EPFL

CIVIL-312: Hydraulic Engineering and Infrastructures

Direct-Step Method

Instructor: Dr. Clemente Gotelli
Sustainable River Engineering, Energy, & Morphodynamics (STREEM)
GC G1 507
E-mail: clemente.gotelli@epfl.ch

Fall 2025

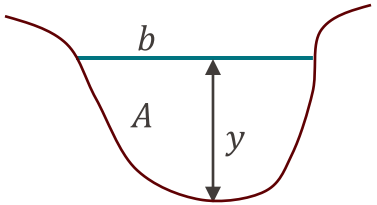
Today's Menu

- Review of previous concepts:
  - Qualitative Analysis of Hydraulic Profiles
    - Types of profiles,
    - Control Points,
    - Hydraulic Jump.
- New content:
  - Quantitative Analysis of Hydraulic Profiles
    - Direct-Step Method

Froude number

- The flow regime is defined by the Froude number (Fr)

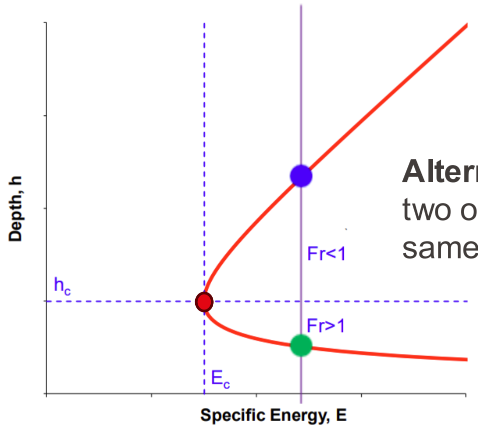
$$Fr = \frac{U}{\sqrt{g\bar{y}}} \quad \text{where} \quad \bar{y} = \frac{A}{b}$$



- Three different regimes:
  - Subcritical ($Fr^2 < 1$):
    - Gravity dominates
  - Supercritical ($Fr^2 > 1$):
    - Inertia dominates
  - Critical: $Fr^2 = 1$
- Specific energy defines depths

$$E = y + \frac{U^2}{2g}$$

  - Minimum at critical ($Fr^2 = 1$)



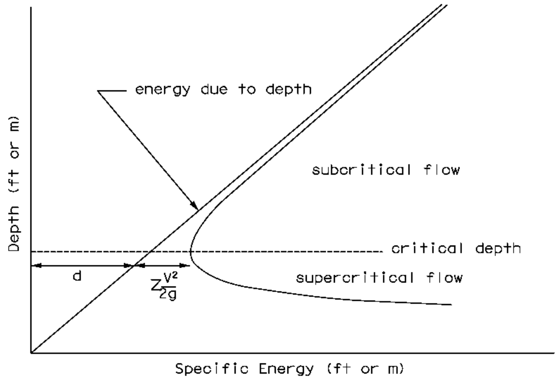
Alternate depths: two options for the same energy level

Normal and Critical depths

- Critical depth:
  - Minimal specific energy
  - Flow independence
  - For rectangular channel of width B:

$$Fr = 1 \rightarrow y_c = \left(\frac{q^2}{g}\right)^{\frac{1}{3}} \qquad \text{where } q = \frac{Q}{B}$$

$$\rightarrow E_c = \frac{3}{2} y_c$$

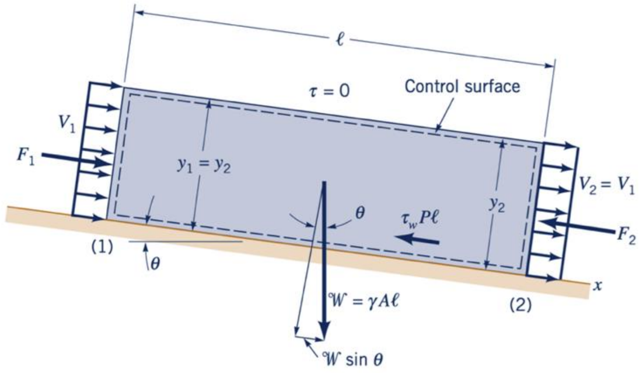


- Normal depth:
  - Flow depth in uniform flow
  - Gravity = Friction
  - From Manning:

$$Q = \frac{1}{n} A R_H^{\frac{2}{3}} \sqrt{S_0}$$

  - From Chézy:

$$V = C\sqrt{R_H S_0}$$



Gradually Varied Flow (GVF) – Equation

- Consider 1D, steady flow in prismatic channel.

$$H \overset{(1)}{=} z_b + E, \qquad E \overset{(2)}{=} y + \frac{V^2}{2g}, \qquad V = \frac{Q}{A(y)}$$

We differentiate (1) and (2) with respect to x:

Energy loss — Bed longitudinal slope

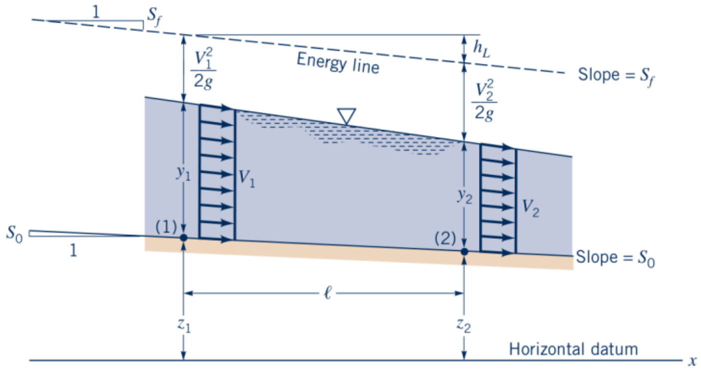
From (1): $$\frac{dH}{dx} = -S_f \quad \& \quad \frac{dz_b}{dx} = -S_0 \quad \rightarrow \quad \frac{dE}{dx} = S_0 - S_f$$

From (2): $$\frac{dE}{dx} = \frac{d}{dx}\left(y + \frac{V^2}{2g}\right) = \frac{dy}{dx} - \frac{Q^2}{g(by)^3}\left(b\frac{dy}{dx}\right)$$

Combining both, we get the **GVF Equation**:

$$\frac{dy}{dx} = \frac{S_0 - S_f}{1 - Fr^2}$$

Imbalance between gravity (bed slope) and **friction (energy slope)** forces scaled by how close the flow is to **critical (Froude) conditions**, which control the **direction and sensitivity** of the profile.



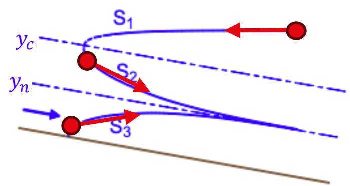
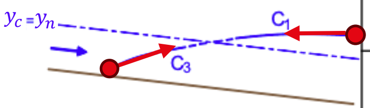
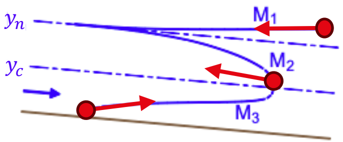
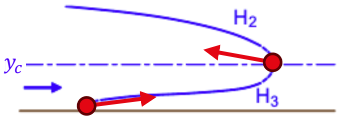
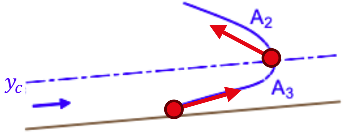
Gradually Varied Flow (GVF) – Profiles

Classification depends on:

- Relation between y_n and y_c
- Where the **known** y **lies**

$$\frac{dy}{dx} = \frac{S_0 - S_f}{1 - Fr^2}$$

- Asymptotic towards h_n
- Perpendicular to h_c

Type	Symbol	Definition	Sketches	Examples
STEEP (normal flow supercritical)	S1	$y > y_c > y_n$		Hydraulic jump upstream with obstruction or reservoir controlling water level downstream.
	S2	$y_c > y > y_n$		Change to steeper slope.
	S3	$y_c > y_n > y$		Change to less steep slope.
CRITICAL (undesirable; undular unsteady flow)	C1	$y > y_c = y_n$		
	C3	$y_c = y_n > y$		
MILD (normal flow subcritical)	M1	$y > y_n > y_c$		Obstruction or reservoir controlling water level downstream.
	M2	$y_n > y > y_c$		Approach to free overfall.
	M3	$y_n > y_c > y$		Hydraulic jump downstream; change from steep to mild slope or downstream of sluice .
HORIZONTAL (limiting mild slope; $h_n \to \infty$)	H2	$y > y_c$		Approach to free overfall.
	H3	$y_c > y$		Hydraulic jump downstream; change from steep to horizontal or downstream of sluice.
ADVERSE (upslope)	A2	$y > y_c$		
	A3	$y_c > y$		

Gradually Varied Flow (GVF) – Profiles

- We know y at **control points**. We start drawing from there.
  - Where the depth is known or can be determined independently (e.g., critical depth at a weir crest, reservoir level, gate opening).
  - Boundary and/or internal conditions in Hydraulic software

- The direction in which a control influences the flow depends on the flow regime:
  - Subcritical flow $(Fr^2 < 1)$: Downstream control.
    - Disturbances propagate upstream;
    - Water surface profile is drawn by marching upstream from the control
  - Supercritical flow $(Fr^2 > 1)$: Upstream control.
    - Disturbances propagate only downstream;
    - Water surface profile is drawn by marching downstream from the control
  - Critical flow $(Fr^2 = 1)$: Independence point
    - Disturbances are “stuck”
    - **We stop drawing at this point and retake from somewhere else**

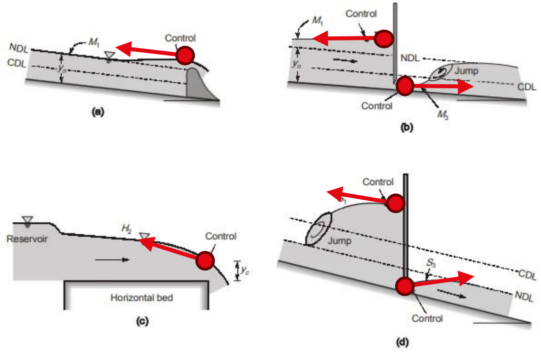
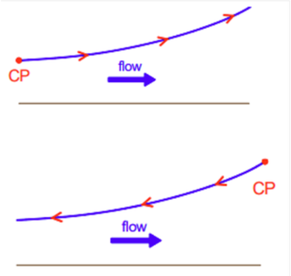


Fig. Examples of Controls in GVF



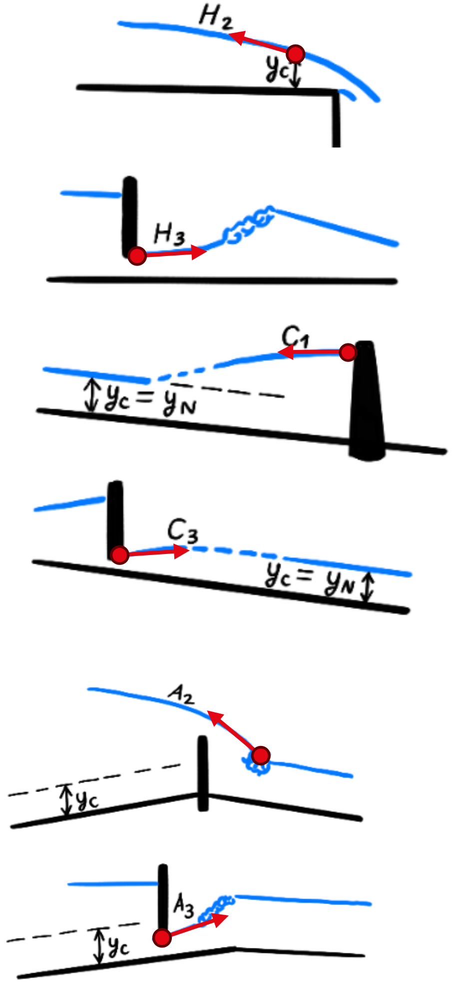
Supercritical $(Fr > 1)$
Upstream control
Forward integration

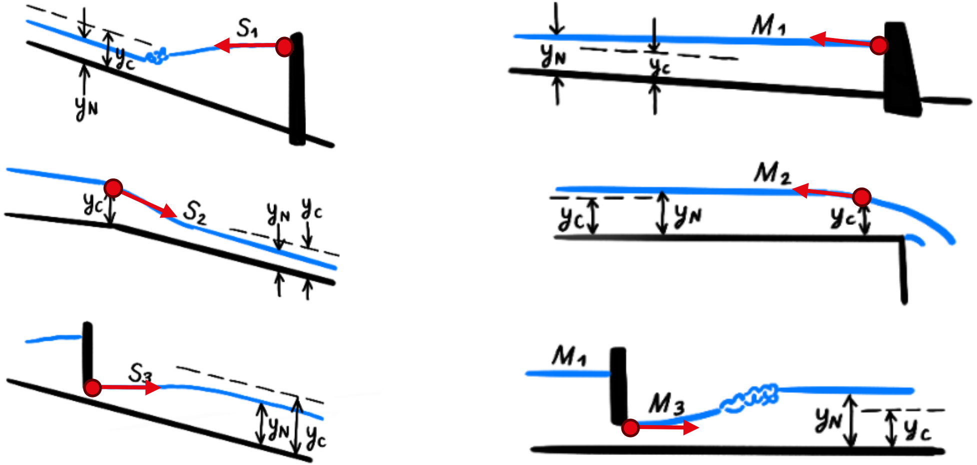
Subcritical $(Fr < 1)$
Downstream control
Backward integration

Gradually Varied Flow (GVF)

- Examples in “real life”
- These are **units** representing **local behavior**

How do they combine to form a full hydraulic profile?



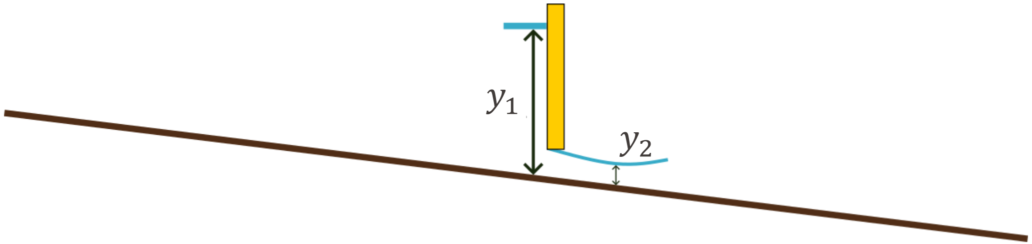


Gradually Varied Flow (GVF)

- Example – Gate on a Steep Slope

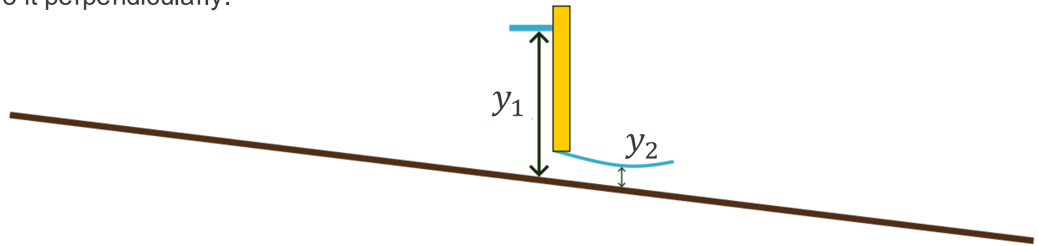
A long rectangular channel of width 2.2 m, streamwise slope 1/100 and Chézy coefficient 80 $m^{1/2}$ s^{-1} carries a discharge of 4.5 m^3 s^{-1}. The depth of parallel flow downstream of the gate (y_2) is 0.35 m. The depth just upstream the gate (y_1) is 2.04 m.

Draw the hydraulic profile on both sides of the gate.



Gradually Varied Flow (GVF)

- Example – Gate on a Steep Slope
- Always three steps:
  1. Compute and draw y_n and y_c
  2. Look for control points. Sometimes we must assume conditions on the borders.
  3. Connect known points with corresponding local profile (i.e., M_i, S_i, C_i, H_i, A_i)
     - From a CP we must move upstream or downstream (depending on the regime).
     - We tend asymptotically to y_n.
     - If we pass through y_c we must do it perpendicularly.



Gradually Varied Flow (GVF)

- Example – Gate on a Steep Slope
- Solution:

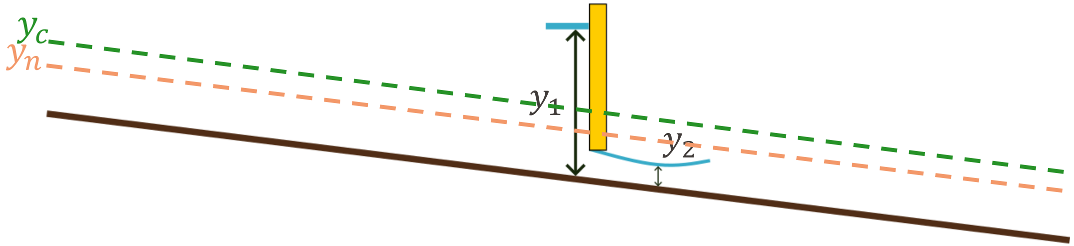
Q = 4.5 m³/s

S_0 = 0.01

C = 80 $m^{1/2}$ s^{-1}

b = 2.2 m

$$y_1 = 2.09\ m$$
$$y_2 = 0.35\ m$$



- Steps:

1. Compute y_n & y_c

y_c from $Fr = 1$

$$y_c = \left(\frac{q^2}{g}\right)^{\frac{1}{3}}$$

$$y_c = 0.7526\ \text{m}$$

y_n from Chézy:

$$V = CR_h^{1/2}S_0^{1/2}$$

$$y_n = 0.4518\ \text{m}$$

Gradually Varied Flow (GVF)

- Example – Gate on a Steep Slope
- Solution:

Q = 4.5 m³/s $y_c = 0.753\,m$

S_0 = 0.01 $y_n = 0.452\,m$

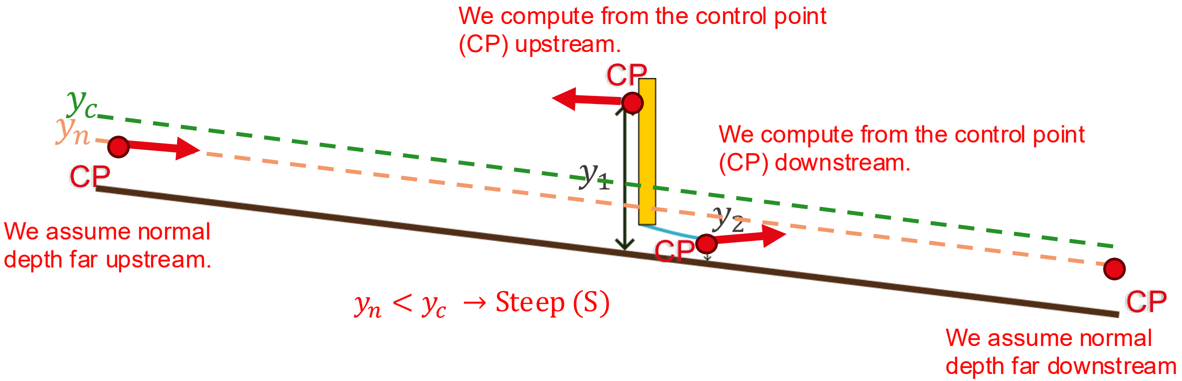
C = 80 $m^{1/2}\,s^{-1}$

b = 2.2 m $y_1 = 2.09\,m$

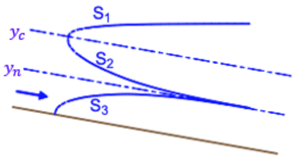
$y_2 = 0.35\,m$

- Steps:

1. Compute y_n & y_c
2. Find Control Points



uniform flow | $y_n < y_c < y$ → $S1$ | $y < y_n < y_c$ → $S3$ | uniform flow



Gradually Varied Flow (GVF)

- Example – Gate on a Steep Slope
- Solution:

Q = 4.5 m³/s $y_c = 0.753\ m$

S_0 = 0.01 $y_n = 0.452\ m$

C = 80 $m^{1/2}$ s^{-1}

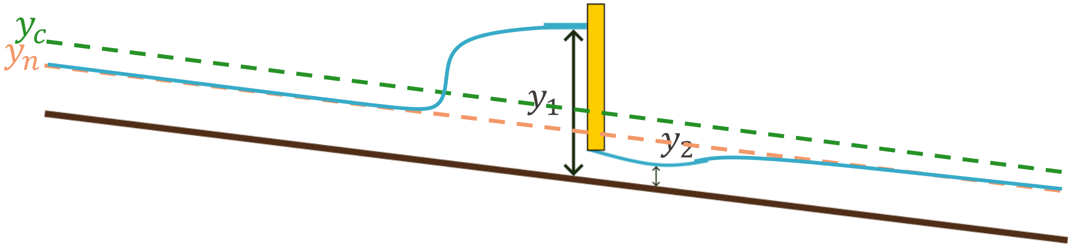
b = 2.2 m $y_1 = 2.09\ m$

$y_2 = 0.35\ m$

- Steps:

1. Compute y_n & y_c
2. Find Control Points
3. Draw profile qualitatively

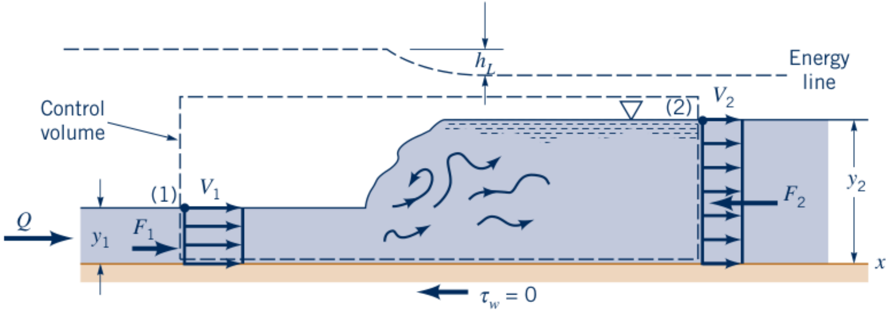
Hydraulic jump because we pass from super to subcritical

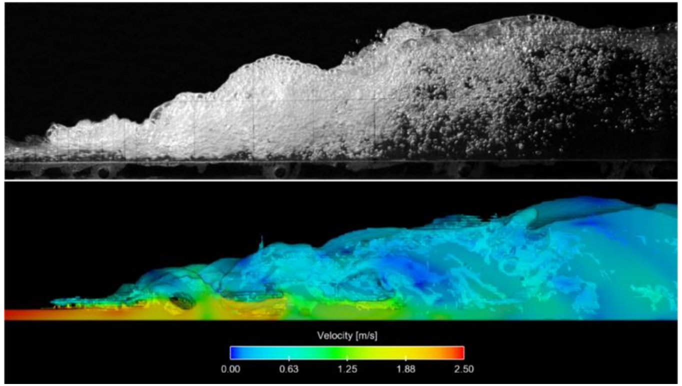


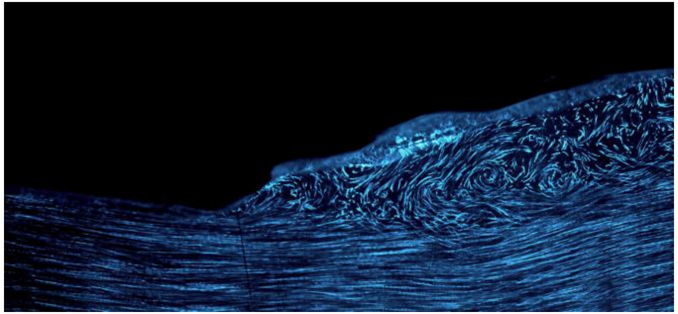
Hydraulic Jump

- Abrupt change from shallow ($Fr > 1$) to deep ($Fr < 1$)
- Occurs where up- and downstream depths are not compatible
- Smooth transition $Fr > 1$ to $Fr < 1$ not possible on a flat bed
- Conjugate or Sequent depths

$$\frac{y_2}{y_1} = \frac{1}{2}\left(-1 + \sqrt{1 + 8Fr_1^2}\right)$$



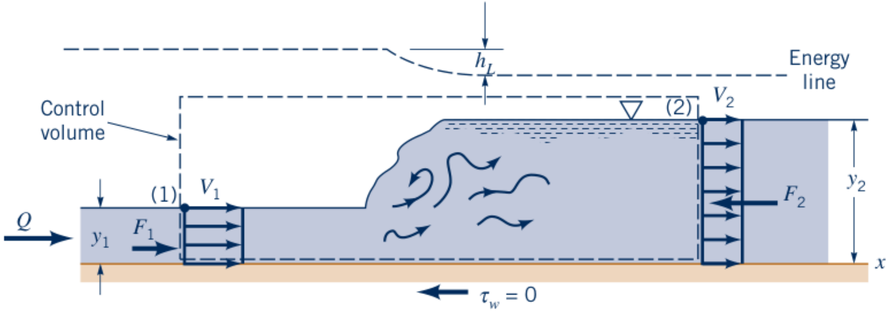


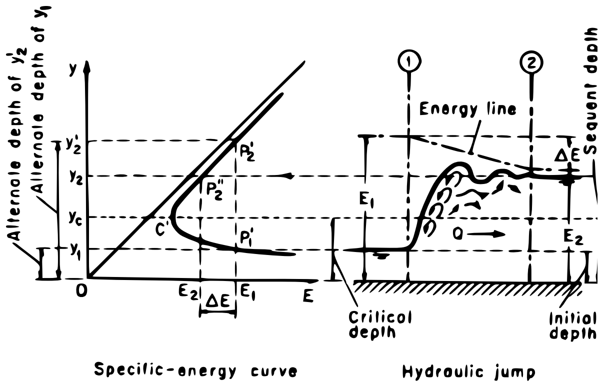


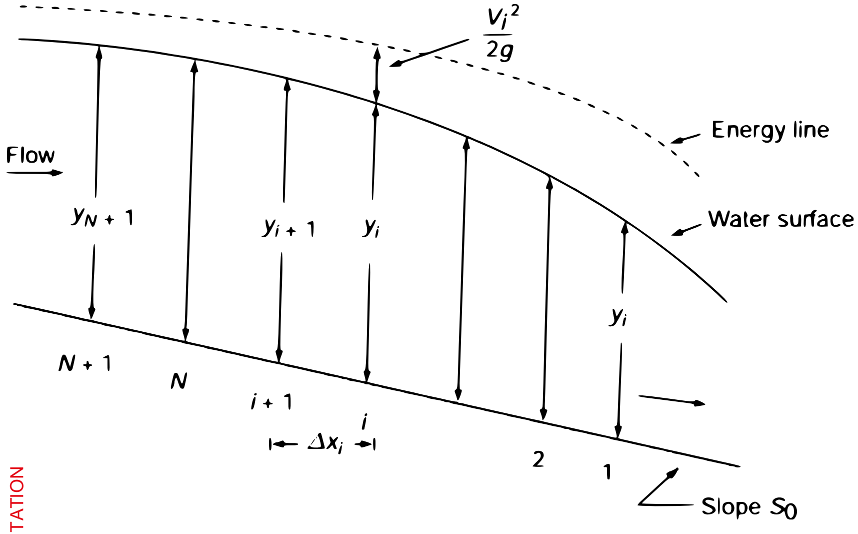
Hydraulic Jump

- Abrupt change from shallow ($Fr > 1$) to deep ($Fr < 1$)
- Occurs where up- and downstream depths are not compatible
- Smooth transition $Fr > 1$ to $Fr < 1$ not possible on a flat bed
- Conjugate or Sequent depths

$$\frac{y_2}{y_1} = \frac{1}{2}\left(-1 + \sqrt{1 + 8Fr_1^2}\right)$$







Direct Step Method

Direct Step Method

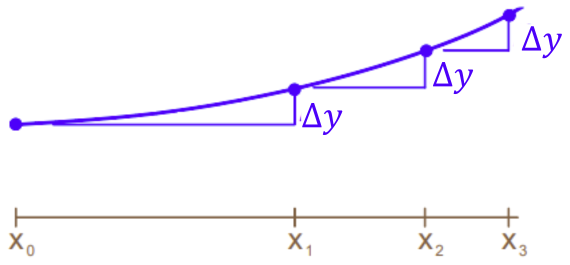
- We want to compute the water surface profile

$$\frac{dy}{dx} = \frac{S_0 - S_f}{1 - Fr^2}$$

- Impossible to solve analytically (in most circumstances)
- Find depths $y_1, y_2, y_3, \ldots$ at discrete points $x_1, x_2, x_3, \ldots$
- We approximate dy/dx by $\Delta y/\Delta x$, where:

$$\Delta y = y_{i+1} - y_i \qquad \Delta x = x_{i+1} - x_i$$

- We compute all depths starting from a known point and moving upstream or upstream (depending on the case)



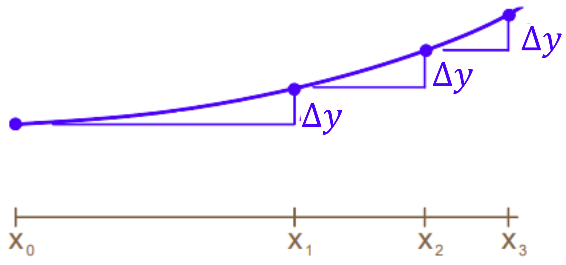
Direct Step Method

- We inverse the equation for stability around h_c

$$\frac{dy}{dx} = \frac{S_0 - S_f}{1 - Fr^2} \quad \rightarrow \quad \frac{dx}{dy} = \frac{1 - Fr^2}{S_0 - S_f}$$

- We use the approximation

$$\frac{dx}{dy} \approx \frac{\Delta x}{\Delta y} \rightarrow \Delta x \approx \left(\frac{dx}{dy}\right)_{\text{mid}} \Delta y$$



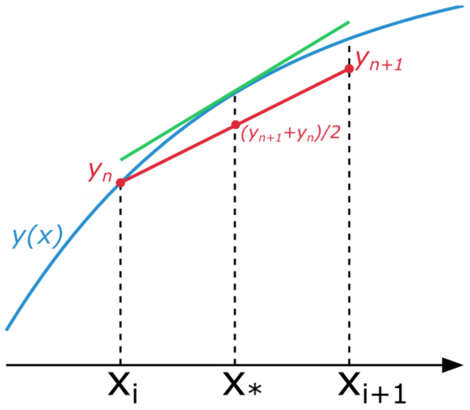
$$\Delta x \approx \left(\frac{1 - Fr^2}{S_0 - S_f}\right) \Delta y$$

← We set Δy and compute Δx

Where Fr and S_f depend on y:

$$Fr(y) = \frac{V(y)}{\sqrt{g\bar{y}(y)}} = \frac{Q}{\sqrt{\frac{gA(y)^3}{b_s(y)}}} \quad , \quad S_f(y) = \frac{n^2 Q^2}{R_h(y)^{\frac{4}{3}} A(y)^2}$$

From Manning or Chézy

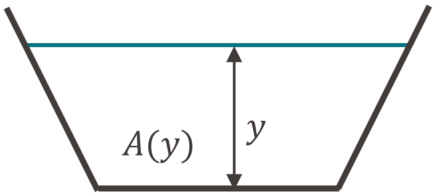


mid: midpoint method

Direct Step Method

- Step-by-step procedure:
  - Input data: Specify $(Q), (S_0), (n)$, channel geometry, and boundary condition (x_0, y_0)
  - Direction of march:
    - *Subcritical flow:* march upstream from downstream control
    - *Supercritical flow:* march downstream from upstream control
  - Initialize: Set $(i = 0), (x_0), (y_0)$, and select initial $(\Delta\, y)$
  - For each step:
    - Propose $y_{i+1} = y_i + \boldsymbol{\Delta\, y}$
    - Compute $y_m = (y_i + y_{i+1})/2$ ← Midpoint method
    - Evaluate $A(y_m), P(y_m), R_h(y_m), V(y_m) = Q/A(y_m)$
    - Compute $Fr(y_m)$ and $S_f(y_m)$
    - Check denominators: if $(|1 - Fr(y_m)^2|)$ or $|S_0 - S_f(y_m)|$ is too small, reduce $|\Delta\, y|$
    - Compute $\Delta\, x$
    - Update: $x_{i+1} = x_i + \Delta x \quad , \qquad i \leftarrow i + 1$
  - Stopping criteria: Continue until reaching target depth, distance, or a transition zone (e.g., approaching (y_c)) or reaching a structure)

Important Note:
This method works only for prismatic channels



Direct Step Method

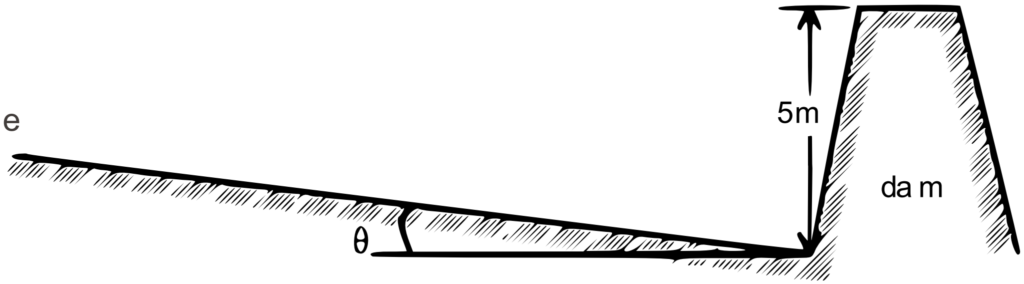
- Example 1 – Flow Approaching a Dam

A prismatic **rectangular channel** carries **Q = 10 m³/s** with **width b = 3 m**, **bed slope S_0 = 0.001**, and **Manning n = 0.022**. A little before the downstream control (the dam crest) the water depth is **y_0 = 5.0 m**.

Task: Using the **direct-step method**, compute the **upstream distance L** over which the dam affects the water surface profile (backwater curve). Define the "limit of influence" of the dam.

- Steps:

1. Compute y_n & y_c
2. Find Control Points
3. Draw profile qualitatively
4. Compute the profile with a Table



Direct Step Method

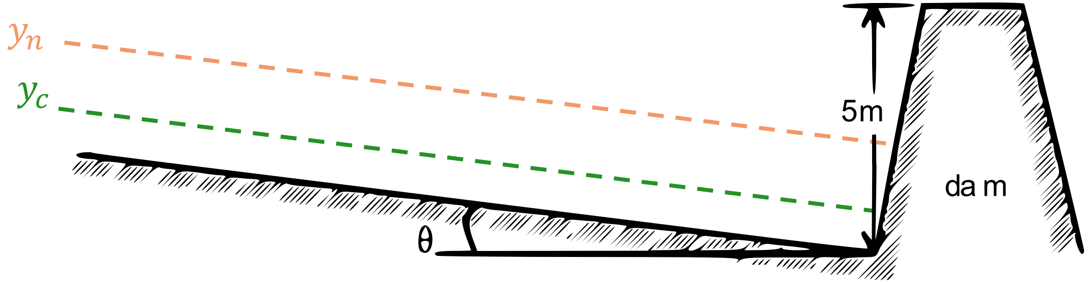
- Example 1 – Flow Approaching a Dam
- Solution:

Q = 10 m³/s $\boldsymbol{y_c = 1.04\ m}$

b = 3 m $\boldsymbol{y_n = 2.44\ m}$

S_0 = 0.001

n = 0.022.



- Steps:

1. Compute y_n & y_c

y_c from Froude:

$$Fr^2 = 1 \rightarrow \frac{U^2}{gy} = 1 \rightarrow \frac{Q^2}{b^2y^3g} = 1$$

$$\rightarrow \boldsymbol{y_c = \left(\frac{Q^2}{b^2g}\right)^{\frac{1}{3}} = 1.04\ m}$$

y_n from Manning:

$$Q = \frac{1}{n}AR^{\frac{2}{3}}S^{\frac{1}{2}} = \frac{1}{n}(by)\left(\frac{by}{b+2y}\right)^{\frac{2}{3}}S^{\frac{1}{2}}$$

$$\rightarrow \boldsymbol{y_n = 2.437\ m}$$

Direct Step Method

- Example 1 – Flow Approaching a Dam
- Solution:

Q = 10 m³/s $y_c = 1.04\ m$

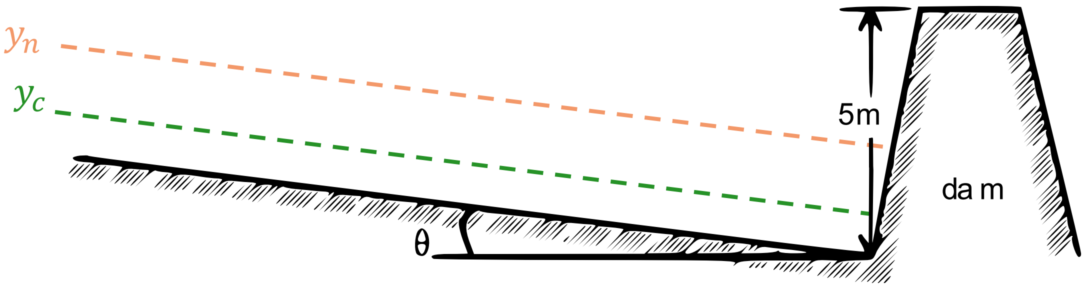
b = 3 m $y_n = 2.44\ m$

S_0 = 0.001

n = 0.022.

- Steps:

1. Compute y_n & y_c



$y_n > y_c \rightarrow$ mild (M)

Direct Step Method

- Example 1 – Flow Approaching a Dam
- Solution:

Q = 10 m³/s $y_c = 1.04\ m$

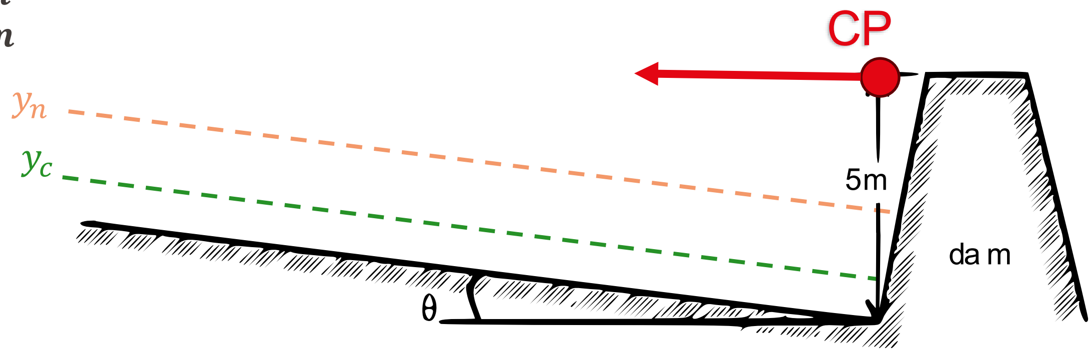
b = 3 m $y_n = 2.44\ m$

S_0 = 0.001

n = 0.022.

- Steps:

1. Compute y_n & y_c
2. Find Control Points

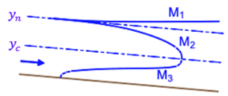


$y_n > y_c \rightarrow$ mild (M)

We compute from the control point (CP) upstream.

$y > y_n > y_c \rightarrow M1$

M1	$y > y_n > y_c$	
M2	$y_n > y > y_c$	
M3	$y_n > y_c > y$	



Direct Step Method

- Example 1 – Flow Approaching a Dam
- Solution:

Q = 10 m³/s $y_c = 1.04\ m$

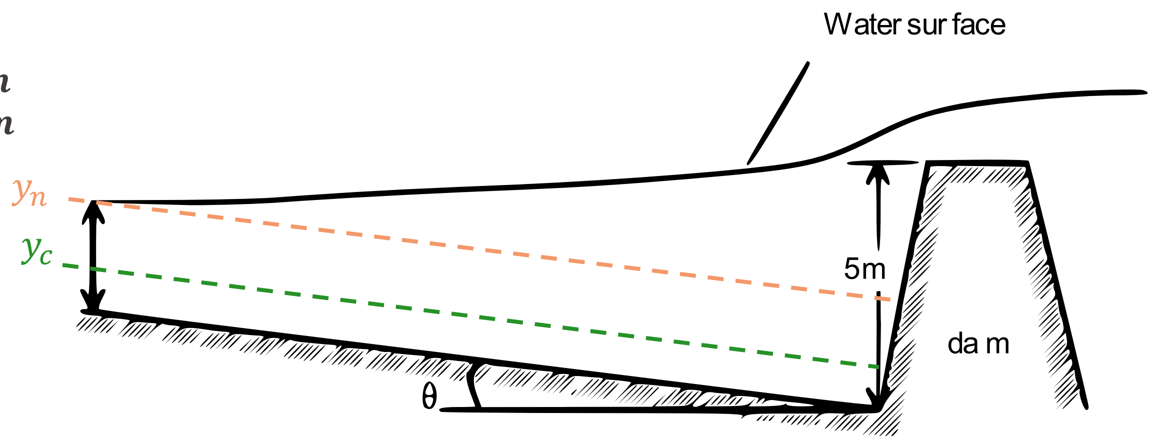
b = 3 m $y_n = 2.44\ m$

S_0 = 0.001

n = 0.022.

- Steps:

1. Compute y_n & y_c
2. Find Control Points
3. Draw profile qualitatively

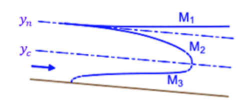


$y_n > y_c \ \rightarrow$ mild (M)

We compute from the control point (CP) upstream.

$y > y_n > y_c \ \rightarrow M1$

M1	$y > y_n > y_c$
M2	$y_n > y > y_c$
M3	$y_n > y_c > y$



Direct Step Method

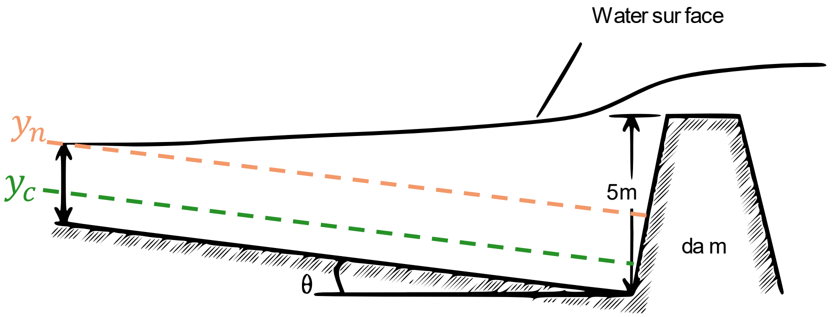
- Example 1 – Flow Approaching a Dam
- Solution:

Q = 10 m³/s $\qquad y_c = 1.04\ m$

b = 3 m $\qquad y_n = 2.44\ m$

$S_0 = 0.001$

n = 0.022.



- Steps:

1. Compute y_n & y_c
2. Find Control Points
3. Draw profile qualitatively
4. Compute the profile with a Table

Section	y_i (m)	dy (m)	y_med (m)	A (m2)	v (m/s)	Fr	1-Fr^2	P (m)	R (m)	S_f	S_0-S_f	dx (m)	x (m)
1	5.00	0.25	4.875	14.625	0.684	0.099	0.990	12.750	1.147	0.00019	0.00081	305.04	0
2	4.75	0.25	4.625	13.875	0.721	0.107	0.989	12.250	1.133	0.00021	0.00079	314.00	305.04
3	4.50	0.25	4.375	13.125	0.762	0.116	0.986	11.750	1.117	0.00024	0.00076	325.53	619.04
4	4.25	0.25	4.125	12.375	0.808	0.127	0.984	11.250	1.100	0.00028	0.00072	340.83	944.58
5	4.00	0.25	3.875	11.625	0.860	0.140	0.981	10.750	1.081	0.00032	0.00068	361.91	1285.41
6	3.75	0.25	3.625	10.875	0.920	0.154	0.976	10.250	1.061	0.00038	0.00062	392.49	1647.31
7	3.50	0.25	3.375	10.125	0.988	0.172	0.971	9.750	1.038	0.00045	0.00055	440.32	2039.81
8	3.25	0.25	3.125	9.375	1.067	0.193	0.963	9.250	1.014	0.00054	0.00046	524.35	2480.12
9	3.00	0.25	2.875	8.625	1.159	0.218	0.952	8.750	0.986	0.00066	0.00034	706.95	3004.47
10	2.75	0.31	2.595	7.785	1.285	0.255	0.935	8.190	0.951	0.00085	0.00015	1992.04	3711.42
11	**2.44**												**5703.46**

Direct Step Method

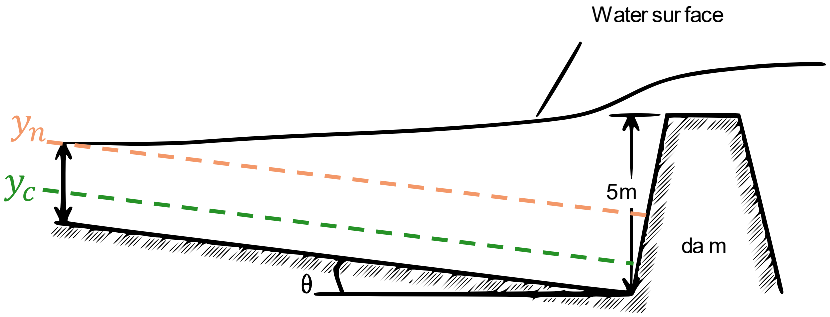
- Example 1 – Flow Approaching a Dam
- Solution:

Q = 10 m³/s $y_c = 1.04\ m$

b = 3 m $y_n = 2.44\ m$

S_0 = 0.001

n = 0.022.



- Steps:

1. Compute y_n & y_c
2. Find Control Points
3. Draw profile qualitatively
4. Compute the profile with a Table

Section	y_i (m)	dy (m)	y_med (m)	A (m2)	v (m/s)	Fr	1-Fr^2	P (m)	R (m)	S_f	S_0-S_f	dx (m)	x (m)
1	5.00	0.25	4.875	14.625	0.684	0.099	0.990	12.750	1.147	0.00019	0.00081	305.04	0
2	4.75	0.25	4.625	13.875	0.721	0.107	0.989	12.250	1.133	0.00021	0.00079	314.00	305.04
3	4.50	0.25	4.375	13.125	0.762	0.116	0.986	11.750	1.117	0.00024	0.00076	325.53	619.04
4	4.25	0.25	4.125	12.375	0.808	0.127	0.984	11.250	1.100	0.00028	0.00072	340.83	944.58
5	4.00	0.25	3.875	11.625	0.860	0.140	0.981	10.750	1.081	0.00032	0.00068	361.91	1285.41
6	3.75	0.25	3.625	10.875	0.920	0.154	0.976	10.250	1.061	0.00038	0.00062	392.49	1647.31
7	3.50	0.25	3.375	10.125	0.988	0.172	0.971	9.750	1.038	0.00045	0.00055	440.32	2039.81
8	3.25	0.25	3.125	9.375	1.067	0.193	0.963	9.250	1.014	0.00054	0.00046	524.35	2480.12
9	3.00	0.25	2.875	8.625	1.159	0.218	0.952	8.750	0.986	0.00066	0.00034	706.95	3004.47
10	2.75	0.31	2.595	7.785	1.285	0.255	0.935	8.190	0.951	0.00085	0.00015	1992.04	3711.42
11	**2.44**												**5703.46**

The effect of the dam is felt almost 6 km upstream!
Longer than the M1 metro line from EPFL to Flon :O

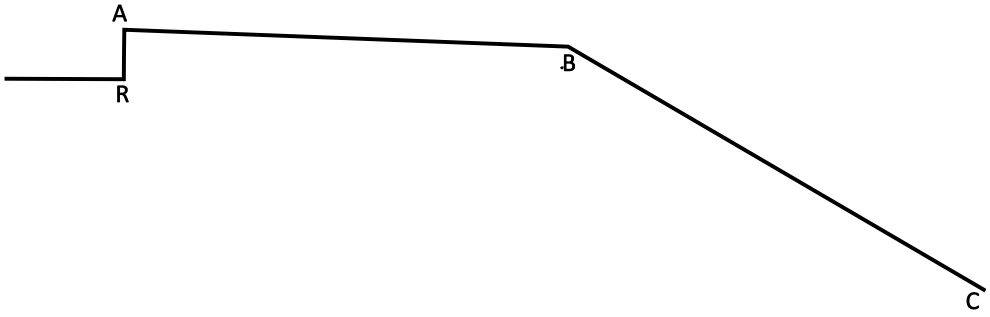
Direct Step Method

- Example 2 – Flow Leaving a Reservoir

A long trapezoidal channel with side slopes of 3H:2V and a bottom width of 1.5 m conveys water from a large reservoir **R** at a discharge rate of **6 m³/s**.

The channel consists of a first reach **AB**, 150 m long, with a slope of **0.001**, followed by a second reach **BC** with a slope of **0.015**. The Manning roughness coefficient is **n = 0.0143**.

Plot the hydraulic grade line from the channel entrance (**A**) to point **C**, located 100 m downstream of point **B**.



Direct Step Method

- Example 2 – Flow Leaving a Reservoir
- Solution:

Q = 6 m³/s

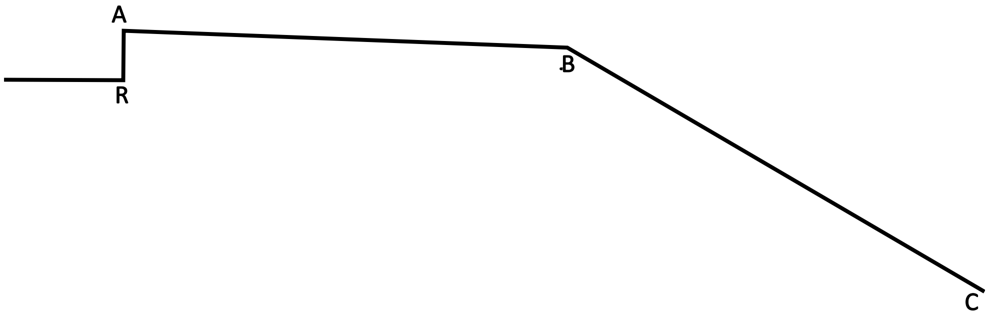
S_1 = 0.001

S_2 = 0.015

n = 0.0143

b = 1.5

H/V = 3/2



- Steps:

1. Compute y_n & y_c

y_c from Froude:

$$Fr^2 = 1 \rightarrow \frac{U^2}{g\bar{y}} = 1$$

$$\rightarrow \boldsymbol{y_c = 0.879\ m}$$

y_n from Manning:

$$Q = \frac{1}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}}$$

$$\rightarrow \boldsymbol{y_{n1} = 1.132\ m}$$

$$\rightarrow \boldsymbol{y_{n2} = 0.570\ m}$$

Direct Step Method

- Example 2 – Flow Leaving a Reservoir
- Solution:

Q = 6 m³/s

S_1 = 0.001

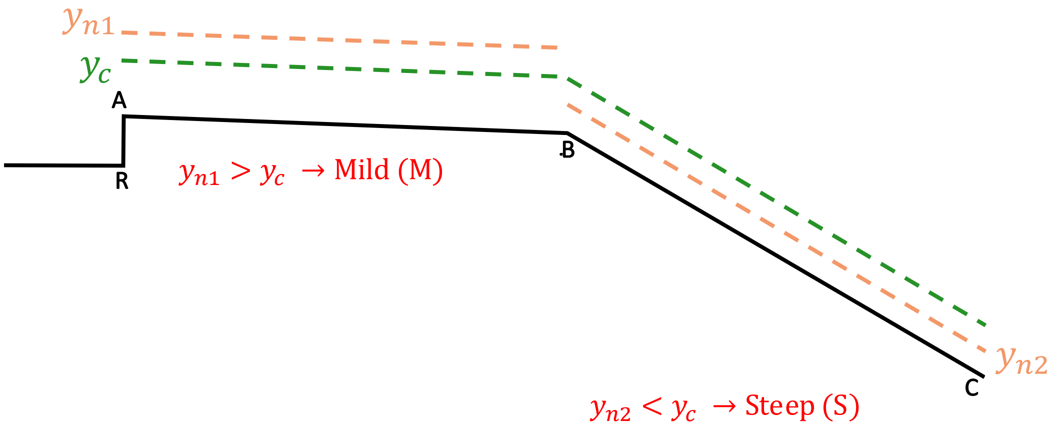
S_2 = 0.015

n = 0.0143

b = 1.5

H/V = 3/2

$$y_c = 0.879\ m$$
$$y_{n1} = 1.132\ m$$
$$y_{n2} = 0.570\ m$$



- Steps:

1. Compute h_n & h_c

Direct Step Method

- Example 2 – Flow Leaving a Reservoir
- Solution:

Q = 6 m³/s

$S_1 = 0.001$

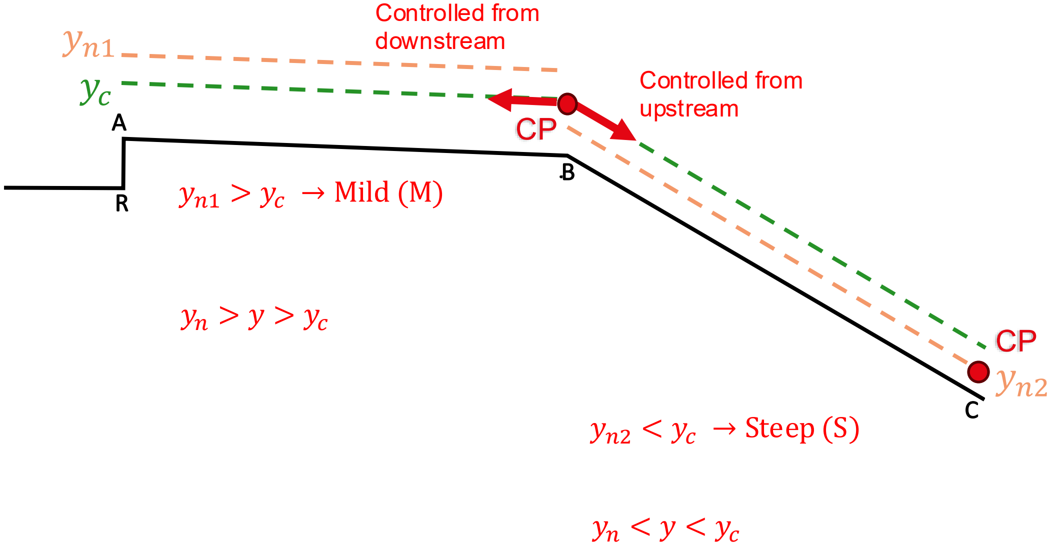
$S_2 = 0.015$

n = 0.0143

b = 1.5

H/V = 3/2

$$y_c = 0.879\ m$$
$$y_{n1} = 1.132\ m$$
$$y_{n2} = 0.570\ m$$



- Steps:

1. Compute h_n & h_c
2. Find Control Points

Direct Step Method

- Example 2 – Flow Leaving a Reservoir
- Solution:

Q = 6 m³/s $y_c = 0.879\ m$

S_1 = 0.001 $y_{n1} = 1.132\ m$

S_2 = 0.015 $y_{n2} = 0.570\ m$

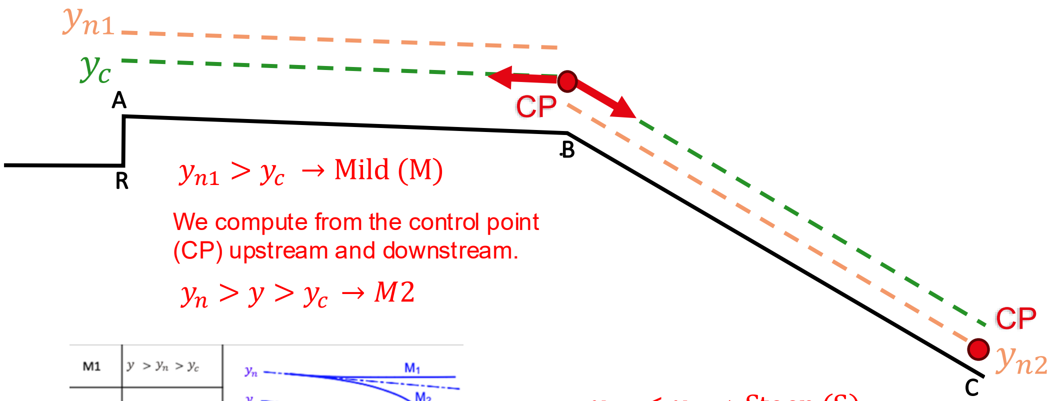
n = 0.0143

b = 1.5

H/V = 3/2

- Steps:

1. Compute h_n & h_c
2. Find Control Points

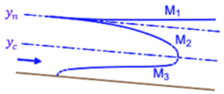


$y_{n1} > y_c$ → Mild (M)

We compute from the control point (CP) upstream and downstream.

$y_n > y > y_c \rightarrow M2$

M1	$y > y_n > y_c$
M2	$y_n > y > y_c$
M3	$y_n > y_c > y$

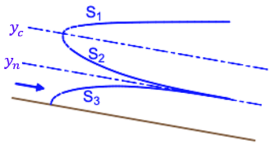


$y_{n2} < y_c$ → Steep (S)

We assume normal depth far downstream

$y_n < y < y_c \rightarrow S2$

S1	$y > y_c > y_n$
S2	$y_c > y > y_n$
S3	$y_c > y_n > y$



Direct Step Method

- Example 2 – Flow Leaving a Reservoir
- Solution:

Q = 6 m³/s

$S_1 = 0.001$

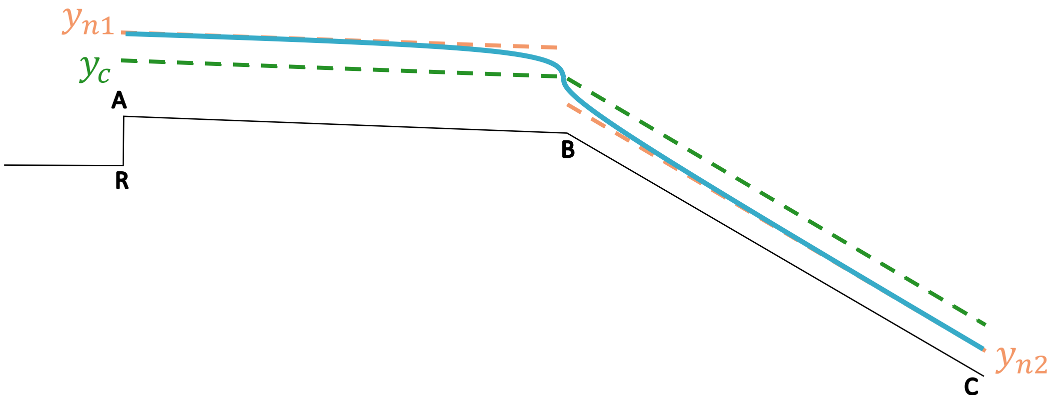
$S_2 = 0.015$

n = 0.0143

b = 1.5

H/V = 3/2

$$y_c = 0.879\ m$$
$$y_{n1} = 1.132\ m$$
$$y_{n2} = 0.570\ m$$



- Steps:

1. Compute h_n & h_c
2. Find Control Points
3. Draw profile qualitatively

Direct Step Method

- Example 2 – Flow Leaving a Reservoir
- Solution:

Q = 6 m³/s

S_1 = 0.001

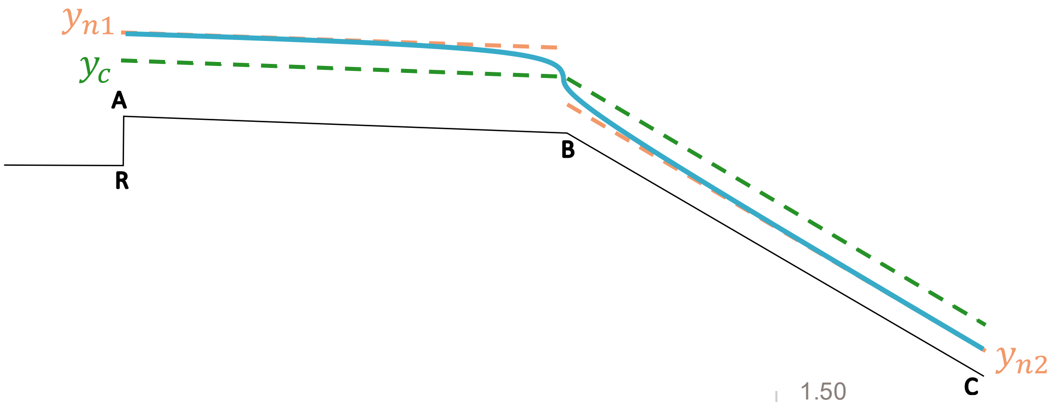
S_2 = 0.015

n = 0.0143

b = 1.5

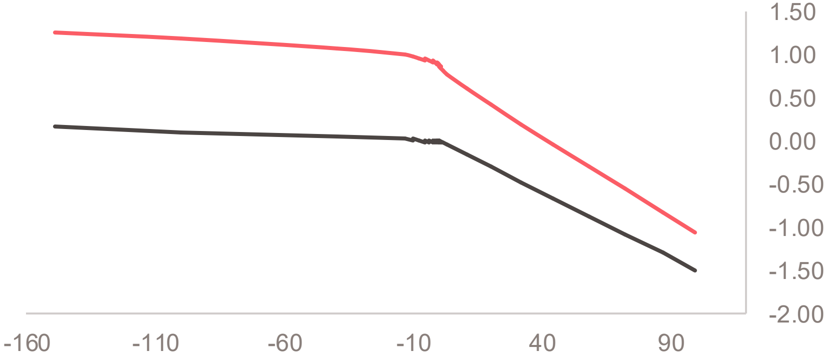
H/V = 3/2

$$y_c = 0.879\,m$$
$$y_{n1} = 1.132\,m$$
$$y_{n2} = 0.570\,m$$



- Steps:

1. Compute h_n & h_c
2. Find Control Points
3. Draw profile qualitatively
4. Compute the profile with a Table



Direct Step Method

- Retaking from Example 1 – Gate on a Steep Slope
- Solution:

Q = 4.5 m³/s $y_c = 0.753\,m$

S_0 = 0.01 $y_n = 0.452\,m$

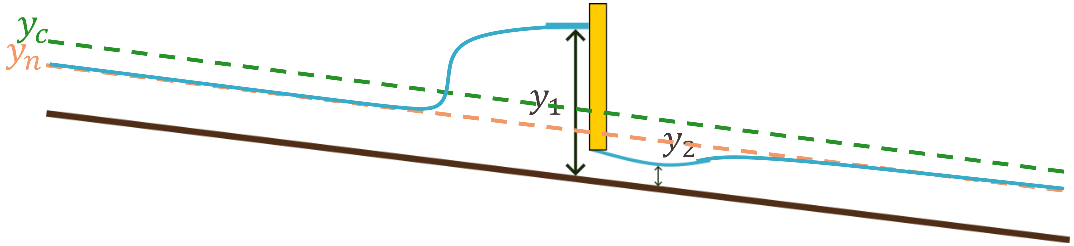
C = 80 $m^{1/2}$ s^{-1}

b = 2.2 m $y_1 = 2.09\,m$

$y_2 = 0.35\,m$

- Steps:

1. Compute y_n & y_c
2. Find Control Points
3. Draw profile qualitatively
4. Compute the profile with a Table



Section	y_i (m)	dy (m)	y_med (m)	A (m2)	v (m/s)	Fr	1-Fr^2	P (m)	R (m)	S_f	S_0-S_f	dx (m)	x (m)

Tomorrow

- Numerical models for Open Channel Flow & Why/What to model?
- HEC-RAS Workshop