

## Chapter 4

### Designing for risk

When designing a structure to carry or store runoff, it is necessary to consider how often it will be acceptable for the structure to fail or to surcharge.

The following terms, which refer to both rainfall and runoff, are used when discussing probability or risk:

- **Average Recurrence Interval (ARI)**, also referred to as average return period, is the average number of years (denoted as  $y$  years) within which an event will be equalled or exceeded.
- **Frequency** is an alternative way of expressing ARI. A frequency of 1 in  $y$  years means that the event will be equalled or exceeded once in  $y$  years on average.
- **Probability** is the inverse of frequency, that is,  $1/y$ . It is often expressed as percentage probability, this being  $100/y$  %.

If an event has an ARI of 10 years, it means that during a 100 year period, that event will be expected, on average, to be equalled or exceeded  $100/10$  or 10 times. The frequency of that event is 1 in 10 years, its probability is 0.1 (1/10) and its percentage probability is 10%. This also means that there is a 10% probability of that event being equalled or exceeded in each and every year. Such an event may occur more than once in any particular year.

It is important to understand that whatever terms are used, they all refer to *long-term averages* and that the periods between events are random. This means, that if an event with an ARI of 10 years occurred last year, the chances of a similar event occurring this year have not lengthened, they remain the same. That is, there is a 10% chance (or odds of 10 to 1) of it happening again. This concept should be fully explained to clients for whom designs are prepared.

For the design of soil conservation structures, the estimation of runoff usually relates only to very small areas such as a paddock or a small catchment on a farm. Extremely high rainfall events that are 'off the scale' of a district rainfall intensity chart can occur in very localised areas. So it is likely that in any district, at the paddock scale, rare events, such as those with an ARI of 100 years, will occur somewhere in a catchment on a much more frequent basis than 1 in 100 years.

It is generally accepted that soil conservation structures should be designed to handle a runoff event with an ARI of 10 years. However, as discussed later in this chapter, this concept is somewhat theoretical when applied to soil conservation structures since their ability to accommodate runoff is subject to considerable variation depending on the season and the stage of the cropping cycle.

A larger ARI should be used when designing soil conservation structures in situations where failure might threaten public safety or cause severe damage, for example, some diversion banks and perched waterways. The largest ARI used for the design of soil conservation works is seldom more than 50 years. On slopes below 1% where surcharging is unlikely to cause significant damage outside a waterway, designs with a lower ARI, for example, 5 years, may be considered.

Structures should be designed for 'average' conditions. Extreme values of the parameters of runoff estimation models are used by some operators to provide safety margins in design. This results in runoff estimates with unknown ARI's and increased construction costs. **If a more conservative design is required, it is better to design for a higher ARI.**

Unlike more permanent structures, the physical dimensions of contour banks are constantly changing. Contour bank capacity declines over time as the bank height reduces by settlement and use of tillage equipment. Channel capacity is also reduced by sediment deposition. For this reason contour banks are normally built to exceed specifications initially so that they will have an effective life of 5 to 10 years before requiring maintenance. In reality, the size of a structure is often determined by the construction technique used by a farmer rather than the theoretical specifications resulting from a design. For example, contour banks in some districts are constructed with one push of a large bulldozer.

For broad-based contour banks, 'failure' may only involve overtopping of the bank (surcharging). When narrow-based banks surcharge, the bank may be completely removed at the point of failure. Contour banks (especially those that are narrow-based) will also be susceptible to failure if preceding dry conditions have resulted in cracks developing across the bank or if animals have burrowed into the bank.

Contour bank failure may result in serious rill and gully erosion below the breakout and subsequent failure of lower contour banks. Such banks must attempt to accommodate the additional amounts of runoff for which they were not designed. Their capacity will have been greatly reduced as a result of sediment deposition resulting from the failure of the above bank. The amount of damage that occurs at the time of bank failure is dependent on the amount of protection provided by crops or stubble and the soil tilth in the contour bay at the time of the event.

In waterways, the depth of flow reached at the point of surcharging may lead to high velocities, which could erode the waterway. Runoff that escapes the confines of the waterway may also cause erosion as it flows parallel to the waterway or flows away from waterways that are not situated in a natural drainage line.

Soil conservation structures are subject to varying conditions in their channel, which adds an additional dimension to their design. Unlike structures made of concrete, soil conservation structures will have different degrees of 'roughness' in their channels depending on the cropping cycle in the case of contour banks, and the season in the case of waterways. This means that although a soil conservation structure may be designed to handle the 10 year ARI runoff event, its ability to handle such an event will vary considerably depending on the condition of the channel at the time of the event.

Table 4.1 shows that a typically shaped contour bank with a smooth bare channel (Mannings roughness coefficient,  $n$ , of 0.03) can carry five times as much runoff as a channel with a wheat crop or stubble from a previous crop where typical roughness coefficients may be around 0.15. This means that a contour bank designed for conditions when there is a sparse grass cover will be able to handle well in excess of the design storm when the channel is bare. However the bank will accommodate a runoff event with a much lower ARI if the channel flow is restricted by a crop or standing stubble. If the stubble in a contour bank channel is burnt, the bank will, within minutes, be able to handle an event with a much larger ARI.

Mannings $n$	Predicted velocity m/sec	Predicted capacity $m^3/sec$
0.03 (bare cultivated channel)	0.72	2.9
0.05 (sparse grass cover)	0.43	1.7
0.15 (standing wheat stubble)	0.14	0.6
Parameters: <ul style="list-style-type: none"> <li>Broad based contour bank with a trapezoidal shape</li> <li>Bank batter 1:6 (V:H) and excavated batter 1:10 (V:H)</li> <li>Bottom width of 4 metres</li> <li>Flow depth of 0.5 metres</li> <li>Gradient 0.2%</li> </ul>		

Considering the example in Table 4.1, it would be reasonable to assume that contour banks should rarely surcharge when the contour bank channel is in a smooth and bare condition. In fact failures are common under these circumstances. Such failures can be attributed to ‘weak links’ at some points in the length of the contour bank. While 90% of the length of a contour bank may have sufficient capacity, the flow it can carry is determined by the capacity of the bank at its weakest point.

A common site for contour bank failure is where contour banks cross old gully lines. At these points contour banks need additional height to provide the gully crossing and to account for additional settlement. Such ‘crossings’ are effectively very small dams, which will in time silt up. Compounding the risk of failure is that these points are likely to have a rill above them which will lead to sediment deposition.

Research involving measurement of soil loss in cropping areas has shown that a large proportion of total soil loss results from a few large events. It would be reasonable to assume that since contour banks are ‘designed to fail’ in an event with an ARI in excess of 10 years, then their effectiveness in reducing soil loss in a paddock must be questioned. However, the data in Table 4.1 indicates that well maintained contour banks are most likely to fail when contour bays and channels are under crop or stubble. In such cases, soil loss will be reduced by the effects of the cover in the contour bay. Contour bank breakages under bare fallow conditions are only likely if contour banks have been poorly maintained and are not up to recommended specifications. In such situations, sediment ‘slugs’ deposited in bank channels below eroding rills will contribute to contour bank failure.

The ability of a grassed waterway to accommodate runoff will be very dependent on the density and length of grass in the channel as illustrated in Table 4.2. During a good season, grass growth may be prolific and will effectively choke the waterway resulting in reduced velocities and discharges. If waterways are heavily grazed or burnt there will be very little retardance to flow resulting in high (and erosive) velocities and high discharges. For this reason, in Chapter 11 *Waterways*, it is recommended that selection of a permissible velocity should be based on the seasonal condition when there is expected to be little retardance; and then depth of the channel based on the expected flow for a higher retardance.

Vegetative condition is also sensitive to management actions such as slashing or periodic grazing and whether or not fertiliser is used to promote vigorous growth for more effective erosion control.

Retardance in waterway channel (Grass length in cm)	Mannings <i>n</i>	Predicted velocity m/sec	Predicted discharge m <sup>3</sup> /sec
High retardance (A) >75 cm	0.3	0.2	1.0
Moderate retardance (C) 15–25 cm	0.04	1.5	7.3
Very low retardance (E) <5 cm	0.025	2.5	11.7

  

<p>Parameters:</p> <ul style="list-style-type: none"> <li>• Bottom width of 15 metres</li> <li>• Batters (V:H) 1:3</li> <li>• Depth of flow 0.3 m</li> <li>• Slope 2%</li> </ul>	<p>(Not to scale)</p>
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