BEFORE THE HEARING COMMISSIONERS
AT SOUTHLAND REGIONAL COUNCIL

IN THE MATTER	of the Resource Management Act 1991 ("**the Act**")
AND	
IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of the proposed Southland Water and Land Plan

STATEMENT OF EVIDENCE BY ANDREW JOHN BARBER
FOR HORTICULTURE NEW ZEALAND

12 MAY 2017

SUMMARY STATEMENT

1. My evidence addresses the following:

(a) Rule 13 – subsurface drainage. Restricting the trigger for providing a drainage map when conducting to drain maintenance to when it is possible.

(b) Rule 25 – cultivation. I agree with the provisions of Rule 25, with the suggestion that the controlled activity Rule 25 (c) could be made permitted where the alternative mitigation measures are checked by an external agency such as NZ GAP as part of their Farm Environment Management Plan.

(c) Rule 36 – Horticulture Wash-water. Support that the main contaminant is sediment. The rules align with our draft COP. Where discharged washwater is following the COP there is no benefit from using a 20m^3/day discharge limit to trigger a resource consent. There needs to be an exception for the chemical presence of HSNO approved sanitisers that have been used following the label and NZS 8409:2004.

(d) Rule 59 – Culverts and sediment traps. Clarify that sediment traps used in cultivated production are not captured by this rule.

QUALIFICATIONS AND EXPERIENCE

2. My name is Andrew John Barber. I am a Director of Agrilink NZ and work as an Agricultural Engineering Consultant based in Auckland (www.agrilink.co.nz). I have a Bachelor of Horticulture (Tech) with first class honours from Massey University. I am an adjunct senior lecturer at Lincoln University.

3. I have spent over 20 years as a consultant in the agricultural industry, specialising in resource use optimisation (energy, water, soil and agrichemicals). This predominantly involves benchmarking and individualised reporting, along with soil erosion and sediment design, preparation of guidelines, and research for indoor and outdoor vegetable production.

4. In my years as a consultant I have helped develop vegetable industry erosion and sediment management guidelines, and individual cultivated property erosion and sediment control plans.

5. I was Project Manager of the Franklin Sustainability Project ("FSP") and provided technical advice on managing soil erosion on cultivated land. This was a multi-stakeholder project that ran between 1996 and 2004, which, while having a broad goal of

improving the overall sustainability of outdoor vegetable production in the Franklin region, had a clear focus on keeping soil on the paddock and mitigating any effects of off-site discharges.

6. I have also worked on stormwater projects for the Franklin District Council (now Auckland Council). I designed the stormwater system for Pukekohe Hill and the Bombay Hills which ensured an integrated system between the council and grower drains, sized to cope with high intensity storm events.

7. I authored the Horticulture New Zealand publication 'Erosion and Sediment Control Guidelines for Vegetable Production' (June 2014).

8. I co-authored the Horticulture New Zealand publication 'Greenhouse Nutrient Discharge Checklist', 'Greenhouse Nutrient Discharge Decision Tree', Management Plan, and Case Study (June 2016).

9. I am the project manager and researcher conducting erosion and sediment control trials for the MPI Sustainable Farming Fund ("MPI SFF") project 'Don't muddy the water - Quantifying the effectiveness of sediment control on cultivated land' (Project number 407925). This is a 3 year project that began in July 2015.

10. I have been provided with the Code of Conduct for Expert Witnesses contained in the Environment Court's Consolidated Practice Note dated 1 December 2014. I have read and agree to comply with that Code. This evidence is within my area of expertise, except where I state that I am relying upon the specified evidence of another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

SCOPE OF EVIDENCE

11. This evidence provides a technical assessment of those provisions on which Horticulture New Zealand ("**HortNZ**") submitted, and addresses the Section 42A report prepared by Environment Southland and dated April 2017.

12. My evidence covers the following:

    (a) Rule 13 – Subsurface drainage

    (b) Rule 25 – Cultivation

    (c) Rule 36 – Horticulture wash-water

SUBMISSIONS AND COUNCIL RECOMMENDATIONS IN THE S42A REPORT

Rule 13 – Subsurface drainage

13. In response to concerns raised by submitters about potentially minor drain maintenance triggering the requirement to provide council with a detailed drainage map, and this not being possible due to the nature of the maintenance work, I suggest Rule 13 (a) (v) should be amended to:

> *for any new drains, or where possible when conducting the maintenance or upgrading of existing drains, the location of the sub-surface drains and outlet relative depth and position is mapped and provided to Environment Southland upon request;*

14. This ensures all new drains are mapped and provided to council, which is easy to do, and only where the maintenance work discovers the location of existing drains does this trigger the requirement to map and supply the drainage location to council.

15. I note the addition of Rule 13 (a) (viii) requires all existing outlets to be mapped. In the course of doing this, it is likely that many will also provide additional in paddock location details.

Rule 25 - Cultivation

16. I do not support the blanket use of a 5m, much less a 20m vegetated buffer in a cultivation rule. Vegetated buffers are simply one measure in a wide range of mitigation measures for cultivated erosion and sediment control. A full description of these control measures is included in the Erosion & Sediment Control Guidelines for Vegetable Production Version 1.1 (2014).

17. While vegetated buffers may be the most appropriate sediment control measure on flat land (< 4º), that may not be the case on land > 4º irrespective of the buffer width. We are currently conducting research through an MPI SFF project to measure the effectiveness of vegetated buffers on cultivated land. On cultivated land as slope increases so does the likelihood of channelised flow. The filtering effect of vegetated buffers is lost where water flows through them in channels.

18. Increasing the buffer width from 3 metres to 5 meters has been justified based on research conducted on a pastoral farm where water goes through the buffer as sheet flow. On cultivated land

water tends to channelise, reducing the effectiveness of a buffer. Simply making it wider does not make it more effective. I support the use of a vegetated buffer where appropriate but seek that provision be made for alternative permitted sediment control measures.

19. A 20-metre buffer on land steeper than 9 degrees is unlikely to reduce sediment loss on cultivated land with channelised flows.

20. A better environmental outcome would be achieved by giving the flexibility of using the buffer strip or alternative measures as outlined in the Erosion & Sediment Control Guidelines for Vegetable Production and captured in a FEMP. This is also the recommendation of science staff (paragraph 7.624) when on land steeper than 9 degrees reducing the buffer to 5m would be acceptable, provided adequate erosion and sediment mitigation measures were undertaken.

21. I therefore support the addition of Rule 25 (c), with the exception that it could be a permitted rather than controlled activity if the FEMP was reviewed by an external organisation such as NZ GAP.

22. For clarity when silt traps are described in the E & S Control Guidelines for Vegetable Production these are not built *in, on, under or over the bed of any river, modified watercourse, or lake*, so are not captured by Rule 59.

<u>Rule 36 - Horticulture wash-water</u>

23. I support the proposed amendments to Rule 36 (b) to address overland flow and not irrigating saturated soils. This aligns with the draft Vegetable Washwater Code of Practice and generally good irrigation practice to minimise overland flow and leaching below the active root zone.

24. I support the comment in paragraph 7.1012 that the main washwater contaminant is sediment and that drainage through the soil profile is a suitable way of removing sediment. Studies cited in a literature review on vegetable washwater[1], conducted to support the development of a Vegetable Washwater Code of Practice, showed that the rate of removal of suspended sediment passing through 1m of soil was between 93% and 100%. Outflows were all less than 1.2 g/m^3, well below the environmental trigger level of 50 g/m^3.

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[1] Barber, A., Wharfe, L, and Hodgson, V., 2017. Vegetable Washwater – Literature and Council Policy Review. Prepared for Horticulture New Zealand.

25. Based on the effectiveness of soil to filter sediment the Vegetable Washwater Code of Practice uses both infiltration beds and land application as effective disposal techniques. The infiltration beds are a viable option if nutrient levels in the discharge water are below threshold levels, otherwise land application is used to mitigate nutrients leaching into water.

26. Where Good Practice is being followed, there seems no benefit from setting a daily volume limit. My recommendation is that discharges greater than $20m^3$/day are a permitted activity where the COP has been implemented.

27. Rule 36 (c) may have the unintended consequence of capturing any washing operation that uses sanitisers. Sanitisers are often used as part of human health risk mitigation to bacterial contamination (*E. coli*). The rule should recognise that these sanitisers can be used and may be present in the discharged water at very low levels. Nylate, a commonly used sanitiser, is an organic product which is broken down by dirt and pathogens found in the washwater. Consequently, when HSNO approved sanitisers are used following the label recommendations and meet NZS8409:2004 Management of Agrichemicals there is minimal risk to the environment.

28. Rule 36 (c)should have this exclusion added.

> *the discharge only contains water and soil, and there are no measurable concentrations of chemical additives present in the discharge* <u>*except for HSNO approved sanitisers that are used following the label and comply with NZS 8409:2004 Management of Agrichemicals.*</u>

Annexed to this document to support this evidence are: Appendix A - HortNZ Draft Vegetable Washwater Discharge Code of Practice, and Appendix B - HortNZ Erosion & Sediment Control Guidelines for Vegetable Production.

Andrew Barber

12 May 2017

APPENDIX A

DRAFT Version 1.0

Draft Vegetable Washwater Discharge Code of Practice

The requirements for achieving Good Practice

The following checklist, decision tree, and reference values is a self-audit to assist you in determining if your discharge of vegetable washwater meets Good Practice.

The primary contaminant is vegetable washwater is sediment. Disposal of washwater through the soil using an infiltration bed is a very effective way of removing suspended sediment. Consideration also needs to be given to nitrogen. If the levels are elevated then land application through an irrigation system may be more appropriate. When applying washwater to land the required application area is generally determined by the volume of water, not the nitrogen level as is the case for most other agricultural discharges.

Good Practice is to discharge the washwater through an infiltration bed where nutrient levels are low enough or apply the washwater to land through an efficient irrigation system where nutrients can be taken up by the plants. With an irrigated system, winter storage is one of the major considerations.

To meet Good Practice you need to achieve the conditions on the following checklist.

Further information on vegetable washwater systems can be found in *Vegetable Washwater – Literature and Council Policy Review* (Barber, Wharfe and Hodgson, 2017), available from HortNZ.

Always aim for Good Practice rather than just achieving council compliance.

Contacts

Horticulture New Zealand 04 472 3795

Draft Version 1.0, May 2017

Good Practice

Good Practice	✓ ×
Minimise discharge volumes through water conservation	
Minimise the volume of water being discharged. This includes monitoring and tracking water use, leak detection, and nozzles attached to end of hoses rather than the tap end. Where possible reuse in continuous recycling system filtered and disinfected water.	
Use of sanitisers	
Any sanitisers used in the washing process must have HSNO approval, follow the label recommendations, and meet NZS 8409:2004 Management of Agrichemicals.	
Soil-aquifer treatment system (SAT) - Infiltration bed	
Pre-treat with a sediment trap to minimise sediment load and clogging.	
Inflow N concentrations are < 1.2 ppm and P < 1.5 ppm[1], or there is a monitoring system below 1m to document that there are not elevated nutrient levels in the drainage water.	
Land application - Infrastructure and maintenance	
All discharged vegetable washwater solution is fully contained within the system (pipe work, sumps, and ponds) prior to land application.	
There are no leakages or discharges to water or land from the storage structure. This means all storage ponds must be adequately sealed and all tanks must be maintained in a water tight condition.	
The storage system for discharged washwater must have sufficient capacity to store water when soil conditions are unsuitable for application. The volume of storage required will vary depending on the volumes discharged in winter, and the soil type. See the Decision Tree for calculating these volumes.	
Application - Getting the right amount of discharged washwater on the soil at the right time and in the right place	
Application does not occur when soils are wet and do not have the capacity to fully accept the discharged solution. The guidance is that soils must have greater than a 10mm soil moisture deficit in the top 300mm of soil.	
No discharges into surface water can occur. The irrigation system must be setup to ensure that discharged washwater is applied in a way that does not result in runoff to waterways or artificial water courses.	
Discharges must not result in ponding of more than 3 hours duration following application.	

1. Inflow N and P concentrations are based on 50% and 98% removal respectively in the top 1m of soil to achieve the environmental standard of 0.61 ppm N and 0.03 ppm P.

Application - Getting the right amount of discharged washwater on the soil at the right time and in the right place (continued)	✓ ×
The application area is large enough to prevent the soils from becoming saturated or exceeding a nitrogen application rate of 150 kgN/ha/yr. See the following *Vegetable Washwater Discharge Decision Tree* for an example of the required application area.	
There is a 20m buffer between the application area and landholding boundary, lake, river, modified watercourse, artificial watercourse, ephemeral waterway, the coastal marine area, or natural wetland.	
There is a 20m buffer between the application area and residential dwelling.	
There is a 250m buffer between the application area and drinking water supply site.	

Recordkeeping for evidence of Good Practice	✓ ×
Correct storage volume (m^3).	
A property map with the size and unique code of each paddock used for irrigating discharged washwater.	
Soil moisture level. Soil moisture probes (see possible examples below), physical soil checks and rainfall records can be used to show that irrigation occurred when the soil had adequate capacity for the volume of solution applied.	
The date, soil moisture level, field code, area irrigated, and total volume of washwater applied is recorded.	

Topography, rainfall, soil moisture, soil type and drainage all influence the risk of runoff and ponding. Therefore, the soil moisture at the time of irrigation must be checked to ensure there is adequate capacity in the soil to accept the discharged solution. Good practice is to walk over the irrigation area prior to each application event to check soil moisture conditions. Soil moisture can be checked using soil moisture probes or records of evapotranspiration, rainfall and irrigation events. As a general guide between May and August do not apply irrigation unless there has been 10 days without rain (<2mm).

Five key elements of successful land application systems	✓ ×
Have sufficient winter storage.	
Know the soil moisture to determine when and how much to irrigate.	
Know and track water volumes and nitrogen application rates.	
Ensure even irrigation.	
Keep a record of your activities and prevailing conditions.	

Possible soil moisture probes:

Quick Draw Tensiometers
Approximately $975

Hand-held time-domain reflectometer (TDR)
Approximately $1,300 - $1,900

Vegetable Washwater Discharge Decision Tree

Are N concentrations < 1.2 ppm and P < 1.5 ppm?

Yes → Consider a soil-aquifer treatment system (SAT) using an infiltration bed.

No ↓

Reference values.
Your measured values should be used as soil characteristics make a significant difference, and there is very limited literature.

Calculate the volume and key characteristics of the discharge.

Discharge prior to treatment	Root vegetables	Lettuce
Discharged water (m^3/t)	1.5 – 3.0	2.2 – 3.2
Sediment (g/m^3)	10,000	-
Nitrogen (ppm)	80	-
E. coli (cfu/100ml)	0.6	0.5

Next ↓

Is irrigating to your land an option?

No → Other options include:

- Collect and supply to a neighbouring landowner with land for irrigation.
- Truck it away as waste.
- Connect to a sewer – consents may be required.
- Investigate denitrification / filter beds.
- Obtain a consent to discharge.

Yes ↓

Calculate the area needed.

Disposal area (ha) 1,000 tonnes - per year	Root vegetables	Lettuce
Water limit @ 150mm/year	**2.0**	-
Nitrogen limit @ 150kgN/ha/year	1.6	-

Next ↓

Calculate the storage volume needed.

Sufficient storage is crucial. You may need 3 months or more storage, at winter discharge rates. See the next page for examples.

Winter Storage 3 months Processing – 250 tonnes	Root vegetables	Lettuce
Covered storage (m^3)	560	675
Uncovered storage (m^3)	1,200	1,500

Next ↓

How will you manage the land application?

Refer to Irrigation NZ guidelines

Next ↓

Do you meet the permitted activity conditions in the Regional Plan?

See regional requirements on the next page

No → Apply for a resource consent.

Yes ↓

Apply discharged washwater to land using good management practices, including keeping records to show how conditions are being met.

Storage – Southland

Sufficient storage is essential for successfully managing your washwater discharges.

Calculating the required storage needs to take into account the period when the soil cannot be irrigated, the discharge rates over this time, the soil type, and for uncovered storage ponds rainfall (rain falling directly on the pond increases the storage requirements).

Dairy NZ has guidance on storage requirements, soil risk, and application systems. The storage calculations below were determined using their Storage Calculator http://www.dairynz.co.nz/environment/effluent/effluent-storage/

The tables below give the storage requirements for an operation processing 1,000 tonnes of root vegetables discharging an average of 10 m^3/day (3,000 m^3/year) into uncovered storage, and where the operation is irrigating onto high or low risk soils. These soil risk categories are described in the Dairy NZ booklet *Pocket guide to determine soil risk for farm dairy effluent application*. High risk soils generally have one or more of these characteristics: > 7 degrees, impeded drainage, low infiltration rate (<10mm/hr), mole or pipe drains, or coarse topsoil structure (> 80% of soil aggregates captured on a 10mm sieve).

High risk soil – average discharge of 10m^3/day when the soil is saturated (cannot irrigate)

	Uncovered storage (includes direct rainfall)				
	Volume (m^3)	Length (m)	Width (m)	Depth (m)	Batter (slope)
Gore	1,200	35	20	4	1.5 : 1
Woodlands	1,600	41	20	4	1.5 : 1

Low risk soil – average discharge of 10 m^3/day

	Uncovered storage (includes direct rainfall)				
	Volume (m^3)	Length (m)	Width (m)	Depth (m)	Batter (slope)
Gore	130	15	10	3	1.5 : 1
Woodlands	140	20	9	2	1.5 : 1

Council	Permitted [1]		Conditions
	Discharge to water	**Discharge to land**	
Southland Regional Council	x	✓ < 20 m^3/day	No overland flow, ponding, or application to saturated soils. No measurable concentrations of chemical additives and a range of separation distances.

1. Permitted subject to conditions.

APPENDIX B

Erosion & Sediment Control Guidelines for Vegetable Production

Prepared by Andrew Barber for:
Horticulture New Zealand
June 2014

PUKEKOHE Vegetable GROWERS ASSOCIATION

Horticulture™ New Zealand

AGRI LINK

EMPOWERING SUSTAINABLE GROWTH

Erosion & Sediment Control Guidelines for Vegetable Production

Good Management Practices

Version 1.1

June 2014

Prepared by
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Cover picture courtesy of Balle Bros - Pukekohe.

This Guideline has been prepared by Andrew Barber of Agrilink NZ with contributions and reviews by commercial vegetable growers, Horticulture New Zealand, Auckland Council and Environment Waikato their contractors and staff. It has been built upon the FSP Doing it Right and the Code of Practice for Commercial Vegetable Growing in the Horizons Region.

INTRODUCTION

These Guidelines have been built upon many years of grower experience and research trials conducted during the Franklin Sustainability Project (FSP), as well as the more recent Holding it Together (HIT) project and the Code of Practice developed in the Horizon Region. The Guidelines also draw on Auckland Council's TP90 Erosion and Sediment Control Guidelines for Land Disturbing Activities in the Auckland Region and the 2007 changes, plus TP223 Forestry Operations in the Auckland Region A Guideline for Erosion & Sediment Control.

The recommended volumes and area protected using various sediment control devices differs from those in TP90, reflecting the difference in soil type and runoff factors from cultivated land compared to earthworks. It was concluded, and accepted in submitted evidence to the Environment Court, that on cultivated land 0.5% storage is equivalent to or outperforms 2.0% storage on an earthworks site. The report Justification of Silt Trap Capacity for Cultivated Land 0.5% vs. 2.0% (Barber, 2012) describes this in more detail. A copy is available from Horticulture New Zealand.

Table 1 outlines a range of control measures with estimated effectiveness and costs. The estimate of effectiveness was provided by John Dymond (Landcare Research). It assumes that the measures are used within their design limitations. For example a well-constructed Super Silt Fence protecting a small area for a short period of time while having high effectiveness would be extremely ineffective protecting a large area. There is no single silver bullet. Therefore, planning and implementation must include a number of complimentary control measures.

Table 1. Cost and effectiveness of various mitigation measures.

Control measure	**Range in effectiveness (%)**	**Cost per hectare ($)**
Detailed erosion mgmt plan	-	$80 - $180
Cover crop	90 - 99	$80
Minimum tillage	-	-
Setback or buffer strip	50 - 80	$100 - $250
Wind break crop	-	-
Stubble mulching	-	$70
Wheel track ripping or dyking	50 - 80	$35
Contour drains	30 - 70	$75
Benched headlands	50 - 80	$65
Super silt fence	80 - 95	$380
Decanting earth bund	80 - 95	$130
Silt trap	80 - 95	$750 - $1,300
Silt trap maintenance	-	$75/ha/year

How to use these Guidelines

The Guideline aims to provide information to growers on a range of possible control measures and options to assist in achieving sustainable land management. The Guideline directs growers to more detailed information contained in FSP Doing it Right, TP90 or TP223.

There are four key steps:

1. Know your paddock – undertake a paddock assessment
2. Measures to stop or control water entering your paddock
3. Erosion control measures
4. Sediment control measures.

Each step is a progression in difficulty, time and energy. It is easier to control water entering a paddock than it is to minimise erosion. Likewise minimising erosion is easier and less costly than managing sediment laden storm water leaving the paddock.

The key to minimising soil erosion is to know your paddock and identify the likely risks. A paddock assessment forms the foundation on which to implement measures that firstly stop or control water entering the paddock, secondly keep the soil on the paddock, and lastly minimise the quantity of soil that is discharged off the paddock.

Minimising erosion and soil loss is about getting each of the four steps right. Within paddock erosion control measures without the planning and risk assessment stage could lead to unforeseen washouts. Likewise erosion control measures without sediment control, leaves the downstream environment vulnerable after cultivation and harvest.

The Soil Resource

Soil is a critical resource for any commercial vegetable growing operation. Natural characteristics such as water holding capacity, soil nutrients, soil structure and biological activity all contribute to the success of a growing operation. When soil moves within or off a paddock, there is a loss in productivity and profitability. Therefore retaining soil and its inherent characteristics is critical to the business of growing.

When soil moves off the property it is not only a loss to the grower, but also creates sediment which ends up on roads, in drains, streams, rivers and lakes. These flow-on impacts create costs which are borne by the whole community.

FOUR STEPS TO MINIMISING SOIL EROSION & SEDIMENT LOSS

1. Paddock assessment

Map and describe the paddock (slope, area, history)

Identify where water is coming from

Identify where water leaves the paddock

2. Implement control measures for stopping or controlling water entering the paddock

Interception drains

Correctly sized culverts

Benched headlands

Bunds

Grassed swales
(controlled overland flow through the paddock)

3. Implement erosion control measures to keep soil on the paddock

Cover crops

Wheel track ripping / Wheel track dyking

Contour drains

Using short row lengths

Cultivation practices including minimising passes

Harvest management – timing / all-weather facilities

Post-harvest field management

Wind break crops (wind erosion)

4. Implement sediment control measures to manage the water and suspended solids that move off the paddock

Ensure access ways are <u>not</u> at the lowest point

Raised access ways / Bunds

Vegetated buffers / Riparian margins / Hedges

Super silt fences

Stabilised discharge points and drains

Decanting earth bunds and silt traps

1. PADDOCK ASSESSMENT

This is a critical step and should be undertaken for every paddock you grow in.

The assessment initially involves walking each paddock, mapping and identifying significant features (drains, culverts, slope, area, etc.) particularly overland flow paths, where water is coming from and going to, and the location and type of existing control measures. Knowing the paddock history is invaluable. This first paddock assessment becomes the basis on which control measures are built as well as future updates planned.

"When we first go into a new block, planning the layout revolves around the lay of the land…where drains logically must go…look at entry and exit points…what is happening around the block...history...row direction etc." Kevin Balle – Balle Bros

1.1 Paddock Plan

Planning should be done on a paddock by paddock basis, building up to a whole farm plan. Erosion and sediment control measures will then be better integrated with your whole farm system to have maximum impact.

Start the planning process by walking around each paddock, particularly during or after heavy rain, and mark on a paddock map:

- Where water is coming from (e.g. roads, drains, buildings etc.),
- Where water is going or should go (e.g. any overland flow paths),
- Drains and bunds,
- Any existing erosion or sediment control measures.

Also on the map:

- Note the paddock dimensions,
- Mark the direction and steepness of the slope in different parts of the paddock,
- Mark any streams and riparian strips.

A picture is worth a thousand words. It is a good idea to document your actions and keep a photographic record of where you started and what changes you have made. Also many of the erosion control measures, like cover crops and wheel track ripping, may only be visible for a few months. Documenting your use of these erosion control measures is invaluable.

This map and information will be used to plan the most efficient and effective set of erosion and sediment control measures.

Maps can be simple hand drawn diagrams, or based on electronic aerial photographs. Electronic maps are readily available from Google Maps, or the Councils' GIS systems like http://maps.aucklandcouncil.govt.nz/aucklandcouncilviewer/ or http://www.waikatoregion.govt.nz/Services/Maps/ .
The advantage of using the electronic mapping systems is that you can easily determine the catchment areas for your various sediment control options.

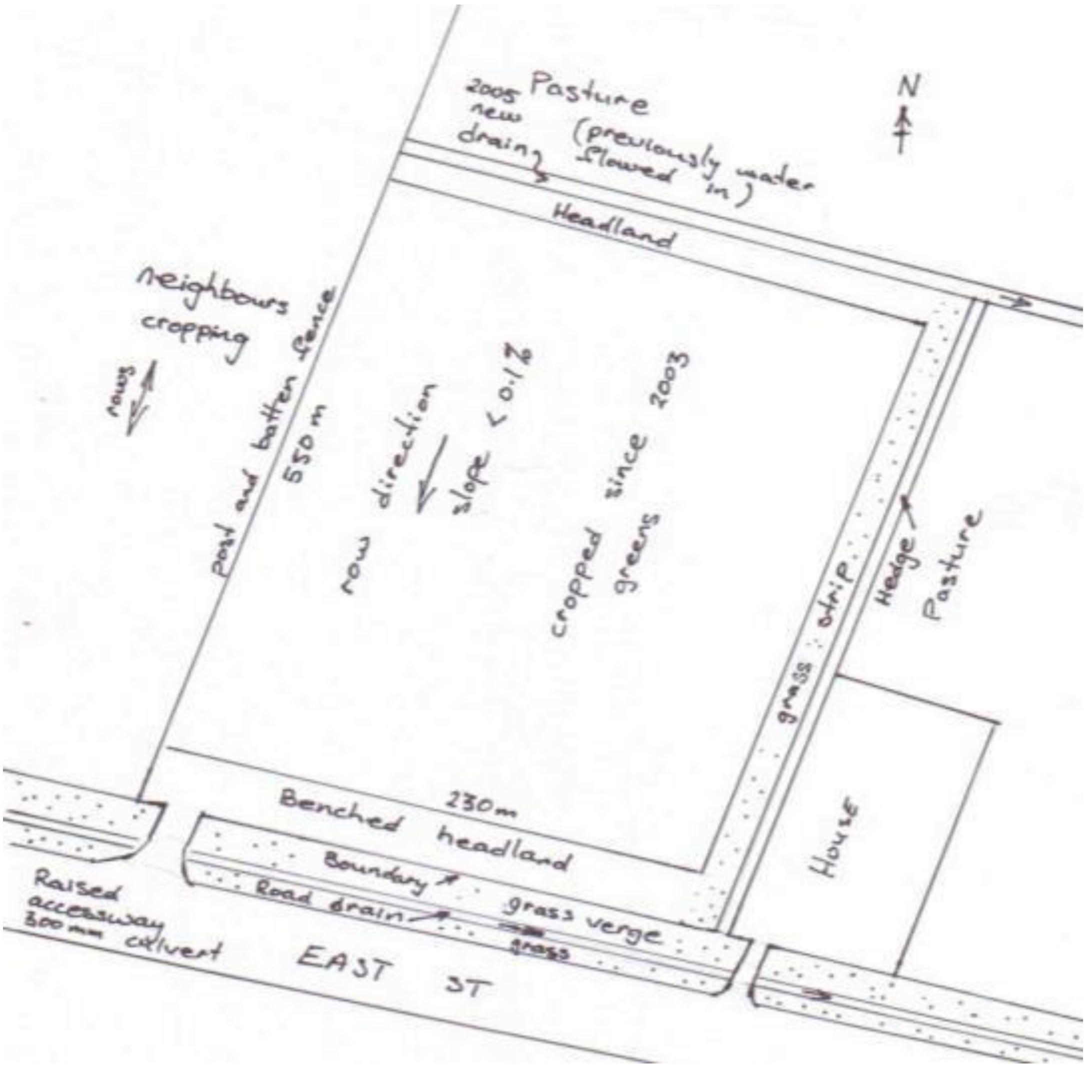


Figure 1. A simple hand drawn paddock map.

REMEMBER: If you fail to plan, you plan to fail

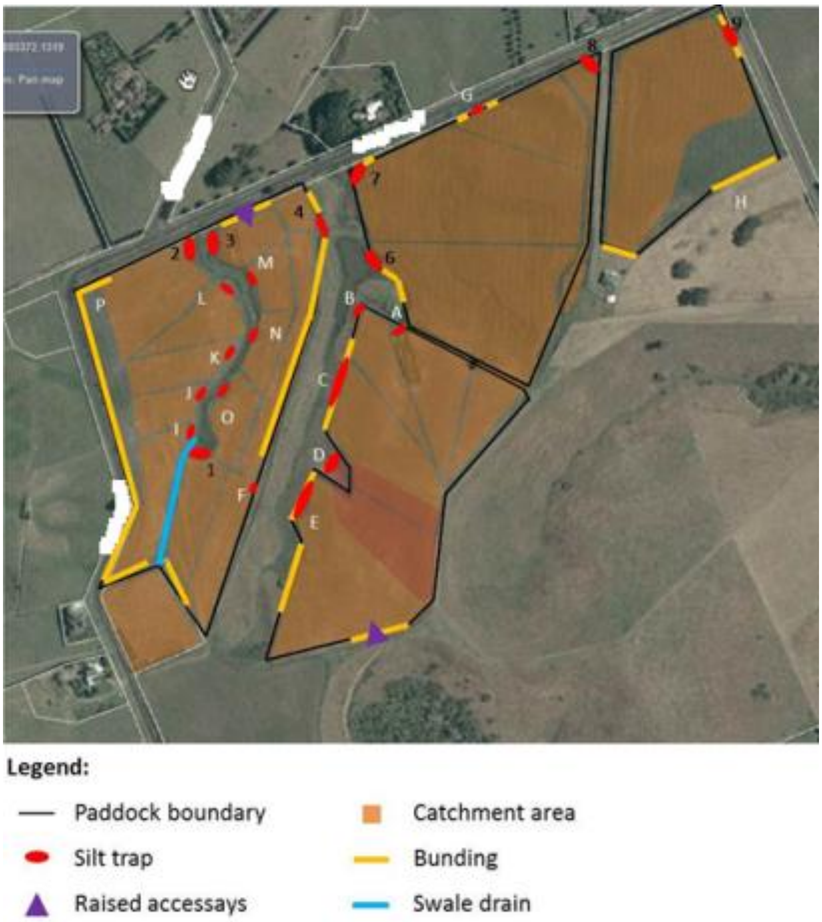


Figure 2. A digit paddock map.

Table 2. Example silt trap details (accompanying the Figure 2 map).

Silt trap	Volume (m^3)	Catchment (ha)	Spillway width (m)	Proposed silt trap dimensions (m)[1]	
				Width	Length
A	35	0.69	1.0	3.0	10.5
B	36	0.72	1.1	3.0	10.9
C	61	1.22	1.8	2.0	27.7

[1] Based on a depth between the silt trap base and spillway of 1.1 m. These are given simply as examples, to get a feel for the trap size.

"When first setting up a paddock we will contact the neighbours, particularly when installing surface drains" Harry Das – B. Das & Sons Ltd

2. IMPLEMENT CONTROL MEASURES FOR STOPPING OR CONTROLLING WATER ENTERING THE PADDOCK

Identifying and then stopping or controlling water entering the paddock is crucial. Drains overtopping can be one of the biggest causes of erosion. In Pukekohe on the 21st January 1999 a short-duration high intensity storm struck. The most severe damage was caused where uncontrolled run-off entered paddocks as a result of overflowing drains. In many places inadequately sized culverts also significantly contributed to the problem of drains overflowing. Keeping clean treated water off the paddock using interception drains wherever possible is crucial. Coordination of drains and erosion and sediment control practices between neighbours and council is essential to minimise soil loss. Meet on site with them to talk through and agree on what needs to be done.

Also:

- Ensure all drains are linked,
- Check that drains and culverts are large enough to cope with the volume of water,
- Carry out regular drain maintenance,
- Discuss with your neighbours linking the drainage systems and know the catchment sizes above you.

Keeping water off the paddock using interception drains or bunds wherever possible is crucial. Where this is not possible, due to the contour, grassed swales through the otherwise cultivated paddock should be considered.

2.1 Interception Drains

These need to be built large enough to cope with the flow of water from the catchment above. Where the drain has a steep gradient check dams (energy dissipaters) should be used to slow water flow and minimise drain scouring. Some drains will need to be stabilised with vegetation or rocks otherwise they themselves can become a source of sediment.

2.2 Culverts

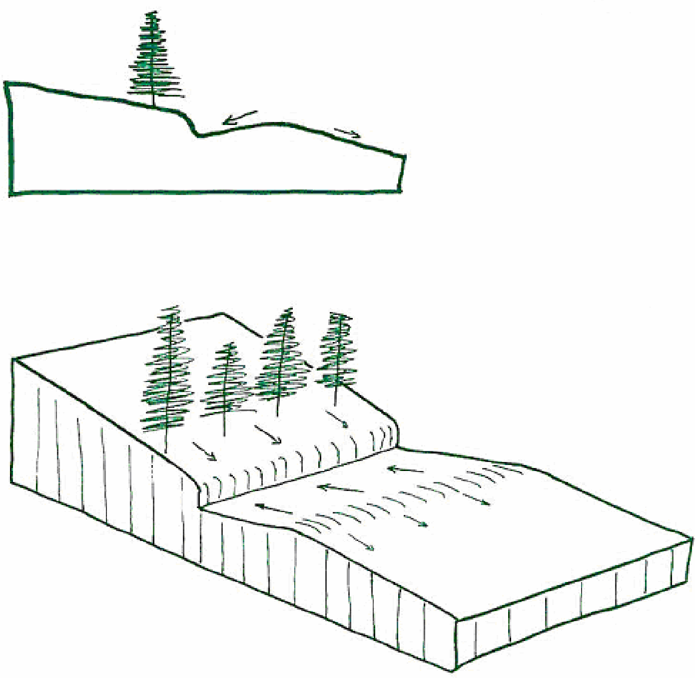
Culverts in drains are often undersized and either quickly blocks with debris and rubbish or simply cannot cope with the volume of water and overtop. Like the drains themselves culverts need to be correctly sized and should have well-formed headwalls. Generally the bigger the better. The drain at the discharge end of the culvert should be protected with rock to prevent scouring. Table 3 gives an indication of the maximum catchment area for a range of culvert sizes for a 20% (1 in 5 year) and 5% (1 in 20 year) AEP rainfall event. The flow is based on having a 0.2m headwall above the top of the socket end culvert. The quantity of stormwater generated from a certain size catchment will vary depending on rainfall intensity, overland flow length, slope, and surface characteristics. The maximum catchment area given in Table 3 is a guide only, and is based on a stormwater study conducted for the Bombay Hills. The area guide is likely to be conservative for most catchments as culverts in flatter catchments with less intense rainfall events could cope with larger catchment areas.

Table 3. Culvert size and associated flows and catchment area.

Culvert size (mm)	Flow (L/sec)	Maximum catchment area	
		20% AEP	5% AEP
300	120	3.4	1.8
375	200	4.8	2.3
450	295	8.1	3.7
525	405	11.3	4.8
600	545	15.0	7.1
675	725	19.3	9.3
750	925	26.9	11.7
825	1100	35.9	14.8
900	1400	48.0	17.8
1050	2000	64.8	29.0
1200	2790	87.5	48.0
1350	3550	115.1	61.4

2.3 Benched Headlands

Modifying headlands is a simple and effective way of controlling and managing soil and water runoff from paddock rows, particularly wheel tracks (a major source of sediment). Often called 'benched' or 'contoured' headlands, the entire headland area is designed to direct water to the side of the paddock or to a drain within the paddock.



Benched headland

The headland slopes away from the rows, sloping towards an earth bund. The headland is still used in the normal manner for access to planting, spraying and harvesting operations.

Grassing headlands will protect them from scouring and encourages silt to drop out before entering surface drains.

The easiest way to construct a benched headland is using a grader blade. Once in place, particularly if it is grassed, the only maintenance is to clear deposited soil and reshape in dry conditions or if major scouring occurs.

Benched headlands are used to good effect in breaking up the length of long paddock runs. If constructed to a broad shallow design, a tractor can be driven across the headland.

When constructing a benched headland attention needs to be paid to:

- Where water from the benched headland is being directed, for example to a permanent drain which will carry it off-site in an effective manner,
- Where silt will be deposited in the benched headland, and further down the drainage system.

Scouring of benched headlands can occur if:

- Excessive water volumes flow into a headland. Use contour drains across the field to reduce this,
- Soil in the headland has not been compacted,
- The slope of the headland is too steep, creating high water speeds during rainfall. Take measures to reduce volumes reaching the headlands by diverting water to drains or vegetate the headland to cope with the high water speed.

Check what happens when the water reaches the end of a headland and make sure the headland connects with a suitable sediment control measure or stabilised discharge point.

2.4 Diversion Bund

Rather than a drain, an earth bund can be used to divert water away from a vulnerable cultivated paddock.

2.5 Grassed Swale (Controlled Overland Flow through the Paddock)

A swale is a surface drain that is often shaped into a shallow saucer. They are used to ensure water flowing along natural overland flow paths through cultivated areas do not cause significant erosion. Clean water can be directed along the swale, following its natural course, to a stabilised discharge point. Once formed the swale needs to be immediately stabilised with grass. The size is based on the catchment area above the paddock. As a minimum the swale should be at least 3m wide. The swale is shaped into a flat shallow saucer about 0.3m deep that can be easily driven across if it needs to intersect the cultivated rows.

Photo 1. Scouring out along a cultivated overland flow path.

A grassed swale may have prevented the damage shown in Photo 1. An interception drain or bund could not be used to cut this water off due to the contour. The water entering the paddock was clean so does not need any further treatment if it had passed over a grassed swale. Without the grassed swale the volume required in the sediment control measures needs to account for the cultivated paddock as well as the catchment area above the paddock.

3. EROSION CONTROL MEASURES FOR KEEPING SOIL ON THE PADDOCK

Implementing in-paddock erosion control measures to minimise soil movement will retain and even improve soil structure. Although eroded soil caught in a sediment control device like an earth bund or silt trap can be redistributed back over the paddock, it is invariably in very poor condition and certainly no substitute for preventing soil from moving in the first place.

The suite of erosion control measures used will predominantly be dependent upon the paddock slope. For example, flat paddocks will benefit from cover crops but contour drains would be of limited value, while even gently sloping paddocks may benefit from wheel track ripping.

Within paddock control measures include the use of:

- Cover crops
- Wheel track ripping
- Wheel track dyking
- Contour drains
- Paddock length
- Cultivation practices including minimising passes
- Harvest management
- Postharvest management minimising the fallow period (with cover crops or grass)
- Wind break crops

3.1 Cover Crops

What are cover crops?

Green manure or cover crop describes any crop which is grown to be ploughed into the soil rather than harvested. This incorporation of a crop back into the soil is to improve soil quality, and long term production.

Photo 2. An emerging oats cover crop through the stubble of the previous crop.

Benefits

The use of cover crops is beneficial in all long-term cropping situations for three main reasons:

1. To stabilise soil from erosion and improves water penetration and drainage
2. To produce dry matter which improves organic matter and soil structure
3. To trap and cycle mobile nutrients from the previous crop

Other benefits of using cover crops include:

- Smothering weeds (can help reduce weed control costs)
- Improved soil fertility (improves productivity)
- Stimulating soil biological activity (e.g. earth worms) and assisting in breakdown of previous crop residues to reduce disease carry over and soil-borne diseases
- Providing a habitat for beneficial insects
- Fixation of nitrogen by some species

The use of cover crops suitable for the Franklin District was investigated by FSP on several grower demonstration sites to address issues of soil erosion, soil stability and nitrate leaching. Results are available in a fact sheet that can be downloaded from http://agrilink.co.nz/archive.php.

3.2 Wheel Track Ripping

Wheel track ripping increases rainfall infiltration rates and significantly decrease soil movement. Ripped wheel tracks allow water to percolate into the soil rather than flow down the wheel tracks.

Compacted wheel tracks can act as drainage channels. Shallow ripping of wheel tracks, to just below the cultivation compaction zone can reduce soil and crop loss.

Water flowing down the wheel tracks undermines the adjoining crop beds leading to extensive crop and soil loss. Where the wheel marks are ripped, water is able to infiltrate into the soil with the result that little soil loss and no crop loss occurs.

Photo 3. Ripped wheel tracks beside the unripped sprayer tracks (sprayer tracks are left unripped to ensure sprayer stability).

Wheel tracks in the rows used for spraying should not be ripped, as the resultant loose track makes spraying difficult.

When any runoff reaches the bottom of the paddock, it needs to be dealt with by sediment control measures (e.g. decanting earth bunds or silt traps). The easiest and most effective way to deal with this problem is to minimise runoff in the first place. Ripped wheel tracks minimise runoff and subsequently reduces the pressure on any sediment control device.

Why rip wheel tracks?

Trials have found that wheel tracks are the key zones for initiation of surface runoff and erosion.

Reduction of water movement along wheel tracks is the key to reducing erosion rates. In a Franklin District trial, ripping wheel tracks increased the infiltration rate from 0.5 mm per hour to more than 60,000 mm per hour (Table 4). This reduced the movement of water down the wheel tracks. The erosion rate from the unripped tracks was 21.3 t/ha, compared to 1.1 t/ha on the ripped wheel tracks (Table 5). Ripping wheel tracks following planting was found to be the single most effective measure for reducing soil erosion within the paddock in the Franklin District.

Table 4. Infiltration rate (mm/hour).

Treatment	**June**	**October**	**January**
Uncultivated wheel track	0.5	12.7	77.2
Cultivated wheel track	60,300	12,500	8,600
Onion beds	400	500	900

Table 5. Erosion rate (t/ha).

Treatment	**Jun – Aug**	**Sept – Dec**	**TOTAL**
Uncultivated wheel track	16.7	4.6	21.3
Cultivated wheel track	0.98	0.13	1.1

Because the infiltration rates are so high in both the ripped wheel tracks and onion beds, runoff would only be generated if the capacity for the soil to store water is exceeded.

As a word of caution, some growers attribute wheel track ripping to increased erosion. This underscores that no single measure will work for everyone in all situations. However, many growers and the research trials show that in most circumstances wheel track ripping will significantly reduce soil erosion.

How to rip wheel tracks?

Wheel track ripping is carried out as soon as possible after planting. A shallow tyned implement pulled behind a tractor is used for this purpose. It has double leg subsoiler shanks with small wing bases, mounted behind the wheels on a straight toolbar. Weights attached to the middle of the toolbar help with penetration of the implement.

Photo 4. Wheel tracking ripping in action (above) and the small torpedo foot (insert).

3.3 Wheel Track Dyking

Dyking is a simple practice that creates a series of closely-spaced soil dams in wheel tracks (pictured below, right). These dams capture water in what amount to small indentations. Water can then soak into the profile, minimising runoff and any associated movement of soil and nutrients. As with wheel track ripping, dyking offers a practical solution to reduce soil erosion before it becomes a bigger issue.

Photo 5. The wheel track dyking implement in action (above).

Photo 6. Small indentations along the wheel track can be seen filled with water (left).

These small dams slow the water down and settles the suspended solids. Water also has a longer duration to infiltrate into the soil.

<u>Why dyke wheel tracks?</u>

Initial trials in the Horowhenua and Hawke's Bay have shown that dyking wheel tracks can be extremely effective in reducing runoff and soil and nutrient loss. In low and high rainfall events dyking eliminated runoff compared to undyked (standard) wheel tracks. This largely reflects the longer retention time water has behind soil dykes.

Photo 7. Dyked wheel tracks.

There is no standing water after a winter rain event.

Photo 8. Undyked wheel tracks.

Alongside the dyked wheel tracks water has ponded in these undyked wheel tracks.

Creating these small dams along the wheel tracks can have clear production benefits too. Ponding within paddocks can be minimised. Recent trials have shown just how costly this type of damage can be. In affected areas there can be total crop loss even as a result of only short-term ponding. Even where crops survive the initial ponding events, crop performance is still often affected.

Photo 9. Areas that are affected by short-term ponding damage (foreground) can significantly reduce profitability.

How to create wheel track dykes?

Soil dykes are created by a propeller-like instrument. A ripper shank works immediately in front of the propellers both to loosen the soil to create the small soil dams and to allow quick drainage (see the previous section). There are several different designs available, though most create soil dams about every 30 to 45 cm. The equipment itself is pulled behind a tractor and is mounted to a standard straight toolbar.

The best time to create the dams is when the soil has been recently worked. It is following this disturbance that soil is most at risk of moving. Soil dykes should be formed slightly below the top of the bed, so that if they overflow during extreme rainfall events the water will flow down the wheel track rather than across the bed. Don’t work the wheel tracks if the soil is too wet – damage to soil structure is likely to outweigh any potential benefits.

In some situations there may be value in reforming dykes several times during the season, where in others once will suffice. Sowing oats at the same time the wheel tracks are dyked can increase the stability of the soil dams, but is not essential. Wheel tracks in the rows used for spraying should not be disturbed.

3.4 Contour Drain

Contour drains can be considered if the paddock is on a slope of 2% (equivalent to about 1° degree) or more.

Contour drains are temporary drains used to collect runoff water. They effectively reduce the length of rows that runoff water can flow down, by collecting water in shallow drains that run at a gentle gradient across the slope of the paddock. Water is then channelled into permanent drains or grassed alleyways. Contour drains also control the speed of runoff water when the correct gradient is used.

Contour drains MUST discharge into a permanent drain; otherwise the problem of erosion is simply shifted from within the paddock to the margins. The permanent drain must be capable of handling the volume of water discharged from the contour drains.

To work well, contour drains must be designed and constructed properly, taking the field’s characteristics into account.

Contour drain spacing

The steeper the slope, the greater the number of contour drains needed.

Table 6. Contour drain spacing.

Paddock slope	**Drain spacing**
> 10% (i.e. 10m rise per 100m length)	20m
3 - 10%	30m
< 3%	50m

As a general rule contour drains should never be more than 80m apart.

Getting the spacing of contour drains right is very important. Getting it wrong can actually create more problems than it solves. The golden rule is to avoid placing drains too far apart, as contour drains spaced too widely can overflow and CAUSE erosion.

Contour drain slope

It is important that contour drains are sloped correctly. If too flat they can silt-up or overflow, if too steep they become gauged-out. The best way to get the slope right is to survey the paddock to get the right fall in the contour drains.

Trials in the Franklin District have found a slope of 1.5 - 2.5% is appropriate for the clay loam soil. Trials in Tasmania found the best results at between 5 to 7% on their clay loam to clay soils and 0.5 to 2.0% on sandy soils.

The most common fault seen with contour drains is that they are too steep and too far apart. To compensate for this they are often deeper than necessary and therefore become a hindrance to sprayers and other field equipment.

Contour drain length

For contour drains, shorter is definitely better. The longer the drain, the more likely it is to overflow. As a guide, the Kindred Landcare Group in Tasmania recommends that contour drains be no longer than 50m.

Contour drain construction

A clinometer, two equal length poles, an assistant and marker pegs should be used to mark out the placement of contour drains.

1. Stand at the top of the paddock halfway between the vertical drains on either side of the paddock or at the far side of the paddock if there is only one vertical drain.
2. Send your assistant to the edge of the paddock, their pole held upright.
3. Set the clinometer to the required angle. Rest it on your pole and look through it.
4. Ask your assistant to move down the paddock until the top of the poles line up with the hairline on your clinometer.
5. Peg both your and your assistant's position. This is the line for the contour drain.
6. Both move down the paddock 20 - 80m, depending on the paddock's characteristics, and repeat steps 3 and 4 and 5.

Once pegged out, drains can be constructed with a blade set on an angle. Soil should be pushed to the downhill side. Drains may need to be finished off by hand.

Contour drains should be put in immediately after sowing the crop - not the next week. It may be too late or may not get done at all.

3.5 Paddock Length

Row length is important if the paddock is on a slope of 2% (equivalent to about 1° degree) or more. If the rows are oriented up and down the slope, restricting row lengths to 200m is recommended, potentially broken with several contour drains. In longer rows erosion is often evident.

3.6 Cultivation Practices

Cultivation reduces the stability of most cropping soils over time. Adopting minimum tillage approaches or minimising the number of cultivation passes can be an effective means to reducing soil erosion.

The how, when and where cultivation is done can have a big impact on the erosion potential of your soil. Good cultivation techniques can increase productivity and help conserve soil and keep it in good condition for the future.

<u>Where possible, paddocks should be cultivated in alternating directions in successive years to avoid moving whole fields downhill.</u>

The soil resource can take many years to rebuild once it is lost through erosion. The exposure of less fertile subsoils can require higher inputs of fertiliser (added cost) to maintain crop productivity.

<u>Excessive cultivation with rotary hoes should be avoided.</u>

Maintenance of good soil structure can actually reduce the costs of cultivation – for example, the number of passes needed to achieve the desired seed bed. Good soil structure also protects the health of the soil by allowing better aeration and drainage.

<u>Leave a setback strip or riparian margin between the cultivated area and any drains or streams.</u>

A riparian margin is a means of managing soil that moves off a paddock, but needs to be planned as part of the cultivation so that an adequate area is left uncultivated. Leaving an uncultivated strip forms a filter than can trap sediment in runoff and prevent it entering the waterway. Many Regional Plans require cultivation to have a setback distance from waterways. However one of the problems is that cultivated paddocks often form channelised flow paths, rather than sheet flow, which can cut through these vegetated margins no matter how wide they are.

Refer to Section 4.3 Vegetated Buffers, Riparian Margins and Hedges below for details and examples of setback strip and riparian margins.

Some dos and don’ts for soil cultivation

1. DO minimise the number of passes over the paddock wherever possible.
   Every cultivation pass results in the loss of organic matter through decomposition and can have a detrimental effect on soil structure.

2. DO build the organic matter level of your soils.
   Cultivation reduces organic matter. Building organic matter can be done with the use of cover crops (see the cover crop Section 3.1 Cover Crops) or compost. Organic matter is critical for maintaining the stability of soil aggregates and reducing nitrate leaching. It also allows for easier preparation of seedbeds.

3. DON’T cultivate right up to the sides of drains or streams.
   This will only speed up the loss of soil from paddocks, block up streams and require more maintenance.

4. DON’T cultivate when the soil is too wet.
   The best way of reducing compaction and the formation of pans is to avoid being on the land when it is too wet. Compaction slows the infiltration of water into the soil and increases the risk of soil erosion.

3.7 Harvest Management

At harvest, operations should be carried out in a manner that has least adverse effect on the soil and water resources.

Working paddocks in wet conditions can lead to loss of soil structure, compaction and increased sediment in the runoff. In addition to these effects, it can also increase wear and tear on plant and machinery, reduce labour efficiency, increase pressure on washing systems and increase product reject levels. Also, mud left on the road can create a traffic hazard as well as result in public animosity toward land users.

However, timing of harvest operations can be dictated by the demands of markets or factory requirements (process vegetables). This makes it difficult for growers to always operate under good soil and climatic conditions.

All-weather facilities should be established for loading and marshalling areas to prevent severe compaction, breakdown of soil structure, or any limitation to access.

Where required, metal should be used in gateways and loading pads. Load out may occur in an adjacent paddock.

3.8 Post Harvest Field Management

Where a new crop is not going to be immediately sown following harvest consideration needs to be given to paddock management to prevent soil erosion. One effective approach is to sow a cover crop such as oats.

Bare soil surfaces that can occur in paddocks following harvest are vulnerable to erosion caused by wind and rainfall. Establishing a cover crop soon after harvest can protect the soil and provide other advantages such as increased soil organic matter, slow the breakdown of the soil structure and provide a feed resource for grazing. See Section 3.1 Cover Crops for a detailed description on the use of cover crops.

Where a cover crop cannot be established following harvest, contour cultivation should be considered so that the soil surface is broken up and left in a condition that avoids erosion.

Contour cultivation (right) can provide a similar effect to contour drains. Because crop management no longer needs consideration, there should be greater choice on where such cultivation occurs and whether the whole area is given a breaking up pass or at regular intervals across the slope.

Photo 10. Strip contour cultivation of a fallow paddock following harvest.

Returning paddocks to pasture at regular intervals is an effective way of building up soil organic matter and avoids the build-up of pests, diseases and weeds. When returning pasture paddocks to cropping take care not to undo all of the good work by over cultivating or working the ground in less than ideal conditions.

Rotation of crops is well recognised as a good management practice. The length of the rotation and cropping practices will influence the extent of soil damage that can result from repetitive cropping. Pasture can be an effective 'recuperation crop' in the rotation.

To gain the best recuperative effect from pasture in the crop rotation, the pasture needs to be carefully managed. Overgrazing, particularly at times when soil is vulnerable to pugging or drought, can negate many of the benefits that pasture can provide. Soils can erode or compact, which in turn can lead to increased levels of soil loss through sediment runoff.

4. SEDIMENT CONTROL MEASURES TO MANAGE THE WATER AND SUSPENDED SOLIDS THAT MOVE OFF THE PADDOCK

Managing the water that flows off the paddock is about minimising the quantity of soil that enters the wider environment and ensuring that water is discharged in a controlled co-ordinated manner. Water is either kept clean by diversion around the paddock or over a stabilised grassed swale, or it is treated and then discharged. Effective treatment relies on a sufficient time for soil to settle out. Having sufficient capacity is critical.

Managing water leaving the paddock can be achieved using:

- Raised access ways and ensuring they are not at the lowest point
- Benched headlands
- Diversion bunds
- Vegetated buffers, riparian margins and hedges
- Silt fences
- Stabilised discharge points and drains
- Decanting earth bunds
- Silt traps

4.1 Raised Access Ways

Raised access ways should form part of your co-ordinated sediment control practices. All runoff can then be managed and treated before leaving your property, stopping the loss of valuable soil from paddocks onto roads and into waterways.

Photo 11. Raised access way.

An access way raised with metal (right) directs water flowing down the track into a small decanting earth bund. Note the black snorkel should be cut below the height of the emergency spillway so that it can act as the primary spillway. Behind the pictured decanting earth bund is a bund protecting the adjacent roadside drain and downstream environment from the paddock above.

Photo 12. Raised access way.

The access way in Photo 12 has been raised using a culvert with bunds either side directing water to a Decanting Earth Bund further down the paddock.

The effect of having the access way in the lowest point is graphically shown in the series of photographs below. Sediment is lost from a paddock through the access way at the lowest point, with some of the sediment settling in a dip beside the road.

Photo 13. Erosion from an unprotected paddock.

Photo 14. (below) Sediment settles in a dip just down from the paddock in Photo 13.

Photo 15. Unprotected access way at the lowest point (above).

Remember – access ways are there to provide for vehicle crossings, they are not a discharge point for stormwater.

The following practices, well planned and used together, will avoid or minimise soil losses from access ways:

1. Position access ways away from lowest point
   Never place access ways at the lowest point of the field where water is naturally diverted or concentrates. This may mean "off-setting" it from the bottom corner where a decanting earth bund is installed.
2. Raise access ways
   Raise the access way above the surrounding area to divert water into your sediment control system. This may be as simple as using a load of metal to form a hump over the access way (see Photo 11).
3. Check point
   Use the access way as a check point where you can spend a few minutes removing soil that has become stuck to the tractor. Soil is a valuable resource. Don't leave it on the road as you drive away. Keep it for your crops.
4. Culvert
   All access ways that go directly onto a road should be piped. The size of the pipes/culverts is important – the BIGGER the BETTER. See Section 2.2 Culverts.

4.2 Diversion Bund

Diversion Bunds are raised earth walls prevent water discharging straight off the paddock. Like raised access ways they divert water into a sediment control device like a decanting earth bund or silt trap.

Photo 16. A diversion bund protecting a pond.

4.3 Vegetated Buffers, Riparian Margins and Hedges

Vegetated buffer strips and riparian margins, strips of land adjacent to waterways, filter water by slowing down the flow of water allowing the sediment to settle out. They should be at least 3 to 6m wide. There is the issue of what to do with the trapped sediment as it builds up over time. Digging it out is likely to take the vegetation with it, while leaving it often means it is susceptible to further erosion. Where the flow is channelised, as occurs in the majority of cases on vegetable cropping land, riparian margins may be of limited value as sediment control devices with water and sediment pass straight through. They do however have other benefits such as stabilising banks and shading streams.

Photo 17. A wide grassed riparian margin protecting a stream.

Photo 18 (below). This recently cultivated paddock is protected by the dense grass buffer left alongside the fence.

Photo 19 and 20. Headlands set back from the paddock boundary with a wide crop strip acting as both a barrier to soil moving off the paddock (vegetated and raised beds) and provides room for tractor implements to swing around in.

Well maintained hedges can act as barriers that catch silt before it can leave the paddock. Their application is often to stabilise earth bunds and along benched headlands. Hedges are only part of the erosion control system and need other control measures in place to complement their benefits.

FSP trialled vetiver grass as a soil barrier. Planted at 20cm intervals it will form a dense hedge, approximately 1.5m tall of stiff erect stems in 3 years. Once established it can filter the water leaving sediment to settle in front. It suits temperate regions of New Zealand.

Photo 21. Vetiver grass established along the lower paddock boundary.

4.4 Silt Fences or Super Silt Fences

Silt Fences and Super Silt Fences are considered a temporary measure for trapping sediment-laden runoff from small catchments of usually less than 0.5 ha. When used on larger catchments careful consideration of the site characteristics is needed or other alternative control measures may be more appropriate. For gradients of less than 10% the slope length behind the Super Silt Fence is unlimited, however Silt Fences have a slope restriction of just 40m. FSP used them in trials as an effective means of demonstrating the quantity of soil that was being lost from a paddock. Inasmuch, they can serve as a means of justifying a more permanent, well-constructed silt trap.

In cultivated growing situations Super Silt Fences are the most appropriate. These use a geotextile fastened to a wire fence (e.g. chain link fence). Regular wind or weed matting cloth is not suitable because these materials do not have good filtering characteristics or high flow rates. Details on suitable geotextiles can be found in TP90 Part B 2B and the 2007 changes. The geotextile fabric must meet the following minimum requirements. Grab Tensile Strength: >440N, Tensile Modulus: 0.140 pa, Apparent Opening Size 0.1 – 0.5mm. Suitable fabric can be found at www.permathene.com/htm/erosion.shtml

Table 7. Super Silt Fence Design Criteria.

Slope Steepness (%)	**Maximum Slope Length (m)**	**Spacing of Returns (m)**
0 – 10%	unlimited	60
10 – 20%	60	50

Source: TP90 (2007)

Detailed construction guidelines can be found on the Auckland Council website's technical publications page. Either TP90 and the 2007 changes or TP223 sediment control for forestry, are excellent guides showing a wide range of erosion and sediment control measures.

4.5 Decanting Earth Bund

A Decanting Earth Bund is often constructed along the flat contour at the bottom of a paddock. By moving the headland itself several meters further up the paddock the full width of the paddock can form a ponding area that will hold runoff long enough to allow sediment to drop out of suspension prior to discharge. This approach can avoid having to build deeper silt traps in the corner of paddocks in order to achieve the required volume.

Photo 22. The cultivated paddock has been pulled back to allow silt detention along the full length the paddock without having to drive tractors into this detention area.

Creating sufficient capacity in Decanting Earth Bunds and Silt Traps is essential for giving sediment sufficient time to settle. The recommended capacity is 0.5% (50 m^3/ha) for catchments of less than 5ha and 1% (100 m^3/ha) for catchments over 5ha. Full details are included in the FSP Soil and Drainage Management Guide. This can be downloaded from http://agrilink.co.nz/archive.php.

Photo 23. Decanting snorkel.

Photo 24. A Decanting Earth Bund.

Decanting rate

Decanting Earth Bunds and Silt Traps need to dewater so as to remove the relatively clean water without removing the settled sediment. The decanting rate is critical. Too fast and the sediment will not have time to settle, slush in and slush out. Too slow and the primary and emergency spillways will operate in even moderate sized rainfall events, which will also result in poor sediment capture efficiencies.

The recommended decant rate is 3 L/sec/ha.

Table 8Table 8 shows the number of 10mm holes required for various lengths of vertical snorkel in order to decant at a rate of 3 L/sec/ha. As the silt trap becomes deeper (longer snorkel) the average flow rate through each hole increases, hence less holes are needed. For example if the Decanting Earth Bund has a 1 hectare catchment; on a 1m snorkel drill 60 10mm diameter holes. This can be done in 6 vertical rows with 65 mm spaces from the top of the snorkel down to 0.3 m from the silt trap floor. A deeper trap with a 1.3m snorkel requires just 54 holes to achieve the same decanting rate of 3 L/sec/ha.

The number of holes will need adjusting based on the catchment area and the snorkel height. Larger catchments may require several vertical pipes or the use of plastic drums has proven to be an effective inexpensive option. The drums provide more surface area to get the required number of holes on larger catchments in shallow silt traps. Getting the height of the drums correct takes a little more work compared to simply cutting a PVC pipe to the correct length. The drums also need a large hole cut in the lid to act as the primary spillway.

Table 8. Snorkel - Number of 10mm holes per hectare.

Snorkel height above base (m)	**Perforation length (m)** [1]	**Average flow per hole (L/hour)**	**Number of holes per hectare of catchment**	**Distance between holes (mm)** [2]
0.5	0.4	2.2	84	25
0.8	0.5	2.7	66	45
1.0	0.7	3.1	60	65
1.3	0.9	3.5	54	90
1.5	1.1	3.9	48	125
1.8	1.2	4.2	42	165

1. The bottom 30% of the snorkel does not have any perforations
2. Based on 6 vertical rows

It is recommended that the bottom 30% of the snorkel is not perforated. This will result in a permanent pool at the bottom of the silt trap, which helps sediment settle. 30% of the volume of the trap should be “dead storage” i.e. a pool of water and the other 70% is operating volume i.e. is the volume decanted off through the perforated upstand during and after rainfall events.

Key decanting snorkel requirements

1. The open top of the snorkel also acts as the primary spillway. There should be 100mm gap between the top of the snorkel and the emergency spillway.
2. The decant rate should be 3 L/sec/ha. See Table 8.
3. The bottom 30% of the snorkel should not be perforated in order to leave dead storage
4. Snorkel should be securely fastened to a stake
5. The discharge point should be stabilised by discharging onto rocks or stabilised ground.

Emergency spillway

The emergency spillway discharges excess water in major storm events when the perforated snorkel and primary spillway are unable to cope. Position the spillway so that it is not inline for the entrance, baffles may be needed to achieve this. The spillway needs to be stabilised with rock, geotextile or on firm vegetated undisturbed ground. The minimum width is 1.5m/ha of catchment. The spillway must be level and 100mm above the primary spillway. There should be 400mm between the top of the bund and the emergency spillway.

4.6 Silt Traps

Silt traps impound runoff water and ensure sufficient time for the suspended soil to settle. Volume is the key attribute.

Whenever possible:

1. Break the paddock into smaller catchments with their own treatment measures and silt trap.
2. Treat runoff from a catchment only once, and discharge it from the paddock into a stabilised drain.

Silt traps work best in combination with other practices that reduce the amount of soil reaching the traps. Silt traps alone are not the only means of controlling soil loss, but are part of an overall system.

Full construction details can be found in the factsheet developed for FSP that can be found at http://agrilink.co.nz/archive.php or design details are included the in the Auckland Council Technical Publication 90 and the 2007 changes.

The Silt Trap should be 3 times longer than it is wide with inflow entering at one end and the discharging through the outlet at the other. Baffles may be necessary to achieve this. A baffle is a barrier constructed across the pond to direct flows and so maximise the efficiency of the Silt Trap. Its height should be the same as that of the top of the perforated snorkel. It can be constructed from silt fence fabric or shaped when being excavated leaving a clay barrier. The clay barrier is easier for maintenance as cloth barriers are invariably ripped out by the excavator.

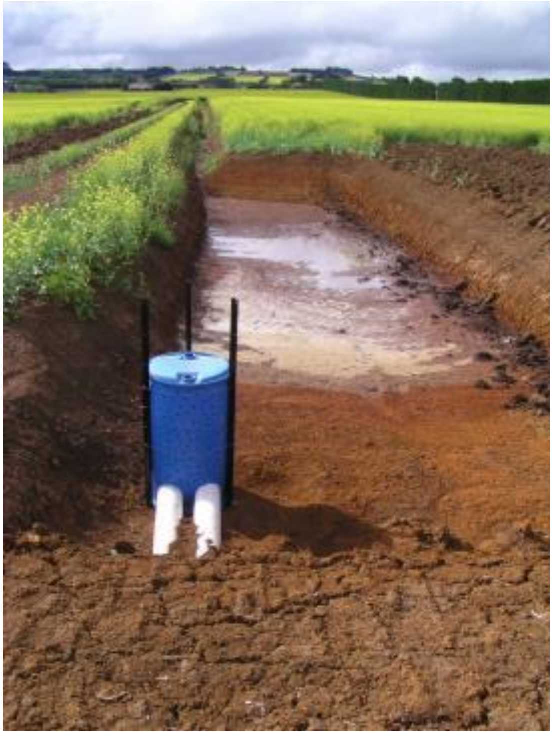


Photo 25. A silt trap with the blue snorkel in the foreground for slowly decanting the trap. A mustard cover crop is planted in the immediate paddock along with many of the paddocks in the background.

GLOSSARY

Annual Exceedance Probability (AEP)
A statistical term defining the probability of an event occurring annually. Expressed as a percentage to define rainstorm intensity and frequency. For example, a 5% AEP event has a 5% chance of being exceeded in any one year. This has replaced the return period concept. A 5% AEP event expresses the 20 year return period in more probability terms.

Baffles
Semi-permeable or solid barriers placed in a sediment retention pond to deflect or regulate flow and effect a more uniform distribution of velocities, hence creating better settling conditions.

Batter
A constructed slope of uniform gradient.

Catchment
An area within which surface runoff flows to a common outlet or outlets.

Channel Stabilisation
Stabilisation of the channel profile by erosion control and/or velocity distribution through reshaping, the use of structural linings, rocks, vegetation and other measures.

Clean Water
Any water that has no visual signs of suspended solids, e.g. overland flow (sheet or channelled) originating from stable well-vegetated or protected surfaces.

Contour
A line across a slope connecting points of the same elevation.

Contributing Drainage Area
All of that drainage area that contributes to the flow into a treatment device (e.g. earth bund). A contributing drainage area can include both clean and sediment-laden water flows. Commonly referred to as the catchment area.

Decant Rate
The rate at which water is decanted from a Decanting Earth Bund or Silt Trap. This should be 3 L/sec/ha.

Deposition
The accumulation of material that has settled because of reduced velocity of the transporting agent (water or wind).

Emergency Spillway
An Earth Bund, Silt Trap or Dam spillway designed and constructed to discharge flow in excess of the structure's primary spillway design discharge.

Energy Dissipater
A designed device such as an apron of rip-rap (rock) or concrete bags placed at the end of a water conduit such as a pipe, paved ditch or flume for the purpose of reducing the velocity and energy of the discharged water.

Rip-rap
Rock or other material used to armour channels, culvert abutments, and spillways against erosion.

Ephemeral Watercourse
A watercourse that flows only part of the year; may include overland flow paths such as grassland swales and dry gullies which only flow during more intensive rainstorms.

Filter Strip
A long, narrow vegetative planting (e.g. vetiver grass) used to retard or collect sediment for the protection of adjacent properties or receiving environments.

Level Spreader
A device used to convert concentrated flow into sheet flow.

Overland Flow Path
The route of concentrated flow.

Perennial Stream
A stream that maintains water in its channel throughout the year

Primary Spillway
The snorkel inlet within a Decanting Earth Bund or Silt Trap.

Riparian margin
An area adjacent to a watercourse designated as a non-disturbance zone to provide a buffer between the watercourse and cultivated paddock.

Sediment
Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from the original paddock by water or air and has come to rest.

Sediment Yield
The quantity of sediment discharged from a paddock in a given time, measured in dry weight or by volume. When erosion and sediment control measures are in place, sediment yield is the sediment discharged from the site after passing through those measures.

Settling
The downward movement of suspended solids through the water column.

Snorkel
In a Decanting Earth Bund or Silt Trap, a vertically placed pipe which decants water and forms the inlet to the primary spillway.

Spreader (Hydraulics)
A device for distributing water uniformly in or from a channel.

Stabilisation
Providing adequate measures, vegetative and/or structural that will protect exposed soil to prevent erosion.

Surface Runoff
Rain that runs off rather than being infiltrated or retained by the surface on which it falls.

Suspended Solids
Solids either floating or suspended in water.

Swale
A constructed depression or shallow channel across a paddock, that can be used to transport clean stormwater. It is usually heavily vegetated, and normally only flows during heavy storm events.

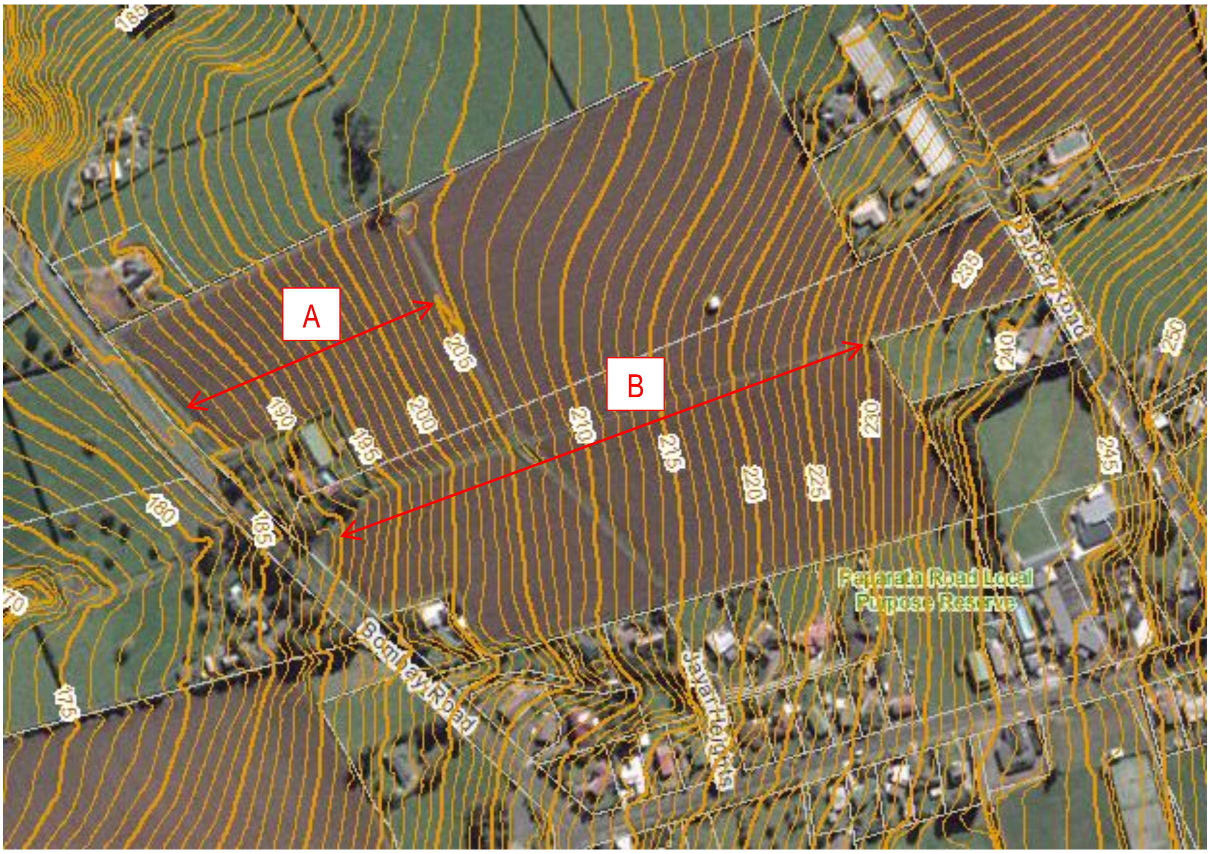
Water Body
Any type of surface water such as watercourses, lakes and wetlands.

Watercourse
Any pathway for concentrated overland flow, including rivers, streams and ephemeral channels.

PADDOCK SLOPE

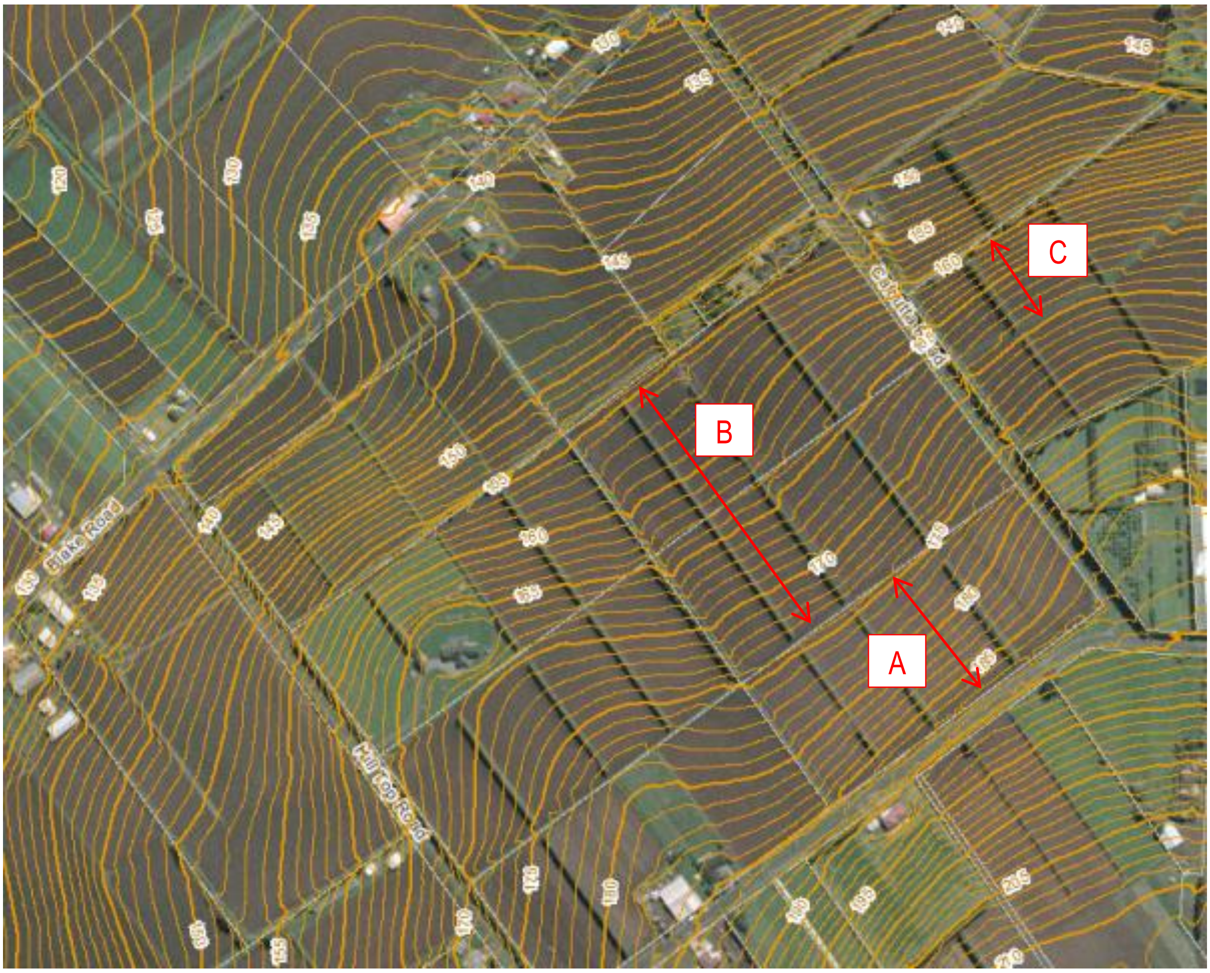
Many erosion and sediment control measures refer to different slopes, as a ratio, percentage or in degrees. With the GIS mapping now available for free on the internet it is reasonably easy to calculate the slope of a paddock. Alternatively a clinometer like that described in Section 3.4 Contour Drains can be used. The figures below show some of the steeper paddocks in the Franklin District to give an idea of the slope at the upper end. Apart from a few areas within a paddock, even the steepest cultivated slopes are generally less than 6 degrees or 10%.

<u>Bombay Hills</u>



Description	ratio	percent	angle
A	10.5 : 1	9.5%	5.4°
B	9.4 : 1	10.6%	6.1°

Pukekohe Hill



Description	ratio	percent	angle
A	10.2 : 1	9.8%	5.6°
B	13.8 : 1	7.2%	4.1°
C	8.2 : 1	12.1%	6.9°

COMMENTS AND FEEDBACK

We will be regularly reviewing these Guidelines. Please help us keep them accurate and practical. Let us know about any changes that need to be made either by contacting the author Andrew Barber directly or by using this form.

1.0 Errors

Are there any errors in the text or diagrams? If so please tell us:

- Which page and/or figure number it is on
- What the error is and how you would correct it

2.0 Omissions

Have we left out any measures/practices commonly used or which you find useful? If so, please tell us, and if possible any pictures and design guidelines for us to include in a future update.

3.0 Effectiveness

Are these Guidelines and the other material that we have linked to (e.g. FSP – Doing it Right) helpful for understanding and implementing erosion and sediment control measures? If not, please tell us how we can improve these Guidelines.