# Greenoakhill landfill site, reclamation monitoring

South west tip December 2006

August 2013, after three seasons' growth

South west tip March 2008

August 2013, after three seasons' growth

## Summary

The southern part of the Greenoakhill landfill site was reclaimed by cultivating with green compost and planting with 5.6 ha of mixed woodland in early 2011. Planting specification including plug plants and tree tubes were effective and growth was good. Weeding was required for the first three seasons and grass seeding reduced vigorous broadleaved weed growth from the second year. Uncultivated 'rides', drainage taps, berms and armoured drains were effective in preventing soil slippage, erosion and water pollution.

There was limited nitrogen deficiency at year three in small areas of faster growing species, although not obviously stunting tree growth. However, given the slow release nature of compost and the very poor initial soil conditions this was not unexpected.

Contract reclamation and establishment operations required intensive supervision by Forester staff. A higher initial specification allowed scope for adjustments than a lower one would have done and tendering on the basis of price per unit of work items made changes easier to agree. The approximate cost of the reclamation to woodland project was £30k per gross and £55k per net planted hectare, excluding VAT.

# Introduction

Forestry Commission Scotland, Scottish Lowlands Forest District let and managed a contract for restoration of a c 20 ha part of the Greenoakhill landfill site, south-east Glasgow, in 2010/11. The planting areas of c 10 ha were treated by excavator complete cultivation with admixture of British Standard PAS100 green-compost. Tree planting with mostly native broadleaved plug plants in 60 cm tubes followed cultivation in spring 2011. Additional works were undertaken including drainage and path creation. The development of the reclamation scheme was monitored through site visits by visual inspection for three growing seasons. Soil and foliar analysis were undertaken and photographic records kept. This report aims to inform future schemes by recording the key technical features of scheme design and implementation, both initially and over subsequent seasons. The site location is shown in **Figure 1**.

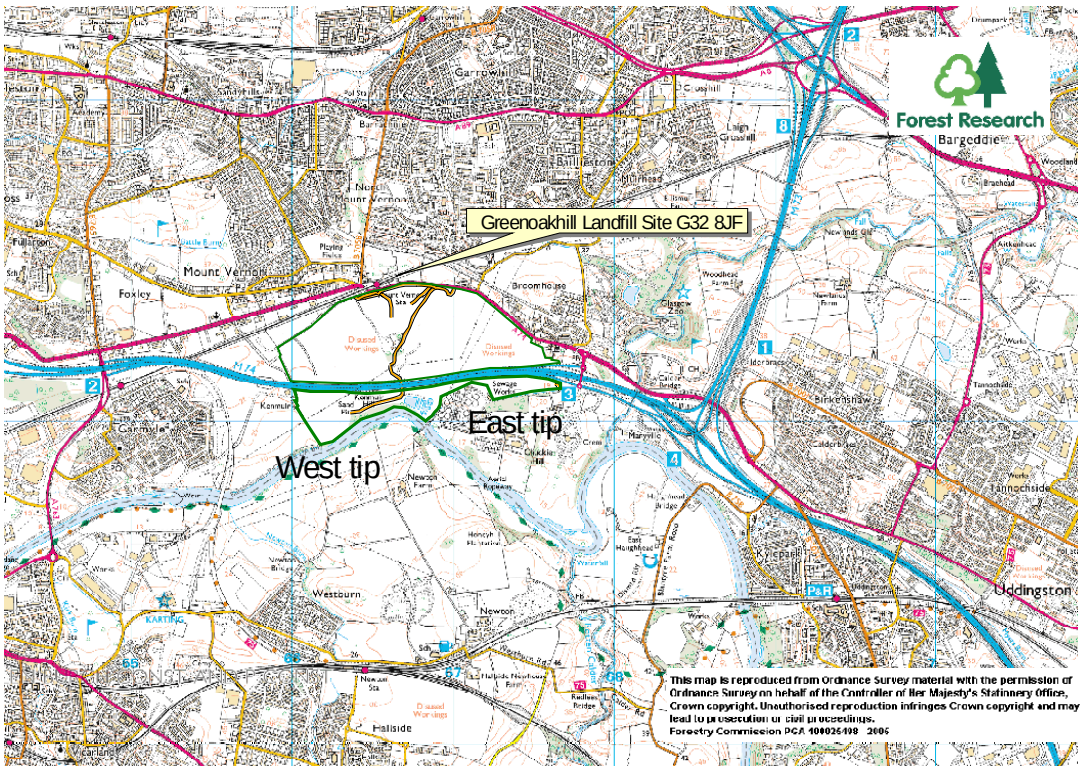


**Figure 1.** Greenoakhill Landfill Site location

# Objectives and method

The detailed elements of the monitoring task were:

1. To record the **pre-restoration** conditions, restoration objectives, specification and work quantities.

2. To describe the **restoration method**, machinery, techniques, work quantities, timescales, climate/weather, costs and practical issues arising during operations. To estimate cost per unit area by operation.

3. To establish a baseline of immediate post restoration **physical site conditions** relevant to long term operational success and devise a monitoring protocol for each site.

4. To implement the post restoration **monitoring protocols** for three complete seasons (i.e. to winter 2013).

5. To produce TD **Report**/s covering objectives 1 - 4 and draw conclusions / recommendations for relevant FCS best restoration practice.

Information was gathered by:

- Inspection of contract specification and completion maps
- Feedback from the Forester supervising the restoration and planting operations
- Regular site inspection for visual assessment and photographic record
- Soil sampling at planting and foliar sampling in year three.

# Results

## Site history, description and location

The Greenoakhill site was first established as a sand quarry by the Paterson family in the 1940s, and subsequently evolved into a landfill site serving Greater Glasgow from the 1960s. By 2008 the site was receiving c 500,000 tones of mixed municipal / domestic and commercial / industrial waste per year. At that stage the site was a 'dilute and disperse' facility whereby wastes were compacted in layers, initially into a void but thereafter in a surcharge 'land raising' operation.

Greenoakhill landfill site occupies a total of c 85 ha bisected into northern and southern sections by the M74 Motorway at the eastern entry point to Glasgow City.
The 2011 reclamation scheme comprised two areas within the southern part of the Greenoakhill site, although larger areas to the north were expected to become available for reclamation to forestry in the future.

The northern section includes two longstanding waste tips. Both the east tip (completed before 2007) and its successor the west tip (completed in c 2011) are of the 'dilute and disperse' type whereby the organic products of waste decomposition eventually disperse through ground-waters. Additionally, methane and other gases rise to the cap where they can be collected or vented.

Once the east and west tips reached the contours approved in the Planning Consent they were 'capped' using compacted clay and surcharged with a layer of soil forming material. The clay caps of the 'east' and 'west' tips, which contained putrescible waste, were provided with gas 'wells' connected by a network of pipes, running over the cap but under the surface soil forming material. The recovered gas powered a battery of 12 cylinder engines to generate electricity for the National Grid.

The southern section of the landfill site is accessed from the north by a motorway underpass. This was only used for commercial / industrial waste, including large quantities of inert geological deposits from construction site excavations. The waste was deposited in a larger tip to the south west (completed in 2010) and a smaller one in the south east, which was largely completed before 2006 but had additional grading in 2008. The latter was seeded and partly planted with broadleaves in the west before 2006, although growth was poor owing to compaction and poor nutrient status. The gross area of the site to be reclaimed was c 11 ha, with approximately half requiring cultivation with compost to enable tree planting

The motorway underpass also forms the access route to an aggregates supply company that occupies a central location within the southern part of the larger site. The extreme southern site boundary of the Greenoakhill site is formed by the steep banks of the River Clyde, which flows westwards into Greater Glasgow.

**Figure 2.** Southern section from south-west tip, with south-east tip beyond the pylon

**Figure 3.** River Clyde along south edge of site

The south tip was not expected to produce organic decomposition products or gas and did not require an engineered clay cap or gas collection infrastructure.

## Pre-restoration conditions

Both the south-west and south-east tips comprised inert, inorganic, non-putrescible waste of commercial / industrial origin that had been laid down over many years, initially filling former sand and gravel pits, which were then surcharged as levels rose.

**Figure 4.** South-west tip, December 2006

**Figure 5**. South-west tip, June 2008

Given the absence of decomposing organic matter, there was no generation of gases such as methane within the tip, and neither gas collection pipe-work infrastructure nor a compacted, engineered clay capping was required. The tips were of the 'dilute and disperse' type and as such were not lined.

The tipped materials were visually characterised as subsoils and geological drift from civil engineering sites, broken concrete, rocks, blocks and brickwork together with associated steel reinforcing and miscellaneous obstructions. Drift and soil forming material formed the majority of materials by bulk, and these generally had a high clay composition and varying stone content.

Landfill site practice was to prepare for final restoration in the months prior to completion of the tip. This was described as setting aside imported loads of the 'better' soil forming materials for subsequent use as final surface. When observed, this practice appeared to be reliant on the judgement of incoming lorry drivers and supervisors.

The larger, south-west tip was completed by surcharging with block-tipped imported materials that were then graded to final contours by the site-based D8 or similar bulldozer in late 2010 **(Figure 6)**.

**Figure 6.** Example of grading practice on north-west tip August 2013

The final contouring was designed to produce natural looking, even slopes. Final slope was influenced by the underlying shape of the historical tipping and the boundary constraints, especially to the south which was formed by the steep banks down to the River Clyde. FE Scotland had arranged for further remedial grading during completion of the west tip prior to forestry works commencing. As a result, the greater slopes were formed on the south face, although overall slopes of ground to be cultivated were generally 6 to 22 degrees (10 to 40%). The steeper ground was not to be cultivated except for one small cell at c 38 degrees. The lower edge of the area to be cultivated along the River Clyde comprised an effective filtration buffer zone of level to slightly sloping, undulating, non-compacted ground with dense grass and scrub.

The smaller, south-east tip had been completed and graded with various soil forming materials selected at the time for the surface layer in c. 2003 - 2006[1], and subsequently grass seeded. The graded tip formed a ridge parallel with the M74 to the north and a public access road on the far side of a deep drain to the south. Ridge side-slopes were c 6 to 32 degrees (c. 10 to 62%), with the steepest to the south side where cultivation blocks were limited as a result. The surface materials included a strip of peat placed along the tip's summit, which effectively formed a steep sided ridge running east-west. The lower edges of the ridge along the M74 to the north and a deep drain to the south comprised slope with a dense grass / shrub cover. An area on the north and west faces had been planted directly into the final surface at this time, comprising mixed broadleaves and shrubs. Observed growth was poor, apparently owing to compacted conditions.

[1] Wise Group Indicative Phasing plan, September 2003

## Restoration objectives

The **objective** of the restoration was to reinstate the former landfill by establishing healthy mixed woodland, thereby improving the landscape, strengthening the Glasgow and Clyde Valley 'Green Network' and, when the site has ceased operating, opening a community woodland for public access and amenity. The restoration was especially important owing to the site's prominent position in the 'Clyde Gateway' area, on the M74 corridor into south-east Glasgow prior to the 2014 Commonwealth Games. An agreement reached with the site owner, whereby Patersons Quarries Ltd completed the primary restoration and then passed the land to Forestry Commission Scotland for additional forestry ground preparation, planting and long term management.

## Restoration specification and method

### Main reclamation works

The reclamation works were the subject of a detailed **specification** and tendering exercise that governed a wide range of factors including site supervision, health and safety, site compound and welfare facilities, pollution prevention, timescales, machinery type and number, operator competency and working methods. The contract specification also covered compost supply and cultivation, and associated engineering features such as drainage taps, berms and stone armoured drains.

Expressions of interest were invited by publication on the FC website in December 2010. The subsequent Invitation to Tender allowed for a contract extension of up to one year on the same terms that could include further sites. The tender required unit prices to be specified against a Bill of Quantities, to facilitate changes in gross contract price owing to necessary increases or decreases in key quantities. All prospective bidders were required to attend an on-site open day was held at which requirements including cultivation method were explained in detail. Documents were issued on 14th January 2011 for tender return by 26th and selection by 28th. The expected start date after a week 'stand still' period was 7th February 2012. The contract was awarded to McArdle Group and the main features delivered (including updates, 'as built') by the reclamation contract is summarised in **Table 1**, which includes machinery required.

The total reclamation contract price on completion was £205,000 excluding VAT, somewhat less than the original tender of £226,000 owing to various changes made in response to conditions according to the rates quoted in the Bill of Quantity.

In addition to the land reclamation contract, separate contractors were engaged for the planting, weeding and later installation of paths. The planting and weeding work was awarded to a single forestry contractor and paths construction to a ground-works business.

**Table 1.** Reclamation Contract, Summary of Requirements

| Feature | Quantity | Specification | Comment |
|---|---|---|---|
| Enabling works and re-grading | | | |
| Construct West tip haul road (Cost includes maintenance) | 356 m plus 4 passing places | Min. 4 m wide, 5% camber / cross-fall, 250 mm recycled aggregate. One 500 mm culvert. Higher spec. allowed for reduced maintenance e.g. geotextile | 'Incompetent' clay graded off sub-base prior. 3.6 tonne / m width vibro-roller to compact max. 125 mm layers at < 2.5 km/hr |
| Construct E & W hard standings for compost storage | > 540 $m^2$ | Construction details similar to haul road | Includes removal of West hard-standing for re-use on paths. East hard-standing retained as car parking |
| Re-grading West tip | 1.0 ha (by rate / $m^2$) | High / low spots to be removed / filled (<250 mm layers). Stones > 250 mm removed & buried > 1 m, metal 'chased back' & cut > 20 mm deep | Surface left smooth. Final surface bucket teeth 'raking' to allow natural re-vegetation. Infill includes arisings from drains etc |
| Re-profile tipped soil / peat on ridge of East tip | 0.3 ha (by rate / $m^2$) | Transport material to achieve even c 750 mm depth | Excavator with grading bucket to work alongside panel & not traverse soil |
| 'Regulate' wet area of adjacent track | 1 of 700 $m^2$ (by rate / $m^2$) | Excavator to level surface of tipped & rutted materials | Drain down to adjacent wetland to dry for 48 hours prior |
| Reclamation works | | | |
| Contour berms | 1,300 m* | 3 m wide, equal cut/fill, cross-fall ~8% into slope, gradient $1^{1}/_{2}$ - $2^{1}/_{2}$% up valley. **See Appendix 2** | Layout to FCS plan. Compacted by traversing |
| Swale | 330 m* | Excavate curved profiled drains | Layout to FCS plan |
| Stone armoured drains | 145 m* | Supply and place hard stone (6-9" with 20% 2-4") over geo-textile in prepared (rounded 80 cm deep, 1.4 m wide) drain profiles. **See Appendix 2** | Stone block sills inset into cross (10 * 10") trenches over geo-textile at 10 m intervals. 1" of 6 mm to dust under & over geo-textile. Layout to FCS plan |
| Complete cultivation of planting cells | 5.5 ha* | 1 m depth to detailed spec. Includes removing stones >25cm | Layout to FCS plan. Detailed method stipulated in contract |

| Feature | Quantity | Specification | Comment |
|---|---|---|---|
| Supply and incorporate green compost into cultivated cells | 3,600 tonnes<br>(amended to >4,000 tonnes) | BSI PAS 100 standard compost at 500 or 750 tonnes / ha to 50 cm depth (amended to 750 tonnes / ha only). Includes removing stones > 15 cm from surface | Detailed method stipulated in contract |
| Excavate drainage taps | 300* | Spaced at c 10 - 12 m. 1 m wide (& c 6 m long), cultivated from base of cells, smooth floor sloping down at $1^{1}/_{2}$ - $2^{1}/_{2}$% to emerge at surface | At lower edge of cultivation cells to drain water, otherwise impounded, by seepage through loose soil. Detailed method stipulated in contract |
| Note: * Actual calculated using GIS measurement | | | |
| Machinery resources required | | | |
| Excavators, tracked, long carriage, 6 m+ effective reach | 5+ | Tracked, 12 - 24 tonnes<br>(> 20 tonnes with 700 mm tracks) | Capacity to increase to speed work if required.<br>2 * 13 tonne m/c for handling compost |
| Tracked dumpers | As required | Tracked 5 - 8 (-10) tonne capacity dumpers | Capacity to increase to speed work if required.<br>Conditions unsuited to wheeled machines |
| Vibrating roller | 1 off | Towed or self propelled | Min. 3.6 tonne / m width |
| Skilled operators experienced in slope working | As required | | Moderate to steep slopes |

The various contracts are summarised in **the Costs section of this report.**

# Restoration method

## Layout

The reclamation was planned to permit planting of trees into suitably cultivated ground. Cultivation areas were effectively 'cells' for planting blocks set within the finished contours of the site. Size, shape and location of cultivation cells, separated by uncultivated, relatively compact ground for rides, paths and berms[2], was intended to provide a high degree of slope stability that would have been compromised by complete cultivation across the site, especially on the more steeply sloping ground. Larger cells were located on more gently sloping ground and smaller, more elongated ones, on steeper ground.

[2] 'Berms' are a form of 'bench' of compact ground set at intervals up a slope for drainage and stability

Drains and berms were marked out by the contractor's surveyor according to the construction drawings for agreement by the FCS Forester prior to commencing. Areas were also identified for deposition and spreading of excavation arisings from drain features and berms, which improved the final contouring of the site. Cultivation cells and drainage taps[3] were marked by FCS. The initial plan of cells and other features was adjusted slightly during operations in response to conditions encountered. No cultivation was allowed within 10 m of the site boundary adjacent to the M74.

The gross area of the two tips was c 11 ha, with some 5.5 ha being cultivated and subsequently planted. Cultivation cell size varied from c 600 $m^2$ to c 4,800 $m^2$ with a mean of c 2,000 $m^2$. Details of the completed design including compost application rate and engineering features are shown in **Figures 7** and **8**.

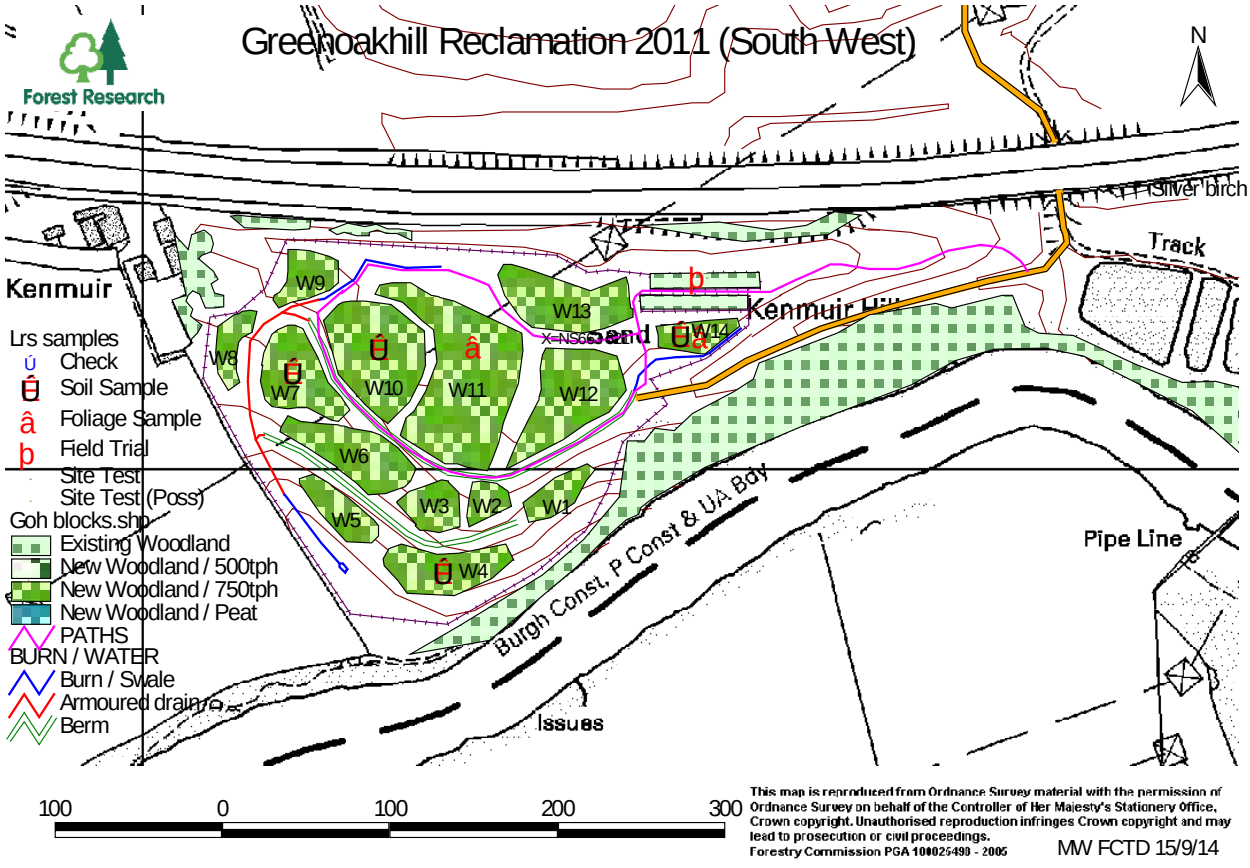


**Figure 7.** South West block completed design

[3] 'Drainage taps' are trenches filled with cultivated soil that allow water to seep out of cells

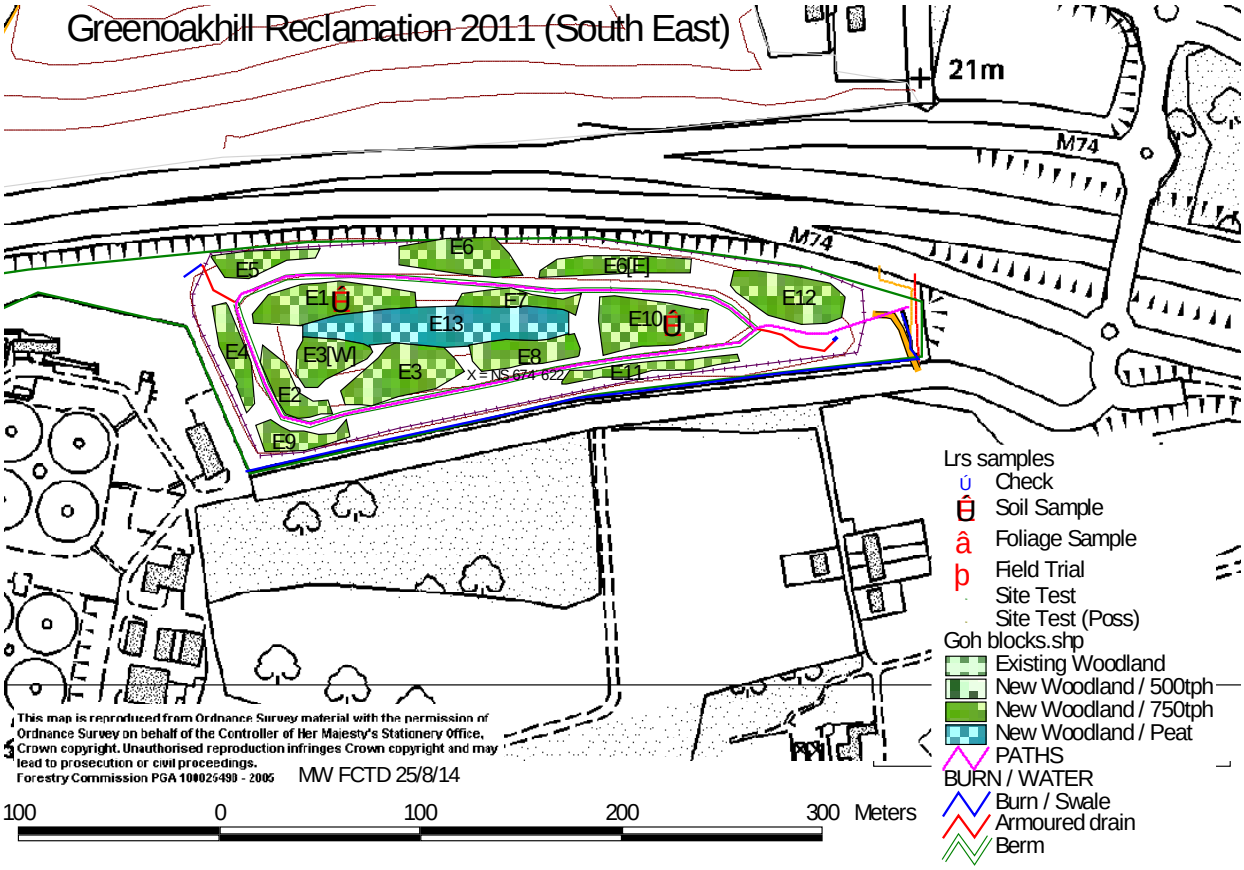


**Figure 8.** South East block completed design

Slopes ranged from generally from 33% to 5% with an average of 14% weighted by cell area. A single small cell of c 600 $m^2$ was located in the west on the steepest ground of c 40% that was otherwise not cultivated.

A medium pressure gas main and an underground electricity cable was located at the east end of the south-east tip outside the working area.

## Mobilisation, organisation and access

Under the Construction (Design and Management) Regulations 2007 Forestry Commission Scotland was the client and designer, the FCS Civil Engineer was the CDM co-ordinator and McArdle Group was the principal contractor. Plant operators were certified by the Construction Industry Training Board with Construction Plant Competence Scheme cards or had CSCS cards. Plant operators were required to be competent at working on steep slopes. For forestry purposes the FCS Forester Gareth Waters acted as Forest Works Manager and a McArdle Foreman was present on site for the duration.

Mobilisation to site was completed in the second week of February and work commenced for a planned eight weeks, to enable completion by the end of March. Operations were five and a half days per week plus maintenance only on Saturday afternoons and with no Sunday working.

Weather conditions were typical for the location and time of year with periods of variable rainfall interspersed with dryer, cold spells.

The south-west and south-east tips were completely separated by an impassable area of lagoons and wet ground, so were managed as two distinct areas that were worked simultaneously. Access to the south-west tip was through the operational Greenoakhill landfill site, utilising the haul road and motorway underpass shared with landfill site traffic and an aggregates supply business premises located between the motorway and the site settlement lagoons. Access to the south-east tip was direct from a minor public road that also served the adjacent water treatment works.

The contractor was required to provide a resources programme updated weekly to ensure that there was sufficient capability to complete the work without undue over-run.

Compost

The contract required supply of general purpose grade PAS100 standard Green Compost (**Appendix 1**) that complied with the SEPA's requirements[4]. The grade could be amended from 0 - 30 mm to 0 - 20 mm or 0- 40 m if necessary and by agreement of FCS. A total of 4,593 tonnes of 0 - 20 mm 'Principal Grade Soil Improver' was supplied by Horizons Environment (part of Scottish Water) nominally equivalent to c 7,600 $m^3$. Most of the compost was from the Deerdykes depot at Cumbernauld but 12 loads were brought from Johnstone, Renfrewshire. Additional characteristics were also specified that were not governed by the PAS standard but had a bearing on finished reclamation such as moisture content, bulk density and also, with some discretion, nutrient content.

Compost deliveries were made by 8 wheel tipper under cover of a 'supply document' providing certification of PAS 100 compliance. Additionally, compost analyses were required of PAS 100 and additional characteristics initially and every 350 tonnes thereafter. At both the south-west and south-east locations a 13 tonne tracked excavator formed the tipped compost into 3 m high bunds that were triangular in cross section. Surfaces were lightly compressed by bucket to shed rain water. Compost was stored on firm, level ground with temporary 'V' ditches / bunds in place to control drainage. Records of daily compost deliveries were kept.

[4] SEPA, Composting Position Statement, 2004

Compost was applied at 750 tonnes / ha, with tonnage calculated on a fresh bulk density of 0.60 tonnes / $m^3$. The application rate was determined on the basis of the results of forestry cultivation and compost trails planted by FCS in 2008 and funded by the Waste Resources Action Programme at Greenoakhill[5]. The 750 tonnes / ha rate was guided to the '25% by volume in the upper 50 cm' treatment used in the planting trials, which was one of the higher rates tested.

Individual cultivation cell mapped areas (horizontal areas) were adjusted for slope, increasing the surface area by an average of 4% to allow for actual surface area spread over the slope. A c 3,600 $m^2$ strip of peat formerly tipped along the top of the south-east tip was cultivated, without any trafficking, but was not included in the compost application area.

The contract and agreed method of working incorporated a range of measures governing supply, analysis, storage and handling of compost **(Appendix 2).**

Cultivation

An important principle in all operations was that on no account was machinery allowed to drive over uncultivated ground so as to avoid any re-compaction.

Prior to cultivation commencing, an effective system of surface water control was established based on landform and vegetated filter zones, with additional earth drains and a silt trap installed down-slope of cultivation areas. Ground cultivation was a two stage operation comprising 'primary cultivation' of the ground to full depth followed by incorporation of compost to c 50 cm depth after it was spread evenly over the surface to a pre determined depth.

Cells were marked out and cultivated by excavator across the two separate tips at the same time, with two or more excavators working simultaneously in separate blocks. The ground was cultivated in successive strips commencing at the top of each cell with the excavator working to the side on the upper edge **(Figure 9)**. Each strip comprised successive transverse 1 m deep trenches dug to the full effective reach to the side of the excavator. Care was taken to ensure that there were no uncultivated 'sliver's of compact soil between successive trenches in each strip, and a 30 cm overlap was required between successive strips of trenches for the same reason. Given that the surface 1 m of soil was relatively uniform, a complete inversion technique was employed whereby the top layer of soil from each new trench was scraped off uniformly and dropped into the bottom of the open trench immediately preceding it, thereby filling the preceding trench with layers of soil from the next strip. The method stipulated that soil was stripped in 15 cm layers and dropped from a

[5] Hipkin, A (2011). The use of compost to manufacture topsoils for brownfield regeneration with tree planting at the Greenoakhill landfill Site, SE Glasgow. Waste Resources Action Programme

height of 1 m into the preceding open trench. This helped to break up clumps but would be less effective in wet, clay soils. The contractor used a one-way cultivation method, in which spoil from the first trench in each strip excavated was placed to the side and eventually moved to fill the bottom trench of the same strip. This inevitably involved a lot of machine movement time compared to an alterative two-way method, in which the last trench of each strip can be filled from the first trench of the next.

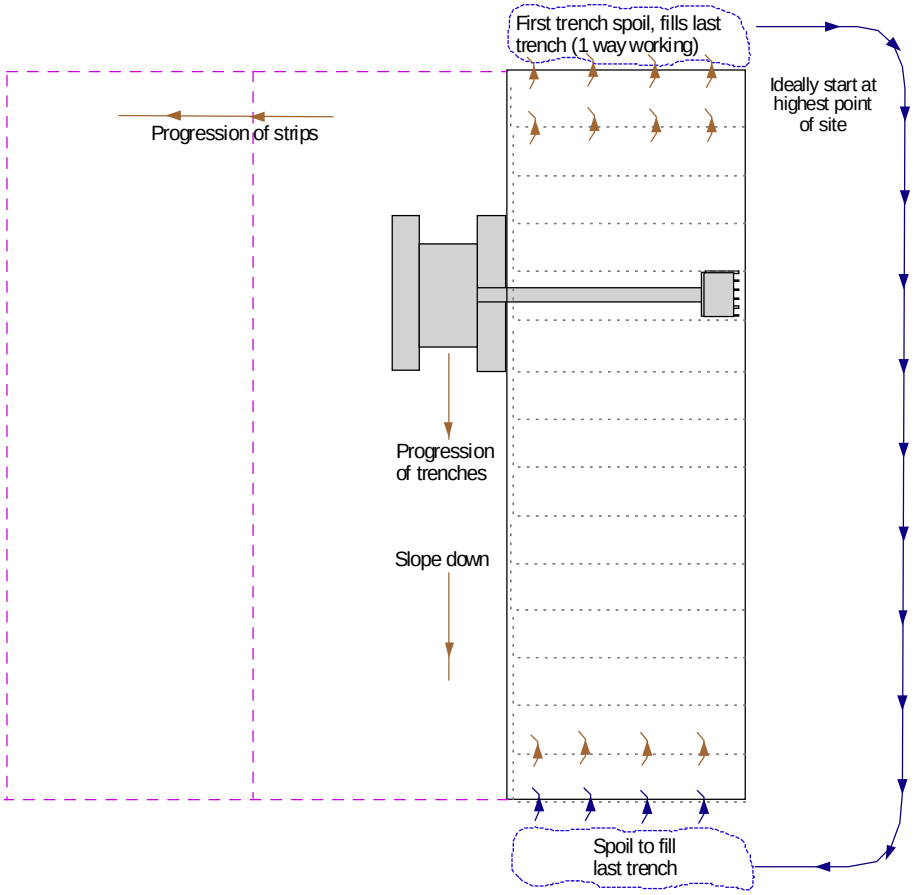


**Figure 9.** Primary cultivation by side strip method

This 'complete inversion' technique is suitable for ground where the upper soil layers are similar in quality to the lower ones, owing to the effect that the 'original' surface is thereby buried. Note that where surface soils are of a better quality an alternative 'partial' inversion method is available[6].

Primary cultivation of each strip was by an excavator with digging bucket, which also placed any large rocks / obstructions to one side to be buried below the base of the trenches in the next strip.

[6] Wall, M. (2014). Using quality compost to reclaim land for forestry and woody biomass. Technical Development Report TDJR104. Forest Research

Compost was loaded into 10 tonne tracked dumpers from stockpile by a 13 tonne excavator and delivered to the cultivation strip where the load was dumped at regular spacing. Dump spacing was calculated according to the length of strip served by each load.

Secondary cultivation was carried out by a second 20 tonne excavator fitted with a stone fork. This machine followed the first excavator at a safe distance beyond its reach to mix the compost layer into the upper 50 cm of cultivated soil. The compost was spread to the required depth using the stone fork (125 mm for 750 tonnes per hectare of compost). The excavator spreading compost was required to lift and drop rather than push the compost to avoid compaction. The mixing method specified in the contract was in two stages: firstly overturning the upper layer, and secondly lifting the fork horizontally through the profile and 'turning off' (for clayey soils) or 'riddling' (for loose soils) from a height of 1 m or 1.5 m so as to help break up clods and improve mixing. This was to be repeated until a uniform mix resulted.

The stone fork comprised c 60 cm long teeth at c 15 cm spacing and was also used to rake out rocks and concrete obstructions from the upper 50 cm. The contract specified removal of obstructions over 20 cm from the full 1 m cultivation depth to be set aside to be buried at the base of the next strip. The specification also required removal of obstructions greater than 10 cm from the upper 50 cm of mixed soil, by hand picking if necessary.

The surface was levelled off (required to 5 cm tolerance) before moving on, with the final cultivated surface slightly elevated by compared to uncultivated ground owing to the 20 - 25% bulking-up effect of de-compaction. The edges of the raised cultivated cells were 'trimmed' to leave a neat edge.

Additional features

Drainage taps: these were constructed at the lower face of cells during their cultivation (**Figure 10**). A total of c 300 taps were planned, distributed amongst the 29 cells in both tips. Taps were to be at a minimum of 10 m intervals and closer if required. The excavator dug a trench 1 m wide in 15 cm layers to the full cultivation depth of 1 m, having a smooth base dipping slightly (5 - 10%) away from the cell. The trenches were backfilled with loosened excavation material such that there was no compact obstruction to seepage of water from the cell. The length of taps so as to emerge at the surface (or adjacent berm) was dependent on slope but they were generally c 6 m long, the length required for a slope of 33%.

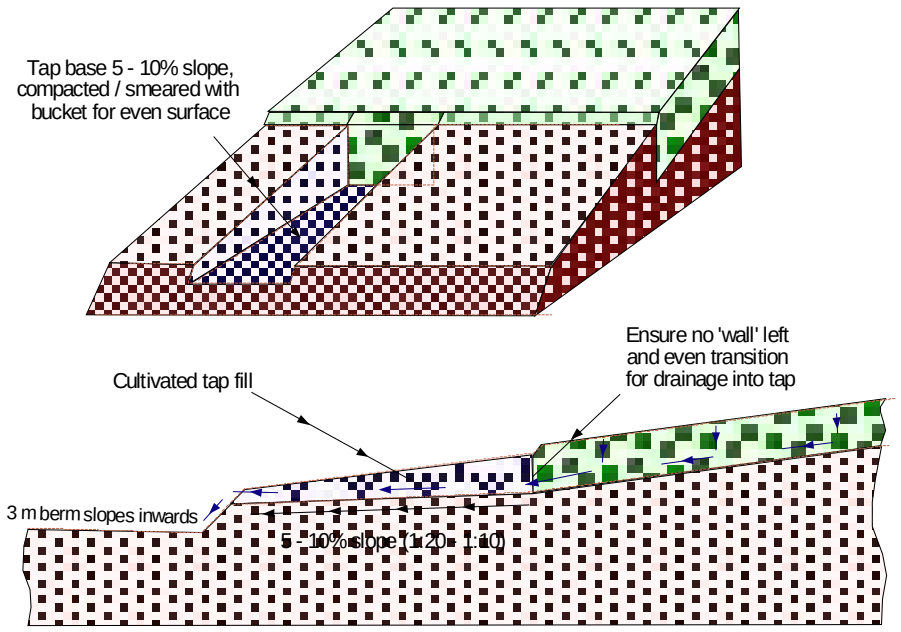


**Figure 10.** Drainage tap (meeting drainage berm). Top: view prior to loose infill

Drainage taps were required to be installed in the course of completion of each cell so that cultivate areas were always drained by them.

Stone armoured drains: a detailed specification was provided for 'minor stone armoured channels' for steeper slopes above the maximum allowed for earth drains (3.5% or 2°) and up to c 15% in the East (**Figure 11**).

**Figure 11.** South-west tip, armoured drain with sill (left) and merging into swale on west boundary (right) on 9/9/11

The specified profile was rounded, 0.8 m at the deepest point, 2.4 m wide and smoothed by excavator grading bucket. Geo-textile sheets, overlapping by 50 cm so as to shed water flowing downhill were laid in the profile, protected by a 25 mm layer of 'whindust' or fine crushed hard rock both above and below. Hard stone (80% 15 - 22.5 cm, 20% 4 10 cm) was spread by excavator ('pitched') as a form of cobbles across the profile (**Figure 12**) as the drain 'armouring' against any possible scouring effect by drainage during periods of high rainfall. The use of fine crushed aggregate for bedding the stone armouring was an important requirement because it sets hard in use, thereby forming a strong matrix that is resistant to erosion.

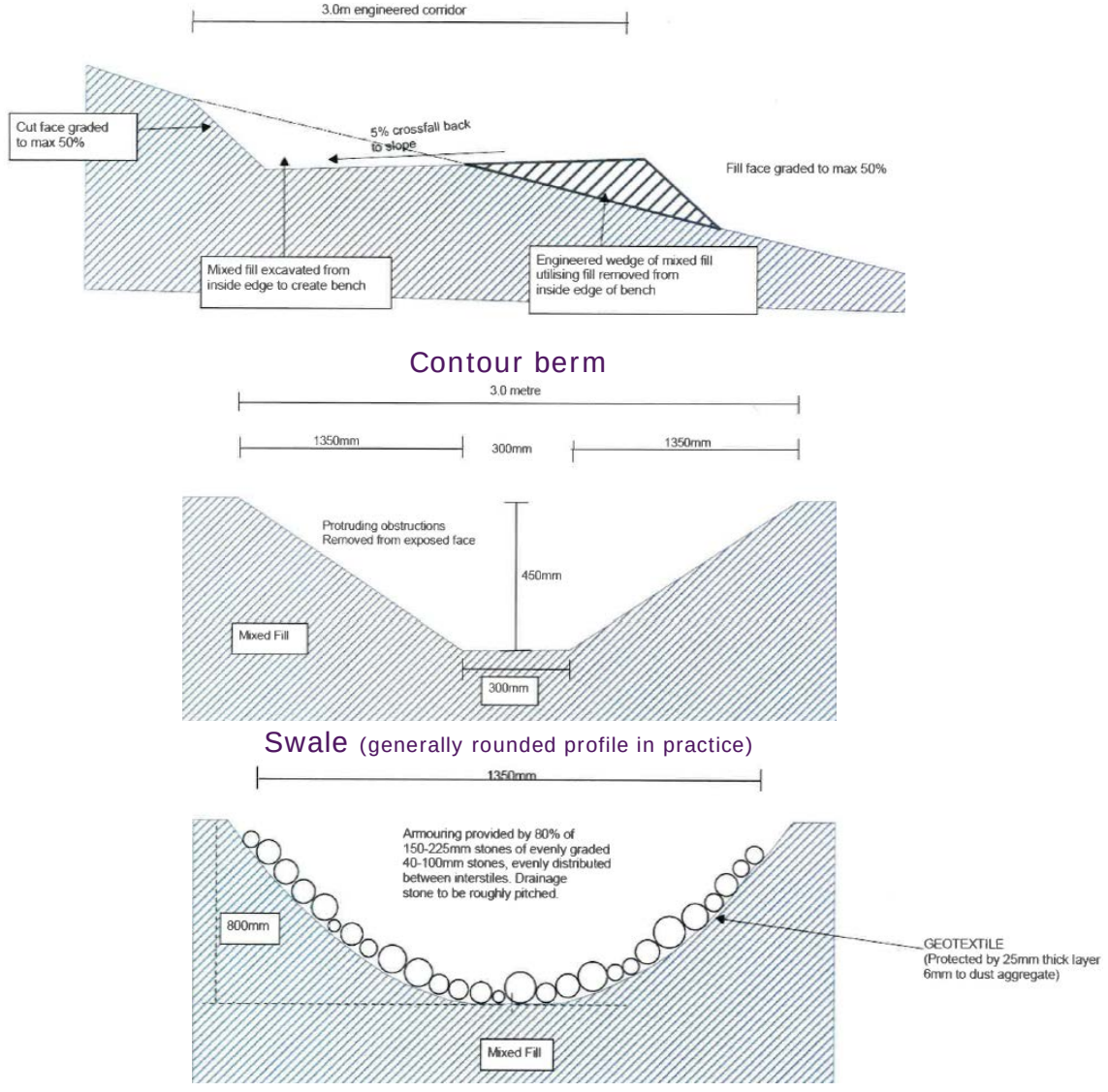


**Figure 12.** Contour berm, Swale and Armoured drain[7]

[7] From Forestry Commission Scotland Schedule 'B' - Detailed specification for ground preparation and drainage works for the establishment of community woodland on a restored inert landfill at Greenoakhill, Broomhouse, Glasgow, January 2011. After Bending, N. & Waters, G. (2011).

The specification required that stone 'sills' were formed every 10 m along the drain and this was a key parameter required by the Forester. The sills comprised stone blocks (nominally 50 cm long * 25 cm * 45 cm) set by hand into 25 cm * 25 cm trenches cut across the drain profile prior to laying the geo-textile so as to accept the blocks in a form of transverse 'weir' stabilising the intervening stone armouring. The intention was that following armouring the sills would not protrude.

Berms: constructed by excavator having the required 5-8% smooth 3 m wide cross-fall back into the slope and a consistent, even longitudinal gradient of $1^{1}/_{2}$ - $2^{1}/_{2}$% around the hill face according to the construction plans (Figure 12). Berms were made by excavator and were formed to feed seamlessly into drains (**Figure 13**). Consolidation was achieved by machine trafficking as berms were planned and used as the primary hard routes for movement of machines, drain spoil and compost etc.

**Figure 13.** South-west tip, lower berm (left) and south-east tip north face prior to path installation (right) on 9/9/11

Swales: a shallow rounded-profile form of earth drain, were constructed by excavator to lead water off-site according to the construction plans (Figure 12). The swale in the upper, north-west part of the western most tip was supplemented by c 15 cm cobbles laid in the base as additional 'armouring'. The layout of swales was designed to collect water seeping into and along the berms for eventual discharge into filtration zones on more level ground. The south-west tip was provided with a silt pond just prior to discharge over an undisturbed, thick grass sward ground surface.

Paths: Some 2 km of paths were constructed in February 2012, the year following reclamation and planting, under a separate contract. Construction by mini-excavator

was according to a standard design onto the firm base provided by berms or graded but uncultivated ground. Other than those situated on berms (**Figure 14**), the path route was alongside existing swale drains. Both the formation and path surface had a cross-fall of 8% on the berms and a camber elsewhere. No geotextile was used but the surface 50 mm of the path formation was removed prior to laying the Type 1 in the resulting 'tray'. The specification was for 1.5 m surface width of two rolled layers: 100 mm Tarmac 'Toptreck' recycled chippings over 100 mm Type 1 aggregate. The recycled chippings were a mixture or asphalt and other recycled materials ground and screened. Culverts were installed where needed using 300 mm or 400 mm twin walled plastic pipe. The path edges were consolidated using a vibrating plate (or 'whacker').

**Figure 14.** South-west tip, path on upper berm looking south-east 28/8/13

The contract also included providing a 646 m2 hard standing / car park of 100 mm rolled Type 2 aggregate near the road entrance to the south-east block.

## Woodland planting and establishment

The planting and establishment of woodland on the reclaimed site comprised planting, seeding and weeding.

### Planting

The planting contract, commencing spring 2011 included seeding at commencement and beating up (replacing dead trees) for up to three seasons.

Planting commenced shortly after the pre-commencement meeting, held in mid May 2011, about two months after cultivation. Cell-grown 'plug'-type planting stock was used as these are more robust than bare root transplants and therefore more reliable for use on difficult soils. The period was a moderately good planting season of mixed dry and increasingly warm weather with periods of rainfall. Trees were protected by

60 cm green plastic tree shelters, each fitted to 38 mm section treated stakes by two releasable nylon ties.

Planting design comprised largely mixed native broadleaf stands and shrubs, although Scots pine, Larch and Norway maple were included in the 'Landscape' mix (**Table 2** and **Figure 15)**.

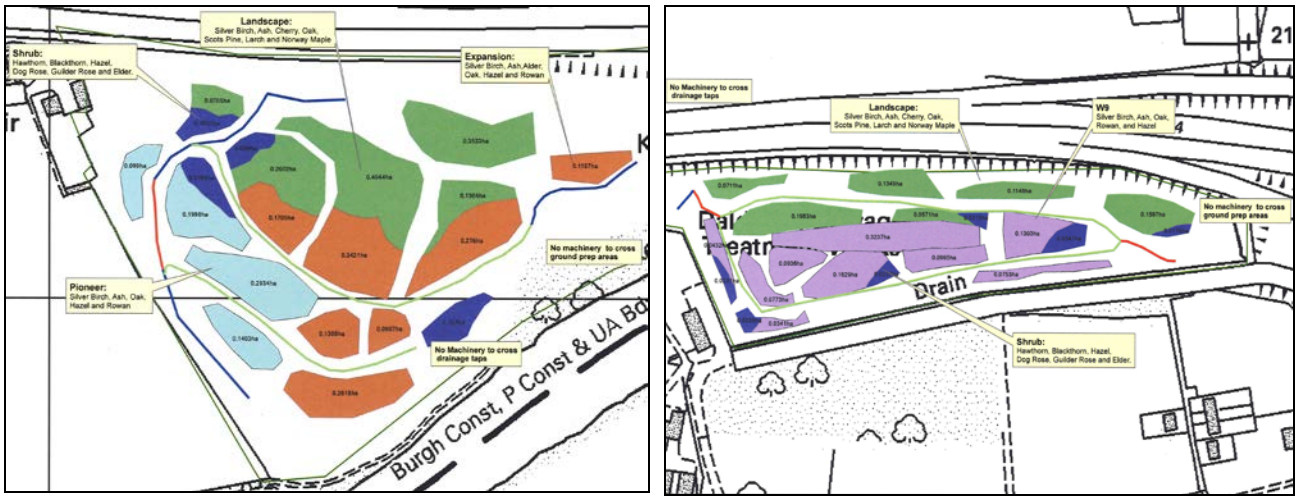


**Figure 15.** Planting design[8]

**Table 2.** Planting mixes

| Mix | Species |
|---|---|
| Pioneer | Silver birch, Ash, Oak, Hazel & Rowan |
| Expansion | Silver birch, Ash, Alder, Oak, Hazel & Rowan |
| Landscape | Silver birch, Ash, Cherry, Oak, Scots pine, Larch & Norway maple |
| Shrub | Hawthorn, Blackthorn, Hazel, Dog Rose, Guilder Rose & Elder |
| Mixed Broadleaves | Silver birch, Ash, Oak, Rowan and Hazel |

The planting contract also provided for beating up (replacing dead trees) as required by the Forester. An 8% beat-up was required after the first season and 5% after the second, mostly within two very clayey blocks on the south west area. No beat-up was required after the third season because the 5% losses were evenly spread and the crop was then within the target stocking density.

Seeding

Grass and wild flower seeding was carried out to establish a sward that would limit anticipated rapid growth and the spread of vigorous broadleaved weeds. This was generally effective over the site, with a dense grass sward formed in most cultivation cells by the end of the second season of 2012. As would be expected, the newly sown

[8] Courtesy of Scottish Lowlands Forest District

grass seed did not prevent the vigorous growth of broadleaved pioneer weeds in the first season.

Seeding was carried out in spring 2011. Grass and wild flower mixes were sown, over cultivated cells and also the remaining ground on berms and between cells. The uncultivated ground between cells had largely been 'scarified' by scraping the surface in 'criss-cross' fashion using excavator's bucket teeth as part of the reclamation works. Seed was applied by hand in two passes at right angles with a calibrated 'fiddle'. Three seed mixes were used as shown in **Table 3**:

**Table 3.** Seeding

| Seed | Species included | Area | Kg | Cost |
|---|---|---|---|---|
| 1. Reclamation grass mix | Red, Chewings & Hard fescues, Brown bent, Flattened meadow grass & White clover | 9.7 ha | 1290 | £4838 |
| 2. Cornfield annuals | Cornflower, Corn marigold, Forget-me-not, Poppy * 2 & Mayweed | 4.0 ha | 13 | £736 |
| 3. Wet meadow mix | 20% wildflowers + Chewings fescue, Smooth meadow grass, Common bent, Crested dogs tail, Meadow foxtail & Tufted hair grass | 0.9 ha | 70 | £3658 |
| 1. / 2. overlap | | -4.0 ha | | |
| Net Area | | 10.6 ha | | |

Note: Cost excludes VAT

Most of the south west, and the entire south east tip, were sown with the Reclamation grass seed mix (**Figure 16**). The 'unplanted' ground in the lower, moister part of the south west tip was sown with the Wet meadow mix. This comprised 80% grasses plus Knapweed, Meadowsweet, Cranesbill, Iris, Hawkbit, Ox-eye daisy, Birdsfoot trefoil, Ragged robin, Ribwort plantain, Selfheal, Meadow buttercup, Sorrel, St John's wort and Devil's-bit scabious. The Cornfield annuals were sown on the most visible slopes of the south east tip and in the north of the south west tip, in combinations with the reclamation mix and included in the planting blocks. The latter areas were not very visible from the M74 to the north.

The growth of grass and wild flowers was, not unexpectedly, limited on areas that had not been cultivated with compost, as surface screefing did not provide a comparable seed bed. As found elsewhere, the white clover included in the seed mix became well established in places where it provided a useful ground cover.

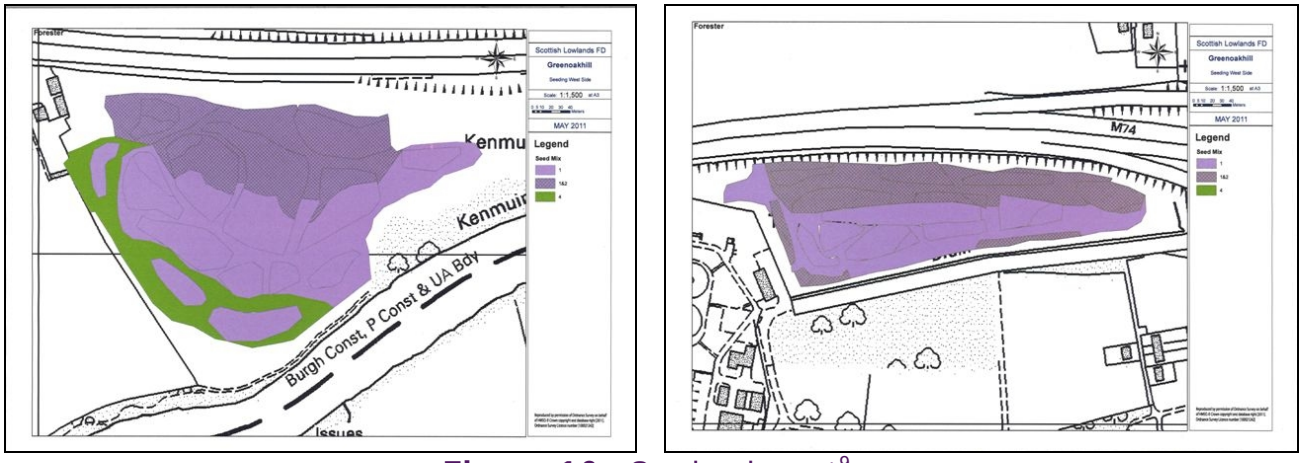


**Figure 16.** Sowing layout[9]

Weeding

The chemical weeding contract covered 1 m radius spot weeding with glyphosate as required by the Forester across the 5.6 ha new planting site for three years, plus strimming as required on a block by block basis in the first two years. Neither was required from the fourth season of 2014. Spraying over the paths to be installed separately in early 2012 was also included to control edge vegetation encroachment.

Owing to variations in weed growth in 2011, largely related to the quality of the soil in individual cells (**Figure 17**), only about a half the area needed spraying and a similar area was strimmed - in July and August respectively.

**Figure 17.** Variation in weed growth (cell W11, south-west tip) September 2011

All trees were spot sprayed in May 2012 and then strimmed, and the 2 km of 1.5 m wide paths were also sprayed. All trees were also spot sprayed in June 2013.

[9] 1. Purple: Reclamation mix, 2. Purple hatched: (1) and Cornfield annuals, 3. Green: Wet meadow mix, courtesy of Scottish Lowlands Forest District

# Post restoration monitoring

## Monitoring protocol

The purpose of monitoring was to establish a 'baseline' of site condition immediately following completion of reclamation and then record performance for three growing seasons. Parameters selected were:

- **Soil characteristics** following reclamation: to compare the soil quality achieved by ground preparation operations with FC standards to achieve the success of the new woodland over the long term.
- **Civil engineering** features for drainage and stability: to assess the effectiveness of berms, swales and armoured drains at collecting water from the ground and conveying from slopes without ponding or erosion.
- **Ground vegetation**: the development of ground flora, particularly aggressive broadleaved weeds and grass.
- **Tree performance**: the survival, growth and health of planted trees.

The protocol was designed to give a clear picture of the overall performance of the reclaimed and planted site in a manner that could readily be replicated elsewhere by experienced foresters, with the minimum of expensive sampling (**Table 4**). Therefore, with the exception of initial soil sampling, monitoring was intended to capture *empirical* rather than *measurement* data.

**Table 4.** Monitoring protocol

| Parameter (What) | How | When |
|---|---|---|
| Reclaimed soil | Soil samples from upper profile cultivated with compost from representative parts of the site | Early season 1 (post reclamation) |
| | Analysis of key parameters for tree growth | |
| Civil engineering | Visual assessment of the initial and ongoing effectiveness of the features in draining the site, and evidence of any erosion, instability or maintenance issues | Early & late season 1,<br>Late seasons 2 & 3 (ideally more) |
| Ground vegetation | Visual assessment of classification, scale, vigour and impact of naturally colonising vegetation ('weeds') and grass seed mix sown to help stabilise and control the ground surface | As above |
| Tree performance | Visual assessment of health and vigour of planted trees across the site | As above |
| | Foliage samples for any obvious nutrition issues | Late season |

## Monitoring results

The performance of the reclaimed Greenoakhill site is described according to the monitoring protocol below:

Reclaimed soil: Evidence from post cultivation observations and soil pits suggest that cultivation and compost application and mixing operations were effective at providing a rootable planting medium in the upper 1 m of soil forming material. Compost was mixed to approximately 50 cm depth according to specification. The standard of completed work appeared high, with an even cultivated surface resulting. There was no evidence of rutting, compaction or erosion associated with cultivated cells, and compost appeared to be evenly mixed throughout to upper 50 cm profile, without undue concentrations at the surface. Given the clayey, cohesive nature of the soil forming material available heavy clods had been sufficiently broken up such that they were not evident on the ground surface following weathering over two to three months. Similarly, there was no evidence of rocks, other obstructions or steel rods etc on the surface in compliance with the specification.

The ground or 'rides' between cultivated cells was purposely left in a relatively compact state to assist slope stability, but the surface screefing by excavator bucket teeth appeared to have created a sufficient tilth for grass and herb seeds to germinate and root without erosion being evident.

There ware no rocks or other extraneous objects left visible on the surface of the site, suggesting that they had been buried as required.

Civil engineering: The swales, berms and armoured drains were effective at intersecting and leading surface water off the land without signs of erosion, both initially and after three seasons. All drains in excess of the earth drain continuous slope maximum of 3.5% ($2^{o}$) were armoured. The west tip silt trap (**Figure 18**) was effective and well separated from the River Clyde by fully vegetated and gently sloping ground.

**Figure 18.** Silt trap and filter zone 9/9/11

The drainage taps allowed water to seep from the lower parts of cultivated cells into the berms and drainage system generally.

As far as could be detected by observations, specifications had generally been met. The Forester reported some issues of divergence from the detailed specification for the armoured drains in that the sills had not been provided according to specification. Nevertheless, these drains did appear effective. The site was not inspected during heavy rainfall, but the absence of erosion and siltation was noted during inspections.

Ground vegetation: As anticipated, there was significant weed growth in the first season, which comprised largely broadleaved annual herbs commonly occurring as agricultural weeds. Considerable variation over the site between cells but also within parts of cells were observed and assumed to be the result of variation in time of cultivation and potentially also soil quality tipped over discrete parts of the site. This was confirmed by the Forester, for example in respect of cell W11 on the west tip which displayed two quite distinct vegetation growth characteristics although the ground was cultivated at the same time. Growth was noticeably less in the southern half where the soil was more cohesive and clayey than to the north of the same cell.

**Figure 19.** West tip, cell W11 on 9/9/11 (left) and 25/6/13 (right). Note change in type of ground vegetation from pioneer herbs to grass

Although variable, the growth of grass seeded as an initial ground cover was evident but was not sufficient to control the rather more vigorous broadleaved weeds in the first season. However, there was a succession of weed species through first, second to third seasons whereby the very varied pioneer cohort of ground colonising annuals tended to be replaced by fewer and less vigorous biennials and the proportion and intensity of grass cover increased significantly **(Figure 19)**. By the third season ground vegetation was generally well established as a thick grass sward with individual and patches of biennials such as dock, which were not a threat to tree survival.

The robust plant and protection specification used at Greenoakhill was justified by the strong initial weed growth that had been forecast as a result of research trial experience on the site. This included the use of cells grown seedlings as compared to bare root transplants and 60 cm tree tubes with two ties per tube. Blocks were strimmed and / or chemically spot weeded so that weed growth was not able to 'swamp' tubes, which FR experience in Central Scotland has shown can happen rapidly in the first season. As would be expected, there was a sucession of ground vegetation over time **(Figure 20)**.

**Figure 20.** South-west tip, cell W13 on 9/9/11 after strimming (left), 21/11/12 and 25/6/13 (right)

As would be expected, growth of seeded grass and colonising vegetation was less vigorous and dense on uncultivated ground, which is an illustration of the extent to which cultivation improved growth conditions.

Tree performance: Survival, early tree growth was generally good across all species. Fast growth of ash, alder, birch, field maple and larch was particularly evident, with some birch and a few ash exceeding the 60 cm tube height by July of the first year **(Figure 21)**. By the end of the first season (2011) many trees were well above the 60 cm rims. Growth of the taller species had attained 1.2 - 1.5 m with an average of c 60 cm by the end of the second season. The slower growth of species such as oak was considered normal and proportionate in comparison.

**Figure 21.** South-west tip, cell W5-6 on 25/6/13 (left) and cell W3-4 on 28/8/13

At the time of late third season inspection approximate *average* height growth assessed visually, although not representing every species present, was:

| | |
|---|---|
| Alder | - 240 cm |
| Ash, Birch, Larch | - 150 cm |

Other species ranged from 60 cm to *maxima* of:

| | |
|---|---|
| Hazel, Scots pine | - 90 cm |
| Oak | - 120 cm |
| Rowan | - 180 cm |

Variation in growth was observed between blocks and the lesser extent within blocks but there were no obvious areas of 'poor' growth.

By June of the third season (2013) some areas of faster growing ash and birch on the south west tip and ash on the ridge of the south east tip were observed to have foliage yellowing, which also affected other species to a greater or lesser extent and was patchy within blocks **(Figure 22)**. This was investigated by foliage sampling, described in the section below.

**Figure 22.** South-west tip, cell W14 on 9/9/11 after strimming (right) and showing leaf yellowing on 28/8/13

Field observations are given in **Appendix 4** and are summarised in **Table 7**.

**Table 7.** Monitoring event summary

| Summary |
|---|
| 12 July 2011. Post restoration & soil sampling (Photos) |
| Soil - loose growing medium created by cultivation to c 100 cm and mixing with compost to c 50 cm (cell W10 = c 40 cm)<br>Vegetation cover - 10 - 50% but occasionally more, mostly broadleaved weeds with generally very little grass growth, probably from seed<br>Trees - survival generally good (>80-90%). Birch growing best. Oak small with limited growth but other species intermediate. Most trees not at 60 cm yet, except some Birch and fewer Ash.<br>Engineering - effective system of drainage taps, berms and drains (including armoured drains) |
| 9 September 2011. Late season 1 |
| Vegetation cover - strong growth of broadleaved agricultural weeds, but not smothering trees yet. Recent strimming of most weedy blocks and evidence of spot chemical weeding in places. Occasional areas of fairly dense sown-grass helping to displace weeds and ryegrass growing on some 'open' spaces<br>Trees - Overall good survival, many now growing above rim of 60 cm tubes e.g. AH, Bi, AR & some ROW & SOK, variation in growth between blocks<br>Engineering - drainage system functioning well, cell drainage evident from drainage 'taps' **(Figure 23)**. |
| 21 November 2012. Late season 2 |
| Vegetation cover - noticeable cover of sown grass, mostly perennial rather than annual broadleaved weeds, not smothering trees. More broadleaved weeds on SE tip but evidence of chemical weeding<br>Trees - Good growth esp. Bi / AR / AH, some OK, scattered larch & Scots pine (in widest tubes), to 1.2 - 1.5 m tall. Ave height c 60 cm<br>Two roe deer seen outside fence and 60 cm Tubex tube's marked for beat-up<br>Engineering - standing water on uncultivated rides but not cultivation areas.<br>Water seeping into berms from drainage taps. No damage to armoured drains. No erosion or slippage seen. New paths of reclaimed asphalt with cambered c 1.5m surface (2m overall). No geo-textile seen |
| 25 June 2013. Mid season 3 |
| Vegetation cover - grass in cultivated cells much thicker and greener than vegetation on untreated rides. More perennial broadleaved weeds on SE tip, especially dock, with some recent strimming and spot chemical weeding evident<br>Trees - healthy new growth: Bi, AH and CAR is c 1.5 m - 1.8 m, with OK < 60 cm - 1.2 m and larch / Scots pine intermediate. Some areas of ash, especially, are yellowish and smaller<br>Signs of deer outside fence<br>Engineering - new paths in good condition. No issues with drains |

28 August 2013. Late season 3 & foliage sampling

Vegetation cover - good grass sward with perennial broadleaved weeds, not smothering trees

Trees - approx. mean heights: AH / BI - 150 cm, CAR - 240 cm. Heights of HAZ, OK and ROW from 60 cm to 90, 120 & 180 cm respectively. Scots pine 60 cm - 90 cm, larch 120 - 180 cm

Patches of obvious yellowing with poorer growth. *CAR is always green.*

Yellow and green foliage samples collected from ash and birch in blocks W11 and W14

Engineering - No issues evident

**Figure 23.** West tip on 9/9/11: Access road (left) and cell W5-6 drainage taps (right)

## Soil and foliage sampling

Soil sampling method: Following completion of soil reclamation in March 2011, soils were sampled in July by means of hand dug soil pits to a minimum of 1 m depth. Sampling was carried out by Andrew Hipkin, an experienced soil specialist and surveyor. Soil density was assessed empirically by resistance to spade and inspection of spoil. The soil profile was inspected to determine the depth of incorporation of compost.

Six soil samples were collected from the two tips the upper 5 - 25 cm layer, within the compost mixing layer and analysed by the Forest Research laboratory service at Alice Holt. The locations of the soils samples are shown in Figures 7 and 8.

Soil sampling results: Soil density was assessed as achieving a loose profile complying with the FC standard of 1.5 kg/m$^3$ in the surface 50 cm and 1.7 kg/m$^3$ to 1 m depth[10]. Soil analytical results are shown in **Table 8**.

[10] Foot, K. & Sinnett, D. (2006). Best Practice Guidance for Land Regeneration. BPG Note 5. Imported Soil or SFMs Placement. Forestry Commission

**Table 8.** Post reclamation soil analysis

| Analysis | Target | Sample Location (top 5 - 20 cm) (Batch 1/11 taken 12/7/11) | | | | | |
|---|---|---|---|---|---|---|---|
| | | W4 | W7 | W10 | W14 | E1 | E10 |
| pH | 4.0 - 8.0 | 8.9 | 8.4 | 8.3 | 7.9 | 8.4 | 8.1 |
| LOI | >10%* | 4.3% | 6.2% | 6.2% | 5.1% | 7.2% | 7.1% |
| C:N | <1:25 | 1:3 | 1:4 | 1:4 | 1:3 | 1:4 | 1:4 |
| Total Carbon | | 2.81% | 4.07% | 3.74% | 3.04% | 5.0% | 4.2% |
| Total Organic Carbon | | 2.37% | 3.48% | 3.35% | 2.66% | 4.11% | 3.94% |
| Nutrients | | | | | | | |
| Nitrogen (N) | >1500kg TN/ha# | 0.116% | 0.208% | 0.204% | 0.135% | 0.193% | 0.208% |
| Sulphur (S) | 0.50%## | 0.05% | 0.10% | 0.10% | 0.07% | 0.07% | 0.15% |
| Nutrients - DEFRA Index (mg / kg d.m.) | | | | | | | |
| Index | Key | 0 Very low | 1 Low | 2 Moderate | 3-7 High | 8-9 Excessive | |
| Phosphate | Index 2* | 19.6 | 28.4 | 29.9 | 20.4 | 29.1 | 29.3 |
| Potassium (K) | Index 2* | 488 | 839 | 713 | 430 | 841 | 532 |
| Magnesium (Mg) | Index 1* | 138 | 171 | 190 | 172 | 214 | 277 |
| Phytotoxic PTEs (mg / kg d.m.) | | | | | | | |
| Copper (Cu) | 130* 2. | 31.4 | 35.7 | 31.0 | 36.6 | 49.7 | 29.5 |
| Nickel (Ni) | 50 3. | 29.8 | 31.8 | 32.1 | 31.5 | 34.0 | 36.5 |
| Lead (Pb) | 300* | 41.4 | 56.7 | 38.3 | 63.5 | 106.2 | 40.4 |
| Zinc (Zn) | 200* 1. | 96 | 126 | 125 | 128 | 179 | 112 |
| Arsenic (As) | 50* | 5.0 | 5.4 | 4.9 | 5.9 | 6.61 | 5.33 |
| Mercury (Hg) | 1** | 0.21 | 0.25 | 0.08 | 0.09 | 0.21 | 0.09 |
| Other PTEs (mg / kg d.m.) | | | | | | | |
| Cadmium (Cd) | 3** | 0.45 | 0.40 | 0.40 | 0.41 | 0.53 | 0.36 |
| Cobalt (Co) | 100*** | 12.8 | 13.9 | 13.0 | 13.8 | 13.6 | 13.7 |
| Chromium (Cr) | 400** | 43.3 | 56.1 | 47.2 | 44.2 | 42.9 | 53.6 |

Analyses: Phosphate, P ($P0_4$) - Olsen. Potassium, K, Magnesium, Mg & Sulphur, S - 1M $NH_4NO_3$. PTEs (Heavy metals) - Aqua Regia
Notes: 1. 300 mg / kg > pH 7. 2. Sludge Code-80 (pH 5-5½), 100 (pH 5½-6) 3. Sludge Code-50 (pH 5-5½), 60 (pH 5½-6), 75 (pH 6-7) & 110 (pH>7)

References:
* Foot, K. & Sinnett, D. (2006). Best Practice Guidance for Land Regeneration. BPG Note 5. Imported Soil or SFMs Placement. Forestry Commission
** Code of Practice for Agricultural use of Sewage Sludge. (at 2013). DEFRA. ('Sludge Code')
*** van Herwijnen & Hutchings (2006). Laboratory analysis of soils and spoils. Best Practice Guide for Land Regeneration, BPG Note 2, Forestry Commission, Forest Research. (Dutch Intervention Level)
# Doick. K. Pers Comm. (2013)
## Defra (2010). Fertiliser Manual RB209. 8th Edition

Cultivation depth achieved the minimum 1 m FC standard, which was exceeded in places. Compost was mixed to c 50 cm, except in the single spot sample taken from cell W10 sample, which was c 40 cm. Visual evidence suggested that mixing was effective given the heavy, cohesive soil texture. This limited sampling suggested that the cultivation had generally achieved the contract specification of 50 cm compost mixing depth.

Soil analysis results show that the alkalinity of the upper soil profile slightly exceeded the FC standard of pH 8. However, experience in such cases is that the pH of soils cultivated with compost will decline gradually over their early years as compost is mineralised. The organic matter content of the soils was similarly below the FC standard of 10%, although levels would be expected to rise slightly as soils and vegetation cover matures. The carbon / nitrogen ratio was well within the required tolerance at 1:3 to 1:4 and, as would be expected for soils uncontaminated by coal fragments, most of the carbon was in organic form.

The major tree nutrients phosphorus, potassium and magnesium were at acceptable levels with indices of moderate or high, and sulphur was present but well below the available threshold level.

Nitrogen levels are very difficult to determine in the field because the soil sample analysis cannot readily be equated to the minimum standard of 1,500 kg total nitrogen per hectare. This is because soil analysis is carried out on soils with all stones > 2 mm removed, and that have been either air or oven dried (depending on test concerned). Thus the laboratory analysis needs to be adjusted by an estimate of site stone volume, rootable depth and field bulk density (which is affected by moisture content).[11] However, an estimate of total nitrogen at the sample locations gave an average of c $7^{1}/_{2}$ tonnes total nitrogen per hectare. Experience of sites in Central Scotland is that this level is not excessive and that there is very significant variation between sites owing to the range of variables concerned.[12] Therefore, the site is assessed as having achieved the FC specification for total nitrogen. The subsequent performance of trees is the key factor to determine whether the nitrogen levels achieved are sufficient, supported by foliage analysis.

Foliage analysis: Routine monitoring during June in the third growing season revealed areas of yellowing trees in parts of the south west tip and on part of the ridge of the south east tip, which is indicative of nitrogen deficiency.

[11] Wall, M. (2014). Using quality compost to reclaim land for forestry and woody biomass. Forest Research, Technical Development Report FCJR104

[12] Wall, M. (in draft). Soil status and amendment needs on forest restoration sites: case studies. Forest Research, Technical Development Report FCJR104

The symptoms were that some patches of broadleaves showed foliage yellowing, especially in ash and silver birch and other species including rowan in the south west **(Figure 24)**. Yellowing appeared more pronounced in faster growing species although alder, which has nitrogen fixing capabilities, was always green and healthy. The areas most obviously affected were in blocks W11 and W14 in the north of the western tip, and tree growth appeared marginally less in ash and birch, but not in larch. The variability between areas within the blocks was suggestive of compost / soil forming material mix variation. This was confirmed by the Forester, who advised that compost mixing in the southern part of W11 had been less effective owing to the highly cohesive (clayey) nature of the soil, and that cell W14 was the last to be completed and so the compost mixing might have been less effective. Similar symptoms were observed in ash on the ridge of the south east tip.

**Figure 24.** Yellowing of ash on part of the south-west tip in June 2013

Foliage sampling took place at the end of August, as late growing season is preferred. Samples of ash and birch were taken and combined from W11 and W14, which were the blocks exhibiting the most yellowing. Samples from both 'healthy' green and yellowing trees were collected, with each sample comprising five leaves from five trees (either 'green' or 'yellowing'). Analysis was carried out by the FR Alice Holt laboratory (**Table 9**).

**Table 9.** Ash and birch foliage samples: blocks W11 and W14 in late third season

| Sample | Nitrogen (N) | | Phosphorus (P) | | Potassium (K) | | Magnesium (Mg) | |
|---|---|---|---|---|---|---|---|---|
| | Target* | Actual | Target | | | Actual | Target | Actual |
| Ash (green) | >2.0% | 2.32% | >0.19% | 0.40% | >0.7% | 1.08% | >0.03% | 0.47% |
| Ash (yellow) | >2.0% | 1.50% | >0.19% | 0.37% | >0.7% | 1.36% | >0.03% | 0.46% |
| Birch (green) | >2.5% | 2.69% | >0.19% | 0.51% | >0.7% | 0.87% | >0.03% | 0.35% |
| Birch (yellow) | >2.5% | 1.29% | >0.19% | 0.26% | >0.7% | 0.72% | >0.03% | 0.33% |
| Key | Adequate | | Marginal | | Deficient | | | |

* Target: 'Deficient' below this level; 'Adequate' is 0.3% higher (0.2% for K and Mg)

The foliage sampling results indicate that **the yellowing of ash and birch foliage is due to nitrogen deficiency**. There was also a tendency towards lower phosphorus and potassium levels in birch, although not deficient. Comparison with the post reclamation soil sampling results **(Table 9)** appear to show a correlation of yellowing in block 14 with lower total soil nitrogen, although insufficient samples were available to confirm this.

The occurrence of nitrogen deficiency symptoms in some areas of faster growing species in season three is not in itself considered to be a concern. This is because the area overall area affected was relatively small (approximately <10 - 15%) and the trees were still growing satisfactorily. Furthermore, nitrogen levels are expected to rise as woody matter in compost gradually mineralises, releasing available nitrogen. In the longer term, nutrient recycling and general development of a healthy soil ecosystem will also improve conditions, although tree health should continue to be monitored.

## Practical issues

Overall, the detailed, high standard of the initial **reclamation specification** safeguarded quality despite changes to plans that had to be made owing to conditions encountered. Price amendments (increases or decreases in quantities of work items) were straightforward owing to the design of tenders, which were made on the basis of cost per unit.

The contractor's anticipated **cultivation** work rate was somewhat 'tight'. Cultivation by one-way working involved more machine time to move spoil from the first trench in each strip to the last, which increased machine trafficking and therefore reduced productivity.

The contractor generally formed the **berms** by cutting them into the ground surface rather than by using an equal mix of cut and fill. Although this resulted in firmer

construction the resulting spoil had to be moved (at the same contract price) to the specified location for depositing site arisings.

The rock for the sills of the **stone armoured channels** was required to meet specification and, as this was not able to be met on site, it was sourced from a commercial hard rock quarry at Croy, Kilsyth at some expense. Although the appearance of sills could have been improved, and some of the loose stone fill at the edge of trenches was undersized, the result was functional.

There were no issues of **silt** draining from the cultivation areas on the steeper slopes owing to excellent infiltration to the cultivated profile and also to the landform at the foot of slopes adjacent to sensitive areas in general. Drainage from the east of the south east tip was enhanced with a 1 m * 1 m * 2m long soak-away filled with stone and filtration zone at its end. Thus there was no direct connection into the deep roadside drain at this location, which has been prone to flooding in the past. This has proved very effective.

Although there were **buried services** in the extreme east of the south east tip they did not constrain works. The electricity cable and gas pipe were marked on the ground and it was confirmed that a hard standing could be constructed over them providing that there was no excavation. Additionally, planting blocks were kept well back.

**Sowing** the Cornfield annuals mix was very effective in providing colour on the southeast tip when seen from the motorway. However, wild flower seeding was not necessary on the south west tip because the area is not very visible from the motorway, although it did give an initial burst of colour. The Reclamation seed mix used over most of the rest of the south west tip would have been sufficient.

**Planting** blocks occasionally had steel rod and other obstructions protruding from the soil surface, so the planting contract required use of goggles for eye protection. The planting and plant protection specification was very robust, which proved worthwhile. The specification comprised external deer fencing, and cell grown 'plug' plants protected by individual 60 cm tree tubes, which also provided important protection against strimmers and voles.

The tubes were essential owing to vigour of **weed growth** and the consequent threat, in places, of 'swamping' the young trees. The broadleaved weeds were surprisingly tough to cut by strimming, so a higher rate might be tendered for this in future.

Following ground cultivation, a small area of the noxious Japanese knotweed was found to be growing in Cell E1 of the south east tip in 2012, apparently having been

carried through on machine tracks. This was eliminated by means of spraying twice with glyphosate and then by stem injection in 2013.

# Costs

The main cost elements of the Greenoakhill reclamation and woodland establishment project are summarised in **Table 10**. Contract preparation, management and VAT, if applicable, would be in addition.

**Table 10.** Cost summary

| Activity | Quantity | Cost (approx.) |
|---|---|---|
| **Reclamation** | | £205k |
| Complete cultivation 5.6 ha with 750 tph compost plus drains & berms | 5.6 ha | |
| **Planting** - labour and materials | | £40k |
| 20k cell grown plants, 60 cm shelters & stakes & beatup years 1 & 2 | 5.6 ha | |
| **Seeding** - grass & wild flowers | | £10k |
| Labour and seed | 10.6 & 4.0 ha | |
| **Paths** | | £45k |
| Including 3 culverts & east parking bay | 2 km | |
| **Weeding** | | £10k |
| 3 years spot weeding, plus slash/strim as required years 1 & 2 | 5.6 ha | |
| **Total** | | **£310k** |

# Conclusions

The conclusions following implementation and three growing seasons of monitoring tree establishment on the southern tips of Greenoakhill Landfill site are:

- Complete cultivation by excavator and incorporation of green compost as a soil improver was a practical and effective method to reclaim sub-standard heavy clay soil and soil forming materials for forestry after-use at Greenoakhill landfill site.
- Engineered features including uncultivated bunds, drainage taps from cultivated cells, berms and armoured drains were effective in preventing soil slippage, erosion and consequent pollution of surface waters.
- Planting specification including plug plants and 60 cm tree tube protection were effective at establishing fully stocked new woodland.
- The grass seeding was very effective at reducing vigorous, damaging broadleaved weed growth and the second and subsequent years.

- A robust regime of chemical spot weed control supplemented by strimming was required, as expected, to overcome excessive broadleaved weed growth in the first two seasons.
- Tree growth, health and stability were good and continuing after three seasons. There was some limited visual evidence, supported by foliar analysis, of nitrogen deficiency at year three, although it was not obviously stunting tree growth. These were related to areas of more cohesive soils where compost mixing had inevitably been less effective. However, given the slow release nature of compost and the very poor initial soil conditions this was not unexpected.
- Species planted at Greenoakhill, largely comprising native broadleaved pioneer and climax trees and shrubs have performed well in the conditions, as have Scots pine and larch. Growth of oak has, as would be expected, been relatively slow.
- The site has been relatively free of vandalism, although this may partly result from its current status as part of a wider commercial site that is closed to the public and distant from housing.
- Contract reclamation and establishment operations required, and received, detailed and intensive supervision by Forester staff.
- A high initial specification allows more scope for amendment, where justified by conditions, than would a lower one.
- The contract design, whereby prices were tendered on the basis of price per unit of work items, was very effective in enabling ongoing amendments to plans owing to site conditions.
- The approximate cost of the reclamation to woodland project was £30k per gross and £55k per net planted hectare, excluding VAT.

# Recommendations

- Green compost is a practical and relatively environmentally safe soil amendment for amelioration of poor quality, disturbed soils for forestry, if used correctly.
- A robust planting stock, tube-protection, grass seeding and weeding specification is highly recommended for similar reclamation sites that are cultivated with compost owing to likely weed growth.
- There is only limited scope to reduce the reclamation specification as used at Greenoakhill, which is based on best practice, is robust and caters for difficult sites.
- Limited contract cost reduction may be possible without compromising the established result, given some carefully applied and targeted relaxation of specifications.
- Contract structure should provide for changes in work quantities during implementation.

# Acknowledgements

The assistance of staff at Scottish Lowlands Forest District is gratefully acknowledged, and in particular information and help with reviewing the draft of this report given by Gareth Waters, who oversaw the reclamation and initial establishment work on behalf of the District.


## Contact


Michael Wall
Technical Development
Forestry Commission
Ae Village
Dumfries-shire DG1 1QB
July 2014


## Technical Development

Technical Development helps develop, evaluate and promote safe and efficient equipment and methods of work, maintains output information, advises on forest operations and provides related specialist services



# References


Bending, N. & Waters, G. (Unpublished, 2011). Schedule 'B' - Detailed specification for ground preparation and drainage works for the establishment of community woodland on a restored inert landfill at Greenoakhill, Broomhouse, Glasgow, January 2011. Forestry Commission Scotland

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# Appendices

## Appendix 1

### Summary of the specification values of BSI PAS 100

| Parameter | Recommended limits[13] | Units |
|---|---|---|
| | PAS100 Specification[14] | |
| Pathogenic | | |
| Salmonella Spp | Absent | MPN in 25g sample dry weight |
| Escherihia coli | < 1,000 | CFU / g fresh mass |
| PTEs / | | |
| Zinc | <400 | mg/kg dm |
| Copper | <200 | mg/kg dm |
| Lead | <200 | mg/kg dm |
| Nickel | <50 | mg/kg dm |
| Chromium | <100 | mg/kg dm |
| Cadmium | <1.5 | mg/kg dm |
| Mercury | <1 | mg/kg dm |
| Arsenic | <10 | mg/kg dm |
| Selenium | <6 | mg/kg dm |
| Boron | <3 | mg/kg hot water soluble |
| Physical | | |
| Glass, metal, plastic & other non-stone fragments > 2mm | 0.25% (0.12% plastic) | % mass / mass air dry sample |
| Stones > 4 mm | 8% (10% in mulch) | % mass / mass air dry sample |
| Other | | |
| Microbial respiration rate | 16 | Mg CO / g organic matter / day |
| Germinating weed seeds or propagule growth | 0 | Mean number / litre compost |

[13] *Moffat, A. (2006). Use of Sewage Sludges and Composts in Forestry. Information Note 79. Forestry Commission. ** Schedule 'B' - Detailed specification for ground preparation and drainage works for the establishment of community woodland on a restored inert landfill at Greenoakhill, Broomhouse, Glasgow. Forest Enterprise Scotland (unpublished, 2011)

[14] PAS100:2011 Specification for composted materials. BSI (2011)

# Appendix 2

## Specifications for compost supply and handling

| Item | Specification | Exclusion  | Comment |
|---|---|---|---|
| | Compost | | |
| Quality | Green Compost to<br>PAS 100 (General Purpose) | No amendment for nutrients & pH. Green compost only<br>e.g. no composted sewage sludge or spent mushroom compost | Approve specification used<br>See 'Example of Additional compost characteristics' table below |
| Screening | 0 - 20 mm to 0 - 40 mm<br>0 - 30 mm preferred | No compost that excludes a fine fraction e.g. no 10 - 30 mm | Fine fraction includes much of the nutrient value |
| Delivery | Handling | No excessive compacting of loose compost to increase load weight | Handle with care. May be denser than planned owing to settling / pressure in load |
| | Inspection | Not over wet or dry, un-friable, no stones, plastic, glass or green plant material & not 'self-heating' | Visually check each load for consistency |
| Handling at site | Handle with care, avoid compaction | Machinery must not traverse compost or contaminate it with mud etc | Avoid loss, contamination on-site with SFM or stones, water-logging & run-off pollution |
| Storage | Location of accessible, free draining (5 - 10% slope), hard standing of sufficient size | No storage where water-logging or mud will spoil quality | As above & ensure space for un/loading<br>e.g. 3 m around windrows, each < 3 m high & with 50% slopes |
| | Minimise wetting | No loose heaps or surfaces, extracting from mid windrow | Windrows with 'pointed' top, 'seal' surface by light bucket pressure |
| Records | Delivery notes include date, weight & batch reference<br>Daily & cumulative total | No payment for undocumented loads | Quantity and quality of compost delivered is a key control point |

Note. Includes extracts from Forest Enterprise Scotland, Scottish Lowlands FD. Greenoakhill Specifications. Bending, N. (unpublished, 2011). May be adjusted to suit local circumstances

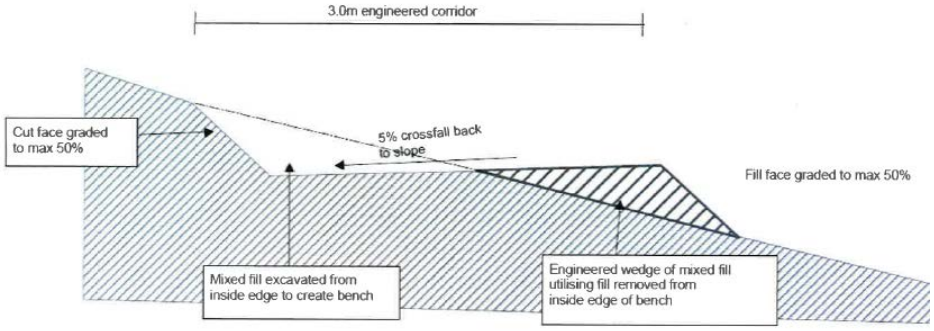
## PAS100 green compost, additional characteristics

| Characteristic | Specification | Comment |
|---|---|---|
| pH | 6.5 - 8.7 | |
| Conductivity | < 2,000 uS/cm | 1:5 soil/water solution |
| Moisture content | 30% to 55% | Wet basis |
| Bulk density | 0.50 to 0.70 g/cm$^3$ | |
| Organic matter content | 40% to 70% | Weight of dry solids |
| C:N ratio | 15:1 to 20:1 | |
| Total nitrogen | 1.0%- 2.0% | Weight of dry solids |
| Ammonium nitrogen | < 25 mg/l | Fresh, water extractable |
| Nitrate nitrogen | < 200 mg/l | Fresh, water extractable |
| Total phosphorus | 0.15% - 0.30% | Weight of dry solids |
| Total phosphorus (as $P_20_5$) | 0.35% - 0.70% | Weight of dry solids |
| Total potassium | 0.75% - 1.5% | Weight of dry solids |
| Total potassium (as $K_20$) | 0.9 % - 1.8 % | Weight of dry solids |

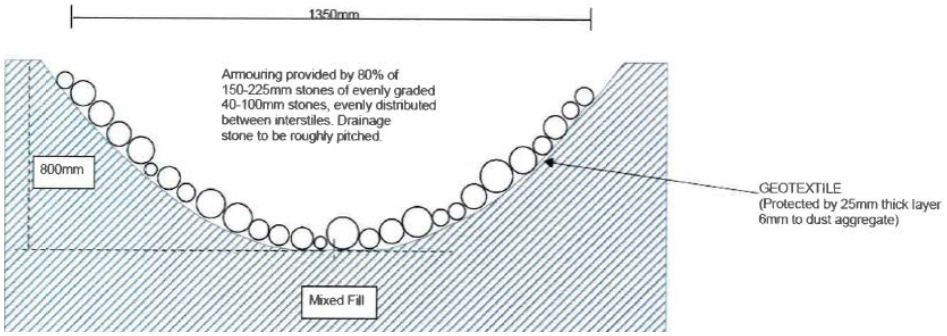
Note *. From Forest Enterprise Scotland, Scottish Lowlands FD. Greenoakhill Specifications. Bending, N. (unpublished, 2011).

# Appendix 3

**Example diagrams of Contour berm and Armoured drain**




Contour berm




Stone armoured drain

From Forestry Commission Scotland Schedule 'B' - Detailed specification for ground preparation and drainage works for the establishment of community woodland on a restored inert landfill at Greenoakhill, Broomhouse, Glasgow, January 2011. After Bending, N. & Waters, G. (2011).

# Appendix 4

| Element | Summary |
|---|---|
| | 12/7/11: Post restoration inspection & soil sampling |
| Summary | Soil - loose growing medium created by cultivation to 100 cm and mixing with compost to c 50 cm<br>Vegetation cover - 10 - 50% but occasionally more, mostly broadleaved weeds with generally very little grass growth, probably from seed<br>Trees - survival generally good (>80-90%). Birch growing best. Oak small and limited growth and other species intermediate. Most trees not at 60 cm yet, except some Birch and fewer Ash.<br>Engineering - effective system of drainage taps, berms and drains (including armoured drains) |
| Specif'n | Tubes - 60 cm Tubex, 1 tie only (2 ties would avoid tubes moving in wind)<br>Engineering - berms 3 m wide with in-slope cross-fall. Seepage into them from cells.<br>Armoured drains along NW and W boundary of West tip down to single silt pond. Little sign of erosion. Approx. 20 cm rocks used for stone armour.<br>Drainage taps on down-slope side from cultivated cells - slightly sloping base from edge of cultivation to berm, c 1.5 m width of cultivated ground. Approx. 5m 'verge' between cultivated cell and berm is uncultivated, as is open space within cell design.<br><br>Deer fencing (both W and E) but un-gated as yet. Deer prints along inside of fence in West. |
| Soils | Clay loam. Top 5-20 cm samples from Blocks W1, W4, W7, W10, E1 & E10<br>Cultivation depth min 1 m. Compost mixing 50 cm (W10 40 cm) |
| Block W1 (500 t/ha) | Compost quality OK but some plastic bag fragments<br>Vegetation cover c 25%, mostly broadleaves:<br>Colts foot, Fat hen, Smooth sow-thistle, Sour / Creeping thistle, Redshank, BL dock, Groundsel, Ribbed plantain, Dead nettle, Creeping buttercup, Pineapple weed, Mayweed, Chickweed, Dandelion, White penny cress? + others not identified on site<br>Grass - < 10% re-growth from seed:<br>Creeping bent, Meadow foxtail, Couch<br>Trees - Bi, AH, some: AR, Ro?, Norway maple? |
| Block W10 (500 t/ha) | Vegetation cover c 65%. 'Very good selection of agricultural weeds', Fat hen (much), Meadow foxtail, Creeping thistle, Redshank, Mayweed, Yellow flowered plant similar to oil seed rape |
| Block W7 (250 t/ha) | Vegetation cover c 50%<br>Trees - as above. Approx. 5 - 10% deaths (drought?) |
| Block W4 (250 t/ha) | Vegetation cover c 5 - 10%<br>Chemical spot weeding done? |

| | |
|---|---|
| Block E1 (500 t/ha) | Vegetation cover c 5 - 10%, mostly Coltsfoot<br>NB: Peat cell Block E13 to south / above is 100% dense Coltsfoot & Creeping thistle in places |
| Block E10 (500 t/ha) | First soil pit on line of Quad track marks was only 30 cm cultivation depth - presumed route of tracking during wet weather or old track.<br>Second pit OK at 100 cm cultivation depth with compost to 50 cm.<br>Vegetation cover c 5 - 10% - Redshank, Meadow foxtail, Broadleaved dock<br>Trees - Bi (much), CP, SP, LA, Dog Rose, Hazel?, AH, OK, Bird cherry?, Ro?.<br>Approx. 20% dead, especially OK / LA |
| Photos | ✓ |

| Element | Summary |
|---|---|
| | 9/9/11: late summer 1 inspection |
| Summary | Vegetation cover - strong growth of broadleaved agricultural weeds, but not smothering trees yet. Recent strimming of most weedy blocks and evidence of spot chemical weeding in places. Occasional areas of fairly dense sown-grass helping to displace weeds and ryegrass growing on some 'open' spaces<br>Trees - Overall good survival, many now growing above rim of 60 cm tubes e.g. AH, Bi, AR & some ROW & SOK, variation in growth between blocks<br>Engineering - drainage system functioning well, cell drainage evident from drainage 'taps' |
| General | Weather warm after heavy rain, becoming sunny and hot<br>60 cm tubes<br>Rides partly scarified by bucket teeth [& sown?]<br>Open area North of W11 is former undisturbed ryegrass<br>Wide tubes include Dog Rose |
| Drainage | Drains / berms - fresh drainage seeping from taps and into drains. Some running water in drains. Silt trap full of water.<br>Armoured channels have larger stone 'cills' c 10m intervals. |
| Block W14 | **WEST OF SOUTH TIP**<br>Survival - Good (95%).<br>Growth - C60% out of tubes especially AH, Bi, AR & some ROW & SOK<br>Vegetation - very heavy broadleaved weed growth although not smothering trees. Recently strimmed. Possibly spot chemical weeded too?<br><br>Vegetation - broadleaved dock, Coltsfoot (*Tussilago farfara*), Charlock (*Sinapis arvensis*) or *Brassica* spp., Redshank (*Polygonum persicaria*), Smooth sow-thistle, Black medick (*Medicago lupulina*) or Lesser trefoil (*Trifolium dubium*) (see photos). Approx. 40% grass cover, probably sown, not heavy growth |
| Block W13 | Vegetation - as above but much Redshank, more grass & Creeping buttercup<br>Trees - also SP planted in wide tubes. 10-15% tubes marked for beat-up |

| | |
|---|---|
| Block W12 | Vegetation - as above but more sown grass (<6" tall). Not strimmed.<br>Also includes Chicory (*Cichorium intybus*), Prickly Sow Thistle (*Sonchus asper*), Shepherd's purse (*Capsella bursa-pastoris*), Fat hen (*Chenopodium album*) or Good King Henry (*C. bonus-henricus*) and Mayweed (Sea-*Matricaria maritime* or Scented-*Chamomilla recutita)*.<br>Trees - c 10% marked for beat-up. A few larch & birch just emerging from the 60 cm tubes |
| Block W11 (North) | Vegetation - few, small broadleaved weeds. Grass, sown, mostly small & short/yellow<br>Trees - few emerging from the 60 cm tubes. Approx. 10% marked for beat-up |
| Block W10 | Vegetation - heavy broadleaved weed growth as W12. Recently strimmed |
| Block W5 | Not strimmed but OK.<br>Vegetation - much Sea Mayweed (*Matricaria maritima*) and Black medic (*Medicago lupulina*) |
| General | **EAST OF SOUTH TIP**<br>Vegetation - heavy growth of broadleaved vegetation, similar to West of South tip. Large areas of recent strimming. Approx. 10% marked for beat-up<br><br>Includes Coltsfoot (*Tussilago farfara*), Redshank (*Polygonum persicaria*), c 40% grass<br>Trees - some now emerging from the 60 cm tubes e.g. c 40% of birch |
| Photos | ✓ |

| Element | Summary |
|---|---|
| | 21/11/12: post season 2 inspection |
| Soils | Top 5-20 cm samples from Blocks W1, W4, W7, W10, E1 & E10 after 2 seasons |
| Summary | Weather: cool, dry, fine & sunny.<br>Vegetation cover - noticeable cover of sown grass, mostly perennial rather than annual broadleaved weeds, not smothering trees. More broadleaved weeds on SE tip but evidence of chemical weeding<br>Trees - Good growth esp. Bi / AR / AH, some OK, scattered larch & Scots pine (in widest tubes), to 1.2 m- 1.5 m tall. Ave height c 60 cm<br>Two roe deer seen outside fence and 60 cm Tubex tube's marked for beat-up<br>Engineering - Standing water on uncultivated rides but not cultivation areas. Seepage from drainage taps. Water seeping into berms. Armoured drains all OK. No erosion or slippage seen. New paths of reclaimed asphalt cambered 1.5m surface (2m overall). No geotextile seen |
| SW tip plots | Vegetation -<br>W1: *Fescue* etc, few Broadleaved weeds (Creeping buttercup, Dock etc)<br>W4: *Fescue*, Creeping bent, *Holcus*, Dock, Creeping thistle, Nettle<br>W7: *Fescue*, Holcus, *Deschampsia cespitosa*, Coltsfoot, Clover [red?], Creeping thistle, Creeping buttercup |

| | |
|---|---|
| | W10: *Fescue*, *Holcus*, some Creeping buttercup, some Cocksfoot |
| SE tip plots | General - more broadleaved weeds than SW tip but evidence of chemical (and strimming?) weeding. All in hand<br>Trees - good tree growth including scattered larch. Some SP in wide tubes. New paths in place (as SW tip)<br><br>SE 5:<br>SE 6: *Holcus*, *Fescue*, Plantain, Creeping thistle, Dock, Creeping buttercup, Nettle. |
| Photos | ✓ |

| Element | Summary |
|---|---|
| | 25/6/13: mid season 3 inspection |
| Summary | Vegetation cover - grass in cultivated cells much thicker and greener than vegetation on untreated rides. More perennial broadleaved weeds on SE Tip, especially dock, with some recent strimming and spot chemical weeding<br>Trees - healthy new growth: Bi, AH and CAR is c 1.5 m - 1.8 m, with OK < 60 cm - 1.2 m and larch / Scots pine intermediate. Some areas of ash, especially, are yellowish and smaller<br>Signs of deer outside fence<br>Engineering - new paths in good condition. No issues with drains |
| General | Weather - warm and overcast, moderate showers in pat few days but now 'dry'. |
| SW tip | General - healthy new tree growth. Main species Ash and Birch plus some SP / larch (in tubes), Cherry, Rowan, Alder, Sloe, Hazel, Dog Rose, Pedunculate Oak, some Sycamore.<br><br>TD and FES plots suggest variability in receiving soils nitrogen content, assuming a reasonably uniform application of compost.<br><br>Vegetation - ground cover of sown grass very thick - Fescue predominates, but also *Holcus lanatus* (Yorkshire Fog) & Bent. Grass in cultivated cells much thicker and greener than vegetation on untreated rides. Some Coltsfoot and a few Docken.<br><br>Trees - some cells e.g. in northwest by path / ride, appear yellower / less nitrogen rich, with lower tree growth, especially in Ash. Apparent variability in yellowing over the plot suggests variation in parent material.<br><br>Some Oak appear to have died back at the shoot tips at the end of last or start of this season, possibly owing to the cold spring. Oak is otherwise healthy. |

| | |
|---|---|
| | Tree growth is variable depending on species. W14 is 5' - 6' total growth of Bi / Ash, elsewhere 4 - 5'. Alder groups in west of site also reaching 5 - 6'. Oak generally 3 - 4' maximum, often only just emerging from the 60 cm tubes. SP / larch have intermediate growth.<br><br>Engineering - 4' to 5' wide asphalt planings paths in good condition. No sign of motorbike use.<br>Armoured drains OK, no sign of erosion or silting anywhere on site.<br>Deer fence generally good condition but Woodland Wardens replacing 3 stobs on west boundary that had been vandalised and broken from the neighbouring unmanaged land, albeit with no apparent access gained. |
| SE tip | General - more weed growth amidst the cells.<br><br>Vegetation - grass is Fescue, Bent and some Crested Dogs Tail in patches.<br>Much Dock, the worst areas being strimmed recently and some spot strimming.<br>Also Creeping buttercup, Field buttercup, vetch and thistles.<br>Evidence of a 'blue dye', possibly Glyphosate.<br><br>Trees - area of mostly pure Ash on [top of mound] is very yellow and only just emerging from the 60 cm tubes: appears to be nitrogen deficiency. Tree height variability similar to West Tip plots.<br><br>Deer - no sign of deer entry but deer tracks in mud outside the fence. |

| Element | Summary |
|---|---|
| | 28/8/13: late season 3 inspection & foliage sampling |
| Summary | Vegetation cover - good grass sward with perennial broadleaved weeds, not smothering trees<br>Trees - approx. mean heights: AH / BI - 150 cm, CAR - 240 cm. Heights of HAZ, OK and ROW from 60 cm to 90, 120 & 180 cm respectively. Scots pine 60 cm - 90 cm, larch 120 - 180 cm<br>Patches of obvious yellowing with poorer growth. CAR is always green<br>Engineering - No issues evident |
| General | Weather - Warm, dry after mostly dry period |
| SW tip Block W11 (by trial) | Vegetation - Fescue, Creeping bent / Smooth meadow grass, Yorkshire fog, Coltsfoot, Silverweed, Creeping buttercup, Nettle, Dock, Rosebay willow herb<br>Trees - AH 5' mean (6'), SBi 5' (6'), CAR 8' (10'), OK 2' - 4', ROW 2' - 6' some yellow 6', HAZ 2' - 3'<br>Approx. 80% of AH and SBi are yellowish - no correlation with tree height. Also some OK & most Rowan<br>Spot weeded (dead grass patches) |

| | |
|---|---|
| Block W14 (large central)<br><br>Other blocks | Vegetation - Fescue, Creeping bent / Smooth meadow grass, Timothy, Coltsfoot, Creeping thistle, Dock<br>Trees - SBi 3'-4' poorer growth but 6'+ in greener central area, AH 3-4' poorer growth, Larch 4-6' some yellow / some green, no height correlation, SP 2-3' green ok, OK 3', Norway maple 3-5', Wild cherry 3', CAR 8' green<br>Yellowish trees mostly in patches<br>Spot weeded<br>Similar yellowish trees interspersed with and adjacent to green trees (even of same species) or in patches. CAR is ALWAYs green and vigorous.<br><br>No motorcycle or other obvious access issues |
| Foliage samples | All numerous leaves from numerous trees in W11 and W14<br>1= AH yellow, 2= AH green, 3= SBi yellow, 4= SBi green |