APPENDIX 7

TECHNICAL DETAILS OF BORROW AREAS AND PROPOSED TECHNIQUES FOR CONSTRUCTION OF GROUND WATER FLOW RETARDERS

by

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1. BORROW AREA FOR CORE MATERIAL

Core material for the dam has been located some 6.5 kilometres from the dam to the north. The material occurs in the shadow of schist formations which have weathered and deposited schistose soils at their base. These materials are found within the gorge area as this develops off the desert plains.

The deposits tend to be ridges of fine grained soil comprising slightly clayey, sandy silt which, as laboratory tests have shown, compacts to a low permeability fill. The deposits are of such geometry that it will generally be possible to excavate and remove the material without creating a crater-like borrow pit since it will be feasible to excavate on grade into the ridges. The ridges are within drainage zones and will rapidly rehabilitate after completion of construction and appropriate re-contouring of the area.

Haulage equipment will need to travel up and down the gorge in order to transport the soil. There will be an impact during the transport phase of construction through the generation of dust and the disturbance of sands and soils in the gorge base. It is proposed to mitigate this impact by restricting the haulage vehicles to specific roadways which will be rehabilitated after completion of construction to return them to a state similar to the adjacent undisturbed areas. Since the haul routes are in the gorge the disturbed areas will rehabilitate relatively quickly after the first flow down the gorge.

2. DESCRIPTION OF AQUIFER RETARDERS

Recharge water that is not abstracted from the aquifer by the lower-most abstraction well is lost to Rössing. At the same time, the maximum rate at which Rössing is able to utilise abstracted water is limited to 7,000 m^3/day due to production limitations. Modelling of the operation of the recharge system has indicated that if it is practical to detain the water within the aquifer without the water rising to surface and being evaporated, the net efficiency of the recharge scheme is considerably increased. Out of this realisation has emerged the concept of aquifer "retarders" whose purpose may be described as follows :

- To reduce the effective gradient within the aquifer. This will have the effect of slowing the flow of water and therefore of increasing the average water level within the aquifer

- To ensure that the rise in water table in the aquifer is not sufficient to bring the water to surface

The above objectives could most simply be attained by constructing an impervious barrier across the river such that the crest of the barrier remains below surface and the water builds up behind the barrier and "spills" over the crest while at all times remaining below the surface of the aquifer. The problem with this proposal is that during low flow times it would not be possible to ensure that base flow in the aquifer is maintained.

To overcome the above problem it is proposed to construct a "leaky" barrier or, more appropriately, a "retarder" as follows :

- Locations for the retarders are selected in such a way that the natural geology provides maximum assistance. This means that as far as possible the retarders should be constructed at locations where dykes or marble bands cross the river and create sub-surface sills or "lips". A number of these features have been identified. The benefit of choosing these locations is that the depth of aquifer treatment to create a retarder will be lower.

- Piezometers are installed either side of the proposed retarder location. It is envisaged that on each section a number of piezometers will be installed across the river. The purpose of the piezometers will be to determine water levels and assist in the design and installation of the retarders.

- At the deepest point across the river ie that location at which the depth of sand and gravel is a maximum as determined from geophysics, a well will be drilled and pump tested. The responses of the piezometers to both draw-down and rise will be monitored and used to develop a hydrogeological model of the section on computer using established software. Using this information the spacing for primary grout holes will be deternined.

- Further holes will be drilled at the primary grout hole locations and into all holes a bentonite grout modified by the addition of cement in order to modify the penetration characteristics of the grout will be pumped between packers. The grout would be pumped under pressure and would ingress into the sand around the borehole creating a zone of lower aquifer permeability. The spacing of the primary holes will be such that the bentonite treated zones will not intersect ie there will be zones of unaltered aquifer sand and gravel between the bentonite grouted zones. The effect of this treatment will be to reduce the cross-sectional area of flow for the aquifer. This will result in a rise in the water table on the upstream side of the aquifer and a lowering of the water table on the downstream side of the aquifer. The changes in the water levels in the aquifers will be monitored using the piezometers. The piezometric information will be used to calibrate the hydrogeological computer model.

- The computer model will be used to evaluate the flow characteristics of the aquifer under varying recharge states so as to verify that during low flow conditions base flow is maintained and whether, during maximum recharge conditions, the water table remains below surface. Since the primary holes will have been spaced far enough apart to ensure that base flow is maintained it is likely to be necessary to locate secondary grout holes which would be installed between the primary holes so as to further retard the water while at the same time ensuring the base flow and maximum water table criteria are met.

- Installation of the secondary holes would proceed in conjunction with continuous piezometer monitoring and re-calibration of the computer model and would be stopped at a stage when the optimum conditions are achieved.

From the above step-wise process it is evident that :

- Each retarder is developed on a site specific basis

- The retarder development is carried out systematically on an observational basis

If at any stage it emerges that too much grout has been injectected it will be possible to excavate the grout out using excavation equipment and indeed this is envisaged as being the measure to be adopted after closure of the mine in order to return the aquifer as close to its original state as practical. However, as is evident from the stepped installation process the intention is to carry out only sufficient grouting as to achieve the stated objectives and to verify that this is the case at every stage through monitoring of response and calibration of a site-specific computer model.

Figure 1, below, illustrates a plan, longitudinal section and cross-section through a retarder on completion of installation.

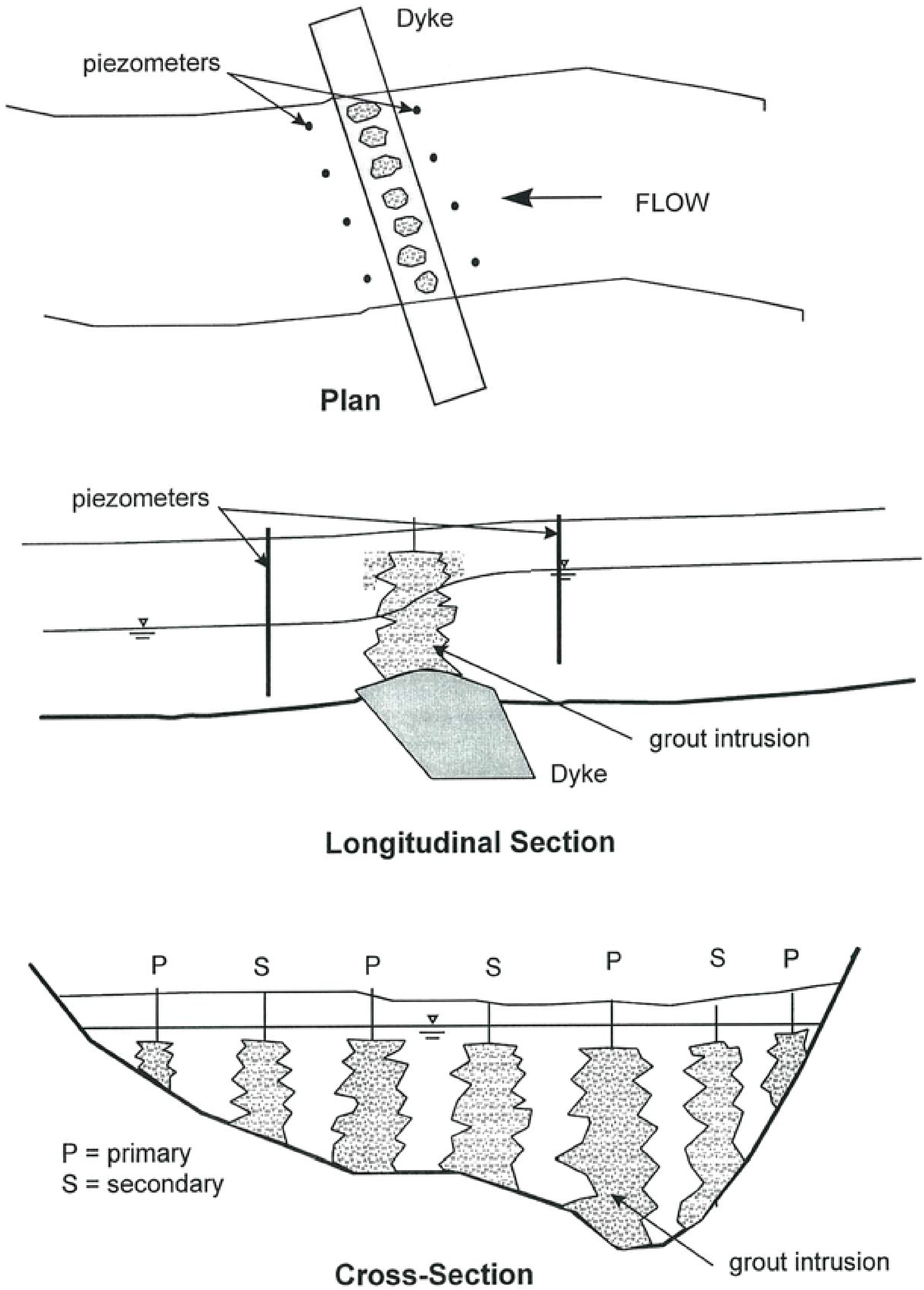

FIGURE 1. PROPOSED PLAN AND SECTIONS THROUGH RETARDERS