ALKANE
RESOURCES LTD

ABN: 35 000 689 216

Tomingley Gold Project

Groundwater Assessment

September 2011

Prepared by

The Impax Group

Specialist Consultant Studies Compendium
Volume 1, Part 3

Tomingley Gold Project

Groundwater Assessment

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September 2011

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EXECUTIVE SUMMARY

This report presents the findings of a Groundwater Assessment of the proposed Tomingley Gold Project ("the Project"). The report was prepared for R.W. Corkery and Co. Pty. Limited on behalf of Alkane Resources Ltd ("the Proponent") and incorporates groundwater modelling completed by Australasian Groundwater and Environmental Consultants Pty Ltd.

The site of the proposed mining, processing and associated waste management activities for the Tomingley Gold Project ("the Mine Site") would be located immediately south of Tomingley, NSW, and approximately 15km north of the Proponent's Peak Hill Gold Mine.

The Project would involve the excavation of ore and waste rock from four open cuts and one underground mine. The open cuts would be excavated to a depth of up to 180m below ground level with the underground mine to a depth of approximately 380m. Excavated waste rock would be placed in three dedicated waste rock emplacements and as backfill for the underground mining stopes. Ore would be processed on the Mine Site to produce gold doré via a system of crushing, grinding, a Carbon-in-Leach circuit, electrowinning and smelting.

The objectives of this assessment are to:

- identify and describe legislation and guidelines that are relevant to the protection of groundwater resources in NSW;
- identify and describe the groundwater resources in the vicinity of the Mine Site;
- identify mining activities that have potential to impact on the quality and/or quantity of groundwater available at and adjacent to the Mine Site;
- assess potential impacts to groundwater at the Mine Site and quantify these impacts, where possible; and
- outline the measures that would be put in place to minimise impacts to groundwater resources in the vicinity of the Mine Site.

In order to meet the project objectives outlined above, The Impax Group completed the following.

- A review of legislation relevant to groundwater management to identify potential constraints on the Tomingley Gold Project was conducted.
- A review of available groundwater bore data and geological information to assess the location and characteristics of groundwater aquifers located within and surrounding the Mine Site, and to establish a conceptual model of groundwater processes within and surrounding the Mine Site ("the Study Area"). This review was also undertaken to assess groundwater quality and potential beneficial uses of groundwater within the Study Area.
- Identification of available groundwater bore data to identify groundwater users within the Study Area.
- Assessment of the potential impacts to groundwater quality within the Study Area.

- Assessment of the potential impacts on the availability of groundwater to other groundwater users within the Study Area.
- Estimation of the volume of groundwater that would need to be pumped from each open cut to allow mining.
- Assessment of the long term steady state groundwater conditions around the open cuts after the cessation of mining.

Based on the results of groundwater review and groundwater modelling undertaken as part of the nominated scope of works, The Impax Group concludes the following.

- Groundwater contained within shallow alluvium aquifers within the Study Area (in particular, the Gundong Creek aquifer) appear to be of good quality and suitable for all beneficial uses. Registered groundwater users within the Study Area use this water for "irrigation" and "stock and domestic" purposes. Groundwater does not occur uniformly across the shallow alluvium of the Study Area. Groundwater yields are typically less than 2L/s. The groundwater appears to exist in narrow sand seams created by the infilling of former creek beds, which are unlikely to interact with each other. As such, any loss of water from shallow alluvium at the Mine Site is not expected to impact on water levels within shallow alluvium aquifers located off the Mine Site. Notably, significant aquifers have not been identified in shallow alluvium at the Mine Site.
- The plains surrounding the Mine Site are typically underlain by andesitic volcanic rock of the Mingelo Volcanics and shale, siltstone and chert of the "Cotton Formation", "Mugincoble Chert" and "Mumbidgle Formation". Recorded groundwater yields in the fractured rock aquifers of these formations range from nil to 3L/s but are typically less than 1.5L/s. Available groundwater quality information indicates that groundwater within this system is saline. An assessment of potential beneficial uses of this water indicated that it may be acceptable as drinking water for sheep only. A search of the NSW registered groundwater bore data identified three deep bores surrounding the Mine Site, all of which have been abandoned. The absence of registered bores within this aquifer surrounding the Mine Site is indicative of the low yielding and poor quality nature of groundwater resources in the fractured rock.
- Dewatering of the open cuts would be likely to result in drawdown in the adjacent fractured rock aquifer(s) but would not impact on groundwater levels in the shallow alluvium located off the Mine Site.
- Based on numerical modelling it is estimated that groundwater would flow into the open cuts and underground working at a rate between 3L/s and 20L/s (94.6ML/yr to 630.7ML/yr). Qualitative assessment of available groundwater information suggests that this is a conservative estimate. It is likely that the actual groundwater inflow rate will be within the lower end of the range, e.g. 3 to 10L/s).
- Total average rainfall entering the open cuts would be 7.4L/s (232.5ML/yr) which would also need to be removed (dewatered) to allow mining to proceed.

- It is possible that evaporation would be adequate to dewater the open cuts in most instances. During periods of heavy or sustained rainfall or low evaporation rates, however, it is likely that some mechanical pumping would be required to achieve the desired drawdown.
- Any water removed from the open cuts would be used on the Mine Site for dust suppression or would be allowed to evaporate from dewatering dams located adjacent to the open cuts.
- Modelling predicts that the cone of depression within the fractured rock aquifer will extend between 2,300m and 5,600m from the Wyoming One Underground. The calculated extend of the cone of depression assumes that the aquifer is infinite in extent. Given the nature of fractured rock aquifers, this is unlikely to be the case. Standing water levels will not fully recover after mining is ceased as there will be ongoing loses of water from the open cuts due to evaporation.
- The underground and open cuts are expected to partially fill with water once mining is completed. The lower portion of the voids are expected to fill relatively quickly as the area of the lower portion of the open cuts are small compared to the area at ground level. It is difficult to predict the depth to which the water level within the final voids will rise. Calculations indicate that water levels would not rise above 207m AHD. However, with natural recharge and evaporation only this level would not be achieved within 50 years of the cessation of dewatering. Calculations of groundwater level recovery indicate that there will be 5 to 30m residual drawdown in the open cuts 50 years after cessation of dewatering operations. There may be up to 20m of residual drawdown within the open cuts 100 years after dewatering ceases.
- Residual drawdown within the open cuts would result in groundwater flow toward the voids. As such, any changes in groundwater chemistry or quality within the open cuts would not impact on groundwater quality within the surrounding fractured rock.
- Surface activities have the greatest potential to impact on groundwater quality. However, the absence of a significant groundwater resource in shallow alluvium at the Mine Site means there is little risk of mining processes impacting on groundwater quality. The underlying alluvium is predominantly clayey material with relatively low permeability, which would prevent any significant spread of potential groundwater quality impacts.
- Chemical and fuel storages at the Mine Site would be above ground and appropriately bunded to minimise potential for groundwater contamination to occur.
- The ore body and waste rock at the Mine Site is non-acid forming so the risk of acid drainage occurring from the waste rock emplacements, Residue Storage Facility (RSF) or the open cuts is very low.
- Leachate from the residue may contain traces of heavy metals and cyanide from ore treatment process. The RSF has been designed, and would operate, in a manner which would prevent leachate entering groundwater aquifers.

- Groundwater dependent ecosystems were not identified on, or in the vicinity of the Mine Site. Mature trees are present along Gundong Creek and at other locations on and surrounding the Mine Site. Whilst these trees may use groundwater in the shallow alluvium they are not considered to be solely dependent on groundwater for their survival and therefore, are not considered to represent a groundwater dependent ecosystem.
- A groundwater monitoring plan would be implemented at the Mine Site once mining commences. The proposed plan would include regular monitoring of water levels and field parameters in the existing deep observation bores and shallow monitoring bores that would be installed around the perimeter of the RSF. The program also provides for annual sampling and analysis for a suite of standard water chemistry analytes.

1 INTRODUCTION

1.1 BACKGROUND

This report presents the findings of a Groundwater Assessment of the proposed Tomingley Gold Project ("the Project"). The report was prepared for R.W. Corkery and Co. Pty. Limited on behalf of Alkane Resources Ltd ("the Proponent") and incorporates groundwater modelling completed by Australasian Groundwater and Environmental Consultants Pty Ltd.

The site of the proposed mining, processing and associated waste management activities for the Tomingley Gold Project ("the Mine Site") would be located immediately south of Tomingley, NSW, and approximately 15km north of the Proponent's Peak Hill Gold Mine (**Figure 1**).

The Project would involve the excavation of ore and waste rock from four open cuts and one underground mine. The open cuts would be excavated to a depth of up to 180m below ground level with the underground mine to a depth of approximately 380m. Excavated waste rock would be placed in three dedicated waste rock emplacements and as backfill for the underground mining stopes. Ore would be processed on the Mine Site to produce gold doré via a system of crushing, grinding, a Carbon-in-Leach circuit, electrowinning and smelting.

The residue left at completion of the ore processing would be placed in a dedicated residue storage facility (RSF). The Mine Site would be progressively rehabilitated over the life of the Project (approximately 9 to 10 years), however, at the cessation of all mining and rehabilitation activities the final landform would retain four open cut voids and modifications to the landform associated with the three waste rock emplacements and the RSF. Section 2.1 provides further information on the proposed activities of the Project.

1.2 STUDY AREA

The area that is the subject of this groundwater assessment ("the Study Area") is the area within a 10km radius from the proposed mining operations. The Impax Group conducted a preliminary assessment which included a review of available groundwater information for the area within a 20km radius. Relevant information identified during the preliminary assessment is also presented within this report.

1.3 OBJECTIVES

The objectives of this assessment are to:

- identify and describe legislation and guidelines that are relevant to the protection of groundwater resources in NSW;
- identify and describe the groundwater resources in the vicinity of the Mine Site
- identify mining activities that have potential to impact on the quality and/or quantity of groundwater available at and adjacent to the Mine Site;
- assess potential impacts to groundwater at the Mine Site and quantify these impacts, where possible; and
- outline the measures that would be put in place to minimise impacts to groundwater resources in the vicinity of the Mine Site.

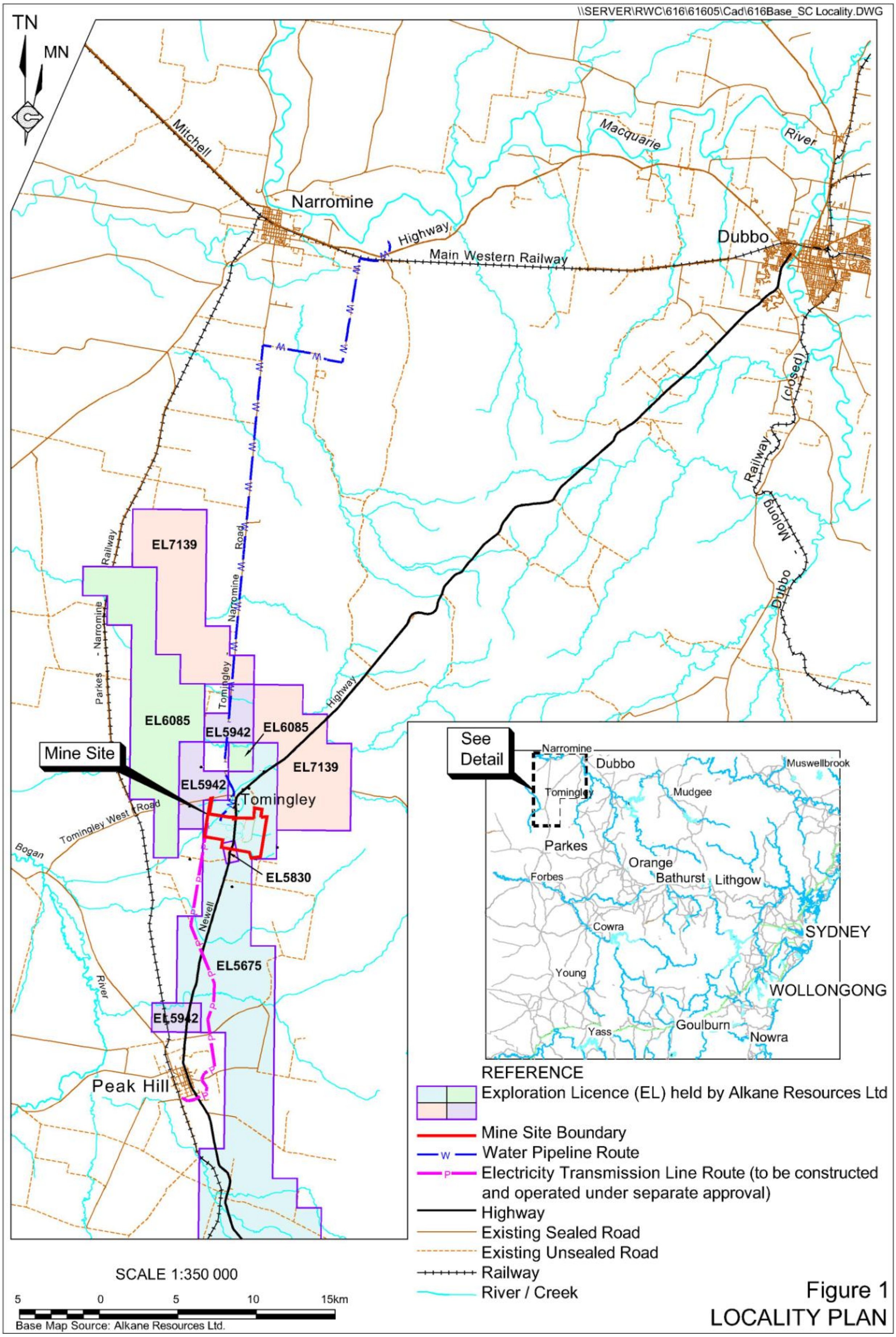


Figure 1
LOCALITY PLAN

In order to meet the project objectives outlined above, The Impax Group completed the following.

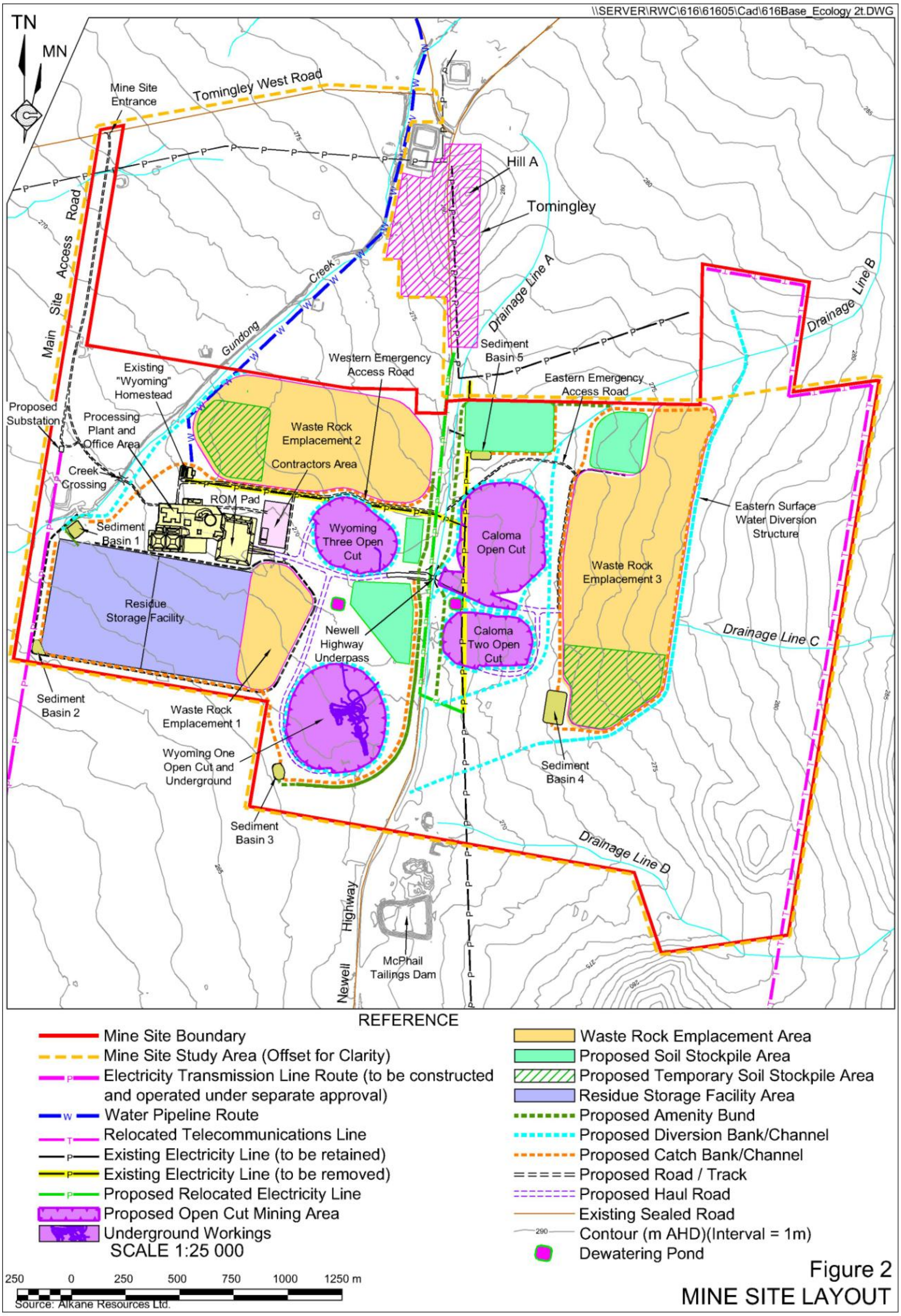
- A review of legislation relevant to groundwater management to identify potential constraints on the Tomingley Gold Project was conducted.
- A review of available groundwater bore data and geological information to assess the location and characteristics of groundwater aquifers located within and surrounding the Mine Site, and to establish a conceptual model of groundwater processes within and surrounding the Mine Site ("the Study Area"). This review was also undertaken to assess groundwater quality and potential beneficial uses of groundwater within the Study Area.
- Identification of available groundwater bore data to identify groundwater users within the Study Area.
- Assessment of the potential impacts to groundwater quality within the Study Area.
- Assessment of the potential impacts on the availability of groundwater to other groundwater users within the Study Area.
- Estimation of the volume of groundwater that would need to be pumped from each open cut to allow mining.
- Assessment of the long term steady state groundwater conditions around the open cuts after the cessation of mining.

2 PROPOSED DEVELOPMENT

2.1 PROPOSED MINING ACTIVITY

The Project incorporates two component areas, a Mine Site on which all mining, processing and associated activities would be undertaken and a water pipeline between a bore(s) located on a property 7km east of Narromine and the Mine Site. **Figures 2, 3** and **4** identify the activities to be undertaken within the component areas which are described as follows.

- Establishment of infrastructure required for the Project, including a water supply pipeline, an underpass beneath the Newell Highway, and vegetated amenity bunds.
- Extraction of waste rock and ore material from four open cut areas, namely:
  - Caloma Open Cut (approximately 19ha);
  - Caloma Two Open Cut (indicative design approximately 9ha);
  - Wyoming Three Open Cut (approximately 10ha); and
  - Wyoming One Open Cut (approximately 19ha).
- Extraction of waste rock and ore material from the Wyoming One Underground.
- Construction of three waste rock emplacements covering a combined area of approximately 129ha.



Source: Alkane Resources Ltd.

Figure 2
MINE SITE LAYOUT

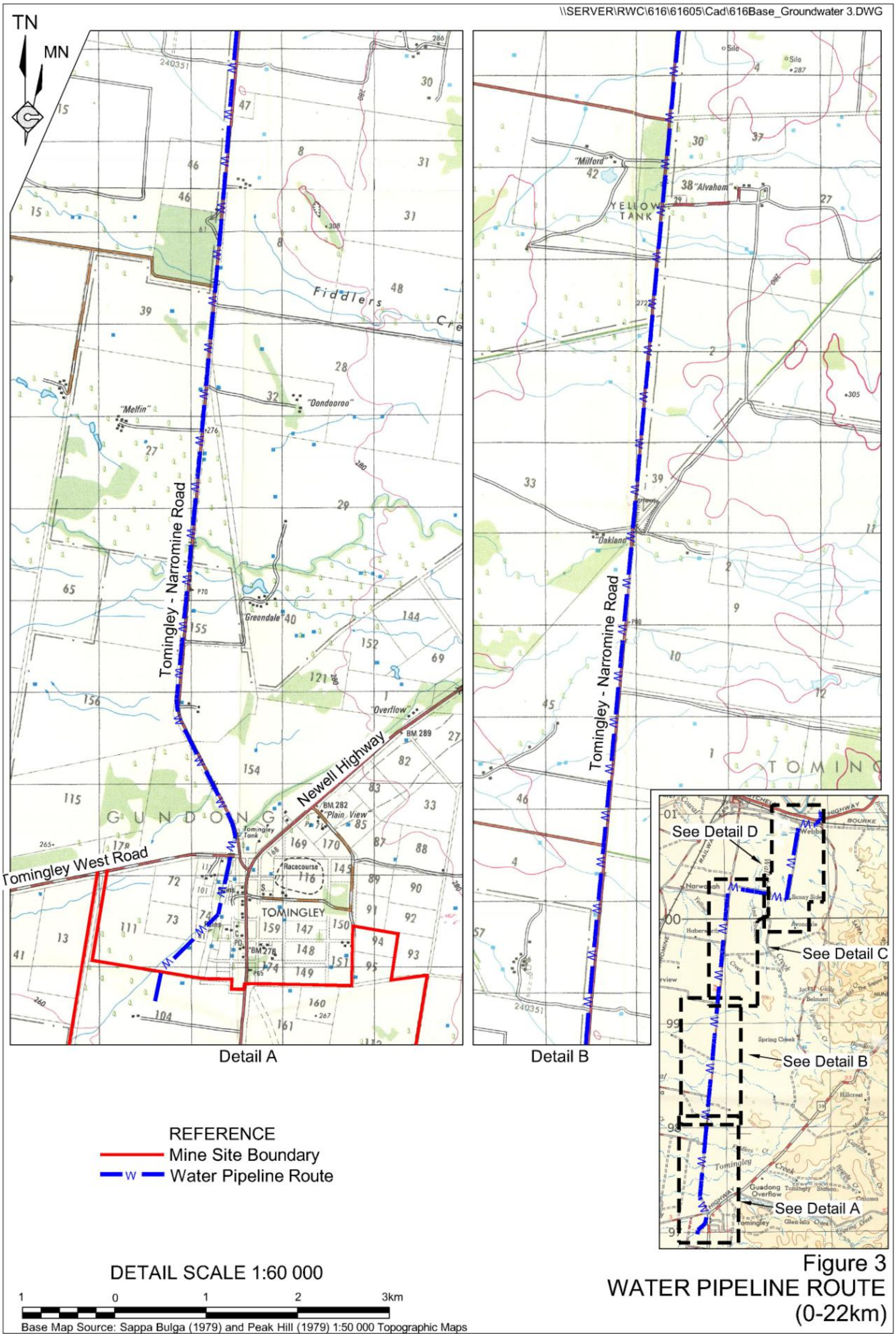
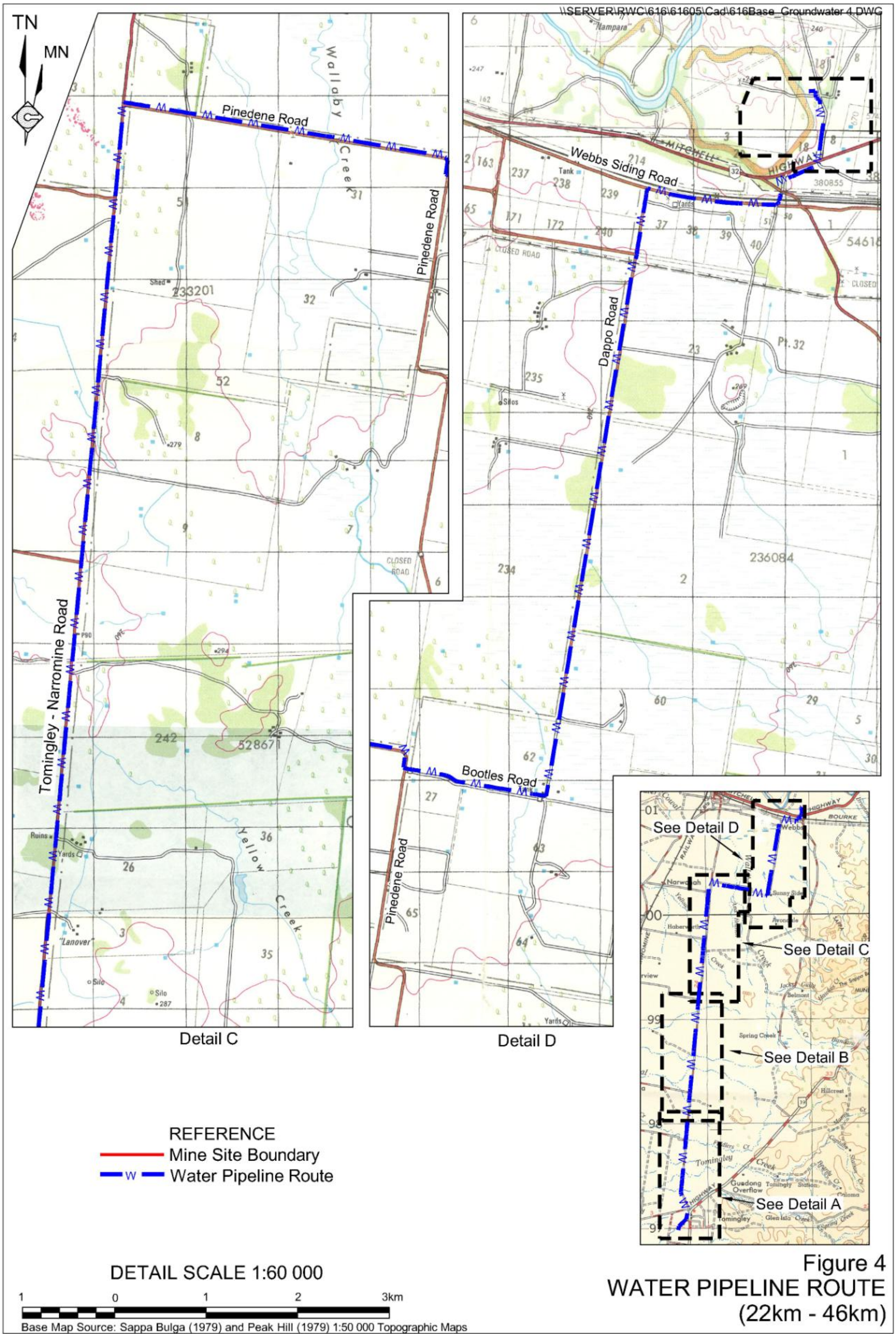


Figure 3
WATER PIPELINE ROUTE
(0-22km)



Base Map Source: Sappa Bulga (1979) and Peak Hill (1979) 1:50 000 Topographic Maps

Figure 4
WATER PIPELINE ROUTE
(22km - 46km)

- Construction and use of various haul roads, including an underpass under the Newell Highway, and a run-of-mine (ROM) pad.
- Construction and use of a processing plant and office area, incorporating a crushing and grinding circuit, a standard carbon-in-leach (CIL) processing plant, site offices, workshops, ablutions facilities, stores, car parking, and associated infrastructure.
- Construction and use of a residue storage facility (approximately 49ha).
- Construction and use of a transformer and electrical distribution network within the Mine Site (from the 20km of 66kV electricity transmission line from Peak Hill to the Mine Site to be constructed under separate approval).
- Construction and use of an approximately 46km water pipeline, from a licensed bore located approximately 7km to the east of Narromine, to the Mine Site (see **Figures 3** and **4**).
- Relocation of existing items of infrastructure, including a 22kV power line which currently passes over the area of the Caloma and Caloma Two Open Cuts.
- Re-routing (node to node) of a 4.2km section of a Nextgen Network fibre optic cable (telecommunications line).
- Construction and use of ancillary infrastructure, including the Main Site Access Road and intersection with Tomingley West Road.
- Construction of soil stockpiles (for use in rehabilitation works).
- Construction of the Eastern Surface Water Diversion Structure to divert surface water flows to the east of mining and waste rock emplacement activities. Additional surface water management structures would be constructed within the Project Site to control surface water flows within the Mine Site.
- Construction and use of dewatering ponds to store water accumulating in and pumped from the open cuts.

Disturbance associated with the mining and associated activities would be progressively rehabilitated to create a geotechnically stable final landform, suitable for a final land use of nature conservation, agriculture, tourism and/or light industry.

It is noted that the design of the proposed Caloma Two Open Cut is an indicative design only, with additional drilling required to further define the mineralisation. As a result, the indicative design for the Caloma Two Open Cut presented (**Figure 2**) represents the maximum area that would be developed. The development of this maximum impact footprint has been taken into account in all other aspects of the Project, including the required capacity, layout and design of the waste rock emplacements and residue storage facility, and the life of the Project. Approval is sought for the proposed design, acknowledging that the final design of the open cut would be the same size or smaller than that displayed.

Full details of the Tomingley Gold Project are described in the Section 2 of the *Environmental Assessment*, prepared by R.W. Corkery & Co. Pty Limited.

2.2 WATER SUPPLY AND CONSUMPTION

Maximum operational water requirements, namely water for processing operations, dust suppression and workshop wash down purposes are estimated to be up to approximately 938ML per year.

The Proponent has purchased 1 000 groundwater shares (1 000ML annual water entitlement) from an existing WAL within Zone 6 of the Lower Macquarie River alluvium (of 1993 groundwater shares) which has been sub-divided. That transfer has been approved by the NSW Office of Water and WAL20270 has been granted to the Proponent for the proposed activities within the Mine Site. The sub-divided WAL was held by Mr Stuart Boland, who owns a property called "Woodlands", which is located approximately 7km east of Narromine. It is noted that approval to extract groundwater from the “Woodlands” property does not form part of this application for project approval and the following is provided for information only.

Under the 2003 Water Sharing Plan for the Lower Macquarie River Alluvium the relevant NSW Minister has the power to reduce or increase the volume of groundwater assigned to each groundwater share. Future increases and/or reductions are based on aquifer recharge estimates. If the estimated recharge in Zone 6 of the aquifer increases or decreases the relevant NSW Minister can increase or decrease the value of a Zone 6 groundwater share. Recharge estimates can only be reviewed once every 5 years and changes to the amount of water allocated to Zone 6 of the aquifer can only be made incrementally.

To confirm that 1 000ML could be obtained from the Proponent’s share of the WAL, a test bore (TB6) was installed at "Woodlands" in January 2009. Results of a preliminary pumping trial conducted in January 2009 indicated that the bore was capable of supplying 1 000ML/yr of groundwater. It is noted that under Section 92 of the *Water Management Act 2000* a groundwater work approval is required before a new bore can be used and the NSW Office of Water (NOW) is required to consider potential impacts to neighbouring groundwater users before granting a groundwater work approval. NOW requested that a 14 day aquifer pumping test be conducted at "Woodlands" to assess potential impacts to neighbouring groundwater users.

A 14 day aquifer pumping test was conducted at "Woodlands" in June/July 2009. Test Bore 6 (TB6) was pumped for 14 days at an average rate of 38.5L/s. Aquifer drawdown and recovery in the pumping bore, and several observation bores located within 3km of the pumping bore, were monitored for the duration of the test. The Impax Group used the observed drawdown and recovery results to estimate the average properties of the aquifer within the vicinity of TB6. The estimates of average aquifer properties were then used in a numerical model to predict the additional drawdown on the aquifer from pumping 1 000ML/yr at TB6.

The results of the pumping test were issued to NOW in The Impax Group's (2009) *'Hydrogeological Assessment - 14 Day Aquifer Pumping Test - Test Bore 6, "Woodlands", NSW'*, which is presented as **Appendix 4**.

At a meeting held at the NOW office on 18 September 2009, NOW indicated that they would approve the extraction of 1 000ML/yr of groundwater from a production bore located adjacent to TB6.

Assessment of the groundwater impacts associated with that bore do not form part of this groundwater assessment and approval for the construction of the bore is to be sought separately of the application for project.

It is proposed that water extracted from "Woodlands" would be transported to the Mine Site via a purpose built water pipeline (**Figures 3** and **4**).

Ore processing (up to 878ML/yr) and dust suppression operations (up to 60ML/yr) are the two most significant water demands for the Project. The 1,000ML/yr of groundwater secured from the lower Macquarie alluvium would be more than adequate to meet the expected maximum 938ML/yr demand of these activities on the Mine Site. This water would also supply potable water to the mining operation and possibly to the town of Tomingley.

Water for processing and wash down purposes would be preferentially sourced from recycled water from each of those facilities. Makeup water would be sourced from the water pipeline. Water for dust suppression purposes would preferentially be sought from the surface water containment structures within the Mine Site, including any in-pit sumps constructed to collect rainfall runoff and groundwater inflows. As such, the actual demand for imported water may be significantly less than 938ML/yr.

3 GROUNDWATER LEGISLATION AND GUIDELINES

3.1 REGULATORY AND LEGISLATIVE INSTRUMENTS & GUIDELINES

The Impax Group completed an evaluation of legislation and regulatory instruments that may be relevant to the Tomingley Gold Project.

- *Water Act 1912*. Groundwater extraction or groundwater interference due to mining operations is currently regulated under Part 5 of the *Water Act 1912*. This act was supplemented on 19 December 2008 to include an embargo on the issuing of new groundwater extraction licences within the Murray-Darling Basin. The embargo is discussed in more detail in Section 3.3.
- *Water Management Act 2000*. Under this Act a Water Access Licence (WAL) is required to extract or interfere with groundwater in areas where a Water Sharing Plan (WSP) is in place. The Water Management Act 2000 applies to the extraction of the mines groundwater supply from the Lower Macquarie River Alluvium at "Woodlands", Narromine. This Act also applies to surface water storages and therefore, would be relevant to the management of any surface water storages at the Mine Site.
- Water Sharing Plan (WSP). At the time this report was prepared the Mine Site was not subject to a WSP. As such, groundwater extraction or groundwater interference due to mining operations would be regulated under the *Water Act 1912*
- *Guidelines for Groundwater Protection in Australia (ARMCANZ and ANZECC 1995)*. This guideline provides a framework for preventing groundwater contamination in Australia.

- *NSW State Groundwater Policy and Framework Document (NSW Department of Land and Water Conservation 1997).* The Framework document sets out the overall direction of groundwater management in NSW and provides broad objectives and principles to guide groundwater management. The document refers to the specific policy documents listed below which outline the objectives and principles of minimising impacts to groundwater quality and quantity, and impacts to groundwater dependent ecosystems.
- *NSW State Groundwater Quantity Protection Policy (NSW Department of Land and Water Conservation 1998)*. Builds on the concepts outlined in the framework document (see above) and provides more detail and guidance on how to manage and protect groundwater quantity.
- *NSW State Groundwater Quality Protection Policy (NSW Department of Land and Water Conservation 1998).* Builds on the concepts outlined in the framework document (see above) and provides more detail and guidance on how to manage and protect groundwater quality.
- *NSW State Groundwater Dependent Ecosystems Policy (NSW Department of Land and Water Conservation 2002).* This policy is specifically designed to protect valuable ecosystems which rely on groundwater for survival. It aims to maintain or restore the ecological processes and biodiversity of groundwater dependent ecosystems for the benefit of present and future generations.
- *Guidelines for Fresh and Marine Water Quality (ANZECC 2000)*. These guidelines would be adopted to assess groundwater quality, potential beneficial use of groundwater at the Mine Site, and to assess potential impacts to groundwater quality from operation of the Tomingley Gold Project.
- *Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales (NSW EPA 2003).* These guidelines would be adopted where sampling and analysis of groundwater samples is required as part of this assessment and during groundwater monitoring.

3.2 GROUNDWATER WORK LICENCE

Under the NSW *Water Act 1912*, any excavation or borehole that intersects groundwater is regarded as a groundwater work and has to be licenced as such by NOW. The proposed open cuts would intersect groundwater and will require a groundwater work licence.

Any groundwater monitoring wells installed at the Mine Site would also require a groundwater work licence.

3.3 MURRAY-DARLING BASIN GROUNDWATER EMBARGO

On 19 December 2008 an embargo was made under the *Water Act 1912* to prohibit the issuing of new groundwater extraction licences within the Murray-Darling Basin (subject to a number of exemptions). The embargo applies to areas within the Murray-Darling Basin which are not already subject to a WSP. Therefore, this embargo applies to the Mine Site, which is located within the Murray Darling Basin but outside an area already subject to a water sharing plan or similar water sharing regulation.

The Tomingley Gold Project would involve the construction of four open cuts that could intercept the water table. In accordance with the *Water Act 1912* the open cuts are considered to be groundwater works (see Section 3.2), and would be required to be licenced. As such, the groundwater embargo would apply to the issuing of a licence for the open cuts.

The Special Supplement outlining the conditions of the embargo is presented in **Appendix 3**. Schedule 2 of the supplement lists circumstances that may give rise to an exemption from the embargo. These include the following.

- A licence may be granted for a monitoring or test bore installed for groundwater investigation and environmental management purposes.
- A licence can be granted for water supply for a person where the Minister determines that a failure to supply the water would cause a prohibitively high social, economic or national security cost and the supply of water will cause no more than minimal environmental harm to any aquifer, or it's dependent ecosystems.
- A licence may be granted for a dewatering activity provided that the annual extraction does not exceed 10ML per annum.
- A licence may be granted to use saline water where the salinity level exceeds 14,000mg/L (this equates to an electrical conductivity of approximately 21000µS/cm).
- Bores on property where there is an existing licence under Part 5 of the *Water Act 1912* and there is no increase in entitlement.

4 EXISTING ENVIRONMENT

4.1 SURROUNDING LAND USES

The village of Tomingley is located immediately north of the Mine Site. The village consists of a mix of residential and commercial development.

With the exception of the village of Tomingley, the Mine Site is surrounded by land used for agricultural purposes. Surrounding land is predominantly cleared and is used for seasonal growing of cereal crops and/or grazing livestock.

4.2 GEOLOGY

The Tomingley Gold Project is located in the eastern zone of the early Palaeozoic Lachlan Orogen in eastern Australia. The Lachlan Orogen is composed of a complex association of sedimentary, volcanic and intrusive rocks of early Cambrian to early Devonian age in a setting which has been interpreted to have similarities to modern southwest Pacific oceanic island arc and back arc basin environments. The Lachlan Orogen has been divided into three provinces, based on a structural and lithostratigraphic criteria, which have been designated the Western, Central and the Eastern Belts. The Eastern Belt, containing the magmatic and fore arc environments, has been named the Macquarie Arc and hosts porphyry-epithermal bodies, including the world class Cadia-Ridgeway deposits.

Within the Macquarie Arc, several individual belts of mafic to intermediate volcanic, intrusive, volcaniclastic and turbiditic rocks have been identified. These sequences are segmented by a number of generally north–south to north-northwest trending arc-parallel structures, many of which are thought to be thrust faults or major strike-slip faults. The volcanic belts comprise Ordovician to early Silurian rocks with predominantly mafic to andesitic composition and display a spectrum of rock types including lavas, breccias, volcaniclastic sandstone and siltstone, and the monzonitic to dacitic intrusions.

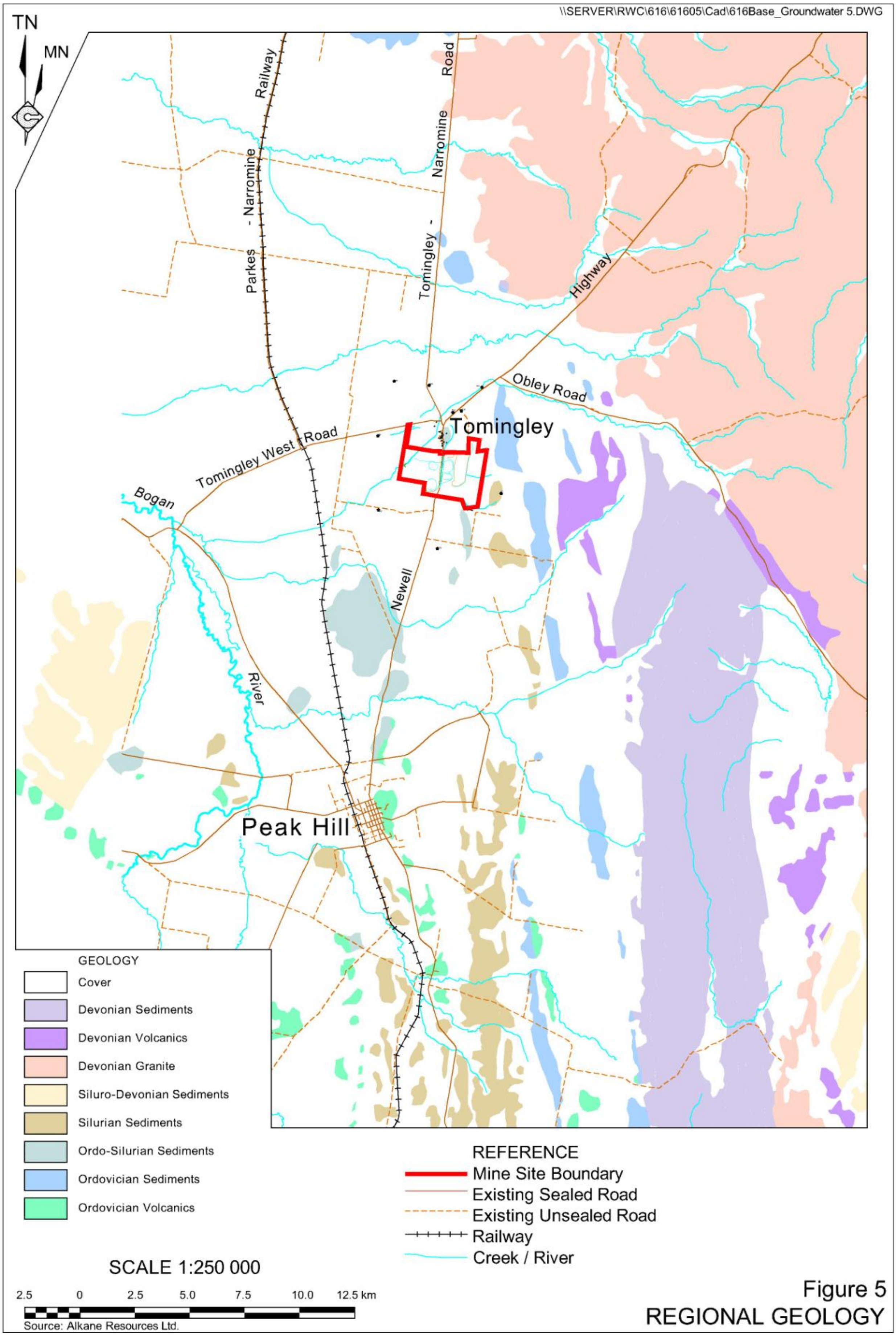
The Tomingley Gold Project is located near the eastern margin of the Junee-Narromine volcanic belt, just east of the interpreted Parkes Thrust. This structure separates the flat lying Goonumbla volcanic complex from a thin slice of north-south trending andesitic volcanics (Mingelo volcanics) (**Figure 5** and **Figure 6**) identified by regional aeromagnetic data. The late Ordovician Mingelo volcanics are overlain sediments thought to be equivalents of the early Silurian Cotton formation.

The deformation of the Lachlan Orogen is complex and reflects multiple events. The Ordovician rocks west of the Parkes thrust are weakly deformed, with broad open folds and sub-greenschist metamorphic assemblages. In contrast, the Ordo-Silurian sequences east of the fault, including the rocks hosting the Wyoming/Caloma deposits, exhibit tight to isoclinal folding, strong axial planar cleavage with greenschist metamorphic assemblages. Northwest trending transverse structures are also evident in regional magnetic and gravity data, and rarely as faults mappable in outcrop. These structures appear to be long lived fundamental crustal breaks that were irregularly reactivated throughout the geological development of the Macquarie Arc. They also show a relationship to intrusive centres and mineralisation where the structures intersect and occasionally offset the arc parallel structures.

The immediate area surrounding the Mine Site is almost entirely covered by alluvial sequences of clays, sand and gravel of Quaternary to Tertiary age. This cover ranges up to 50m thick over in the central part of the Wyoming mineralisation (**Figure 6**). The transported alluvial material thins to the south and to the north with basement outcropping at the historic McPhails gold mine and at the historic Tomingley gold workings. Generally, however, there is a well-developed weathering profile (regolith) which can extend down to 70m below ground level.

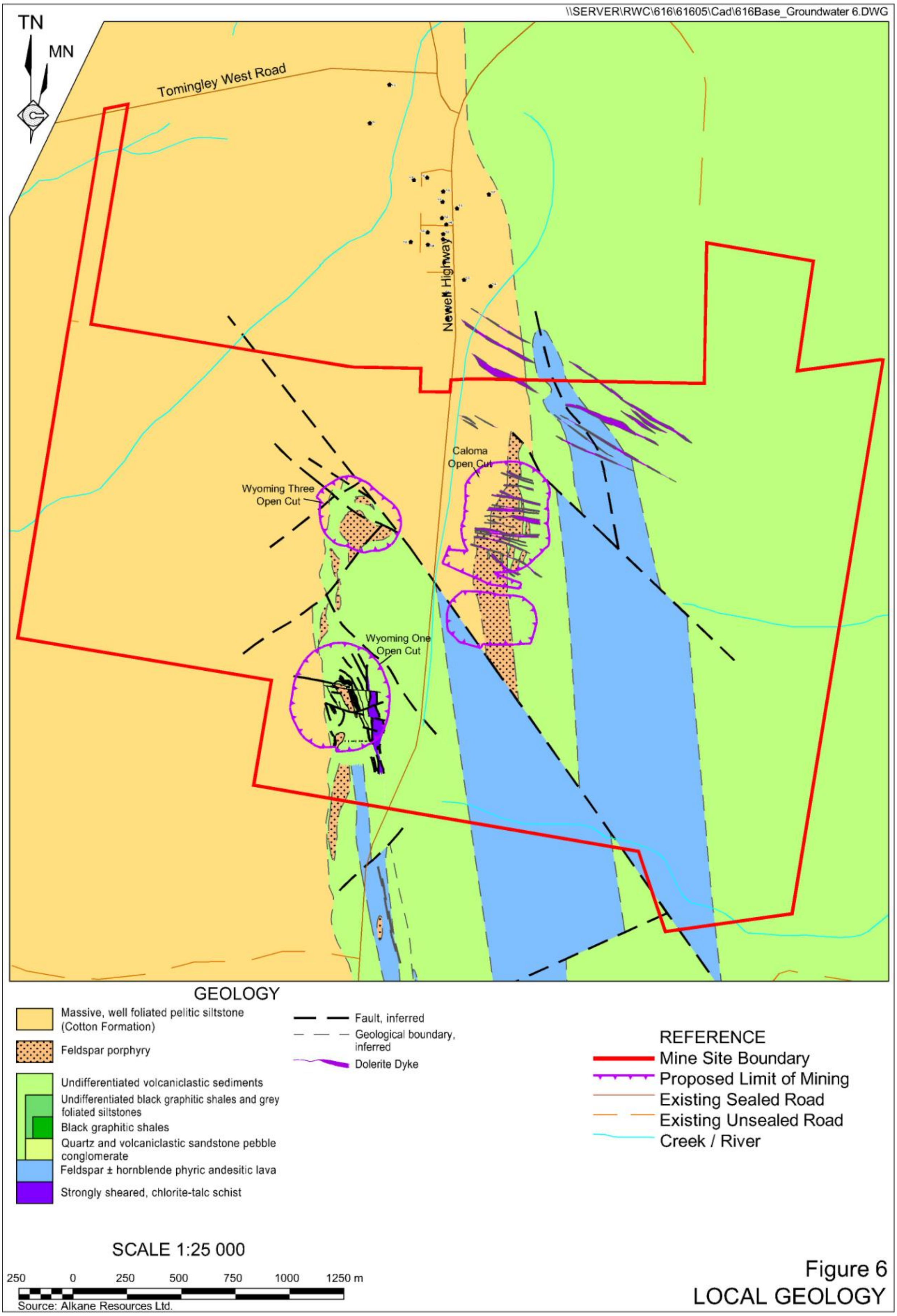
Roach (2007) maps the regolith of the Tomingley 1:25 000 map sheet and identifies a number of regolith units within the Mine Site and immediate surrounds (**Figure 7**). The most widespread mapped units are described as follows.

- Red-brown fine sand and silt with minor angular to sub-angular coarse sand to pebbles of quartz and of other various compositions, and minor sub-rounded maghemite granules. Occurs on broad plains with extremely subdued relief (Apd).
- Light grey coloured sub-angular to sub-rounded quartz and weathered granite lithic coarse sands and granules with rare pebbles and grey clays and minor red-brown fine sand and silt and minor sub-rounded maghemite granules. Occurs in a plain with numerous anastomosing drainage depressions (AOap).
- Plains with poorly to well-developed gilgai with depressions up to 10m diameter and 1m deep. Depressions contain dark organic-rich clays in small swamps (Aag).



Source: Alkane Resources Ltd.

Figure 5
REGIONAL GEOLOGY



Source: Alkane Resources Ltd.

Figure 6
LOCAL GEOLOGY

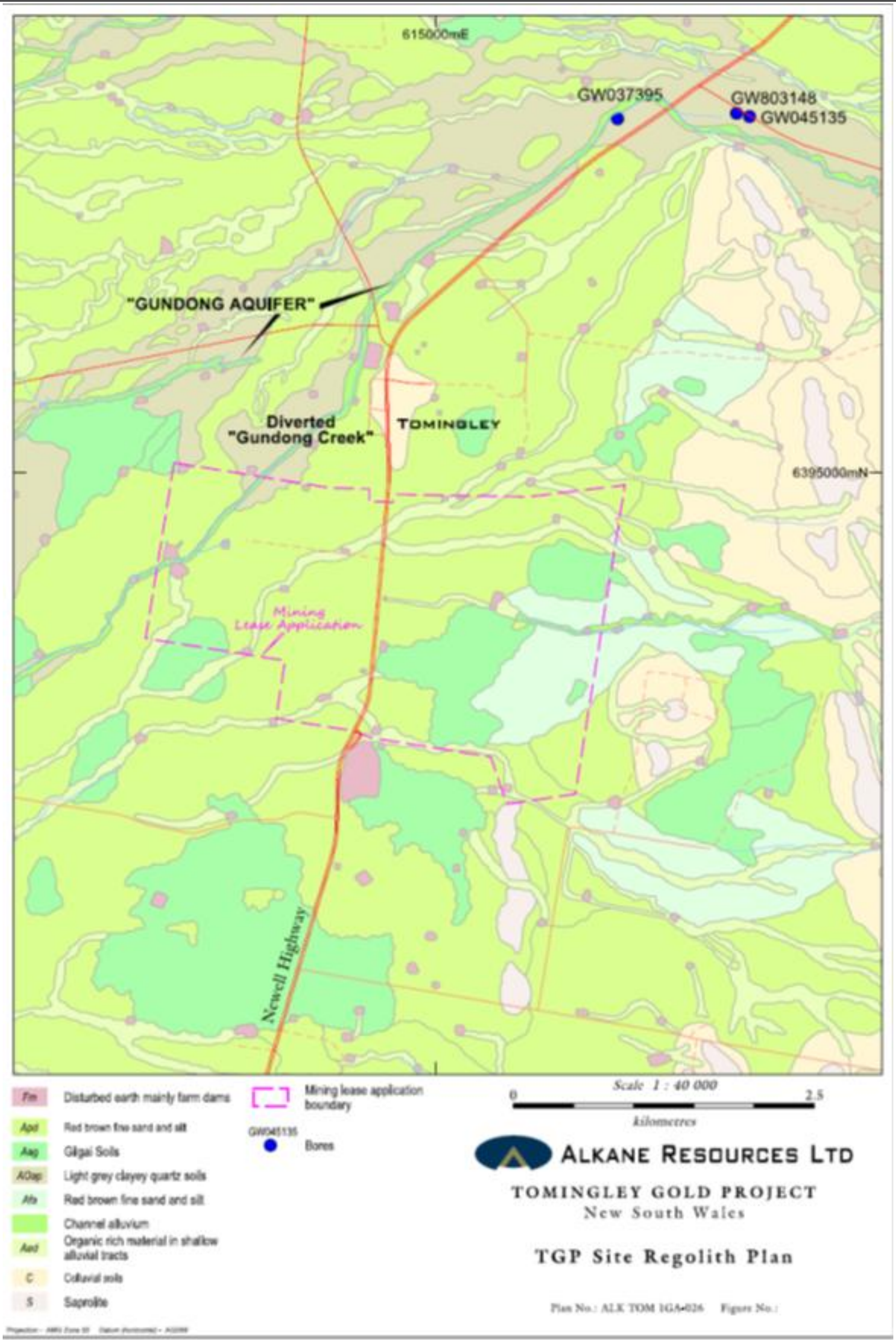


Figure 7
REGOLITH GEOLOGY

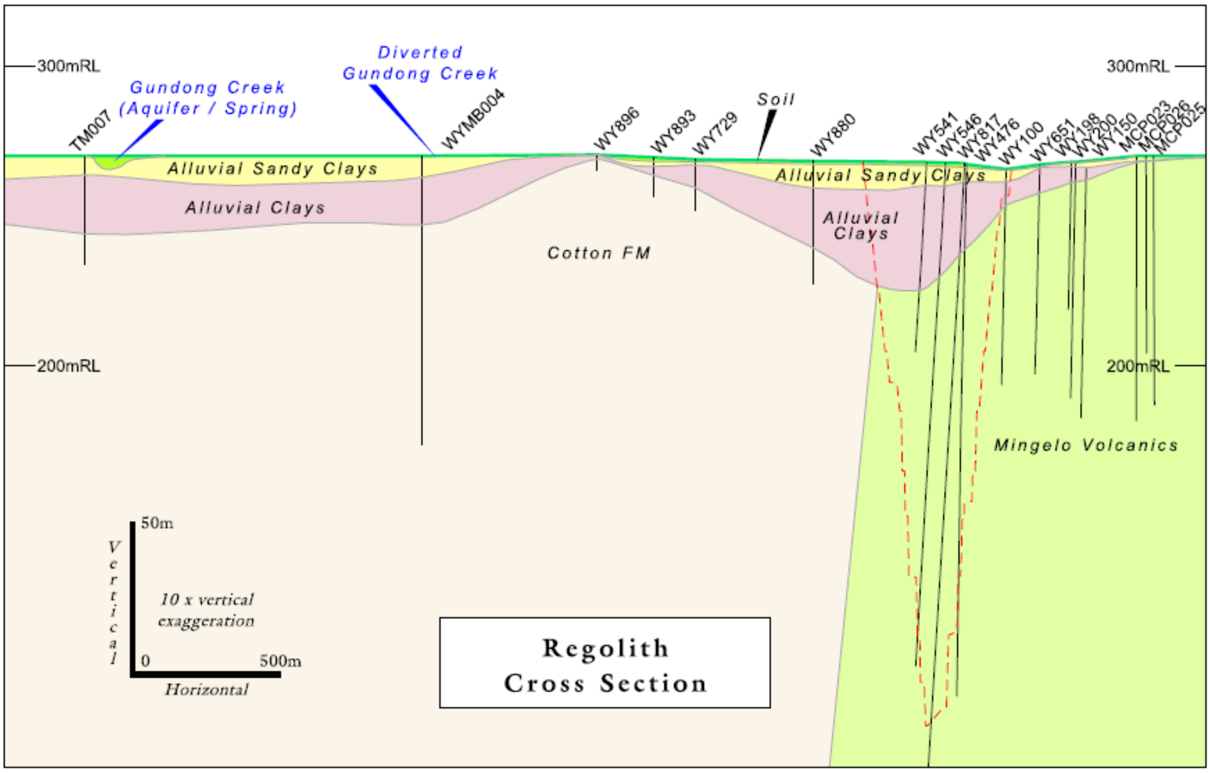
The above widespread units are cut by a number of recent channel deposits.

- Channel alluvium of sub-rounded to rounded silt to cobble sized clasts of various compositions with minor red-brown fine sand and silt. Grey clays and lithic gravels exposed in stream banks. Stream channels <10 m wide and <3 m deep and appear to be those associated with the shallow aquifer commonly referred to as the Gundong Aquifer (ACah).
- Dark red to brown organic rich materials in broad shallow alluvial tracts with clay and quartz silt and minor sub-rounded maghemite granules (Aed).

Drilling within the Mine Site and immediate surrounds has identified three dominant regolith units (Mann, 2009):

- grey coloured, sandy, granite-rich, non-magnetic transported unit probably sourced from the Obley Granite; overlying
- heavily mottled, clayey transported materials containing magnetic nodule-rich gravel bands; overlying
- saprolite.

Exploration drilling indicates that transported regolith varies in thickness from 0 (at Myalls United mine and within the Tomingley village) to >60m in palaeochannels. Drilling to the north of Tomingley indicates that transported sediments reach up to 100m thickness. An idealised cross section is presented in **Figure 8**.



Source: Alkane Resources Ltd

Figure 8
REPRESENTATIVE CROSS-SECTION OF MINE SITE REGOLITH GEOLOGY

Falling head tests carried out on five holes completed to 25m depth in the area of the residue storage facility (**Figure 2**) determined permeability of the transported material in this area to be very low being between 2 x 10^{-8} and 2 x 10^{-9} m/s.

4.3 TOPOGRAPHY

The Mine Site is relatively flat and slopes gently toward the west and south west with an average gradient of approximately 1:200 (V:H). The average elevation of the Mine Site is approximately 265m AHD (**Figure 9**).

The Mine Site, and area to the west of the Mine Site, slope toward the Bogan River, which is located approximately 12km to the west-southwest. The Bogan River has an elevation of approximately 245m AHD at its closest point to the Mine Site.

As shown in **Figure 10**, the slopes and foothills of the Herveys Range are encountered approximately 3km to the east of the Mine Site. The average gradient gradually increases further to the east. The highest point of the Herveys Range to the east of the Mine Site is in excess of 500m AHD (approximately 12km from the project Mine Site).

The area to the south and north of the Mine Site is characterised by rolling plains with very little local relief. These extend to Peak Hill (15km to the south of the Mine Site) and Narromine (40km to the north of the Mine Site).

Areas of increasing local relief are encountered approximately 8km to the northeast of the Mine Site, at the foothills of the Sappa Bulga Range. The Sappa Bulga Range extends as far north as Dubbo (52km to the north east of the Mine Site).

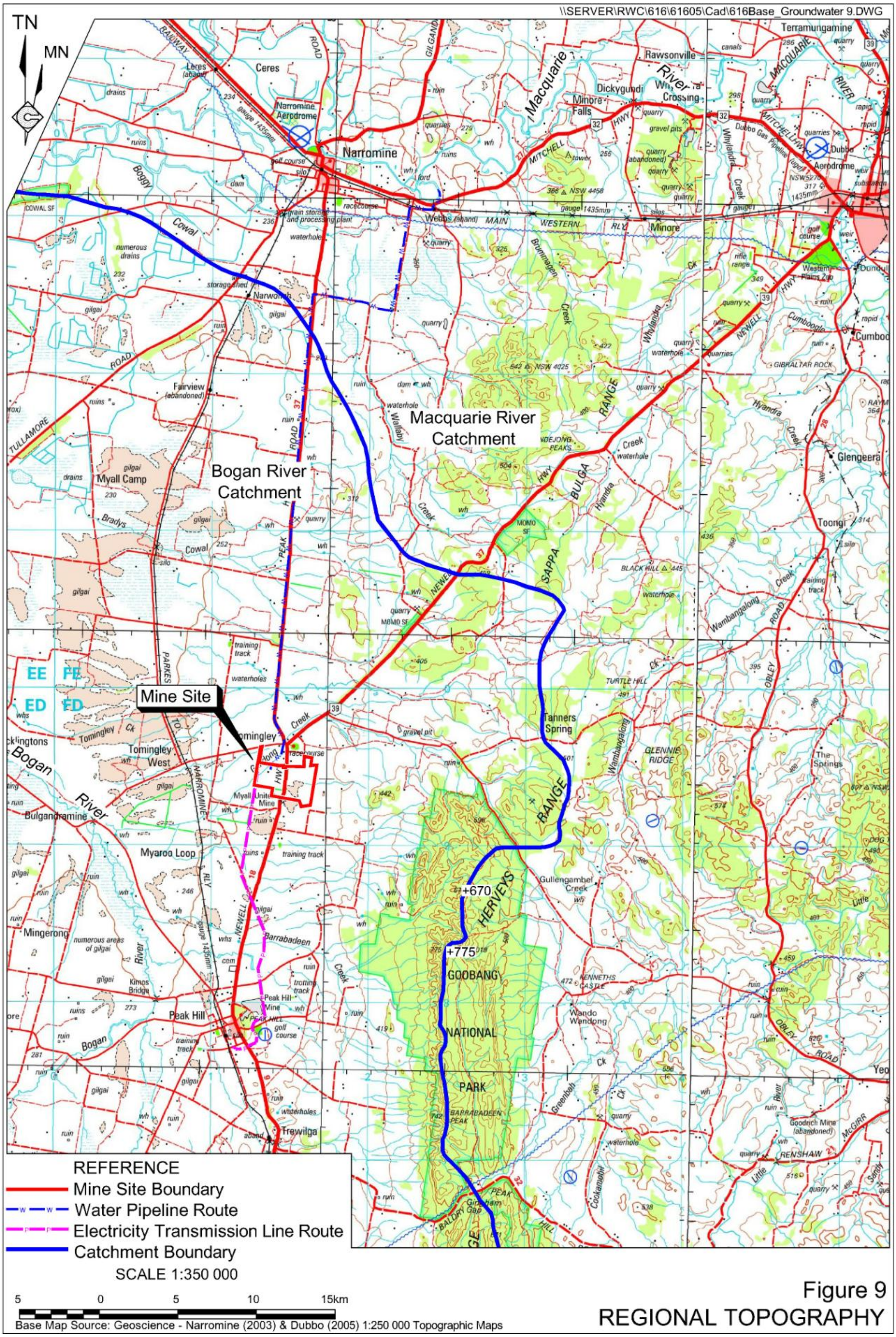
4.4 HYDROLOGY

Several ephemeral streams are present in the vicinity of the Mine Site. These typically flow in an east to west direction from the higher ground of the Herveys Range toward the Bogan River to the west. The creeks tend to dissipate in an area of gilgai (hummocky micro-relief pattern common in heavy alluvial clays). The major creeks from north to south include Fiddlers Creek, Tomingley Creek, Gundong Creek and Bulldog Creek (see **Figure 9**).

4.5 CLIMATE

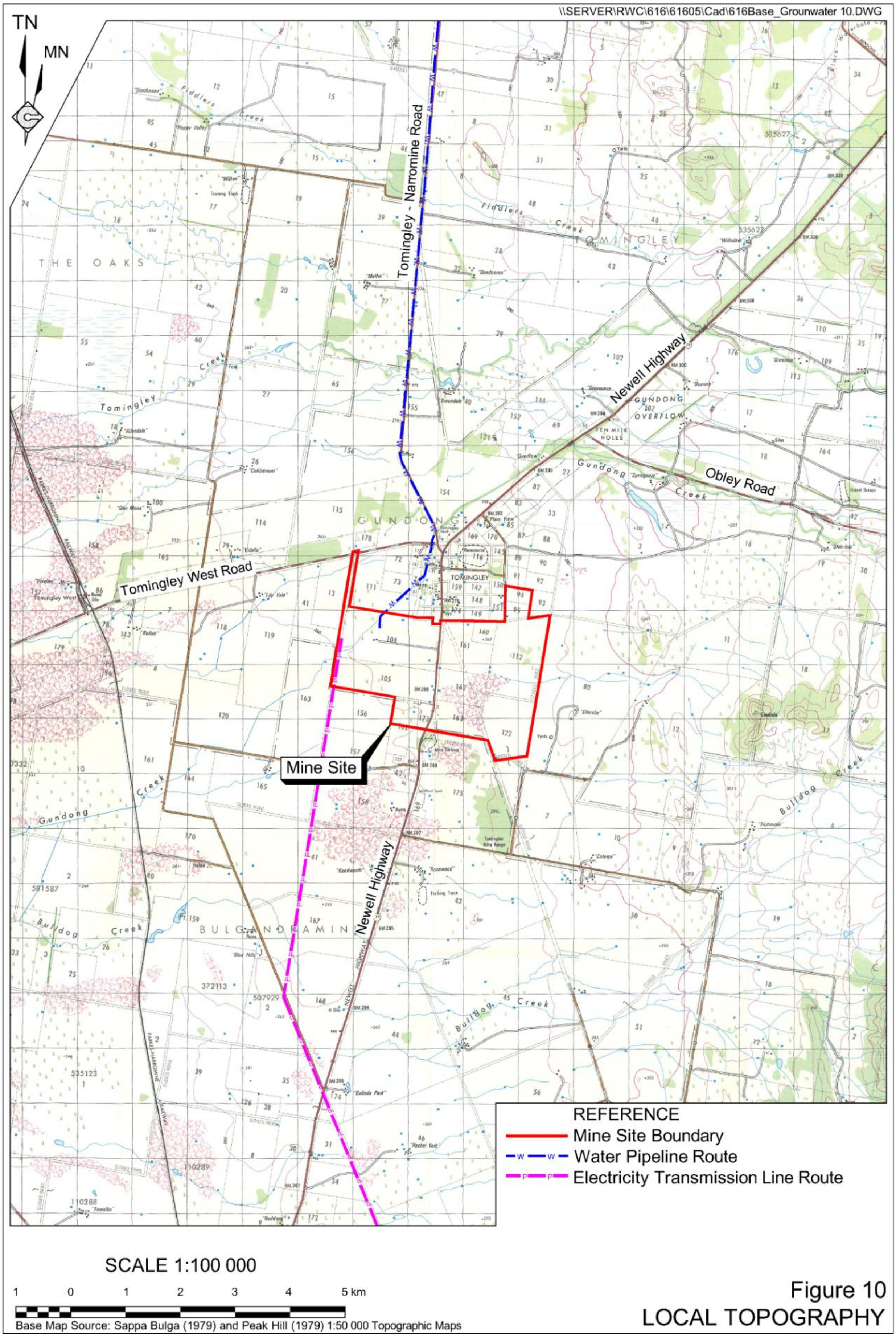
The Mine Site is located on the western margin of the central west slopes of NSW. Key climate statistics for Peak Hill Post Office (the closest Bureau of Meteorology weather station to the Mine Site) and Wellington Research Centre (the closest Bureau of Meteorology evaporation gauging station to the Mine Site) located approximately 15 km to the south and 68km to the east of the Mine Site, respectively, are summarised below.

- Mean daily maximum temperatures range from 15.2 to 33.1°C.
- Mean daily minimum temperatures range from 4.7 to 19.2°C.
- Annual mean of daily maximum temperatures is 24.4°C.
- Annual mean of daily minimum temperature is 11.9°C.



Base Map Source: Geoscience - Narromine (2003) & Dubbo (2005) 1:250 000 Topographic Maps

Figure 9
REGIONAL TOPOGRAPHY



Base Map Source: Sappa Bulga (1979) and Peak Hill (1979) 1:50 000 Topographic Maps

Figure 10
LOCAL TOPOGRAPHY

- Mean monthly rainfall totals range from 37.6mm to 59.6mm.
- Mean annual rainfall is 559mm.
- Mean monthly evaporation totals range from 48mm to 273mm (at Wellington Research Centre).
- Mean annual evaporation is 1 825mm (at Wellington Research Centre).

All data quoted above was obtained from the Bureau of Meteorology website (www.bom.gov.au).

The climate at the Mine Site is typically one of hot summers and cold to mild winters. Mean monthly rainfall figures indicate that rainfall is well distributed throughout the year.

Mean annual evaporation at Wellington is 1 825mm which is significantly higher than mean annual rainfall of 559mm. Given the location further to the west of the Great Dividing Range than Wellington, the evaporation rate at the Mine Site is likely to be higher than that measured at Wellington.

5 EXISTING GROUNDWATER DATA

5.1 INTRODUCTION

The Impax Group completed a review of available groundwater bore information for the area located within a 20km radius of the Mine Site. This included a review of the registered groundwater bore database, which is maintained by the NSW Office of Water, and supplementary information collected during preliminary groundwater studies of the Tomingley area undertaken by Coffey Geotechnics Pty Limited on behalf of Alkane Resources Ltd.

5.2 NSW OFFICE OF WATER REGISTERED BORE DATABASE

The Impax Group conducted a search of the NSW Office of Water (NOW) Registered Groundwater Bore database (www.nratlas.nsw.gov.au) on 7 January 2010. A total of 45 bores were located within an approximate 20km radius of the Mine Site.

Registered groundwater bore locations relative to the Mine Site are presented in **Figure 11**.

Information obtained from groundwater bore work summary forms is summarised in **Table A1** (**Appendix 1**). Groundwater bore work summary forms are presented in **Appendix 2**.

Fifteen registered bores were located within 10km of the Mine Site. This included a cluster of five bores at the Tomingley Service Station (GW803678, GW803679, GW803680, GW803681 and GW803682). These bores were registered as monitoring bores. The recorded depths for these bores ranged from 3.5 to 4.5m below ground level. Groundwater bearing information, standing water levels and groundwater yields were not provided for these bores and it is likely that groundwater was not encountered at these locations.

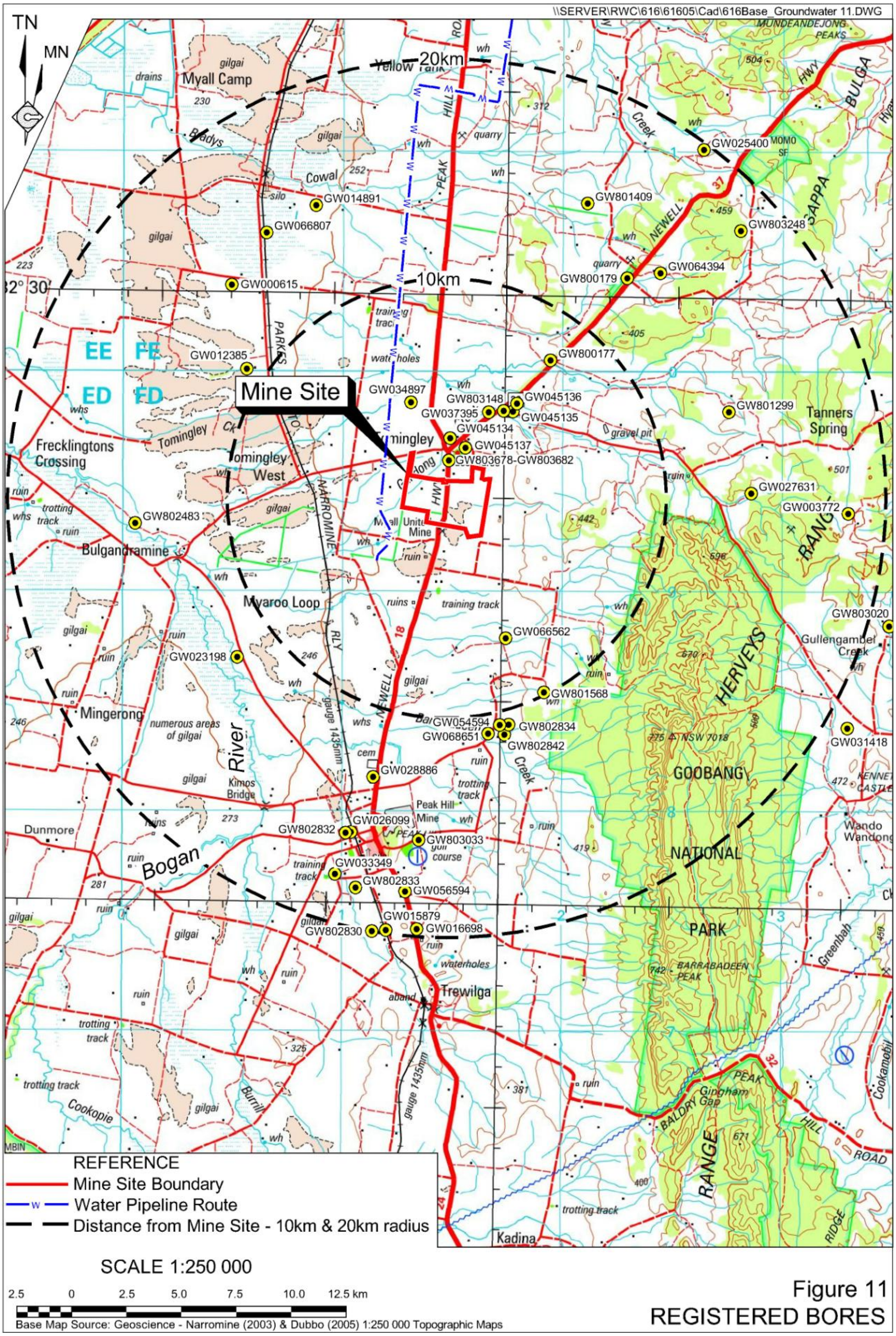


Figure 11
REGISTERED BORES

A second cluster of seven bores (GW045137, GW045134, GW037395, GW034897, GW045135, GW045136 and GW803148) located to the north and northeast of Tomingley village. The recorded depths of these bores range from 1.8m to 18.3m below ground level, which indicates that they were drilled to target relatively shallow sources of groundwater in the alluvium. Most of these bores are located in close proximity to Gundong Creek. Driller's logs indicate that clay, sandy clay, silty sand and siltstone were encountered in these locations. Where provided, recorded groundwater yields ranged from nil to 1.26L/s. An indication of groundwater quality was not provided for any of these bores. Four of these bores appear to have been installed by Narromine Council as test bores for town water supply, however, the groundwater work summary forms indicate that these bores were never converted for this purpose. The groundwater work summary form for GW803148 indicates this bore was also installed by Narromine Council and is used for town water supply.

Three additional registered bores were located within 10km of the Mine Site. Groundwater bore GW800177 is located approximately 8km to the northeast of the Mine Site. It was installed to a depth of 113m below ground level through loam, sand, clay, sandstone and basalt. The groundwater bore work summary indicates that the bore yielded 0.32L/s and that water quality was "good". Groundwater bore GW066562 was located approximately 7km south of the Mine Site. It was advanced to a depth of 73m below ground level through clayey silt and conglomerate bedrock. Water bearing information was not provided for this bore. Groundwater bore GW801568 is located approximately 10km south of the Mine Site. It was advanced to a depth of 81m below ground level through clay topsoil, shale and siltstone. Water bearing information was not provided for this bore.

In addition, a further thirty registered bores were identified between 10km and 20km from the centre of the Mine Site. These are discussed in more general terms as follows.

South of the Mine Site

A cluster of four bores are located approximately 11km to the south of the Mine Site. These bores range from 62m to 97m below ground level and were typically advanced through clay, shale and siltstone. Water bearing zones were recorded at depths between 22m and 94m below ground level in shale and siltstone. Where provided, groundwater yields ranged from 1.5L/s to 3.0L/s. Recorded water salinity was described as "fresh" in one bore. Other salinity readings ranged from 3 900ppm to 4 400ppm.

Peak Hill Area

Ten bores are located in relatively close proximity to Peak Hill. The groundwater work summary form for 3 of these bores did not provide any information on subsurface conditions. The remainder of the bores were advanced to depths ranging between 48m and 121m below ground level. Recorded geology logs indicates that clay, shale, siltstone and slate was encountered in most bores. Water bearing zones were recorded at depths between 49m and 99m below ground level in slate, shale and siltstone. Where provided groundwater yields ranged from 1.0L/s to 1.8L/s. Recorded groundwater salinity was only provided for two bores, and ranged from 2 960ppm to 4 820ppm.

Alluvium to the Northwest of the Mine Site

Four bores are located approximately 11km to 16km northwest of the Mine Site. These bores were advanced to depths ranging from 44m to 175m below ground level. Recorded geology indicates that alluvium was encountered to depths ranging from 35m to 112m below ground level. Alluvium was described as clay, sandy clay, gravelly clay and gravel. Alluvium was typically underlain by shale. Water bearing zones were recorded at depths between 19m and 112m below ground level. This included water in alluvium (gravel and gravelly clay) and in bedrock (shale) with provided groundwater yields ranging from 0.25L/s to 1.14L/s. Recorded groundwater salinity was only provided for two bores. Salinity ranged from 0ppm to 500ppm in one bore and was described as "salty" in another.

Bogan River Alluvium

Two bores are located in close proximity to the Bogan River approximately 12km to 15km to the west and southwest of the Mine Site. These bores were advanced to depths ranging from 49m to 60m below ground level. Recorded geology indicates that alluvium was encountered to depths ranging from 34m to greater than 49m below ground level. Alluvium was described as clay, sand and gravel. One of the boreholes was terminated in alluvium, whilst the other encountered saprolite at a depth of 34m below ground level. Water bearing zones were recorded at depths between 36m and 51m below ground level. This included water in alluvium (clay) and in underlying saprolite. A groundwater yield was only provided for one of the bores, which was 0.4L/s. Recorded water salinity was only provided for one bore, which was 14 000ppm.

Obley Granite

Ten registered groundwater bores were identified in an area approximately 13km to 20km to the northeast, east and southeast of the Mine Site, in an area described as being underlain by "Obley Granite". These bores were advanced to depths ranging from 17m to 162m below ground level. The boreholes typically encountered clay soil near the surface. These were underlain by sandstone, shale, granite and basalt. Water bearing zones were only recorded for three of the bores. Water bearing zones ranged from 32m to 50m below ground level and were typically granite and/or basalt. Where provided, groundwater yields ranged from 0.06L/s to 0.7L/s. A description of groundwater salinity was only provided for one bore, which was described as "good".

In summary, the lack of registered groundwater bores within 10km of the Mine Site indicates that the quantity and quality of groundwater in this area is a constraint on the use of groundwater. Many of the bores identified during the search were registered as "Test Bores" and many bores were listed as being "Abandoned". These results indicate shale and siltstones located within 10km of the Mine Site yield relatively low flow volumes of poor quality water.

Information provided in the registered groundwater bore work summary forms appears to be consistent with inferred geology in the Narromine 1:250 000 Geological Series Sheet SI/55-03.

Information provided on the Narromine 1:250 000 Sheet and in work summary forms for registered groundwater bores indicates that the Mine Site is underlain by “alluvium (clay)”, “shale” and “siltstone”. Groundwater is typically encountered in shale and/or siltstone at depths greater than 50m below ground level. The boundaries of the aquifer beneath the Mine Site are not clear. Similar subsurface conditions appear to exist beneath the surrounding plains, extending approximately 10km to the north of the Mine Site, and up to 20km south of the Mine Site. It is highly likely that the "Obley Granite" (approximately 10km northeast of the Mine Site), "Dulladerry Volcanics" (approximately 7km to the east of the Mine Site), "Hervey Group" (approximately 10km southeast of the Mine Site) form aquifer boundaries to the east of the Mine Site. There appear to be no defined significant aquifer boundaries to the northwest and west of the Mine Site.

Groundwater salinity was described as being "good" or "fresh" in some bores, and was recorded as 0ppm to 500ppm in another. Other bores recorded saline to very saline groundwater. These results indicate that while there are some sources of fresh groundwater within 20km of the Mine Site, these are generally located outside the anticipated radius of influence of the mining operation.

Standing water levels are typically higher than the groundwater bearing zones indicating that the fractured rock aquifers in the vicinity of the Mine Site are confined aquifers.

5.3 TOMINGLEY GOLD PROJECT PRELIMINARY GROUNDWATER DATA

Preliminary groundwater studies of the Mine Site and surrounds were conducted by Coffey Geotechnics Pty Ltd (“Coffey”) between 2006 and 2008. The purpose of the studies was to assess whether sufficient groundwater resources could be obtained to meet the water use demands of the mining operation. Results of the study are outlined in "*Draft Preliminary Groundwater Investigation, Alkane Resources Ltd, Tomingley, NSW* (Coffey, (2007)".

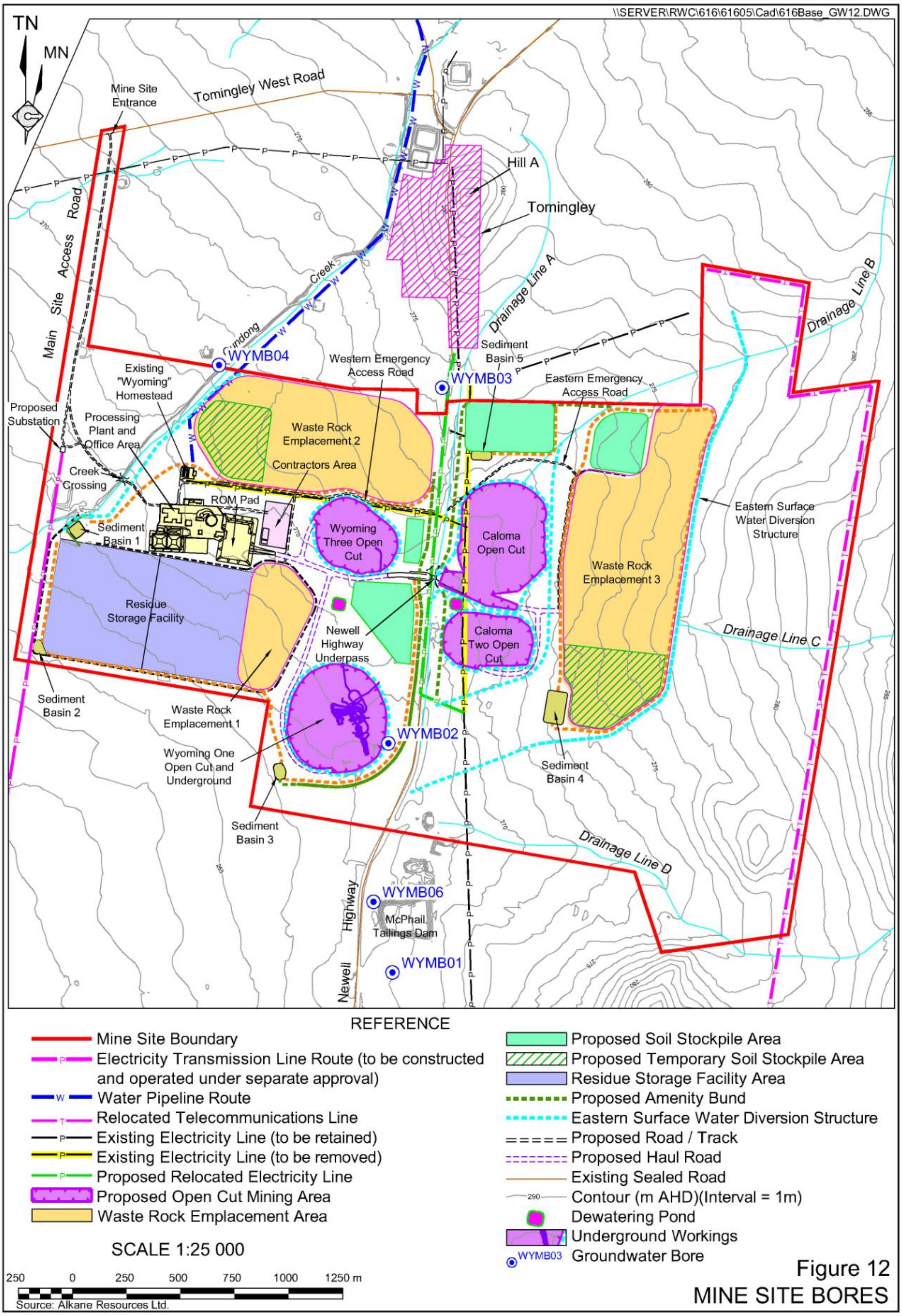
Five groundwater bores were installed within 2km of the Mine Site as part of the assessment. Borehole locations are shown on **Figure 12**. A summary of bore construction details is presented in **Table 1**.

Table 1
Summary of Coffey Geotechnic Pty Ltd Bore Construction Details

Bore ID	Hole Depth	Depth of Casing	Screened Interval	Bentonite Seal	Gravel Pack Thickness	Standing Water Level[1]
WYMB001	90m	90m	84-90m 78-81m	60m	30m	40.4m btc
WYMB002	114.5m	114m	108-114m 102-105m 96-99m	71.2m	43m	59.5m btc
WYMB003	84m	84m	78-84m 69-72m 60-63m	42m	42m	53.7m btc
WYMB004	96m	78m	72-78m	30m	66m	63.4m btc
WYMB006	90m	90m	84-90m 75-81m	60m	30m	37.3m btc
Note 1: m btc = meters below top of casing. All other depths = depth below ground.						

Bores were airlifted after completion. Groundwater yields calculated from air lifting rates ranged from nil to 0.3L/s.

Measured standing water levels in the bores ranged from 37.2 to 63.5m below top of casing, or 208.6m AHD to 231.2m AHD. Standing water levels are typically higher than the groundwater bearing zones indicating that the fractured rock aquifers in the vicinity of the Mine Site are confined aquifers.



Source: Alkane Resources Ltd.

Figure 12
MINE SITE BORES

Coffey logged standing water levels in bores WYMB002, WYMB003, WYMB004 and WYMB006 for a period of nine months between July 2007 and March 2008. Recorded standing water levels in WYMB002 and WYMB003 remained relatively unchanged throughout the monitoring period even though there was a significant rainfall event of approximately 150mm (on the 27 December 2007) during the monitoring period. Standing water levels in WYMB004 and WYMB006 rose by approximately 33m and 9m respectively between July 2007 and January 2008 in response to the significant rainfall event on the 27 December 2007. WYMB004 and WYMB006 are located in close proximity to the former McPhails workings (an old gold mine located approximately 400m to the south of the Mine Site). Coffey concluded that WMYB004 and WYMB006 were likely to have hydraulic connection to caverns associated with McPhails workings and the observed rise in water levels in these bores between July 2007 and January 2008 was likely to be indicative of filling of the mining voids during the 27 December 2007 rainfall event.

Based on the information presented in a following report prepared by Coffey in 2008 (Coffey, 2008) it is concluded that there is little natural connectivity between deep aquifer and shallow alluvial aquifers at the Mine Site.

Coffey also conducted slug tests of each bore to assess the hydraulic conductivity of the surrounding aquifer. The measured hydraulic conductivity in the bores ranged from 0.002m/day to 0.11m/day or 2.3 x 10^{-7}m/s and 1.3 x 10^{-6}m/s.

Finally, Coffey also conducted some basic calculations to assess pumping rates that would be required to lower the standing water level in an open cut to 100m below ground level. The calculations indicated that the standing water level could be lowered 50m with sustained pumping at a rate of 2L/s. It should be noted that this was a basic calculation only and was made to illustrate the relatively low rate of groundwater recharge to an open cut within the Mine Site.

Coffey (2008) indicates that the targeted mineralisation has a higher hydraulic conductivity than the surrounding siltstone and shale. The mineralised zones may yield relatively high volumes of groundwater when fractures are first encountered. However, once the higher hydraulic conductivity areas are drained inflows would be governed by the surrounding relatively low yielding siltstone and shale.

5.4 WATER QUALITY

Coffey (2007) collected samples from WYMB01, WYMB02, WYMB03, WYMB04, WYMB06. The samples were analysed in a laboratory for cations, anions, heavy metals, nutrients and physical parameters to assess the quality of groundwater and the source of groundwater sampled from each bore.

The Impax Group collected a sample from GW037395 on 23 September 2009. The sample was analysed in a laboratory for cations, anions, heavy metals, nutrients and physical parameters.

GW037395, is located adjacent to Gundong Creek approximately 4.5km to the northeast of the Mine Site (**Figure 11**). The well, which is 4.5m deep is currently used to irrigate a relatively small citrus orchard (“The Overflow”).

Laboratory results of Coffey and Impax sampling are summarised in **Table 2**.

Table 2
Water Quality Data

Analyte	Units	WYMB01	WYMB02	WYMB03	WYMB04	WYMB06	GW037395
Field pH	-	8.23	8.24	9.16	8.18	5.7	7.35
Lab pH	-	7.7	8.0	7.7	7.7	7.6	-
EC	µS/cm	10800	25800	22600	29200	16400	444
TDS	mg/L	7310	15000	13800	18100	9690	160
Sodium	mg/L	2100	4980	4090	5480	2870	58.2
Potassium	mg/L	7	12	21	21	8.9	0.9
Calcium	mg/L	220	145	185	230	170	1
Magnesium	mg/L	255	430	455	660	425	1.7
Chloride	mg/L	3310	6990	5730	8380	3420	39
Bicarbonate	mg/L	570	1480	1400	1240	1410	77
Sulphate	mg/L	1080	2060	2210	2560	2246	13
Fluoride	mg/L	0.13	0.30	0.25	1.10	0.26	0.30
Nitrite	mg/L	<0.1	-	-	-	-	0.03
Nitrate	mg/L	<0.1	0.13	<0.1	<0.1	<0.1	0.51
Ammonia	mg/L	<0.1	0.20	<0.1	<0.1	0.50	0.06
Phosphate	mg/L	<0.1	0.52	0.43	<0.1	<0.1	0.040
Hardness	mg/L	160	2130	2340	3290	2180	9
Copper	mg/L	0.005	0.002	0.003	0.003	0.03	0.001
Lead	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Zinc	mg/L	0.010	0.004	0.001	0.002	0.011	0.005
Cadmium	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0001
Nickel	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	0.001
Total Iron	mg/L	0.05	0.01	<0.01	0.17	0.75	28.4
Arsenic	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	0.001
Mercury	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001

Concentrations of cations and anions were plotted on a piper diagram. The piper diagram is presented as **Figure 13**. The plotted results from all Coffey bores were consistent, indicating groundwater sampled from each of the deep bores had a similar origin. Measured total dissolved solids ranged from 7 310ppm to 18 100ppm. Groundwater sampled from WYMB006 had a high proportion of sulphate relative to groundwater sampled from the other wells. This is was likely to be associated with mineralisation and provides further evidence of some connection between McPhails workings and WYMB06.

The chemistry of water sampled from the shallow alluvium (GW037395) was different to that of water sampled from deep fractured rock bores. In particular the concentrations of dissolved solids were significantly lower, which resulted in a much lower EC. The proportion of cations and anions (see **Figure 9**) were also different to those in the deeper bores, indicating no direct connection between groundwater in the shallow alluvium and deeper fractured rock aquifer(s).

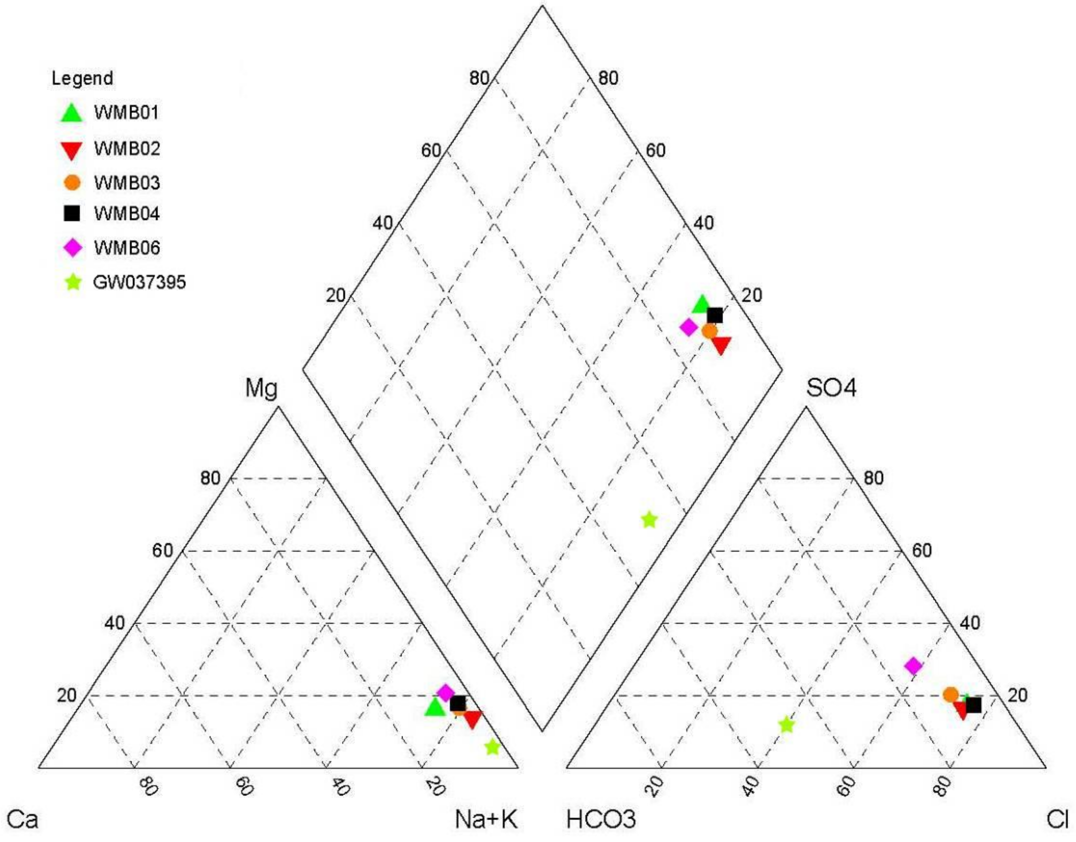


Figure 13
PIPER TRI-LINEAR DIAGRAM

5.5 AQUIFER PERMEABILITY TESTING

5.5.1 Introduction

In October 2009, The Impax Group conducted short duration pumping tests on three of the test bores (WYMB01, WYMB02 and WYMB03). These bores were installed by Coffey Geotechnics Pty Ltd in 2007.

Prior to the commencement of the test, a water level logger was placed in the bottom of each bore. Water was air-lifted from the bores and captured in a graduated container so that the volume of water removed could be assessed. The bores were air-lifted until they were dry, or the groundwater yield became steady. Air-lifting then ceased and the wells were allowed to recover. The recovery data was assessed as a slug test using Hvorslev Method (1951). Data interpretation was conducted by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE).

The pumping data could not be assessed as the pumping rate varied during air-lifting. In addition, the water level loggers (which measure changes in pressure) did not perform well during the injection of pressurised air into the wells.

The results of the analyses indicated a permeability range of 1.2 x 10^{-9}m/s to 7.1 x 10^{7}m/s (0.0001 to 0.06m/day in bores WYMB01 and WYMB03 respectively), indicating generally low permeability values for groundwater hosted in the fractured Ordovician aquifer. The results of the each permeability test are discussed in Sections 5.5.2 to 5.5.4.

5.5.2 WYMB01

WYMB01 was air-lifted for a period of 30 minutes. Approximately 130L of water was removed during this period, giving an average pumping rate of 0.072L/s. The recovery curve for WYMB01 is presented in **Appendix 5**.

The standing water level at the commencement of the test was 37.6m below the top of the well casing. The standing water level at the completion of air lifting was approximately 90m below the top of the well casing, which indicated the well had been pumped dry. The standing water level recovered to approximately 87m below top of casing within 5 minutes of the cessation of air-lifting but the water level remained relatively stagnant for the following 4 hours. The test was discontinued at this stage. The observed 3m of recovery is thought to have represented minor recharge of the well from water that flowed back down the inside of the well casing or the gravel pack when air lifting ceased.

Analysis of the data by AGE estimated the average hydraulic conductivity (K) value for the surrounding aquifer to be 1.2 x 10^{-9}m/sec (0.0001 m/day), which is two orders of magnitude lower than that the average K value of 0.02 m/day determined by Coffey when this monitoring bore was installed.

5.5.3 WYMB02

WYMB02 was airlifted for a period of 55 minutes. Approximately 700L of water was removed during this period, giving an average pumping rate of 0.21L/s. The recovery curve for WYMB02 is presented in **Appendix 5**.

The standing water level at the commencement of the test was 59.54m below the top of the well casing. The standing water level at the completion of air lifting was approximately 98.72m below the top of the well casing, which indicated the total drawdown was 39.18m. The standing water level recovered to approximately 62.15m below top of casing (approximately 93%) within 55 minutes of the cessation of air lifting. The test was discontinued at this stage.

Analysis of the data by AGE after 80% recovery estimated the average K value for the surrounding aquifer to be 1.1 x 10^{-7}m/sec (0.01 m/day), which again is less than the than that the average K value of 0.07m/day determined by Coffey when this monitoring bore was installed.

5.5.4 WYMB03

WYMB03 was air-lifted for a period of 30 minutes. Approximately 65L of water was removed during this period, giving an average pumping rate of 0.036L/s. The recovery curve for WYMB03 is presented in **Appendix 5**.

The standing water level at the commencement of the test was 55.28m below the top of the well casing. The standing water level at the completion of air-lifting was approximately 78.19m below the top of the well casing, which indicated the total drawdown was 22.91m. The standing water level recovered to approximately 55.32m below top of casing (approximately 100%) within 55 minutes of the cessation of air-lifting. The test was discontinued at this stage.

Analysis of the data by AGE after 95% recovery estimated the average K value for the surrounding aquifer to be 7.1 x 10^{-7}m/sec (0.06 m/day), which is only slightly less than the than that the average K value of 0.08m/day determined by Coffey when this monitoring bore was installed.

5.6 PEAK HILL GOLD MINE GROUNDWATER EXPLORATION

A report written by Coffey Partners International Pty Ltd (1997) titled *"Peak Hill Gold Mine Water Supply Development"* outlines the results of a groundwater exploration program that was conducted on behalf of the Peak Hill Gold Mine (Alkane Resources Ltd).

The program included drilling several test holes approximately 10km to 12km to the south to the Mine Site. Three of the five bores drilled did not yield any groundwater. Yields of the two other exploration holes were 0.65L/s and 1.5L/s. The TDS and pH was measured in one of these test bores (GW803834). The measured TDS was 4440ppm and the measured pH was 7.6.

It should be noted that most of these test bores were located outside of the Study Area.

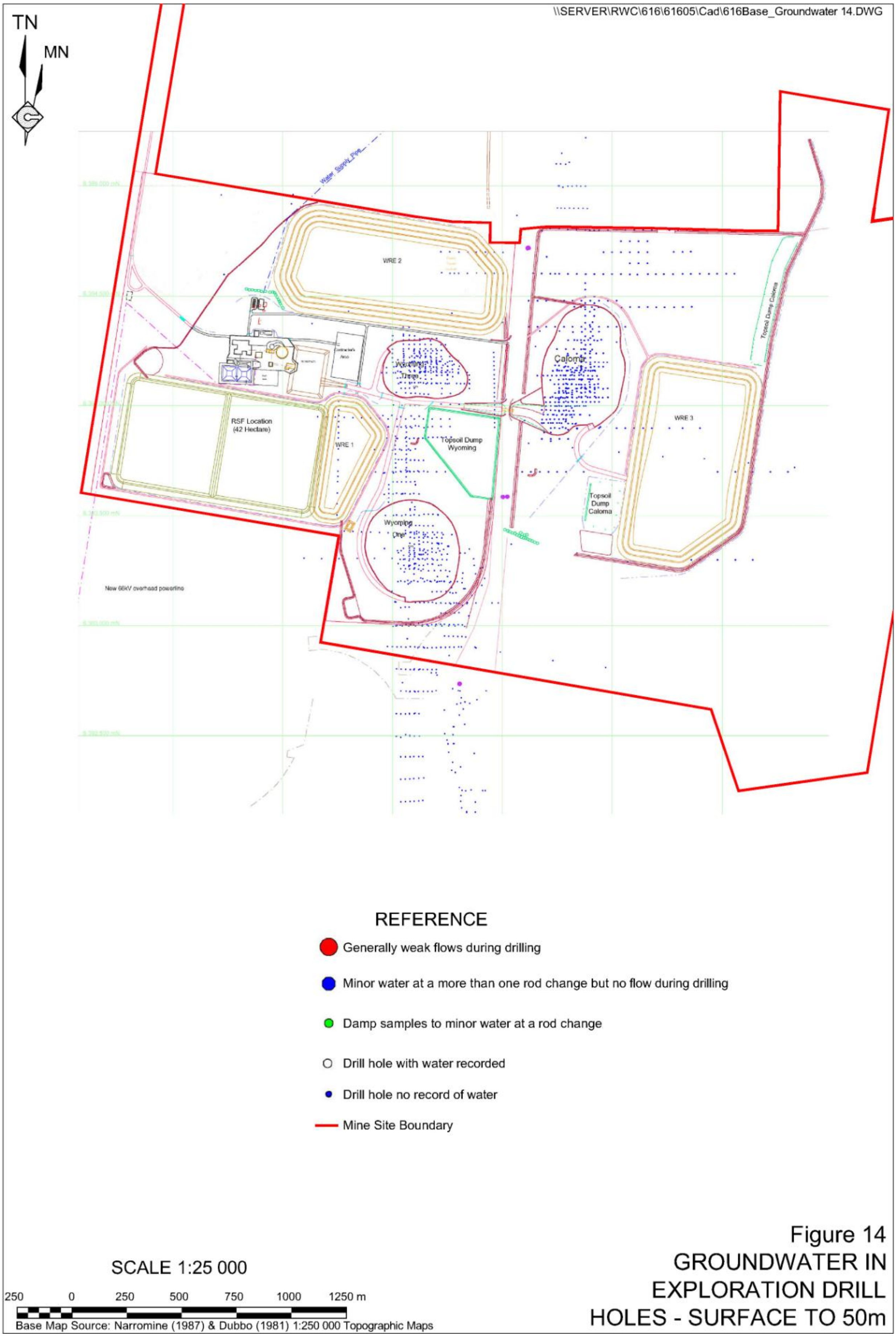
5.7 EXPLORATION DRILLING OBSERVATIONS

The Proponent has advanced over 1 300 exploration drill holes within and in the vicinity of the Mine Site. Observations made during the advancement of all exploration holes have been logged, and these include the occurrence of groundwater. For the purpose of this assessment The Proponent provided a summary of groundwater observations. Groundwater observations from each bore were described as one of the following:

- weak flow during drilling;
- minor water at more than one rod change but no flow during drilling;
- damp samples to minor water at rod change;
- drill hole with groundwater recorded; and/or
- drill hole with no groundwater recorded.

These classifications are presented graphically in **Figures 14**, **15** and **16**. **Figure 14** shows groundwater observations for exploration holes that were drilled to depths of less than 50m below ground level. **Figure 15** shows groundwater observations for exploration holes that were drilled to depths between 50m and 100m below ground level. **Figure 16** shows groundwater observations for exploration holes that were drilled to a depth greater than 100m below ground level.

Groundwater observation data is also presented in **Table 3**.



Base Map Source: Narromine (1987) & Dubbo (1981) 1:250 000 Topographic Maps

Figure 14
GROUNDWATER IN EXPLORATION DRILL HOLES - SURFACE TO 50m

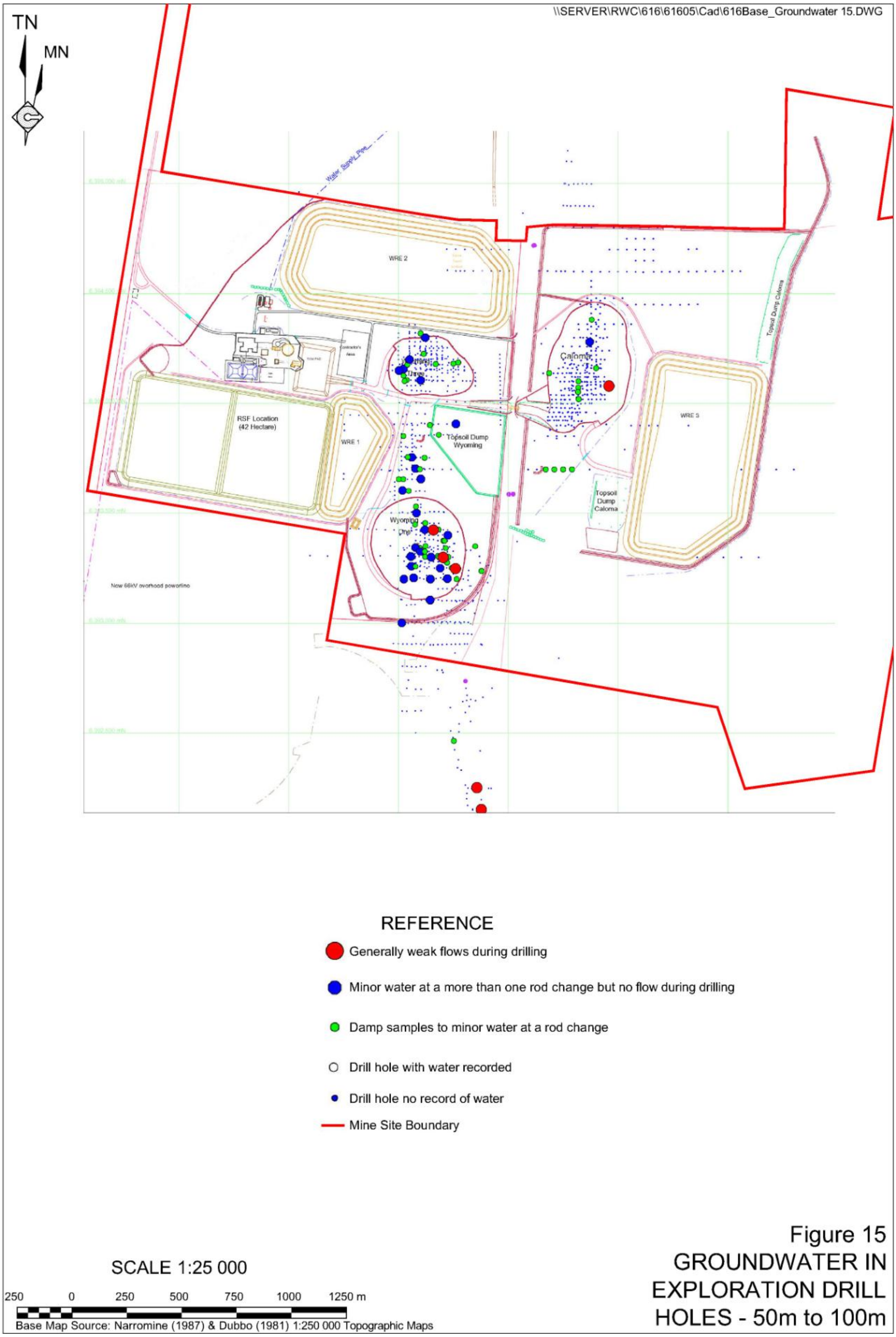
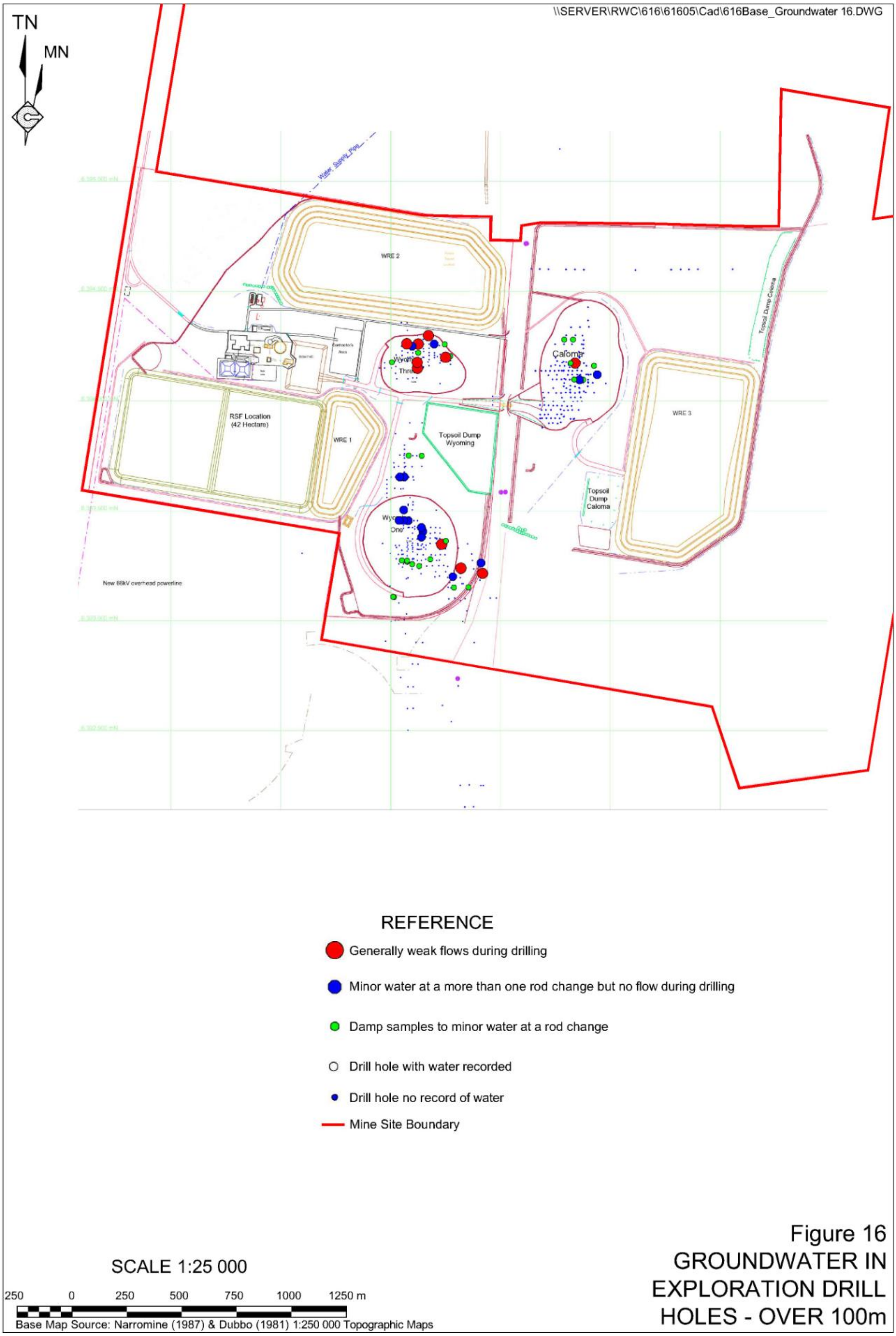


Figure 15
GROUNDWATER IN EXPLORATION DRILL HOLES - 50m to 100m



Base Map Source: Narromine (1987) & Dubbo (1981) 1:250 000 Topographic Maps

Figure 16
GROUNDWATER IN EXPLORATION DRILL HOLES - OVER 100m

Table 3
Occurrence of Groundwater in Exploration Holes

Total Depth	No of Holes	Water Flow <50m	Water Flow 50 – 100m	Water Flow >100m
<50	221	0	-	-
50-100m	638	0	25	-
>100m	450	0	57	48
Source: Alkane Resources Ltd				

As shown in **Table 3** and **Figure 14**, groundwater flow has not been observed during drilling of the upper 50m of the sub-surface. At the time this report was prepared at least 1,309 exploration holes had been advanced to depths of between 0m and 50m below ground level or greater.

At the time this report was prepared at least 1,088 exploration holes had been drilled to depths between 50m and 100m below ground level or greater. Groundwater flow was observed in 82 of these boreholes at depths between 50m and 100m below ground level.

At the time this report was prepared at least 450 exploration holes had been drilled to depths greater than 100m below ground level. Groundwater flow has been observed in 48 of these exploration holes at depths greater than 100m below ground level.

When encountered, groundwater bearing zones were typically identified at depths between 70m and 100m below ground level and 120m and 130m below ground level.

As shown in **Figures 14** to **16**, groundwater was typically encountered in close proximity to the target ore bodies. These observations indicate that fractured water bearing zones are more prevalent within the ore bodies than the surrounding siltstones and shales.

5.8 CURRENT GROUNDWATER USE

The registered uses of bores located within 10km of the Mine Site included "monitoring bore", "test bore / public supply", "test bore", "irrigation" and "stock and domestic".

Groundwater bores GW803678, GW803679, GW803680, GW803681 and GW803682) are the closest registered bores to the Mine Site (**Figure 11**). These bores are registered as monitoring bores and are believed to be used as an environmental groundwater monitoring bores by a service station located in Tomingley.

The registered use of groundwater bores GW045134, GW045135, GW045136 and GW045137 is "test bore/public supply". It is believed that these bores were installed by Narromine Council to investigate potential groundwater supply for Tomingley from the Gundong Creek alluvium.

The registered use of groundwater bore GW803148 is "Town Water Supply". Narromine Council indicated that Tomingley obtains its water supply from surface water flows within Gundong Creek (when it is flowing), and from a ‘gallery of shallow wells’ located approximately 3.5km northeast of the village. This description corresponds with the registered location of GW803148.

The registered use of groundwater bore GW800177 is "test bore". The status of this bore is not known. The Impax Group attempted to locate these bores on 23 September 2009. Information on the NOW groundwater bore database indicates GW800177 is located within the travelling stock route adjacent to the Newell Highway. Bores located within stock routes are typically pumped used windmills. The Impax Group inspected the TSR in the vicinity of bore's location but could not find any evidence of a bore. The adjacent landowner was also unable to identify the bore. Based on the results of the Mine Site inspection it is unlikely that GW800177 was ever cased or used.

The registered use of groundwater bore GW066562 is "test bore". Information contained in the Coffey Partners International Pty Ltd (1997) *"Peak Hill Gold Mine Water Supply Development"* report indicates that GW066562 was drilled as part of a groundwater exploration program to find water for the Peak Hill Gold Mine. The report indicates that GW066562 yielded approximately 0.4L/s, however, this hole was abandoned.

The registered use of groundwater bore GW037395 is "irrigation". This bore is located within Gundong Creek alluvium, approximately 4.5km to the northeast of the Mine Site. The Impax Group obtained a water quality sample from GW037395 on 23 September 2009. The groundwater well was located adjacent to Gundong Creek and was being used to irrigate a small citrus orchard on “The Overflow”. The Impax Group measured EC and pH in the field. The measured EC of the water sampled was 444µS/cm and the measured pH was 7.35.

The registered use of groundwater bores GW034897 and GW801568 is "stock and domestic". The work summary form for GW801568 indicated that this bore has been abandoned. The Impax Group contacted the owner of GW801568 on 23 September 2009. The owner (Mr Ken Carville of "Mallee View") indicated that he attempted to install a bore at his property, but the hole did not yield water and was abandoned, as indicated on the work summary. GW034897 is a 1.8m deep well located approximately 4.7km to the north northwest of the Mine Site. The status of this well is "unknown".

There are several bores registered for stock and domestic use located within 10km to 20km of the Mine Site. Stock and domestic bores located to the east of the Mine Site are within the Obley granite and therefore, should not be affected by operation of the proposed mine. Stock and domestic bores located adjacent to the Bogan River are likely to be recharged from the Bogan River and should also not be affected by the proposed mining operation.

Several stock and domestic bores are located more than 10km to the south of the Mine Site. Given the distance from the Mine Site these bores are unlikely to be affected by operation of the proposed mine.

5.9 GROUNDWATER QUALITY

The majority of work summary forms for the registered groundwater bores did not provide an indication of groundwater salinity (or total dissolved solids). Where data was provided salinity ranged from zero to 14 000ppm. This is equivalent to an electrical conductivity (EC) range of zero to approximately 21 000µS/cm. Descriptors provided included "good", "fresh" and "salty".

Coffey (2007) assessed water quality in five bores installed within 2km of the Mine Site. Measured salinity in these bores ranged from 7 310ppm to 18 100ppm. This is equivalent to an electrical conductivity (EC) range of approximately 10 900µS/cm to 27 000µS/cm.

The Proponent monitored groundwater quality in the vicinity of the open cut gold mining pits at Peak Hill, NSW (approximately 15km south of the Mine Site) between 1995 and 2005. The full results of groundwater quality monitoring can be seen in the *'Peak Hill Gold Mine, Annual Environmental Management Report for 2005'*. This report provides a summary of all groundwater monitoring results between 1995 and 2005.

Whilst the geology at Peak Hill and the Mine Site are different, the mineralogy within both ore bodies is similar, and the geology surrounding the mineralised zone is also similar. As such, groundwater quality monitoring data collected at the Peak Hill mine is considered useful for assessing potential impacts to groundwater quality at the Mine Site.

Data was collected from three groundwater monitoring bores during operation of the mine. The measured EC in Peak Hill monitoring bores ranged from 13 300µS/cm to 29 800µS/cm. Measured pH in Peak Hill monitoring bores ranged from 6.8 to 8.0.

The Impax Group was able to measure the EC and pH of a groundwater sample collected from GW037395. GW037395 is a shallow well located on “The Overflow” adjacent to Gundong Creek approximately 4.5km northeast of the Mine Site. The measured EC of the water sampled was 444µS/cm and the measured pH was 7.35.

5.10 SUMMARY OF SURROUNDING AQUIFERS

5.10.1 Introduction

Based on the information reviewed as part of this assessment groundwater is available in several types of aquifers. These are summarised in the following sub-sections.

5.10.2 Shallow Alluvium

Groundwater appears to exist in discrete, relatively shallow (less than 20m deep, most commonly less than 10m) alluvium which dissects the plains surrounding the Mine Site. The best example of this type of aquifer is the alluvium surrounding Gundong Creek. **Figures 7** and **8** provide the mapped occurrence and representative cross-section of alluvium on and surrounding the Mine Site. Both figures illustrate the discrete nature of the alluvial material and therefore aquifers.

Aquifers of this nature are inferred to be recharged locally, primarily from surface water infiltration. Groundwater is likely to exist along present day and old creek flow paths.

Groundwater within these systems appears to be of relatively good quality. Groundwater yields within these systems are likely to be relatively low and dependent on the occurrence of rainfall.

5.10.3 Deep Alluvium

Deep alluvium (up to 100m below ground level) appears to be present more than 10km to the northwest and west of the Mine Site. Available data indicates that groundwater yields within these systems are relatively low and that water quality is limited. This observation is also supported by the relatively small number of bores in these systems and by the paucity of water encountered within these sequences in the approximately 1,300 exploration drill holes completed within the Mine Site.

These systems may have some interaction with underlying bedrock but are likely to be primarily recharged from surface water.

5.10.4 Fractured Rock

There are several fractured rock aquifer systems located within 20km of the Mine Site. The plains surrounding the Mine Site are typically underlain by shale, siltstone and chert of the "Cotton Formation", "Mugincoble Chert" and "Mumbidgle Formation".

Groundwater yields in this aquifer range from nil to 3L/s but are typically less than 1.5L/s. Available groundwater quality information indicates that groundwater within this system is saline.

Other surrounding fractured rock aquifers include aquifers within the "Obley Granite", located more than 10km to the northeast and east of the Mine Site, the "Hervey Group" sedimentary rocks, located more than 10km to the southeast of the Mine Site, and the "Goonumbla Volcanics", which are located more than 15km to the south of the Mine Site. Groundwater yields in these systems range from nil to 2L/s but are typically less than 1.5L/s. Good quality groundwater may exist in the "Obley Granite" and "Hervey Group". However, it is unlikely that there is any significant interaction between groundwater in the "Obley Granite", "Hervey Group" and the "Goonumbla Volcanics" hard rock aquifers, and/or the hard rock aquifers underlying the Mine Site and its surrounds. As such development within the Mine Site is not expected to have an impact on aquifers within the "Obley Granite" or "Hervey Group" geological units.

6 POTENTIAL BENEFICIAL GROUNDWATER USE

6.1 INTRODUCTION

Groundwater salinity is the only measure of groundwater quality information available for the majority of bores used in this assessment. Groundwater salinity is a simple way to assess potential beneficial uses of groundwater.

6.2 DRINKING WATER

The *National Water Quality Management Strategy, Australian Drinking Water Guidelines (2004)* provide aesthetic based guidelines for total dissolved solids (TDS). These are presented in **Table 4**. The aesthetic guidelines refer to the TDS concentration which affects the taste or palatability of drinking water. These guidelines are not based on potential to cause adverse impacts to human health.

Measured TDS concentrations recorded by Coffey for groundwater sampled from WYMB01, WYMB02, WYMB03, WYMB04, WYMB06 ranged from 7 310ppm to 18 100ppm. These results indicate that deep groundwater that would be intercepted by the proposed mining activities would not be suitable for drinking water.

Table 4
Palatability of Drinking Water According to TDS Concentration

TDS	EC Equivalent	Drinking Water Quality
<80ppm	<120µS/cm	Excellent
80-500ppm	120-750µS/cm	Good
500-800ppm	750-1200µS/cm	Fair
800-1000ppm	1200-1500µS/cm	Poor
>1000ppm	>1500µS/cm	Unacceptable

The measured EC of groundwater sampled from GW037395 (444µS/cm) indicates groundwater in the shallow alluvium along Gundong Creek is suitable for drinking.

Water quality information was not available for GW803148. Given that this bore is used to supply water for Tomingley Village it is assumed to be relatively good quality and suitable for human consumption.

6.3 IRRIGATION

The *ANZECC Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)* provide salinity thresholds for a broad range of commonly grown crops and host soil types (sand, loam and clay). Salinity thresholds for crops grown in loamy soils range from 1 100µS/cm to 7 300µS/cm.

Based on the results of the Coffey groundwater sampling, the deep groundwater in the vicinity of the Mine Site would not be considered suitable for irrigation of any commonly grown crops.

The measured EC of groundwater sampled from GW037395 (444µS/cm) indicates groundwater in the shallow alluvium along Gundong Creek is suitable for irrigation. It should be noted that GW037395 is registered as an irrigation well.

6.4 STOCK WATER

The *ANZECC Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)* provide typical salinity tolerance thresholds of common livestock. These are summarised in **Table 5**.

Based on the results of the Coffey groundwater sampling, the deep groundwater in the vicinity of the Mine Site may be acceptable as drinking water for sheep. Groundwater would not be considered suitable for watering of cattle, horses, pigs or poultry.

The measured EC of groundwater sampled from GW037395 indicates groundwater in the shallow alluvium along Gundong Creek is suitable for stock watering.

Table 5
Tolerance of Livestock to TDS in Drinking Water

Livestock Type	Stock Will Drink Without Loss of Production	Loss of Production and Decline in Animal Condition and Health Expected
Beef Cattle	4000-5000ppm	5000-10000ppm
Dairy Cattle	2500-4000ppm	4000-7000ppm
Sheep	5000-10000ppm	10000-13000ppm
Horses	4000-6000ppm	6000-7000ppm
Pigs	4000-6000ppm	6000-8000ppm
Poultry	2000-3000ppm	3000-4000ppm

6.5 DISCHARGE TO SURFACE WATER

The *ANZECC Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)* provides a range of default trigger values for electrical conductivity in slightly disturbed river ecosystems located in Southeast Australia. The trigger value range provided for "Lowland Rivers" is 125µS/cm to 2200µS/cm.

Results of Coffey (2007) groundwater sampling indicate that deep groundwater within the Mine Site would not be suitable for discharge to surface water.

6.6 FRESHWATER AQUACULTURE

The *ANZECC Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)* indicates that a salinity of <3000ppm is desired for the protection of freshwater aquaculture species.

Results of Coffey groundwater sampling indicate that deep groundwater within the Mine Site would not be suitable for freshwater aquaculture.

The measured EC of groundwater sampled from GW037395 indicates groundwater in the shallow alluvium along Gundong Creek is suitable for freshwater aquaculture.

6.7 INDUSTRY

The availability of groundwater for other industry must be considered as part of this assessment. There are no relevant water quality guidelines for industrial use of groundwater. Whilst good quality water is usually required to protect infrastructure, complex water treatment plants can be used to achieve the desired water quality.

At present, there are no groundwater reliant industries located within the Study Area. Available groundwater information indicates that groundwater yields within the Study Area are relatively low and unreliable. As such, they would not be suitable to guarantee of regular supply of water. In addition, groundwater within fractured rock at the Mine Site is salty and would require treatment prior to being used for most applications.

The Proponent has indicated that should water surplus to operational requirements be drawn from the bore on the “Woodlands” property, this would be made available to Narromine Shire Council for further treatment and supplementation of the Tomingley water supply. The provision of a supplementary supply of good quality water to Tomingley is seen as a positive outcome for industry/business prospects in the village.

7 MINE DEWATERING

7.1 INTRODUCTION

The open cuts and underground mine are the components of the Tomingley Gold Project that are expected to impact on the volume of groundwater within aquifers at, and adjacent to, the Mine Site. The open cuts would be excavated to depths of up to 180m below ground level and the underground to approximately 380m below surface. Available groundwater data indicates that standing water levels in the vicinity of the open cuts range from 40m to 60m below ground level and water bearing zones are located between 70m and 130m below ground level. As such, groundwater is likely to be encountered during the excavation of the open cuts and underground mine. Should groundwater be encountered, it would be necessary to remove this from the open cuts and underground to allow them to extend below the standing water level. Groundwater and rain that falls within the open cuts would be removed from the open cuts by both natural processes (evaporation) and mechanical means (pumping) if necessary.

Dewatering activities would be strictly limited to lowering the water level to a level which would allow mining to proceed safely. The Proponent has no need to extract additional groundwater from the open cuts for operational purposes as they have obtained enough water to supply all mining operations from an external source.

7.2 RELEVANT WATER PROCESSES

It is necessary to establish a conceptual understanding of the processes that would take place in the proposed open cuts in order to assess potential dewatering requirements and associated potential impacts to groundwater.

The open cuts would be constructed in a tapered fashion. The unconsolidated alluvium would be battered at an angle of approximately 50º. The underlying consolidated material would be battered at an angle of up to 70º. The open cuts would feature a 5m wide berm (bench) for every 20 vertical metres of the open cut. The resulting open cuts would have relatively wide opening at the surface and taper to a relatively small area at the base.

The requirement to dewater open cuts is primarily dependent on the water balance for each open cut. Water inputs to each open cut would consist of groundwater inflow and rainfall. Water outputs from each open cut would consist of evaporation and pumping. These factors are discussed in more detail below.

Groundwater Inflow

The amount of groundwater seepage will depend on the depth of the open cut, the storage of water in the adjacent fractured rock aquifer, and the transmissivity of the surrounding fractured rock. Groundwater is not expected to seep into the open cuts until they reach a depth of approximately 70m below ground level. Groundwater is expected to seep into the open cuts from water bearing fractures. The seepage is likely to flow down the walls of the open cut until it reaches a berm, or the bottom of the open cut, where it may accumulate. Seepage is not expected to be uniform around the open cuts, rather it would come from localised fractures. Basic numerical modelling can be used to estimate the amount of groundwater that needs to be removed from the open cuts to lower the potentiometric surface to the base of the open cuts.

Rainfall

Surface features of the Mine Site would be constructed in a manner which directs surface water (from rainfall) away from the open cuts. This is important to maintain stability in the walls of the open cuts. As such, rain inputs to each open cut would be restricted to rain that falls directly within the bounds of the open cut. Only some of the rain that falls within the open cuts would drain to the base of the open cut. A large portion of rainfall is likely to flow down the walls of the open cuts and accumulate on berms. The amount of rain water that reaches the bottom of the open cuts would depend primarily on the intensity and duration of the rainfall event, and the amount of evaporation occurring. For example, a large proportion of rain that falls in a low intensity short duration event would stick to the walls and berms of the open cut and would not flow to the base of the open cut. Rain that falls in a long duration, high intensity event has much greater chance of being able to flow to the base of the open cut.

Evaporation

The rate of evaporation is primarily dependent on the water temperature and the humidity of the air adjacent to the water surface. As such, factors that influence the evaporation rate include the depth of the water body, water temperature, exposure to sun, exposure to wind and atmospheric humidity. The evaporation rates measured by the Australian Bureau of Meteorology (BOM) are measured in a standard evaporation pan that is kept at a relatively constant water level throughout the year and is uniformly exposed to the elements. Whilst the evaporation figures provided by the BOM are useful in assessing evaporation it is difficult to apply these measurements to estimate evaporation from the open cuts. Factors that would affect the amount of evaporation from the open cuts include the following.

- Exposure to the elements. The amount of sun and wind exposure within the open cuts is likely to be much less than an equivalent area at the ground surface. Evaporation may be less than expected in winter months and higher than expected in summer months.
- The presence of water. Evaporation does not occur when there is no water present within the open cut. The BOM evaporation reading is based on water being present 24 hours a day, 365 days a year.
- Water inflow patterns. Water that seeps uniformly down a section of sun exposed wall will evaporate much more readily than water in a localised seepage that flows down a narrow crack on the shady side of the open cut. Similarly, a shallow pool of water spread across a berm will evaporate much faster than a narrow channel of water that is located in a narrow defined drainage channel.

Pumping

Pumping would be used to ensure the open cuts remain free of water (groundwater and rain water). If necessary, water would be pumped from a low point at the base of each open cut.

With the exception of evaporation which would not affect the volume of water held in the underground mine, the factors affecting dewatering requirements for the open cuts would be similar in the underground mine.

7.3 GROUNDWATER MODELLING METHODS AND ASSUMPTIONS

Groundwater modelling was conducted by AGE. The results of groundwater modelling works are provided in full in the AGE letter report titled *"Review of Aquifer Permeability Testing, Groundwater Inflows and Impact on Groundwater Levels for the Tomingley Gold Mine"*, which is presented as **Appendix 6**.

7.3.1 Aquifer Parameters

Estimated aquifer permeability results calculated from the results of aquifer slug tests conducted by Coffey (2007) and short duration pumping tests conducted by The Impax Group in October 2009 are summarised in **Table 6**.

Table 6
Summary of Aquifer Testing Results

Borehole Number	Coffey Geotechnics Slug Tests Calculated Permeability K (m/day)	Impax Short Duration Pumping Tests Calculated Permeability K (m/day)
WYMB01	0.02	0.0001
WYMB02	0.07	0.01
WYMB03	0.08	0.06
WYMB04	0.002	-
WYMB06	0.11	-

As outlined in Section 5.3, WYMB06 is expected to be connected to water filled underground voids associated with the McPhails Mine. As a result, the permeability estimates obtained from WYMB06 were higher than those obtained for the other bores and were not used when calculating the average permeability of the hard rock aquifer.

The average permeability estimates obtained from the short duration pumping tests were lower than those estimated from the Coffey 2007 slug tests. Both tests are only considered to provide a rough estimate of the aquifer properties, however, the short duration pumping test places more stress on the surrounding aquifer than the slug tests and is therefore considered the more reliable indication of aquifer properties.

In order to model the required dewatering volumes AGE assumed the average horizontal permeability (K) value for the fractured rock aquifers adjacent to the open cuts was 0.035m/day. This value was the average of the measured values in WYMB02 and WYMB03.

AGE assumed that the saturated aquifer thickness at the Wyoming One and Caloma Open Cuts was 115m. That is a standing water level approximately 60m below ground level and open cut depths of 170m and 175m below ground level respectively.

AGE assumed that the saturated aquifer thickness at the Wyoming Three Open Cut was 40m. That is a standing water level approximately 60m below ground level and open cut depth of 100m below ground level.

7.3.2 Marinelli and Niccoli (2000) Method

The New South Wales Office of Water (NOW) have indicated that spreadsheet analysis using classical groundwater flow equations would be acceptable for the assessment of groundwater inflow to the mine and of the radius of influence of dewatering, rather than complex 3D numerical flow modelling.

The assessment of likely groundwater seepage rates into the proposed Wyoming One, Wyoming Three and Caloma Open Cuts, as well as the radius of influence on groundwater levels of open cut dewatering was therefore undertaken using equations developed by Marinelli and Niccoli (2000).

The analytical method of Marinelli and Niccoli (2000) requires a simplification of the hydrogeological environment and is used to provide a ‘broad’ range of potential drawdown and open cut inflow. The equations calculate groundwater inflow from the Proterozoic aquifer from the open cut walls and from the base of the open cut separately, based on the conceptual model presented in **Figure 17**.

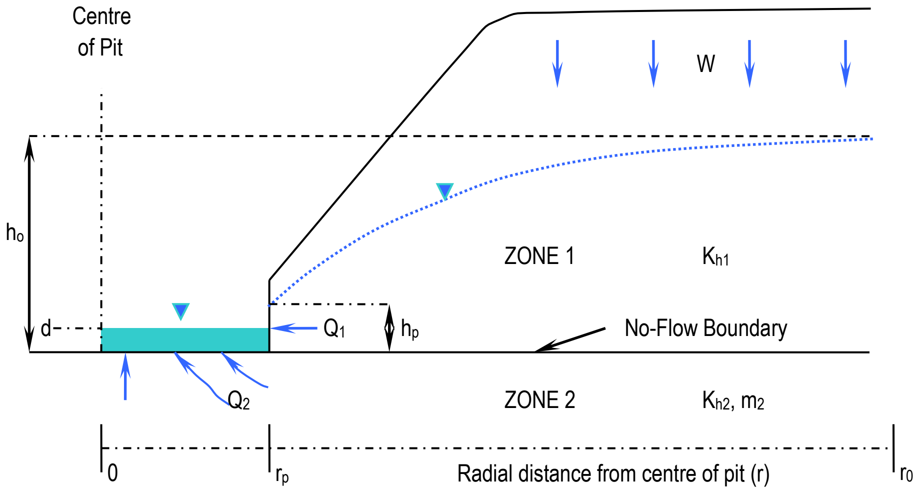


Figure 17 Pit Inflow Analytical Model

Groundwater inflows were calculated for Zone 1 and Zone 2 using the following equations:

Zone 1

$$Q_1 = W \pi (r_o^2 - r_p^2) \qquad m^3/day$$

Zone 2

$$Q_2 = 4 r_p \left\langle \frac{K_{h2}}{m_2} \right\rangle (h_o - d)$$

$$m_2 = \sqrt{\frac{K_{h2}}{K_{v2}}}$$

The extent of drawdown due to the net groundwater inflow then allows for determination of the radius of influence of the inflow on the water table by iteration from the following equation:

$$h_0 = \sqrt{h_p^2 + \frac{W}{K_{h1}}\left[r_o^2 \ln\left(\frac{r_o}{r_p}\right) - \frac{(r_o^2 - r_p^2)}{2} \right]}$$

where:

k_{h1} – *hydraulic conductivity value for the aquifer in Zone 1*
h_o – *saturated thickness of aquifer*
W – *rainfall recharge rate*
h_p – *the height of the aquifer seepage face in the open excavation*
r_p – *equivalent radius of pit as a cylinder*
K_{h2} – *horizontal hydraulic conductivity value for the aquifer in Zone 2*
k_{v2} – *vertical hydraulic conductivity values for the aquifer*
D – *depth of water level in base of pit*

For Zone 1 the analytical solution considers steady-state, unconfined, horizontal, radial flow and assumes that:

- the pit walls are approximated as a circular cylinder;
- groundwater flow is horizontal; the Dupuit-Forchheimer approximation is used to account for changes in saturated thickness due to depression of the water table;
- the static (pre-mining) water table is approximately horizontal;
- uniform distributed recharge occurs across the site as a result of surface infiltration from rainfall; all recharge within the radius of influence (cone of depression), of the excavation is assumed to be captured by the excavation;
- groundwater flow toward the excavation is axially symmetric.

Groundwater inflow to the pits and drawdown in water level was undertaken for the range of hydraulic conductivity values determined from the in-situ permeability testing at the sites. The hydraulic permeability values adopted are assumed to reflect the upper limit for the fractured crystalline rock mass. Thus they could be considered conservative by representing a worse case scenario. The inputs used in the estimates were as follows.

k_{h1}	–	hydraulic conductivity for zone 1	=	4.1×10^{-7}m/sec
k_{h2}	–	hydraulic conductivity for zone 2	=	0.1 x zone 1 value
k_{v2}	–	vertical hydraulic conductivity zone 2	=	equivalent to k_{h2}
h_o	–	saturated thickness of aquifer	=	115m (Caloma Open Cut), 110m (Wyoming One Open Cut), 40m (Wyoming Three Open Cut), and 200m (Wyoming One underground mine)
W	–	rainfall recharge to aquifer	=	1% of annual rainfall or 4.7mm/yr

h_p – the height of seepage face in the excavation = 2m

r_p – equivalent radius of mine pit as a cylinder = 94m (Caloma Open Cut), 97m (Wyoming One Open Cut), 43m (Wyoming Three Open Cut), and 22m (Wyoming One underground mine)

D – assumed depth of water level in base of pit = 1m

7.3.3 Darcy Equation - Post Mining Groundwater Inflow Estimation

Groundwater inflows into the post mining voids were estimated using the following form of the Darcy Equation:

$$Q = KiA \ m^3/day.$$

In estimating the indicative groundwater inflow rates to the open cuts, each spreadsheet model assumed an average 'K' value of 4.1 x 10^{-7}m/sec or 0.035m/day (refer to Section 7.3.1).

The rate of water level recovery within each open cut and the underground mine was determined using the surface area/volume relationship for each mine. The configuration of each open cut and underground mine is presented in **Appendix 6**.

The hydraulic gradient *(i)* and the saturated aquifer surface area (*A*) were both variable and were determined iteratively from the changed open cut water level for each time step. The regional groundwater level was assumed to be 210m AHD for the duration of the simulation which is equivalent to the general pre-mining groundwater level measured at the site.

The model simulation was undertaken as daily time steps for a period of 120 years using the daily rainfall and evaporation data.

7.3.4 Direct Rainfall

Data from the BOM indicates the Mine Site receives an average of 559mm (or 0.559m) of rainfall per year. The surface area and estimated average volume of rainfall occurring within each open cut is summarised in **Table 7**.

Table 7
Estimated Rainfall and Evaporation in Open Cuts

Open Cut	Surface Area (at Ground Level)	Average Annual Rainfall Inflow
Wyoming 1	155 000m^2	86.6ML/yr
Wyoming 3	82 000m^2	45.8ML/yr
Caloma	179 000m^2	100.1ML/yr

As shown in **Table 7**, using BOM annual rainfall data it is estimated that an average of 232.5ML/yr (7.4L/s) of rainfall will fall within the open cuts at the Mine Site. Using BOM evaporation data it is estimated that an average of -759.2ML/yr (24.1L/s) of water will evaporate from the open cuts at the Mine Site.

7.3.5 Water Body Evaporation

Data from the BOM indicates the average annual evaporation rate at Wellington (the nearest evaporation measurement location) is 1,825mm/yr. The rate of evaporation from a surface water body in the Mine Site was estimated assuming a pan-evaporation factor of 0.7 to account for the fact the final void is a deep, semi-shaded open cut and protected from winds, all of which reduce evaporation.

Daily evaporation data was determined using 120-year period SILO climate data provided by the Queensland Department of Environment and Resource Management (DERM) for the Tomingley Mine Project area.

7.4 GROUNDWATER INFLOW AND DRAWDOWN IMPACTS

7.4.1 Caloma Open Cut

This open cut would be the largest and deepest of the four open cuts and hence is predicted to have the greater potential inflows and drawdown impact on groundwater. The range of potential inflows and drawdown presented in **Figure 18** is based on the final void geometry at the end of the proposed mine life for the Caloma Open Cut. Groundwater inflow and drawdown would gradually increase as the pit deepens and reaches a predicted maximum within the range presented in **Figure 18**.

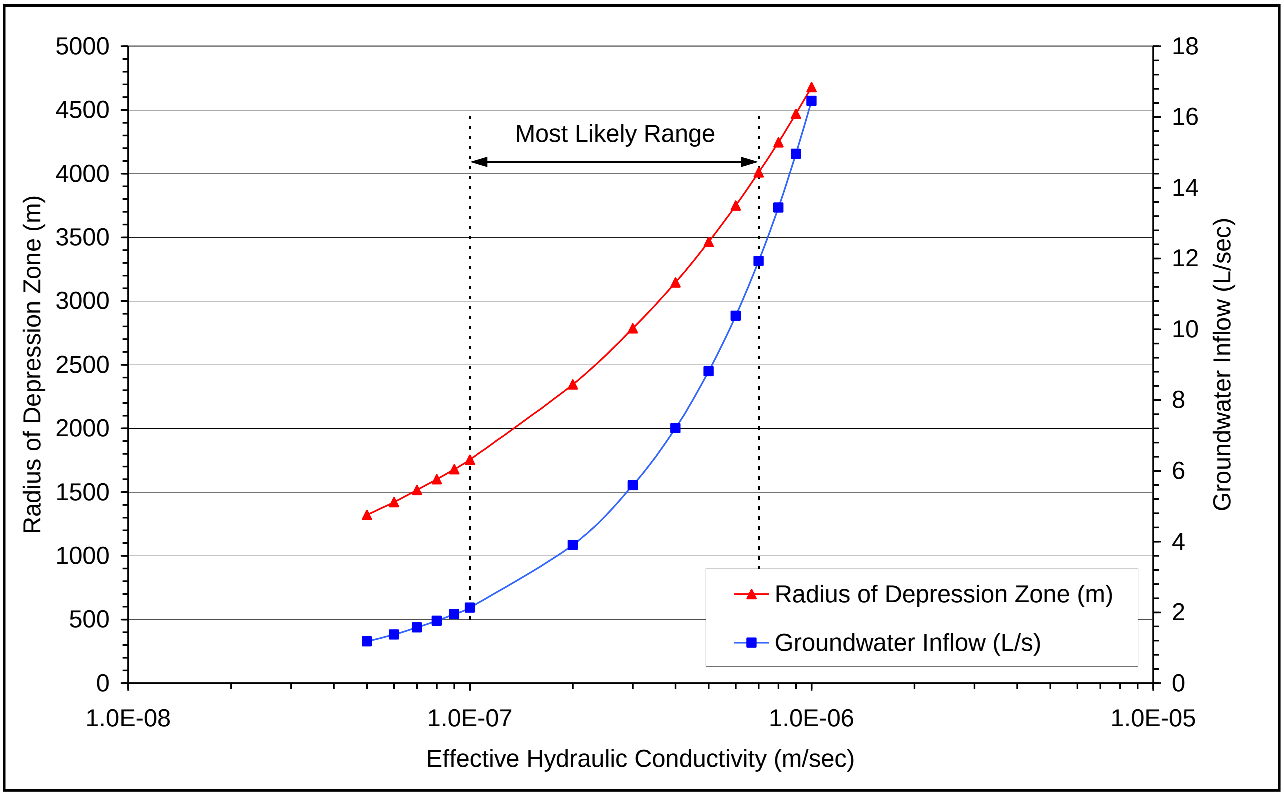


Figure 18 **Estimated Groundwater Inflows and Drawdown - Caloma Open Cut**

Assuming the effective hydraulic conductivity range for the rock mass is between 1 x 10^{-7}m/sec and 7 x 10^{-7}m/sec the analytical method indicates the following:

- groundwater inflows between 2L/sec and 12L/sec; and
- the extent of drawdown (i.e. - radius of the cone of depression) will be between 1,700m and 3,900m.

Not all water would collect in the bottom of the open cut as the majority is likely to be lost to evaporation or removed with the ore. Higher inflows may be experienced periodically when water bearing fractures are intersected, but these inflows are likely to be short term as the fractures are expected to drain relatively quickly.

Based on the general indication that the rock mass is tight, it is concluded that inflow would be at the lower end of the range given, that is to say 2 to 7L/sec with much of this lost to evaporation.

7.4.2 Wyoming One Open Cut

The extents of the Wyoming One Open Cut are slightly smaller than those for the Caloma Open Cut from which the analytical assessment indicates a slight reduction in groundwater inflow but a generally similar extent of drawdown. Assuming the effective rock mass hydraulic conductivity values range between 1 x 10^{-7}m/sec and 7 x 10^{-7}m/sec (as determined from the permeability testing), the analytical method predicts:

- groundwater inflows between 2L/sec and 11L/sec; and
- extent of drawdown between 1,700m and 3,900m.

As for the Caloma Open Cut there is a general indication that the rock mass is tight, it is considered inflow to this open cut would be at the lower end of the range given, that is around 2 - 7L/sec with much of this lost to evaporation.

7.4.3 Wyoming One Underground Extension

The proposed continuation of mining by developing an underground mine from the base of the Wyoming One Open Cut would result in additional and greater impact on the surrounding groundwater regime. The range of potential inflows and drawdown presented in **Figure 19** is based on the final volume of the underground mine at the end of the proposed mine life for the Wyoming One Open Cut underground.

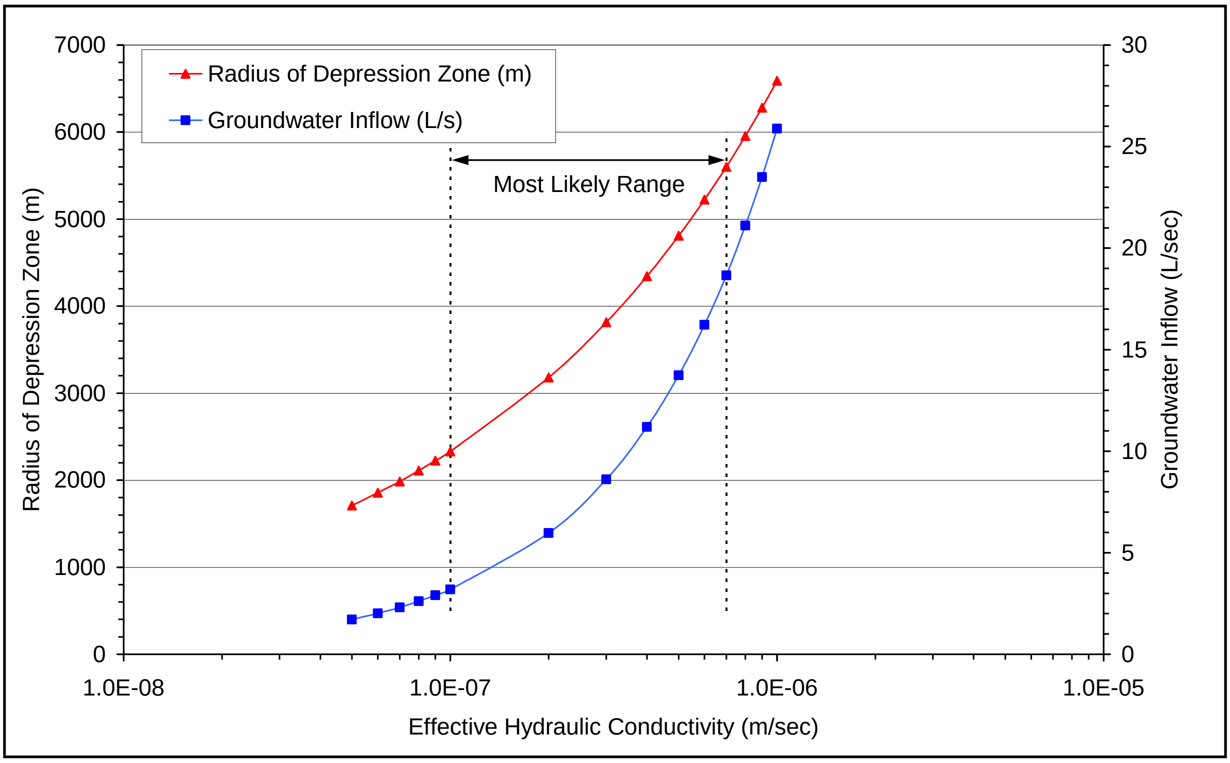


Figure 19 Estimated Groundwater Inflows and Drawdown - Wyoming One Underground Extension

The analytical assessment of the underground mine indicates generally higher groundwater inflows could be expected into the underground workings along with a corresponding increase in the drawdown extent within the range presented in **Figure 19**. Assuming effective rock mass hydraulic conductivity values ranging between 1 x 10^{-7}m/sec and 7 x 10^{-7}m/sec, the analytical method predicts:

- groundwater inflows between 3L/sec and 20L/sec; and
- extent of drawdown between 2,300m and 5,600m.

However, based on the general indication that the rock mass is tight, it is considered this inflow would be at the lower end of the range given, that is around 3 to 11L/sec. Some of this water can be expected to be lost as water vapour removed by extraction through the ventilation system.

7.4.4 Wyoming Three Open Cut

The Wyoming Three Open Cut, which would be 100m deep, is much shallower than the other two open cuts and therefore estimates of inflow rates and extent of drawdown are significantly reduced. Assuming bulk rock mass hydraulic conductivity values determined from the permeability testing of between 1 x 10^{-7}m/sec and 7 x 10^{-7}m/sec , the analytical method predicts:

- groundwater inflows between 0.3L/sec and 1.5L/sec; and
- extent of drawdown between 650m and 1450m.

As for other two open cuts and the general indication that the rock mass is tight, it is considered inflow to this open cut would be at the lower end of the range and hence would be minimal given much of this would be lost to evaporation.

7.4.5 Cumulative Groundwater Inflow and Drawdown Impacts During Mining

The methodology by Marinelli and Niccoli only considers the individual open cut being assessed and not the cumulative effects of all four open cuts being mined, either concurrently or consecutively. Therefore, the predicted inflows outlined in Sections 7.4.1 through Section 7.4.4 are an over estimate of actual groundwater inflows. Where two or more open cuts are mined concurrently, it is probable the inflows to each open cut would be less than that predicted to each individual open cut. Similarly, if mined consecutively, inflows to the second and third open cuts would be less than those to the first mined open cut.

Comparison of the predicted extent of drawdown for an average aquifer permeability value of 4.1 x 10^{-7}m/sec for each open cut relative to that for the Wyoming One Open Cut underground mine is presented graphically in **Figure 20**. This shows the cumulative extent of drawdown would be largely governed by the depth of the underground operation, and hence would not be expected to alter significantly from that predicted for the underground mine (i.e. the predicted drawdown from each of the open cuts is generally within this larger drawdown extent).

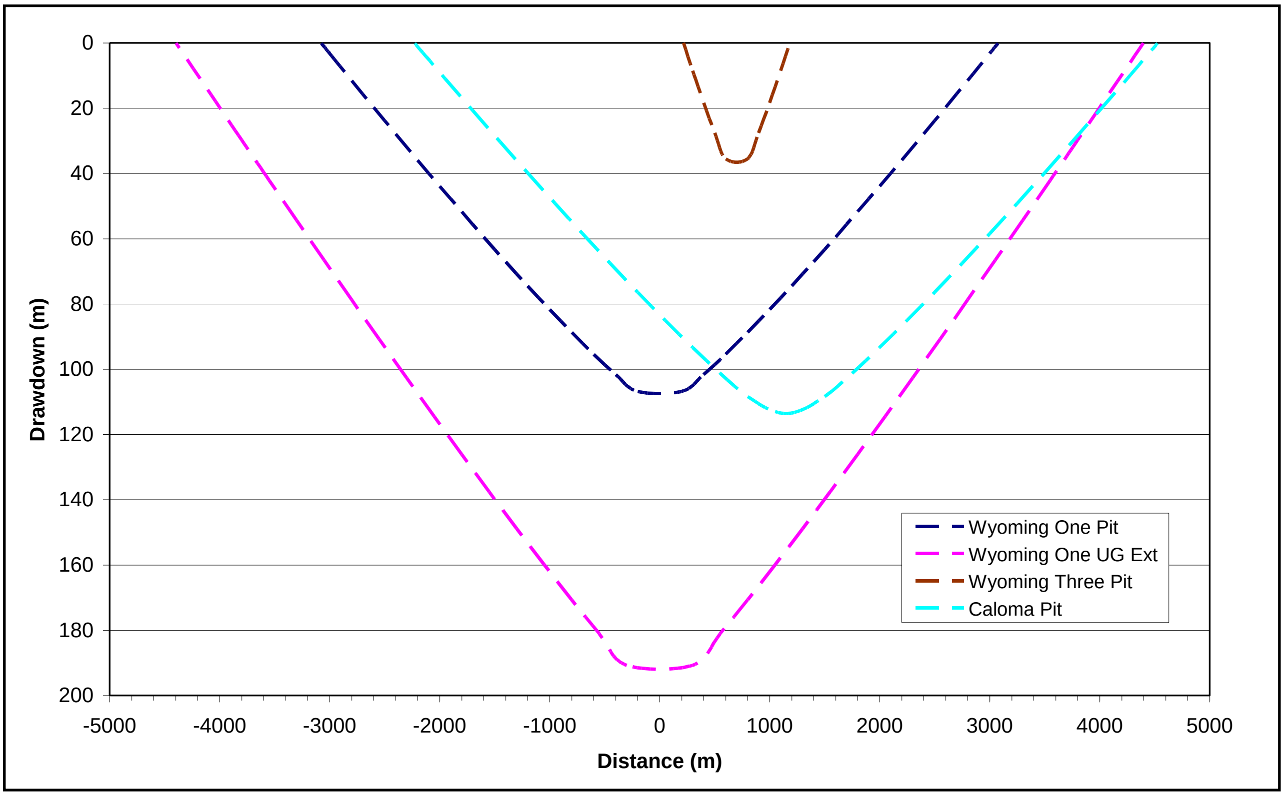


Figure 20 Comparison of Predicted Drawdown Extent for Each Open Cut in Relation to the Wyoming One Open Cut Underground Extension

In summary, if the Wyoming One underground is kept free of water the resulting aquifer drawdown would be sufficient to dewater the adjacent open cuts. That is, the maximum rate of total groundwater inflow to all mine voids would be between 3L/sec and 20L/sec. The maximum extent of the cone of depression would be between 2,300m and 5,600m from the Wyoming One Open Cut.

7.4.6 Caloma Two Open Cut

At the time groundwater modelling was undertaken the Caloma Two Open Cut did not form part of the proposed development. The exact design of the Caloma Two Open Cut is not yet known. The open cut is believed to have a maximum footprint of approximately 9ha and will be approximately 100m deep.

As outlined in Section 7.4.5, groundwater modelling indicates that dewatering of the Wyoming One underground would create a cone of depression which is anticipated to also dewater the adjacent Wyoming Three and Caloma Open Cuts. The cone of depression from the Wyoming One underground is also expected to dewater the Caloma Two open cut.

Whilst the Caloma Two Open Cut has not specifically been assessed, the addition of this open cut to the Project is not expected to create any impacts to groundwater other than those that have already been addressed within this report.

7.5 RESIDUAL DRAWDOWN AFTER MINING

The pits created by open cut mining would remain as voids when mining at the Tomingley Gold Project ceases. Post mining, abstraction of groundwater from the aquifer would cease and the final voids would gradually fill with water until an equilibrium condition establishes. The potential sources of water that may contribute to filling the final void are:

- discharge from the fractured Ordovician aquifer; and
- direct rainfall.

The equilibrium elevation of the water level of the final void would therefore be governed by the following components:

- the size and shape of the void;
- direct rainfall into the void;
- groundwater inflow from the fractured Ordovician aquifer; and
- the rate of evaporation from the surface of the water accumulated in the void.

The rates of recovery of the water levels and the equilibrium water levels for the final Wyoming One, Wyoming Three and Caloma Open Cuts were determined using a spreadsheet water balance model developed for each site. For Wyoming One, recovery of water levels within the proposed underground extension at the base of the open cut was also considered. The equilibrium water level is obtained when evaporation loss is equivalent to inflow and allows for assessment of whether the open cut will act as a sink to groundwater or a source in the long term. The water balance of the final void was based on the following equation:

Water Balance of Final Void = Direct Rainfall + Groundwater Inflow – Evaporation

The water balance of the final underground mine was based on the following equation:

Water Balance of Final Underground Workings = Direct Rainfall (to open cut) + Groundwater Inflow

This assumes that post mining the open cuts and the underground workings will be in hydraulic connection and water reporting to the open cuts as rainfall runoff will ultimately contribute to recovery of water levels within the underground workings.

The water levels within the water accumulated in the final voids were modelled using historical rainfall and evaporation data for the site.

The modelled water level recovery within the Caloma Open Cut is illustrated in **Figure 21**. Water levels initially recover relatively quickly within five to ten years after the mining operation ceases due to the relatively small void volume at the base of the Open Cut. Water levels within the open cut reach quasi-equilibrium approximately 50 years post mining at an elevation of approximately RL 200m. There is a slight rise in open cut level corresponding to increased rainfall events during Years 60 and 66 post mining, with open cut water levels finally stabilising after approximately 85 years at around RL 207m.

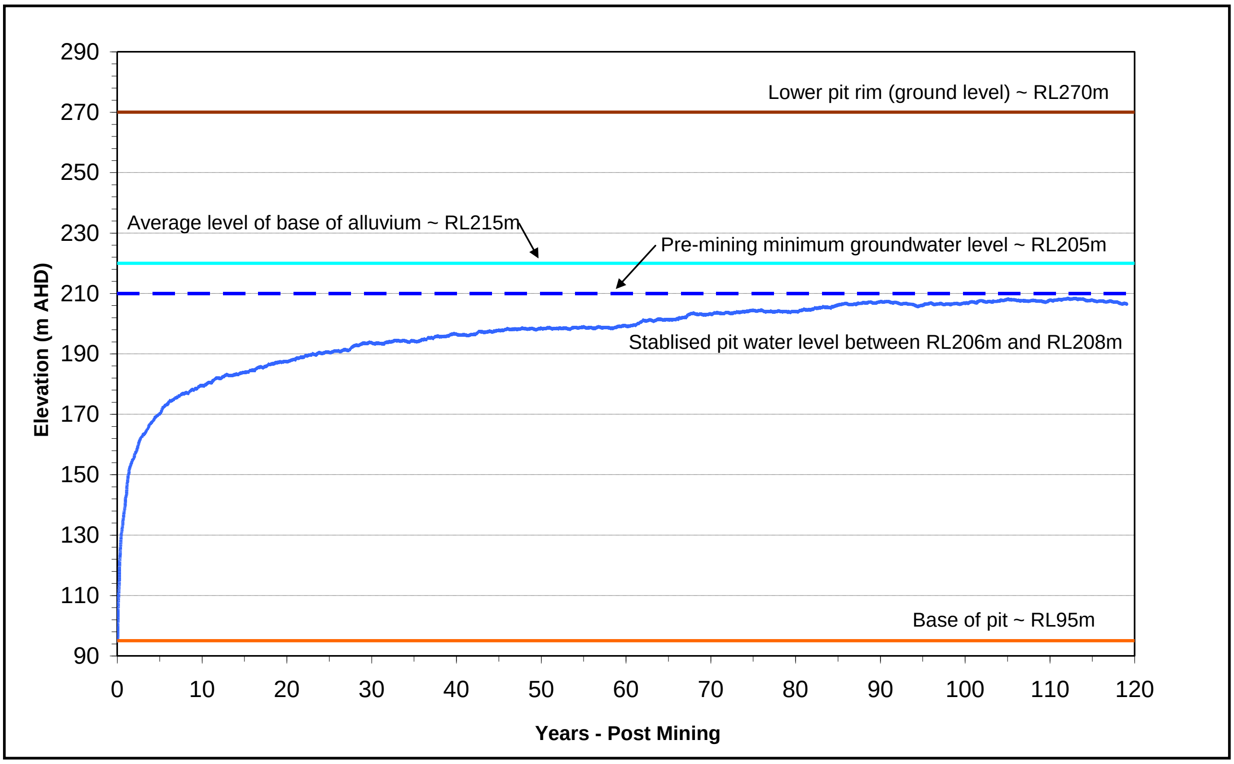


Figure 21 **Caloma Open Cut - Simulated Rate of Recovery and Equilibrium Water Level**

The modelled water level recovery within the Wyoming One Open Cut is illustrated in **Figure 22**. The water level initially recovers relatively quickly within the underground working rising to the base of the open cut in the first year. Thereafter, recovery resembles that of the Caloma Open Cut with further recovery being relative quick to Year 10 post mining due to the relatively small void volume at the base of the open cut. Water levels within the open cut initially stabilise after approximately 50 years of recovery at an approximate elevation of RL180m. A slight rise in open cut water level again occurs corresponding to increased rainfall events during Years 60 and 66 post mining, with the open cut water level stabilising at around RL193m after approximately 85 years.

The modelled water level recovery within the Wyoming Three Open Cut is illustrated in **Figure 23**. The water level within the Wyoming Three Open Cut also rises relatively quickly within the first five to ten years of recovery due to the relatively small void volume at the base of the open cut. Water levels within the open cut stabilise approximately 50 years post mining at an approximate elevation of RL202m. No further rise in open cut water levels is observed after this time, which may be a function of this open cut being shallower with a slightly greater surface area to volume configuration, compared to that for the other two open cuts.

In summary, it is assessed that the open cut water levels will stabilise somewhere between RL193m and RL207m, which is below the pre-mining fractured aquifer level of RL210m and well below the lower open cut crest levels of between RL265m and RL270m. Based on the above, the final voids at the Tomingley Gold Project will remain as sinks to groundwater flow and should not over top or discharge water from the open cuts to the regional aquifer.

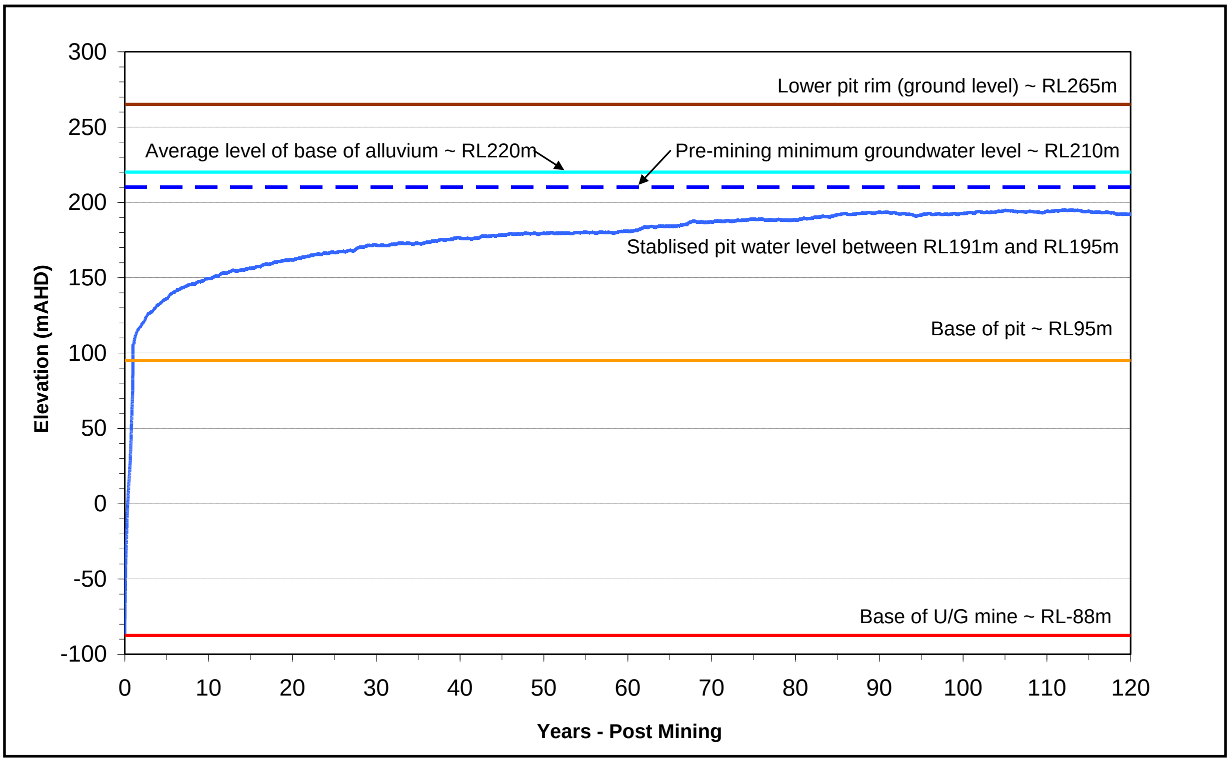


Figure 22 **Wyoming One Open Cut - Simulated Rate of Recovery and Equilibrium Water Level**

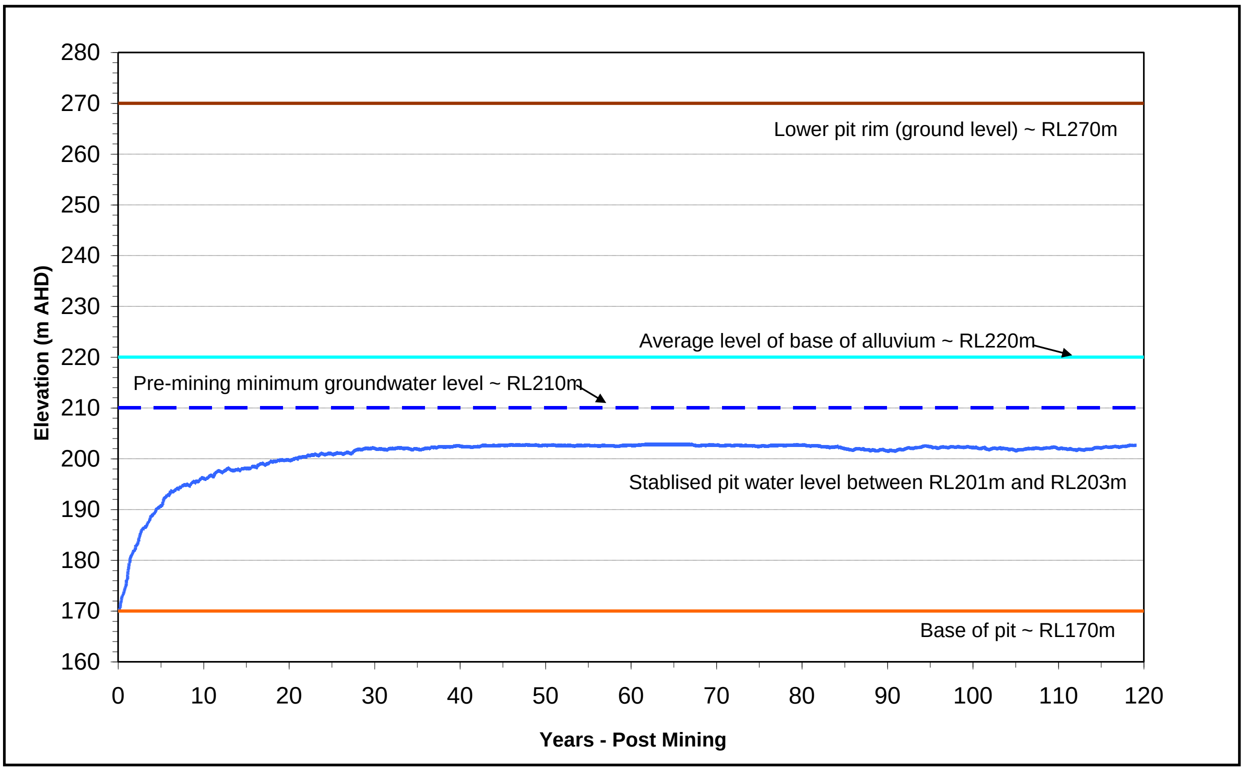


Figure 23 **Wyoming Three Open Cut - Simulated Rate of Recovery and Equilibrium Water Level**

7.6 MECHANICAL DEWATERING

Data from the BOM indicates the Mine Site receives an average of 559mm (or 0.559m) of rainfall per year. Data from the BOM indicates the average annual evaporation rate at Wellington (the nearest evaporation measurement location) is 1,825mm/yr. The surface area and estimated volume of rainfall and evaporation occurring within each open cut is summarised in **Table 8**.

Table 8
Estimated Rainfall and Evaporation in Open Cuts

Open Cut	Surface Area (at Ground Level)	Average Annual Rainfall Inflow	Average Annual Evaporation
Wyoming 1	155 000m^2	86.6ML/yr	-282.9ML/yr
Wyoming 3	82 000m^2	45.8ML/yr	-149.7ML/yr
Caloma	179 000m^2	100.1ML/yr	-326.7ML/yr
TOTAL	**416 000m^2**	**232.5ML/yr**	**-759.2ML/yr**

As shown in **Table 8**, using BOM annual rainfall data it is estimated that an average of 232.5ML/yr (7.4L/s) of rainfall would fall within the open cuts at the Mine Site. Using BOM evaporation data it is estimated that an average of 759.2ML/yr (24.1L/s) of water would evaporate from the open cuts at the Mine Site.

The calculated groundwater inflow to the open cuts ranges between 94.6ML/yr (3L/s) and 630.7ML/yr (20L/s).

As outlined in Section 7.2, there are many variables that could affect the volume of groundwater and rainfall that reaches the base of the open cuts, and the rate at which evaporation occurs from the base of the open cuts. It is difficult to accurately determine the amount and intensity of rainfall, and the amount of evaporation that will occur in the open cuts through the lifespan of the mine. As such, The Impax Group has considered best, worst and average case scenarios to assess dewatering requirements of the open cuts. In the best case scenario groundwater inflow would be low and evaporation would be high. In the worst case scenario groundwater inflow would be high and evaporation would be low. In the average scenario it is assumed that groundwater inflow would be approximately 10L/s and that evaporation would occur from the open cuts at a rate of 50% of the BOM pan evaporation rate. Rainfall is assumed to be average in each scenario.

The results are summarised in **Table 9.**

Table 9
Assessment of Mechanical Dewatering Requirements

Evaporation Scenario	Rainfall Inflow to Open Cuts	Groundwater Inflow to Open Cuts	Losses to Evaporation	Mechanical Dewatering Rate Required
Best Case	232.5ML/yr	94.6ML/yr	-759.2ML/yr	0ML/yr
Average Case	232.5ML/yr	315.4ML/yr	-379.6ML/yr	168.3ML/yr
Worst Case	232.5ML/yr	630.7ML/yr	-0ML/yr	863.2ML/yr

In the worst case scenario the mechanical dewatering requirement would be 863.2 ML/yr or 27.4L/s. In the average case scenario the mechanical dewatering requirement would be 168.3ML/yr or 5.3L/s. In the best case scenario mechanical dewatering would not be required.

In reality, a significant portion of the groundwater and rainfall that enters the open cut would be lost to evaporation. The walls and berms of the open cuts provide a large surface area from which evaporation can occur. Groundwater is expected to seep into the open cuts through fractures in the rock walls of the open cut. In this case relatively low flows of groundwater would travel down the walls of the open cut. Some would come to rest on the berms. This scenario is favourable for evaporation. Similarly, rainfall would flow down the walls of the open cut and is likely to form shallow pools on the berms of the open cuts, which would encourage evaporation.

The Impax Group estimates that there would be some periods of operation where mechanical dewatering is necessary and other periods where evaporation would be adequate to remove groundwater and rain inflows to the open cuts.

It should also be noted that a large volume of stored water would be removed during the excavation of rock within the open cuts. This volume has not been factored into the dewatering calculations.

If mechanical dewatering is required water pumped from the open cuts would be used on the Mine Site for dust suppression or would be allowed to evaporate from dewatering dams located adjacent to the open cuts.

8 POTENTIAL IMPACTS TO GROUNDWATER QUANTITY

8.1 INTRODUCTION

This section of the assessment outlines the potential impacts to the availability of groundwater to surrounding users and the environment posed by the proposed mine development.

8.2 WATER QUANTITY

8.2.1 Shallow Alluvium Aquifers

Several registered bores were identified in shallow alluvium located adjacent to Gundong Creek in the area to the north and north east of Tomingley village. These bores are used for beneficial purposes which include irrigation, stock and domestic use.

Groundwater appears to exist in discrete, relatively shallow (less than 20m deep, most commonly less than 10m) alluvium which dissects the plains surrounding the Mine Site. The best example of this type of aquifer is the alluvium surrounding Gundong Creek (see **Figures 7** and **8**). The shallow aquifers are unlikely to have any significant hydraulic connection to the regional scale alluvial plains or the underlying fractured rock aquifer (see **Figure 8**).

Aquifers of this nature are inferred to be recharged locally, primarily from surface water infiltration. Groundwater is likely to exist along present day and old creek flow paths.

As stated in Section 5.7, groundwater has not been identified in shallow alluvium in over 1,300 exploration boreholes that have been drilled in the vicinity of the proposed open cuts. These observations indicate that there are no significant regional scale aquifers located in shallow alluvium within the vicinity of the proposed open cuts.

8.2.2 Deep Rock Aquifers

As detailed in Section 7, water would be extracted from the proposed open cuts by evaporation and/or mechanical means. It is estimated that 3 to 20L/s (94.6 to 630.7ML/yr) of groundwater would need to be removed from the Wyoming One underground to lower the potentiometric surface to 380m below ground level, which would also be sufficient to dewater the adjacent open cuts.

Modelling predicts that the cone of depression could extend 2,300m to 5,600m from the Wyoming One underground.

Modelling predicts that the water level within the open cuts would recover after mining has ceased, however, groundwater would continue to be lost from the open cuts due to evaporation. The exact rate of recovery of the aquifer cannot be accurately calculated, however, modelling indicates that there would be 5 to 30m of residual drawdown within the open cuts 50 years after the cessation of mining (see Section 7.4).

As such, there would be some remnant drawdown in the vicinity of the open cuts. As discussed in Section 5, The Impax Group did not identify any registered users of groundwater from deep fractured rock aquifers located within 10km of the Mine Site. As such, the extraction of groundwater from the open cuts, and subsequent lowering of aquifer pressure should not have any significant impact on any existing groundwater users.

Also, available water quality data indicates that groundwater within the fractured rock aquifer(s) surrounding the Mine Site is highly saline and therefore has limited potential for beneficial re-use (refer to Section 6). As such it is unlikely that the groundwater resource could be developed for other future uses.

8.3 GROUNDWATER DEPENDENT ECOSYSTEMS

The Impax Group did not identify any groundwater dependent ecosystems on or in the vicinity of the Mine Site.

It should be noted that mature trees are present along Gundong Creek and at other locations on and surrounding the Mine Site. Whilst these trees may use groundwater in shallow alluvium they are not considered to be solely dependent on groundwater for their survival and are therefore, not considered to represent a groundwater dependent ecosystem.

Groundwater in the fractured rock aquifer adjacent to the Mine Site occurs at depths greater than 50m below ground level. Standing water level monitoring data collected by Coffey indicates that there is no significant connectivity between groundwater in the fractured rock aquifer and surface water. Based on this information it is unlikely that groundwater in the fractured rock aquifer supports any groundwater dependent ecosystems.

8.4 POTENTIAL IMPACTS TO GROUNDWATER QUALITY

8.4.1 Potential Groundwater Receptors

The Proponent would comply with all relevant industry guidelines to ensure the potential for degradation of groundwater quality at the Mine Site is kept to a minimum.

Activities which have potential to cause groundwater contamination are restricted to the surface. Shallow alluvium beneath the Mine Site would be the primary receptor of any contamination, should it occur.

Results of exploration drilling indicate that there are no extensive alluvial aquifers at the Mine Site. In most areas of the Mine Site there is at least 30m of unsaturated material which is predominantly low permeability clay. As such, the potential for significant groundwater contamination to occur at the Mine Site is low. If groundwater contamination did occur it would be unlikely to propagate far from the source and would be unlikely to affect off-Mine Site groundwater quality.

Registered users of the Gundong Creek aquifer are located up gradient, and a significant distance from the Mine Site, and would not be affected by any reduced groundwater quality. Within the Study Area, there are no registered users of groundwater from shallow alluvium aquifers down gradient of the Mine Site

The deep fractured rock aquifer at the Mine Site is not vulnerable to contamination for the following reasons:

- It is overlain by a significant amount of low permeability material so contamination from the surface is unlikely.
- There would be a groundwater pressure gradient toward the open cuts during and after mining. This would result in groundwater flow toward the open cuts. If any contamination does occur within the open cuts it should not migrate from the Mine Site.

It is expected that the salinity of water within the open cuts would increase over time as water evaporates leaving naturally occurring salts behind. As stated above there would be a groundwater flow gradient toward the open cuts so the saline water would not impact on the surrounding aquifer.

8.4.2 Geochemical Characteristics of Treated Residue Material

Samples of the residue from metallurgical bench scale treatment of various ore types were sent to GCA Pty Ltd for geochemical characterization. The ore treated in the bench scale tests was sourced from cores collected during exploration drilling of the ore bodies.

Three samples of the residue were tested by GCA to determine the geochemical characteristics, in particular the possibility of the material changing in pH due to oxidation in the storage. Oxidation of residue can result in a lowering of the pH and the release of metals into the pore water and therefore potentially into seepage water released from the storage. A lower pH in the upper surface of the residue could also have long term implications for the decommissioning of the storage.

The three samples included two of mainly oxide material and one of mainly primary material.

- Sample 1 – Caloma – Oxide ore.
- Sample 2 – Wyoming 3 – Oxide ore.
- Sample 3 – Caloma – Primary ore.

Samples 1 and 2 proved to be Non Acid Forming (NAF) due to the negligible sulphide based minerals. Sample 3 contained traces of sulphides, however, there was an equal or greater amount of carbonate material present. Any potential for the sulphides to oxidize and lower the pH of the slurry would be quickly countered by the presence of the carbonates. Therefore, Sample 3 is also NAF.

Traces of arsenic and arsenic complexes were detected in the slurry water. The samples of residue tested had been treated to destroy the cyanide. It is likely that the slurry water would contain traces of cyanide. However, cyanide concentrations would be kept below 50ppm in the Residue Storage Facility (RSF) to protect wildlife. This level is the level typically identified in Environment Protection Licences for similar mining operations in NSW.

8.4.3 Residue Storage Facility

The treatment of the ore would result in the production of approximately 1 Mt of tailings (residue) per year. The residue would be pumped as a slurry to a Residue Storage Facility (RSF) located in the southwestern corner of the Mine Site. The RSF would comprise two 21ha roughly square cells which would share a common embankment. Each cell would be equipped with a centrally located decant tower which would enable water released from the residue, and collected rainwater, to be returned to the plant for re-use.

Leachate from the storage of residue has potential to contain heavy metals, and cyanide. Residue would be stored in the Residue Storage Facility (RSF) which would be designed to minimise the potential for leachate to escape from the RSF.

The RSF would be designed and constructed in a manner which maximises water recovery from the residue. High water recovery is desirable for the following reasons.

- Lower water content in the residue increases the stability and structural integrity of the RSF.
- The recovered water can be re-used in the mining process.
- Recovery of water from the residue reduces potential for leachate to escape from the RSF, i.e. a shallow water body has less potential to migrate into the underlying soils than a deeper water body.

The design and proposed operational procedures for the RSF are outlined in the *'Residue Storage Facility - Design Report' (DE Cooper & Associates Pty Ltd, 2009).* Key design and operational features are outlined as follows.

- The floor is to be constructed of native clay material that would be compacted to achieve a permeability of less than $1x10^{-9}$m/day. The floor would slope towards a central decant tower. A 300mm thick compacted clay layer would be formed around the decant towers, which is the lowest point of the RSF and where water that drains from the slurry would accumulate.
- A drainage channel (referred to as the 'Upstream Filter') would be constructed at the base of the inside wall of the RSF. The upstream filter would be located directly beneath the residue inflow spigots to capture the drainage that occurs at the time of residue placement.
- Both RSF cells would feature a Central Decant. The central decant towers would be located at the lowest point of each cell. The towers are to be fitted with a submersible pump that would be used to remove water from the RSF as quickly as possible. Decanted water would be re-used in ore processing.
- Residue would be placed uniformly around the perimeter of the RSF via several slurry spigots. This placement procedure maximises the amount of exposed surface area and minimises the drainage profile. It also creates a gradient toward the centre of the RSF which enhances drainage.

- Piezometers would be installed at appropriate locations around the perimeter of the RSF and monitored regularly to detect any leakage of leachate form the RSF.
- A Groundwater Monitoring Program, including trigger points and contingency measures, would be prepared (see Section 9).

In summary, the ore at the Mine Site has low potential to form acidic or metal rich leachate so, without any environmental controls in place, the risk of detrimental groundwater contamination occurring is low. The RSF would be constructed and operated in a manner which would reduce potential for leachate to escape from the RSF.

8.4.4 Waste Rock Emplacements

The waste rock from the open cuts is NAF and is not expected to generate acidic drainage.

8.4.5 Storage of Reagents and Fuel

All processing reagents would be handled and stored in accordance with a Reagent Management Plan. Reagents including sodium cyanide, caustic soda and hydrochloric acid would be stored in bunded above ground storage tanks. Any spills or leaks would be contained within bunding. As such, the storage of reagents does not pose a risk to groundwater quality at the Mine Site.

All diesel fuel for mobile equipment would be stored in tanks with a total indicative capacity of 100 000L. These tanks would be either self-bunded or located within a bunded fuel bay. Bunding would be sized to meet DECCW containment requirements and AS 1940:2004. A sealed refueling area would be located adjacent to the fuel bay with all drainage from both areas directed to an oil/water separator. Given the measures that would be adopted, the storage and distribution of fuel at the Mine Site is unlikely to pose a risk to groundwater quality at the Mine Site.

8.4.6 In-situ Acid Generation

In open cut mines there is potential for acid to be generated by the oxidation of sulphur rich material in the ore once it is exposed to the atmosphere. Geochemical testing of three ore samples indicates that the targeted ore bodies are NAF. Therefore, there is unlikely to be any significant generation of acid in the open cuts at the Mine Site.

Acid can only form when sulphur rich material is exposed to the atmosphere. As indicated above, test work has indicated that ore material is NAF. Notwithstanding this, if the water level within the open cuts is lower than the current standing water level the groundwater gradient would be towards the open cuts, so potentially impacted groundwater would remain on site. If the water level within the open cuts recovers to the level of the current standing water level (or above it) any sulphur rich material would not be exposed to the atmosphere so acid would not be generated.

9 GROUNDWATER MONITORING PROGRAM

9.1 OBJECTIVES OF GROUNDWATER MONITORING

Groundwater monitoring would be undertaken to assess impacts to groundwater levels and groundwater quality in the vicinity of the open cuts and the RSF.

The objectives of the proposed groundwater monitoring program would be to:

- establish baseline groundwater conditions at the Mine Site, from which potential future impacts can be assessed;
- obtain data that can be used to assess mining-related impacts to groundwater levels and groundwater quality in the vicinity of the Mine Site; and
- identify unforeseen groundwater problems through the use of trigger levels as early as possible to enable procedures to be changed or improved to prevent significant degradation of groundwater resources at the Mine Site.

9.2 MONITORING BORE LOCATIONS

The existing groundwater test bores WYMB01, WYMB03 and WYMB06 would be used to monitor potential impacts on deep groundwater at the Mine Site. (WYMB02 would be destroyed by the Wyoming 1 Open Cut). In addition, twelve groundwater monitoring bores would be installed around the perimeter of the RSF to assess potential impacts to shallow groundwater in the vicinity of the RSF.

9.3 MONITORING BORE DESIGN

Deep monitoring bores WYMB01, WYMB03 and WYMB06 already exist. Details of their construction are presented in Section 5.3.

The monitoring bores installed around the RSF would be constructed to a depth of approximately 5m below ground level. The bores would be constructed of 50mm Class 18 PVC and would consist of a 3m length of screen (2 to 5m below ground level) and a 3m length of blank (1m above ground level to 2m below ground level). The annulus surrounding the bore casing would be filled with gravel pack (washed 2mm sand) from the base of the hole to a depth of approximately 1m below ground level. The remainder of the annulus would be sealed with bentonite, to minimise potential for surface water to 'short circuit' into the bore. An above ground steel monument would be concreted in place over each of the bore heads to protect them from UV light and vehicular traffic.

Based on existing information relating to shallow groundwater at the Mine Site, the shallow monitoring bores around the RSF are expected to be dry, when installed. The bores would only fill with water if the adjacent soils became saturated. This could occur as a result of a significant rainfall event or as a result of leachate leakage from the RSF.

9.4 MONITORING PROGRAM

The Proponent would conduct baseline monitoring of all monitoring bores prior to the commencement of mining. This would include measurement of standing water levels (SWLs), measurement of water quality parameters (pH, EC, dissolved oxygen (DO) and redox potential) and laboratory analysis of samples for major cations, major anions, metals, acidity, alkalinity and total suspended solids.

Regular monitoring of shallow bores adjacent to the RSF would commence as soon as the RSF is in use.

Regular monitoring of deep monitoring bores (WMB01, WMB03 and WMB06) would commence as soon as mining operations commence.

All bores would be gauged on a monthly basis. If water is present, the standing water level (SWL), pH, EC, dissolved oxygen and redox potential of the water would be measured in the field and recorded.

Deep monitoring bores would be sampled on an annual basis, with samples analysed in a laboratory for major cations, major anion, metals, acidity, alkalinity and total suspended solids.

Shallow monitoring bores around the RSF should be free of water for the life of the Tomingley Gold Project. If water is detected in any of the RSF monitoring bores, a sample would be collected for laboratory analysis for major cations, major anion, metals, acidity, alkalinity and total suspended solids and the SWL recorded. If water is identified in any of the shallow bores on a regular basis then laboratory analysis would be conducted annually. If water was present in all of the shallow bores it would not be necessary to analyse a sample from each bore. Instead, samples would be analysed to achieve adequate coverage of the RSF perimeter.

9.5 REPORTING

A report outlining the results of groundwater monitoring and analysis would be prepared on an annual basis and included in the Annual Environmental Management Report (AEMR).

9.6 EVALUATION AND REVIEW

Based on the available information, the proposed mining and associated activities of the Tomingley Gold Project are not expected to have any significant impact on the groundwater quality, groundwater dependent ecosystems or other registered users of groundwater located within the Study Area. The groundwater monitoring program provides a safeguard against any impacts that have not been anticipated in this assessment. If significant unforseen groundwater impacts are identified during routine monitoring mining operations at the Mine Site, the mining operation and/or monitoring program would be amended to prevent further degradation of groundwater resources.

The relevance and completeness of the groundwater monitoring program would be reviewed as part of each AEMR. If the recommended groundwater monitoring plan is not sufficient it may be necessary to expand the plan.

10 CONCLUSIONS

Based on the results of groundwater review and groundwater modelling undertaken as part of the nominated scope of works, The Impax Group concludes the following.

- Groundwater contained within shallow alluvium aquifers within the Study Area (in particular, the Gundong Creek aquifer) appear to be of good quality and suitable for all beneficial uses. Registered groundwater users within the Study Area use this water for "irrigation" and "stock and domestic" purposes. Groundwater does not occur uniformly across the shallow alluvium of the Study Area. Groundwater yields are typically less than 2L/s. The groundwater appears to exist in narrow sand seams created by the infilling of former creek beds, which are unlikely to interact with each other. As such, any loss of water from shallow alluvium at the Mine Site is not expected to impact on water levels within shallow alluvium aquifers located off the Mine Site. Notably, significant aquifers have not been identified in shallow alluvium at the Mine Site.
- The plains surrounding the Mine Site are typically underlain by andesitic volcanic rock of the Mingelo Volcanics and shale, siltstone and chert of the "Cotton Formation", "Mugincoble Chert" and "Mumbidgle Formation". Recorded groundwater yields in the fractured rock aquifers of these formations range from nil to 3L/s but are typically less than 1.5L/s. Available groundwater quality information indicates that groundwater within this system is saline. An assessment of potential beneficial uses of this water indicated that it may be acceptable as drinking water for sheep only. A search of the NSW registered groundwater bore data identified three deep bores surrounding the Mine Site, all of which have been abandoned. The absence of registered bores within this aquifer surrounding the Mine Site is indicative of the low yielding and poor quality nature of groundwater resources in the fractured rock.
- Dewatering of the open cuts would be likely to result in drawdown in the adjacent fractured rock aquifer(s) but would not impact on groundwater levels in the shallow alluvium located off the Mine Site.
- Based on numerical modelling it is estimated that groundwater would flow into the open cuts and underground working at a rate between 3L/s and 20L/s (94.6ML/yr to 630.7ML/yr. Qualitative assessment of available groundwater information suggests that this is a conservative estimate. It is likely that the actual groundwater inflow rate will be within the lower end of the range (e.g. 3 to10L/s).
- Total average rainfall entering the open cuts would be 7.4L/s (232.5ML/yr) which would also need to be removed (dewatered) to allow mining to proceed.
- It is possible that evaporation would be adequate to dewater the open cuts in most instances. During periods of heavy or sustained rainfall or low evaporation rates, however, it is likely that some mechanical pumping would be required to achieve the desired drawdown.
- Any water removed from the open cuts would be used on the Mine Site for dust suppression or would be allowed to evaporate from dewatering dams located adjacent to the open cuts.

- Modelling predicts that the cone of depression within the fractured rock aquifer will extend between 2,300 and 5,600m from the Wyoming One underground. The calculated extend of the cone of depression assumes that the aquifer is infinite in extent. Given the nature of fractured rock aquifers, this is unlikely to be the case. Standing water levels would not fully recover after mining is ceased as there will be ongoing loses of water from the open cuts due to evaporation.
- The underground and open cuts are expected to partially fill with water once mining is completed. The lower portion of the voids is expected to fill relatively quickly as the area of the lower portions of the open cuts are small compared to the area at ground level. It is difficult to predict the depth to which the water level within the final voids will rise. Calculations indicate that water levels would not rise above 207mAHD. However, with natural recharge and evaporation only this level would not be achieved within 50 years of the cessation of dewatering. Calculations of groundwater level recovery indicate that there will be 5 to 30m residual drawdown in the open cuts 50 years after cessation of dewatering operations. There may be up to 20m of residual drawdown within the open cuts 100 years after dewatering ceases.
- Residual drawdown within the open cuts would result in groundwater flow toward the voids. As such, any changes in groundwater chemistry or quality within the open cuts would not impact on groundwater quality within the surrounding fractured rock.
- Surface activities have the greatest potential to impact on groundwater quality. However, the absence of a significant groundwater resource in shallow alluvium at the Mine Site means there is little risk of mining processes impacting on groundwater quality. The underlying alluvium is predominantly clayey material with relatively low permeability, which would prevent any significant spread of potential groundwater quality impacts.
- Chemical and fuel storages at the Mine Site would be above ground and appropriately bunded to minimise potential for groundwater contamination to occur.
- The ore body and waste rock at the Mine Site is non-acid forming so the risk of acid drainage occurring from the waste rock emplacements, RSF or the open cuts is very low.
- Leachate from the residue may contain traces of heavy metals and cyanide from ore treatment process. The RSF has been designed, and would operate, in a manner which would prevent leachate entering groundwater aquifers.
- Groundwater dependent ecosystems were not identified on, or in the vicinity of the Mine Site. Mature trees are present along Gundong Creek and at other locations on and surrounding the Mine Site. Whilst these trees may use groundwater in the shallow alluvium they are not considered to be solely dependent on groundwater for their survival and therefore, are not considered to represent a groundwater dependent ecosystem.
- A groundwater monitoring plan would be implemented at the Mine Site once mining commences. The proposed plan would include regular monitoring of water levels and field parameters in the existing deep observation bores and shallow monitoring bores that would be installed around the perimeter of the RSF. The program also provides for annual sampling and analysis for a suite of standard water chemistry analytes.

11 REFERENCES

Agricultural and Resource Management Council of Australia, Australia and New Zealand Environment and Conservation Council, *Guidelines for Groundwater Protection in Australia*, September 1995.

Alkane Exploration Limited, *Peak Hill Gold Mine, Annual Environmental Management Report for 2005'*, February 2006*.*

Australian Government Department of Energy Tourism and Resources, *Cyanide Management*, Leading Practice Sustainable Development Program for the Mining Industry, May 2008

Australian Groundwater and Environmental Consultants Pty Ltd (2011), *"Review of Aquifer Permeability Testing, Groundwater Inflows and Impact on Groundwater Level for the Tomingley Gold Mine"*, Letter Report Dated 28 March 2011.

Australian and New Zealand Environment and Conservation Council, and Agriculture and Resource Management Council of Australia and New Zealand, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, 2000.

Australian Government, Bureau of Meteorology Website, *www.bom.gov.au, Weather Observation Data for Peak Hill Post Office and Wellington Research Centre*, viewed on 9 May 2009.

Coffey Geotechnics Pty Ltd, *Draft Preliminary Groundwater Investigation, Alkane Exploration Ltd, Tomingley*, NSW, August 2007.

Coffey Geotechnics Pty Ltd, *Groundwater Monitoring Results*, Facsimile correspondence between Andrew Fulton (Coffey) and Mike Sutherland (Alkane), Coffey Reference - GEOTLCOV22468AB, 8 April 2008.

Coffey Partners International Pty Ltd (1997), *Peak Hill Gold Mine Water Supply Development.*

Geological Survey of NSW, *Narromine Geological Series Sheet SI/55-03*, Published 1997.

Marinelli F and Niccoli W (2000), Simple Analytical Equations for Estimating Ground Water Inflow to a Mine Pit", Ground Water, Volume 38, No. 2, March-April 2000.

National Health and Medical Research Council and the Natural Resource Management Ministerial Council, *Australian Drinking Water Guidelines*, 2004.

NSW Government Spatial Information Exchange Website*, www.six.nsw.gov.au, 2007 Topographic Maps Series for NSW*, viewed on 9 May 2009.

NSW Department of Water and Energy, Natural Resource Atlas Website, *www.nratlas.nsw.gov.au, Registered Groundwater Bore Database*, viewed on 9 May 2009.
NSW Department of Land and Water Conservation, *NSW State Groundwater Dependent Ecosystems Policy*, April 2002.

NSW Department of Environment and Conservation, *Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales*, September 2003.

NSW Department of Land and Water Conservation (1997), *NSW State Groundwater Policy and Framework Document.*

NSW Department of Land and Water Conservation (1997), *NSW State Groundwater Quantity Protection Policy*.

NSW Department of Land and Water Conservation (1997), *NSW State Groundwater Quality Protection Policy.*

NSW Department of Land and Water Conservation (1997), *NSW State Groundwater Dependent Ecosystems Policy*.

NSW Department of Land and Water Conservation (1998), *NSW State Groundwater Quantity Protection Policy.*

NSW Department of Land and Water Conservation (1998), *NSW State Groundwater Quality Protection Policy.*

Alkane Resources Limited (2005), *Peak Hill Gold Mine, Annual Environmental Management Report for 2005.*

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APPENDICES

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Appendix 1	**Summary of Registered Groundwater Bore Details**
Appendix 2	**Registered Groundwater Bore Work Summary Forms**
Appendix 3	**Special Supplement to the Water Act 1912, Groundwater Licence Embargo**
Appendix 4	**Hydrogeological Assessment, “Woodlands”, Narromine NSW**
Appendix 5	**Recovery Charts**
Appendix 6	**Australasian Groundwater & Environmental Consultants Groundwater Modelling Report dated 28 March 2011**

Note: Appendices 1 to 5 are only provided on the Project CD

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