# CHAPTER 10 WATER RESOURCES

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# 10 WATER RESOURCES

*This chapter provides an assessment of potential impacts on water resources within the site and surrounding areas resulting from the Project. Measures to manage these impacts are also provided.*

*This chapter was completed by Golder Associates.*

## 10.1 INTRODUCTION

Water resources include all surface water, drainage networks, groundwater, water supply systems, water treatment and water discharges potentially affected by the Project.

### 10.1.1 Background

An assessment of surface and groundwater resources, within the Project Area was prepared by Golder Associates, 2008b and presented in *Annexure K - Hydrogeological Assessment for Proposed Mine Expansion, Rasp Mine*, *NSW*. The Project will involve changes to water demand and changes to water management including; water storages, associated drainage systems and water management structures. An updated Stormwater Management Plan (SWMP) was prepared by Golder Associates, 2010 and is presented in *Annexure J*.

## 10.2 METHODOLOGY

The water resources assessment comprised:

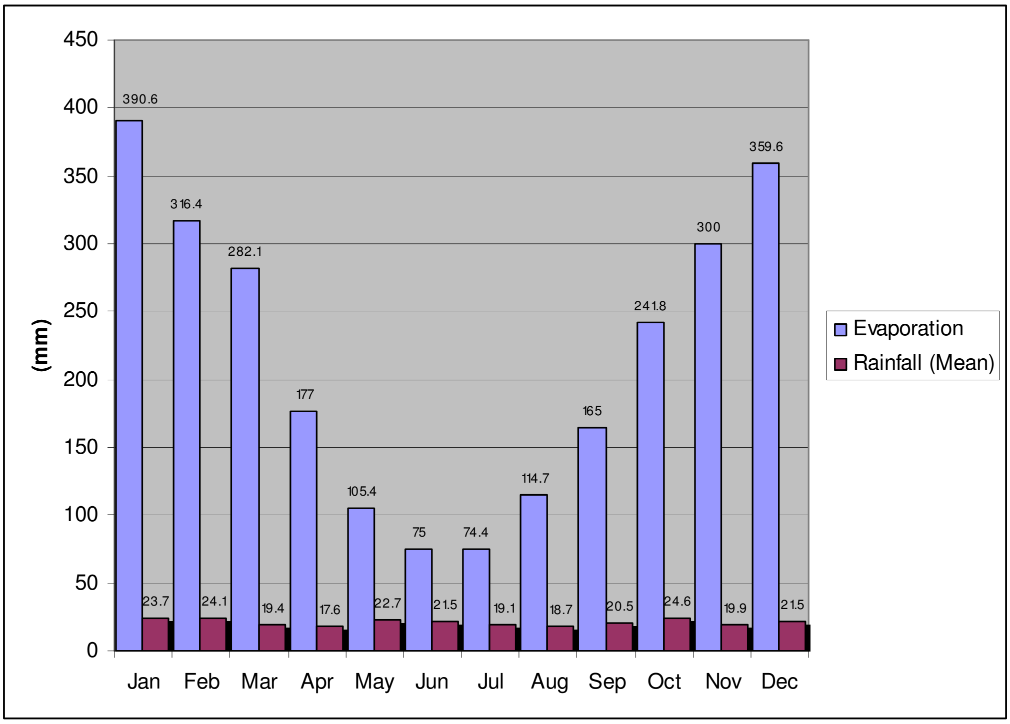
- evaluation of the existing conditions at the site including drainage networks, groundwater conditions, site meteorology, hydrology and topography;
- review of water quality issues and the potential for discharges to receiving waters including groundwater. Assessment of appropriate water management and monitoring plans for the Project, including a revised SWMP for the Project Area and activities;
- assessment of the potential water demand impacts from operation of the facility, including the potential impacts on the city water supply, other groundwater users, surface waters, groundwater and groundwater dependent ecosystems; and
- identification of site-specific management and mitigation measures to promote water reclamation and conservation.

## 10.3 EXISTING ENVIRONMENT

### 10.3.1 Hydrology and surface water

The average annual rainfall in the vicinity of the Project Area is approximately 254mm while the average annual evaporation is approximately 2,614mm. Average monthly values of rainfall and evaporation are shown in *Figure 10-1*.

***Figure 10-1 Average monthly rainfall & evaporation – Broken Hill (reference - Bureau of Meteorology, 2009)***




The Project Area and the City of Broken Hill are located within the catchment of the Stephens Creek Reservoir. West of Broken Hill, all runoff drains to Lake Frome (located in South Australia 250 kms north west of Broken Hill). Three main creeks run within 30 km of the City; Umberumberka Creek to the northwest, Stephens Creek to the east and southeast and Yancowinna Creek to the northeast. The closest major water course is the Darling River approximately 100 km to the south east. The Project Area is not subject to flooding from external water courses.

The surface drainage patterns of the Project Area have been substantially altered by previous mining and rehabilitation works. A major part of the rehabilitation works has been the construction of a number of water storage areas and diversion drains to contain site runoff. The final discharge point for the initial areas of potential impact on the Project Area is the Horwood Dam (which will be able to retain a 1:200 ARI event following de-silting).

The key element of the current SWMP is to retain local rainfall and process water on-site. Disposal of water is by evaporation from storage basins. There can be flows between subcatchments for storms as low as the 20-year ARI; however, the total system retains all runoff up to the 100-year ARI event without discharge from the site. Some modifications to the Horwood Dam and to overland flow paths direct overflows from other catchments to this Dam.

Rail corridors and yards are located on the northern and western sections of the Project Area and surface water management in these areas is the responsibility of ARTC. A stormwater management plan was prepared for the rail corridors; all drainage from the mining lease and rail yard areas was diverted to a major storage basin adjacent to Menindee Road (Miedecke, 1994). Works were undertaken to divert run-off from the railway and contain it within storage basins rather than be directed to the Crystal Street drain and through residential areas of the City.

### *10.3.2 Groundwater*

*Regional groundwater conditions*

Broken Hill is situated on a watershed, with drainage to the north and south. Standing water levels depict general groundwater flow from north to south within the unconfined fractured groundwater system, which is predominantly controlled by natural drainage and the primary fracture orientation.

Groundwater resources in the vicinity of Broken Hill can be classified into three groups on the basis of aquifer type:

- perched aquifers - perched groundwater present in the thin veneer of Quaternary sediments overlying the Proterozoic bedrock formations;
- colluvial aquifers - groundwater present in thick sequences of colluvial sediments that have accumulated on downthrown fault blocks along the western margin of the Barrier Ranges; and
- bedrock aquifers - groundwater present within structural features of the Proterozoic bedrock.

Perched aquifers contain groundwater, primarily within alluvial deposits along water courses. The colluvial aquifers associated with thick sequences of Quaternary sediments contain the principle groundwater resources in the vicinity of Broken Hill. These sediments generally consist of gravel, sand, and silt interbedded with clay, forming unconfined to semi-confined aquifer conditions at depth (Caritat et al., 2002). Whilst these aquifers represent significant regional groundwater resources for rural water supply to the region, they are absent beneath the mine lease. The closest of these colluvial deposits is associated with the Mundi Mundi fault scarp approximately 30 to 40 km west of Broken Hill and therefore well outside the area of interest of mine groundwater studies.

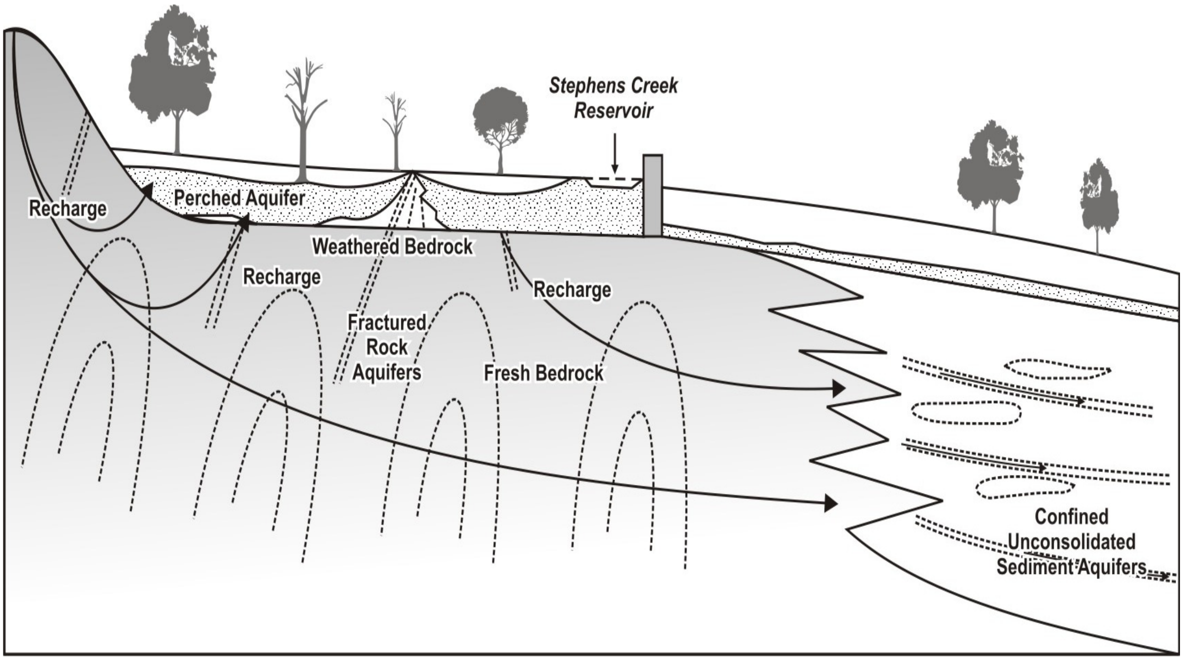
Groundwater storage and flow within the bedrock aquifers is dominated by the structural geology of the formation including faults, lineaments and shear zones due to the low porosity of the rock mass (Caritat et al., 2002; NZG, 2006). Shear zones and faults, present across the study area, are believed to be the primary structural features capable of storing and transmitting water. There is a predominant north-northeast trend to these structures, and hence the groundwater flow, in the area.

According to a Conceptual Hydrogeological Model (CHM) developed for the Broken Hill region, the perched aquifer and thicker colluvial fault scarp aquifers are believed to be recharged primarily through infiltration of rainfall and vertical leakage from surface water bodies. Interaction between bedrock and perched aquifers is also likely close to the foot slopes of the local mountain ranges.

Groundwater in the structural bedrock features is likely to be recharged either through direct infiltration into outcropping structures, or through leakage from perched aquifers.

There is unlikely to be significant interaction between groundwater present in bedrock structural features, and perched groundwater in shallow Quaternary deposits (Caritat, 2002). This represents a robust CHM based on the available hydrogeological data, which may be revised in light of future investigation refer *Figure 10-2*.

***Figure 10-2 Conceptual hydrogeological model of the Broken Hill domain (source – Caritat et al., 2002)***




*Regional groundwater quality*

Groundwater in the Broken Hill region is generally found to be elevated in salinity. Caritat et al. (2005) studied groundwater quality within the Curnamona Province (a 300 km by 300 km block of shallow to outcropping basement rocks that extends from Olary, in the north-east of South Australia, 450 kms north-east of Adelaide, to east of Broken Hill across the New South Wales border), including 46 sample sites associated with the Barrier Ranges which include Broken Hill. Chloride and sulphate levels were found to be elevated above safe drinking water criterion throughout the survey area. Previous investigations have shown variation in hydraulic conductivities and groundwater quality. On average, flow rates were estimated to be relatively low (0.1 m per year) and salinity concentrations usually highest after extended periods of low rainfall.

Lead and zinc levels were also found to be elevated above safe drinking water criterion at particular locations (refer *Table 10-1*). Elevated trace metal concentrations are typical of groundwater that occurs in mineralised bedrock. Heavy metal concentrations in the groundwater adjacent to mining leases were most likely the result of leaching from localised mineralisation, rather than groundwater pollution by on-site sources (Pasminco Mining Broken Hill 1995).

***Table 10-1 Summary of groundwater chemical data***

| ID | Name | Chloride (mg/L) | Sulphate (mg/L) | Lead (mg/L) | Zinc (mg/L) | EC (µS/cm) | TDS (mg/L) |
|---|---|---|---|---|---|---|---|
| BH100 | Zig Zag Bore | ***1360*** | **993** | <0.001 | 0.0148 | *5970* | **<u>4718</u>** |
| BH101 | Alberta Well | ***1260*** | **764** | <0.001 | 0.0154 | *5020* | **<u>3569</u>** |
| BH102 | Old Corona Well | ***1800*** | **829** | 0.0018 | 0.0115 | *6630* | **<u>4886</u>** |
| BH103 | Near Neds Tank | ***3510*** | **1810** | <0.001 | <0.001 | *13060* | **<u>8407</u>** |
| BH105 | Warners Bore | **515** | 253 | <0.001 | <0.001 | 2490 | **1521** |
| BH106 | Stevens Bore | ***1110*** | **734** | <0.001 | <0.001 | 4870 | **<u>3417</u>** |
| BH107 | Brewery Bore | ***3520*** | **2570** | <0.001 | 0.0216 | *13230* | **<u>10053</u>** |

| ID | Name | Chloride (mg/L) | Sulphate (mg/L) | Lead (mg/L) | Zinc (mg/L) | EC (µS/cm) | TDS (mg/L) |
|---|---|---|---|---|---|---|---|
| BH108 | Poolamacca Well | ***4520*** | **2330** | 0.0019 | 0.0687 | *15500* | **11624** |
| BH109 | Homestead Bore | ***1710*** | **881** | <0.001 | 0.022 | *6690* | **4495** |
| BH115 | Three Corners | ***936*** | **740** | 0.0012 | 0.0082 | 4370 | **3190** |
| BH116 | Copper Mine Bore | ***1160*** | **577** | 0.0022 | 0.0055 | 5090 | **3899** |
| BH120 | Nickatime Bore | ***1870*** | **2100** | <0.001 | 0.0557 | *8380* | **6660** |
| BH121 | Corner Bore | ***1600*** | **2100** | <0.001 | 0.0087 | *7610* | **6086** |
| BH122 | Gormans Bore | ***1320*** | **1610** | <0.001 | 0.1404 | *6160* | **4905** |
| BH128 | Old Corona Well Bore | **394** | 201 | <0.001 | 0.0048 | 2380 | **1760** |
| BH130 | Eight Mile Bore | ***2570*** | **1680** | <0.001 | 0.0215 | *10240* | **7192** |
| BH131 | Black Tank Bore | ***5880*** | **2750** | 0.0032 | 0.0147 | *18680* | **14231** |
| BH132 | Silverton Commons Borehole 1 | ***3590*** | **2110** | <0.001 | 0.0207 | *13870* | **9889** |
| BH151 | Mundi Mundi Ck Well | ***4210*** | **2400** | 0.0011 | <0.001 | *14990* | **10986** |
| BH152 | Sundown Borehole | ***1410*** | **1270** | 0.0024 | 0.2581 | *6650* | **4467** |
| BH153 | Mt George Borehole | **332** | **654** | <0.001 | 0.0545 | 2640 | **1721** |
| BH154 | Mt George Well | ***3860*** | **2680** | <0.001 | 0.0045 | *15490* | **10757** |
| BH155 | Penrose Park #1 | ***12000*** | **4150** | <0.001 | 0.0021 | *34900* | **25390** |
| BH158 | Limestone Well | ***2010*** | **1320** | 0.0092 | 0.0993 | *8680* | **5735** |
| BH159 | House Bore | ***884*** | 472 | 0.001 | <0.001 | 4460 | **2843** |
| SCK03 | Farmcote Well | ***4369*** | **1698** | **0.029** | ***12.5*** | *15670* | **9925** |
| SCK04 | Rangers Bore | ***2404*** | **999** | **0.072** | ***8.3*** | *8970* | **5785** |
| SCK05 | Old Railway Bore | ***1410*** | **868** | **0.081** | ***8.4*** | *6620* | **4230** |
| SCK07 | Springs Shear | **472** | 202 | 0.027 | ***10.3*** | 2760 | **1736** |
| SCK10 | Ironblow Bore | ***1066*** | **747** | **0.13** | ***10*** | *5320* | **3428** |
| SCK11 | Mulga Springs | ***2462*** | **769** | 0.007 | ***13.6*** | *10270* | **6381** |
| SCK12 | Fords Well | ***921*** | 304 | 0.006 | ***11*** | 4298 | **2252** |
| SCK13 | Stephens Creek Bore | ***277*** | 100 | **0.018** | ***12.4*** | 1634 | 814 |
| SCK14 | Hidden Bore | ***4784*** | **2389** | **0.02** | ***6.4*** | *19260* | **11570** |
| SCK16 | Parnell Bore | ***4248*** | **2647** | **0.12** | ***7.2*** | *18310* | **11099** |
| SCK17 | Forking Bore | ***2628*** | **1829** | **0.033** | ***8*** | *11110* | **7338** |
| BH307 | Elizabeth Bore | 87 | 159 | <0.001 | 0.0054 | 1697 | **1364** |
| BH309 | Jetpump bore | ***2309*** | **1171** | <0.001 | 0.043 | *9300* | **5851** |
| BH310 | LBH0005 | ***1051*** | **573** | <0.001 | 0.0679 | 5190 | **3303** |
| BH311 | LA011 | ***5231*** | **1677** | <0.001 | 0.0109 | *17890* | **11251** |
| BH312 | Oakdale Explo Bore | ***851*** | **614** | <0.001 | 0.0137 | 4760 | **3088** |
| BH313 | West Mountain Exploration Bore | **634** | **961** | <0.001 | 0.0126 | 4040 | **2745** |
| BH314 | Kadish Bore | 73 | 58.1 | <0.001 | 0.0206 | 792 | 598 |
| BH331 | Clevedale House Bore | **464** | 229 | <0.001 | 0.0108 | 2920 | **2032** |
| BH337 | House Bore | ***1472*** | **806** | <0.001 | 0.035 | *7050* | **4272** |

| ID | Name | Chloride (mg/L) | Sulphate (mg/L) | Lead (mg/L) | Zinc (mg/L) | EC (µS/cm) | TDS (mg/L) |
|---|---|---|---|---|---|---|---|
| BH441 | House Bore | ***860*** | 483 | <0.001 | 0.0501 | 3730 | **2349** |
| Drinking Water Guidelines (ADWG 2004) | | **250[a]** | **500** | **0.01** | **3[a]** | NA | **1000[a]** |
| Irrigation (ANZECC 2000) | | 700[b] | NA | 2[c]/5[d] | 2[c]/5[d] | 5,200[e] | NA |
| Livestock (ANZECC 2000) | | NA | 2000[f] | 0.1 | 20 | NA | 3000[g] |

Notes:
All results are expressed as milligrams per litre (mg/L) unless otherwise indicated.
Results in **Bold** exceed relevant drinking water criterion (ADWG, 2004)
Results in *italics* exceed relevant irrigation criterion (ANZECC, 2000)
Results underlined exceed relevant livestock criterion (ANZECC, 2000)
[a] denotes aesthetic guideline for ADWG (2004) provided as no health-based criterion exists
[b] concentration above which only salt tolerant plants are supported (ANZECC, 2000)
[c] denotes long term trigger value (LTV:100 years) criterion from ANZECC, 2000
[d] denotes short term trigger value (STV:20 years) criterion from ANZECC, 2000
[e] EC value above which only very salt tolerant plants are supported (ANZECC, 2000)
[f] concentration above which acute or chronic health effects may occur (ANZECC 2000)
[g] lowest concentration above which loss of production and a decline in animal condition and health is expected to occur (chickens: 3,000; dairy cattle: 4,000; beef cattle:5,000; horses and pigs:6,000; sheep:10,000) (ANZECC 2000)

The results of Caritat et al. (2005) indicate that the groundwater resource associated with the bedrock aquifer is generally unsuitable for human consumption. The high concentration of total soluble salts renders the groundwater generally unsuitable for crop irrigation (with the exception of very salt tolerant crops) and is marginal for stock watering.

*Current groundwater abstraction*

The low quantity and quality of groundwater is reflected in the lack of groundwater extraction infrastructure. A search of bore information from the DECCW database, as well as information supplied by researchers at Geosciences Australia, indicated that there are only approximately 36 bores within 20 km of the mine lease. The closest of these wells (600132 and 803404) are approximately 2 km from the Project Area (refer *Figure 10.3*).

Groundwater in the region occurs at a relatively shallow depth. Standing water levels between 2 – 46 metres below ground level (mbgl) were found for 25 groundwater bores within a 15 km radius of Broken Hill, based on information available from the NSW Department of Infrastructure Planning and Natural Resource (DIPNR). The two wells in close proximity to the mine are installed to depths of 18 to 30 mbgl, respectively, with standing water levels at the time of installation of 9.0 and 22.0 mbgl, respectively (refer *Table 10.2*).

Groundwater extraction bores in the Broken Hill area are mainly confined to known fault zones and ephemeral creeks, the two geological features that provide the area's most effective groundwater recharge zones and highest groundwater storage capacity. Despite the quality issues, groundwater in the area is primarily used for livestock, mainly associated with the beef cattle industry.

*Figure 10-3 Location of boreholes within the region*


Broken Hill Operations Pty Ltd

Source: Golder Associates

Scale: Not to scale

*Table 10-2 Summary of groundwater bore data*

| ID | Bore Depth (m) | Bore logs | Depth to Top of Aquifer (m) | Supply (m3/day) | Standing Water Level (mbgl) | Quality | Other |
|---|---|---|---|---|---|---|---|
| 4297 | - | | | - | - | | |
| 9812 | 22.3 | | | 112.32 | 7 | - | Adjacent to fault |
| 9653 | 131.1 | | | 0 | - | - | |
| 9782 | 21.3 | | | 6.912 | 18.3 | Brackish | |
| 9785 | - | | 30.5 | 2.592 | 10.7 | Good | |
| 10089 | 15.5 | | | 13.824 | 9.1 | Good | Adjacent to fault |
| 10090 | 54.94 | | | 65.664 | - | Good | |
| 10091 | 27.4 | | | Poor | 18.3 | Good | Adjacent to fault |
| 10094 | 19.8 | | | 112.32 | 17.4 | Good | |
| 10095 | 30.5 | | | 112.32 | 21.3 | Good | |
| 10096 | 21.3 | | | Good | 17.7 | Good | |
| 10097 | 15.2 | | | Fair | 7.6 | Good | |
| 10098 | 15.2 | | | Fair | 6.1 | Good | |
| 10099 | 18.3 | | 15.2 | 54.432 | 12.2 | Good | |
| 10136 | 27.4 | | | 4.4064 | 11.6 | Very good | |
| 10139 | 18.3 | | 12.2 | 65.4912 | 12.2 | Good | |
| 10244 | 15.2 | | | 224.64 | 2.7 | Good | |
| 17685 | 42.7 | 0-42.7m grey shale | | 0 | - | | |
| 18521 | 20.7 | 0-3.3m clay & gravel 3.3-15.9m schist 15-9-18.3m pegmatite 18.3-20.7m schist | 18.3 | 19.872 | 7.6 | Stock | Fractured aquifer T=1.67m3/day/m (S=0.001) |
| 20084 | 15.3 | 0-1.2m sand red clay 1.2-7.9m yellow sandstone 7.9-15.2m grey rock 15.2-15.3m coarse gravel | | 25.92 | 10.1 | - | |
| 21680 | 24.4 | 0-4.3m clay 4.3-24.4m rock | 18.3 | 32.832 | 16.8 | Stock | T=19.4 m3/day/m (S=0.001) |
| | | | | | | | |

*Local groundwater conditions*

Results of exploration drilling undertaken in the early 1980s indicated the presence of groundwater storage within a brecciated zone of the hanging wall contact between the Lode horizon and the regional granite gneiss. Groundwater yields from this zone were estimated to be up to 240 $m^3$ per hour, compared to yields of about 10 $m^3$ per hour from drill holes within the Lode horizon (The Zinc Corporation Ltd 1983). However, BHOP has indicated that it has not encountered this feature in over 50 exploration boreholes drilled along a 1.2 km strike extent. This high yielding zone has not been identified by recent comprehensive studies of the geological structure of the mine (Rothery, 2001), and even if it was present, there would be about 200 m of competent bedrock separating it from the target mining zone.

The hydrologic relationship of the hanging-wall groundwater zone to the Lode groundwater system is unknown. The storage coefficients estimated for the Lode groundwater system range between 0.001 and 0.01, with the thickness assumed to be 150 m. Total dissolved solids (TDS) concentration for much of the groundwater was within the range of 8,000 to 10,000 ppm, however groundwater TDS concentrations of up to 14,000 ppm have been recorded (The Zinc Corporation Ltd 1983).

Private bores in the vicinity of Broken Hill generally utilise groundwater for livestock water supply. This groundwater appears to be of better quality than that extracted within and adjacent to the major mining lease areas, suggesting that the bores access a separate, and likely perched, aquifer system.

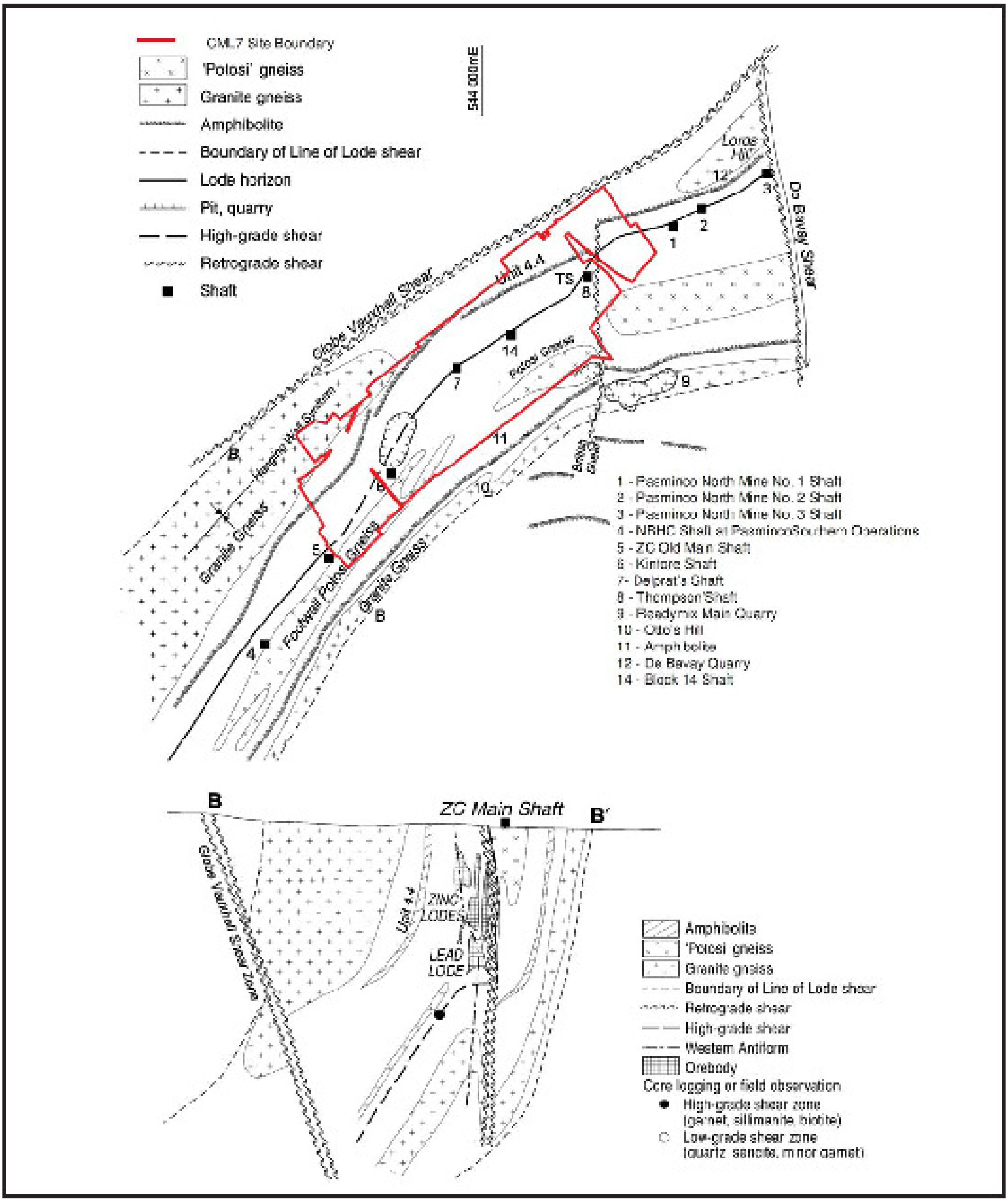
*Groundwater quantity*

The total steady state groundwater inflow with mining at 800 m depth is expected to be around 6 L/s to 6.5 L/s. This comprises the likely rainfall contribution from the catchment to groundwater flow of approximately 3.1 L/s and seepage from the ground around and below the old workings of approximately 3.0 L/s to 3.5 L/s. This flow can be expected to come mainly from the northwest, northeast and southeast as Perilya Broken Hill Operations Pty Ltd, South Mine is actively pumping from its deeper workings to the southwest of the site. The actual inflow could be greater if high permeable zones within the rock mass are encountered during mining, however this is considered unlikely.

Historical evidence suggests that current and past pumping from other mining operations in the region has resulted in a significant cone of depression in the groundwater table within the Line of Lode based groundwater system. The drawdown cone induced by the current pumping is considered to be relatively steep to the northwest and southeast and relatively flat through the permeable old workings to the northeast. The planned deepening and extending of the mine workings within the site area will deepen and extend the base of the drawdown cone but the gradient to the northeast will steepen as mining extends below the base of old workings.

The mine deepening is unlikely to affect the drawdown cone near the surface and therefore is unlikely to impact on the groundwater levels in the two shallow groundwater bores within 2km of the mine. These bores are also separated from the proposed mining zone by the Globe Vauxhall Sheer Zone (refer *Figure 10-4*) running parallel to the western lease boundary. The nature of the structural features in the bedrock suggests that if drawdown or depressurisation associated with the dewatering program were to occur, the effects would propagate preferentially in a north-east to south-west direction consistent with the regional trend of the structural feature.

***Figure 10-4 Geology of the Broken Hill Line of Lode***




Broken Hill Operations Pty Ltd

Date: 02/12/2009

Source: Golder Associates Pty Ltd

Scale: Not to scale

*Groundwater dependent ecosystems*

Groundwater dependent ecosystems (GDEs), specifically river red gums, could potentially be present along creek lines within the vicinity of the mine. However, the local geological structure provides a hydraulic separation between the mine lease area and the closest creek line. Accordingly, mining activities are considered unlikely to impact on perched groundwater resources that may potentially sustain river red gum ecosystems.

## 10.4 WATER SUPPLY

The water balance model prepared by BHOP as shown in *Chapter 2* (*Figure 2-19*) indicates there will be a demand for approximately 638 MLpa of water for the Project. Water will be supplied from the town water supply (9 MLpa potable water and 288 MLpa raw water) and from water reclaimed on-site (350 MLpa).

The water reclaimed from No 7 Shaft dewatering is suitable for use as process water with treatment. BHOP proposes to treat the water by mixing it with the processing plant tailings and precipitating the dissolved minerals out in the backfill plant thickner. Test work has demonstrated that addition of lime or NaOH solutions have a significant impact on the pH of the water and the level of dissolved metals respectively. These results confirmed the waters suitably for use in processing. Reclaimed water will be returned after treatment at the back fill plant to the process water tank which has a three hour holding capacity or to the Silver Tank which has a capacity of 9 ML.

BHOP will obtain a water extraction licence for reclaimed water from No 7 Shaft.

## 10.5 IMPACT ASSESSMENT

Assessment of potential impacts resulting from the Project has been undertaken for:

- town water supply;
- surface water;
- groundwater;
- groundwater users in the immediate vicinity of CML7 (defined as being within 2 km of the site); and
- GDEs in the proximity of the mine lease.

Each of these is evaluated in the following sections.

### 10.5.1 Town water supply

The existing water main on the southern side of the site will be used to provide water form the town water supply. Advice from County Water indicates that the bulk of the town water supply for Broken Hill is supplied form the Menindee Lakes Scheme, with a licensed allocation of 10 GL/year, while the current water consumption for Broken Hill ranges from approximately 7 to 8 GL/year.

Country Water indicate that the estimated requirement from the town water supply in the mine water plan (approximately 297 MLpa: 288 MLpa as raw water and 9 MLpa as potable water) was available and would not impact on the security of water supply for Broken Hill.

The potential to use recycled effluent from Country Water was considered, however there is insufficient infrastructure to connect to the County Water recycled water supply. Investigations into this option will continue and, if and when the network becomes available, further discussions will be undertaken regarding the use of effluent water.

### *10.5.2 Surface water*

Surface water features near to the site are presented in *Figure 10-3*. The closest surface water feature to the mine is a minor creek, Stephens Creek, located approximately 2.5 km to the east of the Project Area. The creek drains to the Stephens Creek Reservoir located approximately 15 km north-east of CML7. Whilst there may be potential for vertical leakage of perched groundwater associated with surface water features into bedrock structural features, previous research has suggested that the connection between bedrock and perched aquifers is likely to be limited. In addition, the creek line is located perpendicular to the regional trend of structural features, and there is at least one significant shear zone separating the mine from the creek.

There is a water well installed approximately 5 km to the east of the Project Area (10094 – refer *Figure 10-3*) adjacent to Stephens Creek. The water level is reported at approximately 20 mbgl (as expected from a perched groundwater resource that has not been impacted by drainage). Water quality information for this well is not available. Stephens Creek Reservoir itself is considered to be too remote from the site to be affected by dewatering activities within CML7, even if a hydraulic connection did exist. Given this, it is considered that it would be unlikely that extension of mine dewatering activities will directly impact on surface water features (Golder Associates, 2008).

Impacts to off-site surface water drainage from the operations are negligible, as the majority of activities will be undertaken within areas that will be bunded and graded to prevent direct off-site runoff. Runoff form all active mine areas is contained on-site for storms up to and including the 100-year ARI event. For larger storms, discharges may occur; from some areas however, water discharged under these conditions will be significantly diluted by surrounding floodwaters.

The layout of proposed stormwater management is described in greater detail in the SWMP prepared by Golder Associates 2010, *Annexure J*.

### *10.5.3 Groundwater*

A review of the physical and chemical properties of the hydrogeological system indicated that the potential risks to the groundwater resource resulting from the Project are negligible for the following reasons:

1. Previous experience with evaluation of aquifer depressurisation associated with mining in low permeability formations typically indicates that significant depressurisation is constrained to the immediate vicinity of the mining operations provided significant water-bearing structural features are not intercepted by the mine workings.

2. A significant structural feature in the bedrock, namely the Globe Vauxhall sheer zone, runs parallel to the western lease boundary separating the proximal bores from the mine site. The nature of this structural feature in the bedrock suggests that if drawdown or depressurisation associated with the dewatering program were to occur, the effects would propagate preferentially in a north east – south west direction (consistent with the regional trend of the structural feature) with limited influence likely to propagate westward in the direction of these bores.

3. There are numerous historical underground mine workings and the cumulative influence of these mining operations is likely to have resulted in significant localised depressurisation of deep water bearing horizons. The additional influence of the proposed mine workings on the

groundwater resource is likely to be indistinguishable relative to existing impacts of past mining activities.

4. The potential for impacts to groundwater quality resulting from mining-related contamination is considered to be limited due to the high natural background concentrations of heavy metals in the groundwater, and the structural features that act to isolate the mine lease area from adjacent groundwater resources. Any potential groundwater quality impacts due to the proposed mining activities are expected to be localised and are unlikely to pose a risk to the shallow groundwater resource accessed by local groundwater users.

5. Broken Hill ore lacks pyrite and contains only traces of protoxide, acid waters are not generated from ore oxidation and tailings oxidation. Furthermore, calcite is a common mineral in Broken Hill ores. This mineral buffers any acid fluid and, with oxidative coatings on galena and sphalerite in tailings, acid mine waters have not derived from the ore or tailings over the last 125 years of mining; and

6. During diamond drilling holes were logged for geology, geotechnical and engineering parameters. This drilling did not intercept any significant water-bearing structural features and indicated that any mining will take place in rocks of low fracture density, low permeability and low porosity. Such rocks reduce the associated radial extent of depressurisation of subsurface water-bearing zones.

. The potential for the Project to impact this groundwater resource is minimal.

### *10.5.4 Groundwater users*

As previously discussed, there are two registered bores within 2 km of CML7, both of which are installed in shallow sediments, and are separated from the proposed mining zone by the Globe Vauxhall sheer zone, a significant structural feature running parallel to the western lease boundary.

Water levels within the mine lease workings have been maintained at approximately 500 mbgl for the past twelve years as a safety measure for the Perilya Broken Hill Operations Pty Ltd South Mine. The nature of the structural features in the bedrock suggests that drawdown or depressurisation associated with this dewatering program would propagate preferentially in a northeast – southwest direction with the regional trend of the structural feature (*Figure 10-4*). Little if any influence is expected to propagate westward, perpendicular to the structural features.

If significant impacts to the groundwater resource being accessed by these shallow bores were to occur, they would have already been realised given the long term dewatering program on-site. The standing water levels for these bores are approximately 10 – 20 mbgl. The dewatering program should have by now influenced the groundwater levels in the bores if there was a direct hydraulic connection.

The future development of the local groundwater resource is considered unlikely by Golder Associates, because of the generally poor quality and low yields. To date, the thick sedimentary sequences of the Mundi Mundi plains have been the target of local water supply schemes, and it is expected that this will remain the case in the foreseeable future.

### *10.5.5 Groundwater dependent ecosystems*

Groundwater dependent ecosystems (specifically river red gums) could potentially be present along creek lines and should be conservatively assessed as such. However, considering the hydraulic separation provided by the local geological structure between CML7 and the closest creek line, the mining activities are considered unlikely to impact on perched groundwater resources that are potentially sustaining river red gum ecosystems.

### 10.6 MANAGEMENT AND MONITORING MEASURES

A water management plan will be developed for the Project and will include the following management and monitoring measures. The Stormwater Management Plan (SMP) developed by Golder Associates will form part of this plan.

*Surface water management*

Golder Associates were engaged by BHOP to identify stormwater management measures that are required on the mine site to facilitate Project operational and environmental objectives. The main surface water management objectives for Project activities are to:

- prevent discharge of potentially contaminated surface waters from active mine areas off-site;
- minimise disruption to the mining activities and provide a safe working environment; and
- identify erosion and sediment control measures for the surface areas of CML7 which fall under the responsibility of BHOP.

The existing landform on site and the arid climate conditions provide unique opportunities in developing a SWMP that satisfies the operational requirements of the mining activity and prevents release of runoff from active areas of the mine site.

The primary feature of the SWMP is the provision of small ponds/storages, spread throughout the mine site, that temporarily hold surface water runoff. Due to high evaporation rates, this runoff would be expected to evaporate in a relatively short period following storm events. This arrangement prevents runoff from active mine areas leaving site and allows the suspended particles to settle in the ponds/storages, better managing contaminated sediment on site.

The following set of goals guided the preparation of this SWMP:

- retain runoff from a 100 year ARI rainfall event from all active mine areas. The high evaporation rate would allow retained water to evaporate in a relatively short period. This goal minimises potential impacts on downstream environments;
- retain runoff locally in small ponds/storages at various locations on the mine site, utilising the existing landform where feasible. This would:
  - eliminate the need to construct a large storage and avoid hazards associated with large storages;
  - help in the sedimentation process that would remove suspended solids from the runoff; and
  - minimise erosion potential by eliminating the requirement to carry large discharges to a smaller number of large storages.
- provide appropriate spillways for the local ponds to convey flows greater than the 100 year runoff event;
- utilise BHP Pit and Blackwood Pit for discharge of local catchments. This would minimise the need to construct a large storage;
- utilise the available capacity of Horwood Dam to contain the 100 year runoff event from various sub-catchments that report to this dam;

- divert runoff away from Kintore Pit to minimise the flooding risk in the Pit and to minimise the impact on mining operations (as the portal and decline for the proposed underground operations are located in the base of Kintore Pit);
- divert runoff away from Little Kintore Pit to Storage 17 to minimise the risk associated with unregulated discharge down the unused shaft;
- provide sediment control ponds in the active mine processing area to minimise the movement of contaminated runoff to local downstream storages. This measure would provide the first level of protection for control of contaminant movement to Horwood Dam. A second level of protection would be provided by the downstream ponds/storages where sedimentation would allow further stripping of the contaminants from the runoff; and
- provide appropriate sediment and erosion control measures on site. Prevention of erosion on site will minimise the production of loose sediment that may otherwise become airborne and create a dust hazard for the surrounding urban area. This measure would be further assisted by the air quality monitoring program at the site.

Based on this management criteria, the mine site was subdivided into small catchments (refer *Figures 10-5* to *10-10*) enabling where possible for the runoff from each catchment to be retained within the catchment by providing bunding along its boundary, refer *Table 10-3*.

***Table 10-3 Catchment details***

| Catchment No. | Storage/Description | Area (ha) | Runoff Volume ($m^3$) |
|---|---|---|---|
| Kintore Pit | | 13.95 | 10,230 |
| Little Kintore Pit | | 2.42 | 1,800 |
| 1 | Large drain and S1A | 4.32 | 3,170 |
| 1A | S1A | 3.48 | 2,550 |
| 2 | ROM (S2) | 6.53 | 4,790 |
| 3 | | 0.48 | 350 |
| 4 | | 1.33 | 980 |
| 5 | | 1.57 | 1,150 |
| 6 | | 1.55 | 1,140 |
| 7 | | 1.10 | 810 |
| 8 | S8 | 0.89 | 650 |
| 9A | S9A | 0.61 | 450 |
| 9B | S9B | 0.59 | 430 |
| 10 | | 7.15 | 5,240 |
| 11A | S11A | 1.78 | 1,310 |
| 11B | S11B | 1.90 | 1,400 |
| 12 | S12 | 0.55 | 400 |
| 13A | S13A | 6.27 | 4,600 |
| 13B | S13B | 1.39 | 1,020 |
| 14 | Drain/sediment retention ponds | 2.07 | 1,520 |
| 15 | | 0.63 | 460 |
| 16 | | 0.83 | 610 |
| 17 | S17 | 2.41 | 1,770 |
| 18 | S18 | 1.45 | 1,060 |
| 19 | Mt. Hebbard | 5.18 | 3,800 |
| 20A | | 6.94 | 5,090 |
| 20B | | 1.80 | 1,320 |
| 21A | | 1.14 | 840 |
| 21B | | 1.80 | 1,320 |
| 22 | | 4.14 | 3,040 |

| Catchment No. | Storage/Description | Area (ha) | Runoff Volume ($m^3$) |
|---|---|---|---|
| 23 | S23 | 0.67 | 490 |
| 24 | | 1.46 | 1,070 |
| 25 | S25 | 3.62 | 2,660 |
| 26 | S26 | 1.58 | 1,160 |
| 27 | | 1.08 | 790 |
| 28 | | 2.40 | 1,760 |
| 29 | | 2.52 | 1,850 |
| 30 | | 1.23 | 900 |
| 31B | Drain | 1.54 | 1,130 |
| 31A | S31A | 2.96 | 2,170 |
| 32 | | 1.92 | 1,410 |
| 33 | | 1.91 | 1,400 |
| 34 | | 2.65 | 1,940 |
| 35 | S35 | 6.13 | 4,490 |
| 36 | | 2.28 | 1,670 |
| 37 | | 2.66 | 1,950 |
| 38 | | 4.02 | 2,950 |
| 39 | S39 | 1.90 | 1,390 |
| 40 | S40 | 0.38 | 280 |
| 41 | | 1.85 | 1,350 |
| 42 | | 5.06 | 3,710 |
| 43 | S43 | 1.09 | 800 |
| 44 | S44 | 3.86 | 2,830 |
| 45 | S45 | 1.00 | 740 |
| 46 | | 1.01 | 740 |
| 47 | | 2.60 | 1,910 |
| Horwood Dam | | 5.39 | 3,950 |
| BHP Pit | | 6.19 | 4,540 |
| Blackwood Pit | | 15.04 | 11,030 |
| TSF 1 | | 11.61 | 8,520 |
| Decant Dam | | 0.59 | 430 |
| **TOTAL** | | **180** | |

***Figure 10-5 Water Catchment Areas***


Rehabilitated areas

Mine lease surface exclusion areas

CML7 Bounday

Catchment Boundaries

Broken Hill Operations Pty Ltd | Source: Golder Associates | Scale: Not to scale

*Figure 10-6 SMP – Proposed west catchment areas*

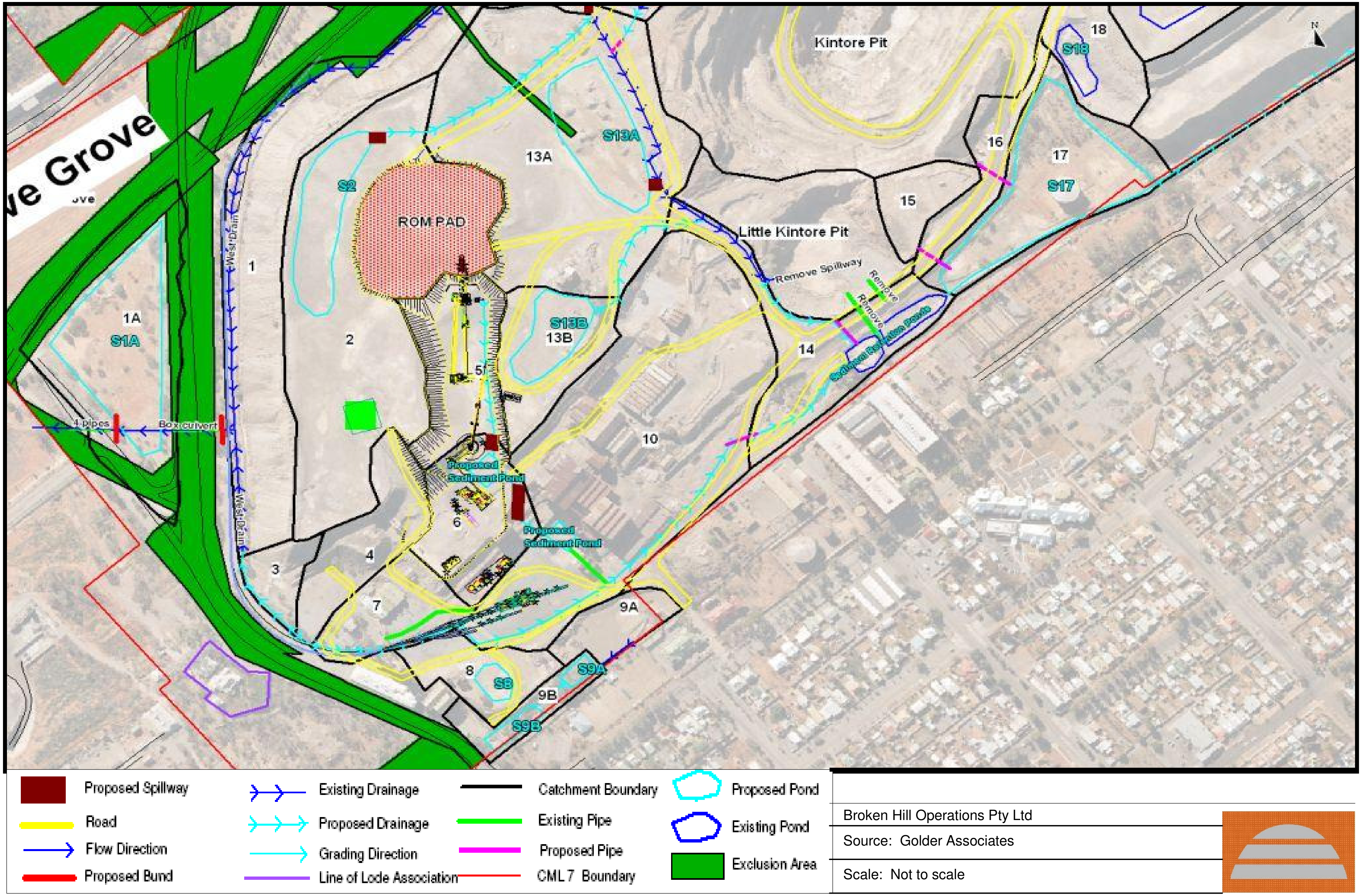


*Figure 10-7 SMP – Proposed west central catchment areas*

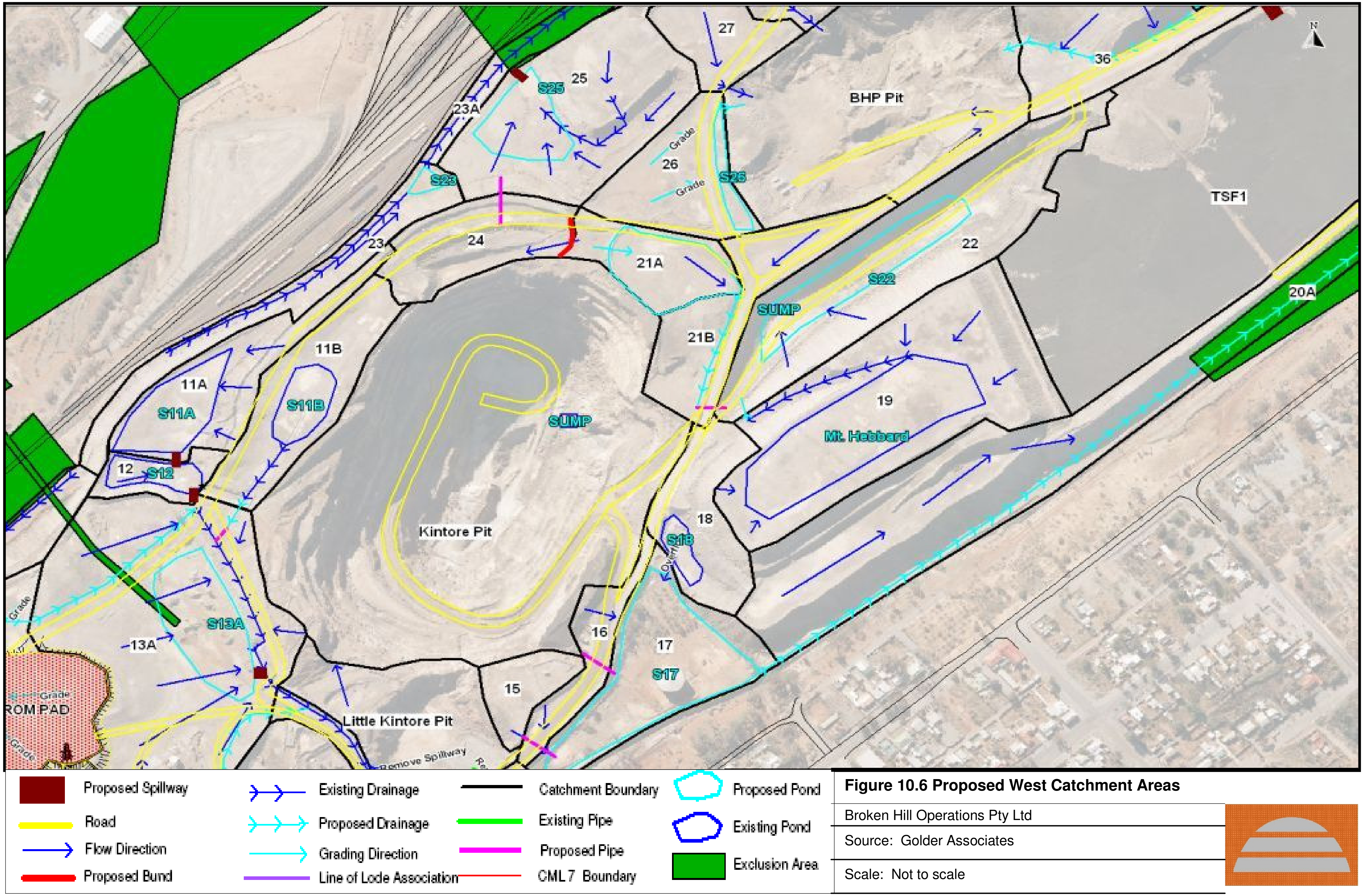


*Figure 10-8 SMP – Proposed central catchment areas*

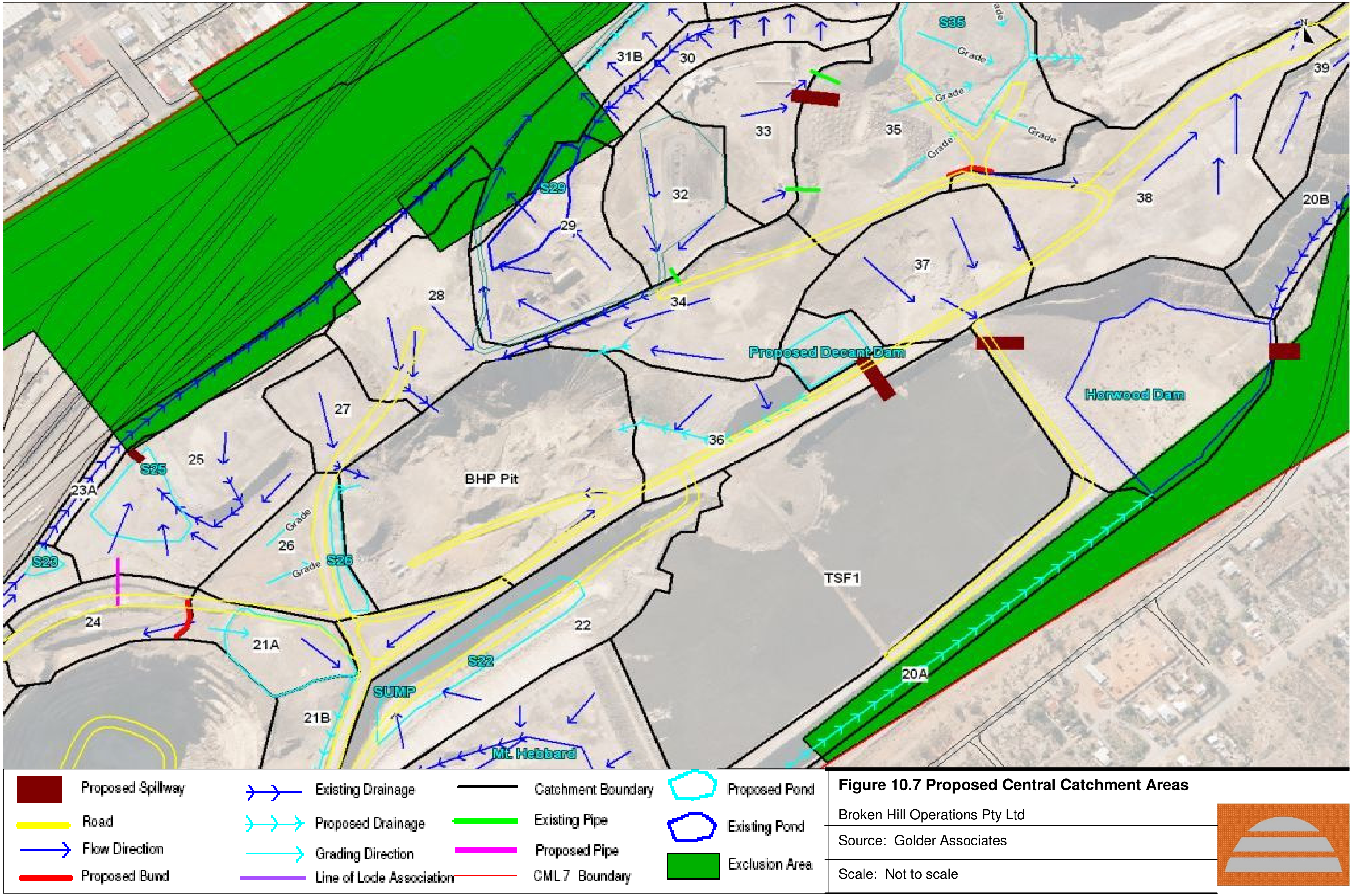



**Figure 10.7 Proposed Central Catchment Areas**

Broken Hill Operations Pty Ltd

Source: Golder Associates

Scale: Not to scale

*Figure 10-9  SMP – Proposed east catchment areas*

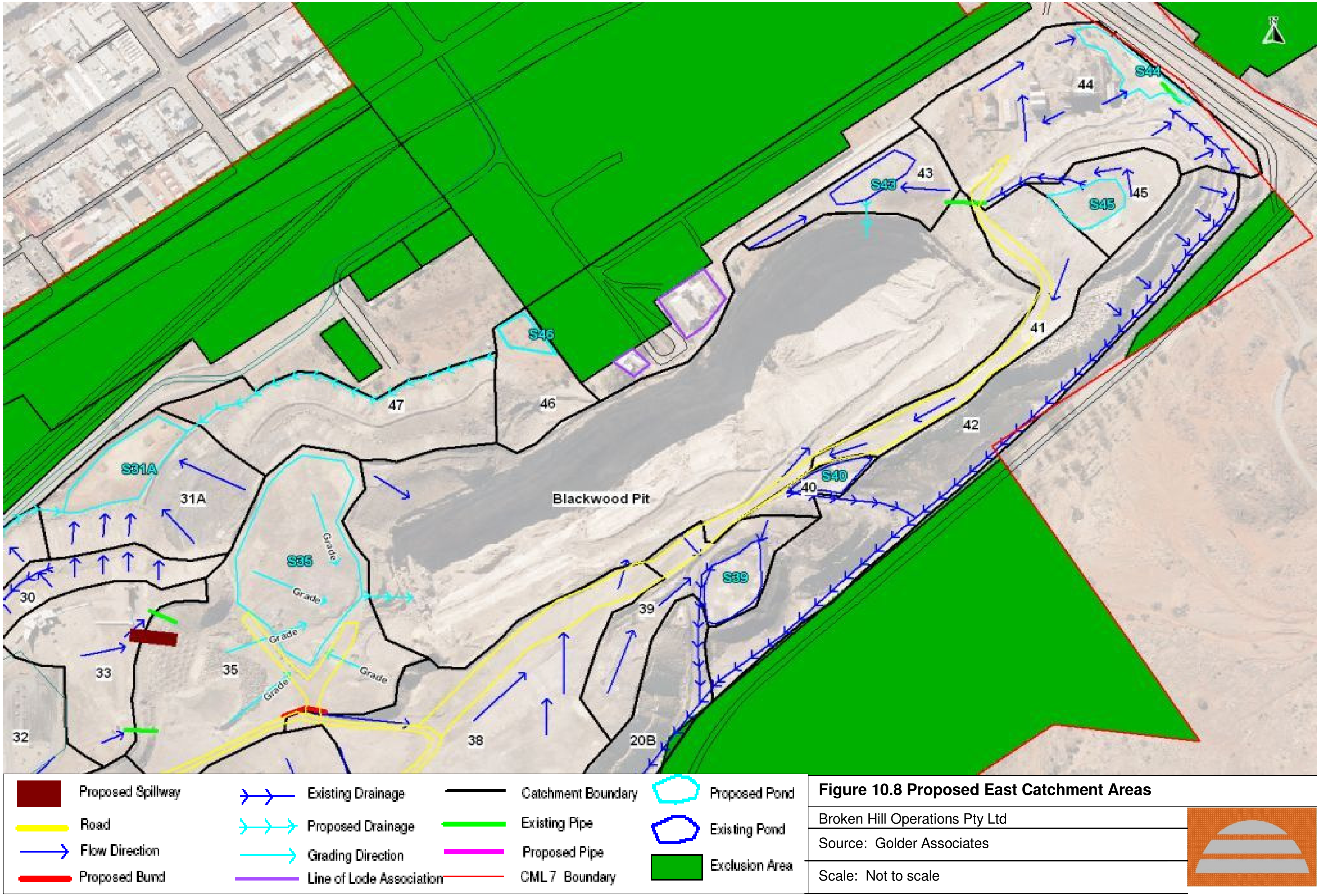


***Figure 10-10 SMP – Proposed erosion and sediment control in the processing area***

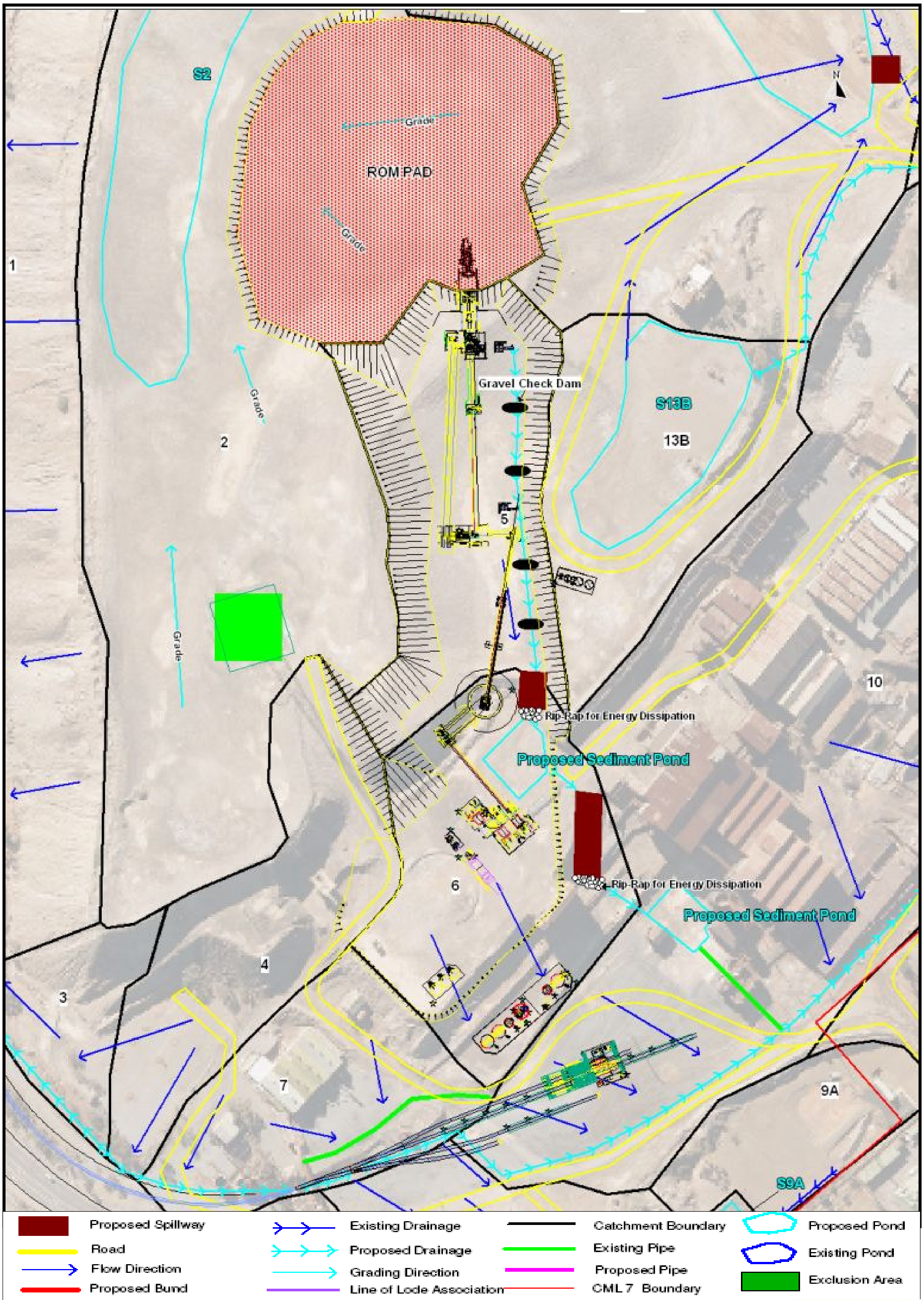
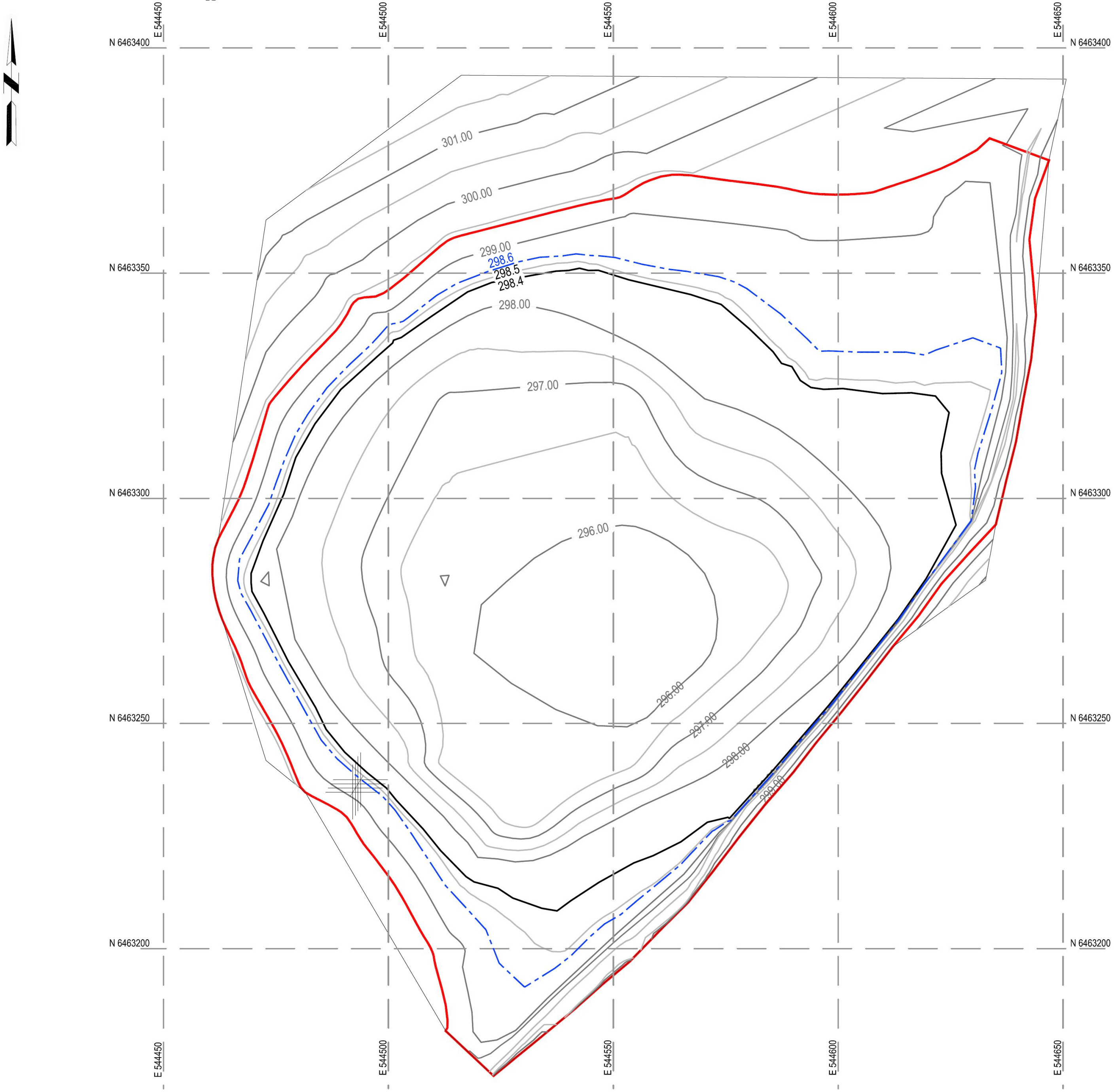



**Figure 10.9 Proposed Erosion & Sediment Control in the Processing Area**

Broken Hill Operations Pty Ltd | Source: Golder Associates | Scale: Not to scale

## *Figure 10-11 SMP – Existing volume of Horwood Dam*




**CALCULATED VOLUMES**
ALL SURFACE AND VOLUME CALCULATIONS ARE CREATED USING AUTOCAD LAND DEVELOPMENT DESKTOP 2008
**BASE SURFACE**
**NS091125_Pond 1**
**COMPARISON SURFACE**
**Ds091125_RL299-40**

**Legend**

| | |
|---|---|
| (red line) | Bunded Area at elevation 299.4m AHD |
| (blue dash-dot line) | 100 Year Runnoff Event Containment Elevation |

Broken Hill Operations Pty Ltd

Source: Golder Associates

Scale: Not to scale

The catchment layout generally conforms to the existing landform. Where practical the catchment area has been reduced to minimise the requirement for storage within the catchment. For large catchments or catchments where significant mining activities are to be undertaken, dedicated water storages have been designed. A review of current facilities will be undertaken prior to final design, in the case of current water storage basins to ensure design capacity and in the case of pipes and bunding, to ensure their integrity. De-silting and repairs will be undertaken where required.

Potential impacts of the Project on surface waters will be mitigated by implementation of the SWMP. As well as fully retaining all runoff from active mine areas for storms up to the 100-year ARI event (and in some cases 1:200 (Horwood Dam) and 1:500 (Catchment 1A) events), the cascade arrangement of storages will enable settlement of most sediment and suspended contaminants before they can reach Horwood Dam. Refer *Figure 10-11* for capacity curves for the Horwood Dam. Storage dams will have markers that indicate when sediment is to be removed so that minimum storage requirements can be maintained. During maintenance, sediment will be removed from the dams and disposed of to the BHP Pit, TSF1 and / or TSF2. Sediment will not be removed off-site.

The SWMP provides for in situ stormwater retention within the catchment areas which will require low level bunding. Ponded water will be disposed of by evaporation from these areas. This will reduce the risk of overflows from all storage areas as well as the required size for each storage basin.

All runoff from the haul roads and hardstands will be directed to storage basins and retained until disposed of by evaporation or returned for use as process water or for other operational uses.

The closed water circuit for the mining operations will result in complete management of process water with no off-site wastewater discharges from the Project operations other than the conventional sewage discharge. Sediment collection ponds are proposed in the vicinity of the processing activities and again between catchments 14 and 17 to capture and return potentially mineralised sediment to the processing circuit.

Details for each catchment, including required water management structures, are outlined in the SWMP report at *Annexure J*.

*Fuel and chemical management*

A permanent refuelling location is planned to the west of the old No.6 Ventilation Shaft. This refuelling facility will include oils and lubricants contained in either self bunded storage containers or a bunded area capable of holding 110% of the oils and lubricants. The refuelling station will be bunded so that any spills will be contained, collected and passed through an oil / water separator. Fuel and lubricants which have to be transferred to remote equipment will be transported via a purpose built fuel trailer.

Chemicals, including reagents and explosives, will be in bunded and roofed facilities to prevent the entry of stormwater.

Potential spills will be contained, in the first instance, by bunding and grading to sumps with backup containment created by the main storage basins. Spill kits will be available on-site and staff will be trained in their use to contain, clean up and dispose of spills as appropriate.

*Vehicle washdown facilities*

There will be three permanent equipment wash down locations within the Project Area; a vehicle wash bay, a small light vehicle wash bay and a heavy vehicle wash bay.

The vehicle wash facility will be located near the exit boom gate for the site. The facility is designed to wash the wheels and undercarriage of vehicles (including semi-trailers) before they leave the Project Area. The water used in the washing process will be fully contained in a closed system, passing through an oil water separator and sediment separator before being reused to wash further vehicles.

The small light vehicle and heavy vehicle wash bays will be located adjacent to the maintenance workshop. These wash bays will be designed to utilise high pressure cleaners and will be fully bunded to contain the wash water. Dirty water from these two bays will be passed through an oil/water separator and then to a dedicated series of two settling dams. Sludge from the wash bay sumps, settling dams and truck wash sediment separator will be periodically removed and disposed of to the BHP and /or Blackwood Pits, as discussed in *Chapter 15*.

*Water quality monitoring and management*

Water quantity and quality in the Horwood Dam will be monitored for the life of the mine with sampling and testing every three months, water permitting. The analyses will include total suspended solids, pH and oil and grease. The water levels within the stormwater storage basins will be managed to gain maximum return to processing and / or evaporation in readiness for collection of stormwater events.

The site stormwater management structures will be inspected quarterly and following significant rainfall events. Any deficiencies or maintenance requirements will be noted and arrangements made for the appropriate remedial works. Regular maintenance activities will include the periodic removal of sediment and other materials from the site storage basins and sediment traps.

Water flow meters will be installed to monitor usage and confirm water balance predictions. Management initiative to control erosion and sedimentation transfer will be included in the updated SWMP, which will provide details of drainage lines, sediment traps, check dams, erosions control, bunds infiltration areas, sediment fences, filters and all other erosion and sediment control devices.

*Water conservation and recycling*

BHOP is committed to minimising its requirement for raw water from town supplies. Dewatering from No 7 Shaft will be treated to enable tis use in processing to reduce clean water demands. Maximum water return will be utilised from processing. The process water tank will have a three hour holding capacity and will receive water from the tailings thickener, lead thickner overflow, tailings storage return water and raw make-up water. In addition the Silver Tank will also be utilised to store water, capacity 9 ML. Process water will be distributed through the grinding and flotation circuits by a dedicated centrifugal pump.

A treatment system has been installed on the vehicle wash facility to enable the water to be reused.

Investigations will continue for the potential to use recycled effluent water from County Water and if the network becomes available further discussions will be undertaken regarding the use of effluent water. Investigations, including the necessary permitting, will also be undertaken in the use of grey water for site irrigation.

## *10.7 MANAGEMENT MEASURES*

In summary BHOP will undertake the following management water control measures to manage water retention within the site, maximise water recycling and water conservation:

- undertake works to implement the surface water management plans outlined in the Golder Report 2010 and amended as required;
- review the surface water management plan at regular intervals to assess its ongoing effectiveness;
- treat mine dewatering to enable usage in the processing plant;
- maximise the use of water reclaimed from the tailings facilities by using this water for dust suppression on the TSF and return tailings water to the processing plant for reuse;
- recycle water from the Horwood Dam to the processing plant for reuse and to maintain maximum capacity;
- investigate the use of the silver tank as water holding tank for water to be recycled to the processing plant. This will reduce evaporation from open storage; and
- investigate the use of grey water from domestic facilities for use in ground management;

Measures to manage water quality that will be included in BHOP's water management programme include:

- provision of spill kits and requirements for training;
- design and installation of chemical storage to include bunds with suitable sumps, and where appropriate roofed to prevent stormwater entry;
- bunding of the diesel refuelling station;
- oil / water separators to be installed at vehicle was facilities;
- water monitoring including groundwater (represented by mine dewatering) and at locations to the east of TSF1, and surface water represented by Horwood Dam; and
- inspections of the site drainage system to confirm it maintains operability.

The construction environment management plan will outline specific requirements for erosion and sediment control.

## *10.8 CONCLUSIONS*

Impacts on groundwater are expected to be minimal and not require mitigation actions.

The SWMP provides the detailed requirements to manage surface water. The SWMP will require periodic revision to include changes to the operations at each stage of development as well as refinements to address, if necessary, actual flow data.

There will be no discharge of potentially contaminated process water from the site and therefore no impact on the environment with stormwater management structures designed to contain, and in some cases more than, 1:100 ARI events. Given the long history of successful water management in the Project Area, impacts to surface water quality from the Project are considered a low risk.

The results of the hydrogeological assessment suggest that the groundwater resource in the vicinity of CML7 is characterised by low yields, poor quality and is hydraulically isolated from potential sensitive receptors identified in the vicinity of the mine. As such the Project is considered to represent a low risk to groundwater resources.