REVISITING THE ADEQUACY OF THE HIGHWAY DRAINAGE SYSTEM USING THE RATIONAL & GEOGRAPHICAL INFORMATION SYSTEM- A CASE STUDY OF N.H-31C, JALPAIGURI

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

Master of Engineering in Water Resources and Hydraulic Engineering

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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 Rational & Geographical Information System- A Case Study of N.H-31C, Jalpaiguri"** is a bonafide work carried out by **Sk. Anisur Rahaman** 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 2016-2019.

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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.

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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 2018-2019.

All information in this document has been obtained and presented in accordance with academic rules and ethical 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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ACKNOWLEDGEMENT

I express my sincere gratitude to my Thesis Advisor **Prof. Asis Mazumdar, Director & Professor** of School of Water Resources Engineering, Jadavpur University and **Dr. Gourab Banerjee, Assistant Professor**, of School of Water Resources Engineering, Jadavpur University, under whose valuable guidance this work has been carried out. It would have been impossible to carry out this thesis work with confidence without his wholehearted involvement, advice, support and constant encouragement throughout. He has not only helped me to complete my thesis work but also have given valuable advice to proceed further in my life.

I also express my sincere gratitude to all the faculty members **Prof. (Dr.) Pankaj Kumar Roy**, Dean & Professor, Faculty of Inter Disciplinary Studies Law & Management & School of Water Resources Engineering, **Prof. (Dr.) Arunabha Majumder**, Professor-Emeritus, School of Water Resources Engineering, **Dr. Subhasis Das**, Assistant professor, School of Water Resources Engineering, & **Dr. Rajib Das**, Assistant Professor, of School of Water Resources Engineering, Jadavpur University for their valuable suggestion.

I also express my thankfulness to **Mr. Arnab Ghosh**, Ph.D Scholar, of School of Water Resources Engineering, Jadavpur University for his help and support.

I am indebted to **Mr. Asish Dhar,** Assistant Engineer, Gairkata N.H Sub-Division, P.W(Roads). Dte., Jalpaiguri, for accessing the real life data for the validation of the design methodology adopted in the present study.

Thanks are also due to all staff of School of Water Resources Engineering and the Regional Centre, NAEB, Jadavpur University for their help and support.

Date : May, 2019

Place : Jadavpur University, **<u>SK. ANISIR RAHAMAN</u>**

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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 Gairkata N.H Sub-Division, P.W.(Roads) Directorate, N.H-31C, Chalsa to Telipara (105.00km to 145.632 km) and its surrounding area of road upto Right of Way (R.O.W) major part of which covered under Chalsa, Chapramari forest, Nagrakata , Daina forest, Banarhat , Bnnaguri, Tea gardens of Jalpaiguri 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 and existing drainage structure in ongoing highway strengthening and widening project.

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CHAPTER-1

INTRODUCTION

1.1 General background

Roads have an important contribution to economic development of a country as well as social development. In addition to the nation grow and development it also provides employments, social, health and education services which make crucial networks in fighting against poverty. For that reasons roads infrastructure is the most important in all aspects.

So these roads networks are important elements of the national infrastructure and its construction, operations and maintenance has a large national annual budget. Roads are built to provide users a safe, comfortable and robust ride throughout their service life. Roads must basically fulfill two major requirements that are functional and structural requirements. In functional or serviceability requirements it has to provide skid resistant and smooth ride experience for users and in structural requirements it has to provide an adequate level of structural adequacy over a period. But the main thing is that these roads networks always obstruct the natural water flow line. So cross- road drainage is always necessary to discharge the water surrounding the roads side.

Though water are vitals natural resource for the humans, plants and animals, but too much water arrested surrounding the road networks can damage the roads seriously. Greater the velocity of water faster will be the deterioration of surfaces. So cross drainage works i.e. culverts and bridges frequency and location are important facter for the water management surrounding the roads.

Clogged culverts or the bridges or the inadequate size of it can lead the water flooding over the road surface. When water flow over the road surfaces continuously it erodes the surface. In wet road surface the driver are also not safe because the wet surface have less frictional value that is why longer time for braking is required ultimately increase the risk of accident. Roads can undergo permanent deformation when proper drainage is not given. These deformations are the leading cause of rutting on small volume of roads. On the other hand low drainage system has larger maintenance costs and smaller life. So by detecting the correct no of cross drainage and designing the proper drainage on the road surface we can increase the life of roads networks and ultimately save the money and reduce the hassle.

Drainage on the road surface are provided by shaping the carriageway with a camber or a cross slope. On most of the roads camber are roof shaped with the highest point at the road centre. On narrower local roads the camber may be provide by continuous slope from one side to another side.

Culverts are the common cross-drainage structure used on roads. They are required in order to allow Natural streams to cross the road, and discharge surface water from drains and the area adjacent to the road. The frequency and location of culverts forms an important part of the water management surrounding the roads.

The culverts form an essential part of the overall drainage system of the road. This implies that their frequency and location need to be carefully assessed in relation to the location, function and capacity of other drainage elements such as bridges, cut-off drains etc. A well functioning drainage system is dependent on the efficient operation of all the elements of the system. If one component in this system fails, such as a blocked culvert, the water will exert more pressure on the remaining parts of the drainage system. The location and the direction of the rivers and streams have an important impact on the optimal positioning of the road alignment. Flood water from rivers and streams can cause serious damage to the road structure, so the crossings need to be carefully designed so that they minimize the chances of any future damage.

If an existing road is being improved, the location of more culverts are obvious, as large quantities of water will leave the existing road structures insufficient cross drainage would lead to washouts of entire road sections. In that situation, it is important to carry out a thorough reassessment of the drainage system before starting the repair works. An investigation should be carried out as to why the washouts happened and how to avoid it again. Careful investigation should be given to how and where the water is discharged. Water collected from the road and discharged through a culvert without any prevention may cause serious soil erosion and damaged to the surrounding areas. Appropriate measures dealing how the water is dispersed downstream of the culverts is an integral part of culvert design. When water is discharged on to the farm land, the water management need to be discussed with the local farmers and thereby damaged to the farming activities can be avoided. In some cases this water can be helpful to the farmer.

1.2 Highway Drainage Scenario: State of the Art

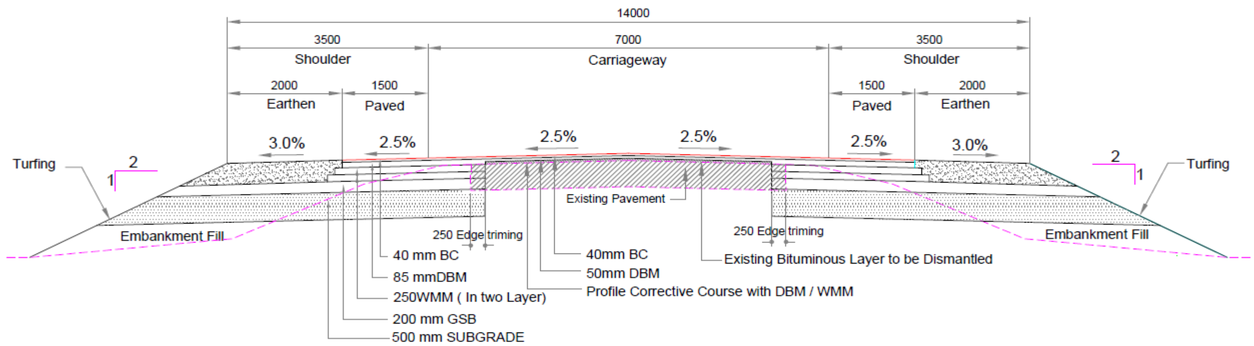
Highways connect capitals, ports, & strategically important places of various states. Total length of national highways in India has 97,991 km as on 31.3.2015 and state highways has 32,87,240 km as on 2012. Out of which West Bengal has 2,377 km of national highway. Though national highway has only 20% 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 thousand 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 method 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.

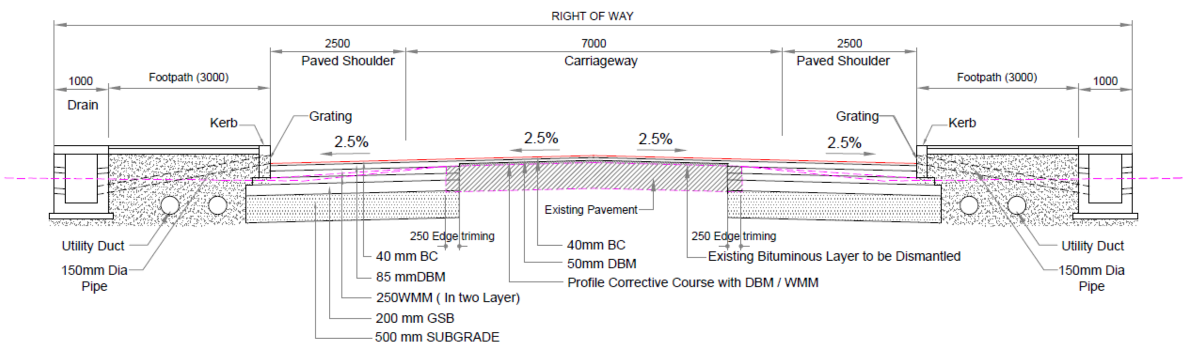
Subsurface moisture which infiltrates from the pavement surface or shoulders has to be drained out to avoid loss of aggregate to aggregate contact so that load transfer is not affected. An upper granular sub-base layer called as Drainage Layer (DL) has been suggested to drain this trapped water lately by both MoRTH Specifications and IRC:SP: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. GSB 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 Granular Sub-Base (GSB). The basic ingredients of both mixes are same but the difference lies in percentage of fines passing in

Drainage Layer and GSB mix. The proposed drainage system in road are given fig.- 1.1, fig.-1.2 & fig.-1.3.



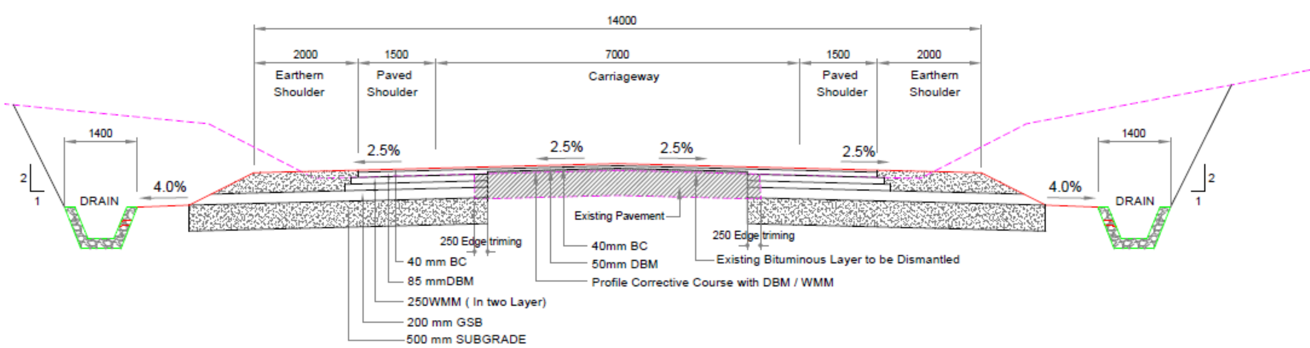
TCS -1 : Typical Cross Section Of Overlay of flexible pavement with BC and DBM for Two lane carriageway with paved shoulde in Rural area

Figure 1.1: Cross section without drain



TCS -2 : Typical Cross Section OF Overlay of flexible pavement with BC and DBM for Two lane carriageway with paved shoulder in built up are(both side cover drain)

Figure 1.2: Side drain used in junctions in proposed road



TCS - 3 : Typical Cross Section OF Overlay of flexible pavement with BC and DBM for Two lane carriageway with paved shoulde in Rural area with both side trapezoidal drain

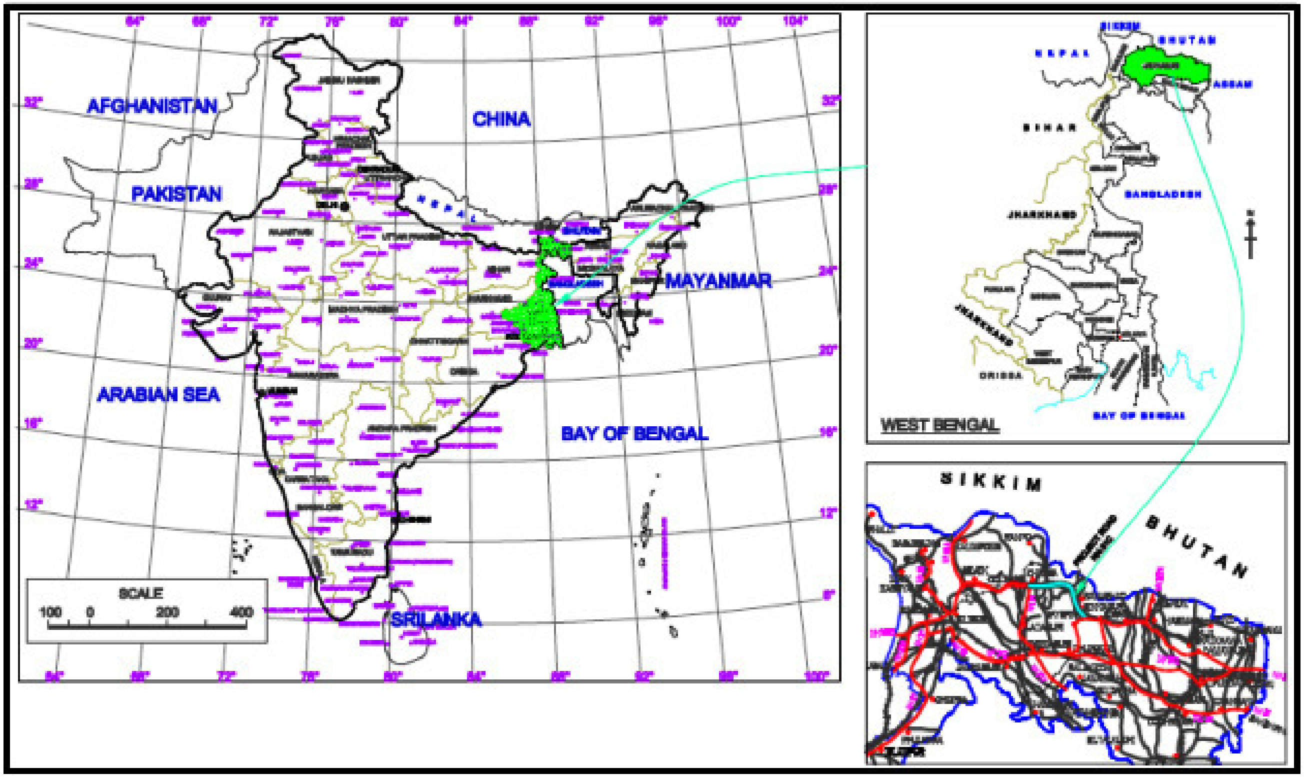
Figure 1.3: Side trapezoidal drain used in cutting portion [Source: Gairkata N.H Sub-Division, P.W.(Roads) Dte.]

1.3 The study Area

The Road NH-31C connected between Chalsa (km105) and Telipara (km 145.632) lies in Jalpaiguri district in the state of West Bengal. This road section is passing through Chalsa (km 105), Sulkapara, Grass more, Banarhat, Binnaguri and ends at Telipara(km 145.632). Total length of the stretch is 40km and improvement and upgradation of the road will benefit the road user as it shortens the distance by 34 km when compare to the distance between Chalsa and Telipara vide NH-31 which is found 74km approx.

Photograph 1.1: Start and end point of the project corridor

The land use pattern of the road stretch is mainly in Tea garden, agricultural, forest land and some of stretches having settlement and residential structures having Rural / semi-urban character. The project road lies in Jalpaiguri district of West Bengal. It is situated between 26° 16' and 27° 0' North latitudes and 88° 4' and 89° 53' East longitudes. The district was established in 1869 in British India. The start and end point shown in Photograph 1.1 and location of the study area shown in Map-1.1.



Map 1.1: Location of the Study Area

1.4 Objectives

The main aim of the research work is to find out the adequacy of highway drainage network of a particular stretch with the application of Q-GIS software with field survey and data collection. An attempt has been made to accommodate water flow along and across the road and suitably transported and drained the water on downstream in the flow through quantification of natural discharge of cross drainage structure like culvert or bridge and finally adequacy assessment and calibration of culvert and bridge design. A case study of N.H-31C, Jalpaiguri has been carried out to illustrate the above mentioned objective.

1.5 Importance of Study

This is a live project study which will give a clear idea about the drainage system existing and proposed 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

LITERATURE REVIEW

2.1: International and National Literature Review

Patil et al. (2017) studied on design considerations in water logged area for flexible pavements. Available different methods for increase the life of road pavements especially in India are divide them into three categories i.e. soil improvement, drainage of road water and pavement design.

For the improvement in black cotton soil research on three kind of procedure i.e. by mixing quarry dust, mixing fly ash and by mixing sand & cement was done. It come out with the result that quarry dust give best result at 30% with CBR value 8.28, fly ash at 20% give CBR value of 6.2 and by cement & sand mixing with 2% cement & 40% sand it give CBR 8.26 where normal CBR value for black cotton soil is near about 2.82.

For drainage solution, camber of 1 in 2 & collect the water in side drain & discharge into the nearest stream for surface drainage. For stream crossing the road alignment a cross drainage work must be provided. For sub-surface drainage procedure has to be adopted to lower the ground water table. Some advantage methodologies for drainage i.e. a vertical filter media of 0.3m boulder, 0.15m metal & 0.15m granite quarry outside the vertical drain to collect the water outside drain through weep hole. Using recycled waste plastic of about 5-10% by wt. of bitumen with the aggregate for bituminous road it improves the Marshall stability, fatigue life, strength & other desirable properties. Application of geogrids beneath the granular layer, confine the overlaying granular/soil materials which decrease the loss of materials.

Dr. Sing et al. (2014) studied on effective drainage system of roads. Highway drainage is important because excess moisture in sub-grade create instability under road surface and also due to variation in volume of clayey soil , lead to sub-grade failure. The wave & corrugations forms also play pavement failure. Continuous contact of water with bituminous roads leads to stripping of bitumen with aggregates which cause pot holes. Mud pumping was happened due to presence of water in subgrade in fine grained soil. Excess water increased wt. which ultimately failed the embankment foundation & side earth slope. In cold area frost action in ground water can caused damage to the pavement. Cut & hill side erosion happened in un-surface roads & slope of embankment top. Due to hydraulic pressure, binder stripping can happen due to improper drainage. Type of drainage methods can depends on various factors like shape, size, geology & gradient of catchment area. For surface drainage underground longitudinal drain which can collect rain water through road camber and ultimately disposed to the cross drainage work like bridge (for span more than 6m), culvert(for span less than 6m) have to be provided. Sub-surface drain which collect the gravitational water and reduce the water in sub-grade level. Using longitudinal drain pipe with sand filter(06m to 0.9m seepage zone) media lower the ground water table and also reduce seepage flow(water table must be kept 1.0m to 1.2m below the subgrade) . Where it is not possible to lower the water table, formation on embankment of height 1.0m to 1.2m has to be constructed. Using granular material layer in between the subgrade & highest water table level can reduce the capillary rise of water.

Rokade et al. (2012) studied on drainage related performance of flexible highway pavements. Pavement life can be increased up to 50% by preventing or drained the infiltrated water without delay. Also good drained pavement has design life two to three times more than the un-drained pavement section. In India most of the highway has very slow drainage system mainly because of all importance given on density & stability and lesser importance on sub-surface drainage.

A permeable base is the most suitable sub-surface drainage alternative. It provides adequate permeability to drain infiltrate water during rain, limit the saturation time of drainage layer and enough structural stability to hold pavement load & traffic load.

Longitudinal drain generally as side drain must be provided to dispose off the surface water quickly to the cross drainage structure like culvert or bridge. Based on saturated flow condition, two different type of hydraulic design of pavements system is incorporated i.e. steady state flow condition (it is very tedious as it have required design rainfall rate & portion of rainfall that enter the pavement) and time-to-drain condition (many engineer it prefers. This is based on flow entering the pavement until the base course is saturated. Excess run-off will not enter the pavement section and only it simply run-off from the pavement surface. As per AASHTO for 50% of drainage road will be called as Excellent, Good, Fair, Poor and very poor if it has time to drain are 2 hours, 1 day, 7 days and does not drain respectively).

To minimise the moisture to enter the pavement system- moisture insensitive materials like cement-treated base & Asphalt treated base can be used, open graded base materials with high amount crushed materials, low fines content & low plasticity may be used in between subgrade & base course and full width paving to eliminate cold joint.

Owuama C.O. et al. (2014) studied on sustainable drainage system at New Qwerri Nigeria. Trenchless drain is a absorption field of relatively permeable material like mixture of sand & cement and grass cover over it on both sides of road. It was found that trenchless drain is more better option than open concrete drain & pipe drain because in flat area where general slope less than 2% generate flow velocity of less than 0.49m/s which is less than 0.75m/s permissible velocity for self-cleansing of open drain, vegetal growth in the drains or silted up, open drain also attract as waste dumping, pipe drain is not suitable where does not have adequate grade to ensure self-cleansing velocity because it promote blocked or silted up, reinforced concrete drain have 4 times more costly than it and open or pipe drain is costly as it required regular cleansing.

Also trenchless drain have some limitation, they are- it is not suitable in area where slope is more than 7%, not suitable in area where very low permeable soil like flat clay and ground water table is very close to the surface or hard rock soil is available less than 1m depth.

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. About 95% research data collected from primary sources and out of this 10% of data collected through questionaries' and interview. The rest collected through field survey. The collected data analysed using Microsoft-Excel, AutocCAD, 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 allocation will increase. Drainage facility is also reduced due to sewerage 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 of water logging in road section. Roads are important factors as it can affect the 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, road side 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. Highway drainage is important part of highway design & also construction because 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 be drained 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.

V. Santhalingam (1999) studied on highway drainage system. Appropriate drainage of highway is an important feature of highway design because by this value of money are achieved & required level of service achieved. Highway drainage should have major objective like safety of the users & longevity of the pavement. In UK drainage is broadly divided into two categories- combine system (where surface & sub-surface water transported by same pipe) and separate system (where two pipe are provided from surface & sub-surface drainage). Road surface drainage by kerb & gullies used in urban & embankment condition. It not depends on longitudinal gradient. Surface water channel are of triangular/trapezoidal concrete section, usually slipform set up at the edge of shoulder & flush with the road surface as economical & suitable at rural locations (trunk roads & motorways) but not suitable in zero longitudinal gradient. Combined filter drain system have aggregate filled trench with a perforated pipe at the bottom which collect surface & sub-surface water but have some disadvantages like stone scatter, embankment surface failure due to extension of sub-base as a drainage layers, softening of sub-grade due to filter drain become water-logged etc. It is best suitable in cutting. Over the edge, drainage is applicable to embankment condition where pavement surface water is allowed to drain over the edge and go downward into the open ditches. In drainage channel block can be applied where water collected along a kerb channel and drain across the verge into verge side ditches. Combine kerb & drainage units, have special kerb that allow lateral entry of surface water from the kerb side channel. Fin & narrow filter drain, usually installed longitudinally along the lower edge of road pavements as low capacity filter drain to remove water from sub-surface difficult to construct. Edge drainage for porous asphalt act as drainage layer underneath the road surface. It also acts as a noise reduction & spray reduction which enhances road safety.

Gurjar et al. (2013) studied on a framework for quantification of effect of drainage quality on structural and functional performance of pavement. In selecting appropriate maintenance strategies, the pavement maintenance cost need to be compared with the drainage quality improving cost. Hence, there is a need to calculate the effect of various type of drainage quality on pavement performance. Simple framework for quantification of effect of drainage quality as well as working performance of the pavement in terms of deflection & roughness respectively was work out.

Gradation and properties of the materials used in layer are such that it had bad drainage properties which lead to entrapment of rain water within layer causing a 'bathtub' condition which ultimately fail the pavement before design life.

Summarisation on detrimental effect of water on the structure which are outlined by AASHTO(1993) was done they are water saturation of asphalt surface can reduce the dry modulus by as much as ≥30%, reduce the strength of loose granular material & sub-grade soil, stripping of bituminous mixture when continuous contact happen, water in loose base & sub-base reduce the stiffness at range ≥50%, for asphalt treated base modulus reduce upto 30% due to water, saturated fine-grained soil reduce modulus ≥50% and surface scouring happen due to flow of surface water.

They framework the effect of drainage quality on structural by Benkelman Beam deflection method and framework the effect of drainage quality on road functional on the basis of roughness as per IRC: 37-2012.

S. Raina et al. (2018) study 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.

Hydrological analysis required to estimate max quantity of water expected to reach on drainage system under consideration. The rational formula Q=C.I.A may be used. Where value of runoff co-efficient(C) depends on type of surface & its slope. C may be taken as 0.8 to 0.9 for bituminous & concrete pavement, 0.35 to 0.7 for gravel and WBM, 0.4 to 0.65 for impervious soil.

Zumrawi (2016) studied on investigating surface drainage problem of roads in Khartoum state of Sudan. It was observed that existing slope of all the three roads in longitudinal direction & cross direction is almost flat that is why water logging happen on small rain. To avoid such accumulation of water, redesigning the geometry of three roads by changing transverse (2 to 3%) & longitudinal (1:1000) gradient was required. Moreover it was observed that soil accumulation almost adjacent to side drain defend run-off water to enter the drain from road surface. Also soil accumulation on culvert & side drain reduces the effective drainage area that is why blocking of water also happen.

Agarwal et al. (2014) studied on the effect of drainage quality & its calculation, on the performance of low volume roads in India. Drainage in terms of roughness quality is important because it affects the performance of low volume roads as it is captured 60-70% of total roads worldwide. Computation was done to determine modified structural number (SNC) which is used to compute roughness using deterioration models. Two cases were created - effect of drainage quality on performance of low volume roads with- its age and saturation time.

The analysis indicate that average deterioration (roughness) growth rate increase with the age of pavement and saturation time for very poor drainage quality then other drainage condition.

H. Aksoy et al. (2016) studied on hydrological & hydraulic models for determination of flood prone and also flood inundation area on watersheds in Turkey. Flood prone areas in watershed used for hydrological model which are done by QGIS software (freely available open source software) by using the digital elevation model of the study area. The result can be used for taking avoidable measures against life & monetary losses due to floods in urban area.

B. Kaviya et al. (2017) stated on watershed delineation using GIS in Selaiyur area which is neighbourhood near Tambaram, Channai. Over the past few year due to continous rain the Swlaiyur lake over flooded & flood the area around Tambaram for a couple of hours. Digital elevation models (DEM) provide good terrain view from which the watershed can be derived automatically using GIS technology.

Watershed is an area of flow that contains a common set of streams & rivers that all discharge into a single larger body of water such as larger river, a lake or ocean. A watershed can cover a small or large area of land. Small watershed is usually part of larger watershed. All the streams flow into small rivers, larger river and eventually into ocean to form a inter connecting network.

DEM is the digital presentation of the land surface elevation with respect to fixed point. The elevation data available in analogue create contour maps. Afterward a digital representation of surface is developed by which we can find the higher and lower elevation which is called DEM. The technological advances provided by GIS and their increasing availability and quality of create DEM have greatly expanded the application of DEM to many hydrologic, hydraulic, water resources works.

M. Toryila et al. (2016) write a review journal on the effects of poor drainage system on road pavement. Poor drainage cause early pavement distress leading to driving problems and structural failure of road. To prevent or minimise it adequate drainage system is required. Drainage designer and road engineer have great importance during road construction. Storm drainage is designed to drain excess rain and ground water from impervious road surface to preserve the pavements structural and its serviceability. Drainage system must be capable of carrying the ultimate design flow from the upstream catchment and discharge to a watercourses or river or sea. Drainage quality also important parameter which can effect the pavement performances. The excessive water content in pavement base, sub-base and sub-grade soils can cause early distress. The primary source of water in pavement is precipitation. This water can enter the pavement through several ways e.g. cracks, infiltration, through shoulders and ditches, high ground water and is moved by energy gradient such as gravity, capillary forces, osmotic forces and temperature & pressure differences. Designer should be concerned with saturated gravity flow which can determine by Darcy's law.

S. Rokade (2012) studied on drainage and flexible pavement performance. Providing adequate drainage to a pavement system has been considered as an important practice considering preventing premature failure due to water related problem such as pumping action, loss of support, rutting, cracks etc. Most water present in road due to rainfall infiltration into unsaturated layers through joints, cracks, shoulder edges etc. Water also seeps upward from a high ground water table due to capillary suction or vapour movement. To minimise premature pavement distress and enhance the road performances, it is mandatory to provide adequate drainage to allow infiltrated water to drain out from the base, sub-base and sub-grade of pavement. Based on field test by Cedergren (1988) estimated that flooded un-drained pavement experiences 10 to 70000 times the damaged from a load than drained pavement. The National Co-operative Research Program stated that (NCHRP-2) key factor for performance of sub-grade drainage is based on whether edge drain outlet pipes were clogged or not. Pavement drainage must be rapidly removed within ideally 2 hours and preferably within 24 hours.

M. Udani et al. (2016) work on QGIS data base design, development and flood analysis: a case study of Olpad Taluka of Surat. Olpad Taluka of Surat is coastal area and highly vulnerable for flood. Tapi river of Gujrat causes flood in Surat and its nearby area. Remote sensing and Q-GIS are used for creating required database for Olpad Taluka. Sudden discharge from Ukai reservoir, coinciding with high tide in Arabian sea, drainage congestion and encroachment in natural depression are the factors for flood effect at Taluks specially Surat city. Q-GIS analysis was done and based on population density of villages, SC/CT population, elevation data and available facilities/shelter data, villages of Olpad were classified into three categories viz. Risk zone, Medium risk zone and Low risk zone villages. GIS framework provides facility for data integrating, query, analysis and decision support.

L. Villanueva (2015) studied on revisiting the adequacy of the existing drainage system using the rational method and Geographical Positioning System (GIS) in 253 km to 255 km along Halsema highway in the La Trinidad. The road stretch has been subjected to flooding during moderate to heavy rainfall situation. Rational method was used to compute for the peak discharge and Q-GIS were used to define the catchment area and computation of run-off. Manning's equation used to compute drainage facility cross section and discharge capacity.

CHAPTER-3

DESCRIPTION OF STUDY AREA

3.1 Introduction

The National Highway wing of the Public Works (Roads) Directorate, Government of West Bengal, is responsible for execution and maintenance of National Highway stretches entrusted to the state Government within the state boundary on behalf of the Ministry of Road Transport & Highways, Government of India (MoRT&H).

Ministry has decided to prepare a Project Report for NH-31C with a minimum of 2-Lane with paved shoulder configuration starting from Chalsa (km 105) to Telipara (km 145) in the District of Jalpaiguri, West Bengal, on Engineering, Procurement & Construction (EPC) basis or SBD mode as will be emerge out on preparation of Project Report.

This research work of Road section of NH-31C connected between Chalsa (km105) and Telipara (km 145.632) lies in Jalpaiguri district in the state of West Bengal. This road section is passing through Chalsa (km 105), Sulkapara, Grass more, Banarhat, Binnaguri and ends at Telipara(km 145.632). Total length of the stretch is 40km and improvement and upgradation of the road will benefit the road user as it shortens the distance by 34 km when compare to the distance between Chalsa and Telipara vide NH-31 which is found 74km approx. The start and end point of the project corridor shown in photograph 3.1 below.

Photograph 3.1: Project start and end point

The land use pattern of the road stretch is mainly in Tea garden, agricultural, forest land and some of stretches having settlement and residential structures having Rural / semi-urban character.

To check the drainage accuracy along this road a particular stretch from 105 to 109.00 km chainage is considered here.

3.2 Geography and Topography

The study lies in Jalpaiguri district of West Bengal. It is situated between 26° 16' and 27° 0' North latitudes and 88° 4' and 89° 53' East longitudes. The district was established in 1869 in British India.

The headquarters of the district are in the Indian city of Jalpaiguri, which is also the divisional headquarters of North Bengal and has its special importance in respect of tourism, forest, hills, tea gardens, scenic beauty and commercialization and business. Jalpaiguri is a part of West Bengal which is situated in North Bengal.

Figure 3.1: Geography of the Study area

The district situated in the northern part of West Bengal has international borders with Bhutan and Bangladesh in the north and south respectively and district borders with Darjeeling hills in the west and northwest Alipurduar district and Cooch Behar district on the east. 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 Jalpaiguri district on which study area belong is given in table 3.1 below.

Table 3.1: Area details of the project corridor

Geographical area(sq. kms)	3386.18
(a) Annual rainfall	2548.8 mm (Up to August'2014)
(b) Temperature	37.9º c (max) 7.8º c (min)
(c) Geographical Location	26º15′47″ & 26º59′34″ N Latitude
	88º23′2″ & 89º7′30″ E Longitude
District Head Quarter	Jalpaiguri
Sub-Division	2
Blocks	7
Panchayat Samities	7
Gram Panchayat	80
Municipal Corporation	01 (14 words of Siliguri Municipal corporation fall Within Jalpaiguri District.)
Municipality	3
Mouza's	418
Gram Sansads	1177
Police Station	9
Inhabited villages	404
Forest villages	29
(a) Male	1217532
(b) Female	1164064
(c) Total	2381596 (as per Census 2011)
(d) Population Density /sq.km	701

(e) Sex Ratio	956.085
Net cropped area	198256
Percentage of irrigated to cultivated area	40%
(c) Forest	64393
(d) Fallow land	11286
(e) Land not available for Cultivation	65696
(f) Cropping intensity	186%
(g) Area brought under HYV seeds	60%

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.

3.4 Existing Drainage Scenario

Project area covers a large number of culverts, major bridge and minor bridges. There are few no culverts which are balancing type. The area is maximum Dooars tea gardens beside the road side, approximately 10 km stretches forest and rest is market area. Though there is a specific drainage system but some places required new culverts and also some balancing culverts. The some existing culverts have damaged apron and in bed. The protection works in major and minor river are damaged. In some portion beside this embankment large quantity water is presents there. Some photograph of existing drainage scenario given in photograph 3.2 below.

Photograph 3.2- Existing culvert & Bridge at study Area

3.5 Ongoing Project photograph

Some photograph of ongoing project work shown in photograph 3.3 below.

Photograph 3.3: Some photograph of ongoing work at study Area

CHAPTER-4

METHODOLOGY

4.1 Introduction

The Project Road section of NH-31C connected between Chalsa (km105) and Telipara (km 145) lies in Jalpaiguri district in the state of West Bengal. This road section is passing through Chalsa (km 105), Sulkapara, Grass more, Banarhat, Binnaguri and ends at Telipara (km 145.632). Total length of the stretch is 40km and improvement and up-gradation of the road will benefit the road user as it shortens the distance by 34 km when compare to the distance between Chalsa and Telipara vide NH-31 which is found 74km approx.

The National Highway wing of the Public Works (Roads) Directorate, Government of West Bengal, is responsible for execution and maintenance of National Highway stretches entrusted to the state Government within the state boundary on behalf of the Ministry of Road Transport & Highways, Government of India (MoRT&H). NH-31C from Chalsa to Telipara (40.5 M) was selected as a part of this development programme from existing 2 lane of 7.0m wide to a minimum of 2-Lane with paved shoulder of total 10.0m wide pavement with a 2m wide earthen shoulder on both side total of 14.0m wide.

4.2 Conceptualization of Methodology

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

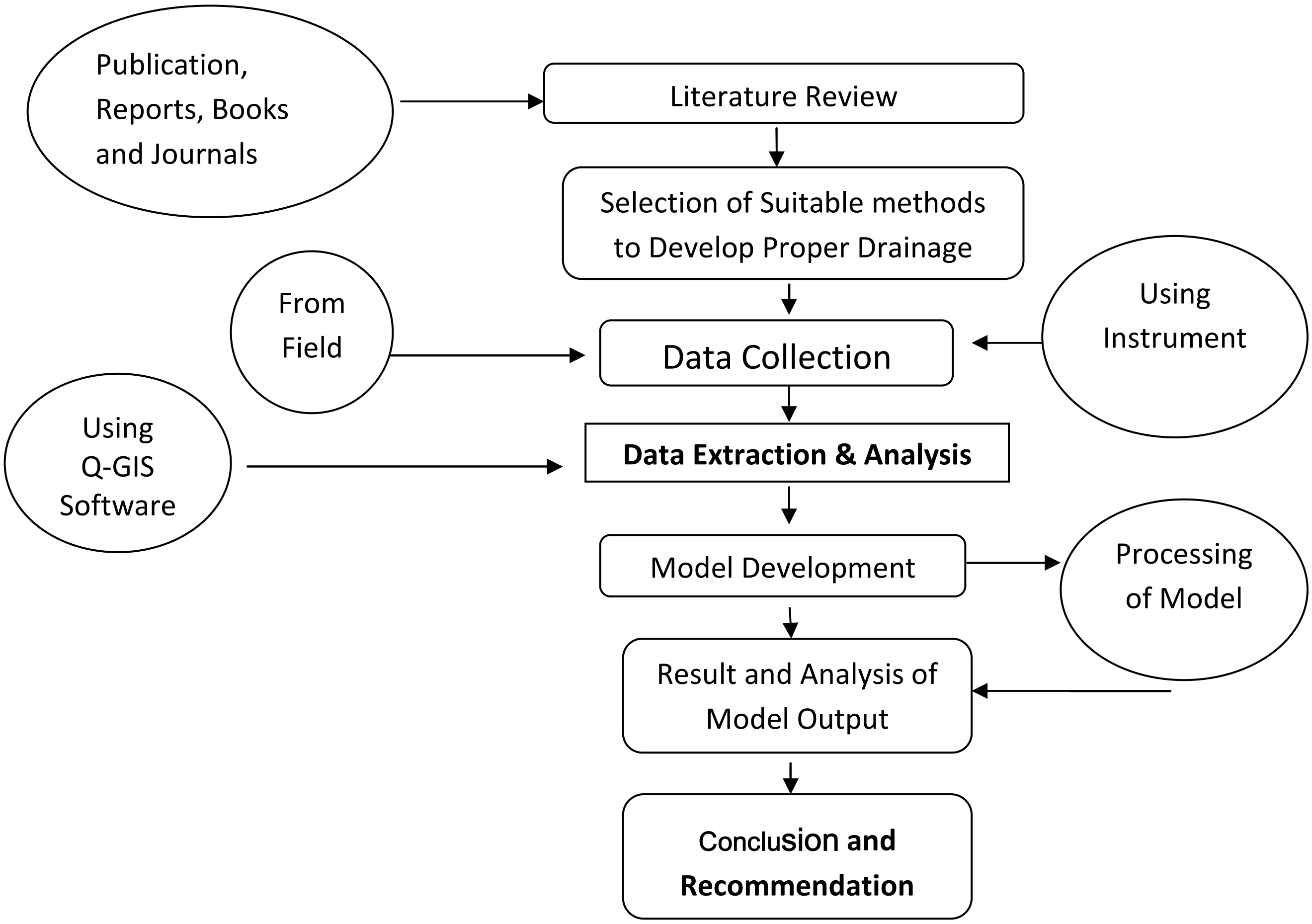


Figure 4.1: Methodology flow diagram

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 the reviewed, were organized in worldwide. 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—

i) Reconnaissance survey
ii) Pavement survey
iii) Land use
iv) Right of way (ROW)
v) GPS and topographic survey
vi) Culverts and bridges condition

i) Reconnaissance survey

This is preliminary survey done to determine an extensive study of an entire area along road. The purpose of the visit on site to gather sufficient information to support a correct decision regarding future action. Also to gather information by visual observation 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:

- Climate of the area surrounding the project road
- Road inventory and condition
- Condition of bridges and cross-drainage structures

- Type and location of existing utility services
- Hydraulic data

ii) Pavement survey

Visual pavement surface condition has been carried out along the entire project stretches in order to gather relevant information. The carriageway width of the existing road varies from 6.4 -6.7 meters. Hence, total formation width varies from 7.1 – 7.7 meter in total stretch of project road. The width of the existing carriageway from centre of road in market area has shown in photograph 4.1 below.

Photograph 4.1: Measurement of carriageway width in market place

The existing pavement condition along the road is basically fair to good. Some portion of the stretch the existing pavement is partially damaged with longitudinal cracks, raveling and edge drop. The thickness of the existing pavement varies from 360mm to 710mm. Data collected on following-

a) Riding quality (good/fair/poor/very poor)

b) Pavement condition

c) Shoulder condition (fair/poor/failed)

d) Embankment condition (good/air/poor)

e) Road side drain (non existing/ partially functional/functional)

f) Special problem if any

a). Riding quality

Riding quality of the entire stretches is good to fair except in few stretches from Banarhat (134.00 km) to Binnagui (141.00km) and also on the major and minor portion.

b). Pavement condition

Pavement condition is valuate on the basis of following parameters-

I. Cracking (%)
II. Raveling (%)
III. Potholing (%)
IV. Rutting (%)
V. Patching (%)

I. Cracking (%)

it has been seen that about 7.5 km on different stretches from Banarhat to Binnaguri section have cracks about 25 % and rest of the stretches have near about 15% and also no cracking found throughout the stretches. The image of the narrow crack on existing road has shown in photograph 4.2 below.

Photograph 4.2: Narrow crack on the project corridor

II. Raveling

Pavement distress is measured in percent area. Raveling is found from Banarhat to Binnaguri and also places of major and minor bridges. It was about 15% all over the stretches. The raveling on existing road has shown in photograph 4.3 below.

Photograph 4.3: Raveling of road on major bridge portion

III. Potholes

Pavement distress potholes are measured in % area. It is found at about 5% on 10km of road stretches from Banarhat to Binnaguri and also on some major and minor bridges.

IV. Rutting

Rutting is measured as severe, moderate and nil. Rutting also found to be moderate to nil. It mainly found from Banarhat to Binnaguri and also some stretches all over the road and bridges. The rutting of the existing road on bridge has shown in photograph 4.4 below.

Photograph 4.4: Rutting on project corridor

V. Patching

Patching is measured in % area. It has been found that 5% patching work found all over the project corridor.

Photograph 4.5: Patching work on project corridor

The patching work of the road has shown in photograph 4.5 above.

c). Existing shoulder Condition

From chainage 105+000 km to 145+632 km on NH-31C the existing road is mostly intermediate lane with earthen shoulder. Width of earthen shoulder varies from 0.50 – 1.0 meter. Condition of the shoulder is fair. There are some issues of drainage problem but rest is fair. Cross slope is near about 3%.

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 1m to 3m. 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 Dain

The project section is in predominantly plain to rolling terrain. There is 1180 m Lined Drain in existing road mainly in road in cutting.

f). Special problem, if any

At minor bridge at 140.275 have less area of water way as there is an over topping during heavy rain as huge water from Hatinala come at rainy season. Water stagnation at market places like Binnaguri, Banarhat, Chalsa market etc. during rainy season happen as there is no such specific water outlet.

iii) Land use

The land use pattern of the road stretch is mainly in Tea garden, agricultural, forest land and some of stretches having settlement and residential structures having Rural / semi-urban character.

iv) Right of way (ROW)

It has been found from the previous data that ROW of the existing varies 112 m to 20m.

v) GPS and Topographic survey

The project road passes through plain to rolling terrain. The topography is mostly rural in nature. GPS value of culverts and Bridges was established on the project road with the help of Google earth map.

Table 4.1: Details of GPS value of Culverts and Bridges of selected project corridor

Sl. No.	GPS No.	Northing	Easting	Chainage (KM)
1	GPS1	26^0 52' 53.68''	88^0 48'25.37''	105.505
2	GPS2	26^0 52' 52.93''	88^0 48'54.97''	106.500
3	GPS3	26^0 52' 52.80''	88^0 49'02.46''	106.527
4	GPS4	26^0 52' 52.28''	88^0 49'19.11''	107.000
5	GPS5	26^0 52' 56.90''	88^0 49'44.92''	107.725
6	GPS6	26^0 52' 52.06'	88^0 50'07.09''	108.396
7	GPS7	26^0 52' 41.22''	88^0 50'12.89''	108.748

vi) Existing Bridges & Culverts

Bridges, culverts form a vital link between the road sections and are basic infrastructure elements in any highway network. Hence it is imperative that they are carefully planned, adequately designed, constructed qualitatively and regularly and meticulously maintained, both for safety of the Highway users and also to retain the viability of the Highway. Bridges, in India, are categorized as follows:

Major Bridge : Total length exceeding 60 m

Minor Bridge : Total length upto 60 m, but exceeding 6 m

Culverts : C D Works of length upto 6 m.

H L Bridge : Bridges with the minimum vertical clearance above design HFL

Submersible Bridge : Bridges designed to cater to normal flow, but submerged under flood conditions

a) Bridges

There are 20 nos. bridges in the project stretch. Out of this 5 no are major bridges and 15 no are minor bridge. The details of existing condition have shown in table 4.2 below.

Table 4.2: Details of Existing Major Bridge

Sl	Existing Chainage	River/ Nallah	Existing				Present condition
			Type of Structure	Span Arrangement (No. x Length) (m)	Carriage way Width (m)	Total Width (m)	
1	107.725	MURTI RIVER	PSC T GIRDER	3 X 42.89	7.4	10.6	Expansion Joint damaged, Guide Bund damaged

Sl	Existing Chainage	River/ Nalla	Existing				Present condition
			Type of Structures	Span Arrangement (No. x Length) (m)	Carriageway Width (m)	Total Width (m)	
2	114.721	JALDHAKA	PSC-T GIRDER	1 X 42.9+ 5 X 43.5+1 X 42.9	7.4	10.7	Expansion Joint damaged, Drainage spout damaged & Guide Bund damaged
3	119.275	GATHIA	BALANCED CANTILEVER	1 X39.15 + 1 X12.15 + 1 X39.15	7.37	10.9	Expansion Joint damaged, Drainage spout damaged & River training required
4	123.71	KUJI DIANA	CONTINUOUs RCC BOX BALANCED CANTILEVER	1 X39.28 + 1 X12.8 + 1 X39.28	7.4	10.9	Expansion Joint damaged, Drainage spout damaged & Guide Bund damaged
5	126.623	DIANA	PSC-T GIREDR	1 X20.78 + 7 X43.6 + 1 X20.78	7.4	10.6	Expansion Joint damaged, Drainage spout damaged& Guide Bund damaged

The damage of the existing river protection work (guide bund) has shown in photograph 4.6 below.

Photograph 4.6: Damage of river protection work

The damage of expansion joint on bridge has shown in photograph 4.7 below.

Photograph 4.7: Damage of expansion joint on bridge

The condition of major bridge deck and girder from bottom has shown in photograph 4.8

Photograph 4.8: Image of major Bridge condition from bed

Table 4.3: Details of Existing Minor Bridge

Sl.	Existing Chainage	River/Nalla	Existing				Present condition
			Type of Structures	Span Arrangement (No. x Length) (m)	Carriageway Width (m)	Total Width (m)	
1	114.118	AMBAKHOLA	SLAB BRIDGE	2 X 9.9	10.1	10.95	Condition of the bridge is good
2	115.93	STREAM	SLAB BRIDGE	1 X 6.94	11.6	12.8	Condition of the bridge is good
3	117.4	MOYNA KHOLA-I	BOX BRIDGE	5 CELL_5 X 3_BOX	10.5	12.5	Condition of the bridge is good

Sl.	Existing Chainage	River/Nalla	Existing				Present condition
			Type of Structures	Span Arrangement (No. x Length) (m)	Carriageway Width (m)	Total Width (m)	
4	109.103	STREAM	SLAB BRIDGE	1 X 6.8	11.3	12.35	Patching required
5	111.63	STREAM	SLAB BRIDGE	1 X 6.75	10.8	11.68	Patching required
6	112.818	KALIKHOLA	A-P_SLAB P-P_T-BEAM	1 X 6.8M+ 1 X 13.25M+1 X 6.8M	7.5	8.55	Expansion Joint & Drainage spout damaged
7	113.548	STREAM	SLAB BRIDGE	1 X 6.7	10.6	11.45	Patching required
8	116.75	SUKHANI	RCC T-BEAM	1 X 13.3 + 1 X 13.3 + 1 X 13.3	7.5	8.32	Expansion Joint, Drainage spout damaged & Concrete Patching, River training required
9	124.525	KALI KHOLA	SLAB BRIDGE	1 X 6.37 + 3 X 10.05	7.5	8.3	Expansion Joint, Drainage spout damaged
10	107	STREAM	SLAB BRIDGE	1 X 6.75	11.8	12.8	Cracks and distress in Side wall

Sl.	Existing Chainage	River/Nalla	Existing				Present condition
			Type of Structures	Span Arrangement (No. x Length) (m)	Carriageway Width (m)	Total Width (m)	
11	117.55	MOYNA KHOLA II	RCC T-BEAM	1 X 13.2	7.6	8.7	Settlement occurred at Abutment towards Teliapara
12	120.975	BALUKHOLA	SLAB BRIDGE	2 X 6.85	7.5	10.95	Cracks and distress observed in Side wall
13	125.571	DHARNIPUR-I	SLAB BRIDGE	2 X 6.9	10	11	Cracks and distress observed in Side wall
14	125.702	DHARNIPUR-II	SLAB BRIDGE	1 X 6.85	11	12	Cracks and distress observed in Super Structure & Side wall
15	140.275	STREAM	SLAB BRIDGE	1 X 7.0	11	12.45	Cracks and distress observed in Super Structure & Foundation broken

b) Culverts

There are 36 nos. Existing Slab culverts and 3 nos. pipe culverts in the project stretch. Taking of existing culvert dimension measurement has shown in photograph 4.9 below.

Photograph 4.9: Taking measurement of the existing culvert

Table 4.4: Details of Existing Culverts

Sl.	Survey Chainage	Type of Structures	Span Arrangement	Present condition
1	106.35	SLAB CULVERT	1_CELL 1.5M X 2.1M	Minor damaged
2	106.527	SLAB CULVERT	1_CELL 4.0M X 1.7M	Minor damaged
3	108.396	SLAB CULVERT	1_CELL 3.1M X 2.5M	Minor damaged

Sl.	Survey Chainage	Type of Structures	Span Arrangement	Present condition
4	109.66	SLAB CULVERT	1_CELL 3.1M X 3.1M	Minor damaged
5	110.2	SLAB CULVERT	1_CELL 3.1M X 1.6M	Minor damaged
6	110.76	SLAB CULVERT	1_CELL 4.1M X 2.4M	Minor damaged
7	111.046	SLAB CULVERT	1_CELL 4.0M X 3.1M	Minor damaged
8	111.29	SLAB CULVERT	1_CELL 3.1M X 3.0M	Minor damaged
9	111.924	SLAB CULVERT	1_CELL 4.1M X 2.6M	Minor damaged
10	113.031	SLAB CULVERT	1_CELL 3.2M X 3.5M	Minor damaged
11	115.519	SLAB CULVERT	1_CELL 2.9M X 4.5M	Minor damaged
12	117.155	SLAB CULVERT	1_CELL 4.5M X 2.55M	Minor damaged
13	118.47	SLAB CULVERT	1_CELL 1.5M X 3.4M	Minor damaged
14	120.596	SLAB CULVERT	1_CELL 1.4M X 1.5M	Minor damaged

Sl.	Survey Chainage	Type of Structures	Span Arrangement	Present condition
15	121.29	SLAB CULVERT	1_CELL 2.5M X 1.2M	Minor damaged
16	121.512	SLAB CULVERT	1_CELL 2.8M X 2.8M	Minor damaged
17	121.652	SLAB CULVERT	1_CELL 1.2M X 2.1M	Minor damaged
18	127.686	SLAB CULVERT	1_CELL 1.5M X 1.2M	Minor damaged
19	129.31	SLAB CULVERT	1_CELL 1.6M X 1.3M	Minor damaged
20	129.464	SLAB CULVERT	1_CELL 2.8M X 2.1M	Minor damaged
21	131.582	SLAB CULVERT	1_CELL 1.7M X 2.2M	Minor damaged
22	132.767	SLAB CULVERT	1_CELL 1.35M X 1.5M	Minor damaged
23	136.397	SLAB CULVERT	1_CELL 1.6M X 1.9M	Minor damaged
24	140.985	SLAB CULVERT	1_CELL 2.5M X 3.8M	Minor damaged
25	143.502	SLAB CULVERT	1_CELL 3.2M X 2.75M	Minor damaged

Sl.	Survey Chainage	Type of Structures	Span Arrangement	Present condition
26	145.265	SLAB CULVERT	1_CELL 3.2M X 1.2M	Minor damaged
27	105.505	SLAB CULVERT	1_CELL 3.0M X 3.25M	Reinforcement of Top Slab exposed
28	108.748	SLAB CULVERT	1_CELL 2.8M X 2.5M	Reinforcement of Top Slab exposed, Top slab badly damaged.
29	109.367	SLAB CULVERT	1_CELL 4.1M X 3.5M	Reinforcement of Top slab exposed. Top slab & Side wall badly damaged.
30	110.468	SLAB CULVERT	1_CELL 3.7M X 3.0M	Reinforcement of Side Wall & Top Slab Exposed. Side wall badly damaged
31	112.173	SLAB CULVERT	1_CELL 2.9M X 2.4M	Reinforcement of Side Wall & Top Slab exposed, Top Slab & Side wall badly damaged
32	117.035	Pipe Culvert	1 x 0.6 dia.	Waterway insufficient, Culvert damaged
33	117.238	SLAB CULVERT	1 X 1.5	Waterway insufficient, top slab & Side wall badly damaged
34	118.961	Pipe Culvert	1 x 0.6 dia.	Waterway insufficient, Culvert damaged

Sl.	Survey Chainage	Type of Structures	Span Arrangement	Present condition
35	119.988	SLAB CULVERT	1 X 1.5	Waterway insufficient, overtopping occurs
36	128.13	SLAB CULVERT	1_CELL 1.8M X 1.5M	Railing totally damaged, Reinforcement of Side Wall & Top Slab exposed
37	134.707	SLAB CULVERT	1_CELL 3.5M X 1.2M	Hutment are constructed on one side opening & other side is damaged
38	117.992	Pipe Culvert	-	CHOCKED
39	134.433	Slab Culvert	1_CELL 1.5M X 1.5M	huge damaged

The damage of girder of a minor bridge has shown in photograph 4.10 below.

Photograph 4.10: Damage of girder of a minor bridge

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 toolbar 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 a surface.
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 drop down 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.

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 and bridges was done in Q-GIS software as shown in figure 4.2 below. The from Google earth pro and TCX converter, contour points elevation generated of the selected area of a particular culvert or bridge was done in Excel sheet and contour was created in Q-GIS software as shown in figure 4.3 below. Then joining the highest elevation near to the culvert or bridge was joined and catchment area created which has shown in figure 4.4. At last the area of the catchment in hector was generated from Q-GIS software as shown in figure 4.5 below.

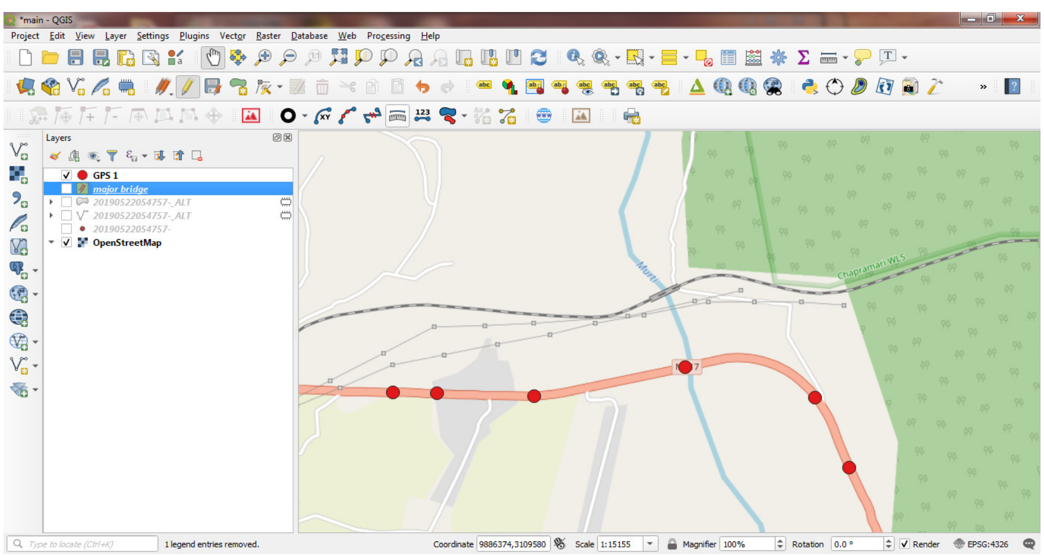


Figure 4.2: Elevation plugin in Q-GIS (step-1)

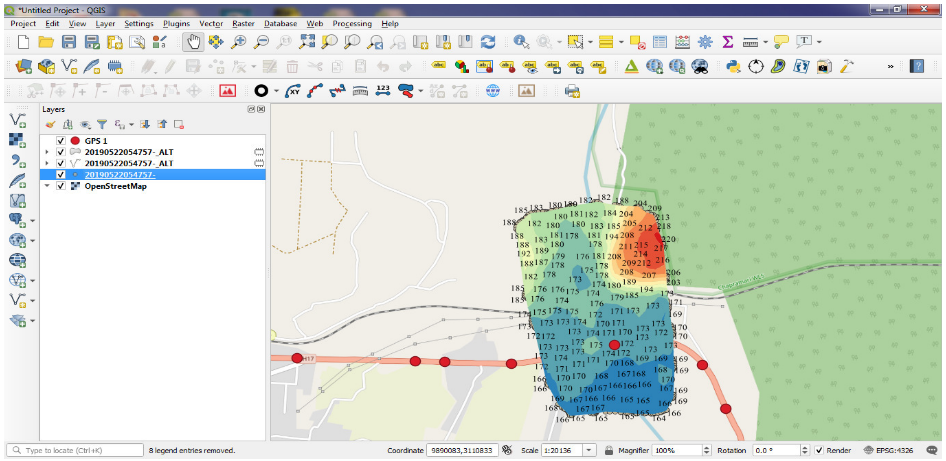


Figure 4.3: Generation of contour map in Q-GIS (step-2)

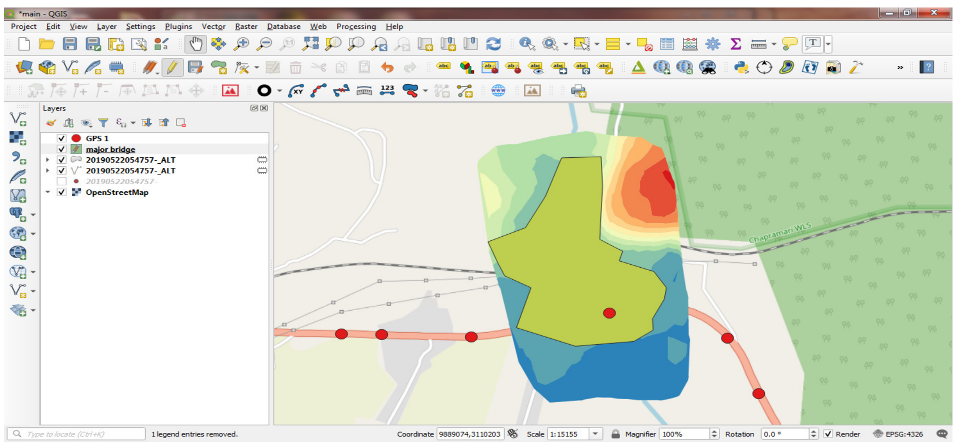


Figure 4.4: Preparation of catchment area in Q-GIS (step-3)

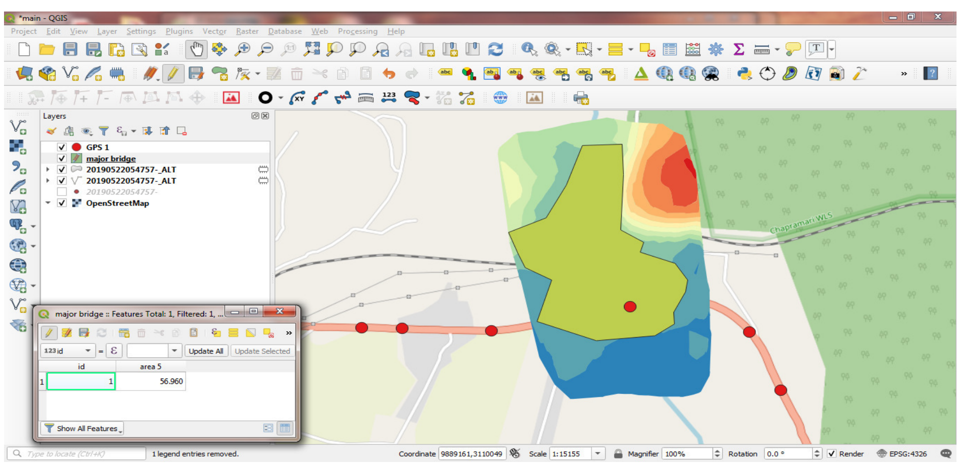


Figure 4.5: Output of area in hector in Q-GIS (step-4)

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 shape and location of it mainly depends on geographical characteristics, 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 figure 5.1.

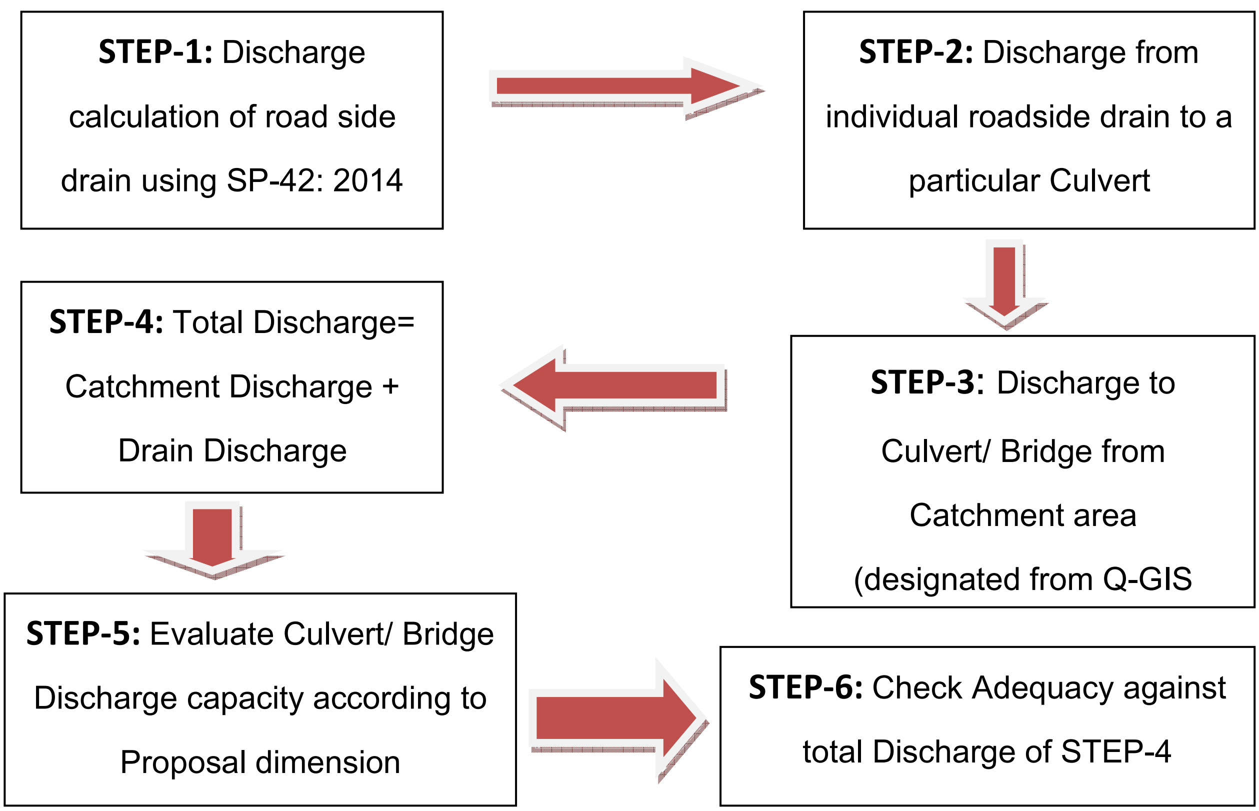


Figure 5.1: Flow diagram of design methodology

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 drains 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: $Q=0.028\ P \times f \times A \times I$ ……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 areal mean rainfall.

A = Catchment area in hectares

I = Design Rainfall intensity in cm/hr for the selected frequency and for duration equal to 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 values of 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 it is 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 entry of 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

$$Q = A \times (1/n \times R^{2/3} \times S^{1/2}) \qquad \text{……Eqn. 5.2}$$

Where,

A= Area of flow in m2

n= Co-efficient of Rugosity

R= Hydraulic mean depth in m

S= Longitudinal slope of drain

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

$$V = k.S^{.5} \qquad \text{……Eqn. 5.3}$$

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 Table 6.6 of IRC: SP: 42-2014.

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5.2 Discharge Calculation of Proposed Road Side Drain to Culvert

Design of Road side Drain (covered)

Chainage: 105.505 km

Length of the road under consideration: 475 m

Width of carriageway: 7m

Width of footpath: 3m

Unpaved/ shoulder portion: 2.5m

Total width of built-up section for one side: 15m

5.2.1 Discharge calculations

(a) Co-efficient of runoff

As per vide table 5.1, the co-efficient of runoff from various surfaces are-

Bituminous or concrete pavement surface = 0.9

Unpaved/Shoulder portion = 0.9

Footpath or paved portion = 0.9

Built-up area = 0.5

Table 5.1: Co-efficient of runoff for different surface

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

Description of Surface	Coefficient of Runoff (P)
Steep, bare rock and watertight 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

Average runoff co-efficient, P = (0.9x3.5+0.9x3+0.9x2.5+0.5x15)/(3.5+3+2.5+15) = 0.65

(b) Time of concentration

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

Time required to reach drain from the remotest point of built-up section taken into consideration is = 15/v sec =15/0.06= 250 sec= 4.17 min

Length of drain with flow in single direction = 475m

Assumed v in drain section= 0.75 m/sec

Time required to reach at outfall from the remotest point of drain taken into consideration= 475/v sec = 475/0.75 sec = 633.33 sec = 10.56 min

Hence time of concentration = 4.17+10.56 = 14.72 min

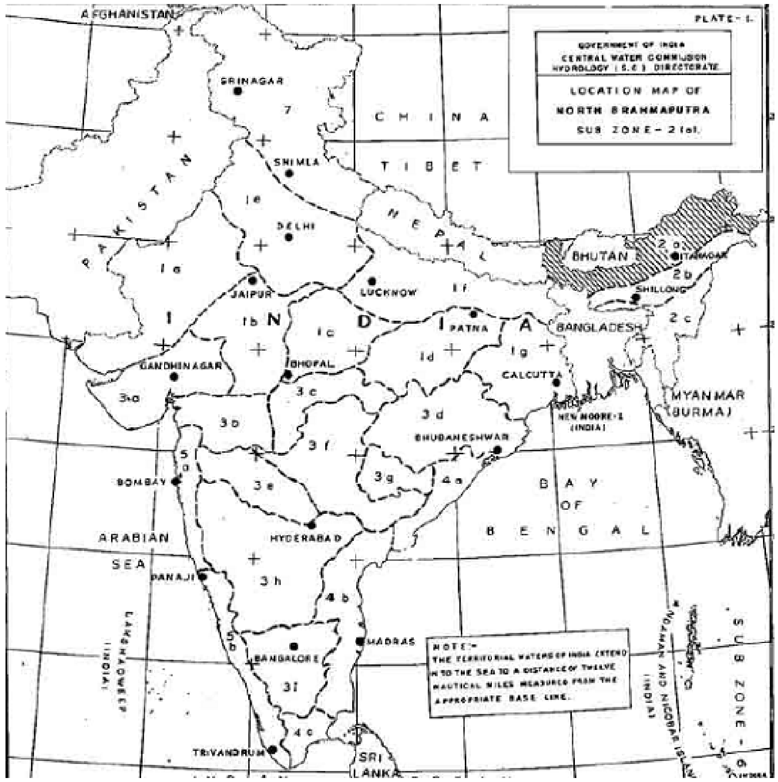
(c) Area Calculation for runoff

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

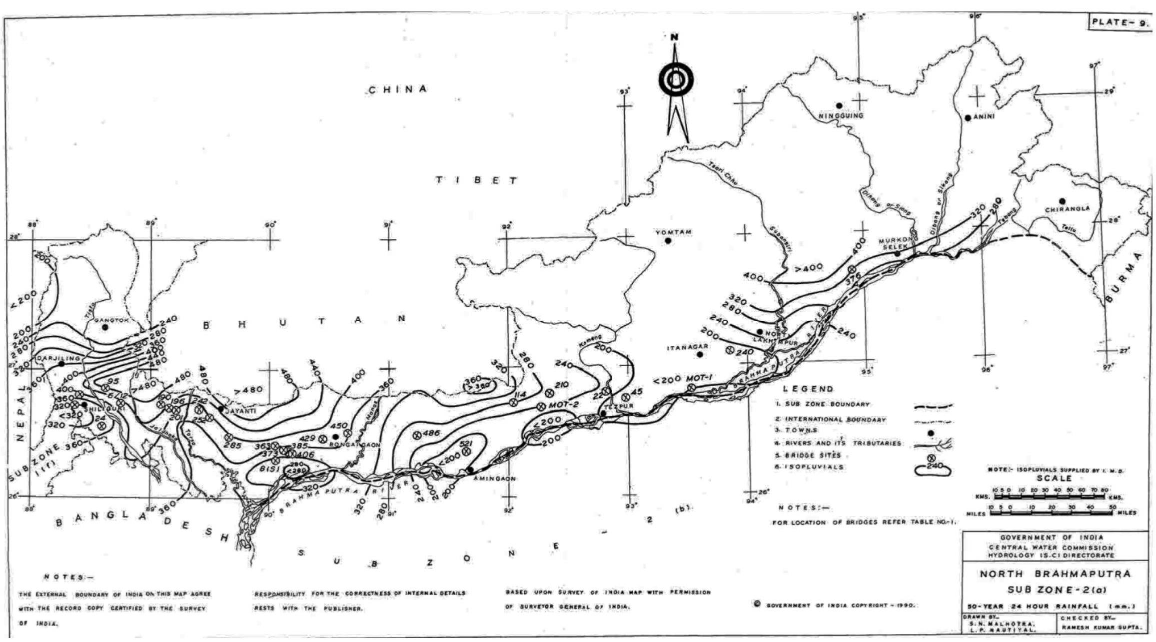
= (15+3.5+3+2.5)x475/10000 ha = 1.14 ha

(d) Rainfall intensity 'I' calculation

24-hour maximum rainfall for 50-year recurring intervals for the location involved from map 5.1 & map 5.2 (CWC map) = 460 mm



Map 5.1: Study area come north Brahmaputra sub-zone 2(a) (source: CWC report)



Map 5.2: Study area receiving the rain falls 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
Percentage of 24 hour rainfall	16	25	31	39	55	65	100

Now conversion factors for converting 24 hr rainfall intensity to shorter duration (1hr) rainfall intensity from table 5.2= 460 x 39/100 = 179.4 mm= 17.94 cm

For time of concentration of 14.72 min conversion factor for shorter duration 14.72 min from table 5.3 = 2.42

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

Duration minutes	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 15.28 min = 17.94 x 2.42 = 43.68 cm

(e) Spread factor

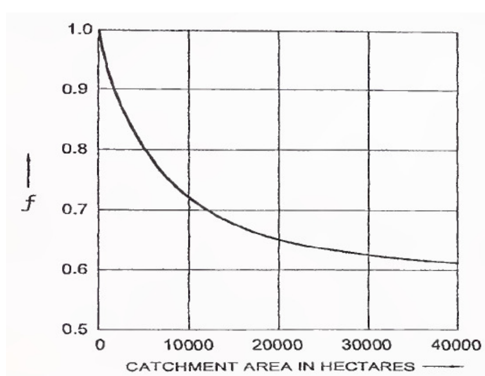


Figure 5.2: Spread factor calculation (source: IRC: SP: 42-2014 fig. 6.1)

For area 1.14 ha. spread factor from figure 5.2, f = 1.0

(f) Discharge to drain from runoff

Discharge, Q is given by eqn.-5.1, Q= 0.028 P x f x A x I = 0.028x0.65x1x1.14x43.68

= 0.906 cumecs

(g) Checking of discharge capacity of Drain

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

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

For concrete surface from table 5.4, n= 0.011

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

Sl. No.	Surface Descriptions	Manning's 'n'
	Surface Description	
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	0.4
10	Dense underbrush	0.8

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

Rectangular drain suggested having following data

Total width at bottom= 1.0 m

Wall thickness = 0.12m

Clear width at bottom = 0.76 m

Depth provide = 1.0 m

Area = 1.0x0.76= 0.76 m^2

Wetted perimeter = 1+0.76+1=2.76 m

R= Area/ Wetted perimeter = 0.76/2.76 = 0.28 m

From eqn- 5.2, Q = 0.76x 1/0.011 x $0.28^{2/3}$ x $0.002^{1/2}$ = 1.322 cumecs (ok)

(h) Discharge from both side drain

For culvert at location ch. 105.505 km total discharge = 0.906x2 = 1.812 cumecs

5.3 Catchment Area calculation of culvert 105.505 km chainage by Q-GIS model

Catchment and drainage network delineation is 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 Helps of GPS on Google Earth Map and chainage by the Rodometer on the selected stretch and mark on the map. An image of fixing of chainage is shown in photograph 5.1 and GPS values in table 5.5.

Photograph 5.1: Fixing of chainage on culvert

Table 5.5: GPS value and chainage of the culverts & bridges

Sl. No.	GPS No.	Descriptions	Northing	Easting	Chainage (KM)
1	GPS1	Culvert 1	26^0 52' 53.68"	88^0 48'25.37"	105.505
2	GPS2	Culvert 2	26^0 52' 52.93"	88^0 48'54.97"	106.500
3	GPS3	Culvert 3	26^0 52' 52.80"	88^0 49'02.46"	106.527
4	GPS4	Minor Bridge	26^0 52' 52.28"	88^0 49'19.11"	107.000
5	GPS5	Major Bridge	26^0 52' 56.90"	88^0 49'44.92"	107.725
6	GPS6	Culvert 4	26^0 52' 52.06'	88^0 50'07.09"	108.396
7	GPS7	Culvert 5	26^0 52' 41.22"	88^0 50'12.89"	108.748

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.

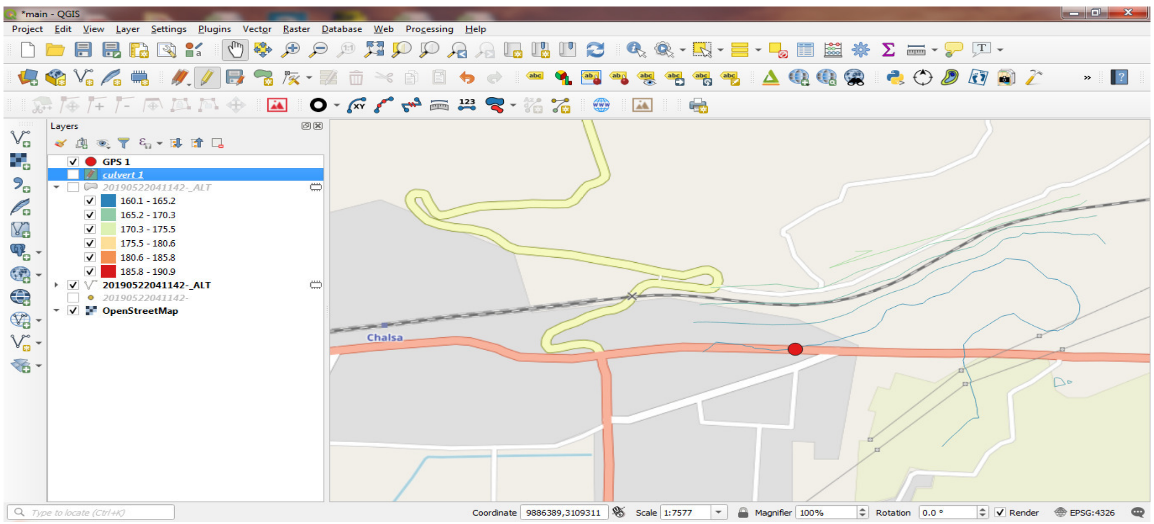


Figure 5.3: Elevation plugin at 105.505 km ch.

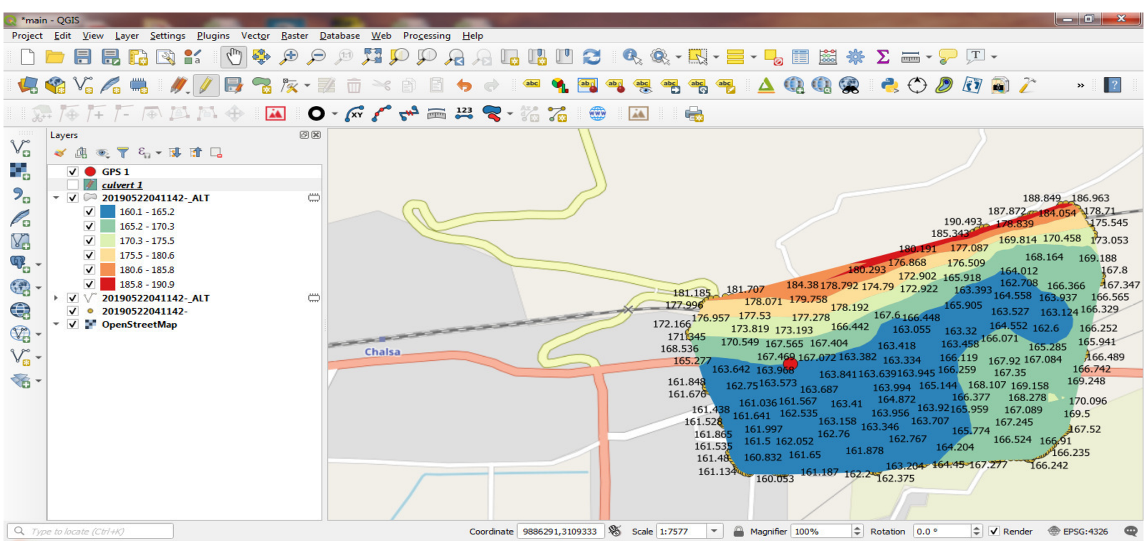


Figure 5.4: Generation of contour map at 105.505 km ch.

5.3.3 Export the Catchment Area from Contour

Contour map consists of number of loop. 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 catchment according to numbering of culverts and bridges are generated from Q-GIS has shown in table 5.6 below.

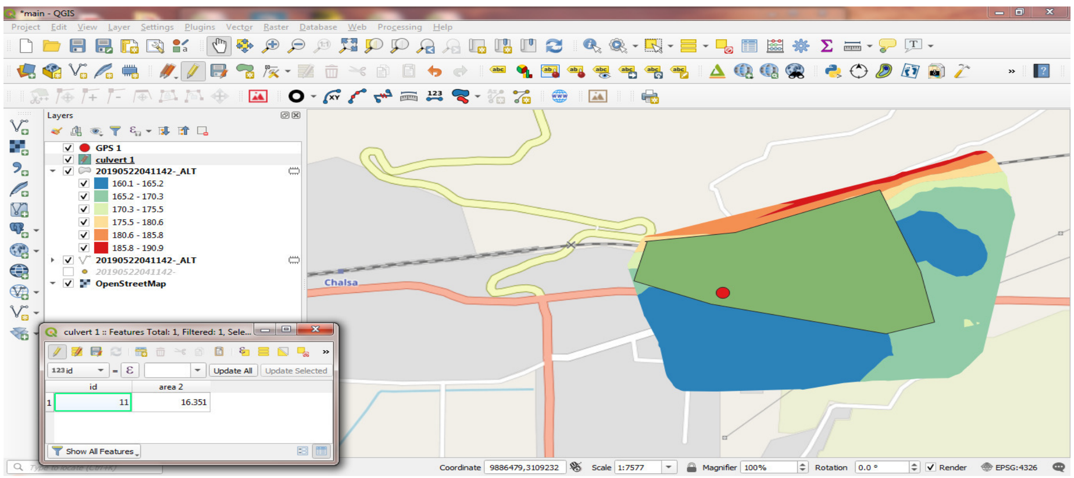


Figure 5.5: Generation of contour map at 105.505 km ch.

Table 5.6: Chainage wise catchment area of culverts and bridges

Sl. No.	GPS No.	Descriptions	Chainage (KM)	Catchment Area (ha.)
1	GPS1	Culvert 1	105.505	16.351
2	GPS2	Culvert 2	106.500	2.33
3	GPS3	Culvert 3	106.527	4.595
4	GPS4	Minor bridge	107.000	21.331
5	GPS5	Major bridge	107.725	56.96
6	GPS6	Culvert 4	108.396	13.491
7	GPS7	Culvert 5	108.748	9.148

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 = 16.351 ha.

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

k	Land cover
0.076	Forest with heavy ground litter, hay meadow (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 waterway (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 105.505 km ch. culvert,

From figure 5.1, f= 1

From table 5.1, P= 0.65

From table 5.7, K= 0.305

Velocity from eqn.- 5.3, $v = k.S^{.5} = 0.305 \times 0.98^{.5} = 0.302$ m/s.

Time of concentration = 25.33 min

Rainfall intensity for min, I = 33.6 cm/hr

Eqn.-5.1, Q =0.028 x f x P x A x I=0.028x1x0.65x16.351x33.6 cumecs = 10.007 cumecs

5.4 Culvert Adequacy check

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

5.4.1 Total Discharge to Culvert

Now, total discharge coming to culvert = Drain Discharge + Catchment Discharge (Q-GIS model) = 1.812 + 10.007 cumecs = 11.819 cumecs

5.4.2 Culvert Discharge capacity (conventional method)

The improvement proposal that was suggested for this project study area are as per table 5.8 below-

Table 5.8: Improvement proposal of slab culverts or bridges

Sl. No.	Chainage	Type	span	Improvement proposal
1	105.505	culvert	3.0 m X 3.25m (single cell)	Dismantling of existing culvert & provide 1 no 3m X 4m box culvert on existing carriageway
2	107.000	minor bridge	1 X 6.75m cell	Dismantling of existing bridge & provide 1 no 8m X 5m box type bridge on existing carriageway
3	108.748	culvert	2.8m X 2.5m (single cell)	Dismantling of existing culvert & provide 1 no 3m X 4m box culvert on existing carriageway

A box culvert was proposed for this location, size of which is mention in table 5.7 under sl no. 1. and also a location drawing has shown below in figure 5.6.

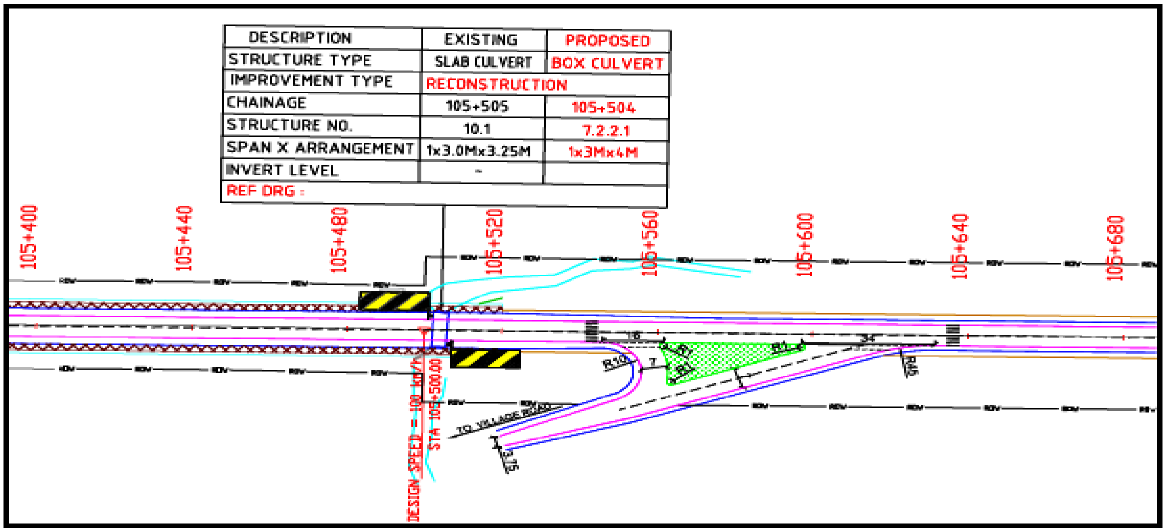


Figure 5.6: Plan showing improvement proposal for culvert to be provided at ch. 105.505 km (source: Gairkar N.H Sub-Division, P.W.(Roads) Dte.)

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 proposed culvert at chainage 105.505 km was shown in figure 5.7, figure 5.8 & figure 5.9 below.

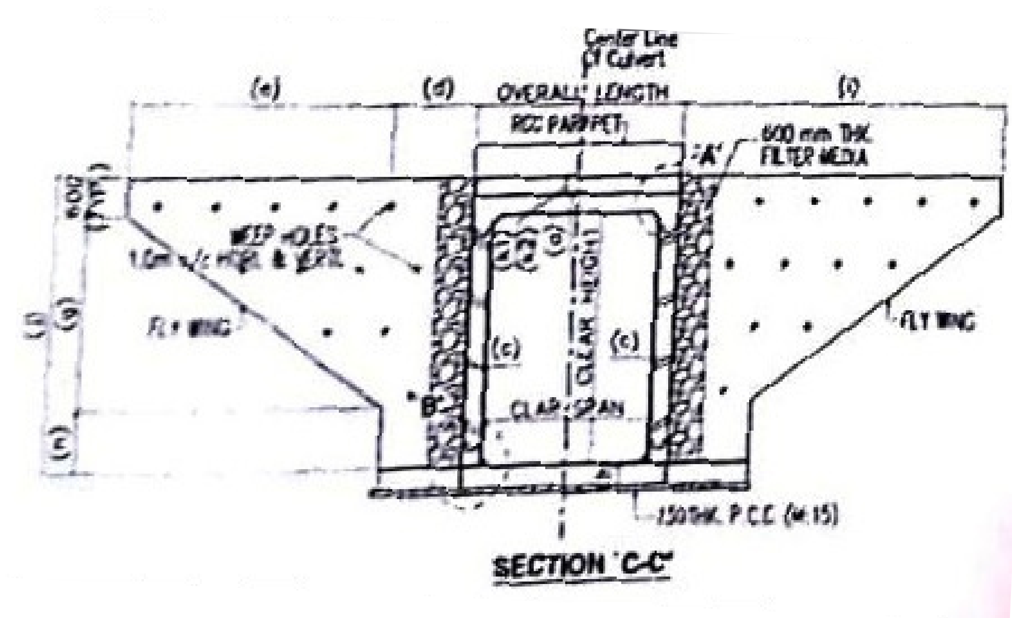


Figure 5.7: Cross section of culvert along road

(source: Gairkar N.H Sub-Division, P.W(Roads) Dte.)

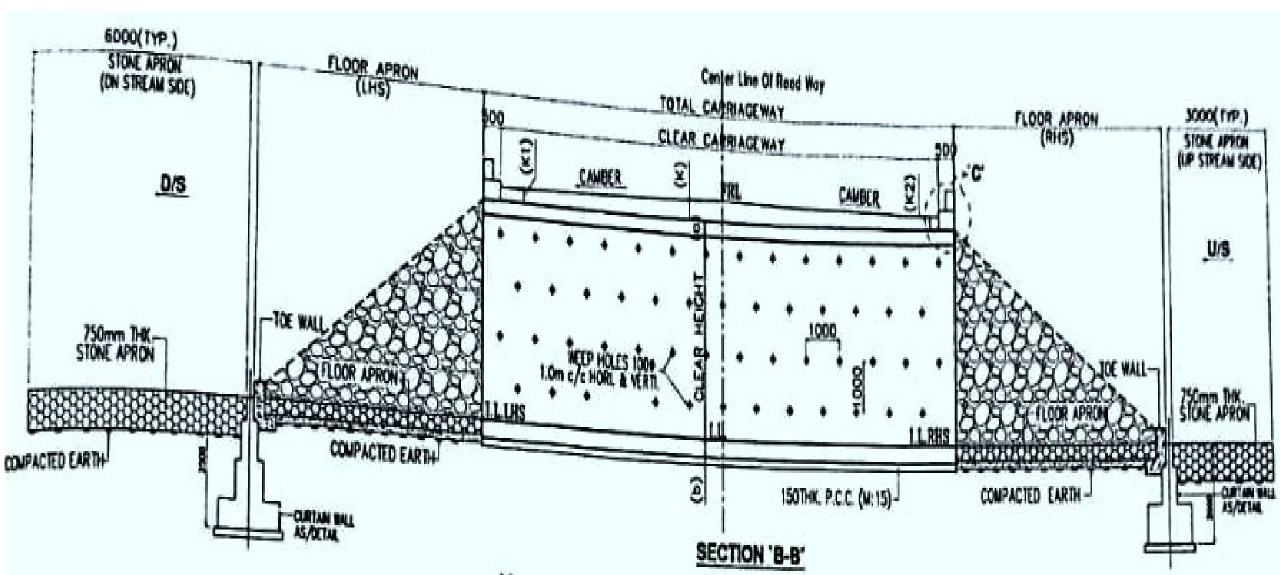


Figure 5.8: Cross section of culvert across road at chainage 105.505 km

(source: Gairkar N.H Sub-Division, P.W(Roads) Dte.)

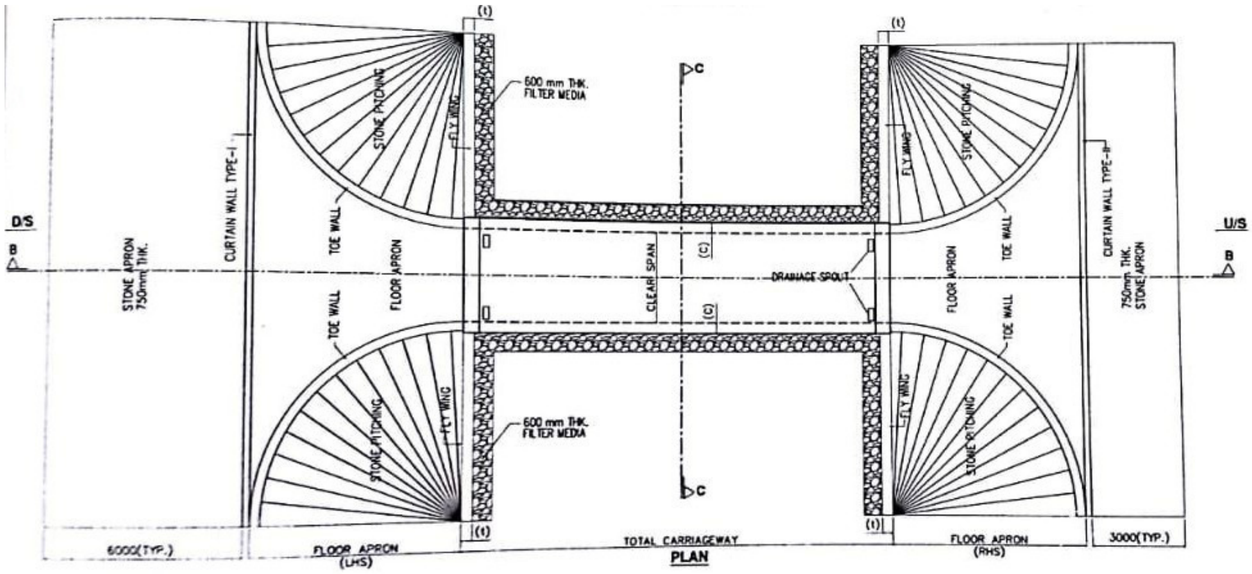


Figure 5.9: Culvert across road (source: Gairkar N.H Sub-Division, P.W(Roads) Dte.)

From proposed culvert dimension, considering full flow condition during rainy season

Span (a) = 3m

Depth (b) = 4m

Considering a max free board = 0.5m

Depth of flow = 4.0 – 0.5 = 3.5m

Area (A) = 3 x 3.5 = 10.5 m^2

Wetted perimeter (P) = 3.5x2 + 3 = 10m

Hydraulic mean depth (R) = A/P = 10.5/10 = 1.05m

Minimum longitudinal slope provided in bed (S) = 0.1% = 0.001

From table 5.9, Manning's roughness co-efficient (n) = 0.013

Table 5.9: 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

Sl. No.	Ditch Lining	Manning's 'n'	Allowable Velocity to Prevent Erosion m/sec.
	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,		
	Good or 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.- 5.2, $Q = A \times v = 1/n \times A \times R^{2/3} \times S^{1/2} = 1/0.013 \times 10.5 \times 1.05^{2/3} \times 0.001^{1/2}$ = 26.386 cumecs, this is greater than the total discharge coming from drain and catchment i.e. 11. 819 cumecs. All details of calculation are attached in Appendix.

CHAPTER-6

RESULT AND DISCUSSION

6.1 Outcomes of Conventional Design

6.1.1 Discussion on Drain Design

Slope check

A typical drain section of dimension 1.0m x 1.2m was already proposed for the selected corridor portion. This typical drain 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. Careful consideration also made so that culvert invert level and drain invert level difference is within the permissible limit. All calculation details is provided in Annexure-A.

Discharge check

Actual discharge coming from individual catchment area to drain was different for different chainage as its area and time concentration different. The rainfall intensity also depends on time of concentration which is also area dependent. Another discharge calculation was done on the basis of the property of typical section assumed. This was also different in different chainage. A cross check was done whether the proposed section is capable to drain off the discharge coming from the catchment due to rain.

6.1.2 Discussion on Culverts & Bridges Hydraulic Capacity

Discharge calculation of culvert & bridges

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 and for major bridges 1.2m. Discharge calculated in cumecs is found very rational. Rainfall intensity is calculated on the basis of time of concentration to reach the discharge point from the farthest pint of catchment.

6.2 Outcomes of Q-GIS based on Hydraulic design model

6.2.1 Contour Map

It is found that elevation of NH-31C from Chalsa to Telipara 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 RHS to LHS of road. So for each culvert and bridges individual contour map generated to get a clear view catchment area. Contour having same value are connected and contour map was generated as shown in figure 6.1 below.

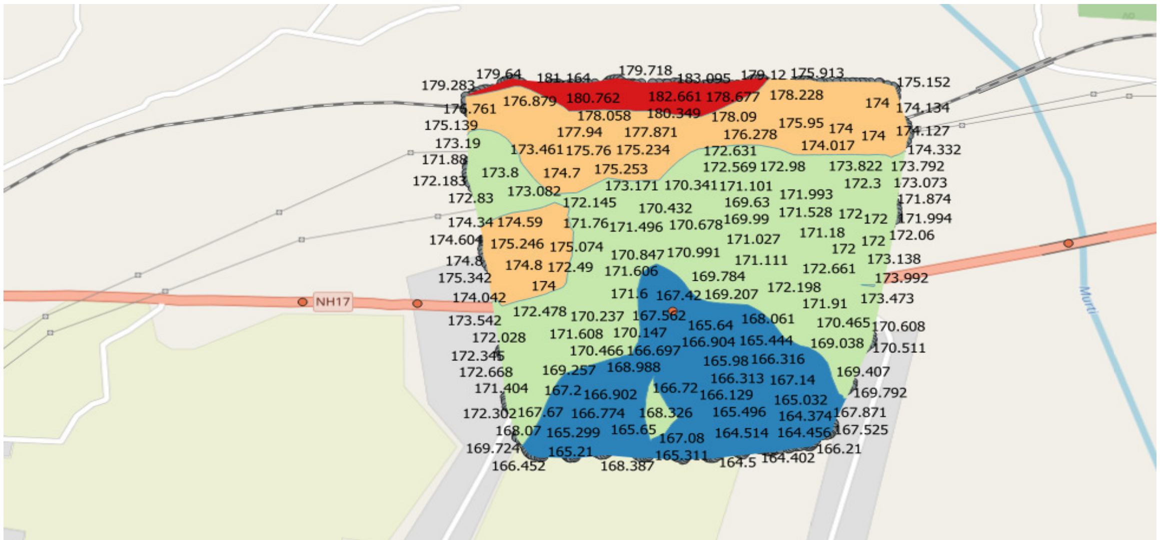


Figure 6.1: Contour map of the minor bridge

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 area all the culverts and bridges has shown in table 6.1 below.

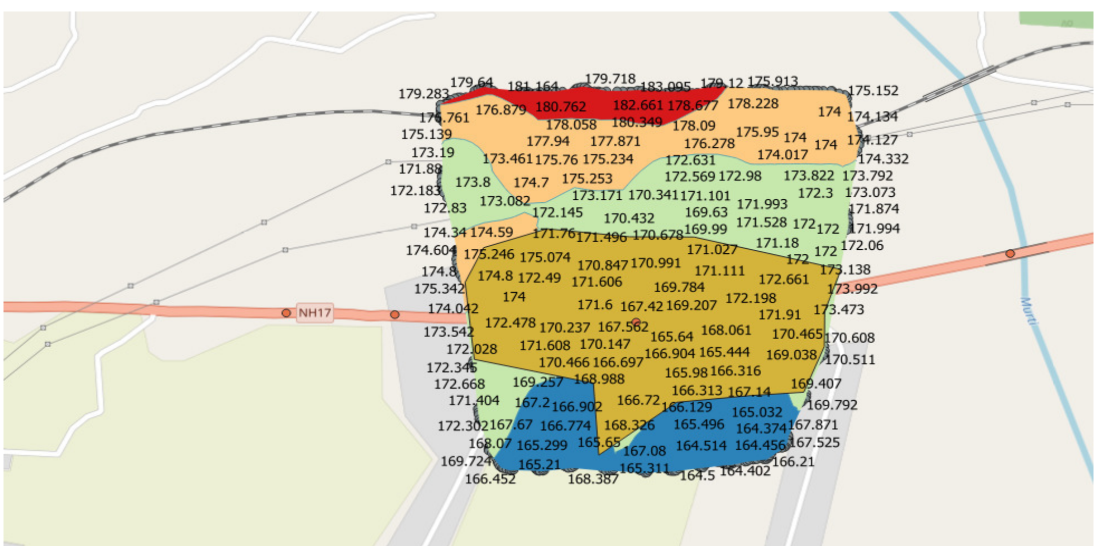


Figure 6.2: Catchment area of the minor bridge

Table 6.1: Catchment area accordingly to culvert & bridge location

Sl. No.	Descriptions	Chainage (KM)	Catchment Area (ha.)
1	Culvert 1	105.505	16.351
2	Culvert 2	106.500	2.33
3	Culvert 3	106.527	4.595
4	Minor bridge	107.000	21.331
5	Major bridge	107.725	56.96
6	Culvert 4	108.396	13.491
7	Culvert 5	108.748	9.148

6.2.3 Culverts & Bridges Discharge Computation

Discharge calculation is done for each culverts and bridges 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 provided in Appendix that all the culverts and bridges in the selected project stretch was sufficient to dispose the discharge coming from catchment area from Q-GIS as well as drain discharge also. It was found from table 6.2 that existing as well as proposed culverts and bridges not only adequate for drainage discharge but also have higher value of factor of safety (F.O.S).

Table 6.2: Discharge from conventional design and Q-GIS model based output

Sl. No.	Descriptions	Chainage (KM)	Discharge from Q-GIS model & Drain (cumecs)	Discharge from conventional design (cumecs)	Remarks
1	Culvert 1	105.505	11.819	26.386	Adequate with a higher margin of F.O.S
2	Culvert 2	106.500	1.894	3.730	Adequate with a higher margin of F.O.S
3	Culvert 3	106.527	4.101	9.638	Adequate with a higher margin of F.O.S
4	Minor bridge	107.000	20.110	144.409	Adequate with a higher margin of F.O.S
5	Major bridge	107.725	20.172	5185.644	Adequate with a higher margin of F.O.S
6	Culvert 4	108.396	9.725	13.779	Adequate with a higher margin of F.O.S
7	Culvert 5	108.748	7.199	26.386	Adequate with a higher margin of F.O.S

CHAPTER-7

CONCLUSION AND RECOMMENDATION

7.1 Conclusion and Recommendation

Q-GIS application tool was used in this research work in order to fix the catchment area for calculating surface run-off based on rational method. The main purpose of this study is to apply freely available open surface tool to check the existing and proposed cross drainage structure dimensions are sufficient or not, to disposed quickly the run-off from catchment area (from Q-GIS software) and road side drain.

Q-GIS is a cost effective tool which has the potential to provide improvements to the projects without extra cost. Moreover this tool can promote the knowledge gathering and the scientific development through GIS application, calibration and checking of discharge in drainage network design can be done.

- ❖ From the study it has been found that all the culvert and bridge section proposed and already exist in the selected study area was sufficient to dispose the discharge coming from catchment area as well as from drain discharge. It was also found that most of the section not only adequate for drainage discharge but also maintaining higher F.O.S.

- ❖ In this study minor bridge situated at 107.00 km is adequate but design discharge is very high with respect to Q-GIS model discharge as F.O.S is 7.18.

- ❖ For major bridge (Murti Bridge) at 107.725 km is adequate but design discharge is extremely high with respect to Q-GIS model discharge as F.O.S is 257.08.

7.2 Future Scope of Work

- 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.

- 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

Appendix

Drain Discharge Check

Parameter of drain are as follow

n = 0.011

A = 0.76 m^2

P = 0.62 m

R = 0.28 m

S = 0.002

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

Assumed v in drain section = 0.75 m/sec

24 hr. maximum rainfall near project site with frequency of 50 years = 460 mm

1 hr. maximum rainfall near project site with frequency of 50 years = 17.94 cm

Sl. No.	Chainage from	chainage to	length	Carriageway		Unpaved/paved shoulder		footpath		land adjacent to footpath		Co-efficient of run-off P_{av}	Time of concentration t_c (min.)	Total area A (ha.)	conversion factor	spread factor f	Rainfall intensity I (cm)	Actual discharge Q= 0.028 $f.P_{av}.A.I$ (cumecs)	Channel section Discharge calculation $Q=1/n.A.R^{2/3}.S^{1/2}$ (cumecs)	Check
				half width (m)	Co-efficient of run-off P	width (m)	Co-efficient of run-off P	Width (m)	Co-efficient of run-off P	width (m)	Co-efficient of run-off P									
1	105.030	105.505	475	3.5	0.9	2.5	0.9	3	0.9	15	0.5	0.65	14.72	1.14	0.95	1	43.68	**0.906**	**1.322**	**OK**
2	106.540	107.000	460	3.5	0.9	2.5	0.9	3	0.9	15	0.5	0.65	14.39	1.10	0.96	1	44.04	**0.885**	**1.322**	**OK**

Calculation of CD Discharge

Sl. No.	Description	Chainage (KM)	Size	Type	Free board (m)	Clear Span (m)	Clear Height (m)	Manning co-efficient n	Area span x height A (m^2)	Wetted perimeter (m)	Hydraulic mean depth R (m)	Bed slope S	CD Discharge $Q= 1/n. A.R^{(2/3)}.S^{(1/2)}$ cumecs
1	Culvert 1	105.505	3.0mX4.0m (single cell)	Box	0.5	3.00	3.50	0.013	10.50	10.00	1.05	0.001	**26.386**
2	Culvert 2	106.500	1.5mX2.1m (single cell)	Box	0.5	1.50	1.60	0.013	2.40	4.70	0.51	0.001	**3.730**
3	Culvert 3	106.527	4.0mX1.7m (single cell)	Box	0.5	4.00	1.20	0.013	4.80	6.40	0.75	0.001	**9.638**
4	Minor bridge	107.000	8.0mX5.0m (single cell)	Box	0.5	8.00	4.50	0.013	36.00	17.00	2.12	0.001	**144.409**
5	Major bridge	107.725	3X42.89 (2x1.2 abutment & 2x1 pier)	PSC T-Girder	1.2	124.27	5.70	0.013	708.34	135.67	5.22	0.001	**5185.644**
6	Culvert 4	108.396	3.1mX2.5m (single cell)	Box	0.5	3.10	2.00	0.013	6.20	7.10	0.87	0.001	**13.779**
7	Culvert 5	108.748	3.0mX4.0m (single cell)	Box	0.5	3.00	3.50	0.013	10.50	10.00	1.05	0.001	**26.386**

Appendix

Discharge calculation for Catchment area from Q-GIS

Sl. 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= 0.028 f.P.A.I cumecs
1	Culvert 1	105.505	16.351	459	0.305	0.98	0.302	25.33	0.731	460	33.6	0.65	1	**10.007**
2	Culvert 2	106.500	2.330	150	0.305	0.33	0.176	14.20	0.971	460	44.7	0.65	1	**1.894**
3	Culvert 3	106.527	4.595	234	0.305	1.28	0.345	11.29	1.066	460	49.0	0.65	1	**4.101**
4	Minor bridge	107.000	21.331	404	0.305	1.40	0.361	18.66	1.027	460	47.2	0.65	1	**18.340**
5	Major bridge	107.725	56.960	960	0.305	0.93	0.294	54.40	0.423	460	19.5	0.65	1	**20.172**
6	Culvert 4	108.396	13.491	403	0.305	1.50	0.374	17.98	0.861	460	39.6	0.65	1	**9.725**
7	Culvert 5	108.748	9.148	298	0.305	0.34	0.177	28.09	0.94	460	43.2	0.65	1	**7.199**

Culvert Adequacy Check

Sl. No.	Drain Chainage		Description	Outlet Chainage	Drain Discharge to Culvert or Bridge (cumecs)		Discharge coming from catchment area to Culvert or Bridge (cumecs)	Total Discharge in Outlet (cumecs)	CD Discharge Capacity cumecs	Check
	Start	**End**			**LHS (1)**	**RHS(2)**	**(3)**	**(1)+(2)+(3)**		
1	105.530	105.505	Culvert 1	105.505	0.906	0.906	10.007	**11.819**	**26.386**	**ok**
2	---	---	Culvert 2	106.500	0	0	1.894	**1.894**	**3.730**	**ok**
3	---	---	Culvert 3	106.527	0.000	0.000	4.101	**4.101**	**9.638**	**ok**
4	106.540	107.000	Minor Bridge	107.000	0.885	0.885	18.340	**20.110**	**144.409**	**ok**
5	---	---	Major bridge	107.725	0.000	0.000	20.172	**20.172**	**5185.644**	**ok**
6	---	---	Culvert 4	108.396	0.000	0.000	9.725	**9.725**	**13.779**	**ok**
7	---	---	Culvert 5	108.748	0.000	0.000	7.199	**7.199**	**26.386**	**ok**