Waterway Technote
Crossings

Contents

Version 1 – April 2015

DairyNZ

Benefits of well-planned and well-constructed crossings

Benefits to your farm:

- Making travel times faster for you and your stock
- Improving stock health by reducing stress, lameness and the potential of liver fluke
- Providing easier access for stock and farm vehicles when streams are running high
- Preventing damage to the stream bed
- Protecting stream habitat for fish and insects
- Reducing the amount of sediment and bacteria getting into waterways
- Improving health and safety for farm staff, owners and any visitors to the farm.

If you have places on the farm where stock and vehicles regularly cross through streams or rivers, it's time to start thinking about alternatives.

The Sustainable Dairying Water Accord

As part of the Sustainable Dairying Water Accord, by May 31, 2018 all dairy farmers will be required to have bridges or culverts on regular stock crossing points used more than once per month. See: dairynz.co.nz/wateraccord.

Remember to also check with your regional council about further stock exclusion and crossing requirements that may be in place.

Plan before you construct

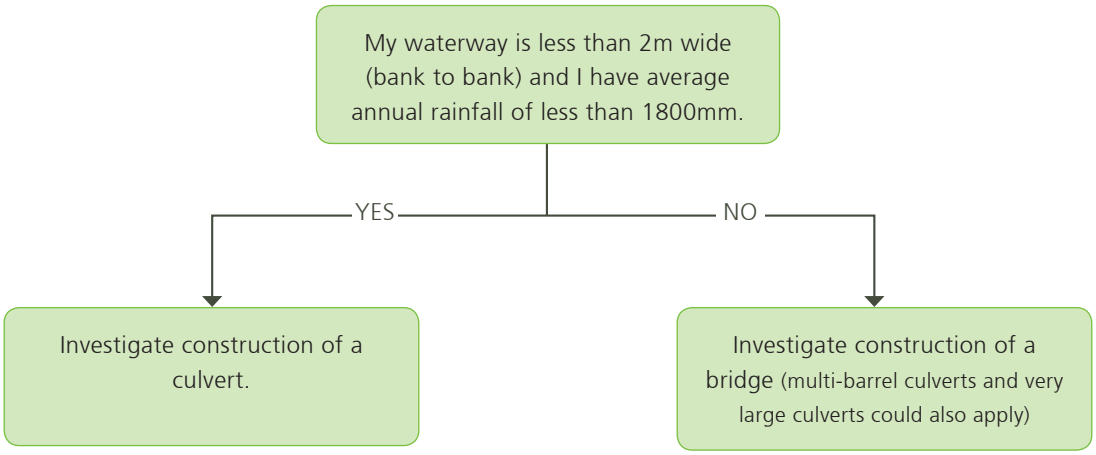
Planning the type of crossing and its location is important to avoid damaging waterway banks, disrupting streams and will help reduce maintenance or refitting costs. The initial considerations when installing a crossing are:

- Taking the time to properly plan any new crossings or crossing upgrades
- Consulting with your regional council to find out what their rules are around constructing crossings
- If your proposed crossing is on a waterway managed by your regional council for flood protection purposes you will also need to talk to them as restrictions on what you can do may apply
- Prioritise crossings on waterways that have the most use. The accord requires constructed crossings where dairy cows cross to access the milking shed, then return following milking more than once per month.

- Understand there may be other crossings e.g forded crossings, in-paddock crossings, ephemeral waterways which will benefit from a constructed crossing.

Culvert or Bridge?

The type of crossing that is suitable in your situation is dependent on a range of variables which include: waterways size, high flow levels, the size and shape of the waterway and the types of vehicles that need to cross. However as a general guide the following can be adhered to:



Selecting the location of your crossing

Ideally a crossing point should be at a narrow point of a waterway stream with flat approaches on either side, or approaches that slope away from the waterway.

Avoid locating crossings where there are steep slopes leading down to it. This is safer for farm vehicles, reduces the risk of stock slipping over and will reduce sediment and nutrient runoff into the waterway.

Choose a straight stretch of stream with a low gradient (bends in the stream near culverts are more likely to cause erosion).

General design considerations for crossings

Crossings should be constructed so that storm water runoff from the track leading to and from the crossing can be diverted away from the stream (using earth cut-off drains) into a grassy area. This can be harder if the crossing has steep entries leading onto the crossing.

Raised edges (often called nib walls) on the crossing will help prevent direct runoff from entering the water.

Which crossing type to use?

Ensure you have the right crossing for each waterway. Below is a summary of common crossing types. See appendix 1 for an expanded explanation of these types of crossings.

Type of crossing	Where suitable	Key considerations
Single barrel arch culvert 	Waterway <2m wide, average rainfall <1800mm.	Can accommodate the full width of a small stream and some of the natural bank. Use culverts that are at least 300mm in diameter. Install the outlet below the level of the waterway; this will prevent a waterfall from forming.
Single barrel circular culvert 	Waterway <2m wide, average rainfall <1800mm.	Ensure a good size culvert is installed to allow for the full width of the stream. Use culverts that are at least 300mm in diameter. Install the outlet below the level of the waterway; this will prevent a waterfall from forming.
Box culvert 	Waterway <2m wide, average rainfall <1800mm.	Box culverts often accommodate the full width of a waterway. Install on a slight angle to allow for fish passage in low flows. Use culverts that are at least 300mm across. Install the outlet below the level of the waterway; this will prevent a waterfall from forming.
Multi barrel circular culvert 	Dependent on the catchment area, but can be used in a higher rainfall area or larger catchment than a single barrel culvert of the same size.	Used to accommodate larger flows, and can be a far cheaper option than installing bridges across large waterways. However they will collect more debris than bridges and require more maintenance. Installation should include having some culverts at different heights to allow for variations in flow. Install the outlet below the level of the waterway; this will prevent a waterfall from forming.
Single span bridge 	Good for streams <10m wide and will be suitable for larger streams in many cases.	A long term option when constructed well, with quality materials. Engineering advice is usually required. Consent is almost always required. Try to avoid using recycled material such as car bodies or trailer parts. Avoid installing bridge in the flow path of flood events.

Type of crossing	Where suitable	Key considerations
Multiple span bridge 	Large river systems.	Not common on farms, and expert advice is required. Ensure resource consent is sought and engineers are involved.

Culverts

Culverts are usually installed on smaller streams than bridges, and are significantly cheaper and easier to install. Correct size and installation will generally save money in the long term by reducing the likelihood of failure and the need for replacement. Poor design often results in erosion and damage to the stream.

Install a bridge instead of a culvert when:

- Overtopping of the culvert could cause flooding to nearby infrastructure
- High debris loads are likely, e.g significant gravel bed load, flood debris such as trees or logs
- Overtopping the culvert could cause embankment failure with significant consequences
- In steep hill catchments which are prone to flash floods
- The catchment is larger than 500ha.

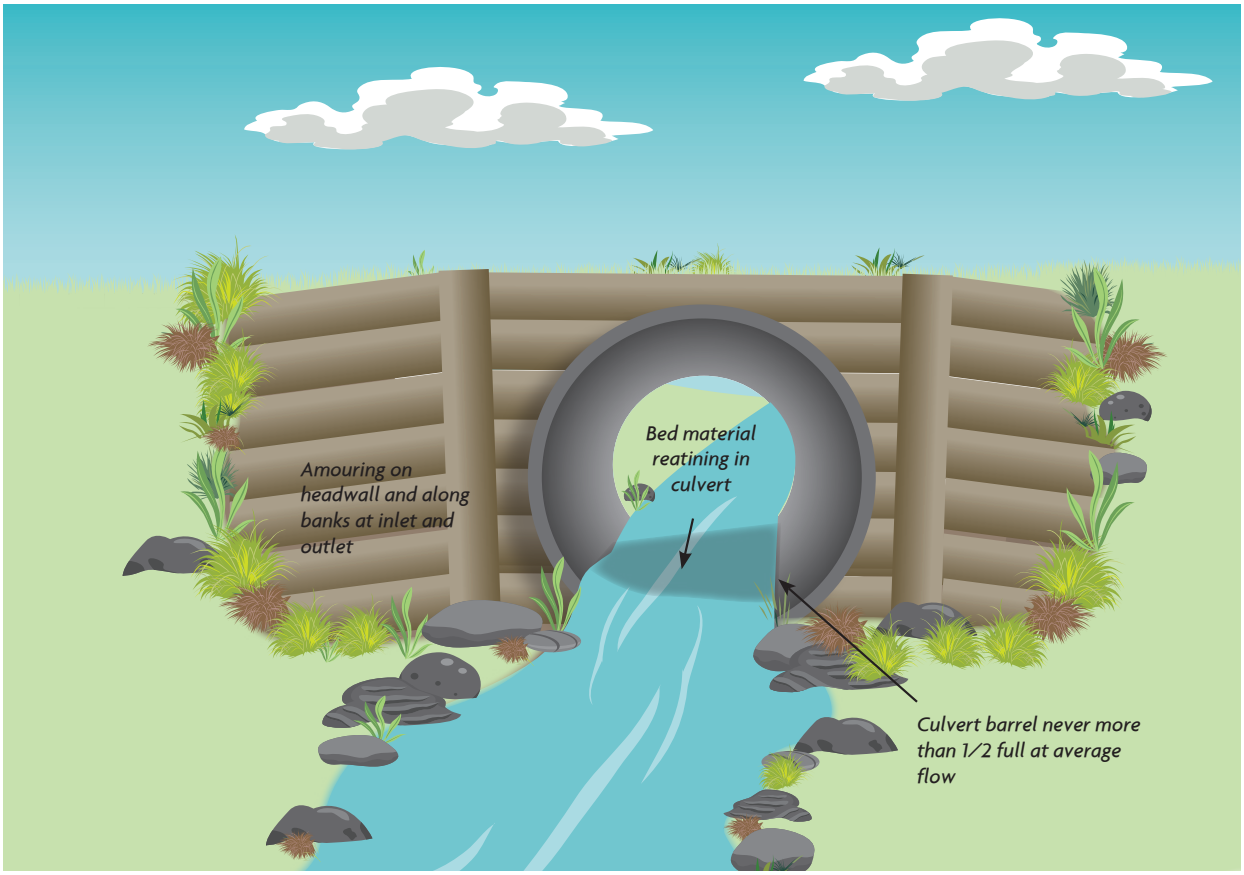
Good management practices for culverts

In general, when building, replacing, or upgrading a culvert consider the following good management practices:

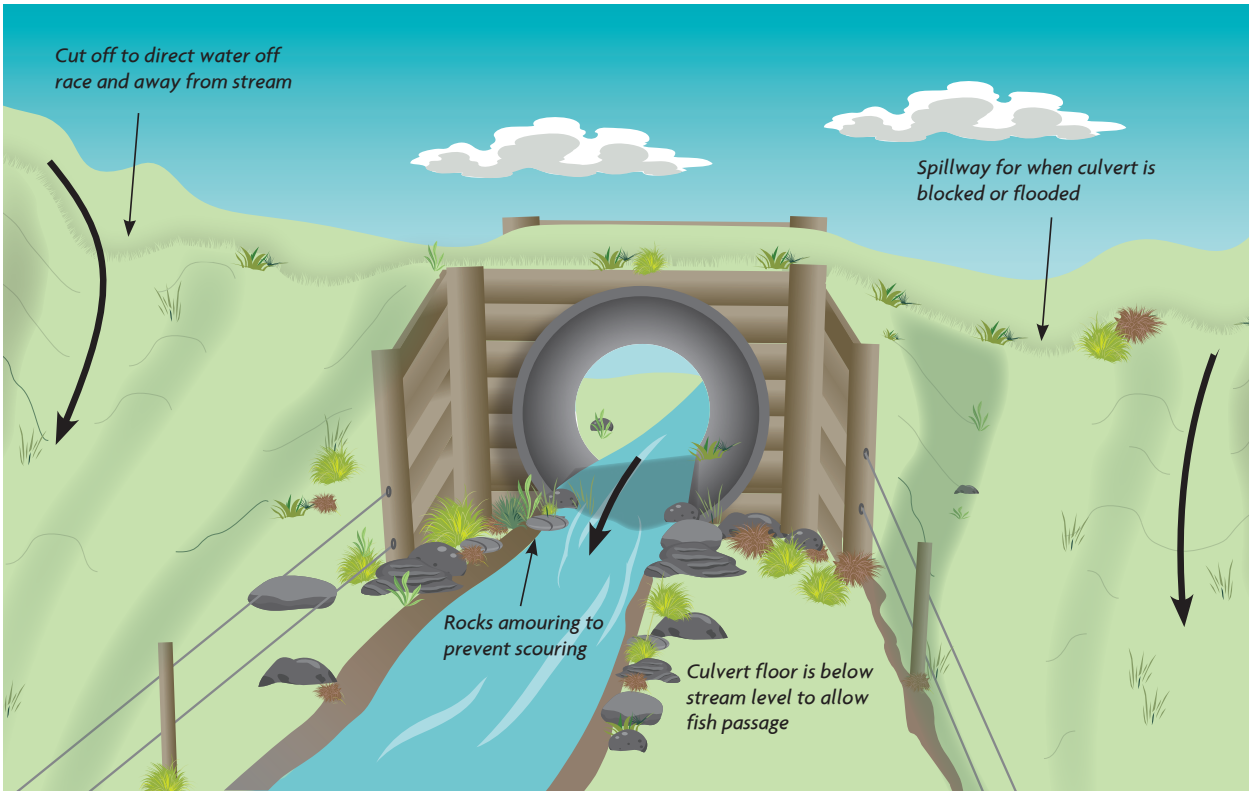
- When choosing a culvert, bigger is generally better if you are concerned about blockages, erosion from over-topping or if high downstream water levels restrict water flow.
- Make sure the width of the culvert is the same as or wider than the average width of the stream. This will help avoid bypassing or blow-outs in floods. A good rule to follow is 1.2 x channel width + 0.5m.
- Position the culvert so that the gradient and alignment are the same as the stream.
- Set the floor of the culvert below the streambed level to avoid vertical drops at the downstream end. Do not create a waterfall as this increases the chance of erosion and restricts fish movement upstream.
- Use armouring materials such as rocks or concrete around the culvert and especially below the outlet to reduce erosion.
- Check the culvert manufacturers' recommendations about the depth of fill to put over your pipe to make sure it can withstand loads.
- Consider building a spillway to cope with extreme floods. A spillway is an area to the side of a culvert where water can flow if the culvert overtops. It should be wide and level across the path of the flow and grassed to prevent scouring. Talk to your regional council or an engineer for advice about good design for your site.
- Allow natural streambed material to settle on the culvert floor along its length so that it is easier for fish to swim through.
- Make sure the culvert is not altering the natural gradient and bed of the stream.

- Take care to minimise the amount of sediment entering the waterway when installing the culvert. Use silt fences or hay bales downstream and minimise soil disturbance where possible. Avoid machinery entering the waterway.

Good practice circular barrel culvert installation.



Good practice culvert design.



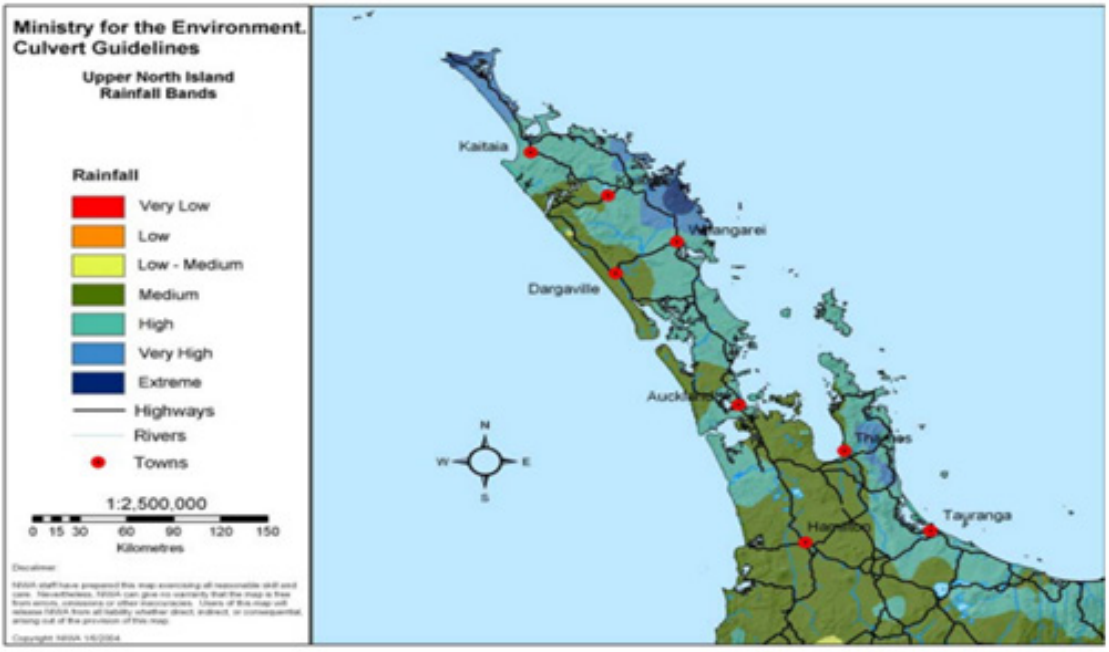
Culvert sizing guidelines

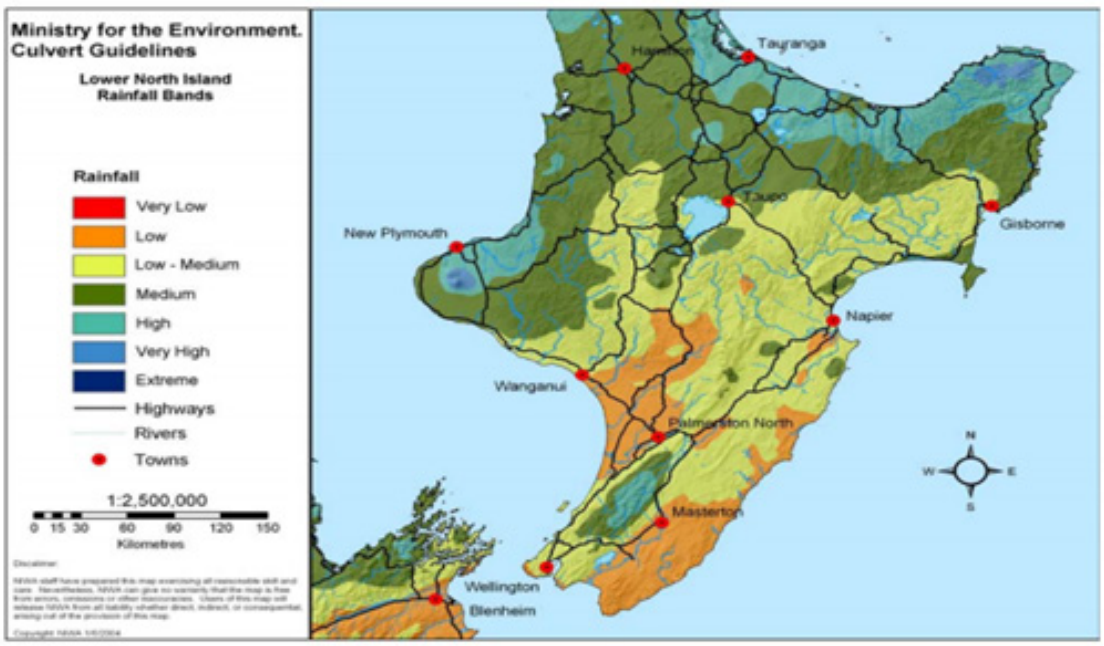
Look near your proposed crossing to see if there are any other culverts on the same stream which work well in high flows (i.e do not flood upstream in smaller floods and do not regularly overtop). This may give you a guide as to an appropriate culvert size, although be wary as in many cases culverts in place on the stream may not be appropriately sized.

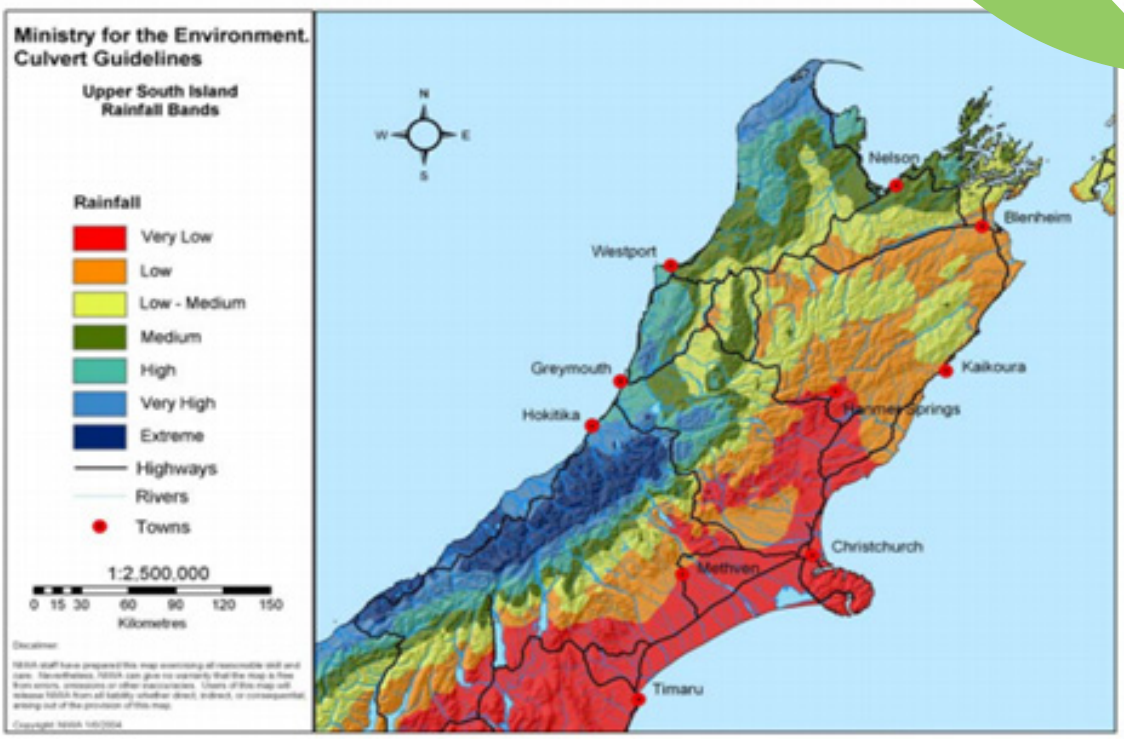
When choosing a culvert, make sure the width of the culvert is the same as or wider than the average width of the stream. This will help avoid water bypassing or causing blow-outs in floods.

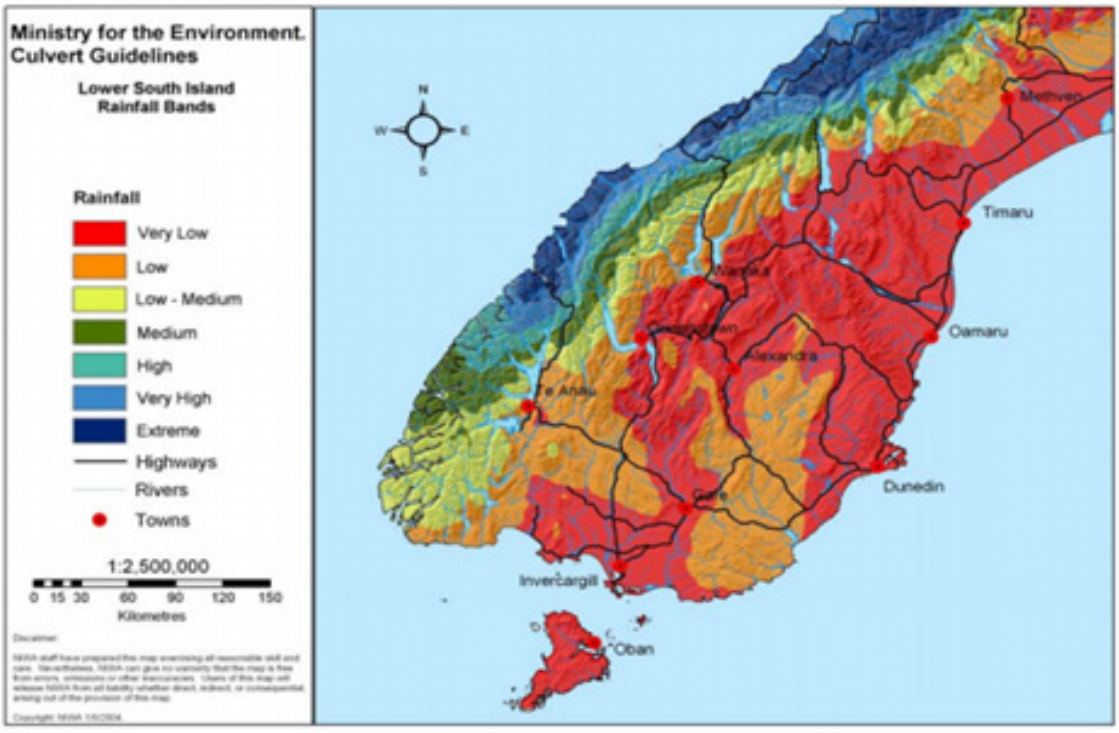
To size a culvert:

1. Determine the catchment area above the crossing point. If using NZMS 1:50,000 maps note that one square on the map equals 100ha.
2. Locate the catchment on the rainfall map below and identify the rainfall band. Note: If the catchment lies across two rainfall bands, use the higher band.









3. Refer to the culvert sizing tables for the relevant rainfall band and choose the catchment area closest to yours. This will give you a recommended culvert diameter. Using 300mm pipe as a minimum will help prevent blockages and overtopping.

Culvert sizing tables for catchment area:

	Very low
5 ha	300 mm
10 ha	375 mm
15 ha	450 mm
20 ha	525 mm
30 ha	600 mm
40 ha	675 mm
50 ha	825 mm
100 ha	975 mm
150 ha	1200 mm
200 ha	1350 mm
250 ha	1600 mm
300 ha	1600 mm
350 ha	1600 mm
400 ha	1800 mm
450 ha	1800 mm
500 ha	1950 mm
	Very low

	Low
5 ha	300 mm
10 ha	450 mm
15 ha	525 mm
20 ha	600 mm
30 ha	675 mm
40 ha	825 mm
50 ha	900 mm
100 ha	1200 mm
150 ha	1350 mm
200 ha	1600 mm
250 ha	1800 mm
300 ha	1800 mm
350 ha	1800 mm
400 ha	1950 mm
450 ha	2100 mm
500 ha	2100 mm
	Low

	Low–medium
5 ha	375 mm
10 ha	450 mm
15 ha	600 mm
20 ha	675 mm
30 ha	825 mm
40 ha	900 mm
50 ha	975 mm
100 ha	1350 mm
150 ha	1600 mm
200 ha	1800 mm
250 ha	1950 mm
300 ha	1950 mm
350 ha	2100 mm
400 ha	2100 mm
450 ha	2550 mm
500 ha	2550 mm
	Low–medium

	Medium
5 ha	375 mm
10 ha	525 mm
15 ha	600 mm
20 ha	675 mm
30 ha	825 mm
40 ha	975 mm
50 ha	1050 mm
100 ha	1350 mm
150 ha	1600 mm
200 ha	1950 mm
250 ha	2100 mm
300 ha	2100 mm
350 ha	2550 mm
400 ha	2550 mm
450 ha	2550 mm
500 ha	n/a
	Medium

	High
5 ha	450 mm
10 ha	600 mm
15 ha	675 mm
20 ha	750 mm
30 ha	900 mm
40 ha	1050 mm
50 ha	1200 mm
100 ha	1600 mm
150 ha	1800 mm
200 ha	2100 mm
250 ha	2550 mm
300 ha	2550 mm
350 ha	2550 mm
400 ha	2550 mm
450 ha	n/a
500 ha	n/a
	High

	Very high
5 ha	450 mm
10 ha	600 mm
15 ha	675 mm
20 ha	825 mm
30 ha	975 mm
40 ha	1200 mm
50 ha	1200 mm
100 ha	1600 mm
150 ha	1950 mm
200 ha	2550 mm
250 ha	2550 mm
300 ha	2550 mm
350 ha	2550 mm
400 ha	n/a
450 ha	n/a
500 ha	n/a
	Very high

	Extreme
5 ha	525 mm
10 ha	675 mm
15 ha	825 mm
20 ha	975 mm
30 ha	1200 mm
40 ha	1350 mm
50 ha	1600 mm
100 ha	1800 mm
150 ha	2550 mm
200 ha	2550 mm
250 ha	n/a
300 ha	n/a
350 ha	n/a
400 ha	n/a
450 ha	n/a
500 ha	n/a
	Extreme

For catchments in excess of 500ha – contact an engineer as you may require a bridge not a culvert

- The minimum recommended culvert size is 300mm in all situations. This is because smaller culverts are easily blocked by debris.
- In some cases a large single culvert may not be the most practical option. The table below gives equivalent multiple barrel culvert installations, which will provide the required culvert capacity.
- The culvert sizes provided will in most cases pass storm flows equating to about a one in five year storm. Therefore from time to time they can be expected to overtop and in very large storms may scour out. If you wish to have a higher level of storm protection, or gain a more site-specific understanding of your risk, you will need to get advice from your regional council or a suitably experienced consulting engineer.

Equivalent pipe diameters when using multiple culverts

Pipe diameter	Equivalent to		
300 mm			
375 mm	2 x 300 mm		
450 mm	2 x 375 mm	3 x 300 mm	
525 mm	2 x 450 mm	3 x 375 mm	4 x 300 mm
600 mm	2 x 450 mm	3 x 375 mm	4 x 375 mm
675 mm	2 x 525 mm	3 x 450 mm	4 x 375 mm
750 mm	2 x 600 mm	3 x 450 mm	4 x 450 mm
825 mm	2 x 675 mm	3 x 525 mm	4 x 450 mm
900 mm	2 x 675 mm	3 x 600 mm	4 x 525 mm
975 mm	2 x 750 mm	3 x 600 mm	4 x 525 mm
1050 mm	2 x 825 mm	3 x 675 mm	4 x 600 mm
1200 mm	2 x 900 mm	3 x 750 mm	4 x 675 mm
1350 mm	2 x 1050 mm	3 x 825 mm	4 x 750 mm
1600 mm	2 x 1200 mm	3 x 975 mm	4 x 900 mm
1800 mm	2 x 1350 mm	3 x 1200 mm	4 x 975 mm
1950 mm	2 x 1600 mm	3 x 1200 mm	4 x 1050 mm
2100 mm	2 x 1600 mm	3 x 1350 mm	4 x 1200 mm
2550 mm	2 x 1950 mm	3 x 1600 mm	

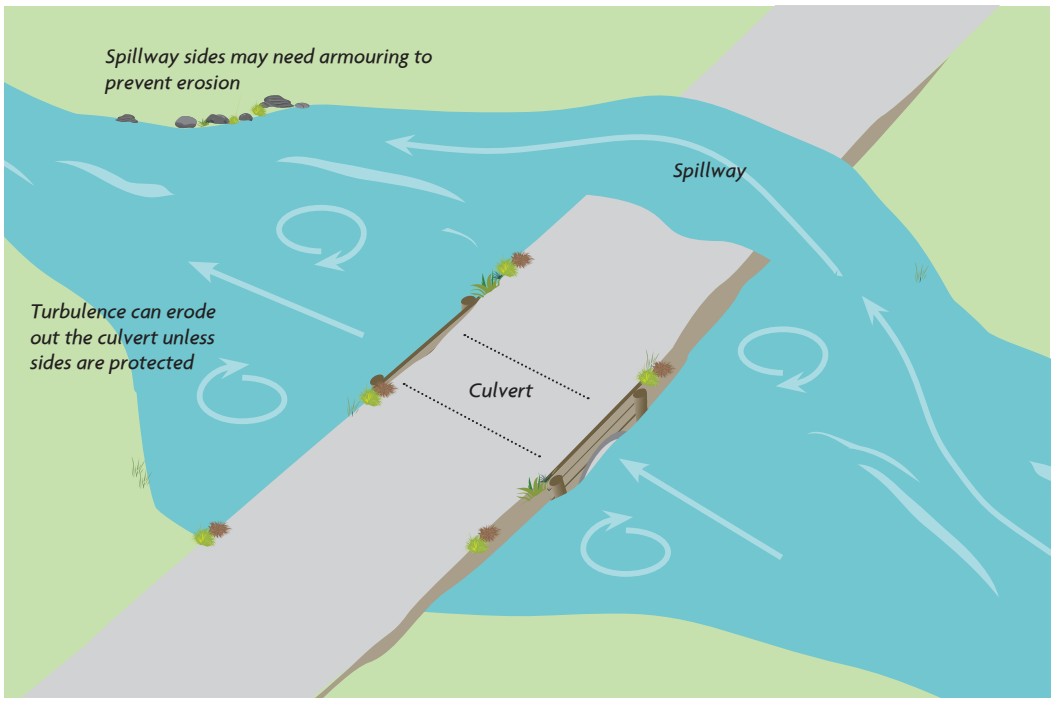
Images from http://www.mfe.govt.nz/publications/land/culvert-and-bridge-construction-guidelines-farmers/2-culvert-guidelines

Installing a spillway

The culvert sizes provided allow for low flood flows. An allowance needs to be made for larger flood flows to prevent damage to the culvert and track. The best way to achieve this is to create a lowered spillway (approx 0.5m deep) to the side of the culvert to allow controlled overtopping of the culvert. The spillway should be wide and level across the track and away from the culvert fill material. The outlet side of the spillway should be gently sloping back to the stream and grassed or rock armoured to prevent erosion.

If there is no suitable location for a spillway adjacent to the culvert, the spillway can be over the culvert. In this case special care must be taken in the construction of the culvert headwalls to protect the fill material from being washed out.

An example of how a spillway should operate.



For further information and design details to simplify the process, see the Culvert and Bridge Construction Guidelines prepared by Ministry for the Environment.

Common types of culverts on dairy farms

Single barrel arch culvert

If the waterway to be crossed is not too wide, a single barrel arch culvert (i.e a culvert with a flattened floor or a full round culvert with no floor) is a suitable and effective crossing option.

This type of culvert works well because the arch shape allows for a wide base that can accommodate the full width of the waterway which allows for a natural stream bed to develop within the barrel.

Good practice – single barrel arch culvert.

Single barrel arch culverts have been widely and successfully used around the country. When sized correctly, these culverts have the ability to allow for good water flow through high and low flow periods as well as enabling for some in-stream habitat and good fish passage.

The arch culvert shown above has been installed to accommodate not only the full width of the stream bed, but also some of the natural bank. Large rocks have been placed in the straight barrel section of the culvert to ensure that high flow velocities do not develop and to provide cover and habitat for fish.

Single barrel circular culvert

These are the most common form of culvert but are not as desirable as arch culverts or bridges in larger waterways. They are a good option if installed using good practice; but bridges and arch culverts will generally provide greater capacity for flows and be able to maintain a more natural stream bed.

Unless oversized, circular culverts tend to reduce the waterway area and so increase water velocities at high and medium flows. This can lead to erosion and prevent fish passage upstream.

Multi barrel circular culvert

Crossings with multiple culverts placed side by side are common in wide channels that have a low to normal flow but occasional experience very high flow events. These types of crossing are prone to collecting debris and becoming blocked, therefore reducing the capacity of the crossing. In cases where streams have low flow volumes for the majority of the time and relatively high flood flows, multiple barrel culverts set at different levels are appropriate.

Multi-barrel circular culvert with culvert pipes at different levels to cater for high flows.

Due to these structures being better suited to wider rivers, it is important to ensure that during periods of high flows,

water can be channelled through the culverts rather than running over the top of the entire structure. This can be achieved by siting pipes at varying heights to accommodate a range of flows.

Box culverts

While box culverts can often accommodate the full natural width of a waterway they also result in a uniform depth of water and a uniform flow. During low flow periods box culverts do not concentrate flows to maintain water depth as circular culverts and natural stream beds do. This consequently results in a thin sheet of water covering the full width of the culvert. The outcome can be an insufficient depth of water for the passage of fish during low flows.

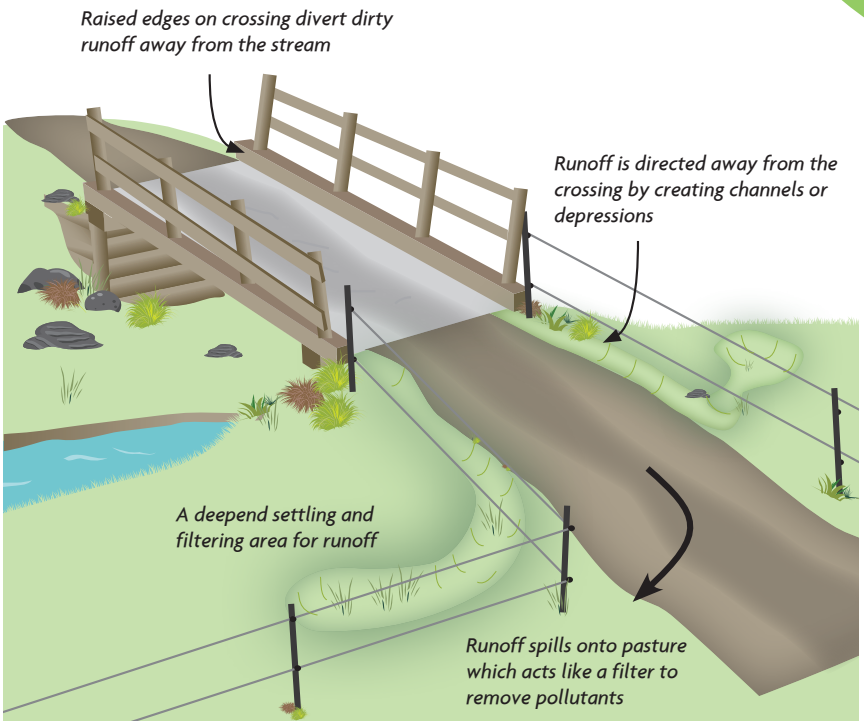
The use of box culverts can be an effective crossing if they are constructed correctly. When box culverts are installed, the base of box culverts should be angled to create low flow channel that fish can utilise during drier periods. This can also be achieved by installing the culvert on a slight angle.

Single box culvert.

Bridges

In general, when building bridges consider the following good management practices:

- Use standardised plans and materials to reduce time and cost of design
- Try to minimise the number of piers (if any) in the waterway to avoid impeding water flow and creating eddies which could contribute to bank erosion
- Avoid locating your bridge on a bend in a waterway, as sediment will build up on the inside
- Construct your bridge high enough so as not to impede high stream flows
- If possible, minimise your bridge span to keep costs down
- Construct raised lips on the deck and edges to prevent runoff entering the waterway
- Raising the bridge above its approaches will also help to reduce runoff from tracks and races from entering the waterway
- Channel runoff from the bridge into grassy areas or planted areas
- Construct your bridge high enough to avoid impeding high stream flows
- Construct a spillway.



Building safe bridges

For information and design details to simplify the process, see the Culvert and Bridge Construction Guidelines prepared by Ministry for the Environment.

You may also want to contact your bridge builder and engineer to discuss designs and costs to suit your situation. You will need to take into account things such as flood flows, bridge use, stream bank material, stream bed profile and preferred construction materials.

Safe bridges will have:

- Railing to ensure vehicles, stock and people will be able to safely cross
- Race surfaces which are maintained and constructed from a durable and sturdy surface
- Crossings that shed water into paddocks will ensure that surfaces are not slippery during wet periods
- Wide entries onto and off of the crossing to allow larger vehicle access and reduce problems in cow flow
- Built using sturdy and durable materials able to withstand high flows and flood levels.

Common types of bridges on dairy farms

Single span bridge

A single span bridge constructed according to good practice is the best type of waterway crossing on-farm. The waterway environment remains largely unchanged, flood flows can easily be accommodated and stock move freely.

Single span bridges have for a long time been the most popular choice of crossing on farms. Whilst there are many historic ways of constructing bridges, it is important to ensure nowadays that construction methods make use of trustworthy long-lasting materials and bridges are located in appropriate areas.

Good practice single span farm bridge. (Note that the footing of the bridge is well away from the water edge at normal flow so that the natural river bank is retained under the bridge.)

Multiple span bridge

Multiple span bridges are common where large river crossings are required and where a single span bridge is not practical. Consent and professional engineering will almost always be required.

Multiple span bridges are also prone to debris build up on the piers, particularly during high flow events, which may result in bed erosion and channel restriction. This is particularly important in flood prone rivers and streams where bridges with small spans and multiple piers can act as funnels for flood waters, creating areas of higher velocity and increasing the erosive impact of the flood waters.

A multiple span road bridge during a high flow event. (Note the debris build-up on the bridge piers.)

Maintenance of bridges and culverts

Inspect your bridges and culverts regularly and especially after heavy rain events. Remove any debris or blockages as this reduces flow capacity, resulting in additional flooding and possible damage. Regional councils can often provide assistance and advice around removing large blockages.

It is important to ensure regular upkeep of the general area around bridges and crossings. In particular, paying attention to areas where sediment and effluent accumulate to avoid this washing into waterways during rain events. These areas include:

- Cut-off drains
- Crossing surfaces
- Hollows around bridge surfaces
- Nib wall edges.

In some cases, filling with race material or fill is enough to stop this accumulation. In others scraping of crossing surfaces might be a better option and this can be pushed into paddocks where it can be filtered before entering water.

Crossings requiring upgrade

In some cases, old crossings require upgrades. This can be due to materials wearing out or because of incorrect initial installation. In most cases, quick fixes may mean some simple patching of an old crossings or possible slight adjustment to the site of the crossing. In other cases, an entire re-build/re-think will be required.

Examples of moderate fixes to improve your crossing might include:

- Redesigning cut off areas to divert water off the raceway away from the stream
- Armouring around the base of bridges and culverts to reduce erosion
- Installing a new top to the bridge or culvert that directs run off away from water.

Examples of when a rebuild may be required:

- The culvert is perched and creates a waterfall
- The culvert is too small
- The culvert gets overtopped
- Any crossings where animals are walking through water.

Ford crossings are entry points for sediment, nutrients and harmful bacteria from faecal matter. . Good practice means upgrading this type of crossing to a bridge or culvert.

A badly installed culvert, placed too high above the stream bed which increases erosion and prevents fish passage.

References

Environment Canterbury. *A Guide to Managing Waterways on Canterbury Farms.* Environment Canterbury. Christchurch.

Environment Canterbury: *Living Streams Handbook – Part 2: Improving the stream environment.* Environment Canterbury. Christchurch.

Environment Waikato, 2004: *Clean Streams – A guide to managing waterways on Waikato Farms.* Waikato Regional Council. Hamilton.

Environment Waikato, 2006: *Environment Waikato Best Practice Guidelines for Waterway Crossings.* Environment Waikato Technical Report 2006/25R. Environment Waikato. Hamilton.

Ministry for the Environment, 2004: *Culvert and Bridge Construction – Guidelines for Farmers.* Wellington. New Zealand.

Otago Regional Council, 2005: *Environmental Considerations for Clean Streams – A guide to managing waterways in Otago.* Otago Regional Council. Dunedin.