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REGIONAL COUNCIL
Te Taiao Tonga

Memorandum

For Your Information

To:	The Independent Hearing Panel for the proposed Southland Water and Land Plan
From:	Roger Hodson
Date:	Thursday, 25 May 2017
File Reference:	pSWLP
Subject:	***Setbacks***

Message:

On 22 May 2017, during the Council Officers' opening presentation at the hearing for the proposed Southland Water and Land Plan, due to time constraints, I was unable to answer a written question from the Panel relating to setback distances based on Land Resource Inventory (LRI) slope classes, for cultivation and intensive winter grazing.

In response to this request to provide an updated analysis in paragraph 7.625 of the hearing report, I have provided a tabulated assessment of the theoretical sediment removal efficiency using the equations provided in Zhang et al. (2010) in Table 1.0. Sediment removal efficacy has been assessed up to 10 degrees slope angle as Zhang et al (2010) found that there were a limited number of empirical studies available over 10 degrees slope to derive that relationship beyond 10 degrees. Additionally an assessment of the sediment removal efficiency is included for the 10 options set out in paragraph 7.608 of the hearing report, and the recommended set back distances for respective LRI slope groupings. Each option has been ranked in terms of theoretical efficiency of sediment removal by summing the individual slope by set back distances, to provide a relative performance assessment. The option with the highest total removal efficiency is ranked number one and the lowest removal efficacy ranked 11th.

Consideration of the LRI slope classes and application of linear set back distances by class has also been included in table 1.0, in the column headed “LRI Recommendation Setback (m)”. A 5 m set back is recommended for slope class “a” < 3 degrees and similarly 5 m for slope class “b” > 3 -7 degrees. The rational for the 5 m set back was provided in the original memo to Clair Jordan, dated 12 December 2016 and reproduced as Appendix 1. In the slope class “c” > 7-10 degree landscape a 20m buffer is recommended. 20 m is recommended because at the upper limit of slope class “c” 10 degrees and with a 20 m buffer the theoretical sediment removal (58.9%) is very similar to the minimum removal efficiency for a 5 m buffer on a 1 degree slope (60.8%).

To provide additional context of the proportion of crop possibly impacted by set back distances on different slope classes, the 2014 winter crop survey (Pearson et al. 2014) has been summarised by slope in table 2.0. In 2014, over 80% of winter crop occurred in the 0-7 degree landscape, with a further 12% in the 8-16 degree landscape and about 4% in the over 16 degree landscape.

Significant water quality and stream habitat benefits will not be achieved if efforts are exclusive of small headwater waterways, i.e. micro channels and ephemeral water ways (Greenwood et al. 2012, and McKergow et al. 2016). Tomer et al. 2008 found that riparian forests likely have the greatest potential to improve water quality along first-order streams, rather than larger streams. Once sediment is entrained in micro channel or channel flow, buffers become less effective at removal (McKergow et al. 2016). Effective removal of entrained sediment from channel flow is likely to necessitate the use of detainment bunds, sediment traps, baffles in micro channels and swales or other mitigation strategies.

Additional improvements in the efficiency of buffers to remove sediment from overland flow will be achieved from implementation of variable width buffers, with wider buffers in areas of concentrated flow i.e. in micro channels and ephemeral water ways (McKergow et al. 2016, Dosskey et al. 2008 and Dosskey and Muler). Consistent and repeatable application of such approaches will require high resolution topography input data sets. Such data sets are currently only available for limited areas in Southland's lowland and low topographical relief areas. However, suitable input data can be generated by several local businesses with surveying capabilities. Costs of creating such input data will vary dependant on the location and travel costs incurred but could be in the order of hundreds of dollars per hectare in contrast to similar data being captured by aerial LiDAR survey at a cost of approximately 3 million for the region.

In the absence of such input data, and while being subjective, it is not unrealistic to make an "on the ground" assessment to identify areas where site specific sediment management is likely to be effective. Areas where micro channel or channel flow develop or are likely to develop may be able to be identified through a combination of historical knowledge of a paddock's surficial hydrological response to high soil moisture or rainfall, visual observation and or basic surveying (e.g. use of a laser or dumpy level) of relative low points/depressions or areas of surficial flow convergence, similar to the approaches a land sustainability officer or other trained person may take.

Table 1.0. Estimated sediment removal efficiency for various set back distances and slope angles adapted from the equations in Zhang et al 2010. Note * used to indicate that there aspects of the submission that are unable to be assessed quantitatively, Rank 1 = most efficient, 11 = least efficient

Slope (deg.)	Rule 23 pSWLP Setback (m)	Eff.	Submission 1 Setback (m)	Eff.	Submission 2 Setback (m)	Eff.	Submission 3 Setback (m)	Eff.	Submission 4 Setback (m)	Eff.	Submission 5* Setback (m)	Eff.
1	5	60.8	3	50.1	3	50.1	1.5	35.3	1	28.4	3	50.1
2	5	64.3	3	53.5	3	53.5	1.5	38.8	2	44.6	3	53.5
3	5	67.8	3	57.0	3	57.0	1.5	42.3	3	57.0	3	57.0
4	5	71.3	3	60.5	3	60.5	5	71.3	4	66.8	3	60.5
5	5	74.8	3	64.1	3	64.1	5	74.8	5	74.8	3	64.1
6	5	75.4	3	64.6	3	64.6	5	75.4	6	78.5	3	64.6
7	5	68.6	3	57.9	3	57.9	5	68.6	7	74.0	3	57.9
8	5	61.9	3	51.2	3	51.2	5	61.9	8	68.8	3	51.2
9	5	55.1	3	44.4	3	44.4	5	55.1	9	63.1	3	44.4
10	20	58.9	10	57.1	5	48.3	5	48.3	10	57.1	3	37.6
Rank	3		8		10		7		4		11	

Submission 6 Setback (m)	Eff.	Submission 7* Setback (m)	Eff.	Submission 8 Setback (m)	Eff.	Submission 9 Setback (m)	Eff.	Submission 10 Setback (m)	Eff.	LRI Recommendation Setback (m)	Eff.
3	50.1	5	60.8	3	50.1	3	50.1	3	50.1	5	60.8
3	53.5	5	64.3	3	53.5	3	53.5	3	53.5	5	64.3
3	57.0	5	67.8	3	57.0	3	57.0	3	57.0	5	67.8
3	60.5	10	80.0	3	60.5	3	60.5	3	60.5	5	71.3
3	64.1	10	83.6	3	64.1	3	64.1	3	64.1	5	74.8
3	64.6	10	84.1	3	64.6	3	64.6	3	64.6	5	75.4
3	57.9	10	77.4	3	57.9	3	57.9	3	57.9	5	68.6
3	51.2	10	70.7	5	61.9	3	51.2	3	51.2	20	72.5
4	50.7	10	63.9	5	55.1	10	63.9	3	44.4	20	65.7
5	48.3	10	57.1	5	48.3	10	57.1	3	37.6	20	58.9
9		1		6		5		11		2	

Table 2.0 2014 winter crop proportion by slope. Adapted from Table 8 in Pearson et al. (2016).

LRI	**Slope (deg)**	**2014 winter crop %**
A	1	
A	2	
A	3	83.2% winter crop
B	4	
B	5	
B	6	
B	7	
C	8	
C	9	
C	10	
C	11	
C	12	
C	13	12.6% winter crop
C	14	
C	15	
D	16	
D	17	
D	18	
D	19	
D	20	4.2% winter crop
E	21	
E	22	
E	23	
E	24	
E	25	

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Appendix 1.0

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Memorandum

For Your Information

To: Clair Jordan

From: Roger Hodson

Date: 19/12/2016

File Reference:

Subject: ***Re: Cultivation Set Back Distance***

Message:

Hi Clair,

Further to several conversations you and I have had, and conversations I have held with colleges within the Environment Southland Science team and externally, I am providing the below summary of literature and of advice related to the sizing of set back distances from areas of cultivation and winter grazing with respect to mitigation of the loss of fine sediment from cultivated areas.

The most effective means of reducing sediment loss from cultivated and winter grazed areas are likely to arise from the application of a combination of risk assessment prior to the selection of land areas for cultivation and implementation of good management. Risk assessment and good management should include but not be limited to careful and considered location, timing and method of cultivation and or grazing of fodder crops along with implementation of sediment runoff management which should include application of buffers between cultivated areas and streams. Buffers could be linear and graduated to increase in width as slope increases or a minimum with, with variable width designed using a GIS-terrain analysis. The implementation of good management practices should be designed with storm size runoff intensity and desired treatment efficiency (percentage load reduction) to define the nature and size and location of additional sediment mitigations (e.g. sediment traps, detention and decanting bunds). Horticulture New Zealand provide a structured framework which should be considered for incorporation into the rule framework or best practice guidance.

Sediment as an environmental contaminant

Sediment is recognised as a leading cause of biological impairment in rivers, streams, lakes and estuaries of many countries (USEPA 2000) including New Zealand (Davies-Colley, 2013).

Suspended sediments affect stream habitat, reducing water clarity and light penetration, and fish health by physical abrasion. Elevated levels of suspended sediments result in increased abrasion of fish gills, resulting in damaged tissue, reduced respiration, leading to increased susceptibility to infection or disease, reduced growth rates or mortality. Reduced water clarity affects the ability of sighted predatory fish to hunt and prey on food items. Reduced light penetration affects the growth of aquatic plants which photosynthesise using light that travels through the water column and can affect fish migration (Ryan 1991 and Cavanagh et al. 2014).

Sediments which settle, or are deposited on the substrate of a waterway, fill interstitial spaces which are important habitat for freshwater benthic invertebrates. Increased cover of deposited sediment is associated with negative impacts on benthic invertebrate indices including declines in taxa richness, altered community composition, reduced abundance of pollution sensitive invertebrate species (Ephemeroptera, Plecoptera, and Trichoptera (**%EPT**)) (Harding et al. 1999). Burdon et al. (2013) have demonstrated that decreased habitat availability as result of fine sediment cover of more than approximately 20% (%EPT) results in a marked decline in the number of pollution-sensitive invertebrates.

Mitigation of non-point source sediment loss

Numerous good management practices are available for use to mitigate non point source loss of sediment from cultivation and winter grazing activities (McDowell et al, 2013; Barber, 2014, Clark et al, 2013) Such practices include but are not limited to; risk assessment prior to selection of cultivated areas; identification and avoidance of surface hydrological pathways; contour cultivation; strategic grazing; implementation of sediment traps; and detainment bunds.

Vegetated buffers to mitigate non-point source sediment loss

In considering the application of vegetated buffers between cultivated areas and streams, it is important to remain cognisant of the important functions of vegetated riparian buffer zones in addition to their potential to mitigate and control sediment. Specifically these include; moderation of shade and; water temperature; maintenance of habitat structural diversity; stream bank protection; provision of aquatic and terrestrial ecological diversity (Broadmeadow and Nisbet, 2004 and Parkyn, 2004).

Vegetated buffers are a widely used and well-studied management practice for reducing non-point source pollution, there are a number of review articles which consider the efficiency and effectiveness of vegetated buffers to reduce non point source pollution including sediment (Zhnag et al, 2010; Parkyn, 2004; Yuan et al, 2009), while specific results vary between studies, climatic regimes, geological areas etc. these studies consistently identify that wider buffers trap more sediment. Zhang et al (2010), review the relationship between sediment removal and set back distance on differing slope angles from 63 published studies, illustrating that sediment removal was positively related to slope when slope was less than

10% (5.7º), and negatively when slope was greater than 10%(Figure 1.0 and Table 1.0). There were no published studies of the efficiency of sediment removal with slope greater than 16% (9.09º) (Figure 1.0).

Linear width vegetated buffers are well suited to the removal of sediments transported by sheet flow, however in many situations as slope angle increases overland flow as sheet flow converges into and moves as channelized flow. Effectiveness and cost-effectiveness of linear width vegetated buffers is reduced because the filter strip is uniformly applied to all locations and could be wider than optimal at locations which receive a small runoff load and not wide enough at convergent flow zones where greater runoff load is received (Dosskey and Muller, 2010).

Table 1.0: Predicted removal efficiency (%) for sediment at different slopes and setback widths, adapted from Zhang et al 2010.

Slope (degrees)	**Setback (m)**				
	3	**5**	**10**	**20**	**30**
1	*51%*	***61%***	*70%*	*72%*	*72%*
3	*57%*	**67%**	76%	78%	78%
4	*61%*	***71%***	*80%*	*82%*	*82%*
6	*67%*	**77%**	86%	88%	88%
7	*58%*	***69%***	*77%*	*79%*	*79%*
8	*51%*	***62%***	*71%*	*72%*	*73%*
9	*48%*	**58%**	67%	68%	68%

NOTE:Italicised text was calculated using the formula provided in the Zhang et al 2010. Extrapolation beyond 9 degrees and below 1 degree was not undertaken as there was no empirical data beyond these slopes. The predicted sediment removal percentages are for riparian margins vegetated with mixed grass and trees (this is the most conservative vegetation type for sediment removal). Greyed box's and bolded text shows the removal efficiency at 5 m setbacks.

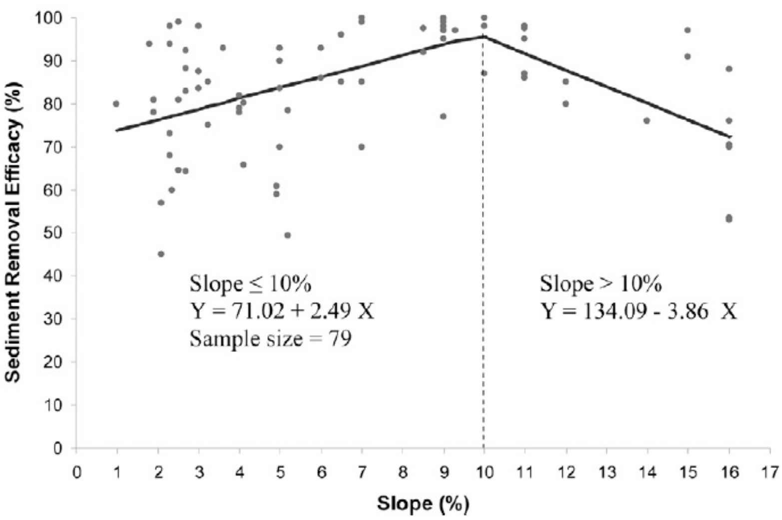

Figure 1.0 correlation between sediment removal efficacy and buffer slope. Modified from Zhang et al. (2010).

Holmes et al. (2016) found that a five meter wide riparian segment (vegetated buffer) with effective stock exclusion was the minimum required to achieve an in stream fine sediment cover below 20%. At greater than 20% fine sediment cover, Burdon et al. (2013) demonstrated a marked decline in the number of EPT taxa as a result of decreased habitat availability. Olsson and Persson (1988) found that the survival of brown trout embryo decreased from 90% to 28% when 20% (volume) of sand was added to redds in coarse gravel.

Summary

The most effective means of reducing sediment loss from cultivated and winter grazed areas are likely to arise from the application of a combination of risk assessment prior to cultivation carefull and considered location and timing of cultivation and grazing of fodder crops along with a GIS-terrain analysis, storm size runoff intensity and desired treatment efficiency to define the nature and size and location of sediment mitigation will be the most cost efficient and efficient application of sediment runoff management. Such a framework is provided by Horticulture New Zealand

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.

Under a permitted activity status, a five meter buffer is recommended to be the minimum vegetated buffer strip to be implemented between cultivated and winter grazed land and a waterway, where the slope angel is less than 9 degrees. *Note: the theoretical % of sediment removal with a five meter buffer is similar at 1 and 9 degrees, 61% and 58% respectively.* Under a permitted activity status, a 20 m vegetated buffer strip where slop angle is greater than 9 degrees.

Under a controlled activity status, where slope angle is greater than 9 degrees to implement a minimum five meter vegetated buffer strip and apply a sediment management plan, including but not limited to: variable buffer width filter strips defined by GIS and terrain analysis; sediment traps; exclude cultivation and grazing from swales, ephemeral water ways (McDowell et al, 2013; Barber, 2014, Clark et al, 2013)

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