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Management practices and mitigation options for reducing contaminant losses from land to water

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1. Background

This document provides a brief description of a range of good agricultural management practices and mitigation measures that are relevant to managing water quality in Southland. This overview has been commissioned by Environment Southland as supporting material that will be used to help underpin policy developments that are being progressed under the Council's Land & Water Plan to be notified in 2016. It draws on a range of generic documents, scientific reports and publications that document the range of potential measures land users can implement to improve water quality outcomes. Section 2 firstly describes general mitigation measures for improving nutrient and effluent management and capturing or attenuating nutrients. Section 3 then provides an overview of mitigation measures that are either targeted at managing critical source areas of contaminant losses (section 3.1) or reducing the accumulation of surplus N in the soil, particularly during autumn and winter (section 3.2).

2. General mitigations

2.1 Nutrient management

2.1.1 Nutrient budgeting

Nutrient budgets account for nutrient flows into and away from farm blocks in fertilizer, feed, animal transfer, animal product and via loss pathways such as leaching, runoff and volatilisation. The planning objective is to ensure that nutrient inputs and outputs are balanced to avoid situations of deficit or surplus. The OVERSEER® nutrient budgeting program (hereafter referred to as Overseer) is a tool that has been developed to assist with such planning decisions.

2.1.2 Reduce use of P fertilizer where Olsen P values are above agronomic optimum

The magnitude of P losses from soil via surface runoff or subsurface flow is generally proportional to soil P concentration. Hence, maintaining a soil test phosphorus (P) concentration in excess of the optimum for pasture production represents an unnecessary source of potential P loss. An optimal soil test P concentration (e.g. Olsen P) can be achieved through regular soil testing and use of nutrient budgeting software, such as Overseer, to guide P inputs. Reducing P inputs and soil test P levels to agronomically-optimum levels will always represent a profitable strategy. The magnitude for P loss mitigation is dependent on how excessive soil Olsen P is. However, soil type also plays a role in P loss and some soil types can lose environmentally-significant quantities of P at Olsen P levels that are less than the agronomic optimum.

2.1.3 Use low solubility P fertilizer forms if runoff risk is high; or fertilize outside risk months (May to September inclusive)

Low water solubility P fertilisers maintain a smaller pool of soluble P in soil solution soon after application than highly water soluble P fertilisers (e.g. superphosphate), thereby minimising the potential for loss should runoff occur. Reactive phosphate rock (RPR) fertiliser has little water soluble P and has been shown to decrease dissolved P losses. However, reactive phosphate rock should not be used where annual rainfall is < 800 mm and soil pH is > 6. Given that only about a third of the applied P in RPR becomes available per annum, a lead-in time is usually required if changing to a fertiliser that has low levels of water soluble P.

2.1.4 Use of Precision Agriculture techniques e.g. GPS guidance and crop sensing

Good design, including the use of novel sensors and automation of crop production, will optimise water and nutrient application according to local plant requirements. Sensors and information usage can also lead to individual animal-based and optimised herd management. By accounting for site-specific growth conditions, water demand and emission risks, precision agriculture can improve local production potentials and increase nitrogen (N) use efficiency.

2.2 Riparian management

2.2.1 Stream fencing

Preventing livestock access to streams decreases stream bank damage (and sediment inputs via bank erosion), bed disturbance of sediments (and entrained *E. coli*, N and P) and stops the direct deposition of excreta into streams.

2.2.2 Improve on-farm infrastructure to keep stock and stock effluent out of waterways

Putting in culverts or bridges at regular stock crossings will prevent animals from fording streams and thus avoid the direct entry of faeces, urine and contaminants entrained in hoof mud. It will also avoid disturbance of the stream bed. Reticulating stock water supplies and planting shade trees away from water will help to reduce animal trafficking through and around stream locations. Reducing runoff from tracks and races using cut-offs and shaping is another particularly important measure that will prevent faecal microorganisms, sediment and P entering streams.

2.2.3 Riparian planting

Planted riparian margins provide a number of ancillary benefits that help to improve the ecological function of waterways. These include the provision of shade to minimise fluctuations in stream temperatures, stabilisation of stream banks, uptake of nutrients from riparian margins, increased biodiversity and aesthetic values.

2.3 Effluent management

2.3.1 Increase land application area to ensure N, P and K returns are not excessive

Because effluent is a particularly rich source of N, P and potassium (K), it makes good economic sense to ensure that inputs of these effluent nutrients are matched to provide the agronomic requirements of pastures on the effluent-treated parts of the farm. The preparation of a nutrient budget will help determine the appropriate area that could be treated with effluent.

2.3.2 Increased effluent pond storage and deferred irrigation

The risk of waterway contamination via land application of farm dairy effluent (FDE, otherwise known as dairy shed effluent) is high on soils with a propensity for preferential flow, rapid drainage via artificial drainage or coarse structure, surface runoff via an infiltration or drainage impediment, or application to rolling/sloping land. Deferred irrigation, which involves storing FDE in ponds when soil moisture is close to or at field capacity and applying FDE to land at other times, has proven effective at decreasing N, P and *E. coli* losses.

2.3.3 Low rate effluent application

Low rate effluent application systems typically use sprinkler-type delivery nozzles to deliver instantaneous rates of effluent application of 10 mm per hour or less. This is much lower than delivered by a rotating twin gun travelling irrigator, and allows effluent more time to infiltrate the soil, helping to ensure the liquid and nutrients contained in the effluent remain in the root zone, available for plant uptake. Runoff or drainage that may occur will at least have had some degree of filtering by the soil if a low rate application system has been used.

2.3.4 Minimise effluent volumes at source

Reducing wash water volumes (e.g. by scraping the yard first and reducing the amount of rainwater captured in the effluent system) will help to minimise the volumes of effluent that need to be pumped, stored and/or applied to land. As well as saving on electricity and pond construction costs, these measures also help to reduce the water quality risks associated with handling the large volumes of liquid effluents that can be generated and re-distributed around dairy farms.

2.4 Capture nutrients, sediment and microbes in wetlands and sediment traps

2.4.1 Facilitated wetlands

These types of wetlands utilise naturally poorly drained parts of the landscape where seepage flows can more easily be intercepted. Fencing and planting of these areas helps to create a wetland environment where sediment, entrained in flow, can be captured, and N removed by denitrification. The beneficial effects of wetlands can be negated if not fenced to exclude cattle and deer, or leaving buffers when over-sowing or topdressing (or if, for some alpine landscapes, burning).

2.4.2 Constructed wetlands

Modification of landscape features such as depressions and gullies to form wetlands. These types of wetlands have also been designed to capture sediment and N discharging from tile drains. Compared to many natural wetlands, constructed wetlands can be designed to remove contaminants from waterways by: 1) decreasing flow rates and increasing contact with vegetation – thereby encouraging sedimentation; 2) improving contact between inflowing water, sediment and biofilms to encourage contaminant uptake and sorption; and 3) creating anoxic and aerobic zones to encourage bacterial nitrogen processing, particularly denitrification loss to the atmosphere. If constructing a wetland, incorporate appropriate plants (such as red tussock, New Zealand flax, purei (carex secta), raupo, and South Island toetoe) and sediment traps, and consider locating near seepage zones where relevant.

2.4.3 Sediment traps

Sediment traps are engineered structures designed to slow water flows, reduce flow energy, filter sediment and allow grass growth. Examples of such structures include decanting dams, detainment bunds, stock ponds or earth reservoirs constructed at natural outlets of zero-order catchments. In-stream sediment traps are useful for the retention of coarse-sized sediment and associated N and P, but do little to retain N and P bound to fine sediment. As the P sorption capacity of fine particles is much greater than coarse particles (w/w basis), sediment traps can be ineffective at decreasing P loss if the soil is finely textured and/or surface runoff is dominated by fines.

3. Targeted mitigations

3.1 Manage critical source areas (CSAs) – protect soil structure, particularly in gullies and near stream areas

Critical source areas account for the majority of a farm's contaminant losses, but come from a minority of the land area. Identification and targeting of mitigations to critical source areas can greatly increase the cost-effectiveness of mitigations.

3.1.1 Minimise fence-line pacing by deer by creating a visual barrier or separating mobs

This strategy is specifically targeted at red deer who have a tendency to pace and erode fence-lines when stressed, for example, when feed is low or near calving. The strategy involves a combination of tree planting to provide shelter and maintaining sufficient feed to ensure stress is minimised. Placing visual barriers between herds will help to minimise social interaction and thus fence-line pacing that can often occur.

3.1.2 Use minimum or no-til cultivation practices such as direct drilling

Minimum or no-til cultivation practices can help to minimise direct and indirect losses of sediment and nutrients to water. A range of techniques is available, from direct drilling of seed into stubble or pasture, through reduced number of cultivation passes, to more judicious use of conventional ploughs and harrows. These help to reduce the proportion of time that land is bare during the growing cycle. Reduced soil disturbance helps to maintain soil aggregation and water infiltration, which in turn helps to reduce the rapid mineralization of soil N and the generation of surface runoff. The suitability of minimum or no-til practices will depend on a range of other agronomic factors, however, and need to be considered on a case-by-case basis.

3.1.3 Cultivate along contours on sloping ground

Cultivation along contours of cropping land will reduce the speed of runoff water, thereby helping to reduce its erosive power and the amounts of sediment, nutrients and faecal micro-organisms entrained in this flow.

3.1.4 Plant spaced poplars or other poles on steep country

Pole planting (and/or retirement of areas) on highly erodible land will lead to the development of tree roots that help to protect soil on steep slopes from mass-movement erosion.

3.1.5 Match stock management to land use capability

Avoiding grazing heavy stock on steeper, more vulnerable soils, especially when wet, will help to reduce soil treading damage and consequently the amounts of surface runoff that can be generated. This will in turn reduce the quantities of sediment, nutrients and faecal micro-organisms entrained in this flow.

3.1.6 Protecting CSAs on winter forage crops to reduce surface runoff

Winter grazing of a forage crop can often lead to large losses of sediment, P and faecal microorganisms in surface runoff that occurs in gullies and swales. Protection of soils in these areas has been shown to be a particularly cost-effective way to minimise the amount of surface runoff that is generated:

- Graze from the top of the slope toward the CSA (such as a gully or swale) – this uses the crop closest or the CSA as a filter for sediment and dung that might be transported in surface runoff. Ensure the CSA is the last break to be grazed by stock.
- Restrict the time spent grazing in the CSA to 3-4 hrs so animals get their maintenance feed requirements whilst minimising the extent of soil treading damage and thus potential for surface runoff.
- Back fence stock off land that has already been grazed to minimise further soil damage.
- Ideally, avoid cultivating the CSA and leave it in pasture to act as a filter for any surface runoff that may occur.

3.1.7 Protecting CSAs on pastures to reduce surface runoff

Rolling and steep pastoral lands often have clearly identifiable CSAs that are frequently wet and prone to damage by stock trampling. Such trampling will exacerbate the potential for surface runoff, which is often already relatively high due to the occurrence of convergent flows that may arise from seeps and wet gully areas. Direct deposition of animal excreta into these areas also provides a source of contaminants that can be transported in these convergent flows. Protecting these locations from stock damage, even just temporarily during wet periods, is likely to avoid these losses.

3.1.8 Provide deer wallows away from waterways

Red deer will use or create areas for wallowing. The wallows are often directly connected to streams thereby providing a direct conduit for deposited excreta. Disturbance of the stream bed and banks can be a major source of sediment during wallowing. Fencing off existing connected wallows and the creation of a wallow that is not connected to a stream will avoid these problems.

3.1.9 Leave vegetated areas around CSAs and stream margins

A vegetated buffer or filter strip is a fenced-off area containing dense grasses or native plants that runoff water passes through before reaching a water body. These areas act as infiltration or deposition zones that are particularly effective at intercepting particulate material. Their recommended size varies depending on soil and landscape features. It is particularly important that they are located in areas where surface runoff is known to occur or converge.

3.1.10 Plant split grass/clover swards in near-stream areas

Using grass–clover monocultures strategically across a dairy farm may decrease P loss to surface water and improve profitability compared with a mixed pasture. The principle of this technique is to ensure that plants that have a relatively high P demand, such as clover, are located away from near-streams areas. Conversely, grasses that have a lower P demand can be located in near-stream areas (the CSA) and fertilised to maintain a lower soil Olsen P test and thus a smaller reservoir of P that could potentially be transported in overland flow (or subsurface drainage).

3.1.11 Move troughs and gateways away from water flow paths

Areas of compacted soil or gravel have minimal infiltration. Excreta deposited to these areas can therefore be easily transported in surface runoff. To avoid this runoff entering streams, ensure that these hard surface areas are located well away (or “disconnected”) from active flow pathways that can deliver water contaminants to streams.

3.2 Reduce the accumulation of surplus N in the soil, particularly during autumn and winter

3.2.1 Reduce inputs of nitrogen, such as fertiliser or N contained in imported feed

Greater N use efficiency can be achieved by the implementation of a number of measures that collectively help to reduce the risk of N losses to water. These include increasing per-animal production, with a commensurate decrease in animal stocking rate (replacement rates particularly) to maintain per hectare production and profitability; using less fertiliser N and some, if prices allow, low N feeds; and maximising the N value of farm dairy effluent by applying it to a greater proportion of the farm. The use of gibberellic acid to boost pasture growth is another option that can allow overall N inputs to the farming system to be reduced accordingly.

3.2.2 Increase the spread of urinary N – change animal type or salt supplementation

Animal type influences N leaching due to inherent differences in the spread of urinary N (the major source of N loss in grazed pastures). Increased urinary spread results in a lower rate of N deposited in urine, greater utilisation by plants and less surplus N that contributes to N losses. Research has shown that N leaching from sheep and deer is approximately half that from beef cows at the same level of feed intake. Potentially, differences also exist between male and female cattle; losses from male cattle being about two-thirds that of female cattle, although there is high uncertainty with this. Similarly, young cattle are assumed to have greater urinary N spread than larger older cattle due to greater animal numbers per unit of feed consumed and thus a greater number of urinations; again, there is limited data on this aspect, however. An alternative way of increasing the spread of urinary N is to supplement animals with salt. Recent research has shown that this increases water intake and urination frequency, resulting in a lower urine N deposition rate and decreased N leaching risk.

3.2.3 Duration-controlled grazing

Research in Southland (and elsewhere) has also shown that restricting autumn grazing rounds to 3-4 hours per break, then excluding the animals (removing them to a pad or barn) can significantly decrease urine deposition to land prior to the on-set of winter drainage. This management system has been shown to decrease nitrate losses in drainage from the milking platform by up to 40%; this does however depend on the extent to which duration-controlled grazing is implemented during autumn months. This principle of duration-controlled grazing as a strategy for reducing N leaching is likely to also apply to grazed winter forage crops, although research quantifying this effect is still in a preliminary stage.

3.2.4 Off-paddock wintering

On-going research in Southland indicates that grazed winter forage crops are a significant source of the nitrate lost in drainage from the dairy farm system.

Strategies that avoid or minimise the deposition of urine to these grazed crops can help to decrease these leaching losses. Stand-off pads (preferably covered) or wintering barns are some of the infrastructure options that could be considered to allow for capture of urinary N that would otherwise be deposited directly in the paddock. Cut-carry fodder crop systems are one example of an off-paddock wintering strategy that might be practical and affordable for some; other approaches that are more commonly used are based around providing ensiled feeds whilst animals are off-paddock during winter.

3.2.5 Re-sow areas of bare or damaged soil as soon as possible

Re-sowing areas of bare or damaged soil as soon as practical will help to minimise periods when exposed soil may be prone to erosion, overland flow or leaching. The rapid establishment of crops or pastures will maximise the opportunity for plants to take up N from the soil, thus reducing the risk of N leaching. This can be particularly important for summer-grazed forage crops that will have much urinary N deposited onto bare soil.

3.2.6 Incorporating low N feeds into diets

Ruminant animals consuming a pasture-based diet typically ingest far more N that they require. Consequently, more than 70% of ingested N is excreted via urine and dung. Because urine is the major source of N lost from grazed pastures in NZ, any strategy that can decrease the amount of urinary N deposited to pasture will help to decrease N leaching losses. The incorporation of low N feeds such as maize or cereals into diets has been shown to decrease urinary N excretion and on-farm N leaching losses. However, it is important to also consider the effects of the production of low-N feed on N losses; when this is done there may only be small whole-system benefits unless N-efficient practices are used to grow the low-N feed crop. Potentially, this strategy will be most beneficial where the low-N feed is a waste by-product from another sector (e.g. vegetable or fruit waste).

3.2.7 Plant catch crops to capture N from grazed winter forages

Preliminary research trials in Canterbury have established that nitrogen (N) leaching from winter forage crop paddocks can be reduced by planting an oat crop immediately after cows harvest the winter forage. The oats crop in this sequence is a “catch crop” that can capture urinary N from the soil, while increasing overall annual crop yield when compared to the standard winter forage crop. Sequence cropping can provide all the feed needed for wintering, whereas kale-only systems require supplements to be brought in to balance the diet. Sequence cropping will only be successful on free-draining soils where machinery can operate soon after kale grazing is completed, where there is irrigation or good rainfall from early December onwards, and where kale is well-utilised during winter grazing so the residues do not interfere with sowing of the oats.

3.2.8 Optimize timing and amounts of irrigation input

The judicious timing of irrigation inputs will minimise the risk of leaching and runoff. Guidance using soil moisture balance calculations or soil moisture sensors will help to ensure irrigation is applied to replace soil moisture deficits, thus minimising applications of surplus water that could transport nutrients beyond the root zone. Regular evaluations of irrigation system performance will help to ensure that water is delivered according to need.

3.2.9 Schedule N applications to meet plant demand using split applications

The principle of scheduling N fertiliser applications to crops and pastures is to synchronise inputs with plant demand, recognising that a range of factors will govern plant requirements. Some important factors are yield potential, the intended use of the crop, moisture and temperature limitations, soil type, paddock history, cultivar and plant establishment. In most situations split applications of N fertiliser will be required to maximise the opportunity for plant N uptake whilst minimising the risk of loss to the wider environment. Due to the potentially wide range of factors to be considered, the use of expert agronomic advice and tools such as crop calculators should be used where appropriate. Detailed guidelines are also provided in Code of Practice Nutrient Management documents prepared by the Fertiliser Association of New Zealand (e.g. NZFMRA 2009).

4. References

McDowell, R.W., Wilcock, R.J., Hamilton, D.P. 2013. Assessment of Strategies to Mitigate the Impact or Loss of Contaminants from Agricultural Land to Fresh Waters. AgResearch Client Report RE500/2013/066 to the NZ Ministry for the Environment. 46p.

Monaghan, R.M. 2013 The influence of land use, soil properties and seasonal factors on contaminant accumulation and loss from farming systems to water. AgResearch Client Report RE500/2014/106 to Environment Southland. 55p.

NZFMRA 2009. Managing soil fertility on cropping farms. Published by the New Zealand Fertiliser Manufacturers' Research Association Inc. http://www.fertiliser.org.nz/Site/resource_center/Booklets.aspx