ST. MARY'S UNIVERSITY COLLEGE

SCHOOL OF GRADUATE STUDIES

ASSESSEMENT OF URBAN STORM WATER DRAINAGE NETWORK SYSTEM AND ROAD FLOODING RISK MANAGEMENT IN ADDIS ABABA, NEFAS SILK LAFTO SUB-CITY.

BY
TADELE FULLE

MAY 2017
ADDIS ABABA ETHIOPIA

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A THESIS SUMITED TO ST. MARY'S UNIVERSITY COLLEGE SCHOOL OF GRADUATE STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR DEGREE OF MASTER'S OF BUSINESS ADMINISTRATION IN PROJECT MANAGEMENT

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DECLARATIONS

I, Tadele Fulle, do here by declare that this Thesis is my original work, prepared under the guidance of _Advisor_____________All sources of materials used for the thesis have been duly acknowledged. I further conform that the thesis has not been submitted partially or in full to any other higher learning institution for the purpose of any degree.

________________________________ ________________________

Name signature

St Mary's University College, Addis Ababa May, 2017

ENDORSEMENT

This thesis has been submitted to St. Mary's University College, School of Graduate Studies for examination with my approval as a university

______________________________ ______________________

Advisor **Signature**

St Mary's University College, Addis Ababa May, 2017

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ACRONYMS

AACRA	Addis Ababa City Roads Authority
AAEPA	Addis Ababa Environmental Protection Authority
AAWSA	Addis Ababa water and Sewerage Authority
ArcGIS	Architectural Geographical Information System
BMP	Best Management Practices
CAD	Computer Assisted Design
FUPI	Federal Urban Planning Institute
FGDs	Focus group discussions
GTZ	German Technical Cooperation
NGOs	Non-Government Organizations
NUPI	National Urban Planning Institute
UN	United Nations

ABSTRACT

Drainage is an important consideration as one of the major components in the road construction. For this reason in most designs of the road, the first thing to be put in place is drainage system. Urbanization along with its impervious structures is the major challenge of urban centers. Poor managed storm water increases total flow, flow rate, flow velocity and depth of water in downstream channels. Properly designed storm water management facilities, particularly detention/recharge basins, can also be used to mitigation-point source pollution impacts by providing extended containment durations, thereby allowing settlement of suspended solids In Addis Ababa, control of runoff at source, flood protection, and safe disposal of excess water/runoff through proper drainage facilities becomes essential. This study was carried out in three sample (kebele 01/02,01/12 and 03/04) within nefas silk lafto sub-city. These kebeles were selected because of they are representative to address the objectives of this study. To assess the status of road drainage network system and risk mitigation measures and strategies are the major problems in the study area. An exploratory and Descriptive type of research design methods were used to describe and explore the existing condition of the general urban drainage system and the natural water ways. Data collection methods were carried out using both primary and secondary data sources. The secondary data source was only relevant to reinforce the primary data. The collected data were analyzed with Ms-excel. The results have been presented with known statistical tools. The findings of this study indicated that the major causes of flooding were found to be deforestation of dertu and surrounding mountain, and inadequate integration between road and urban storm water drainage lines. Solid and liquid waste damping was also the biggest challenges on the general urban drainage system. This study strongly recommends improvement in the integration of road and urban storm water drainage system and over flowing of flooding as a result of blockage of drains.

Key words: Drainage, between road and urban storm water drainage lines, urban areas, flooding.

CHAPTER ONE: INTRODUCTION

1.1. Background of the study

The population increase and the movement of people from rural to urban areas all over the world lead to changes in land use. Evidences show that in 1800 only one percent of the world population lived in cities, whereas in 1970 the urban population of the world increased to 37 percent. According to United Nations world cities report, in 2015, the world population living in urban areas has reached 54 per cent (four billion) (UN HABITAT, 2016). These numbers highlight the extent to which the world population has increasingly come to live in urban areas (Unesco, 1987).

The combined effect of population growth, urbanization and industrialization change the cycle, quantity and quality of urban water and cause various environmental impacts (Unesco, 1987) (Zhou, 2014). Urbanization is accompanied by two major changes. The first change is concentration of people, enterprises, infrastructures and public institutions. The second change, which results from the first change is the large scale urban spatial expansion as cities and towns swell and grow outward in order to accommodate population increases. These changes alter the natural landscape, land uses and land cover. The growth of a city or an urban center is greatly synonymous with land use changes and the growth of its physical infrastructure. As the natural landscape is converted to an urban use and as the associated infrastructure grows both in variety and intensity, it may adversely affect the natural hydrological makeup of the urban built up area, thereby increasing the vulnerability of the area to flooding risk and causing management responses very difficult. Before the increase of built up percentage, greater amount of rain water used to percolate through the earth surface and join the ground water or be used by the plants. Increase in the built up areas will alter the hydrological makeup by blocking natural streams and/or by reducing the water absorption capacity of the surface. This will result in the demand for a manmade drainage infrastructure in order to deal with the water that 'lost its way by human action'.

Urban drainage is part of this cycle and is related to the urban hydrological system in a very complex way. Drainage is a vital city infrastructure that serves to collect and remove excess water, which may be domestic and industrial wastewater or storm water, from an area by surface or subsurface means. Urban drainage systems handle these two types of water with separate or combined drainage system. Appropriate disposal of wastewater and storm runoff contributes to human well-being and to the proper functioning of urban communities Therefore, proper planning of urban drainage systems needs to be integrated in all aspects of urban planning efforts. Despite development over the years, it remains a significant challenge to design an effective functioning drainage system. (Unesco, 1987) (Zhou, 2014) (Eth. Manual, 2008).

Flooding, deterioration of roads, land degradation, sedimentation, blockage of drainage facilities, and water logging are some of the risks that may arise from drainage in urban areas (Eth. Manual, 2008). Managing risks that arise from drainage and flooding in urban areas needs to be in place. Managing risks is a complex task and integrated urban drainage recognizes this complexity. Integrated urban drainage delivers full suite of techniques, adaptation and resilience measures that integrate in a sustainable manner to manage the urban flood risk through the coordinated approach from different stakeholders and in the concepts of project management. Integrated urban drainage system is management of the risk arising from drainage and flooding in urban areas. From the early beginning, the objectives of integrated urban drainage system were to collect rainwater, prevent flooding, and convey wastes.

Among the techniques promoted by integrated urban drainage system are the implementation of sustainable urban drainage quality system, improving water management and environmental protection while contributing to biodiversity and amenity and others. Addis Ababa, capital of Ethiopia, is one of the rapidly urbanizing city of the world. As a result of rapid urbanization and pertinent development of the city, hundreds of thousands of people come from all corners of the country in search of better employment opportunities and services. Intensive infrastructure developments are underway in the city to realize the city to be a megacity to respond to the demand of the society. This urbanization process will increase the impermeable surfaces to be prone to major flood risks unless quality drainage network system and mitigation measures are in place. Lack of quality drainage network system highly reduces the service life of infrastructure.

During the rainy seasons which last from June to September, the highways are covered by surface water. This surface water accelerates the deterioration rate of the roads and results in The findings of this study indicated that the major causes of flooding were found to be deforestation of dertu and surrounding mountain, and inadequate integration between road and urban storm water drainage lines. Solid and liquid waste damping was also the biggest challenges on the general urban drainage system.and other problems. The urban storm water and flooding of the highways could be due to poor integration and improper drainage system of roads and lack of quality management.

Therefore, this study is aimed at investigating urban storm water drainage network system and road flooding risk management in Nefas-silk Lafto sub-city of Addis Ababa, Ethiopia.

1.2. Problem Statement

Drainage is one of the most important factors to be considered in the road design, construction and maintenance projects. Urban Storm drainage network systems of a city are ideally aimed to handle peak flow resulting from rainfall of return period equal or greater to their design year. Drainage systems of a road are expected to function smoothly in handling flow along or across their alignment. Though provision of proper road surface drainage systems have such a great importance for the urban road to give the intended use and thereby contribute to the overall development of a nation, particularly in road sector, there is a gap in the practice of the construction of proper integrated drainage structures in most African cities and Addis Ababa is not an exception.

The storm water drainage network system in Addis Ababa is not sound and the road flooding risk management is also weak. It is almost usual to observe flooding of drainage system of Addis Ababa after every rainfall. Flooding is intensified and has become a critical challenge in the city causing economic damage of infrastructure and creating all the inconvenience and threat to the road users in particular and to the community at large. The occurrence of road over flooding problem during summer in the city of Addis Ababa forces vehicles or automobiles to be stranded for some hours to give usual service. The over flooding of road by storm water runoff results in the accumulation of silt on the road leading to overturn of cars. Flooding during and after the rainfall also causes congested traffic flow, erosion and damage of pavement and the constructed road line, negative effect on health and difficulty on day today activities of the community who are using the road and living alongside the road.

A thorough canvassing of literature disclosed that there are ample studies on urban road drainage network system. For instance, Burian and Edwards (n.d.) studied historical perspective of urban drainage system. Parkinson (2003) also investigated drainage and storm water management strategies for low-income urban communities. Likewise, other researchers including Ellis et al. (2008); Zhou (2014) and Angelakis and Zheng (2015) have studied the issue of urban storm drainage network system. However, none of these studies have given conclusive findings about the urban storm water drainage system.

In the study entitled "Urban Drainage System in Addis Ababa, Yeka Sub-city" Dagnachew (2009) addressed the major environmental problems and causes of urban storm water drainage system in Yeka sub-city. The same researcher, Dagnachew (2011) again assessed an integration of road and urban storm water drainage infrastructure in Addis Ketema Sub-city. Another study was also carried out by Anteneh (2015) on integrated urban drainage system taking Ayat to Megenagna light rail transit system route as a case. In these studies, however, no sufficient exploration was made with regards to the potential risks that could born out of the failure of the drainage system and the risk mitigation strategies in the context of Addis Ababa. On top of that, to the best of the researcher's knowledge, there is no study conducted on urban storm water drainage system and its integration for managing flooding risks in Nefas-silk Sub-city even thought the study have been made in other sub-cities. But these study explored the potential risks that could born out of the failure of the drainage system and the risk mitigation strategies in the context the study area. Therefore the purpose of this study is to assess how the existing urban road drainage network systems manifest themselves and the pertinent risk mitigation strategies employed in Nefas-silklafto Sub-city of Addis Ababa.

1.3. Research Questions

1. What is the status of the existing road drainage network system in Nefas-silk Lafto sub-city of Addis Ababa?
2. What are the major causes of road drainage network failures in Nefas-silk sub-city of Addis Ababa?
3. What types of risks emerge from failure of road drainage network system in Nefas-silk Lafto sub-city of Addis Ababa?
4. What mitigation measures and strategies are existing to address the road drainage network failures in Nefas-silk sub-city of Addis Ababa?

1.4. Objectives of the Study

1.4.1. General Objective

To assess the status of road drainage network system and risk mitigation measures and strategies existing in Nefas-silk sub-city of Addis Ababa.

1.4.2. Specific Objectives

1. To describe the status of road drainage network system in Nefas-silk Lafto sub-city of Addis Ababa.
2. To identify the major causes of road drainage network failures in Nefas-silk sub-city of Addis Ababa.
3. To identify types of risks emerging from failure of road drainage network systems in Nefas-silk Lafto sub-city of Addis Ababa.
4. To assess mitigation measures and strategies existing to address the road drainage network failures in Nefas-silk sub-city of Addis Ababa.

1.5. Significance of the Study

The study, design and construction of road drainage network systems require skilled workforce and intensive financial resources. If the road drainage network systems fail, high investment is required for repair and maintenance. Generally, managing urban storm water drainage system has a significant role for sustainable environment management by keeping the service life of urban utilities like roads, buildings, telephone lines, power supply lines, water supply lines and the existing rivers.

Through this study we have intended to explore the current status of road drainage network systems, major causes of their failures, the types of risks emerging from their failures and assess mitigation measures and strategies existing to address the road drainage network failures in Nefas-silk sub-city of Addis Ababa.

Therefore, this research is aimed at providing up-to-date information and evidence-based recommendations which may help the government and other concerned bodies working in the area of roads drainage network systems to use as an input for proper quality project design, implementation, management and preventive maintenance of roads drainage network systems in a sustainable manner. It may also support policy makers in their effort to address similar problems.

1.6. Scope and Limitations of the Study

This thesis is limited to assess the status of road drainage network system, examine determinants of their failures and discuss the existing management responses to mitigate the problems sampled only in the roads routed from Sarbet to Lebu-Mebrat-Hayil road, Mekenisa to Jamo road and LebuMebrat-Hayil to Hana-Mariyam road in Nefas-silk Lafto sub-city of Addis Ababa. Hence, the research is not aimed at developing new structural designs and road drainage system constructions except forwarding recommendations depending on the findings.

CHAPTER TWO: REVIEW OF RELATED LITERATURE

2.1. Introduction

This chapter discusses concepts, theories, empirical literature and synthesis of the literature review. The chapter starts with the description of the basic concept of urban storm water drainage and then followed by urban storm water drainage system design, importance of urban storm water drainage system, causes of urban road drainage system problems, consequences of urban road drainage system and risk mitigation measures and strategies. In the second section the underpinning theories of urban drainage network system will be presented. Following the presentation pertinent theories, the chapter will present the review of empirical studies undertaken in the area of urban road drainage system. Finally, the synthesis of the existing literature will bring the chapter to end.

2.2. Conceptual literature review

2.2.1. Concept of Urban Storm Water Drainage

The practice of urban drainage system has been traced back to some hundred years ago (Bruce, 1998). The efficient conveyance of storm water from urbanized areas was motivated primarily by reasons of convenience and the reduction of flood damage potential. Such practices which were aimed to improve the quality of urban life have resulted in other problems, such as artificially induced flooding, increased erosion and environmental degradation originating from the pollution of receiving waters (ibid). As a result, attention has given to the comprehensive management of urban drainage systems including the implementation of storage and treatment facilities. The objective of such practice was to effectively utilize components of drainage systems for the betterment of urban life and to protect the environment in a cost-effective manner. To facilitate the effective management of the complex natural elements and engineering works, mathematical modeling is often employed to better understand system behavior and performance which in turn leads to better engineering and Management decisions. Generally, storm water management lies near the heart of basic landscape architecture and engineering. Professional ethics enforces every practitioner to integrate storm water and meaningfully with every community and ecosystem (Adams and Papa, 2000). Essentially all site developments, of all kinds, involve impervious and compacted surfaces. The change in land cover increases runoff over the surface, dumps flood waters in to streams, reduces ground water recharge, diverts water from base flows, and turns oils from the streets to pollutants. That is urban storm water drainage system has started to prevent the environment and the human health from various flooding hazards by safely removing floods.

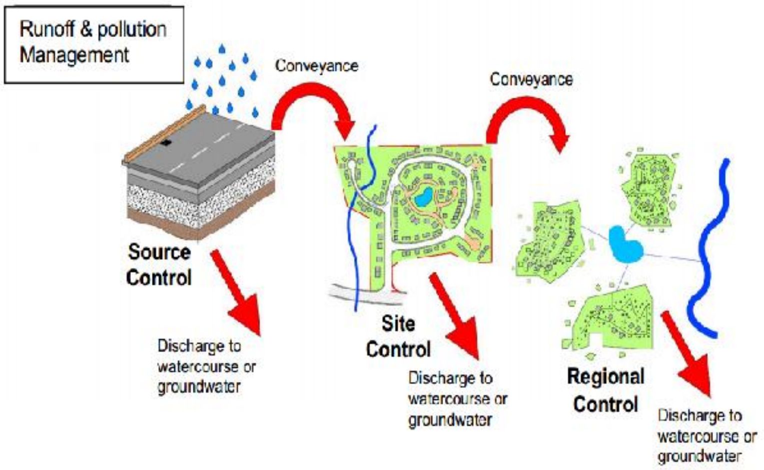

Figure 1: Runoff & pollution Management (Source: Ethiopian Works and Urban Development Manual, 2010)

2.2.2. Urban Storm Water Drainage System Design

Early drainage system design was based largely on peak discharge rates estimated observations of runoff rates that occurred in existing systems (Bruce, 1998). The rational formula (Q=C*I*A, where Q = discharge, I = intensity and A = catchment Area) was established by Mulvaney in 1850, Kuichling in 1889 and Lloyd-Davies in 1906(UNESCO, 1987).

2.2.3. Importance of Storm Water Drainage System

The importance of urban storm water drainage infrastructure. Urban drainage infrastructure is designed to remove the rainfall which accumulates on relatively impermeable surfaces in towns and cities. In doing so, they further increase the speed of runoff and reduce the natural attenuation (=infiltration capacity) of the land surface.

2.2.4. Causes of Storm Water Drainage System Failures

The main causes of storm water drainage system failure are the inadequacy of drainage structures during the rainy season to pass the flood, poor quality construction, inappropriate site selection and improper alignment of some drainage structures with respect to the road alignment. These shortcomings cause damage to superstructures of drainage structures and stream crosscurrents.

Improper skew i.e. improper alignment of drainage structures with respect to the natural channel and the roadway can greatly aggravate the magnitude of scour.

The storm water can be caused by natural as well as anthropogenic activcities.The factors that causes flooding are mainly meterological, hydrogical and human factors and are shown in table below.

Table 1: Table showing causes of storm water

METEROLOGICAL FACTORS	HYDROGICAL FACTORS	HUMAN FACTORS
•*Rainfall* •*Cyclonic Storms* •*Temperature* •*Snowfall/ snowmelt*	•*Soil moisture level* •*Ground water levelbefore storm* •*Natrual surface infiltration* •*Presence of impervious cover* • *Channel cross-sectional slope&roughness* •*Presence or absence of over back flow ,channel network* •*High tide impeding drainage*	•*Landuse change* •*Occupation of flood plain obstructing flows* •*Inefficiency/non maintennance of infrastructure* •*Climate change affects magnitude and frequency of precipitations and floods* •*Lack of flood control measures* •*Multiple authorities in the area but owning responsibility by none*

2.2.5. Impacts of Storm Water Drainage System Failures

The Impact of Urban Storm water Runoff Rainfall runoff in an urban environment effectively takes place instantly for areas served by traditional drainage systems and nearly all the rain that falls on impermeable surfaces runs off. The rate of runoff and the volume of runoff are both important components in analyzing the performance of a network. For storms above a certain magnitude the performance of the network downstream may be exceeded. Rainfall-related flooding of the drainage network, simply defined, is the concentration of storm water to a point from which it cannot escape quickly enough to avoid ponding or passing on as overland flow. In addition to the hydraulic behavior of traditional drainage systems, their water quality management characteristics are poor and this problem is now recognized as a major issue in terms of polluting receiving waters. The quality of receiving waters and the types of main pollutants are covered in detail in the Regional Policy for Environmental Management. The impact of rainfall in an urban environment is summarized below. Foul Sewers – Inflow Foul sewers, designed to be completely dedicated to wastewater, usually have a small proportion of impermeable surface (incorrectly) connected to them. If this is more than a small percentage of the total area, then the network becomes rapidly overloaded by even relatively small events, causing backing up and flooding either directly into houses or externally. Basements that are connected to the foul system are particularly susceptible to this form of flooding, and the social impact can be very high. Normally, foul water is conveyed directly to WwTW after which it is discharged to a river or the sea. Flows passing to treatment works that are diluted by rainfall, result in reduced treatment efficiency at the works as well as discharging excess flows into storm tanks and, if these fill and spill, untreated effluent passes into the receiving waters. Occasionally flood relief is provided to these sewers, due to the degree of impermeable area connected to them, by providing CSOs. The impact on the environment of spills to the river is significant and CSOs on separate foul systems should only be provided as an emergency measure.

2.2.6. Theoretical Framework of the Study

Introducing the complexity of decision making in urban storm water management when arguing for the need of climate change adaptation strategies, much emphasis is placed on terms like uncertainty, variability, vulnerability, resilience and adaptive capacity. In the last decade climate change adaptation strategies and assessments have changed approach to considering also non-physical issues associated with the urban context and, as such, they have become very socio-cultural oriented (Füssel and Klein, 2006). In particular, several studies have correlated the need for climate change adaptation to the need for sustainable development (Cohen et al., 1998; Srivastava, 2006), as an attempt to connect a range of environmental issues with social and economic issues with the idea that "addressing environmental problems can bring economic as well as social and environmental benefits" (Bulkeley, 2001). However, additional studies have clarified how development to be sustainable needs to aim at increasing human well-being and equity rather than societal wealth (Hopwood et al., 2005). But why is so complex to implement concepts like sustainable development and climate change adaptation into practice? Observations on storm water management practice have demonstrated that such a complexity is related to the lack of skills and tools of decision makers to address such challenges (Fratini et al., subm.). Conventionally, storm water management has focused on maintaining and optimizing technical performances. Usually, water engineers use models to simulate the behavior of the urban water system traditionally placed below ground. With the increased uncertainties related to future scenarios, water engineers have become aware that such models need to consider the interaction of the water system with other parts of the urban area. Extra space and attention needs to be given to water above ground in order to enhance the resilience of the urban area (Geldof &Kluck, 2008; Ashley et al., 2007; Tait et al., 2008). Urban planners, architects, natural scientists, citizens and politicians need to be involved to integrate water within the urban space and to implement structures and infrastructures sensitive to the existing water balance (Wong & Brown, 2009). However, different actors interpret and negotiate the urban space differently depending on their daily practices, their profession and their culture. These differences influences decision making. Complexity increases and because decision makers for urban water management are not prepared to address such a complexity, solutions aiming at increasing urban resilience are often not implemented or fail (Fratini et al, subm.).

2.2.7. Review of Empirical Literature on Storm Water Drainage System

The following section will review the significant issues and research that are helping to create change or those that are causing obstructions to revising conventional methods of designing for storm water in the landscape. To begin the discussion, the first section strives to put into focus some key issues by reviewing select literature and research that addresses the problems associated with storm water and design. A major influence on design is the regulatory and permitting process and therefore the second section will explore federal, state and local regulations and how they are changing. The third section will explore the landscape technologies that are associated with changing storm water best management practices with a spotlight on Low Impact Development as outlined in the national guideline manual prepared by the Department of Environmental Resources, Programs and Planning Division of Prince George's County, Maryland. These guidelines have been in development since the late 1980s and have recently been published online as a manual for national application (PCGDER 2000). This document is also supplying other states and cities with a firm background to establish their own guidelines, for example the new Connecticut Storm water Quality Manual (CTDEP 2004). The final section provides a brief review of the tools used in design of storm water structures and systems. These four sections provide an overview of the state-of-the-art of storm water design and management theory and technology. Alternative Storm water Technologies and Practice To begin the review of significant literature one group of researchers provides an interesting accounting of the historical context of drainage design in which they state that evidence of drainage design goes back many centuries, perhaps even 5000 years, however much of this infrastructure has since been abandoned. Prior to the 1800s some urban areas actually developed practices of harvesting human wastes and storm water for reuse. However, in quickly developing urban centers this practice had to be abandoned due to outbreaks of disease. Eventually it was thought that a steady flow of water was needed to maintain healthy systems as with the circulation system of the human body. This began the development of the modern 14 approach to drainage design. Many of the practices in use today were developed during this time (Chocat, Krebs et al. 2001). They go on to explain that the first major advancement came in the late 1800s when an easily-used empirical method was developed for sizing facilities. The Rational Method became the standard and was in use about 100 years ago in New York State and continues in use to this day although more so in developing regions. It was intended to provide a simple "rational" method for sizing culverts. The basis for the Rational Method is to associate over land flow of precipitation to three aspects of a given land area: the area in acres, the surface characteristics of the area (a coefficient representing values for soil, land use, and slope) and rainfall intensity of inches per hour at a pre-selected recurrence interval and duration. (Ferguson 1998).

2.2.8. Synthesis of Literature Review on Storm Water Drainage System

Early storm water or catchment runoff estimation throughout the world was based on designer's experience and judgment. Current practice is that the watershed that is to be drained by a proposed storm sewer system will be generally divided into one or more sub-catchments or sub-watersheds that are of reasonable size and are approximately homogeneous in nature. These watersheds may include residential, commercial or industrial areas, but usually have larger proportions of pavement and the streets and roads which are the principal surface drainage conveyance, have short time of concentration, and have well-defined flow paths, typically through gutters, ditches and medians of streets and roads. Mr. Emil Kuichling, City Engineer of Rochester, New York, developed a method (Rational formula) based on his measurements on five sub-basins in Rochester, ranging in size from 25 to 357 acres (Kuichling, 1889). Based on his measurements, he concluded the following:

1. Runoff volume is proportional to imperviousness.

2. Maximum discharge occurs when the rainfall lasts long enough for the entire watershed area to contribute flow.

3. Peak discharge is proportional to intensity of rainfall.

4. Antecedent moisture levels are likely to have a significant effect on peak flow. Now known as the rational method, the technique developed by Kuichling is used extensively in the United States and has encountered little change since its original

A) 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

Where, Q = peak flow in cubic meters per second (m3/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. The rational method provides the most reliable results when applied to small, developed watersheds and particularly to roadway drainage design. The validity of each assumption should be verified for the site before proceeding. Procedure

1. Obtain the following information for each site:
    a. Drainage area;
    b. Land use (% of impermeable area such as pavement, sidewalks or roofs);
    c. Soil types (highly permeable or impermeable soils);
    d. Distance from the farthest point of the drainage area to the point of discharge; and,
    e. Difference in elevation from the farthest point of the drainage area to the point of discharge.
2. Select the appropriate runoff coefficient
3. Determine the time of concentration (Tc).
4. Determine the rainfall intensity rate (I) for the selected recurrence intervals.
5. Compute the design flow (Q = 0.00278 CIA).Value for C:

The runoff coefficient (C) accounts for the effects of infiltration, detention storage, evaporation 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 the future within a watershed.

The hydrologic analysis for a particular area shall be based on the proposed land use for that area. Contributing runoff from upstream areas shall be based on existing land use and topography. 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 standard s 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.

2.2.9. Storm Water Drainage System Risk Mitigation Strategies

Integrating the master plan for Belize City downtown with Flood Risk Mitigation: a flood compatible strategic master-plan of Belize City downtown there are a number of potential challenges to the master plan for Belize City that arise from possible flood risk control and mitigation measures. It is essential that the risk of flooding is recognized as a key constraint and the drivers of the risk as potential opportunities from the outset. For the master plan to respond to these challenges we propose a sequential, multidisciplinary and integrated approach that starts with:

1. An assessment of the risk (assessment) that a. prioritizes spatial planning (multiple land use planning (see key input 5)) to avoid placing new development in risk areas or at least substitute vulnerable uses wherever possible.

2. Considers strategies to minimize the probability and severity of a flood (control), followed by

3. A review of strategies to minimize the potential consequences of a flood on occupants and properties (mitigation).

4. Finally proposals are re-assessed (re-assessment) to check their impact upon future occupants" safety, neighboring areas, wildlife and ecology. The design process is iterative, with the potential and type of flooding understood first, proposals then developed, their impact assessed and if necessary alterations and revisions considered. Due to time and resource limitations (the assessment of risk and hydraulic modelling of flood events in many circumstances requires the input of specialist consultants (and a multi-disciplinary approach) using sophisticated software. The design of flood defenses, barriers and underground drainage systems requires civil and structural engineering expertise) we will not be able to develop this process in any detail. In what follows I will just simple illustrate some of its main components, but this will require a separated effort.

2.2.10. Summary

Urban drainage infrastructure is designed to remove the rainfall which accumulates on relatively impermeable surfaces in towns and cities. In doing so, they further increase the speed of runoff and reduce the natural attenuation (=infiltration capacity) of the land surface.

Essentially all site developments, of all kinds, involve impervious and compacted surfaces. The change in land cover increases runoff over the surface, dumps flood waters in to streams, reduces ground water recharge, diverts water from base flows, and turns oils from the streets to pollutants. That is urban storm water drainage system has started to prevent the environment and the human health from various flooding hazards by safely removing floods. Urban drainage infrastructure is designed to remove the rainfall which accumulates on relatively impermeable surfaces in towns and cities. In doing so, they further increase the speed of runoff and reduce the natural attenuation (infiltration capacity) of the land surface. The storm water can be caused by natural as well as anthropogenic activities. The factors that cause flooding are mainly meteorological, hydrological and human factors. The impact of rainfall in an urban environment is summarized below. Foul Sewers – Inflow Foul sewers, designed to be completely dedicated to wastewater, usually have a small proportion of impermeable surface (incorrectly) connected to them. If this is more than a small percentage of the total area, then the network becomes rapidly overloaded by even relatively small events, causing backing up and flooding either directly into houses or externally. Urban storm water management when arguing for the need of climate change adaptation strategies, much emphasis is placed on terms like uncertainty, variability, vulnerability, resilience and adaptive capacity. Many of the practices in use today were developed during this time (Chocat, Krebs et al. 2001). They go on to explain that the first major advancement came in the late 1800s when an easily-used empirical method was developed for sizing facilities. The Rational Method became the standard and was in use about 100 years ago in New York State and continues in use to this day although more so in developing regions.

Early storm water or catchment runoff estimation throughout the world was based on designer's experience and judgment. Current practice is that the watershed that is to be drained by a proposed storm sewer system will be generally divided into one or more sub-catchments or sub-watersheds that are of reasonable size and are approximately homogeneous in nature. Finally proposals are re-assessed (re-assessment) to check their impact upon future occupants‟ safety, neighboring areas, wildlife and ecology. The design process is iterative, with the potential and type of flooding understood first, proposals then developed, their impact assessed and if necessary alterations and revisions considered.

At a general level, there are two kinds of storm water which is of concern in storm water management:

• rainwater during and after periods of rainfall which is not absorbed into the soils and flows across the land. In a situation of unimpeded flow, this water finds a natural route across the land and into streams, rivers, lakes or the coast. The level of absorption is affected by the type of soil, the frequency of rainfall and the height of the water table;

• flood water from stream and river corridors that overtops river or stream banks and spreads out into surrounding areas. These natural stream and river flood ways are often areas where people have settled and have subsequently sought to confine the natural flow to avoid impacts on life and property. Sometimes there are flat swampy areas with wetlands and lagoons that sit behind the main coastal dunes. In these areas, streams often merge and flow into each other, creating a series of wetlands. It can take very little water entering this area to have the streams 'flood' or merge, In some situations, storm water may be trapped in low lying areas and sit as pending for a period of time, depending on how high the water table is, how saturated the soils are and how quickly they can absorb the excess water. The level of absorption is also affected by the amount of hard, impermeable surface in an area. In an urban area, the area of hard surfaces from roads, driveways and roofs of buildings will be large and will have a major impact on the nature and extent of storm water run-off.

Figure 2: An example for a storm-water flow

2.2.11. Conceptual Framework

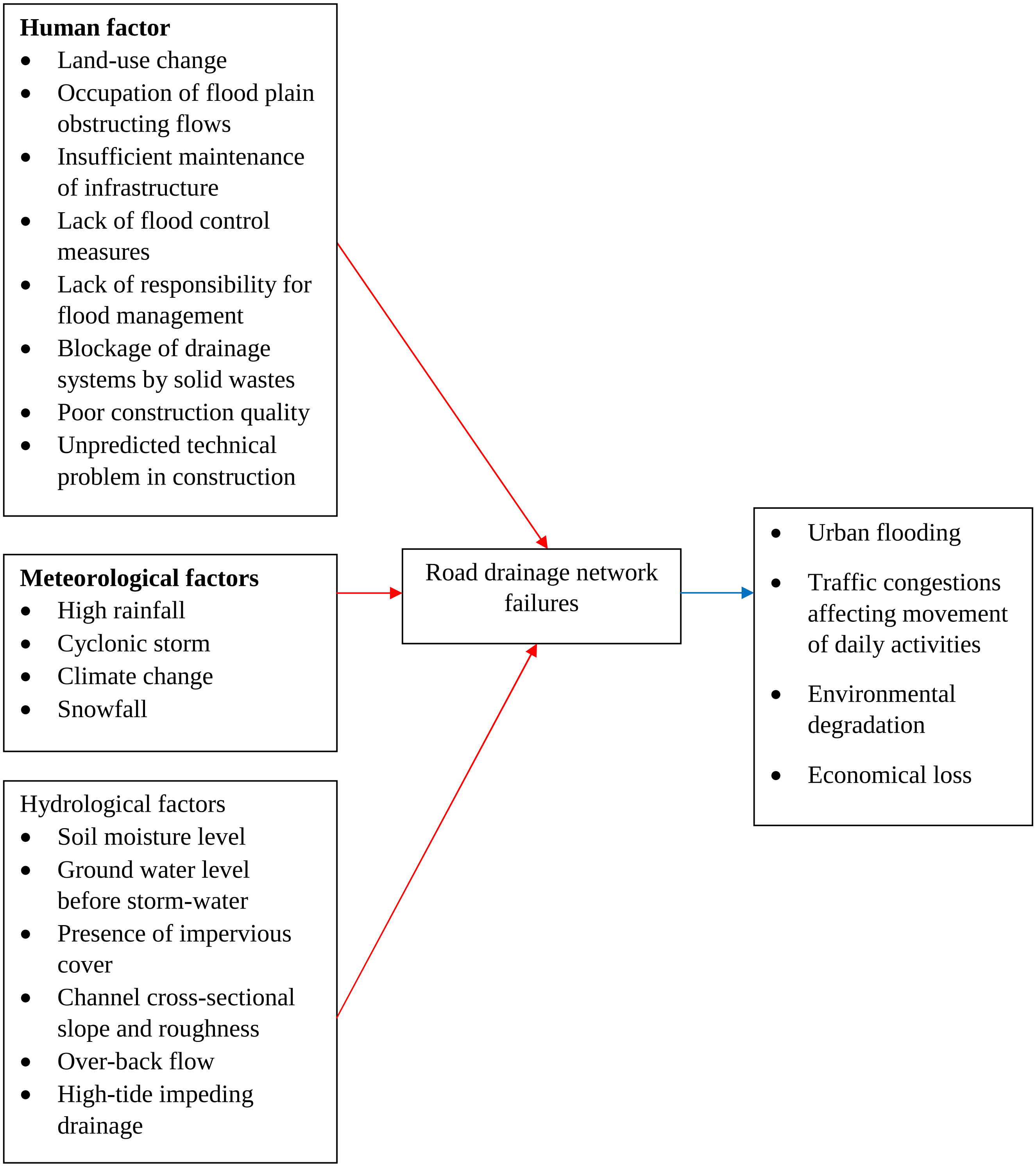

Figure 3: Conceptual framework for urban storm-water drainage network failure

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Study setting

Addis Ababa, capital of Ethiopia, is one of the rapidly urbanizing cities of the world. According to population projection of Central Statistical Agency (CSA) 2007, the total population of Addis Ababa for the year 2016 is 3384569. Administratively, it is divided into ten sub-cities namely – Addis Ketema, Akaki-Kality, Lideta, Arada, Kirkos, Gulelte, Bole, Nefas-silk Lafto, Yeka and Kolfe-Keraniyo. Geographical it is located at the center of the country, and coordinated at latitude of $8^0 50'11''$ - $9^0 05'29''$North and longitude of $38^0 39'40''$ 38054′57′′East on Universal Transverse Mercator projection. The capital lies at the foot of Mount Entoto which is 3400 meters above sea level and extends southwards to its lowest point near to 2000 meters above sea level around Akaki. Its temperature stays nearly constant monthly with no more than 10^0C variations.

Addis Ababa has a pronounced rainfall peak during the summer season locally known as 'Kiremt' which is from June to September. It also exhibits a considerable amount of rainfall during February to May locally known as 'Belg', winter season locally known as 'Bega' is from October and January with minimum rainfall record.

For the purpose of our study, we selected Nefas-silk Lafto sub-city which is located at the southern west of Addis Ababa. It has a total population of 316108. The research will be conducted at the areas where significant urban storm drainage network system and road flooding risk management problems exist. The routes selected for this study are the Sarbet to Lebu-Mebrat-Hayil road, Mekenisa to Jamo road and LebuMebrat-Hayil to Hana-Mariyam road which is 38 km in length. The total length of asphalt roads, 38 km in Nefas-silk Lafto study area is. There are 5 bridges and 38km drainage facilities in the sub-city. The map of Nefas-Silk Lafto sub-city is depicted in the following map:

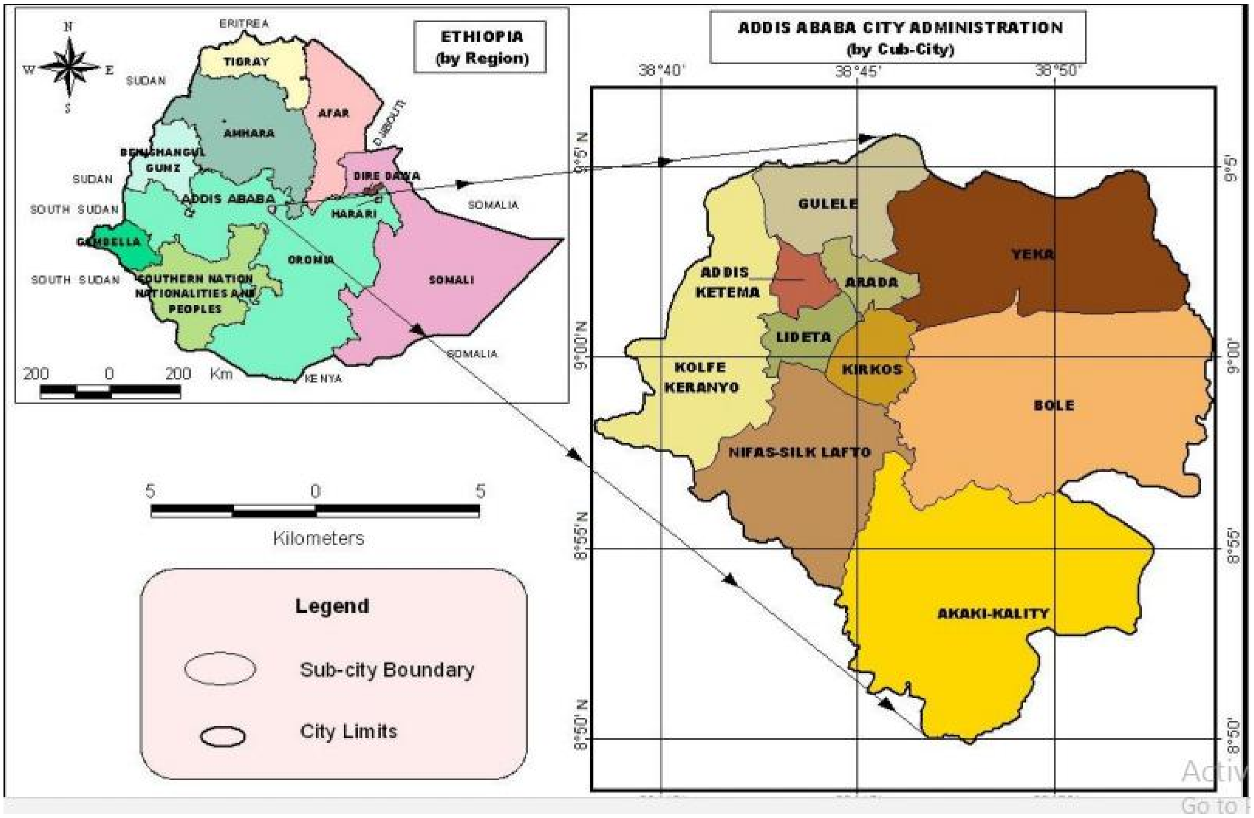

Figure 4: Location Map of Addis Ababa in Relation to Ethiopia

3.2. Research Approach and Stoday Design

In this study, qualitative and quantitative research method was applied. In this study, both descriptive and exploratory research methods were employed to assess urban storm water drainage network systems and management responses to mitigate the drainage risks. We also used secondary data by reviewing documents retrospectively. The descriptive method was used to describe the existing status and coverage of roads and urban storm water drainage facilities, to assess their level of integration and existing natural water ways in the study area. This method will also be used to describe various factors which would contribute to the development of urban storm water drainage system in the sub-city. Whereas, the exploratory type will be particularly used to explore the existing condition by making some required physical measurements and compare with standards.

3.3. Sample size determination

It used purposive sampling technique to determine the number of participants and Kebeles to be included in the study. We used this sampling method due to our resource limitation and also responses from a small number of participants from this study can explain the phenomenon of interest. Totally, there are 13 Kebeles in Nefas-silk Lafto sub-city, of which we sampled three kebeles for our study by means of assessing the treands. Accordingly, for interview, twenty household heads were sampled from each of the three selected areas making the total sample size sixty. Six staffs working in the road construction and urban storm-water drainage system in AACRA office were also participated in this study.

3.4. Sampling technique and procedure

Of the 13 kebeles in the sub-city, we selected three kebeles namely: Kebele 02 (around Mekenisa), Kebele 01 (around Jemo) and Kebele 12 (the area around ring road of Hana-Maryam). The selection of these kebeles has been undertaken discussing with the Addis Ababa road authority team of Nefas-silk Lafto sub-city. The basic reason to select these kebeles is that they are located at the base of risk of storm water drainage problem where flooding is more pronounced and economic damage is occur because of topographic location and high discharge of flooding from dertu mounten and surrounding area.

3.5. Data Collection

It used two sources of data for this study: primary and secondary. For the primary data our sources were field survey (observations and measurements), interviews, and focus group discussions (FGDs). For the secondary data, our sources were Federal Meteorological Agency. A questionnaire was prepared to collect primary data through interviews and FGDs (Annex 1). To extract the secondary data, a checklist was prepared (Annex 2).

Collection of primary data:

Interviews: We conducted interviews with staff working at AACRA offices and with residents in the selected areas of the sub-city. With interview, data like causes of flooding, reasons for damping solid and liquid wastes in the existing drains and to natural water ways, major challenges of storm water drainage management and possible suggestions to handle the challenges of the drainage system in the study area were collected.

Focus group discussions: It is conducted FGDs with staff working in AACRA offices and residents living in the selected areas. The total number of FGDs planned to be undertaken were 9 in number with the staff working in the concerned offices, and three in number with the residents living in the selected areas, each focus group consisting of 8 to 12 persons.

Field survey:

The Field survey was done through observation and measurements using surveying equipment such as tape meter, engineering level, total station with their accessories and GPS. Tape meter is used to measure the existing urban storm water drainage facilities, road and natural water ways/rivers. Engineering level is used to measure elevation the area, Total station is used to measure elevation and distance GPS is used to indicate the location X, Y, Z coordinates.

The field survey will also be conducted with the help of base-map and counter-map. Base map is used to investigate the overall conditions of urban storm water drainage system, natural water ways/rivers and integration of storm water drains and roads in the study area. Contour map is used to examine the elevation and flow length of the catchment areas. Rainfall data- to estimate the rainfall intensity. Pictures of the drainage facilities status in the selected areas will also be taken during field surveys.

Collection of secondary data:

We will collect secondary data using a checklist (Annex2) from Works and Urban Development, Urban Planning Institute and Environmental Protection Team at the sub-city level and from Addis Ababa City Environmental Protection Authority (AAEPA). Sources we use to extract the secondary data will be from federal metrological agency and Addis Ababa city road authority. The data to be collected will focus on rainfall data, elevation, causes of flooding and mitigation measures undertaken, effect of urban storm water drainage system on rivers, effect of rivers on the selected areas of Nefas-silk Lafto sub-city, major challenges in handling the drainage system in the study area and others.

3.6. Data quality control

Field assistances with a minimum qualification of diploma in engineering field will be recruited and trained on the data collection procedures. The data collection will be undertaken in the presence and with closer supervision of the researcher. Data will be checked continuously for completeness. Data entry will be done after checking for completeness and coding. Incomplete questionnaires will be excluded from analysis.

3.7. Data Processing and Analysis

The data collected were cleaned, coded and entered into Microsoft Excel for analysis. They were summarized and presented using percentages, tables and graphs the exploratory type will be particularly used to explore the existing condition by making some required physical measurements and compare with standards.

3.8. Ethical consideration

Ethical approval and ethical clearance letter will be obtained from the St. Mary University. A support letter will also be obtained from Urban and Works Office of Nefas-Silk Lafto sub-city before conducting the study and will be delivered to the selected Kebeles. A consent form will be attached to each questionnaire which explains about the purpose of the study, confidentiality, and the respondent's full right to take part or not in the study. Each questionnaire will be administered after an informed verbal consent is obtained. Confidentiality and anonymity will be ensured throughout the execution of the study. The database will be keep confidential to ensure and protect from unauthorized access to the data.

3.9. Dissemination of results

After completion of the study, the document will be disseminated to St. Mary’s University, Works and Urban Development Office of Nefas-Silk Lafto sub-city and any concerned body that wants to use the findings of the study. A manuscript will also be submitted to a renowned international journal for publications.

CHAPTER FOUR: DATA PRESENTATION AND ANALYSIS

4.1. Introduction

A total of 61 people have participated in this study of which 55 were residents and 6 were engineers working in the bureau of Addis Ababa City Road Authority (AACRA). Accordingly, a baseline characteristic of the residents interviewed shows their mean age is 49.5, ranging from 25 to 74 years, and 45 were males and 16 were females. Their educational level of the residents in number shows that 9, 18, 10, 12 and 6 were degree, diploma, certificate holders, completed primary school and with no formal education respectively. Similarly, of the engineers interviewed, and also five of them were first degree holders and one of them was second degree holder and all of them were males.

Among the residents interviewed, 87% (48/55) of them replied that flooding is a major problem in Nefas-Silk Lafto sub-city, which is in line with the responses given by the interviewed staff (100% or 6/]) and the results from the focus group discussions.. Regarding the extent of flooding problem in the sub-city, 84% (46/55) of the residents responded that it is a serious problem in the sub-city. Status of flooding in some parts of the areas mentioned above is indicated in the next figure 4.1 as follows:

Figure 5: Pictures showing flooding in some areas of Nefas-silk Lafto sub-city during the rainy seasons of August 2016, Addis Ababa

As shown in figure 3 above, the road surface, cross-section slope, longitudinal gradient and shoulders were investigated during the field survey and different types of damages and risks were observed at the study area as a result of road flooding. These are depressions, potholes, cracking, over flooding, pavement erosions, silt & sediment accumulations, washing and deformations of the road pavements.

4.2. Status of storm-water drainage network system

The engineering staff of AACRA who were asked regarding their satisfaction level of current status of storm-water drainage network system in the study area indicated that 67% (4/6) of them are unsatisfied. Fifty percent (3/6) of the staffs also mentioned that the materials used for building pipes and channels are not accurately reflected on the site services plan.

The existing condition and coverage of road infrastructure was surveyed in three kebelesof the sub-city to assess their performance. Accordingly, as indicated in Table 2 below, survey results of existing surface conditions show that in kebele 01/ 02, of the total road surface condition 40.36% is good, 53.94% is light and 5.7% is severe. On the other hand, in kebele 01/12, 57.34% is good, 30.62% light and 12.02% is severe, and in kebele 03/04, 66.59% is good, 21.3% light and 12.09% is severe.

Table 2: Road surface type and existing surface condition in Kebeles 01/02, 01/12, and 03/04 in Nefas-silk Lafto Sub-city, Addis Ababa, April 2017

Kebele	Road surface type	Existing Surface condition (in meters)					Total
		Segments	Very good	Good	Light	Severe	
	Asphalt	8	-	2,665.56	739.23	-	3,404.79
	Coble Stone	79	-	3,898.44	7,906.00	905.23	12,709.67
	Gravel	10	-	265.12	3,211.10	155.12	3631.34
	Stone surface	12	-	2,145.32	139.14	205.56	2,490.02
	Sub total	109	-	8,974.44	11,995.47	1,265.91	22,235.82
01/02	Percentage			40.36%	53.94%	5.7%	100%
	Asphalt	10	-	1,234.62	900.53	453.87	2,589.02
	Coble Stone	100	-	3,122.10	417.17	379.32	3,918.59
	Gravel	2	-	421	1,120.90	168.43	1710.33
	Stone surface	3	-	-	113.01	-	113.01
	Sub total	115	-	4,777.72	2,551.61	1,101.62	8330.95
01/12	Percentage		-	57.34%	30.62%	12.02%	100.00%
	Asphalt	10	-	2,191.47	687.55	111.93	2,990.95
	Coble Stone	18	-	2208	131.01	231.25	2,570.26
	Gravel	3	-	1,141.65	958.06	660.30	2,760.01
	Sub total	31		5,541.12	1,778.62	1,003.48	8,321.22
03/04	Percentage			66.59%	21.3%	12.09%	100%
Grand total				19,293.28	16,325.7	3,371.01	38,887.99
Percent proportion				49.61%	41.98%	8.67%	100.00%

Generally, of the total roads sampled in the three kebeles, almost 50.65%of the roads are deteriorated, degraded and/or eroded due to the absence of adequate urban storm water drainage infrastructure that discharges the flood generated safely into the final receiving systems. Pictures of notable examples for these problems were taken and shown in figure 4 below:

Figure 6: Pictures showing open drainages in some areas of sampled kebeles 01/02, 02/03 and 04/05 of Nefas-silk Lafto sub-city, Addis Ababa, April 2017

With regards to the drainage lines as depicted in table 3 below, survey results show that of the total drains in the three sampled kebeles, about 22.99% is severely degraded, which has resulted in degradation of road and other urban utilities.

As it has also been shown in figure 4 above, most of the rectangular and trapezoidal drains are open and are not environment friendly, which may encourage residents to connect their sewerage systems and dump solid wastes into the drainage systems resulting in unpleasant smells which are also unaesthetic to the environment. As it was drawn from respondents through interview and from field survey, particularly open drainage lines are the major causes of respiratory diseases like Asthma, common cold, upper respiratory tract infections and others.

Table 3: Length and shape of urban storm water drainage lines in Kebeles 01/02, 01/12 and 03/04, Nefas-Silk Lafto Sub-city, Addis Ababa, April 2017

Kebele	Drainage line type	Surface condition (in meters)			
		Good	Light	Severe	Total
	Trapezoidal	985.91	1,364.10	441.00	2,791.01
	Rectangular	6110	1,309.69	1,269.52	8,689.21
	Circular	2,120.73	-	-	2,120.73
01/02	Sub-total	9,216.64	2,673.79	1,710.52	13601
	Trapezoidal	293.02	2,872.16	1,992.32	5117.8
	Rectangular	999.70	1,639.23	1,923.40	4,568.11
	Circular	1,107.17	10.42	-	11.17
01/12	Sub-total	2,399.88	5,553.39	3,915.72	10,808.08
	Trapezoidal	1,192.87	183.0	942.32	2,318.21
	Rectangular	2,867.68	1,419.33	1,721.40	6,008.41

	Circular	1,468.47	2587.3	221.86	4,277.65
03/04	Sub-total	5,529.02	4,189.63	2,885.58	12,604.27
	Grand total	17,145.54	12,416.81	8,511.82	37,013.35
	Percentage	46.32%	33.54%	22.99%	100%

Of the total drains in the three sample kebeles about 22.99% is severely degraded, which has resulted in degradation of road and other urban utilities as evidenced by Fig.4. Whereas most of the rectangular and trapezoidal drains are open and are not environment friendly, which implies that these may encourage residents to connect and dump their sewerage systems and solid waste sources respectively resulting in unpleasant smells and are unaesthetic to the environment. As it was drawn from respondents during field survey, particularly open drainage lines are the major causes of respiratory diseases like Asthma, common cold and air pollution and other respiratory diseases. The implication of these is that: the ever existing flooding problems will be continued, the gap between road and urban drainage integration gets risk widened, the environmental problems like soil erosion keeps continuing, the budget allocated for urban utilities will increase due to degradation of utilities and loss of effective land for other land use function increases.

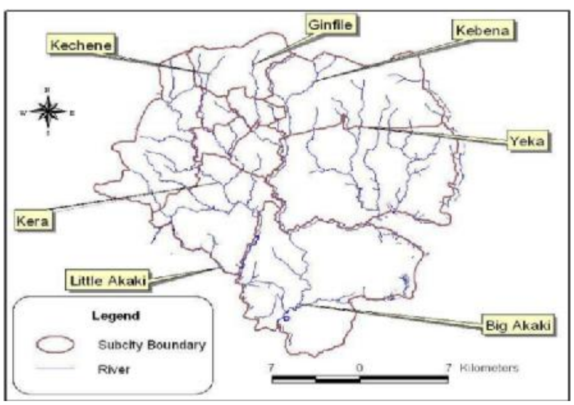

Figure 7: Drainage Map of the Study Area [Source Addis Ababa city administration

Each and every road and urban storm water drainage infrastructures of the study area were observed and assessed during our field survey and also from residents' interviews, the major flood prone areas were identified and are indicated in the table 4 below:

Table 4: Major flood prone areas in Kebeles 01/02, 01/12 and 03/04, Nefas-Silk Lafto Sub-city, Addis Ababa, April 2017

Specific site	Residents No	%	AACRA Staff	%
Sarbet	6	10.9	1	16.6
Mekenisa area	9	16.36	1	16.6
Lebumebrathayil	10	18.18	1	16.6
Jamo area	10	18.18	2	33.3
Hana mariyam	5	10	-	-
Koshe area	15	27.27	1	16.6
Total	55	100	6	100

As depicted in Table 1 and Shown in Figure 4, discussion with the community, the major flood prone areas is Koshe area (27.27%) followed by around Jemo Lebu Mebrat Hayil area (18.18%) and Mekansa area (16.36%), which were evidenced from the respondents' response as well as field observation. The Figure 3, shows the specific locations of these flood prone area

Figure 8: Some specific locations of flood prone areas in the Kebele 01/02 and 03/04 of Nefas-silk Lafto area of Addis Ababa city, April 2017

It is evidenced from the figure 6 above that solid wastes of different types are dumped into storm-water drains that blocked storm-water drainage network system and car wash site that discharges its spent into a river that totally affects the area. Rivers without buffer zones like the pictures shown above (figure 6) will invite the residents not only to connect toilets and liquid wastes into rivers, but also to dump solid wastes into river which is unaesthetic to the environment and may lead the area to harbor disease causing organisms (pathogens).

Similarly, based on the opinions of the residents and engineering staffs interviewed, 40% of the residents and 50% of the staffs agreed that the majority of the drainage systems are blocked by solid wastes as indicated in Table 5 below.

4.3 Causes of urban storm-water drainage network system failures

Table 5: Major Causes of blockage of drainage systems in Nefas-silk Lafto Sub-city, Addis Ababa, April 2017

No	Major causes	Responses by			
		Residents		AACRA Staff	
		No	%	No	%
1	Blockage of drainage of drain by solid waste	22	40	3	50
2	Sewer connection to drains	10	18.18	1	16.6
3	Inadequate drains	14	25.45	1	16.6
4	Absence of drains	19	34.54	1	16.6
	Total	55	100.	6	100

As it has been indicated in the next table 6 below, the general problems in the natural water ways/ rivers as indicated by 50.9% (28/55) of the residents is that it is due to blockage by solid wastes, 23.6% (13/55) of them agreed it is because if encroached by residents and 14.5% (8/55) replied it is due to connection of sewerages to the drainage systems. This finding is also supported by figure 4.4 shown above.

Table 6: General problems in the natural water ways/ rivers in Nefas-silk Lafto Sub-city, Addis Ababa, April 2017

Major cause	Kebele							
	01/02		01/12		03/04		Total	
	Number	%	Number	%	Number	%	Number	%
Encroached by residents	4	21%	3	16.60%	6	33.30%	13	23.6%
Blocked by solid wastes	10	52.60%	11	61.10%	7	38.80%	28	50.9%
Connection of Sewerages	3	15.70%	3	16.60%	2	11.10%	8	14.5%
No recommended buffer	1	5.30%	1	5.50%	2	11.10%	4	7.3%
Design problems	1	5.30%	-	-	1	5.50%	2	3.6%
Total	19	100	18	100	18	100	55	

With regards to the major causes of flooding problems that results in drainage network failures in Nefas-silk Lafto sub-city, upon interview of the residents in the area, 43.6% (24/55), 30.9% (17/55) and 12.7% (7/55) of them respectively replied that blockage of urban storm water drainage structures, inadequate urban storm water drainage infrastructure and absence of urban storm water drainage infrastructure are the major problems.

Figure 9: A river without a buffer zone (source: Field survey April, 2017)

Table 7: Major causes of flood problems that results in drainage network failures in Nefas-silk Lafto Sub-city, Addis Ababa, April 2017

Major cause	Kebele							
	01/02		01/12		03/04		Total	
	Number	%	Number	%	Number	%	Number	%
Absence of urban storm water drainage infrastructure	1	5.30%	2	11.10%	4	22.20%	7	12.7%
Inadequate urban storm water drainage infrastructure	4	21%	8	44.40%	5	27.70%	17	30.9%
Blockage of urban storm water drainage structures	11	57.80%	6	33.30%	7	38.80%	24	43.6%
Rugged topography	1	5.30%	-	-	1	5.50%	2	3.6%
Afforestation	2	10.50%	2	11.1	1	5.50%	5	9.1%
Total	19	100%	18	100%	18	100%	55	100%

In our study, residents were also interviewed regarding the major challenges for the provision of integrated road and urban storm-water drainage infrastructure in the sub-city. Consequently, 43.6% (24/55), 27.3% (15/55) and 20.0% (11/55) of them respectively responded that lack of awareness, design problems and problems with professional ethics are the major challenges for the provision of integrated road and urban storm water drainage infrastructure in Nefas-silk Lafto sub-city.

Table 8: Major challenges in the provision of integrated road and urban storm water drainage infrastructure in Nefas-silk Lafto Sub-city, Addis Ababa, April 2017

Major challenge	Kebele							
	01/02		01/12		03/04		Total	
	Number	%	Number	%	Number	%	Number	%
Finance	2	10.50%	2	11.10%	1	5.50%	5	9.1%
Problems with professional ethics	4	21%	3	16.60%	4	22.20%	11	20.0%
Lackof awareness	7	36.80%	8	44.40%	9	50%	24	43.6%

Design problems	6	31.60%	5	27.70%	4	22.20%	15	27.3%
Total	19		18		18		55	

In the study area, due to inadequate integration of road and urban storm water drains the following major problems have been observed: road base and road surface degradation, widening of river banks, erosion on road bases and road surfaces, degradation of Urban utilities, blockage of urban drainage lines, inundation of rain water on vacant surfaces. The analysis of existing integration between road and urban storm-water drainage infrastructure is discussed here under: We used the formula: (Total drainage lines * 100) / (Kebele built up area) to calculate the urban storm water drainage (USWD) density in each of the sampled Kebeles. Accordingly, in Kebele 01/02 USWD density is (130.6km*100)/688ha = 0.019km of USWD line per hectare of area or 1.9%. The drainage line and road integration is therefore, 13.6km/22.2km = 0.6126 or 613 meters, which means for every kilometer of road there is only 613 meters of drains. Therefore, only 61.26% of the road have drains. The rest 38.74% has no drain that safely discharges the flood generated within the kebele. Similarly in Kebele 01/12, urban storm water drainage (USWD) density is (10.8km*100)/478ha = 0.02259km or 2.6m (0.22%) of drain per hectare of area. The drainage line and road integration is thus, 10.8km/12.56km = 0.8598km. That is, for every kilometer of road there is only 859 meters of drains, which means only 85.43% of the roads have drains. The other 14.57% have no drainage lines. In Kebele ¾, USWD density is Urban storm water drainage (USWD) density is (12.6km*100)/153ha = 0.08235 ~ 8.2m per hectare of area or 8.5%. Hence, road to drainage line integration in this kebele is = 12.6km/13.1km = 0.8618 km ≈ 861m. From this, for every kilometer of road there is only 861 meters of drains, which means only 86.18% of the roads have drains. The other 13.82% have no drainage lines. Generally, the above findings show that due to the gaps in the integration between road and urban storm-water drainage lines there are shortfalls of safely discharging the flood generated to the final receiving system, the problem of flood gets increased to excessive amount leading to environmental degradation like erosion and water pollution, the degradation of urban utilities and road increases to a larger amount, and inundation of storm water on vacant surfaces, which decreases the aesthetic value of the areas.

4.4 Risks emerging from failure of road drainage network systems

Sources of flooding risks in urban storm-water drainage system and flooding risk management were analyzed by interviewing the AACRA staffs (Table 9).The corresponding mean scores of the responses were arranged in the form of risk matrix; i.e., low impact - low probability of occurrence ,high impact - low probability of occurrence, high impact - high probability of occurrence, and low impact - high probability of occurrence.

Table 9: Ranking risk sources on urban storm water drainage system and road flooding risk management as per the respondents

Ser. No	**Identified Risks**	**Level to flooding risk**			**Contribute to cost, time and quality**		
		High	Medium	Low	High	Medium	Low
1	Incomplete definition of scope of work	3	2	1	2	2	2
2	Unpredicted technical problems in construction	3	2	1	2	2	2
3	Poor organizational structure	4	-	2	2	2	2
4	Poor planning and management	4	1	1	2	2	2
5	Shortage of Cash flow	1	4	1	3	2	1
6	Flood, drainage and storm water management problems	4	1	1	3	1	2
7	Environmental pollution and damage	4	1	1	3	1	1
8	Unexpected sub surface conditions (Inadequate ROW Utility information)	2	2	2	3	2	1
9	Negligence for the downstream settlements due absence of Storm water containment/ Storm water runoff control	2	3	1	2	2	2

The corresponding impact on time, cost, and quality as shown in table 9 is that urban storm water drainage network system and road flooding risk management financial related risks and incomplete definition of scope of work study, unpredicted technical problems in construction an d poor organizational structure, poor planning and management related risks are found to be in the category of high impact-high probability of occurrence. Flood, drainage and storm water management problems, environmental pollution and damage, unexpected sub-surface conditions (inadequate ROW Utility information), negligence for the downstream Settlements due to absence of storm-water containment/ storm-water runoff control and related risks are found to be the most significant sources which have an impact on time and cost of projects.

Financial related risks are the other significant sources of risk with high impact on cost. From the matrix as shown in table, quality of roads is a problem in urban storm water drainage network and road flooding risk management. Informants are mentioned that financial related risks and incomplete definition of scope of work study, unpredicted technical problems in construction, poor organizational structure, and poor planning and management risks are found to be in the category to high probability of occurrence, but low impact on quality of the roads. It is to be noted that although the risks are dependent on one another, among the various causes of risks, urban storm water drainage network system and road flooding risk management related risk is emerged as the major one.

In relation to on-site monitoring of storm-water, 67% (four out of the six engineers) have indicated that no monitoring of storm-water drainage system has been undertaken in the previous periods. During our field surveys, it has also been observed that in some areas discharges from car washes and solid wastes are dumped into rivers that directly affects and blocks storm-water discharge network channels which shows lack of supervisory activities. Eighty three percent (5/6) of the AACRA staff also mentioned that due to lack of proper monitoring and provision of timely remedial actions risks that have happened in Nefas-silk Lafto sub-city area due to storm-water flooding. Fifty percent (3/6) of them also supported that economic damages of infrastructures, inconveniences and threats to the road users, residents or others have happened due to road over-flooding during rainy seasons.

4.5 Urban flood risk mitigation measures and strategies

In relation to the weight of responsibility of the staffs working at AACRA for managing risk related issues on urban storm-water drainage network system and road flooding risk management, of the six staffs, three of them cited program managers are the most responsible, two of them informed executive directors are the responsible bodies, however one of them mentioned it is the responsibility of designers or consultants to take the mentioned responsibilities.

Regarding awareness creation activities at the community level by Addis Ababa City Road Authority (AACRA) in the last periods, 83% (5/6) of the staffs interviewed informed us that no campaigns were undertaken to aware the residents to keep drainages clean and not to use them as a refuse dump sites. Sixty seven percent (4/6) of them also responded that their institution does not have a detailed plan for the next few years to renew or repair major assets like bridges, pits, roads, etc… in Nefas-silk Lafto area.

Table 10: Residents' responses showing if any temporary solutions have been undertaken to flood problems in Nefas-silk Lafto Sub-city, Addis Ababa, April 2017

Suggested temporary solutions	**Kebele**						**Total**	
	01/02		01/12		03/04			
	No.	%	No.	%	No.	%	No.	%
Cleaning drainage channels	12	63.10%	13	72.20%	15	83.30%	40	72.7%
Sand bags	2	10.50%	1	5.50%	0	-	3	5.5%
Constructing new drainage facilities	1	5.20%	0	-	1	5.50%	2	3.6%
Earth embankments	2	10.50%	2	11.10%	0	-	4	7.3%
Afforestation	2	10.5	2	11.10%	2	11.1	6	10.9%
Total	19		18		18		55	

As shown in the table 10 above, 72.7% (40/55), 10.9% (6/55) and 7.3% (4/55) have respectively replied that cleaning drainage channels, afforestation and earth embankments have been undertaken as temporary solutions to flood problems in the sub-city. Similarly, to tackle flood problems in the sub-city, 83.6% (46/55), 9.1% (5/55) and 3.6% (2/55) respectively have responded that cleaning drainage channels, afforestation, and earth embankments and constructing new storm-water drainage facilities were undertaken as permanent solutions.

Table 11: Residents' responses showing if any permanent solutions have been undertaken to flood problems in Nefas-silk Lafto Sub-city, Addis Ababa, April 2017

Suggested permanent solutions	Kebele						Total	
	01/02		01/12		03/04			
	No.	%	No.	%	No.	%	No.	%
Cleaning drainage channels	15	78.90%	16	88.8	15	83.30%	46	83.6%
Sand bags	0		0	-	0	-	0	0.0%
Constructing new drainage facilities	1	5.30%	-	-	1	5.50%	2	3.6%
Earth embankments	1	5.30%	1	5.50%	1	5.50%	2	3.6%
Afforestation	2	10.50%	1	5.50%	1	5.50%	5	9.1%
Total	19		18		18		55	

On the other hand, with the activities related to integration among various stakeholders (Environmental protection office, volunteers, individuals, community, Idirs, etc…) to prevent risks arising from flooding in flood risk areas almost all (six out of six) AACRA engineering staffs replied that there was no such experience in the institution. However, in relation to coordinating activities to mitigate further problems once risks have happened in the sub-city due to flooding, 67% (4/6) and 33% (2/6) of the staffs respectively replied that it is the responsibility of Addis Ababa City Administration and AACRA. On top of this, 67% (4/6) of the engineers replied that their organization does not have a formal risk management system.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1. Summary of the major finding

The findings of this study indicated that the major causes of flooding were found to be

- Deforestation of dertu and surrounding mountain, and
- Inadequate integration between road and urban storm water drainage lines.
- Solid and liquid waste damping was also the biggest challenges on the general urban drainage system.
- Blockage of drainage of drain by solid waste
- Sewer connection to drains
- Inadequate drains
- Absence of drains
- Identified Risks
- Economic loss
- Environmental degradation
- Incomplete definition of scope of work
- Unpredicted technical problems in construction
- Poor organizational structure
- Poor planning and management
- Shortage of Cash flow

5.2. Conclusion

We conclude that the storm water drainage network system is one of the most key aspects to be well-thought-out in the road design, construction and maintenance works. In Addis Ababa, the storm water drainage network system are not sound, the road flooding risk management is weak, and it is usual to observe flooding of drainage system after every rainfall. Therefore, the purpose of this study was to assess the status of road drainage network system and risk mitigation measures and strategies existing in Nefas-silk sub-city of Addis Ababa.

The findings of our study show that flooding is a serious problem in Nefas-Silk Lafto Sub-city. The conditions of the roads and drainage systems were unsatisfactory and some of them were not up to standard. Different types of damages of the roads were observed such as depressions, potholes, cracking, over flooding, pavement erosions, silt & sediment accumulations, washing and deformations of the pavements. Of the total roads sampled, more than half of them were deteriorated, degraded and/or eroded.

Blockages, inadequacies and absence of urban storm water drainage infrastructures are the major problems for flooding. Lack of awareness, design problems and problems with professional ethics were the major challenges for the provision of integrated road and urban storm water drainage infrastructure in the sub-city. In places where the drains are open and rivers are without buffer zones, solid wastes of different types were dumped into storm-water drains that blocked storm-water drainage network system and the residents have also connected toilets and liquid wastes to the rivers. These have resulted in producing unpleasant smells and leading the areas to harbor disease causing pathogens. However, no campaigns were undertaken to aware the community to keep the drainages clean and not to use them for dumping refuses. Unpredicted technical problems in construction and poor planning and management are found to have high impact for the occurrence of flooding and financial related risks.

Cleaning drainage channels, afforestation, earth embankments and constructing new storm-water drainage facilities have been used as temporary solutions and to tackle future flooding problems in the sub-city. There are also no integrations among various stakeholders (AACRA, environmental protection office, volunteers, individuals, community, idirs, etc…) to prevent risks arising from flooding in flood risk areas.

The results from this study were undertaken using both quantitative and qualitative research approaches through interviews, focus group discussions and field surveys, though the study has a limitation of scope that it only represents the areas studied due to small sample size. However, the findings provide up-to-date information on the current status of urban storm-water drainage network systems, major causes of their failures, the types of risks emerging from their failures and mitigation measures and strategies existing to address the failures. It might help managers, policy and decision makers, the community, concerned government offices and other concerned bodies working in the area of urban storm-water drainage network systems to use it as an input for proper quality project designs, implementation, management and maintenances of roads and drainage network systems in a sustainable manner.

5.3. Recommendations

- Improvement of drainage facilities through maintenance
- Public awareness campaign. This should be carried out so that people can be aware of the impacts of the rains.
- Carry out frequent inspections to check faults that may occur
- Constructing soil and water conservation structures including water pans
- Continuous monitoring of rainfall in the area through establishment of rainfall observation stations
- Improve the drainage systems along the highways
- Increase tree cover in area especially the neighboring hills, with appropriate tree species including planting of agro-forestry tree species to avoid erosion
- Re-seeding of denuded land with grass cover
- Create possible alternative routes for use in the case the Highway is threatened
- Redesign the drainage system
- Complete overhaul and reconstruction of the whole system
- Proper and frequent maintenance of the drainage facilities in the study area road.

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Annexes

Annex 1: General information sheet and consent form

Assessment of urban storm water drainage network system and road flooding risk management

General information

Hello! My Name is Tadelle Fulle and I am working with "Assessment of urban storm water drainage network system and road flooding risk management" in Nefas-Silk Sub-City of Addis Ababa. Currently I am studying Degree of Maser of Art in Project Management in St. University and this research is part of my study. We hope to learn the status of road drainage network system and identifying major causes of failures, identifying types of risks emerging from failure and assessing mitigation measures and strategies existing to address these problems in Nefas-Silk Sub-City of Addis Ababa.

We want to assure you that your responses will be kept strictly secret. We will not keep a record of your name or address. You have the right to stop the interview at any time, or to skip any questions that you do not want to answer. You will not be obliged to continue the study or give reasons for doing so, and refusing to participate or withdrawing from the study process.

The information that you give will solely be used for this study, but your identity will be treated with confidentiality and your name will not be used in connection with the information that you gave.

Your participation is completely voluntary, but your experiences could be very helpful to the government as well as to stakeholders working on urban road management in the country as a whole.

Consent form

Based on the above information I have understood that the urban road drainage system failure will affect the economic development a country as well as the life of the habitants as a whole. My participation in this study is very important and the information I provide will help to improve the situation.

The information I provide for this study will be kept confidential. I have understood that my name will not be inquired for this study and any unique identification is not given.

The information I provide will help to identify the major causes for urban road drainage network system failures and mitigation measures and strategies available to tackle these problems. Therefore I have shown my willingness and agreed to take part in this study.

Please sign here: ________________________

Date: ________________________

____

Investigator's/Data collector's Name: _______________ Signature: __________________

Date: ____/_____/_________ E.C. (____/_____/_________ G.C.)

Annex 2: QUESTIONNAIRES

Questionnaire – PART ONE (A) - Questions for the *INDEPTH INTERVIEW OF STAFFS*

I. Personal Information

Ser. No.	Variable	Category
1	Sex	1) Male 2) Female
2	Age	______________________________
3	Profession	______________________________
4	Educational level	1) Degree 2) Diploma 3) Certificate
5	What is your job?	1) Expert Engineer 2) Administrative staff

II. Questions related to status of storm-water network system

6. Is flooding a major problem in your sub-city? Yes _______ No_______
7. If your answer is yes to the above question, how do you rate the extent of the problem?
   1) Very serious 2) Serious 3) Not serious
8. What is the level of your satisfaction with the status of stormwater drainage network system?
   a. Satisfied b. Neutral c. Not satisfied
9. Are the materials to be used for building pipes and channels accurately reflected on the site services plan? Yes _____, No _____ If yes, describe. If No, why?
   ____
   ____

III. Questions related to major causes of road drainage network failures

10. Are there any areas subject to stormwater flooding? What is the frequency and impacts?
    ____
    ____
11. Have you undertaken any inspections of pits/holes or drainage systems? Yes___, No ____
    If yes, what was the nature of these problems (blockages, breaks) ______________________
    What is the likely cause? ____
    Is it related to pipe age, material, depth or location or are the stormwater mains beneath heavily-treed areas? ____

Do you have any reports prepared on these problems? Yes, _____, No ______ ***If yes, collect copy of reports***.

12. How have you addressed the problems identified and mentioned in question no. 28 above in the past? – What has succeeded, what has failed?

    ____

    ____
13. What is the cause of this flooding? Network capacity? Building levels? Outlet constraints? etc? ____

    ____
14. General problems in the natural water ways/rivers:
    a. Encroached by residents __________
    b. Blocked by solid wastes__________
    c. Connection of sewerages __________
    d. No recommended buffer_________ & meter
15. Road and USWD lines deterioration scales/indicators.

Indicators classification	Surface condition
Very good	
Good	
Light	
Severe	

16. What do you think is the major causes of flood problem in Nefas-Silk Lafto sub-city?
    i. Absence of urban storm water drainage infrastructure
    ii. Inadequate urban storm water drainage infrastructure
    iii. Blockage of urban storm water drainage structures
    iv. Deforestation of Nefas-Silk Lafto mountain
    v. Rugged topography
    vi. If others, specify ____
17. What are the major challenges in the provision of integrated road and urban storm water drainage infrastructure?
    a. Finance____________________________
    b. Plan_______________________
    c. Profession____________________________
    d. Lack of awareness__________________________
    e. Others ____
18. Does the stormwater discharge to an environmentally sensitive area? If yes, to which areas?

    ____

____

19. What are the major challenges in handling urban storm water drainage system in Nefas-Silk Lafto sub-city?

____

20. Is the flood from Nefas-Silk Lafto Mountain a major problem to the sub-city? Yes_____ No____

If yes, how could it be reduced/solved? ____

____

____

IV. Questions related to types of risks emerging from failure of road drainage network system

21. What were the major risks arisen from failure of storm-water drainage network systems in Nefas-silk Lafto area? (Is there any documented evidence /ask copy?)

____

22. Have you undertaken any monitoring of stormwater quality or quality of the receiving waters? ***If yes, collect copy of the reports.***

____

23. Have you experienced any flooding events? What were the impacts?

____

24. Are there any risks that have happened in Nefas-Silk Lafto area due to stormwater flooding?

____

Are there any economic damages of infrastructures, inconveniences and threats to the road users, residents or others that have happened due to road over-flooding during rainy seasons?

____

What major impacts the drainage systems have on rivers in Nefas-Silk Lafto sub-city?

____

25. What do you see as the biggest risks associated with the stormwater network?

____

26. What impacts do rivers have on Nefas-Silk Lafto sub-city?

____

V. Questions related to flood risk mitigation strategies and measures taken

27. Are there any awareness campaigns undertaken to keep drainages clean and not use them as a refuse dump sites? Yes ______, No______:

If yes, when and how? Explain ____

____

Do you have any preventive or maintenance plans for drainage systems? Yes __, No___
If yes, collect copy of the plan. If No, why ____

____

28. Do you have any contingency plans in place to manage risks? Yes _____, No____
    If yes, collect copy of the plan. If No, why ____

    ____

29. Do you have any major assets (bridges, pits, roads, etc) renewals planned over the next few years? Yes _____, No____
    If yes, collect copy of the plan. If No, why ____

    ____

30. Who is responsible for management of the stormwater network?
    Operation and maintenance?
    - Collection network ____
    - Water quality improvement devices ____
    - What contractors are involved and what is the scope of their services? ____________

      ____

31. Have any remedial actions been undertaken with stormwater systems? Was it successful, less successful or not successful?

    ____

    What temporary solutions have ever been taken to flood problems?
    a. Cleaning drainage channels
    b. Sand bags
    c. Constructing new urban storm water drainage facilities
    d. Earth embankments
    e. Afforestation
    f. Specify, if any____
32. What permanent solutions have ever been taken to flood problems?
    a. Cleaning drainage channels
    b. Earth embankments
    c. Sand bags
    d. Constructing new urban storm water drainage facilities
    e. Specify, if any____
33. Do you have a plan to provide urban storm water drainage infrastructure in Nefas-Silk Lafto sub-city?
    Yes_____ No_______ If Yes, for what purpose________________________________

    ____
34. What solutions do you suggest to handle such problems on existing rivers?

    ____
35. What do you suggest to manage the problem of flooding in Nefas-Silk Lafto sub-city?

36. Who is the responsible body or organization in urban storm water drainage provision in Nefas-Silk Lafto sub-city?

37. Is there any integration among different stakeholders (Urban development office, volunteers, individuals, CBOs, others) to prevent risks arising from flooding in risky areas? Yes_, No_ If not available, why?

38. Once risks have happened due to flooding, who is coordinating to mitigate further problems? What is done due to coordination?

39. General comments/suggestions in handling the impact of the urban drainage system on Nefas-Silk Lafto sub-city?

THANK YOU!

Questionnaire – PART ONE (B) - Guide questions for the *__FOCUS GROUP DISCUSSION OF STAFFS__*

1. Is flooding a major problem in your sub-city or have you experienced any flooding events in the sub-city? How do you rate or describe the extent of the problem? What was the frequency?
2. Are there any awareness campaigns undertaken to keep drainages clean and not use them as a refuse dump sites? If yes, when and how? If No, why?
3. What do you think is the major causes of flooding in the sub-city?
4. Is inspection of pits/holes or drainage systems undertaken in the sub-city? If yes, what was the nature of these problems (blockages, breaks…)? What were the likely causes of these problems? How have you addressed the problems? What has succeeded, what has failed?
5. What are the major challenges in providing/handling integrated road and urban storm water drainage infrastructure??
6. What were the major risks (economic damages of infrastructures, inconveniences and threats to the road users, residents or others) arisen from failure of storm-water drainage network systems in the sub-city? What were the biggest risks associated with the stormwater network?
7. Do you have any preventive, maintenance or contingency plans [or major assets - bridges, pits, roads, etc... renewals plan] for drainage systems? If yes, ask for its implementation. If No, why?
8. What temporary and/or permanent solutions have ever been taken to flooding problems?
9. What do you suggest to manage the problems of flooding in the sub-city?
10. Is there any integration among various stakeholders (Urban development office, volunteers, individuals, community, Idirs, etc…) to prevent risks arising from flooding in risky areas? If yes, who has done it and when? If not available, why?

QUESTIONNAIRE for General land and related Information Tracking

1. Total land area of Nefas-Silk Lafto sub-city: ____________________________ ha
2. Green area in Nefas-Silk Lafto sub-city: _______________________________ ha
3. Total built up area of the sub-city ________ha or_________km^2.
4. Road coverage in the study area ___________________________km.
5. Which specific sites are most prone to flooding and why: use the table below:

Ser. No.	Name of local site	Kebele	Rank	Reason of flooding
1				
2				

NB: Rank 1) Very serious 2) Serious 3) Not serious

6. USWD lines in the built up area ___________________________km.
7. The general existing condition of natural water ways in the study area:
   a. Average width ________
   b. Condition: Good _______light ______severe_______
   c. Average Depth ________
   d. Average length in the study area ------------------
8. Please describe the topography and flow paths within the base (mark up a site plan)
   ____
9. Has any flow monitoring been undertaken on site? Yes ____, No ______
   If yes, collect copy of the plan. If No, why ____
   ____
10. How many discharge points are available in the sub-city? _____________________________
11. Are there any areas of the site that do not have a stormwater collection network? How many? Mention the areas
    ____
12. Where do the drainage network channels discharge the stormwater to?
    ____
13. What is the level of your satisfaction with the status of stormwater drainage network system?
    b. Satisfied b. Neutral c. Not satisfied
14. Are the materials to be used for building pipes and channels accurately reflected on the site services plan? Yes _____, No _____ If yes, show the plan. If No, why?
    ____
    ____
15. The road and USWD pavement condition and type.

Condition	Road			Urban storm water drains	
	Asphalt, km	Red ash(km)	Earth(km)	Masonry	Earth

Good									
Fair									
Poor									
Total									

16. Road Classification

a. High way _________________ Km
b. Collector __________________ Km
c. Arterial ___________________ Km
d. Local _____________________ Km

17. Urban storm water drainage facilities:

Ser. No.	Type of drains	Length (km)	Shape of drains(km)		
			Trapezoidal	Circular	Rectangular
1	Concrete /masonry lines				
2	Earth lines				
	Total				

18. Integration between road and USWD lines

Ser. No	Road surface type	Total length of road (km)	Drain length(km)					
			Trapezoidal		Rectangular		Circular	
			M	E	M	E	M	E
1	Asphalt							
2	Red ash							
3	Gravel surfaced							
	Total							

19. Dimensions of existing USWD

No	Construction material	Shape of drain					
		Trapezoidal		Rectangular		Circular	
		L	H	B	B	H	R

1	Masonry						
2	Earth						

Where L= length B= base H= height R= radius

Questionnaire – PART TWO (A) - Questions for the *INDEPTH INTERVIEW OF STUDY PARTICIPANTS (RESIDENTS)*

I. Personal Information

Ser. No.	Variable	Category
1	Sex	3) Male 4) Female
2	Age	______________________________
3	Profession	______________________________
4	Educational level	_______________________________
5	What is your job?	_______________________________

II. General land information and status of drainage

6. Is flooding a major problem in your living area? Yes _______ No_______
7. If your answer is yes to the above question, how do you rate the extent of the problem?
   1) Very serious 2) Serious 3) Not serious
8. Which specific sites are most prone to flooding and why: use the table below:

Ser. No.	Name of local site	Kebele	Rank	Reason of flooding
1				

NB: Rank 1) Very serious 2) Serious 3) Not serious

III. Questions related to status of drainage network system

9. Has any stormwater monitoring been undertaken on site in this area? Yes ____, No ______
   If yes, when and how often? ____
   ____
10. How many discharge points are available in this area? ______________________________
11. Are there any areas of the site that do not have a stormwater collection? If yes, how many sites? ____
12. Where do the drainage network channels discharge the stormwater to in this area?
    ____

13. What is the level of your satisfaction with the status of stormwater drainage network system in your residential area?
    c. Satisfied b. Neutral c. Not satisfied

IV. Questions related to major causes of road drainage network failures

14. Are there any areas subject to stormwater flooding in your residential area? What is the frequency and impacts? ____
    ____
15. Are there any blockages or breaks of drainage systems in your area? Yes___, No ____
    If yes, what are the likely causes? ____
16. General problems in the natural water ways/rivers:
    e. Encroached by residents __________
    f. Blocked by solid wastes__________
    g. Connection of sewerages __________
    h. No recommended buffer_________
    i. Others ____
17. What do you think is the major causes of flood problem in Nefas-Silk Lafto sub-city?
    vii. Absence of urban storm water drainage infrastructure
    viii. Inadequate urban storm water drainage infrastructure
    ix. Blockage of urban storm water drainage structures
    x. Deforestation of Nefas-Silk Lafto mountain
    xi. Rugged topography
    xii. If others, specify ____
18. Does the stormwater discharge to an environmentally sensitive area? If yes, to which areas?
    ____
19. What are the major challenges in handling urban storm water drainage system in your residence?
20. Is the flood from Nefas-Silk Lafto Mountain a major problem to the sub-city? Yes_____ No____
    If yes, how could it be reduced/solved? ____
    ____

V. Questions related to types of risks emerging from failure of road drainage network system

21. What are the major risks arising from failure of storm-water drainage network systems in your residential area?
    ____
22. Have you experienced any flooding events in your area? What were the impacts?

____

Are there any risks that have happened in this area due to stormwater flooding?

____

23. Are there any economic damages of infrastructures, inconveniences and threats to the road users, residents or others that have happened due to road over-flooding during rainy seasons?

____

24. What do you see as the biggest risks associated with the stormwater network in this area in the past three to five years? And when did it happen?

____

25. Are there any major impacts of the drainage systems on rivers in your residential area?

____

26. What impacts do rivers have on drainage systems in this area?

____

VI. Questions related to flood risk mitigation strategies and measures taken

27. Are there any awareness campaigns undertaken in your area by different organizations (government body or others) to keep drainages clean and not use them as a refuse dump sites? Yes ______, No______:
    If yes, when and how? Explain ____

    ____

28. Is there any preventive or maintenance of drainage systems undertaken in the past two or three years? Yes __, No___
    If yes, collect copy of the plan. If No, why ____

    ____

29. Have any remedial actions been undertaken with stormwater systems? Was it successful, less successful or not successful?

    ____

30. Are there any maintenance activities undertaken on stormwater drainage systems once problems (breakages, blockages) have happened? Yes _________, No __________. If yes, who has maintained the damages ____
    If No, why? ____
31. Do you have any information who is responsible for management of the stormwater network? If yes, mention who is responsible________________________________
32. What temporary solutions have ever been taken to flood problems?
    g. Cleaning drainage channels
    h. Sand bags
    i. Constructing new urban storm water drainage facilities
    j. Earth embankments

   k. Afforestation
   l. Specify, if any____

33. What permanent solutions have ever been taken to flood problems?
   f. Cleaning drainage channels
   g. Earth embankments
   h. Sand bags
   i. Constructing new urban storm water drainage facilities
   j. Specify, if any____

34. What solutions do you suggest to handle existing problems of stormwater drainage network system in this area? ____
   ____
35. What do you suggest to manage the problem of flooding in this area?
   ____
36. Have you ever participated in the preventing risks arising from flooding in risky areas of your residence? Yes ______, No_______ .If yes, who has organized it and when
   ____
37. Is there any integration among different stakeholders (Urban development office, volunteers, individuals, CBOs, others) to prevent risks arising from flooding in risky areas? Yes_, No_ If not available, why?
   ____
38. Once risks have happened due to flooding, who is coordinating to mitigate further problems? What is done due to coordination?
39. General comments/suggestions in handling the impact of the urban drainage system on Nefas-Silk Lafto sub-city?
   ____

THANK YOU!

Questionnaire – PART ONE (B) - Guide questions for the *FOCUS GROUP DISCUSSION OF STUDY PARTICIPANTS (RESIDENTS)*

1. Is flooding a major problem in your residential area or have you experienced any flooding events in this area? How do you rate or describe the extent of the problem? What was the frequency?
2. Are there any awareness campaigns undertaken to keep drainages clean and not use them as a refuse dump sites? If yes, when and how?
3. What do you think is the major causes of flooding in this area?
4. Is inspection of pits/holes or drainage systems undertaken in this area? If yes, who has inspected? What were the problems (blockages, breaks…) identified? What were the likely causes of these problems? Have the problems been addressed? What has succeeded, what has failed?
5. What were the major risks (economic damages of infrastructures, inconveniences and threats to the road users, residents or others) arisen from failure of storm-water drainage network systems in this area? What were the biggest risks associated with the stormwater network?
6. Do the concerned bodies do preventive maintenance of major assets like bridges, pits, roads, etc... renewals for the drainage systems? If yes, when it was done?
7. What temporary and/or permanent solutions have ever been taken to flooding problems?
8. What do you suggest to manage the problems of flooding in this area?
9. Is there any integration among various stakeholders (Environmental protection office, volunteers, individuals, community, Idirs, etc…) to prevent risks arising from flooding in risky areas? If yes, who was organizing it and when it was undertaken?

Questionnaire – PART THREE - FIELD SURVEY CHECKLIST

1) Total built up area of the sub-city: _______________ ha or ___________km^2.
   Green area ______________________ha.
2) Road coverage in the study area ___________________________km
3) USWD lines in the built up area ___________________________km
4) The general existing condition of natural water ways in the study area:
   a. Average width _____________________
   b. Condition: Good ________Light ________ Severe ________
   c. Average depth _______________
   d. Average length in the study area __________________________
5) General problems in the natural water ways/rivers:
   a. Encroached by residents
   b. Blocked by solid wastes
   c. Connection of Sewerages
   d. No recommended buffer ________ &_______ meter

6) Road and USWD lines deterioration scales/indicators.

Indicators classification	Surface condition
Very good	
Good	
Light	
Severe	

Clarification: Indicators classification:

Very good: *Shapes of roads/USWD lines as still in original design condition*

Good: *No significant depressions, undulations and deformation*

Light: *Shape of the road/USWD lines deteriorate, but still sheds water*

Severe: *Total collapse of the road/USWD lines structure & barely passable*

1. The road and USWD pavement condition and type.

Condition	Road					Urban storm water drains			
	Asphalt, km		Red ash(km)		Earth(km)		Masonry		Earth
Good									
Fair									
Poor									
Total									

2. Road classification
   a. High way ____________ km
   b. Collector ____________ km
   c. Arterial _____________ km
   d. Local_______________ km
3. Urban storm water drainage facilities:

Ser. No.	**Type or drains**	Length (km)	Shape of drains(km)		
			Trapezoidal	Circular	Rectangular
1	Concrete /masonry lines				
2	Earth lines				
	Total				

4. Most flood prone sites/areas in the study area.

Ser. No	Specific sites	Causes of flooding	Ranks from observation