Notes by-

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Gradually Varied Flow

Practical Examples of Occurence of flow profiles

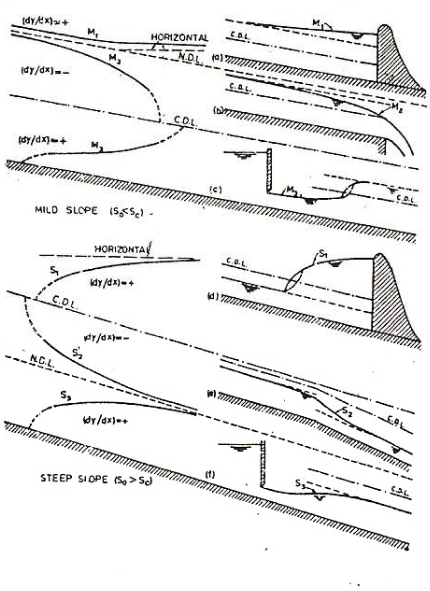


Fig. 16.5 Practical examples of M and S surface profiles

M_1 :- Obstruction to flow such as weirs dams, control structures, bends.

M_2 :- Sudden drop in bed, contraction transition.

M_3 :- Flow from spillway or sluice gate

S_1 :- Dam or weir in steep channel.

S_2 :- Entrance from reservoir to steep or slopes from mild to steep.

S_3 :- Sluice gate in steep sloping channel & Steeper slope to lesser steep slope.

C_1 & C_3 - very rare and highly unstable.

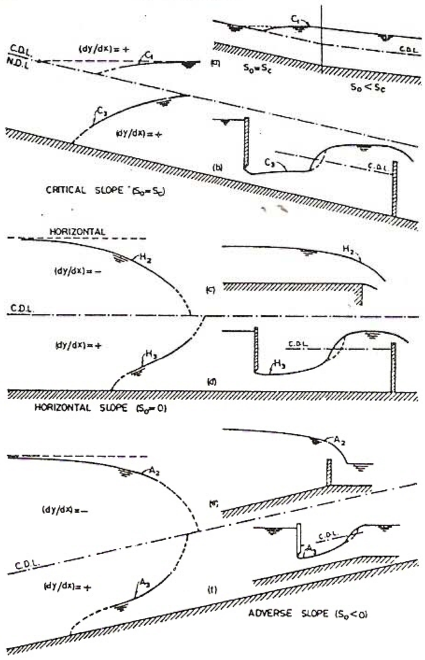
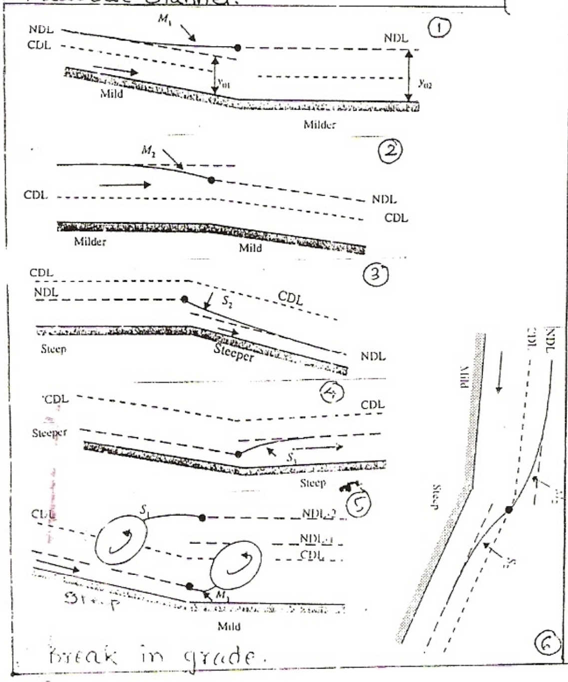


Fig. 16.6 Practical examples of *C*, *H* and *A* surface profiles.

H_2 :- Sudden drop in horizontal channel.

H_3 :- from sluice gate in horizontal channel.

A_2 & A_3 :- Rare and short length profiles flow over weir & dam & sluice gate resp.ly in adverse channel.



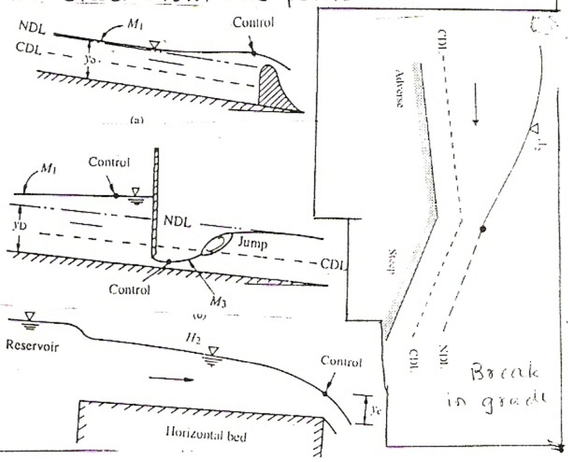
Control Sections

4.5 CONTROL SECTIONS

A control section is defined as a section in which a fixed relationship exists between the discharge and depth of flow. Weirs, spillways, sluice gates are some typical examples of structures which give rise to control sections. The critical depth is also a control point. However, it is effective in a flow profile which changes from subcritical to supercritical flow. In the reverse case of transition from supercritical flow to subcritical flow, a hydraulic jump is usually formed bypassing the critical depth as a control point. Any GVF profile will have at least one control section.

In the synthesis of GVF profiles occurring in serially-connected channel elements, the control sections provide a key to the identification of proper profile shapes. A few typical control sections are indicated in Fig. . It may be noted that subcritical flows have controls in the downstream end while supercritical flows are governed by control sections existing at the upstream

Control sections are the section where depth is known and calculation of flow profile can start from this point.



Gradually Varied Flow

4.3 CLASSIFICATION OF FLOW PROFILES

In a given channel, y_0 and y_c are two fixed depths if Q, n and S_0 are fixed. Also, there are three possible relations between y_0 and y_c as (i) $y_0 > y_c$, (ii) $y_0 < y_c$ and (iii) $y_0 = y_c$. Further, there are two cases where y_0 does not exist, i.e. when (a) the channel bed is horizontal, ($S_0 = 0$), (b) when the channel has an adverse slope, (S_0 is −ve). Based on the above, the channels are classified into five categories as indicated in Table 4.1.

For each of the five categories of channels, lines representing the critical depth and normal depth (if it exists) can be drawn in the longitudinal section. These would divide the whole flow space into three regions as:

Region 1: Space above the topmost line
Region 2: Space between top line and the next lower line
Region 3: Space between the second line and the bed

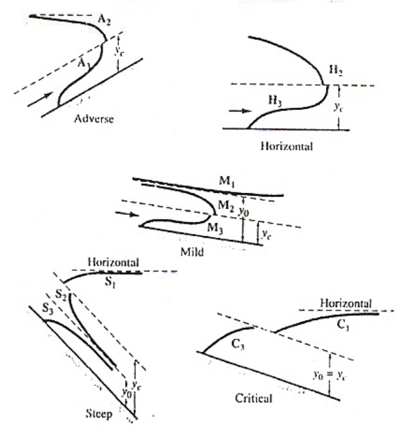
Figure 4.2 shows these regions in the various categories of channels.

Channel	Region	Condition	Type
Mild slope	1	$y > y_0 > y_c$	M_1
	2	$y_0 > y > y_c$	M_2
	3	$y_0 > y_c > y$	M_3
Steep slope	1	$y > y_c > y_0$	S_1
	2	$y_c > y > y_0$	S_2
	3	$y_c > y_0 > y$	S_3
Critical slope	1	$y > y_0 = y_c$	C_1
	3	$y < y_0 = y_c$	C_3
Horizontal bed	2	$y > y_c$	H_2
	3	$y < y_c$	H_3
Adverse slope	2	$y > y_c$	A_2
	3	$y < y_c$	A_3

Table 4.1 Classification of Channels

Sl. No.	Channel category	Symbol	Characteristic condition	Remark
1	Mild slope	M	$y_0 > y_c$	Subcritical flow at normal depth
2	Steep slope	S	$y_c > y_0$	Supercritical flow at normal depth
3	Critical slope	C	$y_c = y_0$	Critical flow at normal depth
4	Horizontal bed	H	$S_0 = 0$	Cannot sustain uniform flow
5	Adverse slope	A	$S_0 < 0$	Cannot sustain uniform flow

Easy to remember (All the 12 profiles combined.)



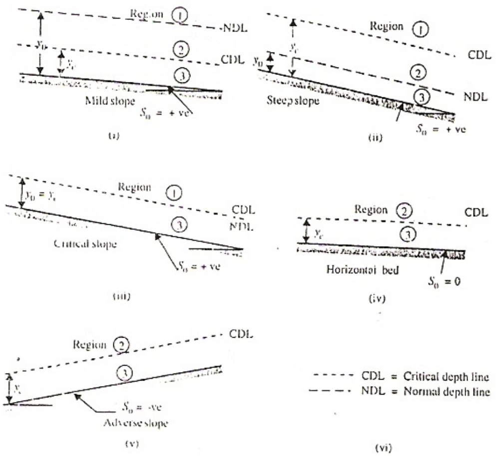


Fig. 4.2 Regions of flow profiles

How to draw?

1. As $y \to y_0$, $\frac{dy}{dx} \to 0$, i.e. the water surface approaches the normal depth line asymptotically.
2. As $y \to y_c$, $\frac{dy}{dx} \to \infty$, i.e. the water surface meets the critical depth line vertically.
3. $y \to \infty$, $\frac{dy}{dx} \to S_0$, i.e. the water surface meets a very large depth as a horizontal asymptote.

TYPES OF FLOW PROFILES IN PRISMATIC CHANNELS

Channel Slope	Symbol	Depth Relations	$\frac{dy}{dx}$ VIP	Type of profile VIP	Type of flow VIP
Horizontal $[S_0 = 0]$	None	$y > y_0 > y_c$		None	None
	H_2	$y_0 > y > y_c$	−	Drawdown	Subcritical
	H_3	$y_0 > y_c > y$	+	Backwater	Supercritical
Mild $[0 < S_0 < S_c]$	M_1	$y > y_0 > y_c$	+	Backwater	Subcritical
	M_2	$y_0 > y > y_c$	−	Drawdown	Subcritical
	M_3	$y_0 > y_c > y$	+	Backwater	Supercritical
Critical $[S_0 = S_c > 0]$	C_1	$y > y_c = y_0$	+	Backwater	Subcritical
	None	$y_c = y = y_0$		None	None
	C_3	$y_c = y_0 > y$	+	Backwater	Supercritical
Steep $[S_0 > S_c > 0]$	S_1	$y > y_c > y_0$	+	Backwater	Subcritical
	S_2	$y_c > y > y_0$	−	Drawdown	Supercritical
	S_3	$y_c > y_0 > y$	+	Backwater	Supercritical
Adverse $[S_0 < 0]$	None			None	None
	A_2	$y > y_c$	−	Drawdown	Subcritical
	A_3	$y_c > y$	+	Backwater	Supercritical

$$\frac{dy}{dx} = S_0 \frac{1 - \frac{S_f}{S_0}}{1 - \frac{Q^2 T}{g A^3}}$$

$$\frac{dy}{dx} = S_0 \left[\frac{1 - \left(\frac{y_0}{y}\right)^{10/3}}{1 - \left(\frac{y_c}{y}\right)^3} \right] \text{Manning}$$

OR

$$\frac{dy}{dx} = S_0 \left[\frac{1 - (y_0/y)^3}{1 - (y_c/y)^3} \right] \text{Chezy}$$

In above equation if Numerator / Denominator

$\frac{dy}{dx}$ = positive when $\frac{+ve}{+ve}$ or $\frac{-ve}{-ve}$

= +ve is called backwater

$\frac{dy}{dx}$ = negative when $\frac{+ve}{-ve}$ or $\frac{-ve}{+ve}$

= −ve is called drawdown

that is.

$\frac{dy}{dx} > 0$ if (i) $y > y_0$ and $y > y_c$ or
(+ve) (ii) $y < y_0$ and $y < y_c$

Similarly, $\frac{dy}{dx} < 0$ if (i) $y_c > y > y_0$ or
(−ve) (ii) $y_0 > y > y_c$

Refer Chezy's eq^n of dy/dx