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Information to support the AgResearch Soil and Landscape Risk Framework for the Marlborough District Council

Report prepared for Marlborough District Council

RE500/2015/056

June 2015

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1. Executive Summary

In 2011 AgResearch provided the Marlborough District Council with a report "*Categorising the environmental risk from land application of liquid wastes based on soil properties*" (Houlbrooke et al. 2011). The report provided details of the AgResearch Soil and Landscape Risk Framework for the safe application of farm dairy effluent to land. A spatial distribution of soils and their associated risk was provided for select areas (primarily intensive agricultural landuse) of the Marlborough region. The 2011 report also provided some basic information on the sustainable management of winery and domestic wastewaters applied to land.

This report provides a summary of the methodology that was undertaken to develop the AgResearch Soil and Landscape Risk Framework, as well as the map of soil distribution by risk category within the Marlborough region. It is the intention of the Marlborough District Council that this brief report accompanies a Soil Trigger Map created by the Marlborough District Council.

Effluent attenuation in the soil's active root zone is the key objective of a land-based effluent system and is influenced by combination of factors including the soil's hydraulic properties and the method (rate and depth) by which effluent is applied. The AgResearch Soil and Landscape Risk Framework identifies suitable methods for applying and scheduling effluent applications with consideration of important soil and landscape factors. The framework identifies soils as category A, B, C, D, and E. A map of soil risk across the Marlborough Region has been created by AgResearch based on soil information (both spatial and static) obtained from the New Zealand national soil databases.

Marlborough District Council has created a soil trigger map that incorporates some of the data contained in this report and the earlier report '*Categorising the environmental risk from land application of liquid wastes based on soil properties*' (Houlbrooke et al. 2011). The Marlborough District Council has also incorporated additional information into the trigger map relating to a sensitive catchment zone feeding an aquifer and the distinction of loessal soils. However, AgResearch has not been involved in developing the additional information incorporated in the soil trigger map which relates to nitrogen leaching and erosion risks rather than effluent treatment. The issue of the risk of nitrogen leaching from the land use activity is a different assessment than that for the risk of land application of farm dairy effluent.

2. Introduction

The objective of this report is to provide a brief summary of the AgResearch Soil and Landscape Risk Framework for applying farm dairy effluent to land and an overview of the methodology used to create the soil risk map included in the 2011 report "*Categorising the environmental risk from land application of liquid wastes based on soil properties*" (Houlbrooke et al. 2011).

A more detailed description of the AgResearch Soil and Landscape Risk Framework including a list of soil types in the Marlborough Region along with their associated risk category can be found in Houlbrooke et al. (2011).

Marlborough District Council has created a 'soil trigger map' that incorporates some of the data contained in this report and the earlier report 'Categorising the environmental risk from land application of liquid wastes based on soil properties' (Houlbrooke et al. 2011). The current report provides supporting information relating to soils identified in the Marlborough District Council soil trigger map as being high risk for farm dairy effluent application due to impeded drainage. It is important to note, the Marlborough District Council have also incorporated additional information into the trigger map relating to a sensitive catchment zone feeding an aquifer and the distinction of loessal soils. However, AgResearch has not been involved in the development of the soil trigger map which relates to leaching and erosion risks as well as effluent treatment. The issue of the risk of nitrogen leaching from the land use activity is a different assessment than that for the risk of land application of farm dairy effluent

3. Basic concept of a land based effluent system

For a land treatment system to be sustainable, it must be efficient in both the retention of farm dairy effluent (FDE) in the soil and the subsequent uptake by plants of the nutrients applied in the effluent. The longer the effluent resides in the soil's active root zone, the greater the opportunity for the soil to attenuate nutrients and maximise their utilisation by the plant.

4. Key principals of effluent hydraulics in soils

A soil's drainage capacity is usually determined by soil texture, pore continuity and location of the water table. Three main mechanisms of effluent movement in soils that are affected by drainage characteristics include:

1. **Matrix flow**- effluent drains through soil in a relatively even manner, wetting the whole soil profile. The percolation of effluent through small pores (micropores) enables a high degree of contact between effluent and the soils reactive surfaces. Well-drained soils typically have high infiltration rates and direct losses of farm dairy effluent in overland flow or subsurface drainage are unlikely, even during periods of low soil water deficit.

2. **Preferential flow**, or bypass flow, describes the rapid flow of effluent through preferred pathways such as earthworm and old plant root channels, continuous cracks or large pore spaces. A large proportion of the soil matrix is bypassed during the drainage process and therefore there is limited contact between effluent and soil. Direct drainage of farm dairy effluent contaminants is commonly observed in soils that exhibit preferential flow characteristics.

3. **Overland flow** (sometimes referred to as surface runoff) is the main mechanism of water movement across the soil surface which can convey effluent from land to surface water. The combination of low soil infiltration rates and wet soil conditions on sloping land will provide the greatest risk for overland flow generation.

5. The AgResearch Soil and Landscape Risk Framework

A management framework has been constructed to guide appropriate effluent management practice considering the effects-based assessment of different effluent land management units (Table 1).

Table 1. Minimum criteria for a land-applied effluent management system to achieve.

Soil Category	A	B	C	D	E
Soil and landscape feature	Artificial drainage or coarse soil structure	Impeded drainage or low infiltration rate	Sloping land (>7°) or land with hump & hollow drainage	Well drained flat land (<7°)	Other well drained but very stony x flat land (<7°)
Application depth (mm)	< SWD*	< SWD	< SWD	< 50% of PAW#	≤ 10 mm & < 50% of PAW#
Instantaneous application rate (mm/hr)	N/A**	N/A**	< soil infiltration rate	N/A	N/A
Average application rate (mm/hr)	< soil infiltration rate	< soil infiltration rate	< soil infiltration rate	< soil infiltration rate	< soil infiltration rate
Storage requirement	Apply only when SWD exists	Apply only when SWD exists	Apply only when SWD exists	24 hours drainage post saturation	24 hours drainage post saturation
Maximum N load	150 kg N/ha/yr	150 kg N/ha/yr	150 kg N/ha/yr	150 kg N/ha/yr	150 kg N/ha/yr
Risk	High	High	High	Low	Low

* SWD = soil water deficit, # PAW = Plant available water in the top 300 mm of soil,
x Very stony= soils with > 35% stone content in the top 200 mm of soil
** N/A = Not an essential criteria, however level of risk and management is lowered if using low application rates

5.1.1 A) Artificial drainage or coarse soil structure

Artificially drained soils have a high degree of preferential drainage pathways due to mole ploughing. Cracks created by the plough can rapidly transport effluent and therefore pose a large risk of direct loss of raw or partially-treated farm dairy effluent entering waterways via the pipe drain network.

Soils with coarse structure are generally developed with large pore spaces (strong pedality with peds >10 mm). The coarse structure causes a high degree of preferential flow of applied effluent.

5.1.2 B) Impeded drainage or low infiltration rate

Impeded drainage (usually a result of a dense soil horizon or regular shallow water table during the winter-spring period) is a key feature identified as increasing the likelihood of overland flow and preferential flow through large continuous soil pores.

5.1.3 C) Sloping land (>7°)

The recommended threshold for sloping land has been defined as 7°. There is a large risk of generating overland flow when applying farm dairy effluent to this landscape. To mitigate this risk it is essential that small application depths are appropriately timed using deferred irrigation criteria. Furthermore, it is essential that the instantaneous application rate (mm/minute) of effluent is less than the soil's infiltration rate so as to prevent infiltration excess conditions.

5.1.4 D) Well drained land

Well drained soils with little or no connection to surface water pose the lowest risk for direct losses of effluent applied to land. Well drained soils are typically characterised by high surface infiltration rates and a large degree of matrix flow.

5.1.5 E) Other well drained but very stony flat land (<7°)

The inclusion of this soil/landscape class has been added to identify that very stony, well drained land should receive farm dairy effluent applications of no more than 10mm depth irrespective of the antecedent soil water content. The depth restriction relates to the low soil water holding capacity of these soils. However, the matrix flow nature of these soils means that they can be considered to have similar management to the well-drained category in all other respects.

6. Soil criteria used in other frameworks and tools

Due to some confusion around soil categorisation methods used in various farm dairy effluent management tools (e.g. Dairy Effluent Storage Calculator, OVERSEER and S-map), the Marlborough District Council have requested a brief summary of the soil categorisation method used in these other tools.

The Dairy Effluent Storage Calculator (DESC) estimates farm-specific storage requirements using 27 years of local meteorological data on a daily time step (Horne et al., 2010). A key driver influencing storage requirement is the daily effluent irrigation depth that can be applied based on soil information. Irrigation depth is dictated by the specific soil risk criteria which include the same categories A, B, C, D and E used in the AgResearch Soil and Landscape Risk Framework.

The OVERSEER model is primarily based around knowledge of the soil's water holding capacity (or plant available water; PAW, defined in mm) which determines the total volume of effluent able to be held in the soil. The PAW is integral information to be aware of when using the Soil and Landscape Risk Framework. For instance the Framework states effluent to be applied to a depth (mm) less than or equal to the soil water deficit; where PAW minus the current soil water content determines the irrigation depth able to be applied to reach field capacity (i.e. no soil water deficit). It should be noted that OVERSEER is designed to model the long term average of nutrient dynamics within a farm. However, the Soil and Landscape Risk Framework aims to better guide the application of effluent on a daily basis.

In S-map, information relating to the soil categories in the Soil and Landscape Risk Framework are provided under the title 'Dairy effluent (FDE) risk category' (page 2 of the S-map output sheet). Information used as input into the OVERSEER model are provided under the title 'Soil information for OVERSEER' (page 3 of the S-map output sheet). An example of the S-map output sheet is provided in Appendix 1.

7. Determining effluent land management units in Marlborough

In essence, the Soil and Landscape Risk Framework relies on knowledge of:

- Soil texture and bulk density
- Drainage limitations such as a shallow water table or fragipan
- Slope of landscape

During a workshop held at Marlborough District Council (February 2011) a default Soil and Landscape Risk category was assigned to all soils on the Wairau Plain where the landuse was known to be intensive agriculture (i.e. dairying or other). Selected areas in the upper Wairau valley, Linkwater and Rai Valley were also included where relevant soil information (soil type and attributes) was available. This information was obtained primarily from the Landcare Research S-map Resource, but also from Land Resource Inventory and the National Soils Database (both databases maintained by Landcare Research Ltd; Appendix 2).

To assign a risk category for land application of farm dairy effluent, the decision flow chart shown in Figure 1 was used. The default categorisation considered all relevant data including: drainage status, stoniness, depth to stones, depth to a slowly permeable layer, permeability of the slowest horizon, water holding capacity, structural vulnerability, soil structure and water logging vulnerability.

It should be noted that knowledge of Soil Order alone was not sufficient to define the risk categorisation for the Soil and Landscape risk framework. For example, soils in the Brown Order could easily fit into categories B, C, D and E. However, Soil Orders mapped in complexes or associations (due to scale of regional mapping) were categorised by the highest risk so as to account for the greater level of management required to adequately apply farm dairy effluent.

Soils of a specific location were re-categorised accordingly from the original default if additional information was available (mainly based on data obtained from soil surveys carried out by the Marlborough District Council). A similar approach has been carried out by all other regional councils who have adopted the framework in their policy.

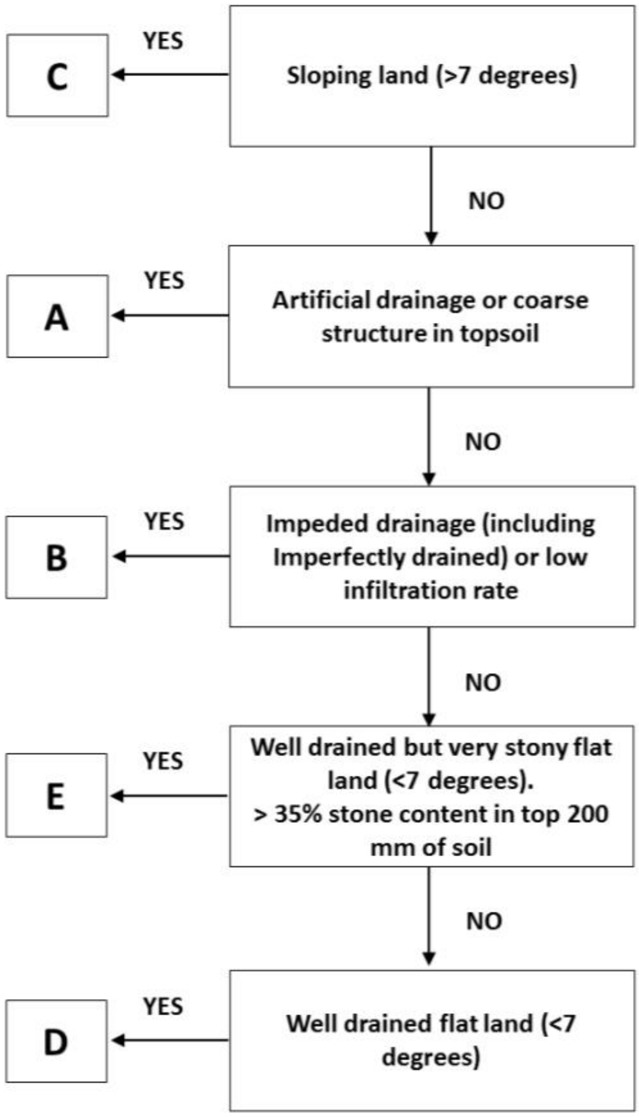

Figure 1. Soil categorisation decision tree

In the report '*Categorising the environmental risk from land application of liquid wastes based on soil* properties' default categorisations for all soils on the Wairau Plains (Figure 2) and upper Wairau Valley (Figure 3), were used to produce maps categorising the effluent management classes (at a scale of 1:50,000).

For soils outside of the Wairau Plains area (Figure 3), information from the Fundamental Soils Layers was used. The observation density in the Fundamental Soils Layer survey is less than S-Map Resource and therefore has greater uncertainty in the soil types mapped. There is more certainty of a soil's categorisation in Wairau Valley as opposed to the areas mapped up the Wairau Valley, Linkwater and Rai Valley.

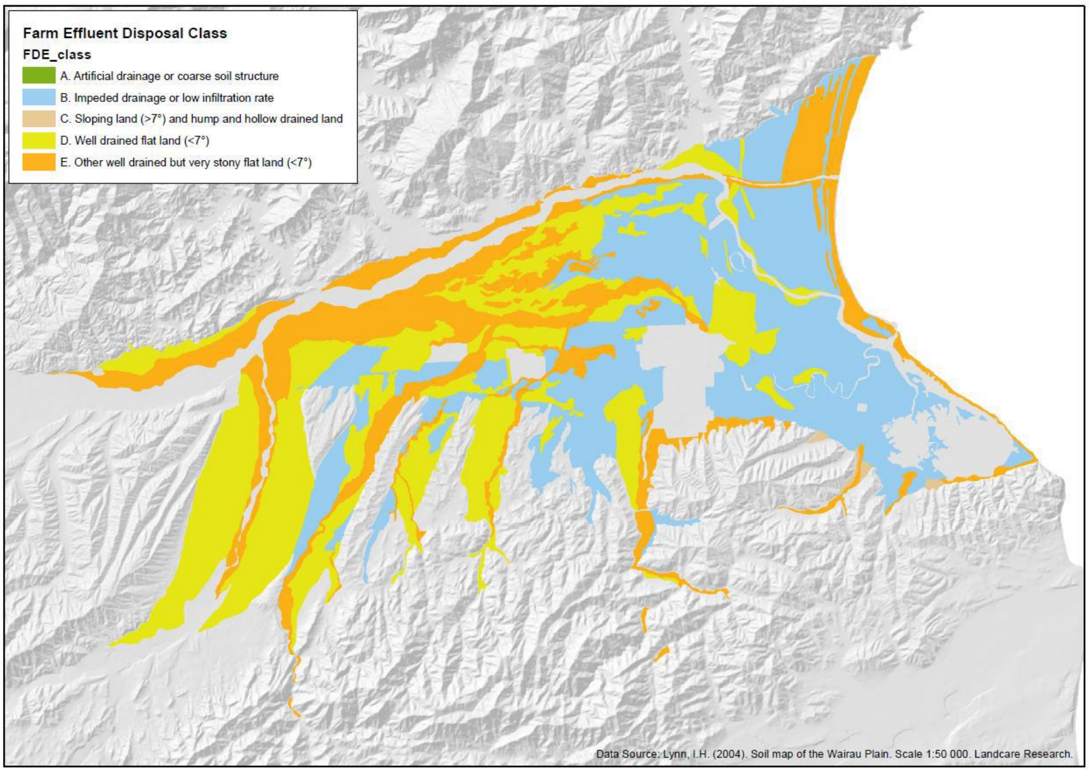

Figure 2. Wairau Valley categorisation of effluent management classes

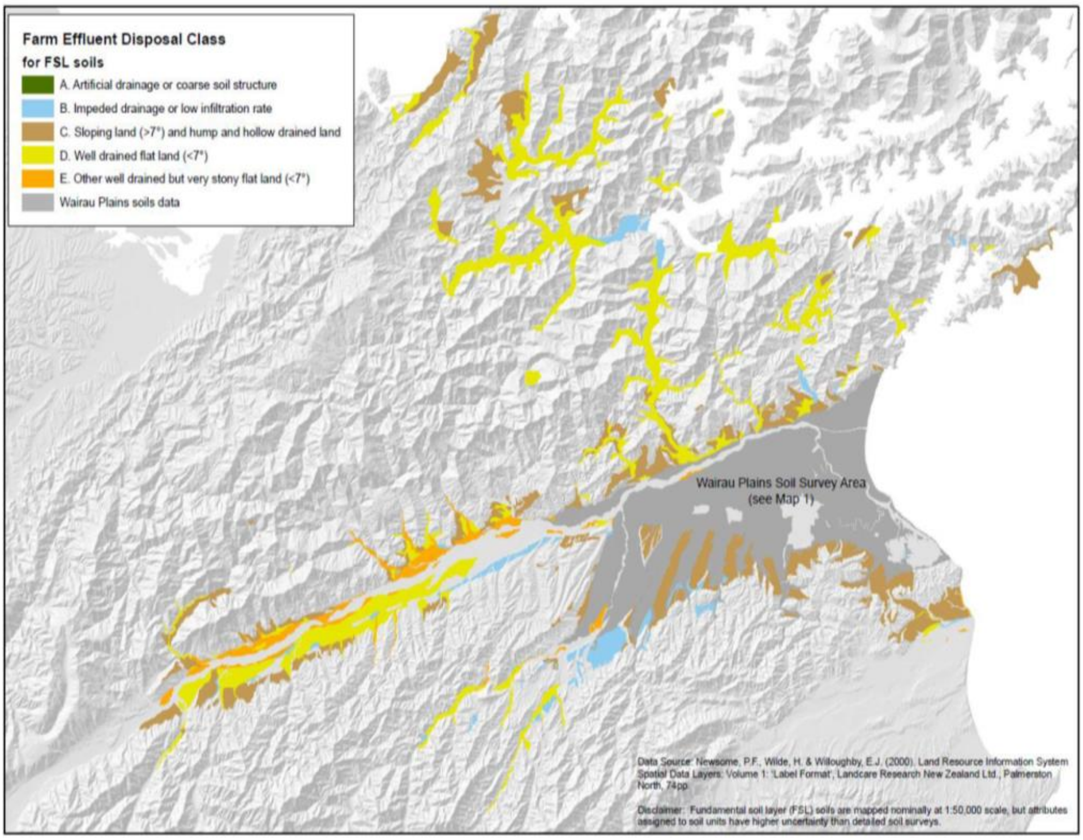

Figure 3. Marlborough region categorisation of effluent management classes

8. Soil trigger map developed by Marlborough District Council

The Marlborough District Council has developed a map titled 'Land discharge Permit Trigger' (Figure 4) which incorporates some of the soil categorisation data provided in the 2011 AgResearch Report ('*Categorising the environmental risk from land application of liquid wastes based on soil* properties'; Houlbrooke et al. 2011). The trigger map will be used by the Marlborough District Council when reviewing Resource Management Plans. Marlborough District Council are proposing a rule that prevents certain activities, for example the application of effluent, to soils identified in the soils trigger map without a resource consent application. During the consent process an assessment will then be made as to whether it is appropriate for that activity to occur on a particular soil type. The soil trigger map identifies soil types that pose a 'high risk' of nutrient loss as well as erosion and specific leaching limits for sensitive aquifers. The current report focuses on the effluent application exclusively.

AgResearch understands this map has been developed by MDC using spatial data inclusive of soil classification, family and sibling name which has been obtained from the Fundamental Soil layers database.

The map identifies three soil risk categories: 'impeded drainage', 'free drainage', and 'Loess'.

1. The impeded drainage category corresponds to the AgResearch soil and landscape risk category B 'impeded drainage or low infiltration rate' which was identified in the 2011 AgResearch Report.

2. The 'free draining' category in the *Land discharge Permit Trigger* Map has been identified by Marlborough District Council as 'high risk'. Soils in this area correspond to the AgResearch Soil and Landscape Risk Category E 'other well drained but very stony flat land ($<7^{o}$)' which is a low risk soil for land application of farm dairy effluent due to its matrix transmission of water. However, Marlborough District Council have re-categorised it as high risk due to an underlying shallow, unconfined aquifer rather than the soil properties. However, leaching risk from sensitive catchments with shallow soils relates to the intensity of land use as opposed to one activity such as farm dairy effluent application. In particular it is animal stocking rate and subsequent urine patch deposition that is the driver of N leaching risk from highly leachable soils.

3. Loess soils have been identified by the Marlborough District Council as 'high risk'. There is no specific categorisation for 'loessal soils' in the AgResearch Soil and Landscape Risk Category. However loessal soils are typically poorly drained and would be mapped as category B which is already high risk.

It is proposed by the Marlborough Regional Council that a resource consent will be required where effluent is to be applied to land classified under one of these three categories.

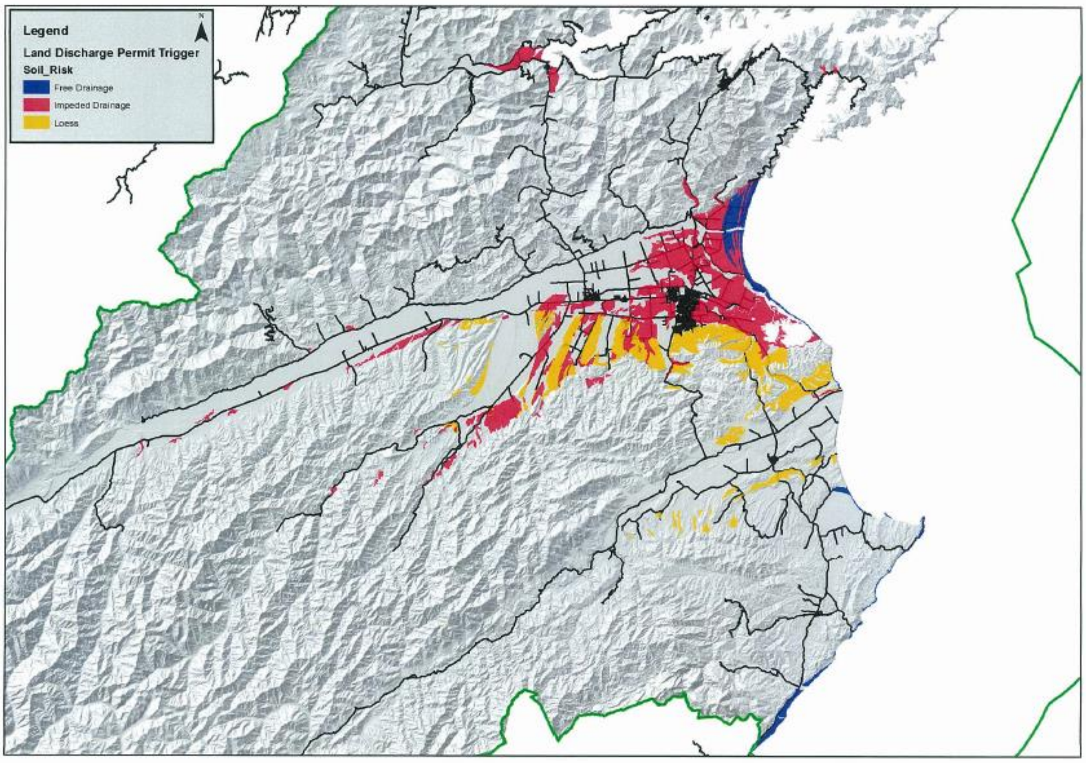

Figure 4. Marlborough District Council Land Discharge Permit Trigger Map. This map has been created by the Marlborough District Council without involvement from AgResearch.

9. Changes to the Soil Trigger Map in response to on-going soil survey information

Soil data obtained from S-map, or other resources, has been determined on a scale of 1:50,000. When soils are mapped at a larger scale, information is generally incorporated into S-map. However, this is a long process and generally carried out as the need for soil mapping arises. Despite a robust procedure for determining a soil's risk category as A, B, C, D or E, this relies on data mapped at a scale where attributes within a particular soil type may not be recognised. As discussed above, where multiple soil categories (i.e. high and low risk soils) were found in close proximity within the same soil type (as depicted on regional scale maps) a precautionary approach was taken which matched the category and subsequent management practices (in the Soil and Landscape risk framework) to the highest risk category present (in lieu of additional information).

It is recommended that land users consider undertaking a site specific investigation of soil types and associated properties by a suitably trained soil pedology expert in order to make sure their soil is appropriately categorised. In some cases there would be considerable benefit in generating a farm scale soil map that would facilitate optimal use of low risk soils and landscape features that may be identifiable at a finer scale of mapping.

We suggest the MDC Soil trigger map should be revised accordingly as new soil information comes to hand. An example of two soil types that have been re-classified into new risk categories since the 2011 report include the Koromiko and Manaroa soils. In the report ‘Soil Properties in the Havelock/Kaituna and Linkwater Districts, (Gray, 2013), these soils were classified as low risk soils, which agrees with the original AgResearch report (Houlbrooke et al. 2011). However, in the report ‘Soil Properties in the Koromiko Area’ (Rait, 2014), the soil type was re-classified as high risk following on-site characterisation. The different risk categorisation within the same soil type will reflect differences in the local soil formation processes as well as other landscape features such as water table depth. This example highlights the importance of being able to modify the soil trigger map in response to new information.

10. **References**

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Rait, R. 2014. Soil Properties in the Koromiko Area. MDC Technical Report No: 14-007. ISSN 1179-819X (Online). File Reference/Record No: E355-004-008-05/14228058. Marlborough District Council, Marlborough.

11. Appendix 1. Example S-map output sheet

Landcare Research Manaaki Whenua **SOIL REPORT**

Marlborough District Council

Report generated: 10-Jun-2015 from http://smap.landcareresearch.co.nz

This information sheet describes the typical average properties of the specified soil to a depth of 1 metre, and should not be the primary source of data when making land use decisions on individual farms and paddocks.

S-map correlates soils across New Zealand. Both the old soil name and the new correlated (soil family) name are listed below.

Family: Temuka*f*

Smap ref: Temu_50a.1

Paynter (Temuka_50a.1)

Key physical properties		
Depth class (diggability)		Deep (> 1 m)
Texture profile		Clay
Potential rooting depth		Unlimited
Rooting barrier		No significant barrier within 1 m
Topsoil stoniness		Stoneless
Topsoil clay range		20 - 35 %
Drainage class		Poorly drained
Aeration in root zone		Very limited
Permeability profile		Moderate over slow
Depth to slowly permeable horizon		Slow (< 4 mm/h)
Permeability of slowest horizon		30 - 50 (cm)
Profile available water	(0 - 100cm or root barrier)	High (224.1 mm)
	(0 - 60cm or root barrier)	Very high (136.5 mm)
	(0 - 30cm or root barrier)	Very high (76.3 mm)
Dry bulk density, topsoil		0.94 g/cm³
Dry bulk density, subsoil		0.86 g/cm³
Depth to hard rock		No hard rock within 1 m
Depth to soft rock		No soft rock within 1 m
Depth to stony layer class		No significant stony layer within 1 m

Key chemical properties	
Topsoil P retention	Medium (38%)

About this publication

- This information sheet describes the *typical average properties* of the specified soil.
- For further information on individual soils, contact Landcare Research New Zealand Ltd: www.landcareresearch.co.nz - Advice should be sought from soil and land use experts before making decisions on individual farms and paddocks.
- The information has been derived from numerous sources. It may not be complete, correct or up to date.
- This information sheet is licensed by Landcare Research on an "as is" and "as available" basis and without any warranty of any kind, either express or implied.
- Landcare Research shall not be liable on any legal basis (including without limitation negligence) and expressly excludes all liability for loss or damage howsoever and whenever caused to a user of this factsheet.

Landcare Research Manaaki Whenua

Marlborough District Council

Family: Temuka*f*

Smap ref: Temu_50a.1

Paynter (Temuka_50a.1)

Additional factors to consider in choice of management practices

Vulnerability classes relate to soil properties only and do not take into account climate or management

Soil structure integrity

Erodibility of soil material	Slight
Structural vulnerability	High (0.61)
Pugging vulnerability	not available yet

Water management

Water logging vulnerability	High
Drought vulnerability - if not irrigated	Low
Bypass flow	Slight
Hydrological soil group	D

Contaminant management

N leaching vulnerability	Very low
P leaching vulnerability	not available yet
Bypass flow	High
Dairy effluent (FDE) risk category	C if slope > 7 deg otherwise B
Canterbury typical profile class	Pd
Septic tank installation category	A1 if slope > 15 deg otherwise B2

Relative Runoff Potential

Slope	0-3°	4-7°	8-15°	16-25°	>25°
Risk	M	H	H	VH	VH

Additional information

Soil classification	Typic Orthic Gley Soils (GOT)
Family	*Temukaf*
Sibling number	50
Profile texture group	Clayey
Soil profile material	Stoneless soil
Rock class of stones/rocks	Not applicable
Rock origin of fine earth	From hard sandstone rock
Parent material origin	Alluvium

Characteristics of functional horizons in order from top to base of profile:

Functional Horizon	**Thickness**	**Stones**	**Clay***	**Sand***
Loamy Weak	15 - 25 cm	0 %	20 - 35 %	10 - 30 %
Clayey Weak	15 - 25 cm	0 %	30 - 50 %	10 - 30 %
Clayey Coarse	35 - 45 cm	0 %	25 - 55 %	20 - 40 %
Loamy Coarse Slightly Firm	5 - 35 cm	0 - 5 %	25 - 40 %	10 - 20 %

* clay and sand percent values are for the mineral fines (excludes stones). Silt = 100 - (clay + sand)

Family: Temuka*f*

Smap ref: Temu_50a.1

Paynter (Temuka_50a.1)

Soil information for OVERSEER

The following information can be entered in the OVERSEER® Nutrient Budget model. This information is derived from the S-map soil properties which are matched to the most appropriate OVERSEER categories. Please read the notes below for further information.

Soil description page

Click the 'Soil moisture values' option. Enter in the 'Sibling name': Temu_50a.1

From the 'Soil order' dropdown box select: Gley

Soil water properties	0-30 cm	30-60 cm	> 60 cm	
Wilting point (15 bar)	20	24	23	mm per 10 cm mm per 10 cm mm per 10 cm
Field capacity	46	44	45	
Saturation	61	55	53	

From the 'Natural drainage class' dropdown box select: Poorly drained

Depth to impeded drainage layer: Enter zero (no impermeable layer above 1m)

Maximum rooting depth: Enter zero (no rooting barrier above 1m)

Top soil horizon chemical and physical parameters

Anion storage capacity (ASC) 38% Subsoil clay: 38 % or phospate retention (PR):

Bulk density: 940 kg/m³

Clay: 28 %

Sand: 20 %

Sub soil [average from 10 to 30 cm]

Is compacted

(this depends on management so cannot be obtained from S-map)

Considerations when using Smap soil properties in OVERSEER

- The soil water values are estimated using a regression model based on soil order, parent rock, soil functional horizon information (stone content, soil density class), as well as texture (field estimates of sand, silt and clay percentages). The model is based on laboratory - measured water content data held in the National Soils Database and other Landcare Research datasets. Most of this data comes from soils under long-term pasture and may vary from land under arable use, irrigation, etc.

- Each value is an estimate of the water content of the whole soil within the target depth range or to the depth of the root barrier (if this occurs above the base of the target depth). Where soil layers contain stones, the soil water content has been decreased according to the stone content.

- S-map only contains information on soils to a depth of 100 cm. The soil water estimates in the > 60 cm depth category assume that the bottom functional horizon that extends to 100 cm, continues down to a depth of 150cm. Where it is known by the user that there is an impermeable layer or non-fractured bedrock between 100 and 150 cm, this depth should be entered into OVERSEER. Where there is a change in the soil profile characteristics below 100 cm, the user should be aware that the values provided on this factsheet for the > 60 cm depth category will not reflect this change. For example, the presence of gravels at 120 cm would usually result in lower soil water estimates in the > 60 cm depth category. Note though that this assumption only impacts on a cropping block, as OVERSEER uses soil data from just the top 60 cm in pastoral blocks.

- OVERSEER requires the soil water values to be non-zero integers (even though zero is a valid value below a root barrier), and the wilting point value must be less than the field capacity value which must be less than the saturation value. The S -map water content estimates provided on this page have been rounded to integers and may be assigned minimal values to meet these OVERSEER requirements. These modifications will result in a slightly less accurate estimate of Available Water to 60 cm (labelled PAW in OVERSEER) than that provided on the first page of this factsheet, but this is not expected to lead to any significant difference in outputs from OVERSEER.

Landcare Research Manaaki Whenua

MARLBOROUGH DISTRICT COUNCIL

12. **Appendix 2 Definitions of NZ soil databases**

The New Zealand Land Resource Inventory is a spatial database containing about 100,000 polygons (map units) across the country. Each polygon describes a parcel of land in terms of five characteristics or attributes (rock, soil, slope, erosion, vegetation). These are contained on about 400 worksheets or maps covering the whole of New Zealand.

The Fundamental Soil Layer was devised from regional soil databases and predates S-map which is considered better quality and more reliable data. However, there is not yet national coverage for S-map. FDLs contain spatial information for 16 key soil attributes. Which were selected through the consultation process with stakeholders. They generally fall into the three groups: soil fertility/toxicity, soil physical properties particularly those related to soil moisture, and topography or climate. Parameters include slope, potential rooting depth, topsoil gravel content, proportion of rock outcrop, pH, salinity, cation exchange capacity, total carbon, phosphorus retention, flood interval, soil temperature, total profile available water, profile readily available water, drainage, and macropores (shallow and deep).

The New Zealand Soil Classification was developed in the 1980s and provides the framework by which New Zealand soils are classified.