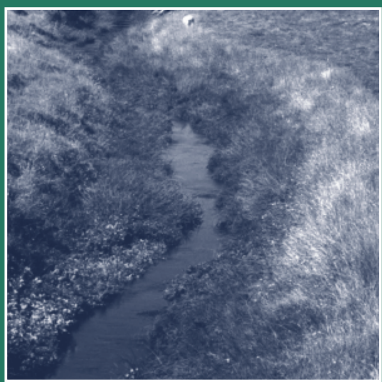
Sustainable drainage management

Field guide





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Preface

This field guide promotes sustainable drainage management by providing a series of critical Best Management Practices (BMPs) and a framework to apply these practices. Problems are placed into four categories: sedimentation, vegetation, water quality and biodiversity. Necessarily, there are management measures and practices that are common. Each section is designed to be stand-alone.

It is expected that practitioners have a working knowledge of "H20-DSS Hillslopes to Oceans: Decision Support System for sustainable drainage management" which provides the science underlying the field guide. Available online: www.nzwerf.org.nz.

Work in progress

This guideline is a work in progress, reflecting best practice in a rapidly evolving field at the time of writing. Any comments and additional information that could help other drainage managers in New Zealand are most welcome and can be directed to NZWERF:

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Recommendations are based on published literature, and are not necessarily supported by extensive local research. The information is provided as a starting point for professionals and advisors in land and water management.

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Some management strategies and recommendations require prior authorisation (i.e. resource consent). The advice of Regional and District Councils should be sought before embarking on the management strategies and recommendations from this guide.

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Selwyn District Council
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Te runanga o Ngai tahu
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Department of Conservation

1 Why do we need drainage management?

New Zealand has a vast network of waterways that are managed for drainage outfall, to alleviate flooding, and to control channel erosion.

Without adequate drainage large areas would be unproductive or inaccessible.

Therefore the main objective of drainage management must be to keep drain systems functioning effectively and efficiently.

Good drain management will keep drain systems functioning effectively and efficiently. Photo: Greater Wellington.

Why do we need better drainage management?

There is a long history of successful drainage management in New Zealand, but the focus has been on hydraulic efficiency (removing water as fast as possible). In this endeavour there is room for improvement and learning from others.

It is now recognised that drains are often important habitats, or could be important habitats, and have multiple uses and values. Many landowners recognise the importance of managed waterways and want to do the right thing environmentally.

A major challenge is to find the best solution for the immediate drainage management issues, while considering the possible effects of these solutions on other interests/values in the waterway. This is consistent with the intent of legislation, such as the Resource Management Act, and Regional Council water plans. It is a proactive response to the potential imposition of non-tariff trade barriers by competing countries that are already operating under stricter environmental regulatory controls than New Zealand.

Whatever the main interest, the long-term solution sought is preferably sustainable with respect to appropriate hydraulic performance, reduced costs, and multi-uses.

What are the problems?

Poor water quality caused by farm runoff and livestock excrement can be a problem for drain systems. Photo: Greater Wellington.

For convenience drainage management related problems were sorted into four groups. Example problems in these groups include:

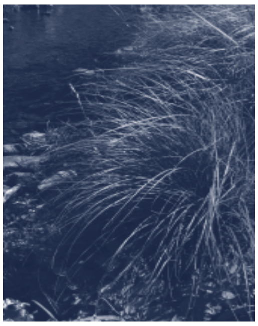
- **Sedimentation:** Sediment build up in the channel causing loss of outfall and water-logging of paddocks; dirty water affecting downstream users
- **Vegetation:** Instream weed growth causing high water levels and reduced habitat (e.g. inanga, the main species of whitebait, prefer open water for feeding)
- **Water quality:** Poor water quality caused by farm runoff and livestock excrement in waterways
- **Biodiversity:** Drain cleaning disrupting trout spawning by directly disturbing the bed and depositing fine sediment on spawning beds downstream; excavation removing eels from drains

Some problems and solutions are obvious, such as sediment deposits obstructing a drain and raising water levels. The quick fix is obvious and necessary - excavate the drain. Cleaning drains is the major drainage management activity.

Sustainable management fixes problems, but also looks past the quick fix to the causes of the problem. In a sense this moves drainage management from being reactive (an ambulance at the bottom of the cliff) to proactive (preventing access to the cliff).

Fixing causes of problems usually requires a bit of investigation. In this example, sediment could be from farmland erosion, livestock trampling stream banks, or erosion of the channel. There are often a few different approaches (management measures) and several methods (best management practices) that can be used to fix the cause of a problem (see Table 2-1).

What are the solutions?



Retaining streamside vegetation provides habitat for fish, moderates stream temperatures and represses weeds in small channels. Photo: Greater Wellington.

The first priority should be to prevent problems:

- Control generation and movement of soil and contaminants from farm lands by managing fertiliser inputs, appropriate land uses, and conservation measures
- Control inputs of sediment and contaminants from the drain itself (e.g. bank erosion and livestock excrement)
- Retain streamside vegetation and buffers to provide habitat, moderate stream temperatures, and repress weeds in small channels
- Avoid disturbing sensitive places, such as remnants of native vegetation; and whitebait spawning habitat

Recognising that it is not possible to completely control all sources, the second priority is to stop sediment and contaminants reaching waterways:

- Trap and treat sediment and contaminants before they reach waterways with various types of buffer strips and wetlands/detention structures
- Streamside planting is typically used with habitat, temperature and weed repression benefits

The third line of defence is to stop downstream spread:

- Trap and treat sediment and contaminants in waterways with instream traps and filters
- Stop the spread of weeds by washing down equipment and containing invasive species

How do you go about this?

First, an integrated approach that looks beyond traditional drainage management requires a broader management view, and organisational support to carry this out (e.g. involvement of land care groups and soil conservation specialists).

Second, objectives have to be clearly defined. There has to be a shift from a process based approach (how much drain was cleaned) to a performance based approach.

- For example, drains should be maintained so as to lower the water table of surrounding agricultural land 30 cm below the soil surface within 24 hours of the cessation of rain and to 50 cm below the soil surface within 48 hours after rainfall. A one-year return period 24 hour storm is the design event
- Drainage performance targets should be based on gains in agricultural productivity and access to farmland resulting from drain management
- Environmental performance objectives to comply with the Resource Management Act, policies and plans are required. These will vary regionally and presumably by eco-region and type of waterway

Third, you need to determine the nature of the problem. Is intervention necessary? What, if any, management measures will be used? Where will they be applied? And what is the likelihood of success and risks? (see Key questions in decision making).

- Keep in mind that treating effects is a necessity in the short term, but the long term solution should involve management measures to treat the causes of the problem
- Long-term solutions, although perhaps more expensive at the time, are often more cost-effective than repeated short-term approaches

Fourth, select management measures and best management practices.

- Rarely is there a “silver bullet” solution - often more than one best management measure is required (e.g. controlling erosion on farmland; and trapping and treating sediment before it gets in the waterway)
- For any one aspect of the problem there is often more than one best management practice required (e.g. to control an eroding bank stock are fenced out and bare soil is grassed; and banks are reshaped and planted with trees to stabilise an undercut bank)

Fifth, follow up and report the successes and failures of your actions.

Key questions in decision making

1. What is the problem?
   A clear identification of the particular problem(s) is a prerequisite to any management intervention.

2. What are the causes?
   There may be multiple causes of a particular problem. The sources, and magnitude and frequency of contribution to the problem must be identified to prioritise actions. Management should always try to address the causes of a problem. Treatment of effects without addressing the causes may result in expensive, repetitive actions that are unsustainable and unsuccessful.

3. What is the objective?
   Have a clear idea of what you have to achieve both locally (e.g. removing sediment) and at a reach (e.g. general channel instability) or perhaps catchment scale (e.g. changing land use). Check if these objectives are realistic and will bring a demonstrable benefit.

4. Is intervention required?
   In some cases indirect actions may solve the problem. E.g. local bank failures may stabilise and the blockage may be naturally removed by streamflow if livestock grazing on the banks is controlled.

5. What are the most appropriate methods to relieve effects and to achieve a long term solution?
   The choice of management practices and the location and timing of operations will determine the success of the project and likely impacts.

6. Is consultation and resource consent required?
   Early and extensive consultation with relevant regulatory authorities, interest groups and individuals is crucial. Obtain the required authorisations.

7. Are there negative local impacts?
   Think what other activities might be indirectly or inadvertently affected. E.g. riparian planting may prevent access for future drainage management; using heavy equipment to clear a channel may cause land disturbance and loss of farm productivity.

8. What effects might the works have elsewhere?
   Actions in part of a waterway may have impacts upstream (e.g. erosion with channel excavation), downstream (e.g. sediment plumes) or laterally (e.g. de-watering wetlands).

9. When is the best time to undertake work?
   Some emergency works have to be undertaken immediately. Routine maintenance should avoid sensitive times and places for fish and animals. Use the most effective period for weed management (which is often not when weeds are causing a problem). Flood or erosion risk should also be considered.

10. What are the chances of success and risks of failure of the proposed actions?

11. What are the risks of no intervention?

12. Is help or consultation required?

2 Sediment-sedimentation

Sediment in drains is largely made up of soil and particles of rock (clay, silt, sand and gravel). Sedimentation includes the processes of erosion, transport and deposition of sediment, in this case by the action of wind and water.

Sediment deposition occurs because the water velocity decreases to the point where the flow can not keep moving the sediment. (It takes a much greater force of water to erode sediment than it does to keep sediment moving).

What is the problem?

Sediment deposition can obstruct channels, and may increase hydraulic roughness, resulting in high water levels and possibly flooding. Weeds often grow quickly in the fresh sediment, which in turn traps more sediment.

While 'muddy' water is natural, particularly during storm runoff, excessive amounts of sediment can have severe effects on stream life (e.g. making it too dirty for fish to feed or migrate; and covering stream beds and suffocating fish eggs and stream bed life) and other water uses (e.g. stock watering, domestic supply).

Drainage management activities may increase suspended particulate matter (dirty water) and cause sediment deposition. However, there are few studies of the actual effects of drainage management and existing sediment guidelines require critical examination.

Effective sediment control will reduce costs by reducing the frequency or eliminating the need to remove sediment from waterways. As well as benefits to land productivity by controlling erosion, there are instream environmental benefits from controlling excessive sediment.

Weeds often grow quickly in fresh sediment, which in turn traps more sediment. Photo: Greater Wellington.

Sources of sediment

It is important to control the sources of sediment otherwise continual maintenance will be required. Drainage managers should be concerned with three sources of sediment:

- Upland erosion, often referred to as "soil erosion," caused by surface wash processes (rain-splash and surface runoff over exposed soil), concentrated flow (rilling, gullying), and mass movements (slumps and slides)
- Channel bed erosion where the force of water is sufficient to pick up bed material. Also, stock, vehicles and other disturbances (e.g. weed removal) may re-suspend sediment on the bed
- Channel bank erosion where the force of flowing water is sufficient to remove bank material, and seepage flows and other forces act on the banks to contribute sediment to the channel (e.g. the toe of a bank is eroded and the bank collapses). Stock may trample and collapse stream banks

Stream bank erosion can be a source of sediment in drains.

Sediment management

It is generally accepted that the most effective approach to reduce sediment obstructions in waterways is to control the supply of sediment from surrounding land and the channel. Not all sources can be controlled, so channel obstructions may still occur, but probably far less frequently.

If a channel is significantly obstructed the correct management response is to excavate to restore the required outfall. BMPs include (Table 2-1):

- Work windows: Using work windows, where appropriate, to avoid adverse effects on fish and wildlife by avoiding sensitive places at particular times. Work windows are discussed under Biodiversity
- Channel excavation: To restore the hydraulic capacity of channels that are obstructed by sediment deposits and weeds by excavating excess bed material and weeds. Hydraulic excavators with conventional buckets or weed rakes are used, normally from one bank, with spoil carted from the site or deposited along the edge of the channel

Sediment can be excavated to restore the hydraulic capacity (as above) but a more proactive approach is to trap sediment at preferred locations by using coarse sediment traps.

A more proactive approach is to trap sediment at preferred locations. This limits the length of channel that is disturbed, reduces costs, and improves habitat:

- Coarse sediment traps: Sediment traps are relatively wide, short and deep excavations in the bed. Trapped sediment does not progress downstream where deposition would reduce channel capacity. The trap itself has to be episodically excavated (after major storms) rather than a much greater length of the stream. Sediment traps confine sediment deposition to a small reach of channel and reduce excavation costs. Used as the upstream control in sediment detention wetlands for fine sediment trapping. Erosion protection may be required

Upland erosion

Soil erosion occurs when water splashes onto the soil surface and dislodges soil particles, or when wind reaches sufficient velocity to dislodge soil particles on the surface. Soil conservation measures are required (Table 2-1), which is beyond traditional drainage management activities, but is within the range of practices required for sustainable drainage management.

The single most important factor controlling soil erosion is ground cover. Crop residues (e.g. straw) or vegetation (e.g. grasses) on the soil surface protect against detachment by intercepting and/or dissipating the energy of falling raindrops, flowing water and wind. Although reduced tillage system results are site specific, erosion reductions in excess of 90% are reported. Strip cropping and terracing have average effectiveness in reducing erosion of 65% and 85% respectively. Critical area planting is frequently used in New Zealand (e.g. planting trees, shrubs and grasses in eroding gullies).

The amount of material generated from upland areas will determine the size and effectiveness of mitigation measures which control the movement of sediment (and associated contaminants) to streams:

- Filter strips >30 m are needed in most cases with erodible soils and poor upland management
- If good land management practices are implemented, the sediment and contaminant load decreases dramatically and the filter requirement greatly reduces to practical widths (generally in the 2 to 5 m range)

The second strategy, which is used in combination with the control of soil erosion, is to divert, filter, trap, or settle soil particles in surface runoff between the source and the channel. BMPs include (Table 2-1):

- Filter strip: A strip of vegetation along a waterway margin that intercepts sediment, organics, nutrients, pesticides, and other contaminants from shallow surface flow. Effectiveness is rated as low to medium for sediment control, but this is highly dependent on the volume of sediment generated, topography, and cover conditions. Highly efficient trapping (>90%) is possible
- Grassed waterways: Broad, shallow, natural or constructed channel that is grassed so as to move surface water across farmland without causing soil erosion (e.g. rills, gullies). Effectiveness is rated as low to medium for sediment control, but these depressions may have been significant sources of sediment in their own right before they were grassed

Grassed waterways have a low to medium effectivenes but such areas may have been high contributors of sediment before grassing.

- Interceptor drains (diversions): Small channels with a minor ridge along one edge that collect and direct surface water to a desired location such as a stable outlet or sedimentation pond. The drains and bunds can either have a natural grass lining or, depending on slope and design velocity, a protective lining, or gravel bed. They protect sensitive areas or work areas from upslope runoff and erosion; ensure that sediment-laden stormwater will not leave the site without treatment (e.g. diversion to a sedimentation pond); and divert water

Stream erosion

Stream bed erosion is normally controlled by structural measures installed across the bed and tied into the bank (e.g. rock or wood grade control structures; boulder clusters). Stream bank erosion is normally controlled by a mix of structural measures (such as riprap, flow deflectors, groynes and retards) and non-structural measures. Non-structural measures include increasing the capacity and hydraulic efficiency of a channel (by straightening, deepening, shaping or widening the channel and constructing new channels); and stabilising banks with vegetation.

Most well rooted vegetation, including pasture grasses, is likely to be a benefit for bank protection, providing resistance to flowing water and other erosion processes (e.g. rainsplash, freeze thaw, slacking, drying and cracking; and mass failures).

- Streamside planting: Plants are established or encouraged to grow along the channel margin, on the banks, floodplain and berms along the stream to provide erosion protection, habitat, food supplies, amenity and cultural values and to enhance water quality by reducing light and temperature and filtering and absorbing sediment and contaminants. Desirable species may suppress weeds in the channel and on the banks (See Biodiversity)

Vegetation is difficult to establish on near vertical banks or banks that are actively eroding or are unstable. Also, if the rooting depth is less than the bank height the streamside vegetation will provide little protection from bank scour. Therefore stream banks may have to be re-shaped (re-battered). Bank reshaping can also be used to increase channel capacity:

- Bank reshaping: Banks are excavated to remove steep drops and unstable materials, and to lower the bank to allow roots to extend through potential failure planes and into the lower bank where there is potential for scour. Channel capacity may be increased by bank reshaping and marginal vegetation may filter contaminants and reduce flow velocities (See Biodiversity)

While streamside planting can be very effective in its own right, particularly in areas with low rates of erosion, planting may have to be combined with structural measures in other situations (e.g. eroding bends). Time is required for the plants to grow to become effective in erosion control. In some cases a sacrifice zone is established, with planting set back to protect the bank from erosion some years in the future.

Stock crossing streams, drinking from streams and grazing in and near streams can have significant impacts on bank erosion, sediment plumes and water quality. Actual impacts are highly dependent on stock management and site conditions. For example, deer wallow in shallow pools while sheep generally avoid water.

- Exclude livestock from waterways: Prevent livestock from entering waterways or trampling riverbanks by fencing the stream corridor. Exclusion will generally reduce erosion and habitat degradation; improve water quality; and health and safety of livestock. Various types of fences can be used (e.g. single wire electric to flood proof multi-strand fences). Any fencing or riparian planting must take access for drain maintenance into consideration

Excluding livestock from drains will generally reduce erosion and habitat degradation. Photo: Greater Wellington.

The overall benefit of excluding livestock from waterways is usually high; but selective grazing can be useful. Fords can be built to minimise bed erosion, but culverts and bridges are recommended for stock and vehicle crossings. If stock is excluded from waterways alternative water supplies are required (e.g. water pumping to a water trough). Where alternative water sources are not feasible, restricted access points should be constructed. There are numerous options for fencing types and design.

Table 2-1. Sediment problems, management measures and selected best management practice.

Problem	Management measure	Best management practice
Sediment build up in the channel	remove sediment deposit	• channel excavation • work windows • coarse sediment trap
Sediment movement downstream	control sediment transport	• grassed waterways • sediment traps • instream filters
Upland erosion	on-farm soil loss control	a large range of practices are available including: - cropping management practices: • conservation tillage • contour strip-cropping • conservation cropping sequence • cover control - stock management practices: • stock & waterways • rotational crazing - water and sediment control practices: • grassed waterways • interceptor drains • critical area planting • control basins • terraces
	off-farm loss control	• filter strips • field borders • wetlands
Bed erosion	grade stabilization	• drop structures – weirs • vanes • deflectors • placement of large organic debris
	bed stability	• stock & waterways • restricted access watering points • stream crossings
Bank erosion	lateral erosion protection	• streamside vegetation • bank reshaping • multi-stage floodways • anchored trees • rip rap • groynes • retards • flow deflectors
	bank stability protection	• streamside vegetation • bank reshaping • stock & waterways • vegetation (weed) control
	surface wash protection	• rehabilitating land • grassed waterways • stock & waterways • farm tracks

3 Vegetation (weeds)

Vegetation management is a major component of drainage maintenance in New Zealand. Traditionally the focus has been on the control of aquatic "weeds" and bank vegetation, for hydraulic efficiency and bank erosion protection, but there is an increasing recognition of the broader role of vegetation in aquatic systems (e.g. habitat, food, amenity and cultural values).

Effective vegetation management is shifting toward careful planning, preparation, and practices to maximise beneficial vegetation growth (e.g. erosion control and habitat), and at the same time minimise potential adverse effects (e.g. flow impedance; and excessive growth causing erosion).

What is the problem?

Vegetation management is generally undertaken to address several drainage problems:

- Weeds are removed as a precaution against weeds being ripped out in high flows and blocking culverts
- Drainage outfall is not achieved as completely as required (i.e. in terms of water table draw down)
- Drainage may not be as rapid as required (e.g. fields may be waterlogged for several days rather than a couple of days, which may destroy crops and impede access for extended periods)
- Weeds elevate water levels and increase the incidence of flooding
- Weeds slow flows and encourage deposition of suspended sediment which reduces capacity and raises water levels
- Weed beds and associated sediment deposits may change the magnitude and direction of currents which may cause bank erosion

Glyceria is an aggressive aquatic plant pest and can form dense impenetrable stands in watercourses. It is troublesome in drains, slowing water flow. Photo: DOC.

While it is recognised that streamside and aquatic plants are an essential component of aquatic ecosystems, excessive weed growth can degrade water quality and aquatic habitats. Problems include water taste and odour, reduced dissolved oxygen levels (from decomposition and respiration at night), weeds out competing more desirable plants, impeding fish passage and feeding, fouling of water intakes, prolific growths interfering with recreation.

Controls of excessive plant growth

Major factors governing plant growth include:

1. Nutrients in the water column and in stream bed sediments: High levels of nutrients can produce proliferations of aquatic weeds; but nutrients alone cannot indicate whether a waterbody actually has a nuisance plant problem.
2. Light and temperature: Sunlight is the source of energy for plant growth, and both the type of light (spectrum) and quantity of light received are important. Temperature influences maximum rates of photosynthesis and growth.
3. Hydrologic regime: Aquatic plants are more abundant in slower moving water. The time between high flow events that uproot plants is particularly important in determining the biomass in streams.

Prevention of weed problems

The first priority is to undertake preventative measures, specifically controlling agricultural inputs and contaminant runoff. This includes selecting the most appropriate land uses; efficiently applying farming inputs; and reducing the generation and losses of sediment and contaminants.

Other preventative measures include controlling the spread of weeds; and modifying the shading and temperature of small streams:

- Limiting the spread of weeds: Cleaning weeds from hydraulic excavators, weed cutters and watercraft to prevent transfer between waterways; control of the disposal of spoil from weed removal; control of upstream sources of weeds
- Streamside planting: Plants are established or encouraged to grow along the channel margin, on the banks, floodplain and berms along the stream to provide erosion protection, habitat, food supplies, amenity and cultural values and to enhance water quality by reducing light and temperature and filtering and absorbing sediment and contaminants. Desirable species may suppress weeds because of competition

Encouraging plants to grow along drain banks improves erosion protection, habitat, food supplies, amenity and cultural values. Photo: Greater Wellington.

The second line of defence is to trap and treat contaminants before they reach waterways:

- Filter strip: A strip of vegetation along a waterway margin that intercepts sediment, organics, nutrients, pesticides, and other contaminants from shallow surface flow. Effectiveness is rated as no control to ineffective for soluble nutrients and pesticides; to low to medium effectiveness for absorbed (attached to sediment) nutrients and pesticides; and report 5-59% removal of dissolved phosphorous and 28-80% removal of particulate phosphorous
- Grassed waterways: Broad, shallow, natural or constructed channel that is grassed so as to move surface water across farmland without causing soil erosion (e.g. rills, gullies). They filter sediment and sediment associated contaminants (e.g. nutrients and pesticides), but are inefficient at filtering soluble contaminants

Treatment of weeds

Even with preventative measure in place, some treatment of weeds is likely to be required (e.g. there may be high nutrient levels in the bed sediments causing excessive plant growth).

The first step in treating weeds is problem framing:

- Determine the nature (e.g. high water levels; invasive species) and extent (e.g. blocked culvert; local invasion) of the problem
- Identify the problem plant species
- Determine the likely benefits of treatment (e.g. removal, containment or eradication). Both the effect on hydraulics and the effects on aquatic ecosystems should be considered
- Determine the risk of not intervening

Determine if immediate relief is required (e.g. clearing a blocked culvert; excavation of the channel to remove weeds and reduce flooding); whether some delay is acceptable (e.g. plants take days to weeks to respond to chemicals); or if a longer term view can or should be taken.

Second, develop a weed management plan to select an appropriate treatment (or combination of treatments) that will not exacerbate the problem, or have major unintended effects; and select an appropriate time frame to undertake weed treatment:

- Successful treatment must be based on the correct identification of plants and knowledge of their behaviour; otherwise treatments can be ineffective or counterproductive (e.g. mechanical removal of Eurasian water milfoil typically produces large amounts of viable fragments that can re-infest or spread)
- Timing, frequency and duration of treatment are often critical (e.g. treatment of emergent New Zealand Pygmy Weed *(Crassula helmsii)* by glyphosate was far less effective in the autumn (~15% control) than in the summer (~85%); but there was better than 90% control of submergent plants by Diquat-alginate in both periods
- Local treatment may be ineffective if re-invasion occurs from upstream or from the import of material on equipment or in soil

Third, treatments should be considered as experiments with monitoring, assessment and reporting of successes and failures so that better treatments can be developed and refined. Treatment may need to continue for several years to be successful; and long term monitoring may be required to assess whether control has been achieved (e.g. persistence of *Hydrilla* propagules).

There are few comprehensive evaluations of treatments for weeds found in New Zealand drains. An example BMP for a problem emergent plant, *Glyceria maxima* has been developed as a template for other species.

4 Water quality problems

Water quality problems were not traditionally considered part of drainage management; but these problems are intimately related to the efficient removal of surface and subsurface water from agricultural lands (and urban areas).

The drainage network (both constructed and natural) becomes a source, a sink, and a conduit of sediment and contaminants. What happens in the catchments ultimately determines water quality in receiving waters.

Problems include:

- Increased range of **water temperature** with the removal of streamside vegetation (effecting biological diversity)
- Low **dissolved oxygen** (asphyxiation of respiring organisms)
- Elevated **nutrient levels** (nuisance growth of aquatic plants)
- Increased suspended **particulate matter** (e.g. smothering of benthic organisms, inhibition of primary production) (see Sedimentation)
- Reduced **water clarity** (e.g. reduction in photosynthesis; change in predator–prey relationships) (see Sedimentation)
- Increased **biological contaminants** (e.g. bacteria, viruses, parasites, micro-algae bio-toxins)

An integrated catchment management approach is required, and drainage management has a major role within this.

Water temperature

Pre-disturbance, many New Zealand waterways had extensive streamside cover. Loss of shading increases water temperatures and daily water temperature fluctuations, especially during summer. Increased water temperature can stress or be fatal to aquatic life. Also, warm water naturally holds less dissolved oxygen (DO) and higher temperatures can cause DO problems for aquatic life.

Many managed streams are likely to benefit when the vegetation casts a shadow over the stream. Shading is likely to be effective where the combined bank and vegetation height is equal to or greater than the channel width. The banks themselves provide shade in narrow streams; but as the channel width increases the vegetation height must increase. For channels >12 m riparian trees are unlikely to be effective for temperature and algal control.

- Streamside planting: Plants are established or encouraged to grow along the channel margin, on the banks, floodplain and berms along the stream to improve erosion protection, habitat, food supplies, amenity and cultural values. Planting also enhances water quality by reducing light and temperature and filtering and absorbing sediment and contaminants. Desirable species may suppress weeds because of competition

Dissolved oxygen & nutrients

Low dissolved oxygen (DO) levels have an adverse effect on many aquatic organisms (e.g. fish, invertebrates and micro-organisms). Prolonged exposure to levels <5-6 mg/L may not directly kill an organism, but increases susceptibility to other stresses. Exposure to <30 % saturation (<2 mg/L oxygen) for 1-4 days may kill most of the biota in a system.

Very low oxygen levels (anaerobic conditions) can result in the mobilisation of many otherwise insoluble compounds. The breakdown of sulphate compounds will often impart a “rotten-egg” smell to the water, affecting its aesthetic value and recreational use.

Oxygen is produced during photosynthesis and consumed during respiration and decomposition. Photosynthesis requires light whereas respiration and decomposition occur 24 hours a day. Proliferation of periphyton (the slime and algae found on the stream bed) may reduce dissolved oxygen to suboptimal or lethal levels at night.

Periphyton production is correlated to the levels of nitrogen (N) and phosphorus (P) in the water column (usually one is limiting). Phosphorus is the primary concern in most freshwater systems because it limits growth. Control of phosphorus (e.g. from fertilisers) is likely to be easier than nitrogen as a means of reducing periphyton proliferations in these situations.

Oxygen loss from decomposition of organic matter is important, particularly when there are accelerated inputs such as sewage waste and agricultural runoff into streams. In severe cases fish kills occur.

DO & nutrient management measures

The underlying problem for algal respiration and organic matter decomposition is excessive nutrients. It is generally accepted that the most effective approach to reduce nutrient (and contaminant) loadings in waterways is by better land management.

Management measures include selecting the most appropriate land use for the site and circumstances; increasing the efficiency in the application of farming inputs so that fewer contaminants are available to be washed into receiving waters; and decreasing the amount of runoff (e.g. control soil compaction and pugging by managing livestock and vehicles; control water paths and flow concentration by contour ploughing; maintaining dense grass cover). Livestock exclusion from waterways is widely practiced.

Not all sources can be controlled, so a second line of defence is to trap and treat nutrients. Constructed wetlands are particularly effective[1]. Filter strips are frequently used:

- Filter strips: A strip of vegetation that intercepts sediment, organics, nutrients, pesticides, and other contaminants from shallow surface flow before these contaminants enter a waterway. Provision of forage, field borders, access and habitat. Effectiveness is medium to high for sediment associated nutrients; and low to medium for absorbed nutrients and pesticides unless specifically designed and managed for the treatment of solid wastes

While filter strips and streamside planting can effectively control sediment and nutrient delivery to streams (at least in the short term), they are an addition to, and not as an alternative to, well-planned land management.

- Filter strips >30 m are needed in most cases with erodible soils and poor upland management
- If good management practices are implemented, the sediment and associated contaminant load decreases dramatically and the filter requirement greatly reduces to practical widths (generally in the 2 to 5 m range)
- To control soluble contaminants such as nitrates, extensive forest buffers are required (in the order of 50 to 100 m wide), or runoff must be routed through constructed wetlands

[1] See Tanner & Kloosterman (1997) for guidelines for constructed wetland treatment of farm dairy wastewaters in New Zealand: www.niwa.co.nz/pubs/no8/dairywaste2/constructed.pdf

- For riparian nitrate removal groundwater must move slowly through the treatment zone, and at a shallow enough depth to be within the rooting zone of riparian vegetation
- Soils must be anaerobic or of low oxidation/reduction potential (Eh) at least part of the year; and vegetation must release enough organic matter at the depth of groundwater to maintain a low enough Eh to allow rapid rates of denitrification

Oxygen declines from decomposition of organic matter may also result from chemical treatment of weeds, with large amounts of dead and dying vegetation left in the stream. Solutions include partial spraying (which may not be very effective because multiple passes are required to control a reach) or removal of dead-dying plants following treatment.

Biological contaminants

Biological contaminants can be derived naturally in waterways (e.g. from fish and birds); with others directly discharged or carried into waterways from various sources (e.g. sewer overflows). Domestic animal waste and agricultural runoff are often significant problems.

Prevention is the most effective management measure. This includes land management practices described above; and exclusion of livestock from waterways.

- Exclude livestock from waterways: Prevent livestock from entering waterways or trampling riverbank by fencing the stream margins. A primary benefit is the reduction of direct inputs of animal waste into waterways

Preventing livestock from entering drains stops erosion (and a resultant increase in siltation) and reduces animal wastes entering waterways. Photo: Greater Wellington.

5 Biodiversity

Drainage of extensive areas of New Zealand caused significant loss or degradation of wetlands and streams. Many drains are new streams or remnants of meandering streams and wetlands that existed prior to agricultural development. These ecosystems often contain valuable fish populations and generally sustain diverse animal and plant communities. A central issue is how to avoid, remedy or mitigate adverse effects and provide optimum drainage management.

Many drains may be the remants of wetlands or streams prior to agricultural development. Photo: DOC.

What are the problems?

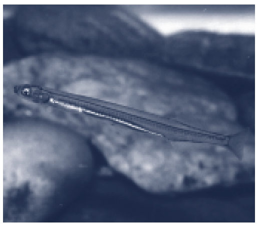
For convenience, drainage management related problems were sorted into three groups. Example problems in these groups include:

- Avoid adverse effects: Drain cleaning destroys whitebait (inanga) spawning habitat; remnants of native vegetation are removed in drain cleaning
- Remedy adverse effects: Land is disturbed along the margins and contributes sediment to the stream; dissolved oxygen is depleted because sprayed vegetation is rotting in the stream
- Mitigate adverse effects: Fish passage is prevented by floodgates and culverts; streamside vegetation is cleared from the banks of the stream reducing habitat and increasing stream temperatures

Avoiding adverse effects

Work "windows" (or exclusions of activity) are often specified to avoid adverse effects. A fair amount of specific knowledge is required to establish the sensitive times and places for a broad range of species. BMPs for whitebait (inanga) and trout were developed to illustrate the type of information drain managers require:

- Whitebait (inanga): Inanga larvae (*Galaxias maculates*) are the most important species in the whitebait catch. Spawning habitats are vulnerable to damage by stock, channelisation, pollution, and a reduction in bank vegetation by mowing. Spawning areas are identified and activities within these areas are avoided during the main period of spawning (February to mid-April). Permanent fencing of spawning areas (native vegetation and long grass at the freshwater-saltwater transition at spring tide levels) is recommended
- Brown trout: Undertake waterway management activities in brown trout (*Salmo trutta*) streams to maintain an adequate food supply, suitable dissolved oxygen levels, cool stream temperatures, instream and overhead cover, clear, clean water; and clean gravel for spawning



Spawning habitats of inanga are vulnerable to damage by stock, channelisation, pollution, and a reduction in bank vegetation by mowing. Photo: DOC.

Trout need an adequate food supply, suitable dissolved oxygen levels, cool stream temperatures, instream and overhead cover, clear, clean water; and clean gravel for spawning. Photo: DOC.

There are few lowland streams which are not in highly modified landscapes. It is important to protect the few sites that remain. This can be achieved in three steps:

1. Identify sensitive areas: Flora, fauna and habitat surveys should be undertaken to identify culturally and ecologically sensitive areas and to identify rare, vulnerable, endangered and protected plant and animal species. Much of this information already exists.
2. Delineate areas to avoid: Care must be taken to protect significant trees and other vegetation during operations. The areas should be identified and marked (e.g. flagged), and preferably fenced off to exclude stock and vehicles.
3. Protect sensitive areas: Vegetated buffers should be left around sensitive areas to prevent water, sediment and contaminant problems.

Best management practices include:

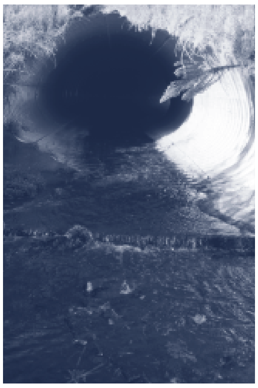
- Filter strip: A strip of vegetation along a waterway margin (or sensitive area) that intercepts sediment, organics, nutrients, pesticides, and other contaminants from shallow surface flow. Effectiveness is rated as low to medium for sediment control; but this is highly dependent on the volume of sediment generated, topography, and cover conditions. Highly efficient trapping (>90%) is possible. Effectiveness is rated as no control to ineffective for soluble nutrients and pesticides; to low to medium effectiveness for absorbed (attached to sediment) nutrients and pesticides; and report 5-59% removal of dissolved phosphorous and 28-80% removal of particulate phosphorous
- Interceptor drains (diversions): Small channels with a minor ridge along one edge that collect and direct surface water to a desired location such as a stable outlet or sedimentation pond. The drains and bunds can either have a natural grass lining or, depending on slope and design velocity, a protective lining, or gravel bed. They protect sensitive areas or work areas from upslope runoff and erosion; ensure that sediment-laden stormwater will not leave the site without treatment (e.g. diversion to a sedimentation pond); and divert water

Remedy adverse effects

Channel works can expose large areas of the bank and stream margins to erosion and contamination of the waterway. Disturbed land should be rehabilitated:

- Rehabilitating land following stream works, such as drain excavation and stream bank protection. The aims are to protect sensitive sites, to prevent off-site damage, and to rehabilitate the stream banks and channel margins to a desirable condition

Strip spraying can work on emergent and bank vegetation.
Photo: Greater Wellington.



Culvert replacement and repair should be carried out ensuring that the culvert has the same gradient as the reach of stream.
Photo: Greater Wellington.

Chemical treatment may result in large amounts of dead and dying vegetation. If left in the stream, decomposition of this material may reduce dissolved oxygen levels and cause fish kills.

- Combination treatments may be required. The bulk of weeds may have to be removed mechanically, with the remainder treated chemically
- Strip spraying (e.g. alternating strips along the banks) has been suggested. Strip spraying could work on emergent and bank vegetation, but it would not be able to be controlled in submergent vegetation treatments. Costs would increase because multiple passes are required to control a reach. Hydraulic effects are unknown
- Dead/dying plants can be removed following chemical treatment

Mitigate adverse effects

Fish migration is often impaired in lowland streams by floodgates and culverts. Gates should be modified or manipulated to allow easier passage. Fish bypasses may be required (e.g. gravel ramps for whitebait).

- Culvert replacement/repair should always be carried out so that the culvert is the same gradient as the reach and the culvert invert is the lesser of either one third of the culvert diameter or 300 mm below the existing bed level

Land retirement and streamside planting is widely advocated overseas and in New Zealand. Developing effective riparian buffer systems require several steps:

1. Identify problems and determine the causes.
2. Determine the critical areas that disproportionately contribute to problems.
3. Set realistic goals.
4. Select appropriate management measures to control the generation of sediment and contaminates in the first instance and to control the movement of sediment and contaminants into and through waterways.
5. Identify the best types of buffer to address the priority problems (Table 5-1).
6. Determine the minimum acceptable buffer width considering other supporting management measures (see Water quality).
7. Develop an implementation and maintenance plan .
8. Follow up with monitoring, assessment and reporting.

Many riparian buffers appear to be designed for aesthetic purposes. The particular problem to be addressed and local conditions should determine the actions taken (e.g. bank reshaping) and type of streamside planting (Table 5-1) and subsequent management.

In planning land retirement and streamside planting, provision must be made for maintenance access as required under the Land Drainage Act (see Drainage management context: policies-legislation) and regional plans-policies. This may effectively limit planting of trees to one bank.

The relative effectiveness of types of streamside vegetation in an agricultural setting varies. Actual effectiveness at a specific site may differ considerably, depending particularly on the hydrology and types of contaminants.

Table 5-1. Relative effectiveness of different buffer vegetation types in an agricultural setting.

Benefit	Vegetation type			
	Reeds	Grass	Shrub	Tree
Stabilise bank erosion	Low-High	Medium	High	High
Filter sediment	High	High	Low	Low
Filter nutrients, pesticides, microbes				
- Sediment bound	High	High	Low	Low
- Soluble	High	Medium	Low	Medium
Aquatic habitat (cover, food, shade)	High	Low*	Medium	High
Terrestrial habitat				
- Grassland species	Medium	High	Medium	Low
- Forest species	Low	Low	Medium	High
Visual diversity	High	Low	Medium	High
Flood attenuation	Low	Low	Medium	High
Economic products	Low	Medium	Low	Med-High

* High for inanga (principal whitebait species) spawning

A hierarchy of approaches can be employed (with various components mixed and matched):

1. Passive management of fenced off streams and wetlands
    - One or both banks are fenced
    - The retired land extends to the top of bank
    - Vegetation is controlled with selective grazing (see Riparian livestock BMP)
    - There may be no further treatment
2. Active management of fenced off streams and wetlands
    - Pest plants and animals are controlled
    - Livestock access is controlled
    - Conventional pasture grasses can be established in the retirement area as a forage crop and nursery crop
    - One bank may be planted with a line of shelter trees (or planting may occur along the top of the bank to maintain drainage outfall)
    - The other bank can be planted with low vegetation that does not stop channel maintenance
3. Specialised buffers to address particular problems
    - Bank erosion is controlled by bank reshaping and planting (e.g. pasture grasses, flax, willows depending on the nature of the problem)
    - Contaminant inputs are controlled by a multi zone buffer extending onto the surrounding land (e.g. grassed along the paddock; tall trees; shrubs and water edge plants)
    - These buffers are relatively wide (often in the order of 30 m)

To ensure banks are stable, and plant roots reach the desired depth, the bank may have to be reshaped:

- Bank reshaping: Banks are excavated to remove steep drops and unstable materials, and to lower the bank to allow roots to extend through potential failure planes and into the lower bank where there is potential for scour. (See Section 2 - Sedimentation)

Plant selection depends on the purpose (Table 5-1), plant tolerances, and ecological region. Plant tolerance includes assessment of the channel shape (profile); frequency of flooding (zones); soil; shading; frost and wind tolerance; browsing pressure. A mix of native and exotic plants (e.g. shrub and osier willows in more erosion prone areas) is often required.

In addition to the streamside planting guidelines provided in "H2O-DSS Hillslopes to Oceans: Decision Support System for sustainable drainage management (www.nzwerf.org.nz) other comprehensive planting guidelines are available online and local planting guide summaries are also available for several regions so check with your local council (see further reading).

Further reading

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Tamar Valley Weed Strategy Working Group. 1997. Strategic plan 1997. *Codes of Best Practice.* Glyceria/reed sweet grass. www.weeds.tassie.net.au/frames/cntrls

Taranaki Regional Council Sustainable Land Management Programme Fact Sheet 24: *Fencing options and costs*. www.trc.govt.nz/PDFs/info_land/24_riparian_fencing.pdf.

Useful websites

Auckland Regional Council, www.arc.govt.nz

Environment Bay of Plenty, www.envbop.govt.nz

Environment Canterbury, www.ecan.govt.nz

Environment Southland, www.es.govt.nz

Environment Waikato, www.ew.govt.nz

Gisborne District Council, www.gdc.govt.nz

Greater Wellington Regional Council, www.gw.govt.nz

Hawkes Bay Regional Council, www.hbrc.govt.nz

Horizons Regional Council, www.horizons.govt.nz

Marlborough District Council, www.marlborough.govt.nz

Nelson City Council, www.nelsoncitycouncil.co.nz

Northland Regional Council, www.nrc.govt.nz

Otago Regional Council, www.orc.govt.nz

Taranaki Regional Council, www.trc.govt.nz

Tasman District Council, www.tdc.govt.nz

West Coast Regional Council, www.wcrc.govt.nz

Department of Conservation, www.doc.govt.nz

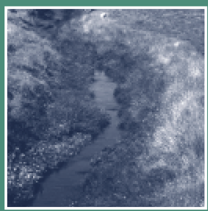
Fish and Game, www.fishandgame.org.nz

Landcare Research, www.landcareresearch.co.nz/research/biodiversity/greentoolbox/gtbweb

New Zealand Ecological Restoration Network, www.bush.org.nz/ planterguide

NIWA, www.niwa.cri.nz



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