Emergency Spillways (Sediment basins)

DRAINAGE CONTROL TECHNIQUE

Low Gradient		Velocity Control		Short-Term	✓
Steep Gradient	✓	Channel Lining		Medium-Long Term	✓
Outlet Control		Soil Treatment		Permanent	[1]

[1] The design of permanent spillways may require consideration of issues not discussed here.

Symbol → ES →

Photo 1 – Rock-lined sediment basin spillway with low-flow pipe outlet

Photo 2 – Rock mattress-lined sediment basin emergency spillway

Key Principles

1. The critical design components of a spillway are the flow entry into the spillway, the maximum allowable flow velocity down the face of the spillway, and the dissipation of energy at the base of the spillway.
2. The critical operational issues are ensuring unrestricted flow entry into the spillway, ensuring flow does not undermine or spill over the edge of the spillway, and ensuring soil erosion is controlled at the base of the spillway.
3. Failure of a spillway is likely to result from one or more of the following issues: inadequate rock size (if used), inadequate depth of the spillway chute, piping erosion caused by dispersive and/or poorly compacted soils, or failure of the energy dissipater.

Design Information

The material contained within this fact sheet has been supplied for use by persons experienced in hydraulic design.

This fact sheet addresses issues associated with the design of open channel spillways used in association with temporary sediment basins.

Design procedures and guidelines on the design of the spillway's chute can be obtained from the separate fact sheets presented for drainage *Chutes*. However, all references to the design of *Outlet structures* within these fact sheets do **not** apply to the design of spillway energy dissipaters. In addition, the recommended freeboard on spillway chutes is 300mm.

Design procedures and guidelines for energy dissipater located at the base of the temporary sediment basin spillways can be obtained from the separate fact sheet on *Energy dissipaters*.

Warning, sediment basin spillways and their associated energy dissipaters are usually major hydraulic structures requiring design input from experienced hydraulics specialists. This fact sheet does **not** provide sufficient information to allow these structures to be designed by inexperienced persons.

The recommended minimum design storm for sizing the emergency spillway is defined in Table 1. Designers should confirm the design standard with the appropriate regulatory authority.

Table 1 – Recommended design standard for emergency spillways on temporary sediment basins [1]

Design life	Minimum design storm ARI
Less than 3 months operation	1 in 10 year
3 to 12 months operation	1 in 20 year
Greater than 12 months	1 in 50 year
If failure is expected to result in loss of life	Probable maximum flood (PMF)

[1] Alternative design requirements may apply to Referable Dams in accordance with State legislation, or as recommended by the Dam Safety Committee (ANCOLD 2000a & 2000b)

The crest of the emergency spillway should be in accordance with the following (default values), unless otherwise supported by appropriate investigation, risk assessment, and design:

- 300mm above the primary outlet (if included);
- 300mm below a basin embankment formed in virgin soil;
- 450mm below a basin embankment formed from fill.

In addition to the above, design of the emergency spillway must ensure that the maximum water level within the basin during the design storm specified in Table 1 is at least:

- 300mm below a basin embankment formed from fill;
- 150mm plus expected wave height for large basins with significant fetch length.

Recommended freeboard for the spillway chute is 300mm (note; this is an increase from the 150mm freeboard recommended for drainage chutes).

Anticipated wave heights generated within the settling pond can be determined from the procedures presented in the *Shore Protection Manual* (Department of the Army, 1984).

The hydraulic design of the spillway chute (Figure 1) is outlined within the separate fact sheets for *Chutes*.

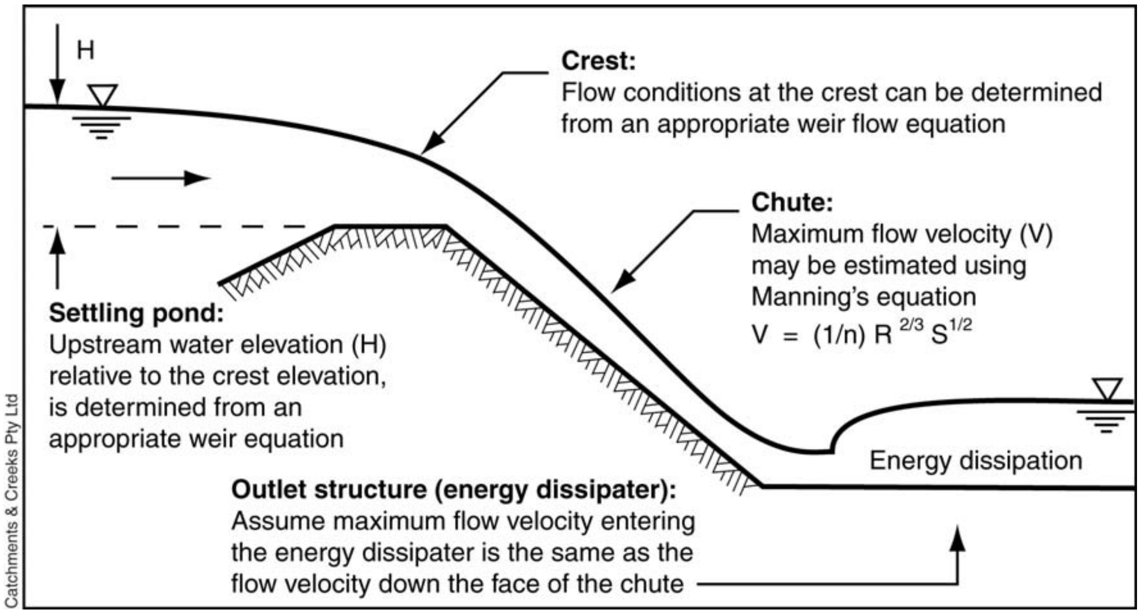

Figure 1 – Hydraulic components of a sediment basin spillway

Design of the flow entry conditions into the spillway:

All reasonable and practicable efforts must be taken to construct the spillway in virgin soil, (Photo 4 & Figure 2) rather than within a fill embankment (Photos 1, 2, 7 & 8). Placement of an emergency spillway within a fill embankment can significantly increase the risk of failure of the embankment.

The approach channel can be curved upstream of the spillway crest, but must be straight from the crest to the energy dissipater as shown in Figure 2. The approach channel should have a back-slope towards the impoundment area of not less than 2% and should be flared at its entrance, gradually reducing to the design width at the spillway crest.

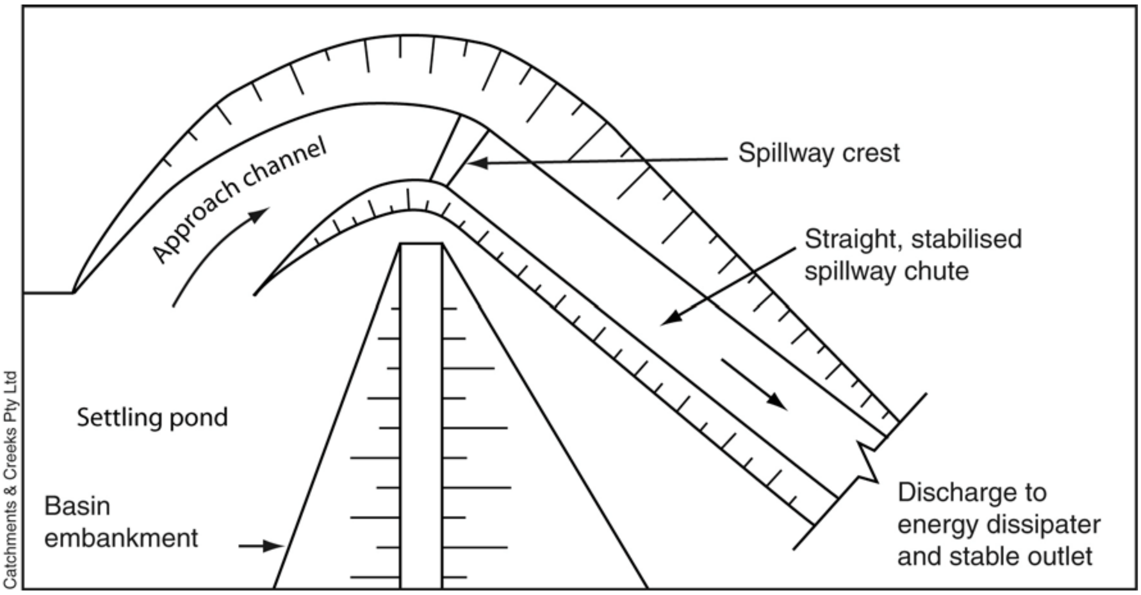

Figure 2 – Emergency spillway (plan view)

If the spillway crest length (L) and its approach channel are short, then friction loss upstream of the spillway crest can be ignored and the water level within the sediment basin 'H' (relative to the spillway crest) can be determined directly from the appropriate weir equation. Figure 3 shows flow approaching a spillway crest along a short approach channel.

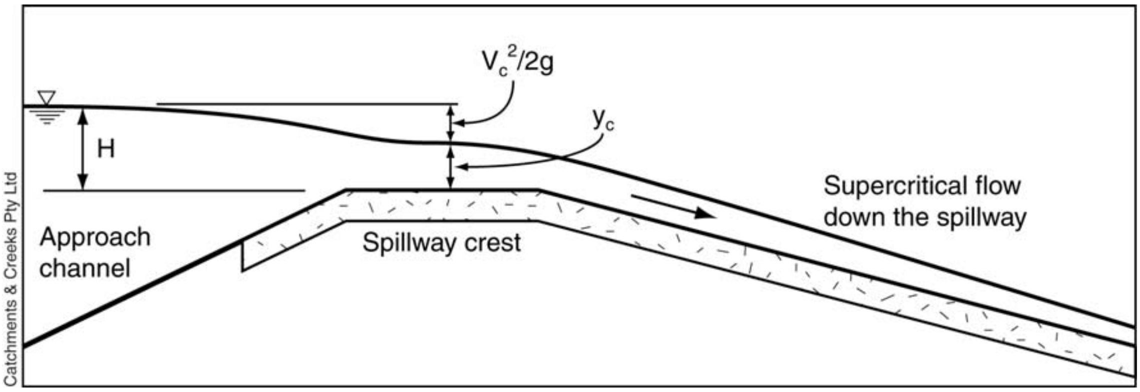

Figure 3 – Hydraulic profile for spillway crest where friction loss within the approach channel is insignificant

In those circumstances where the approach channel is short, the upstream water level (H) relative to the weir crest can be determined from the equations presented in Table 2.

Table 2 – Weir equations for short spillway crest length where friction loss in the approach channel is negligible

Weir cross sectional profile	Side slope (H:V)	Weir equation
Rectangular (b = base width)	vertical sides	$Q = 1.7\ b\ H^{1.5}$
Triangular	m:1	$Q = 1.26\ m\ H^{2.5}$
Trapezoidal	1:1	$Q = 1.7\ b\ H^{1.5} + 1.26\ H^{2.5}$
where : b = base width	2:1	$Q = 1.7\ b\ H^{1.5} + 2.5\ H^{2.5}$
and m = side slope	3:1	$Q = 1.7\ b\ H^{1.5} + 3.8\ H^{2.5}$
(see Figure 4)	4:1	$Q = 1.7\ b\ H^{1.5} + 5.0\ H^{2.5}$
	m:1	$Q = 1.7\ b\ H^{1.5} + 1.26\ m\ H^{2.5}$

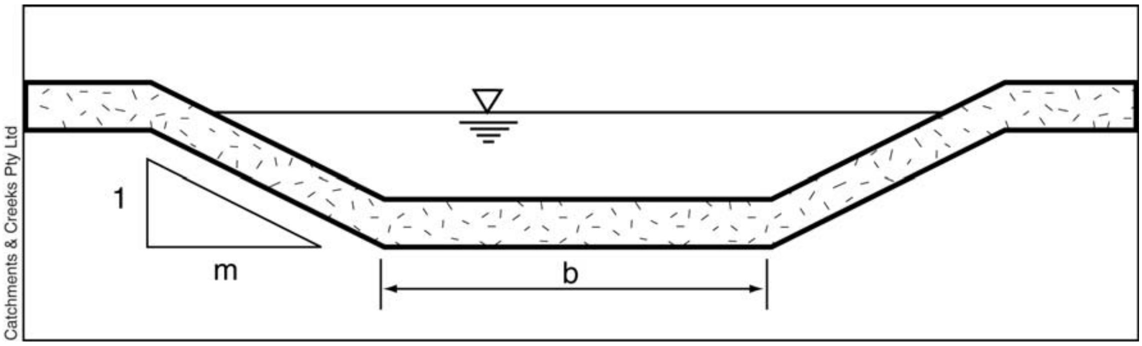

Figure 4 – Trapezoidal spillway (weir) crest

For some sediment basin spillways, however, friction loss within the approach channel is significant and cannot be ignored. In such cases an allowance must be made for this friction loss when determining the relationship between basin water level and spillway discharge. Figure 5 shows flow approaching a spillway crest where friction loss within the approach channel is significant.

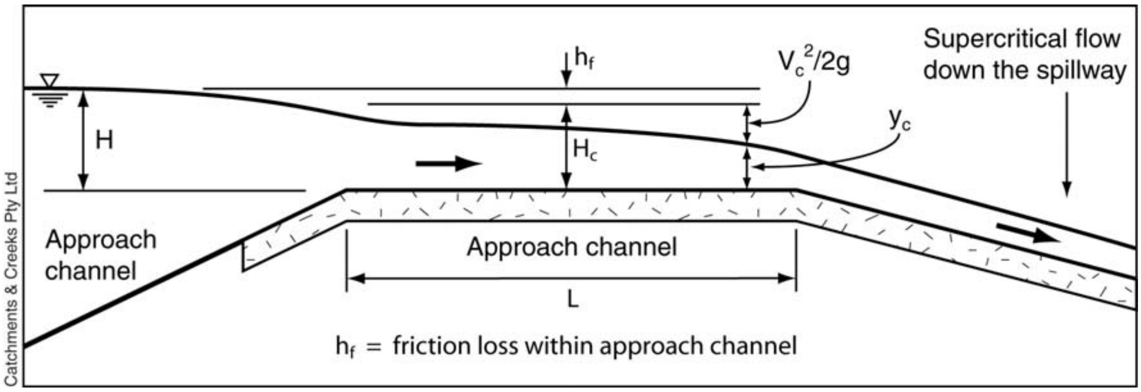

Figure 5 – Hydraulic profile for a spillway where friction loss within the approach channel is significant

A numerical backwater model (e.g. HecRas) should be used to determine the water level profile along the length of the approach channel and thus the anticipated maximum water level within a sediment basin. Such models can also be used to determine flow velocities down the face of the spillway chute. Alternatively, water levels within the basin (H) relative to the spillway crest can be determined from Equation 1.

$$H = H_c + h_f \qquad \text{(Eqn 1)}$$

where:

- H = water level within *Sediment Basin* relative to spillway crest [m]
- H_c = total head (energy level) at the spillway crest = $y_c + V_c^2/2g$ [m]
- y_c = critical depth at spillway crest [m]
- V_c = critical flow velocity at spillway crest [m/s]
- g = acceleration due to gravity = 9.8m/s^2
- h_f = friction loss within the approach channel and across the crest width [m]

Friction loss (h_f) within the approach channel can be estimated using Equation 2.

$$h_f = \frac{V^2 n^2 L}{R^{4/3}} \qquad \text{(Eqn 2)}$$

where:

- V = average flow velocity within the approach channel (if unknown, then assume a velocity of half the critical flow velocity (V_c)) [m/s]
- n = Manning's roughness of the approach channel
- L = length of the approach channel upstream of the spillway crest [m]
- R = average hydraulic radius of the approach channel [m]

In circumstances where friction within the approach channel is significant, but the determination of peak water level within the sediment basin is **not** critical, the total upstream head (H) can be estimated from the equations presented in Table 3.

Table 3 – Approximate weir equations for spillways with a long approach channel where friction loss is significant

Weir cross sectional profile	Side slope (H:V)	Weir equation
Rectangular (b = base width)	N/A	$Q = 1.6\ b\ H^{1.5}$
Triangular	m:1	$Q = 1.2\ m\ H^{2.5}$
Trapezoidal (b = base width)	m:1	$Q = 1.6\ b\ H^{1.5} + 1.2\ m\ H^{2.5}$

To maintain the desired maximum allowable water level within the settling pond, concrete capping (sealing) of the spillway crest (Figure 6) is usually required if porous materials, such as loose rock or rock-filled mattresses, are used to line the spillway crest.

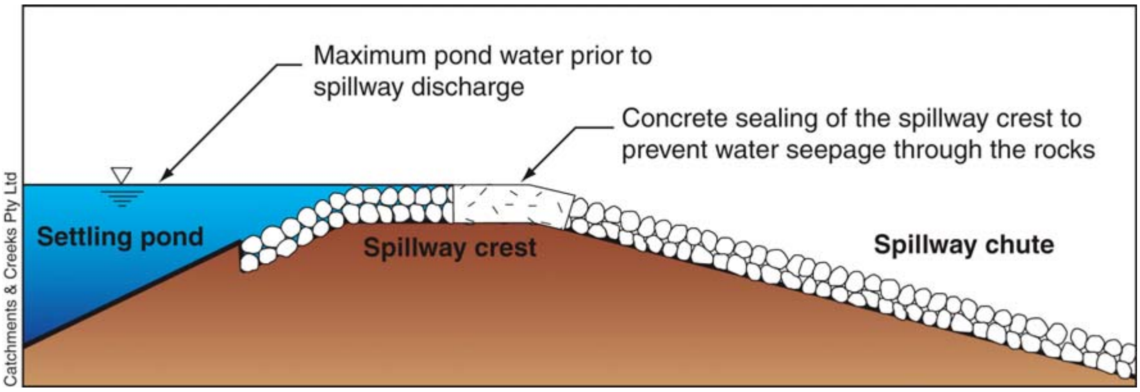

Figure 6 – Concrete sealing of the spillway crest to control seepage through the rock lining

Wherever practical, the spillway should be cut into virgin soil away from any fill embankment as shown in Photo 4.

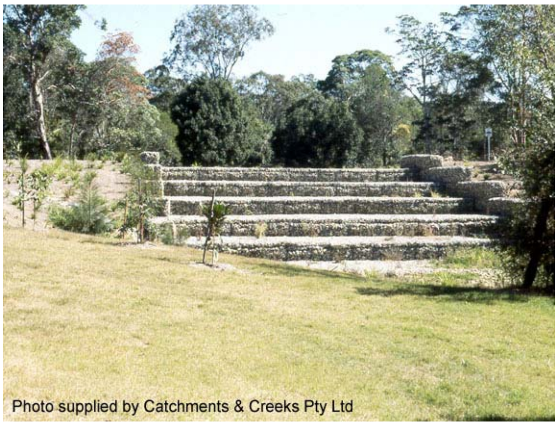

Photo 3 – Permanent, gabion-lined stepped spillway located on a detention basin

Photo 4 – Rock-lined spillway cut into virgin soil (note the spillway is curved up to the crest, after which it remains straight)

Recessing the entire basin into the natural soil (Photo 5) will avoid the need to construct an expensive spillway structure.

Photo 5 – Recessing the basin into the ground allows the natural ground level to become the spillway

Photo 6 – Spillways lined with loose rock generally have a high risk of failure compared to concrete and rock mattress linings

Spillways must have a well-defined cross-section that can fully contain the expected discharge.

Photo 7 – Spillways must have a well-defined profile to fully contain the flow

Photo 8 – A suitable energy dissipater must exist at the base of the spillway

Description

An open channel either passing over or around a sediment basin embankment.

If the basin is fully recessed below natural ground level, the spillway may consist of the natural ground surface.

Spillways are typically lined with materials such as rock, rock-filled mattresses, and concrete.

Purpose

Spillways are used to discharge excess flows from a sediment basin.

The term 'emergency spillway' implies that a primary spillway is incorporated into the low-flow (riser pipe) outlet structure.

Limitations

Bitumen or asphalt is generally not suitable for lining the spillway.

Grass-lined spillways are generally only suitable when the spillway is formed directly on a low-gradient, natural surface.

Common Problems

Inappropriate inlet geometry can cause flow to bypass and/or undermine the spillway.

Severe rilling along the sides of the spillway can be caused by splash. It is noted that spillways generally have a minimum freeboard of 300mm instead of the 150mm applied to minor drainage chutes.

Erosion at the base of the spillway caused by inadequate energy dissipation. Energy dissipation at the base of spillways generally involves complex 3-dimensional hydraulic design.

Common Problems (rock-linings)

Severe erosion problems if rocks are placed directly on dispersive soil. To reduce the potential for such problems, dispersive soils should be covered with a minimum 200mm layer of non-dispersive soil before rock placement.

Failure of rock-lined chutes due to the absence of a suitable filter cloth or aggregate filter layer beneath the primary armour rock layer.

Special Requirements

The spillway and associated energy dissipater must be fully contained within the related property.

An underlying geotextile or rock filter layer is generally required unless all voids are filled with soil and pocket planted (thus preventing the disturbance and release of underlying sediments through these voids).

The upper rock surface should blend with surrounding land to allow water to freely enter the channel.

Site Inspection

Check flow entry conditions to ensure no bypassing, undermining, sedimentation or erosion.

Ensure the spillway chute downstream of the crest is straight.

Check for erosion around the edges of the spillway (top and sides).

Ensure the energy dissipater and the channel downstream of the dissipater are appropriately stabilised.

Ensure the rock size and shape agrees with approved plan.

Check the thickness of rock application and the existence of underlying filter layer.

Check for excessive vegetation growth that may restrict the channel capacity.

Construction

1. The spillway must be excavated as shown on the plans, and the excavated material if classified as suitable, must be used in the embankment, and if not suitable it must be disposed of into spoil heaps.
2. Ensure excavated dimensions allow adequate boxing-out such that the specified elevations, grades, chute width, and entrance and exit slopes for the emergency spillway will be achieved after placement of the rock or other scour protection measures as specified in the plans.
3. Place specified scour protection measures on the emergency spillway. Ensure the finished grade blends with the surrounding area to allow a smooth flow transition from spillway to downstream channel.
4. If a synthetic filter fabric underlay is specified, place the filter fabric directly on the prepared foundation. If more than 1 sheet of filter fabric is required, overlap the edges by at least 300mm and place anchor pins at minimum 1m spacing along the overlap. Bury the upstream end of the fabric a minimum 300mm below ground and where necessary, bury the lower end of the fabric or overlap a minimum 300mm over the next downstream section as required. Ensure the filter fabric extends at least 1000mm upstream of the spillway crest.
5. Take care not to damage the fabric during or after placement. If damage occurs, remove the rock and repair the sheet by adding another layer of fabric with a minimum overlap of 300mm around the damaged area. If extensive damage is suspected, remove and replace the entire sheet.
6. Where large rock is used, or machine placement is difficult, a minimum 100mm layer of fine gravel, aggregate, or sand may be needed to protect the fabric.
7. Placement of rock should follow immediately after placement of the filter fabric. Place rock so that it forms a dense, well-graded mass of rock with a minimum of voids. The desired distribution of rock throughout the mass may be obtained by selective loading at the quarry and controlled dumping during final placement.
8. The finished slope should be free of pockets of small rock or clusters of large rocks. Hand placing may be necessary to achieve the proper distribution of rock sizes to produce a relatively smooth, uniform surface. The finished grade of the rock should blend with the surrounding area. No overfall or protrusion of rock should be apparent.
9. Ensure that the final arrangement of the spillway crest will not promote excessive flow through the rock such that the water can be retained within the settling basin an elevation no less than 50mm above or below the nominated spillway crest elevation.

Maintenance

1. During the construction period, inspect the spillway prior to forecast rainfall, daily during extended periods of rainfall, after significant runoff producing storm events, or otherwise on a weekly basis. Make repairs as necessary.
2. Check for movement of, or damage to, the spillway's lining, including surface cracking.
3. Check for soil scour adjacent the spillway. Investigate the cause of any scour, and repair as necessary.
4. When making repairs, always restore the spillway to its original configuration unless an amended layout is required.

Removal

1. Temporary spillways should be removed when an alternative, stable, drainage system is available.
2. Remove all materials and deposited sediment, and dispose of in a suitable manner that will not cause an erosion or pollution hazard.
3. Grade the area in preparation for stabilisation, then stabilise the area as specified in the approved plan.