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Ranger trial landform: Particle size of surface material samples in 2009 with additional observations in 2010

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Executive summary

A trial landform was constructed during 2008 and 2009 at the Ranger mine site to assist with the landform design and revegetation of the closed mine. The research design tests two types of potential surface material, waste rock and waste rock blended with approximately 30% fine-grained weathered horizon material (lateritic material), for their suitability as cap materials. The purpose of this report is to characterise the particle size statistics of the surface material of the trial landform.

Bulk samples of surface material were collected at 12 sites across the trial landform with two samples collected at each site. Generally one sample was collected from between rip lines and the other sample was collected from the top of the mound formed by the rip lines. Particle size analysis by a combined hydrometer and sieve method was undertaken on the 24 samples and graphic grain size statistics calculated from the cumulative frequency distribution. A software package called 'Digital Gravelometer'™ was also used to derive particle size distributions from vertical photographs of the surface material at the same sites and the graphic grain size statistics were calculated from the cumulative frequency distribution.

The results from the sieve and hydrometer method were used for comparisons and show that there is no significant difference in graphic grain size statistics between the samples collected between the rip lines and those samples collected at the top of the mound created by the rip line. The results also show that for three of the five graphic grain size statistics there was no significant difference between the waste rock and the waste rock mixed with lateritic material. However for graphic mean size and inclusive graphic standard deviation there was a significant difference.

The graphic grain size statistics for the combined hydrometer and sieve method were significantly different to those derived from the 'Digital Gravelometer'™. The reasons for the poor correspondence in graphic grain size statistics between the two methods are that:

- The 'Digital Gravelometer'™ is unable to determine the full range of particle sizes as provided by the sieve and hydrometer method,
- it is unduly influenced by the unevenness of the ground which creates shadows which are wrongly measured as individual clasts,
- it has problems distinguishing the smaller particles and often aggregated the smaller particles into one large particle,
- and it had problems recognising individual angular clasts of waste rock.

Particle size analysis by the combined hydrometer and sieve method provides a better estimation of the size distribution of the particles present on the trial landform surface. It does however underestimate the amount of very large particle sizes because it was not physically possible to collect a large enough sample to inclusively contain a sufficiently representative sample of these very large components.

Acknowledgments

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Ranger trial landform: Particle size of surface material samples in 2009 with additional observations in 2010

MJ Saynor & R Houghton

1 Introduction

A trial landform of approximately 200 m x 400 m (8 ha) in footprint area, was constructed during late 2008 and early 2009 by Energy Resources of Australia Ltd (ERA) adjacent to the north-western wall of the Tailings Storage Facility (TSF) at Ranger mine (Figure 1). The trial landform was constructed to assist with the landform design and revegetation strategies being proposed for rehabilitation of the site at the end of mine life. The research design tests two types of potential final surface materials:

1 Waste rock

2 Waste rock blended with approximately 30% v/v fine-grained weathered horizon material (lateritic material).

Figure 1 Aerial view of the completed trial landform located next to the Ranger mine Tailings Storage Facility (taken 28 August 2009 by M Saynor)

Once the trial landform had been constructed the surface was ripped along the contour using tynes attached to a large bulldozer (Figures 2 & 3). Research on the evolution of the trial landform is being conducted collaboratively by Supervising Scientist Division (SSD) and ERA. SSD is focussing on quantifying exports or eroded cover material and solutes in surface runoff.

Figure 2 Tynes on the back of a large bull dozer. The tynes are raised when not ripping the surface.

Figure 3 Ripping the surface of the trial landform. The mounds created by the tynes can be seen as well as the area yet to be ripped.

To measure surface hydrology, erosion rates and solute loads, four erosion plots measuring 30 m x 30 m (Figure 4) were constructed on the trial landform. Research into revegetation strategies and the evolution of vegetation cover is being primarily undertaken by ERA. The landform is divided into six treatment areas with each treatment designed to test different planting methods and substrate types (Figure 4) as follows:

1 Tube stock planted in waste rock;

2 Direct seeding in waste rock;

3 Direct seeding in waste rock mixed with lateritic material to a depth of 2 m;

4 Direct seeding in waste rock mixed with lateritic material to a depth of 5 m;

5 Tube stock planted in waste rock mixed with lateritic material to a depth of 2 m;

6 Tube stock planted in waste rock mixed with lateritic material to a depth of 5 m.

The focus of the work described here is the determination of the graphic particle size statistics (Folk & Ward 1957, Folk 1974, 1980) of the surface material from different parts of the trial landform.

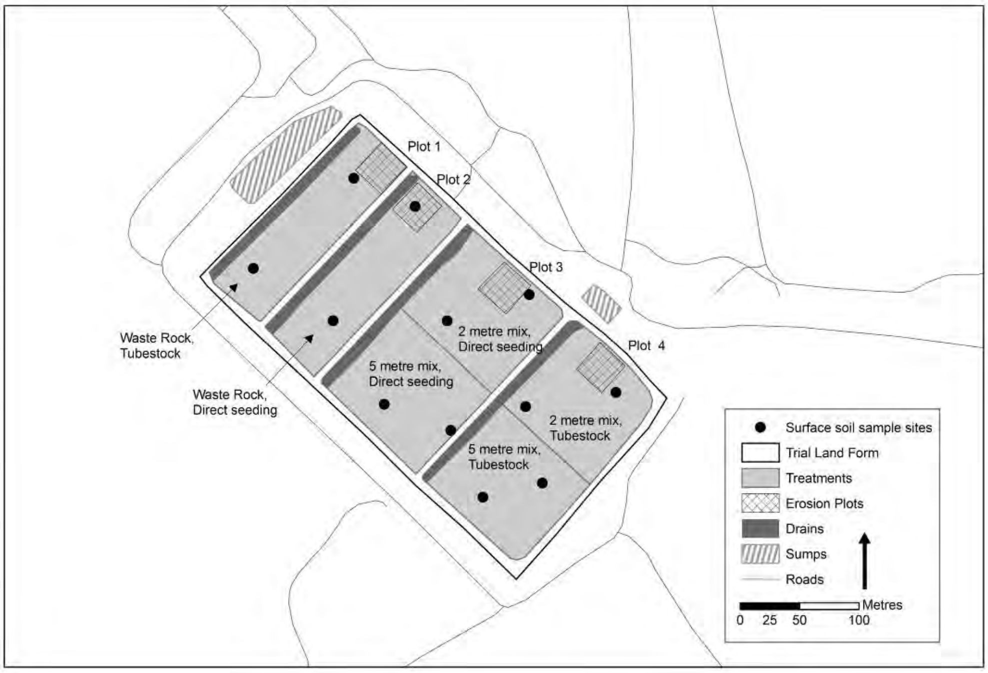


Figure 4 Surface treatments and layout of erosion plots on the trial landform

2 Background on surface material sampling methods

Obtaining bulk samples from specific geomorphic environments is the accepted method of sampling surficial sediments (Kellerhals & Bray 1971). This involves the collection of material from a predetermined volume within a specific geomorphic environment (Kellerhals & Bray 1971). However, there are potential problems with bulk sampling that must be recognised. Very large sample masses are required to obtain reproducible measures of the grain size distributions of samples containing individual large clasts or gravels (de Vries 1970, Church et al 1987, Gale & Hoare 1992, Ferguson & Paola 1997).

Where collection of sediment from a specific depositional environment is difficult because the mass is too large for collection, transport and/or analysis, sub-sampling is practised. Recommended minimum sample mass also depends on sediment sorting or the dispersion of the grain size distribution (Gale & Hoare 1994, Ferguson & Paola 1997). Poorly sorted material, such as on the surface of the trial landform and as found in mixed sand- and gravel-bed rivers, require larger masses than better sorted samples (Gale & Hoare 1994, Ferguson & Paola 1997). For example, Church et al (1987) found that if the maximum grain size in a sample is 90 mm then a minimum sample mass of 1000 kg is required to obtain a reproducible measure of the grain size distribution! Gale & Hoare's (1992) results indicate that the Church et al (1987) relationship may, in fact, underestimate minimum sample masses for some geomorphic environments! Clearly, even if it is possible to bulk sample gravel deposits containing large clasts, the required masses are so large as to be physically impossible to collect, transport, store and sieve. Observations by the authors of material on the trial landform have identified some boulders that are larger than 500 mm. The largest sample of fluvial gravels that Dr Erskine has ever collected over the last 33 years was 32 kg from the Cudgegong River (Benn & Erskine 1994) which only yields reproducible measures of the grain size distribution for samples with a maximum size of 30 mm! It is impossible to collect and transport larger samples without using heavy earth moving machinery (excavators and semi-trailers).

Clearly with the large particle sizes present on the trial landform, collection of the minimum sample mass to satisfy the representative sampling criteria of Church et al (1987) and Gale & Hoare (1992) was not physically possible. For collection of surface material samples from the trial landform it was decided to take a number of bulk samples and to augment this with information obtained from analyses of photographs of surface material taken prior to sampling. Information on particle size and number was to be obtained from the photographs using a method similar to Ibbeken and Schleyer (1986).

3 Methods

3.1 Trial landform surface material collection

In March 2009 ERA staff collected surface material samples from across the surface of the trial landform for the purpose of nutrient analysis. The locations for these samples were randomly generated using GIS. Five samples were collected from each of the 6 different treatments (total of 30 samples). Note, however, that only one of the ERA nutrient samples sites was located within an erosion plot (site 6 is located in erosion plot 2). The GPS locations were supplied to ***eriss*** by ERA (Appendix 1). Two of the sample sites from each of the six treatments were selected by SSD to collect additional samples for particle size analysis (total of 12 samples). The selected sites are shown in Figures 4 and 5.

Figure 5 ERA nutrient sample locations on the Trial Landform. The ***eriss*** sample sites are denoted by the red circles.

In April 2009, surface sample sites were located by GPS (Garmin etrex). A 1 m marked square was laid out on the ground at each sample location to capture a rip line and the area between the rip lines. A small step ladder was used to take photographs looking vertically down onto the area contained within the 1 m x 1 m square (shown in images below). At each location, several images were taken with a Canon 10 megapixel SLR camera. An oblique image was also taken once the samples had been collected to show the location of the sample sites in the context of the landform and to help with future relocation, as required.

Within the 1 m x 1 m square, surface material samples were collected using a spade down to a maximum depth of 10 cm. At each location, two surface samples were collected for particle size analysis, where possible, one from the top of one of the mounds displaced by the tyne and the other in the area between the rip lines (Figure 6). At several of the sample sites mounds displaced by the tyne were not present and samples were collected from the flat areas and named as between rips (sample 1 & sample 2). A total of 24 surface material samples were collected, two from each site shown as the red circled areas in Figure 5. The samples were collected to determine whether there was any difference in graphic grain size statistics between the mounds displaced by the rip lines and the undisturbed area between the rip lines. Each sample was placed in a clearly labelled bag for transport to the ***eriss*** laboratory in Darwin. Prior to leaving the Ranger site, all surface samples were checked by the Radiation Department and issued with a Radiation Release Certificate – 12182 1/5/09.

In September 2010, the original sites were relocated using the GPS coordinates and the oblique images from 2009. The sites were rephotographed and any observed ground surface changes recorded. Surface samples were not collected in 2010.

Figure 6 Shows the top of mounds created by ripping and the areas between the rip lines. A large boulder is also visible in the bottom left of the image.

3.2 Digital photographs

Several digital photographs were taken at each surface sample location prior to sample collection. After the photographs and the samples were collected, the authors became aware of a computer software package (Digital Gravelometer™) that could be used to determine the particle size of samples containing large clasts (Graham et al 2005a).

The introduction to Digital Gravelometer™ web page says that

'Digital Gravelometer™ is a tool for rapidly measuring the surface grain-size distribution of gravel. It has been designed for use on fluvial sediment, but should find application in other environments' http://www.sedimetrics.com/documentation/introduction.html accessed on 19/4/2011.

The two sampled environments on the trial landform should be examples of the 'other environments' for which the Digital Gravelometer™ could be used.

3.3 Digital Gravelometer™

A trial version of the software package Digital Gravelometer™ was downloaded from the http://www.sedimetrics.com/ web site. The Digital Gravelometer™ was applied to at least one image from each of the 12 samples locations and used to calculate particle diameters. For each of the 12 locations, a particle size distribution was obtained. Figure 10 in Graham et al (2005b) suggests that for a 1 m^2 area with a 10 mega pixel camera the minimum particle size that can be resolved is 7 mm. In this context it should be noted that a significant component of some of the trial landform surface material is finer than 7 mm.

3.4 Particle size analysis (PSA)

The 24 surface material samples (two from each sample site) collected in 2009 were subjected to particle size analysis using the hydrometer and sieve method of Gee and Bauder (1986). The samples were dried at 40°C for at least 7 days and then sieved through a 2 mm sieve to split the sample into the gravel fraction (> 2mm) and the fine earth (sand, silt and clay) fraction (< 2mm). The gravel fraction of each of the samples was sieved in its entirety.

For the < 2 mm fraction, a sub-sample (between 80–100 g) was obtained using a riffle splitter. The < 2 mm fraction samples were chemically dispersed with 25 mL of sodium hexametaphosphate before being mechanically dispersed on a shaking wheel or platform for at least 12 hours. The sample was then wet sieved through a 63 µm or 4 ϕ (phi)[1] stainless steel sieve with the mud (silt & clay < 63 µm) fraction collected in a 1000 mL cylinder. The sand fraction retained on the 63 µm or 4 ϕ stainless steel sieve was oven dried at 105°C, weighed and dry sieved through a nest of sieves at $\phi/2$ intervals, using a 15 minute shake time.

The mud suspension retained in the 1000 mL cylinder was made up to volume with distilled water and left in a constant temperature (24°C) room for at least 24 hours to allow temperature equilibration. The equilibrated sample was stirred with a stirring rod before the 5 minute reading to resuspend the material prior to taking the hydrometer readings. Hydrometer readings were taken at 5 min, 10 min, 90 min, 270 min, 480 min and 1440 min and were used to determine the

[1] The phi (ϕ) notation system is often used to describe the grain size of clastic sediment by sedimentologists (Folk 1974, 1980). It is a logarithmic scale in which each grade limit is twice as large as the next smaller grade limit (Folk 1974, 1980) and is denoted by:

$\phi = -\log_2 d$

where d is the grain diameter in mm.

amount of silt and clay in the sample. The fraction coarser than 20 μm or 5.65 ϕ was also determined by decantation using a sedimentation time based on Stokes equation for the water temperature at the time. The grain size data are included in Appendix 2.

3.5 Grain size statistics

Graphic grain size statistics (ie graphic mean size, inclusive graphic standard deviation, inclusive graphic skewness, graphic kurtosis and transformed kurtosis) were calculated using the equations of Folk and Ward (1957) and Folk (1974, 1980). These equations are outlined in Saynor et al (2006) and only use, at most, 90% of the grain size distribution between the 5th and 95th percentiles (Folk & Ward 1957; Folk 1974, 1980).

3.6 Statistical analyses

To test for normality, the values for each grain size statistic were subjected to an Anderson-Darling test. This is a simple but powerful objective measure of how well data follow a particular distribution (Ryan & Joiner 1976). When the data were normally distributed, to test for equal variances the relevant test in Minitab was used to determine whether there were significant differences between the samples collected between the rips and the samples collected from the mound created by ripping. Where the data were not normally distributed, Levene's test was used. Where the data were normally distributed and the variances were equal the Two-Sample t-test was used to determine whether the means for the various grain size statistics between the samples collected between the rips and the samples collected from the mound created by ripping were significantly different. Where the data were non-normally distributed, the Mann Whitney test was used to determine whether the differences in distributions were significant.

4 Results

4.1 Photos of the material sample sites 2009 and 2010

In the photos below an oblique image is used to show the location of both sample sites, namely on top of the mound created by ripping and between the rip lines. The surface material sample sites are shown in numerical order. Photos of each site for 2009 & 2010 are shown below and have been annotated with circles and numbers to indicate the sample on top of the mound created by ripping and the sample collected between the rip lines. The circles indicate where the samples were collected (orange on top of the rip mound and white on the surface between rip lines). Coloured numbers (1 & 2) have been used to identify the same rocks or clasts in each photo. A general observation was that the sample holes usually infilled with finer material after sample collection.

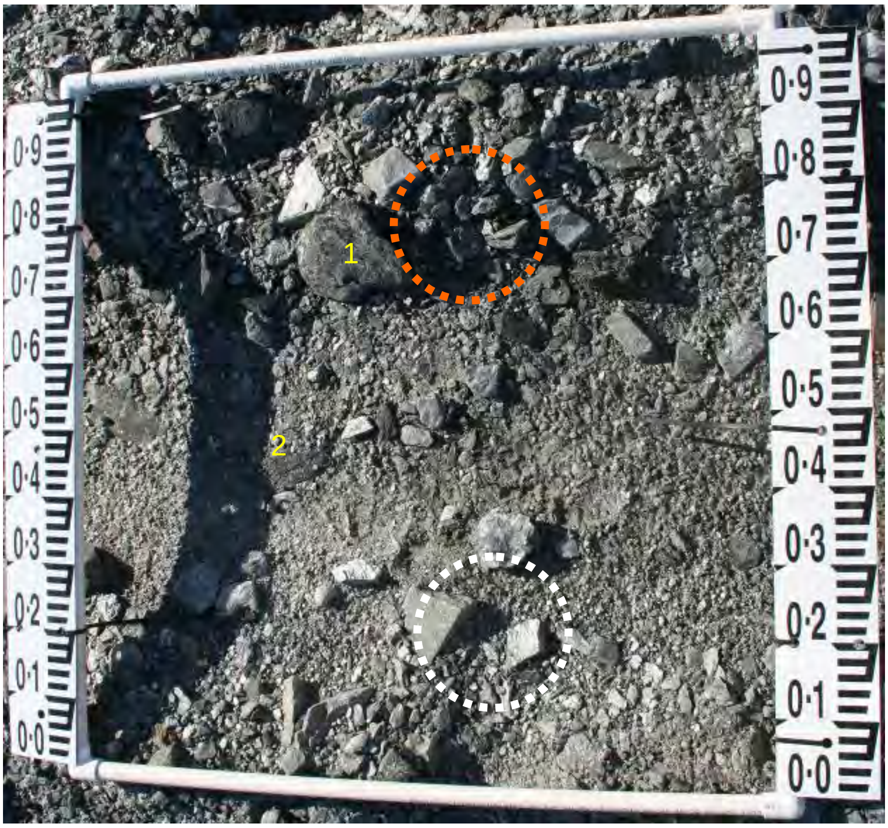
Note – The sample locations were supplied, samples collected and named with a EWLS nomenclature. To keep continuity between the samples that were collected in 2009 the EWLS prefix for the sample site has been kept as is to avoid confusion.

Surface material sample EWLS site 2

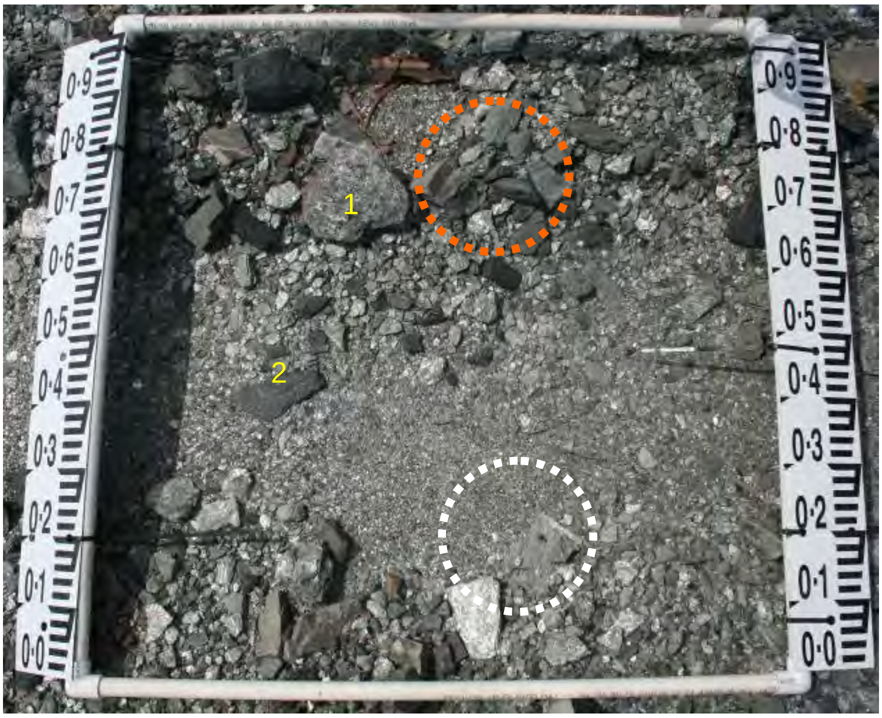
Surface Material sample EWLS site 2. Oblique image of the sample locations and holes created in 2009. Image is taken looking north east across the landform. White circle shows sample collected from between the rip lines and orange circle shows sample collected from the mound created by ripping.

GPS location: 12.680700E, 132.895550S

Treatment: Waste rock material with planted tube stock.



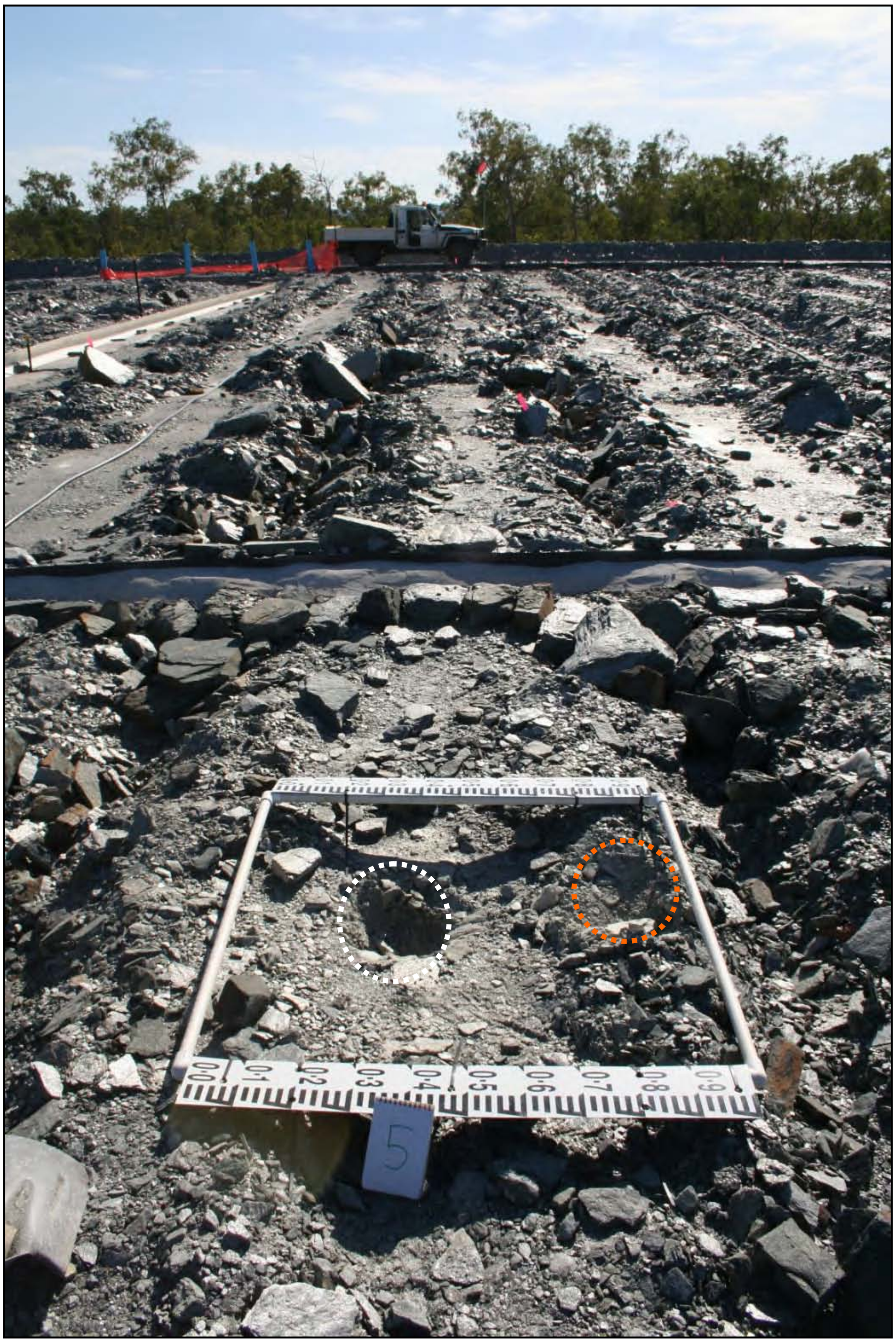
Surface material sample EWLS site 2 in 2009 prior to samples being collected. Sample locations shown by circles.



Surface material sample at EWLS site 2 in 2010 showing the location of samples collected in 2009. The same clasts are indicated by the same number in each photo.

The orange circle was sampled on the top of the mound created by the rip line and has infilled with some large clasts as well as fine material. The white circle has infilled with fine material only.

Surface material sample EWLS site 5

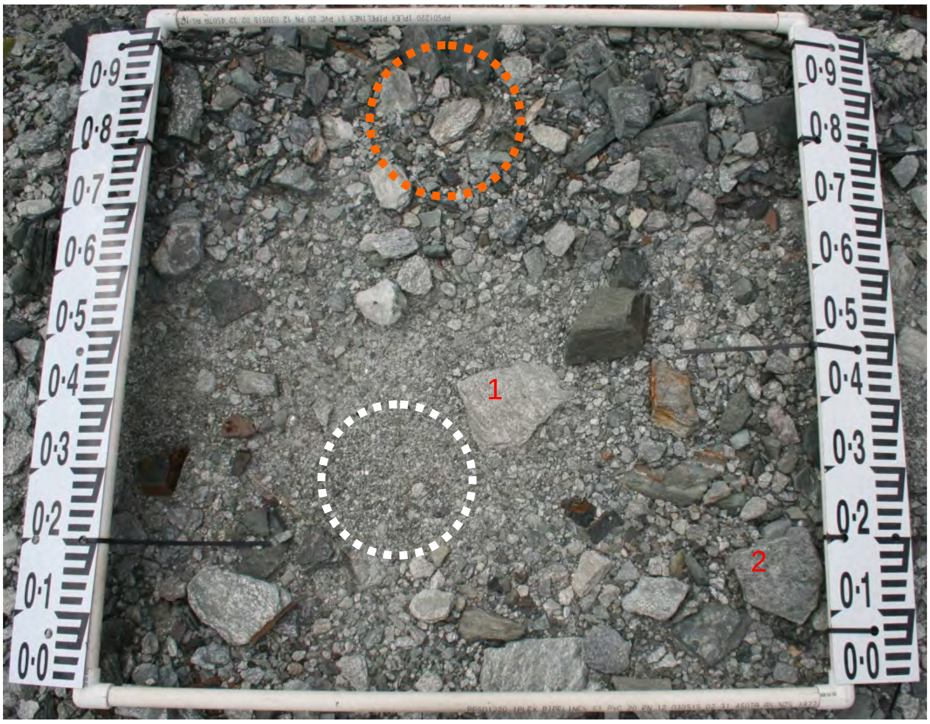


Surface material sample EWLS site 5. Oblique image of the samples collected in 2009. The image is taken looking north east across the landform and also over Erosion Plot 1

GPS location: 12.680000E, 132.896400S

Treatment: Waste rock material with planted tube stock

Surface material sample EWLS site 5 in 2009 prior to samples being collected.



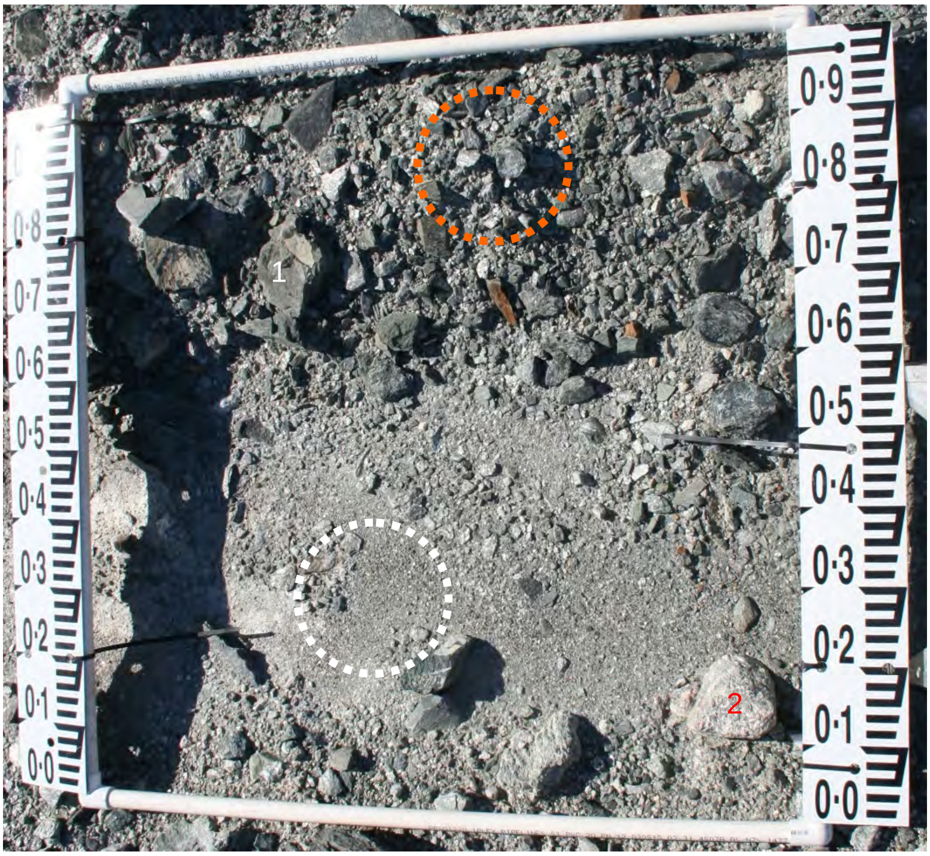
Surface material sample EWLS site 5 in 2010.

Surface material sample EWLS site 6

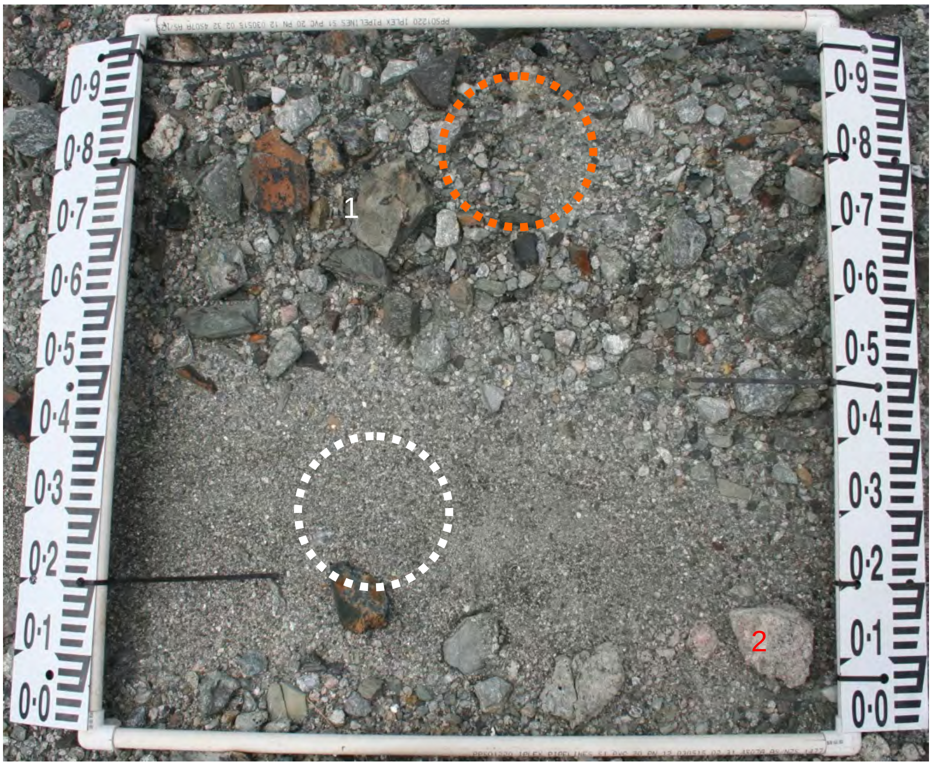
Surface material sample EWLS site 6. Oblique image of the samples collected in 2009. The image is taken looking north east across the landform. This site is located in erosion plot 2.

GPS location: 12.680240E, 132.896810S

Treatment: Waste rock material with direct seeding.

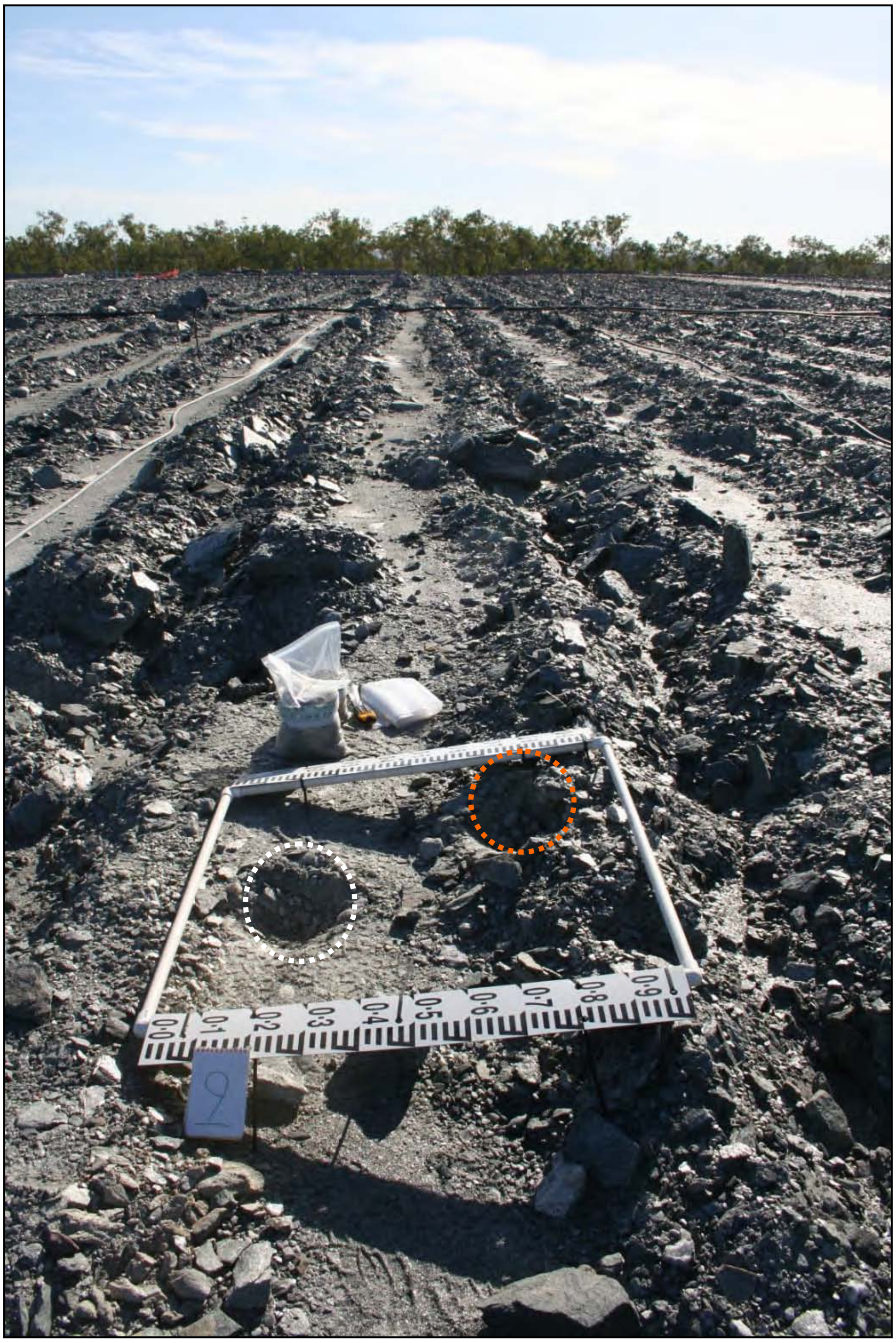


Surface material sample EWLS site 6 in 2009 prior to samples being collected.



Surface material sample EWLS site 6 in 2010.

Surface material sample EWLS site 9



Surface material sample EWLS site 9. Oblique image of the samples collected in 2009. The image is taken looking north east across the landform.

GPS location: 12.681110E, 132.896170S

Treatment: Waste Rock material with direct seeding.