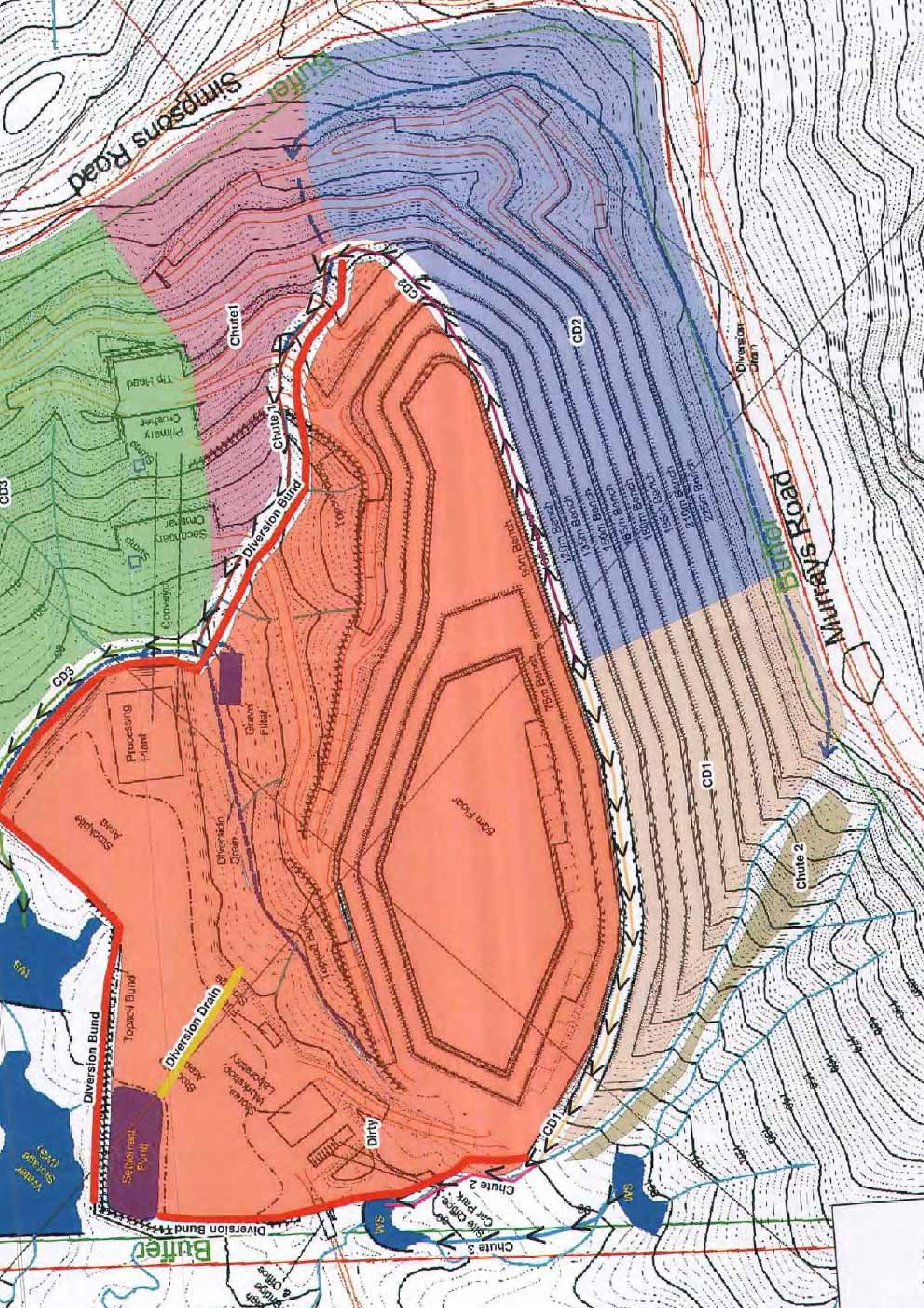
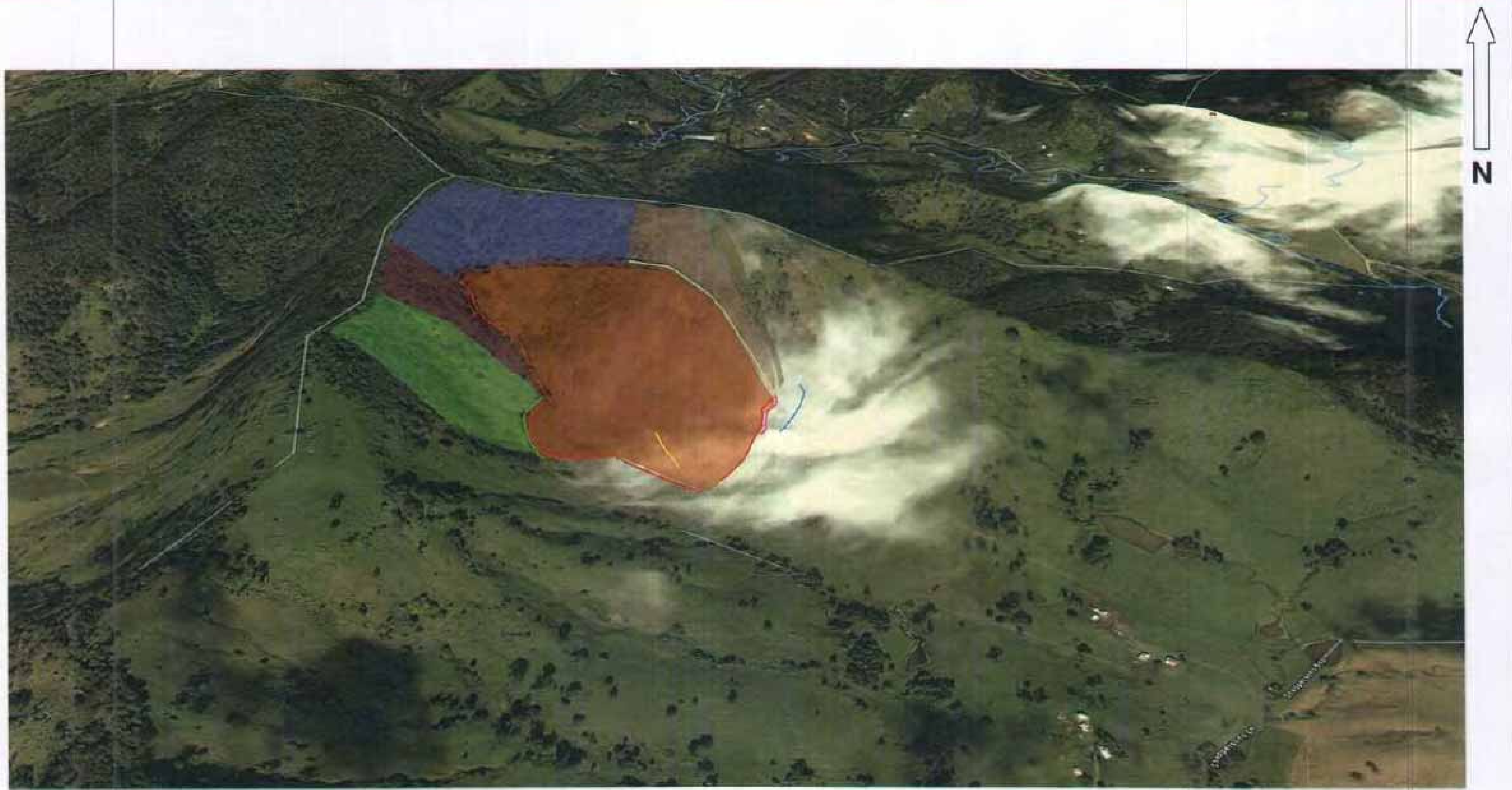

Simpsons Road
Murrays Road
Buffer
Buffer
Buffer
Chute1
Chute 1
Chute 2
Chute 2
Chute 3
CD1
CD1
CD2
CD2
CD3
CD3
Diversion Bund
Diversion Bund
Diversion Bund
Diversion Drain
Diversion Drain
Diversion Drain
Tip Head
Primary Crusher
Secondary Crusher
Conveyor
Processing Plant
Stockpile Area
Gravel Filter
Topsoil Bund
Sediment Pond
Water Storage (WS)
WS
WS
WS
Stores, Workshop, Laboratory
Stock Area
Site Office, Car Park
Dirty
90m Bench
75m Bench
60m Floor
105m Bench
120m Bench
135m Bench
150m Bench
165m Bench
180m Bench
195m Bench
210m Bench
225m Bench

Annexure C Sediment Basin and Drainage Design



Appendix C Catchment and Drainage Layout

File: SC10-0003 / SC-R00758

Appendix C

Type D and F Sediment Basin Sizing

Basin volume = settling zone volume + sediment storage zone volume

Vset = 10 x Cv x A x R $_{y\%ile,x\,day}$ — *Equation 1 BCC 2001 Sed Basin Guidelines*

where:

Vset =	Settling Volume (m³)
Cv=	The volumetric runoff coefficient (dimensionless)
A=	Area (hectare)
$R_{y\%ile,x\,day}$=	Design rainfall event (mm)

Vstor = K1. K2. K3. K4. R. K. LS. P. C — *Equation 2 BCC 2001 Sed Basin Guidelines*

where:

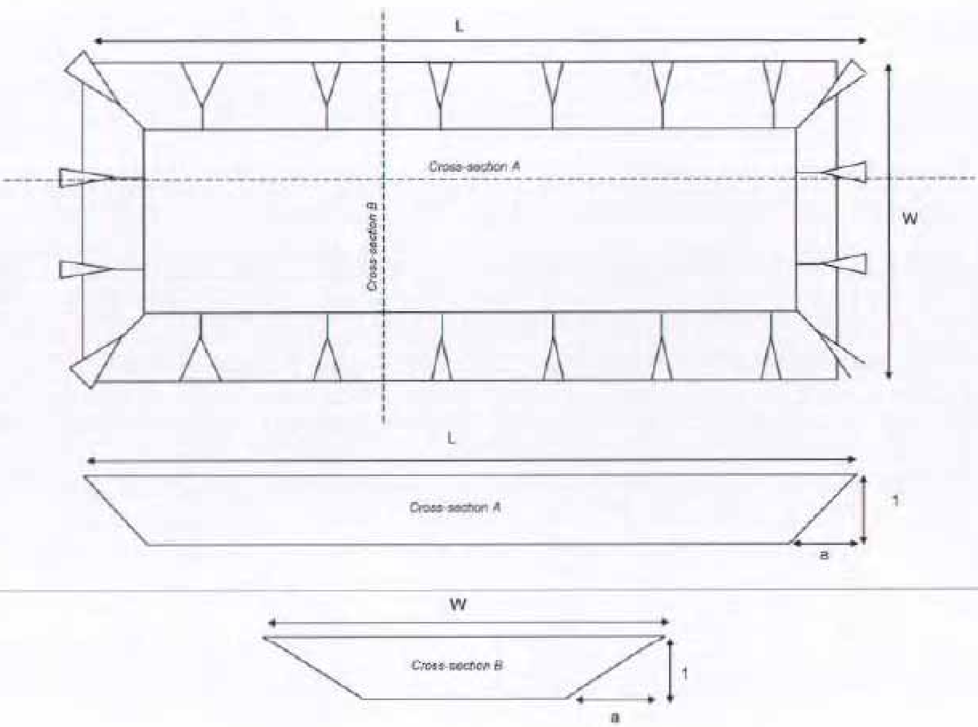
Vstor =	Storage Volume (m^3)
K1=	Inverse of settled bulk density (0.8m^3/tonne adopted)
K2=	Area of exposed soil
K3=	Duration of Exposure (or clean out frequency)
K4=	Expected capture percentage of soil particles (1 adopted - all soil particles captured)
R=	Rainfall erosivity factor
K=	Soil erodibility factor
LS=	topographic slope/length factor
P=	Erosion Control Practice factor
C=	Cover and management factor

Vstor Calculations

	INPUTS					Input				Output
Label	R	K	LS	P	C	K1	K2	K3	K4	Vstor
										-
										-
										-
										-
										-

Total Basin Volume Calculations

	INPUTS			OUTPUTS			Inputs			Outputs	
Description	Volumetric Runoff Coefficient	Catchment Area (ha)	Design Rainfall Event	Settling Zone Volume (m³)	Sediment Storage Volume (m³)	Total Volume	Depth (m)	Pond length width ratio (L/W)	Batter Slope	Length (m)	Width (m)
Label	Cv	A	$R_{95\%ile,5day}$	V_{set}	V_{stor}	V_{total}	d	L/W	a	L	w
Current Development											
Development Approval - 24hr duration, 5yr ARI event	0.83	9	223	16,658	8,329	24,987	1.5	3.0	2.0	232.8	77.6
Quarry Management Plan - 6hr duration, 10yr ARI event	0.83	9	144	10,757	5,378	16,136	1.5	3.0	2.0	188.8	62.9
DECC Best Practice - 5day 95%ile, 20yr ARI event	0.83	9	115.5	8,628	4,314	12,942	1.5	3.0	2.0	170.0	56.7
Interim Development (5 yr horizon)											
Development Approval - 24hr duration, 5yr ARI event	0.83	18.46	223	34,168	17,084	51,251	1.5	3.0	2.0	329.2	109.7
Quarry Management Plan - 6hr duration, 10yr ARI event	0.83	18.46	144	22,063	11,032	33,095	1.5	3.0	2.0	266.4	88.8
DECC Best Practice - 5day 95%ile, 20yr ARI event	0.83	18.46	115.5	17,697	8,848	26,545	1.5	3.0	2.0	239.5	79.8
Final Development										-	-
Development Approval - 24hr duration, 5yr ARI event	0.83	28	223	51,825	25,913	77,738	1.5	3.0	2.0	403.4	134.5
Quarry Management Plan - 6hr duration, 10yr ARI event	0.83	28	144	33,466	16,733	50,198	1.5	3.0	2.0	325.9	108.6
DECC Best Practice - 5day 95%ile, 20yr ARI event	0.83	28	115.5	26,842	13,421	40,263	1.5	3.0	2.0	292.9	97.6



...all intensity (mm/hr) for design duration of tc hours and ARI of Y years.
...ments (ha)
...actor

... crest and approach channel)

...n below using trail and error.
Equation 2 (IECA 2008)

... (m^3/s) of average recurrence interval (ARI) of Y years (calculated using Equation 1)
...wier
...thin Sediment Basin relative to spillway (weir) crest (m)

Refer to Figure 1

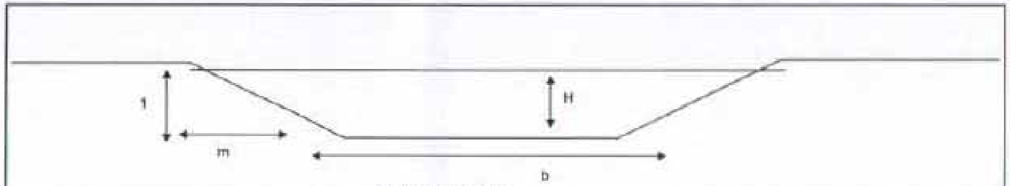


Figure 1 Wier Profile

...ree equations below as per IECA 2008.
Equation 3 (IECA 2008)

... (m^3/s) of average recurrence interval (ARI) of Y years
...fficieint (unitless)
...al area of flow (m^2), refer to Eqaution 4
...ius (m), refer to Equation 5
...y line, equal to slope of chanel bed (m/m)

Equation 4 (IECA 2008)

...al area of flow (m^2)
...channel (m)
...hannel
...channel (m) + required 0.30m freeboard

Equation 5 (IECA 2008)

...s of flow (m)
...channel (m)
...hannel
...channel (m) + required 0.30m freeboard

Refer to Figure 2

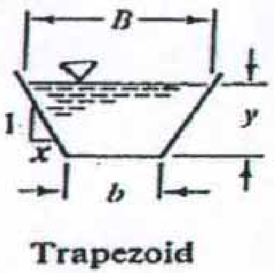


Figure 2 Cross-section of Chute

...Diametre (mm) Table 5 of IECA 2008 Fact Sheet "Chutes Part 1"
...(b+2xy)+0.6
...(b+2xy)+0.4L
...pator (m) Table 6 of IECA 2008 Fact Sheet "Chutes Part 1"

Refer to Figure 3

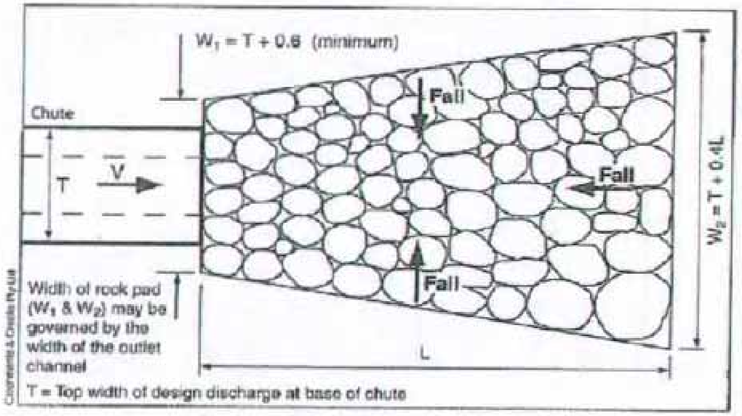


Figure 3 Energy Dissipator

Peak Flow (Entering Basin)				Wier				Chute										Energy Disipator		
INPUTS			OUTPUTS					Inputs				Outputs								
				Base width (m)	Horizontal Slope of Wier	Upstream water level relative to Wier (m)	Minimum Height with 0.30m Freeboard (m)	Channel Base Width (m)	Side Slope Length	Channel Slope (m/m)	Proposed Lining	Mannings	Peak Flow	Flow Depth (m)	Required Chute Depth with 300mm Feeboard	Maximum Permissable Velocity (m/s)	Velocity (m/s)	Mean rock size, d50 (mm)	Width 1 (m)	Width 2 (m)
Itc,y (10 yr)	Tc	A	Q	b	m	H	H + freeboard	b	x	So		n	Q	y	y+0.3m	Vmax	V	d50	W_1	W_2
123	24	18.46	5.676	25.000	1.000	0.250	0.550	15	2	0.2500	Rock (d50 of 300mm)	0.1400	5.676	0.250	0.550	#N/A	1.465	200.000	16.600	17.080
167	12	3.52	0.816					1	2	0.0200	Turf	0.0400	0.816	0.350	0.650	1.700	1.372			
167	13	4.08	0.946					1	2	0.1100	Natural channel with vegetation	0.1000	0.946	0.390	0.690	#N/A	1.363			
167	12	8.70	2.018					1	2	0.0150	Turf	0.0400	2.018	0.590	0.890	1.700	1.569			
167	13	11.55	2.679					1	2	0.3000	Natural channel with vegetation	0.1000	2.679	0.510	0.810	#N/A	2.600			
167	15	29.25	6.784					2.5	2	0.1500	Rock (d50 of 300mm)	0.0800	6.784	0.630	0.930	#N/A	2.864			
123	24	18.46	6.307					5	2	0.0200	Rock (d50 of 300mm)	0.0700	6.307	0.710	1.010	#N/A	1.384			

Annexure D Sediment Basin Management Plan

O₂ environmental

Kin Kin Quarry

Standard Operation Procedure
Type F or Type D Sediment Basin

CLIENT:

Neilsen's Quality Gravels Pty Ltd

STATUS:

Draft

REPORT NUMBER:

SC10-0003 / SC-R00758

APPENDIX D

ISSUE DATE:

March 2010

O2 ENVIRONMENTAL PTY LTD | PO Box 1384 Noosaville BC Qld 4566 | ABN 79 136 340 924 | www.o2environmental.com.au

Important Note

This report has been prepared for the sole use of the **Neilsen's Quality Gravels Pty Ltd** (herein, 'the client'), for a specific site (herein 'the site', the specific purpose specified in Section 1 of this report (herein 'the purpose'). This report is strictly limited for use by the client, to the purpose and site and may not be used for any other purposes.

Third parties, excluding regulatory agencies assessing an application in relation to the purpose, may not rely on this report. O2 Environmental waives all liability to any third party loss, damage, liability or claim arising out of or incidental to a third party publishing, using or relying on the facts, content, opinions or subject matter contained in this report.

O2 Environmental waives all responsibility for loss or damage where the accuracy and effectiveness of information provided by the Client or other third parties was inaccurate or not up to date and was relied upon, wholly or in part in reporting.

Version Register

Issue	Author	Reviewer	Change Notes	Authorised for Release	
				Signature	Date
Draft SC-R00758 APPENDIX D	Terry Clark	Steve Dudgeon		Steve Dudgeon	12 March 2010

Transmission Register

Controlled copies of this document are issued to the persons/companies listed below. Any copy of this report held by persons not listed in this register is deemed uncontrolled. Updated versions of this report if issued will be released to all parties listed below via the email address listed.

Name	Email Address
Robert Snowden	rob@neilsens.com.au

Table of Contents

Figures

Tables

1. Introduction

This guideline applies specifically to the operation of a Wet Type F (fine grained soils) or Type D (dispersive soils) sediment basin at the Kin Kin Quarry, located at 150 Sheppersons Lane, Kin Kin. The document outlines requirements for monitoring, treatment and discharge of sediment laden water from the basin (refer **Figure 1**) on site sized to detain a 24 hour, 5 year ARI rainfall event as per the Development Approval issued by the Environmental Protection Agency (EPA) in February 2006 (ref. IPDE00324405A11).

This procedure does not apply to the design or construction of basins. The location, sizing and design of the sediment basin is specified in the erosion and sediment control plan.

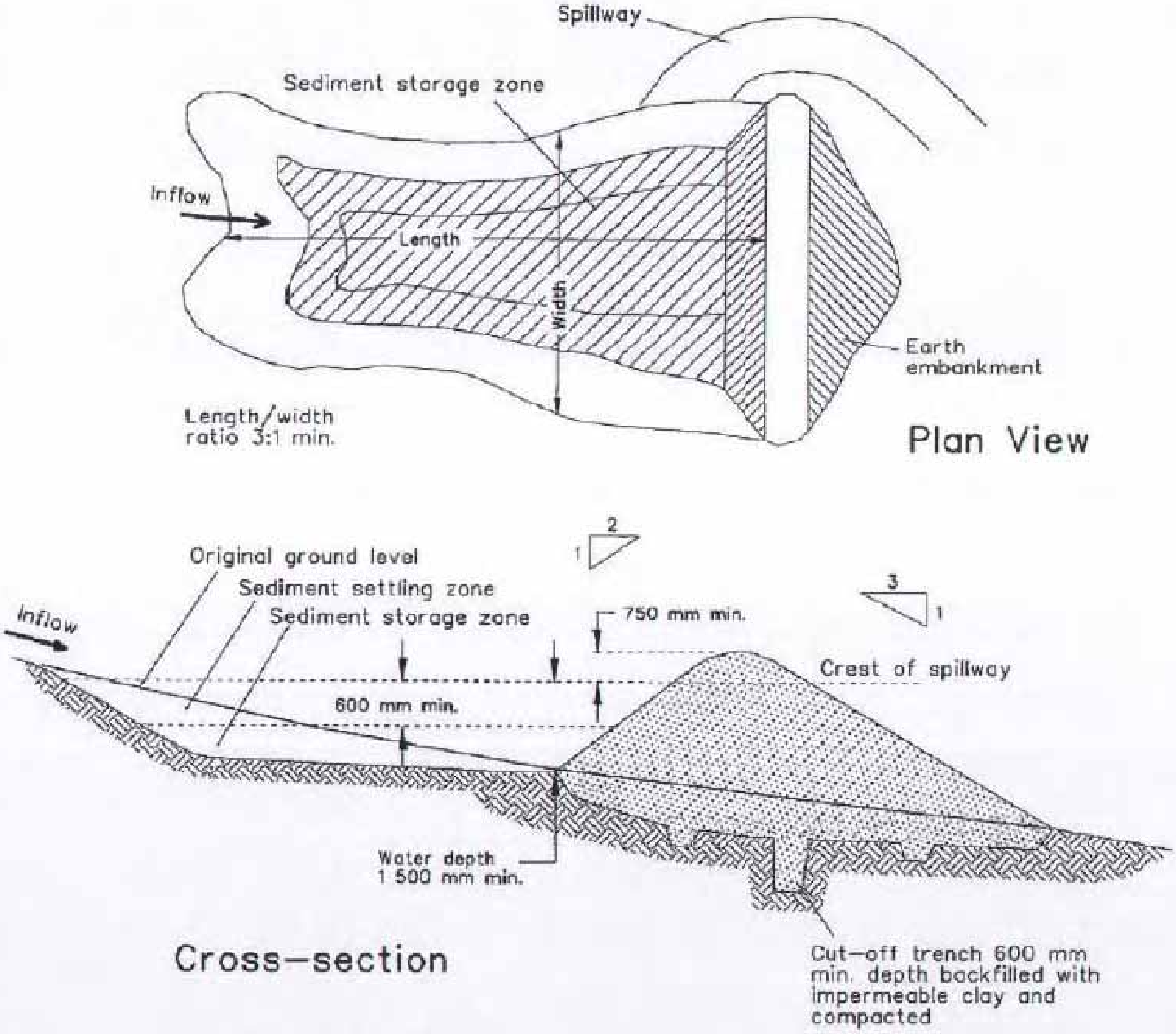


Figure 1 –Standard Drawing of Sediment Basin (Landcom 2004)

2. Sediment Basin Operation Flowchart

Type F and Type D sediment basins operate as 'wet' basins, Wet basins are designed to retain sediment laden water, allowing adequate time for the settlement of fine particles, either by gravitational means or use of chemical flocculants. In operating a wet basin the settled/treated water must be decanted from the basin as soon as a suitable water quality is achieved.

Type F and Type D sediment basins are typically designed for a maximum 5 day cycle; that being the filling, treatment and discharge of the basin within a maximum 5 day period.

The sediment basin procedure described in **Figure 2** below should be carried out daily, prior to commencement of works on site. If water is above the sediment storage zone in the basin, treatment, sampling and discharge should be achieved in the following 48 hours.

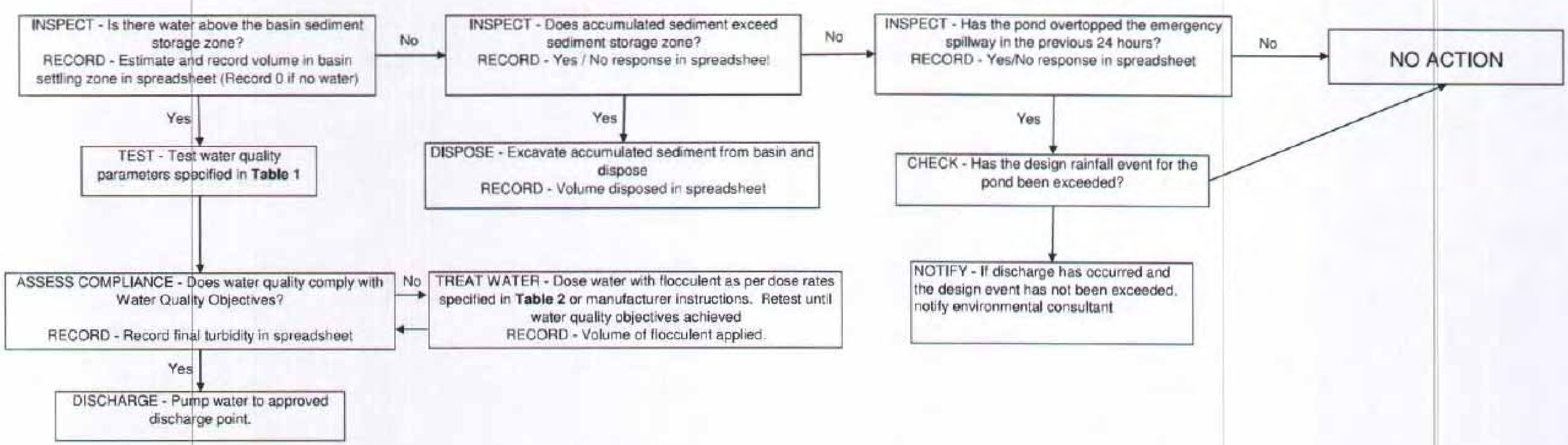


Figure 2 – Sediment Basin Procedure

3. Monitoring

Monitoring of water quality in the sediment basin is to be conducted daily by O2 Environmental or other suitably qualified third party following runoff generating rainfall or when the water level is above the sediment storage zone. The site foreman is responsible for notifying O2 Environmental or other suitably qualified third party of such conditions. Recording and reporting of results is to be carried out as per **Section 4**.

Water quality is to be assessed against objectives outlined in **Table 1.**

It will be necessary to undertake sufficient water testing (approximately 5 test depending on statistics) to enable a site specific calibration between suspended solids concentrations (laboratory analysis for suspended solids is required) and NTU turbidity readings. This would allow utilization of the turbidity meters to determine when water reaches 50mg/L.

Until a site specific relationship is developed the Sunshine Coast Regional Council Maroon book (2007) notes that *'A turbidity reading of around 75 NTU roughly corresponds to 50 mg/L TSS in may of our catchments'*. Until a site specific calibration can be undertaken it is recommended that this figure is used as an interim water quality objective.

Table 1 – Water Quality Objectives

Parameter	Target	Notes
TSS	50mg/L	Is achieved if turbidity target is met.
pH	6.5 – 7.5	Measure using calibrated pH probe
Turbidity	Initially 75 NTU	Measure using calibrated turbidity probe.

4. Records and Reporting

The following items are required to be recorded daily in a spreadsheet. This spreadsheet should be available in digital format upon request as part of any environmental audit or report/inspection by the regulating authority.

- Rainfall in previous 24 hours
- Volume in settling zone (record 0 if water is below settling zone)
- Has spillway overtopped (yes/no)
- Volume of sediment disposed (record 0 if no sediment disposed of)
- Turbidity and pH of water prior to discharge
- Volume of flocculent applied (record 0 if no flocculent applied)

5. Treatment

If monitoring results indicate that water quality objectives have not been achieved, apply appropriate treatment and re-sample water as per Section 3.

5.1. Turbidity / Suspended Solids

If turbidity or suspended solids exceed the target water quality objective, treatment with a flocculent will be required. Treatment is recommended at the rates outlined in **Table 2.**

Table 2 – Dose Rates

Compound	Indicative Dose Rate	Notes
Gypsum	32 kg/100m^3	Gypsum is not readily soluble in water.
PAC	5 to 8 mg/L (target aluminum concentration)	**IMPORTANT** Dose rates are required to be determined by on-site trials, carried out by a suitably qualified person. Over application of PAC or any aluminum based flocculent can result in environmental impacts.

5.1.1. Gypsum

Gypsum is often considered the least ecologically threatening flocculant; however it is also one of the least effective flocculants and can be difficult to apply in a manner that will allow the flocculant to work effectively. The application of gypsum will not generally impact pH levels, with only a slight increase in salinity resulting. Constraints and limitations of gypsum include a even application is required over the entire pond surface and a resulting scum deposit may form on equipment.

If high intensity storms are forecast it is recommended that gypsum dosage rates be increased to 70kg/100m^3. Depending on the clay mineralogy this can achieve flocculation within 24 hours, allowing discharge within 2 days from the conclusion of a storm. The following procedure should be applied for the manual dosing of gypsum:

1. Place required gypsum quantity (say 32kg/100m^3 of water) in an approximately 50L drum perforated with 25mm holes at 150mm spacing;
2. Suspend the screened, re-circulating pump intake into the drum;
3. Lift the drum into the basin such that basin water can enter and circulate through the drum;
4. Using the pump, spray the gypsum-rich solution evenly over the surface of the basin until the gypsum is fully removed from the drum. The pump outlet must spray the mixture over a wide area rather that just discharging as a confined 'jet'.

5.1.2. PAC

The use of PAC as a flocculant is only recommended under controlled circumstances and by users who are aware of the potential downstream risks to the environment. The advantage of PAC as a flocculant is the low dose rate required in comparison to gypsum, fast settling time and resulting stable sludge that binds pollutants.

As mentioned above in **Table 2** assessment of site specific dose rates must be undertaken by an environmental professional prior to use as overdosing will result in reduction of pH among other things. Residual alum concentrations remaining in the basin effluent should not exceed the ANZECC (2000) freshwater quality 'trigger value' of 0.055mg/L for aluminium at pH levels above 6.5. Continuous monitoring of water pH levels should be conducted when using PAC as a flocculant as pH levels lower than 5.5 will result in toxic concentrations of soluble aluminium, which can kill fish and other aquatic life.

5.2. pH

Liming rates for acidified water should be calculated with reference to Table 3.

Table 3 – Quantity of Pure Neutralisiing Agent Required to Raise From Existing Ph To Ph 7 for 1 Megalitre Of Low Salinity Acid Water. ***(From State Planning Policy 2/02 Guideline Acid Sulfate Soils)***

Current Water pH	$[H^+]$ (mol/L)	H^+ in 1 Megalitre (mol)	Aglime to neutralise 1 Megalitre (kg pure $CaCO_3$)	Hydrated lime to neutralise 1 Megalitre (kg pure $Ca(OH)_2$)	Sodium bicarbonate to neutralise 1 Megalitre (kg pure $NaHCO_3$)
0.5	.316	316 228	15 824	11 716	26 563
1.0	.1	100 000	5004	3705	8390
1.5	.032	32 000	1600	1185	2686
2.0	.01	10 000	500	370	839
2.5	.0032	3200	160	118	269
3.0	.001	1000	50	37	84
3.5	.00032	320	16	12	27
4.0	.0001	100	5	4	8.4
4.5	.000032	32	1.6	1.18	2.69
5.0	.00001	10	0.5	0.37	0.84
5.5	.0000032	3.2	0.16	0.12	0.27
6.0	.000001	1	0.05	0.037	0.08
6.5	.00000032	.32	0.016	0.012	0.027

Notes on Table 5:

1. $1\ m^3 = 1000$ litre = 1 kilolitre = 0.001 Megalitre
2. Correlations between current water pH and [H+] (mol/L) do not account for titratable acidity. The titratable acidity component should be included in any calculations of neutralising agent requirements.
3. Agricultural lime has a very low solubility and may take considerable time to even partially react. While aglime has a theoretical neutralising value of 2 mol of acidity (H+), this tends to be only fully available when there is excess acid. This, together with it's very low solubility, means that much more aglime beyond the theoretical calculation will generally be required.
4. Hydrated lime is more soluble than aglime and hence more suited to water treatment. However, as $Ca(OH)_2$ has a high water pH, incremental addition and thorough mixing is needed to prevent overshooting the desired pH. The water pH should be checked regularly after thorough mixing and allowing sufficient time for equilibration before further addition of neutralising product.
5. Weights of material given in the table above are based on theoretical pure material and hence use of such amounts of commercial product will generally result in under treatment.
6. To more accurately calculate the amount of commercial product required, the weight of neutralising agent from the table should be multiplied by a purity factor (100/ Neutralising Value for aglime) or (148/ Neutralising Value for hydrated lime).
7. If neutralising substantial quantities of ASS leachate, full laboratory analysis of the water will be necessary to adequately estimate the amount of neutralising material required.
8. Neutralising agents such as hydrated lime $Ca(OH)_2$, quick lime CaO, and magnesium oxide MgO neutralise 2 mol of acidity (H^+), while sodium bicarbonate $NaHCO_3$ and sodium hydroxide NaOH neutralise only 1 mol of acidity.

6. Discharge of Water

Prior to discharge of water from the sediment basin it is essential that the water quality complies with specified water quality objectives (see Table 1).

If possible, use water on site for dust suppression. Consumption of sediment basin water can be carried out without assessment of water quality. Care should be taken to ensure that this water does not runoff into waterways of drains.

After analytical results have been received and discharge of water authorized by O2 Environmental or other suitably qualified person, water may be discharged to the receiving drainage line. When dewatering the sediment basin care should be taken so as to not re-suspend previously settled sediment. Intake pipes should be housed in an appropriate flow control chamber to prevent settled sediment being removed from the basin. Intake pipes must not rest on the bottom of the basin, or in any other location that will allow the entrainment of settled sediment.

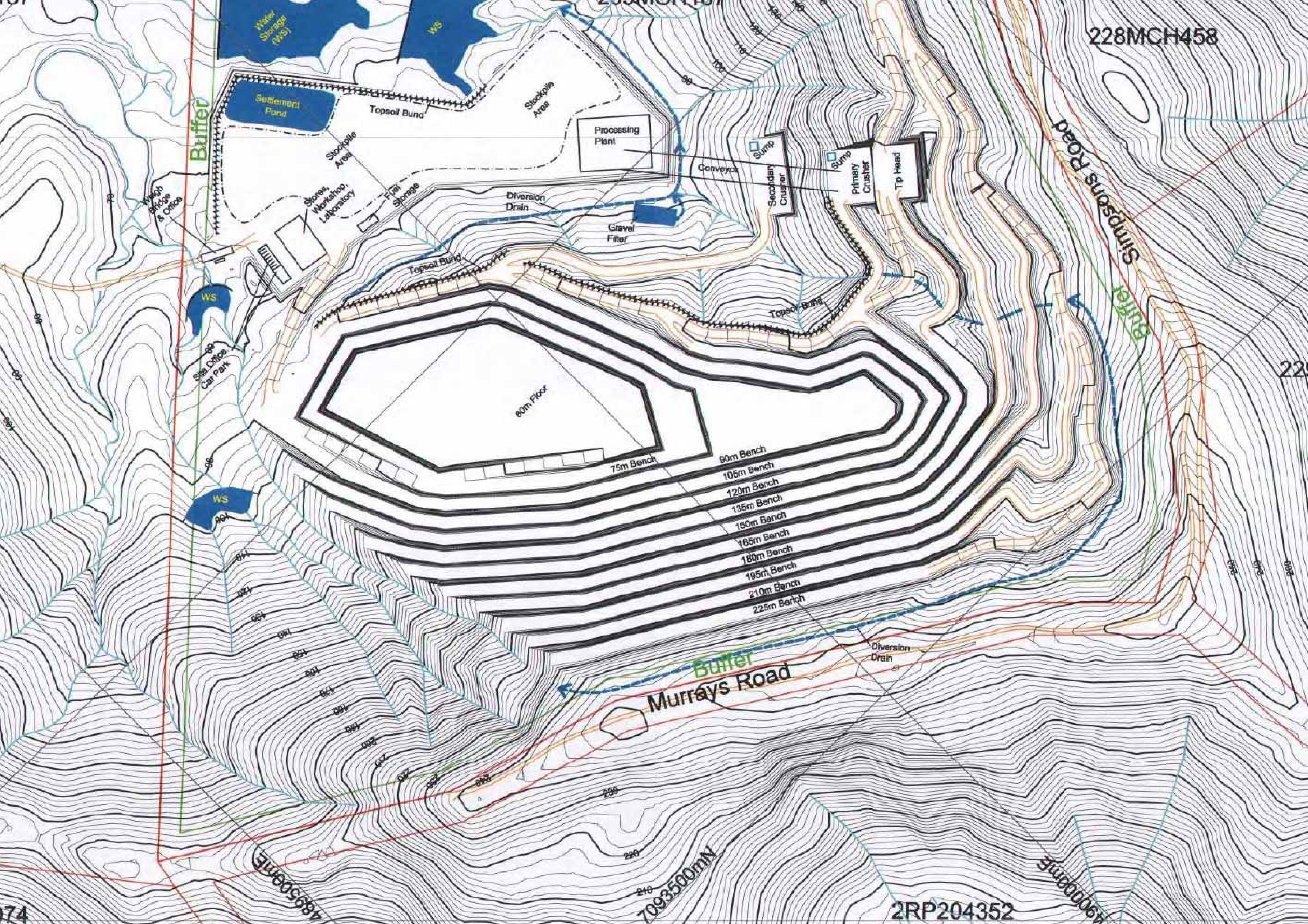
An appropriate housing chamber for an inflow pipe may be formed from a section of PVC drainage pipe, sealed at one end and perforated along its length with inflow holes. An alternative is to suspend the inflow pipe from a floating raft that is designed to prevent the intake pipe from resting too close to the settled sediment. The intake pipe is normally placed inside a horizontal perforated PVC pipe attached to the underside of a floating raft. Perforations in the PVC pipe should only exist along the top of the pipe, thus minimizing the risk of settled sediment being entrained into the outlet.

Pump sizing should aim to discharge the basin's settling zone volume in less than 24 hours

7. Maintenance

During daily inspections, site foreman should ensure that all aspects of the sediment basin are operational and intact, including the emergency spillway. If not, corrective action should be taken.

Annexure E Concept Final Development Plan (Groundwork)



Water Storage (WS)
WS
228MCH458
Settlement Pond
Topsoil Bund
Stockpile Area
Processing Plant
Stockpile Area
Conveyors
Sump
Secondary Crusher
Sump
Primary Crusher
Tip Head
Simpsons Road
Weigh Bridge & Office
Stores, Workshop, Laboratory
Fuel Storage
Diversion Drain
Gravel Filter
Buffer
Topsoil Bund
Topsoil Bund
Buffer
WS
Site Office, Car Park
60m Floor
75m Bench
90m Bench
105m Bench
120m Bench
135m Bench
150m Bench
165m Bench
180m Bench
195m Bench
210m Bench
225m Bench
WS
Diversion Drain
Buffer
Murrays Road
489500mE
7093500mN
2RP204352
490000mE

Annexure F Sediment Control Fact Sheets

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.

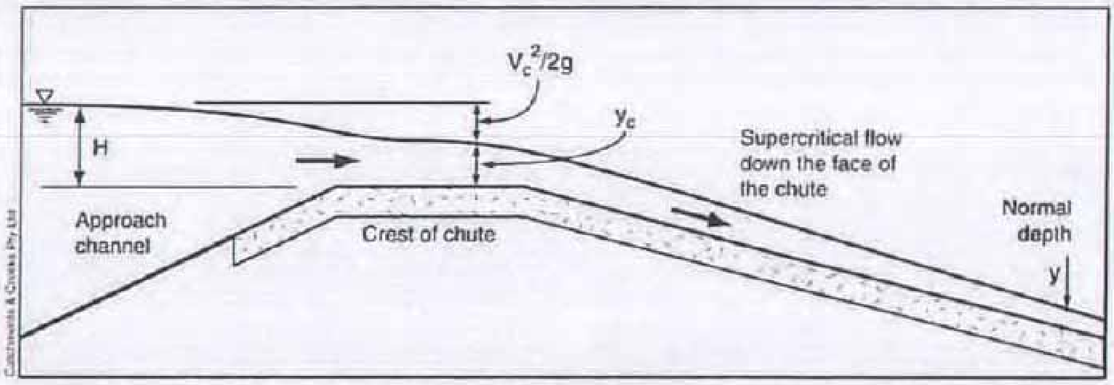


Figure 1 – Hydraulic profile for spillway crest where only minor friction loss occurs within the approach channel

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	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	$Q = 1.7\, b\, H^{1.5} + 3.8\, H^{2.5}$
	4:1	$Q = 1.7\, b\, H^{1.5} + 5.0\, H^{2.5}$
	m:1	$Q = 1.7\, b\, H^{1.5} + 1.26\, m\, H^{2.5}$

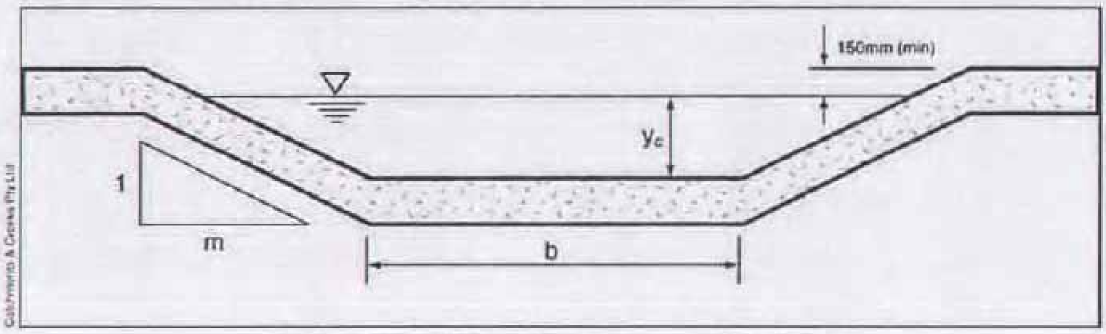


Figure 2 – Inlet profile of a trapezoidal chute

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.

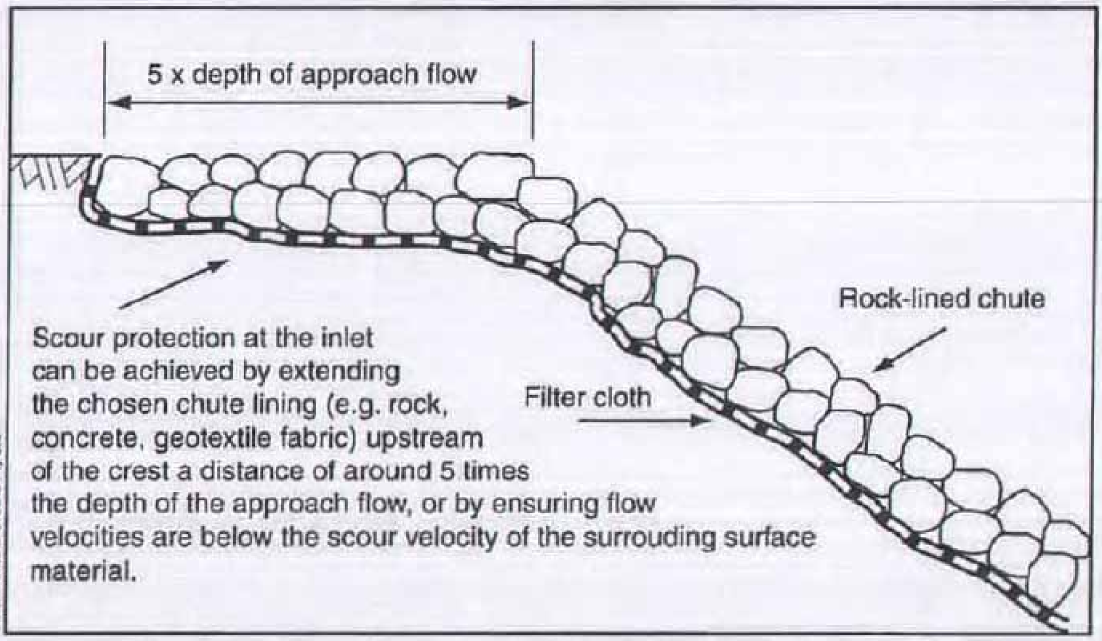


Figure 3 – One option for controlling scour at the chute entrance

A *Flow Diversion Bank* maybe 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).

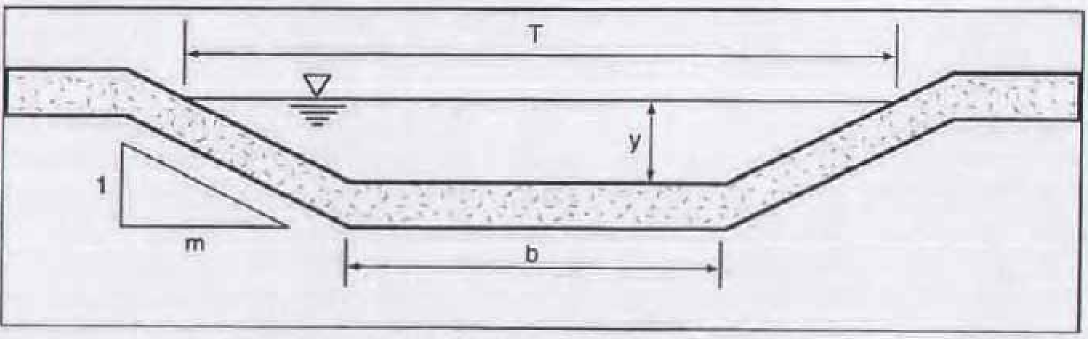


Figure 4 – Typical profile of the face of the chute

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:

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

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

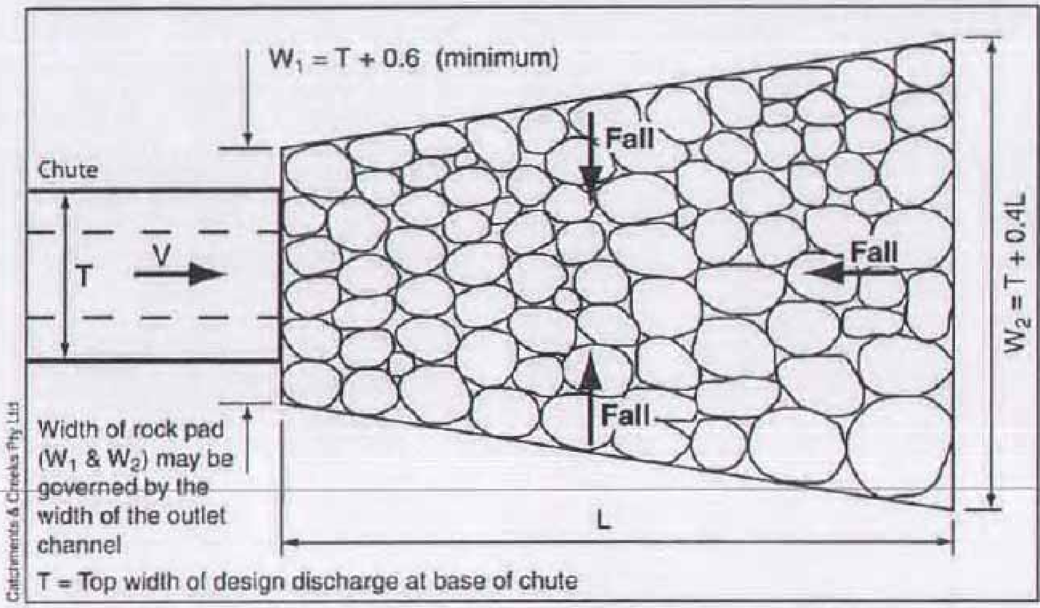


Figure 5 – Typical layout of a recessed rock pad for a chute (plan view)

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) may 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

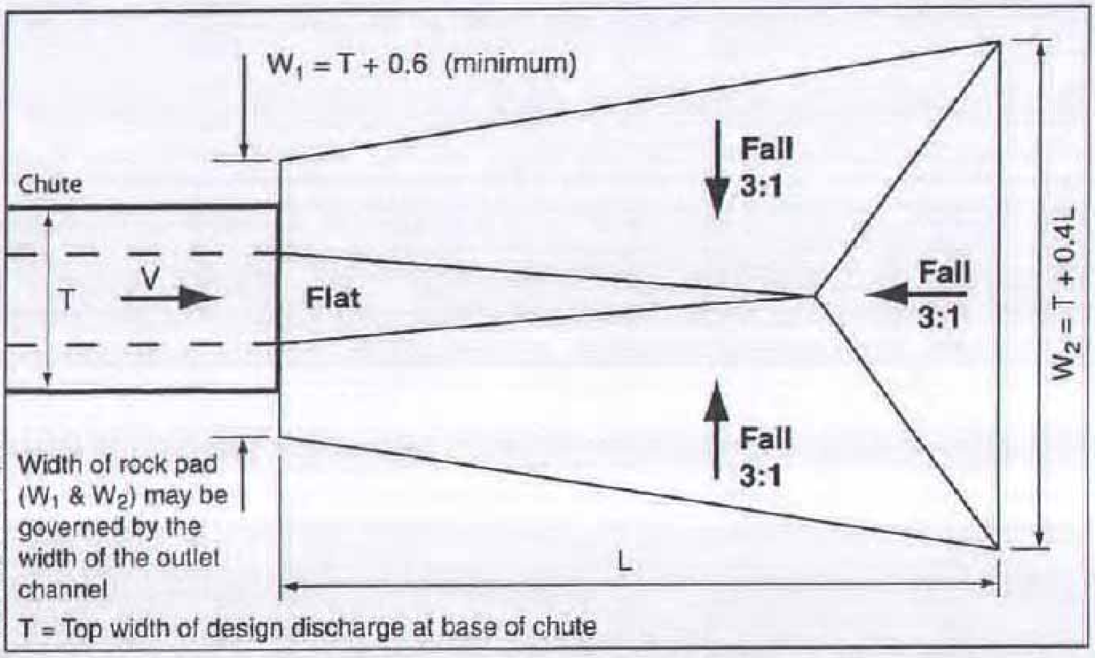


Figure 6 – Typical arrangement of recessed outlet structure for chutes

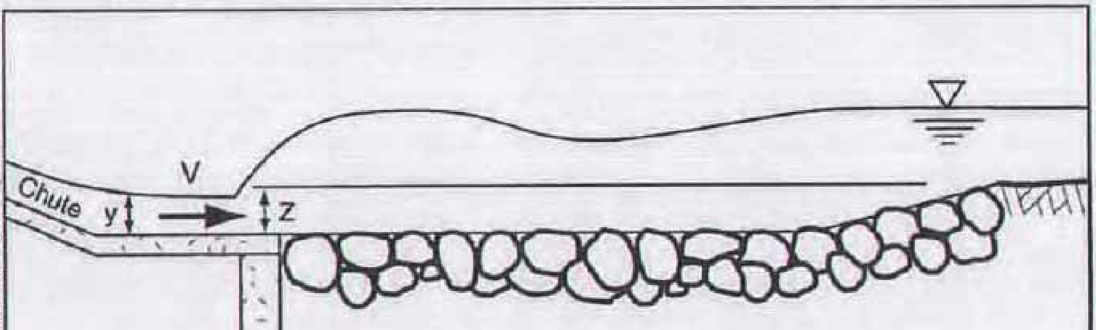


Figure 7 – Typical profile of recessed outlet structure for chutes

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

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.

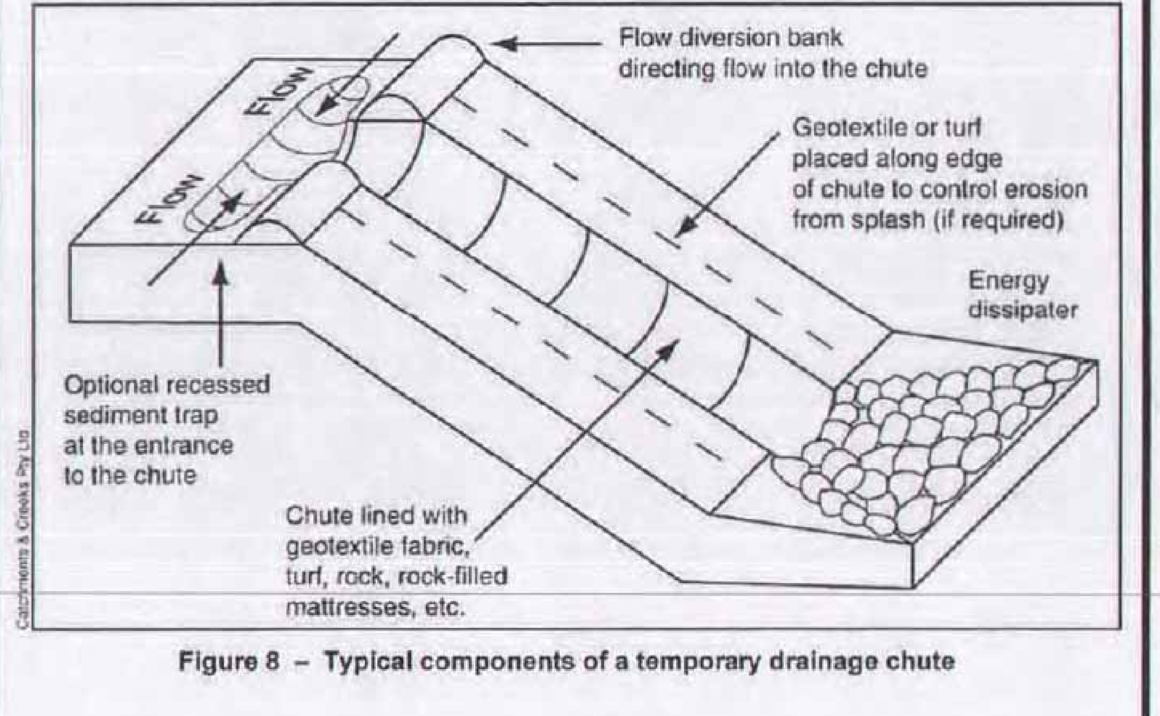


Figure 8 – Typical components of a temporary drainage chute

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 may 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.

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 → CH →

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 fact sheet on *Rock linings*.

The recommended maximum batter slope is 2:1(H:V) un-vegetated, or 2.5:1 if the rock is appropriately integrated with vegetation. Equation 3 can be used for sizing rock on the bank of straight and near-straight reaches of chutes 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.

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

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 = $\tan(\theta)$ [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 the 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 average over the whole 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.

Suggested 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) may 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 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 usually 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), typically minimum 200mm thickness, but preferably 300mm.

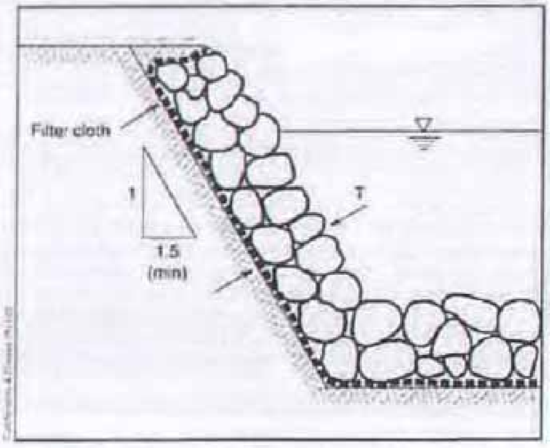


Figure 10 – Rock placement (without vegetation) on non-dispersive soil

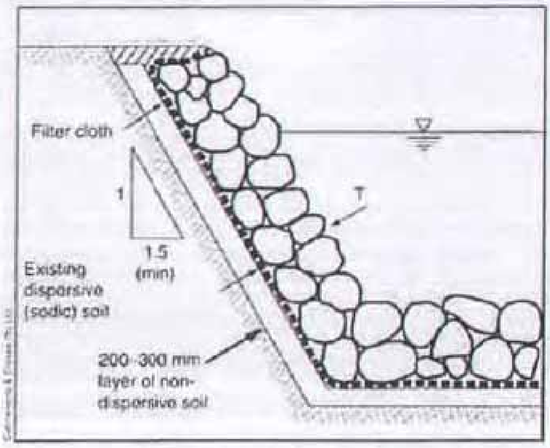


Figure 11 – Rock placement (without vegetation) on dispersive soil

Maximum bank gradient:

The recommended maximum batter slope is 2:1(H:V) un-vegetated, or 2.5:1 if the rock is appropriately integrated with vegetation.

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°	42°
Slightly angular rock	40°	41°
Moderately rounded rock	39°	40°

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 may 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 (d_{50}/d_{90}) 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.

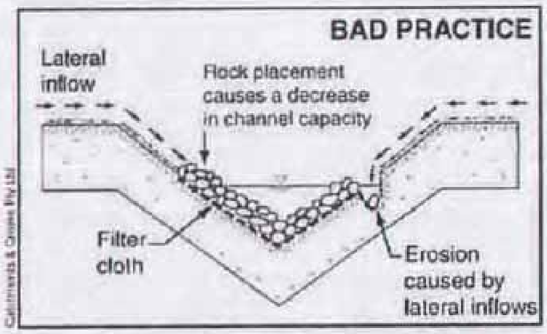


Figure 12 – Incorrect placement of rock causing loss of flow area and erosion along the outer limits of the rock

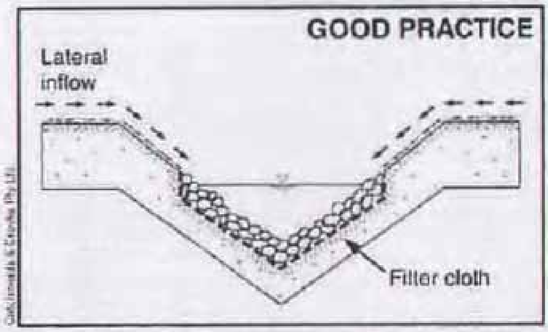


Figure 13 – Rock recessed into the soil to allow the free entry of lateral inflows

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 <u>on</u> 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) may 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 turf).

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 may 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 may 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 may 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(0.3) + 0.15 = 0.351m;

(iii) y + 150mm = 0.19 + 0.15 = 0.34m.

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 may 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 = 1.3m.

Table 7 (Part 1) indicates a dissipation basin recess depth, Z = 0.14m

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(1.3) = 4.48m

Let $W_1 = W_2$ = 4.6m

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 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.

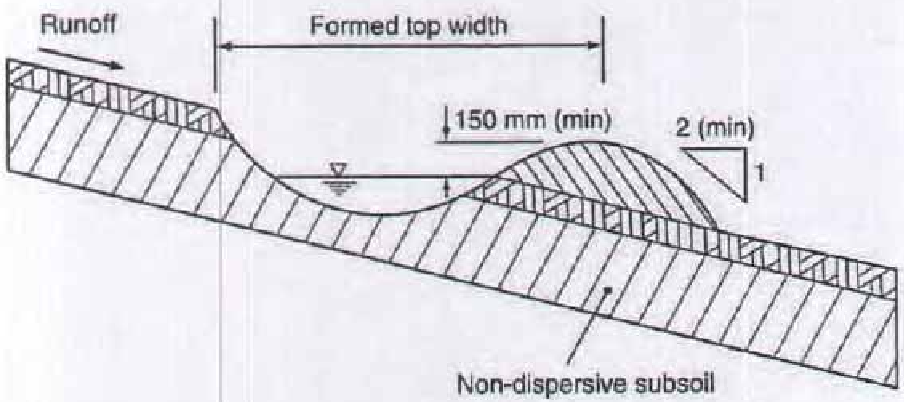
6. Ensure the geotextile fabric is protected from punching or tearing during installation of the fabric and the rock. Repair any damage by removing the rock and placing with another piece of filter cloth over the damaged area overlapping the existing fabric a minimum of 300mm.
7. Where necessary, a minimum 100mm layer of fine gravel, aggregate or sand may 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

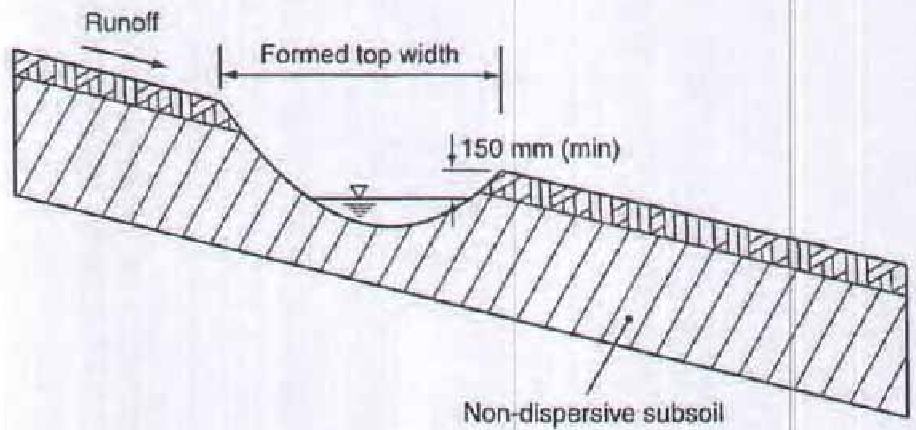
1. During the construction period, inspect all chutes prior to forecast rainfall, daily during extended periods of rainfall, after significant runoff producing storm events, or otherwise on a weekly basis. Make repairs as necessary.
2. Check for scour or dislodged rock. Repair damaged areas immediately.
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. When making repairs, always restore the chute to its original configuration unless an amended layout is required.

Removal

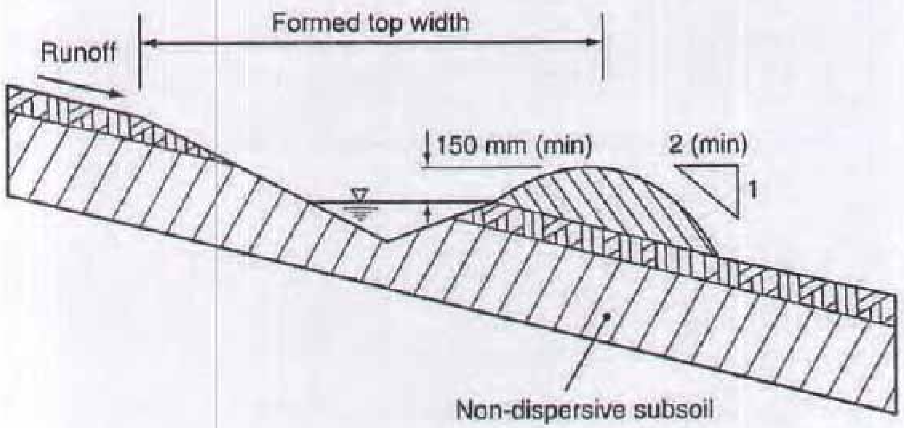
1. When the soil disturbance above the chute is finished and the area is stabilised, the chute and any associated flow diversion banks should be removed, unless it is to remain as a permanent drainage feature.
2. Dispose of any materials, sediment or earth in a manner that will not create an erosion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



(a) Parabolic catch drain with down-slope bank



(c) Parabolic catch drain without bank



(b) Triangular V-drain with down-slope bank

Constructed dimensions of parabolic catch drains

Drain type	Formed top width with or without bank	Formed depth with or without bank
Type-A	1.6 m	0.30 m
Type-B	2.4 m	0.45 m
Type-C	3.6 m	0.65 m

Constructed dimensions of triangular V-drains

Drain type	Formed top width with or without bank	Formed depth with or without bank
Type-AV	2.0 m	0.30 m
Type-BV	2.7 m	0.45 m
Type-CV	3.9 m	0.65 m

NOT TO SCALE

Drawn:	Date:		
GMW	Dec-09	Catch Drains	CD-01

INSTALLATION

1. REFER TO APPROVED PLANS FOR LOCATION, EXTENT, AND CONSTRUCTION DETAILS. IF THERE ARE QUESTIONS OR PROBLEMS WITH THE LOCATION, EXTENT, 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 CATCH DRAIN, 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. DO NOT USE DEBRIS TO BUILD THE BANK.

5. GRADE THE DRAIN TO THE SPECIFIED SLOPE AND FORM THE ASSOCIATED EMBANKMENT WITH COMPACTED FILL. NOTE THAT THE DRAIN INVERT MUST FALL 10cm EVERY 10m FOR EACH 1% OF CHANNEL GRADIENT.

6. ENSURE THE SIDES OF THE CUT DRAIN ARE NO STEEPER THAN A 1.5:1 (H:V) SLOPE AND THE EMBANKMENT FILL SLOPES NO STEEPER THAN 2:1.

7. ENSURE THE COMPLETED DRAIN HAS SUFFICIENT DEEP (AS SPECIFIED FOR THE TYPE OF DRAIN) MEASURED FROM THE DRAIN INVERT TO THE TOP OF THE EMBANKMENT. WHERE NECESSARY, CUT THE DRAIN SLIGHTLY DEEPER THAN THAT SPECIFIED ON THE PLANS SUCH THAT THE CORRECT CHANNEL DIMENSIONS ARE ACHIEVED FOLLOWING PLACEMENT OF THE TURF.

8. ENSURE THE DRAIN HAS A CONSTANT FALL IN THE DESIRED DIRECTION FREE OF OBSTRUCTIONS.

9. TURF SHOULD BE USED WITHIN 12-HOURS OF DELIVERY, OTHERWISE ENSURE THE TURF IS STORED IN CONDITIONS APPROPRIATE FOR THE WEATHER CONDITIONS (e.g. A SHADED AREA).

10. MOISTENING THE TURF AFTER IT IS UNROLLED WILL HELP MAINTAIN ITS VIABILITY.

11. TURF SHOULD BE LAID ON A MINIMUM 75mm BED OF ADEQUATELY FERTILISED TOPSOIL. RAKE THE SOIL SURFACE TO BREAK THE CRUST JUST BEFORE LAYING THE TURF.

12. DURING THE WARMER MONTHS, LIGHTLY IRRIGATE THE SOIL IMMEDIATELY BEFORE LAYING THE TURF.

13. ENSURE THE TURF IS NOT LAID ON GRAVEL, HEAVILY COMPACTED SOILS, OR SOILS THAT HAVE BEEN RECENTLY TREATED WITH HERBICIDES.

14. FOR WIDE DRAINS AND HIGH VELOCITY CHUTES, LAY THE FIRST ROW OF TURF IN A STRAIGHT LINE DIAGONAL TO THE DIRECTION OF FLOW. STAGGER SUBSEQUENT ROWS IN A BRICK-LIKE (STRETCHER BOND) PATTERN. THE TURF SHOULD NOT BE STRETCHED OR OVERLAPPED. USE A KNIFE OR SHARP SPADE TO TRIM AND FIT IRREGULARLY SHAPED AREAS.

15. FOR NARROW DRAINS, LAY THE TURF ALONG THE DIRECTION OF THE DRAIN, ENSURING, WHEREVER PRACTICABLE, THAT A LONGITUDINAL JOINT BETWEEN TWO STRIPS OF TURF IS NOT POSITIONED ALONG THE INVERT OF THE DRAIN.

16. ENSURE THE TURF EXTENDS UP THE SIDES OF THE DRAIN AT LEAST 100mm ABOVE THE ELEVATION OF THE CHANNEL INVERT, OR AT LEAST TO A SUFFICIENT ELEVATION TO FULLY CONTAIN EXPECTED CHANNEL FLOW.

17. ON CHANNEL GRADIENTS OF 3:1(H:V) OR STEEPER, OR IN SITUATIONS WHERE HIGH FLOW VELOCITIES (i.e. VELOCITY >1.5m/s) ARE LIKELY WITHIN THE FIRST 2-WEEKS FOLLOWING PLACEMENT, SECURE THE INDIVIDUAL TURF STRIPS WITH WOODEN OR PLASTIC PEGS.

18. ENSURE THAT INTIMATE CONTACT IS ACHIEVED AND MAINTAINED BETWEEN THE TURF AND THE SOIL SUCH THAT SEEPAGE FLOW BENEATH THE TURF IS AVOIDED.

19. WATER UNTIL THE SOIL IS WET 100mm BELOW THE TURF. THEREAFTER, WATERING SHOULD BE SUFFICIENT TO MAINTAIN AND PROMOTE HEALTHY GROWTH.

20. ENSURE THE DRAIN DISCHARGES TO A STABLE OUTLET SUCH THAT DOWN-SLOPE SOIL EROSION WILL BE PREVENTED FROM OCCURRING. ENSURE THE DRAIN DOES NOT DISCHARGE TO AN UNSTABLE FILL SLOPE.

MAINTENANCE

1. INSPECT ALL CATCH DRAINS AT LEAST WEEKLY AND AFTER RUNOFF-PRODUCING STORM EVENTS AND REPAIR ANY SLUMPS, BANK DAMAGE, OR LOSS OF FREEBOARD.

2. ENSURE FILL MATERIAL OR SEDIMENT IS NOT PARTIALLY BLOCKING THE DRAIN. WHERE NECESSARY, REMOVE ANY DEPOSITED MATERIAL TO ALLOW FREE DRAINAGE.

3. DISPOSE OF ANY SEDIMENT OR FILL IN A MANNER THAT WILL NOT CREATE AN EROSION OR POLLUTION HAZARD.

REMOVAL

1. WHEN THE SOIL DISTURBANCE ABOVE THE CATCH DRAIN IS FINISHED AND THE AREA IS STABILISED, THE DRAIN AND ANY ASSOCIATED BANKS SHOULD BE REMOVED, UNLESS IT IS TO REMAIN AS A PERMANENT DRAINAGE FEATURE.

2. DISPOSE OF ANY SEDIMENT OR EARTH IN A MANNER THAT WILL NOT CREATE AN EROSION OR POLLUTION HAZARD.

3. GRADE THE AREA AND SMOOTH IT OUT IN PREPARATION FOR STABILISATION.

4. STABILISE THE AREA BY GRASSING OR AS SPECIFIED WITHIN THE APPROVED PLAN.

Drawn:	Date:		
GMW	Dec-09	Catch Drains - Grass Lined	CD-03

INSTALLATION

1. REFER TO APPROVED PLANS FOR LOCATION, EXTENT, AND CONSTRUCTION DETAILS. IF THERE ARE QUESTIONS OR PROBLEMS WITH THE LOCATION, EXTENT, OR METHOD OF INSTALLATION, CONTACT THE ENGINEER OR RESPONSIBLE ON-SITE OFFICER FOR ASSISTANCE.

2. CLEAR THE LOCATION FOR THE BANK, CLEARING ONLY THE AREA THAT IS NEEDED TO PROVIDE ACCESS FOR PERSONNEL AND EQUIPMENT.

3. REMOVE ROOTS, STUMPS, AND OTHER DEBRIS AND DISPOSE OF THEM PROPERLY. DO NOT USE DEBRIS TO BUILD THE BANK.

4. FORM THE BANK FROM THE MATERIAL, AND TO THE DIMENSION SPECIFIED IN THE APPROVED PLANS.

5. IF EARTH IS USED, THEN ENSURE THE SIDES OF THE BANK ARE NO STEEPER THAN A 2:1 (H:V) SLOPE, AND THE COMPLETED BANK MUST BE AT LEAST 500mm HIGH.

6. IF FORMED FROM SANDBAGS, THEN ENSURE THE BAGS ARE TIGHTLY PACKED SUCH THAT WATER LEAKAGE THROUGH THE BAGS IS MINIMISED.

7. CHECK THE BANK ALIGNMENT TO ENSURE POSITIVE DRAINAGE IN THE DESIRED DIRECTION.

8. THE BANK SHOULD BE VEGETATED (TURFED, SEEDED AND MULCHED), OR OTHERWISE STABILISED IMMEDIATELY, UNLESS IT WILL OPERATE FOR LESS THAN 30 DAYS OR IF SIGNIFICANT RAINFALL IS NOT EXPECTED DURING THE LIFE OF THE BANK.

9. ENSURE THE EMBANKMENT DRAINS TO A STABLE OUTLET, AND DOES NOT DISCHARGE TO AN UNSTABLE FILL SLOPE.

MAINTENANCE

1. INSPECT FLOW DIVERSION BANKS AT LEAST WEEKLY AND AFTER RUNOFF-PRODUCING RAINFALL.

2. INSPECT THE BANK FOR ANY SLUMPS, WHEEL TRACK DAMAGE OR LOSS OF FREEBOARD. MAKE REPAIRS AS NECESSARY.

3. CHECK THAT FILL MATERIAL OR SEDIMENT HAS NOT PARTIALLY BLOCKED THE DRAINAGE PATH UP-SLOPE OF THE EMBANKMENT. WHERE NECESSARY, REMOVE ANY DEPOSITED MATERIAL TO ALLOW FREE DRAINAGE.

4. DISPOSE OF ANY COLLECTED SEDIMENT OR FILL IN A MANNER THAT WILL NOT CREATE AN EROSION OR POLLUTION HAZARD.

5. REPAIR ANY PLACES IN THE BANK THAT ARE WEAKENED OR IN RISK OF FAILURE.

REMOVAL

1. WHEN THE SOIL DISTURBANCE ABOVE THE BANK IS FINISHED AND THE AREA IS STABILISED, THE FLOW DIVERSION BANK SHOULD BE REMOVED, UNLESS IT IS TO REMAIN AS A PERMANENT DRAINAGE FEATURE.

2. DISPOSE OF ANY SEDIMENT OR EARTH IN A MANNER THAT WILL NOT CREATE AN EROSION OR POLLUTION HAZARD.

3. GRADE THE AREA AND SMOOTH IT OUT IN PREPARATION FOR STABILISATION.

4. STABILISE THE AREA BY GRASSING OR AS SPECIFIED IN THE APPROVED PLAN.

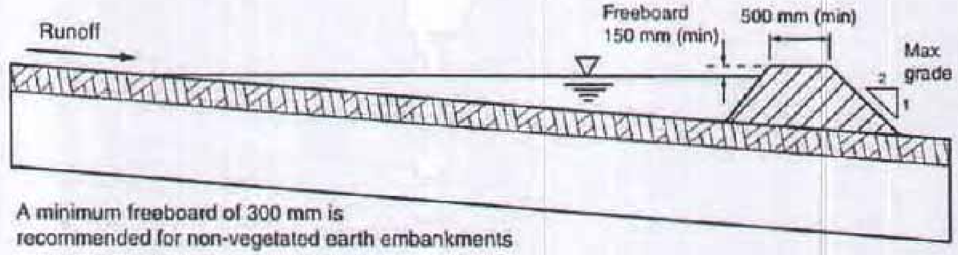


Figure 1 - Typical profile of flow diversion bank formed from earth

Table 1 - Recommended dimensions of flow diversion banks

Parameter	Earth banks	Vegetated banks	Compost berms	Sandbag berms
Height (min)	500 mm	500 mm	300 mm	N/A
Top width (min)	500 mm	500 mm	100 mm	N/A
Base width (min)	2500 mm	2500 mm	600 mm	N/A
Side slope (max)	2:1 (H:V)	2:1 (H:V)	1:1 (H:V)	N/A
Freeboard	300 mm	150 mm	100 mm	50 mm

Drawn:	Date:		
GMW	Dec-09	Flow Diversion Banks	DB-01

INSTALLATION

1. REFER TO APPROVED PLANS FOR LOCATION, EXTENT, AND CONSTRUCTION DETAILS. IF THERE ARE QUESTIONS OR PROBLEMS WITH THE LOCATION, EXTENT, 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 CHANNEL, CLEARING ONLY WHAT IS NEEDED TO PROVIDE ACCESS FOR PERSONNEL AND CONSTRUCTION EQUIPMENT.

4. REMOVE ROOTS, STUMPS, AND OTHER DEBRIS AND DISPOSE OF THEM PROPERLY. DO NOT USE DEBRIS TO BUILD ANY ASSOCIATED EMBANKMENTS.

5. EXCAVATE THE DIVERSION CHANNEL TO THE SPECIFIED SHAPE, ELEVATION AND GRADIENT. THE SIDES OF THE CHANNEL SHOULD BE NO STEEPER THAN A 2:1 (H:V) IF CONSTRUCTED IN EARTH, UNLESS SPECIFICALLY DIRECTED WITHIN THE APPROVED PLANS.

6. STABILISE THE CHANNEL AND BANKS IMMEDIATELY UNLESS IT WILL OPERATE FOR LESS THAN 30 DAYS. IN EITHER CASE, TEMPORARY EROSION PROTECTION (MATTING, ROCK, ETC.) WILL BE REQUIRED AS SPECIFIED WITHIN THE APPROVED PLANS OR AS DIRECTED.

7. ENSURE THE CHANNEL DISCHARGES TO A STABLE AREA.

ADDITIONAL REQUIREMENTS FOR TURF PLACEMENT:

1. TURF SHOULD BE USED WITHIN 12 HOURS OF DELIVERY, OTHERWISE ENSURE THE TURF IS STORED IN CONDITIONS APPROPRIATE FOR THE WEATHER CONDITIONS (e.g. A SHADED AREA).

2. MOISTENING THE TURF AFTER IT IS UNROLLED WILL HELP MAINTAIN ITS VIABILITY.

3. TURF SHOULD BE LAID ON A MINIMUM 75mm BED OF ADEQUATELY FERTILISED TOPSOIL. RAKE THE SOIL SURFACE TO BREAK THE CRUST JUST BEFORE LAYING THE TURF.

4. DURING THE WARMER MONTHS, LIGHTLY IRRIGATE THE SOIL IMMEDIATELY BEFORE LAYING THE TURF.

5. ENSURE THE TURF IS NOT LAID ON GRAVEL, HEAVILY COMPACTED SOILS, OR SOILS THAT HAVE BEEN RECENTLY TREATED WITH HERBICIDES.

6. ENSURE THE TURF EXTENDS UP THE SIDES OF THE DRAIN AT LEAST 100mm ABOVE THE ELEVATION OF THE CHANNEL INVERT, OR AT LEAST TO A SUFFICIENT ELEVATION TO FULLY CONTAIN EXPECTED CHANNEL FLOW.

7. ON CHANNEL GRADIENTS OF 3:1(H:V) OR STEEPER, OR IN SITUATIONS WHERE HIGH FLOW VELOCITIES (i.e. VELOCITY >1.5m/s) ARE LIKELY WITHIN THE FIRST TWO WEEK FOLLOWING PLACEMENT, SECURE THE INDIVIDUAL TURF STRIPS WITH WOODEN OR PLASTIC PEGS.

8. ENSURE THAT INTIMATE CONTACT IS ACHIEVED AND MAINTAINED BETWEEN THE TURF AND THE SOIL SUCH THAT SEEPAGE FLOW BENEATH THE TURF IS AVOIDED.

9. WATER UNTIL THE SOIL IS WET 100mm BELOW THE TURF. THEREAFTER, WATERING SHOULD BE SUFFICIENT TO MAINTAIN AND PROMOTE HEALTHY GROWTH

MAINTENANCE

1. DURING THE SITE'S CONSTRUCTION PERIOD, INSPECT THE DIVERSION CHANNEL WEEKLY AND AFTER ANY INCREASE IN FLOWS WITHIN THE CHANNEL. REPAIR ANY SLUMPS, WHEEL TRACK DAMAGE OR LOSS OF FREEBOARD.

2. ENSURE FILL MATERIAL OR SEDIMENT IS NOT PARTIALLY BLOCKING THE CHANNEL. WHERE NECESSARY, REMOVE ANY DEPOSITED MATERIAL TO ALLOW FREE DRAINAGE.

3. DISPOSE OF ANY COLLECTED SEDIMENT OR FILL IN A MANNER THAT WILL NOT CREATE AN EROSION OR POLLUTION HAZARD.

REMOVAL

1. WHEN THE CONSTRUCTION WORK ABOVE A TEMPORARY DIVERSION CHANNEL IS FINISHED AND THE AREA IS STABILISED, THE AREA SHOULD BE APPROPRIATELY REHABILITATED.

2. DISPOSE OF ANY COLLECTED SEDIMENT OR FILL IN A MANNER THAT WILL NOT CREATE AN EROSION OR POLLUTION HAZARD.

3. GRADE THE AREA AND SMOOTH IT OUT IN PREPARATION FOR STABILISATION.

4. STABILISE THE AREA AS SPECIFIED IN THE APPROVED PLAN.

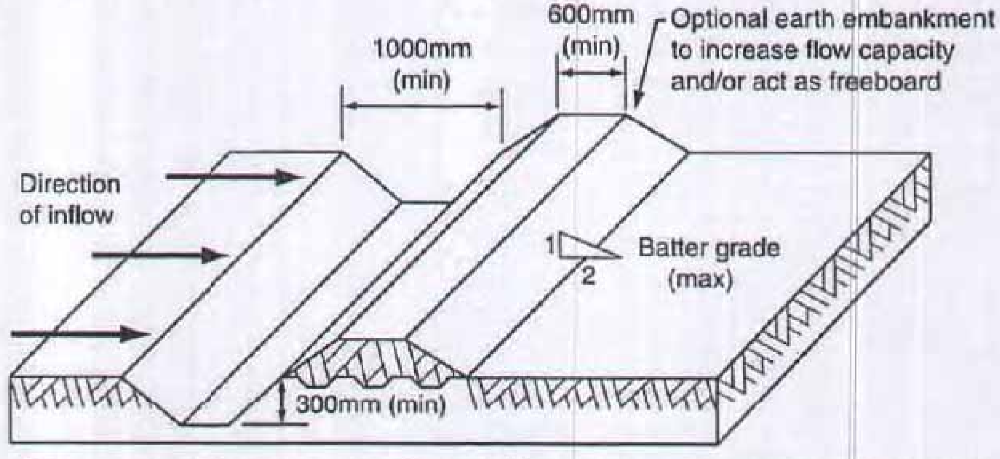


Figure 1 - Typical profile of diversion channel with bank

Drawn:	Date:		
GMW	Dec-09	Diversion Channels	DC-01

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.

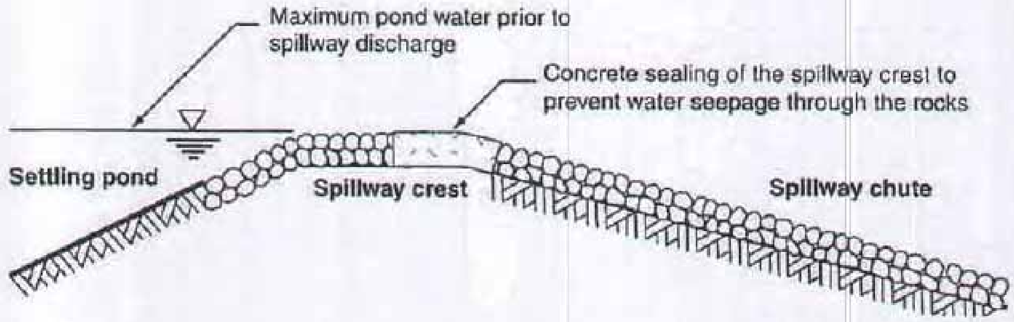
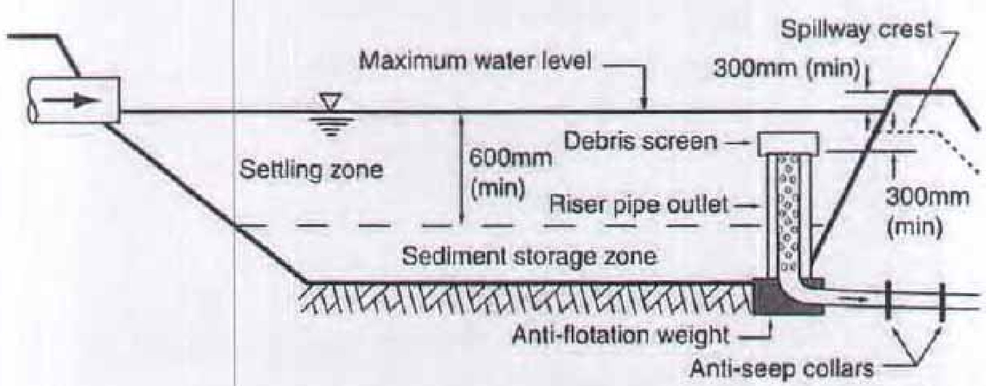
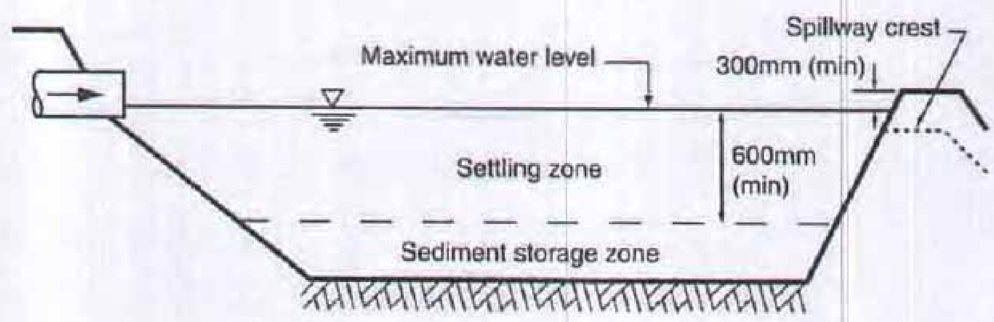


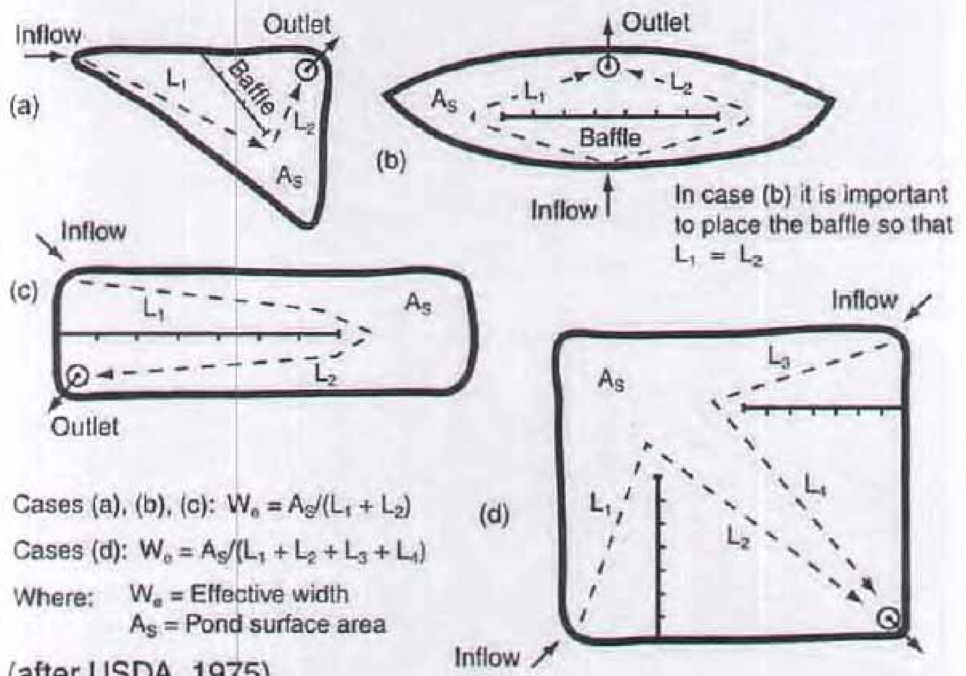
Figure 1 - Example of seepage control on the spillway crest



(a) Type C (dry) basin with riser pipe outlet system



(b) Typical profile of Type F/D (wet) basin



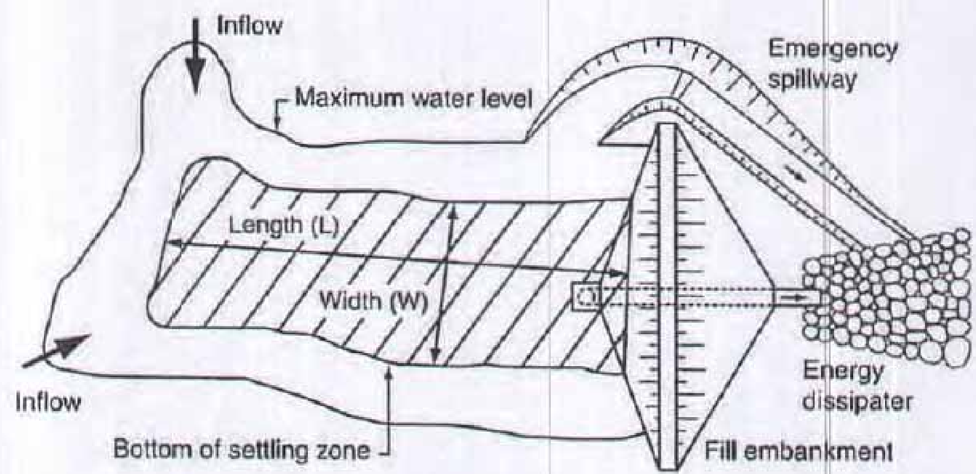
Cases (a), (b), (c): $W_e = A_S/(L_1 + L_2)$

Cases (d): $W_e = A_S/(L_1 + L_2 + L_3 + L_4)$

Where: W_e = Effective width
A_S = Pond surface area

(after USDA, 1975)

(c) Typical arrangement of internal flow control baffles



(d) Type C (dry) basin with riser pipe outlet system

Drawn:	Date:		
GMW	Feb-10	Sediment Basins	SB-01

MATERIALS

EARTH FILL: CLEAN SOIL WITH EMERSON CLASS 2(1), 3, 4, OR 5, AND FREE OF ROOTS, WOODY VEGETATION, ROCKS AND OTHER UNSUITABLE MATERIAL. SOIL WITH EMERSON CLASS 4 AND 5 MAY NOT BE SUITABLE DEPENDING ON PARTICLE SIZE DISTRIBUTION AND DEGREE OF DISPERSION. CLASS 2(1) SHOULD ONLY BE USED UPON RECOMMENDATION FROM GEOTECHNICAL SPECIALIST. THIS SPECIFICATION MAYBE REPLACED BY AN EQUIVALENT STANDARD BASED ON THE EXCHANGEABLE SODIUM PERCENTAGE.

RISER PIPE: MINIMUM 250mm DIAMETER.

SPILLWAY ROCK: HARD, ANGULAR, DURABLE, WEATHER RESISTANT AND EVENLY GRADED ROCK WITH 50% BY WEIGHT LARGER THAN THE SPECIFIED NOMINAL (d50) ROCK SIZE. LARGE ROCK SHOULD DOMINATE, WITH 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. THE SPECIFIC GRAVITY SHOULD BE AT LEAST 2.5.

GEOTEXTILE FABRIC: HEAVY-DUTY, NEEDLE-PUNCHED, NON-WOVEN FILTER CLOTH, MINIMUM BIDIM A24 OR EQUIVALENT.

CONSTRUCTION

1. NOTWITHSTANDING ANY DESCRIPTION CONTAINED WITHIN THE APPROVED PLANS OR SPECIFICATIONS, THE CONTRACTOR SHALL BE RESPONSIBLE FOR SATISFYING THEMSELVES AS TO THE NATURE AND EXTENT OF THE SPECIFIED WORKS AND THE PHYSICAL AND LEGAL CONDITIONS UNDER WHICH THE WORKS WILL BE CARRIED OUT. THIS SHALL INCLUDE MEANS OF ACCESS, EXTENT OF CLEARING, NATURE OF MATERIAL TO BE EXCAVATED, TYPE AND SIZE OF MECHANICAL PLANT REQUIRED, LOCATION AND SUITABILITY OF WATER SUPPLY FOR CONSTRUCTION AND TESTING PURPOSES, AND ANY OTHER LIKE MATTERS AFFECTING THE CONSTRUCTION OF THE WORKS.

2. REFER TO APPROVED PLANS FOR LOCATION, DIMENSIONS, 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.

3. BEFORE STARTING ANY CLEARING OR CONSTRUCTION, ENSURE ALL THE NECESSARY MATERIALS AND COMPONENTS ARE ON THE SITE TO AVOID DELAYS IN COMPLETING THE POND ONCE WORKS BEGIN.

4. INSTALL REQUIRED SHORT-TERM SEDIMENT CONTROL MEASURES DOWNSTREAM OF THE PROPOSED EARTHWORKS TO CONTROL SEDIMENT RUNOFF DURING CONSTRUCTION OF THE BASIN.

5. THE AREA TO BE COVERED BY THE EMBANKMENT, BORROW PITS AND INCIDENTAL WORKS, TOGETHER WITH AN AREA EXTENDING BEYOND THE LIMITS OF EACH FOR A DISTANCE NOT EXCEEDING FIVE (5) METRES ALL AROUND MUST BE CLEARED OF ALL TREES, SCRUB, STUMPS, ROOTS, DEAD TIMBER AND RUBBISH AND DISPOSED OF IN A SUITABLE MANNER. DELAY CLEARING THE MAIN POND AREA UNTIL THE EMBANKMENT IS COMPLETE.

6. ENSURE ALL HOLES MADE BY GRUBBING WITHIN THE EMBANKMENT FOOTPRINT ARE FILLED WITH SOUND MATERIAL, ADEQUATELY COMPACTED, AND FINISHED FLUSH WITH THE NATURAL SURFACE.

CUT-OFF TRENCH:

7. BEFORE CONSTRUCTION OF THE CUT-OFF TRENCH OR ANY ANCILLARY WORKS WITHIN THE EMBANKMENT FOOTPRINT, ALL GRASS GROWTH AND TOPSOIL MUST BE REMOVED FROM THE AREA TO BE OCCUPIED BY THE EMBANKMENT AND MUST BE DEPOSITED CLEAR OF THIS AREA AND RESERVED FOR TOPDRESSING THE COMPLETING THE EMBANKMENT.

8. EXCAVATE A CUT-OFF TRENCH ALONG THE CENTRE LINE OF THE EARTH FILL EMBANKMENT. CUT THE TRENCH TO STABLE SOIL MATERIAL, BUT IN NO CASE MAKE IT LESS THAN 600mm DEEP. THE CUT-OFF TRENCH MUST EXTEND INTO BOTH ABUTMENTS TO AT LEAST THE ELEVATION OF THE RISER PIPE CREST. MAKE THE MINIMUM BOTTOM WIDTH WIDE ENOUGH TO PERMIT OPERATION OF EXCAVATION AND COMPACTION EQUIPMENT, BUT IN NO CASE LESS THAN 600mm. MAKE THE SIDE SLOPES OF THE TRENCH NO STEEPER THAN 1:1 (H:V).

9. ENSURE ALL WATER, LOOSE SOIL, AND ROCK ARE REMOVED FROM THE TRENCH BEFORE BACKFILLING COMMENCES. THE CUT-OFF TRENCH MUST BE BACKFILLED WITH SELECTED EARTH-FILL OF THE TYPE SPECIFIED FOR THE EMBANKMENT, AND THIS SOIL MUST HAVE A MOISTURE CONTENT AND DEGREE OF COMPACTION THE SAME AS THAT SPECIFIED FOR THE SELECTED CORE ZONE.

10. MATERIAL EXCAVATED FROM THE CUT-OFF TRENCH MAY BE USED IN CONSTRUCTION OF THE EMBANKMENT PROVIDED IT IS SUITABLE AND IT IS PLACED IN THE CORRECT ZONE ACCORDING TO ITS CLASSIFICATION.

EMBANKMENT:

11. SCARIFY AREAS ON WHICH FILL IS TO BE PLACED BEFORE PLACING THE FILL.

12. ENSURE ALL FILL MATERIAL USED TO FORM THE EMBANKMENT MEETS THE SPECIFICATIONS CERTIFIED BY A SOIL SCIENTIST OR GEOTECHNICAL SPECIALIST.

13. THE FILL MATERIAL MUST CONTAIN SUFFICIENT MOISTURE SO IT CAN BE FORMED BY HAND INTO A BALL WITHOUT CRUMBLING. IF WATER CAN BE SQUEEZED OUT OF THE BALL, IT IS TOO WET FOR PROPER COMPACTION. PLACE FILL MATERIAL IN 150 TO 250mm CONTINUOUS LAYERS OVER THE ENTIRE LENGTH OF THE FILL AREA AND THEN COMPACT BEFORE PLACEMENT OF FURTHER FILL.

14. PLACE RISER PIPE OUTLET SYSTEM, IF SPECIFIED, IN APPROPRIATE SEQUENCE WITH THE EMBANKMENT FILLING. REFER TO SEPARATE INSTALLATION SPECIFICATIONS.

15. UNLESS OTHERWISE SPECIFIED ON THE APPROVED PLANS, COMPACT THE SOIL AT ABOUT 1% TO 2% WET OF OPTIMUM AND TO 95% MODIFIED OR 100% STANDARD COMPACTION.

16. WHERE BOTH DISPERSIVE AND NON-DISPERSIVE CLASSIFIED EARTH-FILL MATERIALS ARE AVAILABLE, NON-DISPERSIVE EARTH-FILL MUST BE USED IN THE CORE ZONE. THE REMAINING CLASSIFIED EARTH-FILL MATERIALS MUST ONLY BE USED AS DIRECTED BY [INSERT TITLE].

17. WHERE SPECIFIED, CONSTRUCT THE EMBANKMENT TO AN ELEVATION 10% HIGHER THAN THE DESIGN HEIGHT TO ALLOW FOR SETTLING; OTHERWISE FINISHED DIMENSIONS OF THE EMBANKMENT AFTER SPREADING OF TOPSOIL MUST CONFORM TO THE DRAWING WITH A TOLERANCE OF 75mm FROM THE SPECIFIED DIMENSIONS.

18. ENSURE DEBRIS AND OTHER UNSUITABLE BUILDING WASTE IS NOT PLACED WITHIN THE EARTH EMBANKMENT.

19. AFTER COMPLETION OF THE EMBANKMENT ALL LOOSE UNCOMPACTED EARTH-FILL MATERIAL ON THE UPSTREAM AND DOWNSTREAM BATTER MUST BE REMOVED PRIOR TO SPREADING OF TOPSOIL.

20. TOPSOIL AND REVEGETATE/STABILISED ALL EXPOSED EARTH AS DIRECTED WITHIN THE APPROVED PLANS.

(continued on SB-06)

SPILLWAY CONSTRUCTION:

21. 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.

22. 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.

23. 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.

24. IF A SYNTHETIC FILTER FABRIC UNDERLAY IS SPECIFIED, PLACE THE FILTER FABRIC DIRECTLY ON THE PREPARED FOUNDATION. IF MORE THAN ONE 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.

25. 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.

26. 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.

27. 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.

28. 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.

29. 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. ESTABLISHMENT OF SETTLING POND:

30. THE AREA TO BE COVERED BY THE STORED WATER OUTSIDE THE LIMITS OF THE BORROW PITS MUST BE CLEARED OF ALL SCRUB AND RUBBISH. TREES MUST BE CUT DOWN STUMP HIGH AND REMOVED FROM THE IMMEDIATE VICINITY OF THE WORK.

31. ESTABLISH ALL REQUIRED INFLOW CHUTES AND INLET BAFFLES, IF SPECIFIED, TO ENABLE WATER TO DISCHARGE INTO THE BASIN IN A MANNER THAT WILL NOT CAUSE SOIL EROSION OR THE RE-SUSPENSION OF SETTLED SEDIMENT.

32. INSTALL A SEDIMENT STORAGE LEVEL MARKER POST WITH A CROSS MEMBER SET JUST BELOW THE TOP OF THE SEDIMENT STORAGE ZONE (AS SPECIFIED ON THE APPROVED PLANS). USE AT LEAST A 75mm WIDE POST FIRMLY SET INTO THE BASIN FLOOR.

33. IF SPECIFIED, INSTALL INTERNAL SETTLING POND BAFFLES. ENSURE THE CREST OF THESE BAFFLES IS SET LEVEL WITH, OR JUST BELOW, THE ELEVATION OF THE EMERGENCY SPILLWAY CREST.

34. INSTALL ALL APPROPRIATE MEASURES TO MINIMISE SAFETY RISK TO ON-SITE PERSONNEL AND THE PUBLIC CAUSED BY THE PRESENCE OF THE SETTLING POND. AVOID STEEP, SMOOTH INTERNAL SLOPES. APPROPRIATELY FENCE THE SETTLING POND AND POST WARNING SIGNS IF UNSUPERVISED PUBLIC ACCESS IS LIKELY OR THERE IS CONSIDERED TO BE AN UNACCEPTABLE RISK TO THE PUBLIC.

MAINTENANCE OF SEDIMENT BASIN

1. INSPECT THE SEDIMENT BASIN DURING THE FOLLOWING PERIODS:

(i) DURING CONSTRUCTION TO DETERMINE WHETHER MACHINERY, FALLING TREES, OR CONSTRUCTION ACTIVITY HAS DAMAGED ANY COMPONENTS OF THE SEDIMENT BASIN. IF DAMAGE HAS OCCURRED, REPAIR IT.

(ii) AFTER EACH RUNOFF EVENT. INSPECT THE EROSION DAMAGE AT FLOW ENTRY AND EXIT POINTS. IF DAMAGE HAS OCCURRED, MAKE THE NECESSARY REPAIRS.

(iii) AT LEAST WEEKLY DURING THE NOMINATED WET SEASON (IF ANY) OTHERWISE AT LEAST FORTNIGHTLY.

(iv) PRIOR TO, AND IMMEDIATELY AFTER, PERIODS OF 'STOP WORK' OR SITE SHUTDOWN.

2. CLEAN OUT ACCUMULATED SEDIMENT WHEN IT REACHES THE MARKER BOARD/POST, AND RESTORE THE ORIGINAL STORAGE VOLUME. PLACE SEDIMENT IN A DISPOSAL AREA OR, IF APPROPRIATE, MIX WITH DRY SOIL ON THE SITE.

3. DO NOT DISPOSE OF SEDIMENT IN A MANNER THAT WILL CREATE AN EROSION OR POLLUTION HAZARD.

4. CHECK ALL VISIBLE PIPE CONNECTIONS FOR LEAKS, AND REPAIR AS NECESSARY.

5. CHECK ALL EMBANKMENTS FOR EXCESSIVE SETTLEMENT, SLUMPING OF THE SLOPES OR PIPING BETWEEN THE CONDUIT AND THE EMBANKMENT; MAKE ALL NECESSARY REPAIRS.

6. REMOVE ALL TRASH AND OTHER DEBRIS FROM THE BASIN AND RISER.

7. SUBMERGED INFLOW PIPES MUST BE INSPECTED AND DE-SILTED (AS REQUIRED) AFTER EACH INFLOW EVENT.

REMOVAL OF SEDIMENT BASIN

1. WHEN GRADING AND CONSTRUCTION IN THE DRAINAGE AREA ABOVE A TEMPORARY SEDIMENT BASIN IS COMPLETED AND THE DISTURBED AREAS ARE ADEQUATELY STABILISED, THE BASIN MUST BE REMOVED OR OTHERWISE INCORPORATED INTO THE PERMANENT STORMWATER DRAINAGE SYSTEM. IN EITHER CASE, SEDIMENT SHOULD BE CLEARED AND PROPERLY DISPOSED OF AND THE BASIN AREA STABILISED.

2. BEFORE STARTING ANY MAINTENANCE WORK ON THE BASIN OR SPILLWAY, INSTALL ALL NECESSARY SHORT-TERM SEDIMENT CONTROL MEASURES DOWNSTREAM OF THE SEDIMENT BASIN.

3. ALL WATER AND SEDIMENT MUST BE REMOVED FROM THE BASIN PRIOR TO THE DAM'S REMOVAL. DISPOSE OF SEDIMENT AND WATER IN A MANNER THAT WILL NOT CREATE AN EROSION OR POLLUTION HAZARD.

4. BRING THE DISTURBED AREA TO A PROPER GRADE, THEN SMOOTH, COMPACT, AND STABILISE AND/OR REVEGETATE AS REQUIRED TO ESTABLISH A STABLE LAND SURFACE.

Attachment 6

Neilsen's Environmental Policy

ENVIRONMENTAL POLICY

The Neilsen Group of Companies responsibility is to continually improve all aspects of the Environment in which we operate.

Our environmental policy includes the following:

1. Compliance with applicable legal and regulatory requirements and company standards in existing operations, new developments and upgrades;
2. Apply sound environmental management practices, where in our judgement existing legal requirements are insufficient for our operations;
3. Minimise wastes, develop viable recycling opportunities and ensure proper handling and disposing methods;
4. Open, constructive dialogue with communities surrounding our operations;
5. Rehabilitate areas affected by business operations;
6. Communicate Neilsens Environmental policy to our employees, customers & contractors.

To support these commitments, Neilsens will progressively implement and maintain environmental management systems for its business based on international standard ISO 14001 or its equivalent.

Mario Panuccio
CEO

24 June 2009