JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL & ENVIRONMENTAL ENGINEERING

DEPRTMENT OF CIVIL ENGINEERING

HIGHWAY ENGINEERING STREAM

EFFECTS OF URBAN DEVELOPMENT ON THE ROADSIDE DRAINAGE: A CASE OF 07 KEBELE IN DIRE DAWA CITY, ETHIOPIA.

A Research submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirement for the Degree of Masters of Science in Civil Engineering.

By

Molid Hassen

March, 2018

Jimma, Ethiopia

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Molid Hassen

Advisor: Prof.Emer T. Quezon

Co-advisor: Mr. Mesfin Dinku(MSc.)

March, 2018

Jimma, Ethiopia

APPROVAL SHEET

I, the undersigned, declared that the research entitled by **Effects of Urban Development on the Roadside Drainage Problem: A Case Study in 07 Kebele in Dire Dawa City** is my original work, and has not been presented by any other person for an award of a degree in this university or any other universities except citing from listed references attached and all sources of materials used for this research have been duly acknowledged.

Therefore, whatever the result of my research final defense that is based on the criteria as evaluated by the examiners, will be ACCEPTED in a good faith.

Signed:

Mr./Ms**.** Molid Hassen ______________ ______________

Name of Researcher Signature Date

As Master Research Advisors, we hereby certify that we have reviewed and evaluated carefully this MSc research prepared under our guidance by Mr. **Molid Hassen**, his research entitled: **Effects of Urban Development on the Roadside Drainage Problem: A Case Study in 07 Kebele in Dire Dawa City.**

Therefore, we recommend that this document would be submitted to fulfill the MSc research requirements in this university.

Prof. Emer T. Quezon ______________ ______________

Main Advisor Signature Date

Mr. Mesfin Dinku**(**MSc.) ______________ ______________

Co-Advisor Signature Date

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ABSTRACT

An effective and efficient urban drainage system is very important for any urban area to discharge its runoff and wastewater for a better and healthy environment. The rapid urban expansion in Dire Dawa city and lack of controlling informal settlement has led to the massive increase in the human settlement which is growing faster than the rate at which the drainage network is being enhanced causing a mismatch between service and urbanization.

For this reason, the main objective of the study was to evaluate the effects of urban development on the roadside drainage problem and the remedial measure of 07 kebele in Dire Dawa city. An exploratory and descriptive type of research methods were used to describe and explore the existing roadside drainage condition. Field survey, questionnaire and in depth interview with respondents were methods of data collection. In this study, data was analyzed with the help of Microsoft- Excel, ArcGIS 10 and SPSS version 20 software and the analyzed data was presented in tables, charts, graphs and percentages.

The results of the study indicated that, the major existing roadside drainage lines in the study area have lower capacity than the runoff from the surrounding area. From the total lengths of roadside drainage existed in the study area, only 40.8% of the side drainage can convey safely the runoff into the water ways. The main factors that causing the roadside drainage were improper waste disposal, lack of community awareness, lack of frequent clearance of roadside drainage line, informal settlement and damaged roadside drains due to urban expansion. The effects of poor roadside drainages were included road failure, destroys resident's property, dirtying the vehicle of the road users and urban flooding. From the total length of roadside drainage, 59.2% have low hydraulic capacity than the runoff water from the surrounding area. This study strongly recommends that frequently clearance of roadside drainage, enhancement of community awareness to drainage system and proper waste management should be done in the study area to avoid the causes for roadside drainage problem. It also, reconstruction of road and proper side drainage with good capacity should be needed to convey the runoff from the catchment in the study area.

Key words: urban development, roadside drainage, urban drainage, community awareness

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ACRONYMS

CSA	Central Statistical Authority
DDAC	Dire Dawa Administrative Council
DDCA	Dire Dawa City Administration
DDC	Dire Dawa city
DDRA	Dire Dawa Road authority
DDSBA	Dire Dawa sanitation and beautification agency
FUPI	Federal Urban Planning Institute
GIS	Geographical information system
GPS	Global positioning system
GTZ	German Technical Cooperation
ha	Hectare
JIT	Jimma Institute of Technology
NUPI	National Urban planning institute
SPSS	Statistical Package for Social Science
WHO	World Health Organization
WWDSE	Water Works Design and Supervion Enterprise

CHAPTER ONE

INTRODUCTION

1.1. Background

The rapid urbanization in developing countries and world over has led to the massive increase in human settlement which is growing faster than the rate at which the drainage network is being enhanced causing a mismatch between service and urbanization. This leads to health, social and economic problems which affect the urban settlers especially the poor. Because of these enormous mismatch related problems such as drainage [19]. At the worldwide, due to increasing urbanization and its related activities have impacted negatively on the drainage systems in the urban area in developing a country.

World Bank Report as listed in [19] indicated that poor drainage conditions in developing countries are a result of weak institutional capacity, inadequate regulatory policies, inadequate governance, and general lack of public Education/awareness /participation. The resolution of problems associated with the infrastructural provision in most developing countries currently follows the traditions of the developed countries. Often, this is not appropriate for the locality. Urban drainage practice shows that in the past, the philosophy has been based on conveying peak flows of municipal wastewater and storm runoff away from the urban areas as quickly as possible [16]. This has resulted in downstream flooding and heavy pollution of receiving waters. But it should not be forgotten that in some developing countries especially where the qualities mentioned above exist, still drainage problems especially those related to weather conditions do still occur. The problems of poor drainage are adverse in developing countries.

As the Cara [17] claim that developing Africa faces problems due to rapid urbanization and its accompanying overcrowding and congestion of urban areas. Development on land surfaces reduces permeability by replacing vegetated ground with roofs, roads and paved areas. Furthermore, Cara notes that there is an overall lack of physical structures like drainage systems, sanitation systems to support increasing urban population and insufficient funds to provide the good environmental living condition to all. Informal and unplanned settlements with inadequate drainage systems have developed to accommodate most of the people. This situation has resulted in environmental problems of poor management of both the human-generated wastes such as sewage, wastewater, and runoff.

As GTZ reported, Inadequate urban storm water drainage problems represent one of the most common sources of compliant from the citizens in many towns of Ethiopia [37]. Improper waste management practices in Ethiopia urban area and some settlements in urban areas in Dire Dawa are used to dumping solid waste directly into watercourses, drains, culverts, and other drainage structures which results in reduced flow capacity of roadside drainage and therefore overflowing to cause floods. This problem is getting worse and worse with the ongoing high rate of urbanization in different parts of the country. Some buildings in the certainly city in Dire Dawa was positioned close to drainage, whilst others are built only a few meters away from the stream channel or even across natural watercourse which increases the risk of these settlements to flooding. Problems associated with the reduced capacity of side drainage arises as erosion results in a high delivery of sediments from some urbanized areas around the catchment. The urbanization has negative impact on urban drainages system in unplanned cities and towns in our planet. In the densely-populated town and cities are facing water logging and flooding during heavy rainfall. These are common issues mostly in the developing nations [27]. The waste water generated from the domestic as well as institutional bodies is merging with storm water into the existing water channel. Lack of planned for separate waste water management such as grey water (sullage), storm water, sewerage (waste water from toilets) and the huge amount of garbage, solid waste, silt sand accumulation and vegetation has to encourage at urban local bodies. Due to this, the drainage system, which conveys storm runoff from the areas to the river were not fully operated and the existing road side drainage will be blocked.

In Dire Dawa city,07 kebele is a major economic nexus of Dire Dawa city. It is the center and the most economically significant part of the city. In this kebele, the Chatera, Megala Chabtu, Konel, Taiwan market center and Ashawa market center are the largest merchandise market in Dire Dawa city. Unfortunately, improper of solid waste, the huge amount of garbage in side drainage, urban flooding, blockage of drainage, are common in this area. Thus, the existing side drainage are not good capacity in the study area. This improper drainage system causes the failure of road pavements by increase in moisture content, decrease in strength, mud pumping, formation of waves and corrugations, stripping of bitumen and cutting of edges of pavement.

1.2. Statement of problem

According to Ghulam reported that the effects of urban development on the lives, livelihoods, assets, infrastructural, drainage system, environmental quality and economic gains of city residents particularly the urban poorest residents by disposal of garbage in nearby drains low lands, discharge of wastewater into open roadside drains, the concentration of hanging latrines in lower income settlements areas, annual flooding are major environmental problems faced by city inhabitants [58].In most developing countries, solid waste disposal is closely linked with urban wastewater drainage in that open sewers and drainage channels often end up also being receptacles for solid wastes generated in the community. This leads to blockages, reductions in a capacity of roadside drainage and an exacerbation of flooding problems [1].

The pattern of urbanization and modernization in Ethiopia has meant increase densification along with urban infrastructure development. This has led to deforestation use of corrugated roofs and paved surfaces. The combined effect of this results in higher rain drop intensity and consequently accelerated and concentrated runoff in urban area [4]. Due to inadequate integration between road and urban storm water drainage infrastructure provision and poor management, the significant proportion of the area is exposed to flooding hazards/risks. This has resulted in negative impacts on urban storm water drainage provision and management.

In the study area, the existing side drainages have low hydraulic capacity. The main causes are the insufficiency of existing roadside ditch for the duration of the rainy season to pass the runoff and absence of side ditches in the place where it required. These problems cause damage to road pavement and side properties. Also, in the study area, road users and residents are suffering by the problem of runoff that damage both pavements and resident's properties, because of inadequate roadside drainage. The common factors for roadside drainage problem are lack of community awareness to drainage system, lack of frequently clearance of roadside drainage, disposal of garbage in nearby roadside drains, discharge of wastewater into open roadside drains, damaged roadside drainage due to urban infrastructure construction. Informal and unplanned settlements with inadequate drainage systems and poor waste management are the causes for environmental problems in the study area due to urban development. Because of these issues and problems, this study tried to evaluate the current state of roadside drainage and to find out probable causes of roadside drainage problem and remedial measure of 07 kebele in Dire Dawa city.

1.3. Research questions

- What is the existing condition of roadside drainage in the study area?
- What are the factors that cause roadside drainage problem?
- Which factors that are mostly contributory affecting highway and environment due to urban development?
- What will be the appropriate mitigation measures to be recommended to address the problem?

1.4. Objectives of the study

- **General objective**

The general objective of the study is to evaluate the effects of urban development on the roadside drainage problem and remedial measure in case of 07 kebele in Dire Dawa city.

- **Specific objectives: -**
  - To identify the existing condition of roadside drainage in the study area.
  - To identify factors causing the roadside drainage problem.
  - To determine factors that mostly contributory affecting the highway and environment due to urban development.
  - To recommend appropriate mitigation measures.

1.5. Scope of Study

This study was geographically limited to 07 kebele found in Dire Dawa city and is found in eastern part of Ethiopia. The study address issues related to urban development and its impacts on the roadside drainage problem. The specific focus of it includes: existing condition of roadside drainage, factor affecting roadside drainage, effects of urban development on roadside drainage and roadway and related environmental issues.

1.6. Significance of the Study

There is a public demand for drainage provision in the many urban settlements of the developing world. The availability of an efficient and effective drainage network is a major pre-requisite for achieving a clean and healthy environment. It's therefore, imperative to ensure that in any human settlement, drainage systems must be given the priority it deserves in each setting. This aims study will be coming up with findings on the effects of urban development on the roadside drainage problems. It will also come up with the recommendation on the ways forward. It will be supposed to find out reasons for poor roadside drainage and the reasons for poor waste disposal.

The study will be beneficial for academicians and researchers who conduct similar researches on other roadside drainage structures. It may also support policy makers in their effort to address similar problems. Any organization working roadside drainage can use it as a further reference to construct roadside drainage.

1.7. Organization of the study

This research study comprised of five chapters and their contents of each chapter are summarized as follows:

The first chapter introduces the study and contains the introduction, the background of the study, the statement problem, research questions and objective of the study, the scope of the study, the significance of the study, the organization of the study and limitation of the study.

The second chapter contains the review of related literature: the discussion of this chapter mainly focuses on introduction to drainage, history of urban drainage system, history of urban drainage system problem, development of modern urban drainage practices, urban drainage system experience in Ethiopia, urban storm water drainage policy issues in Ethiopia, the importance of urban drainage system, kinds of drainages**,** road side drains, hydrology, hydraulic design of open channels, watershed area, urban storm water drainage system design, manning's equation, causes of poor drainage, drainage problems, urbanization impact on the urban drainage, effects of urbanization on land use and land cover, waste management practice in Dire Dawa city, urban drainage and environmental, urban drainage and public health ,and urban storm water pollution and its prevention.

The third chapter contains the research materials and methodology. These include materials, description of study area, study design, sampling technique and sampling size, study variables, data-collection methods, and data analysis.

The fourth chapter deals with results and discussion that were gathered from field investigation, interview, questionnaire and analysis and discussion were carried.

The last chapter, chapter five deals with a conclusion and recommended were derived from results and discussion.

1.8. Limitation of the Study

During the preparation of this paper, the main problem encountered during this research includes a problem of the availability of well-organized data, data adequacy and reliability. The study was done under some important group such field survey, as interview and questionnaires distribution to road users, residential, Dire Dawa sanitation and beautification agency and Dire Dawa road authority. During the questionnaires, some questioners has not willing to give information on the questionnaire because of they are busy with workloads. Some of the interviewees seemed to hold back in their answers with a fear of negative impacts from their answers. It was very difficult to get useful data and resources from the local authorities. However, a great effort was made to minimize errors by collecting adequate data to overcome the problem.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction

C.A. O'Flaherty stated that drainage is simply defined as the natural or artificial removal of surface and subsurface water from a catchment area. The surface drainage in roads is defined as a process of removing runoff water from road surface and directing it towards a drain to be disposed of away from road in a water course or open area [55]. As the of Linsley and Franzini definition, drainage as a system applied to dealing with excess water additionally, and he states that drainage deals with water before it has reached a major channel [56]. However, this is not concise because in general, the major channel carrying water is part of drainage. According to Abwot that drainage is an accomplishment of causing subterranean water to flow by gravity into swamps at the level which is usually pumped out [57].

Roadside drainage channels perform the vital function of diverting or removing surface water from the highway right-of-way. They should provide the most efficient disposal system consistent with cost, an importance of the road, an economy of maintenance, and legal requirements [32].

2.2 History of Urban Drainage system

The practice of urban drainage system has been traced back to some hundred years ago, the efficient conveyance of storm water from urbanized areas was motivated primarily by reasons of convenience and the reduction of flood damage potential [41].

Natural hydrological processes would have prevailed; there might have been floods in extreme conditions, but these would not have been made worse by human alteration of the surface of the ground. Bodily wastes would have been 'treated' by natural processes.

Artificial drainage systems were developed as soon as humans attempted to control their environment. Archaeological evidence reveals that drainage was provided to the buildings of many ancient civilizations such as the Mesopotamians, the Minoans (Crete) and the Greeks (Athens). The Romans are well known for their public health engineering feats, particularly the impressive aqueducts bringing water into the city; less spectacular, but equally vital, were the artificial drains they built, of which the most well-known is the cloaca maxima, built to drain the Roman Forum (and still in use today) [38].

Historical accounts of ancient civilizations (e.g., Indus and Minoan) suggest urban drainage systems were constructed with great care and that the objectives of the systems were to collect rainwater, prevent nuisance flooding, and convey wastes [42].

The Persians were ancient civilization that constructed urban drainage systems and they considered urban runoff sacred and enacted laws to protect it from pollution. Polluting water in Persia was considered a sin [43]. Moreover, rainwater and urban runoff were collected in cisterns for potable uses (ibid).

The Mesopotamian Empire states of Assyria and Babylonia marked great advances in civilization during the second millennium BC. The ruins from Mesopotamian cities contain well-constructed storm drainage and sanitary sewer systems. For example, the ancient city of Babylon, located in present day Iraq, had effective drainage systems for storm water control [44]. As Maner stated that, the systems contained vaulted sewers and drains for household waste, gutters and drains specifically for surface runoff [45].

According to Reynolds explain, the Babylonians were partially motivated to construct urban drainage systems by their desire to remain clean. The Babylonians, like other ancient civilizations, viewed uncleanness as a taboo; not because of the physical uncleanness but the moral evil it suggested [46]. In retrospect, the Mesopotamians viewed urban runoff as a nuisance flooding concern, waste conveyor, and a vital natural resource.

2.3 History of Urban drainage system problem

As Bruce stated, Archaeological excavations of settlements in the Indus and Tigris river basins have revealed the utilization of drainage conduits as far back as possibly 3500B.C [41]. The Romans were great builders of sewers, roads and bridges. The greater sewer, cloaca maxima, built in the sixteen century B.C to drain the Forum in Rome is still in use today (ibid).

London and Paris in 1840s and 1850s were converting storm sewers to combined sewers (ibid), and new sewers were designed to act as combined sewers, this was done because there was an epidemic broke out due to the increased in number of urban people and discharging of domestic waste in to everywhere.

The practice of urban drainage in developing countries encounters more serious problems than those of developed countries, because urban development occurs under more difficult socio- economic, technological and climatic conditions. Developing counties experience accelerated urbanization without adequate investment in infrastructure, and against a background of deficient public services for water treatment, collection and treatment of foul sewage, garbage collection, urban drainage, transport and health. Urban concentrations have environmental consequences in the form of urban flooding and pollution of water courses, soil and air. Settlements are established in inappropriate areas such as those originally set aside for environmental preservation and on steep hillsides and areas liable to flooding [48].

The specific factors inhibiting modernization of urban drainage in developing countries, basically by means of infiltration and retention of storm runoff, can be grouped under the following headings: (1) concern for the environment is less familiar than concern for conventional sanitary planning;(2) there is no effective control over urban development, whether legal or clandestine; (3) runoff from storm rainfall is highly contaminated; (4) runoff transports large quantities of sediment and garbage ; (5) climatic factors can increase risk of epidemics and construction costs; (6) there is a shortage of engineering 'know-how' concerning modern approaches to urban drainage; (7) there is a lack of interaction between the population and public administrators seeking solutions to urban drainage problems[48]. As different researches were done on the urban drainage, there are different factors that contributory for urban drainage problems.

2.3.1 Uncontrolled Urban Settlement

Impermeable surfaces and the construction of drains for rapid storm-water removal are the major causes of urban floods due to a traditional urban settlement, pursued without regard for the environment [47]. Such urbanization patterns make it difficult to control urban drainage, since it not only causes or aggravates local flooding but can also create problems downstream.

The extent of impermeable cover is directly correlated with runoff coefficients and with population density, so that an indirect method of evaluating the impact of urbanization on drainage is to relate population density with runoff coefficients. There is evidence world-wide that higher urban population density commonly results in greater storm-water generation, [49] but many urban planners take no account of this important effect and neglect the wider costs of their storm-water control procedures.

Dagnachew Adugna studies stated that informal settlement is the biggest challenge in managing the urban drainage system in Addis Ababa, Yeka sub city. This has exacerbated the land degradation/erosion problem due to the increased flooding because of impermeable surfaces, illegal solid and liquid wastes disposal into existing natural water ways and side drains [75]. Likewise, informal settlement is the causes for urban side drainage. Therefore, the local authorities in charge of controlling urban expansion and the other human activities in the urban area.

2.3.2 Dumping of solid wastes into drainage facilities

As Dagnachew Adugna studies dumping of solid wastes into drainage facilities the main causes for urban flooding. This is to mean because of dumped solid waste in to the existing natural water ways and urban drainage facilities the flood over flows and create a problem on residents and other urban infrastructure and utilities [75]. As Eskedar Tafete studies, dumping solid waste materials into drainages and streams is the other challenge of storm water drainage system. As a result of dumping these solid wastes in to drains the drainage system has been clogged and causes flooding over streets and walk ways [76].

As Daniel Sh.et al., a stated that only 31% of solid waste was disposal in proper manner in Dire Dawa city [74]. Dumping solid waste disposal in to open side drainages is the one of the factors that challenge of roadside drainage problem in the Dire Dawa city.

Figure 2.1:Blocked drains because of abuse of drains with waste deposits

Source: [51]

2.3.3 Discharge of liquid wastes into existing side drains

Illegal connection of sewerage system in to existing drains and natural water ways is one of the challenges which have been observed in the sub-city. Most of the drainage lines in Yeka sub-city serve as a sewer and are blocked by liquid wastes [75].

Illegitimate joining of sewerage system into existing drains is one of the challenges of urban storm drainage. Most of the drainage lines in oblige as waste disposal and clogged by liquid and solid waste. Aside its' challenge to the drainage system, it could also cause a health problem and it degrades the aesthetic value of the environment [76]. Releasing of waste water into roadside drain, unlawful connection of latrine into the side drain and absence of drains street flooding is the common storm water drainage in the Dire Dawa city.

2.3.4 Absence of Community Participation

As the David O., et al. stated that one of the main obstructions preventing the successful control of storm runoff measures either by structural or non-structural measures is the absence of community participation in providing solutions to urban drainage problems [51]. Community participation simply depends on the desire and ability to organize themselves, strict compliance with societal goals and rules, and providing the medium of direct communication by the appropriate municipal administration. This provides linkages in which municipal authorities can pass useful information to residents and vice versa. It can also develop the participatory function where clear priorities that pertain to urban drainage can be evaluated. Because of compliance, the level of technical information as well as environmental education increases. The absence of community participation gives room for repetition of earlier errors in tackling drainage problems and low investments in urban facilities.

Community awareness is one of the best proactive measures for the sustainable urban drainage management [75,76]. Community participation is one of the best positive measurement directly or indirectly to control roadside drainage problem. From the observation, it was realized that even though few people have the awareness, the authority should create awareness among the communities and should provide proper waste management technique.

2.3.5 Lack of frequently clearance of roadside drainage

Due to lack of frequent clearance of drainage lines they have become out of services. Sediment load, solid wastes blocked most of the drainage system. So, without scheduled clearance the service life of those ditches could be out of their life span [76]. Roadside drainage problem was affected by the lack of frequently clearance of drainage system due to this sediments, siltation and garbage are blocked the side drainage line in the study area.

2.3.6 Damaged roadside drains due to urban infrastructure construction

The majority of infrastructure development in the city has no attention to the drainage system. housing construction, road construction and upgrading, water supply lines and telephone line installation and expansion have been degrading the urban drainage system and have found that they are the major causes of land degradation and erosion [75,76]. During the construction or maintaining of the urban infrastructure, it should be give more consideration to the else urban drainage system.

2.4 Development of Modern Urban Drainage Practices

Most sewers were designed exclusively for storm water drainage. Sanitary wastes accumulated in privy vaults and cesspools and were periodically collected by scavengers and transported to a suitable disposal location (e.g., farm, dump outside a city). As the nineteenth century progressed the concept of urban drainage changed with the incorporation of a water-carriage sanitary waste collection into the urban drainage systems. Sanitary connections to the sewers were made clean, and new sewers were constructed to drain storm water and sanitary wastewater [46].

The public perspective of urban drainage changed during the nineteenth century from a neglected afterthought to a vital public works system. The public also shifted their stance regarding funding the construction and maintenance of sewer systems. The shift in public perspective was driven by many factors, but the most important was probably the scientific evidence accumulated during the second half of the century linking sanitary wastes and disease transmission [52]. The perspective of urban drainage also changed from a design standpoint during the nineteenth century. Most sewers constructed before the nineteenth century were not planned or designed by an engineer using numerical calculations. Instead, a trial-and-error process was executed, which in some cases eventually produced well-functioning systems [46].

2.5 Urban drainage system experience in Ethiopia

In Ethiopian context, where watersheds of many urban centers receive the significant amount of annual rainfall and where rainfall intensity is high, control of runoff at the source, flood protection, and safe disposal of the excess water/runoff through proper drainage facilities become essential [53]. Drainage problems in Ethiopian urban centers include flooding, deterioration of roads, land degradation, sedimentation, water logging, blockage of drainage facilities and the like.

With urbanization, impermeability increases with the increase in impervious surfaces (i.e., residential houses, commercial buildings, paved roads, parking lots, etc.), drainage pattern changes, an overland flow gets faster, flooding and environmental problems such as land degradation increases. It is a crucial problem facing the existing and future environmental conditions of urban centers [54].After its inception, Federal Urban Planning Institute

(FUPI) has been involving in planning and design of urban storm water drainage facilities as part of the master/development plan of a city/town with the objective of keeping the life of urban infrastructure and to protect the urban environment like water pollution from non-point sources of storm water, Air pollution from stagnated water and Soil from erosion and degradation.

Before the establishment of the National Urban planning institute (NUPI) some twenty years ago, there has been no formal working organization in an urban storm water drainage system. Even now a day the attention towards urban storm water system is at its immature stage that is why most of the urban storm water drainage structures get blocked with a solid waste of various types after the huge amount of money has been invested in them. In some areas, they by themselves are sources of environmental problems [54].

2.6 Urban storm water drainage policy issues in Ethiopia

For an urban storm water drainage system to be effected appropriately in each urban area, policy issues should get priority & thus must focus on following significant points [54]:

- The overall policy goal should focus to improve and enhance the health, safety, and quality of life of the urban and hinterland population and enhance the environment on a sustainable basis.
- Storm water is a component of the total water resources of an area and should not be casually discarded but rather, where feasible, should be used to replenish that resource. In many instances, storm water problems signal either misuse of a resource or unwise land activity.
- Development of storm water drainage system is not possible in isolation from other infrastructure and environmental sectors. Coordination is necessary between different departments, government and other stakeholders and planning should take cognizance of processes such as integration. Storm water drainage planning, design, and management activities should ensure the participation of the people and other stakeholders at all levels.
- Environmental considerations such as soil erosion and sedimentation must also be taken in to account.

2.7 The importance of urban drainage system

Proper drainage systems are needed in urban areas because of the interaction between human activity and the natural water cycle. This interaction has two main forms: the abstraction of water from the natural period to provide a water supply for human life, and the covering of land with impermeable surfaces that divert rainwater away from the local natural system of drainage. These two types of interaction give rise to two types of water that require drainage. The first class, wastewater, is water that has been supplied to support life, maintain a standard of living and satisfy the needs of industry. After use, if not drained properly, it could cause pollution and create health risks. Wastewater contains dissolved material, fine solids, and larger solids, originating from water closets, from the washing of various sorts, from industry, and other water uses. The second type of water requiring drainage, storm water, is rainwater (or water resulting from any form of precipitation) that has fallen on a built-up area. If storm water were not drained properly, it would cause inconvenience, damage, flooding and further health risks. It contains some pollutants, originating from rain, the air or the catchment surface. Urban drainage systems handle these two types of water with the aim of minimizing the problems caused by human life and the environment. Thus, urban drainage has two major interfaces: with the public and with the situation. The public is usually on the transmitting rather than receiving an end of services from urban drainage (flush and forget), and this may partly explain the lack of public awareness and appreciation of a vital urban service [38].

Figure 2.2:Interfaces with the Public and the Environment

Source: [38].

2.8 Kinds of drainages

2.8.1 Surface drainage

Surface drainage is a removal of water collects on the land and surface. Provision must be made for removal of water, from rain or melting snow, or both, that falls directly on the road or comes from the adjacent terrain. The road should be adequately sloped to drain the water away from the travel lanes and shoulders and then directed to drainage channels in the system, such as natural earth swales, concrete gutters, and ditches, for discharge to an adjacent body of water. The channels should be located and shaped to minimize the potential for traffic hazards and accommodate the anticipated storm-water flows. Drainage inlets should be provided as needed to prevent ponding and limit the spread of water into traffic lanes.

2.8.1.1 Elements of a good surface drainage

1. Shoulders

Shoulders help provide lateral support for the pavement, carry water from the pavement to ditches, and give vehicles a place to go if they lose control or need to stop in an emergency. For drainage, they need to be slightly steeper than the pavement and should be able to withstand occasional traffic. Erosion and washing of shoulders is a major problem and should be addressed by using less the erosive material on the surface [20].

2. Cross slope

Cross slope is provided to provide a drainage gradient so that water will run off the surface to a drainage system such as a street gutter or ditch. Water will flow faster on a paved surface. Therefore, the slope of a road surface does not need to be steep. The cross slope should not be too steep. If it is, the water running off the side will start eroding the shoulder and sides of the road [20].

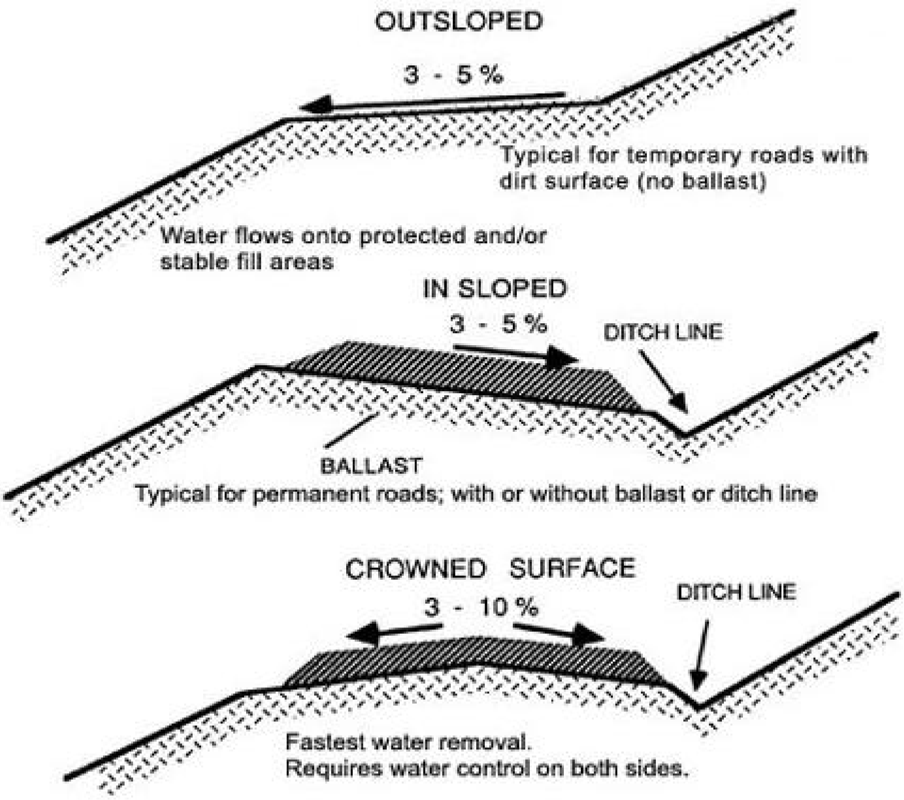

Figure 2. 3:Cross slope

Source: [6]

2.8.2 Longitudinal drainage

The main objective of longitudinal waste is collection and removal of water that is on the road and immediate surrounding or water from adjacent areas [21]. It's fundamental for maintaining the safety of traffic by eliminating water from the road surface at the same point reducing the possibility of water infiltrating into the road and pavement layers or foundation which may lead to deterioration [22]. Longitudinal surface drainage systems include gutters, channels, ditches, permeable land surface and swales complemented by their respective utility holes, retain facilities and catch basins.

2.8.3 Subsurface drainage

The need for subsurface drains as alternatives to open drains depends on site conditions; however, they require careful consideration owing to their high cost. These types of wastes are required in urban areas, places with subsoil wells and in some types of cuttings. Subsurface drains include drains and trench drains. They serve the following purposes;

intercept water before it gets to the road, lower the water table and remove excess free moisture from the road [22].

Subsurface drainage consists of three essential elements. A permeable base which is required to provide for rapid removal of water which enters the road structure, a method of conveying the removed water away from the road structure and this may consist of a base sloped towards a drainage ditch. At the most, this may consist of a pipe collector system and a filter layer to prevent the migration of fines into the permeable base from the subgrade, subbase or shoulder base material [23].

All sub drains should be able to maintain the flow lines and the design slopes. The outlet water flow should be precise and uniform, indicating that erosion is not occurring and the system is not clogged. Side slopes on the road, drainage beds in the pavement and transverse drains are some of the measures of effecting subsurface drainage [13].

2.8.3.1 Elements of a good subsurface drainage

a. Granular drainage layer

A well maintained granular drainage layer is uniform in thickness, the width detailed in the plans and specifications, and of the proper material gradation [24].

b. Under Drains

A well-maintained system of transverse and longitudinal drainage pipes effectively intercepts and carries water out of the granular layer. Under drains carry water from the granular drainage layer to edge drains. Edge drains are installed under shoulders, longitudinally adjacent to the pavement [24].

2.9 Road Side Drains

Side drains Keep water off the surface of the road and keep the foundations of the way dry. Effective side drains will reduce the need for maintenance by preventing deterioration of the surface and will provide a drier and hence safer road. If the side drains are missing or not working then, water running along or across the road may lead to gully erosion. The foundations may get wet and soft leading to rutting. A common reason that side drains stop working is that people were crossing the drain block them: either vehicle driving across the drain damage them [6]. Side drains serve two main functions namely to collect and remove surface water from the immediate vicinity of the road and, where needed, to prevent any sub-surface water from adversely affecting the road pavement structure.

Seepage may occur where the road is in cut and may result in groundwater entering the sub-base or subgrade layers. Inadequate surface or subsurface drainage can therefore adversely affect the pavement by weakening the soil support and initiating creep or failure of the downhill fill or slope. Localized seepage can be corrected in various ways but seepage along more impervious layers, such as shale or clay, combined with changes in road elevation grades, may require subsurface drains as well as ditches.

Channel shapes are determined for a location by considering the terrain, flow regime and the quantity of flow to be conveyed. Typically, ditch geometry is either V-shaped or trapezoidal. Roadway channels should provide recoverable slopes, thereby minimizing the impact of errant vehicles. This can be accomplished by designing ditch cross sections with mild side slopes. Depending on side slopes used, both V-shaped and trapezoidal ditches can provide driver safety and be economical to construct. When mild side slopes are used, the shape tends to approach a parabolic shape, which is recognized as being the most hydraulically efficient shape. V-shaped ditches are more susceptible to erosion, trapezoidal ditches may be preferred on certain soil conditions, such as fill sections and highly erodible soils [31].

The side slopes of the ditch/channel should not exceed the angle of repose of the soil comprising the ditch line and should be 3:1 or flatter. Where local conditions dictate the use of some rigid lining, the use of steeper slopes (>2:1) may be more economical [31].
The successful design of roadside ditches must satisfy two requirements: ditch capacity and stability. In general, the 10-year storm is used to determine ditch capacity, while the 2-year storm is used to check ditch stability. The logic implied in the selection of storm return period is that the initial time after ditch construction before vegetation is developed constitutes the most critical period regarding ditch stability. After vegetation is fully developed, the channel is considered stable, and channel capacity becomes more critical. Highly traveled roads, such as interstates, may require an increase of the design storm to reduce the probability of capacity failure.

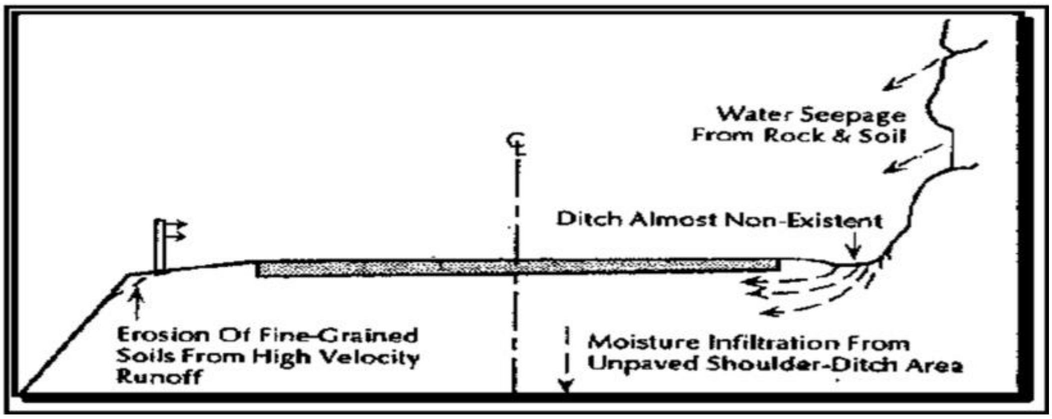

Figure 2. 4:Inadequate side drains

Source: [6]

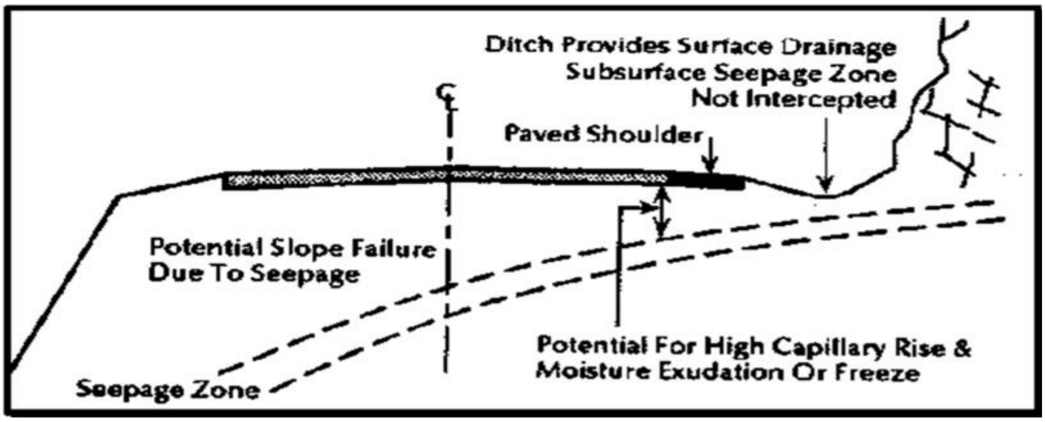

Figure 2. 5:Inadequate side drains and subsurface drainage

Source: [6]

If the road has effective side drains and adequate crown height, then the in-situ subgrade strength will stay above the design value. If the drainage is poor, the in-situ strengths will fall to below the design value.

The choice of side drain cross-section depends on the required hydraulic capacity, arrangements for maintenance, space restrictions, traffic safety and any requirements relating to the height between the crown of the pavement and the drain invert.

Under normal circumstances, the adoption of a trapezoidal cross-section will facilitate maintenance and will be acceptable for traffic safety. It is much easier and appropriate to dig and clean a trapezoidal drain with hand tools, and the risk of erosion is lower. The minimum recommended the width of the side drain is 500mm. This shape carries a high flow capacity and, by carefully selecting the gradients of its side slopes, it will resist erosion [5].

The V-shape is the standard shape for a drainage ditch constructed by a motor-grader or towed grader. It can be easily maintained by heavy or intermediate equipment, but it has relatively low capacity necessitating more various structures for emptying it. Furthermore, the shape concentrates flow at the invert and encourages erosion [32].

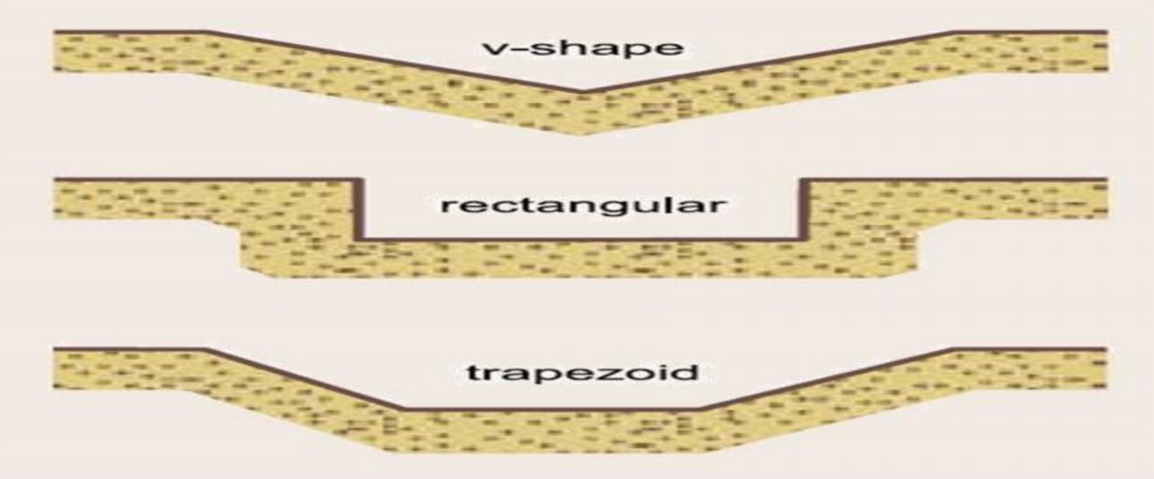

Figure 2. 6:Types of side drains

Source: [32]

The rectangular shaped drain requires little space but needs to be lined with rock, brick or stone masonry, or concrete to maintain its shape. In very flat terrain and reasonable soils, it is often best to use wide unlined “meadow drains." These are formed shallow and continuous depressions in the surface that avoid abrupt changes in surface profile. When properly designed, their capacity is high, and the flow velocity is low so that erosion should be controlled. When the subgrade is an expansive soil, changes in moisture content near to the road itself must be minimized.

Roadside ditches should be grassed channels except where non-erodible lining is warranted. A minimum desirable slope of 0.5% should be used. However, in some very flat areas, the minimum slope could be set 0.4%. To avoid damage or failure of drainage facilities, slope of ditches should not be greater than 6 percent. If it is greater, it should be cascaded or made of concrete [77].

Side drains (as well as the road itself) should have a minimum longitudinal gradient of 0.5%, except on crest and sag curves. The slackening of the side drain gradient in the lower reaches of significant lengths of the drain should be avoided to prevent siltation. Access across side drains for pedestrians, animals and vehicles needs to be considered. Community representatives should be consulted about locations, especially for established routes. The methods that could be used are: Widening the drain and taking its alignment slightly away from the road; hardening the invert and sides of the drain; beam/slab covers or small culverts. The arrangement must be maintainable and not risk blockage of the side drain. Failure to accommodate these needs will usually result in later arrangements that compromise the function of the side drain. Groundwater in the subgrade can be released either by using a drainage layer at sub-base level or by incorporating gravel cross drains in the shoulder that exit via a weep hole in the side drain backed with a piece of filter fabric. The weep holes must be set at the correct level to take the water from the appropriate pavement layer and the drain must be sufficiently deep so that there is little possibility of the water in the drain being of sufficient depth for it to flow back into the road. Deeper drains, comprising a filter-wrapped perforated pipe within a graded gravel backfill, can be constructed under very wet slope conditions to a depth of 1-1.5m below the level of the side drain invert and led to the nearest culvert inlet [5].

2.10 Hydrology

In the design of highway drainage structures, floods are usually considered in terms of peak runoff or discharge in cubic meters per second (m^3/s). The analysis of the peak rate of runoff, volume of runoff, and time distribution of flow is fundamental to the design of highway drainage structures. Errors in the estimates will result in a structure that is either undersized and causes more drainage problems or oversized and costs more than necessary. On the other hand, it is important to realize that any hydrologic analysis is only estimation. Although some hydraulics analysis is necessary for all highway drainage structure design, the extent of such studies should be commensurate with the hazards associated with the hydraulics structures and with other concerns, including economic, engineering, social, and environmental factors. Because hydrology is not an exact science, different hydrologic flow estimation methods developed for determining flood runoff may produce different results for a situation. Therefore, the engineer should exercise sound engineering judgment to select the proper flow estimation method or methods in estimation design flows. While performing the hydrological and hydraulics analysis for the design of highway drainage systems, the hydraulic engineer should recognize and evaluate potential environmental problems that would impact the specific design of a drainage structure early in the design process.

2.11 Hydraulic Design of Open Channels

An open channel is a conduit in which water is conveyed with a free surface. Although closed conduits such as culverts and storm drains are open channels when flowing partially full, the term is generally applied to natural and improved watercourses, gutters, ditches, and channels. While the hydraulic principles discussed in this section are valid for all drainage structures, the primary consideration is given to channels along, across, approaching and leaving the highway. In addition to performing its hydraulic function, the drainage channel should be economical to construct and maintain. Open channels should be reasonably safe for vehicles accidentally leaving the traveled way, pleasing in appearance, convey collected water without damage to the highway or adjacent property and minimize the environmental impacts [6].

2.11.1 Hydraulic Considerations

The hydraulic design of an open channel consists of developing a channel section to carry the design discharge under the controlling conditions, adding freeboard as needed and determining the type of channel protection required to prevent erosion. In addition to erosion protection, channel linings can be used to increase the hydraulic capacity of the channel by reducing the channel roughness. The hydraulic capacity of a drainage channel is dependent on the size, shape, slope and roughness of the channel section. For a, given channel, the hydraulic capacity becomes greater as the grade or depth of flow increases. The channel capacity decreases as the channel surface becomes rougher[6].

A rough channel can sometimes be an advantage on steep slopes where it is desirable to keep flow velocities from becoming excessively high. A good open channel design minimizes the effect on existing water surface profiles.

2.11.2 Safety Consideration

An important aspect of highway drainage design is that of traffic safety. The shape of a roadside channel section should minimize vehicular impact and provide a traversable section for vehicles leaving the traveled way. The ideal channel section, from a safety standpoint, will have flattened side slopes and a curved transition to the channel bottom.

2.11.3 Maintenance Consideration

The design of open channels and roadside ditches should recognize that periodic maintenance inspection and repair is required. Provisions should be incorporated into the design for access to a channel by maintenance personnel and equipment. When assessing the need for permanent or temporary access easements, entrance ramps and gates through the right of way fences, consideration should be given to the size and type of maintenance equipment required. Damaged channels can be expensive to repair and interfere with the safe and orderly movement of traffic. Minor erosion damage within the right of way should be repaired immediately after it occurs and action is taken to prevent the recurrence. Conditions, which require extensive repair or frequently recurring maintenance, may require a complete redesign rather than repetitive or extensive reconstruction. The advice of an Expert Drainage Engineer should be sought when evaluating the need for major restoration [6].

2.11.4 Environmental Considerations

Many of the same principles involved in sound highway construction and maintenance of open channels require environmental considerations. Erosion, sedimentation, water quality, and aesthetics should be of prime concern to the highway design engineer**.** Drainage has the potential of causing environmental harm. Therefore, it is important that environmental impacts are assessed and mitigated (as appropriate) as part of the development and operation of a road drainage system [6].

2.11.5 Channel Design

Hydraulic design associated with natural channels and roadway ditches is a process that selects and evaluates alternatives per established criteria. These criteria are the standards established to ensure that a highway drainage system meets its intended purpose without endangering the structural integrity of the facility itself and without undue adverse effects on the environment or the public welfare.

Side drains are essential for the performance of the road and they should be properly designed. Any savings in design cost will be far outweighed by increased maintenance costs over the life of the road.

2.12 Watershed Area

Most runoff estimation techniques use the size of the contributing watershed as a principal factor. Runoff rates and volumes increase with increasing drainage area. The size of a watershed will not usually change over the service life of the road drainage facility. However, agricultural activity and land development may cause the watershed area to change over time. Flow diversions and catchment area changes due to urbanization and other development inevitably will also occur at some point in the future. The drainage designer should try to identify or otherwise anticipate such changes. The watershed shape will also affect rainfall runoff rates. For example, a long, narrow watershed is likely to experience lower runoff rates than a short, wide watershed of the same size and other characteristics. Some hydrologic methods accommodate watershed shape explicitly or implicitly; others may not. If a drainage area is unusually irregular extremely narrow, the designer should consider using a hydrologic method that explicitly accommodates this watershed shape [6].

2.13 Urban storm water drainage system design

1. Rational Method

The Rational Method is most accurate for estimating the design storm peak runoff for areas up to 50 hectares (0.5 km^2). This method, while first introduced in 1889, is still widely used. Even though it has come under frequent criticism for its simplistic approach, no other drainage design method has achieved such widespread use [5].

The rational formula estimates the peak rate of runoff at any location in a catchment area as a function of the catchment area, runoff coefficient, and mean rainfall intensity for a duration equal to the time of concentration (the time required for water to flow from the most remote point of the basin to the location being analyzed). The rational formula is expressed as:

$$Q = 0.00278\ CIA \qquad (2.1)$$

Where: Q = peak flow in cubic meters per second (m^3/s)

C = runoff coefficient (weighted)

I = rainfall intensity in millimeters per hour (mm/hr)

A = drainage area in hectares (ha)

I. The following information should be obtained:
   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.

II. Select the appropriate runoff coefficient (C) value from standardized table values

III. Determination of the time of concentration (Tc).

IV. Determination of the rainfall intensity rate (I) for the selected recurrence intervals

V. Computation of the design flow, Discharge (Q = 0.00278 CIA)

2. Determination of Rainfall Intensity Rate (I):

The rainfall intensity(I) is the average rainfall rate in millimeters per hour for a drainage basin or sub basin. The intensity is selected based on the design rainfall duration and return period. The design duration is equal to the time of concentration for the drainage area under consideration**.**

$$R^{t}_{T}=(0.21\ln T+0.52)*(0.54t^{0.25}-0.5)R^{60}_{10} \quad \text{.................................} \quad (2.2)$$

for $2 \leq T \leq 100$ Years and $5 \leq t \leq 120$min

Where, R^{t}_{T}= rainfall depth in mm of a 'T' years return period in 't' minute duration,

T = recurrence interval (return period) of storm in years

t = rainfall duration (min**),**

R^{60}_{10} =rainfall depth in mm of one hour duration and 10 years return period.

IDF curves are developed for the corresponding rainfall intensities.

A standard form of the relation often used is

$$i = \frac{a}{(b+td)^c} \quad (2.3)$$

Where, I = rainfall intensity for a selected return period (mm/hr)

b = Regionally applicable constant

a = Obtained through a linear regression method

t_d = Rainfall duration (hrs)

c = for practical purposes it is taken as unity

3. Estimation of Time of concentration(Tc)

The time of concentration is the time required for the runoff to become established and flow from the most distant point of the drainage area to the point of discharge. Of the many equations for estimating Tc, for this study, following Airport formula was employed.

$$Tc = 3.64\,(1.1 - c)\,L^{0.83} / H^{0.33} \quad (2.4)$$

Where, Tc = Time of Concentration (hrs),

H = Elevation difference (m),

C = Runoff coefficient (unit less)

L = Flow length (km)

2.14 Manning's Equation

Discharge is determined for a known opening size of the drainage structure and bottom slope and/or the size of the drainage structure is determined for a known discharge and bottom slope by trial and error method. The Manning's equation can be used for uniform flow in a pipe, and stream channel, but the Manning's roughness coefficient needs to be considered variable, dependent upon the depth of flow. The Manning's equation is used for calculating the cross-sectional area, wetted perimeter, and hydraulic radius for flow of a specified depth in a pipe of known diameter and/or stream channel cross-section. Manning's equation is applicable for a constant flow rate of water through a channel with constant slope, size & shape, and roughness [5].

$$Q = \left(\frac{1}{n}\right) AR^{2/3}S^{1/2} \qquad (2.5)$$

Where, Q is the volumetric flow rate passing through the channel reach in m^3/sec.

A is the cross-sectional area of flow normal to the flow direction in m^2.

S is the bottom slope of the channel in m/m (dimensionless).

n is Manning roughness coefficient.

R is the hydraulic radius = A/P.

P is the wetted perimeter of the cross-sectional area of flow in m.

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on Ethiopian Mapping Authority (EMA) topographic maps (1: 50,000). Average flow velocity is usually determined for bank-full elevation. Manning’s equation or water surface profile information can be used to estimate average flow velocity. When the channel section and roughness coefficient (Manning’s n) are available, then the velocity can be computed using the Manning Equation [5].

$$V = \left(\frac{1}{n}\right) R^{2/3}S^{1/2} \qquad (2.6)$$

Where: V = average velocity, m/s

n = Manning’s roughness coefficient

R = hydraulic radius, m (equal to A/Pw)

A = cross sectional flow area, m^2

Pw= wetted perimeter, m

S = slope of the hydraulic grade line, m/m

2.15 Causes of Poor Drainage

World Bank Report as listed in [19] indicated that poor drainage conditions in developing countries are a result of weak institutional capacity, inadequate regulatory policies, inadequate governance, and general lack of public Education/awareness /participation. The resolution of problems associated with the infrastructural provision in most developing countries currently follows the traditions of the developed countries. Often, this is not appropriate for the locality. Urban drainage practice shows that in the past, the philosophy has been based on conveying peak flows of municipal wastewater and storm runoff away from the urban areas as quickly as possible [16]. This has resulted in downstream flooding and heavy pollution of receiving waters. But it should not be forgotten that in some developing countries especially where the qualities mentioned above exist, still drainage problems especially those related to weather conditions do still occur. The problems of poor drainage are adverse in developing countries.

In most developing countries, solid waste disposal is closely linked with urban wastewater drainage in that open sewers, and drainage channels often end up also being receptacles for solid wastes generated in the community. This leads to blockages, reductions in capacity and an exacerbation of flooding problems [1].

The increasing population concentrations associated with the urbanization process also resulted in increases in waste generation. Household wastewater was connected (disposed of in the nearest open channel) and in turn created problems of smell. Thus, the open channels constructed to alleviate flooding were covered creating combined sewer systems [15].

As the Cara [17] claim that developing Africa faces problems due to rapid urbanization and its accompanying overcrowding and congestion of urban areas. Development on land surfaces reduces permeability by replacing vegetated ground with roofs, roads and paved areas. Furthermore, Cara notes that there is an overall lack of physical structures like drainage systems, sanitation systems to support increasing urban population and insufficient funds to provide the good environmental living condition to all. Informal and unplanned settlements with inadequate drainage systems have developed to accommodate most of the people. This situation has resulted in environmental problems of poor management of both the human-generated wastes such as sewage, wastewater, and runoff. As reported by GTZ-IS that small urban storm water drainage problems represent one of the most common sources of complaint from the citizens in many towns of Ethiopia and this issue is getting worse and worse with the ongoing high rate of urbanization in different parts of the country [37].

As Raven points, out that storm runoff quality is often worse off than that of sewerage. Storm runoff carries salts, oils, untreated garbage, construction sediments and traffic emissions through rain which washes pollutants out of the air [17]. This normally contains asbestos, chloride, lead, organic wastes, sulphuric acid, and zinc. The provision and management of urban drainage system is a challenging problem in most cities/towns of Ethiopia [9].

2.16 Drainage problems

Successful drainage depends on early detection of problems before conditions require major action. Signs of drainage problems requiring attention include: puddles on the surface area, poor surface flow, slope erosion, clogged ditches, pavement edge raveling, preliminary cracking, pavement pumping, and surface settlement [65]. These signs indicate the start of failures which occur as soil particles are gradually washed away and as excess water seeps into the roadway reducing the load carrying ability of the subgrade. Major failures caused by poor drainage conditions include washouts, slides, slip outs, road and pavement breakup and flood damage [65].

Water is the biggest enemy of roads and most experts believe that most of pavement distresses and damages are due to poor drainage [66]. Per Ireri [67], eighty percent of existing road way problems can be traced to the presence of water from poor drainage either in or on the road pavement. Excessive water content in the pavement layers such as base, subbase, and subgrade soils can cause early distresses and lead to structural or functional failure of road, unless counter measures are undertaken.

The negative effects of water on road as softening and reducing the load carrying ability of subgrades and shoulders; increasing the disintegration of pavements and gravel surfaces; eroding roadside surfaces; depositing sediment and debris in ditches, pipes, catch basins and waterways; creating driving hazards for motorists and damaging adjacent property [27].

2.17 Urbanization impact on the urban drainage

The main issue in developing countries is urban development without planned drainage. Its consequences are the followings: population settlements on river flood plains, with increased flood damage, increase on flood frequency due to basin urbanization, degradation of urban areas due to erosion and sedimentation, water quality impact from wash-load of urban surface and solid waste.

2.17.1 Peak and volume impacts

With increasing urbanization and the pressures of population, the impervious surfaces in the metros are increasing, thereby increasing the volume of storm water runoff. In nature, when rainwater falls on a natural surface, some water returns to the atmosphere through evaporation, or transpiration by plants; some infiltrates the surface and becomes groundwater; and some runs off the surface (figure 2.7(a)).The relative proportions depend on the nature of the surface, and vary with time during the storm.

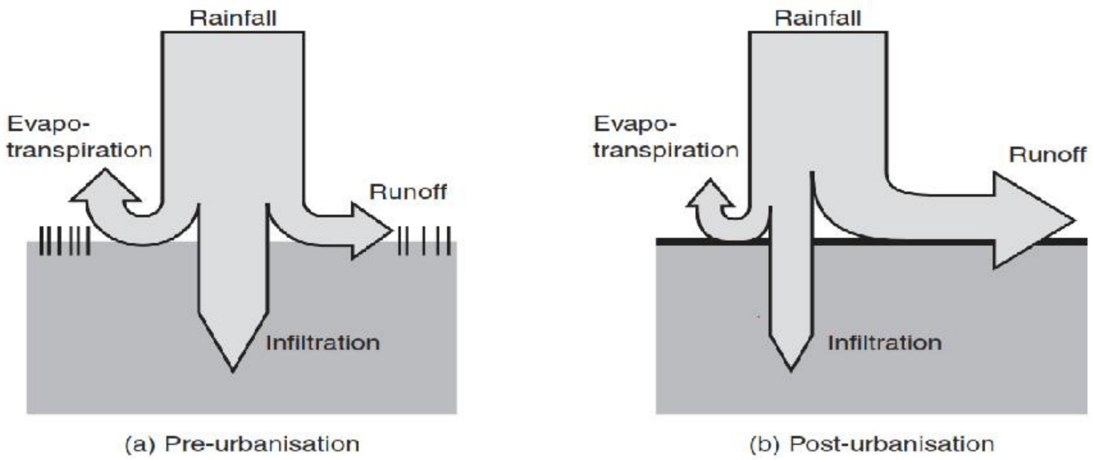

Figure 2.7:Effect of urbanization on fate of rainfall

Source: [38]

Development of an urban area, involving covering the ground with artificial surfaces, has a significant effect on these processes. The artificial surfaces increase the amount of surface runoff about infiltration and therefore increase the total volume of water reaching the river during or soon after the rain (figure 2.7(b)). Surface runoff travels quicker over hard surfaces and through sewers than it does over natural surfaces and along natural streams. This means that the flow will both arrive and die away faster, and therefore the peak flow will be greater [38].

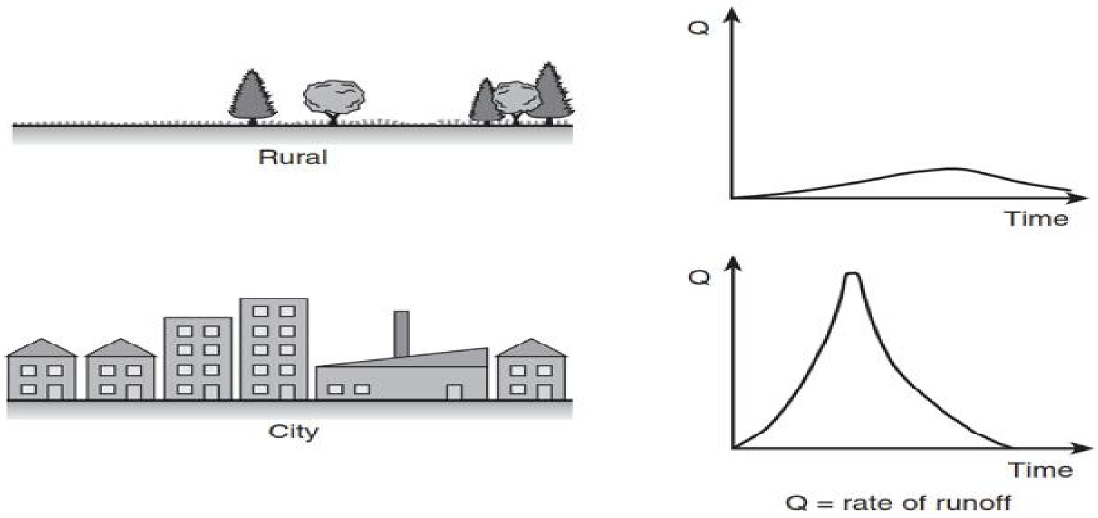

Figure 2.8:Effect of urbanization on peak rate of runoff

Source: [38]

Besides the failure to plan drainage networks adequately, municipalities encounter many difficulties in enforcing legislation. These difficulties are due to the following:

- Large increase in urbanization: most new developments within the city boundaries are not approved by the township and do not have the required storm water and sewer networks. This arises from lack of control and law enforcement;
- Invasion of public areas: public areas, such as planned green areas, become occupied by poor and homeless people who settle there;
- Occupation of flow conveyance areas: during periods when no floods occur, low-lying and other areas that might be reserved for flood-water dispersal is used for poor-quality dwellings. These areas have the high potential risk of damage and loss of life.

2.17.2 Sediment and total solids

Sediments and total solids in urban areas are mainly produced in two stages:

- **Urban development**, when sediment production is due to the lack of soil protection during urban construction. It is much more critical in the tropics since rainfall intensity is higher and the wet seasons are longer with many days of high-intensity rainfall. A major erosion control program was developed in the state to control the impact of urbanization [25].

- **Developed urban area** when the urban area has already been developed, the solids produced in the basin are mainly due to garbage washed away from urban surfaces. The total number of solids is a function of the frequency of garbage collection and cleaning of street surfaces, free disposal of garbage, and rain frequency. One of the main causes of flooding in urban drainage in cities in developing countries are the decreased hydraulic capacity of the storm water drainage due to conduits and trash filling the channels during floods [25].

  Some of the problems related to sediments and total solids in the urban environment of cities in developing countries are:

  - Urban occupation in risk areas such as hill slopes. Without drainage, after several days of rain, landslides destroy houses and kill people and increase the sediment yield to downstream drainage;
  - Lack of a reliable garbage disposal system. Part of the population in poor neighborhood dumps the trash on streets and in the drainage system;
  - Lack of street cleaning or its low frequency;
  - Lack of control in construction sites.

2.18 Effects of urbanization on land use/land cover

The urbanization process can be said to be transformation of landscapes, characterized by rural life styles into urban landscapes and determines lateral and structural changes that result into a new landscape patterns. Per Rimal [60] urbanization is an increased system modernization process, which modifies the socio-economic activities and revolutionizes the land use pattern in accordance with time frame.

Modica et al, [61] define urbanization as a complex diffusion process, that result into dramatic spreading and variously affecting rural landscape at varying spatial scales. Ademiluyi, et al., reported that rapid urbanization/industrialization and large scale agriculture and major changes in human activities have been identified as the major causes of the dramatic changes in land cover and land use patterns globally [62].

Urban expansion is indicated by an increase in the population of people living in these areas. The result of such changes in the urban areas impact on the natural landscape, river morphology, drainage system and land use/land cover of the area increasing the frequency of water induced hazards [63]. Urban land expansion refers to the spreading out of a city and its suburbs towards non-built-up areas at the periphery of an urban area; involving the conversion of other land uses into built-up land over time [64]. Urban land expansion is the most easily identifiable characteristic of urbanization process as it affects land cover/use at both regional and global scales.

2.18.1 Land use System and Urbanization in Dire Dawa City

Dire Dawa is one of the fast-growing city in Ethiopia. It has recorded a dramatic growth since its foundation. The first Master plan of Dire Dawa was prepared in 1967 that has now become outdated. The land use master plan that dates back to late 1967 and 1994 [70] indicated that the total planned area was 2928 and 3241 hectares respectively. By the year of 2004, the city extended to 8386 hectares and still the city is expanding.

The land use system Dire Dawa is mixed. All the urban activities are going on together. The city center is highly populated around 350-500 per hectare (above the normal standard) with poor urban facilities. The land use system of the city is dominantly mixed especially residential areas with commercial activities. This is true notably in the central part of the city where almost all buildings along the streets are used for commercial activities and their backyards or internal courtyards are used for dwelling purpose. Residential areas cover around 680 ha (10%); squatter settlement is estimated 980 ha (12%) and all about consists of 50% of the total built-up area [69].

2.19 Waste Management Practice in Dire Dawa City

Taye report stated that Dire Dawa city is a fast growing industrial and commercial town, which produces pollutants in great quantities. The town has no sewer system and wastewater treatment plant. The main sources of pollution are multiple point sources pollution of pit latrines, septic tanks and linear source pollution of industrial and domestic waste disposal along the sandy seasonal river channels [71].

Waste generated from industries, agricultural activities, households, market centers, institutions, garages, fuel stations and the health centers are the main sources of pollutants that may affect the quality of water in the area. As WWDSE result shows that, over 75 % of the health problems in Ethiopia are due to transmittable diseases attributed to unsafe and inadequate water supply; particularly human waste disposal system [72]. As to the DDAC conservation strategy document stated that the solid waste collection and disposal situation in Dire Dawa is 76% dump outside in an open field, 14% in pit, and 10% burning [73].

As Eyilachew reported that the rapid urbanization and lack of master plan implementation strategy are the main causes of environmental pollution. The city has weak waste management mechanisms. The main sources of pollution are multiple point sources of pit latrines, septic tanks and linear source pollution of industrial and domestic waste disposal. Annually, about 10,000 m^3 of solid wastes and 65,000 tons of human excreta are simply released into the surrounding environment without any pre-treatment mechanisms. There is no 3R (Recycle–Reduce–Reuse) waste management principles. Domestic and industrial wastes are the main sources of pollution. These all urban activities directly or indirectly contribute for the surface and subsurface environmental pollution.

2.20 Urban drainage and environmental

Although flooding problems are prominent during the wet season, other effects of poor drainage are perennial and intrinsically linked to deterioration in sanitation and environmental health conditions. The implications of these problems are less tangible than inundation by storm water but the effects have major implications on the health and livelihoods of urban populations.

In poorly drained areas, urban runoff mixes with sewage from overflowing latrines and sewers, causing pollution and a wide range of problems associated with the increased risk of waterborne diseases. Poor drainage creates faecally contaminated wet soils that are ideal conditions for the spread of intestinal worm infections such as roundworm and hookworm. Open drains carrying sewage or sullage water are potential sources of infection to children who play in them, and flooded septic tanks and leach pits provide breeding sites for mosquitoes that are responsible for the spread of several diseases. The impacts on the environment associated with poor drainage and wastewater management are also widespread. The pollution of natural watercourses from the discharge of untreated wastewater may threaten the livelihoods of poor communities who depend upon water resources for subsistence farming [39].

2.21 Urban drainage and public health

In human terms, the most valuable benefit of an effective urban drainage system is the maintenance of public health. This objective is often overlooked in modern practice and yet is of extreme importance, particularly in protection against the spread of diseases. That diseases such as cholera are almost unknown in the industrialized world today is in major part due to the provision of centralized urban drainage (along with the provision of a microbiologically safe, potable supply of water). Urban drainage has several major roles in maintaining public health and safety. Human excreta (particularly feces) are the principal vector for the transmission of many communicable diseases. Urban drainage has a direct role in effectively removing excreta from the immediate vicinity of habitation [38].

2.22 Urban storm water pollution and its prevention

As Adams and Papa reported that urban storm water pollution results from the small, incremental, and collective activities of the public [40]. The origins of urban storm water pollution are often the result of the unintended and unrecognized consequences of thousands of routines, seemingly inconsequential decisions made daily. Routine home and yard projects can contribute pollutants to the urban storm drain system if preventive measures are not taken. Public education is one key to prevent urban storm water pollution. The better the public understands what causes urban storm water pollution, and the simple measures that can be taken to prevent urban storm water pollution, the cleaner the storm water and local streams will become. To address urban storm water pollution through the cooperative efforts of an informed community it is paramount to increase public awareness about urban storm water pollution and educate the community about specific pollutant sources and on what they can do to reduce them in urban storm water (ibid). Thus, the purpose of public outreach and educational efforts should be to increase community awareness about storm water pollution and to discourage the release of non-storm water discharges into the storm drain system.

CHAPTER THREE

MATERIAL AND METHODOLOGY

This chapter has focused on materials and methods which were employed to address the indicated research objectives. It includes: materials, description of study area, research design, sampling technique and sampling size, study variables, data collection methods, data analysis, and interpretation with appropriate statistical tools.

3.1 Materials

The materials that were used for the study of the research were digital camera, measuring tape, handheld GPS and drainage network map. Digital camera for documentation and measuring tape to measure the existing roadside drainage lines lengths, depth, and width which helps to evaluate the capacity of the drainage system. Drainage network map to consider the overall conditions of urban roadside drainage and its integration, compass survey to indicate the direction and handheld GPS to determine the elevation of roadside drainage and to measure the catchment area in the study area.

3.2 Description of study area

3.2.1 Location

The Dire Dawa City (DDC) is geographically located in the eastern part of the country specifically lying between $9^{0}27'$ and $9^{0}49'$N latitudes and between $41^{0}38'$ and $42^{0}19'$E longitudes, and the city is 515 Km from Addis Ababa the capital city of Ethiopia and 333 km from the international port of Djibouti. The total area of the administration is 133,262 hectares of land, of which only 2 percent constitute the built-up urban areas. The remaining 98 percent constitutes potential expansion areas and rural Dire Dawa. The altitude ranges from 1000-2200 meters above sea level.

The Administration shares common boundaries with Somali National Regional States in the West, North and East and with the Oromia National Regional State in the Southern part of the country. Dire Dawa city Administration is located at a center of Ethio-Djibouti railway. This gives Dire Dawa city the advantage of being a commercial city.

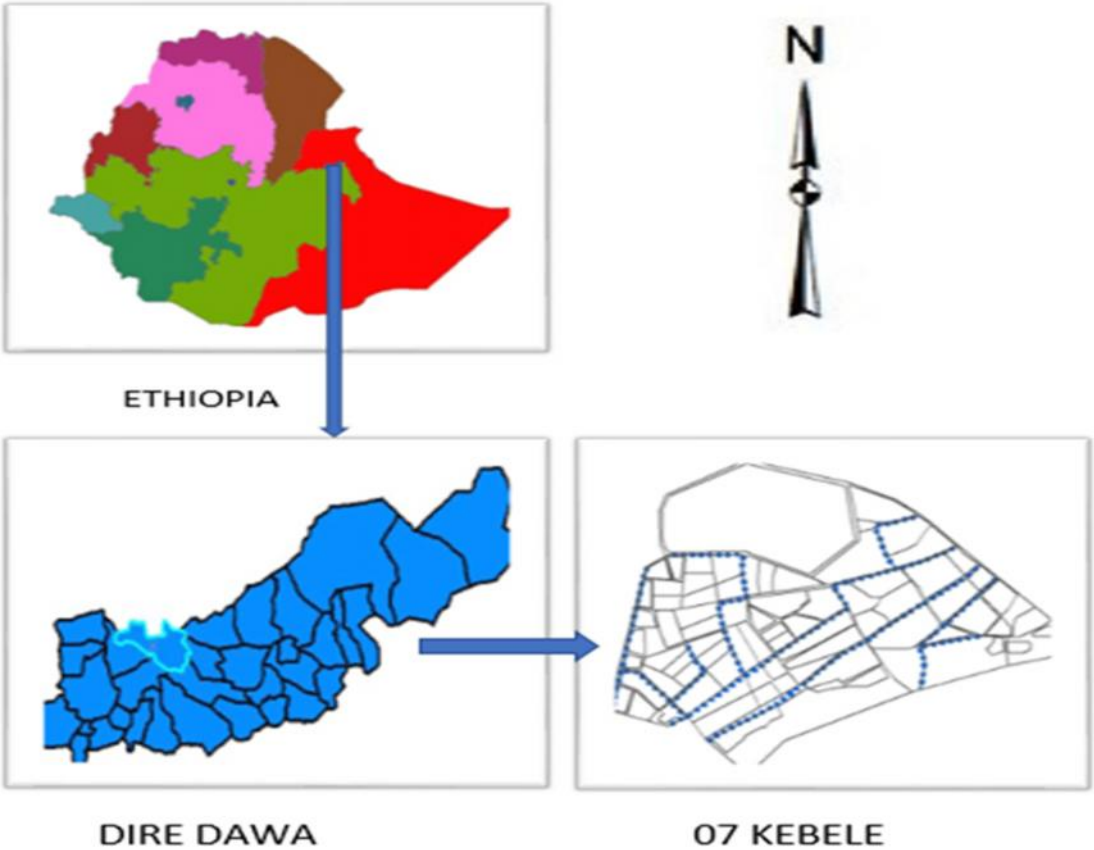

Figure 3.1:Study Area

3.2.2 Population

The study population is that part of the general population that possesses the characteristics that the research aims to study, that is, fulfills the requirements of the research [68]. In this study, the study population is divided into four groups; Dire Dawa road authority, Dire Dawa sanitation and beautification agency, the road users and the residents of 07 kebele in Dire Dawa city.

The engineers from Dire Dawa road authority were chosen as the target population for this study because they have the background knowledge on the general design of the drainage and its construction. Dire Dawa sanitation and beautification agency were chosen as the target population for this study because they have knowledge on how to keep the urban sanitation and beautification.

Road users and residents of the study area were also the target population of this study because they were directly affected by the poor state of the drainage system.

3.2.3 Climate

The Dire Dawa city Administration and its surroundings are among the most broken and mountainous regions of the country, but with a difference that the slope in the Administrative is lower compared to the northern and northeastern part of Ethiopia.

The climatic condition of the DDC is in the range of hot and Kolla agro-climatic zone; per Ethiopian agro-climatic zones the area has predominantly hot and dries climatic features. The mean temperature is 24^0C with minimum temperature 21.5^0C and maximum temperature 27.6^0C. It is hot in March to June, and relatively cold during the months of November-February.

3.2.4 Land use and Land Cover

The vegetation covers of Dire Dawa city (DDC) is categorized as the vegetation of arid and semi-arid lands (highly variable, including cactus scrub, thorn scrub and many kinds of wood and sparse grasses formations). There is no climatic climax forest in the region except patches of few junipers remnants in the upper parts and some acacia trees in the low lands. The vegetation of the region is not found in contiguous form covering the large area; rather it is fragmented patches of bushland, shrubland, and trees in agricultural sites and hillsides. The upper reaches of the western part of the escarpment are covered with scattered junipers open woodland with small eucalyptus plantations. Below the escarpment and in the valleys between the ridges is cultivation with eucalyptus homestead woodlots. The ridges are largely devoid of vegetation with only scattered low shrubs and grassland. The plains to the north-east are also bare, while those to the south-east are covered with low shrubland.

According to the land cover mapping units of DDCA, about 9.19 percent of the total land area of the region is covered by physiognomic vegetation; 4.93% prosaic Juliflora plantation, 3.67 % open shrub land and 0.58% dense shrub land. Whereas, the vast area of the region, 60.48%, is an exposed soil, sand or rock with scrubs and grasses.

3.2.5 Geology and Geomorphology

The general geomorphology of the Dire Dawa region is structure controlled. The escarpment that is formed by rift forming step faults drops about 900 m from Dengago to Dire Dawa city. The city spreads mostly over a vast flat alluvial plain, and it is surrounded by limestone ridges and high grounds on the south and east and volcanic rock ridges on the north. Isolated small sandstone hills are also observed in the scattered manner on the alluvial plain. The alluvial deposits consist of cobbles and coarse-grained sediments near the escarpment on the south, and finer sediments in the plain and towards the north. The thickness of the alluvial deposit is variable, attaining over 200m based on data of previous test wells drilled near Dire Dawa.

From the aspect of general geology, DDA area is composed of:

- Mesozoic sedimentary rocks (sandstone and limestone);
- Tertiary volcanic rocks (aphyric basalt associated with rhyolite or ignimbrites and subordinate trachytes);
- Quaternary sediments consisting of alluvial sediments, lacustrine deposit (travertine) and river sand deposit. The alluvial sediment is a weathering product of the existing rock types in Dire Dawa area and is mainly covering the low-lying depressions of the Dire Dawa city administration. The sediment consists boulders, gravel, sand and silty clay.

3.3 Study design

In this study, descriptive and exploratory types of research methods were employed. The descriptive type was used to describe the existing condition and coverage of roadside drainage of 07 kebele in Dire Dawa city. This method was employed to describe the extent to how urban development affects the roadside drainage and environment. This method was also used to describe various factors which would contribute roadside drainage problem and impact of poor roadside drainage on the highway. Whereas, the exploratory type was particularly used to explore the existing condition by making some required physical measurements (roadside drainage line length, widths, depth and elevation of inlet and outlet).

The data source for this research work were collected both from primary and secondary sources. Field survey, in depth-interview and questionnaires were the primary data sources which were employed in this study with the help of a drainage network map. Secondary data was the other type of data collection method using existing records, master plan, and other proceedings and reports.

Various techniques of data collection such as questionnaires, in depth interview, photographs and field survey, were employed in the study to obtain the information required to meet the objectives. Likert scale was used in questionnaires and in depth-interview to identify the response scale to obtain degree of agreement (strongly agree to strongly disagree) with a statement or set of statements. In field survey, roadside drainage line length, widths and depths of the side drainage was measured by using the tape measurement and elevation of inlet and outlet and catchment area was measured by using handle GPS.

After the data was collected by different methods, the data was analyzed and presented in organized manner. Data collected by questionnaire and in depth interview was analyzed by using statically expression was important to identify and to rank the factors that causing the problems in the study area. The collected data from the field measurement was computed per urban storm water drainage design manual consideration. The data collected was checked and analyzed using the help of Arc GIS 10, SPSS version 20 software and Microsoft-Excel. The analyzed data was presented in tables, charts, graphs, and percentages.

3.4 Sampling Technique and Sampling Size

One of the central objectives of this study was to evaluate the effects of urban development on the roadside drainage problem and remedial measure in case of 07 kebele in Dire Dawa city; to this end to get the necessary information; this study was used to purposive sampling techniques to select respondents.

The basic reasons to select above population groups, Dire Dawa road authority have the background knowledge on the general design of the drainage and its construction, Dire Dawa sanitation and beautification agency have knowledge on how to keep the urban sanitation and beautification, and the road users and the residents were directly affected by the poor drainage condition in the study area. Various methods of data collection such as questionnaires, field survey, and interview were employed in the study to obtain the information required to meet the objectives. The questionnaire was particularly prepared for the Dire Dawa road authority and Dire Dawa sanitation and beautification agency in this study. From questionnaire, 9 respondents from the Dire Dawa road authority and 7 respondents from the Dire Dawa sanitation and beautification agency. Also, the interview was prepared for the road user and the residents in this study. From interview, 27 respondents from the road users and 20 respondents from the residents. Therefore, the sample size in this study was 63 respondents.

3.5 Study Variables

The independent variables of the study are:

- Poor waste disposal
- Lack of community awareness
- Lack of roadside drainage cleaning
- Damaged drain lines due to urban infrastructure construction
- Unsettlement of the population

The dependent variable of the study is:

- Roadside drainage problems.

3.6 Data-collection methods

Various methods of data collection such as questionnaires, photographs, field survey, and interview were employed in the study to obtain the information required to meet the objectives.

Questionnaire

The questionnaire is a research instrument consisting of a sequence of questions for gathering information from respondents. This was particularly prepared for the Dire Dawa road authority and Dire Dawa sanitation and beautification agency in the study area. This has been comprised of those data related to identifying factors causing the roadside drainage problems, impacts of a poor drainage system on residential and road users, the major suggestion solution to roadside drainage problems in the study area and others related to the study objectives. To use Likert scale to identify the response scale primarily used in questionnaires to obtain degree of agreement (strongly agree to strongly disagree) with a statement or set of statements. In this study,4-point scale (1- Strongly agree,2- Agree,3- Disagree and 4- Strongly disagree) can be used evaluate the results using descriptive statistics. Individual responses are normally treated as ordinal data because although the response levels do have relative position, we cannot presume that participants perceive the difference between adjacent levels to be equal (a requirement for interval data). Likert scales are a non-comparative scaling technique and are unidimensional (only measure a single trait) in nature. Respondents are asked to indicate their level of agreement with a given statement by way of an ordinal scale.

Photographs

Photography was used to identify the existing condition of the study area by recording than observations. It a research instrument to capture image to gathering the information from the field. It was meant to give a visual understanding of the research issues to the readers of this research and the state of the urban roadside drainage system.

Figure 3.2:Blocked roadside drainage due to waste disposal and sediment accumulation

Source: From field

Field survey

Field survey refers to the systematic examination of real-time processes or operations with the goal of identifying needs/challenges or improving processes and practices that is, what can be seen. A field survey was employed with the help of the drainage network map as per the objective of this study. In field survey, roadside drainage line length, widths and depths of the side drainage was measured by using the tape measurement and elevation of inlet and outlet was measured by handle GPS. The drainage network map was attached in Annex D.

Interview

Generally, this was employed to collect data related to roadside drainage problem and its causes, major challenges to roadside drainage problems, the possible solution to roadside drainage problem in the view of Dire Dawa road authority, the enforcing factors to dump solid and liquid wastes to existing roadside drainage and possible suggestions in the view of municipality to handle the challenges of the drainage system in the study area. The residents and road users were interviewed to get reliable data as they are the most affected part of the study area.

3.7 Data analysis

After each necessary data for the study were collected, data analysis would be done. The collected data were analyzed per their types of quantitative and qualitative. Data analysis began with arranging data collected from the field and, which data was tabulated and presented. The row data collected were organized and grouped to be easy for the analysis. Using statically expression was important to identify and to rank the factors that causing the problems in the study area. Data were analyzed on the information about the respondents, existing side drainage system in the study area, factors causing for roadside drainage due to urban development, the effects of poor roadside drainage on the highway and environment. The data collected was checked and analyzed using the help of ArcGIS 10, SPSS version 20 software and Microsoft- Excel and the analyzed data was presented in tables, charts, graphs, and percentages.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

This chapter is the central part of this study. It describes and discusses the result obtained in this study; it includes the existing condition of the roadside drainage, the factors causing roadside drainage problem, the effects of urban development on the highway and environment in the study area.

4.1 The Existing Condition of the Roadside Drainage in the Study Area

4.1.1 Capacities of the Existing Roadside Drainage

Urban drainages system is designed based on urban safety and environmental protection criteria to give better services regarding to safely removing the urban runoff into the water ways. One of the most essential for a highway to properly function is proper roadside drainage that needed to minimize water depths occurring on road surfaces during heavy storms and to prevent seepage causing damage to the pavement structure.

The storm drainage facilities are generally classified into closed and open drainage lines. But, all the storm drainage facilities in the study area was rectangular and open drainage channels which was constructed from masonry are found along local roads. This may encourage residents to connect and dump their sewerage system and solid waste, resulting in flooding problems, unpleasant smells and unaesthetic to the environment.

During the field survey, the elevation and dimension of the roadside drainage was made to measure the amount of the discharge conveyed in the existing roadside drainage could be determined. The surface condition of the existing side ditch was gravel bottom with concrete. The value of manning roughness coefficient (n) was identified from Annex B.

The area of side ditch was calculated by multiplying the width with the depth of the rectangular drain ($A = Br * Yr$) and the wetted perimeter was calculated by adding width with the depth of the rectangular drain ($P = Br + 2Yr$). The discharge and channel flow velocity of existing side ditch was computed based on the equation 2.5 and 2.6.

Table 4.1 shows a calculation of the discharge that is conveyed through the existing side drainage in the study area.

Table 4.1:Computation of the capacity of the existing drainage system

No	Flow direction		Drainage types							
			Rectangular							
	From	To	Br(m)	Yr(m)	n	A(m^2)	P(m)	S (%)	Q(m^3/s)	V(m/s)
1	DL1	DL3	0.4	0.4	0.02	0.16	1.20	3.00	0.35	2.18
2	DL2	DL3	0.3	0.4	0.02	0.12	1.10	1.00	0.14	1.17
3	DL3	Outlet	0.5	0.45	0.02	0.23	1.40	4.00	0.68	3.02
4	DL4	Outlet	0.4	0.5	0.02	0.20	1.40	2.00	0.38	1.90
5	DL5	DL6	0.4	0.45	0.02	0.18	1.30	3.00	0.39	2.18
6	DL6	DL7	0.4	0.5	0.02	0.20	1.40	2.00	0.39	1.94
7	DL7	DL8	0.8	0.65	0.02	0.52	2.10	3.00	1.71	3.30
8	DL8	DL9	0.8	0.68	0.02	0.54	2.16	1.00	0.89	1.63
9	DL9	Outlet	0.87	0.77	0.02	0.67	2.41	2.00	1.91	2.85
10	DL10	DL11	0.4	0.4	0.02	0.16	1.20	1.00	0.15	0.96
11	DL11	DL12	0.5	0.4	0.02	0.20	1.30	2.00	0.37	1.87
12	DL12	DL13	0.5	0.45	0.02	0.23	1.40	2.00	0.50	2.22
13	DL13	DL9	0.5	0.6	0.02	0.30	1.70	1.00	0.54	1.79
14	DL14	DL15	0.35	0.4	0.02	0.14	1.15	2.00	0.22	1.59
15	DL15	DL19	0.3	0.35	0.02	0.11	1.00	1.00	0.14	1.32
16	DL16	DL18	0.4	0.4	0.02	0.16	1.20	3.00	0.38	2.38
17	DL17	DL18	0.4	0.38	0.02	0.15	1.16	4.00	0.37	2.42
18	DL18	DL19	0.57	0.47	0.02	0.27	1.51	4.00	0.86	3.22
19	DL19	DL9	0.59	0.75	0.02	0.44	2.09	1.00	0.58	1.31

Source: Own analysis

Note

DL=drainage line, Br = base of a rectangular drain, Yr = depth of a rectangular drain, A = drainage/catchment area, P =wetted perimeter, S =slope, Q =volumetric flow rate and V= average velocity.

Slope is one of the factor that must be considered during the hydraulic design of the open channel in order to convey runoff into the water way. As stated in urban storm water drainage design manual in review literature in section 2.9, the minimum desired slope used for roadside ditch was 0.5% should be used and in flat area, the minimum slope used for roadside ditch could be 0.4%. As it can be seen from table 4.1, all the roadside ditch slope in the study area was greater than the minimum required used for roadside ditch.

Most of side ditches do not have proper size with small width (less than 0.5m) and depths (less than 1m) to let water pass through them. Drainage line 1,2,4,5,6,10,14,15,16 and 17 has less than the recommended width value by ERA drainage manual.

4.1.2 Estimated Runoff for the Study Area

In this study, the runoff water generated from the drainage catchments was determined based on urban storm water drainage design manual. The peak runoff rate of the catchments in the study area was determined using the rational method because of it covers less than 50 ha. To calculate the total basin area or catchment area, the catchment area of the 07 kebele was separated from the Dire Dawa city.

To evaluate the existing capacities of the side drainage system, the current runoff from the catchment area to side drainage must be estimated. From Annex A, the study area was found in rainfall region A4 and hydrologic soil group A. The rainfall intensity (I) was calculated from the 10-years rain fall data which has been obtained from Ethiopia metrology agency. From Annex C, the value of runoff coefficient (C) was identified by considering the types of drainage area. The value of runoff coefficient (C) was identified from Annex C.

Table 4.2:Estimated current runoff for the study area

No	Flow direction		Description of sub catchment	Run off coefficient (c)	Total basin area At (ha)	Length of the basin Lc (m)	Highest elevation of the basin	Lowest elevation of basin	Average slope of the basin So	Time concentration (hr)	Rainfall intensity I(mm/hr)	Total run off for plot of basin Qs (m^3/s)
	From	To										
1	DL1	DL3	Neighborhood	0.6	2.23	321.00	1217	1208	0.028	0.34	166.35	0.62
2	DL2	DL3	Neighborhood	0.6	2.86	285.00	1211	1208	0.011	0.45	143.27	0.68
3	DL3	Outlet	Neighborhood	0.6	1.46	96.00	1208	1204	0.042	0.16	230.26	0.56
4	DL4	Outlet	Sub urban	0.37	9.98	1393.00	1218	1191	0.019	1.18	72.34	0.74
5	DL5	DL6	Sub urban	0.37	1.78	150.30	1219	1215	0.027	0.35	164.91	0.30
6	DL6	DL7	Neighborhood	0.6	0.59	148.00	1215	1212	0.020	0.26	191.28	0.19
7	DL7	DL8	Apartment area	0.5	3.94	392.98	1219	1208	0.028	0.46	141.54	0.78
8	DL8	DL9	Apartment area	0.5	0.97	149.85	1208	1207	0.007	0.45	142.31	0.19
9	DL9	Outlet	Apartment area	0.5	2.68	668.00	1207	1195	0.018	0.69	108.28	0.40
10	DL10	DL11	Cemetery	0.2	9.80	369.20	1210	1208	0.005	1.14	74.32	0.40
11	DL11	DL12	Single family area	0.4	1.76	234.55	1208	1204	0.017	0.48	136.49	0.27
12	DL12	DL13	Single family area	0.4	0.44	88.80	1204	1202	0.023	0.27	187.17	0.09
13	DL13	DL9	Neighborhood	0.6	0.48	154.00	1202	1200	0.013	0.31	176.43	0.14
14	DL14	DL15	Single family area	0.4	2.50	297.85	1204	1199	0.017	0.55	126.15	0.35
15	DL15	DL19	Neighborhood	0.6	0.66	142.00	1199	1197	0.014	0.29	182.44	0.20
16	DL16	DL18	Cobble stone	0.8	2.85	422.00	1213	1199	0.033	0.22	204.45	1.30
17	DL17	DL18	Cobble stone	0.8	0.77	170.00	1205	1199	0.035	0.14	243.79	0.42
18	DL18	DL19	Single family area	0.4	0.62	72.00	1199	1196	0.042	0.20	214.14	0.15
19	DL19	DL9	Single family area	0.4	0.83	184.85	1196	1195	0.005	0.63	115.36	0.11

4.1.3 Hydraulic Capacity and Runoff Water in the Study Area

One of the most important to constructed the urban drainage system was to collect the runoff and convey it into water way. But as it was observed from table 4.1 and 4.2, the runoff water generated from the surrounding area was higher than the hydraulic capacities of side drainage.

As presented in figure below, out of the total lengths of water drainage existed in the study area, only 40.8% of the side drainage can convey safely the runoff into the water ways. This shows that the most of the side drainage lines have lower capacity and runoff water generated in the study area cannot be safely discharged into the nearby river.

There are different reasons why the hydraulic capacities of roadside drainage were lower than the runoff water generated from the study area. Most of the existing roadside drainage line in the study area have been installed long term ago and failing to convey the runoff water from the basin area. It also challenged by improper waste disposal to side drainage, lack of community awareness, lack of frequently clearance of roadside drainage and damaged roadside drains due to urban infrastructure construction. To match the side drainage facilities and runoff water in study area, proper side ditch should be constructed.

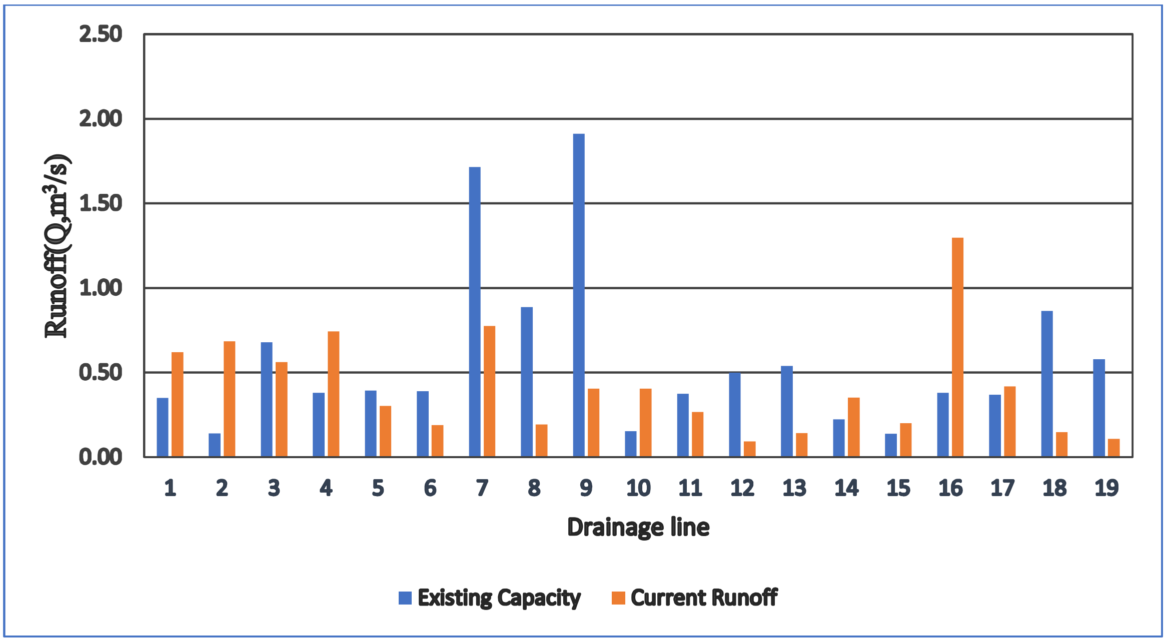

Figure 4.1:Comparison of the capacity and the current runoff for the study area

In 07 kebele, drainage line 1, 2, 4,10,14,15,16 and 17 have low capacity to carry on the amount of runoff from the catchment area. From total length of roadside drainage 59.2%

have low hydraulic capacity than the runoff water. This drainage line was located around Konel, from Konel-Taiwan, from Taiwan -Ashawa, around Muslim Cemetery, and Megala chabtu -Alleybade.

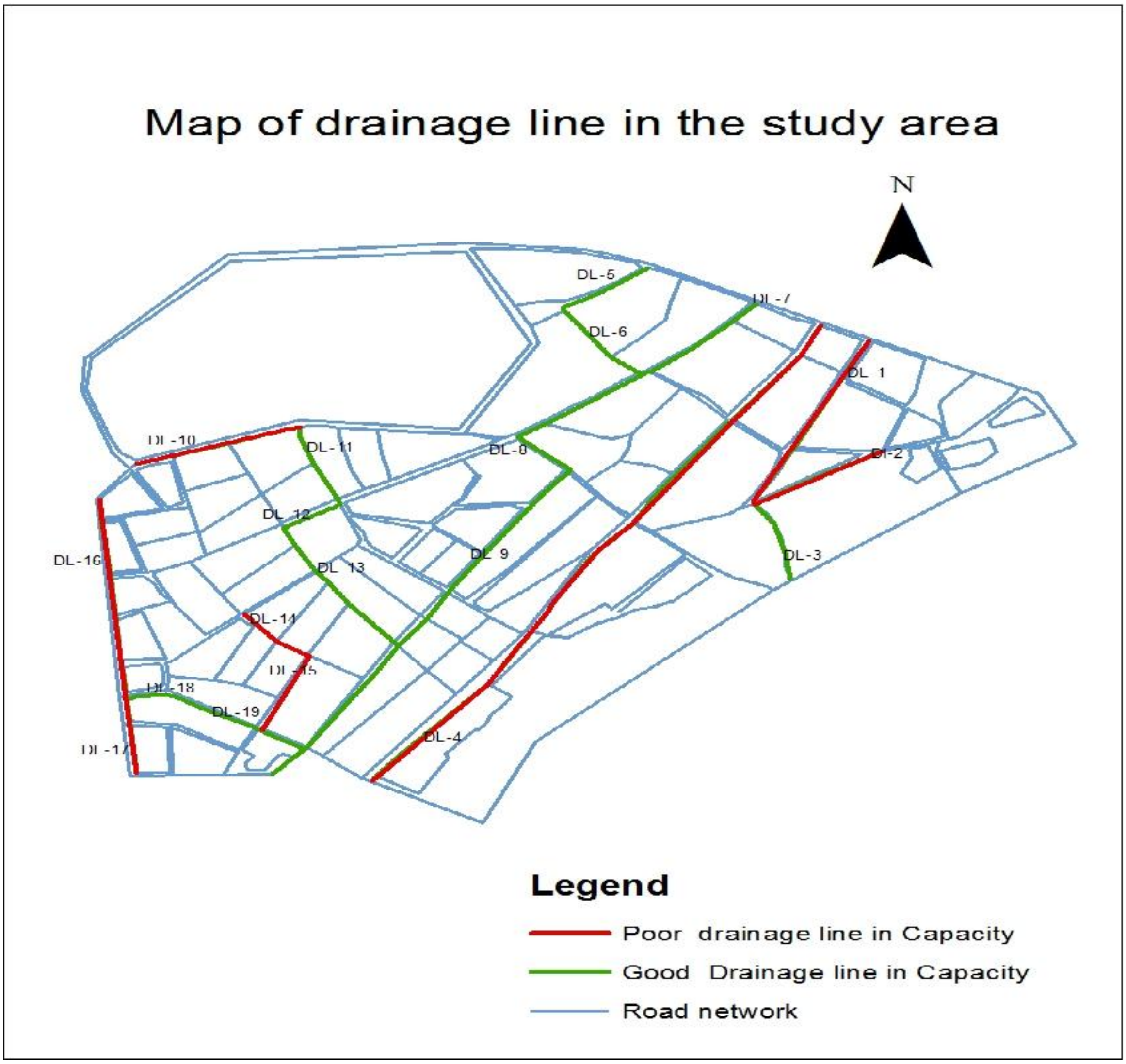

Figure 4.2:Map of drainage line in the study area

Source: Own analysis

4.2 Results from Respondents

Response from the Dire Dawa road authority office

Urban drainage is one of the most an important urban infrastructure in determining the ability of the road pavement to withstand the effects of traffic and environment. Good urban storm water drainage condition was useful to improve and enhance health, safety, improvement of living conditions and human well-being, rehabilitation of urban areas, environment protection and aesthetic reasons. As the respondents stated that the drainage condition in the study area very poor which causes urban flooding, road failure, air pollution and environmental pollution.

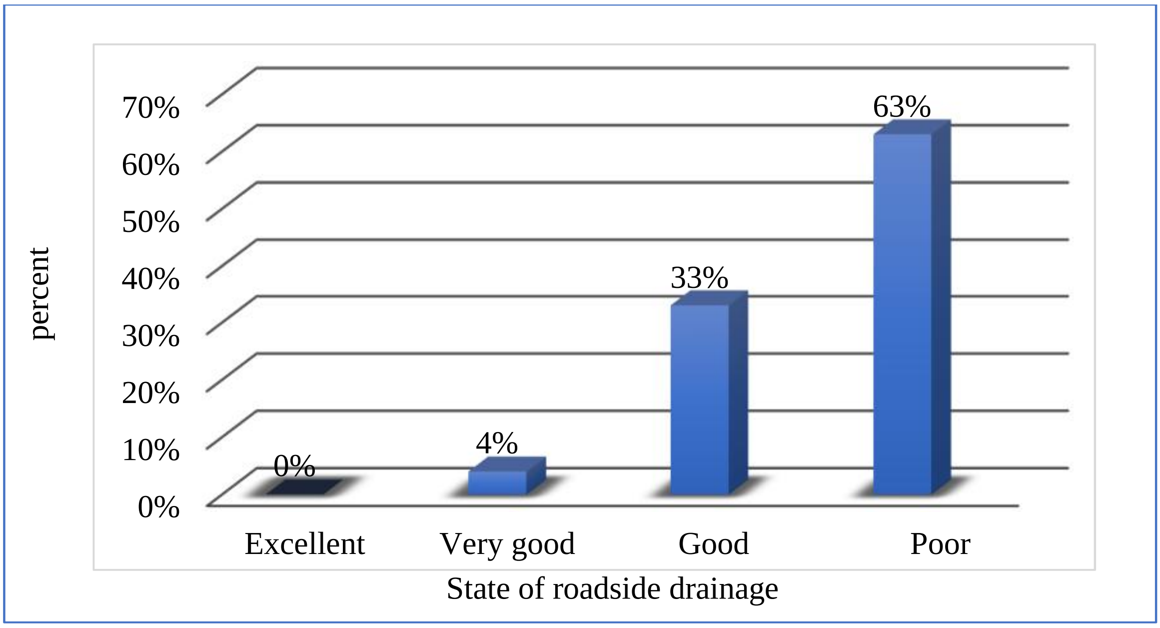

Figure 4.3:State of the roadside drainage of 07 kebele in Dire Dawa city

Source: from the field

Considering the above figure and from the result of respondent perception, the most state of existing condition of roadside drainage is poor. that means 63% is poor ,33% good and 4% is very good. Some of the reasons cited by the respondents were lack of roadway management, poor maintenance, improper waste disposal, lack of the community awareness and lack of properly cleaning the roadside drainage. As the respondent reported that the existing roadside drainage facilities in the study area was poor and immediately requires proper maintenance on the existing drainage facilities to increase their efficiency and effectiveness.

Figure 4.4:Poor roadside drainage in the study area

Source: From field

Responds from Dire Dawa sanitation and beautification agency

As the DDSBA reported, most of the solid waste was dumped inappropriate area. However, only 45% of solid waste was dumped properly. Besides, there is lack of municipal sewerage system, and people must develop their own means to dispose of liquid wastes. Per the respondent perception, poor waste management, lack of community awareness, poor planning, absence of urban development policy, lack of sewerage and storm water drainage systems, were the main factors for environmental problem in the study area. Due to this reason, air pollution and urban flooding were the ongoing problem in the study area.

To keep the environmental sanitation, sanitary landfill was constructed, and advisory councils was started until kebele level. Also, house to house waste collection was started before several years ago. But, poor waste collection, lack of local environmental policy, low level of awareness and poor institutional capacity are other factors contributing to the worsening of the environmental problem in the study area. Therefore, the DDSBA should have to keep the environmental protection and urban sanitation to achieved public health, improvement of living conditions and human well-being, urban rehabilitation and sanitation environment in the study area.

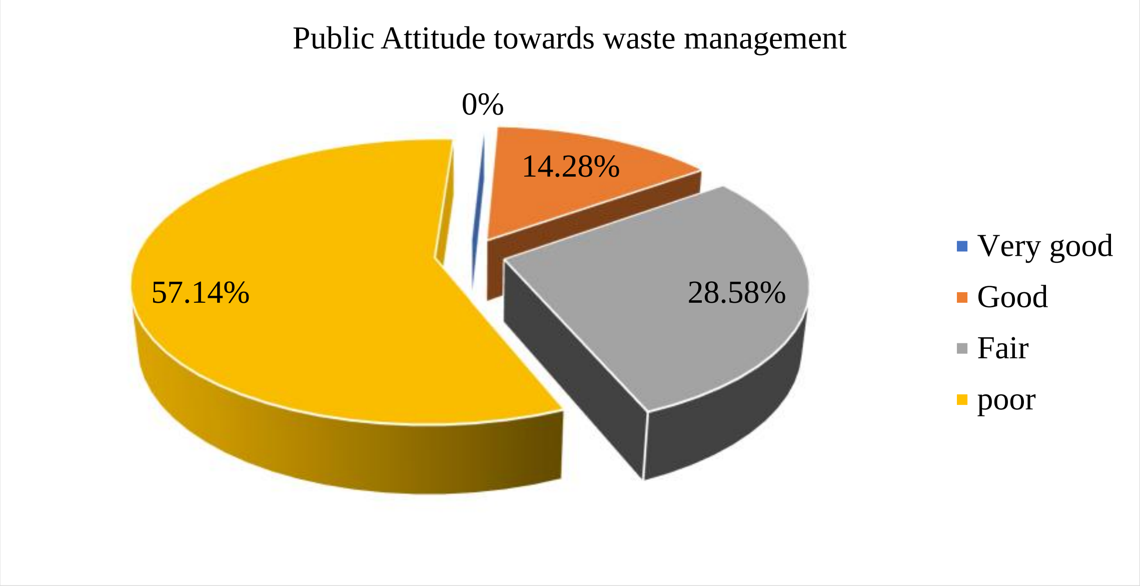

Figure 4.5:Public attitude towards waste management in the study area

Responds From residents

From the respondent's ideas, most of them were nearest to the road. From the results, 59% of the residents have founded 50m interval from the road. This was important to get detailed information related roadside drainage problem in this study.

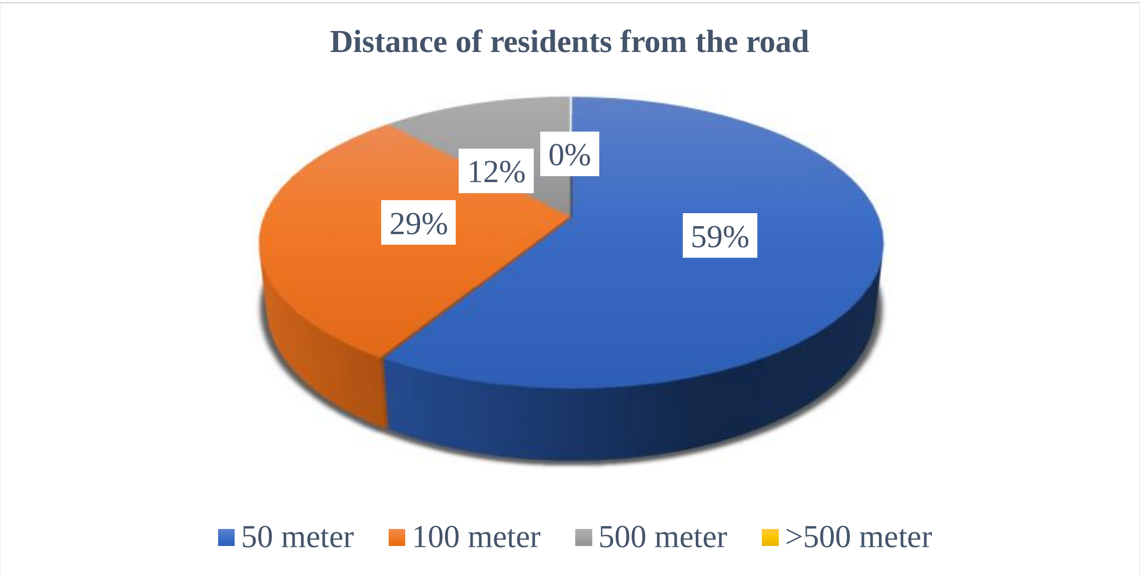

Figure 4.6:Distance of resident's house from the road

From the resident's respondents shows, they were affected by roadside drainage problem in the study area. Most of them were cited that runoff, sediment, and different waste had bad impacts on their house and property during the rainy season. Also, they thought that during rainy, runoff interred to their house and it is difficult to enter and leave their house, ponded runoff water around their property and sediment accumulation around their compound. Ashawa, Megala chabtu and Chatera area were the most faced by this problem in 07 kebele. Therefore, roadside drainage was the serious problem in the study area that required the remedial measure to immediate effects on some residential area in the study area.

Responds From road users

The study area was the central marketing system, and most of the human activity was carried out in Dire Dawa city. Regarding road user respondents, about 53% of respondents said that they were using the road repeatedly on the everyday basis.

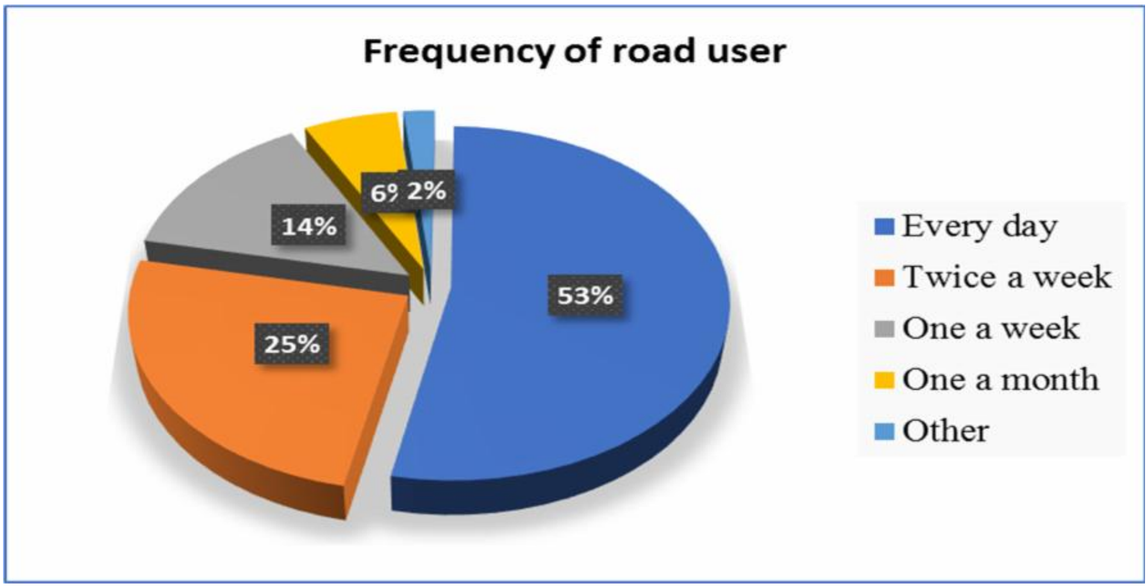

Figure 4. 7:Frequency of road usage by road user

From the above figure indicated that the significant proportion of the respondents either use the road every day or two a week. The data collected from the road user showed that most of respondents use the road every day. This is very important to obtain detail information related this study. In the study area, the road users were concerned about their safety and the convenience of travelling through in the study road during rainy seasons.

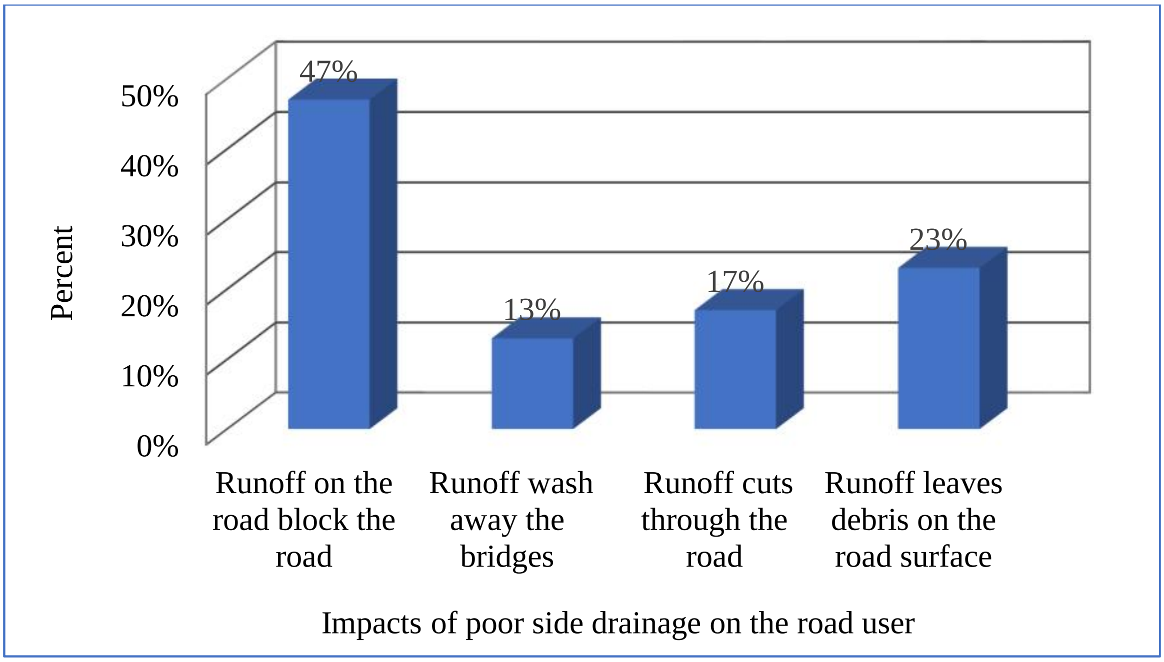

Figure 4.8:Impacts of poor side drainage on the road users

The most respondents claim runoff on the road blocks the road during the rains thereby obstructing free movements of vehicles on the road. It also, runoff obstruct and leaves sediment on the road and sometimes making impossible pedestrian to walk on the side of the road. As the respondent perception, the runoffs commonly overflow during rainy, leave debris and the pond on the carriageway on the study area especially round Alley bade, Lustra, Ashawa and chatera area.

Figure 4.9:Ponding of water on carriageway and the overflow of run water

Source: From field

Road users' satisfaction of the drainage system

From the figure 4.10, the major of the road users were not satisfied with the state of the roadside drainage in the study area. The consideration of the road user's satisfaction was important to enhanced the habit of community toward the roads and drainage system. Therefore, the improvement of the roadside drainage facilities was required to enhance road user satisfaction and environmental condition.

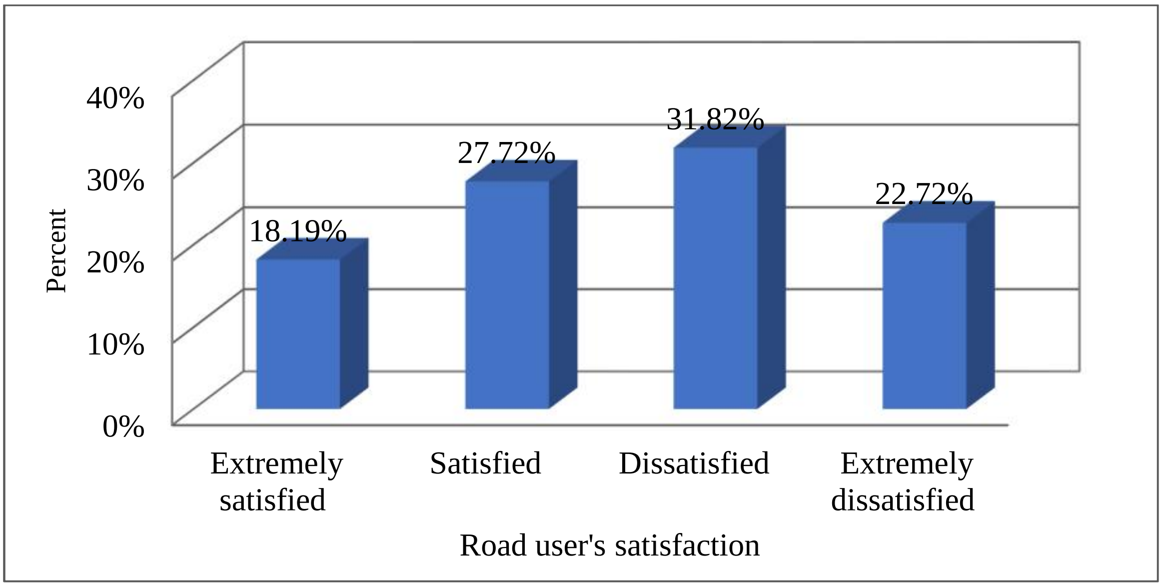

Figure 4.10:Road user's satisfaction

4.3 Factors causing roadside drainage problem

As it was observed from the field observation and the results of respondents, there were many factors that have contributed to roadside drainage problem in the study area like improper waste disposal, lack of community awareness, lack of frequently clearing roadside drainage line, increased urban population, damaged roadside drains due to urban infrastructure construction. Using statically expression was important to identify and to rank the factors that causing the problems in the study area.

Table 4.3:Factors causing the roadside drainage in the study area

No	Factors	N	Sum	Average rate
1	Poor waste disposal	56	142.00	2.53
2	Lack of community awareness	56	138.00	2.46
3	Increased the urban population	56	137.00	2.44

4	Lack of frequently clearing roadside drainage line	56	132.00	2.35
5	Damaged roadside drainage due to urban infrastructure construction	56	123.00	2.19
6	Lack of roadway management	56	122.00	2.17
7	Topography	56	110.00	1.96

Per the results of the ranked, poor waste disposal was the main causes for roadside drainage and lack of community awareness, increasing the urban population, lack of frequently clearing roadside drainage line, damaged roadside drains due to urban infrastructure construction, lack of roadway management and topography, respectively were the factors that affecting the roadside drainage in the study area.

4.3.1 Improper waste disposal

In study area, the waste generation from industries, agricultural activities, households, market centers and institutions, were increasing from time to time. If this waste was not managed properly it was dumped inappropriate area like in drainage lines, open spaces, street sides and openly burned. As it was observed from the field, the roadside drainage line was filled by inappropriate waste disposal. As the results of this, the easily movement of water in the drainage line was obstructed. The reason for dumping the waste disposal in drainage line was lack of community awareness, poor waste management, lack of enforcement of regulation on the waste disposal, carelessness, impacts of urban population and shortage of disposal area. So, mismanagement of waste disposal was affects the roadside drainage services in the study area.

Table 4.4:Factors causing the waste problem in the study area

`No	Factors	N	Sum	Average rate
1	Lack of community awareness	54	126.00	2.33
2	Poor waste management	54	125.00	2.31
3	Lack of enforcement of regulation on the waste disposal	54	124.00	2.29
4	Carelessness	54	122.00	2.25
5	Impacts of urban population	54	120.00	2.22
6	Shortage of disposal area	54	114.00	2.11

Per the results of the ranked, lack of community awareness, poor waste management, lack of enforcement of regulation on the waste disposal, carelessness, impacts of urban development and shortage of disposal area respectively were the factors that affecting the waste problem in the study area.

a. Improper solid waste disposal

In developing countries, improper waste disposal is the serious spoiling the environmental condition in urban area. Solid waste generation in developing countries is increasing annually due to an urbanization movement. Dire Dawa city is one of central selected industry zone in the eastern part of Ethiopia. Solid waste generation in Dire Dawa city is directly related with population growth, industrial expansion and economic status of its residents. Dumping solid waste disposal into open side drainages is the one of the factors that challenge of roadside drainage problem in the study area. Because of dumping these solid wastes into roadside drains, the side drainage has been blocked and causes flooding over streets and increase the problems on residential and property.

Figure 4.11:Filled roadside due to illegal waste disposal

Source: From field

b. Improper liquid waste disposal

In study area, like solid waste, liquid waste is also one of the challenge the cause for roadside drainage problem in the study area. Releasing of waste water into roadside drain, unlawful connection of latrine into the side drain and absence of drains street flooding is the common in the study area during the rainy season.

4.3.2 Lack of community awareness

Community participation is one of the best positive measurement directly or indirectly to control roadside drainage problem in study area. As it has been identified during the field observation and from the results of the respondents, the residents have no enough awareness regarding to dumping improper waste disposal into roadside drains and inappropriate place. Due to this, there is lack of responsibility of the community participation toward waste management and environment. Per residents cited that there is lack of increasing community awareness by government, shortage of disposal area and lack of enforcement regulation from the authority. From the figure 4.12 below show that marketing activities on the roadside drainages and population putting waste disposal in the roadside drainages.

Figure 4.12:Impacts of human activities on roadside drainage problem

Source: From field

4.3.3 Lack of frequently clearance of roadside drainage

Roadside drainage problem was affected by the lack of frequently clearance of drainage system in the study area. Due to this, sediments, siltation and garbage are blocked the side drainage line as it observed from the field. There is no scheduling clearance which needed to remove sediments, siltation and different material that blocks the roadside drainage. Figure 4.13 show that blocked drains due to lack of frequently clearance of roadside drainages.

Figure 4.13:Blocked roadside drain due to waste and filled with grasses and sediment

Source: From field

4.3.4 Increased urban population

Rapid growth of urban population is the results natural increasing in population and migration from the rural area to urban area. One of the most for urban population was internal migration movement from rural urban area from time to time for different events. Per Central Statistical Authority (CSA), the total population of the Dire Dawa City Administration was 440,000 persons in July 2015, of which 221,000 (50.2%) were male, and 219,000 (49.8%) were female. Most the population resides in urban areas, i.e., 277,000 (62.9%) and the remaining 163,000 (37.1%) lives in rural areas. The average population density of the City was estimated to be 241.9/km^2.The urban area of the City Administration is densely populated, about 16,050.5 persons /km^2. The study area is the center merchandise market in the city like Chatera, Megala Chabtu, Konel, market center (Taiwan and Ashawa) was located in this kebele. As it was observed from the field, the storm water drainage in study area is a thoughtful problem due to the inadequacies of the drainage network. The rapid commercial, residential, and urbanization developments in study are responsible for increasing the risk of urban floods resulting from inadequate drainage. The rapid marketing activities leaves no space for provision of drainage systems and different marketing activities going on the roadway and side ditch in the study area.

It also, as the population increased in the urban area the urban expansion also increased. As the result of this, it affects the natural landscape, rivers, drainage systems and land cover and land use in the Dire Dawa city. At the recent time, Dire Dawa city rapidly growth in absence of modern urban planning. However, highly informal and poorly laid out, lack of the road network and drainage network was the problems due to population increased. Therefore, the local authorities should be controlling the urban expansion and the other human activities in the study area are to responsibility for the poor sensitization of the people on drainage system.

Figure 4.14:Increased waste disposal due to urban population increased

Source: From field

4.3.5 Damaged roadside drains due to urban infrastructure construction

As the urban development is expanded, the construction of urban infrastructure was also expanded. During the construction of urban infrastructure (road maintenance, house construction, water supply line, telephone line, cobble stone construction), the roadside drainage line was damaged due to lack of drainage system consideration in the study area. It also, after the construction of urban infrastructure was completed, lack of carelessness to damaged drainage line was observed in the study area.

Figure 4.15:Damaged roadside drainage due to cobble stone construction

Source: From field

4.4 Effects of urban developments in the study area

The Urban area was considered as large densely populated area with a characteristic of different infrastructure. In developing countries, especially in Dire Dawa city, the human settlement is growing faster than urban infrastructure facility that shows the mismatch between human activity and urban infrastructure service. Human activities like the improper waste disposal, discharge of wastewater into open roadside drains, lack of community awareness and lack of responsibility can directly or indirectly affect the highway and environment in the study area.

4.4.1 Effects of urban developments on the highway

The construction of the highway in the urban area the most essential infrastructure that will increase the urban accessibility and enhance human activities along the transportation routes. A convenient highway system attracts new commercial, trades, interdependence grow and real estate projects that lead to a boom in economic development and population. The quality of highway has a significant effect on the urban development and cities. However, population growth, commercial, residential, and urbanization developments expansion in the study area was taking place without roads expansion and in adequate maintenance of the existing road network.

As it was observed from the field, the roads have been narrowed due to illegal structures raised on road reserves; poor parking area causes for blocking pedestrian walk ways and pushing that greatly hamper traffic flow of both pedestrians and motorist. Besides, the carriageway is continually being eroded due to construction of embankments from buildings that encroach on the roads, discharge of wastewater onto road surface, improper waste disposal onto road surface and lack of community awareness also the factors causing the highway problem due urban expansion in the study area. Therefore, Dire Dawa road authority should have to develop the road management habit in the community and maintain existing roads and expand the drainage network in order facilitate free flow of water to avoid water stagnation that erodes the road surface.

Table 4.5:Factors causing the highway problem due to urban development

No	Factors causing highway problem	N	Sum	Average rate
1	Poor roadside drainage	56	145.00	2.58
2	High traffic flow	56	132.00	2.35
3	Poor maintenance	56	132.00	2.35
4	Lack of community awareness	56	130.00	2.32
5	Increasing the urban population	56	121.00	2.16
6	Improper waste disposal	56	118.00	2.10

According to the results of the ranked, poor roadside drainage, high traffic flow, poor maintenance, lack of community awareness, increasing the urban population and improper waste disposal were factors that affecting the highway due to urban development.

4.4.2 Effects of poor roadside drainage on the roadway

Inadequate roadside drainage was affects the road performance in different way. Effective roadside drainage was one of the important drainage types that was used to keep water run -off from the road surface and to keep the foundation of the road dry. On the other hand, improper roadside drainage causes failure of road pavements at its early age thereby radically reducing their service life span. As it was observed from the field investigation, overflowing, ponding of water on the road surface, leave sediment and gullies on the road surface was the common causes for road failure in the study area because of poor road side drainage. As the results of this, road damaged or distress like pothole formation, depression, shoulder drop-off, washing out of bitumen and asphalt, ponding of rainwater on the pavement surface, road edge failure was the main problem in the study area.

a. Ponding water on road surface b. pothole on road pavement

c. washing out of asphalt material d. flooded road

Figure 4.16:Existing condition of road pavement in study area

Source: From field

4.4.3 Effects of urban developments on the environment

Dire Dawa is one of the rapidly urbanizing and industrial zone in the eastern part of the Ethiopia. Urban development has two sides effects on the environments: positive effects and adverse effects. If well planned, managed urban growth and development be positive effects, and unguided urban development like most in developing country has the negative impact on the environment. Similarly, unguided urban development of Dire Dawa city affects the environment and livelihood by poor waste management, urban flooding and air pollution were the major environmental problems faced by 07 kebele in Dire Dawa city.

Table 4.6:Factors causing the Environmental problem due to urban development

No	Factors causing environmental problems	N	Sum	Average rate
1	Poor waste management	54	143.00	2.64
2	Lack of community awareness	54	130.00	2.40
3	Increasing the urban population	54	127.00	2.35
4	Impacts of urban development	54	127.00	2.35

5	Poor roadside drainage	54	125.00	2.31

According to the results of the ranked, poor waste management, lack of community awareness, increasing the urban population, impacts of urban development and poor roadside drainage were respectively the factors that causing the environmental problem in the 07 kebele in Dire Dawa city.

4.4.3.1 Poor waste management

Dire Dawa city is a fast-growing city in eastern part of Ethiopia by industrial and commercial which produces pollutants in great quantities. Different types of waste generated from industries, agricultural activities, households, market centers and garages are the main sources of pollutants that may affect the environmental condition. This was due to the high rate turn overs of goods produced, industrial out puts, commercial out puts, and brought which consequently bring about the waste products. Likewise, disposal of garbage into roadside, discharge of wastewater into open roadside drains and industrial waste into streams, chat geraba into side drains and in open space were the main problem due to poor waste management in the study area. Also, the main waste disposal area is the sandy dry stream channel of Dechatu River channel that divides the city into two almost equal parts. Therefore, the Dire Dawa sanitation and beautification agency should have enhanced the waste management plan within the community to increase the city sanitation and environmental protection.

Figure 4.17:Improper solid waste on the road and side drains

Source: From field

4.4.3.2 Urban flooding problem in study area

urban floods are types of floods which are caused by the interface between heavy rain and urban drainage system. In the urban area, the land surface was covered by roads, roofs and paving which increases the volume runoff, increased wastewater, decreased infiltration and reduced groundwater discharge was the factors to increase urban flooding. In the study area, many side drainage facilities were not in good due to lack of cleaning and rubbish and debris tend to block drainage facilities, thus reducing the normal water flow in the channel and leading to increased surface runoff and backup effects which causing urban floods in summer season. As it was observed during filed investigation, different road failure was observed on the road surface because of urban flooding. It was found that the surface runoff water penetrated through the cracks and potholes cause a progressive inward penetration of the zone of soil movement leading to soil expansion and ultimately failure of the pavement and the main causes for pavement deterioration. During the heavy rainfall, the runoff on the road block the for some hours. So, the city administration should give immediate attention on road and drainage system to reduce the urban flooding before rainy season.

Figure 4.18:Ponding of water on the road pavement and stopped vehicles due flooding

Source: From field

4.4.3.3 Air Pollution

The study area was bounded in the west by Dechatu river. Different waste (solid and liquid) was released into this stream. The mixture of solid waste and liquid waste create the odor. So, the air was polluted by solid waste mismanagement. Also, dumping waste into roadside drains instead of dustbin creates smell. As this results from air become polluted. Air pollution from waste affecting the animals and causes for different types of diseases that spread to the human being. Develop waste management and waste could be transmitted to wealth using modern technology and reused process.

Figure 4. 19:Improper released liquid waste into stream

Source: From field

4.5 Measures to control the problems of roadside drainage

A. Frequently clearance of side drainage

Frequently clearance of roadside drainage should be done in all existing roadside drainage in the study area, to avoiding sediments, siltation and garbage which are the main causes for roadside drainage. If this is applied in the place, it will mitigate the problem of urban flooding, stagnant water, accumulation of sediment on the roadway and inappropriate dumping direct into the drainage by providing garbage container and proper collection of waste in the study area.

B. Enhance community awareness

Enhancement of community awareness to urban drainage system should be done in the study area to avoid the causes for roadside drainage problem. If the community awareness is developed, their ownership responsibility to drainage system and it will mitigate the problem of the roadside drainage and environmental problem due to human activity in the study area.

C. Proper Waste Management

As it observed from the field, waste which is produced by users, industries and commercial should be collected properly and carefully transported to an appropriate treatment plant in such a way that it is not hazardous to health and environment. A government, non - government and community are responsible for the improvement of the waste management, environment, health and sanitation condition in the study area. Co-operative work should be required among government, non-government and community to mitigate waste problem in the study area.

D. Proper maintenance and reconstruct of the road and ditches in the area study area

As the results obtained from the Dire Dawa road authority indicate that reconstruction of road and side ditch in some areas (chatera-megala chabtu, Harar garage-megala chabtu) will be started within two years. Capacities of most of the roadside drainage line can't handle the current runoff that flows over the area. Proper maintenance of the existing the roadside drainage to enhance the drainage service in the study area. Reconstruction of road and proper side drainage with good capacity should be needed to convey the runoff from the surrounding in the study area to solving side drainage problems.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSIONS

This study was major concerns the effects of urban development on the roadside drainage in 07 kebele in Dire Dawa city. Good roadside drainage is fundamental to rehabilitate of an urban area and environmental protection. Generally, the following major points have drawn as conclusions in line with the objectives of this study:

From the total lengths of roadside drainage existed in the study area, 59.2% have low hydraulic capacity than the runoff water. The drainage line 1,2,4,10,14,15,16 and 17 have low capacity to carry on the amount of runoff from the catchment area. Nevertheless, only 40.8% of the side drainage can convey safely the runoff into the water ways. This shows that the most of the side drainage lines have lower capacity and runoff water generated in the study area cannot be safely discharged into the nearby river. This is due to the ever-increasing population and mismatch of human settlement and drainage service in the urban area because of urban expansion.

The factors that have contributed to roadside drainage problems in the study area were:

Blocked roadside drainage due to improper waste disposal to open side drainage, lack of community awareness, lack of frequently clearing of side drainage and lack of drainage system assessment. Increased human settlement in urban area was mismatch to the drainage network service. During the construction of the urban infrastructure like housing construction, water supply lines, electric lines and telephone lines installation has no more consideration to the drainage system in the urban area.

Urban developments without roads expansion, lack adequate maintenance of the existing road network, illegal structures raised on carriage way, improper waste disposal onto road surface and lack of community awareness were the main causing the highway problem due to urban expansion.

The effects of poor roadside drainage were destroyed the residential property, leave sediment on the road pavement which is not possible to pedestrian walk, dirtying the vehicle of the road users. Overflooded of runoff on the road pavement that affects the pavement by making distress (like the pothole, depressions, edge cracking, road edge failure), washing out of bitumen and asphalt material, gully along shoulder were the problem in the study area.

Air pollution, poor waste management, urban flooding and inadequate assessment of urban infrastructure were the environmental challenge due to urban development.

Frequently clearance of roadside drainage, enhance community awareness, proper waste management, proper maintenance and reconstruct of the road and ditches with good capacity were the main measures to control the problems of roadside drainage in the study area.

5.2 RECOMMENDATION

Existing roadside drainage line in the study area have low capacity to discharge runoff from the surrounding. Consequently, roadside drainage with good capacity to discharge runoff from the surrounding area would be need to enhance the drainage facilities in study area.

To improve the problems that has been hindering the roadside drainage in the study, proper waste management should be used to reduce poor waste disposal into open ditch and illegal area, enhancement of community awareness to drainage system should be done in the study area to avoid the causes for roadside drainage problem, frequently clearance of roadside drainage should be done in all existing roadside drainage in the study area, to avoiding sediments, siltation and garbage which are the main causes for roadside drainage, during the construction or maintaining of the urban infrastructure, it should be controlling the construction site in order to give more consideration to the urban drainage system, proper maintenance and reconstruct of the road and ditches with good capacity to increase the drainage capacity in the study area.

Urban expansion management should be needed to control unsettlement, to keep urban sanitation, environmental protection, to reduce poor waste management and air pollution.

To reduce the impacts of poor roadside drainage on the urban population and road damage, proper roadside drainage should be needed to reduce the population problem and will reduce the maintenance cost by preventing deterioration of the surface and will provide a drier and hence safer road.

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ANNEX A: Rainfall Regions

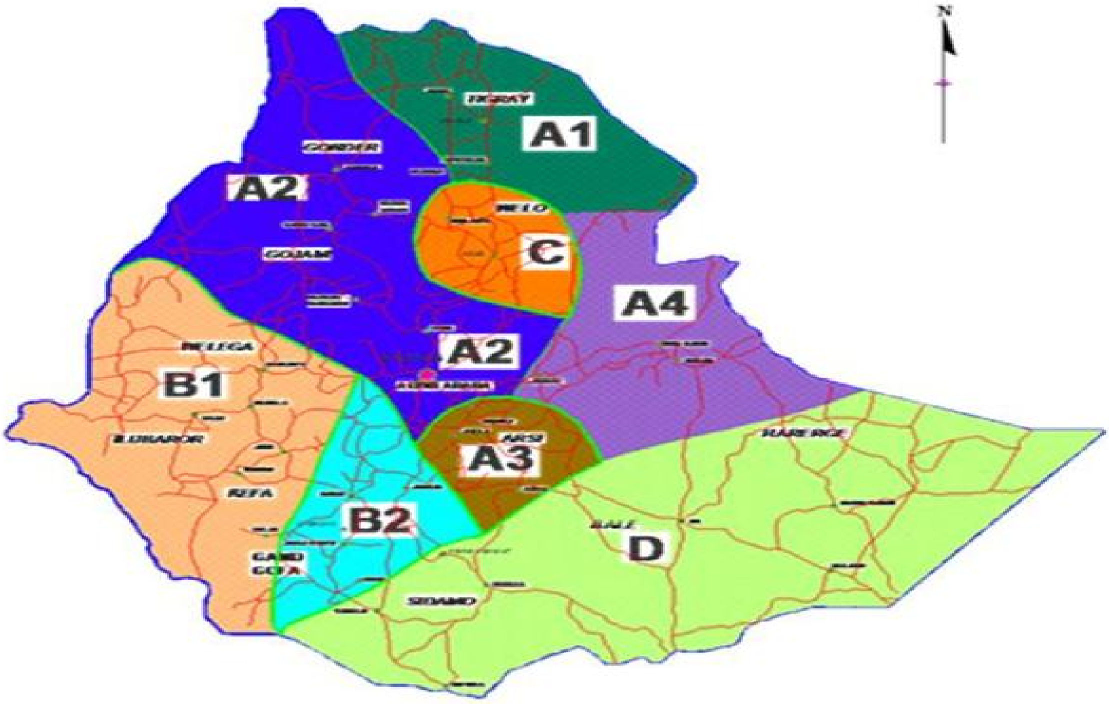


Figure 1: Rainfall Regions

ANNEX B: Manning's Roughness Coefficient (n)

Table 1: Values of Roughness coefficient n (Uniform Flow)

Type of Channel and Description	Minimum	Normal	Maximum
EXCAVATED OR DREDGED			
a. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	0.022	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense Weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.025	0.030	0.035
5. Stony bottom and weedy sides	0.025	0.035	0.045
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Backhoe-excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2 Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140
NATURAL STREAMS			
1 Minor streams (top width at flood stage < 30 m)			
a. Streams on Plain			
1. Clean, straight, full stage, no rims or deep pools	0.025	0.030	0.033
2. Same as above, but more stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8 Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravel, cobbles, and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
2 Flood Plains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050

Type of Channel and Description	Minimum	Normal	Maximum
b. Cultivated area			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of spouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
3 Major Streams (top width at flood stage > 30 m). The n value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	--	0.060
b. Irregular and rough section	0.035	--	0.100

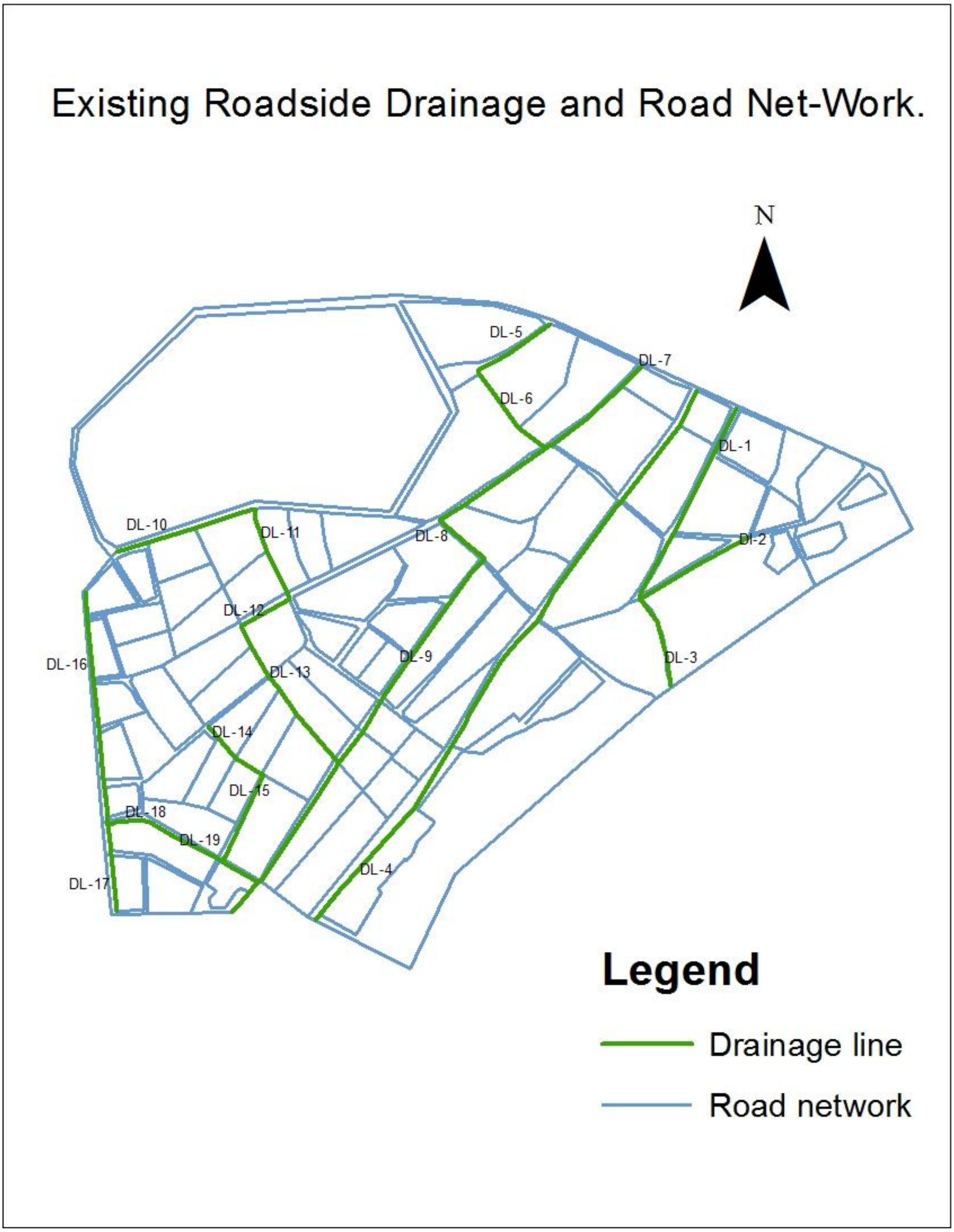
4 Various Open Channel Surfaces	
a. Concrete	0.012- 0.020
b. Gravel bottom with:	
Concrete	0.020
Mortared stone	0.023
Riprap	0.033
c. Natural Stream Channels	
Clean, straight stream	0.030
Clean, winding stream	0.040
Winding with weeds and pools	0.050
With heavy brush and timber	0.100
d. Flood Plains	
Pasture	0.035
Field Crops	0.040
Light Brush and Weeds	0.050
Dense Brush	0.070
Dense Trees	0.100

ANNEX C: Coefficient of runoff (c)

Description of Area	Runoff Coefficients
Business: Downtown areas	0.70-0.95
Neighborhood areas	0.50-0.70
Residential: Single-family areas	0.30-0.50
Residential: Multi units, detached	0.40-0.60
Residential: Multi units, attached	0.60-0.75
Suburban	0.25-0.40
Residential (0.5 hectare lots or more)	0.30-0.45
Apartment dwelling areas	0.50-0.70
Industrial: Light areas	0.50-0.80
Industrial: Heavy areas	0.60-0.90
Parks, cemeteries	0.10-0.25
Playgrounds	0.20-0.40
Railroad yard areas	0.20-0.40
Unimproved areas	0.10-0.30

(Source: Hydrology, Federal Highway Administration, HEC No. 19, 1984)

ANNEX D: Existing Roadside Drainage and Road Net-Work.



ANNEX E: Letter of introduction

Dear Sir,

REQUEST FOR INTERVIEW

I am a master student of the Jimma University carrying out a study on effects of urban development on the roadside drainage problem: a case of 07 kebele in Dire Dawa city. As residents, road users, Dire Dawa road authority sector, Dire Dawa sanitation and beautification agency, your views are important in this study and I would be grateful if you could grant me an interview and questionnaire on this important topic.

I would like to assure you that the information you provide in the interview and questionnaire will be treated confidentially and anonymously and will be used solely for academic purposes.

Please find attached a copy of the interview and questionnaire guide for the discussion.

Thank you for your assistance.

Molid Hassen

Contacts:

hassenmolid@gmail.com

ANNEX F: Questionnaires

Questionnaires 1: questionnaires for Dire Dawa road authority

Basic information

i. Name of officer…………………………………………………………
ii. Position ……………………………………………………………….
iii. Sex ………………………………………………………………….
iv. Date for interview……………………………………………………….

1. From your experience and practice, how can you rate the state of the roadside drainage in 07 kebele in Dire Dawa city?

   Excellent

   Very good

   Good

   Poor

   Any other (specify)………………………………

2. How often do your office carry out check to discover the state of the roadside drainage problems in study area road?

   weekly

   Monthly

   Every three months

   Every six months

   Once a year

   Any other (specify)

3. What do you think is the major causes of roadside drainage problem of 07 kebele in Dire Dawa city (Please put tick mark under your agreement)?

S/N	Causes	strongly agree	Agree	Disagree	strongly disagree
1	Increasing the urban population				
2	Poor waste disposal				
3	Lack of roadway management				

4	Lack of community awareness				
5	lack of frequently clearing roadside drainage line				
6	Damaged roadside drains due to urban infrastructure construction				
7	Topography				

4. How does roadside drainage quality affect the roadway in the 07 Kebele Dire Dawa city?

   …………………………………………………………………………
   …………………………………………………………………………
   …………………………………………………………………………

5. What factors that are mostly contributory affecting highway due to urban development (Please put tick mark under your agreement)?

S/n	Causes	strongly agree	Agree	Disagree	strongly disagree
1	Poor roadside drainage				
2	High traffic flow				
3	Lack of community awareness				
4	Increasing the urban population				
5	Poor maintenance				
6	Improper waste disposal				

6. What do you think is the major solution of roadside drainage problem of 07 kebele in Dire Dawa city?

   …………………………………………………………………………
   …………………………………………………………………………
   …………………………………………………………………………
   …………………………………………………………………………

Questionnaires 2: Questionnaires for Dire Dawa sanitation and beautification agency

Basic information

i. Name of officer………………………………………………………………
ii. Position …………………………………………………………………
iii. Sex ……………………………………………………………………….
iv. Date for interview……………………………………………………….

1. How would you describe the waste situation of the 07 kebele in Dire Dawa city?

   Very serious

   Serious

   Not serious

2. What do you consider to be the causes of the waste problem in the 07 kebele in Dire Dawa city (Please put tick mark under your agreement)?

S/n	Causes	strongly agree	Agree	Disagree	strongly disagree
1	Carelessness				
2	Impacts of urban population				
3	Lack of community awareness				
4	Poor waste management				
5	Shortage of disposal area				
6	Lack of enforcement of regulation on the waste disposal				

3. What is the impacts of improper waste disposal on the environment in 07 kebele?

   ……………………………………………………………………………
   ……………………………………………………………………………
   ……………………………………………………………………………
   ……………………………………………………………………………

4. How will you describe public attitude towards waste disposal of 07 kebele in Dire Dawa city?

   Very good

Good

Fair

Poor

5. What are the remedial measures have ever been taken to the waste disposal problems in 07 kebele?

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

6. Would you say there is adequate commitment to waste management in the 07 kebele in Dire Dawa city?

Yes

No

7. How can waste management be improved in the 07 kebele in Dire Dawa city?

…………………………………………………………………………
……………………………………………

ANNEX G: Interview questionnaires

Interview questionnaires 1: interview questionnaires for residents

Basic information

a. Name ……….…………………………………………………………
b. Occupation ………….……………………………………………………
c. Sex…...…………………………………………………………………….
d. Date for interview……………………………………………………

1. How far is your home from the road?

   50 meters

   100 meters

   500 meters

   More than 500 meters

2. What do you consider to be the major problems affecting this community?

   Poor roadside drainage problem

   Improper waste disposal

   Overflooding

   Environmental pollution

   If any other specify………………………………………

3. Does roadside drainages major problem in your kebele?

   Yes

   No

4. If your answer is yes, how do you rate the extent:

   Very serious

   Serious

   Not serious

5. What do you think is the major causes of roadside drainage problem in your kebele (Please put tick mark under your agreement)?

S/n	Causes	strongly agree	Agree	Disagree	strongly disagree
1	Increasing the urban population				
2	Poor waste disposal				
3	Lack of roadway management				
4	Lack of community awareness				
5	lack of frequently clearing roadside drainage line				
6	Damaged roadside drains due to urban infrastructure construction				
7	Topography				

6. What factors that are mostly contributory affecting highway due to urban development (Please put tick mark under your agreement)?

S/n	Causes	strongly agree	Agree	Disagree	strongly disagree
1	Poor roadside drainage				
2	High traffic flow				
3	Lack of community awareness				
4	Increasing the urban population				
5	Poor maintenance				
6	Improper waste disposal				

7. How will you describe the general waste situation in your kebele?

Very satisfactory

Satisfactory

Poor

8. What are the factors causing the wastage problem in your kebele (Please put tick mark under your agreement)?

s/n	Causes	Strongly agree	Agree	Disagree	Strongly disagree
1	Carelessness				
2	Impacts of urban population				
3	Lack of community awareness				
4	Poor waste management				
5	Shortage of disposal area				
6	Lack of enforcement of regulation on the waste disposal				

9. What are the reasons of the neighborhood to dispose wastes in to the roadside drainage?

Lack of awareness

Shortage of disposing area

Carelessness

Poor waste management

Others, Explain………………………………………………………

10. How would you rank environmental sanitation in your kebele in relation to others kebele in the Dire Dawa city?

One of the cleanest kebele

Averagely clean

Dirty

One of the dirtiest kebele in the city

11. In your view, how can waste disposal be improved in your kebele?

Preparation of waste disposal area

Waste disposal management

Increase community awareness

Enforce the regulations on waste disposal

12. How does poor drainage affect you as the resident?

Runoff erodes the land

Runoff create gullies on your land

Runoff wash away their compound

Runoff washes away house and property

13. What permanent remedial measures have ever been taken to the roadside drainage problems?

Cleaning roadside drainage line

Preparation of waste disposal

Increase community awareness

Enhance regulation on road management

Any other (specify)…………………………………………………

Interview Questionnaires 2: interview questionnaires for road users

Basic information

i. Name ……………………………………………………………………
ii. Occupation ………..……………………………………………………
iii. Sex…...………………….…………………………………………….
iv. Date for interview……..…………………………………………

1. How often do you use 07 kebele road?

    Every day

    Twice a week

    One’s a week

    One’s a month

    Any other (please specify) ………………………………………….

2. In your own view, how satisfied are you as a road user with the state of roadside drainage of the road?

    Extremely satisfied

    Satisfied

    Dissatisfied

    Extremely dissatisfied

3. What are the major factors causing highway problem due to urban development (Please put tick mark under your agreement)?

S/n	Causes	Strongly agree	Agree	Disagree	Strongly Disagree
1	Poor roadside drainage				
2	High traffic flow				
3	Lack of community awareness				
4	Increasing the urban population				
5	Poor maintenance				
6	Improper waste disposal				

4. How does poor roadside drainage affect you as a road user?

    Runoff on the road block the road

Runoff wash away the bridges

Runoff cuts through the road

Runoff leaves debris on the road surface

Any other (specify)…………………………………………………

5. Which types of problem you faced due to roadside drainage problem?

Sediment accumulation the road

Over flooding

Solid waste accumulation in the ditch

Road pavement distress

Any other (specify)…………………………………………………

6. Do the Authorities act to provide some solutions on the problem of overflowing due to roadside drainage problem?

Yes

No