LAKE MAITLAND PEER REVIEW

SEDIMENT AND EROSION

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TORO ENERGY
LAKE MAITLAND
PEER REVIEW – SEDIMENT AND EROSION

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EXECUTIVE SUMMARY

A study was conducted by Golder Associates on sediment transport for the Lake Maitland Uranium Project using the MIKE21C model for a 1 in 1,000 year flood event. The model was run for different flood hydrographs (one in 20, 100, and 1,000 year return intervals), upstream contributing catchment sediment loads (5, 20, 50, and 100 t/km^2), three different Project conditions (pre-disturbance/baseline, disturbed/operating, and post closure/rehabilitated), and two different soil types (cohesive and non-cohesive). The model results for a 1,000 year flood event for pre-disturbance conditions showed an outgoing sediment load of ~200kt. The outgoing sediment load rises in the operating phase to ~300-400kt, and to ~2,500kt for post closure. The post closure result was accounted for by the erodibility of the capping material that will be used for disturbed areas. It was recommended that post closure erosion rates could be returned to pre-disturbance levels (i.e., ~200kt) if the critical shear of the disturbed area capping materials could be increased to >6.5 Pa by placing 100mm of medium sand over the capping materials.

Landloch concludes that the report findings are consistent with methodologies used, assumptions made, and the results are adequately presented and interpreted.

However, Landloch could not support the specific recommendations made in the report. The MIKE21 model is typically used to model coastal, estuarine, and flood events and is not typically used for mine site erosion and sediment studies. The use of the model for a single, high magnitude, low frequency flood event based on scour erosion does not capture the complexity of arid zone catchment-scale erosion. The approach also does not provide information on which to base operational sediment and erosion control plans, nor robust mine closure plans.

Landloch recommends that the broad conclusions of the report that highlight the risk posed by the disturbed areas be adopted, but further work be conducted to quantify that risk more thoroughly. The further work should provide details on soil material variation across the site, conduct material erosion characterisation studies, and use the results to parameterise a model that will simulate typical erosion and sediment transport and provide detailed information for operational and mine closure erosion control plans.

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1 INTRODUCTION

Toro Energy Limited (Toro) acquired the Lake Maitland uranium deposit from Mega Uranium in August 2013 and plans to seek environmental approval for the mining of this deposit as well as the Millipede deposit. Toro plans to process ore from Centipede and Lake Way along with ore from Millipede and Lake Maitland at one central processing plant located adjacent to the Centipede deposit. Toro intends to refer the Millipede and Lake Maitland deposits to the Environmental Protection Authority (EPA) for assessment, which will require detailed surveys and studies across all proposed disturbance areas.

Mega Uranium undertook and completed environmental assessments and surveys across the Lake Maitland project sufficient to allow the proposal to be assessed under an Environmental Review and Management Programme (ERMP) (equivalent to the current PER level) in 2009. Initial discussions between the OEPA and Toro indicate that the existing environmental assessments and surveys for Lake Maitland would be acceptable for submission in a PER following peer review for correctness of content and adequacy. Toro have sought the advice and recommendations of *ecologia* Environment and appropriate sub-consultants who will undertake a peer review of the following reports:

- Regional and local flora,
- Terrestrial fauna,
- Short Range Endemic invertebrates (SREs),
- Stygofauna,
- Troglofauna,
- Aquatic Ecology,
- Sediments and erosion,
- Soils and waster rock characterization and geochemical assessment,
- Human health and ecological risk assessment (human and non human biota), and
- Air quality impact assessment and monitoring.

This peer review report pertains to the MIKE21C Sediment Transport Modelling report which was undertaken by Golder Associates.

The peer review has been undertaken by Brendan Roddy, Evan Howard, and Rob Loch on October 24, 2014 from Landloch Pty. Ltd.

1.1 LEGISLATION AND POLICY BACKGROUND OF PEER REVIEW

1.1.1 Compliance

This peer review will satisfy the requirements of all necessary statutory legislation, guidance and policy, including but not limited to:

- Department of Mines and Petroleum (DMP) 2006, Guidelines for Mining Proposals in Western Australia.

1.1.2 Approach

A review was undertaken of all environmental reports pertaining to the acquired Lake Maitland Project for breadth of scope, technical methodology, correctness of content and adequacy. The main findings of the peer review were to determine:

a) Correctness of findings and conclusions of all reports;
b) Adequacy of scope, methodology and results of all reports;
c) Compliance of all reports with statutory legislation and policy; and
d) Recommendations to address knowledge gaps (if applicable).

2 REVIEW RESULTS

2.1 CORRECTNESS OF FINDINGS AND CONCLUSIONS

A study was conducted by Golder Associates on sediment transport (Golder, 2011a) for the Lake Maitland Uranium Project ('the Project'). The study reported the findings of modelling sediment transport for the Project area using the MIKE21C model for a 1 in 1,000 year flood event. The study was supported by field work to measure the critical shear value of the Project's soils, and assess the incoming sediment load from the upstream contributing catchment (Golder, 2011b).

The MIKE21C model was run for the following conditions:

- three flood hydrographs (one in 20, 100, and 1,000 year return intervals), although only the 1,000 year event is used for the report conclusions due to issues of model stability and to report the worst case scenario,
- different upstream contributing catchment sediment loads (5, 20, 50, and 100 t/km^2), although the range was estimated between 5-20 t/km^2 and the 50 and 100 t/km^2 values were used for model sensitivity purposes,
- three different Project conditions (pre-disturbance/baseline, disturbed/operating, and post closure/rehabilitated), and
- two different soil types. The undisturbed soil was assumed to be a non-cohesive material similar to that found in the upper 100mm of the lake bed material, and the disturbed/rehabilitated areas to be a cohesive compacted clay material similar to a median field sample LMO16.

The model results for a 1,000 year flood event for pre-disturbance conditions showed an outgoing sediment load of ~200kt[1]. The outgoing sediment load rises in the operating phase to ~300-400kt, and to ~2,500kt for post closure. The post closure result was accounted for by the erodibility of the capping material that will be used for disturbed areas. It was recommended that post closure erosion rates could be returned to pre-disturbance levels (i.e., ~200kt) if the critical shear of the disturbed area capping materials could be increased to >6.5 Pa by placing 100mm of medium sand over the capping materials.

Landloch concludes that the report findings are consistent with methodologies used, assumptions made, and details presented in the report.

Landloch could not support the specific recommendations made in this report. Landloch's concerns are based on the model and methodologies used, and the magnitude of event modelled.

2.2 ADEQUACY OF SURVEY

2.2.1 Scope of Works

The scope of works as reported in Golder (2011a) was to conduct an erosion and sedimentation study for the Project area. The aims of the study were to collect information to parameterise the MIKE21C model to examine pre-disturbance, production, and post-disturbance sediment transport rates for the Project site for a 1,000 year flood event.

The report findings met the identified scope of works.

The model outputs reported sediment transport rates in kt for the 1,000 year flood event for the pre-disturbance, production, and post-disturbance project site.

[1] Kilotonne. 1kt = 1,000 metric tonnes.

The survey undertaken was performed by driving through Lake Maitland and the upstream contributing catchment to observe the condition and variability of these two areas. As such, a strict definitional survey (e.g., grid based) was not conducted for this study, but rather a reconnaissance/impression survey. A traditional survey based study will use discrete sampling to characterise the element(s) within the area of interest, and then extrapolate to the study area as a whole. For example, soil pits are used to produce an area soil map. In this study, the Project area and contributing catchment were characterised by discrete sampling (Section 2.2.2 below) that was used to parameterise the model, and the model was used to account for the character of the entire study area. Therefore no survey level can be attributed.

2.2.2 Sampling/Survey adequacy

A field program was conducted to sample the soils of the Project site and the contributing catchment. The contributing catchment was planned to be sampled by a rainfall simulator to determine the erodibility of the upstream areas, and the Project area soils were sampled using a vertical Jet test (VJT). The VJT estimates the critical shear of the soil materials and is a key parameter of the MIKE21 model to determine how much soil is eroded or deposited during simulations (Golder, 2011b).

The sampling method was adequate to support the modelling methodology used in the study for the Project area. The sampling methodology was not adequate for the upstream contributing areas.

A total of 16 samples were characterised by the VJT in the field and supplemented by laboratory techniques due to the limited field deployment time. The 16 samples gave a range of erodibility results (as measured by critical shear values) from low to high and appears to have captured the diversity of the Project's soil materials.

However, it is questionable whether erodibility can or should be described on the basis of critical shear values alone. For flood flows, sediment properties could strongly impact on erosion rates, but no sediment data were obtained or considered. Clay-rich sediments are commonly aggregated (Nanson and Maroulis, 2006), so that estimation of sediment properties on the bias of dispersed particle size is unlikely to yield accurate information.

The contributing catchment area was not sampled due to technical problems with the rainfall simulator whilst in the field. The contributing area sediment load was therefore estimated without any field-based data. In terms of estimating detachment by flood flows, it is questionable whether a measure of rates of detachment by drop impacts and shallow surface flows under a small rainfall simulator (3 m^2 plot area) would have any relevance, but the point is moot given the simulator was not used.

2.2.3 Results

The model results for a 1,000 year flood event for pre-disturbance conditions showed an outgoing sediment load of ~200Kt. The outgoing sediment load rises in the operating phase to ~300-400Kt, and to ~2,500Kt for post closure. The higher post closure result was accounted for by the higher erodibility of the capping material that will be used for disturbed areas. It was recommended that post closure erosion rates could be returned to pre-disturbance levels (i.e., ~200Kt) if the critical shear of the disturbed area capping materials could be increased to >6.5 Pa by placing 100mm of medium sand over the capping materials.

Generally, the results were adequately interpreted and presented. The model methodology and parameter value calculations were presented and supported by tables and graphs. Where no primary data for the contributing area sediment concentration were available, the estimation method was detailed. A sensitivity analysis of the model was conducted to reflect the uncertainty of the contributing area sediment contribution estimation.

An important element in the MIKE21 model is grid size, and this was not presented in the report. Typical approaches use a 20x20m cell size, but it is unclear whether the resolution was finer or coarser for this study. For example, small resolution size is better able to pick up low relief arid zone drainage patterns which can be broad through going braided patterns as distinct from a single well confined channel.

The report also details the outgoing total suspended solids (TSS) and sediment load for pre-disturbance, operational, and post-disturbance scenarios for contributing area sediment loads of 5, 20, 50, and 100 t/km^2. The operational and post-disturbance scenarios use the erodibility characteristics of field sample LMO16 for the disturbed area material. The justification for using this value was not clearly detailed in the report.

2.3 CURRENCY OF RESULTS

Yes, based on the methodologies used.

No further work would be required if the methodology is accepted.

2.4 COMPLIANCE

Western Australian mining legislation, guidelines, as well as other best practice guides are not prescriptive as to the technique required to assess mine site sediment and erosion at a proposal stage. It is the regulators expectations however that any mining waste landform is safe, stable, and not prone to significant erosion at closure (DMP, 2009).

The Department of Water Guideline No. 6 (section 1.1.1) and DMP standard conditions Schedule 2 (Public Drinking Water), Schedule 4 (Waterways Management), Schedule 6 (Proclaimed Surface Water Endorsement and Irrigation District Areas), and Mining Lease (Basic and Ongoing) that:

> *…measures such as effective drainage controls, sediment traps and stormwater retention facilities being implemented to minimise erosion and sedimentation of receiving catchments and adjacent areas.*

The report methodology, being based on such a large flood event, does not provide any information that may inform sediment and erosion control plans such as the size of events that cause runoff, range of runoff events, storm size and sediment concentration correlation, sediment properties, and surface hydrology and flow routing to calculate sediment basin/drain size and location.

2.5 RECOMMENDATIONS AND GAP ASSESSMENT

Landloch could not support the specific recommendations made in the Golder (2011a) report, and has concern with the approach taken in general. These concerns are based on the following points.

<u>The model used</u>

MIKE21 is a powerful hydrodynamic model that was developed in Denmark to model water flows and sediment transport in coastal and estuarine environments. The model is particularly powerful at simulating flow velocity, flow direction, and waves. Typical applications for the MIKE21 model are:

- Design data assessment for coastal and offshore structures,
- Optimisation of port layouts and coastal protection measures,
- Cooling water, desalination and recirculation analysis,
- Optimisation of coastal outfalls,
- Environmental impact assessment of marine infrastructures,
- Ecological modelling including optimisation of aquaculture systems,
- Optimisation of renewable energy systems,
- Water forecast for safe marine operations and navigation,

- Coastal flooding and storm surge warnings, and
- Inland flooding and overland flow modelling.

The model is commonly used to simulate inland flood events and gauge the impacts of sediment detachment and distribution within confined channels, floodplains, and sediment's interactions with man-made structures. Use of MIKE21 to estimate mine site erosion and sediment transport is an atypical application. This has implications for the model input parameters and how the data are generated.

Model parameters

The model looks at the sediment transport of channel bed materials and considers them as either being cohesive (clay) or non-cohesive (sand). The model appears to then assign a single particle size to these two different materials. The reality for soils is that they are a mix of materials with differing particle sizes (sands, silts, clay, rock etc.) and their detachment, transport, and deposition in response to runoff will be complex. Therefore, predicting sediment detachment transport using a single particle size does not capture the inherent complexity of catchment scale erosion and will potentially produce erroneous results.

Further, the VJT test is an appropriate field test to estimate scour in a stream bed for the MIKE21 model. The concern is that catchment scale erosion occurs as a complex interplay of hillslope and channel processes. They operate at scales from millimetres to square kilometres, and over different time periods. Typical catchment scale erosion involves several aspects including the detachment and delivery of sediment from hillslopes (rill, interrill, gully erosion and deposition) to streams for export (streambank, bedload, suspended load erosion) and deposition. The rates at which soils erode within a catchment depends on factors such as:

- Particle size distribution,
- Particle density,
- Aggregation,
- Runoff rate (i.e., how much of a rainfall event will translate to surface flows that can cause erosion?)
- The materials' resistance to rill and interrill erosion by surface flows,
- Wind erosion,
- Chemical, physical, and biological soil processes (e.g., soil sodicity, surface sealing, surface desiccation),
- Catchment cover (e.g., vegetation),
- Soil variability within a catchment,
- Catchment topography (including gradient, slope lengths, slope shape, and hillslope/channel connectivity), and
- Land management (e.g., grazing, fire).

Landloch is concerned that this variability is not accounted for by the assumptions of the site materials being either cohesive (capping materials) or non-cohesive (upper gypsum layer), which are parameterised in the field by the VJT.

Modelled event

Landloch is also concerned by the magnitude of the event modelled. Using a 1,000 year flood event with a duration of 120 hours is appropriate to determine questions around design maxima for dams, closure bund heights, or site flood levels on which to plan the location of infrastructure. However, catchment erosion occurs over much shorter time scales and during much lower magnitude/higher frequency events than the events modelled, and these events will potentially considerably alter the landform surface conditions. For example, a 1,000 year/120 hour storm event for Lake Maitland is 303mm, while the 500 year/120 hours event is 275mm, and the 100 year/120 hour event is 210mm. Thus a doubling of the time period does not double the size of the storm event. Also, shorter duration storm event or an event with a smaller return period may result is higher shear stresses being applied to the land surface. Therefore more typical approaches for modelling catchment erosion simulate a wider range of events that could potentially occur over a long period of time (e.g., 100 years) so as to capture the subsequent range of erosion events, rather than focus on one single atypically large event.

Report conclusion

Based on the critical shear values of the proposed disturbed area capping materials to resist scour, it was identified that these would be highly erodible during a 1,000 year flood event. It was concluded that this could be mitigated by 100mm layer of medium sand, as this would increase the resistance to scour.

This recommendation ignores what may potentially occur to a 100mm sand capping layer at closure over a long period of time and for processes other than flood events. For example, wind erosion is an important erosion process in arid environments and could compromise the sand layer over time, as could concentrated flows from other parts of the site interacting with disturbed areas during storm events. Landloch has experience in examining the failure of cover systems where, even though rock was used, it was inappropriate due to its weathering characteristics. Also, there may be smaller, higher intensity storms that cause greater shear on the sand layer above the 6.5 Pa identified in the report.

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3 CONCLUSIONS

- It is concluded that the use of the MIKE21 model, the parameterisation of the model, and the report findings were sound.
- Landloch however finds that the use of the MIKE21 to model a 1,000 year flood event does not take into account more typical conditions that cause erosion and sedimentation in a WA arid environment, and that have been shown to cause landform failure via erosion.
  - Landloch would be extremely cautious in using the report's recommendation of a 100mm medium sand capping of disturbed areas as a long term option for closure planning.
  - The modelled event does not yield information that could be used to design sediment and erosion control plans for the operational phase, nor for the development of robust mine closure plans, except to highlight the areas of highest risk.

4 RECOMMENDATIONS

- Landloch recommends that the report be used for the Project's proposal, but with the caveat that the findings be limited to indicating that the disturbed areas have been identified as long term erosion hazards and that this will require further investigation for mine closure planning.
- Further investigations should be based on:
  - Determining the variation of soil materials across the catchment.
  - Conducting material characterisation studies on these materials to determine their erosion properties.
  - Using these material erosion characteristics to parameterise a model that will simulate long term erosion and sediment transport over a long period (e.g., 100 years) based on the Lake Maitland climate

Careful planning and execution of such a study can also be used to develop a site erosion and sedimentation plan to control offsite impacts during the production phase of the mine, and to provide preliminary information on which to develop early phase MCPs.

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