PHILIPPINE NATIONAL STANDARD

PNS/BAFS/PAES 216:2017
ICS 65.060.35

Open Channels – Design of Main Canals, Laterals and Farm Ditches

DEPARTMENT OF
AGRICULTURE
PHILIPPINES

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Foreword

The formulation of this national standard was initiated by the Agricultural Machinery Testing and Evaluation Center (AMTEC) under the project entitled "Enhancement of Nutrient and Water Use Efficiency Through Standardization of Engineering Support Systems for Precision Farming" funded by the Philippine Council for Agriculture, Aquaculture and Forestry and Natural Resources Research and Development - Department of Science and Technology (PCAARRD - DOST).

As provided by the Republic Act 10601 also known as the Agricultural and Fisheries Mechanization Law (AFMech Law of 2013), the Bureau of Agriculture and Fisheries Standards (BAFS) is mandated to develop standard specifications and test procedures for agricultural and fisheries machinery and equipment. Consistent with its standards development process, BAFS has endorsed this standard for the approval of the DA Secretary through the Bureau of Agricultural and Fisheries Engineering (BAFE) and to the Bureau of Philippine Standards (BPS) for appropriate numbering and inclusion to the Philippine National Standard (PNS) repository.

This standard has been technically prepared in accordance with BPS Directives Part 3:2003 – Rules for the Structure and Drafting of International Standards.

The word "shall" is used to indicate mandatory requirements to conform to the standard.

The word "should" is used to indicate that among several possibilities one is recommended as particularly suitable without mentioning or excluding others.

Open Channels – Design of Main Canals, Laterals and Farm Ditches

1 Scope

This standard provides minimum requirements and criteria for hydraulic evaluation and stable design of open channels specifically for main canals, laterals, sublaterals and farm ditches assuming uniform and steady flow.

2 References

The following normative documents contain provisions, which, through reference in this text, constitute provisions of this National Standard:

PNS/BAFS/PAES 217:2017 Determination of Irrigation Water Requirements

3 Symbols and Nomenclature

Parameter	Symbol	Unit
Area	A	m^2
channel bed slope	S	-
Depth	$D\ (d)$	m
energy grade line	EGL	-
hydraulic depth	D	m
hydraulic grade line	HGL	-
hydraulic radius	R	m
side slope	Z	-
top width	T	m
wetted perimeter	P	m

4 Definitions

For the purpose of this standard, the following terms shall apply:

4.1
area
cross-sectional area of the flow which is measured perpendicular to the direction of flow (see Figure 1)

4.2
channel bed slope
inclination or elevation drop per unit length of the channel bottom (see Figure 2)

4.3
depth
depth of water in the channel cross-section (see Figure 1)

4.4
energy grade line
specific energy line
grade line of the water surface profile plus the velocity head in open channels (see Figure 2)

4.5
freeboard
vertical distance from the top of the channel to the water surface at the design condition (see Figure 1)

4.6
hydraulic depth
ratio of flow area to the wetted top width (see Figure 1)

4.7
hydraulic grade line
hydraulic gradient
profile of the free water surface (see Figure 2)

4.8
hydraulic radius
cross-sectional area of flow divided by the wetted perimeter

4.9
lined channel
lined canal
canals with impermeable material (usually concrete) for channel stabilization and/or reduced seepage (see Figure 1)

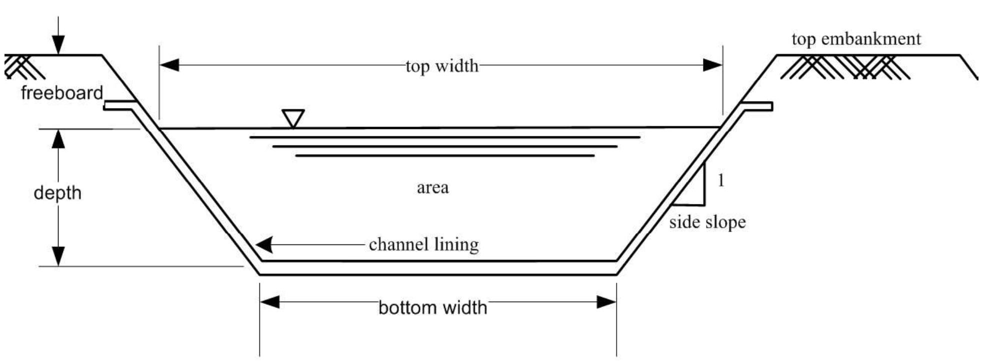

Figure 1. Cross-Section of a Lined Channel

4.10
normal depth
constant flow depth along a longitudinal section of a channel under a uniform flow condition (see Figure 2)

4.11
open channel flow
water flow that is conveyed in such a manner that top surface is exposed to the atmosphere such as flow in canals, ditches, drainage channels, culverts, and pipes under partially full flow conditions

4.12
slope of the hydraulic grade line
slope of the free water surface

4.13
slope of the energy grade line
slope of the water surface profile plus the velocity head in open channels

4.14
side slope
ratio of the horizontal to vertical dimension of the channel wall (see Figure 1)

4.15
top width
width of the channel cross-section at the free surface (see Figure 1)

4.16
uniform flow
occurs when flow has a constant water area, depth, discharge, and average velocity through a reach of channel

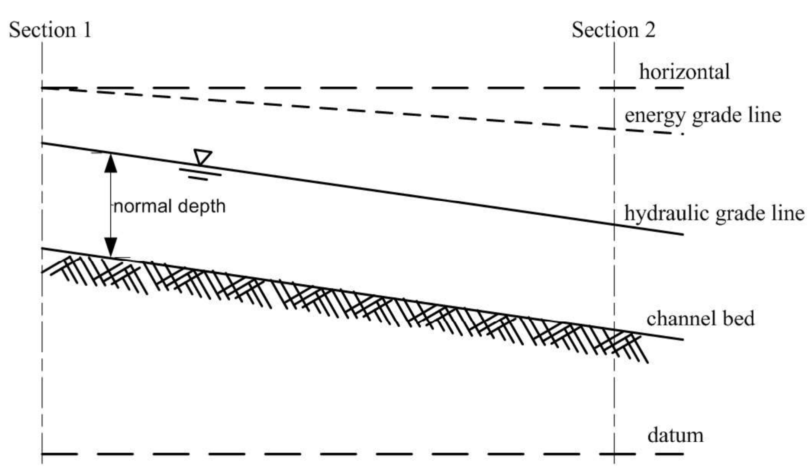

Figure 2. Profile of a Longitudinal Section of an Open Channel with Uniform Flow

4.17
unlined channels
unlined canal
canals that are cut through the soil, in which the soil excavated from the bed are used to form the embankment

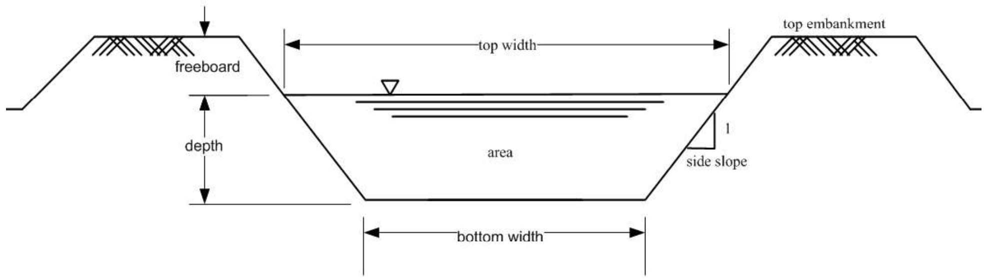

Figure 3. Cross-Section of an Unlined Canal

4.18
wetted perimeter
portion of the perimeter of the canal that is in contact with the flowing water

5 Design Requirements and Procedure

The following parameters shall be determined in order to design an open channel:

1. Design Discharge or Flow Capacity
2. Flow Velocity
3. Roughness Coefficient
4. Canal Cross Section
5. Bottom Slope
6. Freeboard

5.1 Design Discharge

5.1.1 The design discharge for the main canal shall be equal to the diversion water requirement. Determination of diversion water requirement is shown in PNS/BAFS/PAES 217:2017 – Determination of Irrigation Water Requirements.

5.1.2 The design discharge for the main farm ditch shall be equal to the farm water requirement. Determination of farm water requirement is shown in PNS/BAFS/PAES 217:2017 – Determination of Irrigation Water Requirements.

5.2 Flow Velocity

5.2.1 For unlined channels, the design flow velocity of the canal shall not exceed the maximum permissible velocity in order to avoid destructive erosion to the channel and progressively destroy fertile lands. The maximum permissible velocity depends on the resistance to erosion of the banks of the canal. The values for different materials are given in Table 1.

5.2.2 For lined channels, the minimum permissible velocity shall be considered. However, the flow velocity shall be in no case too low to produce sand deposits or allow weed growth inside the canal. The permissible minimum velocity can be estimated as 0.6 m/s for plain water and 0.9 m/s for water with sediments.

Table 1. Maximum Velocities for Different Types of Materials

Type of Material	Maximum Permissible Velocity, m/s
Rock	2.00
decomposed, disintegrated rock	1.50
gravel with silt and sand	1.20
Clay	0.90
clay loam	0.80
Loam	0.70
sandy loam and silty loam	0.60
sandy soil	0.45

SOURCE: Irrigation Engineering Manual for Diversified Cropping, 1991

5.3 Roughness Coefficient

5.3.1 Values for roughness coefficient of different materials forming the channel are shown in Table 2.

5.3.2 The value for roughness coefficient shall not be based on the degree of the original finish but on the surface that will exist after a few years of operation.

5.3.3 For the design of farm ditches, the value for roughness coefficient of 0.03 may be adopted since such canal is not well maintained, section is not uniform and there isusually grass or weed growth (Design Manual On Irrigation Facilities, n.d.).

Table 2. Mean Roughness Coefficients for Different Strata and Condition of the Channel

Material and Condition	Mean Roughness Coefficient
Natural Channels	
Streams on Plain	
1. straight, no weeds, neither cracks nor depths are present	0.0300
2. same as item 1 but weeds and stones are present	0.0350
3. no weeds but sinuous and with some depths and fords	0.0400
4. same as item 3 but weeds and stones are present	0.0450
5. same as item 3 but little changes in slope and cross-	0.0480

section, low water level	
6. same as item 4 but more stones	0.0500
7. weeds and deep crevices are seen along slow stream flow sections	0.0700
8. densely weeded section with many crevices and bushes	0.1000
Streams in mountainous area, no vegetation in channel, usually steep with trees and bushes along banks submerged at high water level:	
1. boulder and gravel bed	0.0400
2. big boulder bed	0.0500
Excavated or Dredged Canal	
Earth, Straight and Uniform:	
1. clean (immediately after completion)	0.0225
2. clean (after weathering)	0.0250
3. gravel, no weed and uniform section	0.0250
4. short grass, but little weeds	0.0270
Earth, Curved and Irregular Section:	
1. no vegetation	0.0250
2. some weeds/grass	0.0300
3. with dense water weeds	0.0350
4. earth bottom and rubble sides	0.0300
5. earth bottom and weedy sides	0.0350
6. cobblestone bottom and clean sides	0.0400
Dragline Excavation or Dredged:	
1. no vegetation	0.0280
2. some bushes on the banks	0.0500
Rock Excavation	
1. smooth and uniform	0.0350
2. irregular	0.0400
Lined Canal	
Rigid	
1. concrete	0.0130
2. grouted riprap	0.0300
3. stone masonry	0.0320
4. soil cement	0.0220
5. asphalt	0.0160
Gravel Riprap	
1. 1-inch D_{50}	0.0330
2. 2-inch D_{50}	0.0410
Rock Riprap	
1. 6-inch D_{50}	0.0690
2. 12-inch D_{50}	0.0780

SOURCE: Irrigation Engineering Manual for Diversified Cropping, 1991

5.4 Canal Cross Section

The recommended shapes for irrigation canals are trapezoidal or rectangular (for lined channels or rock formation) due to their stability and higher resistance to scouring thus, the guidelines in this standard are limited to such shapes.

Sample cross-section is shown in Figure 3. Cross-sections of other canal shapes are shown in Annex A.

5.4.1 Side Slope

5.4.1.1 For lined channels, the recommended side slope is 1.5:1.

5.4.1.2 For unlined channels, side slopes shall depend on soil characteristics and should be flat enough to avoid the possibility of caving in after saturation. Steeper slopes can be permitted in cutting reaches in rock or hard strata but not for embankment reaches. Recommended values are shown in Table 3.

Table 3. Stable Side Slopes for Unlined Channels

Location/Strata	Stable Side Slope (Horizontal:Vertical)
Cutting Reaches	
1. hard rock	¼:1 to ½:1
2. decomposed rock, soft rock	¼:1 to 1:1
3. granular soils, sand, gravel and silt	1:1 to 1.5:1
4. highly plastic, expansive clays, loams	1.5:1 to 2:1
5. noncohesive and loose sand	2:1
Embankment Reaches	
1. with granular material, sandy, silty soils	1.5:1
2. with highly plastic, expansive clays, loams	2:1
3. noncohesive and loose sandy soils	2:1 to 3:1

SOURCE: Design Manual on Irrigation Facilities, n.d.

5.4.2 Channel Bed Width and Depth Ratio (b/d ratio)

5.4.2.1 For lined and unlined channels, several b/d ratio can be selected in order to satisfy a given design discharge.

5.4.2.2 The bed width and channel depth can be computed by trial and error using Annex B.3.

5.4.2.3 The bed width and channel depth can also be determined by using Table 4 which shows the recommended b/d ratio for a corresponding design discharge.

Table 4. Recommended b/d ratio

Channel Discharge, m^3/s	Range of b/d Ratio	
	unlined channel	lined channel
0.1	1.00 - 2.50	1.00
0.5	1.25 – 3.00	
1	1.50 – 3.50	
2	2.00 – 4.00	
5	2.50 – 4.50	
10	3.00 – 5.50	
15	3.50 – 6.00	1.25
20	3.75 – 6.50	
25	4.00 – 7.00	
50	4.50 – 9.00	1.50
75	5.00 – 10.50	2.00
100	5.50 -11.50	
more than 100	-	2.50

SOURCE: Design Manual on Irrigation Facilities, n.d.

5.5 Bottom Slope

The bottom slope or the slope of the channel bed shall be determined from the topographic surveys.

5.6 Freeboard

5.6.1 The flow capacity in the cross sectional area including the freeboard shall be about 1.25 to 1.35 times the design discharge.

5.6.2 For unlined and lined channels, the freeboard shall be calculated based on Annex B.4. The largest value shall be selected for the freeboard.

A sample computation is shown in Annex C.

6 Canal Route Selection

6.1 The canal route shall be selected such that the design discharge and design depth can be maintained.

6.2 The supply canal shall follow the highest points of the land to be irrigated by gravity in order to supply the widest area within the range of the available water head.

6.3 If the project area includes elevated areas or depressions, the use of appropriate conveyance structures shall be considered in the route.

6.4 High-banking or deep-cut sections shall be avoided, taking into consideration the available water head and available velocity.

6.5 Soil conditions, interference with houses and public traffic during construction of canals shall be considered in the canal route selection.

6.6 If the irrigation canal is long and its purpose is to irrigate mainly upland fields, establishing a regulating reservoir shall be considered. A regulating reservoir can decrease construction costs due to the reduction of the required canal sections.

6.7 Regional development plans or projects shall be considered in canal route selection.

7 Formula

The formulas to be used during calculations are given in Annex B.

8 Bibliography

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National Irrigation Administration. 1979. Design Guides and Criteria For Irrigation Canals, O & M Roads, Drainage Channels & Appurtenant Structures.

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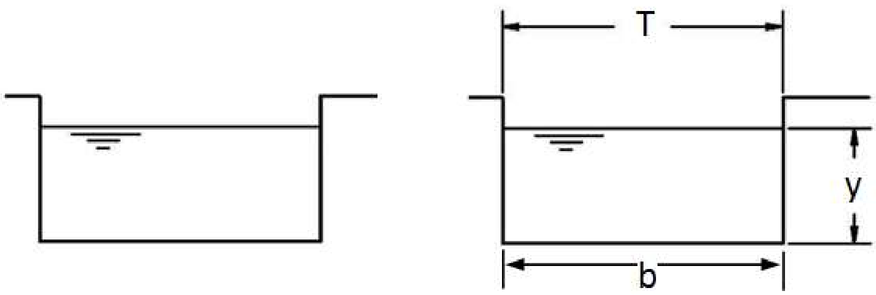
Annex A
(informative)

Canal Cross-Section

A.1 Rectangle



A.1.1 Area $A = by$

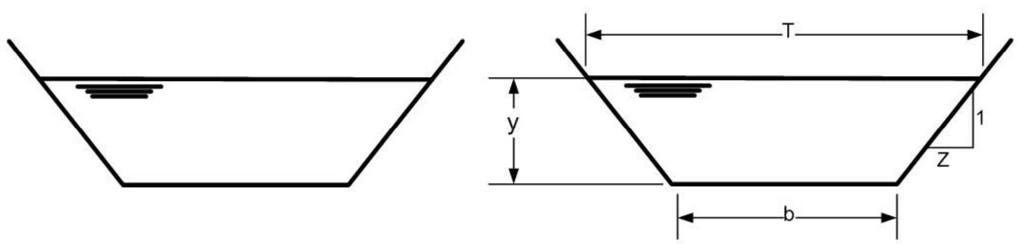
A.1.2 Wetted Perimeter $P = b + 2y$

A.1.3 Hydraulic Radius $R = \frac{by}{b+2y}$

A.1.4 Top Width $T = b$

A.1.5 Hydraulic Depth $D = y$

A.2 Trapezoid



A.2.1 Area $A = (b + zy)y$

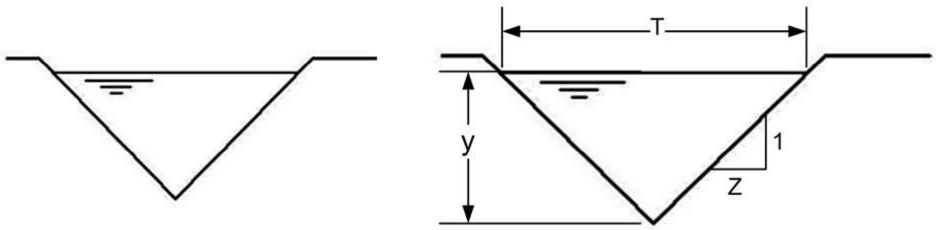
A.2.2 Wetted Perimeter $P = b + 2y\sqrt{1 + z^2}$

A.2.3 Hydraulic Radius $R = \frac{(b+zy)y}{b+2y\sqrt{1+z^2}}$

A.2.4 Top Width $T = b + 2zy$

A.2.5 Hydraulic Depth $D = \frac{(b+zy)y}{b+2zy}$

A.3 Triangle



A.3.1 Area $A = zy^2$

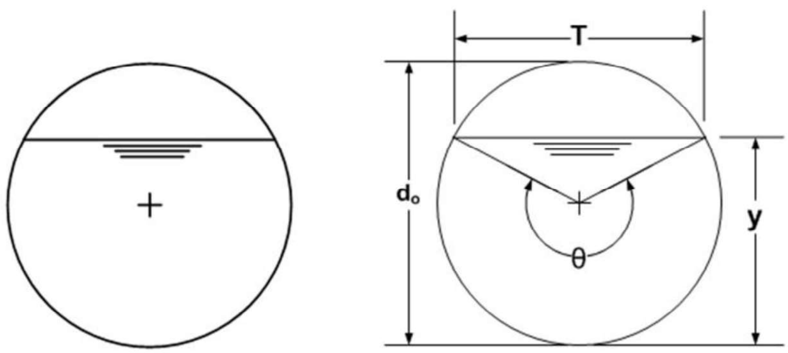
A.3.2 Wetted Perimeter $P = 2y\sqrt{1+z^2}$

A.3.3 Hydraulic Radius $R = \frac{zy}{2\sqrt{1+z^2}}$

A.3.4 Top Width $T = 2zy$

A.3.5 Hydraulic Depth $D = \frac{y}{2}$

A.4 Circle



A.4.1 Area $A = \frac{1}{8}(\theta - \sin\theta){d_0}^2$

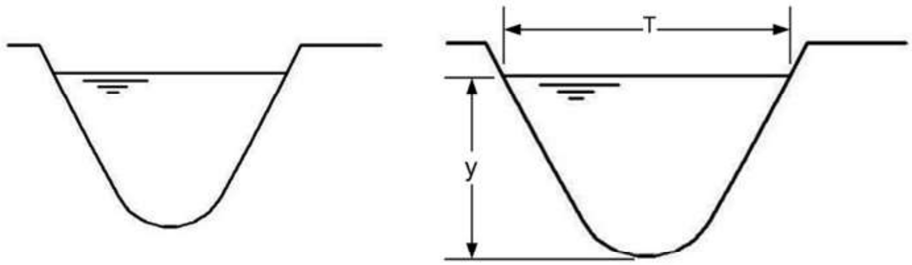
A.4.2 Wetted Perimeter $P = \frac{1}{2}\theta d_0$

A.4.3 Hydraulic Radius $R = \frac{1}{4}\left(1 - \frac{\sin\theta}{\theta}\right) d_0$

A.4.4 Top Width $T = \left(\sin\frac{\theta}{2}\right) d_0 = 2\sqrt{y(d_0 - y)}$

A.4.5 Hydraulic Depth $D = \left[\frac{\theta - \sin\theta}{\sin\frac{\theta}{2}}\right]\frac{d_0}{8}$

A.5 Parabola



A.5.1 Area $A = \frac{2}{3}Ty$

A.5.2 Wetted Perimeter $P = T + \frac{8y^2}{3T}$

A.5.3 Hydraulic Radius $R = \frac{2T^2y}{3T^2+8y^2}$

A.5.4 Top Width $T = \frac{3}{2}Ay$

A.5.5 Hydraulic Depth $D = \frac{2}{3}y$

ANNEX B
(normative)

Formulas

B.1 Hydraulic Depth

$$D = \frac{A}{T}$$

where:

D	is the hydraulic depth (m)
A	is the cross-sectional area of flow (m^2)
T	is the wetted top width, (m)

B.2 Hydraulic Radius

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

where:

R	is the hydraulic radius (m)
A	is the cross-sectional area of flow (m^2)
P	is the wetted perimeter, (m)

B.3 Bed Width and Channel Depth

$$\frac{Qn}{S^{1/2}} = \frac{A^{5/3}}{P^{2/3}}$$

where:

Q	is the discharge (m^3/s)
N	is the roughness coefficient
A	is the cross-sectional area (m^2)
S	is the bed slope
P	is the wetted perimeter (m)

B.4 Freeboard

For depths of flow of 0.3 m up to 2 m,

$$Fb = 0.4d$$

where :

Fb	is the freeboard (m)
d	is the depth of flow during crop maintenance (m)

For depths of flow of more than 2 m,

$$Fb = 0.25d + 0.3m$$

where :

Fb	is the freeboard (m)
d	is the depth of flow during crop maintenance, m

Accounting for velocity head,

$$Fb = 0.05d + h_V + (0.05\ m\ to\ 0.15\ m)$$

where :

Fb	is the freeboard (m)
D	is the depth at design discharge (m)
h_v	is the velocity head, $v^2/2g$ (m)

ANNEX C
(informative)

Sample Computation

B.1 Given:

Flow capacity, Q	20 m^3/s
Type of Material	clay loam
Condition	clean, earth canal with no vegetation
Embankment reach	with granular material, sandy, silty soils
Bed Slope	0.00025

B.2 Required: Trapezoidal Canal Section for an Unlined Open Channel

B.3 From Table 1, the maximum permissible velocity for clay loam, V = 0.8 m/s

$$A = \frac{Q}{V} = \frac{20\ m^3/s}{0.8\ m/s} = 25\ m^2$$

B.4 From Table 2, the mean roughness coefficient of the given strata and condition, n = 0.025

B.5 From Table 3, the stable side slope for the condition of embankment reach, the stable side slope ratio is 1.5:1

B.6 From Table 4, the recommended range of b/d ratio is from 3.75 to 6.50

B.7 Assume b/d = 6; b= 11, d=1.83

B.8 From A.2 of Annex A, the canal dimensions are computed as,
(NOTE: d=y, b and d are in meters)

Area $A = (b + zy)y = (11 + (1.5 \times 1.83) \times 1.83 = 25.21\ m^2$

Wetted Perimeter $P = b + 2y\sqrt{1 + z^2} = 11 + (2 \times 1.83\sqrt{1 + 1.5^2}) = 17.6\ m$

Hydraulic Radius $R = \frac{(b+zy)y}{b+2y\sqrt{1+z^2}} = \frac{25.21}{17.6} = 1.43\ m$

B.9 Compute for the actual flow velocity and flow area.

B.9.1 The computed flow velocity shall be less than or equal to the maximum permissible velocity. Otherwise, adjust the value of base or depth.

B.9.2 The computed flow capacity shall be greater than or equal to but not appreciably different from the design capacity or required flow capacity. Otherwise, adjust the b/d ratio.

$$V = \frac{1}{n}R^{2/3}S^{1/2} = \frac{1}{0.025} \times 1.43^{2/3} \times 0.00025^{1/2} = 0.80 \text{ m/s}$$

$$Q = AV = 25.21 \times 0.80 \text{ m} = 20.25 \text{ m}^3/\text{s}$$

B.10 If all conditions are met, compute for the top width and freeboard

Top Width $T = b + 2zy = 11 + 2 \times 1.5 \times 1.83 = 16.49 \text{ m}$

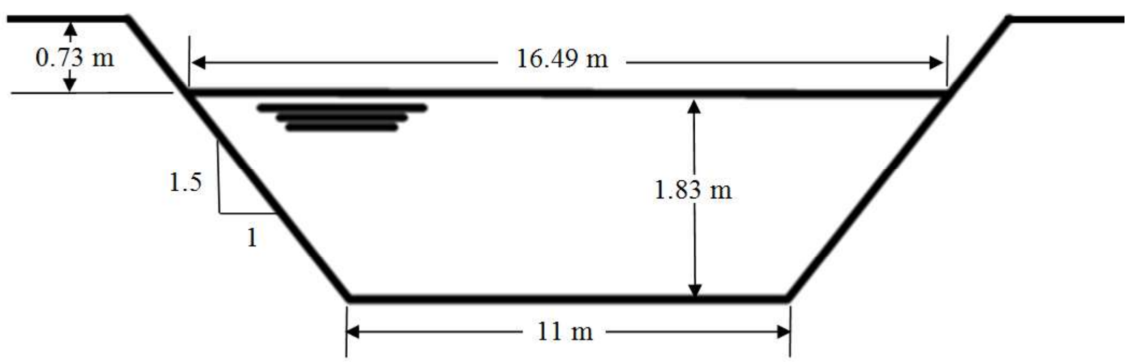
B.11 From section 5.6.2, the freeboard is computed as

From 5.6.2.1 $Fb = 0.4d = 0.4 \times 1.83 = 0.73 \text{ m}$

From 5.6.2.3 $Fb = 0.05d + h_V + (0.05 \text{ m to } 0.15 \text{ m})$
$Fb = 0.05 \times 1.83 + (0.80^2/2 \times 9.81) + 0.10 = 0.22 \text{ m}$

B.12 Take the larger value as freeboard which is 0.73 m.

B.13 The design of the required unlined open channel is shown below.



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