



**Addis Ababa University
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**HIGHWAY DRAINAGE FACILITIES PROBLEMS
(Case Study – Assessment of Drainage
Problems in Adama)**

**Meraf Elias
2015**

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(Case Study – Assessment of Drainage
Problems in Adama)

Meraf Elias Beshah

**A thesis submitted to School of Graduate Studies, Addis
Ababa University in partial fulfillment of the
Requirements for the Degree of Masters of Science in
Civil and Environmental Engineering**

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Thesis submitted to School of Graduate Studies, Addis Ababa
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(Hydraulics Engineering)

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Abstract

Most designs of roads projects have limitations with drainage related issues. Especially, town section drainage design and provision needs a great consideration as the scale of damage due to lack of proper drainage facilities provision is high.

This research paper is an assessment of drainage problems in Adama, section of the Nazareth-Assela road project, Ethiopia. Based on the site investigation, the design and the available data of the area, the analysis has been done.

The design floods are estimated using SCS method per the requirement of Ethiopian Roads Authority Drainage Design Manual, 2013. The spread sheet program has been developed to estimate the design flood using SCS method. The existing structures hydraulics data have been modeled using Hydrologic Engineering Center-River Analysis System and HY8 Culvert analysis to determine the capacity.

The results of the finding include: a) Inadequate structure provision which the hydraulic capacity of the crossing structures, being less than the design discharge b) Lack of properly designed side drains c) Lack of inlet/outlet protection works of the crossing structures d) Growth of vegetation at inlet and outlet of the crossing structures and e) Siltation and blockage with sand and stone respectively of the crossing structures.

In this connection recommendations forwarded include: a) Due consideration, to be given to important factors such as appropriate design method to be employed, variability of the climate and future settlement to be taken into account during the design of the drainage facilities b) Ensure that the drainage facilities are integrated with the master plan c) Ensure that if the town administration takes measure to keep the serviceability of the road, the rehabilitation needs to be supplemented by the design and d) Continuous monitoring of the drainage facilities.

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List of Abbreviations and Definitions

CN	-	Culver Number
CSA	-	Central Stastical Agency
DDAC	-	Dire Dawa Administrative Council
DEM	-	Digital Elevation Model
EDDM	-	ERA Drainage Design Manual
ERA	-	Ethiopian Roads Authority
EW1	-	Express way
FHWA	-	Federal Highway Administration
GIS	-	Geographic Information System
HEC-RAS	-	Hydrologic Engineering Center – River Analysis System
HSG	-	Hydrological Soil Group
la	-	Initial abstraction
MoWUD	-	Ministry of Works and Urban Development
NMSA	-	National Meteorology Service Agency
NRCS	-	Natural Resources Conservation Service
PCC	-	Portland Cement Concrete
SCS	-	Soil conservation service
Tc	-	Time of concentration
TR	-	Technical Release
WS	-	Water Surface elevations

1. Introduction

1.1 General

Adequate drainage facility is an important factor that should be given paramount importance in the design of highways since it greatly determines the highways serviceability and usable life. Drainage problems in urban areas include flooding of residential areas, deterioration of roads, land degradation, sedimentation, and blockage of drainage facilities as well as water logging. In this connection, highway hydraulic structures perform the vital function of diverting or removing surface water from the highway.

This is especially true in the context of Ethiopia, where watersheds of many urban centers receive significant amount of annual rainfall and where rainfall intensity is generally high. Control of runoff at source, flood protection, and safe disposal of excess water through proper drainage facilities becomes very crucial to ensure the serviceability of the highway.

In addition, with urbanization, impermeability increases with the increase in impervious surfaces such as residential houses and commercial buildings and drainage pattern is bound to create increasing environmental problems such as land degradation. This is a crucial problem facing the existing and future road infrastructure of the country.

In spite of these real threats, drainage facilities in most urban centers of Ethiopia are at a lower coverage. Planning and design rarely guide construction of such facilities as well as its management leading significant number of recently constructed roads to be affected and damaged by flood. The construction of improperly designed road and lack of integration with the master plan frequently creates considerable adverse impact on the environment and socio-economic activity making it difficult to achieve the required service from a given infrastructure.

Based on the above background, this research paper attempts to the drainage problems of Adama town along the Nazareth-Assela Road section. While there are no rivers and streams in the Adama town, floods are common sources of complaint from the habitats given the fact that the town is settled in between and on escarped slope that leads to generate greater capacity of runoff and erosion. The flash flood that originate from the surrounding areas of high slope rush down towards the town part and causes damage especially during the rainy season.

The flooding problem is worsened by the lack of adequate drainage structure provisions on the major roads of the city. Nazareth-Assela road is one of such roads which have major drainage problem. The road was upgraded in 2010 by a China Company.

Major highway drainage facilities found in Adama town are four culvers. Hence this research paper mainly based on in the analysis of the culverts.

1.2. Statement of the Problem

Proper drainage is essential for a highway to function properly. Hence, drainage is one of the most important factors to be considered in the road design, construction and maintenance projects.

The road sections which have problems in the study area are road section around km 2+210 (Culvert 1), road segment from km 2+210 to 3+300 (Culvert 2 to Culvert 3) and road section around km 4+325 (Culvert 4). The location and designation of the Culverts are shown on Figure 7.

The major problems that are identified through desk study in the study area are as follows:-

- ◆ Flooding of residential area in Adama Town and damaged road section as result of overtopping
- ◆ Inadequate structures that creates traffic interruption during flood
- ◆ Highly constricted structures that create scouring at the outlet

- ◆ Scouring of the adjacent road side drainage and sand deposition
- ◆ Poor position of roadside drainage and embankment provision
- ◆ Design of structure without considering the environment and
- ◆ The presence of settlements on this flood plain section.

The problem is hereunder described to show the extent of the drainage problem in Adama town section.

i) Road section around km 2+210 (Culvert 1)

The existing slab culvert at this section is 1.0m clear span and 0.60m clear height. The flow that reaches from the right side of the road at this section is more than the capacity of the structures through paved ditch. Therefore, the structure is frequently overtopped. Considering the severity of the flood problem, additional structure, which is a double box culvert 3.0m by 1.5m, has been constructed next to the existing structure by the town administration about a year and half ago. However, according to the residents of the area the flooding problem still exists and this is especially true during the rainy season.



Photo 1: Existing slab culvert and the newly constructed box culvert (Right side of the road)



Photo 2: The newly constructed box culvert at the downstream (Left)



Photo 3: Side drains that discharges at the structures located around Km 2+210

ii) The Road section between km 2+750 and 3+285 (Culvert 2 and Culvert 3)

This section of the road is severely damaged by the flood that comes from right side of the road. The inadequate structure not only affects the road but it also creates flood problem in the surrounding area due to the resulting backwater.

In this section of the road, there are one box culvert (Culvert 2) at km 2+750 with span of 4.0m and clear height of 1.50m and one slab culvert (Culvert 3) at km3+285 with span of 2.5m and clear height of 1.50m. The existing structure at km3+285 (Culvert 3) is located at inappropriate location. The runoff from the catchment reaches at crossing structure after inundating considerable town section.



Photo 4: Box Culvert (Culvert 2) at Km 2+750 (Right)

Photo 5: Slab Culvert (Culvert 3) at Km 3+285 (Right)

The road frequently overtopped and the pavement is damaged as shown in the photo below.



Photo 6: Overtopped and Damaged Asphalt Road Section around Km 3+300

This segment of the road is requiring urgent remedial measure that minimizes the flood damage on the road. In addition, to make the surrounding residential areas habitable during rainy season by minimize flood damage.

iii) Road Section at Km 4+325 (Culvert 4)

There is a slab culvert with 3.0m span and 2.0m clear height. The structure is excessively constricted and the outlet river bank is severely eroded. According to the information acquired from the residents; there is always overtopping of the structure when it rains.



Photo 7: Slab Culvert (Culvert 4) at Km 4+325 (Right)



Photo 8: Eroded River bank at downstream side of the structure (Left)

1.3. Objectives

1.3.1 General Objective

The main objective of the study is to investigate the drainage problems of Adama Town along the Nazareth-Assela road and propose remedial measures.

1.3.2 Specific Objectives

The specific objectives of the study are to:

- ◆ Identify drainage affected section of the road (over flooding, scouring, siltation etc.);
- ◆ Investigate the main causes of the problem;
- ◆ Propose solution for all identified road section with drainage problem;
- ◆ Propose rehabilitation measure that make the subjected town safe and
- ◆ Stops further propagation to environment damage due to erosion that is created around the road and in the surrounding area;

1.4. Scope of the Study

Most designs of road projects have a limitation with drainage related issues. Especially, town section drainage design and provision needs a great consideration as the scale of damage due to lack of proper drainage facilities provision is high.

This study will investigate the drainage problem which occurs in Adama, town section of the Nazareth-Assela road project. Based on the available data, the design and the construction of the drainage facilities, evaluation shall be done and possible mitigation measures will be recommended.

2. Literature Review

2.1 Background

Proper drainage is an important factor that should be given due consideration in design of a highway since inadequate drainage facilities can lead to premature deterioration of the highway and the development of adverse safety conditions. (Mukherjee, 2014) In this connection, the design of pavement drainage is of great importance and should be given due consideration when designing drainage. Pavement must be designed not only to allow for surface drainage but also to allow for adequate subsurface drainage. Mahboub and Allen (2003) noted that long term accumulation of water inside the pavement will reduce the strength of unbounded granular materials and sub grade soils and causes pumping of fine materials with subsequent pavement rapid deterioration. When a pavement is saturated with water heavy vehicle loads cause severe hydraulic shock leading to pumping, disintegrations of cement, stripping of asphalt and overstressing of weakened sub grade. In addition, water is responsible for a large number of non load related distress such as cracking in concrete pavements, and accelerated ageing and oxidization in asphalt pavements. (Cedergren, 1988)

Thus adequate drainage is essential in the design of highways since it affects the highway's serviceability and usable life, including the pavement's structural strength. In this connection, Mahboub and Allen (2003) noted that effective surface water drainage of highway pavements to be an essential part in maintaining a desirable level of service and traffic safety since poor surface drainage causes accidents that result from hydroplaning and loss of visibility from splash and spray. Water is also a lubricant reducing the effectiveness of tyre grip on the carriageway wearing surface which can increase stopping distances (Mukherjee, 2014). Road drainage design has as its basic objective the reduction and/or elimination of energy generated by flowing water.

Mahboub and Allen (2003) stated that significant number of highway engineers have refrained from the concept of pavement sealing owing to the frequent bad experiences that led to thinking that water infiltration into the pavement structure cannot be prevented. In this connection Cedergen (1988) in his article entitled 'Why All Important Pavements Should be Well Drained' indicated that pavement life can be extended up to three times if adequate surface drainage system are installed and maintained. A similar study conducted by Ray and Christory (1989) observed premature pavement distress in undrained pavement section inferring a reduction of service life of nearly 70%. Forsyth (1987) similarly indicated at least a 33% increase service life of asphalt and 50% increase in PCC pavements when subsurface drainage system is used.

It is due to this reasons that much of the cost of most highway projects is attributable to drainage facilities, including storm drains, highway culverts, bridges, and water quality and quantity control structures. (Maidment, 1998) Design of these facilities involves hydrologic analysis to determine the design discharge and hydraulic analysis of the conveyance capacity of the facility.

Highway hydraulic structures perform the vital function of conveying, diverting, or removing surface water from the highway. Accordingly, the U.S. Department of Transportation recommends that it should be designed to be commensurate with risk, construction cost, importance of the road, economy of maintenance, and legal requirements.

2.2 Problems of Drainage Facilities

Drainage problems in urban areas include flooding, deterioration of roads, land degradation, sedimentation, blockage of drainage facilities, water logging, etc (MoWUD, 2008).

Generally, the problems created by inadequate drainage channels have attracted a varying dimension of environmental problem. However, the most prominent among

such problems being the fact that the absence of drainage channels easily translate into environmental deterioration (Jimoh, 2003).

As research conducted by Jimoh (2003) as an assessment of drainage problems in the tropical environment of Ilorin, Nigeria, depicts many problems of diverse dimensions in association with the incidence of drainage problems and these are as follows. First, about 31.5% of the respondents of the research are of the view that one of the effects of drainage channel problem is the incidence of temporary street flooding. Secondary, the development of environmental deterioration consequent upon waste materials that spilled away from the drainage channels onto the land surfaces. This problem accounted for about 43.0% of the respondents.

Finally, is the problem of water being splashed on pedestrians or road users due to either drainage blockage or non-existence of drainage channel? Indeed, this problem attracted about 25.5% of the respondents. The study emphasized that, the overall problems of blocked drainage are one of deterioration in environmental quality, including breeding points for mosquitoes.

The problem of highway drainage structures is world-wide. The document prepared by the international organization describes the problems as follows. The fact, known for centuries, is that as long as road structures and sub grade soil do not have excess water the road will work well. But increased water content reduces the bearing capacity of a soil, which will increase the rate of deterioration and shorten the lifetime of the road. In such cases, the road will need rehabilitation more often than a well drained road structure. Mainly the problem was observed on poorly working structures, such as culverts and ditches. (Saara and Saarenketo, 2006)

2.3 Design Philosophy

The movement of water is the most important factor determining the performance of a road, and when roads fail to render the required service it is often because of inadequate drainage facility. While the primary purpose of highway drainage facilities

is to prevent surface runoff from reaching the roadway and to remove rainfall or surface water efficiently from the roadway, the design of road drainage systems varies with factors such as road importance and age, traffic load and rural/urban area (Fáisca et al., 2009).

One way to select the design flood frequency is through the concept of economics by establishing the least total expected cost for the structure. This concept considers the capital costs, maintenance costs, and the flood hazard costs that are incurred due to damage by a range of flooding events. Flood frequency that generates the least total expected cost for the life of the project would be the one chosen for the design of the structure.

2.4 Storm Water Management

According to Urban Storm Water Drainage Design Manual, storm water management is concerned with the collection, conveyance, storage, treatment and disposal of storm water runoff in a way that minimize accelerated channel erosion, increased flood damage, and/or degradation of water quality and in a manner to enhance and ensure the public health, safety & general welfare, which shall include a system of vegetative or structural measures, or both that control the increased volume and rate of storm water runoff caused by manmade changes to the land(MoWUD, 2008).

While major problems associated with storm water include flash flooding, erosion and sedimentation, water quality degradation as well as surface pollution, the traditional concept for urban-drainage design has been associated with storm-water disposal, with the basic philosophy of transferring any amount of storm water as quickly as possible out of built-up areas. While this temporarily served to eliminate the local flooding problems, it only relayed the problem further downstream, where not only is flooding a concern but pollution and erosion of natural water courses are as well. (Verworn, 2002)

Armitage (2010) noted that a major weakness of urban drainage management to be the tendency of not looking urban drainage management in a holistic manner. Similarly Mohd Nor et al, (2011) noted that in order to prevent problems associated with storm water an integrated approach needs to be appraised so that the effects of an individual problems or a combination of such can be reduced profoundly in downstream areas.

In this connection, Verworn, (2002) in recent years the philosophy of storm-water management has emerged, regarding storm water as a source to be managed. This includes the concept of source control, in which storm-water run-off is not immediately discharged but is stored and treated or re-used locally, at or close to its point of generation with the aim of making use of infiltration capacity wherever possible.

The author also noted that management to be an ideal rehabilitation method, as it has the benefits of recharging soil moisture and groundwater; reducing peak run-offs as well as reducing total run-off volume to drainage systems.

This is due to the fact that with the widening of possible solutions for rehabilitation, a growing need for the assessment of various possible solutions in terms of hydraulic effectiveness and costs has emerged. When funds available are limited, cost–benefit analyses are more important than ever to gain maximum benefit from the available resources. In this connection simulation models play an important role as a tool for finding out what the effects of potential solutions will be, absolutely and in comparison. Storm-water management always incorporates storage volume in one way or another. This means that the continuous simulation approach should be used rather than the design storm concept in order to account for the interactions and interdependencies of storage and transport parts of the system in a more reliable way

Overall, the new concepts of storm-water management present a challenge to hydrologists and engineers. For the design of intelligent drainage solutions, disciplines like landscaping, town planning, ecology and economy have to be included, requiring more skills than in the past, when designing the pipe was only a subordinate task. (Verworn, 2002)

2.5 Storm Water management in Ethiopia

Famuyiwa(nodate) noted that various studies indicate that urban infrastructure in the developing world is often subjected to poor planning, disjointed implementation and poor post installation management. The urban functions to be served and to the sustainability of the facilities. The outcome is poor facility functions, early deterioration and unwanted settlement development, implying wasteful use of scarce resources. In addition Armitage (2010) noted that the main challenge in developing countries has to do with lack of adequate number of skilled personnel who are able to plan and implement urban drainage in timely manner and the lack of funding needed to pay for the work.

In Ethiopia context, where watersheds of many urban centers receive significant amount of annual rainfall and where rainfall intensity is generally high, control of runoff at source, flood protection, and safe disposal of excess water/runoff through proper drainage facilities is very essential. (MoWUD, 2008)

Historically, Dire Dawa, the second largest city of Ethiopia, has been vulnerable to flash flooding, in particular of the Dechatu River which passes through the centre of the city. On the night of 5/6 August 2006, the most devastating flood to date swept through Dire Dawa, resulting in over 300 fatalities and significant damage to the flood defenses, public infrastructure, housing and livelihoods. The high death toll was largely due to the fact that the flood peak occurred at night when people were asleep. Prior to the August 2006 flood, the largest recorded floods were in April 1981, April 1994 and May 2005. Thirty-five people died in the May 2005 flood and damage was estimated at Birr 10 million.

In addition, with urbanization, impermeability increases with the increase in impervious surfaces (i.e. residential houses, commercial buildings, paved roads, parking lots, etc), drainage pattern changes, overland flow gets faster flooding and environmental problems such as land degradation increases. It is a crucial problem facing the existing and future road infrastructure. (Belete.2011)

In spite of these problems, drainage facilities in most urban centers of Ethiopia are nearly absent or at a lower coverage. Planning and design rarely guide construction or provision of such facilities and management (MoWUD, 2008). Similarly, Mahari, and G/Mariam, (2015) noted that whereas in Ethiopia there is a good progress of expansion of roads, many of these roads are not functioning well to the desired life time and quality mainly due to failure on cross drainage structure.

A research conducted by Dagnachew Adugna Belete (2011) on the road and urban storm water drainage network integration in Addis Ababa, Addis Ketema Sub-city, depicts the major causes of flooding as the blockage of urban storm water drainage lines along with inadequate/poor integration between road and urban storm water drainage infrastructures.

Similarly, a research conducted by the same author in connection with urban drainage planning and design in Mekelle city emphasized that, flood generation became a core problem in Mekelle as a result of deforestation followed by impervious structures and it noted that generally, urban drainage management in the city has concentrated only on conventional management and in order to reverse the situation the research paper recommends introducing sustainable urban drainage management technologies to reduce land degradation, river bank erosion, urban utilities degradation, natural water ways pollution and siltation.

2.6 Review of Methods and Computer Software

2.6.1 Review of Hydrological Analysis Methods

According to ERA Drainage Design Manual, 2013, the following are some of the most widely used flow estimation methods:

- Rational Method;
- NRCS Runoff Curve Number Methods(SCS Curve Number method);
- Statistical analysis of stream data; and
- Regional regression equations.

Rational Method: The Rational Method provides estimates of peak runoff rates for small urban and rural watersheds of less than 50 hectares (0.5 square km) and in which natural or man-made storage is small. It is best suited to the design of urban storm drain systems, small side ditches and median ditches, and driveway pipes. It shall be used with caution if the time of concentration exceeds 30 minutes. Rainfall is a necessary input for this method of flow estimation.

Characteristics of the Rational Method that generally limit its use to 50 hectares include:-

- (1) The rate of runoff resulting from any rainfall intensity is a maximum when the rainfall intensity lasts as long as or longer than the time of concentration. That is, the entire catchment area does not contribute to the peak discharge until the time of concentration has elapsed
- (2) The frequency of peak discharges is the same as that of the rainfall intensity for the given time of concentration.
- (3) The fraction of rainfall that becomes runoff is independent of rainfall intensity or volume

NRCS Runoff Curve Number Methods: The Natural Resources Conservation Service (formerly Soil Conservation Service) developed the runoff curve number method as a means of estimating the amount of rainfall appearing as runoff. Technical Release 20 (TR20) employs the Runoff Curve Number Method and a dimensionless unit hydrograph to provide estimation of peak discharges and runoff hydrographs from complex watersheds.

The procedure allows the designer to estimate the effect of urbanization, channel storage, flood control storage, and multiple tributaries. TR 20 can be applied to the design of culverts, bridges, detention ponds, channel modification, and analysis of flood control reservoirs. Technical Release 55 (TR 55) is a simplified form of TR 20 for

use in estimating peak discharges for small watersheds (urban and rural) whose time of concentration does not exceed 10 hours. TR 55 includes a hydrograph development procedure; however, where hydrograph determination is necessary, use TR 20 or another hydrograph procedure. The unit hydrograph used by the SCS method is based upon an analysis of a large number of natural unit hydrographs from a broad cross section of geographic locations and hydrologic regions in USA. The rainfall depth is used as an input.

However, the SCS Curve Number method is applicable to small catchments (maximum area 6,500 ha) with a time of concentration for any sub-area of 0.1 – 10 hours.

As detailed in Highway Hydrology - Hydraulic Design Series -2, the SCS method should be used on watersheds that are homogeneous in CN; where parts of the watershed have CNs that differ by 5, the watershed should be subdivided and analyzed using a hydrograph method, such as TR-20 (SCS, 1984).

The SCS method should be used only when the CN is 50 or greater and the t_c is greater than 0.1 hour and less than 10 hours. The computed value of l_a/P should be between 0.1 and 0.5.

Statistical Analysis of Stream Gauge Data: Where stream gauge data are available, stream gauge data can be used to develop peak discharges. The Ministry of Water & Energy keeps annual stream gauge data. The method commonly used for estimating the peak discharges is usually Log-Pearson Type III distribution. However, as the record length is increased, a Log-Normal distribution or General Extreme Value (GEV) distribution could also be used. The recent data analysis demonstrated that GEV can be used to estimate the peak flow in Ethiopia. It is recommended that the distribution method, which gives a best fit to the record data, should be used.

Regional Regression Equations: Regional regression equations are the most commonly accepted method for establishing peak flows at larger ungauged sites (or sites with insufficient data for a statistical derivation of the flood versus frequency relation).

Regression analyses use stream gauge data to define hydrologic regions. These are geographic regions having very similar flood frequency relationships and, as such, commonly display similar watershed, channel, and meteorological characteristics; they are often termed hydrologically homogeneous geographic areas.

It is difficult to choose the proper set of regression equations when the design site lies on or near the hydrologic boundaries of relevant studies.

Another problem occurs when the watershed is partly or totally within an area subject to mixed population floods.

Care should be exercised using regression equations in these instances:-

- ◆ Conduct a field visit to assess the watershed characteristics for comparison with other watersheds;
- ◆ Collect all available historical flood data; and
- ◆ Use the gathered data to interpret any discharge values.

Of these possible hydrologic methods based on the available data, it should be noted that, at the present time, only the Rational and SCS methods are applicable to the whole country. Regression equations and derivations from stream gauging (Gumbel, Log Pearson, General Extreme Value) are often preferred but rely on data not available

Table 1: Application and limitation of flood estimation methods

Method	Input data	Recommended maximum area(km²)	Return period of flood that could be determined (years)
Rational Method	Catchment area, water course length, average slope, catchment characteristics, rainfall intensity	<0.5	2 – 200, PMF
SCS Method	Catchment area, water course length, length to catchment centroid (centre), mean annual rainfall, veg. type, soil cover and synthetic regional unit hydrograph	0.5 to 65	2 – 200, PMF
Synthetic Hydrograph Method	Catchment area, water course length, length to catchment centroid (centre), mean annual rainfall, veg. type and synthetic regional unit hydrograph	0.5 to 5000	2 -200
Empirical Methods	Catchment area, water course length, distance to catchment centroid (centre), mean annual rainfall	No limitation large areas	2 – 200, PMF
Statistical Method	Historical flood peak records	No limitation, large areas	2 – 200 (depending on the record length)

(ERA Drainage Design Manual, 2013)

2.6.2 Review of Culvert Analysis Methods

Culvert analysis can be done using nomographs and computer programs.

⇒ Nomographs

- ◆ Require a trial and error solution which provides reliable designs for many applications.
- ◆ Require additional computations for tail water, outlet velocity, hydrographs, routing, and roadway overtopping.

⇒ **Computer Software**

There are different computer software methods for culvert design and analysis. Moore Kemset, et al. (1999) listed some of culvert products as shown in Table 2.

Table 2: Computer softwares for culvert design and analysis

Culvert design and analysis	Watershed/river modeling with culvert component	Specialty culvert design and analysis
CAP-Culvert Analysis	CHAN v.2*	Xing-Risk
CulvertMaster*	Eagle Point Watershed*	FishPass
DrainCalc	Eagle Point Water	FishXing
Drainage Calculator	Surface Profiling	
HydroCalc for Windows 95 v. 1.2a*	HEC-RAS v 2.2*	
HY-8, Culvert Analysis*	HydroCAD	
HYDrain*	RiverCAD*	
HydroCulv v.1		
MacCulvert*		
Quick PipePro*		
THYSYS		

*Incorporates Normann (1985) as algorithm source.
(Moore Kemset, et al., 1999)

A research has been conducted under the title “Culvert Hydraulics- Comparison of Current Computer Models” by Thiele Elizabeth A.(2007)

As several computer programs exist to aid in solving culvert hydraulic problems, the comparison had been made on seven of those program in the research. i.e. HY-8, FishXing, BCAP, Hydraflow Express, Culvert Master, Culvert and HEC-RAS.

The researcher has concluded that “Fish X-ing, HEC-RAS, BCAP, and Culvert all have unique features separating them from the other programs. FishX-ing is the only program that analyzes culverts for fish passage, while HEC-RAS is the only program

that analyzes culverts as part of a stream network. BCAP and Culvert are the only programs that will analyze broken back culverts. In terms of program accuracy, FishX-ing, BCAP, Hydraflow Express, and Culvert predicted inaccurate results most frequently. HEC-RAS, Culvert Master and HY-8 produced the most accurate results most consistently in the test cases” (Thiele, 2007).

Generally, HEC-RAS (Hydrologic Engineering Center - River Analysis Systems) and HY8 (FHWA Culvert Analysis Software) are widely used methods for culvert analysis.

◆ **HEC-RAS (Hydrologic Engineering Center - River Analysis Systems):-**

HEC-RAS is a hydraulic model developed by the Hydrologic Engineering Center (HEC) of the U.S Army Corps of Engineers.

The HEC-RAS can be used to design and analysis of drainage system and the system contains four one-dimensional river analysis components for: (1) steady flow water surface profile computations; (2) unsteady flow simulation; (3) movable boundary sediment transport computations; and (4) water quality analysis.

HEC-RAS (US Army Corps of Engineers, 2000)-can be used to design and analysis of drainage system. HEC-RAS is designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. The basic computational procedure is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by Manning’s equation. The momentum equation is used in situations where the water surface profile is rapidly varied. It is capable of modeling subcritical, supercritical, and mixed flow regime flow along with the effects of bridges, culverts, weirs, and structures.

The **advantages** of HEC-RAS are its acceptance by many government agencies and private firms. It is in the public domain and peer-reviewed and available to download free of charge from HEC's web site.

The **disadvantage** HEC-RAS is it is a 1-dimensional hydrodynamic model and will therefore not work well in environments that require multi-dimensional modeling. However, there are built-in features that can be used to approximate multi-dimensional hydraulics.

HEC-RAS Parameters

HEC-RAS uses a number of input parameters for hydraulic analysis of the stream channel geometry and water flow.

At each cross section, several geometry parameters are required to describe shape, elevation, and relative location along the stream:

- ◆ River station (cross section) number
- ◆ Lateral and elevation coordinates for each (dry, unflooded) terrain point
- ◆ Left and right bank station locations
- ◆ Reach lengths between the left floodway, main channel, and right floodway of adjacent river stations (The three-reach lengths represent the average flow path through each segment of the cross section pair. As such, the reach lengths between adjacent cross sections may differ owing to bends in the stream.)
- ◆ Manning's roughness coefficients
- ◆ Contraction and expansion coefficients
- ◆ Geometric description of any hydraulic structures (bridges, culverts, weirs, etc.)

At each cross-section line, HEC-RAS assumes that energy is constant and that the velocity vector is perpendicular. Care should be taken to ensure that the flow through each selected cross section meets these criteria. After defining the stream geometry, flow values for each reach within the river system are entered. The channel geometric description and flow rate values are the primary model inputs for the hydraulic computations (David Maidment, et al., 1998).

◆ **HY-8 Energy Model:-**

The Hydraulic Design 8 Energy Model (HY 8) was created, in 2000, by the Federal Highway Administration (FHWA). This program is utilized to develop the appropriate means of energy dissipation through different types of culverts. The program is capable of examining circular and rectangular culverts. The inputs for this program include: shape, flow, velocity, diameter, channel slope, peak duration, and drop height, if one exists. Once this information has been entered, HY 8 will produce an output screen that has various parameters that can be presented.

The program has a choice of options that include determining the size of the scour hole that will be produced and how to internally or externally reduce the water's energy before it leaves the culvert. Choosing the Scour option will provide details on the length, width, volume and depth of water present. The Internal and External option provide the user with a series of energy dissipation methods on how to reduce the formation of a scour hole.

HY-8 enables to analyze:

- ◆ The performance of culverts
- ◆ Multiple culvert barrels at a single crossing as well as multiple crossings
- ◆ Roadway overtopping at the crossing and
- ◆ Develop report documentation in the form of performance tables, graphs, and key information regarding the input variables.

The followings are a few concerns that need to be addressed concerning the HY 8 program.

- ◆ The program does not have an option to choose what the surface roughness of the culvert in question.
- ◆ The program does not produce an exit Froude number. This can be an issue when trying to determine if the presence and type of hydraulic jump is taking place in the outlet section of the culvert.

- ◆ Hydraulic jumps are another area of concern. HY 8 is not capable of determining if the dissipator selected can produce a hydraulic jump.
- ◆ One last area of concern deals with determining if a given dissipator is feasible or not. The program labels each dissipator type as questionable or feasible. HY 8 does not specify to what extent an energy dissipator is questionable or feasible. It is for these reasons that it is up to the user to make the final decision on whether or not what type of energy dissipator is viable.

2.7 Review of the Design Review Consultant's Analysis

Review has been done on the Hydrology/Hydraulics and structural report of the Design Review consultant.

⇒ Computation of design flood was conducted using the following two methods:-

- I. Regional Flood Equation
- II. Rational Formula

I. The Regional Flood Equation had been used for computing design flood for watershed area exceeding 30km² of the project area.

The regional flood analysis was carried out using the specific flood values along with Boldakov's Method.

Boldakov's formula has been reproduced in the following for estimating the magnitudes of floods of different return periods.

$$Q(T) = (Q(T)/Q_{mean}) \times Q_{mean}$$

Where:

Q(T) – Magnitude of flood of T year return period(m³/s)

Q_{mean} – Mean of observed annual maximum floods (m³/s)

Flood regression equations were derived for various return periods based on the specific flood formula.

The Regression Equation which was derived for the project was:-

$$Q_5 = 5.202 * CA^{0.561757}$$

$$Q_{10} = 6.317 * CA^{0.561757}$$

$$Q_{25} = 7.803 * CA^{0.561757}$$

$$Q_{50} = 8.546 * CA^{0.561757}$$

$$Q_{100} = 9.661 * CA^{0.561757}$$

II. **Rational method** had been used for computing magnitudes of design floods for watershed area less than 30km².

The Rational Formula is given as the following.

$$Q = 0.28 \times A \times C \times I_c \times f$$

Where:

Q – Maximum runoff in m³/s

A – Watershed Area in Km²

C – Runoff Coefficient

I_c – Critical Intensity in mm/hr

f – Watershed area reduction factor

Only structures having significant watershed areas were done with the above method according to the report. For other culverts in which areas cannot be measureable from 1:50,000 scale maps, the design review consultant has extended the size of the existing structures. According to the report, the culverts which are in the town section of Adama, the watershed were considered as not measurable from the map.

⇒ **Hydraulic Analysis**

The Hydrology/Hydraulic & Structural report stated that the discharge capacities of the existing cross section structures have been estimated using Manning Formula.

- ◆ From the dimensions of the openings of the existing structures, the water area and wetted perimeter of each cross-drainage structure were determined.
- ◆ The slope of every cross drainage structure was estimated from 1:50,000 scale maps.
- ◆ Values of Manning's roughness coefficient were estimated for all existing major cross-drainage structures by actual observations in the field and selecting suitable values from standard tables.
- ◆ Permissible flow velocities through various soils and linings of the existing cross-drainage structures were taken from as estimated by actual observations in the field and of suitable values from standard tables.

The discharge capacities of the existing cross-drainage structures have been estimated using Manning's Formula

The maximum possible velocities through the openings of the existing structures have been computed assuming structure nearly full flow using Manning's equation: and

$$V = 1/n \times R^{2/3} \times S^{1/2}$$

Where:

V – Velocity in meters/second

n – Manning's roughness coefficient

R – Hydraulic radius in meters (Area/Wetted Perimeter)

S – Estimated bed slope of structure from 1:50,000 scale maps.

The discharge capacity (Q_c) is then computed using the following formula:

$$Q_c = A \times V$$

Where:

Q_c – Discharge capacity of structure in m^3/s

A – Water Shed area in m^2

V – Maximum permissible velocity of flow through the structure in m/s .

For culverts with no definite catchment areas, the design review consultant applied the method “**Highway and Urban Hydrology in the Tropics**” by L.H Watkins and D.Fiddes (1984)

$$Q_c = C_d A \sqrt{2gH}$$

Where

Q_c = Discharge capacity of Culverts

C_d = Coefficient of discharge

H = Upstream depth of water

g = Acceleration due to gravity

C_d depends on H/D ratio for pipe culverts and is equal to 0.95 for box culverts and H is taken the height above half height of the opening. From the diameter of the standard pipes, the area has been calculated.

3. Description of the Study Area

3.1 General

The development of Adama as an urban center began with the emergence of the Addis Ababa-Djibouti railway, which passes through the city. The indigenous people started to settle to exchange goods and services with railway workers. Adama is a busy transportation center.

The city became the capital of Yerer and Kereyu province in 1946 and the name was changed from Adama to Nazareth. In 1988, Nazareth became the capital of Eastern Shewa Zone.

At present, the name of the city changed back to Adama and it became the capital of Oromiya Regional State. The city plays now an important role in economic and administrative activities.

3.2 Location

Adama is located within grid references point that stretches between 8° 35'00" to 8°36'00" North latitude and 39° 11' 57" to 39° 21' 15" East longitude.

Adama City is located at some 100 kilometers from Addis Ababa, on the southeast along the main road to Harar.

The project route map is located in the figure below.



Figure 1: Location Map of the Project Route

3.3 Climate

Adama lies in somewhat warm climate. Hence, it enjoys hot and dry weather for the greater part of the winter and warm and sunny climate in summer. Thus, the area is generally known for its attractive weekends and summer resort release. Adama has a minimum annual temperature falling between 19° and 22°C. Its yearly minimum rainfall is reported to be 760mm.

3.4 Topography and Geomorphology

Adama being part of the main Ethiopian Rift system, has an extensive Pliocene-
quaternary Volcanism and the geomorphology is the one characteristics of a volcanic
area, modified by erosion and deposition of alluvial sediments.

The Adama town is located with an elevation ranging from 1600 to 1800 meters above
sea level and is characterized by very flat and plain of low land rounded by a lot of
mountainous.

3.5 Geology and Soils

Adama is made of trachyte, ignimbrite, tuff (pumaceous tuff), basalt and lacustrine
sediments. The rocks are belonging to Pliocene and to quaternary age. Trachyte,
rhyolite (Obsidian rich) and ignimbrite are available on the hilly part of the area and the
others in the plain area. The area lies within the floor of the Rift Valley; hence tectonics
and volcanism of different succession has affected the area as a whole.

In the city, silty clay loam to sandy clay loam classifies the soil. The top part of the soil
is silty clay while at depths sands, gravels and some lacustrine sediment prevail.

3.6 Drainage

Due to its location and desertification, there are no rivers and streams in the town but
there is Awash River in the southern part of the town which is used as drinking water
source. This river flow throughout the year and serve the country as source of electric
supply and irrigation purpose.

3.7 Population

Adama city is one of the rapidly growing cities in the country. Based on the 2007 census conducted by the Central Statistical Agency of Ethiopia (CSA), this city has a total population of 220,212, an increase of 72.25% over the population recorded in the 1994 Census, of which 108,872 are men and 111,340 women.

3.8 Drainage facilities

Most parts of the city are relatively flat. Hills surrounded the three sides of the city. Frequent floods occur during the rainy season and these floods damage the streets. An attempt to improve the situation is underway by the Adama Municipality. There are relatively well-built side road ditches in some parts of the city but most of the drainage structures are in a bad condition or badly designed and constructed. (PACE Consulting Architects and Engineers Plc, 2004)

3.9 Natural Hazards/Constraints

a) Flooding

Floods are common sources of complaint from the public in Adama. Since the town is settled in between and on escarped slope this lead to generate greater capacity of runoff and erosion, the flash flood that originate from the surrounding areas of high slope rush down towards the town part and causes damage. This is very common in rainy season.

b) Soil Erosion

It is known that one of the main factors to erosion is topography. Soil erosion in Adama is observed due to the slight soil cover, steep relief and relatively intense rainfall.

c) Seismicity

Adama is located within the Ethiopian Rift Valley Zone, hence Seismic hazard risk may expect. According to the Seismic risk zoning map of Ethiopia, Adama falls within the zone that is characterized by earth quake.

4. Materials and Methods

4.1 Research Framework

The general workflow of this thesis work is presented as follows:-

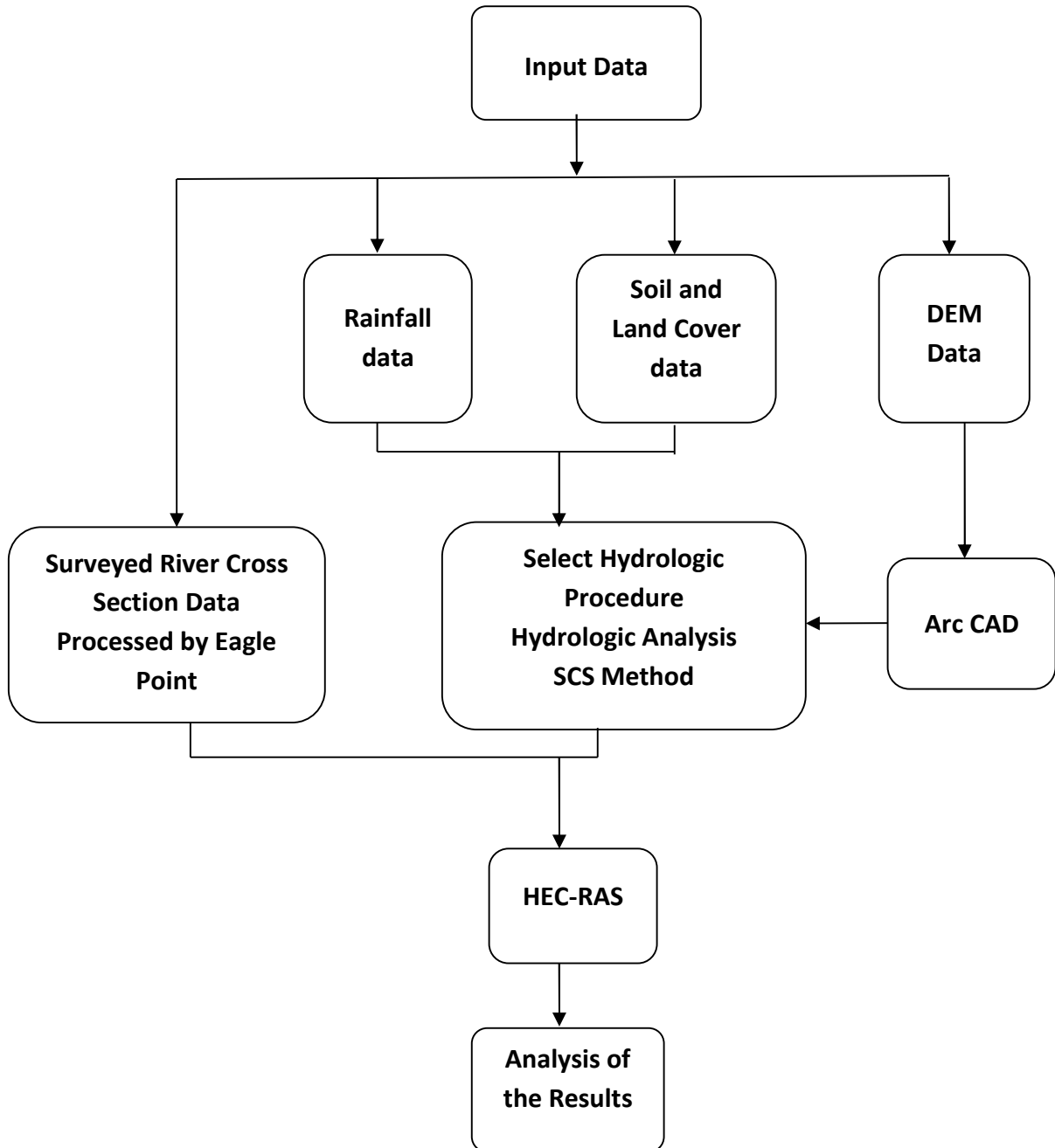


Figure 2 : Conceptual Frame Work

The following procedure outlines the conceptual frame work:

- Collection of input data
 - Rainfall data
 - Soil and land cover data
 - DEM data
 - Surveyed river cross section data

- Selection of hydrological procedure to estimate the peak discharge

- Based on the size of the catchment area, SCS method has been selected

- Steps followed for estimating the peak discharge are;
 - Determine the watershed area in hectares or km²;
 - Determine the time of concentration, with consideration for future characteristics of the watershed;
 - Determine the soil type, soil group, and land use and curve number of the watershed area; determine the hydrologic region ;
 - Determine the 24hr rainfall depth and calculate the Ia/p ratio;
 - Use the Equation to calculate the unit peak flood;
 - Calculate the peak discharge for the watershed for the desired frequency using Equation

- Using the estimated peak discharge data and the Surveyed river cross section data processed by Eagle point as an input data, HEC-RAS model has been used to analyze the capacity of the structures.

4.2 Data Collection

All the required secondary data have been collected from the concerned bodies to accomplish this study.

4.2.1 Site Visit

The site visits were conducted to get the first hand information of the area. Questionnaire has been distributed for different Kebeles and Municipality. (The questionnaire with its feedback is attached as **Annexes No. 1**)

During the site investigation, the following deficiencies in the project road of Adama town have been observed.

- ◆ Lack of properly designed side drains, inlet/outlet protection works and proper channelization of streams
- ◆ Growth of vegetation in the drainage structures and also at the inlet and outlet of the structures
- ◆ Siltation and blockage of culverts due to stones and sand

At the beginning of the Nazerete-Assela road project and end of the Municipality side drain, the drains are not connected properly and also the side drain sizes are not the same. The side drain constructed by the Municipality has a width of 70cm and a depth of 180cm, where as the project side drain has a width of 80cm and a depth of 90cm.



Start of the Project Road
Photo 9: Side drain connection between
Municipality & Nazerete-Assela Road Project
(Right)



Photo 10: Side drain connection between
Municipality & Nazerete-Assela Road Project
(Left)



Photo 11: Side drain constructed by the Municipality



Photo 12: Growth of vegetation

It has been observed that most of the constructed side drains have not effectively served their purpose. As an example, the side drain around Oromia College, its total depth is 90cm. Of which, 20cm is used for Curb Stone, 20cm is used for walkway cover, about 35cm was logged by dirt. The clear water way out of 90 cm depth of side drain has been about 15cm.



Photo 13: Side drain logged by dirt which has only 15cm water way.

4.2.2. Climatic Data

The rainfall data of the area has been collected from the Adama Gauging Station of the National Meteorology Service Agency (NMSA). Twenty nine years rainfall record has been used for analysis. Nazareth (Adama) is meteorological designated as 'A3' in accordance with EDDM, 2013.

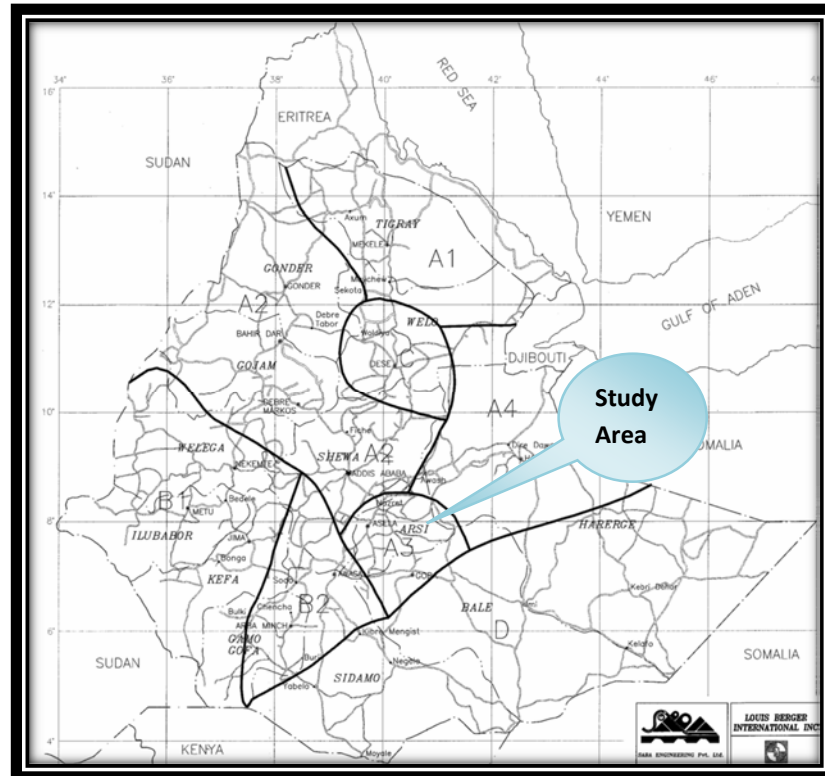


Figure 3: Rainfall Regions of Ethiopia (ERA DDM 2002)

4.2.3. Topographic Maps and Digital Data

Topographic maps of 1:50,000 and the Digital Elevation Model (DEM) from Satellite Imagery data with 30x30meter resolution of the project area have been collected. In addition, Land Use and Land Cover as well as Geomorphology and Soil Maps have also been collected. Contour map of the study area was generated using Digital Elevation Model (DEM) data using Global Mapper software.

4.2.4. Surveying Data and Design Review Reports

The topographic survey data and design review reports of the project area are obtained from the Design Review Consultant. Surveying Data used for the analysis is attached as **Annex 2**.

The surveying data is imported to Eagle point to produce surface model which was subsequently used to generate input data for HEC-RAS software.

4.2.5. Hydraulic Data

The catchments parameters such as average slope, length of the longest water course, difference in elevation are determined from the above mentioned maps.

Manning's 'n' is affected by many factors and its selection in natural channels depends on engineering experience. Based on ERA Drainage design manual guidelines the manning 'n' value for the cross section of the culverts have been selected from the table given in ERA drainage design Manual.

4.3 Hydrologic and Hydraulic Analysis

4.3.1 Hydrologic Analysis

Hydrological study is the basic step that should be done carefully in every flood management and road drainage facilities.

The hydrological investigation has been dealt by analyzing rainfall data, high water mark observations, topographical map, satellite image and aerial photographs for the estimation of design discharge. The investigation has also been supplemented by field inspection of watershed area and interviews. It is known that there are many methods for peak flood calculation but their applicability depends mainly on the availability of hydrological data.

According to ERA Drainage Design Manual (EDDM) 2013, the rational method provide estimates of peak runoff rates for small urban and rural watersheds of less than 50 hectares (0.5 square km) and in which natural or manmade storage is small. Whereas, the United States Soil Conservation Service(SCS) method is most suited for computing flood peak and runoff of volumes for catchments greater than 0.5km² and smaller than 65km² , with slopes of less than 30% and a time of concentration (T_c) less than 10 hours.

As mentioned under Literature Review section, at the present time, only the rational and SCS methods are applicable to Ethiopia. Therefore, for this study, in accordance with the size of the catchment area, the design floods are estimated using Spread Sheet Program that has been developed to estimate the design flood using SCS method.

4.3.1.1 Soil Conservation Service (SCS) method

The method is developed by the U. S. Soil Conservation Service for calculating rates of runoff requires the same basic data as the Rational Method: catchment area, a runoff factor, time of concentration, and rainfall. The SCS approach, however, is more sophisticated in that it considers also the time distribution of the rainfall, the initial rainfall losses to interception and depression storage, and an infiltration rate that decreases during the course of a storm. With the SCS method, the direct runoff can be calculated for any storm, either real or fabricated, by subtracting infiltration and other losses from the rainfall to obtain the precipitation excess.

4.3.1.2 Catchment Area

A catchment area is determined from topographic maps and field surveys. For large catchment areas it might be necessary to divide the area into sub-catchment areas to account for major land use changes, obtain analysis results at different points within the catchment area, or locate storm water drainage structures and assess their effects on the flood flows. A field inspection of existing or proposed drainage systems is made to determine if the natural drainage divides have been altered. These alterations could make significant changes in the size and slope of the sub catchment areas.

4.3.1.3 Rainfall

The SCS method is based on a 24-hour storm event which has a Type II time distribution. The Type II storm distribution is a 'typical' time distribution which the SCS has prepared from rainfall records. It is applicable for interior rather than the coastal regions and appropriate for Ethiopia.

4.3.1.4 Rainfall-Runoff Equation

A relationship between accumulated rainfall and accumulated runoff was derived by SCS from experimental plots for numerous hydrologic and vegetative cover conditions. Data for land-treatment measures, such as contouring and terracing, from experimental catchment areas were included. The equation was developed mainly for small catchment areas for which daily rainfall and catchment area data are ordinarily available. It was developed from recorded storm data that included total amount of rainfall in a calendar day but not its distribution with respect to time. The SCS runoff equation is therefore a method of estimating direct runoff from 24-hour or 1-day storm rainfall. The equation is:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Where:

Q = accumulated direct runoff, mm

P = accumulated rainfall (potential maximum runoff), mm

I_a = initial abstraction including surface storage, interception, and infiltration prior to runoff, mm

S = potential maximum retention, mm.

The relationship between I_a and S was developed from experimental catchment area data. It removes the necessity for estimating I_a for common usage. The empirical relationship used in the SCS runoff equation is:

$$I_a = 0.2 \cdot S$$

S is related to the soil and cover conditions of the catchment area through the CN. CN has a range of 0 to 100, and S is related to CN by:

$$S = \frac{25400}{CN - 254}$$

4.3.1.5 Runoff Factors

Runoff is rainfall excess or effective rainfall - the amount by which rainfall exceeds the capability of the land to infiltrate or otherwise retain the rainwater. The principal physical catchment area characteristics affecting the relationship between rainfall and runoff are land use, land treatment, soil types, and land slope.

i. Land Use

Land use is the catchment area cover, and it includes both agricultural and non agricultural uses. Items such as type of vegetation, water surfaces, roads, roofs, etc. are all part of the land use. Land treatment applies mainly to agricultural land use, and it includes mechanical practices such as contouring or terracing and management practices such as rotation of crops.

The SCS uses a combination of soil conditions and land-use (groundcover) to assign a runoff factor to an area. These runoff factors, called runoff curve numbers (CN), indicate the runoff potential of an area. The higher the CN, the higher is the runoff potential.

ii. Hydrologic Soil Groups

Soil properties influence the relationship between rainfall and runoff by affecting the rate of infiltration. The SCS has divided soils into four hydrologic soil groups based on infiltration rates (Groups A, B, C, and D).

iii. Runoff Curve Numbers

The ERA Design Manual gives a series of tables related to runoff factors. The tables are based on an average antecedent moisture condition, i.e., soils that are neither very wet nor very dry when the design storm begins. Curve numbers shall be selected only after a field inspection of the catchment area and a review of cover type and soil maps. Care shall be taken in the selection of curve numbers (CN's). Use a representative average curve number, CN, for the catchment area.

Selection of overly conservative CN's will result in the estimation of excessively high runoff and consequently excessively costly drainage structures. It is better to use average values and design for a longer storm frequency.

4.3.1.6 Time of Concentration (T_c)

In a defined watercourse, channel flow occurs. The recommended empirical formula for calculating the time of concentration in natural channels was developed by the US Soil Conservation Service.

$$T_c = \left(\frac{0.87L^2}{1000S_{av}} \right)^{0.385}$$

Where:

T_c = time of concentration (hours).

L = hydraulic length of catchments measured along flow path from the catchment boundary to the point where the flood needs to be determined (km).

S_{av} = average slope (m/m).

4.3.1.7 Ia/p Parameter

Ia/p is a parameter that is necessary to estimate peak discharge rates. Ia denotes the initial abstraction and p is the 24 hour rainfall depth for a selected return period. The 24 rainfall depth is taken from the frequency analysis result or from the ERA DDM rainfall region rainfall depth recommendations. For this particular study, the 24 rainfall depth is taken from the frequency analysis of Adama town. For a given 24 hour rainfall distribution Ia/P represents the fraction of rainfall that must occur before runoff begins.

4.3.1.8 Peak Discharge Estimation

The following equation were used for the estimation of the peak discharge in SCS method

$$Q_p = q_u * A * Q$$

Where

q_p = peak discharge, m³/s

q_u = unit peak discharge, m³/s/km²/mm

A = drainage area, Km²

Q = depth of runoff, mm

The unit peak discharge is obtained from the following equation, which requires the time of concentration (t_c) in hours and the initial abstraction rainfall (I_a/p) ration as input:

$$q_u = \alpha * 10^{C_0 + C_1 \log t_c + C_2 (\log t_c)^2}$$

Where C_0 , C_1 and C_2 = regression coefficients given in the table of EDDM. 2013 for various I_a/p ratios:

α = unit conversion factor equal to 0.000431 in SI unit.

4.3.2 Hydraulic Analysis

HEC-RAS (Hydrologic Engineering Center-River Analysis System) is a widely used model and has excellent user interface.

Therefore, all the existing structures in the study area have been modeled using HEC-RAS except Culvert 2 at km 2+275. Only the analysis of Culvert 2 at km 2+275 has been done using HY8 (HY8 Culvert analysis) since the surveying data at the specific location was not adequate to use the HEC-RAS.

The capacity of the structures is compared with the estimated runoff for 25 and 50 years return periods.

4.3.2.1. HEC-RAS HYDRAULIC MODEL

Most of culverts analyses have been done using HEC-RAS as mentioned above.

DATA REQUIREMENTS of HEC-RAS:-

The function of the HEC-RAS program is to determine water surface elevations at all locations of interest. The data needed to perform these computations are separated into geometric data and steady flow data (boundary conditions).

I) GEOMETRIC DATA

The basic geometric data consists of establishing how the various river reaches are connected (River System Schematic); cross section data; reach lengths; energy loss coefficients (function losses, contraction and expansion losses); and stream junction information. Hydraulic structure data (bridges, culverts, etc.) which are also considered geometric data.

a) River System Schematic

The schematic defines how the various river reaches are connected. The program can handle simple single reach modules or complex networks model.

b) Cross Section Geometry

Boundary geometry for the analysis of flow in natural streams is specified in terms of ground surface profiles (cross sections) and the measured distances between them (reach lengths). Cross sections are requires at locations where changes occur in discharge, slope, shape or roughness; at locations where levees begin or end and at bridges or control structures such as weirs.

c) Reach Length

The reach length (distance between cross sections) should be measured along the anticipated path of the center of mass of the left and right over bank and the center of the channel.

d) Coefficients

◆ Manning's n

Manning' n selection of an appropriate value is very significant to the accuracy of the computed water surface profiles. The value of n depends on: surface roughness; vegetation; channel irregularities; channel alignment; scour and deposition; obstructions; size and shape of the channel; stage and discharge; seasonal change; temperature, and suspended material and bed load.

◆ Contraction and Expansion Coefficients

Contraction or expansion of flow due to changes in the cross section is a cause of energy loss between cross sections. The loss may be computed from the contraction and expansion coefficients specified on the cross section data editor.

II) STEADY FLOW DATA

a) Flow Regime

The flow regime must be specified on the Steady Flow Analysis window.

b) Boundary Conditions

Boundary conditions are necessary to establish the starting water surface elevations (WS) at the ends of the river system.

c) Discharge Data

Discharge information is required at each cross section starting from upstream to downstream for each reach.

5. Results and Analysis

5.1 Results

5.1.1 Rain fall

Rainfall data of the area has been collected of the Adama station gauge from the National Meteorology Service Agency (NMSA). Frequency analysis has been done for 29 rainfall data using Gumbel, Log Normal and Log Pearson Type III method and the best fit is selected for the design rainfall of the project area. Computation of the frequency analysis is as follows.

Table 3: Frequency Analysis

Year	Rainfall Data (mm)	Descending Order	Y = Log X	Rank	Plotting Positions	Probability, P [%]	Return Period, Tr [yr]	Reduced Variate, y
1985	57.00	57.00	1.76	14.00	0.47	47%	2.14	0.46
1986	50.00	50.00	1.70	20.00	0.67	67%	1.50	-0.09
1987	44.40	44.40	1.65	24.00	0.80	80%	1.25	-0.48
1988	31.20	31.20	1.49	29.00	0.97	97%	1.03	-1.22
1989	55.00	55.00	1.74	17.00	0.57	57%	1.76	0.18
1990	77.00	77.00	1.89	4.00	0.13	13%	7.50	1.94
1991	73.80	73.80	1.87	5.00	0.17	17%	6.00	1.70
1992	41.10	41.10	1.61	28.00	0.93	93%	1.07	-1.00
1993	70.00	70.00	1.85	8.00	0.27	27%	3.75	1.17
1994	51.00	51.00	1.71	19.00	0.63	63%	1.58	0.00
1995	77.50	77.50	1.89	3.00	0.10	10%	10.00	2.25
1996	47.50	47.50	1.68	22.00	0.73	73%	1.36	-0.28
1997	61.40	61.40	1.79	11.00	0.37	37%	2.73	0.78
1998	59.80	59.80	1.78	12.00	0.40	40%	2.50	0.67
1999	41.50	41.50	1.62	27.00	0.90	90%	1.11	-0.83
2000	99.80	99.80	2.00	2.00	0.07	7%	15.00	2.67
2001	104.80	104.80	2.02	1.00	0.03	3%	30.00	3.38
2002	48.30	48.30	1.68	21.00	0.70	70%	1.43	-0.19
2003	70.40	70.40	1.85	7.00	0.23	23%	4.29	1.33
2004	43.30	43.30	1.64	25.00	0.83	83%	1.20	-0.58
2005	42.30	42.30	1.63	26.00	0.87	87%	1.15	-0.70
2006	62.80	62.80	1.80	10.00	0.33	33%	3.00	0.90
2007	55.10	55.10	1.74	16.00	0.53	53%	1.88	0.27
2008	72.50	72.50	1.86	6.00	0.20	20%	5.00	1.50
2009	54.00	54.00	1.73	18.00	0.60	60%	1.67	0.09
2010	56.10	56.10	1.75	15.00	0.50	50%	2.00	0.37
2011	46.90	46.90	1.67	23.00	0.77	77%	1.30	-0.38
2012	69.60	69.60	1.84	9.00	0.30	30%	3.33	1.03
2013	59.40	59.40	1.77	13.00	0.43	43%	2.31	0.57
n	29							
Mean (Xm)	59.43	Mean (Ym)	1.76			K_N	2.55	
Standard Deviation (Sx)	16.85	Standard Deviation (Sy)	0.12			High Outlier Limit	114.62	
						Low Outlier Limit	28.66	

Table 4: Rainfall Data Analysis using Gumbel Method

$$X_T = X_M + K_T S_X$$

Station	Frequency (yr)	*Frequency factor, K_T	Reduced Variate, y	Potential Max Runoff X_T [mm]
	2	-0.15	0.37	56.9
	5	0.87	1.50	74.1
	10	1.55	2.25	85.5
	25	2.40	3.20	99.9
	50	3.04	3.90	110.6
	100	3.67	4.60	121.3
	500	5.12	6.21	145.8

*Gumble Distribution Frequency Factor (from standard table)

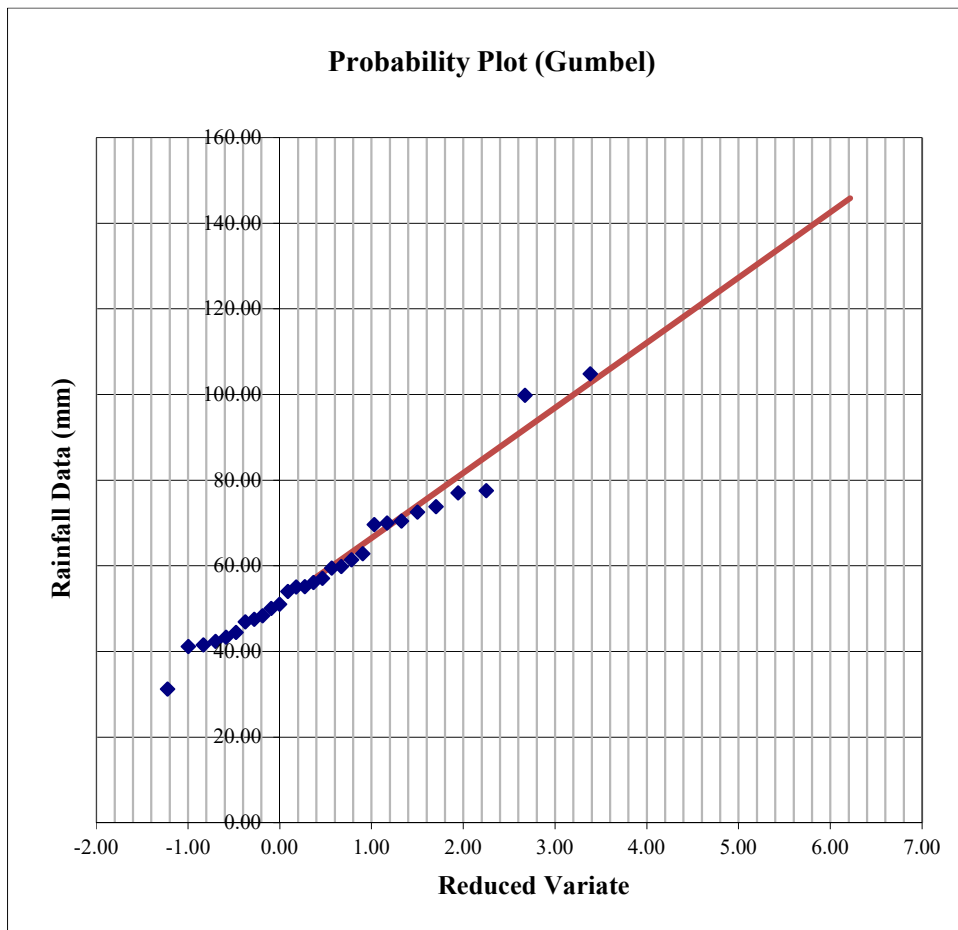


Figure 4 :Probability Plot using Gumbel Method

Table 5: Rainfall Data Analysis using Log Normal Method

$$Y_T = Y_m + K_T S_y$$

$$X_T = 10^{Y_T}$$

Station	Return Period, T [yr]	Exceedence Probability	Skewness Coeff, Cs	*Frequency factor, K _T	Y _T	Potential Max Runoff X _T [mm]
	2	50.0%	0.00	0.00	1.76	57.31
	5	20.0%		0.84	1.86	72.05
	10	10.0%		1.28	1.91	81.21
	25	4.0%		1.75	1.96	92.25
	50	2.0%		2.05	2.00	100.18
	100	1.0%		2.33	2.03	107.89
	500	0.2%		2.88	2.10	125.35

* from standard distribution table, f(Cs, T)

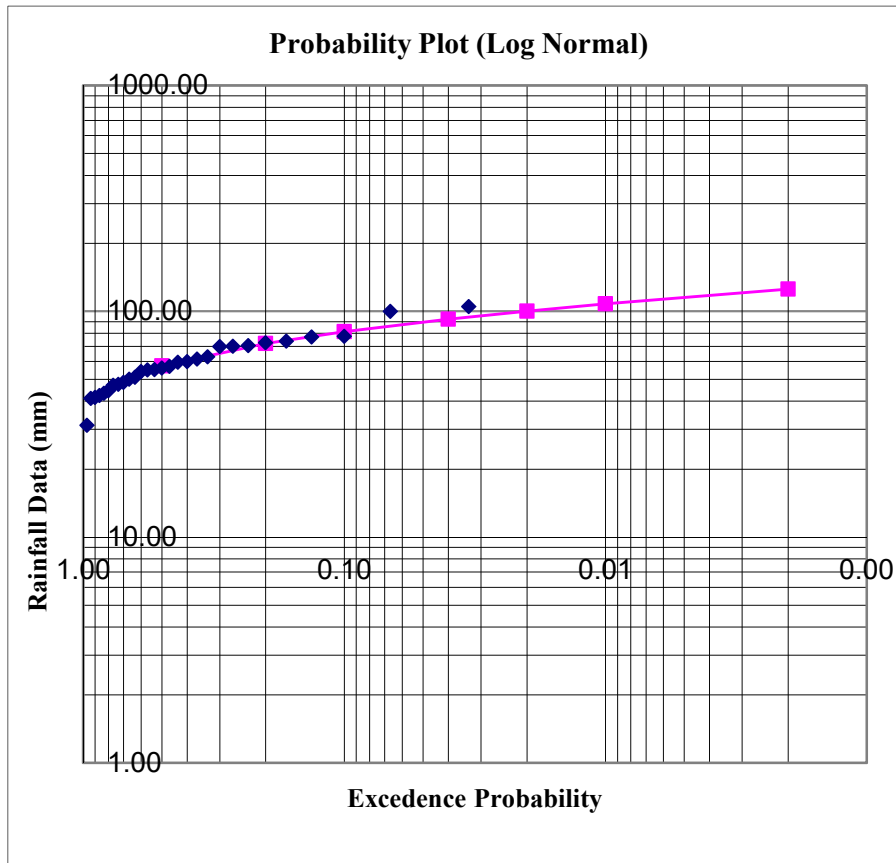


Figure 5 :Probability Plot using Log Normal Method

Table 6 : Rainfall Data Analysis using Log Pearson Type III Method

Station	Return Period, T [yr]	Exceedence Probability	Skewness Coeff, Cs	*Frequency factor, K_T	Y_T	Potential Max Runoff X_T [mm]
	2	50.0%	0.21	-0.04	1.75	56.76
	5	20.0%		0.83	1.86	71.81
	10	10.0%		1.30	1.91	81.66
	25	4.0%		1.82	1.97	94.06
	50	2.0%		2.17	2.01	103.30
	100	1.0%		2.48	2.05	112.56
	500	0.2%		3.14	2.13	134.55

* from standard distribution table, $f(Cs, T)$

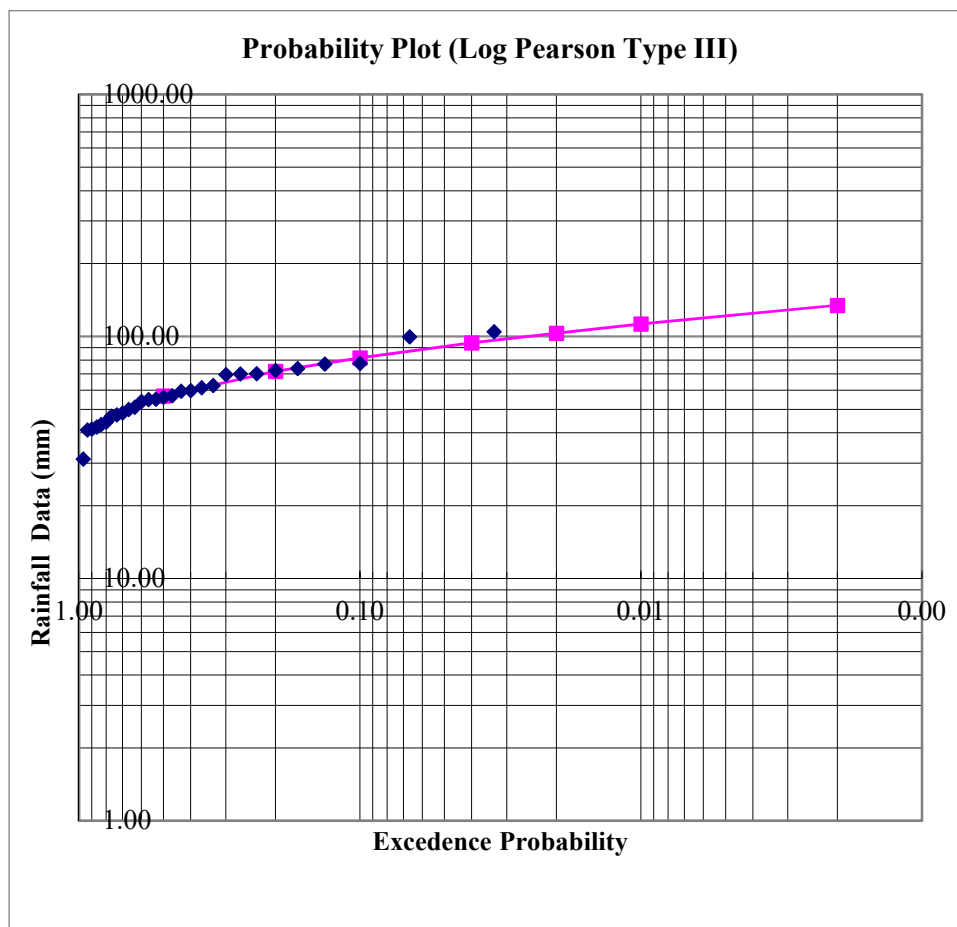


Figure 6 : Probability Plot using Log Pearson Type III Method

The best fit method, Gamble is selected for the design rainfall of the project area.

Table 7: Design Rainfall of the area selected for the Analysis

Return Period	25	50	100	Rainfall Region
24 hr Rainfall (mm)	99.9	110.6	121.6	A3

5.1.2 Catchments Delineation

The catchment delineations have been done on the digital topographic map. The catchment areas that affect the road segment are properly identified and all the catchment parameters that are useful for flood estimation carefully determined.

Table 8: Size of the catchment areas

No	Station	Cat ID	Catchment in Km²
1	2+210	A1	1.93
2	2+750	A2	1.51
3	3+285	A3	4.61
4	4+325	A4	2.30

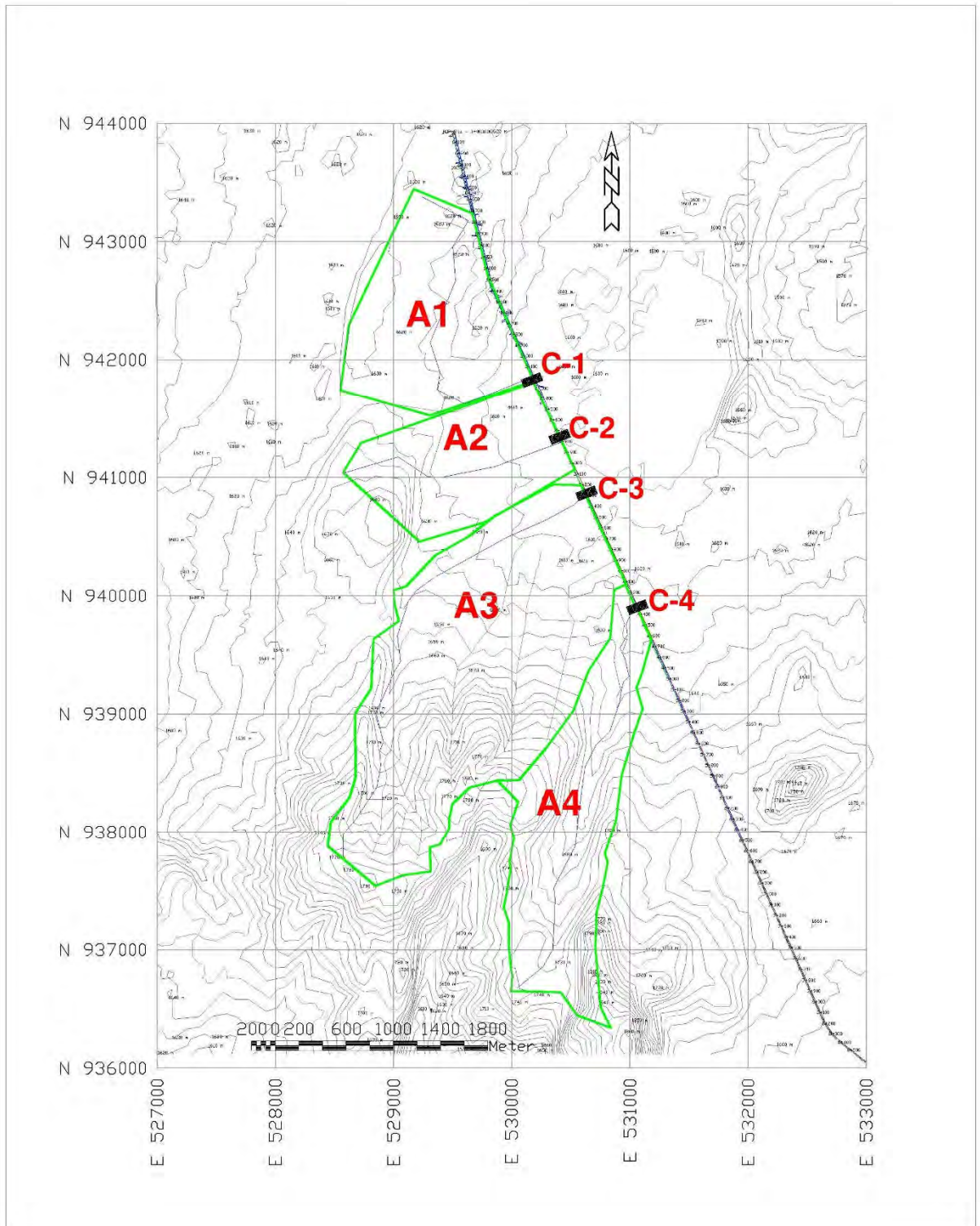


Figure 7: Catchment Areas and Location of Culverts

Table 9: Description of Culverts

Culverts Name	Culvert Designation	Station
Culvert 1	C1	2+210
Culvert 2	C2	2+750
Culvert 3	C3	3+285
Culvert 4	C4	4+325

5.1.3 Soil and Land Cover of the catchments area

i) Soil Type of the Catchments area

One of the factors which affect the rainfall-runoff is the soil type. The soil types of the catchment areas under consideration are Mollic Andosols (Tm) and Vertic Cambisols (Bv) as shown in the figure below. Both soil type classifications are under B Hydrological Soil Group (HSG), soils that have a moderately low runoff potential due to moderate infiltration rates.

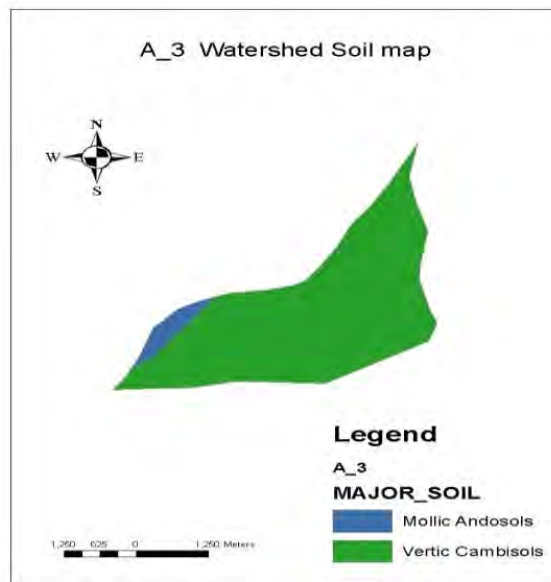


Figure 8: Soil Map of the catchment

ii) Land use of the catchment area

The catchment areas are located in the Adama Town Section. Currently, some sections of the catchments are covered by settlement. However, urbanization is fast and considerable section of these catchments will be changed into town section. Therefore, changes in land use are considered in the determination of runoff curve number for the catchments that are located in the town section.

However, the land cover map indicates that the catchments area as moderately cultivated as shown below.

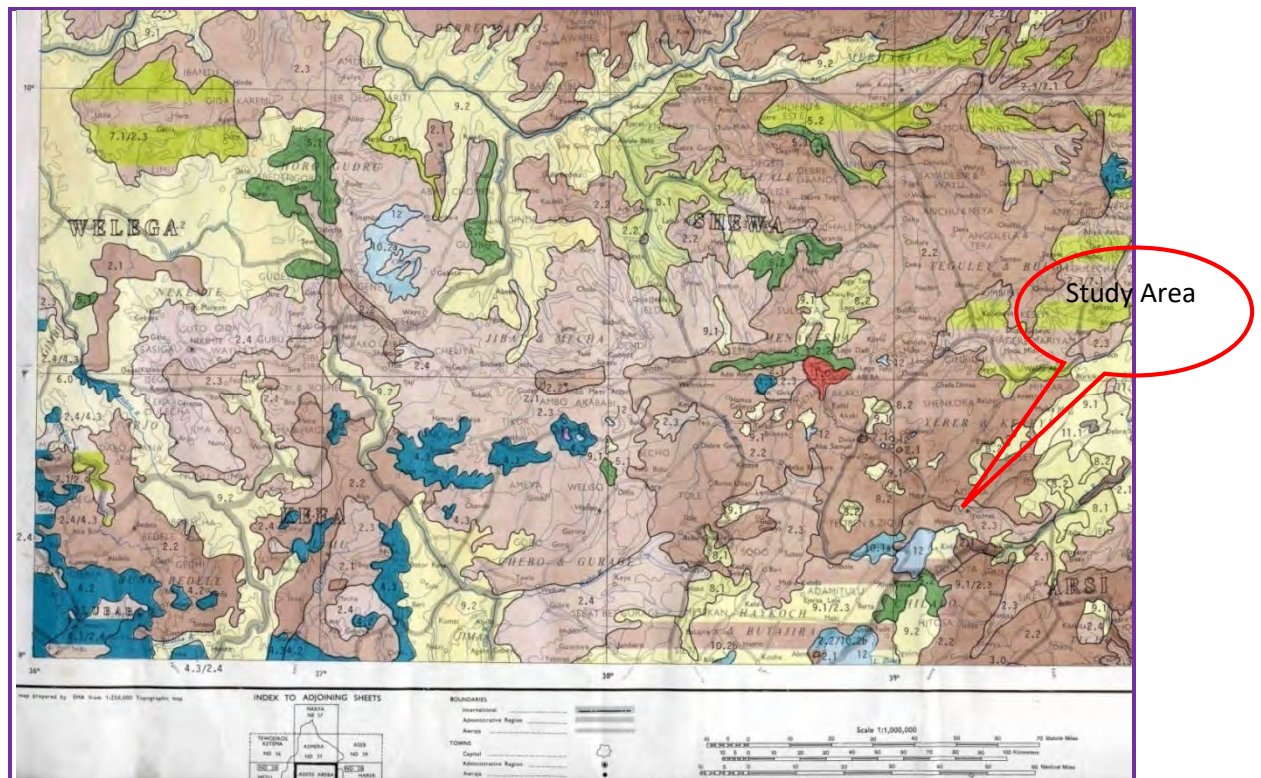


Figure 9 : Land Cover Map of the Study Area (ERA DDM 2013)

5.1.4 Hydraulic characteristics

Slope:-

The average bed slopes of the ground cross section at the locations of structures as well as elevations of the furthest point of the longest water course have been estimated based on contours generated using the DEM data. Furthermore, catchment area delineation and direction of stream flow have been determined using the same. However these data have been reviewed using drainage maps of Adama.

Value of Manning's "n":-

Values of Manning's roughness coefficient were estimated for all cross drainage structures by actual observations in the field and selecting suitable values from standard tables reproduced in ERA DDM, 2013. Therefore, Manning's roughness coefficient $n=0.04$ has been adopted for the channel for the hydraulic analysis of the culverts.

5.2 Hydrological Analysis

5.2.1 General

The hydrological analysis has been under taken to estimate the design discharge for Nazareth-Assela road section of Adama Town based on the site investigation supplemented by desk study.

The study is carried out for the following road section:-

- ◆ Road section around km 2+210
- ◆ Road section between km 2+700 ~ km 3+400
- ◆ Road section around km 4+300

In the above mentioned section, there are four culverts for which the design floods are estimated using a spread sheet program.

ERA DDM states that a design frequency shall be selected commensurate with the facility cost, volume of traffic, potential flood hazard to property, expected level of

service, strategic considerations, and budgetary constraints, as well as the magnitude and risk associated with damages from larger flood events.

The design frequency requirement put in the ERA DDM, 2013 is as follows:-.

Table 10: Design Storm Frequency (yrs) by Geometric Design Criteria

Structure Type	EW1/DC8/DC7		DC6/DC5		DC4/DC3		DC2/DC1/Truck	
	Design	Check	Design	Check	Design	Check	Design	Check
Gutters and Intets	5/5/5	10/10/10	5/5	10/10	5/2	10/5	-	-
Side Ditches	10/10/10	25/25/25	5/5	10/10	5/2	10/5	-	-
Ford/Low-Water Bridge	-	-	-	-	-	-	5/5/5	10/10/10
Culvert, pipe span < 2m	25/25/25	50/50/50	10/10	25/25	10/5	25/10	5/5/5	10/10/10
Culvert, 2m < span < 6m	50/50/50	100/100/100	25/25	50/50	25/10	50/25	10/10/10	25/25/25
Short span Bridges 6m < span < 15m	50/50/50	100/100/100	25/25	50/50	25/10	50/25	10/10/10	25/25/25
Medium span Bridges 15m < span < 50m	100/100/100	200/200/200	50/50	100/100	50/25	100/50	50/25/25	100/50/50
Long span Bridgs spans > 50m	100/100/100	200/200/200	50/50	100/100	50/25	100/50	50/25/25	100/50/50

EW1- Express way

Hence, the design floods for this study are estimated for 25 and 50 years return period rainfall as per the above standard.

5.2.2 Design Flood Estimation

The catchment areas that are addressed under this study (Adama Town in Nazereth-Assela Road section) is greater than 0.5km². Hence, the design floods

are estimated using SCS method as per the recommendation of ERA Drainage Design Manual 2013 (ERADDM-2013).

The required parameters used for the computation of the SCS method have been discussed in the “Results” under section 4.1

Table 11: Curve number that are used for the design flood estimation

No	Station	Cat ID	Catchment in km ²	Land Use	HSG	CN	Remark
1	2+210	A1	1.93	Urban	B	88	Town
2	2+750	A2	1.51	Urban	B	88	Town
3	3+285	A3	4.61	Urban	B	88	Will be town section
4	4+325	A4	2.30	Urban	B	88	Will be town section

Table 12: Design Discharge Using SCS Method Using Spread Sheet

ID NO	Station	Catchment Area No.	Area	Rainfall	Stream Length (m)	H _{max}	H _{min}	River Slope (m/m)	Tc	P (mm)	Tc	CN	Rec. Int.	Sr (mm)	Ia (mm)	Direct Runoff Qd (mm)	Ia/P	q _u	Design Discharge Q _p
			(km ²)	Station		(m)	(m)		(hr)		(hr)		(Years)						(m ³ /s)
1	2+210	A-1	1.93	Adama	1566	1625	1620	0.003	0.86	99.9	1.29	88	25	34.6	6.9	67.7	0.1	0.131	17.1
			1.93		1264	1620	1605	0.012	0.44	110.6	1.29	88	50	34.6	6.9	77.7	0.1	0.131	19.6
			1.93		2830				1.29	121.6	1.29	88	100	34.6	6.9	88.1	0.1	0.131	22.2
2	2+275	A-2	1.51	Adama	886	1655	1618	0.042	0.21	99.9	0.76	88	25	34.6	6.9	67.7	0.1	0.182	18.6
			1.51		1607	1618	1601	0.011	0.55	110.6	0.76	88	50	34.6	6.9	77.7	0.1	0.182	21.4
			1.51		2492				0.76	121.6	0.76	88	100	34.6	6.9	88.1	0.1	0.182	24.2
3	3+285	A-3	4.61	Adama	1068	1765	1675	0.084	0.18	99.9	0.93	88	25	34.6	6.9	67.7	0.1	0.161	50.4
			4.61		1554	1675	1625	0.032	0.35	110.6	0.93	88	50	34.6	6.9	77.7	0.1	0.161	57.9
			4.61		1456	1625	1595	0.021	0.40	121.6	0.93	88	100	34.6	6.9	88.1	0.1	0.161	65.6
					4079				0.93										
4	4+325	A-4	2.30	Adama	969	1740	1695	0.046	0.21	99.9	0.77	88	25	34.6	6.9	67.7	0.1	0.181	28.1
			2.30		2593	1695	1625	0.027	0.56	110.6	0.77	88	50	34.6	6.9	77.7	0.1	0.181	32.3
			2.30		3562				0.77	121.6	0.77	88	100	34.6	6.9	88.1	0.1	0.181	36.6

The design discharge values that will be used for hydraulic analysis are summarized and presented in the table below.

Table 13: Summary of Design Discharge Estimate

ID NO	Station	Cat. ID	Area km ²	DESIGN DISCHARGE m ³ /s		
				Q ₂₅	Q ₅₀	Q ₁₀₀
1	2+210	A1	1.93	17.1	19.6	22.2
2	2+750	A2	1.51	18.6	21.4	24.2
3	3+285	A3	4.61	50.4	57.9	65.6
4	4+325	A4	2.30	28.1	32.2	36.6

5.2.3 The Design Review Consultant's Analysis compared with the design discharge

The method the consultant has followed for hydrological analysis was different from ERA DDM 2013. In the report, it is stated that "The Rational formula has been used for computing design floods for water shed areas less than or equal to 30km². The Regional Flood Equation has also been used for computing design flood for watershed area exceeding 30km² of the project area."

Whereas, in ERA DDM 2013, for watershed area less than or equal to 0.5km² the rational method has to be used. There is a concept difference between the two.

According to the Consultant's report, the culverts which are in the town section, the watershed areas were considered as not measureable from the map.

Hence, for comparison purpose, as the regression equation was derived for the project by the consultant, the regression equation has been used for estimating the discharge.

Table 14: Discharge Estimate using Regression Equation derived for the project

ID NO	Station	Cat. ID	Area km ²	Estimated Discharge using Regression Equation(m ³ /s)		
				Q ₂₅ = 7.803*CA ^{0.561757}	Q ₅₀ = 8.546*CA ^{0.561757}	Q ₁₀₀ = 9.661*CA ^{0.561757}
1	2+210	A1	1.93	11.29	12.36	13.98
2	2+750	A2	1.51	9.84	10.77	12.18
3	3+285	A3	4.61	18.41	20.17	22.79
4	4+325	A4	2.30	12.46	13.65	15.43

As we can see from the above table, the estimated discharges as the design review consultant's result are much lower than the design discharges.

5.3 Hydraulics Analysis

The existing structures have been modeled using HEC-RAS (Hydrologic Engineering Center-River Analysis System) and HY8 (HY8 Culvert analysis) to determine the capacity. The capacity of the structures is analyzed with the estimated runoff for 25 and 50 years return periods.

◆ Culvert at km 2+210

Due to the severity of the drainage problem, a crossing structure was constructed by the Town Administration at km 2+210. The capacity of the newly constructed double box culvert, size 2(3mx1.5m) has been analyzed using HEC-RAS model. The capacity of existing structure has been found inadequate for the design discharges of 17.1m³/s and 19.6m³/s for 25 and 50 years return period respectively as shown in **Figure 10** and **Figure 11**. Therefore, in order to accommodate the design discharge, an additional box culvert of size 3mx1.5m is required. **Figure 12** and **Figure 13** shows that when the size of the crossing structure has increased to 9mx1.5m, the design discharges will be accommodated by the culvert.

◆ Culvert at km 2+275

As the data for this specific case has not fully described the condition of topography of the watershed area and stream pattern, HEC-RAS model couldn't be used for this specific case. The analysis has been done using HY-8. According to the analysis, the existing structure capacity was adequate for both the design discharges of $18.6\text{m}^3/\text{s}$ and $21.4\text{m}^3/\text{s}$ for 25 years and 50 years return period respectively. As shown in **Table 15** and **Table 16** as well as **Figure 14** and **Figure 15** below, the capacity of the existing culvert size $4\text{m}\times 1.5\text{m}$ has been found adequate to accommodate the design discharge.

However, around the specific road section, there is no defined channel around the road. The stream floods the residential area by spreading and crosses the road by overtopping the road section between km 2+275 and km 3+285. Hence, special consideration shall be given for this section.

◆ Culvert at km 3+285

The analysis at this crossing has been done using HEC-RAS model.

The capacity of the existing culvert (size $2.5\text{m}\times 1.5\text{m}$) has been found inadequate for the design discharges of $50.4\text{m}^3/\text{s}$ and $57.9\text{m}^3/\text{s}$ for 25 and 50 years return period respectively as shown in **Figure 16** and **Figure 17** below. Therefore, in order to accommodate the design discharge, the size of the existing culvert shall be replaced by a bigger size. According to the analysis, **Figure 18** and **Figure 19** shows that when the size of the crossing structure has increased to $9\text{m}\times 2.5\text{m}$, the capacity of the culvert will be adequate to accommodate the design discharges.

◆ **Culvert at km 4+325**

The existing structure at km 4+325 is slab culvert with 3m clear span and 2m clear height. It is modeled with HEC-RAS 4.0 and the existing structure is inadequate for the design discharge of 28.1m³/s and 32.2m³/s for 25 and 50 years return period respectively as shown in **Figure 20** and **Figure 21** below. Therefore, in order to accommodate the design discharge, an additional culvert is required. According to the analysis, **Figure 22** and **Figure 23** shows that when the size of the crossing structure has to be increased to 6mx2m, so as to accommodate the design discharges.

The results of the HEC-RAS model and the HY8 culvert analysis for all the above mentioned culverts are as follows.

Hydraulic Analysis of Adama Town

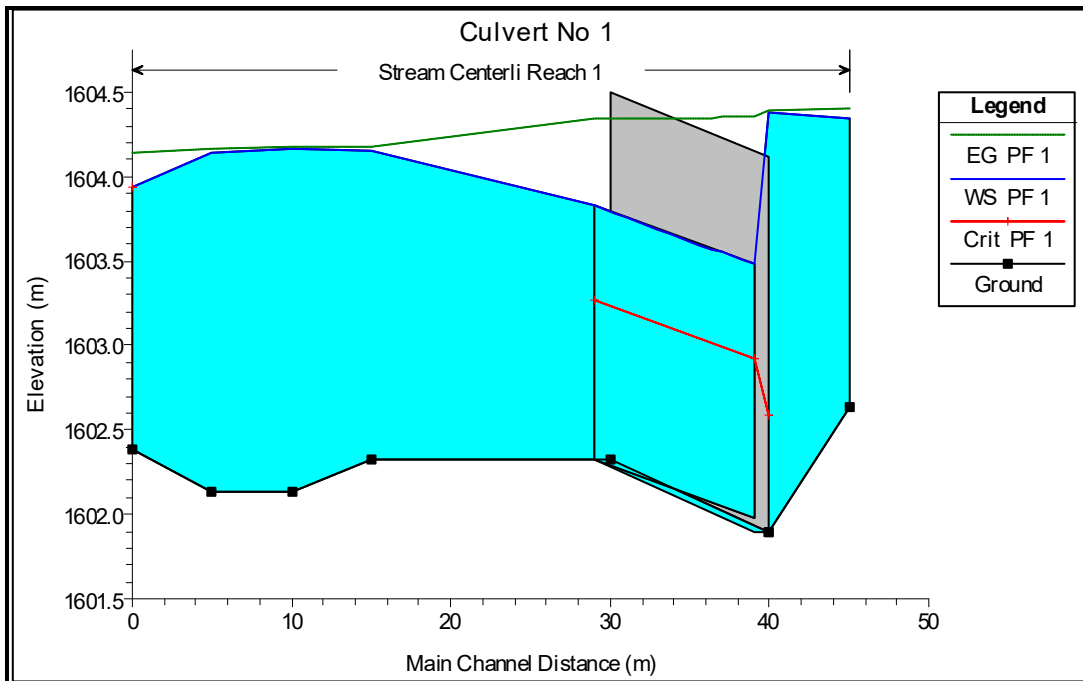


Figure 24: 25 years Peak Flood Profile of Inadequate Culvert at Km 2+210 (Size 6m by 1.5m)

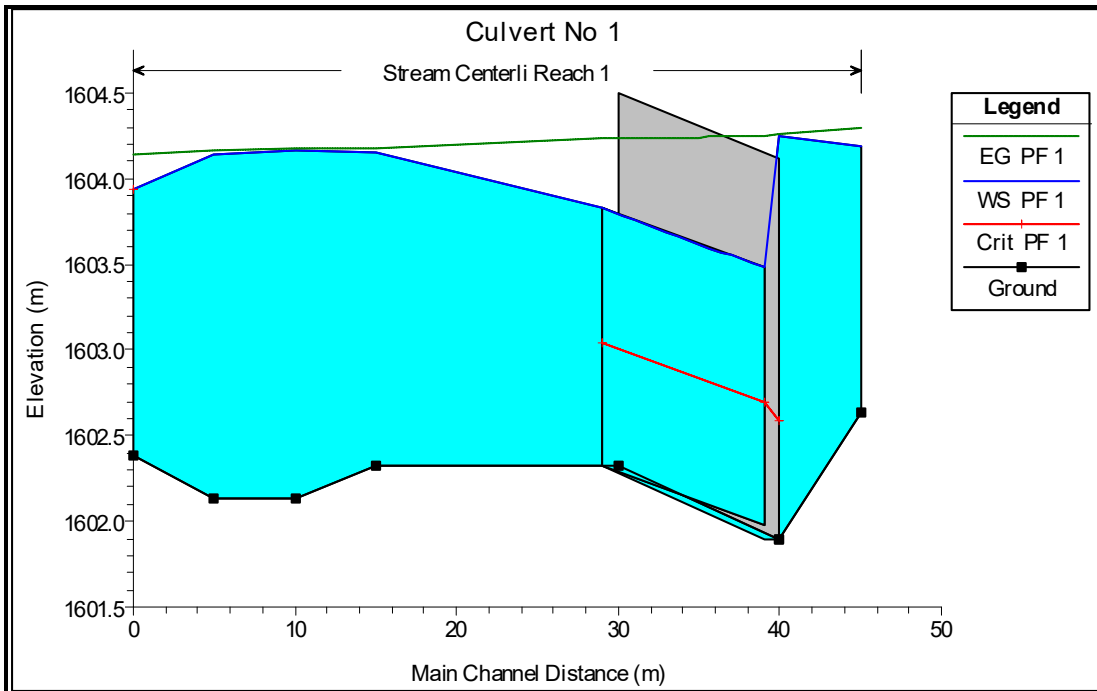


Figure 11: 25 years Peak Flood Profile at Km 2+210 (Size 9m by 1.5m)

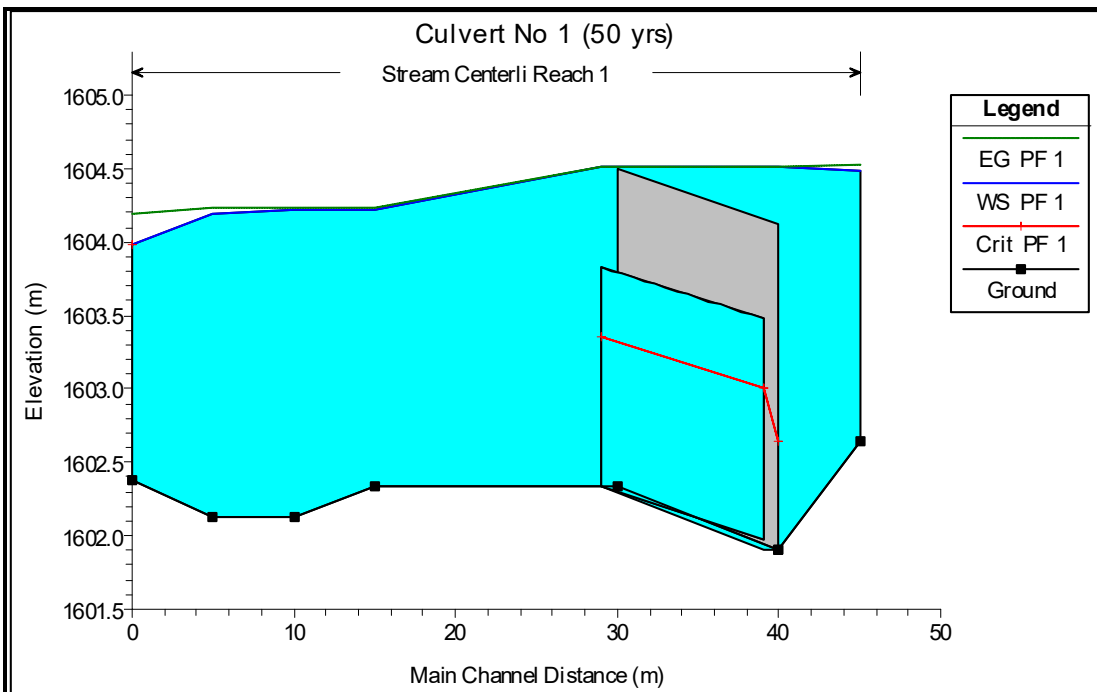


Figure 12: 50 years Peak Flood Profile of Inadequate Culvert at Km 2+210 (Size 6m by 1.5m)

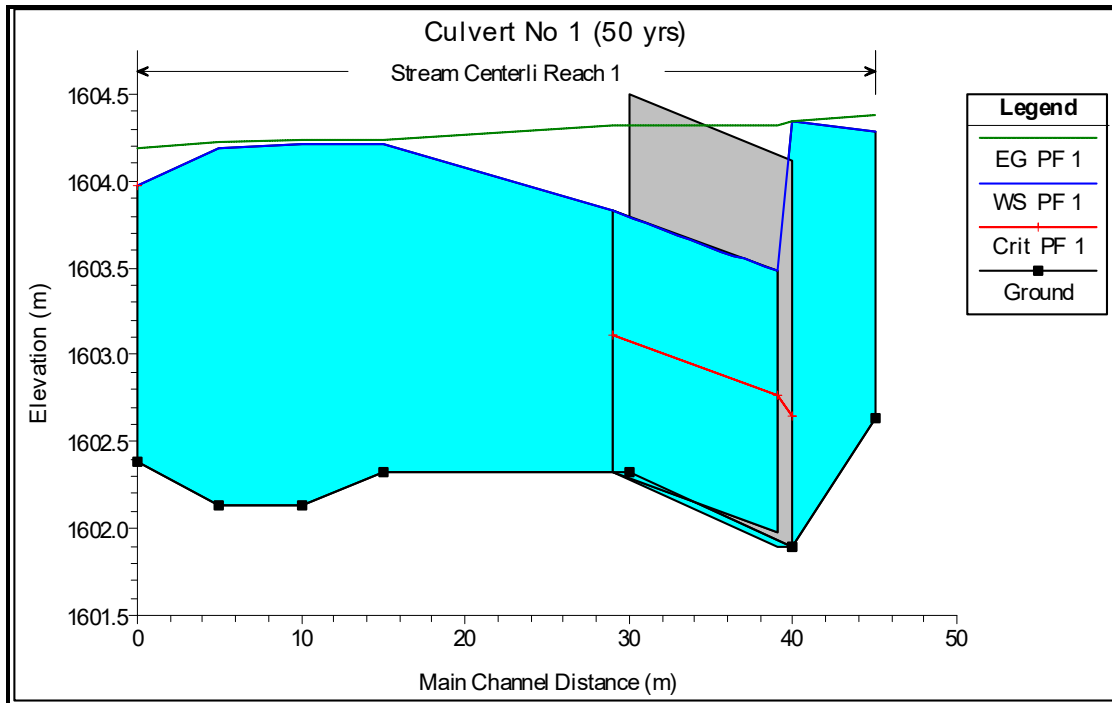


Figure 13: 50 years Peak Flood Profile at Km 2+210 (Size 9m by 1.5m)

Hydraulic Analysis of Adama Town

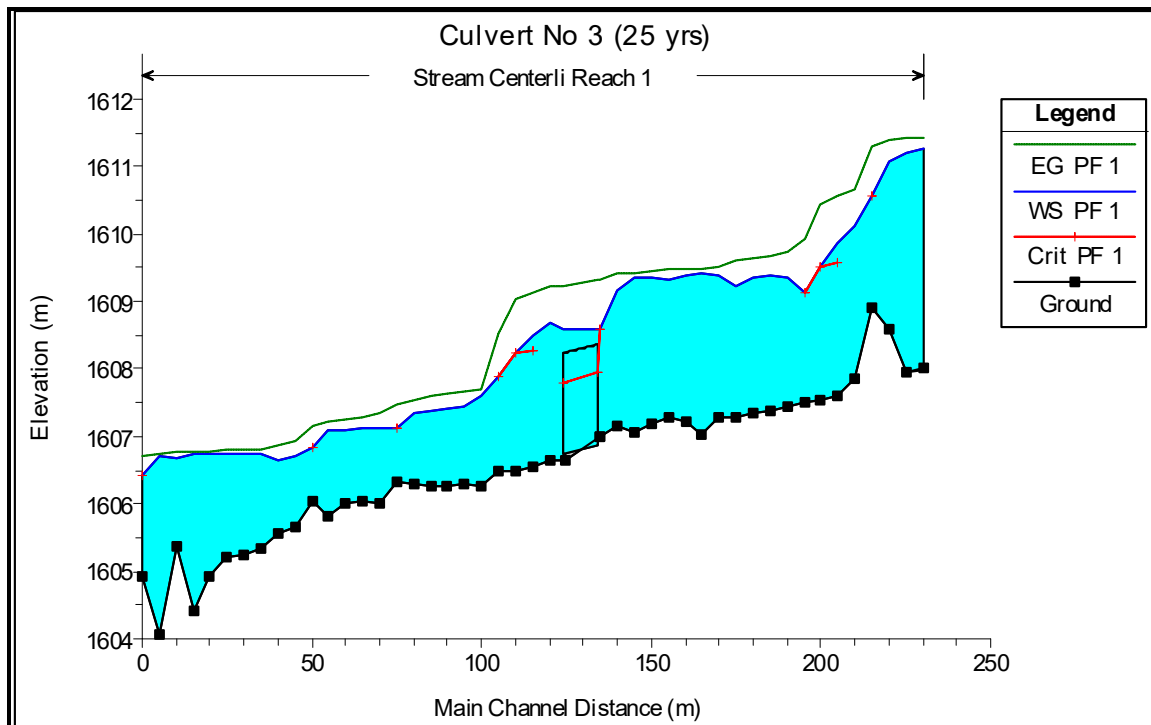


Figure 14: 25 years Peak Flood Profile of Inadequate Slab Culvert at Km 3+285 (Size 2.5m by 1.5m)

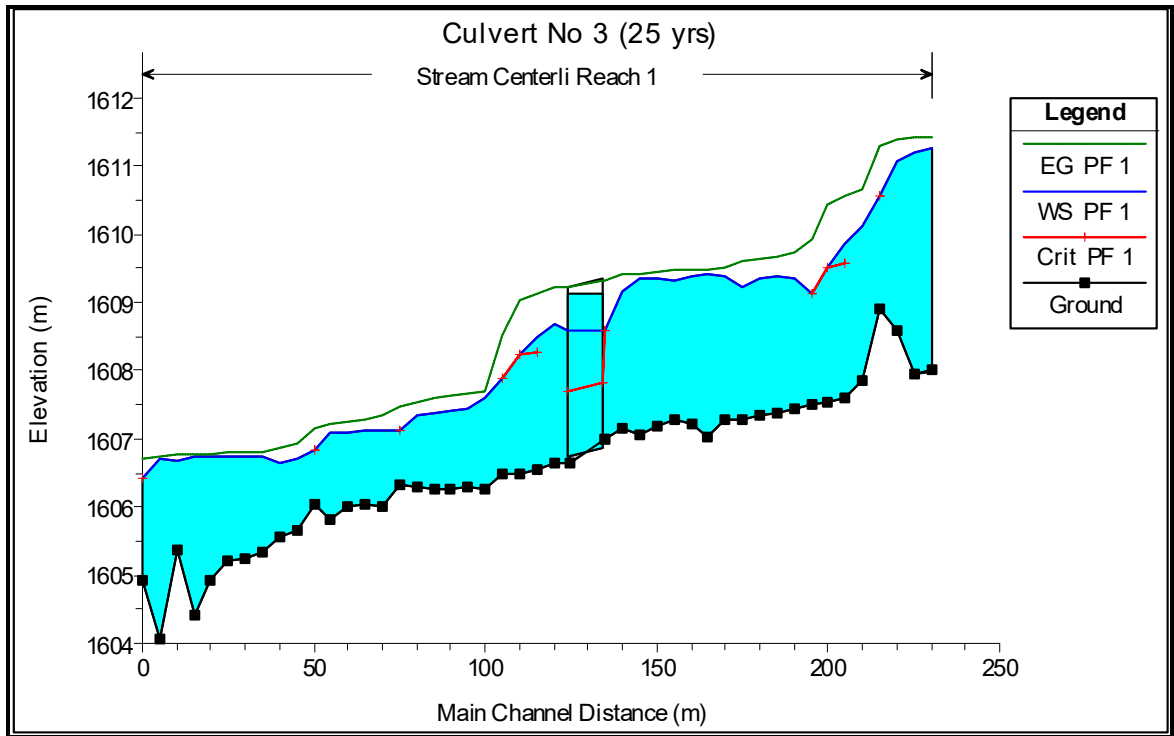


Figure 15: 25 years Peak Flood Profile at Km 3+285 (Size 9m by 2.5m)

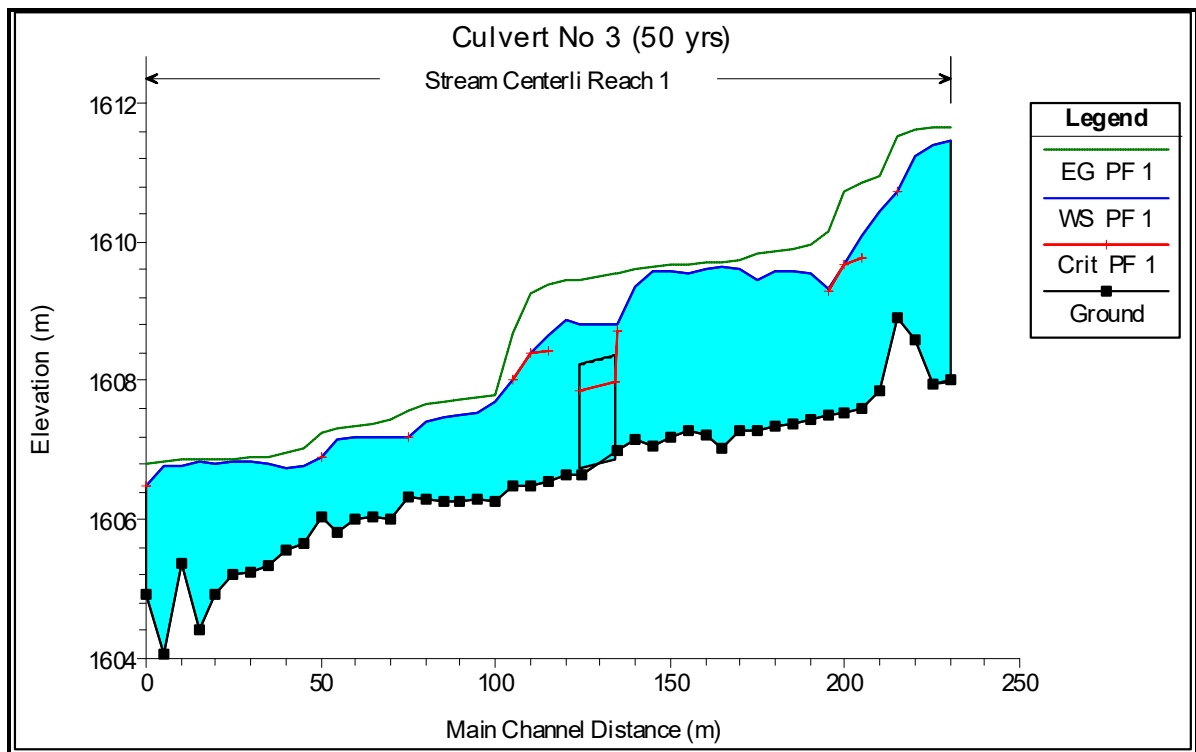


Figure 16: 50 years Peak Flood Profile of Inadequate Slab Culvert at Km 3+285 (Size 2.5m by 1.5m)

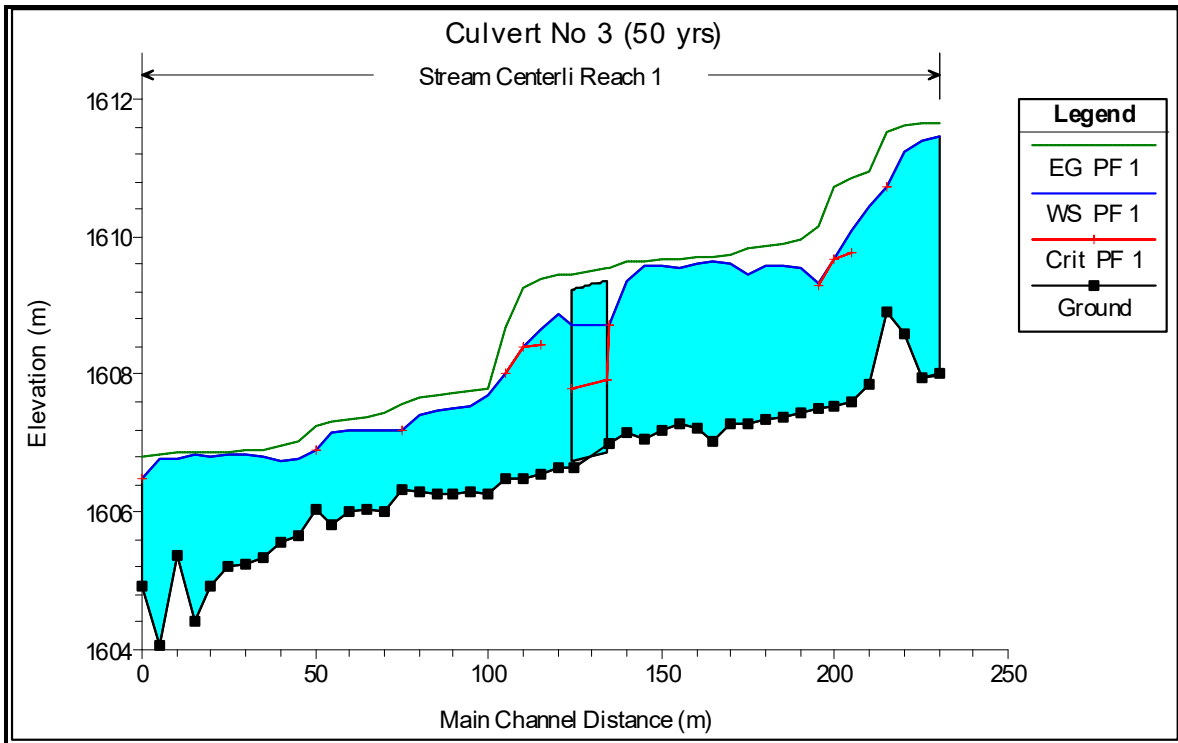


Figure 17: 50 years Peak Flood Profile at Km 3+285 (Size 9m by 2.5m)

Hydraulic Analysis of Adama Town

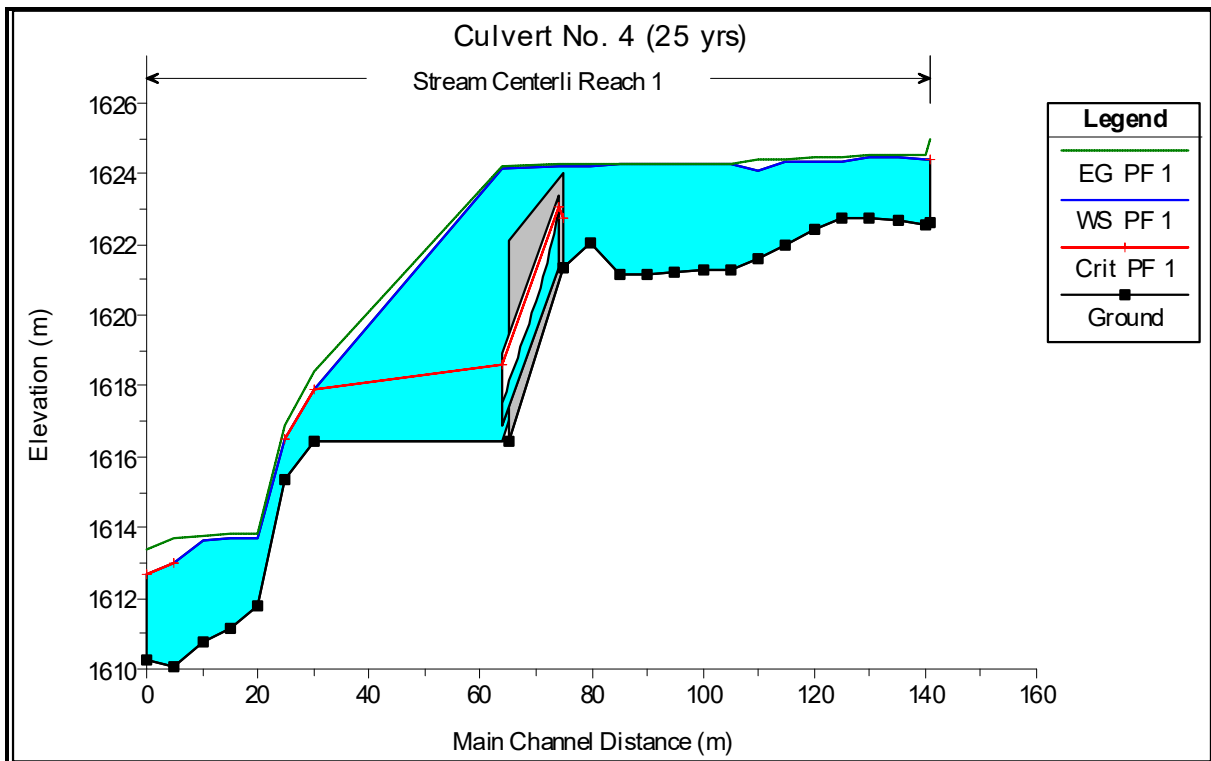


Figure 18: 25 years Peak Flood Profile of Inadequate Slab Culvert at Km 4+325 (Size 3m by 2m)

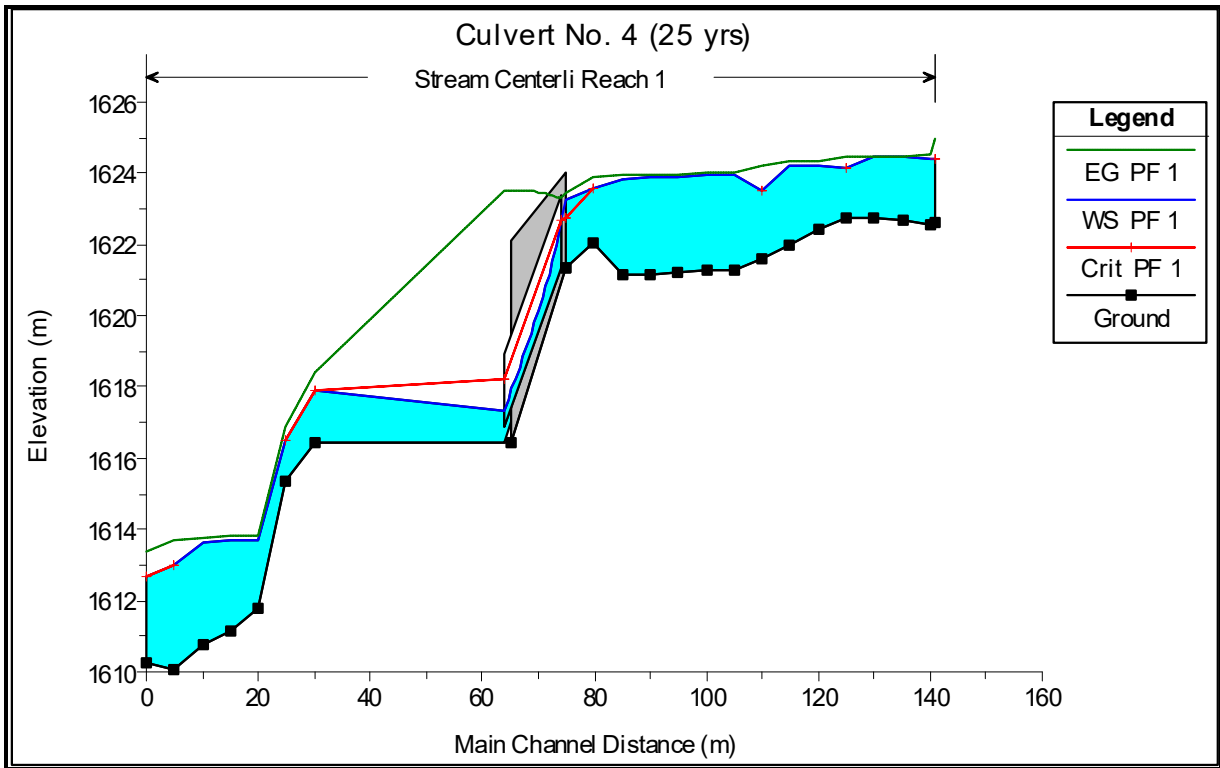


Figure 19: 25 years Peak Flood Profile at Km 4+325 (Size 6m by 2m)

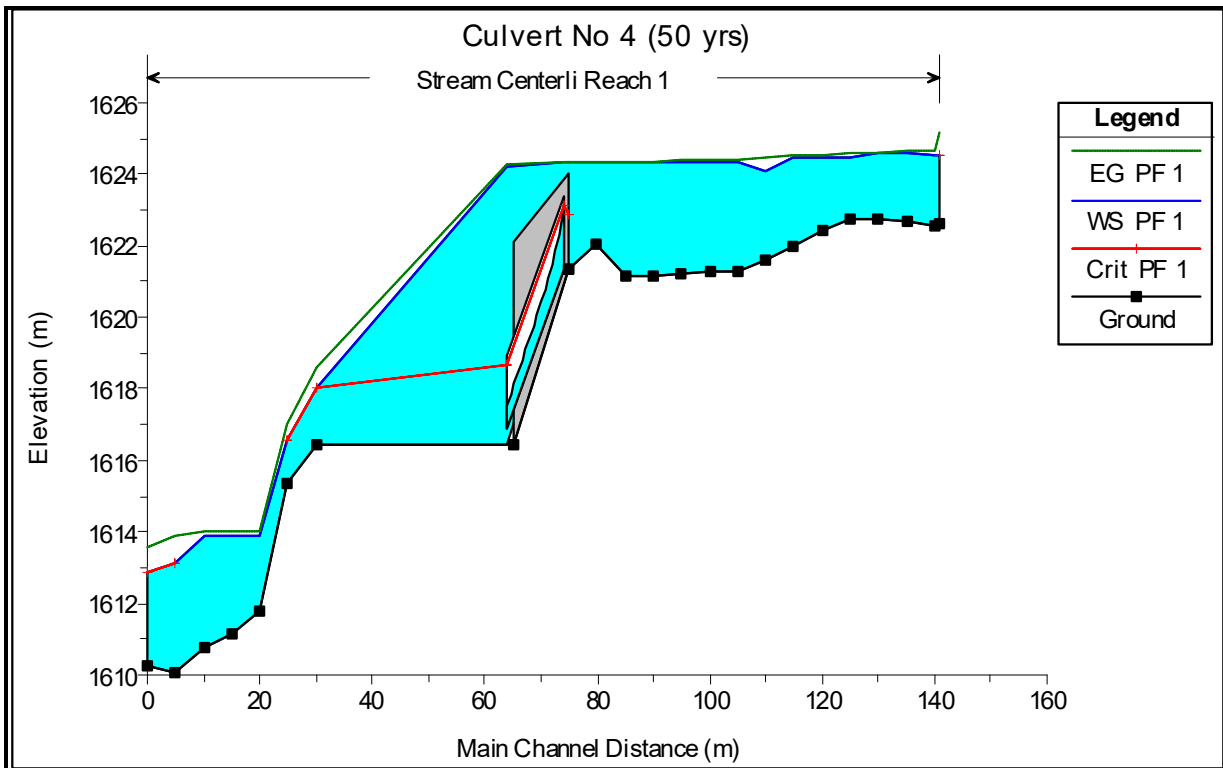


Figure 20: 50 years Peak Flood Profile of Inadequate Slab Culvert at Km 4+325 (Size 3m by 2m)

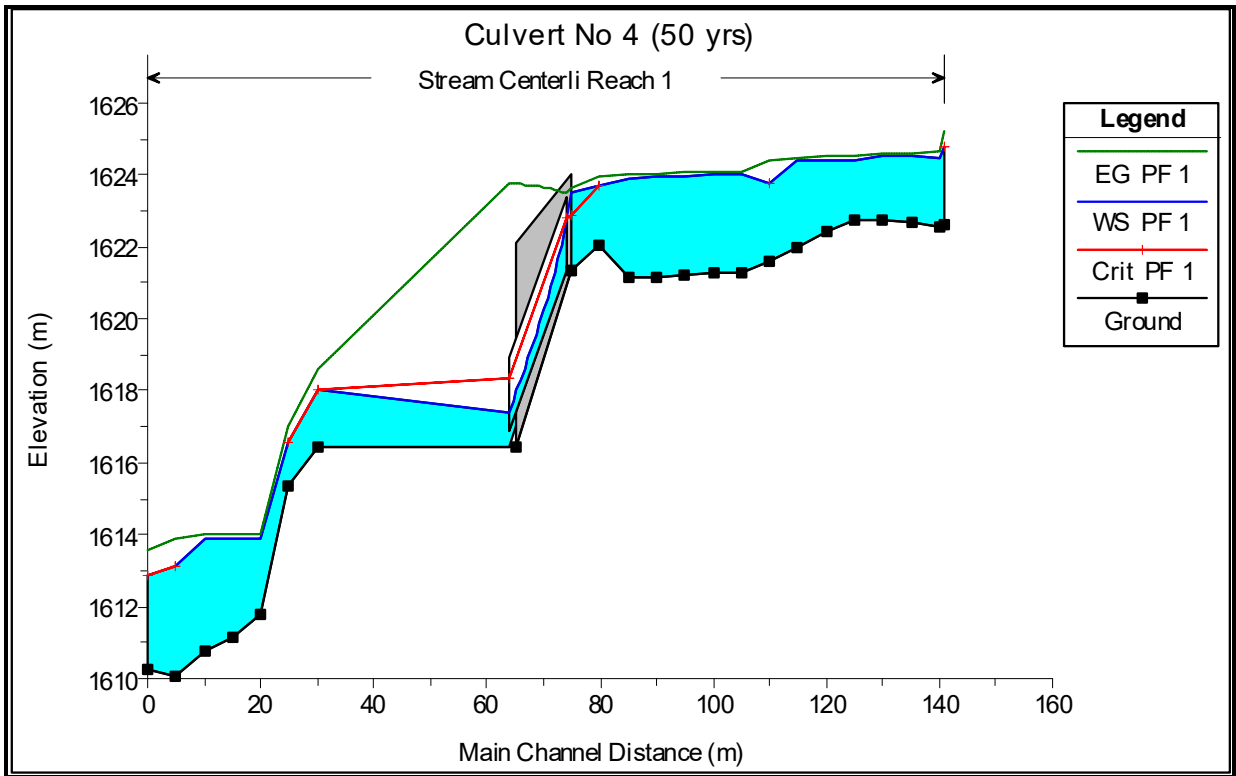


Figure 21: 50 years Peak Flood Profile at Km 4+325 (Size 6m by 2m)

Geometry Data of the Culverts

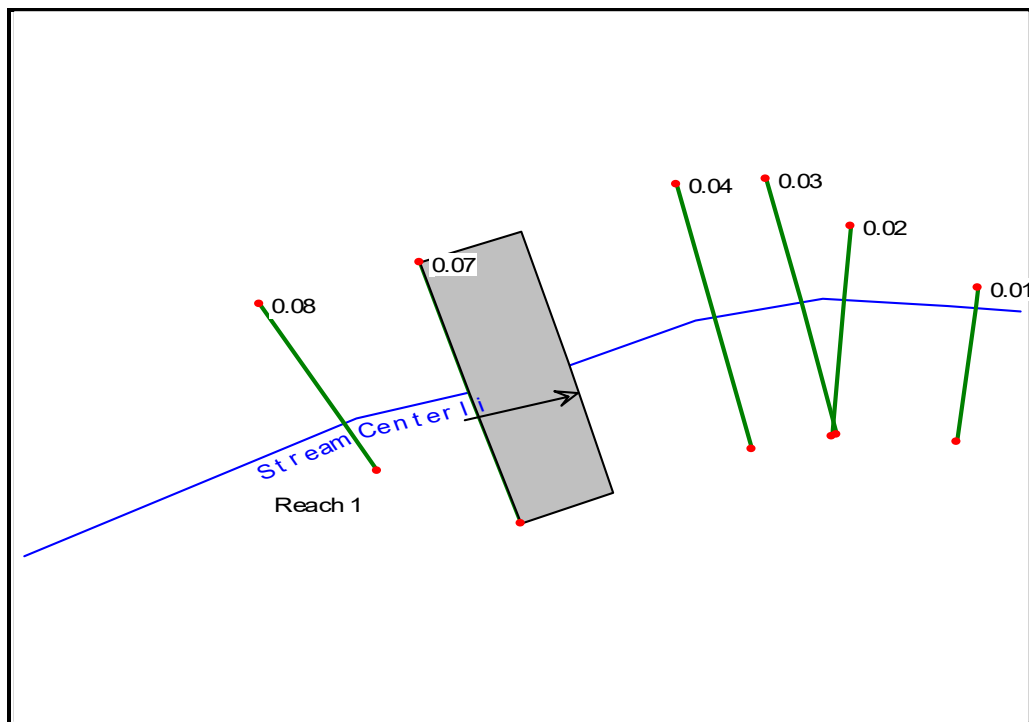


Figure 22: Geometry Data of Culvert No 1

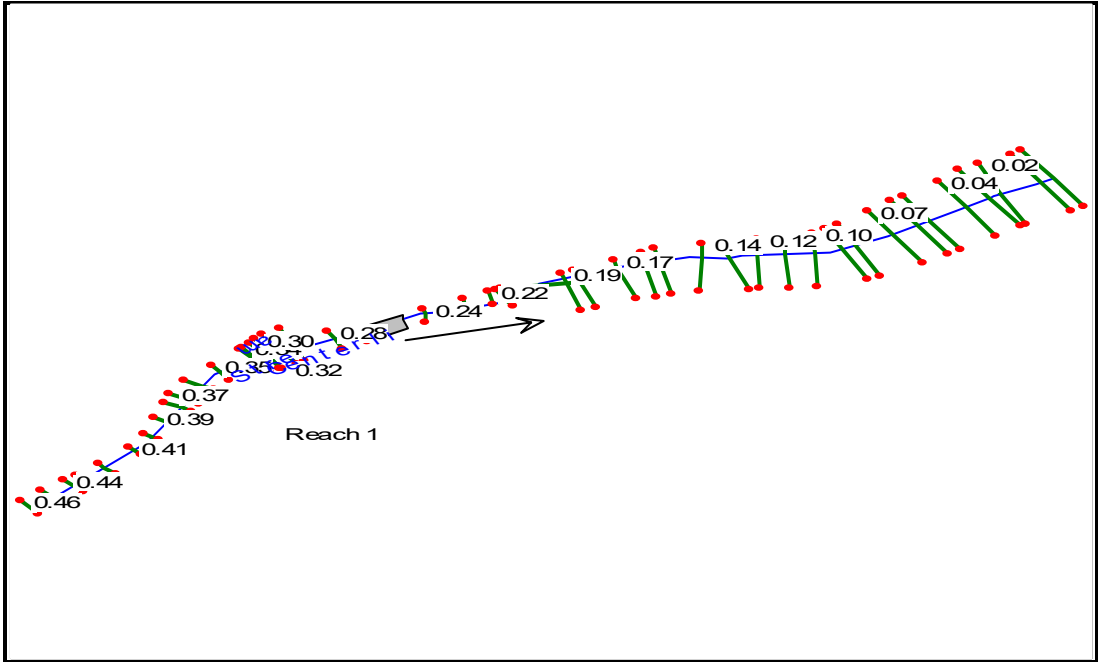


Figure 23: Geometry Data of Culvert No 3

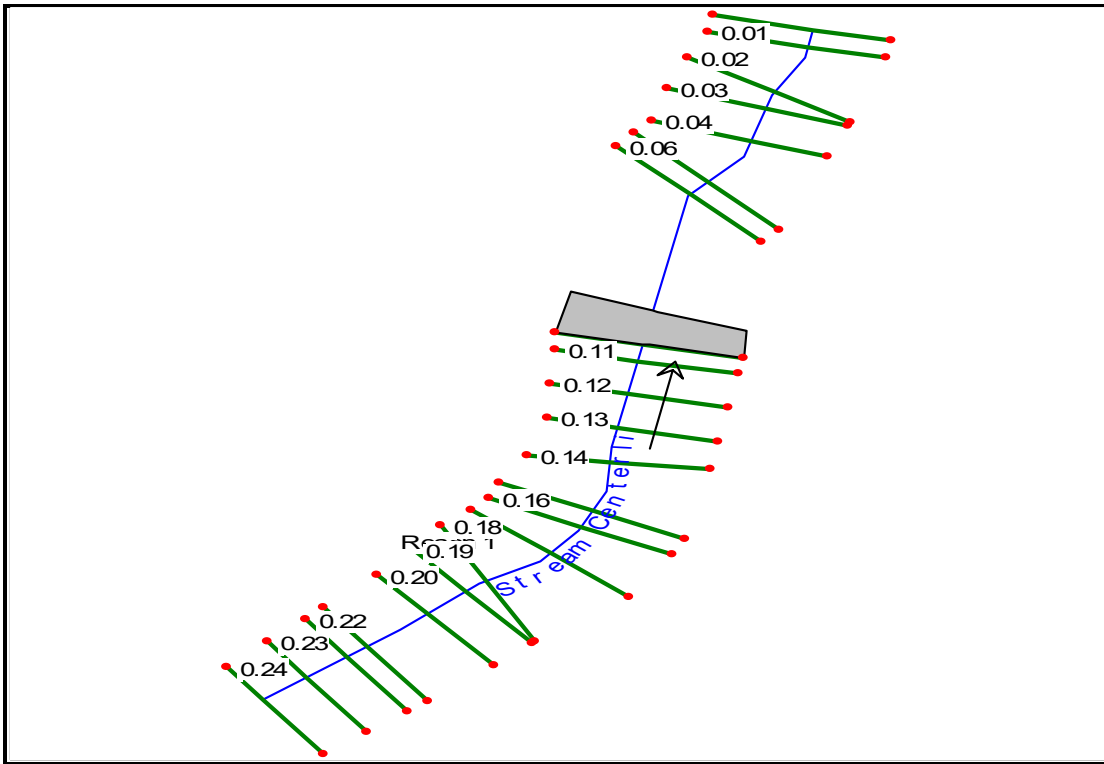


Figure 24: Geometry Data of Culvert No 4

Table15: Summary of Culvert Flows at km 2+275 Crossing (Size of existing culvert = 4mx1.5m) for 25 years return period

Headwater Elevation (m)	Total Discharge (cms)	Culvert at Km 2+750 Discharge (cms)	Roadway Discharge (cms)	Iterations
1601.50	0.00	0.00	0.00	1
1602.04	3.00	3.00	0.00	1
1602.37	6.00	6.00	0.00	1
1602.67	9.00	9.00	0.00	1
1602.94	12.00	12.00	0.00	1
1603.24	15.00	15.00	0.00	1
1603.58	18.00	18.00	0.00	1
1603.65	18.60	18.60	0.00	1
1604.19	24.00	22.52	1.47	9
1604.24	27.00	22.80	4.19	6
1604.27	30.00	23.02	6.97	5
1604.15	22.23	22.23	0.00	Overtopping

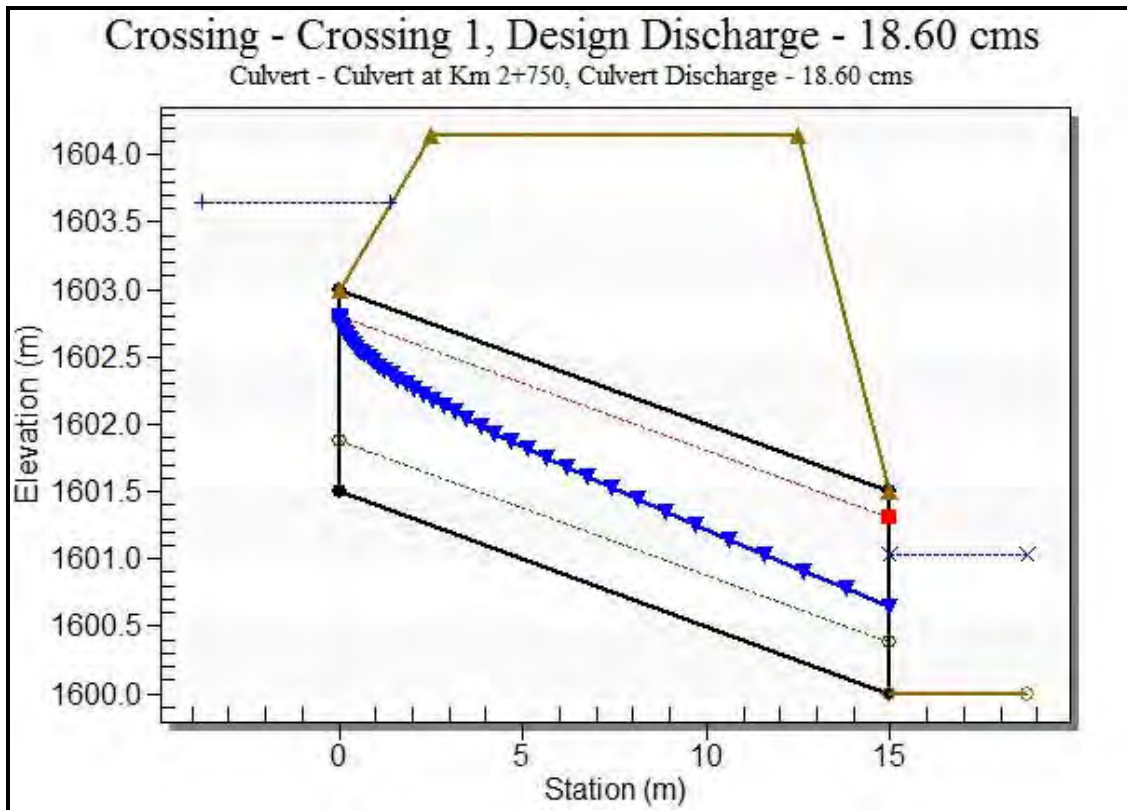


Figure 25: Water Surface Profile Plot for Culvert at Km 2+275 (Design Discharge =Culvert Discharge)

Table 16: Summary of Culvert Flows at km 2+275 Crossing (Size of existing culvert = 4mx1.5m) for 50 years return period

Headwater Elevation (m)	Total Discharge (cms)	Culvert at Km 2+750 Discharge (cms)	Roadway Discharge (cms)	Iterations
1601.50	0.00	0.00	0.00	1
1602.04	3.00	3.00	0.00	1
1602.37	6.00	6.00	0.00	1
1602.67	9.00	9.00	0.00	1
1602.94	12.00	12.00	0.00	1
1603.24	15.00	15.00	0.00	1
1603.58	18.00	18.00	0.00	1
1603.97	21.00	21.00	0.00	1
1604.03	21.40	21.40	0.00	1
1604.24	27.00	22.80	4.18	6
1604.27	30.00	23.02	6.97	5
1604.15	22.23	22.23	0.00	Overtopping

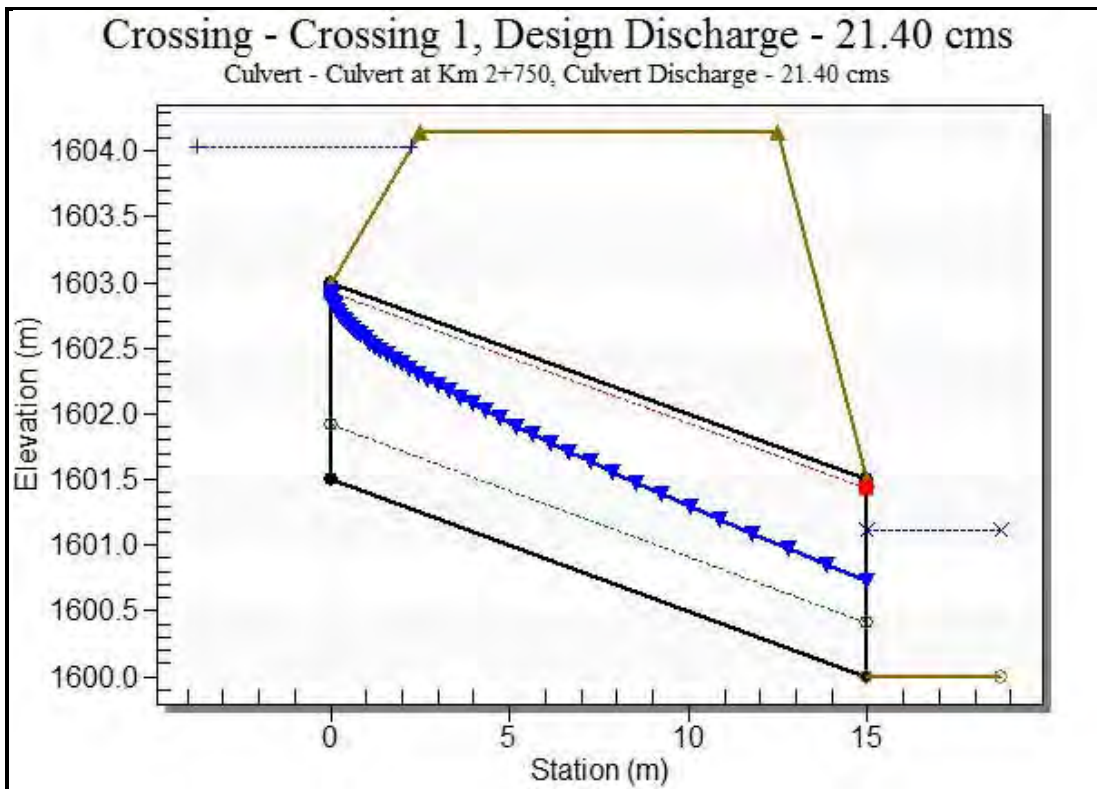


Figure 26: Water Surface Profile Plot for Culvert at Km 2+275 (Design Discharge =Culvert Discharge)

6. Remedial Measures

The drainage problems along the study area indentified during the field investigation, desk study as well as by analysis made based on the estimated design flood.

The followings are the remedial measures of the drainage problems of the study areas.

I. Structure at km 2+210 (Culvert 1)

The flow that reaches from the right side of the road at this location is more than the capacity of the structures through paved ditch. According to the information acquired from the residence and also the analysis made by HEC-RAS, the newly constructed double box culvert is inadequate for the design discharge and the structure is overtopped.

Therefore, in order to avoid the above problem, as shown in the analysis above, an additional one culvert with 3m clear span and 1.5m clear height is required.

II. Road section between km 2+750 to km 3+285

As mentioned above, this section of the road is severely damaged by the flood that comes from right side of the road. In addition to the capacity problem of the structure at km 3+285, the flood inundating the residential area. There is no defined channel around the road. The residence confirmed that whenever it rains, the road will be blocked by the flood and also by the siltation of sand. The traffic used to be interrupted for hours or days in this mentioned road section.

Hence, since the left side of road has sufficient space to construct a wider channel that can accommodate the design discharge ($60.0\text{m}^3/\text{s}$), a channel shall be constructed which takes the flood to the discharging points as shown in the satellite imagery.

The crossing structure at km 3+285, shall also be replaced by slab culvert with 9.0m clear span by 2.5m clear height or two 4.5m clear span by 2.5m box culverts to accommodate the design flood.



Figure 25: Layout of existing stream pattern and structure

III. Structure at km 4+325 (Culvert 4)

The structure modeled with HEC-RAS and the result in the above analysis showed that the existing structure is inadequate for the design discharge. The information acquired from the residence has also verified the computation and it is frequently overtopped.

Therefore, slab culvert with 6m by 2.0m height is required to make this section of the road safe from flood damage and stops erosion on the downstream side. Therefore, an additional one culvert with 3m clear span by 2.0m clear height is required. And also, out let erosion protection measure shall also be required at this section.

IV. Continuous Monitoring of the drainage facilities

During the site investigation, it has been observed that most the drainage facilities opening were silted with sand as well as blocked with stone and dirt. Hence periodically, cleaning of the drainage facilities is required to use effectively the capacity of the structures.

7. Summary, Conclusions and Recommendation

i. Summary

This study has evaluated the drainage problems of Adama town along the Nazareth-Assela Road section. The site investigations supported by desk study and the analysis have indicated that some section of the Road is severely damaged majorly due to inadequate drainage structure provision even if it is upgraded recently.

The drainage problem is serious in the study area. Considering the severity of the problem, the Adama Town administration has tried to minimize the problem by installing additional structure at km 2+210. However, the remedial action seems not carried out through detail study and design that solves the problem permanently. This type of action shall be supplemented by careful investigation with larger scale.

In the road section from km 2+750 to km3+285, flow on the right side is flooded large section of residential area due to lack of adequate structure drainage structures provision in addition to the settlement problem with regard to flooding. The asphalt which was constructed recently is also washed away and sub grade material is eroded.

The structure at km 4+315 is highly constricted and the channel on the downstream side progressively widened. The road used to be overtopped around this section. The structure is inadequate to pass the design flood and shall be replaced.

ii. Conclusions

Town section drainage design and provision needs careful consideration as the scale of damage due to lack of proper drainage facilities provision is high and it may also cost precious human life. In addition damage on human life and the road, property loss in town section is costly as result of flooding damage. The drainage problems adversely affect the surrounding environment as well as socio-economic activities.

After conducting condition survey of the project road and investigating the main causes of the problems, the following conclusions have been drawn from the results of the investigation.

The drainage problems in the study area are as a result of:

- ◆ Inadequate structure provision, which is the hydraulic capacity of the crossing structures, are less than the design discharge.
- ◆ Properly designed side drains are absent
- ◆ Absence of inlet/outlet protection works of the crossing structures
- ◆ Growth of vegetation at inlet and outlet of the crossing structures
- ◆ Siltation and blockage with sand and stone respectively of the crossing structures.

With this regard, the study area has major drainage problem that needs to be addressed and proposed remedial measures shall be implemented as soon as possible.

iii. Recommendation

Drainage problem become major challenge for recently constructed road as it is observed on Adama-Assela Road of Adama town. As a number of road projects are constructed with huge investments, for drainage related issues emphasis shall be given. The following recommendations have been drawn from this study.

◆ Design of the structures

- All consideration, such as appropriate design method which depends on the catchment area, variability of climate, future settlement ...etc shall be taken into account during the detail design of the drainage facilities so as the structures capacity shall accommodate the design flood. At the design stage, consideration shall be given in town section to integrate the drainage facilities with the master plan.
- In case if the problem occurs and the town administration wants to take measure to keep the serviceability of the road, the rehabilitation needs to be supplemented by the detail design to alleviate the problem permanently with low cost.

◆ Continuous Monitoring of the drainage facilities

Continuous monitoring of the drainage facilities is required to take timely action where unexpected problem encounter that may create risk on the road and surrounding environment.

Periodically, cleaning of the drainage facilities is also required to use effectively the capacity of the structures.

References

Armitage, N. (2010) The Challenges of Sustainable Urban Planning in Developing Countries Urban Water Management Group, University of Cape town, South Africa

Belete, D.A. (2011) Road and Urban Storm Water Drainage Network Integration in Addis Ababa: Addis Ketema Sub-city Journal of Engineering and Technology Research Vol. 3(7), pp. 217-225, July 2011,

Belete, D.A., Urban Drainage Planning and Design in Mekelle City, Ethiopia: Part-II: Sustainable Urban Drainage Management Solutions

Cedergen, H.R. (1988) Why All Important Pavement should be well Drained, Transportation Research Record, National Research Council. Washington DC

Chow, V. T. (1964). "Handbook of Applied Hydrology", McGraw-Hill, New York.

David Maidment, Eric Tate, and Francisco Olivera (1998) "GIS for Floodplain Mapping in Design of Highway Drainage Facilities", Research Report 1738-4, The University of Texas at Austin

Ethiopian Roads Authority. (2002). "Drainage Design Manual", Federal Democratic Republic of Ethiopia

Ethiopian Roads Authority. (2013). "Drainage Design Manual", Federal Democratic Republic of Ethiopia

Faísca, J. S., Baena, J., Baltzer, S., Gajewska, B., Nousiainen, A., Hermansson, Å., Erlingsson, S., Brenčič, M., and Dawson, A. (2009). Control of Pavement Water and Pollution Prevention Water in Road Structures. A. Dawson, ed., Water in Road Structures. Springer Netherlands, 299-356

Famuyiwa.,F. (no date)Autocorrelation of Urban Road and Drainage Developments in Environmental Valuation Analyses Department of Estate Management

Forsyth, R.A. (1987) *The Economic Impact of Pavement Subsurface Drainage*, Transportation Research Record 1121, National Research Council, Washington, D.C.),

FUPCoB, Federal Urban Planning Coordinating Bureau(2008) Urban Storm Water Drainage Design Manual. Ministry of Works and Urban Development August 2008, Addis Ababa

HITCON Engineering Plc (2013). "Hydraulic/Hydrology Study and Drainage Design on Nazareth-Assela Road Project" Addis Ababa, Ethiopia

Jimoh H.I., (2003) Drainage Problems in a Tropical Environment, Ilorin Journal of Business & Social Sciences Vol. 8

L.H. Watkins and D. Fiddes (1984) "Highway and Urban Hydrology in the Tropics" Pentech Press Limite, Estover Road, Plymouth, Devon

Mahari, B.T. G/Mariam,B (2015) Investigating Highway Drainage Problem in the Sile River Bridge , South Ethiopia, Journal of Multi disciplinary Engineering , science and Technology, Vol 2 Issue 4 April 2015

Mahboub, G.K. Allen , L.D. (2003) Evaluation and Analysis of Highway Pavement Drainage, Kentucky Transportation Center, Research Report, KTC-03-32

Maidment,D. Tate,E. Olivera, F. (1998) GIS for Floodplain Mapping in Design of Highway Drainage Facilities, Research Report Number 1738-4 Texas Department of Transportation:

Ministry of Works and Urban Development. (2008) "Urban Storm Water Drainage Design Manual", Federal Democratic Republic of Ethiopia

MohdNor, M.D., Lariyah, M.S., Ahmad Husaini, S., Leong, T.M. and Anita, A. (2011) Current Trend in Integrated Urban Storm Water Management Practice in the Tropical Region Malaysia, 12th International Conference on Urban Drainage, Porto Alegre/Brazil, 11-16 September

Moore Kemset, Furniss Michael J., Love Michael A., and Moll Jeff (1999) "A Guide to Computer Software Tools for Culvert Design and Analysis", San Dimas, California

Mukherjee, D. (2014) Highway Surface Drainage System & Problems of Water Logging In Road Section, The International Journal of Engineering And Science , Volume 3, Issue 11, Pages 44-51

PACE Consulting Architects and Engineers Plc, (2004), "Storm Water Drainage Net-work", Addis Ababa, Ethiopia

Ray, M. Christory, J.P. (1989) Combating Concrete Pavement Slab Pumping, State of the art Recommendations, Proceedings of the 4th International Conference on Concrete Design and Rehabilitation.

Rites/Unicone (2003) "Engineering Design Review Report", Addis Ababa, Ethiopia

Sarra. A., and Saarenketo, T. (2006) Managing Drainage on Low Volume Roads, Executive Summary, ROADEX-III, The Northern Periphery Research, Oy, Finland

Thiele, Elizabeth Anne, (2007). "Culvert Hydraulics: Comparison of Current Computer Models", Brigham Young University

U.S. Department of Transportation, Federal Highway Administration (No date) Introduction to Highway Hydraulics: Fourth Edition

Verworn, H.R. (2002) Advances in urban-drainage management and flood protection Institute for Water Resources Management, University of Hannover

APPENDICES

APPENDIX No -1- Adama Town Drainage Problems Questionnaire

Summary of the Feedback

Many problems have been reported by the community in association with the incidence of drainage problems in Adama Town specifically along the Nazareth Assela Road section. 100% of the respondents are of the view that one of the effects of drainage channel problem is flooding. In addition to flooding, siltation and deterioration of roads are the other problems which were cited by 75% of the respondents.

Regarding the extent and gravity of the drainage problems in Adama, 50% of the respondents view the problem as 'very severe' whereas the remaining 50% regard it as 'severe'.

When it comes to the root cause of the problem, 75% of the respondents believe that the main cause of the drainage problems is associated with the inadequate drainage channel.

APPENDIX No. 2 - Surveying Data

Surveying Data for Culvert at Station 2+210

ID	North	East	Elevation	Code
453	941022.387	531136.085	1604.062	B
454	941858	530172	1604	BM
455	941832.129	530213.393	1603.853	BM2
456	941832.117	530213.415	1603.853	BM2
458	941810.543	530128.406	1604.672	C01
459	941811.267	530128.048	1604.679	C01
460	941810.833	530128.336	1603.39	C01
461	941811.199	530128.116	1604.669	C01
462	941812.961	530127.447	1604.797	C01
463	941820.568	530123.722	1604.776	C01
464	941829.064	530120.398	1604.749	C01
465	941827.107	530164.072	1604.49	C01
466	941828.864	530163.297	1604.735	C01
467	941830.138	530162.638	1604.712	C02
468	941830.17	530162.686	1603.231	C02
469	941831.379	530161.871	1604.201	C02
470	941838.282	530157.549	1604.178	C02
471	941838.287	530157.553	1604.178	C02
472	941846.997	530154.486	1604.189	C02
473	941812.294	530194.576	1602.545	C03
474	941825.494	530187.472	1601.161	C03
475	941835.542	530182.722	1601.375	C03
476	941843.078	530180.22	1603.531	C03
477	941851.128	530176.475	1603.745	C03
478	941857.446	530174.12	1603.81	C03
479	941858.288	530173.98	1603.164	C03
480	941876.376	530166.03	1603.329	C03
481	941817.122	530186.796	1604.05	EP
482	941817.135	530186.791	1604.049	EP
483	941832.215	530214.153	1603.76	EP
484	941809.064	530195.464	1603.854	EP
485	941805.023	530224.527	1604.054	EP
486	941803.851	530226.317	1604.105	EP
487	941802.035	530227.127	1604.109	EP
488	941789.443	530236.828	1604.051	EP
489	941789.451	530236.821	1604.051	EP
490	941789.64	530237.403	1604.05	C04
491	941788.331	530232.367	1603.97	C04

492	941787.923	530231.421	1602.968	C04
493	941787.251	530230.355	1603.905	C04
494	941784.086	530221.278	1604.209	C04
495	941779.082	530210.875	1603.904	C04
496	941778.948	530210.374	1603.203	C04
497	941777.945	530208.7	1604.071	C04
498	941781.232	530204.052	1604.042	C04
499	941820.997	530223.497	1603.921	C05
500	941819.327	530218.699	1603.849	C05
501	941818.89	530217.775	1602.85	C05
502	941818.175	530216.276	1603.796	C05
503	941814.679	530206.78	1604.155	C05
504	941810.589	530196.282	1603.715	C05
505	941810.284	530195.632	1602.828	C05
506	941810.076	530195.156	1603.716	C05
507	941807.88	530192.042	1604.123	C05
508	941862.95	530217.678	1603.66	C06
509	941860.299	530206.196	1603.725	C06
510	941858.91	530200.183	1603.75	C06
511	941855.713	530188.402	1604.109	C06
512	941851.901	530178.094	1603.78	C06
513	941848.119	530169.215	1603.882	C06
514	941885.086	530190.363	1603.93	C07
515	941884.114	530188.589	1603.936	C07
516	941884.035	530188.581	1603.936	C07
517	941883.602	530188.013	1603.276	C07
518	941883.189	530187.388	1603.905	C07
519	941878.573	530177.7	1604.352	C07
520	941875.161	530167.242	1603.938	C07
521	941874.961	530166.577	1603.25	C07
522	941874.694	530166.047	1604.084	C07
523	941873.993	530163.919	1604.159	C07
524	941832.044	530166.612	1602.203	RC
525	941835.524	530174.83	1602.806	RC
526	941835.652	530183.519	1602.538	RC
527	941846.124	530204.16	1602.346	RC
528	941849.043	530218.978	1602.086	RC
529	941848.047	530234.647	1601.931	RC
530	941847.228	530242.795	1603.567	RC
531	941838.406	530210.401	1604.356	RX

532	941843.107	530208.442	1603.844	RX
533	941843.943	530207.895	1602.782	RX
534	941846.879	530206.97	1602.33	RX
535	941850.062	530206.1	1602.643	RX
536	941850.64	530205.774	1603.83	RX
537	941854.885	530205.071	1603.748	RX
538	941843.964	530227.639	1603.678	RX
539	941846.759	530226.869	1604.006	RX
540	941847.582	530226.481	1602.639	RX
541	941847.574	530226.527	1602.638	RX
542	941850.122	530226.121	1602.195	RX
543	941851.847	530225.77	1602.268	RX
544	941852.707	530225.744	1603.664	RX
545	941854.501	530225.072	1604.244	RX
546	941854.493	530225.078	1604.243	RX
547	941858.065	530224.102	1603.615	RX
548	941849.06	530202.399	1603.66	BT
549	941842.985	530205.047	1603.708	BT
550	941840.272	530182.869	1603.971	BT
551	941834.822	530185.408	1603.953	BT

19	940939.65	530576.774	1605.059	TP2
20	940869.145	530647.475	1605.024	RC
21	940865.648	530641.937	1604.632	RC
22	940865.528	530641.651	1605.51	RC
23	940858.449	530626.786	1605.864	RC
24	940858.034	530626.218	1604.367	RC
25	940850.212	530613.953	1605.13	RC
26	940835.058	530589.934	1605.358	RC
27	940825.027	530569.726	1605.72	RC
28	940823.625	530538.908	1605.94	RC
29	940821.525	530533.384	1606.076	RC
30	940821.525	530533.384	1606.076	TP3
31	940812.573	530522.345	1606.371	SH
32	940817.311	530520.812	1606.476	SH
33	940819.906	530520.682	1606.122	SH
34	940822.164	530520.851	1605.989	RC
35	940825.791	530520.812	1606.059	SH
36	940829.672	530519.871	1606.67	SH
37	940818.24	530519.572	1606.448	EP
38	940828.683	530509.613	1606.69	EP
39	940823.704	530501.195	1606.753	EP
40	940819.417	530491.619	1606.51	EP
41	940816.786	530495.43	1606.248	RC
42	940812.253	530483.073	1606.238	RC
43	940827.026	530520.02	1606.38	TP4
44	940810.07	530467.671	1606.826	SH
45	940807.204	530468.178	1606.464	RC
46	940805.299	530468.438	1606.351	RC
47	940801.829	530469.343	1606.349	SH
48	940794.995	530453.621	1606.595	RC
49	940796.735	530450.133	1606.503	SH
50	940794.798	530435.03	1606.718	EP
51	940790.158	530435.447	1606.578	RC
52	940791.261	530425.982	1606.675	SH
53	940789.114	530426.655	1606.673	RC
54	940785.943	530427.701	1606.762	SH
55	940783.754	530428.1	1606.765	SH
56	940782.818	530415.054	1606.904	RC
57	940778.332	530399.419	1607.078	SH
58	940771.572	530385.621	1607.358	SH
59	940764.573	530370.145	1607.286	SH
60	940756.59	530352.81	1607.257	TP

Surveying Data for Culvert at Station 3+285

ID	North	East	Elevation	Code
1	940861.928	530651.967	1606.311	EP
2	940892.71	530638.812	1605.919	EP
3	940928.134	530623.539	1606.068	EP
4	940957.214	530610.68	1605.764	EP
5	940987.183	530597.728	1606.03	EP
6	941016.891	530584.937	1605.959	EP
7	941048.437	530571.258	1605.915	EP
8	941078.303	530558.047	1606.114	EP
9	941108.701	530545.251	1606.199	EP
10	941136.833	530532.807	1606.146	EP
11	941166.731	530520.044	1605.591	EP
12	941195.862	530507.237	1605.597	EP
13	941225.837	530494.501	1604.783	EP
14	941251.051	530483.352	1604.474	EP
15	941253.251	530482.147	1604.558	EP
16	941258.582	530478.312	1604.352	EP
17	941338.178	530444.695	1604.276	EP
18	941152.677	530492.34	1604.561	TP1

61	940757.291	530375.423	1607.675	EP	103	940665.471	530254.261	1608.246	TP
62	940760.317	530366.62	1607.482	RC	104	940669.137	530258.583	1609.116	SH
63	940780.516	530375.087	1607.682	SH	105	940669.111	530258.562	1610.549	SH
64	940775.214	530376.933	1606.905	SH	106	940667.472	530258.679	1608.292	SH
65	940769.862	530378.307	1607.21	RC	107	940664.963	530258.702	1608.183	RC
66	940766.842	530380.02	1607.398	SH	108	940661.66	530259.651	1608.33	SH
67	940763.884	530381.166	1607.526	SH	109	940657.227	530262.576	1610.36	RC
68	940758.555	530382.313	1607.607	SH	110	940665.355	530245.458	1608.297	RC
69	940753.923	530364.891	1607.718	F	111	940663.877	530232.555	1608.372	RC
70	940759.442	530354.624	1607.273	F	112	940663.894	530232.548	1608.376	SH
71	940747.58	530341.414	1607.493	F	113	940662.358	530251.25	1608.415	SH
72	940743.365	530348.467	1607.56	SH	114	940667.425	530250.072	1608.228	SH
73	940748.492	530357.043	1607.751	EP	115	940665.14	530239.996	1608.346	RC
74	940753.526	530354.336	1607.407	RC	116	940661.28	530229.686	1608.41	SH
75	940744.827	530345.019	1607.339	F	117	940666.043	530230.763	1610.658	SH
76	940728.403	530337.711	1607.501	F	118	940654.284	530222.358	1608.549	SH
77	940711.997	530330.499	1607.59	F	119	940651.251	530217.92	1608.717	SH
78	940705.099	530325.343	1607.671	TP	120	940651.203	530217.926	1608.718	SH
79	940713.795	530328.634	1607.565	SH	121	940657.642	530225.331	1608.496	SH
80	940712.714	530330.784	1607.594	RC	122	940652.116	530221.45	1608.577	RC
81	940710.788	530332.884	1607.644	SH	123	940646.321	530218.685	1608.629	RC
82	940701.063	530325.466	1608.095	SH	124	940639.12	530216.766	1608.66	RC
83	940698.577	530317.202	1607.699	RC	125	940631.304	530213.996	1608.741	RC
84	940694.586	530307.369	1609.02	SH	126	940622.255	530208.621	1608.843	RC
85	940679.671	530297.863	1607.912	RC	127	940646.123	530212.829	1609.033	SH
86	940670.177	530284.752	1608.002	SH	128	940645.345	530215.502	1608.886	SH
87	940670.219	530284.776	1607.986	TP	129	940645.027	530216.816	1608.633	SH
88	940705.086	530325.328	1607.66	TP	130	940644.855	530218.443	1608.627	RC
89	940691.903	530318.239	1609.381	TP	131	940644.662	530220.546	1608.633	SH
90	940668.971	530291.199	1609.215	SH	132	940613.82	530204.019	1608.905	TP
91	940668.968	530291.211	1610.718	SH	133	940609.959	530200.891	1608.929	RC
92	940671.779	530294.909	1610.562	SH	134	940605.51	530196.356	1609.028	RC
93	940667.216	530285.375	1610.445	SH	135	940597.15	530185.36	1609.163	RC
94	940677.775	530285.655	1609.011	SH	136	940593.48	530178.317	1609.234	RC
95	940676.011	530287.235	1608.081	SH	137	940587.26	530168.47	1609.461	RC
96	940674.283	530290.222	1607.999	RC	138	940580.219	530157.334	1609.551	SH
97	940671.411	530291.323	1607.934	SH	139	940604.018	530197.952	1611.613	SH
98	940670.636	530292.284	1610.256	SH	140	940603.823	530196.844	1609.031	SH
99	940676.011	530287.235	1608.081	SH	141	940606.733	530193.778	1609.288	SH
100	940674.283	530290.222	1607.999	RC	142	940607.719	530194.369	1611.309	SH
101	940671.411	530291.323	1607.934	SH	143	940581.094	530155.826	1609.567	SH
102	940670.636	530292.284	1610.256	SH	144	940596.308	530160.13	1611.732	SH

145	940592.459	530161.303	1612.305	SH	187	940945.104	530572.654	1605.495	SH
146	940590.286	530162.821	1609.411	SH	188	940926.578	530557.37	1605.36	SH
147	940586.605	530164.713	1609.484	RC	189	940928.203	530556.59	1604.766	SH
148	940583.642	530166.538	1609.681	SH	190	940929.711	530556.031	1605.338	SH
149	940581.195	530169.829	1612.254	SH	191	940932.116	530555.076	1604.941	CL
150	940582.996	530143.62	1612.297	SH	192	940935.595	530554.192	1605.197	SH
151	940581.118	530144.003	1609.977	SH	193	940936.948	530553.834	1604.669	SH
152	940577.489	530146.534	1609.677	SH	194	940939.036	530553.724	1605.547	SH
153	940576.143	530146.962	1609.687	RC	195	940919.296	530537.545	1605.653	SH
154	940574.97	530147.738	1609.791	SH	196	940920.728	530536.883	1604.778	SH
155	940569.701	530147.182	1612.064	SH	197	940922.585	530536.459	1605.66	SH
156	940567.954	530149.421	1612.057	SH	198	940925.38	530535.626	1605.47	CL
157	940567.796	530152.185	1609.681	SH	199	940929.503	530533.812	1605.497	SH
158	940568.469	530154.474	1609.731	RC	200	940930.859	530533.243	1604.612	SH
159	940568.786	530156.824	1609.769	SH	201	940932.428	530532.334	1605.369	SH
160	940568.813	530158.145	1612.653	SH	202	940938.109	530530.311	1605.205	SH
161	940569.711	530160.929	1612.741	SH	203	940899.929	530492.628	1605.549	SH
162	940559.16	530157.623	1612.955	SH	204	940900.362	530492.433	1604.805	SH
163	940547.79	530158.828	1613.272	SH	205	940900.744	530492.205	1605.618	SH
164	940547.131	530154.472	1613.358	SH	206	940903.943	530491.11	1605.616	CL
165	940547.504	530152.909	1609.955	SH	207	940910.215	530489.068	1605.563	SH
166	940548.048	530151.469	1609.865	RC	208	940910.497	530488.732	1605.297	SH
167	940548.379	530149.536	1610.118	SH	209	940910.965	530488.629	1605.582	SH
168	940550.993	530146.502	1613.016	SH	210	940915.35	530486.727	1606.375	SH
169	940549.851	530151.832	1609.842	RC	211	940881.914	530454.751	1606.097	SH
170	940559.555	530153.477	1609.774	RC	212	940883.131	530454.507	1606.02	SH
171	940570.733	530154.449	1609.696	RC	213	940883.633	530454.416	1604.977	SH
172	940578.998	530152.184	1609.6	RC	214	940884.005	530454.147	1606.012	SH
173	940572.374	530139.575	1609.797	RC	215	940888.841	530453.067	1606.024	CL
174	940566.161	530127.259	1609.951	RC	216	940893.382	530451.397	1605.975	SH
175	940561.394	530115.98	1610.076	RC	217	940893.804	530451.095	1605.083	SH
176	940561.469	530140.248	1613.224	SH	218	940894.262	530451.078	1605.995	SH
177	940593.958	530147.795	1611.844	SH	219	940858.514	530402.924	1607.642	SH
178	940847.017	530664.673	1605.498	SH	220	940858.499	530402.891	1607.643	SH
179	940866.121	530656.608	1605.969	SH	221	940860.951	530401.908	1606.611	SH
180	940830.92	530624.338	1605.915	SH	222	940861.388	530401.721	1605.52	SH
181	940857.531	530612.684	1605.622	SH	223	940866.936	530399.894	1606.622	CL
182	940931.711	530576.249	1605.385	CL	224	940871.259	530398.59	1606.619	SH
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185	940941.67	530573.748	1605.149	SH	227	940873.93	530397.655	1606.705	SH
186	940943.314	530572.754	1604.708	SH	228	940843.241	530362.906	1606.991	SH

229	940843.957	530362.665	1606.83	SH	271	940789.37	530223.121	1608.429	SH
230	940844.51	530362.7	1605.924	SH	272	940790.568	530222.385	1608.63	SH
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233	940853.755	530358.826	1606.895	SH	275	940757.149	530178.712	1609.089	SH
234	940854.196	530358.636	1605.955	SH	276	940757.679	530178.362	1608.957	SH
235	940854.552	530358.563	1606.887	SH	277	940758.158	530178.123	1608.204	SH
236	940858.354	530356.834	1607.036	SH	278	940758.448	530178.019	1609.039	SH
237	940827.277	530329.158	1607.433	SH	279	940762.747	530176.42	1609.044	CL
238	940827.988	530328.678	1607.435	SH	280	940766.661	530174.852	1609.071	SH
239	940828.521	530328.499	1606.325	SH	281	940767.498	530174.48	1608.792	SH
240	940828.794	530328.367	1607.435	SH	282	940769.998	530174.169	1609.055	SH
241	940833.207	530325.976	1607.484	CL	283	940734.313	530127.253	1610.169	SH
242	940837.88	530324.01	1607.331	SH	284	940739.044	530125.912	1610.232	CL
243	940838.432	530323.929	1606.445	SH	285	940742.741	530124.512	1610.143	SH
244	940838.816	530323.882	1607.392	SH	286	940743.961	530123.299	1609.935	SH
245	940841.996	530322.163	1607.62	SH	287	940725.552	530096.877	1610.928	SH
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247	940801.344	530308.725	1607.79	SH	289	940704.449	530049.096	1612.27	SH
248	940813.692	530302.089	1607.903	SH	290	940689.43	530016.631	1613.49	SH
249	940817.485	530300.589	1607.799	SH	291	941145.267	530489.955	1604.796	EP
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253	940826.171	530297.214	1607.685	SH	295	941154.659	530485.358	1603.487	SH
254	940835.491	530291.763	1607.573	SH	296	941155.553	530485.049	1604.039	SH
255	940813.052	530298.786	1607.838	EP	297	941156.965	530486.396	1604.462	EP
256	940827.159	530328.94	1607.479	EP	298	941141.266	530466.124	1604.604	EP
257	940806.154	530284.105	1608.026	EP	299	941133.612	530461.744	1604.652	EP
258	940800.701	530272.648	1607.939	EP	300	941133.616	530462.007	1604.721	SH
259	940792.243	530254.248	1608.053	EP	301	941137.959	530459.821	1604.298	CL
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261	940797.583	530263.366	1607.825	SH	303	941142.545	530458.693	1603.798	SH
262	940798.13	530263.214	1606.908	SH	304	941144.242	530458.446	1604.414	SH
263	940798.442	530263.044	1607.845	SH	305	941126.461	530442.543	1604.71	EP
264	940802.201	530261.282	1608.023	CL	306	941119.211	530425.31	1604.864	SH
265	940806.676	530260.334	1608.007	SH	307	941122.33	530423.89	1604.414	CL
266	940780.571	530227.765	1608.486	EP	308	941126.554	530422.37	1604.502	SH
267	940780.878	530227.429	1608.36	SH	309	941110.679	530407.109	1604.923	EP
268	940781.257	530227.292	1607.446	SH	310	941106.567	530400.209	1604.912	EP
269	940781.665	530227.023	1608.37	SH	311	941096.101	530374.238	1605.141	EP
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313	941099.27	530372.452	1604.831	CL	355	940727.2914	530704.102	1606.407	C1
314	941101.524	530371.619	1604.8	SH	356	940739.4717	530707.5019	1607.091	EP
315	941083.521	530347.55	1604.953	SH	357	940738.9255	530707.5764	1606.483	EP
316	941083.91	530343.332	1604.979	SH	358	940759.5207	530690.4728	1606.624	EP
317	941078.214	530337.396	1605.313	SH	359	940767.7254	530692.7643	1606.63	EP
318	941081.743	530335.595	1604.98	CL	360	940745.3367	530678.4703	1606.461	EP
319	941085.659	530333.552	1605.267	SH	361	940767.7107	530692.7397	1606.847	EP
320	941086.345	530333.141	1604.423	SH	362	940783.3491	530679.2533	1606.457	EP
321	941087.22	530332.474	1605.103	SH	363	940784.4882	530685.7447	1606.492	EP
322	941070.94	530320.297	1605.222	EP	364	940777.0515	530663.6573	1606.204	EP
323	941058.078	530294.696	1605.596	EP	365	940788.3544	530689.6367	1606.44	EP
324	941058.09	530294.689	1605.597	SH	366	940788.2777	530689.7866	1606.348	F
325	941062.427	530292.879	1605.256	CL	367	940786.0378	530682.2274	1606.451	C2
326	941066.31	530291.161	1605.819	SH	368	940784.0797	530678.7813	1606.144	C2
327	941066.768	530290.567	1604.494	SH	369	940783.3272	530677.8026	1606.299	C2
328	941067.401	530290.613	1605.961	SH	370	940783.7226	530678.2346	1606.38	C2
329	941048.117	530275.278	1607.089	EP	371	940783.2756	530677.7799	1605.467	C2
330	941032.141	530244.148	1607.332	SH	372	940780.456	530671.1232	1606.37	C2
331	941038.187	530241.727	1605.792	CL	373	940778.1455	530664.939	1606.523	C2
332	941042.029	530239.439	1606.07	SH	374	940778.006	530664.2045	1606.313	C2
333	941043.243	530238.842	1605.027	SH	375	940777.7465	530663.8407	1605.665	C2
334	941042.663	530239.201	1606.405	SH	376	940775.9985	530659.926	1606.446	C2
335	941043.204	530238.866	1604.995	SH	377	940774.227	530656.5146	1606.125	C2
336	941017.114	530213.2	1606.02	SH	378	940783.8832	530648.1116	1606.085	C2
337	941023.436	530210.584	1605.955	CL	379	940783.9459	530647.3117	1606.195	EP
338	941028.156	530208.411	1606.271	SH	380	940801.28	530678.6568	1606.172	F
339	941029.431	530207.885	1605.178	SH	381	940806.8499	530667.7495	1606.116	EP
340	941009.636	530182.226	1606.158	CL	382	940807.2536	530679.6786	1606.187	EP
341	940991.787	530144.497	1606.517	CL	383	940805.5327	530680.4388	1605.852	EP
342	940975.525	530108.717	1607.321	CL	384	940819.1273	530676.4804	1605.883	EP
343	940959.42	530073.036	1608.57	CL	385	940808.8299	530649.4591	1605.502	F
344	940734.3709	530713.4318	1605.974	SH	386	940830.3355	530678.1996	1606.145	EP
345	940734.478	530713.3411	1606.135	SH	387	940824.7526	530667.8125	1605.393	C3
346	940731.5802	530708.6283	1606.133	F	388	940820.1551	530659.6818	1605.59	C3
347	940728.8622	530703.4059	1606.532	C1	389	940817.4145	530653.1837	1605.741	C3
348	940728.5459	530702.665	1606.801	C1	390	940815.1528	530648.4956	1606.136	C3
349	940727.7689	530702.2459	1606.201	C1	391	940810.3663	530640.3655	1605.96	C3
350	940724.9678	530696.4732	1606.956	C1	392	940806.4572	530633.6847	1605.831	C3
351	940722.9093	530690.3137	1607.117	C1	393	940802.2469	530633.9696	1605.997	C3
352	940722.6928	530689.5069	1606.904	C1	394	940802.292	530638.7682	1605.902	EP
353	940722.4332	530689.0657	1606.095	C1	395	940802.3156	530636.0669	1605.743	EP
354	940720.7954	530685.7015	1606.948	C1	396	940800.2761	530630.2312	1605.89	F

397	940833.8113	530663.4141	1606.122	F	439	940864.9481	530610.5941	1605.25	EP
398	940839.0433	530667.5194	1606.173	EP	440	940890.7217	530598.061	1605.253	F
399	940845.177	530664.6894	1606.305	F	441	940899.6072	530634.1165	1605.258	EP
400	940843.209	530661.6757	1606.821	C4	442	940904.3591	530622.4113	1605.905	EP
401	940843.4197	530661.0211	1606.137	C4	443	940928.4359	530620.8408	1605.485	EP
402	940840.3862	530656.2884	1604.762	C4	444	940936.5025	530607.6398	1605.664	EP
403	940837.8165	530653.1278	1604.439	C4	445	940936.7127	530590.2082	1605.189	EP
404	940837.8275	530653.1367	1604.11	C4	446	940958.1736	530612.2125	1605.146	EP
405	940837.7048	530653.1174	1604.11	C4	447	940957.2334	530609.3632	1605.302	F
406	940833.6893	530645.7017	1605.511	C4	448	940955.6842	530605.2828	1606.592	C
407	940829.9332	530638.4015	1606.032	C4	449	940954.6745	530603.1004	1604.26	C
408	940829.5411	530638.0093	1605.866	C4	450	940953.2609	530599.8132	1603.635	C6
409	940824.5606	530631.4774	1604.046	C4	451	940953.0115	530599.1527	1604.704	C6
410	940816.8087	530620.9835	1604.774	C4	452	940952.7294	530598.8606	1604.368	C6
411	940812.0937	530612.29	1605.068	C4	453	940949.8799	530592.924	1604.913	C6
412	940806.2891	530603.0081	1605.034	C4	454	940946.9569	530587.1109	1605.007	C6
413	940806.2852	530602.9995	1605.273	C4	455	940946.9213	530586.7245	1604.815	C6
414	940801.0707	530593.1327	1605.273	RC	456	940946.4066	530586.0848	1604.208	C6
415	940828.2316	530624.0839	1605.306	RC	457	940944.418	530581.3156	1604.773	C6
416	940835.2643	530622.8426	1605.685	EP	458	940941.7829	530574.1097	1605.017	C6
417	940828.9076	530624.221	1605.599	EP	459	940941.7753	530574.1135	1605.017	EP
418	940842.8261	530650.5759	1605.596	F	460	940968.4086	530575.7512	1604.739	EP
419	940843.4122	530633.1812	1605.854	EP	461	940970.8599	530564.3523	1604.67	EP
420	940854.5578	530659.6729	1605.935	EP	462	940969.0757	530592.633	1604.911	EP
421	940864.2764	530649.9602	1606.373	EP	463	941001.2245	530577.9021	1604.728	EP
422	940872.0271	530637.2067	1605.8	EP	464	941000.2445	530560.9144	1604.605	EP
423	940873.1492	530619.6883	1605.793	EP	465	940987.8606	530594.5731	1605.871	EP
424	940887.0964	530645.9336	1605.596	EP	466	941019.216	530580.1197	1605.832	EP
425	940887.0964	530645.9336	1605.813	F	467	941023.5497	530583.7524	1605.052	F
426	940885.3839	530643.1786	1605.813	C5	468	941023.5497	530583.7524	1605.051	C7
427	940884.1142	530640.2363	1607.044	C5	469	941022.236	530579.6834	1606.033	C7
428	940883.5692	530639.2418	1606	C5	470	941020.1049	530575.1092	1603.716	C7
429	940882.6102	530636.5765	1604.522	C5	471	941019.1903	530572.8565	1603.127	C7
430	940880.7745	530633.1276	1603.907	C5	472	941018.0358	530570.0247	1604.386	C7
431	940880.6083	530632.7237	1605.435	C5	473	941017.7935	530569.4891	1603.387	C7
432	940877.4266	530626.2862	1604.809	C5	474	941017.5543	530568.9452	1604.292	C7
433	940874.5221	530620.6007	1605.635	C5	475	941014.7802	530563.1515	1604.484	C7
434	940874.2564	530620.1199	1604.923	C5	476	941012.4425	530557.0334	1604.309	C7
435	940873.802	530619.5855	1604.757	C5	477	941012.2018	530556.5128	1603.463	C7
436	940871.1426	530614.0322	1605.356	C5	478	941011.9667	530555.8738	1604.402	C7
437	940868.8706	530609.6276	1605.049	C5	479	941010.0984	530552.3358	1604.261	C7
438	940865.9297	530610.5864	1605.285	C5	480	941089.5245	530517.5356	1604.845	TP1

481	940794.7385	530588.5096	1605.477	BM2	523	940773.778	530599.8639	1605.959	SH
482	940795.6145	530616.8916	1605.548	TP2	524	940807.3744	530580.6269	1606.208	SH
483	940800.4376	530614.7273	1606.307	RX	525	940805.0545	530572.8217	1606.15	SH
484	940805.6131	530612.5099	1606.033	RX	526	940804.9291	530572.5473	1606.39	SH
485	940808.2899	530610.7704	1605.566	RX	527	940821.8852	530573.7918	1606.624	EP
486	940810.6832	530609.0607	1605.477	RX	528	940822.0898	530577.5068	1605.989	EP
487	940813.2388	530607.2496	1605.132	RX	529	940817.1868	530570.1713	1606.349	SH
488	940815.0464	530604.9801	1605.273	RX	530	940837.3603	530565.3602	1606.429	SH
489	940821.7754	530599.9518	1605.964	RX	531	940836.2614	530562.5216	1605.921	SH
490	940786.6037	530596.7595	1606.153	RX	532	940834.6662	530558.616	1605.8	SH
491	940793.4215	530592.7375	1606.298	RX	533	940834.6765	530558.6089	1606.162	SH
492	940795.8013	530591.6547	1605.966	RX	534	940801.5018	530571.9685	1606.162	EP
493	940798.8061	530590.2909	1605.763	RX	535	940799.6994	530572.3652	1606.072	SH
494	940802.0928	530588.5185	1605.508	RX	536	940797.1455	530572.7494	1605.596	SH
495	940803.3373	530587.904	1605.497	RX	537	940792.1454	530573.2973	1605.696	SH
496	940809.1277	530584.8215	1605.963	RX	538	940791.8592	530573.435	1605.69	SH
497	940813.8958	530581.8657	1606.142	RX	539	940799.0845	530555.7323	1606.153	SH
498	940825.9997	530567.1169	1606.3	RX	540	940794.8088	530556.0934	1605.174	EP
499	940815.6167	530572.1655	1605.898	RX	541	940791.2975	530556.9051	1603.8	SH
500	940801.7104	530578.6765	1606.172	RX	542	940791.3569	530556.8868	1603.866	SH
501	940798.8931	530579.7581	1605.943	RX	543	940794.4101	530556.4994	1605.862	SH
502	940796.3842	530580.5699	1605.51	RX	544	940799.0152	530531.0442	1605.821	SH
503	940792.0866	530581.6694	1605.699	RX	545	940799.0118	530531.1069	1606.48	F
504	940785.4125	530583.9016	1605.55	RX	546	940796.8088	530532.16	1606.467	SH
505	940775.9897	530587.9261	1606.311	RX	547	940794.242	530532.985	1606.261	SH
506	940764.1426	530603.9409	1605.78	RX	548	940792.9695	530533.3622	1605.853	SH
507	940705.8654	530619.1288	1606.374	F	549	940788.2879	530531.6705	1605.875	SH
508	940705.8962	530619.0783	1606.305	F	550	940788.2862	530531.6546	1606.405	SH
509	940707.4172	530622.1541	1606.303	SH	551	940789.4394	530503.215	1606.405	EP
510	940708.4441	530624.8244	1606.067	SH	552	940788.9801	530503.7912	1606.491	F
511	940725.5524	530610.39	1606.114	SH	553	940788.9799	530503.7892	1606.443	EP
512	940725.564	530610.3858	1606.191	F	554	940786.8315	530504.2424	1606.444	SH
513	940726.9606	530612.7658	1606.191	SH	555	940784.4579	530505.3457	1606.151	SH
514	940728.1028	530616.2846	1605.983	SH	556	940801.5169	530571.9599	1606.195	SH
515	940743.7631	530600.1765	1606.288	SH	557	940809.2507	530587.6642	1606.081	F
516	940745.4494	530604.4798	1606.073	SH	558	940807.7696	530595.5815	1606.215	F
517	940748.2899	530610.0533	1605.939	SH	559	940817.8312	530612.5011	1605.723	F
518	940748.6738	530610.4724	1606.455	SH	560	940824.43	530620.3098	1605.395	F
519	940770.4388	530589.9588	1606.491	F	561	940824.4163	530620.2941	1605.682	F
520	940770.4208	530589.9597	1605.848	F	562	940825.2951	530617.9222	1605.681	SH
521	940771.393	530594.1459	1605.848	SH	563	940822.5272	530612.7523	1605.511	SH
522	940772.3672	530596.2003	1605.707	SH	564	940808.7921	530619.6958	1606.132	SH

565	940801.8328	530621.6554	1605.468	SH	607	941128.7882	530502.2114	1604.273	EP
566	940803.561	530631.568	1606.184	SH	608	941125.538	530493.038	1604.089	EP
567	940810.6046	530626.5961	1605.964	SH	609	941165.742	530514.3473	1604.203	EP
568	940815.3592	530624.2681	1606.299	SH	610	941131.1995	530518.047	1605.567	EP
569	940783.7304	530595.9898	1605.382	SH	611	941160.6115	530487.6655	1604.157	EP
570	940789.3451	530599.9182	1606.072	F	612	941163.2319	530503.2328	1604.129	EP
571	941048.8459	530566.7647	1606.512	F	613	941165.8021	530514.4878	1604.126	EP
572	941079.1518	530553.3468	1606.132	EP	614	941174.7254	530519.483	1605.652	EP
573	941107.1505	530540.6792	1606.226	EP	615	941174.6623	530519.5902	1604.597	F
574	941136.8394	530527.5895	1606.093	EP	616	941171.5334	530513.5593	1604.596	C9
575	941033.4488	530563.0104	1605.566	EP	617	941168.6096	530506.3616	1605.703	C9
576	941032.5573	530546.1662	1604.479	EP	618	941170.1218	530508.7797	1602.317	C9
577	941098.2529	530533.26	1604.52	EP	619	941166.4745	530501.8059	1604.093	C9
578	941064.2912	530531.5544	1604.211	EP	620	941166.2802	530501.211	1603.786	C9
579	941066.4775	530547.8984	1604.366	EP	621	941166.098	530500.6741	1602.935	C9
580	941054.0109	530527.6531	1604.395	EP	622	941163.4157	530494.6727	1603.759	C9
581	941054.0109	530527.6531	1604.796	EP	623	941163.4196	530494.6713	1604.098	C9
582	941078.5144	530515.5009	1604.796	F	624	941161.3319	530488.5591	1604.098	C9
583	941077.597	530516.9226	1604.944	F	625	941160.4694	530486.8972	1603.812	C9
584	941045.9019	530532.0754	1605.023	EP	626	941160.1825	530486.4829	1603.712	C9
585	941087.6677	530512.0889	1604.775	EP	627	941159.9812	530485.4583	1602.806	C9
586	941034.6285	530536.21	1604.584	EP	628	941158.8045	530482.5484	1603.896	C9
587	941096.2127	530516.9188	1605.029	EP	629	941156.5034	530478.2415	1604.457	C9
588	941110.5236	530544.0891	1604.171	EP	630	941156.4892	530478.25	1604.587	C9
589	941112.2803	530546.929	1605.082	EP	631	941162.5725	530476.6903	1604.587	F
590	941112.3157	530546.9504	1604.716	F	632	941192.2794	530472.9329	1604.775	EP
591	941108.4807	530539.9802	1604.703	C8	633	941196.2433	530502.2129	1604.08	EP
592	941107.615	530538.7852	1605.961	C8	634	941195.3749	530488.4764	1605.251	EP
593	941105.7869	530534.9785	1605.405	C8	635	941220.7269	530489.4987	1604.144	EP
594	941105.3277	530532.9162	1602.952	C8	636	941196.7824	530461.4229	1604.573	EP
595	941103.7914	530530.4604	1603.719	C8	637	941190.4933	530463.2818	1604.822	EP
596	941103.6571	530529.9859	1603.736	C8	638	941190.4867	530463.2855	1604.847	EP
597	941103.4919	530529.5528	1602.899	C8	639	941223.884	530458.1808	1604.847	F
598	941100.2067	530523.7948	1603.834	C8	640	941227.2674	530473.6699	1604.222	EP
599	941097.3926	530518.4246	1604.137	C8	641	941255.6803	530443.5604	1604.3	EP
600	941097.1934	530517.974	1604.125	C8	642	941259.4935	530459.2546	1604.393	EP
601	941096.5122	530516.8119	1604.144	C8	643	941334.2431	530442.604	1604.399	EP
602	941094.84	530513.3216	1604.084	C8	644	941287.7197	530429.0421	1603.896	TP4
603	941092.5295	530508.8195	1604.293	C8	645	941296.256	530442.1854	1604.561	EP
604	941137.1777	530528.4639	1604.704	C8	646	941256.0765	530443.5227	1604.516	EP
605	941114.8868	530498.0886	1605.64	EP	647	941256.0746	530443.5229	1604.388	EP
606	941126.7512	530494.114	1604.813	F	648	941259.7229	530459.0163	1604.388	EP

649	941268.3025	530466.5092	1604.379	EP	691	941306.6753	530460.4117	1603.003	C10
650	941289.9319	530417.6734	1603.652	EP	692	941303.8626	530455.3803	1603.977	C11
651	941292.6777	530457.3729	1604.271	EP	693	941301.7842	530451.9759	1604.058	C11
652	941307.539	530449.7409	1604.744	EP	694	941300.7266	530450.1033	1604.355	C11
653	941263.6664	530430.0803	1604.371	EP	695	941300.0793	530449.006	1603.613	C11
654	941309.6956	530452.0238	1604.254	EP	696	941298.7511	530446.6741	1601.277	C11
655	941318.5292	530452.8857	1604.161	EP	697	941297.0477	530443.6708	1601.595	C11
656	941317.2854	530455.5535	1604.174	EP	698	941296.4832	530441.7925	1603.798	C11
657	941265.4038	530426.2737	1603.855	F	699	941296.2407	530441.3323	1604.302	C11
658	941291.8907	530414.3945	1604.358	F	700	941295.9673	530440.7115	1603.603	C11
659	941291.5773	530467.3235	1604.438	F	701	941293.0396	530435.0255	1604.348	C11
660	941302.5263	530409.3959	1604.086	F	702	941289.7104	530429.3656	1604.511	C11
661	941309.5613	530406.7134	1603.882	F	703	941289.5786	530428.8194	1604.302	C11
662	941327.487	530400.932	1603.905	F	704	941289.2791	530428.4286	1603.561	C11
663	941322.6244	530412.7997	1604.324	F	705	941287.2668	530424.8786	1604.466	C11
664	941337.7401	530429.6171	1604.499	EP	706	941287.7657	530426.0378	1604.024	C11
665	941337.7387	530429.6233	1603.91	F	707	941287.3034	530424.9019	1602.235	C11
666	941350.9966	530464.316	1603.909	EP	708	941285.5221	530421.1959	1603.014	C11
667	941331.1303	530481.5913	1603.524	F	709	941283.8029	530418.1198	1603.084	C11
668	941363.1579	530487.2901	1603.609	F	710	941237.9093	530476.0088	1603.347	C11
669	941396.9221	530606.8537	1603.348	F	711	941237.4583	530475.4107	1600.703	RB
670	941326.7631	530432.899	1602.062	F	712	941237.2276	530475.1675	1600.657	RB
671	941332.5084	530440.164	1604.16	TP5	713	941263.287	530464.3197	1600.67	RB
672	941334.3965	530442.5517	1603.987	TP5	714	941262.6032	530462.4449	1600.531	RB
673	941266.8094	530478.2236	1603.895	TP5	715	941283.6444	530455.7206	1600.826	RB
674	941264.8644	530472.7127	1604.304	C10	716	941282.2059	530453.6305	1600.556	RB
675	941263.8281	530467.9832	1604.457	C10	717	941278.3158	530455.1909	1600.912	RB
676	941262.5522	530464.7137	1603.285	C10	718	941308.2225	530446.4202	1600.921	RB
677	941261.6054	530463.2165	1601.562	C10	719	941307.4033	530444.071	1600.38	RB
678	941261.6548	530461.8217	1601.555	C10	720	941319.9592	530445.7631	1600.441	RB
679	941260.5107	530460.4267	1603.26	C10	721	941320.3485	530442.6866	1600.238	RB
680	941260.0325	530458.5755	1603.601	C10	722	941324.4395	530442.8255	1600.16	RB
681	941259.853	530457.978	1604.138	C10	723	941322.9752	530446.7532	1600.045	RB
682	941259.5759	530457.3988	1603.689	C10	724	941331.9747	530454.0118	1600.29	RB
683	941257.2466	530451.4558	1604.119	C10	725	941328.7415	530455.5755	1599.845	RB
684	941254.245	530445.8993	1604.315	C10	726	941334.4129	530469.2142	1600.208	RB
685	941253.9793	530445.4375	1604.121	C10	727	941339.5687	530468.0526	1600.269	RB
686	941253.912	530444.7307	1603.683	C10	728	941347.2147	530490.8872	1600.201	RB
687	941252.8599	530442.3467	1604.285	C10	729	941349.8205	530489.2668	1599.827	RB
688	941253.7102	530443.1461	1604.784	C10	730	941365.7183	530519.5744	1599.871	RB
689	941253.1445	530442.1941	1603.346	C10	731	941356.0125	530505.092	1600.38	RC
690	941249.6485	530437.4718	1603.768	C10	732	941344.9745	530483.8599	1599.978	RC

733	941334.9628	530464.1066	1600.149	RC
734	941326.1579	530447.3958	1600.59	RC
735	941321.8557	530438.2204	1600.991	RC
736	941319.552	530433.6101	1600.961	RC
737	941318.0474	530431.532	1601.451	RC
738	941317.3924	530430.7543	1601.548	RC
739	941314.5684	530425.0976	1604.441	RC
740	941311.3018	530417.9671	1604.626	RC
741	941309.546	530414.8677	1604.372	RC
742	941308.4775	530414.4502	1604.104	RC
743	941305.7289	530411.7106	1601.264	RC
744	941355.4272	530421.3661	1603.678	RC
745	941355.4272	530421.3661	1604.093	F
746	941354.1815	530417.648	1604.093	C13
747	941353.2114	530415.9099	1604.144	C13
748	941352.8209	530415.0651	1604.369	C13
749	941352.4664	530414.7917	1603.914	C13
750	941349.2929	530409.025	1604.628	C13
751	941345.7033	530403.6901	1604.764	C13
752	941345.3387	530403.091	1604.656	C13
753	941344.0416	530400.9207	1603.827	C13
754	941342.3044	530397.2332	1604.483	C13
755	941341.8509	530396.1808	1602.954	C13
756	941340.8927	530393.4561	1603.78	C13
757	941340.8363	530393.4459	1604.005	C13
758	941337.6583	530397.3899	1604.006	F
759	941337.7987	530442.3759	1604.137	F
760	941332.2045	530445.1532	1603.677	C
761	941329.5128	530447.3246	1603.895	C14
762	941326.7454	530448.7659	1601.509	C14
763	941324.9502	530449.6324	1600.942	C14
764	941321.6771	530451.5341	1601.292	C14
765	941318.767	530455.3001	1604.263	C14
766	941346.5401	530461.753	1603.827	C14
767	941342.5553	530463.4933	1603.515	C15
768	941338.3376	530465.8885	1603.579	C15
769	941336.0126	530466.5553	1601.134	C15
770	941334.0643	530467.1996	1600.576	C15
771	941330.1047	530469.5717	1601.276	C15
772	941326.7977	530471.4569	1603.95	C15
773	941355.7487	530476.4797	1603.632	C15
774	941349.1859	530478.3453	1603.368	C16

775	941345.2766	530479.0258	1603.799	C16
776	941343.1581	530479.4477	1601.157	C16
777	941340.7081	530480.4082	1600.208	C16
778	941338.0977	530481.8702	1601.11	C16
779	941334.3525	530483.9483	1603.087	C16
780	941315.7945	530435.1706	1603.464	C16
781	941312.2476	530440.004	1602.598	M
782	941304.1367	530443.6342	1602.419	M
783	941306.2409	530439.7488	1602.406	M
784	941273.9149	530456.8382	1603.66	M
785	941272.7761	530454.9972	1602.487	M
786	941259.5626	530461.1066	1603.546	M
787	941234.6009	530472.5729	1603.502	M
788	941320.6646	530431.8843	1603.346	M
789	941315.6804	530434.2857	1601.866	B
790	941315.651	530432.6196	1602.744	B
791	941319.7185	530430.7671	1604.51	B
792	941308.8359	530415.1043	1604.545	B

Surveying Data for Culvert at Station 4+325

ID	North	East	Elevation	Code
1	939777	531033	1629	BM
2	939807	531095	1623	BM
3	939807	531031	1626	BM
4	939777.647	531032.957	1624.568	SH
5	939809.179	531092.205	1625.243	BM
6	939699.773	530907.563	1633.783	BM
7	939709.008	530901.687	1628.248	SH
8	939715.263	530899.219	1628.184	CL
9	939718.873	530896.407	1628.268	SH
10	939718.863	530896.39	1628.268	MH
11	939719.894	530899.734	1628.049	MH
12	939723.19	530900.336	1627.98	MH
13	939730.789	530897.64	1627.842	SH
14	939715.332	530940.896	1633.72	SH
15	939715.485	530941.136	1633.731	SH
16	939726.131	530934.234	1627.563	SH
17	939732.244	530930.796	1627.039	CL
18	939743.344	530926.112	1626.87	SH
19	939746.89	530924.647	1627.37	SH
20	939752.175	530921.636	1630.461	SH

21	939727.837	530965.78	1633.62	SH	63	939834.291	531042.885	1621.528	SH
22	939738.752	530959.373	1626.905	SH	64	939834.419	531041.085	1624.008	SH
23	939745.304	530957.475	1626.228	CL	65	939836.5	531034.162	1625.237	SH
24	939753.053	530954.904	1625.983	SH	66	939860.491	531100.004	1623.486	SH
25	939756.254	530952.079	1626.247	SH	67	939857.054	531085.365	1623.646	SH
26	939758.362	530951.799	1624.555	SH	68	939852.905	531072.64	1623.57	CL
27	939759.048	530950.545	1626.113	SH	69	939848.678	531057.482	1623.727	SH
28	939764.038	530947.398	1626.609	SH	70	939845.098	531048.341	1621.156	RB
29	939743.345	530996.519	1633.443	SH	71	939844.743	531045.026	1621.494	RB
30	939755.455	530990.209	1625.607	SH	72	939846.287	531042.413	1623.868	SH
31	939760.492	530987.928	1625.201	CL	73	939849.375	531032.908	1624.926	SH
32	939767.056	530985.013	1625.056	SH	74	939876.887	531078.07	1623.577	SH
33	939767.725	530987.07	1624.969	SH	75	939874.222	531073.187	1623.687	CL
34	939771.591	530981.332	1625.073	SH	76	939872.056	531069.242	1623.649	SH
35	939773.56	530979.924	1622.566	SH	77	939868.711	531063.315	1623.788	SH
36	939777.195	530978.053	1622.884	SH	78	939864.501	531052.962	1623.936	SH
37	939778.505	530977.2	1624.489	SH	79	939864.632	531050.826	1621.122	RB
38	939784.191	530971.843	1626.293	SH	80	939865.497	531048.227	1620.938	RB
39	939763.139	531037.964	1633.404	SH	81	939865.287	531047.04	1622.591	SH
40	939776.813	531031.782	1624.494	SH	82	939865.882	531037.695	1623.605	SH
41	939782.917	531028.444	1624.195	CL	83	939906.837	531042.553	1622.572	SH
42	939788.069	531025.586	1624.037	SH	84	939759.846	530968.67	1625.615	SH
43	939797.913	531015.411	1624.49	SH	85	939758.054	530964.069	1625.643	SH
44	939798.94	531014.684	1623.008	SH	86	939765.222	530969.423	1623.253	SH
45	939802.8	531011.739	1622.91	SH	87	939762.038	530962.897	1623.142	SH
46	939805.575	531010.168	1625.378	SH	88	939760.086	530968.495	1622.898	SH
47	939815.026	531004.599	1625.956	SH	89	939758.257	530964.242	1622.808	SH
48	939794.122	531065.841	1624.473	SH	90	939767.821	530963.979	1622.73	RB
49	939805.198	531051.763	1624.225	SH	91	939768.918	530962.823	1625.553	SH
50	939799.456	531056.314	1624.408	CL	92	939772.305	530959.703	1625.492	SH
51	939803.866	531050.202	1624.232	SH	93	939766.68	530969.834	1623.033	RB
52	939816.026	531037.805	1624.176	SH	94	939777.706	530978.663	1622.81	SH
53	939816.99	531036.516	1621.393	RB	95	939773.479	530980.858	1622.791	SH
54	939818.833	531034.472	1621.526	RB	96	939778.633	530989.103	1622.536	SH
55	939819.848	531033.347	1624.025	SH	97	939781.57	530986.654	1623.024	SH
56	939823.92	531028.321	1625.493	SH	98	939796.193	531003.816	1622.999	SH
57	939826.555	531084.223	1623.888	SH	99	939792.352	531007.313	1622.939	SH
58	939828.383	531074.882	1623.899	CL	100	939793.902	531012.336	1623.194	Calv
59	939830.368	531064.78	1623.96	SH	101	939800.579	531009.684	1622.732	Calv
60	939832.495	531054.64	1623.934	SH	102	939785.607	531017.648	1623.82	Calv
61	939833.515	531046.743	1624.053	SH	103	939785.137	531019.94	1624.162	Calv
62	939833.78	531045.492	1621.359	SH	104	939774.751	531024.355	1624.449	Calv

105	939809.771	531020.481	1621.99	SH	147	939892.878	531050.759	1620.285	SH
106	939807.905	531022.317	1622.287	SH	148	939891.874	531048.79	1620.563	SH
107	939814.266	531028.632	1621.903	SH	149	939890.619	531046.918	1622.522	SH
108	939812.186	531030.684	1622.074	SH	150	939889.876	531040.238	1623.446	SH
109	939819.288	531034.794	1621.603	SH	151	939901.821	531046.731	1620.167	SH
110	939817.82	531037.14	1621.365	SH	152	939899.62	531044.281	1620.599	SH
111	939827.018	531040.017	1621.745	SH	153	939897.754	531042.453	1623.348	SH
112	939826.532	531043.064	1621.286	SH	154	939892.91	531035.889	1622.808	SH
113	939785.795	531047.22	1624.566	SH	155	939902.094	531046.864	1620.408	Bridge
114	939787.606	531051.483	1624.663	SH	156	939901.843	531046.972	1621.278	SH
115	939774.895	531053.882	1624.877	SH	157	939905.048	531048.096	1622.72	Bridge
116	939763.993	531056.953	1625.104	SH	158	939904.981	531047.904	1620.346	SH
117	939749.843	531064.958	1625.451	SH	159	939907.742	531046.746	1622.727	Bridge
118	939734.844	531079.105	1625.7	SH	160	939907.607	531046.687	1620.352	SH
119	939744.099	531090.157	1625.686	SH	161	939903.586	531040.652	1621.641	SH
120	939751.89	531080.286	1625.519	SH	162	939904.776	531040.853	1622.527	SH
121	939761.387	531072.715	1625.329	SH	163	939931.365	531049.841	1622.659	SH
122	939773.018	531067.711	1625.081	SH	164	939928.342	531044.523	1622.861	CL
123	939786.143	531065.641	1624.687	SH	165	939926.537	531039.077	1622.618	SH
124	939799.702	531067.044	1624.365	SH	166	939925.28	531034.009	1622.561	SH
125	939812.636	531072.39	1624.094	SH	167	939936.289	531048.955	1622.81	EP
126	939821.899	531079.466	1623.847	SH	168	939962.842	531035.576	1622.092	EP
127	939830.447	531089.73	1623.924	SH	169	939900.11	531040.178	1621.914	FO
128	939835.333	531100.702	1623.884	SH	170	939893.195	531042.773	1623.163	SH
129	939836.98	531123.23	1623.755	SH	171	939886.8	531047.07	1623.251	FO
130	939832.112	531138.636	1623.875	SH	172	939878.661	531050.628	1622.344	FO
131	939780.587	531069.109	1625.346	SH	173	939868.085	531054.557	1623.89	FO
132	939753.348	531083.129	1625.913	SH	174	939913.438	531068.587	1621.881	BM
133	939742.888	531062.795	1625.998	SH	175	939929.368	531054.337	1621.643	Bridge
134	939770.207	531048.737	1625.546	SH	176	939920.948	531058.958	1618.737	Bridge
135	939884.403	531074.065	1623.441	SH	177	939921.131	531058.521	1621.634	Bridge
136	939882.483	531067.927	1623.553	CL	178	939925.247	531058.091	1619.168	SH
137	939881.171	531064.748	1623.504	SH	179	939919.402	531057.785	1622.332	Bridge
138	939878.985	531059.286	1623.215	SH	180	939916.108	531059.359	1622.606	Bridge
139	939878.501	531057.467	1621.265	SH	181	939915.192	531061.729	1621.6	Bridge
140	939879.339	531052.867	1620.916	SH	182	939915.296	531061.797	1618.826	Bridge
141	939878.504	531050.036	1622.784	SH	183	939915.526	531063.256	1618.38	SH
142	939878.13	531039.851	1624.357	SH	184	939930.579	531058.729	1616.969	SH
143	939901.222	531065.468	1623.098	SH	185	939917.068	531065.572	1616.918	SH
144	939898.839	531059.49	1623.282	CL	186	939933.509	531062.867	1615.637	SH
145	939895.115	531054.489	1622.999	SH	187	939920.675	531069.42	1615.4	SH
146	939893.166	531051.686	1622.134	SH	188	939934.28	531063.87	1612.628	SH

189	939928.708	531067.863	1612.088	SH	231	939906.483	531047.308	1622.73	Road er
190	939925.596	531069.278	1612.141	SH	232	939906.289	531047.367	1620.161	CL
191	939929.866	531074.437	1612.041	SH	233	939902.703	531043.579	1620.463	CL
192	939936.419	531064.906	1613.701	SH	234	939973.289	531093.383	1621.149	SH
193	939932.808	531077.339	1612.5	SH	235	939969.274	531101.341	1621.172	SH
194	939943.504	531065.088	1613.186	SH	236	939960.509	531094.006	1621.099	SH
195	939942.407	531079.485	1612.974	SH	237	939962.31	531074.859	1621.222	SH
196	939951.188	531064.427	1613.868	SH	238	939957.367	531097.041	1621.202	SH
197	939947.774	531080.992	1613.667	SH	239	939964.901	531068.571	1621.174	SH
198	939955.879	531070.427	1613.634	SH	240	939955.181	531098.896	1621.243	SH
199	939951.705	531081.221	1613.435	SH	241	939958.487	531066.865	1621.519	SH
200	939957.614	531083.061	1612.976	SH	242	939942.372	531086.673	1621.562	SH
201	939958.049	531081.164	1610.534	SH	243	939940.401	531088.894	1621.733	SH
202	939961.323	531083.443	1610.289	SH	244	939938.838	531091.185	1621.759	SH
203	939967.149	531084.204	1610.291	SH	245	939933.452	531083.608	1621.646	SH
204	939969.527	531085.918	1610.331	SH	246	939931.959	531086.111	1621.66	SH
205	939976.416	531086.707	1610.341	SH	247	939947.185	531059.936	1621.726	SH
206	939975.872	531087.696	1610.304	SH	248	939930.543	531087.804	1621.578	SH
207	939983.186	531087.848	1610.252	SH	249	939937.735	531062.282	1621.1	SH
208	939986.416	531088.862	1610.124	CL	250	939923.574	531083.983	1621.647	SH
209	939981.178	531088.187	1610.129	CL	251	939942.117	531056.544	1621.918	SH
210	939973.716	531086.602	1610.239	CL	252	939922.986	531078.37	1620.058	SH
211	939965.614	531084.445	1610.022	CL	253	939933.292	531054.041	1621.798	SH
212	939957.765	531081.532	1610.482	CL	254	939921.789	531076.795	1619.212	SH
213	939950.507	531077.229	1610.79	CL	255	939919.011	531080.604	1621.991	SH
214	939943.105	531074.635	1611.477	CL	256	939938.61	531050.041	1622.468	SH
215	939933.755	531070.767	1612.041	CL	257	939915.985	531074.73	1621.486	SH
216	939928.547	531068.326	1612.061	CL	258	939911.716	531067.181	1622.06	SH
217	939955.551	531064.891	1613.73	SH	259	939913.484	531066.205	1621.685	SH
218	939956.276	531073.627	1612.559	SH	260	939921.871	531038.985	1622.792	EP
219	939941.234	531065.393	1613.124	SH	261	939957.808	531036.528	1622.204	SH
220	939926.408	531066.467	1615.356	CL	262	939953.348	531031.186	1622.408	CL
221	939925.438	531064.587	1615.598	CL	263	939951.24	531025.719	1622.201	SH
222	939925.474	531064.468	1615.6	SH	264	939956.943	531021.173	1622.208	EP
223	939924.196	531062.2	1615.618	CL	265	939909.729	531062.996	1622.461	Pipe
224	939924.121	531062.046	1616.845	CL	266	939915.239	531060.226	1622.205	Pipe
225	939920.161	531060.856	1616.937	CL	267	939923.098	531056.198	1622.005	Pipe
226	939920.197	531060.789	1618.669	SH	268	939928.513	531053.526	1621.994	Pipe
227	939918.204	531058.376	1618.795	CL	269	939928.14	531085.396	1621.705	EP
228	939918.024	531058.531	1620.116	CL					
229	939917.687	531058.67	1622.799	Road er					
230	939911.161	531052.963	1623.077	Road Cl					