APPENDIX C

Mine Closure and Tailings
MINE CLOSURE & TAILINGS

During the ERMP public consultation process, the management of tailings and long-term mine closure were identified as key aspects of interest. Accordingly, Toro provides further detail and reports from key consultants on the design, operation and management of the in-pit tailings storage facility at the Centipede deposit. These reports are provided in chronological order in this Appendix. They will form the basis of the detailed tailings facility design which will be included in the Mining Proposal that is to be assessed and approved by the Department of Mines and Petroleum.

The Centipede Tailings Storage Facility will be constructed using three types of embankments as shown below in the layout in Figure 1:

a) perimeter bunds on natural land surface

The purpose of this bund is to prevent surface runoff from rainfall from entering the tails storage. Perimeter bunds will be constructed adjacent to the top of the excavation face (Figure 2). The sides of the excavation will be shaped and proof rolled to provide a firm base.

b) freestanding perimeter embankments

As mining and tailings deposition will occur within the same general area of excavation, TSF perimeter walls will be required to separate the two activities. The internal tailings containment walls will be constructed with a zoned earth fill consisting of a 5 m wide upstream low permeability zone and a downstream structural zone.

c) TSF cell divider walls

Each TSF will be subdivided into three cells by constructing TSF cell divider walls. The purpose of these walls is to assist in the efficient deposition of the tailings throughout the life of the TSF cell. These walls will be constructed of structural fill.

The details of the design of the embankments are shown in Figures 1 and 2 below. The TSF design and construction parameters will be set by a qualified engineer who will also monitor construction to ensure the facility is built to design.
Figure 1: Tailings Plan View
Figure 2: Tailings Section View
Materials of construction of cell walls

Suitable earthen construction material (mostly clays) will be selected from the non mineralised overburden and waste rock during mining and either placed directly onto embankments or stockpiled for later use. Coarser rock will also be stockpiled as it is mined to be used as erosion protection layers on embankments.

Liner

Clay that is in situ at the base of the mining cells will be prepared as a low permeability base by firstly smoothing the base of the TSF cells then scarifying. Moisture conditioning and compaction will provide a base equivalent to a 300 mm engineered liner. If the in-situ material is not suitable for compaction or is insufficient to form a 300mm liner, material of suitable low permeability from elsewhere in the mining area will be imported and compacted to form a uniform engineered base. Testing of the clay that underlies the ore has confirmed permeabilities of less than 1x10^{-9} m/s, and the clay is known to be present to a depth of greater than 5 metres below the Centipede deposit.

Site investigations and testing

Testwork has been undertaken on tailings samples taken from the metallurgical pilot test program in October 2011. This testwork has confirmed that in the range of expected densities, the tailings permeability is likely to be less than 1 x 10^{-8} m/s.

Further investigations undertaken to date include a review of the logs of existing drillholes and testing of samples from geological drillholes that has provided permeabilities of the in-situ clay material that lies below the ore. These further studies have been undertaken as part of the development of the detailed tailings facility design that will be included in the Mining Proposal.

A further site investigation program is scheduled for mid 2012 to coincide with the planned resource drilling that is part of the Project development. This program will include a series of boreholes and test pits within and immediately adjacent to the proposed pit to confirm the detailed tailings design.

Operations and management of the TSF

The management and operation of the tailings storage facility will be according to the Tailings Storage Guidelines provided by the Department of Mines and Petroleum (1999, currently under review) for in-pit tailings disposal. A detailed tailings management and operations manual is being developed as part of the Mining Proposal and Project Management Plan. The manual will include the following elements:

- Water level management
- Dust management
- Groundwater monitoring
- Rehabilitation
- Radiation management
- Safety
- Contingency actions
During the operation of each cell, it is anticipated that the tailings will be dried to below 60% moisture content within 8 days in summer and 28 days in winter as a result of the local climatic conditions. The estimated time for drying in order to prepare a tailings mass suitable for rehabilitation would be about 0.5 to 1 month in summer and 3 to 4 months in winter. This will allow the tailings to develop a reasonable strength prior to placing the cover layers and final rehabilitation.

**Cover and capping of the TSF**

After tailings deposition and drying in the pre-prepared and conditioned tailings cells, non-mineralised waste will be placed over the tailings to form a minimum 2 metres of compacted cover, including a radiation control layer at the base of this cover. This layer will be placed in a single pass and will not require compaction control. It is expected to be possible to place this radiation control layer over the tailings surface using low pressure dozers with the tailings still at 60% moisture content.

The strength of the tailings plus the radiation control layer will be sufficient to form a suitable base for the cover. The top surface of the radiation layer will be proof rolled to provide a firm smooth surface for the placement of the cover.

**Mine Closure, Rehabilitation and Monitoring**

Design criteria for the tailings facility have addressed the following contingency scenarios through a risk assessment process:

1. seepage
2. cover failure and radon emanation
3. short term shut down - <90 days
4. suspension of operations - > 90 days
5. flooding

Any non-performance would be remediated as soon as practicable with the method to be determined at the time of any occurrence (see attached reports from Knight Piesold).

Monitoring of tailings facility performance will be undertaken both during operations and post closure to determine:

- TSF cover performance, specifically radon emanation;
- Rehabilitation and landform integrity (including vegetation re-establishment and erosion effects); and
- Potential seepage of radionuclides into groundwater.

If any aspect does not achieve the agreed outcomes, correction action will be undertaken to ensure agreed environmental values are protected.

**Tailings characterisation and groundwater modelling**
As part of the ongoing development of the Project, Toro has continued a program of testwork on samples of tailings taken following completion of the metallurgical pilot testwork in October 2011.

This program has included:

- Further analysis and testing of the physical characteristics of the tailings;
- Testing and analysis of the chemical characteristics of the tailings, including leachability and the radionuclide balance;
- Additional work on the TSF design and an assessment of alternative disposal systems; and
- Further studies into the fate of contaminant modelling.

The outcomes of these studies are provided in the attached reports. These studies confirm that the originally proposed construction and operation of the TSF will achieve the expected environmental outcomes.

1. Physical characteristics of the tailings

The permeability of the process tailings is low. The range of expected dry densities is expected to be less than $1 \times 10^{-8}$ m/s.

The final average density of the settled tailings is expected to be in the range of 1.0-1.2 t/m$^3$.

2. Chemical and Radionuclide Characteristics of Tailings

The chemical characteristics of the solid phase of the tailings are predominantly the same as the starting ore except that it is devoid of the majority of uranium which is selectively recovered by the process (around 85%).

Radionuclides:

Testwork has demonstrated that the daughter radionuclides that report to the tailings are predictable, behaving in a way that is consistent with results from similar processing circuits reported in the available literature. Key findings from the testwork are that the uranium daughter radionuclides report to the tailings in the solid phase and have low solubility.

Leachability:

Modelling has shown that migration of radionuclides in groundwater will be limited such that they will be at background levels within 15 metres of the tailings facility after 1,000 years. PHREEQC modelling has further confirmed the limited migration of radionuclides in groundwater over 1,000 and 10,000 years. Testwork has concluded that the tailings to be backfilled into the pits will be relatively inert, with mobilisation significantly retarded by the geochemical and hydrological conditions within the local geology hosting the deposit.

The PHREEQC modelling adopted a worst case scenario for tailings mobilisation, using the tailings liquor as a proxy for leachate. This was a conservative (and somewhat unrealistic) approach which assumed that the largest possible concentration of contaminants would be released into the aquifer in a single pulse. In reality, any release of contaminants would be at considerably lower levels than predicted by the model, as the concentration of elements in any leachate would be very low relative
to the original tailings liquor. For example, uranium would be less than 0.5% of the concentration in the liquor.

3. Adsorption values measured for uranium

In the studies on chemical characteristics of tailings, the sorption behaviour of uranium in concentrated solutions was extrapolated beyond the measured uranium sorption isotherms determined in the laboratory to predict uranium behaviour if released into the environment. Specifically, the studies assumed that all leachable uranium contained in tailings would be instantaneously released to groundwater. This is an unrealistic outcome, used as a ‘worst case’ modelling scenario. This assumption has been challenged, and Toro agrees to encompass the full range of modelled uranium in solution concentrations when calculating a retention isotherm.

Reports

The following reports have been provided to the EPA by Toro to support the proposed TSF design and the assessment of TSF performance:

KNIGHT PIESOLD

Alternative Tailings Disposal Options

Alternative disposal options are discussed with a rationale for choosing the in-pit disposal options. The report confirms that the in-pit tailings disposal option provides the lowest risk and hazard rating, and that the in-situ permeabilities of the underlying clays are $1 \times 10^{-9}$ m/s, sufficient to be used for a clay liner in the TSF.

Tailings Testing and Storage Facility Design/Operation

This report confirms that the clay liner will be an engineered structure, constructed from either the existing clay material that underlies the ore, or clay imported from other areas of the mining pits. It will be an engineered liner of minimum 300 mm thickness and compacted to achieve permeability requirements.

Site investigation – interim results of Phase 2 testing

The tailings testwork undertaken to date and the proposed site investigation program planned for mid 2012 are described.

The results of the testwork confirm that the permeability of the underlying clays in the proposed TSF footprint is $1 \times 10^{-9}$ m/s, sufficient to be used for a clay liner in the TSF.

Wiluna Preliminary Tailings Physical Testing Results

This report describes the results of the physical tests undertaken on tailings samples taken from:

a) the early 2011 bench scale testwork

b) the 2011 pilot scale metallurgical test program
Specific tests include viscosity, sedimentation, air drying and permeability with the report including a summary of predicted tailings behaviour.

Based on these results, the rate of supernatant release is predicted to be very low, and lower than the daily evaporation rate in the Wiluna region such that supernatant is likely to be evaporated with no runoff anticipated. The tests also indicated that the tailings reached very low dry densities from settling which further confirms that the TSF design and operating proposal is appropriate.

**Monitoring, maintenance and contingency response planning**

The conceptual approach to the design of a monitoring and maintenance programme and the development of Contingency Response Plans are discussed.

The report identifies the concepts to be fully developed in the next design stage and presented with the Mining Proposal.

**AUSTRALIAN NUCLEAR SAFETY AND TECHNOLOGY ORGANISATION**

**Comments on radionuclide solubility and mobility from alkaline carbonate tailings**

This report presents the radionuclide deportment to tailings measured in the 2011 pilot scale testing of the process. It concludes that:

- The long-lived radionuclides predominantly report to tailings solid phase
- The daughter radionuclides of uranium have low solubility in tailings
- Uranium can be used as a ‘worst-case’ scenario indicator for radionuclide mobility

These radionuclide deportment results are consistent with expectations from the literature and confirm the suitability of the TSF design and operations proposal.

**SOILWATER**

**Leachate results**

Results from three tailings samples are discussed.

The leachability of most elements in the mine tailings was low and in most cases zero.

**PHREEQC model results**

Geotechnical model results are discussed. The modelling was undertaken to predict the fate and transport of uranium from backfilled tailings material as they enter the aquifer system.
The following provides further technical information on the operation and closure of the Tailings Storage Facility.

MEMORANDUM

To: TORO ENERGY LIMITED
Attn: Richard Dossor
cc:

Date: 28 November 2011
Our Ref: PE801-00125 agr M11001
KP File Ref.: PE801-125 EMEM-KP001
From: Peter Veld

RE: TAILINGS TESTING AND STORAGE FACILITY DESIGN / OPERATION

1. INTRODUCTION

The Wluna Uranium Project is being developed by Toro Energy Ltd (Toro). Toro engaged Knight Piésold Pty Ltd (KP) to undertake the design of the tailings disposal system for the project.

The project is based on mining two uranium deposits (Centipede and Lake Way deposits) located to the south / southwest of the town of Wluna in Western Australia.

2. DESIGN PARAMETERS

2.1 DESIGN DATA

The design is based on a number of design parameters provided by Toro. Other parameters were generated from testwork or based on Government regulations / guidelines. The design parameters are outlined below:

- Throughput and total tonnage
  - High grade (>250 ppm): 12.5 Mt
  - Low Grade (<250, >150 ppm): 5.4 Mt
  - Plant processing rate: 1.3 Mtpa

  All ore from the Lake Way deposit will be hauled to the plant adjacent to the Centipede deposit with the tailings disposed of in the Centipede TSF.

- Processing System
  The ore will be processed using an agitated leach process. Leaching will be undertaken in alkaline conditions using sodium carbonate. The leach solution will then be recovered via a seven stage CCD circuit with the underflow from the final stage of the CCD’s pumped to the tailings storage facility (TSF).

- Topography
  Toro provided a detailed LIDAR survey of the area surrounding the mine site plus an approximate profile of the base of the orebody at Centipede.

- Tailings Disposal Principles
  In Toro’s “Environmental Scoping Document”, June 2010 Toro committed to disposing of the tailings back into the pit specifically below existing ground levels. This was incorporated into the design concepts.

- Water Management
  Toro indicated that no recycle from the TSF area would be used so the system was designed as a zero recycle system.
2.2 TAILINGS STORAGE FACILITY HAZARD RATING

2.2.1 General

In accordance with the WA Guidelines the Hazard Rating for the TSF was assessed. This was assessed in two phases. Phase 1 assessed the facility in accordance with “Guidelines on the Safe Design and Operating Standards for Tailings Storage” DMP May 1999 and “Water Quality Protection Guidelines No. 2 – Mining and Mineral Processing – Tailings Facilities” 2000. The second phase considered additional hazards resulting from the radioactivity of the tailings in accordance with “Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing” Radiation Protection Series No. 9 ARPANSA and “Managing naturally occurring radioactive material (NORM) in mining and mineral processing – guideline” NORM 4.2 DMP 2010.

2.2.2 Phase 1 Assessment

The Hazard rating for the TSF was rated as SIGNIFICANT based on the criteria as provided in Table 2.1.
Table 2.1: Hazard Assessment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Rating</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncontrolled Releases or Seeage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of human life</td>
<td>Low</td>
<td>Water is generally saline to hypersaline in the area and is unsuitable for human use. A public drinking water source protection area (supply for Willuna) is over 10 km north of Lake Way deposit and upgradient.</td>
</tr>
<tr>
<td>Loss of stock</td>
<td>Low</td>
<td>Water saline to hypersaline and unsuitable for use.</td>
</tr>
<tr>
<td>Environmental damage</td>
<td>Low to Significant</td>
<td>Potential damage to local environment. The site does not contain any Threatened Ecological Communities but some Priority Ecological Communities potentially intersect the project.</td>
</tr>
<tr>
<td>Embankment Failure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of human life</td>
<td>Low</td>
<td>Tailings will be stored below ground so only internal embankments have any potential risk – area will be controlled access only with no public access allowed.</td>
</tr>
<tr>
<td>Direct economic loss</td>
<td>Low to Significant</td>
<td>The facility will have multiple cells available for disposal – economic impact of embankment failure would be low to appreciable.</td>
</tr>
<tr>
<td>Indirect economic loss</td>
<td>Low</td>
<td>Multiple cells available so repairs to storage will be practicable.</td>
</tr>
</tbody>
</table>

Based on the assessment the TSF hazard rating would be SIGNIFICANT. From the hazard rating and height of the storage the facility would be rated as CATEGORY 2.

2.2.3 Phase 2 Assessment

The tailings would be classified as a naturally occurring radioactive material (NORM) and thus will require a Radioactive Waste Management Plan. It should be noted that removal of the uranium will only reduce the radioactivity to about 80-90% of the radioactivity of the original ore.

Based on the frequency of monitoring required for radioactivity the facility would effectively be classified as CATEGORY 1.
2.2.4 TSF Hazard Rating
Based on the most critical requirements outlined above the TSF is assessed as follows:

- SIGNIFICANT hazard rating.
- CATEGORY 1 (design and operating requirements).
- Radioactive Waste Management Plan required.

2.3 CLIMATE
The climate at the site can be described as semi arid with hot summers and mild winters. The average annual rainfall is 255 mm while the average annual evaporation is about 3400 mm. A 1 in 100 year 72 hour storm generates about 230 mm of rainfall.

2.4 SEISMICITY
The site has a relatively low seismicity and the following parameters were selected for design:

- Operating Basis Earthquake (OBE) = 0.05g (10% exceedance probability in 50 years).
- Maximum Design Earthquake (MDE) = 0.13g (Magnitude 7.5 earthquake, 15 km depth, 100 km from site).

2.5 TSF LOCATION PHYSICAL CONDITIONS
General physical conditions in the vicinity of the Centipede pits can be described as follows:

- Foundation Soils
  The orebody (and the zone below) consists of a sequence of layers of calcrite, siltstone, sand and clay. The typical stratigraphy is summarized below:

  0 – 0.7 m  SILT – sandy to clayey silt, slightly calcareous.
  0.7 – 4.7 m  CALCRITE/SILT – vuggy calcrite with silt.
  4.7 – 7.0 m  SAND/SILT/CALCRITE – fine to coarse sand intercalated with silt and silty sand with variable calcrite content.

  The thickness and depth of the layers across the area are also variable.

- Hydrology
  Surface water in the area generally drains into Lake Way. Surface water is ephemeral and only occurs after high rainfall events. The 1 in 100 year flood level for the lake is just below RL492.0 m. The lake has the potential to spill to the southeast to Lake Maitland under extreme climatic conditions. There is an unnamed creek which flows through the southern edge of the Centipede orebody area and no tailings will be deposited within the boundaries of this creek.

- Hydrogeology
  Subsurface water generally flows towards Lake Way which usually acts as an evaporation source. There is a potential for subsurface flow to the southeast towards Lake Maitland. The groundwater flow occurs within distinct geological units with the calcrite layers being the primary higher permeability zones.

PEBO1-000125 agr M1001 PLV Tailings Testing and Storage Facility Design Operation.docx
A water flow barrier will be installed to reduce the horizontal flow of water into the orebody area as part of the dewatering management strategy. This will reduce horizontal groundwater inflow into the areas of the orebody used for the TSF but will have minimal impact of groundwater flow through the base of the relevant areas.

The depth of groundwater is typically 2 to 5 m below surface with the depth reducing closer to Lake Way. The groundwater is expected to be hypersaline with a neutral to slightly alkaline pH. The measured salinity generally increases the closer to Lake Way the sample is taken.

3. TAILINGS TESTING

3.1 GENERAL

A tailings sample was sent to the KP Testing Laboratory (date: 20\textsuperscript{th} April 2011) from ALS AMMTEC’s benchtop metallurgical testing program as follows:

- 2 X 20 L containers of tailings in slurry form.
- 1 X 20 L container of water from the site area.

In addition Toro provided a copy of Outotec’s thickener testing undertaken in March 2011 (File Reference S1278TA).

The following tests were carried out on the sample:

i. Supernatant liquor density and pH.
ii. Viscosity test.
iii. Undrained and drained sedimentation tests.
iv. Air-drying tests.
v. Permeability tests.
vi. Consolidation tests.
vii. Strength testing.

3.1.1 Classification Testing

Classification tests were carried out on the sample as follows:

- Supernatant Density
  A density of the liquor was measured using a hydrometer. A measured value of 1.052 was recorded.

- Supernatant pH
  The pH of the supernatant was measured using a pH meter as 8.09.

- Specific Gravity
  For the purposes of this testwork a value of 2.85 was used.

3.1.2 Viscosity Testing And Percent Solids

The viscosity of tailings is related to the solids content of the slurry. Laboratory measurement of the viscosity of the slurry at varying solids contents was conducted using the Marsh Flow Cone Apparatus, which involves timing of the efflux of a known volume of slurry (1.7 litres) through a standard flow cone. At lower percent solids, the time taken for the slurry to flow through the cone is similar to water. As the slurry increases in solids content there is a slow linear increase in the time taken. At a certain percentage solids,
defined as the Critical Solids Content, the time taken for the slurry to flow through the cone increases rapidly, and within a 5% to 10% increase in the solids content the time measured will more than double.

The critical solids content ranged from 30 to 35% solids.

The Outotec thickener report indicated that a standard thickening would achieve an underflow density of 36.6% at a feed rate of 0.22t/(m².h) with a flocculent dose rate of 4.5 g/t. The paste simulation indicated a potential increase to about 41 - 42% solids. These values are consistent with the results of the Marsh Cone testing. Based on the results it was decided to undertake the laboratory testing at about 38% solids.

3.1.3 Sedimentation Tests

Drained and undrained sedimentation tests were carried out for both percent solids to determine the settling rate, volume of supernatant, and settled dry density of the tailings.

The results of the sedimentation tests are presented in Table 3.1.

**Table 3.1: Sedimentation test results**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Test</th>
<th>Initial Solids (%)</th>
<th>Supernatant (% of initial water volume)</th>
<th>Underdrainage (% of initial water volume)</th>
<th>Time to Achieve 90% of total density increase (days)</th>
<th>Final Density (t/m³)</th>
<th>Final Dry Density (t/m³)</th>
<th>Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>38% Solids</td>
<td>Undrained Drained</td>
<td>38.1</td>
<td>10.2</td>
<td>-</td>
<td>34</td>
<td>60*</td>
<td>0.58</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>39.7</td>
<td>5.6</td>
<td>10.7</td>
<td>26</td>
<td>32</td>
<td>0.70</td>
<td>2.2</td>
</tr>
</tbody>
</table>

*Undrained test terminated

The tests indicate the tailings sample is extremely slow settling taking from 30 to 60 days to complete. Supernatant release ranged from 6 – 10% of the water in slurry.

The settled densities achieved are very low. There is a slight increase in settled density between the undrained and drained tests for the samples.

3.1.4 Air-drying Tests

Air-drying tests were carried out on slurry samples to determine the effect of natural drying of the tailings after initial settling and removal of supernatant liquor, thereby simulating conditions expected following sub-aerial deposition. Continuous monitoring of the weight and volume of each specimen was carried out in order to quantify the relationship between dry density, moisture content, volumetric change and the degree of saturation of the tailings.

The results of air-drying tests are summarised in Table 3.2.

**Table 3.2: Results of air-drying tests**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Moisture Content at Breakaway Point (%MC)</th>
<th>Dry Density at Breakaway Point (t/m³)</th>
<th>Limiting Saturation Value (%Sat)</th>
<th>Final Dry Density (t/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>38% Solids</td>
<td>130</td>
<td>0.65</td>
<td>70</td>
<td>1.28</td>
</tr>
</tbody>
</table>
Air-drying of the tailings significantly improves the achieved dry density compared to the sedimentation test result. The increase is approximately 82%. The air-drying of the tailings is still slow with the samples taking approximately 30 days at an evaporation rate of 5.6 mm/day to achieve final density. However, 90% of the final density (1.0 t/m³) is achieved in 18 days. At Wlluna, the evaporation rate varies seasonally from 4 to 12 mm/day. In the design of the TSF, the drying time will need to be adjusted to suit the actual monthly evaporation rates as well as the exposed beach area and throughput rate.

3.1.5 Permeability Tests

Falling head permeability tests were completed on saturated tailings samples with drainage through the drained sedimentation sample being measured. In addition, permeability values were derived from the results of consolidation tests. Measured permeability data are summarised in Table 3.3 and presented in Figure 3.1.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Test Type</th>
<th>Dry Density (t/m³)</th>
<th>Permeability (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>38% Solids</td>
<td>Falling Head</td>
<td>0.69, 0.72</td>
<td>1.6 x 10⁻⁸, 1.6 x 10⁻⁸</td>
</tr>
<tr>
<td></td>
<td>Consolidation Test</td>
<td>0.61, 0.64, 0.69</td>
<td>3.4 x 10⁻⁷, 3.6 x 10⁻⁸, 1.5 x 10⁻⁸</td>
</tr>
<tr>
<td></td>
<td>Consolidation Test Stage 2</td>
<td>0.70, 0.72</td>
<td>1.0 x 10⁻⁸, 4.7 x 10⁻⁹</td>
</tr>
</tbody>
</table>

These results represent the permeability of saturated tailings prior to additional consolidation due to additional deposition loading or air-drying. The permeability is expected to decrease further at higher densities. In the range of expected settled densities, the permeability is likely to be less than 5.0 x 10⁻⁷ m/s indicating low permeability tailings.

3.1.6 Consolidation Tests

The consolidation of the tailings can be quantified in terms of the compression index $C_C$ and the coefficient of consolidation $C_V$. The compression index relates the void ratio or tailings density to the effective stress of the tailings sample.

The settlement with respect to time and the variation in permeability with density for the test is presented in Figure 3.1 and the results of the consolidation tests are summarised in Table 3.4.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Dry Density (t/m³)</th>
<th>Stress Range (kPa)</th>
<th>Coeff of Consolidation $C_V$ (m²/y)</th>
<th>Coeff of Volume Decrease $M_d$ (m²/kN)</th>
<th>Comp. Index $C_C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>38% Solids*</td>
<td>0.60 – 0.71</td>
<td>1.32 – 4.91</td>
<td>&lt;1.2</td>
<td>&lt;0.04</td>
<td>&gt;1.3</td>
</tr>
</tbody>
</table>

*The 38% solids test was terminated after 2 months due to time constraints.
3.1.7 Undrained Shear Strength

Undrained shear strength testing was undertaken on a tailings sample to determine the relationship between undrained shear strength, saturation, and moisture content of the tailings.

The test is designed to determine the effect of air drying on the undrained shear strength of the tailings solids, after initial setting. The strength versus moisture content data will be used to assess trafficability as part of the closure design.

A sample of the tailings slurry was placed in a large container (approximately 5 kg) and air dried under heat lamps. The unconfinéd compressive strength of the tailings was measured over several weeks as the tailings dried. A pocket penetrometer was utilised to determine the undrained shear strength of the tailings during desiccation.

The undrained shear strength begins to increases at a moderate rate as the moisture content reduces below approximately 70%. At a moisture content of 50-55% (at a saturation point 80% or lower) the increase in undrained shear strength becomes more rapid, as the tailings approaches the maximum dry density. Drying below a limiting saturation produces no further consolidation, and the density at this point represents the maximum that can be achieved via air drying of the waste fines. However, the rapid increase in undrained shear strength continues below the limit of saturation until it reaches values of greater than 200 kPa at a moisture content of 42% and a saturation of 75%.

The results of the shear strength testing is presented in Figure 3.2 and summarised in Table 3.5.

<table>
<thead>
<tr>
<th>Moisture Content (%)</th>
<th>Undrained Shear Strength (kPa)</th>
<th>Saturation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>7*</td>
<td>88</td>
</tr>
<tr>
<td>65</td>
<td>22*</td>
<td>85</td>
</tr>
<tr>
<td>53</td>
<td>60</td>
<td>81</td>
</tr>
<tr>
<td>50</td>
<td>82</td>
<td>80</td>
</tr>
<tr>
<td>48</td>
<td>105</td>
<td>78</td>
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<tr>
<td>45</td>
<td>145</td>
<td>77</td>
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<tr>
<td>43</td>
<td>190</td>
<td>76</td>
</tr>
</tbody>
</table>

* Estimated values

In conclusion the tailings can achieve significant undrained shear strength if dried sufficiently, but in general the size of the storage facility is designed such that the tailings achieve their maximum dry density (saturation levels of 75-85%) and not necessarily the maximum undrained shear strength. As such a period of drying after deposition prior to closure may be required.

Access onto the tailings surface will be possible with low ground pressure machinery (swamp dozers) once a shear strength of approximate 75 to 100 kPa has been achieved within at least the upper 1 m of the tailings. This would require an overall saturation level of approximately 75% or lower to be achieved.
3.2 PREDICTED PHYSICAL BEHAVIOUR OF TAILINGS

Based on the physical testing of the sample and assuming the sample is representative of the tailings as a whole, the following predicted behaviour is expected for the tailings.

3.2.1 Water Production

The release of water following deposition of the tailings can be estimated from the results of drained and undrained sedimentation tests. The rate of release will determine the amount of supernatant reaching the decant pond. The testing indicated that the rate of supernatant release is very low. Table 3.6 provides approximate maximum rates of supernatant release in mm/day for different deposited layer thicknesses.

<table>
<thead>
<tr>
<th>%Solids of Tailings</th>
<th>Test</th>
<th>Total Supernatant Release % of Initial Water Volume</th>
<th>Thickness (mm)</th>
<th>Maximum Daily Release Rate of Supernatant (mm/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>38%</td>
<td>Undrained</td>
<td>10.2</td>
<td>100</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>200</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>300</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Drained</td>
<td>5.6</td>
<td>100</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>200</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>300</td>
<td>3.5</td>
</tr>
</tbody>
</table>

The evaporation rates in the WIluna area vary from a maximum of about 15 mm/day in summer to a minimum of about 4 mm/day in the winter. As the rate of supernatant production is lower than the daily evaporation rate typically all of the supernatant would evaporate with no runoff. Thus the surface water management would only need to consider rainfall events.

The quantity of underdrainage release in the field would be expected to be lower than the values indicated by the test work, due to the thickness and low permeability of the deposited tailings, further consolidation of the tailings and drying of intermediate layers. Underdrainage release was about 11% (for a free draining sand base) but at a relatively slow rate taking 20 – 30 days to complete. Underdrainage losses in the field would likely average around 0 – 2%.

3.2.2 Tailings Density

The settled dry density of tailings deposited into the storage facility can be predicted from laboratory testing. The test results indicated that the tailings reached very low dry densities from settling with a significant improvement due to air-drying of the sample. It has been observed over a number of years that densities achieved in the field are generally lower than those obtained in the laboratory. In addition, field densities achieved are dependent on the area available for drying and the thickness of deposited layers. The area / rate of rise requirement is even more critical for very low drying tailings. A suitable deposition plan and efficient operation of the facility can greatly improve settled density. Assuming that sufficient area is available and the facility is efficiently operated, it is estimated that the average settled density for the facility could be as high as 1.0 – 1.2 t/m³.
4. TAILINGS STORAGE FACILITY DESIGN

4.1 MINING PLAN

There are two orebodies mined during the Project, Centipede and Lake Way. Toro has developed a mining plan for both orebodies as part of the project development.

The principles from the mining plan which affect the TSF design are as follows:

- Centipede orebody will be mined first.
- Ore from Lake Way will be transported down to the processing plant at Centipede and tailings disposed of in Centipede TSF.
- Ore from Lake Way will be transported down to the processing plant at Centipede and tailings disposed of in Centipede TSF.
- A preliminary section of the Centipede orebody is to be mined and stockpiled to generate void space to develop an initial TSF area prior to commissioning.
- Centipede orebody covers a relatively large area but is generally between 4 and 6 m deep.
- The sequence of mining blocks at Centipede can be modified to suit the TSF development.
- The current mining plan only covers processing of high grade ore however the TSF will be sized to allow for potential processing of low grade ore as well.

The nominal sequence of mining block availability at Centipede is provided in Table 4.1.

<table>
<thead>
<tr>
<th>Pit</th>
<th>Mining Blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centipede</td>
<td>Blocks 5 &amp; 6</td>
</tr>
<tr>
<td></td>
<td>Blocks 7 &amp; 10</td>
</tr>
<tr>
<td></td>
<td>Blocks 8 &amp; 9</td>
</tr>
<tr>
<td></td>
<td>Block 11</td>
</tr>
<tr>
<td></td>
<td>Blocks 12, 13 &amp; 16</td>
</tr>
<tr>
<td></td>
<td>Block 14</td>
</tr>
<tr>
<td></td>
<td>Block 15</td>
</tr>
<tr>
<td></td>
<td>Blocks 2, 3 &amp; 4</td>
</tr>
<tr>
<td></td>
<td>Block 1</td>
</tr>
</tbody>
</table>

The void developed from mining the Centipede orebody was assessed with regards to size, depth to base ground levels, current mining sequence and required storage capacity. Based on these criteria Mining Blocks 1 to 4 were eliminated due to their shallow depth. Mining Blocks 5 to 15 were selected for the TSF (depth 4 to 6 m). The area will be divided into three facilities only one of which will be active at any one time. As each facility approaches full capacity the next facility will be developed.

Each facility will be divided into three cells for deposition control purposes.
4.2 EMBANKMENT DESIGN

4.2.1 General
For each facility potentially four embankment types will be utilised as follows:

- Perimeter embankments built against existing ground.
- Freestanding perimeter embankments between the TSF facility and the adjacent active/completed mining area.
- TSF cell divider walls.
- TSF supplementary deposition walls.

The layout of the facility and embankment locations are shown on Figure 4.1.

A description of each embankment type is provided below.

4.2.2 Existing Ground Perimeter Embankment
The TSF will be constructed within the orebody excavation. Thus in a number of locations the perimeter embankment will be built against an existing excavation face. For these locations the existing face will be reshaped to a slope of 1V:3H (or flatter) and proof rolled to provide a firm base for placement of tailings.

In areas where the existing ground surface is less than the nominal perimeter embankment RL a bund will be constructed up to the required height using clay and/or structural fill materials (silt/sand gravel material). The crest width of the bund will be 5 m with side slopes of 1V:3H.

The purpose of the bund is to isolate the TSF area from any upstream catchments. To facilitate the removal of surface runoff a diversion drain will be built along the upslope side of each facility to divert any runoff around the TSF area.

4.2.3 Freestanding Perimeter Embankment
In TSF 1 and TSF 2 a freestanding perimeter embankment will be required between the TSF facility and the adjacent mining area. This embankment will be a zoned earthfill embankment consisting of a 5 m wide upstream low permeability zone and a downstream structural zone. The crest width will be 5 m and the upstream and downstream slopes will be 1V:3H.

As the TSF will be progressively filled with tailings and the mining area will be in a dewatered state the embankment will be provided with a drain to prevent buildup of water pressure in the downstream structural zone. Water from the drain will be discharged into the adjacent mining zone. When this area is incorporated into the next TSF the drain will be decommissioned.

4.2.4 TSF Cell Divider Walls
In each facility the area will be divided into three major cells by constructing TSF Cell Divider walls. The purpose of these walls is to improve deposition control as discussed in Section 5.

These walls will be constructed of structural fill won from local excavation (uranium content to be <82 ppm) and will be provided with an erosion protection layer on each side.
The divider walls will be constructed with a crest width of 5 m and side slopes of 1V:3H.

4.2.5 TSF Supplementary Deposition Walls
As the storage area is relatively shallow the beach slope of the tailings may result in a loss of storage in the active cell. In this case a cross wall will be constructed to allow the deposition pipeline to be relocated. This wall will be constructed by end dumping material across the cell at an appropriate location and then filling the upstream cell with tailings prior to relocating the pipeline. Coarse material will be dumped off the sides of the deposition wall to provide erosion protection.

The use and/or number of supplementary deposition walls will be a function of the deposition method and achieved beach slope as discussed in Section 5.

4.3 STABILITY
A preliminary stability assessment was undertaken to ensure that all of the embankments at various stages over the life of the operation have adequate stability.

The stability of the proposed embankment section was assessed under both normal and seismic loading conditions using limit equilibrium methods. The computer program XSTABL, developed at the Purdue University, was used for the analysis, which was carried out using the Janbu method.

The stability of the embankments under earthquake loading conditions was assessed using pseudo-static methods of analysis. A horizontal bedrock acceleration of 0.05g was adopted for the initial analysis based on an assessment of the seismicity of the site. Based on the seismic analysis, a horizontal bedrock acceleration of 0.13g was adopted for Maximum Design Earthquake (MDE).

There are four nominal embankment profiles which may be used in the TSF.

- Existing ground perimeter embankments
  These embankments will be built against existing excavated surfaces. In the upstream direction the embankment will be buttressed progressively by tailings. Thus it is expected that stability for this type of embankment will be acceptable.

- Freestanding Perimeter Embankment
  Between the facilities a freestanding embankment will need to be constructed. As the embankment will remain freestanding potentially for a number of years the embankment was assessed for downstream stability. The results of the stability analysis are provided in Table 4.2.

<table>
<thead>
<tr>
<th>Loading Condition</th>
<th>Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static</td>
<td>2.14</td>
</tr>
<tr>
<td>Pseudo Static</td>
<td></td>
</tr>
<tr>
<td>- OBE</td>
<td>1.83</td>
</tr>
<tr>
<td>- MDE</td>
<td>1.48</td>
</tr>
</tbody>
</table>

The results indicate the embankment has adequate stability.

- TSF cell divider walls
  These embankments will be constructed within each facility. Initially these will be similar to the perimeter embankments however tailings will be progressively
placed on both sides of the embankment. Thus it is expected that the stability of these walls will be adequate.

- TSF Supplementary deposition walls
  These walls will be pioneered across the existing active cells. The material will continue to be placed until the embankment is stable with minimal movement occurring.

  These walls will be constructed across/through the tailings thus there is a potential for local instability to occur. As the walls will only be used for tailings deposition and are internal to each cell any local instability can be repaired without any major impact on the operation and with no probability of tailings release.

5. FACILITY OPERATION

5.1 TAILINGS STORAGE FACILITY DEVELOPMENT

The current concept for tailings disposal is as follows:

- Area dewatered as part of the mining sequence.
- Ore and waste removed for processing and disposal respectively (dewatering maintained).
- Base of target cell area smoothed by dozer to remove local high and low areas.
- Sub base drainage system installed (if required for subsurface/dewatering control).
- Base scarified, moisture conditioned and compacted and perimeter embankments constructed. In areas with calcrete, material from other areas will be imported to form a 300 mm base liner. This will prevent the migration of tailings from the facility.
- Internal bunds for individual deposition cells constructed over the compacted base.
- Internal drainages constructed at toe of perimeter embankment to reduce phreatic surface through embankment.
- Tailings deposition commenced using sub-aerial deposition (dewatering maintained).
- Construction of next cell commenced when active cells are partly filled.
- When cell is filled, deposition is switched to the next cell and the tailings in the deactivated cell is allowed to dry (Phase 1 drying period).
- When tailings has achieved the required strength an initial cover layer is placed over surface.
- Tailings cell allowed to continue drying with the internal drainage and pit dewatering (if required) systems still operating (Phase 2 drying period).
5.2 WATER BALANCE

A nominal water balance was developed to check whether operating the cells using subaerial methodology would be an issue. The following base data were assumed:

- No recycle.
- Supernatant release – max of 7 to 8% over 10 days. As release is slower than available daily evaporation rates this means effectively 0% supernatant reaching the decant pond.
- Climate data
  - Rainfall = 225 mm/yr
  - Evaporation = 3410 mm/yr
  Thus pond will be formed after each storm and then evaporated away.
- Seepage – testwork indicated 8% over 10 days with free draining base – will be lower with air drying of layer and underlying previously dried tailings (estimated as range of 0 – 2% in total).

The water balance check indicates that the facility will be largely dry and there will be minimal water management issues during operation.

5.3 FACILITY SEEPAGE

Seepage rates from the facility will be controlled by a number of factors. The following factors will impact on the potential seepage rate and migration of water away from the facility:

- The natural groundwater level is a couple of metres below the existing ground surface. During the operating period the area will be dewated so the water level in the pit area will be lower than the surrounding area and thus the pit will act as a local groundwater sink during the operation (ie water will flow towards the pit area). This also means the water level in the pit area will not be higher than the local groundwater system at any time during the operation or after closure.
- The tailings has a low permeability and will only release minimal amounts of water especially after it is air dried and consolidated during deposition. Thus the availability of water for seepage release will be very low.
- Studies of the natural groundwater flow in the area indicates extremely low rates of water movement so there is no mechanism for any rapid release of seepage to be moved away from the facility.
- After closure the water table is expected to recover back to its original levels over a very long period of time. However even after the water table recovers and groundwater flows return to their original configuration the tailings permeability will be generally lower than the surrounding materials and thus local groundwater flows will tend to move through the surrounding materials rather than through the tailings mass itself.
5.4 DEPOSITION CONTROL

The orebody is typically between 4 and 6 m deep thus tailings deposition will be mostly controlled by the need to maximise the storage efficiency.

The number of tailings disposition locations, the use of supplementary bunds and the frequency of pipeline relocations will in large part be a function of the beach slope of the deposited tailings. The steeper the beach slope the higher the number of discharge locations that will be required to maintain a suitable range depth of tailings across each cell.

The estimated particle size distribution (provided by Toro) is relatively coarse so beach slopes particularly adjacent to the deposition location could be as steep as 1V:50H with flatter slopes further away. It should be noted that the beach slope is also affected by viscosity and other factors.

Discharge will commence off one embankment for a period of time. As the tailings approaches the top of the embankment a supplementary bund will be constructed at a suitable distance down the cell. When the tailings reaches the maximum level the pipeline will be relocated to the supplementary bund. Initially deposition will be into the first cell to fill the remaining void and then deposition into the next section of the cell commenced.

The spacing of the bunds will be adjusted to ensure maximum utilisation of the storage. One of the deposition criteria is that the tailings remains below ground level. On this basis the cells have all been aligned to run from the higher ground on the northwest towards the lake edge. The alignment of the cells is shown on Figure 4.1.

Deposition into each cell will be undertaken until the cell is full. Alternatively all three cells in each facility will be filled at the same time in an alternating deposition sequence if additional area is required to achieve adequate densities.

5.5 ENVIRONMENTAL ISSUES MANAGEMENT

5.5.1 General

There are a number of environmental issues relating to the tailings area which will need to be managed. The two primary issues are radiation and dusting.

5.5.2 Radiation Control

The ore is being mined, the uranium being extracted and the tailings replaced back into the void. Thus the impact on the surrounding environment from the tailings should not be significantly greater than the impact of the original orebody.

However because the orebody and tailings will be exposed for some period during the operation there is a risk of exposure for mine personnel. Radiation control in the mining area will be covered elsewhere. In the tailings area the following procedures/controls will be implemented:

- The TSF will be a restricted access area off limits with access only allowed for suitably trained mine personnel.
- The tailings discharge system will be designed to minimize the length of time the operator needs to spend in the TSF area.
- For most of the time the active cells are used near to 100% saturation. As a result radiation levels will be relatively low.
• After deposition into a cell has been completed a nominal cover will be placed as soon as possible. This will reduce the radiation exposure for the workers building the final rehabilitation cover. Depending on the deposition sequence, some of the cells could be partly rehabilitated during the operation.

5.5.3 Dust Control

For the bulk of the deposition into the active cell the tailings will be close to 100% saturated. Thus dusting is not likely to be an issue for the tailings during this period. However after a cell has been filled, any remaining water will be evaporated away and the surface of the tailings will dry out. During this period there is a potential for dusting to occur if the facility is not managed correctly.

In order to minimise this potential the following criteria will be applied:

• Access to the surface during drying will be minimized thus preventing breakup of the surface and/or any salt crust which develops.

• The nominal cover will be placed as rapidly as possible. The timing of this layer will be based on bearing capacity for equipment rather than drying of the surface. Given the tailings characteristics it is expected that the surface will not have to be completely dry before low pressure dozers/graders will be able to place the cover layer. Once this layer is in place the cell will be allowed to dry completely prior to completion of the rehabilitation cover.

Thus it is anticipated that dusting will be a controllable issue. Testing of a representative tailings sample will include assessment of dusting potential.

6. CLOSURE DESIGN AND CONCEPTS

6.1 CAPPING DESIGN

The proposed capping cover system has not been designed yet, however it is envisaged to consist of the following components (starting from the base of the cover):

• Radiation Control Layer

A radiation control layer will be placed over the tailings surface. “Half Value Layer” (HVL) thickness for soil/sand is approximately 150 to 200 mm (that is, the thickness of soil required to reduce radiation levels by about 50% is approximately 150 to 200 mm). The target would be three HVL layers of 200 mm thickness each. Discarding the effectiveness of the first HVL due to scattering effects from the tailings surface this will reduce radiation at the surface of the radiation control layer to 25% of the rate of the exposed tailings surface. The thickness of the radiation control layer (which is also the initial layer placed over the tailings surface) will be adjusted based on two factors:

i. Reduction of radiation levels on the surface of the layer so that rehabilitation work can be undertaken.

ii. The thickness and timing of the layer will also need to factor in the strength of the underlying tailings and the equipment size. Timing of the placement after the cell shutdown will be a function of the rate of increase of tailings strength over time during the Phase 1 drying period.

This layer will consist of material excavated from over the orebody. Material with some low level mineralisation could be used in constructing the radiation control layer provided the required reduction in radiation levels was achieved.
• Shaping Layer
The overall cover will be designed to maintain a suitable profile to match local landforms and prevent ponding. This will be achieved by placement of a shaping layer. This will vary in thickness across each cell so that the integrated landform/profile at the end of the operation matches the required final profile.

• Capillary Break Layer
A capillary break will be incorporated into the cover to prevent upward migration of contaminants from the tailings mass into the cover system. If the radiation control layer and shaping layer material are suitable a separate capillary break layer may not be necessary.

• Surface Water Shedding Layer
A compacted liner will be built over the capillary break layer (nominally 300 mm thickness) to reduce infiltration of rainfall into the tailings mass. The layer will be shaped so that the top surface drains.

• Growth medium and topsoil
Over the entire surface a growth medium layer will be placed. Any topsoil that has been stripped from the pit area will be placed back over the top of the growth medium layer.

• The growth medium layer will consist of nonmineralised overburden stripped from the pit area. The material will be selected and tested to ensure the material meets the required quality standards for its use.

• Vegetation
The surface will be planted with suitable local provenance vegetation.

6.2 CLOSURE CONCEPTS
6.2.1 General
During the deposition of tailings into the first cell a detailed closure plan will be developed.

A closure criteria checklist will be produced consisting of general targets and specific items for each government authority, if required, developed through interaction with the relevant authorities.

• The general targets will include the following:
  i. All batters reshaped to suitable slope for rehabilitation.
  ii. Closure cover placed (matching nominal design).
  iii. Top surface contoured to prevent local ponding.
  iv. Surface and slopes planted with suitable local provenance vegetation.
  v. Closure materials selected and designed to minimise long term erosion.
  vi. No pipework, valves or tailings facility infrastructure to remain in rehabilitated area.

6.2.2 Measurement
In order to assess the closure criteria a detailed set of targets will be developed with associated methods of measurement. A monitoring program will be undertaken during the closure phase to assess whether the specific targets have been met. For measurement purposes a number of transects down the length of the cells plus a selection of shorter
transects in critical areas will be generated (locations to be defined by GPS or other suitable technique).

For specific areas such as vegetation selection and establishment the program will be developed in consultation with Toro’s specialist consultants.

6.2.3 Water Movement Monitoring
The water control system consists of several components which will be shutdown progressively during closure as follows:

- The subsurface drainage will be shutdown at the time deposition ceases.

- A temporary pump will be provided for the cell to pump any rainfall pond from the inactive cell into the active cell to minimise water buildup and maximise drying in the inactive cell.

- Dewatering of the area around each cell will be shutdown on completion of the cover. If necessary some dewatering will be continued to ensure the adjoining cells remained drained.

- All monitoring systems which are installed in the tailings deposition areas will continue during the full operating period and for a suitable length of time after the facility is shutdown.

6.2.4 Timing and Rehabilitation
The facility consists of potentially nine active cells (depending on the extent of low grade ore which is processed).

Each cell will be utilised in turn. As a result the first cell will be available for rehabilitation after a period of about 2 years. The operation has a projected life of 9 to 13 years depending on processing of high and low grade material. Thus the first cell can be filled, dried, a cover constructed and rehabilitated before the end of the operating life. This allows alternative methods of rehabilitation to be evaluated and a period of monitoring to be undertaken for the first cell during the operation. Based on these results the closure plan for the remaining cells would be modified to ensure they are rehabilitated in the most effective manner.

7. ONGOING DESIGN AND TESTWORK
The design of the tailings storage facility is in progress and a number of stages are required prior to completion of the design. Some of the ongoing work is listed below:

- The tailings tests described in Section 3 were provided from bench scale metallurgical testwork. The testwork has progressed and expanded to a pilot plant level and tailings from the pilot plant (which are expected to be more representative of the tailings generated by the full scale plant) is currently undergoing testwork. Preliminary results indicate that the tailings from the pilot plant are similar in behaviour to the bench scale samples (particularly in regard to water release), thus all of the design decisions arising from the bench scale testwork are likely to remain valid.

- Site investigation work to obtain samples for grading, characterisation and compaction testing.

- Geochemical and radioactivity characterisation of pilot plant tailings samples.
Based on this ongoing work the design will be modified as necessary to meet all the relevant regulatory requirements.

Yours faithfully

KNIGHT PIERSOLD PTY LTD

DAVE MORGAN
Managing Director
FIGURES
WILUNA URANIUM PROJECT
TAILINGS SAMPLE
CONSOLIDATION TEST

Ref: Memo KP001
Figure 3.1
Memo from Knight Piesold (Peter Veld) to Toro Energy (Richard Dossor) of 21 Nov 2011 regarding the nature and permeability of the process tailings.

1. Tailings characteristics – the testwork indicates the tailings tend to hold water and only release it slowly. This has a number of impacts on the operation of the facility as follows:
   a. The rate of supernatant release (even in the winter time) would be lower than the evaporation rate so there would be minimal to no supernatant runoff. As a result water would only be present on the surface of the facility after rain events and all of this water would be rainwater. This also means there would be minimal supernatant available for release as seepage.
   b. The permeability of the tailings at a density of about 0.7 t/m$^3$ was measured at about 2 x $10^{-8}$ m/s. Additional modelling has shown that at higher densities of about 0.9 t/m$^3$ this reduces further to around 8 x $10^{-9}$ m/s. The tailings modelling indicates densities in the range of 1 – 1.2 t/m$^3$ could be achieved in the facility indicating the permeability of the tailings could be expected to be below the values measured in the testwork.
   c. Strength versus moisture content testwork indicates that the tailings after a period of drying (weeks to months only) would be strong enough to allow placement of cover materials so rehabilitation of the facility could commence within a relatively short time period after the termination of deposition.

2. Embankment stability – the tailings would be deposited into a mined out shallow pit so stability would not be a critical issue. The main point to note for this aspect is that the pits would be only 4 to 8 metres deep and extend over several hundred hectares in area. Thus any instability of the walls would be a local issue only with potential failure occurring into the facility rather than out of it. Deposition of tailings would act as a buttress for the walls and thus improve the stability over time. One of the primary purposes of the perimeter embankment would be to prevent erosion of the walls due to deposition of the tailings.

3. Available materials – the process testwork discusses calcrite tailings and clayey tailings. In addition the site investigation of the pit area provides information which indicates some areas have calcrite soils and some areas have clayey soils. Even in the calcrite areas the calcrite is underlain by clayey materials. Thus the bulk of the facility base would be excavated into clayey soils. Non mineralized material from the pit area would be similar so it is expected that sufficient quantities of material for embankment construction would be available for those areas where reworking of the in-situ materials was not possible.

4. Seepage rates from the facility would be controlled by a number of factors. The following points should be highlighted:
   a. The natural groundwater level is a couple of metres below the surface. During the operation period the area would be dewatered so the water level in the pit area would be lower than the surrounding area and thus the pit would act as a local groundwater sink during the operation (ie water would flow towards the pit area). This also means the water level in the pit area would not be higher than the local groundwater system at any time during the operation or after closure.
b. The tailings would have a low permeability and would only release minimal amounts of water especially after they were air-dried and consolidated during deposition. Thus the availability of water for seepage release would be very low.

c. The studies of the natural groundwater flow in the area indicate extremely low rates of water movement so there would be no mechanism for any rapid release of seepage to be moved away from the facility.

d. After closure the water table is expected to recover back to its original levels over a very long period of time. However even when the water table recovered and groundwater flows returned to their original configuration the tailings permeability would be generally lower than the surrounding materials and thus local groundwater flows would tend to move through the surrounding materials rather than through the tailings mass itself.
MEMORANDUM

TO: Vanessa Guthrie, Executive GM, Wiluna Project, Toro Energy Limited
DATE: 28 February 2012
FROM: Dr Bob Ring
SUBJECT: Comments on Radionuclide Solubility and Mobility from Alkaline Carbonate Tailings for Toro Energy Limited - Wiluna Project

No. of Pages: 4 inclusive

Introduction
The company has requested advice on the solubility of long lived radionuclides from the U238 decay chain in relation to its tailings storage facility. Specifically;

- Where do radionuclides report during alkaline tank leach processing – ie % in ore product, % in solids and liquor tailings, % retained in circuit and final product?

- For the % that reports to tailings, how mobile/soluble would the long lived radionuclides (Th, Ra, Pb, Po) be expected to be?

- Can uranium mobilisation be used to estimate the ‘worst case scenario’ for the mobilisation of other long lived radionuclides in groundwater?

Background
The proposed Toro Energy uranium mining operation at Wiluna in central Western Australia has opted to use an alkaline leach process (carbonate, CO$_3^{2-}$) to extract uranium. Alkaline leaching is typically used with ores which either cannot be readily leached with acid, or which contain mineral phases which consume to much acid to be economical.

The proposed process will produce an alkaline tailings which will be disposed of in the mine out pits. The pits will have a pre-prepared base consisting of compacted clay. Tailings will be deposited in layers and when sufficiently dry, will be covered with inert material as part of planned rehabilitation of the site.

During 2011, ANSTO conducted testwork on a pilot metallurgical plant treating Toro Energy ore. As part of this testwork, radionuclide concentrations in a number of the process streams (solid and liquid) were determined. Information from this testwork was to be used as the basis for addressing certain specific issues, along with the experience and knowledge of the authors who have extensive experience in the area of radionuclide mobility.
ANSTO staff supervised the collection and preparation of various process streams during the pilot operations. Samples were analysed using radioanalytical techniques such as high resolution gamma spectrometry, alpha spectrometry and delayed neutron activation. The deportment of radionuclides in the pilot plant was determined using these results in combination with various process data. The main observations from this testwork are as follows:

- Uranium is readily solubilised under the alkaline leach conditions with ~94% of the uranium liberated to the alkaline leach liquor.

- Some uranium reports to the mill tailings due to incomplete washing of the leach residues and U-containing minerals which do not leach under the conditions of the alkaline leach.

- U-containing minerals not attacked during leaching are not likely to leach further in the alkaline carbonate mill tailings.

- Uranium displays much greater solubility in alkaline carbonate solutions than any of the other radionuclides in the U238 decay chain.

- Thorium radionuclides report almost exclusively (~99%) to the mill tailings due to the low solubility of thorium complexes in alkaline and alkaline carbonate solutions.

- Radium displays some solubility in alkaline carbonate solutions with ~0.2% reporting to the tailings liquor, whereas, lead and polonium display significantly less solubility with approximately <0.12 and 0.06%, respectively, reporting to the tailings liquor.
Theoretical Radionuclide Solubility

The following provides a general overview of the typical behaviour of radionuclides expected in alkaline carbonate solutions.

**Uranium**

Uranium is relatively mobile in aqueous environments owing to the stability of $\text{UO}_2^{2+}$ cations and the fact that it is readily complexed by inorganic anions such as sulphate, carbonate, phosphate etc to form soluble complexes. In alkaline carbonate media the principle uranium complex is $\text{UO}_2(\text{CO}_3)^{3-}$.

Adsorption of uranium on common mineral phases in soils under alkaline conditions would be expected, however, the literature on the adsorption of $\text{UO}_2(\text{CO}_3)^{4-}$ is scant.

**Thorium**

The mobility of thorium in aqueous environments is normally low due to the insoluble nature of the hydroxide ($\text{Th(OH)}_4$) and oxide ($\text{ThO}_2$). Even if solubilised, thorium would be expected to precipitate at pH $>$5, with the freshly precipitated $\text{Th(OH)}_{4\text{(am)}}$ ‘aging’ over time to the crystalline oxide, $\text{ThO}_2(\text{cr})$, which is even less soluble than the hydroxide. In natural groundwater of pH 5–8, thorium is colloidal and these species should be strongly adsorbed to clay minerals and organic matter.

It is likely that only a very small proportion of the thorium radionuclides present in mill tailings would be solubilised by carbonate to form soluble $\text{Th(CO}_3)^{6-}$.

**Radium**

The speciation of soluble radium is dominated by the hydrate ion (Ra$^{2+}$) and chloride and sulphate complexes, however, the solubility of all radium complexes is generally very low. Complexation by carbonate does result in solubilisation of some radium (~0.2%), as observed in the ANSTO radionuclide deportment testwork.

Mobility of radium in natural groundwaters should be expected to be low given that it can co-precipitate with alkali earth (Ca, Mg) sulphates which are regularly found in natural groundwaters. Although the exact speciation of radium in alkaline carbonate solutions is not clear, it is likely that it would be adsorbed readily onto natural soils and sediments containing iron hydroxides, quartz, muscovite, albite, clay minerals, carbonates, aluminium oxides and organic matter.
MEMORANDUM

Lead and Polonium

Complexation by carbonate does result in some solubilisation of lead (<0.12%) in alkaline carbonate solutions, as observed in the ANSTO radionuclide deportment testwork. The exact speciation of lead in alkaline carbonate solutions is not clear, however, in natural groundwaters lead should be expected to adsorb onto natural soils containing clay minerals, various metal oxides and hydroxides, and organic matter.

Polonium readily associates with precipitated solids and colloidal species. The ANSTO radionuclide deportment testwork has shown that only 0.06% of polonium is solubilised under the alkaline leach conditions proposed by Toro Energy for the Wiluna deposit.

Conclusions

- The observed behaviour of radionuclides in the U238 decay chain clearly shows that all are significantly less soluble than uranium in alkaline carbonate solutions.

- The deportment of radionuclides in the Toro Energy circuit is in broad agreement with that expected from the individual chemistries of the radionuclides.

- It is likely that low solubility would be observed for most radionuclides (excluding U238) in natural groundwaters.

- Uranium could be considered as a potential ‘worst case scenario’ indicator for radionuclide mobility from alkaline carbonate tailings management operations.
RE: ALTERNATIVE TAILINGS DISPOSAL OPTIONS

1. INTRODUCTION

The Wiluna Uranium Project is being developed by Toro Energy Ltd (Toro). Toro engaged Knight Piésold Pty Ltd (KP) to undertake the design of the tailings disposal system for the project. The project is based on mining two uranium deposits (Centipede and Lake Way deposits) located to the south / southwest of the town of Wiluna in Western Australia.

As part of the initial design stage a number of alternative tailings options were assessed prior to selecting the current design option of deposing of the tailings in the Centipede pit void.

This memo outlines and reviews the alternative options considered based on the updated design data.

2. DESIGN PARAMETERS

2.1 DESIGN DATA

The design is based on a number of design parameters provided by Toro. Other parameters were generated from testwork or based on Government regulations / guidelines. The design parameters are outlined below:

- Throughput and total tonnage
  - High grade (>250 ppm) 12.5 Mt
  - Low Grade (<250, >150 ppm) 5.4 Mt
  - Plant processing rate 1.3 Mtpa

  All ore from the Lake Way deposit will be hauled to the plant adjacent to the Centipede deposit.

- Processing System
  The ore will be processed using an agitated leach process. Leaching will be undertaken in alkaline conditions using sodium carbonate. The leach solution will then be recovered via a seven stage CCD circuit with the underflow from the final stage of the CCD’s pumped to the tailings storage facility (TSF).

- Topography
  Toro provided a detailed LIDAR survey of the area surrounding the mine site plus an approximate profile of the base of the orebody at Centipede.
• Water Management
  Toro indicated that no recycle from the TSF area would be used so the system was designed as a zero recycle system.

2.2 2011 BENCH SCALE TAILINGS TESTING

A sample of tailings from bench scale metallurgical testwork was prepared and tested by Knight Piésold Pty Ltd (KP) from May 2011 onwards. The results of the testwork were reported in KP Report “Wiluna Uranium Project – Tailings Testing” Ref. PE801-00125/04, August 2011.

The conclusions of the testwork related to the design and operation of the tailings storage facility were as follows:

• The rate of supernatant release was very low. A comparison of the rate of release to the daily evaporation rate in the Wiluna area indicated that the rate of release (mm/day) was lower than the typical daily evaporation rate even in winter. Thus no supernatant pond is expected to develop and the surface water management would only need to consider rainfall events.

• The density achieved by the tailings in the testwork varied as follows:

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Density (t/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undrained test</td>
<td>0.58</td>
</tr>
<tr>
<td>Drained test</td>
<td>0.70</td>
</tr>
<tr>
<td>Airdrying test</td>
<td>1.28</td>
</tr>
</tbody>
</table>

Based on the testing it was estimated that the density in the field would be in the range of 1.0 – 1.2 t/m³.

The permeability of the tailings was measured as follows:

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Permeability (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falling head test</td>
<td>1 – 2 x 10⁻⁸</td>
</tr>
<tr>
<td>Consolidation test – Phase 1</td>
<td>1 – 5 x 10⁻⁸</td>
</tr>
<tr>
<td>Consolidation test – Phase 2</td>
<td>5 – 9 x 10⁻⁹</td>
</tr>
</tbody>
</table>

Based on the testing it was estimated that due to the higher density achieved in the field permeabilities below 5 x 10⁻⁹ m/s would be achieved.

The low permeability indicates the seepage from the tailings during the operation and the groundwater flow through the tailings deposition after the operation is shut down would be very low.

The design and operation of the facility was based on the tailings characteristics as measured in the testwork.

3. TAILINGS STORAGE OPTIONS

3.1 GENERAL

There are four potential storage options for the Wiluna project as follows:

• Above ground storage – valley configuration.
• Above ground storage – four sided facility – single or multiple cells.
• Below ground storage in existing pits.
• Below ground storage in pit void generated during mining.
3.2 PRELIMINARY ASSESSMENT OF OPTIONS

A preliminary assessment of the options has undertaken to determine whether they were viable. The general area is shown on Figure 1. The conclusions are as follows:

**Above Ground – Valley Storage**

The area is relatively flat so there are no suitable sites for an above ground valley storage. This option was not considered any further.

**Above Ground – Four Sided Facility**

The plant site will be located close to the Centipede orebody. There is large flat areas on the site close to the plant both on the lake itself (Lake Way) and on the surrounding area. A four sided facility would be viable.

**Below Ground Storage in Existing Pits**

There is only one existing pit in the area around Lake Way. This pit is approximately halfway between the Centipede and Lake Way deposits (refer to Figure 1).

The capacity of this pit was measured based on the available topography. The results are as follows:

- 40 m deep (the base of the pit was filled with water so this is the depth to the water level).
- 735 m long.
- 200 m wide.
- 12.6 ha in area at the top.
- Capacity (to water level) = 2.95 Mm$^3$.

The project will generate a total of 17.9 Mt of high and low grade ore at an estimated density of between 1.0 and 1.2 t/m$^3$. On this basis it is considered that this pit is too small to be viable as a storage facility.

**Below Ground Storage in Pit Void Developed During Mining**

The project plans to start mining Centipede ore body followed by Lake Way ore body. As the Lake Way ore body is not mined until about halfway through the operation it was discarded as an option for tailings storage.

Centipede pit is relatively shallow and will be mined in segments. Thus areas of the pit will be available from the beginning of the plant operation. The volume of overburden plus ore removed from the pit is sufficient to allow the tailings to be stored below ground level. This is also a viable option.

3.3 CONCEPT DESIGN OF ABOVE GROUND STORAGE – FOUR SIDED

The total tonnage of tailings generated by the plant is 12.5 Mt of high grade ore and 5.4 Mt of low grade.

Based on a standard four sided 2 cell facility and a nominal 15 m thickness of tailings the facility details would be as follows:

- Height : 15 m
- Number of cells : 2
- Area (per cell) : 55 ha (740 x 740 m); Total = 110 ha
- Achieved density : 1.1 t/m$^3$
Given the tailings is radioactive it is considered that embankments would need to be modified centreline or downstream construction.

The hazard rating for the facility would be SIGNIFICANT, CATEGORY 1 (refer to Appendix A for Hazard Assessment table).

The site investigation work and information provided from site personnel indicates that there are permeable layers in the upper 1 – 3 m of the soil profile particularly in areas with calcrete. The facility will need to be located away from these areas. Notwithstanding this the facility will need an engineered base liner. As reported in KP memo “Interim Results for Phase 2 Testing”, Ref. PE801-00125 EMEM-KP003 recompacted samples from the base area below the Centipede orebody gave permeabilities of $1 \times 10^{-9}$ m/s or lower. Thus the base of the orebody could potentially be used as a borrow area for the engineered liner.

The cover design for the facility would be based on placement of sufficient thickness to reduce the radioactivity level to a suitable low level for rehabilitation.

### 3.4 CONCEPT DESIGN FOR STORAGE IN CENTIPEDE PIT VOID

A conceptual design for storage of the tailings into the Centipede pit has been undertaken (details summarised in KP memo “Tailings Testing and Storage Facility Design / Operation”, Ref. PE801-00125 EMEM-KP001).

In summary the facility would have the following parameters:

- **Height**: Below ground
- **Number of Cells**: 9
- **Area (total)**: 272 ha
- **Achieved density**: 1.2 t/m$^3$ (due to increased drying area)
- **Average thickness of tailings**: 5.5 m

Internal embankments would be required for deposition control.

The hazard rating for the facility would be SIGNIFICANT, CATEGORY 1 (refer to Appendix A for Hazard Assessment table).

Testing of undisturbed samples from the base of the pit area (refer to KP memo KP003) indicate in situ permeabilities of less than $1 \times 10^{-9}$ m/s. So treatment of the base would be limited to recompaction of materials and isolation of any localised higher permeability zones.

The cover design would be based on restoring the radioactivity to the levels that originally existed over the orebody.

### 3.5 COMPARISON OF ABOVE GROUND FOUR SIDED FACILITY TO CENTIPEDE PIT VOID STORAGE

A qualitative comparison of the two tailings storage options was undertaken and the details provided in Table 3.1.
### Table 3.1: Comparison of tailings options

<table>
<thead>
<tr>
<th>Item</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard Rating</td>
<td>Both options are rated as SIGNIFICANT however the above ground storage has a higher risk in a number of categories.</td>
</tr>
<tr>
<td>Stability</td>
<td>The Centipede pit option is a below ground facility so the stability risk is limited to internal embankments only. A potential embankment failure would still be contained in the pit void rather than being released into the environment.</td>
</tr>
<tr>
<td>Deposition Control</td>
<td>The Centipede pit void is relatively shallow (average thickness 5 – 6 m) making deposition control more difficult particularly related to maximising storage efficiency.</td>
</tr>
<tr>
<td>Base Liner and Seepage Control</td>
<td>The foundation under the Centipede pit area has a very low permeability thus minimising the required work to control seepage losses.</td>
</tr>
<tr>
<td>Long Term Erosion Stability</td>
<td>The surface of the Centipede pit area after rehabilitation will be flatter than 1V:20H. The above ground facility will have downstream embankment profiles of 1V:3-4H. Thus the Centipede pit option will be more stable.</td>
</tr>
<tr>
<td>Local Radioactivity / Contamination</td>
<td>The Centipede pit area is already contaminated by radioactivity thus placing the tailings back into the pit will not increase the area in which radioactivity is present. The above ground storage will result in a new area of radioactivity being generated.</td>
</tr>
<tr>
<td>Groundwater Impact</td>
<td>The above ground facility would isolate the tailings from the groundwater flow through the area.</td>
</tr>
<tr>
<td>Cover Design</td>
<td>Similar for both options.</td>
</tr>
</tbody>
</table>

### 4. CONCLUSION

Based on the qualitative review it was assessed that use of the Centipede pit void for tailings storage had a number of advantages over the construction of an above ground and that these advantages outweighed the disadvantages.

It should be noted that both options are viable solutions for tailings disposal for this project.

Yours faithfully

**KNIGHT PIÉSOLD PTY LTD**

**PETER VELD**
Senior Technical Consultant
## Appendix A – Phase 1 Hazard Assessment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Rating</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Uncontrolled Releases or Seepage</strong></td>
<td></td>
<td><strong>Loss of human life</strong>                                                                                                                   <strong>In Pit Option</strong> Low <strong>Above Ground Option</strong> Low <strong>Comment</strong> Water is generally saline to hypersaline in the area and is unsuitable for human use. A public drinking water source protection area (supply for Wiluna) is over 10 km north of Lake Way deposit and upgradient.</td>
</tr>
<tr>
<td><strong>Loss of stock</strong></td>
<td></td>
<td><strong>In Pit Option</strong> Low <strong>Above Ground Option</strong> Low <strong>Comment</strong> Water saline to hypersaline and unsuitable for use.</td>
</tr>
<tr>
<td><strong>Environmental damage</strong></td>
<td></td>
<td><strong>In Pit Option</strong> Low to Significant <strong>Above Ground Option</strong> Significant <strong>Comment</strong> Potential damage to local environment. The site does not contain any Threatened Ecological Communities but some Priority Ecological Communities potentially intersect the project. Above ground option impact higher due to potential surface release</td>
</tr>
<tr>
<td><strong>Embankment Failure</strong></td>
<td></td>
<td><strong>Loss of human life</strong>                                                                                                                   <strong>In Pit Option</strong> Low <strong>Above Ground Option</strong> Low <strong>Comment</strong> Tailings will be stored below ground so only internal embankments have any potential risk – area will be controlled access only with no public access allowed.</td>
</tr>
<tr>
<td><strong>Direct economic loss</strong></td>
<td></td>
<td><strong>In Pit Option</strong> Low to Significant <strong>Above Ground Option</strong> Significant <strong>Comment</strong> The facility will have multiple cells available for disposal – economic impact of embankment failure would be low to appreciable. Above ground option would involve higher cost impact for repairs / replacement</td>
</tr>
<tr>
<td><strong>Indirect economic loss</strong></td>
<td></td>
<td><strong>In Pit Option</strong> Low <strong>Above Ground Option</strong> Low <strong>Comment</strong> Multiple cells available so repairs to storage will be practicable.</td>
</tr>
</tbody>
</table>
Based on the assessment the TSF hazard rating for both options would be SIGNIFICANT. From the hazard rating and height of the storage the in pit option facility would be rated as CATEGORY 2. The above ground option would be rated as CATEGORY 1.

Phase 2 Assessment

The tailings would be classified as a naturally occurring radioactive material (NORM) and thus will require a Radioactive Waste Management Plan. It should be noted that removal of the uranium will only reduce the radioactivity to about 80-90% of the radioactivity of the original ore.

Based on the frequency of monitoring required for radioactivity both facility options would effectively be classified as CATEGORY 1.
RE: SITE INVESTIGATION – INTERIM RESULTS OF PHASE 2 TESTING

1. INTRODUCTION

The Wiluna Uranium Project is being developed by Toro Energy Ltd (Toro). The project is based on mining two uranium deposits (Centipede and Lake Way deposits) located to the south / southwest of the town of Wiluna in Western Australia.

It is currently proposed to store the tailings generated from the process into the Centipede pit void.

As part of the design work a site investigation is being undertaken to examine the soil types, permeabilities and suitability for use in construction of the foundation materials over, under and adjacent to the orebody.

2. SITE INVESTIGATION PROGRAMME

This investigation consists of three components as follows:

- Phase 1 – obtain existing information from previous geological investigation work.
- Phase 2 – undertaken permeability testing of existing drill core samples.
- Phase 3 – field and laboratory testwork assessing geotechnical parameters and characteristics.

Phase 1

Logs of existing drillholes have been obtained from Toro. These primarily target the orebody but do extend into the underlying foundation. Figure 1 shows the location of all of the boreholes obtained to date. The information is currently being assessed to determine the variability of the foundation material across the base of the orebody.

Phase 2

As part of the geological investigation of the orebody cored samples were taken. The cores were inspected and six suitable sections were selected for permeability testing (as shown on Figure 1). In addition samples from some of the boreholes were broken down and recompacted and the permeability of the recompacted samples also tested.

It should be noted that the holes were drilled several months prior to the samples being tested.
Phase 3

The Phase 3 testing will target determination of the suitability of materials for construction purposes, investigation of the area around the perimeter of the orebody and confirmation of the foundation permeabilities.

The testing will consist of four categories as follows:

- Boreholes just outside the orebody area (15 m depth) – these will be logged, packer tests done at a shallow (4-5 m) and deep level (8-10 m). Undisturbed samples will also be taken for laboratory permeability testing.
- Boreholes inside the orebody area (15 m depth) – these will be logged, packer tests done at a deep level only (8-15 m). An undisturbed sample will also be taken for laboratory permeability testing. Two of the locations are adjacent to the locations of the current permeability testing areas to assess consistency of results. Some of the core will be sent to the lab for grading, Atterberg and compaction / permeability testing.
- Testpits outside the orebody area – these will extend to the limits of the machine (target 5+ m) and will be logged to examine variability in the profile and develop an understanding of the profile through the nominal perimeter embankments. Samples will be taken for grading, Atterberg and compaction / permeability testing.
- Testpits on the orebody – these will be shallow and terminate at the top of the orebody. Samples will be taken for grading, Atterberg and compaction / permeability testing. The data will be used to assess the suitability of the surface materials for use in embankments, erosion resistance and radiation control layer.

The proposed location of the boreholes and testpits are shown on Figure 2. The phase 3 investigation will be modified depending on the results of the Phase 1 and Phase 2 assessment.

3. RESULTS OF PHASE 2 PERMEABILITY TESTING

The permeability testing of the “undisturbed” and remoulded samples is almost complete. The test results are provided in Table 3.1 and the test sheets are located in Appendix A.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Condition</th>
<th>Dry Density (t/m³)</th>
<th>Moisture Content (%)</th>
<th>Coefficient of Permeability (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPS171</td>
<td>Depth : 8.8 - 8.9m</td>
<td>Undisturbed</td>
<td>1.489</td>
<td>28.1</td>
</tr>
<tr>
<td>CPS164</td>
<td>Depth : 8.7 - 8.8m</td>
<td>Undisturbed</td>
<td>2.174</td>
<td>10.2</td>
</tr>
<tr>
<td>CPS099</td>
<td>Depth : 7.4 - 7.5m</td>
<td>Undisturbed</td>
<td>1.944</td>
<td>14.9</td>
</tr>
<tr>
<td>CPS096</td>
<td>Depth : 7.7 - 7.8m</td>
<td>Undisturbed</td>
<td>1.869</td>
<td>17.9</td>
</tr>
<tr>
<td>CPS091</td>
<td>Depth : 7.8 - 7.9m</td>
<td>Remoulded</td>
<td>1.586</td>
<td>18.7</td>
</tr>
<tr>
<td>CPS147</td>
<td>Depth : 7.6 - 7.7m</td>
<td>Remoulded</td>
<td>1.555</td>
<td>19.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remoulded</td>
<td>1.663</td>
<td>16.3</td>
</tr>
</tbody>
</table>
The results indicate that the vertical permeability of the in situ foundation materials is very low. In addition low permeabilities are also achievable if the material is scarified and recompacted. The range of results are presented in Figure 3.

4. CONCLUSIONS

As the Phase 2 samples are from core that has been exposed for a number of months prior to the testing it will be necessary to confirm the results with new “undisturbed” samples. This will be done as part of the Phase 3 testwork. Notwithstanding this it is considered that the Phase 2 testing does indicate that the permeability of the foundation zone directly under the orebody is generally below $1 \times 10^{-9}$ m/s.

Yours faithfully

KNIGHT PIÉSOLD PTY LTD

PETER VELD
Senior Technical Consultant
FIGURES
Summary of testing Figure A4

WILUNA URANIUM PROJECT
TAILINGS STORAGE FACILITY
PERMEABILITY RESULTS

PERMEABILITY RESULTS

1.00E-10
1.00E-09
1.00E-08

Coefficient of Permeability (m/s)

Dry Density (t/m³)

1 1.2 1.4 1.6 1.8 2 2.2 2.4

Insitu undisturbed
Insitu remoulded
APPENDIX A

Laboratory Results
Determination of Permeability of a Soil
Constant Head Method using a Flexible Wall Permeameter
-acCORDING TO AS 1289.6.7.3 - 1999

CLIENT : Knight Piésold Pty Ltd
JOB NO : 1112470
PROJECT : Wiluna Permeability Study
LOCATION : Wiluna
Sample Id : CPS171, Depth : 8.8 - 8.9m
Lab No. : TT 06470001
Test Type : Constant Head, Flexible Wall
Date Tested : Feb-2012

SPECIMEN DETAILS
Sample Description : Mod. Brownish Orange, Clayey Sand (med. Gr.)
Sample Type : nom. 60mm Ø sub-core taken insitu core sample
Dry Density - Initial : 1.473 t/m³
Moisture Content - Initial : 23.2 %
Dry Density - @ Test : 1.489 t/m³
Moisture Content - Final : 28.1 %

TEST DETAILS
Specimen Diameter - @ Test : 60.2 mm
Length / Diameter Ratio - @ Test : 1.53
Filter Thickness (Bottom / Top) : 11 / 11 mm
Percolation Head of Water : 720 mm
Effective Confining Stress : 100.3 kPa
Permeant Used : Distilled Water
Temperature at Test : 22 °C

TEST DETAILS
Coefficient of Permeability : 4.3 x 10⁻¹⁰ m/sec

Notes : Sample supplied by Client

Authorised Signatory : ____________________________
Date : 18/02/2012
(S. Brodie)
Form No TXL/51/BA 06/1 R
Determination of Permeability of a Soil

Constant Head Method using a Flexible Wall Permeameter

-acording to AS 1289.6.7.3 - 1999

CLIENT : Knight Piésold Pty Ltd
JOB NO : 1112470
PROJECT : Wiluna Permeability Study
LOCATION : Wiluna
Sample Id : CPS164, Depth : 8.7 - 8.8m
Lab No. : TT 06470002
Test Type : Constant Head, Flexible Wall
Date Tested : Feb-2012

SPECIMEN DETAILS

Sample Description : Mod. Yellowish Brown, Silty Sand with Clay (med - coarse Gr.)

Sample Type : nom. 60mm Ø sub-core taken insitu core sample

Dry Density - Initial : 2.165 t/m³
Moisture Content - Initial : 6.5 %
Dry Density - @ Test : 2.174 t/m³
Moisture Content - Final : 10.2 %

TEST DETAILS

Specimen Diameter - @ Test : 60.3 mm
Length / Diameter Ratio - @ Test : 1.53
Filter Thickness (Bottom / Top) : 11 / 11 mm
Percolation Head of Water : 720 mm
Effective Confining Stress : 100.3 kPa
Permeant Used : Distilled Water
Temperature at Test : 22 °C

TEST DETAILS

Coefficient of Permeability : 8.7 x 10⁻¹⁰ m / sec

Notes : Sample supplied by Client

Authorised Signatory : ( S. Brodie )
Date : 18/02/2012
Form No TXL/51/BA 06/1 R
Determination of Permeability of a Soil  
Constant Head Method using a Flexible Wall Permeameter  
-according to AS 1289.6.7.3 - 1999

CLIENT : Knight Piésold Pty Ltd  
JOB NO : 1112470

PROJECT : Wiluna Permeability Study  
LOCATION : Wiluna

Sample Id : CPS099, Depth : 7.4 - 7.5m  
Lab No. : TT 06470003

Test Type : Constant Head, Flexible Wall  
Date Tested : Feb-2012

SPECIMEN DETAILS
Sample Description : Mod. Brownish Orange, Sandy Clayey Silt (fine Gr.)

Sample Type : nom. 60mm Ø sub-core taken insitu core sample
Dry Density - Initial : 1.919 t/m³
Moisture Content - Initial : 14.2 %
Dry Density - @ Test : 1.944 t/m³
Moisture Content - Final : 14.9 %

TEST DETAILS
Specimen Diameter - @ Test : 60.0 mm
Length / Diameter Ratio - @ Test : 1.53
Filter Thickness (Bottom / Top) : 11 / 11 mm
Percolation Head of Water : 720 mm
Effective Confining Stress : 100.3 kPa
Permeant Used : Distilled Water
Temperature at Test : 22 °C

TEST DETAILS
Coefficient of Permeability : 6.6 x 10⁻¹⁰ m / sec

Notes : Sample supplied by Client

Authorised Signatory : ______________________  Date : 18/02/2012
(S. Brodie)  Form No TXL/51/BA 06/1 R
Determination of Permeability of a Soil
Constant Head Method using a Flexible Wall Permeameter
-according to AS 1289.6.7.3 - 1999

CLIENT: Knight Piésold Pty Ltd
PROJECT: Wiluna Permeability Study
Sample Id: CPS096, Depth: 7.7 - 7.8m
Test Type: Constant Head, Flexible Wall

Specimen Details:
Sample Description: Mod. Brownish Orange, Silty Sand with Clay (med. Gr.)
Sample Type: nom. 60mm Ø sub-core taken insitu core sample
Dry Density - Initial: 1.845 t/m³
Moisture Content - Initial: 14.8 %
Dry Density - @ Test: 1.869 t/m³
Moisture Content - Final: 17.9 %

Test Details:
Specimen Diameter - @ Test: 59.9 mm
Length / Diameter Ratio - @ Test: 1.53
Filter Thickness (Bottom / Top): 11 / 11 mm
Percolation Head of Water: 720 mm
Effective Confining Stress: 100.3 kPa
Permeant Used: Distilled Water
Temperature at Test: 22 °C

Coefficient of Permeability: 1.0 x 10^-09 m/sec

Notes: Sample supplied by Client

Authorised Signatory: ____________________
(S. Brodie)
Date: 18/02/2012
Form No TXL/51/BA 06/1 R
Determination of Permeability of a Soil
Constant Head Method using a Flexible Wall Permeameter
-according to AS 1289.6.7.3 - 1999

SPECIMEN DETAILS
Sample Description : Mod. Brownish Orange, Silty Clayey Sand (fine - med. Gr.)
Sample Type : nom. 60mm Ø sub-core taken from remoulded sample
Dry Density - Initial : 1.586 t/m³
Moisture Content - Initial : 18.7 %
Dry Density - @ Test : t/m³
Moisture Content - Final :%

TEST DETAILS
Specimen Diameter - @ Test : 60.3 mm
Length / Diameter Ratio - @ Test : 1.53
Filter Thickness (Bottom / Top) : 11 / 11 mm
Percolation Head of Water : 720 mm
Effective Confining Stress : 100.3 kPa
Permeant Used : Distilled Water
Temperature at Test : 22 °C

TEST DETAILS
Coefficient of Permeability : 8.7 x 10⁻¹⁰ m / sec

Notes : Sample supplied by Client
Specimen remoulded to estimated 95% SMDD & 100% OMC
Determination of Permeability of a Soil
Constant Head Method using a Flexible Wall Permeameter

-according to AS 1289.6.7.3 - 1999

CLIENT : Knight Piésold Pty Ltd
JOB NO : 1112470
PROJECT : Wiluna Permeability Study
LOCATION : Wiluna
Sample Id : CPS091, Depth : 7.8 - 7.9m
Lab No. : TT 06470005B
Test Type : Constant Head, Flexible Wall
Date Tested : Feb-2012

SPECIMEN DETAILS
Sample Description : Mod. Brownish Orange, Silty Clayey Sand (fine - med. Gr.)

Sample Type : nom. 60mm Ø sub-core taken from remoulded sample
Dry Density - Initial : 1.745 t/m³
Moisture Content - Initial : 15.3 %
Dry Density - @ Test :
Moisture Content - Final :

TEST DETAILS
Specimen Diameter - @ Test : 60.3 mm
Length / Diameter Ratio - @ Test : 1.53
Filter Thickness (Bottom / Top) : 11 / 11 mm
Percolation Head of Water : 720 mm
Effective Confining Stress : 100.3 kPa
Permeant Used : Distilled Water
Temperature at Test : 22 °C

TEST DETAILS
Coefficient of Permeability : $6.5 \times 10^{-10}$ m / sec

Notes : Sample supplied by Client
Specimen remoulded to estimated 100% MMDD & 100% OMC

INTERIM TEST REPORT ONLY
Determination of Permeability of a Soil
Constant Head Method using a Flexible Wall Permeamaneter
-according to AS 1289.6.7.3 - 1999

<table>
<thead>
<tr>
<th>CLIENT</th>
<th>Knight Piésold Pty Ltd</th>
<th>JOB NO</th>
<th>1112470</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROJECT</td>
<td>Wiluna Permeability Study</td>
<td>LOCATION</td>
<td>Wiluna</td>
</tr>
<tr>
<td>Sample Id</td>
<td>CPS147, Depth: 7.6 - 7.7m</td>
<td>Lab No.</td>
<td>TT 06470006A</td>
</tr>
<tr>
<td>Test Type</td>
<td>Constant Head, Flexible Wall</td>
<td>Date Tested</td>
<td>Feb-2012</td>
</tr>
</tbody>
</table>

**SPECIMEN DETAILS**

Sample Description: Mod. Brown, Clayey Silty Sand (fine - med. Gr.)

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>nom. 60mm Ø sub-core taken from remoulded sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Density - Initial</td>
<td>1.555 t/m³</td>
</tr>
<tr>
<td>Moisture Content - Initial</td>
<td>19.2 %</td>
</tr>
<tr>
<td>Dry Density - @ Test</td>
<td>t/m³</td>
</tr>
<tr>
<td>Moisture Content - Final</td>
<td>%</td>
</tr>
</tbody>
</table>

**TEST DETAILS**

<table>
<thead>
<tr>
<th>Specimen Diameter - @ Test</th>
<th>60.3 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length / Diameter Ratio - @ Test</td>
<td>1.53</td>
</tr>
<tr>
<td>Filter Thickness (Bottom/Top)</td>
<td>11/11 mm</td>
</tr>
<tr>
<td>Percolation Head of Water</td>
<td>720 mm</td>
</tr>
<tr>
<td>Effective Confining Stress</td>
<td>100.3 kPa</td>
</tr>
<tr>
<td>Permeant Used</td>
<td>Distilled Water</td>
</tr>
<tr>
<td>Temperature at Test</td>
<td>22 °C</td>
</tr>
</tbody>
</table>

**TEST DETAILS**

Coefficient of Permeability: $7.4 \times 10^{-10}$ m/sec

Notes: Sample supplied by Client
Specimen remoulded to estimated 95% SMDD & 100% OMC

INTERIM TEST REPORT ONLY
**REPORT CERTIFICATE**

**Determination of Permeability of a Soil**

Constant Head Method using a Flexible Wall Permeameter

-according to AS 1289.6.7.3 - 1999

---

<table>
<thead>
<tr>
<th>CLIENT</th>
<th>Knight Piésold Pty Ltd</th>
</tr>
</thead>
<tbody>
<tr>
<td>JOB NO</td>
<td>1112470</td>
</tr>
<tr>
<td>PROJECT</td>
<td>Wiluna Permeability Study</td>
</tr>
<tr>
<td>LOCATION</td>
<td>Wiluna</td>
</tr>
<tr>
<td>Sample Id</td>
<td>CPS147, Depth: 7.6 - 7.7m</td>
</tr>
<tr>
<td>Lab No.</td>
<td>TT 06470006B</td>
</tr>
<tr>
<td>Test Type</td>
<td>Constant Head, Flexible Wall</td>
</tr>
<tr>
<td>Date Tested</td>
<td>Feb-2012</td>
</tr>
</tbody>
</table>

**SPECIMEN DETAILS**

Sample Description: Mod. Brown, Clayey Silty Sand (fine - med. Gr.)

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>nom. 60mm Ø sub-core taken from remoulded sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Density - Initial</td>
<td>1.663 t/m³</td>
</tr>
<tr>
<td>Moisture Content - Initial</td>
<td>16.3 %</td>
</tr>
<tr>
<td>Dry Density - @ Test</td>
<td>t/m³</td>
</tr>
<tr>
<td>Moisture Content - Final</td>
<td>%</td>
</tr>
</tbody>
</table>

**TEST DETAILS**

Specimen Diameter - @ Test: 60.3 mm

Length / Diameter Ratio - @ Test: 1.53

Filter Thickness (Bottom / Top): 11 / 11 mm

Percolation Head of Water: 720 mm

Effective Confining Stress: 100.3 kPa

Permeant Used: Distilled Water

Temperature at Test: 22 °C

**TEST DETAILS**

Coefficient of Permeability: $5.3 \times 10^{-10}$ m / sec

---

Notes: Sample supplied by Client
Specimen remoulded to estimated 100% MMDD & 100% OMC

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**INTERIM TEST REPORT ONLY**
RE: WILUNA PRELIMINARY TAILINGS PHYSICAL TESTING RESULTS

1. 2011 BENCH SCALE TAILINGS TESTING

A sample of tailings from bench scale metallurgical testwork was prepared and tested by Knight Piésold Pty Ltd (KP) from May 2011 onwards. The results of the testwork were reported in KP Report “Wiluna Uranium Project – Tailings Testing” Ref. PE801-00125/04, August 2011.

The conclusions of the testwork related to the design and operation of the tailings storage facility were as follows:

- The rate of supernatant release was very low. A comparison of the rate of release to the daily evaporation rate in the Wiluna area indicated that the rate of release (mm/day) was lower than the typical daily evaporation rate even in winter. Thus no supernatant pond is expected to develop and the surface water management would only need to consider rainfall events.

- The density achieved by the tailings in the testwork varied as follows:

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Density (t/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undrained test</td>
<td>0.58</td>
</tr>
<tr>
<td>Drained test</td>
<td>0.70</td>
</tr>
<tr>
<td>Airdrying test</td>
<td>1.28</td>
</tr>
</tbody>
</table>

Based on the testing it was estimated that the density in the field would be in the range of 1.0 – 1.2 t/m³.

The permeability of the tailings was measured as follows:

- Falling head test   1 – 2 x 10⁻⁸ m/s.
- Consolidation test – Phase 1 1 – 5 x 10⁻⁸ m/s.
- Consolidation test – Phase 2 5 – 9 x 10⁻⁹ m/s.

Based on the testing it was estimated that due to the higher density achieved in the field as permeabilities below 5 x 10⁻⁹ m/s would be achieved.

The low permeability indicates the seepage from the tailings during the operation and the groundwater flow through the tailings deposit after the operation shutdown would be very low.

The design and operation of the facility was based on the tailings characteristics as measured in the testwork.
2. LATE 2011 – EARLY 2012 PILOT PLANT – TAILINGS TESTING

In 2012 the metallurgical testwork advanced and a pilot plant was constructed and operated.

The ore consists of two different types. The first is a calcrete ore type labelled as “WU100”; the second is a clay ore type labelled as “WU200”. The metallurgical testwork indicated that a blend of the two ore types gave the best recovery. On this basis a tailings sample was generated based on an approximate 50:50 blend labelled as WU100/200.

This sample was sent to KP for testing. In addition samples of WU100 and WU200 were also tested so that if the blend needed to be varied estimates of the changes in tailings behaviour could be made.

Due to the slow settling and drying characteristics of the samples this testing is still in progress at this time. This memo provides interim results and compares the results to date to the tailings sample tested in May 2011 to determine whether there are any significant differences which may impact the design.

3. TESTING RESULTS

3.1 GENERAL

The following discusses the physical testing results for the tailings sample. Predicted tailings behaviour is discussed in Section 4; however, it should be noted that field results are also dependent on the processing plant operation, layout of the proposed storage facilities and climatic variations.

The following tests were carried out on the sample:

- Classification tests to determine:
  - Particle size distribution of the tailings;
  - Supernatant liquor density;
  - Liquid and plastic limits of the tailings solids;
  - Tailings solids particle density.
- Viscosity tests;
- Undrained and drained sedimentation tests;
- Air drying tests;
- Permeability tests;
- Consolidation tests.

During laboratory testing it is Knight Piesold’s normal practice to duplicate each test as a means to verify the consistency of the test results. The interpreted mean values are given in the tables and text of the document. A brief description of the method employed in each test is also provided.

The samples were received as a thick paste from the pilot plant test work at the proposed percent solids for the plant site operation. It was considered that at the proposed %solids used in the pilot plant there would be pumping issues due to the high viscosity. Viscosity tests were performed to select a slightly lower percent solids in order to allow efficient pumping to the TSF. Rheology test work has been planned at the completion of the current test work.
3.2 CLASSIFICATION TESTING

Classification tests were carried out on the sample as follows:

- Supernatant Density – density of the liquor was measured using a hydrometer. A measured value of 1.052 was recorded.
- Supernatant pH – the pH of the supernatant was measured using a pH meter as 8.09.
- Specific Gravity – for the purposes of this testwork a value of 2.85 was used.

3.3 VISCOSITY

The viscosity of tailings slurry is related to the solids content of the slurry. Laboratory measurement of the viscosity of the slurry at varying solids contents was conducted using the Marsh Flow Cone Apparatus. The critical solids content provides an indication of the approximate upper limit of the range in which the slurry can be pumped using standard pumping equipment before efficiencies begin to reduce.

Table 3.1: Percent solids of tailings samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>As Received (% solids)</th>
<th>Critical Range (% solids)</th>
<th>Tested Value (% solids)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WU 100/200</td>
<td>46</td>
<td>33 – 39</td>
<td>40</td>
</tr>
<tr>
<td>WU 100</td>
<td>57</td>
<td>40 – 48</td>
<td>49</td>
</tr>
<tr>
<td>WU 200</td>
<td>35</td>
<td>27 – 33</td>
<td>32</td>
</tr>
</tbody>
</table>

The previous testing was performed at about 38% solids.

3.4 SEDIMENTATION TESTS

Drained and undrained sedimentation tests were carried out to determine the settling rate, volume of supernatant, and settled dry density of the tailings. The results of the sedimentation tests are presented in Table 3.2 presents a summary of the measured sedimentation data.

Table 3.2: Sedimentation test results

<table>
<thead>
<tr>
<th>Sample</th>
<th>Test</th>
<th>Initial Solids (%)</th>
<th>Supernatant (% of initial water volume)</th>
<th>Underdrainage (% of initial water volume)</th>
<th>Time to Achieve (days)</th>
<th>90% of total density increase (days)</th>
<th>Final Density (t/m3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2011</td>
<td>Undrained</td>
<td>38</td>
<td>10</td>
<td>-</td>
<td>34</td>
<td>60+</td>
<td>0.58</td>
</tr>
<tr>
<td>Sample</td>
<td>Drained</td>
<td>40</td>
<td>6</td>
<td>11</td>
<td>26</td>
<td>32</td>
<td>0.70</td>
</tr>
<tr>
<td>WU 100/200</td>
<td>Undrained</td>
<td>40</td>
<td>20</td>
<td>-</td>
<td>5</td>
<td>6</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>Drained</td>
<td>40</td>
<td>12</td>
<td>29</td>
<td>13</td>
<td>15</td>
<td>0.86</td>
</tr>
<tr>
<td>WU 100</td>
<td>Undrained</td>
<td>50</td>
<td>15</td>
<td>-</td>
<td>4</td>
<td>5</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>Drained</td>
<td>49</td>
<td>8</td>
<td>24</td>
<td>8</td>
<td>12</td>
<td>0.94</td>
</tr>
<tr>
<td>WU 200</td>
<td>Undrained</td>
<td>31</td>
<td>12</td>
<td>-</td>
<td>5</td>
<td>6</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>Drained</td>
<td>32</td>
<td>8</td>
<td>26</td>
<td>15</td>
<td>20</td>
<td>0.62</td>
</tr>
</tbody>
</table>
The tests indicate that the tailings samples have slow settling characteristics taking around 6 days to complete. The sample releases approximately 12 – 20% of the water in slurry to supernatant.

The settled densities achieved are low. There is a slight increase in settled density compared to the May 2011 samples.

3.5 AIR DRYING TESTS

Air drying tests were carried out on slurry samples to determine the effect of air drying on the tailings after initial settling and removal of supernatant liquor, thereby simulating conditions expected following sub-aerial deposition. Continuous monitoring of the weight and volume of each specimen was carried out in order to quantify the relationship between dry density, moisture content, volumetric change and the degree of saturation of the tailings.

The results of air drying tests are summarised in Table 3.3.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Moisture Content at Breakaway Point (% MC)</th>
<th>Dry Density at Breakaway Point (t/m³)</th>
<th>Limiting Saturation Value (% Sat)</th>
<th>Final Dry Density (t/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UC 100/200</td>
<td>55</td>
<td>1.15</td>
<td>55</td>
<td>1.23</td>
</tr>
<tr>
<td>May 2011 Sample</td>
<td>130</td>
<td>0.65</td>
<td>70</td>
<td>1.28</td>
</tr>
<tr>
<td>WU 100</td>
<td>45</td>
<td>1.25</td>
<td>40</td>
<td>1.32</td>
</tr>
<tr>
<td>WU 200</td>
<td>75</td>
<td>1.10</td>
<td>55</td>
<td>1.24</td>
</tr>
</tbody>
</table>

Air-drying of the tailings significantly improves the achieved dry density compared to the sedimentation test. The increase is approximately 50% - 80%. The air-drying of the tailings is still slow with the samples taking approximately 15 days at an evaporation rate of 10 mm/day to achieve final density. At Wiluna, the evaporation rate varies seasonally from 4 to 15 mm/day. In the design of the TSF, the drying time will need to be adjusted to suit the actual monthly evaporation rates as well as the exposed beach area and throughput rate.

3.6 PERMEABILITY TESTS

Falling head permeability tests were completed on saturated tailings samples with drainage through the drained sedimentation sample being measured. In addition, permeability values were derived from the results of consolidation tests. Results are summarised in Table 3.4.
Table 3.4: Permeability test results

<table>
<thead>
<tr>
<th>Sample</th>
<th>Test Type</th>
<th>Dry Density (t/m³)</th>
<th>Permeability (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2011 Sample</td>
<td>Falling Head</td>
<td>0.72</td>
<td>1.6 x 10⁻⁸</td>
</tr>
<tr>
<td></td>
<td>Consolidation Test – Phase 1 and Phase 2</td>
<td>0.61</td>
<td>3.4 x 10⁻⁷</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.69</td>
<td>1.5 x 10⁻⁸</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.72</td>
<td>4.7 x 10⁻⁹</td>
</tr>
<tr>
<td>WU 100/200</td>
<td>Falling Head</td>
<td>0.86</td>
<td>7.1 x 10⁻⁸</td>
</tr>
<tr>
<td></td>
<td>Consolidation Test – Phase 1</td>
<td>0.74</td>
<td>1.1 x 10⁻⁷</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.79</td>
<td>2.8 x 10⁻⁸</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Still in progress</td>
<td></td>
</tr>
<tr>
<td>WU 100</td>
<td>Falling Head</td>
<td>0.94</td>
<td>1.0 x 10⁻⁷</td>
</tr>
<tr>
<td>WU 200</td>
<td>Falling Head</td>
<td>0.62</td>
<td>4.4 x 10⁻⁸</td>
</tr>
</tbody>
</table>

These results represent the permeability of saturated tailings prior to additional consolidation due to additional deposition loading or air-drying. The permeability is expected to decrease further at higher densities. In the range of expected settled densities, the permeability is likely to be less than 1.0 x 10⁻⁸ m/s indicating low permeability tailings.

4. PREDICTED PHYSICAL BEHAVIOUR OF TAILINGS

Based on the physical testing of the sample, the following predicted behaviour is expected for the tailings. It should be noted that field results are also dependent on the processing plant operation, layout of the proposed storage facilities and climatic variations. Generally the WU100/200 sample closely reflects all the properties tested in May 2011 for parameters such as water release, densities and permeability.

4.1 WATER PRODUCTION

The release of water following deposition of the tailings can be estimated from the results of drained and undrained sedimentation tests. The rate of release compared to the daily evaporation will determine whether a supernatant pond forms in the facility. The testing indicated that the rate of supernatant release is very low. The evaporation rates in the Wiluna area vary from a maximum of about 15 mm/day in summer to a minimum of about 4 mm/day in the winter. As the rate of supernatant production is lower than the daily evaporation rate typically all of the supernatant would evaporate with no runoff. Thus the surface water management would only need to consider rainfall events.

4.2 TAILINGS DENSITY

The settled dry density of tailings deposited into the storage facility can be predicted from laboratory testing. The test results indicated that the tailings reached very low dry densities from settling with a significant improvement due to air-drying of the sample. It has been observed over a number of years that densities achieved in the field are generally lower than those obtained in the laboratory. In addition, field densities achieved are dependent on the area available for drying and the thickness of deposited layers. The area / rate of rise requirement is even more critical for very low drying tailings. A suitable deposition plan and efficient operation of the facility can greatly improve settled density.
Assuming that sufficient area is available and the facility is efficiently operated, it is estimated that the average settled density for the facility could be as high as 1.0 – 1.2 t/m³.

Yours faithfully
KNIGHT PIÉSOLD PTY LTD

PETER VELD
Senior Technical Consultant
RE: TAILINGS TESTING AND STORAGE FACILITY DESIGN / OPERATION

1. INTRODUCTION

The Wiluna Uranium Project is being developed by Toro Energy Ltd (Toro). Toro engaged Knight Piésold Pty Ltd (KP) to undertake the design of the tailings disposal system for the project.

The project is based on mining two uranium deposits (Centipede and Lake Way deposits) located to the south / southwest of the town of Wiluna in Western Australia.

2. DESIGN PARAMETERS

2.1 DESIGN DATA

The design is based on a number of design parameters provided by Toro. Other parameters were generated from testwork or based on Government regulations / guidelines. The design parameters are outlined below:

- Throughput and total tonnage
  - High grade (>250 ppm) 12.5 Mt
  - Low Grade (<250, >150 ppm) 5.4 Mt
  - Plant processing rate 1.3 Mtpa

  All ore from the Lake Way deposit will be hauled to the plant adjacent to the Centipede deposit with the tailings disposed of in the Centipede TSF.

- Processing System
  - The ore will be processed using an agitated leach process. Leaching will be undertaken in alkaline conditions using sodium carbonate. The leach solution will then be recovered via a seven stage CCD circuit with the underflow from the final stage of the CCD’s pumped to the tailings storage facility (TSF).

- Topography
  - Toro provided a detailed LIDAR survey of the area surrounding the mine site plus an approximate profile of the base of the orebody at Centipede.

- Tailings Disposal Principles
  - In Toro’s “Environmental Scoping Document”, June 2010 Toro committed to disposing of the tailings back into the pit specifically below existing ground levels. This was incorporated into the design concepts.

- Water Management
  - Toro indicated that no recycle from the TSF area would be used so the system was designed as a zero recycle system.
2.2 TAILINGS STORAGE FACILITY HAZARD RATING

2.2.1 General

In accordance with the WA Guidelines the Hazard Rating for the TSF was assessed. This was assessed in two phases. Phase 1 assessed the facility in accordance with “Guidelines on the Safe Design and Operating Standards for Tailings Storage” DMP May 1999 and “Water Quality Protection Guidelines No. 2 – Mining and Mineral Processing – Tailings Facilities” 2000. The second phase considered additional hazards resulting from the radioactivity of the tailings in accordance with “Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing” Radiation Protection Series No. 9 ARPANSA and “Managing naturally occurring radioactive material (NORM) in mining and mineral processing – guideline” NORM 4.2 DMP 2010.

2.2.2 Phase 1 Assessment

The Hazard rating for the TSF was rated as SIGNIFICANT based on the criteria as provided in Table 2.1.
### Table 2.1: Hazard Assessment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Rating</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Uncontrolled Releases or Seepage</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of human life</td>
<td>Low</td>
<td>Water is generally saline to hypersaline in the area and is unsuitable for human use. A public drinking water source protection area (supply for Wiluna) is over 10 km north of Lake Way deposit and upgradient.</td>
</tr>
<tr>
<td>Loss of stock</td>
<td>Low</td>
<td>Water saline to hypersaline and unsuitable for use.</td>
</tr>
<tr>
<td>Environmental damage</td>
<td>Low to Significant</td>
<td>Potential damage to local environment. The site does not contain any Threatened Ecological Communities but some Priority Ecological Communities potentially intersect the project.</td>
</tr>
<tr>
<td><strong>Embankment Failure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of human life</td>
<td>Low</td>
<td>Tailings will be stored below ground so only internal embankments have any potential risk – area will be controlled access only with no public access allowed.</td>
</tr>
<tr>
<td>Direct economic loss</td>
<td>Low to Significant</td>
<td>The facility will have multiple cells available for disposal – economic impact of embankment failure would be low to appreciable.</td>
</tr>
<tr>
<td>Indirect economic loss</td>
<td>Low</td>
<td>Multiple cells available so repairs to storage will be practicable.</td>
</tr>
</tbody>
</table>

Based on the assessment the TSF hazard rating would be **SIGNIFICANT**. From the hazard rating and height of the storage the facility would be rated as **CATEGORY 2**.

#### 2.2.3 Phase 2 Assessment

The tailings would be classified as a naturally occurring radioactive material (NORM) and thus will require a Radioactive Waste Management Plan. It should be noted that removal of the uranium will only reduce the radioactivity to about 80-90% of the radioactivity of the original ore.

Based on the frequency of monitoring required for radioactivity the facility would effectively be classified as **CATEGORY 1**.
2.2.4 TSF Hazard Rating

Based on the most critical requirements outlined above the TSF is assessed as follows:

- SIGNIFICANT hazard rating.
- CATEGORY 1 (design and operating requirements).
- Radioactive Waste Management Plan required.

2.3 CLIMATE

The climate at the site can be described as semi arid with hot summers and mild winters. The average annual rainfall is 255 mm while the average annual evaporation is about 3400 mm. A 1 in 100 year 72 hour storm generates about 230 mm of rainfall.

2.4 SEISMICITY

The site has a relatively low seismicity and the following parameters were selected for design:

- Operating Basis Earthquake (OBE) = 0.05g (10% exceedance probability in 50 years).
- Maximum Design Earthquake (MDE) = 0.13g (Magnitude 7.5 earthquake, 15 km depth, 100 km from site).

2.5 TSF LOCATION PHYSICAL CONDITIONS

General physical conditions in the vicinity of the Centipede pits can be described as follows:

- Foundation Soils
  The orebody (and the zone below) consists of a sequence of layers of calcrete, siltstone, sand and clay. The typical stratigraphy is summarized below:

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 0.7</td>
<td>SILT – sandy to clayey silt, slightly calcareous.</td>
</tr>
<tr>
<td>0.7 – 4.7</td>
<td>CALCRETE/SILT – vuggy calcrete with silt.</td>
</tr>
<tr>
<td>4.7 – 7.0</td>
<td>SAND/SILT/CALCRETE – fine to coarse sand intercalated with silt and silty sand with variable calcrete content.</td>
</tr>
</tbody>
</table>

  The thickness and depth of the layers across the area are also variable.

- Hydrology
  Surface water in the area generally drains into Lake Way. Surface water is ephemeral and only occurs after high rainfall events. The 1 in 100 year flood level for the lake is just below RL492.0 m. The lake has the potential to spill to the southeast to Lake Maitland under extreme climatic conditions. There is an unnamed creek which flows through the southern edge of the Centipede orebody area and no tailings will be deposited within the boundaries of this creek.

- Hydrogeology
  Subsurface water generally flows towards Lake Way which usually acts as an evaporation source. There is a potential for subsurface flow to the southeast towards Lake Maitland. The groundwater flow occurs within distinct geological units with the calcrete layers being the primary higher permeability zones.
A water flow barrier will be installed to reduce the horizontal flow of water into the orebody area as part of the dewatering management strategy. This will reduce horizontal groundwater inflow into the areas of the orebody used for the TSF but will have minimal impact of groundwater flow through the base of the relevant areas.

The depth of groundwater is typically 2 to 5 m below surface with the depth reducing closer to Lake Way. The groundwater is expected to be hypersaline with a neutral to slightly alkaline pH. The measured salinity generally increases the closer to Lake Way the sample is taken.

3. TAILINGS TESTING

3.1 GENERAL

A tailings sample was sent to the KP Testing Laboratory (date: 20th April 2011) from ALS AMMTEC’s benchtop metallurgical testing program as follows:

- 2 X 20 L containers of tailings in slurry form.
- 1 X 20 L container of water from the site area.

In addition Toro provided a copy of Outotec’s thickener testing undertaken in March 2011 (File Reference S1278TA).

The following tests were carried out on the sample:

- i. Supernatant liquor density and pH.
- ii. Viscosity test.
- iii. Undrained and drained sedimentation tests.
- iv. Air-drying tests.
- v. Permeability tests.
- vi. Consolidation tests.
- vii. Strength testing.

3.1.1 Classification Testing

Classification tests were carried out on the sample as follows:

- Supernatant Density
  A density of the liquor was measured using a hydrometer. A measured value of 1.052 was recorded.

- Supernatant pH
  The pH of the supernatant was measured using a pH meter as 8.09.

- Specific Gravity
  For the purposes of this testwork a value of 2.85 was used.

3.1.2 Viscosity Testing And Percent Solids

The viscosity of tailings is related to the solids content of the slurry. Laboratory measurement of the viscosity of the slurry at varying solids contents was conducted using the Marsh Flow Cone Apparatus, which involves timing of the efflux of a known volume of slurry (1.7 litres) through a standard flow cone. At lower percent solids, the time taken for the slurry to flow through the cone is similar to water. As the slurry increases in solids content there is a slow linear increase in the time taken. At a certain percentage solids,
defined as the Critical Solids Content, the time taken for the slurry to flow through the cone increases rapidly, and within a 5% to 10% increase in the solids content the time measured will more than double.

The critical solids content ranged from 30 to 35% solids.

The Outotec thickener report indicated that a standard thickening would achieve an underflow density of 36.6% at a feed rate of 0.22t/(m²·h) with a flocculent dose rate of 4.6 g/t. The paste simulation indicated a potential increase to about 41 - 42% solids. These values are consistent with the results of the Marsh Cone testing. Based on the results it was decided to undertake the laboratory testing at about 38% solids.

3.1.3 Sedimentation Tests

Drained and undrained sedimentation tests were carried out for both percent solids to determine the settling rate, volume of supernatant, and settled dry density of the tailings.

The results of the sedimentation tests are presented in Table 3.1.

**Table 3.1: Sedimentation test results**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Test</th>
<th>Initial Solids (%)</th>
<th>Supernatant (% of initial water volume)</th>
<th>Underdrainage (% of initial water volume)</th>
<th>Time to Achieve 90% of total density increase (days)</th>
<th>Final Density (days)</th>
<th>Final Dry Density (t/m³)</th>
<th>Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>38% Solids</td>
<td>Undrained</td>
<td>38.1</td>
<td>10.2</td>
<td>-</td>
<td>34</td>
<td>60+*</td>
<td>0.58</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>Drained</td>
<td>39.7</td>
<td>5.6</td>
<td>10.7</td>
<td>26</td>
<td>32</td>
<td>0.70</td>
<td>2.2</td>
</tr>
</tbody>
</table>

*Undrained test terminated

The tests indicate the tailings sample is extremely slow settling taking from 30 to 60 days to complete. Supernatant release ranged from 6 – 10% of the water in slurry.

The settled densities achieved are very low. There is a slight increase in settled density between the undrained and drained tests for the samples.

3.1.4 Air-drying Tests

Air-drying tests were carried out on slurry samples to determine the effect of natural drying of the tailings after initial settling and removal of supernatant liquor, thereby simulating conditions expected following sub-aerial deposition. Continuous monitoring of the weight and volume of each specimen was carried out in order to quantify the relationship between dry density, moisture content, volumetric change and the degree of saturation of the tailings.

The results of air-drying tests are summarised in Table 3.2.

**Table 3.2: Results of air-drying tests**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Moisture Content at Breakaway Point (%MC)</th>
<th>Dry Density at Breakaway Point (t/m³)</th>
<th>Limiting Saturation Value (%Sat)</th>
<th>Final Dry Density (t/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>38% Solids</td>
<td>130</td>
<td>0.65</td>
<td>70</td>
<td>1.28</td>
</tr>
</tbody>
</table>
Air-drying of the tailings significantly improves the achieved dry density compared to the sedimentation test result. The increase is approximately 82%. The air-drying of the tailings is still slow with the samples taking approximately 30 days at an evaporation rate of 5.6 mm/day to achieve final density. However 90% of the final density (1.0 t/m$^3$) is achieved in 18 days. At Wiluna, the evaporation rate varies seasonally from 4 to 12 mm/day. In the design of the TSF, the drying time will need to be adjusted to suit the actual monthly evaporation rates as well as the exposed beach area and throughput rate.

3.1.5 Permeability Tests

Falling head permeability tests were completed on saturated tailings samples with drainage through the drained sedimentation sample being measured. In addition, permeability values were derived from the results of consolidation tests. Measured permeability data are summarised in Table 3.3 and presented in Figure 3.1.

Table 3.3: Permeability test results

<table>
<thead>
<tr>
<th>Sample</th>
<th>Test Type</th>
<th>Dry Density (t/m$^3$)</th>
<th>Permeability (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>38% Solids</td>
<td>Falling Head</td>
<td>0.69</td>
<td>1.6 x 10$^{-9}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.72</td>
<td>1.6 x 10$^{-9}$</td>
</tr>
<tr>
<td></td>
<td>Consolidation Test</td>
<td>0.61</td>
<td>3.4 x 10$^{-7}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.64</td>
<td>3.6 x 10$^{-8}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.69</td>
<td>1.5 x 10$^{-8}$</td>
</tr>
<tr>
<td></td>
<td>Consolidation</td>
<td>0.70</td>
<td>1.0 x 10$^{-8}$</td>
</tr>
<tr>
<td>Test Stage 2</td>
<td></td>
<td>0.72</td>
<td>4.7 x 10$^{-9}$</td>
</tr>
</tbody>
</table>

These results represent the permeability of saturated tailings prior to additional consolidation due to additional deposition loading or air-drying. The permeability is expected to decrease further at higher densities. In the range of expected settled densities, the permeability is likely to be less than 5.0 x 10$^{-9}$ m/s indicating low permeability tailings.

3.1.6 Consolidation Tests

The consolidation of the tailings can be quantified in terms of the compression index $C_C$ and the coefficient of consolidation $C_V$. The compression index relates the void ratio or tailings density to the effective stress of the tailings sample.

The settlement with respect to time and the variation in permeability with density for the test is presented in Figure 3.1 and the results of the consolidation tests are summarised in Table 3.4.

Table 3.4: Consolidation test results

<table>
<thead>
<tr>
<th>Sample</th>
<th>Dry Density (t/m$^3$)</th>
<th>Stress Range (kPa)</th>
<th>Coeff. of Consolidation $C_V$ (m$^2$/y)</th>
<th>Coeff. of Volume Decrease $M_v$ (m$^2$/kN)</th>
<th>Comp. Index $C_C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>38% Solids</td>
<td>0.60 – 0.71</td>
<td>1.32 – 4.91</td>
<td>&lt;1.2</td>
<td>&lt;0.04</td>
<td>&gt;1.3</td>
</tr>
</tbody>
</table>

*The 38% solids test was terminated after 2 months due to time constraints.
3.1.7 Undrained Shear Strength

Undrained shear strength testing was undertaken on a tailings sample to determine the relationship between undrained shear strength, saturation, and moisture content of the tailings.

The test is designed to determine the effect of air drying on the undrained shear strength of the tailings solids, after initial settling. The strength versus moisture content data will be used to assess trafficability as part of the closure design.

A sample of the tailings slurry was placed in a large container (approximately 5 kg) and air dried under heat lamps. The unconfined compressive strength of the tailings was measured over several weeks as the tailings dried. A pocket penetrometer was utilised to determine the undrained shear strength of the tailings during desiccation.

The undrained shear strength begins to increases at a moderate rate as the moisture content reduces below approximately 70%. At a moisture content of 50-55% (at a saturation point 80% or lower) the increase in undrained shear strength becomes more rapid, as the tailings approaches the maximum dry density. Drying below a limiting saturation produces no further consolidation, and the density at this point represents the maximum that can be achieved via air drying of the waste fines. However, the rapid increase in undrained shear strength continues below the limit of saturation until it reaches values of greater than 200 kPa at a moisture content of 42% and a saturation of 75%.

The results of the shear strength testing is presented in Figure 3.2 and summarised in Table 3.5.

**Table 3.5: Results of shear strength tests**

<table>
<thead>
<tr>
<th>Moisture Content (%)</th>
<th>Undrained Shear Strength (kPa)</th>
<th>Saturation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>7*</td>
<td>88</td>
</tr>
<tr>
<td>65</td>
<td>22*</td>
<td>85</td>
</tr>
<tr>
<td>53</td>
<td>60</td>
<td>81</td>
</tr>
<tr>
<td>50</td>
<td>82</td>
<td>80</td>
</tr>
<tr>
<td>48</td>
<td>105</td>
<td>78</td>
</tr>
<tr>
<td>45</td>
<td>145</td>
<td>77</td>
</tr>
<tr>
<td>43</td>
<td>190</td>
<td>76</td>
</tr>
</tbody>
</table>

* Estimated values

In conclusion the tailings can achieve significant undrained shear strength if dried sufficiently, but in general the size of the storage facility is designed such that the tailings achieve their maximum dry density (saturation levels of 75-85%) and not necessarily the maximum undrained shear strength. As such a period of drying after deposition prior to closure may be required.

Access onto the tailings surface will be possible with low ground pressure machinery (swamp dozers) once a shear strength of approximate 75 to 100 kPa has been achieved within at least the upper 1 m of the tailings. This would require an overall saturation level of approximately 75% or lower to be achieved.
3.2 PREDICTED PHYSICAL BEHAVIOUR OF TAILINGS

Based on the physical testing of the sample and assuming the sample is representative of the tailings as a whole, the following predicted behaviour is expected for the tailings.

3.2.1 Water Production

The release of water following deposition of the tailings can be estimated from the results of drained and undrained sedimentation tests. The rate of release will determine the amount of supernatant reaching the decant pond.

The testing indicated that the rate of supernatant release is very low. Table 3.6 provides approximate maximum rates of supernatant release in mm/day for different deposited layer thicknesses.

Table 3.6: Maximum Supernatant Deposited Layer Release Rates

<table>
<thead>
<tr>
<th>%Solids of Tailings</th>
<th>Test</th>
<th>Total Supernatant Release % of Initial Water Volume</th>
<th>Thickness (mm)</th>
<th>Maximum Daily Release Rate of Supernatant (mm/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>38%</td>
<td>Undrained</td>
<td>10.2</td>
<td>100</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>200</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>300</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Drained</td>
<td>5.6</td>
<td>100</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>200</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>300</td>
<td>3.5</td>
</tr>
</tbody>
</table>

The evaporation rates in the Wiluna area vary from a maximum of about 15 mm/day in summer to a minimum of about 4 mm/day in the winter. As the rate of supernatant production is lower than the daily evaporation rate typical all of the supernatant would evaporate with no runoff. Thus the surface water management would only need to consider rainfall events.

The quantity of underdrainage release in the field would be expected to be lower than the values indicated by the test work, due to the thickness and low permeability of the deposited tailings, further consolidation of the tailings and drying of intermediate layers. Underdrainage release was about 11% (for a free draining sand base) but at a relatively slow rate taking 20 – 30 days to complete. Underdrainage losses in the field would likely average around 0 – 2%.

3.2.2 Tailings Density

The settled dry density of tailings deposited into the storage facility can be predicted from laboratory testing. The test results indicated that the tailings reached very low dry densities from settling with a significant improvement due to air-drying of the sample. It has been observed over a number of years that densities achieved in the field are generally lower than those obtained in the laboratory. In addition, field densities achieved are dependent on the area available for drying and the thickness of deposited layers. The area / rate of rise requirement is even more critical for very low drying tailings. A suitable deposition plan and efficient operation of the facility can greatly improve settled density. Assuming that sufficient area is available and the facility is efficiently operated, it is estimated that the average settled density for the facility could be as high as 1.0 – 1.2 t/m³.
4. TAILINGS STORAGE FACILITY DESIGN

4.1 MINING PLAN

There are two orebodies mined during the Project, Centipede and Lake Way. Toro has developed a mining plan for both orebodies as part of the project development.

The principles from the mining plan which affect the TSF design are as follows:

- Centipede orebody will be mined first.
- Ore from Lake Way will be transported down to the processing plant at Centipede and tailings disposed of in Centipede TSF.
- Ore from Lake Way will be transported down to the processing plant at Centipede and tailings disposed of in Centipede TSF.
- A preliminary section of the Centipede orebody is to be mined and stockpiled to generate void space to develop an initial TSF area prior to commissioning.
- Centipede orebody covers a relatively large area but is generally between 4 and 6 m deep.
- The sequence of mining blocks at Centipede can be modified to suit the TSF development.
- The current mining plan only covers processing of high grade ore however the TSF will be sized to allow for potential processing of low grade ore as well.

The nominal sequence of mining block availability at Centipede is provided in Table 4.1.

<table>
<thead>
<tr>
<th>Table 4.1: Nominal sequence of mining block availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pit</td>
</tr>
<tr>
<td>Centipede</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

The void developed from mining the Centipede orebody was assessed with regards to size, depth to base ground levels, current mining sequence and required storage capacity. Based on these criteria Mining Blocks 1 to 4 were eliminated due to their shallow depth. Mining Blocks 5 to 15 were selected for the TSF (depth 4 to 6 m). The area will be divided into three facilities only one of which will be active at any one time. As each facility approaches full capacity the next facility will be developed.

Each facility will be divided into three cells for deposition control purposes.
4.2 EMBANKMENT DESIGN

4.2.1 General

For each facility potentially four embankment types will be utilised as follows:

- Perimeter embankments built against existing ground.
- Freestanding perimeter embankments between the TSF facility and the adjacent active/completed mining area.
- TSF cell divider walls.
- TSF supplementary deposition walls.

The layout of the facility and embankment locations are shown on Figure 4.1.

A description of each embankment type is provided below.

4.2.2 Existing Ground Perimeter Embankment

The TSF will be constructed within the orebody excavation. Thus in a number of locations the perimeter embankment will be built against an existing excavation face. For these locations the existing face will be reshaped to a slope of 1V:3H (or flatter) and proof rolled to provide a firm base for placement of tailings.

In areas where the existing ground surface is less than the nominal perimeter embankment RL a bund will be constructed up to the required height using clay and/or structural fill materials (silt/sand gravel material). The crest width of the bund will be 5 m with side slopes of 1V:3H.

The purpose of the bund is to isolate the TSF area from any upstream catchments. To facilitate the removal of surface runoff a diversion drain will be built along the upslope side of each facility to divert any runoff around the TSF area.

4.2.3 Freestanding Perimeter Embankment

In TSF 1 and TSF 2 a freestanding perimeter embankment will be required between the TSF facility and the adjacent mining area. This embankment will be a zoned earthfill embankment consisting of a 5 m wide upstream low permeability zone and a downstream structural zone. The crest width will be 5 m and the upstream and downstream slopes will be 1V:3H.

As the TSF will be progressively filled with tailings and the mining area will be in a dewatered state the embankment will be provided with a drain to prevent buildup of water pressure in the downstream structural zone. Water from the drain will be discharged into the adjacent mining zone. When this area is incorporated into the next TSF the drain will be decommissioned.

4.2.4 TSF Cell Divider Walls

In each facility the area will be divided into three major cells by constructing TSF Cell Divider walls. The purpose of these walls is to improve deposition control as discussed in Section 5.

These walls will be constructed of structural fill won from local excavation (uranium content to be <82 ppm) and will be provided with an erosion protection layer on each side.
The divider walls will be constructed with a crest width of 5 m and side slopes of 1V:3H.

4.2.5 TSF Supplementary Deposition Walls

As the storage area is relatively shallow the beach slope of the tailings may result in a loss of storage in the active cell. In this case a cross wall will be constructed to allow the deposition pipeline to be relocated. This wall will be constructed by end dumping material across the cell at an appropriate location and then filling the upstream cell with tailings prior to relocating the pipeline. Coarse material will be dumped off the sides of the deposition wall to provide erosion protection.

The use and/or number of supplementary deposition walls will be a function of the deposition method and achieved beach slope as discussed in Section 5.

4.3 STABILITY

A preliminary stability assessment was undertaken to ensure that all of the embankments at various stages over the life of the operation have adequate stability.

The stability of the proposed embankment section was assessed under both normal and seismic loading conditions using limit equilibrium methods. The computer program XSTABL, developed at the Purdue University, was used for the analysis, which was carried out using the Janbu method.

The stability of the embankments under earthquake loading conditions was assessed using pseudo-static methods of analysis. A horizontal bedrock acceleration of 0.05g was adopted for the initial analysis based on an assessment of the seismicity of the site. Based on the seismic analysis, a horizontal bedrock acceleration of 0.13g was adopted for Maximum Design Earthquake (MDE).

There are four nominal embankment profiles which may be used in the TSF.

- Existing ground perimeter embankments
  These embankments will be built against existing excavated surfaces. In the upstream direction the embankment will be buttressed progressively by tailings. Thus it is expected that stability for this type of embankment will be acceptable.

- Freestanding Perimeter Embankment
  Between the facilities a freestanding embankment will need to be constructed. As the embankment will remain freestanding potentially for a number of years the embankment was assessed for downstream stability. The results of the stability analysis are provided in Table 4.2.

<table>
<thead>
<tr>
<th>Loading Condition</th>
<th>Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static</td>
<td>2.14</td>
</tr>
<tr>
<td>Pseudo Static OBE</td>
<td>1.83</td>
</tr>
<tr>
<td>Pseudo Static MDE</td>
<td>1.48</td>
</tr>
</tbody>
</table>

The results indicate the embankment has adequate stability.

- TSF cell divider walls
  These embankments will be constructed within each facility. Initially these will be similar to the perimeter embankments however tailings will be progressively
placed on both sides of the embankment. Thus it is expected that the stability of these walls will be adequate.

- **TSF Supplementary deposition walls**
  These walls will be pioneered across the existing active cells. The material will continue to be placed until the embankment is stable with minimal movement occurring.

  These walls will be constructed across/through the tailings thus there is a potential for local instability to occur. As the walls will only be used for tailings deposition and are internal to each cell any local instability can be repaired without any major impact on the operation and with no probability of tailings release.

### 5. FACILITY OPERATION

#### 5.1 TAILINGS STORAGE FACILITY DEVELOPMENT

The current concept for tailings disposal is as follows:

- Area dewatered as part of the mining sequence.
- Ore and waste removed for processing and disposal respectively (dewatering maintained).
- Base of target cell area smoothed by dozer to remove local high and low areas.
- Sub base drainage system installed (if required for subsurface/dewatering control).
- Base scarified, moisture conditioned and compacted to provide a base equivalent to a 300 mm engineered liner and perimeter embankments constructed. In areas where the in-situ base material is unable to achieve a suitable permeability, material from other areas, and from within the pit voids whenever possible, will be imported to form a 300 mm engineered base liner. This will prevent the migration of tailings from the facility.
- Internal bunds for individual deposition cells constructed over the compacted base.
- Internal drainages constructed at toe of perimeter embankment to reduce phreatic surface through embankment.
- Tailings deposition commenced using sub-aerial deposition (dewatering maintained).
- Construction of next cell commenced when active cells are partly filled.
- When cell is filled, deposition is switched to the next cell and the tailings in the deactivated cell is allowed to dry (Phase 1 drying period).
- When tailings has achieved the required strength an initial cover layer is placed over surface.
• Tailings cell allowed to continue drying with the internal drainage and pit dewatering (if required) systems still operating (Phase 2 drying period).

• Capping layer completed and revegetation commenced.

5.2 WATER BALANCE

A nominal water balance was developed to check whether operating the cells using subaerial methodology would be an issue. The following base data were assumed:

• No recycle.

• Supernatant release – max of 7 to 8% over 10 days. As release is slower than available daily evaporation rates this means effectively 0% supernatant reaching the decant pond.

• Climate data
  Rainfall = 225 mm/yr
  Evaporation = 3410 mm/yr

Thus pond will be formed after each storm and then evaporated away.

• Seepage – testwork indicated 8% over 10 days with free draining base – will be lower with air drying of layer and underlying previously dried tailings (estimated as range of 0 – 2% in total).

The water balance check indicates that the facility will be largely dry and there will be minimal water management issues during operation.

5.3 FACILITY SEEPAGE

Seepage rates from the facility will be controlled by a number of factors. The following factors will impact on the potential seepage rate and migration of water away from the facility:

• The natural groundwater level is a couple of metres below the existing ground surface. During the operating period the area will be dewatered so the water level in the pit area will be lower than the surrounding area and thus the pit will act as a local groundwater sink during the operation (i.e. water will flow towards the pit area). This also means the water level in the pit area will not be higher than the local groundwater system at any time during the operation or after closure.

• The tailings has a low permeability and will only release minimal amounts of water especially after it is air dried and consolidated during deposition. Thus the availability of water for seepage release will be very low.

• Studies of the natural groundwater flow in the area indicates extremely low rates of water movement so there is no mechanism for any rapid release of seepage to be moved away from the facility.

• After closure the water table is expected to recover back to its original levels over a very long period of time. However even after the water table recovers and groundwater flows return to their original configuration the tailings permeability will be generally lower than the surrounding materials and thus local groundwater flows will tend to move through the surrounding materials rather than through the tailings mass itself.
5.4 DEPOSITION CONTROL
The orebody is typically between 4 and 6 m deep thus tailings deposition will be mostly controlled by the need to maximise the storage efficiency.

The number of tailings disposition locations, the use of supplementary bunds and the frequency of pipeline relocations will in large part be a function of the beach slope of the deposited tailings. The steeper the beach slope the higher the number of discharge locations that will be required to maintain a suitable range depth of tailings across each cell.

The estimated particle size distribution (provided by Toro) is relatively coarse so beach slopes particularly adjacent to the deposition location could be as steep as 1V:50H with flatter slopes further away. It should be noted that the beach slope is also affected by viscosity and other factors.

Discharge will commence off one embankment for a period of time. As the tailings approaches the top of the embankment a supplementary bund will be constructed at a suitable distance down the cell. When the tailings reaches the maximum level the pipeline will be relocated to the supplementary bund. Initially deposition will be into the first cell to fill the remaining void and then deposition into the next section of the cell commenced.

The spacing of the bunds will be adjusted to ensure maximum utilisation of the storage. One of the deposition criteria is that the tailings remains below ground level. On this basis the cells have all been aligned to run from the higher ground on the northwest towards the lake edge. The alignment of the cells is shown on Figure 4.1.

Deposition into each cell will be undertaken until the cell is full. Alternatively all three cells in each facility will be filled at the same time in an alternating deposition sequence if additional area is required to achieve adequate densities.

5.5 ENVIRONMENTAL ISSUES MANAGEMENT
5.5.1 General
There are a number of environmental issues relating to the tailings area which will need to be managed. The two primary issues are radiation and dusting.

5.5.2 Radiation Control
The ore is being mined, the uranium being extracted and the tailings replaced back into the void. Thus the impact on the surrounding environment from the tailings should not be significantly greater than the impact of the original orebody.

However because the orebody and tailings will be exposed for some period during the operation there is a risk of exposure for mine personnel. Radiation control in the mining area will be covered elsewhere. In the tailings area the following procedures/controls will be implemented:

- The TSF will be a restricted access area off limits with access only allowed for suitably trained mine personnel.
- The tailings discharge system will be designed to minimize the length of time the operator needs to spend in the TSF area.
- For most of the time the active cells are used near to 100% saturation. As a result radiation levels will be relatively low.
• After deposition into a cell has been completed a nominal cover will be placed as soon as possible. This will reduce the radiation exposure for the workers building the final rehabilitation cover. Depending on the deposition sequence, some of the cells could be partly rehabilitated during the operation.

5.5.3 Dust Control

For the bulk of the deposition into the active cell the tailings will be close to 100% saturated. Thus dusting is not likely to be an issue for the tailings during this period. However after a cell has been filled, any remaining water will be evaporated away and the surface of the tailings will dry out. During this period there is a potential for dusting to occur if the facility is not managed correctly.

In order to minimise this potential the following criteria will be applied:

• Access to the surface during drying will be minimized thus preventing breakup of the surface and/or any salt crust which develops.

• The nominal cover will be placed as rapidly as possible. The timing of this layer will be based on bearing capacity for equipment rather than drying of the surface. Given the tailings characteristics it is expected that the surface will not have to be completely dry before low pressure dozers/ graders will be able to place the cover layer. Once this layer is in place the cell will be allowed to dry completely prior to completion of the rehabilitation cover.

Thus it is anticipated that dusting will be a controllable issue. Testing of a representative tailings sample will include assessment of dusting potential.

6. CLOSURE DESIGN AND CONCEPTS

6.1 CAPPING DESIGN

The proposed capping cover system has not been designed yet, however it is envisaged to consist of the following components (starting from the base of the cover):

• Radiation Control Layer

A radiation control layer will be placed over the tailings surface. “Half Value Layer” (HVL) thickness for soil/sand is approximately 150 to 200 mm (that is, the thickness of soil required to reduce radiation levels by about 50% is approximately 150 to 200 mm). The target would be three HVL layers of 200 mm thickness each. Discarding the effectiveness of the first HVL due to scattering effects from the tailings surface this will reduce radiation at the surface of the radiation control layer to 25% of the rate of the exposed tailings surface. The thickness of the radiation control layer (which is also the initial layer placed over the tailings surface) will be adjusted based on two factors:

i. Reduction of radiation levels on the surface of the layer so that rehabilitation work can be undertaken.

ii. The thickness and timing of the layer will also need to factor in the strength of the underlying tailings and the equipment size. Timing of the placement after the cell shutdown will be a function of the rate of increase of tailings strength over time during the Phase 1 drying period.

This layer will consist of material excavated from over the orebody. Material with some low level mineralisation could be used in constructing the radiation control layer provided the required reduction in radiation levels was achieved.
• Shaping Layer
The overall cover will be designed to maintain a suitable profile to match local landforms and prevent ponding. This will be achieved by placement of a shaping layer. This will vary in thickness across each cell so that the integrated landform/profile at the end of the operation matches the required final profile.

• Capillary Break Layer
A capillary break will be incorporated into the cover to prevent upward migration of contaminants from the tailings mass into the cover system. If the radiation control layer and shaping layer material are suitable a separate capillary break layer may not be necessary.

• Surface Water Shedding Layer
A compacted liner will be built over the capillary break layer (nominally 300 mm thickness) to reduce infiltration of rainfall into the tailings mass. The layer will be shaped so that the top surface drains.

• Growth medium and topsoil
Over the entire surface a growth medium layer will be placed. Any topsoil that has been stripped from the pit area will be placed back over the top of the growth medium layer.

• Vegetation
The surface will be planted with suitable local provenance vegetation.

6.2 CLOSURE CONCEPTS
6.2.1 General
During the deposition of tailings into the first cell a detailed closure plan will be developed. A closure criteria checklist will be produced consisting of general targets and specific items for each government authority, if required, developed through interaction with the relevant authorities.

• The general targets will include the following:
  i. All batters reshaped to suitable slope for rehabilitation.
  ii. Closure cover placed (matching nominal design).
  iii. Top surface contoured to prevent local ponding.
  iv. Surface and slopes planted with suitable local provenance vegetation.
  v. Closure materials selected and designed to minimise long term erosion.
  vi. No pipework, valves or tailings facility infrastructure to remain in rehabilitated area.

6.2.2 Measurement
In order to assess the closure criteria a detailed set of targets will be developed with associated methods of measurement. A monitoring program will be undertaken during the closure phase to assess whether the specific targets have been met. For measurement purposes a number of transects down the length of the cells plus a selection of shorter
transects in critical areas will be generated (locations to be defined by GPS or other
suitable technique).

For specific areas such as vegetation selection and establishment the program will be
developed in consultation with Toro’s specialist consultants.

6.2.3 Water Movement Monitoring

The water control system consists of several components which will be shutdown
progressively during closure as follows:

- The subsurface drainage will be shutdown at the time deposition ceases.

- A temporary pump will be provided for the cell to pump any rainfall pond from the
inactive cell into the active cell to minimise water buildup and maximise drying in the
inactive cell.

- Dewatering of the area around each cell will be shutdown on completion of the cover.
  If necessary some dewatering will be continued to ensure the adjoining cells
  remained drained.

- All monitoring systems which are installed in the tailings deposition areas will continue
during the full operating period and for a suitable length of time after the facility is
shutdown.

6.2.4 Timing and Rehabilitation

The facility consists of potentially nine active cells (depending on the extent of low grade
ore which is processed).

Each cell will be utilised in turn. As a result the first cell will be available for rehabilitation
after a period of about 2 years. The operation has a projected life of 9 to 13 years
depending on processing of high and low grade material. Thus the first cell can be filled,
dried, a cover constructed and rehabilitated before the end of the operating life. This
allows alternative methods of rehabilitation to be evaluated and a period of monitoring to
be undertaken for the first cell during the operation. Based on these results the closure
plan for the remaining cells would be modified to ensure they are rehabilitated in the most
effective manner.

7. ONGOING DESIGN AND TESTWORK

The design of the tailings storage facility is in progress and a number of stages are
required prior to completion of the design. Some of the ongoing work is listed below:

- The tailings tests described in Section 3 were provided from bench scale
  metallurgical testwork. The testwork has progressed and expanded to a pilot plant
  level and tailings from the pilot plant (which are expected to be more representative of
  the tailings generated by the full scale plant) is currently undergoing testwork.
  Preliminary results indicate that the tailings from the pilot plant are similar in
  behaviour to the bench scale samples (particularly in regard to water release), thus all
  of the design decisions arising from the bench scale testwork are likely to remain
  valid.

- Site investigation work to obtain samples for grading, characterisation and
  compaction testing.

- Geochemical and radioactivity characterisation of pilot plant tailings samples.
Based on this ongoing work the design will be modified as necessary to meet all the relevant regulatory requirements.

Yours faithfully

KNIGHT PIÉSOLD PTY LTD

DAVE MORGAN
Managing Director
FIGURES
Figure 3.1

CONSOLIDATION TEST

TIME (minutes)

SETTLEMENT (mm)

PERMEABILITY (m/s)

DRY DENSITY (t/m³)

CONSOLIDATION TEST

Permeability Test

Consolidation Test

Consolidation Test 2

One day
Figure 3.2

UNDRained SHEAR STRENGTH

Strength (kPa) or Saturation (%)

Moisture Content (%)

Strength

Saturation

Ref: Memo KP001

WILUNA URANIUM PROJECT
TAILINGS SAMPLE
UNDRAINED SHEAR STRENGTH
RE: MONITORING, MAINTENANCE AND CONTINGENCY RESPONSE PLANNING

1. INTRODUCTION

The Wiluna Uranium Project is being developed by Toro Energy Ltd (Toro). Toro engaged Knight Piesold Pty Ltd (KP) to undertake the design of the tailings disposal system for the project. It is currently proposed to store the tailings generated from the process in the Centipede pit void.

As part of the design a monitoring and maintenance programme is being developed and Contingency Response Plans (CRP) are being generated.

This memo outlines the conceptual approach to these areas with full development of the concepts being generated in the next design stage.

2. TSF MONITORING AND MAINTENANCE

2.1 GENERAL

A monitoring programme for the TSF will be developed to monitor for any potential issues which may arise prior to and during operations and as part of the closure period. The plan will include the following:

- Survey pins to check embankment movement.
- Piezometers in embankments to monitor the phreatic surface.
- Monitoring bores and surface water sampling stations on each side of the TSF.
- Regular dust and radiation monitoring.

If the monitoring programme indicates that potential issues are developing, an increase in monitoring frequency will be implemented and a contingency response plan developed.

2.2 PRE-COMMISSIONING MONITORING

As part of the overall monitoring programme baseline information will be collected to allow comparison with pre-existing conditions to be made and closure concepts to be targeted towards re-establishing the area back to generally equivalent to pre-mining conditions. Some of this data is already in the process of being collected. The items listed below primarily relate to the TSF area only. Some of the baseline measurements include the following:

- Original surface radiation profile across the area.
- Existing vegetation patterns.
- Groundwater levels and water quality (including radiation extent and levels).
2.3 OPERATING MONITORING ASPECTS

2.3.1 General
An operational monitoring program will be implemented targeting four primary areas:

- Seepage.
- Embankment performance.
- Tailings behaviour and deposition control.
- Emergency control systems.

2.3.2 Seepage Monitoring
The TSF design incorporates a number of measures to reduce the amount of seepage which will occur from the TSF, in order to mitigate the extent of any effects on the downstream environment. Eight groundwater monitoring stations will be installed around the TSF to facilitate early detection of changes in groundwater level and/or quality, both during the operating life and following decommissioning.

Each monitoring bore station consists of one shallow bore, extending to a depth of approximately 4 to 6 m in the surface horizon, and one deep bore terminating at approximately 15 – 20 m in the subsurface aquifer zone. The shallow bore is intended to detect any seepage from the facility flowing within the surface sediment, whilst the deep bore will monitor the chemical composition of the groundwater. Each borehole will be cased and screened over an interval set in the field during installation, and sealed back to surface with low permeability grout. The casing for the monitoring bores will be 150 mm diameter so that each monitoring bore can be converted to a de-watering bore if required.

2.3.3 Embankment Performance Monitoring
2.3.3.1 Facility Layout
The tailings will be stored in the Centipede pit. Thus the tailings will be below ground level. Notwithstanding this in order to allow deposition of tailings during the mining period and for flood control purposes a number of embankments will be required both around the perimeter and across the pit area. A layout of the facility is shown on Figure 1.

There are a number of different embankment types which will be used in the facility as follows:

- Perimeter bunds
  These will be built above ground around the pit edge. The purpose of these bunds is rainfall runoff diversion and isolation of the pit from major flooding of the lake. As these will be short term events monitoring will be based on inspections after rainfall events targeting erosion control.

- Perimeter TSF Embankment
  The wall of the pit itself will be used as an embankment. The wall will be reshaped to a 1V:3H maximum slope and proof rolled to provide a suitable surface for deposition and seepage control.

  Monitoring will be primarily targeting towards ensuring the elevated groundwater outside the pit area does not affect the wall stability prior to tailings deposition and erosion control during the deposition phase.

- Internal Embankments
  The pit area is proposed to be divided into three facilities each of which will be filled prior to commissioning the next. Each facility will be divided into three cells
all of which will be used at the same time to achieve the appropriate level of tailings drying and consolidation.

Due to the shape of the orebody, the embankments in places are up to 10 m in height. During the operation deposition will be occurring on one side of the embankment while the other side will be empty or will have mining equipment operating in it. For these reasons these embankments have been classified as “free standing” and will be monitoring during operations to an equivalent level to a standard TSF embankment wall.

2.3.3.2 Stability Monitoring

Pore water pressures will be monitored at several locations within the downstream section of the freestanding embankments to ensure that stability is not compromised. To this end, standpipe piezometers will be installed at five locations on the TSF1 embankment. When TSF2 is constructed the freestanding embankment for TSF2 will have similar piezometers installed.

Each standpipe will consist of a 50 mm diameter PVC tube slotted at the base or supplied with a filter tip. The slotted section will be surrounded by sand, and bentonite pellets will be placed above the sand to provide a seal. The remainder of the hole will be sealed with a bentonite/cement grout. The top of the piezometer will be provided with a lockable cap to prevent tampering or vandalism. The base of each piezometer will be located within the embankment fill to ensure that the phreatic surface within the embankment, as opposed to natural groundwater level, is being measured. Alternatively vibrating wire piezometers can be utilised.

The piezometers will be monitored at regular intervals as outlined in the monitoring programme and any rises in water level noted. Increases of greater than 10% of the embankment height should be referred to a qualified geotechnical engineer for further investigation. The piezometer levels should be monitored to ensure that the phreatic surface does not reduce the overall stability of the embankments below acceptable levels. Remedial action will be undertaken if increases in pore water pressure are unacceptably high.

2.3.3.3 Survey Pins

Survey pins will be installed at regular intervals along the upstream face of each of the TSF perimeter embankments and on the downstream face of each freestanding embankment, in order to monitor embankment movements to assess effects of any such movement on the embankment. The details of each pin (date of installation, survey pin ID, Northing, Easting and RL) will be recorded on installation.

Each pin will be monitored for movement at regular intervals as outlined in the monitoring programme. Any displacement of the embankment which is considered excessive or ongoing may indicate embankment stability problems and will require investigation by a qualified geotechnical engineer. Remedial action will be undertaken if required based on the conclusions drawn from such an investigation.

2.3.4 Tailings Performance Monitoring

Tailings performance monitoring at the TSF will include monitoring of the following variables on a continuous basis:

- Solids tonnage to the TSF.
- Water volume to the TSF.
- Rainfall and evaporation at the TSF.
• Water levels in each active cell.

Monitoring of tailings moisture contents and densities, and survey of the tailings beach and supernatant pond locations will be conducted quarterly.

2.3.5 Emergency Controls

Under normal operation conditions the following systems should be in place:

• The tailings pipeline will be located on the upstream crest of the embankment, which will have a minimum cross fall to the tailings beach of 2%. Any leakage from the pipeline will therefore flow towards the TSF.
• Between the Plant Site and the TSF, the tailings pipeline will be contained within a bunded, low permeability material liner trench.

These systems should greatly reduce the likelihood of uncontrolled spillages from the TSF.

2.3.6 Annual TSF Inspection Requirements

The TSF is considered to be SIGNIFICANT hazard CATEGORY 1 TSF and thus, in accordance with the requirements of the ANCOLD “Guidelines on Tailings Dam Design, Construction and Operation”, will require annual audits by a suitably qualified geotechnical engineer to ensure that the facility is operating in a safe and efficient manner. The audit should include, but not be limited to, the following items:

• Current survey plan of TSF showing spot elevations along walls and across tailings beaches, if possible.
• Reconciliation of stored tailings volume and calculated densities with the expected values given in the design, and assessment of available capacity remaining in terms of volume and time.
• Assessment of in situ tailings properties, including particle size distribution, in situ strength, density and moisture properties.
• Water balance studies with approximate reconciliations of slurry volumes, solids content, supernatant production (if any), site rainfall and evaporation. In conjunction with contained moisture information, this will provide an indication of possible seepage losses.
• Validation of storage design, using input parameters derived from site measurements and testing, implications for future storage if present trends are continued, and recommendations for any necessary operational or design modifications.
• Presentation and interpretation of monitoring results, proposals for additional monitoring of identified areas, changes to operational procedures resulting from monitoring results and proposals for any necessary seepage recovery systems.
• General description of facility, complete review of residue and water management practices and operating manual procedures, their problems, failures and successes, and any alteration to the facility or operating procedures that are proposed.
• A complete description of the previous embankment construction with as-built drawings and design proposals for the next embankment construction phase (as appropriate) based on the recorded data.
2.3.7 Monitoring and Maintenance Programme

2.3.7.1 Monitoring Programme

As part of the operation of the TSF, extensive monitoring of all aspects of the operation should be undertaken. This monitoring falls into three basic categories:

- **Short-term operation monitoring** – this includes items such as offtake location, whether pipe joints are leaking, etc., which are part of ensuring that each facility is operating smoothly.
- **Compliance monitoring** – this includes items such as checking survey pins for movement and monitoring bores for contamination, etc., which are used to ensure that the project is meeting all of its commitments in regard to a safe, secure operation.
- **Long-term performance monitoring** – this includes such items as residue and water level surveys and water flow measurements, etc., which are used to monitor the long term performance of the facility and refine future embankment lift levels and final residue extent.

Table 2.1 summarises the monitoring requirements for the TSF.

**Table 2.1: Monitoring programme for TSF**

<table>
<thead>
<tr>
<th>Area</th>
<th>Monitoring Requirement</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Section 1:</strong> TSF</td>
<td><strong>Short Term Operation Monitoring</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pipeline integrity</td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td>Visual check on tailings/water levels versus embankment crest</td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td>Offtake location</td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td>Blockage of discharge</td>
<td>Daily</td>
</tr>
<tr>
<td><strong>Section 2:</strong> TSF Embankment Monitoring Bores</td>
<td><strong>Compliance Monitoring</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Survey pins</td>
<td>Monthly</td>
</tr>
<tr>
<td></td>
<td>Water volume</td>
<td>Monthly</td>
</tr>
<tr>
<td></td>
<td>Water level</td>
<td>Monthly</td>
</tr>
<tr>
<td></td>
<td>Water quality – conductivity</td>
<td>Monthly</td>
</tr>
<tr>
<td></td>
<td>Water quality – major component analysis</td>
<td>Annually</td>
</tr>
<tr>
<td></td>
<td>Water level</td>
<td>Monthly</td>
</tr>
<tr>
<td></td>
<td><strong>Section 3:</strong> Climatic</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Performance Monitoring</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Precipitation</td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td>Evaporation</td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td>Maximum - minimum temperatures</td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td>Wind direction and speed</td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td>Tailings solids (tonnes)</td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td>Water in tailings (tonnes or m³)</td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td>Average tailings flow (m³/s)</td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td>Tailings surface survey</td>
<td>Quarterly</td>
</tr>
<tr>
<td></td>
<td><strong>Technical Audit</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Independent geotechnical engineer</td>
<td>Annually</td>
</tr>
</tbody>
</table>

2.3.7.2 Maintenance Programme

Inspection and maintenance of the TSF is largely aimed at mitigating potential issues by dealing with them before they can develop into problems.

Some aspects of the maintenance programme such as inspections can be integrated into the monitoring programme. If issues are detected then the issue is either to be corrected.
immediately or is to be noted and a maintenance request form filled in. The form will allow for different levels of urgency depending on how quickly the maintenance is required. The assessment of urgency should be based on the potential for the issue to affect the operation or integrity of the facilities. The maintenance will then be integrated with the overall site maintenance programme.

Table 2.2 outlines the maintenance requirements for each area of the TSF. Modifications to the maintenance programmes as a result of emergency situations or annual reviews should be reviewed regularly.

Table 2.2: Maintenance programme

<table>
<thead>
<tr>
<th>Area</th>
<th>Monitoring Requirement</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSF Pipelines</td>
<td>Inspect pipeline for pipe bursts, leaking joints.</td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td>Inspect outlet(s) for blockages, failure etc. Repair and/or replace as necessary. Re-locate outlet(s) to new location and check that flow at new location is acceptable.</td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td>Break pipeline at selected locations and observe wear on valves, fittings and pipes. Remove any accumulated material from valves etc. Rotate pipeline if excessive wear is occurring along pipe.</td>
<td>Annually during programmed plant shut down</td>
</tr>
<tr>
<td></td>
<td>Carry out maintenance on valves and fittings as recommended by suppliers.</td>
<td>As recommended</td>
</tr>
<tr>
<td>TSF Embankment</td>
<td>Check general structural integrity and visual signs of seepage through embankment.</td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td>Visual inspection for slips, erosion problems including around survey pins, tension cracks etc. Problems to be referred to qualified geotechnical engineer for assessment.</td>
<td>Weekly</td>
</tr>
<tr>
<td>TSF Toe Drains</td>
<td>Check for damage, collapse or ingress of material.</td>
<td>Monthly or after significant rain events</td>
</tr>
<tr>
<td>Freestanding Embankment</td>
<td>Inspect all instrumentation and repair/replace as required.</td>
<td>Frequency as per instrumentation instructions</td>
</tr>
<tr>
<td>General</td>
<td>General inspection of TSF and all structures</td>
<td>Monthly</td>
</tr>
<tr>
<td></td>
<td>Geotechnical audit and report.</td>
<td>Annually</td>
</tr>
</tbody>
</table>

In addition to the monitoring and maintenance programme outlined above the TSF area will be incorporated into the sitewide Radiation Monitoring Programme.

2.4 CLOSURE MONITORING

2.4.1 General

During the deposition of tailings into the first facility a detailed closure plan will be developed. A closure criteria checklist will be produced consisting of general targets and specific items. The general targets will include the following:

i. All batters reshaped to suitable slope for rehabilitation.
ii. Closure cover placed (matching nominal design).
iii. Radiation reduced to suitable levels.
iv. Top surface contoured to prevent local ponding.
v. Surface and slopes planted with suitable local provenance vegetation.
vi. Closure materials selected and designed to minimise long term erosion.
vii. No pipework, valves or tailings facility infrastructure to remain in rehabilitated area.
2.4.2 Monitoring Areas

In order to assess the closure criteria a detailed set of targets will be developed with associated methods of measurement. A monitoring program will be undertaken during the closure phase to assess whether the specific targets have been met. Monitoring will target a number of areas as follows:

**Vegetation**
For measurement purposes a number of transects down the length of the cells plus a selection of shorter transects in critical areas will be generated (locations to be defined by GPS or other suitable technique).

For specific items such as vegetation selection and establishment the program will be developed in consultation with Toro’s specialist consultants.

**Water Movement and Quality Monitoring**
The water control system consists of several components which will be shutdown progressively during closure as follows:

- The subsurface drainage will be shutdown at the time deposition ceases.
- A temporary pump will be provided for the cell to pump any rainfall pond from the inactive cell into other cells to minimise water buildup and maximise drying in the inactive cell.
- Dewatering of the area around each cell will be shutdown on completion of the cover. If necessary some dewatering will be continued to ensure the adjoining cells remained drained.
- All monitoring systems which are installed in the tailings deposition areas will continue during the full operating period and for a suitable length of time after the facility is shutdown. Monitoring will include ongoing measurements of water quality around the facility.

**Radiation Monitoring**
As each area is rehabilitated radiation monitoring will continue across the rehabilitated surface to measure the effectiveness of the cover with regards to radiation control. Based on the measurements the cover design will be modified as required.

3. **CONTINGENCY RESPONSE PLAN**

3.1 GENERAL

As part of any monitoring programme Contingency Response Plans (CRP) need to be in place so that the site personnel know what is required if the monitoring program indicates there is an issue in the operation or performance of the facility. General CRP’s are provided as part of the Operating Manual which is developed and issued during of the final design / construction stage.

At this stage of design the conceptual outline of contingency plans for various issues detected by the monitoring programme can be provided.

3.2 EMBANKMENT STABILITY MONITORING

If monitoring of the survey pins indicates excessive movement or the water level rises in the piezometers by more than the specified amount the appropriate CRP would be initiated. For this situation the following steps would be followed:
• The measurements would be repeated to confirm that the original measurement was correct.
• Deposition of tailings would be moved away from the affected area.
• The facility designers / qualified geotechnical engineer would be brought to site to examine the situation and develop an action plan.
• The action plan would be implemented and the results monitored.

The action plan may include such things as additional local dewatering or buttressing of affected embankment sections.

3.3 SEEPAGE DETECTION
Any indications of elevated water levels or concentration of critical constituents in the monitoring system would activate the CRP. The following procedures would be initiated:

• A repeat measurement / sample would be taken to check the validity of the initial measurement.
• The facility designers / qualified geotechnical engineering could be contacted to assist in developing an action plan. This action plan would be monitored and, if necessary, modified until the concentration of water levels were restored to acceptable levels.

The action plan may include items such as changes in operating procedures, installing dewatering pumps in monitoring bores and / or installation of additional monitoring / dewatering bores.

3.4 STORM MANAGEMENT
Diversion bunds around the pit will prevent ingress of rainfall from external catchments. Thus only rainfall falling on the facility area itself will need to be handled. There are a number of competing issues relating to water storage as follows:

• The mining area will need to be dry to allow mining to proceed.
• The tailings achieves low densities if deposited under water.
• Closure areas need to be maintained in a dry condition to allow the tailings to increase in strength sufficiently to place the cover.

With the exception of the initial period when three cells (or more) are not available the contingency plan for large storm events is to store water in inactive areas of the pit. The priority of water movement will be as follows:

• Dewater active mining area.
• Dewater cell into which tailings is being currently deposited.
• Dewater all cells in the active TSF facility.

Water in the mining area and the inactive cells may potentially be captured by the pit dewatering system and sent to the plant. Any surplus water will be evaporated away.

A 1 in 500 year 72 hour storm (331 mm) falling of the facility area generates a volume of 0.9 Mm$^3$ which is equivalent to about 5-8% of the total pit void volume. Thus it is anticipated that sufficient storage will be available at most periods to store the rainfall runoff.

3.5 ELEVATED RADIATION LEVELS POST CLOSURE
A cover design has been nominally developed. A more detailed design of the cover will be undertaken in the next phase of design. It is also envisaged that as the first cell nears completion trial pads will be set up to test the effectiveness of the cover.
After construction of the cover, ongoing monitoring will be used to ensure that the selected cover meets the radiation control requirements. Because the TSF is divided into three facilities each of which will be used in turn the first facility will be available for rehabilitation during the operating period (approximately 3 years after commissioning). The operation has a projected life of 9 to 13 years depending on processing of high and low grade material. Thus the first cell can be filled, dried, a cover constructed and rehabilitated well before the end of the operating life.

If the radiation monitoring indicates that the constructed cover is insufficient additional alternative cover designs can be trailed and tested (e.g. increased thickness of cover, addition of bentonite or cement to the cover, use of HDPE etc.) to achieve the required radiation level.

3.6 LONG TERM SHUTDOWN / CARE AND MAINTENANCE PERIODS

If for some reason the plant has to be shut down for an extended period CRP’s for the TSF will be implemented. In part these plans will depend on the length of the shutdown.

Short Duration (nominally <3 months)
If the shutdown is for a short period, personnel will be maintained on site and access to the TSF area restricted. Care and maintenance will include for items such as pumping rainfall runoff from one cell into another and management of water inflow when the pit dewatering system is shut down.

The maximum length of the short duration shutdown will in part be determined by the drying of the tailings and the potential for dust generation.

Long Duration (nominally >3 months)
For long duration shutdown periods all exposed tailings surfaces will be covered with a nominal 500 mm temporary soil cover to remove the potential for dust generation.

If the plant is recommissioned deposition will continue over the temporary cover to the full height of the facility.

If it is determined that the plant will not recommence operations the TSF will move into the closure design and construction phase.

3.7 DETAILED CONTINGENCY RESPONSE PLANS

Contingency response plans need to be developed separately for the specifics of each individual site and in part are dependent on aspects of the operational and construction approaches selected.

Yours faithfully

KNIGHT PIÉSOLD PTY LTD

PETER VULD
Senior Technical Consultant
NOTES:
1. Supplementary deposition walls to be constructed across cells as required for deposition control.
2. Perimeter slopes to be provided with additional erosion protection along creek alignment.

## Tailings Storage Facility

<table>
<thead>
<tr>
<th>FACILITY</th>
<th>CELL</th>
<th>AREA (ha)</th>
<th>SPREADING LNK (m)</th>
<th>AVERAGE DEPTH (m)</th>
<th>EMANKMENT LEVEL (Ft, m)</th>
<th>CAPACITY (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFS 1</td>
<td>A</td>
<td>24.3</td>
<td>3.2</td>
<td>4.0</td>
<td>492.3</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TFS 2</td>
<td>D</td>
<td>15.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>25.6</td>
<td></td>
<td></td>
<td>493.0</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>31.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TFS 3</td>
<td>G</td>
<td>31.0</td>
<td>6.8</td>
<td>5.6</td>
<td>492.3</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>50.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Scale:** 1:15,000 (43)

**Knight Pijsold**

Ref: PE801-00125 EMEM-KP005

Figure 1

Rev: 0
Lisa,

Please find below the geochemical model results for the proposed Wiluna Uranium Deposit. This modelling was undertaken to predict the fate and transport of Uranium (U), and other solutes, from backfilled tailings material if they enter the aquifer system; this memo report only addresses U transport. All modelling was undertaken using PHREEQC (Parkhurst and Appelo, 19991), which considers solute speciation, mineral equilibrium, ion exchange and surface complexation reactions in predicting the fate and transport of solutes. The MINTEQ Geochemical Database (Allison et al., 19902) was used for all equilibria, including ion exchange, mineral/phase reactions, whilst the surface complexation database of Dzombak and Morel (19903) was used for all surface reactions onto iron oxy-hydroxides. The results obtained from this work are compared to those previously obtained using the solute transport function of HYDRUS 2D/3D, which considers only adsorption-desorption surface reactions. Moderate adsorption parameters were applied and these are detailed in Table 1.

The model setup is shown in Figure 1. Only 1D transport was considered in this study with the aquifer adjacent to the tailings backfilled minepit divided into 5 m cells. To model U release/escape from the minepit and transport in the aquifer a pulse of tailings liquor was applied to Cell 1. The geochemical properties of the tailings liquor (as a surrogate for the tailings pore fluid) is provided in Table 2. The pulse of “tailings seepage water” supplied 38.5 mg/L of U, with a pH of 9.91. The released tailings liquor was pushed through the aquifer by flushing through groundwater (Table 2), the chemical composition of which was determined on a representative sample of filtered groundwater recovered from a monitoring bore near the proposed Centipede operations area.

The model was run for a period of 1,000 and 10,000 years to determine the distance that U may travel in the aquifer following release from the tailings backfilled minepit. Given the uncertainty as to the heterogeneity of the aquifer system surrounding the proposed minepit the following parameters were varied:

- Adsorption properties of the aquifer materials (i.e. ion exchange and surface complexation parameters).
- Mineralogy of the aquifer materials.

---

• Flow velocity through the aquifer system.

The parameters for each scenario are detailed in Table 3 and the results from the PHREEQC modelling are presented in Figures 2 – 9.

**Figure 1: PHREEQC model setup to predict U transport from tailings backfilled minepit.**

**Table 1: Adsorption parameters used in the simulations**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Weak adsorption scenario</th>
<th>Strong adsorption scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ion exchange (mol/kg of water)</td>
<td>0.011</td>
<td>0.100</td>
</tr>
<tr>
<td>Surface complexation of Hfo (mg/g)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Weak (Hfo\text{_w})</td>
<td>7.16 \times 10^3</td>
<td>7.16 \times 10^1</td>
</tr>
<tr>
<td>- Strong (Hfo\text{_s})</td>
<td>1.79 \times 10^4</td>
<td>1.79 \times 10^2</td>
</tr>
<tr>
<td>Specific surface area (m\text{\textsuperscript{2}}/g)</td>
<td>600</td>
<td>1200</td>
</tr>
<tr>
<td>Specific mass of Fe-oxide (g/kg)</td>
<td>4.19</td>
<td>50</td>
</tr>
</tbody>
</table>

**Table 2: Geochemical properties of the tailings liquor and groundwater used in the PHREEQC model.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Limit of Reporting (LOR)</th>
<th>Groundwater (Aquifer)</th>
<th>Tailings Liquor</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>-</td>
<td>-</td>
<td>7.08</td>
<td>9.91</td>
</tr>
<tr>
<td>EC</td>
<td>mS/m</td>
<td>-</td>
<td>11,350</td>
<td>7,830</td>
</tr>
<tr>
<td>TDS</td>
<td>mg/L</td>
<td>-</td>
<td>104,360</td>
<td>63,720</td>
</tr>
<tr>
<td>pe (redox)</td>
<td>-</td>
<td>-</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Temperature</td>
<td>°C</td>
<td>-</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Alkalinity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydroxide Alkalinity as CaCO\text{_3}</td>
<td>mg/L</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Carbonate Alkalinity as CaCO₃</td>
<td>mg/L</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bicarbonate Alkalinity as CaCO₃</td>
<td>mg/L</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total Alkalinity as CaCO₃</td>
<td>mg/L</td>
<td>1</td>
<td>86</td>
<td>300</td>
</tr>
</tbody>
</table>

**Major anions**

| Total S | mg/L | 1  | 4620 | 3965 |
| SO₄-S | mg/L | 1  | 11200 | 10250 |
| Chloride | mg/L | 1  | 48800 | 23850 |
| Fluoride | mg/L | 0.1 | 0.5 | 13.4 |
| Total Nitrogen as N | mg/L | 0.1 | < 1 | < 1 |

**Major cations**

| Calcium | mg/L | 1  | 550 | 2  |
| Magnesium | mg/L | 1  | 3750 | 3  |
| Sodium | mg/L | 1  | 30500 | 23400 |
| Potassium | mg/L | 1  | 2780 | 1185 |

**Metals and Metalloids**

| Aluminium | mg/L | 0.01 | < 0.01 | < 0.01 |
| Antimony | mg/L | 0.001 | 0.002 | 0.005 |
| Arsenic | mg/L | 0.001 | < 0.001 | 0.162 |
| Boron | mg/L | 0.05 | 1.37 | 0.435 |
| Barium | mg/L | 0.001 | 0.049 | 0.087 |
| Bismuth | mg/L | 0.001 | < 0.001 | < 0.001 |
| Cadmium | mg/L | 0.0001 | 0.0002 | < 0.0001 |
| Chromium | mg/L | 0.001 | < 0.001 | 0.056 |
| Cobalt | mg/L | 0.001 | 0.004 | 0.006 |
| Copper | mg/L | 0.001 | 0.038 | 0.062 |
| Iron | mg/L | 0.05 | < 0.05 | < 0.05 |
| Lead | mg/L | 0.001 | < 0.001 | < 0.001 |
| Manganese | mg/L | 0.001 | < 0.001 | < 0.001 |
| Mercury | mg/L | 0.0001 | < 0.0001 | < 0.0001 |
| Molybdenum | mg/L | 0.001 | 0.066 | 0.1315 |
| Nickel | mg/L | 0.001 | 0.013 | 0.0105 |
| Selenium | mg/L | 0.01 | < 0.01 | 0.01 |
| Silver | mg/L | 0.001 | < 0.001 | < 0.001 |
| Strontium | mg/L | 0.001 | 12.3 | 0.091 |
Table 3: Details of scenarios and the sensitivity values applied to each

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Figure number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>Typical calcrete aquifer scenario over 1000 years; flow rate 0.5 m/y</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>Typical calcrete aquifer scenario over 10000 years; flow rate 0.5 m/y</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Typical calcrete aquifer scenario over 1000 years; flow rate 5 m/y</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>Typical calcrete aquifer scenario over 1000 years; flow rate 50 m/y</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>Typical dolomite aquifer scenario over 1000 years; flow rate 0.5 m/y</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>Typical kaolinite aquifer scenario over 1000 years; flow rate 0.5 m/y</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>Typical calcrete aquifer scenario over 1000 years; flow rate 0.5 d/y; with high adsorption</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>Typical kaolinite aquifer scenario over 1000 years; flow rate 0.5 d/y; with high adsorption</td>
</tr>
</tbody>
</table>

**MODEL RESULTS**

Predicted U transport away from the tailings backfilled minepit, for a 1,000 and 10,000 year period, are provided in Figures 2 and 3, respectively. These results were obtained for a calcite dominated aquifer system and with a flow velocity of 0.5 m/yr, which is similar to that predicted from the hydrological modelling undertaken by RPS-Aquaterra.

The model results show that after 1,000 years the released U (38.5 mg/L) is predicted to drop appreciably to concentrations of < 0.4 mg/L at a distance of 18 m of the minepit, and that concentrations of < 0.2 mg/L are expected at distances > 45 m. This significant drop in U concentrations is likely due to adsorption on to the calcite, and associated Fe-oxide surfaces. The model results predicted using PHREEQC are similar to those previously obtained using HYDRUS 2D/3D (SWC, 2011).

For a 10,000 year period (Figure 3), it is predicted that the groundwater U concentration will decrease to < 0.40 mg/L at distances > 100 m from the minepit and that by 200 m the U concentration is expected to decrease to below 0.2 mg/L.
Influence of flow velocity on modelled U transport

The influence of flow velocity on U transport was measured by varying the flow rate through the aquifer. In Figures 2 and 3 a flow velocity of 0.5 m/yr was used, and this was increased to 5 and 50 m/yr (0.037 and 0.137 m/day). The results for the calcite dominated aquifer, with all previous ion exchange and surface complexation parameters kept constant, are presented in Figures 5 and 6.

The model results show that increasing the flow velocity in the aquifer results in a greater distance travelled by the released U. At a flow velocity of 5 m/yr (10 times larger than used in Figure 2) the U concentration after 500 years remains above 0.4 mg/L for a distance of 50 m (Figure 5), compared to the same concentration at only 20 m with a flow rate of 0.5 m/yr (Figure 2). By increasing in flow velocity to 50 m/yr will likely result in U concentrations above 0.5 mg/L for a distance > 500 m after 500 years (Figure 6). This observed influence of flow velocity on U transport is likely due to the lower residence or contact time between the U in solution and the surfaces of the aquifer materials, as surface reactions are generally rate dependent.

Figure 2: Predicted U transport from tailings backfilled minepit over a 1,000 year period.
Figure 3: Predicted U transport from tailings backfilled minepit over a 10,000 year period.

Figure 4: Predicted U transport within the calcite aquifer with a flow velocity of 5 m/yr (0.0137 m/d).
Influence of mineralogy on modelled U transport

The influence of aquifer mineralogy on U transport was measured by varying the nature of the aquifer materials surrounding the proposed minepit. Figures 7 and 8 show the results obtained for simulated U transport through dolomite and kaolinite aquifers respectively.

For the dolomite aquifer, the model results show that the U concentrations in the aquifer, following release of U from the tailings, never exceeds 0.2 mg/L after the initial pulse at year 0 (38.5 mg/L measured in cell 1). The contrasting adsorption properties of the dolomite, compared to that of calcite (Figure 2), are due to the different equilibrium constants for both minerals: Calcite has a dissociation constant of $10^{-8.48}$, whilst for Dolomite it is $10^{-17.09}$. This results in Dolomite [CaMg(CO3)$_2$] dissolution being favoured. Released CO$_3^{2-}$ in this process, complexes with UO$_2^{2+}$ in the presence of abundant Ca, Mg and Na, and subsequently precipitates out of solution. This is clearly observed by the high positive Saturation Indices observed for these minerals.
It is interesting to note that U concentrations in the kaolinite aquifer generally remain above 0.4 mg/L for distances up to 150 m after 200 years (Figure 8) and that after 1000 years the U concentration is expected to be > 0.4 mg/L for distances > 500 m from the minepit. This is likely due to the kaolinite remaining in mineral form, with negligible dissolution ($K = 10^{7.435}$). In contrast, laboratory work undertaken by Murdoch University researchers⁴ has observed that kaolinite present in the aquifer system strongly absorbs U, and that complete adsorption was observed in the laboratory for all U concentrations tested. This strong adsorption was due to the very large surface area of the kaolinite and the number of exchange/adsorption site per mass of material; hence the results shown in Figure 10 are more likely to occur in the aquifer system surrounding the minepit.

Figure 7: Predicted U transport in a kaolinite dominated aquifer.

Influence of adsorption properties on modelled U transport

The adsorption properties for the various mineral phases in PHREEQC can be varied by adjusting the ion exchange and surface complexation properties of the solids. In all of the above simulations, a relatively modest adsorption profile was set. If the adsorption properties are increased to what is likely to occur in the field (values taken from the Murdoch University research) the U transport shown in Figures 9 and 10 are likely to occur.

In both ‘high’ adsorption scenarios, the released U concentrations remain below 0.2 mg/L (calcite) and 0.5 mg/L (kaolinite) at distances greater than 20 m from the proposed minepit after 1,000 years.

CONCLUSIONS

Geochemical modelling using PHREEQC was undertaken to determine the likely transport of U away from the tailings backfilled minepit. The results showed that under the conditions existing within the aquifer system surrounding the proposed minepit, any released U is expected to be confined to a relatively short distance from the minepit. Additional geochemical modelling and laboratory testwork is currently being undertaken to further constrain the various parameters that are likely to impact on U transport through the aquifer system.
Figure 8: Predicted U transport in a calcite dominated aquifer system with high adsorption properties.

Figure 9: Predicted U transport in a kaolinite dominated aquifer system with high adsorption properties.
Should you have any queries regarding this report, please do not hesitate to contact us.

Yours sincerely

Adam Pratt
Director
Principal Soil Scientist
Soil Water Consultants
m: +61 (0)427 105 200
t: +61 8 9228 3060
f: +61 8 228 3210
e: adam.pratt@soilwatergroup.com
MEMO

TO: John Baines
COMPANY: Toro Energy Limited

FROM: Hayley Castlehouse
PROJECT: PN212

DATE: 16th March 2012
DOCUMENT: 005

SUBJECT: Tailings leachability results

John,

Please find below a summary of the leachate results recently obtained for the three tailings samples provided to the Soil Water Group.

On the 9th of January 2012 the following samples (ca. 20kg of each) of tailings slurry and groundwater were received at Soil Water Analysis (SWA) Laboratories in East Perth:

- WU 100/200 (50/50) blend CCD U/F
- WU 200 CCD 6 U/F
- WU 100 CCD 6 U/F
- 10 L of groundwater collected from the Centipede deposit.

Upon receipt of the slurries a small (ca. 500g) sub-sample was removed for oven drying to determine the solids content. The tailings liquor was extracted by creating a well in the slurry to allow the free liquor to collect. A 200 mL sample of the liquor was collected for analysis. For each of the tailings materials, extracted liquors and groundwater pH, EC, TDS and solids content was measured and the results are presented in Table 1.

Determination of the leachability of various elements (including U) was carried out on the tailings by static extraction, using the Australian Standard Leaching Procedure (ASLP; AS4439.3-1997). This method uses a high soil solution ratio (1:20) which results in a shift in the equilibrium encouraging a maximum desorption of the elements from the solid phase into solution.

For each of the tailings materials, a suspension consisting of 100 g of tailings in 2 L of ground water (Table 1) was shaken end over end for 18 hours, with each material tested in duplicate. After shaking the suspensions were allowed to sit and the solid phase to settle. The leachate solution was then decanted off and a subsample taken from multi-element analysis. Multi element analysis was also undertaken on the tailings solids-phase, the tailings liquor and the groundwater.
Table 1 — The physical and chemical parameters of the tailings slurries and associated liquors.

<table>
<thead>
<tr>
<th>Material</th>
<th>pH</th>
<th>EC (mS/m)</th>
<th>TDS (mg/L)</th>
<th>Solids content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solid phase tails</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WU 100/200 50/50 Blend CCD U/F</td>
<td>10.38</td>
<td>1,270</td>
<td>-</td>
<td>49.89</td>
</tr>
<tr>
<td>WU 200 CCD 6 U/F</td>
<td>10.63</td>
<td>2,430</td>
<td>-</td>
<td>51.72</td>
</tr>
<tr>
<td>WU 100 CCD 6 U/F</td>
<td>10.25</td>
<td>1,349</td>
<td>-</td>
<td>50.06</td>
</tr>
<tr>
<td><strong>Decanted Liquor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WU 100/200 50/50 Blend CCD U/F</td>
<td>9.91</td>
<td>7,830</td>
<td>63,720</td>
<td>-</td>
</tr>
<tr>
<td>WU 200 CCD 6 U/F</td>
<td>10.04</td>
<td>8,670</td>
<td>77,260</td>
<td>-</td>
</tr>
<tr>
<td>WU 100 CCD 6 U/F</td>
<td>9.47</td>
<td>6,310</td>
<td>44,960</td>
<td>-</td>
</tr>
</tbody>
</table>

The results of the multi element analysis and the calculated % leachability of each element are provided in Tables 2 – 4. The main findings from this study are:

- For all elements the % shift in the groundwater concentration following leaching was calculated. Where the increase in concentration was less than 10% this was taken to be the result of natural variation. For elemental concentrations in the leachate were greater than 10% this was accounted for by leaching from the tailings and the % leached was calculated.

- For most elements of environmental concern there is negligible risk of leaching or mobilisation from the tailings materials. Only Uranium and Vanadium were leached to an appreciable extent, with 6.6 – 16.3 % and 4.5 – 7.8 % leached from the solid-phase, respectively.

- There was negligible leaching for all the base cations (Ca, Mg, K, Na).

- Of the other elements only barium was consistently leached from all slurry types but was always less than 5% of the total in the tailings.

- Other elements that were found to have leached from the tailings were nickel (1.3%) and phosphorus (79%) however, neither showed any appreciable leaching in the mixed blend slurry.

- Only Vanadium exceeded the reported Ecological Investigation Limits (EIL; DEC, 2010), with all other elements being less than the corresponding EIL criteria. It is therefore considered that the tailings to be backfilled into the minepit at both the Centipede and lake Way deposits is relatively inert, with the PHREEQC modelling recently undertaken by SWC (2012) showing that the transport and mobilisation is significantly retarded by the conditions existing with the geochemical and hydrological within the lake systems hosting the deposit.

The PHREEQC modelling previously conducted by SWC for Toro Energy Limited used the tailings liquor as a proxy for leachate in the simulation. This was a conservative approach and represented a worst case scenario, whereby the largest possible concentration of contaminants would be released into the aquifer in a single pulse. In reality the liquor would be diluted significantly by the inflow of groundwater into the tailings material and therefore any release of contaminants would be at considerably lower levels than predicted by the model. The concentrations of the elements of concern in any subsequent leachate would be also at very low concentrations with U for example being less than 0.5% of the concentration in the liquor (Table 2). Any further leaching from the tailings would be unlikely to result in a significant change in the outcomes in the model.
Table 2 – Concentrations of analytes in the groundwater and leachate and solid phase for the blended aquifer material with calculated % leached. NB values in italics are below the limit of reporting (LOR), values in red are above the EIL.

<table>
<thead>
<tr>
<th>Element</th>
<th>LOR</th>
<th>EIL</th>
<th>Liquor (mg/L)</th>
<th>Groundwater (mg/L)</th>
<th>Leachate (mg/L)</th>
<th>Solid (mg/kg)</th>
<th>% leached</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>0.1</td>
<td>-</td>
<td>&lt;0.01</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>4300.00</td>
<td>-</td>
</tr>
<tr>
<td>Antimony</td>
<td>0.001</td>
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Table 3 – Concentrations of analytes in the groundwater and leachate and solid phase for the 200 CCD 6 U/F aquifer material with calculated % leached. NB values in italics are below the limit of reporting (LOR), values in red are above the EIL.

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<th>Element</th>
<th>LOR (mg/L)</th>
<th>EIL (mg/L)</th>
<th>Liquor (mg/L)</th>
<th>Groundwater (mg/L)</th>
<th>Leachate (mg/L)</th>
<th>Solid (mg/kg)</th>
<th>% leached</th>
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<td>-</td>
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<td>&lt;0.01</td>
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Table 4 – Concentrations of analytes in the groundwater and leachate and solid phase for the 100 CCD 6 U/F aquifer material with calculated % leached. NB values in italics are below the limit of reporting (LOR)

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<th>Groundwater (mg/L)</th>
<th>Leachate (mg/L)</th>
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Conclusions

The majority of the elements in the tailings were below the ecological investigation levels provided by DEC, with the exception of V that was almost twice the EIL in the 200 CCD.

For the majority of elements there is no appreciable change in concentration in the groundwater following exposure to the leachate and most minor increases can be attributed to natural variation.

The leachability of most elements in the mine tailings were low and in most cases zero under the conditions of this study. Exceptions to this include U and V which showed variability in leaching between the slurry types studied.

Should you have any queries regarding this proposal and associated costs, please do not hesitate to contact us.

Yours sincerely

Hayley Castlehouse
Senior Scientist
Geochemistry
Soil Water Consultants
t: +61 8 9228 3060
f: +61 8 9228 3210
e: hayley.castlehouse@soilwatergroup.com
Should you have any queries regarding this proposal and associated costs, please do not hesitate to contact us.

Yours sincerely

Adam Pratt
Director
Principal Soil Scientist
Soil Water Consultants
m: +61 (0)427 105 200
t: +61 8 9228 3060
f: +61 8 228 3210
e: adam.pratt@soilwatergroup.com