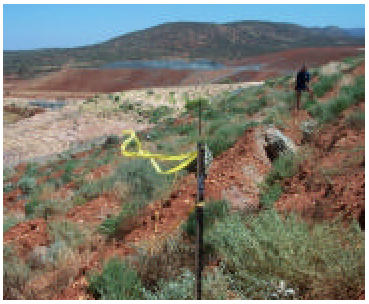
APPENDIX 15: CHARACTERISATION OF TOPSOILS – OUTBACK (2004)



outback ecology

Phillips River Gold Project Tectonic Resources NL - Kundip and Trilogy Projects

Topsoil characterisation at Kundip and Trilogy and recommendations for rehabilitation

August 2004

outback ecology

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Table of Contents

List of Tables

List of Figures

Appendices

EXECUTIVE SUMMARY

Outback Ecology was commissioned by Tectonic Resources NL to characterise topsoils from the Kundip and Trilogy Projects, as part of the preparation of Notices of Intent for each project. The objectives were as follows:

- Topsoil characterisation at both sites, including basic soil analysis (pH, salinity, available nutrients) together with estimates of dispersion potential (Emerson tests) by Outback Ecology.
- Field description of subsoils
- Briefly highlight implications for a rehabilitation program for both sites, particularly in relation to adverse parameters such as low or high pH, highly saline soil, or dispersive clays.

Soils were sampled at the Kundip and Trilogy Projects areas on May 12th and 13th, 2004. At Kundip, sampling points were located on the respective areas for each of four separate deposits and some materials were collected from the abandoned Western Gem and Two Boys Pits. At Trilogy, sampling points were on the area of the deposit. Some of the topsoils from each area were selected for chemical analysis at the CSBP Soil and Plant Laboratory. Soil texture and dispersion properties of representative topsoils and subsoils were also assessed.

Kundip

At each of the four areas sampled at the Kundip Project, the topsoils have properties that make them important resources for rehabilitation. Firstly, they have greater physical stability and content of gravel or rock fragments than their associated subsoils, and secondly they will contain seeds of native plant species, beneficial soil micro-organisms, and nutrients. Nutrients and the beneficial biological components of the topsoils will be concentrated in the surface few centimetres of the soil, thus optimal stripping depth is a maximum of around 15cm. It is recommended that where rocky topsoils occur, that they are salvaged to greater depth than just the surface 15cm, and used to supplement the quantity of topsoil available.

The physical and chemical properties of the topsoils from each of the deposits are sufficiently similar, that managing soil from each deposit separately is not required. However, it may be appropriate to consider separating the soils on the basis of their associated vegetation communities. A key to preserving the seed and biological components in the soils will be to minimize the time in stockpiles after stripping.

Most of the subsoils sampled at Kundip had the potential to slake and were somewhat dispersive. Therefore they are likely to be unstable if exposed on landform surfaces, creating risks of hardsetting and erosion. If placed as shallow subsoil in a reconstructed soil, then the net effect may be to retard infiltration of water, and lead to increased risk of erosion. Strategies to minimize the risk of erosion may include, increasing the depth of rocky topsoils, identifying waste materials that

may be more structurally stable to use as a subsurface layer, and minimizing the external slopes of landforms.

Trilogy

The Trilogy Deposit occurs on cleared farmland, that is flat and with little perennial vegetation. The topsoils had high levels of extractable nutrients, and 3% to 4% organic carbon. The soils were moderately acidic but the underlying subsoils were more alkaline. The topsoils had low salinity, but salinity tended to be higher in one of the subsoil samples analysed.

The topsoils were relatively stable, reflecting their high organic matter content, but subsoil clay slaked and dispersed. Therefore, these subsoil materials will be prone to structural breakdown, hard-setting and erosion. Although the undisturbed topsoils appeared to be relatively stable, it is likely that stripping and re-spreading will break down some of the structural stability, and they will become less able to resist erosion on waste landform surfaces.

Consideration may need to be given to strategies to reduce the erosion risk associated with Trilogy soils, including reduced slope angle of outer batters, and incorporating competent, chemically-benign, rocky material into outer layers. The topsoils will contain a substantial seed bank of pasture and weed seeds. If native perennial vegetation is planned, then strategies to reduce the seed bank may need to be considered. .

1.0 INTRODUCTION

Outback Ecology was commissioned by Tectonic Resources NL to characterise topsoils from across the Kundip and Trilogy Projects, as part of the preparation of Notices of Intent for each project.

The objectives were as follows:

- Topsoil characterisation at both sites, including basic soil analysis (pH, salinity, available nutrients) together with estimates of dispersion potential (Emerson tests) by Outback Ecology.
- Field description of subsoils
- Briefly highlight implications for a rehabilitation program for both sites, particularly in relation to adverse parameters such as low or high pH, highly saline soil, or dispersive clays.

2.0 MATERIALS AND METHODS

2.1 Sampling regime

Soils were sampled from the areas of the Kundip and Trilogy Projects on May 12th and 13th, 2004. At Kundip, four separate deposits (potential pits) had been identified and the sampling points were located on the respective areas for each deposit (**Figure 1**) all within Mining Lease M74/51. Soils were sampled from a total of 19 points in the area of the Kundip Project. GPS locations were recorded for each sampling point (**Appendix A**). Topsoil (0-10cm) and subsoil samples were collected at each sampling point. In addition, some materials were collected from exposed faces in each of the abandoned Western Gem and Two Boys Pits, within the Kundip Project area. The location of an existing waste dump, west of the existing Kaolin pit was noted but materials were not sampled.

There is a single deposit at Trilogy, and sampling points were on the area of that deposit (**Figure 2; Appendix A**), within Mining Lease M74/176.

At most sampling sites there was a clear textural change between the topsoil and underlying clay-rich subsoils. Subsoil samples were generally taken from this clay-rich horizon. In most cases subsoil samples were taken from exposed profiles from existing costeans or excavations.

2.2 Laboratory methods

Some of the topsoils from each area were selected for chemical analysis at the CSBP Soil and Plant Laboratory. CSBP conducted analyses for ammonium and nitrate (Scarle, 1984), extractable phosphorus and potassium (Colwell, 1965; Rayment and Higginson, 1992), extractable sulfur (Blair *et al*., 1991), and organic carbon (Walkley and Black, 1984). Measurements were also carried out for electrical conductivity and pH (Rayment and Higginson, 1992). To determine reactive iron, soils were mixed with Tamm's reagent (oxalic acid / ammonium oxalate) for 1 hour employing a soil:solution ratio of 1:33. The concentration of iron was then determined using a flame atomic absorption spectrophotometer at 248.3nm.

Soil texture and dispersion properties of representative topsoils and subsoils were assessed by Outback Ecology staff (methods in **Appendix B**).

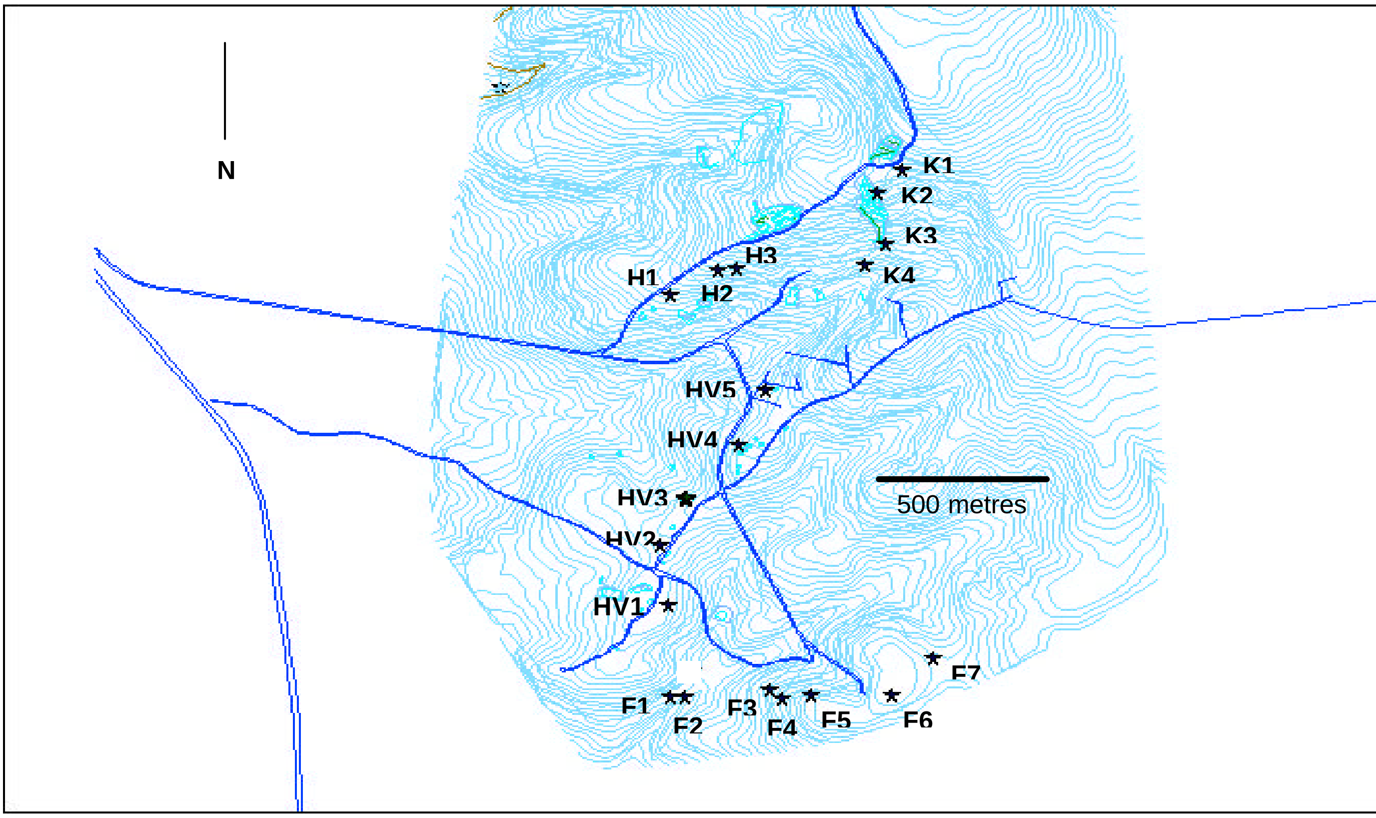

Figure 1 **Schematic plan of the Kundip project area showing access roads ( ) and soil sampling sites (★) for the Flag (F), Harbour View (HV), Hillsborough (H) and Kaolin (K) Deposits (GPS co-ordinates listed in Appendix A)**

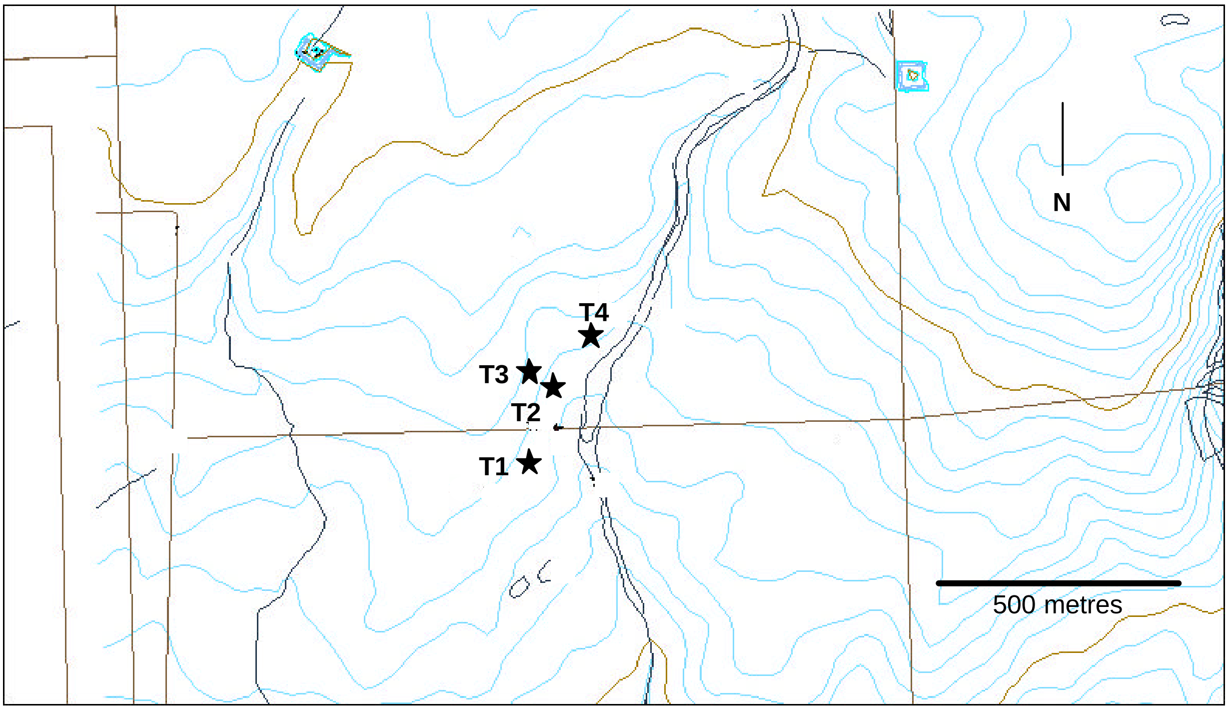

Figure 2 **Schematic plan of the soil sampling sites at the Trilogy Project area (★) (GPS co-ordinates listed in Appendix A)**

3.0 KUNDIP PROJECT AREA

3.1 Results and Discussion - Kundip Project Area

The project area at Kundip, lies at the southern end of the Ravensthorpe Range, and supports diverse native vegetation (Craig, 2004). The area has been heavily impacted by previous mining activity, and mine shafts and old diggings are frequent, particularly in the areas of the four identified deposits for this project. There are three small existing open pits at the northern end of the project area, Kaolin, Western Gem and Two Boys (**Figure 1**).

3.1.1 Flag Deposit

Surface soils at Flag were typically gravelly loams overlying medium clays (**Table 1**; **Plate 1**). The topsoils were relatively stable with little tendency for slaking or dispersion. By contrast, the clay subsoils (below 15cm depth), were unstable, slaking quickly and with some evidence of dispersion. The difference in the relative stability of these horizons was evident in erosion and undercutting of the clay subsoil on exposed areas (**Plate 1**).

Slaking and dispersion can both lead to loss of soil structure. A well-structured soil has fractures and pores which allow water, air and roots to enter the soil easily. Slaking is a process by which aggregated particles in a structured soil will collapse during wetting, breaking down to leave primary particles and micro-aggregates. This occurs because they have insufficient strength to resist the stresses caused by rapid-water intake (Needham *et al*., 1998). Soil organic matter, particularly plant roots and soil microbes, is the most important factor that can restrict slaking of soil. Soil organic components can bind the soil particles and help resist the destructive forces generated by rapid water intake. There is no chemical remediation strategy to prevent slaking.

In dispersive soils, clay particles swell in the presence of water, because water can penetrate between the clay layers and weaken the binding forces. As a result, individual clay layers may disperse into the soil solution. This reaction is principally due to a dominance of sodium ions adsorbed to the clay surfaces. Both slaking and dispersion can lead to a poorly-structured soil, which is not favourable for infiltration by water (leading to run-off and erosion), or for root exploration (Needham *et al*., 1998; Carlstrom *et al*., 1987). Dispersion can be suppressed through the application of gypsum. This is effective in two ways. Firstly, dissolved gypsum leads to increased ionic strength in the soil solution, which tends to reduce the swelling response of the clay layers. Secondly, the calcium ions in solution can replace the sodium ions on the clay surfaces. Clays with higher proportions of adsorbed calcium are less dispersive than sodium-dominated clays

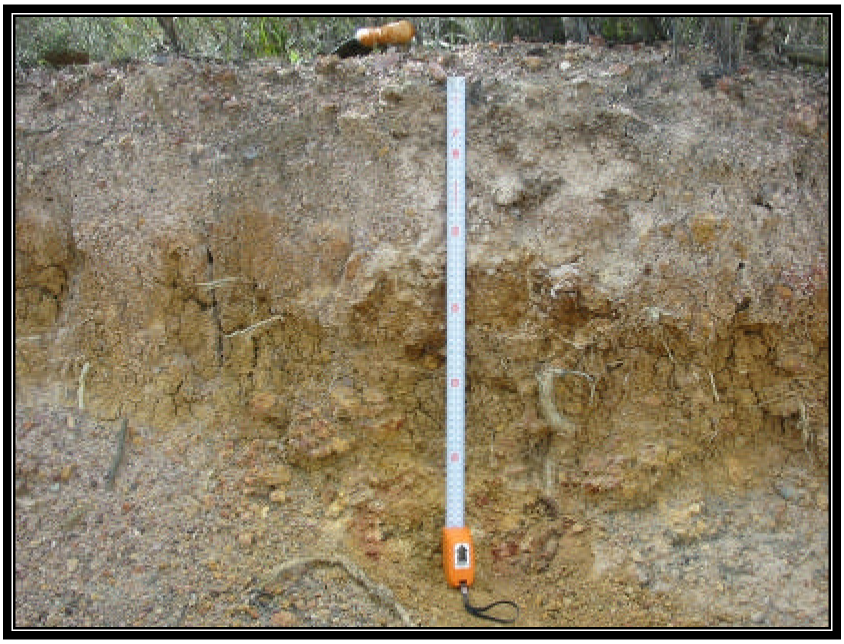

Plate 1 F6-2 soil profile.

In areas of previous mining activity, the surface soils have been heavily disturbed, particularly around a creek line at the western end of the deposit. This disturbed area is centred around 69200m North, and from 40138m East to 40244m East. The most south-easterly point of this disturbed area is at 40244m East and 69281m North. There are some remnants of tailings on the creek line in this area, and dams on the creek line to the northern edge of this disturbance. The tailings were analysed and found to have no chemical properties that would be hostile for plant growth. There is also substantial disturbance near the original Flag shaft towards the eastern end (around 40500E and 69200N) of the area of the Flag deposit. Salvaging topsoils in very disturbed areas such as those described may not be justified.

Topsoils on the Flag deposit, typically had a gravel 'lag' on the surface, acting to protect the soil from raindrop splash and erosion and the protective properties of these rocky topsoils should be replicated on constructed landforms. Nutrients and the beneficial biological components of the topsoils will be concentrated in the surface few centimetres of the soil, thus optimal stripping depth is a maximum of around 15cm. Topsoils to the northern side of the east-west line of this deposit had a substantial content of rock fragments (**Plate 2**). Given the likely susceptibility of the subsoil clays to erosion, these areas of rocky topsoil will be especially valuable for erosion protection on waste landforms. It is recommended that where rocky topsoils occur, they are salvaged to greater depth than just the surface 15cm, and used to supplement the supply of topsoil from this site.

Plate 2 Flag – rocky subsoil at road cutting to north of Flag shaft.

Topsoils from the Flag deposit had low levels of salinity (EC) and were slightly acidic, ranging from pH 4.5 to 5.4 (1:5; 0.01M $CaCl_2$) (pH 5.5 to 6.2, in 1:5 H_2O) (**Table 1**). Measurement of pH in dilute $CaCl_2$ solution is regarded as being more appropriate, because it most closely reflects the ionic strength of the *in situ* soil solution, and therefore the pH of the undisturbed soil. Commonly however, pH is also measure in a water suspension, because that soil suspension can also be used to record electrical conductivity. Therefore this pH value in water, has also been included in case comparison is required to other soil tests.

The soils were low in plant-available nitrogen, but had moderate levels of extractable phosphorous. There were moderate levels of organic matter in the soils (ranging from 2 to 4% organic carbon). The low levels of salinity indicate that there should be no effect on germination or plant growth. The low to moderate levels of nutrients and organic carbon will provide some fertility for plant growth.

In summary, topsoils from the Flag deposit have good properties for supporting plant growth and their gravelly nature gives them added value as an erosion-resistant surface for rehabilitation. It is recommended that topsoils are salvaged from all undisturbed vegetated areas to approximately 15cm depth, and deeper where there is greater content of rock fragments. Care should be taken to not include clay subsoils which appear to be structurally unstable and potentially erosive.

3.1.2 Harbour View

The chemical fertility of topsoils from the Harbour View deposit was similar to those from the Flag deposit, but with generally greater levels of organic carbon (generally between 2.5% to more than 5%), and slightly higher soil pH (5.0 to 6.1 ($CaCl_2$)) (**Table 1**). The physical properties of the gravelly-loam topsoils, and clay subsoils, were similar to those from the Flag deposit.

In well-vegetated areas of Harbour View, as for Flag area, the existing soil surface is physically well-protected with gravel lag, cryptogamic crusts and plant litter, and typically the soil crust is very firm (**Plate 3**). Cryptogamic crusts are a diverse assortment of macro- and micro-organisms within the top few millimetres of soil (Eldridge, 1996). These organisms may include principally, lichens, mosses, liverworts, cyanobacteria and fungi. These crusts can bind the soil particles together, providing a barrier against raindrops and erosion, and regulate the flow of water and nutrients through the soil (Eldridge, 1996). Cryptogamic crusts are destroyed during soil disturbance and their recovery under revegetation takes years to decades. In general, recovery is likely to be most rapid on moist soils that are fine-textured, stable, and vegetated (Belnap and Eldridge, 2004).

The protective features of the soil surface at Kundip will not be able to be immediately re-created in rehabilitated areas, and therefore care is recommended in reconstruction of soil profiles to ensure that the risk of erosion is minimised. Inclusion of rocky material to supplement the topsoil, (see Section 3.1.1 above) may be important for initial protection, before vegetation cover is established.

Plate 3 HV4 soil surface – gravels, litter, cryptogams.

3.1.3 Kaolin

Soils from the area of the Kaolin Deposit followed the pattern of all other areas, generally being loamy topsoils over clay subsoils (**Table 1**). The topsoils from Kaolin were stable in terms of the Emerson test, but subsoils slaked and had some potential to disperse.

At site K2 (**Figure 1**), soils were sampled from the pit face of the Two Boys pit (**Plate 4**). These soils were a brown-yellow mottled medium clay (0.3m to 1m) overlying red-grey heavy clay (1m to 2m) and then powdery light, white-yellow pink clays to depth (**Table 1**). These deeper, light clays were also obvious in the existing Kaolin pit (**Plate 5**). The uppermost sample at K2 (0.3 to 1m), was acidic (pH 4.2, 1:5 $CaCl_2$), had low organic carbon and extractable K, but substantially higher extractable S than was typical of topsoils at Kaolin. Both this medium clay (0.3 to 1m) and red-grey heavy clays (1m to 2m) from the upper sections of this exposed profile slaked, but did not disperse in de-ionised water (**Table 1**). The deeper light clays were unable to be tested due to lack of aggregates.

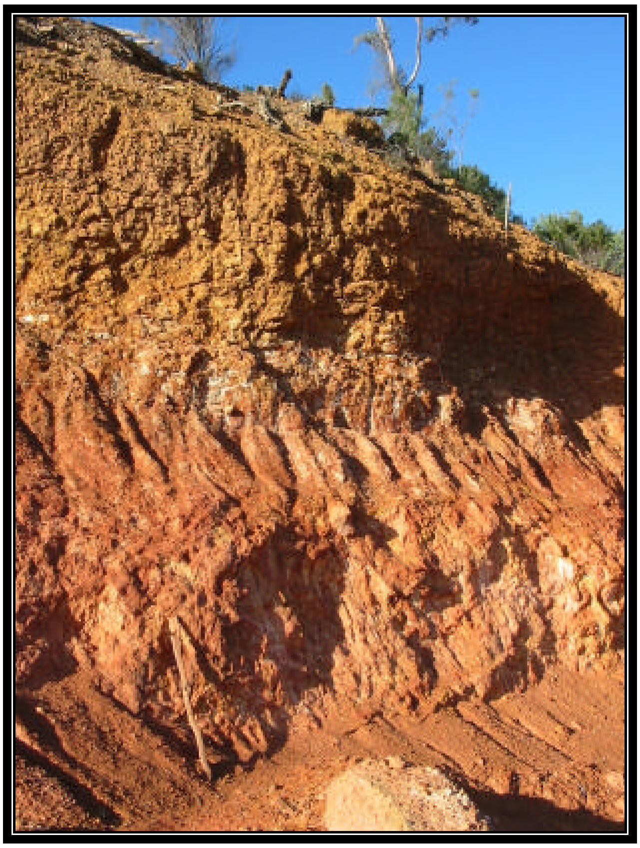

Plate 4 Site K2, the upper profile of Two Boys pit.

Plate 5 Kaolin pit, looking to the north-east.

3.1.4 Hillsborough

Soils from the Hillsborough Deposit appeared to have similar physical properties as the other areas in the Kundip Project, but most samples were not able to be tested for slaking and dispersion due to the lack of aggregates in the collected samples. As with the other areas, the topsoils were gravelly, loamy sands overlying medium to heavy clay subsoils (**Table 1**; **Plate 6**). The underlying clays were similar to those recorded in the upper horizons in the exposed face of the Two Boys Pit (see section 3.1.3 above) and could be expected to be slightly acidic and slaking. A similar profile of gravelly topsoils over orange-brown clays and then red-brown cracking heavy clays was exposed in the Western Gem Pit further to the north of the area of this deposit (**Plate 7**).

In the region of site H3, cemented conglomerate was occasionally exposed at the surface and was also present underlying the clay layer (>30cm) at H3 (**Plate 6**). The occurrence of this shallow cemented layer appeared to be associated with a more-open and shorter vegetation community. These local differences in vegetation are likely to reflect a less-favourable environment for plant growth in these shallow soils.

Topsoil samples from the area of the Hillsborough Deposit contained less plant-available macro-nutrients (N,P,K and S) than Flag or Harbour View and relatively-low organic carbon (**Table 1**). The soils had very low electrical conductivity (salinity) but were similar in pH to the other soils from the Kundip Project, ranging from 4.9 to 5.8 (1:5 $CaCl_2$) (**Table 1**). This pH range is within the normal range and should pose no problems for plant species occurring locally in similar soils.

Plate 6 H3 soil profile.

Plate 7 H3 soil profile at the west end of Western Gem.

Table 1 Physical and chemical properties of selected samples of topsoil and subsoil from the Kundip Project (units in mg/kg unless otherwise stated).

Area	Sample	Depth	Texture*	Emerson Class*	Colour	Nitrate Nitrogen	Ammonium Nitrogen	Total Nitrogen (%)	Extractable Phosphorus	Total Phosphorus	Extractable Potassium	Extractable Sulfur	Organic Carbon (%)	Reactive Iron	Electrical Conductivity (mS/m)	pH ($CaCl_2$)	pH (H_20)
Flag	F1-1	Topsoil	Loam	NA	BR	2	2		6		200	10	2.6	1384	6	5.4	6.6
	F1-2	>15 cm	Medium Clay	1													
	F2-1	Remnant tailings			BR	6	4		12		79	155	0.2	2160	31	5.2	5.5
	F3-1	Topsoil			BRGR	1	2	0.06	8	44	148	17	1.6	1009	14	5.4	6.3
	F4		Medium Clay	3													
	F5-1	Topsoil	Sandy Loam	8 (H)	GR	1	4	0.16	9	60	148	26	3.7	516	13	4.5	5.5
	F6-1	Topsoil	Loamy Sand	8	GR	1	2	0.08	6	53	194	33	4.0	712	17	5.2	6.2
	F6-2	>15 cm	Medium Clay	2													
	F7-1	Topsoil			LTBR	4	2	0.06	5	42	255	168	2.6	503	35	5.4	6.2
Harbour View	HV1-1	Topsoil	Loam	8	BR	1	2	0.22	10	161	329	8	3.7	796	15	6.1	7.3
	HV2-1	Topsoil			BR	1	2	0.24	7	112	335	7	5.3	883	9	5.6	6.7
	HV3-1	Topsoil	Clayey Sand	8	BR	1	2	0.09	4	58	163	6	1.1	793	3	5.1	6.1
	HV3-2	>15 cm	Medium Clay	3													
	HV4-1	Topsoil			BR	1	2	0.17	4	69	217	12	3.1	1551	12	5.0	6.1
	HV5-1	Topsoil	Loam	3	BR	1	2	0.11	5	89	208	6	2.4	640	13	5.8	6.9
	HV5-3		Medium Clay	2													

Table 1 continued.

Area	Sample	Depth	Texture*	Emerson Class*	Colour	Nitrate Nitrogen	Ammonium Nitrogen	Total Nitrogen (%)	Extractable Phosphorus	Total Phosphorus	Extractable Potassium	Extractable Sulfur	Organic Carbon (%)	Reactive Iron	Electrical Conductivity (mS/m)	pH ($CaCl_2$)	pH (H_20)
Kaolin	K1-1	Topsoil	Loam	8	BRGR	1	2	0.07	5	29	285	22	2.8	810	20	6.0	7.3
	K1-2	>15 cm	(Predominantly rocks)#	2													
	K2-1	0.3m to 1m	Medium Clay	5	BR	2	7	0.09	3	24	59	184	0.4	491	49	4.2	5.4
	K2-2	1 to 2m	Heavy Clay	5													
	K2-3	>3m	Light Clay	NA													
	K3-1	Topsoil	Sandy Loam	8 (H)	BR	1	2	0.29	7	130	370	21	4.0	1273	19	5.4	6.5
	K4-1	Topsoil			BR	1	2	0.1	7	73	309	9	3.6	1601	4	4.8	5.9
Hillsborough	H1-1	Topsoil	Loamy Sand	NA	BR	1	2	0.03	4	22	56	4	1.1	547	2	5.2	6.2
	H1-2	>15 cm	Medium Heavy Clay	NA													
	H1-3		Heavy Clay	5													
	H2-1	Topsoil			BR	1	2	0.03	3	18	58	5	0.9	531	2	4.9	6.2
	H3-1	Topsoil	Loamy Sand	NA	BR	1	2	0.05	2	22	263	8	1.9	963	10	5.8	6.9

* See Appendix A for method details.
(H) = hydrophobic.
NA = no aggregates available.
# Texture could not be assessed due to the lack of soil and predominance of rocks.
BR = Brown, GR = Grey, BRGR = Brown Grey, LTBR = Light Brown.

3.2 Conclusions and recommendations – Kundip Project Area

3.2.1 Topsoil Management

At each of the four areas sampled at the Kundip Project, the topsoils have properties that make them important resources for rehabilitation. Firstly, they are the best material to be placed as an outer surface on rehabilitated areas, because of their greater physical stability and content of gravel or rock fragments. Secondly, the topsoils are an important resource for rehabilitation because they will contain seeds of a diverse suite of plant species, together with beneficial soil micro-organisms, and substantially greater nutrient levels than any of the deeper materials.

The physical and chemical properties of the topsoils from each of the deposits are sufficiently similar, that managing soil from each deposit separately is not required. However, it may be appropriate to consider separating the soils on the basis of their associated vegetation communities (Craig, 2004), if each or any of those communities are set as specific restoration targets in rehabilitation.

Nutrients and the beneficial biological components of the topsoils will be concentrated in the surface few centimetres of the soil, thus optimal stripping depth is a maximum of around 15cm. A key to preserving the beneficial components will be to minimize the period of time that it is stockpiled after stripping. If soil is stored moist, or becomes wet in a stockpile, then all biological components can be severely impacted.

Soil samples K3-1 and F5-1 were observed to be water repellent (hydrophobic). Water repellent behaviour is caused by dry coatings of hydrophobic material on soil particles or aggregates, as well as hydrophobic organic matter such as fungal hyphae and particles of decomposing plant material (Moore and Blackwell, 1998). Water repellence can retard infiltration into soils, increase the risk of erosion and lead to poor seed germination (Moore and Blackwell, 1998).

3.2.2 Reconstructed soil profiles on waste landforms

Although this investigation did not allow detailed characterization of the properties of subsoils in the Kundip Project area, it is apparent that most of the subsoils immediately underlying the topsoil had potential to slake and were somewhat dispersive. Therefore these soils were likely to be structurally unstable if exposed on landform surfaces, creating risks of hardsetting and erosion. If placed as shallow subsoil in a reconstructed soil, then the net effect may be to retard infiltration of water, which in turn could lead to increased risk of erosion during high-rainfall events, because of rapid saturation of topsoils leading in turn to surface run-off.

Strategies to minimize the risk of erosion being caused by the clay subsoils may include:

- increasing the depth of the layer of rocky topsoil materials,
- identifying waste materials that may be more structurally stable to use as a subsurface layer, and

- minimizing the external slopes of constructed landforms.

The first strategy of increasing the depth of soil that overlies any slaking and dispersive materials, will increase the effective water storage capacity of the covering soil layer. This will reduce the risk of saturation and runoff, and also increase the likelihood that wetting up will be slow, avoiding rapid wetting that could lead to slaking. It will be important that this surface material has as much rock or gravel as possible, such as the rocky soils observed at Flag and gravelly soils at Hillsborough. To achieve this, it is recommended that where rocky topsoils occur, that they are salvaged to greater depth than just the surface 15cm, and used to supplement the quantity of topsoil available.

The second strategy of using more suitable materials for subsurface layers on the constructed landforms may need to focus on deeper, rocky waste units, rather than the clays that are exposed in the existing open pits. Finally, reducing the steepness of external batters on constructed landforms will increase the time for water to infiltrate before it moves down slope, and will also minimize the erosive potential of any surface flow.

4.0 TRILOGY PROJECT AREA

4.1 Results and Discussion - Trilogy Project Area

The Trilogy Deposit occurs on cleared farmland, on Myamba farm (**Plate 8**). The general topography is flat and there is little remaining perennial vegetation except for a narrow strip along a drainage line to the immediate east of the area of the deposit. At the time of sampling the area had been closely grazed, and there was approximately 60% pasture cover over the soil (**Plate 9**). Gravel and quartz fragments also contributed some protective cover (up to 20%) to the soil surface. The soil surface showed some cracking, suggesting a relatively high content of potentially-unstable clays.

Plate 8 Myamba farm.

Soils were sampled at four sites across the area of the deposit (**Figure 2**). In general, the surface soil consisted of an organic-rich loam in the first 5cm, over a gravelly, brown, medium clay (5-20cm) (**Table 2**). Below this (to 60cm), the soil tended to become darker brown but with less gravel content (**Plate 10**). This general pattern was repeated across the area, except on the western edge (site T3) where there were white rocks visible on the surface and the clay subsoils were grey-pink-white, noticeably paler in colour when compared to the other three sampling sites (**Plate 11**).

Plate 9 T1 soil surface cover gravel and pasture.

Plate 10 T1 soil profile.

Plate 11 T3 soil profile.

The topsoils had high levels of extractable nutrients (**Table 2**), particularly phosphorus, and 3% to 4% organic carbon. The soils were moderately acidic (pH 4.8 to 6.5; 0.01M $CaCl_2$) (**Table 2**). The underlying subsoils were more alkaline, and could be expected to contain less available nutrients.

The topsoils had low salinity, but salinity tended to be higher in one of the subsoil samples analysed (**Table 2**). The level of salinity in this sample is sufficient to restrict the growth of non-tolerant plants, but the possibility of contamination from drilling operations may need to be considered. The chemical properties of the soils, such as pH and salinity will not change during stockpiling and re-spreading, however the availability of nutrients is likely to increase, as a result of breakdown of organic matter.

The topsoils tested were relatively stable, reflecting their high organic matter content, but subsoil clay slaked and dispersed. Therefore, these subsoil materials will be prone to structural breakdown, hard-setting and erosion, if placed on or near the surface of constructed waste landforms. Although the undisturbed topsoils appeared to be relatively stable, it is likely that stripping and re-spreading will breakdown some of the structural stability currently provided by organic matter, and they will become less stable and less able to resist erosion on waste landform surfaces.

The dispersive potential of the Trilogy soils may be able to minimized through the addition of gypsum. Their actual responsiveness to gypsum could be defined in further testing. Gypsum is most effective if it is mixed with the soil. This mixing may be best achieved if gypsum is spread onto the soil before stripping. The processes of stripping, stockpiling and re-spreading will act to thoroughly mix the gypsum through the soils. Gypsum is not likely to affect subsequent seed germination or plant growth.

4.2 Conclusions and recommendations – Trilogy Project Area

In summary, the topsoils and subsoils at Trilogy are likely to be relatively susceptible to structural instability and erosion on the surfaces of constructed landforms. Therefore, consideration may need to be given to strategies to reduce the erosion risk. This could include reducing the slope angle of outer batters, possibly applying gypsum, and incorporating competent, chemically-benign, rocky material into the outer layers. Clearly, the latter approach will depend on availability and on rock geochemistry and salinity. Any materials that may be potentially acid-forming, or highly-saline, would not be suitable.

The surface topsoils will contain a substantial seed bank of pasture and weed seeds. This may be an important issue if pasture is not the intended vegetation on final landforms. For example, if native perennial vegetation is planned, then strategies to reduce the seed bank may need to be considered. This could include the application of herbicides during the current growing season, to prevent seed set, and reduce the seed load before topsoil stripping. Stockpiling of the topsoils is not normally recommended, but will also reduce this seed bank.

Table 2 Physical and chemical properties of topsoil and subsoil from the Trilogy Project (units is mg/kg unless otherwise stated).

Area	Sample	Depth	Texture*	Emerson Class*	Colour	Nitrate Nitrogen	Ammonium Nitrogen	Extractable Phosphorus	Extractable Potassium	Extractable Sulfur	Organic Carbon (%)	Reactive Iron	Electrical Conductivity (mS/m)	pH ($CaCl_2$)	pH (H_20)
Trilogy	T1-1	Topsoil	Loam	8	BR	16	9	22	518	13	4.0	685	25	6.5	7.3
	T1-2	>15 cm	Medium Clay	2											
	T2-1	Topsoil			GR	9	69	42	473	13	3.1	494	14	5.3	6.2
	T3	>15 cm			BRGR	3	4	2	175	208	0.6	382	168	7.2	8.0
	T4-1	Topsoil	Sandy Loam	NA	GR	7	4	39	239	8	3.3	1039	5	4.8	5.7
	T4-2	>15 cm	Medium Clay	5											

* See Appendix A for method details.
(H) = hydrophobic.
NA = no aggregates available.
# Texture could not be assessed due to the lack of soil and predominance of rocks.
BR = Brown, GR = Grey, BRGR = Brown Grey, LTBR = Light Brown.

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Appendix A

GPS co-ordinates (GDA 94) of sampling sites at the Kundip and Trilogy Project areas

Kundip Deposits		**Easting**	**Northing**
Kaolin	K1	240673	6270737
	K2	240616	6270670
	K3	240633	6270522
	K4	240582	6270459
Hillsborough	H1	240102	6270374
	H2	240221	6270442
	H3	240264	6270450
Harbour View	HV1	240094	6269466
	HV2	240074	6269640
	HV3	240160	6269876
	HV4	240268	6269934
	HV5	240337	6270095
Flag	F1	240100	6269200
	F2	240138	6269196
	F3	240348	6269218
	F4	240377	6269193
	F5	240451	6269203
	F6	240650	6269201
	F7	240754	6269311
Trilogy	T1	241613	6261337
	T2	241649	6261502
	T3	241622	6261536
	T4	241749	6261617

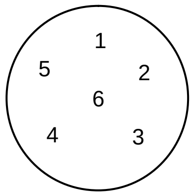
Appendix B

Summary of Outback Ecology Soil Analysis Methods

Emerson Dispersion Test

Emerson dispersion tests were carried out on all samples according to the following procedure:

A petri dish was labelled 1 to 6. eg.



The petri dish was filled with DI water.

A 3-5mm aggregate piece was taken from each sample and gently placed into the labelled petri dish (6 per dish).

Observations were made of the dispersive or slaking nature of the sample according to the following table:

Emerson Aggregate test classes (Moore, 1998)

Class	Description
Class 1	Dry aggregate slakes and completely disperses
Class 2	Dry aggregate slakes and partly disperses
Class 3	Dry aggregate slakes but does not disperse; remolded soil does disperse
Class 4	Dry aggregate slakes but does not disperse; remolded soil does not disperse; carbonates and gypsum are present
Class 5	Dry aggregate slakes but does not disperse; remolded soil does not disperse; carbonates and gypsum are absent; 1:5 suspension remains dispersed
Class 6	Dry aggregate slakes but does not disperse; remolded soil does not disperse; carbonates and gypsum are absent; 1:5 suspension remains flocculated
Class 7	Dry aggregate does not slake; aggregate swells
Class 8	Dry aggregate does not slake; aggregate does not swell

The samples were left in the dish for a 24 hour period, after which the samples were observed again and rated according to the above Table.

Soil Texturing

Soils were worked by hand, and the texture, shearing capacity, particle size and ribbon length were observed according to guidelines of McDonald *et al*. (1990) from the table below.

Texture Grade	Behaviour of Moist Bolus	Approximate clay content	Code
Sand	Nil to very slight coherence; cannot be molded; single sand grains adhere to fingers	<5%	S
Loamy sand	Slight coherence; can be sheared between thumb and forefinger to give minimal ribbon of about 5mm	About 5%	LS
Clayey sand	Slight coherence; sticky when wet; many sand grains stick to fingers; discolours fingers with stain; forms minimal ribbon of 5-15mm	5-10%	CS
Sandy loam	Bolus coherent but very sandy to touch; dominant sand grains of medium size and readily visible ; ribbon of 15-25mm	10-20%	SL
Loam	Bolus coherent and rather spongy; no obvious sandiness or silkiness; forms ribbon of about 25mm	About 25%	L
Sandy clay loam	Strongly coherent bolus; sandy to touch; ribbon of 25-40mm	20-30%	SCL
Clay loam	Coherent plastic bolus, smooth to touch, ribbon of 25mm to 40mm	30-35%	CL
Clay loam, sandy	Coherent plastic bolus, sand grains visible in finer matrix, ribbon of 40-50mm; sandy to touch	30-35%	CLS
Light clay	Plastic bolus, smooth to touch; slight resistance to shearing; ribbon of 50-75mm	35-40%	LC
Light medium clay	Ribbon of about 75mm, slight to moderate resistance to ribboning shear	40-45%	LMC
Medium clay	Smooth plastic bolus, handles like plasticine and can be molded into rods without fracture; moderate resistance to ribboning shear, ribbon of 75mm or longer	45-55%	MC
Medium heavy clay	Ribbon of 75mm or longer, handles like plasticine, moderate to firm resistance to ribboning shear	=50%	MHC
Heavy Clay	Handles like stiff plasticine; firm resistance to ribboning shear, ribbon of 75mm or longer	=50%	HC