Impact Of Installation Of Erosion And Drainage Control Structures In Flood Prone Section Of Road: The Case Of Wolaita Soddo Town In South Ethiopia

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Abstract
This thesis emphasis on the study of Impact of installation of erosion and drainage Control structures on Flood prone section of Road that represent high and low volume roads in urban area. Because of an increase in Urbanization, impermeable areas increases and causes the major flooding problems in the areas. Generally erosion can be caused by wind, gravity, or storm water. However, erosion generated by storm water is the most damaging factor, especially in developing Countries in the World. In Ethiopia, most of the towns were established in highlands and river areas where as the study area, Soddo Town is established at the foot of Mountain Damota and its altitude descends to all direction (1900-1600 m.a.s.l.). The altitude descends abruptly and has steep slopes; this is the reason why the town and its infrastructures are mostly affected by the storm water erosion frequently.

The objective of this study is to assess the existing condition of erosion and drainage control structures on section of road networks in Wolaita Soddo Town. Specifically, to examine and evaluate the impacts of installation of erosion and drainage control structures in section of road with respect to slopes and flooding or runoff effects; and to make the technical recommendations on installation of erosion control structures on section of road and storm water drainage net-work construction and management. This research is both descriptive and exploratory types. To achieve the research goal the primary and secondary data were collected by using questionnaires, interview, soil laboratory and field survey. For analysis, Topographic maps of the area, AUTOCAD, Arch GIS and Excel spread sheets software were used.

In this study, the causes and effects of storm water drains and the factors that affects roads and its infrastructures were discussed in detail. The root causes of road failure interns erosion are geographical and management factors. The common tribulation on small towns in Ethiopia constructing access roads by without followed national and international road construction guideline. Finally, the area was recommended to improve the method of installation of erosion and drainage control structures and storm water management on road net-work based on terrain type and amount of runoff estimated.

Acknowledgement

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Chapter 1: Introduction

1.1. Background

Flooding and erosion are serious ecological problems in world and commonly caused by storm water, wind and gravity. However, storm water-generated erosion is the most damaging factor, especially in developing Countries in the World; whereas, the Roadside erosion and runoff is also a trouble during and after the road construction and maintenance in all rural and urban area.

Unplanned urbanization has drastically altered the drainage characteristics of natural catchments, or drainage areas, that increase the volume and rate of surface runoff on the stage it development. The drainage systems are unable to cope with the increased volume of water and are often encountered with the blockage due to indiscriminate disposal of solid wastes or debris.

Urban flooding creates considerable infrastructure problems and huge economic losses in terms of development, as well as significant damage to property and goods. It also causes large damage at buildings and other public and private infrastructure. Besides, the street flooding can limit or completely hinder the functioning of traffic systems and has indirect consequences such as loss of business and opportunity. The expected total damage; direct and indirect monetary damage costs as well as possible social consequences is related to the physical properties of the flood, such as the water level above ground level, the extend of flooding in terms of water volume escaping from or not being entering the drainage system, and the duration of flooding. With sloped surfaces even the flow velocity on the surface might have an impact on potential flood damage. It is known that the precipitation of intensity and the durations of time are the key elements that decide flooding.

Effective erosion control requires an integrated approach, which considers government status and regulations, a broad knowledge of temporary and permanent erosion control methods; design, construction, and maintenance considerations; and the use of material of the modern technology products. In Ethiopia; Ethiopian Road Authority (ERA) and Regional road sectors have a long times gone by in road research works, study and design, construction supervision; and maintenance works since 1965.

Relatively, the Wolaita Soddo Town is located west of the Great Ethiopian rift valley & at the eastern margin of south western highlands. The town is established at the foot of mount Damota and its altitude descends to all directions. The relief of the town is mainly characterized by mountains, gorges and plain lands especially towards southern direction. The highest & lowest altitude of the town ranges from 1900-1600 meters above sea level. Accordingly, the average altitude of the town is 1,800 meters above sea level. The mean annual temperature of the town is 20°C & the mean annual rainfall is 1,212 mm and it is very high related to surrounding areas. Due to all the above reasons the town and its infrastructures are mostly affected by the storm water erosion frequently (*Source: SNNPRS-UPI Socio Economic Study Department Report. March, 2007*).

With urbanization, impermeability increases because of the increase in impervious surfaces. This in turn changes the drainage pattern, increases overland flow result in flooding and related environmental problems. The impact of this is severe on spatial structures like roads. This is because; flooding and its related environmental problems like sheet and gulley erosion, surface inundation tends to affect road services and its life span. Given the significance not only in socio-economic development, but also a path way for the location of other infrastructure, issues that affect its performance and longevity are critical areas of this research. So street flooding, over topping, and ditch bed erosion and failures are common in this area. This is particularly severe in areas where road infrastructure appears to be without adequate storm water drainage infrastructure and poor method of installation erosion control structures.

The administration in the town gives great emphasis to this research because the peoples living in the downstream of the area were suffered by seasonal storm water disaster and the road networks were affected by gulley erosion. So in this research it was focused to investigate the problems, to evaluate the causes of problems, identify the impacts of erosion control structures and to determine the suitable structures and method of installation on road drainage networks. Finally the output of this research was used as guideline for the urban road drainage networks and as finding of scientific research on the area of this study.

1.2. Statement of the problem

As much as having the long history on the road construction and maintenance works in the World where as Africa and our country Ethiopia, there were many supporting guidelines and published research materials that used for road structures but also the problems have taken equal life history. Erosion is the Geotechnical and Hydraulic effect that caused by storm water runoff on bare or unprotected area of land and the road erosion has the same impact on the section of road.

Drainage and erosion problems in urban areas include flooding, deterioration of roads, land degradation, sedimentation, blockage of drainage facilities, water logging and etc. 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. In spite of these problems, the drainage facilities in most urban centers of the country (Ethiopia) are nearly absent or at a lower coverage (*FUPCoB, 2008*).

The Ethiopia Road Authority (ERA) has the general road construction design manual and specification that used in different regions in Ethiopia. The roads that constructed in different areas have faced severe damages because of the construction materials quality problems, inadequate storm water drainage and poor method of construction. In another way, Ministry Of Works And Urban Development has prepared 'Urban Storm Water Drainage Design Manual' for storm water and the infrastructures management on urban areas; however its implementation is the serious challenges in the most parts of regional City and Towns in Ethiopia. The major ones are geographical natures (having different terrain types), improper drainage net-works, and low discharge carrying capacity of ditch, roadside canal bed erosion and material composition; and the influence of installed erosion control structures on surrounding environment.

To minimize the problems on the environment so as to increase the performance of construction methodology, ERA preferred to conduct research on the areas of road construction. From the various given topics 'Impact of installation of Erosion and drainage control structures in flood prone section of road' is selected for this thesis.

The ideas from the topic and the scope of objective emphasis; the investigation of the impacts, evaluation of the exiting problems and determination of suitable solutions are assumed hypotheses.

As far as the researcher is concerned, there is no research conducted on erosion and drainage control structures in the section of roads in south Ethiopia around Wolaita Sodo Town. This study tried to address the impact of installation of these structures on the flood prone section of road particularly on urban areas of Ethiopia.

1.3. Research Questions

- Which part of the area the most prone to erosion and flooding hazards?
- What type of erosion control structures existed on the urban roads and their drainage net- works?
- What are the impacts of installation of drainage and erosion control structures on section of road with respect to amount of storm water flow or runoff, soil, slopes types and materials made of?
- What type of recommendation that will be given to manage storm water flow on road drainage net-works and method of installation erosion control structures based on general topography?

1.4. Objective

1.4.1. General Objective

To assess the impact of installation of erosion and drainage control structures on flood prone section of road with respect to the terrain type, soil, and runoff condition in Wolaita Soddo Town.

1.4.2. Specific Objectives

- To identify the areas that are most affected by erosion and prone to flooding hazards
- To assess the existing condition of erosion and drainage control structures on section of road net-work and the factors that affect management
- To examine and evaluate the impacts of erosion and drainage control structures on section of road with respect to Soil type, terrain types and, flooding effects or runoff
- To recommend on installation of erosion and drainage control structures on section of road network and storm water management

1.5. Significance of the research study

This study, generally, contributes the following major significances:

1) The study town, Wolaita Soddo; and other developing towns in the country will use it as a reference when they prepare annual and financial plans in relation to spatial, and roads and urban storm water drainage infrastructure, respectively
2) Policy makers and any organization working in the area of roads and urban storm water drainage infrastructure can use it as a further reference to fill the existing gap between road and urban storm water drainage demand and supply.
3) It will be an alternative means of solution in ensuring sustainable development in Wolaita Soddo town by strengthening the environmental and socioeconomic activities with regard to road and urban storm water drainage infrastructures.

Chapter 2: Literature Review

2.1. General Overview

There are many internationally published literatures on this topic and many guidelines of different countries state the problems and its solution. The nature of flood and their impacts depend on both nature and human made conditions in the flood plain. Economic developments and the installation of flood protection measurement have political, economic and social dimension as well as engineering aspect. Hydrologic and hydraulic analysis of flood provides a sound technical basis for facilities design as well as for management decision making that must weigh numerous other factors (*Daniel. H. Hoggan, 1997*).

Urbanization along with its impermeable structures is the major causes of flooding in urban areas. The storm water drainage management and erosion control system on road-network is complex than that of major roads. Before last 40 years the road construction system in Ethiopia was unsatisfactory, the construction material and construction design were the major problems. To solve the problems the Ethiopia Road Authority (ERA) prepared the general low and high volume road design manual based on international road construction guidelines where as Ministry Of Works And Urban Development has prepared 'Urban Storm Water Drainage Design Manual' for storm water design and the infrastructures management on urban areas.

The manuals that stated above are standard manual in Ethiopia and contain all design and study procedures in construction and maintenance work. But the problems are also not solved completely because the interpretation and understanding of manuals before implementation the projects are challenges in urban and rural areas of the country. In this research many literatures that related to this topic are reviewed and the gaps that are open for further studies have been discussed as necessary.

2.2. Related Literatures

Currently, many research and the study reports were conducted in other countries and Ethiopia related with this research topic. Such as: Road and urban storm water drainage network integration in Addis Ababa: Addis Ketema Sub-city (*Dagnachew, 2011*). In this research the road and its drainage structures networks; and the damage and insufficient drainage capacity impact on the environment was searched however the different structures that used to control erosion with respect to slopes and cross drainage works was not discussed in depth.

The ditch erosion and the factors that causes failure of ditch; types and their material properties were discussed on the topic of 'Research on design for prevention of ditch erosion on Virginia highways' (*P. Diplas,et al,1999*) but the factors such as the geographical factors that influence on ditch performance; and development of rational design procedures to account for their impact was not elaborated based on cross sectional area as well as longitudinal slopes. On other hand "Assessing the impact of urban drainage measures with regard to water frame work directives" (*Dipl.-Biol. Carolina Engelhard, 2006*) has a strengthening idea. Accordinning to this literature the biological factors of the ditches on the surrounding environment was well discussed but the physical factors such as structures that safe for its stability and surrounding world were omitted.

Drainage systems include the pavement and the water handling systems. They must be properly designed, built, and maintained. The water handling system by itself includes: shoulders, ditches, culverts and storm sewer. When a road fails (whether it's concrete, asphalt or gravel), inadequate drainage often is a major factor (*Drainage design manual: (2000) Wisconsin Department of Transportation and the University of Wisconsin*) and *Allan A. (2006).* This study emphasis on the problems of design that is serious challenge on road drainage infrastructures, so in this research work it has given the attention to design an implementation drainage and erosion control structures.

In this study, attention is given to sample and collect the actual data from the site, analyzing and interpreting the scientific method, finding the output, fill the gap in previous study and come up with the general solution that used to solve the problems of the storm water management with respect to the terrain, erosion control structures and method of construction.

2.3. Methods of drainage and erosion control

New roadways and urban development, generally, can and should be designed to minimize the higher in storm water run-off rates. To control it there is source-control and structural control methods can be employed (*P. Diplas,et al,1999*).

2.3.1. Source-control or non-structural management

It is aimed at reducing the amount of run-off that enters urban streams rather than attenuating flood peaks. This strategy generally integrates storm water management into the design criteria for new urban development. It focuses on reducing the proportion of impervious surfaces and reducing storm water run-off rates. There is increasing interest in non-structural management as methods of both reducing the rate of run-off and removing contaminants at source (*P. Diplas,et al,1999*).

2.3.1.1. Recurrence Interval

It is the average interval between floods of a given magnitude **ROW** **(**Right of Way). Generally, drainage systems will be designed to prevent road damage during the most usual floods such as 2-year, 5-year, 10-year, 20/25-year, 50-year, or 100-year flood, depending on the importance of the road and the type of structures on the area. A flood recurrence interval which is consistent with table 3.1 below should be selected.

Table 2.1 Recurrence Interval versus Facility Description

Land Use/ Facility Description	**Recurrence Interval**
Residential, recreational, open space	2 years/5 years
Commercial/Business, dense residential, small detention/retention facilities	10 years
Main collector drainage lines cross drain pipes of collector roads/a highway. Culverts under local and collector streets and small embankments. Also, pipes along a highway that conveys runoff to the disposal point or a waterway.	20 years/25 years
Bridges/large culverts along major arterials or high ways, any drainage or flood protection facility/dam along rivers, or other relatively larger water bodies.	50 years to 200 years

Source: FUPCoB. (2008),Urban Storm Water Drainage Design Manual, Addis Ababa.

2.3.1.2. Selection of Hydrologic Methods

The following guidelines should be used to select the hydrology method for computing the design peak flow:

Size of Drainage Area	**Hydrologic Method**
1 - 50 Hectares	Rational Formula
50 - 1300 Hectares	NRCS* TR-55 / SCS Method and Other Unit Hydrograph Methods
Greater than 1300 Hectares	NRCS TR-20 or HEC-1 Method

Source: U.S. Natural Resources Conservation Service (NRCS), formerly the U.S. Soil Conservation Service (SCS), No. 55 (2nd Edition).

The peak flow from a drainage basin is a function of the basin's physiographic properties such as size, shape, slope, soil type, land use, as well as Climatological factors such as selected rainfall intensities.

Rational Formula

The rational formula is an empirical formula relating runoff to rainfall intensity. It is expressed in the following form:

$$Q = 0.00278\ CIA \quad \ldots\ldots 2.1$$

Where,

Q = peak flow in cubic meters per second (m^3/s)
A = drainage area in hectares
C = runoff coefficient (weighted)
I = rainfall intensity in millimeters per hour (mm/hr)

Basic Assumptions:

- The peak rate of runoff (Q) at any point is a direct function of the average rainfall intensity (I) for the time of concentration (Tc) to that point.
- The recurrence interval of the peak discharge is the same as the recurrence interval of the average rainfall intensity.
- The time of concentration is the time required for the runoff to become established and flow from the most distant point of the drainage area to the point of discharge.

A. Runoff coefficient (C):

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The runoff coefficient (C) accounts for the effects of infiltration, detention storage, evapo transpiration, surface retention, flow routing and interception. The product of C and the average rainfall intensity (I) is the rainfall excess of runoff per hectare. The runoff coefficient should be weighted to reflect the different conditions that exist or expected to exist in the future within a watershed.

Table 2.2 Recommended Runoff Coefficients (C) for Urban Watersheds

Run Off Coefficients for Urban Watersheds	
Type of Drainage Area	**Runoff Coefficient**
Business: • Down town/ city center areas • Neighborhood area	 0.70-0.95 0.30-0.70
Residential: • Single-family areas • Multi-units, detached • Multi-units, attached • Suburban • Apartment dwelling areas	 0.30-0.30 0.40-0.60 0.60-0.75 0.35-0.40 0.30-0.70
Industrial: • Light areas • Heavy areas	 0.30-0.80 0.60-0.90
Parks, cemeteries	0.10-0.25
Playgrounds	0.30-0.40
Railroad yards	0.30-0.40
Unimproved areas: • Sand or sandy loam soil, 0-3% • Sand or sandy loam soil, 3-5% • Black or fine-grained soil, 0-3% • Black or fine-grained soil, 3-5% • Black or fine-grained soil, >5% • Deep sand area • Steep grassed slopes	 0.15-0.20 0.20-0.25 0.18-0.25 0.25-0.30 0.70-0.80 0.05-0.15 0.70
Lawns: •Sandy soil, flat 2% •Sandy soil, average 2-7% •Sandy soil, steep 7% •Heavy soil, flat 2-7% •Heavy soil, average2-7% •Heavy soil, steep 7%	 0.05-0.10 0.10-0.15 0.15-0.20 0.13-0.17 0.18-0.22 0.25-0.35
Streets: • Asphalt • Concrete • Brick	 0.85-0.95 0.90-0.95 0.70-0.85
Drives and walks	0.75-0.95
Roofs	0.75-0.95

Source: Horner (2001), Hydraulic Design ManualTxDOT

B. Determination of Rainfall Intensity Rate (I):

The rainfall intensity i is the average rainfall rate in millimeters per hour for a particular drainage basin or sub basin. The intensity is selected on the basis of the design rainfall duration and return period. The design duration is equal to the time of concentration for the drainage area under consideration. The return period is established by design standards or chosen by the hydrologist/engineer as a design parameter.

Runoff is assumed to reach a peak at the time of concentration Tc when the entire watershed is contributing to flow at the outlet.

C. Time of concentration (Tc):

The time of concentration is the time required for the runoff to become established and flow from the most distant point of the drainage area to the point of discharge or in other words it is the time for a drop of water to flow from the remotest point in the watershed to the point of interest. Usually two times of concentration are employed: one for inlet spacing and another for pipe sizing:

Different equations of time of concentration could be used for inner and peripheral areas of urban centers

1) Airport or Federal Aviation Administration (1970) Methods could preferably be used for inner areas (for the developed areas of urban centers)

Table 2.3: Equations Used to Determine Time of Concentration

Method and Date	**Equations for Tc (in min otherwise stated)**	**Remarks**
Air port	$Tc = 3.64 (1.1 - c) L^{0.83} / H^{0.33}$ Where: Tc = Time of Concentration (hrs) L = Flow length from the remotest point to the point of interest in km H = Elevation difference in m C= Runoff coefficient (Unitless)	Air port formula used when the land is covered more than 75% by impervious layer.
Federal Aviation Administration (1970)	$Tc = 1.8(1.1\text{-}C)L^{0.50}/S^{0.333}$ C = Rational method runoff coefficient L = Length of overland flow, ft S = Surface slope, %	Developed from air field drainage data assembled by the corps of Engineers; method is intended for use on airfield drainage problems, but has been used frequently for overland flow in urban basins.

Source: Applied Hydrology, Ven Te Chow, p. 500

2) SCS method, for peripheral catchments (cultivated areas, ridges etc.)

$$T_c = \left[\frac{0.87L^3}{H}\right]^{0.385}$$

- Units of Tc, L, and H are the same as above.

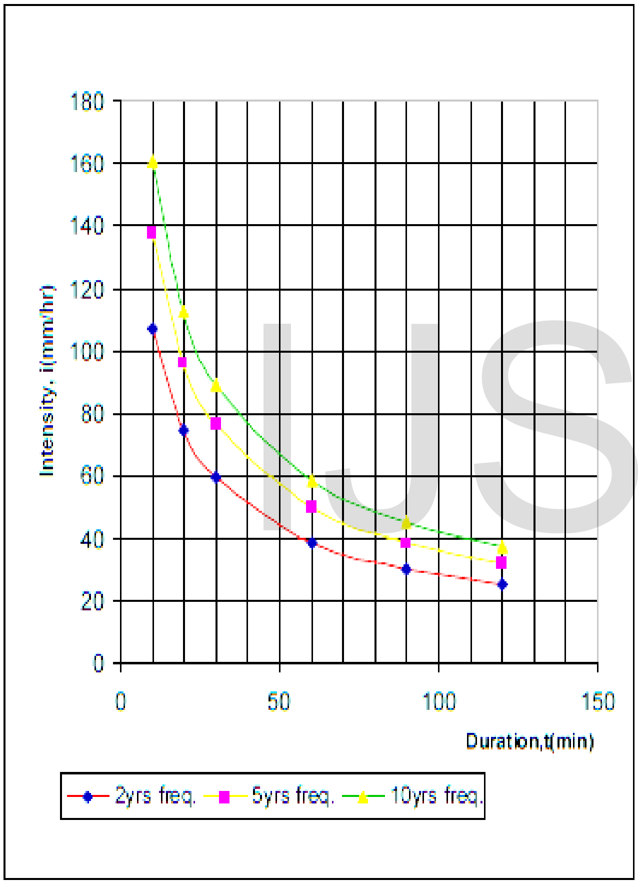

Figure 2.1 Typical rainfall intensity duration frequency curves.

Source: (FUPCoB**,** Urban Storm Water Drainage Design Manual of Ethiopia, 2008)

2.3.2. Structural control or management
It involves construction of conveyance structures that are designed to attenuate the peak flows in flood events. Collected run-off is then released gradually into the stream over time.

2.3.2.1. Storm Water Conveyance Channel

A permanent, designed waterway shaped and lined with appropriate structural material to safely convey excess storm water runoff from a developing area. The main purpose is to convey concentrated surface runoff water without damage from erosion.

A. Hydraulic Capacity

The most widely used formula for determining the hydraulic capacity of storm drains for gravity and pressure flows is the Manning's formula and it is expressed by the following equation.

Manning's Formula

For a given depth of flow in a channel with a steady, uniform flow, the mean velocity, V, can be computed with Manning's equation:

$$V = (1/n) R^{2/3} S^{1/2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.2$$

Where:
V = velocity, m/s
n = Manning's roughness coefficient
R = hydraulic radius = A/P, m
P = wetted perimeter, m
S = channel slope, m/m)

The selection of Manning's 'n' is generally based on observation; however, considerable experience is essential in selecting appropriate 'n' values. The range of 'n' values for various types of channels and floodplains is given in Table 2.4.
For a given channel geometry, slope, and roughness, and a specified value of discharge
Q, a unique value of depth occurs in steady uniform flow. It is called the normal depth.

The normal depth is used to design artificial channels in steady, uniform flow and is computed from Manning's Equation:

$$Q = (1/n) AR^{2/3} S^{1/2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.3$$

Where:
Q = discharge, m^3/s (Result from Eqn 2.1)
n = Manning's roughness coefficient
A = cross-sectional area of flow, m^2
R = hydraulic radius = A/P, m
P = wetted perimeter, m
S = channel bed slope, m/m

Table 2.4: Manning Roughness Coefficients, n for Various Open Channel Surfaces

Material	**Typical Manning roughness coefficient, n**
Concrete	0.013
Gravel bottom with sides	

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Concrete	0.020
Mortared stone	0.023
Riprap	0.033
Natural stream channels	
Clean, straight stream	0.030
Clean, winding stream	0.040
Winding with weeds and pools	0.050
With heavy brush and timber	0.100
Flood plains	
Pasture	0.035
Field crops	0.040
Light brush and weed	0.050
Dense brush	0.070
Dense trees	0.100

Source: Chow, 1959

B. Permissible Velocity

All storm drains shall be designed such that velocities of flow will not be less than 0.76m/s at design flow. The storm drainage system shall be checked to be sure there is sufficient velocity in all of the drains to prevent settling of particles (ERA, 2002 and FUPCoB, 2008). The maximum allowable velocity for lined canal is 2m/s to 2.5m/s (S.K.Garg, 2006).

C. Minimum Grades

For very flat grades the general practice is to design components so that flow velocities will increase progressively throughout the length of the channel system. Minimum slopes required for a velocity of 0.76 m/s can be calculated by rewriting Manning's formula as shown in equation Eq. 2.2 or by using values given in Table 3.4:

$$S = (n \quad V)^{2} / R^{4/3} \quad \ldots\ldots 2.4$$

2.3.2.2. Inlets and Outlets Control of Cross-Drains and Ditches

Water should be controlled, directed, or have energy dissipated at the inlet and outlet of culverts, rolling dips, or other cross-drainage structures. This can ensure that water and debris enters the cross-drain efficiently without plugging, and that it exits the cross-drain without damaging the structure or causing erosion at the outlet.

A. Inlets Protection

Culvert inlet structures (drop inlets) are usually placed in the inside ditch line at the location of a culvert cross-drain. They are commonly constructed of concrete, masonry or from round metal pipe. They are typically used where the ditch is eroding and down cutting, so that the structure controls the ditch elevation. Inlet structures are also useful to change the direction of water flowing in the ditch, particularly on steep grades, and they can help stabilize the cut bank behind the pipe inlet (Gordon K and James S**,** 2003).

B. Outlet Protection

Structurally lined aprons or other acceptable energy-dissipating devices placed at the outlets of pipes or paved channel sections. The most common types are riprap aprons or concrete aprons with energy dissipater blocks or walls. The main purpose is to prevent scour at storm water outlets and to minimize the potential for downstream erosion by reducing the velocity of concentrated storm water flows (Tallahassee, Florida, 2008).

The outlet of pipes and dips are ideally located in a stable, non erosive soil area or in a well-vegetated or rocky area. The accelerated velocity of water leaving a roadway can cause severe erosion or bullying if discharged directly onto erosive soils.

Other energy dissipation measures include the use of stilling basins, reinforced splash aprons, or use of dense vegetation or bedrock in erosive soils, and with flow velocities over one meter per second may require armoring or the use of small ditch dike or dam structures placed in the ditch to slow down the velocity of water.

Ditches are commonly armored with grass, erosion control matting, rock, or masonry /concrete paving. Grasses can resist flow velocities to 1-2 meters per second. A durable armoring such as graded rock riprap or concrete is recommended on grades over 5 percent in erosive soils or for velocities over a few meters per second.

A ditch dike prevents ditch erosion, and dikes can serve to catch sediment, but they require maintenance and to be periodically cleaned out.

Common ditch dike construction materials include loose rock, masonry, concrete, bamboo, and wooden posts. Each dike structure should be keyed into the banks of the ditch and a notch is needed over each structure to keep the flow in the middle of the ditch (*Gordon K and James S***,** *2003*).

Figure 2.2: Riprap Outlet Protection of Pipe Drains

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Chapter 3: Methodology

3.1. Study area

Wolaita Sodo town, the study area, is situated at a distance of 395 km and 170 km south west of Addis Ababa and Hawassa respectively. Geographically, the town is located 6°29'24'' North and 37° 27'00"East latitude & longitude respectively. The intervention behaviors and it plan to conduct in Southern Ethiopia in Wolayta Soddo Town, Road drainage net-works. The roads are low and high volume, and has paved and unpaved parts.

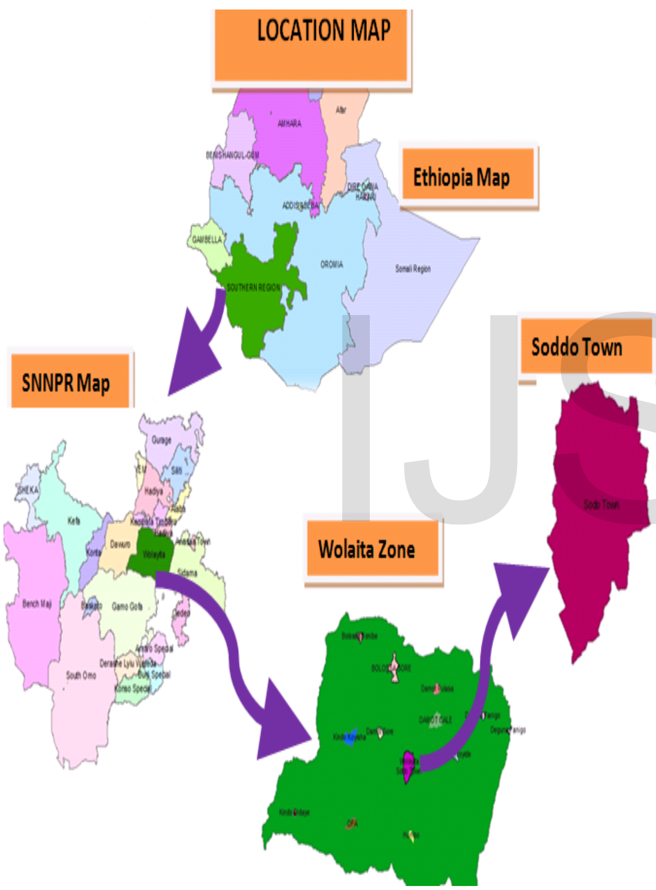

Figure 3.1: Map of Soddo Town, SNNPRS in National Level, Ethiopia.

(Source: GIS Software data source and Sodo Town Municipality)

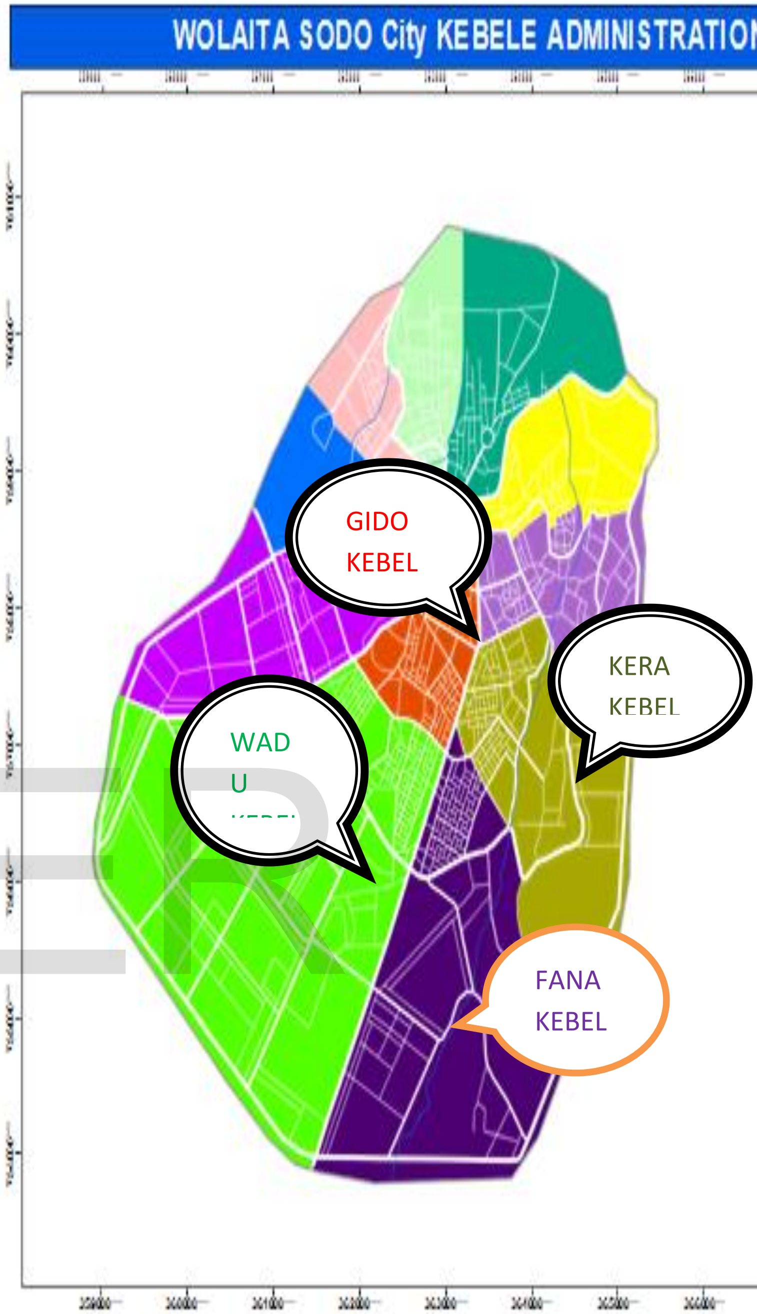

Figure 3.2: Map of Soddo Town, Adminstrative Areas, Ethiopia
(Source: GIS Software data source and Soddo Town Municipality)

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Figure-3.3: Morphology of Wolaita Soddo Town
(Source: Google Map 2009)

3.2. Study Design
This research is, both descriptive and exploratory types, having impact and case study; to achieve the objective of the research was conducted accordance with the methodology (Appendix 2). All methods such as visiting the site, discussing the problems, collecting necessary data, analyzing and interpreting the data, by considering all the time and cost, were used.

3.3. Source of population

A systematic sampling was conducted and measured on the impact and methods that are involved in construction area, geographical information and rainfall data and in addition several possible participants available in road construction works.

3.3.1. Study population

Study population consists of the terrain type or slope, runoff of the catchment, road networks plan and standards, and method of construction of drainage and erosion control structures in access road sides.

3.4. Sample size and sampling procedure

Based on the research objective, about 95% of the data obtained from the field survey and the remaining 5% from interviews for selected community representatives and questionnaires for 30 professionals from regarding sectors.

In order to generate data for the specific objectives, field survey was conducted. A reconnaissance survey was carried out for identifying representative areas in three sub-cities of a town.

The procedure of sampling was started from investigation of problems and evaluating of the existing erosion control structures on road networks and storm water drainage structures impact on surrounding environment; and then collecting all the data and information based on population size and variables it depends.

3.5. Study variables

During the study period, the variables were grouped into two:-

a. Dependent variable
Impact of installation of Erosion and drainage control structures on flood prone section of road with respect to the terrain types, soil and runoff effect.

b. Independent variable

- Erosion and drainage control structures on section of road
- Terrain types (slope ranges),soil type and runoff effects
- Road storm water drainage net- work and management

3.6. Data collection process
During this study, both primary and secondary data were collected
The primary data were obtained through field survey, laboratory analysis, and interview and questionnaire survey.
The secondary data were obtained from various published and unpublished sources of the governmental and the non-governmental organizations. Books, journals, research reports, archives and records were employed for acquiring the necessary information.
The data was collected by data collection format, and from Topographic Map of the area, AUTOCAD, EAGLE POINT and Arch GIS Software's out puts that important for the research.

3.7. Data processing and analysis
The following data collection methods were used (See on Appendix **2.**Dummy Table for research data analysis).
A). Questionnaires were prepared for Kebele /Community, sub-city and Municipal professionals, Urban Administration to identify: areas prone to flooding, major causes of flooding and erosion, and urban storm water drainage infrastructure (Appendix 1).
B). Interview was employed to collect data related to flooding hazards and causes of flooding through household survey.
C). Field survey was the dominant method of data collection in this study using base map and check list. The sizes of urban storm drains and roads have been measured and checked for their length, width, height and/or radius and longitudinal slopes. It was also employed to identify the existing hierarchy, condition and pavement of road and urban storm Water drainage infrastructures (Appendix 2**.**Dummy Table for research data analysis).

Then, all the data were presented in the form of tables, graphs, percentage, photos and maps; so as to get qualitative and quantitative outcome information. Soil textural analysis was done at Sodo Agricultural Research center and then, properly tabulated and described using standard soil description guidelines. From Such data,

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soil texture was generated from soil laboratory analysis (the soil samples are analyzed at Sodo Agricultural Research Center) was properly tabulated and described using standard soil description guidelines. The qualitative information from the questionnaire was also analyzed using appropriate method. Moreover, the analyzed qualitative data were used together with the quantitative data.

3.8. Ethical considerations

The Jimma University Institute of Technology, Ethiopia Road Authority (ERA) and Wolaita Soddo Town administration have permitted to conduct this research on Soddo Town, SNNPRS.

- The data was formally obtained by Field survey in direct observation; and Interview and Questionnaires for Community, sub-city and Municipal professionals and representative that are directly or indirectly flood hazards in areas.
- The research was approved by an ethics review committee to make sure the study area not violating any of the above considerations and reporting the results were accurately represent on what observed or what told.

3.9. Data Quality Assurance

During the data collection, the data collectors were trained and oriented to collect accurate data and they took each and every data by using data format required for the research in neat and clear hand writing or computer.

3.10. Limitation of the study

In conducting research works, there were problems expected to occur and obstruct the validity of the study. Having awareness to these problems, it helped me to search solutions for them before starting the research. The problems that occurred during conducting this study include; unavailability of secondary data sources due to poor organization and documentation culture which is very common in many government institutions of our country. But serious problems were time and financial constraints to collect as much data and information as required for a better reliability of the study.

These and other problems that occurred during the data collection period were tried to be minimized by using alternative sources to get the required data instead of those unavailable documents, approaching the respondents in a clear and friendly manner, and utilizing resources (like time, money, etc) efficiently so as to achieve the intended objectives of the study.

3.11. Operational definition

During the study there were unclear or not common terms like: local names, laboratory instruments and uncommon abbreviations happen; and they defined and their definitions were stated on the acronym parts.

3.12. Expected Output

Based on all the sort of data and the actual study result of the site, by referring the standard study and design manual of ERA and others international guidelines, the expected output was identifying the terrain type, evaluating the impact of existing erosion/drainage control structures and material made of; and the recommendation has to be manage the storm water drains that affects roads and its infrastructures on the study areas.

3.13. Plan for the dissemination of finding

This research result should serve as a guide to locate, assess, rate, and improve drainage conditions on your roads. It could be disseminating by using different means of dissemination methods.

These are as follows:-

- By using International publications.
- By using Civil Engineering Societies website.
- By using International website.
- By using ERA website.
- By using Jimma University Research, Publication, Graduate Studies & Consultancy Office

Chapter 4: Results and Discussions

4.1. General

This chapter focused on data presentation and analysis of primary and secondary data composed from the households (Figure 4.1); and Sodo Town Administration, Municipality, sub-city and Kebele officials and from researcher's direct observation. The majority of this research work was drawn from researcher's field survey with the help of base map and checklists. The interviews and questionnaires were employed to reinforce the field survey data. Every road and urban storm water drainage infrastructures of the study area have fully been surveyed and observed.

4.2. Major flood prone sites in the study area

The major flood prone sites in the study area were identified through interviews from respondents, and questionnaires from kebele and sub-city officials along with field observations. The purposes of identifying such flood prone areas was to investigate the root causes of the flooding problems and to give priority during the provision of urban storm water drainage facilities.

As depicted in Table 4.1 and Shown in Figure 4.1 below, a discussion with the community, it was found out that flood prone areas such as Fana Kebele comprised of 66.67%, Kera Kebele of 16.67% in Merkato Sub-City; and WADU Kebele (13.33%) and Gido

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Kebele(3.33%) in Central Sub-City, which are based on the respondents response as well as field observation.

From the result, the area's that are most affected or prone to flooding hazards is Fana Kebele because it was observed that this area is located at the lowest part of the downstream areas of the town but the Gido Kebele is found on the highest parts and the source of flooding.

Figure 4.1: Discussion and interview with the respondents/Community. (Source: Field survey on June, 2014).

Table: 4.1: Major flood prone sub-cities on the study area.

Specific sites		Respondents in		Ranking of flood prone areas	
		Number	Percentage	Respondents' response	Field observation
Merkato Sub-City	Fana Kebele	20	66.67%	1st	1st
	Kera Kebele	5	16.67%	2nd	2nd
Centeral Sub-City	WADU Kebele	4	13.33%	3rd	3rd
	Gido Kebele	1	3.33%	4th	4th
Total		30	100.00%		

4.3. Existing conditions of drainage systems

A drainage system includes the pavement and the water handling system. They must be properly designed, built, and maintained. The water handling system includes: shoulders, ditches and culverts; curb, gutter and storm sewer. When a road fails, whether it's asphalt or gravel; the inadequate drainage often is a major factor. From the field survey and its analysis, the condition of urban drainage lines in road provision projects is summarized in Table: 4.2; so as on Figure 4.2 and 4.3 below.

Table: 4.2: Summary of the conditions of urban road drainage lines in the study area

S.No	Road Section	Road Type	Length (m)	Longitudinal Slope (%)
1	New Bus Station – Agricultural Collage	Asphalt	2070	1-9
2	Fana Kebele Adminstration –Kalte River	Gravel	1300	2.9-5
3	Abiot Chora School-Kalhiywot Church-Kalte River	Cobble Stone	1570	0.5-12
4	Abiot Chora School-Ethio-Commodity Exchange,Sodo	Cobble Stone	560	10-10.61
5	Asphalt Road-Abidela Powder Factory	Cobble Stone	745	3-10
6	Fikir Café - Kera	Cobble St one and Gravel	987	4-12

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Figure: 4.2. The storm drains are blocked by solid wastes and silt. (Source: Field survey on June, 2014)

Figure: 4.3 Inadequate Road drains and Ditch Erosion. (Source: Field survey on June, 2014

4.4. Causes of erosion and flooding on the section of road

There are two major factors such as geographical and management factors.

4.4.1. Geographical Factors

As it was observed during field survey and the information gathered from the community, the major causes of erosion and flood problems in Wolaita Soddo Town are geographic factors. Geographical factors represent topographic, geologic and environmental problems in the areas (*P. Diplas et al, 199*).

4.4.1.1. Topographic Condition

It is one of the factors that directs runoff and leads increasing velocity and erosion rates. Where steep slopes are found within a study area, runoff is accelerated down slope to receiving features such as watercourse, wetlands and woodlots. Based on a field survey result, the area is geographically the most prone to erosion and runoff hazards. As stated on Table 4.2 above and on Figure 4.4 below the longitudinal slope of road drainage ditches have also an undulating behaviors.

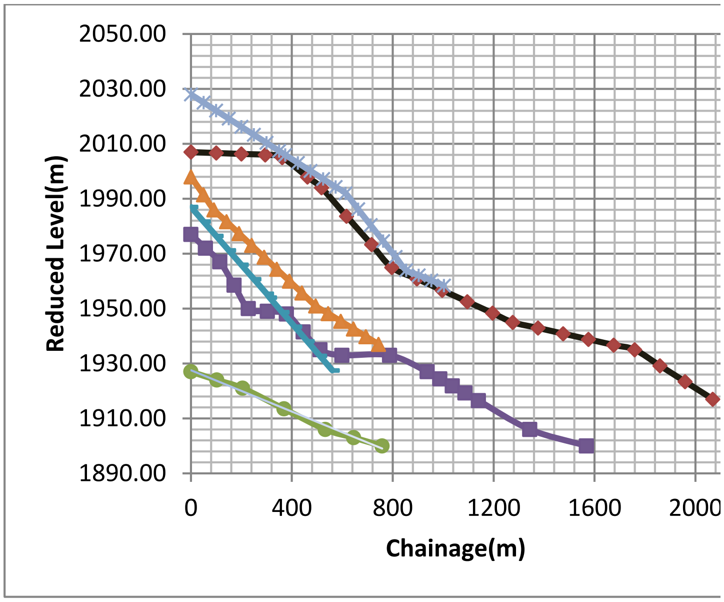

Figure 4.4.The main drainage ditches profile along six selected road net works. Source: Data in Appendix 3

4.4.1.2. Geologic Formation

The Geological formation of the catchment and its storm water conveyance canal (Inlet, Conveyance and Outlet) route investigation was made by field observation. Soil samples were collected from three different representative sites of flood prone section of road and Soil texture was determined at SNNPR Soil laboratory by hydrometric and wet sieve analysis for grain size determination as shown on Figure 4.5 and Table 4.3 below. The result is clay loam according to FAO (1990) and similar on different sites of the study areas.

Figure 4.5: Soil Laboratory for Grain Size analysis (Wet-sieve and Hydrometer) Source: Wolaita Soddo Soil Laboratory Work on July, 2014

Table: 4.3: Soil Laboratory Result

No	Lab Code	Client Code	Sand (0.063 – 2 mm) (%)	Silt (2 – 63 μm) (%)
1	2673	T	26.57	44.94
2	2670	T	29.7	39.8
3	2645	T	31.46	40.71

Source: According to FAO (1990): Relation of constituents of fine earth by size and defining textural classes.

4.4.1.3. Environmental Problems

As information gathered from the community, increasing urbanization from time to time has led to significant changes in the natural environment. Infiltration capacity of the area has been decreasing due to the increase in impervious surface; and disrupted native soils and vegetation. Natural retention and detention capabilities of a catchment are removed through channelization of

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natural waterways and the installation of formal drainage systems such as pipes, gutters and ditches along the road networks.

The increased peak discharges such as rates and amounts of runoff for a developed watershed in summer season assumed to be two to five times higher than those for a watershed prior to development (ideas from the community). Infiltration and evapotranspiration are much reduced at this time of the year under developed conditions. The imperviousness of urban areas along with the greater hydraulic efficiency of urban conveyance elements cause increased peak stream flows in the areas.

4.4.2. Management Factors

Management factors include enforcement of urban storm water regulations and acquisition of sufficient roadway right-of ways (*P. Diplas et al, 1999*). It also impacts the storm water drainage or ditch design on road net-works. The roadside ditch design fundamentally focuses on two issues in this research such as ditch capacity and ditch stability. In general, the 10-year storm is used to determine ditch capacity, while the 2-year storm is used to check ditch stability. The computations for evaluating both ditch capacity and stability depend on site-specific information that follows.

4.4.2.1. Ditch Capacity

Ditch capacity, for a selected storm return period (Table 2.1**)**, is generally calculated by using the Rational Method (Eqn. 2.1). The drainage area (A), in our case, is commonly divided into six catchment areas (Watershed); on this the road surface, the road shoulder, and the area outside of the right-of-way are the part of drains toward the ditch segment. The weighted runoff coefficient (C) from Table 2.2 is obtained by applying individual coefficient values to each land use within the tributary drainage area (i.e., business, residential, pasture, etc.), and divided by the total drainage area.

The rainfall intensity (I) is the average rainfall rate in millimeters per hour for a particular drainage basin or sub basin (ERA, Drainage design manual,2002.Table 5-2 Metrological Station, Region B) and Fig. 2.1 above (Urban Storm Water Drainage Design Manual of Ethiopia, 2008) . The intensity is selected on the basis of the design rainfall duration and return period. The design duration is equal to the time of concentration (Table 2.3, Eqn 2.Federal Aviation Administration, 1970) for the drainage area under consideration.

As stated on Table: 4.4 and Table: 4.5 below, the results have taken from direct measurement from field survey and topographic map of the area (Revised on 2012). Before this research there was no estimated discharge to check ditch capacity and the structures constructed based on simple assumption.

Table 4.4: Shows watershed/catchment areas and average overland slope; and conveyance canals/ditches length, shapes and longitudinal slopes.

No	Road Section	Catchment Area (ha)		Length(m)	Longitudinal Slope (%)	Average Overland Slope (%)
	Station – ural Collage	90	35	2070	1-9%	3.0
			30			
			25			
2	Fana Kebele Adm –Kalte River	15		1300	2.9-5%	4.0
3	Abiot Chora School-Kalhiywot Church- Kalte River	20		1570	0.5-12%	4.0
4	Abiot Chora School-Ethio-Commodity Exchange,Sodo	16		560	10-10.61%	4.5
5	Asphalt Road-Abidela Powder Factory	15		745	3-10%	4.5
6	Fikir Café - Kera	14		987	4-12%	4.0

Table 4.5: Shows the Catchment area (A), Tributary length (L), Average over Intensity (I) and Ditch capacity (Q) as dimension stated

No	Road Section	A (ha)	L (m)	L (ft)
1	New Bus Station – Agricultural Collage	90	2200	721
2	Fana Kebele Adm –Kalte River	15	700	229
3	Abiot Chora School-Kalhiywot Church-Kalte River	20	950	311
4	Abiot Chora School-Ethio-Commodity Exchange,Sodo	16	500	164
5	Asphalt Road-Abidela Powder Factory	15	450	147
6	Fikir Café – Kera	14	450	147

4.4.2.2. Ditch Stability

Based on the literature review (ERA, Drainage design manual, 2002 and FUPCoB, Urban storm water drainage design manual, 2008 and P. Diplas,et al,1999) above the concept of the stable channel or ditch design procedures includes both the permissible velocity approach which is discussed in this research and the permissible tractive force or shear stress approach is but not discussed in this research. As the permissible velocity approach all storm drains shall be designed such that velocities of flow will not be less than 0.76m/s and the maximum allowable velocity for lined canal is 2m/s to 2.5m/s (*S.K.Garg, 2006*).

As shown on the Table: 4.6, the field survey was conducted on the existing conditions of roadside conveyance channels or ditches on flood prone areas and results were used to evaluate the problems on its stability. For the analysis the continuity equation has been used for lined rectangular channels.

Table: 4.6: Shows the designed ditch capacity and velocity for stability in terms of longitudinal slopes, Manning's coefficient (n),depth (D), width (W) and flow velocity (V) on estimated discharges (Q)

No	Starting to End	Q (m^3/s)	n	S	$S^{1/2}$
	Drain Shape				
	Rectangular				

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1	New Bus Station – Agricultural Collage	9.11	0.013	0.05	0.22
2	Fana Kebele Adm –Kalte River	2.77	0.013	0.05	0.22
3	Abiot Chora School-Kalhiywot Church- Kalte River	3.58	0.013	0.04	0.20
4	Abiot Chora School-Ethio-Commodity Exchange,Sodo	3.77	0.013	0.06	0.24
5	Asphalt Road-Abidela Powder Factory	3.68	0.013	0.04	0.20
6	Fikir Café - Kera	3.27	0.013	0.04	0.20

As results shown on table above, under the permissible velocity approach, the channel is unstable because the adopted mean velocity is higher than that of the maximum permissible velocity for the each channel boundary conditions and that causes bed erosion and instability of the channels.

Figure4.6: Road ditch erosion because of steep slope and flow over permissible velocity. (Source: Own Field survey on July, 2014)

4.4.2.3. Inlets and Outlets of Cross –Drainage and Ditches

It is known that the inlets and outlets structures on road cross – drainage and ditches have major impacts on road life span and on surrounding environment. As shown on Figure: 4.7 and 4.8 below the cross-drainage structures and ditch outlets have faced severe problems. This can ensure that water and debris enters the cross-drain inefficiently with plugging, and that it exits the cross-drain with damaging the structure or causing erosion at the outlet.

Figure 4.7: Cross drainage structures impacts on the environment (downstream gully formation and solid wastes accumulation). (Source: Field survey on July, 2014)

When a drainage outlet is needed on an erosion control structures, locate the outlets on stable soils with established ground cover. The accelerated velocity of water leaving a roadway can cause severe erosion or gulling if discharged directly onto erosive soils (Figure: 4.8). Water has not energy dissipated at the inlet and outlet of culverts, rolling dips, or other cross-drainage structures. They are commonly constructed of concrete, masonry or from round metal pipe, as seen in Figure 4.7.
The drain outlet area can be stabilized, and the energy of the water dissipated, by discharging the water onto 1-2 cubic meters of a graded rock riprap, stilling basins, reinforced splash aprons, grass or use of dense vegetation or bedrock in erosive soils (clay loam in all study areas), and with flow velocities over one meter per second may require armoring or the use of small ditch dike or dam structures placed in the ditch to slow down the velocity of water.

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Figure 4.8: Shows unprotected outlet of the drainage canals impact on natural environment (causes soil erosion, stream pollution and its structural failures). (Source: Field survey on July, 2014)

Table: 4.7. Overview of problems, effects and actions concerning road drainage in Soddo Town as reported in questionnaire and interview responses

Problems related to:	Causes	Effects
Management and planning	Lack of knowledge of location of drainage installations	Inefficient planning and performance of measures
	Unclear responsibility for drainage; personal dependence	Varying standing of drai management in different par the road network
	Varying age of different parts of the road drainage network	Limited overview of characteristics and functionality of drainage systems in different parts o town
	Improper depth of drainage installations	Inefficient drainage
Construction and design	Limited diameter of pipe or culvert or opening of bridge	Insufficient capacity to ha large water volumes
	Limited stabilization of ditch slopes	Soil erosion; decrease in drainage function
	Insufficient inspection and periodic maintenance	Limited base for planning. Deterioration of drainage capacity
Operation and maintenance	Obstruction and overgrowth of drainage device inlets	Limited function of drai devices. Accelerated deterioration of road construction
	Mechanical damage to ditches, culverts, pipes, etc.	Limited function of drai devices. Accelerated deterioration of road construction
	Pavement rutting	Shortened life time of maintenance measures
Other actors and conditions	Nature conservation	Restrictions on type maintenance of drai installations. Inapprop drainage facilities. Defi drainage. Water-logging adjacent land. Flooding
	Land transformation: paving; construction of buildings	Substitution of pipes for ditches; increased run-off; watercourses taking new paths; flooding

Chapter 6: Conclusions and Recommendation

6.1. Conclusions

Urbanization generally increases the size and frequency of floods and may expose communities to increasing flood hazards. It creates considerable infrastructure problems and huge economic losses in terms of production, as well as significant damage to property and goods. Flooding in urban areas causes large damage at buildings and other public and private infrastructure. Road networks and its infrastructures failure are the major problem in the study areas. These

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problems basically caused by geographical and management factors. The study results and findings are listed below.

- Within the urban and road network plan the changing the natural stream flow and absence of alternative enough drainage facility with road network and cross drainage are the causes flooding hazards.
- The drain outlets are constructed and installed not properly due to that the stormwater passed through the conveyance system released onto unstable and bare soil at downstream and results gully formation and joined with water bodies' causes' water pollution.
- Inadequate integration between road and urban storm water drainage lines followed by blockage of drains by debris and silts are the major causes of flooding in the study area.
- The capacity and stability of drainage and erosion control structures design were not incompliance with the ERA's Drainage Design Manual, 2002 and FUPCoB, Urban Storm Water Drainage Design Manual, 2008.
- Sewerage connection and solid waste dumping reduce the effective carrying capacity of drains.
- To safely discharge the flood generated within the study area the urban storm water drainage facilities should be renovated.
- Urban storm water drainage facilities should be constructed with roads for timely accomplishing and good work man ship.

6.2. Recommendation

- Proactive measures should be taken to reduce and manage flooding hazards: such that Ditches clogged with debris or sediment need cleaning to avoid overflowing and washouts.
- There should be the integrated solid waste management and periodical follow up.
- Encourage site infiltration through: Permeable pavements like porous concrete, coble stone, vegetated structures or grassing on road sides and vacant spaces/ gardens.
- To ensure sustainable urban drainage management, there should be an integrated urban storm water drainage management.
- Avoid steep road and ditch grades in excess of 12 to 18%. It is very difficult and expensive to properly control drainage on steep grades.
- It is better to protect cross-drain outlets with rock (riprap), brush, or logging slash to dissipate energy and prevent erosion, or locate the outlet of cross drains on stable, non-erosive soils, rock, or in well vegetated areas.
- Install culvert cross-drains with an angle of 0-30 degrees perpendicular to the road, using an out slope of 2% greater than the ditch grade to prevent plugging.
- Vegetation and brush that obstruct water flow need to be mowed or cut. However, when removing sediment from ditches are careful to disturb vegetation as little as possible to limit erosion. It may be necessary to re-seed, mulch, or use other erosion protection methods on steep slopes or in areas sensitive to severe erosion. Sediments from eroding slopes can fill downstream road ditches and culverts or pollute streams.
- Culverts need to be kept free of sediment so water flows freely and doesn't wash out roads and flood adjacent property. Inspect periodically for sediment buildup and for cracks or corrosion that might lead to culvert failure.

Future Research

- For the stability of ditch, the maximum allowable velocity and tractive force methods are the common criteria. The maximum allowable velocity effects are studied on this thesis but the tractive force method is open for the future studies.
- Study the storm water drains based on biological and chemical factors and that effect on the community.
- Study the surface and sub surface drainage effects on roads and its infrastructures.

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Appendix

Appendix 1: Major Research Questionnaires on impact of installation of Erosion and Drainage structures on flood prone section of road in Wolaita Soddo Town.

Date: _________
Persons present at survey meeting:________
Gender: M____ _______F____
Living place: _____________________
Jobs: Governmental __________Private___________
Educational Level: __________
Uneducated: ____________

Major Research Questionnaires

1. Is there any erosion and storm water/runoff hazards occurred in the Wolaita Soddo Town? Yes No
If yes choose the major reasons/causes
a) The area, geographically, is the most prone to erosion /runoff hazards.
b) There is no erosion and storm water runoff control structures
c) The flood hazards occurs : whole a year ______
: 1 x a year _____
: 2 x a year _____
: 3x a year _____
: 4x a year_____
: -----------
d) The impermeability of soil decreases with increase in size of town frequently
e) Lack of enough capacity of storm water runoff passages/flow

2. Does the Town have: Urban plan? Yes No
: Road networks plan? Yes No
: Drainage networks plan? Yes No
3. Is there the impact of existing drainage and erosion control structures of flood prone section of road on surrounding environment? Yes No

4. Have you ever seen the effect of storm water erosion on road networks, road side drainage ditches and embankment? Yes No
If yes, choose the major reasons/causes
a) The road drainage networks were not constructed proportionally.
b) The capacity of drainage ditches and cross drainage structures was not proportional to runoff flow estimated
c) The longitudinal slope of the road side ditches is very steep and faced to ditches bed erosion and failures.
d) The problem of method of construction, types of construction materials and soil natures.
e) Ifany,
____
____

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Appendix 2: Rainfall Regional Division in Ethiopia, Rainfall Intensity Curve (ERA), and OGL Profile of existing ditches.

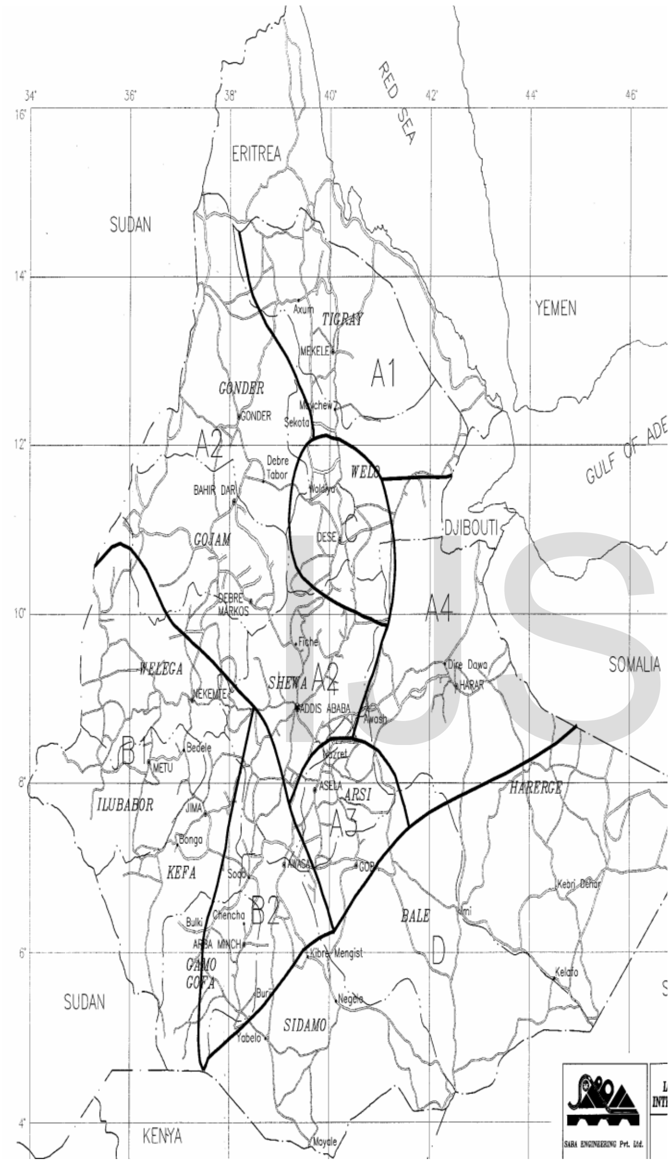

Figure 1: Rainfall Regional Division in Ethiopia

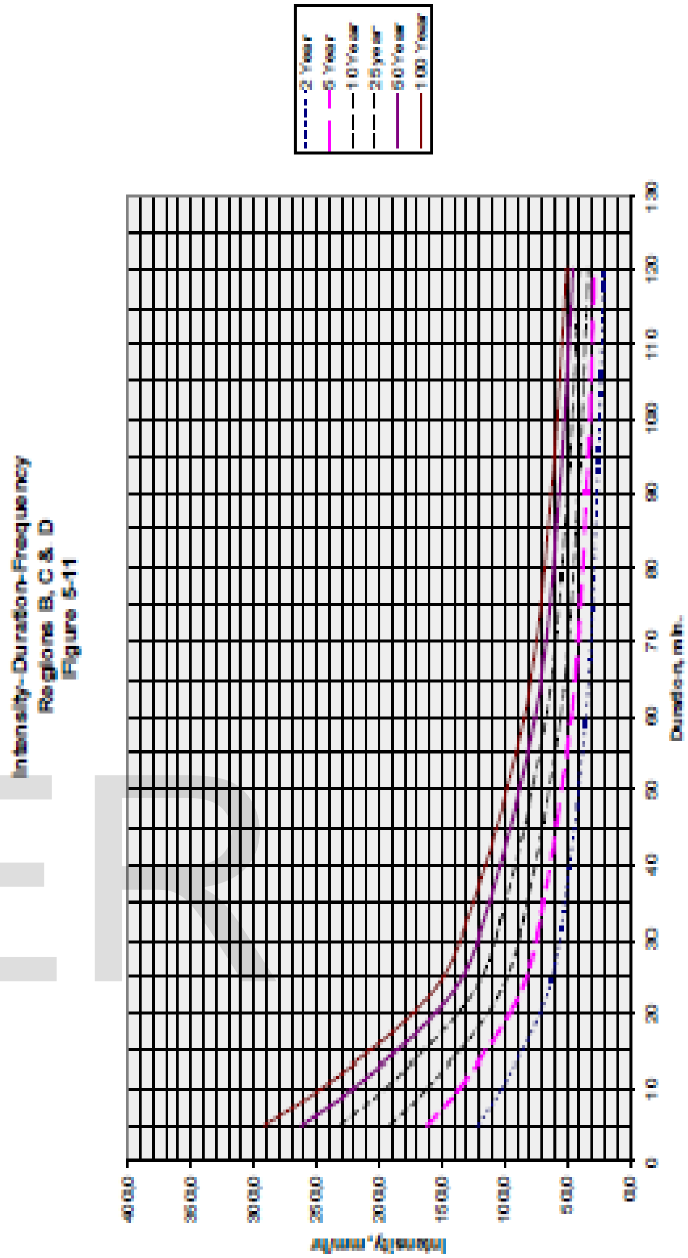

Figure 2: Rainfall Intensity Curve (Source: ERA Drainage Design Manual, 2002)

Table 1: Dummy Table for research data analysis

S.No	Items	Methods and materials used	Remarks
1	Determination of study areas	-Taking (X,Y) Coordinate data from GPS/Total Station	

		-Topographic map/GIS Software -Land Use Map -Urban Plan	
2	Laboratory analysis to determination of Soil Type/Textile	Disturbed Soil samples from 3 different sites -Grain size analysis (Sieve and hydrometer)	
3	Determination of longitudinal slopes on section of main roads	-Road networks plan -EAGLE POINT/ArchGIS/ AUTOCAD Software -Leveling/Total Station/Hand GPS	
4	Determination of Runoff on section of main roads	-Road Drainage network plan -Soil properties -Meteorological/ Rainfall data -Peak Discharge by Rational Method -Distribution of Discharge to Drainage network	
5	Evaluation of existing erosion and drainage control structures	-Drainage structures Capacity -Road ditches bed and longitudinal slopes -Construction Materials types and method of installation -Recommendation on the impact of installation of structures and method of management	

Table 2: OGL Profile the drainage ditches of the study area.

1.New Bus Station-Agricultural Collage		2.Fana Kebele Adm –Kalte River		3.Abiot Chora School-Kalehiywot Church-Kalte River	
Chainage	Reduced Level	Chainage	Reduced Level	Chainage	Reduced Level
0	2007.00	0	1927.00	0	1977.00
100	2006.66	103	1924.00	58	1972.00
200	2006.32	205	1921.00	115	1967.00
294	2006.00	369	1913.50	172	1958.50
362	2005.00	533	1906.00	228	1950.00
462	1997.95	646	1903.00	304	1949.00
517	1994.00	758	1900.00	379	1948.00
617	1983.65			446	1941.50
716	1973.30			512	1935.00
796	1965.00			599	1933.00
896	1960.84			788	1933.00
996	1956.67			937	1927.00
1096	1952.51			987	1924.42
1196	1948.34			1037	1921.84
1276	1945.00			1087	1919.26
1376	1942.93			1140	1916.50
1476	1940.86			1344	1906.00

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1576	1938.80	1569	1900.00
1676	1936.73		
1759	1935		
1859	1929.196		
1959	1923.392		
2069	1917		

Table 3: OGL Profile the drainage ditches of the study area.

4.Abiot Chora School-Ethio-Commodity Exchange,Sodo		5.Asphalt Road-Abidela Powder Factory		6.Fikir Café - Kera	
Chainage	Reduced Level	Chainage	Reduced Level	Chainage	Reduced Level
0	1987.00	0	1998.00	0	2028
50	1981.74	50	1991.46	50	2025
100	1976.48	91	1986.00	100	2022
150	1971.22	141	1981.67	150	2019
200	1965.96	191	1977.35	200	2016
250	1960.70	240	1973.02	250	2013
300	1955.45	290	1968.70	299	2010
312	1954.00	340	1964.37	349	2007
362	1948.70	390	1960.04	374	2006
412	1943.40	440	1955.72	424	2003
461	1938.11	494	1951.00	474	2000
511	1932.81	544	1948.20	524	1997
561	1927.51	594	1945.40	574	1994
		644	1942.60	613	1992
		694	1939.80	663	1986
		744	1937.00	712	1980
				762	1975
				812	1969
				853	1964
				903	1962
				953	1960
				1003	1958