FUNDAMENTALS OF HYDRAULIC ENGINEERING SYSTEMS - 5TH Edition

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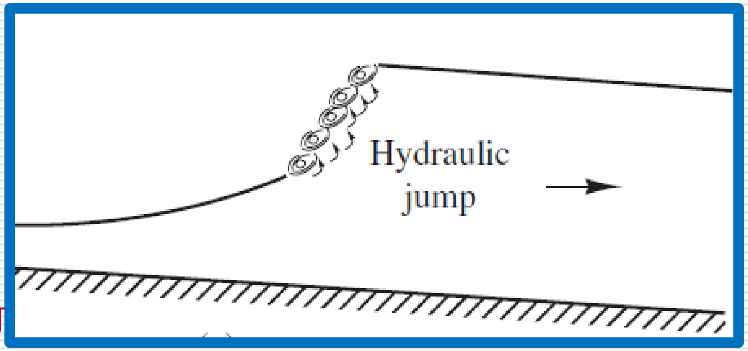
Pearson/Prentice Hall

Chapter 6

Water Flow in Open Channels

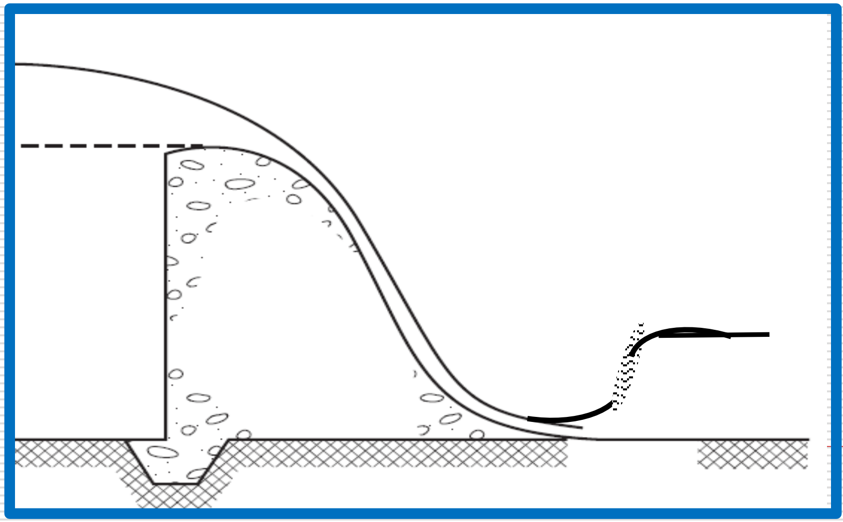
Hydraulic Jumps
(Principles & Occurrence)

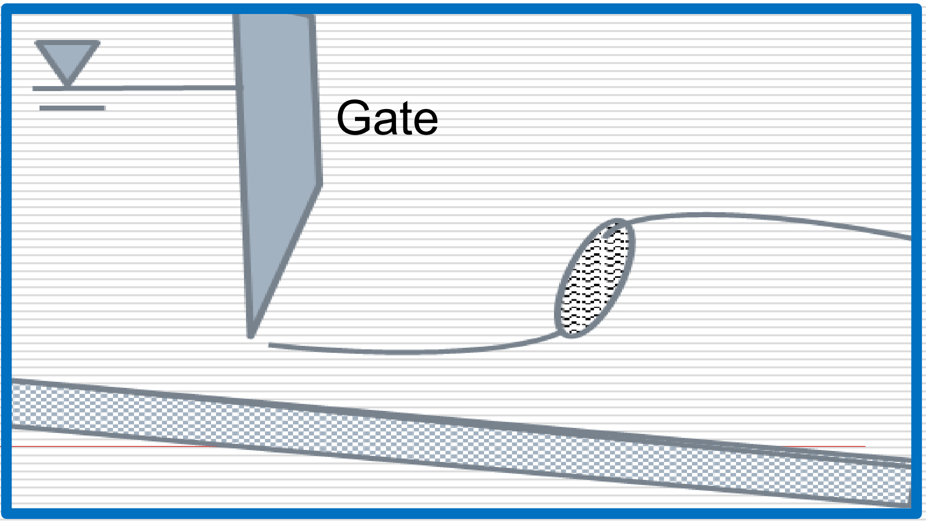


Definition: an abrupt reduction in flow velocity due to a sudden increase in water depth in the downstream direction

Principles: High velocity supercritical flow is converted to low velocity subcritical flow with a significant loss of energy.

Occurrence:





Hydraulic Jumps: Rapidly Varied Flow

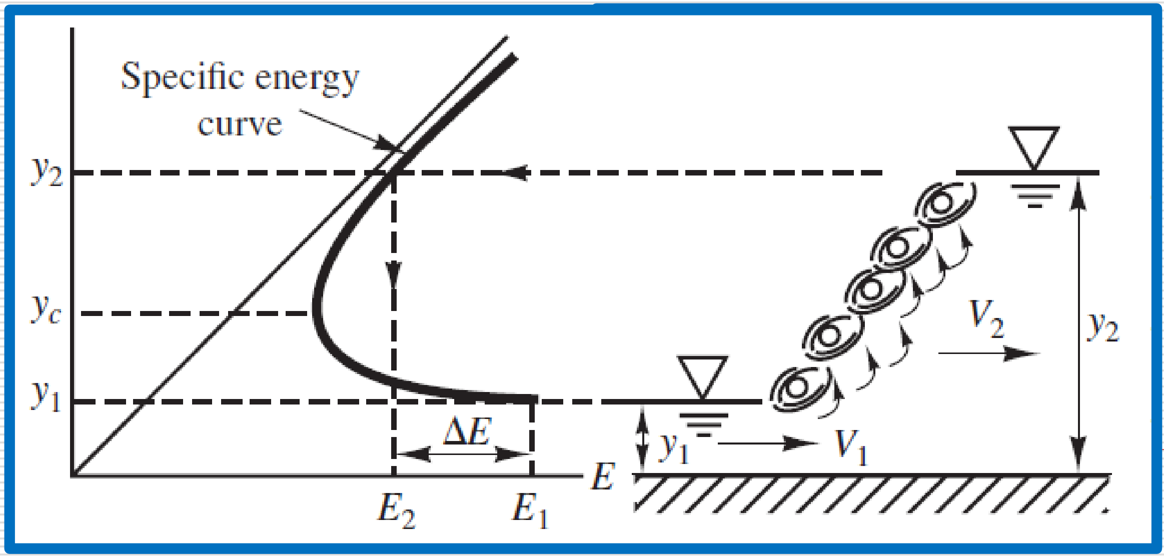
(Energy Loss and Sequent Depth Calculations)

Water Depth: The **initial** depth (y_1 ➔ supercritical) quickly changes to a **sequent** depth (y_2 ➔ subcritical).

Energy Loss: $\Delta E = E_1 - E_2$ (see specific energy curve below)

Calculate y_2 knowing y_1: Apply impulse-momentum equation.

y_2/y_1 = where N_{F1} =



Calculate ΔE: Apply impulse-momentum & energy equations:

ΔE =

Gradually Varied Flow
(Definition & Energy Principles)

Definition: depth of flow changes slowly along a channel's length (in contrast to uniform flow & rapidly varied flow)

Water Surface Profile: graph of depth vs. channel length computed using energy principles

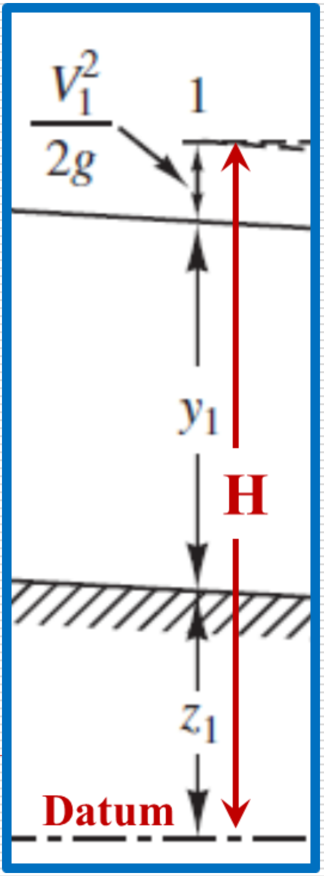
$H = z + y + Q^2/2gA^2$ ➔ to determine change in H:

dH/dx =

Noting that dA = T(dy) and rearranging yields:

$$\frac{dy}{dx} = \frac{(dH/dx) - (dz/dx)}{1 - (Q^2T)/(gA^3)}$$

➔ **Note:** dH/dx & dz/dx are slopes of the EGL and channel bottom.



Channel Classifications

(Based on Normal & Critical Depths)

Normal Depth (y_n):	
Critical Depth (y_c):	

S → Steep Channels: $y_n < y_c$ → $y_n/y_c < 1.0$

C → Critical Channels: $y_n = y_c$ → $y_n/y_c = 1.0$

M → Mild Channels: $y_n > y_c$ → $y_n/y_c > 1.0$

H → Horizontal Channels: $S_0 = 0$

A → Adverse Channels: $S_0 < 0$

Note: In most natural channels, the actual depth of flow (y) is different from both critical and normal depth.

Water Surface Profile Classifications

(Based on Normal, Critical, and Actual Depths)

Three Profile Types based on the actual flow depth (y):

Type 1 Curves:

$y > y_c$ and $y > y_n$

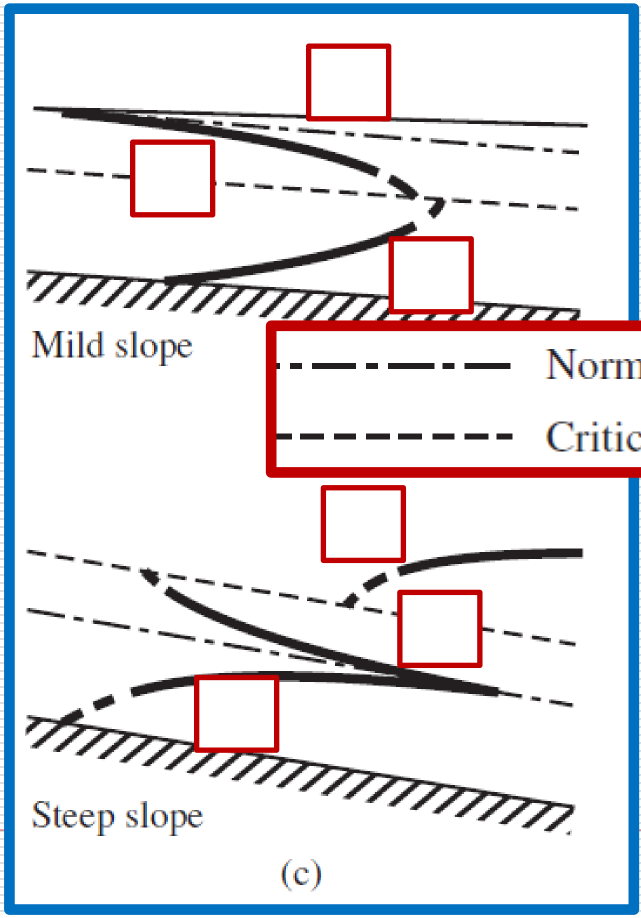
Type 2 Curves:

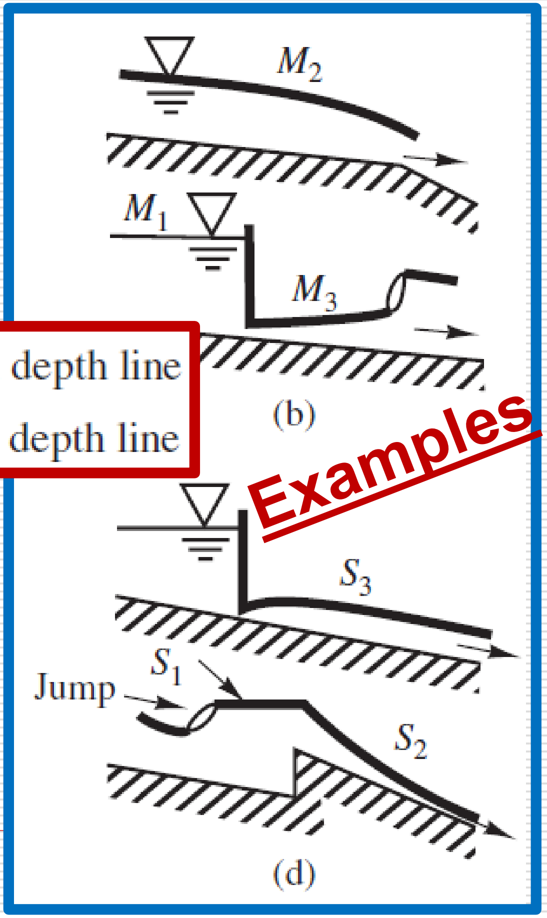
$y > y_c$ and $y < y_n$

Type 3 Curves:

$y < y_c$ and $y < y_n$

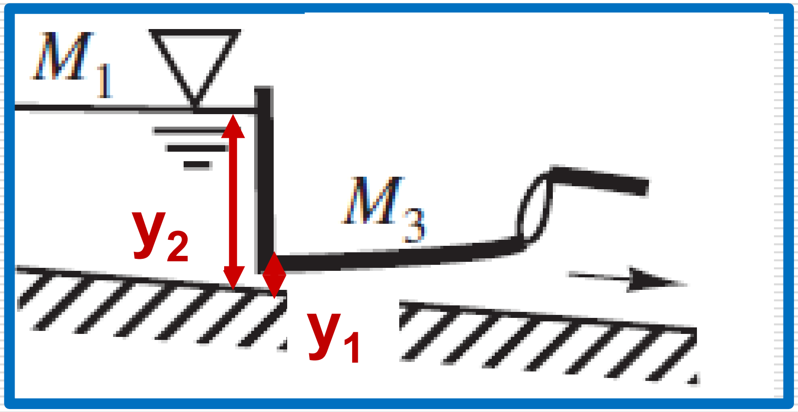
Classify Profiles (as M or S, and 1,2, or 3) ➔





Water Surface Profiles
(Control Sections and Calculation Direction)

Control Section: A location where depth (and Q) are known. Water surface profile calculations begin here and proceed upstream for subcritical flow (downstream for supercritical flow) using the energy equation.



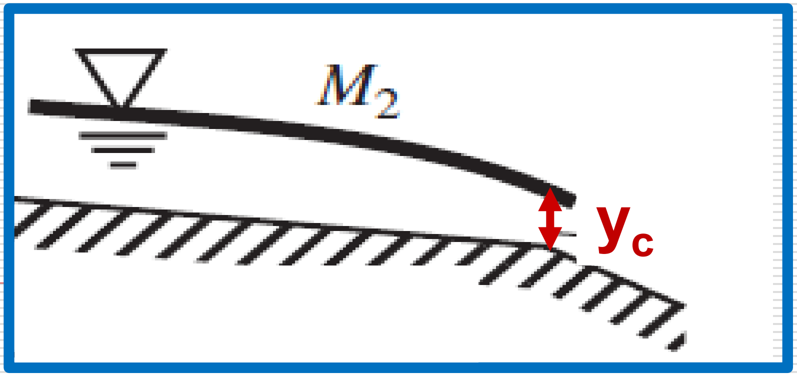
Examples: Open Sluice Gate

y_1=opening; proceed downstream

y_2=driving head behind gate (Eqn. 8.19); proceed upstream

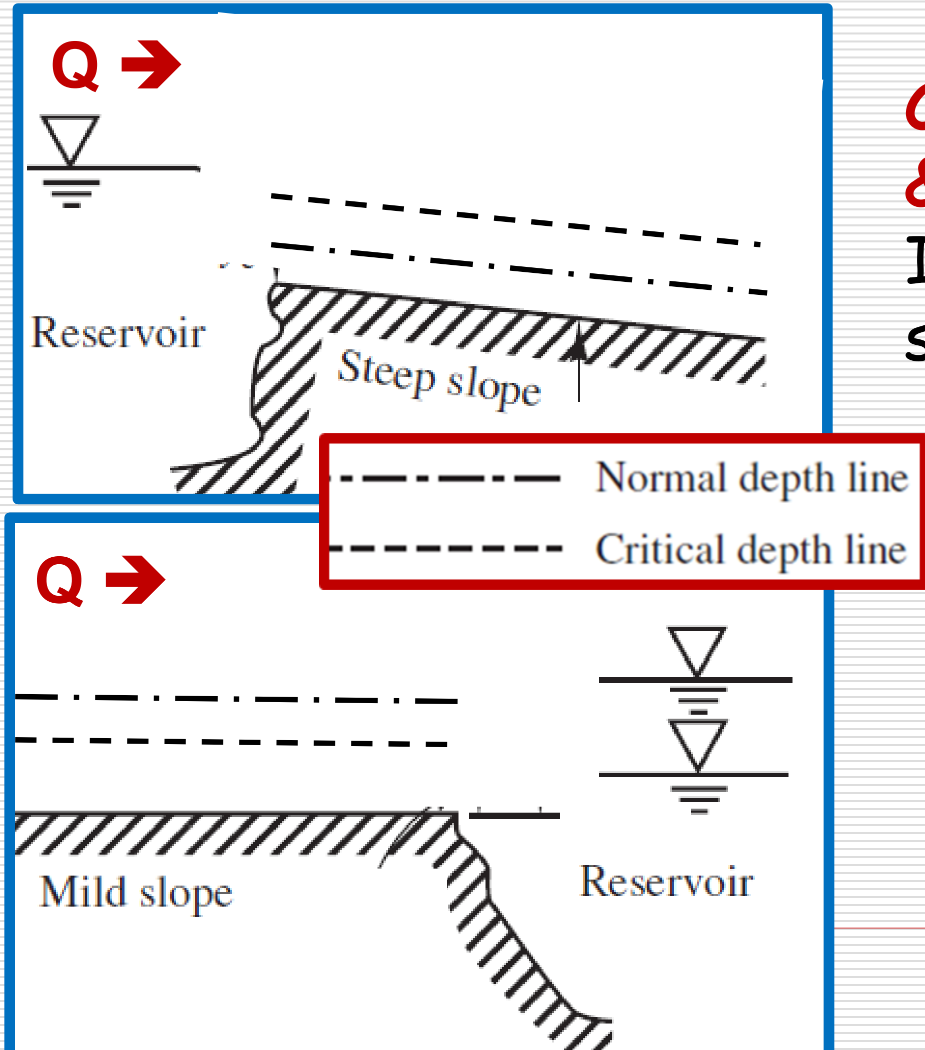
Example: Mild to Steep Channel

y_c at break; proceed upstream and downstream



Water Surface Profiles

(Example Problems - Control Sections)



Channel #1 (steep→ normal & critical depths shown): Identify control section & sketch water surface profile.

Channel #2 (mild→ normal & critical depths shown): Identify control sections for two possible reservoir elevations & sketch the water surface profiles.

Water Surface Profile Computations
(Gradually Varied Flow)

Primary Computation Algorithm:

Process Initiation: At where depth and flow rate are known (mathematically it is a boundary condition)

Methodology:
from a known water surface elevation to obtain the water surface elevation at the next (adjacent) x-section

Process Direction: Begin at the control section & proceed upstream for flow (downstream for

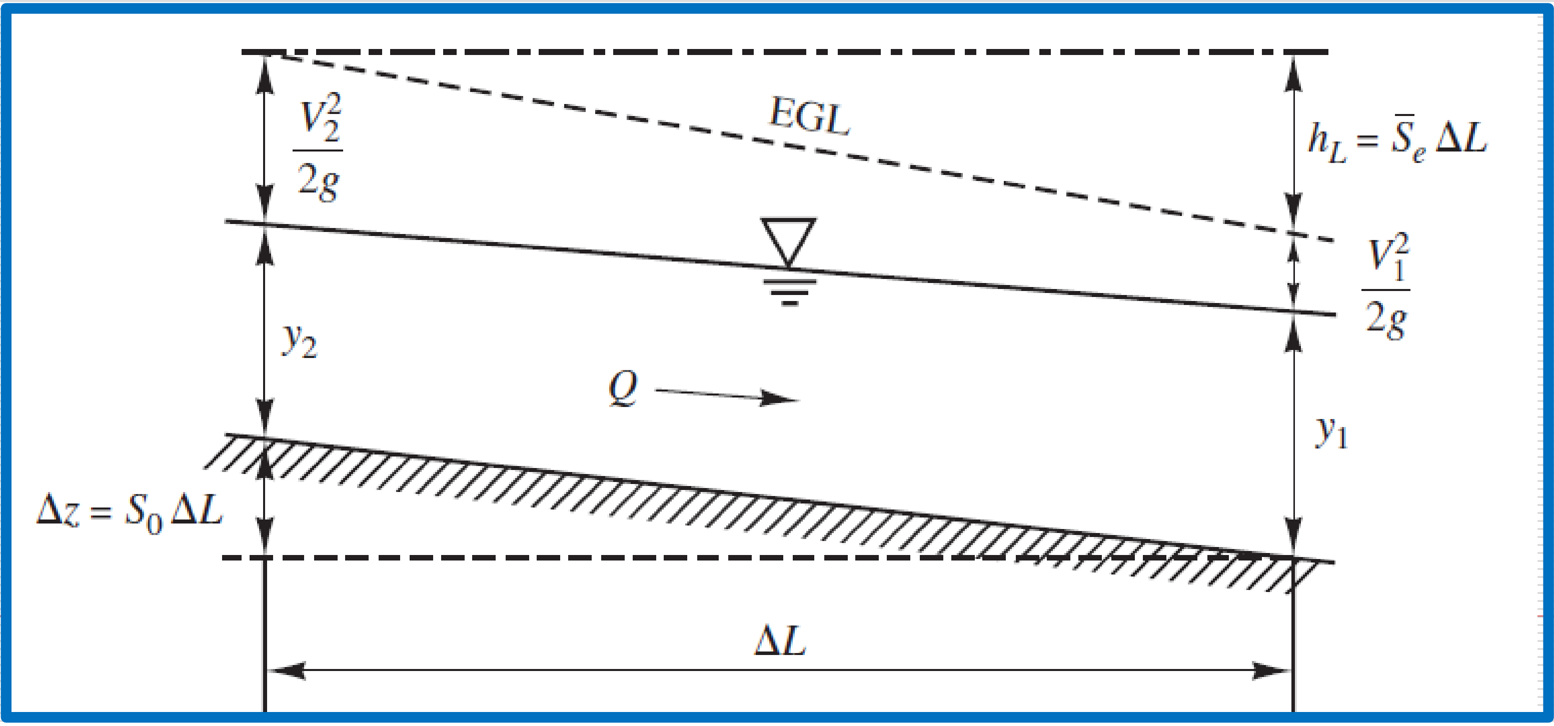
X-Section Spacing: Close spacing necessary when depths are changing rapidly to account for accurately

Standard Step Method

(Gradually Varied Flow)

Based on the figure below, write the energy balance:

What does each term in the equation represent?



Standard Step Method

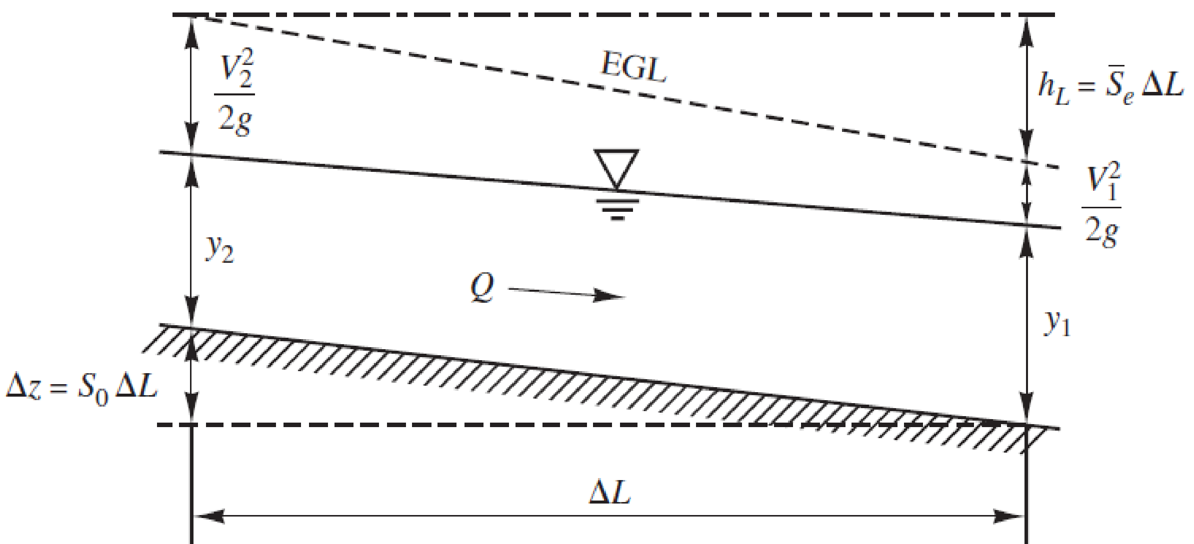
(Gradually Varied Flow)

Also, $z_2 + y_2 + (V_2)^2/2g = z_1 + y_1 + (V_1)^2/2g + \Delta L(S_e)_{avg}$

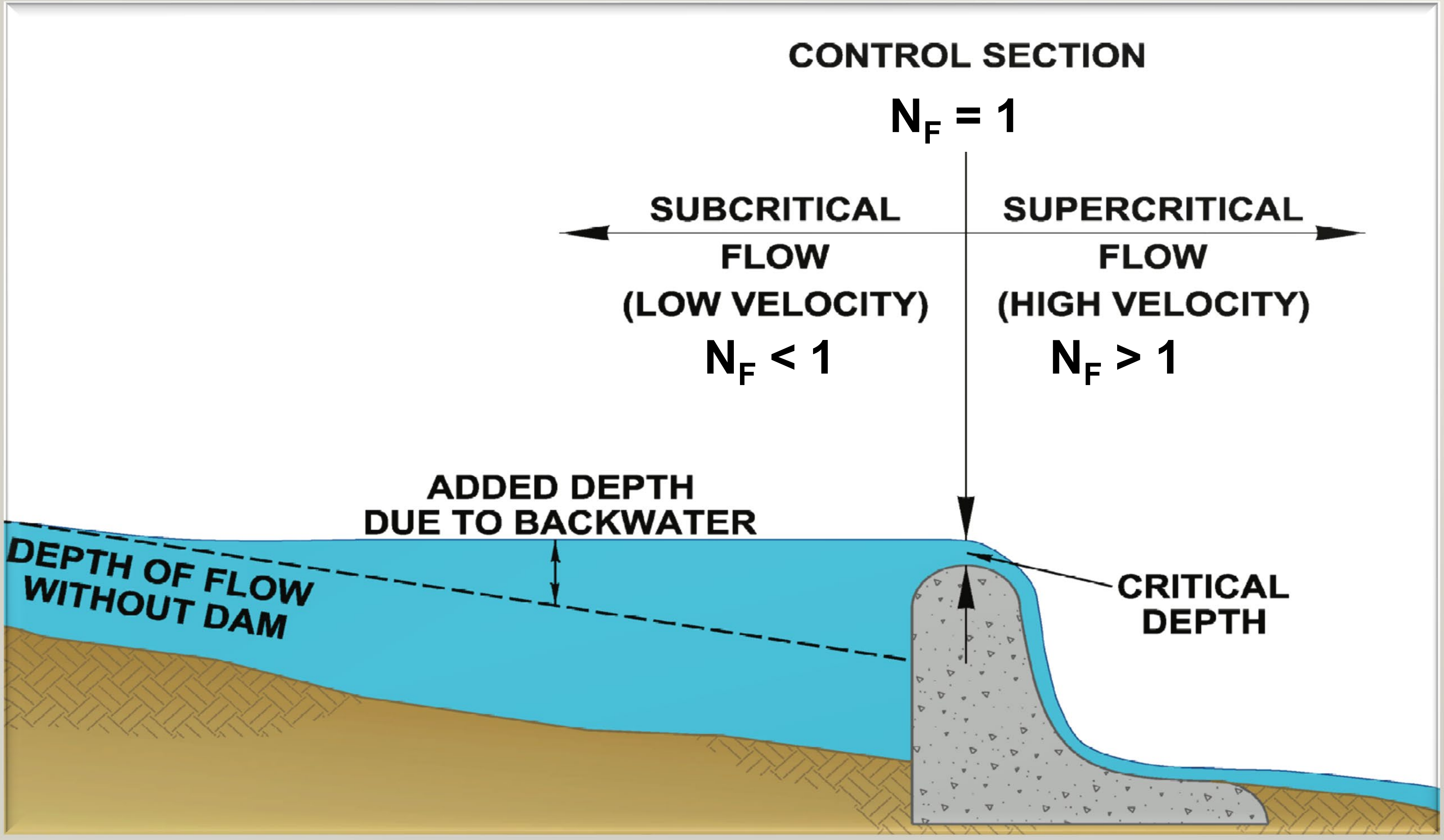
where S_e can be computed from the Manning equation as:

$S_e =$ [ ] → SI or $S_e =$ [ ] → BG

$(S_e)_{avg}$ is the average EGL at upstream & downstream sections.



Homework Problems:



Flow Over a Dam and Down a Spillway

Subcritical and Supercritical Flow

Rf.→Hydraulic Design of Highway Culverts (HDS-5), Federal Highway Administration, 2012