Pipe Construction Manual

Topics Covered

- Construction Related Performance Problems
- Pipe Manual Overview
- Trench Widths
- Bedding and Backfill
- Documentation Requirements

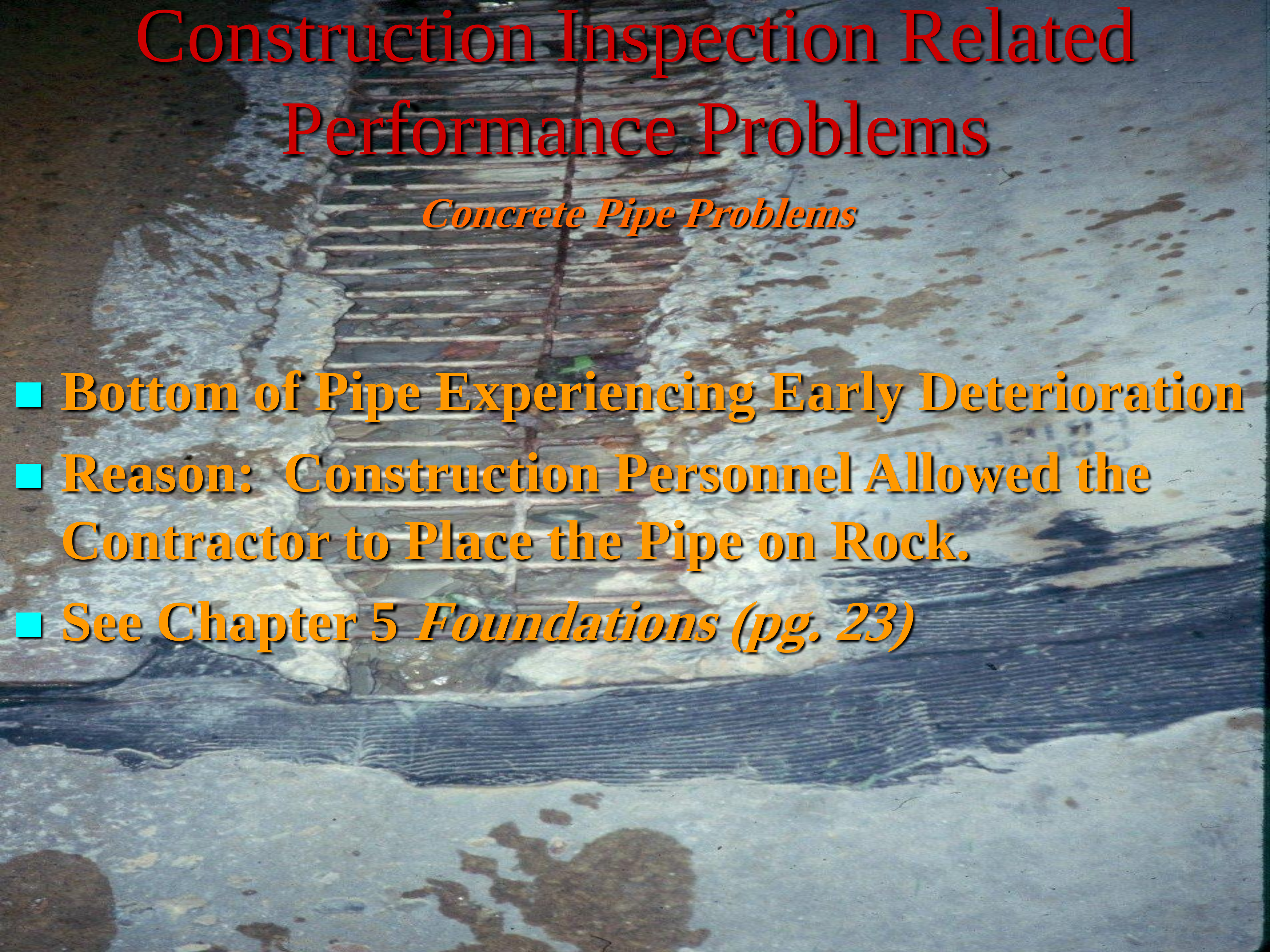
Construction Inspection Related Performance Problems

Corrugated Metal Pipe Problems

- In the 1980's CMP's were Failing
- Reason: Construction Personnel were allowing Contractors to End Dump Backfill and Use Soil Instead of Granular Material.
- See Chapters 7 through 10 *(pgs. 26-41)*

Construction Inspection Related Performance Problems

Concrete Pipe Problems



- **Bottom of Pipe Experiencing Early Deterioration**
- **Reason: Construction Personnel Allowed the Contractor to Place the Pipe on Rock.**
- **See Chapter 5 *Foundations (pg. 23)***

Construction Inspection Related Performance Problems

Thermo Plastic Pipe Problems

- **Several of These Pipe Failed During Construction**
- **Reason: Construction Personnel Allowed Heavy Construction Equipment on the Pipe without Proper Cover.**
- **See Figure 900-8** ***(pg. F-68)***

Check the Trench Width

Chapter 4 in Manual and in CMS 603.03

- Maximum Trench Width Minimizes the Load on the Pipe
- Minimum Trench Width Allows for Proper Jointing
- Trench Width is Measured at the Top of the Pipe

Check the Foundation

Manual in Chapters 5& 6, CMS 603.03

- Soft Foundation
- Rock Foundation
- Wet Conditions

Dip in the Road

Preventable Construction Related Problems

- If you Use Open Graded Material and Put Sand or Soil on Top as Backfill
- The Fine Sand or Soil will Migrate into the #57's or #67's and Cause Dips
- See Piping in Manual 601.0 *(pg. 24)*

Placing the Bedding & Backfill

Manual in Chapter 8 & 9, and in CMS 603.08 & 603.081

- This is Obviously *Incorrect!*
- Material is Placed in 8” lifts

Placing & Spreading the Bedding

- Trackhoe or Loader are Often Used
- Truck End Dumping Can Not Place Material in 8” Lifts
- Place the Material in 8” Lifts!!

Compact the Bedding Material

Manual in Chapter 8, and in CMS 603.081

- Leave the Middle 1/3 of the Pipe Bedding Uncompacted
- See *Figure 1000-1 (pg. 69)*
- Avoids Causing Point Loading on the Pipe
- Check the Grade and Rake if needed

Place the Next Section of Pipe

Manual in Chapter 11, and in CMS 603.05, 603.06 & 603.082

Each Manufacturer will Cover the Details of the Placement and Jointing of the Different Types of Pipe.

Check the Joint Gap

Manual in Chapter 11, and in CMS 603.06

- One Inch Tolerance is Acceptable for Most Pipe
- Should Get Closer than 1”
- Look for Non-uniform Gaps

Look for Leaking Joints

Make Corrections as Necessary

Backfill Placement

Manual in Chapter 9, and in CMS 603.08 & 603.081

- Place and Spread the Backfill in 8” Lifts
- Manipulate in and around the Pipe Prior to Compaction
- Use Shovels if Necessary

Compact the Backfill

Manual in Chapter 10, and in CMS 603.081

- Compact Thoroughly
- Particularly From the Bottom of the Pipe to the Middle of the Pipe *(a.k.a. haunch area)*

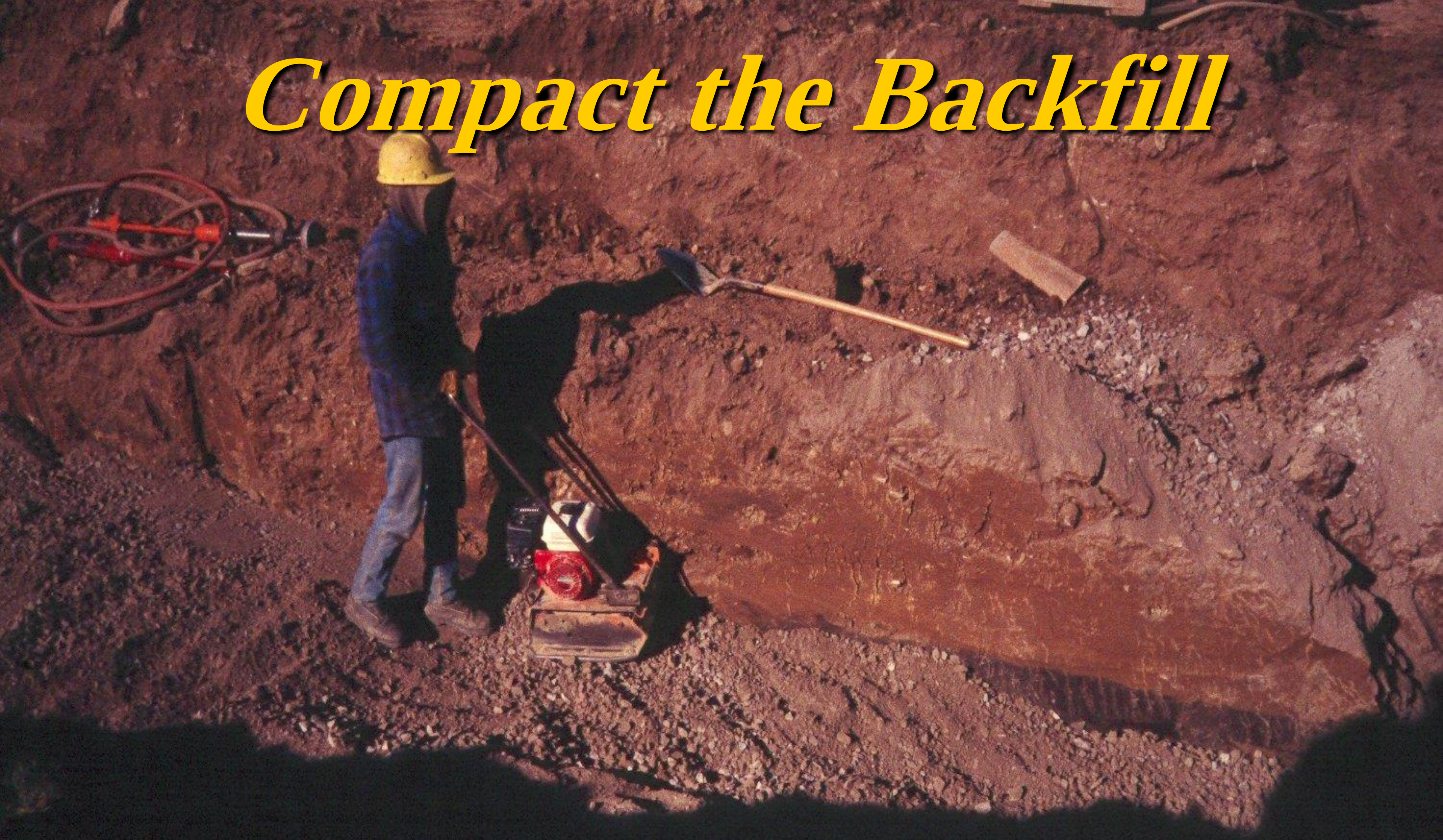
Compact the Backfill

A Hoe-Ram Usually can get close enough to the Pipe for Full Coverage of the Backfill.

Compact the Backfill

Use Spud Bars, Shovel Slicing or Automated Spud Bar in Tight Areas.

Compact the Backfill



- Use Combinations of Compaction Equipment
- Notice the Automated Spud Bar *(above to the left)*

Check Compaction

Manual in Chapter 10, and in CMS 603.081

- Type 1 *(304)* Compaction Testing
- Use Test Section and Moisture from M-D Curve to Establish Maximum Density
- Average a Minimum Compaction of 96% of Maximum.
- Minimum Individual Reading 92% of Maximum
- Make a New Test Section When Conditions Change

Check for Compaction

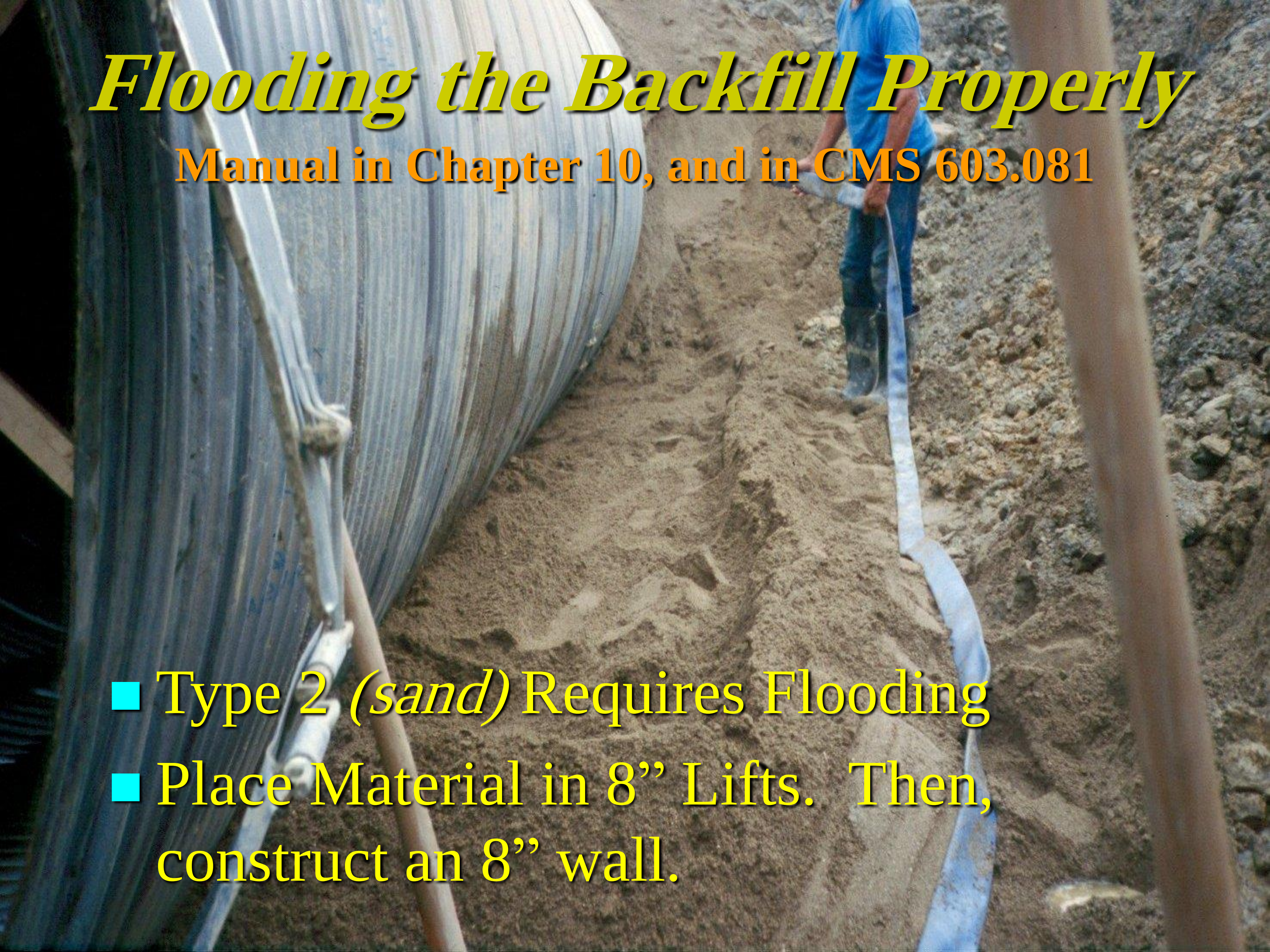
- Add Water to Stockpile if Needed
- Type 1 *(304)* Optimum Moisture +/- 5 to 10%

Check Compaction

- Add Water in Trench if Needed
  - This is not Flooding!!

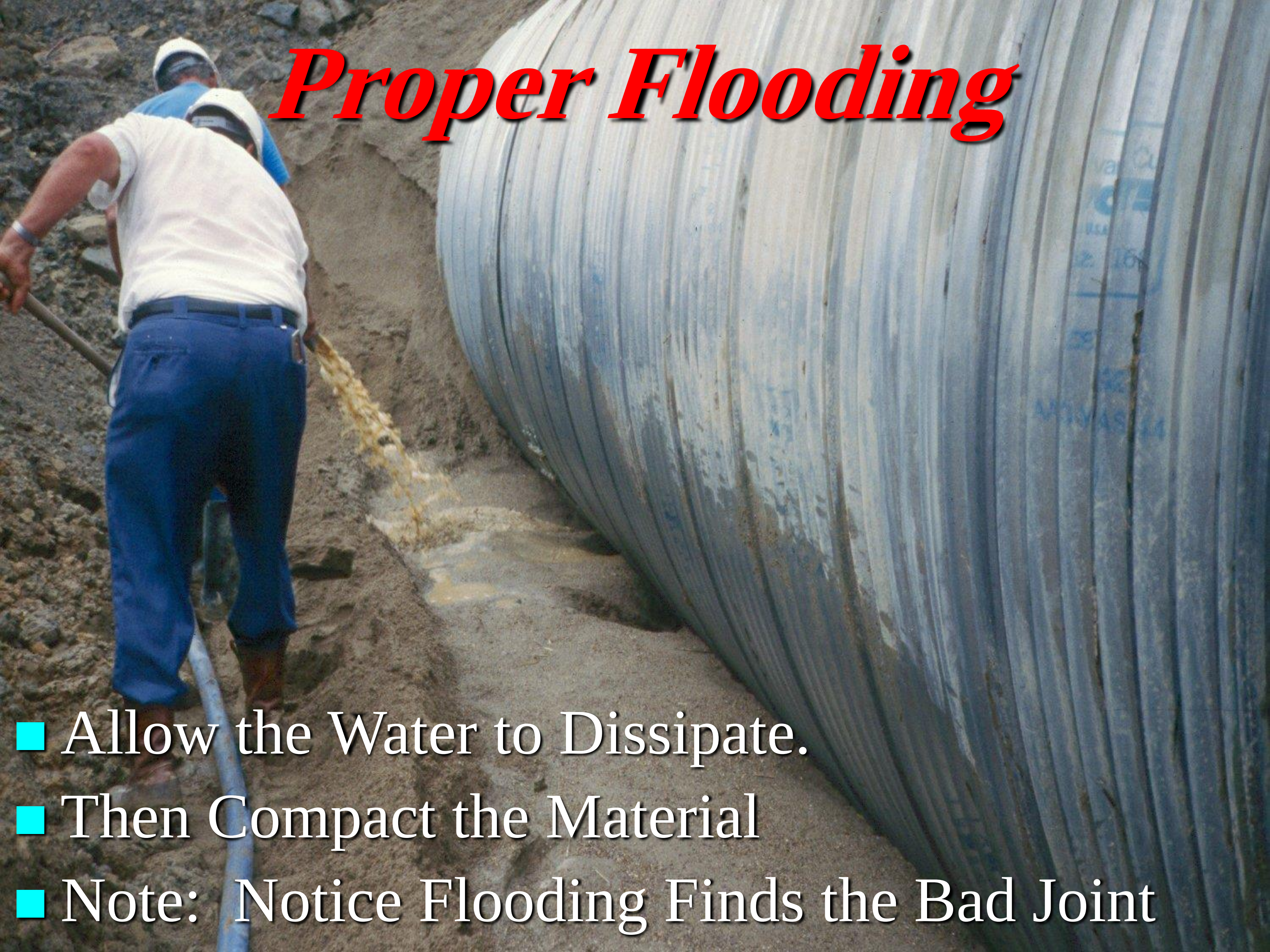
Flooding the Backfill Properly

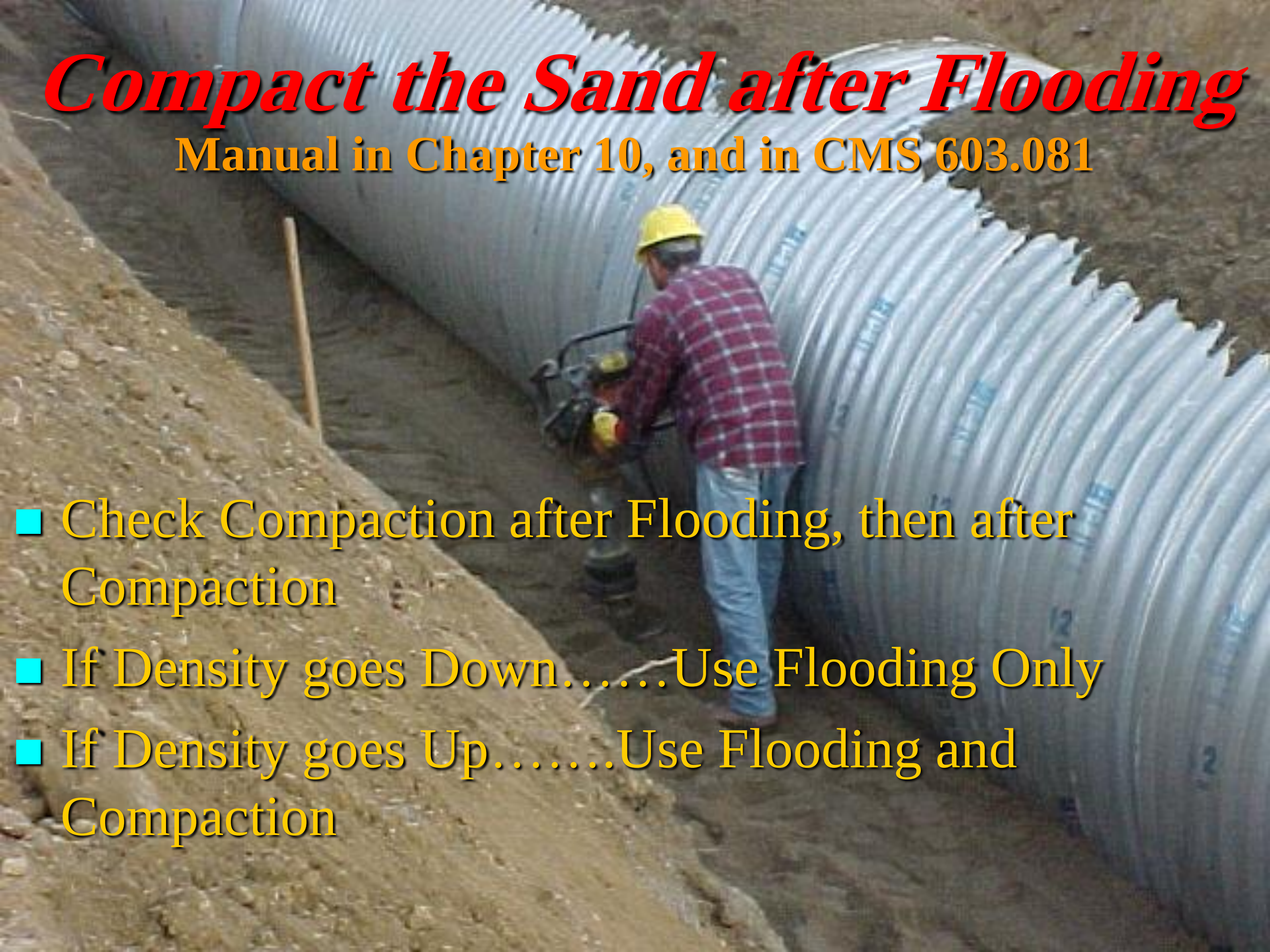
Manual in Chapter 10, and in CMS 603.081



- Type 2 *(sand)* Requires Flooding
- Place Material in 8” Lifts. Then, construct an 8” wall.


Proper Flooding Technique
Fill the Trench up with Water


Proper Flooding
Allow the Water to Dissipate.
Then Compact the Material
Note: Notice Flooding Finds the Bad Joint



Compact the Sand after Flooding

Manual in Chapter 10, and in CMS 603.081

- Check Compaction after Flooding, then after Compaction
- If Density goes Down……Use Flooding Only
- If Density goes Up…….Use Flooding and Compaction

Granular Material Requirements

Manual in Chapter 9, and in CMS 603.08

- Granular Material is Required for a Minimum Height above the Pipe
- See *Figures 900-1 thru 900-8*
- Changes with:
  - Kind and Type of Pipe as well as Fill vs. Cut Situations

Compaction in Confined Spaces

- Trench Boxes Complicate the Process
- Place and Compact in the Trench Box

Raise the Front of the Trench Box

Trench May Collapse

- **Place Material in the Trench as the Box is Removed**
- **Notice that the Center of the Backfill is Not Displaced when the Box is Removed**
- **Not the Best Situation, but Acceptable**

Compact Material to Road Surface

- Remember to Protect the Pipe
- See *Figure 900-8*
- Remember the Example

BRIDGES

Whenever a new road has to cross an existing drain or canal, a small bridge or culvert is constructed at the point of crossing

<u>Bridges classification</u>

Bridges can be classified as :

- **According to function as :** ***Pedestrians ,Highway ,Railway .***
- **According to material of construction as:** ***Timber, Masonary, Iron and Concrete.***
- **According to the form or type of superstructure as:** ***Slab, Beam Truss, Arch, Fram and Suspension bridge.***
- **According to span length as:**

  (Culvert) **which its length is less than 8m** ***.***
  (Minor bridge) **which its length is 8-30m**

  (Major bridge) **which its length is 30m .**

- **According to type of service and duration of use as :** ***Permanent Temporary ,Military*** **.**

Components of Bridge

Components of bridge can be divided into two groups :

- **Substructure**
- **Superstructure**

The substructure consist of : [foundation ,piers ,and abutment]
The Superstructure consist of : [main bridge ,bridge girders ,bridge floor and railing .

Pier: **it is a support of concrete or masonry , it is shaped to give smooth flow of water to prevent eddy current and scour .**

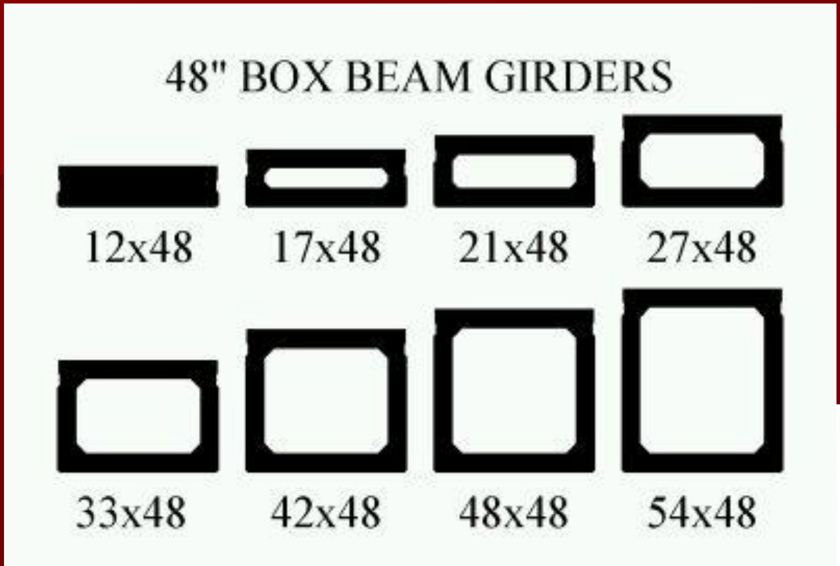
Abutment: **it is a structure that support one end of a bridge and at the same time support the embankment upon bridge rests.**

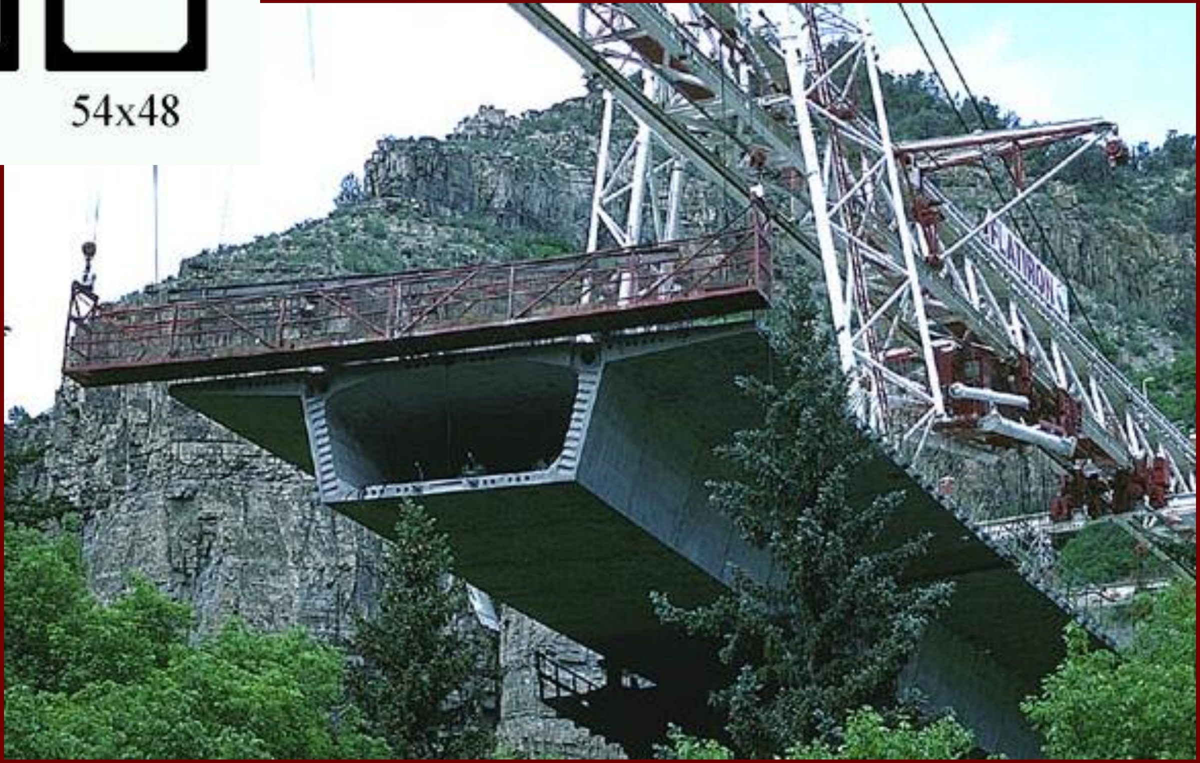
Wing walls: **walls which regulate the entrance and exit of water into irrigation structures, they may either be placed at right angle to the current or splayed out.**

Beam Bridges

Box Girder Bridges

Box Girder Sections





Arch Bridges




Arch Bridges

Truss Bridges




Suspension Bridges

Suspension Bridge Wobble

Cable Stayed Bridges

History of Bridge Development

Natural Bridges

Clapper Bridge

- Tree trunk
- Stone

700 A.D. Asia

Great Stone Bridge in China

- Low Bridge
- Shallow Arch

Roman Arch Bridge

- The Arch
- Natural Cement

100 B.C. Romans

- Strength of Materials
- Mathematical Theories
- Development of Metal

1300 A.D. Renaissance

History of Bridge Development

1800 A.D.

1900 A.D.

2000 A.D.

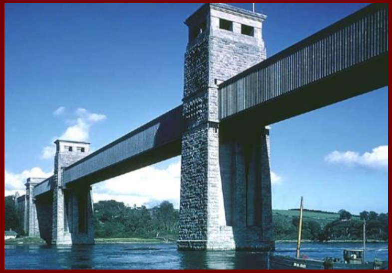
First Cast-Iron Bridge

Coalbrookdale, England

Truss Bridges

- Mechanics of Design

- Prestressed Concrete
- Steel



Britannia Tubular Bridge

- Wrought Iron

Suspension Bridges

- Use of Steel for the suspending cables

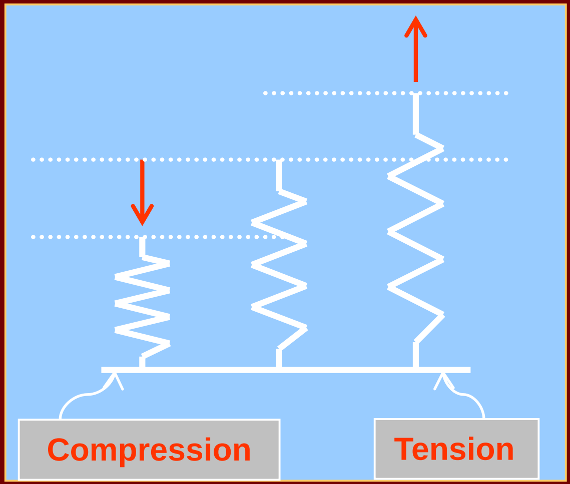
1850 A.D.

1920 A.D.

Basic Concepts

Span - the distance between two bridge supports, whether they are columns, towers or the wall of a canyon.

Force - any action that tends to maintain or alter the position of a structure



Compression - a force which acts to compress or shorten the thing it is acting on.

Tension - a force which acts to expand or lengthen the thing it is acting on.

Basic Concepts

Beam - a rigid, usually horizontal, structural element

Pier - a vertical supporting structure, such as a pillar

Cantilever - a projecting structure supported only at one end, like a shelf bracket or a diving board

Load - weight distribution throughout a structure

Basic Concepts

Truss - a rigid frame composed of short, straight pieces joined to form a series of triangles or other stable shapes

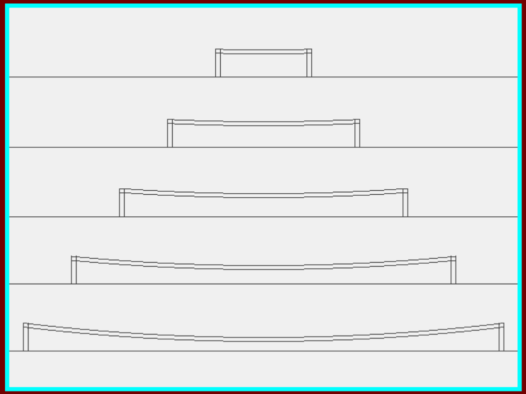
Stable - (adj.) ability to resist collapse and deformation; stability (n.) characteristic of a structure that is able to carry a realistic load without collapsing or deforming significantly

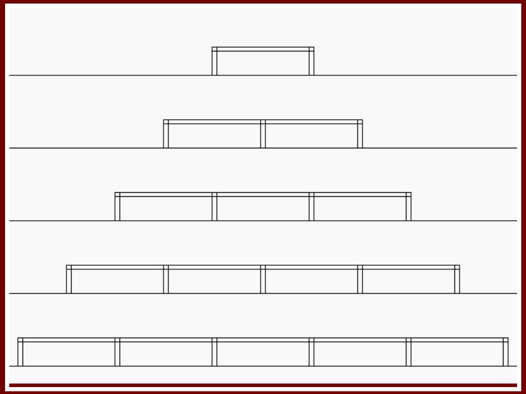
Deform - to change shape

Types of Bridges

Beam Bridge

Consists of a horizontal beam supported at each end by piers. The weight of the beam pushes straight down on the piers. The farther apart its piers, the weaker the beam becomes. This is why beam bridges rarely span more than 250 feet.



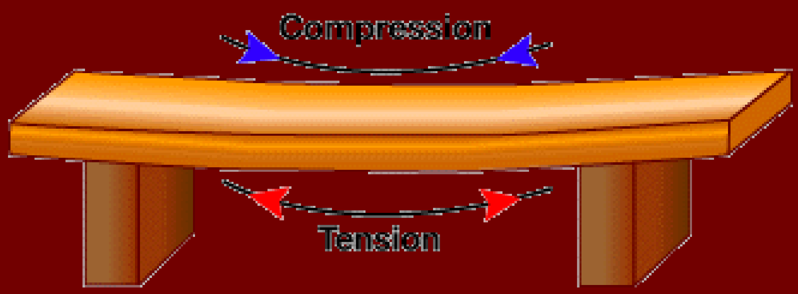


Types of Bridges

Beam Bridge

Forces

When something pushes down on the beam, the beam bends. Its top edge is pushed together, and its bottom edge is pulled apart.



Types of Bridges

Truss Bridge

Forces

Every bar in this cantilever bridge experiences either a pushing or pulling force. The bars rarely bend. This is why cantilever bridges can span farther than beam bridges

Types of Bridges

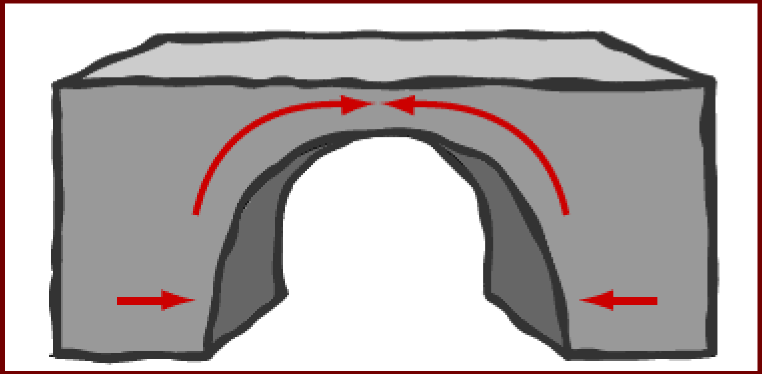
Arch Bridges

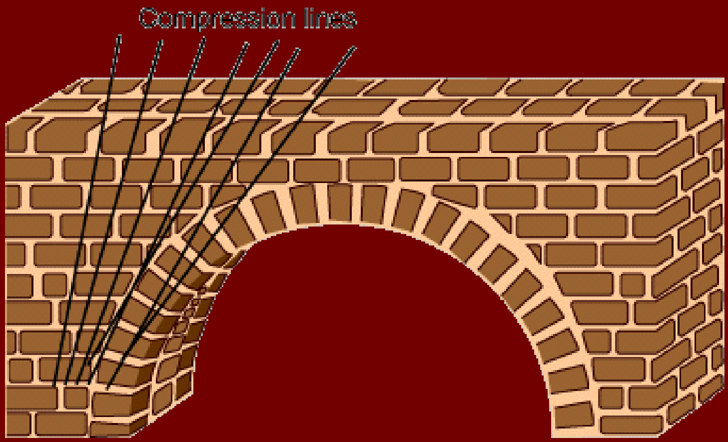
The arch has great natural strength. Thousands of years ago, Romans built arches out of stone. Today, most arch bridges are made of steel or concrete, and they can span up to 800 feet.

Arch Bridges

Forces

The arch is squeezed together, and this squeezing force is carried outward along the curve to the supports at each end. The supports, called abutments, push back on the arch and prevent the ends of the arch from spreading apart.





Types of Bridges

Suspension Bridges

This kind of bridges can span 2,000 to 7,000 feet -- way farther than any other type of bridge! Most suspension bridges have a truss system beneath the roadway to resist bending and twisting.

Types of Bridges

Suspension Bridges

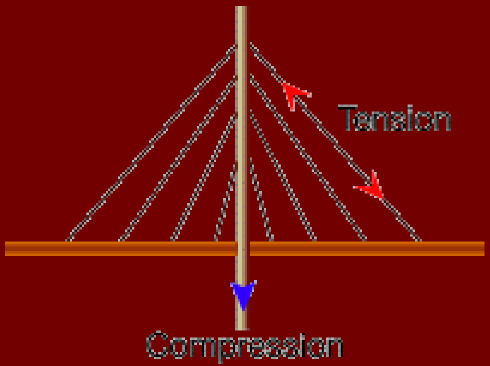
Forces

In all suspension bridges, the roadway hangs from massive steel cables, which are draped over two towers and secured into solid concrete blocks, called anchorages, on both ends of the bridge. The cars push down on the roadway, but because the roadway is suspended, the cables transfer the load into compression in the two towers. The two towers support most of the bridge's weight.

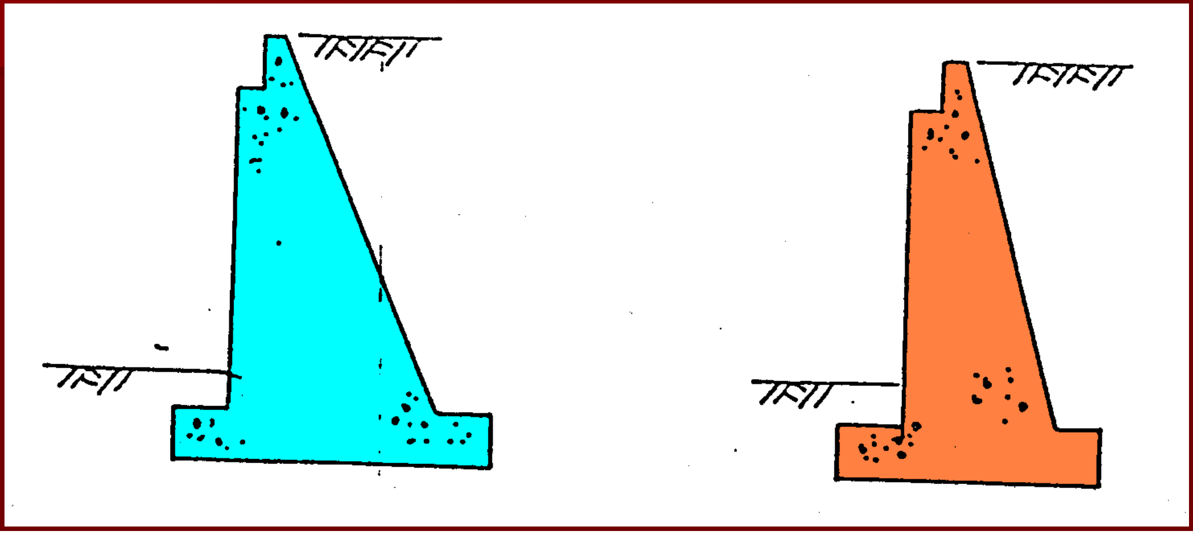
Cable-Stayed Bridge

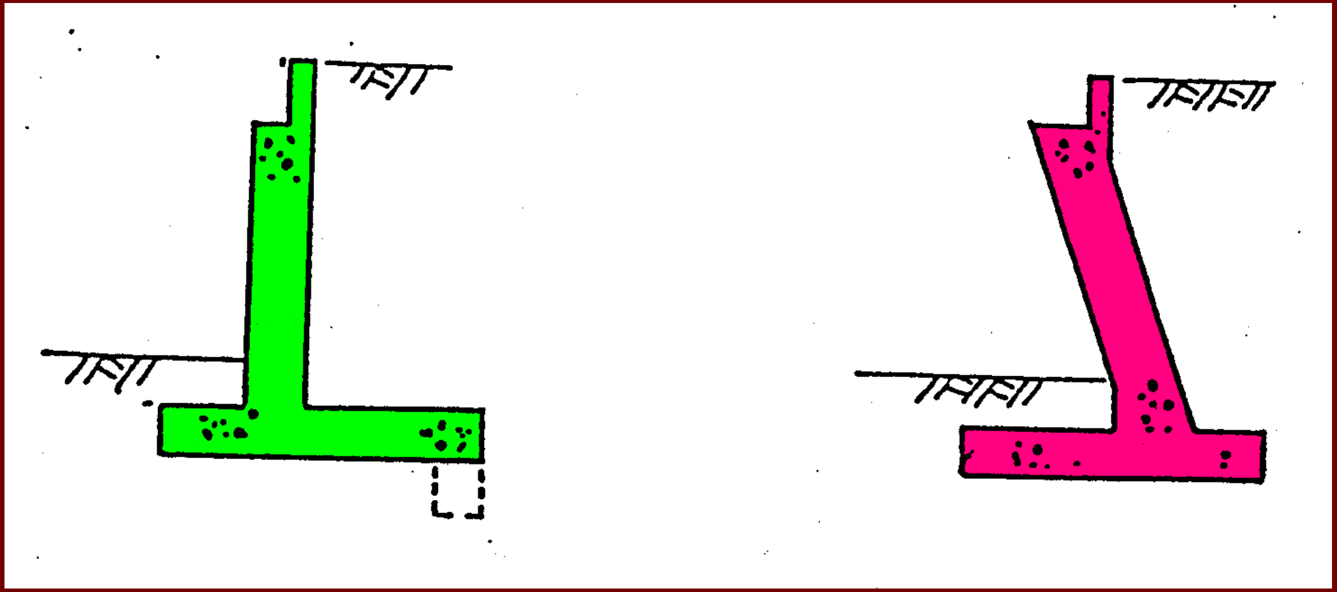
The cable-stayed bridge, like the suspension bridge, supports the roadway with massive steel cables, but in a different way. The cables run directly from the roadway up to a tower, forming a unique "A" shape.

Cable-stayed bridges are becoming the most popular bridges for medium-length spans (between 500 and 3,000 feet).



Other Types of Wall Abutments





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CTC 261 Hydraulics
Culvert Design Form

Objectives

- Know how to use the culvert design form to evaluate and size simple culverts

Definitions

- HW_o=Headwater depth above outlet invert

Step 1

- Summarize all known data and select a preliminary culvert size, shape and entrance type

Step 2

- Choose a culvert type and size

Step 3-Inlet Control Calculations

- Inlet control calculations
  - Determine HW/D from Design Charts
  - Calc HW depth
  - Calc Fall
  - Calc the Elev of the HW for inlet control

Step 4-Outlet Control Calculations

- Outlet control calculations
  - Determine TW depth
  - Determine critical depth
  - Find the average of critical depth and diameter
  - Determine depth from culvert outlet invert to HGL
  - Determine all head losses
  - Calc the Elev of the HW for outlet control

Step 5-Evaluate Results

- Higher of the two elevations designates control
- Choose larger culvert if the highest elevation is unacceptable

PROJECT :	STATION :	CULVERT DESIGN FORM
	SHEET ____ OF ____	DESIGNER / DATE : ____ / ____
		REVIEWER / DATE : ____ / ____

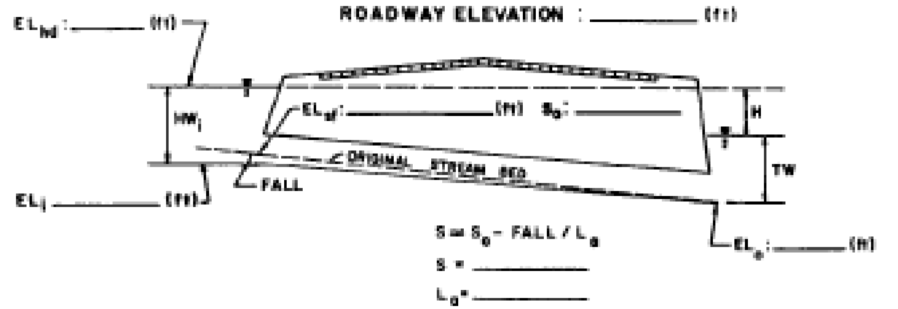
HYDROLOGICAL DATA

SEE ADD'L SHTS.

- ☐ METHOD: ____
- ☐ DRAINAGE AREA: ____ ☐ STREAM SLOPE: ____
- ☐ CHANNEL SHAPE: ____
- ☐ ROUTING: ____ ☐ OTHER: ____

DESIGN FLOWS/TAILWATER

R.I. (YEARS)	FLOW (cfs)	TW (ft)



CULVERT DESCRIPTION: MATERIAL - SHAPE - SIZE - ENTRANCE	TOTAL FLOW Q (cfs)	FLOW PER BARREL Q/N (1)	HEADWATER CALCULATIONS: INLET CONTROL HW_i/D (2)	HW_i	FALL (3)	EL_{hi} (4)	OUTLET CONTROL TW (5)	d_c	$\frac{d_c+D}{2}$	h_o (6)	k_e	H (7)	EL_{ho} (8)	CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS

TECHNICAL FOOTNOTES:

(1) USE Q/NB FOR BOX CULVERTS

(2) $HW_i/D = HW/D$ OR HW_i/D FROM DESIGN CHARTS

(3) $FALL = HW_i - (EL_{hd} - EL_{sf})$; FALL IS ZERO FOR CULVERTS ON GRADE

(4) $EL_{hi} = HW_i + EL_i$ (INVERT OF INLET CONTROL SECTION)

(5) TW BASED ON DOWN STREAM CONTROL OR FLOW DEPTH IN CHANNEL.

(6) $h_o = TW$ or $(d_c + D)/2$ (WHICHEVER IS GREATER)

(7) $H = \left[1 + k_e + (K_u n^2 L) / R^{1.33}\right] v^2 / 2g$ WHERE K_u = 19.63 (29 IN ENGLISH UNITS)

(8) $EL_{ho} = EL_o + H + h_o$

SUBSCRIPT DEFINITIONS :

a. APPROXIMATE
f. CULVERT FACE
hd. DESIGN HEADWATER
hi. HEADWATER IN INLET CONTROL
ho. HEADWATER IN OUTLET CONTROL
i. INLET CONTROL SECTION
o. OUTLET
sf. STREAMBED AT CULVERT FACE
tw. TAILWATER

COMMENTS / DISCUSSION :

CULVERT BARREL SELECTED :

SIZE: ____
SHAPE: ____
MATERIAL: ____ n ____
ENTRANCE: ____

Figure III-17--Culvert Design Form

Example Problem 1

- Q_{25}=200 cfs
- Natural channel slope=1%
- TW=3.5 ft
- L=200 ft
- Natl streambed elev. @ entrance = 100 ft
- Shoulder Elev=110 ft (2-ft freeboard)
- Evaluate 72" (6') CMP (45 deg bevel)

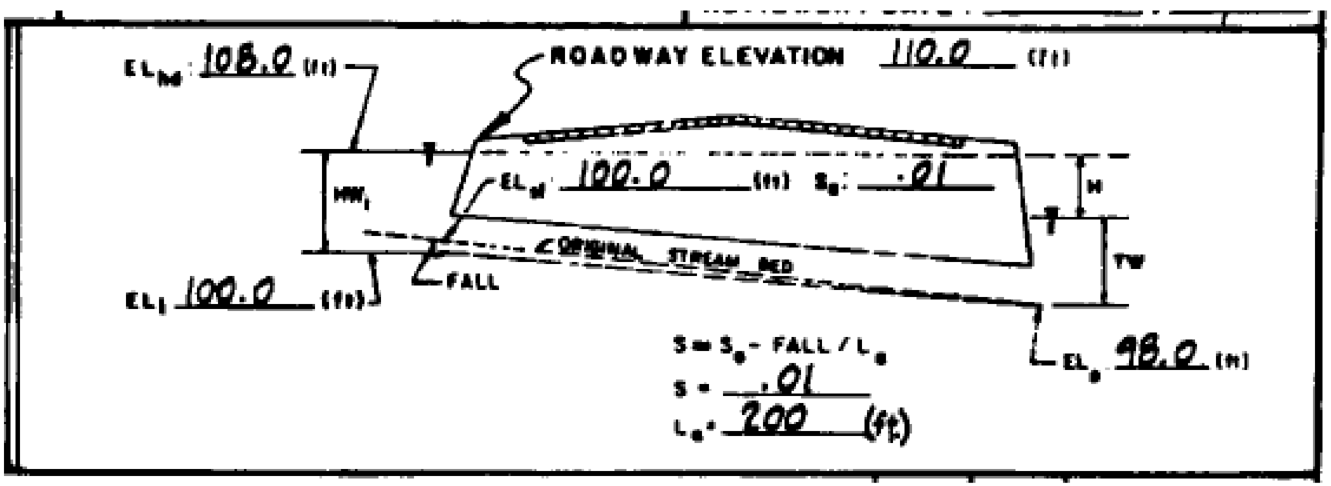
HYDROLOGICAL DATA

SEE ADD'L SHTS

- ☐ METHOD: RATIONAL
- ☐ DRAINAGE AREA: 125 Ac. ☐ STREAM SLOPE: 1.0%
- ☐ CHANNEL SHAPE: TRAPEZOIDAL
- ☐ ROUTING: N/A ☐ OTHER:

DESIGN FLOWS/TAILWATER

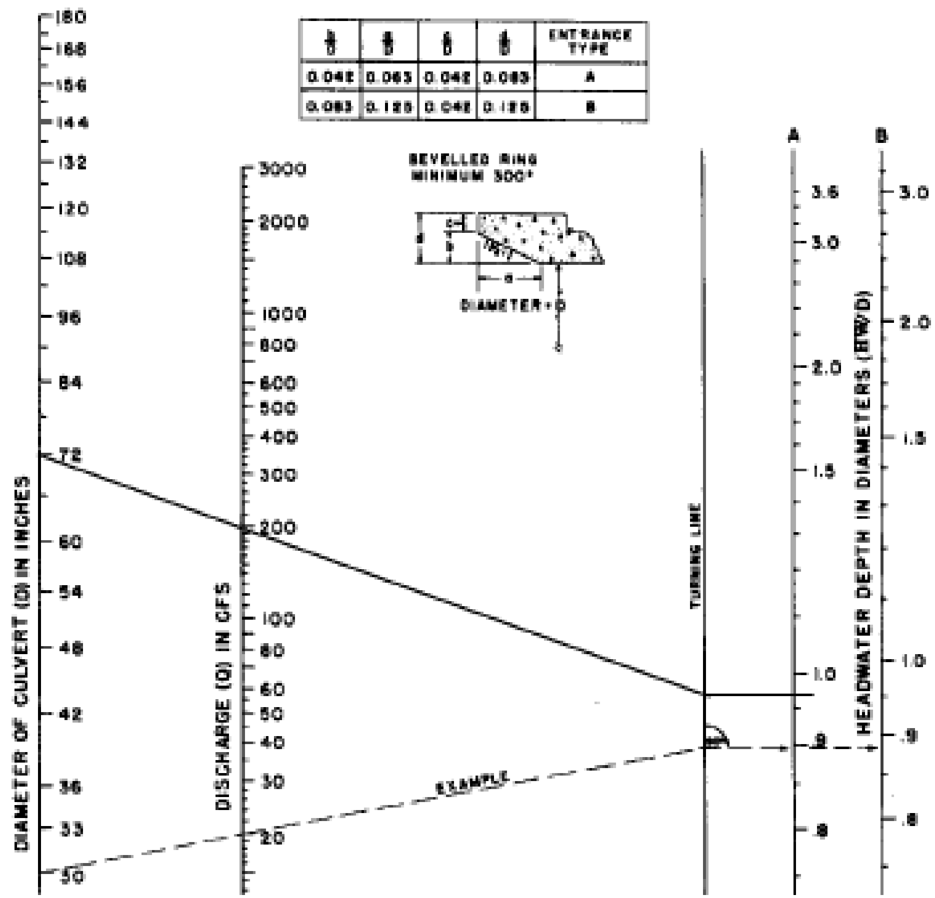
R.I. (YEARS)	FLOW (cfs)	TW (ft)
25	200	3.5



Step 2

Inlet Control Calculations

CHART 3B



- HW/D from Design Chart 3B = 0.96
- HW=0.96*6’=5.8’
- A =45 deg bevel, pg 27
- B =33.7 deg bevel

Step 3-Inlet Control Calculations
Calculate Fall

- Max. Available HW depth = 108-100= 8’
- Fall = Calc HW depth – Available HW depth
  - 5.8’-8’= -2.8 ft
  - Fall is negative; therefore set fall = 0
  - Note: If fall is + then the invert must be lowered to allow enough head to “push” desired Q through the culvert

Step 3-Inlet Control Calculations
Calculate HW Elev for inlet control

- $EL_{hi} = HW_i + EL_i$
- 5.8 ft + 100 ft = 105.8 feet

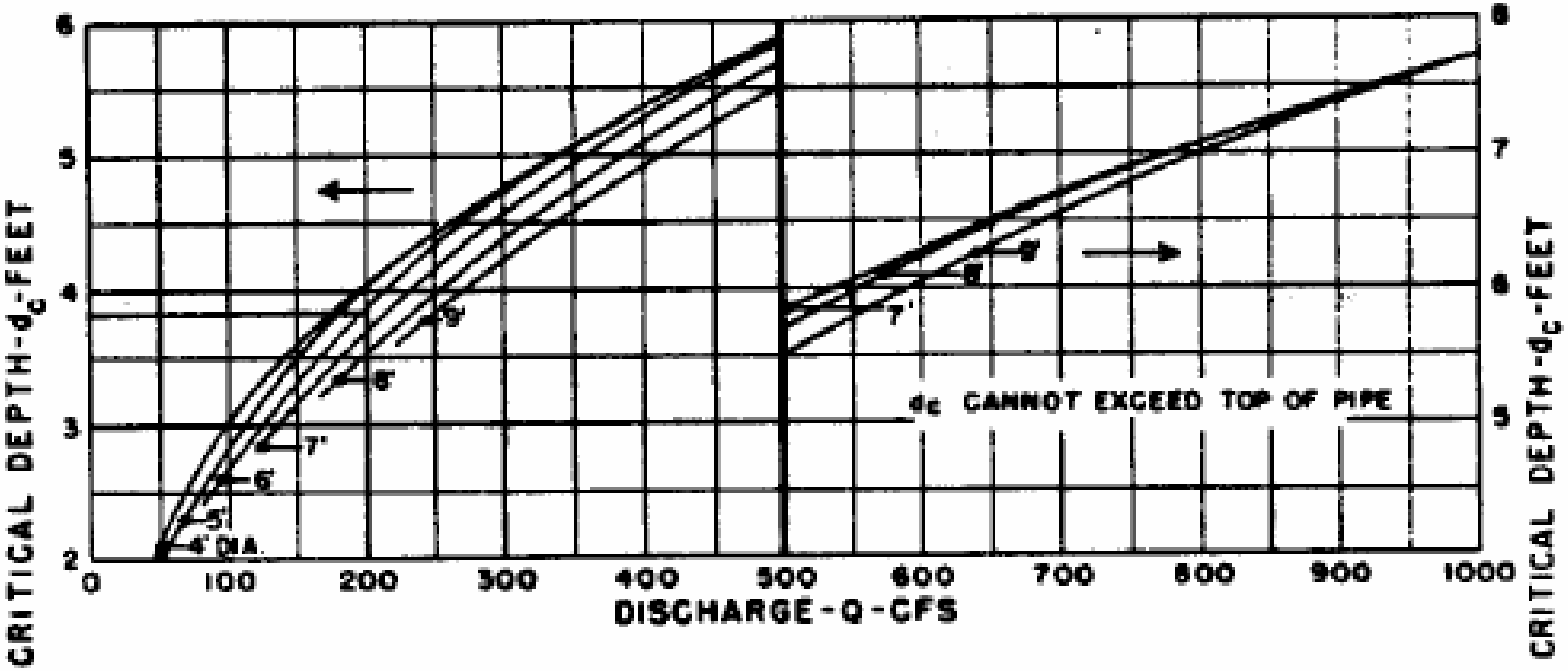
CULVERT DESCRIPTION: MATERIAL - SHAPE - SIZE - ENTRANCE	TOTAL FLOW Q (cfs)	FLOW PER BARREL Q/N (1)	HEADWATER CALCULATIONS: INLET CONTROL HW_i/D (2)	HW_i	FALL (3)	EL_{hi} (4)	OUTLET CONTROL TW (5)	d_c	$\frac{d_c+D}{2}$	h_o (6)	k_e	H (7)	EL_{ho} (8)	CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS
C.M.P. - CIRC. - 72 IN. - BEVEL 45° IN HEADWALL	200	200	96	58	–	105.8	3.5	3.8	4.9	4.9	02	2.6	105.5	105.8	9.0	TRY 60" C.M.P.

Step 4-Outlet Control Calculations TW Depth

- Determine TW depth
- backwater or normal depth calculations
- Given as 3.5’

Step 4-Outlet Control Calculations Critical Depth

- Determine Critical Depth (Chart 4A) 3.8’



Step 4-Outlet Control Calculations
Find average of dc + D

(3.8+6)/2 = 4.9’

CULVERT DESCRIPTION: MATERIAL - SHAPE - SIZE - ENTRANCE	TOTAL FLOW	FLOW PER BARREL	HEADWATER CALCULATIONS											CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS
			INLET CONTROL				OUTLET CONTROL									
	Q (cfs)	Q/N (1)	HW_i/D (2)	HW_i	FALL (3)	EL_{hi} (4)	TW (5)	d_c	$\frac{d_c+D}{2}$	h_o (6)	k_e	H (7)	EL_{ho} (8)			
CMP - CIRC. - 72 IN. - BEVEL 45° IN HEADWALL	200	200	96	58	—	105.8	3.5	3.8	4.9	4.9	0.2	2.6	105.5	105.8	9.0	TRY 60" CMP.

Step 4-Outlet Control Calculations Determine ho

- h_o is the depth from the culvert outlet invert to the hydraulic grade line
- Larger of:
  - TW (3.5’) or
  - Avg. of (d_c & D-4.9’) ---See Figure III-9 (D)

CULVERT DESCRIPTION: MATERIAL - SHAPE - SIZE - ENTRANCE	TOTAL FLOW Q (cfs)	FLOW PER BARREL Q/N (1)	HEADWATER CALCULATIONS: INLET CONTROL HW_i/D (2)	HW_i	FALL (3)	EL_{hi} (4)	OUTLET CONTROL TW (5)	d_c	$\frac{d_c+D}{2}$	h_o (6)	k_e	H (7)	EL_{ho} (8)	CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS
CMP - CIRC. - 72 IN. - BEVEL 45° IN HEADWALL	200	200	.96	5.8	–	105.8	3.5	3.8	4.9	4.9	0.2	2.6	105.5	105.8	9.0	TRY 60" CMP.

Step 4-Outlet Control Calculations Find Entrance Loss Coefficient, K_e

- K_e= 0.2

Table 12--Entrance Loss Coefficients.

Outlet Control, Full or Partly Full Entrance Head Loss

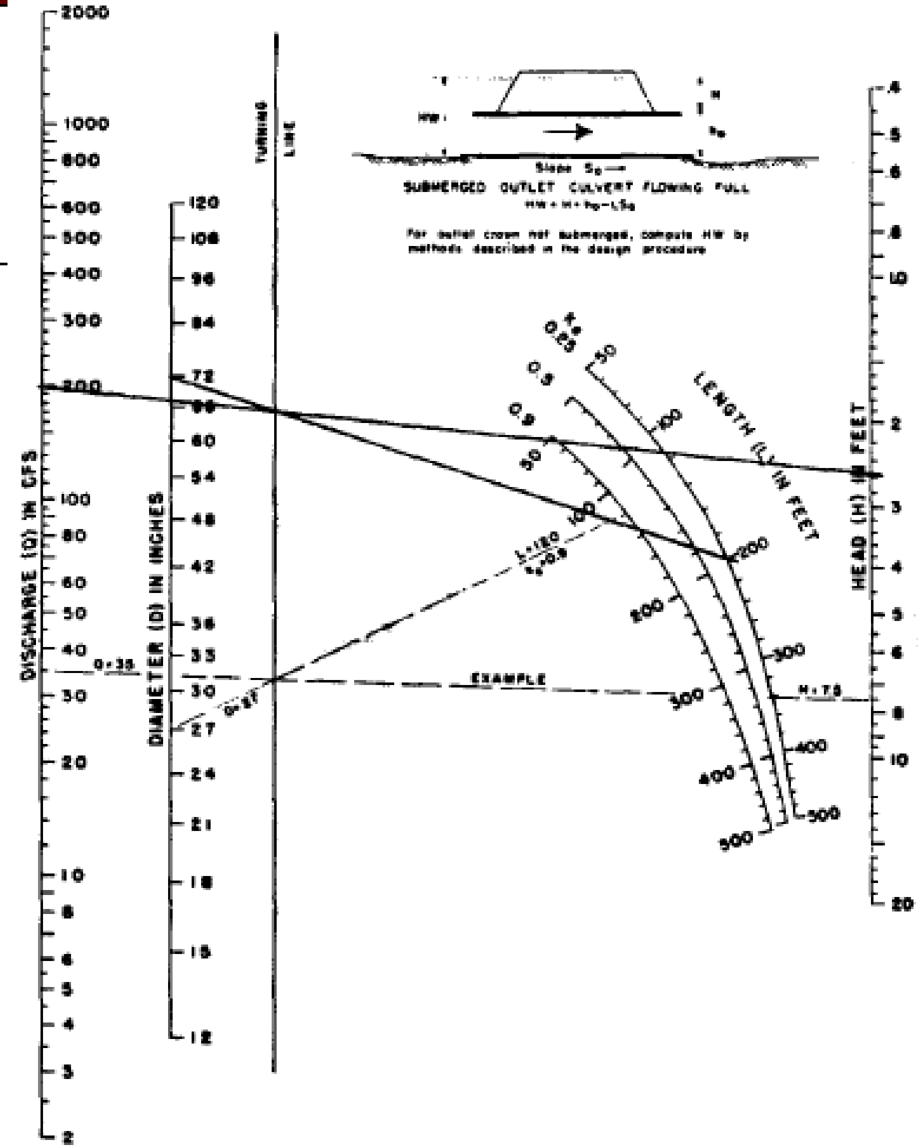
$$H_e = K_e\left[\frac{V^2}{2g}\right]$$

Type of Structure and Design of Entrance	Coefficient K_e
• Pipe, Concrete	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove-end	0.2
Square-edge	0.5
Rounded (radius = D/12	0.2
Mitered to conform to fill slope	0.7
*End-Section conforming to fill slope	0.5
Beveled edges, 33.7^0 or 45^0 bevels	0.2
Side- or slope-tapered inlet	0.2
• Pipe. or Pipe-Arch. Corrugated Metal	
Projecting from fill (no headwall)	0.9
Headwall or headwall and wingwalls square-edge	0.5
Mitered to conform to fill slope, paved or unpaved slope	0.7
*End-Section conforming to fill slope	0.5
Beveled edges, 33.7^0 or 45^0 bevels	0.2
Side- or slope-tapered inlet	0.2

Outlet Control Head Losses

- Can use Chart 6
- Line D/Ke
- Line Q/Turning Pt
- H=2.6’

CHART 6B



BUREAU OF PUBLIC ROADS JAN 1963

HEAD FOR STANDARD C. M. PIPE CULVERTS FLOWING FULL n = 0.024

Step 4-Outlet Control Calculations Calculate HW Elevation

- Outlet Invert Elev + Head Losses + h_o
- 98+2.6+4.9
- HW elevation based on outlet control = 105.5’

CULVERT DESCRIPTION:	TOTAL FLOW	FLOW PER BARREL	HEADWATER CALCULATIONS											CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS
			INLET CONTROL				OUTLET CONTROL									
MATERIAL - SHAPE - SIZE - ENTRANCE	Q (cfs)	Q/N (1)	HW_i/D (2)	HW_i	FALL (3)	EL_{hi} (4)	TW (5)	d_c	$\frac{d_c+D}{2}$	h_o (6)	k_e	H (7)	EL_{ho} (8)			
CMP - CIRC. - 72 IN. - BEVEL 45° IN HEADWALL	200	200	96	58	–	105.8	3.5	3.8	4.9	4.9	02	2.6	105.5	105.8	9.0	TRY 60" CMP.

Step 5 Evaluate Results

- Culvert is operating under inlet control
- There is still 2 ft of head available
- Try a smaller culvert

Outlet Velocity – Inlet Control

- Velocity at normal depth (in the culvert barrel) is assumed to be the outlet velocity
- Use Manning's equation
  - Calculate d/D which gives a Q of 200 cfs
  - Velocity = 9.2 cfs

Outlet Velocity- Outlet Control

- Use critical depth if TW>critical depth
- Use TW if TW is between critical depth and top of barrel
- Use full depth of barrel if TW is above top of barrel

Culvert Design

CULVERT DESCRIPTION: MATERIAL - SHAPE - SIZE - ENTRANCE	TOTAL FLOW Q (cfs)	FLOW PER BARREL Q/N (1)	HEADWATER CALCULATIONS: INLET CONTROL HW_i/D (2)	HW_i	FALL (3)	EL_{hi} (4)	OUTLET CONTROL TW (5)	d_c	$\frac{d_c+D}{2}$	h_o (6)	k_e	H (7)	EL_{ho} (8)	CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS
CMP - CIRC. - 72 IN. - BEVEL 45° IN HEADWALL	200	200	96	58	–	105.8	3.5	3.8	4.9	4.9	0.2	2.6	105.5	105.8	9.0	TRY 60" CMP.
" " - 60 IN. - " 45°			1.63	7.15	–	107.2		4.1	4.6	4.6		6.3	108.9	108.9	11.9	TRY 60" CONC.
CONC. " - 60 IN. - GROOVE END			1.36	6.8	–	106.8			4.6	4.6		2.9	105.5	106.8	15.6	TRY 54" CONC.
" " - 54 IN. - "	↓	↓	1.77	7.97	–	108.0	↓	↓	4.3	4.3	↓	4.7	107.0	108.0	15.3	OK

COMMENTS / DISCUSSION:

HIGH OUTLET VELOCITY - OUTLET PROTECTION OR LARGER CONDUIT MAY BE NECESSARY

Culvert Design

- Multiple structures
  - For 2 pipes or boxes of same size, etc. Q/2

- For concrete box culvert
  - 6’ x 5’ (span x height)—note
    - Ex 9-4 in book violates this “usual”
  - Q/H = Flow per foot of span
  - D = height of culvert box (5’)

Chapter VI – Special Considerations Flow Control & Measurement

- Irrigation Canals
- Stormwater Management Ponds
- Cooling Waterchannels

Figure VI-1--Stormwater Management Pond with Culvert as Outflow Control Device

- Use routing to determine inflow into any pond upstream of culvert

Chapter VI – Special Considerations Low Head Installations

- Convey water under a roadway w/ min. HW and energy loss
- Usually found in irrigation systems
- Sag culverts sometimes used

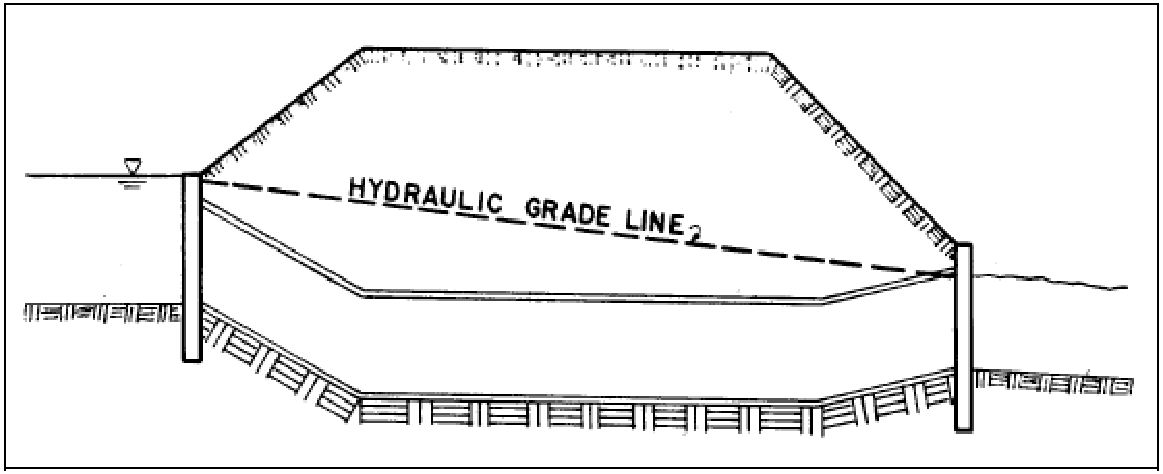


Figure VI-2--Sag Culvert

Chapter VI – Special Considerations Bends – Horizontal or Vertical

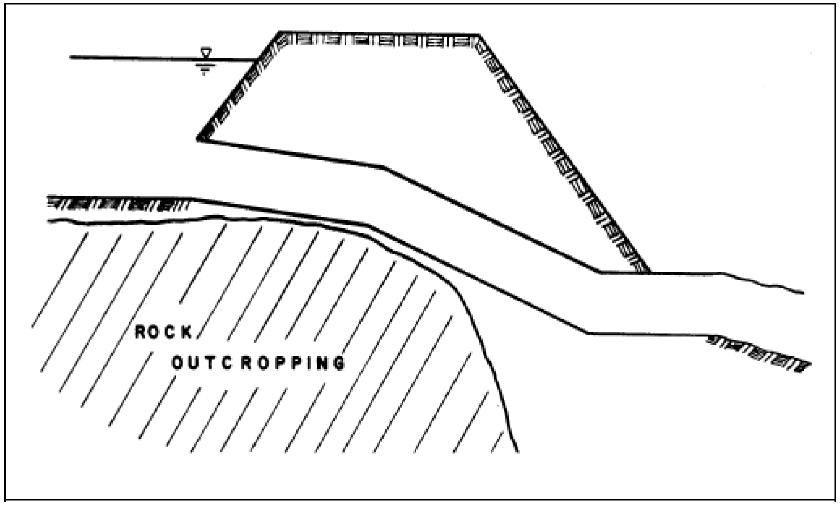


Figure VI-3--"Broken-Back" Culvert

Figure VI-4--Culvert with a Horizontal Bend (Contech)

Chapter VI – Special Considerations Junctions

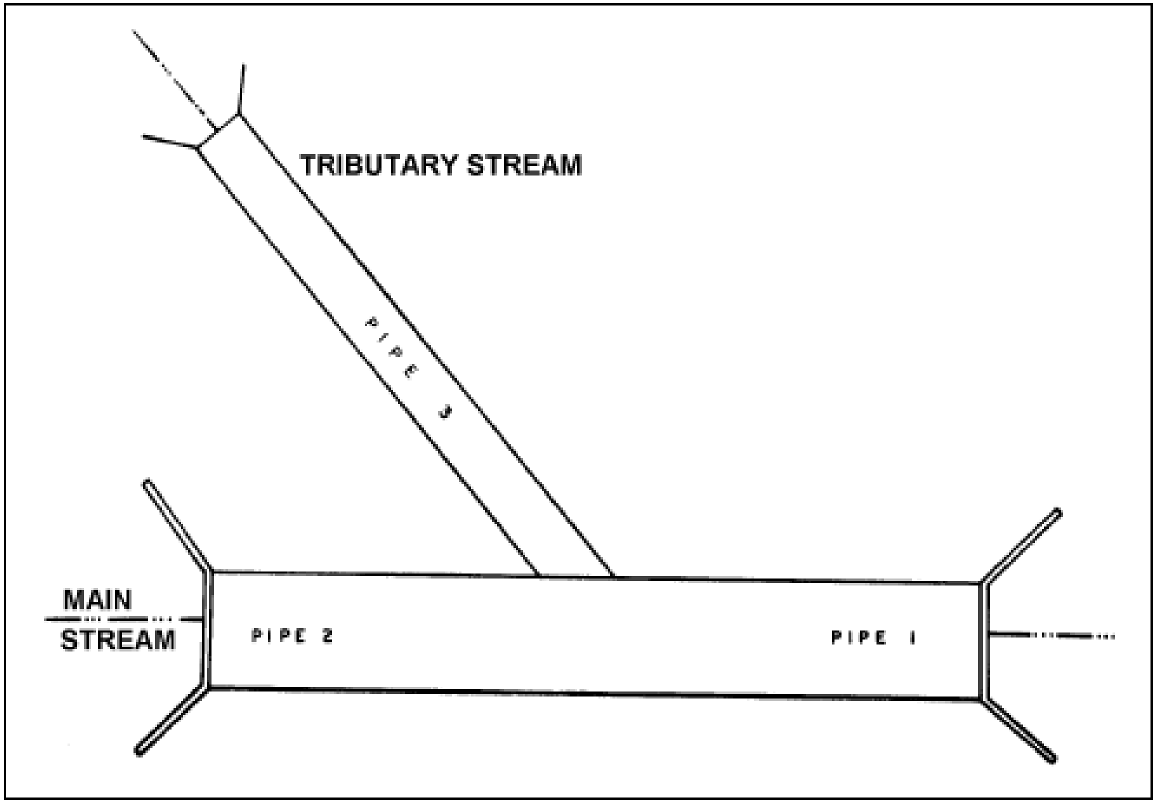


Figure VI-5--Culvert Junction

Chapter VI – Special Considerations
Siphons (vacuum)-rarely designed

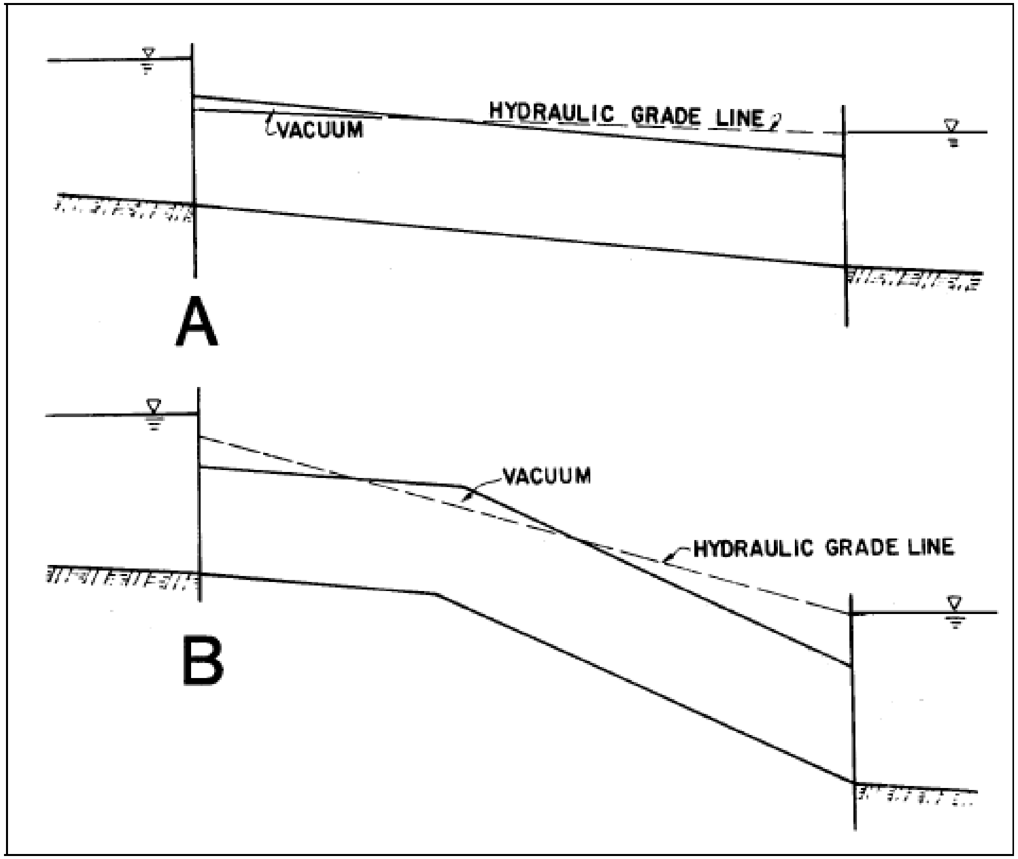


Figure VI-6--Subatmospheric Pressure in Culverts

Chapter VI – Special Considerations
Fish Passage

Figure VI-7--Fish Baffles in Culvert

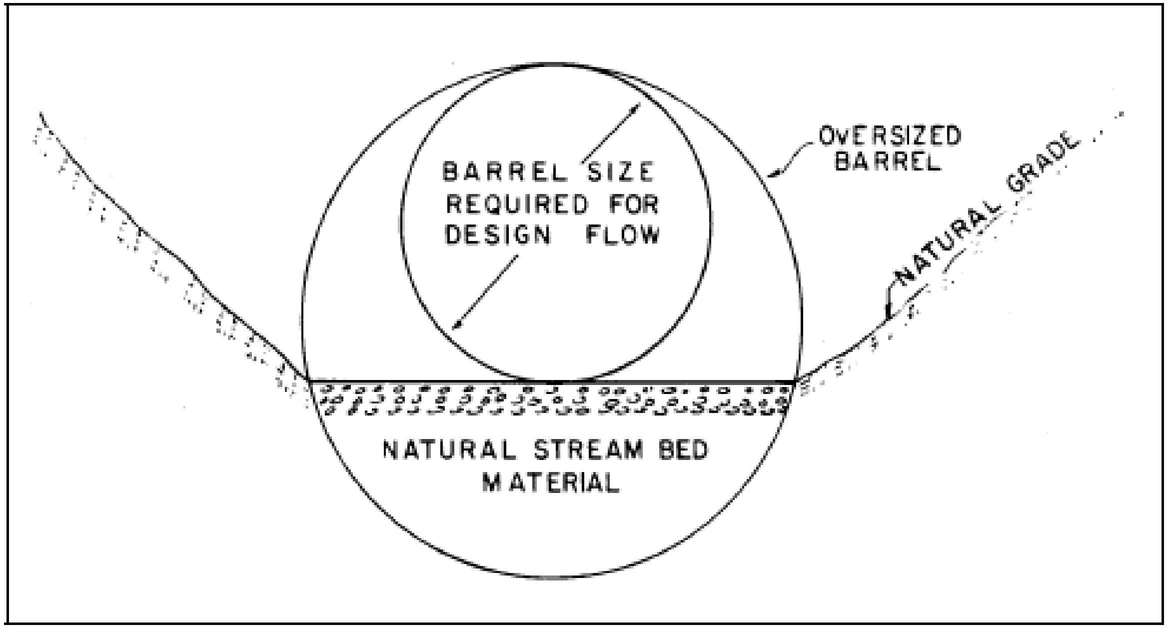


Figure VI-8--Culvert Barrel Partially Buried to Preserve Natural Stream Bed

DAMS

Dam is a solid barrier constructe at a suitable location across a river valley to store flowing water.

- ***Storage of water is utilized for following objectives:***
- **Hydropower**
- **Irrigation**
- **Water for domestic consumption**
- **Drought and flood control**
- **For navigational facilities**
- **Other additional utilization is to develop fisheries**

Type of dams

1. **Gravity dams**
2. **Buttress dams**
3. **Arch dams**
4. **Earth dams**

Gravity dam **- A dam constructed of concrete and/or masonry, which relies on its weight and internal strength for stability.**

Advantages of gravity dams

1. **Gravity dams are more strong and stable .**
2. **Gravity dams are used as an over flow spillway crest .**
3. **Gravity dams can be constructed of any heigh .**
4. **Gravity dams required the least maintenance .**
5. **The failure of Gravity dam is not sudden .**

Disadvantages of gravity dams

1. **Gravity dams can be constructed only on sound rock foundations .**
2. **The initial cost is always higher than an earth dam.**
3. **Gravity dams required skilled labour.**

Buttress dam **- A dam consisting of a watertight part supported at intervals on the downstream side by a series of buttresses. Buttress dam can take many forms, such as a flat slab or massive head buttress.**

Advantages of buttress dams

1. **It is less massive than gravity dams , so the foundation pressures are less and it can be constructed on weak foundation .**
2. **Power house and water treatment plants can be housed in between buttresses ,so saving cost and construction.**
3. **The amount of concrete used in these dams is about 1/2 to1/3 of concrete used in gravity dams of the same height .**

Disadvantages of buttress dams

1. **It needs skilled labour for construction .**

Arch dam **- A concrete, masonry, or timber dam with the alignment curved upstream so as to transmit the major part of the water load to the abutments**.

Advantages of arch dams

- **Arch dams are preferred to the gorges .**
- **For the same height ,the section of arch dam is lesser than gravity dam.**
- **Because of much less base width ,the problem of uplift pressure is minor.**

Disadvantages of arch dams

- **It requires skilled labour.**
- **It requires very strong foundation.**
- **The speed of construction is low.**

Earth dam **- An embankment dam in which more than 50% of the total volume is formed of compacted earth layers are generally smaller than 3-inch size .It is trapezoidal in shape ,and mainly built with clay ,sand ,and gravel. It also called as rock fill dam.**

Advantages of earth and rock fill dams

- ❖ **Earth dams can be constructed on any type of available foundation**
- ❖ **Earth dams can be constructed rapidly with unskilled labour and with material available on the spot .**
- ❖ **They ae cheaper than other types.**

Disadvantages of earth and rock fill dams

- ❖ **They are more affected by floods and fail suddenly .**
- ❖ **They can not be used as over flow dams .**
- ❖ **They require heavy maintenance cost and constant supervision.**

Note **{The earth dams are built of locally available material and used for moderate heights.}**

Depending on method of construction they can be classified as:

- ✓ **Rolled fill dams.**
    1. **Homogeneous embankment type.**
    2. **Zoned embankment type.**
    3. **Diaphragm embankment type.**
- ✓ **Hydraulic fill dams.**

Homogeneous embankment type

It composed of a single kind of material with or without internal drain.

Zoned embankment type

It is made of more than one material.

Diaphragm embankment type

It is constructed of pervious material and a thin diaphragm of impervious material is provided to check the seepage .[The diaphragm may be placed at the center or at the upstream]

Cutoff trench - A foundation excavation later to be filled with impervious material so as to limit seepage beneath a dam.

Hydraulic fill dam - An earth dam constructed of materials, often dredged, which are conveyed and placed by suspension in flowing water.

Diaphragm wall (membrane) - A sheet, thin zone, or facing made of an impervious material such as concrete, steel, wood, plastic, etc. Also see core wall.

Core wall - A wall built of relatively impervious material, usually of concrete or asphaltic concrete in the body of an embankment dam to prevent seepage.

Energy dissipater - A device constructed in a waterway to reduce the kinetic energy of fast flowing water.

Gallery - A passageway in the body of a dam used for inspection, foundation grouting, and/or drainage.

Ogee - A double curve shaped like an elongated S, usually associated with a spillway configuration designed with optimal overflow characteristics

Reservoir - A body of water impounded by a dam and in which water can be stored.

Riprap - A layer of large uncoursed stone, precast blocks, bags of cement, or other suitable material, generally placed on the slope of an embankment or along a watercourse as protection against wave action, erosion, or scour. Riprap is usually placed by dumping or other mechanical methods, and in some cases is hand placed. It consists of pieces of relatively large size, as distinguished from a gravel blanket.

Spillway - A structure over or through which flow is discharged from a reservoir. If the rate of flow is controlled by mechanical means, such as gates, it is considered a controlled spillway. If the geometry of the spillway is the only control, it is considered an uncontrolled spillway.

Stilling basin - A basin constructed to dissipate the energy of rapidly flowing water, e.g., from a spillway or outlet, and to protect the riverbed from erosion.

Water hammer - Any rapid increase of pressure in a pipeline caused by stopping the flow suddenly. Surge tanks are used to counter water hammers.

2.5 Stilling Basins

A stilling basin is a basin-like structure in which all or a part of the energy is dissipated. In a stilling basin, the kinetic energy causes turbulence and it is ultimately lost as heat energy. The stilling basins commonly used for spillways are of the hydraulic jump type, in which dissipation of energy is accomplished by a hydraulic jump.

A hydraulic jump can be stabilised in stilling basin b y using appurtenances (or accessories such as chute blocks, basin blocks and end sill.

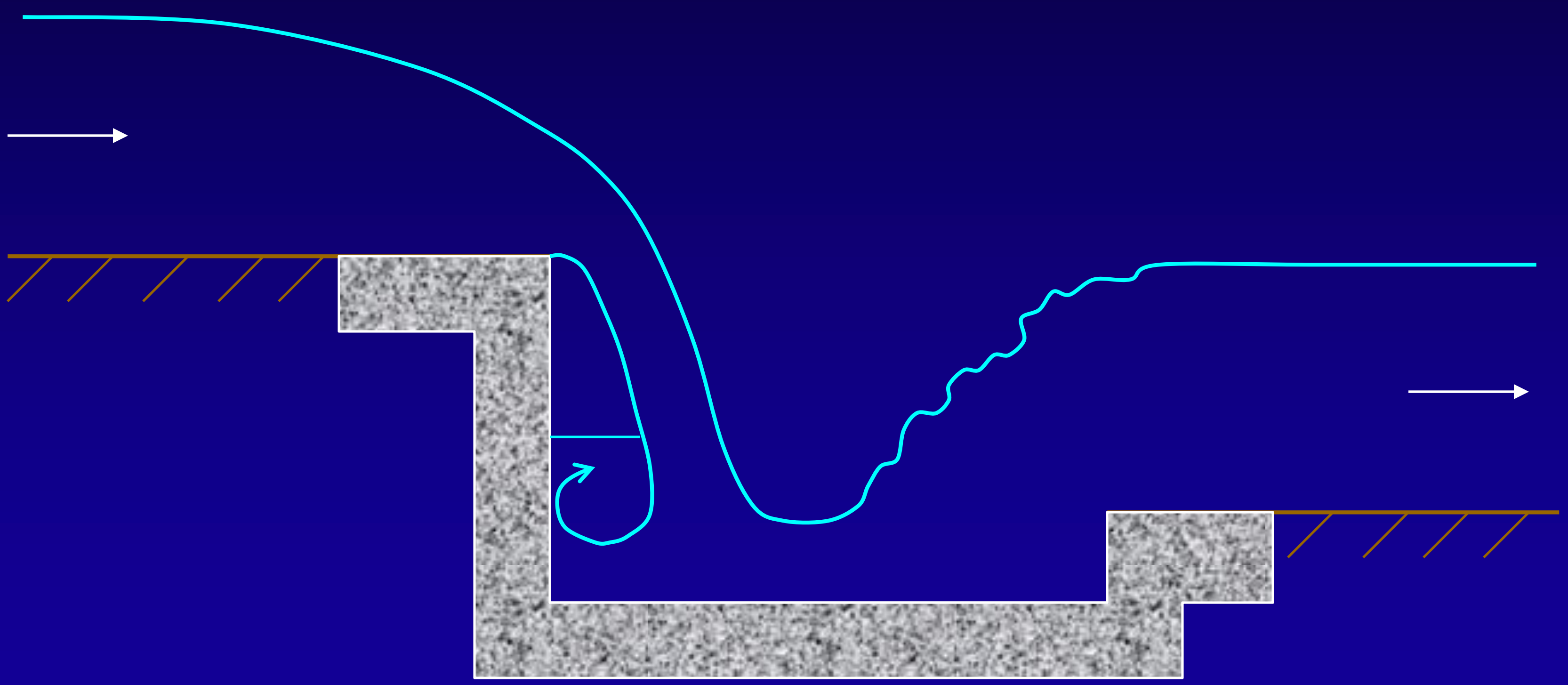
Modeling Drop Structures in HEC-RAS Version 3.1

Modeling Drop Structures

- Overview
- Modeling a Drop Structure as an Inline Structure (Weir).
- Modeling a drop structure with cross-sections through the drop.
- Example using Lab Data.

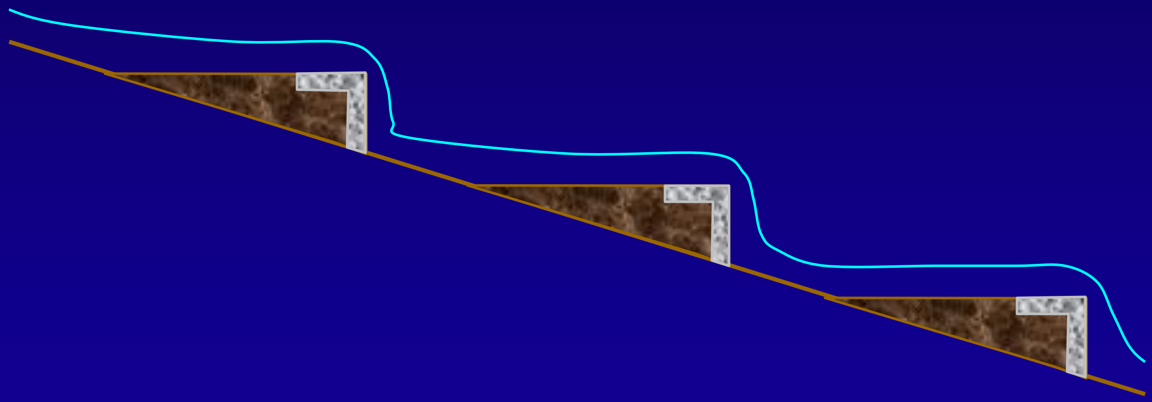
Overview

- What is a Drop Structure?



Overview

- Why do we use Drop Structures ?



Overview

Overview

Overview

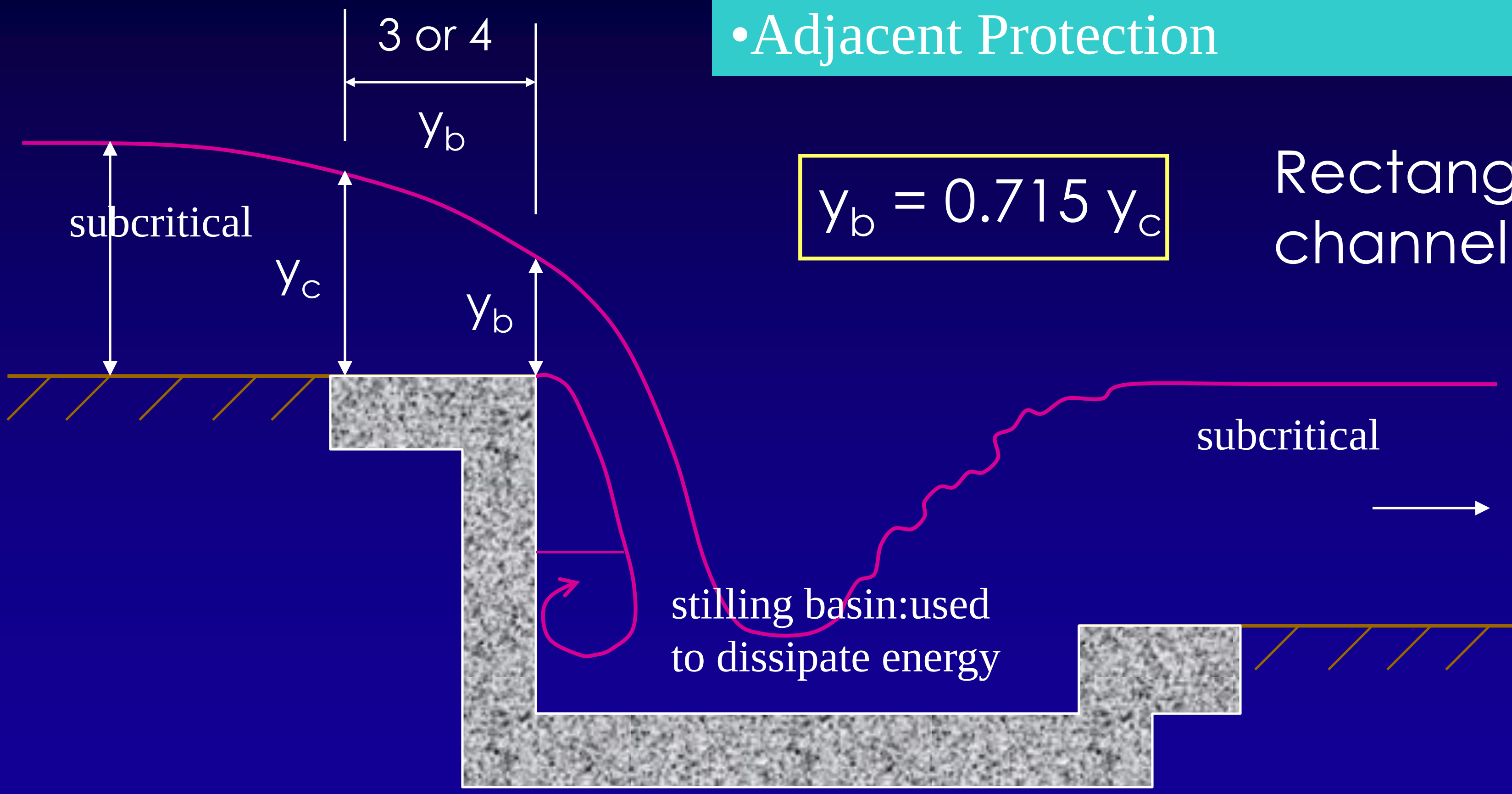
Overview

Overview

Overview

Components of Drop Structure

- Control Section
- Energy Dissipation Section
- Adjacent Protection



$$\boxed{y_b = 0.715\, y_c}$$

Rectangular channel

Overview

- How can we Model a Drop Structure with HEC-RAS ?
  - Inline Weir Option
  - Using Cross Sections

Overview

- Which is more appropriate?
  - Inline Weir Option - probably better if just interested in elevations upstream and downstream of structure.
  - Using Cross Sections - better if interested in profile through the structure.

Cross-Section Locations

When placing cross-sections near and through a drop structure, they need to be placed where the water surface and velocity are changing rapidly (this applies when using an inline weir also).

Modeling a Drop Structure as an Inline Weir

- The standard weir equation is used:

$$\boxed{Q = CLH^{3/2}}$$

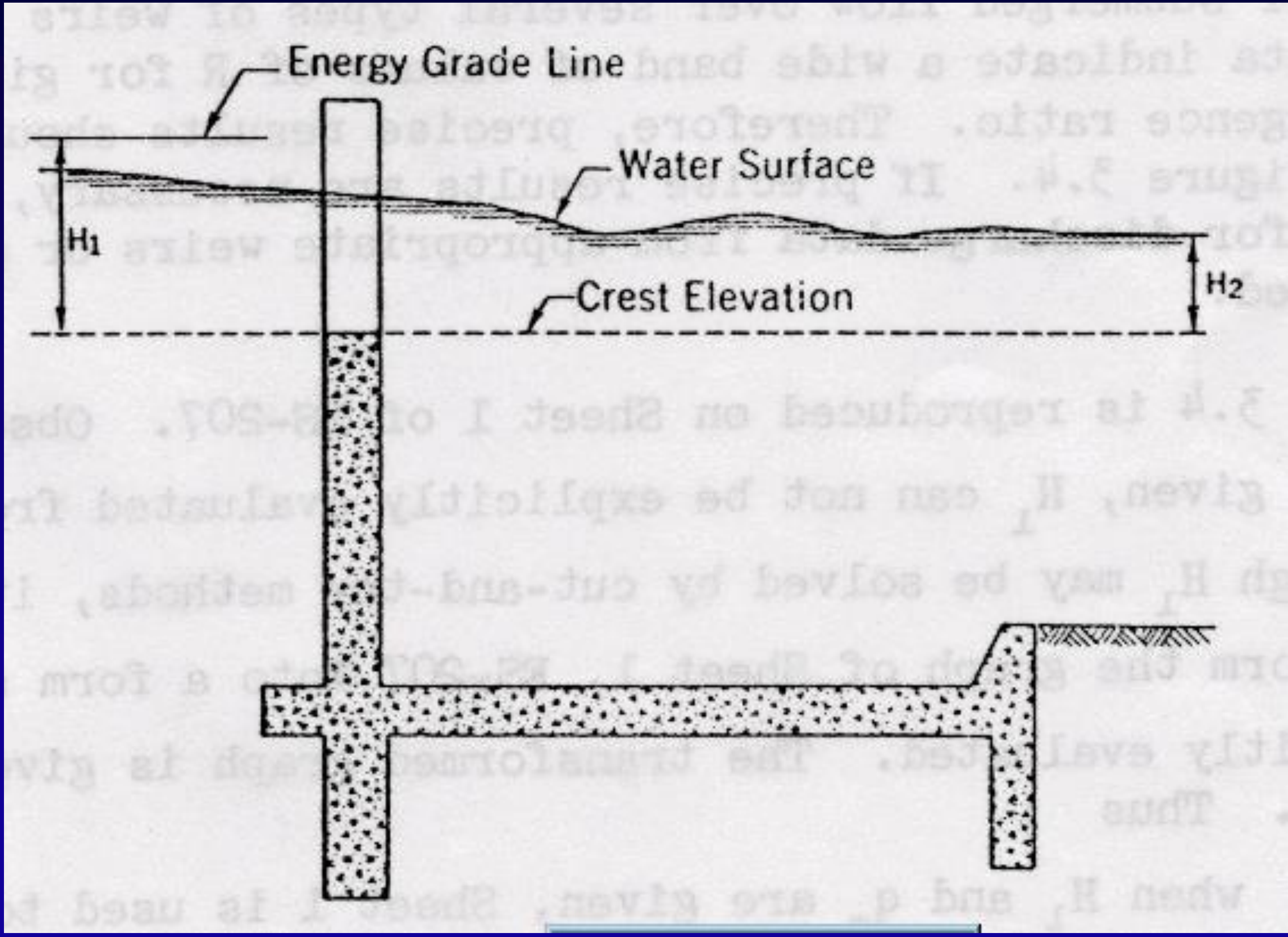
  - where: C = 2.6 - 4.0 (dependent on shape)

    L = Length of weir

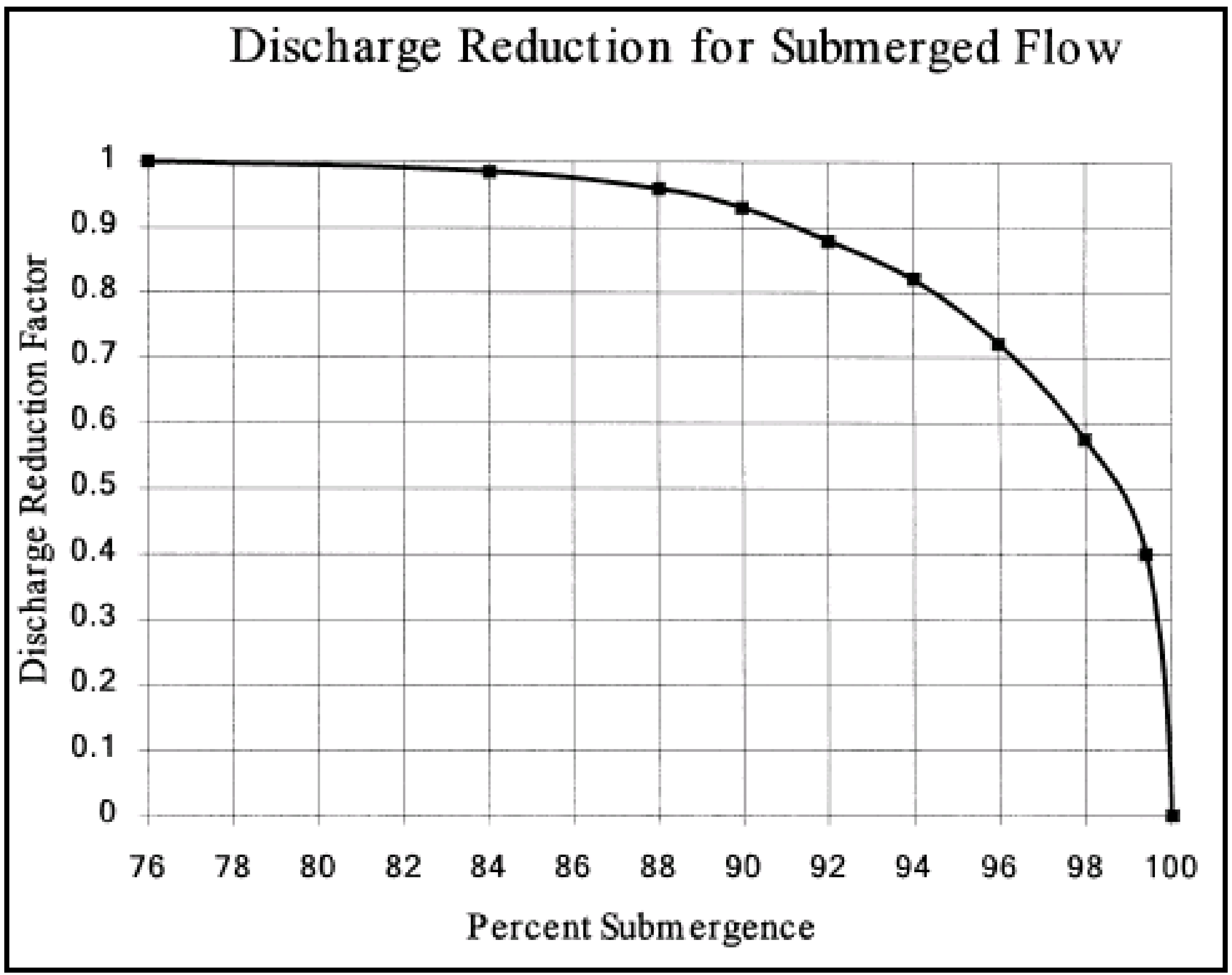
    H = Upstream Energy Head

Inline Weir - Submergence

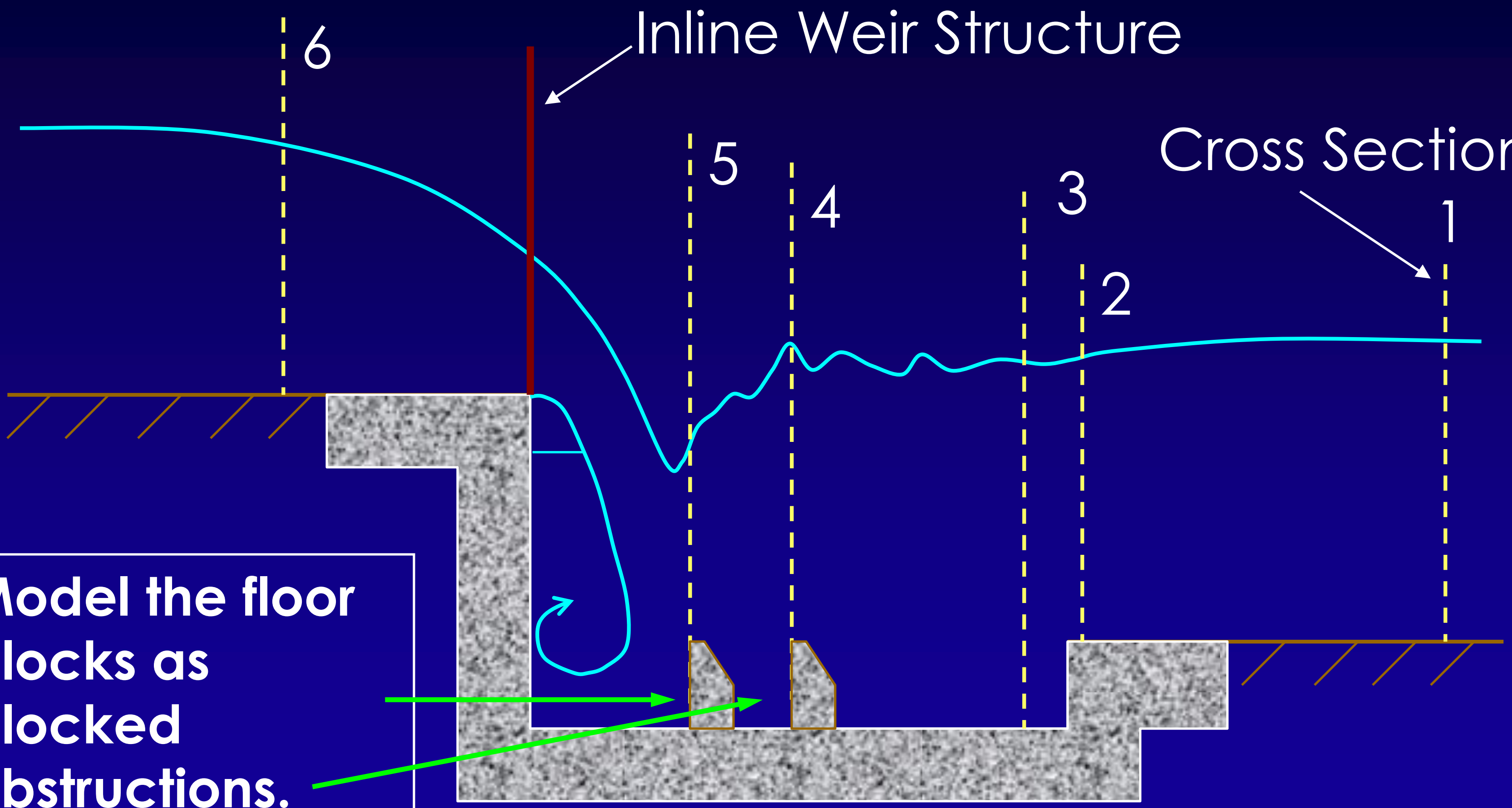
Submergence is defined as H_2/H_1



Inline Weir - Submergence



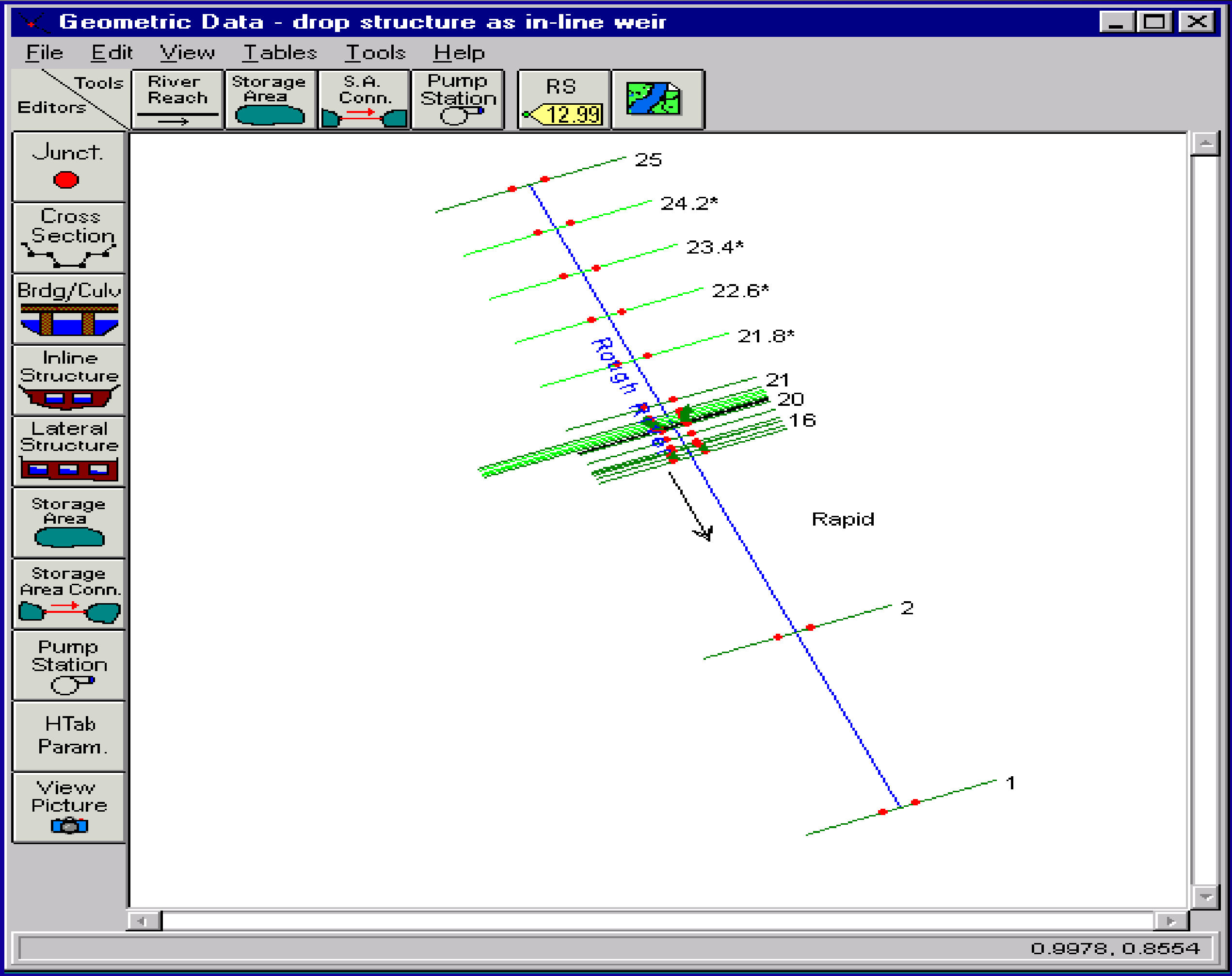
Inline Weir - Cross Section Layout



Model the floor blocks as blocked obstructions.

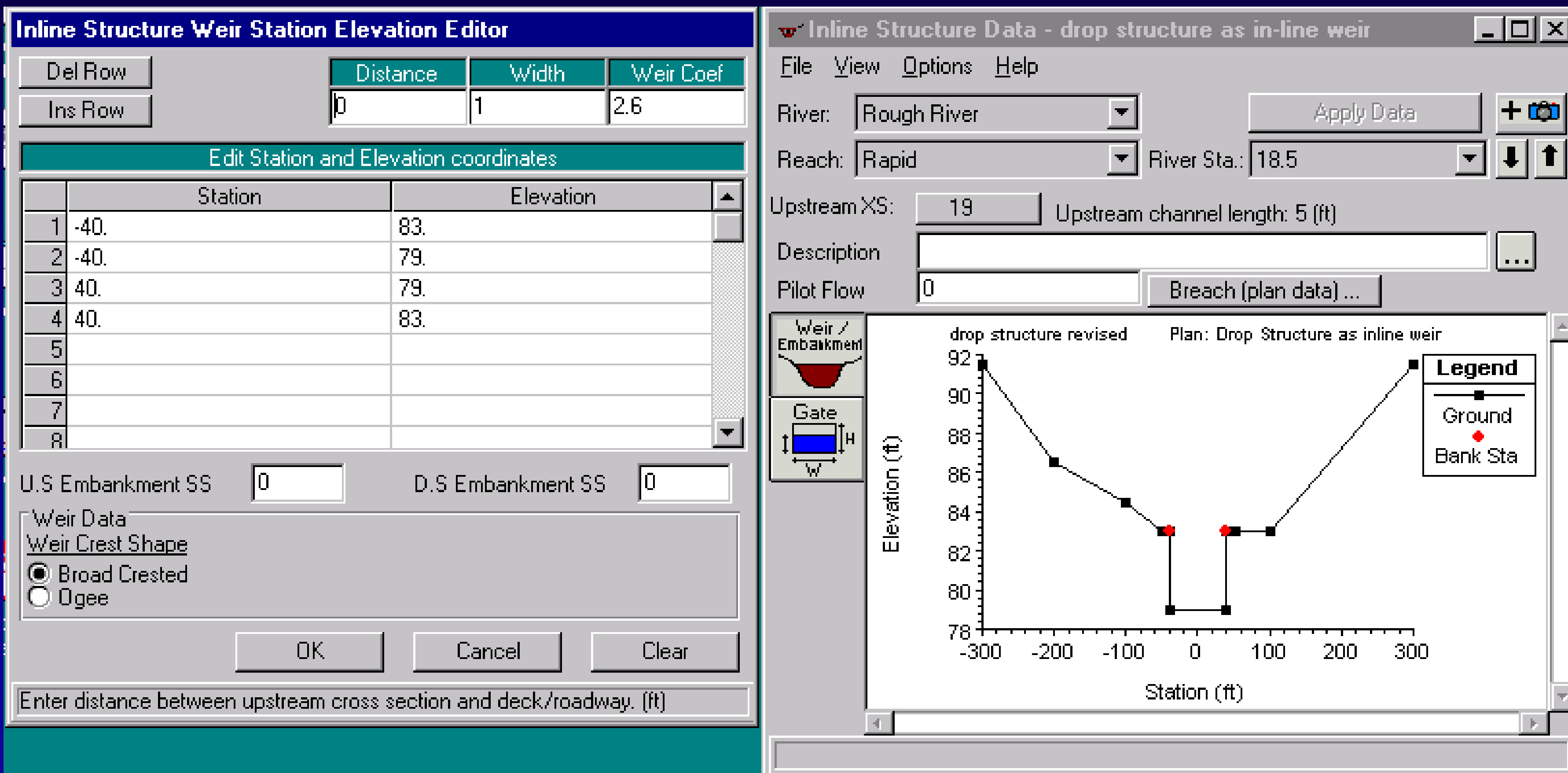
Modeling a Drop Structure as an Inline Structure

Under the "Geometric Data"click on "Inline Structure"

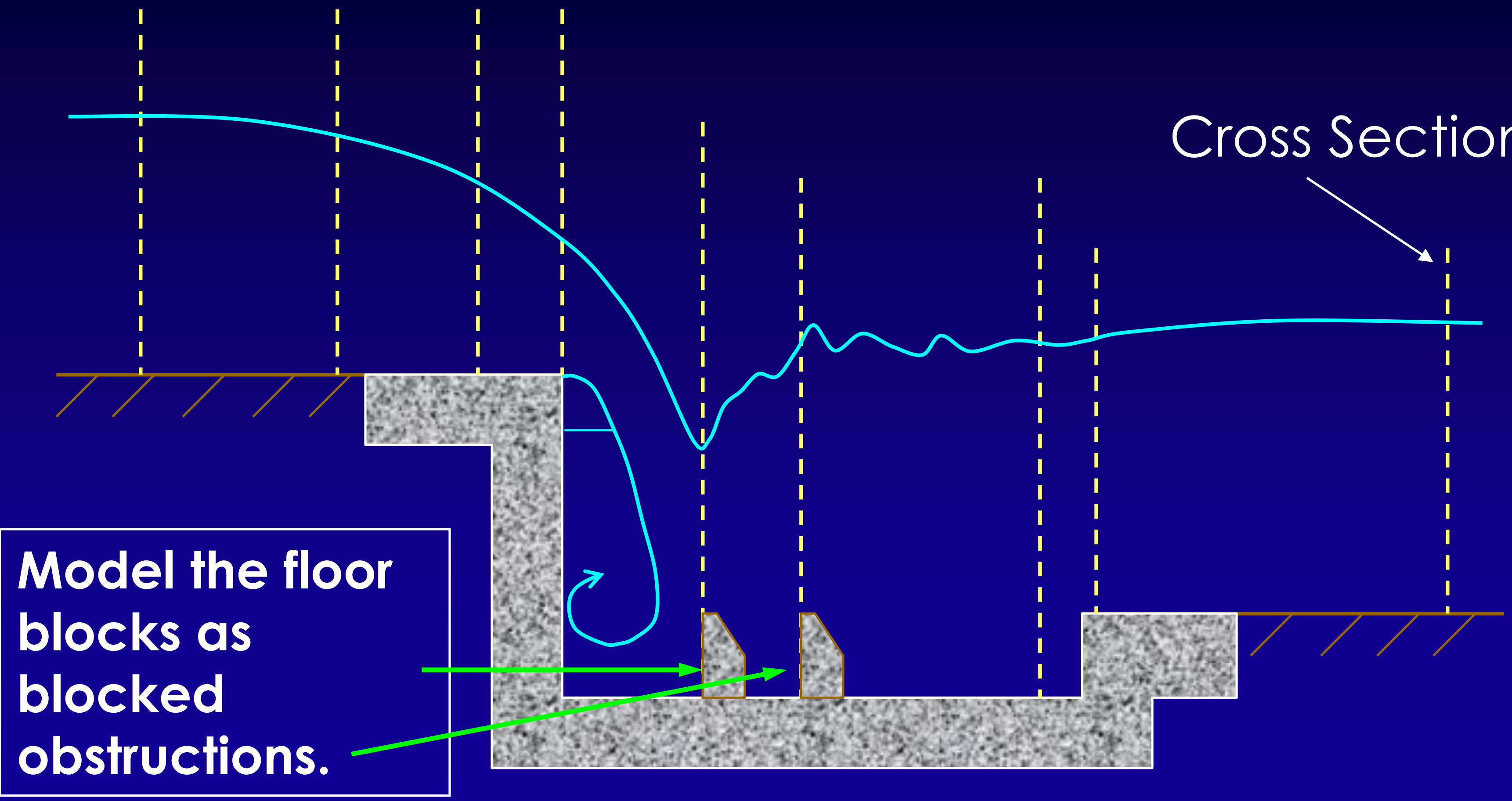


Modeling a Drop Structure as an Inline Structure

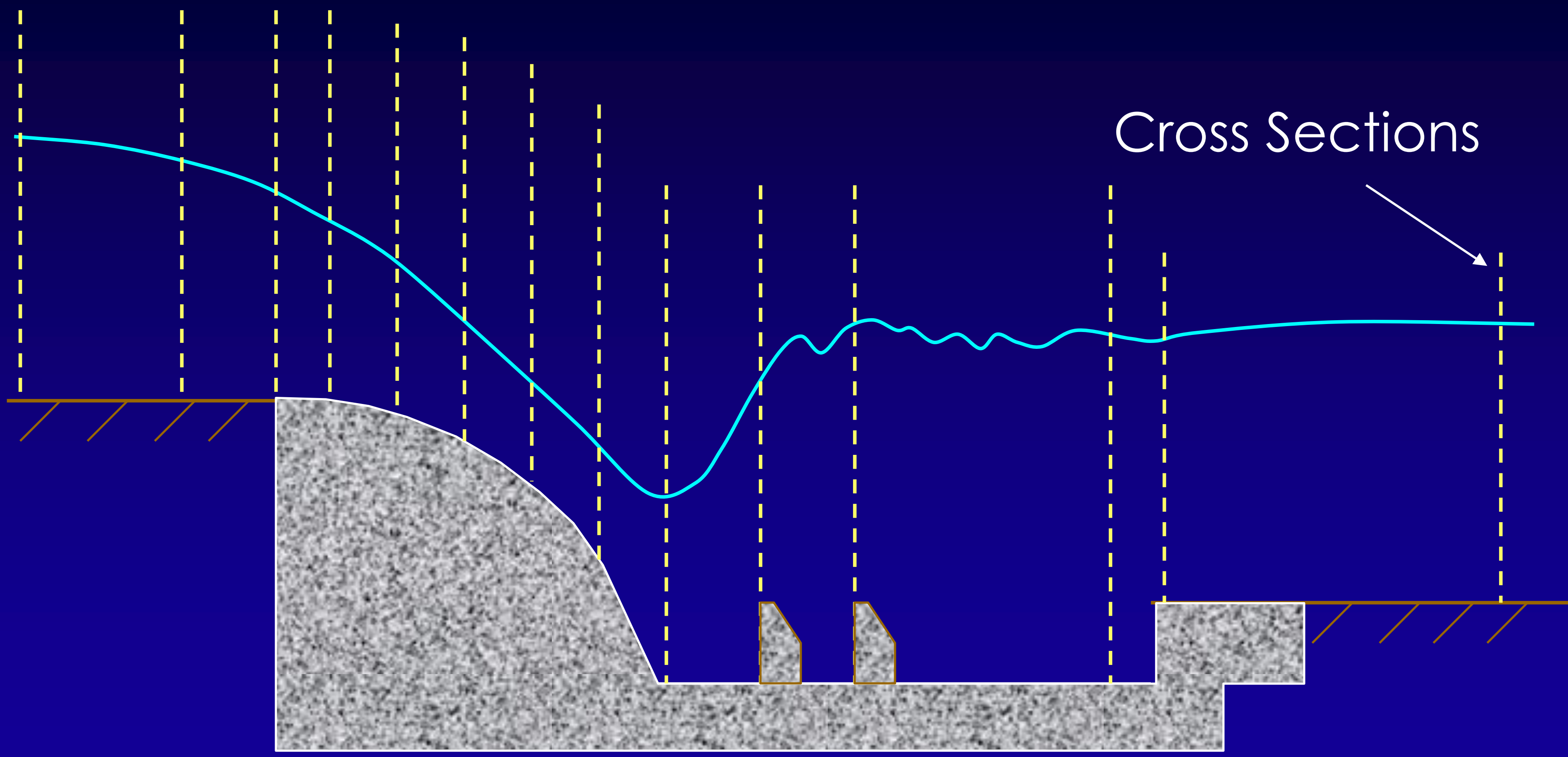
A series of windows allow for entry of weir characteristics



Modeling a Drop Structure with Cross Sections

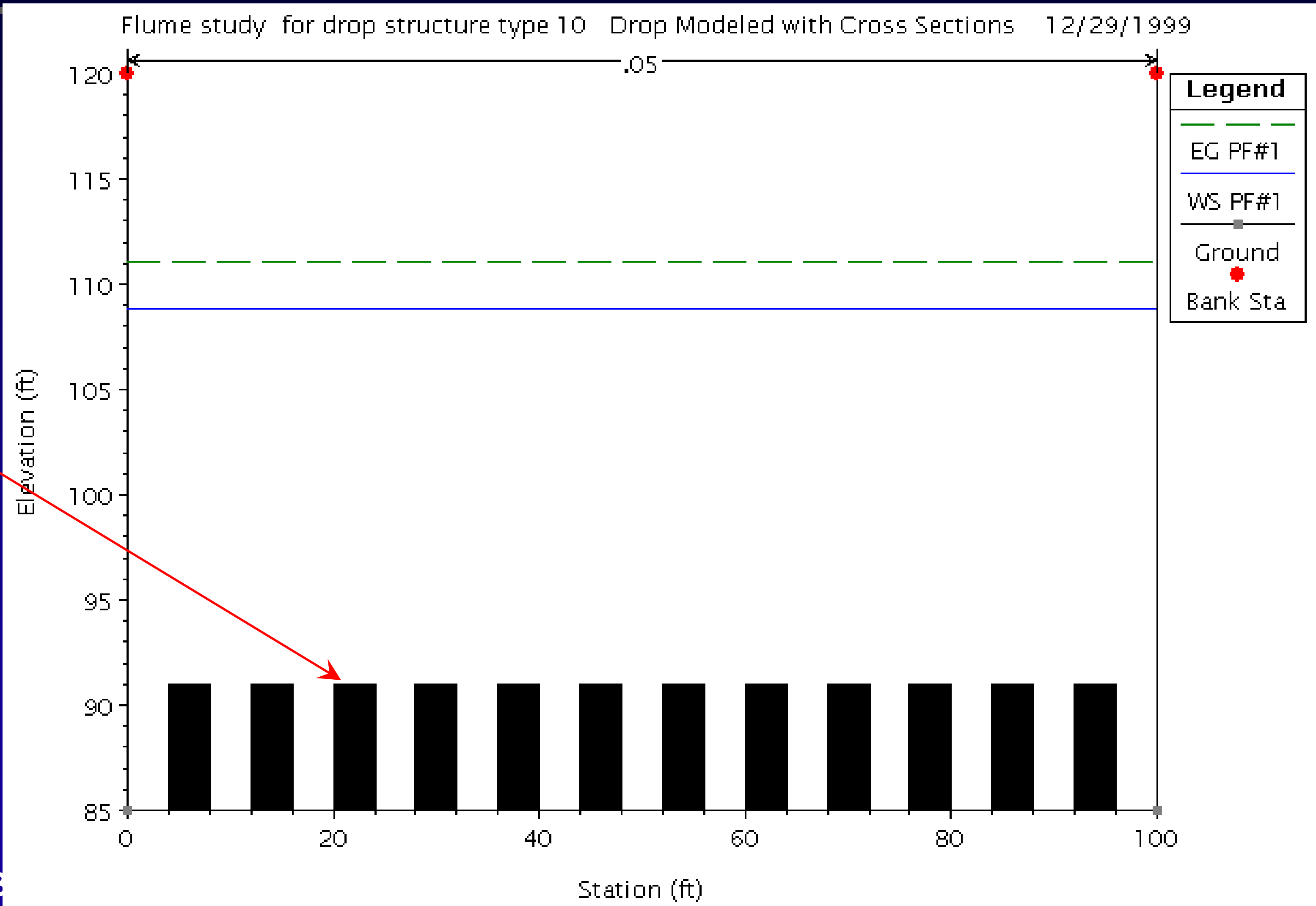


Cross Section Layout for Ogee Shapes Drop Structure



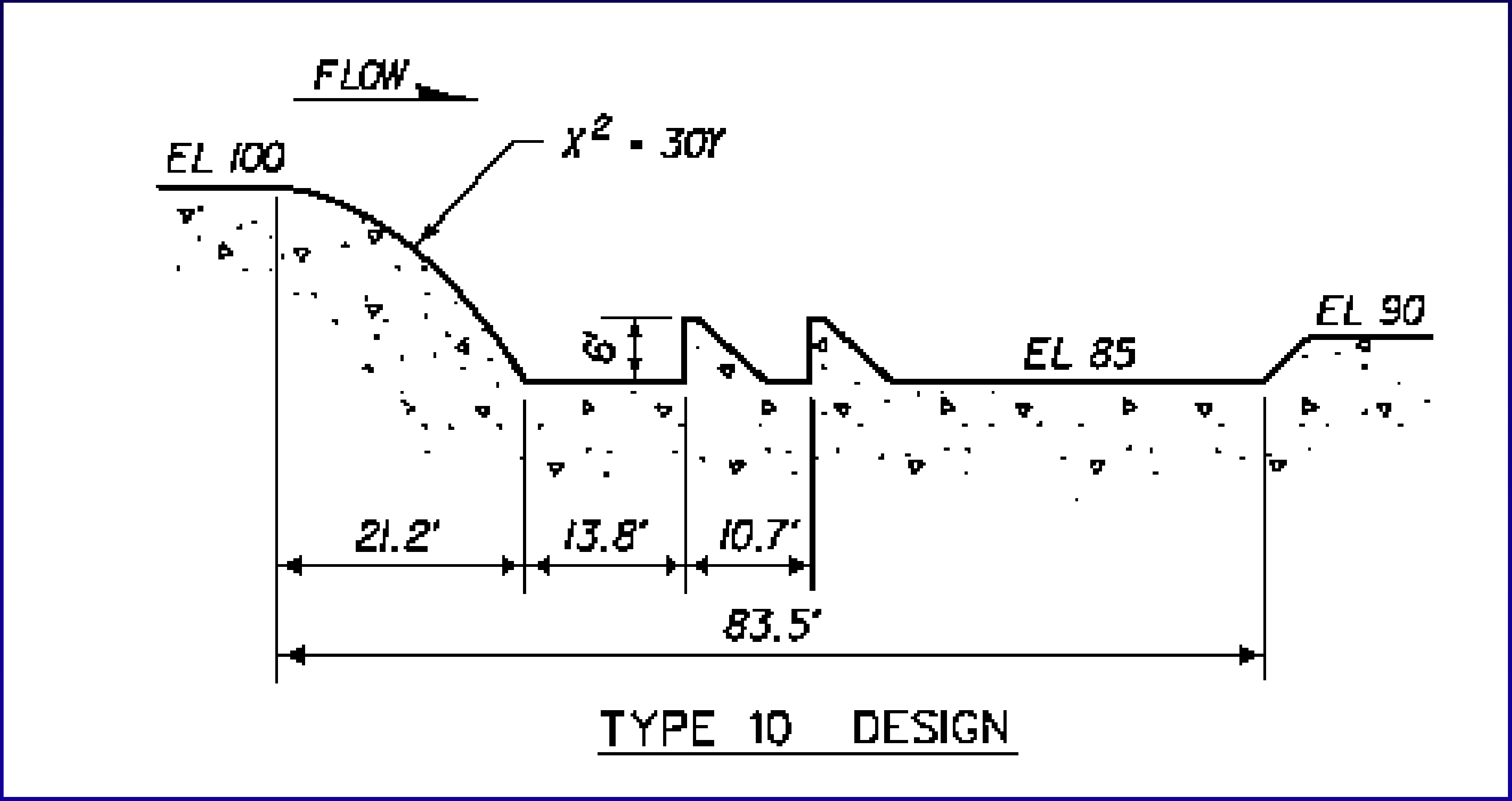
Modeling Baffles in the Stilling Basin

Increase 'n' values at baffle blocks to account for increased roughness

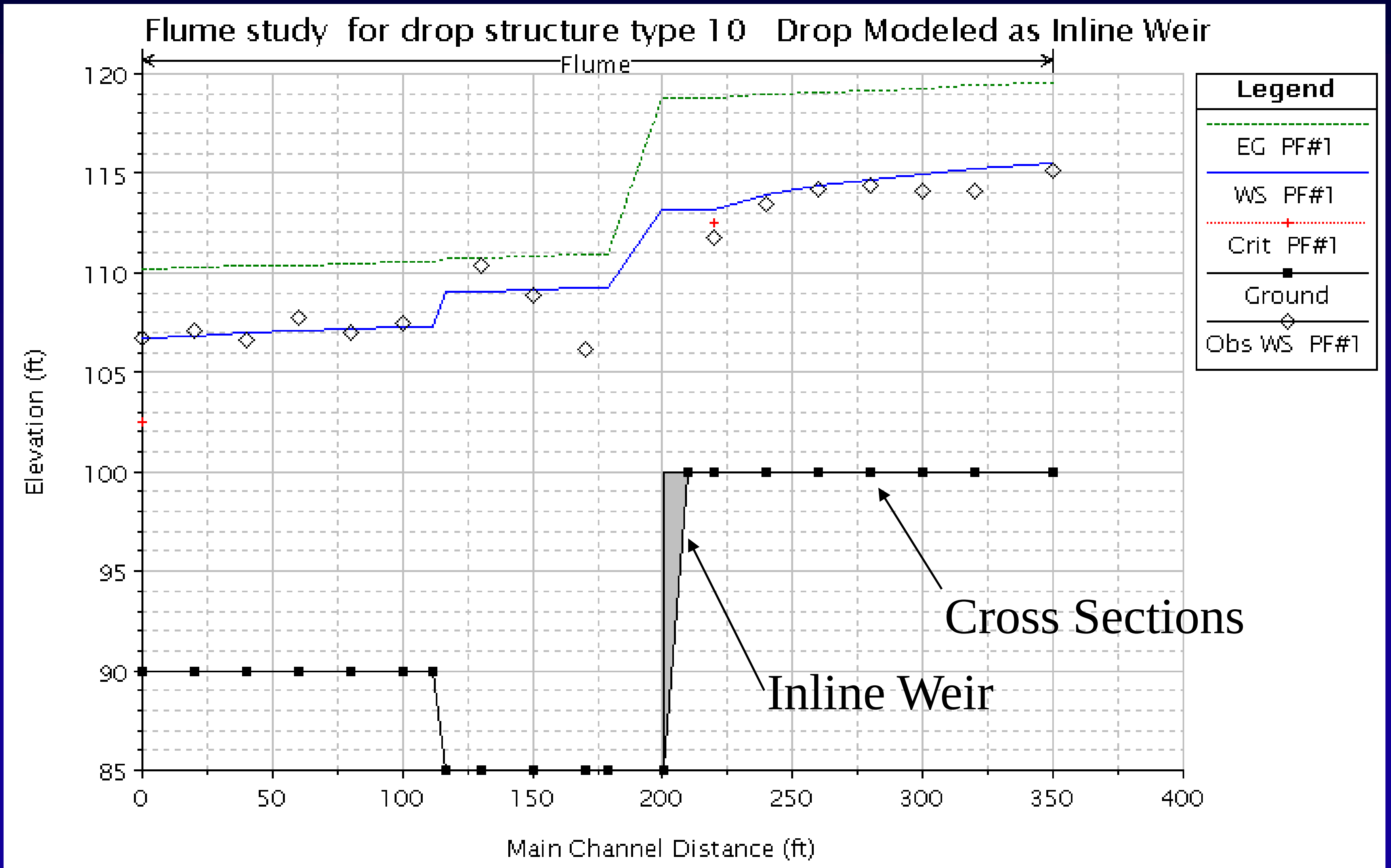


Example Using Lab Data

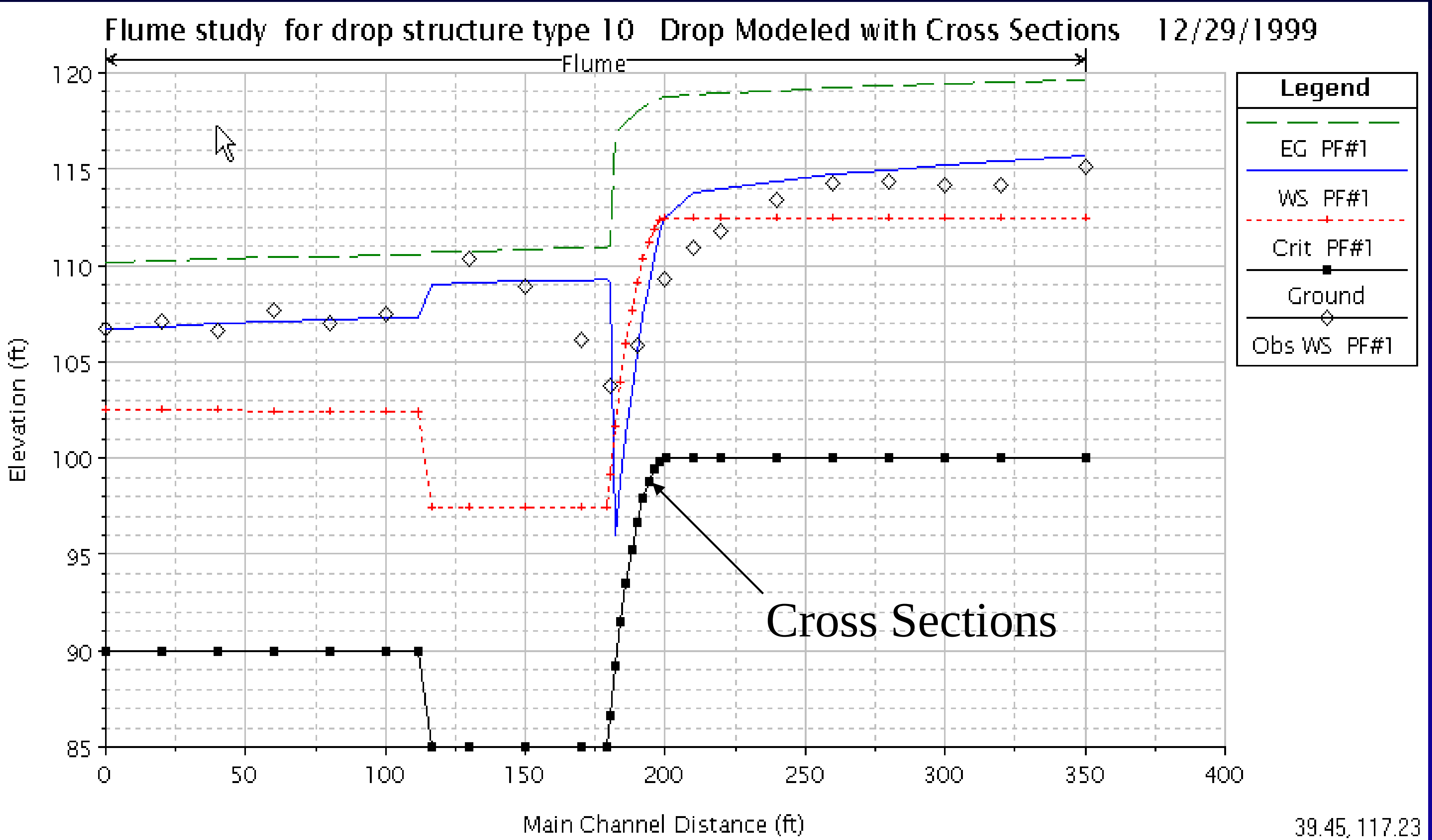
- WES Physical Model Study (WES, 1994)



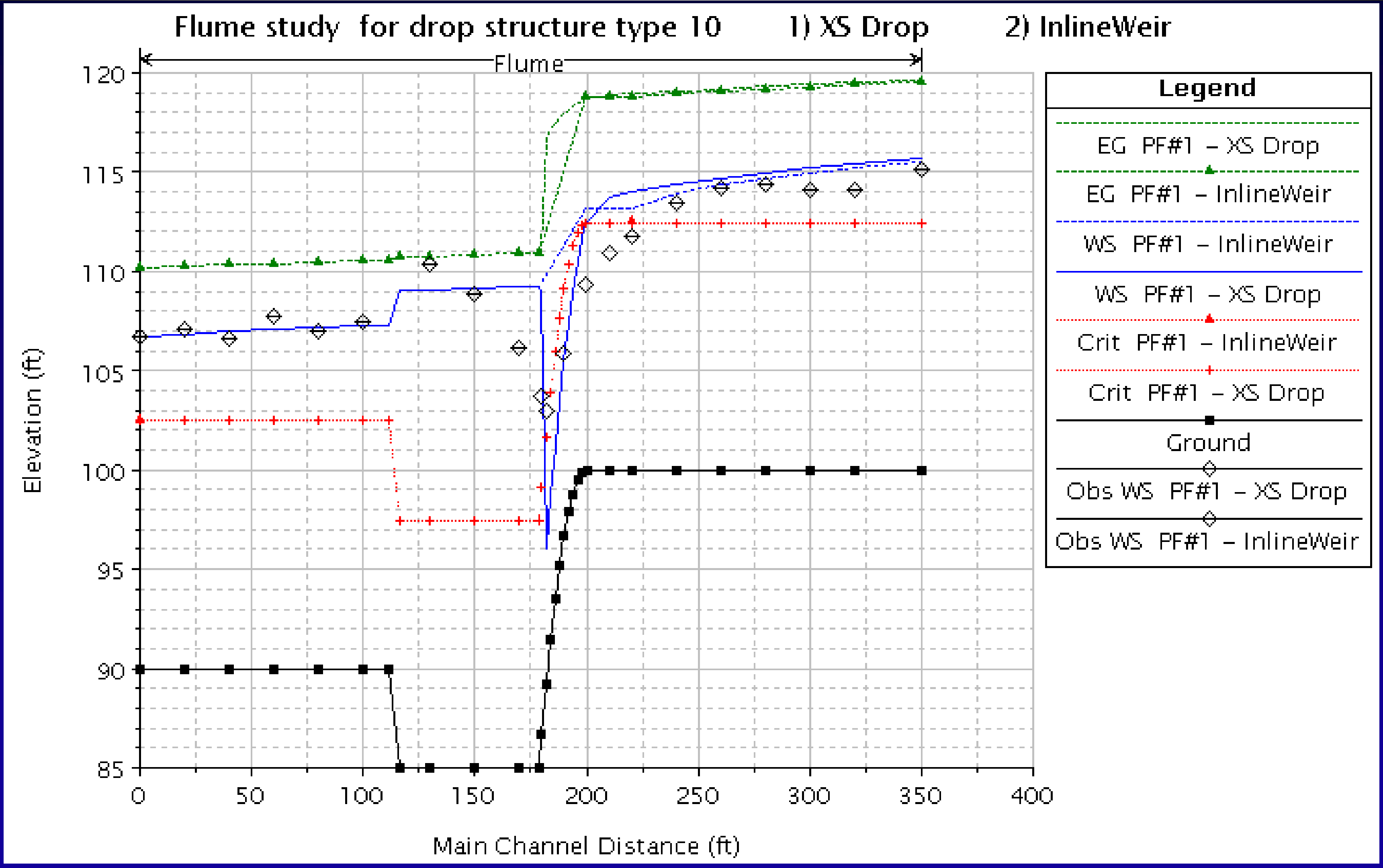
Example - Modeled as a Weir



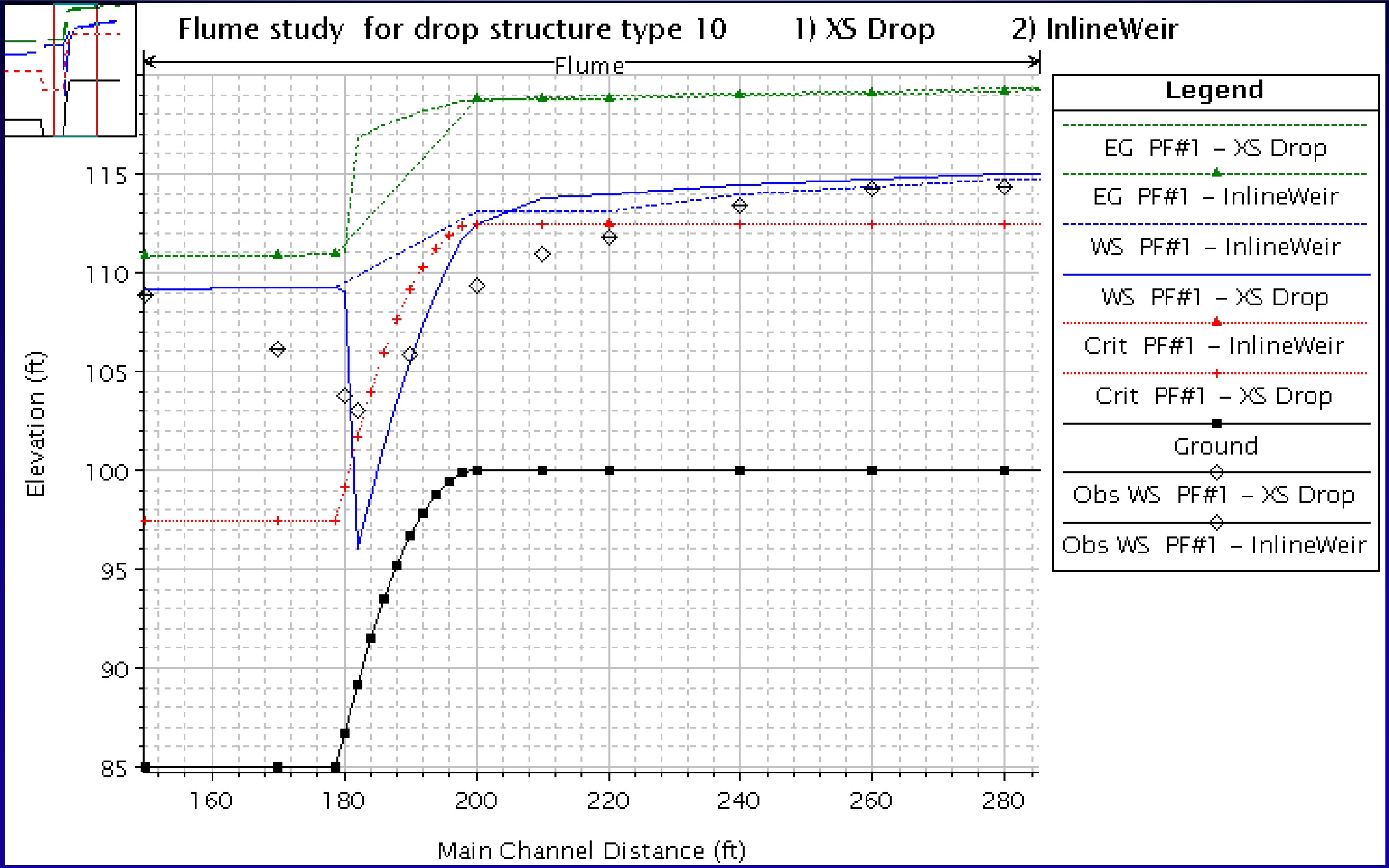
Example - Modeled with Cross Sections Only



Example - Comparison of Two Methods



Example - Comparison Zoomed In



The End

ENERGY DISSIPATORS

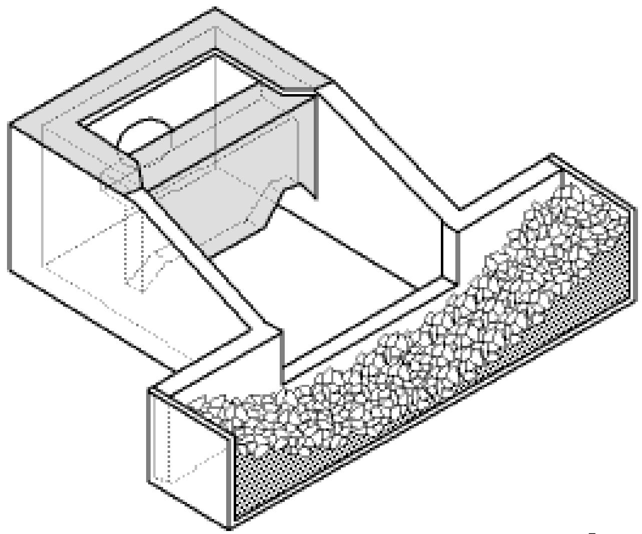
Structures used to dissipate excess kinetic energy possessed by flowing water through irrigation structures .

Types of energy dissipators

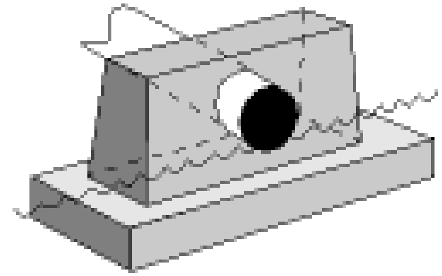
1. **Baffeled outlet**
2. **Stilling basin**
3. **Hydraulic jump**

Baffeled out let

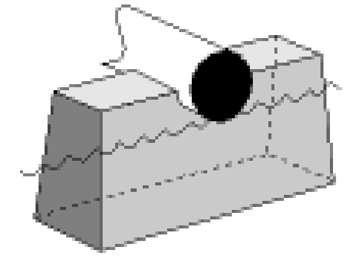
The outlet has many obstructions higher than the bed of canal dissipate the excess energy of flow water.



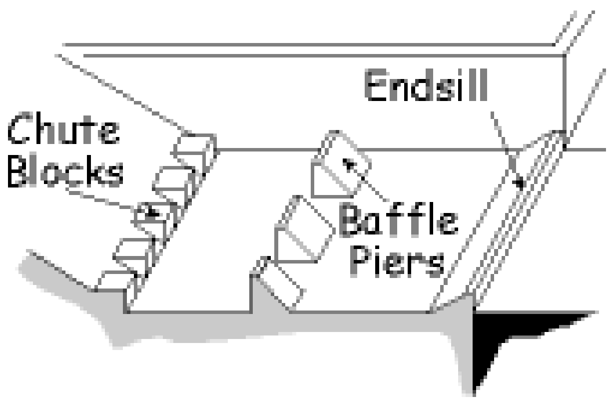
Impact Basin



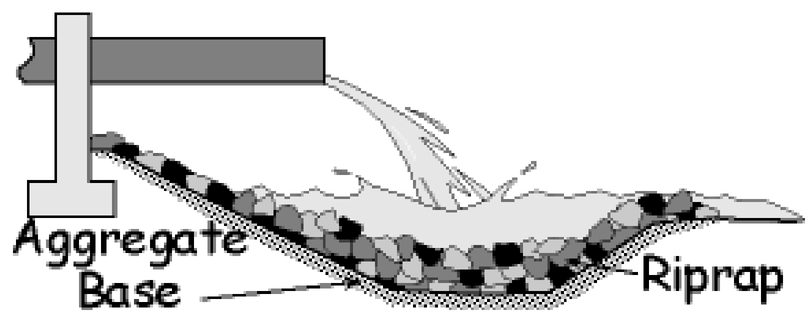
Headwall



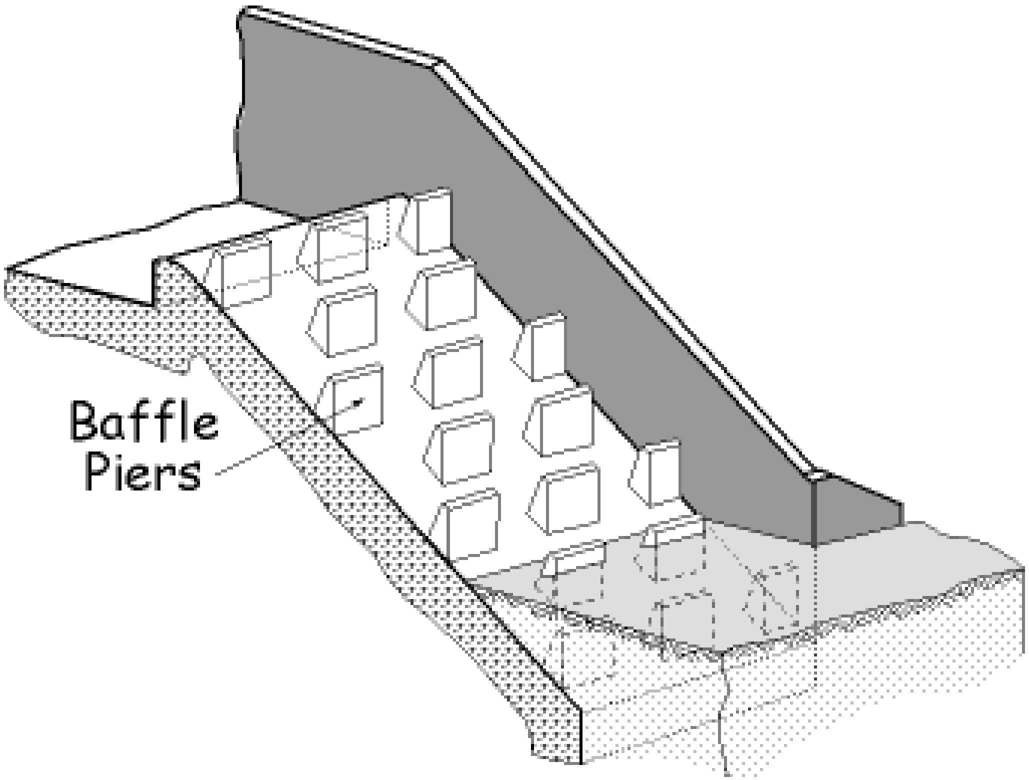
Endwall



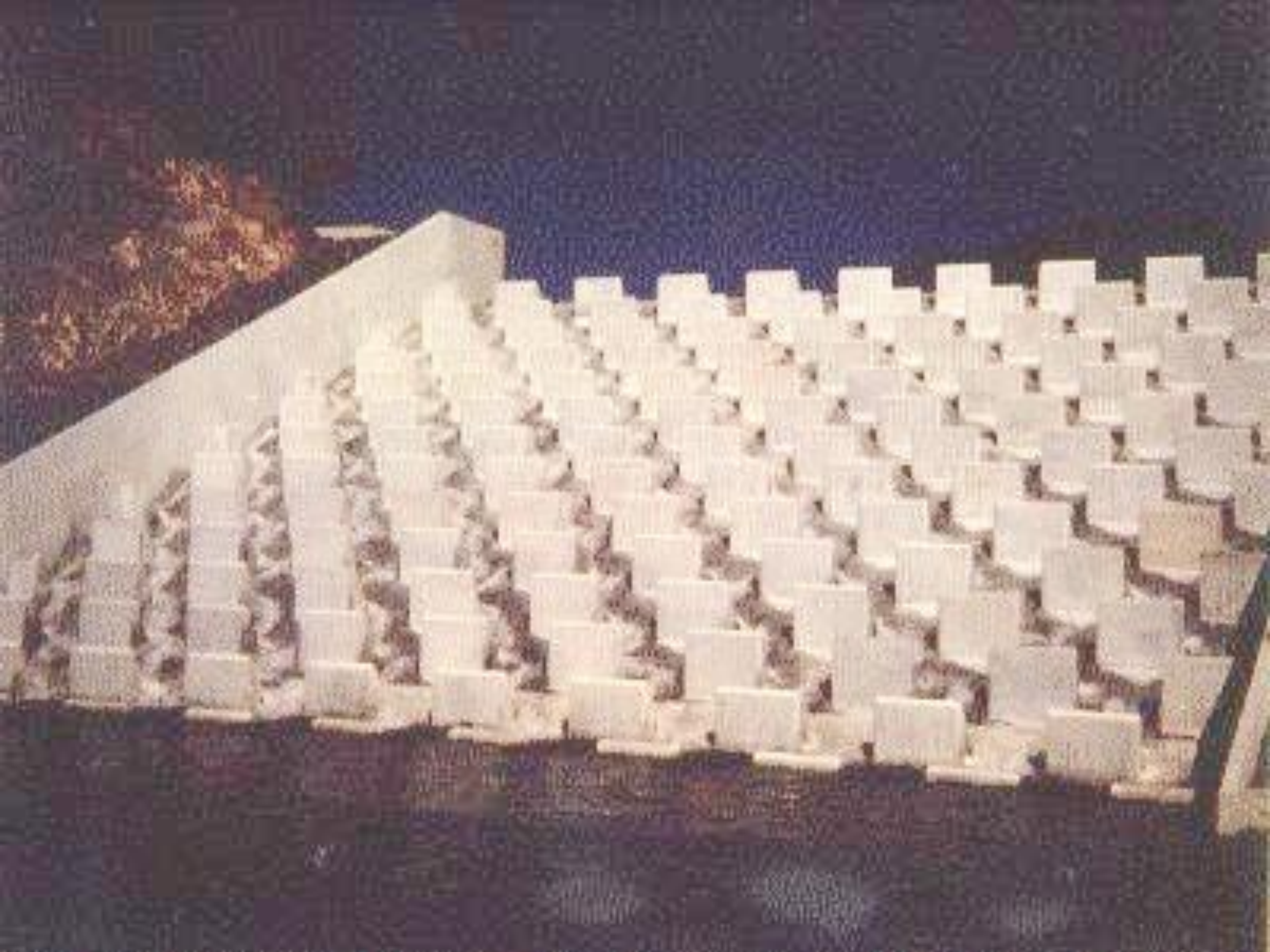
Type III Basin



Plung Pool



Baffeled Chute Basin



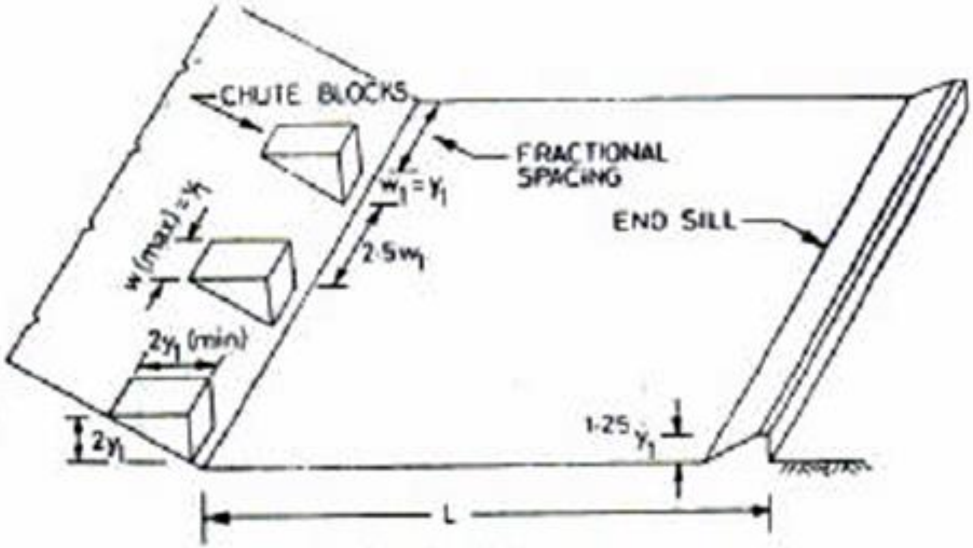
Stilling basin

Basin contains the turbulent water until it can be discharge into the down stream channel with out damage to the channel.

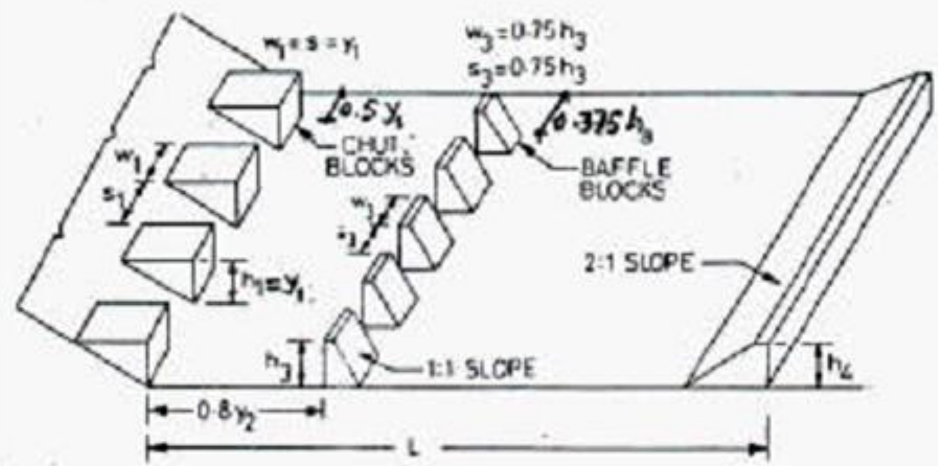
Hydraulic jump

It is a jump of water that takes place when super-critical flow changed into a sub- critical flow.

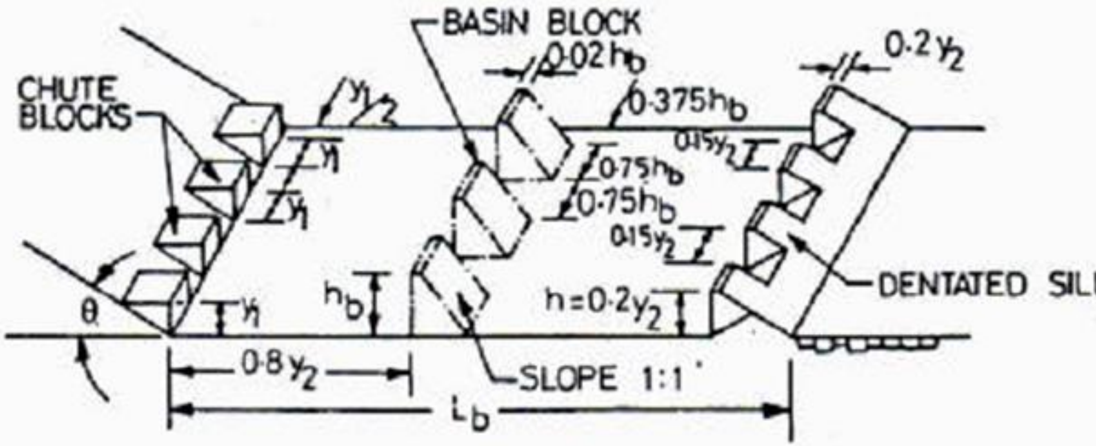
A hydraulic jump can be stabilised in stilling basin by using appurtenances (or accessories such as chute blocks, basin blocks and end sill.



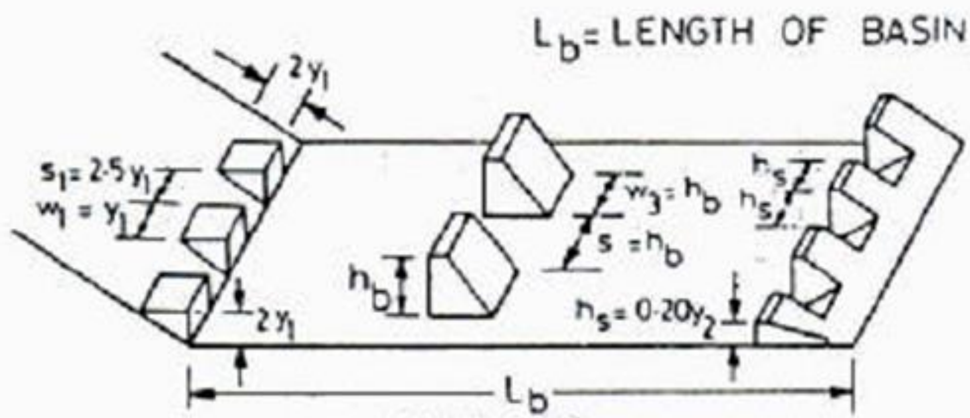
U S BR TYPE 1



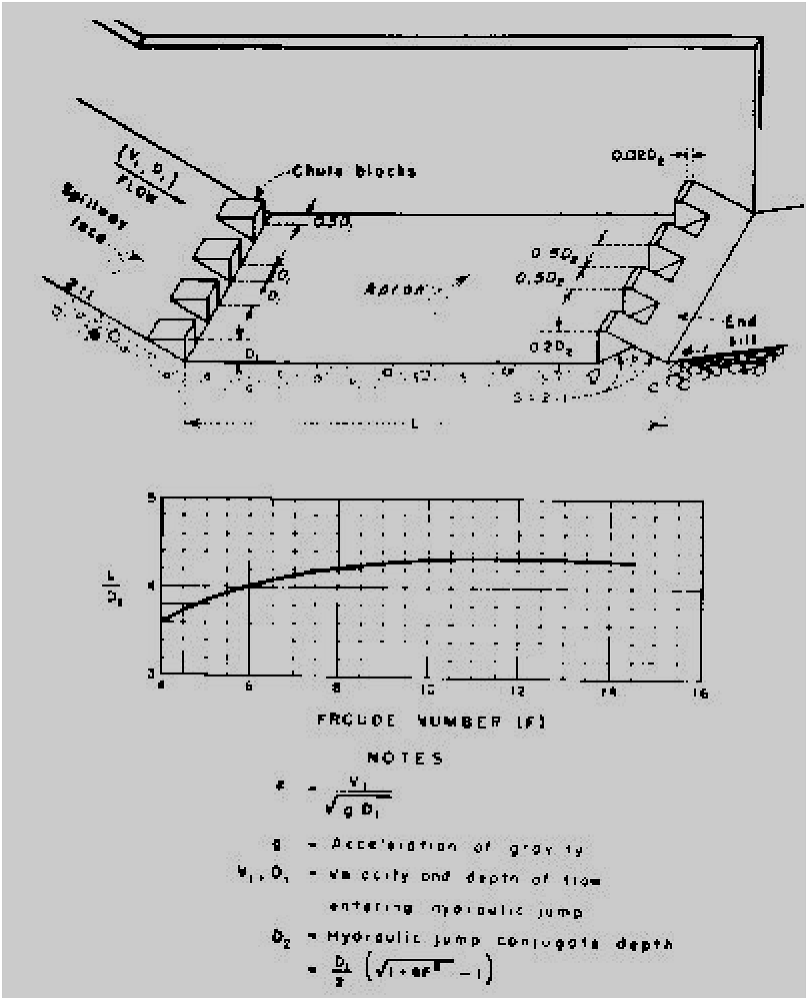
U S B R TYPE II



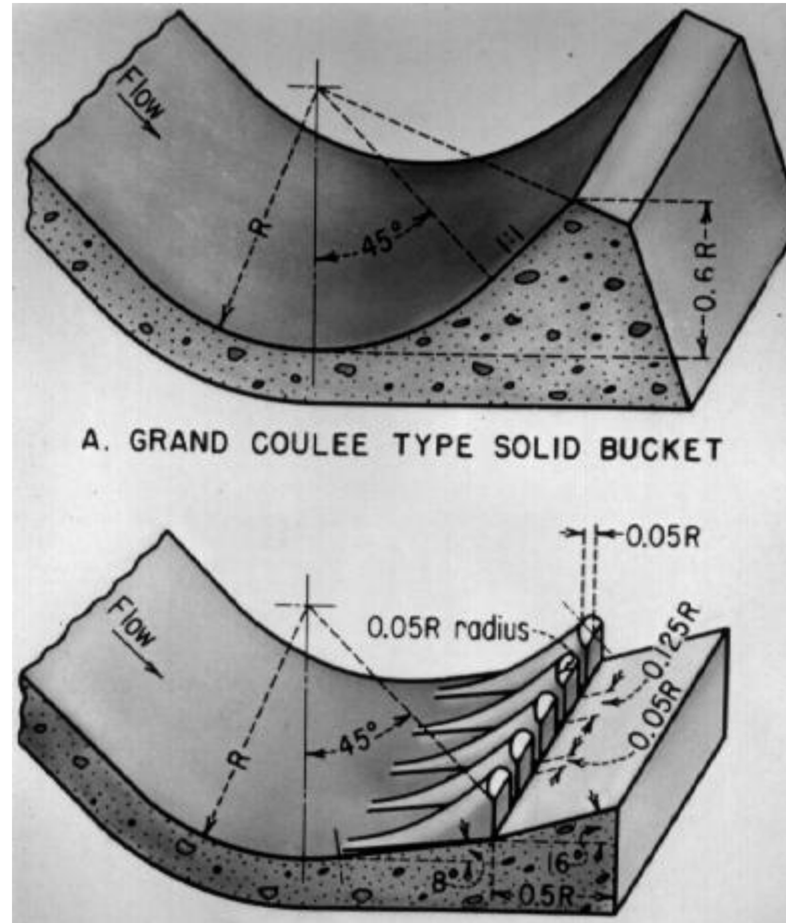
IS TYPE II



IS TYPE I



CHUTE BLOCK STUDIES
STILLING BASIN — TYPE II
RECOMMENDED PROPORTIONS



A. GRAND COULEE TYPE SOLID BUCKET

B. ANGOSTURA TYPE SLOTTED BUCKET

SUBMERGED BUCKETS

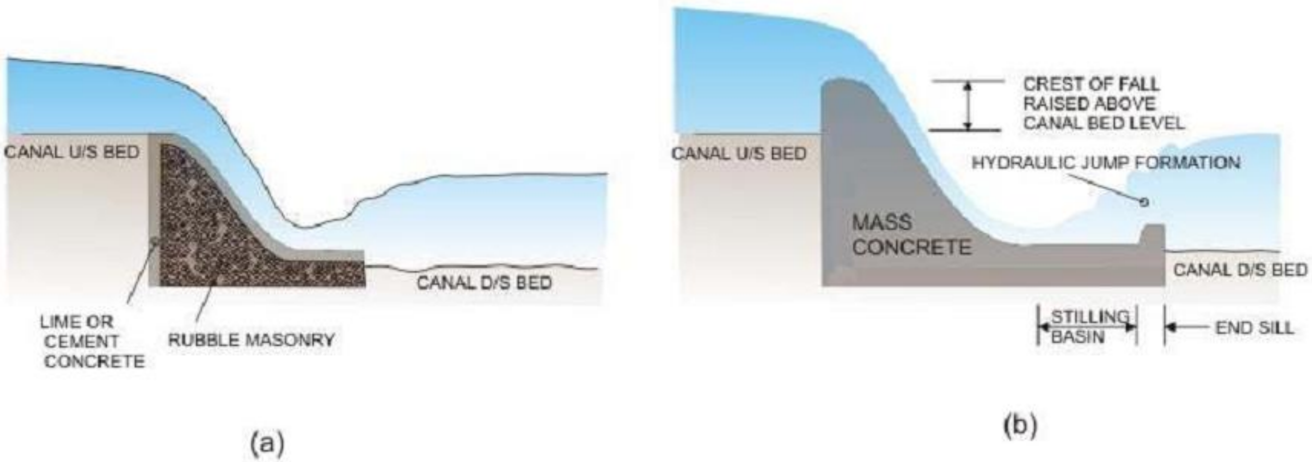
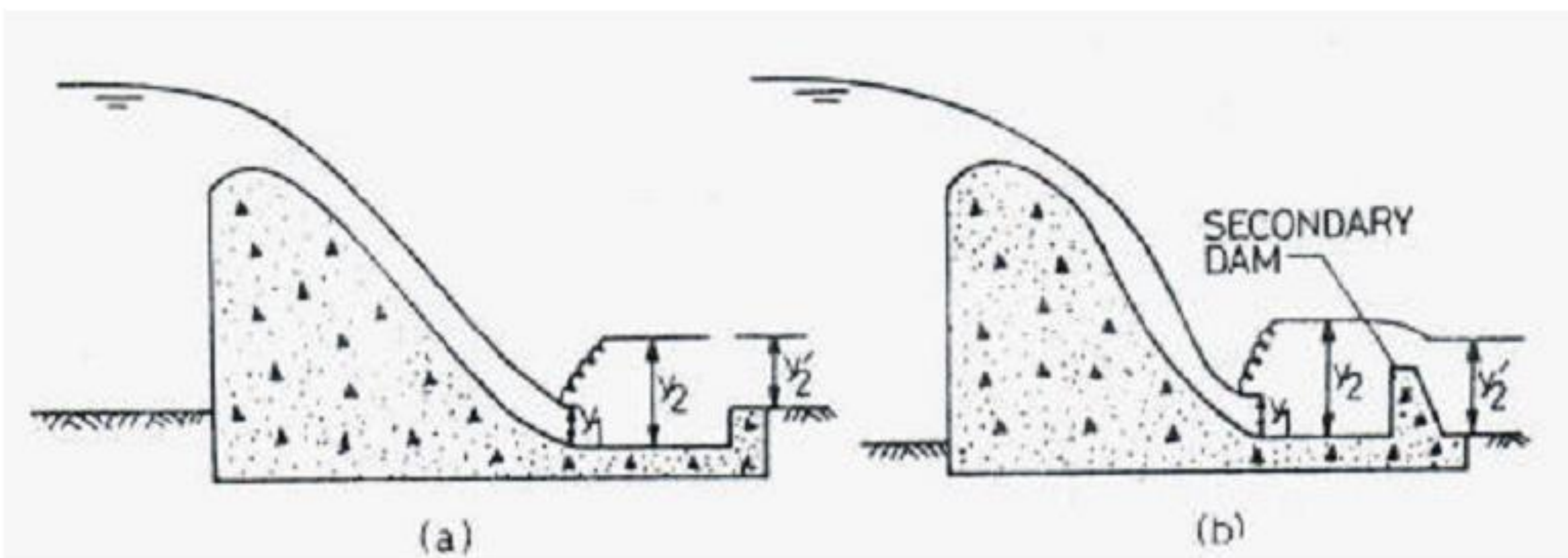
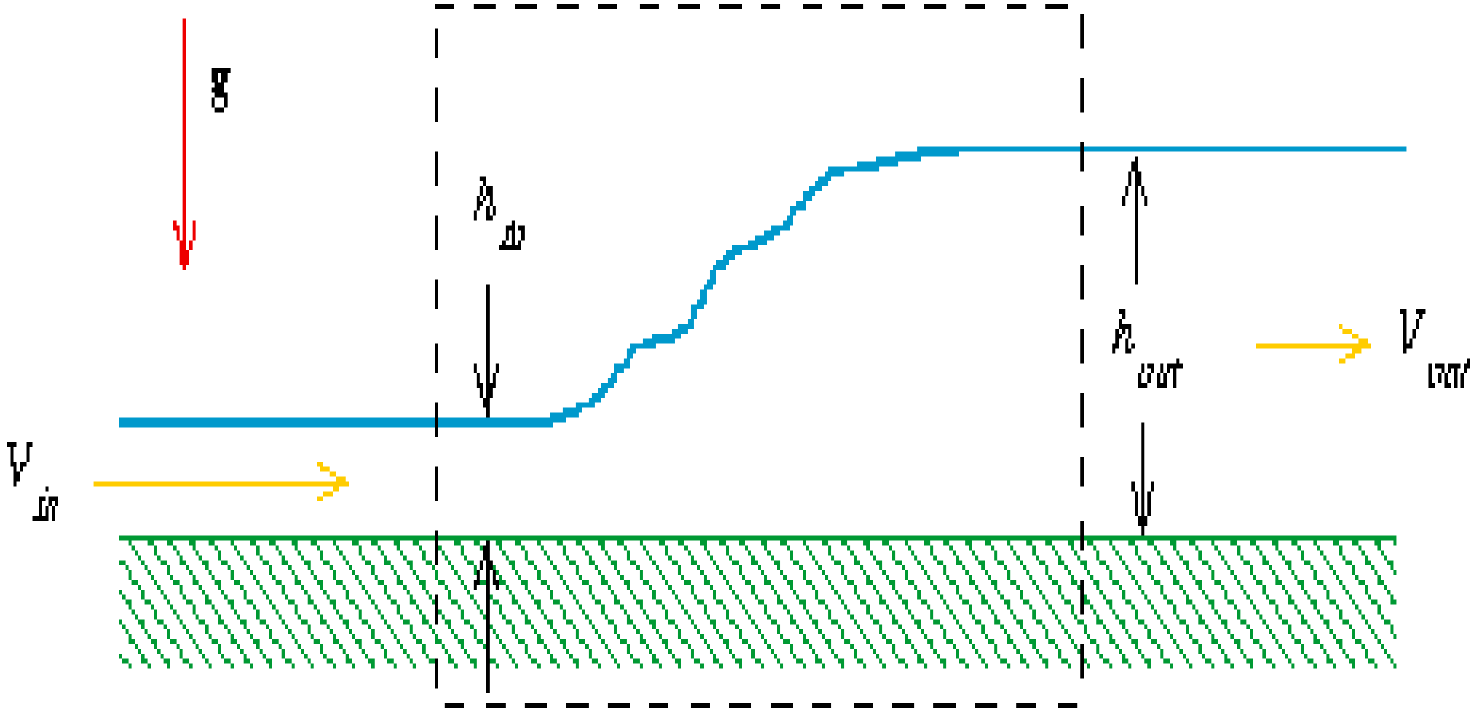


FIGURE 3. (a) Ogee-type fall made of rubble masonry
(b) Same type of fall, but made of concrete and equipped with a stilling basin for energy dissipation





g
h_{in}
V_{in}
h_{out}
V_{out}

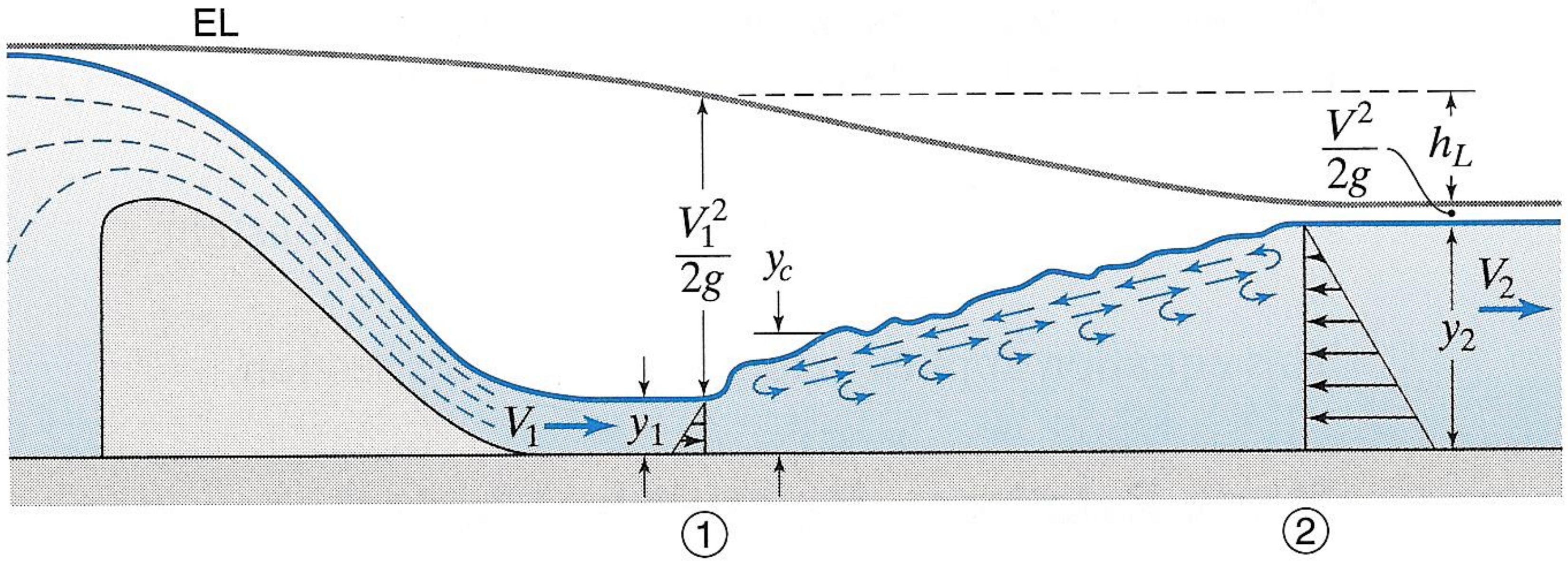


Figure 10.23
Hydraulic jump on horizontal bed following a spillway; horizontal scale foreshortened between sections 1 and 2 approximately $2\frac{1}{2}$:1.

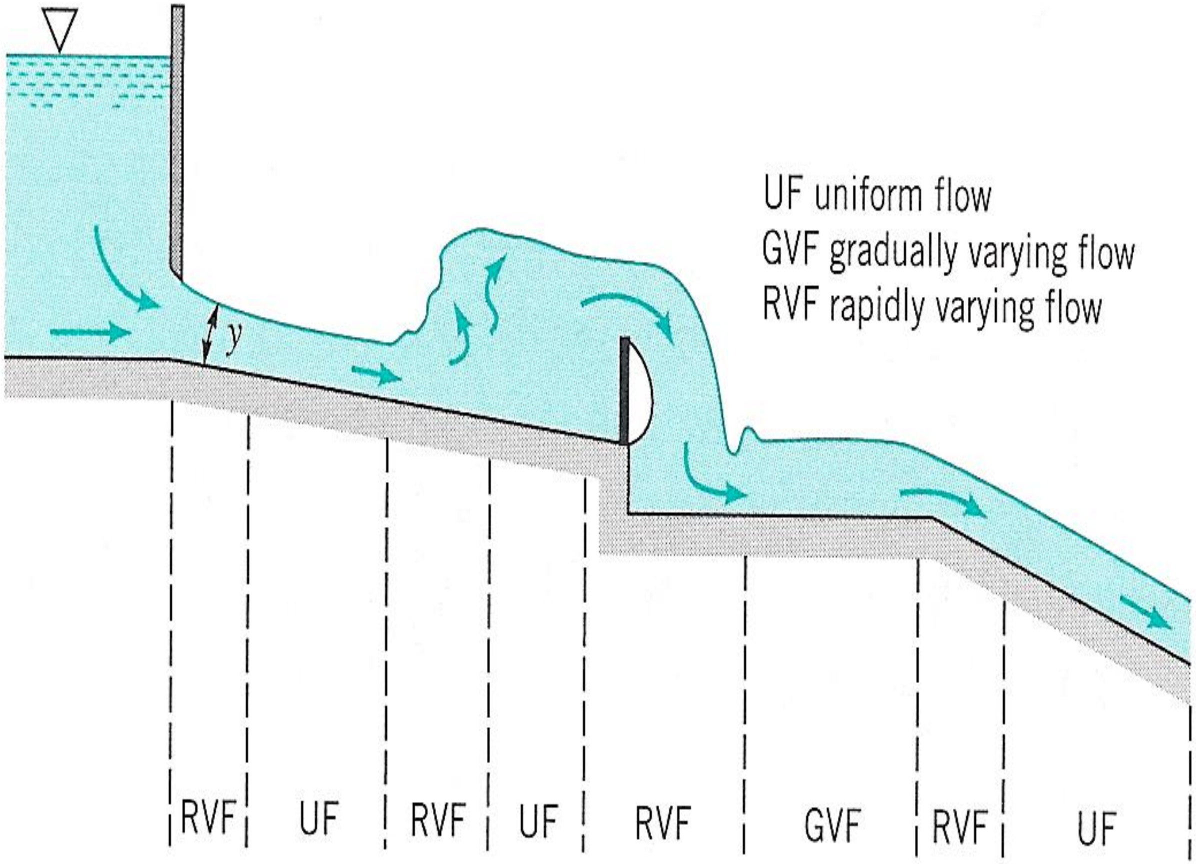


FIGURE 10.1 Classification of open-channel flow.

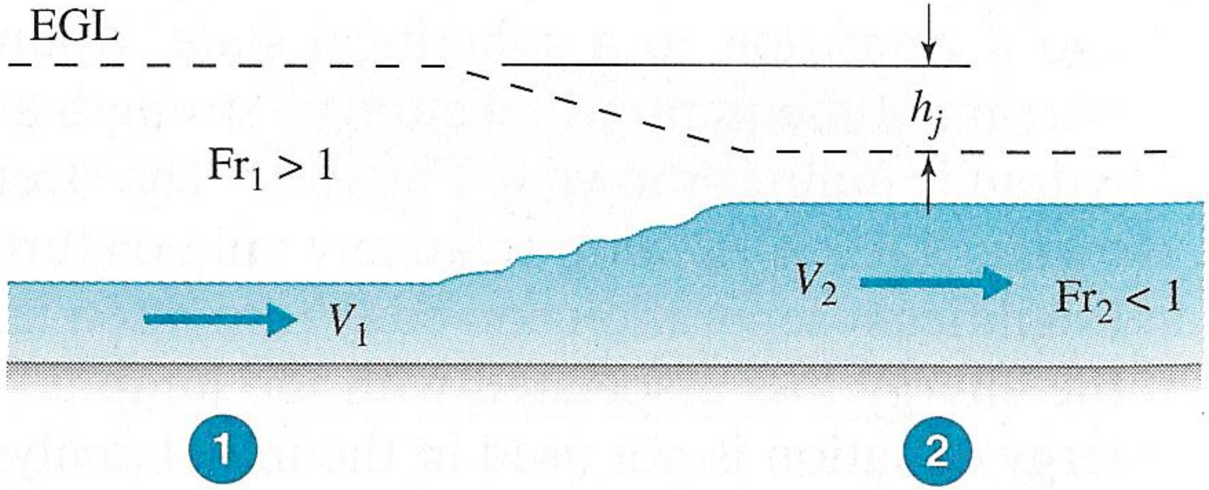
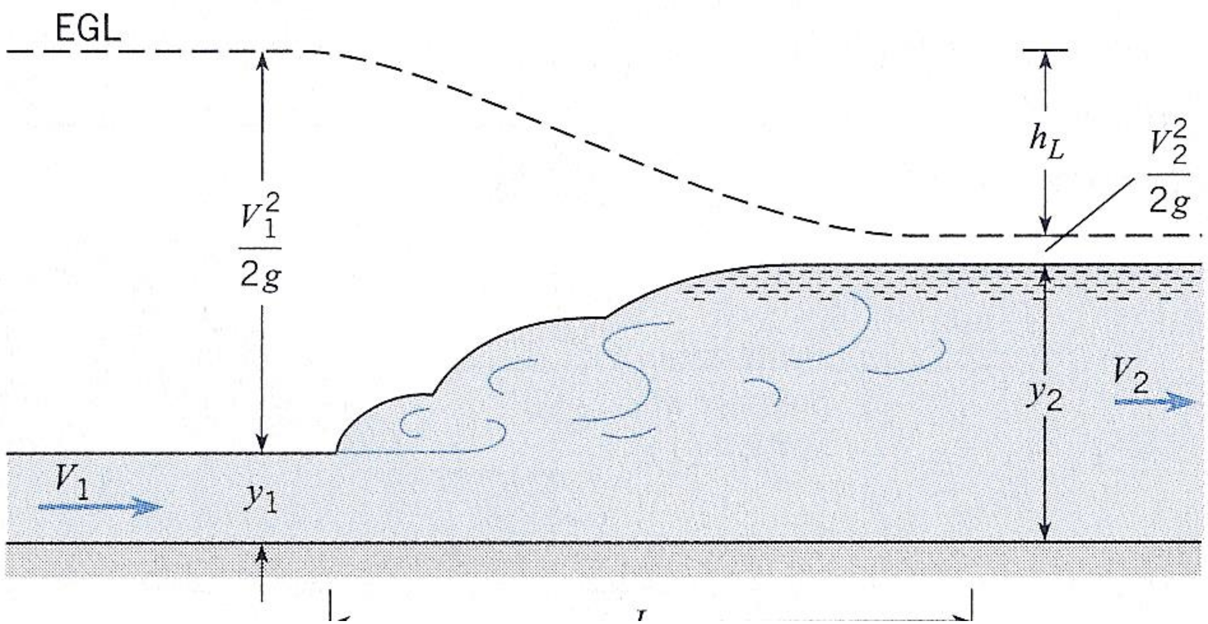
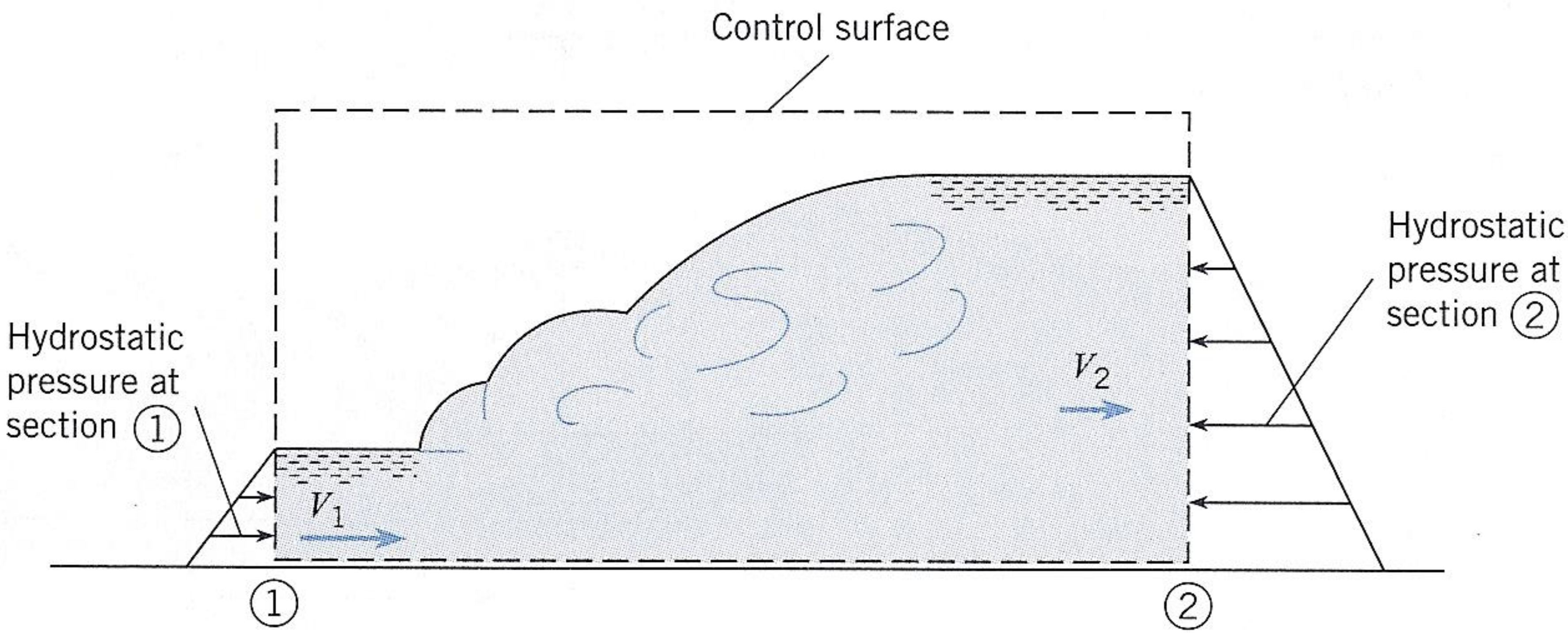


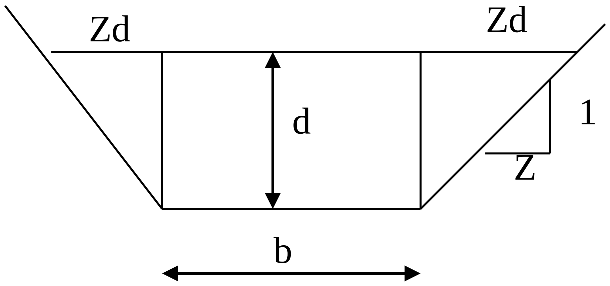
FIGURE 10.15 Idealized hydraulic jump.




Control surface
Hydrostatic pressure at section ①
Hydrostatic pressure at section ②
V_1
V_2
①
②

For a Trapezoidal Section

Area of cross section(A) = $b\,d + Z\,d^2$
Width , b = $A/d - Z\,d$ ....(1)
Perimeter = $b + 2\,d\,(1 + Z^2)^{1/2}$
From (1), Perimeter = $A/d - Z\,d + 2\,d(1 + Z^2)^{1/2}$



<u>Water- level in Canals and Drains</u>

It is shown in one single chart the longituinal section 0f the main canal and of the banch canals depending on :

1. **Longitudinal scale 1:100000.**
2. **Vertical scale 1:100 or 1:50.**
3. **Preparing Longitudinal sections of the ground surface for the main and the branch canals.**
4. **Fix the water –levels, the design is begun with the branch canals and the water level in the main canal are then obtained as a function of the water level in the branch canals.**
5. **The water level in branch canal must be 25 cm above the ground level.**

<u>Cross- Section of an irrigation canal</u>
A canal section may be :

- **In cutting.**
- **In filling.**
- **In partial cutting and filling.**
-

Side Slope (Z):

The ratio of the horizontal to vertical distance of the sides of the channel. The side slope of the canal depend on the type of the soil.

Berm

It is a narrow strip of land, left on either side of a canal at G.L. between upper edge of the cut and the inside toe the bank . The width of berm depends upon the size of the canal . Berm perfoms following functions:

- **The width of the canal can be easily increased if required .**
- **Slipping soils and boulders are held up at berms and do not allow them to be dropped into th canal .**
- **It acts as a storage space for materials if some repair or construction work is to be done in the canal.**
- **They strength the canal banks.**
- **They also provide easy path for inspection.**
- **They increase the width of bank, and thus seepage line not likely to be exposed**

THE WIDTH OF THE BERM CAN BE TAKEN AS:

1. **For canal in cutting ; Berm=D**
2. **For canal in filling ; Berm=3D**
3. **For canal partly in cutting and in filling ; Berm=2D**

D=depth of water in the canal (m).

Free board

The vertical distance between full ssupply level t0 the top of the canal . The distance should be sufficient to prevent waves or fluctuations in water surface from overtopping the sides.

$F=\sqrt{C}D$

F=free board(m)

C=constant varying from 0.46 to 0.76

Or

F=0.2+0.15Q1/3

Q=discharge of canal (m3/sec)

Bed width

Bed width (b) is limited by the practical capability of the machinery used for constraction.
So min.(b)=0.4m

or $b=Q^{0.33}$
for b<1m rounded off to the nearest 0.1m
for b=1-3m rounded off to the nearest 0.25or0.2m
for b=3-6m rounded off to the nearest 0.5m
for b>6m rounded off to the nearest 1m

Maximum permissible velocity($V_{max.}$)

$V_{max} = C_1 y^{0.64}$
Where y=depth of flow
C_1=coefficient for max. permissible velocity which depend on the Material of the canal bed

Type of bed material	C_1 for **($V_{max.}$)**
Fine light sandy soil	0.55
Coarse light sandy soil	0.6
Sandy loamy silt	0.66
Coarse soil	0.71

Minimum permissible velocity($V_{min.}$)

$V_{min} = C_2 y^{0.64}$
C_2 = coefficient for min. permissible velocity which depend on the Suspended material

Type of suspended material	C_2
Light loam and very fine sand	0.4
fine sand	0.55
Moderate coarse sand	0.65
coarse sand	0.67
Very coarse sand	0.9

IRRIGATION STRUCTURES

Water delivery to the land must be provided by a reliable and efficient irrigation system

- **Different types of irrigation structures are required in an irrigation system to effectively and efficiently *store,convey,regulate and measure* the canal discharge and also to protect the canal from storm runoff damage**

Types of Irrigation Structures

- Storage structures (dams ,lakes)
- Conveyance structures (canals, culverts)
- Regulating structures (regulators, gates,diversion structures)
- Water measurement structures (weirs,orifices,parshall flumes)
- Protective structures (spillway,barrages,pitching)

Problem statement

Types of leaks in irrigation channels

Unpredicted offtakes Affect the farmer offtakes ▪

Problem statement

Types of leaks in irrigation channels

- Failures in the civil engineering: Affect the walls of the channel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Multiple Functions of Water Management in Paddy Fields

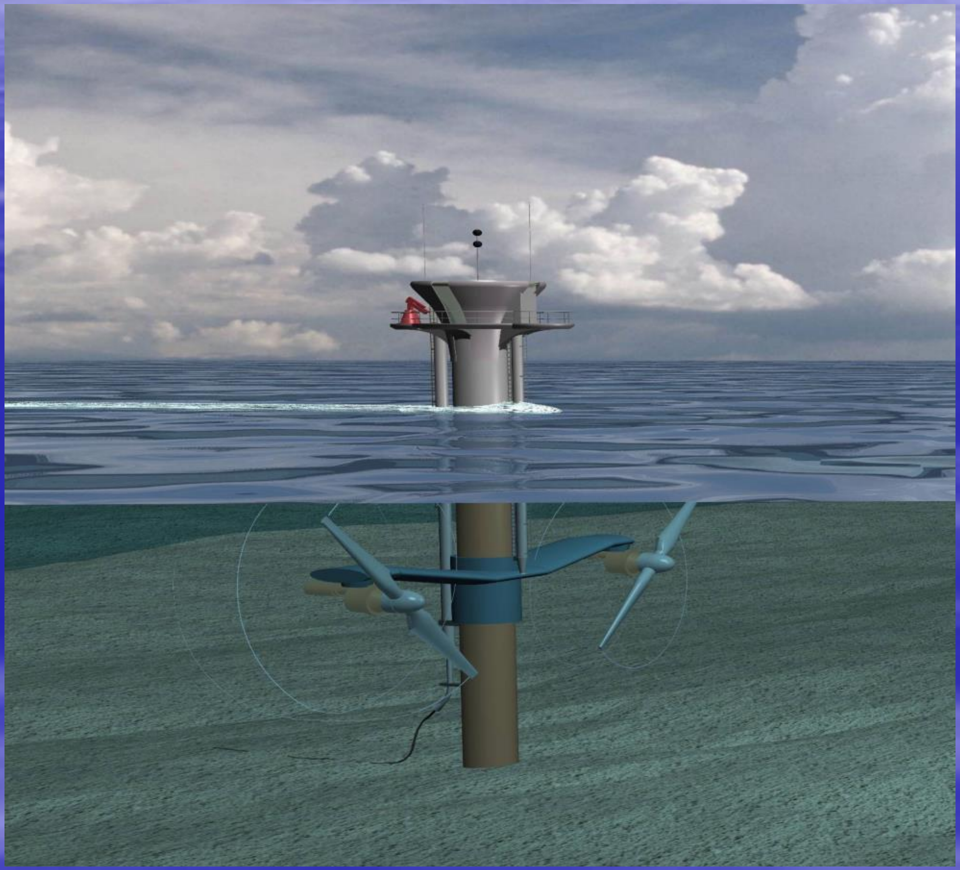
Formation of social capital, culture and traditional events

Farmers have recognized irrigation canals as a social overhead capital. And their collective water management, such as allocation of water and maintenance of irrigation structures, has inevitably promoted community systems and social capital among them.

The water management has also been a base of traditional ceremonies, rituals and cultures with respect or worship to water and the nature.

Option 1: Tidal Barrage

Option 2: In-Stream Tidal





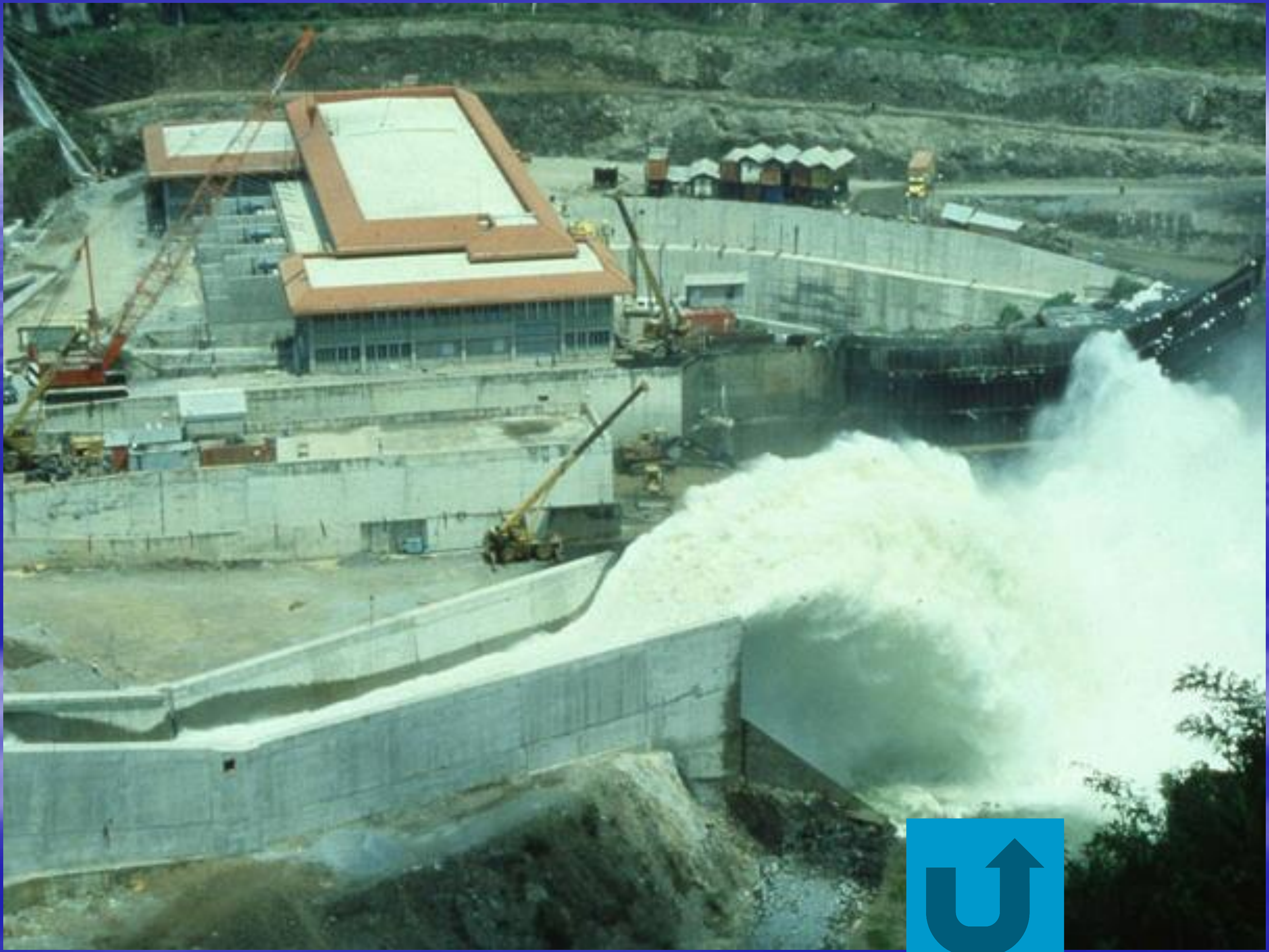


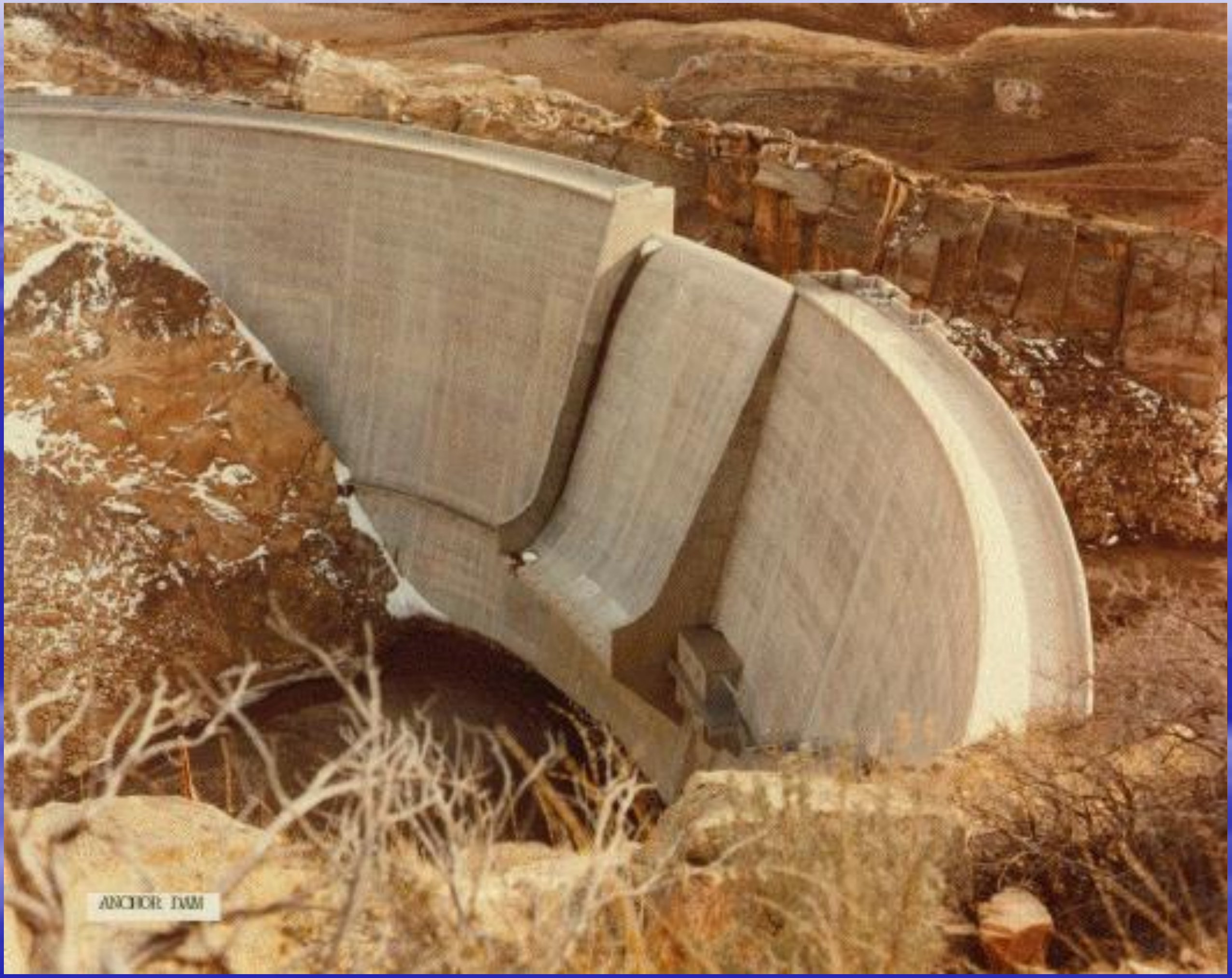











ANCHOR DAM

Edit View Zoom Modify Tools Help

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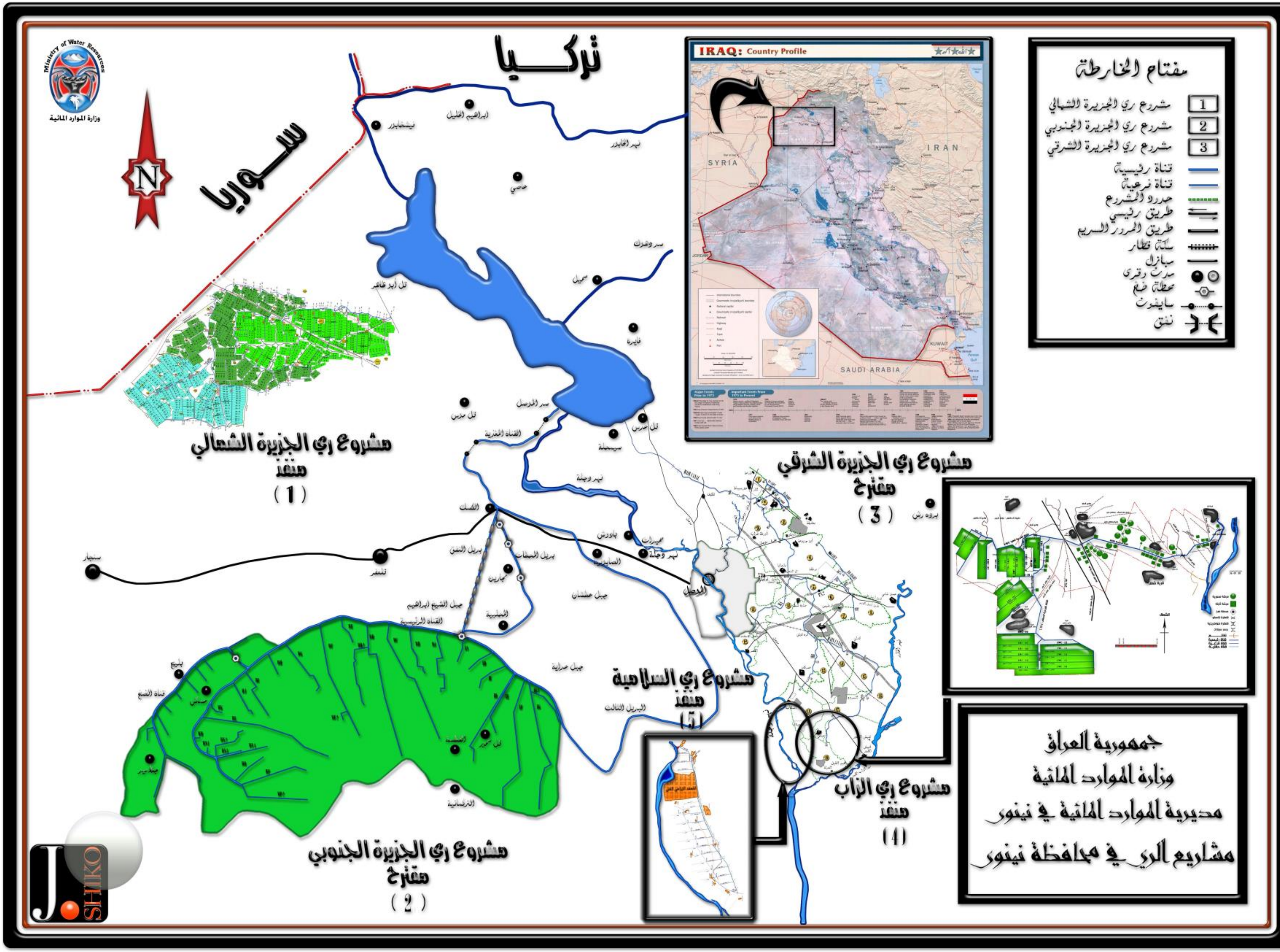


تركيا
سوريا
N
Ministry of Water Resources
وزارة الموارد المائية
IRAQ: Country Profile
SYRIA
IRAN
SAUDI ARABIA
KUWAIT
مفتاح الخارطة
1 مشروع ري الجزيرة الشمالي
2 مشروع ري الجزيرة الجنوبي
3 مشروع ري الجزيرة الشرقي
قناة رئيسية
قناة فرعية
حدود المشروع
طريق رئيسي
طريق المرور السريع
سكة قطار
مبازل
مدن وقرى
محطة ضخ
سايفون
نفق
مشروع ري الجزيرة الشمالي
منفذ
(1)
مشروع ري الجزيرة الجنوبي
مقترح
(2)
مشروع ري الجزيرة الشرقي
مقترح
(3)
مشروع ري الزاب
منفذ
(4)
مشروع ري السلامية
منفذ
(5)
الموصل
سنجار
تلعفر
الكسك
نهر دجلة
نهر الخابور
جمهورية العراق
وزارة الموارد المائية
مديرية الموارد المائية في نينوى
مشاريع الري في محافظة نينوى
J. SHIKO

Classification&Alignment of Canals and Drains

Canals

Based upon the relative position in agiven network of canals ,it consist of

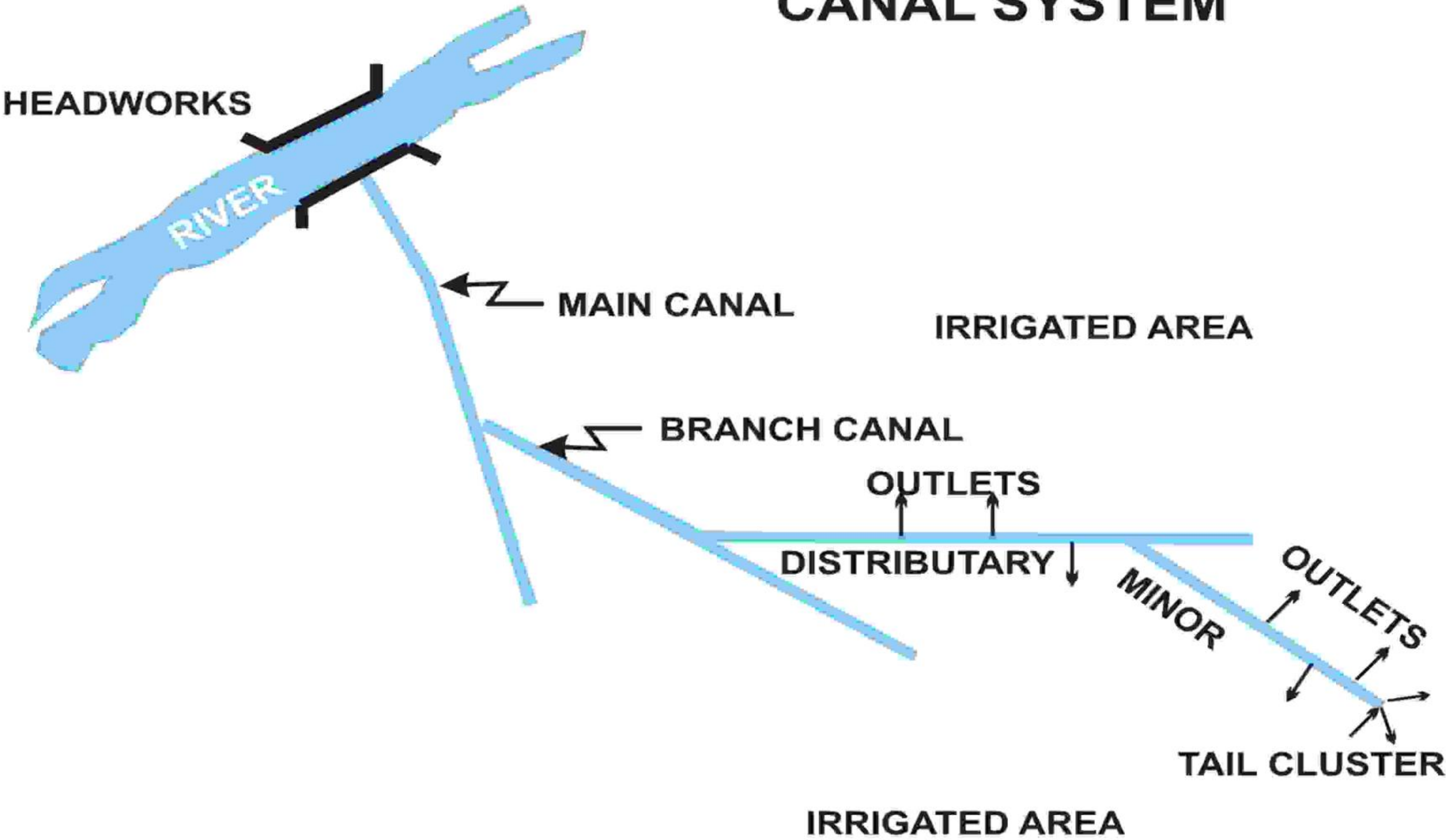
1. Main canal
2. Branch canal
3. Major distributary channels
4. minor distributary (water courses)
5. Farm supply channels

Drains

Similarly the network of drains consist of

1. Main drain
2. Branch drains
3. Major collector drains
4. Minor collector drains
5. Farm drains

SCHEMATICS DIAGRAM OF A CANAL SYSTEM



Alignment of Canals and Drains

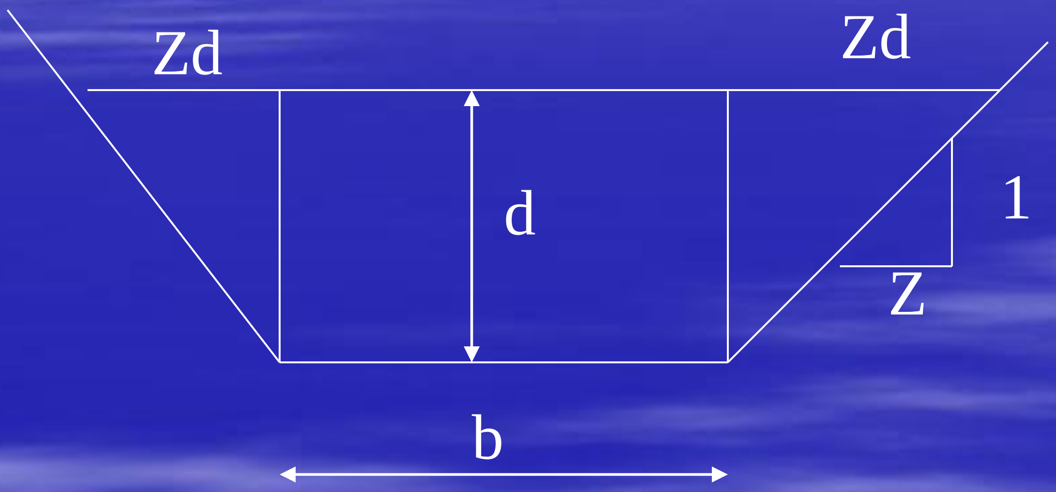
Principles in designing a scheme of perennial irrigation canals are the following:-

1. The canals must be situated on ridges and the drains in depressions.
2. The main canals takingoff directly from the river or reservoir; these canals supply the primary canals ,which in turn feed the secondary canals and so on .
3. The main canals must be situated along the main ridge and the branch canals along secondary riders .
4. The slope of the main ridges is generally less than the slope of the secondary ridges
5. The alignment of a drain or a canal must always consist of straight lines . When it is not possible the minimum radius of curvature of center line of main ,branch ,and distributary canal is (7WS)or (50m) which is greater.

WS =the width of the water surface in (m) .

Other wise the sharpener bend and banks of the canal are to be fully protected by dry stone pitching .

For a Trapezoidal Section



Area of cross section(A) = $b\,d + Z\,d^2$

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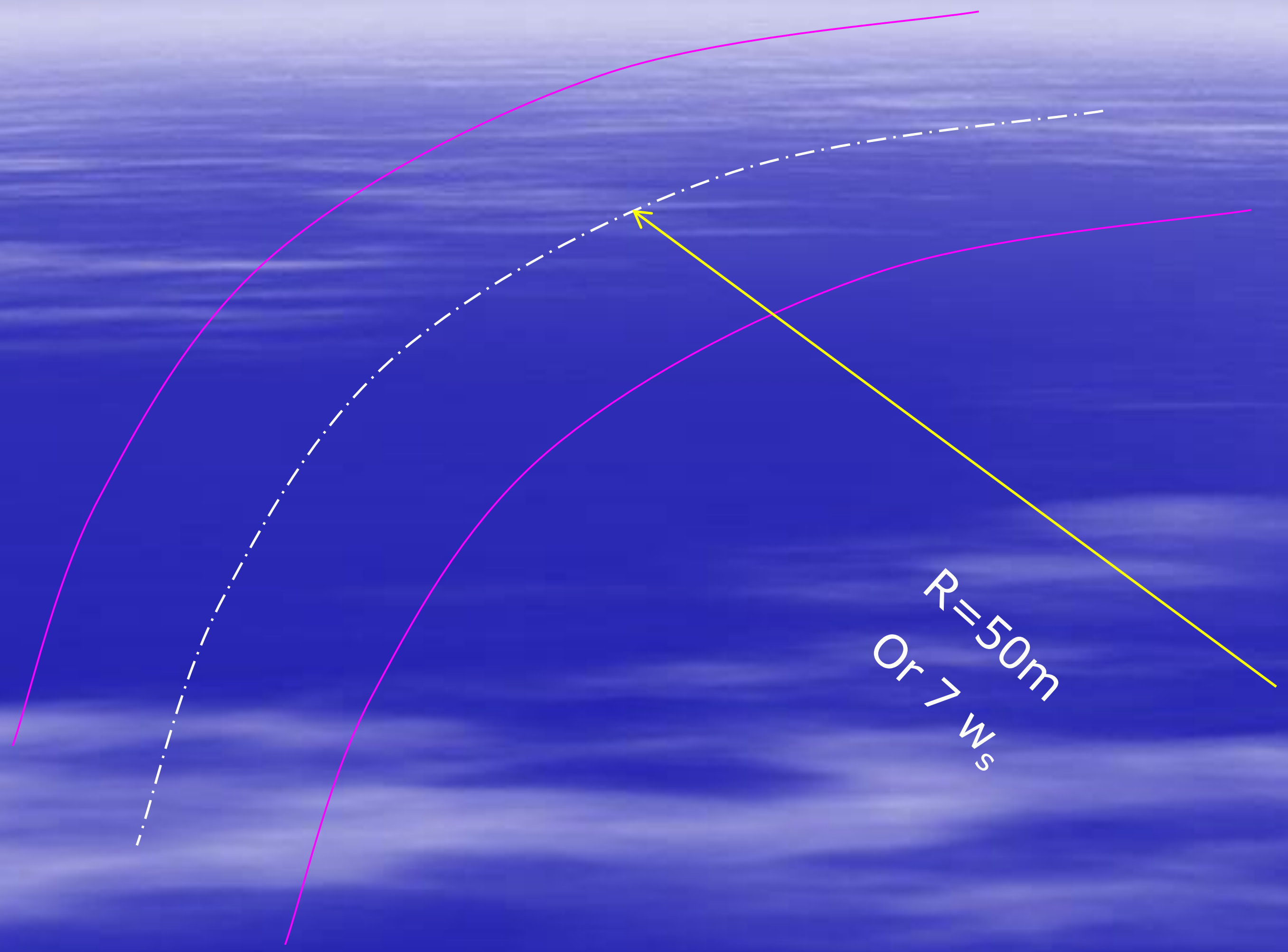
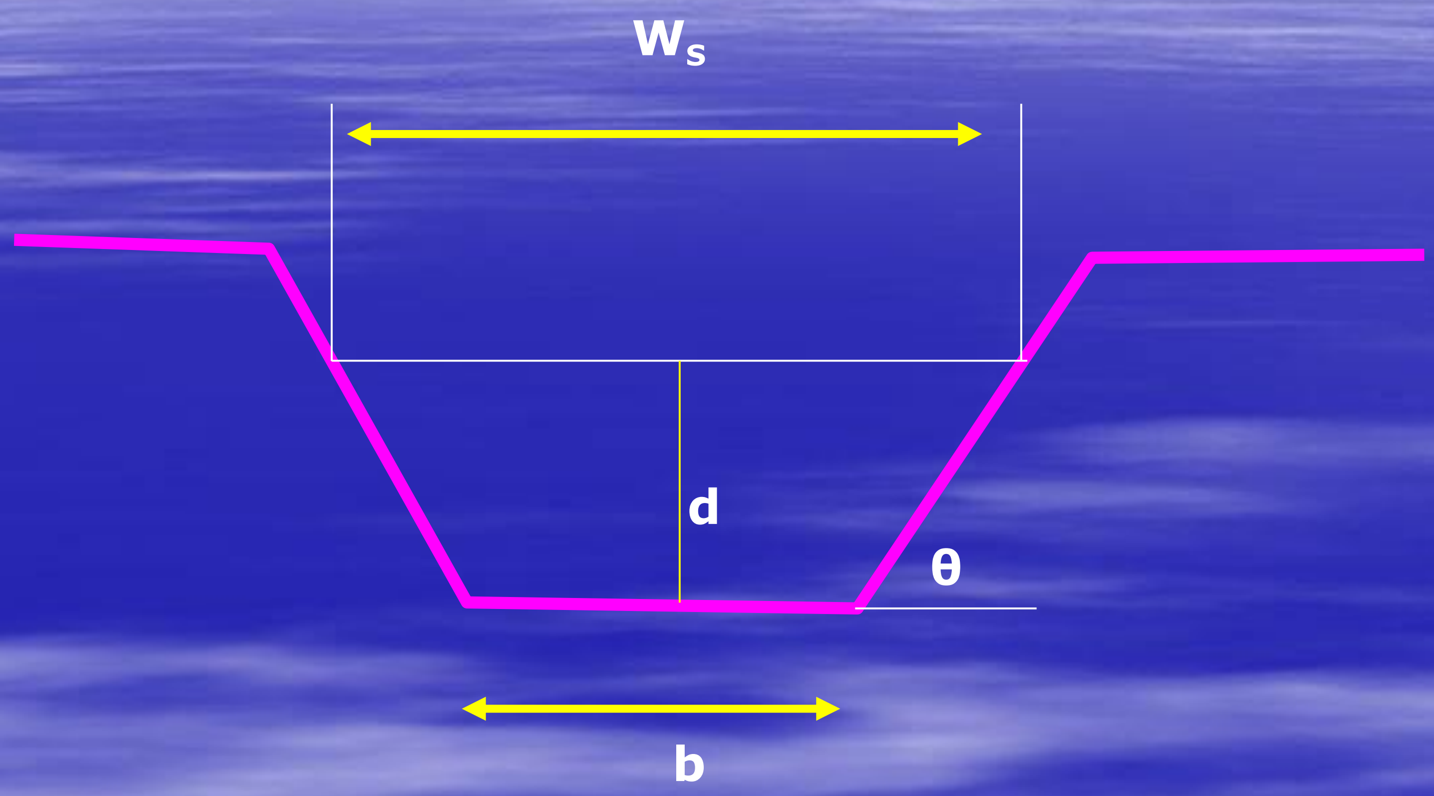
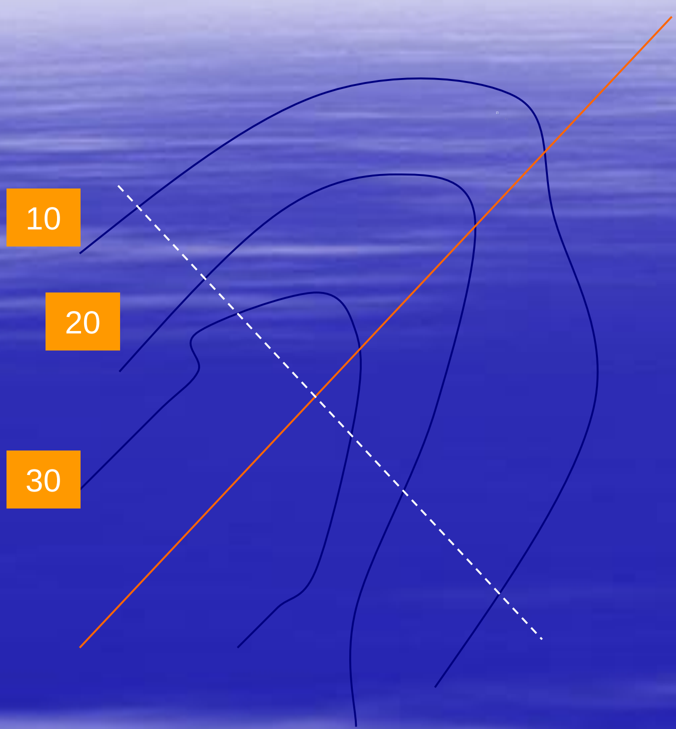
Perimeter = $b + 2\,d\,(1 + Z^2)^{1/2}$

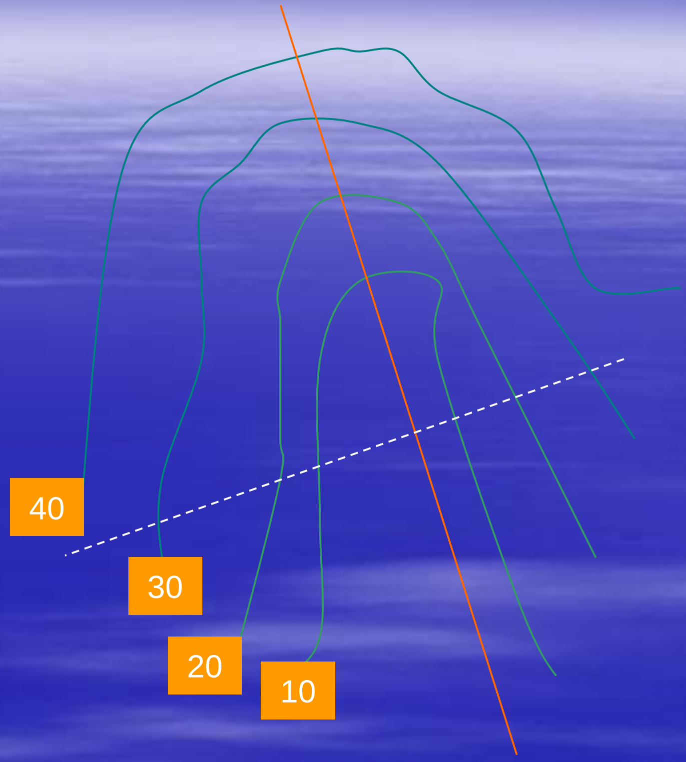
From (1), Perimeter = $A/d - Z\,d + 2\,d(1 + Z^2)^{1/2}$


R=50m
Or 7 w_s



Ws
d
θ
b





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20	
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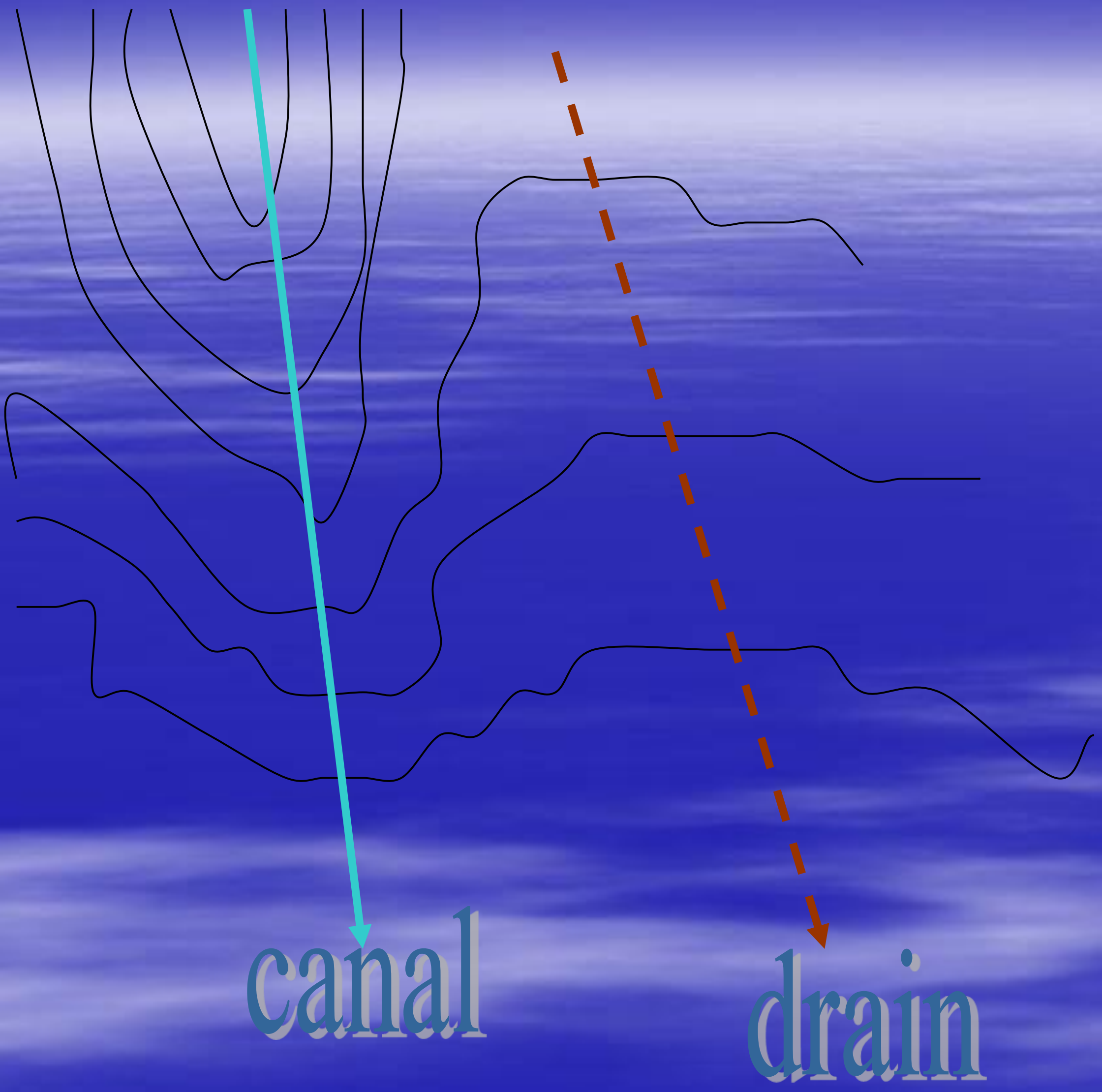
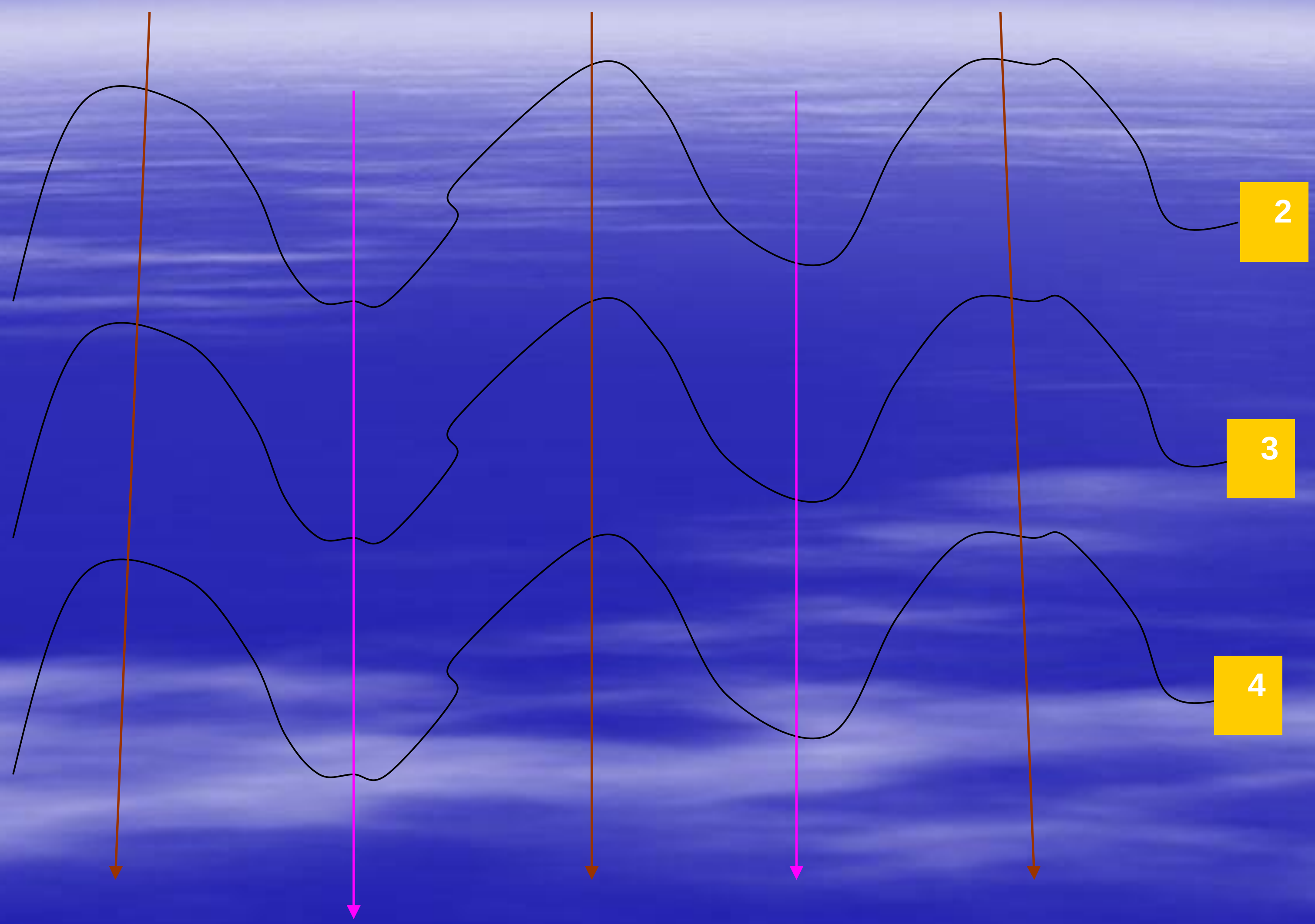

canal
drain

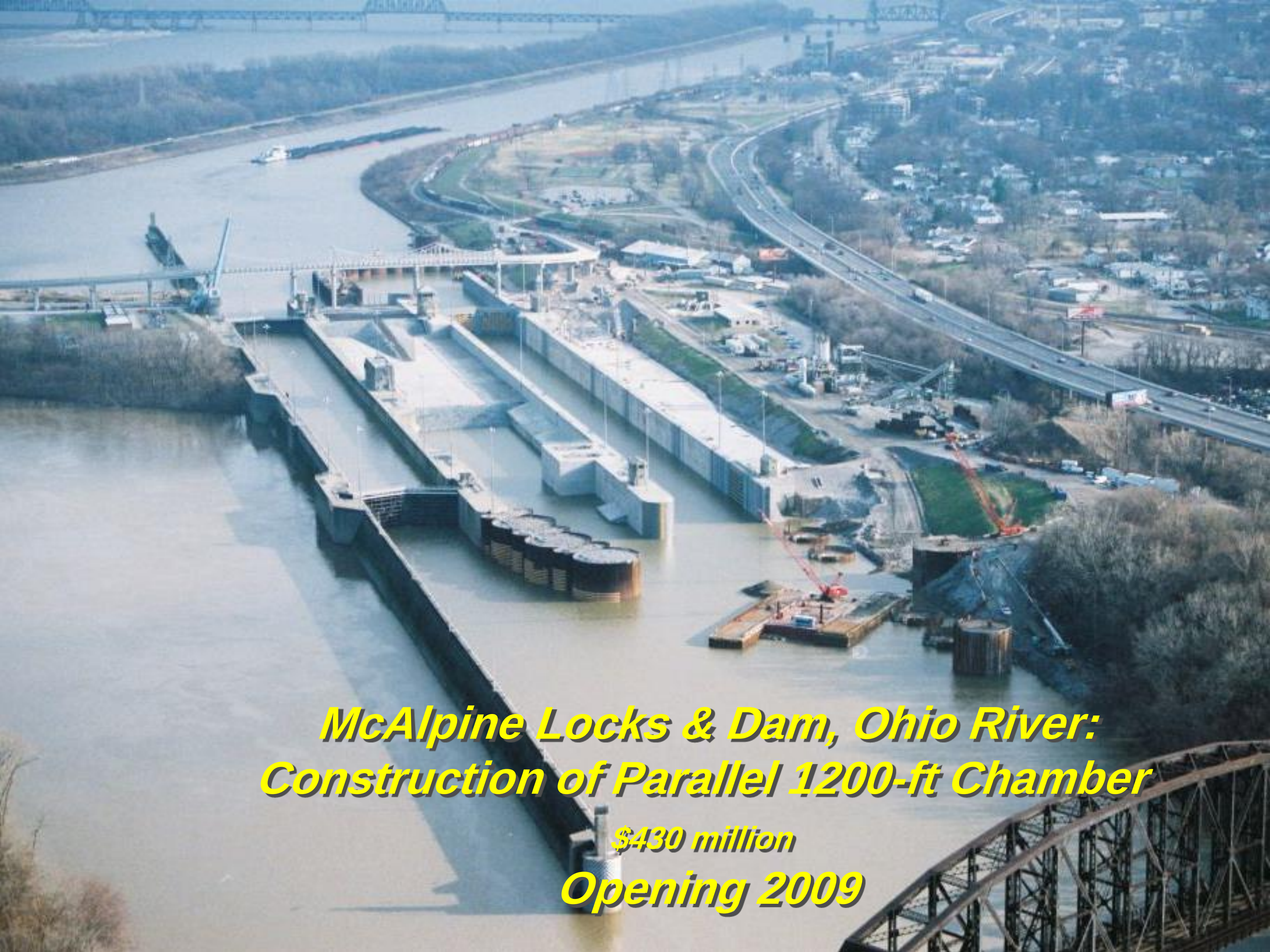

2
3
4


regulator


سدة سامراء

Overview

- Why do we use Drop Structures ?


McAlpine Locks & Dam, Ohio River:
Construction of Parallel 1200-ft Chamber
$430 million
Opening 2009

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Types of leaks in irrigation channels

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صرف المياه المعالجه فى قنوات الرى

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The ratio of the horizontal to vertical distance of the sides of the channel. The side slope of the canal depend on the type of the soil.

Berm
It is a narrow strip of land, left on either side of a canal at G.L. between upper edge of the cut and the inside toe the bank . The width of berm depends upon the size of the canal . Berm perfoms following functions:

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3. For canal partly in cutting and in filling ; Berm=2D

1. D=depth of water in the canal (m).

Free board

The vertical distance between full ssupply level t0 the top of the canal . The distance should be sufficient to prevent waves or fluctuations in water surface from overtopping the sides.

F=√CD
F=free board(m)
C=constant varying from 0.46 to 0.76

Or
F=0.2+0.15Q1/3
Q=discharge of canal (m3/sec)

Cross section design of canals

Design of canal basis on maximum permissible velocity (non erodible velocity)

❖ **Generally (v)not less than o.5 m/sec ,not more than 1.5 m/sec**

- **The best hydraulic cross section has**

  b= 2 d (for rectangular cross section)•

  b=2d tan θ (for trapezoidal cross section •

  Where b= canal bed width (m)

  d =water depth in canal (m)

- **Generally bed width (b) is limited by the practical capability of the machinery used for construction [min. b = 0.4 m]**

- **Side slop**
- **Berm**
- **Free board**
- **Manning coefficient (n)**

Dimensions of Channels and Definitions

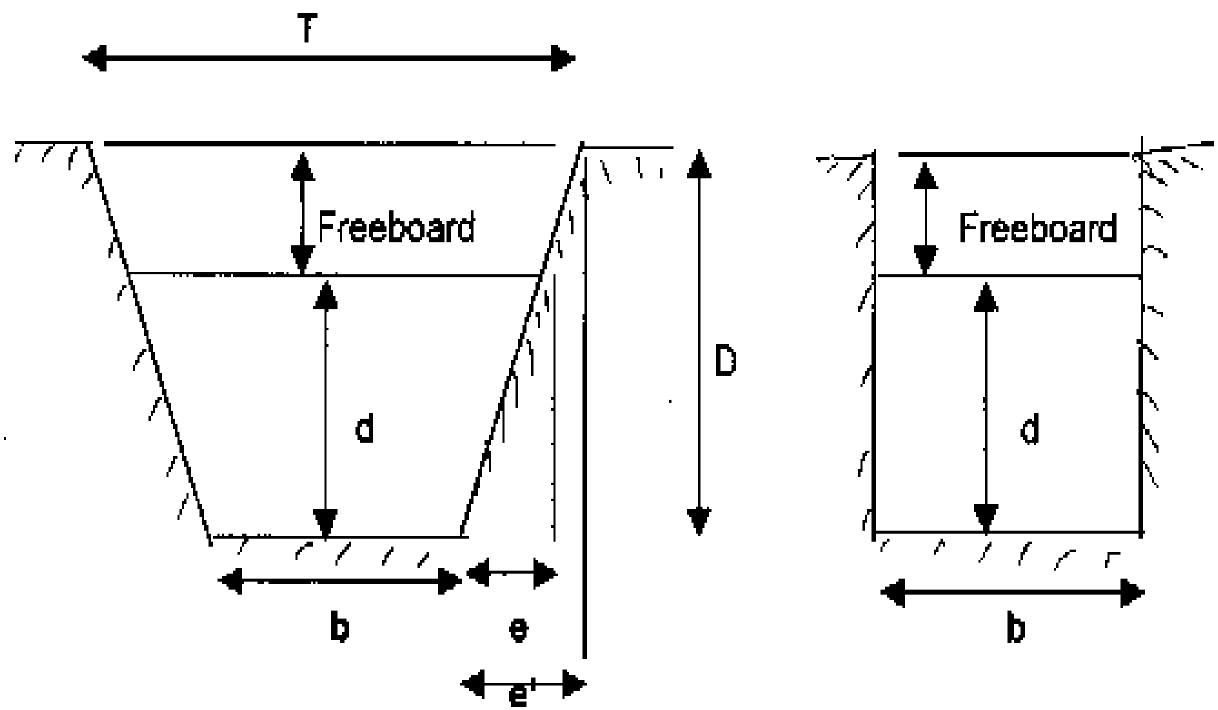


Figure 6.1: Main Parts of Trapezoidal and Rectangular Channels

Table 6.1: Maximum Canal Side Slopes (Z)

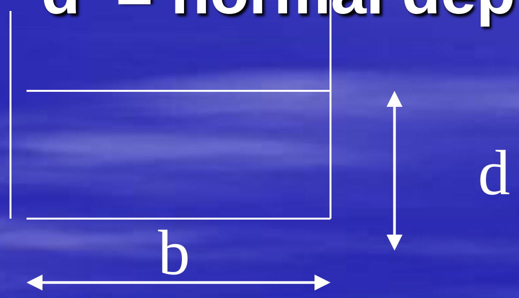
Sand, Soft Clay	3: 1 (Horizontal: Vertical)
Sandy Clay, Silt Loam, Sandy Loam	2:1
Fine Clay, Clay Loam	1.5:1
Heavy Clay	1:1
Stiff Clay with Concrete Lining	0.5 to 1:1
Lined Canals	1.5:1

Parameters of Open Channels

- **a) Wetted Perimeter, P :** The Length of contact between Liquid and sides and base of Channel

- **P = b + 2 d ; d = normal depth**

Wetted Perimeter



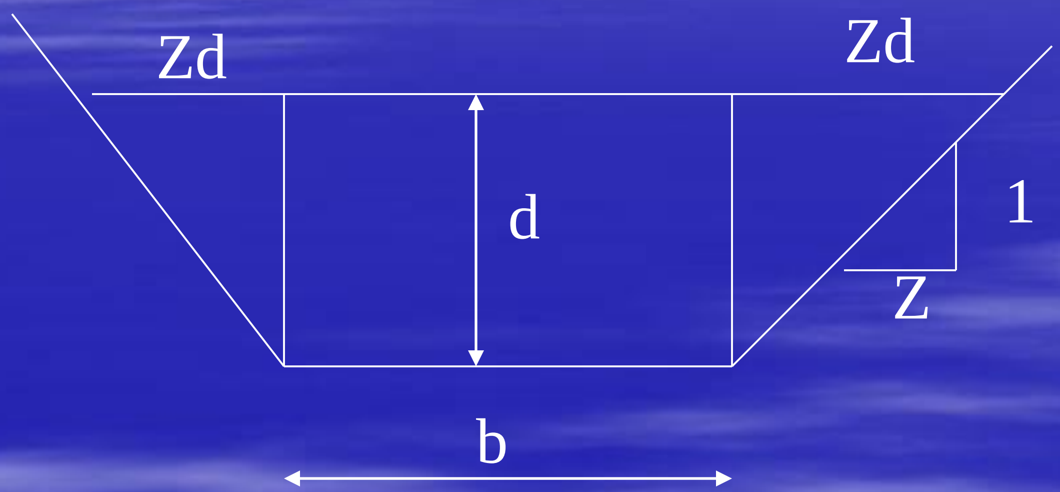
Hydraulic Mean Depth or Hydraulic Radius (R): If cross sectional area is A, then R = A/P, e.g. for rectangular channel, A = b d, P = b + 2 d

Definitions

- **a) Freeboard:** Vertical distance between the highest water level anticipated in the design and the top of the retaining banks. It is a safety factor to prevent the overtopping of structures.

- **b) Side Slope (Z):** The ratio of the horizontal to vertical distance of the sides of the channel. $Z = e/d = e'/D$

For a Trapezoidal Section



Area of cross section(A) = b d + Z d^2

Width , b = A/d - Z d ....(1)

Perimeter = b + 2 d (1 + Z ^{2})$^{1/2}$

From (1), Perimeter = A/d - Z d + 2 d(1 + Z^2)$^{1/2}$

EXAMPLE 3.4 A trapezoidal channel is 10.0 m wide and has a side slope of 1.5 horizontal: 1 vertical. The bed slope is 0.0003. The channel is lined with smooth concrete of n =0.012. Compute the mean velocity and discharge for a depth of flow of 3.0 m.

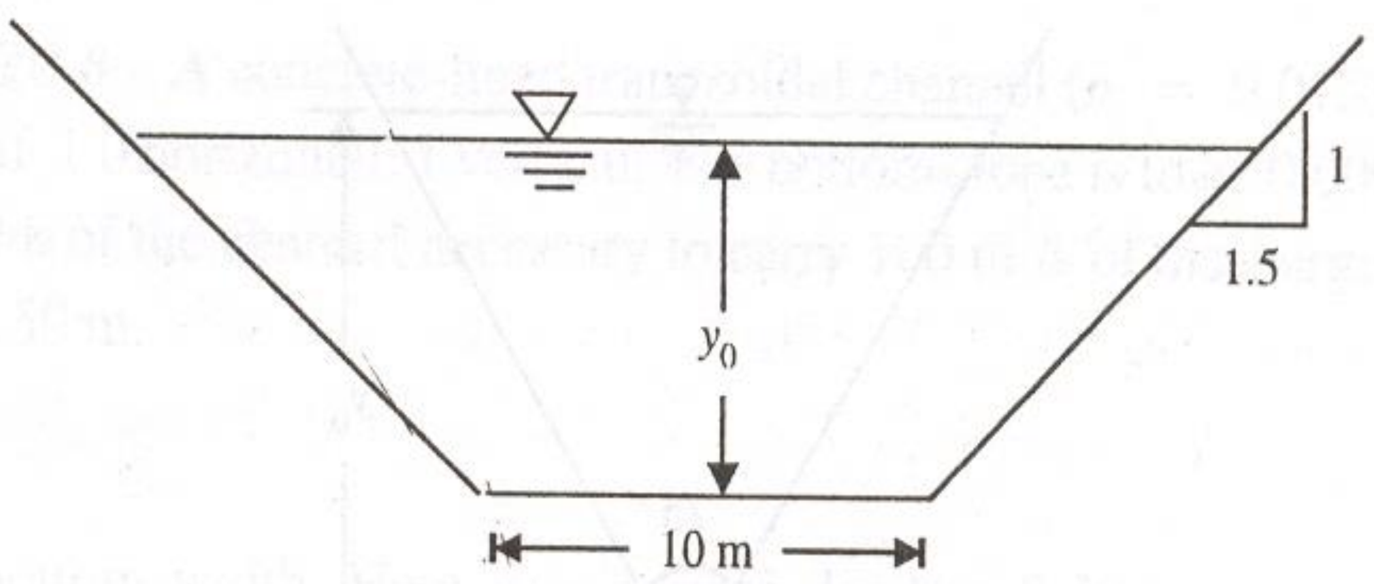


Fig. 3.11 Example 3.4

- **Solution**
- Let
- Here
- Area
- Wetted perimeter

$$y_0 = \text{uniform flow depth}$$

$$B = 10.0 \text{ m and side slope } m = 1.5$$

$$A = (B + my)y$$

$$= (10.0 + 1.5 \times 3.0)3.0 = 43.50\ m^2$$

$$P = B + 2\sqrt{m^2 + 1}y$$

$$= 10.0 + 2\sqrt{2.25 + 1} \times 3.0 = 20.817\ m$$

$$R = \frac{A}{P} = 2.090\ m$$

$$V = \frac{1}{n} R^{2/3} S_0^{1/2}$$

$$= \frac{1}{0.012} \times (2.09)^{2.3} \times (0.0003)^{1/2}$$

$$= 2.36\, m/s$$

- $$Q = AV = 102.6\, m^3/s$$

-

- Discharge

- ***EXAMPLE 3.5*** In the channel of Example 3.4 find the bottom slope necessary to carry only 50 m^3/s of the discharge at a depth of 3.0 m.
- ***Solution***

$$A = 43.50\, m^2$$

$$P = 20.817\, m$$

$$R = 2.09\, m$$

$$S_0 = \frac{Q^2 n^2}{A^2 R^{4/3}} = \frac{(50.0)^2 \times (0.012)^2}{(43.5)^2 \times (2.09)^{4/3}}$$

$$= 0.0000712$$

LOCK

Lock is an navigation and hydraulic structure used to overcome the difference of water level between two positions, it consist of entrance ,lock chamber , outlet , gates or orifices .

Length and Width of Lock

The size of the lock depends on the size of the largest boat pass through it with clearances to allow the boat to enter the lock .

Filling and Empting the Lock

This prosses is done by :-

1. **Gates**
2. **Orifices through the gates**
3. **Orifices at the side and lower walls of the lock**

Time of Filling and Empting the Lock

Time of filling(t_f) = $\dfrac{A(H+h)}{C_d a_1\sqrt{2gh}}$

Time of empting(t_e) = $\dfrac{2AH}{C_d\, a_2\sqrt{2gh}}$

Let A= area of the lock chamber

a_1= area of the upper sluice .

H = difference of water level in the two canals .

h = hight of the water surface in the upper canal above the upper sluice G

a_2= area of the lower sluice.

C_d =coefficient.

Classification&Alignment of Canals and Drains

Canals

Based upon the relative position in agiven network of canals ,it consist of

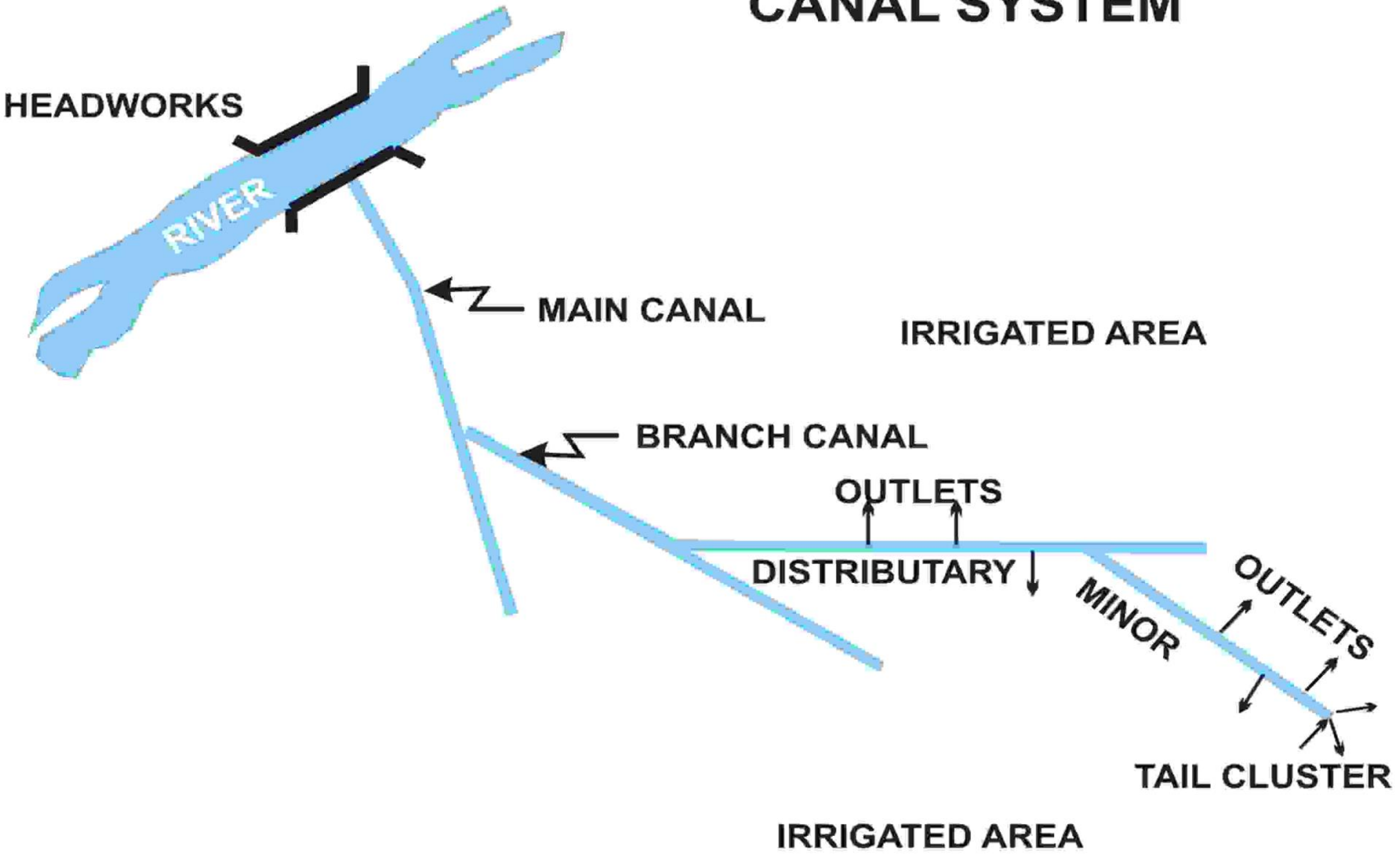
1. **Main canal**
2. **Branch canal**
3. **Major distributary channels**
4. **minor distributary (water courses)**
5. **Farm supply channels**

Drains

Similarly the network of drains consist of

1. **Main drain**
2. **Branch drains**
3. **Major collector drains**
4. **Minor collector drains**
5. **Farm drains**

SCHEMATICS DIAGRAM OF A CANAL SYSTEM



Alignment of Canals and Drains

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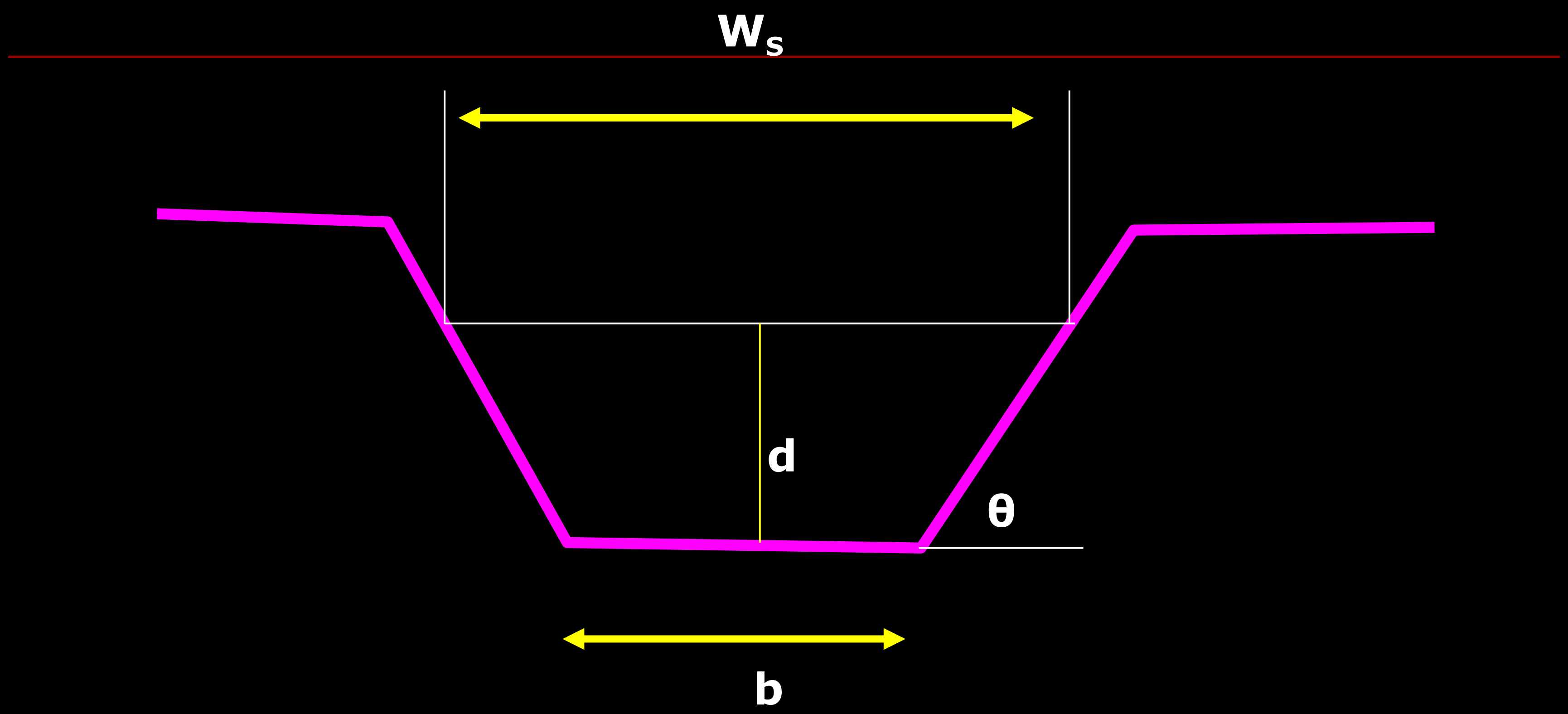
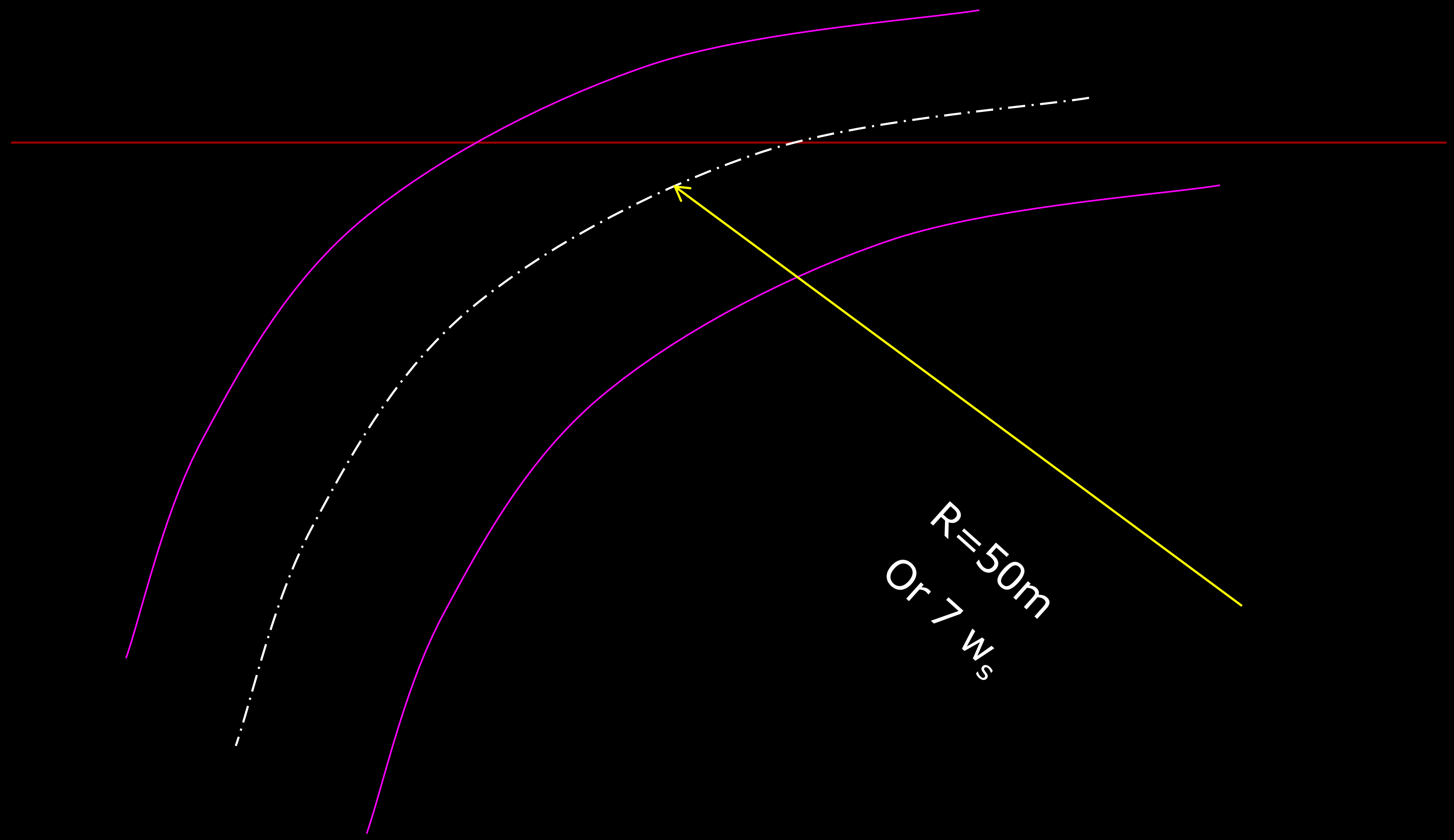
and distributary canals is (7 Ws)or (50 m) which is the greater

where Ws = the width of the water surface in (m) ,otherwise the

sharpner bend and banks of the canal are to be fully protected by dry stone pitching based on a gravel filter]



w_s
d
θ
b


R=50m
Or 7 w_s

RETAINING WALLS

A wall that designed to maintain a difference in the elevations of the ground surface on each side of the wall.

Uses of retaining walls

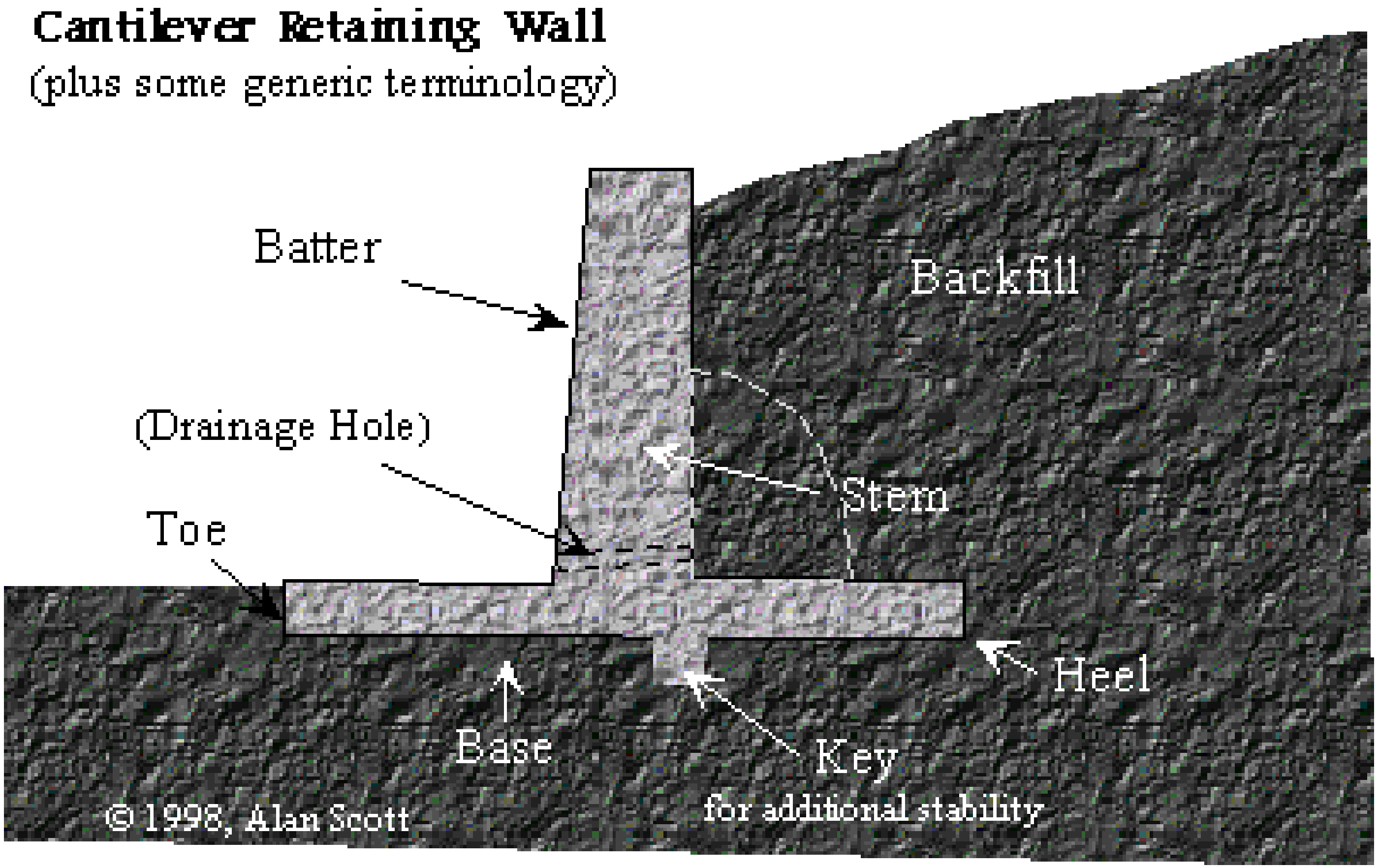
1. **Retain rock fill, soil, water, gravel….etc at the back of it.**
2. **Retaining walls used in connection with railway, highway, bridge and canals.**
3. **Retaining walls usually placed at an angle at the entrance and outlet of irrigation structures.**

Note

1. **Retaining walls connected with bridge called (ABUTMENT).**

- **Retaining walls at the entrance and outlet of irrigation structures called (WING WALLS).**

Cantilever Retaining Wall



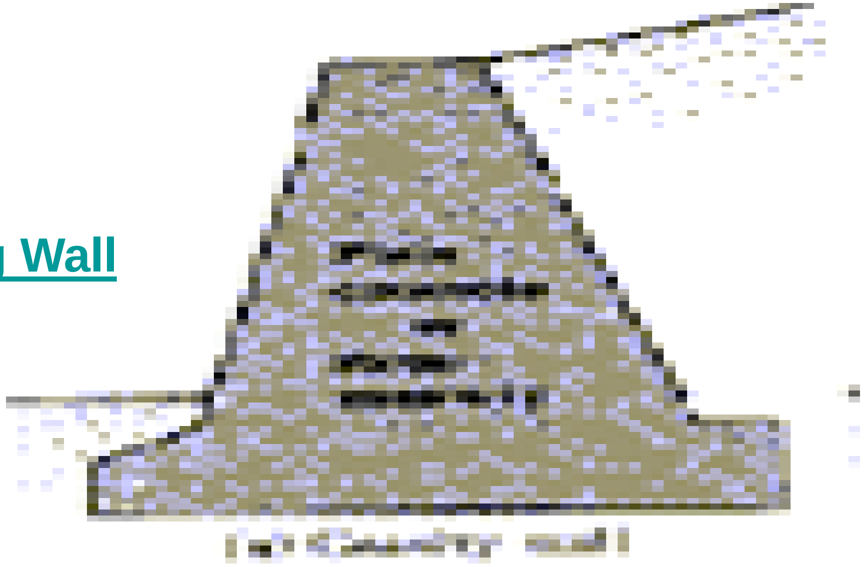
Type of Retaining walls

- *Gravity Retaining Walls*
- Semi-Gravity Retaining Walls
- Cantilever Retaining Walls
- Counterfort Retaining Walls

Solid gravity retaining walls

1. It is suitable for low walls
2. Depends on its own weight in resisting lateral earth forces.
3. Its stability depends on its own weight.
4. It has large cross section.

Gravity Retaining Wall

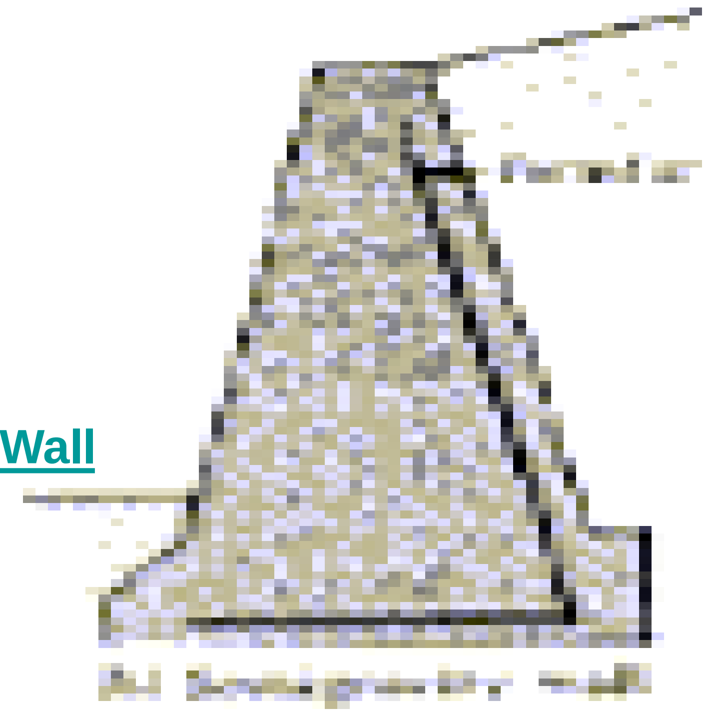


Semi gravity retaining walls

A specialized form of gravity walls is a semi-gravity retaining wall. These have some tension reinforcing steel included so as to minimize the thickness of the wall without requiring extensive reinforcement. They are a blend of the gravity wall and the cantilever wall designs.

1. **It is a modification of solid gravity type.**
2. **It has small amount of reinforcing steel in the back.**
3. **Its cross section is smaller than gravity walls.**
4. **The amount of concrete used is less t**
5. **It is more economical than gravity wa**
6. **It is suitable for low and high walls.**

Note:(**reinforcement tie the vertical stem to the base).**

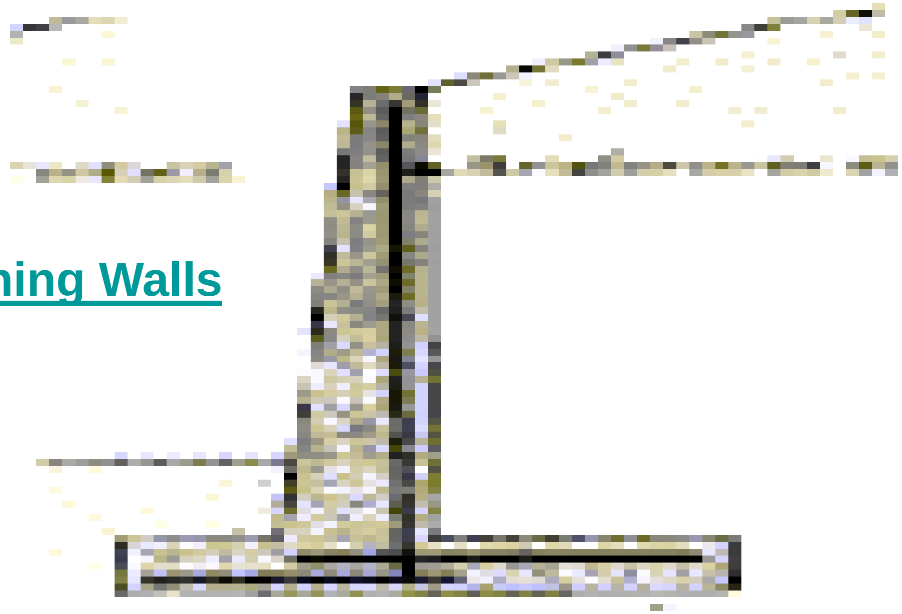


Semi-Gravity Retaining Wall

Cantilever retaining walls

1. **It is also called a(T) type wall.**
2. **It is suitable for low and high walls.**
3. **Its cross section is smaller than other types.**
4. **It consists of three parts (vertical stem, toe projection and heel projection).**

Cantilever Retaining Walls

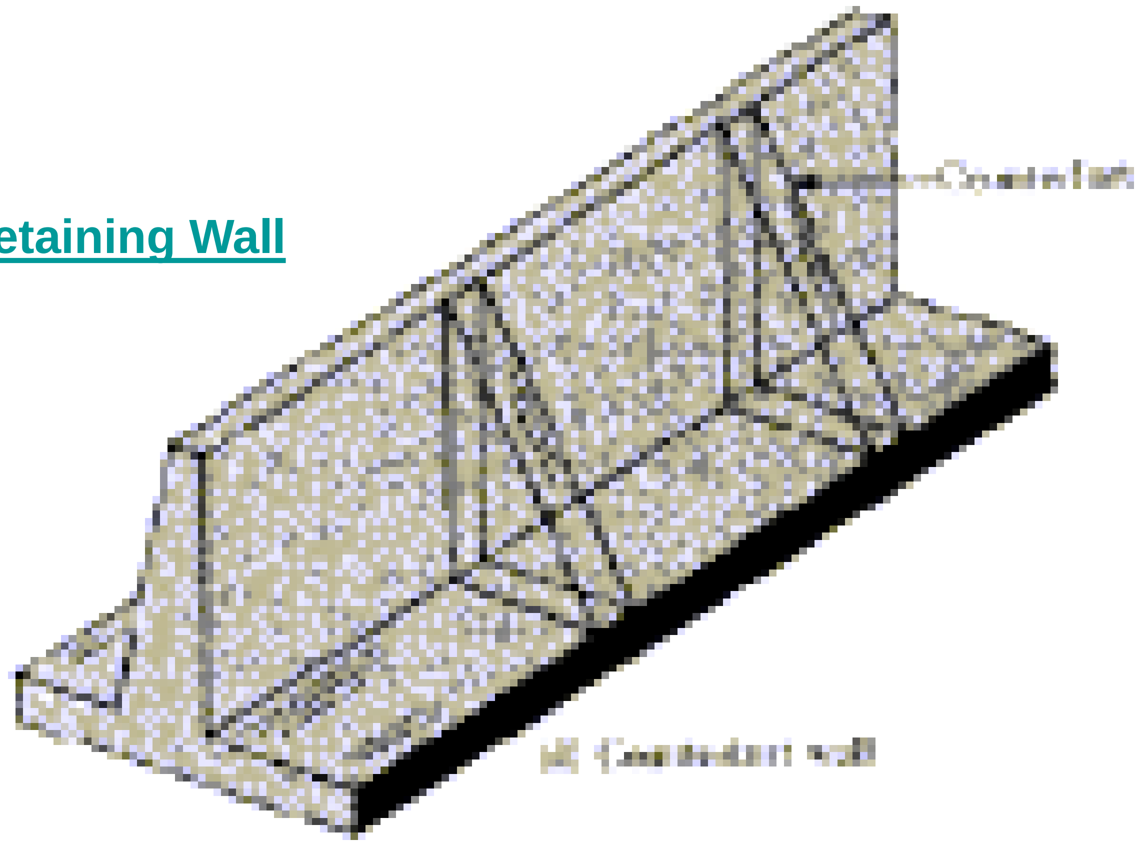


Counterfort retaining walls

Counterfort retaining walls are similar to cantilever walls except they have thin vertical concrete webs at regular intervals along the backside of the wall. These webs are known as *counterforts*.

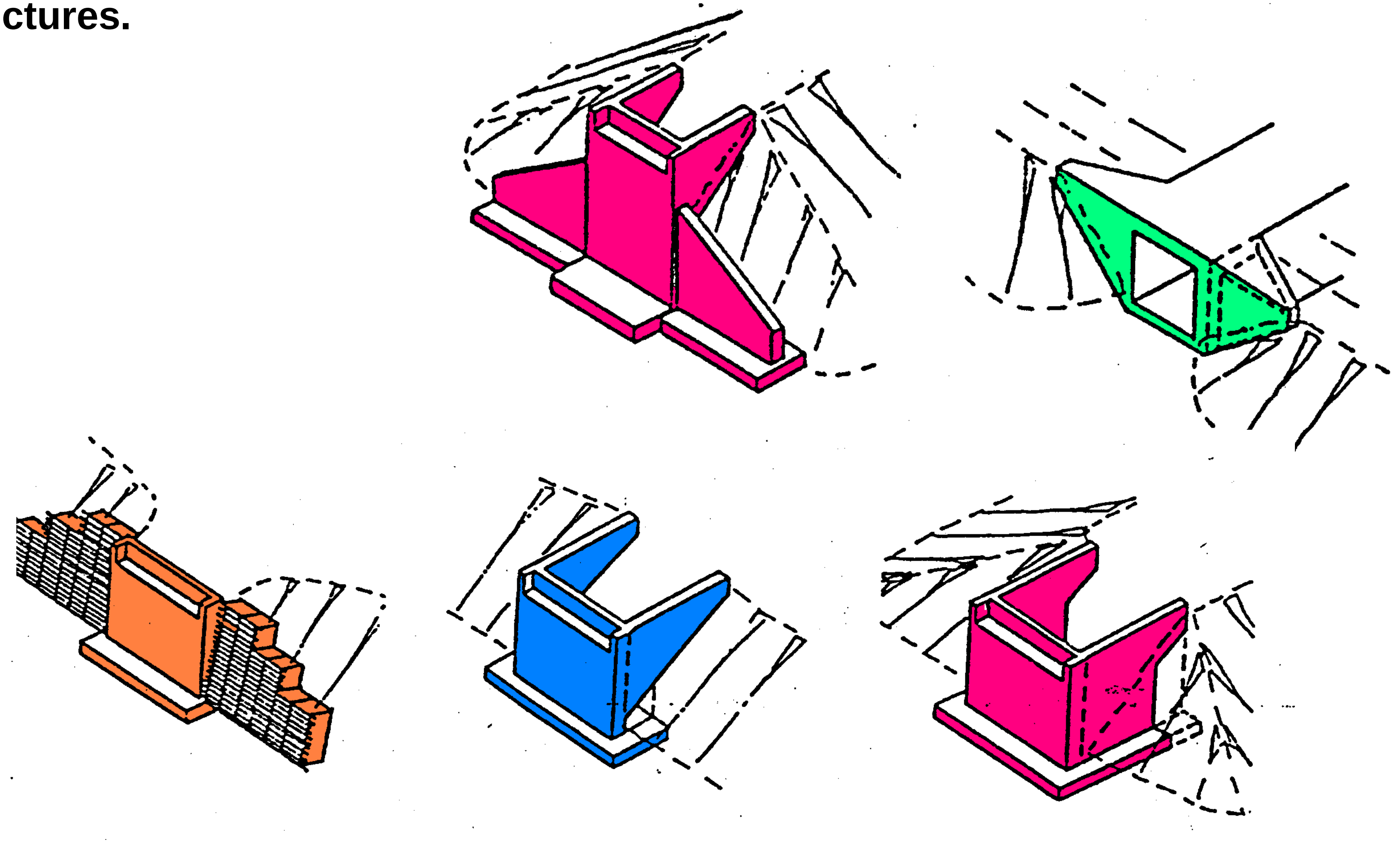
1. **It is similar to cantilever walls.**
2. **It is used when the difference between the levels is very high.**

Counterfort Retaining Wall



Wing Walls

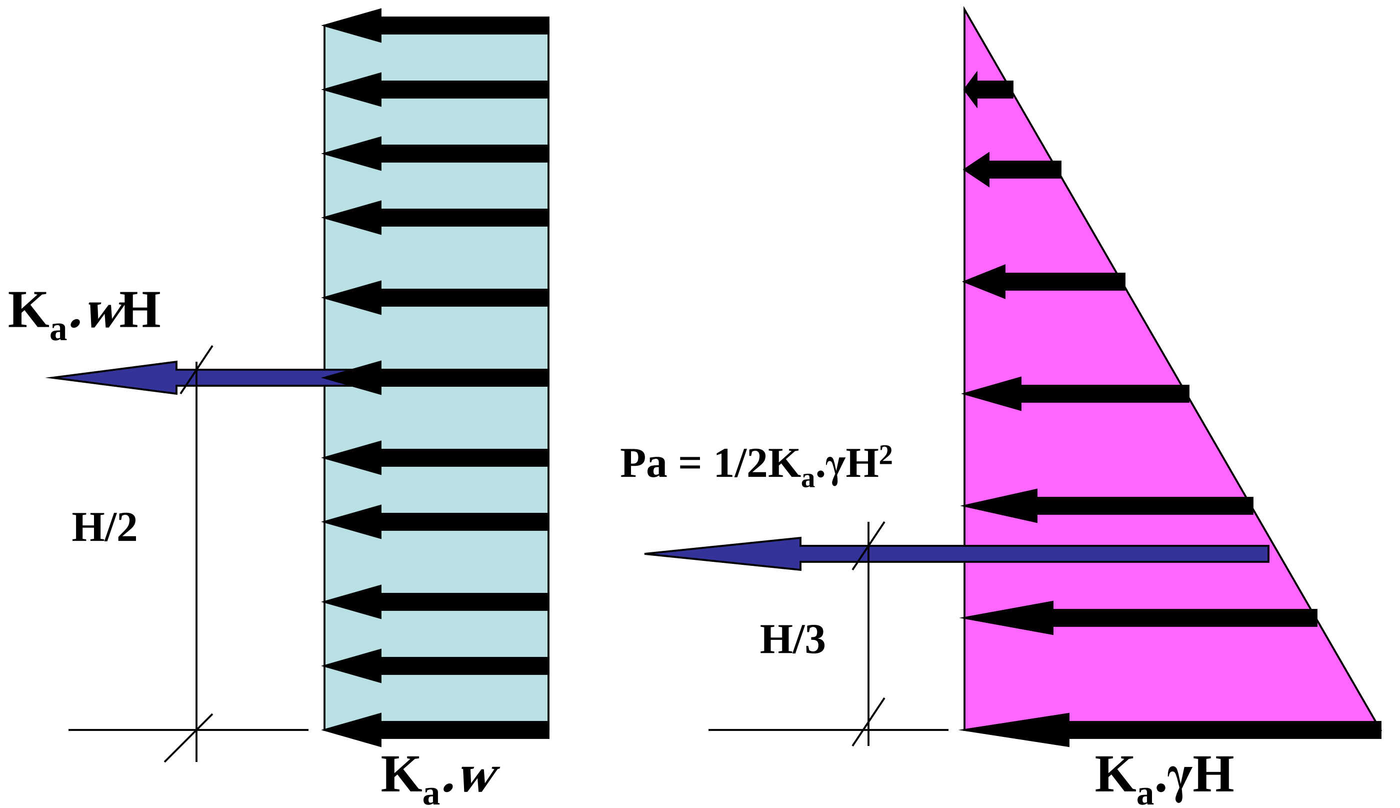
The walls are usually placed at an angle with the normal to the direction of the fill used to regulate the entrance and exit of water of irrigation structures.



Forces acting on retaining walls

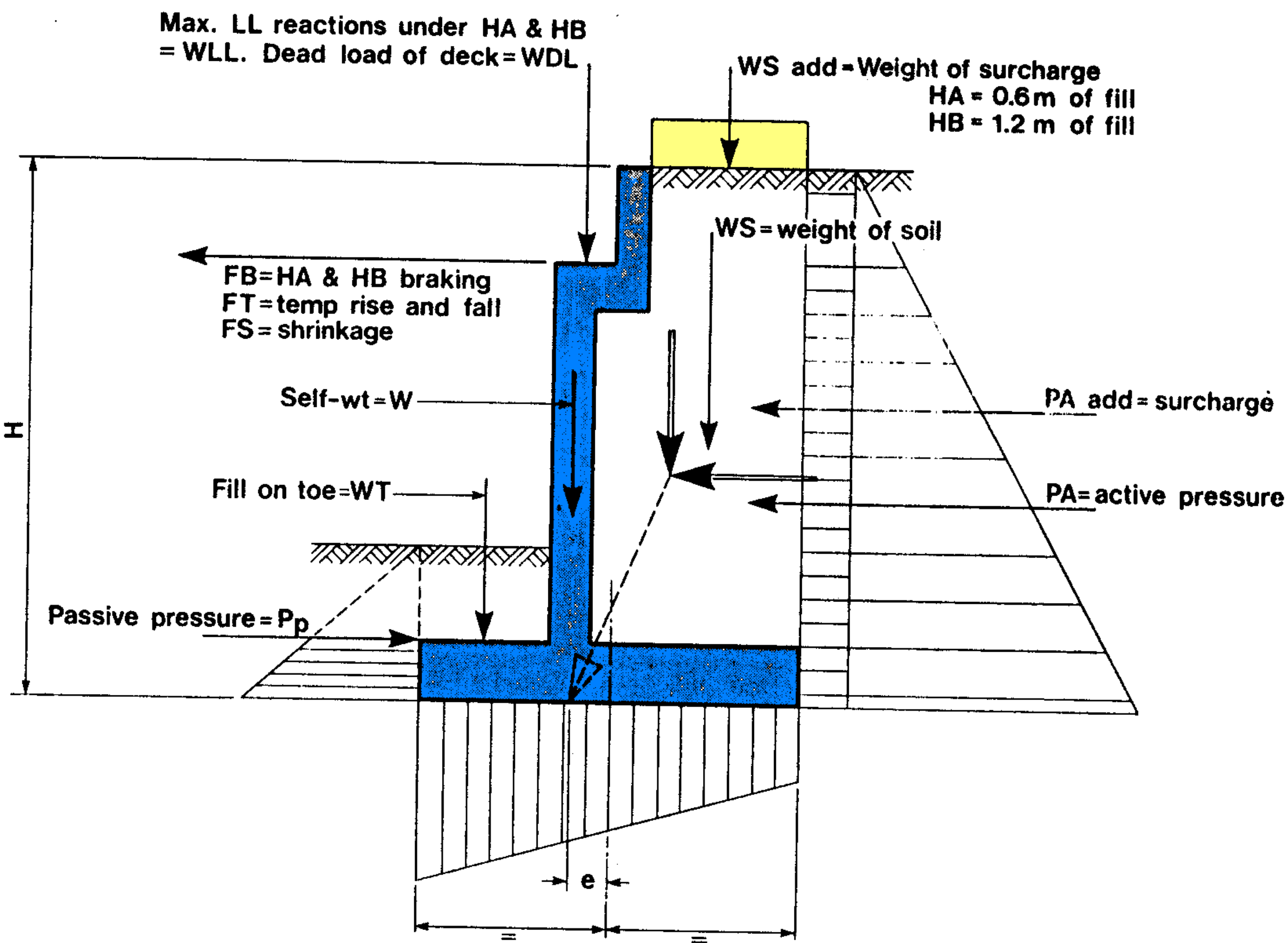
1. **The weight of the wall.**
2. **The normal component of the foundation pressure.**
3. **The horizontal component of the foundation pressure.**
4. **Surcharge loads.**
5. **Water and seepage pressure.**
6. **The earth pressure against the back of the wall.**
7. **The earth pressure against the face of the wall.**
8. **Bridge reactions.**
9. **Uplift pressure.**
10. **Earthquakes.**

Lateral Earth Pressures

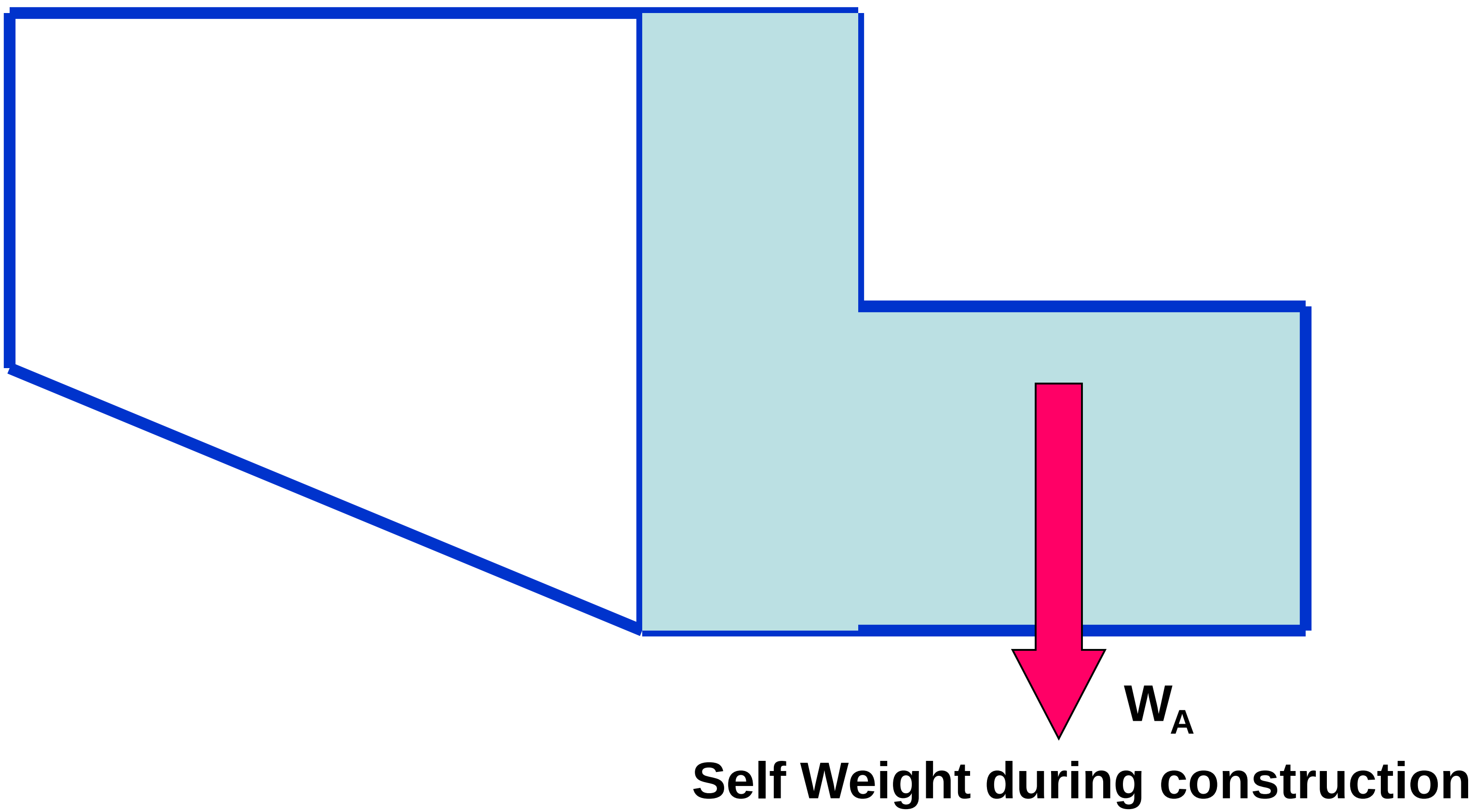


Due to surcharge **Due to backfill soil**

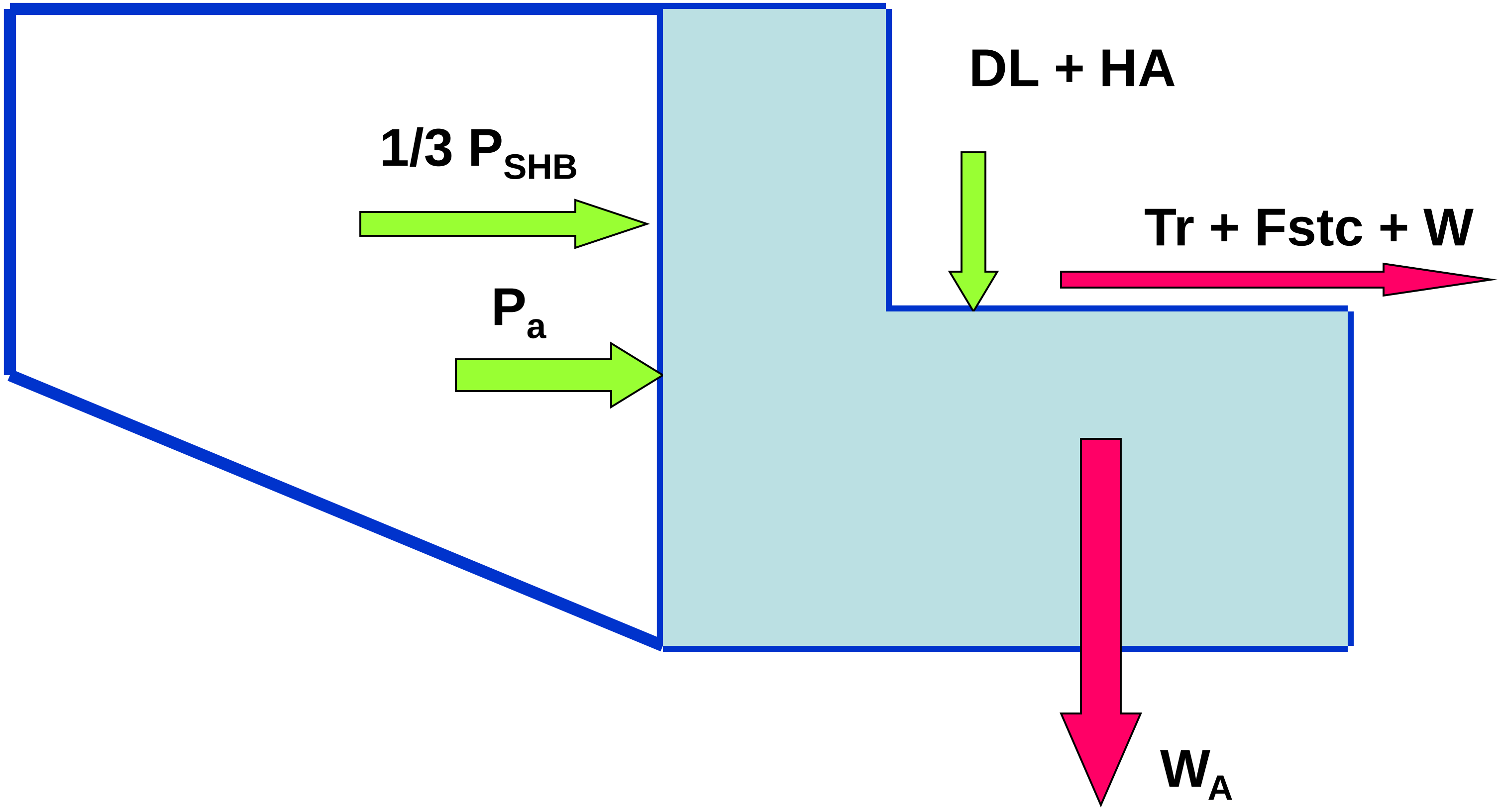
Forces on the Abutment



Abutment (Load Case 1)



Abutment (Load Case 2)



retaining wall

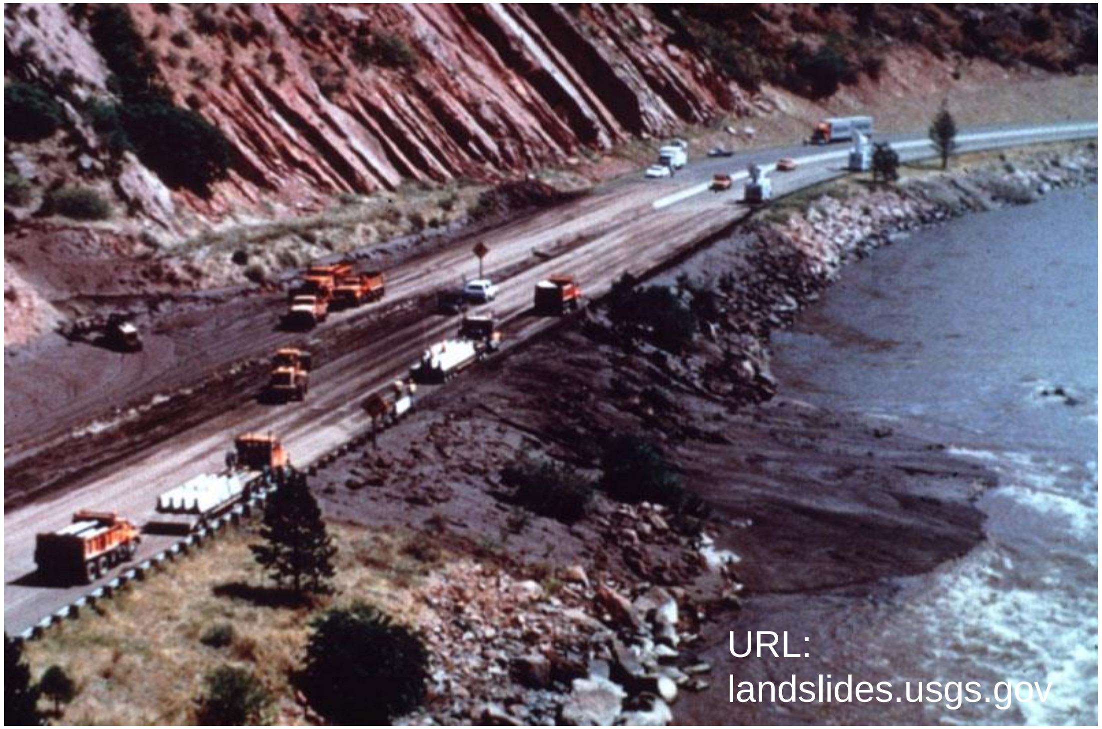
- high retaining wall with facing bricks

retaining wall

- small retaining wall with piers

Rock Retaining Wall
Supports fill slope

Landslides



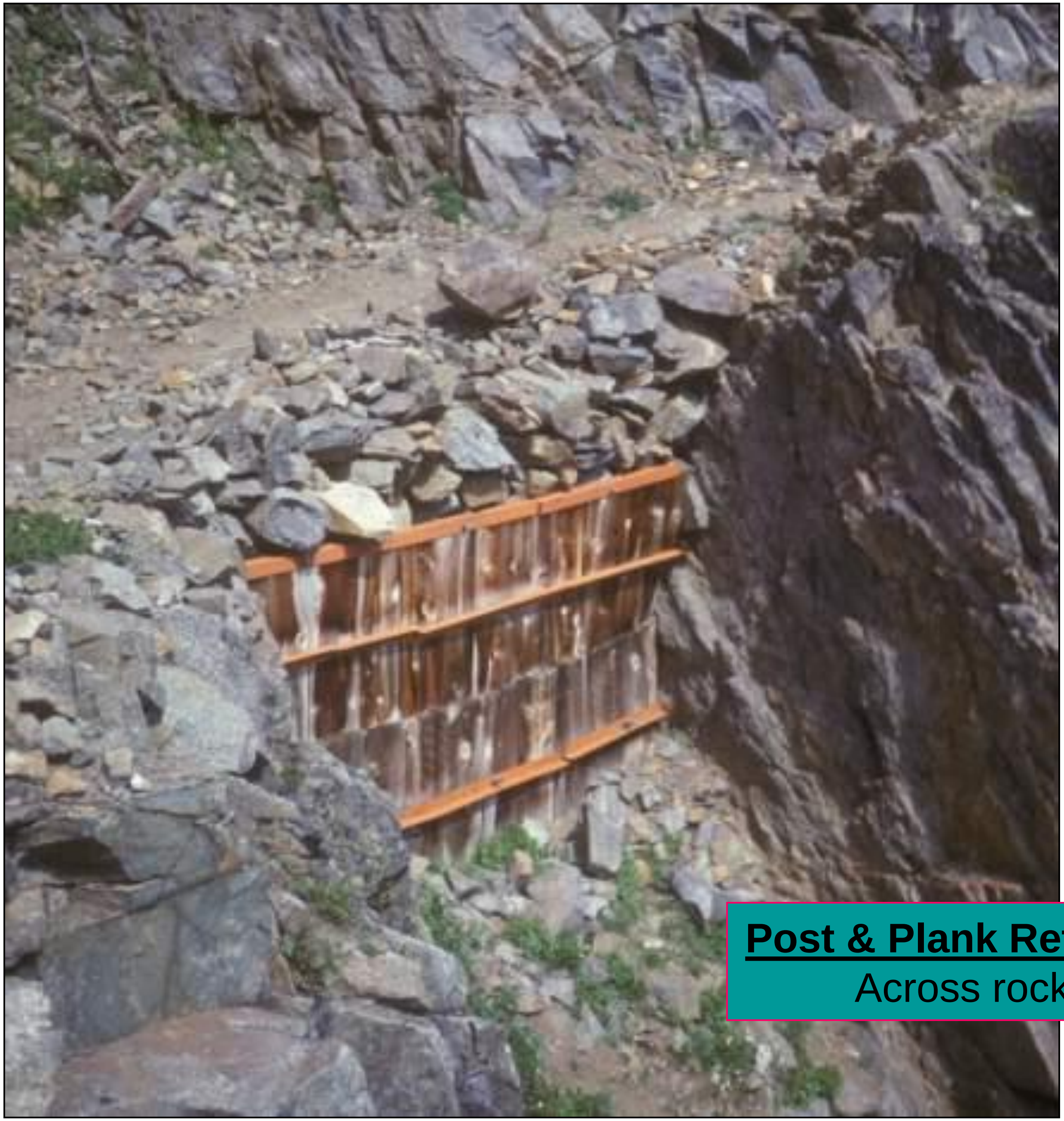
Fire-related debris flows from Storm King Mountain, Colorado. Debris flows blocked Interstate-70 during Labor Day weekend, 1994. A very hot and fast-moving wildfire in July of that year on the slopes of Storm King Mountain denuded the slopes of vegetation. An intense rainstorm generated debris flows from material on the burned hillslopes and in the channels between hills. Interstate traffic was disrupted for a day and caused serious delays for emergency vehicles and hospital access, due to the fact that Interstate-70 is the only access route through this part of the Rockies. The Interstate-70 corridor through the Rocky Mountains experiences numerous problems from landslides, debris flows, and rockfalls.

Landslides

Sinkhole at Winter Park Florida-Sinkholes (1981): Subsidence occurs when carbonate layers that lie below the surface dissolve. When the weight of the overlying ground becomes too great, or the dissolved area too large, the surface collapses into the void. These features occur in what is known as karst topography which is common in FL, KY, MO, PA, and TN

Rock Retaining Wall

Supports tread



Post & Plank Retaining Wall

Across rock chute

Log Retaining Wall
Cribbing to support bridge

Log Retaining Wall
Cribbing across old landslide

Flooding Protection

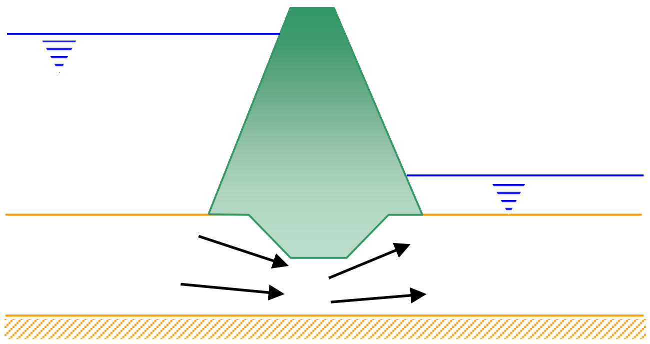
Levees (McMillan, J. - The Advocate 2002)

"Deep fissures on the batture - land between the levee and the Mississippi River - reveal the ground is again sinking at the spot where the levee collapsed in 1983."

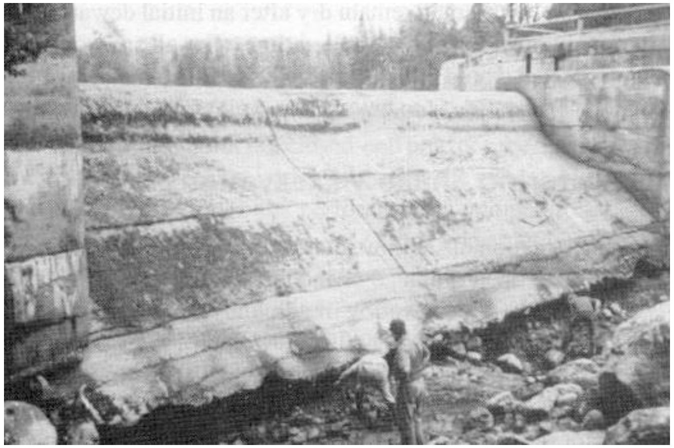
Flooding Protection

Dams and reservoirs (US Society on Dams 2002)

- A dam is built to control water. Dams are made from earth, rocks or concrete.
- Dams are usually constructed on rivers to store water in a reservoir.
- Dams help people have water to drink and provide water for industry, irrigation, fishing and recreation, hydroelectric power production, navigation in rivers, etc. <u>Dams also serve people by reducing or preventing floods.</u>



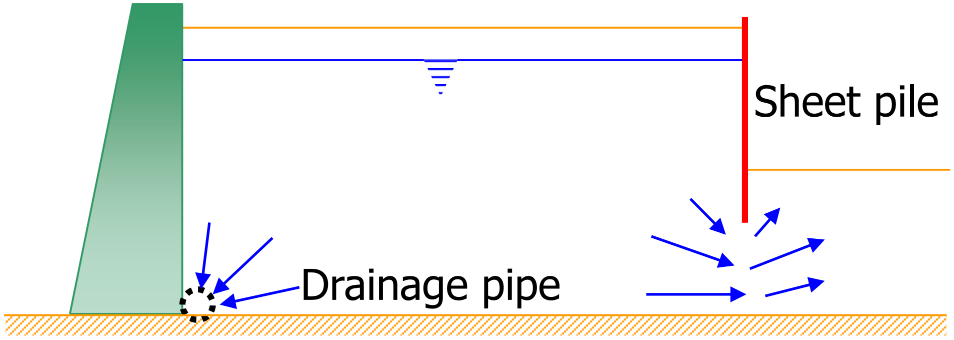
(from McCarthy 1998)



Flooding Protection

Retaining walls and sheet piles (Bowles 1988)

- Retaining walls are structures used to retained soils or other granular materials.
- Materials: masonry, concrete, wood, metal sheeting, reinforce earth, etc.
- The analysis and design of retaining walls is governed by the stiffness of the wall: rigid or flexible.



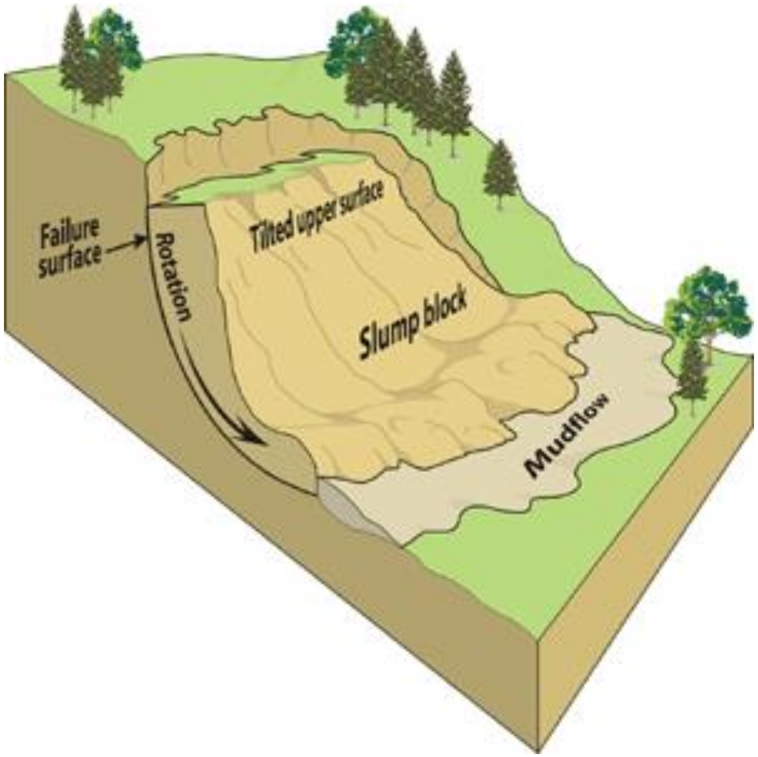
(Cheifetz 2002)

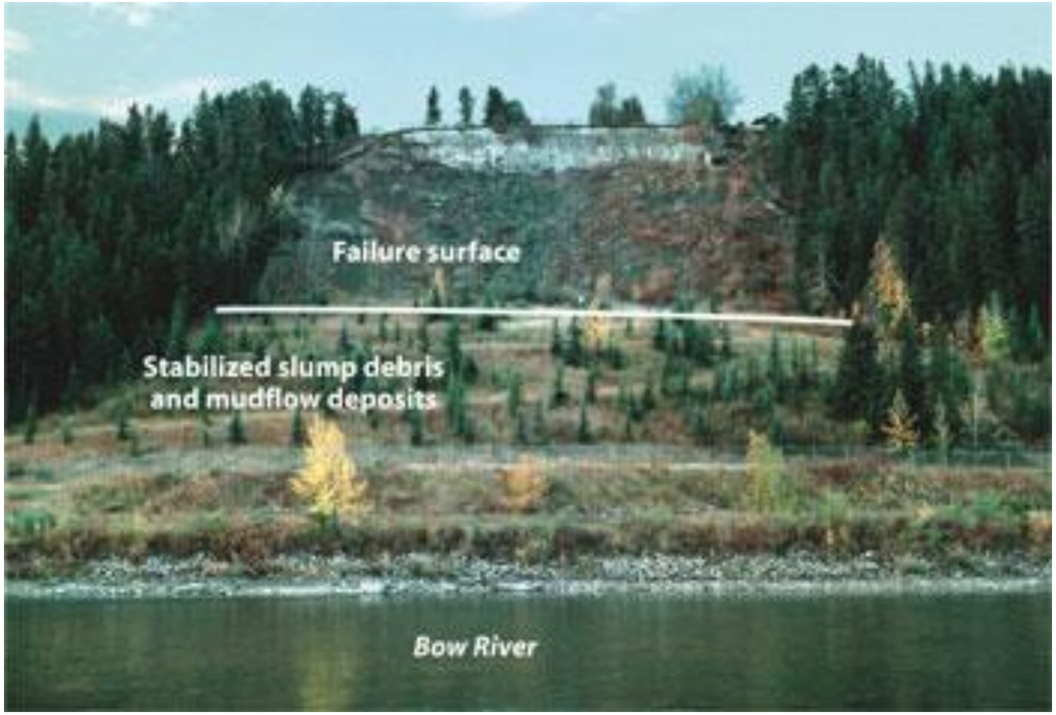
Landslides

La Conchita, California-a small seaside community along Highway 101 south of Santa Barbara. This landslide and debris flow occurred in the spring of 1995. Many people were evacuated because of the slide and the houses nearest the slide were completely destroyed. Fortunately, no one was killed or injured.

Landslides

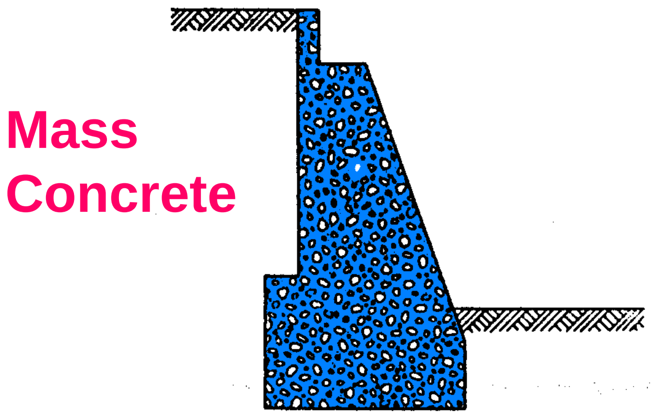
- Types and Processes





(Canada Natural Resources 2002)

Wall Abutments

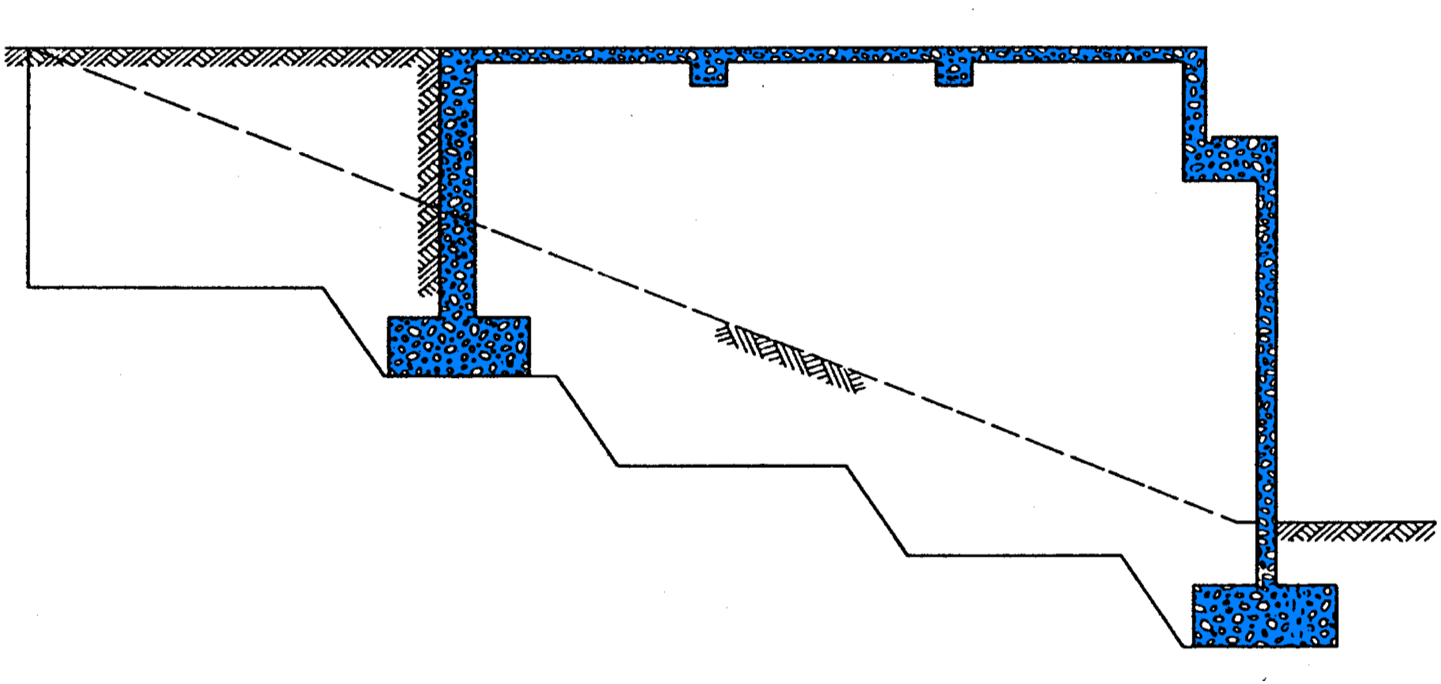


- Mass concrete is economic for small heights, such as where headroom is less than that needed for vehicular traffic.
- Cantilever is simple to form but demanding high concentration of reinforcement in the stem as height increases

Bridge Abutments

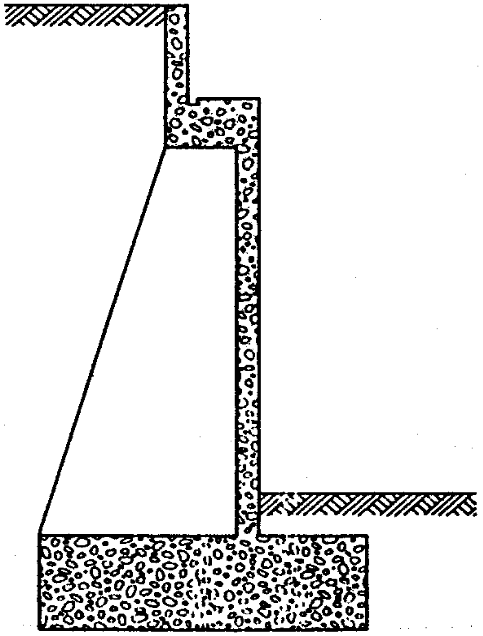
- Solid abutments for narrow bridges should only be adopted where the open abutment solution is not possible. In the case of wide bridges the open abutment solution is to be preferred, but there are many cases where economy must be the overriding consideration.

Hollow Abutment

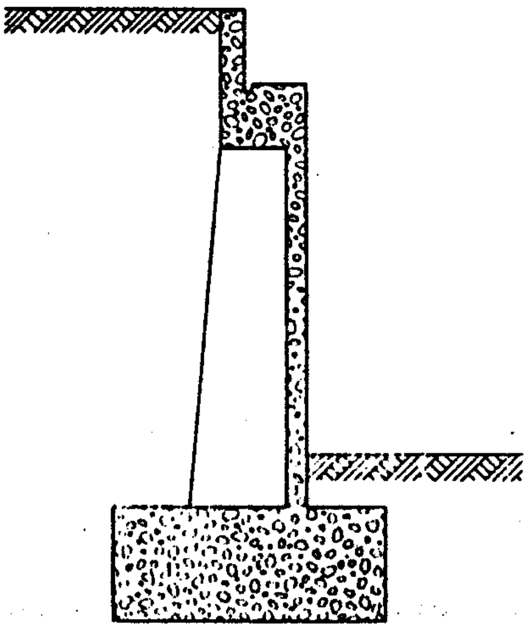


- For high abutments on sloping ground, this construction offers advantages over heavy counterfort construction.

Wall Abutments



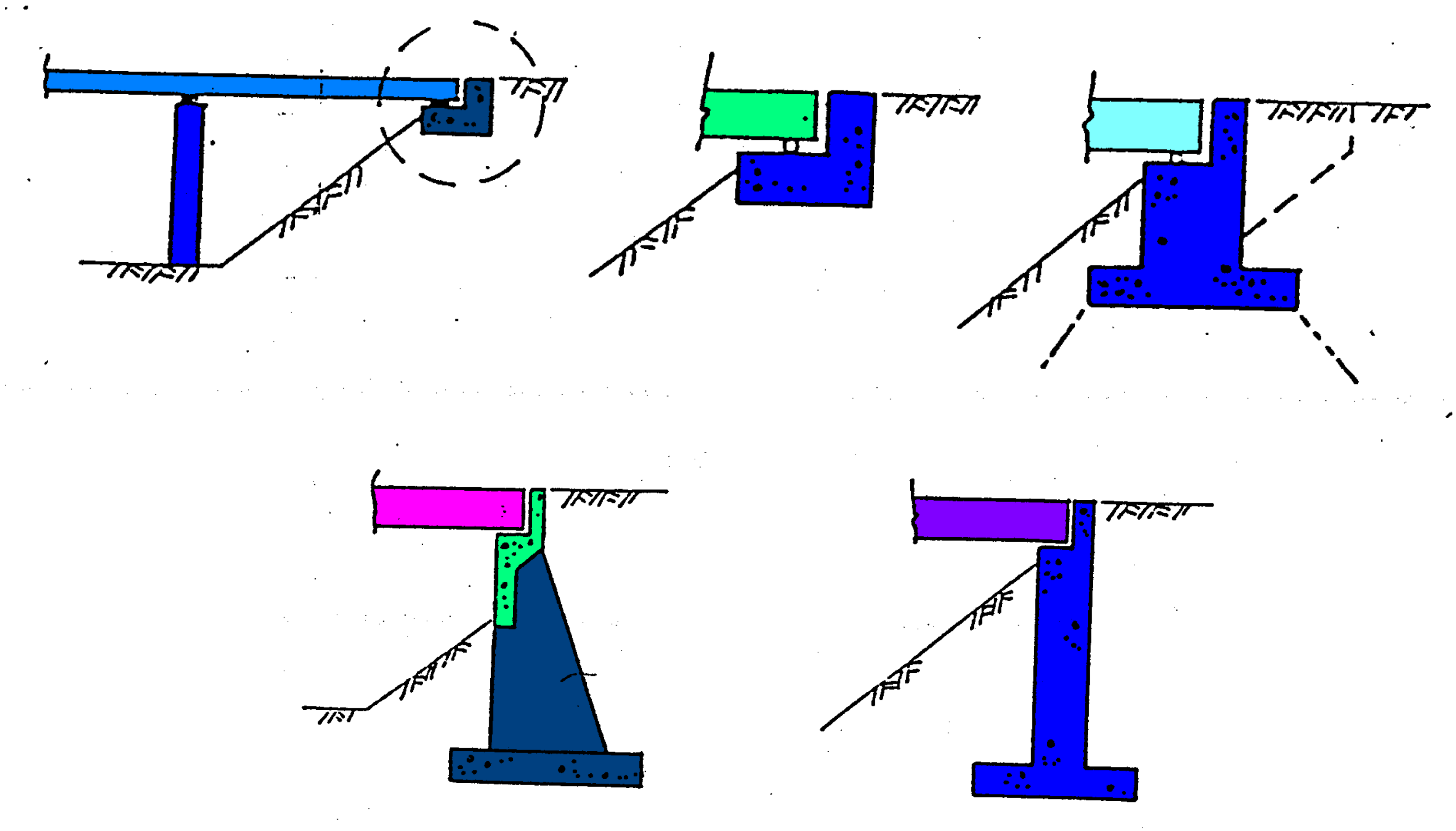
Counterfort



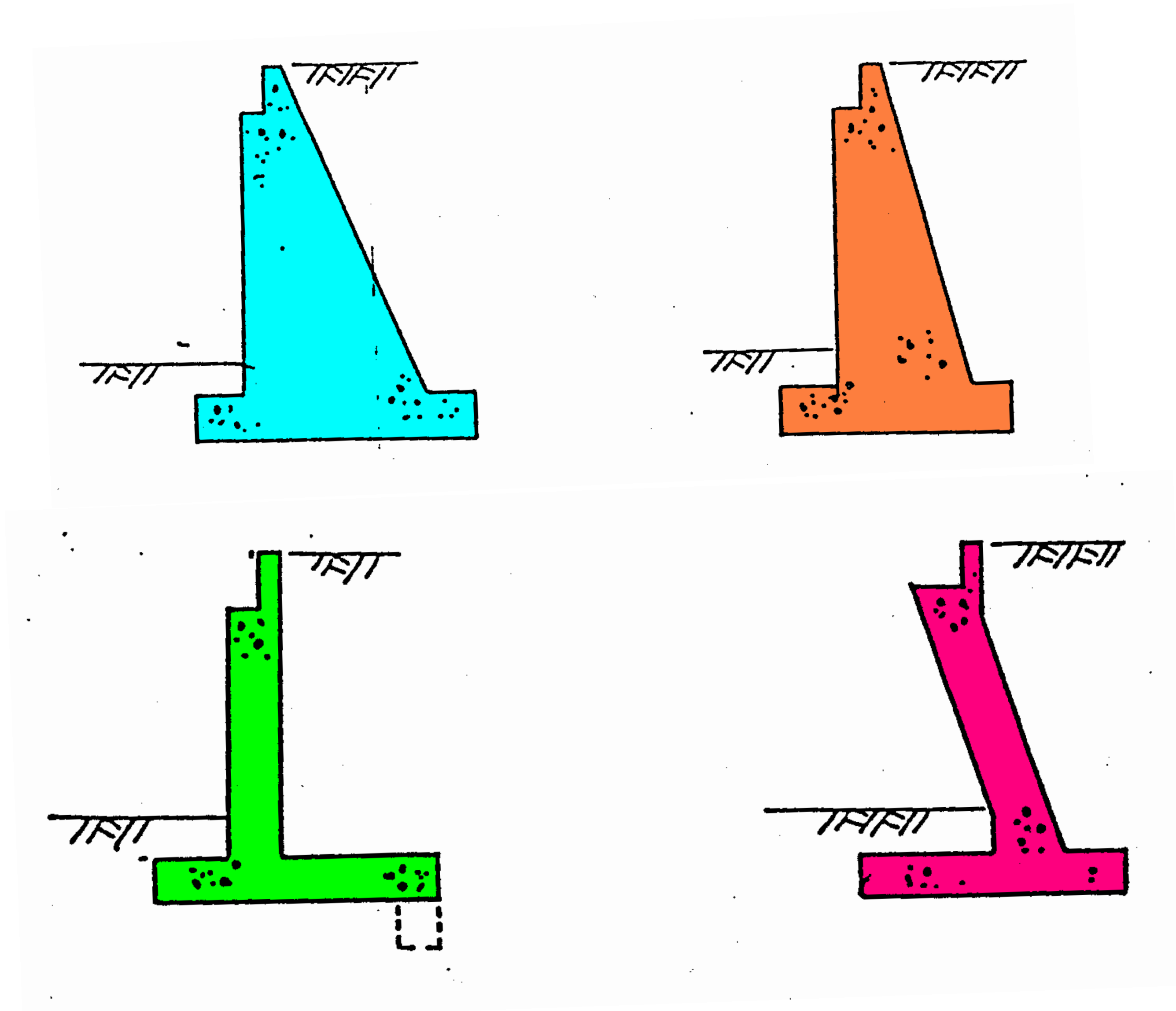
Stub Counterfort

- Counterfort and Stub Counterfort abutments. Reduces weight of reinforcement compared with cantilever, but calls for more complex shuttering.

Various Types of Open Abutments



Other Types of Wall Abutments



Modes of Failure

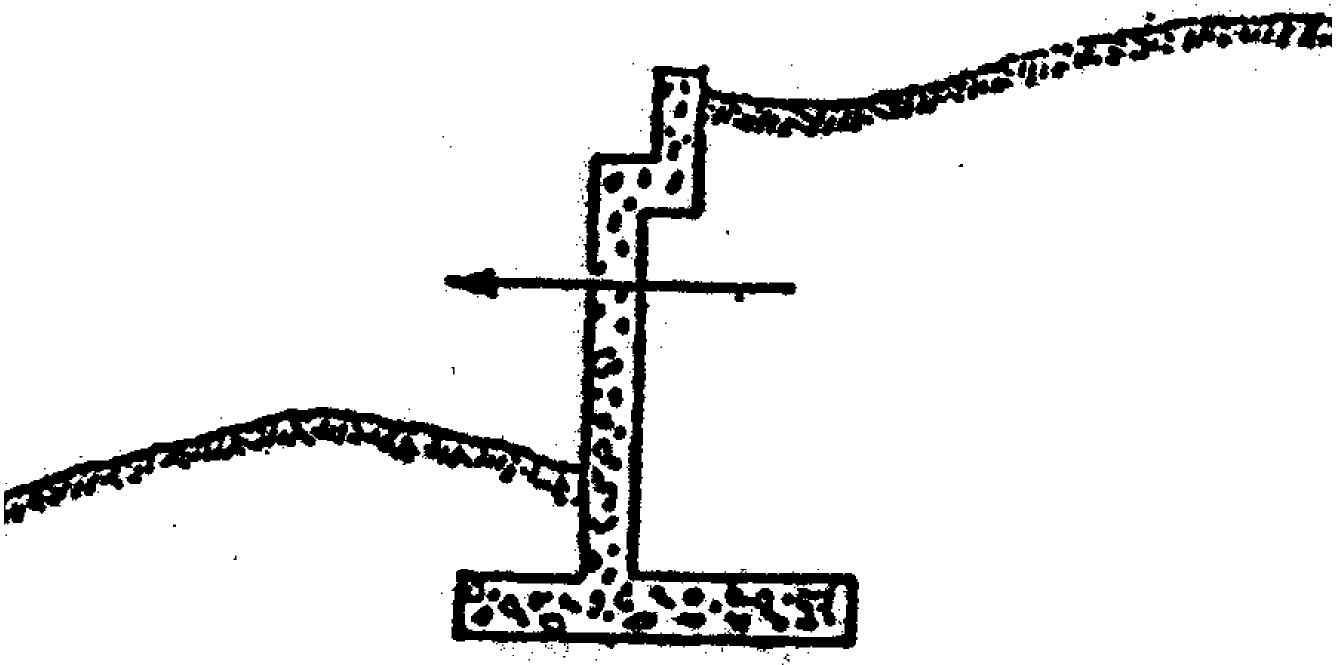
The stability of an abutment should be checked for several modes of failure :

- Sliding failure
- Overturning
- Foundation yield
- Slip Circle
- Structural failure

Modes of Failure

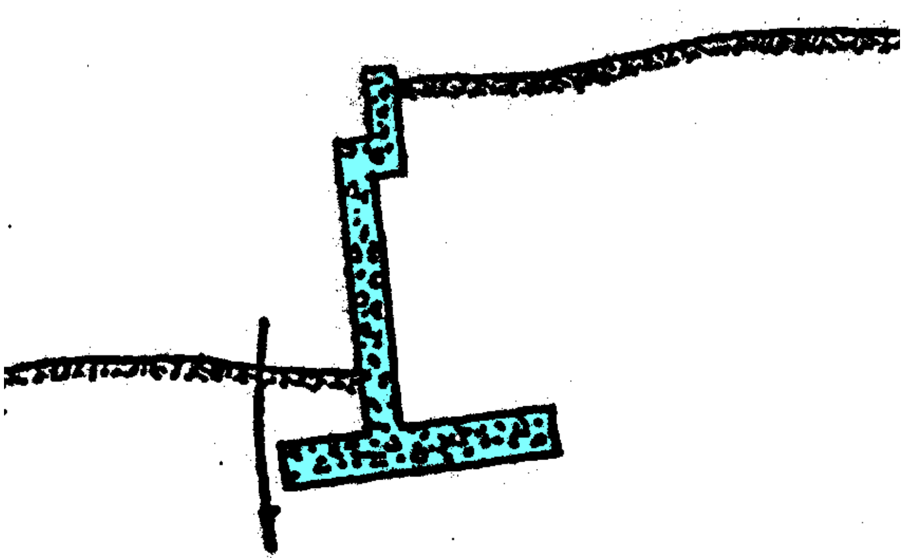
- Overturning
- Sliding/Translation
- Bearing capacity
- Bending or shear failure of stem
- Bending or shear failure of heel
- Bending or shear failure of toe
- Bending or shear failure of key

Abutments – Modes of Failure

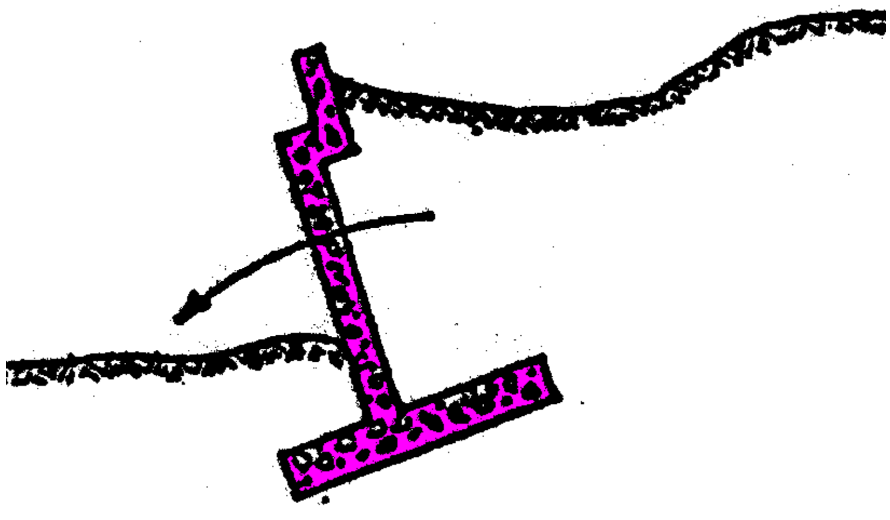


Sliding Failure

Abutments – Modes of Failure

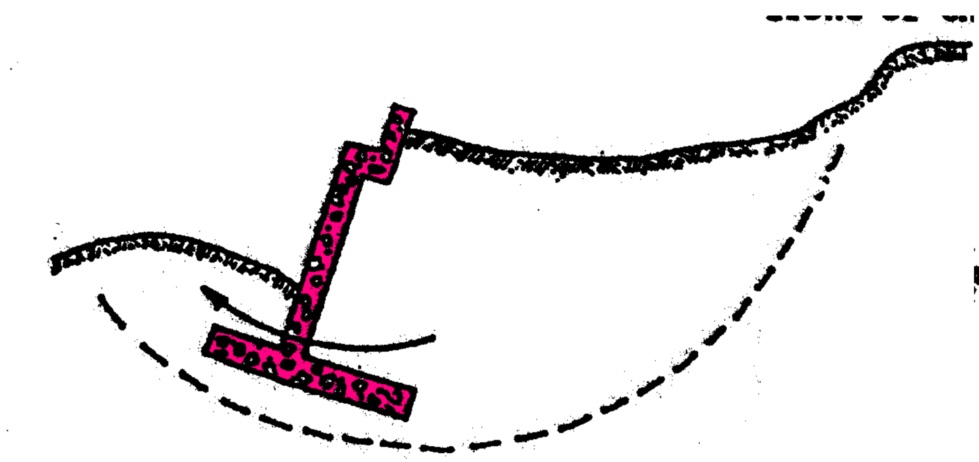


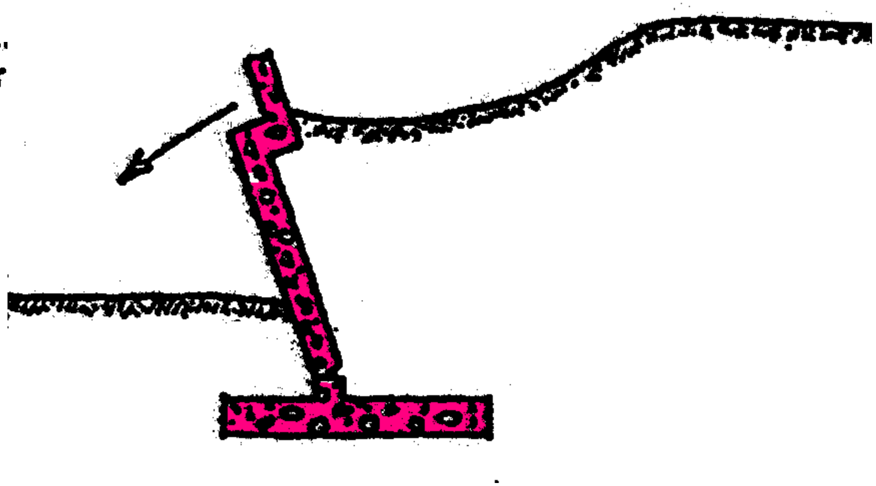
Foundation Yield



Overturning

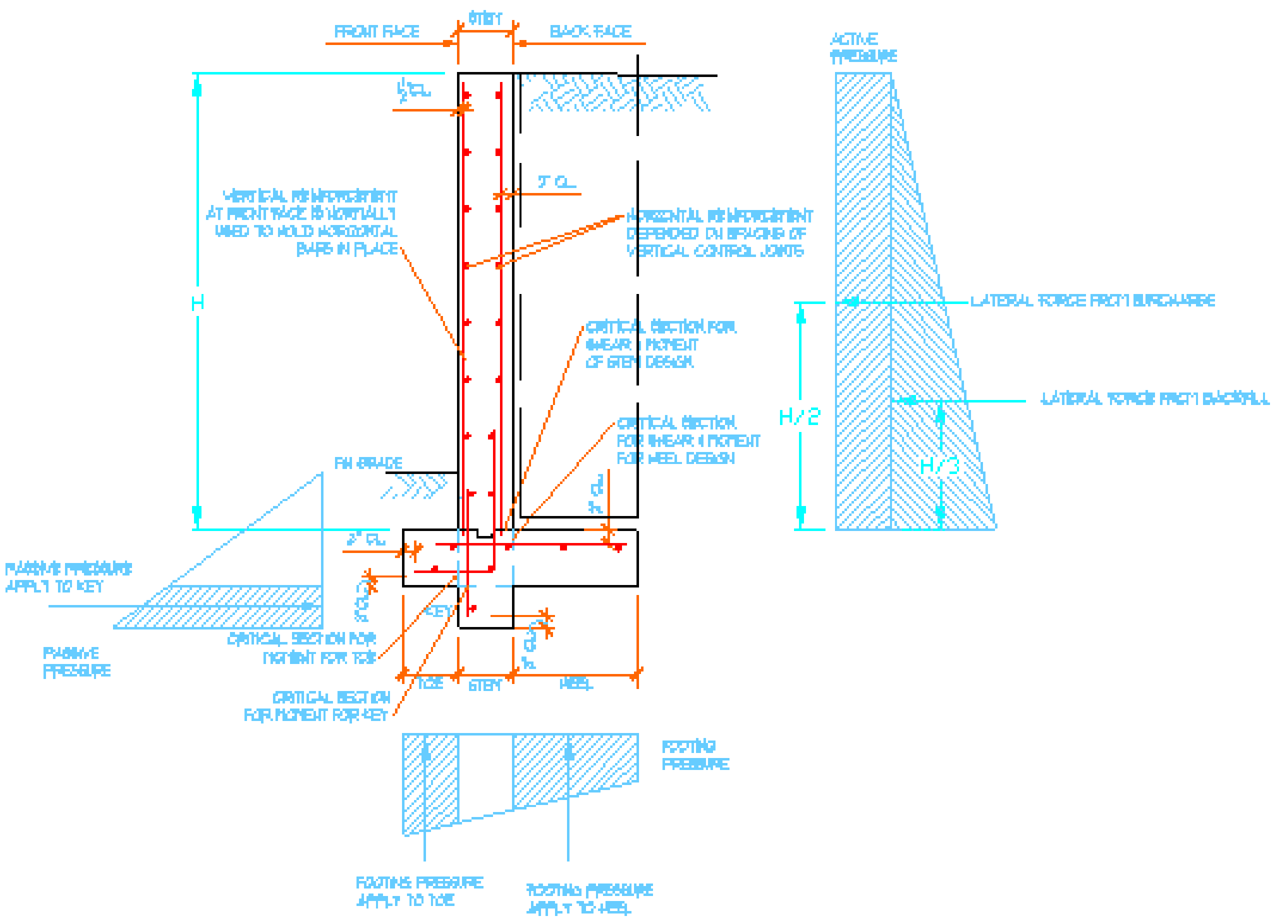
Abutments – Modes of Failure



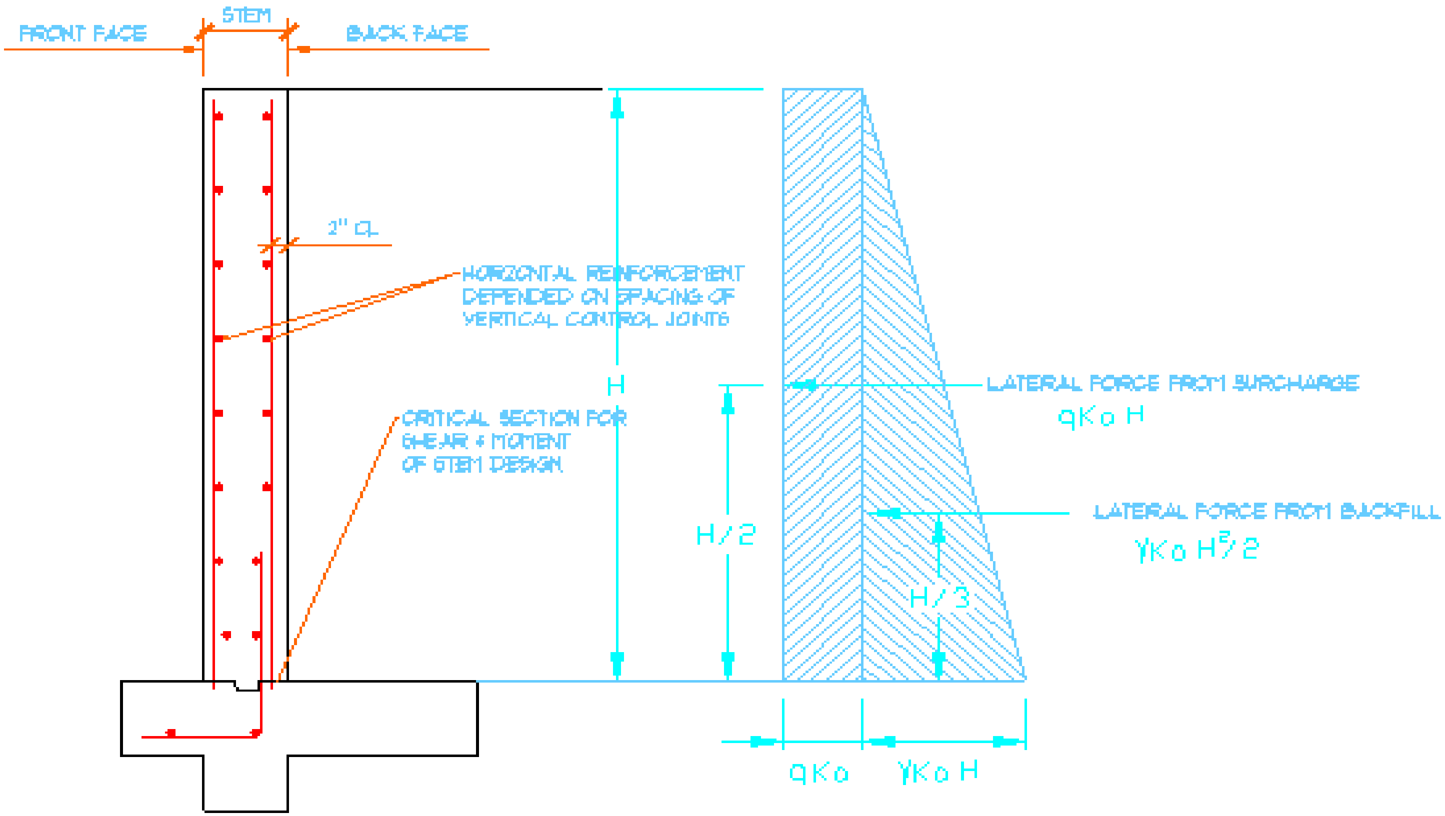


Slip Circle **Structural Failure**

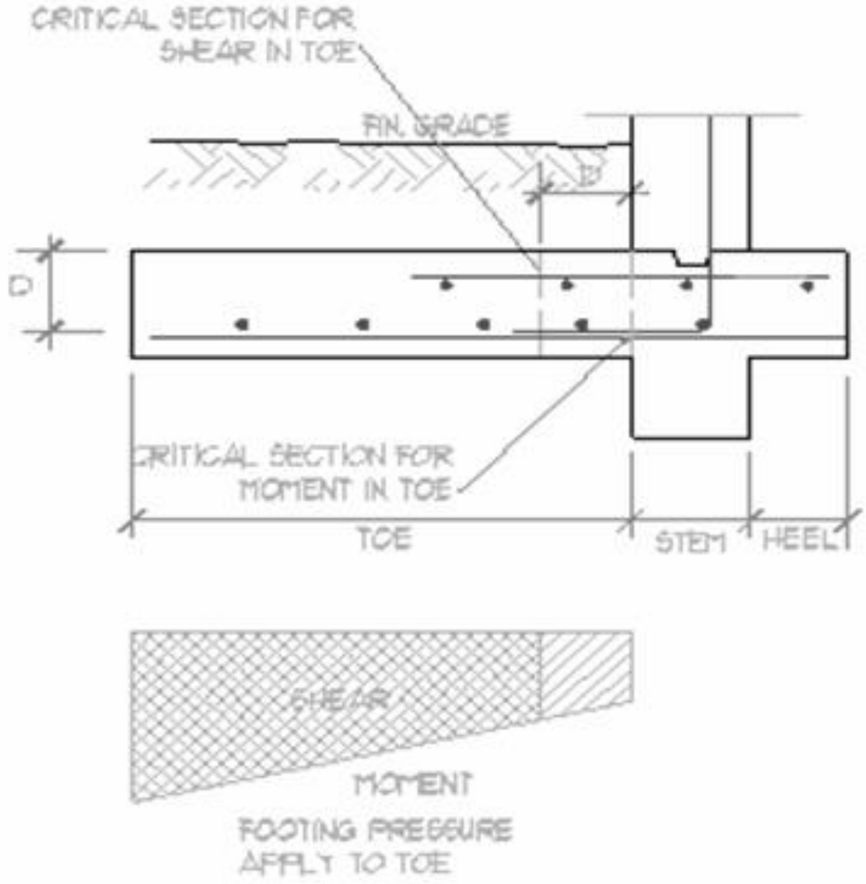
Forces on Cantilever Wall



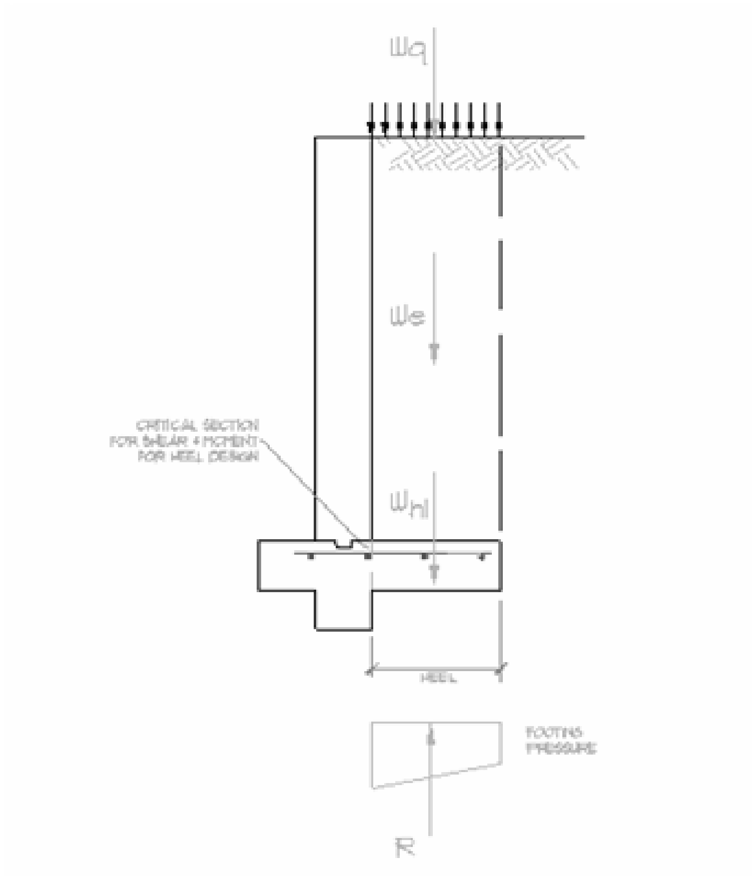
Design of Stem



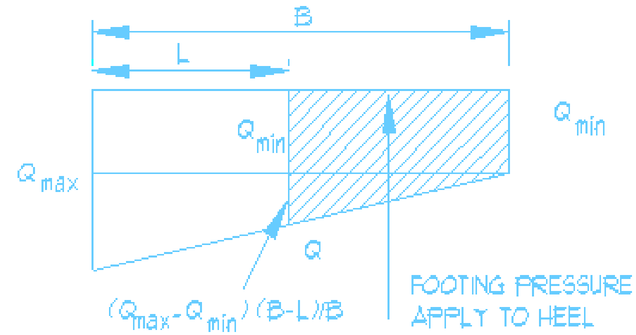
Design of Toe



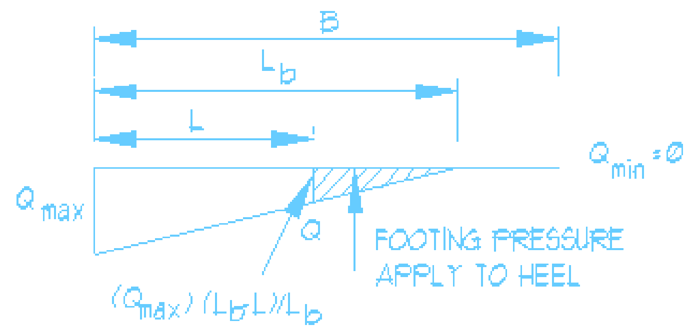
Design of Heel



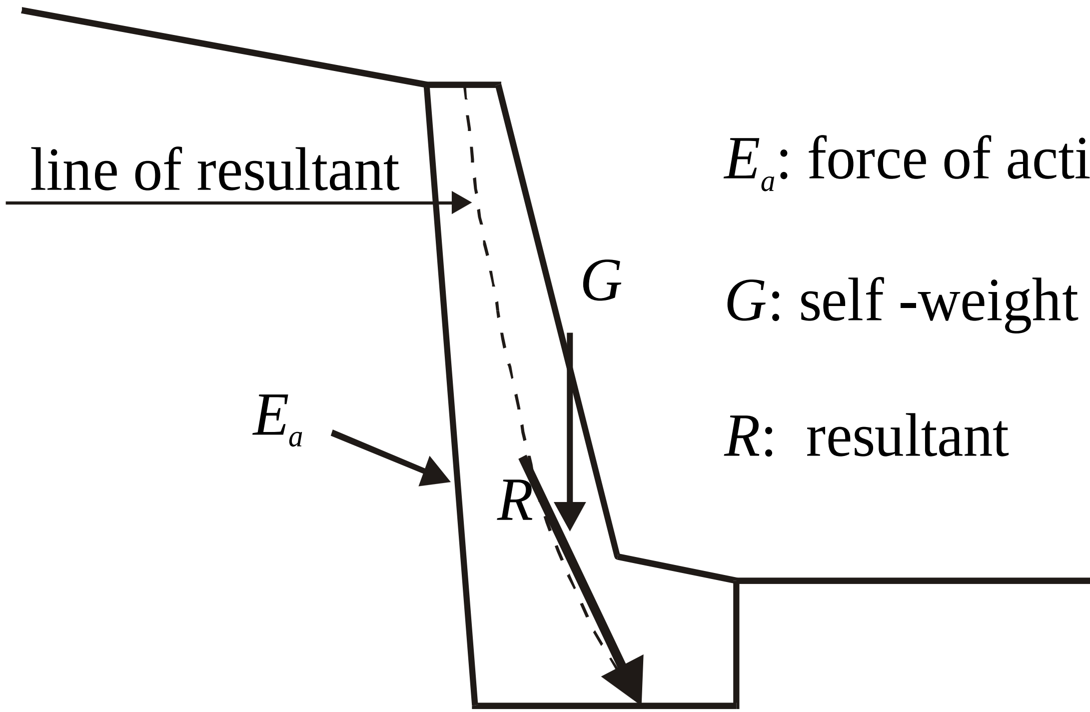
$e_u \leq B/6$



$e_u > B/6$



gravity dam



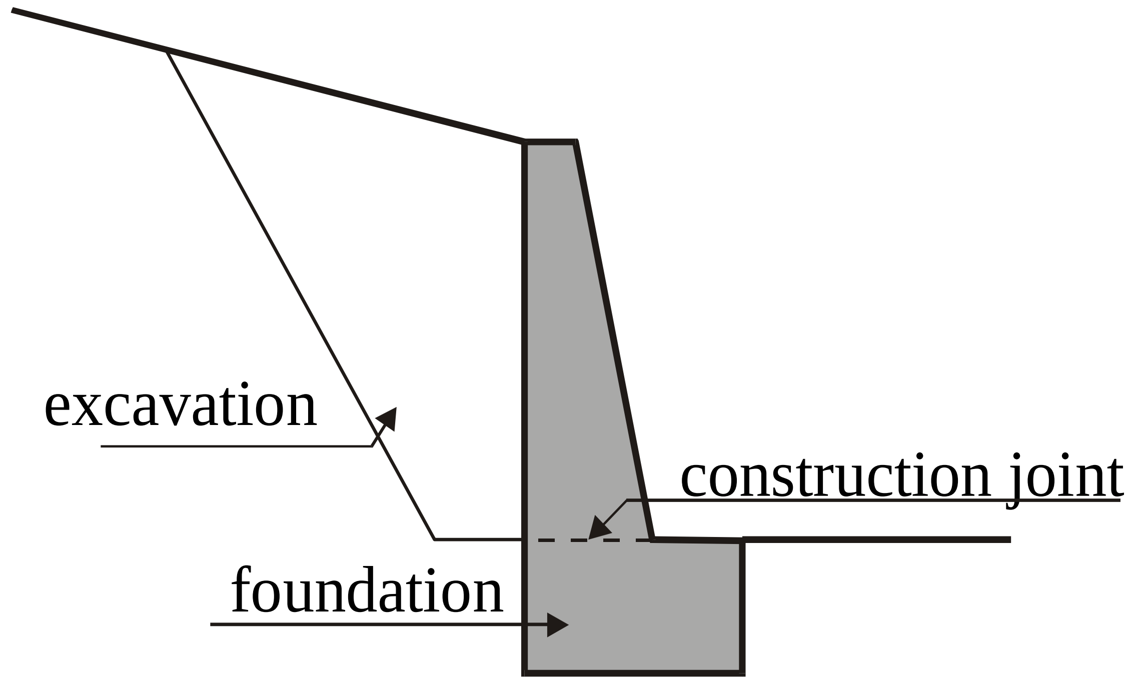
E_a: force of active earth pressure

G: self -weight load

R: resultant

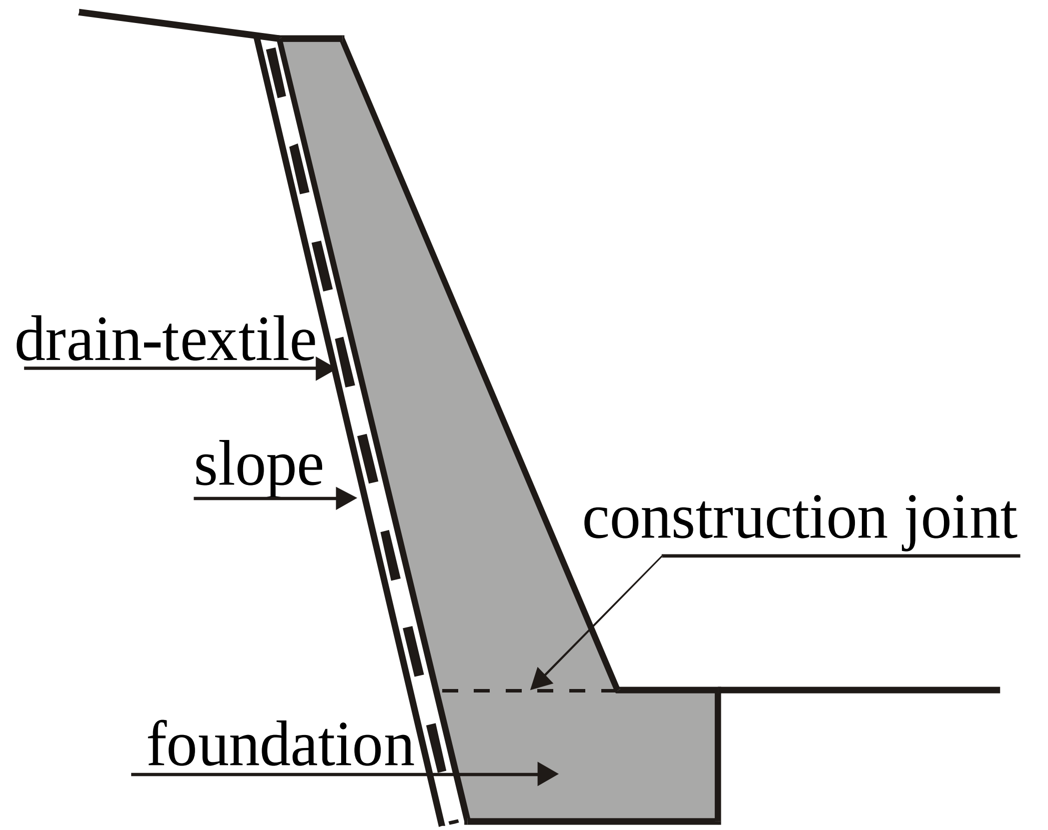
gravity dam

- low retaining wall



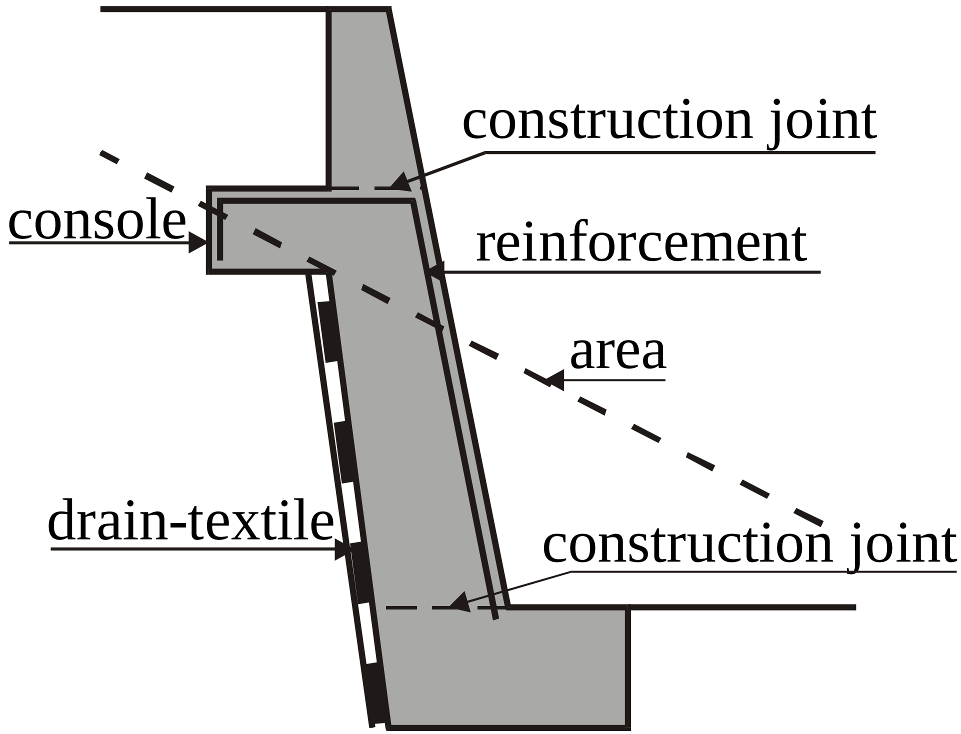
gravity dam

- high retaining wall



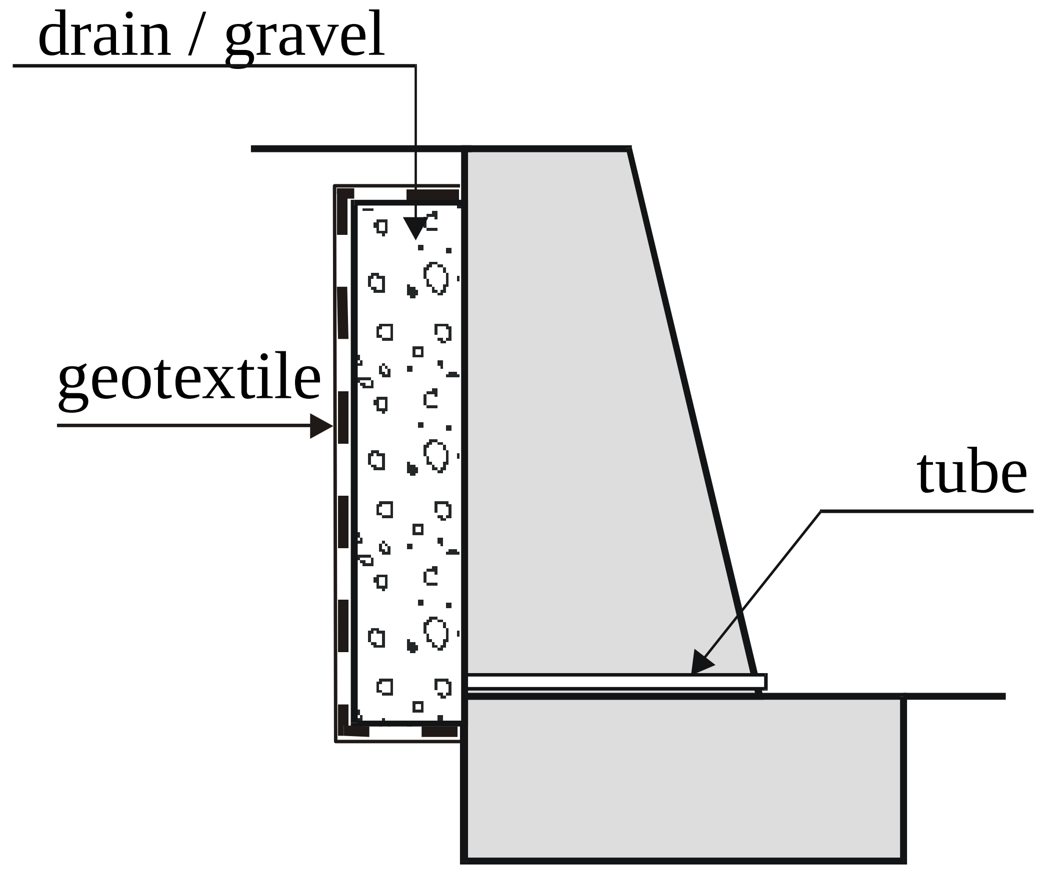
gravity dam

- wall with console



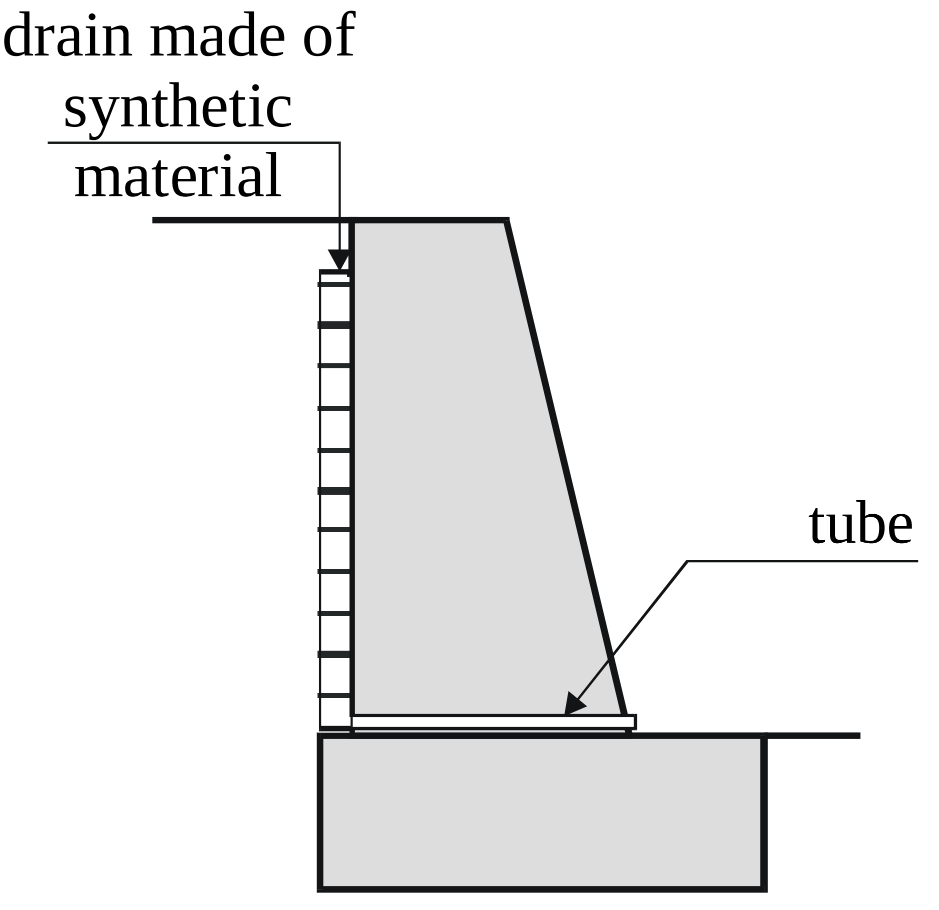
drain

- drain with gravel



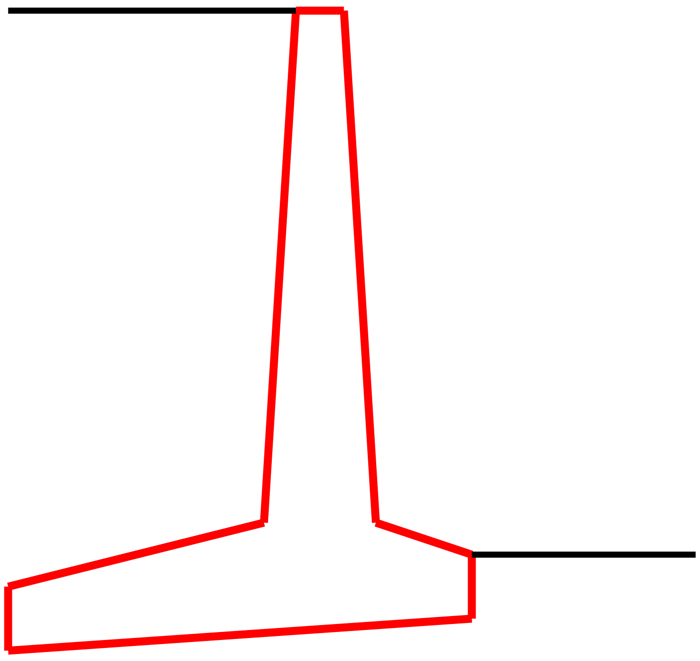
drain

- drain with synthetic materials



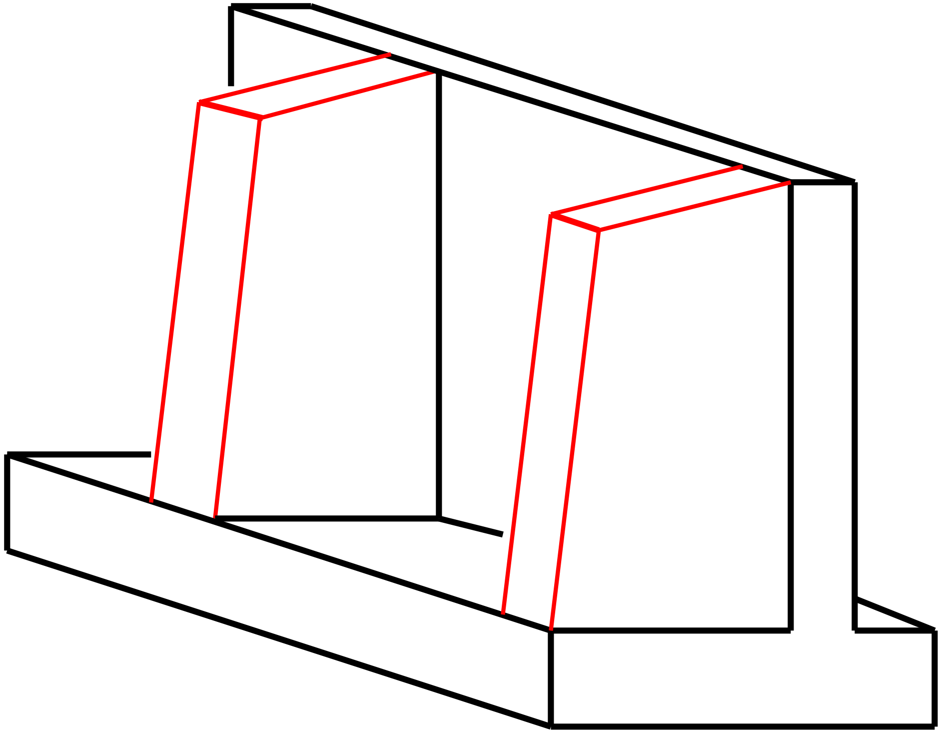
different types of angular retaining walls

- normal angular retaining wall



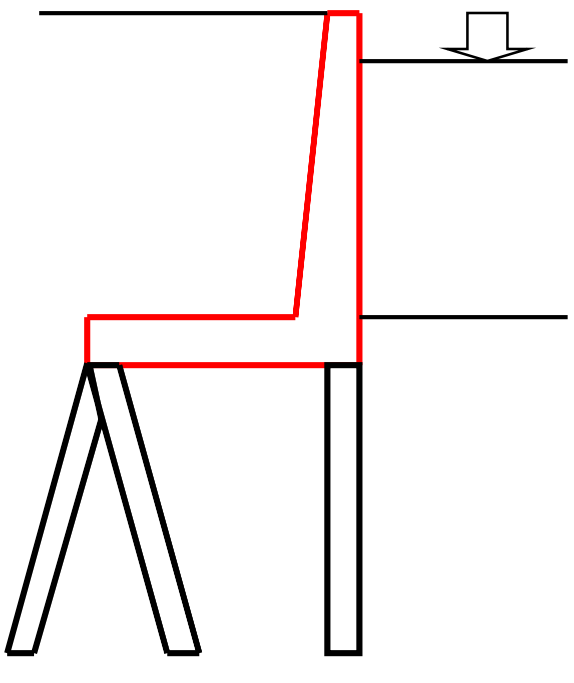
different types of angular retaining walls

- angular retaining wall with cross shear walls

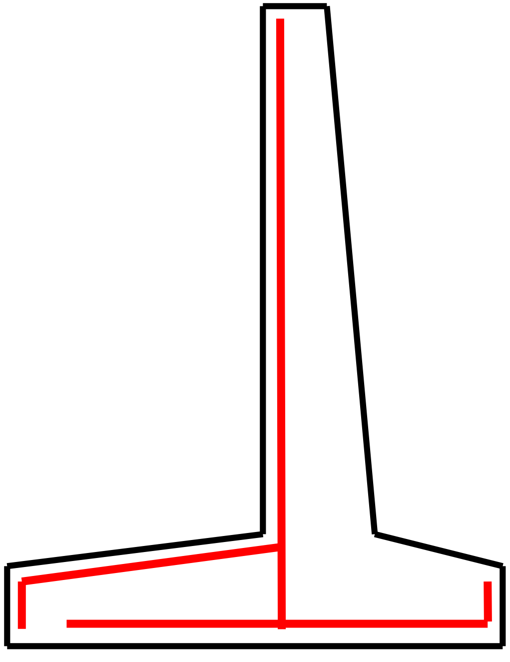


different types of angular retaining walls

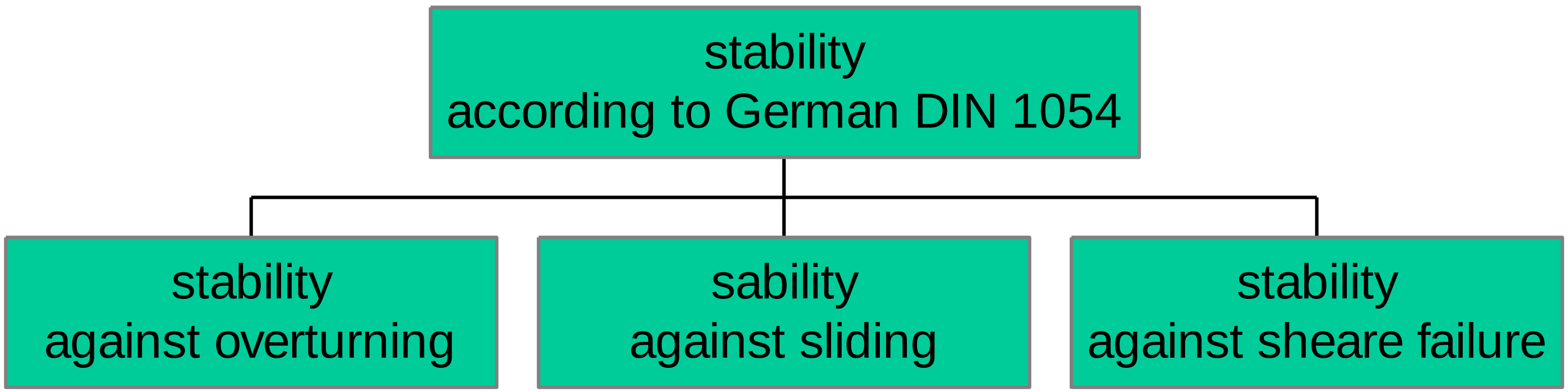
- retaining wall with pile foundation



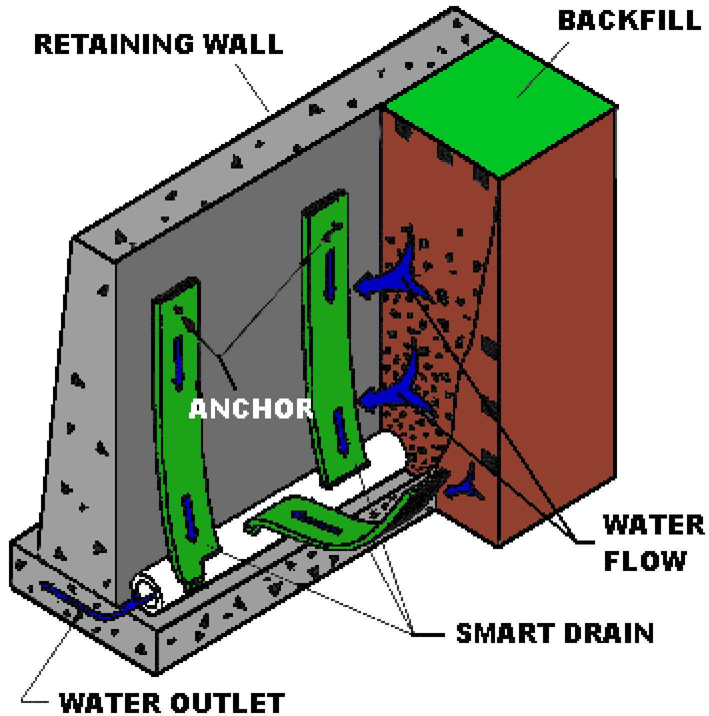
reinforcement in a angular retaining wall



calculation of stability

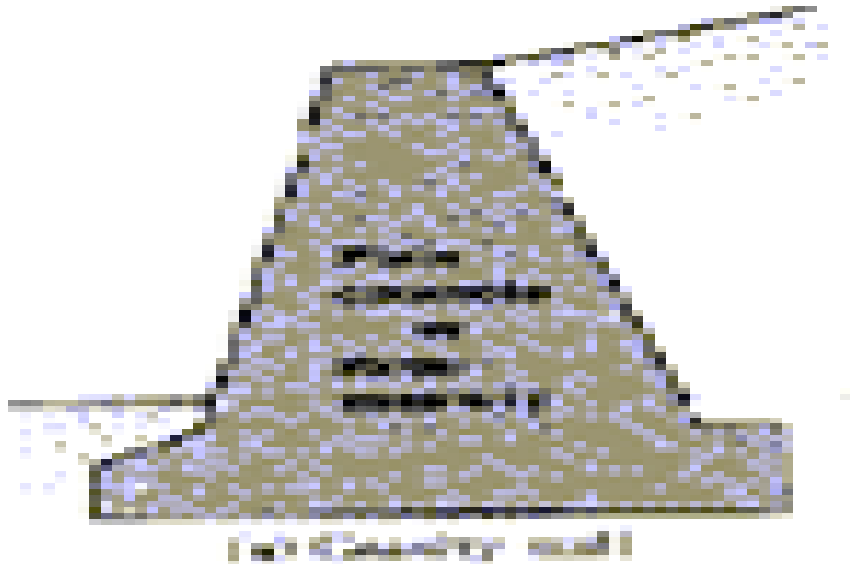


Retaining walls shall be designed to resist sliding by at least 1.5 times the lateral force and
overturning by at least 1.5 times the overturning moment, using allowable stress design loads.”

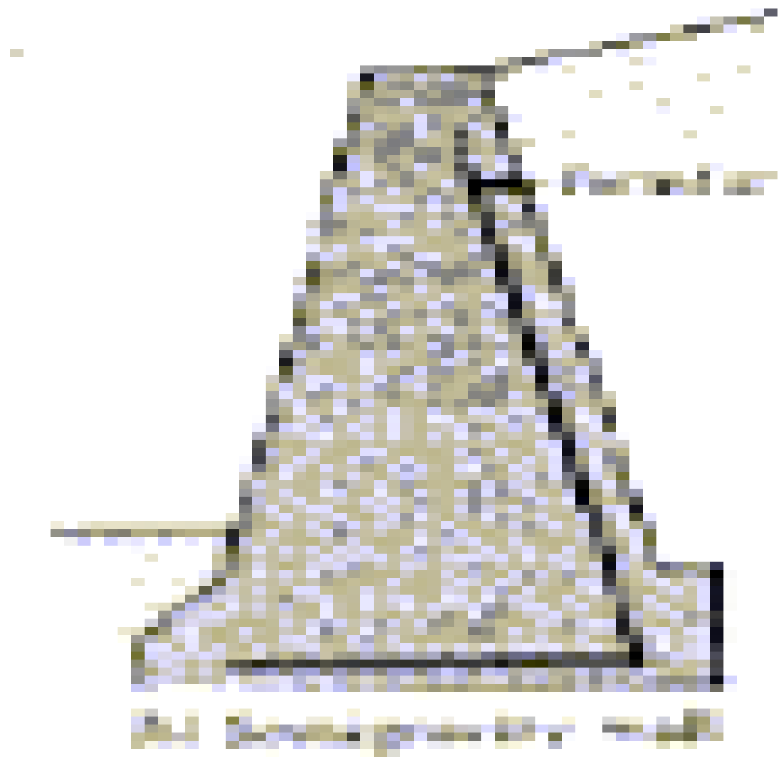

RETAINING WALL
BACKFILL
ANCHOR
WATER
FLOW
SMART DRAIN
WATER OUTLET

Drainage of water as a result of rainfall or other wet conditions is very important to the stability of a retaining wall. Without proper drainage, the backfill can become saturated, which has the dual impact of increasing the pressure on the wall and lessening the resistance of the backfill material to sliding. Granular backfill material offers the benefits of good drainage, easy compaction, and increased sliding resistance.

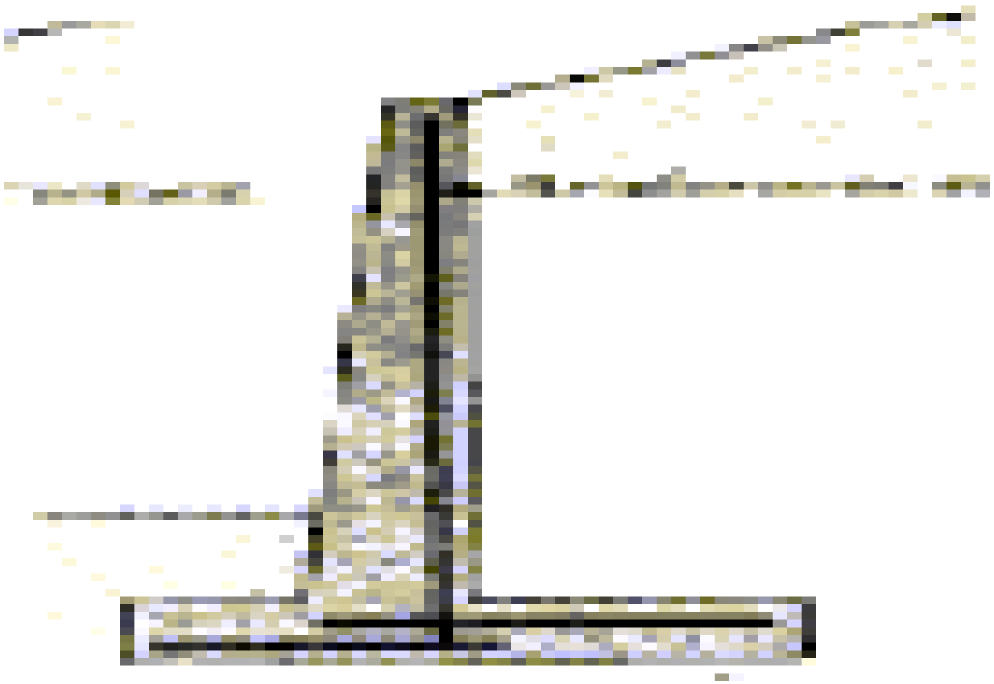
Gravity Retaining Wall



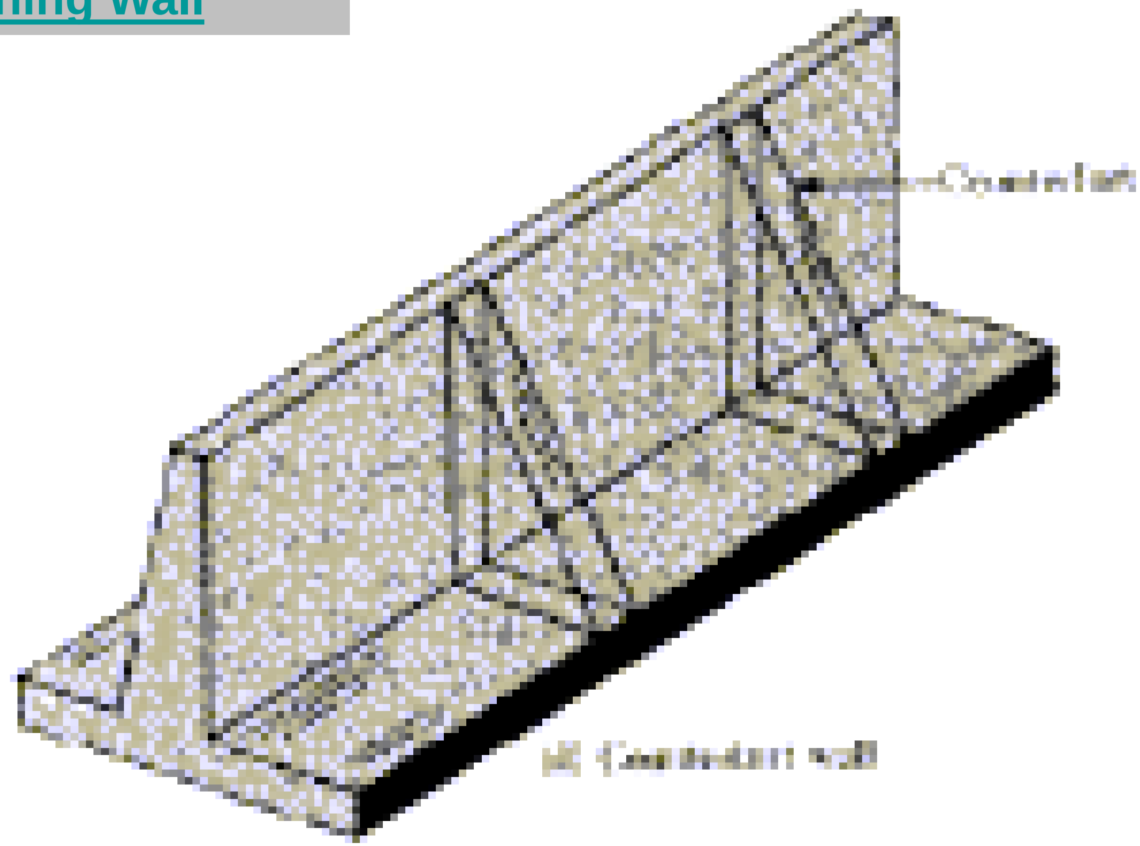
Semi-Gravity Retaining Wall



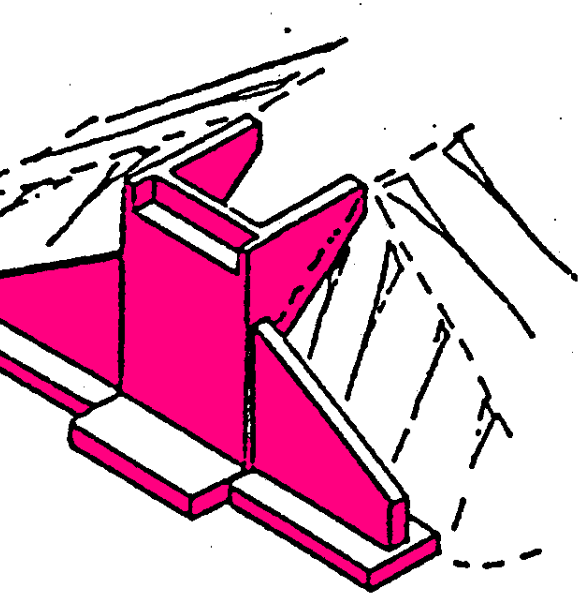
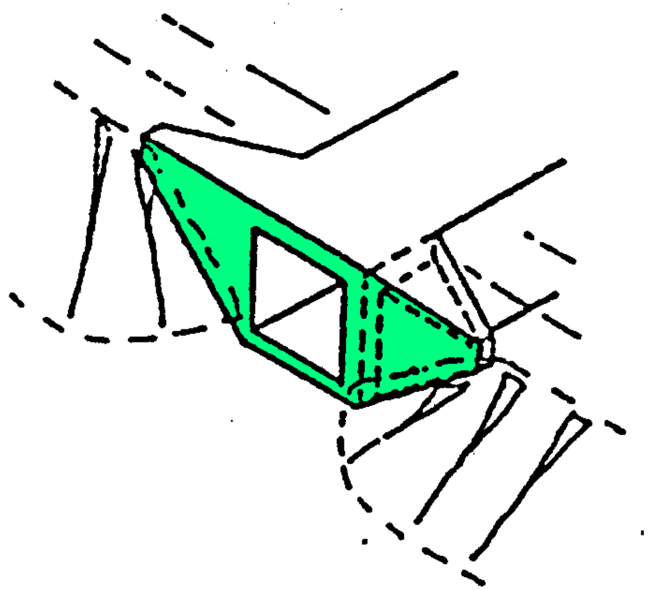
Cantilever Retaining Walls



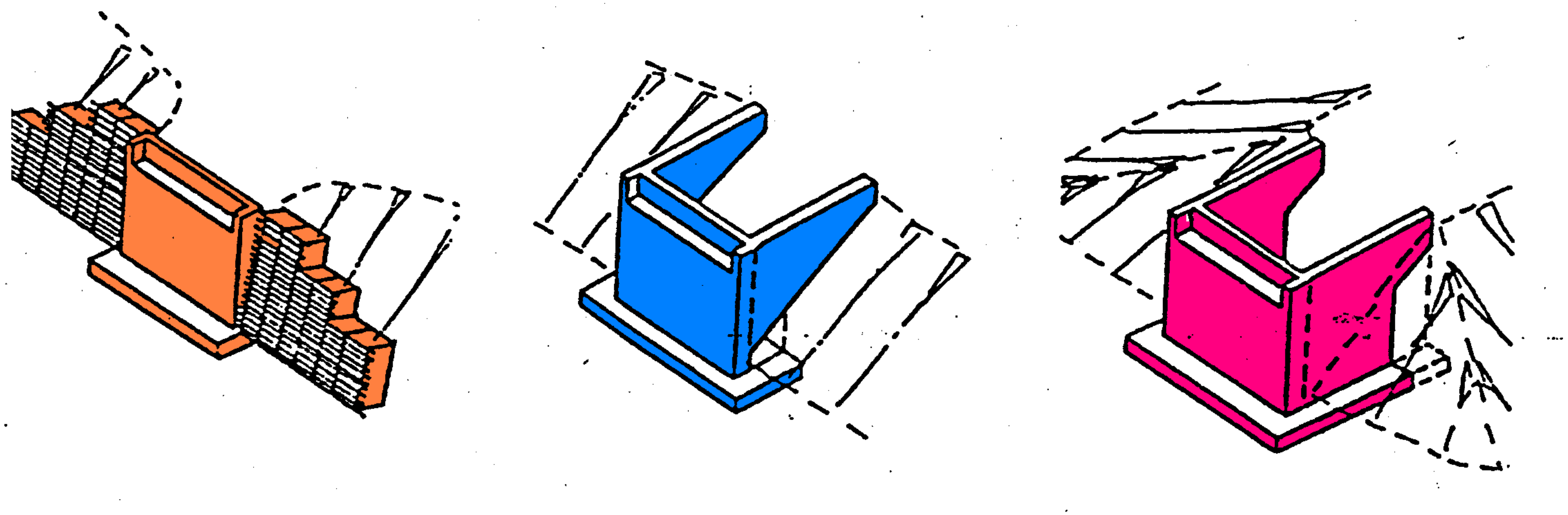
Counterfort Retaining Wall



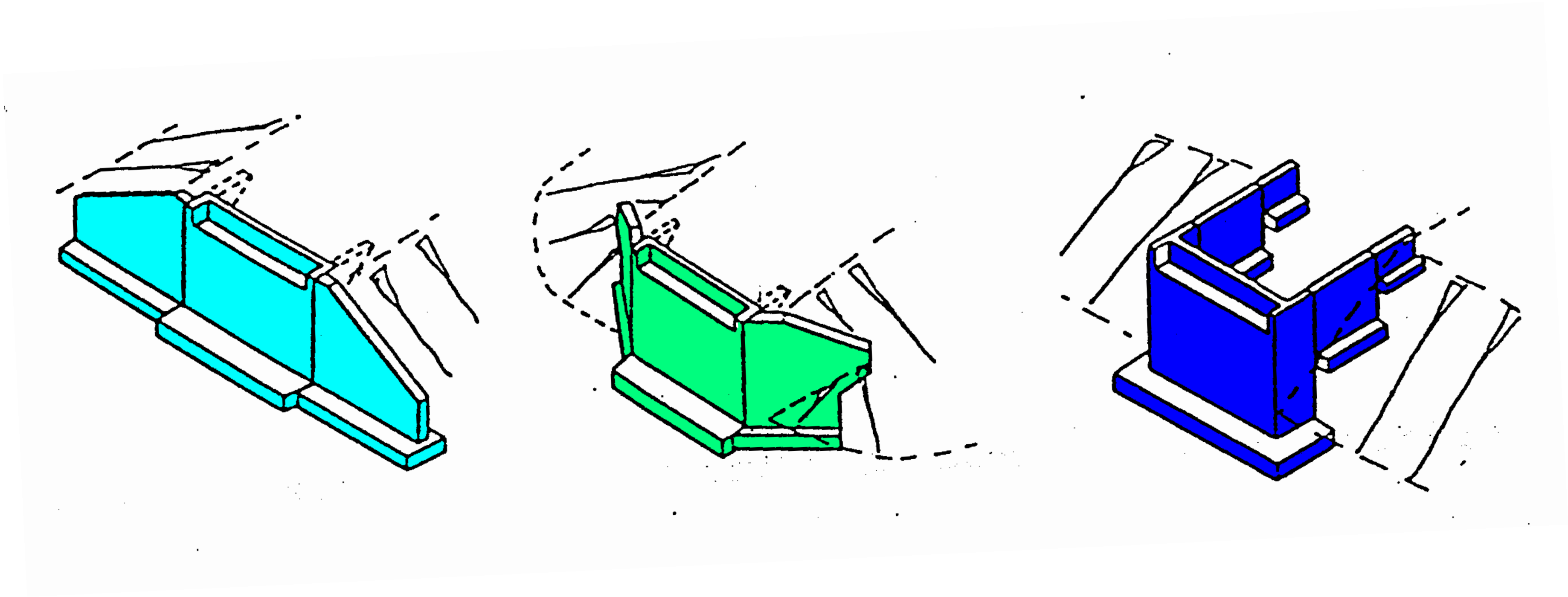
Wing Walls

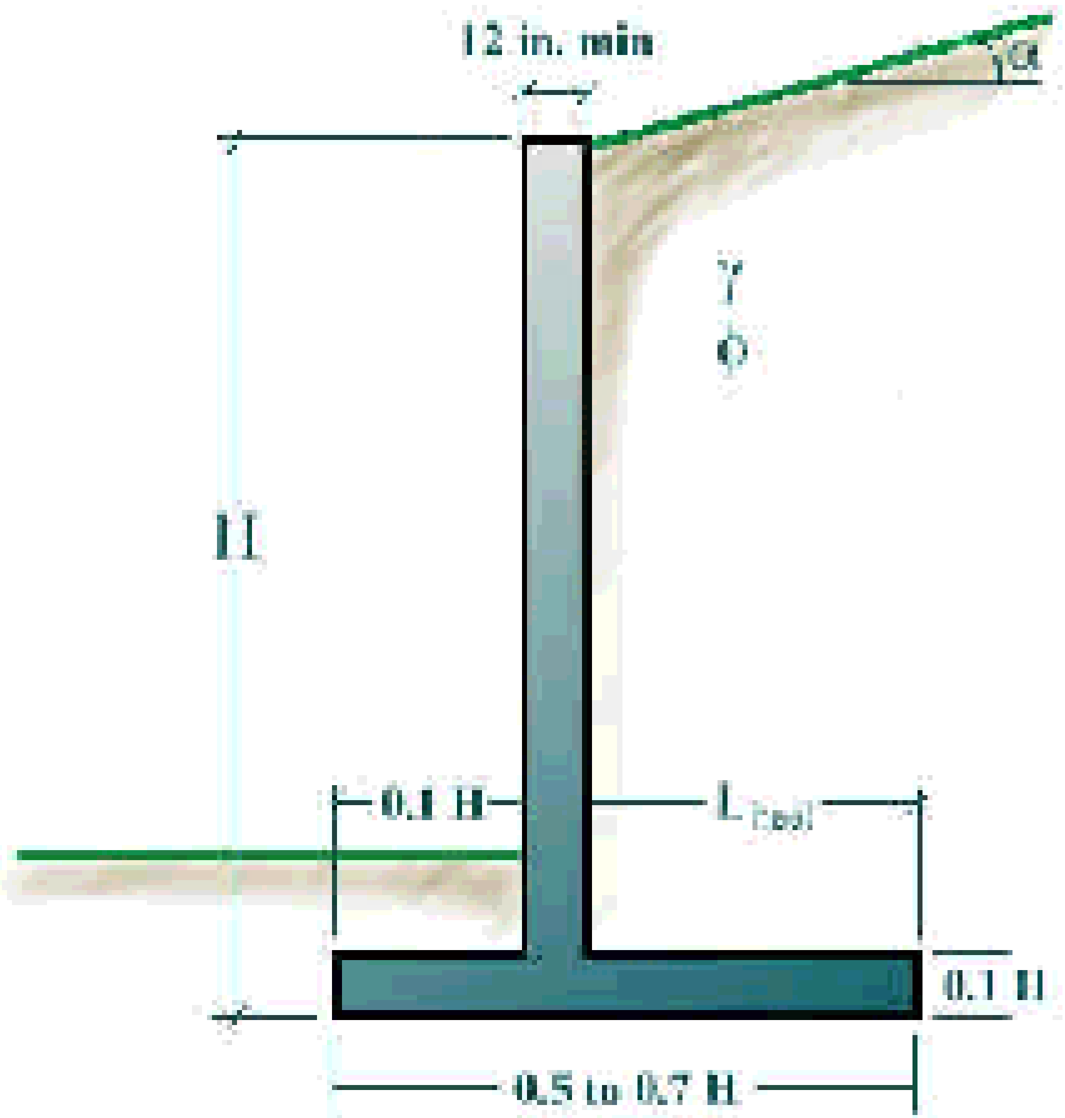



Wing Walls



Wing Walls





12 in. min
α
γ
φ
H
0.1 H
L
0.1 H
0.5 to 0.7 H

REGULATORS

The works which are constructed in order to control and regulate discharges , depths , velocities , etc in canals , are known as canal regulation works .

Types of regulators

1. **Barrages**
2. **Head regulators**
3. **Cross regulators**
4. **Escape regulators**

- **A regulators essentially consist of (piers , gates , wing walls , planks or light bridge plate , grooves)**
- **There are two types of grooves (the first one used for regulating the discharges where the second type used for maintenance works .**

Functions of a head regulator

1. **To regulate and control the discharges entering the off-take channel.**
2. **TO control silt entry into the off-take channel.**

Functions of a cross regulator

1. **To effectively control the entire canal irrigation system.**
2. **It helps in heading up water in the U/S and to feed the off –take channel.**
3. **They help in absorbing fluctuations in various sections of the canal system.**

Functions of escape regulator

It is used to extract either only excess water which has got entered into the canal by mistake

PIERS

A pier is a support of concrete or masonary with base rest directly on the ground or piles .

The shape of the pier below water level is shaped to give smooth flow of water to prevent eddy currents and scour .

RIVER TRAINING WORKS

Any work constructed in order to contain the rivers in their specified path of flow.

Classification of rivers

The rivers on alluvial soils may be classified into three types :

1. **The meandering type**
2. **The aggrading type**
3. **The degrading**

Objects of river training

1. **To achieve safe and expeditious passage of flow through the river.**
2. **To achieve efficient transport of bed silt and suspended silt.**
3. **To achieve stable stream course with minimum bank erosion.**
4. **To achieve sufficient depth of flow for navigation.**

Types of river training works

1. ***Guide banks:* they are used to guide the river to pass through the constrained width of the river at the structure as bridge or diversion structures .**
2. ***Margnal Bunds:* (levees) they are earthen bunds whose face towards the river is generally pitched . they ae constructed parallel to river banks to protect the marginal land from inundation caused by floods.**
3. ***Pitching of Banks:* it is a protection of concrete blokes to the river bank or stone pitching and asphalt. The thickness of the pitching is governed by the velocity of the current ner the bank .**
4. ***Artificial and Natural c*ut-off: when meandering river develops very sharp horse-shoe bends,a small cut is given to connect the peaks with slope more than the slope of the river ,then less Q will pass through the curved river and silted ,then the shape of the river will change after many years to straight river.**
5. ***Spurs or Groynes:* they are structures built transverse to the river flow ,extending from the bank towads the river , they perform many functions as :**
   - **Increase silting**
   - **Cause scouring**
   - **Deflecting the flow of water**
6. ***Pitched Islands:* it is an artificially created in the river . It may be made of masonry or earth embankment . but pitched all-round.**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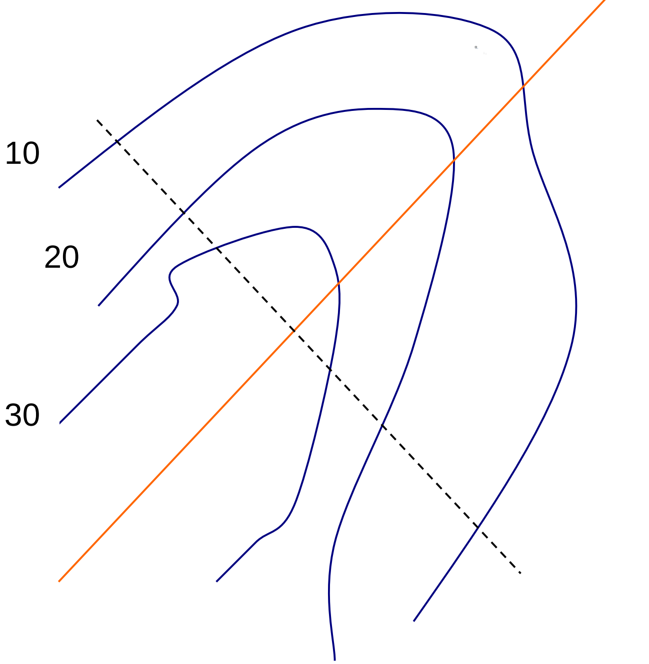
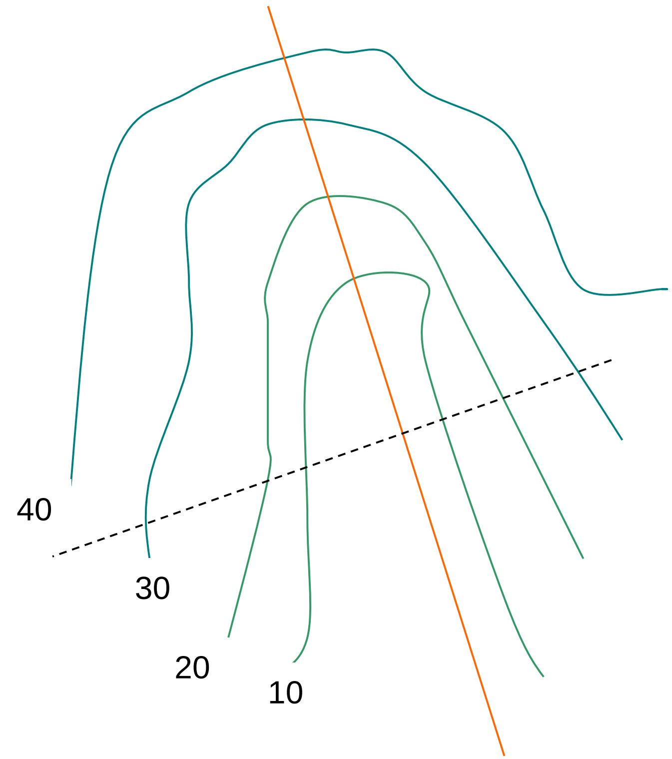
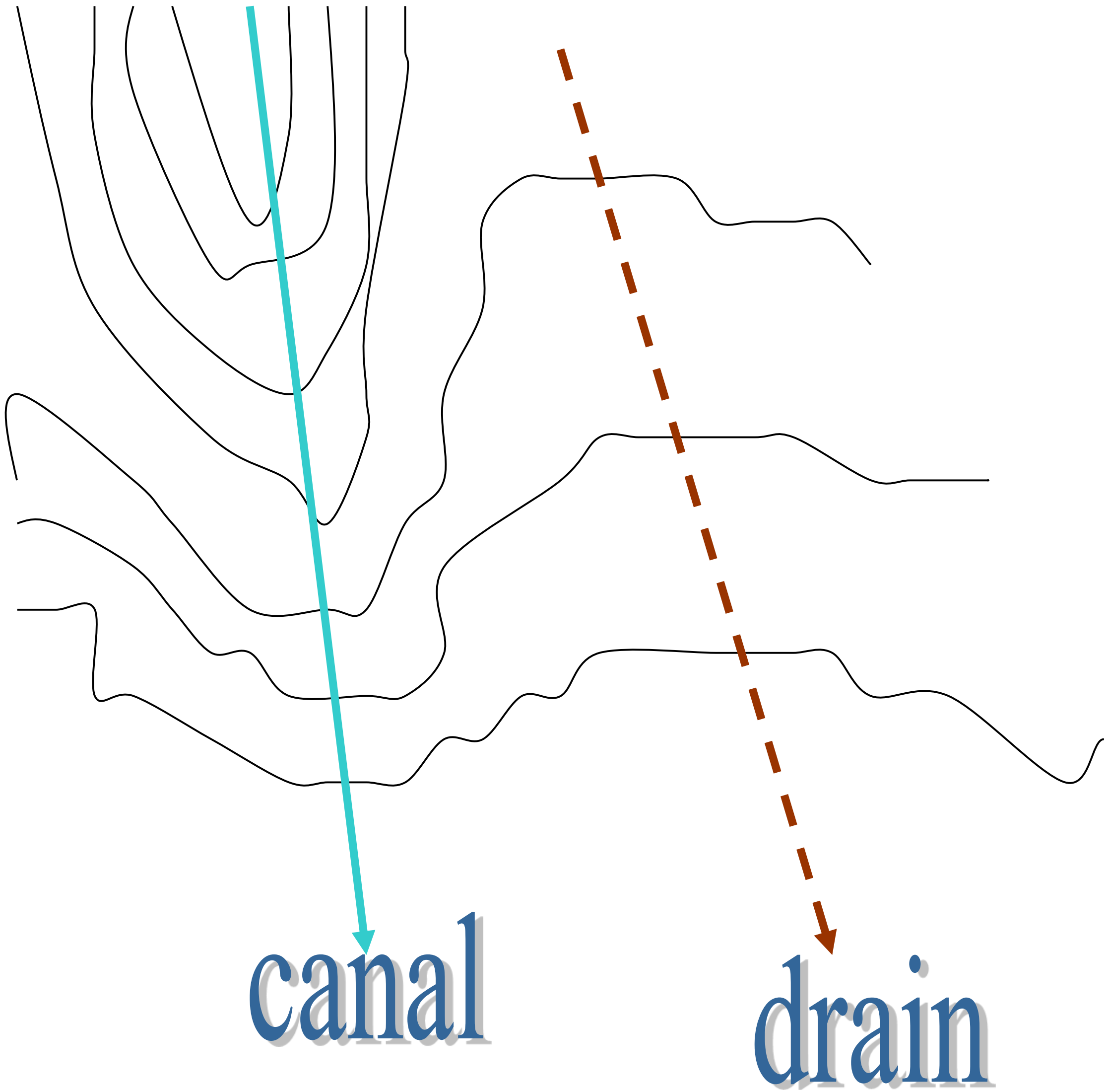
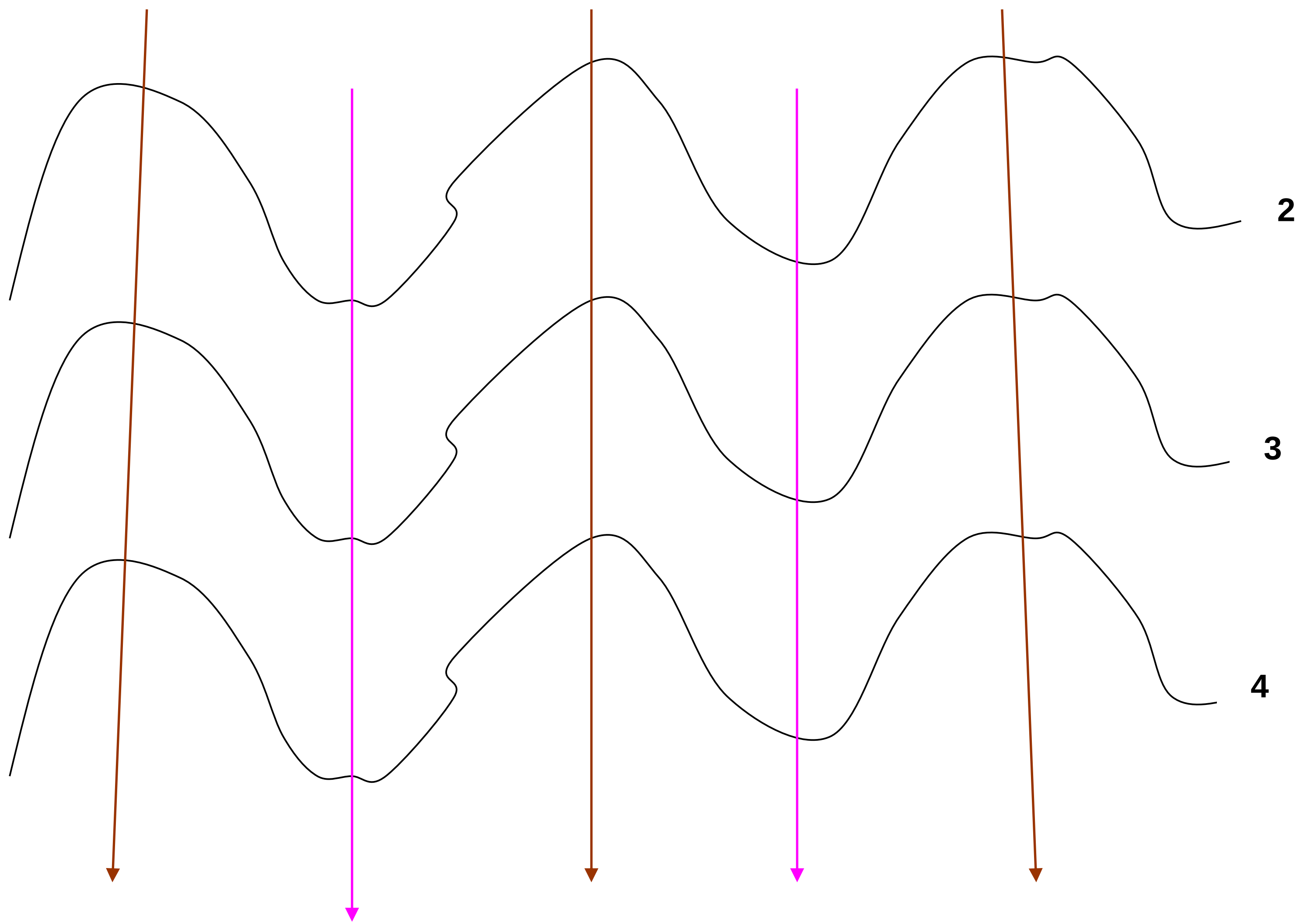




10	
20	
30	
40	


canal
drain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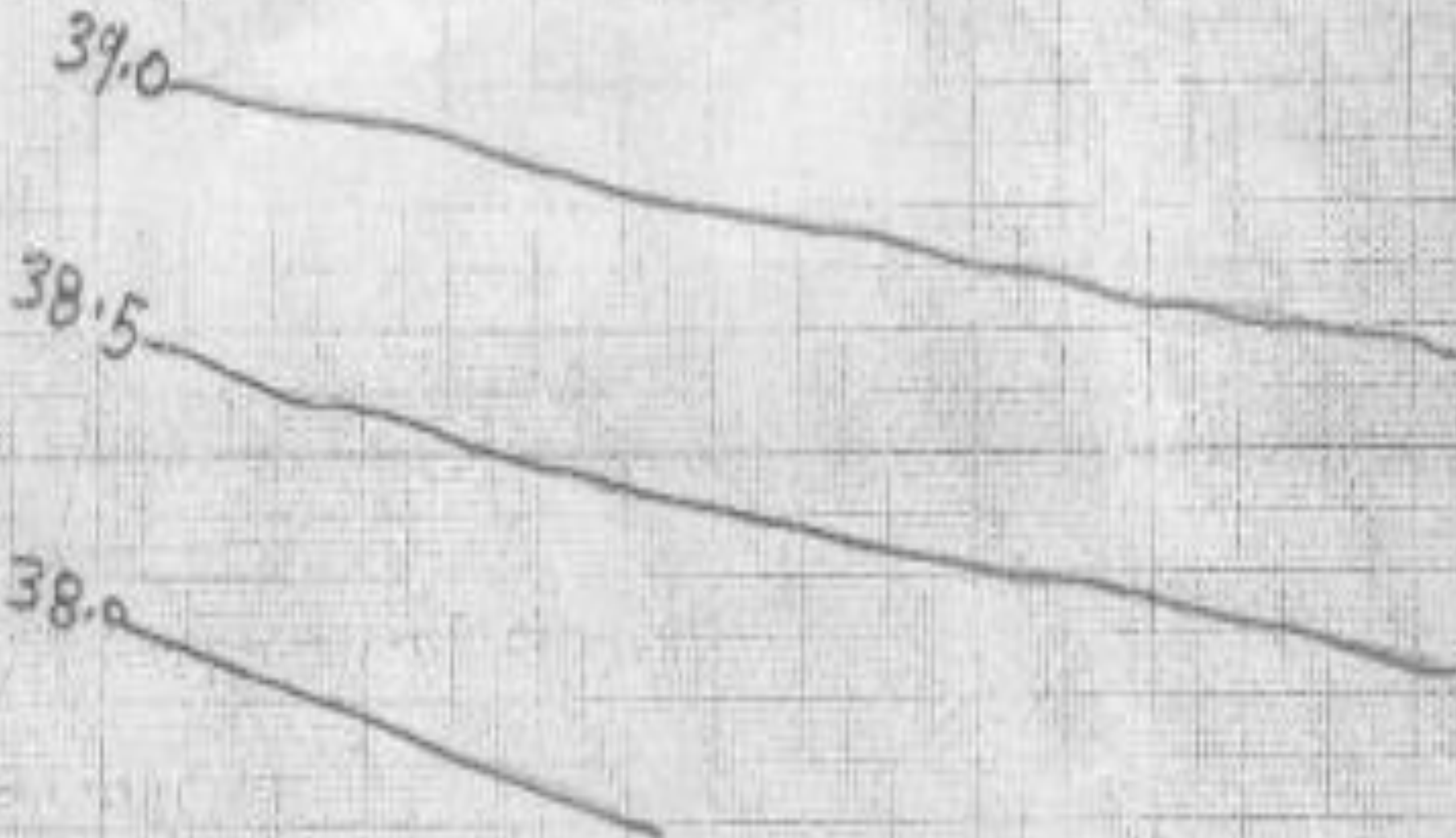
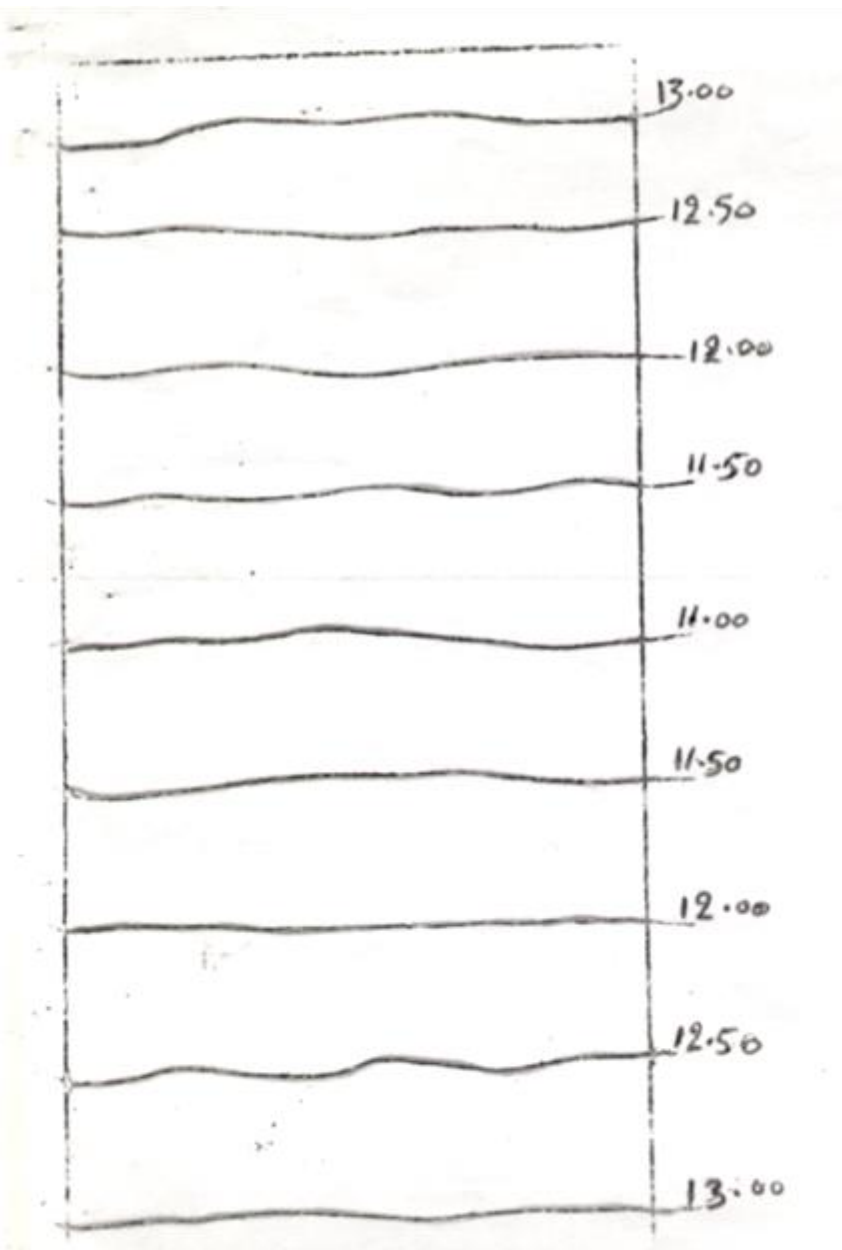
3
4


39.0
38.5
38.0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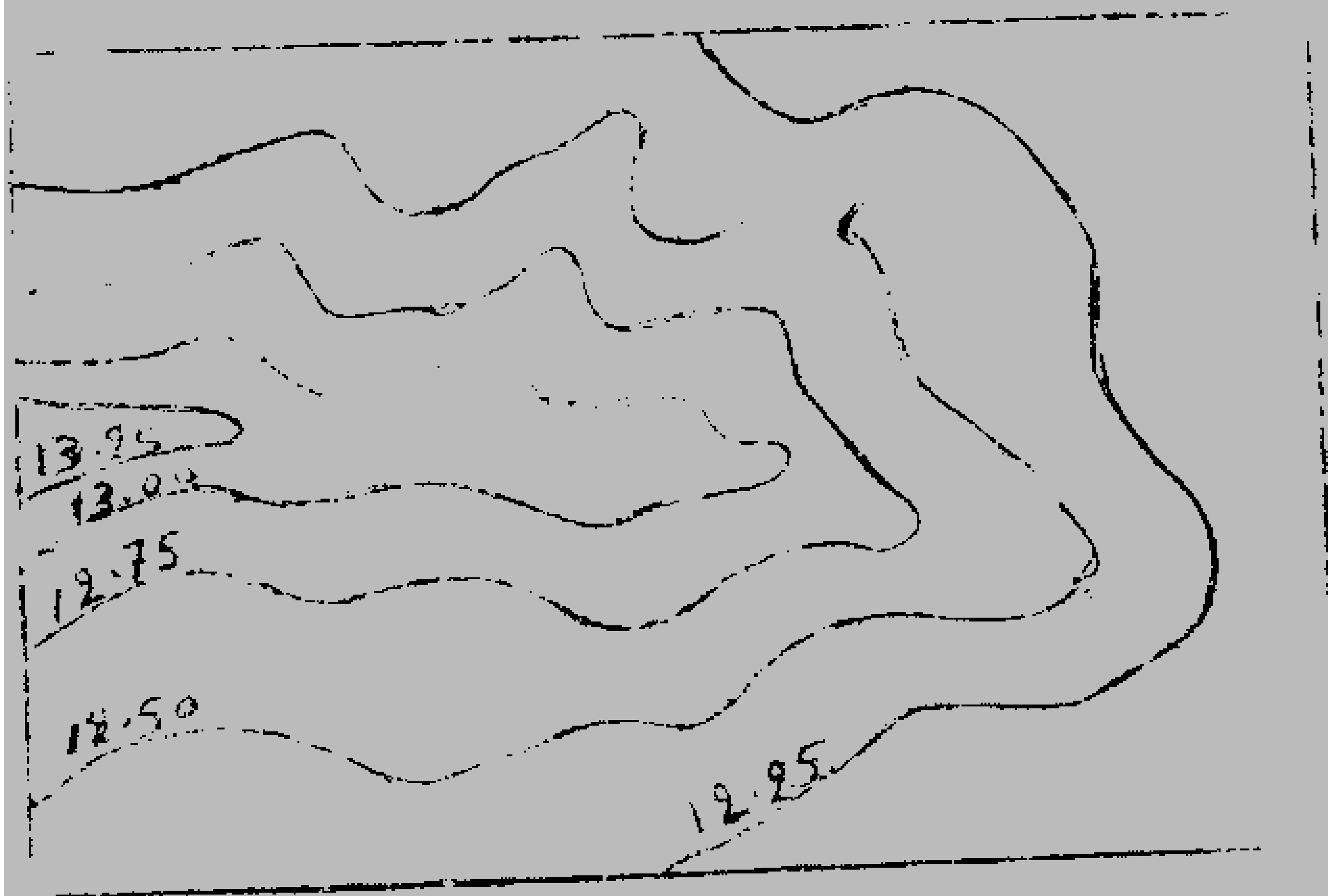
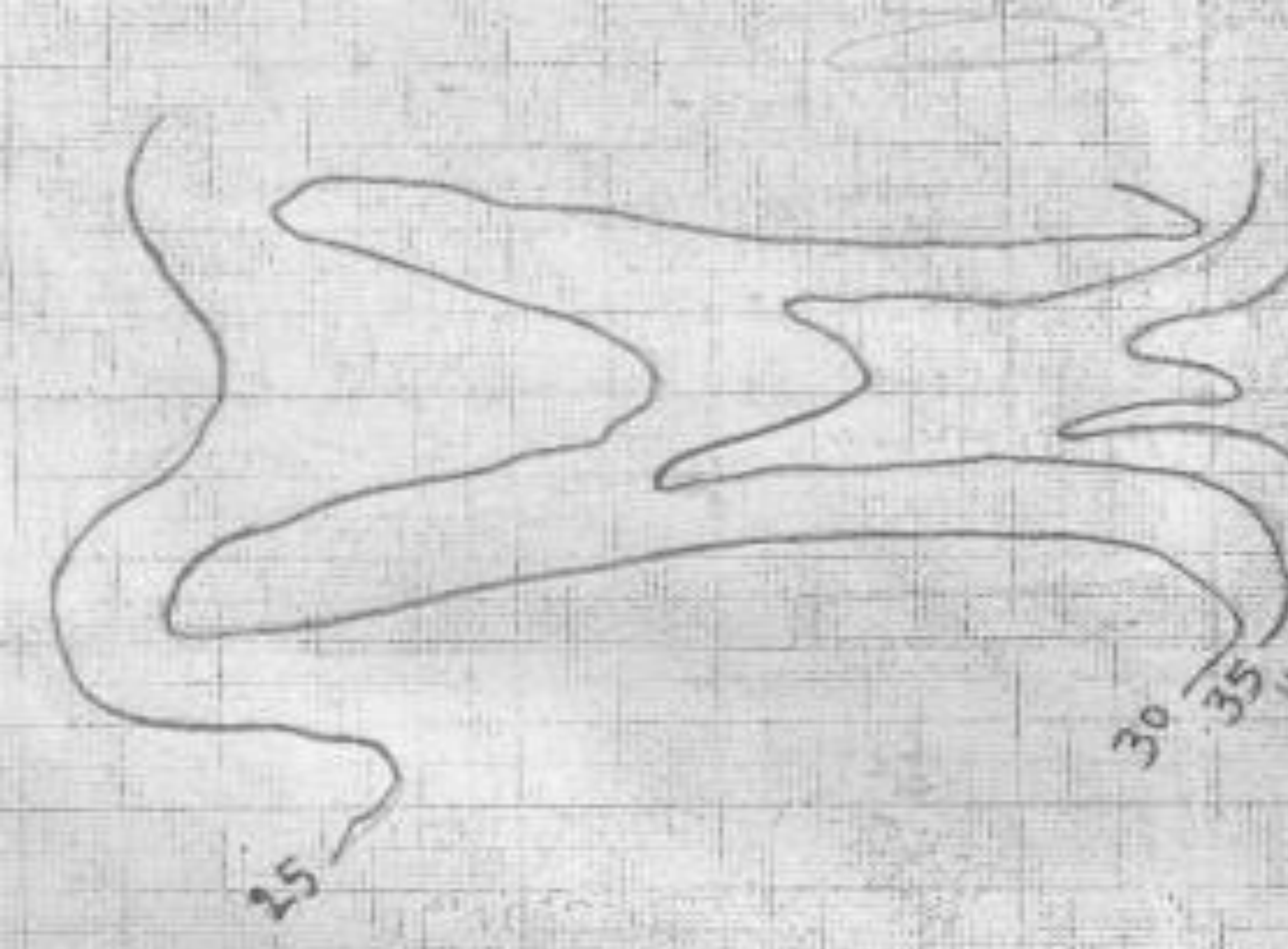
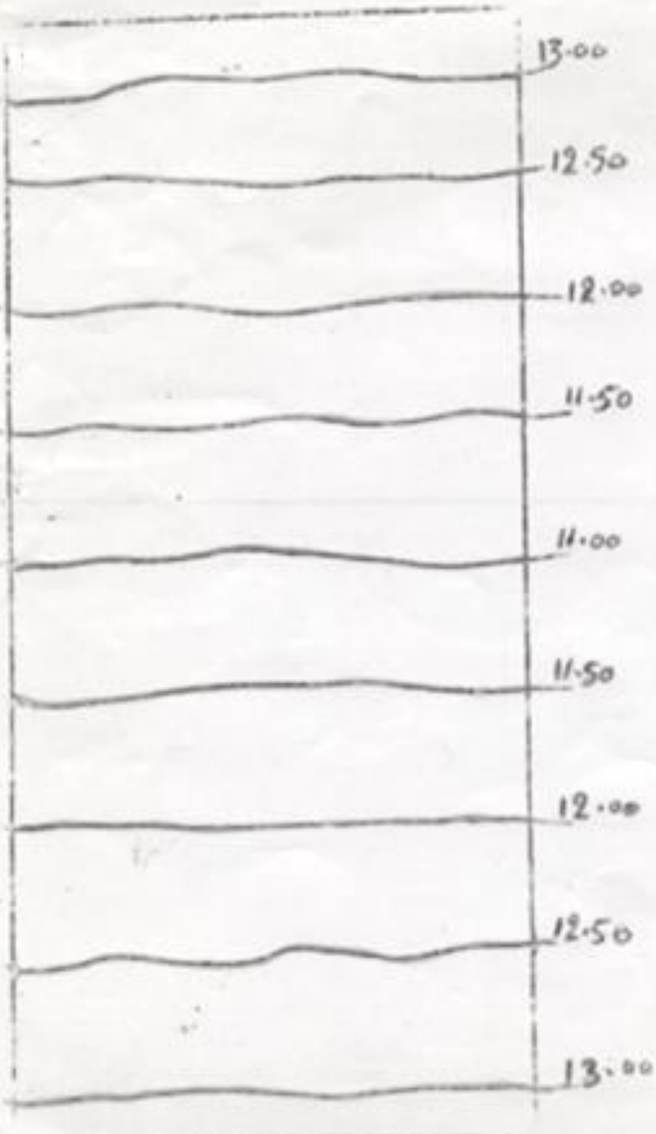
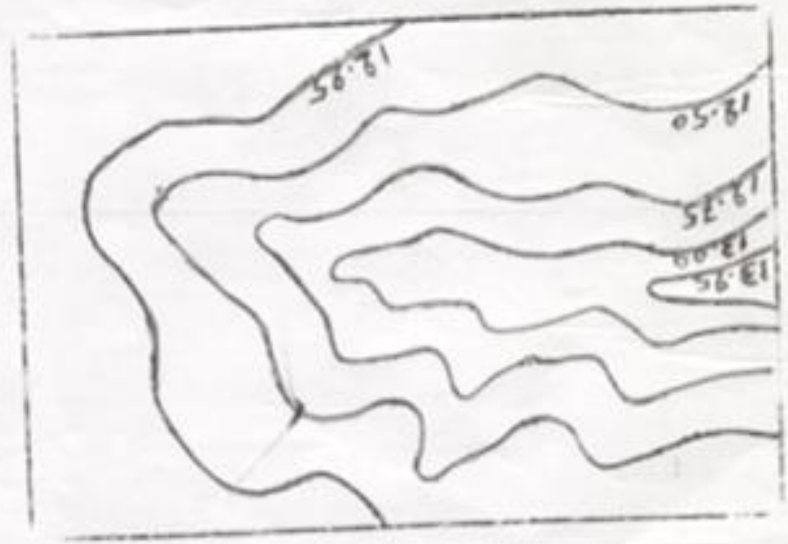
12.50
12.00
11.50
11.00
11.50
12.00
12.50
13.00

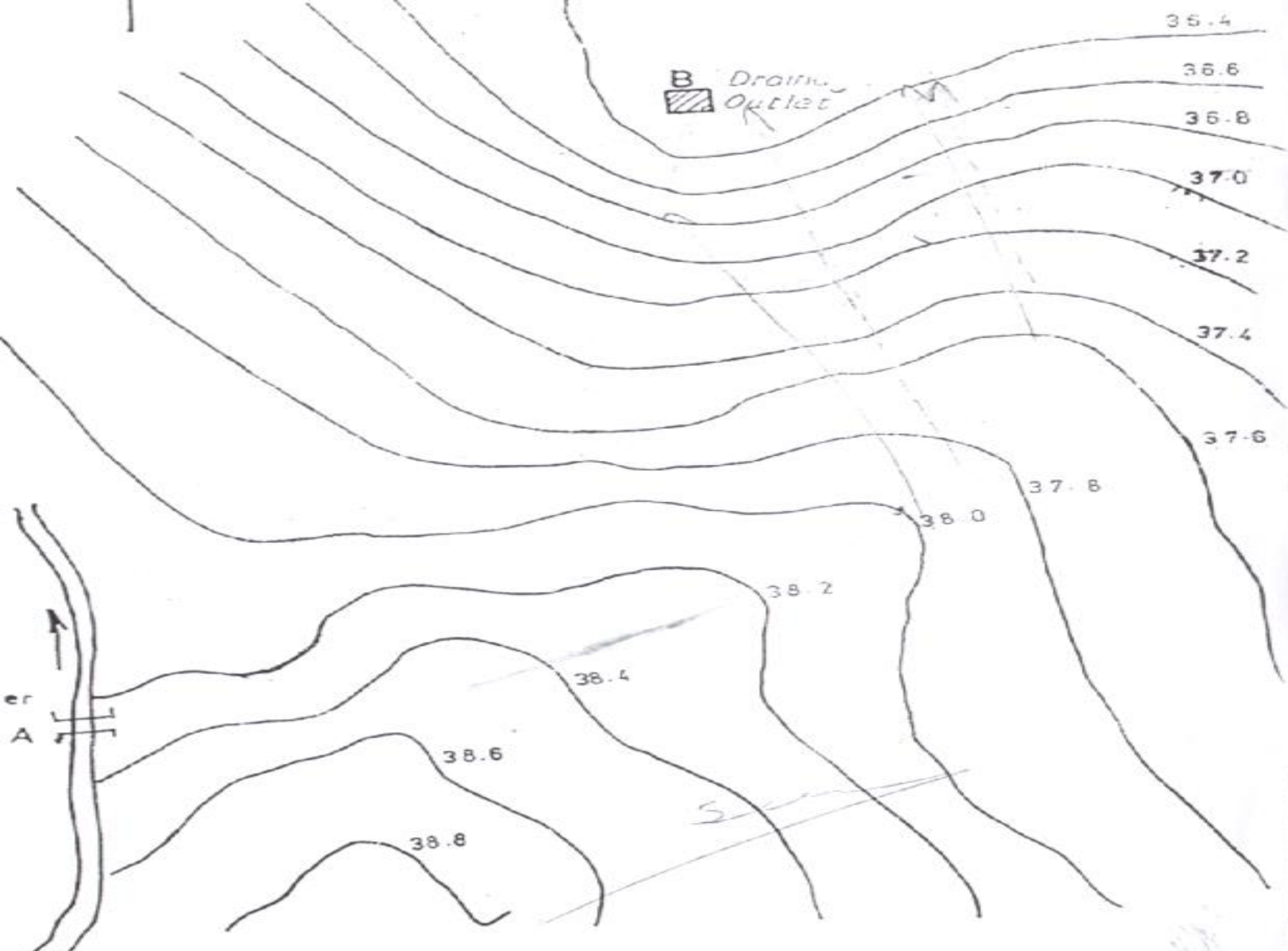


13.25
13.00
12.75
12.50
12.25


25
30
35


13.00
12.50
12.00
11.50
11.00
11.50
12.00
12.50
13.00





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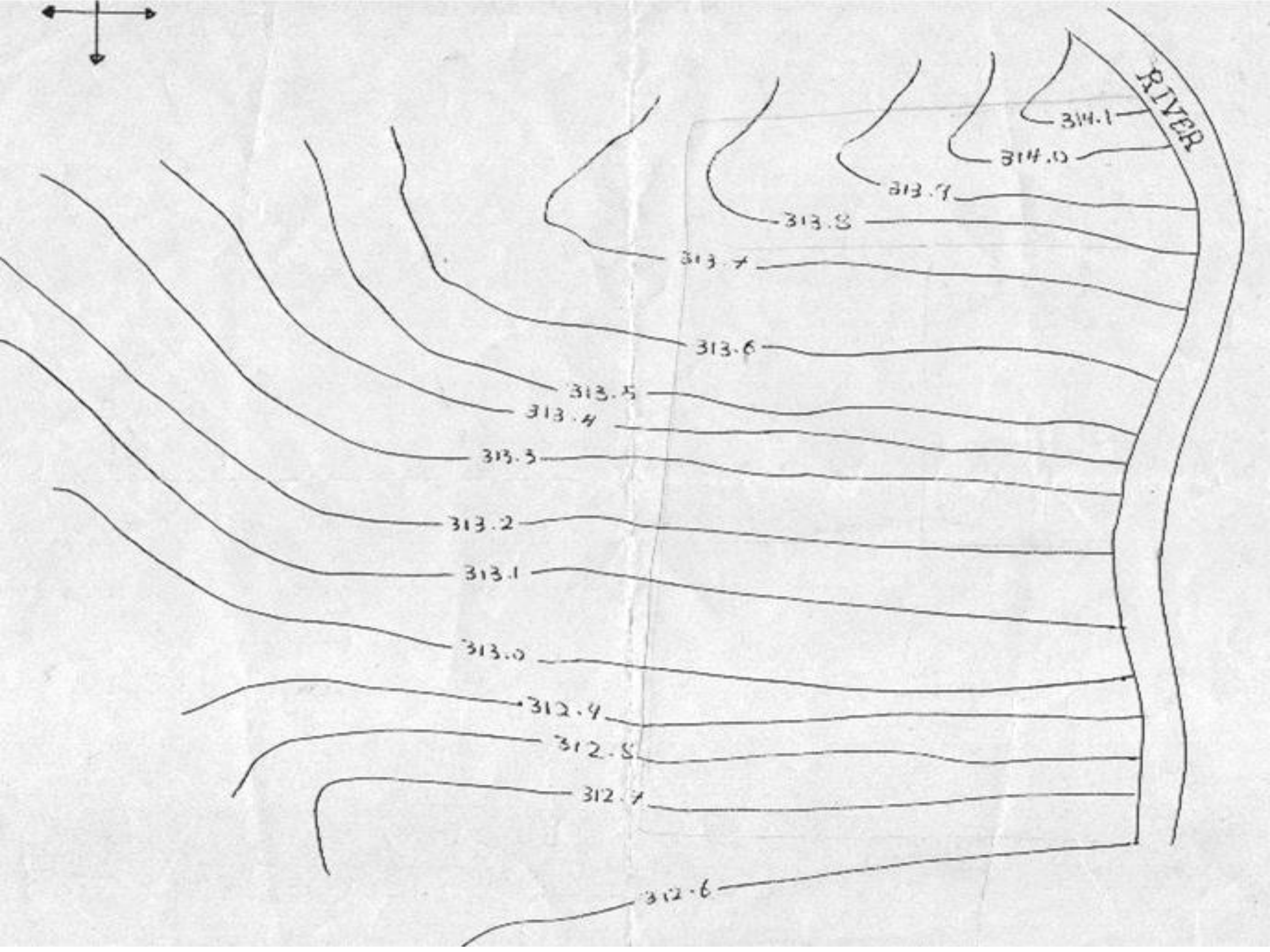
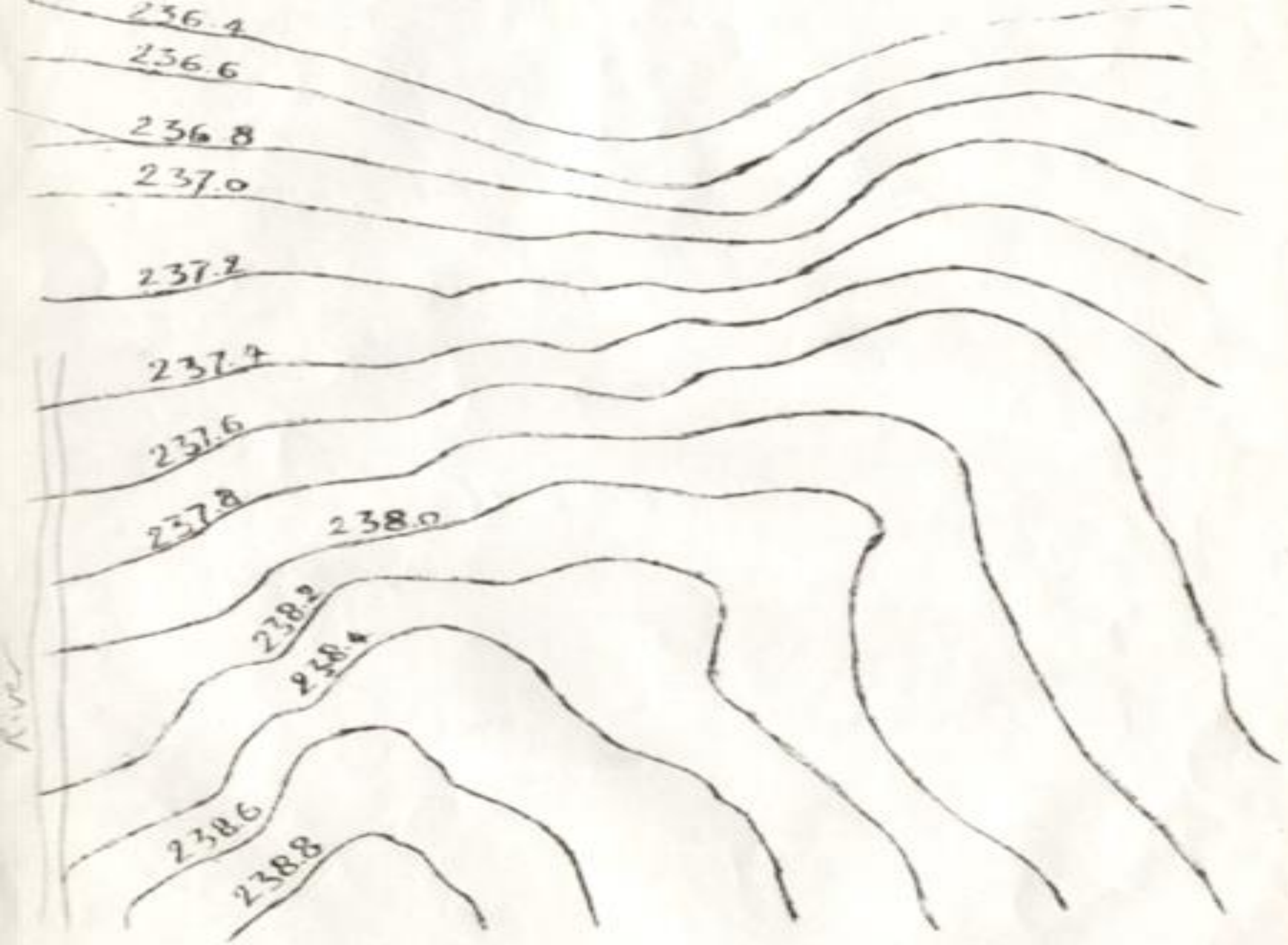
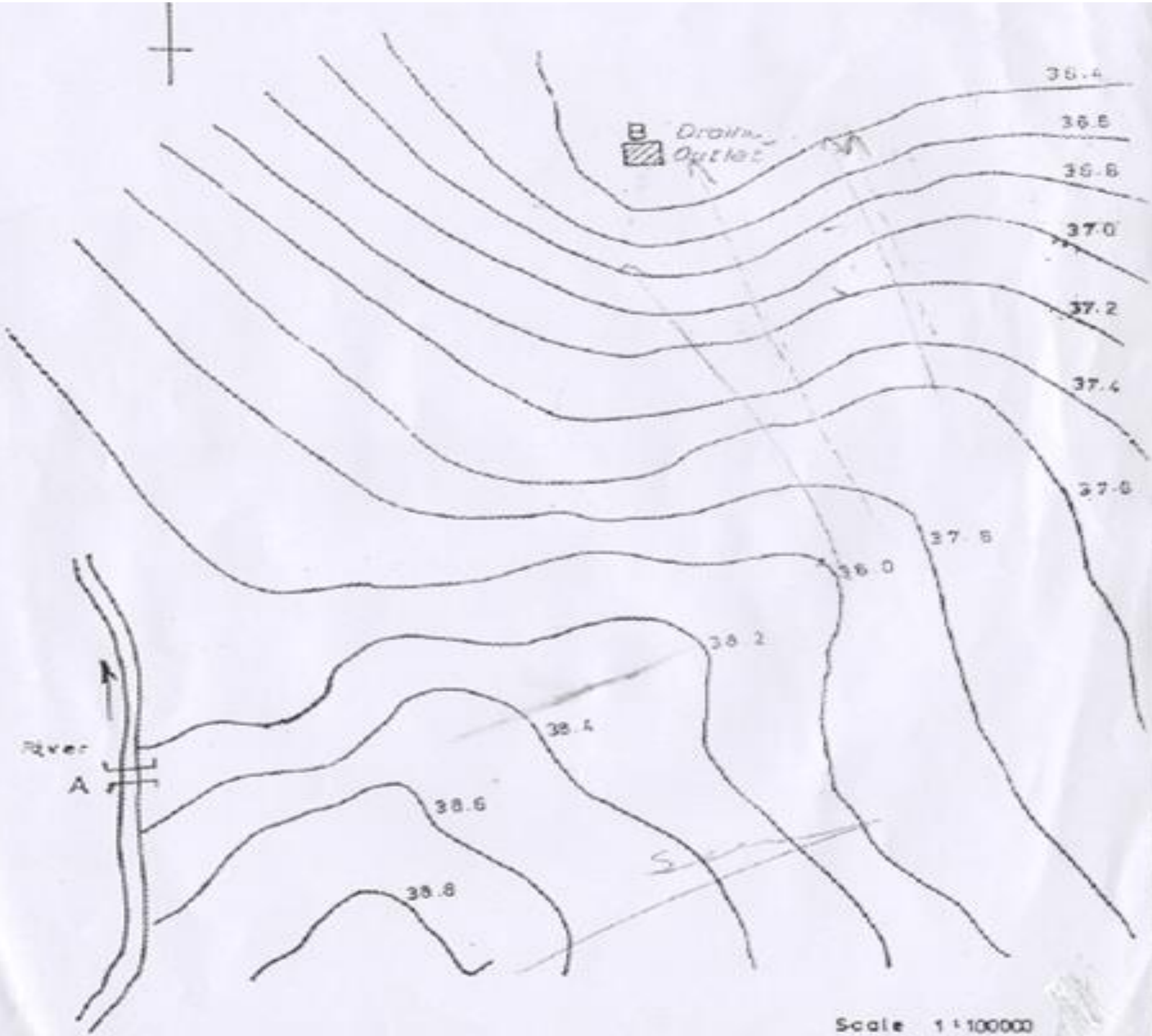
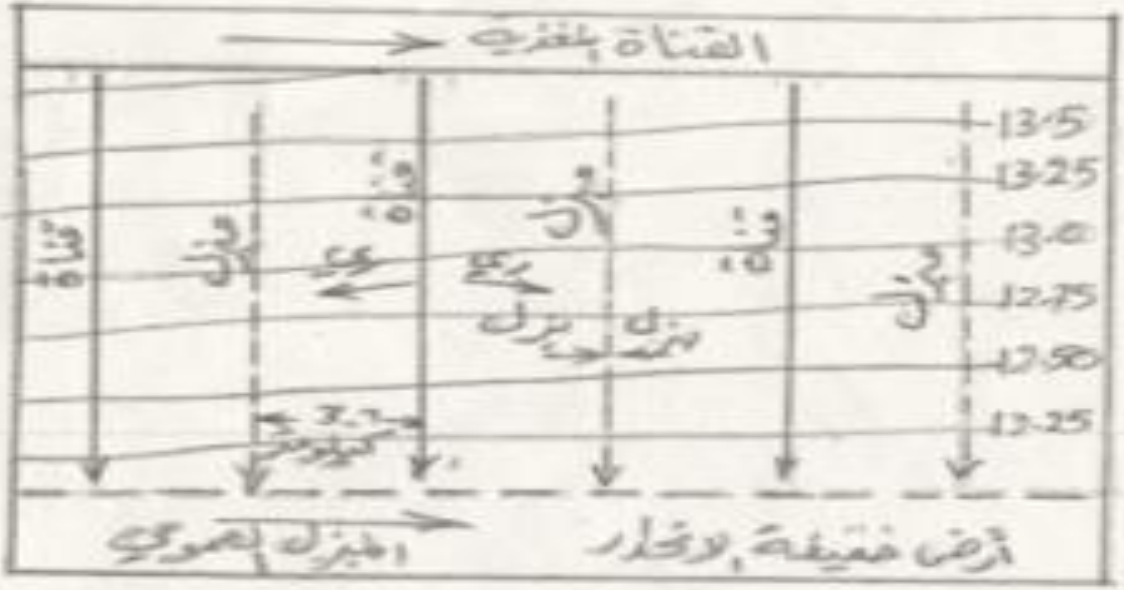

RIVER
314.1
314.0
313.9
313.8
313.7
313.6
313.5
313.4
313.3
313.2
313.1
313.0
312.9
312.8
312.7
312.6



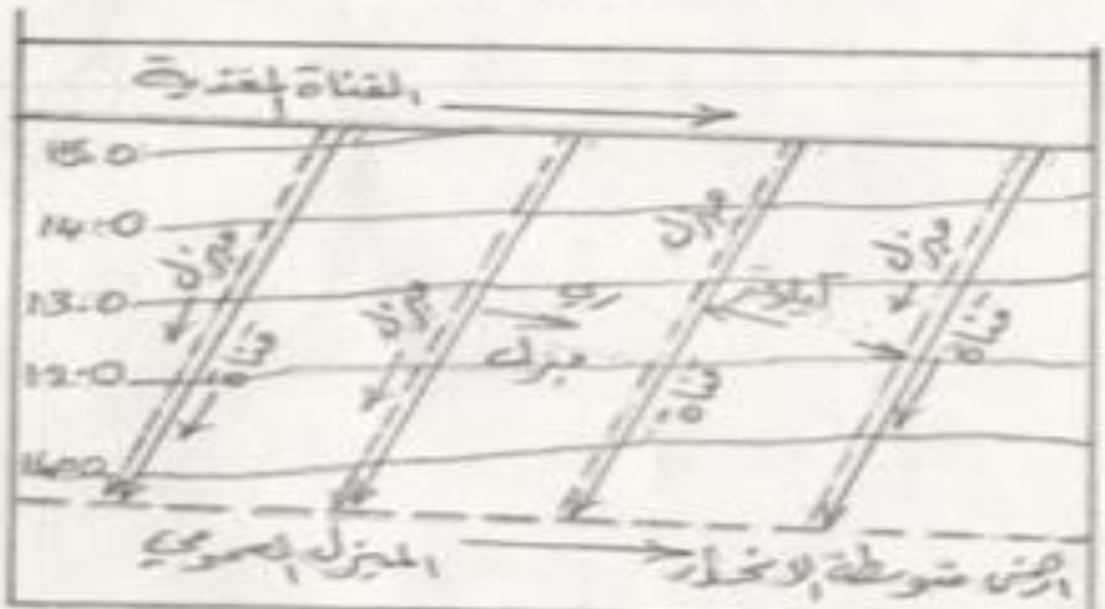
Scale 1:100000

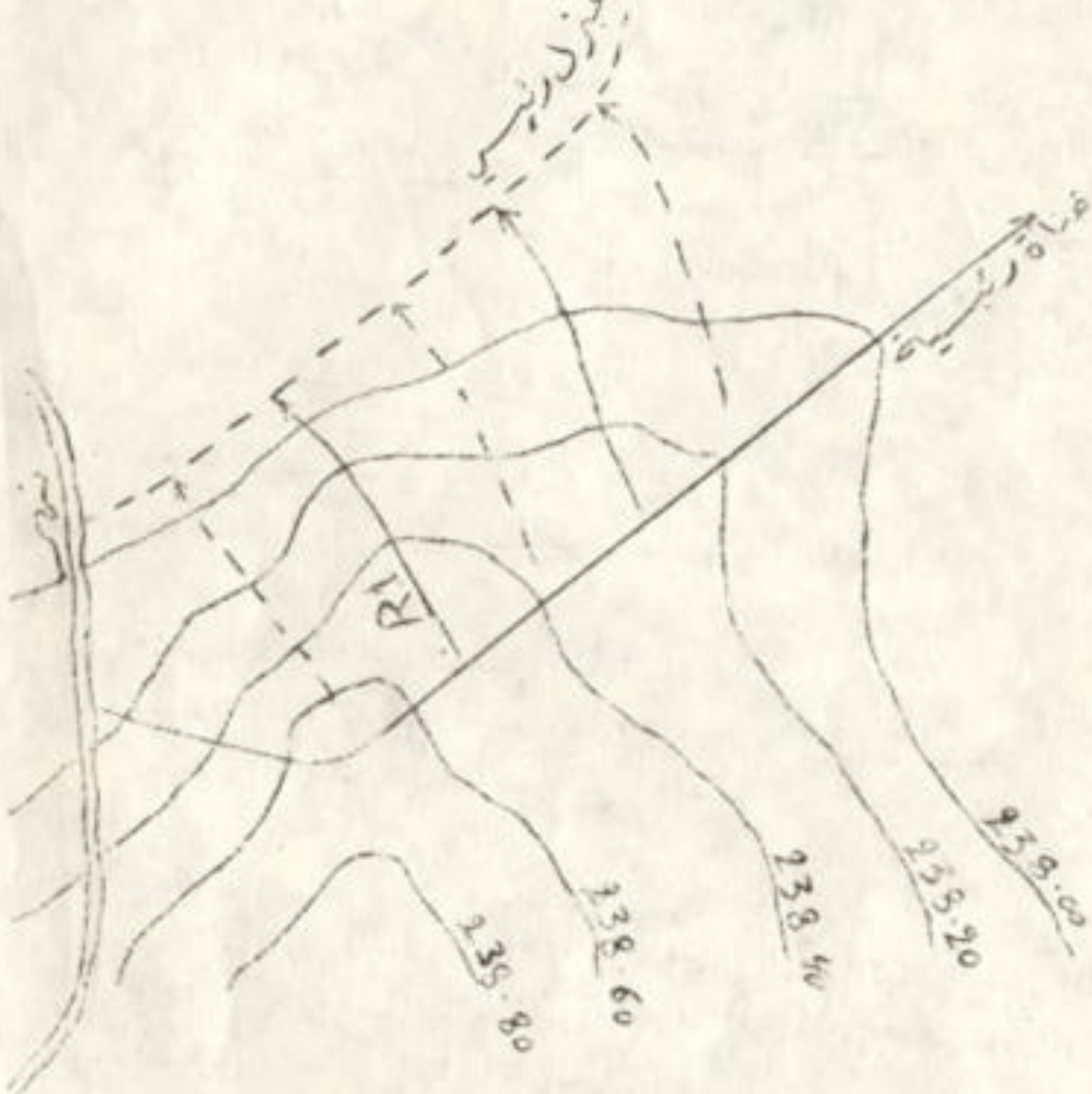


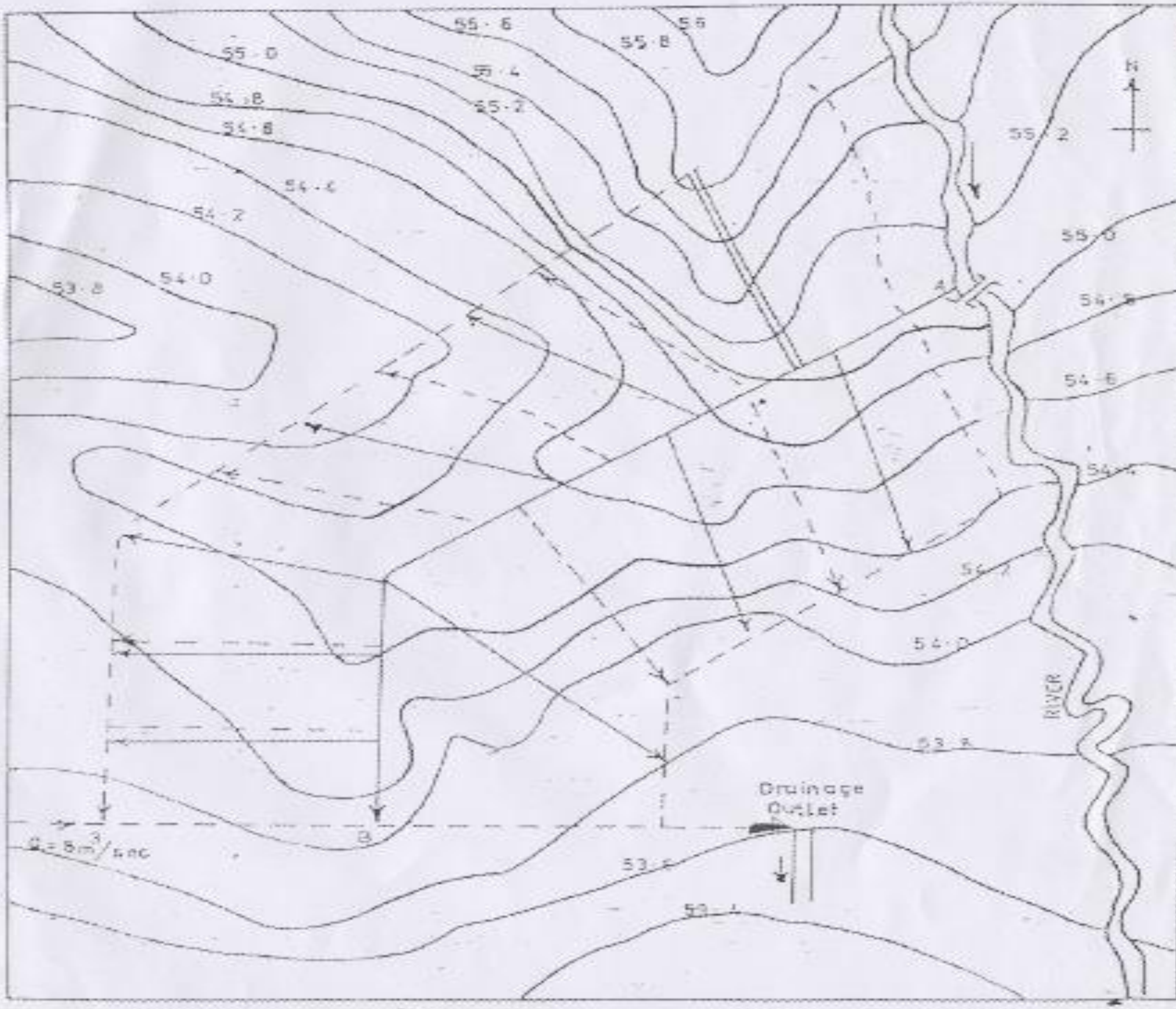
36.4
36.6
36.8
37.0
37.2
37.4
37.6
37.8
38.0
38.2
38.4
38.6
38.8
B
Drain
Outlet
River
A
Scale 1:100000


القناة الفرعية
13.5
13.25
13.0
12.75
12.50
12.25
أرض خفيفة الانحدار

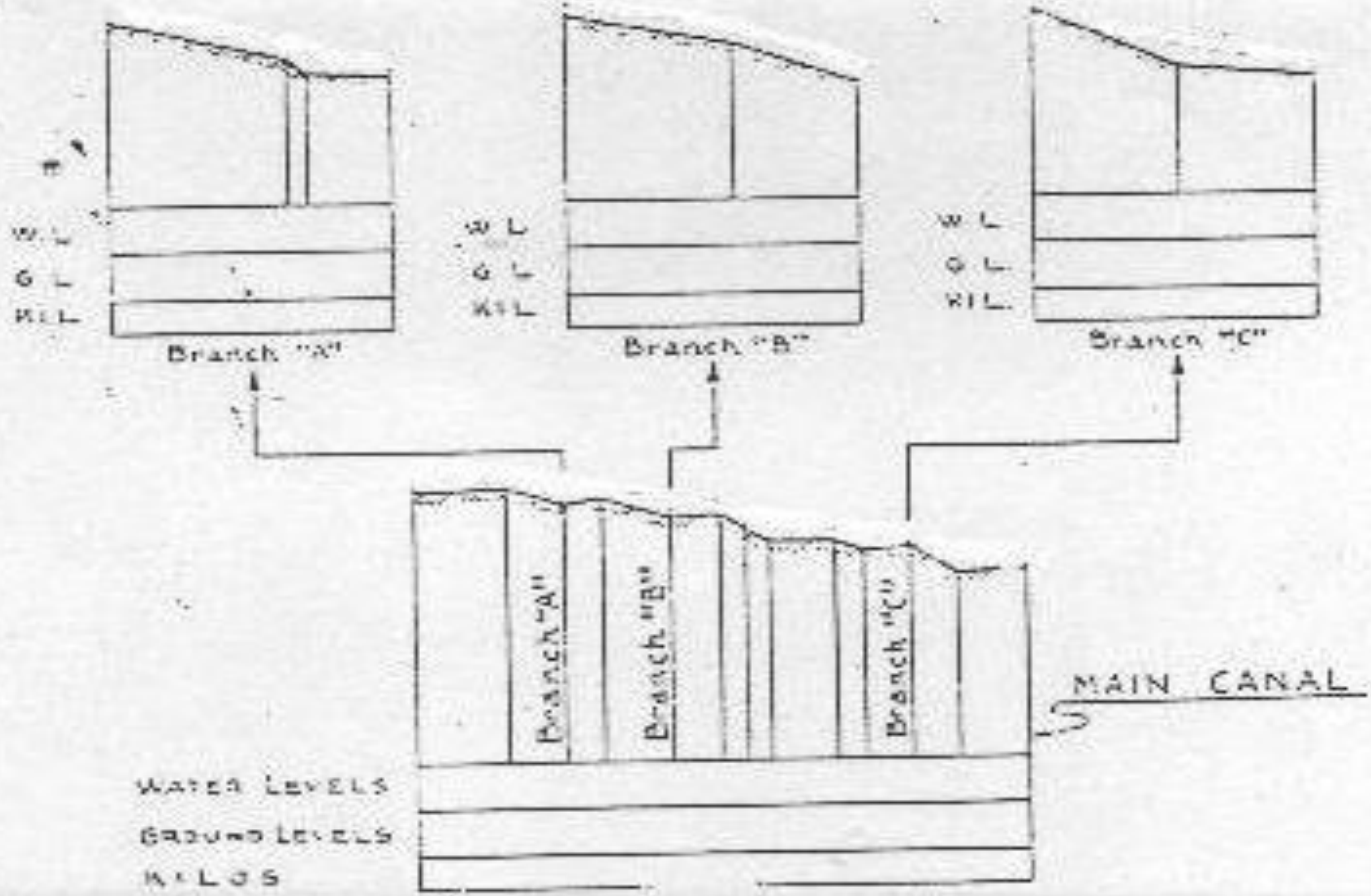
شكل رقم -(5_8)


القناة الفرعية
15.0
14.0
13.0
12.0
11.0
أرض متوسطة الانحدار


مبزل رئيسي
قناة رئيسية
R1
239.00
238.40
238.60

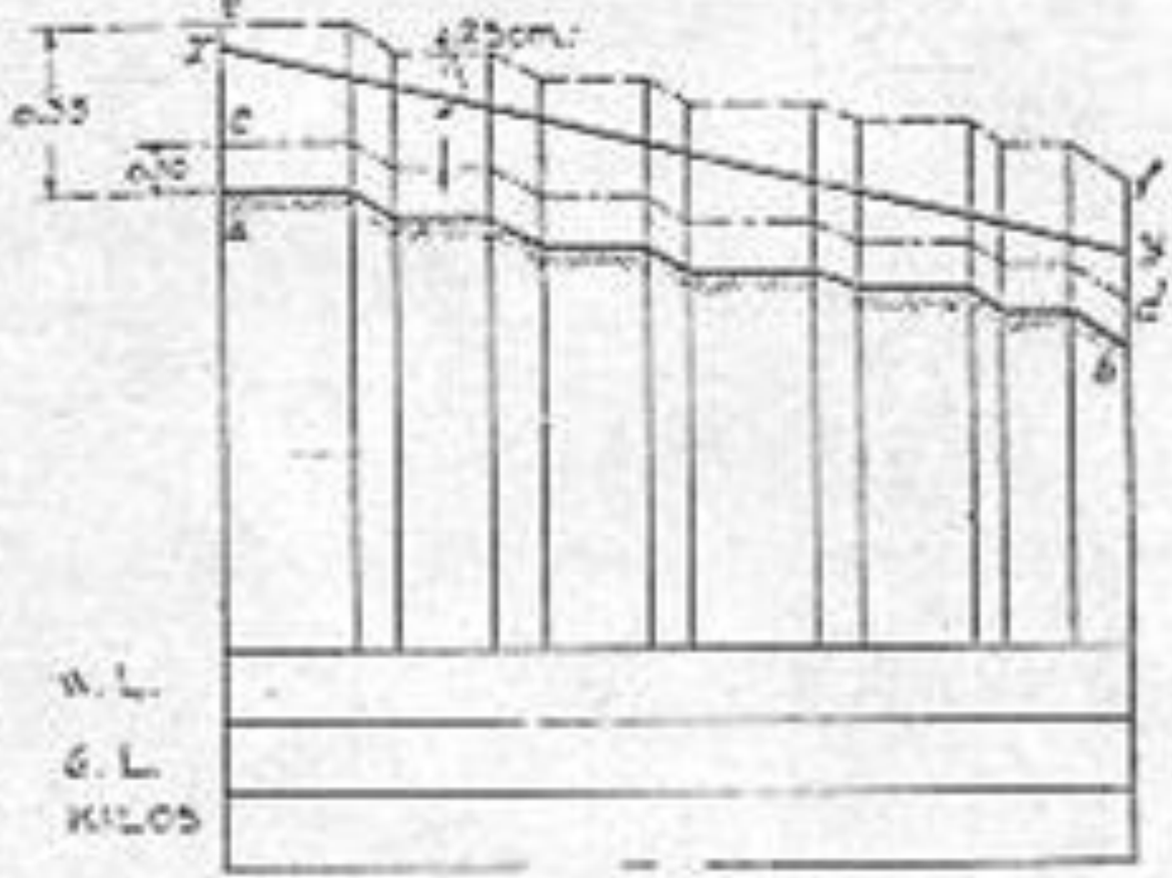


SCALE 1 : 50,000

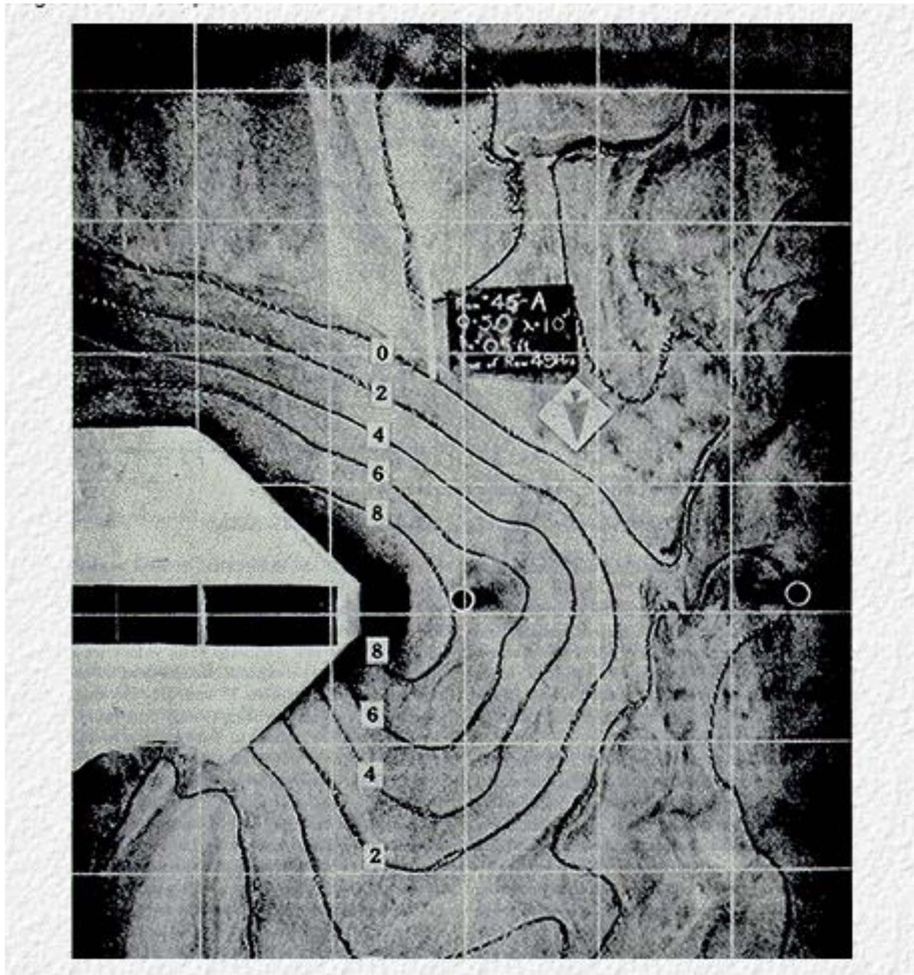

W.L
G L
KIL
Branch "A"
W L
G L
KIL
Branch "B"
W L
G L
KIL.
Branch "C"
Branch "A"
Branch "B"
Branch "C"
MAIN CANAL
WATER LEVELS
GROUND LEVELS
KILOS

(Fig. ~~Key~~ 2 - 8

9 - 9



0.25
0.10
0.25 cm
N. L.
G. L.
KILOS


45-A
0
2
4
6
8
8
6
4
2