APPENDIX S8

TAILINGS STORAGE FACILITY VEGETATION CAPPING TRIALS

ANGAS PROCESSING FACILITY

MISCELLANEOUS PURPOSES LICENSE APPLICATION 2019/0826

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TERRAMIN AUSTRALIA LIMITED

ANGAS ZINC MINE

Tailing Storage Facility - Rehabilitation Trials

Annual Report 2 - December 2012

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Care Of Our Environment

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Terramin Australia Limited

Angas Zinc Mine

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1 Introduction

Terramin Australia Limited owns and operates the Angas Zinc Mine (AZM) located around 2 kilometres north of the South Australian town of Strathalbyn and approximately 60 kilometres from Adelaide, Figure 1.

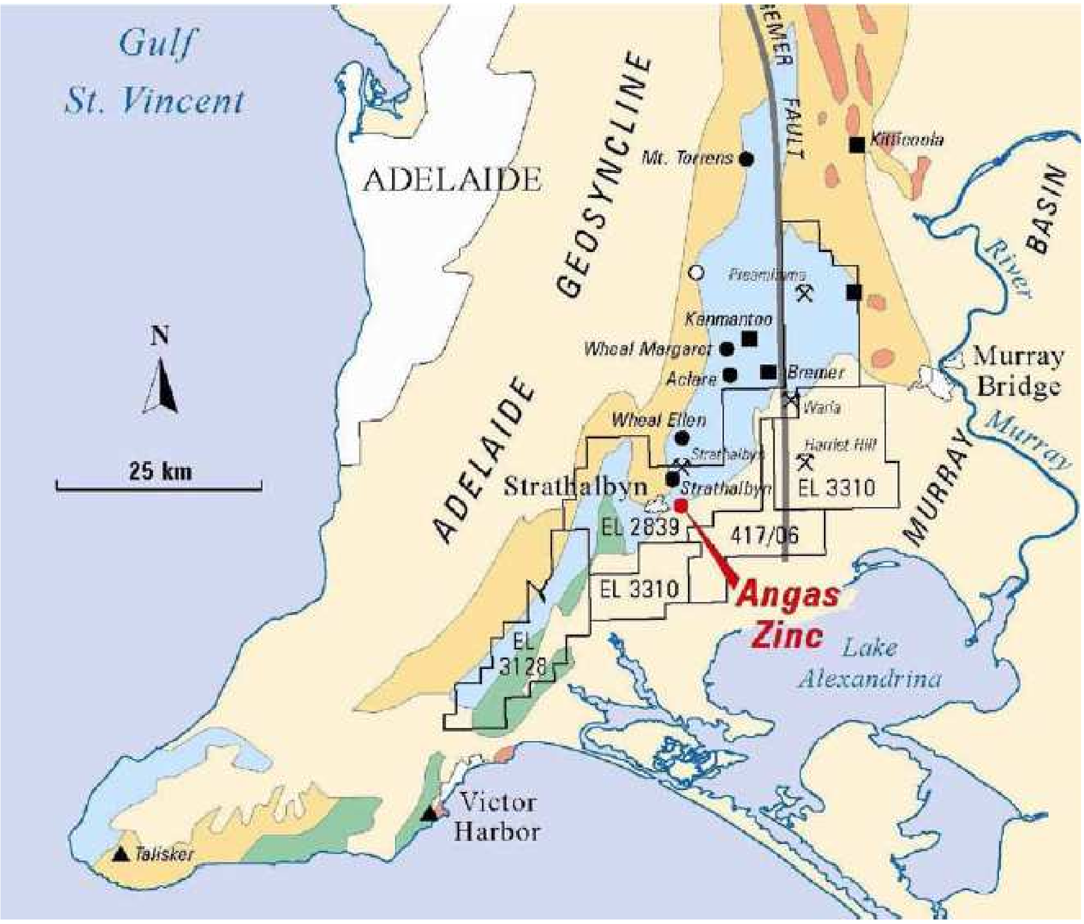

Figure 1: Locality Map of the Angas Zinc Mine

The Final Mining and Rehabilitation Program (MARP) was submitted in March 2007 after a long process of scrutiny by South Australian Government specialists and community consultation, Terramin (2007). Production of lead and zinc concentrate commenced in July 2008, at the time the Probable Reserves were reported as 2.15 million tonnes at 10% lead and zinc, with a projected mine life of seven years. Section 9.3.4 of the MARP stated that:

"Terramin will undertake rehabilitation trials and investigations as part of the progressive rehabilitation of the TSF. These trials will include topsoil and subsoil analysis and seeding trials conducted adjacent to the topsoil stockpiles adjacent to the TSF. These trials are designed to confirm the designed depth and profile of cover."

In compliance with this commitment AZM commissioned COOE Pty Ltd in August 2011 to commence a series of trials and investigations to confirm the designed depth and profile of the cover system will support vegetation. The First of these trials was constructed and revegetated in late September 2011.

This is the Second Annual Report generated for Terramin; some of the information relating to the construction phase is repeated to make this a stand alone document. The harvest for the 2012 season was undertaken on 6 December 2012.

2 Trial Design and Implementation

The overall objective of these trials was to demonstrate that the proposed cover system is able to store water and support a sustainable cover of vegetation.

In September 2011 a trial was established to replicate the proposed Tailings Storage Facility (TSF) soil cover near the AZM Tourist Observation Centre. The soil layers in the trial consisted of a plastic liner covered by 600 mm of sandy loam (supplied by Garwood Earthmovers from their Strathalbyn Quarry) and 100 mm of topsoil (from the AZM topsoil stockpile). In addition a second cover simulation was constructed using approximately 1,000 mm of sandy loam for comparative purposes with the TSF design of 600 mm, Figure 2 shows a schematic of the trial cover layers and the placement of soil moisture sensors.

* note a layer of sand was placed below and above the plastic liner to protect from stone from puncturing
Figure 2: Schematic of the Tailing Storage Facility and placement of soil moisture sensors.

The treatments were connected and therefore some potential for recharge and runoff from the higher stockpile was possible. However the soil moisture sensors were placed around 60 m apart to minimise this potential edge effect. In addition vegetation sampling was made at least 1m from any edge.

A pictorial record of the construction phases is presented in Figure 3 showing site preparation, placement of the PVC liner sandwiched between two layers of sand, covered by two subsoil treatments (~600 mm and ~1,000 mm) and 100 mm of topsoil. Figure 4 shows the completed landform and the installed soil moisture sensors prior to plant emergence.

Figure 3: Tailing Storage Facility - Trial Covers Construction Sequence

* High profile and 2 soil moisture sensors in background and sensors on low profile in foreground.
Figure 4: Rehabilitation Trial Covers – 2011

The trials were sown to Saia Oats (*Avena strigosa*) in early October 2011 and soil moisture sensors were installed to track soil moisture just below the topsoil at around 200 mm and near the bottom of the soil cover at around 650 mm / 750 mm. Native grass seed (*Austrostipa* and *Austrodanthonia* sp) were collected in December 2011 from the surrounding area and hand sown and raked in on the 28th May 2012 on the top and Saia oats were planted on the shoulders of the trial plots.

2.1 Monitoring - Methods

The monitoring program was designed to generate information that will help demonstrate that rainfall is stored in the cover system and is able to support a sustainable cover of vegetation. To achieve this rainfall, soil water content and tension and the vegetation cover was monitored:

1. Approximately every 14 days a scientist visited the site to observe changes and collect data from the instrument data loggers.
2. Daily rainfall totals were recorded at the Angas Zinc Mine meteorological station located approximately 250m from the cover trial. This information provides a context to the soil moisture measurements reported in this study.
3. Soil moisture monitoring consisted of measuring soil water content using theta probes with MEA T-bugs and soil water tension (suction pressure) using MEA G-bugs. Two probes one of each type were placed below the topsoil at around 200mm and just above the plastic liner on each treatment at 650mm (low profile) and 750mm (high profile) cover as shown in Figure 2.
4. Vegetation measurements included ground cover percentage by species type and biomass as an indicator of productivity.

2.1.1 Vegetation and Biomass

A desired landuse post mining is pasture for grazing or related agricultural activities. Biomass was measured to evaluate the potential difference in productivity between cover treatments. Note that productivity is not the same as yield. Yield is dependent on pasture or crop species used. In addition yield could be increased by agronomic activities such as the application of fertiliser and irrigation, beyond the scope of this study.

The sites were selected randomly from a numbered grid covering the surface with a minimum of 2m away from the plot boundary. Prior to visiting the site 4 sampling sites were selected using a random number generator on each treatment. A one metre quadrat was placed to delineate the area and a ground cover estimate by plant species was recorded.

Plants whose base was at least half in the quadrat were cut at ground level taking care not to collect soil and placing in a pre labelled calico bag and tying so that no plant matter could fall out in transit.

The samples were oven dried using force fan and heat set at 105°C for 4 hours allowed to stand for a few days and the process repeated. The samples were checked to make sure that all plants were brittle dry and allowed to adjust to room temperature prior to weighing. The dry mass was weighed on a Sartorius 4 digit balance with sensitivity set to 2 decimal places. The whole weight was recorded. The contents were removed and the clean bags were weighed separately. Field and laboratory data were transferred to electronic tables on an Excel spreadsheet for processing.

3 Results and Discussion

3.1 Observations 2012

A good even germination of oats was observed on the shoulders, but the native grasses on the top of the trial had much lower germination rates. A vegetation cover was established on top of the trials consisting mostly of self sown Saia oats and weeds, Figure 5 taken in October and Figure 6 taken in December prior to harvesting.

Figure 5: Plant Germination - 5 October 2012

Figure 6: Vegetation Prior to Harvesting 6 December 2012

3.2 Rainfall Data

Daily rainfall totals are shown in Figure 7, with individual dates for significant rain events of more than 20mm.

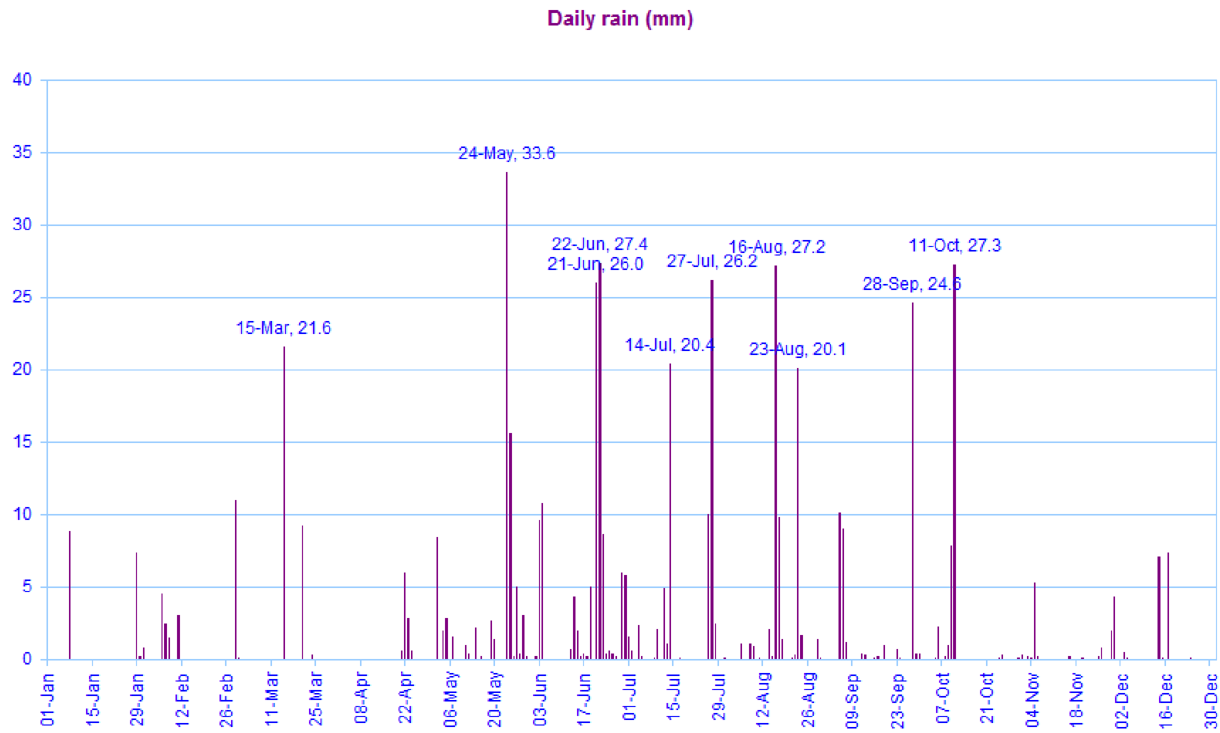

Figure 7: Angas Zinc Mine Daily Rainfall (highlighting key rainfall events)

3.3 Soil Water

3.3.1 Volumetric Soil Water Content

Theta probes tracked the moving wetting fronts through the soil profile, For example on the high profile treatment the first pulse of rain took nearly five days to travel 550mm, but only around a day once the soil profile stabilised at around 30% soil water content, Figure 8. This delay after the first rains was also observed on the low profile treatment, Figure 9.

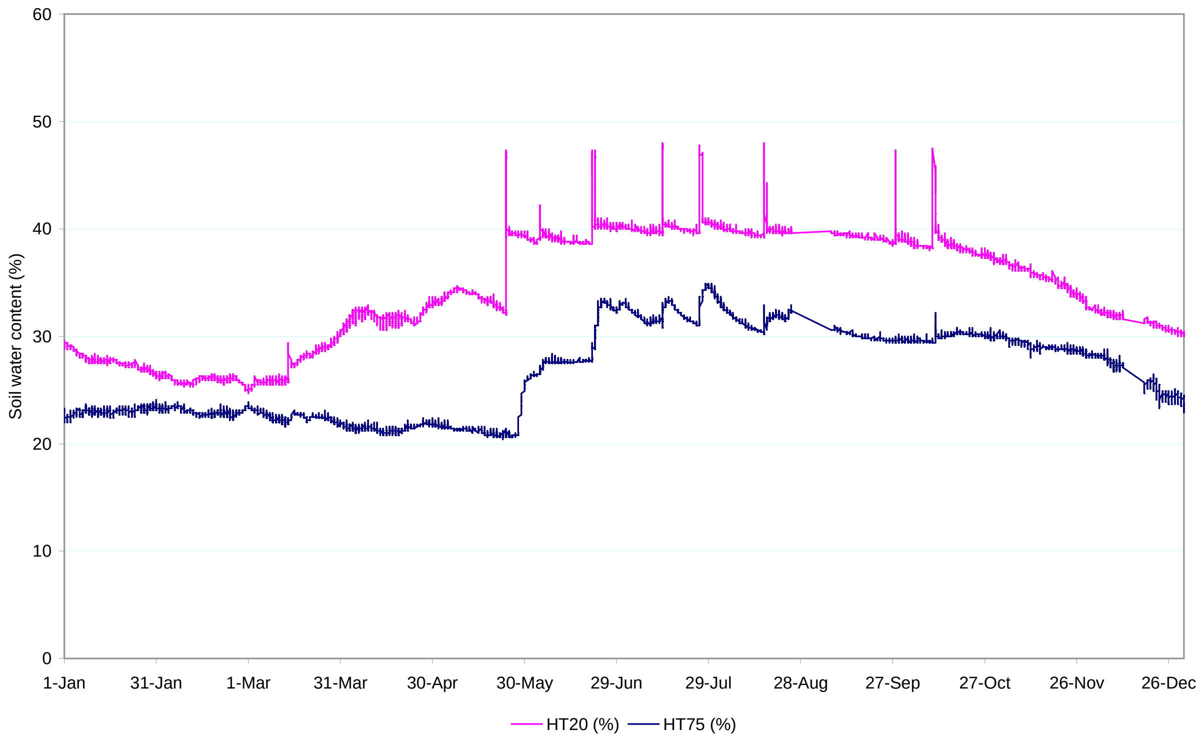

Figure 8: Soil Water Content through the High Profile Soil Layers

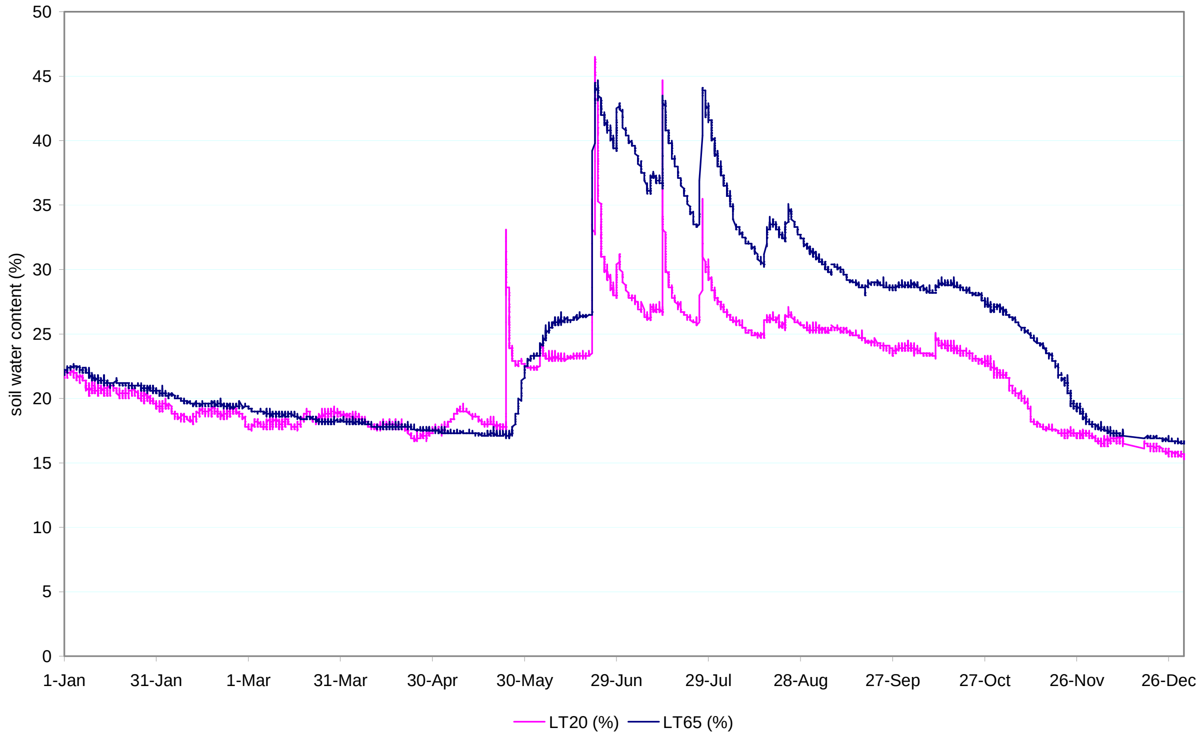

Figure 9: Soil Water Content through the Low Profile Soil Layers

The soil water content at 200mm below the surface of the high profile started to respond to rain in March moving from the summer drought conditions (the lowest point reached in March at 24.9%) to around 32% soil water content and spiked on the 24th of May in response to a 33.6mm rain event. The soil moisture content stayed moist (around 40% soil water content) until early November falling back to around 30% by the end of December.

Soil water content at the 200mm sensor on the low profile started at lower levels than the high profile and continued to drift down to around 17% until the rain event of 24th May where it spiked to around 30.2%. Soil water content stabilised at between 23% and 26% over the winter months responding with a spike to each rain event of more than 20mm. In the two weeks of November soil moisture fell back quickly to around 17.5% and then gradually fell to around 15.3% by the end of the year.

The graph comparing the shallow soil water content between the two treatments (600mm and 1,000mm subsoil) is shown in Figure 10.

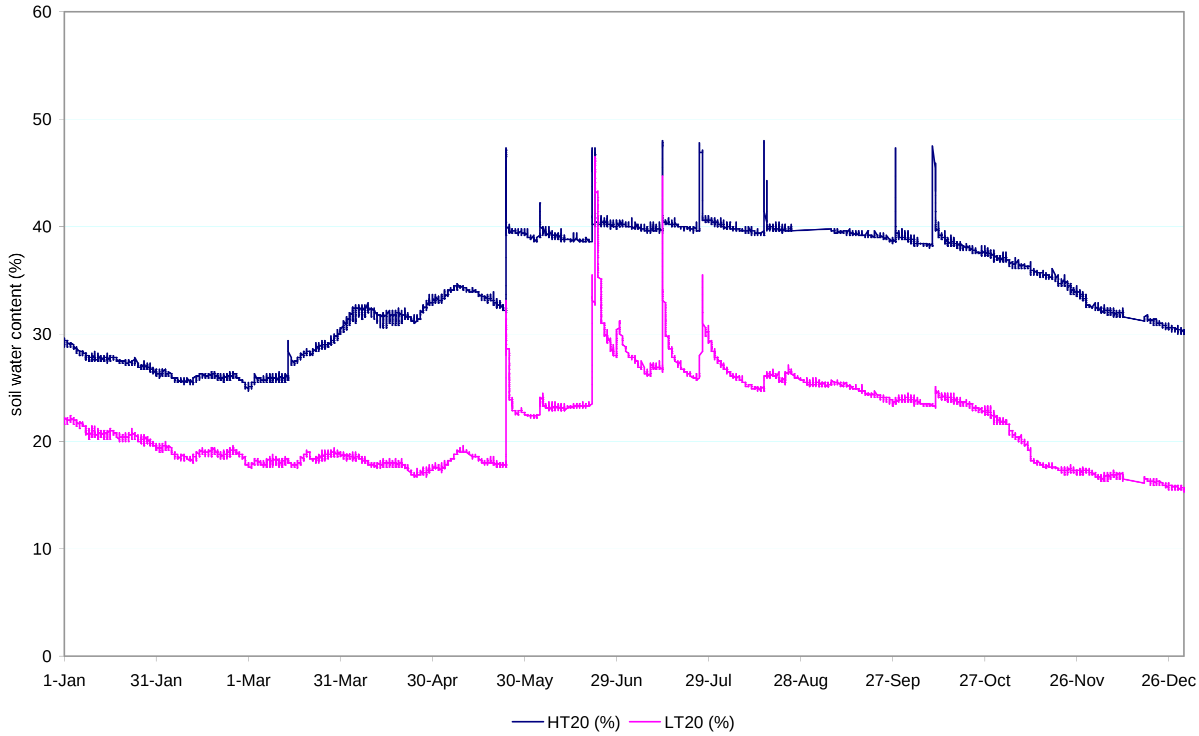

Figure 10: Soil Water Content at 200mm below the Surface

The deep Theta probe on the high profile continued to dry out to 20.6% recorded at 6PM on the 27th May. The soil moisture content spiked on the 28th May, nearly 4 days after the 33.6mm rain event, gradually increasing to around 30% during winter. The deep probes responded with a smaller and more rounded spike than the shallow probes to rain events of more than 20mm. The soil at around 750mm dried more slowly than the shallower layers but a similar rapid drying phase occurred in the second week of December over one month after the shallower probes drying, reaching 24.5% by the end of the year.

Similarly the deep Theta probe on the low profile continued to dry to 16.9% on the 25th May. The soil moisture content increased rapidly from the 25th to the 31st May reaching 23.1% and than more gradually oscillating around 30% over winter, responding with a rounded spike for rain events of more than 20mm. The deeper soil retained its moisture longer with a rapid drying phase in the last two weeks of November, reaching 16.7% by the end of 2012.

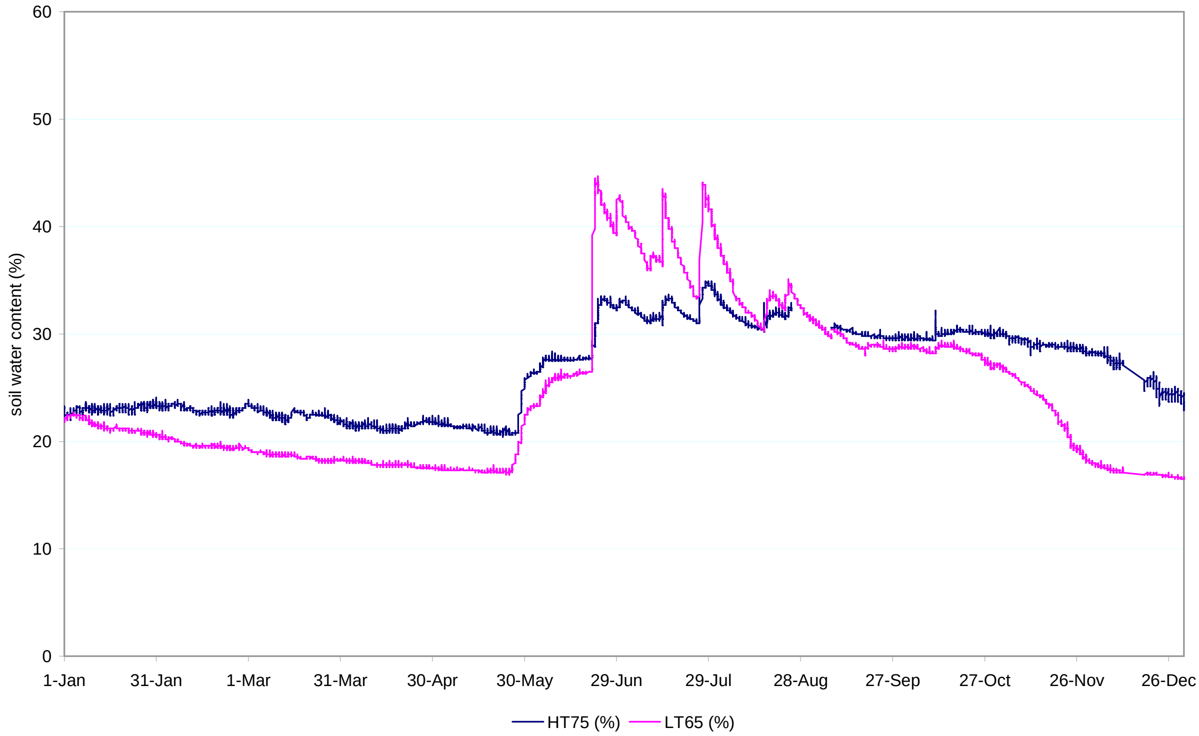

Figure 11: Soil Water Content above the Underlying Plastic Liner

The soil water content response to rain events was larger and sharper on the 600mm subsoil treatments especially in mid winter. This suggests that pulses of water are passing this sensor and presumable draining laterally above the plastic liner. These observations have potential implications for soil erosion and it is recommended that underdrainage should be monitored in the next series of rehabilitation trails.

3.3.2 Soil Water Tension

Soil water tension at the 200mm sensors on the high cover profile started to increase from the summer drought conditions (< -200 kPa[1]) with rains in February through to late April. After the opening rains in May the soil water tension increased to around -20 kPa. Soil water tension stabilised over winter at around -20 kPa and started to fall in October with a steep decline over the month of November to -141 kPa by the end of the year.

The shallow gypsum block on the low profile cover responded to earlier rains and was relatively wet by the first week of March at around -50 kPa, by the end of April the soil water tension stabilised to around -20 kPa. The soil on the low profile treatment also dried out sooner than the high profile cover reaching -200 kPa by the 2nd of December. The comparison of soil water tension at the 200mm sensors on both treatments is shown graphically Figure 12.

[1] -200kPa is also the level of detection for the gypsum blocks used, which are designed for irrigation monitoring. In theory soil water tension at -200kPa will severely stress horticultural crops.

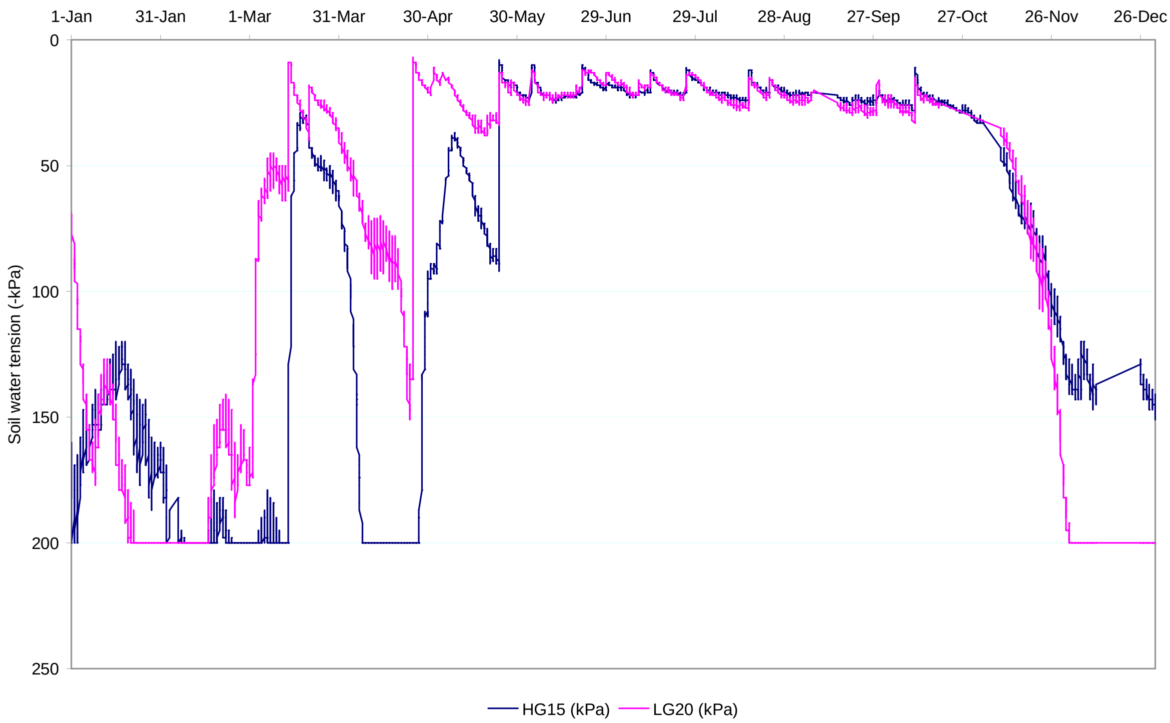

Figure 12: Soil Water Tension at 200mm below the surface

The deeper sensors took a month longer to rehydrate than the shallow sensors and continued to dry on the high profile treatment until the opening rains of the 24th May. The subsoil on the lower profile did not get as dry and seemed to recharge quicker from summer rains in February and March. In contrast soil water content in the deeper layers of the low profile treatment dried much quicker than the high profile treatment. Figure 13 shows this clear contrast between the two treatments.

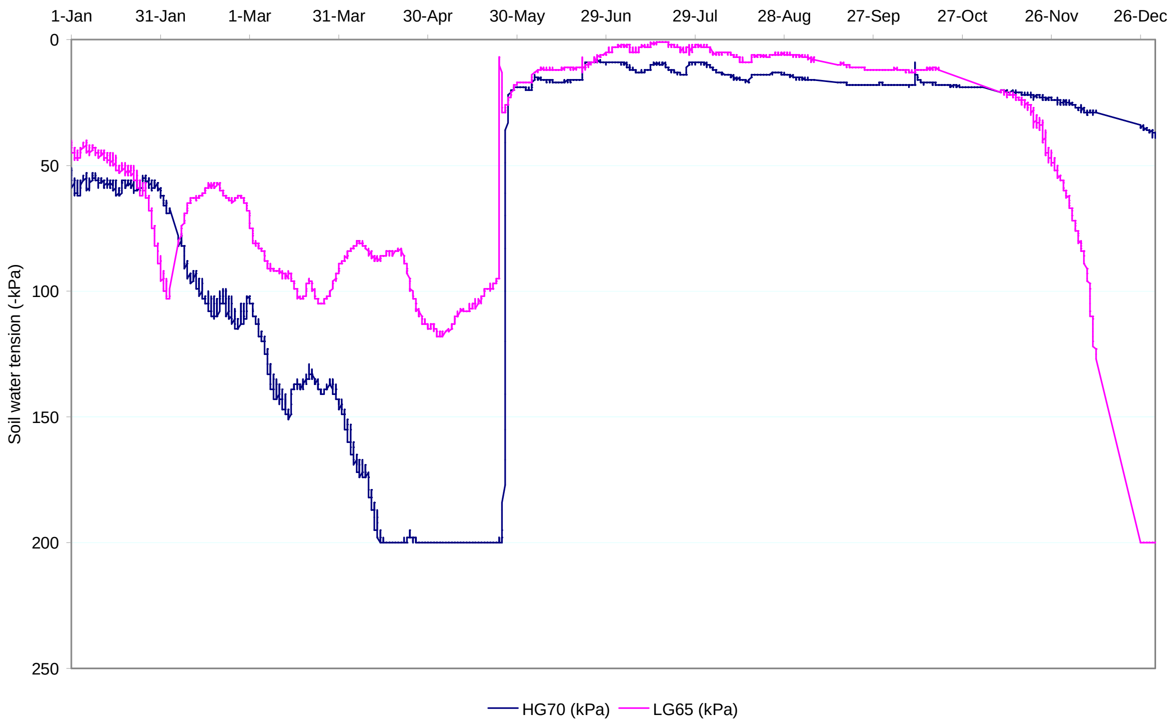

Figure 13: Comparing Sol Water Tension in the deeper layers

3.3.3 Comparison between Soil Profile Treatments

Some differences in soil water content and tension were observed between cover treatments in response to significant rain events (more than 20mm). The differences in part can be ascribed to local differences in soil texture and small differences in the location of the probes below the surface. However, there is clear evidence that the thicker soil profiles take longer to wet up and dry out as would be expected.

The results of soil water content and soil water tension observed during 2012 demonstrate that soil water monitoring provides a better understanding of how the vegetation responds to rain and to a lesser extent how plants draw water out of the soil. The latter will require a considerably longer monitoring period to see any clear connection between vegetation and soil moisture usage.

3.4 Vegetation Cover

The native grasses did not establish well on these trials, the reason is not known; however self sown Saia Oats from the previous season established and covered most of the trials as shown in Figure 5 and Figure 6. This demonstrates that a sustainable vegetation cover can be achieved on both cover treatments. The average vegetation ground cover for each of the main species observed was calculated and plotted for each treatment, Figure 14. Some native grasses were recorded but represented around 0.5% of the overall vegetation ground cover. The main weeds observed were, Wire weed (*Polygonum arenastrum*), Twiggy turnip (*Brassica fruticulosa*) and Couch grass (*Cynodon dactylon*).

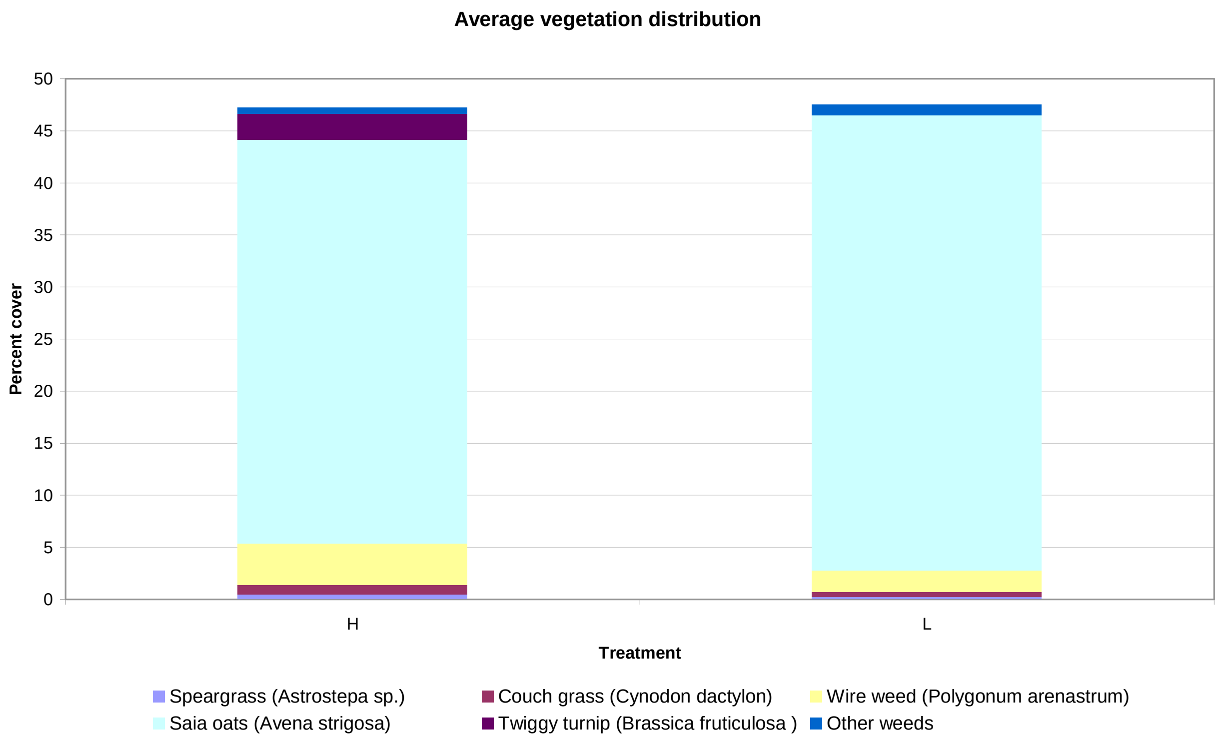

Figure 14: Average Vegetation Ground Cover Percentages

Wire weed and couch grass were generally scattered but the Brassica was found in one quadrat (H3) and was green and flowering therefore covering much of the area, Figure 15

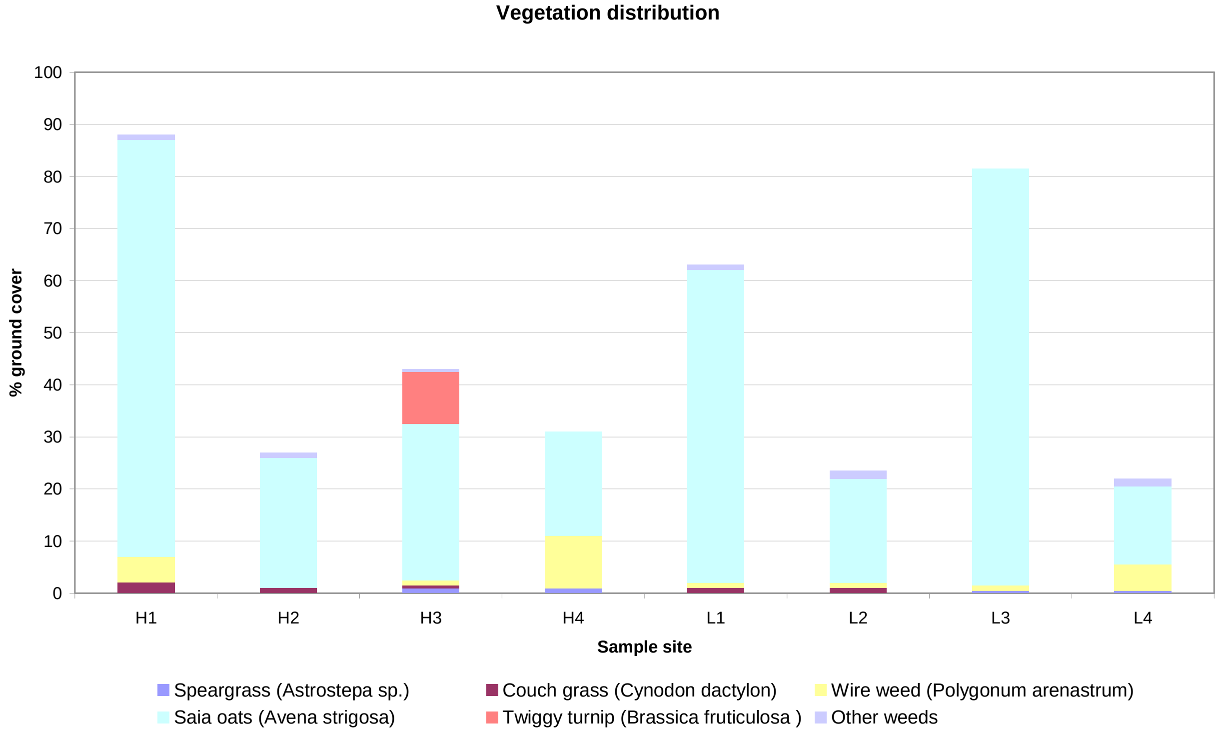

Figure 15: Vegetation Ground Cover and Weed Distribution

The plant biomass data was reduced and plotted to observe trends or patterns and average biomass for the two treatments, Figure 16. Analysis of variance (ANOVA) was undertaken to examine differences between the high plots and low treatments as presented in, Table 1.

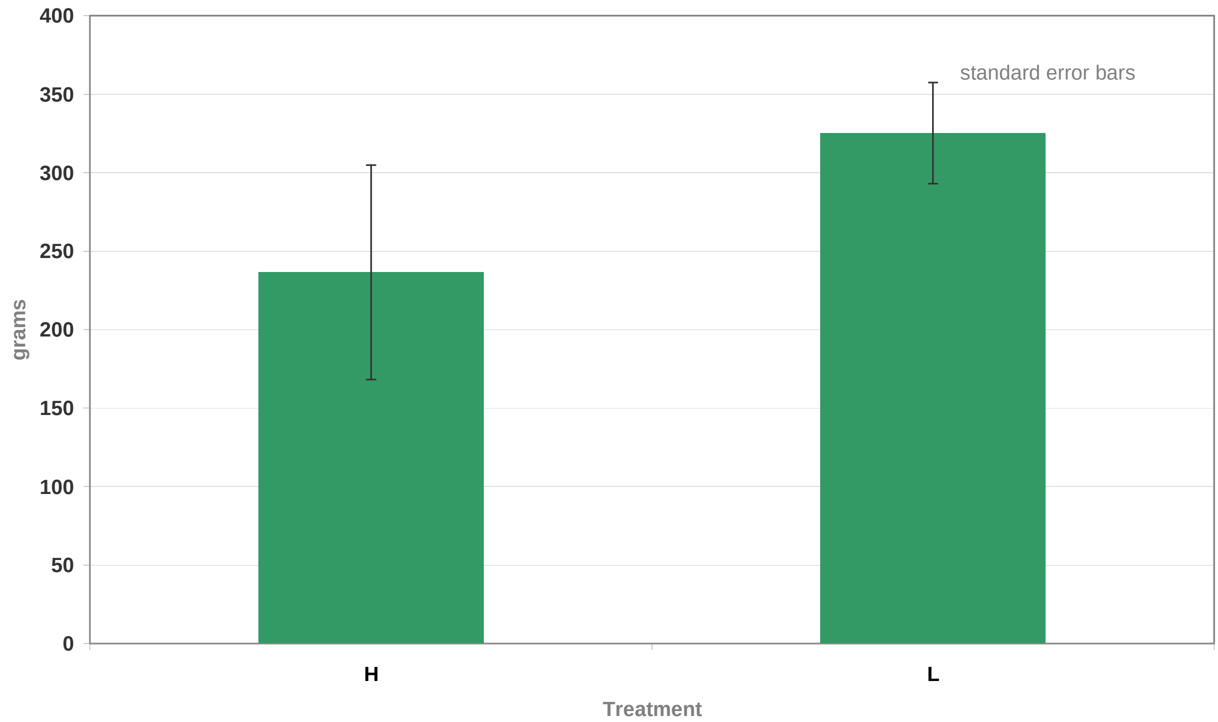

Figure 16: Average Dry Biomass of Vegetation Growing on the Rehabilitation Trial

Table 1: Analysis of variance

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance	Standard Error
High	4	946.07	236.5175	18659.24	68.29941
Low	4	1300.86	325.215	4148.533	32.20455

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	15734.49	1	15734.49	1.379749	0.284647	5.987378
Within Groups	68423.3	6	11403.88			
Total	84157.8	7				

Although the average ground cover was higher in the 600mm subsoil treatment the difference was not statistically significant ($p > 0.05$).

4 Conclusion

The rehabilitation trial set up to simulate the proposed cover layers consisting of a plastic liner over the TSF plus 600mm of sub-soil and 100mm of topsoil. A thicker sub-soil layer of around 1,000mm was also established to provide a contrast and a potential alternative should the proposed cover not achieve its sustainability targets.

Soil water content and soil water tension were measured over the twelve months of this reporting period with Theta probes and Gypsum blocks. The instruments tracked the moving wetting fronts through the soil profile and noted that the first rains take around 4 to 5 days to reach the deeper layers on both treatments but within one day as the soil water content stabilised at around 30% in winter.

Some differences in response to significant (20mm+) rain events between cover treatments were observed and these differences in part can be ascribed to local differences in soil texture and the small difference in the location of the sensors below the surface.

The deep soil water content sensors on the low profile treatments suggest that water is moving through this layer quickly, with implications of potential underdrainage over the plastic liner and associated potential for soil erosion.

After nearly two seasons of monitoring the rehabilitation trials the main observations made are:

1. The proposed TSF cover (the low profile treatment) supported vegetation right through to harvest in December 2012. Although not statistically significant the proposed TSF cover supported more vegetation that the higher profile cover.
2. The soil dried quicker on the proposed TSF cover especially at the deeper layers, the reason needs further testing but is currently thought to be due to (i) lower total water holding capacity due to 40% less soil volume (ii) deep soil water content sensors on the low profile treatments suggest that water may possibly be moving through this layer quickly.

The information presented in this study confirms that the proposed rehabilitation cover for the TSF will support vegetation and there is reasonable evidence at this stage to suggest that vegetation will be sustainable in the long term. The main difference is that the proposed TSF cover will hold less total water volume than the 1,000mm subsoil cover because it has 40% less soil.

The main recommendation from this work is to investigate the movement of water at the intersection of the cover layer and plastic liner.

5 References

COOE (2012). *Tailing Storage Facility - Rehabilitation Trials Interim Report 1 – February 2012*. Prepared by COOE Pty Ltd for Terramin Australia.

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