Appendix 8

Review of Groundwater Supply Prospects

Prepared by: Environmental Earth Sciences

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Note: A colour version of this Appendix is available on the Project CD

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ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW

29 August 2013

RW Corkery & Co Pty Limited
62 Hill Street
Orange NSW 2800

Attention: **Alex Irwin**
Senior Environmental Consultant

Dear Alex

545 – DZP – Groundwater Assessment: desktop review of groundwater supply prospects within the Dubbo Zirconia Project (DZP) Site

1.0 Objective

The objective of this correspondence is to provide a pre-feasibility desktop evaluation of the potential to extract groundwater for water supply purposes from the Dubbo Zirconia Project (DZP) Site and surrounding land owned by Australian Zirconia Limited (AZL). This evaluation is based on a desired supply of 1 giga-litre per year (GL/a) from each of the underlying alluvial sediment and fractured bedrock aquifers. For context, 1 GL/a is equivalent to a continuous long-term pumping rate of 32 litres per second (L/sec).

2.0 Background

Two primary aquifer systems have been identified beneath the footprint of the DZP Site and were described in the Groundwater Assessment prepared by Environmental Earth Sciences, as follows:

- Jurassic age alkaline volcanics that have intruded with / extruded upon Triassic age sedimentary rocks of the Gunnedah Basin; overlain by
- Cainozoic age unconsolidated alluvial / colluvial sediments along the primary ephemeral creek systems that drain the catchments associated with the DZP Site.

Based on research into regional registered and unregistered water supply users in the catchment, the unconsolidated sediments are known to be at least partly exploited for water supply (stock and domestic, and potential irrigation use) on and surrounding the DZP Site. The fractured rock aquifer identified in the Jurassic basalts is not known to be currently exploited for any use other than stock watering supplied by windmills or solar powered pumps within the DZP Site footprint.

Localised yields (determined by air-lifting during bore installation) of up to 6 L/sec in fractured rock and 9 L/sec in alluvium have been reported.

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3.0 Bedrock aquifer – potential yields and aquifer properties

3.1 Summary based on existing information

- Yields from air lifting of 5-6 L/s have been reported at two locations, GW064727 and GW803000 in different formations, limestone and shale, respectively (from the NOW Form 1a's). (Note that the water bearing zone in GW803000 is reported to be shale, however, we believe the yield of 6 L/s reported from this bore is more likely to be from the basalt underlying the shale than from the shale as reported). These locations are both within the DZP Site, approximately 2.5km apart and on opposite sides of a groundwater divide. Therefore, they are interpreted to be in separate aquifers.
- The above is evidence of a combined yield more than 10 L/s at two locations in the bedrock alone. There are other areas where bedrock with high fracture permeability is likely to be present. Therefore, further groundwater exploration is considered likely to produce similar yields in other areas.
- In the north-eastern part of the DZP Site in the vicinity of bore DWB023, the groundwater level is considerably lower than the lowest part of the topography. This suggests that the basalt described in the borehole log of bore DWB023 not only has a high transmissivity but is laterally extensive. This would be an example of an area where further groundwater exploration would be warranted.
- From the air-lifting yields, the bedrock transmissivity has been interpreted to be at least 10 m^2/day and is likely to be considerably greater at the two locations described above.

3.2 Lineament survey

Geological maps and an aerial photograph were studied as part of this desktop review. The following physical and geological features were noted.

- Alluvium is present along Paddys Creek and Wambangalang Creek, with the confluence of these two creeks occurring at the north-western edge of the DZP Site.
- Paddys Creek to the west of the DZP Site is underlain by bedrock consisting of the Silurian aged Toongi Group (mixed sedimentary and volcanics). The creek follows the geological boundary between the older Silurian aged Toongi Group and the younger Devonian aged Gregra Group (sediments and volcanics) which is present on the western edge of the DZP Site.
- Structurally, an anticline (a folding of rock) is interpreted to be present to the south-west of the DZP Site, within the Silurian aged rocks, with bedding planes dipping outward. A system of faults is also present in the area (NE-SW oriented), likely to be associated with later intrusion of the Tertiary aged volcanics. It is expected that localised faults oriented NW-SE would also be generated from the intrusion of the Tertiary aged volcanics, however, these have not been previously mapped. Paddys Creek appears to be in part controlled by faults and shears (NE-SW and NW-SE oriented) associated with the anticline and the intrusive Tertiary aged volcanics.
- Wambangalang Creek to the north-west of the DZP Site is oriented north-east to south-west and also appears to be controlled in part by a major fault in the same orientation.
- Topography is dominated by outliers of Tertiary aged volcanics (topographically high areas), and creeks (topographically low areas).

It is possible that Paddys Creek and Wambangalang Creek formed along fault plains. These are areas that have been sheared and fractured and would be prone to weathering more so than other parts of the rock formations.

In addition, the bedrock along the hinge line of the anticline (where the limbs of the fold meet) is also expected to be highly fractured.

The fault line along which Wambangalang Creek runs, and the hinge line and fault lines which control Paddys Creek, coincide with the confluence of the two creeks. Groundwater can be expected to move through the fractured and sheared zones at a higher rate than elsewhere in the aquifer, and may be in hydraulic connectivity with the overlying alluvium. In addition, it would be expected that these creeks have a high potential to be providing enhanced recharge to the underlying fractured rock aquifer, in addition to the aquifer in the alluvium.

For the above reasons, the confluence of the creeks would therefore be the area closest to the DZP Site most likely to provide higher yielding extraction rates, from both the alluvial and bedrock aquifers.

4.0 Alluvial aquifer – potential yields and aquifer properties

The following is a summary based on existing information:

- Well TWB is located just outside the DZP SITE (within 200 m of the boundary), but on land that the Applicant has an opportunity to purchase on a "call" option. Environmental Earth Sciences pumped this well for 2.5 hours, measured the recovery of the water level, and evaluated the transmissivity from the water level recovery data. The well was interpreted to be constructed in sandy alluvium. From this test, the transmissivity of the alluvium was interpreted to be 50 m^2/day. Assuming an available drawdown of 5-10 m (there is 10 m of standing water in this well), the potential yield from a well at this location in this aquifer would be approximately 2-3 L/s. If the sandy alluvium has a significantly greater saturated thickness than 10 m, the potential yield in this area can be expected to be greater.
- Although well TWB is interpreted from its relatively high yield and transmissivity to be installed in sandy alluvium, there is no known borehole log for this well and sandy alluvium has not been encountered in any borehole drilled on site to date. Therefore, sandy alluvium is considered most likely to be encountered in close proximity to Paddys Creek or Wambangalang Creek. The DZP Site extends closest to the creeks in the vicinity of the proposed DZP Site Administration Area.
- A number of off-site registered (and some unregistered) bores and wells exist at the intersection of Eulandool and The Springs Roads (known as Cockleshell Corner) beyond the south-western boundary of the DZP Site near Paddys Creek. One of these (GW802169) is licensed for irrigation use and has a reported yield of 9 L/sec (measured by air lift during installation). It was installed in 2004 into "gravel and shattered rock" from 4.0 to 6.0 m depth, but has never been equipped for use. An adjacent bore (GW044705) is installed into "slate water supply" rock from 10.4 m to 22.4 m depth and yielded 2 L/sec.

5.0 Consideration of Groundwater Storage and Recharge Rate in the Vicinity of the DZP Site

The total area of the DZP Site is approximately 2,860 ha, while the total area owned by AZL including along Wambangalang and Paddys Creeks is approximately 3,500 ha. Assuming a saturated thickness of 30 m, and a bedrock specific yield of 0.01 (1%), the total volume of groundwater stored in the area would be close to 10 GL. This does not take into account the alluvial aquifer which exists just outside the DZP Site and partly beneath land that the Applicant has under "call" contract (i.e. land owned by AZL).

In reality, the alluvial aquifer would have a specific yield more than an order of magnitude greater than the bedrock aquifer. Therefore, the total combined volume of groundwater stored within the DZP Site and in the alluvial aquifer adjacent to the DZP Site can be expected to be tens of GL. This does not however mean that it would be possible to extract at rates of tens of GL/a.

If 2% of the average annual rainfall becomes groundwater recharge, the average annual recharge rate within the DZP Site and surrounding AZL land footprint would be 11 mm/yr. Over an area of 2,860 ha (DZP Site), this would be equivalent to approximately 0.33 GL/yr, and over an area of 3,500 ha (including surrounding AZL owned land), approximately 0.40 GL/yr recharge. This does not consider the recharge from the major streams.

As the streams are ephemeral, they are likely to be a significant source of recharge to the underlying alluvial aquifers. Therefore, the total combined recharge rate within the DZP Site (primarily located on fractured rock) and into the alluvial aquifer adjacent to the DZP Site (i.e. beneath land partly owned by AZL) is considered likely to be close to 1 GL/a.

6.0 Summary and Recommendations

From the information currently available, we consider it likely that the sustainable rate of groundwater extraction from the combined bedrock and alluvial aquifers within and in the vicinity of the DZP Site would be several hundred ML/a. It may be possible to extract a combined total of up to 1 GL/a.

We recommend that the feasibility be confirmed as follows:

1. Additional groundwater exploration is recommended initially, particularly in areas of previously reported high yields and in other areas where high yields are considered likely, including areas to the west of the DZP Site where an alluvial aquifer overlies a fractured rock aquifer associated with geological faulting. We recommend that these areas include but not be limited to:
   a) The vicinity of bore DWB023 in the north-eastern part of the DZP Site (see Figure 8 of the Groundwater Assessment);
   b) The vicinity of the proposed DZP Site Administration Area (see Figure 8 of the Groundwater Assessment), including to the north, west and south of this area.
2. Perform aquifer testing in both bedrock and alluvium areas. Aquifer testing should take place either at, or in close proximity to, registered bores GW064727 and GW803000. This would include the installation of supplementary observation bores at those locations to measure drawdown during aquifer testing.

The extraction of groundwater has the potential to cause impacts to groundwater resources, other groundwater users also using those resources, and surface water systems and associated ecosystems which are dependent on groundwater. NOW would require a written assessment of the potential impacts of the proposed groundwater extraction, similar to the assessment of other project components undertaken in the Groundwater Assessment. The results of the aquifer testing would be used to evaluate the potential impacts in addition to the feasibility of the groundwater extraction at the planned rates.

At this pre-feasibility stage, the potential for impacts caused by groundwater extraction is considered likely to be greater in the alluvium than in bedrock. However, this should not preclude the possibility of extracting groundwater from the alluvium. For example, should impacts be predicted to other groundwater users along Wambangalang Creek, an option would be replacement of the water supply of other groundwater users who may be impacted.

7.0 Limitations

Preliminary estimates of potential aquifer yields in this document are based primarily on the reported yields on NOW Form 1A's and short-term testing of Well TWB. They would require confirmation by further testing in the field.

Should you have any further queries, please contact us on (07) 3852 6666.

On behalf of
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