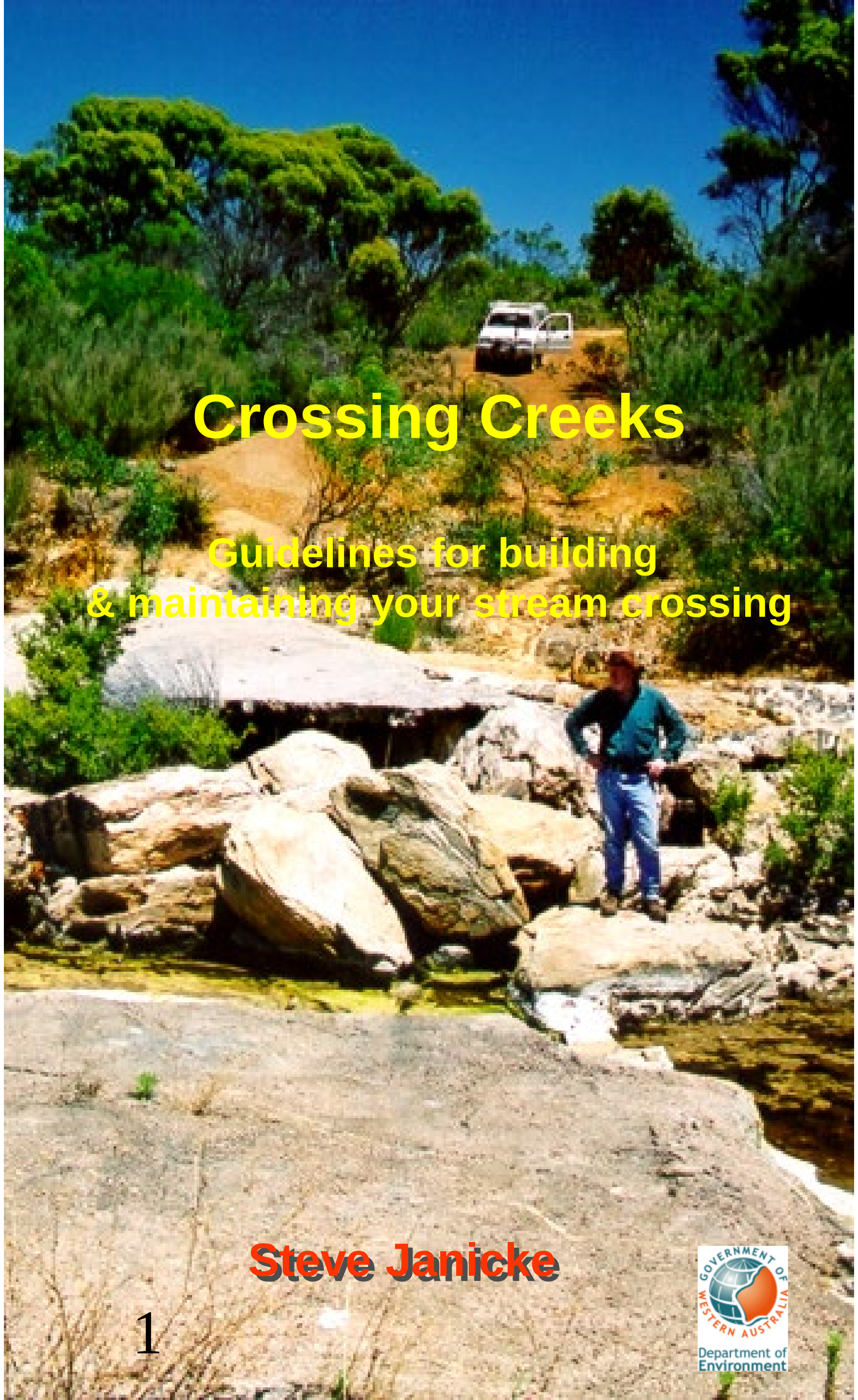

Crossing Creeks

Guidelines for building & maintaining your stream crossing

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A *good crossing* is one that functions with least maintenance in a range of flow conditions, for long periods of time and has negligible upstream or downstream environmental impacts

Every stream reach has its own collection of features and as a result, local experience as well as a scientific approach are needed for designing and building a suitable crossing.

The images in these guidelines are used to explain some of the basic principles of water flow in natural channels and how these principles can be applied to improve the design of your stream crossing and to hopefully increase its longevity.

Rivers and creeks are changing systems. The following guiding principles can help when deciding on a stream crossing design;

The long term pattern of rainfall run-off from a catchment creates a channel whose size will adequately carry floods that commonly tend to occur every one or two years.

The materials that make up the bed and bank of a stream determines how the flowing water will alter the local shape of the channel.

Changes to the bed and bank will be worked on by all flows to re-build the channel that best suits moderate flood levels.

The construction issues for rivers and small stream crossings are much the same.

Crossing constructions fall into three common categories, **Fords, Culverts & Bridges**

A **ford** is a shallow part of a stream channel where people or vehicles may cross with reasonable ease. All surface flow moves over the ford. In Western Australia many streams are saline and this may cause corrosion of vehicles and machinery.

A **culvert** crossing is a raised access-way designed to allow low to medium flows to pass beneath and to keep the track dry, however larger floods inevitably flow over the top. The low cost of construction, compared to a bridge, make these types of crossing popular.

A **bridge** is designed to raise the access above the level of most floods the stream is likely to carry. Support structures are designed for minimum bed interference, but must be able to carry the required load and resist the impact of floods.

Other relevant words;

Armouring - protective covering for soil (often rock) to reduce the risk of erosion.

Battering - excavation to reduce the slope of a bank.

Chute - A short section of channel having a higher water velocity.

Ramp - a sloping stabilised area on the upstream or downstream edge of a structure.

Gradient - The amount of vertical drop in a stream bed over a fixed distance

STREAM BEHAVIOUR

Flowing water behaves in certain ways and these need to be taken into account when planning to construct or modify a stream crossing.

MEANDERING

The *meandering* nature of flow means that channels are rarely straight, or remain straight, for any great distance. If a channel is straightened water velocity will increase and to maintain it will generally require ongoing maintenance and perhaps further engineering works to deal with bank erosion. Where possible work with stream curvature rather than trying to modify it.

The water velocity is highest on the outside of bends and this is where erosion is greatest. The inside of a bend (or point bar) is where deposition of sediment is more likely to occur. Constructing a crossing at a bend is not a good idea.

RESTRICTED FLOW

If a channel is narrowed, the concentration of flow acts to increase the upstream water depth. To maintain the discharge the water speeds up at the constriction. Greater water velocity increases the risk of bed and bank erosion and therefore the risk of crossing failure.

If a part of the the inner surface of a channel is *roughened*, by placing rock, logs, vegetation or rubbish in the channel, water passage will be restricted as for narrowing. As the depth increases water may find an easier path around the partial obstruction, eroding the banks and perhaps eventually shifting the position of the main channel. Roughening a channel can be used to effectively control water speed and direction, but it must be done carefully.

DIRECTED FLOW

An obstacle will redirect water flow causing bank or bed erosion. This is not the same process as meandering. If obstacles, such as rocks, logs and other natural barriers, are completely removed from a channel, the increase in water velocity will often increase bed and bank erosion. Rearrangement of logs, branches and rocks is preferable and can save effort and money.

The clay bar shown in the top image was removed to stop water flow being directed at the bank. To prevent the water velocity increasing along the straighter, therefore steeper path, a low rocky riffle was created immediately downstream. The build up of sediment seen opposite was a natural process and clearly indicates that the erosion of the bank has been halted. It is important that a crossing does not deflect water into the banks.

CHANNEL WIDTH & DEPTH

Vegetation holds stream banks together and tends to maintain narrower and deeper channels. In this image a small stream emerges onto a beach where loose sand has little strength to confine water flow. As a result the width of the channel increases rapidly and the depth decreases. Another undesirable result of removing vegetation from stream banks, is that the local path of the flow becomes less predictable and may change from season to season. Native vegetation provides an important tool for controlling channel width and location.

CHANNEL DEEPENING (INCISION)

A head-cut or natural waterfall is evidence that a channel bed is unstable and actively deepening. These features can proceed upstream rapidly. In loose sandy conditions the rate may be measured in terms of metres per hour, during a storm event. In more compact material such as clay, rates are usually much lower, but can still be significant. Head-cuts are very difficult to stabilise, but may be slowed by converting the drop into a rock chute of much lower slope. Back-flooding is another way to reduce their progress. A crossing immediately upstream of a head-cut is at risk of being undermined eventually.

Checklist for choosing a good stream crossing site

- ☐ The site is not on a bend
- ☐ The site is a natural high point in the stream bed
- ☐ The stream bed and banks are naturally erosion resistant and well vegetated
- ☐ The approach banks are not too steep
- ☐ The crossing can be built at right angles to the channel
- ☐ The channel is not deepening rapidly with time
- ☐ Access to the crossing is convenient in all seasons

If you can tick all of the above, you are off to a good start!

FORDS

To create a ford, the bed is armoured in such a way that the natural channel cross-section is reduced as little as possible. This is easier to do in larger channels.

The armouring material should be interlocking to resist movement and should not consist of oversized, isolated or clumped material, such as rocks or logs. The material should extend above the high water mark to avoid a bypass channel forming.

EXTENT OF BED ARMOURING

The crossing shown opposite is well sited and easy to maintain, but the cobbled surface could be extended further up the approach banks. Periodic floods will move some material downstream, but it may be recoverable. If culverts are required, several smaller diameter pipes would be preferable to carry the low flows, which in this case are very salty.

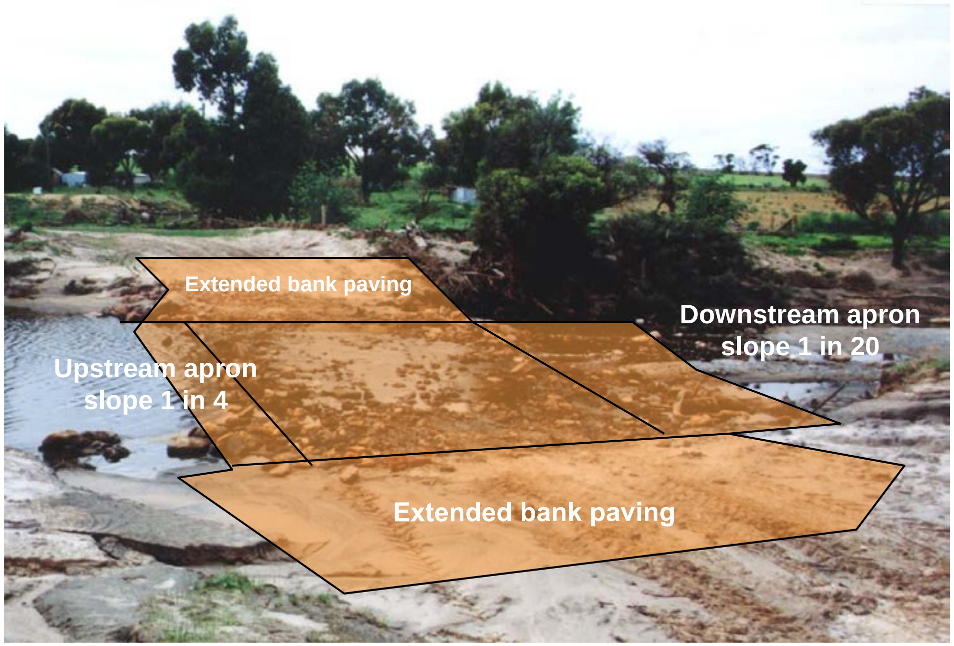
Rock armour needs to be strategically sized and placed. Scattered rocks like those shown opposite serve little purpose and large boulders can cause local erosion by concentrating flow. Rocks can be used to make the bed firmer for vehicle access and to steer flow away from banks, reduce bed & bank erosion. A variety of rock sizes produce an interlocking effect that resists being moved by flow. In addition rocky paving can deter stock from spending too much time standing in the water and therefore helps to reduce erosion and improve water quality. Rocks also help to oxygenate the water by creating turbulence.

FOCUS ON THE BROADER FLOODWAY

The well designed crossing shown in the top image, opposite was designed to conform to the features of the stream (fresh) and the site was chosen carefully to avoid problem areas. The rock paving allows stock to have access for watering purposes, but does not encourage them to stay thus helping to maintain better water quality. Note that where the rock paving did not extend to the fence line, that stock have worn a preferred path. Of course circumstances are often such that it is not possible to achieve this level of efficient design.

Broad shallow valley cross-sections pose other difficulties for crossing construction. Bed paving will require larger amounts of material. Also flows can easily re-route around any obstacles such as a raised bank, rocks or pipes. In the case opposite, the track could be graded flat to keep the water depth as low as possible across the floodway. This helps relieve water pressure on any one point.

If culverts are desired, a raised arch over the pipes may relieve flood pressure since flows have room to pass around. Sediment infill of pipes is often a problem in these situations and ongoing maintenance is inevitable for such sites.



APPROACH & DEPARTURE RAMPS

The crossing shown opposite is a simple ford that could benefit from further stabilisation to protect the banks from erosion at higher flows and to reduce the risk of rock being moved downstream

Water approaching the upstream edge of the crossing is hindered by a sudden rise in the bed. By providing a sloping rock ramp on the upstream edge of the crossing a smoother flow can be maintained over the crossing during flooding. The gradient of the rocky ramp should be no steeper than 1 in 4.

Likewise to prevent a sudden waterfall on the downstream edge a loose rock ramp can be extended downstream, but this time at a much shallower slope no steeper than 1 in 10.

Since a roughened surface, such as a ramp, will increase water depth upstream, it is important that the crossing approach banks be well protected to avoid flow finding a path around the sides of the crossing.

CHECK OUT OTHER CROSSINGS

A useful aid to designing a crossing is to have a look at other local crossings, in a similar environment, that are either operational or have failed in the past. Observe the features that have worked and those that have been ineffective or may have caused a problem.

The crossing shown above has had just enough flow through flow capacity and bank protection to remain serviceable for many years, however the bed has gradually been deepening and undermining the support timbers and steep rock walls. As a result the crossing is on the point of collapsing. The solution would be to keep the essential design, but increase the width spanned, batter the downstream banks and arrange the bed rocks as a chute with a slope no steeper than 1 in 20, with a slight 'V' shaped cross-section to keep flow in the centre of the channel.

CULVERTS

Water flows through a culvert pipe in a complex way. For this reason installation is not necessarily simple. Culverts are the most difficult crossing style to maintain since their effectiveness is purely determined by how much water the pipes can carry. When their capacity is exceeded the crossing acts as a dam and overflow on the downstream edge can create an extremely erosive situation.

Most culvert pipe manufacturers will provide some installation advice.

The culvert pipes should be bedded in a way that anchors the base firmly to the stream bed and limits water passing beneath or around the outer surfaces.

If at all possible provision should be made for floodwaters to spread out across the floodplain if the culvert capacity is exceeded.

Armouring of the adjacent upstream and downstream banks is necessary to protect the crossing.

PROBLEMS WITH REDUCED FLOW CAPACITY

In this flood situation the road was overtopped and loose road verge material was quickly washed away creating a vertical drop. When water falls over a substantial drop, stream power is sharply focussed. For example water flowing horizontally at one metre per second, then falling for a height of one metre, may accelerate to nearly four metres per second and gains almost sixteen times as much energy. This energy is then released at the foot of the drop. The benefits of downstream bed and bank armouring can be clearly appreciated and its purpose would be to maintain a gentler slope. In many cases the cost of preventative actions can outweigh the cost of ongoing repairs.

Crossings designed to pass only low to medium flows, will eventually be overtopped or bypassed during larger floods. As a result these crossings are at greatest risk of being damaged or completely destroyed. The box culverts shown here were very well bedded and survived an extreme flood, but the approaches were totally destroyed, which may be an advantage.

LOW FLOW CHANNEL CAPACITY

For good crossing design, the cross-sectional area of the culvert pipes approaches the area of the low flow channel. If the adjacent floodplain is level, the crossing may be built up to *arch over* the creek. If care is taken to protect the approaches and the corners of the crossing from erosion, then pressure on the main structure can be substantially eased as floods pass around the crossing and spread out across the floodplain. Bare ground should be avoided along the bypass to reduce the risk of an erosion scour forming.

The top crossing has reasonable cross-section area and a level floodplain adjacent. However the base of the pipe sits too high above the bed and the crossing sides are minimally armoured. The crossing will fail in a substantial flood.

The crossing shown opposite has a very large culvert matching the channel dimensions and it is well bedded. However the near side bypass pathway could be better armoured to reduce the risk of scouring.

AVOID BUILDING A DAM

As mentioned, any crossing that raises the bed level will act as a dam and therefore create a potential waterfall or cascade. If there is a weakness in the banks the water can then flow around the obstacle and erode a new channel. The best option is to keep the crossing as low as possible. In this case several smaller diameter pipes would have been preferable to the one large pipe. Many of the rocks shown are much too large to be placed mid-channel, although they could be appropriate to armour the banks adjacent to the approaches to the crossing.

Not only can a crossing dam water, but it restricts the movement of sediment. Where water slows down, sediment can be deposited. In this case, excavation of the upstream channel to supposedly 'improve' on channel flow has destabilised the banks releasing tonnes of sediment into the system. A larger box culvert may not solve the problem. The upstream bed and banks require urgent stabilisation.

BED & BANK ARMOUR

Rigid bed and bank armouring, such as concrete or cemented rock is prone to movement and collapse along the edges where eddy's are created and erode away the less consolidated soil. The ad hoc dumping of old tyres, posts and other junk, although a popular 'quick fix' will not necessarily prevent this happening. The photo shows a structure only a few years old that is already beginning to fall apart. Further downstream are many examples of similar rigid structures that have failed in the past. Bank armour should extend below the bed level to prevent undermining and 'flexible' material is more desirable.

Loose rock is more flexible and is widely used. The main considerations are sensible rock size and placement. At a more sophisticated level, wire mesh baskets called gabions provide relatively cheap, rocky mattresses that can be used to armour streambeds and banks. Their flexibility enables them to conform to irregular surfaces and they are not easily moved. Gabions can reduce undermining as they are able to settle without fracturing. Since they dissipate energy and slow water flow, it is still important that gabions extend above the high flow level. They can also provide opportunities for vegetation to establish, unlike rigid structures .

DOWNSTREAM BED & BANK PROTECTION

This crossing has been poorly designed on the downstream edge. Rock and concrete have been repeatedly added to try and deal with bypass erosion. There was one small culvert pipe which ensured that the 'dam' was always being overtopped. After many years and quick fix repairs, the entire crossing was removed and rebuilt using large box culverts with a capacity near that of the natural channel.

The crossing left is well armoured on the downstream side. The loose rock apron should ideally be no steeper than a slope of 1 in 10 and extend up the channel sides above the higher flood flows. In this case the dense native vegetation protects the edges of the rock ramp even though it does not extend far up the bank.

Gabion baskets are ideal for areas where stream flow is highly concentrated. In other areas well positioned loose rock can be successfully used for bank protection Rocks of various sizes should cover the entire area to be protected as shown in the above image. The establishment of native vegetation not only provides extra protection, but indicates that the banks are quite stable.

NOTES ON CULVERT PIPE INSTALLATION

The base of the culvert should sit at the level of the stream bed and be oriented to keep flow central to the channel and not directed into the banks

Bedding material can be used and generally should not consist of rubble or blue-metal greater than 30 mm in diameter. This also applies to backfill along the sides.

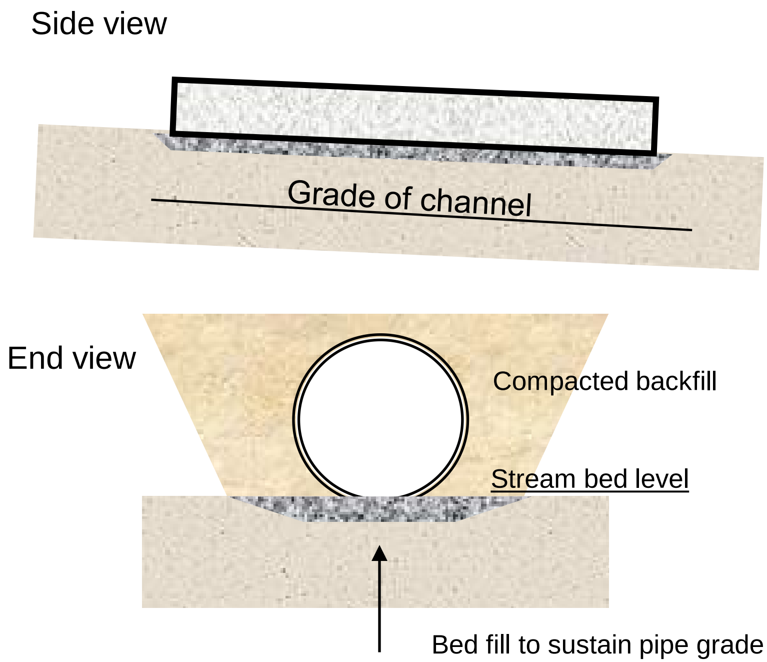
Bedding depth should be at least 100 mm deep to enable the gradient (slope) of the pipe to be maintained with firm support

Side support is important and backfill should be compacted to firmly seal the spaces between the pipe and the crossing material or between pipes.

The complex pattern of flow upstream and downstream of the pipe entry and exit points puts these flanking areas at risk of erosion and collapse. Battered slopes and lining is required. The establishment of suitable vegetation can assist greatly to stabilise the areas around the crossing.

The diagrams opposite illustrate the basic arrangement.

The culvert shown on page 36, sits too high above the bed, creating a waterfall. The through flow is digging a deep hole and the edges are not armoured as a result, although less than a year old this crossing is already starting to disintegrate.



BRIDGES

For private properties, bridges are often the most expensive option, but they may be the logical long term requirement where channels are deeply incised, with steep banks and where most flood flows are usually contained in the channel or can spread out across a floodplain if the bridge is over topped.

SPANNING INCISED CHANNELS

The crossing opposite demonstrates a number of poor design features that have led to its rapid failure. First it lies on a bend in the channel, secondly most low flow leaks beneath and around the culvert pipes and thirdly the capacity of the pipes is too small to handle moderate to high flows. The crossing was only a few years old when it failed. Various oversized boulders, poorly placed have done little to stabilise the situation.

Because the channel is relatively narrow and incised there may be a case for spanning the entire width with a bridge or to install much larger box culverts. The banks beneath such a crossing would need to be well armoured and this should extend below the channel bed to the bank top. Adequate cross-section will need to be maintained to prevent water velocity increasing as it passes through the crossing. If the bridge is not a viable option then the crossing should be relocated to a straight section of the stream with lower banks and a lower profile ford or culvert design should be used.

The bridge style farm crossing shown opposite was fabricated from salvaged materials and is well designed to maintain the stream cross-section. The bank slopes beneath are the key area for stabilising. The disadvantage, in this case, is that only vehicles of width less than three metres, can cross over and it may be for stock movement.