# Savage River Revival

**NEWSLETTER 4**

**June 2012**

**SAVAGE RIVER REHABILITATION PROJECT**

***A cooperative program between the Tasmanian Government and Grange Resources***


## SRRP Proud of its Success

Acid Rock Drainage (ARD) is an international problem threatening not only riverine water quality and habitats, but resulting in costly long term remediation and treatment challenges. The technical solutions are diverse and the financial implication for remediation work is expensive. The work being undertaken by the Savage River Rehabilitation Project (SRRP) has, and will continue to assist in achieving cost effective solutions, and contribute to knowledge in the field, both locally and abroad.

**Figure 1: Savage River Mine Downstream Survey Site, 2011 (Courtesy Tom Krasnicki)**

The SRRP was initiated in 1996 as a cooperative project between the Tasmanian Government and the Savage River Mine operator, Grange Resources (formerly Australian Bulk Minerals), and considerable progress has been made to remediate legacy acid mine drainage issues on site caused from mining practices in the 1960's and 1970's.

The SRRP Management Committee held its 100th meeting in December 2011 and is proud to celebrate a number of major achievements including:

- River health improvement by diverting a major acid drainage seep out of the Savage River via the North Dump Drain;
- Improvement of river health through the addition of alkalinity to Main Creek via the B Dump cover system;
- Further research into the SRRP Carbonate Reactor Plant;
- Extensive water quality and biological monitoring of the Savage River and tributaries;
- Hosting the 6th Australian Workshop on Acid and Metalliferous Drainage in 2008;
- AMIRA research project underway investigating alternative Acid Rock Drainage treatment options; and
- Presentation of SRRP technical papers at the 8th International ICARD conference in Sweden.

The EPA administers the remediation funds and overseas the project as a whole. Staff from the EPA Division of the Department of Primary Industries, Parks, Water and Environment, manage day to day activities of the project. The close working relationship between Grange Resources mine personnel and the EPA Division's personnel will ensure the continued success of this project into the future. The SRRP also acknowledges the experts in various fields of knowledge who have contributed to the success of the project to date.

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## SRRP Background

The Savage River mine is located in northwest Tasmania in steep, mountainous terrain surrounded by wilderness areas, including the Savage River National Park. The original open cut iron ore mine was established in 1967. Operations during the first 30 years of the operation caused environmental harm to the Savage River and its tributaries.

The Tasmanian Government entered into the Savage River Rehabilitation Project (SRRP) with Australian Bulk Minerals, to remediate the pollution from past mining operations.

In January 2009 Grange Resources Limited acquired the 100 percent interest in the Savage River Mine and has continued to maintain a close working relationship with the government, particularly staff in the EPA Division of the Department of Primary Industries, Parks, Water and Environment (DPIPWE), who project manage much of the SRRP work, in collaboration with Grange Resources.

The SRRP has clear objectives, which are set out in the strategic plan focussing on developing long-term solutions for mitigating historic pollution by passive methods and by water treatment.

The objectives of the plan are:

- To promote the recovery of a modified but healthy ecosystem in the Savage River downstream of the mine, and encourage native fish migration into the upper Savage River;
- To develop and implement an agreed long-term strategic plan for the rehabilitation and remediation of historical disturbances at the Savage River Mine;
- To integrate remediation works with ongoing mining operations wherever practical and to co-operate with Grange Resources with the planning and implementation of projects; and
- To demonstrate best practice in all aspects of the project and to communicate progress and findings to the community.

## Independent Expert Review

The third independent expert review of the SRRP was completed in 2009. The review was conducted by John Miedecke (John Miedecke and Partners Pty Ltd), Peter Scott (AECOM), Dr David Williams (University of Queensland), and Dr Ward Wilson (Unsaturated Soils Engineering Ltd).

The panel commented that Grange Resources and DPIPWE staff have demonstrated excellent progress in achieving the objectives of the SRRP. Improvements are clearly evident in all aspects of waste and water management between 2005 and 2009.

These include:

- Improved water quality monitoring sites and data acquisition for Main Creek;
- Completion of B Dump complex remediation with a water-shedding non-acid generating cover which is diverting rainfall runoff and reducing infiltration;
- Successful implementation of the North Dump Drain diversion to South Lens Pit;
- Comprehensive studies of the Old Tailings Dam;
- Completion of small scale carbonate neutralisation trials; and
- Study of Broderick Creek water quality.

## AMIRA Project Underway

The SRRP is a major sponsor of the AMIRA International funded research project P933A "Alternative Treatment Options for Long-term ARD Control".

The objective of the project is to examine methods of reducing acid generation rates (AGR) from wastes by a factor of 10 to 100 times, by:

- Broadening the range of materials, including on-site silicates that can maintain pH 5 to 7 conditions;
- Quantifying addition rates of limestone, silicates and natural phosphate rock, separately and in combination;
- Investigating delivery methods including co-disposal, cover layers and recycle solutions;
- Defining AGR control factors to maintain passivating coatings; and
- Defining scope of application including climatic conditions and waste types.

As part of the project a survey of the B Dump calcite-chlorite schist (CCS) side cover was carried out. Excavation sampling of the CCS side cover was undertaken with the cover having been in place for about four years.

The B Dump complex (Figure 2), a sizeable, historic dump of acid-leaching waste rocks, was capped in 2006 with clay and waste alkaline rocks to reduce further acid drainage.

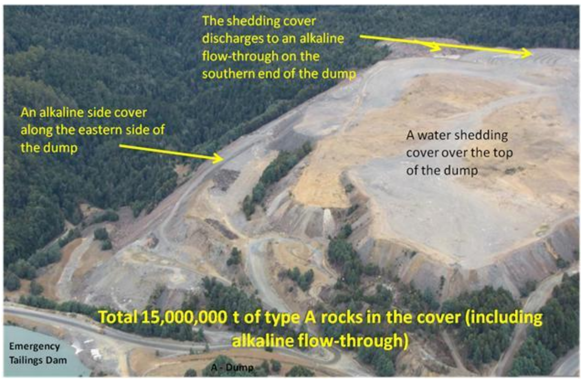


**Figure 2: The rehabilitated B Dump complex (Li et al., 2011)**

The cap comprises:

- A water shedding cover over the top of the dump that minimises rain water infiltration;
- An alkaline side cover along the eastern side of the dump; and
- An alkaline flow-through on the southern end of the dump.

Recently, two sonic bores were also drilled through the B Dump complex to investigate the geochemical process at work (Figure 3). One borehole was drilled to intersect the CCS side cover, along with the underlying Potentially Acid Forming (PAF) material and the basement. The second borehole was drilled through the surface of a section of uncapped PAF material to basement.

Research is being undertaken to determine to what extent the alkaline covers are allowing rainfall infiltration to take up alkalinity and dissolve silicate.

Water seeping through the cover material may neutralise existing ARD, and produce a stable coating of secondary products at the sulphide grain surfaces, reducing their acid generation rate.

The research team has found evidence of this occurring and the results are published in the paper "*Assessment of alkaline cover performance for abatement of ARD from waste rock dumps at Savage River Mine*" (Li et al., 2011).

Li et al. (2011) found the water monitoring results from B Dump alkaline flow-through show this drainage has neutral pH. They also found alkalinity derived from this material is available at a faster rate than acidity is generated in the PAF waste. This result indicates good performance of the alkaline flow-through cover.

Seeps from below the alkaline side cover have a lower pH (4) and a calculated acid generation rate to acid neutralisation rate ratio of 1.2. This suggests that currently acid generation in the PAF material occurs at a faster rate than alkalinity is supplied from the CCS cover.

**Figure 3: Inspection of sonic bore samples B Dump (courtesy Shengjia Zeng, 2011)**

The results of this study show that alkalinity from the side cover has been migrating down into the PAF waste below over the past four years, and forming passivating layers on pyrite grains. It may be some time before the remaining PAF waste in the dump is fully passivated. The CCS alkaline side cover contains sufficient neutralising minerals (calcite and dolomite) to deliver alkalinity for passivation of the PAF waste below the cover well into the future.

## Water Quality Database

Water quality monitoring undertaken since the beginning of the SRRP has resulted in large amounts of data.

The development of a new database system, known as Spigot, now allows for easier integration of flow data, laboratory data and field measurements. Spigot allows for flux calculations to be made as well as a number of other useful calculations. This development also facilitates better data sharing between the project partners.

The EPA Division has developed Spigot with funding from the Bureau of Meteorology Water Information Modernisation and Extension Program.

## South Lens Water Quality

South Lens is a disused mine pit, now set aside as a passive 'treatment pit' for the central part of the site. It receives water inputs from North Pit, Centre Pit North, Broderick Creek (via Bretts Drain) and North Dump (via North Dump Drain). South Lens overflows at its southern end into the Savage River.

An extensive monitoring program has been implemented within South Lens (Figure 4) and at the outlet in order to gain a better understanding of changes within the pit and of the quality of water entering the Savage River at that point.

The lake is periodically monitored through the collection of water column profiles for physical parameters (pH, temperature, conductivity, dissolved oxygen, salinity, turbidity and chlorophyll a) at three points in the lake (north, middle and south end). Water samples are also collected regularly from the surface, at 20m and 40m depth for chemical analysis.

Depth profiles show an annual cycle within the South Lens Pit, with stratification occurring in spring/summer followed by complete destratification/vertical mixing in winter.

In the warmer months, the surface layer is characterised by warmer, fresher, slightly alkaline and well oxygenated water.

In winter, the water column becomes well homogenised at a pH of around 7.3 and a conductivity around 1500 µS/cm. While oxygen tends to be depleted at depth in summer, no anoxia has been observed within South Lens.

**Figure 4: South Lens Pit**

Understanding water layers can be relevant to mine sites for the following reasons:

- Destratification may lead to sudden pollutant releases;
- Anticipated treatment efficiencies may be reduced if water travels along a particular layer;
- Reagent requirements for pit neutralisation may be substantially higher than suggested by surface water quality; and
- Stratification may limit the ecosystem health of the water body.

Water quality within South Lens has been influenced by the diversion of water of high acidity and high metal loads via North Dump Drain since September 2006. Metals have increased from 10 to 30 µg/L for copper and zinc, and from 50 to 100 µg/L for nickel. However, total alkalinity within the pit is still quite high, around 110 mg $CaCO_3$/L and overall pH is still above neutral.

The diversion of this acid drainage into South Lens has lead to improvements in the Savage River, as discussed in the *River Heath* section below.

## River Health - Water Quality

*Savage River*

Construction of the North Dump Drain has reduced the pollutant load by removing more than 36,000 kg of heavy metals per annum from the upper Savage River, diverting it into South Lens for neutralisation. The North Dump is responsible for 17 percent of the total copper and aluminium load from the site.

Ongoing water monitoring in the Savage River has shown that dissolved manganese, nickel, zinc and copper levels have declined at the furthest upstream monitoring site. This is associated with the diversion of seepage from the North Dump. Sulphate levels have also declined.

*Main Creek*

Recent data suggest that acidity, metal and sulphate fluxes have decreased in Main Creek, while the alkalinity flux has increased. A longer monitoring record is required to confirm this trend due to the high flow variability at the site.

A comparison of recent against historical data suggests that total copper concentrations have decreased in the creek, dissolved copper has decreased relative to total copper, and calcium concentrations have increased over the same time period.

These changes are likely attributable to:

- increased alkalinity inputs in 2009-10 from the Main Creek Tailings Dam;
- additional alkalinity inputs from the B Dump alkaline flow through; and
- reduced metal and acidity inputs from B Dump due to the cover system.

**Figure 5: Sample point in Main Creek (courtesy Shengjia Zeng, 2011)**

*Environmental Targets for Water Quality*

Environmental targets for water quality have been set based on toxicological studies conducted in 2001. The studies found that copper concentrations were often at toxic levels in the Savage River, and that copper toxicity was affected by calcium and alkalinity. Targets have been set for both fish and sensitive macro-invertebrate species, such as *Ceriodaphnia*.

In the Savage River in the vicinity of the mine site, dissolved copper values are generally within the fish toxicity limit, and all but a few of the medium flow values are below the invertebrate limit. The water quality during low and medium flows poses the larger risk to the ecosystem.

**Figure 6: *Ceriodaphnia spinata* (courtesy Aquatic Science)**

Downstream of the mine at the Savage River at Smithton Bridge monitoring site, dissolved copper values are generally below the fish toxicity limit, and most are below the invertebrate target.

Reductions in total copper levels entering Main Creek, combined with the increased alkalinity in the creek have lead to decreased dissolved copper concentrations. These parameters frequently achieve the site-specific fish target and were close to the *Ceridaphnia* target on several occasions.

A study to reassess toxicity thresholds based on a sensitive west-coast species (*Ceriodaphnia spinata*) (Figure 6) is planned.

## River Health - Biological Health

Freshwater Systems conducted rapid assessment (AUSRIVAS) macro-invertebrate sampling and semi-quantitative fish sampling in 2007-08 to compare with the 1997-2001 studies. In 2007-08 a significant increase in species richness and abundance of fish was observed in the lower and middle reaches of the Savage River, while reference and control sites did not change substantially in species richness and decreased in abundance. This suggests that improved water quality in the Savage River has allowed an increase in fish populations in the lower reaches.

A degree of recovery in macro-invertebrate communities was observed at sites both in the vicinity of the mine site and downstream in species richness, and community composition.

The reach in the immediate vicinity of the mine was shown to be largely harmful to fish and a barrier to fish migration into the upper Savage and this was likely to be exacerbated by low river flows.

Main Creek continued to be severely impacted with no fish and very poor macro-invertebrate communities present.

The next biological assessment is planned for 2011-12.

## Old Tailings Dam Research

Construction of the Savage River Old Tailings Dam (OTD) commenced in 1962, with the dam being used as the disposal site for the pyrite-rich tailings produced at the mine until 1982. Tailings are now deposited into a new dam (Main Creek Tailings Dam) which is located immediately to the south of the OTD.

The tailings in the southern part of the OTD are exposed, while in the northern part of the dam the tailings are submerged beneath a 1 to 2 m deep lake. The dam contains approximately 14 million cubic metres of tailings, to a depth of 30 to 35 m.

The seeps discharge into the Main Creek Tailings Dam. With the current operation of the mine, the alkalinity in the tailings discharged to the Main Creek Tailings Dam by Grange Resources, provides adequate short-term neutralisation of the seeps. This will cease when the mine closes or the tailings dam reaches its full capacity. The SRRP is considering options for addressing this long-term problem.

_Geochemistry_

A geochemical assessment of the near-surface tailings on the OTD (Figure 7) was conducted by SRK Consulting in 2009-10. During the programme, seven piezometers and eight pore gas sampling holes were installed and a conceptual geochemical model was proposed. Results indicated that the sulphide mineralogy in the tailings was dominated by pyrite which increased with depth below the top 1 m.

**Figure 7: Streams of iron-rich acid rock drainage seep from the Old Tailings Dam southern wall**

The acid potential from the tailings was highly variable and copper, manganese, nickel and cobalt are the most abundant trace elements. No consistent trends in metal content were noted, either as a function of depth or spatial distribution across the tailings deposit. Leach extraction tests indicated that cadmium, copper, cobalt, mercury and sulphate may be leached at potentially significant concentrations. Oxygen fluxes measured for the tailings varied and the time to oxidise all sulphide minerals in the upper 3 m layer of the tailings was estimated to range from 180 to 390 years.

_Geophysical Monitoring_

A geophysical study of the OTD was completed by Darren Andrews in 2010. The aim of this study was to use various electrical and electromagnetic techniques to image the conductivity structure and identify areas within the tailings beach and dam wall where acidity is generated and/or transported.

Techniques included the Frequency Domain Electromagnetic (FEM) method (Figure 8), DC resistivity method and the Time-Domain Electromagnetic (TEM) method.

Work was concentrated on the southern dam wall and the southern 200 m of the tailings beach, including the south-west corner of the beach.

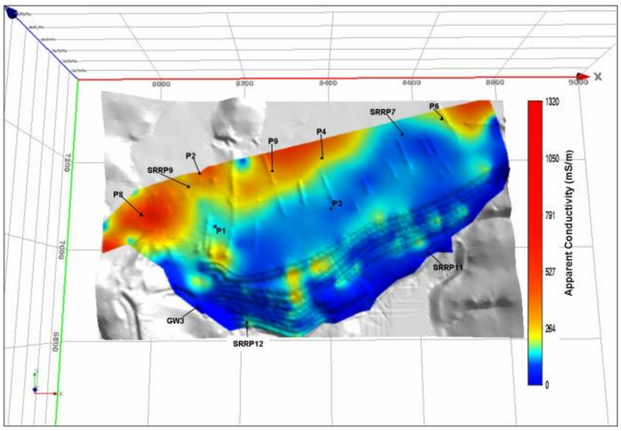


**Figure 8: Near-surface apparent conductivity of the OTD tailings beach, draped on a digital elevation model. Piezometer locations are marked. (courtesy D.Andrews, 2009)**

Major findings of the study include:

- Highly conductive areas occur at depth close to the basement - tailings interface suggesting that acids and other oxidation products travel downwards through the groundwater column and concentrate at the base of the dam.
- Migration of the contaminated water is strongly controlled by basement topography;
- The clay cap on some areas on the upper dam wall is permeable with percolation driving oxidation in the coarse tailings underneath;
- ARD may be trapped behind the eastern starter dam wall and may then seep slowly beneath the starter dam and through the underlying weathered bedrock profile;
- The southwest corner of the tailings beach is highly conductive at the surface (Figure 8) with the combination of very coarse tailings and a shallow water table providing a suitable environment for oxidation and ARD production;
- Chemical and physical stratification occurs within the water table at the main tailings beach indicating a relatively “fresh” layer of water overlying a more contaminated layer. This indicates that ARD products “sink” down through the water column; and
- Temporal changes in groundwater chemistry and saturation levels are significant influences on conductivity variations.

# ARD Management Options

The SRRP is continuing to investigate options for addressing the long-term problem with the acid drainage seeping from the Old Tailings Dam and the B Dump complex. These options are discussed below.

*Depyritised Thickened Tailings Cover*

The 2009 Expert Review of the SRRP identified that there is potential to opportunistically thicken and/or depyritise Grange Resource's tailings to provide a hydraulic cover over the OTD and Main Creek Tailings Dam as a means to reduce oxygen infiltration into the underlying tailings in the OTD and thus reducing oxidation of sulphides.

ATC Williams has been engaged by the SRRP to establish the viability and practical application of depyritised thickened tailings at Savage River. Initial work conducted has revealed promising results for producing a suitable tailings product and ongoing work will now be undertaken to cost the required plant modifications and impact on the OTD in terms of physical cover design, acid production and flow of pollutants.

**Figure 9: Aerial view of the Main Creek Tailings Dam with the Old Tailings Dam in background left (courtesy Grange Resources)**

*Neutralisation System Development*

The SRRP is planning to treat acid seepage at various locations on site using neutralisation plants. Conventional lime treatment is not affordable and the SRRP aims to develop a cost-effective alternative.

The concept involves mixing crushed carbonate rock with the acid drainage to neutralise the acidity and remove heavy metals. The aim is to achieve sufficient removal of heavy metals via precipitation and production of a sludge that has characteristics favourable for disposal.

Small scale field trials were carried out in 2007-08 on both the B Dump and the Old Tailings Dam seeps, using Savage River carbonate and commercially produced crushed limestone as neutralising agents. The limestone was found to be effective at removing iron, acidity, aluminium and the majority of the copper. A bund filled with cobber (an inert waste rock from the mill process) was constructed in order to capture the sludge produced by the neutralisation process. This sludge contained precipitated metal hydroxides, as well as limestone fines from the pilot plant overflow. The system proved successful as the effluent leaving the cobber bund was well clarified. Another objective of the cobber bund was to increase the acid neutralising capacity of rainwater passing through the bund in the longer-term, due to the excess alkalinity contained within the sludge.

CH2M Hill is currently engaged by the SRRP to assist in the further development of the neutralisation system. The aim of this study is to assist the SRRP to move from the current stage of the system's development to a stage where there is sufficient verification of design parameters to enable the SRRP to undertake an engineering, procurement, commissioning, and construction project for a full-scale system.

The performance of the cobber bund as a clarifier and alkalinity producing system will also be investigated in the years to come.

## ICARD Attendance

The International Conference on Acid Rock Drainage (ICARD) is the leading acid rock drainage event. It is held every three years and brings together mining industry representatives, consultants, researchers and regulators from all continents. It represents an invaluable opportunity for sharing information on current good practice, emerging technologies, on-going research, and developments in regulation. The conference also helps to highlight advances in our knowledge as well as gaps and challenges. In this way, the conference is a significant catalyst for determining future research directions.

During 2009, project committee members, Alison Hughes, Stephen Kent and Bruce Hutchison attended the 8th ICARD held in Sweden where they presented three papers on the SRRP. Learning outcomes from the conference attendance are being incorporated into the Savage River strategic plan.

## Future Directions

Given that the mine life and its associated processing plants have been extended until 2029, a new strategic plan is under development. This extension provides an opportunity for the SRRP to incorporate new technologies into the planning process and to work closely with Grange Resources to achieve the targets. A new strategic plan will be developed during 2012 and will cover issues including, but not limited to:

- Remediation of the Old Tailings Dam and tailings disposal options incorporating the Main Creek Tailings Dam and Old Tailings Dam by thickened tailings and depyritised tailings;
- Further research and development of the carbonate neutralisation reactor and the implementation of a pilot plant;
- B Dump remediation assessment and monitoring; and
- Ongoing river health monitoring program including biological health and a site water audit.

Further information about the SRRP, contact the Tasmanian EPA Division

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