3.8 Hydrology & Hydraulic Study

3.8.1 Objective

The objective of the hydrological and hydraulic study is to mathematically model the project area to design cross drainage structures and road embankment height to protect it from future floods. The major objectives are:

- Establishment of Waterway
- Marking extents of the catchments' area along with its characteristics
- Calculating Maximum Peak Flood Discharge based on meteorological data.
- Marking of flood plains and High Flood Levels
- Location of Cross Drainage structures
- Hydraulic Design of Cross Drainage structures (Type, sizes / geometry and Energy dissipaters for erosion control etc.)
- Calculating Scour Depth for bridges

3.8.2 Scope of Work / Activities

The consultant shall adopt state-of-the-art mathematical modeling approach using industry-standard software's for the hydrological and hydraulic assessment that shall incorporates following activities:

a. Reconnaissance Survey

The field survey will include geo-tagged photographs of the existing cross drainage structures, measurement of structure sizes; evaluation of structural condition, general soil evaluation and land use in the area. In case there is track alignment, all possible locations of water crossings shall be identified with water marks and width of waterway.

b. Meteorological Analysis

The meteorological analysis shall be based on maximum available record (preferably more than 30 years) from all the surrounding observatories. The analysis must include;

- Review and analysis of historic Rainfall and Peak Storm events;
- Use of statistical methods to evaluate meteorological and hydrometric records and determining best data best fitting on either of Gumbel Max, Weibull or Log Pearson 3 distributions.
- Calculation of return periods for 25 years, 50 years, 100 years and for bridge 500 years.
- Instead of using meteorological station data far away from the road, the consultant shall use spatial analysis (for meteorological models) for finding out design storm value in the study area / watershed derived from the surrounding observatories.
- Selecting and calculating design storm for hydrological model

c. Watershed Delineation

The activity includes delineation of watershed affecting road and evaluating physiography and topography of the catchment / watershed-area. The watershed delineation shall be carried out using industry standard GIS software's like ArcHydro, Topaz, WMS and DHI MIKE suite etc. The digital elevation model (DEM) for watershed delineation shall be of at least 30meter resolution or better. Satellite imagery and any available topographic survey shall be used for stream / river correction in the DEM.

d. Soil and Land Use

The hydrological soil type and land use shall be assessed in the catchment to evaluate Loss, routing and roughness. The hydrological soil

type and land use may be marked using satellite imagery and classification methods available in GIS with spot site verification.

e. Surface Runoff Model

The surface runoff for all ungauged basins shall be calculated using "Hydrological Modeling System" (HEC-HMS) and Watershed Modeling System (WMS) for large basins and for small TR-20 can be used. The model shall be prepared using GIS techniques / software like HEC-GeoHMS and WMS etc. The preparation shall include complete sub-basin characterization like basin area, slope, roughness and lag-time etc. The preferred method is as follows:

- Land use marked according to Anderson method / Land use type
- Loss Method = SCS Curve No.
- Roughness = Manning's n
- Transform SCS Unit Hydrograph
- CN curve numbers estimated from Land use
- Muskingum-Cunge or dynamic for routing
- Streams sections estimated from DEM

The hydrological model shall be integrated into hydraulic model based on field survey and judgment, stream and cross drainage structures identification through imagery and marking streams through GIS methods.

The consultant may also take into consideration future catchment changes likely to influence flooding risk.

f. Hydraulic Analysis

The calculated storm flows shall be modeled through or around road structures using 1D models like HEC-RAS, HY-8, MIKE 11 and SWMM. The culverts in general shall be designed using HY-8 based on data prepared through "Watershed Modeling System" and field survey. The bridges and mapping of flood plains shall be carried out through 1D hydraulic models like HEC-RAS or MIKE 11. The hydraulic model shall be prepared using GIS techniques like HEC-GeoRAS, WMS or MIKE 11.

The hydraulic model results shall be used for assessment of flood impact and analysis of alternatives for its mitigation. The hydraulic structures shall be designed taking into account standard design criteria for highways.

	Design AEP					Check Flood
Functional classification and structure type	**50% (2-yr)**	**20% (5-yr)**	**10% (10-yr)**	**4% (25-yr)**	**2% (50-yr)**	**1% (100-yr)**
Freeways (main lanes):						
Culverts					X	X
Bridges+					X	X
Principal arterials:						
Culverts			X	[X]	X	X
Small bridges+			X	[X]	X	X
Major river crossings+					[X]	X
Minor arterials and collectors (including frontage roads):						
Culverts		X	[X]	X		X
Small bridges+			X	[X]	X	X
Major river crossings+				X	[X]	X
Storm drain systems on controlled access highways (main lanes):						
Inlets, drain pipe, and roadside ditches			X			
Inlets for depressed roadways*					X	
Storm drain systems on other highways and frontage roads:						
Inlets, drain pipe, and roadside ditches	X	[X]	X			
Inlets for depressed roadways*				[X]	X	
+ The 0.5% (200-yr) and 0.2% (500-yr) AEP events should be calculated for scour computations.						

All structures must be evaluated to the 1% Annual Exceedance Probability (AEP) flood event or 100yr return period. Selecting a design flood is a matter of judgment; it requires balancing the flood risk with budgetary constraints, therefore the consultant is required to submit its proposal and take approval from national highway authority. The designer should design a facility that will operate:

- Efficiently for floods smaller than the design flood.
- Adequately for the design flood.
- Acceptably for greater floods.

3.8.3 **Outputs / Reporting**

The following reports shall be submitted by the consultant: -

1. Reconnaissance survey report;
   a. The Visit report shall include geo-tagged pictures in soft form.

2. Layout of structures:
    a. marked on satellite imagery
    b. marked with respect to catchments

3. Draft report
    a. Detail watershed delineation and analysis
    b. Meteorological analysis
    c. Soil and land use classification
    d. Surface runoff model results
    e. 1D hydraulic model results for design
    f. Hydraulic design of structures
    g. Embankment height according to HFL
4. Final report