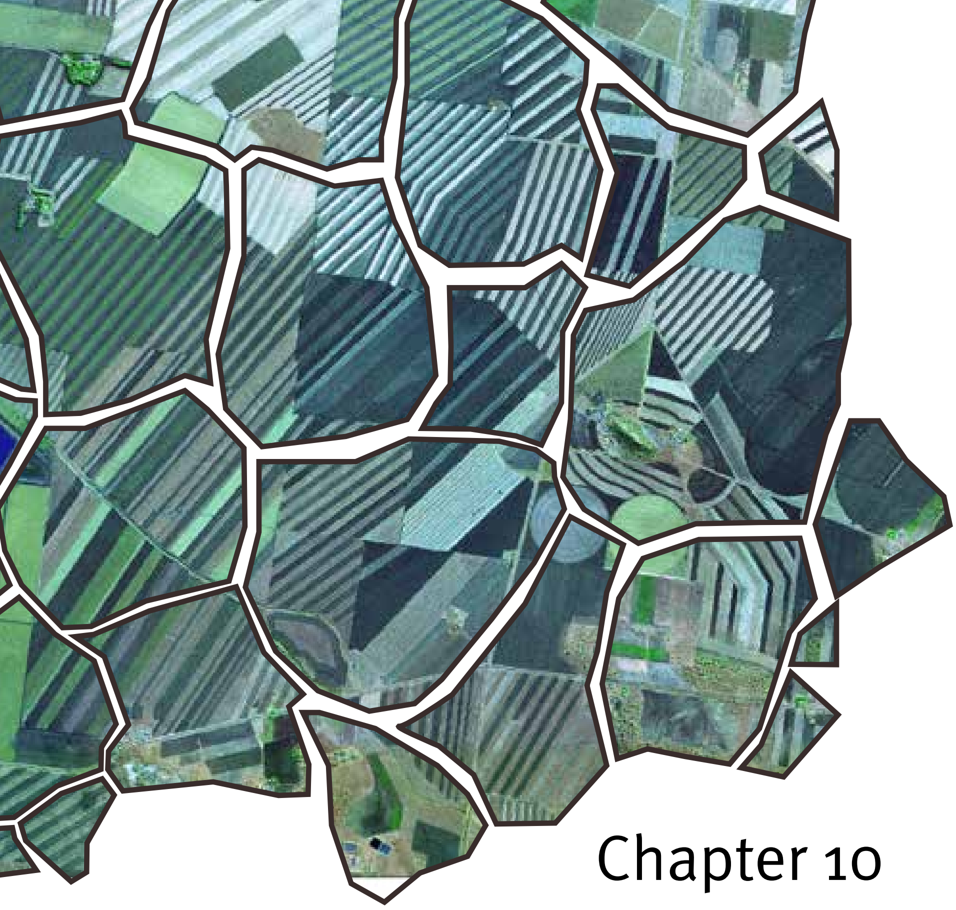


Chapter 10

Land management on flood plains

Key points

- Agriculture is by far the most extensive land use on floodplains in Queensland. Much of the State's most productive agricultural land lies on floodplains.
- Floods are a mixed blessing. On the one hand floods can threaten lives, damage infrastructure, destroy crops and pastures, spread weeds, reduce water quality and cause serious erosion. On the other hand floods replenish groundwater, deposit fertile silt and restore wetlands and other habitats.
- Floodplain erosion can be minimised by maintaining groundcover and by protecting streambanks and channels. This can be done by:
  - — on grazed lands, managing stocking rates to maintain pasture cover and vigour and restricting stock movement over and along banks and into streams through fencing and/or installing off-stream water points to avoid creating bare paths which can initiate gullying
  - — on cropped lands, using strip-cropping systems that have been specifically developed to protect cropped floodplains from erosion by spreading floodwaters and dissipating their energy
  - — with built infrastructure, giving careful thought to the location and design of structures such as roads, channels and levees, to avoid diverting and concentrating flood flows.

Contents

Glossary

aggradation: the process of building up of surfaces, such as streambeds of floodplains, by the deposition of sediment.

flood return period: the average period in years between the occurrence of a flood of specified magnitude and an equal or greater flood. It is an average figure, not an interval. For example, a flood with a return period of 5 years does not occur every fifth year, but would be expected to occur 10 times every 50 years.

knick point: An abrupt change of gradient in the profile of a stream or river, typically due to a change in the rate of erosion.

natural sequence farming (NSF): an agricultural approach based on understanding landscape and biological processes and implementing practices compatible with these processes to achieve sustainability. Central to the implementation of NFS is the manipulation of the hydrologic regime by the introduction of small structures into a stream to slow flows and spread them out across the floodplain.

opportunity cropping: a flexible cropping procedure whereby advantage is taken of unexpected favourable seasonal conditions, particularly those relating to soil moisture, to grow more than one crop per year on the same piece of land.

pivot line: a line joining turning points on a strip cropping plan. It represents the projection along which each strip changes direction due to changes in topography.

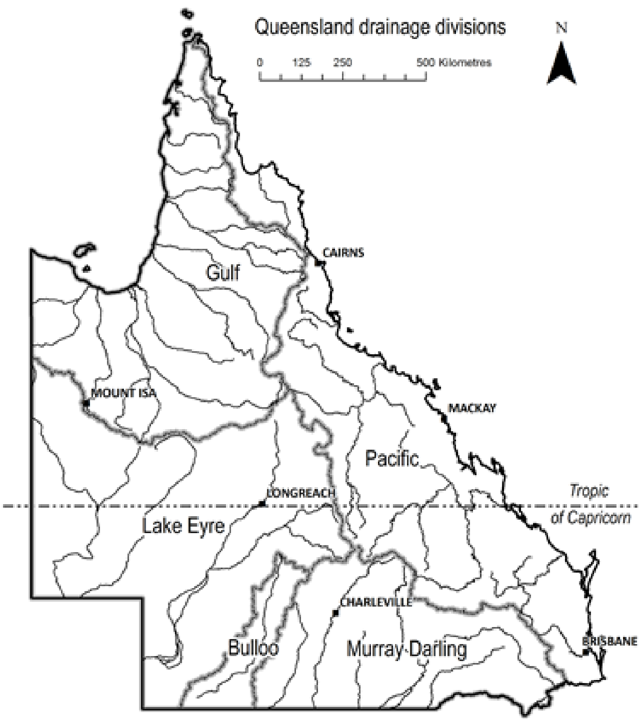
residual flow drains: a drain designed to carry trickle flows such as might be used in conjunction with a strip cropping scheme.

stream avulsion: abandonment of a part or the whole of a channel belt by a stream in favour of a new course. The old channel may be abandoned either instantaneously or gradually.

10.1 Introduction

Queensland covers a very large area of land and has a wide variety of climates, ranging from wet tropical areas (average annual rainfall 2000–4000 mm) to dry inland deserts (average annual rainfall 150–250 mm). It contains many different floodplain landscapes. East of the Great Dividing Range in the Pacific drainage division (see Figure 10.1), catchments vary between being small (restricted to the near coast, such as in the Wet Tropics and south-east catchments) to much larger and extending well inland (such as the Burdekin and Fitzroy catchments). Streams with small coastal catchments tend to be active and have relatively narrow floodplains. Inland streams such as those of the Gulf, Lake Eyre and the Murray Darling Drainage divisions flow more slowly and have wide floodplains often extending across vast areas.

Figure 10.1: Queensland drainage divisions



Flooding is a natural occurrence. Floodplains help to dissipate the potentially damaging energy of floods by allowing the water to spread and slow down. Floodplains act like dams, mitigating floods by storing water and rereleasing it slowly over a long period to lower flood peaks and reduce the downstream impacts of flooding in the drainage line. In doing this they help shape our landscapes.

Rural landholders are generally more aware of floods than are urban people. While floods in urban areas are usually associated with disaster, floods in rural areas can provide benefits such as a natural irrigation of agricultural lands. However, major flooding events may also cause extensive damage in rural areas. Major floods can be decades apart and, because of this, past lessons about how to manage floodplains to reduce these impacts are easily forgotten.

In managing land on a floodplain it is necessary to consider a broad range of aspects. These include (but are not limited to) erosion potential, downstream impacts, maintenance of biodiversity, flood dynamics, river geomorphology, existing land uses and infrastructure requirements. This chapter provides guidance on how to manage land on floodplains in order to minimise the effects of soil erosion, to help stabilise floodplains and to keep these highly valuable lands in productive agricultural use.

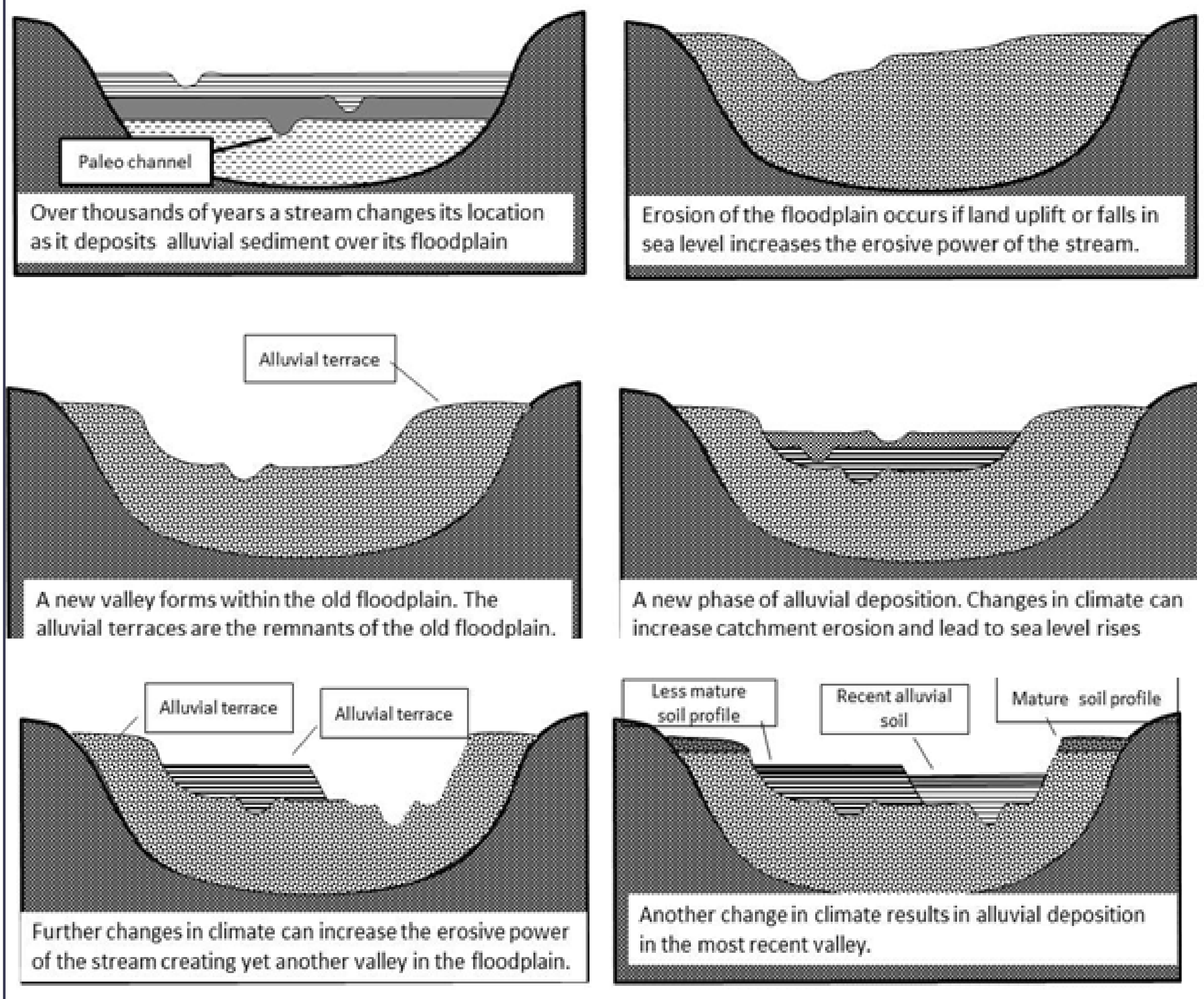
This chapter provides information about the nature of flooding in rural areas, its impacts and strategies for managing flooding on floodplains. It should be read in conjunction with Chapter 11 Stream stability.

10.2 Floodplain evolution

When we observe a stream and its floodplain for the first time, it is easy to think that they are static. However, this is not true; all floodplains are evolving. They have undergone major changes to reach their current state and will continue to evolve in the future. Figure 10.2 (based on an animation from the Victoria Resources Online website) shows how a floodplain can evolve as a result of landscape uplift and past changes in climate and sea level.

Over thousands of years streams move as alluvial sediment is deposited across the floodplain. Ancient flood plain erosion occurred when the erosive power of streams increased as a result of land uplift or sea level fall. Alluvial (sometimes called fluvial) terraces can be formed by downward cutting and bed erosion. This can further increase the velocity of a tributary, causing that tributary to erode inland toward its headwaters. Alluvial terraces are underlain by sediments of variable thickness. They may be well above current flood levels even in extreme events. The conspicuous stream terraces at the back of some coastal plains in North Queensland can be attributed to stream levels associated with lower sea levels during the last ice age (Kapitzke et al. 1998).

Caption 10.2: Terrace development on floodplains (Victoria Resources Online)



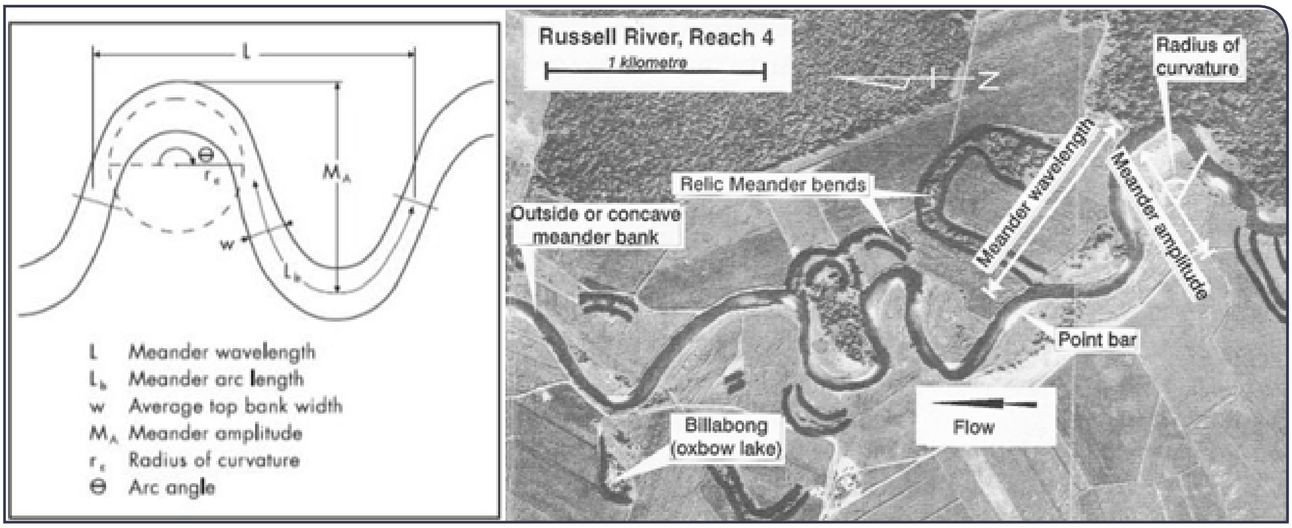
The catchments of the neighbouring Fitzroy and Burdekin Rivers in central Queensland are by far the largest of any rivers along the eastern seaboard of Australia. It is believed that these two rivers were both once confined to small coastal catchments with their headwaters in the coastal hinterland mountain range which is still present today (Jones 2006). These coastal streams were short and steep and actively eroding, especially in comparison with those of the interior. As these smaller coastal streams eroded, the east–west drainage divide moved rapidly westwards through gaps in the coastal range. Other streams were eventually captured, beginning a phase of regional erosion, where rills and gullies transported large quantities of sediments to the coast. During periods of low sea level, large volumes of sediment were transported beyond the present coastal shelf contributing to a major eastward bulge of the continental shelf off central Queensland.

There is evidence of other coastal streams having developed through a similar process. For instance, it is believed that the lungfish and turtle species in the Mary River were once confined to inland streams. However this changed when the inland streams they inhabited were captured by the Mary River (Peter McAdam personal communication).

The higher parts of catchments are usually steep, and the upper reaches of streams normally have a rocky base and flow quickly with high erosive force. Sediment produced in these upper reaches is progressively moved to downstream parts of the catchment and out to sea. Sections of streams in higher areas can develop floodplains but they are usually narrow and sloping (they may have slopes of around 0.5%). In lower reaches, the stream velocity declines, sediment is deposited and the floodplain becomes wider and flatter (with slopes of around 0.1% or less).

As the slope in the stream reduces, streams start to meander. Where the sediment supply exceeds the capacity of the stream to transport it further downstream alluvial floodplains are created. Figure 10.3 shows features associated with a stream on a floodplain. These include meanders, billabongs (oxbow lakes) and point bars.

Figure 10.3: The principal components of meander geometry (sources: Kapitzke et al 1998, Rutherford et al 2006)



The meander wavelength of streams in north-east Queensland is typically equal to around 10 times the channel width and about 5 times the mean radius of curvature (Kapitzke et al. 1998). Such regularity indicates that meanders are not the result of purely random processes such as local differences in bed and bank cohesion, but rather a function of an internal property of the stream, such as excess free energy. This leads to the hypothesis that by developing meanders a stream is able to increase its length and reduce its gradient to minimise and uniformly expend energy along its course.

Depending on the steepness of the channel, coarse sediments can travel down a stream network in pulses (Rutherfurd et al. 2006). Coarse sediments, such as sands and gravels, are the result of gully erosion (especially in granite catchments) or stream widening. Slugs of coarse sediments travelling downstream can fill pools and degrade habitat. Slugs typically move slowly downstream as a 'sediment wave'. The stream bed rapidly aggrades as the sediment slug arrives, and then gradually erodes as the wave passes. Evidence of this movement of bed material can be observed where there is infrastructure such as bridges, piers and pipes. As fine sediment moves through, an armoured gravel bed of the coarser material can remain. Some sediment will be left behind as deposits on the floodplains and will form point bars and benches. If these deposits become colonised by vegetation the channel will gradually narrow and a new sinuous channel will form.

Visual indicators that a stream has been impacted by a sediment slug (Brooks et al. 2006) include:

- homogenised bed form
- reduced channel capacity
- overbank sedimentation in the form of sand sheets or crevasse splays deposited on fine-grained floodplain material
- channel avulsion and/or excessive lateral channel migration
- braiding.

Sediment deposition in large streams leads to braiding. Braiding is the development of multiple parallel channels divided by islands or bars. Streams usually develop braided channels when they have a high load of coarse sediment, when banks are erodible, and when discharge is high and slope low. Similar processes lead to the development of deltas such as those found at the mouths of the Burdekin River and some of the rivers flowing into the Gulf of Carpentaria such as the Mitchell and the Gilbert.

Extreme floods can cause stream avulsion. Avulsion is an abrupt change in stream course to a new alignment, with consequential abandonment of the pre-existing channel. It is usually the result of aggradation, that is, the height of the stream bed being raised due to progressive sediment deposition. The stream alignment can also change drastically due to the sudden removal by a single extreme flood of vegetation that may have been growing in a stream for a very long time.

10.3 Soils and land use on floodplains

If flood deposits remain in situ long enough they will form soils. Soils derived from flood deposits can vary from clays to loams, sands and gravels. Coarser material is the first to be deposited when a stream breaks its banks and hence is deposited closest to the channel. Finer materials such as silt and clay are deposited in back plains further away from the stream.

Some of the best agricultural lands in Queensland are located on floodplains where deep, fertile soils have been created by flood deposition over millennia. Irrigation, either from surface or groundwater sources that are normally more readily accessible due to the proximity of streams, greatly increases the value of floodplain soils for agriculture.

Terraces, as shown in Figure 10.2, are a combination of different soil types depending on their age and parent material. For example, some tributaries of the Lockyer River in south-east Queensland have high terraces of grey and brown vertosols, lower terraces of black vertosols, and more recent terraces with black and brown dermosols (Bernie Powell personal communication).

The largest expanse of floodplain soils used for cropping in Queensland is on the Darling Downs. The grey and black vertosols of the Condamine River floodplain stretch for 220 km from north to south (from Warwick to Chinchilla) and up to 40 km from east to west (Figure 10.4). These soils are extensively used to grow grains and cotton. They are highly prized as some of the most productive agricultural land in Queensland.

Figure 10.4: The Condamine River floodplain

In coastal areas, floodplains are used for growing sugar cane and horticultural crops. In the south-east corner, the floodplains of creeks like the Lockyer and Warrill are valuable areas for horticultural production. In western and northern inland Queensland, vast areas of floodplain are used for grazing, whilst the floodplains of southern inland areas around St George and Dirranbandi are used for growing cotton under irrigation and for broadacre cropping of summer grains.

10.4 Impacts of flooding in rural areas

High velocity flood flows can have a range of impacts on agricultural activities on floodplains. Negative impacts include:

- loss of top soil and associated nutrients, organic matter and biological activity
- loss or damage to crops from high-velocity flows and waterlogging
- loss and damage to farm infrastructure including roads, irrigation equipment, fences and farm machinery
- sediment deposition that affects land productivity and impairs the use of machinery
- debris deposition in cropping lands that affects crop production and possible contamination
- prevention of access to land
- streambank erosion and the loss of adjacent land.

Although floods can damage floodplains in a number of ways, they can also be beneficial. For example, pastures growing on the broad flat floodplains of the Channel Country in the Lake Eyre catchment of the arid south-west are heavily reliant on natural irrigation from floods occurring as a result of heavy rainfall in upper catchments that could be 500 km away. Floods can also play an important role in soil development. Sediment deposited on the floodplain can affect soils in varying ways. Fine sediments such as silt can usually be incorporated into existing soils relatively quickly and can help rejuvenate soils to improve soil fertility. However, sand deposits on floodplain soils can significantly reduce their quality and cause them to become ‘droughty’ because of reduced moisture-holding capacity (Wilson 2013).

Flooding can also affect land downstream. These effects can include:

- reduced water quality, and consequential loss and damage to terrestrial and riparian ecosystems
- deposition of sediment and nutrient in water courses, lakes and coastal areas
- loss of riverine, estuary and marine habitat and biodiversity
- damage to infrastructure
- spread of weeds.

Sediment in streams originates from hill slopes, floodplains, or from the bed and banks of streams. A high proportion of this sediment results from gully erosion and the erosion of stream beds and banks during major floods. In rural areas, hill slopes are mostly used for grazing. Such land is susceptible to erosion when heavy rain occurs at times when pasture cover is low, as may result from excessive grazing. Where grazed landscapes are susceptible to gully erosion this often becomes a significant source of sediment for streams.

It is important to understand the episodic nature of soil erosion when considering its impact on the water quality of streams. Significant rainfall events occur infrequently, and soil loss may be minimal in the intervening years between rainfall events. This point is well illustrated by the results of long-term experiments. The longest soil loss experiment ever conducted in Queensland ran from 1976 until 1990 on a cropped hill slope in the eastern Darling Downs. In this study the treatment that most exposed soil to erosion (stubble burnt annually) recorded periodic annual average soil losses that varied from a high of 78 t/ha between 1980 and 1983 to a low of 14 t/ha between 1984 and 1987 (Wockner and Freebairn 1991).

The rate that sediment moves through the stream network is also an important factor to consider in understanding the impacts of erosion. The size of particles is the key determinant of sediment movement. Under given flow conditions the finest particles, such as fine clays produced from erosion of dispersive soils, travel the greatest distance whilst the coarsest particles such as gravels and heavy sands travel the least. Sediment does not follow a direct pathway from its source to its outlet. There are many locations throughout a catchment where sediment may accumulate and remain for long periods. Much hill-slope erosion is the result of localised storms, the runoff from which may not reach a significant stream. It may be many years, decades, or even centuries before soil lost from a hill slope reaches the catchment outlet (Finlayson and Silburn 1996).

10.5 Erosion on floodplains

Erosion on floodplains occurs both in streams and in outflow areas. This section focuses on the latter—erosion of the floodplain. Erosion of streambanks and beds is covered in Chapter 11.

The risk of erosion occurring on floodplains depends on the use to which the land is being put and the land management practices in place, the velocity of the flows and the degree of incision in stream channels. On steeper landscapes, floodplains are generally narrower, resulting in higher velocities during floods. On flatter landscapes, floodplains are generally much wider, allowing flood flows to spread, slow and lose energy.

The risk of erosion from a flood varies considerably between different parts of a floodplain. Flow velocities are generally higher where channels have been created on the floodplain, due to the flow being concentrated by infrastructure or the inflow of local runoff. Fast-flowing creeks entering rivers will also have a high erosion potential. However, in such situations if the flood in the river rises, inflow from the creek will be retarded, and may even become stationary, due to the backwash effect.

No two floods are the same. The following factors may affect the nature and impact of a flood event:

- the season of the flood (flooding in Queensland is most common in the summer months, although winter floods also occur, especially in southern parts of the state)
- the duration and intensity of the rainfall that caused the flood
- the location and extent of the rainfall
- the direction that the rain producing system moves in relation to the catchment (e.g. whether it was stationary, moving upstream or downstream)
- the condition of the soils and other catchment surfaces that affects their ability to accept rainfall (depends on soil type and depth, vegetation and the amount of soil moisture when the rainfall occurs).

The concept of a flood 'return period' is not generally well understood. Across an area as large as the state of Queensland, extreme flood events are more common than we might expect. Queensland contains many thousands of streams. For every thousand streams in the state, a 1-in-1000-year runoff event may occur in one of these streams each year. The event could occur at the mouth of a river after a widespread rainfall event or in a small tributary in an upper catchment following an exceptionally high local rainfall event. For instance, a cloudburst confined to the catchment of a small creek might produce a 1-in-100 flood event in that creek. However, this is not likely to have a major effect on the river into which the creek flows unless it provides a major component of the river's flow.

It seems natural to assume that most flooding occurs when a stream breaks its banks. On many floodplains, however, the streambanks form elevated, natural levees. Levees are among the last areas on the floodplain to become submerged. As a stream level rises, the most common points through which flooding initially occurs are low areas where the stream is able to spill over onto its floodplain. These are usually the points where local runoff would enter the stream under normal runoff flow conditions—sometimes referred to as 'breakout' areas. As a flood level rises further, a stream may start to follow preferential paths and take 'short cuts' (e.g. by bypassing a meander) greatly increasing the risk of erosion.

Some parts of a floodplain can form a backwater where velocities are slowed and the risk of erosion is very low. On the vast floodplains of inland Queensland, floods are usually slow-moving, gradually spreading out over broad flat plains.

Because of their low velocities, these floods generally cause minimal erosion on the floodplain even if they occur when there is very little pasture cover. However, significant erosion can occur in areas where deeper flows and higher velocities occur, such as in old channels where water leaves or re-enters the main stream.

The risk of erosion can be high where creeks from upland areas discharge onto floodplains. This situation occurs on the eastern slopes of the Darling Downs where streams such as Linthorpe Creek and Ashall Creek spread out onto poorly defined flow paths across the Condamine River floodplain. As these flows get closer to the Condamine River their velocities and erosion potential are reduced because the landscape becomes flatter and the floods spread over a very large area. The risk of erosive flooding in the Brigalow floodplains between Dalby, Jandowae and Chinchilla is generally lower than that for the creek outlets on the eastern Darling Downs. However, the practice of levelling melon holes (gilgai) to make land in these areas more suitable for cropping has reduced the capacity of this landscape to retain rainfall on the surface, increased the speed and volume of flood flows (McLatchey and Watts 1985), and increased the risk of erosion.

10.5.1 Gully formation on floodplains

The risk of gully erosion on a floodplain and in the contributing catchment is much greater where streams are incised. As discussed earlier in this chapter, stream incision is often a natural occurrence that can be driven by processes occurring downstream rather than upstream. Runoff from floodplains occurs as a result of local rainfall or when floodwaters are draining away as flood levels fall. These flows can be concentrated at steep streambanks by cattle pads, roads and tracks or levee banks. Under these conditions the ‘knick point’ where runoff enters an incised stream will become a cascading waterfall leading to the formation of gullies. These gullies can retreat into adjacent river terraces and elevated floodplains as they expand headward (Figure 10.5). More information on alluvial gullying is provided in Chapter 11.

Figure 10.5: Cross-section of an alluvial gully eroding into a terrace from a riverbank (Shellberg and Brooks 2013)

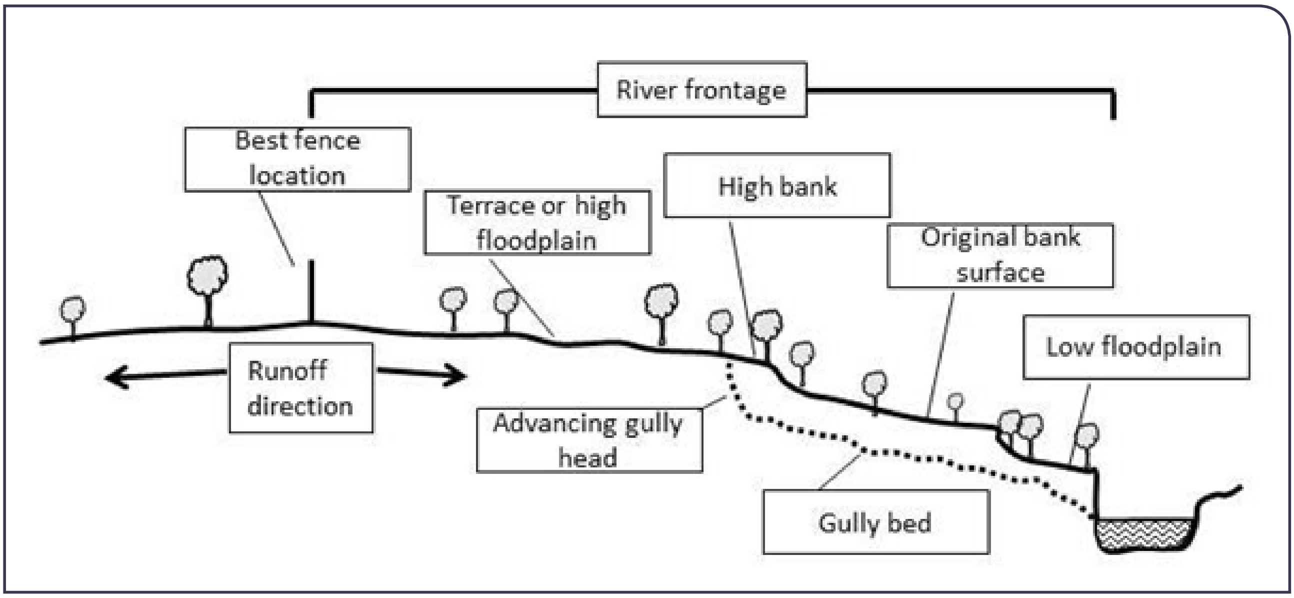
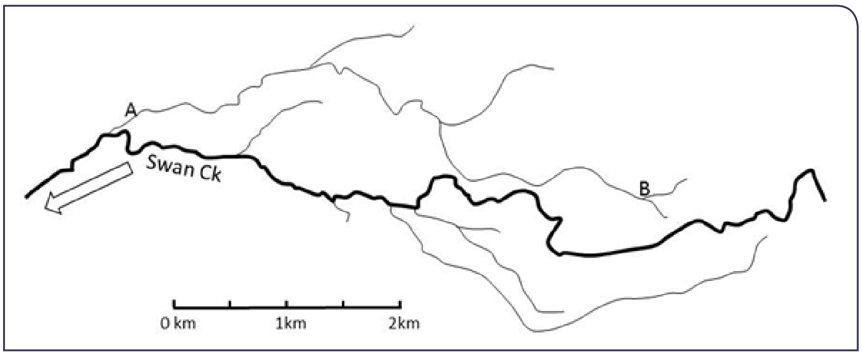


Figure 10.6 illustrates a typical situation where gullying may occur on a floodplain. The channel section A–B is initially flooded from a downstream direction when flood flows from the creek escape at point A where there is less creek incision. As the depth of flow in Swan Creek increases, flood waters enter

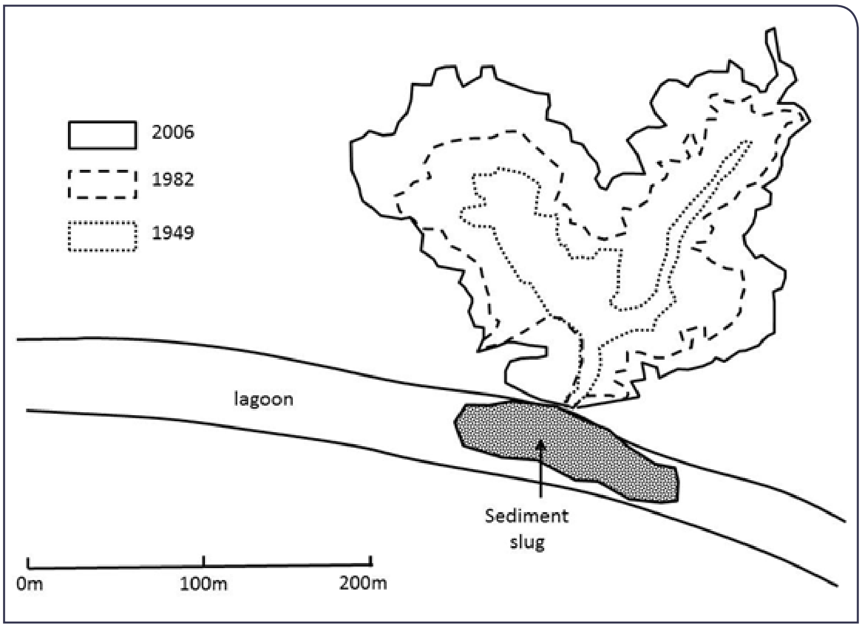
A–B from upstream. Flows in the channel will be deeper and faster than the flow on the land surrounding it, and gullying may occur. As the flood recedes, channels such as A–B drain the floodplain. The saturated condition of these channels makes them susceptible to further gullying, especially if there is a head cut where runoff flows into the gully (e.g. point A in Figure 10.6). It is possible that the channel A–B was once the main channel of Swan Creek or that it could become the main channel at some time in the future.

Figure 10.6: Gullies may form in channels on floodplains



A complex of advancing gullies on a floodplain may coalesce and form a continuous eroding front (Figure 10.7). Examples of this process are found in the rivers flowing into the Gulf of Carpentaria in far north inland Queensland. This situation arises where alluvial gullies are associated with dispersive soils fed by runoff generated from local rainfall, river backwater, over-bank flooding, or groundwater seepage. Growth of a gully system under these circumstances would normally occur as a flood recedes and floodwaters from the floodplain drain into the stream channel. In other situations alluvial gullies may drain in the opposite direction, away from main rivers, depositing sediment into local creeks and lagoons.

Figure 10.7: Growth of an alluvial gully system on the Mitchell River floodplain (Shellberg and Brooks 2013)



10.6 Strategies for controlling erosion on floodplains

When developing strategies to control erosion on floodplains it is important to consider the erosion that occurs in channels as well as the general removal of soil from the floodplain. Where floodplains are subject to erosive flooding, the main objectives of soil conservation will be to avoid practices that concentrate flood flows and to keep the whole of the floodplain covered in suitable protective vegetation. Cultivation creates a surface layer of loosened topsoil above a subsurface layer of soil that has been compacted by the regular trafficking of tractors, equipment and harvesters. The fertility and productivity of the land depends largely on the nutrients and organic matter contained within the topsoil. Floods can easily strip away the valuable topsoil layer exposing the compacted subsurface soil. Zero tillage practices ensure the surface layer of the soil is more erosion-resistant and is protected by standing stubble or crops planted into the stubble. However, young crops planted into a stubble-free paddock will still be vulnerable to erosion until their root systems are well developed.

Many floodplains are natural grasslands. These areas are usually highly prized for grazing as the increased availability of moisture and nutrients means that the grasses are generally more productive and nutritious. Close-growing pasture species protect the soil by reducing flow velocities and by holding the soil surface together. Pasture grasses can also play a beneficial role in filtering out sediment, nutrients and pesticides. When floodplains are cropped, the aim should be to mimic this perennial grassland system as much as possible through careful selection of crop types and management practices.

While maintaining a cover of dense herbaceous vegetation such as grasses and crops is the most effective way to protect soil on floodplains from erosion, maintaining trees and shrubs is the best way to protect streambanks. Tree roots act like reinforcing rods that interlock and hold the soil together. This is especially important when streambanks are weakened under saturated conditions. Trees and shrubs also reduce flow velocities against the bank. The contribution of trees to stabilising streams and reducing gully erosion is discussed further in Chapter 13.

The following sections here provide more information on erosion control strategies for floodplains.

10.6.1 Surface drainage on floodplains

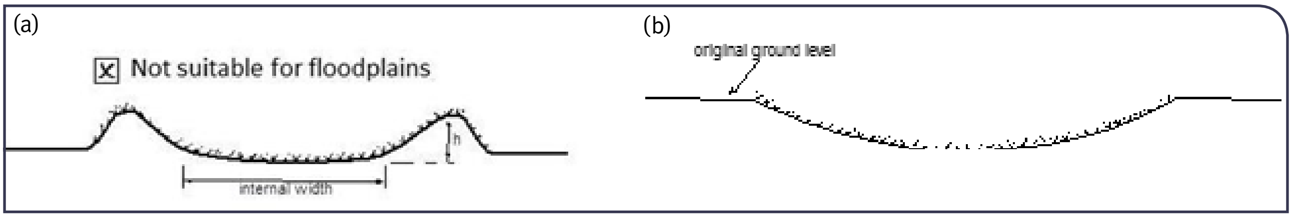
Most floodplains are traversed by channels. These channels play an important hydrological and ecological role. The flow in these channels is episodic and they are usually lined with a variety of close-growing species including grasses and other herbaceous species that protect channels when they are subject to erosive velocities. Trees and shrubs are often a component of this protective vegetation, growing on the banks and sometimes in the channel itself.

When a local storm event occurs, floodplain channels convey runoff from the local catchment to the main stream. In this situation, as well as protecting the banks, dense vegetation in the channel functions as a sediment trap. Like any filter, this sediment trap can become overloaded. Over time, sediment deposited in a channel can lead to prolific grass and weed growth increasing the flow resistance. Whilst this deposition improves the filtration affect it may lead to the next runoff event overtopping and starting to scour a new channel in an attempt to find a new route. This process is more likely to occur on very low sloping floodplains and where the channel has minimal capacity. It explains how deltas form at the outlets of some rivers.

When a stream is in flood, the initial overflow is accommodated in adjacent floodplain channels. Once the flood has inundated the entire floodplain, these channels will carry a greater depth of flow at higher velocities than the more level parts of the floodplain unless they are part of a backwater. As the flood recedes, the floodplain channels carry the residual flows back towards the stream. Flows over floodplains follow pathways of least resistance influenced by channels, roads, railway lines, levee banks and variation in the vegetation density and structure. Diverting flood flows on higher parts of the floodplain may have a dramatic impact on the direction the flood takes.

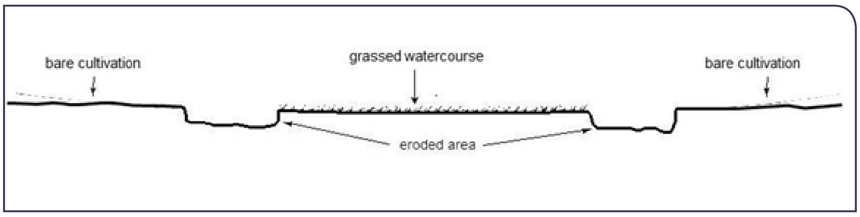
Waterways are often constructed on floodplains to facilitate surface drainage. Chapter 9 describes the process of designing waterways in cropping lands. In upland areas, the flow in waterways is normally contained between retaining banks as shown in Figure 10.8a. However, waterways with continuous retaining banks are not suitable for floodplains because the banks interfere with the spreading of floods during a major event. Also, retaining banks restrict the entry of residual flows into the channel to drain the floodplain when a flood is receding. For channels to successfully accommodate runoff on floodplains they need to be subsurface with no retaining banks (Figure 10.8b).

Figure 10.8: Waterways constructed with retaining banks (a) are not suitable for floodplains, whilst subsurface waterways (b) are



A vegetated strip along a channel in floodplain land used for cropping is not likely to accommodate runoff. This is because the resistance to flow provided by the vegetation cover in the channel will divert runoff onto bare cultivation on one or both sides of the strip. If the flow velocity is great enough, erosion will occur and parallel gullies will develop (Figure 10.9).

Figure 10.9: Flows on floodplains seek out bare soil in preference to grassed areas



Similar problems as that shown in Figure 10.9 can occur if subsurface waterways on floodplains are not adequately maintained. Grass-lined channels should be slashed regularly so that grass growth in the channel does not provide too much resistance to flood flows. Also, sediment deposited in waterways should be removed regularly, before it creates problems. Such work is best done in autumn after the period of greatest flood risk and when there is sufficient warmth and moisture for new grass to quickly grow on areas disturbed by maintenance activities. If the grass cover is removed as part of the maintenance work, oversowing with a temporary crop (e.g. oats in winter or millet in summer), may be necessary to provide protection until the grass cover is re-established.

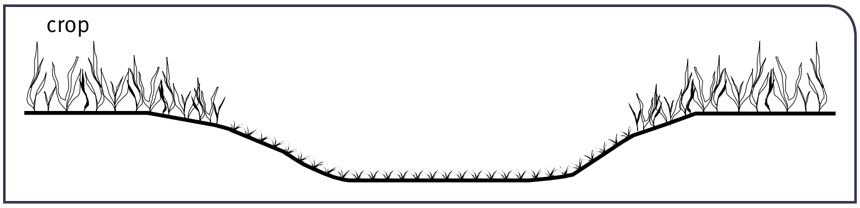
Some texts (e.g. Lovett and Price 2001 and Lovett et al. 2003) have recommended that trees and shrubs be planted along drains in paddocks to shade them. These authors consider that shading has environmental benefits by reducing the temperature of water draining into adjacent waterways and also by reducing the growth of in-stream nuisance plants and algae that may also be flushed into adjacent waterways during floods. However, flows in channels draining paddocks are usually episodic and dense grass growth maintained in a relatively short condition is best for erosion control and filtration in waterways and channels draining paddocks. Shade provided by trees will normally reduce grass growth and will inhibit access by earthmoving equipment necessary to desilt the channel. Also, trees may restrict the capacity of the channel. Where a tree-lined channel on a floodplain has insufficient hydraulic capacity, the solution could be to construct a subsurface channel on one or both sides of it to augment the capacity of the channel. However, this can lead to further erosion problems as outlined above (Figure 10.9).

Channels also connect wetlands to streams. Wetlands can be incorporated in surface drainage systems to improve the quality of runoff before it leaves a property.

Residual flow drains

In some parts of a floodplain, residual flows may persist for several weeks after a major flooding event or a prolonged wet period. Residual flows can restrict access and hence interrupt farming operations. They can also reduce productivity by prolonged waterlogging of soils. Residual flow drains (Figure 10.10) have been used on the Darling Downs floodplain in particular, to remove residual flows from cultivated paddocks. These drains allow quicker access after floods and even out moisture conditions over the cultivated area (Begbie 1977, Cummins and Bass 1978). If the trickle flows are saline, a residual flow drain will also protect agricultural land from salt contamination.

Figure 10.10: Residual flow drain



Residual flow drains should be constructed so that they do not interfere with flood flows and should be coordinated from property to property. On the Darling Downs, they have been located along the length of the main flow paths of some of the floodplain catchments. Their location and effectiveness has been reliant on the goodwill of and cooperation between the floodplain stakeholders across whose land the residual flow drains have been constructed.

Residual flow drains should be aligned as closely as possible to parallel the natural flow path. This will minimise earthworks and decrease the potential for flows to become diverted. Where it is necessary to change the direction of a flow drain, a gentle curve should be used. Sharp bends should be avoided due to the risk of them leading to erosion-inducing turbulence. The risk of erosion in a residual flow drain can be minimised if the drain is not located in the deepest section of the flood flow where high velocities may occur during floods. With approval and cooperation from Local Government, residual flow drains may be constructed along roadsides. However, they should remain separate from road table-drains to avoid destabilising the road as a result of any long-term saturation of foundations associated with residual flows.

Residual flow drains may be subject to local authority by-laws pertaining to levee banks. In catchments where water resource plans have been approved under the provisions of the *Water Resources Act 2000*, there may be controls on new works requiring additional approvals if such works are likely to increase the 'take' of overland flow water.

Residual flow drains should be subsurface without any banks above normal ground level that could divert flood flows. There are no hard and fast rules for determining the capacity of a residual flow drain. If possible, observations of the trickle flow should be made to determine the required capacity. Cummins and Bass (1978) quote a 'rule of thumb' method for drain design for the Pittsworth Plains as 0.21 m3/s per 1000 ha for upland catchments and 0.07 m3/s per 1000 ha for plains catchments. Because they are located on floodplains where slopes would normally be less than 0.3%, it is possible to ensure that shallower flows can be kept below a velocity of 0.3–0.4 m/s.

Residual flow drains with a bare channel are vulnerable to erosion. This is especially so considering the saturated soil conditions that exist during flooding and that they are commonly surrounded by crops that have a high retardance to flood flows. Residual flow drains can be stabilised using species such as kikuyu and African star grass. In wetter areas, water couch and salt-tolerant couch grasses could be considered (Bass 1985). Where spring flows persist, it may not be possible to maintain a permanent vegetation cover and designing the drain for bare soil conditions may be the only option. Outfalls from residual flow drains are particularly vulnerable to erosion. Where water flows freely from the drain into a disposal area such as a deeper drain or pump sump, rock protection or other stabilisation measures may be necessary to prevent erosion. Additional protection could be provided with drop structures or sod chutes with energy dissipaters.

Drains should be constructed during dry periods. They should be built with very broad-sided batters that can be cropped part-way down the channel sides to avoid scours developing from the channel sides back into the cultivation. The construction of drains generally produces significant amounts of spoil because they are excavated below normal ground level. This spoil should be placed so as not to interfere with overland flow paths. It could be spread as shallow fill on adjacent cultivation, placed as spoil banks aligned with the direction of flow, or removed totally from the area. It is not advisable to construct a raised road parallel to the drain as this can interrupt or divert flow, or induce erosive flow velocities as a consequence of increased depth of flow.

Crossings over residual drains should be constructed to not affect flows in the drain. Ideally, crossings should be constructed as gravel inverts either at or slightly above (by at most 100 mm) the bed level of the drain. The depth of gravel required will depend on the weight and frequency of traffic; a minimum of 200 mm depth is necessary, but for heavy traffic loading, up to 300 mm over a suitable geofabric would be required. Culverts require sufficient cross-sectional area to allow flow to pass with minimal surcharge level upstream of the structure. Box-shaped culverts are preferable. The advice of a professional design service will often be necessary when planning crossings.

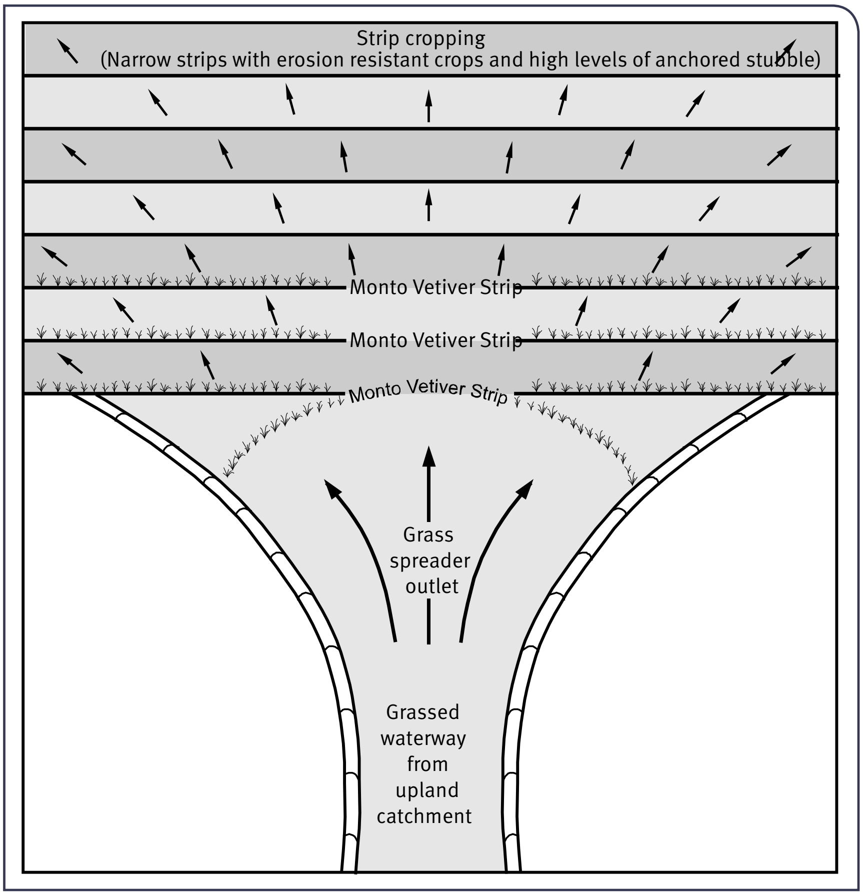
Residual flow drains require maintenance to function well. Vegetation should be slashed, sprayed, or lightly grazed. Silt deposits should be removed. In many cases it will be necessary to virtually re-form the drain at regular intervals. Ancillary structures such as inlet works, outfalls and drop structures also require ongoing maintenance. Care should be taken with the timing of maintenance. When the channel is wet, vehicles should only cross drains at a constructed crossing. Access for maintenance is not possible until the drain has dried out.

Managing concentrated runoff flowing onto floodplains

There are a number of options for dealing with the situation where concentrated flows spill onto floodplains. A grass spreader outlet (Figure 10.11) may be used at the point where a waterway meets a strip cropping area. Another option is to design and build a dam with provision for by-washes on either side discharging into a subsurface channel or sill. Maintenance of these outlet areas is critical. Sediment will accumulate rapidly in them on occasions, which, if not removed, may direct flows away from the grassed area and onto adjacent areas that will be vulnerable to erosion.

High retardance vegetation (such as vetiver) should be planted in relatively narrow strip widths immediately below any spreading devices to accommodate the high velocity flows. The waterway delivering runoff to the grass spreader will also require regular slashing or strategic grazing (to maintain the vegetation) and desilting.

Figure 10.11: Grass spreader at a waterway outlet onto a floodplain



10.6.2 Managing grazing on floodplains

On floodplains used for grazing, the streambanks and riparian land, often referred to as 'frontage country', are the most susceptible to erosion. These areas are usually subjected to the heaviest grazing pressure. Livestock are attracted to them because they offer water, shade and favourable pastures. These areas can also be steep, especially the streambanks, which greatly increases the risk of erosion. Where streams have high and steep or wooded banks there may be few points of access and cattle scrambling up or down banks can incise paths, thereby eroding streambanks and creating gullies.

Erosion in riparian areas is often associated with local rainfall rather than with flooding from widespread or distant rainfall. Heavy grazing pressure can lead to bare soil or 'scalds'. Bare soil is vulnerable to raindrop impact and can be relatively impermeable, leading to runoff which soon concentrates to cause erosion. Areas with dispersive soils are especially vulnerable in these circumstances.

Trees and grasses play different roles in protecting streambanks and riparian areas from erosion. As discussed above, tree roots play an important role in strengthening steep streambanks. However, competition from trees can suppress ground covering herbs and grasses, making soil under trees very susceptible to erosion. Groundcover species such as grasses provide protection by absorbing raindrop impact and reducing the erosion potential of overland flows. Gully formation is common in land adjacent to incised streams. Dry gullies flowing into streams can best be managed by encouraging grass growth rather than tree growth.

Woodland thickening can be a particular problem in frontage land (Department of Environment and Resource Management 2011). Heavy grazing pressure reduces competition from the herbaceous layer allowing woody plants to proliferate. The initial increase in woody plant cover suppresses fire, leading to a persistent change in the structure of the vegetation from one dominated by grasses and herbs to one dominated by shrubs and trees. Woodland thickening can lead to:

- reduced grazing value
- reduced soil surface cover
- increased risk of erosion
- colonisation by pest plants
- reduced access for management purposes (e.g. mustering and weed control).

Clearing of native vegetation to manage woodland thickening needs to be carried out in accordance with the Vegetation Management Act 1999 and may require a permit.

Erosion of grazed floodplains is best managed by controlling stock access. Benefits from fencing riparian zones and providing off stream water points can include:

- preventing the disturbance and bogging of the stream bed
- preventing the formation of cattle pads that can cause gullies
- assisting the rehabilitation of gullies
- improving water quality
- reducing the spread of weeds
- making stock mustering easier.

Fencing of riparian areas also allows grazing pressure to be manipulated throughout the year in line with seasonal conditions. Limiting grazing of riparian areas to just early in the dry season can have the following benefits:

- It directs grazing onto the green leaf of pasture grasses (reducing the amount of browsing on trees and shrubs).
- High levels of ground cover are maintained (pastures have had a chance to be spelled over the wet season).
- It takes advantage of high feed quality compared to surrounding areas.
- It reduces the risks of erosion damage and sedimentation of the stream which can result from stock accessing saturated streambanks.

Watering points

Fencing riparian land can be expensive. Because streams rarely follow straight lines, riparian fences are usually longer and more complicated (e.g. requiring more corner posts and strainers) than would be necessary for fencing other parts of the property. Also, riparian fences are prone to flood damage, resulting in higher maintenance costs and/or a need to construct them to a higher standard in the first place. The high cost usually limits the amount of riparian land that can be fenced. This is especially so on large outback properties where the area of floodplain or riparian land can be significant.

Off-stream watering points (e.g. troughs) can be used as an alternative to fencing to protect riparian areas. Off-stream water points provide stock with an alternative source of water thus reducing the time cattle spend drinking in creeks and waterholes. In many cases stock prefer to drink from well-placed troughs, particularly if access to the watercourse is difficult, water quality is low, or there is danger (e.g. crocodile habitats).

Where streambanks are susceptible to erosion, damage can be limited if stock access is restricted to a section of the streambank. The section where access is provided should be selected because it is less prone to erosion than other parts of the streambank. For instance, boggy areas and bends should be avoided. Ideally, the access point would be formed with a graded slope into the stream. The surface of the access point can then be protected with concrete, compacted gravel, logs, or similar materials that form a walkway for the stock. Cross-stream fencing may be required to prevent animals crossing the stream and wandering along the streambank.

Locating riparian fences

When planning to fence riparian areas consideration should be given to:

- establishing a frontage paddock by fencing out the upland areas adjacent to the floodplain
- fencing out high-priority water bodies such as natural springs
- fencing out areas that are especially vulnerable to gully and streambank erosion
- fencing the immediate riparian area (refer to Chapter 11 for advice on riparian zone widths for streambank stabilisation).

Fences commonly collect debris such as dead grass during a flood. The presence of debris increases the forces upon the fence and can cause it to be flattened or swept away. If a fence is not a boundary fence, and there is flexibility in how the fence is aligned, consideration should be given to aligning it at a low angle to the direction of the flood flow. Fences at right angles to the direction of moving floodwaters are most susceptible to flood damage. When planning new fences or realigning existing fences, it may be possible to reduce the length of fences exposed to flood flows. Fences parallel to the flow and fences in a flood backwater will suffer the least damage.

It is worth spending some time planning riparian fences. A well-fenced riparian area can create opportunities for strategic grazing. It also means the bends and curves of the stream can be cut out reducing the construction and maintenance costs. Sections of fences that are regularly damaged by floods and that are not able to be relocated can be constructed so that they lay flat during a flood. In accessible areas that are prone to significant flooding, an option may be to remove the wire from some sections of the fence shortly before flood levels rise.

Riparian fences should not be constructed too close to the stream. Chapter 11 provides guidance on suitable widths for riparian areas. Where it is necessary to fence down a streambank, the amount of disturbance required can be reduced by using existing live trees as fence posts (tree to tree) to avoid the need to clear the fence line and disturb the soil.

Types of fencing for floodplains

This section should be read in conjunction with Section 14.3 in Chapter 14 *Property infrastructure*.

During a flood, fences trap flowing debris such as grasses. This increases the pressure on the fence depending on its orientation to the direction of flood flow. Mesh or ring-lock fences provide the most resistance and are most likely to fail or to divert flood flows. Barbed-wire fences are also prone to trapping sediment compared to plain wire fences.

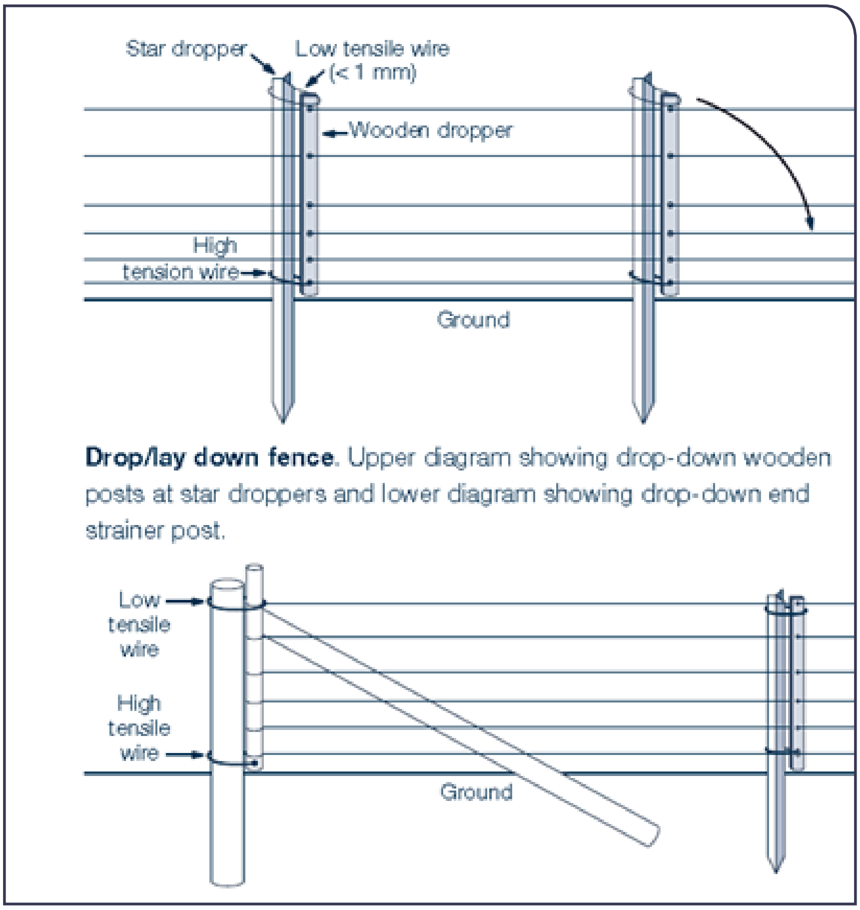
Lovett et al. (2003) describe a number of fencing options for use on floodplains and in riparian areas, including hanging fences, electric fences, drop fences and electronic fencing.

Hanging fences can be built across narrow streams to prevent and stock from walking along the stream to bypass fence lines. Hanging fences are usually suspended from steel cable or multi-stranded, high-tensile fencing wire strung across the stream. In order to prevent hanging fences being damaged or destroyed during floods, they include hanging panels which are designed to ride up with heavy flows and return to their normal position once the peak flow has passed. The hanging panels are usually galvanised iron or ring-lock hinged across the cable. They may be damaged by debris coming down in a big flood, but the damage is usually not severe and the panels can be cheaply and easily repaired or replaced.

Electric fences can be used along and across streams. An electric fence is not only much cheaper to construct, but it is much cheaper to repair following an unexpectedly large flood. Steel droppers will usually survive a flood unless hit by large debris, so it is often only the electric fencing wire that needs to be replaced. When an electric fence is placed across the stream a steel cable is used as a horizontal support, from which steel chains or hinged panels are hung. The chains and/or panels are separately earthed from the grounded cable, and all are electrified and able to move independently, allowing floodwater and debris to pass underneath. Portable electric fences are another alternative that landholders can use to control stock movement along streamsides. Portable fences have the added advantage that they can be quickly moved if there is advance notice of a likely flood peak.

Drop fences (Figure 10.12) are designed to be either manually operated (dropped) before a flood, or to automatically drop from anchor points under the pressure of floodwater and debris. Once the floodwaters have receded, drop fences can be quickly and simply pulled back up and reattached to their anchor points. Drop fences can also be useful even when there is no flood as an alternative to gates for moving stock or vehicles from one paddock to another.

Figure 10.12: Drop.lay down fence (lovett et al. 2003)



Drop/lay down fence. Upper diagram showing drop-down wooden posts at star droppers and lower diagram showing drop-down end strainer post.

Electronic fencing is an alternative to fixed fencing, particularly for cattle. With electronic fencing stock wear a receiver initially developed in the form of an ear-tag, and transmitter boxes are located to form a boundary between the riparian area and the rest of the paddock. The transmitters emit a continuous signal which defines the boundary. The receivers respond by producing firstly an audio signal, followed by an electric stimulus if the animal attempts to enter the exclusion land. Electronic fencing is cheaper than conventional fixed fences and can be moved quickly in the event of a flood peak. Tests have shown that cattle quickly become used to it. Electronic fencing is under active development in Australia (e.g. by CSIRO), with the aim of bringing the price down to a level at which it can be adopted widely.

10.6.3 Managing extensive cropping on floodplains

The key to controlling erosion on floodplains is to reduce flow velocities by encouraging flows to spread out over the floodplain. Cropping practices play a major role in achieving this but roads, railway lines, fence lines, levee banks and irrigation infrastructure must also be considered. Such structures can contribute to erosion by diverting and concentrating flood flows.

Effective control of erosion on floodplains requires the cooperation of landholders, agencies and companies responsible for infrastructure, as well as all levels of government. Soil conservation measures on floodplains need to be planned and implemented in a coordinated manner. Affected landholders and agencies need to work together to ensure that floodwater is spread over the entire floodplain. A piecemeal approach is seldom effective in managing widespread flooding or controlling erosion on floodplains.

Cropping systems on floodplains

Where broadacre cropping is practised on a floodplain there is a high risk of erosion. Management practices such as zero tillage and strip cropping should be routinely used to reduce this risk. However, in areas where the risk is particularly high (say a flood frequency of greater than 1:5 years) the best option may be to change to a native or introduced sown pasture that will provide permanent cover.

Crops with multiple stems and leaf material that remain intact for a long time after harvest provide the most resistance to flood flows and the best erosion protection. In Queensland this includes, in summer, crops such as sorghum and maize and, in winter, wheat and barley. Sunflower, cotton, mung beans and chickpeas provide less protection because they have single stalks and their mature leaves readily disintegrate. Where a crop that provides less protection is grown, a more resistant variety such as wheat can be planted into the stubble immediately after harvest as a cover crop to provide rapid protection from flood erosion.

It is recommended that zero tillage be practised because it ensures that stubble remains anchored into the soil. Loose stubble can be a hazard on a floodplain when it floats downstream in a flood and gets deposited against a standing crop or a fence line or where it blocks a road cross-drainage structure. This leads to obstruction and diversion of flows. Zero tillage should also be combined with opportunity cropping, such as planting a crop whenever soil moisture reserves are considered sufficient irrespective of the time in a rotation cycle. This results in an increase in cropping frequency (e.g. three crops in two years) and ensures that the soil is protected by vegetation cover for a greater proportion of time.

Heavy farming equipment such as tractors and harvesters can create depressed wheel ruts especially under moist conditions. These ruts can divert and concentrate flows leading to erosion. The impact of wheel ruts can be minimised if they are at right angles to the flood flow or by levelling them with specialised renovating machinery.

Direction of crop rows

Flowing water will always take the easiest pathway. Floodwaters seek out paddocks or parts of paddocks that offer the least resistance to flow, such as bare fallows or crops that have minimal cover. Similarly, floods can be diverted away by crops, depending on their density and their orientation to the contour. Figure 10.13 compares three different directions for crops in relation to flood flow.

Figure 10.13: How crop direction affects flood flows

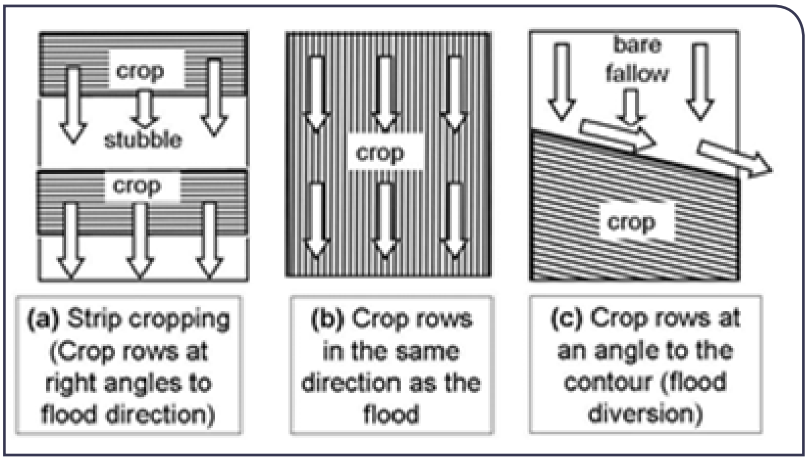


Figure 10.13 (a) shows floodwaters flowing through alternating summer and winter crops grown in a rotation on the contour. This layout is typical of strip cropping. Strip cropping (see Figure 10.14) has been used in the Darling Downs since the late 1950s to control erosion on parts of the floodplain subject to erosive flooding. It can be readily seen on aerial photographs and satellite imagery of the landscape around Dalby, Jimbour, Norwin and Bongeen. More information about strip cropping is provided in the next section.

Figure 10.13 (b) shows crop rows aligned along the floodplain in the same direction as the floodwater flows. This cropping layout has been adopted by a number of farmers in recent years in conjunction with controlled traffic farming (CTF), zero tillage and opportunity cropping. 'Up and down' directions can improve drainage in wetter years on lower sloping parts of the floodplain. However, with this layout, there is an increased risk of erosion under flooding as flows can be diverted and concentrated along wheel tracks. Such paddocks would also be vulnerable to erosion if a crop was not planted because of drought. By comparison, in a strip cropping system half of the strips would still carry sufficient cover even in a drought situation.

Figure 10.13 (c) shows how floodwaters can be diverted by crops grown in rows diagonal to the contour. This is likely to concentrate flows with the consequent potential for serious erosion. It may also divert flows out of their natural catchments and create problems for downstream landholders. Strip cropping implemented independently by different farmers across a floodplain often follows quite divergent directions. These strips are often established without the use of topographic data and without taking into account the need to manage flows across the whole of the floodplain.

Strip cropping

Strip cropping is the method of growing alternating strips of crop on the contour at right angles to the flood flow direction to reduce floodplain erosion. The aim of strip cropping is to reduce flow velocities by encouraging runoff flows to spread rather than to concentrate. This protects soil in the paddock from erosion as well as improving water quality downstream by filtering out sediment, nutrients and pesticides.

The widespread adoption of zero tillage over recent decades means that now entire properties may be protected by crop or standing stubble at the one time. If such a result could be guaranteed, irrespective of seasonal conditions, and the crop rows were always at right angles to flood flows, then strip cropping would not be necessary. However, strip cropping still provides additional flexibility to ensure that the property is always protected, such as by:

- allowing low-resistance crops, such as sunflower and cotton, to be alternated in strips with high-resistance crops, and
- ensuring that areas forced to remain in fallow due to drought are alternated in strips with stubble from the previous season's crop.

In Queensland, strip cropping is practised in broadacre cropping on the Darling Downs floodplains. To be effective the crops sown in a strip-cropping system need to be of types that present high resistance to flood flows. Examples of such crops include some winter and summer cereals.

The aim when strip cropping is to ensure that there will always be either a crop or standing stubble in each strip to help spread water and reduce flow velocity. Even in drought, when that season's crop is unable to be planted, strip cropping will ensure some protection as the alternate strips planted in the previous season will still have residual cover. Since strip cropping is carried out in parallel strips, it is compatible with controlled traffic farming (CTF).

Local flooding can sometimes occur when there is heavy rainfall in an upland catchment but little rain on the floodplain. In this situation, strip cropping can ensure that flood flows are spread and thus provide a free natural irrigation of crops. Soils within strips carrying a mature or harvested crop may often contain significant cracks that can accept runoff from adjacent strips that are in fallow and more likely to produce runoff.

Minor drainage lines passing through strip cropping areas can become waterlogged in wet years. This can lead to some crop loss in wet years (although they may also yield more in drier years). Low-lying areas can also interfere with machinery access until the soil dries out. Low-lying areas can be eliminated by land levelling. They may also tend to infill naturally due to sedimentation occurring when flows are slowed by meeting strips of crop.

Strip cropping requires a higher level of management compared with standard practices. For example, when controlling weeds care needs to be taken to ensure spray does not drift from one strip to another. This problem can however be managed with shields, changing droplet size and attention to wind speed and direction.

Strip cropping should be combined with conservation cropping and crop rotation techniques to ensure that there is always either a crop or standing stubble in every strip to help spread water and reduce flow velocity. Stubble needs to be anchored to avoid it floating and subsequently being deposited in places where it may cause problems such as blocking road cross-drainage structures.

Opportunity cropping with a strip cropping system can increase the protection of soil from erosive flooding. It can also increase cropping frequency (e.g. two crops in three years rather than just every second year) and thus increase the average amount of surface cover across the full rotation.

Figure 10.14: Strip cropping on the Darling Downs floodplain

The design and implementation of strip cropping layouts need to be coordinated. Adoption of strip cropping practices on a single property will have limited overall benefit unless the neighbouring properties also adopt the practice. All landholders affected by flooding, including farmers and local and state governments, must work together to ensure that floodwater is spread over the entire floodplain. Strip cropping on cultivated lands must be coordinated with a range of other measures across the whole floodplain. This is required to avoid problems caused by flood flows being diverted and concentrated by structures such as roads, railway lines, irrigation infrastructure and levee banks.

Formulae have been developed to estimate the width that strips should be, based on criteria such as land slope, flow rates, soil erodibility and crop rotations and management (Ruffini et al. 1988). Table 10.1 is a guide to strip cropping widths based on the topographic situation and the level of protective cover provided by the crop rotation and management system.

Table 10.1: Recommended strip cropping widths for floodplains subject to erosive flooding

Level of protective cover provided by the crop management system	Recommended strip cropping width (metres)		
	Creek outlets and narrow valley floors (slopes of 0.4–0.5%)	Plains–upland flow (slopes of 0.2–0.3%)	Plains in lower areas subject to widespread inundation (slopes of 0.1% and less)
High	50	80	100
Moderate	25	40	50
Low	No recommended	Not recommended	30

The level of protective cover provided varies with the crop management system (Table 10.2) and the crop type (Table 10.3).

Table 10.2: Guide to determining the level of protective cover provided by a crop management system

Level of protective cover provided by the crop management system	Stubble management	Cropping system
High	Zero tillage	High proportion of crops providing high cover levels. Opportunity cropping whenever possible.
Moderate	Reduced tillage	A moderate proportion of crops providing high cover levels. Low levels of opportunity cropping.
Low	Bare fallow	One crop per year with a high proportion of crops providing low levels of cover.

It may also be necessary to vary the width of the strip recommended by this process to be compatible with the widths of the machinery commonly used on the property.

Table 10.3: Level of protective cover provided by crop type

Level of protective cover	Crops	Comment
High	wheat, barley, sorghum, maize	Crops grown in wide rows provide less protection.
Low	sunflowers, chick peas, cotton, mung beans	Legume crops leave little or no stubble after harvest. Cotton is an effective crop at slowing floodwaters during active growth but the stubble provides little protection after harvest.

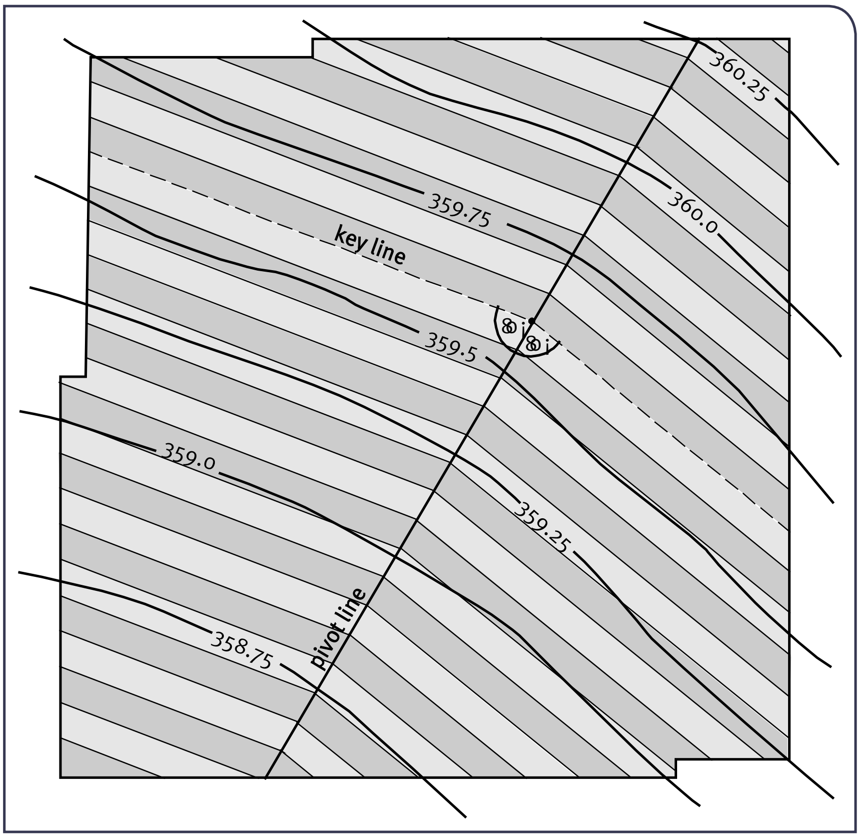
Detailed topographic information and likely paths of flood flows is required to determine the most appropriate orientation for strips on floodplains. Topographic information would normally be in the form of contours, ideally at an interval of 0.25 m or less for slopes of less than 0.5%.

Sometimes it may be necessary to change the orientation of strips along their length due to a change in the direction of flow or slope. Where a change in strip direction is required it will be necessary to use a pivot line (Figure 10.15).

When implementing a pivot line, the angle that each strip deviates from the pivot line must be identical to ensure the strip width is the same for each strip either side of the pivot line. Unequal pivot angles should be avoided if possible. If the pivot angles are unequal it will be necessary to manage the strips on either side of the pivot line as separate blocks. Such systems are more difficult to manage as it is necessary for the pivot line to become a headland where tractors and machinery can turn around. Also, because no crop is grown on the pivot line in such circumstances, it could easily become a route for floodwaters to follow and cause erosion.

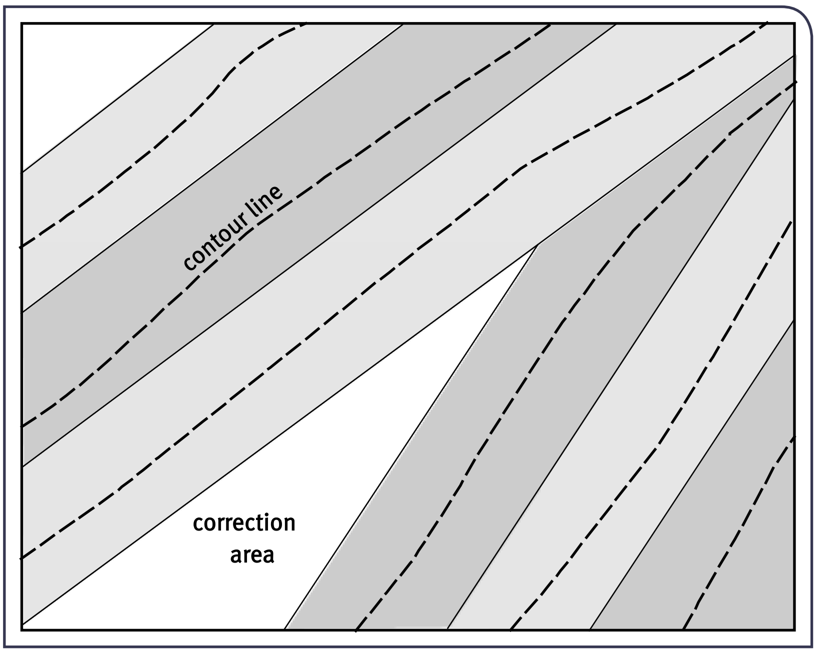
The angle of a pivot is dependent on machinery width and manoeuvrability. However, the minimum is generally about 70 degrees, as sharper angles will leave extensive areas of unplanted headlands especially when multiple-hitch machinery is used.

Figure 10.15: Strip cropping layout with a pivot to provide for change in strip direction (Eacott 1979)



To improve workability of a strip-cropped paddock and to ensure that strips are located on the contour, it may be necessary to insert a correction strip (Figure 10.16). Correction areas would normally be kept as pasture, although they can be cropped if they are of sufficient size.

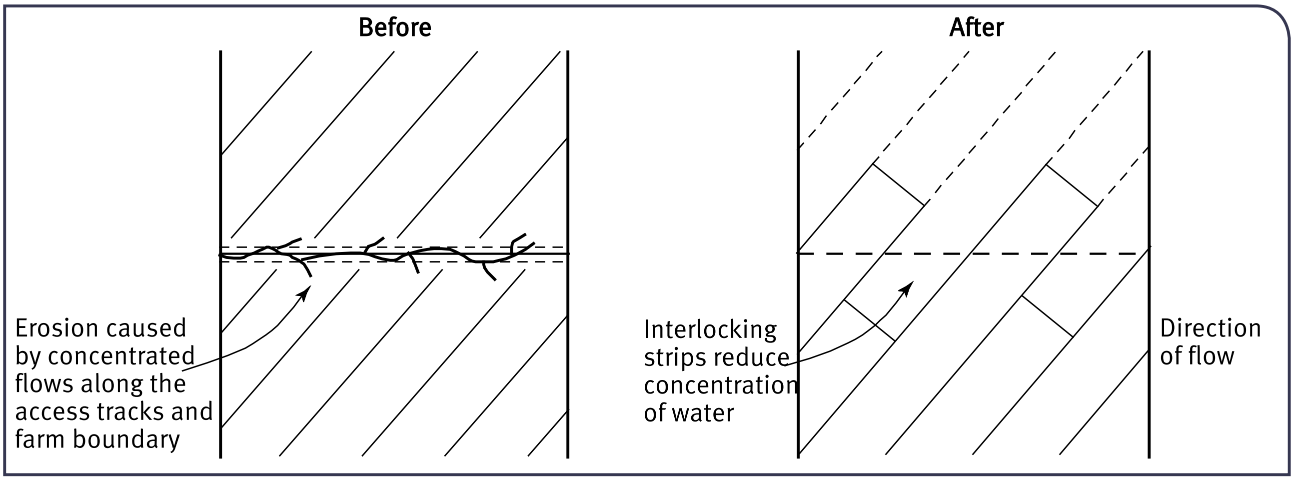
Figure 10.16: Correction area in a strip cropping layout (Macnish 1980)



Strip cropping can also be used to protect cropping land against wind erosion; however, it is not widely used for this purpose in Queensland. The heavy texture of most cropping soils in Queensland means that they are not susceptible to wind erosion. Also, to be effective against wind, strips would need to be at right angles to erosive winds and would often not be compatible with any strips or runoff control measures that may be required for control of erosion by water. For these reasons, where wind erosion is an issue, conservation cropping measures where cover is retained across the whole paddock are a better option for protection.

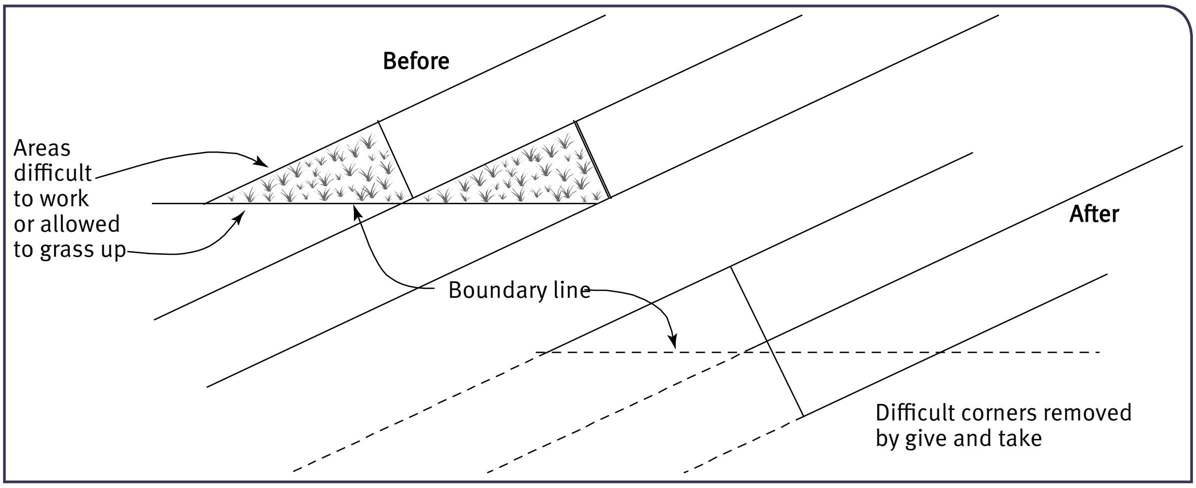
Erosion problems may arise at a boundary line between neighbouring properties practising strip cropping. Along such a boundary there are usually two parallel access tracks, one on each side. These access tracks tend to concentrate water, causing washouts. This problem can be overcome by neighbours interlocking their strip cropping layouts and each landholder farming an equivalent area of their neighbour's land as shown in Figure 10.17. This process of exchanging land between neighbours to help the spread of floodwaters is referred to as 'give-and-take'.

Figure 10.17: 'Give and take' to overcome concentrated flows along boundaries



In some strip cropping layouts, the strip may meet a boundary at very sharp angles creating corners that are difficult to work. These corners are often left to grass up, creating potential weed problems. By using 'give-and-take' with a neighbour, the problems of these difficult corners can be overcome (Figure 10.18).

Figure 10.18: Give adn take to vaoid difficult corners



Land levelling

Rills and gullies can make it difficult to effectively spread flood flows across a paddock. They can also create difficulties for crop management. Rills and gullies concentrate flows and are susceptible to further erosion during a flooding event. Runoff flowing in such depressions may also disturb and expose (or bury) crop seed, inhibiting establishment and leading to the need to replant. Conversely, old headlands and fence lines can act as barriers diverting and concentrating flood flows or causing them to pond, leading to waterlogging.

Land levelling combined with strip cropping can assist in spreading floodwaters more effectively. Levelling may be carried out using a land plane drawn behind a tractor, or with a scraper or tractor-drawn bucket. Using laser survey in conjunction with this equipment greatly improves the effectiveness and efficiency of the process.

Land levelling should aim to have minimal impact on natural flow paths. To achieve this, all land levelling should be carried out in such a way that the down-field and cross-field slopes align with the natural slope of the land. Land levelling should be designed to blend with natural surface profiles both within and surrounding the block. This will avoid significant differences in finished heights on the block boundaries, which can promote concentration of flows and erosion.

In many parts of the Darling Downs floodplain where there are no stock on farms and no stock routes, fences have been removed. When removing fences it is important to also level soil build-up and erosion scours along them at the same time. Where fences have been removed, corner posts should be retained along portion boundaries to prevent the need for a re-survey on the sale of the property and to prevent cultivation encroaching onto road reserves.

10.6.4 Managing intensive cropping on floodplains

Valley floors and floodplains are ideal locations for horticultural cropping because of the fertility of their soils and the ready availability of water for irrigation. Because of the low slopes in these areas, the risk of erosion is minimal, provided the land is not subject to erosive flooding. Where the risk of erosive flooding is high, an alternative land use such as a permanent pasture should be considered. Levee banks can be used to protect some paddocks, but they may increase the risk of erosion in adjacent areas as discussed below. Drainage lines between blocks of crops also need to be managed to minimise erosion. A suitable buffer width should be maintained on all drainage lines and riparian areas (refer to Section 13.5.4).

Horticultural crops are generally more susceptible to erosion than broadacre cereal crops such as wheat, barley and sorghum which are closely sown, where cultivation is limited and where stubble is maintained between crops. The strip cropping approach used to reduce the risk of erosion from flood flows in cereal growing areas on the Darling Downs floodplain has not been adapted for use in horticulture on floodplains. Beds or mounds, which are commonly used in horticultural cropping to assist drainage, may concentrate flood flows leading to increased erosion and would also limit the effectiveness of strip cropping if it were applied in horticulture.

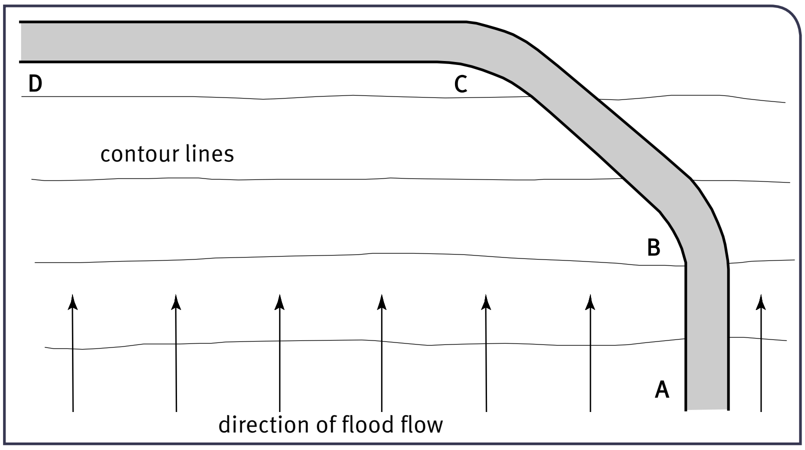
10.6.5 Infrastructure on floodplains

Roads, railway lines, fences, levee banks and irrigation structures can significantly interfere with the natural spread of floodwaters. Structures such as these can concentrate floodwaters and increase the risk of erosive flooding and damage to other lands and properties. This section should be read in conjunction with Chapter 14 Property infrastructure.

Roads

Roads are normally constructed above ground level by 300–600 mm. Depending on their height and on their orientation in relation to the direction of the flood flow, roads can have a major or a minor impact on flood flows. Figure 10.19 shows how the direction of a road might be orientated within a floodplain landscape. The section of the road A–B is running directly up and down slope and would cause no diversion of floods no matter how elevated it was. The section B–C is running diagonal to the slope and may cause significant diversion. The section C–D is on the contour and at right angles to the direction of flood flow and should not cause diversion of flow providing there is adequate cross-drainage.

Figure 10.19: Orientation of a road to the contour affects its impact on flood flows (Marshall 1988)



Where the floodplain is wide and properties are numerous (such as on the Darling Downs), roads will generally cross the floodplain in a variety of directions in relation to the topography. However, in most floodplain situations, roads are located to take the shortest route across the floodplain which is at right angles to the direction of flow (Figure 10.19, section C–D). Roads located with this orientation are generally constructed with culverts or inverts that are adequate to accommodate normal flows. A series of box culverts (rectangular shape) are preferred to pipe culverts because they allow the road profile to be lower and they spread flows more widely, reducing their downstream erosion potential. Road cross-drainage structures can also control erosion by acting as a drop structure to halt the upstream advance of a gully head. However, their success in this role depends on their not being undermined by the advancing gully.

In major floods, when the capacity of the culverts is exceeded the road can act like a weir, with floodwaters flowing over the road surface. Under these circumstances the risk of erosion can be high. On sections of the Darling Downs floodplain where erosive flooding is a problem for cropping areas, a number of roads have been lowered to between 100 mm and 200 mm above natural ground level (Figure 10.20). Under high flow conditions a road built in this way acts as a long floodway. Floodwaters flow over its full length in a shallow controlled flow creating much less backup of water than a raised road. As the overfall below such a road is small, turbulence is minimal and damage to cultivated land on the downstream side will be reduced. Roads that have been lowered in this way need to be adequately signed and should be constructed with a cross-fall to prevent water lying on the road after the flood has passed. Where an invert is required to be constructed in such roads it should be no more than 100 mm above natural ground level.

Figure 10.20: Floodwaters spreading across a low level road on the Darling Downs

Low floodways may be unacceptable for major highways if they flood too frequently and create road safety issues. Where a road is causing frequent major erosion or pondage problems, the best solution may be to relocate it.

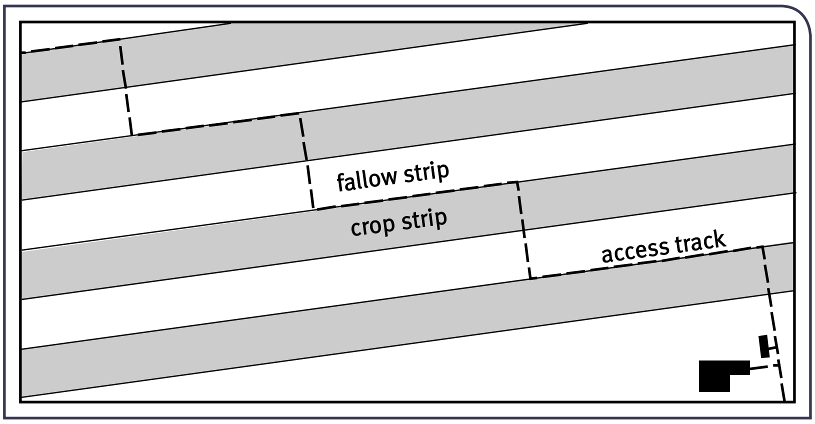
Farm roads and access tracks

The issues that apply to public roads apply equally to farm roads and access tracks. Roads connecting a farmhouse and buildings on a floodplain to a public road are often built to the same height as the public road to maintain access during a flood. However, tracks built in this way will divert flood flows which can be significant depending on how the track is orientated to the contour. Where flood flow diversion is likely to be significant, formed property roads on floodplains should be constructed no more than 100 mm above natural ground level.

Unformed roads and access tracks often end up at a level below the normal ground surface after a period of use and maintenance by a grader. Roads that are below ground level concentrate runoff and flood flows and can eventually become an eroding gully. Low banks, or 'whoa-boys', constructed to cross such roads at intervals and extending into adjoining cultivation will alleviate this problem. Whoa-boys constructed on floodplains should be no more than 200 m apart so that runoff flows only short distances between them and is shed in only small quantities onto adjoining land. Where spoil windrows are created by grading of the road surface during maintenance, they should be levelled and the soil moved back onto the road.

Access tracks through cultivated paddocks should be relocated regularly where practical. This is to avoid them becoming subsurface. Crops can be planted across tracks and right up to paddock boundaries so that the whole paddock is protected from erosion by a growing crop. Tracks through a strip-cropped area can be zigzagged to reduce the possibility of flow concentrating along the track and causing erosion (Figure 10.21).

Figure 10.21: Track zigzagged through a strip-cropping layout



Where a road is abandoned as a result of serious erosion, the land should be levelled as part of the rehabilitation of the area. If this is not practical, close-growing vegetation should be planted and whoa-boys constructed at regular intervals.

Where formed roads cross a drainage line or creek, an invert, floodway, causeway, culvert, or bridge will be required. Inverts are constructed by removing soil from the crossing and replacing it with coarse gravel or concrete. A sheet of geofabric should be laid below the gravel to ensure that the soil and gravel remain separated as layers. The diameter of culverts needs to be matched to the area they drain and the amount of runoff anticipated. Culverts are susceptible to blockage from siltation as well as the growth of grass and weeds so maintenance is essential.

Railway lines

Railway embankments located on floodplains are typically raised at least 500 mm above normal ground level. This means that they have the potential to significantly impede and divert flood flows. The loose stone ballast that supports railway tracks can be removed by floods, leaving the rails and sleepers unsupported and dangerous to travel across. For this reason, railway lines are always constructed on embankments to raise the railway above expected flood levels.

Railway lines on the Darling Downs were mostly constructed in the late 1800s or early 1900s when there was little cultivation on the floodplain. Since that time the patterns of overland flow have changed considerably. As a result, railway cross-drainage is inadequate in many locations. The authorities responsible for managing railway lines are responsive to suggestions to improve rail cross-drainage.

Levee banks

Artificial levee banks are usually constructed on floodplains to protect land and infrastructure from the impacts of flooding. Levees can be constructed parallel to a watercourse or across the floodplain. The purpose of constructing levees parallel to a watercourse is to contain floods within the watercourse. The purpose of building levee banks across the floodplain at right angles or diagonal to the flow direction is to divert floods around an area for its protection.

The Water Act 2000 defines a levee bank as: “an artificial embankment or structure which prevents or reduces the flow of overland flow water onto or from land”. However, there are some structures that are excluded from the effects of the associated Regulation that controls the construction or modifications of levees. Exemptions under this legislation include “prescribed farming activities” such as cultivating, levelling, contouring, irrigation infrastructure and clearing or replanting vegetation.

Any above-ground structure on a floodplain can divert or concentrate flood flows. As such it may have a similar effect as a levee bank. Such structures include those built to harvest or to distribute water as part of an irrigation scheme, roads or railway lines. Depending on their orientation to the direction of flood flow, even debris-laden fences can act like levee banks and cause some diversion of floods.

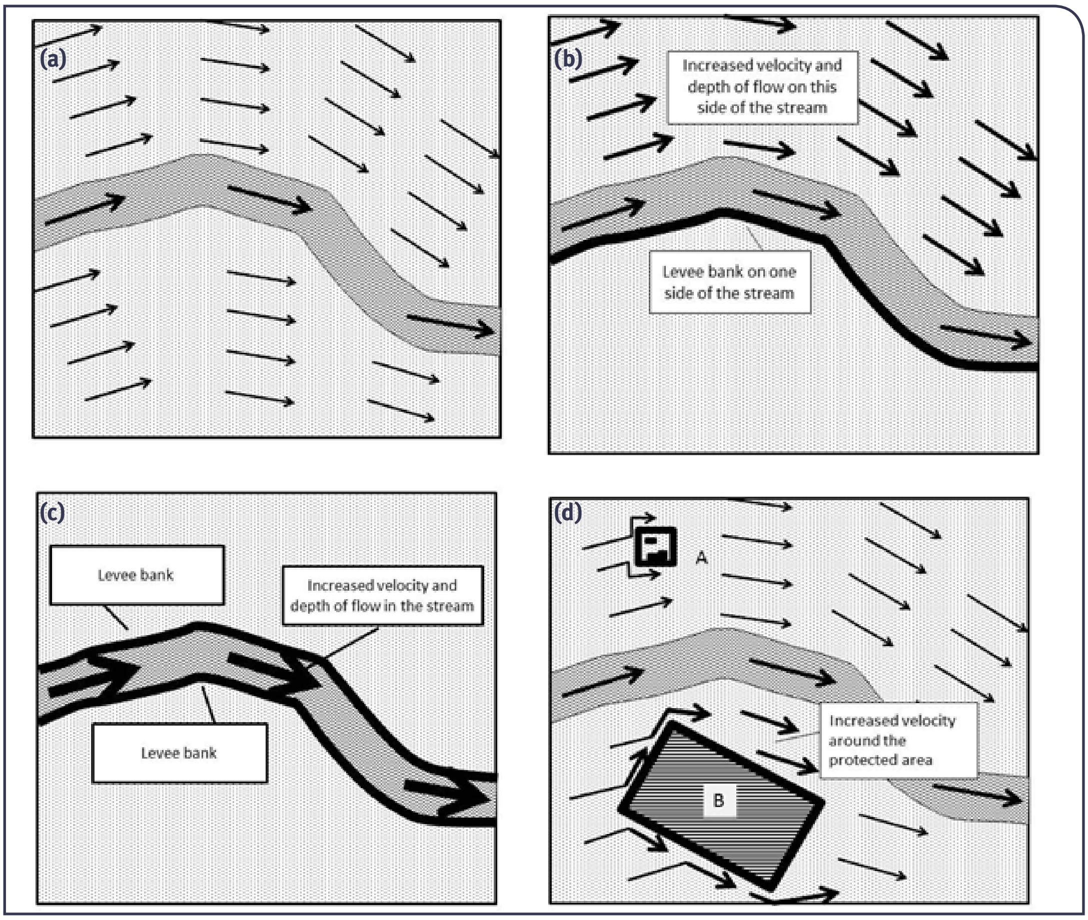
Levee banks and other above-ground structures can have the following impacts on floodplains:

- They can concentrate flows leading to higher velocities, erosion of land, loss of crops and damage to irrigation infrastructure as well as public infrastructure such as roads.
- They may divert floods and increase the flood risk in other areas.
- They may result in deeper flows and higher velocities in streams, increasing the risk of bed and streambank erosion and increasing flooding problems for downstream properties.
- If they fail, or overtop, damage may result to the area they were intended to protect.
- They can act like a dam and prevent local flows from the 'protected area' from entering the stream.

Figure 10.22(a–d) shows the range of different situations in which constructed levee banks might function on a floodplain:

- Figure 10.22a shows a flood spreading across a floodplain.
- In Figure 10.22b a levee bank prevents flooding on one side of the stream and diverts flood flows to the other side of the stream.
- In Figure 10.22c levee banks on both sides of the stream prevent floods from spreading onto the floodplain.
- In Figure 10.22d levee banks are protecting a house and buildings (A) on one side of the floodplain and a paddock (B) on the other side.

Figure 10.22: Flood flow across a floodplain: (a) unconstrained, (b) confined to one side of a stream by a levee bank, (c) confined by levee banks on both sides of a stream, and (d) impact of levee banks on flow rate



The impact of levee banks depends on the velocities of flow normally experienced on a floodplain. The velocities on some sections of a floodplain can be very low even during a major flood. For instance, on extensive floodplains with very low slopes, floods can spread out over wide areas and velocities remain low. Velocities may also be low where land is flooded as a backwater. In general, flood velocities increase as the depth of flow increases. The adverse impact of a levee bank may be minimal in a small flood event, but may be considerable during a major flood.

Where levee banks on a floodplain intercept runoff and divert it to an incised stream, the risk of erosion is high. In such circumstances a virtual waterfall occurs at the outlet of the bank which has the potential to cause serious gullying.

Levee banks can be designed to incorporate a ‘fail-safe’ spillway. This will allow a levee to be overtopped during a major flood at a point where the risk of damage is minimised. In designing levee banks, consideration should also be given to the need to accommodate runoff that is generated from the area protected by the levee bank. For example, if a levee bank parallel to a river obstructs flows from a local creek or drainage line it will act as a dam for any runoff flowing towards the river. In such cases it may be necessary to provide pipes or flood-gates through the levee to release confined runoff.

It is important to carefully consider any relevant legislative requirements before constructing levee banks. Currently, operational works provisions under a local government planning scheme require development approval for construction or modification of levee banks. Regulations define three categories of levees depending on the potential level of impact on properties. Category 1 levees —no impact beyond the property boundaries—are self-assessable. Categories 2 and 3 require an application for development approval by the Local Council. Category 2 requires code assessment by the Council; and Category 3, having the potential highest level of impact, requires an impact assessment with reference to a Queensland Government agency.

Irrigation structures

Above-ground structures constructed on a floodplain and associated with irrigation, such as ring tanks, diversion banks, supply channels and head ditches, may interfere with flood flows. To minimise their adverse impacts on flood flows such structures should be designed and constructed to allow floodwaters to pass through without concentrating or diverting flows onto other lands. In the past, most irrigation infrastructure on the Darling Downs floodplain was located on sections of the floodplain less vulnerable to erosive flooding. However, in recent years irrigation has expanded into areas that can experience erosive flooding. In the same way as levee banks, irrigation infrastructure may also be subject to development controls under local government laws or water resource plans.

Weirs

Weirs are low barriers constructed across creeks and rivers primarily to store water for use by the community and to increase groundwater recharge. The major difference between a weir and a dam is that dams usually have relatively narrow spillways, whereas floods pass over the entire length of the wall of a weir. The crest of a weir in a stream is normally below the high banks of the stream.

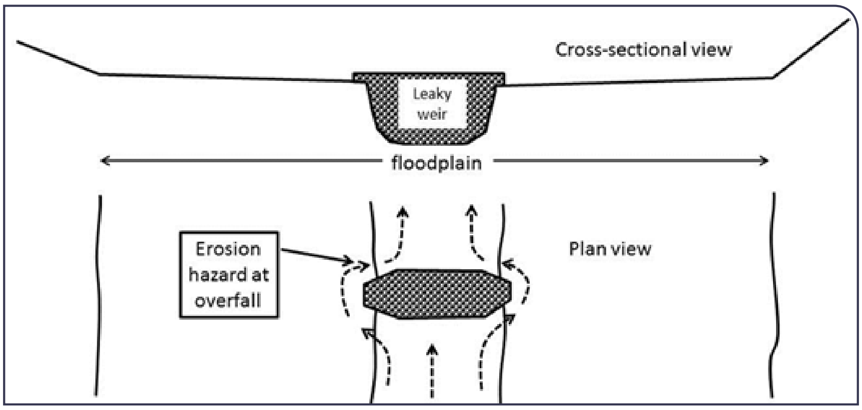
Weirs are very effective at trapping bed-load sediment. With time, the amount of sediment deposited in weirs can significantly reduce their storage capacity. Also, as pointed out by Brooks et al. (2006), by trapping sediment, weirs and dams can starve downstream sections of the stream of sediment. This can lead to channel incision as the stream attempts to compensate for the missing sediment.

Development of the 'minimum energy loss' (MEL) approach by Professor Gordon McKay in the late 1950s (Chanson 2002) led to major advances in the design of weirs. This approach streamlines flows above and below the weir structure, providing significant cost savings. An MEL weir is typically curved, with converging sidewalls and a relatively flat overflow spillway chute. This design concentrates downstream energy near the channel centreline and away from the banks where the risk of erosion would be greatest. With the MEL approach the amount of energy dissipation required is less than with a traditional weir design. A number of weirs have been constructed in Queensland using this approach, including the Chinchilla Weir on the Condamine River.

One of the cornerstones of the 'natural sequence farming' (NSF) approach is the construction of 'leaky weirs'. Proponents of NSF claim that these structures (in conjunction with planted vegetation) help to spread streams across adjacent floodplains to 'rehydrate' them. Leaky weirs are constructed from materials such as rocks or logs which retard flows but allow a proportion of water to continuously pass through them.

In rural areas it is desirable to encourage floods to spread out over their floodplain. This can be accomplished using various management techniques as discussed earlier in this chapter. Leaky weirs are just one of these techniques but they have limitations. In order to make floods spread out, the wall of a leaky weir would need to be higher than the general ground surface across the floodplain (Figure 10.23). However, there is nothing to stop floodwaters rising above the creek bank, bypassing the weir and returning to the creek immediately downstream. This is likely to create an erosion hazard at the overfall as shown. Furthermore, leaky weirs (like any filter) will gradually become clogged by sediment and eventually will lose most of their permeability.

Figure 10.23: A weir with a height above the level of a floodplain is prone to failure



Leaky weirs are, however, an important method to stabilise gullies (see Chapter 13). In this application, their purpose is to cause sediment to be deposited behind them, encouraging growth of vegetation and further sedimentation in turn. This will progressively fill the base of the gully. However, it would generally be impossible to completely fill a gully using this technique. Most gullies carve out far more capacity than they require and even in a major runoff event, they carry a relatively small amount of runoff.

Weirs constructed for gully stabilisation need to be low (less than 50 cm high), especially in dispersive soils that are those most prone to gullying. A common cause of failure of gully structures built in dispersive soils is bypassing of the structure due to erosion of the side walls. The higher the structure, the more likely this is to occur. High weirs are also more expensive to build and present additional technical difficulties to deal with the energy of the water that flows over the structure.

10.7 Riparian filter strips

Riparian vegetation fulfils many essential environmental functions:

- The roots of trees and shrubs play a vital role in stabilising streambank soil and in reducing flow velocities against the bank (see Chapter 11).
- Groundcover vegetation and litter from trees and shrubs help to protect the banks above the stream from erosion caused by raindrop impact or by the force of runoff flowing along or over the bank.
- Remnant riparian native vegetation plays a key role in promoting biodiversity. It provides habitat (including shade) that benefits both terrestrial and aquatic forms of life and can act as an important corridor for the passage of a variety of wildlife.
- Riparian strips provide a useful physical buffer between the stream and any cropland, protecting streambanks from machinery disturbance and screening the stream from accidental drift of agricultural chemicals. Reserving such a buffer has minimal impact on the area of land available for cultivation—a 2 km long buffer that is 5 m wide (the width commonly recommended, see Chapter 11) takes up just 1 ha of land—but may be critical in protecting aquatic ecosystems and water quality.
- Riparian vegetation can protect the quality of ground water by the process of denitrification (Rassam et al. 2006). Runoff from agricultural land can carry high concentrations of nitrates from sources such as fertilisers, nitrogen-fixing legumes and animal dung. This nitrate can pollute groundwater and lead to eutrophication. Denitrification enzymes are present in most soil and can function in anaerobic conditions where there is a carbon-rich root zone to fuel bacterial processes. Denitrification occurs where there is a flow of shallow, slow-moving, nitrate-rich groundwater through the riparian zone towards the stream. However, this process requires either a watertable that is higher than the stream or seepage from the stream into the streambank. Watertables above stream level can occur in humid climatic zones but are rare in drier environments.

It is widely held [for example, Boulter et al. (2000); Karssies and Prosser (1999); Lovett and Price (Eds) (1999); Lovett and Price (2001); Lovett et al. (2003); and McKergow et al. (1999, 2004)] that riparian vegetation strips play a major role in filtering out sediment and nutrients in runoff from adjacent catchments from reaching streams. However, a critical appraisal of the evidence suggests that this contribution may be overplayed. Or, as pointed out by Land & Water Australia: 'There may be large parts of the landscape where little or no overland flow enters the stream channel. You may decide to maintain healthy riparian vegetation in these areas to improve bank stability or provide wildlife habitat, but they are less important if your primary objective is to reduce sediment and nutrient movement' (LWA fact sheet 3: Improving water quality—see *Other information* at end of this chapter.

Runoff progressively concentrates into drainage lines then into streams as it moves down through a catchment towards a river and eventually into the ocean or an inland lake. This is apparent from examining any topographic map or satellite image (e.g. Figure 10.24). Drainage lines are assigned a progressively increasing 'stream order" moving down through a catchment. Maps of various catchments in south-east Queensland showing the proportion of different stream orders can be found on the Healthy Waterways website ‹healthywaterways.org›.

Figure 10.24: Flows concentrate as they move down a catchment

Numbering system of stream orders

Most of the runoff from a catchment originates from lower-order streams in the upper reaches of the catchment. Individually such streams may flow on only two or three occasions in a year and yet collectively, across the catchment as a whole, they still account for the great majority of runoff. Runoff rarely enters streams by flowing over streambanks. It generally exits from a paddock, for instance, at one or two well-defined points, as a level one, two or (rarely) three order stream. These streams in turn normally drain into higher-order streams at a few well-defined points. Alternatively they may discharge onto a floodplain or sometimes into wetlands. Very little 'new' runoff, however, is added to a high-order stream by just flowing over the banks.

Runoff from eroding soils adjacent to drainage lines on a floodplain is very unlikely to reach the stream by filtering through a vegetated riparian strip. This is because to be effective as filters such strips need to be vegetated densely—for example, with grass—and dense vegetation resists overland flows, especially on the very low slopes of floodplains. This resistance causes sediment to be deposited at the interface between the bare ground and dense vegetation, which both increases the growth and density of the vegetation and raises the level of the ground surface along the leading edge of the filter strip. This further increases the resistance, in turn increasing the tendency for flows to divert around the vegetation riparian strip.

Runoff will always take the easiest pathway. Vegetated strips (or sediment fences) are often used in agricultural areas (or in construction sites) as filters to remove sediment from runoff arising from bare ground before it enters a stream. Because runoff follows the line of least resistance, such a filter can only function correctly if it is on the contour. If the vegetated strip (or fence) is on a diagonal to the contour, it will only serve to divert and concentrate runoff. This behaviour has major implications for the effectiveness of vegetated riparian strips as sediment filters for runoff entering a stream (as shown in Figure 10.25), as it is not possible, by definition, for streamside vegetation strips to be on the contour.

Figure 10.25: Grass strips parallel to streams on floodplains are unlikely to accept runoff

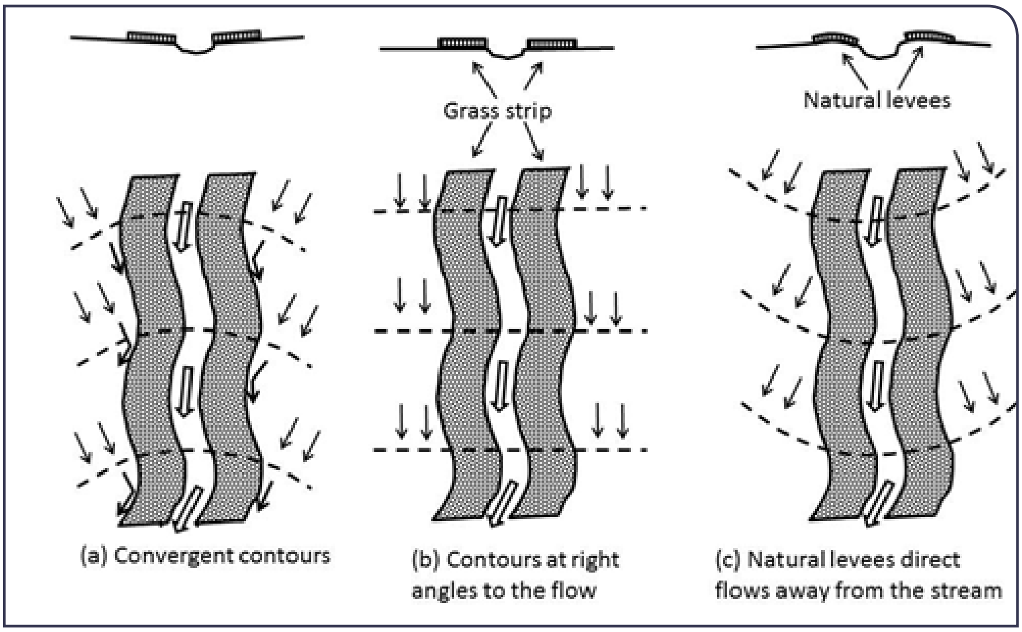


Figure 10.25a represents the situation that would be expected to occur where an order I or order 2 stream is bordered by densely vegetated riparian strips. Typically a low-order stream such as this will occur in sloping country where the contours converge strongly towards the stream and in the direction of flow. In these circumstances any runoff flowing towards the stream will, as shown in the figure, be readily diverted by a densely vegetated riparian strip to follow a path parallel to the stream.

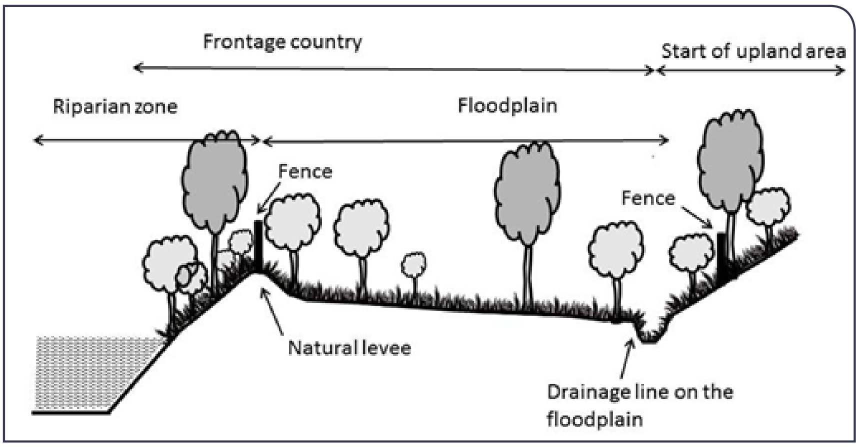
Figure 10.25b represents the situation that would be expected to occur where a stream on a floodplain is bordered by densely vegetated riparian strips. Typically on a floodplain runoff flows parallel to the stream. This effect will only be increased by the dense vegetation of the riparian strip. Runoff will only eventually enter the stream where it finds a gap through the dense riparian vegetation. This would normally be at a point where a smaller tributary or a gully joins the main stream.

Figure 10.25c shows a stream with natural levees and divergent contours, typical of the higher-order streams. Many streams on floodplains have natural levees (Figure 10.26) that direct local runoff away from the stream. Natural levees are usually near to the top of the banks, where coarse sediments have been deposited when past floods escaped from the stream channel and their velocity dropped. These natural levees can be the highest land on some floodplains and are usually only submerged in a major flood event. The safest place to build a home on a floodplain is often the natural levee on the streambank. When streams have natural levees, their floodplains are first flooded from breakout areas where drainage lines on the floodplain join the main stream.

Sediment in streams originates either from erosion of the streambank or from erosion of the land in the catchment that is then transported to the stream. Where the catchment is used for agriculture, the aim should be to keep soil where it is—in the paddock—in the first place, rather than relying on filtering it from concentrated runoff after it has already been displaced. Retaining soil in the paddock is also important to prevent loss of nutrients such as phosphorus and nitrogen into higher-order streams, estuaries and wetlands where they can potentially cause eutrophication. A significant proportion of such nutrients lost from agricultural land are attached to clay particles held in suspension in runoff.

When grass acts as a filter it is more likely to trap coarser sediments such as sands and silts rather than very small clay particles. However, if these clays are of a non-dispersive type they tend to coalesce to form larger particles in water and can be deposited when the flow velocity is reduced as by grass cover.

Figure 10.26: Cross-section of a floodplain showing a natural levee on the streambank (Coughlin et al. 2008)



Sediment loss from agricultural land can be minimised by using land only within its suitability, and by adopting soil conservation measures such as maintaining adequate levels of ground cover and managing runoff so that it leaves the paddock via well grassed waterways:

- On floodplains, the whole area can effectively function as a filter strip if the land is all protected under good cover. Where the floodplain is used for broadacre cropping the best way to minimise soil movement is by practising strip cropping and zero tillage. Where the floodplain is pastoral land, grazing pressure can be managed to maintain a permanent cover. Where a floodplain is used for horticulture, it is more difficult to protect it from erosive flooding as it is cultivated more intensively and is often without vegetative cover for extended periods. However, there are a range of strategies and options that can help mitigate potential erosion of horticultural land. These are outlined in more detail in Chapter 12.
- Preventing soil from entering streams from upland agricultural areas requires implementing measures such as contour banks as well as minimal or zero tillage. Contour banks can trap up to 80% of the sediment they receive from the contour bay above them (refer to Chapter 7). Stubble-covered contour bank channels and grassed waterways reduce the velocity of flows and filter runoff in the paddock as it flows towards a stream.
- In urban areas, a range of erosion control measures can be used to reduce runoff from and transported sediment from new land developments and construction sites. Water-sensitive urban design (WSUD) measures specifically aim to reduce the rate at which runoff flows from catchments with a high component of impervious areas. Drainage lines that connect urban areas to streams can also act like a filter and trap sediment if they are lined with dense vegetation.

Heavy rainfall in one part of a catchment can contribute runoff to vegetation on floodplains in another part that may have received minimal rainfall. Under these circumstances the receiving vegetation itself can benefit from the additional runoff as well as providing a filtering function for the benefit of downstream aquatic ecosystems. This situation sometimes occurs on the Eastern Darling Downs when runoff from upland areas meets the floodplain. Strip cropping at creek outlets can spread this runoff, making best use of the natural irrigation it provides. In outback river systems such as the Channel Country, dry floodplains can absorb runoff that may take a week or more to flow from higher parts of the catchment that have received good rainfall.

10.8 Wetlands

Wetland is a broad term used for different kinds of wet ecosystems or ecosystems that are wet for a period of time (wetlandinfo.ehp.qld.gov.au/wetlands). Queensland contains a diverse array of wetlands including flowing waterways (rivers and creeks), shallow coastal waters (e.g. mangroves, salt marshes and tidal flats), permanent and seasonally ponded water bodies, lakes, swamps, marshes, peat lands, mangroves, dams and reservoirs. The variable nature of Queensland's climate means that many wetlands are ephemeral and can remain dry for lengthy periods. Wetlands are an important component of floodplains. They cover many habitat types and provide a range of biological and hydrological values. Artificial wetlands, often constructed in drainage lines, are a strategy commonly used to protect and improve water quality and downstream aquatic ecological functions.

Natural wetlands can be lost or degraded by clearing, draining, or exotic weed invasion. To maintain wetlands in good condition, it is important that the amount of sediment and nutrients they receive is limited. Adopting sound soil conservation practices throughout their catchments is critical to maintaining wetlands in healthy condition. Runoff flows directly into wetlands from the land around them. Another important strategy for protecting wetlands is to ensure they are surrounded by buffers of intact vegetation to filter that runoff.

Grazing animals are attracted to wetlands. Damage through trampling of soil and vegetation as well as excess grazing pressure on vegetation in and around wetlands can have a significant impact on their condition. Grazing needs to be carefully managed in areas adjoining wetlands to ensure that they and the land surrounding them are protected by adequate levels of vegetation (refer to Section 10.6.2 on managing grazing, earlier in this chapter).

10.9 Legislation

In Queensland, activities that may influence or have an impact on floodplains are required to comply with a range of Acts and regulations. This legislation changes frequently, but at the time of publication the following all contain sections that are relevant to floodplains:

- *Water Resources Act 2000*
- *Vegetation Management Act 1999*
- *Land Act 1994*
- *River Improvement Trust Act 1940*
- *Rural Lands Protection Act 1985*
- *Fisheries Act 1994*
- *Nature Conservation Act 1992*
- *Environmental Protection Act 1994*
- *Sustainable Planning Act 2009*
- *Chemical Usage (Agriculture and Veterinary) Control Act 1988*.

10.10 Further information

References

Bass, GA (1985) Residual flow drains on the Darling Downs. In: *Proceedings of the fourth Australian soil conservation conference*, Maroochydore, Queensland.

Begbie, DK (1977) Report on the study of the *Linthorpe and Aubigny Catchments, Darling Downs, Queensland*. A report prepared for Linthorpe No. 5 Soil Conservation Group and the Central Darling Downs Advisory Group Committee, Queensland Department of Primary Industries, Brisbane.

Boulter, SL, Wilson, BA, Westrup, J, Anderson, ER, Turner, EJ and Scanlan, JC (2000) *Native vegetation management in Queensland*. The State of Queensland, Department of Natural Resources, Brisbane.

Brooks, AP, Abbe, T, Cohen, T, Marsh, N, Mika, S, Boulton, A, Broderick, T, Borg, D, and Rutherfurd, I. (2006) *Design guideline for the reintroduction of wood into Australian streams*. Land & Water Australia, Canberra.

Chanson, H, (2002) *History of minimum energy loss, weirs and culverts, 1960–2002*. Special Seminar SS1, Department of Civil Engineering, the University of Queensland, Brisbane.

Coughlin, T, O'Reagan, P, Nelson, B, Butler, B, and Burrows, D (2008) *Managing for water quality within grazing lands of the Burdekin Catchment—Guidelines for land managers*. Burdekin Dry Tropics NRM Solutions Ltd, Townsville.

Cummins, VG and Bass, GA (1978) *Report on a study of the Pittsworth Plains and associated upland catchments, Darling Downs, Queensland*. Queensland Department of Primary Industries, Brisbane.

Department of Environment and Resource Management (2011) *Queensland wetland buffer planning guideline*, 54 pp., Queensland Wetlands Program, Brisbane, Queensland.

Eacott, LS (1979) *Practical aspects of planning and implementing strip cropping systems on very low gradient land*. Division of Land Utilisation Report 79/4, Queensland Department of Primary Industries, Brisbane.

Finlayson, B and Silburn, M (1996) Soil, nutrient and pesticide movement from different land use practices and subsequent transport by rivers and streams. In: *Downstream effects of land use*, edited by HH Hunter, AG Eyles and GE Rayment, Queensland Department of Natural Resources, Brisbane.

Jones, MR (2006) Cenozoic landscape evolution in central Queensland, *Australian Journal of Earth Sciences* 53, 433–444.

Kapitzke, IR, Pearson, RG, Smithers, SG, Crees, MR, Sands, LB, Skull, SD, and Johnston, AJ (1998) *Stream stabilisation for rehabilitation in north-east Queensland*. Land and Water Resources Research and Development Corporation, Occasional Paper 05/98, Canberra.

Karssies, LE, and Prosser, IP (1999) *Guidelines for riparian filter strips for Queensland irrigators*. CSIRO Land and Water, Technical Report 32/9, Canberra.

Lovett, S, and Price, P (Eds) (1999) *Riparian land management technical guidelines: Volume 1, Principles of sound management; Volume 2: On-ground management tools and techniques*. Land and Water Resources Research and Development Corporation, Canberra.

Lovett, S, and Price, P (2001) *Managing riparian lands in the sugar industry: A guide to principles and practices*. Sugar Research & Development Corporation/Land & Water Australia, Brisbane.

Lovett, S, Price, P, and Lovett, J (2003) *Managing riparian lands in the cotton industry*. Cotton Research and Development Corporation, Narrabri, New South Wales.

Macnish, S (1980) *A review of strip cropping practices on the eastern Darling Downs*. Division of Land Utilisation 80(1), Queensland Department of Primary Industries, Brisbane.

Marshall, JP (1988) *Floodplain management for erosion control and high productivity on the Darling Downs*. Division of Land Utilisation, Queensland Department of Primary Industries, Brisbane.

McKergow, L, Prosser, I, and Heiner, D (1999) *Preliminary results on the effectiveness of riparian buffers in Far North Queensland*. Proceedings, Second Australian Stream Management Conference, 8–11 February, Adelaide, South Australia, pp. 439–444.

McKergow, LA, Prosser, IP, Grayson, RB, and Heiner, D (2004) Performance of grass and rainforest riparian buffers in the wet tropics, Far North Queensland. 2. Water quality, *Australian Journal of Soil Research* 42(4), 485–498.

McLatchey, JF, and Watts, TR (1985) The implications of levelling gilgais in southern inland Queensland. In: *Proceedings of the fourth Australian soil conservation conference*, Maroochydore, Queensland.

Rassam, DW, Fellows, CS, De Hayr, R, Hunter, H, and Bloesch, P (2006) The hydrology of riparian buffer zones: two case studies in an ephemeral and a perennial stream. *Journal of Hydrology* 325, 308–324.

Ruffini, J, Smith, R, Hancock, N, and Glasby, T (1988) *Flood strip cropping, Guidelines for selection of strip widths*. Darling Downs Institute of Advanced Education, School of Engineering, Centre for Engineering in Agriculture, Technical Report 11(88), Toowoomba, Queensland.

Rutherfurd, I, Anderson, B, and Ladson, A (2006) Managing the effect of riparian vegetation on flooding. In: *Principles for riparian lands management*, edited by S Lovett and P Price. Land & Water Australia, Canberra, pp. 63–84.

Shellberg, JG and Brooks, AP (2013) *Alluvial gully prevention and rehabilitation options for reducing sediment loads in the Normanby Catchment and Northern Australia*. Final report for the Australian Government's Caring for our Country—Reef Rescue Initiative, Griffith University, Australian Rivers Institute, 312pp. ‹www.capeyorkwaterquality.info›.

Victorian Resources on Line (2013) Diagrammatic representations of terrace development (animation) ‹vro.depi.vic.gov.au/dpi/vro/wgregn.nsf/pages/wg_soil_maffra_geology_geomorphology_diagram›.

Wilson, PR, (2013) *Floodplain management in the Burnett Catchment*, Burnett Mary Regional Group, ‹www.bmrg.org.au/files/9713/7827/4601/Flood_plain_managementa.pdf›.

Wockner, GH and Freebairn, D M, (1991) Water balance and erosion study on the eastern Darling Downs—an update, *Australian Journal of Soil and Water Conservation*, 4(1), 41–47.

Other information

The following provide additional relevant information that readers of this chapter may find useful.

Locating infrastructure on floodplains

- Queensland government fact sheets:
  - L239 Erosion control on property roads and tracks—cross-sections and locations.
  - L240 Erosion control on property roads and tracks–managing runoff.
- Australian Landcare magazine special issue on riparian fencing, December 2003.
- Water and Rivers Commission (2000) Flood proofing fencing for waterways. Advisory note for land managers on river and wetland restoration. Water and Rivers commission, Western Australia.

Land use and land management practices

- Department of Environment and Resource Management (2011) *Managing grazing lands in Queensland*, Brisbane.
- Department of Natural Resources (1999) *Better management practices—Floodplain management on the Darling Downs*, Brisbane.
- Department of Natural Resources (1999) *Land use practices for wet tropical floodplains*, Brisbane.
- Fitzroy Basin Association fact sheets (author G Peck)
  - Property planning: fencing to land type-riparian lands.
  - Property planning: Sustainable grazing on riparian lands—Why and how to do it.
  - Property planning: Using off-stream watering points.
- Standing Committee on Agriculture and Resource Management (2000) *Floodplain management in Australia—Best practice principles and guidelines*. CSIRO Publishing, Canberra.
- Staton, J and O'Sullivan J (2006) *Stock and waterways: a manager's guide*. Land & Water Australia, Canberra.

Species suitability for grassing waterways

- Queensland government fact sheet L271 *Soil conservation waterways—Plants for stabilisation*.
- The publication by Lovett and Price (2001) *Managing riparian lands in the sugar industry: A guide to principles and practices* (cited in References above) provides a list of grass species suitable for riparian buffer strips (Lovett and Price 2001).

Floodplain management in urban areas

- The 120 page (2000) publication from the Standing Committee on Agriculture and Resource Management, *Floodplain management in Australia—Best practice principles and guidelines*, published by CSIRO Publishing, Canberra.
- Department of Natural Resources and Water (2007) Queensland urban drainage manual.

Riparian vegetation

Land & Water Australia has published a series of fact sheets on riparian vegetation management which are available online ‹lwa.gov.au›. Topics include:

- 1 Managing riparian land
- 2 Streambank stability
- 3 Improving water quality
- 4 Maintaining in-stream life
- 5 Riparian habitat for wildlife
- 6 Managing stock
- 7 Managing woody debris in rivers
- 8 Inland rivers and floodplains
- 9 Planning for river restoration
- 10 River flows and blue-green algae
- 11 Managing phosphorus in catchments
- 12 Riparian ecosystem services
- 13 Managing riparian widths

- Lovett, S and Price, P (Eds) (2007) Principles for riparian lands management, Land & Water Australia, Canberra.

- Prosser, I and Karssies, L (2001) Designing filter strips to trap sediment and attached nutrients, River and Riparian Land Management Technical Guideline No. 1, Land & Water Australia, Canberra.

Wetlands and waterways

- The Queensland Government website WetlandInfo ‹wetlandinfo.ehp.qld.gov.au/wetlands› contains a wide range of information about wetlands and their management. This website includes the publication Queensland wetland buffer guidelines (Department of Environment and Resource Management 2011), which provides information for designing a wetland buffer and identifies its benefits and future management needs.
- Department of Sustainability and Environment (2007) Technical guidelines for waterway management, Department of Sustainability and Environment, Victoria.
- Layden, I (2011) *Wetland management handbook: Farm management systems (FMS) guidelines for managing wetlands in intensive agriculture*. Department of Employment, Economic Development and Innovation, Queensland Wetlands Program, Brisbane.
- Shellberg, J and Brooks, A (2007) *A fluvial audit of the Brisbane River: A basis for assessing catchment disturbance, sediment protection, and rehabilitation potential*, Australian Rivers Institute, Griffith University, Queensland.
- Witheridge, GW (2010) *Watercourse erosion: Part 1*, Fact Sheet, Catchments and Creeks Pty Ltd, Brisbane.

Legislation

- The publication by Lovett and Price (2001) *Managing riparian lands in the sugar industry: A guide to principles and practices* (cited in references provides concise summaries of Queensland legislation related to floodplain management at that time.

The presentation by Mal Jones entitled ‘A tale of two rivers’ contains useful general information. Contact bcarey@tpg.com.au if you would like a copy.