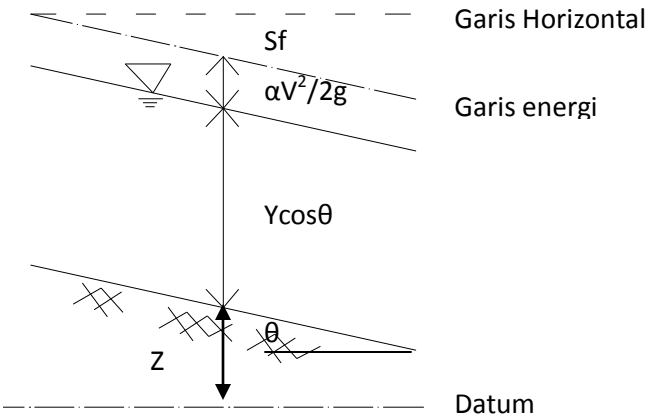
Aliran Berubah Beraturan

Kondisi ini terjadi jika gaya penggerak dan gaya geser tidak seimbang, hasilnya bahwa kedalaman aliran berubah beraturan sepanjang saluran



Persamaan dynamic pada aliran berubah beraturan diperoleh dengan diferensiasi persamaan energy

$H = Z + Y \cos \theta + \alpha (V^2/2g)$

Ddiferensiasi terhadap sumbu- x (sepanjang dasar saluran)

$dH/dX = dZ/dX + \cos\theta.dy/dx + d/dX (\alpha (V^2/2g))$

jika $Sf = -dH/dx$; $So = \sin\theta = - dZ/dX$

- $Sf = - So + \cos\theta\ dy/dx + d/dx (\alpha (V^2/2g))$

  $So – Sf = \cos\theta\ dy/dx + d/dx (\alpha (V^2/2g))$ → Untuk memperoleh dy/dx jika rusa kanan dikalikan dy/dy

  $= \cos\theta\ dy/dx + dy/dx.\ d/dy (\alpha (V^2/2g)) = dy/dx [\cos\theta + d/dx (\alpha (V^2/2g))]$

  Jika θ <, cos θ = 1

  Maka $dy/dx = (So-Sf)/(1+d/dy).(\alpha (V^2/2g))$

  $dy/dx\ .\ (\alpha (V^2/2g) = (d/dy).((Q^2/2g.A^2)) = -(2Q^2/2gA^3).(dA/dy)$ → $dA/dy = B$

  $dy/dx\ .\ (\alpha (V^2/2g) = - Q^2.B/gA^3$ → B = lebar permukaan

  $dy / dx = (So - Sf) / (1 – \alpha.Q^2.B/g.A^3)$

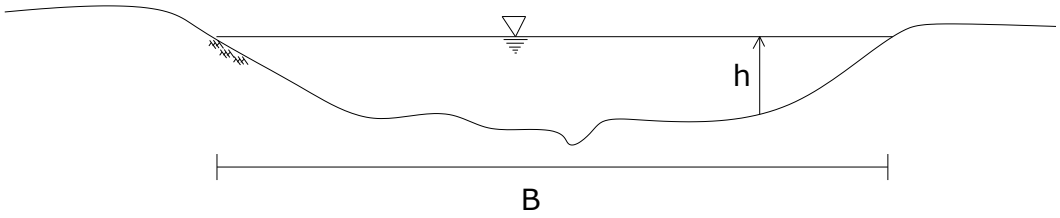
persamaan manning : $Sf = n^2.\ V^2/\ R^{4/3} = n^2.\ Q^2/\ A^2\ R^{4/3}$

persamaan Chezy : $Sf = V^2/ C^2R^{4/3} = Q^2/ C^2A^2 R$

Karakteristik Garis Muka Air

Persamaan umum: $dh/ds = So [(1- C^2A^2 R.So)/(1 - \alpha.Q^2.B/g.A^3)]$

Untuk mempermudah analisis digunakan saluran lebar (B = ~)



$R \approx h$; $q = Q/B$

$Q = q.B$

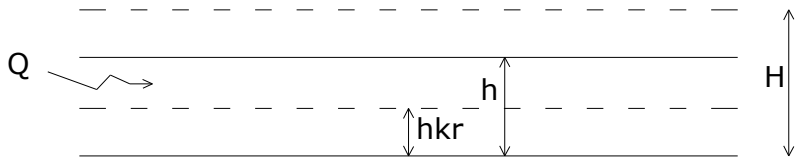
$dh/ds = So [(1- q^2B^2/ C^2.B^2.h^2.h.So)/ (1- \alpha q^2B^2B/ g.B^3.h^3)] = So = [(1- q^2/ C^2.h^3.So)/ (1- \alpha q^2/ g.h^3)]$

kedalaman air normal : $H^3 = q^2/ C^2 .So$

kedalaman kritik : $hkr^3 = \alpha.q^2/g$

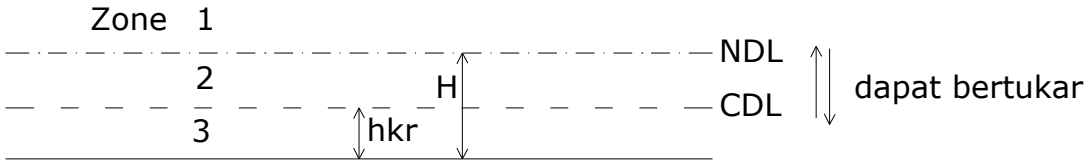
$dh/ds = So.(h^3 – H^3)/(h^3 –hkr^3)$

h = kedalaman air untuk debit Q



dh/ds>0 → aliran diperlambat (Backwater)

dh/ds < 0 → aliran dipercepat (dramdown)



tinjauan persamaan untuk dh/ds

dh/ds > 0 (+) → backwater, kurva naik

dapat terjadi bila

$h^3 - H^3 > 0$ (+) → h > H, dan

$h^3 - hkr^3 > 0$ (+) → h > hkr

} Zone 1 (subkritik)

$h^3 - H^3 < 0$ (-) → h < H, dan

$h^3 - hkr^3 < 0$ → h < hkr

} Zone 3 (superkritik)

Dh/ds < 0 → drawdown, kurva turun

$h^3 - H^3 > 0$ → h > H, dan

$h^3 - hkr^3 < 0$ (+) → h< hkr

} Zone 2 (superkritik)

$h^3 - H^3 < 0$ → h > H, dan

$h^3 - hkr^3 > 0$ (+) → h< hkr

} Zone 2 (subkritik)

Klasifikasi Kurva air

Perubahan profil muka air tergantung pada Ao

So > 0 → So < So kr → Mild Slope : M (landai)

So > So kr → Steep slope : S (curam)

S0 = So kr → Critical Slope : C (kritik)

So = 0 → Horizontal Slope : H

So < 0 → Adverse slope (kemiringan balik): A

Tinjau persamaan umum:

$dh/ds = So\ (h^3 - H^3)/(h^3 - hkr^3) \rightarrow : h^3$

$dh/ds = So\ (h^3 - (H/h)^3)/(1 - (hkr/h)^3)$ ……I

untuk mengetahui jenis kurva muka air dapat digunakan persamaan I, dengan mengetahui nilai H/h dan hkr/h (+ atau -)

	H/h	Tanda pembagi	Hkr/h	Tanda penyebut	Tanda dh/ds	Perubahan kedalaman	Nama kurva
1							
So > 0	< 1	+	< 1	+	+	Naik	M1
So < Sokr	< 1	+	> 1	-		Tidak mungkin	-
H > hkr	> 1	-	< 1	+	-	Turun	M2
Subkritis	> 1	-	> 1	-	+	naik	M3
2							
So > 0	< 1	+	< 1	+	+	Naik	S1
So < Sokr	< 1	+	> 1	-	-	Turun	S2
H > hkr	> 1	-	< 1	+		Tidak mungkin	
Suprkritis	> 1	-	> 1	-	+	naik	S3
3							
So > 0							
So = Sokr	< 1	+	< 1	+	+	Naik	C1
H = hkr	> 1	-	> 1	-	+	naik	C3
4							
So =0	>>1	-	< 1	+	-	Turun	H2
H = ≈	>>1	-	> 1	-	+	naik	H3
5							
So < 0	< 1	-	< 1	+	-	Turun	A2
H < 0	< 1	-	< 1	-	+	naik	A3

Pada adverse slope, So < 0

$H^3 = q^2/ So.C^2 < 0 \rightarrow h^3 – H^3 > 0$

Dari $dh/ds = So .(h^3 – H^3)/(h^3 – hkr^3) \rightarrow$ -

$dh/ds > 0 \rightarrow (h^3 – hkr^3) < 0 \rightarrow h < hkr \rightarrow A_3$

$dh/ds < 0 \rightarrow (h^3 – hkr^3) >0 \rightarrow h > hkr \rightarrow A_2$

contoh untuk mendapatkan kurva M_1

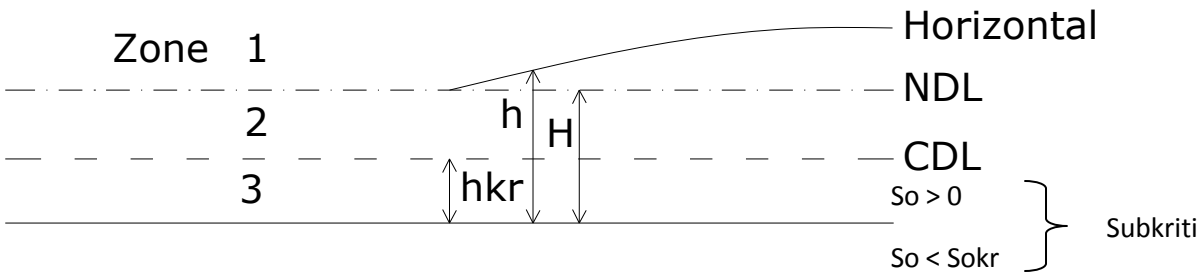
1. $dh/ds = So .(1 – (H/h)^3)/(1 – (hkr/h)^3)$

$So > 0 + \rightarrow$ subkritik

$H/h < 1 \rightarrow (1 – (H/h)^3 > 0 (+)$

$H/h < 1 \rightarrow (1 – (hkr/h)^3 > 0 (+)$

$dh/ds = (+). (+)/(+) = (+) \rightarrow$ naik



$H/h < 1 \rightarrow H < h \rightarrow$ Zone 1

$Hkr/h < 1 \rightarrow hkr < h \rightarrow$ zone 1

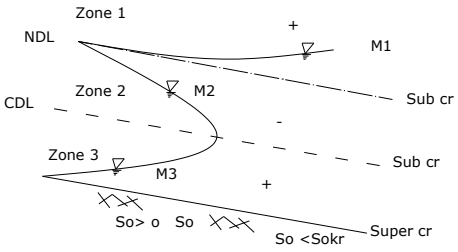
Zone 1

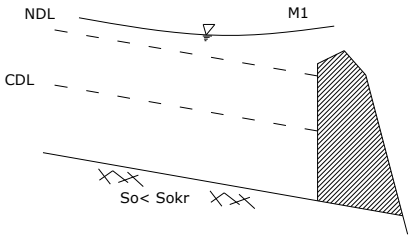
2. $H/h < 1 \rightarrow [1 – (H/h)^3] > 0 (+)$

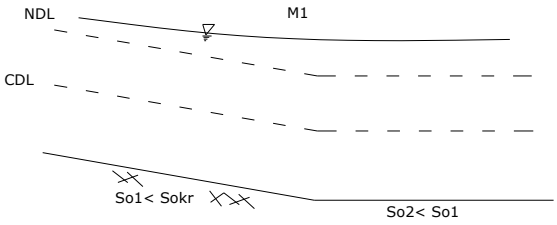
   $Hkr/h > 1 \rightarrow [1 – (hkr/h)^3] < 0 (-)$

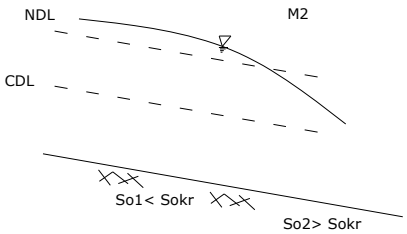
   $dh/ds = (+). ((+)/(-)) = (-)$

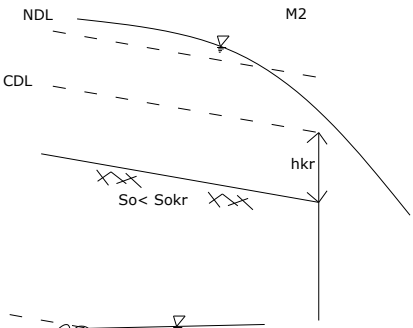
KURVA M

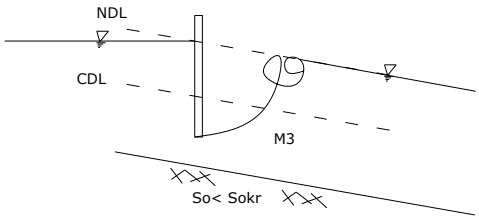

Zone 1
NDL
+
M1
Zone 2
M2
Sub cr
CDL
-
Zone 3
Sub cr
M3
+
So> o So
So <Sokr
Super cr

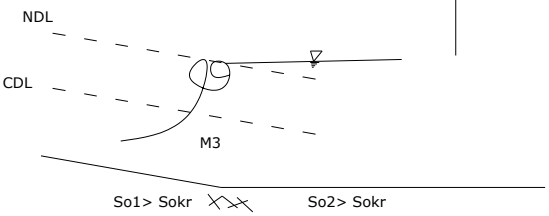

NDL
M1
CDL
So< Sokr


NDL
M1
CDL
So1< Sokr
So2< So1

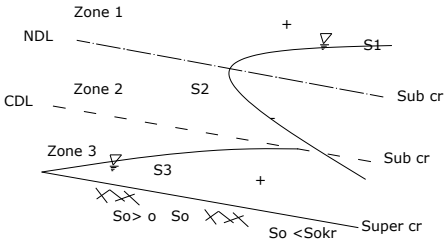

NDL
M2
CDL
So1< Sokr
So2> Sokr

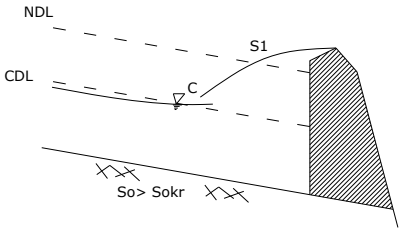

NDL
M2
CDL
hkr
So< Sokr

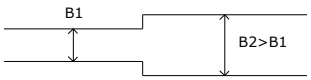

NDL
CDL
M3
So< Sokr

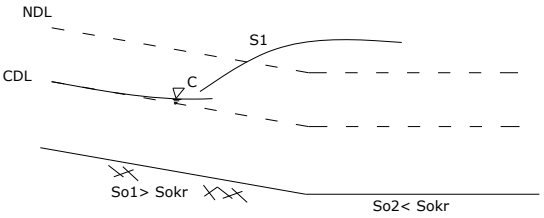

NDL
CDL
M3
So1> Sokr
So2> Sokr

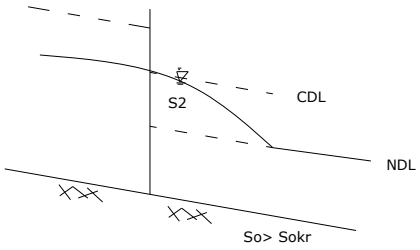
KURVA S

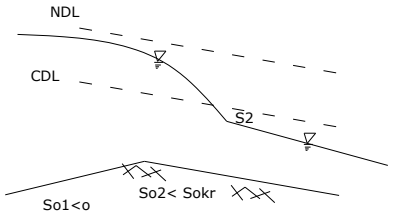

Zone 1
NDL
+
S1
Sub cr
CDL
Zone 2
S2
Zone 3
S3
Sub cr
+
So> o
So
So <Sokr
Super cr

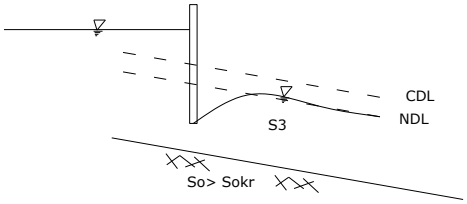

NDL
S1
CDL
C
So> Sokr

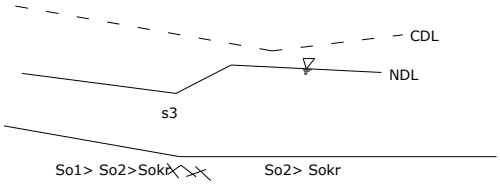

B1
B2>B1


NDL
S1
CDL
C
So1> Sokr
So2< Sokr

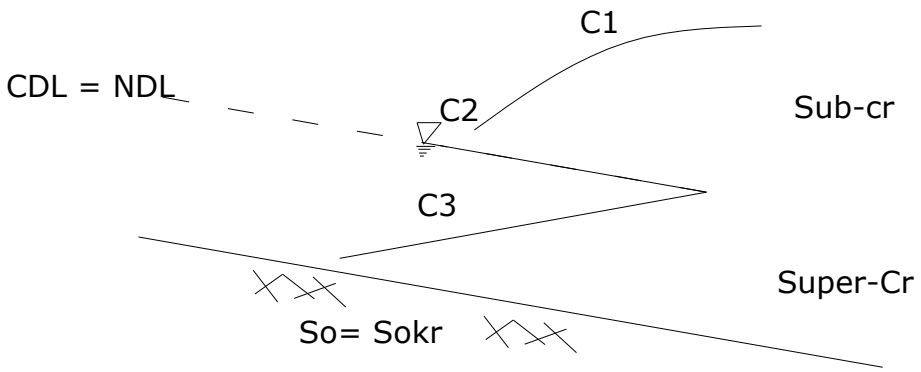

S2
CDL
NDL
So> Sokr

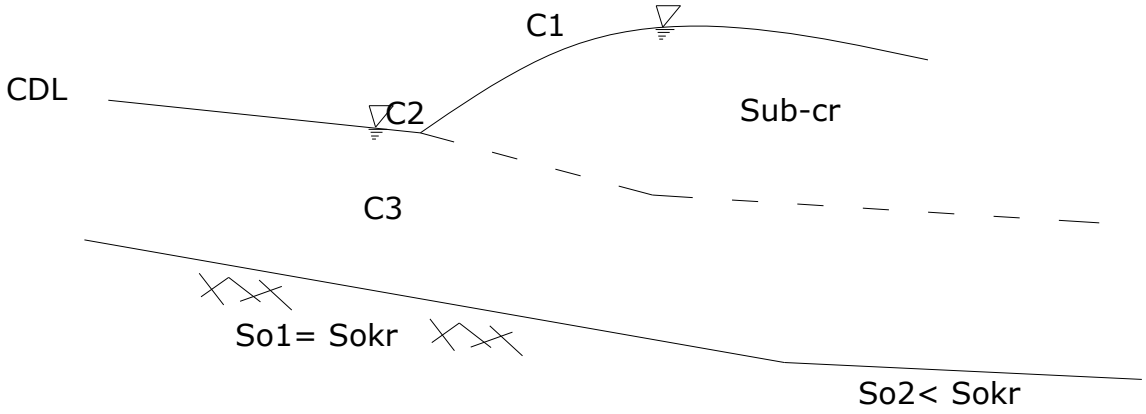

NDL
CDL
S2
So1<o
So2< Sokr

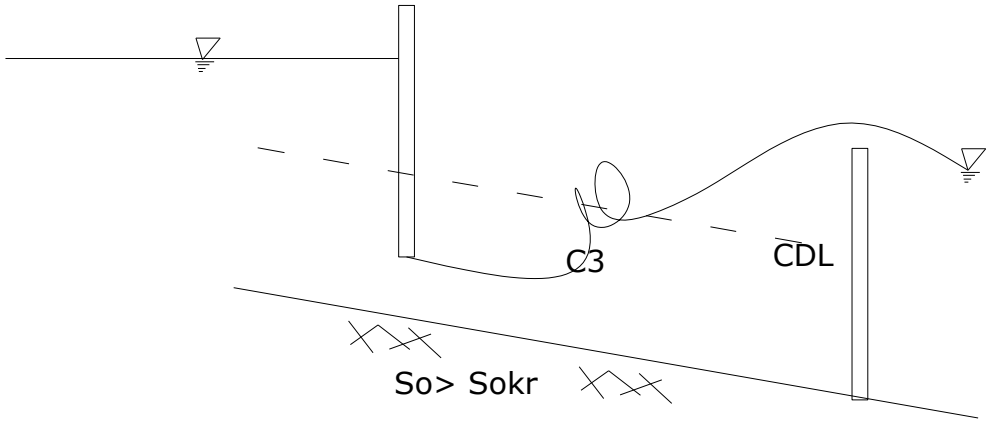

CDL
S3
NDL
So> Sokr


CDL
NDL
s3
So1> So2>Sokr
So2> Sokr

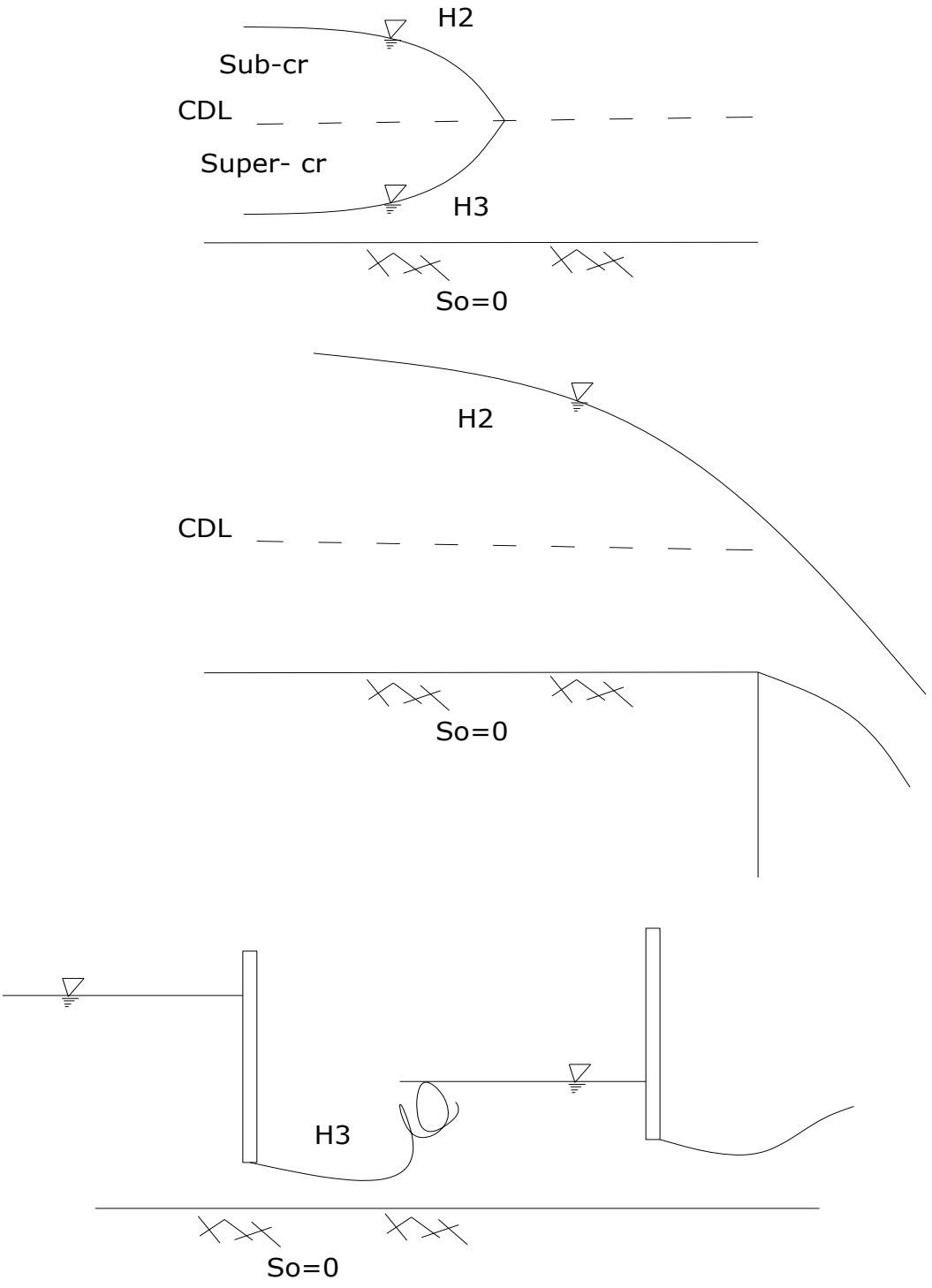
KURVA C


C1
CDL = NDL
C2
Sub-cr
C3
Super-Cr
So= Sokr

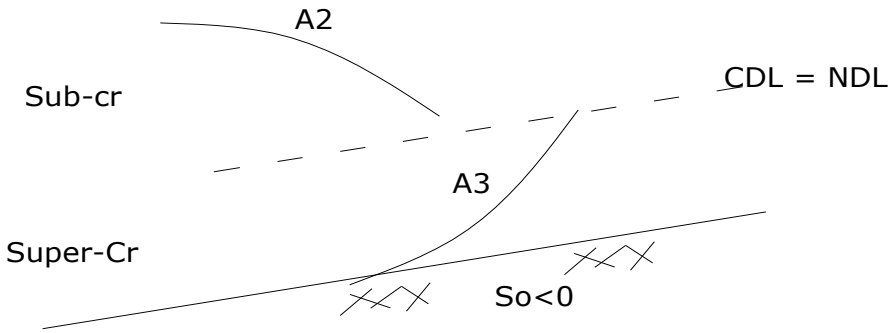

C1
CDL
C2
Sub-cr
C3
So1= Sokr
So2< Sokr

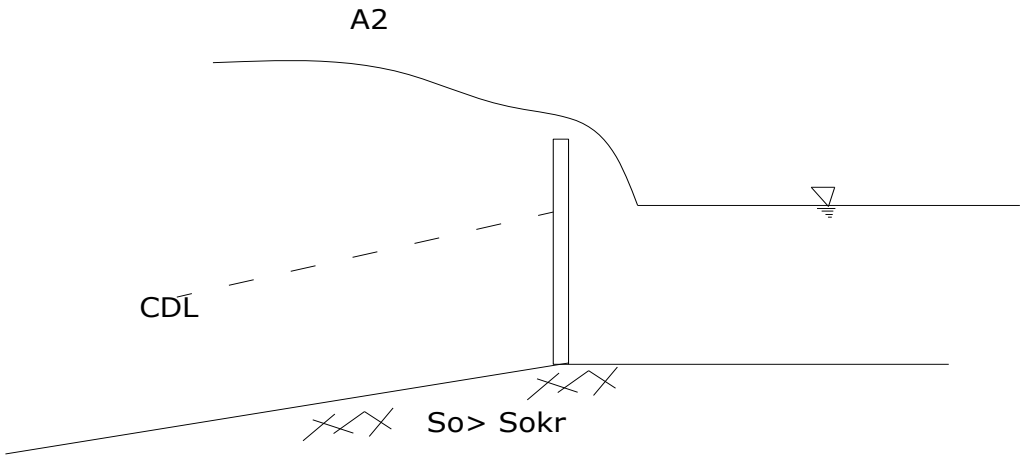

C3
CDL
So> Sokr

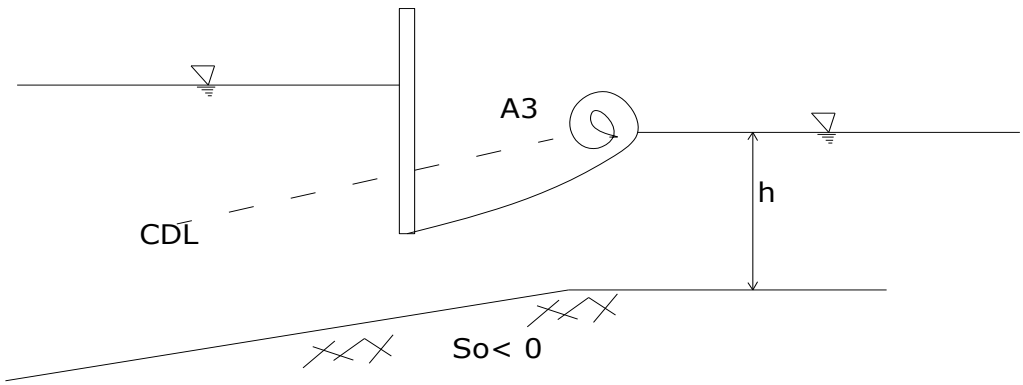
KURVA H



KURVA A







Hitungan profil aliran

Persamaan aliran non – uniform

$Dh/ds = (So - Sf)/(1 - \alpha.Q^2.\ B / g.A^3) = So.\ (1- So/Sf)/(1 - \alpha.Q^2.\ B / g.A^3)$

Metode Integrasi Grafis

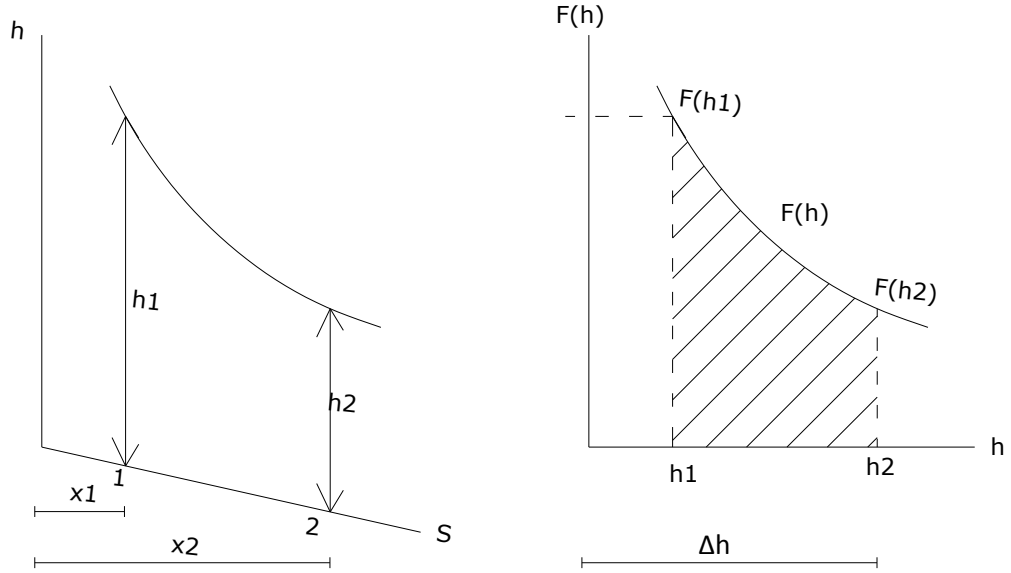
- Baik untuk saluran prismatic

$ds = ((1 - \alpha.Q^2.\ B / g.A^3)/(So - Sf)).dh$

$= F(h)$

$ds = F(h).dh \rightarrow S_{1-2} = \int_{x1}^{x2} ds = \int_{h1}^{h2} F(h).dh$

F9h) → merupakan fungsi yang sulit untuk diintegralkan diselesaikan secara grafis



$S_{1-2} = \int_{h1}^{h2} F(h).dh = \sum_1^2 .F(d).\Delta h$

Langkah perhitungan:

1. Hitung hkr, h normal (H) → H >hkr, Fr < 1 → subkritik

   H = hkr , Fr = 1 → kritik

   H < hkr, F > 1 → superkritik

2. Tentukan bentuk aliran yang terjadi

3. Tentukan interval Δh, dimulai h batas (tergantung no.2) makin kecil Δh, makin teliti hasilnya

   $((b+mH)^3.H^3)/(b+2H.\sqrt{1+m^2} = Q^2/C^2.So$

   $((15+1,5)^3.1,5^3)/(15+2.1,5.\sqrt{1+1^2} = Q^2/52,14^2.0,0001$

   $Q = 14,63\ m^3/s$

   Cek jenis aliran → kemiringan dasar atau Fr

   $U = Q/A = (14,63/(15+1.1,5).1,5) = 0,591\ m/s$

   $Fr = u/\sqrt{g}.D$ → $D = A/B$

   $Fr = u/\sqrt{g}.(b+mh)h)/(b+2mh)) = 0,161 < 1,0$ (aliran subkritik)

   Kemiringan dasar landai → kurva M

   Menghitung kedalaman air kritik

   $A^3/ B = \alpha.Q^2/g$ → $.hkr^3(b+hkr)^3)/(b+2mhkr)) = \alpha.Q^2/g$ → $\alpha \approx 1$

   $hkr^3(15+hkr)^3)/(15+2.1.hkr = 21,82$ → hkr dihitung dengan trial dan error

   $hkr = 0,5$ → $29,09 \neq 21,82$

   $hkr = 0,45$ → $21,14 \neq 21,82$

   $hkr = 0,455$ → $21,85 \approx 21,82$

   karena $h > H$ dan $h > hkr$ → kurva M_1 (dizoma 1)

4. Hitung F (h) dengan rumus, untuk setiap h

   $F(h) = ((1 - \alpha.Q^2.\ B\ /\ g.A^3)/(So - Sf))$→ $Sf = Q^2.n^2/A^2.R^{2/3}$ atau $Q^2\ /A^2.C^2.R$

5. Hitung jarak $h_1 - h_2$ yaitu $S_{1\text{-}2}$ dengan menghitung luas daerah yang dibatasi oleh:

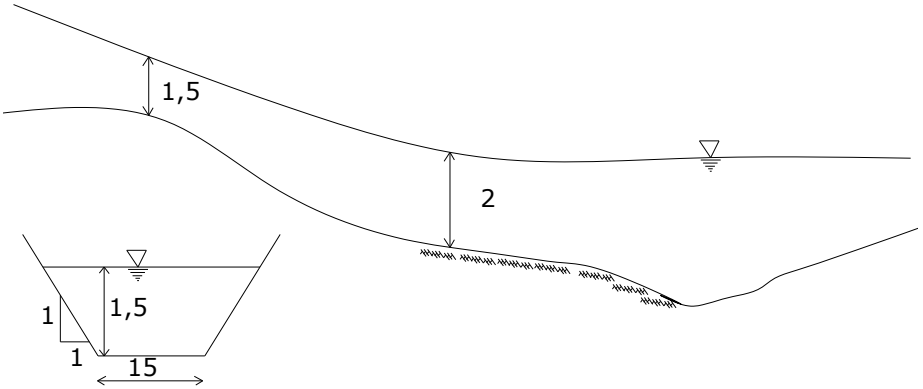
   a. 2 garis // ; $F(h_1)$ dan $F(h_2)$

   b. Tinggi trapezium : $\Delta h = h1 - h2$

      Luas daerah (trapezium) = $(F(h_1) + F(h_2))/2.\Delta h$

6. Ulangi hitungan mulai langkah no.4 untuk setiap harga h

Contoh



Kedalaman air normal, H = 1,5 m

So = 1.10^{-4}

N = 0,02

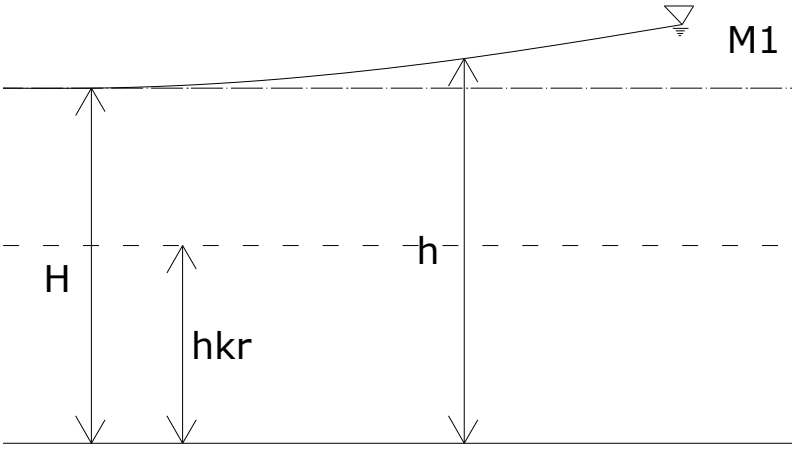
Tentukan profil muka air dihulu reservoir!

Penyelesaian

Kedalaman air normal → perlu Q

$A^3/ P = Q^2/C^2.So$; $C = 1/n. R^{1/6} = 1/n.(A/P)^{1/6}$

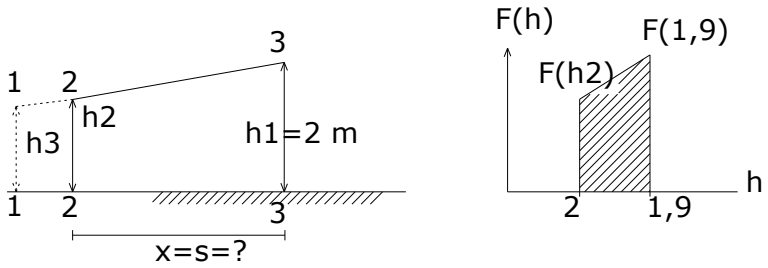
$C = 1/0,02.[(15+1,5)1,5/(15+2.1,5.\sqrt{2})]^{1/6} = 52,142$



Profil muka air dihitung dengan metode integrasi grafis

$S_{1-2} = = \int_{h1}^{h2} F(h).dh = \sum_1^2 .F(h).\Delta h$

$F(h) = ((1 - \alpha.Q^2.\ B / g.A^3)/(So - Sf))$



S_{1-2} = luas arsiran = [F(1,9)+F(2)]/2.(2-1,9)

= 1,71 km

S_{2-3}= [F(1,75)+F(1,9)]/2.(1,9-1,75) = 3,20 km

h(m)	B(m)	A(m2)	R(m)	Sf(-)	F(h) (-)	S (Km)	Skum (km)
2.00	19.000	34.000	1.646	5.313.10^-5	1.60.10^4	0.000	0.000
1.90	18.800	32.110	1.576	6.134.10^-5	1.81.10^4	1.710	1.710
1.75	18.500	29.310	1.469	7.712.10^-5	2.44.10^4	3.200	4.910
1.65	18.300	27.500	1.400	9.046.10^-5	3.57.10^4	3.000	7.910
1.515	18.030	25.020	1.297	1.149.10^-4	3.05.10^4	22.700	30.600
1.505	-	-	-	-	-	-	-
1.501	-	-	-	-	-	-	-
1.500	-	-	-	-	-	-	-