CHAPTER – 2

HYDROLOGICAL STUDY AND ANALYSIS

2.1 Introduction

Drainage is the most important fundamental factor governing the stability, load carrying capacity, structural soundness and functional efficiency of Double lane Meka-Roing-Hunli road in Arunachal Pradesh.

The Project road passes through hilly terrain in Lower Dibang Valley district of Arunachal Pradesh baring small part of the road in plains between Meka and Roing town.

Part–1 Plain terrain
Part–2 Hilly terrain
Part–3 Hilly terrain

The alignment in Part–1 and Part–2 follows existing road with correction in geometry, whereas Part–3 will be built as new one.

2.2 Hydrological Survey/Assessment

The catchment area for Part–1 is not well defined and is interfered by the city/town development. There are no major drainage structures in Part-1. In Part–2 passing through hilly terrain, there are two major bridges either built or under construction. There are no other major water course and only culverts functioning satisfactory. Hydrological assessment for Part–1 and Part–2 has been based on local observations of flood marks on the cross drainage structures supplemented by local enquiries.

Hydrological survey for Part–3 (New alignment) is primarily based on catchment area demarcation. Survey of India maps for large catchment supplemented by satellite and Google images for very large catchment.

Other relevant data as rainfall is obtained from past observation record of major weather stations around project area (there is no measuring station available near project area).Height and shapes are picked for digital terrain data/cross/long section of streams. Soil/bed characteristics are drawn from representative soil test data supplemented by experience of similar conditions.

Cross drainage works are broadly of two types of structure:

- Roadside Drainage Outfall Structures
- Defined Stream / Nalla Structures

- **Road side Drainage Outfall Structures**

The surface water from the roadside and adjoining land / area will be collected in the longitudinal road side drains by providing camber / cross slope, which in turn carried to the nearest cross drainage structure.

- **Defined stream / nalla structures**

There are defined nallas/streams and rivers where major and minor bridges are proposed to cross over.

2.3 Hydrological Study

Hydrological Study is an important step prior to hydraulic design of road drainage system. The hydrological data obtained for design includes catchments area; water shed delineation, flow direction, outfalls, other surface drainage facilities, ground surface conditions, rainfall and flood frequencies. The major factors which effect run off are:

- Intensity of rainfall
- Size and shape of the catchments area
- Slope of the ground and Nature of the surface over which the flow occurs.

The Hydrological Study has been carried out on the proposed road in three parts such as Part-1 Part-2 and Part-3. Part-3 has been divided into three sub parts such as Part-3A, Part-3B and Part-3C.

Part-3 New alignment
Section-3A 15.4 km. (Roing-Hunli road) to Munli (PKG RH/N1)
Section-3B Munli to Kronli (PKG RH/N2)
Section-3C Kronli to 22.5km (Hunli – Anini road) (PKG RH/N3)

Note: The Hydrological Study of Part-1 and Part-2 is already submitted in FDPR of Package RH/E1

2.3.1 Detailed Hydrological Study

Part -3
This portion of project road is divided into three sub parts.

Part -3A 15.4 km to Munli (Roing-Hunli road)

This portion of project road is on new alignment. One major bridge over Ashupani river and two minor bridges over nala are proposed on this section. Proposed major bridge location is 12+365 of span 6x40 and minor bridges locations are 15+370 and 18+120 of span 2x10 m and 1x30 m. Based on the ground contour it is noted that flow of the water is from right to left considering increasing chainage of project road. Discharge of each river is finalised based on the Rational , Emperical and Area-Velocity methods of IRC SP-13 and details are described in tabulated format with topo map later part of this chapter.

Part –3B Munli to Kronli

This portion of project road is on new alignment. One major bridge over Munli nala and two minor bridges over Ltti and Ayyu nala are proposed on this section.Proposed major Bridge location is 3+607 of span 2x30m and minor bridges locations are 13+209 and 20+343 of span 1x40 m and 3x10 m.

Based on the ground contour it is noted that flow of the water is from right to left considering increasing chainage of project road. Discharge of each river is finalised based on the Rational , Emperical and Area-Velocity methods of IRC SP-13 and details are described in tabulated format with Topo map later part of this chapter.

Part -3C Kronli to 22.5km (Hunli-Anini road)

This portion of project road is on new alignment. Three major bridges and one minor bridge are proposed on this section.Proposed major bridges locations are 2+690, 18+180 over Eha nala and 20+815 over Ithun river of span 2x30 m, 1x150 m and 1x130.m. One minor bridge location is 13+337 of span 1x40m.

Based on the ground contour it is noted that flow of the water is from right to left considering increasing chainage of project road. Discharge of each river is finalised based on the Rational , Emperical and Area-Velocity methods of IRC SP-13 and details are described in tabulated format with topo map later part of this chapter.

Methodology for the Determining the Design Discharge

Design discharge for bridges has been computed by using various methods as recommended by IRC: 5 and IRC-SP-13. Methods adopted in any particular case vary depending on data available. Various methods to be adopted for discharge computation are listed below. Analysis based upon cross-sections & long–section information and catchment characteristics, to determine the design discharge and capacity of the existing Bridges over the study road project.

Catchment based methods

Empirical method (Dicken's formula), Rational method are used for computation of flood discharge based on catchment area.

Method based on river sections

Slope- Area method is being used. Topographical survey data is being used for cross-sections of the river at c/s of the bridge site including the longitudinal profile for the same.

Empirical Formula

Dicken's and Ryve's empirical formula are commonly used for computation of flood discharge using catchment area of the stream.

Dicken's Formula:

$$Q = C_1 A^{0.75} \qquad (1)$$

Ryve's Formula:

$$Q = C_2 A^{0.67} \qquad (2)$$

Where: A = Catchment area in Sq. km.

C_1 and C_2 = Run-off coefficients which depends on the topography, type of the soil, vegetation, ground slope, climate of the region, etc

Because of the varying topography and catchment characteristics C_1 or C_2 values will vary appreciably, and reliability of computed discharge depends on the accuracy of the adopted value for these coefficients. Dicken's formula is being used in most of the cases. Run-off Coefficient C_1 as an average value determined between 11 to 14 should be considered.

Rational Formula

$$Q = 0.028\, PfAI_C \qquad (3)$$

Where:

Q = Maximum runoff in cumecs

A = Catchment area in hectares

Ic = Critical intensity of rainfall in cm/ hr.

P = Coefficient of run-off for the given catchment characteristics.

f = Spread factor for converting point rainfall into areal mean rainfall.

$Ic = (F/T)*((T+1) / (T_c+1))$

F = Total Rainfall of T hours duration (24 hrs.) in cm corresponding to either 25 yrs (for culverts) or 50 yrs (for bridges) return period.

T = Duration of total rainfall (F) in hours= 24 hrs.

Tc= Time of concentration in hour.

Ic value from the above formula (as per IRC: SP-13) gives relatively high intensity of rainfall when 24 hrs rainfall is considered. Design rainfall intensity Ic, is therefore computed from rainfall distribution. The values of run-off coefficient P and spread factor f are taken as per **Table 5.46** and **Fig 5.14** of IRC-SP: 13, respectively. Catchment characteristics and area were taken from topo-sheet for discharge computation which is attached with this document.

Area-velocity Method

This method is based on Hydraulic mean depth (R) and the longitudinal bed slope (S) of the stream. For calculation cross-sections at bridge centre is being used. The discharge is calculated by Manning's formula given below:

$Q = A.V$ (4)

V =Velocity in m/s

$V = 1/N \times S^{1/2} \times R^{2/3}$ (5)

Where:

Q = Discharge in m^3/sec.

A = Cross-sectional area of flow in sq. m.

P = Wetted perimeter in m.

R = Hydraulic mean depth in m = A/P

S = Mean longitudinal slope of the channel.

N = Rugosity coefficient as per IRC: SP –13 as given below:

Rugosity Co-efficient used in Area-velocity Method

Sl. No.	**Surface (Natural Streams)**	**Manning's N-values.**			
		Perfect	**Good**	**Fair**	**Bad**
1.	Clean, straight bank, full stage, no rifts or deep pools	0.025	0.0275	0.030	0.033
2.	Same as (1), but some weeds and stones	0.030	0.033	0.035	0.040
3.	Winding, some pools and shoals, clean	0.035	0.040	0.045	0.050
4.	Same as (3), lower stages, more ineffective slope	0.040	0.045	0.050	0.055
5.	Same as (3), some weeds and stones	0.033	0.035	0.040	0.045
6.	Same as (4), stony sections	0.045	0.050	0.055	0.060
7	Sluggish river reaches, rather weedy or with very deep pools	0050	0.060	0.070	0.080
8	Very weedy reaches	0.075	0.100	0.125	0.150

If the shape of the cross-section is irregular as it happens quite often in streams with flood plains with deep water in main channel and shallow overflows in the flood plains, it is necessary to subdivide the channel into various subsections. Then 'A' and 'P' of each subsection are computed and summed up to get total area and perimeter. Discharge passing through each cross-section is found as

Q = A.V

It may be noted that the discharge found from Area-Velocity method is based upon flood marks being obtained at the site from local enquiry. Hence, such discharge cannot be assigned any defined return period unless year wise records of HFL are available. However, this method is extremely useful to assess the accuracy or determine HFL corresponding to design discharge. Wherever the discharge found by Area-Velocity method varies widely with the discharge found from other methods, under considerations.

Design Discharge

Based upon Input data and various methods (Empirical, Rational and Area-Velocity) for discharge computation as discussed were used to compute the discharge and followed the following criteria to adopt the design discharge.

1) When the variation between the highest two values of discharges computed by different methods is less than 50%, the highest discharge is taken as design discharge. Depending upon the local features, if the method is not suitable for a particular bridge, the discharge by that method is ignored.

2) When the variation between the highest two values of the computed discharge by different methods is more than 50%, the design discharge is taken as 1.5 times the lower of the two maximum values or the outlier is ignored.

Design HFL /FSL

HFL/FSL are computed/checked by using design discharge and Area-Velocity methods for the clear span of existing structures as well as proposed span in the case of drain/canal. HFL based on local enquiry/normal HFL approximation is given in Area-velocity method computation/abstract.

Scour Depth (For Major and Minor Bridges)

Lacey's equation is adopted for estimating normal scour depth as per IRC: 5

$$R = 1.34\ (q^2/f)^{1/3} \qquad (6)$$

Where R is the Lacey's regime scour depth measured below HFL, q is the design discharge intensity under bridge in cumecs per meter and f is the silt factor given by the equation

$$f = 1.76\ (d_m)^{1/2} \qquad (7)$$

Where d_m is the weighted mean diameter in mm.

For computing scour depth, enhancement of flood flow to the extent of 30% has been taken as per IRC: SP-5 recommendations. Maximum scour level for pier and abutment are calculated using a factor of safety by 2 and 1.27, respectively as per IRC: SP-5 code.

Computation of Afflux

Afflux is due to constriction in normal waterway under the bridge. It has been computed using formula (given below).

$$\text{Afflux} = ((v^2/17.88)+0.015)*((A/A_1)^2-1) \qquad (8)$$

Where, v = Average velocity of river prior to obstruction in m/s.

A = Unobstructed sectional area of river in sq. metre.

A_1 = Sectional area of river at obstruction in sq. metre.

Mols-worth formula is however independent of head loss. Wherever required, average of afflux values obtained by both the methods and as per local conditions, if any, has been considered to finalise the likelihood afflux.

Abstract of Hydrologic and hydraulic computation

The hydrologic and hydraulic computations for all the bridges are given in **Table below**. Various other hydraulic parameters e.g. design FSL/HFL, Linear waterway, normal depth of scour under bridge, velocity and vertical clearance are given in the table of Abstract of each bridge.

Summary of Hydrology of Meka-Roing-Hunli.

						Discharge (cumec)														
Sl. no.	Section	Design Chainage	Proposed span	Type	Catchment area(Ha)	Rational	Emperical	Area-Velocity	Maximum Discharge Q	Velocity (m/s)	Depth of water	VC	Super. Depth (incl camber+wc)	Type of Superstructure	L reqd (m)	Total Length Provided (m)	1.3*Q for scour	dsm	Type of foundation	Remarks
1	3A	12.365	6x40	MJB (Ashupani)	6887	510	335	802	765	3.7	2.0	9.8	3.2	Steel Plate Girder	135.5	240	994.5	3.16	Open	Abutment foundation rest on weathered rock and foundation is above HFL .So scour depth is immaterial at abutment location. Pier foundation rest on soil but bed is protected so scour depth is immaterial.

Summary of Hydrology of Meka-Roing-Hunli.

						Discharge (cumec)															
Sl. no.	Section	Design Chainage	Proposed span	Type	Catchment area(Ha)	Rational	Emperical	Area-Velocity	Maximum Discharge Q	Velocity (m/s)	Depth of water	VC	Super. Depth (incl camber+wc)	Type of Superstructure	L reqd (m)	Total Length Provided (m)	1.3*Q for scour	dsm	Type of foundation	Remarks
2	3A	15.370	2/10x7/2 Box	MNB	210	24.7	19	35	35	4.708	0.85	3.783	1	RCC Box	19.6	20	45.5	1.5	Raft	2 Cell Box rest on soil and bed is protected so scour depth is immaterial.
3	3A	18.120	1x30	MNB	798	97	67	93	93	6.227	2.6	3.16	2.5	Steel Plate Girder	27.9	30	120.9	2.1	Open	Abutment foundation rest on weather rock and is above HFL .So scour depth is immaterial at abutment location.

Summary of Hydrology of Meka-Roing-Hunli.

						Discharge (cumec)															
Sl. no.	Section	Design Chainage	Proposed span	Type	Catchment area(Ha)	Rational	Emperical	Area-Velocity	Maximum Discharge Q	Velocity (m/s)	Depth of water	VC	Super. Depth (incl camber+wc)	Type of Superstructure	L reqd (m)	Total Length Provided (m)	1.3*Q for scour	dsm	Type of foundation	Remarks
4	3B	3.607	2x30	MJB (nala)	3568	303	204	308	306	6.27	4.3	6.2	2.5	Steel Plate Girder	32.1	60	397.8	3.0	Open	Abutment foundation rest on weather rock and is above HFL .So scour depth is immaterial at abutment location. Pier foundation rest on weather rock so scour depth is immaterial.

Summary of Hydrology of Meka-Roing-Hunli.

						Discharge (cumec)														
Sl. no.	Section	Design Chainage	Proposed span	Type	Catchment area(Ha)	Rational	Emperical	Area-Velocity	Maximum Discharge Q	Velocity (m/s)	Depth of water	VC	Super. Depth (incl camber+wc)	Type of Superstructure	L reqd (m)	Total Length Provided (m)	1.3*Q for scour	dsm	Type of foundation	Remarks
5	3B	13.209	1x40	MNB Ltti Nala	736	72	63	64	64	6.68	1.8	1.87	3.2	Steel Plate Girder	16.0	40	83.2	1.4	Open	Abutment foundation rest on weather rock and is above HFL .So scour depth is immaterial at abutment location.
6	3B	20.343	3/10x8/2 Box	MNB Ayyu Nala	1082	117	84	133	126	5.14	1.8	7.01	1	RCC Box	29.7	30	163.8	2.7	Raft	3 Cell Box rest on soil and bed is protected so scour depth is immaterial.

Summary of Hydrology of Meka-Roing-Hunli.

						Discharge (cumec)															
Sl. no.	Section	Design Chainage	Proposed span	Type	Catchment area(Ha)	Rational	Emperical	Area-Velocity	Maximum Discharge Q	Velocity (m/s)	Depth of water	VC	Super. Depth (incl camber+wc)	Type of Superstructure	L reqd (m)	Total Length Provided (m)	1.3*Q for scour	dsm	Type of foundation	Remarks
7	3C	2.690	2x30	MJB	1106	116	84.9	154	154	3.32	3.9	9.783	2.5	Steel Plate Girder	55.9	60	200.2	1.9	Open	Abutment foundation rest on weather rock and is above HFL .So scour depth is immaterial at abutment location. Pier foundation rest on weather rock so scour depth is immaterial.

Summary of Hydrology of Meka-Roing-Hunli.

						Discharge (cumec)														
Sl. no.	Section	Design Chainage	Proposed span	Type	Catchment area(Ha)	Rational	Emperical	Area-Velocity	Maximum Discharge Q	Velocity (m/s)	Depth of water	VC	Super. Depth (incl camber+wc)	Type of Superstructure	L reqd (m)	Total Length Provided (m)	1.3*Q for scour	dsm	Type of foundation	Remarks
8	3C	13.337	1x40	MNB Ithu Nala	1592	174	112	173	173	4.97	2.8	7	3.2	Steel Plate Girder	37.3	40	224.9	2.64	Open	Abutment foundation rest on weather rock and is above HFL .So scour depth is immaterial at abutment location.
9	3C	18.180	1x150	MJB Eha Nala	6123	486	314	616	616	2.31	7.9	122.4	10	Unblanced cantilever with PSC Box.	105.8	130	800.8	2.49	Box type Gravity foundation.	-

Summary of Hydrology of Meka-Roing-Hunli.

						Discharge (cumec)															
Sl. no.	Section	Design Chainage	Proposed span	Type	Catchment area(Ha)	Rational	Emperical	Area-Velocity	Maximum Discharge Q	Velocity (m/s)	Depth of water	VC	Super. Depth (incl camber+wc)	Type of Superstructure	L reqd (m)	Total Length Provided (m)	1.3*Q for scour	dsm	Type of foundation	Remarks
10	3C	20.815	1x130	MJB Ithun River	11059	698	478	810	810	4.531	8.8	93.8 8	10	Unblanced cantilever with PSC Box.	126. 8	140	1053.0	5.73	Box type Gravity foundation.	-