TUI MINE TAILINGS REMEDIATION PROJECT – GEOTECHNICAL, ENVIRONMENTAL AND CONSTRUCTION CHALLENGES - Project case study of the recently completed, largest contaminated site remediation in New Zealand. (Abridged version)

G.P Quickfall  Hiway Environmental Ltd, Auckland, New Zealand

G. Basheer  Environment Waikato, Hamilton

B. Croucher  Ministry for Environment, Wellington

I. R. Jenkins, D.L Fellows  URS New Zealand Ltd

T. Willson  Tonkin and Taylor, Hamilton

Keywords: Insitu Mass stabilising (IMS), Ex situ Mass stabilising (EMS),

ABSTRACT

1 INTRODUCTION

The Tui Mine is an abandoned mine site on the western flanks of Mt Te Aroha. The mine produced a range of base metals, including copper, lead, zinc, gold and silver.

The site is located within the catchments of the Tui and Tunakohoa Streams, both of which flow into the Waihou River at the base of Mt Te Aroha, in the Waikato.

The site consisted of some 100,000 m³ of impounded tailings, a number of mine adits, waste rock and ore dumps and stockpiles (see figure 1). Various water types discharge from the site including adit drainage, natural catchment drainage and contaminated under drainage (low pH, high dissolved metals concentrations) from waste rock and tailings.

Previous rehabilitation initiatives have been unsuccessful in improving water quality discharging from the site. Temporary buttressing of the tailings was constructed in the 1970’s.

Concerns over contaminated water and the risk of landslide of the 100,000m³ of tailings caused the Local and Regional Authorities, Department of Conservation and Ministry for the Environment to review site remediation options.
From 1974 to 2009, a number of site investigations, geochemical and geotechnical characterisation testing and reporting was carried out on the Tui mine site primarily by URS and Tonkin and Taylor Consultants. An assessment of various remedial options was also completed. The options were assessed and assigned a ranking based on long term effectiveness, risk assessment, constructability and cost. The favoured option to stabilise the tailings on site and to create a regraded landform was selected in 2009.

The remediation aimed to provide a long term solution by providing geochemical and geotechnical improvement, meet cultural and social objectives and preserve the mining heritage.

In 2009, Hiway Environmental (HE) provided advice and potential methodologies and carried out a full scale field trial to prove the Geotechnical and Geochemical performance, constructability and to enable design refinement. Both In situ Mass Stabilising (IMS) and Ex situ Mass Stabilising (EMS) and blending of approximately 3000 m3 volume were carried out by HE. The results of this were reported in URS (2009d) and published by Fellows and Jenkins (2010).

2 KEY CONSTRUCTION RISKS AND CHALLENGES

The Tui tailings dam comprised of 100,000 m3 of tailings contained within a dam, situated in a steep sided valley. The dam which had been constructed using waste rock and tailings was suspected of having a factor of safety of 1. (refer to figure 2 and the dam cross section figure 3).
The key construction issue facing the project was the very low strength of the tailings which were up to 14 metres deep. The works required a progressive process of excavation to 5m above the base to allow for IMS which was followed by EMS carried out on the excavated material to achieve the final landform. (Refer figure 4)

The key geotechnical and environmental challenges in constructing the remedial design included:

- Geotechnical instability. There was a static risk of dam failure during construction. Thus careful staging and management of the works was required to mitigate this risk. The assessed cost of damage caused by possible failure was $170m.
- The tailings were saturated and would quickly liquefy under the loads of construction equipment. Work was planned to start at the eastern and proceed west thus unloading the dam.
- Unforeseen ground conditions could not be ruled out despite thorough investigation.
- Quantities and types of materials were uncertain meaning cost uncertainty.
- Possible buried cyanide drums on site would require careful excavation, testing, health and safety controls and potential for disposal.
- High short duration rainfall conditions prevented work during winter months.
The site required full time security with public safety being a major consideration.

- The site was steep confined and difficult to access.
- The site access road was steep and narrow and one way. Effective traffic management was essential to ensure safe access for the 4 property owners, DOC, Kordia and up to 60 site deliveries a day.
- Comprehensive health and safety management ensured staff were protected from contamination.
- Stakeholder objectives were paramount. Local Iwi, DOC, MfE, Waikato Regional Council and Matamata-Piako District Council were well represented in the project structure.
- With this being the first major IMS project in NZ HE invested heavily in machinery, survey gear and skilled staff.

3 TENDER PROCESS – ALTERNATIVES, CONTINGENCIES

Waikato Regional Council (WRC), funded largely by the Ministry for the Environment (MfE) was the principle and Project Manager with Tonkin and Taylor as the Engineer to the Contract and URS the project designers.

HE was awarded a contract valued at $12.377 million. The contract period was 70 weeks commencing in October 2011 and with a completion date of March 2013. This included a winter shutdown period from 1 May to 1 October 2012.

4 CONSTRUCTION WORKS

HE mobilised to site in September 2011.

The access road was realigned, stabilized and sealed (to allow for truck and trailers) prior to site establishment. This road was critical to efficient access. With the road only one way a push button traffic light system was designed and installed. This worked well.

The site compound was squeezed into the process plant area which saved valuable space.

4.1 INSITU MASS STABILISING (IMS)

The IMS process uses dry binder injection and suits weak saturated soils. Mixing is via an excavator mounted mixing head to 5m deep. Dry binder is pumped from a pressure pod through a 75mm hose to the mixing head.

Environmental controls were installed on site and IMS work commenced at the eastern shallow end. The premixed binder (a blend of 10 parts cement, 1 part CaO and 2 parts CaCO3) was delivered to site in articulated tankers, stored in pressure tanks and
pumped to the pressure pod. The pod controls pressure and binder delivery rate using a special valve and load cells which are integrated via a computerised control system.

The mass mixing head attached to the 35 tonne excavator was guided by a GPS grade control system. This combined with the binder delivery computer provided sound quality control, quality assurance records and as built. Binder was evenly mixed at a rate of 160 kg per m3.

Initial progress was slower than anticipated. This due to the confined operating area, minimising native bush clearance, and design changes required to address the reality of the site. Some unexpected ground conditions and slower than anticipated mixing production all put pressure on the programme.

Utilising a purpose built, track mounted cement pressure pod helped speed up the IMS production. However by April 2012 the project was 2 months behind programme.

In April 2012 as works proceeded west the nature of the tailings became coarser and firmer. This change initially slowed IMS progress and by May 2011 had precluded IMS as a stabilizing method. With no other options available HE proposed to excavate the remaining tailings to the base and exsitu stabilise them. HE urgently developed a safe and efficient construction method. As one of the risk mitigation options tagged in the tender it was readily accepted by the client. Payment for this methodology was as per contract rates. Excavation to the base of tailings provided certainty that all tailings were stabilised.

Updated changes to tailings volumes predictions during the construction were monitored by URS to ensure that a stable engineered landform could be developed. The landform final levels were redesigned several times as the works progressed, accounting for bush clearance limits, surveyed quantities and bulking. The final quantities were confirmed in Jan 2013 and while the base was exposed URS had obtained definitive soil properties on the underlying colluviums. This information allowed them to provide the final design which utilised a shear key at the western toe and eliminated the need for substantial deep soil mixing.

A total of 25,000 m3 of IMS was completed.

Figure 5: 35 Tonne Insitu mass stabilising rig with Pressure pod in the background
4.2 EXSITU MASS STABILISING (EMS)

By Jan 2012 enough IMS was constructed at the eastern end to provide a stabilised platform from which excavation to 5m above base level and the EMS of the excavated material could be started. By May 2012 the combined process of excavation, IMS and EMS had provided an efficient work area for filling. Excavated tailings were trucked, bladed out in 250mm thick layers, cement and lime were mechanically spread and the layer was mixed using a tracked hoe. The hoed material (EMS) was bladed smooth and compacted to specification with a pad foot roller.

This EMS used the IMS cement blend at 146 kg / m3 plus an additional 60 kg/m3 of CaCO3

The above mix was an accepted alternative to blending with rock and stabilising which utilised tailings without rock and saved on the demand for the limited amount of waste rock available onsite.

The other main EMS product to be constructed was a mix of 2 parts tailings to 1 part rock with 40kg/m3 of CaCO3 and 50kg/m3 of CaO. This consumed the piles of contaminated ore around the site and provided strength to the blend.

In round figures the EMS products constructed.
- 32,000m3 of Rock/Tailings blend with 3 different binder recipes.(11,000m3 of rock)
- 46,000m3 of tailings blended with cement blend and lime.
- 18,000m3 of 6 different blends.

At tender time there were only 4 blend types proposed but as the project progressed unforeseen types of materials emerged, rapid sampling and geochemical testing was carried out and new mixes formulated to amend the varying degrees and types of contamination in them. Among these materials were organics from vegetation buried under the tailings. The varying materials required 9 different recipes with associated handling problems on the confined site. As well a dark soil there was approximately 2000m3 of logs that had to be sorted and separated and were disposed of in the log dump further east of the tailings.

Figure 6: Ex situ mass stabilising operation
4.3 EARTHWORKS

The number of material variants excavated and requiring characterising caused some delay due to the logistics of stockpiling, sorting and designation of position in the landform. The efficient handling and treatment of these materials was paramount to achieving budget. The testing, redesign and change in construction plans were carried out with urgency and collaboratively by the client, designer, engineer and contractor. Earthworks figures area as follows.

- Onsite Rock for Stabilising – 12,000m³ excavated and Crushed
- Oxidised tailings – 4,500m³ Cut
- Unoxidised Tailings – 85,700m³ Cut
- Ore Chip – 4,000m³ Cut
- Rock for Swale Drains – 3,000m³ Imported
- Clay – 5000m³ Imported Fill for Capping
- GAP40 Rock – 3000m³ Imported Fill for Capping
- Topsoil – 6500m³ Imported Fill for Capping and Contour Drains

This created a total volume of 115,000m³ of Earthworks. Note that all materials were stabilised and used on site.

4.4 DRAINAGE

The design required the construction of 700m of 5m wide open swale drains around the perimeter of the stabilised landform. These consisted of a 600mm layer of rock riprap 300mm to 600mm in size. These were designed to reroute surface water off and around the tailings earth fill.

A cut-off drain at the head of the impoundment was constructed to collect and redirect any groundwater before it came in contact with the tailings. A collection drain at the toe of the stabilised landform was constructed to pick up both ground water and possible leachate and at the interface between the natural material and the stabilised material.

4.6 LANDFILL CAPPING

The capping consisted of four layers of material. Figure 7 displays the thickness and structure of the capping layers. The Separation layer utilised EMS of oxidised tailings, organics, rock and clay with 4 different application rates of lime and cement to ensure the economic use of site materials. Clay was sourced from Hyndmans Quarry 40km south of the site. GAP40 was sourced as the drainage layer from Taotaoaroa Quarry 70km south of the site. Topsoil was sourced from a farm only 8km north of the site. A total of 30,000 tonnes of material was imported to site for the capping layer.
4.7 PROGRAMME

The critical path followed the initial enabling works and then IMS and EMS works followed by the capping layers. Other work items such as drainage were programmed around critical path.

The first key milestone was to complete in situ stabilising (0 to 5 m depth) in the eastern end of the impoundment. Due to previously mentioned delays, this milestone was achieved in December 2011, some 6 weeks behind programme.

The next key milestone was completing the stabilising works to chainage 150. The area west of chainage 150 was considered a critical zone where the designers aimed to achieve better geotechnical and chemical results. This material essentially buttressed the up slope. Construction west of Ch 150 put the short term stability of the dam at greatest risk.

Seeing the 2 month program slip looming at the end of April HE applied for and was granted approval to work beyond April. Work was continued until early June which put the contract back on time.

An early recommencement of work in the second week of September 2012 enabled some work to recommence with full production ramped up by October.

Stabilising works were completed by February 2013 with the capping works, more variations and landscaping works running to a well planned but demanding and tight programme. Drought conditions were beneficial and the entire project achieved practical completion on 10 May. This was ahead of the revised due date for completion allowing for time extensions related to variations and wet weather.

4.8 QUALITY CONTROL

Delivery of quality was essential to achieve the project goals and stakeholder objectives.

HE invested effort at the start to ensure that robust contract plans were compiled to our client’s satisfaction and that would provide an overall delivery structure. The quality assurance plan was comprehensive and it called up all the standard requirements of a major civil project. In addition to this the designer required that a
high frequency of sampling and testing of tailings pre treatment and post treatment was undertaken on a tight frame to give the designer results to check the effectiveness of the remediation throughout the works. To this end HE engaged GHD consultants to undertake sampling, testing and reporting for the project. GHD supplied a full time Environmental Engineer and supported him from their head office. GHD collated all results and supplied them with a detailed report every 2 weeks. The dedication of this resource to the task required was key to delivering this essential aspect.

Testing included NDM, scalar, shear vane, sampling by rotary coring and push tubes for triaxial strength and permeability testing and geochemical testing.

At the time of publishing this paper (10 May 2013) validation testing was still underway it is not appropriate to include any results in this report.

5 PROJECT STATISTICS
- Final contract claim $13.2 million (delivered within the total project budget)
- Total Man hours on site: approximately 100,000 man-hours
- Total LTI’s (Lost time injuries): 2 minor reported incidents
- Total FAI’s (First aid injury): 1 minor incident
- Total truck movements to site calculated as: 3,500 trucks
- Cement use: 12,000 tonnes : Lime use: 6,000 tonnes
- IMS: 25,000 m³ : EMS: 85,000 m³
- Earthworks: 115,000 m³
- Imported Material: 50,000 tonnes
- Public complaints 3 related to truck traffic movements.

6 CONCLUSION
Despite the years of investigation and knowledge gained by the Tui veterans at URS, Tonkin and Taylor, WRC and HE. Tui Phase 2 was always going to be an unpredictable and challenging project. Knowledge and technology employed with focus by skilled staff was gelled by an effective overall client project management structure. With all the stakeholders working towards a common goal cooperation was the key to this project’s success.

Figure 8: Tui tailings dam 2009  
Figure 9: Tui mine completed. May 2013
REFERENCES


URS. (2011, September 12). Tui Mine Site Remediation Phase 2 design drawings for construction.


URS 2004 Summary of Tui Mine Remedial Options


