A Brief Scoping Study of Landscape Recontouring for Viticulture in Eastern Marlborough

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Project and Client

A scoping study of the extent, site characteristics, and potential on- and off-site environmental impacts of 'landscape recontouring' for viticulture was undertaken by Landcare Research for the Marlborough District Council in December 2008.

Objective

- Undertake a review of the extent, site characteristics, and the potential on- and off-site environmental impacts of landscape recontouring in Marlborough.

Background

- In Marlborough there has been a marked increase in the amount and type of land being developed for viticulture. Extensive viticultural development has recently been undertaken on rolling to strongly rolling hill and downland slopes often involving significant landscape recontouring.
- The impacts on the environment and the potential on- and off-site environmental hazards of this land management practice have yet to be systematically assessed.

Discussion

- Landscape recontouring is being undertaken to create land that is suitable for viticulture. As such, the preservation and redistribution of agromonically important soil, or the rebuilding of a soil profile with properties that will readily allow plant root extension, are paramount.
- On- and off-site erosion and deposition and the impact on natural drainage conditions are also potential significant environmental hazards.
- The location, underlying geology, geomorphology, regional climate, soil properties and characteristics, and soil physical conditions affected by landscape recontouring and which may inhibit plant growth are outlined and discussed under the following headings:
    - Topsoil loss, redistribution and/or degradation
    - Surface and subsurface compaction
    - Cut benches and batters
    - Fills
    - Erosion of restored surfaces
    - Recontouring procedures currently being undertaken in Marlborough.

Summary

- Landscape recontouring is occurring on strongly rolling to moderately steep hill and downland slopes, colluvial footslopes, and low-angle fans with variable degrees of dissection. These landforms are underlain by loose to very compact or weakly consolidated lithologies, which are prone to sheet, rill, tunnel gully and gully erosion. The redistribution of eroded materials both on- and off-site and their transport through the drainage network are potential issues.

- The recontoured landscapes are either mantled by silty loess or have loess as a significant soil-forming component. These predominantly silty Pallic soils have many soil properties that make them a demanding environment for plant establishment and growth, especially on bared surfaces and on sunny aspects. High slaking and dispersion potential, high bulk density subsoil horizons with restricted permeability, limited potential rooting depths and soil moisture storage, and fragile topsoil structures that break down under prolonged impact by heavy machinery or by continuous tillage are properties that must be carefully managed to minimise detrimental impacts.
- On the rolling to strongly rolling terrain involved in landscape recontouring, existing soil profile information is also limited.

Recommendations

1. That a database be set up that accurately records the location and extent of all the known landscape recontouring sites in the Marlborough District.
2. That the characteristics of each site be accurately recorded and validated.
3. That the development history, project plans, construction methodology and procedures used at each site are recorded.
4. That a brief environmental impact assessment of each site be undertaken to identify any potential on- and off-site environmental hazards.
5. That a monitoring plan be designed and implemented based on the level of environmental hazard determined from 4 above.
6. That baseline soil profile characterisation of the dominant soils involved in landscape recontouring are established by undertaking a programme of representative profile sampling, description, characterisation and analyses.
7. That a study be considered that compares and contrasts in situ soil characteristics and behaviour (e.g. slaking, dispersion, soil infiltration rates, aggregate stability tests) on representative natural and recontoured sites in order to quantify the impact of recontouring on soil properties.
8. That the value of developing a set of best management practices or guidelines for landscape recontouring in this environment be investigated.

1. Introduction

A scoping study to gain an understanding of the extent, site characteristics, and the potential on- and off-site environmental impacts of 'landscape recontouring' for viticulture was undertaken by Landcare Research for the Marlborough District Council in December 2008. The work was funded by an Envirolink small advice grant.

2. Objective

- Undertake a review of the extent, site characteristics, and the potential on- and off-site environmental impacts of landscape recontouring in Marlborough.

3. Background

All land uses potentially have detrimental effects on soil and water resources. This potential is greatly enhanced when substantial earthworks and/or landscape recontouring are involved.

In Marlborough there has been a marked increase in the amount and type of land being developed for viticulture. As well as expansion on the flat to gently sloping floodplains and terraces, extensive viticultural development has recently been undertaken on rolling to strongly rolling hill and downland slopes. The latter often involves significant landscape recontouring (Fig. 1).

The locations, site characteristics, development history and construction methods used in these landscape recontouring activities are generally poorly known. The impacts on the environment and the potential on- and off-site environmental hazards of this land management practice have yet to be systematically assessed.

Under the Marlborough District Council's operative *Proposed Wairau/Awatere Resource Management Plan*, excavation and tracking is a permitted activity, provided on land greater than 20 degrees slope no more than 1000 m^3 is moved in any 2-year period. (See the *Proposed Wairau/Awatere Resource Management Plan*, section 1.7.3.)

Fig. 1 Significant earthworks are involved in much of the landscape recontouring for viticulture currently being undertaken in Marlborough. An example of at least 1 m of ground surface lowering, south of Seddon; Grid reference: 2601660E; 5943426N. (Photo: Colin Gray, Marlborough District Council)

3.1 Definition and concepts

For this report landscape recontouring is defined as ‘deliberate re-forming of the surface contour of land used or intended for use in plant production (specifically vineyard production)’.

Soil is defined as ‘the upper weathered layer of the earth’s crust, commonly but not always differentiated into horizons of mineral and organic constituents; it differs from the parent material below in morphology, physical properties and constitution, chemical properties composition and biological characteristics’ (Taylor & Pohlen 1979).

The soil profile is defined as ‘a vertical section of the soil’. The majority of soil profiles embrace three master horizons (layers):

- The A horizon or topsoil, which is commonly characterised by the accumulation of organic matter, maximum biological activity, and removal of materials dissolved or suspended in water.
- The B horizon, or subsoil, which is commonly characterised by soil structural features differing from those above and below, and commonly by accumulation of materials carried down from the A horizon.
- The C horizon, or underlying parent material, which is presumed to resemble the material from which the overlying horizons were developed.

3.2 Characteristics of the landscape recontouring environment in Marlborough

Location

District council staff identified 18 sites where landscape recontouring had recently or is currently taking place. They are centred in the lower Awatere Valley and on the low coastal hills between Seddon and Ward (Figs 2 and 3). The general locations and characteristic landforms and soils mapped at the sites in small-scale regional studies are summarised in Table 1. Data sources include the 2nd edn NZLRI at a scale of 1:50 000 (Lynn 1996), and Campbell et al. (2007). The current distribution of vineyards in the area is shown in Fig. 4.

Underlying geology

The majority of landscape recontouring has been undertaken on ‘soft rock’ loess-mantled hill and downlands, or on fans and terrace treads underlain by formations and lithologies mapped by Begg & Johnston (2000) or Rattenbury et al. (2006). The formations have been identified as Q2, Q6, Q6a, Q8, or *Mau* and *Pas* on the current 1:250 000 geological map series. Formations on the true left of the Awatere River (Map 10) are specified as:

- *Q6 & Q8* – weathered, poorly sorted to moderately sorted gravel underlying loess-covered, commonly eroded, aggradational surfaces.
- *Mau* – Awatere Group, Upton Formation; poorly sorted, poorly bedded, channelised greywacke conglomerate with lenses of sandstone and sandy siltstone.

In the Seddon to Ward area (Map 13) the formations are specified as:

- *Q2* – river gravel, sand and minor silt
- *Q6a* – river gravel and sand, commonly slightly weathered
- *Pas* – Awatere Group, Starborough Formation, poorly sorted sandstone and siltstone

All these lithologies are loose to very compact or weakly consolidated and prone to sheet, rill, tunnel gully and gully erosion by fluvial activity, and wind erosion when bared of vegetation.

Geomorphology / landforms / landform components

Recontoured landscapes consist predominantly of strongly rolling to moderately steep hill and downland slopes, colluvial footslopes, low-angle fans along the valley floor margins, and terrace treads with variable degrees of dissection. The valley floor landscape to the south of the Awatere River is mantled by loess and aeolian sand of variable thickness, with only isolated patches occurring on the north bank (Eden 1989). Loess is also a significant soil-forming component on the hill and downlands landscape to both the north and south of the Awatere River.

Table 1 Location, landform and soils mapped at the identified landscape recontouring sites in NE Marlborough

Site	Grid reference		Landform	Soil*	Soil code*	General location
1	2601465E	5955255N	Rolling to strongly rolling hill slopes, north-easterly aspect	Wither	15d*	True right of Redwood Pass
2	2600465	5952935	Gently sloping stream terraces and fans	Warwick shallow Starborough stony Castlebrae stony	Wa2zU◊ Sb3sU◊ Cb3sU◊	Wainui Farm
3	2597260	5951690	Gently sloping footslopes? Fan? Or remnant valley fill. Confirmation required	Waihopai Hill	17bH*	Redwood Hills
4	2596010	5951900	Terrace tread	Warwick stony Starborough shallow	Wa3zG◊ Sb2zG◊	Top of Dumgree Road, true left
5	2595010	5952015	Terrace tread	Warwick stony	Wa3zG◊	Top of Dumgree Road
6	2589335	5945365	Terrace tread, loess mantled	Seaview deep	Sv0zU◊	Marama (Farm)
7	2590450	5944135	Terrace tread, loess mantled	Sedgemere deep	Sm0zU◊	Near Little Langford
8	2595380	5944980	Terrace tread, and loess-mantled hill slopes	Sedgemere moderately deep Flaxbourne	Sm2zR◊ 16eH*	Waterfalls Road / Marama Road intersection
9	2600305	5945735	Rolling hill / downland slopes	Wither Flaxbourne	15d* 16eH*	SH1 Lions Back
10	2602370	5946270	Rolling hill / downland slopes	Wither Flaxbourne	15d* 16eH*	Caseys Road
11	2600980	5944745	Rolling downland slopes	Sedgemere	20c*	Tetley Park
12	2600280	5943135	Rolling hill / downland slopes Terrace tread	Flaxbourne Templeton	16eH* 96a*	Sedgemere
13	2601755	5943710	Rolling hill / downland slopes	Flaxbourne	16eH*	SH1 Tetley Brook to Lake Grassmere
14	2602005	5942640	Rolling hill / downland slopes	Flaxbourne	16eH*	SH1 Tetley Brook to Lake Grassmere
15	2602580	5943540	Undulating to rolling downland slopes	Flaxbourne	16eH*	Lackwood
16	2608660	5939265	Undulating to rolling downland slopes	Wither Flaxbourne	15d* 16eH*	Marfells Beach Road, Flaxbourne
17	2608980	5938250	Hill slopes	Flaxbourne Weld in upper catchment	16eH* 17a*	Upper catchment, Marfells Beach Road, Flaxbourne
18	2604065	5949310	Undulating to rolling loess mantled downland slopes	Seaview	15b*	Station Creek area

Slope criteria: Undulating 4–7°, rolling 8–15°, strongly rolling 16–20°, moderately steep 21–25°; *soil codes from New Zealand Soil Bureau Bulletin 27 (1968), ◊ soil codes from Campbell et al. (2007).

Regional climate

The dominant characteristic of the Marlborough climate is its dryness. Summer droughts are frequent, and the region is often swept by warm, desiccating northwesterly winds (Pascoe 1983). Annual rainfall in north-eastern Marlborough is low (500–635 mm), with a slight summer minimum, high sunshine hours and evapotransporation rates (New Zealand Meteorological Service undated). While predominantly dry the region also experiences episodic high-rainfall events (Tomlinson 1980). The establishment and maintenance of a vigorous vegetative cover is thus difficult, especially on bared surfaces and on sunny aspects.

Soils

The dominant Soil Orders (Hewitt 1998) involved in landscape recontouring, and their characteristics are summarised in Table 2. Pallic Soils – primarily Argillic Fragic Pallic [PXJ] and Typic Argillic Pallic [PJT], limited areas of Pedal Immature Pallic [PID] and Typic Immature Pallic [PIT] soils – are involved. Lesser amounts of Recent Soils, Weathered Fluvial Recent [RFW] soils on terrace treads, and Typic Orthic Recent soils on hill slopes are also potentially involved (see Table 2).

Pallic soils are characterised by moderate to high base status and low contents of secondary iron oxides. They have pale colours, high slaking potential and high density in subsurface horizons; and have water deficits in summer and soil water surpluses in winter or spring.

Accessory properties of Pallic Soils include:

- Low concentrations of secondary iron oxides. P retention is <30% in topsoils and, usually, in subsoils. Extractable iron and aluminium values are low or moderate with a significant proportion of secondary iron oxides occurring in redox segregations.
- High base status. Base saturation values are high (>50%) except in perched-gleyed soils, where values may be lower in horizons overlying fragipans.
- Siliceous parent materials. Parent materials are predominantly loess or sediments derived from quartzo-feldspathic rocks (schist or greywacke).
- Slow permeability. Subsurface horizons have restricted permeability, particularly in soils with fragipans or duripans in which the permeability is very slow.
- Perched water tables. Soils that are poorly or moderately well drained have water tables perched on slowly permeable layers.
- Limited root depth. Potential rooting depth in most soils is limited by a subsoil horizon of high bulk density at shallow depths or by brittle silty cappings on stones.
- Strongly worm mixed. Topsoils generally have a significant proportion of worm casts and a distinct worm-mixed horizon occurs in the transition from A to B horizons. Topsoil worm activity is greatly reduced during summer periods of moisture deficit.
- High slaking and dispersion potential. Soil material, particularly in B horizons, is strongly dispersive and will readily slake. Topsoil structures may break down under prolonged impact by heavy machinery or by continuous tillage.
- Droughty summers, moist winters. Precipitation ranges from about 500 to 1000 mm per year. A spring surplus of soil water is common but the annual surplus is as low as 35 mm at Grassmere, and the average annual deficit can be up to 650 mm.
- Phosphorus status. A high proportion of the inorganic phosphorus is non-occluded and a relatively high proportion of total phosphorus is in an organic form.
- Sulphur status. Levels of extractable sulphate are low.

Table 2 Dominant soils of the recontoured areas in Marlborough.

Name	Soil code	NZSC		Smap sibling	horizontion	Parent material	Topography	Elevatior (m)	Rainfall (mm)	comment
Seaview	15b*/ Sv0zU◊	PXJ Md z s	Argillic Fragic Pallic	Seav_1	A Bw Bwg Bt BCx	Loess over alluvium	Undulating to rolling terrace tread	30–150	500–635	
Wither	15d	PXJN Md z s	Argillic-sodic Fragic Pallic	Sedg_7	A Bw Bg Bt BCx	Deep loess over gravels	Strongly rolling and rolling ridges with short moderately steep slopes	30–120	500–635	Prone to tunnel gully erosion
Wither Hill	15dH	PXJN	Argillic-sodic Fragic Pallic	na	A Bw Bt BCx	Loess over gravels				
Sedgemere	20c / Sm0zU	PXJN Md z s	Argillic-sodic Fragic Pallic	Sedg_1	A Bw Bg Bgt BCx	Loess	Undulating and flat terrace treads (dissected)	0–300	500–760	
Warwick	Wa2zG	PIT Ma Hs z r	Typic Immature Pallic	Tngm_	A Bw Bw(t) BC C	Gravelly subangular alluvium	Fan surfaces on high terraces	0–300	500–760	Minor area
Starborough	Sb3sU	RFW Ma Hs l r	Weathered Fluvia Recent	Star_1	A Bw 2Bw 2BC	Gravelly alluvium	Fan surfaces on intermediate terraces	0–300	500–760	Minor area
Flaxbourne zl, stony zl	16eH	PJT Mm Hs l m/s	Typic Argillic Pallic	na	A Bt BCt(x)	Siltstone & sandstone, greywacke gravels, thin loess	Moderately steep; short slopes with rolling ridges, remnants of ancient terraces	30–300	500–635	Dominant area
Waihopai Hill sl to stony zl	17bH	PJT Mp Hs l r; PJT Mm Hs l r	Typic Argillic Pallic	na	A Bw(t) C	Greywacke conglomerate gravels & loess	Steep to moderately steep slopes	0–300	500–760	Minor area. Prone to shallow soil slip erosion
Weld, zl & stony zl	17a	PID Ml Hs l r; PIT Ml Hs l r; ROT Ml Hs l r	Pedal Immature Pallic; Typic Orthic Recent	na	A Bw BC C	Greywacke colluvium, some loess	Moderately steep slopes	0–300	500–760	Very small area, correctly mapped?

Soil codes from: *New Zealand Soil Bureau Bulletin 27 (1968) / ◊Campbell et al. (2007). Slopes: undulating 4–7°, rolling 8–15°, strongly rolling 16–20°, moderately steep 21–25°. na = not applicable

Available information on profile characteristics and general soil properties for the dominant soils involved in landscape recontouring on the rolling to strongly rolling terrain is limited.

No profiles for the Flaxbourne, Wither, Waihopai or Weld soil sets are present in the National Soil Database. Brief profile descriptions are published in Gibbs & Beggs (1953) and New Zealand Soil Bureau (1968). The Waihopai and Wither soils are also described by Laffan & Cutler (1977). These profile descriptions are included below.

Flaxbourne soils, derived from siltstone and sandstone, greywacke gravels and some loess, are mapped as being present at nine sites. They are classified as Typic Argillic Pallic soils [PJT Mm Hs l m/s], (soil map code 16eH). The Flaxbourne profile description from New Zealand Soil Bureau (1968) is:

horizon depth (cm)
A 0–15 dark grey brown, nutty/granular, silt loam friable
Bt 15–53 pale olive brown, blocky, clay loam, firm
BCt(x) 53+ on pale olive brown, prismatic/blocky, clay loam – very hard when dry

Gibbs & Beggs (1953) describe a typical Flaxbourne soil profile as:

horizon depth (cm)
A 0–15 light-yellow-grey, very friable, silt loam with a weak fine granular structure
Bt 15–31 to 46 dull-brownish-yellow, compact clay loam, with strong coarse blocky structure
BCt(x) 46+ greyish-yellow, compact clay loam derived from siltstone

The soil pattern is considered to be a complex of Flaxbourne hill soils on the convex upper slopes grading into Wither soils on the concave lower slopes (Gibbs & Beggs 1953). The Flaxbourne soil-landscape is generally stable but is subject to sheet erosion when cultivated or when the vegetation is depleted.

Wither soils, derived from thick loess and loess colluvium are mapped as being present at four sites. They are classified as Argillic-sodic Fragic Pallic soils [PXJN Md z s], (soil map codes 15d, and 15dH). Wither silt loam soils are characterised by greyish brown A horizons with weakly developed crumb and granular structure; B horizons are brown clay loams with moderately developed blocky structure overlying very compact clay loam fragipans. The type section of a Wither silt loam described by Laffan & Cutler (1977) is:

horizon depth (cm)
A 0–25 dark greyish brown (10YR4/2) silt loam; friable, weakly developed fine crumb and nut structure
Bw(t)25–40 brown (10YR4/3) clay loam; firm; very weakly developed fine block structure
Bt 40–62 brown (10YR4/3) clay loam, firm, moderately developed medium block structure, thin discontinuous clay-skins
BCt 62–84 brown to dark brown (7.5Y4/4) clay loam, firm to very firm, moderately developed medium block structure
bBCx84–104+ dark yellowish brown (10YR4/4) clay loam, very firm, massive in place, but moderately developed very fine nut structure (relict?) present
The Wither soil profile descriptions from New Zealand Soil Bureau (1968) are:

15d
horizon depth (cm)
A 0–20 dark grey brown, crumb/granular, silt loam, friable
Bw(t)20–41 olive yellow, massive, silt loam, friable
BCx 41–102 yellow brown, prismatic, clay loam; very hard when dry
C 102+ yellow massive sandy clay loam; very hard

15dH
horizon depth (cm)
A 0–13 grey brown, granular/crumb, silt loam, firm-friable
Bw(t)13–31 brown yellow, massive, silt loam, firm
BCx 31–77 yellow brown, blocky/massive, hard silt loam, firm
C 77+ on gravels in silt matrix

The Wither soil-landscape is prone to sheet erosion, and is typically dissected by varying degrees of tunnel gully erosion.

Waihopai Hill soils, derived from massive greywacke conglomerates (Upton Formation) with a discontinuous very thin cover of loess and loess colluvium, are mapped as being present on one site. They are classified as Typic Argillic Pallic soils [PJT Mp or Mm Hs l r], (soil map code 17bH). Waihopai stony silt loam soils are characterised by greyish brown A horizons with weakly developed crumb and granular structure; B horizons are dark yellowish brown stony and bouldery heavy silt loams with thin discontinuous cutans around stones and peds. The type section of a Waihopai stony silt loam described by Laffan & Cutler (1977) is:

horizon depth (cm)
A 0–22 grey brown to brown (10YR5/2–5/3) stony silt loam, friable; weakly to moderately developed fine crumb and medium granular structure
Bw 22–38 dark yellowish brown (10YR4/4) stony silt loam; friable to firm, weakly to moderately developed fine nut structure
Bwt 38–73 dark yellowish brown (10YR4/4) stony silt loam, friable to firm, weakly to moderately developed very fine and fine nut structure; thin patchy clayskins around stones
Bt 73+ dark yellowish brown (10YR4/4) stony gritty silt loam, firm, moderately developed fine nut structure, clayskins around stones and peds are thicker and more continuous than in the Bwt horizon, some reddish iron staining around and between stones

The Waihopai Hill profile description from New Zealand Soil Bureau (1968) is:

horizon depth (cm)
A 0–15 very dark grey brown, crumb, stony silt loam, friable
Bw(t)15–45 brown yellow, blocky, stony, silt loam, firm
2C On weathered stones in sandy silt matrix, very firm

Also:
horizon depth (cm)

A 0–8 dark grey brown, nutty/crumb, stony bouldery sandy loam, very friable
2Bw(t)/C 8+ grey brown to olive brown nutty/blocky, very stony bouldery sand

From Gibbs & Beggs (1953):

horizon depth (cm)
A 0–15 light-greyish-brown, stony sandy loam with a weak fine granular structure
Bw(t)/C 15–46 to 61 stone and boulders with a sandy matrix and slightly compacted

The Waihopai soil-landscape is considered to be susceptible to shallow slip erosion particularly on steep upper backslope positions (Laffan & Cutler 1977).

Weld Steepland soils, derived from greywacke colluvium, with some loess, are tentatively mapped on one site. They are classified as either Pedal or Immature Pallic soils [PID / PIT Ml Hs l r]; or Typic Orthic Recent soils [ROT Ml Hs l r], (soil map code 17a). The Weld Steepland profile description from New Zealand Soil Bureau (1968) is:

horizon depth (cm)
A 0–15 very dark grey brown, crumb/granular, stony silt loam, friable
Bw 15–41 pale yellow brown, nutty, stony, silt loam, friable to firm
C 41+ on fragmented greywacke

From Gibbs & Beggs (1953):

horizon depth (cm)
A 0–13 light-greyish-brown, friable, silt loam with a weak fine granular structure
Bw 13–26 light yellow-brown, stony silt loam
C 26+ on greywacke

The Weld soil-landscape is relatively stable but is subject to sheet erosion when the vegetation is depleted.

Soil physical conditions affected by landscape recontouring and which may inhibit plant growth

On the rolling to strongly rolling terrain involved in landscape recontouring the majority of soils are shallow or moderately deep, stony or very stony, have coarse-structured and/or compact subsoils, limited rooting depth and water storage capacity. These profile characteristics and properties in combination with the prevailing climatic conditions mean the establishment and maintenance of a vigorous vegetative cover is difficult.

Soil physical conditions that are likely to be affected by landscape recontouring and which may limit plant growth include:

(a) A-horizon removal, degradation and or redistribution
(b) The formation of zones of compaction or reduction of soil depth to expose subsoil pans though stripping of the upper soil layers
(c) The presence or formation of contrasting layers down the profile with sharply defined boundaries which affect soil moisture properties such as drainage characteristics
(d) Both (b) and (c) above increase the possibility of increased runoff
(e) Ponding water on the soil surface
(f) Water tables within 1 m of the surface
(g) The presence of anaerobic conditions, indicated by blue-grey soil colours and/or sulphurous-smelling soil material
(h) The presence of sand or clay textured materials within 1 m of the soil surface (these materials store only small amounts of plant available water and so make the soil drought prone)
(i) Buried organic material (vegetation or topsoil) within 2 m of the soil surface

These factors in combination with the natural characteristics of the dominant Pallic soils means that any landscape recontouring should be undertaken in a carefully planned and controlled manner.

4. Discussion

The prime purpose of landscape recontouring is to create land that is suitable for viticulture. As such, the preservation and redistribution of agromonically important soil, or the rebuilding of a soil profile with properties that will ready allow plant root extension, are paramount. On- and off-site erosion and deposition and the impact on natural drainage conditions should be minimised. Ideally operations should be completed as quickly as possible to minimise potential erosion risks, and be undertaken during the drier part of the year.

4.1 Topsoil loss, redistribution and/or degradation

As topsoil depths are limited, construction should be designed to preserve topsoil at the surface. Topsoils contain large amounts of organic matter, which is vital for plant growth as it serves as a reservoir of plant nutrients and contributes to good soil physical properties, especially with respect to infiltration and hydraulic conductivity. Reduction in topsoil organic matter and hence soil fertility levels can cause nutrient and carbon cycle deficits, and negatively affect physical and biological soil conditions. Topsoil exposure and susceptibility to wind, sheet wash, or rill erosion should be minimised wherever possible by maintaining or re-establishing a vigorous vegetative cover.

Typical natural depths of silt loam topsoil in this Pallic soil environment is approx 15 cm. Silt loam topsoil depths of approx. 15 cm should be evenly respread on recontoured, ripped surfaces. Topsoils should not be replaced directly on contrasting materials such as clays as this could result in poor water infiltration and, potentially, erosion. Whereever possible an intermediate transitional layer should be reconstituted by incorporating A-horizon material.

Topsoils should not be buried within fill. Decomposition of buried topsoil and organic matter can lead to anaerobic conditions, and an increased risk of slope failures of fill materials.

4.2 Surface and subsurface compaction

Surface and subsurface compaction by earthmoving machinery results in increased bulk density, aggregate density, and penetration resistance; reduced aggregate stability, infiltration and hydraulic conductivity rates; restricted profile drainage; water retention; reduced plant available water; and aeration. These features singly or in combination restrict root growth, limit general plant vigour, and increase the site's susceptibility to surface runoff, wind and fluvial erosion.

The type and size of machinery, bulldozers, tracked hydraulic excavators, scrapers, rubber-tyred truck and trailer units, etc., and their operation need to be matched with the soil (especially soil water content) and site conditions to minimise their impact on soil and subsoil physical characteristics, especially soil structure. Compacted layers need to be ripped and cultivated to allow effective infiltration

4.3 Cut benches and batters

Inadequate restoration procedures on cut benches and batters in materials with poor physical characteristics for plant growth are likely to be common. The materials exposed include clays, which have low porosity, low plant available water, poor drainage, and are susceptible to compaction and sheet erosion. Exposure of high-sodium subsoils and the possible increased risk of tunnel gully initiation through slaking and dispersion are likely to be an issue, especially on the Wither, Argillic-sodic Fragic Pallic soils. Over-steepened cut banks can be subject to slope failure, especially as they seldom have any solum restoration, have little or no vegetative cover, and are also prone to surface erosion.

4.4 Fills

Large fills should be avoided if possible. Fills should be adequately constructed with appropriate drainage, and not contain adjacent layers of texturally contrasting materials, topsoil or peat. Poorly constructed and drained fills are potentially unstable and susceptible to slope failure when saturated.

4.5 Erosion of restored surfaces

Sheet and rill erosion of restored solum can occur, especially immediately after restoration, before a stabilising vegetative cover can be established. Eroded material is liable to be deposited downslope, frequently burying more productive soils, or infilling natural or artificial drainage channels. Stabilisation, restoration and revegetation of recontoured surfaces will be difficult without irrigation due to the generally unfavourable soil, subsoil and climatic conditions.

Other off-site issues that need to be carefully managed include the potential for increased runoff and sedimentation in waterways and wetlands, contamination of waterways and wetlands by suspended sediment, and the redistribution of soil materials down slope.

4.6 Recontouring procedures currently being undertaken in Marlborough

Currently the actual physical processes involved in land recontouring in Marlborough are poorly known and inadequately documented. To what depths are soils typically removed? Are topsoils being replaced? Are topsoils and subsoils being stockpiled, and if so where, for how long, and under what conditions? Where is any excess soil material going? All these on- and off-site procedures and conditions need to be investigated and documented.

5. Summary

There are a number of environmental issues associated with landscape recontouring being undertaken in Marlborough.

Landscape recontouring is occurring on strongly rolling to moderately steep hill and downland slopes, colluvial footslopes, and low-angle fans with variable degrees of dissection. These landforms are underlain by loose to very compact or weakly consolidated lithologies that are prone to sheet, rill, tunnel gully and gully erosion. The redistribution of eroded materials both on- and off-site and their transport through the drainage network are potential issues in this environment.

The recontoured landscapes are either mantled by silty loess or have loess as a significant soil-forming component. These predominantly silty Pallic Soils have many soil properties that make them a demanding environment for plant establishment and growth, especially on bared surfaces and on sunny aspects. High slaking and dispersion potential, high-bulk-density subsoil horizons with restricted permeability, limited potential rooting depths and soil moisture storage, and fragile topsoil structures that break down under prolonged impact by heavy machinery or by continuous tillage are properties that must be carefully managed to minimise detrimental impacts.

On the rolling to strongly rolling terrain involved in landscape recontouring, existing soil profile information is limited. Better soil information is needed to identify environmental issues and to develop guidelines for sustainable recontouring on these landscapes. A programme to address this shortage of soil profile characterisation and property determination is highly recommended.

6. Recommendations

1. That a database be set up that accurately records the location and extent of all the known landscape recontouring sites in the Marlborough District.
2. That the characteristics of each site be accurately recorded and validated.
3. That the development history, project plans, construction methodology and procedures used at each site are recorded.
4. That a brief environmental impact assessment of each site be undertaken to identify any potential on- and off-site environmental hazards.

5. That a monitoring plan be designed and implemented based on the level of environmental hazard determined from 4 above.
6. That baseline soil profile characterisation of the dominant soils involved in landscape recontouring are established by undertaking a programme of representative profile sampling, description, characterisation and analyses.
7. That a study be considered that compares and contrasts in situ soil characteristics and behaviour (e.g. slaking, dispersion, soil infiltration rates, aggregate stability tests) on representative natural and recontoured sites in order to quantify the impact of recontouring on soil properties.
8. That the value of developing a set of best management practices or guidelines for landscape recontouring in this environment be investigated.

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