REVISITING THE ADEQUACY OF THE HIGHWAY DRAINAGE SYSTEM USING THE GEOGRAPHICAL INFORMATION SYSTEM-A CASE STUDY OF NH-717A, KALIMPONG

A thesis submitted towards partial fulfilment of the requirements for the degree of

Master of Engineering in
Water Resources and Hydraulic Engineering
Submitted by

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This thesis work is dedicated to my family

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CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled "***REVISITING THE ADEQUACY OF THE HIGHWAY DRAINAGE SYSTEM USING THE GEOGRAPHICAL INFORMATION SYSTEM- A CASE STUDY OF NH-717A***"is a bonafide work carried out by Kazi Rejaul Sohel under our supervision and guidance for partial fulfilment of the requirement for Post Graduate Degree of Master of Engineering in Water Resources & Hydraulic Engineering during the academic session 2019-2022.

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CERTIFICATE OF APPROVAL**

This foregoing thesis is hereby approved as a credible study of an engineering subject carried out and presented in a manner satisfactorily to warranty its acceptance as a pre-requisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made or opinion expressed or conclusion drawn therein but approve the thesis only for purpose for which it has been submitted.

Committee of final Examination for the evaluation of the thesis

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Declaration of Originality and Compliance of Academic Ethics

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as a part of my Master of Water Resources & Hydraulic Engineering degree during academic session 2021-2022.

All information in this document has been obtained and presented in accordance with academic rules and conduct.

I also declare that, as required by this rules and conduct, I have fully cited and referred all material and results that are not original to this work.

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ABSTRACT

Adequate drainage is very important for maintaining the structural soundness and functional efficiency of a road. Pavement structure including sub-grade must be protected from any infiltration of water, otherwise over a time it may weaken the sub- grade by saturating it and cause distress in the pavement structure ultimately. This is why rapid dispersal of water from pavement and sub-grade is a basic consideration in road design. Also proper drainage diverts the water from pavement surface quickly and reduces the chance of skidding of vehicles. This thesis work deals with the drainage design which is based on the science of hydrology and hydraulics. Former deals with the road side drainage system while the letter deals with the Q-GIS application in drainage. In this study an attempt has been made for adequacy checking the existing and proposed drainage system in a live project. All have been done on the basis of field survey, GPS and topography survey. Detailed reconnaissance and inventory was also carried out along the project road corridor in order to collect relevant information of existing drainage structure. All data were collected from NHIDCL, PMU-Kalimpong, N.H-717A,Barbot to Kaffer (26.100 km to 40.000 km) and its surrounding area of road upto Right of Way (R.O.W) major part of which covered under Pemling and Kaffer forest of Kalimpong district. Existing drainage pattern is also studied briefly so that Hydrologic calculation can be done easily which is a very important step prior to the hydraulic design. Design of drain is based on methods suggested in IRC: SP: 42-2014. An Emphasis has been made within a time boundary to check the adequacy of proposed drainage structure in ongoing highway strengthening and widening project.

Key Word: Q-GIS, Highway, Drainage, GIS

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CHAPTER-1

INTRODUCTION

1.1 General background

The primary purpose of a road drainage system is to remove the water from the road and its surroundings. The road drainage system consists of two parts: dewatering and drainage. “Dewatering” means the removal of rainwater from the surface of the road. “Drainage” on the other hand covers all the different infrastructural elements to keep the road structure dry. In Sweden “dewatering” is further divided into two parts: runoff (“avrinning”) and dewatering (“avvattning”). “Runoff” covers the water flowing from the surface of the pavement via road shoulders and inner slopes to the ditches. “Dewatering” covers the collection and transport of water from the surface and structure of the road so that there will be no ponds on the road or in the ditches.

Figure: 1 The components of a pavement structure dewatering system

The components of a pavement structure dewatering system consist of a) crossfall leading water away from pavement, road shoulders allowing water to flow to the ditches and not infiltrate into the pavement structure and c) impermeable pavement, which means practically a high enough compaction degree and a low enough air voids content.

The dewatering system should be always improved during a paving or pavement rehabilitation process. The best results will be obtained if this is done one year before paving operations. This will for instance make asphalt compaction easier.

“Dewatering” consists of following elements:
– Cross fall
– Road shoulders
– Impermeable road surface materials

A typical “drainage” system consists of following elements:
– Outlet ditches
– Side ditches
– Culverts
– Inner/outer slopes
– Road structures
– Underdrains

The general score of road drainage system is dependent on its “weakest link”. This means that if any of its elements is out of order, the whole system will not operate as planned and the road will be damaged. On the other hand, a well built and maintained road drainage system is a very sustainable investment policy. The main advantages of a good drainage system are: effective removal of rainwater out of the road surface and its surroundings, road structures that stay dry, good bearing capacity, and a road that is nice and safe to drive.

1.2 Highway Drainage Scenario: State of the Art

Highways connect capitals, ports, & strategically important places of various states. Total length of national highways in India has 97,991 km as on 31.3.2015 and state highways has 32,87,240 km as on 2012. Out of which West Bengal has 2,377 km of national highway. Though national highway has only 20% of the total road length but they carry nearly 1/3 of the total traffic. In 1947, approximately 2500 km of missing road was linked and thousands of culverts and bridges which were did not exist, were constructed to have a continuous network.

Designing of proper drainage of highway network is very crucial to increase their life regardless how well other aspects of road are designed and constructed. Each highway drainage system is site specific and can be very complex as it mainly depends on geography of the region. A highway engineer must determine which particular design process should be applied. Usually several appropriate methods in combined and material to direct water way from the structure are applied. Erosion control also is a vital component in the design of highway drainage system. Surface water must be allowed for drainage to drain or cross drainage structure away from the pavement surface. Highway must be designed with slope on crown or camber of about 2.5% at paved & bituminous surface, 2% on cement surface and 3% on earthen shoulder and also with a longitudinal slope of 0.3% for quick removal of surface run-off into ditch or drain or cross drainage structure. Designing drainage system required calculation of run-off, infiltration, open channel analysis and culvert& bridges design for dispose of surface water to an appropriate location.

Drainage is a vital part of road maintenance. Each highway project consistently designed with well drainage plan. Also, a note was issued by World Bank to make aware about the road maintenance and its importance in January 2005. In India a manual on ‘four-laning of highway through public private partnership’ was published by planning commission on 2010. It is also emphasis on drainage planning. MoRTH also emphasis on drainage which is mention on clause 309. IRC: SP:42-2014 have given clear guideline for road drainage system. IRC: SP:50-2014 have given clear guideline for designing drainage system of road on urban area. In IRC:SP:13-2004 give guidelines for the design of small bridges and culverts. All of these codes can be followed for designing a road drainage network.

Subsurface moisture which infiltrates from the pavement surface or shoulders has to be drained out to avoid loss of aggregate-to-aggregate contact so that load transfer is not affected. An upper granular sub-base layer called as Drainage Layer (DL) has been suggested to drain this trapped water lately by both MoRTH Specifications and IRC: 37-2017. The drainage layer is part of a pavement structure which is considered to perform the function of both structural as well as a drainage layer. CTSB layer can be constructed in two layers such that one layer can serve the purpose of Drainage Layer (DL) and the other layer can serve as Cement Treated Sub-Base (CTSB). The basic ingredients of both mixes are same but the difference lies in percentage of fines passing in Drainage Layer and CTSB mix. The proposed drainage system in road are given fig. -1.1.

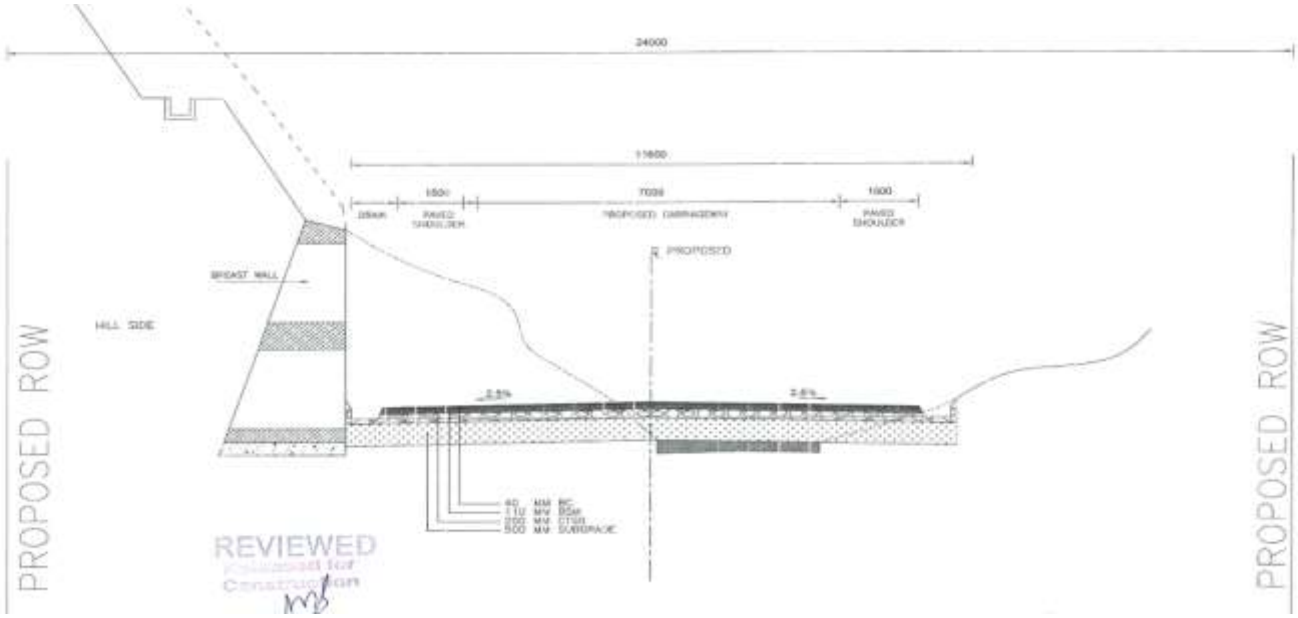


Figure1.1:Typical Cross section (Source: NHIDCL PMU-Kalimpong)

1.3 The study Area

The Road NH-717A connected between Barbot (km 26+100) and Kaffer (km 40+000) lies in Kalimpong district in the state of West Bengal. This road section is passing through Nimbong village (km 28) and Pemling forest area and ends at Kaffer(km 40+000). Total length of the stretch is 13.9 km and improvement and upgradation of the road will benefit the road user as NH-717A shortens the when compare to the distance between Sevok and Gangtok vide NH-10.

The road stretch is mainly situated in forest land and partly in revenue land. The project road lies in Kalimpong district of West Bengal. It is situated between 27° 4' 0.0048° and 27° 0.66' North latitudes and 88° 28' 0.0012° E and 89° 46 ' East longitudes. The district was established in 2017. The start and end point of the project is shown in above.

Map 1.1: Location of study area

1.4 Objectives

The main objective of the research work is to find out the efficacy of road drainage network of a particular stretch with the application of Q-GIS software for estimation of discharge of cross drainage structure like culvert or bridge and finally adequacy assessment and calibration of culvert and bridge design. A case study of NH-717A, KALIMPONG has been carried out to illustrate the above-mentioned objective.

1.4 Importance of Study

This is a live project study which will give a clear idea about the proposed drainage system will be functioning properly or not. If it is not function properly then alternative solution can be proposed to improve the system for better running.

1.6 Thesis Outline

The thesis consists of 7 chapters. Chapter 2 contains literature review. Chapter 3 describes the study area and its characters. Chapter 4 presents the research methodology. Chapter 5 describes the calculation of drainage and modeling by QGIS. Chapter 6 consists of result and discussion of the model. Finally, conclusions and recommendations are discussed in chapter 7.

CHAPTER-2
LITERATUREREVIEW

2.1: International and National Literature Review

Ger Finn, et al (2004) designed the guidelines for road drainage which stressed that drainage is a basic consideration in the establishment of road geometry and in general this means that the drainage should meet the following: cross falls should be a minimum of 2.5% on carriageways, with increased cross falls of up to 5.0% on hard shoulders draining to filter drains; longitudinal gradients should not be less than 0.5% on kerbed roads; flat areas should be avoided and consideration of surface water drainage is particularly important at rollovers, roundabouts, and junctions; outfall levels must be achievable; the spacing of road gullies should be sufficient to remove surface water whilst achieving an acceptable width of channel flow. One gully for every 200sq. m of paved surface is generally found to be satisfactory.

Victor, (2010). Carried out an investigation into the adequacy of the drainage system on Narok-Mai Mahiu road which was determined to: examine the adequacy of the drainage system in Narok-Mai Mahiu road, study the effects of inadequate drainage systems on roads and the surrounding environment, and to investigate the reasons for inadequate drainage systems in Narok-Maai Mahiu road and the challenges faced by the institutions mandated with the responsibility of maintaining them. They employed a research survey in order to obtain the information that would describe the state of drainage infrastructure in Narok Maai Mahiu road and how poor drainage affected the surrounding environment and the road users. Various data collection techniques that were used include questionnaires, photographs, observation, and interviews. The results indicated that Narok Maai Mahiu road drainage system was not adequate to satisfactorily drain the runoffs. As a result, the surrounding environment was greatly affected as exemplified by runoffs washing away some sections of the road and bridges, creating gullies on peoples' land, blockage of the road, loss of life and property and washing away of the fertility of the land. Poor design, workmanship, and maintenance were the main challenges. He then pushed that drainage facilities should be improved through maintenance, gabions be built for remedying of gullies and construction of water conservation structures e.g. water pans to hold and reduce the speed of water. Furthermore, redesign of the whole drainage system in Narok-Mai Mahiu road should be considered.

Patil and Jalinder (2011) studied the effects of bad drainage on roads with precision on some roads in India. It was found that increase in moisture content increases the chances of road failure before the stipulated or expected design life. It was observed that on Service Road to Mumbai Pune Expressway the blockage of drainage channels leads to accumulation of water on pavement thus, leading to the stripping of bitumen. On walhekar wadi chowk road, poor drainage leads to formation of waves and corrugations which as well leads to increase in weight and thus increases the stress causing the simultaneous reduction in strength of soil mass. On Nehru Nagar Road, Pimpri Akurdi Railway Station Road, and Holkar Bridge Chowk, Khadaki it was found that water penetrated into the subgrade thus making it weakandsubsequentlydevelopmentofpotholesasaresultofwaterlogging.TheApproachRoadtorai lway tunnel near Akurdi Railway Station was observed to be bad condition due to flood in rainy seasons.

Jitendra et al (2013) carried out a framework for quantification of the effect of drainage quality on structural and functional performance of pavement by identifying a simple framework for quantification of the effect of drainage quality on structural as well as functional performance of the pavement. They presented the structural and functional performance of the pavement in predicted terms of deflection and roughness respectively. Their study was useful to reduce the maintenance cost of highway pavement system and to preserve huge highway network in India.
To determine whether a drainage system is adequate or not, Jitendra et al (2013) presented a table of AASHTO classification of drainage system as shown in table 2 below

Dipnoan, (2014) studied highway surface drainage system and problems of water logging and concluded that adverse roadway elements contributing to highway accidents were substandard roadway alignment or geometry, lack of shoulders and shoulder defects, absent or inappropriate pedestrian facilities, narrow and defective lanes and bridges/bridge approaches, roadside hazards, undefined pavement centre and edge lines, poor sight distances and visibility, unmarked and inappropriate design of intersections, serious allocation deficiencies along the route, haphazard bus shelters/stops, and others are causes of water logging problem in highway. This research traced that Proper drainage is a very important consideration in design of a highway. Inadequate drainage facilities can lead to premature deterioration of the highway and the development of adverse safety conditions such as hydroplaning. It is common, therefore, for a sizable portion of highway construction budgets to be devoted to drainage facilities.

Muhammad, (2014) studied highway drainage system and started that highway is importance for removing water from the road surface, preventing ingress of water into the pavement, passing water across the road, either under or over and preventing scour and/ or washout of the pavement, shoulder, batter slopes, water courses and drainage structures. He identified types of drainage on the highway to include kerb and gullies, surface water channel, combined filter drain (French drain), over-the-edge drainage, drainage channel locks, combined kerb and drainage units, linear drainage channels, fin and narrow filter drain (sub-surface drainage) and edge drainage for porous asphalt.

Navpreet and Nitin (2014), a well-designed and well maintained road drainage is important in order to: minimize the environmental impact of road runoff on the receiving water environment, ensure the speedy removal of surface water to enhance safety and minimize disruption to road users and to maximize the longevity of the road surface and associated infrastructures. Water in the pavement system can lead to moisture damage, modulus reduction and loss of strength. In order to prevent such damages to the pavement, it is essential to provide proper drainage to the roads. They maintained that the presence of water in a highway layer reduces the bearing capacity of the road, and in doing so it also reduces the structure's lifetime. Highway drainage is used to clear surface water from the highway. Roads need to be well drained to stop flooding; even surface water can cause problems with ice in the winter. Water left standing on roads can also cause maintenance problems, as it can soften the ground under a road making the road surface break up.

Magdi, (2014) studied the impacts of poor drainage on road performance in Khartoum, a city in Sudan with two case studies; attempts were made to find out the reasons for road failure within the first five years as a result of poor drainage. In this quest, it was discovered that four basic reasons lead to early deterioration of road pavements in the study, these factors according to the research includes, Poor drainage design and construction, poor maintenance structure, use of low-quality materials and no local standard of practice .It was concluded that if these factors are put into consideration in planning and execution and if improved on pavement structures would serve within its expected design life.

Owuama et al (2014) studied Sustainable Drainage System for Road Networking, the research was aimed at suggesting an alternative and sustainable drainage system which is a trenchless drain comprising absorption unit and grass cover. It was found that the technology would provide a cheap, aesthetic and effective method of disposing road surface runoff with minimal distress to users and minimal damage to the environment. It was concluded that trenchless drains dispose accumulated surface water easily and introduces aesthetics to the environs, and an antidote to mosquito breeding which consequently reduces the incidence ofmalaria.

Dipanjan, (2014) did a study on a road stretch in India and came up with the following reasons contributing tremendously to water logging and subsequently fast road deterioration substandard roadway alignment or geometry, lack of shoulders and shoulder defects, absent or inappropriate pedestrian facilities, narrow and defective lanes and bridges/bridge approaches, roadside hazards, undefined pavement centre and edge lines, poor sight distances and visibility, unmarked and inappropriate design of intersections, serious allocation deficiencies along the route, haphazard bus shelter/stops, and others are causes of water logging problem in highway.

Getachew et al (2015) based their research on the assessment of the effect of urban road surface drainage: A case study at Ginjo Guduru Kebele of Jimma town. They: assessed the pavement damage due to improper drainage, identified areas most prone to flooding problems, assessed the existing condition of road and surface drainage infrastructure, examine the impacts of road surface drainage structures integration on road performance and related social as well as environment issues and make recommendations on urban road and drainage structures integration, their provision and management. They conducted a cross-sectional study in Ginjo Guduru Kebele of Jimma town from JanuarytoAugust2014.Thedatatheycollectedwasthenanalyzedquantitativelyandqualitatively,and the results from their study were presented in tables and in themes. From the study made, generally, they observed that the road surface drainage found to be inadequate due to insufficient road profile, insufficient drainage structures provision, improper maintenance and lack of proper interconnections between the road and drainage infrastructures thereby resulting to the damages to road surface material and flooding in the area.

Getachew and Tamene (2015) made a study on Assessment of the Effect of Urban Road Surface Drainage using Ginjo Guduru Kebele of Jimma Town in Ethiopia as a case study. It was found that road surface drainage of the study area was found to be inadequate due insufficient road profile, insufficient drainage structures provision, improper maintenance and lack of proper interconnection between the road and drainage infrastructures thereby resulting damages to road surfacing material and flooding problems in the area.

D.A. Belete (2011) studied on road and urban storm water drainage system integration in Addis Ketema sub-city which is located in the capital of Ethiopia Addis Ababa.About95%researchdatacollectedfromprimarysourcesandoutofthis 10% of data collected through questionaries' and interview. The rest collected through field survey. The collected data analysed using Microsoft-Excel, AutoCAD, ArcGIS & tables, graphs etc. provision of urban storm water drainage infrastructure & road are indispensible, basically in urban area to protect infrastructure from flood. Due to gap between drainage facilities provided in road & actually required, environmental problem like soil erosion keep continuing & budget allocationwillincrease.Drainagefacilityisalsoreducedduetosewerage connection & blockage by solid waste. To overcome such problem measure should be taken to reduce the flooding hazards by cleaning the drains, improvement on integration between urban storm water drainage & road, by inducing solid waste management, storm water drainage network should be contracted with road network and infiltration of rainfall should be increase by different methods.

D. Mukherjee(2014) studied on highway surface drainage system & problems ofwaterlogginginroadsection.Roadsareimportantfactorsasitcanaffectthe natural surface & sub-surface drainage system of a watershed. The water must not be allowed in the road to develop sufficient volume or velocity because it can cause excessive wear in ditches, below culverts or along road surface, cuts or fills. Water has no. of harmful characteristics like it reduce friction between tyre& road &increase stopping distance, spray by car tyre reduce visibility, drag by car tyre from local water ponding in pavement can misbalance the car travelling at speed and in heavy rain, water can wash way the road on embankment & block culverts. For surface drainage in rural area, road on embankment, runoff should be drained by providing side slope & spread over adjacent area. When this water effects local area then surface water should be collected by longitudinal ditches and dropped into the nearby watercourse. Highway in cut, runoff collected by shallow ditches shape of trapezoidal, triangular or rounded cross section. It should be deep enough to drain the pavement sub-base water and care should also be given so that it could not erode the toe of adjoining sloping fill. To drain the surface water to ditches storm sewer of underground pipes can be provided to receive the runoff and change in sewer direction can be made at inlet, catch basin or manholes. For access manhole must be provided at every 500ft. Open channel ditches may be trapezoidal or V-shaped or rectangular shaped. V-shaped have low capacity but trapezoidal have greater capacity. When steep slope are present then lining of ditches have to be given.

Culvert must be provided to pass the run-off from one open channel to another. For small run-off corrugated metal pipe culvert &for large run-off concrete box or multiple pipe may be needed. When Culvert foundation is not susceptible to erosion then bridge may be constructed (bridge culvert).

Drainage is a basic considering in deciding road geometry & vertical alignment should be such that outfall easily achievable and sub-grade drainage can drained above the design flood level of any outfall water courses. From this minimum height of embankments and cutting

depth are ensured.
Sometimes special software can be used to calculate peak flow rates, storage volume & flow control devices . According to him highway accident are happened due to sub-standard roadway alignment or geometry, absent or inappropriate pedestrian facilities, lack of shoulders and defects, narrow and defective lanes, bridge/bridge approaches, undefined pavement centre & edge line, roadside hazards, poor sight distance &visibility, haphazard bus shelters/stops, inappropriate design of intersection & others.

D. Khediya (2016) studied surface and sub surface highway drainage system.Highwaydrainageisimportantpartofhighwaydesign&alsoconstructionbecause it protect sub-grade failure, strength of pavement material frost action, decrease the change in volume of sub-grade due to moisture variation in clayey soil protect from mud pumping and protect slope failure of embankment. This can be protected by providing correct camber in pavement, longitudinal drain in urban area in cutting & embankment for surface drainage of rain water. Where cross drainage work like culvert & bridge required, have to be provided. Sub-surface drainage is also important because it reduce the bearing capacity of soil. This can be achieved by seepage flow, deep side drains under the pavement, lower the water table below the sub-grade by 1.2m, longitudinal drainage trenches with drain pipe & filter media within it and by controlling the capillary rise, a layer of granular material of correct thickness in between the sub-grade and highest level of surface water table have to be provided.

Mittal et al.(2017) studied on improvement of road drainage system for Indian roads. Framework suggested for calculating the impact of evacuation quality on pavement structural performance. Water can enter into the pavement layer from loose rain fill in the median, shoulder and porous surface at some locations of the DBM(dense bituminous macadam) layer, may not drain it from impervious GSB (granular sub-base) layer, thus entrapped water in between and saturating the WMM(wet mix macadam)& BM(bituminous macadam) layer. For this BM & DBM layer get deteriorated due to stripping & weakening of the hydro-carbon.

Footpath should have cross fall towards the kerb to allow surface rainfall water to be collected by the kerb side gullies on the carriageway. For this total width of footpath & carriageways should be considered for drained width. For wide paved area adjacent to carriageway gullies at close spacing may be required. For rural area with low pedestrian, surface water can bed rained by open or covered channel next to the paved area. At pedestrian crossing, special consideration in design of position of gullies have to be given like no gully within the width of any pedestrian , longitudinal gradient of 0.5% or above, located at upstream of pedestrian crossing and for rest another gullies also at downstream. For wide carriageway in flat area or flood prone area, gullies need to be provided at very close spacing.

S.Rainaetal.(2018) studied on the needs for strengthen of pavement & suggest the ways to improve the drainage facilities for road at Raipurrani to Naraingarh which is part of SH-01 in Hariyana. Roads need to be well drainage facilities to stop flood and also suitable surface &sub-surface drainage system. Designing of proper drainage is very much important for success of highway regardless of other factor like road design, construction etc. Proper method may be depending on geography of the region. Also during the design drainage erosion control measure should be incorporate. The success of drainage design hidden in prediction of accurate runoff and infiltration, open channels analysis and design of culvert for disposing surface water to an appropriate location.

CHAPTER-3

DESCRIPTION OF STUDY AREA

3.1 Introduction

National Highways & Infrastructure Development Corporation Limited (NHIDCL), Government of India has decided to construct the newly declared National Highways to two lane/two lane with paved shoulder and /or strengthening of various sections of National Highways. The work would be taken up for up gradation on corridor concept. Therefore, corridors include strengthening (in adjoining stretches) in addition to widening to 2 lanes with paved shoulder standards in order to have a better facility in a long continuous stretch. SA Infrastructure Pvt. Ltd, Noida (UP) have been appointed as Consultants to carry out the Feasibility Study and Detailed Project Report for rehabilitation and upgrading to 2 lane with paved shoulders configuration of Bagrakot to Kafer(km26+100 to Km 40+000) of NH-717A in West Bengal State. This research work of Road section of NH-717A connected between Barbot (km 26+100) and Kafer (km 40+000) lies in Kalimpong district in the state of West Bengal. This road section is passing through Nimbong village (km 28+300) and ends at Kafer (km 40+000). Total length of the stretch is 13.9 km and improvement and upgradation of the road will benefit the road user as it shortens the distance when compare to the distance between Sevok and Gangtok videNH-10. The start and end point of the project corridor shown in photograph 3.1 below. The land use pattern of the road stretch is mainly in forest land (10 km) and rest of stretches having revenue land and residential structures having Rural / semi-urban character.

Photograph1.1: Start and end point of the project corridor

To check the drainage accuracy along this road a particular stretch from 34 km to 39 km chainage is considered here.

Geography and Topography

The project road lies in Kalimpong district of West Bengal. It is situated between 27° 4' 0.0048° and 27° 0.66' North latitudes and 88° 28' 0.0012° E and 89° 46 ' East longitudes. The district was established in 2017.

The headquarters of the district are in the Indian city of Kalimpong has its special importance in respect to tourism, forest, hills, scenic beauty and commercialization.

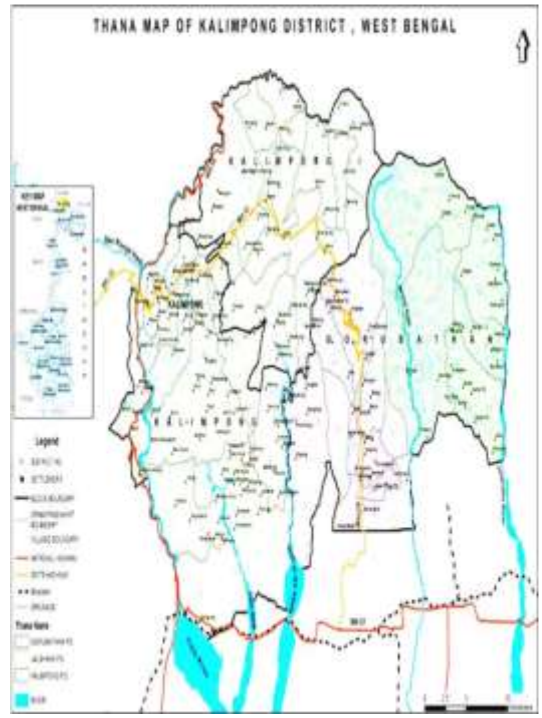


Figure3.1: Geography of the Study area

The district situated in the northern part of West Bengal has international borders with Bhutan in the e a s t , Darjeeling hills in the west and Jalpaiguri district in the south. The geographical location of the study area shown in figure 3.1 above.

3.2.1 Social Economic Profile of the Area

The social and economic profile of the Kalimpong district on which study area belong is given in table 3.1 below.

Table3.1: Area details of the project tcorridor

Name of District	Kalimpong
Geographical area(sq.kms)	1053.60
(a)Annual rainfall	2200mm

(b)Temperature	22.ºc(max) 11ºc(min)		
(c)Geographical Location of road	Point	Latitude	Longitude
	Start point	26.969557	88.573356
	End point	27.02046	88.568051
District Head Quarter	Kalimpong		
Sub-Division	3		
Blocks	3		
Gram Panchayat	42		
Municipal Corporation	01(Kalimpong Municiplity.)		
Municipality	1		
Police Station	9		
Population density/Sq. Km (as per 2011 census)	239		
No of villages connected	6		
No. of Villages Benefitted	6		
No. of Marketing Centres	3		
Area	1053.60 Sqm^2		
Population	82,869		
Total Ward	23		

3.3 Description of catchment Area

Catchment area is called as the area from which rainfall flows into river, reservoir, lake or the area of a land which contributes water by rainfall precipitation and stream flow. Catchment area generally selected by the terrain elevation or height of the area of a land.

Table 3.2: Details of GPS value of Culverts and Bridges of selected project corridor.

Sr.	Northing	Easting	Chainage(KM)	Height	Structure

No.					type
1	655269.516	2986138.584	34+155	2	Box culvert
2	655069.781	2986380.619	34+709	2	Box culvert
3	655083.205	2986464.196	34+799	3	Box culvert
4	654940.414	2986386.920	35+222	3	Box culvert
5	654580.448	2986747.051	36+141	3.5	Box culvert
6	654794.394	2988372.830	38+340	3.5	Box culvert
7	654885.077	2988953.295	38+942	2	Box culvert
8	654973.328	2989290.925	39+102	2	Box culvert
9	655126.419	2989290.925	39+364	2	Box culvert

Table 3.3: Details of Existing Culverts and Causeway

Sl. No.	Existing Chainage (Km)	Type of Culvert
1.	25+776	RCC Slab
2.	25+977	RCC Slab
3.	26+103	RCC Slab
4.	26+231	RCC Slab
5.	26+460	RCC Slab
6.	27+380	RCC Slab
7.	28+883	RCC Slab
8.	29+221	RCC Slab
9.	29+543	RCC Slab
10.	29+774	RCC Slab
11.	29+985	RCC Slab
12.	30+300	RCC Slab
13.	35+670	RCC Slab

The Site has the 54No’s Causeway at following chainages:

1.	25+083	Cause way
2.	25+544	Cause way
3.	26+642	Causeway
4.	26+774	Causeway

5.	27+728	Causeway
6.	28+613	Causeway
7.	28+715	Causeway
8.	30+025	Causeway
9.	30+150	Causeway
10.	30+250	Causeway
11.	30+508	Causeway
12.	30+790	Causeway
13.	30+814	Causeway
14.	30+853	Causeway
15.	31+016	Causeway
16.	31+159	Causeway
17.	31+194	Causeway
18.	31+313	Causeway
19.	31+424	Causeway
20.	31+992	Causeway
21.	32+214	Causeway
22.	32+381	Causeway
23.	32+596	Causeway
24.	32+483	Causeway
25.	33+000	Causeway
26.	33+187	Causeway
27.	33+427	Causeway
28.	33+769	Causeway
29.	33+856	Causeway
30.	34+099	Causeway
31.	34+244	Causeway
32.	34+487	Causeway
33.	34+582	Causeway
34.	34+591	Causeway
35.	34+798	Causeway
36.	34+904	Causeway
37.	35+132	Causeway
38.	35+185	Causeway
39.	35+337	Causeway
40.	35+456	Causeway
41.	35+521	Causeway
42.	35+819	Causeway
43.	35+929	Causeway
44.	36+150	Causeway
45.	36+218	Causeway
46.	36+280	Causeway
47.	36+377	Causeway
48.	36+835	Causeway

49.	37+377	Causeway
50.	38+022	Causeway
51.	38+222	Causeway
52.	38+483	Causeway
53.	38+585	Causeway
54.	39+085	Causeway

Table 3.4: Right of way (as per site condition)

Chainage (From-To) (Km)	**Length (m)**	**Row (m)**
26.100 to 40.000	13900	24

Table 3.5: Details of Protective Work:

Chainage (from)	**Chainage(to)**	**Name of protection work**	**Side**	**Length (in M)**	**Proposal**
26.100	**40.000**	Breast wall	**Left side**	**6500**	The minimum requirement of 4m height Breast wall are suggested as following which may vary as per final drawings and design approved by competent authority
			Right side	**5100**	

Table 3.6: Details of line drain:

Sr. No	**Description**	**Total**	**Side (no)**	**Total Length**
1	Two lane with Paved shoulder Concentric Widening (One Side Hill, One side Valley section)	3110	1	3110
2	Two lane with Paved shoulder Eccentric Left Widening (One Side Hill, One side Valley section)	3150	1	3150
3	Two lane with Paved shoulder Eccentric Right Widening (One Side Hill, One side Valley section)	2160	1	2160
4	Two lane with Paved shoulder Realignment (One Side Hill, One side Valley section)	1840	1	1840
5	Two lane with Paved shoulder Concentric Widening (Both Side Hill section)	2880	2	5760
6	Two lane with Paved shoulder Realignment	340	2	680

	(Both Side Hill section)			
Total				**16700**

3.4 Existing Drainage Scenario

Project area covers a large number of culverts and viaducts. There are few number of culverts which are balancing type. The area is maximum forest area beside the road side, approximately 10 km stretches forest and rest is revenue area. Though there is a specific drainage system but some places required new culverts and also some balancing culverts.

Rainfall induced landslides are creating havoc in hilly areas and have become an important concern for the stakeholders and public. Many approaches have been proposed to derive rainfall thresholds to identify the critical conditions that can initiate landslides. Most of the empirical methods are defined in such a way that it does not depend upon any of the in situ conditions. Soil moisture plays a key role in the initiation of landslides as the pore pressure increase and loss in shear strength of soil result in sliding of soil mass, which in turn are termed as landslides. Hence this study focuses on a Bayesian analysis, to calculate the probability of occurrence of landslides, based on different combinations of severity of rainfall and antecedent soil moisture content. A hydrological model, called Système Hydrologique Européen Transport (SHETRAN) is used for the simulation of soil moisture during the study period and event rainfall-duration (ED) thresholds of various exceedance probabilities were used to characterize the severity of a rainfall event.

Ongoing Project Photograph

Some photograph of ongoing project work shown in photograph at below






Photograph: 3.1 Ongoing project works

CHAPTER-4
METHODOLOGY

4.1 Introduction

The Project Road section of NH-717A connected between Barbot (km 26+100) and Kafer (km 40+100) lies in Kalimpong district in the state of West Bengal. This road section is passing through Nimbong village (km 28+300) and ends at Kafer (km40+000). Total length of the stretch is 13.9 km and improvement and up-gradation of the road will benefit the road user as it shortens the distance when compare to the distance between Sevok and Gangtok vide NH-10.

4.2 Conceptualization of Methodology

The conceptualization of the methodology followed for this thesis paper shown in flow diagram below figure 4.1.

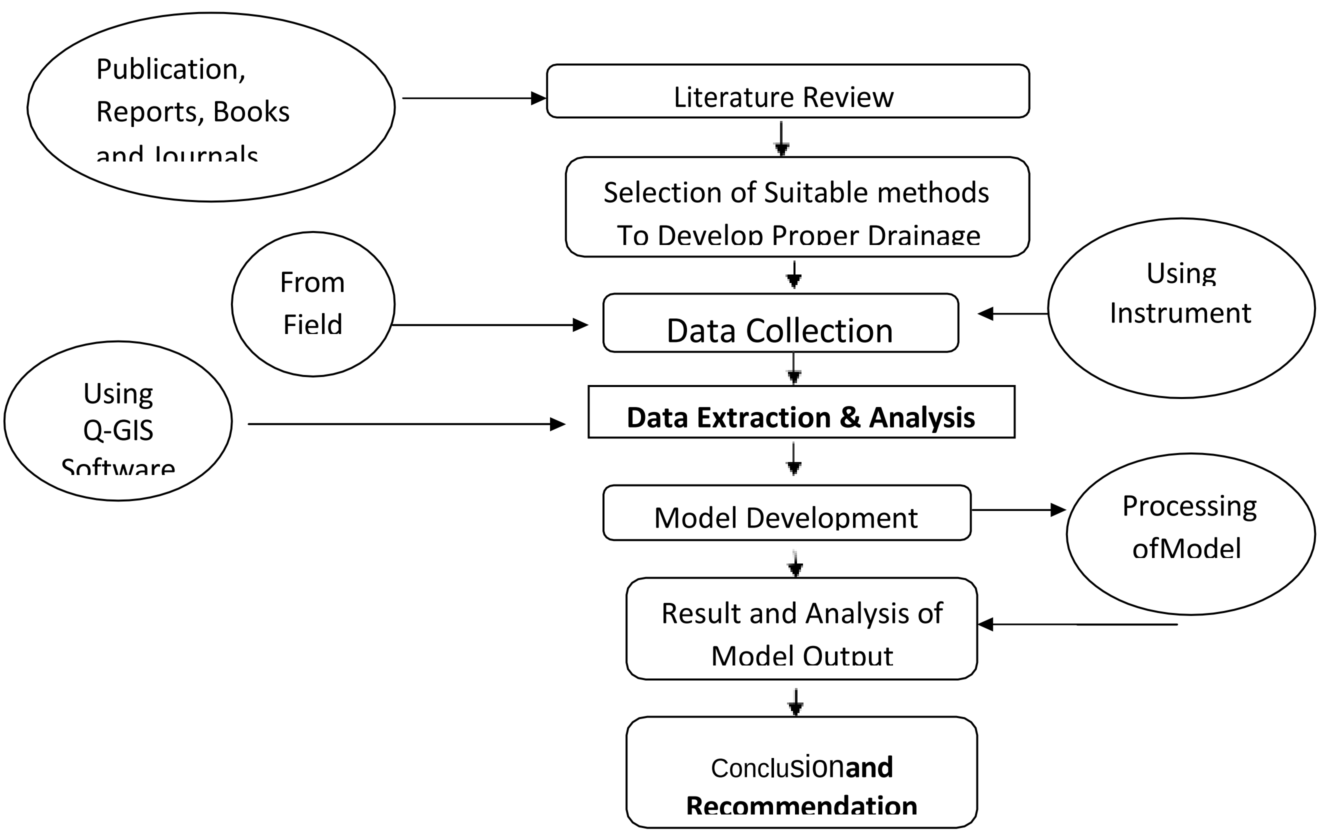


Figure4.1:Methodology flow diagram

4.3 Methodology for Data Processing

4.3.1 Literature Review

Literature review data was carried out to select the proper proceeding or method for drainage estimation and to analysis the survey data collected. Based on the literature review field data has collected for better knowledge and understanding about the existing drainage pattern. Man of their viewed, were organized in world wide. These studies were helped for making appropriate decision about incorporation of software in the part of calculation.

4.3.2 Data Collection

Field investigation is carried out along the entire stretch of the project corridor. The studies carried out careful and precise collection of all valuable field data and these have been utilized in design works. The main studies are—

4.3.2.1 Reconnaissancesurvey

4.3.2.2 Pavement survey

4.3.2.3 Land use

4.3.2.4 Rightofway(ROW)

4.3.2.5 GPSandtopographicsurvey

4.3.2.6 Condition of Culverts

i) Reconnaissancesurvey

This is preliminarysurvey done to determine an extensive study of an entire areaalong road. The purpose of the visit on site to gather sufficient information to support a correctdecision regarding future action.Also to gatherinformation byvisualobservation and other methods about the activities need to be performed for making idea about the geographic character of the area.

The following documents and data have been collected the process of procurement during the reconnaissance survey by the team:

- Climateoftheareasurroundingtheprojectroad
- Roadinventoryandcondition
- Conditionofbridgesandcross-drainagestructures

- Typeandlocationofexistingutilityservices
- Hydraulicdata

a). Riding quality

As the project execution work is in progress, the riding quality of the project is not measured.

b). Pavement condition

Pavement layers are laying in progress.

Photograph: 4.1: Laying of pavement layers i.e. DBM

c). Existing shoulder Condition

From chainage 26+100 km to 40+000 km on NH-717A the existing road is mostly intermediate lane with earthen shoulder. Width of earthen shoulder varies from0.50–1.0 meter. Condition of the shoulder is fair. There are some issues of drainage problem but rest is fair. Cross slope is not observed properly.

d). Existing Embankment Condition

Road section mostly throughout the stretches is on embankment except some place road on cutting and at built up area. Average height of embankment varies from 3m to 5m. At approaches of major and minor bridge have higher embankment. Rain cut also can be found on the side shoulder at various places.

e). Road side Drain

The project section is in predominantly mountainous terrain. There is no lined drain exists in the existing road.

ii) Land use

The landuse pattern of the road stretch is mainly in forest land and some of stretches having revenue land and residential structures having Rural / semi-urban character.

iii) Right of way (ROW)

Right of way is the legal right, established by grant from a landowner or long usage (i.e. by prescription), to pass along a specific route. It has been found that the ROW is 24 m.

iv) GPS and Topographic survey

The project road passes through mountainous terrain. The topography is mostly ruralin nature.

GPS value of culverts were established on the project road with the help of Google earth map.

4.3.3 Model Concept

A) Procedure for Creating Contour through Q-GIS:

Development and delineation of catchment area with the application of Q-GIS software was done through following steps:

1. Select the raster menu and over the mouse curser to extraction tools stand select the contour tools to open the contour window.
2. In the contour window, for input file(raster) select the SRTM file from the drop down menu.
3. For the output directory for contour lines (shape file)
4. Elevation plugin was used for the extraction of elevation data from SRTM files.
5. Display the levels for contours using the ELEV field.
6. Using the level tool bar display the levels for contours with ELEV as field.
7. Contour plugin was used to develop contour region map on the specific study area and from the contour map catchment area of each culvert and bridge was determined and extracted.

B) Identification of Slope:

1. Slope identifies the steepest downhill slope for location on asurface.
2. The slope command takes an input surface raster and calculates an output raster containing the slope at each cell.
3. Lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain. The output raster can be calculated as % slope or degree of slope.
4. Open the GRASS tools and under Modules list, type r.slope and select it, for “Name of the elevation raster map”.
5. DEM from the dropdown menu.
6. Name the output slope raster map as DEM_slope and click on the advance options and make sure that percent has been selected and Run the slope module.
7. Once done, click on view output and close the module and the GRASS tool set wind.

A. Procedure for Creating Contour through Q-GIS:

1. To create contour lines from DEM we can use the Contour tool in the Raster menu >> Extraction >> Contour. See figure below figure:

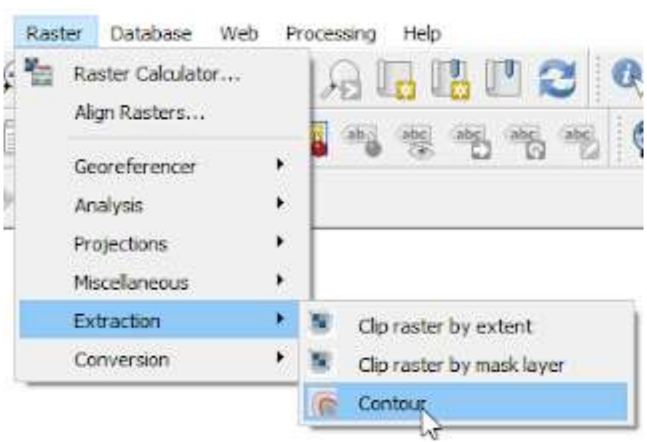
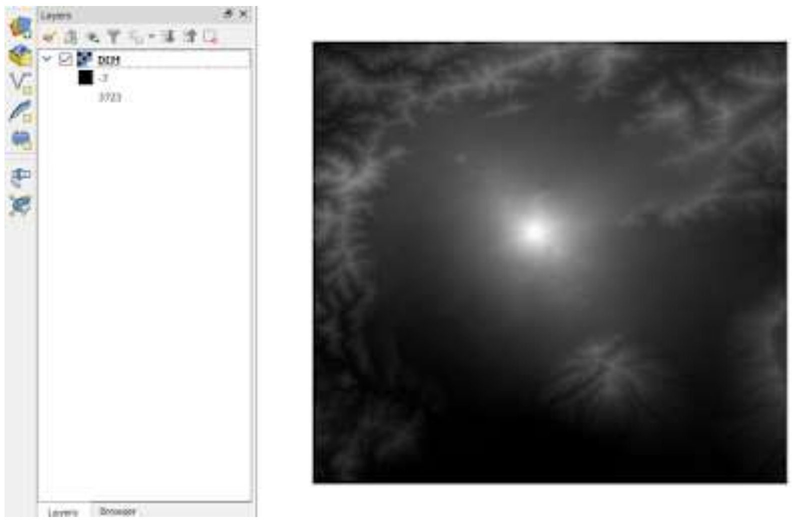


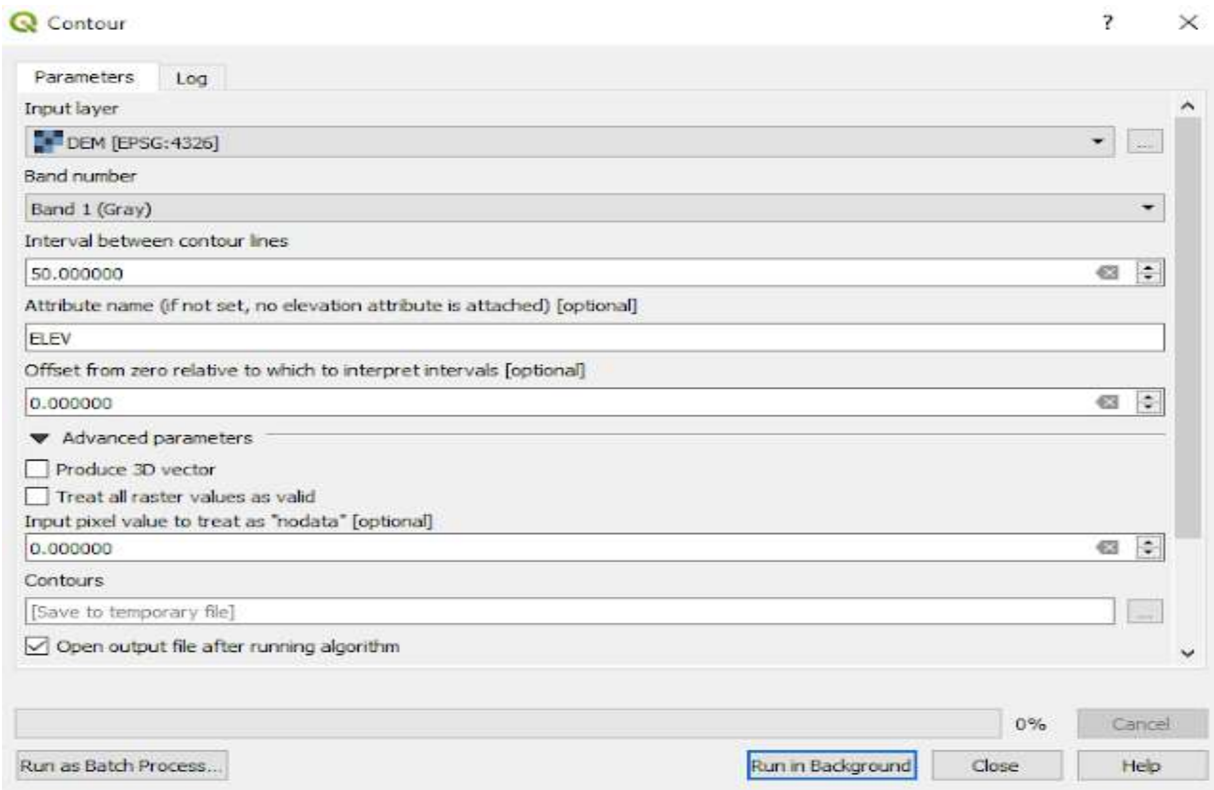
Fig: Control Tool

2. Add DEM data into QGIS map canvas, as in figure below. We can also download DEM data directly from earthexplorer.gov.in.



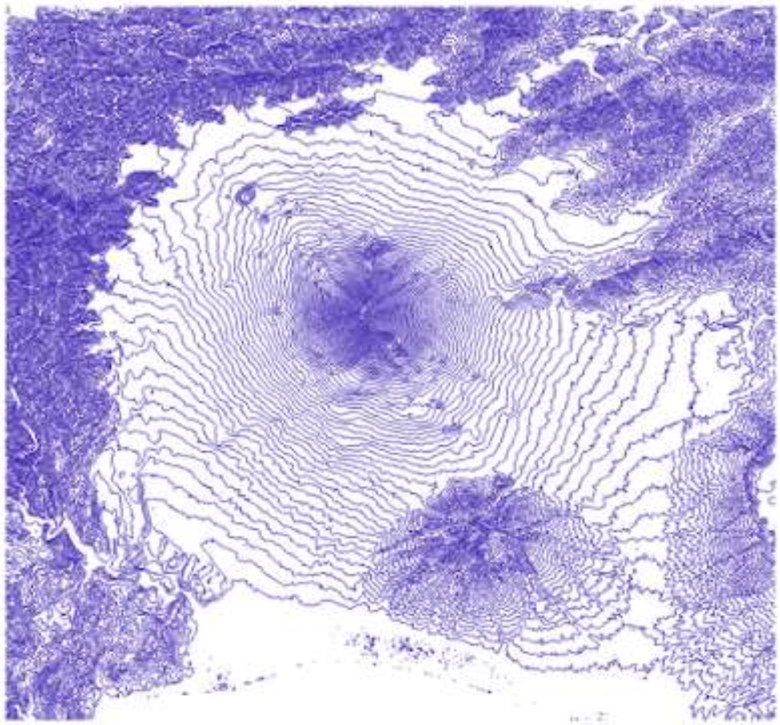
Photograph: 4.2: Adding of DEM file in QGIS

3. Open the Contour tool. The contour tool window will appear as in figure below,



Photograph: 4.3: Before running the DEM file for contour

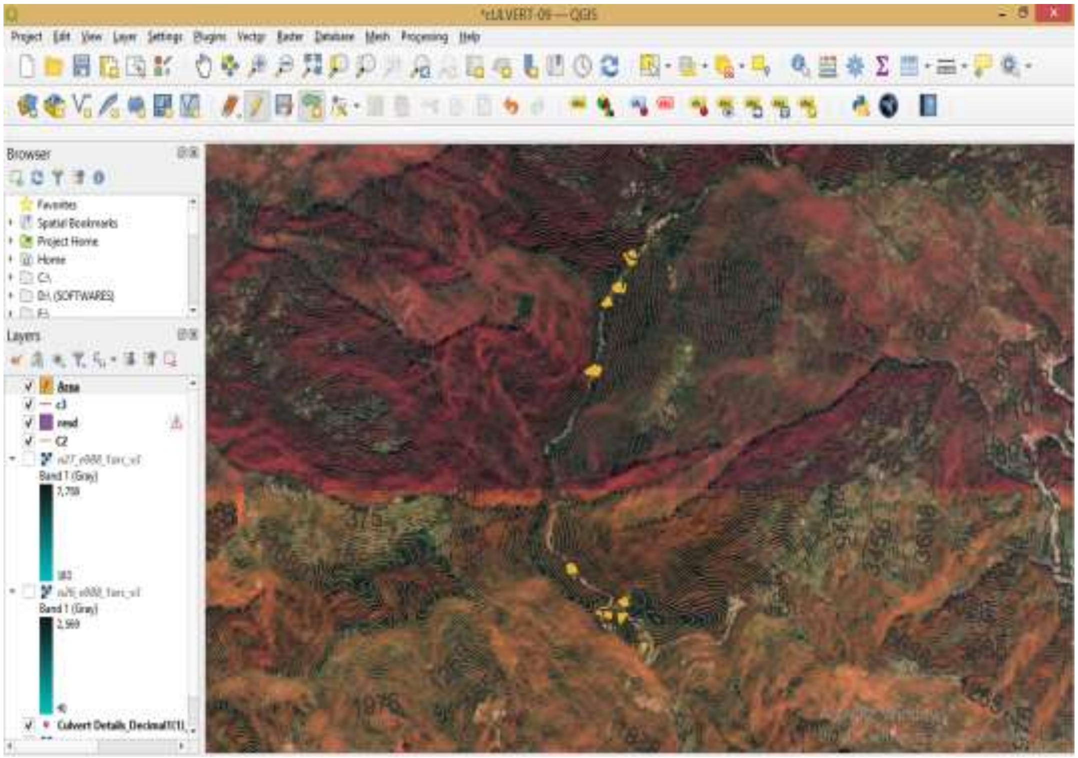
4. Select the DEM data. Then set the contour interval, in this case I used 10 m. In the Contours option, we can specify the contour output path or save it to temporary file.
5. If all the settings already set. Click the Run in Background button. The result will show in QGIS map canvas as in figure below.



Photograph: 4.4: Contour in QGIS

4.3.4 A brief Pictorial step of Catchment Area delineation with help of Q-GIS:

At first the elevation plugin of the selected culverts was done in Q-GIS software. Then from Google earth pro and TCX converter, contour points elevation generated of the selected area of a particular culvert or bridge wasdoneinExcelsheetand contourwas created in Q-GISsoftware. Then joining the highest elevation near to the culvert was joined and catchment area created. At last, the area of the catchment in hector was generated from Q-GIS software as shown in figure below.



Photograph: 4.5: Contour and catchment area pointing in QGIS

CHAPTER-5

DESIGN CALCULATION DRAINAGE AND MODELING BY Q-GIS

5.1 Introduction

A road in cut or fill suffers damaged due to presence of water. So the surface water(run-off) and sub-surface water must be channelized into structures say drain, culverts or bridges for flow without damage to any elements of the roads.

The drains collect the run-off from the pavement surface due to camber on it. Capacity of drain, its shapeandlocationof it mainlydepends ongeographicalcharacteristics, soil condition, rainfall intensity etc. Based on the calculation of total run-off water flow to be transferred through the drain it is vital thing to find out the critical length of the drain for its outlet.

5.1.1 Steps followed in Design Methodology

The steps followed in design methodology have shown in diagram below figure5.1.

- **STEP-1:** Calculation of discharge from the road side drain Using SP-42:2014

↓

- **STEP-2:** Discharge from drain to adjacent culvert

↓

- **STEP-3**: Discharge from catchment area to culvert (Data taken from Q-GIS)

↓

- **STEP-4:** Total discharge= discharge of drain + discharge of catchment

STEP-5: Input and output checking of the culvert

STEP-6: Adequacy checking of the total output

Figure5.1**:** Flow diagram of design methodology

5.1.2 Hydrological Calculation for Drain Chainage wise

Hydrological calculation is a very important step before to the hydraulic design of road drainage system. Such analysis is very important to determine the magnitude of flow and duration time for which it prevails. Hydrological data which are required for design are area map, watershed delineation, outfalls, direction of flow; others surface drainage facilities, rainfall, ground surface and flood frequencies. Factors on which the run-off mainly depends are size & Shape of the drainage area, slope of ground, geology, land use characteristics, soil types, storage and surface infiltration etc.

The design of drain is based upon the steps suggested in IRC: SP: 42-2014. The Empirical rational method is a universally accepted formula for calculating rainfall to run-off and it is applicable to catchment area not exceeding 25 KM^2.

The formula is: $Q = 0.028P \times f \times A \times I \ldots\ldots\ldots\ldots\ldots\ldots Eqn5.1$

……Eqn.

5.1 Where,

Q=Maximum runoff in cumecs

P=Co-efficient of runoff for the given catchment characteristics f=Spread factor for converting point rainfall into area l mean rainfall.

A = Catchment area in hectares

I =Design Rainfallintensity in cm/hrforthe selected frequencyandfordurationequalto the time of concentration.

The primary component for designing drains is the design rainfall (storm) value of specific duration and specific return period. As the area of drainage system for roads is small, even intense rainfall of short duration may create heavy runoff. Extreme valuesof rainfall of short duration are therefore required for designing road drainage systems.The storm duration selected for design purpose is equal to time of concentration and itis based on the assumption that the maximum discharge at any point in a drainage system occurs when the whole catchment area is contributing to the flow. The time of concentration for any catchment is the time required for a given drop of water from the most remote bank of catchment to reach the point of study. It may have 2 components i.e. entry time and time of flow. If the drainage point under consideration is at the entryof the drainage system, then the entry time is equal to the time of concentration. If it is situated elsewhere, then the time of concentration is sum of the entry time and the time required by the raindrop to travel the length of the drainage system to the point under study.

Once the time of concentration has been fixed, the next step consists in calculating the intensity of rainfall from the appropriate rainfall map for storm duration for the already fixed time of concentration and adopted design frequency. Unfortunately, rainfall maps of India for less than 1 hr. duration are not yet given. A general equation in IRC: SP: 42-2014 is used for deriving intensity for shorter duration which was given in IRC: SP: 13.

5.1.3 Drainage Design

After determining the quantity of runoff, the discharge of drain has to be calculated from the Manning’s formula

$Q = A\ X(\frac{1}{n} x R^{\frac{2}{3}} x\ S^{1/2})$ ……Eqn.5.2

Where,

A=Area of flow in m^2

n=Co-efficient of Rugosity

R=Hydraulic mean depth in m

S= Longitudinal slope of drain

Values of 'n' for various channel surfaces areadoptedfrom Table 6.7of IRC: SP: 42-2014. The Flow velocity could be followed from following equation which is given in IRC: SP: 42-2014.

$V=k.S^{.5}$ ……Eqn5.3

Where S=channel slope in percent and k is a function of land cover.
Some values of k for selected land covers are given in Table6.6 of IRC:SP:42-2014.

.

5.2 Discharge Calculation of Proposed Road Sideline Drain to Culvert

Design of Road side line Drain

Chainage: 38+340 km

Length of the road under consideration:325 m

Width of carriageway: 7m

Paved shoulder:3m

Unpaved/shoulder portion: 1m

Total width of built-up section for one side: 11m

5.2.1 Discharge calculations

(a) Co-efficient of runoff

As per vide table5.1,the co-efficient of runoff from various surfaces are-Bituminous

or concrete pavement surface = 0.9

Unpaved/Shoulderportion=0.9

Footpath or paved portion=0.9

Built-uparea= 0.5

Table5.1: Co-efficient of runoff for different surface

(source: IRC: SP: 42-2014 table 6.5)

Description of Surface	Coefficientof Runoff (P)
Steep, bare rock and water tight pavement surface (concrete or bitumen)	0.9
Steep rock with some vegetative cover	0.8
Plateaus areas with lightly vegetative cover	0.7
Bare stiff clayey soils (impervious soils)	0.6
Stiff clayey soils (impervious soils) with vegetative cover and uneven Paved road surface	0.5
Loam lightly cultivated or covered and macadam or gravel roads	0.4
Loam largely cultivated or turfed	0.3
Sandy soil, light growth, parks, gardens, lawns & meadows	0.2
Sandy soil covered with heavy brush or wooded/forested areas	0.1

Averagerunoffco-efficient,P=(0.9x3.5+0.9x1.5+0.9x1+0.5x11)/(3.5+1.5+1+11)=0.64

(b) Time of concentration

Assumed v in built-up section=0.06m/sec

Time required to reach drain from the remotest point of built-up section taken into consideration is = 11/vsec =11/0.06= 183 sec= 3.05 min

Length of drain with flow in single direction=325m

Assumed v in drain section= 0.75 m/sec

Time required to reach at out fall from the remotest point of drain taken into consideration= 325/v sec = 325/0.75 sec = 433.33 sec = 7.22 min

Hence time of concentration=3.05+7.22=10.27min

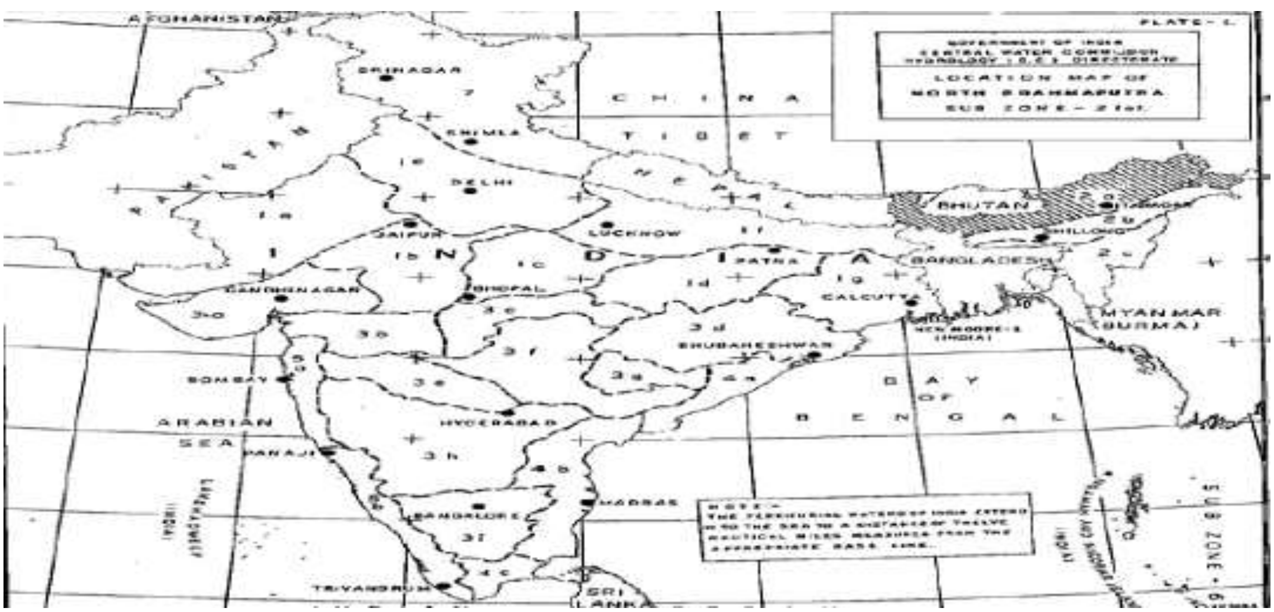
(c) Area Calculation for runoff

Area contributing to flow for one side drain from the start point is given by

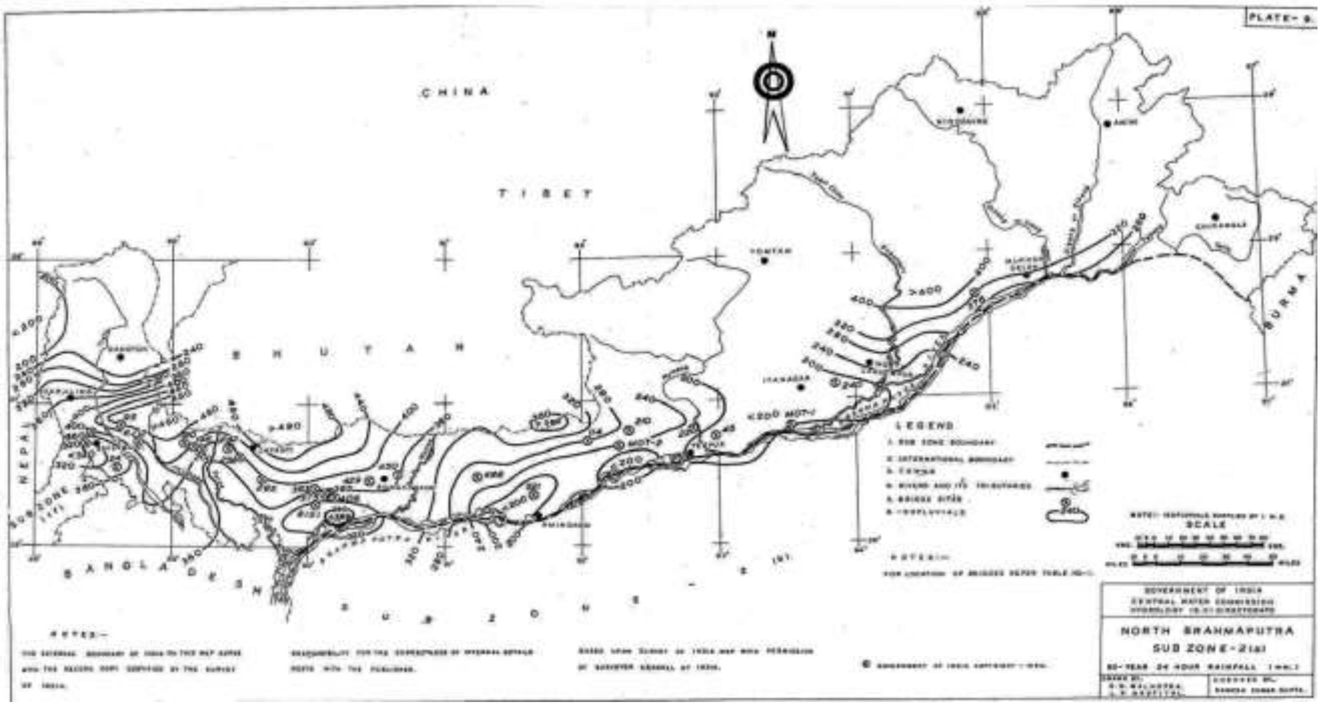
= (3.5+1.5+1+11) x325/10000ha=0.5225 ha

(d) Rainfall intensity ‘I’ calculation

24-hour maximum rainfall for 50-year recurring intervals for the location of Kalimpong District data taken from map 5.1 & map 5.2 (CWC map) = 460 mm.



Map5.1: Study area come north Brahmaputra sub-zone2(a)(source: CWC report)



5.2; MAP; Study area receiving the rainfalls of 460 mm(source: central water commission report)

Table 5.2:Conversion factor from 24 hr duration to any other duration (source: IRC: SP: 42-2014 table 6.2)

	Minutes			Hour			
Duration	15	30	45	1	3	6	24
Percentageof24hour Rainfall	16	25	31	39	55	65	100

Now conversion factors for converting 24hr rainfall intensity to shorter duration(1hr) rainfall intensity from table 5.2= 460 x 39/100 = 179.40 mm= 17.94 cm

For time of concentration of 10.27 min conversion factor for shorter duration 10.27 min from table 5.3 = 2.78

Table 5.3: Conversion factor from as a ratio of 60 mins duration (source: IRC: SP: 42-2014 table 6.1)

Durationminutes	5	10	15	20	30	40	50	60	90	120
Ratio	3.7	2.85	2.4	2.08	1.67	1.33	1.17	1	0.835	0.661

The rainfall intensity for 10.27min=17.94x2.78= 49.78cm

(e) Spread factor

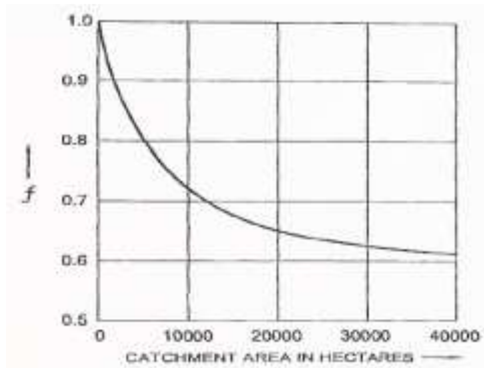


Figure5.2:Spread factor calculation (source: IRC: SP:42-2014fig.6.1) For

area 0.5225 ha. spread factor from figure 5.2, f = 1

(f) Discharge to drain from runoff

Discharge, Q is given by eqn.-5.1,Q=0.028PxfxAxI =0.028x0.64x1x0.5225x49.78

=0.466 Cumecs

(g) CheckingofdischargecapacityofDrain

For, flow through drain, we consider the Manning’s formula.

Hence capacity of a drain is given by eqn-5.2,Q=AxV=Ax(1/nx$R^{2/3}$x$S^{1/2}$)

For concrete surface from table 5.4, n= 0.011.

Table5.4:Manning Roughness co-efficient (source: IRC: SP:42-2014table6.7)

Sr. No.	SurfaceDescriptions	Manning's'n'

	Surface Description	
1	Smooth surfaces (concrete, asphalt,gravel,orbaresoil)	0.011
2	Fallow no residue)	0.05
	Cultivated soils:	
3	Residue cover<20%	0.06
4	Residue cover>20%	0.17
	Grass:	
5	Short grass prairie	0.15
6	Dense grasses	0.24
7	Bermuda grass	0.41
8	Range(natural)	0.13
	Woods:	
9	Light under brush	0.4
10	Dense under brush	0.8

Longitudinal slope of road at this stretch, S=0.002asperIRC:SP:73-2015

Trapezoidal drain suggested having following data

Top opening = 0.6m

Bottom width =0.4 m

Depth provide = 0.5 m

Trapezoidal Area=(0.4+0.6)*0.5/2=0.25 m^2

Wetted perimeter=0.4+0.5+0.5=1.4

R=Area/Wetted perimeter=0.25/1.4=0.1785

From eqn-5.2,Q=0.25x1/0.011x$0.1785^{2/3}$ x$0.002^{1/2}$ =0.325 Cumecs (ok)

(h) Discharge from both side drain

For culvert, at location ch.38.340 km total discharge coming to catch pit =0.325+0.466=0.791 Cumecs.

In this case, we consider the Manning's formula i.e., Q=AXV= A x ($1/nxR^{2/3}$ x $S^{1/2}$)

For concrete surface from table 5.4, n= 0.15

Table 5.4: Manning Roughness co-efficient (source: IRC SP: 42-2014 table 6.7)

SI. No.	Surface Descriptions	Manning's 'n'
1	Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
2	Fallow (no residue)	0.05
	Cultivated soils:	
3	Residue cover <20%	0.06
4	Residue cover >20%	0.17
	Grass:	
5	Short grass prairie	0.15
6	Dense grasses	0.24
7	Bermuda grass	0.41
8	Range (natural)	0.13
	Woods	
9	Light underbrush	0.1
10	Dense underbrush	0.8

Longitudinal slope of road at this stretch, S = 0.002 as per IRC: SP: 73-2015

Rectangular catchpit having following data
Total width at bottom= 3 m
Slope= 1:1000
Clear width at bottom = 3 m
Depth provide = 1.2 m
Area = 3x1.2 =3.6 m^2
Wetted perimeter = 3+(2x1.2) =5.4 m
R= Area/ Wetted perimeter = 3.6/5.4 = 0.66 m

From the Manning's eqn, we get =3.6x1/0.15x$0.66^{2/3}$x $0.002^{½}$ = 0.815 cumec>0.791 cumec (Hence ok).

i. Discharge from both sides borrow pit;

For culvert at location Ch. 38.340 km total discharge 0.466x2 = 0.932 cumec.

5.3 Catchment Area calculation of culvert 38+340 km chainage by Q-GIS model

Catchment and drainage network delineations an important step for hydrological model development that represent hydrologic boundary. Due to spatial and temporal variations variation of the watershed characteristics, it is often necessary to delineate a watershed into smaller sized model areas where variable can be homogeneous. The traditional manual catchment delineation for large scale is time consuming. With the development of computer and information technology, automatic catchment delineation becomes widely popular. In this thesis catchment area delineation at culvert locations are done by Q-GIS software.

5.3.1 Fixing of Culvert & Bridge location:

Fixing of culvert and bridges locations was done with the help of Total Station. An image of data collection by using Mobile Note camerais shown in photograph 5.1 and GPS values in table 5.5.

Sr. No.	GPSNo.	Northing	Easting	Chainage(KM)
1	GPS1	655269.516	2986138.584	34+155
2	GPS2	655069.781	2986380.619	34+709
3	GPS3	655083.205	2986464.196	34+799
4	GPS4	654940.414	2986386.920	35+222
5	GPS5	654580.448	2986747.051	36+141
6	GPS6	654794.394	2988372.830	38+340
7	GPS7	654885.077	2988953.295	38+942
8	GPS8	654973.328	2989290.925	39+102
9	GPS9	655126.419	2989290.925	39+364

5.3.2 Preparation of Contour Map

After fixing culverts and bridges location, elevation plugin was done in Q-GIS. The location of culvert on Q-GIS has shown in figure 5.3 below. Randomly elevation plugin were inserted in a large number to increase the accuracy. Next with the help of contour plugin a contour map was generated using same contour value. Contour map of different elevation was developed as shown in figure 5.4 below.

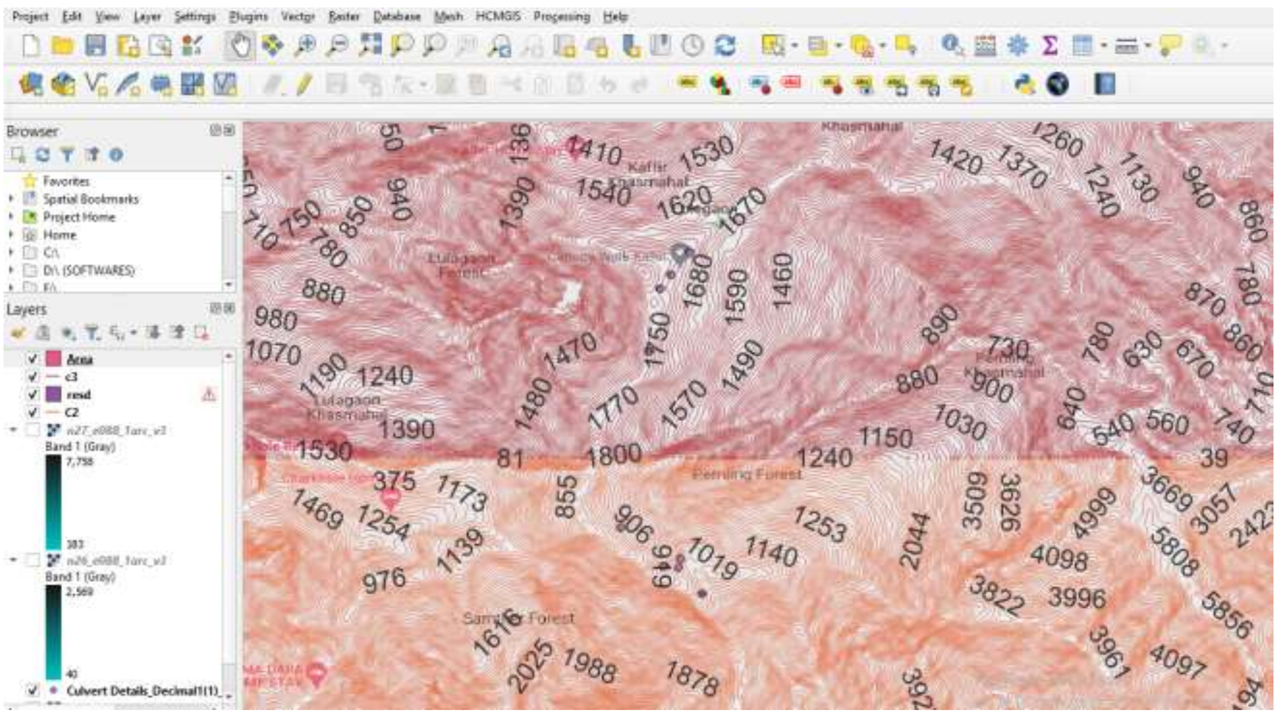


Figure5.4: Generation of contour map

5.3.3 Export the Catchment Area from Contour:

Contour map consists of number of loops. Each loop indicates the RL of same value. A loop with highest value among the others will be considered as ridge one. Demarcation of ridge as a close pattern will indicate the catchment area for a particular culvert or bridge location. The catchment area generation and area of it in hectare has shown in figure 5.5 below. The output list of catchments according to numbering of culverts are generated from Q-GIS has shown in table 5.6 below.

Table 5.6: Chainage wise catchment area of culverts

Sr.No.	GPS No	Description	Chainage	Catchment area (in SqKm)
1	GPS 1	Culvert 1	34+155	1.25
2	GPS 2	Culvert 2	34+709	1.31
3	GPS 3	Culvert 3	34+799	1.19
4	GPS 4	Culvert 4	35+222	1.025
5	GPS 5	Culvert 5	36+141	1.20
6	GPS 6	Culvert 6	38+340	2.12
7	GPS 7	Culvert 7	38+942	1.23
8	GPS 8	Culvert 8	39+102	1.07
9	GPS 9	Culvert 9	39+364	1.04

5.3.4 Discharge from Q-GIS delineated catchment to culvert

From the previous described process catchment area can be delineated. The catchment area delineated from Q-GIS, A = 2.12Sq.km.

Table 5.7: Some value of k of selected land cover (source: IRC: SP: 42- 2014 table 6.6)

k	Landcover
0.076	Forest with heavy ground litter, haymeadow(overland flow)
0.152	Trash fallow or minimum tillage cultivation, contour or strip cropped, woodland (overland flow)
0.213	Short grass pasture (overland flow)
0.274	Cultivated straight row(overland flow)
0.305	Nearly bare and unfilled (overland flow),alluvial fans in western mountain regions
0.457	Grassed water way(shallow concentrated flow)
0.491	Unpaved(shallow concentrated flow)
0.619	Paved area(shallow concentrated flow),small upland gullies

Now the discharge using Rational formula for chainage 38.340 km culvert,
From figure 5.2, f= 1
From table 5.1, P = 0.64
From table 5.7, K = 0.305

Velocity from eqn – (5.2), $v = k.S^{0.5} = 0.305 * 0.001^{0.5} = 0.096$ m/s

Time of concentration = 10.27 min
Rainfall intensity for min, I = 33.60 cm/h
Eqn.- 5.1, Q = 0.028*f*P*A*I = 0.028* 0.64*2.12* 49.87 cumecs = 1.89 cumecs

5.4 Culvert Adequacy check

Assessment of adequacy will be done on the basis of total discharge received from sidedrain as well as from catchment of local area nearest to culvert which solely depend on naturalrunoff. Here contribution from each household is not considered. As from field investigation itwas found that no waste water is coming in to the catchment from any other sources.

5.4.1 Total Discharge to Culvert

Now, total discharge coming to culvert = Catch pit water Discharge + Catchment Discharge (Q-GIS model) = 0.932 + 0.791cumecs = 1.723cumecs.

5.4.2 Culvert Discharge Capacity (conventional method)

Box culvert was proposed for this location, size of which is mention in table 5.8 under sl. No.6:

Table 5.8: Size of box culverts and minor bridge.

Sr.No.	Description	Chainage	Span	Depth
1	Culvert 1	34+155	3	2
2	Culvert 2	34+709	3	2
3	Culvert 3	34+799	3	3
4	Culvert 4	35+222	3	3
5	Culvert 5	36+141	3	3.5
6	Culvert 6	38+340	3	2.5
7	Culvert 7	38+942	3	2
8	Culvert 8	39+102	3	2
9	Culvert 9	39+364	3	2

The hydraulic capacity of concrete box culvert is similar to those for arch, circular and elliptical pipe. The Manning's formula is the most accepted method for evaluating the hydraulic capacity

of non-pressure conduits. The drawing of the culvert at chainage 38+340 km was shown in figure
5.6. figure 5.7 & figure 5.8 below

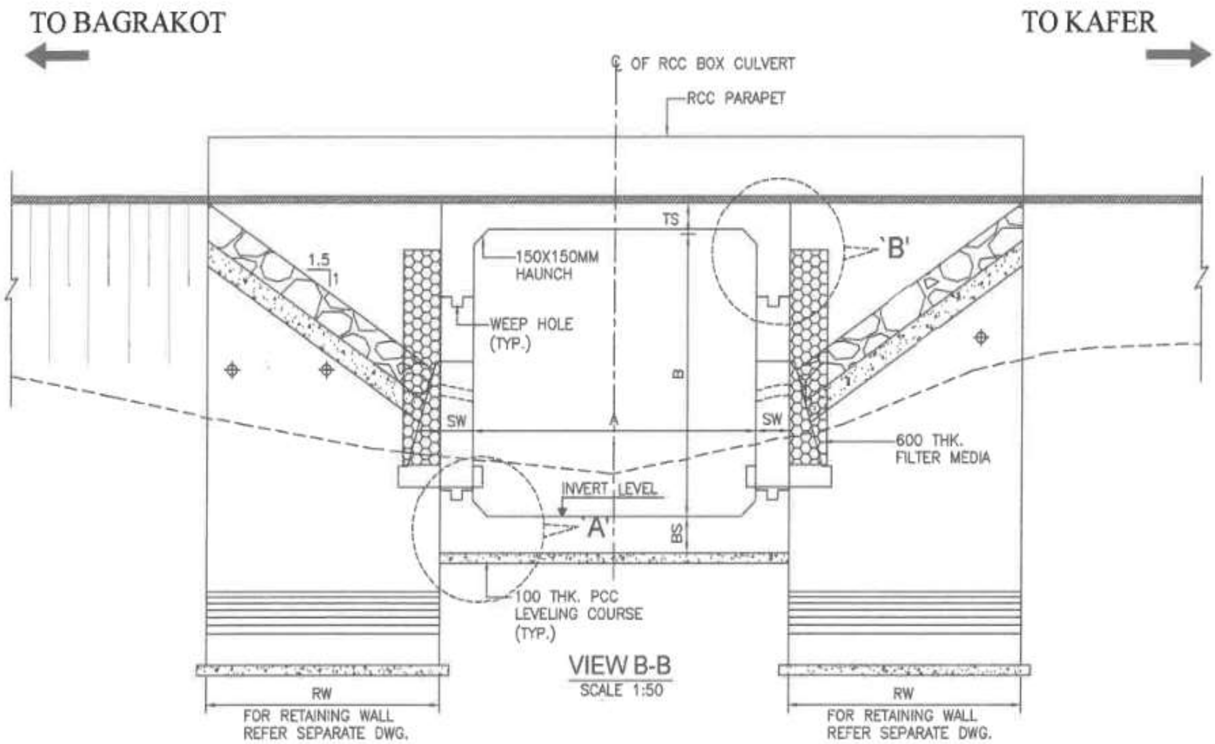


Figure 5.6 : Cross section of 1 box culvert along road. (Source: NHIDCL, PMU-Kalimpong)

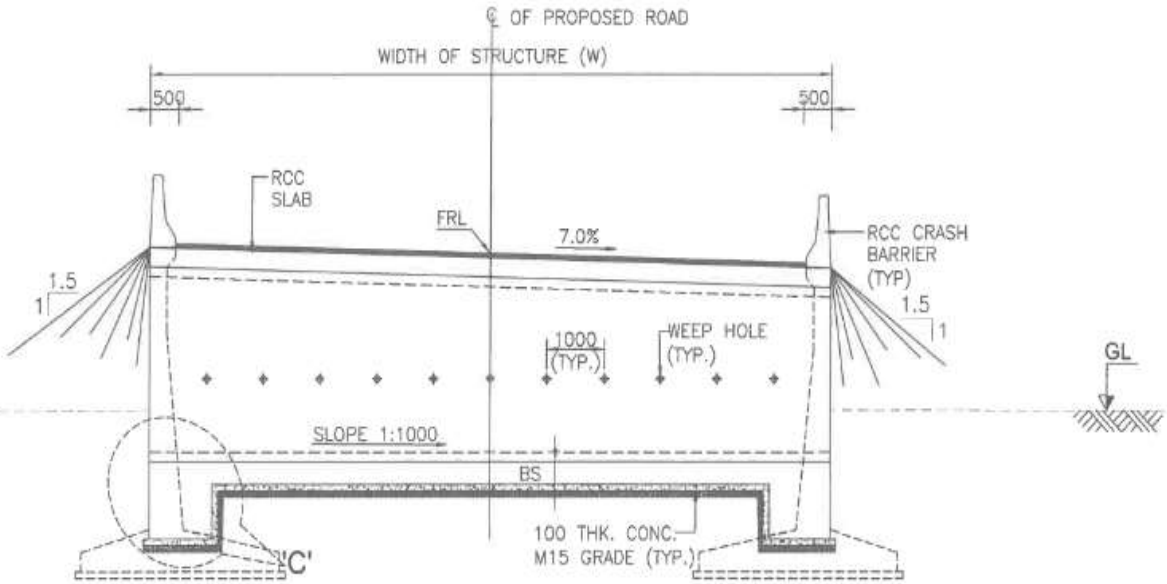


Figure 5.7: Cross section of culvert across road at chainage 38.340 km. (Source: NHIDCL, PMU-Kalimpong)

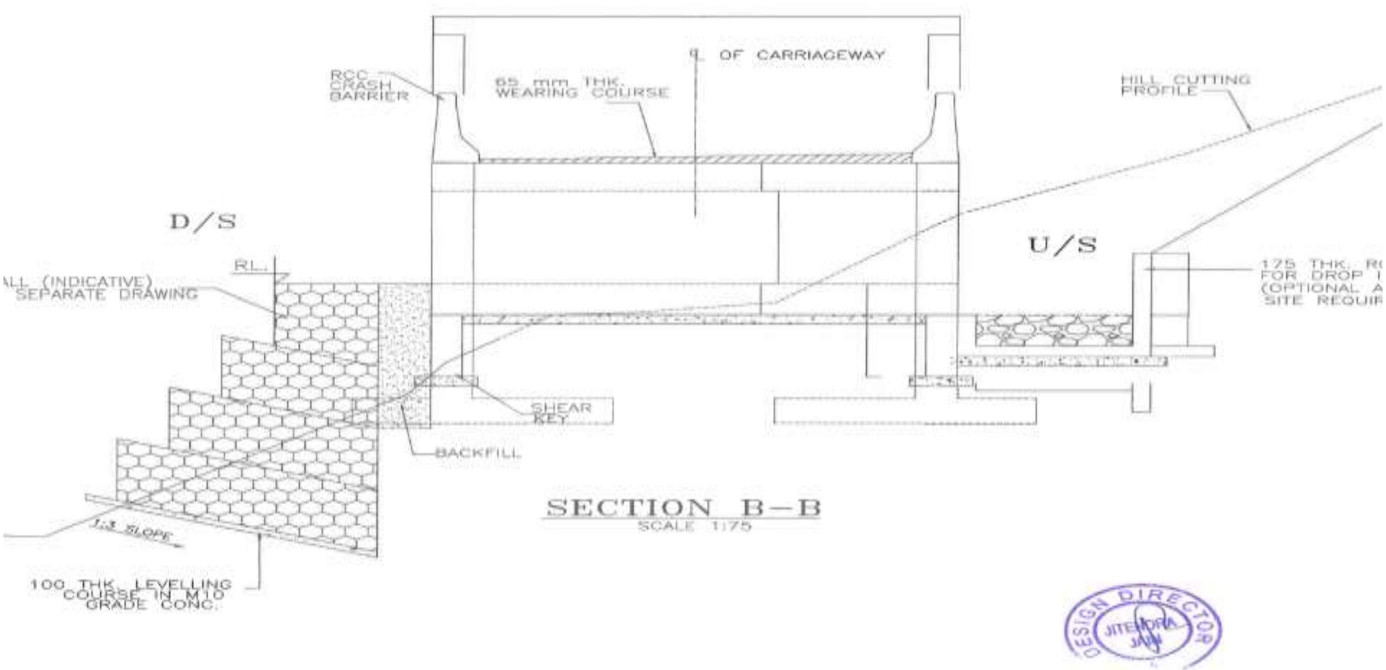


Figure 5.8: Cross section of box culvert along road (Source: NHIDCL, PMU-Kalimpong

From proposed culvert dimension, considering full flow condition during rainy season
Span (a) = 3m
Depth (b) = 2.5 m

Considering a max free board = 0.5m
Depth of flow = 2.5- 0.5 = 2m
Area (A) = 3 x 2 = 6m2.
Wetted perimeter (P) = (2x2) +3 = 7 m
Hydraulic mean depth (R) = A/P = 6/7 = 0.86m
Minimum longitudinal slope provided in bed (S) = 0.1% = 0.001
From table 6, Manning's roughness co-efficient (n) = 0.013

Table5.9: Manning's 'n' Values and Maximum Permissible Velocities for open channel (source: IRC: SP: 42-2014 table 7.1)

Sl. No.	Ditch Lining	Manning's 'n'	Allowable Velocity to Prevent Erosion m/sec.
1	**Natural Earth**		
A	**Without Vegetation**		
	i)Rock		
	Smooth &Uniform	0.035-0.040	6
	Jagged &irregular	0.04-0.045	4.5-5.5
	ii)Soils (Extended Casagrande Classification)		
	G.W.	0.022-0.024	1.8-2-1
	G.P	0.023-0.026	2.1-2.4
	G.C	0.020-0.026	1.5-2.1
	G.S	0.024-0.026	1.5-2.1
	S.W	0.020-0.024	0.3-0.6
	S.P	0.022-0.024	0.3-0.6
	S.C	0.020-0.023	0.6-0.9
	S.F	0.023-0.025	0.9-1.2
	CL and CT	0.022-0.024	0.6-0.9
	Ml and ML	0.023-0.024	0.9-1.2
	Ol and OI	0.022-0.024	0.6-0.9
	CH	0.022-0.023	0.6-0.9
	MH	.023-0.024	0.6-0.9
	OH	0.022-0.024	0.6-0.9
	Pt	0.022-0.025	0.6-0.9
B	**With Vegetation**		
	Average turf		
	Erosion resistant soil	0.050-0.070	1.2-1.5
	Easily eroded soil		
	Dense turf	0.030-0.050	0.9-1.2
	Erosion resistant soil		
	Easily eroded soil clean bottom with bushes on sides	0.070-0.090	1.0-2.4
	No sprouts	0.050-0.080	1.2-1.5

	With sprouts	0.040-0.050	1.5-2.1
	Dense weeds	0.060-0.080	1.8-2.4
	Dense brush	0.080-0.012	1.5-1.8
	Dense willows	0.100-0.140	1.2-1.5
2	Paved		
A)	Concrete with all Surfaces,		
	Goodor Poor		
	i)Trowel finished	0.012-0.014	6
	ii)Float finished	0.013-0.015	6
	iii)Formed, no finish	0.014-0.016	6
B)	Concrete Bottom, Float Finished, with Sides of		
	i)Dressed stone in mortar	0.015-0.017	5.4-6
	ii)Random stone in mortar	0.017-0.20	5.1-5.7
	iii)Dressed stone or smooth concrete rubble (Rip-rap)	0.020-0.025	4.5
	iv)Rubble or random stone (Rip-rap)	0.025-0.030	4.5
C)	Gravel bottom with sides of		
	i)Formed concrete	0.017-0.020	3
	ii)Random stone in mortar	0.020-0.038	2.4-3
	iii)Random stone or rubble (Rip-rap)	0.023-0.033	2.4-3
D)	Brick	0.014-0.017	3
E)	Bitumen(Asphalt)	0.013-0.016	5.4-6

From eqn., Q= A x v = 1/n x A x R2/3 x S1/2 = 1/0.013 x 6 x 0.862/3 x 0.0011/2= 13.18 cumec, this is greater than the total discharge coming from catch pit and catchment i.e. 1.723cumec.

CHAPTER-6

RESULT AND DISCUSSION

6.1 Outcomes of Conventional Design

6 Discussion on Drain Design

a) Slopecheck

A typical drain section of dimension 0.400m x 0.600m was already proposed for the selected corridorportion. This typicaldrain section was checked against the amount of discharge that may come from surrounding catchment to the disposal point for that particular chainage. During that checking a key parameter was slope of the drain. This slope is different value for different chainage so that it can be able to drain off the coming discharge without any stagnation or backflow.

The slope is also provided along longitudinal profile of road in such a manner that invert level at start point of drain and end point of drain was able to maintain provided section depth.

b) Discharge check

Real release coming from individual catchment region to deplete was distinctive for distinctive chainage as its region and time concentration distinctive. The precipitation concentrated too depends on time of concentration which is additionally region subordinate. Another release calculation was done on the premise of the property of commonplace area expected. This was moreover distinctive in several chainage. A cross check was done whether the proposed area is competent to deplete off the release coming from the catchment due to rain.

6.1.1 Discussion on Culverts Hydraulic capacity

Discharge calculation of culvert

The hydraulic capacity of box culverts is similar to those for circular, arch and elliptical pipe. The Manning formula is the most widely accepted method for evaluating the hydraulic capacity of non-pressure conduits. For the hydraulic calculation slope was considered as 0.1% which was standardized by MoRTH different standard drawings. Discharge of different culvert or bridge was different due to dimension. Maximum free board was considered as 0.5m for culvert. Discharge calculated in cumecs is found very rational. Rainfall intensity is calculated on the basisof time of concentration to reach the discharge point from the farthest pintof catchment.

6.2 Outcomes of Q-GIS based on Hydraulic design model

6.2.1 Contour Map

It is found that elevation of NH-717A from Barboat to Kaffer is gradually down from LHS to RHS of road as it situated at Plateau of Himalaya Mountain near Bhutan in the entire corridor. The water also came from LHS to RHS of road. So for each culvert individual contour map generated to get a clear view catchment area. Contour havingsamevalueareconnectedandcontourmapwasgeneratedasshowninfigure6.1below.

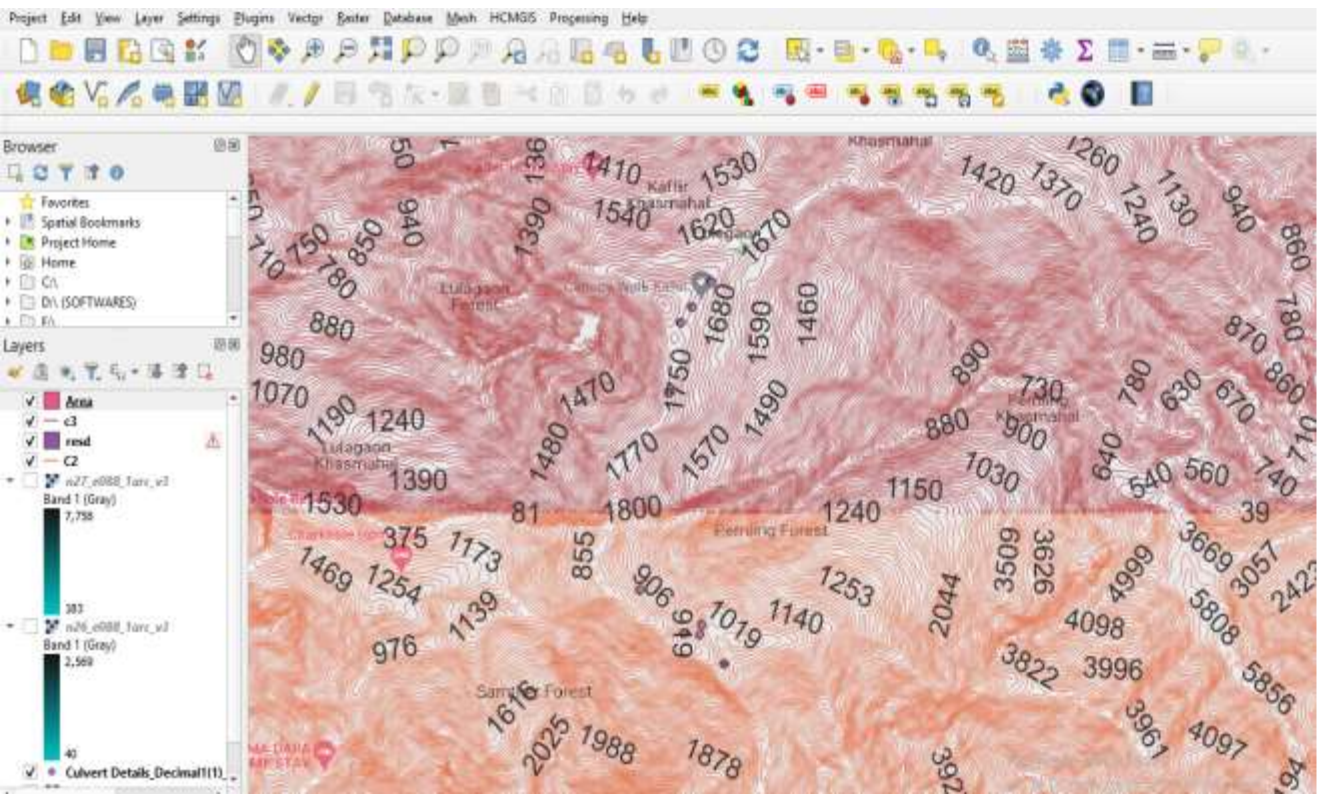


Figure6.1:Contour map of the Culverts

6.2.2 Catchment Area Development

After the preparation of contour map a catchment area is generated based on lower contour to higher contour which shown in figure 6.3. The catchment areaall the culverts and bridges has shown in table 6.1 below.

Table6.1:Catchment area accordingly to culvert & bridge location

Sr.No.	Description	Chain age	Catchment area (in SqKm)

1	Culvert 1	34+155	1.25
2	Culvert 2	34+709	1.31
3	Culvert 3	34+799	1.19
4	Culvert 4	35+222	1.025
5	Culvert 5	36+141	1.20
6	Culvert 6	38+340	2.12
7	Culvert 7	38+942	1.23
8	Culvert 8	39+102	1.07
9	Culvert 9	39+364	1.04

6.2.3 Discharge Computation of Culverts

Discharge calculation is done for each culvert location. Rainfall intensity is calculated on the basis of time of concentration to reach the discharge point from the farthest point of catchment area.

6.3 Discussion on Conventional Design and Q-GIS Model Design

It was found from the detail calculation sheet given in Reference section that all the culverts and bridges within the chosen venture extend was adequate to arrange the release coming from catchment range from Q-GIS as well as deplete release too. It was found from table 6.2 that existing as well as proposed culverts and bridges not as it were satisfactory for waste release but too have higher esteem of figure of security (F.O.S).Table 6.2- Details of existing cross drainage structure.

Sr.No.	Description	Chainage	Catchment area (in Sq Km)	Span	Depth
1	Culvert 1	34+155	1.25	3	2
2	Culvert 2	34+709	1.31	3	2
3	Culvert 3	34+799	1.19	3	3
4	Culvert 4	35+222	1.025	3	3
5	Culvert 5	36+141	1.2	3	3.5

6	Culvert 6	38+340	2.12	3	3.5
7	Culvert 7	38+942	1.23	3	2
8	Culvert 8	39+102	1.07	3	2
9	Culvert 9	39+364	1.04	3	2

Table6.2:Discharge from conventional design and Q-GIS model based output

Sr.No.	Description	Chainage	Discharge from Q-GIS model & Drain water (cumec)	Discharge from conventional design (cumec)	Remarks
1	Culvert 1	34+155	1.278125333	7.08449955	Adequate with a higher margin of F.O. S
2	Culvert 2	34+709	1.355385275	7.08449955	Adequate with a higher margin of F.O. S
3	Culvert 3	34+799	1.252906637	13.47960117	Adequate with a higher margin of F.O. S
4	Culvert 4	35+222	1.110305803	13.47960117	Adequate with a higher margin of F.O. S
5	Culvert 5	36+141	1.248861286	16.79739186	Adequate with a higher margin of F.O. S
6	Culvert 6	38+340	1.894702817	13.18326606	Adequate with a higher margin of F.O. S
7	Culvert 7	38+942	1.182983693	7.08449955	Adequate with a higher margin of F.O. S
8	Culvert 8	39+102	1.146055805	7.08449955	Adequate with a higher margin of F.O. S
9	Culvert 9	39+364	1.145500351	7.08449955	Adequate with a higher margin of F.O. S

CHAPTER-7

CONCLUSION AND RECOMMENDATION

7.1 Conclusion and Recommendation

Q-GIS application tool was utilized in this analysis add order to repair the geographic region for calculative surface run-off supported rational methodology. the most purpose of this study is to use freely out their open surface tool to examine the present and planned cross voidance structure dimensions square measure adequate or not, to disposed quickly the run-off from geographic region (from Q-GIS software) and road side drain.

From the above study it has been found that all the duct proposed within the chosen road network range was adequate to arrange the release coming from catchment zone as well as from deplete release. It is to find that most of the segment not as it were satisfactory for water release but too keeping up higher F.O.S.

7.2 Future Scope of Work

i. The application of the present methodology based on open source software i.e. Q-GIS should be applied in a number of project works for checking the accuracy of the structure or model.

ii. Since the Q-GIS application tool has the inbuilt capacity of simulating drainage catchment area with ground truth data, the accuracy of estimation may be taken up as a future study through field measurement.

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APPENDIX

<u>Calculation of Box culvert Discharge</u>

Sr.No	Description	Chainage (KM)	Size		Type	Freeboard(m)	ClearSpan(m)	ClearHeight (m)	Manningco-efficient n	Areaspanxheight A (m2)	Wetted perimeter (m)	Hydraulic meandepth R(m)	BedslopeS	CDDischarge Q=1/n.A.R$^{(2/3)}$.S$^{(1/2)}$ cumecs
			Span	Depth										
1	Culvert 1	34+155	3	2	Box	0.5	2.5	1.5	0.013	3.75	5.5	0.68	0.001	7.08449955
2	Culvert 2	34+709	3	2	Box	0.5	2.5	1.5	0.013	3.75	5.5	0.68	0.001	7.08449955
3	Culvert 3	34+799	3	3	Box	0.5	2.5	2.5	0.013	6.25	7.5	0.83	0.001	13.47960117
6	Culvert 4	35+222	3	3	Box	0.5	2.5	2.5	0.013	6.25	7.5	0.83	0.001	13.47960117
7	Culvert 5	36+141	3	3.5	Box	0.5	2.5	3	0.013	7.5	8.5	0.88	0.001	16.79739186
8	Culvert 6	38+340	3	2.5	Box	0.5	2.5	2	0.013	6	7	0.86	0.001	13.18326606
9	Culvert 7	38+942	3	2	Box	0.5	2.5	1.5	0.013	3.75	5.5	0.68	0.001	7.08449955
10	Culvert 8	39+102	3	2	Box	0.5	2.5	1.5	0.013	3.75	5.5	0.68	0.001	7.08449955
11	Culvert 9	39+364	3	2	Box	0.5	2.5	1.5	0.013	3.75	5.5	0.68	0.001	7.08449955

DischargecalculationforCatchmentareafromQ-GIS

Sr. No	Descriptions	Chainage(KM)	Catchment Area from Q-GIS model (A) ha.	Travel length (m)	Factor(k)	channel slope in % (S)	Velocity $v=k.S^{0.5}$ m/s	Time of Concentration(t_c) in min.	Conversion factor	Rainfall(mm)	Rainfall Intensity (I)cm/hr	Co-efficient of Run-off (P)	Spread factor(f)	Total Discharge from Catchment Area Q=0.028f.P.A.I cumecs
1	Culvert1	34+155	1.25	225	0.305	.10	0.096	8.06	3.18	460	57.06	0.64	1	**1.27**
2	Culvert2	34+709	1.31	215	0.305	.10	0.096	7.83	3.22	460	57.74	0.64	1	**1.35**
3	Culvert3	34+799	1.19	200	0.305	.10	0.096	7.50	3.28	460	58.75	0.64	1	**1.25**
4	Culvert4	35+222	1.025	175	0.305	.10	0.096	6.94	3.37	460	60.45	0.64	1	**1.11**
5	Culvert5	36+141	1.2	210	0.305	.10	0.096	7.72	3.24	460	58.08	0.64	1	**1.24**
6	Culvert6	38+340	2.12	325	0.305	.10	0.096	10.28	2.78	460	49.87	0.64	1	**1.89**
7	Culvert7	38+942	1.23	275	0.305	.10	0.096	9.17	2.99	460	53.67	0.64	1	**1.18**
8	Culvert8	39+102	1.07	185	0.305	.10	0.096	7.17	3.33	460	59.77	0.64	1	**1.14**
9	Culvert9	39+364	1.04	160	0.305	.10	0.096	6.61	3.43	460	61.46	0.64	1	**1.14**