and ROM Pad

In July (2014), operations involving the concentrator and float plant (Figure 6) (a.k.a. flotation circuit including the TSF) were temporarily suspended. The investiture of the float plant, in 2012, was to treat ore containing sulphides on a mining rate of approximately 600,000 tonnes per annum (tpa). When in operation, the generation of tailings was estimated to be 582,000 tpa; which was transported to the TSF. Discernibly, the TSF has not been in operation since activities involving the flotation circuit have been suspended. Furthermore, when in operation the float plant utilised water in the PWP (Figure 7); however, this pond [now] only stores clean-water. The function of the PWP is to change ahead of the 1-November wet season deadline. For more information pertaining to the PWP, please review the URS DSA and Water Management Plan (to be released 15-October, 2014).

Due to the intrinsic nature of the materials stored on the ROM pad (i.e. fine-grained metal concentrates etc.) and; therefore, the potential for their release to the environment, the ROM pad has been modified to capture all runoff and diverted to SP6 (Figure 7). This is discussed in more detail in the forthcoming URS WMS and DSA Report (to be released 15-October, 2014).

5.3 Heap Leaching

The current Project consists of a conventional heap leach, Solvent Extraction (SX) plant and copper crystallisation circuit producing copper sulphate pentahydrate. The active heap leach pads at GAM have previously covered approximately 15 ha and consisted of cells 1 - 19. Original EA approvals for the GAM Project sanctioned 32 ha for heap leach pads. The heap leach process involves crushing, agglomerating and stacking copper oxide ore in approximately 2 - 3 m high lifts up to a height of up to 8m[5] on each cell. The ore is placed on heap leach pads constructed from compacted clay, which are lined with a HDPE liner to prevent migration of contaminants to groundwater. Fill and clay material was sourced from the area of Stormwater Pond 5 (SP5) when it was excavated and stockpiled for use. The heap leach pad and perimeter drain is bunded and lined with HDPE to prevent leachate migration to the surrounding area.

With reference to Figure 7, an irrigation system irrigates the heap leach pads with sulphuric acid (H_2SO_4). This acid solution percolates through the heap (e.g. crushed copper ore) and solubilises copper compounds. The copper-enriched solution is then collected in the HDPE-lined drains (i.e. launders) surrounding the perimeter of the heap leach pad, and flows into the PLS ponds. The PLS solution is then fed to the SX plant and copper crystallisation circuit for processing. Return solution from the processing circuit is stored in the RAF pond prior to adding further acid if required and re-irrigating over the heap leach pads.

To date, remedial work on the heap leach pad area has included HDPE relining of heap leach cells 1 to 3 (2011) and extending the launders for cells 7 & 8 (2013).

5.4 GAM, Paddock Lode and Orphan Shear Pits

The GAM Pit is located to the northwest of the site and has not undergone any mining activities since 2012. Since this time, the pit has been used as a store for rainwater and purchased town water.

The Paddock Lode and Orphan Shear Pit are situated southwest and northeast of the GAM Pit, respectively. Traditionally these pits have been operated as emergency storage for rainwater and for water harvesting as a means to supplement much needed water demands for the GAM operations.

[5]Current EA amendment application to increase this height

As a result of the high evaporation and low permeability of the rock hosting the pits, groundwater dewatering is not required or carried out. These pits remain dry unless, in the case of the GAM pit, town water is pumped directly to it. Effectively these pits act as natural groundwater sinks.

Surface runoff from the GAM, Paddock Lode and Orphan Shear Waste Rock Dumps (WRDs) is collected and stored onsite. For more information regarding the capture and storage of surface water runoff from and to these pits and WRDs, please see the URS DSA and Water Management Plan (to be released 15-October, 2014).

6 Groundwater Sampling Programme

With reference to the Environmental Evaluation as issued by DEHP (12-June, 2014), this EE report aims to investigate the "Grounds" for its issue. The "Grounds" referenced by DEHP are:

"*The notice to conduct or commission an environmental investigation is issued on the following grounds:*

- *Pursuant to section 326B of the Environmental Protection Act 1994, an environmental investigation is required;*

  (1) If the administering authority is satisfied on reasonable grounds that –
  - *(b) an activity or proposed activity is causing, or is likely causing environmental harm".*

More specifically, the DEHP EE refers to the potential contamination of groundwater from CopperChem's mining operations at Mining Leases (ML) 90065 and 90108.

Although it is stipulated in the EE that particular attention be made to all contaminants exceeding the EA "Trigger" or "Release" Criteria (Schedule C, Table C11); however, one analyte that is of particular concern to DEHP is the elevated concentration of sulphate (SO_4^{2-}) as measured from some groundwater observation bores.

The following section describes the available groundwater data used in this EE report; including data sets acquired from previous titleholders to the present day.

6.1 Groundwater Monitoring Bores

There are numerous groundwater bores present on the GAM MLs; all of which have a varying number of data points associated with them. The number of available data points associated with each bore reflects the length of time they have been installed.

For the purpose of this EE report, groundwater monitoring bores and the associated hydrochemical results, have been divided into four groups.

The groupings are General Observation Bores (OB-prefix), Tailings Storage Facility Observation Bores (TSFOB-prefix) and Paddock Lode and Orphan Shear Observation Bores (PLOB and OSOB-prefix, respectively). These are discussed in more detail below.

Note: There are additional groundwater bores installed onsite that undergo routine monitoring; however, these supplementary bores will be discussed under Section13; Groundwater Management. These include Coppermine Creek Observation Bores (COB-prefix), and Leak Detection & Interception Bores (located immediately down-gradient to the Heap Leach facility).

6.1.1 General Observation Bores (OBs)

General Observation Bores (prefix "OB") are used to monitor groundwater conditions in the area of, and down-hydraulic gradient to, GAM processing operations (i.e. Heap Leaching, Stormwater Ponds etc.).

There are a total of 18 OBs: i.e. OB1 to OB18.Table 4 identifies the installation date and the number of available data points for each OB. The overall number of data points for OBs in Table 4 show the division between previous GAM operators. These are: Great Australia Mine Cloncurry (GAMC), Tennant Ltd (Tennant) and CopperChem Ltd (CopperChem).

Table 4 Bore I.D (Observation Bores) and Data Points Used For Hydrochemical Interpretations

Bore I.D	# Data Points	Bore I.D	# Data Points
OB1 Installed 1996	**272** 48- GAMC, 193 –Tennant, 58 CopperChem	**OB10** Installed 2005	**114** 58 –Tennant, 56 CopperChem
OB2 Installed 1996	**254** 48- GAMC, 213 –Tennant, 41 CopperChem	**OB11** Installed 2005	**106** 48 –Tennant, 58 CopperChem
OB3 Installed 1996	**259** 48- GAMC, 201 –Tennant, 58 CopperChem	**OB12** Installed 2005	**112** 57 –Tennant, 55 CopperChem
OB4 Installed 1996	**270** 48- GAMC, 212 –Tennant, 58 CopperChem	**OB13** Installed 2005	**112** 64 –Tennant, 48 CopperChem
OB5 Installed 1996	**271** 48- GAMC, 213 –Tennant, 58 CopperChem	**OB14** Installed 2006	**95** 39 –Tennant, 56 CopperChem
OB6 Installed 1996	**271** 48- GAMC, 213 –Tennant, 58 CopperChem	**OB15** Installed 2006	**94** 39 –Tennant, 55 CopperChem
OB7 Installed 2005	**130** 72 –Tennant, 58 CopperChem	**OB16** Installed 2006	**76** 38 –Tennant, 38 CopperChem
OB8 Installed 2005	**128** 72 –Tennant, 56 CopperChem	**OB17** Installed 2012	**21** 21- CopperChem
OB9 Installed 2005	128 72 –Tennant, 56 CopperChem	**OB18** Installed 2012	23 23- CopperChem

6.1.1.1 Background to General OBs

In a report by AustralAsian Resource Consultants (AARC, 2011), the following describes some legacy issues of specific OBs.

"Observation bores OB1 to OB6 were installed by previous operators, GAMC, in 1996 and have been monitored on a regular basis ever since. In 2000, OB1 started showing signs of SO_4^{2-} contamination, followed by similar observations in groundwater from OB2 and OB3 in 2002 (AARC, 2011).

In March 2005, OB7 to OB9 were installed by Tennant to further investigate the potential sources of contamination that were revealed by the original OBs. In August 2005 an additional four OBS were installed, (i.e. OB10 to OB13) and in May 2006, another three bores were installed (OB14 to OB16) (AARC, 2011)".

6.1.2 Tailings Storage Facility Observation Bores

Tailings Storage Facility (TSF) groundwater monitoring bores (prefix "TSFOB") are used to monitor any changes in groundwater quality down-gradient to the TSF. These include a total of nine bores: TSFOB1 and TSFOB4a to TSFOB11. Bores TSFOB2 to TSFOB4 have been damaged, and as a result, were absent from the sampling suite until 15/9/2014.

identifies the installation date and number of data points for each TSF Observation Bore. This suite of TSFOBs was installed by CopperChem following the construction of the TSF in 2010.

Table 5Bore I.D (TSF Observation Bores) and Data Points Used For Hydrochemical Interpretations

Bore I.D	# Data Points	Bore I.D	# Data Points
TSFOB1 Installed 2011	**96**	**TSFOB6** Installed 2011	**111**
TSFOB2[6] Installed 2011	**103** Bore damaged	**TSFOB7** Installed 2011	**111**
TSFOB3[6] Installed 2011	**102** Bore Damaged	**TSFOB8** Installed 2011	**112**
TSFOB4[6] Installed 2011	**100** Bore Damaged	**TSFOB9** Installed 2011	**113**
TSFOB4a	**105**	**TSFOB10**	**113**

[6] Bores damaged and have not been sampled since February 2014. Replacement bores installed on 15-Sept 2014

Installed 2011		Installed 2011	
TSFOB5 Installed 2011	111	**TSFOB11** Installed 2011	113

6.1.3 Paddock Lode and Orphan Shear Observation Bores

Paddock Lode and Orphan Shear Observation Bores (prefix "PL" and "OS" respectively) are named after the open-cut pits they are near to. These bores were installed in 2013 by CopperChem to monitor any changes to groundwater quality as a result of the mining activities of the associated pits.

Table 6 identifies the installation date and number of data points for each PL or OS Observation Bore.

Table 6 Bore I.D (Paddock Lode/Orphan Shear Bores) and Data Points Used For Hydrochemical Interpretations

Bore I.D	# Data Points
PLOB1 Installed [Dec] 2013	**8**
PLOB1 Installed [Dec] 2013	**8**
OSOB1 Installed 2013	**16**
OSOB1 Installed 2013	**16**
OSOB1 Installed 2013	**16**

6.1.4 Groundwater "Reference Bore" Criteria

In alignment with the purpose of the EE, in an effort to identify if mining operations has had any impact to groundwater quality, hydrochemical results should be investigated. To determine if the effects from mining operations has caused any contamination to groundwater quality, all hydrochemical results should be compared to baseline criteria or a "reference" bore. However, at the time of preparing this report, the two compulsory "reference" bores, as required in the GAM EA, had not been installed[7]. Therefore, in an effort to define reference criteria for analytical comparisons, a suite of groundwater bores were used as a proxy. The bores that were chosen include (refer Figure 8):

- OB15 and OB18;

[7]Completed 15-Sept., 2014

- PLOB1 & PLOB2; and
- OSOB1 to OSOB3.

The basis for choosing these bores, to serve as [provisional] “reference” bores, was based on their lower than average SO_4^{2-} concentrations (refer to EA and Section 1); when compared to remaining groundwater data. Lower concentrations of SO_4^{2-} (< e.g. 400 mg/L), as measured in these groundwater bores OB15 and OB18, suggests that groundwater occurring in these areas of the GAM site has not been impacted by any mining activities (if appropriate). Where groundwater may have been impacted from mining activities, SO_4^{2-} concentrations are in excess of the 1000 mg/L “Release” limits (as specified in the EA).

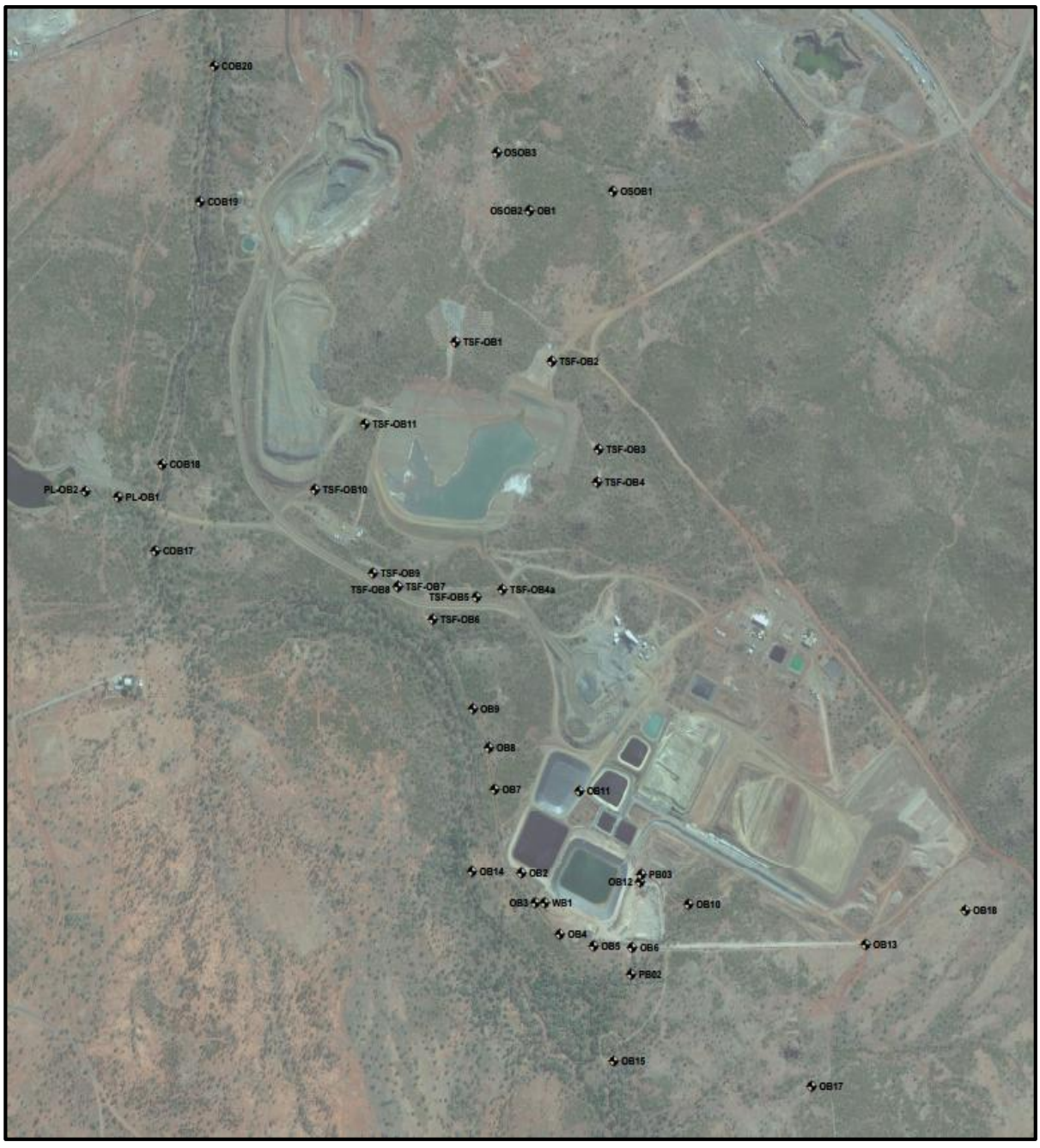

Figure 8Location of the GAM groundwater monitoring bores.

7 Background to Groundwater Sampling

In an effort to ensure that quality and representative groundwater results are collected, CopperChem confirm that suitably qualified personnel undertake this sampling. Groundwater sampling is carried out in reference to Sundaram *et. al.,* (2009), Australian Standards/New Zealand Standards (AS/NZS) 5667.11:1998 “Water-quality sampling” and the CopperChem Standard Operating Procedure (Appendix 1). The procedure for sampling groundwater, as performed by CopperChem personnel, is summarised below:

7.1 Groundwater Purging

Groundwater sampling is conducted using 12-V submersible monsoon type pumps with a variable flow controller. Purging of groundwater is considered to be completed when either three (3) bore volumes have been abstracted from the monitoring bore or when the monitoring bore was purged dry. In the second case, if the monitoring bore recharges within a 24-hour period, samples could then be obtained for analysis.

During purging a TPS multi-parameter field probe and flow cell was used to measure the physicochemical parameters (Table 7) of the groundwater. The stabilisation of these physicochemical parameters indicates that groundwater can be sampled for detailed chemical analysis (i.e. it is representative of the formation).

Field parameters may be considered stable when successive measures of at least three parameters (obtained at least five minutes apart) differ by less than the acceptable ranges listed below in Table 7 (Puls, 1995; Nielsen 1991).

During purging, observations were noted regarding groundwater colour, clarity and odour (where applicable).

Table 7 Field parameter stabilisation criteria prior to sample collection

Measurement	Variability	Recording
pH	+/- 0.05	Previous measurement at time of sampling
Temperature	+/- 0.2°C	Previous measurement at time of sampling
Electrical Conductivity	+/- 3%	Previous measurement at time of sampling
Redox potential (Eh)	+/- 10mV	Previous measurement at time of sampling
Dissolved Oxygen (mg/L or %)	+/- 10%	Previous measurement at time of sampling

7.2 Groundwater Sample collection

Groundwater samples were only collected once it was determined that field parameters had sufficiently stabilised during purging. All samples collected are analysed for the detailed water quality analytes shown in Table C11 of the CopperChem EA. The exception to this; however, although not specified in the EA, CopperChem environment personnel also have major anions and cations analysis performed.

Samples collected for “Dissolved” metals/metalloids species are field filtered using a hand operated vacuum pump fitted with 0.45µm nitrocellulose filter membranes; whereas, “Total” metals/metalloids species are sampled in the appropriate bottle as groundwater is abstracted from the bore.

7.3 Quality Assurance/Quality Control (QA/QC)

It is important to ensure that “verification” samples are collected during each day of sampling. This QA/QC approach is critical and ensures the results obtained from any sampling program is of known quality. Verification of analytical results should be conducted once analytical results have been received. The inclusion of QA samples should be considered when field sampling programs are being organised.

The following describes the type and frequency of QA/QC or “verification” samples that are added to each sampling event. These include:

- **Field Duplicates:**

“Field duplicates” are duplicate samples that are sent as independent samples to the same NATA-accredited laboratory for analysis to assess the precision and accuracy of the analytical results and of the sampling process.

Field duplicates are collected typically at a frequency of 1 in every 10 samples OR, if you are only collecting a few samples, ensure you always collect 1 field duplicate per sampling programme (e.g. per day).

Field duplicates should be collected from the same sample of water that the primary samples are being collected from; where samples should be bottled in immediate succession, each given its own identification number. Field duplicates should be labelled in such a way that the laboratory has no indication that the samples have been duplicated. These samples should also be stored and transported to the analytical laboratory in the same way as the primary samples.

- **Field Triplicates:**

Field triplicates are the same as field duplicate samples in terms of collection, storage, transportation, and analysis. The main difference is that field triplicates are sent to an independent NATA-accredited laboratory for analysis. Sending a field triplicate to a second NATA-accredited laboratory independently verifies the quality and performance of the primary laboratory’s procedures and practices to obtain precise and accurate analytical results.

Field triplicate samples are typically collected at a frequency of 1 in 20 samples or 1 per sampling programme (e.g. per day), whichever is greater.

- **Field Blanks**

A field blank is deionised water which is treated as a sample and is used to identify errors or contamination in sample collection and analysis. The deionised water should be collected, sealed and labeled as a sample. Equipment blanks are typically analysed for total concentrations of all minor and trace species of interest in the monitoring programs (i.e. everything excluding major ions and physical parameters).

Field blanks are collected typically at a frequency of 1 field blank per sampling programme (e.g. per day).

As a result of the field equipment used to sample groundwater at GAM, it is difficult to collect more than ten (10) samples per day. Therefore, the QA/QC samples generally consist of one (1) Duplicate and a one (1) Blank sample per day.

7.3.1 Groundwater Sample and Water Quality Data Integrity

Groundwater samples are collected and stored in the appropriate containers. These containers, along with the required sample preservative, are supplied directly by the chosen National Association of Testing Authorities (NATA) accredited laboratory; ALS Group.

Once groundwater samples are collected they are transferred to, and stored in, a cooler with a temperature less than 4°C (i.e. to retard microbial activity and maintain sample representativeness).

All samples and analysis were recorded on a laboratory-appropriate Chain of Custody (COC) form, with associated procedures followed. Samples are couriered to the ALS Group office in Townsville, Queensland. Samples were then despatched from this location to the appropriate laboratories.

7.3.2 Data QA/QC

To determine the quality of the analytical data, and therefore the confidence of the data's use, The QA/QC of the data is conducted by both the laboratory and by CopperChem. The QA/QC procedures performed by each party are outlined below in

Table 8 and summarised in the following subsection

Table 8 Summary of QA/QC procedures performed by the laboratories and CopperChem

Procedure	Performed by	Purpose
Analysis of Holding Time Compliance	All	Provides information on sample integrity and data accuracy.
Duplicate	All	Provides information regarding analytical method precision and sample heterogeneity.
Blank	All	Monitor potential contamination by using an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation.
Control Spike	ALS Group	Monitor method precision and accuracy independent of the sample matrix by using a certified reference material "spiked" with target analytes.
Matrix Spike	ALS Group	Monitor potential matrix effects on analyte recoveries using a split sample spiked with a representative set of target analytes.
Ionic Balance	CopperChem ALS Group	Provides information regarding the accuracy of the chemical analysis, specifically that of the major ions.
Comparison between Dissolved or Total Constituents	CopperChem	Provides information regarding the accuracy of the chemical analysis – using Relative Percent Difference (RPD) calculations

7.3.2.1 Ionic Balance

Ionic balance calculations are used to verify the accuracy of the major ion analysis. The concentration of the major ions is first converted from milligrams per litre (mg/L) to milli-equivalents per litre (meq/L) before being used in the following calculation:

$$\%\ \mathbf{Difference} = \mathbf{100} \times \frac{\boldsymbol{\Sigma}\mathbf{cations} - \boldsymbol{\Sigma}\mathbf{anions}}{\boldsymbol{\Sigma}\mathbf{cations} + \boldsymbol{\Sigma}\mathbf{anions}}$$

The anion sum determines the acceptable percentage difference as follows:

- Anion sum of 0 – 3 meq/L: Acceptable difference of ± 0.2meq/L;
- Anion sum of 3 -10 meq/L: Acceptable difference of ± 2%; and
- Anion sum of 10 – 800 meq/L: Acceptable difference of ±5%.

7.3.2.2 Comparison between Duplicate Samples

The similarity of a duplicate sample to the primary sample is determined via a Relative Percentage Difference (RPD) calculation, with the acceptance criterion being dependent on the detection limit of the analyte. The RPD value is calculated by the following equation:

$$\mathbf{Relative\ Percentage\ Difference}\ (\%) = \frac{\mathbf{Concentration}_{\mathbf{Sample\ A}} - \mathbf{Concentration}_{\mathbf{Sample\ B}}}{\mathbf{Average\ concentration\ of\ Sample\ A + Sample\ B}}$$

The acceptance criterion for the RPD value is as follows:

- No limit: result is less than 10 times the detection limit of the analyte;
- 0% – 50%: result is between 10 and 20 times the detection limit of the analyte; and
- 0% – 20%: result is greater than 20 times the detection limit of the analyte.

8 Groundwater Characterisation (Hydrochemistry) at GAM

In order to characterise the "type or facies" of groundwater present, only appropriate hydrochemical data could be analysed. For example, although it is specified in the EE that aquifer types be identified, not all available data in the CopperChem dataset was suitable. In order to characterise aquifer types or hydrochemical facies, specific analytes must be analysed for. Typically these include major cations (sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+})) and anions (sulphate (SO_4^{2-}), chloride (Cl^-), bicarbonate (HCO_3^-) and carbonate (CO_3^{2-})).

However, the CopperChem EA does not specify that complete major anion and cation suites are required; therefore previous datasets were incomplete. Therefore in order to identify hydrochemical facies of groundwater, complete anion and cation suites are required. Nevertheless, some historical and more recent (May 2014 onwards) anion/cation data exists; these datasets were used in this assessment.

8.1 Hydrochemical Characterisation Methods

A variety of methods were carried out to examine the hydrochemistry of groundwater across the GAM site; especially in an effort to identify groundwater "facies". Where satisfactory data was available, the assessment process included:

- Calculation of ionic relationships for all major ions ($Na^+ + K^+$, Ca^{2+}, Mg^{2+}, SO_4^{2-} & $HCO_3^- + CO_3^{2-}$), and in some cases, ionic ratios with respect to chloride (Cl^-);
- Determination of major hydrochemical water types (i.e. facies); and
- Preparation of Piper diagrams (Trilinear diagrams) used to identify water quality (using major ions).

These methods are described in more detail in the subsections below.

The following screening criteria were applied to the GAM hydrochemical dataset to identify useable data. The criteria included:

- The available data must have measureable concentrations of all major cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) and anions (SO_4^{2-}, Cl^-, HCO_3^- and CO_3^{2-});
- pH values of the available data must be within a range of 6 to 9 standard units; and
- Ion balance of the available data must be within ± 5%.

These are discussed in more detail in the following subsections.

8.1.1 Ionic Ratios/Relationships

Select ion ratios/relationships for all major cations and anions ($Na^+ + K^+$, Ca^{2+}, Mg^{2+}, SO_4^{2-}, and $HCO_3^- + CO_3^{2-}$) were assessed from detailed hydrochemical results from each bore location. In some cases ratios were calculated with respect to Cl^- because of its conservative nature as an anion (i.e. it is rarely involved in mineral dissolution/precipitation reactions within an aquifer). Therefore, using Cl^- in this manner limits its source to recharge and mixed waters, thus, potentially identifying a source. Also, the chemical inertness of Cl^- means that its concentration in an aquifer is mainly influenced by dissolution of resident salts or dilution processes. Therefore, by calculating major ion to Cl^- ratios, groundwater chemistries can be easily compared since the processes of salt concentration and dilution within an aquifer have been nullified.

In order to calculate and illustrate ionic ratios, in a spatial context, all water quality data was changed from mg/L to meq/L. The concentration of various constituents must be converted to meq/L so that the various ions can be presented, in a chemically meaningful way.

8.1.2 Facies Determination

The calculation/determination of hydrochemical [groundwater] facies was carried out to identify or establish a hydrogeochemical “fingerprint” of groundwater occurring in GAM systems. Hydrochemical facies represent the chemical response of the interrelated effects of the lithology, anthropogenic activities and the pattern of groundwater flow.

The determination of hydrochemical facies was carried out using software package AquaChem 2014.1; in conjunction with PHREEQ.

8.1.3 Trilinear (Piper) Diagrams

Trilinear diagrams (i.e. Piper diagrams) were also prepared as a means to help identify groundwater facies in a spatial context. Piper diagrams show the relative concentrations of ions in solutions, in this case, cations Ca^{2+}, Mg^{2+}, and $Na^+ + K^+$, and anions Cl^-, SO_4^{2-}, and HCO_3^-. In most [natural] waters, these ions make up 95% to 100% of the ions in solution.

The Piper diagram includes two Trilinear diagrams, one for anions (on the lower right) and one for cations (on the lower left). For each sample, the information from each Trilinear diagram is projected up into the central [diamond] quadrilateral. Therefore, each sample will plot in each frame of the Piper, one representing cations, one representing anions, and one representing the combination.

For each constituent, the concentration (in mg/l) is converted to milli-equivalents (meq/l) based on the valence and atomic weight, normalised to 100% and plotted on the Piper. Each Trilinear diagram shows the relative percentages of each of the ions. Each apex in the Trilinear system represents 100% of that ion.

Trilinear diagrams (Piper diagrams) were developed using software package Rockworks 16.

9 Results of Hydrochemical Assessments

In an effort to identify groundwater "types of facies" at the GAM site, and the potential impacts to groundwater quality as a result from operational activities, this section discusses the results from the chemical and statistical assessments as performed on groundwater data from each bore group(refer Section 6.1). These will be discussed in turn.

9.1 Observation Bores (OB-series)

General Characteristics and Hydrochemical Facies:

Based on the data compiled for this study, groundwater pH as measured from the Observation Bores (OB) ranges from 6.30 to 8.24, but can be considered circumneutral based on a median pH of ~6.90. The Total Dissolved Solids[8] (TDS) also exhibits a considerable range from 1,142 mg/L to 8,098 mg/L.

Magnesium (Mg^{2+}) exists as the dominant cation, exhibiting a range from 79 to 917 mg/L (median 298.5 mg/L); this is followed by Na^{+} which ranges from 142 to 791 mg/L (median 326 mg/L) and Ca^{2+} ranging from 48 to 482 mg/L (median of 265 mg/L)). Potassium offers little contribution to the TDS concentration as it ranges from 2 to 8 mg/L. The dominant anions as measured in groundwater are SO_4^{2-} and HCO_3^{-}; ranging from 258 to 4880 mg/L and 265 to 768 mg/L, respectively. Chloride (Cl^{-}) and CO_3^{-} offer little contribution to the overall anion budget.

The distribution of the major ions, as measured from groundwater in the OB-series bores, is shown in the Piper diagram on Figure 9. It is evident from Figure 9 that an ionic signature in groundwater, from most of the OB-series bores, has a common provenance. However, the exception to this includes OB15 and OB18.

In terms of hydrochemical facies, groundwater from the OBs varies from $Mg^{2+}>Na^{+}>SO_4^{2-}>HCO_3^{-}$ to $Mg^{2+}>Na^{+}>SO_4^{2-}$ types. Although most groundwater, as measured from the OBs is dominated by Mg^{2+}, there is some degree of ion exchange occurring with Na^{+} at bore OB15 (Figure 8).

Major Ion Relationships:

Spatial coverage of the OBs, in terms of sampling locations, showed strong positive ionic relationships between:

- Mg^{2+} with SO_4^{2-} ($r^2 = 0.92$).
- Ca^{2+} with SO_4^{2-} ($r^2 = 0.85$).
- Ca^{2+} with Mg^{2+} ($r^2 = 0.73$).
- Ca^{2+} with Cl^{-} ($r^2 = 0.63$).
- Ca^{2+} with Na^{+} ($r^2 = 0.59$).
- Cl- with SO_4^{2-} ($r^2 = 0.51$).

[8]Calculated using Rockworks®

- Mg^{2+} with Na^{+} (r^2 = 0.72).

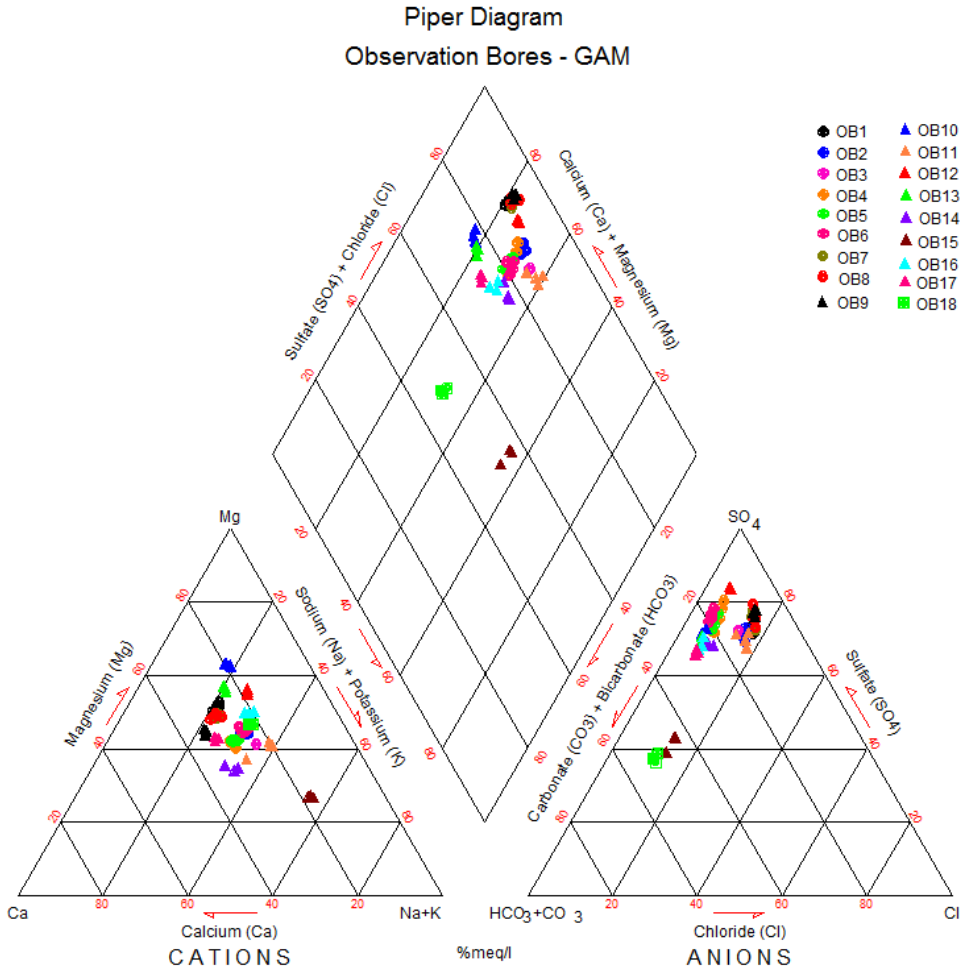

Figure 9 Piper Diagram of major ions measured from groundwater bores OB1 to OB18

Spatial coverage of all groundwater OBs at GAM, showing strong ionic relationships, will be discussed in Section10. A complete correlation coefficient analysis, for all major ions, is provided in Table 9.

Table 9 Correlation coefficient of major ions in Observation Bores OB1 to OB18

	Ca	Mg	Na	K	Cl	SO4	CO3	HCO3
Ca	1							
Mg	0.729138	1						
Na	0.594003	0.716095	1					
K	0.285019	0.041986	0.504524	1				
Cl	0.631585	0.42522	0.349881	0.084597	1			
SO4	0.845226	0.95843	0.804004	0.192544	0.509555	1		
CO3	-0.3519	-0.23587	-0.13558	0.029325	-0.17052	-0.28143	1	
HCO3	-0.19284	0.269152	0.378494	0.10008	-0.65582	0.182848	0.062806	1

Analyte Exceedances:

As specified in the EE (Section 3B(ii)), the following section lists the analyte exceedances, to those specified in Table C11 of the GAM EA (MIN100476406), as measured from groundwater bores OB1 to OB18.

Table 10 shows the results of the maximum (Max.), minimum (Min.) and median (Med.) results of physicochemical parameters (EC & pH) and metal/metalloid concentrations. The results compiled in Table 10were calculated from all available data. These are as follows:

- OB1 to OB6 – 1996 to present;
- OB7 to OB14 – 2005 to present; and
- OB15 to OB18 – 2006 to present.

As specified in the GAM EA, groundwater "Trigger" Levels and "Release" Limits are established by using the 80thand 95thpercentile, respectively, from reference bores. However, as previously discussed (Section 6.1.4), GAM reference bores were only recently installed on 15-Sept, 2014, and had not been sampled at the time of preparing this EE report. Therefore OB15 and OB18 have been used as proxy "Reference" bores for all OBs. However, as OB15 and OB18 are not official EA "Reference" bores, hydrochemical results from these will be used as a representation of baseline groundwater quality only for the purposes of the EE Report. These bores will not be used for establishing the "Reference Criteria" as specified in Table C11 of the GAM EA. Therefore, the "Trigger and Release" values, for reference in this report, will be the non-percentile concentrations as shown in Table C11 of the GAM EA and those presented in the ANZECC Guidelines (2000).

With reference to Table 10, this data shows the maximum (Max), minimum (Min) and median (Median) results for physicochemical and metal/metalloid parameters for all OBs. These are examined against ***1) Release Limit ANZECC – Guidelines for Livestock and Drinking Water (ANZECC[1]), and 2) Trigger level - ANZECC Guidelines for 95% protection of aquatic ecosystems (ANZECC[2]).*** Results in Table 10 show that most parameters have exceed one or both of the ANZECC criteria listed above.

However, the physicochemical parameter and analytes that continuously are in breach of the EA "Release" limit is EC and SO_4^{2-}, and for Cr and Cu for the "Trigger" limits.

Discussions involving physicochemical and analyte exceedances can be found in Section 10.

Table 10 Concentrations (Max, Min and Median) of physicochemical parameters (EC, pH) and metals/metalloids of groundwater measured from Observation Bores (OBs) - as specified in Table C11 of the CopperChem EA (MIN100476406).

		pH pH units	EC µS/cm	SO_4^{2-} mg/L	As mg/L	Cd mg/L	Cr mg/L	Co mg/L	Cu mg/L	Pb mg/L	Mg mg/L	Hg mg/L	Zn mg/L
ANZECC[1] "Release"		5.5-9.0	1000	1000	0.5	0.01	1.0	1.0	1.0	0.1	2000	0.002	20
ANZECC[2]"Trigger"		6.0-7.5	435	80th	0.013	0.0002	0.001	*80th	0.0014	0.0034	80th	0.0006	0.008
OB1	Max	**7.79[2]**	**4510[1]**	**2540[1]**	**0.013[2]**	0.000	**0.008[2]**	0.035	**0.060[2]**	0.002	490	0.000	**0.015[2]**
	Min	5.73	820	15	0.002	0.000	**0.001[2]**	0.001	0.001	0.001	7.00	0.000	0.006
	Median	**6.75[2]**	**2590[1]**	938	0.010	0.002	**0.005[2]**	0.007	**0.016[2]**	0.011	189	0.000	**0.008[2]**
OB2	Max	7.53	**11860[1]**	**3240[1]**	**0.030[2]**	0.002	**0.040[2]**	0.080	**0.308[2]**	**0.028[2]**	470	0.001	**0.216[2]**
	Min	**5.84[2]**	**1910[1]**	11.0	0.002	0.000	0.000	0.001	**0.001[2]**	0.000	5.00	0.000	0.001
	Median	6.73	**3880[1]**	**1176[1]**	0.009	0.000	**0.009[2]**	0.009	**0.038[2]**	**0.006[2]**	176	0.000	**0.033[2]**
OB3	Max	8.22	**4600[1]**	**5130[1]**	0.100	0.001	**0.151[2]**	0.065	**0.084[2]**	**0.016[2]**	900	0.001	**0.420[2]**
	Min	**5.60[2]**	**2360[1]**	110	0.001	0.000	**0.001[2]**	0.001	**0.001[2]**	0.001	42.0	0.001	0.004
	Median	6.84	**3680[1]**	**1890[1]**	0.007	0.000	**0.016[2]**	0.006	**0.014[2]**	**0.005[2]**	275	0.001	**0.034[2]**
OB4	Max	7.57	**4570[1]**	**5900[1]**	**0.020[2]**	0.002	**0.050[2]**	0.016	**0.140[2]**	**0.040[2]**	393	0.001	**0.270[2]**
	Min	**5.78[2]**	**1280[1]**	26.0	0.001	0.000	0.000	0.001	**0.001[2]**	0.001	15.0	0.000	0.005
	Median	6.70	**2850[1]**	893	0.007	0.000	**0.007[2]**	0.003	**0.018[2]**	**0.007[2]**	137	0.001	**0.023[2]**
OB5	Max	7.31	**5890[1]**	**3650[1]**	**0.030[2]**	0.001	**0.023[2]**	0.080	**1.150[1, 2]**	**0.089[2]**	513	0.001	**0.110[2]**
	Min	**5.59[2]**	**1800[1]**	28.0	0.001	0.000	**0.001[2]**	0.001	**0.001[2]**	**0.001[2]**	16.0	0.000	0.005
	Median	6.61	**3460[1]**	**1218[1]**	0.009	0.000	**0.006[2]**	0.005	**0.028[2]**	**0.015[2]**	201	0.000	**0.021[2]**
OB6	Max	8.23	**4970[1]**	**2830[1]**	**0.043[2]**	0.006	**0.100[2]**	0.080	**0.621[2]**	**0.056[2]**	432	0.001	**10.00[2]**
	Min	**5.70[2]**	**1240[1]**	8.00	0.001	0.000	**0.001[2]**	0.001	**0.001[2]**	0.001	4.0	0.000	0.005
	Median	6.68	**3270[1]**	**1091[1]**	0.009	0.001	**0.016[2]**	0.014	**0.049[2]**	0.010	183	0.000	**0.253[2]**
OB7	Max	**8.24[2]**	**5660[1]**	**3910[1]**	**0.018[2]**	0.002	**0.019[2]**	0.119	**0.927[2]**	**0.018[2]**	576	0.000	**0.310[2]**

		pH pH units	EC µS/cm	SO_4^{2-} mg/L	As mg/L	Cd mg/L	Cr mg/L	Co mg/L	Cu mg/L	Pb mg/L	Mg mg/L	Hg mg/L	Zn mg/L
ANZECC[1] "Release"		5.5-9.0	1000	1000	0.5	0.01	1.0	1.0	1.0	0.1	2000	0.002	20
ANZECC[2]"Trigger"		6.0-7.5	435	80th	0.013	0.0002	0.001	*80th	0.0014	0.0034	80th	0.0006	0.008
	Min	**4.84**[1]	0.10	28.0	0.001	0.000	**0.001**[2]	0.001	**0.004**[2]	0.001	2.00	0.000	0.005
	Median	6.63	**2410**[1]	970	0.008	0.000	**0.004**[2]	0.019	**0.073**[2]	**0.004**[2]	200	0.000	**0.037**[2]
OB8	Max	7.78	**4160**[1]	**2300**[1]	0.011	0.005	**0.010**[2]	0.361	**0.565**[2]	**0.013**[2]	388	0.000	**0.450**[2]
	Min	**5.40**[2]	0.14	11.00	0.001	0.000	**0.001**[2]	0.001	**0.001**[2]	0.001	2.00	0.000	0.005
	Median	6.76	**2003**[1]	663	0.005	0.001	**0.004**[2]	0.026	**0.049**[2]	**0.003**[2]	140	0.000	**0.044**[2]
OB9	Max	**7.90**[2]	**4110**[1]	**2540**[1]	**0.071**[2]	**0.003**[2]	**0.047**[2]	0.188	**0.287**[2]	**0.040**[2]	971	0.001	**0.354**[2]
	Min	**5.41**[1]	0.17	6.00	0.003	0.000	**0.001**[2]	0.001	**0.001**[2]	0.001	53.0	0.000	0.005
	Median	6.75	**2290**[1]	813	**0.020**[2]	0.000	**0.004**[2]	0.014	**0.016**[2]	**0.004**[2]	253	0.001	**0.015**[2]
OB10	Max	**7.74**[2]	**9690**[1]	**10200**[1]	**0.023**[2]	**0.002**[2]	**0.013**[2]	0.013	**0.091**[2]	**0.010**[2]	1200	0.001	**0.215**[2]
	Min	**5.71**[2]	**2180**[1]	**1220**[1]	0.003	0.000	**0.001**[2]	0.000	**0.001**[2]	0.001	0.018	0.000	0.001
	Median	6.51	**5130**[1]	**4746**[1]	**0.014**[2]	0.000	**0.003**[2]	0.003	**0.011**[2]	**0.004**[2]	720	0.000	**0.020**[2]
OB11	Max	7.46	**7660**[1]	**6970**[1]	**0.026**[2]	0.007	**0.062**[2]	0.219	**0.170**[2]	**0.030**[2]	1680	0.001	**0.480**[2]
	Min	**5.77**[2]	**1710**[2]	361	0.002	0.000	**0.001**[2]	0.000	**0.002**[2]	0.001	56.0	0.000	0.005
	Median	6.65	**3730**[1]	**1629**[1]	0.008	0.000	**0.007**[2]	0.008	**0.017**[2]	**0.006**[2]	279	0.001	**0.028**[2]
OB12	Max	7.11	**8180**[1]	**5910**[1]	**0.080**[2]	**0.010**[2]	**0.015**[2]	0.023	**0.144**[2]	**0.021**[2]	593	0.001	**0.187**[2]
	Min	**5.76**[2]	**2650**[1]	**1000**[1]	0.002	0.000	**0.001**[2]	0.001	**0.001**[2]	0.001	40.0	0.000	0.005
	Median	6.43	**5960**[1]	**3934**[1]	0.008	**0.001**[2]	**0.003**[2]	0.004	0.009	**0.006**[2]	91.8	0.001	**0.020**[2]
OB13	Max	7.63	**5160**[1]	**7060**[1]	0.010	**0.001**[2]	**0.029**[2]	0.058	**0.114**[2]	**0.020**[2]	99.0	0.001	**0.072**[2]
	Min	**5.53**[2]	0.49	174	0.002	0.000	**0.001**[2]	0.001	**0.001**[2]	0.001	2.00	0.000	0.004
	Median	6.67	**2690**[1]	**1356**[1]	0.004	0.000	**0.004**[2]	0.005	**0.007**[2]	**0.004**[2]	62.0	0.000	**0.015**[2]
OB14	Max	7.76	**2870**[1]	**1240**[1]	**0.014**[2]	**0.018**[2]	**0.011**[2]	0.060	**0.179**[2]	**0.017**[2]	680	0.001	**0.070**[2]

		pH pH units	EC µS/cm	SO_4^{2-} mg/L	As mg/L	Cd mg/L	Cr mg/L	Co mg/L	Cu mg/L	Pb mg/L	Mg mg/L	Hg mg/L	Zn mg/L
ANZECC[1] "Release"		**5.5-9.0**	**1000**	**1000**	**0.5**	**0.01**	**1.0**	**1.0**	**1.0**	**0.1**	**2000**	**0.002**	**20**
ANZECC[2]"Trigger"		**6.0-7.5**	**435**	**80th**	**0.013**	**0.0002**	**0.001**	***80th**	**0.0014**	**0.0034**	**80th**	**0.0006**	**0.008**
	Min	4.93[2]	0.43	60.0	0.002	0.000	**0.001[2]**	0.001	**0.001[2]**	0.001	41.0	0.000	0.006
	Median	6.64	**1980[1]**	507	0.006	**0.002[2]**	**0.003[2]**	0.009	**0.013[2]**	**0.004[2]**	349	0.001	**0.016[2]**
OB15	**Max**	**7.87[2]**	**2300[2]**	576	0.011	0.000	**0.001[2]**	0.002	**0.006[2]**	0.001	209	0.000	**0.041[2]**
	Min	**5.35[1]**	0.82	2.00	0.006	0.000	**0.001[2]**	0.001	**0.001[2]**	0.001	150	0.000	0.005
	Median	6.79	**1720[2]**	273	0.007	0.000	**0.001[2]**	0.002	**0.003[2]**	0.001	180	0.000	**0.017[2]**
OB16	**Max**	7.29	**6810[1]**	**4360[1]**	**0.233[2]**	0.000	0.000	0.022	**0.032[2]**	0.000	111	0.000	**0.011[2]**
	Min	**4.97[2]**	0.81	106	**0.142[2]**	0.000	0.000	0.007	**0.007[2]**	0.000	83.0	0.000	0.006
	Median	6.63	**3450[1]**	**1952[1]**	**0.182[2]**	0.000	0.000	0.013	**0.018[2]**	0.000	101	0.000	0.007
OB17	**Max**	7.37	**2770[1]**	**1280[1]**	0.018	**0.001[2]**	**0.016[2]**	0.035	**0.192[2]**	**0.014[2]**	921	0.000	**0.112[2]**
	Min	6.50	**2180[1]**	826	0.001	0.000	**0.001[2]**	0.001	**0.001[2]**	0.001	73.0	0.000	0.005
	Median	6.83	**2400[1]**	**1064[1]**	0.010	0.000	**0.003[2]**	0.007	**0.015[2]**	**0.004[2]**	401	0.000	**0.021[2]**
OB18	**Max**	8.45	**1600[1]**	333	**0.233[2]**	**0.018[2]**	0.000	0.060	**0.192[2]**	0.000	921	0.000	**0.112[2]**
	Min	6.80	**1400[1]**	229	0.001	0.000	0.000	0.001	**0.001[2]**	0.000	41.0	0.000	0.005
	Median	7.23	**1600[1]**	333	**0.067[2]**	**0.003[2]**	0.000	0.017	**0.051[2]**	0.000	324	0.000	**0.033[2]**

9.2 Tailings Storage Observation Bores (TSF-OB Series)

General Characteristics and Hydrochemical Facies:

Based on the data compiled for this study, groundwater pH as measured from the TSF-OBs ranges from 7.1 to 6.5, but can be considered circumneutral based on a median pH of 6.58. The Total Dissolved Solids[9] (TDS) and Electrical Conductivity (EC) also range from 1,142 mg/L to 8,098 mg/L and 0.81 mS/cm to 4.1 mS/cm.

In terms of relevant abundance, Ca^{2+} exists as the dominant cation, exhibiting a range from 140 to 774 mg/L (median 573 mg/L); this is followed by Na^{+} which ranges from 162 to 428

[9]Calculated using Rockworks®

mg/L (median 162 mg/L) and Mg^{2+} (ranging from 115 to 396 mg/L and a mean of 254 mg/L)). Potassium offers little contribution to the TDS concentration as it ranges from 2 to 11 mg/L.

The anions, as measured in groundwater are SO_4^{2-}(ranging between 606 to 3090 mg/L and an average of 2066 mg/L) with similar concentrations of Cl^- (ranging between 147 to 501 mg/L, and an average of 374 mg/L) and HCO_3^-(ranging between 231 to 398 mg/L and an average of 273 mg/L). Carbonate (CO_3^{2-}) offers no input to the overall contribution to the anion budgets.

The distribution of the major ions, as measured from groundwater in the TSFOB-series bores, is shown in the Piper diagram on Figure 10. It is evident from Figure 10 that ionic signatures in groundwater, from most of the TSFOB-series bores, have a common provenance. However, the exception to this includes TSFOB7. The disparity in ionic concentration, as observed from water analysed from TSFOB7, is likely a direct result of the bore construction. For example, groundwater bore TSFOB7 is almost twice as deep as neighbouring bores; therefore, perhaps intersecting a different aquifer.

In terms of hydrochemical facies, groundwater from the TSFOBs varies from $Mg^{2+}>Na^+>SO_4^{2-}>Cl^-$ to $Mg^{2+}>Na^+>SO_4^{2-}$ types. Although most groundwater, as measured from the TSOBs is dominated by Ca^{2+}, there is some degree of ion exchange occurring with Na^+ at bore TSF-OB7 (Figure 8).

Major Ion Relationships and Statistical Analysis:

Spatial coverage of the TSFOBs, in terms of sampling locations, showed strong positive ionic relationships between:

- Ca^{2+} with HCO_3^- ($r^2 = 0.90$);
- Ca^{2+} with Cl^- ($r^2 = 0.73$);
- Mg^{2+} with SO_4^{2-}($r^2 = 0.71$);
- Na^+ with SO_4^{2-}($r^2 = 0.59$); and
- Cl^- with HCO_3^-($r^2 = 0.50$).

Spatial coverage of all TSFOBs at GAM, showing strong ionic relationships, will be discussed is discussed in Section 10. A complete correlation coefficient analysis, for all major ions, is provided in Table 11.

Table 11

Table 11 Correlation coefficient of major ions in Tailings Storage Facility Observation Bores TSFOB1, TSFOB4a to TSFOB11

	Ca	Mg	Na	K	Cl	SO4	CO3	HCO3
Ca	1							
Mg	0.132311	1						
Na	-0.14002	0.47527	1					
K	0.052193	0.642194	0.595024	1				
Cl	0.728944	-0.14179	-0.35697	-0.44688	1			
SO4	0.471065	0.713525	0.593302	0.647014	0.033452	1		
CO3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1	
HCO3	-0.90454	-0.43436	-0.09761	-0.39368	-0.50028	-0.67556	0.0000	1

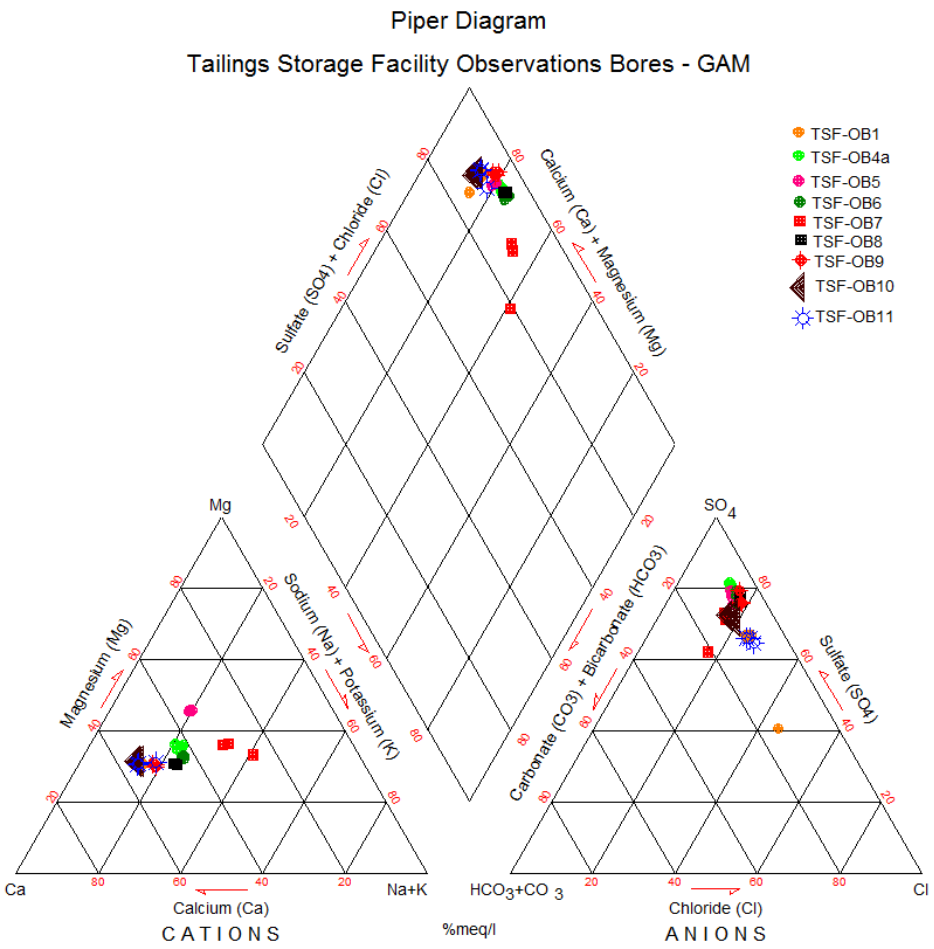

Figure 10 Piper Diagram of major ions measured from groundwater bores TSFOB1, TSFOB4a & TSFOB5 to TSFOB11

Analyte Exceedances:

As specified in the EE (Section 3B(ii)), the following section lists the analytes and their accepted exceedances, to those specified in Table C11 of the CopperChem EA (MIN100476406), as measured from groundwater bores TSFOB1, TSFOB4a to TSFOB11.

As discussed with the General OBs, groundwater "Trigger" Levels and "Release" Limits are established by using the 80thand 95thpercentile, respectively, from reference bores. However, as previously discussed (Section 6.1.4), GAM reference bores were only recently installed on 15-Sept, 2014, and had not been sampled at the time of preparing this EE report. OSOB1 to OSOB3 and PLOB1 and PLOB2 were used as proxies. Results for these proxy "Reference" bores are discussed under Section 9.3.

As the abovementioned bores are not official EA "Reference" bores, hydrochemical results from these will be used as a representation of baseline groundwater quality only for the purposes of the EE Report. These bores will not be used for establishing the "Reference Criteria" as specified in Table C11 of the GAM EA. Therefore, the "Trigger and Release" values, for reference in this report, will be the non-percentile concentrations as shown in Table C11 of the GAM EA and those presented in the ANZECC Guidelines (2000).

With reference toTable 10, these data show the maximum (Max), minimum (Min) and median (Median) results for physicochemical and metal/metalloid parameters for all OBs. These are examined against ***1) Release Limit ANZECC – Guidelines for Livestock and Drinking Water (ANZECC[1]), and 2) Trigger level - ANZECC Guidelines for 95% protection of aquatic ecosystems (ANZECC[2]).*** Results in Table 12 show that most parameters have exceed one or both of the ANZECC criteria listed above.

However, the physicochemical parameter and analytes that continuously are in breach of the EA "Release" limit is EC and SO_4^{2-}, and for Cr and Cu for the "Trigger" limits.

Discussions involving physicochemical and analyte exceedances is discussed in Section 10.

Table 12 shows the concentrations of physicochemical parameters (EC & pH) and metals/metalloids as measured in groundwater from TSFOBs and as specified in Table C11 of the GAM EA. The results compiled in Table 12 were calculated from historical data; following the date of bore installation. These are as follows:

- TSFOB1 to TSFOB11 – 2011 to present.

With reference to Table 12 it is evident that most physicochemical and metal/metalloid results have exceeded the EA Trigger, at each bore, since its installation. Similarly to the General OBs, EC and SO_4^{2-} persist in exceeding EA "Release" limits.

Further analyses involving physicochemical and analyte exceedances is discussed in Section 10.

Table 12 Concentrations (Max, Min and Avg) of physicochemical parameters (EC, pH) and metals/metalloids of groundwater measured from Tailings Storage Facility Observation Bores (TSFOBs) - as specified in Table C11 of the CopperChem EA (MIN100476406).

		pH *pH units*	EC µS/cm	SO_4^{2-} mg/L	As mg/L	Cd mg/L	Cr mg/L	Co mg/L	Cu mg/L	Pb mg/L	Mg mg/L	Hg mg/L	Zn mg/L
ANZECC[1] "Release"		5.5-9.0	1000	1000	0.5	0.01	1.0	1.0	1.0	0.1	2000	0.002	20
ANZECC[2]"Trigger"		6.0-7.5	435	80th	0.013	0.0002	0.001	*80th	0.0014	0.0034	80th	0.0006	0.008
TSFOB1	**Max**	7.57[2]	4130[1]	1800[1]	0.003	0.000	0.007[2]	0.089	**0.404[2]**	0.003[2]	226	0.000	0.093[2]
	Min	6.02	0.83	60.0	0.001	0.000	0.001[2]	0.001	**0.002[2]**	0.001	47.0	0.000	0.005
	Median	6.66	2500[1]	419	0.001	0.000	0.004[2]	0.019	**0.051[2]**	0.002	169	0.000	0.023[2]
TSFOB4a	**Max**	7.76	**4580[1]**	**3190[1]**	0.006	0.001	**0.003[2]**	**0.032**	**0.596[2]**	**0.008[2]**	366	0.000	**0.148[2]**
	Min	6.18	**1750[1]**	**1540[1]**	0.002	0.000	**0.001[2]**	0.001	**0.001[2]**	**0.008[2]**	203	0.000	0.006
	Median	6.68	**3610[1]**	**2335[1]**	0.004	0.000	**0.002[2]**	0.005	**0.048[2]**	**0.008[2]**	291	0.000	**0.025[2]**
TSFOB5	**Max**	7.79	**4400[1]**	**2930[1]**	0.006	0.000	**0.003[2]**	0.014	**0.030[2]**	0.000	484	0.000	**0.022[2]**
	Min	6.20	**1770[1]**	831	0.003	0.000	**0.001[2]**	0.001	**0.001[2]**	0.000	145	0.000	0.006
	Median	6.80	**3460[1]**	**2183[1]**	0.004	0.000	**0.002[2]**	0.003	**0.005[2]**	0.000	344	0.000	**0.011[2]**
TSFOB6	**Max**	7.34	**4740[1]**	**2900[1]**	0.007	0.000	**0.003[2]**	0.039	**0.137[2]**	**0.004[2]**	352	0.000	**0.067[2]**
	Min	6.30	**1870[1]**	612	0.002	0.000	**0.001[2]**	0.001	**0.001[2]**	0.002	109	0.000	0.006
	Median	6.67	**3550[1]**	**2130[1]**	0.005	0.000	**0.002[2]**	0.005	**0.011[2]**	**0.003[2]**	253	0.000	**0.014[2]**
TSFOB7	**Max**	8.00	**3890[1]**	**2160[1]**	0.022	0.000	0.005	0.001	**0.025[2]**	0.002	259	0.000	**0.029[2]**
	Min	6.45	**1510[1]**	219	0.004	0.000	0.004	0.001	**0.001[2]**	0.001	18.0	0.000	0.005
	Median	7.34	**2490[1]**	914	0.010	0.000	0.005	0.001	**0.007[2]**	0.002	124	0.000	**0.013[2]**
TSFOB8	**Max**	7.91	**4840[1]**	**2820[1]**	0.007	0.000	**0.002[2]**	0.010	**0.024[2]**	0.001	276	0.000	**0.021[2]**
	Min	6.38	**1630[1]**	872	0.002	0.000	**0.001[2]**	0.001	**0.001[2]**	0.001	104	0.000	**0.006[2]**
	Median	6.80	**3580[1]**	**2216[1]**	0.004	0.000	**0.002[2]**	0.005	**0.005[2]**	0.001	231	0.000	**0.011[2]**

		pH *pH units*	EC µS/cm	SO_4^{2-} mg/L	As mg/L	Cd mg/L	Cr mg/L	Co mg/L	Cu mg/L	Pb mg/L	Mg mg/L	Hg mg/L	Zn mg/L
ANZECC[1] "Release"		**5.5-9.0**	**1000**	**1000**	**0.5**	**0.01**	**1.0**	**1.0**	**1.0**	**0.1**	**2000**	**0.002**	**20**
ANZECC[2]"Trigger"		**6.0-7.5**	**435**	**80th**	**0.013**	**0.0002**	**0.001**	***80th**	**0.0014**	**0.0034**	**80th**	**0.0006**	**0.008**
TSFOB9	**Max**	7.57	**4720[1]**	**2830[1]**	0.003	0.000	**0.002[2]**	0.006	**0.104[2]**	0.002	282	0.000	**0.031[2]**
	Min	6.12	**1930[1]**	**1880[1]**	0.001	0.000	**0.001[2]**	0.001	**0.002[2]**	0.001	193	0.000	0.005
	Median	6.60	**3660[1]**	**2346[1]**	0.002	0.000	**0.001[2]**	0.002	**0.011[2]**	0.002	246	0.000	**0.011[2]**
TSFOB10	**Max**	7.77	**4000[1]**	**1920[1]**	0.004	0.001	**0.011[2]**	0.048	**0.162[2]**	**0.004[2]**	259	0.000	**0.083[2]**
	Min	5.70[2]	**1520[1]**	678	0.001	0.000	**0.001[2]**	0.001	**0.001[2]**	0.001	82.0	0.000	0.005
	Median	6.66	**2700[1]**	**1456[1]**	0.002	0.000	**0.004[2]**	0.010	**0.021[2]**	**0.003[2]**	166	0.000	**0.019[2]**
TSFOB11	**Max**	7.59	**3830[1]**	**2580[1]**	0.002	0.000	**0.002[2]**	0.046	**0.124[2]**	0.000	203	0.000	**0.080[2]**
	Min	6.05	**1100[1]**	380	0.001	0.000	**0.001[2]**	0.001	0.000	0.000	57.0	0.000	0.005
	Median	6.69	**2640[1]**	**1402[1]**	0.002	0.000	**0.001[2]**	0.006	**0.017[2]**	0.000	156	0.000	**0.019[2]**

9.3 Paddock Lode and Orphan Shear Observation Bores (PLOB and OSOB)

General Characteristics and Hydrochemical Facies:

Based on the data compiled for this study, groundwater pH as measured from the PLOBs ranges from 6.98 to 7.24, but can be considered circumneutral based on a median pH of 7.10. The Total Dissolved Solids[10] (TDS) also exhibits a considerable range from 1,179 to 3,500 mg/L. Groundwater abstracted and analysed from Orphan Shear bores (OSOBs) show pH ranging from 6.87 to 7.04 and TDS concentrations between 1,024 mg/L and 1,965 mg/L.

In terms of relevant abundance, Na^+ exists as the dominant cation, exhibiting a range from 83 to 438 mg/L (median 263 mg/L); this is followed byCa^{2+} and Mg^{2+}which ranges from 56 to 385 mg/L (median 136 mg/L) and Mg^{2+} (ranging from 49 to 200 mg/L and a median of 95 mg/L)). Potassium offers little contribution to the TDS concentration as it ranges from 1 to 29 mg/L; PLOBs and OSOBs have the highest concentration of K^+ than any other bores at GAM.

[10]Calculated using Rockworks 16®

The anions in decreasing order of significance, as measured in groundwater, are SO_4^{2-} (ranging between 222 to 1,380 mg/L and an average of 453 mg/L), HCO_3^- (ranging between 439 to 916 mg/L and an average of 582 mg/L) and Cl^- (ranging between 45 to 311 mg/L and an average of 115 mg/L) and HCO_3^-. Carbonate (CO_3^{2-}) offers no input to the overall contribution to the anion budgets.

Major Ion Relationships and Statistical Analysis:

Spatial coverage of the OSOBs and PLOBs, in terms of sampling locations, showed strong positive ionic relationships between:

- Mg^{2+} with Cl^- ($r^2 = 0.98$).
- Cl^- with SO_4^{2-} ($r^2 = 0.97$).
- Mg^{2+} with SO_4^{2-} ($r^2 = 0.95$).
- Mg^{2+} with HCO_3^- ($r^2 = 0.93$).
- Ca^{2+} with SO_4^{2-} ($r^2 = 0.87$).
- Na^+ with HCO_3^- ($r^2 = 0.86$).
- Ca^{2+} with Cl^- ($r^2 = 0.78$).
- Ca^{2+} with Mg^{2+} ($r^2 = 0.77$).
- Mg^{2+} with Na^+ & Na^+ with Cl^- ($r^2 = 0.76$).
- Na^+ with SO_4^{2-} ($r^2 = 0.66$).
- Ca^{2+} with HCO_3^- ($r^2 = 0.62$).

Spatial coverage of OSOBs and PLOBs at GAM, showing strong ionic relationships, is discussed in Section 10. A complete correlation coefficient analysis, for all major ions, is provided in Table 13.

Table 13 Correlation coefficient of major ions in Orphan Shear and Paddock Lode Observation Bores (i.e. OSOB1 to OSOSB3 and PLOB 1 and PLOB2)

	Ca	Mg	Na	K	Cl	SO4	CO3	HCO3
Ca	1							
Mg	0.766565	1						
Na	0.231229	0.756737	1					
K	0.787088	0.590207	0.344484	1				
Cl	0.78321	0.980811	0.755352	0.650072	1			
SO4	0.873491	0.953882	0.657579	0.733935	0.971229	1		
CO3	0.244253	0.164215	0.101495	0.453666	0.140825	0.161423	1	
HCO3	0.616727	0.934907	0.860846	0.609206	0.934717	0.8713	0.143486	1

The distribution of the major ions, as measured from groundwater in the OSOB/PLOB-series bores, is shown in the Piper diagram on Figure 11. It is evident from Figure 11 that ionic signatures in groundwater from this suite of bores are somewhat variable. For example, despite their spatial separation, there appears to be some degree of clustering between OSOB1, OSOB3 & PLOB1 (Figure 8). Similarly another cluster seems to appear between OSOB2 and PLOB2.

In terms of hydrochemical facies, groundwater from the PLOBs and OSOBs is of the $Na^{+}>Mg^{2+}>HCO_3^{-}>SO_4^{2-}$type; however, there is some degree of ionic substitution with Mg^{2+}(opposed to Na^{+}) at bore OSOB2 (Figure 8).

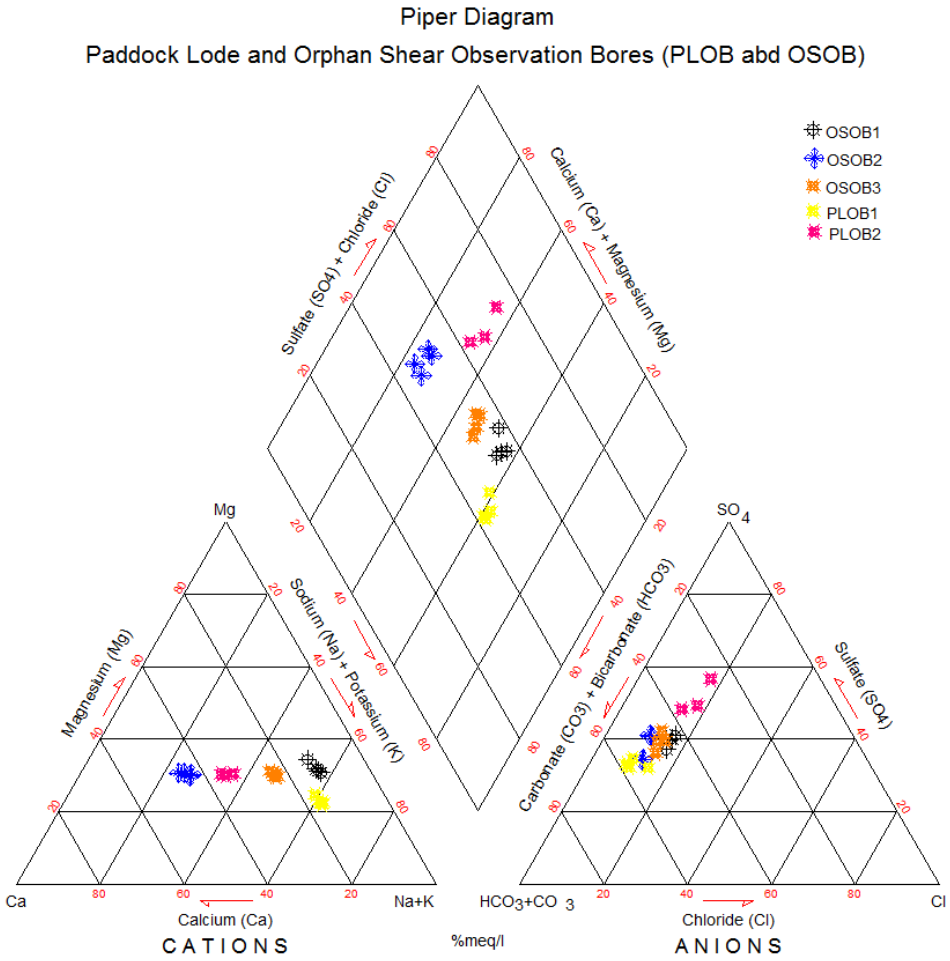

Figure 11 Piper Diagram of major ions measured from groundwater bores OSOB1 to OSOB3 & PLOB1 & PLOB2

Analyte Exceedances:

As specified in the EE (Section 3B(ii)), the following section lists the analytes and their accepted exceedances, to those specified in Table C11 of the CopperChem EA (MIN100476406), as measured from groundwater bores OSOB 1 to OSOB3 and PLOB1 to PLOB2.

As discussed previously, groundwater "Trigger" Levels and "Release" Limits are established by using the 80th and 95th percentile, respectively, from reference bores. However, as previously discussed (Section 6.1.4), GAM reference bores were only recently installed on 15-Sept, 2014, and had not been sampled at the time of preparing this EE report. Therefore OSOB1 to OSOB3 and PLOB1 and PLOB2 were used as proxies.

However, these are not official EA "Reference" bores, hydrochemical results from these will be used as a representation of baseline groundwater quality only for the purposes of the EE Report. These bores will not be used for establishing the "Reference Criteria" as specified in Table C11 of the GAM EA. Therefore, the "Trigger and Release" values, for reference in this report,will be the non-percentile concentrations as shown in Table C11 of the GAM EA and those presented in the ANZECC Guidelines (2000).

With reference to Table 10, these data show the maximum (Max), minimum (Min) and median (Median) results for physicochemical and metal/metalloid parameters for all OBs. These are examined against ***1) Release Limit ANZECC – Guidelines for Livestock and Drinking Water (ANZECC[1]), and 2) Trigger level - ANZECC Guidelines for 95% protection of aquatic ecosystems (ANZECC[2]).***Results in Table 10Table 14 show that most parameters have exceed one or both of the ANZECC criteria listed above. Table 14 shows the concentrations of physicochemical parameters (EC & pH) and metals/metalloids as measured in groundwater from OSOBs and PLOBs and as specified in Table C11 of the GAM EA. The results compiled in Table 12Table 14 were calculated from historical data; following the date of bore installation. These are as follows:

- OSOB1 to OSOB3 – 2013 to present; and
- PLOB1 and PLOB2 – 2013 to present.

With reference to Table 14 it is evident that EC has exceeded the EA "Release" limit at all bores; and SO_4^{2-}exceeds "Release" limits at PLOB1 and PLOB2, since their installation. However, the analytes that continuously are in breach of the EA "Trigger" limit is Cu and Zn for most bores.

Further analyses involving physicochemical and analyte exceedances is discussed in Section Table 10.

Table 14 Concentrations (Max, Min and Med) of physicochemical parameters (EC, pH) and metals/metalloids of groundwater measured from Orphan Shear and Paddock Lode Observation Bores (OSOB and PLB- series) - as specified in Table C11 of the CopperChem EA (MIN100476406).

		pH *pH units*	EC µS/cm	SO_4^{2-} mg/L	As mg/L	Cd mg/L	Cr mg/L	Co mg/L	Cu mg/L	Pb mg/L	Mg mg/L	Hg mg/L	Zn mg/L
ANZECC[1] "Release"		**5.5-9.0**	**1000**	**1000**	**0.5**	**0.01**	**1.0**	**1.0**	**1.0**	**0.1**	**2000**	**0.002**	**20**
ANZECC[2]"Trigger"		**6.0-7.5**	**435**	**80th**	**0.013**	**0.0002**	**0.001**	***80th**	**0.0014**	**0.0034**	**80th**	**0.0006**	**0.008**
OSOB1	**Max**	7.55[2]	**2460[1]**	483	0.003	0.000	0.000	0.006	**0.013[2]**	0.000	116	0.000	**0.009[2]**
	Min	6.59	**1860[1]**	204	0.003	0.000	0.000	0.006	0.001	0.000	76.0	0.000	**0.009[2]**
	Median	7.11	**2100[1]**	358	0.003	0.000	0.000	0.006	0.005	0.000	98.1	0.000	**0.009[2]**
OSOB2	**Max**	7.64	**2190[1]**	666	0.004	0.001	0.011	0.048	**0.162[2]**	0.000	282	0.000	**0.083[2]**
	Min	6.86	**1400[1]**	235	0.001	0.000	0.000	0.001	0.000	0.000	57.0	0.000	0.005

		pH *pH units*	EC µS/cm	SO_4^{2-} mg/L	As mg/L	Cd mg/L	Cr mg/L	Co mg/L	Cu mg/L	Pb mg/L	Mg mg/L	Hg mg/L	Zn mg/L
ANZECC[1] "Release"		**5.5-9.0**	**1000**	**1000**	**0.5**	**0.01**	**1.0**	**1.0**	**1.0**	**0.1**	**2000**	**0.002**	**20**
ANZECC[2]"Trigger"		**6.0-7.5**	**435**	**80th**	**0.013**	**0.0002**	**0.001**	***80th**	**0.0014**	**0.0034**	**80th**	**0.0006**	**0.008**
	Median	7.22	**1750[1]**	393	0.002	0.000	0.002	0.013	**0.035[2]**	0.000	146	0.000	**0.025[2]**
OSOB3	**Max**	7.56	**1880[1]**	329	0.003	0.000	0.000	0.002	0.006	0.002	75.0	0.000	**0.008[2]**
	Min	6.49	**1370[1]**	192	0.002	0.000	0.000	0.002	0.001	0.002	65.0	0.000	**0.008[2]**
	Median	6.97	**1560[1]**	266	0.002	0.000	0.000	0.002	0.003	0.002	70.7	0.000	**0.008[2]**
PLOB1	**Max**	7.76	**4150[1]**	**1370[1]**	0.003	0.000	0.000	0.004	**0.007[2]**	0.002	227	0.000	0.006
	Min	7.13	**1440[1]**	210	0.002	0.000	0.000	0.001	**0.001[2]**	0.000	37.0	0.000	0.006
	Median	7.51	**1830[1]**	507	0.002	0.000	0.000	0.002	**0.003[2]**	0.000	75.3	0.000	0.006
PLOB2	**Max**	7.23	**4110[1]**	**1480[1]**	0.010	0.000	0.000	0.006	0.002	0.001	200	0.000	**0.011[2]**
	Min	6.96	**3890[1]**	**1380[1]**	0.008	0.000	0.000	0.005	0.002	0.001	197	0.000	0.006
	Median	7.09	**4000[1]**	**1430[1]**	0.009	0.000	0.000	0.006	0.002	0.001	198	0.000	**0.009[2]**

10 Discussion of Results

Historical to present-day hydrochemical data was interpreted in an effort to better understand the groundwater regime at GAM. More precisely, groundwater chemistry results were interpreted to study the extent to which mining operations has affected groundwater quality (if any). In summary, the suite of groundwater bores that were studied included:

- A total of 18 general Observation Bores (OB) have been installed down-hydraulic gradient from the CopperChem Administration Building and Crystal/SX Plant, Heap Leach area, Stormwater and Process Ponds and Run-of-Mine (ROM) pad and up-hydraulic gradient to the Coppermine Creek (Figure 8);

- A total of 11 Tailings Storage Facility Observation Bores (TSFOB). These TSFOB-series bores have been installed to the north, south, west and east of the TSF footprint (Figure 8);and up-gradient to the Coppermine Creek; and

- A total of 5 groundwater bores that have been installed near to former mine operations, Orphan Shear and Paddock Lode Pits, to be used as monitoring points

to measure the effects (if any) these former operations had on receiving waters(Figure 8).

- In the case of Orphan Shear Observation Bores (OSOB-series), these bores were installed to monitor any negative effects to groundwater and receiving waters as a result of these former mining operations.
- In the case of Paddock Lode Observation Bores (PLOB-series), these bores were installed to monitor the effects (if any) of these previous mining activities to down-gradient receptors (i.e. Coppermine Creek).

In an effort to better understand the groundwater regime at GAM, all hydrochemical results were interpreted using several analytical methods. These are discussed in Section 9.

10.1 Groundwater Quality

Groundwater quality at the GAM site was evaluated using major ion (Mg^{2+}, Ca^{2+}, Na^{+}& K^{+}& Cl^{-}, SO_4^{2-}, CO_3^{2-} and HCO_3^{-}) chemistry and the use of metal/metalloid concentrations (i.e. Cu, As etc.).

Through the application of Piper diagrams (refer Section 8.1.3) water quality characteristics from each of the groundwater bore “groupings” were assessed. The Piper diagrams for the OB-series bores, TSF-series bores and OSOB/PLOB-series bores are presented as Figure 9, Figure 10 and Figure 11, respectively. Results from the hydrochemical facies assessment indicate that water chemistry, across the GAM site, is highly variable. The variability has little to do with geology and may be a result of mining activities. For example, Figure A (Appendix 2) shows the spatial distribution of groundwater bores across the GAM site and superimposed over the local geology. Figure A (Appendix 1) shows that the majority of groundwater bores occur within a brecciated calc-silicate unit known as the Stavely Formation; a calcareous to ferruginous, feldspathic and siliceous arenite with siltstone and mudstone (minor marble and conglomerate). While most of the groundwater bores have been installed in the Stavely Fm., PLOB1, PLOB2 and TSFOB10 have been constructed in the Corella Fm.; a calcium silicate unit dominated by calc-silicate rocks and other metasediments in the vicinity of a copper mineralised zone.

Although most of the groundwater bores have been completed in the Stavely Fm., there is little difference in the hydrochemical facies, between this unit (Mg^{2+}>Na^{+}>SO_4^{2-}>HCO_3)and the Corella Fm.,(Na^{+}>Mg^{2+}>HCO_3^{-}>SO_4^{2-}), apart from minor ionic substitution between Na^{+} and Mg^{2+} and HCO_3^{-}andSO_4^{2-}. This ionic substitution is likely a product of simple hydrochemical mixing of different water types; either natural background groundwater or from potential mining-affected groundwater. For example, and as a recap, as discussed previously the groundwater “Reference” bores used for the purposes of this report include, OSOB1, OSOB2, PLOB1 to PLOB3, OB15 and OB18. The hydrochemical facies of these bores is of the Na^{+}<>Mg^{2+}>HCO_3^{-}>SO_4^{2-} type. However, as intimated from previous investigations, shallow groundwater in the vicinity of the Heap Leach area and TSF, may be subjected to varying degrees of SO_4^{2-} exposure from the sulphuric acid (H_2SO_4) leach, or as a result of the [re]dissolution of salts. The exposure to additional sources of SO_4^{2-}may be a driving factor in altering the groundwater type (facies). For instance, where groundwater becomes enriched in SO_4^{2-}, increases in Ca^{2+} and Mg^{2+} can be observed. Similarly, and with reference to Figure B (Appendix 2), there is a clear decrease in Na^{+} to Cl^{-} ratios in the

area of the TSF. This may be the possible result of the [re]dissolution of sulfate-salts occurring in the TSF; and high salt-loaded waters intercepting fresher waters, the Na/Cl ratio decreases. In terms of the ionic ratios and Cl- comparisons, as described in 8.1.1, only the Na/Cl ratio provided reasonable results.

10.1.1 Contaminants of Concern

As specified in the DEHP EE, one of the contaminants of concern is groundwater being enriched in SO_4^{2-}; potentially as a result of mining activities (past and present). This can be observed in the SO_4^{2-} contour map (Figure C – Appendix 2). It can be seen in Figure C (Appendix 1) that those locations deemed as "reference" bores, for the purposes of this study, have much lower concentrations of SO_4^{2-} than in areas immediately down-gradient of the Heap Leach and TSF. For example, with reference to Ca^{2+} to SO_4^{2-} relationships, Figure D (Appendix 2), it is evident that the increased budget of SO_4^{2-}, potentially resulting from mining activities, skews the ratio away from Ca^{2+}. Conversely, in the areas of the "reference" bores (i.e. OSOB1, OSOB2, PLOB 1 to 3, OB15 and OB18 - Figure 8), where there is a decreased SO_4^{2-} budget in groundwater, the Ca^{2+} to SO_4^{2-} ratio shows an increase towards Ca^{2+} (0.2 to 0.3). The atypical ratio as seen in the area of TSFOB1 (Figure 8), where $Ca^{2+}$to SO_4^{2-} is 0.41, is likely a product of partial evaporite dissolution. And where there is an increased SO_4^{2-} budget in groundwater, there is a [not surprisingly] positive correlation with EC (Figure E – Appendix 2).

With the application Piper Diagrams, when comparing the proxy "Reference" bores to the General OBs and TSFOBs, there is evidence to suggest that a secondary source of SO_4^{2-} may be altering the groundwater quality at the OBs and TSFOBs (Figure 12). Similarly, the clustering of all bores with respect to the anion and cation apices in Figure 12 may be indicating a chemical fingerprint in relation to the local geology (i.e. mineral dissolution); however, this does not explain all bores in the suite.

With respect to increased SO_4^{2-} in groundwater at GAM, and with reference to historical trends (Figure 14), there appears to be some legacy issues associated with some groundwater bores. For example, historical trends of SO_4^{2-} in all General OBs, with the exception of OB 8 and OB14, exceeded the SO_4^{2-} "Release" trigger prior to CopperChem taking over operations in 2009.

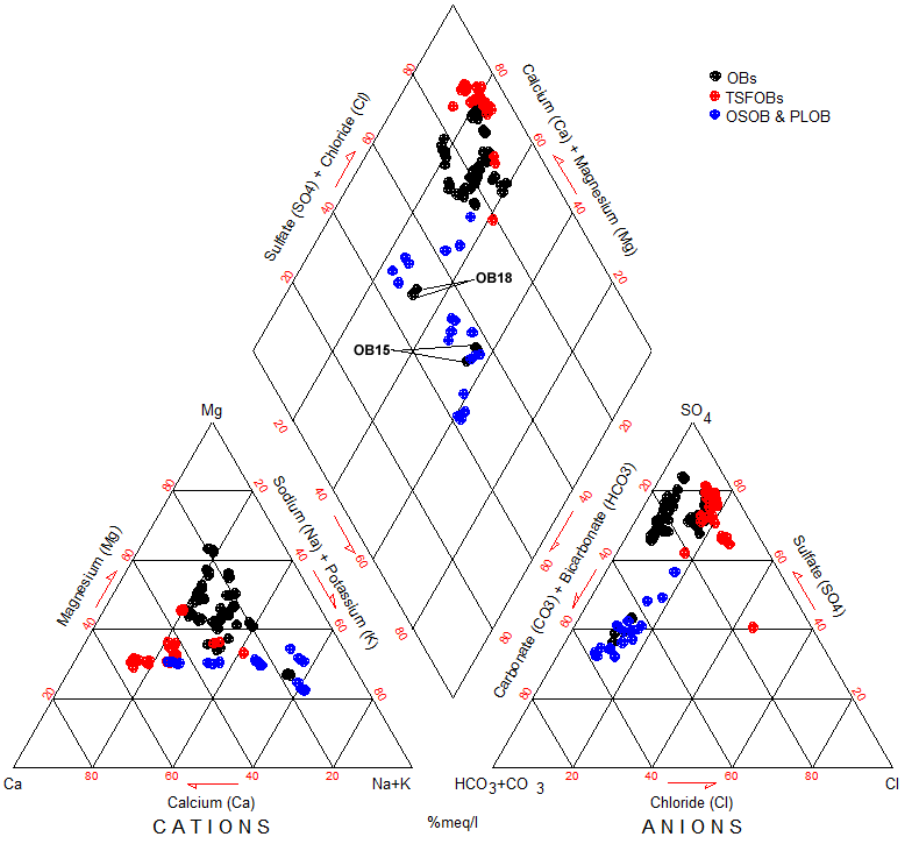

Figure 12 Piper Diagram showing clustering of OBs, TSFOBs and "Reference" Bores (i.e. OSOB, PLOB and OB15 & OB18)

With respect to SO_4^{2-} in groundwater as measured in TSFOBs (Figure 14), these appear to be highly variable since their installation. Although most exceed the SO_4^{2-} "Release" limit, some SO_4^{2-} concentrations appear to be decreasing in some bores. In, 2012 Rob Lait reported that seepage of environmental significance had occurred from the TSF and towards Coppermine Creek. If this seepage was occurring, and as a result of not using the TSF at GAM, perhaps a further decline in SO_4^{2-} concentrations will be observed.

Similarly to SO_4^{2-}, and although not identified as a contaminant using "Release" limit triggers for the present groundwater study, Cu has been raised as a potential contaminant of concern in surface water systems. For example, used as a "Reference" site for surface water and sediment sampling, location GAM 4, located to the east of the TSF and GAM Pit (Figure 13) and outside the lease boundary of the GAM MLs, has been identified as having elevated concentrations of Cu. Despite this location being outside of the ML boundary for GAM operations, it is not surprising that Cu occurs in measureable concentrations. Similarly, Figure F (Appendix 2) shows contours of Cu concentrations as determined in groundwater, using the current groundwater database. Not surprisingly, groundwater from proxy "Reference" bores (i.e. OB15, OB18) have similar or higher Cu concentrations than measured from operational areas.

Figure 13 Location of surface water – sediment "Reference" site - GAM 4

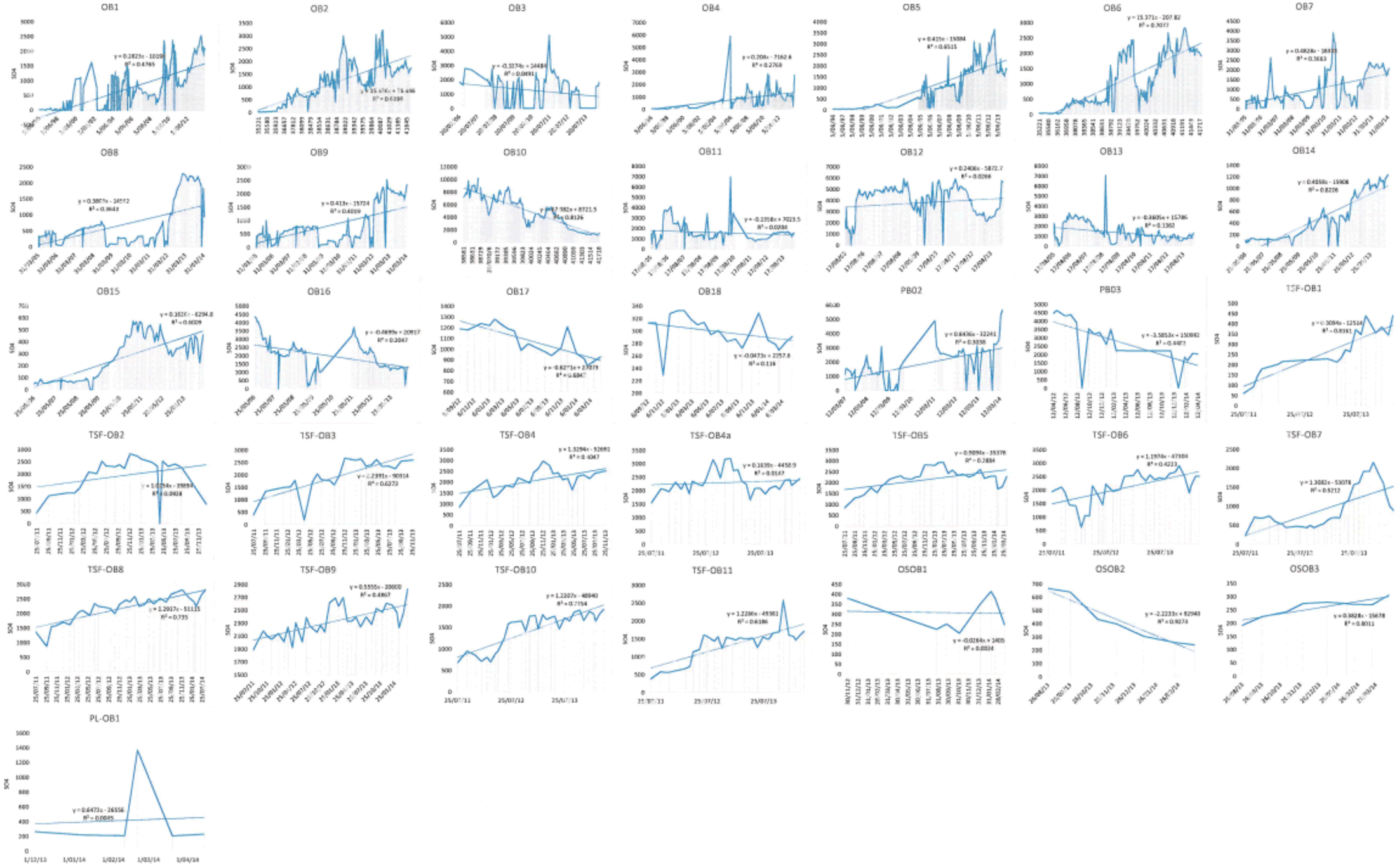

Figure 14 Historical Trends of Sulphate (SO_4^{2-}) in General Observation Bores (OBs),Tailings Storage Facility Observations Bores (TSFOBs) and Orphan Shear and Paddock Lode Observations Bores (OSOBs and PLOBs)

11 Potential Contaminant Sources and their Contaminants

One of the fundamental investigations that was to be undertaken, as part of this EE, was to identify potential source(s) of contamination that may be negatively affecting groundwater quality at GAM.

With reference to the primary site activities discussed in Section 5, a summary of potential sources of contamination at GAM is listed in Table 15 and shown on Figure **15**. These contamination sources have the potential to negatively impact groundwater quality and the biodiversity assets that rely on this resource.

Table 15 Possible contaminant sources and associated contaminants associated with operations at GAM

Possible Contaminant Sources	Possible Contaminants
Regulated Dams (Stormwater ponds, TSF)	Low pH, High EC, elevated concentrations of metals/metalloids (i.e. Cu) and SO_4^{2-}
Concentrate processing area and ROM Pad	Elevated concentrations of metals/metalloids (i.e. Cu) from dust particulate
Waste Rock Dumps (WRD)	Low pH from sulphide oxidation (i.e. wetting/drying cycles), elevated concentrations of metals/metalloids (i.e. Cu) and SO_4^{2-}
Administration Offices & Workshops	Hydrocarbons from fuel spillage, sewage, chemicals
Heap Leach Processing plant	Sulphuric acid (H_2SO_4) from heap leach irrigation cells and resultant low pH and elevated concentrations of metals/metalloids and SO_4^{2-}
Tailings Storage Facility (TSF)	Low pH from sulphide oxidation (i.e. wetting/drying cycles), elevated concentrations of metals/metalloids (i.e. Cu) and SO_4^{2-}
Heap Leach Pregnant Liquor Ponds (i.e. PLS Ponds)	Sulphuric acid (H_2SO_4) from heap leach irrigation cells and resultant low pH and elevated concentrations of metals/metalloids and SO_4^{2-}

The following section (Section 12) provides more detail regarding the sources of potential contaminants as shown in Table 15. Furthermore, the following section discusses the potential effects to the receiving environment as a result of mine-affected groundwater.

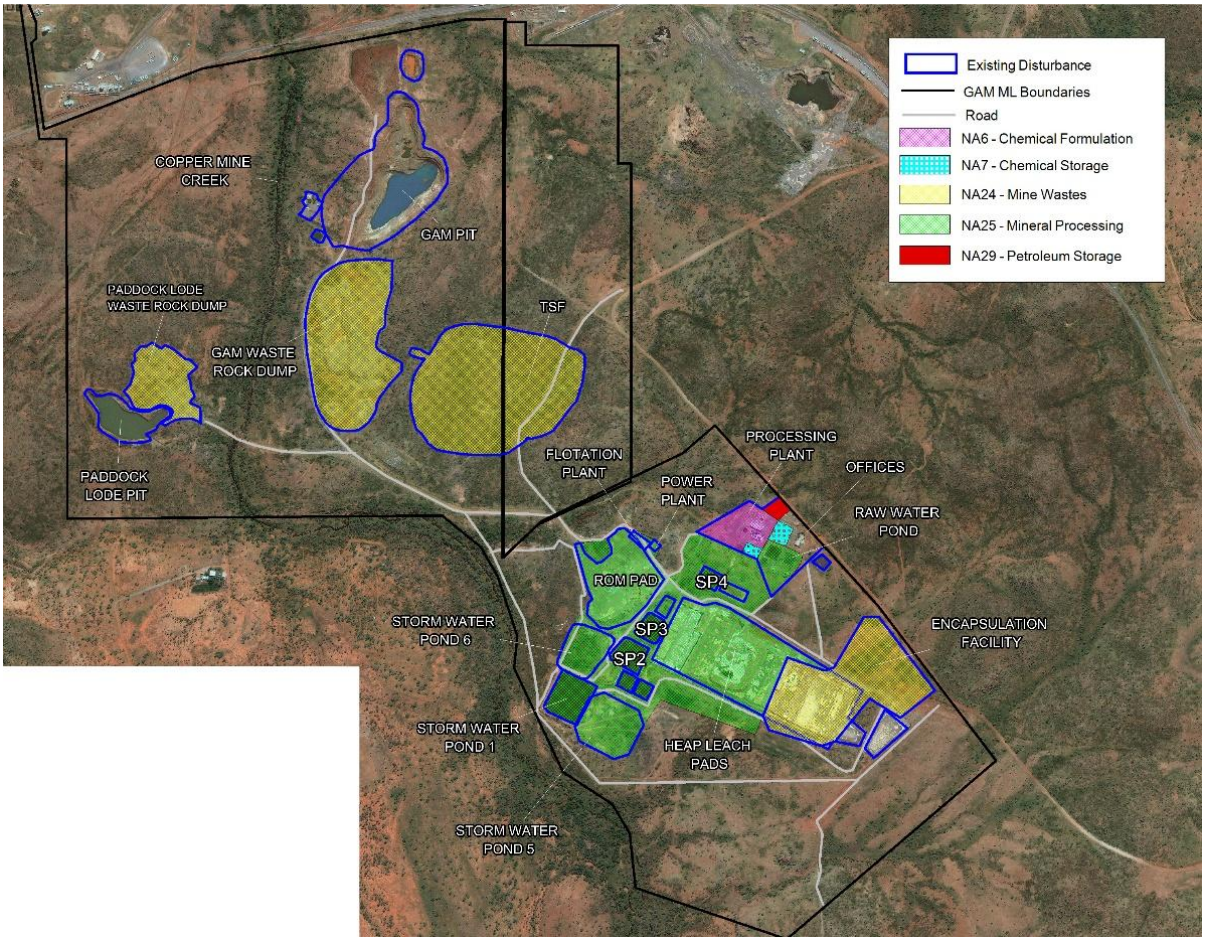

Figure 15 Potential contamination sources at GAM(AARC, 2014)

12 Receiving Environment

It was fundamental to this EE report that a better understanding be gained of the effects that mine site contamination (if any) was having on the receiving environment (in accordance with ANZECC 2000 methodology), and assess the impacts (if any).

The following section provides a brief outline of the potential sources of contamination (discussed in Section 11) that may impact groundwater quality and how it pertains to the receiving environment.

12.1 Environmental Values and Beneficial Uses

The GAM site is situated in a rural landscape that has historically been subject to low-intensity cattle grazing, and more recently, mining and exploration activities. Using the Environmental Protection (Water) Policy (EPP Water, 2009) and the Queensland Water Quality Guidelines (QWQG, 2009), waterways in the catchment surrounding the Project can be defined as a slightly to moderately disturbed ecosystem.

The GAM site is located within the Flinders River Catchment (915); however, surface waterways in the Flinders River Catchment are not listed in Schedule 1 of the EPP Water. Therefore, there is no pre-determined Water Quality Objectives (WQO) or Environmental Values (EV) that applies to the GAM site.

To protect the receiving environment in the absence of pre-determined EV or WQO for the Flinders River Catchment, the Project EA has adopted the ANZECC (2000) Aquatic Ecosystem Guidelines - 95% Species Protection for slightly to moderately disturbed ecosystems as default trigger values, and the ANZECC (2000) Stock Water Quality Guidelines as contaminant limits for the GAM Project. The trigger levels and contaminant limits as outlined in the GAM EA.

12.2 Surface Water Quality

When present, surface water quality monitoring within existing water management features is undertaken monthly by CopperChem. The results of this monitoring provides an overview of the potential contaminants existing within the water stored and/or collected on-site, and the quality of water within the surface water and groundwater regimes.

Surface water quality within the site was undertaken by AARC between April 2011 and March 2013 in addition to the sampling completed by CopperChem personnel. The results of the most recent round of surface water monitoring (AARC, 2012) indicate:

- pH, Cu and Zn exceed the guideline values for ecosystem protection (ANZECC, 2000 and Queensland Water Quality Guidelines – DEHP (2009)) for slightly to moderately disturbed systems; and

- pH typically exceeds lower guideline values for ecosystem protection. This is most likely due to the high acidity of the contaminants released from the study area.

12.3 Groundwater Quality and the Receiving Environment

As discussed in Section 4.1.4, as a result of the depth to groundwater, when compared to the depth of incision of the watercourses on the GAM site, it is extremely unlikely that a groundwater-surface water connectivity exists. However, it is somewhat reasonable to consider that some degree of shallow connectivity may occur in Coppermine Creek; however, only during extreme flow events.

With reference to the abovementioned, it is reasonable to consider that the primary receiving environment where contaminant-laden groundwater could cause negative effects in the context of the GAM facility, would be elevated concentrations of SO_4^{2-} rich waters affecting livestock. For example, ANZECC (2000) Stock Water Quality Guidelines state *"no adverse effects to stock are expected if the concentration of sulfate in drinking water does not exceed 1000 mg/L. Adverse effects may occur at sulfate concentrations between 1000 and 2000 mg/L, especially in young or lactating animals or in dry, hot weather when water intake is high. These effects may be temporary and may cease once stock become*

accustomed to the water. Levels of sulfate greater than 2000 mg/L may cause chronic or acute health problems in stock".

Moreover, in 2012 AARC conducted field investigations as part of their report "Environmental monitoring report – Environmental Protection Order (STAT705)". In that document they reported that groundwater quality, when compared to Release Limit ANZECC – Guidelines for Livestock and Drinking Water (ANZECC[1]), and Trigger level - ANZECC Guidelines for 95% protection of aquatic ecosystems (ANZECC[2]), commonly exceeded "Release" limits for SO_4^{2-} and EC in most bores, and exceeded "Trigger" limits for Cr, Cu and Zn. The findings by AARC are in alignment with the results of the present study. Further to AARCs study, it was found that no visible signs of distressed riparian vegetation in the Coppermine Creek as a result of suspected TSF seepage were identified. AARC stated in their report, following the identification of TSF seepage in the Coppermine Creek in 2012, "riparian vegetation in the impacted areas of the Coppermine Creek had not been affected by the TSF seepage".

Similarly, just as this investigation has identified historical trends in the occurrence of elevated Cu and Zn in groundwater samples; AARC also identified these analytes as exceeding EA Trigger Levels from historical monitoring results in the downstream catchment from the GAM site.

12.3.1 Off-lease Groundwater Investigations

As a result of elevated SO_4^{2-} concentrations, measured from various groundwater bores at the GAM site, and since groundwater flow is towards Coppermine Creek (Figure 5) and potentially flowing off-lease towards landholders keeping livestock, an investigation was carried out. To the southwest of GAM and located down-hydraulic gradient, the Robertson family occupy a large portion of the land where they allow their cattle to graze. On this property are three homesteads, all owned by the Robertsons'. Each homestead uses groundwater as a source of drinking water for their families and their livestock (Figure 16).

In August (2014) personnel from the CopperChem environment team undertook a groundwater sampling and analysis programme aimed at sampling all Robertson bores. Table 16 shows the results of the detailed chemical analysis of groundwater from the Robertson-family bores. Results show that, much like the GAM site, SO_4^{2-} concentrations are highly variable (but <1000 mg/L) while Cu concentrations are comparable to, and in excess of, some groundwaters as measured at GAM.

It is not surprising that SO_4^{2-} and Cu are in appreciable concentrations in Robertson-bores; especially given the strong mineralisation in the immediate area

Table 16 Groundwater results of Robertson bores

I.D*	pH	As	Cu	Pb	Se	Zn	Hg	Ca^{2+}	Cl^-	SO_4^{2-}
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
		0.01	2	0.01	0.01	n/a	0.001		n/a	500
A	7.16	0.003	0.008	0.003	0.02	0.011	<0.0001	229	150	634
A	6.81	0.003	0.009	0.003	<0.01	0.118	<0.0001	301	198	866

B	7.37	0.003	0.011	0.004	<0.01	0.017	<0.0001	101	118	349
C	7.61	0.004	0.01	0.001	<0.01	0.014	<0.0001	31	63	56

*Refer to Figure 16

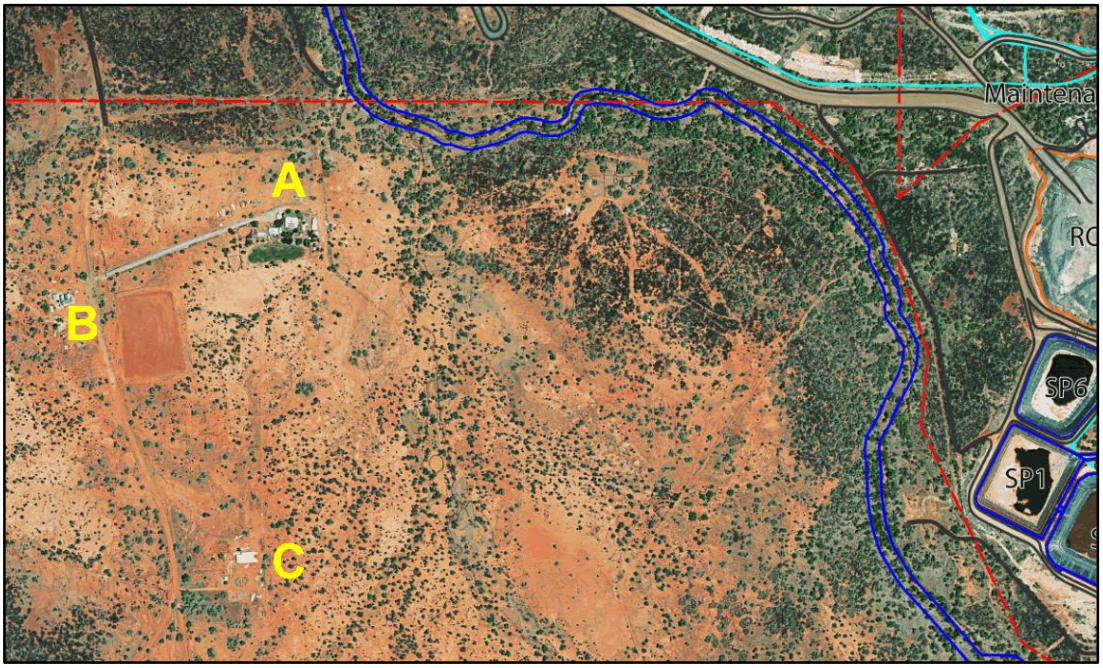

Figure 16 Location of the Robertson homesteads (A, B & C) in relation to the GAM site

12.3.2 Clean-up Creek Observations Bores

In 2009, due to an unplanned release of contaminated water to the Coppermine Creek, the Department of Environment and Resource Management (DERM) issued CopperChem with a Clean-Up Notice following the event. Soon after the unplanned release, it became a concern that some riparian vegetation in the immediate vicinity of the release had been affected. In August 2009, CopperChem commenced a program of pumping clean water to Coppermine Creek and flushing the alluvial gravels in the creek through a low impact river gravel washing process in order to remove stream sediment precipitates and flush the alluvial aquifer. The contaminated water from flushing the alluvial gravels was returned to GAM (AARC, 2014).

Forming part of the contamination investigations, CopperChem installed four (4) Creek Observation Bores (COB-series) immediately down-gradient from the spill source in July, 2009. Immediately following the installation of the COBs, there was some indication of the effects of the contamination event identified in groundwater. However, within a few weeks the elevated concentrations of SO_4^{2-} and Cu returned to background levels; similar to those as measured from proxy reference groundwater bores (e.g. OB15, OB18, PLOB1 & PLOB2 and OSOB1 to OSOB3).

This consequence, and the follow-up monitoring programme, provides a strong case that groundwater is not [typically] hydraulically connected to surface water systems in the area;

a statement also substantiated by RLA (2012). The exception to this; perhaps, would be following an unplanned/planned contaminant release. Therefore, any future releases need to be prevented; this is an agenda that CopperChem aims to maintains through management water and waste water management.

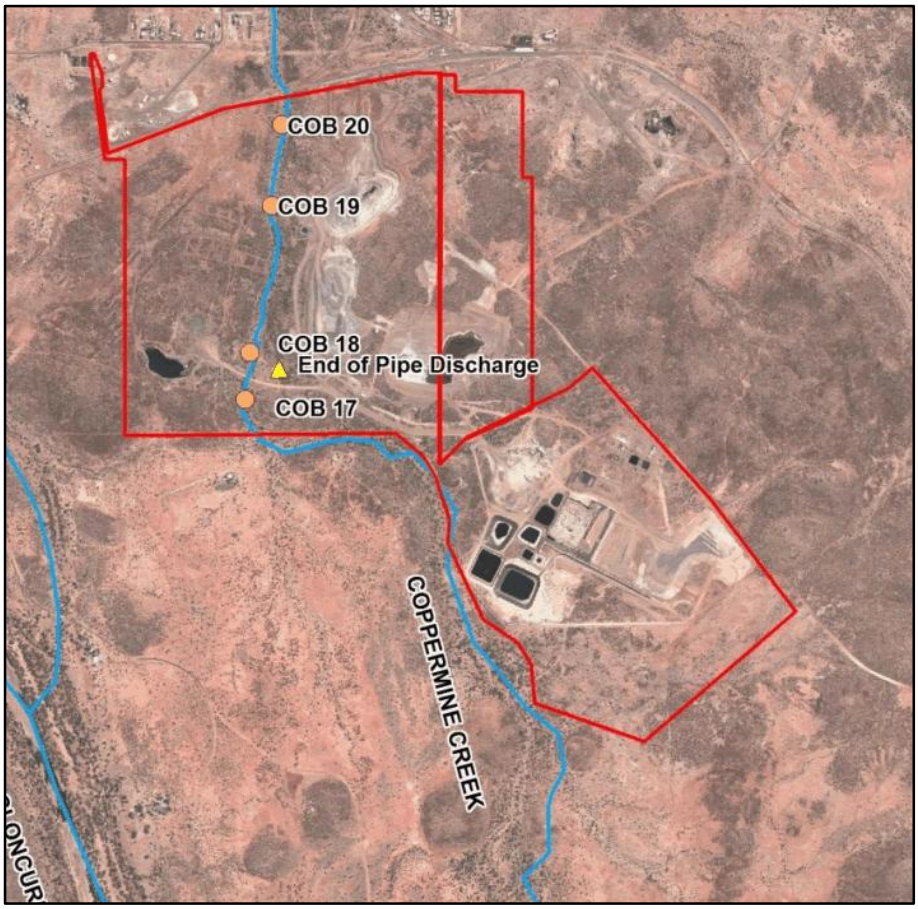

Figure 17 Location of the Creek Observation Bores (COBs) and location of spill discharge (AARC, 2014)

12.4 Surface Water Management

At present CopperChem are working with consultancy, URS, in preparing and improving the current Water Management Strategy (WMS) and investigating the Design Storage Allowance (DSA) for all regulated dams at GAM ahead of the EA compliance date of 1-Nov. Unfortunately, the results of this WMS and DSA study were not available at the time of preparing this EE Report.

For information regarding the WMS and DSA study, and the significance of protecting the receiving environment from unplanned releases from regulated dams etc., the reader is encouraged to review this URS report (due for release in 15-October).

13 Groundwater Management

Although there is a general hydraulic disconnect between groundwater and surface water systems at GAM, CopperChem have developed groundwater management programmes to minimise off-lease discharge of potentially mine-affected waters.

The following subsections describe the current groundwater management systems currently in use at GAM to monitor and manage off-lease releases (if any).

13.1 Pump Back Bores

For example, in 2006 AGE provided a report to Tennant describing a pump-back groundwater system to be used to intercept groundwater, with elevated SO_4^{2-} concentrations, potentially sourcing from the area of the Heap Leach stockpiles and leaving the GAM lease. The implementation of this groundwater interception system formed part of a commitment made in Tennant's Environmental Management Program (EMP) and submitted to the Queensland Environmental Protection Agency (EPA) by 15-June the same year.

On the basis of their field investigations, AGE recommended that a series of pump-back bores be installed. The pump-back bores that were installed are shown in Figure 18.

Figure 18 Location of pump-back groundwater bores used to intercept off-lease discharge of high SO_4^{2-} groundwater

The sampling of the pump-back bores forms part of the EA compliance "monthly" sampling programme. Since their installation the SO_4^{2-} (and subsequently EC) and Cu concentrations has remained comparable. As reported by AARC (2011), pumping from OB3, PBO2 and PBO3 (Figure 18) did not occur during the years the GAM site was in care and maintenance; however, since CopperChem have taken over operations, and identified the need for managing potential off-lease discharge of groundwater, the pump-back interception system has re-commenced.

13.2 Tailings Storage Facility (TSF) Pump-Back Bore

Following the identification of possible TSF seepage expressions in the Coppermine Creek in 2012, RLA was consulted to investigate groundwater quality in the vicinity of the TSF. And as a result of these seepages, the DEHP issued Environmental Protection Order (EPO) STAT705 to CopperChem on 21-Aug of the same year. Forming part of the EPO, CopperChem was required to provide a statement to the DEHP describing the source, controls and remediation of the potential seepage.

Following the RLA (2012) investigation, it was proposed that to intercept any seepage occurring from the TSF, an interception trench be constructed. Using the recommendations in the RLA report, the TSF sump (TSFPB) was constructed at the location shown in Figure 19.

Figure 19 Location of TSF pump-back bore (interception trench). Also, yellow "x" markers depict the locations of where [possible] TSF solution was observed to be seeping to the Coppermine Creek.

Although the TSF is no longer in use (i.e. not receiving mine-generated solids or solutions), it is CopperChem's policy to continue monitoring the effectiveness of this pump-back bore.

However, at present, and since input to the TSF have ceased, the requirement for this pump-back bore is becoming less; especially given its current design.

Since inputs to the TSF have ceased, there has been a noticeable decrease in SO_4^{2-} concentrations, as measured from groundwater, from all down-gradient bores (i.e. TSFOB7 to TSFOB9). As per the GAM EA, CopperChem will continue to monitor these bores.

13.3 Heap Leak Detection and Interception Bores

There are a number of Leak Detection (LD) bores installed at the GAM facility. These LD bores are installed down-gradient to the HL facility and associated launders, PLS ponds and SP2, SP5 and SP6 (Figure 20).

Figure 20 Location of Leak Detection (LD) Bores in the area of the Heap Leach Facility and associated dams

13.3.1 Shallow LD Bores

In 1996 a total of seven LD bores (denoted as “LD1 to LD7 in Figure 20) were installed immediately down-gradient to the HL pads (i.e. <20m). However, these were installed too superficially; only extending to a depth of 1.5m below ground. As a result of their shallow depths, these have been reported as dry since 2005. Since these shallow LDs have been dry for many years they are no longer being monitored.

13.3.2 PLS Pond Leak Detection Bores

In 2002, prior to CopperChem taking over the GAM operations, a total of two pump-back bores were installed, under the poly-liners, of PLS Ponds east and west. Since their installation these pump-back bores undergo fortnightly pumping to abstract solution. Judging by their low pH and high SO_4^{2-} (>40,000 mg/L), Cu (>300 mg/L) and EC (39 mS/cm), it seems possible that PLS may be leaking to groundwater. However, it doesn’t appear that PLS is leaking to groundwater in any great volume; as it is predicted that <50L

was abstracted from the pump-back bore associated with PLS east for the entire month of August. No groundwater could be abstracted from PLS west. The beneficial feature of the area, especially if PLS is leaking to groundwater, is this area is in a topographic low-stand.

13.3.3 Heap Leach Leak Detection Bores

In 2007 a total of six HL detection (denoted as “HL1 to HL6 in Figure 20) were installed to a depth of 11m; immediately adjacent to, and below the depth of, the base of the Heap Leach launders. These HL bores undergo monthly monitoring and have been designated as “dry” since their installation.

13.3.4 Regulated Dam Leak Detection Bores

Between the years of 2011 and 2012, a total of six LD bores (denoted as SP5LD1 to SP5LD6 in Figure 20) were installed near to regulated dams SP2, SP5 and SP6. These were installed as a means to identify if any potentially contaminated solutions stored in these regulated dams, was having any negative impacts to groundwater quality. However, as these dams are generally dry, there has been no detection of groundwater in these LD bores. CopperChem maintain monitoring of these LDs on a monthly basis.

13.3.5 Leak Interception (INT) Bores

In February 2013, a series of seven Interception bores (denoted as INT1 to INT7 in Figure 20) were installed immediately down-gradient to HL1 to HL6. These INT bores were installed on a 45° angle and to a depth of 10m to 12m below ground level (bgl) as a means to provide early warning that PLS may be discharging to groundwater. These INT bores are monitored monthly; however, since their installation, these bores continue to be monitored as “dry”.

14 Maintenance Schedules

In an effort to assist with the protection of environmental assets (i.e. receiving environment) at GAM, CopperChem conduct regular maintenance checks of areas that have a high potential to cause environmental harm. For example, there is certain infrastructure located on the GAM site that can be particularly harmful to the environment if not managed appropriately. The primary infrastructure, at the GAM site, that is particularly harmful to the environment, are those associated with the Heap Leach Facility. These are:

- Poly-pipe containing low pH raffinate solution; and
- Heap Leach launders containing low pH, copper-enriched solution.

Although there is no detailed maintenance schedule, at present CopperChem engage in daily inspections of these facilities. Such inspections are focussed on checking the integrity of the HDPE liners associated with regulated dams and launders and inspecting pipeline infrastructure (including couplings) that transport raffinate (etc.) around the site.

Where visual inspections identify where maintenance is required, these are then logged into the CopperChem maintenance schedule. The daily routine checklist for the Heap Leach Pads, Launder System, Ponds and Pipe infrastructure is located in Appendix 3.

15 Future Groundwater Management

The purpose of this Environmental Evaluation (EE) Report was to investigate concerns raised by DEHP; based on the “Grounds” detailed in their letter dated 12-June. This EE Report was to undertake an environmental investigation, principally involving groundwater assets, to address matters involving the potential contamination of groundwater from GAM site activities. Additionally, forming part of this investigation, was to also address what effects (if any) groundwater contamination was having on the receiving environment.

Historical to present day hydrochemical data was compiled, analysed and interpreted using industry-standard modelling software (i.e. AquaChem, PHREEQ) and techniques. As identified in this study, and as corroborated by previous researchers, the groundwater quality across the GAM site, and the region, is highly variable. The current study investigated hydrochemical data using a suite of groundwater bores at GAM; including [proxy] reference bores (see 6.1.4). Although there is some indication of increased sulphate (SO_4^{2-}) concentrations in groundwater, down-gradient to the TSF and Heap Leach facility, CopperChem are presently assessing this matter and aim to provide DEHP with a proactive groundwater management plan. This may involve improving the management of pump-back bores, the installation of supplementary pump-back bores and building a database of “Reference” criteria from the newly installed “Reference” bores. Furthermore, CopperChem are currently improving the identification, maintenance schedule and replacement of ageing or damaged infrastructure. As soon as this document is finalised a copy will be provided to DEHP.

16 References

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APPENDIX 1

APPENDIX 2

APPENDIX 3