Material change for
a better environment

Compost use for geotechnical stability of engineered slopes, erosion control and restoration of riparian habitats.

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WRAP works in partnership to encourage and enable businesses and consumers to be more efficient in their use of materials and recycle more things more often. This helps to minimise landfill, reduce carbon emissions and improve our environment.

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Front cover photography: [Slope treatment plots at Nafferton Farm in August 2009]

Executive summary

This interim report provides details of progress to the end of August 2009, in accordance with the terms of the research contract between WRAP and Soil Environment Services.

- All conditions for Milestone 1 and 2 have been satisfied and details submitted in previous reports.
- The aims, setup and operation of the experiment are summarised.
- Results are presented from monitoring over the period May-August 2009:
    - Soil fertility and grass growth were increased by PAS 100 compost application.
    - Nutrient and sediment losses were higher with compost than geotextile slope stabilisation treatments.
    - Surface incorporation of compost reduced nutrient runoff losses
    - Differences between treatments were much larger on the north than the south facing slope, as low moisture availability on the south slope limited runoff and grass growth.

The report also includes a work plan for the next five months (up to the next interim report on February 1st 2010).

Contents

1 Introduction

1.1 Background

The project examines the effectiveness of PAS100 compost to stabilise the surface and subsurface of an engineered slope in order to both prevent erosion and enhance vegetation establishment.

There is a need for information on performance under realistic field conditions such that industry will be encouraged to use compost as a slope stabilisation treatment and be able to apply best practice methods with confidence and within budgets. This is part of the UK Governments drive to recycle waste materials and funded by the Waste and Resources Action Programme (WRAP).

1.2 Site description

The experimental site is located at Nafferton Farm, near Hexham, Northumberland. The trial is being conducted on a purpose-built artificial embankment constructed by the University of Newcastle upon Tyne. The embankment is 90 m long, 29 m wide and 6 m tall and is made of sandy clay of medium plasticity well compacted according to modern construction standards. The embankment is orientated east to west, providing maximum contrast of microclimatological conditions between north and south facing slopes.

Photo 1: Trial location

2 Trial design and establishment

2.1 Plot Construction

Plot areas were established in four 6 x 9 m replicate blocks at either end of the embankments on both the north and south facing slopes. Plot construction firstly involved removing the topsoil using an excavator on the current slope to simulate the surface of a typical newly established unvegetated slope within an infrastructure project (Photos 1 and 2).

Photo 1

Photo 2

Following topsoil removal, wooden plot borders were inserted (Photo 3) and the surface was scarified with a rotavator (Photo 4). This simulates the degree of surface preparation recommended as per CIRIA report *The Use of Vegetation in Civil Engineering* (Hardcover) by N.J. Coppin (Editor), I.G. Richards (Editor). Construction Industry Research & Information Association (CIRIA) (Mar 1990). Each plot measures 1.2 x 9 m.

Photo 3

Photo 4

2.2. Treatments.

Five slope stabilisation treatments are compared in the trial; two treatments received a surface dressing of PAS 100 municipal green waste compost of either 5 or 10 cm depth. Two further treatments received a 5 or 10 cm depth PAS 100 compost application incorporated into the soil surface using a rotavator. The compost was applied to the plots by wheelbarrow - considered appropriate to simulate the placement that would take place by an excavator within a construction scenario (i.e. the compost would be loose-tipped onto the plot rather than dozered into place). The fifth treatment consists of geotextile matting included as an industry best practice control. The geotextile used is Verdamat 300, biodegradable double net coconut blanket. This was pinned to the surface as per the manufacturers recommendations. The five treatments were randomly assigned to plots within each replicate block (see experimental layout below).

Experimental layout

SW Corner NW Corner

REF			REF	
1	10 cm compost incorporated	T	11	5 cm compost incorporated
2	5 cm compost on surface	O	12	10 cm compost incorporated
3	5 cm compost incorporated	P	13	5 cm compost on surface
4	Geotextile		14	10 cm compost on surface
5	10 cm compost on surface	O	15	Geotextile
		F		
6	5 cm compost on surface	M	16	5 cm compost incorporated
7	Geotextile	O	17	5 cm compost on surface
8	5 cm compost incorporated	U	18	10 cm compost incorporated
9	10 cm compost incorporated	N	19	Geotextile
10	10 cm compost on surface	D	20	10 cm compost on surface

SE Corner NE Corner

Runoff collection troughs were dug in to the base of each plot following treatment application (see photos 7-10). Final preparations included a bentonite clay seal along the outside of the top border to prevent water movement into the plot from above and a loose brick placement at the base to prevent slumping into the runoff collection troughs.

Photo 7 NE corner

Photo 8 NW Corner

Photo 9. SW Corner

Photo 10. SE Corner

2.3 Seeding and fertilizer

A British Seed Houses landscaping and embankment mix (Mix A3) was selected as this has been formulated for such situations. The mix is designed to develop a robust root system whilst being slow growing above ground with drought and wetness tolerance. Seeding took place on the 27th March 2009.

The mix consisted of:

Aniset Strong Creeping Red Fescue, *Festuca rubra ssp rubra*	60%
Raisa Chewings Fescue, *Festuca rubra ssp commutate*	20 %
Falcon IV Tall Fescue, *Festuca arundinacea*	15 %
Highland Bent Grass, *Agrostis castellena*	5 %

The seed mix was applied as per typical recommended rates of 35 g/m2.

An NPK granular fertilizer (20:10:10) was applied at 200 kg/ha to the geotextile treatment plots following seedling emergence.

2.4 Monitoring

2.4.1 Weather

Rainfall and temperature measurements were collected hourly using an automated weather station located on the experimental site.

2.4.2 Grass growth

Grass growth was assessed qualitatively at 2 month intervals. Quantitative assessment was undertaken in August, when total above-ground plant yield was measured by cutting all grass from each plot which was then weighed (fresh weight).

2.4.3 Erosion and sediment accumulation

Eroded material was recovered from the collection troughs in at the end of May, start of July and August 2009 and dried at 100 degrees centigrade in an oven before being weighed.

2.4.4 Nutrient loss and pollution potential

Samples of water were taken from the collection troughs at the base of each plot in May, June and August 2009. Samples were tested for nitrate and ammoniacal nitrogen, pH and electrical conductivity. Samples collected in May were also tested for available phosphate and potassium and total dissolved solids.

2.4.5 Slope strength and moisture change

Soil samples were taken on the 15th April 2009, following plot establishment. Samples were taken at 30 cm depth. 20 cm below the treatment zone of approximately 5 to 10 cm.

Soil shear strength readings were taken on the 15th April after plot establishment and on the 30th July 2009 and 24th August with a Geovane hand held shear vane fitted with 19 mm blades. Samples were taken at 50 cm depth.

3 Baseline conditions

3.1 Soil moisture

Table 1. Soil moisture content (%) April 2009

Treatment	Ref	NW	Ref	NE	Ref	SW	Ref	SE
10 cm compost on surface	**14**	22	**20**	24	**5**	20	**10**	24
10 cm compost incorporated	**10**	19	**18**	19	**1**	17	**9**	18
5 cm compost on surface	**13**	22	**17**	17	**2**	18	**6**	17
5 cm compost incorporated	**11**	22	**16**	25	**3**	16	**8**	18
Geotextile	**15**	33	**19**	19	**4**	19	**7**	24
Average		23.6		20.8		18		20.2
SE of the mean		2.4		1.6		0.7		1.6

The results in Table 1 indicate no significant variation between plots on either side of the mound but a significant variation between the north and south sides of the mound. On average, the north is wetter at approximately 25 cm depth from the surface. This will be expected to result in variations in growth in due course.

3.2 Slope stability

Table 2. Baseline soil shear strength after plot establishment (units kPa/m^2)

Treatment	Ref	NW	Ref	NE	Ref	SW	Ref	SE	
10 cm compost on surface	**14**	158	**20**	110	**5**	142	**10**	173	
10 cm compost incorporated	**12**	195	**18**	165	**1**	213	**9**	189	
5 cm compost on surface	**13**	221	**17**	142	**2**	221	**6**	126	
5 cm compost incorporated	**11**	113	**16**	126	**3**	205	**8**	205	
Geotextile	**15**	67	**19**	142	**4**	221	**7**	221	
Mean		151		142		200		183	
SE of the mean		27.7		9.2		14.9		16.4	

The results in Table 2 indicate no significant variation between plots on either side of the mound but a significant variation between the north and south sides of the mound. On average, the north is 25% stronger at approximately 25 cm depth from the surface. This is a function of moisture but will be expected to vary in conjunction with growth variation in due course.

4 Results

4.1 Weather conditions

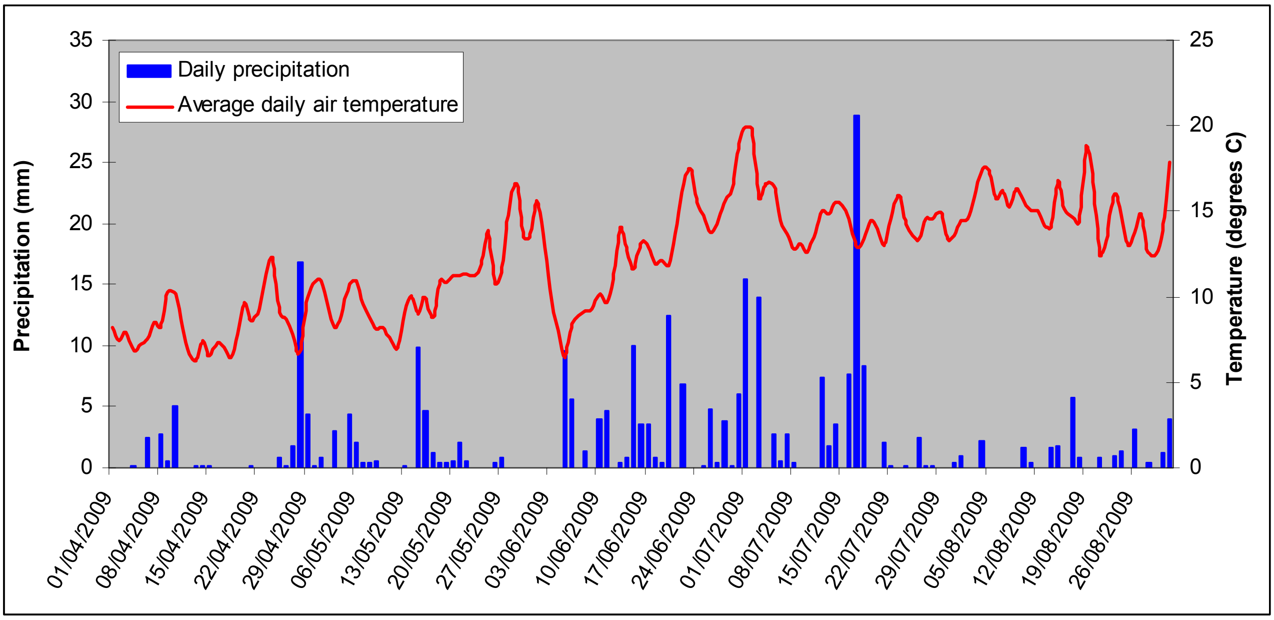

Figure 1. Rainfall and temperature data April-August 2009

The monitoring period during 2009 has included a period of unusually wet weather from late June to mid July. This included a large storm event on the 16th and 17th of July when 36 mm of rainfall fell within a 24 hour time period.

4.2 Plant nutrient supply

Table 3. Soil nutrient concentrations May 2009 (0-20 cm)

Treatment	Mg (mg/kg)	P (mg/ kg)	K (mg/ kg)	Nitrate (mg/kg)	EC	N (%)	Ammonia (mg/kg)	OC (%)	pH
10 cm incorporated	478	113	2375	818	1800	0.85	23.5	6.8	7.48
5 cm incorporated	440	99	2025	903	2000	0.57	17.8	6.2	7.50
10 cm surface	575	153	4075	1400	2675	0.84	16.0	9.9	7.68
5 cm surface	560	133	2975	895	2025	0.82	19.5	8.7	7.70
Geotextile	295	17	160	94	398	0.14	6.9	1.9	7.83
Mean	470	103	2322	822	1779	0.64	16.7	6.7	7.64

Addition of PAS 100 green waste compost led to a significant increase in soil nutrient content (Table 3). The addition of organic material led to large increases in organic carbon, total and available nitrogen, phosphate, potassium and magnesium, and also led to a similar increase in electrical conductivity (salinity) relative to the geotextile treatment.

4.3 Plant growth

The effects of increased fertility due to compost application can be seen in the differences in grass yields (Table 4) and are also illustrated in Photos 11-14 taken on July 30th 2009. While the results demonstrate the major effect of slope aspect on soil moisture content and resultant grass growth, the treatment comparison on the north facing slopes suggests significant increases in growth as a result of compost addition. Yield increases appear proportional to the compost application rate.

Table 4. Grass yield (kg/10m^{2}) August 2009

Treatment	Slope aspect North	Slope aspect South	Mean
10 cm incorporated	11.00	1.31	6.16
5 cm incorporated	6.73	1.32	4.02
10 cm surface	10.75	1.33	6.04
5 cm surface	5.25	2.25	3.75
Geotextile	3.18	1.83	2.50
Mean	7.38	1.61	

Photo 11. South west block. Treatments left to right: 10 cm incorporated; 5 cm surface; 5 cm incorporated; geotextile.

Photo 12: South east block. Treatment left to right: 5 cm surface; geotextile; 5 cm incorporated; 10 cm incorporated; 10 cm surface.

Photo 13: North west block. Treatments left to right: goetextile; 10 cm surface; 5 cm surface; 10 cm incorporated; 5 cm incorporated.

Photo 14: North east block. Treatments left to right 10 cm surface; geotextile; 10 cm incorporated; 5cm surface; 5 cm incorporated.

4.4 Runoff

The figures in Table 6 indicate that solute runoff concentrations were greater when compost was applied as a treatment than with geotextile. This may be explained both by the reduction in runoff rates, and by the lower soil nutrient concentrations (Table 3) with the geotextile treatment. However, geotextile application appeared to result in a much higher ammonia concentrations in runoff water. Ammonia has a highly detrimental effect on the health of aquatic ecosystems. These results may suggest that geotextile leads to anaerobic soil surface conditions preventing the nitrification process. The results also illustrate the effect of slope aspect on nutrient losses; the wetter, north facing slope results in greater surface runoff leading to higher solute losses than the south facing slope.

Compost incorporation appears more effective in limiting solute losses than a surface application.

Table 5. Runoff solute chemistry May 2009

	P (mg/l)			K (mg/l)		
	Aspect			Aspect		
Treatment	North	South	Mean	North	South	Mean
10 cm incorporated	2.5	2.5	2.5	375	185	280
5 cm incorporated	2	1.5	1.75	165	157	161
10 cm surface	3	4	3.5	645	305	475
5 cm surface	2.5	2.5	2.5	410	350	380
geo	2	1.5	1.75	76.5	29.5	53
Mean	2.4	2.4		334.3	205.3	

	NO3 (mg/l)			NH4 (mg/l)		
	Aspect			Aspect		
Treatment	North	South	Mean	North	South	Mean
10 cm incorporated	405	136.5	270.8	7.9	9.8	8.8
5 cm incorporated	325	199.5	262.3	9.1	4.4	6.7
10 cm surface	715	184	449.5	4.9	14.0	9.4
5 cm surface	615	360	487.5	4.9	6.0	5.4
geo	108.5	61.5	85	46	19.5	32.7
Mean	433.7	188.3		14.5	10.7	

	pH			Electrical Conductivity		
	Aspect			Aspect		
Treatment	North	South	Mean	North	South	Mean
10 cm incorporated	6.8	7	6.9	2000	1094	1547
5 cm incorporated	6.9	6.8	6.9	1775	1274	1525
10 cm surface	6.7	6.9	6.8	3205	1575	2390
5 cm surface	6.7	6.8	6.7	2660	1555	2108
geo	6.5	7.0	6.7	1470	1156	1313
Mean	6.7	6.9		2222	1331	

	Dissolved Solids (mg/l)		
	Aspect		
Treatment	North	South	Mean
10 cm incorporated	2150	1165	1658
5 cm incorporated	1750	1250	1500
10 cm surface	3250	1500	2375
5 cm surface	2700	1915	2308
geo	1550	1300	1425
Mean	2280	1426	

Results for later in the season (Table 6 and Table 7) are more variable and do not show conclusive differences between treatments.

Table 6. Runoff solute chemistry July 2009

	NO_3 (mg/l)			NH_4 (mg/l)		
	Aspect			Aspect		
Treatment	N	S	Mean	N	S	Mean
10 cm incorporated	7.5	3	5.3	54.5	10	32.3
5 cm incorporated	50.5	42.5	46.5	47	32.5	39.8
10 cm surface	42.5	50.5	46.5	16.5	24.5	20.5
5 cm surface	1	1	1.0	55	7	31.0
Geotextile	47.5	21	34.3	39.5	5.5	22.5
Mean	29.8	23.6		42.5	15.9	

	pH			Electrical Conductivity		
	Aspect			Aspect		
Treatment	N	S	Mean	N	S	Mean
10 cm incorporated	7.3	7.5	7.4	2145	820	1483
5 cm incorporated	7.4	7.6	7.5	2172	1652	1912
10 cm surface	7.5	7.6	7.5	2816	2388	2602
5 cm surface	7.6	7.3	7.5	2260	694	1477
Geotextile	7.5	7.4	7.4	895	1845	1370
Mean	7.4	7.5		2057	1480	

Table 7. Runoff solute chemistry August 2009

	NO_3 (mg/l)			NH_4 (mg/l)		
	Aspect			Aspect		
Treatment	N	S	Mean	N	S	Mean
10 cm incorporated	1.5	94.5	48	66.5	59	62.8
5 cm incorporated	1.5	50.5	26	79.5	45.5	62.5
10 cm surface	98.5	92	95.25	61.5	53.0	57.3
5 cm surface	83.5	67.5	75.5	0.7	0.9	0.8
Geotextile	91	57.5	74.25	0.5	1.4	0.9
Mean	55.2	72.4		41.7	31.9	

	pH			Electrical Conductivity		
	Aspect			Aspect		
Treatment	N	S	Mean	N	S	Mean
10 cm incorporated	7.9	8.8	8.4	1865	829	1347
5 cm incorporated	8.2	8.0	8.1	1776	1230	1503
10 cm surface	8.5	7.7	8.1	900	1114	1007
5 cm surface	8.5	8.3	8.4	898	732	815
Geotextile	8.3	7.9	8.1	1095	1164	1129
Mean	8.3	8.1		1306	1014	

4.5 Slope stability

Table 8. Soil shear strength at 50 cm (kPa/m²) July 2009

Treatment	N	S	Mean
10 cm incorporated	181	181	181.0
5 cm incorporated	120	205	162.5
10 cm surface	134	177	155.5
5 cm surface	181	197	189.0
Geotextile	110	205	157.5
Mean	145.2	193	

Table 9. Soil shear strength at 50 cm (kPa/m²) August 2009

	Aspect		
Treatment	**N**	**S**	**Mean**
10 cm incorporated	213	200	206.5
5 cm incorporated	171	206	188.5
10 cm surface	155	221	188
5 cm surface	173	138	155.5
Geotextile	150	221	185.5
Mean	172.4	197.2	

Table 10. Suspended sediment (g/l of runoff) yield May 2009

	Aspect		
Treatment	**N**	**S**	**Mean**
10 cm incorporated	2.15	1.17	1.43
5 cm incorporated	1.75	1.25	1.48
10 cm surface	3.25	1.50	1.54
5 cm surface	2.70	1.92	1.55
Geotextile	1.55	1.30	1.36
Mean	2.28	1.43	

Table 11. Suspended sediment (g/l of runoff) yield July 2009

	Aspect		
Treatment	**N**	**S**	**Mean**
10 cm incorporated	1.16	1.34	1.26
5 cm incorporated	1.22	0.92	1.06
10 cm surface	1.38	1.3	1.34
5 cm surface	1.12	0.56	0.84
Geotextile	0.62	0.68	0.64
Mean	1.1	0.96	

Table 12. Suspended sediment (g/l of runoff) yield Aug 2009

	Aspect		
Treatment	**N**	**S**	**Mean**
10 cm incorporated	1.22	2.29	1.76
5 cm incorporated	0.92	1.64	1.28
10 cm surface	1.55	1.86	1.71
5 cm surface	0.9	0.86	0.88
Geotextile	0.44	0.81	0.63
Mean	1.0	1.49	

Soil shear strengths (Table 8 and Table 9) in the compacted material are relatively high in all treatments, as a result of the compaction involved in the original construction of the embankment. It appears that this standard construction procedure is relatively effective in the prevention of mass movement of surface material (without secondary surface treatment) at least in fine textured construction material as used in this embankement. However, this process is likely to reduce precipitation infiltration rates and result in high runoff coefficients and water erosion.

It is notable that the lower soil moisture contents on the south facing slope result in greater shear strength than those on the north, although these differences are unlikely to lead to direct differences in slope stability as all readings are relatively high.

Rates of particulate loss (Table 10) show appreciable differences between the geotextile treatment and the compost treatments. There do not appear to be differences between the two compost application methods. However, the higher rate of compost application appears to lead to higher rates of particulate loss. This may suggest that the compost itself comprises a sizeable proportion of the eroded material.

5 Work plan for next 5 months

- Sediment and nutrient losses will be monitored according to occurrence of rainfall events.
- Soil shear strength will be measured in on a 2 monthly basis.
- Grass yield assessment will take place in late January.