Chutes Part 5: Rock linings

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

Photo 17 – Permanent, rock-lined batter chute

Photo 18 – Permanent, rock-lined batter chute

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.

The following information must be read in association with the general information presented in *Part 1 - General information*.

Part 5 of this fact sheet addresses design issues associated with rock-lined chutes.

Tables 43 and 44 provide design, mean rock size (rounded up to the next 0.1m unit) for a safety factor of 1.2 and 1.5, based on Equation 3. Additional rock-sizing tables (for flatter slopes and higher flow rates) are provided in the separate 'Chute & Channel Linings' fact sheet on *Rock Linings*.

Equation 3 can also be used for sizing rock on the sides (banks) of the chute provided the bank slope (relative to the horizontal) does not exceed a gradient of 2:1. Rock size should be increased 25% for bank slopes of 1.5:1.

Equation 3 represents the recommended design formula for sizing rock on the bed of chutes.

$$d_{50} = \frac{1.27 . SF . K_1 . K_2 . S_o^{0.5} . q^{0.5} . y^{0.25}}{(s_r - 1)} \qquad \text{(Eqn 3)}$$

where:

- d_{50} = nominal rock size (diameter) of which 50% of the rocks are smaller [m]
- K_1 = correction factor for rock shape
  = 1.0 for angular (fractured) rock, 1.36 for rounded rock (i.e. smooth, spherical rock)
- K_2 = correction factor for rock grading
  = 0.95 for poorly graded rock ($C_u = d_{60}/d_{10} < 1.5$), 1.05 for well graded rock ($C_u > 2.5$), otherwise $K_2 = 1.0$ ($1.5 < C_u < 2.5$)
- q = flow per unit width down the embankment [$m^3/s/m$]
- s_r = specific gravity of rock
- S_o = bed slope = tan(θ) [m/m]
- SF = factor of safety (refer to Table 37)
- y = depth of flow at a given location [m]

Table 37 – Recommended safety factor for use in determining rock size

Safety factor (SF)	Recommended usage	Example site conditions
1.2	• Low risk structures. • Failure of structure is most unlikely to cause loss of life or irreversible property damage. • Permanent rock chutes with all voids filled with soil and pocket planted.	• Embankment chutes where failure of the structure is likely to result in easily repairable soil erosion. • Permanent chutes that are likely to experience significant sedimentation and vegetation growth before experiencing high flows. • Temporary (<2yrs) spillways with a design storm of 1 in 10 years of greater.
1.5	• High risk structures. • Failure of structure may cause loss of life or irreversible property damage. • Temporary structures that have a high risk of experiencing the design discharge while the voids remain open (i.e. prior to sediment settling within and stabilising the voids between individual rocks).	• Waterway chutes where failure of the chute may cause severe gully erosion and/or damage to the waterway. • Sediment basin or dam spillways located immediately up-slope of a residential area or busy roadway where an embankment failure could cause property flooding or loss of life. • Spillways and chutes designed for a storm frequency less than 1 in 10 years.

Design unit flow rate (q), flow velocity (V), and flow depth (y):

Wherever practical, the unit flow rate ‘q’ (m^3/s/m), flow velocity ‘V’ (m/s), and flow depth ‘y’ (m) used to determine rock size should be based on the ‘local’ conditions (e.g. the unit flow rate at a given location within the chute cross-section, or the depth-average flow velocity at a given location), rather than a value averaged over the full cross-section.

Rock type, size and grading:

The rock should be durable and resistant to weathering, and should be proportioned so that neither the breadth nor the thickness of a single rock is less than one-third its length. Generally, crushed (angular) rock is more stable than rounded stone.

Typical relative densities of various types of rock are provided in Table 38.

Table 38 – Typical relative density (specific gravity) of rock

Rock type	Relative density (s_r)
Sandstone	2.1 to 2.4
Granite	2.5 to 3.1, commonly 2.6
Limestone	2.6
Basalt	2.7 to 3.2

The maximum rock size should generally not exceed twice the nominal (d_{50}) rock size.

Table 39 provides a typical rock size distribution for use in preliminary design. Table 39 is provided for general information only, it does not represent a recommended design specification.

Table 39 – Typical distribution of rock size [1]

Rock size ratio	Assumed distribution value
d_{100}/d_{50}	2.00
d_{90}/d_{50}	1.82
d_{75}/d_{50}	1.50
d_{65}/d_{50}	1.28
d_{40}/d_{50}	0.75
d_{33}/d_{50}	0.60
d_{10}/d_{50}	> 0.50

[1] Wide variations in the rock size distribution can occur unless suitably controlled by the material contract specifications.

Thickness of rock protection:

The thickness of the rock protection should be sufficient to allow at least two overlapping layers of the nominal (d_{50}) rock size.

The thickness of rock protection must also be sufficient to accommodate the largest rock size.

In order to allow at least two layers of rock, the minimum thickness of rock protection (T) can be approximated by the values presented in Table 40.

Table 40 – Minimum thickness (T) of rock lining

Min. Thickness (T)	Size distribution (d_{50}/d_{90})	Description
1.4 d_{50}	1.0	Highly uniform rock size
1.6 d_{50}	0.8	Typical upper limit of quarry rock
1.8 d_{50}	0.67	Recommended lower limit of distribution
2.1 d_{50}	0.5	Typical lower limit of quarry rock

Backing material or filter layer:

Non-vegetated armour rock must be placed over a layer of suitably graded filter rock or geotextile filter cloth (minimum bidim A24 or the equivalent). The geotextile filter cloth must have sufficient strength and must be suitably overlapped to withstand the placement of the rock.

Armour rock that is intended to be vegetated by appropriately filling all voids with soil and pocket planting, generally will not require an underlying filter layer, unless the long-term viability of the vegetation is questioned due to possible high scour velocities, or limited natural light or rainfall conditions.

If the soils adjacent to the rock surface are dispersive (e.g. sodic soils), then prior to placing the filter cloth or filter layer, the exposed bank must first be covered with a layer of non-dispersive soil (Figure 11). The typically minimum thickness of non-dispersive soil is 200mm, but preferably 300mm.

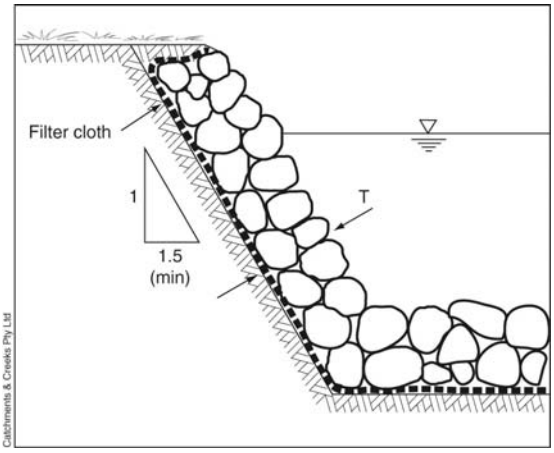

Figure 10 – Rock placement (without vegetation) on non-dispersive soil

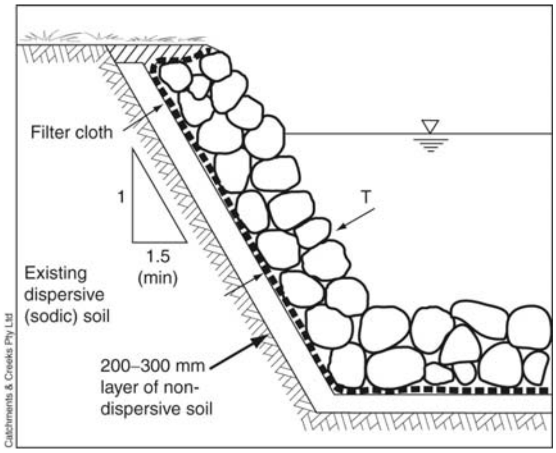

Figure 11 – Rock placement (without vegetation) on dispersive soil

Maximum bank gradient:

The recommended maximum desirable side slope of a large rock-lined chute is 2:1(H:V); however, side slopes as steep as 1.5:1 can be stable if the rock is individually placed rather than being bumped.

Typical angles of repose for dumped rock are provided in Table 41.

Table 41 – Typical angle of repose for rock

Rock shape	**Angle of repose (degrees)**	
	Rock size >100mm	**Rock size >500mm**
Very angular rock	41^{o}	42^{o}
Slightly angular rock	40^{o}	41^{o}
Moderately rounded rock	39^{o}	40^{o}

Placement of vegetation over the rock cover:

Vegetating rock-lined chutes can significantly increase the stability of these drainage structures, but can also reduce their hydraulic capacity. Obtaining experienced, expert advice is always recommended before establishing vegetation within drainage structures.

Manning roughness of rock-lined surfaces:

The Manning's (n) roughness for rock-lined surfaces can be determined from Table 42 or Equation 4.

Table 42 – Manning's (n) roughness of rock-lined surfaces

	d_{50}/d_{90} = 0.5				d_{50}/d_{90} = 0.8			
d_{50} =	**200mm**	**300mm**	**400mm**	**500mm**	**200mm**	**300mm**	**400mm**	**500mm**
R (m)	Manning's roughness (n)				Manning's roughness (n)			
0.2	0.10	0.14	0.17	0.21	0.06	0.08	0.09	0.11
0.3	0.08	0.11	0.14	0.16	0.05	0.06	0.08	0.09
0.4	0.07	0.09	0.12	0.14	0.04	0.05	0.07	0.08
0.5	0.06	0.08	0.10	0.12	0.04	0.05	0.06	0.07
0.6	0.06	0.08	0.09	0.11	0.04	0.05	0.05	0.06
0.8	0.05	0.07	0.08	0.09	0.04	0.04	0.05	0.06
1.0	0.04	0.06	0.07	0.08	0.03	0.04	0.05	0.05

The roughness values presented in Table 42 have been developed from Equation 4. Equation 4 (Witheridge, 2002) was developed to allow estimation of the Manning's n of rock lined channels in shallow water.

$$n = \frac{d_{90}^{\;1/6}}{26\left(1 - 0.3593^{(X)^{0.7}}\right)} \qquad \text{(Eqn 4)}$$

where:
- X = $(R/d_{90})(d_{50}/d_{90})$
- R = Hydraulic radius of flow over rocks [m]
- d_{50} = mean rock size for which 50% of rocks are smaller [m]
- d_{90} = mean rock size for which 90% of rocks are smaller [m]

For 'natural' rock extracted from streambeds the relative roughness value (d50/d90) is typically in the range 0.2 to 0.5. For quarried rock the ratio is more likely to be in the range 0.5 to 0.8.

Placement of rock:

It is important to ensure that the top of the rock surface is level with, or slightly below, the surrounding land surface to allow the free entry of water including lateral inflows (if required) as shown in Figure 13.

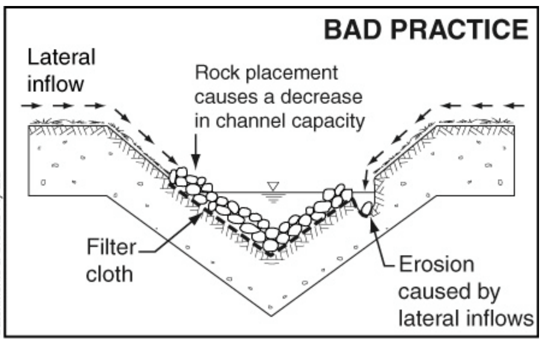

Figure 12 – Incorrect placement of rock causing loss of flow area and erosion along the outer limits of the rock

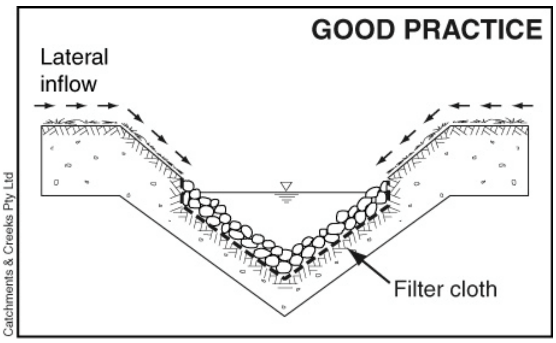

Figure 13 – Rock recessed into the soil to allow the free entry of lateral inflows

Most failures of rock-lined hydraulic structures are believed to occur as a result of inappropriate placement of the rock, either due to inadequate design detailing, or poorly supervised construction practices. Rock-lined chutes are usually most vulnerable to damage in the first year or two after placement while the voids remain open and free of sedimentation.

Where appropriate, permanent rock-lined chutes should be topped with a light covering of soil and planted to accelerate the integration of these structures into the surrounding environment. Revegetation is not however always advisable, and should be assessed on a case-by-case basis.

Photo 19 – Rock-lined spillway with well-defined crest profile

Photo 20 – Rock-lined spillway with poorly defined crest profile

Photo 21 – Placement of the rock on the soil can result in erosion problems if significant lateral inflows occur

Photo 22 – In this example, placement of the rock has resulted in the rock-lined table drain being higher than the road shoulder

Photo 23 – Rounded rock can be significantly less stable than angular, fractured rock, especially when placed on steep slopes

Photo 24 – Placement of a few large, anchor rocks down a steep slope will not help stabilise adjacent, under-sized rocks, and will likely cause flow diversion

Hydraulic design of rock-lined chutes:

Step 1 Determine the design discharge (Q) for the chute.

Step 2 Determine the slope (S) of the chute from the site geometry. The chute should be straight, with no bends or curves, from the crest to the base of the chute.

Step 3 Nominate the chute profile: e.g. trapezoidal or rectangular.

Step 4 Determine the maximum allowable approach flow depth, 'H' (relative to the inlet crest) upstream of the chute's inlet for the nominated design discharge.

Where necessary, design and specify appropriate *Flow Diversion Banks* or the like to appropriately control the approach flow and prevent any water bypassing the chute.

Step 5 Determine the required inlet geometry of the chute using an appropriate weir equation.

If the approach channel (the channel immediately upstream of the chute's crest) is short, then the relationship between the upstream water level (H) and discharge (Q) can be determined from one of the weir equations presented in Table 1 (*Part 1 – General information*). Tables 2 to 4 (Part 1) provide specific H–Q information for various chute profiles.

If the approach channel is long, and friction loss within this channel is likely to be significant, then an appropriate backwater analysis may be required.

Step 6 Ensure the entrance to the chute is suitably designed to allow the free flow of water into the chute (i.e. flow is not diverted along the up-slope edge of the rocks).

Where necessary, detail appropriate measures to control scour at the entrance to the chute (see Part 1 of this fact sheet, including Figure 3).

Step 7 Determine the design unit flow rate (q). This can be estimated by dividing the design discharge by the bed width determined in Step 5.

Step 8 Determine the likely density (specific gravity, s_r), and a size distribution (d_{50}/d_{90}) of the rock to be used on the chute.

Step 9 Using Manning's equation, or Tables 43 and 44, determine the uniform flow depth (y) and required size of the rock size (d_{50}) for the chute.

Manning's equation: $Q = A.V = (1/n)\,A\,.\,R^{2/3}.\,S^{1/2}$

Additional rock-sizing tables (for flatter slopes and higher flow rates) are provided in the separate fact sheet – *Rock linings*.

Step 10 Specify the required depth of the chute, being the greater of:

(i) 300mm (unless a lower depth is supported by expected flow conditions);

(ii) 0.67(H) plus minimum freeboard of 150mm; ('H' determined from Step 4)

(iii) the uniform flow depth (y) plus a minimum freeboard of 150mm, or the equivalent of the flow depth, whichever is smaller.

Step 11 Design the required outlet energy dissipation structure at the base of the chute.

For the design of the outlet structure, refer to Part 1 of this fact sheet or the fact sheet on *Outlet Structures*.

The 'local' uniform flow velocity (V) down the chute can be estimated by dividing the design unit flow rate (q) by flow depth (y). This flow velocity will be slightly greater than the average flow velocity, which is equal to the total discharge (Q) divided by the total flow area (A).

Design example: rock-lined chutes:

Design a rock-lined chute suitable to carry a discharge of 1m^3/s on a 3:1 slope with a maximum allowable upstream water level (H) of 300mm.

Step 1 Design discharge given as 1.0m^3/s.

Step 2 The chute slope is given as, S = 33% (3:1).

Step 3 Try a trapezoidal profile with side slopes of 2:1

Step 4 The maximum allowable approach flow depth is given as, H = 0.3m

Step 5 Table 3 (Part 1) indicates that for an approach flow depth, H = 0.3m, a bed width of b = 3.2m (interpolated) is required to allow the design discharge of 1.0m^3/s to enter a trapezoidal chute with side slopes of 2:1

Step 6 To control water movement and erosion at the chute entrance, specify on the plans that the rock must be suitably recessed into the ground to allow the unrestricted entry of water.

Flow diversion banks will need to be constructed each side of the chute entrance to direct water into the chute with minimum height of, H + 0.3m = 0.3 + 0.3 = 0.6m

To control soil erosion near the entrance, the rock will extend a distance of 5(H) = 1.5m upstream of the crest. Otherwise, suitable erosion control matting shall be placed over the soil and overlapping the upstream edge of the rock lining.

Step 7 As a first trial, the unit flow rate can be estimated by dividing the design discharge by the bed width determined in Step 5.

Trial unit flow rate, q = Q/b = 1.0/3.2 = 0.313m^2/s (approximation)

Step 8 Assume rock is available with a specific gravity, s_r = 2.6, and a size distribution, d_{50}/d_{90} = 0.5

Step 9 Given the estimate unit flow rate of 0.313m^2/s, the chute slope of 3:1, Table 43 indicates that the required mean rock size, d_{50} = 300mm.

Even though Table 43 is applicable for rock with a specific gravity of 2.4, thus the results are considered conservative for rock with a specific gravity of 2.6.

If it is assumed that this rock size is available on the site, then the bed width, b = 3.2m obtained in Step 5 appears suitable.

Step 10 From Table 43 the uniform flow depth is expected to be 0.19m (interpolated); however there is expected to be significant variation in this depth due to turbulence.

The required depth of the chute should be the greater of:

(i) 300mm;

(ii) 0.67(H) plus freeboard of 150mm = 0.67(300) + 150 = 351mm;

(iii) y + 150mm = 190 + 150 = 340mm.

Thus, choose a total chute depth, Y = 350mm.

Step 11 Design of outlet structure as per Part 1 – 'General Information':

Given the flow depth, y = 0.19m; the local uniform flow velocity can be estimated as, V = q/y = 0.313/0.19 = 1.65m/s.

Given that the flow approaching the outlet structure is less than 200mm in depth, and the velocity is less than 2m/s, Table 5 (Part 1) indicates a rock size of 100mm; however, choose the same 300mm rock as used on the face of the chute.

Table 6 (Part 1) indicates a length of rock protection, L = 2.1m.

Table 7 (Part 1) indicates a dissipation basin recess depth, Z = 0.12m

The flow top width at the base of the chute, T = b + 2my = 3.2 + 2(2)0.19 = 3.96m

From Figure 6 (Part 1), W_1 = 3.96 + 0.6 = 4.56m, and W_2 = 3.96 + 0.4(L) = 4.8m

Let W_1 = 4.6m and W_2 = 4.8m

Table 43 – Flow depth [1], y (m) and mean rock size, d_{50} (m) for SF = 1.2

Safety factor, SF = 1.2			Specific gravity, s_r = 2.4			Size distribution, d_{50}/d_{90} = 0.5		
Unit flow rate (m^3/s/m)	**Bed slope = 5:1**		**Bed slope = 4:1**		**Bed slope = 3:1**		**Bed slope = 2:1**	
	y (m)	**d_{50}**	**y (m)**	**d_{50}**	**y (m)**	**d_{50}**	**y (m)**	**d_{50}**
0.1	0.09	**0.10**	0.09	**0.10**	0.09	**0.20**	0.09	**0.20**
0.2	0.15	**0.20**	0.14	**0.20**	0.14	**0.20**	0.14	**0.30**
0.3	0.19	**0.20**	0.19	**0.20**	0.19	**0.30**	0.18	**0.30**
0.4	0.23	**0.30**	0.23	**0.30**	0.23	**0.30**	0.22	**0.40**
0.5	0.27	**0.30**	0.27	**0.30**	0.26	**0.40**	0.26	**0.40**
0.6	0.31	**0.30**	0.30	**0.40**	0.30	**0.40**	0.29	**0.50**
0.8	0.37	**0.40**	0.37	**0.40**	0.36	**0.50**	0.35	**0.60**
1.0	0.43	**0.40**	0.42	**0.50**	0.42	**0.60**	0.41	**0.70**
1.2	0.49	**0.50**	0.48	**0.50**	0.47	**0.60**	0.46	**0.70**
1.4	0.54	**0.50**	0.53	**0.60**	0.52	**0.70**	0.51	**0.80**
1.6	0.59	**0.60**	0.58	**0.70**	0.57	**0.70**	0.56	**0.90**
1.8	0.64	**0.60**	0.63	**0.70**	0.62	**0.80**	0.60	**1.00**
2.0	0.68	**0.70**	0.67	**0.70**	0.66	**0.90**	0.65	**1.00**
3.0	0.89	**0.90**	0.88	**1.00**	0.87	**1.10**	0.85	**1.30**
4.0	1.08	**1.00**	1.07	**1.20**	1.05	**1.30**	1.02	**1.60**
5.0	1.26	**1.20**	1.24	**1.30**	1.22	**1.50**	1.19	**1.80**

[1] Flow depth is expected to be highly variable due to whitewater (turbulent) flow conditions.

Table 44 – Flow depth [1], y (m) and mean rock size, d_{50} (m) for SF = 1.5

Safety factor, SF = 1.5			Specific gravity, s_r = 2.4			Size distribution, d_{50}/d_{90} = 0.5		
Unit flow rate (m^3/s/m)	**Bed slope = 5:1**		**Bed slope = 4:1**		**Bed slope = 3:1**		**Bed slope = 2:1**	
	y (m)	**d_{50}**	**y (m)**	**d_{50}**	**y (m)**	**d_{50}**	**y (m)**	**d_{50}**
0.1	0.10	**0.20**	0.10	**0.20**	0.10	**0.20**	0.10	**0.20**
0.2	0.16	**0.20**	0.16	**0.20**	0.15	**0.30**	0.15	**0.30**
0.3	0.21	**0.30**	0.21	**0.30**	0.20	**0.30**	0.20	**0.40**
0.4	0.25	**0.30**	0.25	**0.40**	0.25	**0.40**	0.24	**0.50**
0.5	0.29	**0.40**	0.29	**0.40**	0.28	**0.50**	0.28	**0.50**
0.6	0.33	**0.40**	0.33	**0.40**	0.32	**0.50**	0.31	**0.60**
0.8	0.40	**0.50**	0.40	**0.50**	0.39	**0.60**	0.38	**0.70**
1.0	0.47	**0.60**	0.46	**0.60**	0.45	**0.70**	0.44	**0.80**
1.2	0.53	**0.60**	0.52	**0.70**	0.51	**0.80**	0.50	**0.90**
1.4	0.58	**0.70**	0.58	**0.80**	0.57	**0.90**	0.55	**1.00**
1.6	0.64	**0.70**	0.63	**0.80**	0.62	**0.90**	0.60	**1.10**
1.8	0.69	**0.80**	0.68	**0.90**	0.67	**1.00**	0.65	**1.20**
2.0	0.74	**0.80**	0.73	**0.90**	0.72	**1.10**	0.70	**1.30**
3.0	0.97	**1.10**	0.96	**1.20**	0.94	**1.40**	0.92	**1.70**
4.0	1.17	**1.30**	1.16	**1.50**	1.14	**1.70**	1.11	**2.00**
5.0	1.36	**1.50**	1.34	**1.70**	1.32	**1.90**	1.29	**2.30**

[1] Flow depth is expected to be highly variable due to whitewater (turbulent) flow conditions.

Common Problems

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.

Weed invasion of the rock protection can become unsightly. The control of weed growth can be an expensive, labour intensive exercise.

Rill erosion can occur along the upper edge of the rock if they are not properly set into the soil.

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

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.

Flow Diversion Banks are often required to direct flows into the chute.

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.

Check for piping failure, scour holes, or bank failures.

Check for erosion around the outer edges of the treated area.

Ensure the chute is straight.

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.

Ensure the outlet is appropriately stabilised.

Installation (chute formation)

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. Ensure all necessary soil testing (e.g. soil pH, nutrient levels) and analysis has been completed, and required soil adjustments performed prior to planting.
3. Clear the location for the chute clearing only what is needed to provide access for personnel and equipment for installation.
4. Remove roots, stumps, and other debris and dispose of them properly.
5. Construct the subgrade to the elevations shown on the plans. Remove all unsuitable material and replace with stable material to achieve the desired foundations.
6. 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.
7. Avoid compacting the subgrade to a condition that would prevent the turf from bonding with the subgrade.
8. Ensure the sides of the chute are no steeper than a 1.5:1 (H:V) slope.
9. Ensure the completed chute has sufficient deep along its full length.
10. Ensure the chute is straight from its crest to the toe of the chute.
11. 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.
12. Place and secure the turf as directed.
13. Install an appropriate outlet structure (energy dissipater) at the base of the chute (refer to separate specifications).
14. Ensure water leaving the chute and the outlet structure will flow freely without causing undesirable ponding or scour.
15. Appropriately stabilise all disturbed areas immediately after construction.

Materials

- 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 placement)

1. Over-cut the channel to a depth equal to the specified depth of rock placement such that the finished rock surface will be at the elevation of the surrounding land.
2. Rock must be placed within the channel as specified within the approved plans, including the placement of any specified filter layer.
3. If details are not provided on the rock placement, then the primary armour rock must be either placed on:

- a filter bed formed from a layer of specified smaller rock (rock filter layer);
- an earth bed lined with filter cloth;
- an earth bed not lined in filter cloth, but only if all voids between the armour rock are to be filled with soil and pocket planted immediately after placement of the rock.

4. If a rock/aggregate filter layer is specified, then place the filter layer immediately after the foundations are prepared. Spread the filter rock in a uniform layer to the specified depth but a minimum of 150mm. Where more than one layer of filter material has been specified, spread each layer such that minimal mixing occurs between each layer of rock.
5. If a geotextile (filter cloth) underlay is specified, place the fabric directly on the prepared foundation. If more than one sheet of fabric is required to over the area, overlap the edge of each sheet at least 300mm and place anchor pins at minimum one metre spacing along the overlap.
6. Ensure the geotextile fabric 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. Where necessary, a minimum 100mm layer of fine gravel, aggregate or sand should be placed over the fabric to protect it from damage.
8. Placement of rock should follow immediately after placement of the filter layer. Place rock so that it forms a dense, well-graded mass of rock with a minimum of voids.
9. Place rock to its full thickness in one operation. Do not place rock by dumping through chutes or other methods that cause segregation of rock sizes.
10. The finished surface 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.
11. Immediately upon completion of the channel, vegetate all disturbed areas or otherwise protect them against soil erosion.
12. Where specified, fill all voids with soil and vegetate the rock surface in accordance with the approved plan.

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 scour or dislodged rock. Repair damaged areas immediately.
3. Closely inspect the outer edges of the rock protection. Ensure water entry into the channel or chute is not causing erosion along the edge of the rock protection.
4. Investigate the cause of any scour, and repair as necessary.
5. Carefully check the stability of the rock looking for indications of piping, scour holes, or bank failures.
6. Replace any displaced rock with rock of a significantly (minimum 110%) larger size than the displaced rock.
7. Ensure sediment is not partially blocking flow entry into the chute. Where necessary, remove any deposited material to allow free drainage.
8. Dispose of any sediment in a manner that will not create an erosion or pollution hazard.
9. 9. When making repairs, always restore the chute to its original configuration unless an amended layout is required.

Removal

1. When the soil disturbance above the chute is finished and the area is stabilised, the chute and any associated flow diversion banks should be removed, unless it is to remain as a permanent drainage feature.
2. Dispose of any materials, sediment or earth in a manner that will not create an erosion or pollution hazard.
3. Grade the area in preparation for stabilisation, then stabilise the area as specified in the approved plan.