BUSSELTON WATER

Rethinking Drainage

BUAYANYUP SUBCATCHMENT PILOT PROJECT

DRAINAGE MANAGEMENT PLAN

busseltonwater.wa.gov.au

FOREWORD

It gives us great pleasure to present this Drainage Management Plan (the Plan).

The opportunity for Busselton Water to develop this Plan emerged from two separate drivers; our growth strategy following corporatisation and our participation in the Vasse Taskforce. The content however builds on work done throughout the South West over the last 25 years and work currently underway in Victoria.

This Plan marks an important milestone as Busselton Water seeks to manage Busselton's rural drainage and flood protection services. In addition to identifying practical management practices to improve waterways in the Buayanyup Catchment it also proposes a drainage blueprint to guide the future management of the rural drainage systems across the Geographe Catchment.

We acknowledge those who have contributed to the development of this Plan; including the Pilot Project team, stakeholders and community members. Your insightful contributions have been invaluable.

Busselton Water will continue to pursue the opportunities identified within this Plan.

Helen Shervington
Chair
Busselton Water Corporation

Chris Elliott
Chief Executive Officer
Busselton Water Corporation

ACKNOWLEDGEMENTS

Krish Seewraj, Department of Water
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Kathryn Heaton, Water Corporation
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David Kemp, GeoCatch
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Busselton Water also gratefully acknowledges those landholders, community members and other stakeholders who have provided input into this project.

EXECUTIVE SUMMARY

The Busselton rural drainage system was originally created to remove excess water and reduce the likelihood of localised flooding. Construction was commenced in the 1880s and expanded during periods of high rainfall in the 1900s to allow access to more land and to support the development of the local agricultural industry (Davies & Muir, 1994).

Today there is a greater awareness of the value of all water, including waste water, as a potential resource and communities and government are looking for opportunities to gain value from the water rather than purely mitigating flooding of agricultural land.

Historically the drainage operator has focused on managing assets such as levees, bridges and culverts within the drainage system. This report proposes a more holistic management approach in which the waterways are managed as assets and the full range of services provided by the drainage network are considered.

This change in management objectives will enable a range of environmental, social and economic concerns to be addressed ultimately improving the liveability of our neighbourhoods and the sustainability of our community. There are also opportunities to minimise the negative impacts of the drainage network and the potential to provide some treatment for polluted drainage waters.

The report builds on the work done throughout the South West over the past 25 years. It explores treatment options for drainage waters within the Buayanyup drainage system and proposes a drainage blueprint – a Waterways Transition Framework – to guide the future management of the rural drainage systems across the Geographe Catchment.

CONTENTS

BACKGROUND

WATER AS A RESOURCE

Traditionally, flooding of agricultural land during winter rainfall has been viewed as a problem that restricted the effective use of productive agricultural land during the winter growing period. The problem was dealt with by employing simple engineering solutions to remove the excess water as quickly as possible to minimise any immediate detrimental impacts from flooding.

Little consideration was given to the downstream impacts of this water and the nutrients and sediments it may be carrying. Equally the potential benefits which could be provided by controlled retention or more sophisticated management of this water was not considered.

Locally, significant volumes of nutrients and soil are lost each year from agricultural land. This has serious implications for water quality in local waterways and Geographe Bay, not to mention the loss of potential productivity from agricultural land.

Once the nutrients and sediments enter the waterways it becomes more challenging to slow flows enough to provide opportunities to remove pollutants and ensure sufficient flood protection, particularly as the vast majority of soil and nutrients are carried by the peak flow events.

Today there is a greater awareness of the value of all water, including waste water, as a potential resource and it is generally understood that the most effective way to manage water quality is at the source through sustainable land management practices on farms. This change in perspective fits within the context of a greater appreciation of the accountability of land managers for their actions, particularly those that influence or impact on the broader sustainability of our communities and our local environment.

This report proposes a more holistic management approach in which the waterways are managed as assets and the full range of services provided by the drainage network are considered.

LIVEABLE NEIGHBOURHOODS

The long term sustainability and liveability of our communities requires a holistic and engaged approach. Through integration of water and urban planning we can improve both the liveability and sustainability of our surroundings.

There is an opportunity through the pilot project to open sections of the Buayanyup Drain to the public and provide community amenity benefits including pedestrian and cycle routes and easy access to the picturesque Geographe Bay. It could also provide a key landscape feature for the new Vasse development.

COLLABORATION

Busselton Water is committed to understanding what customers and other stakeholders value, now and in the future, to enable organisational direction, strategy and action; and to continually improve our customer service as we strive for business excellence.

Delivering on the broad range of objectives that have been identified for the management of local drainage requires effective collaboration with all our stakeholders. Successful implementation will rely on the local community to embrace and support the proposed changes.

Busselton Water invited local authorities and groups involved in water management to join a

Project Team to determine how the management of rural drainage can be improved. This team has high level representation from the City of Busselton, the Department of Water, GeoCatch and the Water Corporation, who provided guidance and technical support for the project.

This inter-agency collaborative approach demonstrates the commitment of all agencies in delivering the best possible outcome for the community.

We have consulted with the Buayanyup community specifically about the Buayanyup drainage system. Participants at a stakeholder forum helped identify the broad range of needs of the community and the challenges and opportunities available.

WATERWAYS TRANSITION FRAMEWORK

BACKGROUND

In 2009 the Department of Water proposed a conceptual management response framework for coastal drainage called the *Coastal Drainage Scenario Transition Framework*. Busselton Water is building on this work and developing a Waterways Transition Framework (the Framework).

The Framework is intended to guide management and identify where it would be appropriate to expand the management objectives beyond flood protection. It will enable sites to be assessed to determine where they fit currently and where they should be progressed to, based on the services they could deliver.

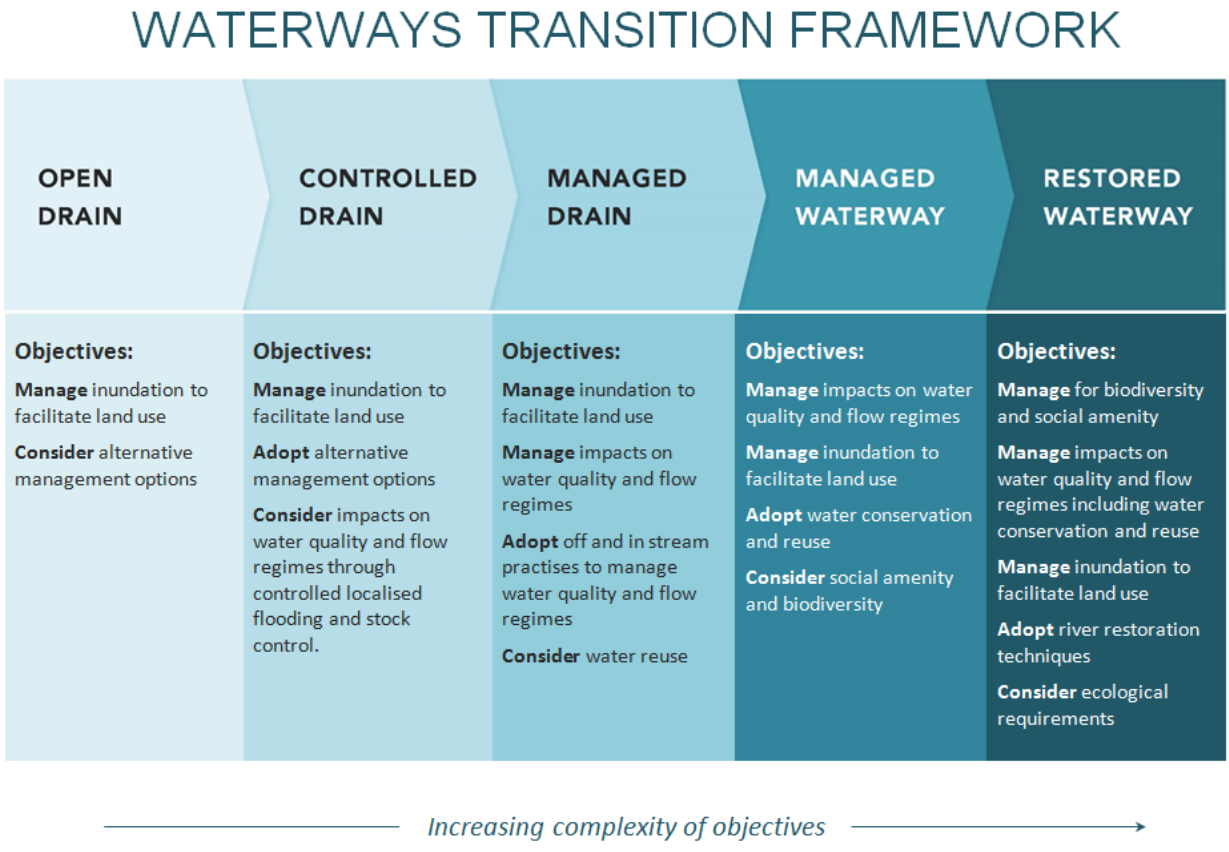


Figure 1: Waterways Transition Framework

THE OPPORTUNITY

Implementing the Framework and broadening the drainage management objectives beyond flood management provides a number of opportunities including:

- water quality improvements;
- water re-use and conservation;
- recharge of aquifers;
- productivity increases through summer;
- ecological enhancement;
- biodiversity conservation;
- recreational uses; and
- social amenity.

As water becomes a limiting factor for local industry and agriculture, the water in the drains will be seen more as an asset than an issue. With local groundwater resources already fully allocated the surface water will become a valuable resource and it is likely that local landholders will push for proclamation to ensure that the supplies are managed in an equitable way.

There is significant potential for collaboration with other stakeholders to deliver multiple benefits. This could include community education programs, joint funding projects, demonstration sites, field trials and research projects to trial and measure the relative cost/benefit of different management options.

The Buayanyup Drain runs through the centre of the town site of Vasse. It could provide a stunning focal point for the development and a shortcut for cyclists and pedestrians (and potentially people on kayaks and paddle boards) to the pristine beaches of Geographe Bay. There are significant environmental, social and economic benefits to be gained by developing this stretch into a lush community space.

Alternative funding sources for environmental projects are being investigated through the Vasse Taskforce's *Vasse Geographe Strategy*. Some of these funds could be used to support key projects and ensure ongoing work in the catchment.

GENERAL MANAGEMENT RECOMMENDATIONS

DRAIN DESIGN AND MAINTENANCE

The Manual of Standards for rural drainage (PWD, 1977) states that “The basis of design is to provide relief from severe flooding, from prolonged submergence and from recurrence of flooding at frequent intervals. It does not aim to completely prevent inundation of agricultural land.”

The design capacity of subsidiary drains is based on the ability to convey a rainfall event with a twice per year occurrence. Main drain Design Capacity is based on rainfall events expected once every two years or a greater capacity based on the potential for damage to infrastructure if a main drain floods. The diagram below depicts a drain design based on the Manual of Standards.

Early drainage was installed and maintained using horses and scoops or dug by hand. During the 1960s the cost of labour escalated which led to the use of excavators for drain construction and maintenance. The use of machinery reduces the accuracy and results in steeper slopes which are more prone to erosion, particularly in sandy soils. Access for machines can also require the removal of established trees and other vegetation (Davies & Muir, 1994).

It is likely that most drains were constructed without being designed to the standards, particularly smaller subsidiary drains. Also the ongoing maintenance is likely to increase the width and depth over time (unless there is a rock base). It is therefore likely that some drains are larger than required.

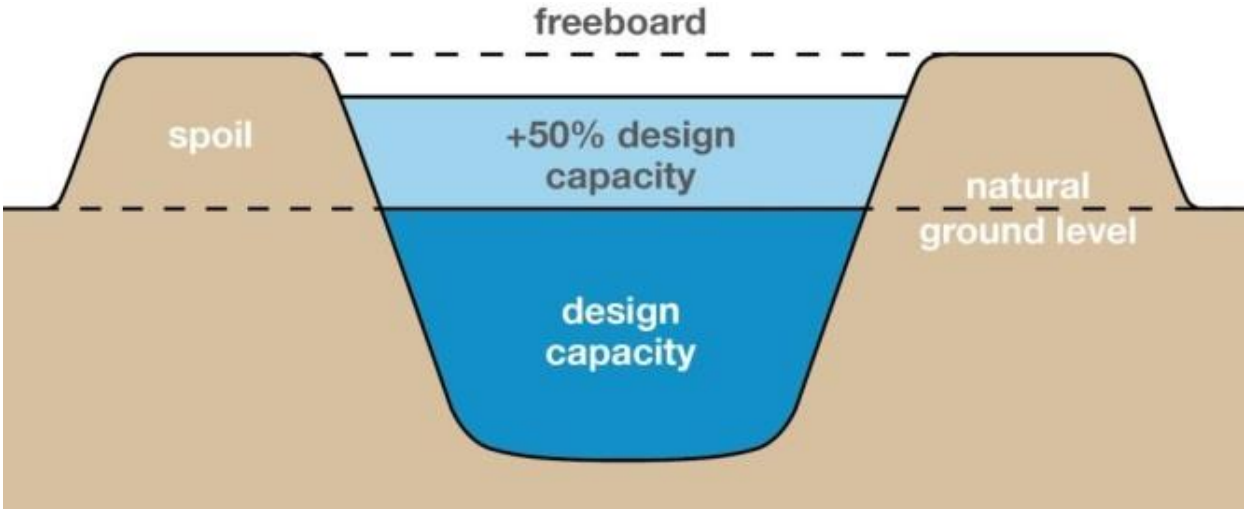


Figure 2: Drain design based on The Manual of Standards (PWD, 1977)

The removal of rock in the base of drains to increase capacity can also cause semi-artesian waters to be released into the system which will deplete groundwater sources and can overload the drainage system. Over-engineered drains have the potential to remove excessive volumes of superficial groundwater which can have a number of undesirable impacts including:

- overloading and flooding the system downstream;
- loss of soil moisture reducing the growing season for pasture and crops;
- loss of nutrients from farmland;
- shorter residence time for water in the drains resulting in minimal opportunity to harvest nutrients; and
- higher quantities of nutrients and other pollutants carried to receiving environments.

There has been some work done to date to model the expected flows which can be used to determine the design capacity. Further catchment modelling should be carried out to determine the design capacity for sections of the drainage network where this information is not currently available. This would help to inform the maintenance of the drains rather than possibly over-reacting to public pressure during wetter periods. It is important to keep the public informed and to manage their expectations to meet the realities of managing the system for multiple objectives.

LOCATION IN THE CATCHMENT

The relative success of a management practice can be influenced by where it is applied in the catchment. The greatest improvements to water quality are generally achieved on the first order streams (see Figure 3 adapted from Steele, 2008). This is due partly to the fact that all the water is entering the channel from the surrounding land and therefore has to pass through any buffers.

The other main factor is the lower risk of flooding associated with any changes.

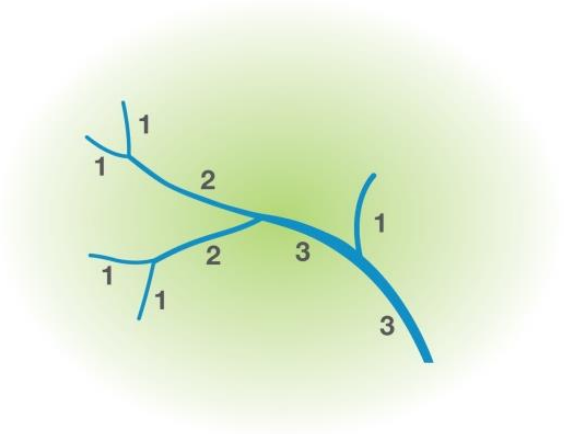


Figure 3: Stream order, adapted from Steele, 2008

By the time water is flowing through a third order stream it is often moving too quickly to allow effective nutrient stripping and slowing the flows may not be possible without increasing the risk of damage from flooding to an unacceptable level.

It is important to note that the Water Corporation use an alpha numeric system to classify the drainage network as indicated in Figure 4. This classification is referred to in the recommendations and should not be confused with the stream order as shown below.

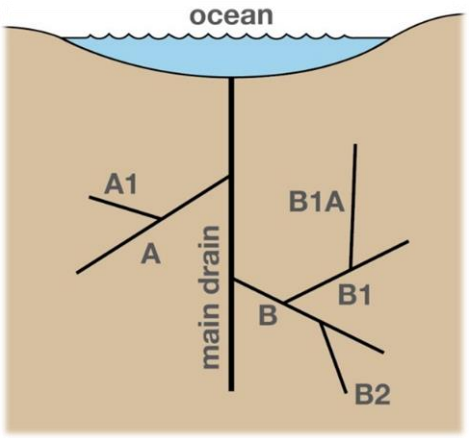


Figure 4: Alpha numeric classification

LEGISLATION

There is potential under the *Water Services Act* to control new drainage works and require drains to be maintained or modified if required.

Pollution from nutrients is managed under the *Environmental Protection Act 1986* and regulated through the *Environmental Protection Regulations 1987* for prescribed premises such as cattle feedlots, intensive piggeries and large wineries. The *Environmental Protection (Unauthorised Discharges) Regulations 2004* prohibit the discharge of animal wastes, animal oils, food waste and sediment to the environment.

These regulations allow for the control of pollution from businesses and commercial activities (such as dairy sheds) that are not considered to be prescribed premises.

Industry groups are generally keen to work with government and members to develop programs to support and encourage compliance and self-management. Underperforming sites can then be targeted by the Department of Environment Regulation to enforce compliance.

PLANNING TOOLS

The Town Planning Scheme can also be used to control the construction of new rural drains if excavations are included under the definition of development for rural and lifestyle lots. This provides an opportunity to assess the need and direct the design of drainage works. Guidelines could help planners and proponents to incorporate best management principles in the design and maintenance.

Agricultural intensification projects or upgrades that require planning or building approval could have conditions placed on them to meet best management practices. This provides an alternative option to licencing, however it can only be applied as businesses upgrade or undertake new developments.

ADOPTION

The level of uptake of alternative management techniques depends largely on the perceived benefits and the quality of information about the technique. Land managers require information about costs and benefits as well as practical details about how to implement management practices. Recommendations should therefore be supported by practical guides for landholders.

The quality/environmental assurance programs can be a good mechanism for introducing best practice techniques.

Benchmarking also encourages local producers to meet a certain management standard which may be supported by an accreditation system. The integration of planning, economic, social, quality assurance and environmental issues is generally more appealing to a wide audience (Summers, undated). The University of Queensland's Gatton Campus runs a best practice course for landholders called "Best Prac".

CHALLENGES

Nutrient-hotspot analysis revealed that the highest rates of nutrient export were located in the centre of the Geographe Catchment – in the regions surrounding the Sabina River, the Vasse Diversion Drain, and the Buayanyup River (Hall, 2009). It is also likely that the local agricultural industry will continue to intensify into the future, further increasing nutrient loading if left unmanaged.

Since drainage rates were abolished the funding for maintenance is limited. This constrains the available management options. The recommendations in this report are largely those which are likely to be adopted as they are easy to implement, deliver multiple benefits, provide productivity benefits or reduce the management costs over time.

RECOMMENDED ACTIONS FOR THE GEOGRAPHE CATCHMENT

The recommended actions for the Geographe Catchment are to:

1. Develop a catchment-wide policy for the management of the drainage network based on the results of the management trials and the revised framework.
2. Determine where there are gaps in knowledge that are limiting the optimal management then prioritise and address.
3. Prioritise the remaining sub-catchments and generate management plans for each of them.

BUAYANYUP PILOT PROJECT

INTRODUCTION

Busselton Water undertook a pilot project in the Buayanyup sub-catchment to determine the condition of the drainage system and enable treatment options to be proposed for polluted drainage waters.

The Buayanyup sub-catchment was chosen as the location for this pilot project as it represents a broad range of land uses. It also provides a direct interface between the urban community of Vasse and the rural drainage network.

HISTORY OF THE BUAYANYUP DRAINAGE SYSTEM

The Buayanyup River begins as a number of small tributaries in the Whicher Scarp before it extends across the Swan Coastal Plain as several main branches coming together near Vasse as a single channel, which discharges directly into Geographe Bay. Prior to European settlement the Buayanyup, along with most of the rivers in the Geographe Catchment flowed into a series of inter-connected wetlands running parallel to the coast. The waters from the Buayanyup River would have eventually flowed out to sea through the Vasse Estuary (Lane et al. 1997).

Modifications to the natural hydrology of the Geographe Catchment began in the 1880s with the Higgins cut diverting the Capel River away from the Wonnerup Estuary and connecting it directly to the ocean. Resettlement projects throughout the Swan Coastal Plain occurred onwards from the 1920s and prompted the establishment of an extensive network of artificial drains to allow agricultural development in seasonally inundated areas (WRM 2007).

There are now more than 100 kilometres of managed drains on the Buayanyup system. The majority of the waterways through the Swan Coastal Plain have been straightened and modified.

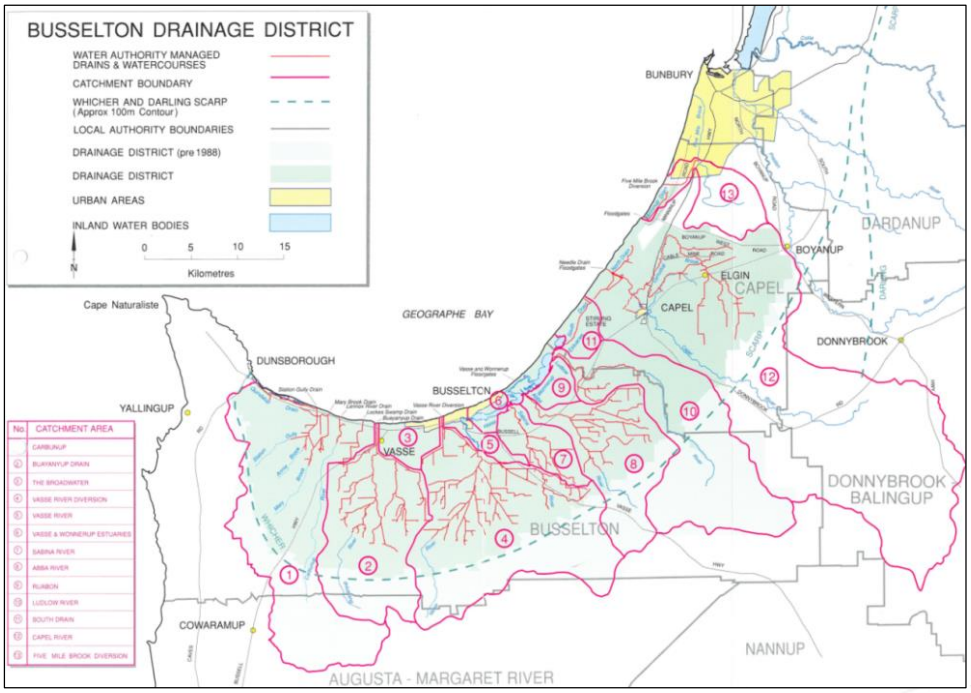


Figure 5: Busselton Drainage District including the Buayanyup Drainage Catchment (Water Authority of WA, 1994)

These rural drains have been engineered and constructed for the purpose of water conveyance – removing excess water from the landscape as quickly as possible to mitigate inundation and facilitate land-use. Whilst some consideration was given for their impacts on wetlands, other environmental impacts (such as water quality, nutrients and sediments) were poorly understood and therefore not considered (Davies and Muir, 1994).

LAND USE

The Buayanyup drainage system is in an area that supports a variety of high quality agricultural industries; including annual horticulture, equestrian studs, vineyards, and grazing for sheep, dairy and beef cattle (GeoCatch 2010). The majority of the land is used for grazing. The town site of Vasse Newtown is located near to the northern end of the catchment and is experiencing a significant period of growth.

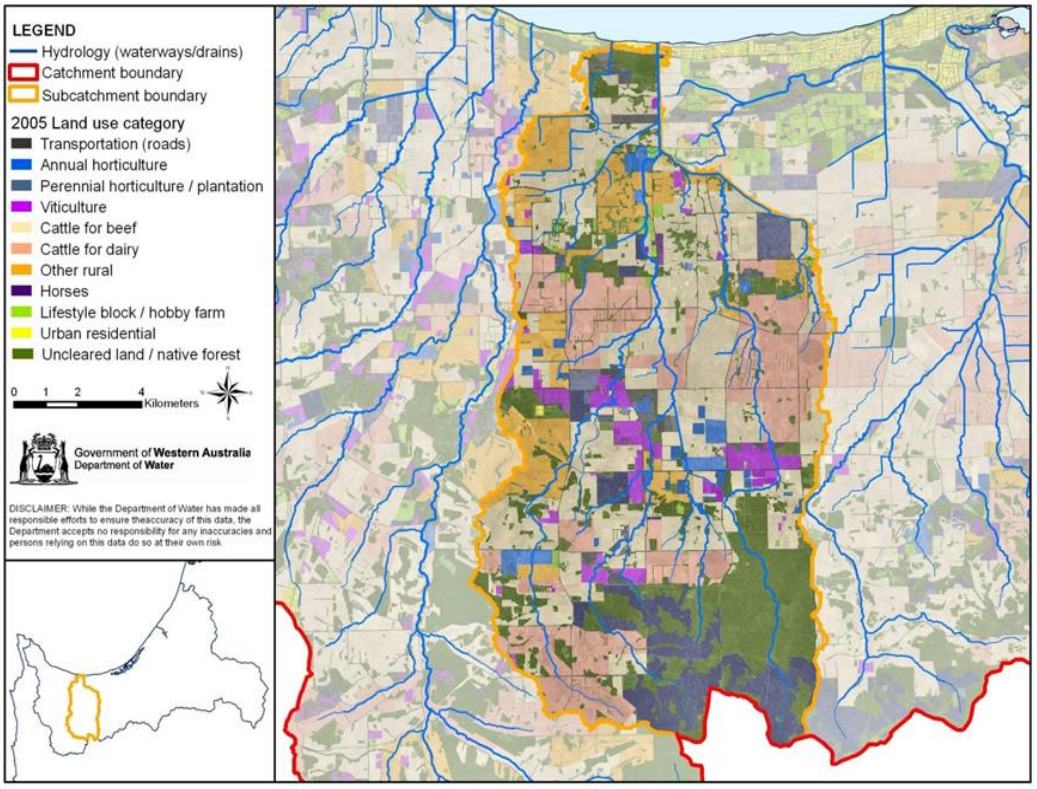


Figure 6: Land use in the Buayanyup Catchment

CATCHMENT CHARACTERISTICS

Soils

The characteristics of the major soil zones are outlined in the table below.

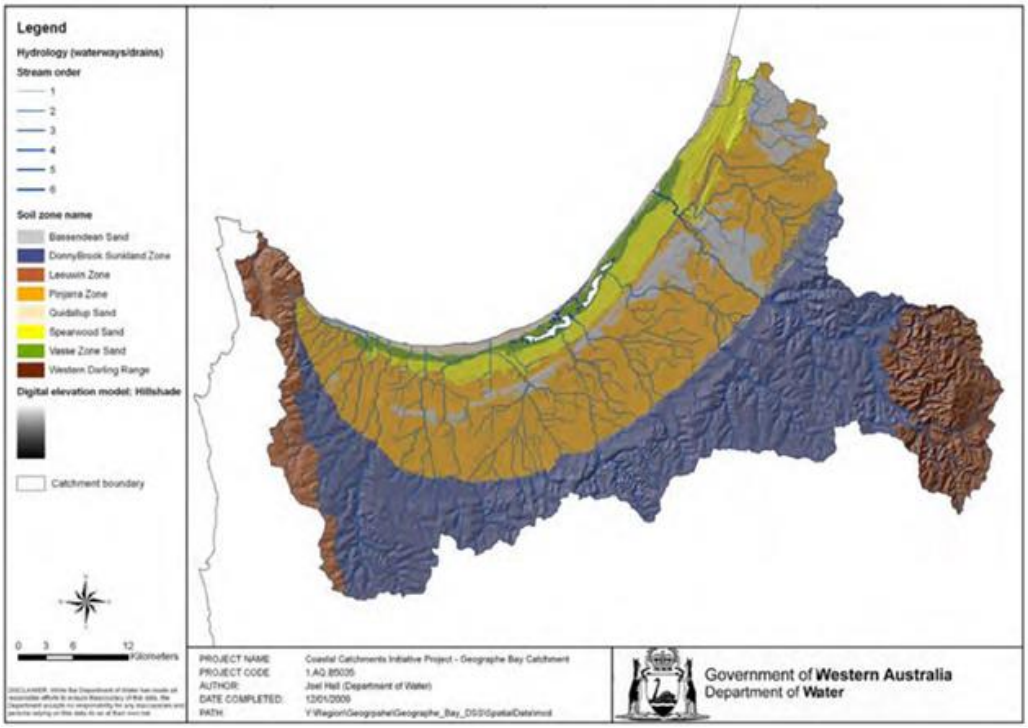


Figure 7: Major soil zones of the Geographe Catchment (reproduced from Hall, 2009)

Table 1: Major soil zones of the Buayanyup Catchment:

Zone	Description
Quindalup	Coastal dunes of the Swan Coastal Plain with calcareous deep sands and yellow sands. Coastal scrub is the principle vegetation.
Vasse	Poorly drained estuarine flats on the Swan Coastal Plain. Soils include tidal flat soil, saline wet soil and pale deep sand. The main vegetation types include samphire, sedges and paperbark woodland.
Spearwood	Dunes and flats overlying limestone on the Swan Coastal Plain with deep yellow sand, pale deep sand and yellow/brown shallow sand. The predominant vegetation is tuart forest and woodland.
Pinjarra	Poorly drained flats on the central coastal plain with grey deep sandy duplex soils, yellow loamy earth, cracking clay and sandy duplex. The vegetation consists of jarrah-marri-wandoo-paperbark forest and woodland.
Bassendean	Dunes, flats and swampy depressions of the Swan Coastal Plain with pale deep sand. Main vegetation types are banksia woodlands and heath on dunes and paperbark woodland flats.
Whicher Scarp	Low scarp and raised platform on the northern edge of the Donnybrook Sunkland. Main soils include sandy gravel, pale deep sands, loamy gravel and non-saline wet soils. Principal vegetation consists of jarrah-marri forest.

** As described in Rivers 2001 and cited in Department of Agriculture 2003.*

Climate

The Geographe Catchment experiences a Mediterranean climate with hot dry summers and mild wet winters. According to the Bureau of Meteorology website, the long-term average rainfall for Busselton is 804 millimetres; however, the region has experienced a reduction in rainfall over the last few decades.

Climate modelling predicts that the decline in autumn and early winter rains is likely to continue as the South West gets hotter and drier (GeoCatch 2010). It is also expected that the frequency of extreme weather events will increase into the future. This could have implications for the drainage network and will need to be considered in future modelling of flows.

METHODOLOGY

Field work for the pilot project was carried out between June and August 2015.

The drainage channels in drainage reserves were traversed on foot where accessible, whilst channels on private land were assessed from roadsides where possible. Some areas could not be sighted from the roadsides; these were assessed from aerial photography for a very basic indication of the condition.

Figure 8 is a copy of the field sheet used showing the information gathered during the site assessments.

The information gathered has been mapped in the Waterway Condition and Recommendations section of this Plan.

Location				Date	
Vegetation					
Weeds		Extent		Nativeness	
Declared		Banks		Understrorey	
Agricultural		Toe		Shrub	
Environmental		In Channel		Canopy	
Comments					
Soils					
Soil Texture		Rock			
Comments					
Physical Form					
Erosion		Vertical Profile		Channel Shape	
Bank Stability		Pools		Bank Angle	
Erosion Extent		Riffles		Curvature	
Sedimentation		Variability		Shape	
Comments					
Adjacent Landuse					
Land owner		Landuse			
Comments					
Animals					
Ferals		Fencing			
Comments					

Figure 8:
Field data sheet

RESULTS SUMMARY

The current condition of the drains is largely linked to the soil type and vegetative cover.

Soils

Sandy soils have poor stability and are prone to erosion whilst soils with significant clay content are more resistant to erosion. Much of the Buayanyup Catchment is characterised by duplex soils which consist of a sand layer over a clay layer. This is often underlain by a solid ironstone base.

The photo centre right shows the steep bare walls through the clay layer under the highly eroded sand layer. Much of the sand has washed away other than where it is stabilised by the tree roots resulting in mounds under each tree. The clay is clearly much more stable than the sand.

Where ironstone forms the base of the channel it provides significant protection from erosion, particularly during high flows and under heavy stocking rates. The erosion and sedimentation issues would be a lot worse in this system without these sections of ironstone.

Vegetation

The majority of the drainage system has little or no native understorey. It is predominantly grassy weeds with or without trees overhead. In some sections the soil is well protected by perennial grasses. Areas where these grasses have been sprayed tend to have a lot more bare soil and a variety of annual weeds recolonising.

Over grazing is an issue for some sections of drain. The channel banks are highly susceptible to degradation due to grazing pressure. Paddocks that are grazed on short rotations such as on dairy farms appear to maintain a much better cover of vegetation. The photo at the top of this page shows a drain passing from a rotationally grazed paddock to a continuously grazed one. The drain is completely denuded in the house paddock as the vegetation is not given the chance to re-establish.

There are some significant stretches of good quality bush and numerous sections with native tree cover over a degraded understorey. Those areas that have been protected from grazing for a long time and possibly only had limited to no grazing in the past, tend to have a good quality native understorey. Sections that have been grazed for an extended period tend to have an understorey dominated by grassy weeds.

Where there are trees growing alongside the drains, the banks are often steeper and more stable. These photos show the roots protecting the banks and maintaining steeper slopes. Exposed soil further away from the trees tends to erode leaving the trees perched on a protected mound of soil.

Feral animals

Feral animals are a significant management issue in the Buayanyup Catchment. Both rabbits and foxes have established their burrows in the banks exposing loose soil which is washed into the channel when it rains or during high flows.

The tunnels they create also compromise the integrity of the banks and have previously caused spoil banks to collapse in this system. Foxes and rabbits are also a nuisance for adjacent landholders.

DISCUSSION

The most significant opportunities for reducing the nutrient and sediment loads are likely to be through holding water back for longer and maintaining the vegetative cover. These management options are discussed below. The full suite of recommended management options are outlined in Appendix 1.

Vegetation management

Areas of native vegetation enhance biodiversity through shading and creation of habitat. They also provide important linkages between patches of remnant bushland. Good quality sections of bush should be protected from degradation. Those areas that provide important linkages should be protected and revegetated as necessary.

The plant roots provide some filtering of groundwater and harvest nutrients as they grow. They also hold the soil together and protect the banks from erosion. Trees should be combined with perennial groundcovers to provide the best protection for the soil.

Where there is no native understorey, perennial grasses should be encouraged to establish and replace annual weeds. This will provide filtration, nutrient stripping and improve soil stability, particularly during the first rains of the season when annual weeds have died off leaving bare soil.

Maintaining the vegetative cover requires effective grazing management in paddocks or a targeted weed control program outside of grazing areas. Extended stock access to an area will result in overgrazing with the channel banks being highly susceptible to degradation. Grazing pressure can be managed through rotation or with fencing and crash grazing. Weed control should only target noxious weeds in degraded areas to encourage perennial grasses to establish and provide ongoing protection for the soil.

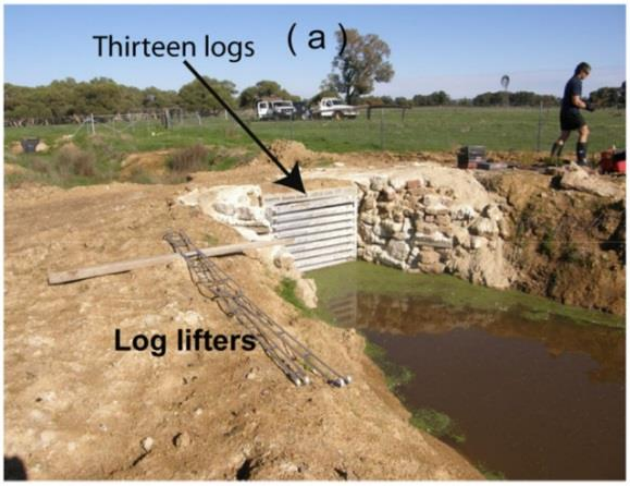
Water retention

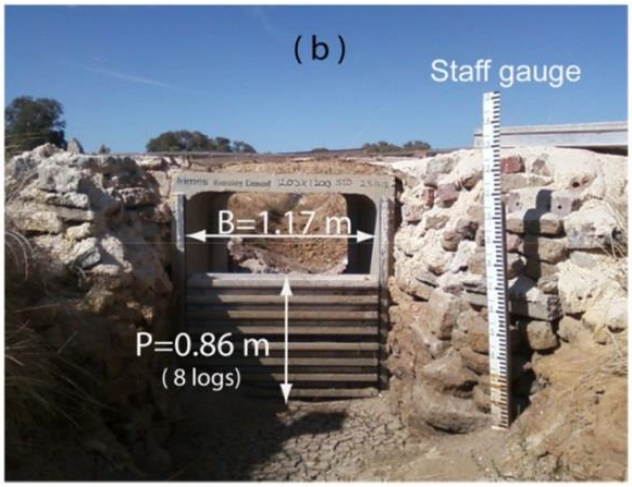
A recent trial in the Peel Catchment has achieved major reductions in nutrient loads through the installation of a small weir (Ocampo, 2015). The weir is adjustable so that major flows can be conveyed and the water levels can be adjusted as needed. By holding water in the drains the local water table can be raised in sandy soils. The longer the water resides in the soil and the channels the greater the opportunity to remove the nutrients and sediments. This means that a greater proportion of the nutrients are harvested for productive outputs rather than reducing the water quality downstream.

During discussions with the local Buayanyup community, a number of landholders raised concerns about being over drained. There was significant interest in exploring options to hold more water back in some sections to elevate the local water table and extend the summer growing season. It is recommended that trials are undertaken in the Buayanyup Catchment to determine the feasibility and potential benefits. Consideration will need to be given to aquatic fauna in the design.

Aquatic plants

There may be potential to provide nutrient harvesting by growing aquatic plants in slow moving sections of waterway. Duckweed (Lemna spp.) is grown around the world for both water treatment and as a high protein commercial stockfeed. It is also keenly sought out by lifestylers as a stockfeed and to produce high quality compost, with websites dedicated to locating populations and processing the material. Lemna disperma is native to the local area and should be trialled to determine its bioremediation potential.





RECOMMENDED ACTIONS FROM THE BUAYANYUP PILOT PROJECT

This Pilot Project aims to trial the application of the Waterways Transition Framework in a sub-catchment and generate a blueprint for the wider Geographe Catchment. The learnings from this project and input from stakeholders will inform any further development of the framework and guide future management decisions.

- Trial the application of the Framework, review its strengths and weaknesses and look for opportunities to enhance it.
- Review the Drain Design Capacity modelling to determine any gaps and where it is currently exceeded
- Review land use requirements; look for potential to establish agreements that increase the acceptable period of inundation in specific areas.
- Undertake a public launch of the plan to help identify interested landholders in the catchment.
- Work with other stakeholders to identify opportunities.
- Trial a number of the management options in the Buayanyup catchment

.

This report is intended to provide a framework to guide management and identify where it would be appropriate to apply various management techniques. Application of the ideas will depend on the willingness of individual landholders and the availability of funds where costs are limiting uptake

WATERWAY CONDITION RATINGS AND RECOMMENDATIONS

busseltonwater.wa.gov.au

MAP 1: *Ocean to 4.5km mark*

Legend

- Open Drain
- Controlled Drain
- Managed Drain
- Managed Waterway
- Restored Waterway
- Fence
- Drop Structure
- Floodgate

MAIN DRAIN

Ocean to Caves Rd

*Aim for **Restored Waterway***

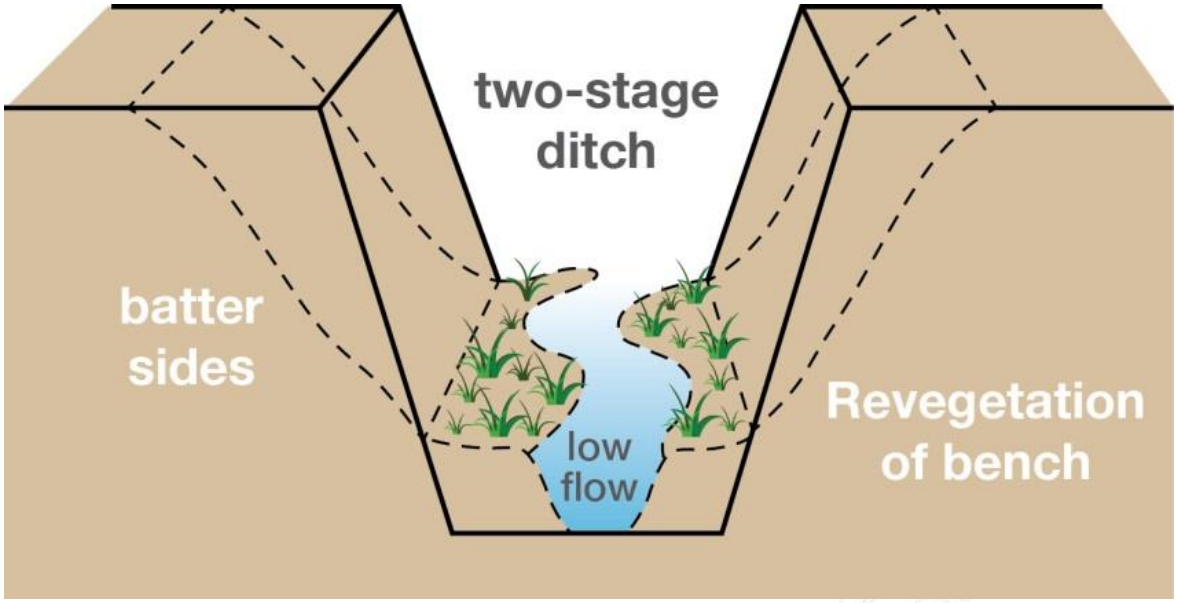
This section is well vegetated although it has significant erosion issues. It would benefit from some defined pathways, weed control and supplementary planting. Brushing could be used to stabilise some sections ready for revegetation with local native species. Could be a good spot to build some small jetties or platforms for fishing to focus recreational use and allow regeneration.

Caves Rd to Bussell Highway

*Aim for **Restored Waterway***

This section runs through the centre of the Vasse town-site and could provide a much more direct link to the beach for pedestrians and cyclists, encouraging a healthier community. This area could be revegetated predominantly with local native reeds and rushes. It would be a great spot for a 2 stage ditch (see *Management Options* for details). Excess spoil could be removed to allow reprofiling for safer access.

Playgrounds and recreation areas could be established at the top of the banks. The maintenance access track could double as a dual use path for walkers and cyclists. Canoe/ paddleboard launching sites and fishing jetties could be established. Access for recreation should be defined to minimise erosion. If sediment needs to be removed, the banded drain clearing technique should be used. A designated sediment trap would minimise the need for regular maintenance of the entire channel length and reduce maintenance costs over time.



Bussell Highway to Florence Rd

*Aim for **Restored Waterway***

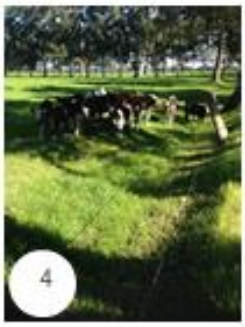
This section has a bush corridor alongside which would enhance the ecological values of the waterway as well as the social amenity. This section could also be reprofiled, revegetated and the connectivity improved between the bush and the waterway. If sediment needs to be removed, the banded drain clearing technique should be used. A designated sediment trap would minimise the need for regular maintenance of the entire channel length and reduce maintenance costs over time.

Florence Rd to 4.5km mark

*Aim for **Restored Waterway***

This section is in relatively good condition with minimal access from the public. There are many natural features in this stretch that would benefit from the minimum of interference. Staged weed control and replacement with natives could improve the ecological value. Sediment traps before this section would reduce the amount of sedimentation. Enhancing the pool riffle sequence could help to maintain summer habitat for aquatic species given the excellent shading, otherwise any works to disturb the bed and banks should be minimised.

Map 2: *4.5km mark to Hairpin Rd*



Legend

- Open Drain
- Controlled Drain
- Managed Drain
- Managed Waterway
- Restored Waterway
- Fence
- Drop Structure
- Floodgate

4.5km mark to 6.5km mark

*Aim for **Managed Waterway***

This section couldn't be accessed therefore it has only undergone a desktop analysis.

Some sections have a dense tree canopy whilst others are more open. This vegetation should be protected through fencing with infill planting where required. Some work has been undertaken for this section looking at establishing weirs to elevate the water-table in the surrounding area. This should be further investigated to determine the viability and to ensure that aquatic fauna are considered in the design. It may be appropriate to elevate this site to a restored waterway.

6.5km mark to 8km mark

*Aim for **Restored Waterway***

Some of this section couldn't be accessed therefore parts have only undergone a desktop analysis.

A substantial plume of cloudy water was entering the main drain just upstream of the Kaloorup Rd Bridge (see photo). The source of this plume is worth investigating as it could potentially be contributing large volumes of sediment to the system.

The Kaloorup Rd Bridge is surrounded by significant areas of good quality bush and the channel retains a number of natural features including meanders, pools and riffles. This would be a great location for a canoe launching site and a picnic area with a walk trail linking it to the Vasse townsite.

8km mark to Hairpin Rd

*Aim for **Managed Waterway***

This section retains some natural features such as meanders and rock riffles. The northern part has good stands of native trees whilst the southern part is quite open. It would be worthwhile undertaking some basic revegetation through this stretch to provide some connectivity between well vegetated sections to the north and south.

D Drain

*Aim for **Controlled Drain** or **Managed Waterway***

This is a very short section of drain coming from a small dam spillway and running under a native canopy with an understorey of grasses. It has been recently burnt exposing much of the soil.

Either perennial grasses or a native understorey should be established to protect the drain from erosion and sedimentation.

Map 3: *Hairpin Rd to G Drain*

Legend

- Open Drain
- Controlled Drain
- Managed Drain
- Managed Waterway
- Restored Waterway
- Fence
- Drop Structure
- Floodgate

E Drain

*Aim for **Controlled Drain***

The section running past Amelia Park has scattered trees with bare ground in the channels. The channels appear to be relatively stable although they could be grassed and mowed for greater stability. Part of the drain west of Kaloorup Rd is in the road reserve with some reasonable quality vegetation which should be protected through weed control. The rest of the drain is more degraded with trees over weedy grasses. Perennial grasses should be encouraged through this section to protect the channel. The western most part of the drain runs through the paddock. This part should continue to be managed through controlled grazing or fenced and crash grazed. *See Map 2*

Hairpin Rd to 9.5km mark

*Aim for **Managed Waterway***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

This section retains some natural features such as meanders, pools and rock riffles. The northern part is basically denuded whilst the southern part has good stands of native trees. It would be worthwhile undertaking some basic revegetation through this stretch to provide some connectivity between well vegetated sections to the north and south. The large pool should ideally be well shaded as it could provide important summer refuge for aquatic fauna.

9.5km mark to Payne Rd

*Aim for **Managed Waterway***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

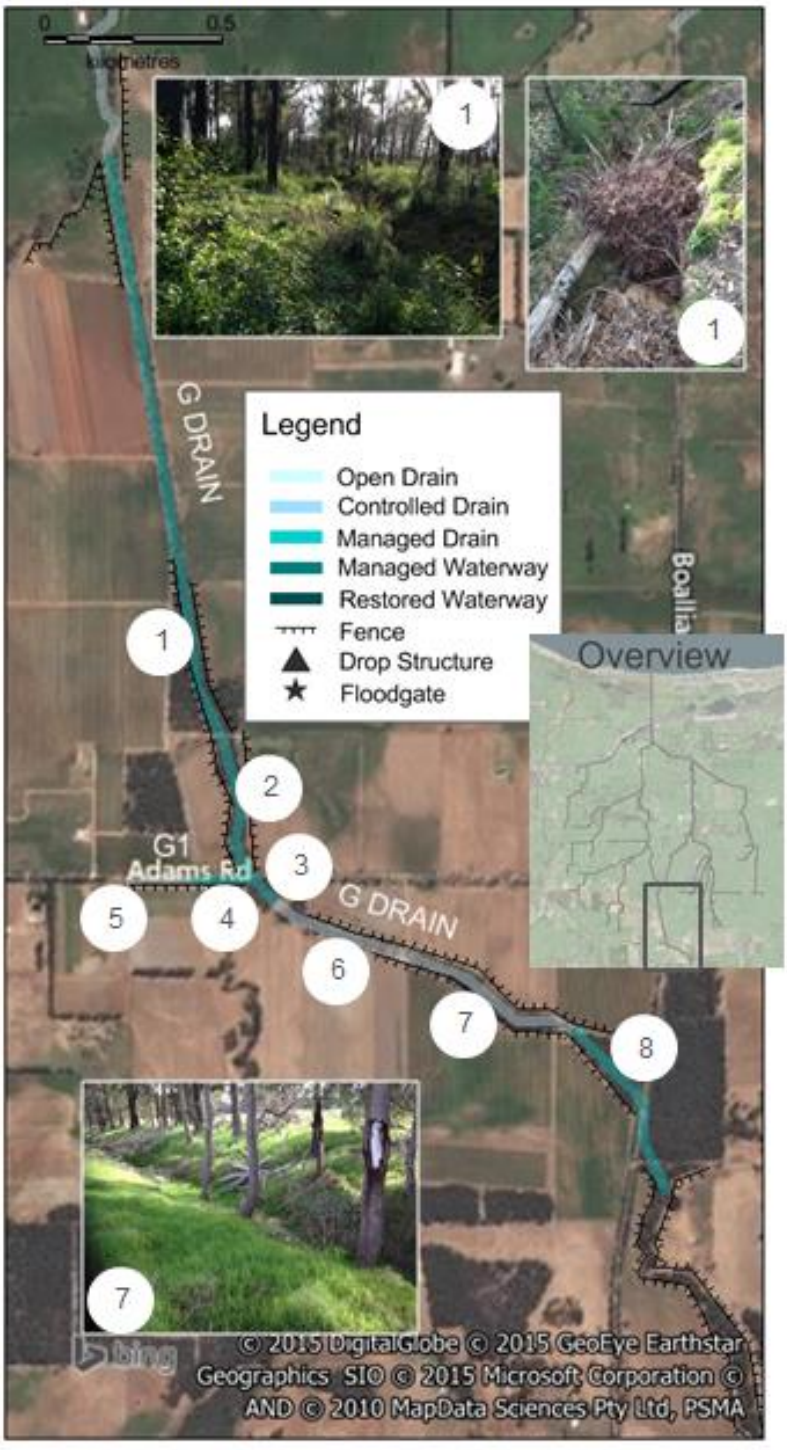
This section has a good canopy cover of native trees which is relatively wide in parts. According to the River Action Plan (GeoCatch, 2010) this stretch is completely fenced although there was a sandy crossing point which allowed stock to access a section of the channel and could deliver sediment to the system. An improved crossing could reduce the potential for sedimentation downstream.

Payne Rd to start of G Drain

*Aim for **Controlled Drain** or **Managed Waterway***

The majority of this section isn't fenced and the unrestricted stock access is causing the banks to erode adding sediment to the system. The understorey has also disappeared. This could be managed in a number of ways. Managing as a *Controlled Drain* would require fencing and crash grazing. Managing as a Managed Waterway would involve some revegetation works to improve the linkage between well vegetated areas above and below this stretch. There is a significant, wide stand of trees alongside part of the waterway that would enhance the habitat values if it was included in the fenced area.

Map 4: *G Drain*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kilometres
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G DRAIN
Legend
Open Drain
Controlled Drain
Managed Drain
Managed Waterway
Restored Waterway
Fence
Drop Structure
Floodgate
Boallia
Overview
1
2
3
4
5
6
7
8
G1
Adams Rd
G DRAIN
7
© 2015 DigitalGlobe © 2015 GeoEye Earthstar Geographics SIO © 2015 Microsoft Corporation © AND © 2010 MapData Sciences Pty Ltd, PSMA


4


5


8


2


3


6

G Drain South to 1.5km mark

*Aim for **Managed Waterway***

This section couldn't be accessed therefore it has only undergone a desktop analysis.

This section has a good canopy cover of native trees and, according to the River Action Plan (GeoCatch, 2010), there has been good regeneration of understorey species in parts. Those sections that remain unfenced and accessible to stock should be fenced. The River Action Plan also indicates that there are a number of erosion sites due to the straightening of the channel and resulting increased velocity of the flows. Some sections may benefit from infill planting and rock placement to improve the ecological values and stabilise erosion zones.

1.5km mark to 2km mark

*Aim for **Managed Waterway***

This section has been recently burnt and the understorey regeneration is very diverse. There are significant stands of trees either side of the riparian strip. Collections of sticks and branches in the waterway act as coarse filters and help to reduce the velocity of flows and the sediment loads carried in faster flows. Stock should not be allowed into this section due to the quality of the regenerating understorey.

2km mark to 2.5km mark

*Aim for **Managed Waterway***

This section has a good canopy cover of native trees with sections of good understorey, however previous grazing has resulted in the majority of the understorey being replaced by weedy grasses. Foxes have dug a number of dens in the banks of the waterway which can destabilise the banks and exposes new soil which is likely to be carried downstream in the next significant flows. Fox control is recommended. It would be interesting to trial controlled burns given the success of the regeneration in the section to the north.

2.5km mark to 3.5km mark

*Aim for **Controlled Drain**, **Managed Drain** or **Managed Waterway***

There is a mix of native and exotic eucalypt species along this stretch. The section with thick Bluegums has very little understorey growth. It would be interesting to find out whether the thick layer of litter provides the same degree of soil protection as perennial plants would or whether it gets washed away to expose the soil to erosion.

Some sections are fully fenced, some are just fenced on one side with clear evidence of sheep access and trampling along the banks. Fencing should be completed. Foxes have dug a number of dens in the banks of the waterway which can destabilise the banks and exposes new soil which is likely to be carried downstream in the next significant flows. Fox control is recommended. A sediment trap would help to minimise the transport of sediment downstream. This length could either be fenced and crash grazed or revegetated.

3.5km mark to end of G Drain

*Aim for **Managed Waterway** or **Restored Waterway***

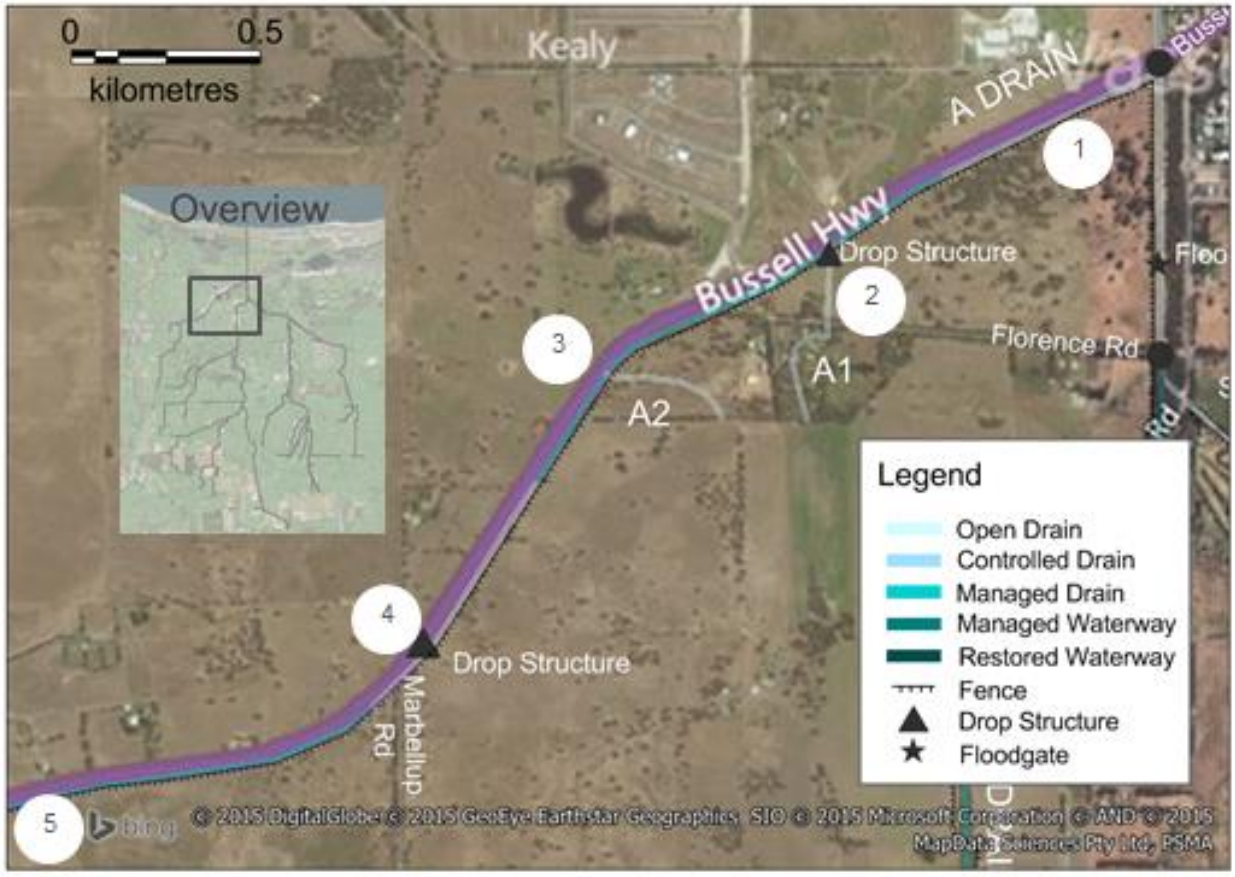
This section has good quality vegetation which is part of a larger patch of bush. There is some evidence of foxes, which should be controlled. Fallen branches are creating natural trash racks which help to filter the flows. Interference in these channels should be minimised.

G1 Drain

*Aim for **Open Drain***

The upstream half of this drain is more open with scattered trees and thick grass growth in the channel. These grasses would be better slashed than sprayed to encourage perennials to establish and provide year round protection of the bed and banks. The downstream half has a thicker canopy and more natives in the understorey. Weed control for the whole length should only focus on noxious weeds.

Map 5: *A Drain*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kilometres
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A DRAIN
Bussell Hwy
Drop Structure
Florence Rd
A1
A2
Overview
Legend
Open Drain
Controlled Drain
Managed Drain
Managed Waterway
Restored Waterway
Fence
Drop Structure
Floodgate
Marbellup Rd
Drop Structure
1
2
3
4
5


1


2


3


2


4


5

A DRAIN

A Drain

*Aim for **Managed Drain***

Most of the length has a good canopy of native trees on one or both sides but the understorey is mostly weeds. The downstream end has a more open canopy and much more of the channel is exposed with active erosion and bank slumping in parts. The upstream end is well vegetated with grasses and aquatics.

The roadworks upstream of the drain are contributing significant sediment loads to the drain. There are significant slugs of sediment in the drains. It would be worth installing a couple of sediment traps to minimise the maintenance. Weed control should be focused on noxious weeds to encourage the establishment of perennial grasses in the channels.

A1 Drain

*Aim for **Open Drain***

Some of this section couldn't be accessed therefore parts have only undergone a desktop analysis.

There are some sections with a canopy but much of this drain is open. It appears to have been completely sprayed in parts. It would be better to allow perennial grasses to establish in the drain to protect the channel and provide some filtering.

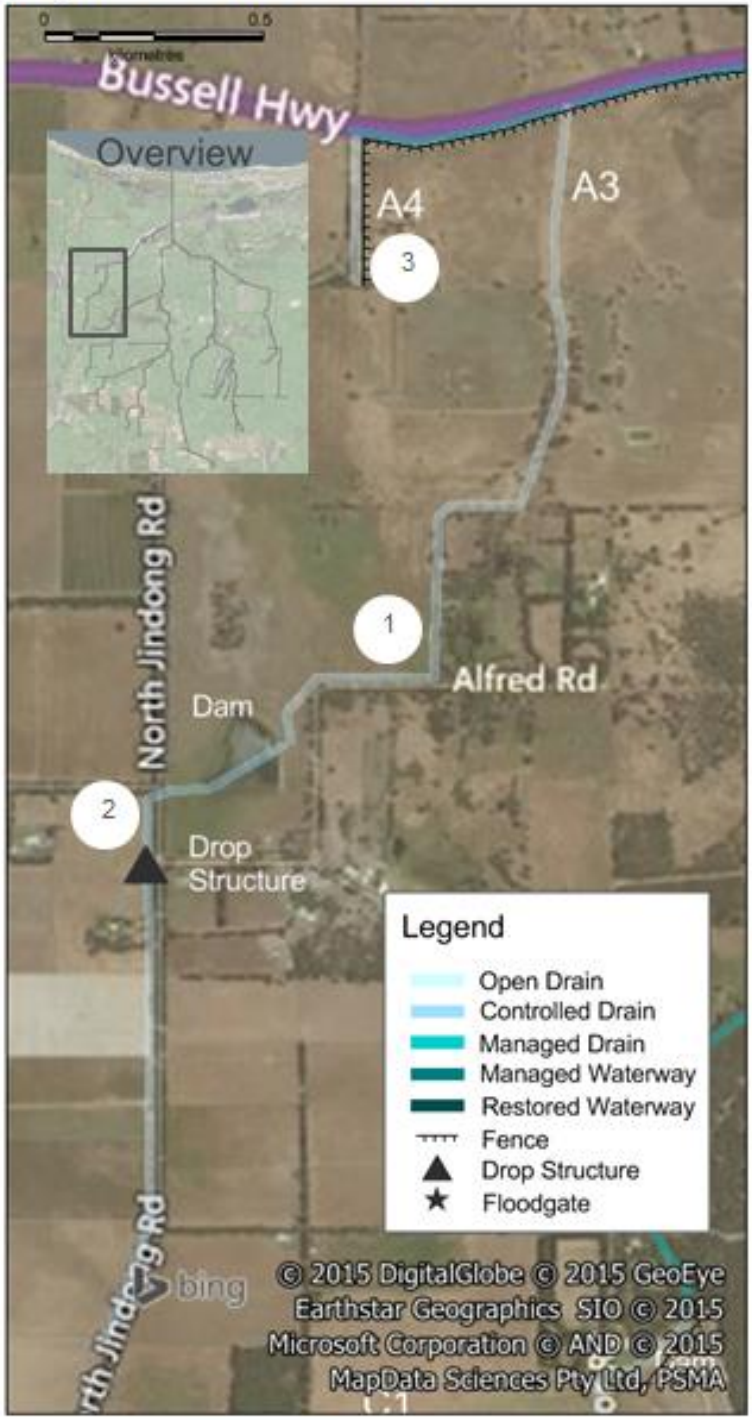
A2 Drain

*Aim for **Controlled Drain** or **Managed Drain***

Some of this section couldn't be accessed therefore parts have only undergone a desktop analysis.

This drain is quite well vegetated with pasture grasses and would benefit from controlled grazing or fencing and crash grazing. If it was fenced more trees could be established along the channel to provide some additional nutrient stripping. Small weirs could be installed to backflood the pasture late in the season providing greater productivity through summer and reducing the loss of nutrients.

Map 6: *A3 and A4 Drain*



A3 Drain

*Aim for **Managed Drain***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

This drain is quite well vegetated with pasture grasses and would benefit from controlled grazing or fencing and crash grazing. If it was fenced more trees could be established along the channel to provide some additional nutrient stripping.

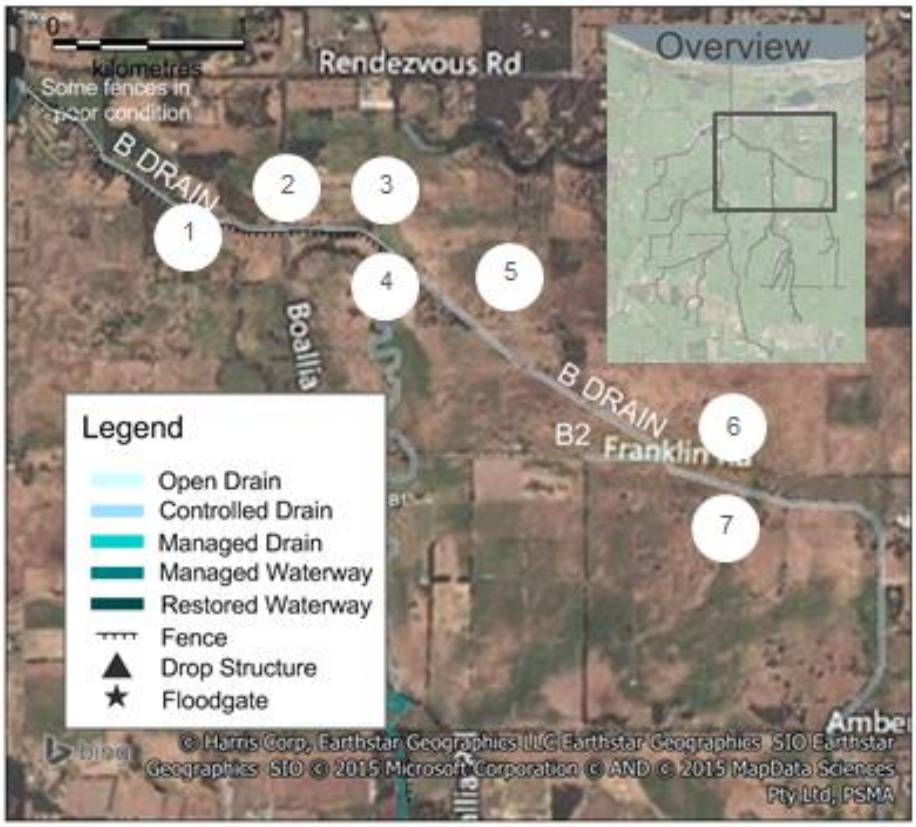
A large dam has been installed on the drain and there may be more opportunities for dams or small weirs to hold more nutrients back in the system and provide water to improve productivity through summer.

A4 Drain

*Aim for **Managed Drain***

This drain runs through the road verge and is relatively stable although recent work on a roadway has exposed a large area of sandy soil with very poor structure. The new road drain, which is connected to the end of A4, is likely to deliver significant volumes of sediment to the system. At least one sediment trap should be installed to minimise the amount of sediment that is carried further downstream.

Map 7: *B Drain to Ambergate Rd*



B DRAIN

Drain to B1

*Aim for **Controlled Drain** or **Managed Drain** or **Managed Waterway***

The standard of fencing varies along this section with stock causing significant damage to the banks resulting in erosion and sedimentation in parts. Fencing should be completed and repaired where necessary. Parts of this area could be crash grazed to managed the growth of grasses and manage the fire risk. A walk/horse trail could be established along the access track. Trees could be planted along the drain to provide greater stability to the banks.

There are several sites of serious active erosion and bank slumping due to the steep banks, poor soil structure, rapid flows and lack of deep rooted vegetation to hold the banks together. The installation of sediment traps would reduce the maintenance. The construction of this drain has cut straight across a natural drainage line. It would be interesting to investigate sending some of the flows through this more natural system to reduce the flows in the drains, allow for greater treatment of the water and increase the ecological values of the natural system.

B Drain from B1 to Ambergate Rd

*Aim for **Controlled Drain** or **Managed Drain***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

The majority of this stretch is not fenced (other than part of lot 880) with significant trampling and erosion along the banks. Controlled grazing or fencing and crash grazing would provide much greater protection for the banks. Perennial grasses should be encouraged to establish in the channel and along the banks. Additional trees could be established to enhance the ecological values, stabilise the banks and provide some filtering of ground water. There may be opportunities to trial small adjustable weirs to elevate the water table in autumn and spring to increase productivity and reduce the transport of nutrients.

B2

Aim for ***Controlled Drain***

Half of this drain runs just inside the paddock and half runs through the road verge. The section in the paddock has stabilised to a spoon shaped profile and is currently well vegetated. Grazing pressure should continue to be managed to prevent stock destabilising this stretch. Weed control for the section in the road reserve should be managed to address noxious weeds but allow perennial grasses to stabilise the channel. The grasses could be slashed as needed to manage the fire risk with the clippings ideally removed. More trees could be planted along the road verge to provide further nutrient stripping and bank stability along with some biodiversity benefits.

Map 8: *B Drain Ambergate Rd to Payne Rd*

B Drain from Ambergate Rd to B3

*Aim for **Managed Drain***

Some of this section couldn't be accessed therefore parts have only undergone a desktop analysis.

There are some good stands of *Juncus pallidus* along this stretch that should be protected and encouraged to spread. There are also significant stands of trees. This section should be fenced and crash grazed. There are also several sections where the channel splits and some of the flow deviates through more convoluted channels. These would provide ideal treatment locations using vegetated filters and possibly sediment traps and amended substrates. They could be designed to convey peak flows without damaging assets. There may also be opportunities to trial small adjustable weirs to elevate the water table in autumn and spring to increase productivity and reduce the transport of nutrients downstream.

B Drain from B3 to end

*Aim for **Controlled Drain** or **Managed Waterway***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

This section is fenced and could be managed through crash grazing where the banks aren't too steep. Otherwise slashing would be better than spraying to maintain the perennial grasses to stabilise the banks. More trees could be planted to provide filtering of ground water, bank stability and ecological benefits. There is evidence of aquatic fauna in this stretch of the waterway.

B3 through private land

*Aim for **Controlled Drain***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

This section appears to be well fenced and vegetated. If it is mostly trees over grasses it could be managed through crash grazing. This could be a good section to grow the local duckweed to provide nutrient stripping and potentially a supplementary feed source.

B3 in the road reserve

*Aim for **Controlled Drain** or **Managed Drain***

Temporary connections have been dug to enhance the drainage of some paddocks. Given the large areas of poorly structured, exposed sands, these drainage works have delivered significant quantities of sediment to the drain which has management implication downstream (including a partially blocked culvert). It highlights the need to manage access to the drains appropriately. Some simple sediment traps could greatly reduce the ongoing maintenance of the system.

Weed control in this section should aim to control noxious weeds and allow the perennial grasses to establish in the channel. The grasses could be slashed as needed to manage the fire risk with the clippings ideally removed. More trees could be planted along the channel to provide further nutrient stripping and bank stability along with some biodiversity benefits.

B3A

*Aim for **Controlled Drain***

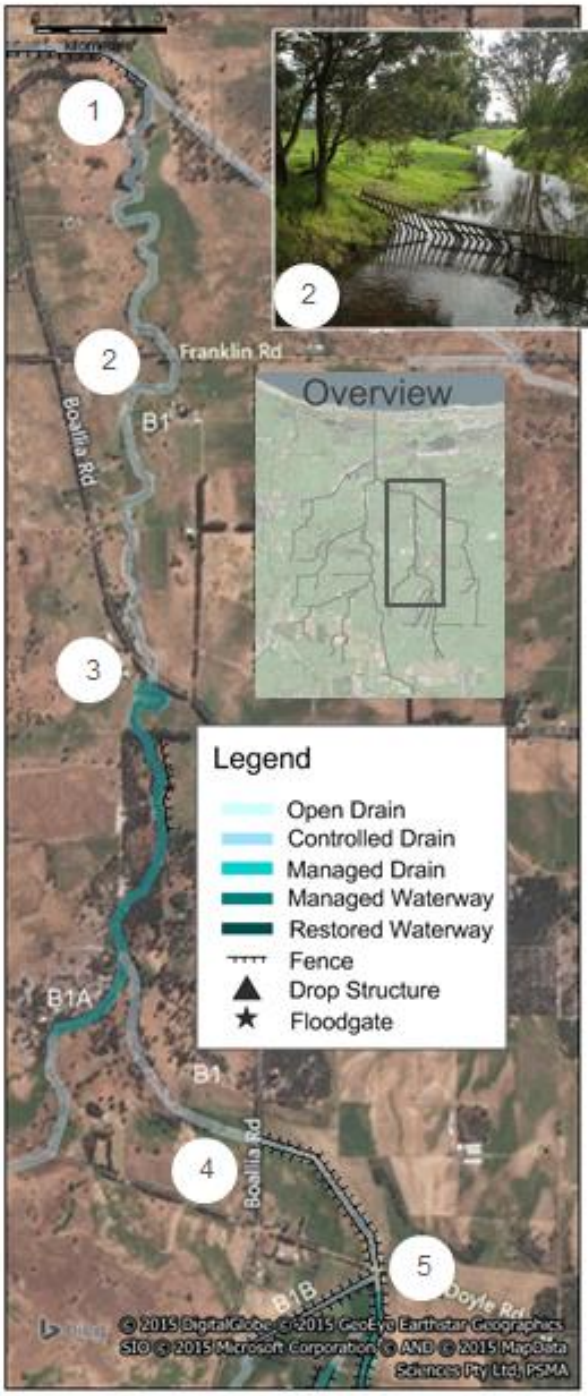
The channel is fenced and well vegetated with grasses which could be managed through crash grazing. More trees could be planted along the channel to provide further nutrient stripping and bank stability along with some biodiversity benefits. This could also be a good section to grow the local duckweed to provide nutrient stripping and potentially a supplementary feed source.

B4

*Aim for **Controlled Drain***

The noxious weeds should be controlled along this section whilst the perennial grasses are left to stabilise the channel. They will need to be periodically slashed and ideally the clippings should be removed. More trees could be planted along the channel to provide further nutrient stripping and bank stability along with some biodiversity benefits.

Map 9: *B1 to Doyle Rd*



B1 from B Drain to Boallia Rd

*Aim for **Managed Drain***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

This section retains a natural meandering shape. There are some thick patches of trees but the majority has more scattered trees with pasture underneath and stock accessing the channel and causing erosion. This section should be control grazed or fenced and crash grazed. If it was fenced more trees could be established to improve the stability of the banks and provide some filtering of the groundwater. Given that this is the natural drainage line and the landscape is shaped to handle a range of flows, it would be an ideal area to install a series of small adjustable weirs to elevate the water table in autumn and spring to increase productivity and reduce the transport of nutrients downstream.

B1 between Boallia Rd crossings

*Aim for **Managed Drain***

Some of this section couldn't be accessed therefore parts have only undergone a desktop analysis.

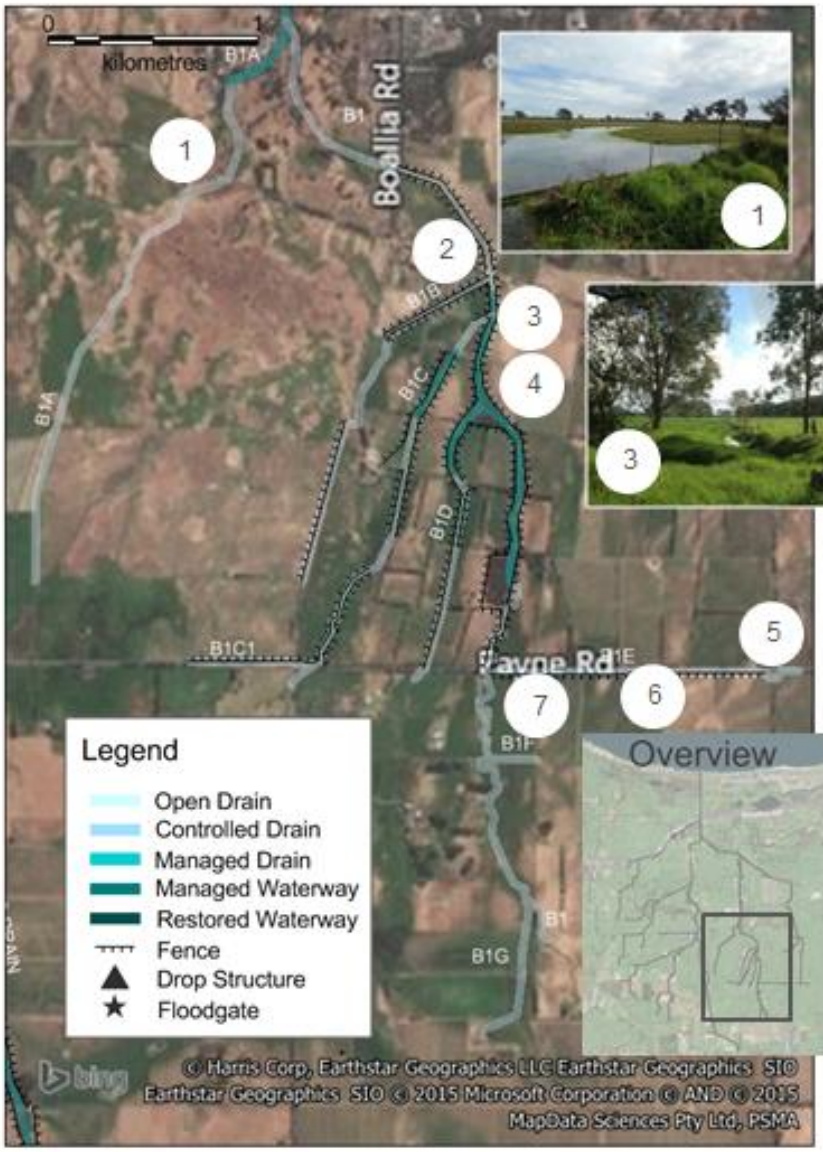
This section looks like pasture that appears to be currently ungrazed and may be used as hay or silage paddocks. The drain appears to be in better condition and is well vegetated. It should be protected from heavy grazing in the future and any fertiliser spreading should avoid the area immediately around the channel. Given that this is the natural drainage line and the landscape is shaped to handle a range of flows, it would be an ideal area to install a series of small adjustable weirs to elevate the water table in autumn and spring to increase productivity and reduce the transport of nutrients downstream.

B1 from Boallia Rd to Payne Rd

*Aim for **Managed Waterway***

This area has a wide fenced area either side of the drain with a continuous canopy along most of the length. Some sections also have a good understorey of natives. It appears that there has been occasional crash grazing carried out along this section. Additional plantings could add to the understorey and improve the biodiversity values. This could be a good site to install small weirs to manage seasonal flow

Map 10: *B1A to B1G*



B1 South of Payne Rd

*Aim for **Controlled Drain** or **Managed Drain***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

It appears that the majority of this section is not fenced and is grazed. There are several patches of trees but the majority appears to be denuded or may have pasture species growing along the channel. Grazing should be controlled to allow the establishment of perennial grasses to stabilise the banks and provide some filtering of flows. Small weirs and/or sediment traps could be used to manage flows and sediment in the system.

B1A

*Aim for **Controlled Drain***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

Doyle Rd is completely flooded throughout the winter at the point where this drain crosses. It appears that this drain is largely unfenced. Grazing should be controlled to allow the establishment of perennial grasses to stabilise the banks and provide some filtering of flows. This could also be a good site to establish *Lemna disperma* (the local native duckweed) to harvest some of the nutrients from the drainage water.

B1B

Aim for ***Controlled Drain***

Some of this section couldn't be accessed therefore parts have only undergone a desktop analysis.

Part of this drain is fenced and has been revegetated with eastern states eucalypts which are now mature and forming a dense stand. It appears that not much is growing underneath these trees and it would be interesting to see whether the channel is stable and what impact the trees have on the water quality as it passes through, particularly the ground water.

The middle section is unfenced and grazed. Half of it is in the home paddock and is completely denuded from the continual grazing pressure. The ironstone base is providing some protection but the soil on the banks is eroding. There is a stark contrast to the adjacent paddock that is rotationally grazed and the channel is mostly vegetated through this section. Grazing control or fencing and crash grazing are recommended here.

Where the drain runs through the road reserve it is protected from grazing pressure and the channel appears relatively stable. There are patches of native vegetation but it is largely degraded. Weed control along this section should just focus on noxious weeds and perennial grasses should be left to protect the channel during early and peak flows.

B1C

Aim for ***Controlled Drain***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

There are a couple of significant sections of drain with good quality canopy however the majority appears to be denuded and unfenced. One section has been recently fenced and sprayed and looks as though it is undergoing revegetation. It is difficult to determine how much of the length has been fenced in this project. Any sections that remain unfenced could either be fenced and revegetated or fenced and crash grazed or managed through controlled grazing.

B1C1

*Aim for **Open Drain***

Given that along this section of drain there is very little native vegetation left it would be worth targeting the weed control at noxious weeds and allowing the perennial grasses to establish to provide protection for the bed and banks. This could be slashed to reduce the fire risk as needed and ideally the cut material should be removed.

B1D from B1 to end of vegetation

*Aim for **Managed Waterway***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

There is an area of bush adjacent to where B1D connects to B1. This section of the drain is well vegetated with good quality bush including understorey that is well protected by fencing. This area should be protected from grazing to maintain the understorey species. Past the bush block there is a good canopy cover along the drain and it appears to be well protected by fencing. The next length is also fenced and appears to have been revegetated in the last few years.

B1D remainder

*Aim for **Controlled Drain** or **Managed Drain** or **Managed Waterway***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

The remainder of B1D is either only fenced one side or not at all. This could be managed through controlled grazing to maintain a perennial pasture cover or fenced and crash grazed or fenced and revegetated. There may be potential to use small adjustable weirs to hold water back seasonally to provide greater productivity and water quality benefits. The local duckweed species could be grown in the water as a feed source and to provide further water quality benefits.

B1E in paddock

*Aim for **Controlled Drain** or **Managed Drain***

Weed control in this section should aim to control noxious weeds and allow the perennial grasses to establish in the channel. This should then be managed through controlled grazing or fencing and crash grazing. Stock is currently trampling the banks causing erosion and sediment to be carried downstream. This could be a good section to grow the local duckweed to provide nutrient stripping and potentially a supplementary feed source.

B1E in road reserve

*Aim for **Controlled Drain***

Weed control in this section should aim to control noxious weeds and allow the perennial grasses to establish in the channel. The grasses could be slashed as needed to manage the fire risk with the clippings ideally removed. More trees could be planted along the channel to provide further nutrient stripping and bank stability along with some biodiversity benefits.

B1G, B1F and B1 South of Payne Rd

*Aim for **Controlled Drain** or **Managed Drain** or **Managed Waterway***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

This section appears to be a largely natural meandering waterway with a number of cut off channel loops along the course. These loops could provide extra treatment potential for drainage waters if designed to allow excess flows to take the shorter route to avoid unacceptable flooding. The majority of the length appears to be unvegetated. Perennial grasses should be encouraged to establish along the channels which should be managed with controlled grazing or fencing and crash grazing. This could be a good area to install a series of small adjustable weirs to elevate the water table in autumn and spring to increase productivity and reduce the transport of nutrients downstream.

Map 11: *C Drain*

C DRAIN

C Drain from Main Drain to 3km mark

*Aim for **Controlled Drain** or **Managed Drain** or **Managed Waterway***

None of this section could be accessed therefore it has only undergone a desktop analysis.

The majority of this section has a good canopy and passes through some significant areas of bushland. It appears that there are no fences along most of the length. It would be good to fence out stock and either manage the grasses through crash grazing or enhance the ecological values with infill revegetation using local native species. This could be a good area to install a series of small adjustable weirs to elevate the water table in autumn and spring to increase productivity and reduce the transport of nutrients downstream.

C Drain from 3km mark to Hairpin Rd

*Aim for **Controlled Drain** or **Managed Drain** or **Managed Waterway***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

There is already a small dam on the drain next to Hairpin Rd. More of these could be constructed and revegetated with local native sedges and rushes and possibly some patches of trees to provide summer shade. They should allow for fish passage in the design. These could be used to grow the local duckweed to provide nutrient stripping and potentially a supplementary feed source. The grasses growing along the banks could be managed through crash grazing or mowing.

C Drain south of Hairpin Rd

*Aim for **Controlled Drain** or **Managed Drain** or **Managed Waterway***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

This section appears to be mostly an unfenced paddock drain. Perennial grasses should be encouraged and managed through controlled grazing or fencing and crash grazing. This could be a good area to install a series of small adjustable weirs to elevate the water table in autumn and spring to increase productivity and reduce the transport of nutrients downstream.

C1 from C Drain to 1.5km mark

*Aim for **Managed Waterway***

None of this section could be accessed therefore it has only undergone a desktop analysis.

This section is very well vegetated and passes through some significant areas of bushland. This vegetation should be protected from grazing as it will have significant biodiversity values.

C1 from 1.5km mark to start

*Aim for **Controlled Drain** or **Managed Waterway***

The section to the east of Taylor Rd is fenced and the grass appears to be mown either side of the channel and sprayed out in the channel itself. There is also a small dam in the channel. It would be worth

establishing some native sedges and rushes around the dam and some trees for shading.

The section to the west runs along the edge of a poorly drained paddock. It is not fenced and unvegetated. Perennial grasses should be encouraged and managed through controlled grazing.

C2 along road verge to 1km mark

*Aim for **Controlled Drain***

The sections that are in the road verge should be managed to control the noxious weeds. Perennial grasses should be maintained to stabilise the banks and managed through slashing. The section that runs through the paddock is highly degraded with completely denuded banks causing significant amounts of sediment to enter the drain. This should be either fenced and managed through crash grazing or at least protected until the vegetation can re-establish at which point it could be managed through controlled grazing.

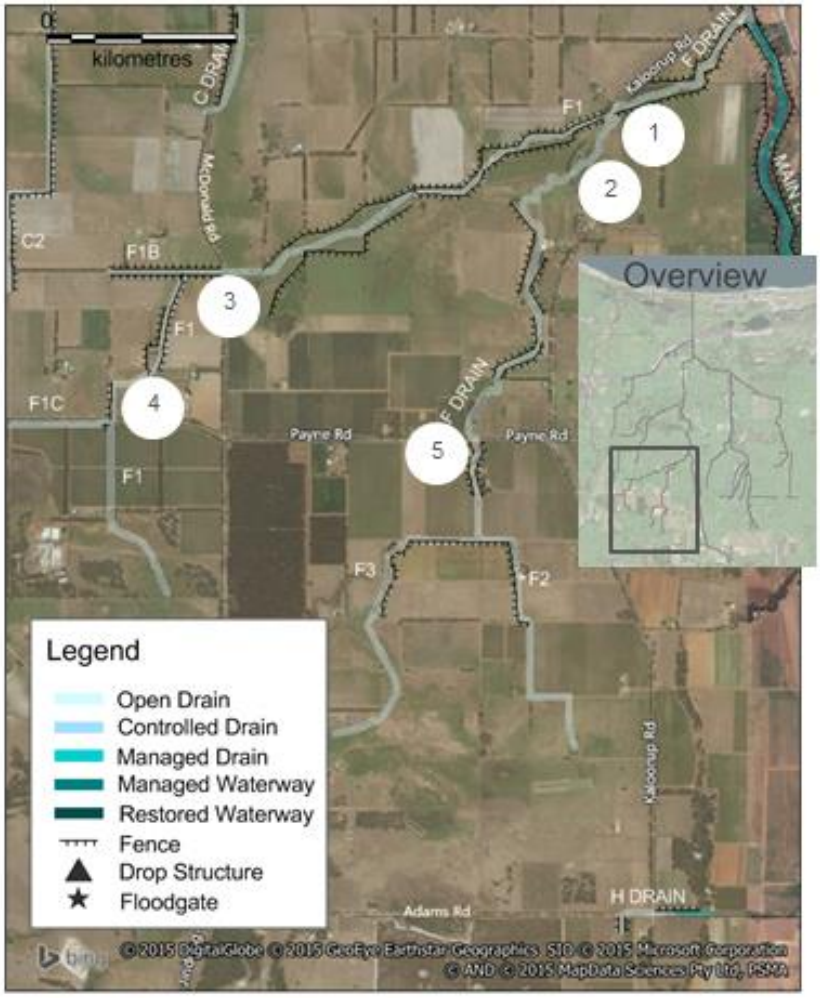
C2 south of Hairpin Rd past 1km mark

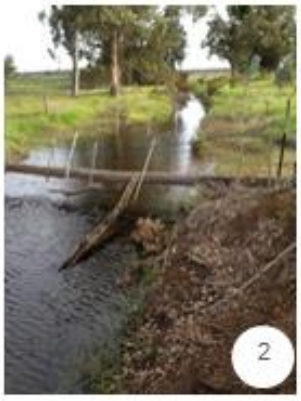
*Aim for **Controlled Drain** or **Managed Waterway***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

This section of drain runs along a paddock fence with very few trees. Perennial grasses should be encouraged to grow along the channel to provide protection for the bed and banks. These grasses could either be managed through controlled grazing or they could be fenced and crash grazed. If it was fenced trees could be grown alongside the channel to provide extra stability and nutrient stripping.

Map 12: *F Drain and H Drain*





F DRAIN

F Drain to almost 1km

*Aim for **Controlled Drain** or **Managed Waterway***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

This section appears to be fenced with vegetation along most of it. The part closest to Kaloorup Rd has an area of quality vegetation alongside adding to the biodiversity values. These sections may benefit from additional plantings of local native species.

F Drain and F1 East of Kaloorup Rd

*Aim for **Controlled Drain***

This section is highly degraded and actively eroding along the banks due to stock. This should be a high priority for controlled grazing or fencing and crash grazing. The ironstone base is providing some protection for the channel.

F Drain West of Kaloorup Rd (including F2, F2A and F3)

*Aim for **Controlled Drain** or **Managed Drain** or **Managed Waterway***

The majority of this section couldn't be accessed therefore some parts have only undergone a desktop analysis.

Most of this section appears to be vegetated with grasses and scattered patches of shrubs and trees. Some sections appear to be fenced with a wide reserve around the channel. Any sections which aren't fenced should be managed through controlled grazing or fencing and crash grazing. This could be a good area to install a series of small adjustable weirs to elevate the water table in autumn and spring to increase productivity and reduce the transport of nutrients downstream.

These weirs could also be used to grow the local duckweed to provide nutrient stripping and potentially a supplementary feed source.

F1 (including F1A and F1B)

*Aim for **Controlled Drain** or **Managed Drain***

The majority of this section couldn't be accessed therefore most of the length has only undergone a desktop analysis.

From the aerial photos it appears that some parts are fenced both sides, some just one side and some are not fenced. The majority of the length doesn't have any canopy cover other than limited plantings of exotic trees. Perennial grasses should be encouraged to grow through the channels to provide stability and filtering to flows. Controlled grazing or fencing and crash grazing could be used to manage the growth. Trees could be planted alongside the channel to provide extra stability and nutrient stripping.

This could be a good area to install a series of small adjustable weirs to elevate the water table in autumn and spring to increase productivity and reduce the transport of nutrients downstream. These weirs could also be used to grow the local duckweed to provide nutrient stripping and potentially a supplementary feed source.

F1C in road reserve

*Aim for **Managed Waterway***

This road reserve has a good quality stand of bush that should be protected. It would not be appropriate to encourage perennial grasses in this stretch.

F1C in vineyard

*Aim for **Controlled Drain***

Natural trash racks created by fallen branches and leaves are helping to filter flows through this channel. More vegetation along the channel would help to increase the stability of the banks.

H Drain in road reserve

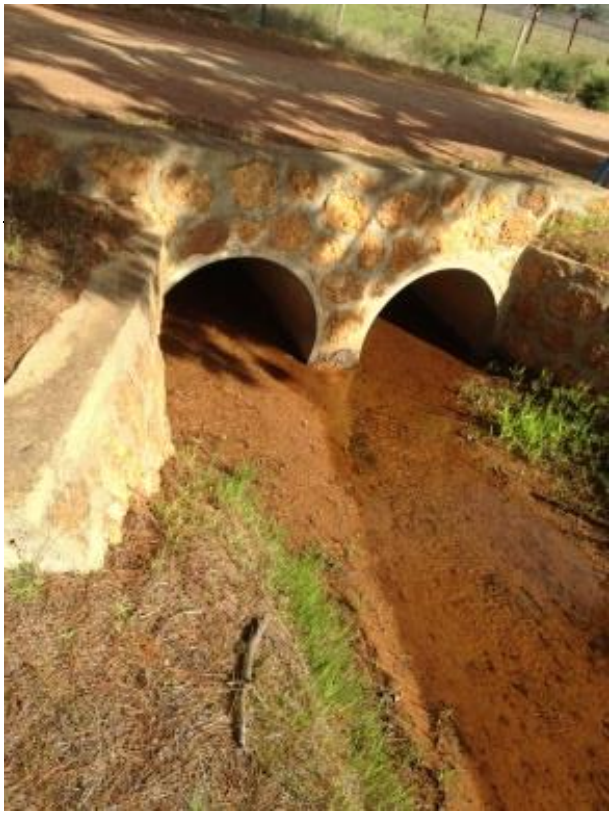
*Aim for **Managed Waterway***

The bush along the channel is in good condition and should be protected. There are native fish living in the channel.

H Drain on private land

*Aim for **Controlled Drain** or **Managed Drain***

There have been recent works to create a rocked crossing with culverts which are causing water to pool behind and helping to allow sediment to fall out of suspension. These works appear to have created some sediment during their creation however they are likely to reduce the amount of sediment flowing downstream in the future. The section running next to the potato paddock would benefit from more vegetation in the channel to provide stability and filtering. This could be a good location for the local duckweed to provide nutrient stripping and food and shelter for the native fish.



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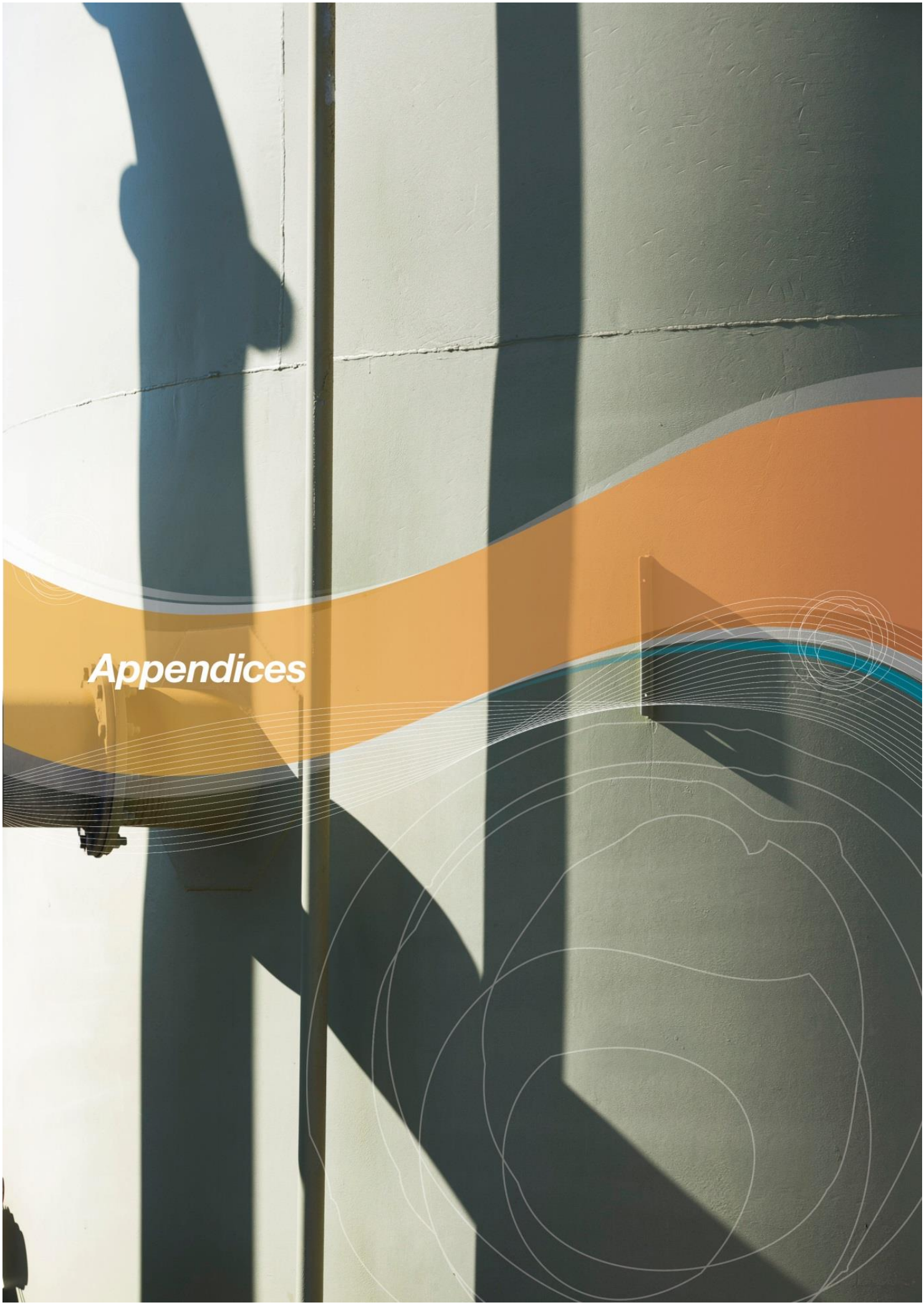


Appendices

APPENDIX 1 WATERWAYS TRANSITION FRAMEWORK

MANAGEMENT OPTIONS

VEGETATION

WOODY BUFFERS

Definition Vegetated buffers consisting mostly of trees and large shrubs generally running parallel to the waterway.

Details The extensive root systems filter the groundwater before it enters the waterways. This is particularly useful in sandy soils with high infiltration rates where much of the rainfall penetrates the soil and travels through the soil carrying dissolved nutrients and other pollutants to the waterways. Harvesting some of the growth periodically will encourage maximum nutrient stripping.

Application This will have the greatest impact on water quality when it is applied to minor source tributaries as it has minimal impact on water already flowing through the stream.

GRASS BUFFERS

Definition A strip of grass designed to evenly spread flow to increase infiltration, intercept sediment and other pollutants, and reduce stormwater flow and velocity.

Application Grass filter strips have the greatest impact on water quality in soils with low infiltration rates (such as clay rich and/or heavily compacted soils) where much of the rainfall flows over the surface before entering the waterways. They are also valuable adjacent to bare soil areas such as recently ploughed soils and mines/quarries etc. Regular harvesting increases the effectiveness. (See image from Alabama Soil and Water Committee, 2003).

INSTREAM RUSHES & SEDGES

Definition These are the rushes and sedges growing in the bed and banks of the waterway

Application Where there is adequate flow capacity in the system, rushes and sedges are useful in the more major channels to stabilise the bed and banks and provide instream nutrient stripping without greatly compromising the flow capacity. Rushes and sedges can compete with weeds and reduce the maintenance of drainage channels.

INSTREAM WOODY VEGETATION

Definition These are the trees and large shrubs growing in the stream bed and banks.

Details The roots provide structural support for the soil and limited nutrient stripping, the branches and leaves provide shading of the waterway. The trees can reduce flow rates and impact on channel patterns therefore they are not appropriate in areas that carry large flows and may flood.

Application They are useful in unstable areas not likely to flood such as waterways with excessive capacity and minor source tributaries.

AQUATIC PLANTS

Definition These are the plants growing in the water column.

Details There are a mixture of native and introduced aquatic plant species present in the catchment. Species such as *Callitriche* (introduced but naturalised) and *Lemna* (native) can harvest nutrients from the water. *Lemna* (duckweed) is used in bioremediation systems around the world due to its rapid growth rates. It is also grown commercially as an animal feed as it contains 25 – 45% protein based on the dry weight (Leng et al, 1995). There is potential for farmers and life-stylers to harvest the growth for stock feed and compost.

Application Many of the minor drains receiving runoff from dairy paddocks already have *Callitriche* growing in them. *Lemna* could be introduced in the upper catchment.

REVEGETATION

Definition	Planting local native species
Details	Re-establishing a suite of suitable riparian species along the channel to provide stability to the banks, filtering for surface runoff and ecological niches for local native species. Revegetated waterways can provide important linkages between patches of remnant bushland.
Application	This is applicable where the landholder is supportive and the area is suitably protected from stock. It will provide the greatest benefit where it connects existing areas of vegetation.

CHANNEL MAINTENANCE

WEED CONTROL

Definition: The control and/or removal of weeds from the waterway.

Details: Weeds can stabilise sediments in the drains and encourage suspended material to drop out of suspension. They also harvest nutrients from the system as they grow. Invasive weeds are sometimes dug out in an attempt to control them. This can have a massive impacts on the stability of the system. Alternative techniques such as regular slashing and drowning or spraying may be less damaging on the overall system. Weed control should be targeted at

- weeds constricting the channel below the design capacity;
- declared agricultural weeds; and
- serious environmental weeds.

If the design capacity can be maintained, perennial grasses such as Kikuyu should be excluded from the weed control programs (see Managed Instream Pasture section following). Spraying with herbicides will cause nutrients and sediments to be re-released into the system as they decompose (WML, 2005).

Application: Where the native understorey has been replaced with weeds it would be preferable to encourage perennial grasses such as kikuyu to stabilise the banks.

BANDED DRAIN CLEARING

Definition — Only clearing half the length of channel at a time as alternating sections to reduce the loss of sediments from newly exposed bed and banks.

Details — Vegetation can re-establish in the cleared sections ready to provide filtration for the next stage of channel clearing.

Application — This technique could be applied to the main drains and major channels.

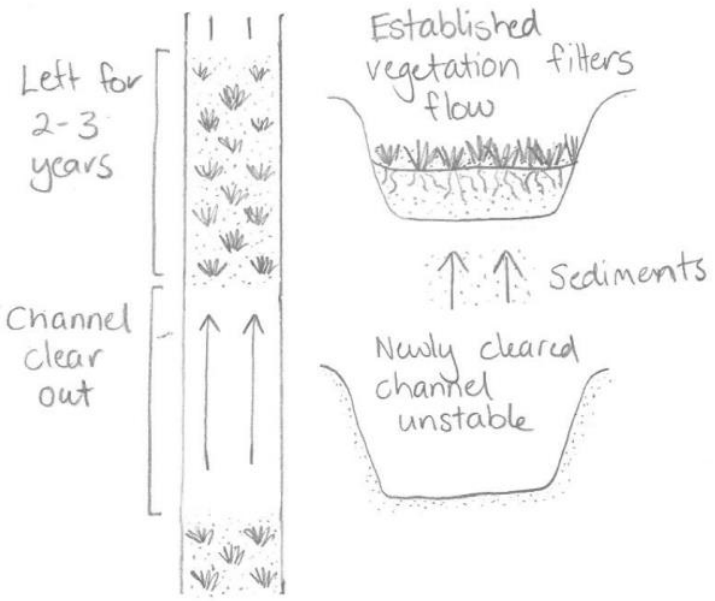


Figure: Banded drain clearing adapted from Del Marco 2007 (not to scale)

SEDIMENT REMOVAL

Definition — The removal of sediment build up in waterways.

Details — This practise is more concerned with nutrient enriched fine sediment (clay and silt or 'mud'). Management of bedload or coarse sediment issues would be more appropriately dealt with through Sediment Traps or Stable Channel Development sections following.

The removal of fine sediment build up is only appropriate where it avoids removing native vegetation and the removal does not destabilise the channel causing further erosion. Techniques such as vacuum extraction of sediments should be explored to minimise the damage to the bed and banks. It is also important to dispose of the material appropriately to ensure that it is not released back into the system.

Application — Where ever there is an excessive build-up of sediment requiring removal

MAINTENANCE OF DRAINAGE ASSETS

Definition — Any works associated with maintaining drainage assets

Details — There is a significant amount of confusion amongst landholders about who should maintain the drainage assets. It would be worthwhile clarifying this with landholders so that assets are maintained appropriately to minimise erosion and sedimentation in the system. Since the cessation of drainage rates it is now the responsibility of landholders to maintain the cattle stops and outlet structures.

Application — Where ever drainage assets are located

MANAGED GRAZING

CONTROLLED GRAZING

Definition — Managing the grazing pressure on an area by regularly resting it to allow regrowth.

Details — Grazing pressure has a significant impact on the vegetation in the drain and subsequently the bank stability. Paddocks that are continually stocked will generally have completely denuded and eroding banks. Where rotational grazing is used, vegetation such as grasses have the opportunity to regrow between grazing. Fencing stock out completely provides the best protection for the channel banks.

Where there is prolific growth of grasses and weeds, “crash grazing” can be used to control growth and as a means of harvesting the nutrients captured from the system. Crash grazing is essentially allowing stock into a fenced area for short periods to remove excess growth without causing much damage from trampling.

Areas that are seasonally inundated may also benefit from being rested to reduce the damage to the soils structure that occurs when stock trample waterlogged soils. This can also reduce the loss of valuable topsoil to the drainage system. Modern electric fences provide a flexible solution to fencing.

Application — Paddock drains

MANAGED INSTREAM PASTURE

Definition — Establishing perennial pastures such as Kikuyu on bare or non-vegetated bed and banks and allowing controlled grazing or slashing (with removal) to manage the growth and stability of the system.

Details — Kikuyu has an extensive, deep root system that can survive in relatively dry conditions through to extended inundation. The network of roots stabilise the banks and harvest nutrients from the system. The thick matt of leaf growth filters flows into and through the channels. To encourage ongoing nutrient removal from the drains it is recommended that the grass is harvested regularly. It is important to control grazing pressure by managing the timing, duration and intensity.

Application — This technique is most applicable on minor paddock drains but can be used on more major drains where the channel shape allows safe stock access without risking erosion.

FENCING

Definition — Fencing waterways to permanently exclude stock.

Details — Fenced areas should either be revegetated with native species or perennial grasses such as Kikuyu which can be managed through crash grazing.

Application — Where the waterways retain riverine features or banks are steep or exposed and vulnerable to erosion, stock should be excluded.

OFFSTREAM WATERING POINTS

Definition — Providing a paddock trough or equivalent watering point for stock to drink from

Application — This is generally applicable where there is permanent water in the waterway and is required when stock are fenced out.

INSTREAM STRUCTURES

BANK STABILISATION

Definition — A number of ‘soft’ and ‘hard’ engineering techniques are available to stabilise and protect banks.

Details — Soft engineering includes battering and terracing, brushing, large woody debris and geotextile cover. Hard engineering includes log walling, rock gabions and rock pitching. Bank stabilisation techniques are generally expensive and the cause of bank erosion should be determined before proceeding with plans for restoration. For example, there is a certain degree of bank erosion and deposition present in natural waterways.

Application — Where bank erosion can’t be controlled through stock exclusion and revegetation, engineering options are required to secure and protect banks.

GABIONS

Definition Rock filled cages placed across the flow path to reduce the velocity.

Details Slotted pipe containing nutrient stipping products can be built into the gabions. They should be designed appropriately so that they don't pose an erosion or destabilisation risk.

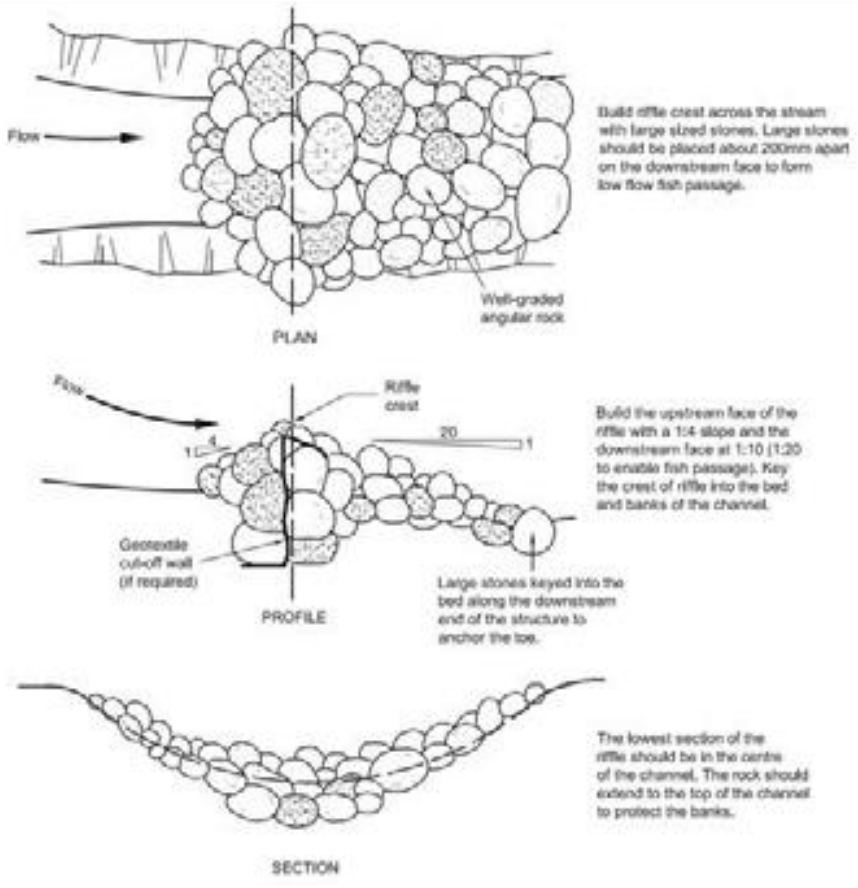
Application Gabions can be used where there is a large amount of suspended material or dissolved nutrients (where they have nutrient stipping capabilities).

ROCK RIFFLES

Definition Rock pitching or loose rock dams to protect the bed and banks and disperse the energy of the water in a waterway.

Details In steep areas riffles can provide stable rapid level drops. Headcuts are best dealt with by filling with rocks. Loose rock dams can provide effective sediment traps in catchments ≤ 4ha. Rock riffles can double as stream crossing points or provide a stable controlled stock access point.

Application Areas prone to erosion, particularly during larger flow events

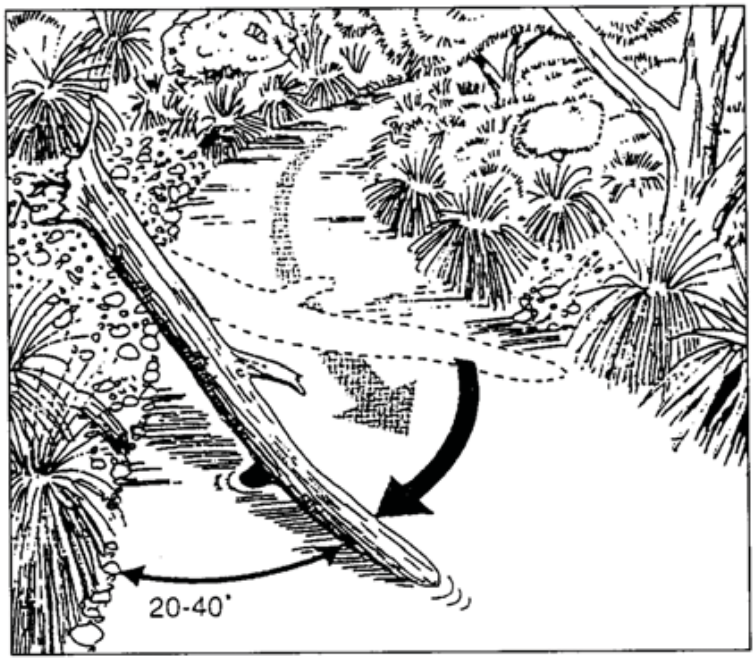


LARGE WOODY DEBRIS

Definition Large logs used to protect the banks.

Details Logs shouldn't reduce the flow by any more than 10%. They are best placed parallel to the bank or the downstream end angled into the stream up to 40˚.

Application Logs work particularly well in sandy soils.



SEDIMENT TRAPS

Definition Sediment traps are water holding areas designed to detain water long enough so that particulates can settle out before water is discharged downstream.

Details They can be constructed by excavating a pit or by placing a small rock riffle across the channel. This limits the length of channel that is disturbed by excavation, reduces maintenance costs and improves stream habitat. The volume and size gradation of sediment needs to be understood when designing a sediment trap to ensure the velocity is reduced enough to allow the material to drop out of suspension. Amended substrates can be incorporated to provide additional nutrient stripping benefits. May be used to reduce flood peaks if designed appropriately.

Application Generally more suitable on channels with a large amount of coarse sediment. Often located on the end of a stream branch just before it discharges into another channel.

CHANNEL CROSSINGS

Definition A designated point for crossing a waterway

Details There are three main types of crossing:

- Fords (includes rock riffles) – natural or artificial shallow parts of the channel
- Culverts – raised thoroughfares that use round or rectangular conduits to allow low to medium flows to pass and keep the track dry and firm
- Bridges – designed to raise the thoroughfare above the level of most floods

Channel crossings should be used in conjunction with stock exclusion fencing.

Application Where traffic or stock are causing damage to a channel as they cross it.

CHANNEL STOPS

Definition Small dams or weirs to backflood an area.

Details These structures can potentially reduce the nutrient load to downstream environments and increase summer productivity by maintaining higher water tables for longer in summer. A trial on a 100ha catchment in the Peel-Harvey Catchment reduced the annual total nitrogen load by 79% and the total phosphorous load by 90% (Ocampo, 2015).

There is a substantial risk of flooding upstream landholders, as well as reducing flow to downstream landholders. A typical slope of 0.1 per cent would mean a stop board of 1 m above the drain invert would cause back flooding 1 km upstream. For this reason the Water Corporation requires agreement of the two upstream landholders and the landholder immediately downstream.

Application Detailed catchment planning would be required to determine where these would be suitable.

BANKS AND CONTROLLED DRAIN OUTLETS

Definition Levee or spoil banks used to confine overland flows to designated entry points.

Details This allows greater opportunity for pollutants to drop out of solution before they enter the drain and for uptake of dissolved nutrients by crops and soil. Defined access points should be engineered to minimise erosion. The use of control structures such as floodgates can reduce flow rates and hold water back temporarily during periods of high flow reducing the peak flows experienced downstream. These are ideal points to incorporate sediment traps to minimise and focus maintenance.

Some sections may benefit from having the banks removed to allow for periodic inundation of the flood plain. These areas would need to have stable, well vegetated banks to ensure that they wouldn't contribute sediment to the system during flood events.

Application Banks are applicable where there is a risk of erosion and pollution associated with overland flow.

DRAIN OUTLET PROTECTION

Definition Assets or designs that protect the area where drain branches connect

Details A rock apron and or vegetation can be used to protect the banks at the outlet of one drain into another. Floodgates can control

Application Generally more applicable where minor drains enter deeper major drains. They are suited to actively eroding outlets or those that may be at risk of erosion.

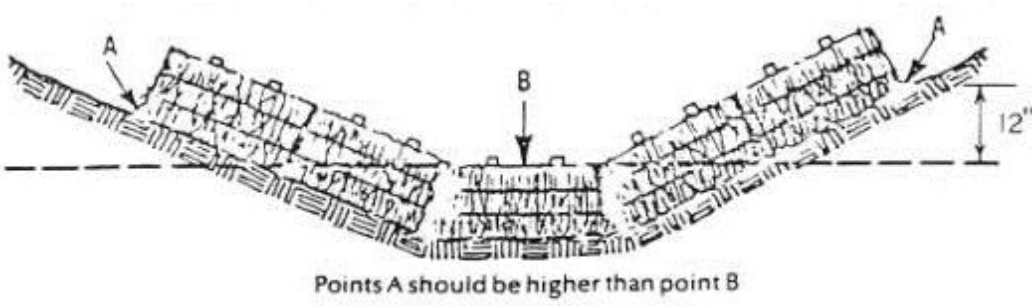
STRAW BALE FILTERS

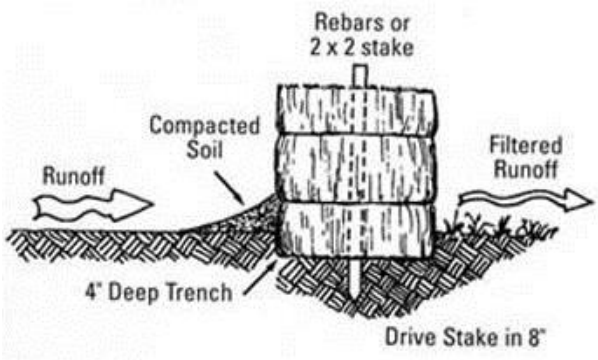
Definition Temporary dams made from straw bales

Details Straw bales work in the following ways:

- Slowing the water to allow sediment to settle out.
- Some filtration of sediment also occurs as run-off passes through the bales.
- Nutrients can be removed from the water by adhering to the straw
- Bacteria use the straw as a carbon source to allow them to consume the nitrogen where bacterial growth is limited by the proportions of carbon and nitrogen in the system.

Application Where there are issues with sediments and excess nitrogen. Where soils are exposed such as with the first flush and after the ground has been worked for a new crop.





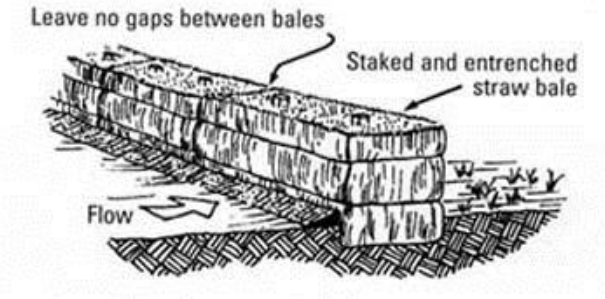


Figure: Strawbale filter installation from www2.dnr.cornell.edu and www.rpitt.eng.ua.edu

NUTRIENT RETENTION

AMENDED SUBSTRATE

Definition	A medium with the ability to remove pollutants (often phosphorous) or alter pH that water is passed over or through for treatment.
Details	Examples include woodchips, lateritic gravel, zeolite, crushed limestone, red mud and red sand. The more of the water in contact with the substrate and the longer the contact period, the greater the treatment potential.
Application	This technique is therefore best where flow is slow and there is easy access to exchange the substrate as it becomes saturated.

VEGETATED DISCHARGE AREAS

Definition	A vegetated area designed to slow the flow of discharged water and trap sediments.
Details	May require silt traps for easy sediment removal. May be constructed with grass buffers or woody vegetation.
Application	Most applicable on minor sections (low risk of flooding) where paddock drains discharge into a drainage easement and there is excessive sediment transport or a significant erosion risk.

SOIL UPTURNING

Definition	Where high PRI (Phosphorous Retention Index) subsoil is mixed into the upper soil layers to provide greater nutrient retention onsite.
Details	Ideally the topsoil should be removed and stockpiled prior to upturning. Should be done in conjunction with grass filter strips or a vegetated discharge area to minimise the risk of erosion and sediment transport.
Application	Applicable where a high PRI subsoil occurs under a low PRI topsoil for example duplex soils where there is sand over clay.

WETLANDS

LARGESCALE WETLAND CREATION

Definition	The creation of large-scale artificial wetlands.
Details	These wetlands can incorporate amended substrates and sediment traps. They can be constructed as an environmental offset for a major project. They also require a large area for installation.
Application	As these can be very expensive to install they are often associated with water reuse schemes or large-scale construction projects and developments.

USE OF EXISTING WETLANDS

Definition	Existing, degraded wetlands can be rehabilitated to provide nutrient stripping. Flows can be redirected through these improved wetlands.
Details	Discharge of drainage water into an existing wetland would need to be approved. Flows would need to be modelled on more major systems to avoid flooding.
Application	It would be easier to take advantage of existing wetlands on low flow sections or where inflows can be controlled.

BIOFILTERS

Definition	Biofiltration is a pollution control technique using living material to capture and biologically degrade pollutants
Details	Biofilters differ from wetlands in that they include some kind of filtration medium.
Application	Treating stormwater runoff

CHANNEL MODIFICATION

CHANNEL BROADENING

Definition Widening the drain instead of deepening to maintain the capacity.

Details This technique allows more of the channel to remain intact and results in greater stability. It also results in slower flows with more of the water in contact with the bed and banks allowing for greater treatment potential.

Application This technique could be applied to any channel that requires an increase in capacity as long as it doesn't result in removal of native vegetation or other vegetated buffers.

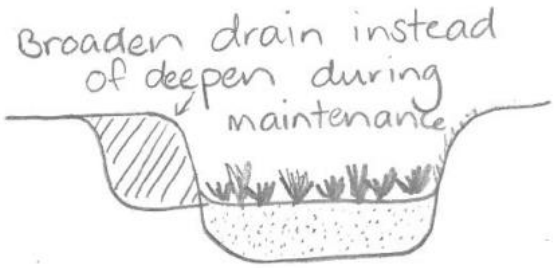


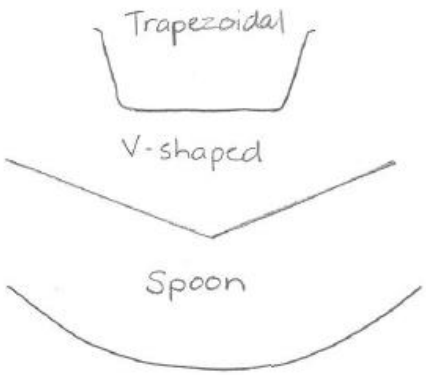
Figure: Channel broadening to increase capacity (Del Marco 2007)

CHANNEL RESHAPING

Definition Altering a small trapezoidal drain to a wide V-shaped or spoon drain.

Details This spreads and slows the flow to allow sediment to drop out and allows more time for nutrients to be removed. The drains should be grassed and managed with grazed for ongoing nutrient removal.

Application This technique is easily applied to paddock drains using a grader or similar.



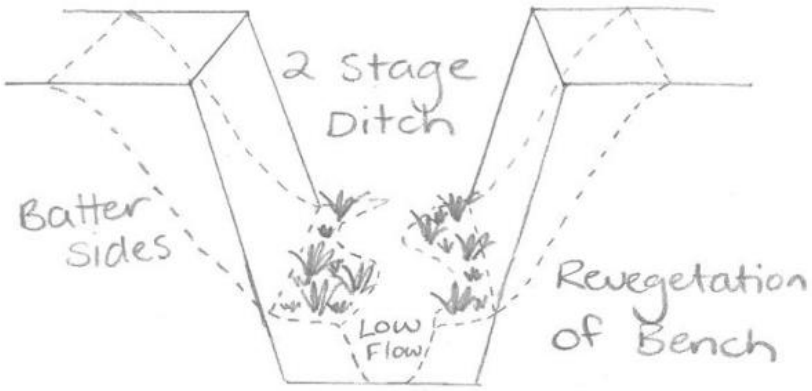
LIVING STREAMS

Definition — A channel with a natural meander.

Details — This can be achieved through the 2 stage ditch with a meandering low flow channel and revegetated bench or realignment of the whole channel to achieve a meander.

Many of the main drains already have a 2 stage ditch forming naturally. If there is adequate flood capacity these low flow meanders could be stabilised with native sedges and rushes and retained rather than removed and straightened during channel maintenance.

Application — Main drains, particularly those running through town centres where social amenity is a consideration.



FARMING PRACTICES

There are many farm management practices that influence the amount of pollution entering the drainage network. These are largely outside the scope of drainage management. It is important however to develop partnerships to encourage sustainable land management and compliment the work in the waterways. Some of these options are outlined below.

OFF STREAM WATER USE

Definition — Water can be harvested during high flow periods for storage and use later.

Details — Nutrients in the water can be recycled if it is used for irrigation.

Application — Where ever the cost and space for storage can be justified.

FARM PLANNING

Definition	The design, operation and management of a farm can have a significant influence on the way it impacts on waterways.
Details	The location and design of infrastructure such as milking sheds, raceways, shearing sheds etc should minimise the discharge of nutrients into waterways. Windbreaks and cover crops can be used to minimise wind erosion. Fertiliser programs should be tailored to the range of conditions across a property to reduce the impacts on the surrounding environment and reduce unnecessary costs. Nutrient budgeting can take that further to ensure that nutrient inputs are providing sufficient outputs in terms of productivity.
Application	All farms in the catchment.

EFFLUENT MANAGEMENT

Definition	Minimise the discharge of pollutants from manures to surface and groundwater.
Details	Some agricultural industries are required to obtain licences to discharge to the environment. These licences provide strict limits on pollution to be adhered to. Some potential point source polluters such as dairies are not licenced and therefore rely on farmer goodwill for the implementation of effluent management programs. Industry groups such as Western Dairy provide information on Best Management Practices for intensive agricultural activities.
Application	Where there are concentrated manures with the potential to pollute groundwater and waterways.

SOIL MANAGEMENT

Definition	Encourage greater soil stability through reduced soil disturbance and increased organic matter.
Details	Techniques such as reduced tillage, green manures and composting protect and enhance the soil. Soil amendments such as clays can be added to increase the ability of the soil to hold nutrients.
Application	Farmland at risk of erosion and/or with poor soils.

SUBSURFACE DRAINAGE

Definition The installation of subsurface channels to encourage drainage.

Details In some circumstances it may be preferable to have subsurface drainage to avoid excess water washing over the soil surface. The majority of the nutrients from fertiliser application are in the top layer of soil. In some circumstances if the water moves through the soil profile rather than over the surface there may be less dissolved solids in the water and a greater opportunity for nutrients to be re-adsorbed before entering the drain. These figures show how a mole drainage tractor attachment works.

Application This technique could be applicable on heavier soils for crops such as potatoes with a low tolerance for waterlogging.

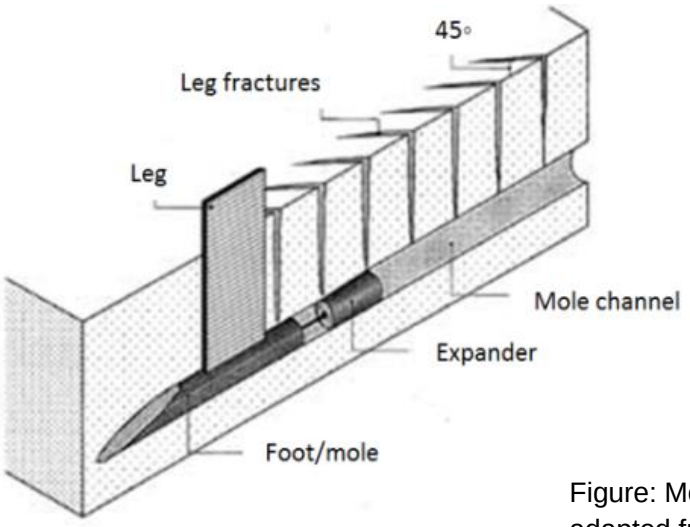


Figure: Mole drain operation adapted from www.icid.org

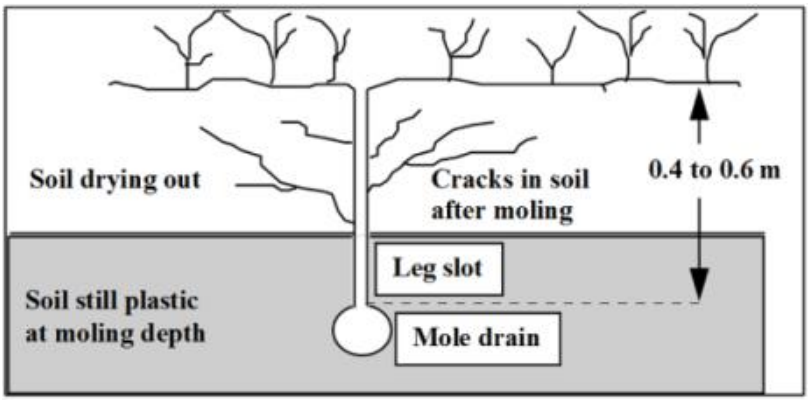


Figure: Impact on soil moisture in heavier soils from www.fertsmart.dairyingfortomorrow.com.au

FERAL ANIMAL CONTROL

Definition	Reducing the populations of feral animals
Details	Rabbits and foxes cause erosion and destabilise the banks by burrowing in them. They often invade the adjacent farmland looking for food. Feral animal control in the drains will improve relations with landholders.
Application	Where ever there are populations of feral animals.

GENERAL APPLICATION GUIDELINES

The attached table in Appendix 2 indicates which management options could be used along each stretch of the Buayanyup drainage network. Some of the options selected may be mutually exclusive but have been selected as appropriate to certain stages of the progression towards a higher state. This should be kept in mind when interpreting the results.

APPENDIX 2 MANAGEMENT OPTIONS

Management Options	Main Drain	Ocean - Caves	Caves - Florence	Florence - 4.5km	4.5km - 6.5km	6.5km - 8km	8km - Hairpin Rd	Hairpin Rd - 9.5km	9.5km - Payne Rd	Payne Rd - G Drain	A Drain	A Drain	A1 Drain	A2 Drain	A3 Drain	A4 Drain
OPEN DRAIN																
Weed management (retain perennial grasses)			✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	✔
Banded drain clearing			✔	✓	✓	✔	✔	✔	✔	✔		✔				✔
Sediment removal			✔	✓	✓	✔	✔	✔	✔	✔		✔	✔	✔	✔	✔
Asset maintenance					✔	✔	✔	✔	✔	✔			✔	✔	✔	✔
Controlled grazing					✔	✔	✔	✔	✔	✔			✔	✔	✔	
Managed instream pasture							✔	✔	✓	✔		✔	✔	✔	✔	✔
Feral animal control		✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	✔
CONTROLLED DRAIN																
Fencing				✔	✔	✔	✔	✔	✔	✔			✓	✔	✔	
Off stream watering points										✔						
Channel broadening			✔									✓				
Channel reshaping			✔									✓				
MANAGED DRAIN																
Grass buffers			✔				✔	✔				✔		✔	✔	✔
Woody buffers			✔		✔	✔	✔	✔		✔		✔		✔	✔	✔
Aquatic plants				✔	✔	✔	✔	✔	✔	✔		✔		✔	✔	✔
Bank stabilisation		✔	✔				✓		✓	✔		✔				✔
Gabions			✓									✔				
Sediment traps			✔	✔	✔	✔	✔	✔	✔	✔		✔		✔	✔	✔
Channel crossings					✔				✔	✔				✔	✔	
Channel stops			✓	✔	✔	✔	✔	✔	✔	✔		✔		✔	✔	✔
Banks & controlled drain outlets			✔	✔	✓	✓				✓		✔		✓		
Drain outlet protection			✔	✓	✔	✔	✔	✔	✔	✔		✔		✔	✔	✔
Strawbale filters								✔	✓	✓		✔		✔	✔	✔
Amended substrate			✓	✓					✔	✔		✔		✔	✔	✔
Vegetated discharge areas																
Soil upturning					✓	✔	✓	✓	✔	✔				✔	✔	
Biofilters			✔	✔		✔	✔	✔	✔	✔		✔		✔	✔	
Off stream water use			✓	✔	✔	✔	✔	✔	✔	✔		✔		✔	✔	
Farm planning					✔	✔	✔	✔	✔	✔			✓	✔	✔	
Effluent management							✔	✔	✔							
Soil management					✔	✔	✔	✔	✔	✔			✓	✔	✔	
Subsurface drainage*																
MANAGED WATERWAY																
Instream rushes & sedges				✔		✔	✔	✔	✔	✔						
Instream woody vegetation				✓		✓	✓		✓	✓						
Revegetation		✔	✔	✔	✔	✔	✔	✔	✔	✔						
Use of existing wetlands				✔		✔	✔	✔	✔	✔						
RESTORED WATERWAY																
Rock riffles			✔			✔										
Large woody debris		✓	✓	✔		✔										
Largescale wetland creation			✓	✓		✓										
Living streams		✔	✔	✔		✔										
Recreational access		✔	✔	✔		✔										
Jetty		✔	✔													

*This technique requires further investigation to determine how and where it would work

✔ = appropriate, ✓ = may be appropriate

Management Options	B Drain	B Drain - B1	B Drain B1 - Ambergate	Ambergate Rd - B3	B Drain B3 - end	B1 -Boallia Rd	B1 Boallia Rd - Payne Rd	B1 Payne Rd - end	B1A Drain	B1B Drain	B1C Drain	B1C1 Drain	B1D vegetated	B1D - end	B1E in road reserve	B1E in paddock
OPEN DRAIN																
Weed management (retain perennial grasses)		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔
Banded drain clearing		✔	✔		✔										✔	
Sediment removal		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔
Asset maintenance			✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔		✔
Controlled grazing			✔	✔	✔	✔	✔	✔	✔	✔	✔			✔		✔
Managed instream pasture		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔			✔		✔
Feral animal control		✔	✔	✔	✔	✔			✔			✔	✔		✔	
CONTROLLED DRAIN																
Fencing		✔	✔	✔		✔		✔	✔	✔	✔			✔		✔
Off stream watering points			✔	✔		✔										
Channel broadening		✔			✔											
Channel reshaping		✔			✔											
MANAGED DRAIN																
Grass buffers		✔	✔	✔		✔	✔	✔						✔		
Woody buffers		✔	✔	✔	✔	✔	✔	✔			✔	✔		✔	✔	✔
Aquatic plants		✔	✔	✔	✔	✔	✔	✔			✔	✔		✔	✔	✔
Bank stabilisation		✔	✔			✔										
Gabions		✔														
Sediment traps		✔	✔	✔	✔	✔	✔	✔				✔		✔	✔	✔
Channel crossings		✔	✔	✔		✔		✔						✔		
Channel stops		✔	✔	✔	✔	✔	✔	✔					✔	✔		✔
Banks & controlled drain outlets		✔	✔	✔		✔										
Drain outlet protection		✔	✔	✔												
Strawbale filters		✔	✔	✔	✔	✔	✔	✔					✔	✔		
Amended substrate		✔	✔	✔	✔	✔	✔	✔						✔		
Vegetated discharge areas		✔	✔	✔		✔	✔	✔	✔					✔		
Soil upturning		✔	✔	✔	✔	✔	✔	✔						✔		
Biofilters		✔	✔	✔	✔	✔	✔	✔						✔		
Off stream water use		✔	✔	✔	✔	✔	✔	✔					✔	✔		
Farm planning		✔	✔	✔	✔	✔	✔	✔					✔	✔		
Effluent management					✔		✔	✔			✔		✔	✔		
Soil management		✔	✔	✔	✔	✔	✔	✔					✔	✔		
Subsurface drainage*																
MANAGED WATERWAY																
Instream rushes & sedges		✔		✔									✔			
Instream woody vegetation																
Revegetation		✔		✔	✔		✔						✔			
Use of existing wetlands		✔		✔				✔								
RESTORED WATERWAY																
Rock riffles		✔														
Large woody debris		✔														
Largescale wetland creation		✔														
Living streams		✔														
Recreational access		✔														
Jetty																

*This technique requires further investigation to determine how and where it would work

✔ = appropriate, ✔ = may be appropriate

Management Options	B1F + B1G	B2 Drain	B3 private land	B3 road reserve	B3A Drain	B4 Drain	C Drain	Start - 3km	3km - Hairpin Rd	Hairpin Rd - end	C1 - 1.5km	C1 1.5km - end	C2 - 1km	C2 1km - end	D Drain	D Drain
OPEN DRAIN																
Weed management (retain perennial grasses)	✔	✔	✔	✔	✔	✔		✔	✔	✔		✔	✔	✔		✔
Banded drain clearing				✔												
Sediment removal	✔	✔		✔												
Asset maintenance	✔		✔		✔				✔			✔	✔	✔		
Controlled grazing	✔	✔	✔		✔			✔	✔	✔		✔	✔	✔		✔
Managed instream pasture	✔	✔	✔		✔			✔	✔	✔		✔	✔	✔		✔
Feral animal control		✔	✔	✔							✔		✔			
CONTROLLED DRAIN																
Fencing	✔	✔						✔	✔	✔	✔	✔	✔	✔		
Off stream watering points																
Channel broadening																
Channel reshaping																
MANAGED DRAIN																
Grass buffers	✔			✔												
Woody buffers	✔	✔		✔	✔	✔		✔	✔	✔	✔	✔		✔		✔
Aquatic plants	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	✔		✔		✔
Bank stabilisation																
Gabions																
Sediment traps		✔		✔					✔	✔	✔	✔	✔	✔		✔
Channel crossings																
Channel stops		✔	✔	✔				✔	✔	✔	✔	✔	✔	✔		✔
Banks & controlled drain outlets																
Drain outlet protection				✔												
Strawbale filters	✔			✔				✔	✔	✔		✔				
Amended substrate				✔				✔	✔	✔		✔				
Vegetated discharge areas									✔	✔		✔				
Soil upturning																
Biofilters				✔							✔	✔				✔
Off stream water use				✔				✔	✔	✔	✔	✔	✔	✔		✔
Farm planning																
Effluent management																
Soil management																
Subsurface drainage*																
MANAGED WATERWAY																
Instream rushes & sedges								✔			✔	✔				✔
Instream woody vegetation																
Revegetation								✔			✔	✔				✔
Use of existing wetlands																
RESTORED WATERWAY																
Rock riffles																
Large woody debris																
Largescale wetland creation																
Living streams																
Recreational access																
Jetty																

*This technique requires further investigation to determine how and where it would work

✔ = appropriate, ✔ = may be appropriate

Management Options	E Drain	E Drain	F Drain	F Drain - 1km	1km - Kaloorup Rd	Kaloorup Rd - end (incl. F2, F2A + F3)	F1 (incl. F1A + F1B)	F1C road reserve	F1C vineyard	G Drain	G Drain - 2.5km	2.5km - 3.5km	3.5km - end	G1 Drain	H Drain	H Drain
OPEN DRAIN																
Weed management (retain perennial grasses)		✔		✔	✔	✔	✔		✔		✔	✔		✔		✔
Banded drain clearing											✔			✔		
Sediment removal						✔	✔		✔		✔	✔		✔		✔
Asset maintenance					✔	✔	✔		✔		✔	✔				✔
Controlled grazing		✔		✔	✔	✔	✔		✔		✔	✔				✔
Managed instream pasture		✔		✔	✔	✔	✔		✔			✔		✔		✔
Feral animal control						✔	✔	✔			✔	✔	✔	✔		✔
CONTROLLED DRAIN																
Fencing					✔	✔	✔				✔	✔	✔			✔
Off stream watering points																
Channel broadening																
Channel reshaping											✔					
MANAGED DRAIN																
Grass buffers						✔	✔		✔		✔	✔				✔
Woody buffers		✔		✔	✔	✔	✔		✔		✔	✔		✔		✔
Aquatic plants		✔		✔	✔	✔	✔		✔		✔	✔				✔
Bank stabilisation											✔	✔				
Gabions											✔					
Sediment traps		✔		✔	✔	✔	✔	✔	✔		✔	✔	✔	✔		✔
Channel crossings						✔	✔				✔	✔				
Channel stops		✔		✔	✔	✔	✔		✔		✔	✔	✔	✔		✔
Banks & controlled drain outlets											✔					✔
Drain outlet protection											✔	✔				✔
Strawbale filters					✔	✔	✔	✔	✔		✔	✔				✔
Amended substrate						✔	✔		✔		✔	✔				✔
Vegetated discharge areas						✔	✔									
Soil upturning						✔	✔				✔	✔				
Biofilters				✔		✔	✔		✔		✔	✔				✔
Off stream water use		✔		✔	✔	✔	✔		✔		✔	✔				✔
Farm planning					✔	✔	✔		✔		✔	✔				✔
Effluent management		✔				✔	✔									
Soil management						✔	✔				✔	✔				✔
Subsurface drainage*																
MANAGED WATERWAY																
Instream rushes & sedges				✔				✔			✔	✔	✔			
Instream woody vegetation											✔	✔	✔			
Revegetation				✔				✔			✔	✔	✔			
Use of existing wetlands											✔		✔			
RESTORED WATERWAY																
Rock riffles																
Large woody debris																
Largescale wetland creation																
Living streams													✔			
Recreational access																
Jetty																

*This technique requires further investigation to determine how and where it would work

✔ = appropriate, ✔ = may be appropriate

APPENDIX 3 RETHINKING DRAINAGE: BUAYANYUP STAKEHOLDER FORUM

Details

A Stakeholder Forum was held on Tuesday 14th July, 2015 for the Buayanyup Drainage Pilot Project. The Forum was held at the Vasse Hall and was facilitated by Tammie Reid from focussed facilitation. A selection of representative landholders and community members were invited to represent the broader stakeholder views. A total of 28 people attended including the facilitators

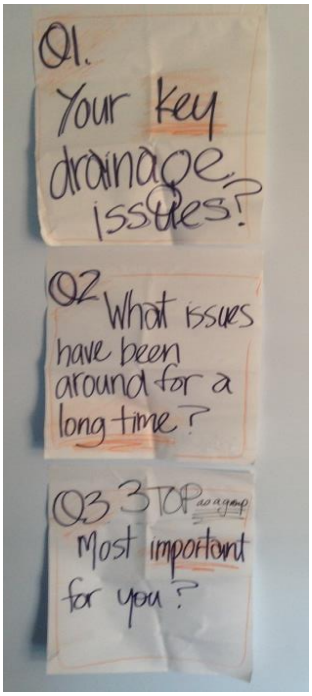
Chris Elliot (CEO, Busselton Water) welcomed everyone, explained Busselton Water's growth plans and set the scene for the workshop sessions. Between the two workshop sessions Joel Hall (Senior Modeller, Department of Water) gave a snapshot of the health of the Buayanyup system based on recent surveys and modelling. Katie Biggs (Environmental Scientist, Busselton Water) gave an overview of the Buayanyup Drainage Pilot Project and how the results of the workshop sessions would be used.

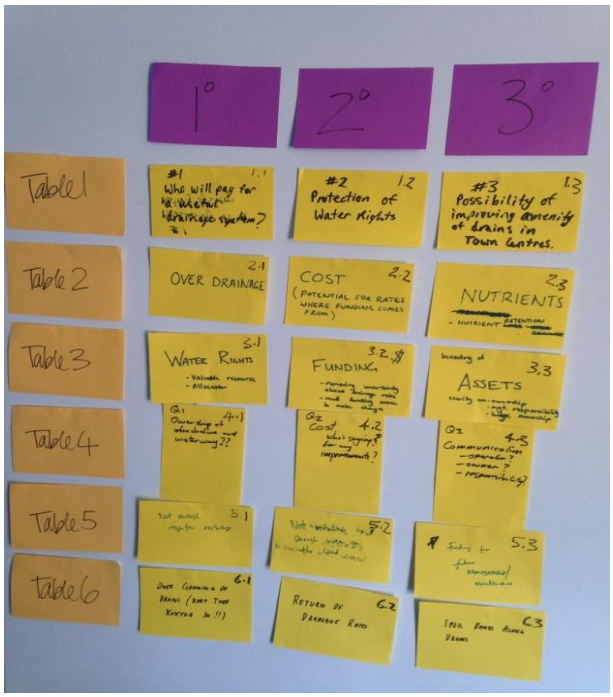
Workshop Session 1: Issues

The first workshop session identified and prioritised the issues faced by the stakeholders. Three questions were put to the participants with the results shown below.

1. What are your key drainage issues?
2. What issues have been around for a long time?
3. Which 3 issues are most important to your group?

	First	Second	Third
Table 1	Who will pay for a useful drainage system?	Protection of water rights	Possibility of improving amenity of drains in town centres
Table 2	Over drainage	Cost (potential for rates where funding comes from)	Nutrients (nutrient retention)
Table 3	Water rights (valuable resource, allocation)	Funding (removing uncertainty about drainage rates & need funding source to make changes)	Assets (clarity on ownership, management responsibility, bridge ownership)
Table 4	Ownership of infrastructure and waterway	Who is paying for any improvements?	Communication – Operator? - Owner? - Responsibility?
Table 5	Not enough aquifer recharge	Not retaining enough water on the land	Funding for future management/maintenance
Table 6	Over-cleaning drains (maintain kikuyu)	Return of drainage rates	Spoil banks along drains





Workshop Session 2: Ideas

The main issues identified through the first workshop session were workshopped to generate ideas for how they could be managed differently into the future.

Amenity - Improving the drains and reducing the nutrients running off the land

Details	Possible Actions	Timeframe		Likelihood of Success		
		Short	Long	H	M	L
Poor amenity	Use 100yr profile for paths, playgrounds and parks					
Poor ecological value/ connections	Use 10yr profile for ecological rehabilitation					
Access to beach from Vasse	Paths to the beach along drain					
Water quality	Plant more riparian vegetation					
Landuse Planning						
Redirect water into Broadwater	Use gates to control flooding around Broadwater					

Overdraining – Retain water on properties, recharge the aquifer

Details	Possible Actions	Timeframe		Likelihood of Success		
		Short	Long	H	M	L
Retain water	Weir, floodgates, locks, turkey nest dams, compensation basins (success depends on cost and management)			X		
Slow water	As above			X		
Infill drains					X	

Communication – Access to information. Landowners' responsibilities and obligations. Who do we speak to about problems? *Also relevant to asset responsibility.

Details	Possible Actions	Timeframe		Likelihood of Success		
		Short	Long	H	M	L
Clarity around ownership and responsibilities	Need access to information on ownership and responsibilities related to drainage assets (Shire database?) with a designated contact person	X				
	Settlement Agents informed and passing on information	X				
Agencies pass buck	Need a central inventory / database with clear information about who is responsible for what	X	X			
	Create a plan for each subcatchment covering all the competing objectives and variety of land uses (urban, hobby farms and intensive agriculture) and produce regular report cards (Gantt chart) to measure progress and success		X			
Drains not maintained						
Dangerous situation exists						
Public Health Bill	Opportunity for drains to be part of CoB Health and Wellbeing Plan as recreation locations.		X			

Funding – How will drainage be paid for (improvements, management, maintenance)? Will / should beneficiaries pay?

Details	Possible Actions	Timeframe		Likelihood of Success		
		Short	Long	H	M	L
Assets	$40 million break-up of the assets					
	Fixed assets – maintenance of weirs/floodgates					
	Check inventory of assets -put costs alongside each asset					
Who will pay?	Produce funding model -part of communication					

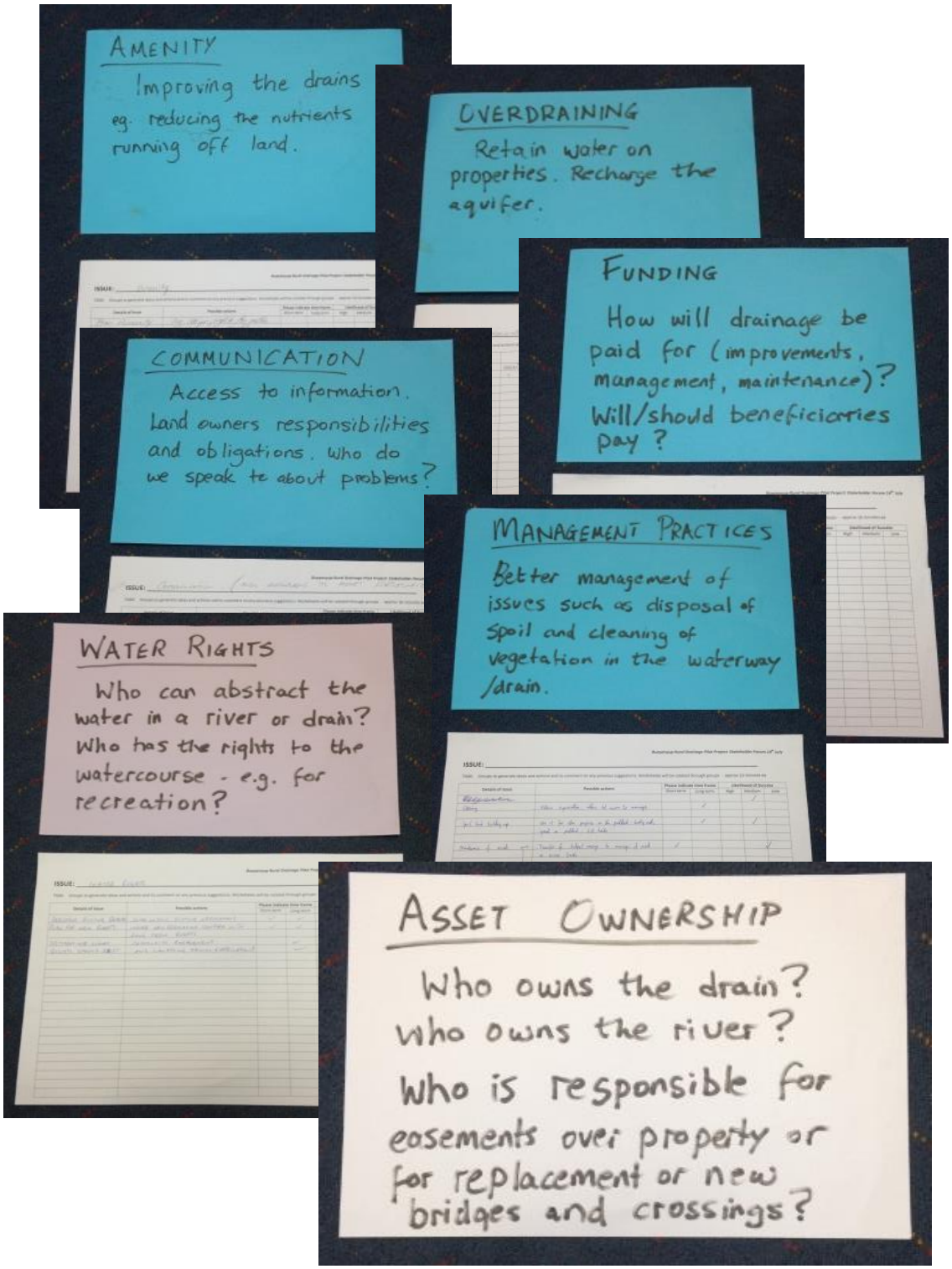
Management Practices – Better management of issues such as disposal of spoil and cleaning of vegetation in the waterway/drain.

Details	Possible Actions	Timeframe		Likelihood of Success		
		Short	Long	H	M	L
Cleaning	Allow regeneration, allow lot owner to manage		X		X	
Spoil bank building up	Use spoil for other purposes on the paddock – levelling out, spread on paddock, fill holes		X		X	
Maintenance of assets	Transfer of bridges/crossings to manager of road or access track	X			X	X
	Clarity of standard to which some assets need to be maintained (e.g. cattle stops)	X		X		
Liability of access to drain	Check liability status afforded to service provider, landowner in differing situations drains on freehold or easement)	X			X	
Keeping water on land	Should this be landholder managed and if so how do you avoid adversely affecting upstream properties if it is not well managed?					

Water Rights – Who can abstract the water in a river or drain? Who has the rights to the watercourse – e.g. for recreation?

Details	Possible Actions	Timeframe		Likelihood of Success		
		Short	Long	H	M	L
Preserve existing rights	Work within existing legislations	X	X	X		
Plan for new rights	Ensure new regulations conform with long term rights	X	X	X		
Determine what rights should exist	Community engagement and canvassing opinions and applications		X	X		

Asset Ownership – Who owns the drain? Who owns the river? Who is responsible for easements over property or for replacement or new bridges and crossings? *No-one worked on this topic.



Message Board

A message board was set up to capture individual thinking and ideas that weren't captured through the other processes. Two comments were recorded on this board

1. Water Rights Protection
2. Not enough contribution within their own property to retention and water quality

The management and protection of water rights will be managed by the Department of Water. The level of management varies across different catchments. The level of management can be increased by proclaiming a catchment under the Rights in Water and Irrigation Act, 1914.

The retention of nutrients on farmland is addressed through programs run by the Department of Agriculture and Food WA, South West Catchments Council, GeoCatch and industry groups such as Western Dairy. This is outside the scope of the drainage manager at this stage, however it is likely that in the future there will be strong collaboration between the drainage operators, landholders and these groups to improve water quality outcomes.

Feedback

The feedback from the forum was overwhelmingly positive. Many participants stayed beyond the finishing time to continue discussing ideas. The thermometers below were used to anonymously measure how participants felt about the workshop and the project in general.