1. ABSTRACT

Western Mining Corporation (WMC) Fertilisers' Phosphate Hill project in north-west Queensland is a combined open cut mine and phosphoric acid, ammonia and fertiliser manufacturing plant. The area has a mean annual rainfall of about 360 mm/year. The water demand for the site is more than 6000 M L/year. As it is not possible to supply the project's water requirement from surface water harvesting, all water must be drawn from groundwater.

The project lease boundary encompasses a fault bounded, Cambrian sedimentary basin that comprises three major formations of marine origin. The intermediate, Beetle Creek Formation, hosts both the orebody and the aquifer. Hydrogeological assessment of the Beetle Creek Formation commenced with early feasibility studies of the Phosphate Project in the 1970s. There have been several phases of interest in the Project, which culminated in the current operations in 1999. Precise management of the plant water supply and the mine's dewatering are essential for the operation. Subtle variations in the chemistry of groundwater supplied to the plant have implications for industrial processes within the plant and need to be closely monitored.

This paper describes the hydrogeology of the Beetle Creek Formation aquifer and the implications for optimal groundwater management are considered.

2. THE PROJECT

Phosphate Hill is located at the site of a geological phosphate deposit approximately 200km South of Mount Isa. The Phosphate Hill project is a world class chemical processing plant twinned with a phosphate mine to produce high-analysis fertiliser.

Phosphate bearing ore is mined in open pits using excavators and transported in trucks. Other major raw materials are sulphuric acid and nitrogen. Sulphur dioxide emissions from the Mount Isa Mines' copper smelter are converted to sulphuric acid and transported to the Phosphate Hill by rail. Nitrogen, a by-product of the petrochemical industry, is piped to the plant for conversion to Ammonia.

At the processing plant, crushed ore is reacted with sulphuric acid to form phosphoric acid which, in turn, is reacted with ammonia, producing high-analysis fertiliser for agricultural use. The fertiliser is transported to Townsville by rail for export or national distribution.

By-products from the process include gypsum, water, and minor amounts of hydrofluoric acid.

The area is remote with a relatively dry climate thus the most effective water supply is sourced from groundwater. Five producing bores supply the processing plant, associated light industries and potable requirements. The production bores will also form part of a future dewatering program for the mining area.

3. CLIMATE and PHYSIOGRAPHY

Phosphate Hill is located in the tropical savannah grasslands of north-west Queensland. The annual average rainfall is about 360 mm, but annual totals vary greatly from year to year, depending on the magnitude of the tropical influence during the hotter months of any given year. Annual average pan evaporation exceeds 3000 mm.
With the exception of small rounded hills of limited relief (such as Phosphate Hill), the topography is relatively flat being an alluvial plain between mesas (such as Mount Murray and Blucks Bluff) situated east and west of the mine area. Stream channels are typically incised approximately one to two metres into the alluvial plain. The banks of drainage channels are dominantly sub-vertical, with few areas having unconfined sub-horizontal banks. Flow events in the three major streams that traverse the site (Galah, Dead Horse and Kolar) are typically short lived (hours to days) with water remaining within alluvium below the streambed for extended periods. Small pools may remain in the deeper sections of the channel for several weeks following flow events, recharged by water stored in the stream-bed alluvium.

4. GEOLOGY

The Phosphate Hill deposit is part of the Duchess Embayment which comprises a sequence of marine sediments of Cambrian age. These sediments are obscured by a superficial covering of alluvium, which is underlain by the Inca Formation (IF), Beetle Creek Formation (BCF) and the stratigraphically lower Thorntonia Limestone. The relatively impermeable Mount Birnie Beds form the local basement. The sedimentary succession overlying the hydrogeological basement is generally less than 150m thick (Rockwater, 1990).

The regional geology of the Phosphate Hill mining area is shown in Figure 2. A summary of the geological units and their hydrogeological properties is provided in Table 1. The Cambrian, marine sedimentary succession (Figure 2) has been described by Russell & Trueman (1971), Crase (1979), Rogers & Crase (1979), Rogers & Associates (1991). These rocks were deposited in a shallow to moderate depth marine shelf environment and contain a significant proportion of carbonate minerals. The carbonate minerals give rise to characteristic, weathered rock-textures and groundwater chemistry.

The geological formations within the embayment have been subjected to periods of structural deformation, including extension - forming faults, and compression - forming open folds. The resulting faults now bound the embayment in the east and west, they limit of the aquifer extent and thus have some control over groundwater flow.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Code</th>
<th>Lithology</th>
<th>Aquifer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvium (Quaternary)</td>
<td>Qa</td>
<td>Sand, gravel and silt. Generally unconsolidated in drainage channels (as sand and gravel), but semi-consolidated on plain lands.</td>
<td>Localised</td>
</tr>
<tr>
<td>Monastery Creek Phosphorite Member</td>
<td>MCM</td>
<td>Upper unit of the Beetle Ck Formation, target ore body for mining operations. Phosphatic siltstone varying in thickness to 60-80m. Mined sequence thickness is 8-14m.</td>
<td>Aquifer</td>
</tr>
<tr>
<td>Beetle Creek Formation</td>
<td>BCF</td>
<td>Fossiferous siltstone up to 48.5m thick (Rogers and Crase, 1979). Siliceous and calcareous siltstones, with phosphatic cherts and dolomites in calcareous facies. Bedding plane and sub-vertical jointing (Rockwater, 1996).</td>
<td>Primary Aquifer</td>
</tr>
</tbody>
</table>
5. **GROUNDWATER USE**

In the past, limited quantities of groundwater have been extracted, for potable supplies, mining use (dust suppression) and pit dewatering.

In 1999, PPK Environment & Infrastructure Pty Ltd constructed five large diameter production bores within 1000m of the fertiliser plant. The new borefield was designed and equipped to produce a maximum of 7000ML/year to supply mine water requirements as well as the (then) expected demand from the processing plant and power station. The new bore depths are from 97.5 to 116m, they are equipped with Grundfos SP215-6 submersible electric pumps. Bore construction includes a 375mm diameter steel cased pump chamber and screened with telescoped 300mm diameter stainless steel screens from the top of the MCPM.

6. **CONCEPTUAL HYDROGEOLOGY MODEL**

6.1 **Type of Aquifer**

The Inca Formation has generally been considered to be a relatively impermeable layer overlying the BCF. This results in the BCF being interpreted as a confined aquifer.

Data supporting the confined aquifer model:

- Piezometric head fluctuations caused by earth tides, (eg p54, Passmore 1975 and p11, Rockwater 1995);
- A relatively quick response to pumping at distant observation bores (p13 Rockwater, 1985).

Data supporting an unconfined aquifer:

- $S$ values estimated from the pumping tests, in all but one case, are higher than what might be expected for a confined aquifer thus suggest an unconfined aquifer, (refer to Table 6, Rockwater 1996). In addition, $S$ values seem too high for what is also interpreted to be a fracture-type aquifer system.
- Most measured drawdowns during pumping tests appear to be above the base of the IF.

Pumping data also indicates that leaky (semi-confined) conditions are evident, eg Bore S8, observation bore S8B (Passmore, 1975; Rockwater, 1997, 1985). Leaky aquifer conditions may be more widespread than suggested by Rockwater. This would affect estimates of aquifer storativity ($S$).

The extent of (un)confined conditions may also be affected by the geological structures in the area, in particular the interpreted broad fold patterns and erosion, which has locally exposed anticlinal windows of the BCF (Figure 2).

Based on the data available, the aquifer is likely to vary locally between confined and unconfined. Long term abstraction is expected to produce some vertical leakage from the IF particularly where it thins near the basin margins and near anticlinal structures (Figure 1). (PPK, March 1998)
6.2 Boundary Conditions

The faulted boundary conditions in the south-east of the project area are of particular interest, (Figure 2). Similar conditions are evident in the Lower Burdekin River catchment where similar structures have a significant effect on regional groundwater flows.

Groundwater flow is toward the south-east corner of the basin. Basement faulting is likely to cause this boundary to act as a weir in this area (Figure 2), such that groundwater may flow out of the basin but won’t flow back in when water levels are lowered. Further monitoring of the hydrographic response in this area is required to establish their hydrological character.

The Mehaffey fault forms the eastern limit of the extent of the BCF and is indicated to form a major barrier to groundwater flow. Typically, the difference in standing water level (SWL) across the Mehaffey Fault averages 20m.

Figure 2: Regional geology and cross section of the Phosphate Hill Mining area.

6.3 Transmissivity

Testing has indicated that the BCF transmissivity (T) values are typically very high. The very high transmissivity and partly unconfined response to pumping tests has limited the magnitude of the stress that can be applied to the system under test conditions. The transmissivity of the overlying Inca Formation or the underlying Mount Birnie Beds is very much lower but may contribute significant groundwater over the long term.

The BCF varies from a siliceous to calcareous facies and also varies in thickness across the embayment. Rockwater indicate that the calcareous facies of the BCF has a lower relative permeability in comparison to
the siliceous facies. This would be consistent with the drilling observation that aquifer flow is mainly controlled by secondary structures (e.g. fractures, faults, etc) rather than by primary porosity of the formation. (PPK, March 1998).

6.4 Storativity

Due to the very high aquifer transmissivity, relatively small drawdown has been induced during a number of pumping tests, some lasting up to 32 days. The 32-day test showed a localised unconfined response, with the more widespread drawdown being that of a confined aquifer. The future long-term drawdown trends will be controlled primarily by unconfined aquifer storage characteristics, so that better definition of this parameter on a regional basis is a priority for long term management.

6.5 Recharge

Recharge to the aquifer is thought to occur where the stream alluvium overlies sub-cropping Beetle Creek Formation. In these areas direct recharge to the aquifer occurs from water stored within the stream bed gravels. Other sources of recharge occur through direct infiltration in the three open pits as well as along areas of Beetle Creek Formation that crops out in the western margin of the lease area and around topographic features such as Mount Murray.

The preliminary estimate of steady state recharge used in the numerical flow model was 800 ML/year (Rockwater, 1996). Recharge estimates using chloride analyses (rainfall values from Blackburn and McLeod, 1983) suggest recharge to the aquifer is between 4 and 11 mm per year, supplying approximately 440M L/year to the aquifer, assuming recharge occurs over an area of 40 km² (PPK, May 2000).

These estimates will be improved by analysis of detailed stream-flow gauging and ground water level responses. The distribution and rates of groundwater recharge can be expected to change with the influence of mining and the stream bed diversions that are part of the mine plan.

A summary of aquifer properties is presented in Table 2.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storativity</td>
<td>0.0001 (confined)</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>0.05 to 0.1 (unconfined)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Rockwater, 1990)</td>
<td></td>
</tr>
<tr>
<td>Transmissivity</td>
<td>1 to 2700 (Rockwater, 1990)</td>
<td>m²/day</td>
</tr>
<tr>
<td>Recharge</td>
<td>4 to 11 (PPK, April 2000)</td>
<td>mm/y</td>
</tr>
<tr>
<td>Mean thickness</td>
<td>24.7 (Rockwater, 1985)</td>
<td>m</td>
</tr>
</tbody>
</table>

7. CURRENT WATER MANAGEMENT

Water use is managed by a dual reticulation system. Very low chloride water from the southern bores (directly down-gradient from the main natural recharge area) is used in the power station and ammonia
plant. The northern bores supply water for general use. This water is of potable quality but does not meet the stringent requirements of the power station and ammonia plant.

7.1 MANAGEMENT PRIORITIES

- The capacity of the southern low chloride water supply system is to be expanded into the centre of the defined zone of low chloride water
- Detailed surface hydrology and hydrogeological monitoring is ongoing
- A regional programme of porosity and permeability evaluation will be undertaken using geophysical and drill-hole techniques
- The aquifer parameter data will be amalgamated with monitoring data in the calibration of an upgraded numerical flow model
- The predicted drawdown, from abstraction for plant water requirements, will be co-ordinated with the mine plan and mine dewatering requirements.

8. REFERENCES


PPK Environment & Infrastructure, May 2000, Surface & Groundwater Monitoring – Phosphate Hill – April 2000 Site Visit, Brisbane, QLD.


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PPK Environment & Infrastructure, September 1999, Phosphate Hill: Groundwater Quality Investigation – September 1999, Brisbane, QLD.

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