GOVERNMENT OF ORISSA

WORKS DEPARTMENT

ORISSA STATE ROAD PROJECT

FINAL DETAIL ENGINEERING REPORT FOR PHASE-I ROADS

HYDROLOGY REPORT

BHADRAK TO CHANDBALI (0 - 45 km) & BHADRAK TO ANANDPUR (0 - 50 km)

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INTRODUCTION

HYDROLOGICAL STUDIES RELATED TO ORRISA STATE HIGHWAY NET WORK

1. General:

Hydrological inputs play a very vital role in planning, execution and operation of any water related structure. Hydrological studies are carried out at all the stages of project development starting from the pre-feasibility stage and are continued even during operation of the project. A casual approach may lead in extreme case to loss and destruction of structure due to higher flood than the expected floods; where as over-designed structure may lead to very costly and uneconomical ones Proper selection of design value is of great importance. The Highway net work in a project area crosses a number of rivers/ tributaries / streams / nallahs with small, medium or large catchment and therefore for design of bridges and other structures, hydrological parameters of these structures are essentially required. It is an admitted fact that generally in most of the cases, the river net work does no have sufficient hydrological & meteorological records and most of the structure sites are ungauged. Though for determination of waterway, design flood at desired frequency for such structures are required, but economic constraints do not justify detailed hydrological and meteorological investigations at every such site on large scale and on long term basis for estimation of design flood with a desired return period. The system need to be based on a specific return period for fixing the water-way vis-à-vis the design highest flood level (HFL) and foundation depth of structure depending upon their life and importance to ensure safety as well as economy.

2. Criteria and standards in regard to design flood of structures of small and medium catchments

Khosla Committee of Engineers, appointed by the Government of India, had recommended a design flood of 50-Year return period for fixing the water ways of the structures/bridges. The Committee had also recommended designing the foundation and protection works for larger discharge by increasing the design flood for water ways by 30 % for small catchments and up to 500 Sq. km. by 25 to 20% for medium catchments up to 500 to 5000 Sq.km., by 20 to 10 % for large catchments up to 5000 Sq. km.to 25,000 Sq. km. and by less than 10% for very large catchments above 25,000 Sq. km.IRC 5-1985, clause 103 of Section-I,"General features of design" specifies that the water way of a bridge is to be designed from a maximum flood of 50-Year return period. To provide for adequate margin of safety, the foundation and protection works should be designed for larger discharges. The percentage increase over the design discharge recommended in this code is the same as suggested by the Committee of Engineers.

3. Methods /Models estimation of design flood peak

Depending upon the size of Project catchment, availability of field data and other primary data of Project area and the purpose for which it to be used ,various methods are available for design flood peak estimation such as,

(a) Empirical formulae
(b) Rational formula
(c) Hydro-meteorological model
(d) Statistical methods

3.1 Use of empirical formulae

During the past decade, number of inventers/scientists has evolved many empirical formulae, to be utilized in different zones across the World.I.R.C: SP: 13-2004, though have recommended using empirical formulae like Dicken's, Ryves and Inglis.Wherever hydrological records are inadequate, empirical formulae developed for the region is used. The common type of formula makes the flow function of catchment area i.e.M=C*(M)n. The important formulae used in India are Dicken's, Ryve and Inglis.The exponent 'n' assigned the value of 3/4,2/3 and1/2 respectively in Dicken,Ryve and Inglis formulae. Most popular formula in the region is Dicken's formula and is adopted for catchment area up to 25- 30 sq. Km.

However for small catchment area, the peak flood may be estimated using most popular Dicken's empirical formula can be adopted for catchment area up to 25-30 Sq.Km.

$$Q = C * (M)^{3/4}$$

Where, Q = Peak runoff in cumecs
M = Catchment area in Sq.km.
C= Dicken's constant
= 11-14 where the annual rainfall is 600 mm to 1200 mm
= 14- 19 where the annual rainfall is more than 1200 mm
=22 in Western Ghats

3.2 Rational formulae

The rational formula for assessment of peak discharge from project catchment takes into account rainfall, runoff under various circumstances, time of concentration and critical intensity of rainfall. Basic formulae are as under:

One hour rainfall (I_o), $I_o = (F/T)*(T+1)/(1+1)$

Critical rainfall intensity $I_c = I_o*(2/(1+t_c)$

Discharge $Q=0.028 * P*f* A* I_c$

Time of concentration (SP-13, page 12), $t_c = (0.87*L^3/H)^{0.385}$
Where,
t_c= Time of concentration i.e time taken by runoff from farthest point on the periphery of catchment (hrs)
I_o= One hour rainfall in cm.
I_c= Critical intensity of rainfall in cm per hour

P= Coefficient of runoff for the catchment characteristics
(Ref.Table-4.1, P-13, I.R.C. SP: 13-2004)
A= Catchment area in hectare
Q= Maximum discharge in cumecs.
L= Distance from the critical point to the structure (Length of path) in Km.
H= The difference in level from the critical point to the structure in metre

F= Maximum rain fall in mm
T = Duration of storm in hours
f = A fraction of maximum point intensity at the centre of he storm and related with the catchment area (Determined from Fig.4.2, Page-14, I.R.C.: SP: 13-2004.)

In the present study, storm rainfall and storm duration data of 50 –Year return period have been utilized from design flood hydrograph of near by project sites, developed on the basis of Hydro-meteorological studies as per Flood estimation reports of Mahanadi & Upper eastern coast sub-zones.

3.3 Hydro-meteorological methods-- Use of Unit Hydrograph

3.3.1 General

The regional flood estimation reports under long term plan of 26 Sub-Zones in India are available. The reports pertaining to Orrisa State, of various Corridors which cover under the present consultancy are as under:

(a) Sub-zone-III-d-Mahanadi basin: The sub-zone comprises of Mahanadi, Mahanadi and Baitarani are peninsular rivers, out falling into Bay of Bengal. The basin boundaries are located between
Longitudes 80 0 25 ‘to 87 0 East and Latitudes 19 0 to 23 0 35 ‘North.

(b) Sub-zone- IV-a- Upper Eastern coast: This sub-zone comprises of east flowing coastal rivers between deltas of Mahanadi and Godavari rivers. The Godavari delta falls in the sub-zone. A part the Sub-Zone lies in the Orrisa State approximately in between
Longitudes 84 0 to 85 045‘East and Latitudes 18 0 30’ to 20 0 05 ‘.North

These reports have been formulated as a joint venture by the Ministry of Water resources through Central Water Commission, Research, and Designs & Standards Organization (RDSO) of Ministry of Railways, Ministry of Shipping & Transport (MOST) and India Meteorological Department (IMD) of Government of India.

The approach consists of working out regional Synthetic Unit hydrograph (SUG) parameters with pertinent physiographic characteristics from the recommended formulae in the particular Sub Zone flood estimation report, drawing and adjusting SUG , computation of design storm duration and point rainfall & areal rainfall, distribution of areal rainfall during design storm duration to obtain rainfall increments for unit duration intervals, assessment of effective rainfall units after subtraction of prescribed loss rate from rainfall increments ,estimation of hourly rainfall excess

,estimation of base flow and computation of 50-year peak flood and 50-year design flood hydrograph.

3.3.2 Approach for development of flood hydrograph (on regional basis)

3.3.2.1 Determination of physiographic parameters

Step 1: Preparation of Catchment area plan
The structure site point under study is located on the Survey of India map (G.T. sheet) and catchment/water shed boundary is marked.

Step 2: Determination of physiographic parameters from catchment area plan:
(i) Catchment area: **(A):** The area enclosed in the catchment area boundary up to structure site is referred as the catchment area and measured.

(ii) Length of longest stream (L): Length of the longest main stream in Km. from the farthest point of catchment /water shed boundary to the point of study of structure site is marked and measured on catchment area plan.

(iii) Length of the longest main stream (L_c): From a point opposite/near to centre of gravity of catchment to point of study

(iv) Centre of gravity of catchment area: Determination of center of gravity of the catchment.

(v) Stream slope: Equivalent stream slope (S_{eq}): Equivalent slope can be computed by the formula: Longitudinal section is broadly divided into 3 to 4 segments and the following formula is used to calculate the Equivalent slope of main stream.

$$S_{eq} = \frac{\Sigma L_{I} * [\, D_{I} - D_{i-1} \,]}{L^2}$$

Where, L_i = Length of the ith segment in Km.

D_I, D_{i-1} = Heights of successive bed location at the contour points and intersections (Elevations of the river/nallah bed at ith intersections points of contours are reckoned from the bed elevation at the point of study point/structure site considered as datum)

L = Length of the longest main stream, Km.

3.3.2.2 Determination of Synthetic Unit graph parameters

Step-3: The following SUG relationships are used to compute 1-hour SUG parameters for each structure site of different sub-zones pertaining to Orrisa State.

Recommended relations for determination of Synthetic Unit Hydrograph
(a) Synthetic relation between basin lag tp and physiographic parameters: tp-Time from the centre of unit rainfall duration to the peak of unit hydrograph in hours, tp =a1*[(L*Lc)* (S)1/2]b1

(b)Synthetic relation between unit peak rate (qp) of the unit hydrograph and basin lag (tp): qp- Peak discharge of unit hydrograph per unit area in cmecs./Sq.Km, qp =a2 / (tp) b2

(c) Qp-Peak discharge of unit hydrograph in cumecs. = qp *A

(d) Synthetic relation between unit discharge (qp) and W50- Width of unit graph measured in hours at discharge ordinate equal to 50 % of Qp , W50 =a3 / (qp)b3

(e) Synthetic relation between unit discharge (qp) and W75- Width of unit hydrograph measured in hours at discharge ordinate equal to 75 % of Qp, W75 =a4 / (qp)b4

(f) Synthetic relation between unit discharge (qp) and WR-50- Width of the rising limb side of unit hydrograph measured in hours at discharge ordinate equal to 50% of Qp, WR-50 =a5 / (qp) b5

(g) Synthetic relation between unit discharge (qp) and WR-75-Width of the rising limb side of unit hydrograph measured in hours at discharge ordinate equal to 75 % of Qp , WR-75 = a6 / (qp) b6

(h) Synthetic relation between the basin lag (tp) and base width of unit hydrograph-TB –Base width of unit hydrograph in Hours, TB = a7 *(tp) b7

(i) Tm- Time from start of rise to the peak of the unit hydrograph in hours = tp + tr / 2

(j) TD- Design storm duration in hours = 1.

Values of constants ‘a ‘ and ‘b ‘ for various Synthetic hydrograph parameters are as under

S.No.	Unit hydrograph Parameter	Mahanadi basin-III(d)	Upper Eastern Coast-VI(A)
(1)	(2)	(3)	(4)
1	t_r	1	1
2	t_{p} – a_1	1.757	0.376
	-b_1	0.261	0.434
3	q_p - a_2	1.260	1.215
	- b_2	0.725	0.691
4	W_{50} -- a_3	1.974	2.211

	-- b_3	**1.104**	**1.070**
5	**W_{75} -- a_4**	**0.961**	**1.312**
	-- b_4	**1.125**	**1.003**
6	**W_{R-50}- a_5**	**1.150**	**0.808**
	- b_5	**0.829**	**1.053**
7	**W_{R-75}- a_6**	**0.527**	**0.542**
	- b_6	**0.932**	**0.965**
8	**T_B - a_7**	**5.411**	**7.621**
	- b_7	**0.826**	**0.623**
9	**T_m**	**t_p + tr/2**	**t_p + tr/2**
10	**Q_p**	**A * q_p**	**A * q_p**
11	**T_D**	**1.1*t_P**	**1.1*t_P**

Step-4-The steps for derivation of 1-hour unit graph are as under

(i) Obtain unit graph parameters viz. t_p, q_p, W_{50}, W_{75}, W_{R-50}, W_{R-75} and T_B by substituting appropriate basin/unit graph parameters given in the above equation.

(ii) The above estimated parameters of unit graph are plotted on a natural graph paper and the plotted points are joined to draw synthetic unit graph. Suitable adjustment is made to ensure that volume of unit graph is 1 cm. depth of effective rainfall over the catchment.The discharge ordinates (Qi) of the unit graph at ti=tr =1 hr interval is summed up i.e. $\sum$ Qi * ti (cumecs./hr.) and compared with the volume of 1.0 cm. direct runoff depth over the catchment with the formula . $\sum Qi * t_i = 2.78*A*d / t_i$

Where, A= Catchment area in Sq.Km.
d=1.0 cm. depth
$t_i = t_r$ (the unit duration of the UG) =1.0 hr.
$\sum Q_i * t_i = A*d / 0.36 * t_r = A*1 / 0.36*1$ (cumecs./ hr.)

In case the $\sum$ Qi * ti for the unit graph drawn is higher or lower than the volume worked out by the above formula ,then the falling limb and / or rising limb(preferably falling limb) may be suitably modified to get the correct volume under the hydrograph, taking care not to disturb the smooth shape of the unit graph.

3.3.2.3 Step 5: Design loss rate: The loss rate is an index of all the hydrologic abstractions like infiltration and evapotranspiration etc. Different loss rate and procedures are applicable for different sub-zones:

(a) For Mahanadi sub basin –Sub-zone -III-d: Estimation of loss rate for this sub zone is calculated as per the prescribed design loss rate curve. With t_p less than 5 hours, design loss rate of 0.26 cm. /hour is recommended. Between storm durations of 5 to 13 hours, the loss rates vary between 0.26 cm. / hr to 0.15 cm. / hr.For a storm duration of more than 13 hours, it remains constant at 0.15 cm. /hour.

(b) For Eastern coast region sub-zone-IV-a: Design loss rate of 0.75 cm /hour is recommended for adoption in this sub-zone.

3.3.2.4 Step-6 -Design Base flow: The base flow is separated through the normal procedure to obtain direct run off hydrograph and direct runoff depth over the catchment for each flood event.

(a) For Mahanadi sub basin (III-d): Estimation of design base flow for this sub zone is recommended to calculate at the rate of 0.10 cumecs./ Sq.Km.

(b) For eastern Coast region sub-zone-IV-a: The base flow q_b in cumecs./Sq.Km. is calculated for this sub-zone : $q_b = 0.536 / (A)^{0.523}$

3.3.2.5 Procedure for estimation of design storm rainfall: The areal distribution and time distribution of rainfall of a given duration are two main meteorological factors deciding the design flood peak and the shape of the hydrograph. This input has to be converted into effective rainfall and applied to the transfer function (Synthetic unit hydrograph) to obtain the response (flood hydrograph).

(a) Isopluvial maps:.. The isopluvial maps of 50- Year, 24- hour rainfall are available, which can be used to derive 24-hour rainfall estimates for 50-year return period at any desired location in the sub-zone

Procedure: Locate project site / structure site, with the help of their Latitude and Longitude, under study on 50-Year, 24-hour isopluvial map and obtain the 50-Year, 24-hour point rainfall value in cm. For a catchment covering more than one isopluvial, compute the average point rainfall.

(b) Short duration ratios:.

Procedure- Read the conversion ratio for particular storm duration T_D from the available Table/Figure and multiply the 50-Year .24-hour point rain fall values in Step 8 (a) to obtain 50-Year T_D hour point rainfall.

(c) Areal reduction factor (ARF):

Procedure-Read the areal reduction factor corresponding to storm duration T_D and the given catchment area of Project site in the available Table / Figure and multiply the 50- Year, T_D-hour rainfall in Step-8(b) by this factor to obtain the 50-Year , T_D-hour areal rain fall over the catchment.

(d) Time distribution factor:.

Procedure- Read the time distribution co-efficients for 1,2,-------(T_D-1) hours corresponding to storm duration T_D from the relevant graph/Table and multiply the 50- Year T_D-hour areal rainfall in Step -8(C) by these coefficients to obtain cumulative depths of 1, 2,------(T_D-1) hour catchment rainfall.

(e) Depth of storm rainfall -Obtain the depths of storm rain fall occurring every hour in the structure site catchment by subtracting (d) of the successive depths of 1,2 ,-------(T_D-1) and T_D hours in Step -8(d).

3.3.2.6 Estimation of design flood:

Step-9-Effective rain fall increments:

i. Obtain design storm rain fall and hourly areal rain fall units as per Step-8(e).

ii. Obtain hourly effective rainfall increments by subtracting the design loss rate.

Step-10: Estimation of 50-yr. flood (Peak only):

i. Arrange 1-hour effective areal rainfall values against the 1-hour Unit graph ordinates such that the maximum value of effective rainfall is positioned against the maximum ordinate of Unit graph, the next lower of effective rainfall against the next lower Unit graph ordinate and so on up to TD hour duration.

ii. Obtain the base flow for the catchment area under study.

iii. Obtain total surface runoff by summing the product of unit hydrograph ordinate and the effective rainfall increments give the total direct run-off peak.

(iv)By adding base flow, 50-year flood peak is obtained.

3.3.2.7 Design flood hydrograph:

Step-11: Computation of design flood hydrograph:

For computation of design flood hydrograph, carry out the following additional steps;

iv. Reverse the sequence of effective rainfall units obtained in the above step-10(i) to get the critical sequence of the effective rainfall units.

v. Multiply the first 1-hour effective rainfall with the ordinates of Unit graph to get the corresponding direct run off ordinate. Like wise, repeat the procedure with the rest of the hourly effective rainfall values giving a lag of 1-hour to successive direct runoff ordinate.

vi. Add the direct runoff ordinates at 1-hour interval to get the total direct runoff hydrograph.

vii. Add the base flow to the direct runoff ordinates at 1-hour interval to get 50-Year flood hydrograph.

4.0 Linear Water way of the bridge

4.1 The linear water way/regime width (W) of a bridge across a purely alluvial stream in regime state according to Lacey's formula,

$W = C (Q)^{1/2}$

Where, W= Liner water way in metre
C = A coefficient varying according to local conditions, the usual value adopted being 4.5 to 6.3 (for regime channel). I.R.C.-13 recommends to adopt value of C = 4.8
and Q = Design flood discharge in cumecs.

4.2 Criteria and standard for design flood: Indian Road Congress (I.R.C-5) specifies * That water way for a highway bridge needs to be designed for a maximum peak flood discharge of 50-year return period.

* Foundation and protection works of the structure should be designed for larger discharge by increasing design flood

a) Waterways may be increased by 30% to 25% for small catchments up to 500 sq.km

b) Waterways may be increased by 25% to 20% for medium catchments up to 500 to 5000 sq.km.

c) Waterways may be increased by 20% to 10% for large catchments up to 5000 to 25000 sq.km. and

d) Waterways may be increased by 10% for very large catchments, above 25000 sq.km.

4.3 Scour depth:
As per I.R.C.:78-2000, Clause: 703.1.1
Scour depth in metre,

$$d_{sf} = 1.34 * [(D_b)^2] / (K_{sf})^{1/3}$$

D_b= Unit discharge in cu.mecs/ metre
Q_R= Total discharge in cu.mecs

Design discharge per metre width at effective linear water way over scourable bed
D_b = Increase design discharge (Q_R) /Regime width (W)

4.4 Silt factor: For the regime characteristics of an alluvial channel, Lacey suggested a silt factor and its value depends upon the size and looseness of the grains of the alluvium. The value of silt factor (K_{sf}) is given by the relation,

$K_{sf} = 1.76 (d_m)^{1/2}$
Where, d_m is the weighted mean diameter of the particles in mm.

In design calculations value of silt factor based on geotechnical investigation of a particular or near by site by taking value at average depth has been considered.

4.5 Regime velocity of flow: $V = 0.44 * (Q)^{1/6} / (K_{sf})^{1/3}$

4.6 Maximum scour depth: The maximum depth of scour below the highest flood Level (HFL) at obstructions and configurations of the channel should be estimated from the value of 'd_{sf}'on the following basis:

(a) For the design of piers and abutments located in a straight reach and having individual foundations without any floor protection works

(i) In the vicinity of piers = 2.0 * dsf

(ii) Near abutments = 1.27 * dsf

4.7 Vertical clearance and other parameters as per I.R.C. standard

Discharge in cumecs.	Vertical clearance / Free board (metre)
Below 0.30	0.15
0.30 -- 3.00	0.30
3.00 –30.0	0.60
30.0—300.0	0.90
300.0—3,000.0	1.20
Above 3,000.0	1.50

4.8 Manning's formula: For estimation of design flood based on field data, knowing the slope of the stream (S) , Velocity as per Manning's formula is given by the relation,

Velocity of flow in a channel

$$V = 1 / \eta * (R)^{2/3} * (S)^{1/2}$$

Where, V = Mean velocity of flow in m/sec.

R= Hydraulic radius in metre = A/P,

A = Water area i.e. area of flow in Sq.m.

P =Wetted perimeter in metre

S = Slope of the energy line (When flow is uniform, energy slope gradient may become parallel to the water surface slope and bed of the channel)

η = Coefficient of roughness

Discharge, $Q = A* V$, in cumecs.$= A * 1 / \eta * (R)^{2/3} * (S)^{1/2}$

$= 1 / \eta * W *(R)^{2/3} * (S)^{1/2}$

$R = A/P$

$Q = A * (A/P)^{2/3} * [1 / \eta * (S)^{1/2}]$

or $Q =1 / \eta * (S)^{1/2}* [(A)^5 /(P)^2] ^{1/3}$

Knowing Q, W and S, D can be calculated.

4.9 Afflux: When a bridge is constructed across a contracted stream, water on the upstream will rise up. Afflux is the rise or heading up of water level, above the normal, on the upstream side of a structure caused by an obstruction across the channel (abutments and piers of structure). Since the downstream depth is not affected by the bridge, as the same is governed by the hydraulic characteristics (conveyance factor and slope of the channel below the bridge), of the downstream channel, it can be safely assumed that the upstream depth which prevailed before the bridge construction is the same as the downstream depth (D_d) that prevails after the bridge construction. Hence, D_d is the depth that prevailed at bridge site before the

construction of the bridge. To estimate, it is essential to know D_d. This can be calculated by the hydraulic parameters of the channel.

4.9.1 Broad Crested Weir formula:

$Q = 1.706 * C_w * L * H^{3/2}$

Where, Q =Discharge through the opening in cumecs.

C_w = Coefficient of discharge accounting for losses in friction.

L = Linear water way in metre

H = Total energy head upstream of the obstruction in metre = $D_u + V^2 / 2 * g$

D_u = Depth of flow upstream in metre

$V^2 / 2 * g$ = Velocity head, where V is the average velocity in the approach section worked out from the known width (W) of the unobstructed section.

W = Width of unobstructed section

So long as the afflux (D_u-D_d) is not less than 1/4 *D_d , Weir formula is applies ,i.e. Q depends on D_u and independent of D_d. The fact that the downstream depth D_d has no effect on the discharge Q , nor on the upstream depth D_u when the afflux is not less than 1/4*D_d is due to the formation of the standing wave.

4.9.2 Orifice formula: When the downstream depth is more than 80 % of the upstream depth i.e. the afflux is less than 1/4D_d , the weir formula is not valid as the performance of the Bridge opening gets affected by the downstream depth(D_u). In such a case, the discharge can be calculated by using the Orifice formula given by the relation,

$Q = C_0 *(2 * g)^{1/2} * L * D_d * [h + (1+e)* V^2 / 2 * g]^{1/2}$

Where, Q = Discharge through the opening in cu.mecs.

C_0= Coefficient of discharge

g = Acceleration due to gravity

L = Linear water way in metre

D_d = Depth downstream of the obstruction in metre

h = Afflux in metre

e = A factor accounting for recovery of some velocity as potential head on emergence from the cross drainage openings, and V = Average velocity in approach section in metre/sec.

The value of 'C_0 'and 'e 'to be adopted are given in I.R.C .The afflux can be calculated knowing (i) Discharge, (ii) the unobstructed width of the stream and (iii) the average depth downstream of the cross drainage work opening.

5.0 Present study: Detailed hydrological studies of bridge structures located on Bhawanipatna-Kheriar, State Highway-16 has been carried out. Physiographic parameters of various structure sites have assessed on the basis of G.T. sheets of the area as available on scale 1: 50,000 & 1: 2, 50,000.Inputs in the study includes the

field surveys data, road inventory records, geo-technical investigations and informations gathered during field visit. Presently this corridor has 14 minor bridges at independent locations, one major bridge on river Sunder and one major bridge on river Tel including another five minor bridges at nearby locations on Tel River. Design discharge at each structure site has been estimated through various available approaches. Use of IRC-5-1998, IRC-SP-13-2004, I.R.C-78- 2000 and Regional Hydro meteorological Flood Estimation Reports prepared by Hydrology Organization, Central Water Commission, Government of India for Mahanadi Subzone-3(d) and East Coast region Sub-Zone Report-4(a).The detailed hydrological parameters of various structures are given in the report.

(BHADRAK TO CHANDBALI,SH-9) (0 TO 45 km)

CHAPTER-1

BRIDGE AT CH:1/005

1. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1 Name of the Nala : 2. No. polo

Road No :	S.H - 9
G.T S No :	73K
Nearest Village :	Bhadrak
RD :	Km.1.005
Latitude	21^0 4' 00"
Longitude	86^0 31' 00"
Sub-Zone	3(d)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (Refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted	(Since Rain fall is more than 120 cm)	19
M = Catchment area		0.230 sqkm
Q =		6.31 cum/s

3 Discharge by Rational Formula

Catchment area		0.230 sqkm	23.00 hectares
Length of path from toposheet (L)			1.500 km
Difference in levels from toposheet (H)			10 m
(Ref: Index map)			
Maximum rain fall (F)	(Ref. SUG of Nanojora River)		216.05 mm
Duaration of storm (T)			5 hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)		129.63 mm/hr
Time of concentration (SP-13, Page 12)	$tc = (0.87*L^3/H)^{0.385}$		0.62 hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)			159.65 mm/hr
Discharge Q = 0.028 * P*f* A* Ic			
P = (for loam, lightly cultivated or covered)			0.400
f =			1.00
A =			23.00 Hectares
Ic =			15.965 cm/hr
Q =			4.113 cum/sec

Here,

t_c= Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchment

I_o= One hour rainfall in cm.

I_c= Critical intensity of rainfall in cm per hour

P = Coefficient of runoff for the catchment characteristics (Ref.Table-4.1P-13,SP:13-2004)

A = Catchment area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in metre

4 Design Discharge (Refer SP-13, page 21)

Discharge by Dicken's Formula		6.31 cum/sec
Discharge by Rational Formula		4.11 cum/sec
Maximum discharge		6.31 cum/sec
Next maximum discharge		4.11 cum/sec
Hence design discharge		**6.17 cum/sec**

5 Linear Water Way

Regime width $W = 4.8*Q^{1/2}$ 11.92 m

(Refer IRC:5-1998, Clause 104.3 or SP-13, Page 23)

6 Span arrangement

In proposed span arrangement, triple cell of 3.0 m has been proposed 9.00 m

with bed protection.

7 Scour depth

Increase in design discharge, as per IRC:78-2000,Clause 703.1.1 30%

Increased design discharge 8.02 cum/sec

Mean depth of scour, as per IRC:78-2000, Clause 703.2

$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width		0.89 cum/sec/m
K_{sf} = Silt factor		2.09
d_{sf} =		0.97

Maximum scour depth, as per IRC:78-2000, Clause 703.3

for Pier	2 d_{sf}	1.94 m
for Abutment	1.27 d_{sf}	1.23 m

8 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point

0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.6 m

9 Deck level

HFL at existing bridge site	17.770 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600 m
Depth of super structure including camber	0.450 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	18.876 m
Deck level of the existing bridge	18.070 m
Minimum deck level proposed	18.876 m

As per the proposed allignment, the formation level of bridge has been kept as 18.97 m

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	6.17	cum/sec
HFL	17.770	m
Bed level	16.061	m
Maximum scour depth	1.94	m
Maximum scour level	15.829	m

Curtain wall shall be provided below maximum scour level

Bed level	16.061	m
Scour depth below bed	0.23	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	2.0	m
	d/s	2.5	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	0.46	3.0	m
	d/s	6.0	0.46	6.0	m

CHAPTER-2

BRIDGE AT CH:1/800

2. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1 Name of the Nala : 3. No. polo

Road No.:	S.H - 9
G.T S No :	73K
Nearest Village :	Bhadrak
RD :	Km.1.800
Latitude	21^0 3' 00"
Longitude	86^0 31' 00"
Sub-Zone	3(d)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted	(Since Rain fall is more than 120 cm)	19
M = Catchment area		0.225 sqkm
Q =		6.21 cum/s

3 Discharge by Rational Formula

Catchment area	0.225 sqkm	22.50 hectares
Length of path from toposheet (L)		1.500 km
Difference in levels from toposheet (H)		10 m
(Ref: Index map)	(Ref. SUG of Nanojora River)	
Maximum rain fall (F)		216.05 mm
Duaration of storm (T)		5 hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)	129.63 mm/hr
Time of concentration (I.R.C. SP-13, Page 12)	$tc = (0.87*L^3/H)^{0.385}$	0.62 hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		159.65 mm/hr

Discharge Q = 0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)	0.400
f =	1.00
A =	22.50 Hectares
Ic =	15.965 cm/hr
Q=	4.023 cum/sec

Here,

t_c= Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchment

I_o= One hour rainfall in cm.

I_c= Critical intensity of rainfall in cm per hour

P = Coefficient of runoff for the catchment characteristics (Ref.Table-4.1P-13,I.R.C.:SP:13-2004)

A = Catchment area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in metre

4 Design Discharge (Refer I.R.C.SP-13, page 21)

Discharge by Dicken's Formula	6.21 cum/sec
Discharge by Rational Formula	4.02 cum/sec
Maximum discharge	6.21 cum/sec
Next maximum discharge	4.02 cum/sec
Hence design discharge	**6.03 cum/sec**

5 Linear Water Way

Regime width $W=4.8*Q^{1/2}$ 11.79 m

(Refer IRC:5-1998, Clause 104.3 or SP-13, Page 23)

6 Span arrangement

In proposed span arrangement, triple cell of 3.0 m has been proposed with bed protection. 9.00 m

7 Scour depth

Increase in design discharge, as per IRC:78-2000,Clause 703.1.1 30%

Increased design discharge 7.85 cum/sec

Mean depth of scour, as per IRC:78-2000, Clause 703.2

$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width	0.87 cum/sec/m
K_{sf} = Silt factor	1.750
d_{sf} =	1.01

Maximum scour depth, as per IRC:78-2000, Clause 703.3

for Pier	$2\ d_{sf}$	2.03 m
for Abutment	$1.27\ d_{sf}$	1.29 m

8 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.6 m

9 Deck level

HFL at existing bridge site including	16.306 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600 m
Depth of super structure including camber	0.450 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	17.412 m
Deck level of the existing bridge	17.730 m
Minimum deck level proposed	17.730 m

As per the proposed alignment,the formation level of bridge has been hept as 17.73 m

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	6.03	cum/sec
HFL	16.306	m
Bed level	14.700	m
Maximum scour depth	2.03	m
Maximum scour level	14.277	m

Curtain wall shall be provided below maximum scour level

Bed level		14.7	m
Scour depth below bed		0.42	m
Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	2.0	m
	d/s	2.5	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	0.85	3.0	m
	d/s	6.0	0.85	6.0	m

CHAPTER-3

BRIDGE AT CH:3/200

3. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1 Name of the Nala : 6. No. Bridge

Road No.:	S.H - 9
G.T S No :	73K
Nearest Village :	Mirjapur
RD :	Km.3.200
Latitude	21^0 3' 00"
Longitude	86^0 31' 30"
Sub-Zone	3(d)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (Refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted	(Since Rain fall is more than 120 cm)	19
M = Catchment area		2.200 sqkm
Q =		34.32 cum/s

3 Discharge by Rational Formula

Catchment area		2.200 sqkm	220.00 hectares
Length of path from toposheet (L)			1.200 km
Difference in levels from toposheet (H)			10 m
(Ref: Index map)			
Maximum rain fall (F)	(Ref: SUG of Nanojora River)		216.05 mm
Duaration of storm (T)			5 hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)		129.63 mm/hr
Time of concentration (I.R.C. SP-13, Page 12)	$tc = (0.87*L^3/H)^{0.385}$		0.48 hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)			174.92 mm/hr

Discharge Q = 0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)		0.400
f =		1.00
A =		220.00 Hectares
Ic =		17.492 cm/hr
Q=		43.101 cum/sec

Here,

t_c= Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchment

I_o= One hour rainfall in cm.

I_c= Critical intensity of rainfall in cm per hour

P = Coefficient of runoff for the catchment characteristics (Ref.Table-4.1P-13,I.R.C.:SP:13-2004)

A = Catchment area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in metre

4 Design Discharge (Refer I.R.C.SP-13, page 21)

Discharge by Dicken's Formula	34.32 cum/sec
Discharge by Rational Formula	43.10 cum/sec
Maximum discharge	43.10 cum/sec
Next maximum discharge	34.32 cum/sec
Hence design discharge	**43.10 cum/sec**

5 Linear Water Way

Regime width $W=4.8*Q^{1/2}$ 31.51 m

(Refer IRC:5-1998, Clause 104.3 or SP-13, Page 23)

6 Span arrangement

In proposed span arrangement, double cell of 8.0 m has been proposed with bed protection. 16.00 m

7 Scour depth

Increase in design discharge, as per IRC:78-2000,Clause 703.1.1 30%

Increased design discharge 56.03 cum/sec

Mean depth of scour, as per IRC:78-2000, Clause 703.2

$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width 3.50 cum/sec/m

K_{sf} = Silt factor 1.676

d_{sf} = 2.60

Maximum scour depth, as per IRC:78-2000, Clause 703.3

for Pier	$2\ d_{sf}$	5.20 m
for Abutment	$1.27\ d_{sf}$	3.30 m

8 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.9 m

9 Deck level

HFL at existing bridge site	16.765 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.900 m
Depth of super structure including camber	0.400 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	18.121 m
Deck level of the existing bridge	16.765 m
Minimum deck level proposed	18.121 m

As per the proposed allignment, the formation level of bridge has been kept as 18.24 m

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	43.10	cum/sec
HFL	16.765	m
Bed level	13.844	m
Maximum scour depth	5.20	m
Maximum scour level	11.562	m

Curtain wall shall be provided below maximum scour level

Bed level	13.844	m
Scour depth below bed	2.28	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	3.0	m
	d/s	3.5	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	4.56	5.0	m
	d/s	6.0	4.56	6.0	m

CHAPTER-4

BRIDGE AT CH:3/900

4. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1 Name of the Nala : Haladia Bypass Bridge

Road No.:	S.H - 9
G.T S No :	73K
Nearest Village :	Haladia
RD :	Km.3.900
Latitude	21^0 2' 00"
Longitude	86^0 31' 00"
Sub-Zone	3(d)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (Refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted	(Since Rain fall is more than 120 cm)	19
M = Catchment area		2.5 sqkm
Q =		37.78 cum/s

3 Discharge by Rational Formula

Catchment area		2.500 sqkm	250.00 hectares
Length of path from toposheet (L)			3.750 km
Difference in levels from toposheet (H)			5 m
(Ref: Index map)			
Maximum rain fall (F)	(Ref.SUG of Nanojora River)		216.05 mm
Duaration of storm (T)			5 hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)		129.63 mm/hr
Time of concentration (I.R.C. SP-13, Page 12)	$tc = (0.87*L^3/H)^{0.385}$		2.35 hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)			77.45 mm/hr

Discharge Q = 0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)	0.400
f =	1.00
A =	250.00 Hectares
Ic =	7.745 cm/hr
Q =	21.69 cum/sec

Here,

t_c= Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchment

I_o= One hour rainfall in cm.

I_c= Critical intensity of rainfall in cm per hour

P = Coefficient of runoff for the catchment characteristics (Ref.Table-4.1P-13,I.R.C.:SP:13-2004)

A = Catchment area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in metre

4 Design Discharge (Refer I.R.C.SP-13, page 21)

Discharge by Dicken's Formula	37.78 cum/sec
Discharge by Rational Formula	21.69 cum/sec
Maximum discharge	37.78 cum/sec
Next maximum discharge	21.69 cum/sec
Hence design discharge	**32.53 cum/sec**

5 Linear Water Way

Regime width $W=4.8*Q^{1/2}$ 27.38 m

(Refer IRC:5-1998, Clause 104.3 or SP-13, Page 23)

6 Span arrangement

In proposed span arrangement, double cell of 8.0 m has been proposed with bed protection. 16.00 m

7 Scour depth

Increase in design discharge, as per IRC:78-2000,Clause 703.1.1 30%

Increased design discharge 42.29 cum/sec

Mean depth of scour, as per IRC:78-2000, Clause 703.2

$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width	2.64 cum/sec/m
K_{sf} = Silt factor	2.05
d_{sf} =	2.02

Maximum scour depth, as per IRC:78-2000, Clause 703.3

for Pier	2 d_{sf}	4.03 m
for Abutment	1.27 d_{sf}	2.56 m

8 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point of deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.9 m

9 Deck level

HFL at existing bridge site inculding afflux	14.953 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600 *m
Depth of super structure including camber	0.400 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	16.009 m
Deck level of the existing bridge	15.878 m
Minimum deck level proposed	16.009 m

* Min. vertical clearance has been kept as 0.6 m as Discharge is just exceeding 30.0 cum/sec.

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	32.53	cum/sec
HFL	14.953	m
Bed level	13.467	m
Maximum scour depth	4.03	m
Maximum scour level	10.922	m

Curtain wall shall be provided below maximum scour level

Bed level	13.467	m
Scour depth below bed	2.55	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	3.5	m
	d/s	4.0	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	5.09	5.5	m
	d/s	6.0	5.09	6.0	m

CHAPTER-5

BRIDGE AT CH:6/050

5. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1 Name of the Nala : Kala Polo
Road No.: S.H - 9
Km : Km 6.050

This bridge is across the irrigation canal. Hence there is no need of hydraulic calculations.
This bridge has been retained.

CHAPTER-6

BRIDGE AT CH:9/200

6. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1 General details

Name of the Nala :	Kundi Polo - 1
Road No.:	S.H - 9
G.T S No :	73K/4
Nearest Village :	-
RD :	Km.9.200
Latitude	21^0 2' 00"
Longitude	86^0 31' 30"
Sub-Zone	3(d)

2 Discharge by Manning's Formula

HFL at proposed bridge site	10.294	m

Cross-section of the stream at different locations are as follows

Discharge by Manning's Formula at U/S location

HFL at proposed bridge site	10.294	m
Cross-section of the stream at different locations are as follows		
Cross-sectional area of flow	23.20	sqm
Width of flow	21.00	m
Wetted perimeter perpendicular to direction of flow	21.19	m
Hydraulic mean radius R = A/P	1.09	m
Longitudinal slope as calculated	0.0019	m per m
Velocity by Manning's formula		
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n =	0.06	
Velocity V =	0.772	m/s
Discharge Q = A*V	17.90	cum/s

Discharge by Manning's Formula at existing location

Cross-sectional area of flow	15.21	sqm
Width of flow	18.00	m
Wetted perimeter perpendicular to direction of flow	18.07	m
Hydraulic mean radius R = A/P	0.84	m
Longitudinal slope as calculated	0.0069	m per m
Velocity by Manning's formula		

$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)

For sluugish type bed (Table 5.1)

n =	0.06	
Velocity V =	1.234	m/s
Discharge Q = A*V	18.78	cum/s

Discharge by Manning's Formula at D/S location

Cross-sectional area of flow	30.90	sqm
Width of flow	24.00	m
Wetted perimeter perpendicular to direction of flow	24.14	m
Hydraulic mean radius R = A/P	1.28	m
Longitudinal slope as calculated	0.0021	m per m

Velocity by Manning's formula

$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)

For sluugish type bed (Table 5.1)

n =	0.06	
Velocity V =	0.901	m/s
Discharge Q = A*V	27.83	cum/s

The hydrological calculations has been done at three sections I.e. at upstream side, downstream side and near existing bridge location

By comparision of upstream and downstream side and Existing bridge location.

The design discharge may be taken as **18.78 cum/s**

3 Discharge by Dicken's Formula

Discharge as per Dicken's formula (Refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted (Since Rain fall is more than 120 cm)	19	
M = Catchment area	1.075	sqkm
Q =	**20.06**	**cum/s**

4 Discharge by Rational Formula

Catchment area	1.075 sqkm	107.50	hectares
Length of path from toposheet (L)		0.880	km
Difference in levels from toposheet (H)		0.785	m

(Ref: Index map)

Maximum rain fall (F)	(Ref.SUG of Nanojora River)	216.05	mm
Duaration of storm (T)		5	hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)	129.63	mm/hr
Time of concentration (SP-13, page 12)	$tc = (0.87*L^3/H)^{0.385}$	0.90	hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		136.63	mm/hr

Discharge Q = 0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)	0.400	
f =	1.00	
A =	107.50	Hectares
Ic =	13.663	cm/hr
Q =	**16.450**	**cum/sec**

5 Design Discharge (Refer SP-13, page 21)

Discharge by Manning's Formula	18.78	cum/sec
Discharge by Dicken's Formula	20.06	cum/sec
Discharge by Rational Formula	16.45	cum/sec
Maximum discharge	20.06	cum/sec
Next maximum discharge	16.45	cum/sec

The difference is within 50% of the next maximum discharge

Hence design discharge **20.06** **cum/sec**

6 Water Way

Regime width	$W = 4.8Q^{1/2}$	21.50	m

(Refer IRC:5-1998, cl 104.3 or SP-13, page 23)

Provide	Clear span	3	m
	No. of spans	3	no.
	Total waterway provided L	9.00	m

7 Scour depth

Increase in design discharge, as per IRC:78-2000, cl 703.1.1	30%	
Increased design discharge	26.08	cum/sec

Mean depth of scour, as per IRC:78-2000, cl 703.2

$d_{sf} = 1.34\ (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width	2.90	cum/sec/m
K_{sf} = Silt factor	1.0	(Assumed)
Mean depth of scour, d_{sf} =	2.72	m

Maximum scour depth, as per IRC:78-2000, cl 703.3

for Pier	2 d_{sf}	5.45 m
for Abutment	1.27 d_{sf}	3.46 m

8 Deck level

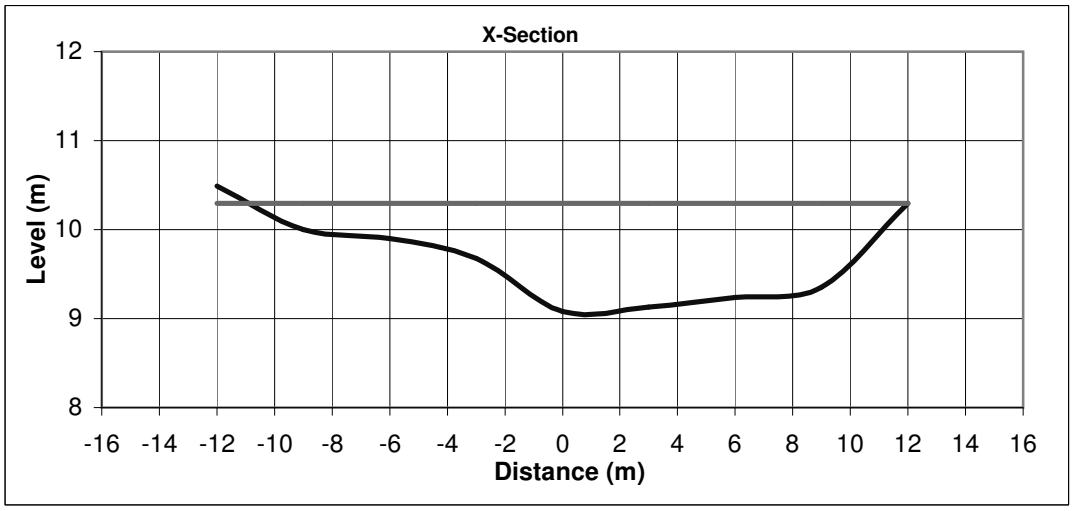
HFL at proposed bridge site including afflux	10.294 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600 m
Depth of super structure	0.450 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	11.400 m
Deck level of the existing bridge	11.769 m
Minimum deck level proposed	11.769 m

As per the proposed allignment, the formation level of bridge has been kept as 11.9 m

Cross-sectional area of nallah at proposed bridge site is as follows:

HFL at this location 10.294 m

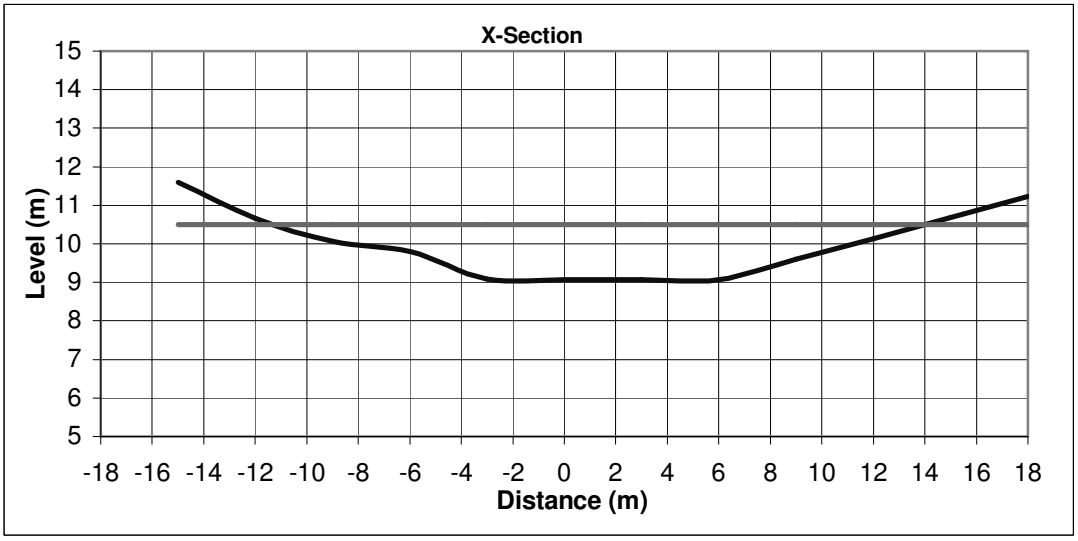
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-12	10.486	10.294					
-9	9.998	10.294	0.296				
-6	9.899	10.294	0.395	0.346	1.037	3.002	3.000
-3	9.675	10.294	0.619	0.507	1.521	3.008	3.000
0	9.079	10.294	1.215	0.917	2.751	3.059	3.000
3	9.129	10.294	1.165	1.190	3.570	3.000	3.000
6	9.236	10.294	1.058	1.112	3.335	3.002	3.000
9	9.352	10.294	0.942	1.000	3.000	3.002	3.000
12	10.298	10.294					
Total					**15.21**	**18.07**	**18.00**



Cross-sectional area of nallah at u/s of the proposed bridge is as follows:

Distance from proposed bridge 110 m
Longitudinal slope u/s side 0.0019
HFL at this location 10.503 m

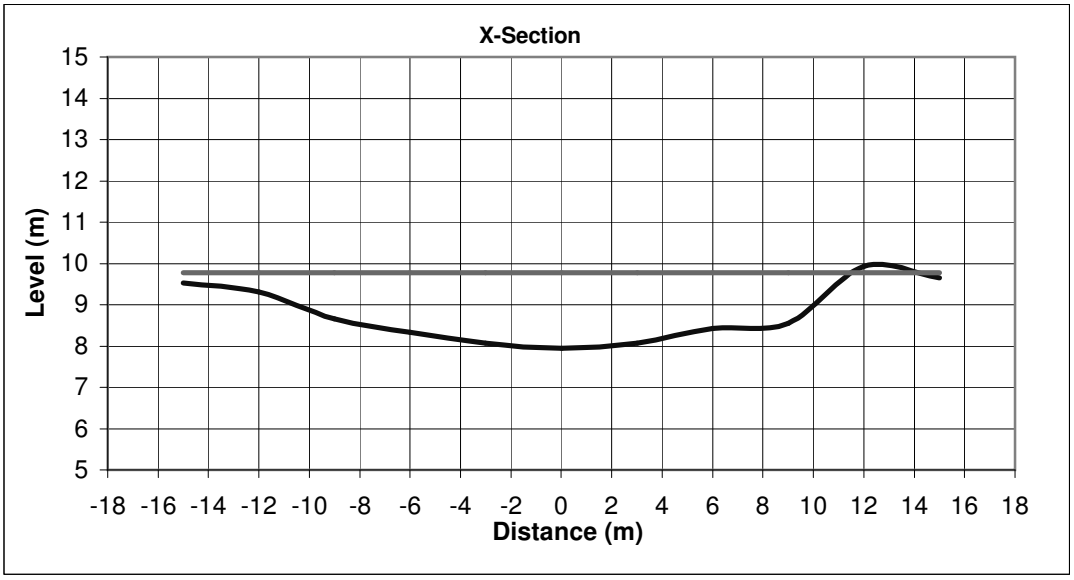
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-15	11.598	10.503					
-12	10.669	10.503					
-9	10.073	10.503	0.430				
-6	9.801	10.503	0.702	0.566	1.698	3.012	3.000
-3	9.08	10.503	1.423	1.063	3.188	3.085	3.000
0	9.074	10.503	1.429	1.426	4.278	3.000	3.000
3	9.063	10.503	1.440	1.435	4.304	3.000	3.000
6	9.063	10.503	1.440	1.440	4.320	3.000	3.000
9	9.603	10.503	0.900	1.170	3.510	3.048	3.000
12	10.135	10.503	0.368	0.634	1.902	3.047	3.000
15	10.685	10.503					
18	11.235	10.503					
Total					**23.20**	**21.19**	**21.00**



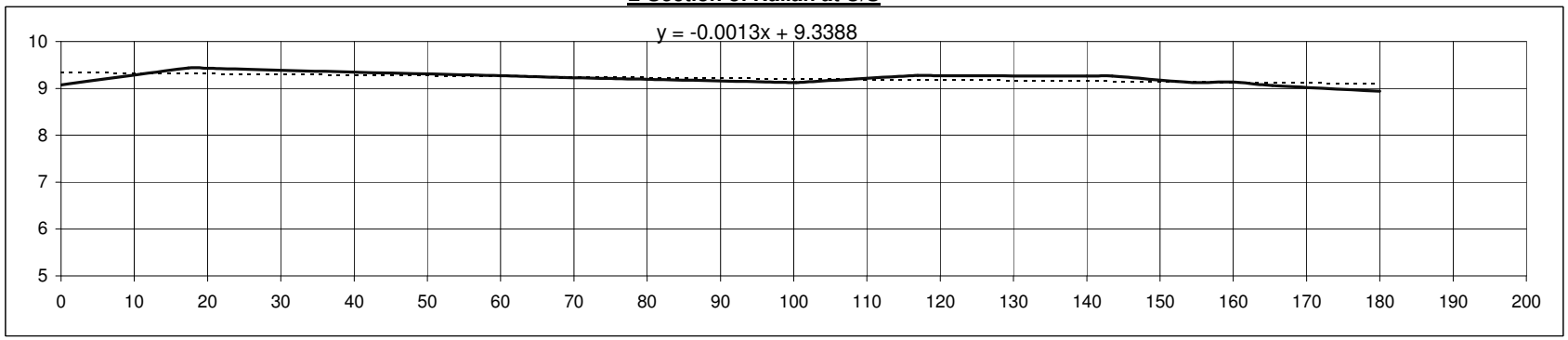
Cross-sectional area of nallah at d/s of proposed bridge is as follows:

Distance from proposed bridge 250 m
Longitudinal slope d/s side 0.0021
HFL at this location 9.769 m

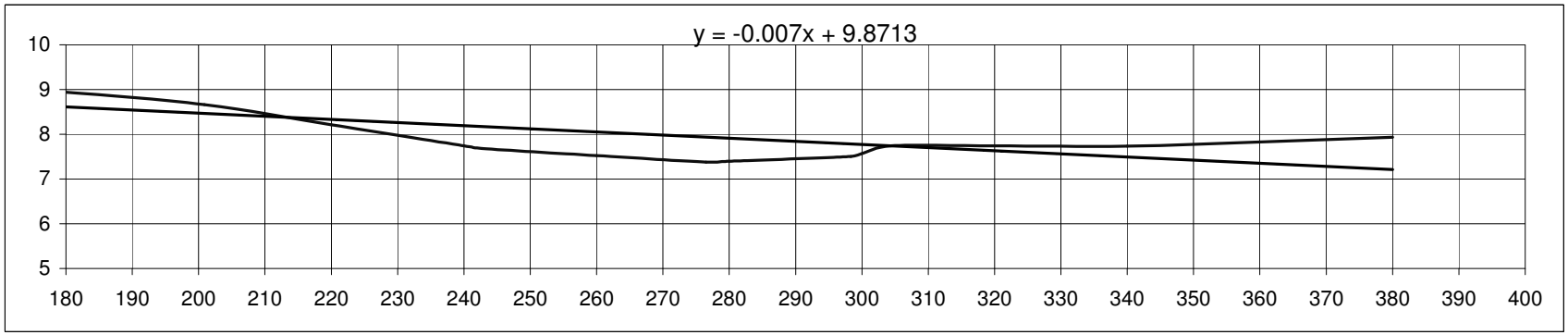
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-15	9.521	9.769	0.248				
-12	9.307	9.769	0.462	0.355	1.065	3.008	3.000
-9	8.657	9.769	1.112	0.787	2.361	3.070	3.000
-6	8.331	9.769	1.438	1.275	3.825	3.018	3.000
-3	8.069	9.769	1.700	1.569	4.707	3.011	3.000
0	7.949	9.769	1.820	1.760	5.280	3.002	3.000
3	8.069	9.769	1.700	1.760	5.280	3.002	3.000
6	8.431	9.769	1.338	1.519	4.557	3.022	3.000
9	8.557	9.769	1.212	1.275	3.825	3.003	3.000
12	9.923	9.769					
15	9.653	9.769	0.116				
Total					**30.90**	**24.14**	**24.00**



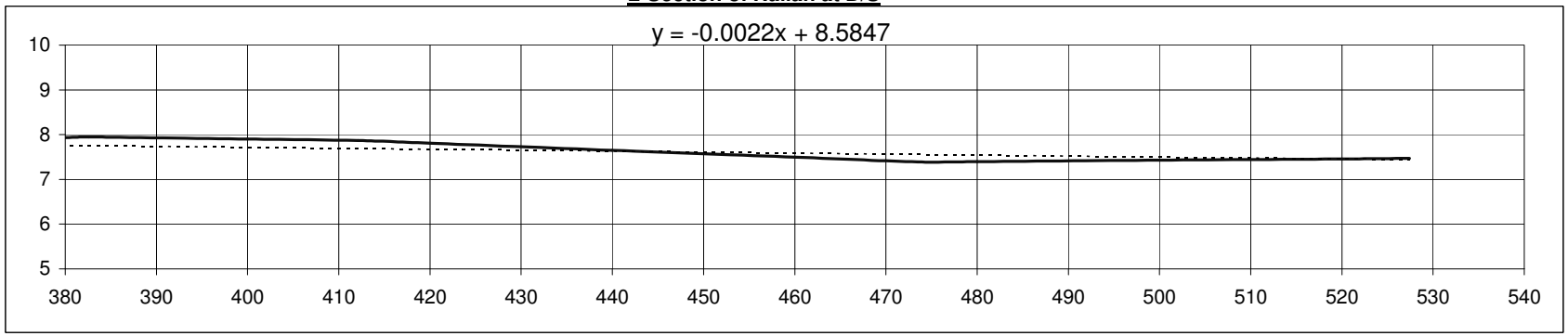
L-Section of Nallah at U/S



L-Section of Nallah at Existing Bridge



L-Section of Nallah at D/S



Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	20.06	cum/sec
HFL	10.294	m
Bed level	9.059	m
Maximum scour depth	5.45	m
Maximum scour level	4.847	m

Curtain wall shall be provided below maximum scour level

Bed level	9.059	m	
Scour depth below bed	4.21	m	
Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	5.0	m
	d/s	5.5	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	8.42	8.5	m
	d/s	6.0	8.42	8.5	m

CHAPTER-7

BRIDGE AT CH:9/300

7. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1 General details

Name of the Nala :	Kundi Polo
Road No.:	S.H - 9
G.T S No :	73K/4
Nearest Village :	-
RD :	Km.9.300
Latitude	21^0 2' 00"
Longitude	86^0 32' 00"
Sub-Zone	3(d)

2 Discharge by Manning's Formula

HFL at proposed bridge site	10.270	m

Cross-section of the stream at different locations are as follows

Discharge by Manning's Formula at U/S location

Cross-sectional area of flow	30.36	sqm
Width of flow	27.00	m
Wetted perimeter perpendicular to direction of flow	27.37	m
Hydraulic mean radius R = A/P	1.11	m
Longitudinal slope as calculated	0.0086	m per m
Velocity by Manning's formula		
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n =	0.07	
Velocity V =	1.419	m/s
Discharge Q = A*V	43.08	cum/s

Discharge by Manning's Formula at existing location

Cross-sectional area of flow	41.73	sqm
Width of flow	24.00	m
Wetted perimeter perpendicular to direction of flow	24.52	m
Hydraulic mean radius R = A/P	1.70	m
Longitudinal slope as calculated	0.0040	m per m
Velocity by Manning's formula		
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n =	0.07	
Velocity V =	1.288	m/s
Discharge Q = A*V	53.74	cum/s

Discharge by Manning's Formula at D/S location

Cross-sectional area of flow	44.23	sqm
Width of flow	24.00	m
Wetted perimeter perpendicular to direction of flow	24.10	m

Hydraulic mean radius R = A/P		1.84	m
Longitudinal slope as calculated		0.0033	m per m
Velocity by Manning's formula			
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)			
For sluugish type bed (Table 5.1)			
n =		0.07	
Velocity V =		1.230	m/s
Discharge Q = A*V		54.41	cum/s

The hydrological calculations has been done at three sections I.e. at upstream side, downstream side and near existing bridge location

By comparision of upstream and downstream side and Existing bridge location.

The design discharge may be taken as **53.74 cum/s**

3 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted (Since Rainfall is more than 120 cm)	19	
M = Catchment area	3.200	sqkm
Q =	45.46	cum/s

5 Discharge by Rational Formula

Catchment area	3.200 sqkm	320.00	hectares
Length of path from toposheet (L)		1.800	km
Difference in levels from toposheet (H)		1.95	m
(Ref: Index map)			
Maximum rain fall (F)	(Ref.SUG of Nanojora River)	216.05	mm
Duaration of storm (T)		5	hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)	129.63	mm/hr
Time of concentration (SP-13, page 12)	$tc = (0.87*L^3/H)^{0.385}$	1.45	hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		106.03	mm/hr

Discharge Q = 0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)	0.400	
f =	1.00	
A =	320.00	Hectares
Ic =	10.603	cm/hr
Q=	38.002	cum/sec

6 Design Discharge (Refer SP-13, page 21)

Discharge by Manning's Formula	53.74	cum/sec
Discharge by Dicken's Formula	45.46	cum/sec
Discharge by Rational Formula	38.00	cum/sec
Maximum discharge	53.74	cum/sec
Next maximum discharge	45.46	cum/sec

The difference is within 50% of the next maximum discharge

Hence design discharge **53.74 cum/sec**

7 Water Way

Regime width		$W = 4.8Q^{1/2}$	35.19	m
(Refer IRC:5-1998, cl 104.3 or SP-13, page 23)				
Provide	Clear span		7	m
	No. of spans		3	no.
	Total waterway provided L		21.00	m

8 Scour depth

Increase in design discharge, as per IRC:78-2000, cl 703.1.1		30%	
Increased design discharge		69.86	cum/sec
Mean depth of scour, as per IRC:78-2000, cl 703.2			
	$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$		
	Db = Design discharge per metre width	1.99	cum/sec/m
	K_{sf} = Silt factor	1.0	(Assumed)
Mean depth of scour, d_{sf} =		2.12	m
Maximum scour depth, as per IRC:78-2000, cl 703.3			
	for Pier	4.23	m
	for Abutment	2.69	m

9 Deck level

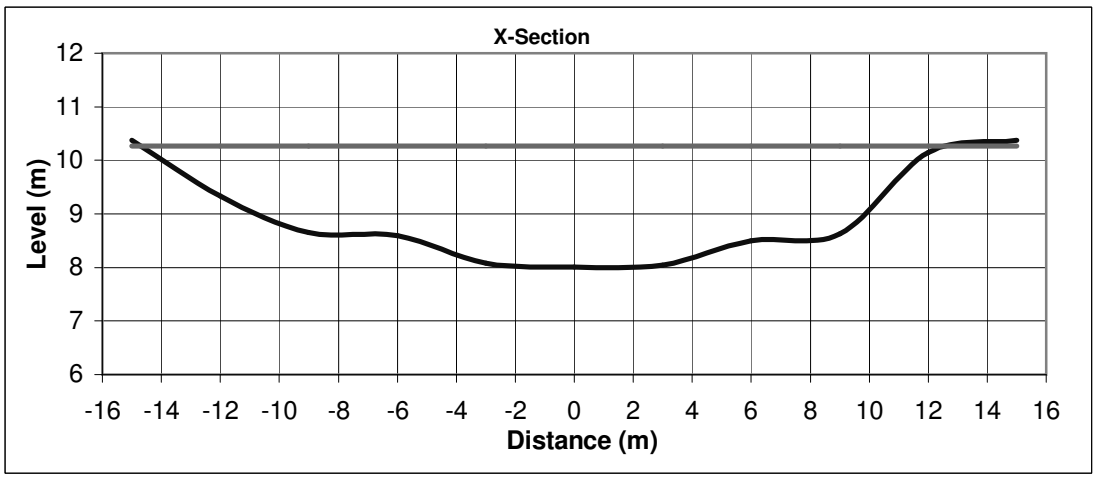
HFL at proposed bridge site including afflux	10.270	m
Minimum vertical clearance (Table 12.1 of SP-13)	0.900	m
Depth of super structure	0.550	m
Wearing coat	0.056	m
Minimum deck level required as per hydraulic conditions	11.776	m
Deck level of the existing bridge	11.900	m
Minimum deck level proposed	11.900	m

Keeping in view of the hydraulic performance of the existing bridge, it is recommended to retain the existing bridge, no raising required.

Cross-sectional area of nallah at proposed bridge site is as follows:

HFL at this location 10.270 m

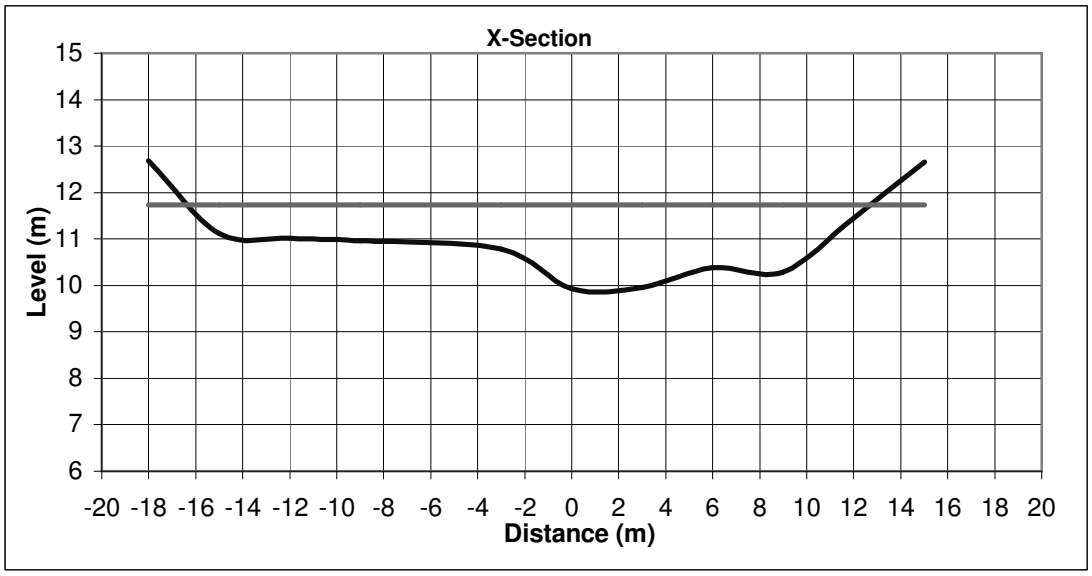
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-15	10.369	10.270					
-12	9.329	10.270	0.941				
-9	8.652	10.270	1.618	1.280	3.839	3.075	3.000
-6	8.595	10.270	1.675	1.647	4.940	3.001	3.000
-3	8.079	10.270	2.191	1.933	5.799	3.044	3.000
0	8.004	10.270	2.266	2.229	6.686	3.001	3.000
3	8.049	10.270	2.221	2.244	6.731	3.000	3.000
6	8.499	10.270	1.771	1.996	5.988	3.034	3.000
9	8.632	10.270	1.638	1.705	5.114	3.003	3.000
12	10.153	10.270	0.117	0.878	2.633	3.364	3.000
15	10.369	10.270					
Total					**41.73**	**24.52**	**24.00**



Cross-sectional area of nallah at u/s of the proposed bridge is as follows:

Distance from proposed bridge	170	m
Longitudinal slope u/s side	0.0086	
HFL at this location	11.732	m

Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-18	12.691	11.732					
-15	11.108	11.732	0.624				
-12	11.014	11.732	0.718	0.671	2.013	3.001	3.000
-9	10.968	11.732	0.764	0.741	2.223	3.000	3.000
-3	10.785	11.732	0.947	0.855	5.133	6.003	6.000
0	9.93	11.732	1.802	1.375	4.124	3.119	3.000
3	9.95	11.732	1.782	1.792	5.376	3.000	3.000
6	10.382	11.732	1.350	1.566	4.698	3.031	3.000
9	10.285	11.732	1.447	1.399	4.196	3.002	3.000
12	11.45	11.732	0.282	0.865	2.594	3.218	3.000
15	12.656	11.732					
Total					**30.36**	**27.37**	**27.00**

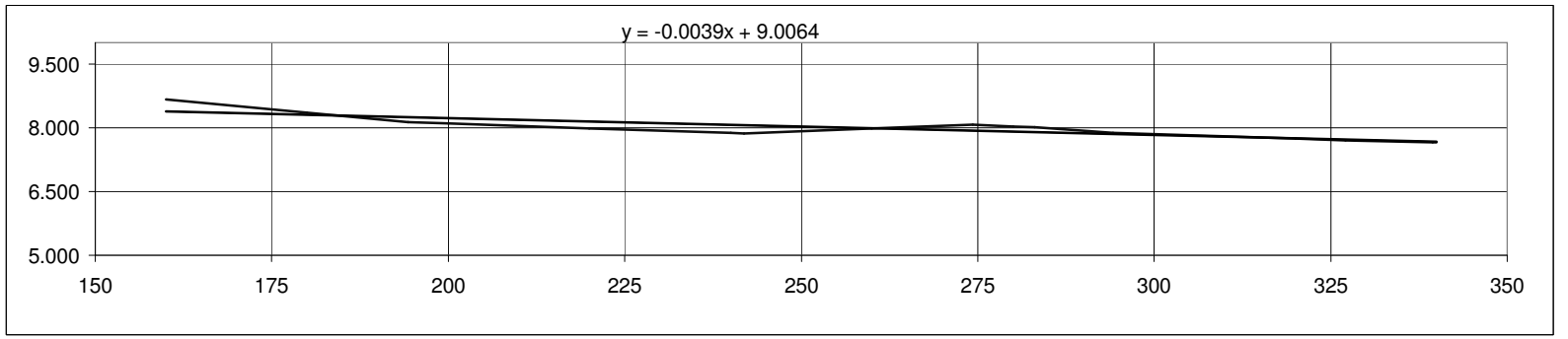


Cross-sectional area of nallah at d/s of proposed bridge is as follows:

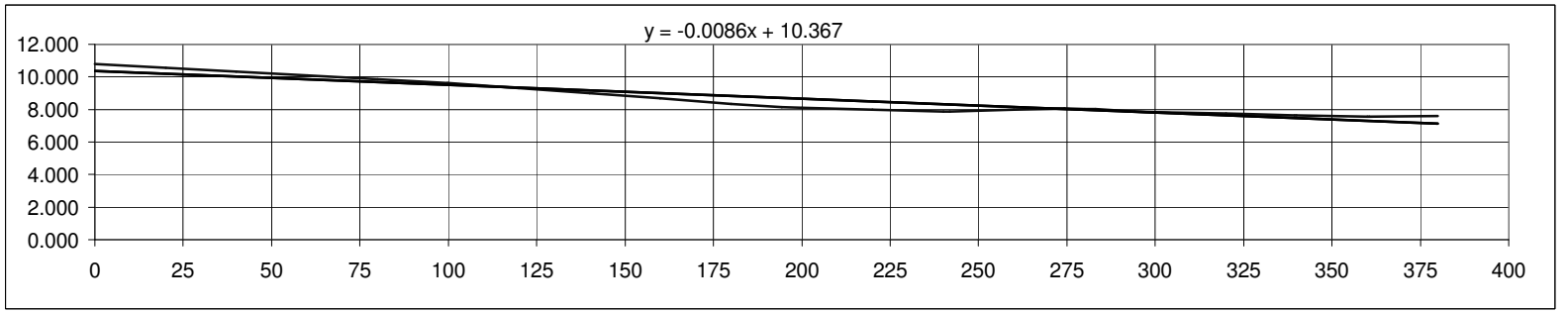
Distance from proposed bridge 110 m
Longitudinal slope d/s side 0.0033
HFL at this location 9.907 m

Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-15	10.643	9.907					
-12	8.625	9.907	1.282				
-9	8.392	9.907	1.515	1.399	4.196	3.009	3.000
-6	7.978	9.907	1.929	1.722	5.166	3.028	3.000
-3	7.826	9.907	2.081	2.005	6.015	3.004	3.000
0	7.573	9.907	2.334	2.208	6.623	3.011	3.000
3	7.832	9.907	2.075	2.205	6.614	3.011	3.000
6	7.979	9.907	1.928	2.002	6.005	3.004	3.000
9	8.393	9.907	1.514	1.721	5.163	3.028	3.000
12	8.456	9.907	1.451	1.483	4.448	3.001	3.000
15	10.383	9.907					
Total					**44.23**	**24.10**	**24.00**

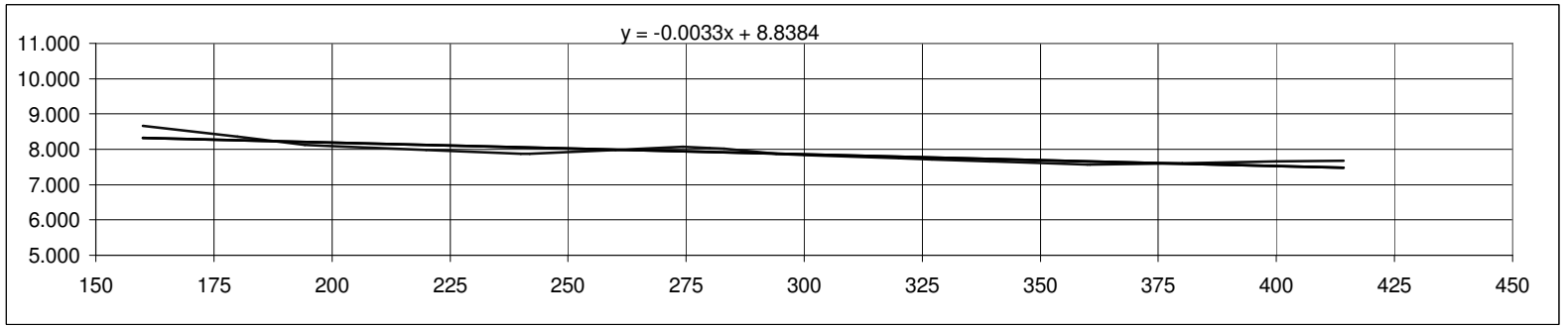
L-Section of Nallah at Existing Bridge



L-Section of Nallah at U/S



L-Section of Nallah at D/S



Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	53.74	cum/sec
HFL	10.270	m
Bed level	8.064	m
Maximum scour depth	4.23	m
Maximum scour level	6.037	m

Curtain wall shall be provided below maximum scour level

Bed level	8.064	m
Scour depth below bed	2.03	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	2.0	m
	d/s	2.5	m

Rigid apron as per IRC:89-1997 Upto the end of splayed wing walls on both sides.

Formation level	11.9	m
Width of bridge	8.3	m
Camber	2.50%	
Road top level at edge of bridge	11.796	m
Natural bed level	8.064	m
Floor level	7.764	m
Height of retained earth at high end	4.03	m
Height of retained earth at low end	1.00	m
Side slope, 1 V : H	2.0	
Length of rigid apron	6.1	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	4.05	3.0	m
	d/s	6.0	4.05	6.0	m

CHAPTER-8

BRIDGE AT CH:13/600

8. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1 General details

Name of the Nala :	Nandapur Polo
Road No.:	S.H - 9
G.T S No :	73K/4
Nearest Village :	-
RD :	Km.13.600
Latitude	21^0 1' 00"
Longitude	86^0 32' 00"
Sub-Zone	3(d)

2 Discharge by Manning's Formula

HFL at proposed bridge site	7.269	m

Cross-section of the stream at different locations are as follows

Discharge by Manning's Formula at U/S location

Cross-sectional area of flow	15.20	sqm
Width of flow	18.00	m
Wetted perimeter perpendicular to direction of flow	18.13	m
Hydraulic mean radius R = A/P	0.84	m
Longitudinal slope as calculated	0.0021	m per m
Velocity by Manning's formula		
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n =	0.06	
Velocity V =	0.679	m/s
Discharge Q = A*V	10.32	cum/s

Discharge by Manning's Formula at existing location

Cross-sectional area of flow	16.47	sqm
Width of flow	18.00	m
Wetted perimeter perpendicular to direction of flow	18.01	m
Hydraulic mean radius R = A/P	0.91	m
Longitudinal slope as calculated	0.0021	m per m
Velocity by Manning's formula		
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n =	0.06	
Velocity V =	0.720	m/s
Discharge Q = A*V	11.85	cum/s

Discharge by Manning's Formula at D/S location

Cross-sectional area of flow	20.19	sqm
Width of flow	21.00	m
Wetted perimeter perpendicular to direction of flow	21.00	m
Hydraulic mean radius R = A/P	0.96	m
Longitudinal slope as calculated	0.0015	m per m

Velocity by Manning's formula

$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)

For sluugish type bed (Table 5.1)

n = 0.06

Velocity V = 0.629 m/s

Discharge Q = A*V 12.70 cum/s

The hydrological calculations has been done at three sections I.e. at upstream side, downstream side and near proposed bridge location

By comparision of upstream and downstream side and Existing bridge location.

The design discharge may be taken as **11.85 cum/s**

3 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted (Since Rainfall is more than 120 cm) 19

M = Catchment area 2.500 sqkm

Q = 37.78 cum/s

4 Design Discharge (Refer SP-13, page 21)

Discharge by Manning's Formula	11.85 cum/sec
Discharge by Dicken's Formula	37.78 cum/sec
Maximum discharge	37.78 cum/sec
Next maximum discharge	11.85 cum/sec

The difference is beyond 50% of the next maximum discharge

Hence design discharge **17.77 cum/sec**

5 Water Way

Regime width $W = 4.8Q^{1/2}$ 20.24 m

(Refer IRC:5-1998, cl 104.3 or SP-13, page 23)

Provide	Clear span	3 m
	No. of spans	3 no.
	Total waterway provided L	9.00 m

6 Scour depth

Increase in design discharge, as per IRC:78-2000, cl 703.1.1 30%

Increased design discharge 23.11 cum/sec

Mean depth of scour, as per IRC:78-2000, cl 703.2

$d_{sf} = 1.34\ (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width 2.57 cum/sec/m

K_{sf} = Silt factor

Silt factor has been calculated according to data collected from site

	Depth	Silt factor	
	3	0.624	1.872
	6	1.259	7.554
Weighted average	9	9.426	0.955

Mean depth of scour, d_{sf} =	2.55 m
Maximum scour depth, as per IRC:78-2000, cl 703.3	
for Pier	5.10 m
for Abutment	3.24 m

7 Deck level

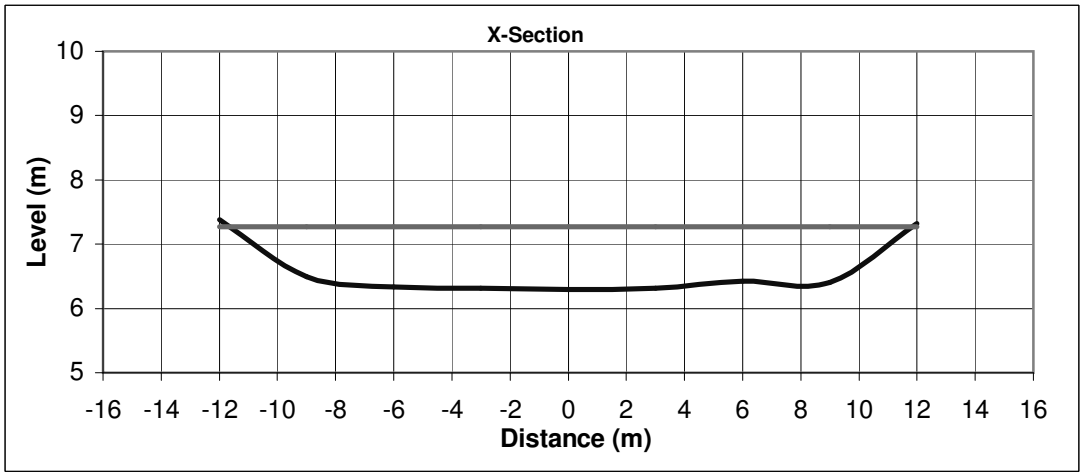
HFL at proposed bridge site including afflux	7.269 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600 m
Depth of super structure	0.450 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	8.375 m
Deck level of the existing bridge	8.344 m
Minimum deck level proposed	8.375 m

As per proposed alignment the proposed level has been kept as 8.7 m

Cross-sectional area of nallah at proposed bridge site is as follows:

HFL at this location 7.269 m

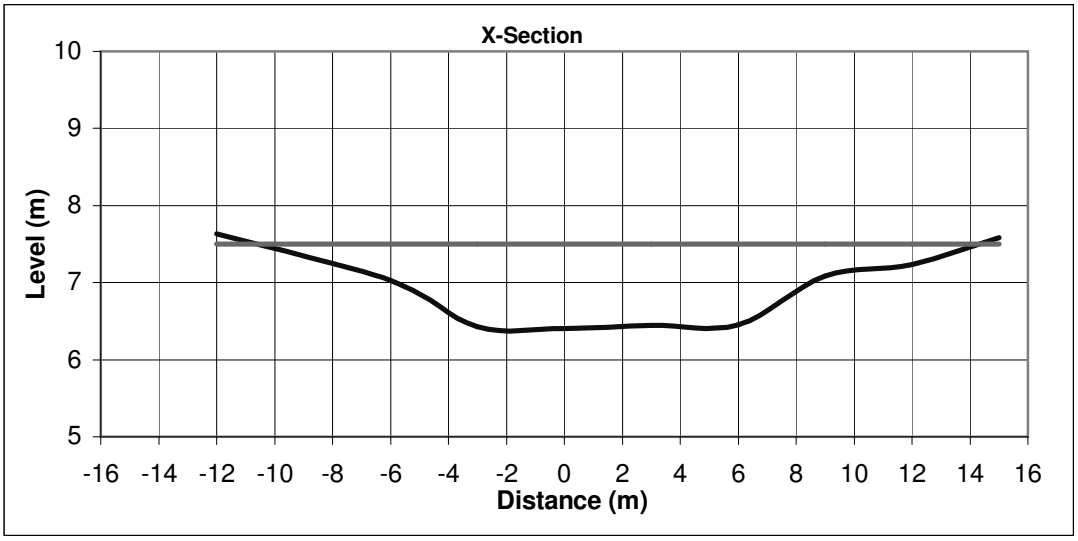
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-12	7.379	7.269					
-9	6.493	7.269	0.776				
-6	6.333	7.269	0.936	0.856	2.568	3.004	3.000
-3	6.313	7.269	0.956	0.946	2.838	3.000	3.000
0	6.293	7.269	0.976	0.966	2.898	3.000	3.000
3	6.315	7.269	0.954	0.965	2.895	3.000	3.000
6	6.423	7.269	0.846	0.900	2.700	3.002	3.000
9	6.403	7.269	0.866	0.856	2.568	3.000	3.000
12	7.325	7.269					
Total					**16.47**	**18.01**	**18.00**



Cross-sectional area of nallah at u/s of the proposed bridge is as follows:

Distance from proposed bridge 110 m
Longitudinal slope u/s side 0.0021
HFL at this location 7.500 m

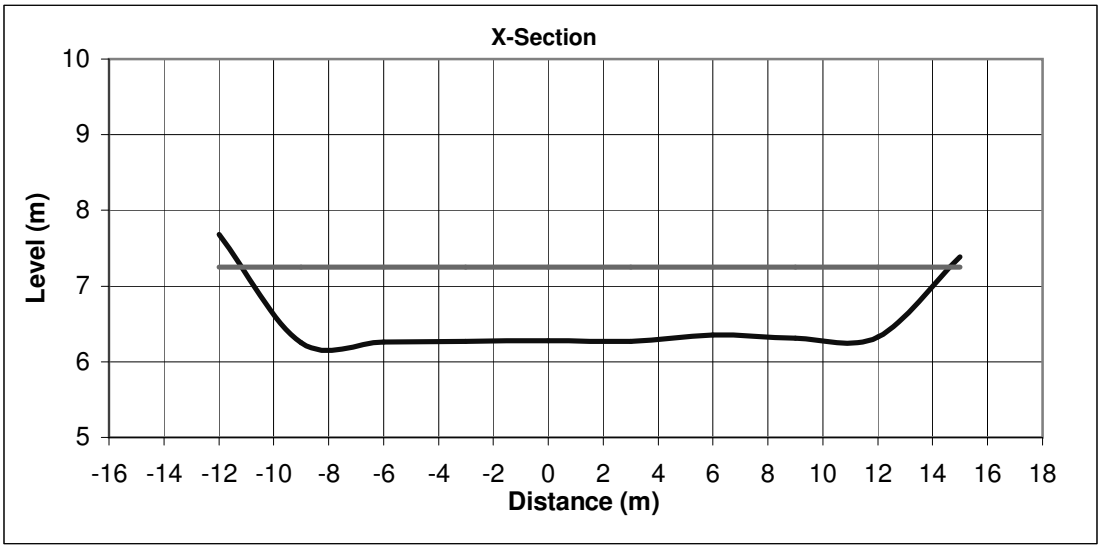
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-12	7.635	7.500					
-6	7.023	7.500	0.477				
-3	6.427	7.500	1.073	0.775	2.325	3.059	3.000
0	6.4	7.500	1.100	1.087	3.260	3.000	3.000
3	6.4421	7.500	1.058	1.079	3.237	3.000	3.000
6	6.453	7.500	1.047	1.052	3.157	3.000	3.000
9	7.083	7.500	0.417	0.732	2.196	3.065	3.000
12	7.234	7.500	0.266	0.342	1.025	3.004	3.000
15	7.584	7.500					
Total					**15.20**	**18.13**	**18.00**



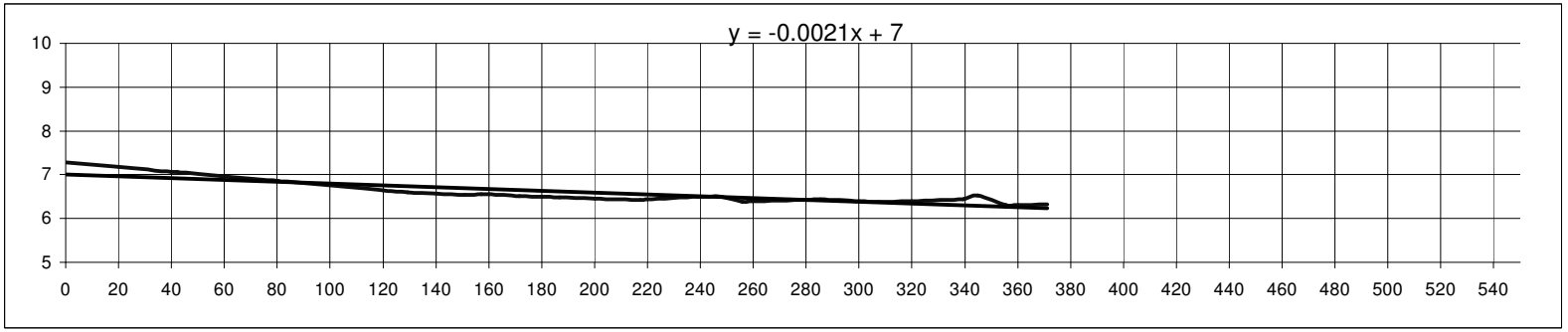
Cross-sectional area of nallah at d/s of proposed bridge is as follows:

Distance from proposed bridge 110 m
Longitudinal slope d/s side 0.00015
HFL at this location 7.253 m

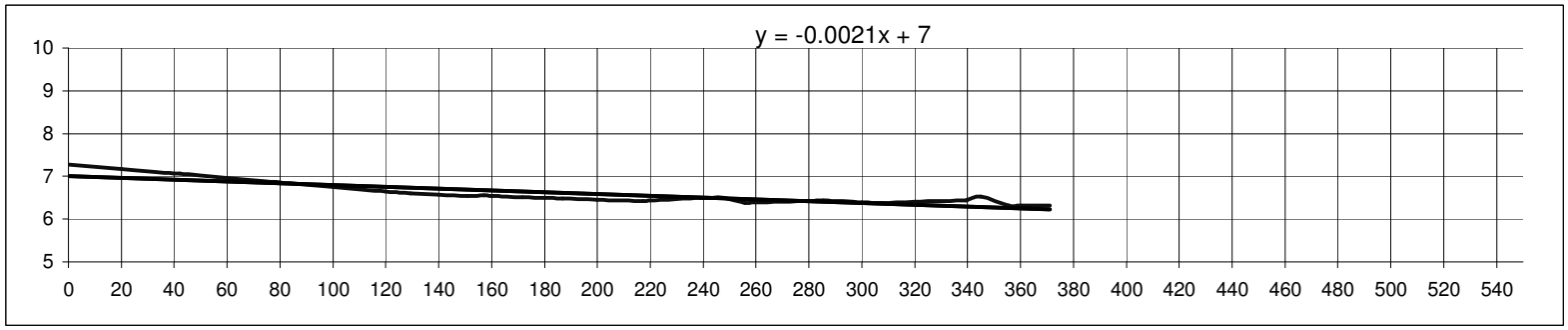
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-12	7.683	7.253					
-9	6.253	7.253	1.000				
-6	6.262	7.253	0.991	0.995	2.985	3.000	3.000
-3	6.271	7.253	0.982	0.986	2.958	3.000	3.000
0	6.275	7.253	0.978	0.980	2.939	3.000	3.000
3	6.273	7.253	0.980	0.979	2.936	3.000	3.000
6	6.353	7.253	0.900	0.940	2.819	3.001	3.000
9	6.313	7.253	0.940	0.920	2.759	3.000	3.000
12	6.325	7.253	0.928	0.934	2.801	3.000	3.000
15	7.384	7.253					
Total					**20.19**	**21.00**	**21.00**



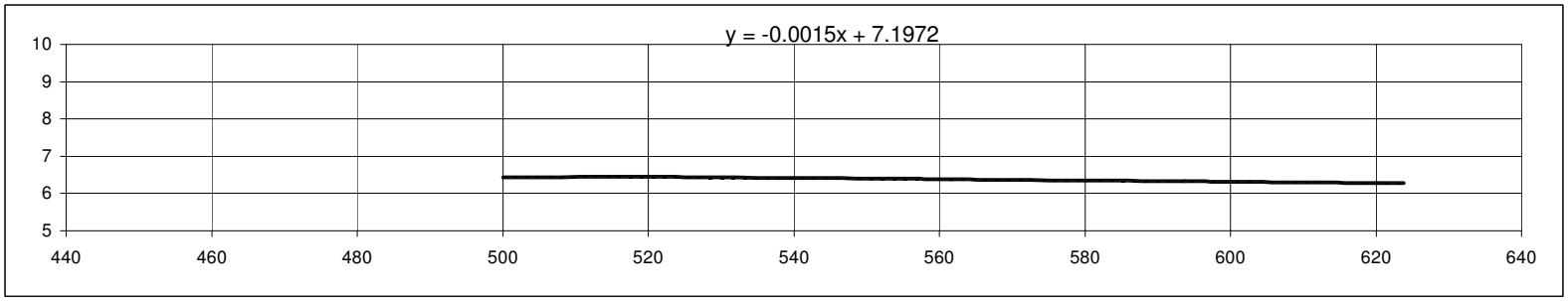
L-Section of Nallah at U/S



L-Section of Nallah at Existing Bridge



L-Section of Nallah at D/S



Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	17.77 cum/sec
HFL	7.269 m
Bed level	6.313 m
Maximum scour depth	5.10 m
Maximum scour level	2.166 m

Curtain wall shall be provided below maximum scour level

Bed level		6.313 m
Scour depth below bed		4.15 m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2 m
	d/s	2.5 m
Provide depth of curtain wall	u/s	5.0 m
	d/s	5.5 m
Rigid apron as per IRC:89-1997	u/s	3.0 m
	d/s	5.0 m

		As per IRC:89	2xscour depth	Provided
Flexible apron	u/s	3.0	8.29	8.5 m
	d/s	6.0	8.29	8.5 m

CHAPTER-9

BRIDGE AT CH:28/100

9. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1 Name of the Nala : Luharbada

Road No.:	S.H - 9
G.T S No :	73K/4
Nearest Village :	Luharbada
RD :	Km.28.100
Latitude	20^0 55' 00"
Longitude	86^0 41' 00"
Sub-Zone	3(d)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted	(Since Rain fall is more than 120 cm)	19
M = Catchment area		0.780 sqkm
Q =		15.77 cum/s

3 Discharge by Rational Formula

Catchment area	0.780 sqkm	78.00 hectares
Length of path from toposheet (L)		1.500 km
Difference in levels from toposheet (H) (Ref: Index map)		2 m
Maximum rain fall (F)	(Ref.SUG of Nanojora River)	216.05 mm
Duaration of storm (T)		5 hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)	129.63 mm/hr
Time of concentration (I.R.C. SP-13, Page 12)	$tc = (0.87*L^3/H)^{0.385}$	1.16 hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		120.07 mm/hr

Discharge Q = 0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)		0.400
f =		1.00
A =		78.00 Hectares
Ic =		12.007 cm/hr
Q=		10.489 cum/sec

Here,

t_c= Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchment

I_o= One hour rainfall in cm.

I_c= Critical intensity of rainfall in cm per hour

P = Coefficient of runoff for the catchment characteristics (Ref.Table-4.1P-13,I.R.C.:SP:13-2004)

A = Catchment area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in metre

4 Design Discharge (Refer I.R.C.SP-13, page 21)

Discharge by Dicken's Formula	15.77 cum/sec
Discharge by Rational Formula	10.49 cum/sec
Maximum discharge	15.77 cum/sec
Next maximum discharge	10.49 cum/sec
Hence design discharge	**15.73 cum/sec**

5 Linear Water Way

Regime width $W = 4.8*Q^{1/2}$ 19.04 m

(Refer IRC:5-1998, Clause 104.3 or SP-13, Page 23)

6 Span arrangement

In proposed span arrangement, double cell of 6.0 m has been proposed with bed protection. 12.00 m

7 Scour depth

Increase in design discharge, as per IRC:78-2000,Clause 703.1.1 30%

Increased design discharge 20.45 cum/sec

Mean depth of scour, as per IRC:78-2000, Clause 703.2

$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width	1.70 cum/sec/m
K_{sf} = Silt factor	1.00 (Assumed)
d_{sf} =	1.91

Maximum scour depth, as per IRC:78-2000, Clause 703.3

for pier	2 d_{sf}	3.82 m
for Abutment	1.27 d_{sf}	2.43 m

8 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.6 m

9 Deck level

HFL at existing bridge site including afflux	6.460 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600 m
Depth of super structure including camber	0.680 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	7.796 m
Deck level of the existing bridge	7.235 m
Minimum deck level proposed	7.796 m

As per the proposed allignment, the formation level of bridge has been kept as 8.0m

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	15.73	cum/sec
HFL	6.460	m
Bed level	4.050	m
Maximum scour depth	3.82	m
Maximum scour level	2.636	m

Curtain wall shall be provided below maximum scour level

Bed level	4.05	m
Scour depth below bed	1.41	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	2.0	m
	d/s	2.5	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	2.83	3.0	m
	d/s	6.0	2.83	6.0	m

CHAPTER-10

BRIDGE AT CH:28/800

10. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1 Name of the Nala :	Kalapahada Ghusura	
Road No.:	S.H - 9	
G.T S No :	73K/4	
Nearest Village :	Kalapahada Ghusura	
RD :	Km.28.800	
Latitude	20^0 55' 00"	
Longitude	86^0 41' 30"	
Sub-Zone	3(d)	

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (Refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted	(Since Rain fall is more than 120 cm)	19
M = Catchment area		1.010 sqkm
Q =		19.14 cum/s

3 Discharge by Rational Formula

Catchment area	1.010 sqkm	101.00 hectares
Length of path from toposheet (L)		0.850 km
Difference in levels from toposheet (H)		0.75 m
(Ref: Index map)		
Maximum rain fall (F)	(Ref.SUG of Nanojora River)	216.05 mm
Duaration of storm (T)		5 hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)	129.63 mm/hr
Time of concentration (I.R.C. SP-13, Page 12)	$tc = (0.87*L^3/H)^{0.385}$	0.88 hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		138.08 mm/hr

Discharge Q = 0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)		0.400
f =		1.00
A =		101.00 Hectares
Ic =		13.808 cm/hr
Q =		15.620 cum/sec

Here,

t_c= Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchment

I_o= One hour rainfall in cm.

I_c= Critical intensity of rainfall in cm per hour

P = Coefficient of runoff for the catchment characteristics (Ref.Table-4.1P-13,I.R.C.:SP:13-2004)

A = Catchment area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in metre

4 Design Discharge (Refer I.R.C.SP-13, page 21)

Discharge by Dicken's Formula	19.14 cum/sec
Discharge by Rational Formula	15.62 cum/sec
Maximum discharge	19.14 cum/sec
Next maximum discharge	15.62 cum/sec
Hence design discharge	**19.14 cum/sec**

5 Linear Water Way

Regime width $W = 4.8*Q^{1/2}$ 21.00 m

(Refer IRC:5-1998, Clause 104.3 or SP-13, Page 23)

6 Span arrangement

In proposed span arrangement, triple cell of 3.0 m has been proposed with bed protection. 9.00 m

7 **Scour depth**

Increase in design discharge, as per IRC:78-2000,Clause 703.1.1 30%

Increased design discharge 24.89 cum/sec

Mean depth of scour, as per IRC:78-2000, Clause 703.2

$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width 2.77 cum/sec/m

K_{sf} = Silt factor 2.09

d_{sf} = 2.06

Maximum scour depth, as per IRC:78-2000, Clause 703.3

for Pier $2\ d_{sf}$ 4.13 m

for Abutment $1.27\ d_{sf}$ 2.62 m

8 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.6 m

9 Deck level

HFL at existing bridge site including afflux	6.793 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600 m
Depth of super structure including camber	0.450 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	7.899 m
Deck level of the existing bridge	5.993 m
Minimum deck level proposed	7.899 m

As per the proposed allignment, the formation level of bridge has been kept as 8.1 m

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	19.14	cum/sec
HFL	6.793	m
Bed level	4.552	m
Maximum scour depth	4.13	m
Maximum scour level	2.664	m

Curtain wall shall be provided below maximum scour level

Bed level	4.552	m	
Scour depth below bed	1.89	m	

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	2.5	m
	d/s	3.0	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	3.78	4.0	m
	d/s	6.0	3.78	6.0	m

CHAPTER-11

BRIDGE AT CH:30/050

11. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1 Name of the Nala : Gadi Ghusura

Road No.:	S.H - 9
G.T S No :	73K
Nearest Village :	Gadi Ghusura
RD :	Km.30.050
Latitude	20^0 55' 00"
Longitude	86^0 43' 00"
Sub-Zone	3(d)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted	(Since Rain fall is more than 120 cm)	19
M = Catchment area		2.400 sqkm
Q =		36.64 cum/s

3 Discharge by Rational Formula

Catchment area		2.400 sqkm	240.00 hectares
Length of path from toposheet (L)			1.200 km
Difference in levels from toposheet (H)			1.5 m
(Ref: Index map)			
Maximum rain fall (F)	(Ref.SUG of Nanojora River)		216.05 mm
Duaration of storm (T)			5 hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)		129.63 mm/hr
Time of concentration (I.R.C. SP-13, Page 12)	$tc = (0.87*L^3/H)^{0.385}$		1.00 hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)			129.57 mm/hr

Discharge Q = 0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)	0.400
f =	1.00
A =	240.00 Hectares
Ic =	12.957 cm/hr
Q =	34.830 cum/sec

Here,

t_c= Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchment

I_o= One hour rainfall in cm.

I_c= Critical intensity of rainfall in cm per hour

P = Coefficient of runoff for the catchment characteristics (Ref.Table-4.1P-13,I.R.C.:SP:13-2004)

A = Catchment area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in metre

4 Design Discharge (Refer I.R.C.SP-13, page 21)

Discharge by Dicken's Formula	36.64 cum/sec
Discharge by Rational Formula	34.83 cum/sec
Maximum discharge	36.64 cum/sec
Next maximum discharge	34.83 cum/sec

Two additional Structures has been provided I.e. series of 10 pipes of 1200 mm dia at two location .

The discharge taken by these two additional structures assuming velocity of 1 m/sec on conservative side.

= 2 x 1.13 x 10 x 1 = 22.6 Cum/sec

Remaining discharge = 34.64 - 22.6 = 12.04 cum/sec

Hence design discharge **12.04 cum/sec**

5 Linear Water Way

Regime width $W=4.8*Q^{1/2}$ 16.66 m

(Refer IRC:5-1998, Clause 104.3 or SP-13, Page 23)

6 Span arrangement

In proposed span arrangement, triple cell of 3.0 m has been proposed 9.00 m

with bed protection.

7 Scour depth

Increase in design discharge, as per IRC:78-2000,Clause 703.1.1 30%

Increased design discharge 15.65 cum/sec

Mean depth of scour, as per IRC:78-2000, Clause 703.2

$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width 1.74 cum/sec/m

K_{sf} = Silt factor 1.00

d_{sf} = 1.94

Maximum scour depth, as per IRC:78-2000, Clause 703.3

for Pier $2\ d_{sf}$ 3.88 m

for Abutment $1.27\ d_{sf}$ 2.46 m

8 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point	
0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16)	0.6 m

9 Deck level

HFL at existing bridge site including afflux	6.599 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600 m
Depth of super structure including camber	0.450 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	7.705 m
Deck level of the existing bridge	6.099 m
Minimum deck level proposed	7.705 m

As per the proposed allignment, the formation level of bridge has been kept as 8.2 m

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	36.64	cum/sec
HFL	6.599	m
Bed level	4.753	m
Maximum scour depth	3.88	m
Maximum scour level	2.723	m

Curtain wall shall be provided below maximum scour level			
Bed level		4.753	m
Scour depth below bed		2.03	m
Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	3.0	m
	d/s	3.5	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	4.06	4.5	m
	d/s	6.0	4.06	6.0	m

CHAPTER-12

BRIDGE AT CH:30/200

12. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1 General details

Name of the Nala :	Kadanga Canal Gadi Bridge
Road No.:	S.H - 9
G.T S No :	73K
Nearest Village :	Gadi
RD :	Km.30.200
Latitude	20^0 55' 00"
Longitude	86^0 43' 30"
Sub-Zone	3(d)

2 Discharge by Manning's Formula

HFL at proposed bridge site	6.226	m

Cross-section of the stream at different locations are as follows

Discharge by Manning's Formula at U/S location

Cross-sectional area of flow	21.74	sqm
Width of flow	18.00	m
Wetted perimeter perpendicular to direction of flow	18.41	m
Hydraulic mean radius R = A/P	1.18	m
Longitudinal slope as calculated	0.0012	m per m
Velocity by Manning's formula		
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n =	0.06	
Velocity V =	0.645	m/s
Discharge Q = A*V	14.02	cum/s

Discharge by Manning's Formula at existing location

Cross-sectional area of flow	23.61	sqm
Width of flow	18.00	m
Wetted perimeter perpendicular to direction of flow	18.85	m
Hydraulic mean radius R = A/P	1.25	m
Longitudinal slope as calculated	0.0012	m per m
Velocity by Manning's formula		
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n =	0.06	
Velocity V =	0.671	m/s
Discharge Q = A*V	15.84	cum/s

Discharge by Manning's Formula at D/S location

Cross-sectional area of flow	27.12	sqm
Width of flow	21.00	m

Wetted perimeter perpendicular to direction of flow	21.43	m
Hydraulic mean radius R = A/P	1.27	m
Longitudinal slope as calculated	0.0014	m per m
Velocity by Manning's formula		
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n =	0.06	
Velocity V =	0.730	m/s
Discharge Q = A*V	19.79	cum/s

The hydrological calculations has been done at three sections I.e. at upstream side, downstream side and near proposed bridge location

By comparision of upstream and downstream side and Existing bridge location.

The design discharge may be taken as **15.84 cum/s**

3 Discharge by Dicken's Formula

Discharge as per Dicken's formula (Refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted (Since Rainfall is more than 120 cm)	19	
M = Catchment area	0.700	sqkm
Q =	**14.54**	**cum/s**

4 Discharge by Rational Formula

Catchment area	0.700 sqkm	70.00	hectares
Length of path from toposheet (L)		1.300	km
Difference in levels from toposheet (H)		1.5	m
(Ref: Index map)			
Maximum rain fall (F)	(Ref.SUG of Nanojora River)	216.05	mm
Duaration of storm (T)		5	hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)	129.63	mm/hr
Time of concentration (SP-13, page 12)	$tc = (0.87*L^3/H)^{0.385}$	1.10	hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		123.59	mm/hr
Discharge Q = 0.028 * P*f* A* Ic			
P = (for loam, lightly cultivated or covered)		0.400	
f =		1.00	
A =		70.00	Hectares
Ic =		12.359	cm/hr
Q =		9.689	cum/sec

5 Design Discharge (Refer SP-13, page 21)

Discharge by Manning's Formula	15.84	cum/sec
Discharge by Dicken's Formula	14.54	cum/sec
Discharge by Rational Formula	9.69	cum/sec

Maximum discharge		15.84 cum/sec
Next maximum discharge		14.54 cum/sec
The difference is within 50% of the next maximum discharge		
Hence design discharge		**15.84 cum/sec**

6 Water Way

Regime width		$W = 4.8Q^{1/2}$	19.10 m
(Refer IRC:5-1998, cl 104.3 or SP-13, page 23)			
Provide	Clear span		6 m
	No. of spans		2 no.
	Total waterway provided L		12.00 m

7 Scour depth

Increase in design discharge, as per IRC:78-2000, cl 703.1.1		30%
Increased design discharge		20.59 cum/sec
Mean depth of scour, as per IRC:78-2000, cl 703.2		
$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$		
Db = Design discharge per metre width		1.72 cum/sec/m
K_{sf} = Silt factor		

Silt factor has been calculated according to data collected from site

Depth	Silt factor	
3	0.362	1.086
6	0.945	5.670
9		6.756

Weighted average	1.332
Mean depth of scour, d_{sf} =	1.75 m
Maximum scour depth, as per IRC:78-2000, cl 703.3	
for Pier	3.49 m
for Abutment	2.22 m

8 Deck level

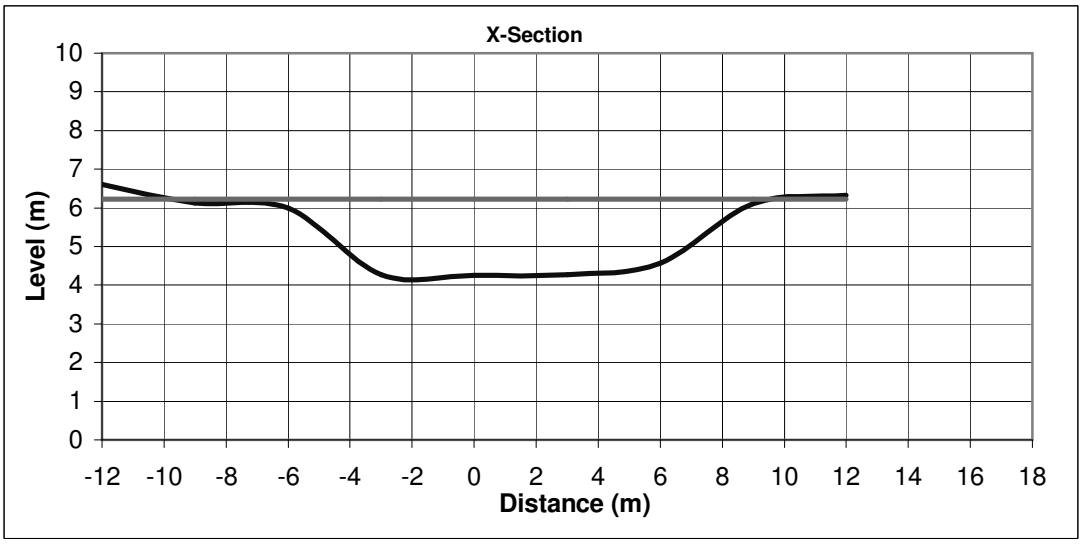
HFL at proposed bridge site including aflux	6.226 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600 m
Depth of super structure	0.500 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	7.382 m
Deck level of the existing bridge	7.680 m
Minimum deck level proposed	7.680 m

Keeping in view of the hydraulic performance of the existing b Hence O.K
to retain the existing bridge, no raising required.

Cross-sectional area of nallah at proposed bridge site is as follows:

HFL at this location 6.226 m

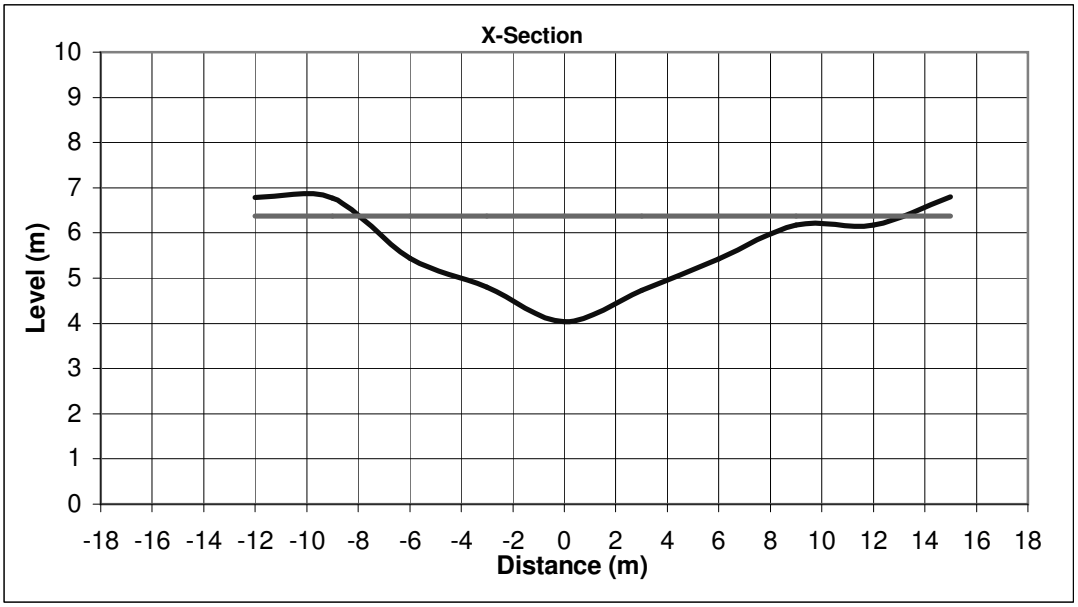
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-12	6.604	6.226					
-9	6.131	6.226	0.095				
-6	6.001	6.226	0.225	0.160	0.480	3.003	3.000
-3	4.269	6.226	1.957	1.091	3.273	3.464	3.000
0	4.263	6.226	1.963	1.960	5.880	3.000	3.000
3	4.264	6.226	1.962	1.963	5.888	3.000	3.000
6	4.573	6.226	1.653	1.808	5.423	3.016	3.000
9	6.101	6.226	0.125	0.889	2.667	3.367	3.000
12	6.321	6.226					
Total					**23.61**	**18.85**	**18.00**



Cross-sectional area of nallah at u/s of the proposed bridge is as follows:

Distance from proposed bridge	120	m
Longitudinal slope u/s side	0.0012	
HFL at this location	6.370	m

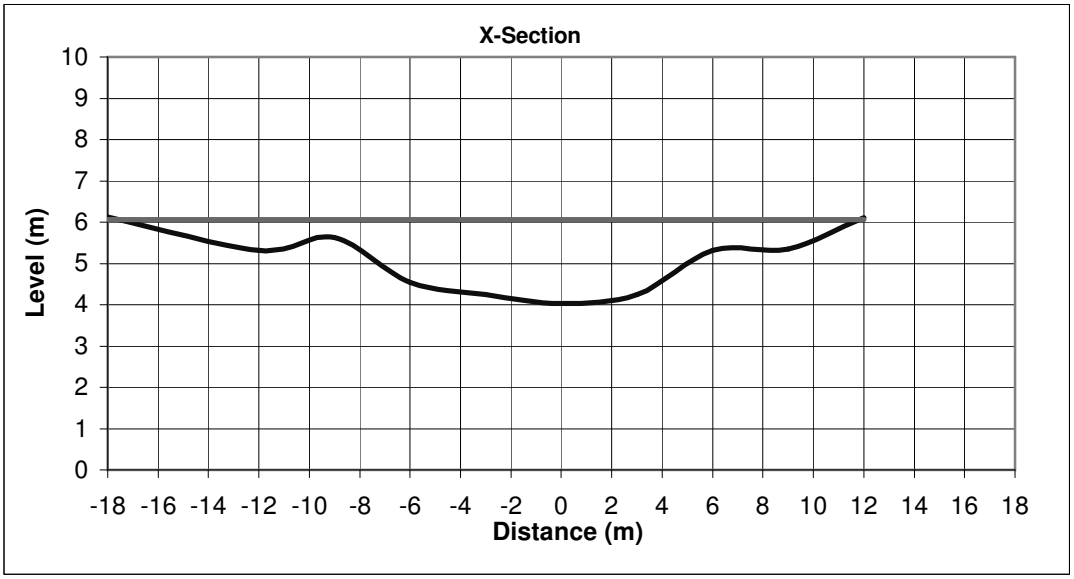
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-12	6.786	6.370					
-9	6.765	6.370					
-6	5.433	6.370	0.937				
-3	4.801	6.370	1.569	1.253	3.759	3.066	3.000
0	4.035	6.370	2.335	1.952	5.856	3.096	3.000
3	4.735	6.370	1.635	1.985	5.955	3.081	3.000
6	5.423	6.370	0.947	1.291	3.873	3.078	3.000
9	6.176	6.370	0.194	0.571	1.712	3.093	3.000
12	6.176	6.370	0.194	0.194	0.582	3.000	3.000
15	6.793	6.370					
Total					**21.74**	**18.41**	**18.00**



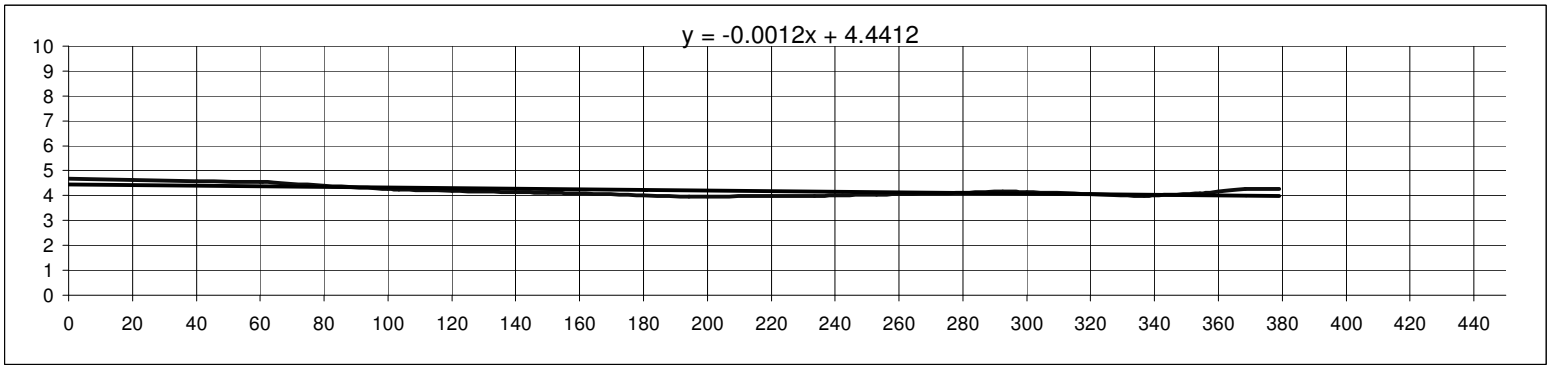
Cross-sectional area of nallah at d/s of proposed bridge is as follows:

Distance from proposed bridge	120	m
Longitudinal slope d/s side	0.0014	
HFL at this location	6.058	m

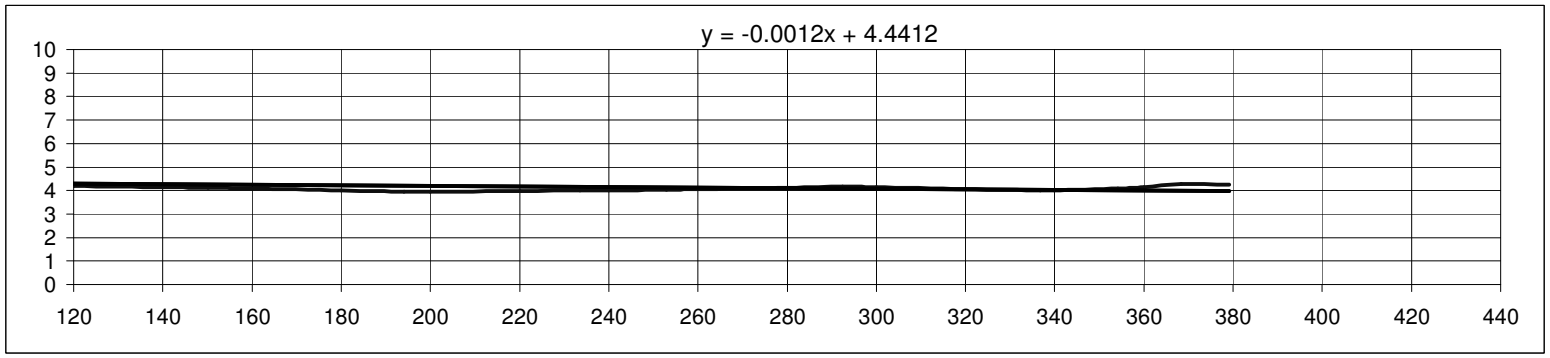
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-18	6.125	6.058					
-12	5.32	6.058	0.738				
-9	5.634	6.058	0.424	0.581	1.743	3.016	3.000
-6	4.542	6.058	1.516	0.970	2.910	3.193	3.000
-3	4.253	6.058	1.805	1.661	4.982	3.014	3.000
0	4.035	6.058	2.023	1.914	5.742	3.008	3.000
3	4.245	6.058	1.813	1.918	5.754	3.007	3.000
6	5.321	6.058	0.737	1.275	3.825	3.187	3.000
9	5.35	6.058	0.708	0.723	2.168	3.000	3.000
12	6.113	6.058					
Total					**27.12**	**21.43**	**21.00**



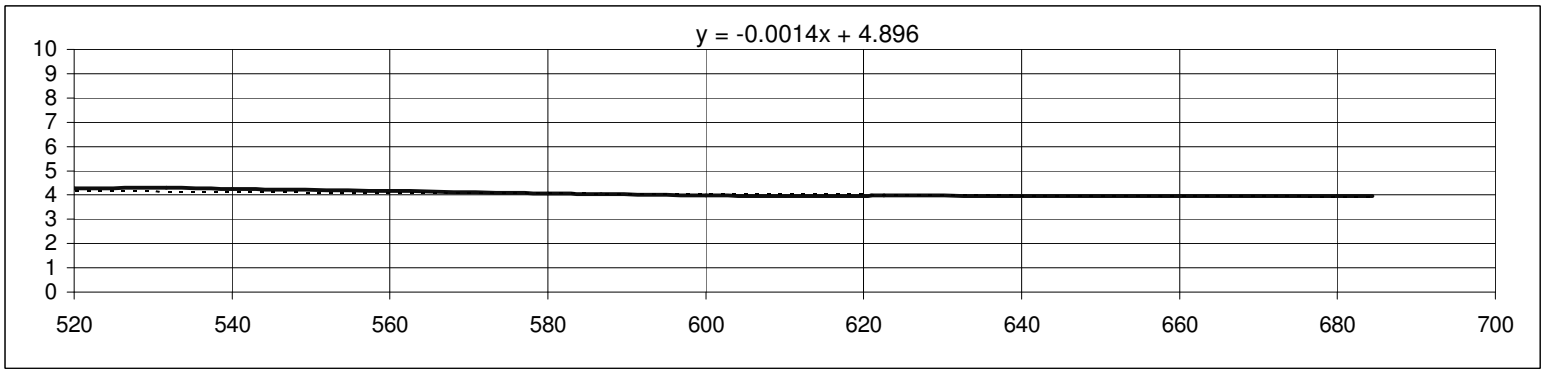
L-Section of Nallah at U/S



L-Section of Nallah at Existing Bridge



L-Section of Nallah at D/S



Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	15.84	cum/sec
HFL	6.226	m
Bed level	4.263	m
Maximum scour depth	3.49	m
Maximum scour level	2.735	m

Curtain wall shall be provided below maximum scour level

Bed level		4.263	m
Scour depth below bed		1.53	m
Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	2.5	m
	d/s	3.0	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	3.06	3.5	m
	d/s	6.0	3.06	6.0	m

CHAPTER-13

BRIDGE AT CH:32/100

13. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1	**Name of the Nala :**	32.100
	Road No.:	S.H - 9
	G.T S No :	73K
	Nearest Village :	-
	RD :	Km. 32.100
	Latitude	20^0 54' 00"
	Longitude	86^0 43' 30"
	Sub-Zone	3(d)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (Refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted	(Since Rain fall is more than 120 cm)	19
M = Catchment area		0.250 sqkm
Q =		6.72 cum/s

3 Discharge by Rational Formula

Catchment area		0.250 sqkm	25.00 hectares
Length of path from toposheet (L)			2.500 km
Difference in levels from toposheet (H)			1.5 m
(Ref: Index map)			
Maximum rain fall (F)	(Ref.SUG of Nanojora River)		216.05 mm
Duaration of storm (T)			5 hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)		129.63 mm/hr
Time of concentration (I.R.C. SP-13, Page 12)	$tc = (0.87*L^3/H)^{0.385}$		2.34 hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)			77.71 mm/hr

Discharge Q = 0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)	0.400
f =	1.00
A =	25.00 Hectares
Ic =	7.771 cm/hr
Q =	2.176 cum/sec

Here,

t_c= Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchment

I_o= One hour rainfall in cm.

I_c= Critical intensity of rainfall in cm per hour

P = Coefficient of runoff for the catchment characteristics (Ref.Table-4.1P-13,I.R.C.:SP:13-2004)

A = Catchment area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in metre

4 Design Discharge (Refer I.R.C.SP-13, page 21)

Discharge by Dicken's Formula		6.72 cum/sec
Discharge by Rational Formula		2.18 cum/sec
Maximum discharge		6.72 cum/sec
Next maximum discharge		2.18 cum/sec
Hence design discharge		**3.26 cum/sec**

5 Linear Water Way

Regime width $W=4.8*Q^{1/2}$ 8.67 m

(Refer IRC:5-1998, Clause 104.3 or SP-13, Page 23)

6 Span arrangement

In proposed span arrangement, single cell of 6.0 m has been proposed with bed protection. 6.00 m

7 Scour depth

Increase in design discharge, as per IRC:78-2000,Clause 703.1.1 30%

Increased design discharge 4.24 cum/sec

Mean depth of scour, as per IRC:78-2000, Clause 703.2

$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width 0.71 cum/sec/m

K_{sf} = Silt factor 1.00 (Assumed)

d_{sf} = 1.06

Maximum scour depth, as per IRC:78-2000, Clause 703.3

for Abutment 1.27 d_{sf} 1.35 m

8 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.6 m

9 Deck level

HFL at existing bridge site including afflux	6.226 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600 m
Depth of super structure including camber	0.680 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	7.562 m
Deck level of the existing bridge	6.914 m
Minimum deck level proposed	7.562 m

As per the proposed allignment, the formation level of bridge has been kept as 7.8 m

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	3.26	cum/sec
HFL	6.226	m
Bed level	5.090	m
Maximum scour depth	1.35	m
Maximum scour level	4.875	m

Curtain wall shall be provided below maximum scour level

Bed level	5.09	m
Scour depth below bed	0.21	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	2.0	m
	d/s	2.5	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	0.43	3.0	m
	d/s	6.0	0.43	6.0	m

CHAPTER-14

BRIDGE AT CH:33/500

14. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1 Name of the Nala : Baharapal Ghusura

Road No.:	S.H - 9
G.T S No :	73K
Nearest Village :	-
RD :	Km.33.500
Latitude	20^0 54' 00"
Longitude	86^0 44' 30"
Sub-Zone	3(d)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted	(Since Rain fall is more than 120 cm)	19
M = Catchment area		0.400 sqkm
Q =		9.56 cum/s

3 Discharge by Rational Formula

Catchment area		0.400 sqkm	40.00 hectares
Length of path from toposheet (L)			2.500 km
Difference in levels from toposheet (H)			1.5 m
(Ref: Index map)			
Maximum rain fall (F)	(Ref.SUG of Nanojora River)		216.05 mm
Duaration of storm (T)			5 hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)		129.63 mm/hr
Time of concentration (I.R.C. SP-13, Page 12)	$tc = (0.87*L^3/H)^{0.385}$		2.34 hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)			77.71 mm/hr

Discharge Q = 0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)	0.400
f =	1.00
A =	40.00 Hectares
Ic =	7.771 cm/hr
Q =	3.481 cum/sec

Here,

t_c= Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchment

I_o= One hour rainfall in cm.

I_c= Critical intensity of rainfall in cm per hour

P = Coefficient of runoff for the catchment characteristics (Ref.Table-4.1P-13,I.R.C.:SP:13-2004)

A = Catchment area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in metre

4 Design Discharge (Refer I.R.C.SP-13, page 21)

Discharge by Dicken's Formula	9.56 cum/sec
Discharge by Rational Formula	3.48 cum/sec
Maximum discharge	9.56 cum/sec
Next maximum discharge	3.48 cum/sec
Hence design discharge	**5.22 cum/sec**

5 Linear Water Way

Regime width $W=4.8*Q^{1/2}$ 10.97 m

(Refer IRC:5-1998, Clause 104.3 or SP-13, Page 23)

6 Span arrangement

In proposed span arrangement, triple cell of 3.0 m has been proposed 9.00 m

with bed protection.

9.00 m

7 Scour depth

Increase in design discharge, as per IRC:78-2000,Clause 703.1.1 30%

Increased design discharge 6.79 cum/sec

Mean depth of scour, as per IRC:78-2000, Clause 703.2

$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width	0.62 cum/sec/m
K_{sf} = Silt factor	0.61
d_{sf} =	1.15

Maximum scour depth, as per IRC:78-2000, Clause 703.3

for Pier	$2\ d_{sf}$	2.29 m
for Abutment	$1.27\ d_{sf}$	1.46 m

8 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point

0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.6 m

9 Deck level

HFL at existing bridge site	7.043 m
Afflux	0.003 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600 m
Depth of super structure including camber	0.450 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	8.152 m
Deck level of the existing bridge	7.043 m
Minimum deck level proposed	8.152 m

As per the proposed allignment, the formation level of bridge has been kept as 8.3 m

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	5.22	cum/sec
HFL	7.043	m
Bed level	4.860	m
Maximum scour depth	2.29	m
Maximum scour level	4.748	m

Curtain wall shall be provided below maximum scour level

Bed level	4.86	m
Scour depth below bed	0.11	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	2.0	m
	d/s	2.5	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	0.22	3.0	m
	d/s	6.0	0.22	6.0	m

CHAPTER-15

BRIDGE AT CH:33/900

15. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1	**Name of the Nala :**	Kheranga Teraturia Canal
	Road No.:	S.H - 9
	G.T S No :	73K
	Nearest Village :	-
	RD :	Km. 33.900
	Latitude	20^0 53' 00".
	Longitude	86^0 44' 30"
	Sub-Zone	3(d)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted	(Since Rain fall is more than 120 cm)	19
M = Catchment area		0.370 sqkm
Q =		9.01 cum/s

3 Discharge by Rational Formula

Catchment area	0.370 sqkm	37.00 hectares
Length of path from toposheet (L)		2.500 km
Difference in levels from toposheet (H)		1.5 m
(Ref: Index map)		
Maximum rain fall (F)	(Ref.SUG of Nanojora River)	216.05 mm
Duaration of storm (T)		5 hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)	129.63 mm/hr
Time of concentration (I.R.C. SP-13, Page 12)	$tc = (0.87*L^3/H)^{0.385}$	2.34 hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		77.71 mm/hr

Discharge Q = 0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)	0.400
f =	1.00
A =	37.00 Hectares
Ic =	7.771 cm/hr
Q=	3.220 cum/sec

Here,

t_c= Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchment

I_o= One hour rainfall in cm.

I_c= Critical intensity of rainfall in cm per hour

P = Coefficient of runoff for the catchment characteristics (Ref.Table-4.1P-13,I.R.C.:SP:13-2004)

A = Catchment area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in metre

4 Design Discharge (Refer I.R.C.SP-13, page 21)

Discharge by Dicken's Formula	9.01 cum/sec
Discharge by Rational Formula	3.22 cum/sec
Maximum discharge	9.01 cum/sec
Next maximum discharge	3.22 cum/sec
Hence design discharge	**4.83 cum/sec**

5 Linear Water Way

Regime width $W=4.8*Q^{1/2}$ 10.55 m

(Refer IRC:5-1998, Clause 104.3 or SP-13, Page 23)

6 Span arrangement

In proposed span arrangement, triple cell of 3.0 m has been proposed with bed protection. 9.00 m

7 Scour depth

Increase in design discharge, as per IRC:78-2000,Clause 703.1.1 30%

Increased design discharge 6.28 cum/sec

Mean depth of scour, as per IRC:78-2000, Clause 703.2

$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width	0.60 cum/sec/m
K_{sf} = Silt factor	0.47
d_{sf} =	1.22

Maximum scour depth, as per IRC:78-2000, Clause 703.3

for Pier	$2\ d_{sf}$	2.44 m
for Abutment	$1.27\ d_{sf}$	1.55 m

8 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.6 m

9 Deck level

HFL at existing bridge site including afflux	6.801 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600 m
Depth of super structure including camber	0.450 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	7.907 m
Deck level of the existing bridge	6.501 m
Minimum deck level proposed	7.907 m

As per the proposed allignment, the formation level of bridge has been kept as 8.3 m

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	4.83 cum/sec
HFL	6.801 m
Bed level	5.610 m
Maximum scour depth	2.44 m
Maximum scour level	4.362 m

Curtain wall shall be provided below maximum scour level

Bed level		5.61 m
Scour depth below bed		1.25 m
Minimum depth of curtan wall as per IRC:89-1997	u/s	2 m
	d/s	2.5 m
Provide depth of curtain wall	u/s	2.0 m
	d/s	2.5 m
Rigid apron as per IRC:89-1997	u/s	3.0 m
	d/s	5.0 m

		As per IRC:89	2xscour depth	Provided
Flexible apron	u/s	3.0	2.50	3.0 m
	d/s	6.0	2.50	6.0 m

CHAPTER-16

BRIDGE AT CH:34/700

16. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1 General details

Name of the Nala :	Talajharia Katha Polo
Road No.:	S.H - 9
G.T S No :	73K
Nearest Village :	-
RD :	Km.34.700
Latitude	20^0 53' 00"
Longitude	86^0 45' 00"
Sub-Zone	3(d)

2 Discharge by Manning's Formula

HFL at proposed bridge site	6.632 m

Cross-section of the stream at different locations are as follows

Discharge by Manning's Formula at U/S location

Cross-sectional area of flow	28.51 sqm
Width of flow	15.00 m
Wetted perimeter perpendicular to direction of flow	15.12 m
Hydraulic mean radius R = A/P	1.89 m
Longitudinal slope as calculated	0.0033 m per m
Velocity by Manning's formula	
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)	
For sluugish type bed (Table 5.1)	
n =	0.06
Velocity V =	1.461 m/s
Discharge Q = A*V	41.66 cum/s

Discharge by Manning's Formula at existing location

Cross-sectional area of flow	32.54 sqm
Width of flow	18.00 m
Wetted perimeter perpendicular to direction of flow	18.06 m
Hydraulic mean radius R = A/P	1.80 m
Longitudinal slope as calculated	0.0033 m per m
Velocity by Manning's formula	
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)	
For sluugish type bed (Table 5.1)	
n =	0.06
Velocity V =	1.418 m/s
Discharge Q = A*V	46.13 cum/s

Discharge by Manning's Formula at D/S location

Cross-sectional area of flow	59.67	sqm
Width of flow	27.00	m
Wetted perimeter perpendicular to direction of flow	27.60	m
Hydraulic mean radius R = A/P	2.16	m
Longitudinal slope as calculated	0.0058	m per m
Velocity by Manning's formula		
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n =	0.06	
Velocity V =	2.122	m/s
Discharge Q = A*V	126.61	cum/s

The hydrological calculations has been done at three sections I.e. at upstream side, downstream side and near proposed bridge location

By comparision of upstream and downstream side and Existing bridge location.

Hence the design discharge may be taken as **46.13 cum/s**

3 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted (Since Rain fall is more than 120 cm)	19	
M = Catchment area	0.400	sqkm
Q =	9.56	cum/s

4 Discharge by Rational Formula

Catchment area	0.400 sqkm	40.00	hectares
Length of path from toposheet (L)		3.010	km
Difference in levels from toposheet (H)		4.2	m
(Ref: Index map)			
Maximum rain fall (F)	(Ref.SUG of Nanojora River)	216.05	mm
Duaration of storm (T)		5	hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)	129.63	mm/hr
Time of concentration (SP-13, page 12)	$tc = (0.87*L^3/H)^{0.385}$	1.95	hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		87.96	mm/hr
Discharge Q = 0.028 * P*f* A* Ic			
P = (for loam, lightly cultivated or covered)		0.400	
f =		1.00	
A =		40.00	Hectares
Ic =		8.796	cm/hr
Q=		3.940	cum/sec

5 Design Discharge (Refer SP-13, page 21)

Discharge by Manning's Formula	46.13 cum/sec
Discharge by Dicken's Formula	9.56 cum/sec
Discharge by Rational Formula	3.94 cum/sec
Maximum discharge	46.13 cum/sec
Next maximum discharge	9.56 cum/sec
The difference is beyond 50% of the next maximum discharge	
Hence design discharge	**14.33 cum/sec**

6 Water Way

Regime width $W = 4.8Q^{1/2}$ 18.17 m

(Refer IRC:5-1998, cl 104.3 or SP-13, page 23)

Provide	Clear span	9.3 m
	No. of spans	1 no.
	Total waterway provided L	9.3 m

7 Scour depth

Increase in design discharge, as per IRC:78-2000, cl 703.1.1	30%
Increased design discharge	18.64 cum/sec

Mean depth of scour, as per IRC:78-2000, cl 703.2

$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width	2.00 cum/sec/m
K_{sf} = Silt factor	1.0 Assumed
Mean depth of scour, d_{sf} =	2.13 m

Maximum scour depth, as per IRC:78-2000, cl 703.3

for Abutment $1.27\ d_{sf}$ 2.70 m

8 Deck level

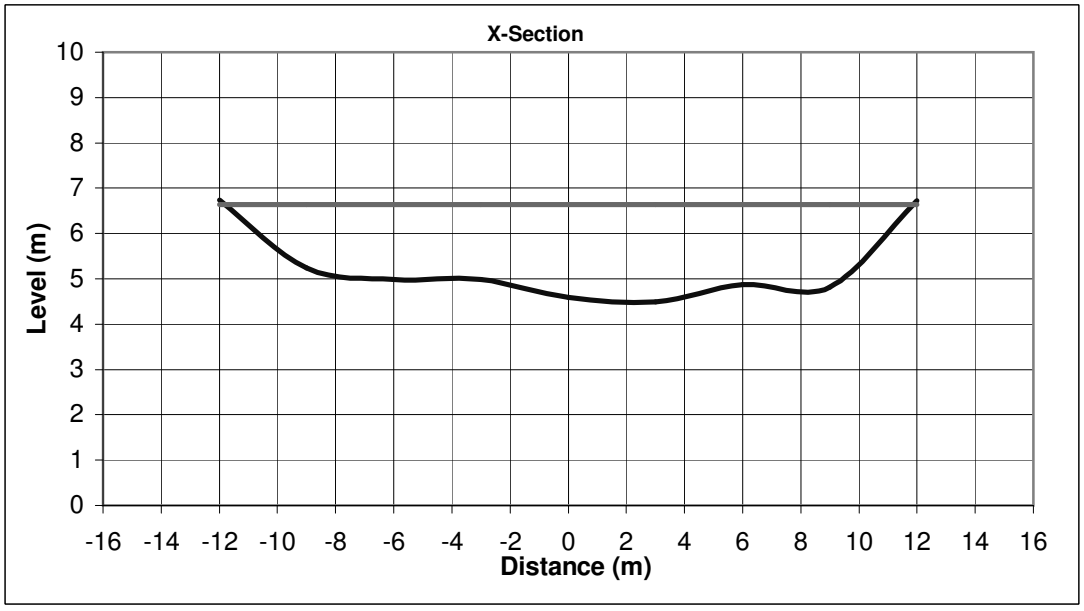
HFL at proposed bridge site	6.632 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600 m
Depth of super structure	0.850 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	8.138 m
Deck level of the existing bridge	8.280 m
Minimum deck level proposed	8.280 m

Keeping in view of the hydraulic performance of the existing bridge, it is recommended to retain the existing bridge, no raising required.

Cross-sectional area of nallah at proposed bridge site is as follows:

HFL at this location 6.632 m

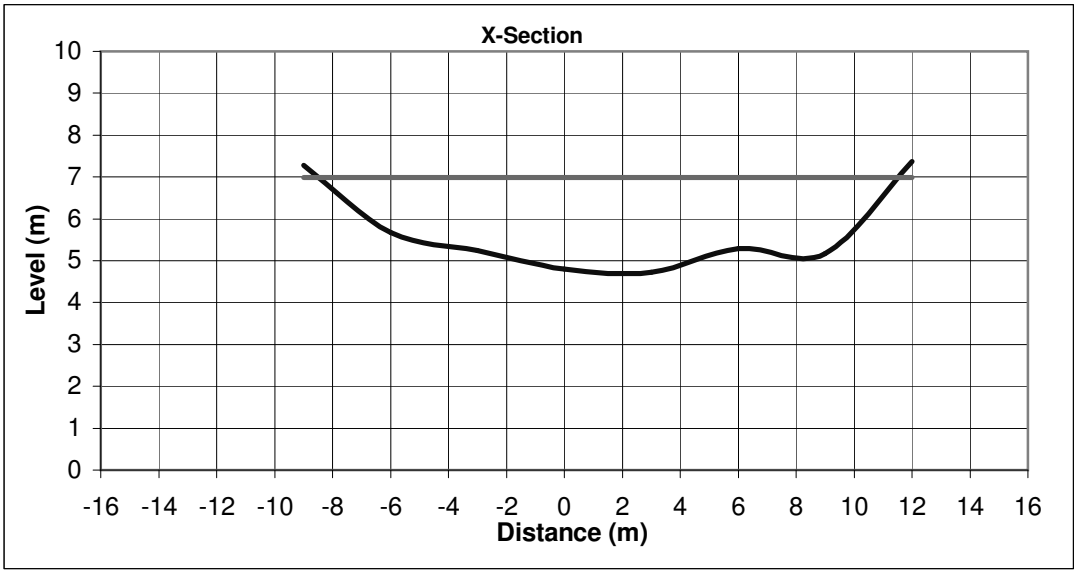
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-12	6.744	6.632					
-9	5.235	6.632	1.397				
-6	4.984	6.632	1.648	1.523	4.568	3.010	3.000
-3	4.985	6.632	1.647	1.648	4.943	3.000	3.000
0	4.588	6.632	2.044	1.846	5.537	3.026	3.000
3	4.487	6.632	2.145	2.095	6.284	3.002	3.000
6	4.873	6.632	1.759	1.952	5.856	3.025	3.000
9	4.821	6.632	1.811	1.785	5.355	3.000	3.000
12	6.723	6.632					
Total					**32.54**	**18.06**	**18.00**



Cross-sectional area of nallah at u/s of the proposed bridge is as follows:

Distance from proposed bridge	110	m
Longitudinal slope u/s side	0.0033	
HFL at this location	6.995	m

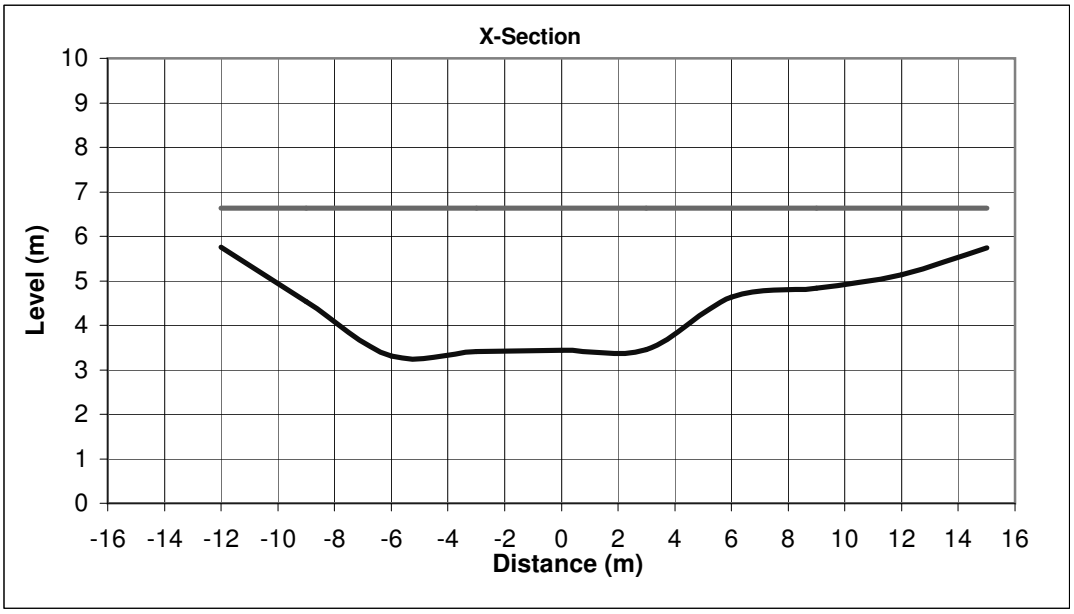
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-9	7.283	6.995					
-6	5.667	6.995	1.328				
-3	5.238	6.995	1.757	1.543	4.628	3.031	3.000
0	4.796	6.995	2.199	1.978	5.934	3.032	3.000
3	4.726	6.995	2.269	2.234	6.702	3.001	3.000
6	5.296	6.995	1.699	1.984	5.952	3.054	3.000
9	5.165	6.995	1.830	1.765	5.294	3.003	3.000
12	7.372	6.995					
Total					**28.51**	**15.12**	**15.00**



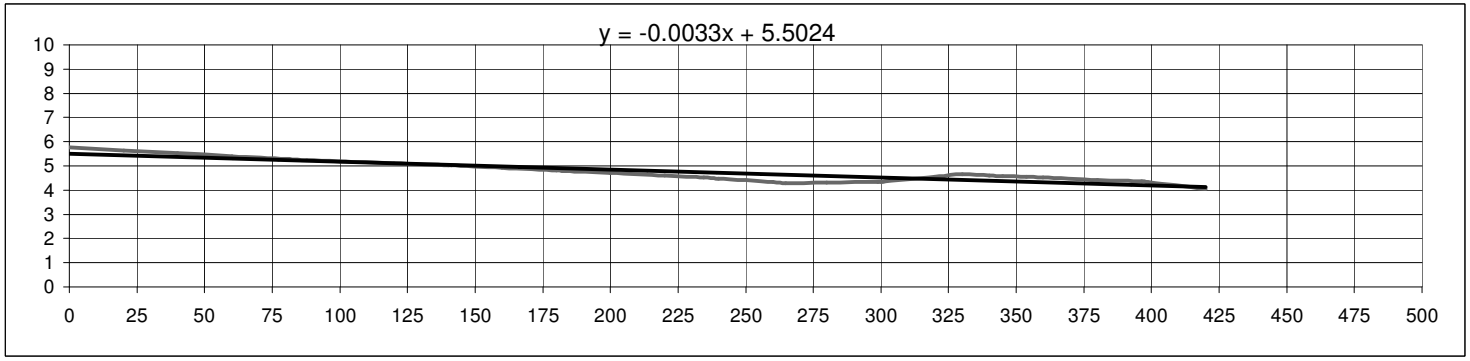
Cross-sectional area of nallah at d/s of proposed bridge is as follows:

Distance from proposed bridge 110 m
Longitudinal slope d/s side 0.0058
HFL at this location 6.632 m

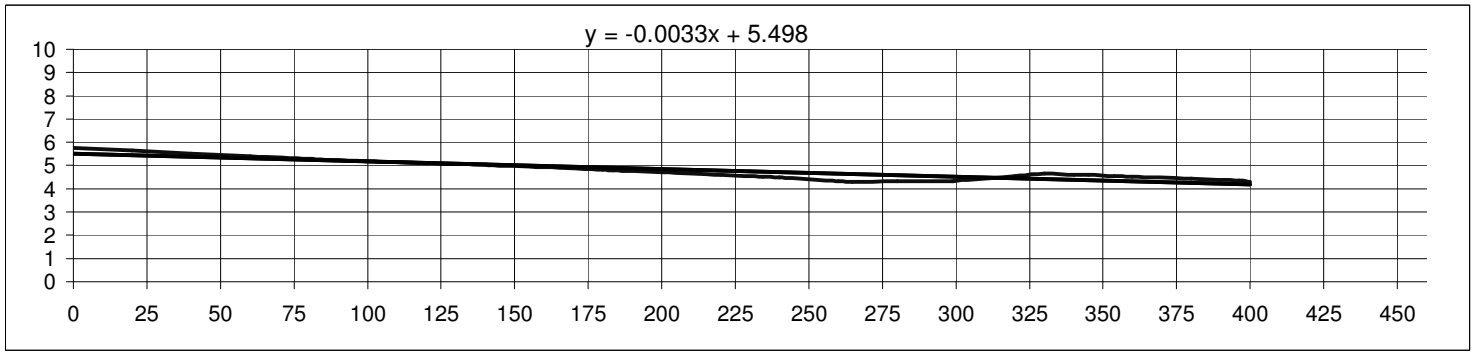
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-12	5.752	6.632	0.880				
-9	4.532	6.632					
-6	3.316	6.632					
-3	3.41	6.632	3.222	2.051	18.459	9.300	9.000
0	3.433	6.632	3.199	3.211	9.632	3.000	3.000
3	3.456	6.632	3.176	3.188	9.563	3.000	3.000
6	4.626	6.632	2.006	2.591	7.773	3.220	3.000
9	4.834	6.632	1.798	1.902	5.706	3.007	3.000
12	5.13	6.632	1.502	1.650	4.950	3.015	3.000
15	5.745	6.632	0.887	1.195	3.584	3.062	3.000
Total					**59.67**	**27.60**	**27.00**



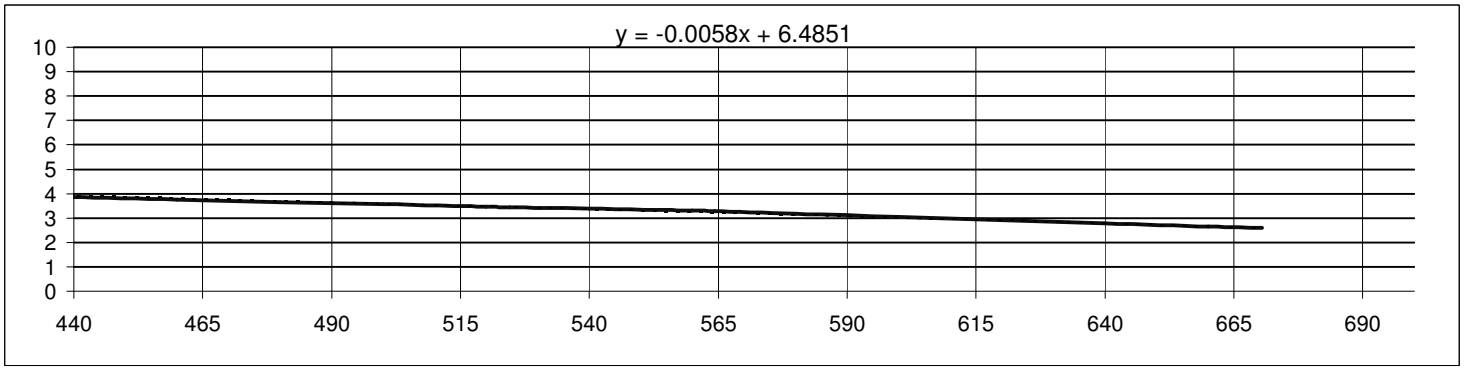
L-Section of Nallah at U/S



L-Section of Nallah at Existing Bridge



L-Section of Nallah at D/S



Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	14.33	cum/sec
HFL	6.632	m
Bed level	4.544	m
Maximum scour depth	2.70	m
Maximum scour level	3.927	m

Curtain wall shall be provided below maximum scour level

Bed level	4.544	m
Scour depth below bed	0.62	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	2.0	m
	d/s	2.5	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	1.23	3.0	m
	d/s	6.0	1.23	6.0	m

CHAPTER-17

BRIDGE AT CH:36/005

17. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1 Name of the Nala : Nalagandha Ghusura

Road No.:	S.H - 9
G.T S No :	73K
Nearest Village :	Talabandha
RD :	Km.36.005
Latitude	20^0 53' 00"
Longitude	86^0 45' 30"
Sub-Zone	3(d)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted	(Since Rain fall is more than 120 cm)	19
M = Catchment area		3.200 sqkm
Q =		45.46 cum/s

3 Discharge by Rational Formula

Catchment area	3.200 sqkm	320.00 hectares
Length of path from toposheet (L)		2.200 km
Difference in levels from toposheet (H)		1.5 m
(Ref: Index map)		
Maximum rain fall (F)	(Ref.SUG of Nanojora River)	216.05 mm
Duaration of storm (T)		5 hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)	129.63 mm/hr
Time of concentration (I.R.C. SP-13, Page 12)	$tc = (0.87*L^3/H)^{0.385}$	2.02 hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		85.97 mm/hr

Discharge Q = 0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)	0.400
f =	1.00
A =	320.00 Hectares
Ic =	8.597 cm/hr
Q=	30.812 cum/sec

Here,

t_c= Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchment

I_o= One hour rainfall in cm.

I_c= Critical intensity of rainfall in cm per hour

P = Coefficient of runoff for the catchment characteristics (Ref.Table-4.1P-13,I.R.C.:SP:13-2004)

A = Catchment area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in metre

4 Design Discharge (Refer I.R.C.SP-13, page 21)

Discharge by Dicken's Formula	45.46 cum/sec
Discharge by Rational Formula	30.81 cum/sec
Maximum discharge	45.46 cum/sec
Next maximum discharge	30.81 cum/sec

5 Linear Water Way

Regime width $W=4.8*Q^{1/2}$ 32.36 m

(Refer IRC:5-1998, Clause 104.3 or SP-13, Page 23)

This is a submersible zone and additional structures has been provided in this stretch, which will take care . additional discharge. Hence scour depth has been calculated on the basis of full discharging capacity of that structure assuming 1 m/sec velocity.

*Disharge of 9.0 m clear waterway = (7.49-0.056-0.45-4.772)*9*1= 24.462 cumecs*

Hence design discharge **24.462 cum/sec**

6 Span arrangement

In proposed span arrangement, three cells of 3.0 m has been proposed with bed protection. 9.00 M

7 Scour depth

Increase in design discharge, as per IRC:78-2000,Clause 703.1.1	30%
Increased design discharge	31.80 cum/sec

Mean depth of scour, as per IRC:78-2000, Clause 703.2

$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width	3.53 cum/sec/m
K_{sf} = Silt factor	1.00 (Assumed)
d_{sf} =	3.11

Maximum scour depth, as per IRC:78-2000, Clause 703.3

for Pier	$2\ d_{sf}$	6.22 m
for Abutment	$1.27\ d_{sf}$	3.95 m

8 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point	
0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16)	0.600 m

9 Deck level

HFL at existing bridge site including afflux	7.490 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600 m
Depth of super structure including camber	0.450 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	8.596 m
Deck level of the existing bridge	5.990 m
Minimum deck level proposed	8.596 m

As per the proposed allignment, the formation level of bridge has been kept as 8.7 m

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	24.46	cum/sec
HFL	7.490	m
Bed level	4.772	m
Maximum scour depth	6.22	m
Maximum scour level	1.273	m

Curtain wall shall be provided below maximum scour level

Bed level	4.772	m
Scour depth below bed	3.50	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	4.0	m
	d/s	4.5	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	7.00	7.0	m
	d/s	6.0	7.00	7.0	m

CHAPTER-18

BRIDGE AT CH:38/100

18. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

The existing Bridge at km-**38**/**100** is a Irrigation Canal
the Bridge has been constructed in 2005 by Irrigation Department
so there is no need of Hydrology.

CHAPTER-19

BRIDGE AT CH:42/400

19. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1	**Name of the Nala :**	42.400
	Road No.:	S.H - 9
	G.T S No :	73K
	Nearest Village :	-
	RD :	Km.42.400
	Latitude	20^0 50' 30"
	Longitude	86^0 46' 00"
	Sub-Zone	3(d)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted	(Since Rain fall is more than 120 cm)	19
M = Catchment area		0.205 sqkm
Q =		5.79 cum/s

3 Discharge by Rational Formula

Catchment area		0.205 sqkm	20.50 hectares
Length of path from toposheet (L)			2.100 km
Difference in levels from toposheet (H)			2 m
(Ref: Index map)			
Maximum rain fall (F)	(Ref.SUG of Nanojora River)		216.05 mm
Duaration of storm (T)			5 hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)		129.63 mm/hr
Time of concentration (I.R.C. SP-13, Page 12)	$tc = (0.87*L^3/H)^{0.385}$		1.71 hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)			95.67 mm/hr

Discharge Q = 0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)		0.400
f =		1.00
A =		20.50 Hectares
Ic =		9.567 cm/hr
Q =		2.197 cum/sec

Here,

t_c= Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchment

I_o= One hour rainfall in cm.

I_c= Critical intensity of rainfall in cm per hour

P = Coefficient of runoff for the catchment characteristics (Ref.Table-4.1P-13,I.R.C.:SP:13-2004)

A = Catchment area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in metre

4 Design Discharge (Refer I.R.C.SP-13, page 21)

Discharge by Dicken's Formula	5.79 cum/sec
Discharge by Rational Formula	2.20 cum/sec
Maximum discharge	5.79 cum/sec
Next maximum discharge	2.20 cum/sec
Hence design discharge	**3.29 cum/sec**

5 Linear Water Way

Regime width $W=4.8*Q^{1/2}$ 8.71 m

(Refer IRC:5-1998, Clause 104.3 or SP-13, Page 23)

6 Span arrangement

In proposed span arrangement, single cell of 6.0 m has been proposed with bed protection. 6.00 m

7 Scour depth

Increase in design discharge, as per IRC:78-2000,Clause 703.1.1 30%

Increased design discharge 4.28 cum/sec

Mean depth of scour, as per IRC:78-2000, Clause 703.2

$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width	0.71 cum/sec/m
K_{sf} = Silt factor	0.64
d_{sf} =	1.24

Maximum scour depth, as per IRC:78-2000, Clause 703.3

for Abutment 1.27 d_{sf} 1.58 m

8 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.45 m

9 Deck level

HFL at existing bridge site including afflux	7.811 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.450 *m
Depth of super structure including camber	0.680 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	8.997 m
Deck level of the existing bridge	8.336 m
Minimum deck level proposed	9.000 m

* Min. vertical clearance has been kept as 0.45 m as Discharge is just exceeding 3.0 cum/sec.

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	3.29	cum/sec
HFL	7.811	m
Bed level	4.721	m
Maximum scour depth	1.58	m
Maximum scour level	6.234	m

Curtain wall shall be provided below maximum scour level

Bed level	4.721	m
Scour depth below bed	0.00	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	2.0	m
	d/s	2.5	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	0.00	3.0	m
	d/s	6.0	0.00	6.0	m

CHAPTER-20

BRIDGE AT CH:43/500

20. Hydraulic calculations for Minor Bridge of road Bhadrak-Chandbali

1	**Name of the Nala :**	Chandanpur Polo
	Road No.:	S.H - 9
	G.T S No :	73K
	Nearest Village :	Chandanpur
	RD :	Km.43.500
	Latitude	20^0 50' 00'
	Longitude	86^0 46' 00"
	Sub-Zone	3(d)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted	(Since Rain fall is more than 120 cm)	19
M = Catchment area		0.190 sqkm
Q =		5.47 cum/s

3 Discharge by Rational Formula

Catchment area		0.190 sqkm	19.00 hectares
Length of path from toposheet (L)			1.200 km
Difference in levels from toposheet (H)			2.2 m
(Ref: Index map)			
Maximum rain fall (F)	(Ref.SUG of Nanojora River)		216.05 mm
Duaration of storm (T)			5 hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)		129.63 mm/hr
Time of concentration (I.R.C. SP-13, Page 12)	$tc = (0.87*L^3/H)^{0.385}$		0.86 hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)			139.11 mm/hr

Discharge Q = 0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)		0.400
f =		0.53
A =		19.00 Hectares
Ic =		13.911 cm/hr
Q =		1.569 cum/sec

Here,

t_c= Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchment

I_o= One hour rainfall in cm.

I_c= Critical intensity of rainfall in cm per hour

P = Coefficient of runoff for the catchment characteristics (Ref.Table-4.1P-13,I.R.C.:SP:13-2004)

A = Catchment area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in metre

4 Design Discharge (Refer I.R.C.SP-13, page 21)

Discharge by Dicken's Formula	5.47 cum/sec
Discharge by Rational Formula	1.57 cum/sec
Maximum discharge	5.47 cum/sec
Next maximum discharge	1.57 cum/sec
Hence design discharge	**2.35 cum/sec**

5 Linear Water Way

Regime width $W = 4.8*Q^{1/2}$ 7.36 m

(Refer IRC:5-1998, Clause 104.3 or SP-13, Page 23)

6 Span arrangement

In proposed span arrangement, single cell of 6.0 m has been proposed with bed protection. 6.0 m

7 Scour depth

Increase in design discharge, as per IRC:78-2000,Clause 703.1.1 30%

Increased design discharge 3.06 cum/sec

Mean depth of scour, as per IRC:78-2000, Clause 703.2

$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width	0.51 cum/sec/m
K_{sf} = Silt factor	1.00 (Assumed)
d_{sf} =	0.86

Maximum scour depth, as per IRC:78-2000, Clause 703.3

for Abutment 1.27 d_{sf} 1.09 m

8 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.45 m

9 Deck level

HFL at existing bridge site	8.121 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.450 m
Depth of super structure including camber	0.680 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	9.307 m
Deck level of the existing bridge	8.746 m
Minimum deck level proposed	9.307 m

As per the proposed allignment, the formation level of bridge has been kept as 9.3 m

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	2.35	cum/sec
HFL	8.121	m
Bed level	6.699	m
Maximum scour depth	1.09	m
Maximum scour level	7.033	m

Curtain wall shall be provided below maximum scour level

Bed level	6.699	m
Scour depth below bed	0.00	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	2.0	m
	d/s	2.5	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	0.00	3.0	m
	d/s	6.0	0.00	6.0	m

APPENDIX

ORISSA STATE ROAD PROJECT

HYDROLOGICAL STUDY

Road	: Chandbali-Bhadrak(S.H-49)
Name of River/Nallah/Stream	: Nanojora Nala
Name of nearest Village/Town	:
RD	:
Lattitude	: 86^0 2' 51"
Longitude	: 21^0 54' 44"
GT Sheet No.	: 73 L

Estimation of slope

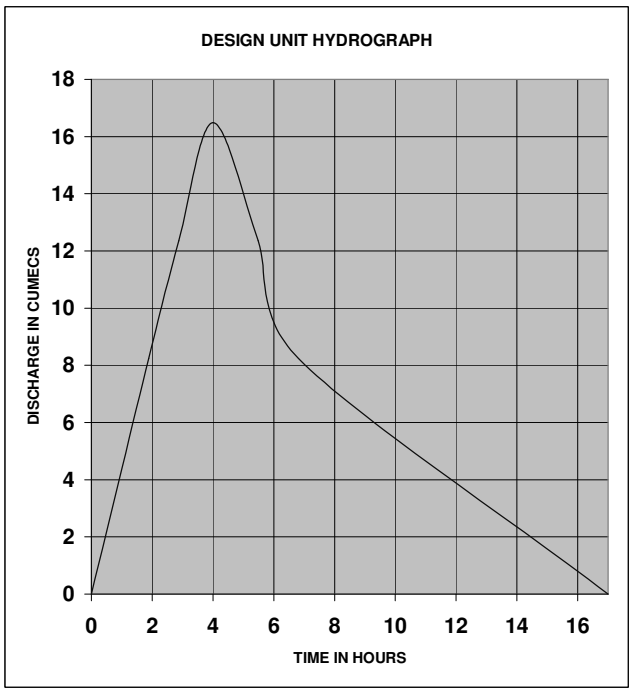
Sl No.	Reduced Distance starting	Reduced Levels of River Bed	Length of each segment Li	Diff in RL	(Di-1+ Di)	Li (Di-1 + Di) (4) x (6) (m x km)
1	0	393	0	0	0	0
2	2350	400	2350	7	7.0	16.45
3	8500	420	6150	20	27.0	166.05
4	8900	425	400	5	25.0	10
						192.5

$$S = \frac{\Sigma L_i (D_{i-1} + D_i)}{L^2} = 2.43 \text{ m/km}$$

Synthetic Unitgraph

Catchment area =	36.75 sq.kms.
L =	8.9 km
Lc =	3.4 km
LxLc/(sqrt(s)) =	19.412
tp = 1.97((L X Lc)/sqrt(S))0.24 =	4.014 hrs
	4 hrs
qp = 1.12 (tp)-0.66 =	0.449
Qp = Catchment area x qp =	16.486 cumec
W50 = 2.195 (qp)-1.008 =	4.924
W75 = 1.221 (qp)-0.95 =	2.615
WR50 = 0.995 (qp)-0.94 =	2.114
WR75 = 0.532 (qp)-0.93 =	1.121
Q50 = 0.5 x Qp =	8.243
Q75 = 0.75 x Qp =	12.365
TB = 5.72 (tp)0.77 =	16.633

Unit Graph(1 cm 1 hour)		
Sl. No	Time	Ordinate
1	0	0
2	1	4.9
3	2	9
4	3	13.1
5	4	16.49
6	5	14
7	6	10.2
8	7	7.8
9	8	6.4
10	9	5.2
11	10	4.2
12	11	3.3
13	12	2.7
14	13	2
15	14	1.4
16	15	1
17	16	0.5
18	17	0
Total =		**102.19 cumec hours**
=		**10.01044898 mm**



STORM DURATION Td = 1.1 Tp

= 1.1 X 4 = 4.4 say 5 Hrs

From Plate 9(a), 50 Year- 24 Hour Rainfall = 320 mm . **320 mm**

Areal Rainfall = 69 % of Point Rainfall **69 220.8 mm**

Areal reduction factor =97.85 % **97.85 216.05 mm**

Cumulative percentage Loss Rate 0.26 cm / Hour **2.6 mm /hour**

Hours	Storm Percentage	Storm Rainfall	Excess Rainfall	Incremental R.E.
0	0	0	0	0
1	64	138.27	135.67	135.67
2	83	179.32	174.12	38.45
3	91	196.61	188.81	14.68
4	97	209.57	199.17	10.36
5	100	216.05	203.05	3.88

GT Sheet No. 73 L

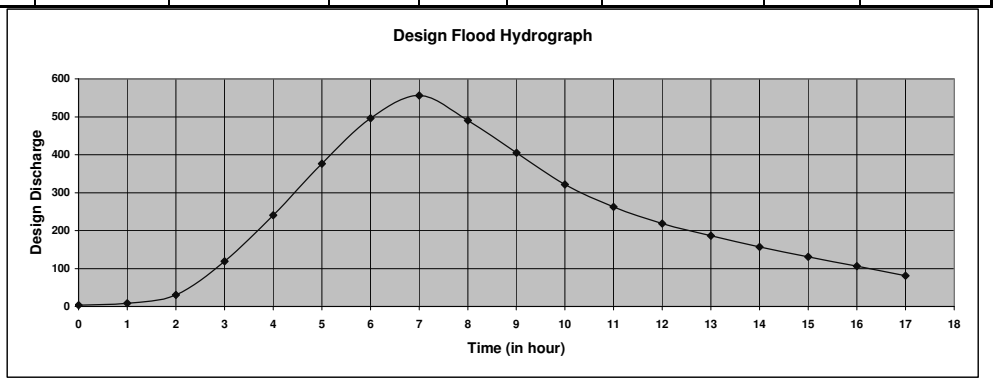
Estimation of Design Flood Hydrograph

Unit Graph(1 cm 1 hour)			R.E.	R.E.					Base	Design
Sl.	Time	Ordinate	Peak to	Reverse					Flow	Flood
No			Peak	order	1.036	3.845	13.567	1.468		Hydrograph
1	**0**	0			0				3.7	3.70
2	**1**	4.25			4.40	0.00			3.7	8.10
3	**2**	10.25			10.62	16.34	0.00		3.7	30.66
4	**3**	17.25	**3.88**	**10.36**	17.87	39.41	57.66	0.00	3.7	118.64
5	**4**	24	**14.68**	**38.45**	24.86	66.33	139.06	6.24	3.7	240.19
6	**5**	29	**135.67**	**135.67**	30.04	92.28	234.03	15.05	3.7	376.75
7	**6**	25	**38.45**	**14.68**	25.90	111.51	325.61	25.32	3.7	496.01
8	**7**	20.5	**10.36**	**3.88**	21.24	96.13	393.44	35.23	3.7	556.43
9	**8**	16			16.58	78.82	339.18	42.57	3.7	490.16
10	**9**	13			13.47	61.52	278.12	36.70	3.7	404.76
11	**10**	10.75			11.14	49.99	217.07	30.09	3.7	321.69
12	**11**	9.25			9.58	41.33	176.37	23.49	3.7	262.43
13	**12**	7.75			8.03	35.57	145.85	19.08	3.7	218.43
14	**13**	6.5			6.73	29.80	125.49	15.78	3.7	186.55
15	**14**	5.25			5.44	24.99	105.14	13.58	3.7	157.03
16	**15**	4.0			4.14	20.19	88.19	11.38	3.7	131.18
17	**16**	3.25			3.37	15.38	71.23	9.54	3.7	106.22
18	**17**	0			0.00	12.50	54.27	7.71	3.7	80.69
						0.00	44.09	5.87	3.7	55.70
							0.00	4.77	3.7	10.02
								0	3.7	4.96
									3.7	3.70

Qp = 556 Cumecs

C.A. = 36.75 Sq. Kms.

Dicken's constant c= 37.25



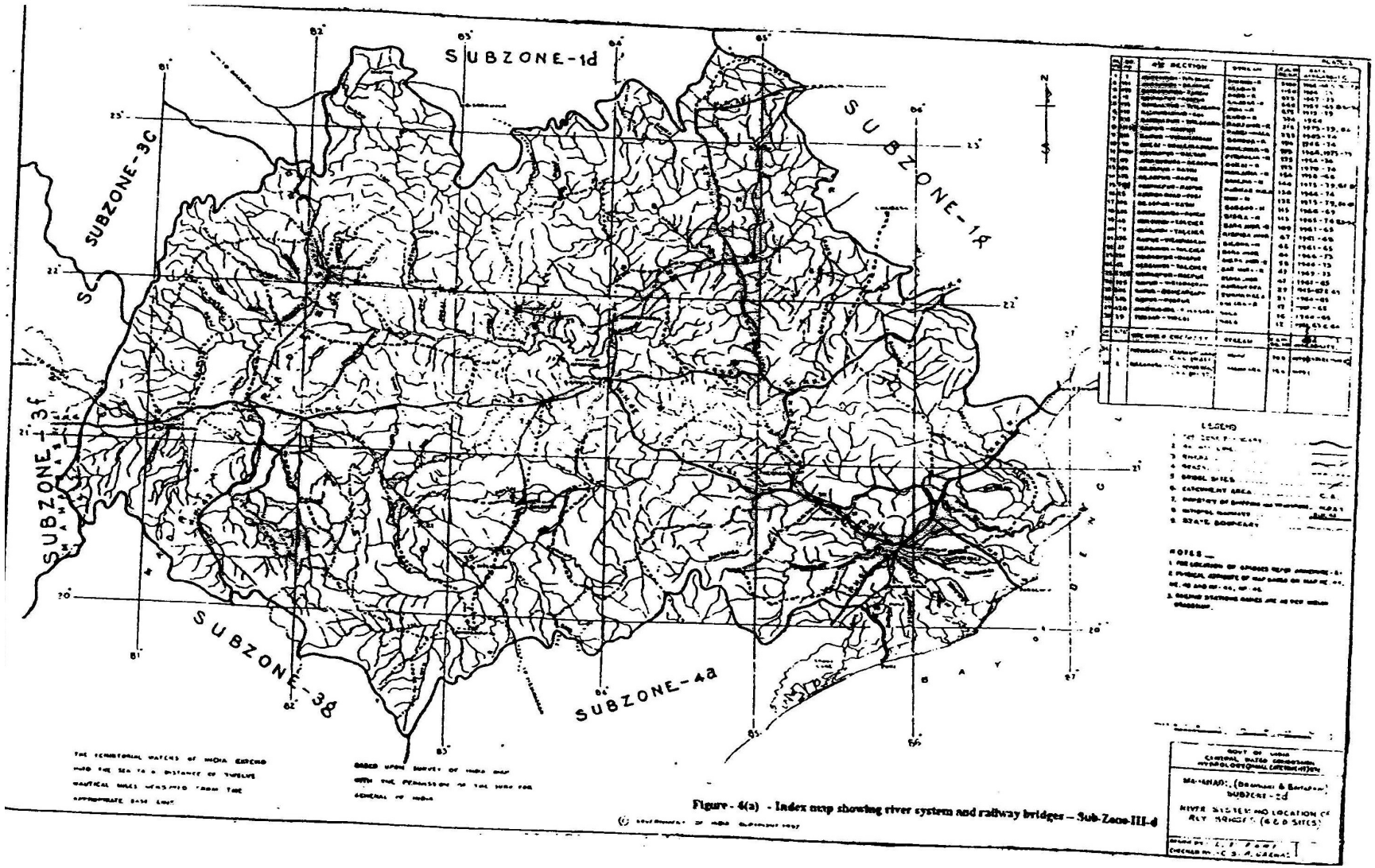
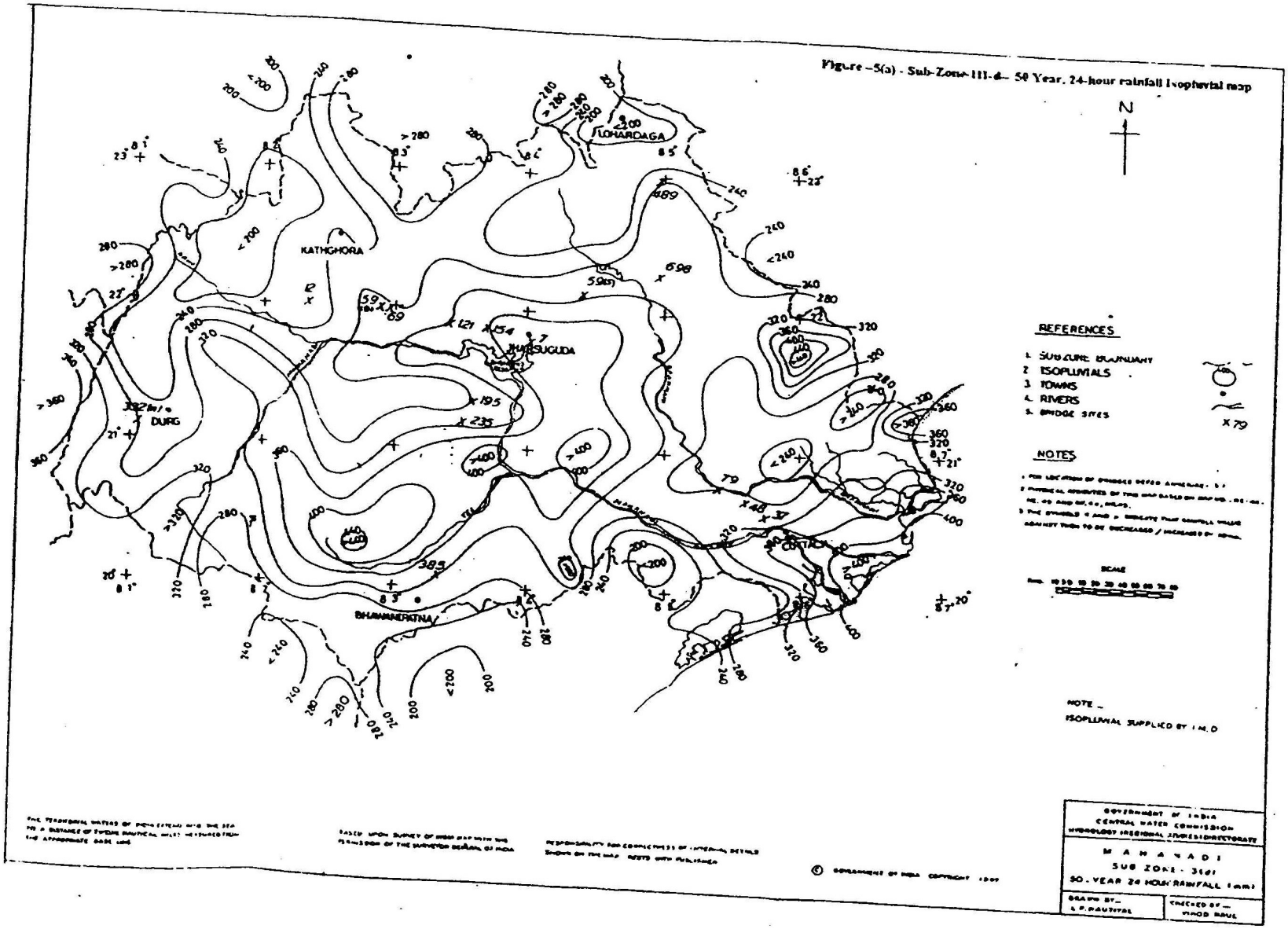
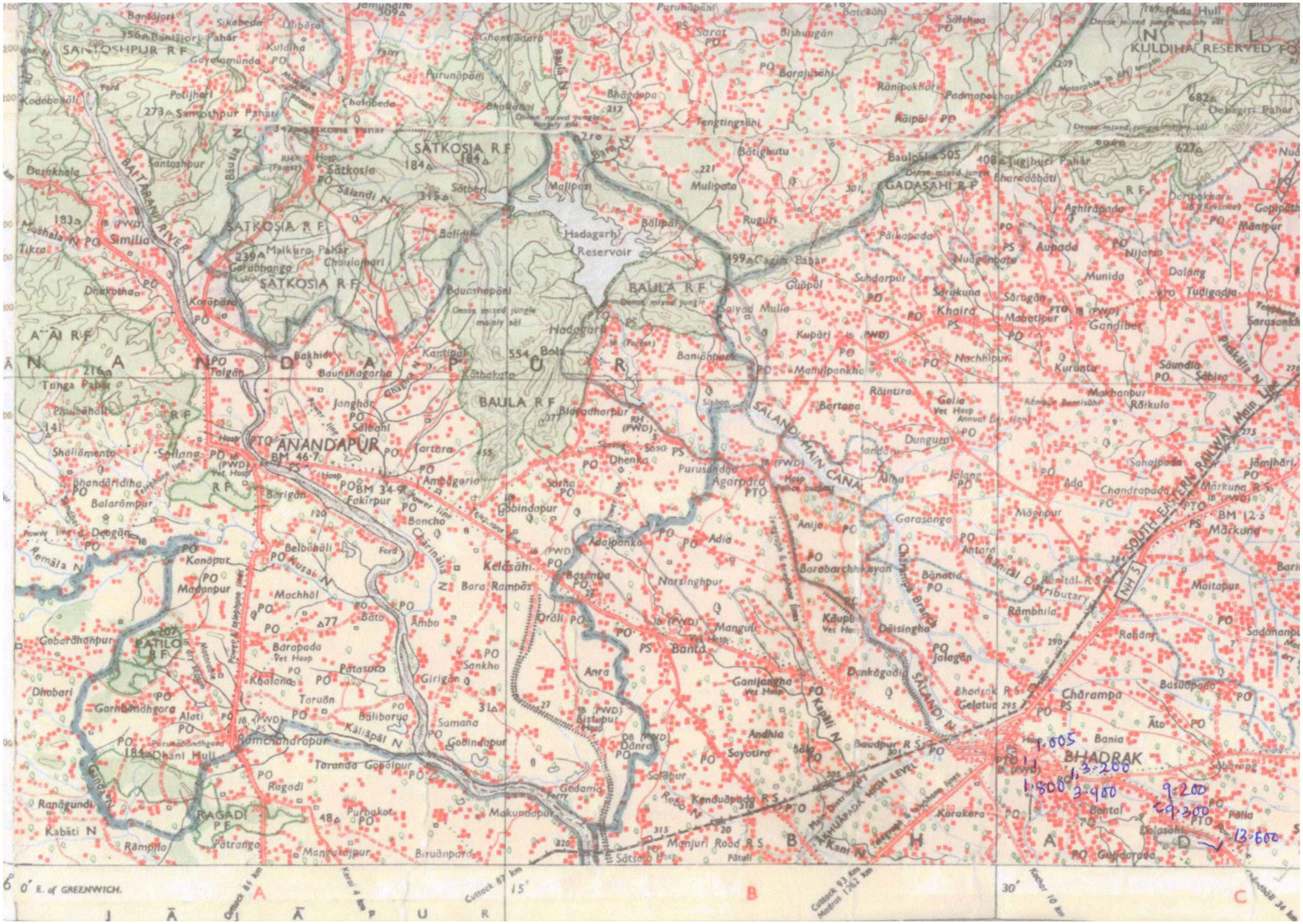


Figure - 4(a) - Index map showing river system and railway bridges – Sub-Zone-III-d

Figure –5(a) - Sub-Zone III-d – 50 Year, 24-hour rainfall Isophevial map




BAY OF BENGAL
Mangrove swamp
Low water line
Ghanteshwar
Karanjadiha
Nuasahi
Karanpalli
Bhejjadiha
Panchukukri
Manipur
Narendrapur
Hatapur
Saraswati
Karanjmal
Nuagan-Ichhapur
Subudhia
Talabandha
Jaleshwarpur
Kudakanthi
Chhedak
Pir Hat
Singol
Sahapur
Khadijan
Kherang
Hengupati
Baro
Kurua
Singhia
Bodak
Kanpatha
Salandi N
Gurumahara
Genguti N
Nuabandh
Dhusuri
Nadigan
Shyamsundarpur
Pendrabatia
Rampur
Madhupur
Karandimal
Mato
Karanpokhari
Nalagohira
Guanla
Karthkola
BM 3·1
Nandpur
Sundarpur
Husainpur
Kotapur
Bada Olag
Aradi
Bauljora
Ugratara
Mriganayani
Jaladharpur
Gobindapur
Dosingha
Narasinghapur
Nangalpur
Kamardihi
Dhubkarha
Bada Ostia
Kuanrpal
Charadia
Dhamra
Naya Tapu
Jafarpur
Kanpur
Panki
BAITARANI R
Bijoynagar
Urasahi
DHAMRA R
KALIBHANI DIAN
Chandbali
Adhasahi
Bada Aria
Talchua
Tikaitnagar
Champapal
Hatsahi
BM 4·7
Bhulanpur
Raj Kanika
Balarampur
Palace
Sikuri
Kanriapal
Manjulapalli
Khasmunda
Banipal
Kandia
Namtara
Olabhar
Baruna
Orogiria
Bajarpur
Dense mixed jungle
BHITAR KANIKA R F
Bhitar Kanika
Rongini
Bangara
Mirzapur
Bharigoda
Raulia
Righagam
MAIPURA N
Madhuban
Gobinda dr
BM 4·8
Aul
BM 2·5
Ayatan
Malipur
Iswarpur
Bhuinpur
Udaypalli
KHARSUA R
BRAHMANI R
PATSALA N
Bansgarh N
Kalaspur
Usually flooded during rainy season
Purila
Mahu
Katna
Gharjamal
Jonesnagar
SUNIPUPI P F
Satiaban
Sansida
Ballada
Gupti
Nuagan
Sathbhaya
Kanhupur
Sahera
Rasula
Patarpur
Roota
Belpal
Kararogarh
Dhalmara
Balipatana
Gopalpur
Liable to flood
Bhitargarh
Haribarpur
Gopalpur
Chandanpur
Damarpur
Madhyapara
Rajgarh
Hatigari
Kathpangra
BM 3·9
Patamundai
Alabha
Rajnagar
Kuruhti
Batiparha
Gunthi
Hansua N
Kharianta
Anandapur
Chandanpur
Gajarajpur
Bindhananakana
Gobari N
Jigarana
Kailipur
GOBARI CANAL
Aradpalli
Teroi
Mangrove swamp
Loknathpur
Barapada
Ratpang
Ratanpur
Manpatana
Bodhgan
Nuna N
Gogua
Open mixed jungle
Nambra
Anduli
Babar
Gobindapur
Balisahi
Ranki
Rajgarh
Deulparha
Sogal
Benakanda
Barpal
Nuna N
Bijaynagar
Pankhpal
Dasipur
Mahakalparha
Baradanga
Kendraparha N
KENDRAPARHA CANAL
Pareswarpur
Baratota
Jambu
Gopinathpur
Karanja
Mangalpur
Hukitola
BM 8
High water line
Barakul
Adol
Baulakani
JAMBU N
Balikuda
Teragap
Chherakani
Dense mixed jungle
R F
Jadupur
Kentia
Ramnagar
Haribank
Kharnasi
Fairly dense mixed jungle
P F
Gatanai
Sardeipur
Khurusiapat
Patiparha
Borajbanukud
Kajalpata
Low water line
28·100
30·050
30·200
28·800
32·100
33·500
33·900
34·700
36·005
42·900
43·500


SANTOSHPUR R F
Santoshpur Pahar
SATKOSIA R F
Sātkosia
Sālandi N
BAITARANI RIVER
Similia
Hadagarh Reservoir
Hadagarh
BAULA R F
Dense mixed jungle mainly sāl
KULDIHA RESERVED FO
GADASAHI R F
Jugjhuri Pahar
Debagiri Pahar
Bisuagān
Rānipokhari
Padmapokhari
Muliposi
Ruguri
Baulāpāni
Nuāgaon
Aupada
Khaira
Mahulpankha
Nachhipur
Kuruntu
Markhanpur
Saundia
N A N D A P U R
Tunga Pahar
ANANDAPUR
BM 46·7
Fakirpur
BM 34·9
Salbani
Tartara
Ambagaria
Dhenka
Agarpada
SALANDI MAIN CANAL
Jalang
Dunguri
Chandrapada
SOUTH EASTERN RAILWAY Main Line
NH 5
Markuna
BM 12·3
Maitapur
Kelāsāhi
Bara Rampās
Kusai N
Remāla N
Narsinghpur
Barabarchhi
Bānatia
Rāmbhila
Mangal
Banta
Rahani
Jalagān
Dalsingha
Salandi N
Kapali N
Charampa
Bhadrak R S
BHADRAK
Bania
Bontol
Dolasahi
PATILO R F
Gobardhanpur
Dhobari
Garhbandhgora
Ramchandrapur
Kalaspal N
Tarandia Gopalpur
Ragadi
RAGADI R F
Rampilo
Kabāti N
Ranagundi
Patrango
Purbakot
Mangalpur
Biruānpara
Makundapur
Gobindapur
Samana
Girigān
Sankho
Ambo
Dānra
Gedama
Satsal
Manjuri Road R S
Kenduāpada R S
Baudpur R S
Kani N
HIGH LEVEL
Korakara
Gulnagar
B H A D R A K
86° 0' E. of GREENWICH
15'
30'
A
B
C
J Ā J Ā P U R
Cuttack 81 km
Cuttack 87 km
Cuttack 93 km
Madras 1262 km
Kochar 10 km
Chandbali 34 km
1.005
1.800
3.200
3.900
9.200
9.300
13.600

(BHADRAK TO ANANDPUR,SH-53) (0 TO 50 km)

INDEX
Bhadrak to Anandpur (0.0 - 50.0 km)

CHAPTER-1

BRIDGE AT CH:9/800

The Bridge at chainage 9/800 Hansinapur Culvert,existing Span (1x 3.55+1x 3.95)m is an irrigation Canal.So there is no need of Hydrology.The span arrangement is same as existing.

CHAPTER-2

BRIDGE AT CH:11/600

2. Hydraulic calculations for Minor Bridge of road Bhadrak-Anandpur

1 General details

Name of the Nala :	Ganijanga Bridge
Road No.:	S.H - 53
G.T S No :	73K
Nearest Village :	Ganijanga
RD :	Km.11.600
Latitude	21^0 5' 00"
Longitude	86^0 27' 00"
Sub-Zone	3(d)

2 Discharge by Manning's Formula

HFL at bridge site	25.485	m

Cross-section of the stream at different locations are as follows

Discharge by Manning's Formula at U/S location

Cross-sectional area of flow	62.01	sqm
Width of flow	24.00	m
Wetted perimeter perpendicular to direction of flow	24.85	m
Hydraulic mean radius R = A/P	2.50	m
Longitudinal slope as calculated	0.0015	m per m
Velocity by Manning's formula		
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n =	0.05	
Velocity V =	1.425	m/s
Discharge Q = A*V	88.36	cum/s

Discharge by Manning's Formula at existing location

Cross-sectional area of flow	53.93	sqm
Width of flow	24.00	m
Wetted perimeter perpendicular to direction of flow	24.97	m
Hydraulic mean radius R = A/P	2.16	m
Longitudinal slope as calculated	0.0034	m per m
Velocity by Manning's formula		
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n =	0.05	
Velocity V =	1.948	m/s
Discharge Q = A*V	105.07	cum/s

Discharge by Manning's Formula at D/S location

Cross-sectional area of flow	65.47	sqm
Width of flow	24.00	m
Wetted perimeter perpendicular to direction of flow	25.37	m
Hydraulic mean radius R = A/P	2.58	m
Longitudinal slope as calculated	0.0022	m per m
Velocity by Manning's formula		
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n =	0.05	
Velocity V =	1.765	m/s
Discharge Q = A*V	115.52	cum/s

The hydrological calculations has been done at three sections I.e. at upstream side, downstream side and near proposed bridge location

By comparision of upstream and downstream side and Existing bridge location.

Hence the design discharge may be taken as **105.07 cum/s**

3 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted (Since Rainfall is more than 120 cm)	19	
M = Catchment area	9.375	sqkm
Q =	101.80	cum/s

4 Discharge by Rational Formula

Catchment area	9.375 sqkm	937.50	hectares
Length of path from toposheet (L)		5.500	km
Difference in levels from toposheet (H)		6	m
(Ref: Index map)			
Maximum rain fall (F)	(Ref: SUG of Taradadiha River)	150.93	mm
Duaration of storm (T)		4	hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)	94.33	mm/hr
Time of concentration (SP-13, page 12)	$tc = (0.87*L^3/H)^{0.385}$	3.41	hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		42.82	mm/hr
Discharge Q = 0.028 * P*f* A* Ic			
P = (for loam, lightly cultivated or covered)		0.400	
f =		1.00	
A =		937.50	Hectares
Ic =		4.282	cm/hr
Q =		44.960	cum/sec

5 Design Discharge (Refer SP-13, page 21)

Discharge by Manning's Formula	105.07 cum/sec
Discharge by Dicken's Formula	101.80 cum/sec
Discharge by Rational Formula	44.96 cum/sec
Maximum discharge	105.07 cum/sec
Next maximum discharge	44.96 cum/sec
The difference is beyond 50% of the next maximum discharge	
Hence design discharge	**67.44 cum/sec**

6 Water Way

Regime width $W = 4.8Q^{1/2}$ 39.42 m

(Refer IRC:5-1998, cl 104.3 or SP-13, page 23)

Provide	Clear span	8 m
	No. of spans	2 no.
	Total waterway provided L	16.00 m

Two additional box culverts is also provided within this location to take care discharge

Hence total waterway = 16 + 2 + 2 = 20 m

7 Scour depth

Increase in design discharge, as per IRC:78-2000, cl 703.1.1	30%
Increased design discharge	87.67 cum/sec

Mean depth of scour, as per IRC:78-2000, cl 703.2

$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width 4.38 cum/sec/m

K_{sf} = Silt factor

Silt factor has been calculated according to data collected from site

Depth	Silt factor	
3	1.307	
4.5	1.93	
Average	1.6185	1.619

Mean depth of scour, d_{sf} = 3.06 m

Maximum scour depth, as per IRC:78-2000, cl 703.3

for Pier	6.11 m
for Abutment	3.88 m

8 Deck level

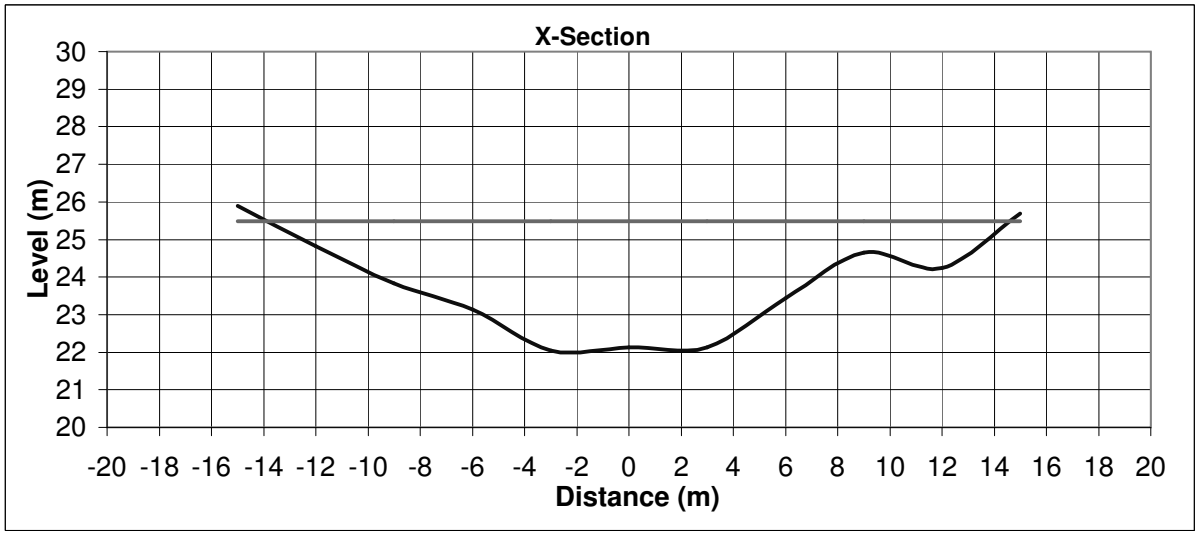
HFL at proposed bridge site including afflux	25.485 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.900 m
Depth of super structure	0.400 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	26.841 m
Deck level of the existing bridge	26.410 m
Minimum deck level proposed	26.841 m

As per the proposed allignment, the formation level of bridge has been kept as 27.16 m

Cross-sectional area of nallah at proposed bridge site is as follows:

HFL at this location 25.485 m

Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-15	25.898	25.485					
-12	24.815	25.485	0.670				
-9	23.836	25.485	1.649	1.160	3.479	3.156	3.000
-6	23.136	25.485	2.349	1.999	5.997	3.081	3.000
-3	22.05	25.485	3.435	2.892	8.676	3.191	3.000
0	22.134	25.485	3.351	3.393	10.179	3.001	3.000
3	22.125	25.485	3.360	3.356	10.067	3.000	3.000
6	23.441	25.485	2.044	2.702	8.106	3.276	3.000
9	24.658	25.485	0.827	1.436	4.307	3.237	3.000
12	24.235	25.485	1.250	1.039	3.116	3.030	3.000
15	25.685	25.485					
Total					**53.93**	**24.97**	**24.00**



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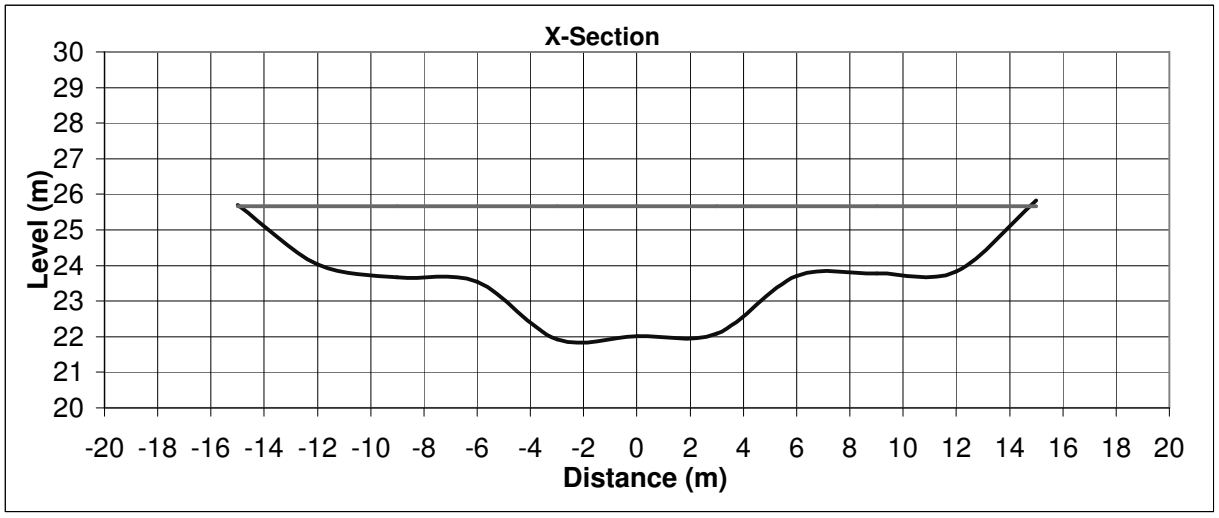
Cross-sectional area of nallah at u/s of the proposed bridge is as follows:

Distance from proposed bridge	120	m
Longitudinal slope u/s side	0.0015	
HFL at this location	25.665	m

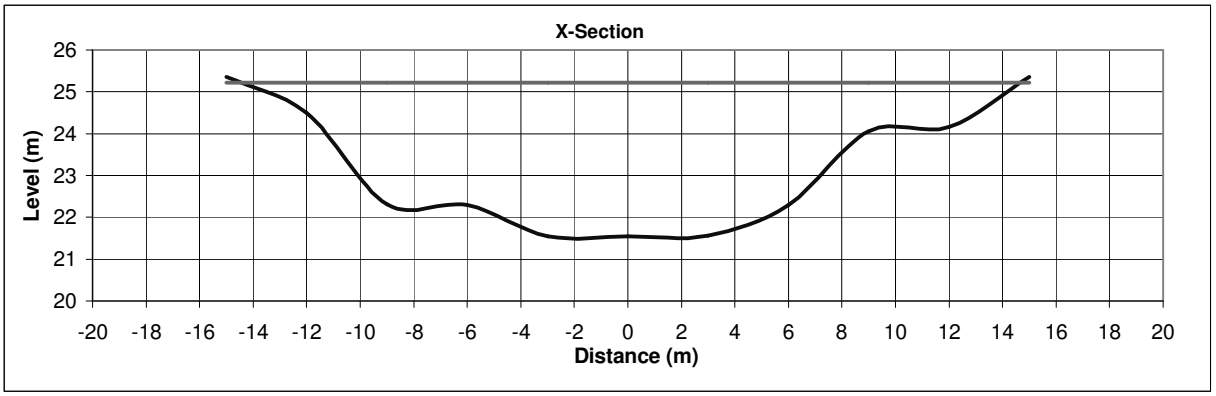
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-15	25.698	25.665					
-12	24.025	25.665	1.640				
-9	23.672	25.665	1.993	1.817	5.450	3.021	3.000
-6	23.542	25.665	2.123	2.058	6.174	3.003	3.000
-3	21.918	25.665	3.747	2.935	8.805	3.411	3.000
0	22.007	25.665	3.658	3.703	11.108	3.001	3.000
3	22.095	25.665	3.570	3.614	10.842	3.001	3.000
6	23.712	25.665	1.953	2.762	8.285	3.408	3.000
9	23.777	25.665	1.888	1.921	5.762	3.001	3.000
12	23.832	25.665	1.833	1.861	5.581	3.001	3.000
15	25.834	25.665					
Total					**62.01**	**24.85**	**24.00**



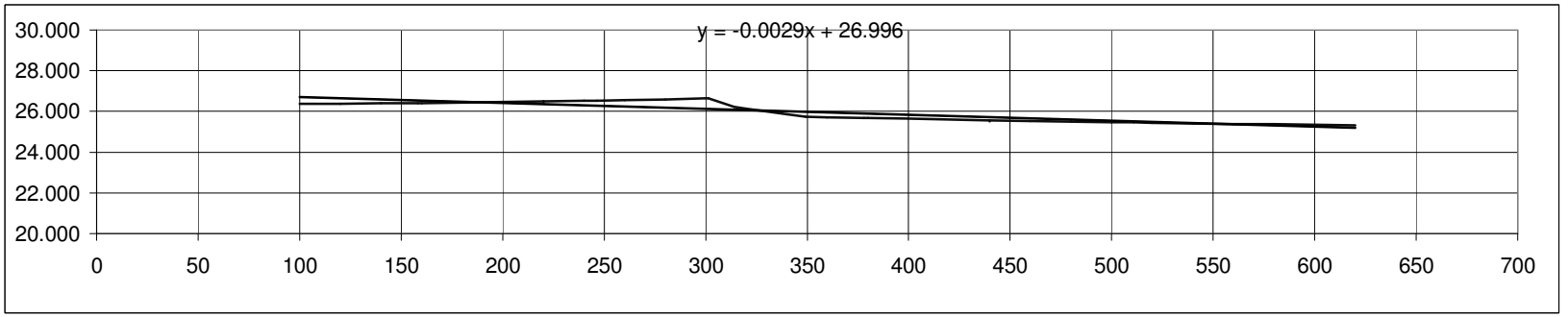
Cross-sectional area of nallah at d/s of proposed bridge is as follows:

Distance from proposed bridge	120 m
Longitudinal slope d/s side	0.0022
HFL at this location	25.221 m

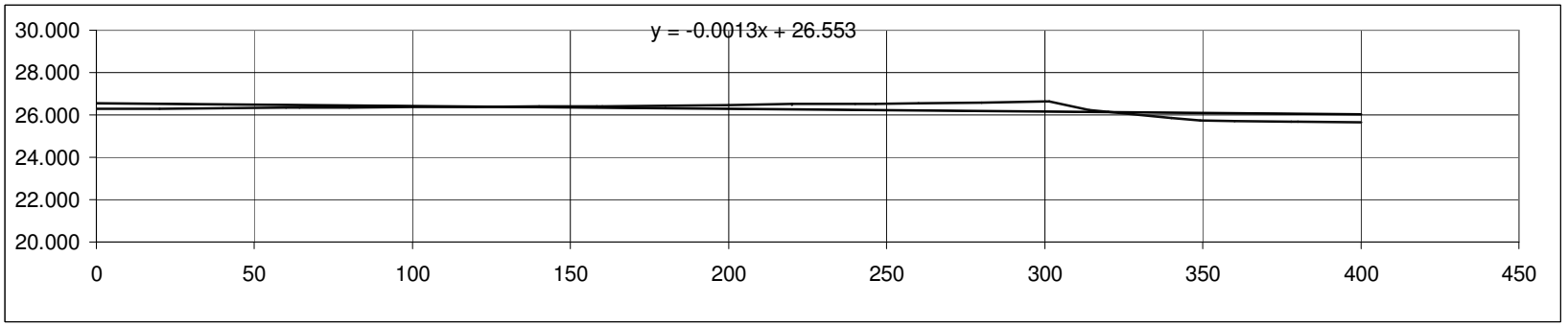
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-15	25.354	25.221					
-12	24.499	25.221	0.722				
-9	22.307	25.221	2.914	1.818	5.454	3.715	3.000
-6	22.298	25.221	2.923	2.919	8.756	3.000	3.000
-3	21.541	25.221	3.680	3.302	9.905	3.094	3.000
0	21.553	25.221	3.668	3.674	11.022	3.000	3.000
3	21.565	25.221	3.656	3.662	10.986	3.000	3.000
6	22.298	25.221	2.923	3.290	9.869	3.088	3.000
9	24.051	25.221	1.170	2.047	6.140	3.475	3.000
12	24.167	25.221	1.054	1.112	3.336	3.002	3.000
15	25.352	25.221					
Total					**65.47**	**25.37**	**24.00**



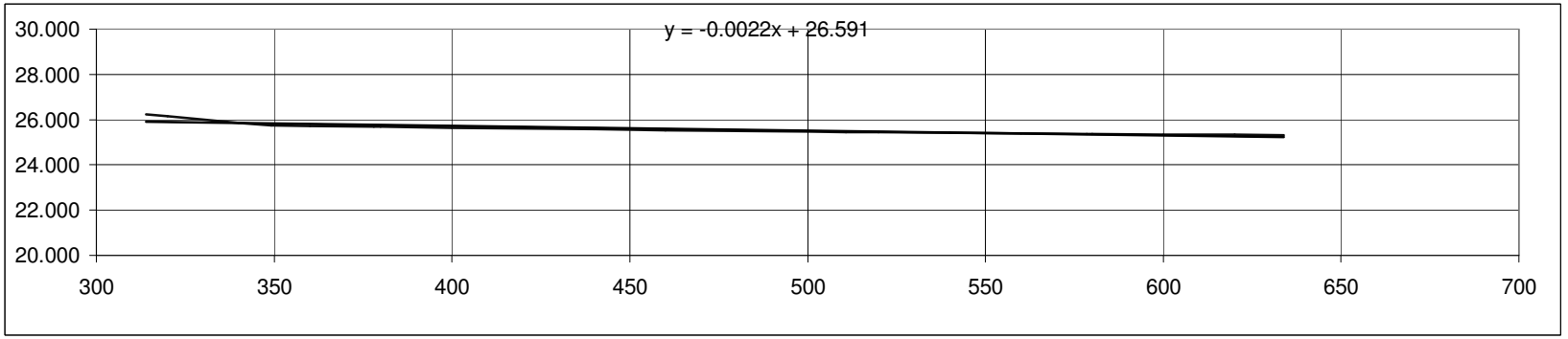
L-Section of Nallah at Existing Bridge



L-Section of Nallah at U/S



L-Section of Nallah at D/S



Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	67.44	cum/sec
HFL	25.485	m
Bed level	22.050	m
Maximum scour depth	6.11	m
Maximum scour level	19.371	m

Curtain wall shall be provided below maximum scour level

Bed level	22.05	m
Scour depth below bed	2.68	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	3.5	m
	d/s	4.0	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	5.36	5.5	m
	d/s	6.0	5.36	6.0	m

CHAPTER-3

BRIDGE AT CH:17/700

3. Hydraulic calculations for Minor Bridge of road Bhadrak-Anandpur

1 General details

Name of the Nala :	Kapali Nala
Road No.:	S.H - 53
G.T S No :	73K
Nearest Village :	Banta
RD :	Km.17.700
Latitude	21^0 6' 00"
Longitude	86^0 26' 00"
Sub-Zone	3(d)

2 Discharge by Manning's Formula

HFL at bridge site	30.935 m

Cross-section of the stream at different locations are as follows

Discharge by Manning's Formula at U/S location

Cross-sectional area of flow	72.30 sqm
Width of flow	24.00 m
Wetted perimeter perpendicular to direction of flow	25.57 m
Hydraulic mean radius R = A/P	2.83 m
Longitudinal slope as calculated	0.0001 m per m
Velocity by Manning's formula	
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)	
For sluugish type bed (Table 5.1)	
n =	0.05
Velocity V =	0.400 m/s
Discharge Q = A*V	28.91 cum/s

Discharge by Manning's Formula at existing location

Cross-sectional area of flow	62.91 sqm
Width of flow	24.00 m
Wetted perimeter perpendicular to direction of flow	25.97 m
Hydraulic mean radius R = A/P	2.42 m
Longitudinal slope as calculated	0.0002 m per m
Velocity by Manning's formula	
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)	
For sluugish type bed (Table 5.1)	
n =	0.05
Velocity V =	0.510 m/s
Discharge Q = A*V	32.09 cum/s

Discharge by Manning's Formula at D/S location

Cross-sectional area of flow	80.79 sqm
Width of flow	24.00 m
Wetted perimeter perpendicular to direction of flow	26.42 m
Hydraulic mean radius R = A/P	3.06 m

Longitudinal slope as calculated	0.0015	m per m
Velocity by Manning's formula		
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n =	0.05	
Velocity V =	1.632	m/s
Discharge Q = A*V	131.84	cum/s

The hydrological calculations has been done at three sections I.e. at upstream side, downstream side and near proposed bridge location

By comparision of upstream and downstream side and Existing bridge location.

Hence the design discharge may be taken as 32.09 cum/s

3 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted (Since Rainfall is more than 120 cm)	19	
M = Catchment area	18.750	sqkm
Q =	171.20	cum/s

4 Discharge by Rational Formula

Catchment area	18.750 sqkm	1875.00	hectares
Length of path from toposheet (L)		10.100	km
Difference in levels from toposheet (H)		10	m
(Ref: Index map)			
Maximum rain fall (F)	(Ref.SUG of Taradadiha River)	150.93	mm
Duaration of storm (T)		4	hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)	94.33	mm/hr
Time of concentration (SP-13, page 12)	$tc = (0.87*L^3/H)^{0.385}$	5.65	hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		28.39	mm/hr

Discharge Q = 0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)	0.400	
f =	1.00	
A =	1875.00	Hectares
Ic =	2.839	cm/hr
Q =	59.618	cum/sec

5 Design Discharge (Refer SP-13, page 21)

Discharge by Manning's Formula	32.09	cum/sec
Discharge by Dicken's Formula	171.20	cum/sec
Discharge by Rational Formula	59.62	cum/sec
Maximum discharge	171.20	cum/sec
Next maximum discharge	59.62	cum/sec

The difference is beyond 50% of the next maximum discharge

Hence design discharge **89.43 cum/sec**

6 Water Way

Regime width		$W = 4.8Q^{1/2}$	45.39 m
(Refer IRC:5-1998, cl 104.3 or SP-13, page 23)			
Provide	Clear span		9 m
	No. of spans		3 no.
	Total waterway provided L		27.00 m

The existing bridge is of 2 spans of 7.0 m. As per site condition, PMGSY has constructed a bridge at 1.0 km U/s of 4 x 7.0 m. Hence the same ventway has been adopted .

One additional box culvert of 3 m clear ventway is also provided within this location to take care discharge

Hence total waterway = 27 + 3= 30.0 m

7 Scour depth

Increase in design discharge, as per IRC:78-2000, cl 703.1.1		30%
Increased design discharge		116.25 cum/sec
Mean depth of scour, as per IRC:78-2000, cl 703.2		
	$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$	
	Db = Design discharge per metre width	3.88 cum/sec/m
	K_{sf} = Silt factor	1.0 (Assumed)
Mean depth of scour, d_{sf} =		3.31 m
Maximum scour depth, as per IRC:78-2000, cl 703.3		
	for Pier	6.61 m
	for Abutment	4.20 m

8 Deck level

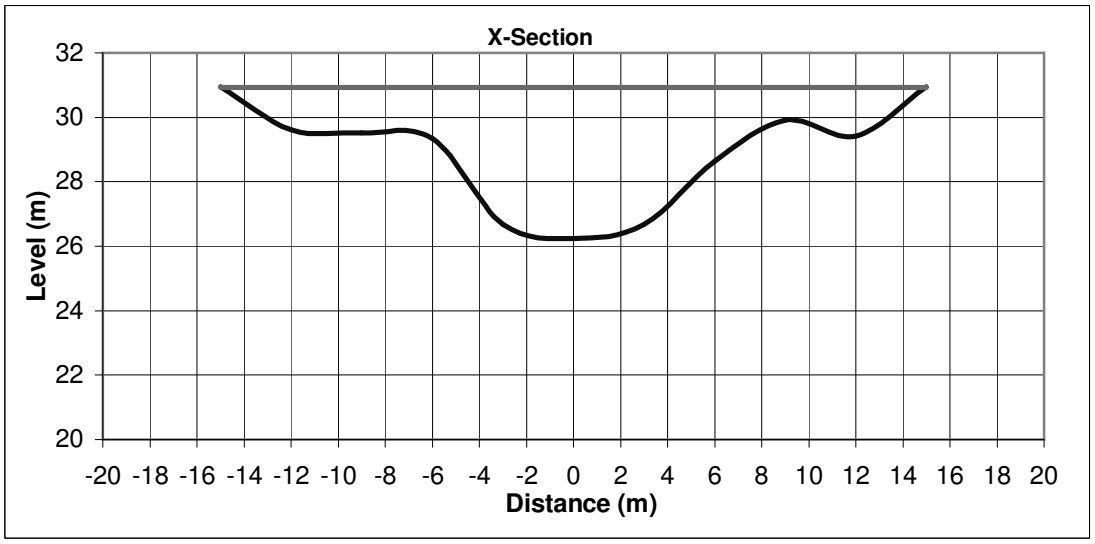
HFL at proposed bridge site	30.935 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.900 m
Depth of super structure	0.500 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	32.391 m
Deck level of the existing bridge	31.860 m
Minimum deck level proposed	32.391 m

As per the proposed allignment, the formation level of bridge has been kept as 32.91 m

Cross-sectional area of nallah at proposed bridge site is as follows:

HFL at this location 30.935 m

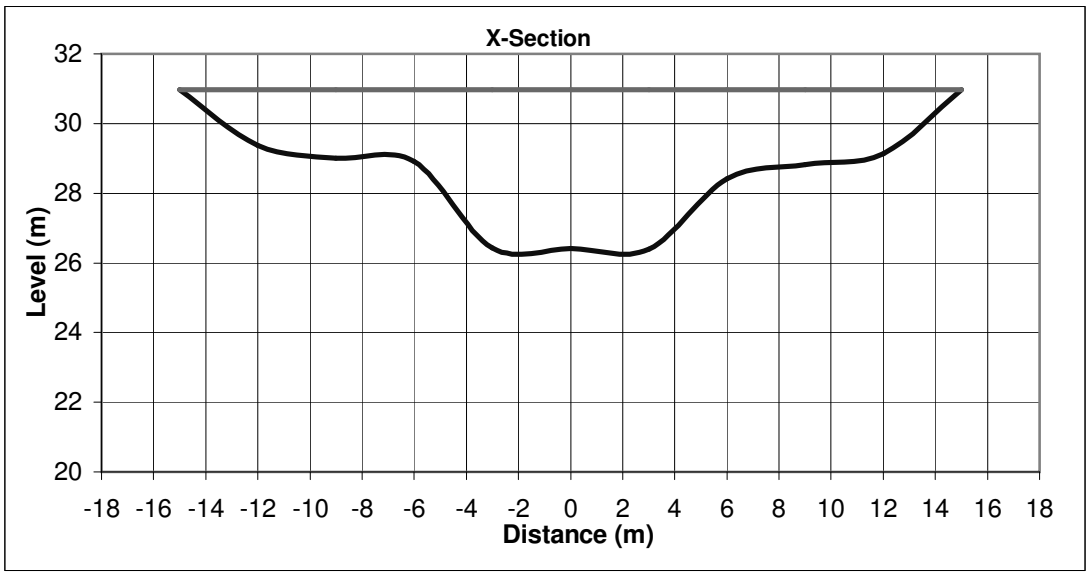
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-15	30.951	30.935					
-12	29.623	30.935	1.312				
-9	29.524	30.935	1.411	1.362	4.084	3.002	3.000
-6	29.333	30.935	1.602	1.507	4.520	3.006	3.000
-3	26.669	30.935	4.266	2.934	8.802	4.012	3.000
0	26.23	30.935	4.705	4.486	13.457	3.032	3.000
3	26.679	30.935	4.256	4.481	13.442	3.033	3.000
6	28.645	30.935	2.290	3.273	9.819	3.587	3.000
9	29.914	30.935	1.021	1.656	4.966	3.257	3.000
12	29.412	30.935	1.523	1.272	3.816	3.042	3.000
15	30.942	30.935					
Total					**62.91**	**25.97**	**24.00**



Cross-sectional area of nallah at u/s of the proposed bridge is as follows:

Distance from proposed bridge	300	m
Longitudinal slope u/s side	0.0001	
HFL at this location	30.965	m

Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-15	30.967	30.965					
-12	29.365	30.965	1.600				
-9	29.013	30.965	1.952	1.776	5.328	3.021	3.000
-6	28.905	30.965	2.060	2.006	6.018	3.002	3.000
-3	26.43	30.965	4.535	3.298	9.893	3.889	3.000
0	26.408	30.965	4.557	4.546	13.638	3.000	3.000
3	26.386	30.965	4.579	4.568	13.704	3.000	3.000
6	28.409	30.965	2.556	3.568	10.703	3.618	3.000
9	28.819	30.965	2.146	2.351	7.053	3.028	3.000
12	29.134	30.965	1.831	1.989	5.966	3.016	3.000
15	30.972	30.965					
Total					**72.30**	**25.57**	**24.00**

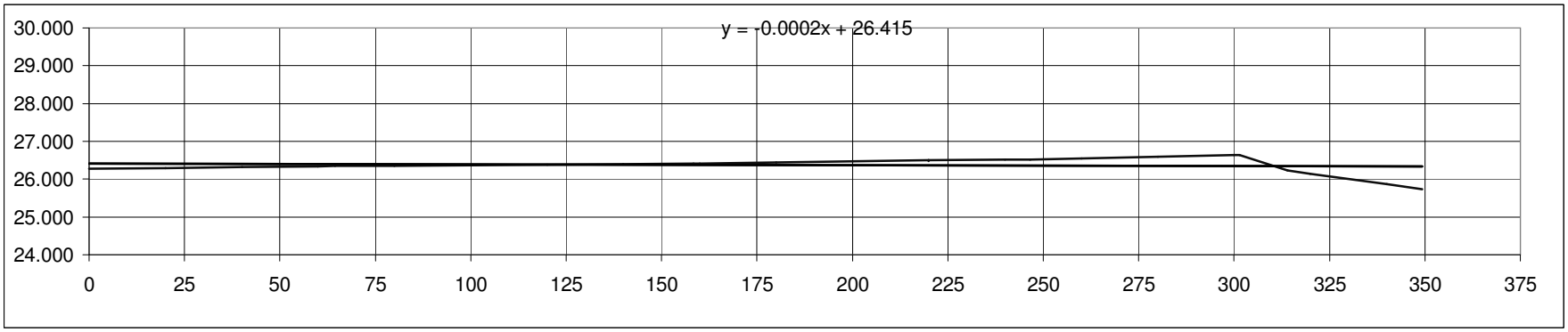


Cross-sectional area of nallah at d/s of proposed bridge is as follows:

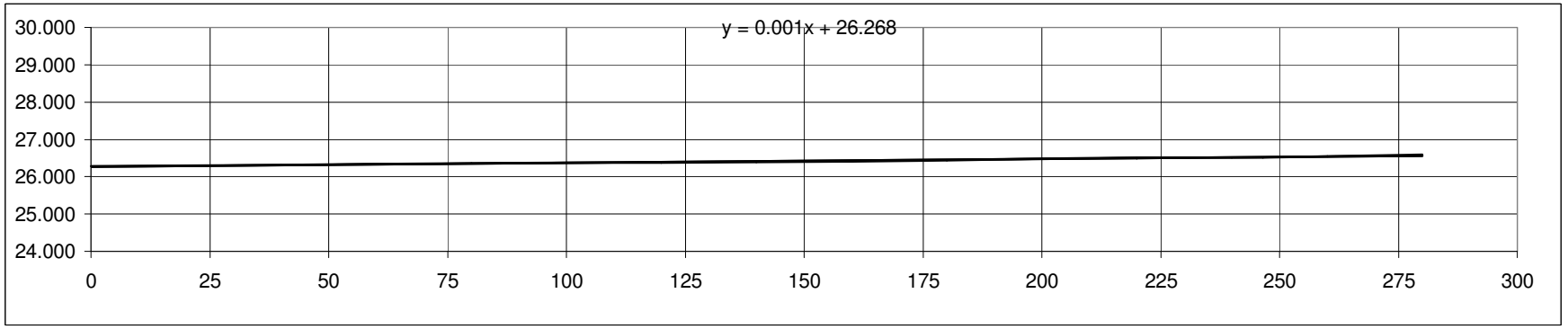
Distance from proposed bridge	300	m
Longitudinal slope d/s side	0.0015	
HFL at this location	30.485	m

Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-15	30.832	30.485					
-12	29.856	30.485	0.629				
-9	27.958	30.485	2.527	1.578	4.734	3.550	3.000
-6	27.95	30.485	2.535	2.531	7.593	3.000	3.000
-3	26.356	30.485	4.129	3.332	9.996	3.397	3.000
0	25.456	30.485	5.029	4.579	13.737	3.132	3.000
3	25.456	30.485	5.029	5.029	15.087	3.000	3.000
6	26.97	30.485	3.515	4.272	12.816	3.360	3.000
9	27.047	30.485	3.438	3.477	10.430	3.001	3.000
12	29.659	30.485	0.826	2.132	6.396	3.978	3.000
15	30.782	30.485					
Total					**80.79**	**26.42**	**24.00**

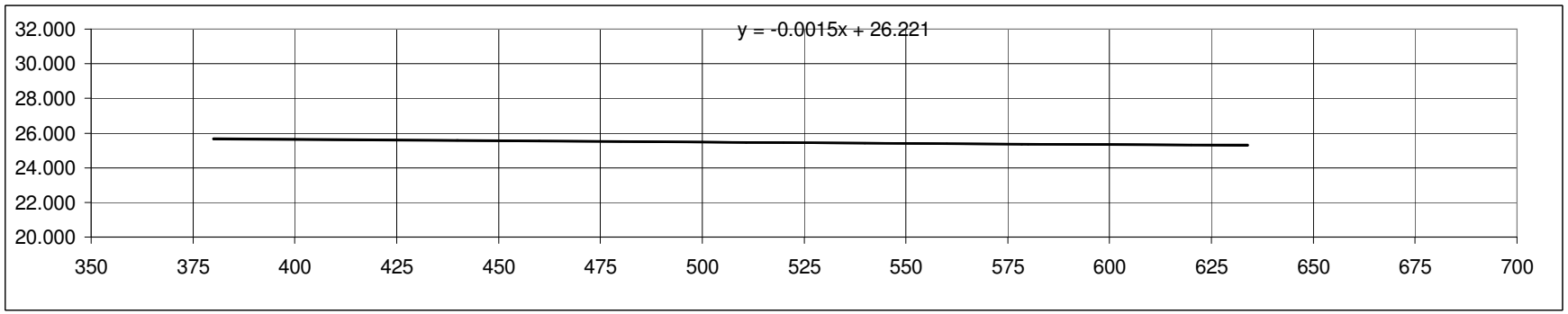
L-Section of Nallah at Existing Bridge



L-Section of Nallah at U/S



L-Section of Nallah at D/S



Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	89.43	cum/sec
HFL	30.935	m
Bed level	26.230	m
Maximum scour depth	6.61	m
Maximum scour level	24.323	m

Curtain wall shall be provided below maximum scour level

Bed level	26.23	m
Scour depth below bed	1.91	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	2.5	m
	d/s	3.0	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	3.81	4.0	m
	d/s	6.0	3.81	6.0	m

CHAPTER-4

BRIDGE AT CH:18/400

3. Hydraulic calculations for Minor Bridge of road Bhadrak - Anandpur

1	**Name of the Nala :**	Malisahi Polo
	Road No.:	S.H. No.- 53
	G.T S No :	73K
	Nearest Village :	Malisahi
	RD :	Km.18/400
	Latitude	86^0 23 '00"
	Longitude	21^0 08' 00"
	Sub Zone	3(d)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (Refer I.R.C.SP-13, Page 7)

$Q = CM^{3/4}$

C=14-19 where annual rainfall is more than 120 cm

=11-14 where annual rainfall is 60-120 cm

=22 in western Ghats

C adopted	(Since Rain fall is more than 120 cm)	19
M = Catchment area		0.450 sqkm
Q =		10.44 cum/s

3 Discharge by Rational Formula

Catchment area		0.450 sqkm	45.00 hectares
Length of path from toposheet (L)			1.500 km
Difference in levels from toposheet (H)			10 m
(Ref: Index map)			
Maximum rain fall (F)	(Ref : SUG of Taradadiha nadi)		150.93 mm
Duaration of storm (T)			4 hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)		94.33 mm/hr
Time of concentration (I.R.C.SP-13, Page 12)	$tc = (0.87*L^3/H)^{0.385}$		0.62 hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)			116.18 mm/hr

Discharge Q=0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)	0.400
f =	1.00
A =	45.00 Hectares
Ic =	11.618 cm/hr
Q =	5.86 cum/sec

4 Design Discharge (Refer I.R.C. SP-13, Page 21)

Discharge by Dicken's Formula	10.44 cum/sec
Discharge by Rational Formula	5.86 cum/sec
Maximum discharge	10.44 cum/sec
Next maximum discharge	5.86 cum/sec
Hence design discharge	**10.44 cum/sec**

5 Linear Water Way

Regime width	$W = 4.8Q^{1/2}$	15.51 m

(Refer IRC:5-1998, Clause 104.3 or SP-13, Page 23)

6 Scour depth

Increase in design discharge, as per IRC:78-2000, clause 703.1.1	30%
Increased design discharge	13.57 cum/sec
Mean depth of scour, as per IRC:78-2000, Clause 703.2	
$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$	
Db = Design discharge per metre width	0.88 cum/sec/m
K_{sf} = Silt factor	2.25
d_{sf} =	0.94 m
Maximum scour depth, as per IRC:78-2000, Clause 703.3	
For Pier $2 d_{sf}$	1.87 m
For Abutment $1.27 d_{sf}$	1.19 m

7 Span arrangement

In proposed span arrangement, double cell of 3.0 m has been proposed with bed protection.	6.00 m

8 Scour depth

Increase in design discharge, as per IRC:78-2000,Clause 703.1.1	30%
Increased design discharge	2.93 cum/sec
Mean depth of scour, as per IRC:78-2000, Clause 703.2	
$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$	
Db = Design discharge per metre width	0.49 cum/sec/m
K_{sf} = Silt factor	2.09
d_{sf} =	0.65
Maximum scour depth, as per IRC:78-2000, Clause 703.3	
for Pier $2 d_{sf}$	1.30 m
for Abutment $1.27 d_{sf}$	0.82 m

9 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16)	0.6 m

10 Deck level

HFL at existing bridge site	31.750 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600 m
Depth of super structure including camber	0.470 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	32.876 m
Deck level of the existing bridge	31.200 m
Minimum deck level proposed	32.876 m

As per the proposed allignment, the formation level of bridge has been kept as 32.925 m

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	10.44	cum/sec
HFL	31.750	m
Bed level	29.140	m
Maximum scour depth	1.30	m
Maximum scour level	30.451	m

Curtain wall shall be provided below maximum scour level

Bed level	29.14	m
Scour depth below bed	0.00	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	2.0	m
	d/s	2.5	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	0.00	3.0	m
	d/s	6.0	0.00	6.0	m

CHAPTER-5

BRIDGE AT CH:19/300

The Bridge at chainage 19/300 Banta Canal,existing Span (2x6.3)m
is an irrigation Canal.So there is no need of Hydrology.The span arrangement is same existing.

CHAPTER-6

BRIDGE AT CH:30/950

The Bridge at chainage 30/950 Hadagoda Canal,existing Span (1x5.5)m
is a Syphone Aquatacte.So there is no need of Hydrology.

CHAPTER-7

BRIDGES AT CH:37/600,37/700,37/850,38/010 & 38/200

The Bridges at Ch.37/600,37/700,37/850,38/010 & 38/200 are known as Charnallah, Including 5 No of bridges, the total vent way of all bridges is 40.1 m (7.6+7.6+7.6+7.3+10.0).As per site condition these bridges do not seem to be defined channel, however Bridge at Ch.38/010 seem to be defined.
These bridges carry water from a Catchments area of 26.3 Sqkm and vent way of these Bridge has been suggested on the basis of rational method and Dicken's method for all the Bridge combined.

11. Hydraulic calculations for Minor Bridge of road Bhadrak-Anandpur

1 General details

Name of the Nala :	Charinalia
Road No.:	S.H - 53
G.T S No :	73K
Nearest Village :	Fakirpur
RD :	Km.38.010
Latitude	21^0 13' 00"
Longitude	86^0 12' 00"
Sub-Zone	3(d)

2 Discharge by Manning's Formula

HFL at bridge site	40.055	m

Cross-section of the stream at different locations are as follows

Discharge by Manning's Formula at U/S location

Cross-sectional area of flow	130.92	sqm
Width of flow	68.00	m
Wetted perimeter perpendicular to direction of flow	69.81	m
Hydraulic mean radius R = A/P	1.88	m
Longitudinal slope as calculated	0.0055	m per m
Velocity by Manning's formula		
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n =	0.06	
Velocity V =	1.880	m/s
Discharge Q = A*V	246.10	cum/s

Discharge by Manning's Formula at existing location

Cross-sectional area of flow	144.81	sqm
Width of flow	75.00	m
Wetted perimeter perpendicular to direction of flow	75.80	m
Hydraulic mean radius R = A/P	1.91	m
Longitudinal slope as calculated	0.0051	m per m
Velocity by Manning's formula		
$V = 1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n =	0.06	
Velocity V =	1.833	m/s
Discharge Q = A*V	265.37	cum/s

Discharge by Manning's Formula at D/S location

Cross-sectional area of flow	182.07	sqm
Width of flow	75.00	m

Wetted perimeter perpendicular to direction of flow	75.96	m
Hydraulic mean radius R = A/P	2.40	m
Longitudinal slope as calculated	0.0040	m per m
Velocity by Manning's formula		
$V=1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n =	0.06	
Velocity V =	1.888	m/s
Discharge Q = A*V	343.71	cum/s

The hydrological calculations has been done at three sections I.e. at upstream side, downstream side and near proposed bridge location

By comparision of upstream and downstream side and Existing bridge location.

Hence the design discharge may be taken as 265.37 cum/s

3 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q = CM^{3/4}$

C = 14-19 where annual rainfall is more than 120 cm

= 11-14 where annual rainfall is 60-120 cm

= 22 in western Ghats

C adopted (Since Rainfall is more than 120 cm)	19	
M = Catchment area	26.300	sqkm
Q =	220.66	cum/s

4 Discharge by Rational Formula

Catchment area	26.300 sqkm	2630.00	hectares
Length of path from toposheet (L)		6.750	km
Difference in levels from toposheet (H)		120	m
(Ref: Index map)			
Maximum rain fall (F)	(Ref.SUG of Taradadiha River)	150.93	mm
Duaration of storm (T)		4	hrs
One hour rainfall (Io)	Io = (F/T)*(T+1)/(1+1)	94.33	mm/hr
Time of concentration (SP-13, page 12)	$tc = (0.87*L^3/H)^{0.385}$	1.36	hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		79.88	mm/hr

Discharge Q = 0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)	0.400	
f =	1.00	
A =	2630.00	Hectares
Ic =	7.988	cm/hr
Q =	235.309	cum/sec

5 Design Discharge (Refer SP-13, page 21)

Discharge by Manning's Formula	265.37	cum/sec
Discharge by Dicken's Formula	220.66	cum/sec
Discharge by Rational Formula	235.31	cum/sec

Maximum discharge		265.37	cum/sec
Next maximum discharge		220.66	cum/sec
The difference is within 50% of the next maximum discharge			
Hence design discharge		**265.37**	**cum/sec**

6 Water Way

Regime width	$W = 4.8Q^{1/2}$	78.19	m
(Refer IRC:5-1998, cl 104.3 or SP-13, page 23)			
Provide Clear span	**(1x7.6+1x7.6+1x7.6+1x7.3+1x10.0)**	40	m

7 Scour depth

Increase in design discharge, as per IRC:78-2000, cl 703.1.1	30%	
Increased design discharge	344.97	cum/sec
Mean depth of scour, as per IRC:78-2000, cl 703.2		
$d_{sf} = 1.34 (D_b^2/K_{sf})^{1/3}$		
Db = Design discharge per metre width	4.41	cum/sec/m
K_{sf} = Silt factor		
Silt factor has been calculated according to data collected from site	1.0	(Assumed)
Mean depth of scour, d_{sf} =	3.60	m
Maximum scour depth, as per IRC:78-2000, cl 703.3		
for Abutment	4.58	m

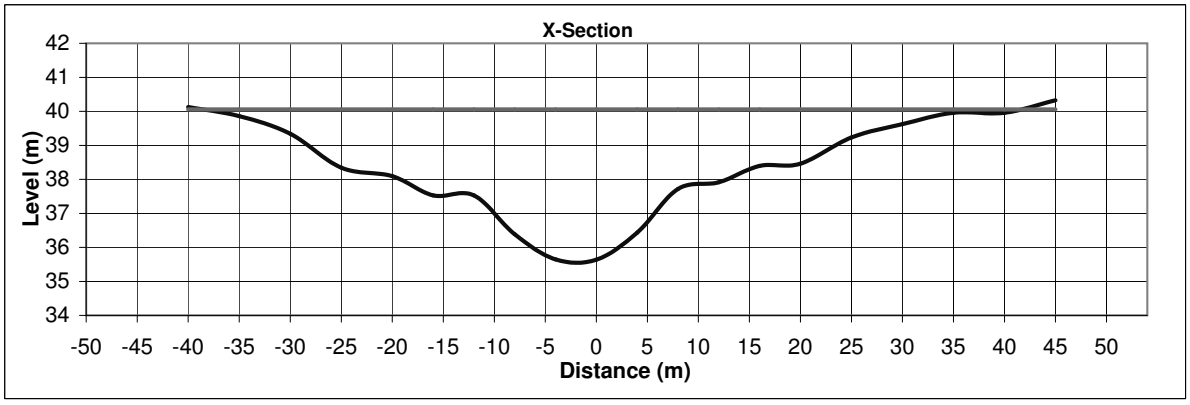
8 Deck level

HFL at proposed bridge site	39.090	m
Minimum vertical clearance (Table 12.1 of SP-13)	0.900	m
Depth of super structure	0.600	m
Wearing coat	0.056	m
Minimum deck level required as per hydraulic conditions	40.646	m
Deck level of the existing bridge	40.650	m
Minimum deck level proposed	**40.650**	**m**

Cross-sectional area of nallah at proposed bridge site is as follows:

HFL at this location 40.055 m

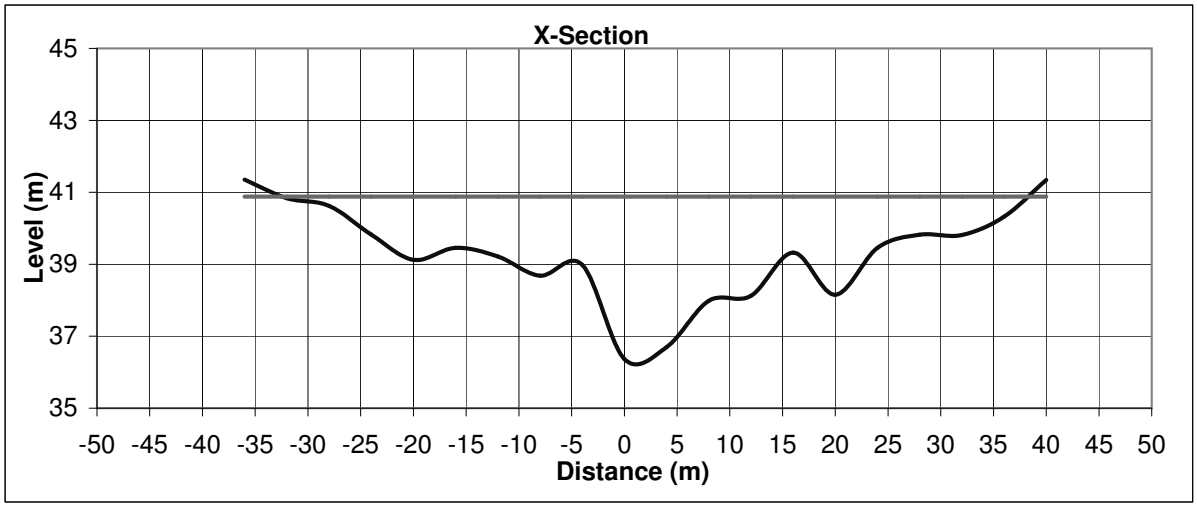
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-40	40.125	40.055					
-35	39.86	40.055	0.195				
-30	39.342	40.055	0.713	0.454	2.270	5.027	5.000
-25	38.345	40.055	1.710	1.212	6.058	5.098	5.000
-20	38.093	40.055	1.962	1.836	9.180	5.006	5.000
-16	37.531	40.055	2.524	2.243	8.972	4.039	4.000
-12	37.531	40.055	2.524	2.524	10.096	4.000	4.000
-8	36.385	40.055	3.670	3.097	12.388	4.161	4.000
-4	35.649	40.055	4.406	4.038	16.152	4.067	4.000
0	35.638	40.055	4.417	4.412	17.646	4.000	4.000
4	36.432	40.055	3.623	4.020	16.080	4.078	4.000
8	37.72	40.055	2.335	2.979	11.916	4.202	4.000
12	37.915	40.055	2.140	2.238	8.950	4.005	4.000
16	38.393	40.055	1.662	1.901	7.604	4.028	4.000
20	38.463	40.055	1.592	1.627	6.508	4.001	4.000
25	39.232	40.055	0.823	1.208	6.038	5.059	5.000
30	39.625	40.055	0.430	0.627	3.133	5.015	5.000
35	39.956	40.055	0.099	0.264	1.322	5.011	5.000
40	39.956	40.055	0.099	0.099	0.495	5.000	5.000
45	40.325	40.055					
Total					**144.81**	**75.80**	**75.00**



Cross-sectional area of nallah at u/s of the proposed bridge is as follows:

Distance from proposed bridge	150 m
Longitudinal slope u/s side	0.0055
HFL at this location	40.880 m

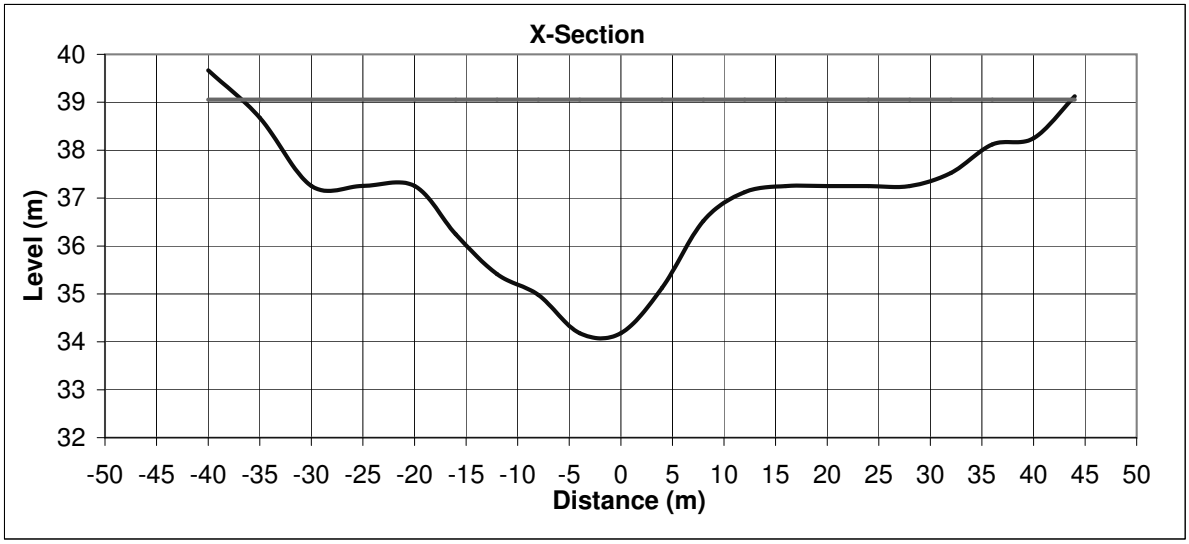
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-36	41.352	40.880					
-32	40.835	40.880	0.045				
-28	40.625	40.880	0.255	0.150	0.600	4.006	4.000
-24	39.825	40.880	1.055	0.655	2.620	4.079	4.000
-20	39.125	40.880	1.755	1.405	5.620	4.061	4.000
-16	39.456	40.880	1.424	1.590	6.358	4.014	4.000
-12	39.215	40.880	1.665	1.545	6.178	4.007	4.000
-8	38.685	40.880	2.195	1.930	7.720	4.035	4.000
-4	38.985	40.880	1.895	2.045	8.180	4.011	4.000
0	36.364	40.880	4.516	3.206	12.822	4.782	4.000
4	36.697	40.880	4.183	4.350	17.398	4.014	4.000
8	37.983	40.880	2.897	3.540	14.160	4.202	4.000
12	38.125	40.880	2.755	2.826	11.304	4.003	4.000
16	39.324	40.880	1.556	2.156	8.622	4.176	4.000
20	38.152	40.880	2.728	2.142	8.568	4.168	4.000
24	39.456	40.880	1.424	2.076	8.304	4.207	4.000
28	39.82	40.880	1.060	1.242	4.968	4.017	4.000
32	39.812	40.880	1.068	1.064	4.256	4.000	4.000
36	40.325	40.880	0.555	0.812	3.246	4.033	4.000
40	41.342	40.880					
Total					**130.92**	**69.81**	**68.00**



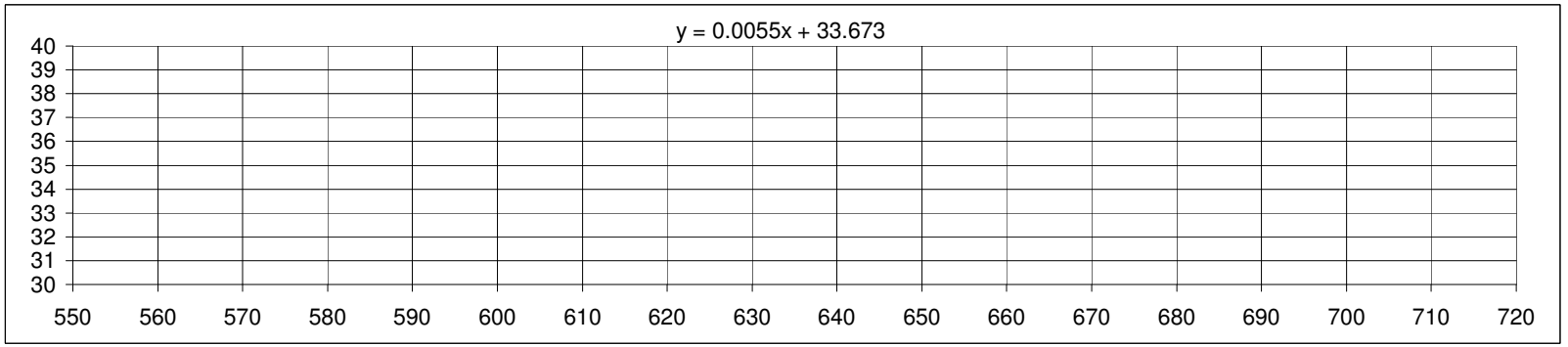
Cross-sectional area of nallah at d/s of proposed bridge is as follows:

Distance from proposed bridge 250 m
Longitudinal slope d/s side 0.004
HFL at this location 39.055 m

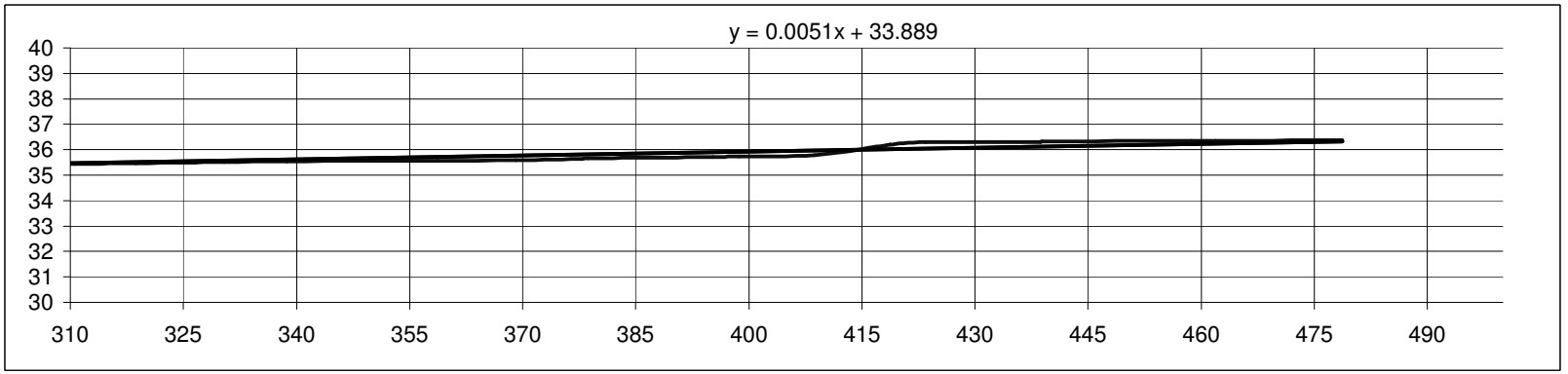
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
-40	39.666	39.055					
-35	38.677	39.055	0.378				
-30	37.254	39.055	1.801	1.090	5.448	5.199	5.000
-25	37.254	39.055	1.801	1.801	9.005	5.000	5.000
-20	37.254	39.055	1.801	1.801	9.005	5.000	5.000
-16	36.245	39.055	2.810	2.306	9.222	4.125	4.000
-12	35.415	39.055	3.640	3.225	12.900	4.085	4.000
-8	34.981	39.055	4.074	3.857	15.428	4.023	4.000
-4	34.181	39.055	4.874	4.474	17.896	4.079	4.000
0	34.181	39.055	4.874	4.874	19.496	4.000	4.000
4	35.125	39.055	3.930	4.402	17.608	4.110	4.000
8	36.524	39.055	2.531	3.231	12.922	4.238	4.000
12	37.125	39.055	1.930	2.231	8.922	4.045	4.000
16	37.25	39.055	1.805	1.868	7.470	4.002	4.000
20	37.25	39.055	1.805	1.805	7.220	4.000	4.000
24	37.25	39.055	1.805	1.805	7.220	4.000	4.000
28	37.25	39.055	1.805	1.805	7.220	4.000	4.000
32	37.524	39.055	1.531	1.668	6.672	4.009	4.000
36	38.12	39.055	0.935	1.233	4.932	4.044	4.000
40	38.25	39.055	0.805	0.870	3.480	4.002	4.000
44	39.125	39.055					
Total					**182.07**	**75.96**	**75.00**



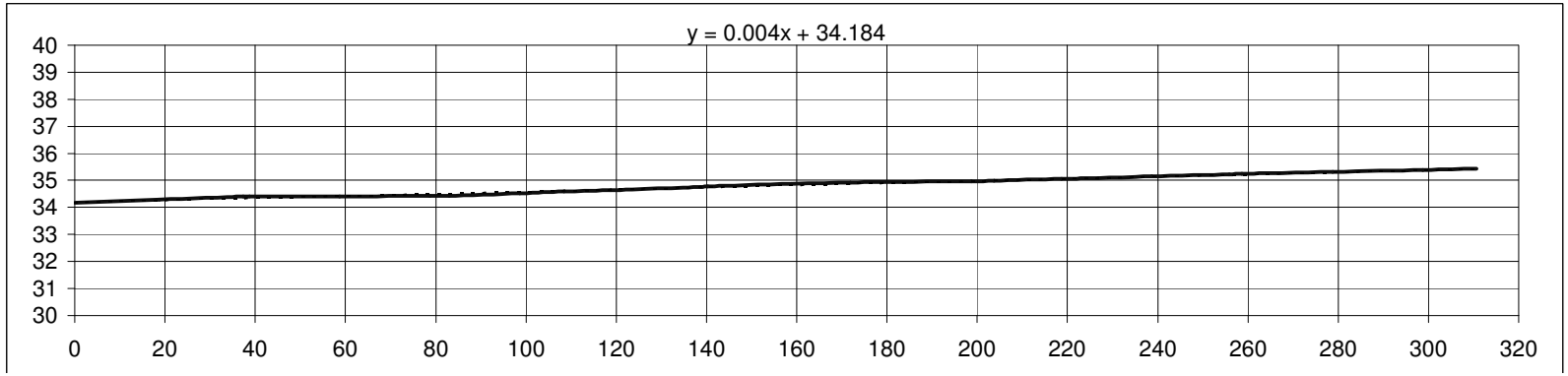
L-Section of Nallah at U/S



L-Section of Nallah at Existing Bridge



L-Section of Nallah at D/S



Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	265.37	cum/sec
HFL	39.090	m
Bed level	36.240	m
Maximum scour depth	4.58	m
Maximum scour level	34.512	m

Curtain wall shall be provided below maximum scour level

Bed level	36.24	m
Scour depth below bed	1.73	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	2.5	m
	d/s	3.0	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	3.46	3.5	m
	d/s	6.0	3.46	6.0	m

APPENDIX

ORISSA STATE ROAD PROJECT

HYDROLOGICAL STUDY

Road : Bhadrak-Anandpur(S.H-53)

Name of River/Nallah/Stream **: Ghaghara Nadi**

Name of nearest Village/Town :

RD : 37.600 km

Lattitude : 86^0 0'

Longitude : 21^0 15'

GT Sheet No. : 73K

Estimation of slope

S. No.	Reduced Distance Starting from Gauging Site (Point of Study) (kms)	Reduced Levels of River Bed (m)	Length of each Segment L_i (km)	Height Above Datum *(D_i Difference Between the Datum and the ith R.L. (m)	$(D_{i-1}+ D_i)$	$L_i (D_{i-1} + D_i)$ (4) x (6) (m x km)
1	**2**	**3**	**4**	**5**	**6**	**7**
1	0	20	0	0	0	0.00
2	1.35	40	1.35	20	20	27.00
3	11.6	60	10.25	40	60	615.00
4	15.9	80	4.3	60	100	430.00
5	16.65	100	0.75	80	140	105.00
6	17.25	120	0.6	100	180	108.00
7	17.75	140	0.5	120	220	110.00
8	20.25	160	2.5	140	260	650.00
9	20.7	180	0.45	160	300	135.00
10	20.9	200	0.2	180	340	68.00
11	21	220	0.1	200	380	38.00
12	21.05	225	0.05	205	405	20.25
					$\Sigma L_i (D_{i-1} + D_i)$ =	2306.25

$$S = \frac{\Sigma L_i (D_{i-1} + D_i)}{L^2} = 5.205 \text{ m/km}$$

Synthetic Unitgraph

Catchment area = 131.500 Sq.Km.

L = 21.05 km

Lc = 9.0 km

LxLc/(sqrt(s)) = 83.0394

$t_p = 1.757((L \times Lc)/sqrt(S))^{0.261}$ = 5.5681 hrs

Say 5.5 hrs

$q_p = 1.260\ (tp)^{-0.725}$ = 0.36611

Q_p = Catchment area x q_p = 48.1430 cumecs

$W_{50} = 1.974\ (q_p)^{-1.104}$ = 5.9858 hrs

$W_{75} = 0.961\ (q_p)^{-1.125}$ = 2.9762 hrs

$W_{R50} = 1.150\ (q_p)^{-0.829}$ = 2.6453 hrs

$W_{R75} = 0.527\ (q_p)^{-0.932}$ = 1.3444 hrs

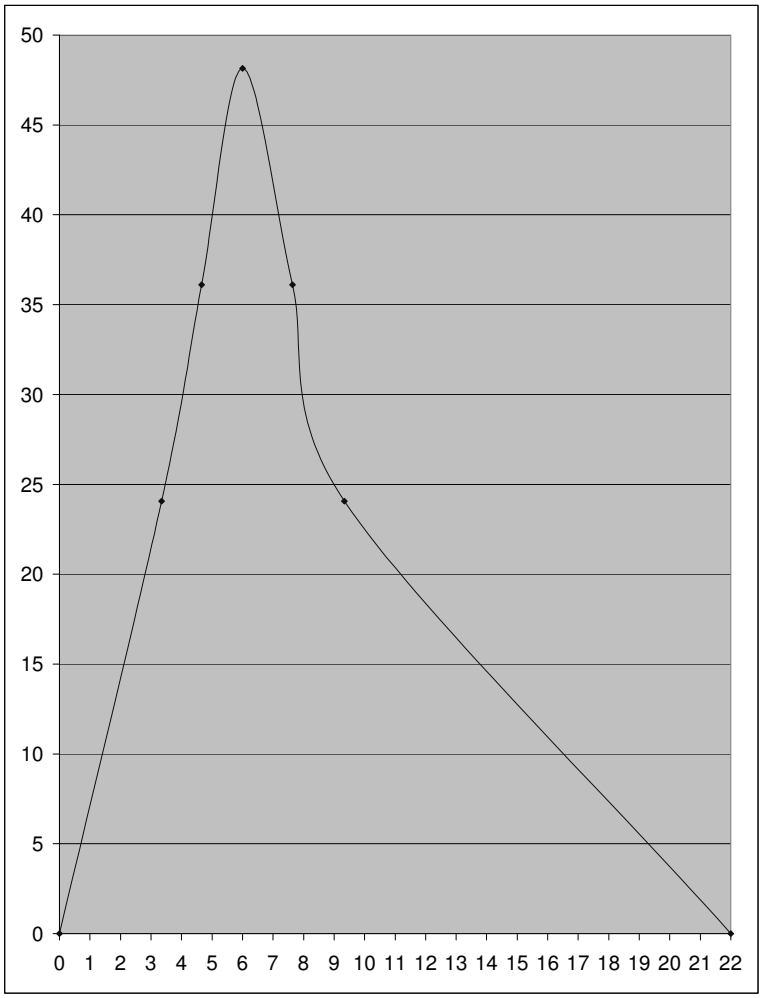
$Q_{50} = 0.5 \times Q_p$ = 24.0715 cumecs

$Q_{75} = 0.75 \times Q_p$ = 36.1073 cumecs

$T_B = 5.411\ (tp)^{0.826}$ = 22.1216 hrs

Storm duration, t_r = 1 Hour

Unit Graph (1cm 1 hour)		
Sl. No	**Time**	**Ordinate**
1	0	0
2	1	7
3	2	14
4	3	21
5	4	30
6	5	40
7	6	48.14
8	7	41
9	8	33
10	9	26
11	10	21
12	11	17
13	12	14
14	13	12
15	14	10.5
16	15	8.5
17	16	7
18	17	5.5
19	18	4
20	19	3
21	20	2
22	21	1
23	22	0
		365.64 cumec hours
		= 10.009916 mm



STORM DURATION Td = 1.1 t_p

= 1.1 X 5.5 = 6.1 **say 6 Hrs**

From Plate 8c , the 50 -Year return period , 6 hour point rainfall = 180 mm .

Areal Rainfall = 90 % of Point Rainfall Ref: Para 4.4

= 162.00

Loss rate = 0.26 cm / hour

Cumulative percentage

Hours	Storm Percentage	Storm Rainfall	Excess Rainfall	Incremental R.E.
0	0	0	0	0
1	47	76.14	75.88	75.88
2	68	110.16	109.64	33.76
3	80	129.6	128.82	19.18
4	91	147.42	146.38	17.56
5	97	157.14	155.84	9.46
6	100	162	160.44	4.6

Estimation of Design Flood Hydrograph

Unit Graph (1 cm 1 hour)			R.E.	R.E.							Base Flow	Design Flood Hydrograph
Sl. No	Time	Ordinate	Peak to Peak	Reverse order	0.46	1.756	3.376	7.588	1.918	0.946		
1	0	0			0						13.15	13.15
2	1	7			3.22	0					13.15	16.37
3	2	14			6.44	12.292	0				13.15	31.882
4	3	21			9.66	24.584	23.632	0			13.15	71.026
5	4	30	9.46	4.6	13.8	36.876	47.264	53.116	0		13.15	164.206
6	5	40	19.18	17.56	18.4	52.68	70.896	106.232	13.426	0	13.15	274.784
7	6	48.14	75.88	33.76	22.1444	70.24	101.28	159.348	26.852	6.622	13.15	399.636
8	7	41	33.76	75.88	18.86	84.5338	135.04	227.64	40.278	13.244	13.15	532.746
9	8	33	17.56	19.18	15.18	71.996	162.521	303.52	57.54	19.866	13.15	643.773
10	9	26	4.6	9.46	11.96	57.948	138.416	365.286	76.72	28.38	13.15	691.860
11	10	21			9.66	45.656	111.408	311.108	92.3325	37.84	13.15	621.155
12	11	17			7.82	36.876	87.776	250.404	78.638	45.5404	13.15	520.204
13	12	14			6.44	29.852	70.896	197.288	63.294	38.786	13.15	419.706
14	13	12			5.52	24.584	57.392	159.348	49.868	31.218	13.15	341.08
15	14	10.5			4.83	21.072	47.264	129.00	40.278	24.596	13.15	280.186
16	15	8.5			3.91	18.438	40.512	106.232	32.606	19.866	13.15	234.714
17	16	7			3.22	14.926	35.448	91.056	26.852	16.082	13.15	200.734
18	17	5.5			2.53	12.292	28.696	79.674	23.016	13.244	13.15	172.602
19	18	4			1.84	9.658	23.632	64.498	20.139	11.352	13.15	144.269
20	19	3			1.38	7.024	18.568	53.116	16.303	9.933	13.15	119.474
21	20	2			0.92	5.268	13.504	41.734	13.426	8.041	13.15	96.043
22	21	1			0.46	3.512	10.128	30.352	10.549	6.622	13.15	74.773
23	22	0			0	1.756	6.752	22.764	7.672	5.203	13.15	57.297
						0	3.376	15.176	5.754	3.784	13.15	41.24
							0	7.588	3.836	2.838	13.15	27.412
								0	1.918	1.892	13.15	16.96
									0	0.946	13.15	14.096
										0	13.15	13.15

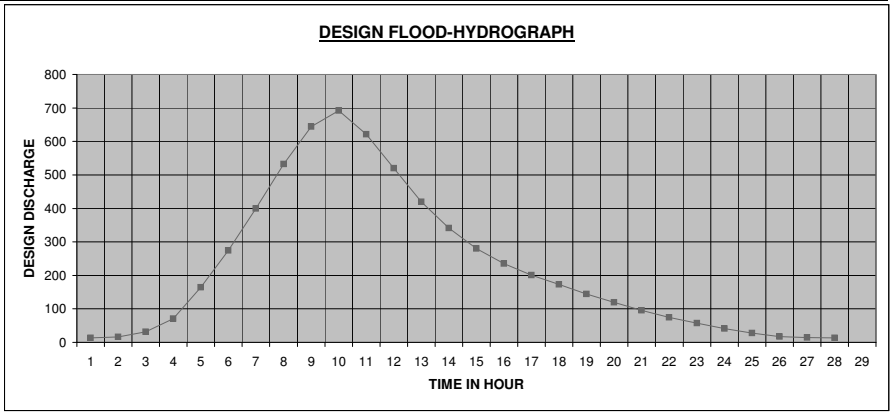
Qp = 692 Cumecs

= 24441.44 Cusecs

C.A. = 131.5 Sq. Kms.

= 51.3671875 Sq. Mile

Dicken's C = 1273.83286 F.P.S.



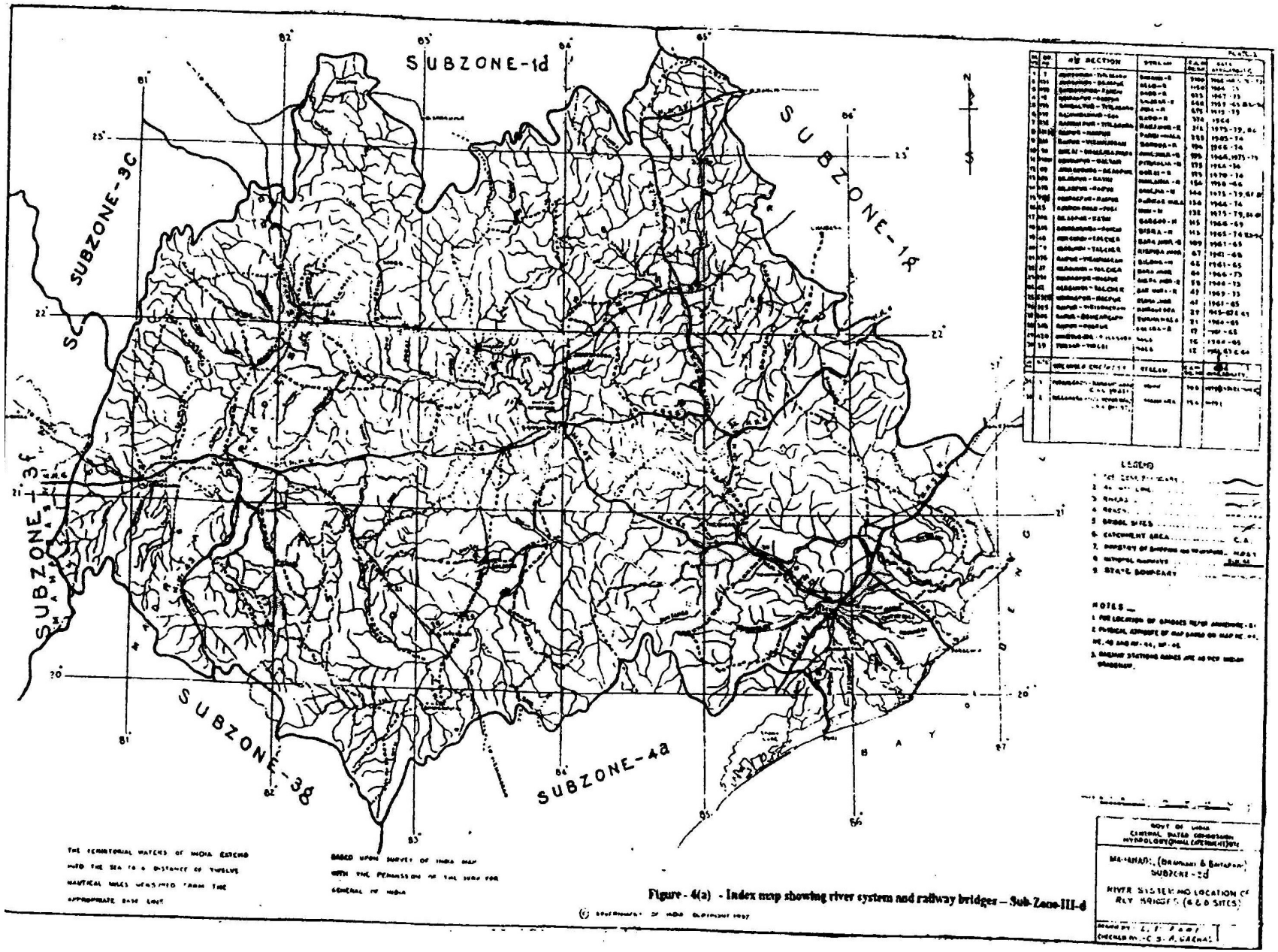


Figure - 4(a) - Index map showing river system and railway bridges – Sub-Zone-III-d

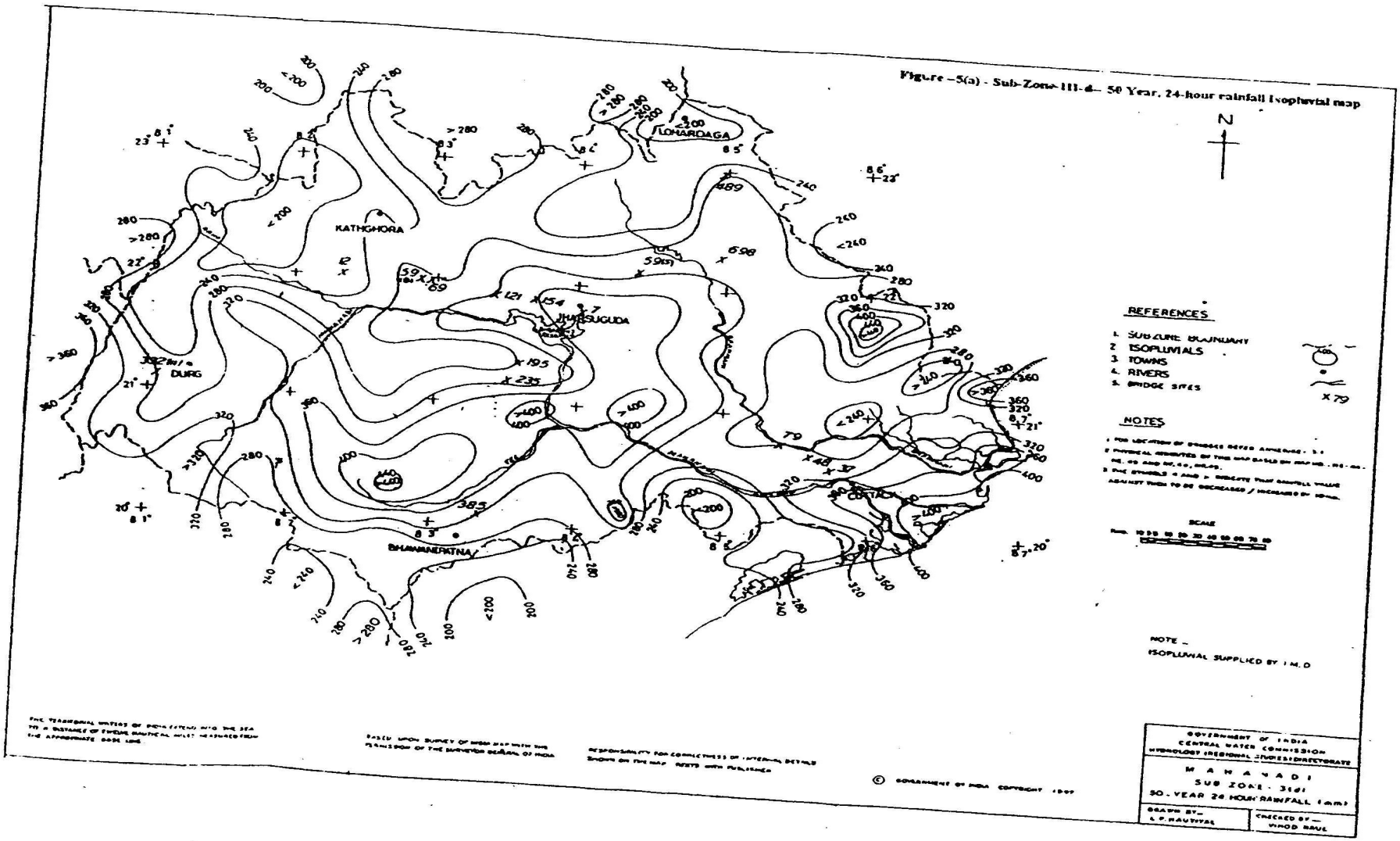


Figure –5(a) - Sub-Zone III-d – 50 Year, 24-hour rainfall Isopluvial map
N
KATHGHORA
LOHARIDAGA
JHARSUGUDA
DURG
BHAWANIPATNA
REFERENCES
1. SUB ZONE BOUNDARY
2. ISOPLUVIALS
3. TOWNS
4. RIVERS
5. BRIDGE SITES
NOTES
SCALE
NOTE –
ISOPLUVIAL SUPPLIED BY I.M.D
GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DIRECTORATE
M A H A N A D I
SUB ZONE - 3(d)
50 - YEAR 24 HOUR RAINFALL (mm)
DRAWN BY –
L.P. HAUTIYAL
CHECKED BY –
VINOD RAUL
© GOVERNMENT OF INDIA COPYRIGHT 1997


SANTOSHPUR R F
Santoshpur Pahar
BAITARANI RIVER
SATKOSIA R F
Sātkosia
Sālandi N
Hadagarh Reservoir
BAULA R F
ĀNANDAPUR
BM 46·7
BM 34·9
Fakirpur
CHARNALIA
Kelāsāhi
Bara Rampās
Banta
18·400
17·700
11·600
Adalbanka
Narsinghpur
Manguli
Ganijangha
Kapali N
SALANDI MAIN CANAL
Charampa Branch
SOUTH EASTERN RAILWAY Main
NH 5
BHADRAK
Chārampa
Bania
1·005
3·200
1·800
3·900
9·200
9·300
13·6
Baulpur R S
Kenduapada R S
Manjuri Road R S
AKHUAPADA HIGH LEVEL
KULDIHA RESERVED
GADASAHI R F
Khaira
Aupada
Gandibed
Māttapur
Basudpada
Dolasahi
Pālia
Gohiranda
PATILO R F
RAGADI P F
Rāmchandrapur
Dhani Huli
Garhbandhgora
Kāliāpāl N
Kusai N
Remala N
Girigan
Taranda Gopalpur
Ragadi
Rāmpilo
Kabati N
Ranagundi
Dhobari
Tunga Pahar
Talgan
Dhenka
Purusandha
Agarpara
Jalagan
Dunguri
Ada
Chandrapada
Markuna
BM 12·5
Rāmbhila
Rahanj
Kaupur
Kuplri
Bartana
Rāintira
Kuruntia
Nuagan
Sundarpur
Baulpur
Jugjhuri Pahar
Mulipada
Bāghdapa
Tentingsāhi
Raipāl
Rānipokhari
Padmapokhari
Bishungan
Baraiusāhi
0° E. of GREENWICH
A
B
C
15′
30′
J Ā J Ā P U R
Cuttack 85 km
Kanai 4 km
Cuttack 87 km
Cuttack 93 km
Madras 1262 km
Kaibar 10 km

ORISSA STATE ROAD PROJECT
HYDROLOGICAL STUDY

Road : Bhadrak-Godabhanga Gate
Name of River/Nallah/Stream : Taradadiha Nadi
Name of nearest Village/Town : Sarangi
RD : 50/950km
Lattitude : 86^0 9'
Longitude : 21^0 13'
GT Sheet No. : 73 K/4

Estimation of slope

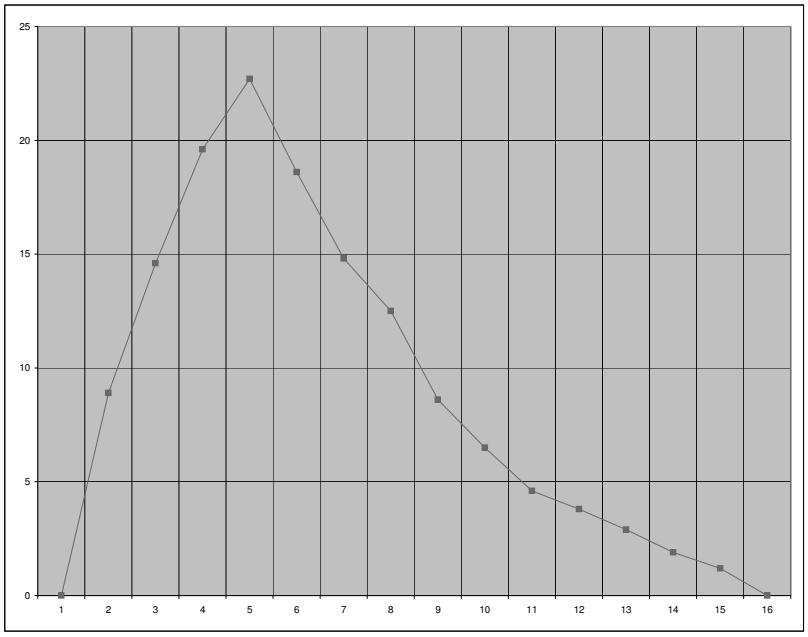
S. No.	Reduced Distance Starting from Gauging Site (Point of Study) (kms)	Reduced Levels of River Bed (m)	Length of each Segment L_i (km)	Height Above Datum *(D_i Difference Between the Datum and the ith R.L. (m)	$(D_{i-1}+ D_i)$	$L_i (D_{i-1} + D_i)$ (4) x (6) (m x km)
1	2	3	4	5	6	7
1	6.1	30	0	0	0	0.00
2	8.3	60	2.2	30	30	66.00
3	8.9	80	0.6	50	80	48.00
4	9.1	100	0.2	70	120	24.00
5	11.2	120	2.1	90	160	336.00
6	11.7	140	0.5	110	200	100.00
7	13.2	160	1.5	130	240	360.00
8	15.7	180	2.5	150	280	700.00
9	16.4	200	0.7	170	320	224.00
10	17	220	0.6	190	360	216.00
11	19.5	240	2.5	210	400	1000.00
					$\Sigma L_i (D_{i-1} + D_i)$ =	3074.00

$$S = \frac{\Sigma L_i (D_{i-1} + D_i)}{L^2} = 8.084 \text{ m/km}$$

Synthetic Unitgraph

Catchment area = 50.5 Sq.Km.
L = 19.5 km
Lc = 8.5 km
LxLc/(sqrt(s)) = 58.30
$t_p = 1.757((L \times Lc)/sqrt(S))^{0.261}$ = 5.08 hrs
Say 3.5 hrs
$q_p = 1.260\ (tp)^{-0.725}$ = 0.51
Q_p = Catchment area x q_p = 25.66 cumecs
$W_{50} = 1.974\ (q_p)^{-1.104}$ = 4.17 hrs
$W_{75} = 0.961\ (q_p)^{-1.125}$ = 2.06 hrs
$W_{R50} = 1.150\ (q_p)^{-0.829}$ = 2.02 hrs
$W_{R75} = 0.527\ (q_p)^{-0.932}$ = 0.99 hrs
$Q_{50} = 0.5 \times Q_p$ = 12.83 cumecs
$Q_{75} = 0.75 \times Q_p$ = 19.24 cumecs
$T_B = 5.411\ (tp)^{0.826}$ = 15.23 hrs
Storm duration ,t_r = 1 Hour
$Tm = t_p + t_r/2 = 3.5 + 1/2$ = 4 hrs

Sl. No	Unit Graph(1 cm 1 hour) Time	Ordinate	
1	0	0	
2	1	8.9	
3	2	14.6	
4	3	19.6	
5	4	22.7	
6	5	18.6	
7	6	14.8	
8	7	12.5	
9	8	8.6	
10	9	6.5	
11	10	4.6	
12	11	3.8	
13	12	2.9	
14	13	1.9	
15	14	1.2	
16	15	0	
		141.2	**cumec hours**
		= 10.0657426 mm	



STORM DURATION Td = 1.1 t_p

= 1.1 X 3.5 = 3.9 **say 4 Hrs**

From Plate 9(a) , the 50 -Year return period , 24 hour point rainfall = 240 mm . **240 mm**

Areal Rainfall = 65 % of Point Rainfall **65 156 mm**

Areal reduction factor= 96.75 % **96.75 150.93 mm**

Loss rate = 0.26 cm / hour **2.6 mm /hour**

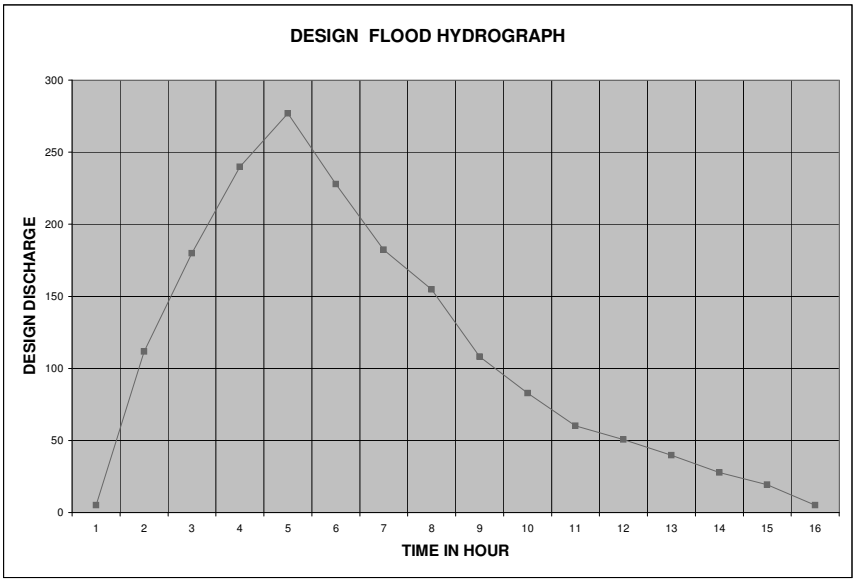
Cumulative percentage

Hours	Storm Percentage	Storm Rainfall	Excess Rainfall	Incremental R.E.
0	0	0	0	0
1	70	105.65	103.05	103.05
2	87	131.31	126.11	23.06
3	96	144.89	137.09	10.98
4	100	150.93	140.53	3.44

Estimation of Design Flood Hydrograph

Unit Graph(1 cm 1 hour)			R.E.	R.E.								Base Flow	Design Flood Hydrograph
Sl. No	Time	Ordinate	Peak to peak	Reverse order	0.344	1.098	10.305	0.2306					
1	0	0			0	0	0	0				5.05	5.05
2	1	8.9			3.06	9.77	91.71	2.05				5.05	111.65
3	2	14.6			5.02	16.03	150.45	3.37				5.05	179.92
4	3	19.6	23.06	3.44	6.74	21.52	201.98	4.52				5.05	239.81
5	4	22.7	103.05	10.98	7.81	24.92	233.92	5.23				5.05	276.94
6	5	18.6	10.98	103.05	6.40	20.42	191.67	4.29				5.05	227.83
7	6	14.8	3.44	23.06	5.09	16.25	152.51	3.41				5.05	182.32
8	7	12.5			4.30	13.73	128.81	2.88				5.05	154.77
9	8	8.6			2.96	9.44	88.62	1.98				5.05	108.06
10	9	6.5			2.24	7.14	66.98	1.50				5.05	82.90
11	10	4.6			1.58	5.05	47.40	1.06				5.05	60.15
12	11	3.8			1.31	4.17	39.16	0.88				5.05	50.56
13	12	2.9			1.00	3.18	29.88	0.67				5.05	39.79
14	13	1.9			0.65	2.09	19.58	0.44				5.05	27.81
15	14	1.2			0.41	1.32	12.37	0.28				5.05	19.42
16	15	0			0	0	0	0				5.05	5.05

Qp = 277 Cumecs
= 9783.64 Cusecs
C.A. = 50.5 Sq. Kms.
= 19.726563 Sq. Mile
Dicken's C = 1045.2301 F.P.S.




SANTOSHPUR R F
Santoshpur Pahar
SATKOSIA R F
Satkosia
BAITARANI RIVER
Similia
Hadagarh Reservoir
BAULA R F
Hadagarh
ANANDAPUR
BM 46·7
Fakirpur
Jamunalia
Ghontadara
Purunapani
Mulipada
Batighutu
Tentingsahi
Bishugan
Barajisahi
Ranipokhari
Padmapokhari
KULDIHA RESERVE
GADASAHI R F
Baulpada
Aupada
Khaira
Gandibed
Nachhipur
Kuruntia
Saundia
Manupankha
Bartana
Dungura
SALANDI MAIN CANAL
Agarpara
Adia
Narsinghpur
Barabarchhi
Bantala
Manguli
Banta
Ganijangha
Kapali N
Salandi N
Daisingha
Jalagan
Bhadrak R S
Charampa
BHADRAK
Bania
Basudpada
Bantal
Dolasahi
Gudapada
Palia
SOUTH EASTERN RAILWAY Main
NH 5
Rambhila
Rabani
Markuna
Maitapur
Sahajpada
Chandrapada
Garasanga
Magarpur
Kendupada R S
Manjuri Road R S
Korakara
Salbani
Anra
Danra
Sayatira
Andhia
Kelasahi
Bara Rampas
Adalbanka
Basanta
Orali
Ambo
Girigan
Sankho
Samana
Gobindapur
Makundapur
Gedama
Baruanpada
Manduajpur
Ramchandrapur
Kaliapal N
Taranda Gopalpur
Ragadi
RAGADI P F
Patranga
Dhani Huli
Garhbandhgora
Kabati N
Ranagundi
Dhobari
Gobardhanpur
PATILO R F
Kanapur
Machhol
Barapada
Khalana
Taruan
Baliborua
Belbahali
Kusai N
Charinalia N
Balarampur
Bhandaridiha
Shaliamento
Seilang
Talgan
Bakhidi
Baunshagarba
Janghar
Tartara
Ambagaria
Barigan
Bancho
Tunga Pahar
Tikra
Dhakotha
Korapara
Balidih
Gobindapur
Dhenka
Purusandha
Baniapara
Kuparl
Sarukuna
Munida
Dalang
Tudigadia
Makhanpur
Raikula
Mahatipur
Nuagan
Aghirapada
Nijarna
Suhdarpur
Paikapada
Guapal
Sibhou
Bolsa
Kantipal
Sathakata
Panchu
Ramchu
Cuttack 81 km
Cuttack 87 km
Cuttack 93 km
Madras 1362 km
Kaupur 10 km
15′
30′
86° 0′ E. of GREENWICH.
A
B
C
J Ā J Ā P U R
N A N D A P U R
B H A D
N I L