Appendix 9.

O'kane (2015d) *Rum Jungle Dyson's Backfilled Pit Cover Systems Modelling.* Memorandum from Allen, G. Environmental Engineer to O'Kane Consultants Pty. Ltd. November 2015.

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Memorandum

To: André Kemp

From: Gillian Allen, Environmental Engineer

Cc: Bonnie Dobchuk, Dave Christensen – O'Kane Consultants

Our ref: 871/6

Date: 2 November 2015

Re: **Rum Jungle Dyson's Backfilled Pit Cover System Modelling**

As part of the Northern Territory Government Department of Mines and Energy (NT DME) Rum Jungle project, O'Kane Consultants (OKC) is developing a conceptual cover system design for various landforms including Dyson's backfilled pit.

The objective of this portion of the overall project is to develop an understanding of the current groundwater and seepage conditions at Dyson's backfilled pit and to examine the potential impacts of a new cover system and landform at Dyson's backfilled pit. The current conditions were examined using a SEEP/W analysis. Following characterisation of current hydrological conditions, a SEEP/W model was completed to estimate impacts of a reduction in net percolation to the tailings.

Conceptual Model of Current Conditions

It is currently conceptualised that Dyson's backfilled pit experiences higher groundwater recharge rates (net percolation) compared to surrounding undisturbed ground. It is understood that Dyson's backfilled pit is located near a local topographic high that is assumed to be a groundwater divide. Groundwater is assumed to flow from north-west to south-east through generally saturated tailings inside the backfilled pit. It is assumed that a unidirectional gradient exists and that no back flow occurs to the north-west due to mounding, although groundwater is assumed to be elevated in the backfilled tailings. It is thought that there is up-gradient flow through the tailings as part of the regional groundwater regime and that the pit walls do not act as no-flow boundaries. Previous estimates completed by RGC estimate that groundwater moves through Dyson's pit at a rate of 0.5 L/s to 1.0 L/s. It is also assumed that although groundwater levels within Dyson's backfilled pit change seasonally, that there is continuous seepage occurring at the outlet of the rock blanket (shown in Figure 2). The rock blanket is estimated to be 1 m thick.

Development of Model Cross-Section

A two-dimensional (2-D) cross section through piezometer DO21 (Figure 1) was chosen to represent Dyson's backfilled pit. The location of the rock blanket was estimated based on borehole logs from the installation of DO21. A water table was initially set to 76.8 masl at DO21 (red line in Figure 2). This corresponds with the monthly average piezometric level observed at DO21 in November. The water table was initially assumed to follow the slope of topography.

A monthly net percolation function was applied to the top of the rock blanket shown in Figure 2 (blue arrows). A four year transient analysis was then completed, loosely calibrating the location of the water table to the observed piezometric levels at DO21 (Figure 3).

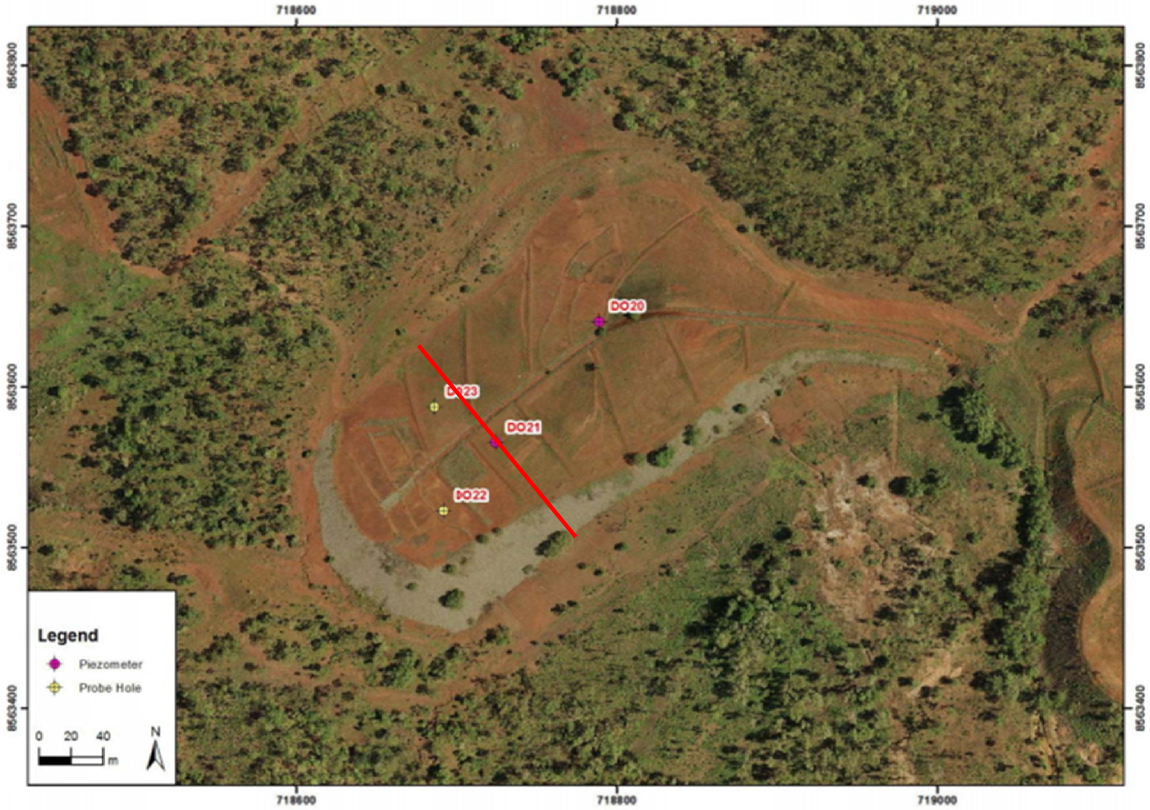

Figure 1: Aerial photo of Dyson's backfilled pit with approximate location of cross section shown.

SRK Consulting. 2012. Geochemical Characterisation of Waste at the Former Rum Jungle Mine Site. Prepared for the Department of Resources Northern Territory Government September 2012.

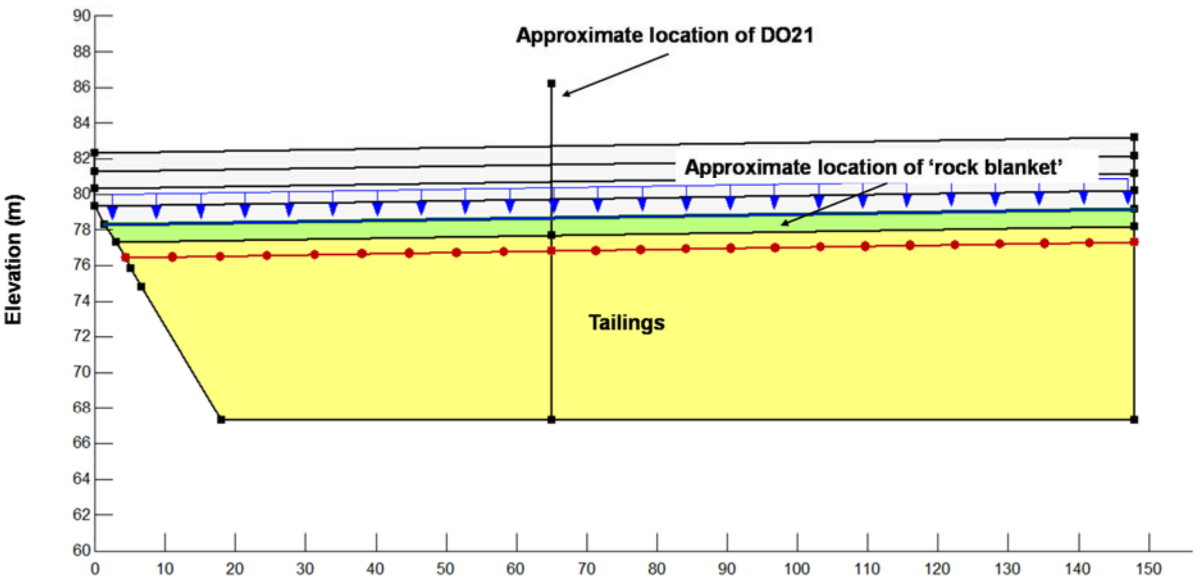

Figure 2: Idealized cross-section of Dyson's backfilled pit.

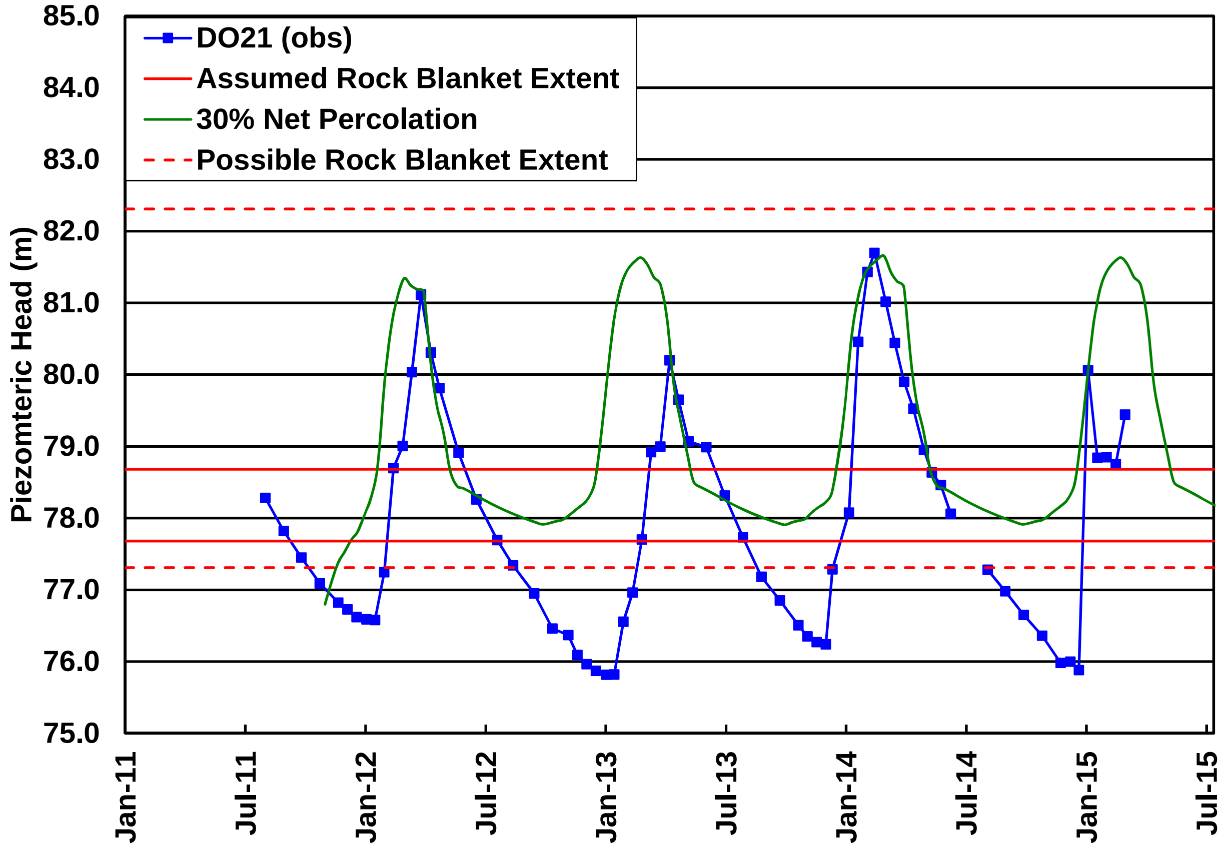

Figure 3: Results of calibration to current conditions.

Results of Initial Model Calibration

The green line shown in Figure 3 represents the SEEP/W predicted water table level at DO21 given a net percolation rate of 30% of average annual rainfall. It was assumed that no net percolation occurs in the dry months of May to September. The net percolation function applied is shown in Table 1. The piezometric head at DO21 predicted by the model, never dips below the base elevation of the assumed location of the 1 m rock blanket. It is possible that the assumed location of the rock blanket is incorrect or that the boundary between tailings and the rock blanket across the footprint of Dyson's pit is not as well defined as the idealized model depicts. The location of the water table is also controlled by the seepage face defined in the model. It is currently assumed that water exits Dyson's pit primarily and continuously through the rock blanket. This creates a bound on the minimum piezometric heads at DO21 attainable by the SEEP/W model for a positive gradient to be maintained. It is possible that seepage exits Dyson's backfilled pit through other 'drains' at lower elevation than the rock blanket or at three dimensional (3-D) locations not represented by a 2-D cross-section. The timing and rate of net percolation may also be more varied than the values assumed in the model. Longer periods with no net percolation could potentially allow the water table to drop beyond what is currently predicted in the model.

The results shown in Figure 3 do not include any up-gradient inflows. The flow rates suggested by RGC (0.5 L/s to 1.0 L/s) were initially included within the model as up gradient flow. However, these flow values are 'global' flow values which are difficult to properly apportion to a 2-D cross section. It was found that this applied up gradient flow dwarfed the magnitude of applied cover system surface flux producing unreasonable results. As a result, the guideline values provided by RGC were not utilized in estimating current conditions.

Table 1: Climatic inputs to the current conditions SEEP/W model.

Month	Monthly Rainfall (mm/month)	30% Net Percolation (mm/month)
November	133.8	41.6
December	245.6	75.1
January	327.2	99.6
February	316.0	96.3
March	268.6	82.0
April	75.2	24.0
May	12.6	0.0
June	2.1	0.0
July	1.0	0.0
August	3.7	0.0
September	14.8	0.0
October	58.3	19.0
Annual	*1,459.2*	*437.8*

Predicted Conditions

A SEEP/W model was completed to estimate impacts of a reduction in net percolation to the tailings. It was found that reduction in net percolation to 10% of average annual rainfall (Table 2) will ensure that the water table remains within the 1 m rock drainage blanket or in the upper reaches of the tailings profile ensuring the capillary fringe reaches the tailings interface (Figure 4).

Table 2: Climatic inputs to the SEEP/W model.

Month	Monthly Rainfall (mm/month)	10% Net Percolation (mm/month)
November	133.8	13.9
December	245.6	25.0
January	327.2	33.2
February	316.0	32.1
March	268.6	27.3
April	75.2	8.0
May	12.6	0.0
June	2.1	0.0
July	1.0	0.0
August	3.7	0.0
September	14.8	0.0
October	58.3	6.3
Annual	*1,459.2*	*145.9*

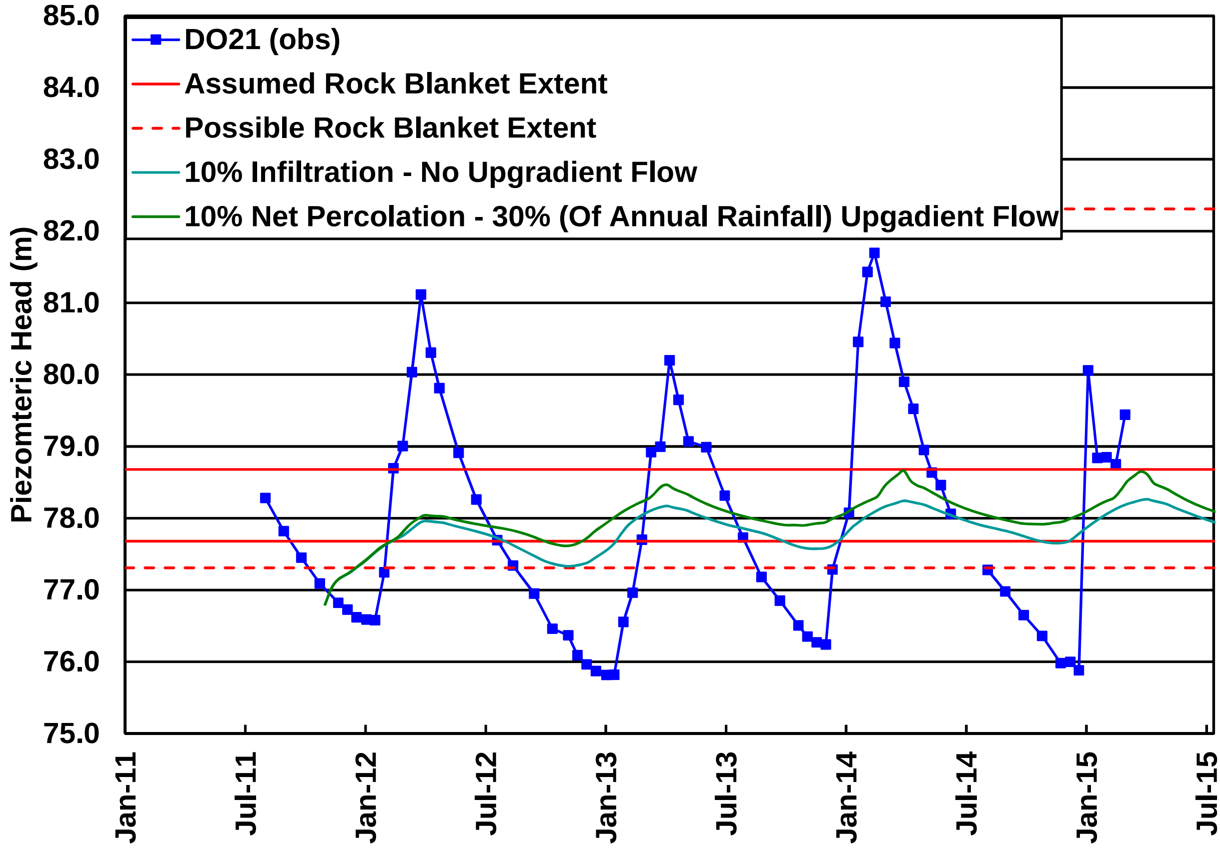

Figure 4: SEEP/W estimates of piezometric head given a decreased net percolation to Dyson's backfilled pit.

Annual net percolation of 30% of rainfall (shown in green in Figure 3) does not take into account the effect of up-gradient flow on the water table. Based on OKC's best engineering judgment, the current cover system is likely limiting net percolation to less than 30%. As discussed, there is likely an active up-gradient component of flow not being captured in the current model.

In order to bound acceptable net percolation given that an up-gradient flow component within Dyson's backfilled pit is likely, a constant up-gradient flow rate was applied to the right hand boundary of the model (Figure 2). It is challenging to meaningfully characterise the up-gradient flow as the up-gradient infiltration rate and contributing area to the 2-D cross-section can't be defined. Instead, it more meaningful to characterise the up-gradient flow in comparison to the volume of net percolation moving through the tailings cover system.

The maximum constant up-gradient flow possible to maintain the water table within the rock blanket was found to be three times the volume produced from the tailings cover system. In this scenario, where the water table is maintained within the current 1 m rock blanket and net percolation is limited to 10%, up-gradient flow represents 75% of total inflows to the Dyson's backfilled pit system compared to 25% being contributed to the tailings surface through the cover system. If more than three times the cover system flux is applied as an up-gradient inflow, the 10% net percolation applied becomes unacceptable in terms of driving the water table upwards into the cover system (Figure 4). It is important to note that further efforts should be made to understand the basis of the up-gradient contribution to Dyson's pit in order to properly characterise the system.

Discussion

It is estimated that current net percolation to the Dyson's backfilled pit is less than 30% of annual rainfall suggesting that it is likely that there is an up-gradient source of flow into the 2-D cross-section examined in this analysis. It is thought that under the current cover system configuration that the water table reaches above the drainage rock blanket approximately half the time. In order to maintain a water table below a proposed cover system, the cover system should aim to reduce net percolation to approximately 10% of annual rainfall. Assuming that up-gradient flow accounts for less than 75% of inflows to the Dysons' backfilled system this should also maintain the water table above the current tailings. However, since the effect of the up-gradient component of flow through Dyson's backfilled pit on the water table is not well understood it is recommended that an increased factor of safety be included in the design thickness of a drainage layer underlying any proposed cover system. At a minimum, a 2 m coarse backfill layer is recommended over the existing tailings surface before placement of the cover system. This provides four benefits in cover system design; 1) it provides a potential drainage layer to transport up-gradient flow and net percolation waters through the system without contacting tailings; 2) it increases the distance between the tailings surface and the base of a potential cover system which will likely include a finer-textured barrier layer at the base; 3) it provides a textural break between the tailings and barrier layer of the cover system improving cover system performance; and 4) the coarse-textured layer provide a working platform for trafficability during cover system construction.

Closure

We trust information provided in this memorandum is satisfactory for your requirements. Please do not hesitate to contact me at 011 306 715 1300 or gallen@okc-sk.com should you have any questions or comments.