Environmental Best Practice Guidelines 3. Excavating in Waterways

Many works in waterways involve excavating stream beds and banks. Such works include stabilising stream beds, protecting and stabilising stream banks, diverting streams, creating channels to drain land and alleviate floods, deepening stream holes to increase the capacity of water off-takes, extracting sand and gravel, and works associated with developing infrastructure, such as bridges and pipelines.

Excavating can severely degrade or destroy ecosystems in waterways and wetlands so the precautionary principle should be followed. Excavating should not be allowed if it is likely to cause significant environmental harm. If the works will result in substantial benefits and minimal harm to the waterway and surrounding environment, excavating the bed and banks may be acceptable. However, the appropriate safeguards must be taken.

1. Potential environmental effects

1.1 Changes stream geomorphology

River systems will move towards a state of dynamic equilibrium after disturbance. A stream modified by removing alluvial material or channelising will attempt to revert to its 'natural' state. The resulting erosion, increased sediment transport, and reduced water quality may continue or even accelerate for many years after the works have been completed. Continual maintenance may be needed to control this process.

Removing alluvial material from the stream bed

Extracting material from the stream bed can trigger changes in the stream profile, along the stream and from bank to bank. Changes to the flow regime and disturbing the balance between the supply of sediment and the sediment carrying capacity of the flow can have the following effects.

Headcut erodes the stream bed: Excavating the channel deepens the stream bed. A nick point is created in the bed at the point where the flow velocities increase due to the steeper gradient. If the increased flow velocities erode the stream bed, the nick point migrates upstream in a process known as 'headcutting'. This continues until the gradient of the stream stabilises or the nick point meets an obstacle, such as a rock outcrop. Headcutting releases large amounts of sediment from the stream bed, which is transported and deposited downstream. The deposition fills in deep holes and pools, and changes the form of the channel.

Headcut eroding stream bed

Increased flow capacity affects sediment movement: Excavating the channel increases its cross-sectional area and hence its flow capacity. Larger floods ('1 in 2 year floods' and up) are more readily contained within the modified channel and are less likely to have their energy dissipated across the flood plain. This increases the stream energy during floods, which further erodes the channel, and increases sediment supply and transport from the stream reach.

Collapse of stream banks due to increased height: Deepening the stream bed can increase the height of the stream banks and make them more prone to erosion and collapse. If the banks collapse, the sediment load in the stream will increase. Widening of the stream due to extensive bank collapse increases flow capacity, and increases sediment supply and transport downstream.

Removal of gravel armouring the stream bed: Removing gravel that is protecting or 'armouring' the stream bed and stabilising the banks and bars may expose material that is more susceptible to erosion. If this occurs, excessive scouring of the bed and movement of sediment may result.

Loss of stream roughness: Removing objects that create roughness in the stream, such as large woody debris and boulders, when excavating can reduce the structural integrity of the stream and ecosystem health. These objects help control the morphology and hydraulics of the stream, and help regulate the storage of gravel and other sediments.

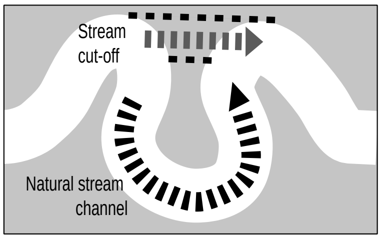
Channelising

In general, increasing the stream's flood carrying capacity by channelising the stream - that is, re-aligning the channel and smoothing the banks - decreases the stability of the stream. This can result in unforeseen and unintended erosion upstream and downstream of the channelled section.

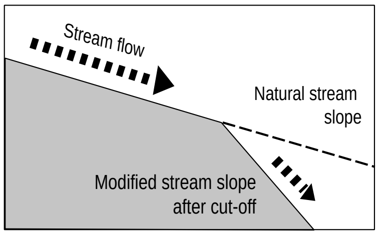
Increased slope increases flow velocities: Constructing meander cut-off channels and re-aligning the stream usually shortens the stream, which steepens its gradient. Abrupt changes in the slope of the channel cause can cause erosion and degradation of the channel upstream, and aggradation (increased silt, sand or gravel deposition) of the channel downstream (see Figure).

The significance of increased flow velocities depends on the composition of the bed and banks and the state of the riparian vegetation cover. Coarse, rough materials, such as cobbles and gravel, are more resistant to erosion from increased flow velocities than clay, fine sand and unconsolidated fill. A wide, healthy cover of native riparian vegetation helps resist erosion.

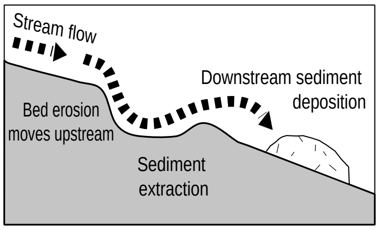
Increased flow downstream increases bank erosion: Larger volumes of flow being funnelled downstream can destabilise the banks due to the greater erosive forces of the flow and more frequent overtopping of the banks. The amount of water flowing in a waterway shapes the profile of the stream channel (along with sediment load) so increasing the flow may trigger further changes in the stream profile.



Channel diversion & loss of meander will shorten the channel, and...



...this will increase the slope of stream bed, which...



... increases flow velocity, causing 'headcut' erosion in the upstream direction and sediment deposition downstream.

Bed erosion due to channel diversion
(adapted from W.A. Water & Rivers Commission, River Restoration Report No. RR10 - Stream Stabilisation.)

1.2 Effects on surface and ground water flows

In-stream works can change the local hydrology and lead to unpredictable changes in the surface and ground water flows.

Removing alluvial material

Excavating the stream bed and banks may lead to

- a lower water table
- reduced bank storage
- drainage of associated wetlands
- greater variations in stream flow
- more intermittent stream flows
- more uniform stream flow conditions.

Channelising

Straightening the stream and smoothing the banks will increase the flow capacity and flow velocities of the stream. This may have a number of consequences, including

- The higher average flow velocities may aggravate flooding downstream.
- The greater quantity of water flowing may trigger unintended changes in the course of the stream.
- Improved drainage of the land adjacent to the stream may increase the discharge of ground water, which may reduce the amount of water available for stream flows during dry periods.
- Stockpiles of soil and overburden left on the floodplain after excavating may change the hydraulics of the channel during floods.

1.3 Degrades aquatic and riparian habitat

The physical and biological changes arising from works in streams may reduce the abundance, composition and diversity of plant and animal species, especially sensitive species, and reduce the health of ecosystems. The effects may not be confined to the works site. They may also extend a long way upstream and downstream.

Excessive suspended sediment: Excavating changes the physical composition and stability of substrates in the stream and releases large amounts of sediment into the stream. Other activities at the works site, such as clearing, grading, stockpiling of materials and constructing an access track, can erode soil into the waterway and increase sediment loads (see *Environmental Best Practice Guidelines 2. Construction Practices in Waterways and Wetlands*). Clearing the riparian vegetation when excavating may increase the sediment load in the stream because less sediment is filtered from the overland flow. Operating heavy equipment in the channel bed can increase turbidity and suspended sediment downstream (see *Environmental Best Practice Guidelines 2. Construction Practices in Waterways and Wetlands*).

Increased sediment loads and increased deposition can create a unstable environment that is hostile to many fish and other aquatic animals by

- creating conditions favourable only to silt-tolerant plants and animals
- reducing the availability of benthic food due to smothering
- reducing light penetration and productivity of the waterway
- making it difficult for plants and animals to respire
- reducing the tolerance of fish to diseases and pollutants
- increasing physiological stress in fish by clogging and damaging their gills
- smothering fish eggs and reducing the success of spawning.

Removal of riparian vegetation: Trees and vegetation may have to be removed from the banks so workers and equipment can reach the excavation site. Collapse of the stream banks and lowering of the water table as a result of excavation can also destroy riparian vegetation. Less riparian vegetation may

- exacerbate fluctuations in water temperature and reduce the concentration of oxygen in the water by reducing shade
- reduce the amount of food, shelter, and spawning and breeding habitat available for aquatic and terrestrial animals.

Channelising the stream can destroy riparian habitat

Less diversity of aquatic habitat: Channelising the stream produces a straight, uniform channel with fewer features, such as pools, riffles, and undercut banks, that are important habitat for aquatic animals. Removing large woody debris, boulders, and so on during excavation works further simplifies the structure of the stream and reduces the range of habitats available. Operating heavy equipment in the channel bed may degrade or destroy habitat.

Habitat may also be lost if the works result in a shallower stream. Low water levels may expose riffles and cobble substrate in high gradient streams, and logs and snags in low gradient streams - all of which are important habitat for fish and other aquatic animals.

Restricts fish movement: Shallower surface flows caused by excavating in the stream may stop fish migrating upstream during low flows. The water may be too shallow for fish to remain submerged as they cross shallow sections. Previously submerged structures, such as logs and rock shelfs, may no longer be submerged and may a create a barrier that fish cannot get over.

1.4 Damages infrastructure

Excavating the stream may lead to infrastructure loss

Erosion triggered by excavating the stream may damage public and private property far from the works site. Channel incision may undermine bridge piers and expose buried pipelines and utility lines. Exacerbating flooding downstream may increase the risk of damaging infrastructure and necessitate the construction of flood-protection structures, such as flood levees.

Excavating streams does not always cause instability upstream and downstream. However, nearby landowners may attribute such problems to the excavation works and may take legal action to recoup their perceived costs.

1.5 Degrades water quality

Excavating streams can increase sediment loads and turbidity downstream, which may degrade the quality of domestic and stock water supplies. A new channel course may increase or decrease runoff and sediment input from the adjacent land. If the increased runoff is from agricultural land, more salts, nutrients and pesticides may be discharged into the stream. If town water supplies have to be treated, this will involve additional costs for the supplier.

1.6 Reduces recreational and aesthetic values

Recreational activities, such as fishing, swimming and bird-watching, need streams that are relatively free of sediment and visible pollutants. Excavating streams can reduce their recreational values if sediments and pollutants are mobilised. Preserving landforms and vegetation cover when excavating will preserve the stream's aesthetic values.

2. Methods for controlling erosion

Before undertaking works to control erosion in streams it must be determined that the rate of erosion justifies the cost of the works, and that the works are likely to be successful and not create new problems. The methods used will depend on the scale of the erosion problem. Methods that stabilise and protect the banks are usually appropriate for managing localised bank instability, such as erosion of meander bends. If there is severe degradation of the stream bed, the bed may need to be stabilised before stabilising the banks. A variety of bed-control structures (also referred to as grade-control or full-width structures) can be used for this purpose. Extensive degradation of the river system may need a catchment-based approach that focuses on changing land use in the catchment.

The design requirements of structures to control and stabilise stream beds and banks can be found in the following publications

- The WES Stream Investigation and Streambank Stabilization Handbook (Biedenharn et al., 1997)
- Riparian Land Management Technical Guidelines Volume 2: On-ground Management Tools and Techniques (Lovett & Price, 2002)
- A Rehabilitation Manual for Australian Streams, Volume 2 (Rutherfurd et al., 2000)
- Guidelines for Stabilising Waterways (SCR&C, 1991)
- Stream Stabilisation. River Restoration Report No. 10 (WRC, 2001b).

2.1 Stabilising the banks

The two main approaches to controlling bank instability are re-aligning the flow and modifying the stream bank. At some sites both approaches will be needed.

Re-aligning the flow

The re-aligning approach uses structures that extend part-way into the channel to redirect the flow so the hydraulic forces along the bank are reduced and do not cause erosion, or the flow is directed away from the erodible bank. The partial-width structures most commonly used are groynes (extend from the eroding bend into the channel at an angle to the flow) and retards (a series of piles with cross members that provide a permeable barrier to flow). Large woody debris anchored to the bank can also be used (see *Environmental Best Practice Guidelines 6. Managing Large Woody Debris in Waterways*). If placed appropriately, a series of any of these structures will reduce flow velocities near the bank and increase sediment deposition along the bank, which will allow revegetation.

Seek expert advice if installing bank stabilisation structures such as pin groynes

Other structures that can be used are pin retards (unconnected pins), brush retards (pins connected by branches), jacks (tripods anchored by cables to each other and the bed), and low flow deflectors (low profile structures extending into the stream).

Modifying the banks

Stream flow is not the only cause of bank erosion. Inadequate vegetation cover, trampling by stock, and overland flow can also trigger bank erosion. It is important to determine the cause of the erosion so the most appropriate remedy can be used. The range of remedies is considerable. Revegetating the bank is probably the best remedy from an environmental and aesthetic perspective. However, revegetation must be combined with other approaches if the bank instability is too great. Battering or terracing the bank may be necessary to reduce the slope of the bank and allow plants to establish. Using organic geo-textile mats (natural fibre mats) will provide better conditions for growing plants if the area is not subject to high velocity flows. If the bank instability is due to undermining of the bank, the bank toe can be hardened by installing rock gabions (stone-filled wire cages) or rock rip-rap (loose rock). Dead trees and root wads can be used instead of rock in some situations.

2.2 Stabilising the bed

Bed-control structures stabilise the stream bed. They stop the active headcut moving upstream (including into tributaries) by creating a hard point in the bed that resists the erosive forces. Alternatively, they change the hydraulic conditions so the stream energy no longer scours the bed. Some bed-control structures do both.

Seek expert advice if installing bed control structures such as rock chutes

Bed-control structures usually span the width of the channel and allow some overflow. They also allow a temporary backwater pool to form upstream, and a permanent, stable scour pool to form downstream. Rock chutes are the most commonly used bed-control structures because rock is long lasting and copes with high flows. Grass chutes are sometimes used on seasonal waterways with low base flows. Reinforced-concrete drop structures and piped drops are less desirable because they may stop fish swimming upstream. Timber, can also be used, either a single log that spans the channel to form a low weir or angled logs that meet in the centre and concentrate low flows.

2.3 Changing land use in the catchment

Activities such as clearing vegetation, draining wetlands and damming streams will affect erosion in the catchment's waterways by changing the sediment loads and water yields. A catchment-based approach, such as a natural resource management framework, can be used to restore the sediment loads and water yields in the catchment to as close to their 'natural' levels as possible. For example, sediment going into the catchment's waterways may be reduced by establishing riparian buffer zones throughout the catchment and promoting better ways of managing stormwater.

3. Environmental management principles

Before excavating in waterways and wetlands a works plan should be prepared. The plan should outline the works to be undertaken and the measures that will be used to minimise the risk of causing environmental harm. The measures outlined should include those described below.

3.1 Get expert advice

- Undertaking works in streams without expert advice can cause environmental harm that may be difficult and expensive to remediate. Expert advice should be sought before excavating the bed and banks of waterways. Depending on the scale of the works, advice may be needed from one or more experts, including a stream biologist, river engineer, fluvial geomorphologist or hydrologist.

3.2 Avoid works on high risk sites

- The location and extent of any proposed excavation should be assessed on a case-by-case basis.
- The proposed works should meet the requirements of all relevant legislation, policies and regional strategies. Other ways of achieving the objectives of the works should be considered.
- Streams containing threatened plants and animals and having pristine ecosystem Protected Environmental Values should not be excavated.
- Significant geomorphological and cultural heritage sites should be protected.
- Avoid excavating upstream of nearby drinking water supplies and industrial water off-takes that need high quality water.
- The risk of damaging public and private infrastructure should be considered.
- The works should not damage recreational and aesthetic amenities.
- The likelihood that the sediments contain toxic materials, such as pesticides and metals, should be determined. If sediments upstream and downstream of the works site could be disturbed, these should also be assessed.
- Extracting sand and gravel from a waterway is only acceptable in rare situations where it benefits the waterway and surrounding environment. For example, where human activities outside the river reach have caused a build-up of sand and gravel (sediment slugs) that has eroded or changed the course of the stream, or destroyed habitat.

3.3 Understand site and system

- Waterways are complex systems and excavating them can cause unexpected consequences. Having accurate information about the stream channel and the discharge of water that shapes it, is critical to ensuring the works will be successful and harm minimised. Information about the geomorphology and land use in the catchment and sub-catchment should also be obtained. Stream Channel Analysis. River Restoration Report No. 9 (WRC, 2001a) (available on the internet) describes the information that should be collected before starting works. Groups and individuals excavating streams without this information risk causing environmental degradation, and having structures fail and costly maintenance problems afterwards.

Desk top survey to gather information about the stream area and catchment history	**Field work** to survey the stream and its catchment and gather information from locals	**Calculations** based on the information gathered that help plan the works
Catchment area and use	Longitudinal channel survey	Channel slope
Estimates of channel dimensions	Bank-full level	Average bank-full
Flow records	Stream cross-section	Wetted perimeter
Determine channel forming flow from flow records	Existing flow velocity	Channel roughness
Longitudinal survey of river channel	Assess bed material	Hydraulic radius
	Sketch map of channel	Median bed paving
	Assess foreshore and habitat	Flow velocity
		Discharge
		Stream power
		Critical flow

3.4 Adopt construction practices guidelines

- Contractors and plant operators undertaking works in streams should adopt the principles outlined in *Environmental Best Practice Guidelines 2. Construction Practices in Waterways and Wetlands* to minimise the risk of causing environmental harm. These guidelines focus on preparing for works, controlling sediment and erosion, avoiding contaminant spills, and stabilising and rehabilitating the stream.

3.5 Retain stream geometry, materials and habitat

- The stream should be restored to its 'natural' state after works have been completed. This will be easier if information about the waterway's environmental and aesthetic values was collected before the works started. Similar healthy, unmodified reaches in the catchment can be used as models if the site is degraded.
- Local, natural materials, such as rock and timber, should be used if possible. Artificial materials, such as concrete, old tyres and gabions, are less attractive. They also create a different flow regime to that of the original channel, need considerable maintenance, and do not provide good habitat for aquatic animals. The local materials should come from an appropriate source, such as an approved quarry.
- Creating large discontinuities in the water surface profile should be avoided. A vertical drop of more than 10 centimetres will stop native fish swimming upstream.
- A series of structures (eg a pool and riffle sequence or a series of large woody debris) should be used rather than a single structure if possible. More complex structures create a greater variety of habitats while still preventing erosion.
- Elements that create roughness in the stream, such as large woody debris, are critical for maintaining healthy aquatic ecosystems and should be restored.

3.6 Stabilise stream diversion (if required)

- If the channel is being re-aligned, the flow must be diverted into a properly designed and constructed channel that has been stabilised. It should not be diverted into an undefined channel.

3.7 Protect stream-entry points

- If extensive surface runoff may enter the receiving channel, the runoff should be directed through properly designed and constructed drainage ditches.
- It is best if drainage ditches and streams have small gradients as they approach and enter the receiving channel. If the gradient of the incoming drain or stream is steep, it may be necessary to line it with protective rock to prevent erosion of the receiving stream. If necessary, rip-rap may be used to line the bank of the receiving channel and prevent erosion and slumping of its banks.

3.8 Avoid constructing levee banks

- Levee banks are considered to be channel works even though they are not constructed in the stream channel. Levee banks deepen the flow channel during floods, which increases the likelihood of erosion along the stream bed and banks.
- Using large, long levees to prevent flooding of flood plains adversely affects the channel system and adjacent areas. Wetlands and riparian areas often rely on flooding to supply nutrients and trigger plant growth. Diverting flood waters away from these areas may make it difficult or impossible for plants to survive.
- If possible, development should be avoided on flood-prone areas. This removes the need to construct flood-protection structures.

3.9 Revegetate

- Deep-rooted plants, such as trees and shrubs, should be planted along the banks to stabilise the channel, provide shade to control water temperature, provide habitat and food for animals, and create an attractive and healthy waterway. Local, native riparian species should be used if possible.

- The works site should be monitored and maintained after revegetation to make sure the plants establish and weeds are controlled.

4. References

Biedenharn, D., Elliott, C. & Watson, C. 1997. *The WES Stream Investigation and Streambank Stabilization Handbook.* US Army Engineer, Mississippi. http://chl.wes.army.mil/library/publications/

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These guidelines should be used in conjunction with the appropriate technical advice and literature.

Checklist

This checklist summarises the environmental management principles outlined in *Environmental Best Practice Guidelines 3. Excavating in Waterways*. The plan of works prepared for all works involving excavation in a waterway should describe the proposed works and show that the measures listed below will be used to minimise the risk of causing environmental harm during and after the works.

- ❑ Works plan prepared

Methods for controlling erosion (Section 2)

- ❑ Appropriate erosion-control method/s selected

Get expert advice (Section 3.1)

- ❑ Expert advice sought

Avoid works on high risk sites (Section 3.2)

- ❑ Environmental risk assessed
- ❑ Legislative and policy requirements met
- ❑ Sensitive ecosystems protected
- ❑ Geomorphological and cultural heritage sites protected
- ❑ Downstream water supplies and sensitive industrial off-takes not affected
- ❑ Public and private infrastructure not threatened
- ❑ Recreational and aesthetic effects minimal
- ❑ Public safety and use protected
- ❑ Contaminated sediments not present

Understand site and system (Section 3.3)

- ❑ Stream survey undertaken

Adopt construction practices guidelines (Section 3.4)

- ❑ Works conform to *Environmental Best Practice Guidelines 2. Construction Practices in Waterways and Wetlands*

Retain stream geometry, materials and habitat (Section 3.5)

- ❑ Natural geometry, materials and habitat maintained or restored

Stabilise stream diversion (Section 3.6)

- ❑ Diversion channels stabilised

Protect stream-entry points (Section 3.7)

- ❑ Stream entry points protected

Avoid constructing levee banks (Section 3.8)

- ❑ Flood protection used to minimise environmental effects

Revegetate (Section 3.9)

- ❑ Rehabilitation and revegetation program prepared