Chutes Part 1: General information

DRAINAGE CONTROL TECHNIQUE

Low Gradient		Velocity Control		Short Term	✓
Steep Gradient	✓	Channel Lining		Medium-Long Term	✓
Outlet Control	[1]	Soil Treatment		Permanent	[2]

[1] Chutes can act as stable outlet structures for *Catch Drains* and *Flow Diversion Banks*.

[2] The design of permanent chutes may require consideration of issues not discussed here.

Symbol → CH →

Photo 1 – Permanent, grouted-stone batter chute

Photo 2 – Temporary batter chute lined with filter cloth

Key Principles

1. The critical design components of a chute are the flow entry into the chute, the maximum allowable flow velocity down the face of the chute, and the dissipation of energy at the base of the chute.
2. The critical operational issues are ensuring unrestricted flow entry into the chute, ensuring flow does not undermine or spill out of the chute, and ensuring soil erosion is controlled at the base of the chute.
3. Most chutes fail as a result of water failing to enter the chutes properly. It is critical to control potential leaks and flow bypassing, especially at the chute entrance.

Design Information

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

Drainage chutes are hydraulic structures that need to be designed for a specified design storm using standard hydrologic and hydraulic equations. The hydraulic design can be broken down into three components:

- **Inlet design:** flow conditions may be determined using an appropriate **weir equation**. It is important to ensure that the water level upstream of the chute's inlet will be fully contained by the associated *Flow Diversion Banks*.
- **Chute lining:** selection of an appropriate chute lining is governed by the estimated flow velocity, which can be determined on long chutes through use of **Manning's equation**.
- **Outlet design:** a suitable energy dissipater or outlet structure is required at the base of the chute. The design of these structures is usually based on the use of standard design charts.

Inlet design:

A basin spillway is just one type of chute. If the length of the approach channel is short, then friction loss upstream of the chute crest can be ignored and the upstream water level (relative to the crest invert) can be determined directly from the appropriate weir equation. Figure 1 shows the flow profile of a typical emergency spillway chute. It is noted that flow conditions approaching a roadway batter chute may be significantly different from that shown below.

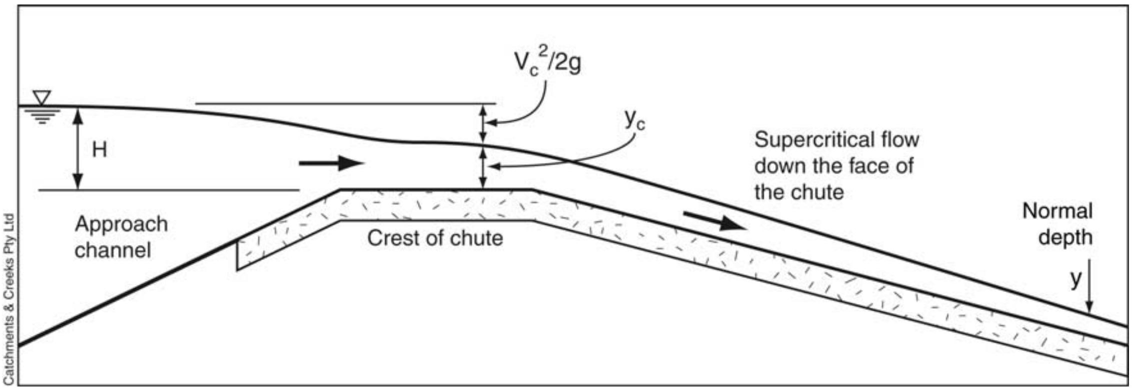

Figure 1 – Hydraulic profile for spillway crest where only minor friction loss occurs within the approach channel

In cases where the approach channel is short, the upstream water level (H) relative to the chute crest can be determined from an appropriate weir equation presented in Table 1.

Table 1 – Weir equations for short spillway crest length where only minor friction loss occurs within the approach channel

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	$Q = 1.26\ m\ H^{2.5}$
Parabolic ($T = 3.3(Y)^{0.5}$)	N/A	$Q = 2.06\ H^{1.5}$
Trapezoidal where : b = base width and m = side slope	1:1	$Q = 1.7\ b\ H^{1.5} + 1.26\ H^{2.5}$
	2:1	$Q = 1.7\ b\ H^{1.5} + 2.5\ H^{2.5}$
	3:1	$Q = 1.7\ b\ H^{1.5} + 3.8\ H^{2.5}$
	4:1	$Q = 1.7\ b\ H^{1.5} + 5.0\ H^{2.5}$
	m:1	$Q = 1.7\ b\ H^{1.5} + 1.26\ m\ H^{2.5}$

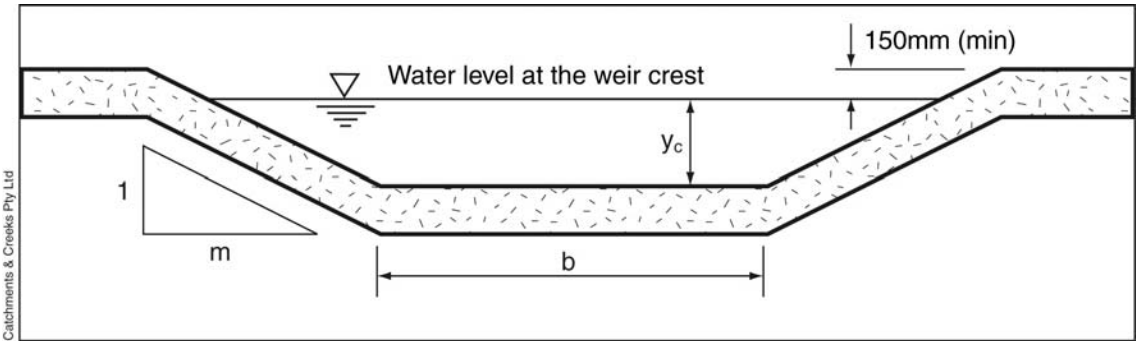

Figure 2 – Inlet profile of a trapezoidal chute

Tables 2 and 3 provides the *Head–Discharge* relationship for a parabolic weir ($T = 3.286(Y)^{0.5}$), and a trapezoidal weir with 2:1 (H:V) side slopes and base width (b).

Table 2 – Inlet weir capacity for various parabolic and trapezoidal chutes [m³/s]

Head (H) upstream of the chute inlet (m)	Parabolic top width = $3.3(y)^{0.5}$	Crest width (b) of a trapezoidal chute [1] (m)				
		0.3	**0.5**	**1.0**	**1.5**	**2.0**
0.1	0.065	0.024	0.035	0.062	0.089	0.115
0.2	0.184	0.091	0.121	0.197	0.273	0.349
0.3	0.338	0.208	0.264	0.404	0.543	0.683
0.4	0.521	0.384	0.470	0.685	0.900	1.115
0.5	—	0.626	0.746	1.047	1.347	1.648
0.6	—	0.940	1.098	1.493	1.888	2.283
0.7	—	1.332	1.531	2.029	2.527	3.024
0.8	—	1.807	2.051	2.659	3.267	3.875
0.9	—	2.372	2.662	3.388	4.114	4.839
1.0	—	3.030	3.370	4.220	5.070	5.920

[1] Flat crested, trapezoidal weir profile with 2:1 (H:V) side slopes (m = 2).

Table 3 – Trapezoidal chute inlet weir capacity [1] [m³/s]

Head (H) required upstream of the chute entrance (m)	Crest width (b) of a rectangular chute (m)				
	2.5	**3.0**	**4.0**	**5.0**	**6.0**
0.1	0.14	0.17	0.22	0.28	0.33
0.2	0.43	0.50	0.65	0.81	0.96
0.3	0.82	0.96	1.24	1.52	1.80
0.4	1.33	1.55	1.98	2.41	2.84
0.5	1.95	2.25	2.85	3.45	4.05
0.6	2.68	3.07	3.86	4.65	5.44
0.7	3.52	4.02	5.02	6.01	7.01
0.8	4.48	5.09	6.31	7.52	8.74
0.9	5.57	6.29	7.74	9.19	10.65
1.0	6.77	7.62	9.32	11.02	12.72

[1] Flat crested, trapezoidal weir profile with 2:1 (H:V) side slopes (m = 2).

Table 4 provides the head–discharge relationship for a rectangular weir with base width (b).

Table 4 – Rectangular chute inlet weir capacity [m³/s]

Head (H) required upstream of the chute entrance (m)	Crest width (b) of a rectangular chute (m)				
	1.0	**2.0**	**3.0**	**4.0**	**5.0**
0.1	0.054	0.108	0.161	0.215	0.269
0.2	0.152	0.304	0.456	0.608	0.760
0.3	0.279	0.559	0.838	1.117	1.397
0.4	0.430	0.860	1.290	1.720	2.150
0.5	0.601	1.202	1.803	2.404	3.005
0.6	0.790	1.580	2.370	3.160	3.950
0.7	0.996	1.991	2.987	3.983	4.978
0.8	1.216	2.433	3.649	4.866	6.082
0.9	1.451	2.903	4.354	5.806	7.257
1.0	1.700	3.400	5.100	6.800	8.500

If the flow path upstream of the chute consists of erodible material, then it is important to ensure adequate scour protection exists. Such scour protection should extend upstream of the chute's crest a distance of at least 5 times the depth of approaching flow (Figure 3). This scour protection should be suitably recessed into the ground to allow the free flow of water.

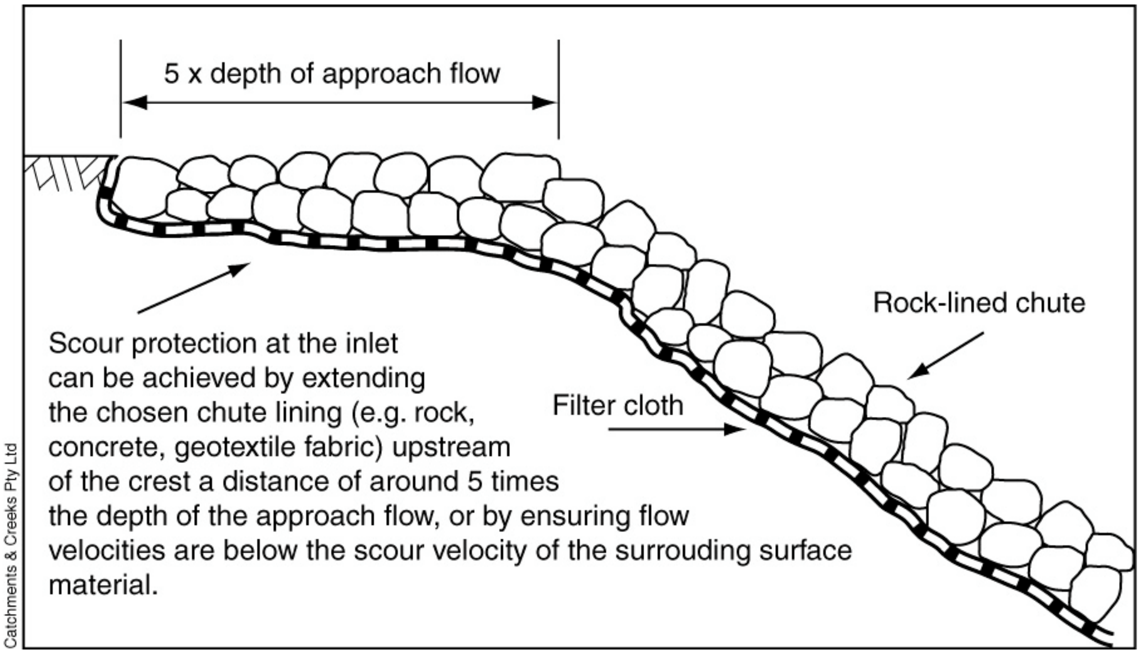

Figure 3 – One option for controlling scour at the chute entrance

A *Flow Diversion Bank* may be required adjacent the inlet to control flow entry. If a raised bank is used, then the height of the bank should allow for a minimum freeboard of 0.15m.

Dimensions and geometry:

- Minimum recommended chute depth of 300mm. Shallower depths may be appropriate for smooth chutes (i.e. minimal splash) with very low flow depths.
- Freeboard of 150mm, or the equivalent of the flow depth, whichever is smaller. A greater freeboard may be required if it is necessary to contain any splash.
- The chute must be straight from inlet to outlet (i.e. no bends or curves).

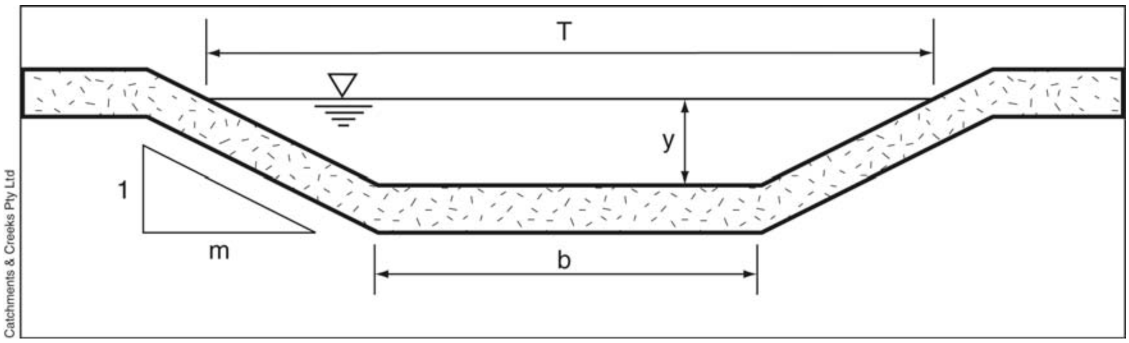

Figure 4 – Typical profile of the face of the chute

Chute linings:

Refer to the Parts 2 to 5 of this fact sheet for relevant design information.

Warning: it is essential that rock-lined chutes have a gradient significantly less than the natural angle of repose of the rock, usually around 38 degrees (1 in 1.3) for smooth round rock, to 41 degrees (1 in 1.2) for angular rock.

Flexible chute linings should be adequately anchored to the foundations to avoid slippage. A maximum spacing of 3 metres is recommended between anchor points down the chute.

If splash is expected down the chute, then the sides of the chute should be lined with suitable scour protection such as 300mm wide turf strips.

Outlet structures for temporary drainage chutes:

The following design procedure is <u>not</u> appropriate for the design of energy dissipaters at the base of Sediment Basin spillways.

Recommended mean (d_{50}) rock sizes and length (L) of rock protection for minor chute are presented in Tables 5 and 6. These rock sizes are based on information presented within ASCE (1992) rounded up to the next 100mm increment, with a minimum rock size set as 100mm.

Table 5 – Mean rock size, d_{50} (mm) for batter chute outlet protection [1]

Depth of approach flow (mm) [2]	Flow velocity at base of *Chute* (m/s)						
	2.0	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**
50	100	100	100	200	200	200	300
100	100	100	200	200	300	300	400
200	100	200	300	300	400	[3]	[3]
300	200	200	300	400	[3]	[3]	[3]

[1] For exit flow velocities not exceeding 1.5m/s, and where growing conditions allow, loose 100mm rock may be replaced with 75mm rock stabilised with a good cover of grass.

[2] This is the flow depth at the base of the chute as it approaches the outlet structure. The flow depth is based on the maximum depth, <u>not</u> the average flow depth.

[3] Consider using 400mm grouted rock pad, or a rock-filled mattress outlet.

The pad lengths provided in Table 6 are suitable for temporary, rock-lined outlet structures only. These rock pad length will not necessarily fully contain all energy dissipation and flow turbulence; therefore, some degree of scour may still occur downstream of the outlet structure.

Table 6 – Recommended length, L (m) of rock pad for batter chute outlet protection

Depth of approach flow (mm)	Flow velocity at base of *Chute* (m/s)						
	2.0	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**
50	1.0	1.5	2.1	2.6	3.1	3.6	4.2
100	1.3	2.0	2.7	3.4	4.1	4.8	5.5
200	2.1	2.7	3.4	4.3	5.2	6.1	7.0
300	2.7	3.6	4.3	4.8	5.8	6.8	7.9

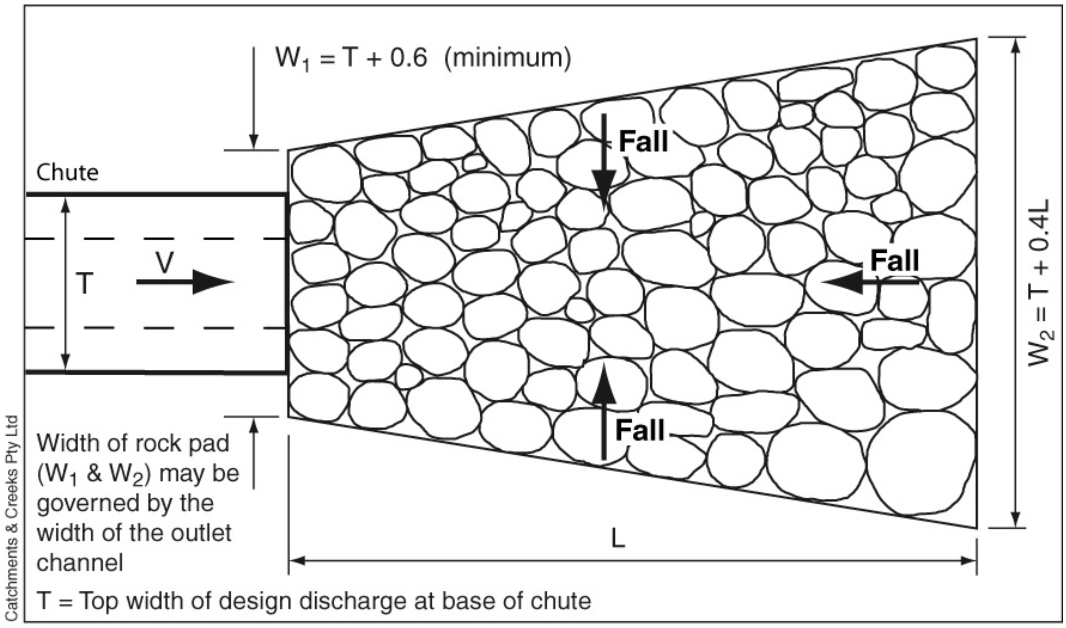

Figure 5 – Typical layout of a recessed rock pad for a chute (plan view)

As indicated in Figures 5, 6 and 7, outlet structures for minor chutes should be recessed below the surrounding ground level to promote effective energy dissipation. The recommended recess depth (Z) can be determined from Table 7.

Table 7 – Recommended recess depth, Z (m) for batter *Chute* outlet protection

Depth of approach flow (mm)	Flow velocity at base of *Chute* (m/s)						
	2.0	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**
50	0.13	0.20	0.28	0.36	0.43	0.50	0.60
100	0.14	0.23	0.32	0.42	0.50	0.60	0.70
200	0.12	0.21	0.31	0.42	0.50	0.60	0.70
300	0.07	0.16	0.25	0.35	0.44	0.55	0.65

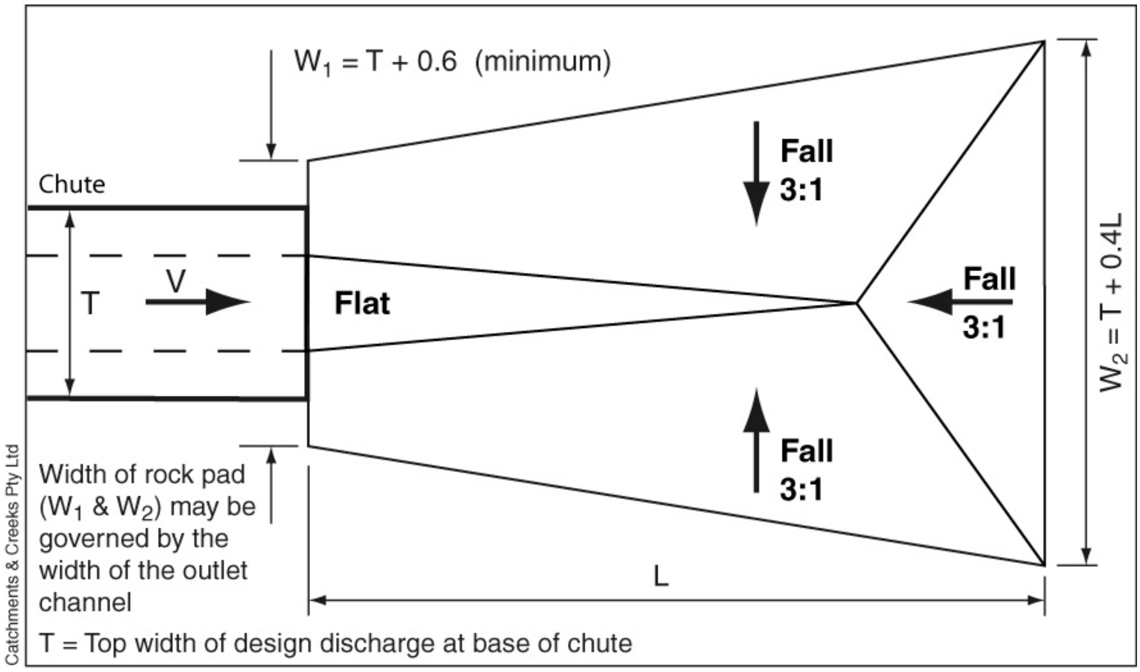

Figure 6 – Typical arrangement of recessed outlet structure for chutes

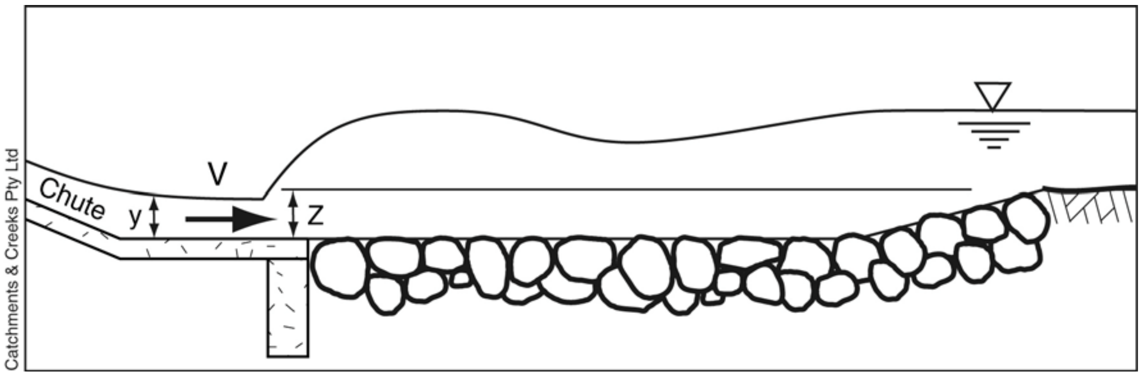

Figure 7 – Typical profile of recessed outlet structure for chutes

Note: *In circumstances where the outlet structure is located downstream of a smooth surface chute, e.g. concrete-lined, then the rocks should be grouted in place to avoid displacement.*

Reference:

ASCE 1992, *Design and construction of urban stormwater management systems*. ASCE Manuals and Reports of Engineering Practice No. 77, and Water Environment Federation Manual of Practice FD-20, American Society of Civil Engineers, New York.

It is important to ensure enters the chute properly (Photos 3 and 4), and in a manner that does not cause water to bypass along or around the edge of the chute.

Photo 3 – Sandbags (temporary) used to control flow entry into grass chute

Photo 4 – Geotextile socks used to control flow entry into temporary batter chute

To ensure appropriate flow entry into a chute, the chute must have a well-defined profile (either rectangular or trapezoidal) with adequate depth to fully contain the design discharge.

Photo 5 – Spillway chute with well-defined inlet profile

Photo 6 – Turf chute with poorly-defined inlet profile causing flow bypass

The chute must also have sufficient depth and/or scour controls to prevent any erosion resulting from splash.

Photo 7 – Severe erosion along edge of chute caused by water spilling out of the chute

Photo 8 – Erosion caused by inadequate rock size and water bypassing around the poorly located boulders

Design example – Chute outlet structure:

Design the outlet protection for a temporary, trapezoidal chute lined with filter cloth on a 3:1 batter slope with a base width of 1.0m, side slopes of 2:1, and design discharge of 600L/s.

Solution

Adopting a Manning's roughness of, n = 0.022 for the filter cloth, the flow conditions at the base of the chute can be determined from Manning's equation as:

Discharge, Q = 0.6m^3/s

Manning's roughness, n = 0.022 (based on an expected flow depth > 0.1m)

Channel slope, S = 0.333 (m/m)

Bed width, b = 1.0m

Channel side slope, m = 2:1

Flow depth, y = 0.1m

Flow top width, B = b + 2my = 1.8m

Hydraulic radius, R = 0.083m

Velocity, $V = \frac{1}{n} R^{2/3} S^{1/2} = \frac{1}{0.022} (0.083)^{2/3} (0.333)^{1/2} = 5.0 m/s$

From Table 5 the mean rock size, d_{50} = 200mm

From Table 6 the length of the rock pad, L = 2.0m

From Table 7 the recommended recess depth, Z = 0.42m

From Figure 6 the upstream width of the rock pad, W1 = B + 0.6 = 2.4m

From Figure 6 the downstream width of the rock pad, W2 = B + 0.4L = 2.6m

If it is assumed that the largest rock is likely to be around 1.5 times the size of the average rock size, i.e. d50/d90 approximately equals 0.67, then we can estimate the required depth of rock protection as, T = 1.8(d50) = 0.36m. In any case, a minimum of two layers of rock should be specified on the construction plans.

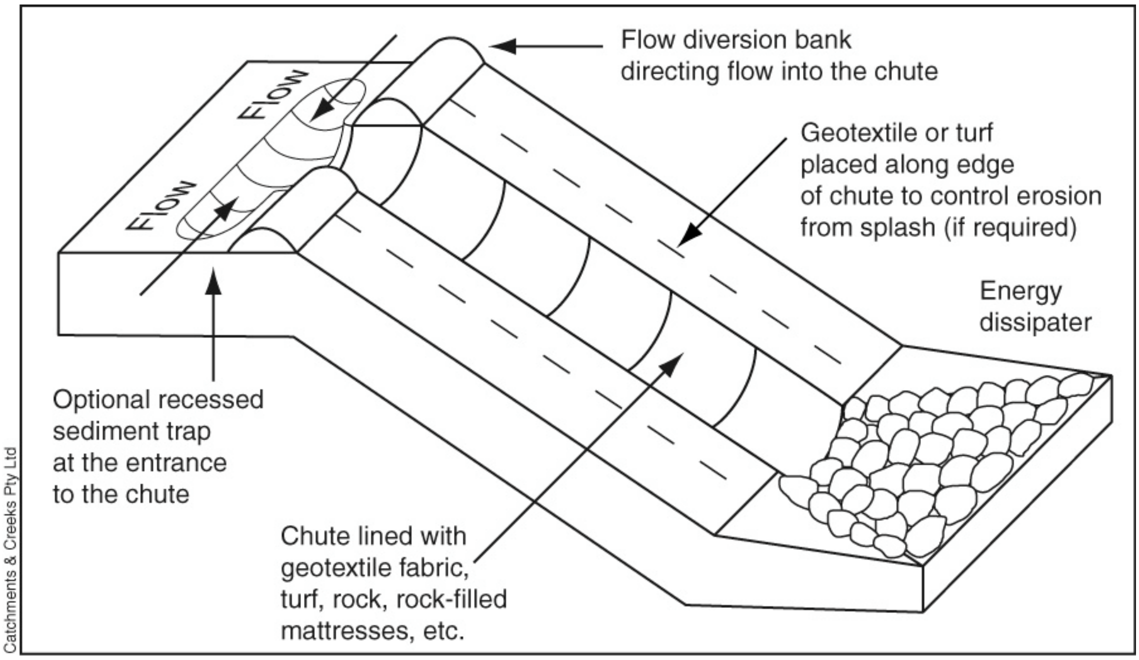

Figure 8 – Typical components of a temporary drainage chute

Description

A steep, open channel passing down a slope. The channel gradient is usually steeper than 10%.

Temporary chutes are usually lined with fabrics such as filter cloth. Permanent chutes can be constructed from materials such as turf, rock, rock-filled mattresses or concrete.

Purpose

Chutes are used to transport concentrated flow down steep slopes. They are most commonly used on constructed slopes such as road batters.

The emergency spillways of a *Sediment Basin* is a special form of chute.

Limitations

Local topography must allow safe collection and passage of water into the chute.

Bitumen or asphalt is generally not suitable as a permanent chute liner.

Advantages

Temporary chutes can be both quick and cheep to construct.

Chutes typically have a flow capacity significantly greater than most *Slope Drains*.

Disadvantages

Some chute linings have a short service life.

Significant damage can result from overtopping flows.

The chute lining may be subject to slippage caused by poor foundations.

Common Problems

Inappropriate inlet geometry can cause inflow to bypass or undermine the chute.

Severe rilling along the sides of the chute can be caused by splash or lateral inflows being deflected by the edge of the chute.

Erosion at the base of the chute caused by inadequate energy dissipation.

Special Requirements

Flow Diversion Banks are often required to control inflows.

Good subsoil drainage and foundations are required to stabilise the chute lining.

Site Inspection

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

Ensure the chute is straight.

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

Ensure the outlet is appropriately stabilised.

General specifications for chutes:

Installation

1. Refer to approved plans for location and construction details. If there are questions or problems with the location or method of installation, contact the engineer or responsible on-site officer for assistance.
2. Construct the subgrade to the elevations shown on the plans. Remove all unsuitable material and replace with stable material to achieve the desired foundations.
3. If the chute is temporary, then compact the subgrade to a firm consistency. If the chute is intended to be permanent, then compact and finish the subgrade as specified within the design plans.
4. If the chute is to be lined with rock, then avoid compacting the subgrade to a condition that would prevent the rock lining from adequately bedding into the subgrade.
5. Ensure the subgrade is firm enough to minimise water seepage.
6. On fill slopes, ensure that the soil is adequately compacted for a width of at least one metre each side of the chute to minimise the risk of soil erosion, otherwise protect the soil with suitable scour protection measures such as turf or erosion control mats.
7. Place and secure the chute lining as directed.
8. If concrete is used as a lining, then keep the subgrade moist at the time concrete is placed. Form, cut-off walls and anchor blocks as directed in the approved plans.
9. Install an appropriate outlet structure (energy dissipater) at the base of the chute (refer to separate specifications).
10. Ensure water leaving the chute and the outlet structure will flow freely without causing undesirable ponding or scour.
11. Appropriately stabilise all disturbed areas immediately after construction.

Maintenance

1. During the construction period, inspect all chutes 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 chute lining, including surface cracking.
3. Check for soil scour adjacent the chute. Investigate the cause of any scour, and repair as necessary.
4. When making repairs, always restore the chute to its original configuration unless an amended layout is required.

Removal

1. Temporary chutes 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.

Specifications for rock pad outlet structure:

Materials (Rock outlet pads)

- Rock: hard, angular, durable, weather resistant and evenly graded with 50% by weight larger than the specified nominal rock size and sufficient small rock to fill the voids between the larger rock. The diameter of the largest rock size should be no larger than 1.5 times the nominal rock size. Specific gravity to be at least 2.5.
- Geotextile fabric: heavy-duty, needle-punched, non-woven filter cloth, minimum bidim A24 or equivalent.

Installation (Rock outlet pads)

1. Refer to approved plans for location and construction details. If there are questions or problems with the location, dimensions or method of installation contact the engineer or responsible on-site officer for assistance.
2. The dimensions of the outlet structure must align with the dominant flow direction.
3. Excavate the outlet pad footprint to the specified dimension such the when the rock is placed in the excavated pit the top of the rocks will be level with the surrounding ground, unless otherwise directed.
4. If the excavated soils are dispersive, over-excavated the rock pad by at least 300mm and backfill with stable, non-dispersive material.
5. Line the excavated pit with geotextile filter cloth, preferably using a single sheet. If joints are required, overlap the fabric at least 300mm.
6. Ensure the filter cloth is protected from punching or tearing during installation of the fabric and the rock. Repair any damage by removing the rock and placing with another piece of filter cloth over the damaged area overlapping the existing fabric a minimum of 300mm.
7. Ensure there are at least two layers of rocks. Where necessary, reposition the larger rocks to ensure two layers of rocks are achieved without elevating the upper surface above the pipe invert.
8. Ensure the rock is placed in a manner that will allow water to discharge freely from the pipe.
9. Ensure the upper surface of the rock pad does not cause water to be deflected around the edge of the rock pad.
10. Immediately after construction, appropriately stabilise all disturbed areas.

Maintenance

1. While construction works continue on the site, inspect the outlet structure prior to forecast rainfall, daily during extended periods of rainfall, after significant runoff producing rainfall, and on at least a weekly basis.
2. Replace any displaced rock with rock of a significantly (minimum 110%) larger size than the displaced rock.

Removal

1. Temporary outlet structures should be completely removed, or where appropriate, rehabilitated so as not to cause ongoing environmental nuisance or harm.
2. Following removal of the device, the disturbed area must be appropriately rehabilitated so as not to cause ongoing environmental nuisance or harm.
3. Remove materials and collected sediment and dispose of in a suitable manner that will not cause an erosion or pollution hazard.