BEST PRACTICE GUIDELINES FOR IMPROVED WETLAND AND RIVER MANAGEMENT ON DAIRY FARMS IN SOUTH AFRICA

THE IMPLEMENTATION OF SECTOR-SPECIFIC BUFFER ZONES AND WETLAND ENHANCEMENT

confluent
aquatic consulting & research

Milk South Africa
Promoting the South African Dairy industry

WWF

Project lead organisation:

Institute of Natural Resources

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Executive Summary

This guideline aims to support sustainability in the dairy sector through provision of best practice guidelines for improved management of water resources using aquatic impact buffer zones and enhanced wetlands.

Dairy farming in South Africa is a major contributor to the agricultural sector in terms of meeting nutritional demands and contributing to the economic development and sustainability of the country. South Africa's average annual rainfall is relatively low (about half of the global average), with the result that dairy farming (a high water use industry) is concentrated in areas of higher rainfall in the southern and eastern provinces. Irrigated pastures for dairy production require high volumes of water abstraction and storage in dams resulting in seriously reduced flows in surface waters. Unfortunately, dairy farming is also a contributing factor to declining surface and groundwater quality. Furthermore, pasture layout generally aims for maximal productivity with minimal consideration for riparian / wetland habitat or vegetated buffers. This not only impacts on water quality, but on habitat connectivity for biodiversity. It can also create direct costs to the farming operation through factors such as dam eutrophication with associated nuisance algal blooms, increased flood risk and damage due to wetland loss, and siltation of dams requiring ongoing costly maintenance.

There is increasing pressure on business to acknowledge the scarcity of natural resources and to move towards a more equitable economy where risk and uncertainties are buffered by improved resilience of the socio-ecological frameworks within which we all function.

Activities such as water abstraction, fertilization, pasture management regimes, wastewater disposal, and grazing cattle can impact aquatic ecosystems. These actions may manifest in eutrophication due to nutrient inputs, associated blooms of algae or macrophytes, human health issues related to pathogenic microbes, habitat degradation, siltation and erosion and impacts to biodiversity. Aquatic impact buffers are one measure that can contribute to mitigating several of these issues. Buffers are defined as a strip of land with a use, function or zoning specifically designed to protect one area of land against impacts from another. In the case of dairy farms, buffers provide a long list of benefits: Maintenance of channel stability; control of microclimate and water temperature; stormwater and flood attenuation; provision of terrestrial and aquatic wildlife habitat; sediment, nutrient, pathogen and toxics removal; visual screening; and habitat connectivity. However, buffer zones offer limited protection from point sources of pollution which should preferably be managed at source.

A range of best practice actions which compliment buffer zones for the protection of watercourses in South Africa are described. These include fencing streams to exclude cattle, improvements to pivot and cattle crossings of watercourses, limiting erosion and runoff, control of effluent applications, nutrient management, invasive alien vegetation management, water conservation and demand management, and the use of vegetated buffer strips.

Legislation with respect to regulations around activities in and near watercourses was reviewed. While many actions to improve the condition of watercourses may require an authorisation, there are a range of actions which may be undertaken without authorisation. One option is to compile and authorise a rehabilitation or maintenance management plan to guide improvements to watercourses across the

entire property without exposing the landowner to liability. An alternative is to register a project with Landcare using the Environmental Management Programme authorised by the Department of Forestry Fisheries and Environment and the Department of Water Affairs, which provides a powerful mechanism for undertaking maintenance and rehabilitation within watercourses under an existing authorisation. This option should be explored with the Department of Agriculture's LandCare Programme to determine whether the required management actions qualify for this pre-existing approval.

The Buffer Tool developed by Macfarlane and Bredin (2017) is spreadsheet-based and helps users determine suitable buffer requirements (widths). Alternative versions were developed to determine buffers for rivers, wetlands and estuaries and include a rapid desktop tool, and a more comprehensive site-based tool. This method is widely applied by aquatic consultants in South Africa and is supported by the Department of Water Affairs as a complimentary tool for the assessment and management of aquatic ecosystems. The existing tool was developed for a wide range of sectors (e.g. mining, housing, energy etc.) and this guideline provides a refinement of the tool for the dairy sector.

The buffer guideline is presented using two case study dairy farms; one in the southern Cape and the other in KwaZulu-Natal. Each step in the process to complete the Buffer Tool is explained and applied to the case study farms by way of example. Application of the site-specific Buffer Tool requires desktop and field assessments. The inherent environmental attributes (e.g. soils, rainfall, slopes etc.) of each site were listed, and mapped watercourses were ground-truthed during site visits. The ecological condition and sensitivity of watercourses was determined considering existing impacts to watercourses on both farms. Discussions were held with farm management to determine where management actions were mitigating ecological threats versus increasing threats to watercourses. Dairy-sector specific generalised and region-specific threats were identified and refined. Thus, ensuring the full range of interconnected land uses that potentially occur on dairy farms were accounted for when riparian buffer widths were determined. Buffer zones offer limited protection in several scenarios including poor water quality from upstream users, watercourses under pivots, and linear agricultural drains. Recommendations to address these impacts are made through the creation and / or enhancement of wetlands.

Results of the Buffer Tool were presented under a low mitigation and high mitigation scenario, assuming minimal or maximal application of best practice guidelines respectively. Under the low mitigation scenario, the calculated buffer widths ranged between 18 - 21 m on the southern Cape farm and between 20 - 30 m on the KZN farm. In the high mitigation scenario, the buffer widths ranged between 5 – 10 m and 5 – 12 m respectively on the southern Cape and KZN farms. Buffers intersected with existing pasture and semi-natural areas.

The cost implications of implementing buffers including the different mitigation scenarios was further explored in a Cost Assessment. The assessment considered three cost categories: establishment costs; maintenance costs and opportunity costs. This determined that the main cost associated with establishing buffer zones is the income forgone from reduced pasture area which is seen as a recurring annual cost (opportunity cost). The total respective area of pasture conversion under low and high mitigation for the southern Cape farm was 39.3 ha and 16.91 ha, compared to the KZN farm with 26.12

and 11.28 ha. In both cases this was approximately 5% of pasture area reduced to around 2% under the high mitigation scenario.

Along with the guidelines for implementing riparian and wetland buffers, this report provides a range of practical solutions aimed at improving aquatic ecosystem health on dairy farms. It is unlikely that dairy management teams could implement all measures at once, as substantial efforts will be required. Rather, it is recommended that farm managers prioritise activities most relevant to their situation, needs and concerns and consult aquatic scientists for assistance if needed. Land Care in the Western Cape can also be consulted for assistance, as well as various local branches of the Department of Agriculture who can assist with developing a plan. Implementation of the plan can then focus on various goals over the short- to long-term. It is hoped that milk buyers and dairy-specific sustainability trackers consider the inclusion of some of these interventions in sustainability monitoring to encourage a more widespread uptake across the sector.

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Acronyms

CBA	Critical Biodiversity Area
COD	Chemical Oxygen Demand
DFFE	Department of Forestry, Fisheries and the Environment
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
EI	Ecological Importance
EMPr	Environmental Management Programme
ES	Ecological Sensitivity
EKZNW	Ezemvelo KZN Wildlife
FBIS	Freshwater Biodiversity Information System
GA	General Authorisation
GIS	Geographical Information Systems
GPS	Global Positioning System
HGM	Hydrogeomorphic
INR	Institute of Natural Resources NPC
IUCN	International Union for Conservation of Nature
KZN	KwaZulu-Natal
MAP	Mean Annual Precipitation
MilkSA	Milk South Africa
MPO	Milk Producers Organisation
MSP	Multi-Species Perennial Pastures
NEMA	National Environmental Management Act
NFEPA	National Freshwater Ecosystem Priority Areas
NWA	National Water Act (Act 36 of 1998)
NWM5	National Wetland Map Version 5
PES	Present Ecological State
R&D	Research and Development
RQO	Resource Quality Objectives
SACNASP	South African Council of Natural Science Professionals
SANParks	South African National Parks
SQR	Sub-Quaternary Catchment Reach
TEC	Target Ecological Category
TN	Total Nitrogen
TP	Total Phosphate
VSD	Variable Speed Drive
WC	Western Cape
WMA	Water Management Area
WRC	Water Research Commission
WUL(A)	Water Use Licence (Application)
WWF-SA	World Wildlife Fund - South Africa

1 Introduction

The demands of human populations globally continue to significantly impact natural resources and food security in particular (Visser *et al*., 2020). In South Africa, the current human population of approximately 60,14 million people (Statistics South Africa, 2021) is estimated to increase to 72.8 million people by the year 2050 (United Nations, 2017). National nutritional demands, such as the demand for animal protein, are likely to follow a similar trend.

Dairy farming in South Africa is a major contributor to the agricultural sector in terms of meeting nutritional demands and contributing to the economic development and sustainability of the country (Esterhuizen and Fossey, 2015). There are close to 14 million cattle of which 1.2 million are in dairy herds. Job creation is significant, and the sector provides around 26 000 jobs on approximately 1 200 farms (DAFF, 2019; Visser *et al*., 2020). This number does not account for the number of dependents reliant on each person employed or the jobs created through the supply chain. The number of people dependent on the dairy sector is therefore much higher than this figure.

Water is a fundamental resource in all stages of the dairy industry, including livestock watering, irrigation of pastures, cleaning, sanitisation, heating, cooling, and floor washing (Esterhuizen and Fossey, 2015). Most dairy farming areas are concentrated in the south and southwest coastal provinces where pasture-based grazing systems are supported by higher rainfalls. The agricultural sector is by far the largest water user in South Africa, using 61% of the country's water supplies (Figure 1). South Africa's average annual rainfall is 450 mm per year (mm/a) compared to the global average of 860 mm/a meaning that in global terms, South Africa's water resources are scarce and extremely limited. Most available water resources have already been fully exploited with remaining water only available at significant social, economic, and environmental cost. It is therefore imperative that all water users aim to improve Water Conservation and Water Demand Management which will play an increasingly crucial role in social equity, economic development and environmental sustainability (Draft NWRS3, 2022).

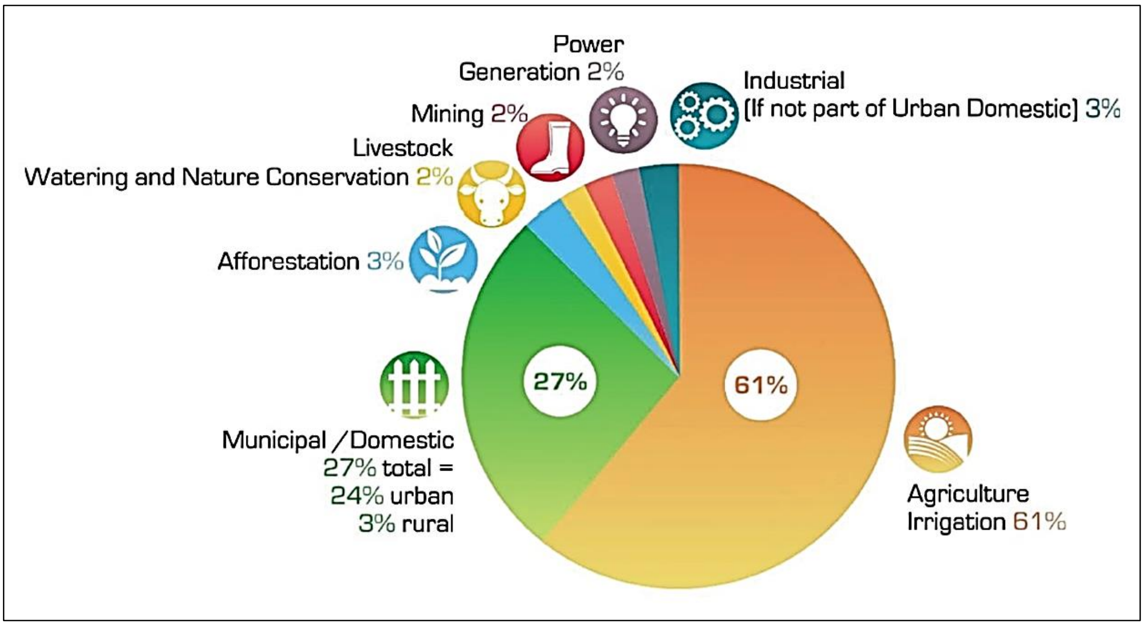


Figure 1. Water resource use by sector in South Africa (Draft National Water Resource Strategy 3, 2022)

Dairy farming is a contributor to declining surface water and groundwater quality (Esterhuizen and Fossey, 2015). Irrigated pastures for dairy production require high volumes of water abstraction and storage in dams resulting in serious reductions in flows in surface water resources. At present, there are very few examples of water releases to maintain the Ecological Reserve in the agricultural sector because the water use is historical and classified as an Existing Lawful Use in terms of the National Water Act. There is a growing focus on incorporating the Ecological Water Release (EWR) into the design of new dams (SANCOLD, 2022) and existing dams can have a siphon system to effect release of the reserve where no outlet is built into the impoundment.

The impact of reduced surface flows due to abstraction by dairy farms is further exacerbated by impacts to water quality, which include: i) nutrient enrichment due to fertilizer or slurry carried in surface runoff, ii) sedimentation of streams through livestock trampling and pasture rotation and management (e.g. planting maize which has poor surface water interception compared to pasture or cultivating steep slopes), and iii) *E. coli* contamination through the direct deposition of faecal matter into streams (Bewsell *et al.,* 2007; Aarons and Gourley, 2013). This combination of impacts can seriously impact biodiversity, with reduced presence and abundance of sensitive species and major shifts in species assemblages towards undesirable states where pests such as blackflies and midges are dominant, and eutrophication (nutrient enrichment) promotes dominance of nuisance (sometimes toxic) algal or macrophyte blooms.

This guideline aims to provide the dairy sector and supporting consultants with the information and tools necessary to improve the management of wetlands and rivers using buffer zones and enhanced wetlands. Dairy farming on pasture-based systems produces a range of diffuse pollution sources, the impacts of which can be mitigated at least in part through implementing vegetated buffer zones. This is part of the strategy already adopted and widely implemented as Best Management Practice in countries such as New Zealand. The shift is towards more sustainable approaches to dairy farming and includes practices such as stock exclusion through stream fencing, controlling manure and nutrient (fertilizer) applications, limiting soil compaction and erosion, and reducing slurry pond effluent discharge. This guideline is industry-driven, sector-specific and has been informed by case studies of large pasture-based dairy farms in KwaZulu-Natal and the Western Cape. Additional motivation for the implementation of these guidelines relates to conditions attached to the lawful use of water, whether that be in the form of an Existing Lawful Use or a Water Use License. In either case, the water use must be sustainable if the continued use is to be supported.

1.1 Purpose of the guidelines

This guideline aims to support sustainability in the dairy sector by providing best practice guidelines for improved management of water resources using riparian buffer zones and enhanced wetlands.

This guideline is for dairy farm owners and managers, farm study groups, milk buyers, agricultural and environmental researchers, dairy business consultants, sustainability practitioners, and aquatic specialists.

This guide describes what good environmental management looks like on a dairy farm based on results of the two case studies, engagement with sector experts with a range of backgrounds (regulation, operational, soils, pasture, sustainability) through two engagement sessions, and a broad literature review. The emphasis throughout relates to actions that influence aquatic ecosystems and aquatic impact buffer zones. The reader should easily identify practices on farm that support sustainable management of water resources, versus those that do not. Implementing good environmental management practices is not only efficient, it minimises business risk and reduces environmental impact.

This guideline was primarily informed by two case studies which provided practical guidance. This also represents a limitation of the guideline as it cannot be considered representative of the entire dairy sector. Furthermore, dairy farming is a complex business with a multitude of different management practices that vary by region, by season, by herd size and by management approach. While every attempt was made to consult with dairy sector professionals through various stakeholder engagements, it is feasible that management practices affecting water resources (both positively and negatively) could have been overlooked.

Working through this guide aims to empower those involved with dairy farm operations with the knowledge required to improve riparian zones and buffers, while focussing on sustainable pasture management practices aimed at reducing impacts to water resources. Farms in question may not meet all the practices today, but by implementing a plan with realistic timeframes and prioritised interventions sustainable management of water resources is achievable.

1.2 Introduction to the Buffer Tool

The Buffer Tool developed by Macfarlane and Bredin (2017) was applied to each of two case study farms and forms the basis of the guideline presented. The Buffer Tool is spreadsheet-based and helps users determine suitable buffer requirements (widths). Alternative versions were developed to determine buffers for rivers, wetlands and estuaries and include a rapid desktop tool, and a more comprehensive site-based tool. This method is widely applied by consultants and researchers in the field of aquatic science in South Africa and is supported by the Department of Water Affairs as a complimentary tool for the assessment and management of aquatic ecosystems. The existing tool was developed for a wide range of sectors (e.g. mining, housing, energy etc.) and this guideline provides a refinement of the tool for the dairy sector.

1.3 Sustainability of Dairy Production in South Africa

The dairy industry in South Africa (SA) is signatory to the FAO/IDF Dairy Declaration of Rotterdam which endorses the UN 2030 Agenda for Sustainable Development and guides sustainable development from an environmental, social, economic and health perspective. The SA industry is also a member of the Dairy Sustainability Framework (DSF) whose vision is aligned with the Rotterdam Declaration and provides 11 sustainability criteria, including water. Each criterion has a goal, and for water this is: “Water availability, as well as water quality, is managed responsibly throughout the dairy value chain”. Biodiversity is also a listed criteria where the goal is: “Direct and indirect biodiversity risks and opportunities are understood, and strategies to maintain or enhance it are established” (Milk SA, 2020).

The importance of responsible management of water has been recognised by the dairy sector in South Africa through the following actions. The Milk Producers Organisation (MPO) in collaboration with WWF-SA have introduced a water stewardship program to encourage innovative initiatives in water management, ecosystem protection, recycling, and effluent treatment in factories. Following from this, the current project funded by Milk SA aims to contribute to the sustainability of the dairy sector by developing best practice guidelines for improved wetland and river management through the implementation of sector-specific buffer zones, a core focus area in the strategy to improve sustainability of the sector in SA (Milk SA, 2020; Figure 2).

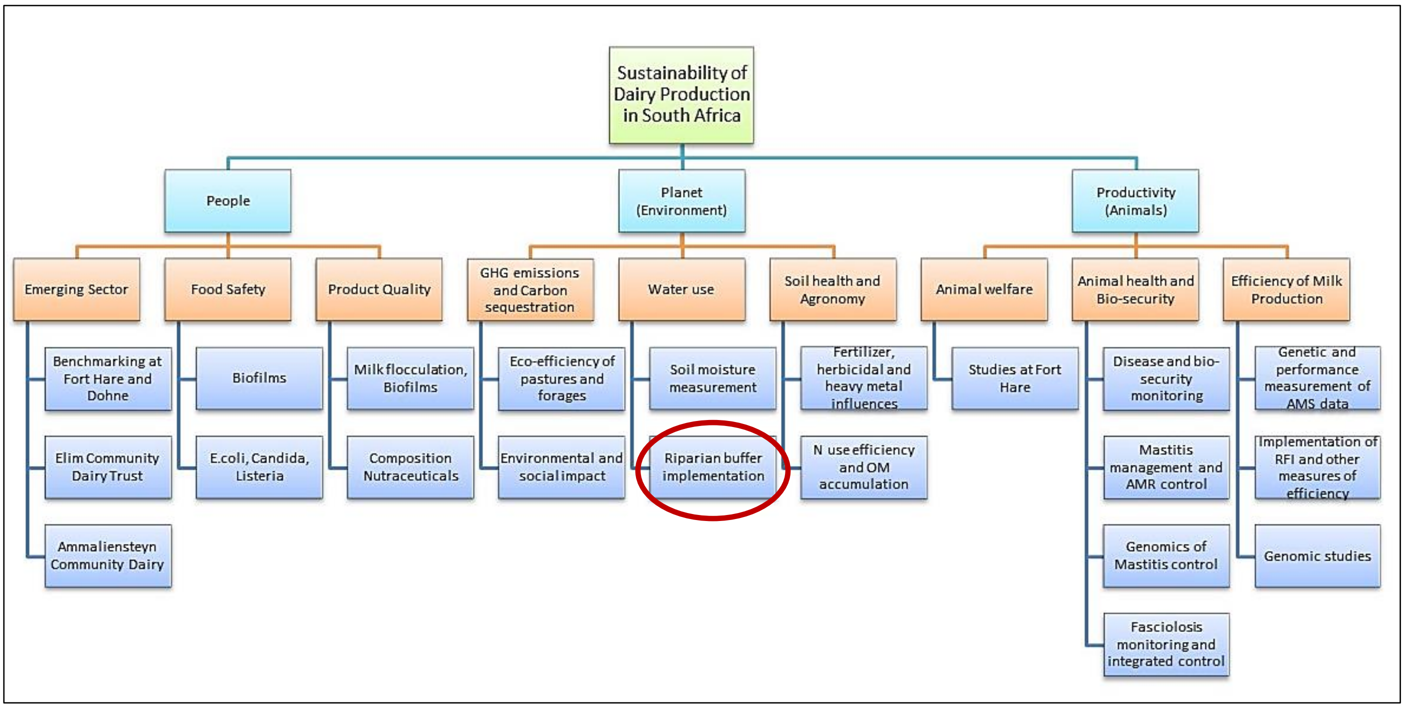


Figure 2. Sustainability of dairy production in South Africa (Milk SA, 2020)

While the focus of this guideline is sustainability from the perspective of water resources, it is necessary to consider the economic constraints under which dairy farming operates in South Africa. Recent global events such as the Covid-19 pandemic, the Russian war in Ukraine, and global supply chain interruption have created external shocks (MPO Pointer, 2022), while South Africa has had a series of internal shocks such as prolonged load-shedding and social unrest during the riots in KwaZulu-Natal. These issues are not subject to extensive review in this document and are by no means unique in affecting the dairy sector alone, but some of the recent challenges affecting profitability of dairy farmers are provided for context:

- Inadequate energy supply (load-shedding)
- Increasing fuel costs
- Soaring fertiliser costs
- Increasing inflation rates
- Comparatively low milk prices

These challenges directly affect profitability and can drive short-term decisions which impact negatively on environmental sustainability. Such decisions include increasing irrigation with slurry to reduce fertiliser costs or reducing investment in actions such as alien vegetation clearing. This period of uncertainty is likely to continue for the foreseeable future, added to which are extreme weather events which can result in production shocks causing losses. Climate change affects the certainty of water supply and can manifest in high costs as droughts require expensive food imports for cows and more frequent floods result in damage to infrastructure. In this sense, environmental and business sustainability are closely linked. The impacts of drought and flooding can be mitigated to an extent by the implementation of aquatic impact buffers which attenuate floodwaters and stabilise riverbanks, protecting soil from erosion. Wetlands act as a sponge in the landscape by absorbing water during rainfall and slowly releasing it during droughts. As such they are often associated with base-flow maintenance of flowing watercourses and improve prospects for flow maintenance during dry weather.

Sustainability makes good business sense, and we're all on the same team at the end of the day. That's the truth about the human condition.
Paul Polman, former CEO of Unilever.

Business is increasingly expected to take on additional roles and responsibility that promote sustainable development including protection of the environment and social responsibility (Haywood *et al.,* 2010). Numerous factors are driving this responsibility and are directly relevant to the dairy sector in South Africa (Table 1).

Table 1. Factors driving increasing responsibilities of businesses, including dairy farms.

Force / Factor	**Comment**
Lack of capacity or will within government to protect environmental goods and services or to provide social upliftment.	It is now widely recognised that to meet global goals of sustainable development, private sector actions must supersede those of the public sector.
Rapidly deteriorating natural and social environments that are reaching critical thresholds beyond which it is not known how businesses will be required to operate.	• Businesses now make decisions in the context of extreme deficiencies of natural resources upon which they depend, forcing a re-think of the way in which they operate within the environment. • Operating in the neoclassical economic model where profitability is the ultimate goal, scarcities in natural resources are not accounted for, and the environment is considered merely the provider of production inputs and a sink for wastes is no longer feasible. The economic system must be transformed towards one that is sustainable, equitable, and operates within planetary boundaries. • Businesses must recognise 'fundamental uncertainty' where the probabilities of possible outcomes cannot be predicted. These are properties of complex socio-ecological ecosystems in which businesses are

	embedded. This requires a different approach with different decision-making tools.
Increasing awareness of the public of environmental and social problems with pressure for green and socially responsible products and processes.	The rising popularity of plant-based diets or recognition of social misconduct in the supply chain such as child labour are examples of this increased awareness.
Tighter controls on environmental and social standards being imposed on business processes which are internationally sanctioned and enforced.	Compliance of companies and their supply chain to eco-labels to obtain access to international markets for instance.
Availability of technologies that improve efficiency and product quality at lower cost.	The above forces imply a greater demand for technology that can buffer business which may be hampered by the inability to supply such technology to meet these demands.

(Source: adapted from Munster and Lochner, 2006)

Extreme climate events, outbreaks of disease and economic downturns have always been part of the landscape affecting agricultural enterprise and represent the fundamental uncertainty referred to in

Table 1. While the knee-jerk reaction to such events may be to cut back on investments in environmental sustainability, sustained effort to maintain the ecological services provided by healthy, functioning ecosystems are worthwhile in the long-term. For instance, large, mature stands of alien trees are not only a fire risk, but extract high volumes of groundwater, which would otherwise contribute towards sustaining streamflow and groundwater recharge during low flow or drought periods (Le Maitre *et al*., 2016). Well maintained wetlands can act as a biological filter and sponge as many such wetlands absorb and slowly release water downstream, clearing water of sediment and other pollutants, maintaining stream flow and reducing the impacts of flooding. Watercourses are an intrinsic element of the natural resource base upon which the dairy farm is built. It is therefore imperative to preserve and maintain this base to support business and environmental sustainability. Investing in water resource protection and preservation can only improve the resilience of these systems, and the resilience of the business which depends on them in turn.

The concept of sustainable development was first defined by the World Commission on Environment and Development (WCED, 1987) and offered the view that environmental protection and economic development could be opposite sides of the same coin. Since then, several global bodies representing business interests have been formed and offered a range of definitions of sustainable development. These definitions generally state that sustainable development should meet the needs of the present without compromising the ability of future generations to meet their own needs (Haywood et al., 2010).

Principles of the National Water Act of South Africa (Act No. 36 of 1998) that guide the protection, use, development, conservation, management, and control of water resources are based on **sustainability**, **equity** and **efficiency**, described in the Guide to the Water Act as follows:

Sustainability means promoting social and economic development and at the same time ensuring that the environment is protected both now and for the future. The environment needs to be protected because it is where water comes from. If there is a good balance between using and protecting water resources, then current **and future** water needs can be met.	**Equity** means that everyone must have access to water and to the benefits of using water. Decisions to allocate water must be equitable (fair) to all people.	**Efficiency** means that water should not be wasted. Water must be used to the best possible social and economic advantage.

Sustainable management of water on dairy farms must consider both the *quantity* and *quality* of affected water resources, and how these factors interact to create negative impacts to aquatic ecosystems, downstream water users, and water resources on farm. Current industry-driven initiatives to encourage sustainability on dairy farms in South Africa tend to focus on water use efficiency (ie. irrigation and wastewater re-use) as opposed to aquatic ecosystem health. The relationship between business and environmental sustainability was the subject of a review of 62 dairy farms subscribed to the Trace & Save sustainability assessment platform (http://traceandsave.com). The review reported that lower environmental impacts were associated with higher profitability (Trace & Save, 2020). However accurate water use figures could not be provided by subscribing farmers, and this aspect was therefore excluded from the report. This reflects a widespread issue that water use (abstraction) is not metered or measured throughout the agricultural sector. As you cannot manage what you cannot measure, this represents a significant challenge to more efficient water use in terms of conservation and demand management.

It also reflects the poor conception and implementation of truly proactive and sustainable methods to improve the state of aquatic ecosystems on dairy farms in South Africa. The concept of regenerative agriculture has made positive inroads to more sustainable management of soil such as increasing soil carbon, minimum tillage, and reducing fertiliser inputs. These methods also reduce impacts to watercourses such as sedimentation and nutrient enrichment. Direct interventions aimed at improving water quality and / or quantity in watercourses are limited in contrast.

This situation may partially be driven by current legislation. Water resources in the agricultural sector were very nearly fully exploited at the time when the National Water Act (NWA) was enacted in 1998. At that time, the concept of sustainable development was in its infancy, and water resource utilisation had taken a maximum use approach with low regard for ecological structure or function in aquatic ecosystems. Riparian buffer zones as conserved areas that could protect watercourses was a concept barely conceived at that time. To preserve food security and stability in the agricultural sector, the NWA permitted all lawful water use occurring at that time (abstraction and storage) to continue under the auspice of Existing Lawful Use (ELU) which allows the *status quo* to continue as it did in 1998 in the present day. Most ELUs would not be permitted under current legislation as they make no provision for the ecological reserve and do not consider aspects such as fish migration, pollution prevention, wetland protection or riparian buffers. In many ways current legislation actually makes it more difficult for a farm owner to implement positive changes to riparian zones and buffers in existing pastures than leaving them as they are. In contrast most new activities require some form of environmental authorisation. It is also possible that the Competent Authority can request a license application for water use including the management of riparian zones and attach conditions to Existing Lawful Use of water.

We cannot however allow these challenges to deter us from taking proactive steps to protect water resources, as we are mutually dependent on them, and their improved resilience can only benefit the farm owner in the long run.

> *"Given current ecological and social circumstances, merely eliminating further negative impacts is not enough. Eliminating overspending does not save us from debt any more than lessening destruction to a battered house yields a decent place to live*."
> Maggs & Robinson (2016)

As water is a shared and highly connected resource, isolated attempts at improving aspects of aquatic ecosystems can have limited success. The sustainability of efforts such as controlling alien vegetation in catchments, improving flows through better wetland management, and considering the ecological reserve through water releases will be more successful if farmers form partnerships and collaborate. The formation of formalised Water User Associations is encouraged in this regard. Isolated efforts must not be ignored however, as the cumulative impacts of not doing anything are significant. By getting started on improving riparian buffers for instance, an example is set, and standards are raised among neighbours and peers.

1.4 Dairy-specific impacts to aquatic ecosystems

1.4.1 Water Quality

This section considers the generalised threats posed by pasture-based dairy farming to water quality, both to surface water and groundwater. Pasture-based farming is more likely to have widespread impacts to aquatic systems than cows raised on a total mixed ration (TMR) and fed in a confined area. The latter may present a more concentrated pollution risk, while pasture-based systems tend to have diffuse (dispersed) impacts.

A clear understanding of the impacts affecting aquatic ecosystem health, better informs actions that can be taken to reduce these impacts. Direct impacts resulting from management actions can combine and have indirect effects on aspects of aquatic ecosystem health (Figure 3). These impacts can be monitored as indicators of stream health, and many can be improved through the implementation of riparian buffer zones.

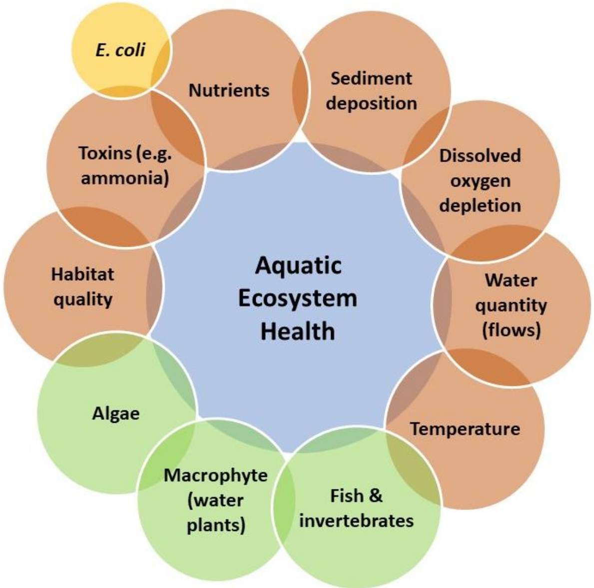


Figure 3. Factors that impact water quality and aquatic ecosystem health directly (brown) and indirectly (green) through actions on farm. *E. coli* directly affects human and animal health (Adapted from Dairy NZ).

As water is a fundamental resource upon which dairy farming is dependent, any impact which affects water quality, has the potential to impact farm efficiency and productivity. This could be experienced directly on farm, or by neighbouring farmers and other water users.

Eutrophication (nutrient enrichment) of water resources is a serious threat to the sustainable use of water resources. This is especially relevant in South Africa where water supplies are limited by low rainfall and periodic drought, and poor water quality can render remaining water resources unsuitable for use. Eutrophication causes excessive growth of nuisance algae or aquatic plants (macrophytes) which are often invasive species (e.g. water hyacinth or Kariba weed) resulting in a cascade of impacts affecting ecosystem health including fish die-offs (Figure 4). Blooms of cyanobacteria (blue-green algae) can also occur which potentially produce toxins harmful for human and livestock health. Eutrophication impacts water chemistry through oxygen depletion and elevated pH, two parameters which strongly influence the speciation and bioavailability of a wide range of other chemical constituents. As eutrophication stimulates high productivity at the base of the food web (primary producers) and promotes conditions that can result in the die-off of more sensitive species, food webs and species interactions can be permanently altered. High inputs of organic matter associated with slurry overflows for instance, can exacerbate the process by increasing the biological oxygen demand and further reducing oxygen levels.

Once a waterbody such as a dam or lake has been enriched with nutrients, the cycle of uptake and release by aquatic macrophytes or algae is very difficult to break. Nutrients are retained in the biotic (algae) or mineral (bottom sediment) phase of the dam and can only be removed through costly and time-consuming interventions. Impacts may only be experienced downstream of actual nutrient sources and could be on the farm itself or on neighbouring farms. Prevention of eutrophication is better than cure!

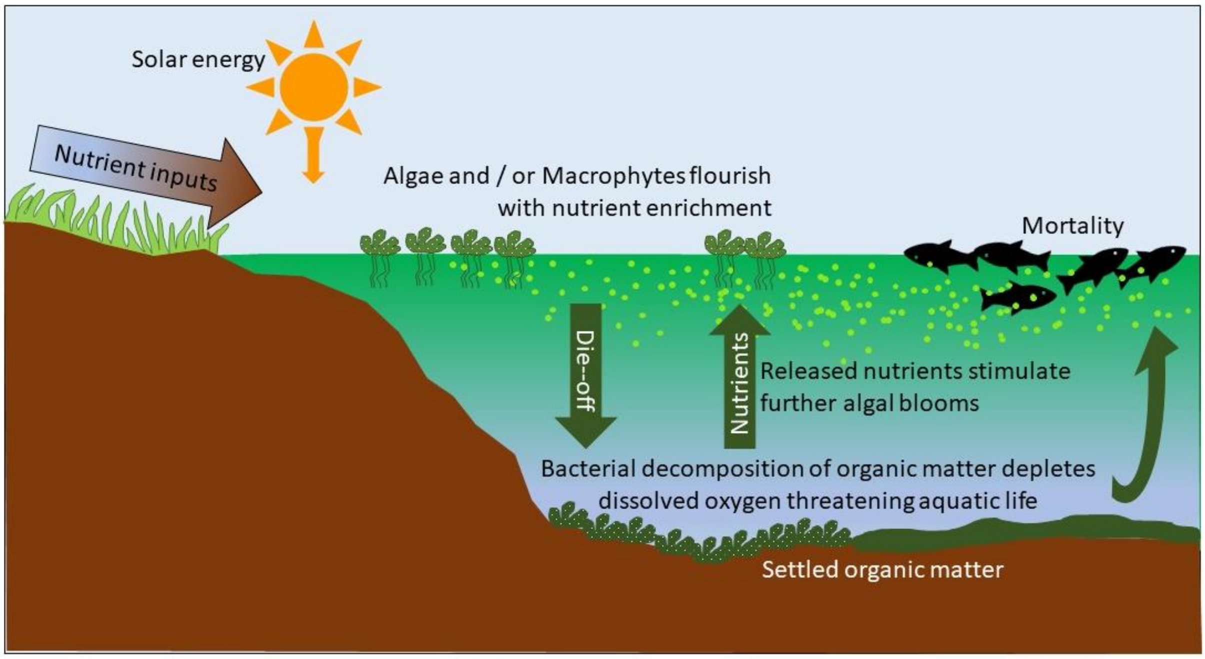


Figure 4. Typical cycle of eutrophication in an enclosed waterbody (e.g. dam) receiving sustained nutrient inputs.

The sources of Nitrogen and Phosphorus on dairy farms stem from the application of fertilisers and production and disposal of excrement from livestock (Table 2). In South Africa, dairy farm effluent is irrigated and spread onto pastures and land by most farmers (Esterhuizen and Fossey, 2015). This effluent is usually comprised of cow manure and urine passed by the cows plus chemical residues used during the milking process and is thereafter washed down from the milking parlour (Williamson *et al.,* 1998; Hooda *et al*., 2000). Nutrients in excess of those assimilated into pasture and soil, are transported to surface and groundwater and can directly impact the sustained use of water resources (Esterhuizen and Fossey, 2015). Storm events can also create high wash off events.

Table 2. Sources and impacts of excess nitrogen (N) and phosphorus (P) on dairy farms (adapted from Dairy NZ).

	Sources on farm	Potential impacts to water resources	Potential impacts on farm
Nitrogen	• Urine and dung from livestock • N in fertiliser • Slurry dams as concentrated outflow or dispersed through irrigation • Seepage from silage	• Promotes **eutrophication** through nuisance growth of algae or aquatic plants, creating unpleasant conditions for recreation, and poor conditions for aquatic life. • Ammonia (organic N) is toxic to fish and invertebrates even in low concentrations (0.1 mg/L; Craggs *et al*., 2003). • High nitrates in water (ground or surface) for drinking purposes pose a	• Loss of income through inefficient use and loss of nutrients. • Algal or plant growth blocks water intakes and irrigation equipment. • Excess plant growth in streams can exacerbate flooding and erosion, damaging roads, fences and pastures.

		significant human health risk through a serious condition called methaemoglobinaemia (Fewtrell, 2004).	• Dams are sinks for nutrients and water quality can be permanently compromised on farm or downstream on neighbouring farms, limiting irrigation value. • Poor water quality exacerbates impact of low quantities during periods of drought. • Excessive aquatic plants can increase water loss through evapotranspiration
Phosphorus	• Dung from livestock • P in fertiliser • Slurry dams as concentrated outflow or dispersed through irrigation	• Limiting nutrient in most aquatic ecosystems, so a strong driver of **eutrophication** through nuisance growth of algae or aquatic plants, creating unpleasant conditions for recreation, and poor conditions for aquatic life (Gourley *et al.*, 2012).	

Excess sediment originates from disturbed areas of soil, or erosion within watercourses which can occur along the stream bed or banks (
Table 3; Figure 5). Fields which have been recently disturbed through any type of tillage, especially on sloping land are vulnerable to erosion of soil into the closest watercourse. Farm roads and tracks can provide preferential flow paths creating routes for erosion and sedimentation in watercourses as they may erode themselves if they're not properly graded and drained. 'A road is a river in disguise' was a phrase used to describe preferential flow paths created by roads when planning for stormwater management (*Pers. comm.* Prof. Neil Armitage, 2022)

Table 3. Sources and impacts of excess sediment on dairy farms.

Sources on farm	Potential impacts to water resources	Potential impacts on farm
• Recently disturbed soil on steep slopes such as renovated fields or new fields. • Rotation of crops involving planting and harvesting of crops with low water interception such as maize. • Trampling in concentrated areas of streams and riparian zones by cattle. • Surfaces of road tracks, races, and pastures. • Increasingly concentrated flows in watercourses caused	• Smothering of bottom substrates and habitat, reducing areas for feeding and breeding of invertebrates which form the food web base of streams. • Sediment transport carries phosphorus into watercourses, contributing to eutrophication. • Suspended sediments can clog the gills of aquatic fauna, suffocating them. • Suspended sediments cause low visibility which impacts feeding success and changes the dominance of different algal species.	• Excess sediment settles out in bends where it deflects water flows to the opposite bank, increasing erosion of the outside bend. • Excessive sedimentation can cause flooding and erosion in new areas, resulting in damage to infrastructure. • When occurring upstream of dams, sediment transported into dams reduces dam storage capacity, increasing maintenance requirements and costs. Can occur on farm or for neighbours. • Excess sedimentation indicates erosion is occurring somewhere on the property or

by alien tree invaded banks, and draining of wetland areas.		upstream which may incur costs for maintenance and repair.

Figure 5. High suspended sediment loads (left) and instream sedimentation (right) following establishment of new fields for irrigated pasture in a normally clear stream (Southern Cape).

Studies conducted in New Zealand have shown an increase in dairy farming profitability due to a doubling of the total number of dairy cattle between 1990 and 2014 (Wright-Stow and Wilcock, 2017). In that period, a growth of 70% in the total area of dairy farming was observed with an intensification of pastoral land use (i.e., the larger density of livestock units and increased level of inputs such as fertiliser) and average dairy stocking rates rising from 2.4 to 2.9 cows per ha (Wilcock *et al*. 2013). However, this sharp increase in land-use intensity resulted in a significant decrease in surface water quality due to higher concentrations of nutrients (particularly N and P), increased levels of sedimentation which caused reduced visual clarity, reduced dissolved oxygen (DO) content and habitat degradation within stream beds from sediment deposition, and increased levels of faecal microbes (Wilcock *et al.,* 2007; Quinn *et al*., 2009; Ranåker *et al.,* 2012; Wright-Stow and Wilcock, 2017). Furthermore, cows that graze within riparian areas of seeps, springs, and rivers cause damage to the habitats of many freshwater species through the loss of riparian canopy cover, trampling, and increased release of sediment through erosion (Matthaei *et al*., 2006; Figure 6).

Figure 6. Example of a stream where cows have grazed the banks and trampled through instream habitat (KwaZulu-Natal).

The use of water in the South African dairy sector was quantified across different components, and water for irrigation is by far the highest consumption (Figure 7). Servicing water in contrast, utilises just 0.25%. Servicing includes activities such as cleaning milking tanks and the milking apparatus. This water is often recycled and used to wash dung from the milking parlour and cattle runs into slurry / effluent dams. Some separation of solid and liquid fractions may occur. For instance, a screw press, sediment trap, or rotary or static screen separation can be used to separate solids. Waste stored in dams is therefore as a sludge or in a predominantly liquid form. Water in slurry dams has very high concentrations of nutrients, fats, oil and grease (FOG) which are from the milk, solids, organic matter and pathogens. Even though it represents a relatively small volume of water, it can be a significant pollution source on dairy farms (Figure 8).

Slurry dams can act as point or diffuse sources of pollution. If they are unlined, or overflow into nearby watercourses they leach or discharge very poor water quality into ground or surface water resources. If the water is diluted with other sources and irrigated onto pastures, the impact is reduced through dilution and more dispersed. While wastewater or sludge can represent a cost-effective alternative to fertilisers, and an efficient use of waste, their application must be carefully moderated to ensure nutrient loading doesn't occur and water resources are not contaminated with faecal coliforms. Pathogens derived from faeces, such as *Escherichia coli* (*E. coli*) can significantly impact water quality and human health, particularly if this water is consumed without sufficient treatment (Oliver *et al*., 2009). Elevated faecal coliforms also have a significant impact on water quality for recreation.

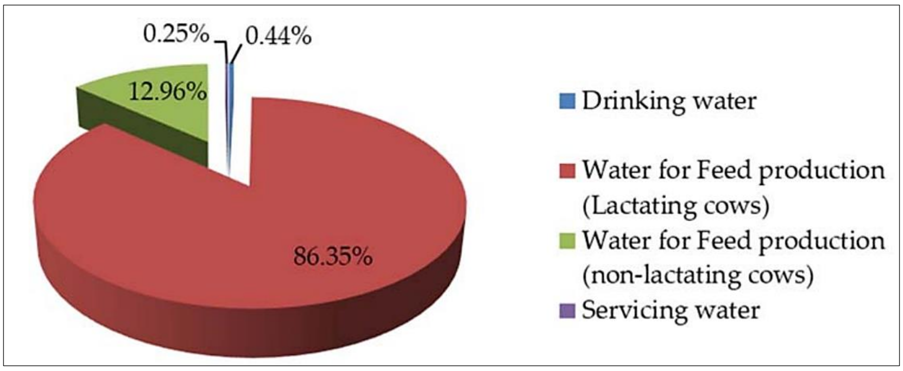


Figure 7. Contribution of various components to the total dairy footprint for water use in South Africa (Owusu-Sekyere *et al.,* 2016).

Figure 8. A slurry dam that has overtopped and discharged sludge and wastewater downslope acting as a point source of pollution (left) and a manure canon which discharges waste into a manure dam.

1.4.2 Water Quantity

Pasture-based dairy farming is a water intensive undertaking, requiring large volumes of water from a secure supply. A water footprint study for the dairy sector in South Africa determined that to produce a tonne of milk with 4% average fat content and 3.3% protein content takes 1 352 m^3 of water (Owusu-Sekyere *et al.,* 2016). Water security is therefore improved through the construction of instream impoundments such as dams or weirs, or off-channel dams. The latter have a reduced ecological impact because they do not create a physical barrier restricting movement of aquatic biota, however, if the abstraction of water is excessive in relation to supply then the movement and even survival of aquatic species can be threatened in either case. Water supply may be secured through surface water resources or groundwater via boreholes.

River flow regimes include floods, droughts, high pulses and base flows under natural conditions. This variation in flows is one of the key drivers dictating the presence or absence of aquatic organisms and influences the longitudinal and lateral connectivity of rivers and streams (Bunn and Arthington, 2002). The cumulative impact of numerous small dams in regions across South Africa has been shown to significantly impact water quality and aquatic ecosystem health as measured through macroinvertebrate assemblages (SASS5). Numerous small dams result in significantly reduced base flows and increased values of certain physico-chemical variables, especially total dissolved salts (TDS; Mantel *et al*., 2010). This may be due to evaporative losses resulting in higher concentration of salts, or it could be related to the land use itself contributing runoff or leachate with elevated concentrations of various salts. Dams act as a sink for nutrients in agricultural return flows from lands in their catchment, thereby reducing water quality downstream when they do overflow (Figure 9). Other downstream changes associated with dams and abstraction points are reduced wetted perimeter, increased concentration of pollutants due to reduced dilution, and modified transport rates for organic matter and sediment. This would all have an impact on aquatic communities downstream and demonstrate how reduced water quantity exacerbates threats to water quality due to farming in general, but dairy farming in particular as a heavy water use activity.

Figure 9. Water abstraction points above instream weirs showing reduced base flow downstream during low rainfall season (summer rainfall area, Kwa-Zulu Natal). Water quality upstream has obviously high suspended sediment and algal growth, and barriers restrict upstream movement of aquatic biota.

1.4.3 Habitat

Instream and riparian habitat as well as wetlands can be seriously impacted by poor management practices on dairy farms. Some of the main impacts are illustrated in Figure 10 and are listed as follows:

- Unrestricted access to watercourses by cows causes trampling of instream and riparian habitat, overgrazing and disturbance to vegetation, and fouling of water with excrement.
- Clearing and dumping of woody vegetation in the watercourse. This practice smothers instream habitat, increases water temperatures due to shade loss, causes debris / log jams following high flows resulting in erosion.
- Burning woody (alien) vegetation in a watercourse. This practice completely alters water chemistry and seriously increases turbidity. Huge quantities of organic matter are introduced resulting in depletion of oxygen. Habitat is totally smothered.
- Removal of riparian vegetation renders riverbanks unstable and prone to erosion. Ecosystem services such as sediment trapping and nutrient removal by vegetation in the riparian zone are lost.
- River and stream crossings (roads and pivot wheels) that involve dumping large volumes of earth or other materials into a watercourse provide limited or no through-flows, interrupting hydrological connectivity.
- Dumping of rubble, wood, garden waste, rubbish, tyres, or any other waste material into or adjacent to a watercourse.
- Working with heavy vehicles in or adjacent to a watercourse. This can seriously destabilise the soil and destroy vegetation increasing the risk of erosion.

Many of these impacts are not unique to dairy farming and may occur in association with other land uses where management of watercourses is not prioritised.

Figure 10. Examples of habitat degradation at the confluence of two streams on a pasture-based dairy farm (Southern Cape).

2 Best Practice for Protecting Watercourses on Dairy Farms in South Africa

A wide range of literature was reviewed from the perspective of relevant policies and guidelines aimed at protecting waterways on dairy farms both in South Africa and abroad. These policies and guidelines provide a benchmark of best practice. Many best practices relate directly to the support and good management of riparian buffer zones.

2.1 Stream Fencing to Exclude Cattle

The main purpose of fencing and bridging is to exclude cattle from aquatic habitats to improve the quality of streams on dairy farms (Bewsell *et al*., 2007). According to DairyNZ (2016), stock exclusion is amongst the most effective strategies a farmer can implement to improve the water quality on a dairy farm. Stream fencing ensures livestock do not have direct access to streams ultimately limiting the deposition of faecal material and urine into streams. Excluding cattle also prevents erosion and disturbance of the stream bank and bed and protects the aquatic habitat (Bewsell *et al*., 2007; DairyNZ, 2016), while ensuring that livestock do not graze on riparian vegetation.

Specific guidelines were developed in Australia for fencing to exclude livestock (Water and Rivers Commission, 2000). The guideline lists numerous benefits of fencing waterways and provides recommendations for the location of fencing. These generally acknowledge the need to include riparian vegetation, floodplains, and steep slopes in fenced off areas. The New Zealand Ministry of Agriculture also recommends that livestock be excluded from slopes subject to intermittent channelized flow following a rainfall event as this represents another point of inflow to streams (Kay et al., 2012). Electric fencing is listed as the most cost effective and practical with benefits of being quick to erect, moveable, and able to accommodate curves (Figure 11). Electric fencelines can be periodically unclipped to allow access to riparian zones for maintenance (e.g. alien vegetation clearance). Dairy cows generally need only one 'hot' wire. Strategies to reduce damage to fencing include locating fencing out of flood-prone areas to avoid over-bank flooding, channel widening, meandering and new channel formation. Fences that cross waterways should be kept to an absolute minimum as they are frequently damaged, cause a build-up of debris during floods, and restrict movement of wildlife.

Figure 11. A single electric wire fenceline along a buffer of vegetation protecting a wetland (southern Cape).

2.2 Cattle and Pivot Crossings

Constructing bridges over streams limits livestock access to watercourses (Kay *et al*., 2012), reducing impacts to the bed, banks, vegetation, and water quality. For instance, cattle standing in water defecate five times more than the average frequency on land (Bond *et al*., 2012). Standing in water can also have negative health effects for stock, increasing the risk of foot rot and of ingesting parasites and pathogens from the water. Cattle drinking from troughs are less likely to become infected by pathogens present in natural watercourses, especially where they have been defecating. Suitable drinking troughs with clean water should be provided in pastures. The New Zealand Sustainable Dairy Farming Accord recommends that all points on a waterway where livestock cross over and return more than once a month should either be bridged or culverted. Bridges and culverts must have raised sides or mounds to ensure that runoff is not deposited into water bodies (DairyNZ, 2016). Several guidelines for the construction of crossings are available including the New South Wales (NSW) Stock and Waterways guide to crossings (Staton and O'Sullivan, 2019) and DairyNZ Waterway Technote on crossings (2017).

Crossings can either be culverts, bridges or bed-level crossings. Culverts can be round pipes or rectangular box culverts. The latter are considered preferable in streams with regular flow as they disperse flows reducing flow velocity and erosion risk. Culverts are the most common crossing type for small perennial and non-perennial streams in South Africa. The NSW guideline gives detailed instruction for the construction of crossings that provide safe passage for cattle while maintaining key aspects of aquatic ecosystem function. Most guidelines emphasize that culverts must not restrict the movement of fish or other aquatic life and they should maintain the natural bed level and slope (Figure 12). If the invert level is too high this causes erosion around the inflow and a plunge pool at the outflow, while too low can result in sedimentation and blockage. Culvert size must maintain the natural channel width because undersized culverts can restrict fish movement due to high flow velocities and are easily blocked by sediment and woody material (Figure 12).

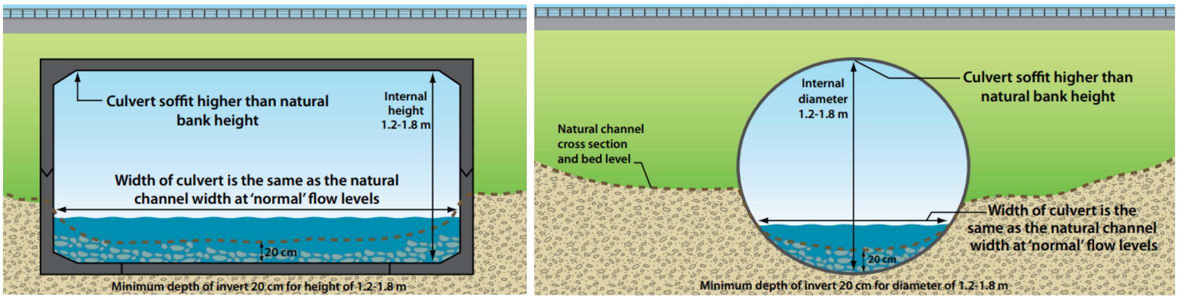


Figure 12. Cross sections of well positioned culverts showing invert buried below bed level to maintain the natural bed level, slope and material. The width of the natural channel is maintained (Scottish EPA, 2010).

Crossings not only apply to cattle crossing points, but pivot crossings too. Ideally pivots should not cross over natural watercourses as this directs irrigation into the watercourse which may periodically include fertigation and diluted wastewater (slurry). This practice renders riparian zones along the affected watercourse redundant. A stopper placed on either side of the watercourse and buffer, so it is excluded from the irrigated area is ideal. Where crossings are historical or unavoidable, they should aim to maintain the natural hydrology and movement of wildlife with minimal obstruction in the watercourse. The minimum footprint of disturbance for wheel crossings should be the goal. Welded steel pivot bridges have a very low footprint of disturbance but have not been implemented widely in South Africa (Figure 13). Alternatively, a gabion crossing with suitably sized piped culverts would have the benefit of allowing seepage as well as periodic flows in headwater streams that do not always flow.

Figure 13. Examples of welded steel pivot crossings over streams and rivers (Commercial suppliers).

In small streams where the gradient of stream banks is low and the aim is simply to prevent the pivot wheels from getting bogged down and reducing sedimentation in the stream, a strip in line with the stream bed can be lined with open pavers / grass blocks / canal liner blocks to create a firmer footing for pivot wheels (Figure 14). This allows vegetation to establish while preventing erosion but would only be suitable for short sections of a stream and should not be installed as a continuous channel lining.

Figure 14. Example of a stream bed with narrow section replaced with open pavers suitable for pivot wheel crossing (Day *et al*., 2016).

2.3 Limiting erosion and surface runoff

Soil compaction is an important aspect of land management that can significantly impact water quality. Soil compaction on grazing pastures increases the rate of contaminant losses via drainage and runoff, increases N_2O emissions, and reduces productivity through yield reduction and nutrient (N, P, K) runoff (Hu *et al.,* 2021). Compaction also reduces soil permeability, resulting in reduced water infiltration rates and higher surface runoff which can carry pathogens and cause erosion and soil losses (Kay *et al*., 2012). Soil is transported into nearby streams where it eventually settles out potentially smothering habitat (Figure 5). While these impacts can be diffuse (spread out) in nature, they can also become concentrated through distinct flow paths which render riparian buffers ineffective at mitigating these impacts.

The sensitivity of soil to compaction and its level of erodibility is highly variable due to differences in soil type. Soils with higher sand and silt content are more vulnerable to compaction than clay or loam soils. Soil compaction is promoted by intensive tillage which may temporarily loosen the soil but increases bulk density through depletion of organic matter and weakening the soil structure. Certain implements compact the soil below their working depth leading to plough pans between 15-30 cm. Plough pans form as a compacted layer in cultivated soil resulting from frequent ploughing. The presence of a plough pan decreases soil permeability, increasing the likelihood of lateral water flow through the soil and waterlogging (Bertolino *et al*., 2010). A basic principle for avoiding soil compaction and resultant erosion is the exclusion of livestock and vehicles from wet pastures and fencing off wet areas. Practicing conservation / minimum tillage is an effective way to reduce the impact of soil compaction.

Soil losses can occur as sheet, rill or gully erosion which are essentially differentiated by the movement of water overland in sheets or in channels. While sheet erosion often remains unseen, gully erosion is more active and visible (DairyNZ). However, the latter can start as tunnels beneath the soil surface, which is common in the southern Cape of South Africa.

It is advised that dairy farmers practise conservation tillage by maintaining a minimum surface cover of root plants of 30%; this can be done by leaving crop residues on fields. When compared to a bare, fallow soil, a field with a 30% surface cover has been found to reduce soil erosion by half while maintaining a 50 to a 100% surface cover throughout the year can reduce erosion levels to negligible (Hawkins and Stanway, 2013).

Erosion tends to occur on moderate to steep slopes or along stream banks in floodplains or on river bends. Restricting cattle access to steep slopes and ensuring adequate vegetation cover in these areas is recommended to prevent erosion. No or minimum tillage, crop rotation and cover crops can also be implemented to reduce the erosion and surface runoff associated with dairy farms (DairyNZ, 2016). Livestock congregation points should be located on flat areas to reduce the risk of erosion and concentrate compaction in areas where it is less likely to impact on pasture health and water quality. Areas of concentrated livestock should also be bunded so that runoff from these areas can be treated or diverted for treatment instead of flowing into the nearest watercourse.

2.4 Control of effluent application

Dairy effluent can be a valuable fertilizer or a pollution source to surface or groundwater depending on how it is managed. Controlling the timing and location of manure applications can attenuate microbial and nutrient transport within the catchment. When it comes to disposing of slurry from slurry ponds or wash down wastewater from dairy parlor floors, the most common practice is to either irrigate or pump the slurry out onto pastures. Irrigation with wastewater / effluent can significantly reduce fertilizer costs and improve soil condition. However, this depends on well-informed decisions which must be made to ensure this valuable resource does not become a pollutant to watercourses. Farmers are advised to analyse effluent to determine N, P, K, EC, COD and pathogens as high Na levels in detergents used to clean dairy lanes may increase soil salinity levels (Hawkins and Stanway, 2013) and reduce infiltration rates. Soil analysis prior to application is important to ensure that application of effluent is not going to exceed the soil’s ability to recirculate nutrients and salts (Vorster, 2016).

Measuring EC in the soil and water regularly provides a good idea of trends and should form part of the farm's monitoring plan.

Effluent should be applied to pastures at the correct depth, timing and rate to minimize the risk of it leaching nutrients and pathogens into water bodies and being carried by surface runoff (DairyNZ, 2016). The soil water deficit in pastures must be well understood to prevent surface ponding and runoff from saturated soils. Effluent should not be spread on steep slopes or during wet conditions to reduce the risk of runoff. Ensure spray nozzles are functional and there are no leaking lines as these will cause ponding in areas which may runoff to aquatic systems. Effluent solids have higher nutrient content than liquid, therefore samples should be analysed for nutrient content before spreading to determine the actual nutrient requirements of the pasture. Soil tests for nutrients in the pasture to be irrigated should also be conducted. The aim is to prevent nutrient loading which can leach nutrients into surface runoff and aquatic systems if applied in excess. DairyNZ provides a Fam Dairy Effluent Spreading Calculator to determine application rates more accurately, and a checklist for good effluent management on farms. Apply effluent regularly to keep storage in slurry dams low to prevent dams overflowing during high rainfall (Wilcock *et al*., 2009). Fields receiving slurry should be rotated because repeated applications can lead to nutrient loading and unpalatable pasture for grazing.

The transfer of effluent from washdown areas to slurry ponds should preferably be through a lined channel to (usually two) lined slurry dams to reduce or prevent seepage from contaminating groundwater or surface water through lateral flows (Figure 15). Stormwater management must be implemented to divert runoff from entering the ponds potentially causing them to overflow into streams and rivers.

Figure 15. Slurry transferred from wash down areas via a concrete channel (Photo credit ARC), and a slurry dam with plastic liner (Free State).

According to South Africa's National Water Act (Act No. 36 of 1998), irrigation with limited volumes of wastewater within specific quality limits is possible (See Government Notice 665, 2013). The location of wastewater irrigation must be at least 50 m above the 1:100 year floodline or the riparian zone (whichever is greatest), or alternatively at least 100m from a watercourse, and 500 m from the boundary of a wetland. Wastewater irrigation may not take place within 500 m of a borehole used for drinking water or stock irrigation. Irrigation may not result in pooling of water on the landscape or surface runoff. A comprehensive risk of precautionary practices for wastewater irrigation are listed in GN665 of the NWA.

2.5 Nutrient Management

Nutrient loading of cultivated pasture soils can occur where fertiliser guidelines do not fit the farming system or baseline nutrient status of the pasture. For instance, drastically elevated levels of phosphorus and zinc were measured in soils on irrigated minimum-till kikuyu-ryegrass pastures in the southern Cape (Swanepoel *et al*., 2015). This was because lime and fertiliser application rates developed for conventional tillage annual pastures were followed despite the advent of minimum-tillage systems. As a consequence, runoff and leaching from these pastures could cause deleterious effects for aquatic ecosystems (Figure 4) and threaten the sustainability of pastures. This threatens the dual goals of economic and environmental sustainability and emphasises that fertiliser guidelines should be strictly followed and should be applicable to the farming system (Swanepoel *et al.,* 2015).

Irrigation systems must operate efficiently to ensure that water is applied at the correct depths across irrigated areas. Managing efficiency and appropriate scheduling of irrigation applications ensures that excess water doesn't drain the soils of nutrients or result in runoff which may contaminate surface and groundwater resources (DairyNZ, 2016). Likewise, fertigation systems must be well maintained and calibrated to avoid over-irrigation, drift and leaks. Applications of fertiliser should be undertaken during optimal weather conditions including minimal wind and no rainfall (Hawkins and Stanway, 2013). Regular soil and leaf analysis should be conducted and form the basis of fertiliser applications to avoid the over application of fertilizer on crops and pastures.

2.6 Alien Vegetation Management

Different regions of South Africa are afflicted by different Invasive Alien Plants (IAPs) and many are aggressive invaders of riparian zones and wetland areas because seeds are often transported along watercourses and the more reliable water supply provides good conditions for establishment. Alien clearing along riparian zones and in wetlands is the responsibility of the landowner in terms of the Conservation of Agricultural Resources Act (Act No. 43 of 1983). However, it must be undertaken responsibly.

Some particularly detrimental practices observed on farms (including dairy farms) for the removal of aliens include the use of excavators to 'push' alien vegetation into streams, followed by burning of the material instream, and no follow-up control to remove subsequent regeneration of aliens. Photos of examples of this practice are provided in Figure 16 and Figure 17, demonstrating that this type of practice is damaging for the following reasons:

- Mass quantities of soil and woody material pushed into the watercourse smothers habitat, and interrupts flow paths with negative consequences for biodiversity.
- Soil and woody material piled into stream beds reduce their flood conveyance ability, exacerbating flooding during high flows and causing erosion where floodwaters are diverted.
- In flowing streams and rivers, pushing or dumping trees or slashed alien vegetation into watercourses can create debris dams downstream and block culverts and bridges increasing flood risk and erosion where floodwaters are diverted.
- The complete removal of all shade-providing trees (alien or otherwise) completely exposes aquatic biota to harsh temperature changes and predation (Figure 17).
- Once large trees such as *Eucalyptus* have been pushed into watercourses, it is costly and difficult to remove them so that the system can be rehabilitated.

Furthermore, the above practice is unlawful without an authorisation (which would be unlikely to be granted) in terms of both the NWA and the NEMA.

Figure 16. Photos showing burnt alien trees pushed into a wetland (left) and a culvert blocked by slashed alien vegetation discarded in the river upstream.

Figure 17. Example of clearing and burning riparian vegetation adjacent to a pasture (left), with a striped stream frog left vulnerable and exposed to temperature fluctuations and predation in the same stream (right).

Alternative best practice methods for the removal of alien vegetation are provided as a guideline. Generally, the clearing of light to moderate density invasions of alien plants in wetlands and riparian zones should be undertaken using the following methods:

- Minimal disturbance to soil using hand tools only (e.g. Tree Poppers, chainsaws, loppers).
- Restrict the use of herbicides close to the watercourse. Use only products registered for use on the target species at the correct dosage, and preferably use the cut stump method as opposed to foliar sprays which can drift and cause non-target effects.
- Minimise disturbance to indigenous vegetation as this will rebound naturally once alien vegetation has been removed, thus limiting the establishment and regrowth of alien seedlings.
- Large and very large trees should preferably be ring-barked to reduce soil disturbance and the possibility of trees falling into the watercourse. Ring-barked trees die off slowly, often taking 12-18 months. They continue to provide shade while indigenous trees and shrubs take over in

the wake of alien clearing, ensuring stream temperatures remain stable and providing perching and nesting sites for birdlife.

- Any woody slash or fallen trees must be removed from watercourses so they do not accumulate and block infrastructure or create debris dams. This includes following uncontrolled fires which can result in many trees falling into watercourses (Figure 18).
- Control and management of alien plants is not a once-off exercise. Unfortunately, the opportunistic characteristics of alien plants ensures that they will re-establish easily unless follow up control is maintained on a regular basis.

Figure 18. Riparian vegetation invaded by Black Wattle post-fire and high winds which resulted in high windfall of trunks and branches into the stream bed.

2.7 Manage Water Use

As a semi-arid country prone to prolonged periods of drought, South African dairy farmers are well-advised to maximise the efficiency of irrigation water use. This strategy benefits the dual aims of economic and environmental sustainability. As most irrigation water is from surface water resources which are stressed by high rates of abstraction and degraded by numerous instream dams, inefficient use of water is wasteful and irresponsible. In a case study of water use and irrigation efficiency on irrigated and dryland dairy pastures in the Southern Cape (Tsitsikamma and Outeniqua), instances of excessive water use, and wastage were observed (Phadu *et al*., 2022).

Very few pump and pivot systems were fitted with meters with the result that detailed records of volumes abstracted for irrigation were not available. This hinders the assessment of pivot efficiency. Water use efficiencies ranged widely. Measured as the number of litres (L) of water used to produce a litre of milk, values in the Tsitsikamma region ranged between 23 and 253 L of water (average = 135 L). Important factors influencing water use efficiency are system, scheduling and calibration efficiency. System efficiency in turn is influenced by wind speed (higher = wastage), distance from the ground (higher = greater loss), and droplet size (smaller = greater loss). Other forms of wastage are through leaks and evaporation. The latter is easily corrected through more efficient scheduling. The study concluded that improved water use efficiency improved bottom line profits through reduced energy costs, reduced carbon emissions, and reduced water wastage. The latter has important implications for maintaining ecological functions such as hydrological connectivity in aquatic ecosystems.

2.8 Vegetated Buffer Strips

Vegetated buffer strips are essentially riparian buffer zones, although they can be applied at any location where the interception of surface runoff and promotion of infiltration is desired (Figure 19). The restoration and maintenance of vegetated buffer strips around water bodies has been shown to reduce pollutant and nutrient entry by surface runoff. These buffer strips should be fenced to ensure they are protected from grazing cows. Grass buffer strips have been found to decrease phosphorus loss by surface runoff through filtration, deposition, and improving infiltration. For vegetation strips to be functional the vegetation cover must by high and dense to perform functions like sediment trapping, even if it’s just grass.

Figure 19. Photo of a wetland protected by a well vegetated grassland buffer from a dairy, slurry dams and irrigation pivot located > 100 m away (KwaZulu-Natal, S. Viljoen).

3 The concept of an aquatic impact buffer zone

3.1 What are buffer zones?

Definitions of buffer zones vary depending on their purpose. In the context of the national guideline (Macfarlane and Bredin, 2017), buffer zones have been defined as:

“A strip of land with a use, function or zoning specifically designed to protect one area of land against impacts from another.”

Aquatic buffer zones are typically designed to act as a barrier between human activities and sensitive water resources to protect them from adverse negative impacts (Figure 20). The need to ensure that buffer zones provide adequate protection for the movement of terrestrial and semi-aquatic indigenous fauna along riverine corridors is also addressed in the recommended guidelines (Macfarlane and Bredin, 2017). It should be noted that various factors including fencing, buffer width, plant species selection, configuration and management of buffer zones greatly influence the effectiveness of the buffers (Aarons and Gourley, 2013). Vegetation in the buffer zone is meant to act as a biological filter protecting aquatic ecosystems from contaminants produced by the surrounding land use but also acting to retain soil, decrease flood velocities and absorb noise pollution.

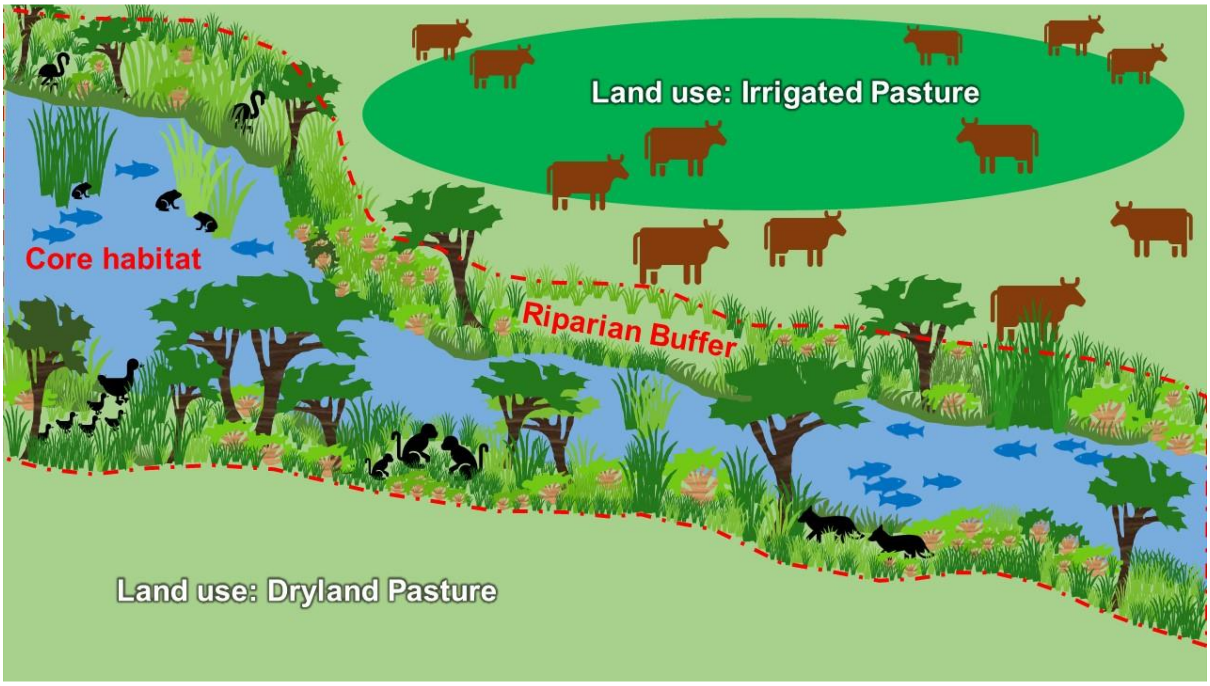


Figure 20. An illustration of a final buffer zone for an activity adjacent to a watercourse that takes into consideration an aquatic impact buffer for the activity, and biodiversity buffer requirements which may include aspects such as a core habitat area and an additional biodiversity buffer requirement for the core habitat (J. Dabrowski).

The width required for buffer zones may vary depending on the surrounding land use (e.g. irrigated or non-irrigated pasture) and inherent environmental factors such as the angle of slope and type of vegetation cover (Figure 21).

Figure 21. Irrigation dam in the southern Cape with well buffered banks varying in width according to slope. Alien vegetation has been well managed, and the vegetation coverage is excellent.

3.2 Why are buffer zones important?

Buffer zones associated with watercourses have been shown to perform a wide range of functions, and while there has been no formal requirement, they have been widely adopted as a standard measure to protect watercourses and associated biodiversity (Macfarlane and Bredin, 2017). Some of these key functions include:

- Maintaining basic aquatic processes;
- Reducing impacts to watercourses from upstream activities and adjoining land uses;
- Providing habitat for aquatic and semi-aquatic species;
- Providing habitat for terrestrial species; and
- A range of ancillary societal benefits.

A brief description of each of the functions and associated services is outlined in Table 4. Numerous case studies have demonstrated the benefits described in Table 4 on dairy farms.

Table 4. Summary of roles and associated functions provided by aquatic impact buffer zones (Macfarlane and Bredin, 2017)

PRIMARY ROLE	AQUATIC IMPACT BUFFER FUNCTIONS
Maintaining basic aquatic processes, services and values.	• **Maintaining channel stability:** The root systems of riparian vegetation strengthen and stabilise stream banks, and groundcover increases resistance to erosion. This improves channel stability and reduces the impacts on aquatic systems and downstream users. Stream bank stability is particularly important during flood events, with the amount of erosion being greatly reduced by good vegetation cover along stream banks. Buffer zones can also prevent direct

PRIMARY ROLE	AQUATIC IMPACT BUFFER FUNCTIONS
	access of livestock to a waterway, thereby preventing hoof-damage to stream banks and direct input of nutrients, organic matter and pathogens in dung and urine. • **Control of microclimate and water temperature:** Riparian vegetation may affect the microclimate of the stream area nearest the stream bank and reduce water temperatures. This can have serious consequences for aquatic biota as water temperature plays a key role in the life cycles of many species. The occurrence of riparian vegetation also has a significant effect on aquatic plant growth, as light incidence is the main variable controlling productivity in shaded streams. Removing stream bank vegetation is likely to increase primary stream productivity, increase the risk of eutrophication and change the species structure and community composition in the water body. The lower temperature caused by shading also have important consequences for other water quality variables such as the dissolved oxygen concentration (DO), which increases with lower temperatures. • **Flood attenuation:** Well-developed riparian vegetation increases the roughness of stream margins, reducing the momentum and magnitude of flood-flows. This may reduce flood damage in downstream areas. Aquatic buffers are therefore a cost-effective alternative to engineered structures to reduce erosion and control flooding, particularly in urban settings. • **Maintenance of general wildlife habitat:** Riparian zones typically have intrinsically high biodiversity value due to their structural diversity and location at an interface between aquatic and terrestrial systems.
Reducing impacts from upstream activities and adjoining land uses	• **Storm water attenuation:** Flooding into the buffer zone increases the area and reduces the velocity of storm flow. Roots, branches and leaves of plants provide direct resistance to water flowing through the buffer, trapping sediments, and decreasing flow velocity which reduces erosion potential. • **Sediment removal:** Surface roughness provided by vegetation, or leaf litter, reduces the velocity of overland flow, and enhances settling of particles. Buffer zones can therefore act as effective sediment traps, by removing sediment from runoff water from adjoining lands and thus reducing the sediment load of surface waters. • **Removal of toxics:** Buffer zones can remove toxic pollutants, such as pesticides, metals and other chemicals that would otherwise affect the quality of water resources and thus their suitability for aquatic biota and for human use. • **Nutrient removal:** Riparian vegetation and vegetation in terrestrial buffer zones may significantly lower the level of nutrients (Nitrogen (N) and Phosphorus (P)) entering a water body, thereby reducing the potential for excessive outbreaks of microalgae that can have an adverse effect on both freshwater and estuarine environments. • **Removal of pathogens:** By slowing water contaminated with faeces, buffer zones encourage deposition of pathogens, which soon die when exposed to the elements.

PRIMARY ROLE	AQUATIC IMPACT BUFFER FUNCTIONS
Meeting life-need requirements for aquatic and semi-aquatic species	• **Provision of habitat for aquatic species:** Riparian vegetation along stream paths provides food which supports in-stream food chains, branches and trees that fall into the stream also provide vital habitat for certain species of aquatic fauna. • **Provision of habitat for semi-aquatic species:** Many semi-aquatic species rely on terrestrial habitats for the successful recruitment of juveniles and to maintain optimal adult survival rates. Buffer zones maintain the link between aquatic and terrestrial habitats. • **Screening of adjacent disturbances:** Anthropogenic disturbances to aquatic and semi-aquatic species may be direct (for example human presence and traffic), or indirect (for example through noise and light). These adversely impact species survival either by disrupting natural wildlife activities such as feeding, breeding and sleeping, or affecting habitat quality. • **Habitat connectivity:** Buffers along watercourses provide potentially useful corridors, allowing the connection of breeding, feeding and refuge sites crucial to maintain the viability of populations of semi-aquatic species.
Providing habitat for terrestrial species	• **Provision of habitat for terrestrial species:** In certain situations, buffers established alongside water resources may be critical for the persistence of terrestrial species. This is particularly likely in highly developed landscapes where undeveloped buffers may provide the only remaining terrestrial habitat. • **Habitat connectivity:** (See above).
Ancillary societal benefits	• **Reduces flood risk:** Through increased resistance to flow, riparian areas and buffer zones can increase residence time of floodwaters, reducing flow velocities and thereby reducing flood peaks. This can reduce safety risks to people and property in the downstream catchment. • **Enhances visual quality:** Buffer zones can create visual interest and screen undesirable views, thereby enhancing visual quality, particularly in urban areas. • **Control noise levels:** Wooded buffer zones can reduce noise from roads and other sources to levels that allow normal outdoor activities to occur. • **Improve air quality:** Vegetation in buffer zones can affect local and regional air quality by reducing temperature and removing air pollutants. • **Provides recreational and tourism opportunities:** The availability of open space associated with buffer zones can provide opportunities for a range of recreational and tourism activities. • **Economic benefits:** The proximity of residential areas to well-managed buffer zones can lead to increased property values because of perceived aesthetic, recreational and other benefits. Such areas can also offer opportunities for tourism activities and provide a sustainable supply of natural resources for local communities.

3.3 Limitations of Aquatic Impact Buffer Zones

Despite the range of functions potentially provided by buffer zones, buffer zones are not the appropriate mitigating measure for addressing all watercourse related problems. According to Macfarlane and Bredin (2017), buffers can do little to address impacts such as hydrological changes caused by stream flow reduction activities or changes in flow brought about by abstractions or upstream impoundments. Buffer zones are also not the appropriate tool for mitigating against point-source discharges (e.g. slurry dam overflows), which can be more effectively managed by targeting these areas through specific source-directed controls. Contamination or use of groundwater is also not well addressed by buffer zones and requires complementary approaches such as controlling activities in sensitive groundwater zones.

Riparian buffers planted in patches and ditches aren't useful for trapping overland flow contaminants. A recent study in New Zealand shows that the fencing and replanting of short sections of New Zealand's rivers has not improved stream water quality even after 30 years of implementation (Harvie, 2019). From the study it is apparent that rivers and catchments are connected ecosystems and restoration should ideally occur at a catchment scale to achieve the best outcome (Harvie, 2019). The cumulative impacts of riparian buffers applied by multiple landowners increase the benefits of habitat connectivity and improve water quality.

There is no "one size fits all" approach to determining the appropriate width or vegetation composition of buffers. Sites need to be considered on an individual basis with variation in slope, surrounding land use, soil type and vegetation cover just some of the variables influencing the appropriate buffer.

Despite these limitations, buffer zones are well suited to perform functions such as sediment trapping and nutrient retention which can significantly reduce the impact of pasture-based dairy farming adjacent to watercourses. Buffer zones are therefore proposed as a standard mitigation measure to reduce impacts linked with diffuse surface runoff or shallow interflow from land-uses / activities adjacent to watercourses. These must, however, be considered in conjunction with other mitigation measures which may be required to address specific impacts for which buffer zones are not well suited. Riparian buffers should be considered a secondary restorative measure after controlling pollutants at their original sources (Low *et al*., 2012).

3.4 Benefits and Costs of Implementing Watercourse Management Practices

Buffer zones aim to support continued land-use while simultaneously maintaining the health of aquatic ecosystems. Implementing buffer zones on dairy farms may entail replacing pasture that has encroached into the buffer or riparian zone with a suitable mix of indigenous vegetation, and potentially extending the area of indigenous vegetation to further buffer the watercourse from the impacts of the land-use. Establishing buffers on dairy farms has consequences for the dairy farmer, the environment and broader society. These outcomes result in both local (on-farm) and broader (societal) costs and benefits.

The New Zealand dairy sector has adopted riparian buffer zones as a national initiative to mitigate impacts associated with intensification of the dairy sector. The national riparian restoration programme was reviewed to determine whether it represented a ‘value for money’ strategy (Daigneault et al., 2017). An economic land use model weighed up the benefits (GHG emissions, N leaching, P loss, sedimentation and biodiversity gain) against the costs (fencing, alternative stock water supplies, restorative planting, and opportunity costs) of restoring 5 – 50 m buffers on all NZ streams flowing through primary sector land. With varying underlying cost assumptions benefits outweighed the costs with monetary values ranging between NZ$ 1.7 billion and NZ$ 5.2 billion per year. This demonstrates that the benefits to climate and freshwater resources are significantly greater than the implementation costs of riparian restoration.

A recent Water Research Commission (WRC) study investigating watercourse buffer zones in the sugarcane landscape in South Africa (Browne *et al*., 2020), identified that there are a range of potential benefits and costs associated with watercourse buffer zones in agricultural landscapes. The literature reviewed for the study emphasised that these costs and benefits are not evenly distributed, both between the current land user and society, and between current and future generations (Currie *et al*., 2009; Jenkins *et al*., 2010; Chang *et al*., 2011; Robertson *et al*., 2014; Carvaljal and Janmaat, 2016). The costs and benefits also occur at different spatial scales, generally with the costs accruing at the local scale (to the landowner) and the benefits at a larger catchment scale. Increasingly however, local scale benefits are being identified, particularly those related to soil moisture and soil health. The following points emerged from the international literature (Browne *et al*., 2020):

- The implementation of watercourse buffer zones in agricultural landscapes has predominantly focused on water quality protection / improvement.
- Watercourse buffer zones are often viewed / evaluated as part of a broader management plan (towards sustainable agriculture and or watercourse protection / restoration).
- While many of the cost-benefit studies that were reviewed identified a range of potential benefits associated with watercourse buffer zones, generally only a sub-set of these were quantified. Many of the benefits, particularly those related to ecosystem services, are difficult to quantify (or require long-term monitoring data) and, further, to express in monetary values which are often preferred for cost-benefit analysis.

From the perspective of the dairy farmer, the main cost associated with establishing watercourse buffer zones is the income forgone from reduced pasture area. This cost is associated with the conversion of pasture area to buffer area (and / or back to unplanted watercourse). In addition, there are costs associated with the establishment and maintenance of buffer zones. Establishment activities include the removal of pasture crops from the buffer area and the planting of replacement vegetation and fencing. Maintenance activities include the management of biomass and alien plant encroachment within the buffer zone and watercourse. On the other hand, there is a growing recognition that sustainable management practices within agriculture can provide numerous ‘on farm’ benefits such as erosion control and topsoil retention (Rein, 1999), and aesthetic and cultural benefits associated with well-functioning natural habitats (Robertson *et al.,* 2014). Further, rehabilitated watercourses (and especially wetlands) are associated with more water being retained, and for longer periods, in the adjacent hillslopes. A major benefit is the reduction in eutrophication of farm dams, which can result in various operational challenges. The wider the buffer zone, the more productive land is retired for this purpose. However, through implementation of this guideline it is possible to reduce buffer widths and therefore productivity losses through the implementation of multiple best practice actions.

From the perspective of society, buffer zones in agricultural landscapes are desirable for the protection of aquatic ecosystem health and the maintenance of ecological services and the associated benefits, for the contribution to maintaining water quantity and quality, and to support biodiversity maintenance. Key impacts associated with agricultural land-use include increased sediment and nutrient loads to the receiving watercourse and changes to the flow of water through the landscape to the watercourse (surface and sub-surface flow paths). Establishing buffer zones adjacent to watercourses on dairy farms will assist in reducing these impacts and improve / maintain aquatic ecosystem health.

4 Applicable Legislation and Guidelines

Undertaking work in the riparian area of a river or stream, or in a wetland, can trigger the requirement for a water use and/or environmental authorisation in terms of the National Water Act (NWA; Act No. 36 of 1998) and the National Environmental Management Act (NEMA; Act No. 107 of 1998), respectively. As a start, it is important to understand the definition of a watercourse. According to the NWA and NEMA, a watercourse means:

(a) A river or spring;
(b) A natural channel in which water flows regularly or intermittently; and
(c) A wetland lake or dam into which, or from which, water flows

While permanent wetlands, rivers and dams are easily distinguished, seasonal wetlands and non-perennial drainage lines with intermittent flows are not always readily identified as a watercourse by farm managers. However, they are given the same level of recognition and protection in terms of legislation because of the interconnected nature of water resources. While wetlands tend to occur in valley bottoms they can occur naturally in almost any location in the landscape (Figure 22). From a legal perspective, no distinction is made between natural and artificial wetlands.

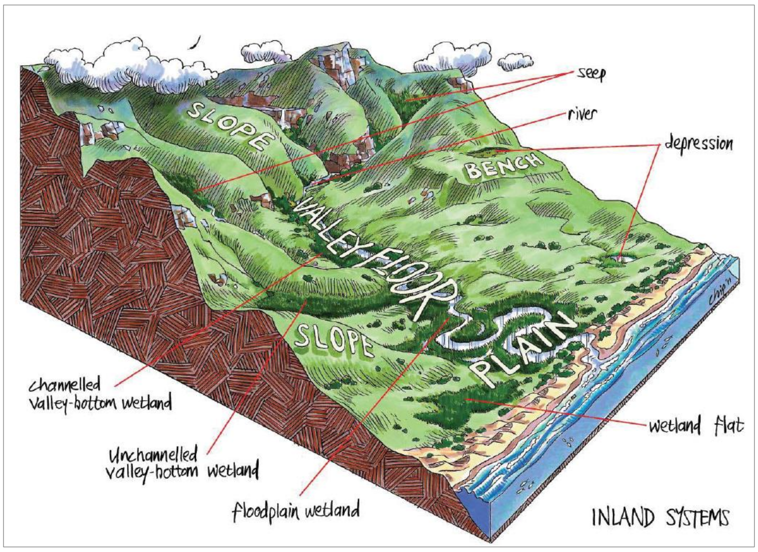


Figure 22. Potential locations of wetlands in different topographical settings (Ollis *et al*., 2013)

Section 21 of the NWA defines different forms of water use, which require a level of authorisation in the form of either a General Authorisation (GA) or a Water Use License (WUL). Water uses frequently associated with dairy farming are presented in Table 5 (Adapted from Guidelines to Water Use: authorisations and registration for dairy farmers; MPO, 2017). Activities that would typically be undertaken to manage and improve riparian buffer zones would constitute Section 21 (c) and (i) water uses and are highlighted in Table 5.

Table 5. Examples of typical water uses on dairy farms that may require authorisation in terms of the National Water Act.

Water use under NWA	**Description of Activities**
Section 21 (a) Taking water from a water resource	Abstraction from a borehole, river, or dam in volumes required for commercial agriculture.
Section 21 (b) Storing of water	Storage of water in off-stream or instream dams, or the enlargement of existing dams.
Section 21 (c) Impeding or diverting the flow of water in a watercourse	Construction of new infrastructure including instream dams, weirs (for water abstraction or erosion control), road crossings, pivot crossings. Maintenance work required for the upkeep of diversion weirs for irrigation furrows.
Section 21 (e) Engaging in a controlled activity	Irrigation with wastewater of varying quality can be authorised through either a GA or a WUL
Section 21 (g) Disposing of waste in a manner that may detrimentally impact a water resource	Construction and operation of slurry dams and septic tanks associated with dairies which may impact groundwater or be located with the Regulated Area of a watercourse.
Section 21 (i) Altering the bed, banks, course or characteristics of a watercourse	Use of earthmoving machines or heavy equipment such as industrial wood-chippers, felling large trees and burning woody material in the Regulated Area of a watercourse. Clearing of vegetation densely invaded with aliens. Construction of instream barriers (dams, weirs, bridges). Drilling a borehole in the Regulated Area of a watercourse.

The area within a watercourse where Section 21 (c) and (i) activities may trigger the need for an environmental authorisation is defined as the Regulated Area in Government Notice 509 of the NWA as follows:

(a) The outer edge of the 1 in 100-year flood line and / or delineated riparian habitat, whichever is the greatest distance, measured from the middle of the watercourse (Figure 23);
(b) In the absence of a determined 1 in 100-year flood line or riparian area, the area within 100 m from the edge of a watercourse where the edge of the watercourse is the first identifiable annual bank fill flood bench;
(c) A 500 m radius from the delineated boundary (extent) of any wetland or pan (Figure 23).

Furrows and canals are not considered watercourses but could be located within the regulated area of a watercourse, in which case work on these structures may require authorisation. For instance, the point at which a furrow diverts water from a stream is in the regulated area of the stream.

The NEMA regulates activities that occur both within a watercourse, as well as within 32 m of the edge of a watercourse.

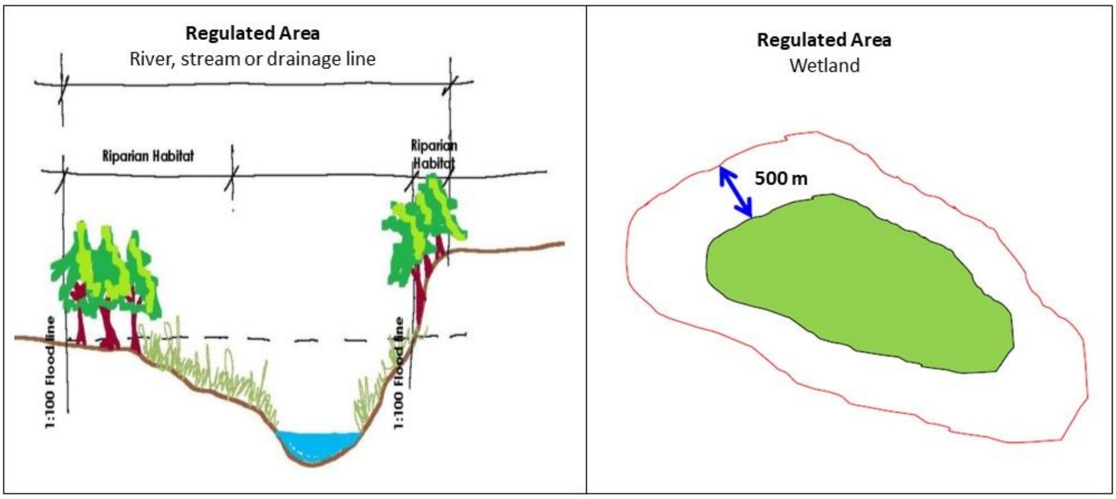


Figure 23. Extent of the Regulated Area of a river, stream or drainage line is the outer edge of the riparian zone or 1:100-year floodline (whichever is greatest; left). The Regulated Area of a wetland is 500 m from the delineated edge (right).

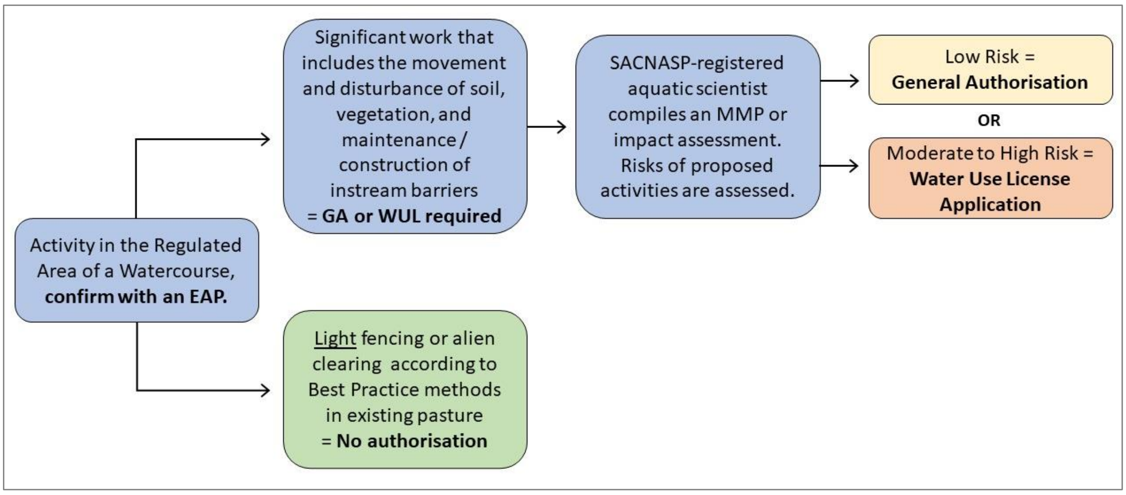


Figure 24. Process to determine the level of water use authorisation required in terms of the NWA.

The steps required to determine whether activities in the Regulated Area require an authorisation in terms of the NWA are simplified in Figure 24. It is first necessary to establish whether work is being undertaken in the regulated area of the watercourse or not. If riparian zones are the subject of management, then it is possible that either a General Authorisation (GA) or Water Use License (WUL) would be required. The level of authorisation depends on the risk associated with the proposed work which is classed as low, medium or high risk by a SACNASP-registered aquatic scientist. In most cases, work to improve or maintain watercourses and their buffers will be considered low risk which means the work can be Generally Authorised. A General Authorisation is a simpler, less complex and less costly authorisation to obtain than a Water Use License.

As much of the work usually undertaken to manage and improve riparian zones can be classed as maintenance and rehabilitation, the current approach would be to compile a Maintenance Management Plan (MMP) for all affected watercourses on a farm. In brief, such a plan would identify and classify all watercourses, determine effective buffers, and stipulate methods to improve these areas while controlling negative impacts through mitigation measures. Any other maintenance actions required for work within watercourses should be included in the plan. For instance, as dams are also classified as watercourses under the NWA, any maintenance actions such as removal of vegetation and silt to maintain capacity constitute Section 21 (c) and (i) water uses, and should be included in the MMP. The MMP would require authorisation in terms of NEMA and the NWA before being implemented. Given that most rehabilitation and maintenance work in riparian zones is undertaken to improve the system and does not typically include mass earthworks or heavy machinery, the MMP can usually be Generally Authorised in terms of the NWA and may require a Basic Assessment in terms of the NEMA.

The current NWA legislation governing General Authorisations for Section 21 (c) and (i) water uses was published in December 2023. This provides the conditions and applicability for General Authorisations and indicates when a Risk Matrix (specialist report) is necessary and under what circumstances it is not required. Once relevant Section 21 (c) and (i) water uses have been approved and registered with the Department of Water Affairs, compliance with conditions of the General Authorisation are monitored by the regulating authority. Appendix D1 of this legislation contains several actions for which a General Authorisation is necessary, but a Risk Matrix (specialist report) is not required. Actions frequently related to farming operations are listed below:

- Emergency river crossings for vehicles to gain access to livestock, crops or residences;
- Maintenance to private roads and river crossings provided that footprint remains the same and the road is less than 4m wide;
- Erection of fences provided that the fence will not in any way impede or divert flow, or affect resource quality detrimentally in the short, medium and long term.

4.1 Generic EMPr for Landcare Projects

A powerful tool for the rehabilitation and maintenance of aquatic ecosystems and their buffers is provided in the form of GN 276 (in GG44341 on 29 March 2021) of the National Environmental Management Act (NEMA) titled **Adoption of a generic environmental management programme for the management and mitigation of environmental impacts resulting from the implementation of the LandCare projects and the exclusion of these projects from the requirement to obtain an environmental authorisation** (DFFE, March 2021).

This Environmental Management Programme (EMPr) was compiled for LandCare interventions which aim to rehabilitate, conserve and enhance the productivity of agricultural land. Interventions include hard engineering or softer, less invasive actions and are often used in combination to achieve a desired objective. Three project categories are identified as follows:

1. **SoilCare:** Includes interventions such as the construction of erosion control structures, establishment of vegetation for erosion control, construction of contour banks and the clearing and preparation of new crop fields on virgin land;
2. **VeldCare:** Includes interventions such as the control of bush encroachment and alien invasive plants (AIPs), firebreak construction and maintenance, veld restoration (e.g. reseeding), fencing of homestead boundaries, fencing to facilitate rotational grazing or to protect erosion sites and cultivated areas and the provision of water points for livestock, and;

3. **WaterCare**: Includes project controlling AIPs in wetlands and agricultural areas or along rivers; water harvesting, including the construction and maintenance of water harvesting infrastructure and the removal of sand and silt from earth dams to restore capacity.

The purpose of the EMPr is to provide rules and mitigation measures which must be complied with when implementing LandCare projects. The EMPr aims to ensure compliance with the principles such as duty of care in Section 28(1) of NEMA. Generally accepted impact management measures are provided to ensure impacts are avoided, mitigated and managed in an acceptable manner. The EMPr is an environmental instrument which allows for the exclusion of activities identified in the EIA Regulations Listing Notice 1, 2 or 3 of 2014 from the requirement to obtain environmental authorisation. It is applicable in all nine provinces across South Africa.

Once a LandCare project has been identified and planned according to conditions in the EMPr, the appointed provincial coordinator must submit a declaration of compliance indicating that all parties will comply with the conditions of the EMPr. Templates are provided for all steps of the process in the gazetted EMPr. The EMPr is applicable to private agricultural lands if LandCare approves the project and provides a powerful mechanism for avoiding the need to obtain Environmental Authorisation for work which is largely beneficial in nature and has mostly generic impacts and associated mitigation measures.

4.2 Working Without Authorisation

Several activities that could benefit the condition of riparian buffer areas may be undertaken without authorisation in existing pasture environments (Table 6). In every case however, there are examples where well-intentioned activities have been undertaken in a manner resulting in negative impacts to the aquatic ecosystems, triggering the need for specialist inputs and authorisation. It is therefore best to consult with a professional in this field to ensure that work to be undertaken is planned according to Best Practice guidelines and will not cause unnecessary degradation.

If ongoing maintenance is required to maintain bridges, pivot crossings, dam siltation, dam embankments, river abstraction points, slurry dams or alien vegetation associated with watercourses across the farm, the simplest approach would be to compile an MMP and get it authorised by the relevant authorities. In this way, all maintenance activities can be included, Best Practice methods stipulated, and work can proceed without the risk of triggering rectification processes.

Where work is undertaken in the Regulated Area of a watercourse without obtaining the correct authorisations, there is a significant risk that a rectification process would be triggered (e.g. Section 24g of the NEMA) or rehabilitation would be required. Compliance, monitoring and enforcement officers from the Departments of Water Affairs and Environmental Affairs open a case which ultimately results in lengthy time delays and costs. The nett result is usually that the required authorisations are subsequently obtained under duress.

Table 6. Activities undertaken using best practice guidelines may not require environmental authorisation.

Activities where no authorisation is typically required	**Best Practice**	**Poor Practice** *Could trigger requirements for environmental authorisations*
Fencing along riparian buffers within the farm (excluding boundary fencing)	One or two strand electrical fence is appropriate. Fence excludes cattle from the watercourse, but other wildlife can move freely along the length of the watercourse. Fence must not restrict movement of wildlife or create an obstruction to the flow of water through the watercourse. Fencing should not cross streams unless on official designated cattle crossing points.	Use of mesh fencing with excessive protection (barbed / razor wire or electric strands). Fence crosses watercourses and blocks movement of wildlife (e.g. otters, mongoose, buck). Obstructs water flow through debris blockages during peak flow events.
Clearing of light to moderate density invasive alien plants	Use hand tools only (e.g. saws & tree poppers), do not disturb the soil, restrict use of herbicides in proximity to the watercourse & limit disturbance to indigenous vegetation. Methods include herbicide application to cut stumps and ring barking. All woody material must be removed from the watercourse. Follow up control must be planned and implemented.	Burning to remove woody debris in the Regulated Area. The use of heavy machinery (e.g. excavators) to push alien trees into watercourses or drag them out. Indiscriminate herbicide use. Piles of woody material left in the watercourse which alters habitat and causes debris dams.

4.3 Establishing New Pastures

Laying out and development of new irrigated or dryland pastures for grazing entails activities that may trigger the need for an environmental authorisation. It is necessary to obtain advice from a registered Environmental Assessment Practitioner (EAP) prior to embarking on any work to establish new pastures. Depending on the historic land use at the site, there may be several listed activities triggered in terms of the NEMA, and Section 21 (c) and (i) water uses of the NWA may be relevant. Proceeding without the correct authorisations in place exposes the landowner to significant risk in terms of costs and time associated with rectification processes. Some of the more common actions that trigger the need for authorisation are listed in Table Table 7.

Table 7. Typical actions associated with establishment of new pastures where authorisations are usually required.

Action	NWA Water Use	NEMA Listed Activity
Clearance of 1 ha or more indigenous vegetation* for planting pasture or other temporary crops.	No authorisation unless vegetation is in the Regulated Area of a watercourse. Then Section 21 (c) and (i) water use is applicable, and authorisation is required.	Activity 27 Authorisation required
Infilling and depositing or excavation and removal of > 5 m^3 of material (e.g. soil or sand) from a watercourse.	Section 21 (c) and (i) Authorisation required.	Activity 19 Authorisation required

* In the NEMA, indigenous vegetation is defined as any vegetation (indigenous or alien species) where the topsoil has not been disturbed for the preceding ten years. Therefore, a land unit may be almost completely invaded by alien vegetation but if it has not been ploughed or worked for > 10 years, vegetation clearance may require authorisation. An Environmental Assessment Practitioner must be consulted in this regard.

Where watercourses are present adjacent to proposed pastures, the landowner will be required to set aside and protect riparian areas with a suitable buffer zone as determined by an aquatic specialist following these guidelines. A plan to maintain or improve the benefits associated with the buffer will be developed and must be implemented. Buffer zones and the watercourse itself need to be protected during the establishment of new pastures (construction phase) especially as large amounts of soil are vulnerable to erosion and deposition into watercourses during this phase. These are all aspects which are addressed in specialist studies typically associated with an environmental authorisation.

A benefit of delineating and protecting distinct riparian buffers during the establishment of new pastures is that they can be set out and managed as separate units to the pasture from the start (Figure 25). As a result, no rehabilitation from pasture will be required.

Figure 25. A newly established irrigated pasture fenced along a 15m buffer to protect a rehabilitated unchanneled valley-bottom wetland (Southern Cape, J. Dabrowski).

5 Aquatic Buffer Guidelines

Guidelines for determining riparian and wetland buffers for the dairy sector are presented using worked examples from two case study dairy farms in the southern Cape and in KwaZulu-Natal. While much of the planning and implementation of the Riparian and Wetland Buffer Tool should be undertaken by an aquatic / wetland specialist, a comprehensive stepwise approach is provided using examples from the case study farms and elsewhere. The aim is to provide farmers and practitioners with direct insights into all the factors which influence the determination of buffers as well as land management practices on dairy farms which can reduce threats to watercourses. This guideline aims to promote a critical assessment of the condition of watercourses and land management practices which can translate to impacts. An overview of the steps required is provided in Figure 26.

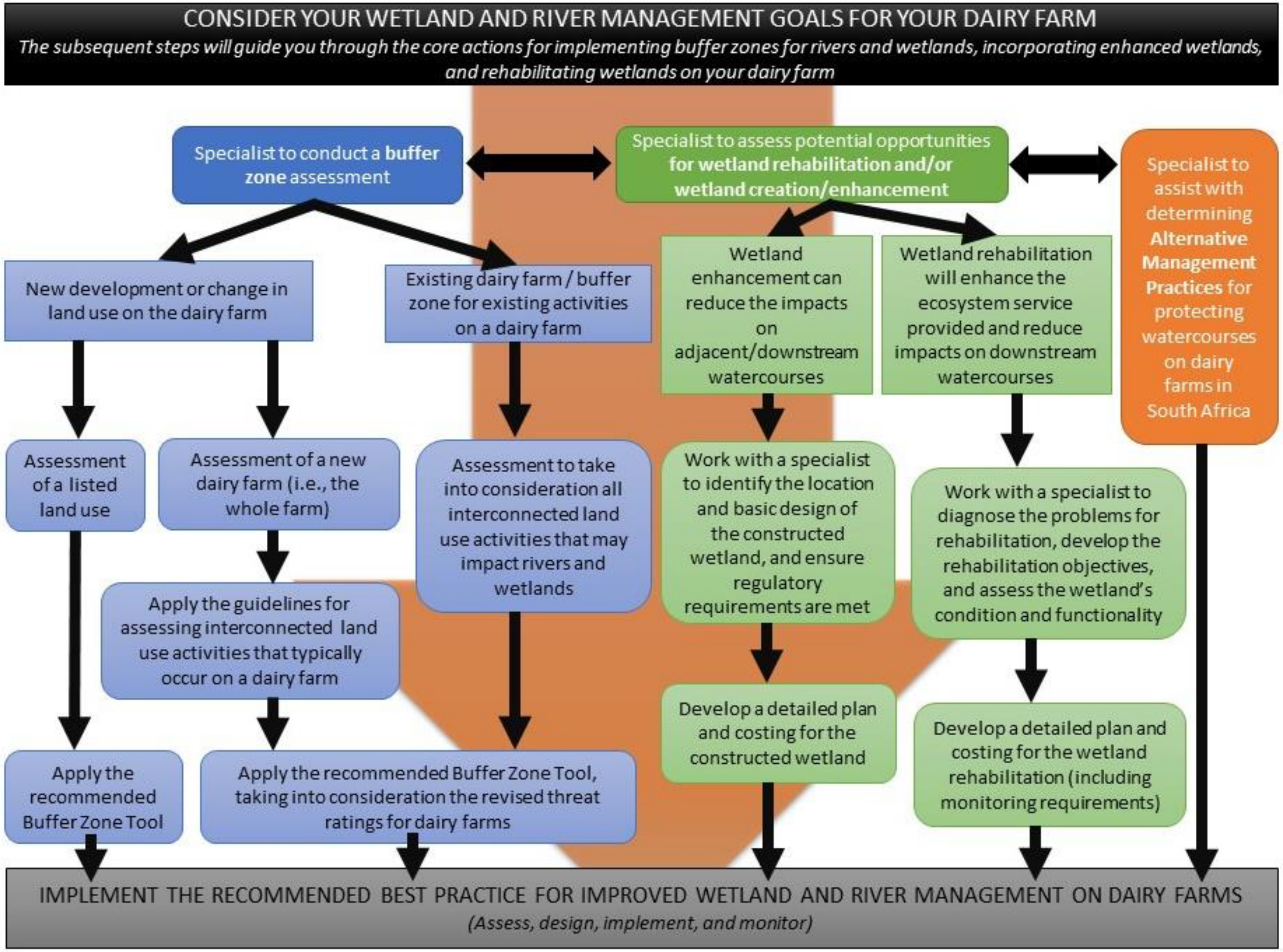


Figure 26. Summarised steps to implement riparian buffer zones and wetland enhancement on dairy farms.

5.1 Background

Case studies were conducted on two dairy farms, one in the Western Cape (WC) and the other in KwaZulu-Natal (KZN). The overall aim was the application of the national buffer zone tool to wetlands and rivers (Macfarlane and Bredin, 2017) on each farm to determine whether the existing tool is adequate for application in the dairy sector specifically. The following components formed part of the overall assessment for each case study:

- Desktop and field assessments of all watercourses across each farm including classification, delineation, and condition assessments.
- Dairy sector specific impacts to water resources were noted. Region-specific threats related to inherent environmental variables at each site were considered.
- Any existing best management practices to reduce threats to water resources were noted at each site.
- The national tool to determine buffer zone widths for different land uses was applied to each case study site under a high risk (low mitigation) scenario and low risk (high mitigation) scenario.
- An investigation into the likely benefits of implementing buffers zones on dairy farms, and a cost assessment of implementing buffer zones at the case study sites. The cost assessments took into consideration the costs of establishing and maintaining appropriate buffer zones under different management scenarios. The cost assessment included an evaluation of costs associated with the different management scenarios.

5.2 Case Study Sites: Environmental Attributes and Biodiversity

The two case study site selections were made considering the extent and variability of watercourses on the farm; the pro-active application of sustainable management practices; and the farm owners' willingness to participate. Throughout the assessment both the farm owners and managers, as well as their key consultants were engaged to help gain a better understanding of the farms' operation. The farms are located in the Southern Cape near the town of Sedgefield, and in KwaZulu-Natal near the town of Mooi River (Figure 27).

Both farms have significant water resources available with storage provided in numerous dams from perennial and non-perennial sources, as well as wetland areas. Watercourses for each farm were mapped using the National Wetland Map (5) and 1:50 000 drainage lines (DWS; Figure 27).

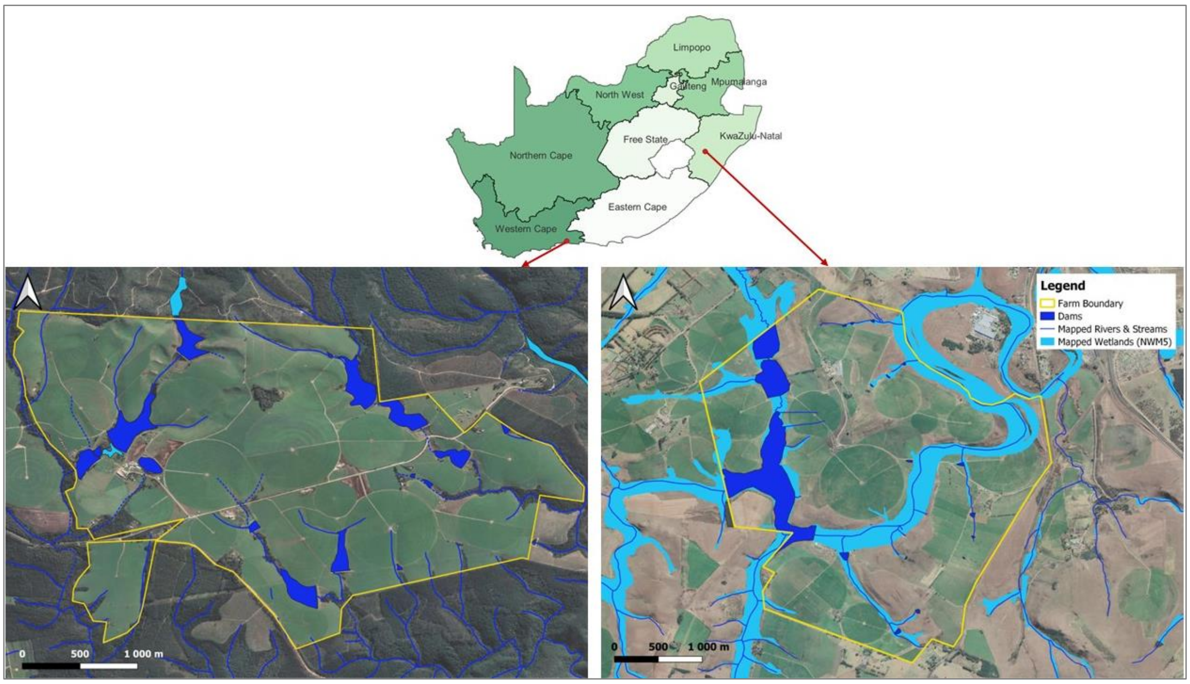


Figure 27. Case study farms in WC and KZN showing farm boundaries and mapped water resources.

Environmental attributes of each case study site are listed in Table 8 for comparison and to provide region-specific context. Most of the attributes listed are used as inputs to the riparian buffers model which calculates appropriate buffer widths.

Table 8. Environmental attributes for each case study site.

Site-specific Environmental Attributes	WC Case Study	KZN Case Study
Mean Annual Rainfall (mm)	800	800
Mean Annual Runoff (mm)	240	88
Mean Annual Temperature (°C)	16.0	15.5
Rainfall Intensity	High (Zone 3)	High (Zone 3)
Inherent Runoff Potential of Soils	Low, A/B	Moderate, B/C North of Mooi River Moderate – High, C South of Mooi River
Soil Erodibility (K Factor)	Very High (0.74)	Low, North of Mooi River (0.24) Moderate, South of Mooi River (0.39)
Salt Affected Soils (mS/m)	< 200	< 200
Geomorphological Zone	Upper Foothills	Lowland River
Perennialism	Intermittent Streams (< 3 months flow)	Perennial River system (> 9 months flow)
Average Slope of the Catchment	6-8%	< 3%
Retention Time	Generally free flowing	Generally slow moving

Riparian buffers play a critical role in maintaining essential habitat for aquatic species that may be rare or unique at some level, and are also important as corridors for the movement, feeding and breeding of wildlife. Significant site-specific conservation features must be identified at the desktop level and then verified during site assessments or through consultation with specialists. Conservation features for each case study site are listed in Table 9.

The Department of Forestry, Fisheries and the Environment (DFFE) Screening Tool provides a list of plant, animal and invertebrate Species of Conservation Concern (SCC) based on the farm location at a desktop level. The list of SCCs provided in Table 9 was pre-screened to include animals and plants that would benefit from improved habitat connectivity or those that are strongly associated with riparian zones or aquatic habitats (Table 9). Discipline-specific specialist assessments were not completed for each case study site, but the listed SCCs indicated in Table 9 could benefit from improving watercourse habitat whether they already occur in the system or could potentially move into the habitat in the future.

Table 9. Site specific features of conservation concern.

Site-specific Conservation Features	WC Case Study	KZN Case Study
Animal Species of Conservation Concern	African Marsh Harrier (LC, Decreasing) Knysna Warbler (VU) Knysna Leaf-folding Frog (EN)	Grey Crowned Crane (EN) Wattled Crane (VU) African Marsh Harrier (LC, Decreasing) Lesser Jacana (LC) African Grass Owl (LC) Long-toed Tree Frog (EN) Oribi (LC, Decreasing) Spotted-necked Otter (NT, Decreasing)
Plant Species of Conservation Concern	None listed in association with seeps, wetlands, or streams.	*Lotononis virgata* (VU) *Erica cooperi var. cooperi* (Rare) *Geranium ornithopodiodes* (EN)
Site Sensitivities	Aquatic Critical Biodiversity Areas Strategic Water Source Area Wetlands Freshwater Ecosystem Priority Area Estuarine Lake Catchment (7th most important in SA)	Critical Biodiversity Area 1 Ecological Support Area: species FEPA sub-catchments Protected Areas Expansion Strategy Strategic Water Source Areas Vulnerable Ecosystem
Vegetation Type	Garden Route Granite Fynbos (CR)	Mooi River Highland Grassland (EN)

CR=Critically Endangered; EN=Endangered; VU=Vulnerable; NT=Near Threatened; LC=Least Concern as defined by the International Union for the Conservation of Nature (IUCN).

Both case study farms have extensive wildlife including commonly encountered species as well as potentially rare or threatened species. During a wildlife survey on the W Cape farm conducted by SANParks, camera traps identified a range of wildlife that would benefit from improved buffer zones and connectivity between habitats (Figure 28).

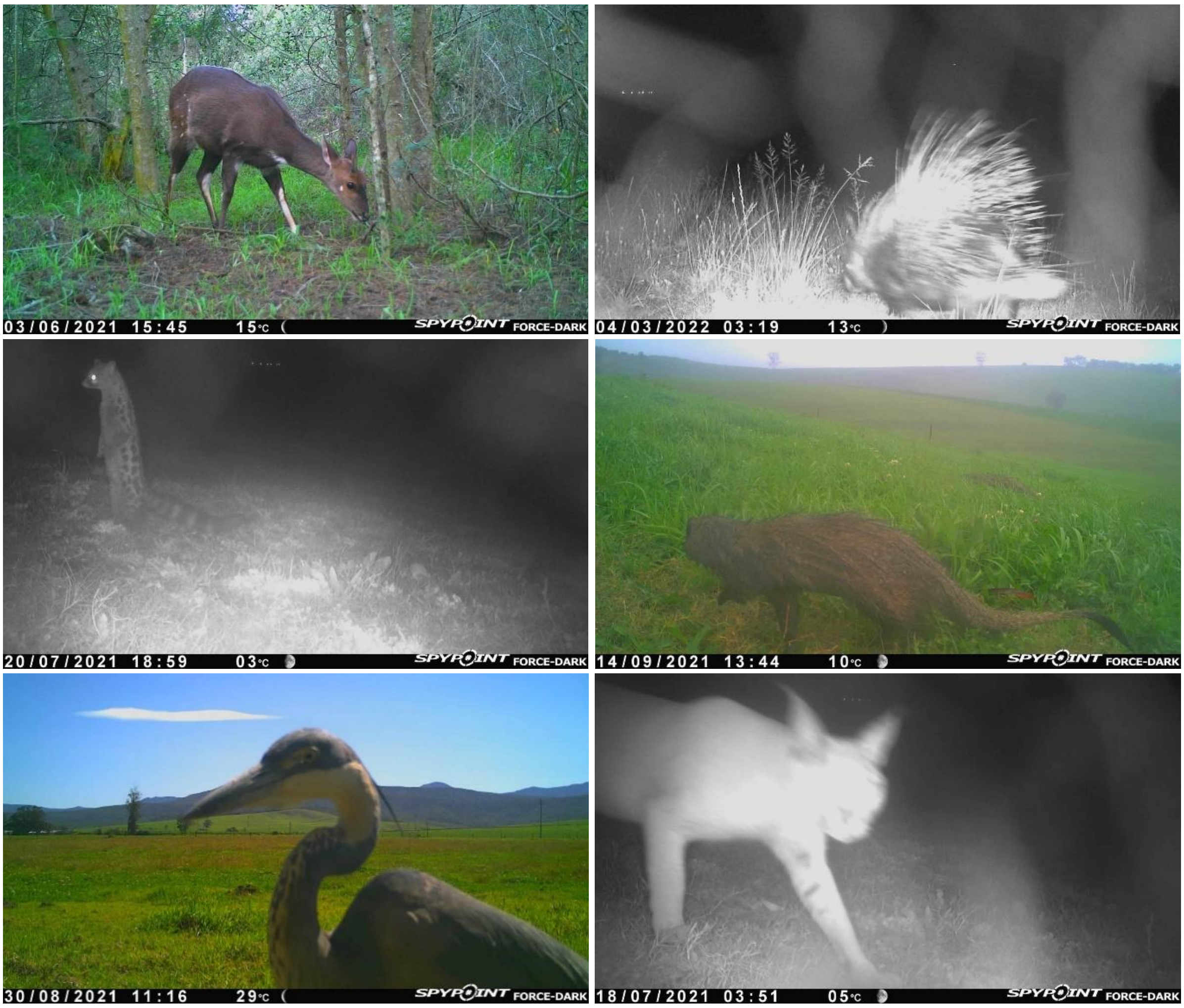


Figure 28. Images from a camera trap at the WC farm site indicating some of the wildlife on site that could benefit from improved aquatic buffer zones and wetland habitat.

5.3 Site Assessment of Watercourses

Site visits were undertaken on each farm to inspect mapped watercourses to:

- Verify the presence of mapped watercourses (as indicated in Figure 27);
- Classify watercourses and different hydrogeomorphic (HGM) units using Level 4 of the classification system developed by Ollis *et al*. (2013). These were subsequently grouped as wetlands, dams and streams/rivers in order to simplify mapping and spatial layers;
- Identify farming practices that are negatively impacting watercourses as well as examples of good management which protects or enhances aquatic ecosystem health. Using this information along with other impacts present, Determine the Present Ecological State (PES) of wetland and riparian zone condition using the WET-health framework (Macfarlane et al., 2020) for wetlands or the Index of Habitat Integrity (IHI; Kleynhans, 1996) for riparian zones of rivers, streams or drainage lines. The method selected depends on the classification as either a wetland or stream/river system.

5.3.1 Delineation of Watercourses

The delineation of wetlands and riparian zones followed methods prescribed by DWAF (2005): Wetlands are delineated using a combination of features including the presence of soil or vegetation indicative of periodic or permanent waterlogging of the soil. Riparian zones are delineated by the distinctively different plant species of adjacent areas, containing species similar to adjacent areas but exhibiting more vigorous growth forms.

Each watercourse was divided into relevant hydrogeomorphic units (HGMs) and classified according to Ollis et al. (2013). At the Western Cape farm all watercourses defined as drainage lines or streams have intermittent flows which are further restricted by the presence of numerous dams along each drainage system (Figure 29). There are no perennial watercourses on the farm. Wetlands were mostly unchanneled valley bottom or hillslope seeps. There were numerous small wetlands or flow paths under pivots where 'wetness' is augmented by irrigation. These are small drainage features following topographic lows and are characteristic of wetlands but are undoubtedly wetter than their reference state. The site assessment revealed that the wetland area is greater in extent than that mapped in the NWM5 for the WC farm, while watercourses on the KZN farm were fairly similar to those mapped (Figure 27).

When mapping watercourses for spatial analysis, polygons were created along the riparian zone of streams and zones of vegetation difference for wetlands. Historical aerial photos and satellite imagery were used along with recent Google Earth images to most accurately depict the extent of each watercourse (Figure 29). Polygons were then split according to unique features of the adjacent riparian zone (Figure 29). For instance, a greater slope along with irrigated fields adjacent to a stream poses a more significant risk to water quality in the stream than dryland pasture on flat terrain.

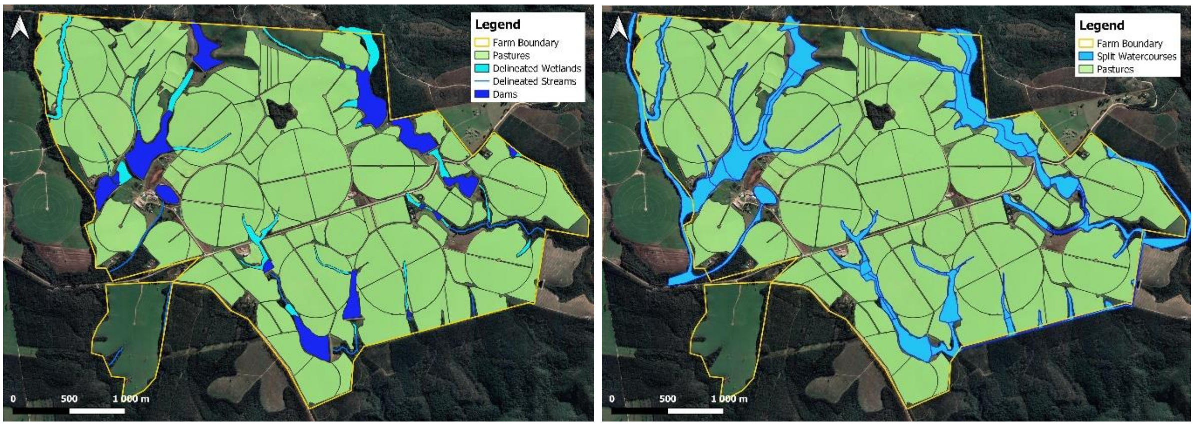


Figure 29. Delineated wetlands, streams and dams (left) which were then split based on environmental and land use attributes of riparian areas (right) using the WC farm as an example.

5.3.2 Present Ecological State of Wetlands and Riparian Zones

The commonly used DWS categories, which allow for the evaluation of the Present Ecological State (PES) or condition of aquatic ecosystems were used (Table 10). For wetlands, the Wet-Health framework (Macfarlane *et al*., 2020) was taken into consideration for the assessment of the condition of the wetlands at the case study sites.

Table 10. Health categories used to evaluate the PES or condition of aquatic ecosystems (Macfarlane *et al.*, 2020).

HEALTH CATEGORY	DESCRIPTION	RANGE
A	Unmodified, natural.	0-0.9
B	Largely natural with few modifications. A slight change in ecosystem processes is discernible and a small loss of natural habitats and biota may have taken place.	1-1.9
C	Moderately modified. A moderate change in ecosystem processes and loss of natural habitats has taken place but the natural habitat remains predominantly intact	2-3.9
D	Largely modified. A large change in ecosystem processes and loss of natural habitat and biota has occurred.	4-5.9
E	The change in ecosystem processes and loss of natural habitat and biota is great but some remaining natural habitat features are still recognizable.	6-7.9
F	Modifications have reached a critical level and the ecosystem processes have been modified completely with an almost complete loss of natural habitat and biota.	8-10

Wet-Health (Macfarlane *et al.*, 2020) provides an appropriate framework for undertaking an assessment to indicate the condition of a wetland system. The outcomes of the assessment also highlight specific impacts, therefore highlighting issues that should be addressed through mitigation and potentially rehabilitation interventions. The wet-health approach relies on a combination of desktop and on-site indicators to assess various aspects of wetland condition, including:

- **Hydrology**: defined as the distribution and movement of water through a wetland and its soils.
- **Geomorphology**: defined as the distribution and retention patterns of sediment within the wetland.
- **Vegetation**: defined as the structural and compositional state of vegetation.
- **Water quality**.

In general, the PES determined for watercourses on both study sites ranged between **C, Moderately Modified** to **D, Largely Modified**. Neither farm had watercourses in better or worse categories. Some of the main impacts affecting the ecological state of watercourses from both sites are presented in Figure 30. The presence of numerous dams with no provision for the ecological reserve, results in serious habitat degradation and impacts to aquatic biota downstream. Alien vegetation was commonly observed growing in watercourses below dams. Large trees such as black wattles can grow densely within the riparian zone and their roots cause streambank armouring. This exacerbates the down-cutting and erosion of streams leading to bank collapses. A common method to control aliens in the southern Cape is to use heavy machinery to push them into the watercourse, where they are either left to decompose (which takes many decades) or they are burnt. Inevitably alien seedlings re-establish along the now highly disturbed banks, and without follow up control this damaging practice was undertaken in vain. Several examples of fencing to exclude cattle from watercourses were observed which was positive, however in most cases fence lines were very close to the watercourse edge with no allowance for riparian vegetation or a buffer. To a large extent, riparian vegetation was replaced by pasture along several watercourses.

Figure 30. A selection of commonly encountered impacts which influenced the PES of watercourses.

5.4 Threat Rating Assessment

Once all watercourses on the farm have been verified, classified and their ecological condition assessed, the next step of the assessment is to select appropriate threat ratings posed to the aquatic ecosystem by dairy farming.

The risk of a proposed activity for water resources is used as the primary driver for defining the level of mitigation (including buffer zone width) required. In this context, a risk assessment is a process of gathering data and making assumptions about the probable effects on the environment based on the probability of an event occurring, the factors that could bring about that event, likely exposure levels, and the acceptability of the impact resulting from exposure.

Where risk is high, a more conservative approach (e.g., larger buffer zone) is recommended, whereas a less conservative approach (e.g., narrower buffer zone) is regarded as appropriate where risks are low. For determining buffer zones, the risk is based on two criteria, namely (i) the threat or potential impact of the activity on the resource, and (ii) the sensitivity of the water resource that would be affected by the proposed development/activity. These are integrated into a risk score which is then used to inform the level of mitigation required (refer to Macfarlane and Bredin, 2017).

5.4.1 Refined Threats for the Dairy Sector

The Buffer Tool uses a basic threat assessment as the initial step to inform decision-making. This relies on generic threat tables. While these threat ratings must be reviewed by an aquatic specialist as part of the site-based assessment, it is important that the initial threat ratings adequately cover the likely threats from the land use of interest. The current threat ratings available for selection are designed to cater for individual developments/changes in land uses that may take place on a dairy farm. They do not provide an adequate representation of threats stemming from the interconnected activities that typically take place on an existing dairy farm (e.g. rotating pasture with maize production). Based on selection of the Sector as ‘Agriculture’ the Sub-Sectors and associated activities listed in Table 11 were all considered as likely activities that could take place on a dairy farm. Those indicated in grey are typical dairy farm activities, and the other activities are potential activities that may take place on specific dairy farms.

Table 11. Description of relevant land uses/activities included in the threat assessment (adapted from the Buffer Tool).

SECTOR	SECTOR DESCRIPTION	SUB SECTOR	DESCRIPTION OF LAND USE / ACTIVITY
Agriculture	Agricultural-based land-use activities that range from the large-scale commercial production of crops and timber to small-scale subsistence crop farming and livestock rearing. May be associated with rural and/or urban contexts.	**Intensive livestock grazing operations**	Includes the rearing and husbandry of a range of domesticated livestock (e.g., cattle, sheep, horses, goats) on cultivated pastures, typically supplemented with irrigation.
		Concentrated livestock operations	Livestock intensive operations associated with areas of concentrated animal activities including (1) Dairies; (2) Piggeries; (3) Poultry Facilities; (4) Stables, (5) Sale yards (6) Feedlots and (7) Zoos.
		Sludge dams associated with concentrated livestock operations	Sludge dams containing wastewater from intensive livestock operations.
		Irrigated commercial cropland	The agricultural production of produce including crops, trees, seeds, fruit, vegetables or other plant material using conventional means of irrigation.
		Dryland commercial cropland with Annual rotation	The agricultural production of produce including crops, vegetables or other plant material using conventional tillage cultivation with no irrigation and requiring annual re-establishment.
		Dryland commercial cropland with infrequent rotation	The agricultural production of produce including crops, trees, seeds, fruit, or other plant material using conventional tillage cultivation with no irrigation. Re-establishment takes place on a bi-annual or more infrequent basis.

A stakeholder workshop, with representatives from the dairy sector (pasture and soil specialists) and the Department of Water and Sanitation (DWS), was held to discuss the threats posed by typical dairy farming to watercourses. The outcome of the workshop was a refinement of dairy farming specific threats that should be used in the Buffer Tool (Table 12). Ideally one would select 'Intensive livestock grazing operations' as the Sub-Sector, and then manually adjust the standard threat ratings for a more conservative assessment using the threat values indicated in Table 12. For instance, instead of Nutrient Inputs being rated M for Medium, the threat rating should be adjusted to VH for Very High as this incorporates the range of interconnected land uses and activities that typically occur on dairy farms. Note that only operational phase threats and resulting buffers are applicable, as the construction phase is not relevant to the establishment of buffer zones.

Table 12. Recommended desktop threat ratings that should be used in the Buffer Tool to determine appropriate buffer zones on dairy farms.

Sub-Sector Land Use / Activity	Desktop Threat Ratings									
	Operational Threats									
	Alteration to flow volumes	Alteration of patterns of flows	Sediment inputs & turbidity	Nutrient inputs	Toxic organic contaminants	Toxic heavy metals	Alteration of acidity (pH)	Increased inputs of salts	Elevation of water temperature	Pathogen inputs
Intensive livestock grazing operations	VL	L	M	M	L	L	VL	VL	VL	M
Concentrated livestock operations	L	M	H	VH	M	L	L	L	VL	H
Sludge dams associated with concentrated livestock operations	M	VL	VL	VH	H	L	M	VL	VL	VH
Irrigated commercial cropland	H	M	H	H	H	VL	L	H	VL	VL
Dryland commercial cropland – *Annual rotation*	L	L	H	M	M	VL	L	L	VL	VL
Dryland commercial cropland – *infrequent rotation*	M	L	M	M	M	VL	L	L	VL	VL
Dairy farming – a combination of all six land uses listed above (i.e., interconnected activities)	**H**	**M**	**H**	**VH**	**H**	**L**	**M**	**H**	**VL**	**VH**

5.4.2 *Region-specific Threat Ratings*

Agroecosystems encompass communities of plants and animals which interact with the physical and chemical environment to generate products for human consumption. Management practices to manipulate the physical and chemical environment for agricultural production are region-specific, driven by environmental variation in factors such as rainfall, soil types, and naturally occurring vegetation. While the adjusted threat ratings presented in Table 12 may be applicable in most dairy farming contexts across South Africa, local specialist knowledge of region-specific threats should be applied to further refine the threat ratings if necessary.

Parts of the southern Cape present a good example where threat ratings were further refined. An understanding of the reference conditions of aquatic ecosystems in their natural state is required. Streams and rivers draining the Outeniqua Mountains are naturally acidic with pH ranging between

3.7 and 6.8, low conductivities ranging between 10 and 50 µS/cm and very low nutrients (oligotrophic). Catchment soils are generally acidic, sandy and nutrient-poor (Midgley and Schafer, 1992; Swanepoel et al., 2015). Poorly drained duplex soils with a high texture contrast and a shallow topsoil (50-70cm) are common. Freshwater ecosystems of the southern Cape have a high conservation value due to their rich Gondwanaland relict aquatic macroinvertebrate fauna that are sensitive to temperature variations (Rivers-Moore et al., 2018). High rates of species endemism occur in macroinvertebrates, diatoms (algae) and certain fish species that are adapted to these unique physico-chemical conditions.

Natural rangelands of the southern Cape had inherently low animal production potential and cultivated pastures had to be established to support dairy cattle (Swanepoel *et al*., 2015). To improve production on dairy farms, certain aspects of these intrinsic environmental features (especially soil) are manipulated. Productive pasture crops were established, fertilised, and irrigated. Soils were conventionally tilled from the 1960s to the 1980s until minimum tillage was widely implemented in the 1990s. Despite this, significant change in physical management of the soil, lime and fertiliser guidelines that were developed for annual pastures under conventional tillage were widely followed on minimum tillage systems. This has led to excessive loading of soils with extractable phosphorus and zinc (Swanepoel *et al.,* 2015). Liming agents such as calcitic or dolomitic lime are applied to raise the soil pH as the natural pH is too acidic to support optimal production. Excess CaCO2 can enter watercourses through surface runoff or interflow through soil from adjacent fields. Together with higher Total Dissolved Solids (TDS) and increased turbidity due to suspended sediments, the result is watercourses that are more alkaline and buffered. The pH values of streams flowing through dairy farms in the southern Cape usually range from 7.5 – 8.0.

Dairy farming in the southern Cape occurs between the mountain foothills and coastal plateau on soils generally formed from granite or shale. High Na (sodium) levels are often present in soils of cultivated pastures and are significantly elevated when compared to uncultivated 'virgin' soils (Swanepoel *et al*., 2015). Groundwater in the southern Cape is often naturally enriched with Na, and therefore irrigation with groundwater as well as slurry leads to enrichment of soil with Na. Excess Na in the soil requires the application of gypsum which replaces Na with Ca resulting in Na leaching out of the soil. Solubilised Na is leached from the soil profile and into the receiving watercourse either as surface runoff or through interflow. This effect is exacerbated in shallow soils with limited drainage frequently encountered in the region. Fertiliser such as KCl is frequently used in preference to K_2SO_4 because it is cheaper. However, the Cl ion binds with Na in the soil forming a highly soluble compound which is also susceptible to washing out of the soil profile. Along with other soil ameliorants and practices such as irrigation with slurry water this has the effect of increasing the electrical conductivity of surface waters substantially, and values ranging from 2 500 to 6 200 µS/cm have been measured during water quality monitoring of receiving streams on dairy farms in the area.

Alien invasive plant species have established along many riparian zones and wetlands. These plants are dominated by species such as black wattle (*Acacia mearnsii*), blackwood (*Acacia melanoxylon*), bugweed (*Solanum mauritianum*) and bramble (*Rubus spp.).* While these species have many negative impacts on watercourses, they do replace the shade provided by indigenous species, which moderates water temperature. A common practice undertaken on farms in the southern Cape to control aliens is to push alien vegetation into the watercourse with an excavator, and then burn it. Among the many negative impacts of this practice, exposure to temperature extremes by sensitive taxa is relevant to the threat ratings selection (Rivers-Moore *et al*., 2018).

Local knowledge of the aquatic environment and management practices routinely applied to manipulate environmental conditions result in an adjusted threat rating for the southern Cape with higher risk levels for altered pH, increase in salts, and elevation of temperature (Table 13).

Table 13. Recommended desktop threat ratings for dairy farms in the southern Cape.

Land use/activity	Desktop Threat Ratings									
	Operational Threats									
	Alteration to flow volumes	Alteration of patterns of flows	Sediment inputs & turbidity	Nutrient inputs	Toxic organic contaminants	Toxic heavy metals	Alteration of acidity (pH)	Increased inputs of salts	Elevation of water temperature	Pathogen inputs
Dairy farming in the southern Cape – a combination of all six land uses considering regional threats (i.e., interconnected activities)	**H**	**M**	**H**	**VH**	**H**	**L**	**H**	**VH**	**M**	**VH**

5.5 Threat Reducing Mitigation Measures

The preceding section is largely a desktop assessment of the threats posed by dairy farming in general with region-specific adjustments recommended where applicable. As threat levels related to the land use directly influence the buffer width determined by the Buffer Tool, it is necessary to consider any management actions that mitigate the impacts of identified threats. These will be highly contextual and may vary between regions and farms within regions. A comprehensive site assessment and meeting with farm management is recommended to determine the extent to which management interventions are translating to reduced threats to aquatic ecosystems. Examples of the types of management actions that reduce the operational threats are provided in Table 14. Where there is evidence to this effect, the threat ratings can be downgraded accordingly, resulting in a reduced buffer width.

Table 14. Mitigation measures aimed at reducing threats in the dairy sector.

Operational Threat	Mitigation Examples
Alterations to flow volumes	• Trim pump impellers where pressures are unnecessarily high. • Install soil moisture probes to inform irrigation scheduling and reduce wastage. • Install Variable Speed Drives on irrigation pumps to ensure efficient irrigation at the correct pressure. • Manage stormwater to disperse surface runoff and avoid concentrated flows wherever possible. • Avoid cultivation on steep slopes where infiltration rates are low and runoff is high. • Slot lines made along contours to prevent formation of concentrated flow paths downslope.

	• Control alien vegetation responsible for lowering the water table and abstraction of high volumes of water. • Plant multi-species perennial pastures with mixtures including chicory, lucerne, tall fescue, cocksfoot, plantain, clover, kikuyu, and perennial ryegrass. There are numerous soil health benefits of this practice, but it also promotes water infiltration and water holding capacity.
Alteration to patterns of flows	In addition to the above examples: • Patterns of flows can be improved by implementing the ecological reserve to ensure sufficient water is present to sustain the aquatic ecosystem. • Use soil moisture probes and irrigation scheduling to avoid over-watering.
Sediment inputs and turbidity	• Maintain a ‘No till’ approach once fields have been prepared. • Using slotting to reduce soil compaction and improve aeration instead of mechanical ripping. • Avoid ripping compacted soils as this promotes erosion and the soil recompacts rapidly following this treatment. Preferably plant deep-rooted species such as chicory, plantain, lucerne or tall fescue. • Sow cover crops on maize lands to prevent runoff of sediment and nutrients and encourage infiltration. Maize alone has minimal capacity for flow interception. • Move cattle between pastures along stable roads to prevent widespread trampling and soil disturbance. • Keep cattle fenced out of all natural watercourses. Rather provide drinking water troughs on hardened surfaces. • Control alien vegetation along stream banks where channel incision occurs due to the rooting patterns of alien trees. Preferably ring-bark trees on the banks to preserve a degree of shading and prevent disturbance of the soil which would lead to erosion. • No burning of vegetation in or adjacent to watercourses as this results in an increase in turbidity. • Ensure stormwater off farm roads is well managed and does not carry high silt loads into watercourses. Vegetated swales (roadside drains) work effectively to prevent this.
Nutrient inputs	• Apply fertilisers based on precision farming methods (intensive soil sampling; precision fertiliser application which avoids paddock edges, watercourses, roadways), considering the growth stage of plants, physico-chemical attributes of the soil, season, and potential impacts to water quality. • Avoid irrigating wastewater onto areas that slope towards watercourses.

	• Use biocatalysts to accelerate the decomposition of solids in slurry dams. This also reduces siltation and the risk of overflows entering nearby watercourses. • Separate solid and liquid wastes to reduce storage volumes required in slurry dams. • Ensure wastewater (slurry) dams have a clay or plastic liner to prevent contamination of groundwater. • Prevent defecation by livestock in watercourses by preventing access.
Toxic organic contaminants	• Do not use pesticides during windy conditions or prior to rainfall to prevent excessive spray drift and runoff entering watercourses. • Use pesticides according to the instruction leaflet supplied in terms of the volumes for application, mixing volumes, and risk reduction. • Do not spray pesticides in the riparian zone. If herbicide is needed to kill alien vegetation, then apply as a gel to cut stumps. Preferably ring-bark large alien trees in wetland and riparian zones. • Refuelling area, fuel stores, and vehicle maintenance areas located well away from any watercourse.
Alteration of acidity (pH)	• Apply calcitic lime (or dolomitic lime in KZN) based on precision farming methods considering the species growth stage of plants, soil chemistry, season, and potential impacts to water quality.
Increased inputs of salts	• Use fertilisers that are least likely to leach salts. For example, chloride is more rapidly leached from the soil than sulphate, and therefore potassium sulfate would be the preferable form of potash compared to potassium chloride. • Only use gypsum in well drained soils as waterlogging will lead to the concentration of Na in soil which can then be easily leached. • Include deeply rooted plants in pasture mixes and irrigate to saturate the full profile less frequently than more frequent, shallow irrigation, which results in high concentrations of Na in the soil due to evaporation.
Elevation of water temperature	• No heavy machinery permitted in riparian zones. • Alien vegetation to be controlled in a manner that preserves shade or shaded sections. Blocks can be selectively cleared, or trees may be ring-barked. • Riparian zones cannot be burnt deliberately.
Pathogen inputs (Similar mitigation for Nutrient inputs)	• Minimise irrigation with slurry water where runoff leads directly to watercourses on sloping ground. • Line slurry dams to reduce the risk of pathogens entering groundwater. • Restrict cattle access from watercourses to prevent instream defecation.

Many of the mitigation measures mentioned in Table 14 are fully or partially implemented at both case study farms. Both farms have adopted a no- to minimum-till approach to pasture management with multi-species pastures which improve water holding and infiltration, as well as trap nutrients and sediment in runoff. The KZN farm was involved in an irrigation efficiency study to reduce water wastage which identified potential savings of 232 049 m^3 per annum, and many of the recommended water conservation and demand measures have since been implemented. Both farms have partially implemented the exclusion of cattle from watercourses through fencing. Fertiliser application rates are informed by detailed soil testing on a regular basis to prevent loading pastures and to save on costs. This also prevents excessive leaching of nutrients to watercourses.

5.6 Buffer Zone Assessment

The Buffer Tool was applied to each of the case study farms under a low mitigation and a high mitigation scenario. Low mitigation is the highest risk scenario using the default threat ratings. In contrast, the high mitigation scenario assumes the best hypothetical threat reduction by implementing most of the mitigation measures in Table 14. This does not mean that all threats were mitigated to a Very Low level, rather they were adjusted to the best-case scenario that could be expected given appropriate mitigation actions.

5.6.1 Low Mitigation Scenario

The calculated buffer widths ranged between 18 - 21 m on the southern Cape farm and between 20 - 30 m on the KZN farm (Table 15). The actual buffer selected within this range was dependent on refined features selected for each segment which included the slope, vegetation characteristics, soil permeability, adjacent land use and micro-topography of the buffer zone. Due to the scale of both farms, a selected sub-section of the mapped buffer areas on the southern Cape farm is presented in Figure 31. Areas where buffers overlap with pasture are outlined in yellow. Watercourses indicated in Figure 31 include dams, wetlands and streams and buffer width varies according to the adjacent slope and land use (irrigated or dryland pasture).

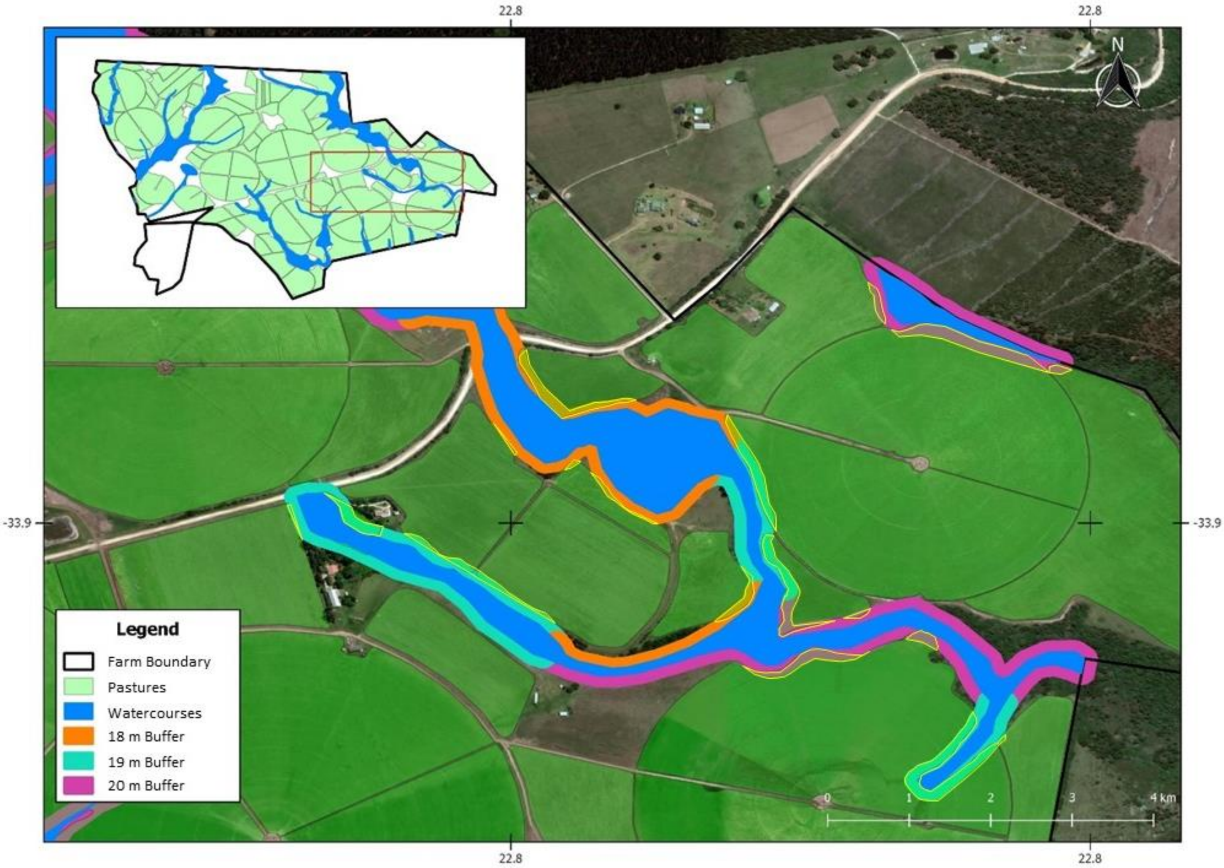


Figure 31. Enlargement of a mapped portion of the southern Cape farm indicating buffers under a Low Mitigation scenario. Note areas of buffer overlap with pasture outlined in yellow.

5.6.2 High Mitigation Scenario

Under a high mitigation scenario, the buffer widths ranged between 5 – 10 m and 5 – 12 m respectively on the southern Cape and KZN farms (Figure 32; Table 15). A 5 m buffer at the lowest end of the extreme would only be applicable in a very low risk scenario where the adjacent land use is dryland pasture with no tillage or crop rotation on generally flat ground with cattle exclusion fencing. Buffer measurements extend from the edge of the defined watercourse area (stream riparian zone or wetland area). As expected, the area of overlap by buffers into current productive pastures is significantly reduced under a High Mitigation scenario by over 50% on both farms (Table 15). The cost implications of this difference are further explored in the Cost Benefit Analysis.

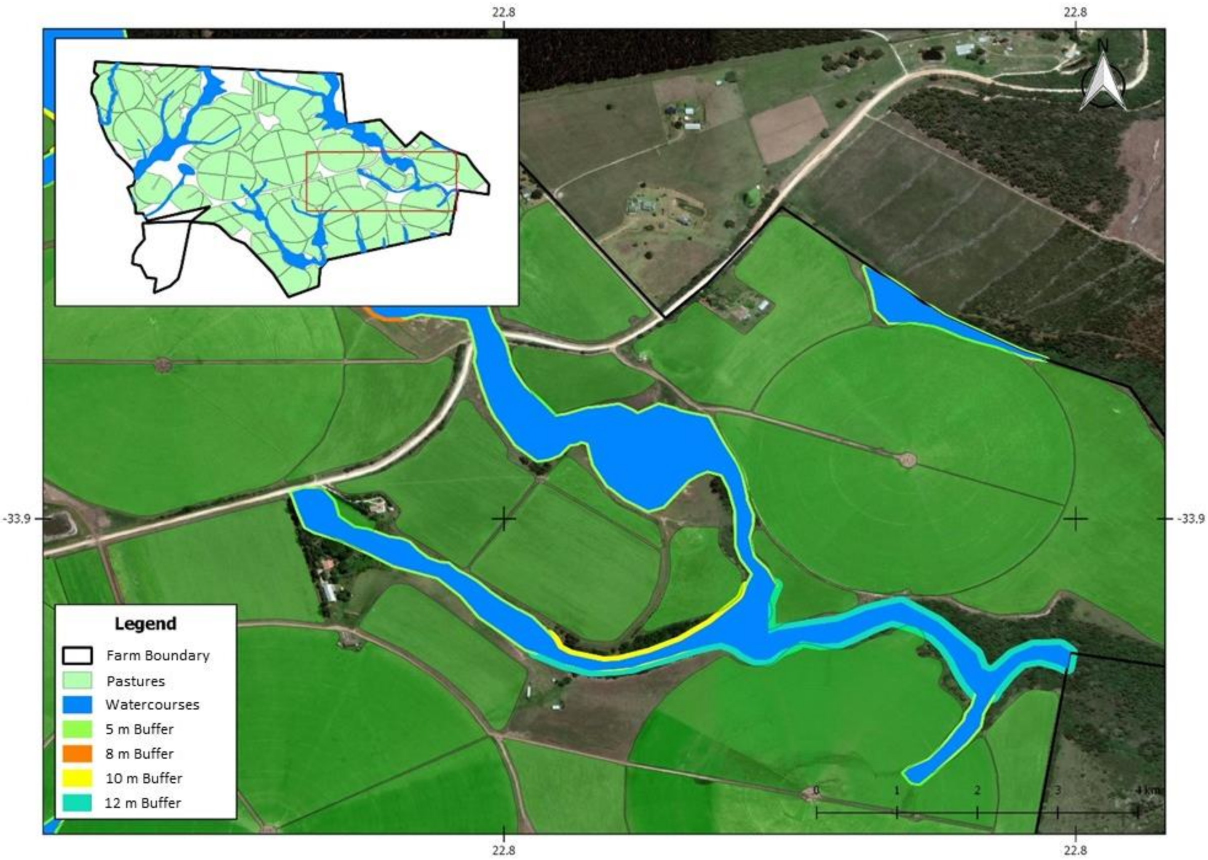


Figure 32. Enlargement of a portion of the southern Cape farm indicating buffers under a High Mitigation scenario.

Table 15. Summarised differences in buffer widths under high and low mitigation scenarios on both case study farms.

Farm	Mitigation level	Range of Buffer Widths	Total Pasture Area (ha)	Pasture Area Loss Due to Buffer Overlap (ha)
Southern Cape Farm	Low	19-21 m	736.24	34.48
	High	5-12 m		12.09
KwaZulu-Natal Farm	Low	20-30 m	549.71	26.12
	High	5-10 m		11.28

5.7 Buffer Zone Limitations

5.7.1 Point-source Discharge

A well-known limitation of buffer zones is that they provide no protection from point-source discharges. As such, buffer zones are not effective mitigation measures against discharges from point-source wastewater discharges on dairy farms. Whilst assessing the case study sites it became apparent that there are a number of activities that may result in concentrated flows of dairy effluent directly and / or indirectly into adjacent watercourses. Linear drains provide an example on the KZN farm (Figure 33). In these situations, the creation or enhancement of wetlands to promote lower flow velocities, infiltration, sedimentation and nutrient uptake would be recommended, and are discussed in the section of this report on wetland enhancement. However, if the linear drain contains pure wastewater, then a constructed wetland could be a suitable alternative.

Figure 33. Examples of linear drains on the KZN farm site.

5.7.2 Watercourses Under Pivots

It has already been mentioned that irrigation pivots create wetter wetlands, flow paths and streams on irrigated pastures than under reference / natural conditions. Fenced buffers around these watercourses would prevent cattle access but have limited benefit in terms of water quality as the pivot irrigates directly overhead when crossing the watercourse (Figure 34).

Figure 34. End of a pivot that irrigates into a wetland in the southern Cape, fortunately on flat ground where impacts can be mitigated to an extent (J. Dabrowski).

If fertilization and/or wastewater is managed through pivot irrigation, this introduces nutrients directly into the watercourse and no amount of buffering can prevent this. This issue is a common occurrence in the southern Cape as indicated in a 100 km^2 of predominantly dairy farming area (Figure 35), and therefore warrants discussion as to how this impact can be mitigated. Mitigation measures which avoid or minimise impacts to watercourses when planning new pivots should be implemented. The mitigation measures discussed in this section can be applied to both new and existing irrigated fields (Table 16).

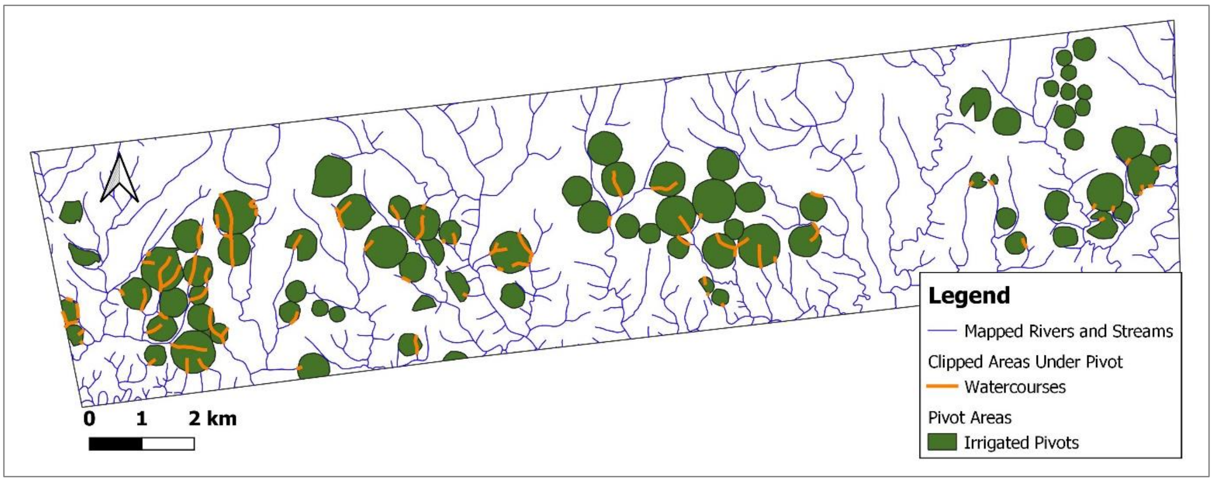
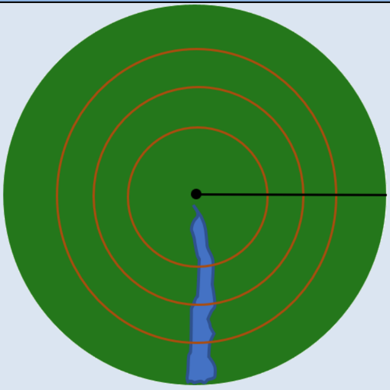
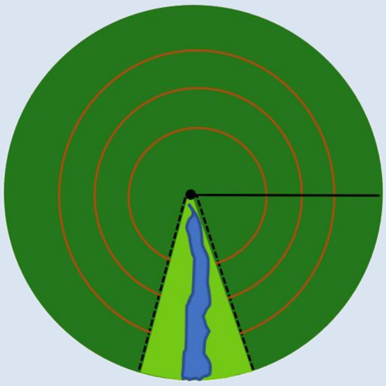
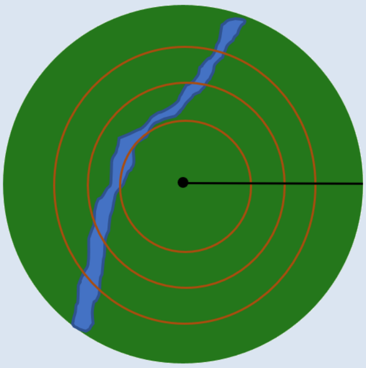
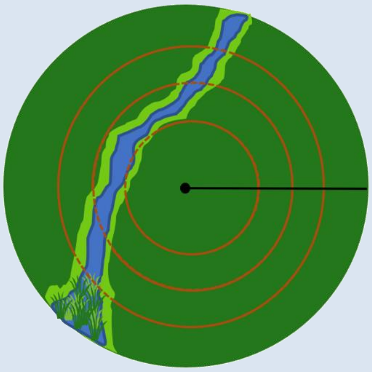
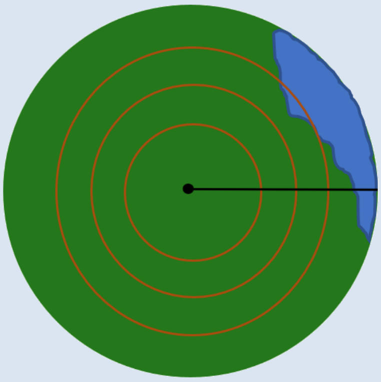
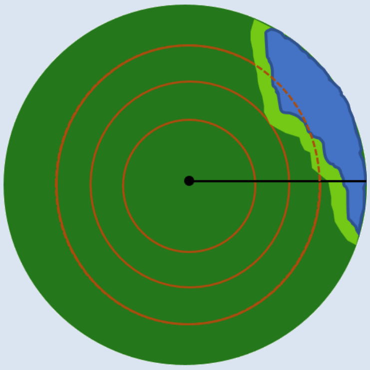


Figure 35. Mapped watercourses intersecting with irrigated pivots in a 100 km^2 area of the southern Cape. Note very few river systems are not impacted by pivot irrigation at some point.

When it comes to mitigating negative impacts due to irrigation pivots there is no 'one best way' to do this. There are individual methods with can be combined in many ways depending on the layout of the pasture in relation to the watercourse. In all cases applying a buffer zone and excluding cattle is recommended. A single strand electric wire is sufficient, and a pivot can cross over these wires. Where crossings are necessary, upgrade them to low impact, low footprint options like the ones indicated in Figure 13 and Figure 14. Where pasture loss will be minimal beyond a buffer zone, install a stopper on either side of the watercourse to prevent irrigation directly into it. Where it isn't possible to exclude irrigation over a watercourse, it may be an option to construct / enhance wetland features downstream to improve water quality.

Finally, precision irrigation systems have not been taken up by mainstream dairy farms in South Africa yet. However, these systems are available and are widely implemented elsewhere, like New Zealand. These systems are GIS-enabled and programmed to deliver variable irrigation rates based on soil characteristics and the presence of features such as roads and wetlands. Sprinklers switch off when they get to the latter, and on again when they get back to the pasture. These systems are designed not only to save water, but they also result in better protection of water resources. It is hoped they will soon be available in South Africa at a cost that makes them reasonable to install.

Table 16. Suggested actions to improve protection of aquatic ecosystems under irrigated pivots.

Current Approach	Improved watercourse protection	Mitigating Actions
		Install a pivot stopper on both sides of the watercourse so the pivot does not irrigate into the watercourse. Establish a riparian buffer zone and fence to exclude cattle. Remove pivot crossings.
		Establish buffer zone and fence to exclude cattle except for crossing points (also fenced). Install light footprint best practice crossings (See Figure 13 & Figure 14) Enhanced wetland to improve water quality downstream.
		Establish buffer zone and fence to exclude cattle. Install light footprint best practice pivot crossing (See Figure 13 & Figure 14) Investigate precision irrigation systems to switch sprinklers off over wetland and buffer. *

* Currently not widely used in South Africa, but the technology is available and widely implemented on New Zealand dairy farms.

A worked example is provided from the southern Cape farm site where an irrigated field is completely intersected by a tributary (Figure 36). The watercourse has been infilled at every pivot crossing point which negatively impacts the hydrology and habitat, alien vegetation has been pushed into the watercourse, and the pivot irrigates directly into the full length of the watercourse beneath it. A combination of mitigation measures could greatly improve water quality and habitat along this stream, whilst preserving a large area of irrigated pasture, through the following interventions:

- Remove all instream pivot crossings consisting of earth piles and replace those in the northern section of the pivot with light footprint bridge crossings x 6. This will improve habitat and hydrological connectivity along the watercourse.

- Remove piles of alien woody material and clear remaining aliens along the stream banks (using best practice methods).
- Determine the appropriate buffer and mark it off with single strand electric wire to restrict cattle access.
- Install a pivot stopper on either side of the watercourse on the southern portion of the pivot.
- Create an enhanced wetland area to the edge of the pivot to improve the quality of water discharged downstream.

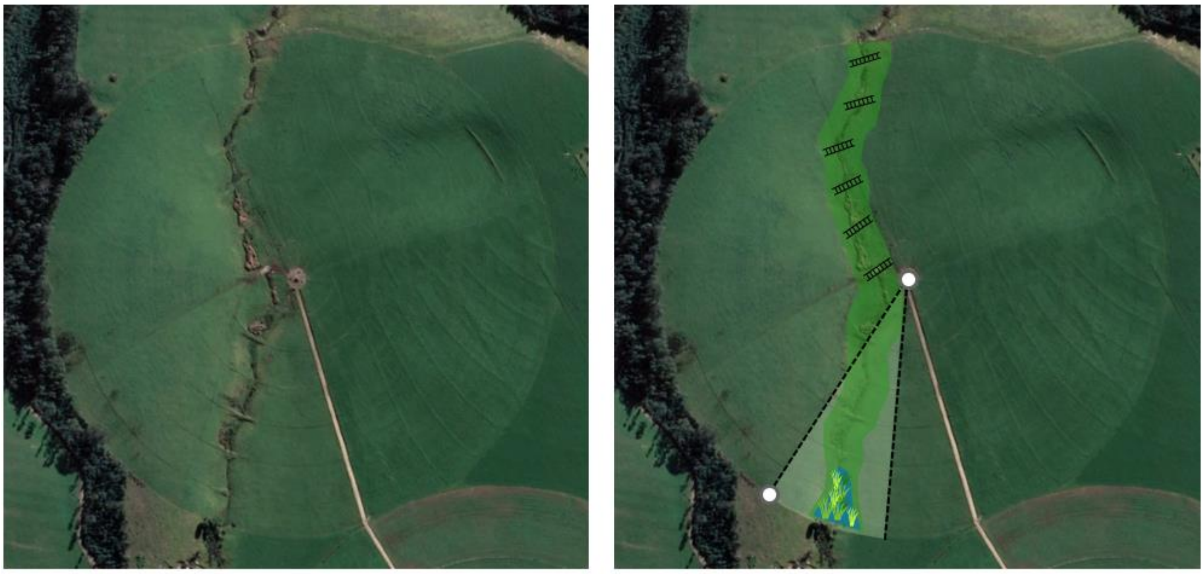


Figure 36. Worked example of improved watercourse management under pivot irrigation.

6 Cost Assessment

Aquatic impact buffer zones aim to support continued land-use while simultaneously maintaining the health of freshwater ecosystems. The cost assessment considers implementing buffer zones on *existing* pastures on dairy farms which entails replacing pasture that has encroached into watercourses and adjacent areas to buffer the watercourse from impacts of the land-use. Arguably these areas should never have been cultivated in the first place, but historically little was known about the impacts of encroachment or the value of buffers. Establishing buffers on dairy farms has consequences for the farmer, the environment and broader society. These outcomes result in both local (on-farm) and broader (societal) costs and benefits.

6.1 Benefits and Costs of Implementing Buffers

In another sector-specific assessment, a Water Research Commission (WRC) study investigated riparian buffer zones in the sugar cane landscape (Browne et al*.,* 2020). The study identified a range of potential benefits and costs for implementing buffer zones that are not evenly distributed between the farmer and society, or between current and future generations. Spatial scales differ too, with costs accruing at the local scale while benefits are felt at the catchment scale. However, increasing local benefits are being identified as in many cases the downstream user is still the same landowner.

Many of the cost-benefit studies that were reviewed identified a range of potential benefits associated with watercourse buffer zones, but generally only a sub-set of these were quantified. Many of the benefits, particularly those related to ecosystem services, are difficult to quantify (or require long-term monitoring data) and, further, to express in monetary values which are often preferred for cost-benefit analysis.

From the perspective of the dairy farmer, the main cost associated with establishing buffer zones is the income forgone from reduced pasture area. This cost is associated with the conversion of pasture area to buffer area (and / or back to unplanted watercourse). In addition, there are costs associated with the establishment and maintenance of buffer zones. Establishment activities include the removal of pasture crops from the buffer area, the possible planting of replacement vegetation and fencing. Maintenance activities include the management of biomass and alien plant encroachment within the buffer zone and watercourse. On the other hand, there is a growing recognition that sustainable management practices within agriculture can provide numerous 'on farm' benefits such as erosion control and topsoil retention (Rein, 1999), and aesthetic and cultural benefits associated with well-functioning natural habitats (Robertson *et al*., 2014; Evidentiary, 2016). Further, rehabilitated watercourses (and especially wetlands) are associated with greater water retention which recharges groundwater resources and improves water quality.

From the perspective of society, buffer zones in agricultural landscapes are desirable for the protection of aquatic ecosystem health, maintenance of ecological services, maintenance of water quantity and quality, and to support biodiversity. Where agricultural impacts to watercourses are not well managed, the societal impacts may be poor water quality for recreation, increased human health risk, and reduced aesthetic value of downstream water resources which may undergo eutrophication associated with nuisance blooms of algae or macrophytes. The latter can impact on property values and tourism, with direct financial implications. The establishment of buffer zones, and ongoing maintenance required for alien clearing provides employment opportunities for unskilled workers including women, providing an additional societal benefit.

6.2 High-level Case Study Costing

The potential costs of watercourse buffers are diverse and site specific and related to local conditions and objectives. Ideally, any cost assessment of a proposed intervention should consider all benefits and costs associated with the intervention relative to the case without the intervention. However, data and resource limitations often constrain the analyst's ability to measure and value many environmental benefits (Barbier *et al*.,1997) and generally only a sub-set of benefits are quantified (e.g., Campana, 2011; Rein; 1999). An additional challenge in this context is the spatial and distributional 'mismatch' between the primary costs (local farm scale) and the primary benefits (catchment scale social benefits). While broad benefits of implementing watercourse buffer zones have been highlighted, the case studies focus on the costs associated with the implementation of buffer zones.

The assessment of financial costs to the dairy farmer relate back to the two case study farms in the southern Cape and KZN. A farm-level cost assessment was undertaken based on the hypothetical implementation of buffer zone areas as determined using the Buffer Tool (Macfarlane and Bredin, 2017). **The cost assessment pertains to the conversion of pasture to buffer zones where existing pasture overlaps with these areas.** The costing does not include the costs of activities to improve the present condition of riparian and buffer areas not currently under pasture.

A spatial analysis was conducted to establish the area of pasture that would need to be converted (retired) under the Low Mitigation and High Mitigation scenarios for both farms. Unit cost measures (e.g., ZAR/ha) were applied to the calculated areas to estimate the costs of implementing the buffer scenarios determined for each case-study farm in terms of the costs associated with establishing and maintaining the buffer zones and the opportunity cost of the land converted to buffer zone.

As an indicator of the opportunity cost (income forgone by farmers) of the conversion of pasture to watercourse and buffer, the area of pasture to be converted under each of the scenarios was multiplied by the annual gross margin per hectare for pasture-based dairy production. The annual gross margin per hectare was sourced from dairy consultants for the relevant case study areas and reflects indicative estimates of the gross margin for an average farm in the region. The estimated opportunity cost is an indication for the case study area, actual values are farm specific and highly variable.

<u>Important caveat:</u> the direct and indirect costs of the implementation of buffer zones, as for any better management practice, can vary considerably from farm to farm and are contingent on the recommended buffer width and existing land-use along with additional factors including the initial land-scape conditions (e.g., hydrology, soils, extent and condition of water courses, terrain), production system characteristics (e.g., irrigation, own fodder production), management practices (e.g., nutrient management) and realized / experienced opportunity costs (which can be highly variable). As for all these types of broad financial assessments, the costs presented here are indicative estimates and are meant to be informative rather than prescriptive. The assessment provides a point of departure for future refinements.

6.3 Cost Types

There are three broad categories of costs associated with the implementation of water course buffer zones in agricultural landscapes (Tyndall and Grala, 2009; Daigneault and McDonald, 2012; Iftekhar *et al.,* 2017).

1. **Establishment Costs**
   The upfront costs to establish the buffer zone involving the conversion of one land-use (e.g., pasture) to another (e.g., natural vegetation) and includes the cost of activities related to site preparation, revegetation, fencing and licence applications / approvals if required. Establishment costs may vary from site to site in relation to the condition of the buffer area and the associated rehabilitation requirements (e.g., stabilising erosion, rehabilitating wetlands), the replacement vegetation required (e.g., grassland vs. forest), terrain and access, and regulatory requirements. Fencing is regarded as an upfront (once-off) cost, however fences will need replacing over time and inclusion as a once-off cost depends on the planning horizon and expected life of the fencing materials. Existing fences can also be reused and moved.

2. **Maintenance Costs**
   Recurring (annual) costs to maintain the buffer in a functional (healthy) condition. Maintenance costs are largely related to biomass management and alien plant control but can include the maintenance of any infrastructure (e.g., gabions) related to stream and wetland

rehabilitation and any monitoring costs. Maintenance costs are influenced by site-specific characteristics such as vegetation type, terrain and access.

3. **Opportunity Costs**
   A measure of the value of the 'next-best' use of the land; in this context, it reflects the forgone (annual) revenue associated with pasture that is effectively retired (i.e., the loss of productive pasture). Opportunity cost is typically measured using the gross margin of the productive use of land or using methods based on property prices. In both cases, opportunity cost is highly variable and depends on land quality, land use, management factors, land tenure and the economic context. In this assessment, opportunity cost has been measured using region specific gross margin per hectare estimates for an average farm under pasture-based dairy production.

6.4 Timing of Costs

The costs associated with implementing buffer zones occur over different timeframes. Buffer establishment costs occur upfront (generally over the first 1 to 3 years). Maintenance costs are incurred annually into perpetuity but should decrease over time as ecosystem resilience improves. Opportunity costs represent a recurring cost in the form of annual production forgone associated with the buffer area.

6.5 Data Sources

Unit cost estimates were derived from a combination of data provided by dairy consultants per region quotes from local suppliers, expert consultation, and relevant literature review. The data source and assumptions for each cost is provided in Table 17. The assessment reflects the 'hypothetical' implementation of estimated buffer zone areas for the two case study farms rather than a site-specific costing (which would need to be based on a detailed implementation plan).

Table 17. Summary of data sources and key assumptions for each cost measure.

COST TYPE	DESCRIPTION	SOURCE	ASSUMPTION/LIMITATION
Establishment Upfront (once-off) cost.	Approximate costs to establish natural vegetation in place of pasture in riparian and buffer areas.	Spatial analysis and secondary sources for unit cost (R/ha) estimates.	Actual costs vary according to site specific conditions (e.g., erosion, replacement vegetation). Does not reflect costs for additional site-specific practicalities (e.g., irrigation system adjustments, construction of gabions or water crossings) or to obtain authorisations.
Vegetation establishment	Approximate costs associated with land preparation and re-vegetation.	Literature - marginal cost estimates of grassland rehabilitation from a study of the uMngeni River Catchment (Jewitt et al., 2020).	Based on estimates for grassland rehabilitation. Grassland is the 'natural vegetation' option for buffers for the KZN case study.

			For the southern Cape case study, a mix of fynbos and natural forest makes up the natural vegetation which may incur different costs. However, initial land preparation and soil stabilization activities (e.g., grass cover) are similar, and the preferred option is to allow natural vegetation to re-establish from the existing seed bank. As such, grassland rehabilitation costs are considered indicative for the WC context.
Fencing	Approximate cost to fence buffer areas with 2-strand electric fence.	Commercial quote Marginal cost (R/km) based on a 4 km solar powered, 2-strand electric fence - R 17 205; includes 900 poles & 20 gate breaks, excludes contractor costs. KZN case study indicates costs in the region of R10 000 to R15 000 / km for 2-strand electric fence.	Assumes new fencing along all pasture converted to buffer areas (i.e., existing pasture / watercourse fences not accounted for). Life of system considered up to 40 years – and future fence replacement costs not indicated. The marginal cost (R/km) of fencing likely to decline with increasing length.
Maintenance Annual recurring cost following pasture conversion.	Indication of costs to maintain buffer areas in an ecologically functional condition.	Spatial analysis and secondary sources for unit cost (R/ha) estimates.	Indicative – based on literature, not dairy farm specific costs. Actual costs will vary according to site specific conditions.
Biomass control	Costs largely related to biomass management activities.	Literature - marginal cost estimates of grassland maintenance (Jewitt et al., 2020).	Assumes grassland vegetation. Assumes maintenance activities are the same for the buffer areas and the riparian areas.
Alien plant control	Costs related to alien plant control activities.	Literature - marginal cost estimates of alien plant control (Jewitt et al*.,* 2020).	Assumes maintenance activities are the same for the buffer areas and the riparian areas.
Fence maintenance	Costs to maintain buffer fences.	n/a	No fence maintenance costs were included. *Ad hoc fence* repairs are typically

			included under general maintenance (as a fixed cost); it is difficult to isolate a marginal cost estimate for this category. Case study information indicates that fences are replaced once they become run-down (rather than undertaking extensive repairs or maintenance works).
Opportunity cost Annual recurring cost from the first year pasture area is retired/converted.	The value forgone associated with the alternative (next-best) land-use.	Data sourced from dairy consultants from each region.	Basic approach to a complex cost.
Gross margin	Reflects annual opportunity cost of foregone revenue associated with pasture that is effectively retired. Estimates of average gross margin of dairy production across region-specific study groups.	Data sourced from dairy consultants for an average farm for the **respective regions**.	Regional average estimates applied. Can be highly variable and depends on land quality, land use, management factors and land tenure. Other possible impacts on productivity or financial performance (e.g., economies of size) are not accounted for. Assumes constant gross margin across all areas of pasture.

6.6 High level case study costings

The results of the costing analysis, based on the assumptions identified in the preceding section, are reported in this section. Table 18 presents a summary of the physical dimensions associated with the conversion of pasture to buffer area under the two scenarios, for each case study farm. Table 19 reports the costing estimates by cost category under each scenario for each of the farms.

Table 18. Physical dimensions of buffer implementation reflecting areas of pasture to be converted to natural vegetation.

	KwaZulu-Natal Farm		Southern Cape Farm	
	LOW	**HIGH**	**LOW**	**HIGH**
Case study area (ha)	1206.50		1050.00	
Pasture area (ha)*	549.71		736.24	
Riparian area under pasture				
Area (ha)	8.14	8.14	4.82	4.82
Buffer area under pasture				
Area (ha)	17.98	3.14	34.48	12.09
Total area of pasture for conversion *	**26.12**	**11.28**	**39.30**	**16.91**
Difference between scenarios		â56.8%		â56.9%
As a proportion of case study area	2.2%	0.9%	3.7%	1.6%
As a proportion of pasture area	4.8%	2.1%	5.3%	2.3%
Length of buffer (km)	12.0	7.6	22.3	13.6

* Total area of pasture in each case study area, includes irrigated and dryland paddocks; LOW = Low Mitigation and HIGH = High Mitigation Scenario.

With regard to the costing results, the following observations are noted:

- For both case studies, the threat adjusted buffer scenario (HIGH) reduces the area that would need to be retired from pasture and converted to buffer vegetation compared to the low mitigation scenario; the percent reduction is similar for the two case studies at approximately 56% (Table 18).
- As a proportion of pasture, the area to be retired is greater for the southern Cape farm (under both scenarios). The area of the KZN case study includes larger water bodies, while watercourses are smaller and more numerous on the southern Cape farm. This is also indicated by the greater length of buffer on the southern Cape farm under both scenarios, which is approximately half of that for the KZN farm (Table 18).
- The cost assessment pertains to the conversion of pasture to watercourse riparian and buffer zones where existing pasture overlaps with these areas only. Costs were not included for the rehabilitation of existing riparian / buffer areas where no overlap with pastures occurred. This is why the costs for alien vegetation clearing is very low (Table 19), as minimal alien vegetation is expected to be present in historically managed pasture. However, alien clearing in invaded areas of riparian buffers can be at a high cost depending on the level of invasion. Estimates range between R15 000 and R 30 000 per hectare but are highly variable.
- Buffer establishment costs for fencing and rehabilitation are incurred upfront (reflected here as a once-off cost). In practice these activities and associated costs may extend over the first few years of establishment for buffers. Costs may also be staggered as establishment of buffers is likely to be a phased process as opposed to happening all at one time. Costs for establishment under the HIGH mitigation scenario are approximately half the costs of the LOW mitigation alternative (Table 19).
- For both case studies, the greatest cost derives from the gross margin associated with the area of existing pasture that would be retired / converted under these hypothetical scenarios. The 'opportunity cost' is incurred annually. It reflects the financial loss, relative to current production, incurred every year the area remains as buffer rather than pasture, assuming that there is no financial benefit associated with the buffer (Table 19).

- Maintenance and opportunity costs are incurred annually into perpetuity; the estimates reported in Table 3 reflect annual costs. The far greater of these costs is that of the opportunity cost, which is more than halved under the HIGH mitigation scenario on both farms (Table 19).
- Fencing costs are driven to a large extent by the number of fence poles required, which given the higher length (km) of buffers on the southern Cape, translates to higher costs (Table 19).

The costing reflects the hypothetical implementation of watercourse buffers for two case study farms. Several practical aspects that would affect on-site implementation would need to be considered, which include factors such as costs to adjust irrigation infrastructure around buffer areas and management decisions to implement variable buffers. Where buffers may not be feasible, alternatives such as constructed / enhanced wetlands could be considered, which introduce a different set of costs including possible environmental authorisations.

Table 19. Estimated costs of watercourse buffer implementation under two scenarios of implementation.

	KwaZulu-Natal Farm				Southern Cape Farm			
	UNIT	RATE	LOW COST (R)	HIGH COST (R)	UNIT	RATE	LOW COST (R)	HIGH COST (R)
Establishment (up-front)			**465 877**	**242 823**			**773 334**	**402 099**
Vegetation establishment	R/ha	9 931	259 421	112 067	R/ha	9 931	390 348	167 960
Fencing	R/km	17 205	206 456	130 756	R/km	17 205	382 985	234 139
Difference between scenarios (%)				â48%				â48%
Maintenance (recurring annual)			**5 628**	**2 431**			**8 469**	**3 644**
Biomass control	R/ha	25	662	286	R/ha	25	996	429
Alien plant control	R/ha	190	4 966	2 145	R/ha	190	7 472	3 215
Opportunity cost (recurring annual)			**1 316 024**	**568 508**			**1 551 995**	**667 798**
Gross margin (for region)	R/ha	50 381	1 316 024	568 508	R/ha	39 486	1 551 995	667 798
Total recurring cost (annual)			**1 321 652**	**570 940**			**1 560 464**	**671 442**
Difference between scenarios (%)				â57%				â57%

Note: Some costs are incurred 'once-off', while others recur annually; as presented here establishment and recurring maintenance and opportunity costs are not directly additive. LOW refers to the Low Mitigation scenario; HIGH refers to the H

7 Wetland Enhancement on Dairy Farms

7.1 Introduction

The increasing scarcity of clean fresh water for human consumption is a global issue, which is why the protection of wetlands is fundamental given they can play a role in improving water quality. Unfortunately, human activities have not only resulted in the loss of wetlands but have also resulted in the drastic and severe pollution of rivers, particularly in urban and large-scale agricultural areas (de la Ray *et al*., 2004, NBA, 2018). South Africa's National Biodiversity Assessment (2018) identified that 64% of rivers, 79% of wetlands and 68% of estuarine ecosystems are threatened.

The protection and promotion of wetlands on dairy farms can play an important role in trapping sediment, nutrients (Nitrogen and Phosphorus) and metals (Verhoeven *et al*., 2006), decreasing flood impacts, and enhancing valuable habitat for indigenous plants and animals. Wetlands are often referred to as the kidneys of the environment given their role in water filtration (Dairy NZ), and some have been shown to effectively remove toxicants and pathogens, such as organic pollutants, viruses and bacteria (e.g. faecal coliforms) which pose potential health risks to humans (Kotze *et al*., 2009; Philips *et al*., 2015). Significant amounts of nitrate are removed through denitrifying bacteria, and uptake by plants. Low flow velocities and dense vegetation trap suspended sediments, reducing sedimentation and improving water quality downstream. The ecotone between terrestrial and aquatic habitats creates biologically diverse ecosystems, sustaining indigenous plants and animals. The protection and enhancement of wetlands on dairy farms therefore has many benefits for water quality both on the farm and for downstream users, as well as for the environment (Figure 37).

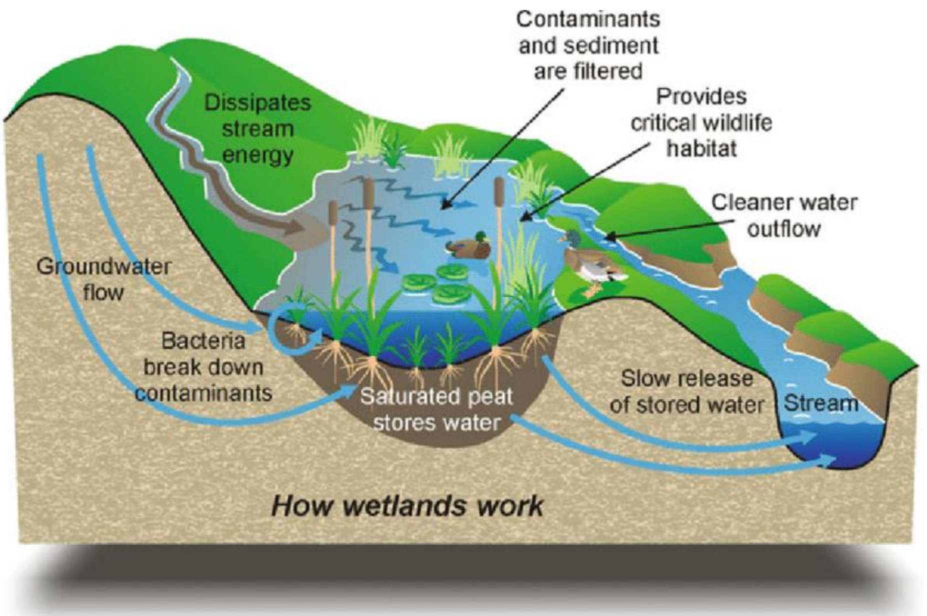


Figure 37. Some of the key functions of wetlands that improve water quality and habitat on dairy farms (Ma *et al*., 2019).

7.2 Definition and Purpose

Several terms regarding the use of wetlands to improve water quality are often used synonymously. It is worthwhile providing definitions of these terms for clarification of the different types of wetland improvements and their purpose. The United States Department of Agriculture's (USDA) Natural Resources Conservation Service provides a series of conservation practice standards for different types of wetland improvements with clear definitions and explanations of their purpose which serve to distinguish these terms (Table 20).

Table 20. Definitions and purpose of wetland use for improvement of water quality (USDA, 2010)

	WETLAND ENHANCEMENT	WETLAND CREATION	WETLAND CONSTRUCTION
Definition	The augmentation of wetland functions beyond the original natural conditions on a former degraded, or naturally functioning wetland site; sometimes at the expense of other functions.	A wetland created on a site location that was historically not a wetland.	An artificial wetland ecosystem with hydrophytic vegetation for biological treatment of water.
Purpose	To increase the capacity of specific wetland functions (such as habitat for targeted species, and recreational and educational opportunities) by enhancing: • Hydric soil functions (changing soil hydrodynamic and/or bio-geochemical properties). • Hydrology (dominant water source, hydroperiod, and hydrodynamics). • Vegetation (including the removal of undesired species, and/or seeding or planting of desired species). • Enhancing plant and animal habitats.	This practice is used to accomplish one or more of the following primary purposes: • Create wetland functional capacity for floodwater storage • Create wetland functional capacity to provide fish and wildlife habitat • Create a native plant community adapted to growth and regeneration in anaerobic conditions In addition to one or more of the primary purposes, this practice can be applied to create wetland functional capacity to improve water quality.	Use this practice to accomplish one or more of the following purposes: • Treat wastewater or contaminated runoff from agricultural processing, livestock, or aquaculture facilities • Improve water quality of storm water runoff, tile drainage outflow, or other waterflows.

While rehabilitation would be the ultimate aim for natural wetlands within buffer zones, wetland enhancement or wetland creation would be the most complimentary improvement for water quality where riparian buffer zones have limited benefit, such as watercourses under pivots (See Section 5.7.2). Point source discharges of wastewater such as from slurry dams or washdown areas from dairy parlours may benefit from constructed wetlands. However, these require detailed environmental engineering design to ensure the correct substrates, vegetation, cell / chamber sizing and treatment sequences are prescribed for the wastewater concerned. They also often require large areas to achieve a measurable improvement to water quality and can be useful for the removal of Nitrogen and sediment, but less so for Phosphorus.

Wetland enhancement is applicable to degraded and non-degraded wetlands with hydric soils where the enhancement of certain wetland functions would be beneficial. Enhanced wetlands cannot be used to treat point- and non-point sources of pollution such as wastewater from slurry dams, as that would be a case for constructed wetlands. Wetland enhancement assumes the presence (historical or current) of natural wetland features such as hydric soils, where wetland creation involves creating or enhancing wetland conditions at a new location where no wetland existed previously. This well describes many of the enhanced flow paths and wetlands observed under pivots on the case study farms and the dairy sector in general.

While the generic purpose of enhanced and created wetlands is provided in Table 20, the more specific purpose on dairy farms is to improve water quality and habitat both on-farm as well as downstream through the mechanisms listed below:

- Trapping of sediments and other suspended matter;
- Reduction of nutrients (especially N) through denitrification and uptake by plants;
- Reduction of pesticide pollution;
- Improvement to the structure and function of habitat for biodiversity support;
- Reduction in erosion and channel incision of watercourses during high flow events.

7.2.1 Wetlands and Greenhouse Gases

Of concern for the dairy sector is the release of greenhouse gases (GHG) which is primarily driven by enteric methane (CH_4) and nitrous oxide (N_2O) from soil management across all dairy farm management systems in South Africa (Reinecke and Casey, 2017). In a study of pasture based dairy farms in the southern and Eastern Cape it was shown that while restoring soil carbon leads to a reduction in carbon emission, the result across all the farms in the study was still a net negative effect (Galloway, 2020).

Wetland soils are widely acknowledged as important stores of organic carbon (C) which is trapped as soil organic matter. Decomposition of organic matter is slowed down under waterlogged anoxic conditions which increases the capacity of wetlands for storing organic C. The contribution of wetlands to C sequestration is highlighted by the fact that while they occupy only 5-8% of land area globally, they hold between 20 and 30% of terrestrial C (Mitch and Gosselink, 2007). Accurate carbon accounting in wetlands has been highlighted as an important step that would allow the inclusion of wetlands in carbon-offset programs (Nahlik and Fennessy, 2016) which is directly relevant to the dairy sector in South Africa.

Simply put, soil disturbance diminishes the amount of carbon stored in wetlands through exposure of fresh soil surfaces to the atmosphere resulting in depletion of soil organic matter (C). Wetlands can switch from being a sink for N and C to being a source if they are poorly managed. Where wetlands are actively drained, disturbed, or temperatures are increased (e.g. during drought or if shading vegetation is removed) N_2O emissions increase significantly due to changes in the functional diversity

of microbes (Bahram *et al.,* 2022). The implications are serious as (N_2O) has a global warming potential 265 times greater than CO_2.
This emphasises an additional benefit of protecting existing wetland environments on dairy farms, and harnessing the inherent ecosystem services provided by creating or enhancing wetlands for improved aquatic ecosystem health.

7.3 Applicability on Dairy Farms

There are a number of common scenarios where created or enhanced wetlands would be applicable on dairy farms. These were observed at both the case study sites, as well as on other dairy farms. As already mentioned, implementing riparian buffers has many benefits, but they are not always entirely effective in every situation. Typical situations where impacts affect water quality and buffers offer limited benefit are listed below:

- At property boundaries where the downstream neighbour receives water of a poor quality from an upstream neighbour;
- Watercourses under pivots where irrigation water often including wastewater or fertilisers is irrigated directly into the watercourse; and,
- Linear drains carrying runoff from fields to watercourses.

There may be other situations where enhanced or created wetlands could be applicable, and this list is by no means exhaustive.

7.3.1 Poor Water Quality from Upstream Users

While it has been emphasised repeatedly that the most sustainable and effective strategy to manage water resources is to take a catchment-based approach involving all water users, it is not always possible to gain commitment from neighbours to this cause. Where upstream users negatively impact water quality, it can cause problems on dairy farms such as eutrophication of dams and associated algal blooms, or siltation requiring costly maintenance. The solution provided in Figure 38 shows an enhanced wetland which was essentially a small dam created upstream of an irrigation dam. Wetland plants already present in the natural wetland rapidly colonised the enlarged area and now trap silt and nutrients that would otherwise be flushed straight into the irrigation dam downstream, affecting productivity. This scenario is most likely to occur in an instream environment, and would therefore require an authorisation in terms of NEMA and the NWA.

Figure 38. Example of an enhanced wetland habitat (area indicated) used to trap sediments and other pollutants introduced by users upstream, thus reducing impacts to the irrigation dam.

7.3.2 Watercourse Under Pivots

Challenges regarding the management of watercourses under pivots were dealt with in Section 5.7.2. It is useful to remember that natural watercourses can be affected, but artificial watercourses may be created where there were none previously. The creation of artificial wetland habitat due to frequent irrigation provides the opportunity to create a wetland in a linear form along the flow path, and / or to enlarge an area for water collection just beyond the pivot before it joins another watercourse. An example of an enhanced wetland area beyond a pivot is provided in Figure 39 where a natural, unchanneled valley bottom was rehabilitated and enlarged, creating a small basin which improves habitat and water quality (Figure 39). No replanting of vegetation (wetland or buffer) was required in this area, but extensive and ongoing alien clearing has been undertaken using female workers on the farm who have been trained to identify and remove dominant alien species.

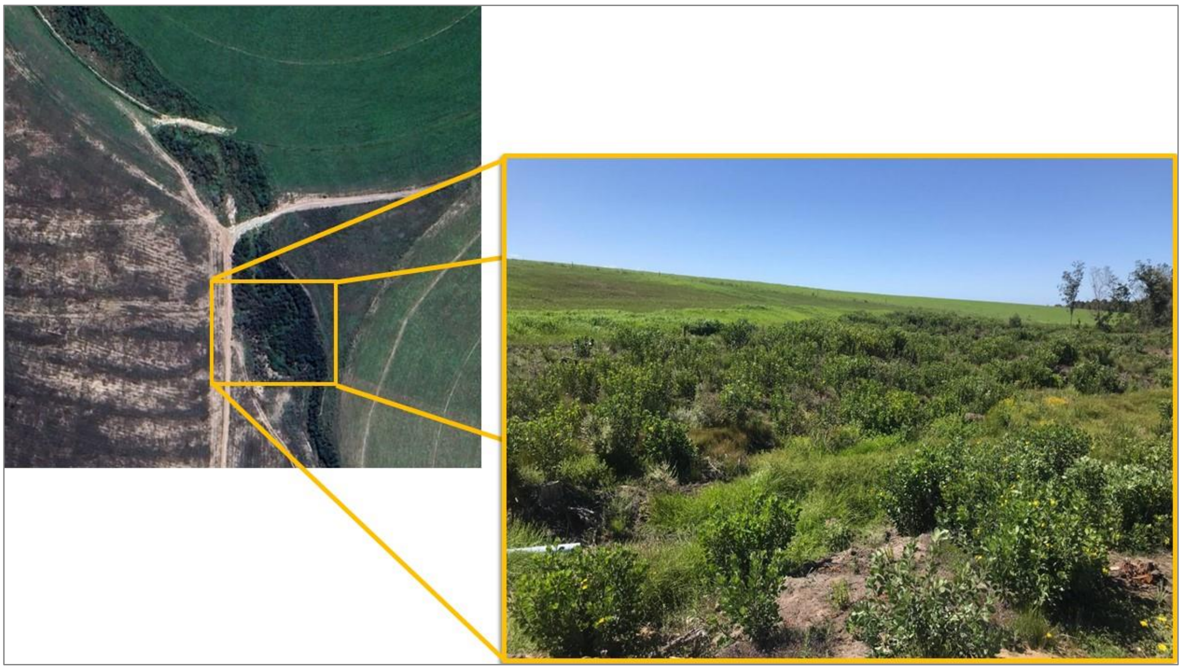


Figure 39. An enhanced wetland in an existing wetland area downstream from an irrigated pivot. This includes an additional 15 m buffer which has been fenced to exclude cattle.

7.3.3 Linear Drains

Linear drains carrying agricultural runoff may or may or may not be located in natural watercourses. In some cases, natural flow paths are artificially straightened and excavated to more effectively convey water to its discharge point, which is usually the nearest watercourse. Examples of such drains on the KZN farm were provided in Figure 33. While these drains may collect diffuse runoff from different areas of the farm, they represent a point source of pollution where they enter a watercourse which cannot be mitigated by a buffer zone at that location. Creation of a wetland or enhancement of a wetland if it is a natural feature is an option to improve this water before it enters the watercourse.

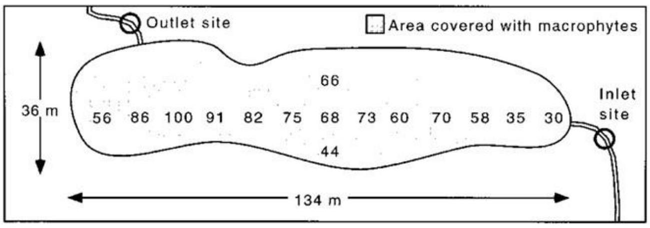
An excellent example of such an approach where a wetland was created to treat agricultural runoff from a drain is provided in Figure 40. Note that this wetland was created in the regulated area of the river and an authorisation in terms of the NWA would be required, most likely a General Authorisation as part of a Maintenance Management Plan. Also note that engineering inputs in terms of sizing may be required to ensure the flooding risk both from the catchment and the river in this instance (1:100-year floodline) is mitigated. It is worth considering the placement of constructed or enhanced wetlands outside of the regulated area and away from flood sensitive areas to minimise these risks and reduce administrative burden.

CREATED WETLAND CASE STUDY: *Lourens River, Western Cape (Schulz and Peall, 2001)*

<u>Problem statement</u>: Runoff from fruit orchards was being channelled into a linear drain connecting to the Lourens River. High levels of nutrients, pesticides and sediment were being carried into the river with little to no mitigation.

<u>Solution</u>: A wetland was constructed by excavating an area of 0.44 ha near the bottom of the drain adjacent to the Lourens River. The drain was diverted via a culvert into the wetland on one end, and water was discharged to the river through a pipe on the other end.

<u>Results:</u> Total suspended solids, orthophosphate, and nitrate were retained in the wetland in proportions 15, 54, and 70% respectively during dry conditions (< 2mm/d rainfall). During wet conditions (2-35 mm/d rainfall) these values increased to 78, 75, and 84%. Pesticides azinphos-methyl and chlorpyrifos were measured at the inlet at 0.85 µg/L and up to 0.2 µg/L respectively. Both pesticides were undetectable in the outlet water samples.



Schematic view of the wetland showing the size, sample locations and water depth (cm)

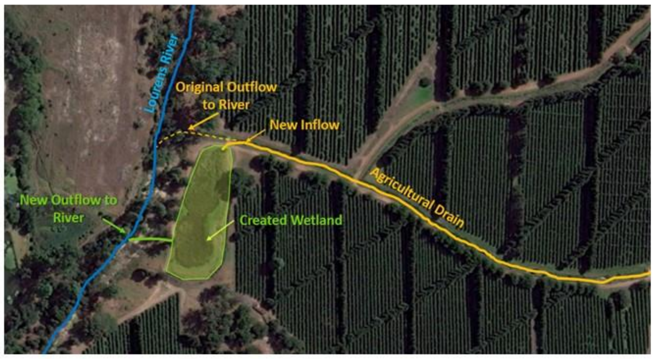


Figure 40. Example of a wetland created to treat point-source and diffuse runoff from agricultural fields adjacent to the Lourens River, Western Cape (Schulz and Peall, 2001).

7.3.4 Limitations and Monitoring

While constructed or enhanced wetlands can provide a range of beneficial ecosystem services, each wetland has its limits as to the loads of inputs they can measurably process. Wetlands can be overwhelmed and transition from a nutrient and pollutant sink, to a source. The extent to which this occurs is dependent on the quality and quantity of inflowing water, and wetland features such as the substrate type and vegetation complex. Monitoring of key water quality parameters at the inflow and outflow should be undertaken on a routine basis to provide assurance of the wetland's ongoing function. Wetlands that have been overwhelmed may need maintenance in the form of vegetation harvesting which should be undertaken as part of a greater Maintenance Management Plan and with guidance from a wetland ecologist.

8 Conclusions

This guideline provides the dairy farmer and their network of supporting consultants, researchers and milk buyers with the necessary steps to develop a plan for improved management of wetlands and rivers using aquatic impact buffer zones and enhanced wetlands. Information provided in this guideline is substantive and aims to address as many of the observed aquatic ecosystem impacts on dairy farms as possible. While riparian and wetland buffers are the primary tool, a wide range of other supporting best practices are recommended and described, especially where riparian buffers have limited benefit.

It is acknowledged that full implementation of the complete suite of recommendations would require significant resources (time, money, staff and persistence), but it is recommended that farm management begin with establishing a plan which identifies the 'low-hanging fruit' where low-cost interventions could yield benefits in the short- to medium-term. Environmental authorisations may or may not be required, but one can work on trying to limit triggering legislation and a lengthy authorisation process where possible. The benefits of riparian buffers are most tangible when continuous strips of unbroken buffers are implemented. Therefore, it is advisable that landowners within a catchment work together to form coordinated management plans for the catchment (from headwater to higher order streams) to ensure maximum effectiveness of implemented strategies. Such catchment-based management plans are also more likely to qualify for the LandCare project exemption from Environmental Authorisation in terms of the gazetted EMPr.

For milk buyers and dairy sector sustainability trackers, this guideline provides a range of measurable interventions to improve the quality of water resources on dairy farms. To date, most incentives / criteria have revolved around carbon sequestration (mainly in pasture soils) with some emphasis on water use efficiency. As long as there is no industry-lead emphasis on improvements to aquatic ecosystem health there will be limited uptake of these recommendations. It is hoped that the strong case provided for improved sustainability on dairy farms along with the knowledge that wetlands can act as tremendous carbon sinks will encourage a shift to greater emphasis on water resource protection using these guidelines.

While the opportunity cost of pasture conversion to buffers represents a significant figure, this is offset by a range of benefits both on farm and beyond. Sustainable dairy farming is an essential requirement to ensure that receiving freshwater systems are protected from harmful point-source and diffuse sources of runoff. To achieve that goal, trade-offs have to be made between dairy production and the associated environmental impact.

> *Doing something costs something. Doing nothing costs something. And, quite often, doing nothing costs a lot more!*
> Ben Feldman, CEO Feldman Group.

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