THE IMPACT OF SEDIMENT TRANSPORT ON IRRIGATION CANAL AND ITS EFFECT ON APPLICATION UNIFORMITY OF SPRINKLER IRRIGATION SYSTEM ON EAST BANK CANAL, FINCHAA SUGAR ESTATE, ETHIOPIA

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DEDICATION

I dedicate this thesis manuscript to my father **FEKADU TADESSE,** and my mother **KISI NURFETA**, for nursing me with affection and love and for their dedicated partnership in the success of my life.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is my bona fide work and that all sources of materials used for thesis have been properly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for an advanced M.Sc degree at Haramaya University and is deposited at the University Library to be made available to borrowers under rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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BIOGRAPHICAL SKETCH

The author, Zerihun Fekadu Tadesse, was born in Western Oromia, Horro-Guduru Wollega Zone, Finchaa valley, in May, 1987. He attended his elementary and secondary schools at Finchaa Sheleko Agemsa Primary School and Ambo Comprehensive Senior Secondary School, respectively. After completing his Secondary School, he joined then Haramaya University in 2007 and graduated with BSc. degree in Soil and Water Engineering and Management by the year 2009. Soon after graduation, he was employed at West Showa Zone, Ambo Wereda Water, Mine and Energy office and served for three years. In September 2012, he was employed Finchaa Sugar Factory and he has been working at the Factory at different positions until he joined Haramaya University Haramaya Institute of Technology, School of Post Graduate Studies in 2016 to pursue his M.Sc study in Irrigation Engineering.

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LIST OF ABBREVIATIONSAND ACRONYMS

A	Cross-sectional Area of Flow
ARIS	Ango River Irrigation System
A_i	Cross sectional area of the canal sub-section
ASCE	American Society of Civil Engineers
CU —	Coefficient Uniformity
CUC	Christiansen Uniformity Coefficient
CUWS	Coefficient of Uniformity Wilcox and Swailes
Cv	Coefficient of Variation
CWC	Central water commission
d_{50}	The median diameter
DU_{lh}	Lower Half Distribution Uniformity
DU_{lq}	Lower Quarter Distribution Uniformity
EC	Electro conductivity
ETB	Ethiopian birr
FAO	Food and Agricultural Organization
hdro	hydrodynamic parameter
IA	Irrigation Association
Km^3	Kilometre cube
µS/cm	Microsiemens Per Centimeter
MoWIE	Ministry of Water, Irrigation and Electricity
NBCBN-CE	Nile Basin Capacity Building Network Civil Engineering
Q	Discharge
q_{bed}	The bed load
t/km^2/yr	Tone Per kilometre square per year
USBR	United States Bureau of Reclamation
V	Flow Velocity
V_{Total}	Average depth of application over all catch can measurement
V1q—	Average of the lowest one fourth of catch can measurement
$V_{\overline{i}}$	The flow velocity in Sub-section
V_i	Individual catch can measurement
WMO	World Meteorological Organization

TABLE OF CONTENTS

TABLE OF CONTENTS CONTINUED

TABLE OF CONTENTS CONTINUED

LIST OF TABLES

List of Tables **Page**

LIST OF FIGURES

List of Figures **Page**

LIST OF TABLES IN APPENDIX

List of Tables **Page**

LIST OF FIGURES IN APPENDIX

List of Figures **Page**

ABSTRACT

Sprinkler irrigation technology helps in more efficient use of water by eliminating field water conveyance channels, thereby reducing water loss. The amount of sediment transport and the impact on irrigation uniformity is important for better management of an irrigation system. This study was focused on the impact of sediment transport in the canal and its effect on application uniformity of sprinkler system on east bank canal Finchaa Sugar Estate. Its objective was to determine the effect of sediment on the canal and application uniformity distribution of sprinkler irrigation system at Finchaa, East Bank Sugar Estate .Currently serious irrigation problems were observed at Finchaa East bank sugar estate which raised from poor irrigation water quality containing sediment entered from upstream of the river which affects both canal structure and application uniformity of the system canal conveyance efficiency leading to inadequacy and inequity in water distribution to crops. This poor distribution could be due to the reason that the sprinkler nozzles were worn out and increase in diameter because of the action of wear and tear by the sediments.In order to analyze the effect of the problem different techniques have been taken in to account, it includes: Suspended sediment samples were collected from weir, inlet to end of canal at an average of eight kilometers along the canal using US D-74 suspended sediment sampler. The samples were analyzed in laboratory for sediment concentration, sediment rate discharge and particle size distribution along the canal and its effect on application uniformity of water distribution. The CUC and DU results for the new nozzle were above the minimum recommended values of 85% and 80% respectively at all test pressures. The specific discharge measurement showed that, both the upstream and downstream old nozzles were applying excess irrigation water causing loss of water, energy and yield in extreme cases may result in groundwater rise. But sediment deposition in irrigation canals results in rising canal bed levels, reduced canal capacities, and problems in supplying the required amounts of water to some or all parts of the irrigated area. Sediment deposition in irrigation canals results in rising canal bed levels, reduced canal capacities, and problems in supplying the required amounts of water to some or all parts of the irrigated area and there was a high over flowing of water occurring in the conveyance system at the end of the canal due to the accumulation of sediment in the canal.

Key Words: *Sprinkler irrigation, Sediment transport, Application Uniformity, East Bank Canal.*

1. INTRODUCTION

1.1. Background

Worldwide, the use of sprinkler irrigation system has been progressively increasing in order to cope with the declining water extractions to irrigations. Sprinkler irrigation technology helps in more efficient use of water by eliminating field water conveyance channels, thereby reducing water loss. It is well adapted to a range of topographies and is suitable in all types of soil, except heavy clays. Sprinkler irrigation system is suited for most row and close growing crops such as cereal, sugarcane, cotton, vegetables and fruits (Kundu*et al.,* 1998).

Modern irrigation equipment and technology like sprinkler and drip systems have the capability of applying the desired quantity of water with high precision and uniformity. Consequently, there is a considerable saving in the use of water as compared to surface irrigation, sometimes to the extent of 25% to 50%, depending on the type and design of the system (Michael, 2008). In sprinkler irrigation system, water flows out of the nozzle in the form of a jet which breaks down in to drops of water which fall on the land surface resembling rain drops. The area of land wetted by a sprinkler depends on the velocity head given to the water jet, the angle of flow of the jet, the type of sprinkler and its design, and the wind condition during irrigation (Olumana and Chemeda, 2011). The efficiency of a sprinkler system depends on the pressure head available at each of the sprinklers, the proper spacing of the sprinklers in the field, and the wind condition during irrigation. The quantity of water applied, depends on diameter of the nozzle and operating pressure and can be adjusted precisely to meet the crop water requirement. When properly designed, sprinkler irrigation can achieve high values of water application and water distribution efficiencies.

One of the main challenging problem and beyond the proper design of sprinkler irrigation system is irrigation water quality. The amount and nature of suspended solids found in irrigation water have a considerable effect especially on those systems such as sprinkler and drip irrigation which use nozzles and emitters to apply water to the crop.Excess sediment in irrigation water can cause severe wear and tear of sprinkler nozzles, pipes, pump and pump components. Additionally, sediment degrades water quality, and carries soil-adsorbed polluting chemicals. According to (Janssen, 2003), the presence of sediment can hinder the performance of the water management facilities and can have a detrimental impact on downstream receiving water bodies. Sediment deposition in irrigation canals, stream channels, reservoirs, water conveyance system reduces the water carrying capacity of structures and would require costly operation for sediment removal (Foster, 1982). According to a study conducted in Ethiopia on 84 small-scale irrigation projects, canal siltation is among the most serious problems in irrigation (NBCBN-CE, 2004).A survey conducted in the study area (Finchaa watershed) revealed that, cropland has been expanded to steep and fragile parts of the watershed. This enormous expansion of cropland, especially on the steeper parts of the watershed has made the land more vulnerable to soil erosion (Bezuayehu and De Graaff, 2006).

Another study conducted in Finchaa sugar estate indicated that there exists a continuous disturbance on vegetation cover, soil, and water. If the trend continues, there will be an extreme effect on the environment (Ahmed, 2007). Generally, the increased pressure on the land in Finchaa watershed could have resulted in more erosion and sediment concentration in the reservoir. Hence, sediment load in Finchaa irrigation system which is diverting its water downstream of the hydropower plant could also have been affected.

Generally, sediment has both technical and economic impactson the development and utilization of water resources and hence, its control is very essential. There are a number of options for sediment control (Lawrence *et al.,* 2001). The choice among the control options will depend upon many factors such as: technical feasibility, economic analysis, time scale of sediment control, specific characteristics of the system. For example, catchments treatment will be effective after long period of its implementation as compared to other options. The economic analysis has to be made to justify the implementation of sediment control measures as well as to choose the best alternative among all technically feasible sediment control alternatives.

Sediment management system which may include: preventing the intake of sediment; removing sediment from water; transporting sediment through water conveyances; and discharging sediment in a controlled manner. Settling basins are one of the most commonly used structures for sediment management, reducing the through-flow velocity to allow settling.The irrigation system at Finchaa (East bank canal) is provided with a settling basin downstream of the first pump station in order to trap suspended sediments diverted with the irrigation water. However, now a day's irrigation operation reports are indicating that, the pump stations and gravity off take fields were suffering from sediment problems clogging of nozzles and sediment deposition in pipes and frequent damage of irrigation pumps. In addition to this, the sprinkler nozzles have a problem of wear and tear from sediments resulting in undesirable spray patterns of sprinklers. Consequently, it may lead to poor water distribution uniformity, loss of water and rise of groundwater table (Olumana and Chemeda, 2011).

Information to investigate about the impact of sediment transport on irrigation canal and its effect on application uniformity of sprinkler irrigation system is important for better management of sprinkler irrigation system. However, there were no sufficient research investigations made to address the existing problems of sediment transport in irrigation canal on the study area. Olumana and Chemeda (2011), has conducted research on evaluation of sediment trapping efficiency of a settling basin on the west bank side of the Finchaa sugar estate irrigation canal. But, the limitations of their studies werethat they only focused on evaluation of the west bank canal settling basin trapping efficiency rather than the impact of sediment transport on irrigation canal. The other limitation was that the research conducted could not represent for the east bank canal. Therefore, this study is very crucial to investigate the impact of sediment transport problems in the east bank irrigation canal and its effect in the field.

1.2. Statement of the problem

Finchaa, East Bank irrigation scheme is one of the recent sugar cane farms under Finchaa Sugar Estate which accounts about 33% of the whole estate. So far, there was no any scientific research made regarding the impact of sediment on the irrigation system of East bank canal.
The impact of sediment on irrigation canal, application uniformity of sprinkler irrigation system was not yet done at East bank Finchaa sugar estate. But, the present performance of the irrigation scheme is not according to the envisioned objectives. Currently, serious irrigation problems were observed at Finchaa East bank sugar estate which was raised from poor irrigation water quality containing sediment entered from upstream of the river which affects both canal structure and application uniformity of the system by reduces canal conveyance

efficiency leading to inadequacy and inequity in water distribution to crops.This poor distribution could be due to the reason that the sprinkler nozzles were worn out and increase in diameter because of the action of abrasion by the sediments. In addition, sedimentation may lead to increased risk of canal breach due to reduction in freeboard and waterlogging.Sediment deposition in irrigation canals results in rising canal bed levels, reduced canal capacities, and problems in supplying the required amounts of water to some or all parts of the irrigated area (Chancellor *et al.,* 1996).

At present, the impact of sediment on irrigation canal and its effect on application uniformity of sprinkler irrigation system of East bank, Finchaa Sugar estate was carried out to analyze the impact of sediment on irrigation canal and its effect on application uniformity of sprinkler irrigation system on east bank canal using different techniques related to application uniformity of sprinkler, sediment size analysis along the canal, sediment measurement in the canal and surface uniformity.

1.3. Objectives

1.3.1. General Objective:

- The general Objective of this study was to determine the effect of sediment on the canal and application sprinkler irrigation system at Finchaa, East Bank Sugar Estate.

1.3.2. Specific objectives

The specific objectives of this study were:

- To analyze the effect of sediment on the application uniformity of sprinkler irrigation system.
- To determine the effect of sediment on irrigation canal.

2. LITERATURE REVIEWS

2.1. Sprinkler Irrigation Utilization in Ethiopia

In sprinkler irrigation, water droplets will be sprayed as a natural rainfall through sprinkler nozzles on land surface at rate less than the infiltration rate. Sprinkler irrigation is adaptable to most crops, soils and topographical features (De LaineandGeary, 1973). Among different irrigation methods, sprinkler irrigation is becoming more popular worldwide and progressively increasing in order to cope with declining water extraction for agriculture. In the sprinkler method of irrigation, water is sprayed into the air and allowed to fall on the ground surface in the form of rainfall. The spray is developed by the flow of water under pressure through small orifices or nozzle (Abdulrazzaq and Jahad, 2013).

Sprinkler irrigation is more suitable for Ethiopian lands with undulating topography and marginal soils for extensive agricultural crop production. But there are limitations for well adoption of sprinkler irrigation system due to high initial cost and lack of local fabrication technology (Haile and Kassa, 2015). The use of sprinkler irrigation in Ethiopia started for production of sugar cane crops for large farms and now extensively practiced at Finchaa, Tana Beles,Wonji-Shoa,Arjo-didesa sugar cane irrigation farms.

2.2. Water Quality of the Scheme and Sedimentation Over-View

2.2.1. Water quality of the scheme

Water quality, regarding the physical as well as chemical parameters of Finchaa sugar estate can be rated as very good for irrigation purposes. However, the increase of the electrical conductivity (EC) values of Finchaa River from 96µS/cm measured in the upstream area of the scheme to121 µS/cm in the downstream of the area shows the impact of irrigation on the downstream water bodies. This value does not include the indirect impact of irrigation by releasing pollutants by the sugar factory because the outlet of the factory was closed while EC measurements were taken. The values of the EC measurement in the field are all below the threshold value of none saline to slightly and moderate saline of 700 µS/cm given by FAO (1989). This indicates no problems with salinity caused by the available water resource. The EC value of Lake Choman (Finchaa Dam) is 96µS/cm. The ground water sample shows slightly increased EC values of 352 and 477µS/cmdue to accumulation of salts in the aquifer. Finchaa River drains Lake Choman to Blue Nile basin and therefore has the same EC values. The assumption can be made that the natural EC value of surface water bodies in Finchaa valley area is below100 µS/cm.

The EC values of the drainage water (164 µS/cm) and of tributaries of Finchaa river, example Agemsa river (286 µS/cm) which are located further downstream of the estate are much higher compared to the values in the upstream area. This fact together with the increased EC values of Finchaa river (121 µS/cm) measured at a location downstream of the irrigated field indicates that the tributaries of Finchaa river crossing the increasing the irrigated area serve as the natural drainage area system of the sugar farm. The increasing EC-value of Finchaa River makes the impact of irrigation downstream water bodies clearly visible. Drainage waters as well as surface water possibly mixed with agro-chemicals affect the water quality of the natural water resource in the adjacent area of the scheme.In general, the study conducted shows that the irrigation water used in the investigated case studies is of good quality with regard to FAOs standards for water used in agriculture and does not spell any risk for irrigation purposes (Awulachew *et at.,* 2008)

2.2.2. Sedimentation over-view

Sedimentation is the process by which different sized particles are transported and deposited into the water bodies and any other points along the water flow paths. Sedimentation is a worldwide concern as it affects the design of irrigation systems and their operational performance (Sousa*et al*., 2019). The sediment transport aspect is a major factor in irrigation development as it determines to a large extent the sustainability of an irrigation scheme, particularly in case of unlined canals in alluvial soils. Modern irrigation schemes are increasingly demand based, which means that the water flow in a canal is determined by the crop water requirements. Accordingly the flow in the canal network is not constant as the crop water requirement changes with the climate and the growing stages of the crops.

The study of sediment transport is mainly focused on the sediment and erosion processes in irrigation canal networks. In view of maintenance activities, the head works should be designed in such a way that they prevent or limit the entrance of sediment into canals (Depeweg and Mendez, 2015).Improving water management of irrigation schemes through sediment management is very importantin order to achieve efficient water supply system for sustainable crop production. Hydraulic and operational performance analysis is therefore important in irrigation canal conveyance system where sedimentation is a big problem. By having better details of water intake, reservation and distribution, the sedimentation analysis helps to identify constraint in hydraulic and operational performance which will inform on finding alternatives for improvement. Sedimentation reduces canal conveyance efficiency leading to inadequacy and inequity in water distribution to crops. In addition, sedimentation may lead to increased risk of canal breach due to reduction in freeboard and water logging (Ochiere*et al.,* 2015).

According to (Onyando*et al.,* 2004),all rivers and canals conveying water may contain eroded sediments. Increase of soil erosion due to catchment degradation especially in developing countries has resulted into increased siltation problems in rivers as reported. When flow in the canal is below the fall velocity of a given sediment size, the sediment would be deposited. As the sediments accumulate in the canal, the canal gradually loses its capability to transport water. Such canals lose water conveyance capacity due to sedimentation although the rate at which this happens varies widely. Sometimes the rate of sedimentation is higher than the rate at which revenue required for maintenance of the canal (Ochiere*et al.,* 2015). Canal sedimentation is the most serious technical problem facing irrigation systems (Depeweg and Mendez, 2006).

The proportion of sediments entering a diversion canal depends on the sediment load in the river source. Transport capacity is compared to the sediment load to determine whether detachment or deposition is occurring (Finkner *et al.,* 1989). Therefore, deposition occurs when the sediment transport capacity of flow is less than the sediment load carried by the flow. The sediment deposited in the canal can be flushed out only if the transport capacity of the canal flow is increased. The sediments transported through flushing should be discharged at non-erosive velocity at the end of the canal.

2.3. Sediment Transport in Irrigation Systems

Main objective of an irrigation engineer is to design an irrigation system that requires least or no maintenance. The canal should be capable of delivering the required amount of water to the targeted command area, without the need for excavation of sediment for the full life of the system. Dealing with sediment is one of the major difficulties in irrigation system design, yet one of the most important aspects(Paudel, 2010).Sediment transport starts when shear forces applied by the flow overcome the weight of the particle and in the process, detaches and initiates down-slope motion(Sousa*et al.,*2019).Causes of sedimentation may include natural occurrence, changes in gradient, erosion and obstruction of canals. Depending upon the hydrodynamic conditions and sediment characteristics, particles may move in three different forms such as bed load, suspension and siltation processes (Sousa*et al.,* 2019).

2.3.1. Suspended sediment transport

Transport of sediment takes place in suspended mode, when the bed-shear velocity exceeds the particle fall velocity. The particles can be lifted to a level at which the upward turbulent forces will be comparable to or higher than the submerged particle weight and as a result the contact of the particle with the bed in the suspension mode is occasional and random. The particle velocity in longitudinal direction is almost equal to the fluid velocity (Galappatti, 1983).Suspended load is that part of the sediment transport that moves with the water flow without contact with the bottom. It includes the suspension mode and the wash load, which consist of cohesive and very fine sediments (smaller than 0.05 mm) and which tend to be suspended by Brownian motion (Raudkivi, 1990).

Usually, the behavior of the suspended sediment particles is described in terms of sediment concentration, which is the solid volume per unit fluid volume or the solid mass (kg) per unit fluid volume. The principle feature that distinguishes the suspended sediment transport from the bed-load transport is the time taken for the suspension to adapt to changes in flow conditions (Galappatti, 1983).Suspended sediment transportation is closely related to the turbulent bursting phenomenon. The following frames show the observed phenomena and the related mechanism of particle suspension for a smooth bed. If the low-speed streak of flow near the bed is lifted due to a burst of turbulence, the sediment will be carried upward. If the fall velocity of a particle is large, the particle will quickly fall back to the bed. Such particles are part of the siltation load (WMO, 2003). However, in the process a continuous exchange occurs between the suspended sediment and the sediment in the near-bed region (Moninger*et al.,* 2003). The suspended load may also include the fine silt particles brought into suspension from the catchments area rather than from the streambed material (Bed material load) and is called the wash load. There is no general agreement as to when wash load becomes suspended bed material load and vice versa, although definitions for wash load based on suspension criteria have been proposed by (Vries,1981).

2.3.2. Bed load

The transport of bed material particles by a flow of water can be in the form of bed-load and suspended load, depending on the size of the bed material particles and the flow conditions. Although in natural conditions there is no sharp division between the bed-load transport and the suspended load transport, it is necessary to define a layer with bed-load transport for mathematical representation. Bagnold, (1966) defines bed-load as the particles which are in successive contacts with the bed and the processes are governed by gravity. The particles in bed-load move by siltation, rolling or sliding in the bed layer. Suspended load is defined as the sediment that is lifted by the upward components of turbulent currents and that stays in suspension for an appreciable length of time (Simons*et al.,* 1992).

According to Einstein's(1950), bed load function provides a method for computing the bed material load and considers bed material, bed load and suspended load in combination. For the sake of convenience, one can assume that the transition from bed load to suspended load occurs entirely at one elevation, i.e. below a given elevation bed load movement prevails, and above this, suspension prevails. The results of flume experiments reveal that unless the movement of sediment is quite intense, this critical elevation is about two grain diameters above the river bed.

According to Van Rijn (1984), the bed load makes up only a small part of the sediment load and is a function of the median diameter and hydrodynamic properties of the channel like water depth, flow velocity etc.

2.3.3. Total sediment load

The total sediment load includes both bed load and suspended load. In the previous sections, relationships and characteristics of bed load and suspended load were discussed. The sum of the amount of bed load and suspended load is the total bed material load that can be transported for a given flow and in given boundary conditions. The characteristics of bed material load are different from those of wash load. Consequently, formulae and methods for calculating the bed material load and the wash load are also different. Only sediment discharge in the form of bed material load can be calculated on the basis of mechanics(Moninger*et al.,*2003).

2.4. Impacts of Sedimentation

Reservoir sedimentation is a serious worldwide problem leading to loss of valuable storage which is estimated to be 35 km^3 to 70 km^3 per year, with the annual replacement cost of US$10 billion to US$20 billion (Palmieriet*et al.,* 2003). A regional approach to estimating sediment damages in lakes and reservoirs indicated that 0.22% of the nation's water storage capacity is lost annually. Of this, an average of 24% is due to soil erosion on cropland. The greatest water storage capacity losses from deposited sediment originating from cropland occurred in the central United States. Annual national damages to storage capacity ranged from $597 million to $819 million, with cropland's contribution being $144 million to $197 million (Crowder, 1987).

Maintenance budgets in many run-of-river irrigation schemes are dominated by the costs of removing sediment from canals. The problem results from the limited sediment transporting capacity of most canal networks, and occurs when water is diverted from rivers carrying high sediment loads. Sediment deposition results in rising canal bed levels, reduced canal capacities, and problems in supplying the required amounts of water to some or all parts of the irrigated area(Chancellor *et al.,*1996).In Ethiopia, the rates of on-site soil erosion and downstream sedimentation in water reservoirs are alarmingly high (Haregeweyn*et al.,* 2006; Tamene*et al.,* 2006a). Many reservoirs which have been established for hydroelectric power, drinking water supply and irrigation accumulate larger amounts of sediment than expected (Amare, 2005; Kebede, 2012). According to Eyasu(2003), the average annual soil loss from the Legadadi watershed, Ethiopia, is estimated to be 76 tons/ha. A 20 year survey between 1978 and 1998 on the reservoir shows an average silt accumulation of 26,000 m^3 per year.

Salutation of water reservoirs has a considerable impact on the reservoir functions: First, it causes reduced storage capacity and resulting in shortage of water. Secondly, the suspended solids in the eroded material increase turbidity of the raw water and this increases water treatment costs. The cost of water treatment increased from ETB 7.7 million in 1993 to ETB 21.4 million in 2001 due to the increasing rate of reservoir sedimentation (Eyasu, 2003), reported that, siltation in the Koka dam reservoir was increased from 857 t/km^2/yr in 1970 to 2115 t/km^2/yr now.

2.4.1. Impact of sediments on irrigation canals

Sedimentation reduces canal conveyance efficiency leading to inadequacy and inequity in water distribution to crops. In addition, sedimentation may lead to increased risk of canal breach due to reduction in freeboard and water logging. Canal sedimentation is the most serious technical problem facing irrigation systems (Depeweg and Mendez, 2006).Sedimentation affects the efficiency of irrigation canals by reducing discharge capacities and raising water levels. In many schemes, de-silting costs are excessive, and in some the sediment settles faster than it can be removed by maintenance dredging. These results in problems of under supply, inequality and inevitable decline in the command area that can be irrigated (Chancellor*et al.,* 1996; Philip and Atkinson, 1998; Sahabrabude, 2000).

Based on studies conducted to evaluate the effect of sedimentation on the Agno River Irrigation System (ARIS) in Philippines, (Castenda and Bhiyan, 1993) found that the system suffered from continuous process of high sediment deposition rates. It was estimated that about 269,200 tons of sediment enter the irrigation canal network annually, causing severe canal aggregation. Consequently, the water conveyance capacity of the system has been reduced by 24% and irrigation to rice farmers was discounted in 40% of the service area between 1974 and 1985. A canal can accommodate some sedimentation if it is operated at water levels above the design full supply level. As sedimentation continues, the free board limit will be reached, and the conveyance capacity then reduces as the canal silts up. Reduction of the conveyance capacity results in a reduction in the volume of water that can be supplied and hence, in the area that will be irrigated (Lawrence *et al.,* 2001).

2.4.2. Impact of sediments on underground irrigation pipes

Sediment accumulation in irrigation pipes can reduce the flow area and increase flow velocity thereby increasing the head loss in the system and increase the cost of pumping (Cuenca, 1989). Hence, sedimentation will have both cost implication and technical difficulties on underground irrigation pipes. In pressurized irrigation systems that use underground pipe networks for conveyance and distribution of water to the fields, like the case in Finchaa irrigation system, sedimentation causes frequent clogging and thus increasing the maintenance frequency.

2.4.3. Impact of sediments on irrigation pumps

Pumps used for catching raw water, installed in rivers of sedimentary waters intended for projects of irrigation and urban and rural supply, undergo wear on impellers caused by the abrasion of the sediments in suspension. According to (Xing*et al.,*2009), diameter and concentration of sediment particles have great influence on the wear conditions of centrifugal pumps, causing points of deformation resulting from the impact of particles on the surface of the impeller blades. On (Maio*et al.,*2012), study shows that analyzing the wear in the presence of solids in suspension in centrifuge pumps, concluded that the increase in vibration, resulting from the erosion caused by the abrasion of the sediments, may indicate an evolution in pump wear and is the main cause of the reduction in its efficiency and useful life.
According to (Upadhyay and Kumaraswamidhas, 2014) it is important to know the characteristics of the abrasive agent to subsequently verify the alternatives to improve the resistance to wear. In centrifuge pumps, wear by abrasion occurs between the impeller and stationary cover of the casing, between the shaft and stationary casing and, mainly, on the surface of impeller blades, possibly causing imbalance and losses of efficiency (Maio*et al.,* 2012). According to (Tilerm, 1997), in pumped irrigation system, if the water to be pumped has a large amount of silt in it, due to its abrasive nature, it results wear to the pump parts like impellers, bearings, shafts. Though it is difficult to get silt free irrigation water, the amount and type should not be as such to cause problems on the pumps.

Excessive sediment will cause erosion of pump components. The erosion of pump component depends on: 1) eroding particles - size, shape, hardness, 2) substrates–chemistry, elastic properties, surface hardness, surface morphology, and 3) operating conditions – velocity, impingement angle, and concentration and like that(Olumana and Chemeda, 2011).Hard minerals like quartz and feldspar cause more wear and tear to turbines and irrigation pumps than soft minerals. The material erosion rate of steel confronting water having quartz is found to be proportional to the sediment load and the velocity of the flow into the power of 3 to 4 (Aravind, 2005).

2.4.4. Impact of sediments on sprinkler nozzles

It was revealed that wear of the nozzle: increases droplet sizes, upset the sprinkler spray pattern, decrease the uniformity of water application, increase pipe friction loses and as well change the pump operating point and efficiency thereby contributing to increased pumping costs to grower in addition to yield reduction (King *et al.,* 1999). In addition to clogging, sediment in irrigation water may cause wear and tear of nozzles, especially if it has an abrasive nature. Due to abrasion, the nozzle opening may be increased more than the designed value and results in excess water application, because the discharge through the sprinkler is a function of nozzle diameter and operating pressure (Cuenca, 1989).

2.5. Design Discharge and Management of Sediment in the Canal.

The capacity of the canal should be such that the embankments are not overtopped or the canal network is not at risk, when maximum or peak water demand (Q peak) is being met. Hence Q peak should be taken as the design discharge. The problem lies in the selection of the design sediment concentration, i.e., what is the sediment concentration that the canal should convey in equilibrium condition while carrying the design discharge. It is clear that the water and sediment inflow rate in any canal system is not constant. The peak water flow (Qpeak) may not correspond to the peak sediment concentration. If there is provision of a sediment removal facility then there will be a known upper limit of sediment concentration (Paudel, 2010).

The design concentration which will be called “dominant concentration” is that value, for which there will be least erosion and deposition after one crop calendar year. The dominant concentration is not the expected peak concentration that the canal has to convey. It is a value that will result in no net erosion or deposition after one irrigation season. Hence depending upon the inflow discharge and sediment concentration, erosion during one part and deposition during another part of the irrigation season is allowed, thus balancing the net effect in one irrigation cycle. Moreover, in this case the sediment concentration will be used explicitly to arrive at a stable design (Paudel, 2010).

2.5.1. Operation aspect

In modern irrigation schemes the crop based water delivery plans are prepared in an attempt to increase the irrigation efficiency and crop production. Accordingly the canal network and the flow control systems are designed to make the system more flexible to meet the changing demand. From sediment transport aspect, flexibility means more control of the flow and hence more deviation from uniform flow conditions. That means the difference of actual sediment transport and the one predicted by the sediment transport equations becomes more. Irrigation schemes that carry a sediment load need extra efforts to operate them properly. According to (Paudel, 2010), there are two objectives have to be met simultaneously, firstly to supply the water as per the demand or as per the previously agreed schedule and secondly to ensure that the effects due to sedimentation/erosion are minimal. Delivery of water as per the demand requires adjustment in the water level and flow rate. The operation of control gates to manipulate the water level and discharge makes the flow in the canal system unsteady and non-uniform and will affect in the sediment transport behavior. It is not possible to operate the scheme in a flexible way and also to reduce the sedimentation problem at the same time. Hence a compromise has to be made between the flexibility in water delivery and sediment deposition.

2.5.2. Conveyance aspect

In the study of (Paudel, 2010),the objective of design of a canal for sediment transport should be to convey the incoming sediment load all the way down to the location where it can be disposed or deposited safely. But, most design procedures assume each reach as an individual element. In such cases there will be no relationship between higher order and subsequent lower order canals in terms of their sediment transport capacity. If an off-taking canal has a smaller transport capacity than the parent canal then sediment diverted from the parent canal will be deposited near the head of the off-taking canal. If, however, the off-taking canal is designed with a higher transport capacity than the parent canal, the canal will always have more energy in the flow than necessary to transport the available sediment in the flow. Then, there is possibility of bed erosion in the off-taking canal. The scheme can be operated optimally if the sediment transport capacities of the off-taking and parent canals are comparable.

2.5.3. Provision of settling pockets

It is seldom possible to have the same slope for all the canals in an irrigation scheme. When there is restriction on slope then the B-h ratio is adjusted to arrive at the required sediment transport capacity. The settling basin at the head may become very large and expensive if it is designed to reduce the concentration to avoid deposition problems in the entire canal network. Under such conditions, the provision of settling pockets may be helpful to reduce the social, operational and water distribution problem (Paudel, 2010).

2.5.4. Maintenance activities

Maintenance of a canal is primarily meant to restore the canal to the designed or planned state. In the process the level, cross sectional dimensions as well as the roughness of the section are corrected. Removal of deposited sediment from a canal network is the major maintenance activity of irrigation schemes carrying sediment laden water. Sediment deposition in the canal will have two fold influences. Firstly, the water diversion towards the canal is reduced due to the reduction in the driving head (difference in water level or in piezometric head between inflow and outflow cross-sections) and secondly the capacity is reduced due to the reduction in canal capacity (Paudel, 2010).

2.6. Sediment Management Options in Irrigation Canals

Sediment control strategies start with the selection of a proper point for the diversion and the choice of appropriate structures at river intakes in order to prevent unwanted sediment entry into the irrigation canals. The entered sediments into the canals are ejected through different means, by structures or sometimes sediments are deposited in the oversized canal sections, settling basins, at the head of the canals and then periodically removed. Further, the canals are so designed that the hydraulic conditions during canal operation allow neither sediment deposition nor scouring in the canal prism. The off taking structures are designed for maximum withdrawal of the sediments from the parent canal depending upon the command areas (Munir, 2011).

2.6.1. Sediment control at intakes

Careful selection of the point of diversion is very important in reducing sediment entry to the irrigation canals. In general, the outside or concave side of the curve of a river has been proved the best location for river intake structure. Because the heavy bed load is swept towards the inside of the curve due to spiral flow (ASCE, 1972). The angle of diversion between the directions of flow in the parent channel is generally called “Angle of Diversion” and sometimes “Angle of Twist”. The higher velocity of surface water requires a greater force to turn it than the slower moving water near the bed. The most commonly used angle of diversion is 90^o, which is definitely not the proper one (ASCE, 1972). The use of an angle of diversion between 30^o and 45^o (from downstream side) is recommended (Munir, 2011).

2.6.2. Sediment diverters (silt excluders)

A sediment diverter is a device or structure arrangement at a canal headwork which is designed to prevent the greater part of the stream sediment from entering the canal. Training walls are the curved walls of the intake channel which create a curve in the flow artificially in which the helicoidally currents sweep the bed load to the inside of the curve and away from the head gates. Guide banks used in some diversion works are curved banks which are designed to perform the same function as the curved training walls, that is, to divert sediment away from the canal intake. Pocket and divider walls are constructed upstream from a dam so as to form a pocket in front of the canal intake. Sand screens, Guide vanes, Tunnel type sediment diverters are some of sediment diverter used to divert sediment entrance to the canal (Munir, 2011).

2.6.3. Sediment ejectors

Sediment ejectors employ the same general principle of sediment removal as the diverters described previously except they are designed to remove sediment from the canal prism and are located downstream of the canal head gate. Vortex tube ejectors consist of an open-top tube or channel. This open top tube is installed at an angle of 45° to the axis of flow in the canal head works channel. The edge, or lip, of the tube is set level with the bottom grade of the canal. Water flowing over the opening induces a spiraling flow in the tube throughout its length. The spiral flow picks up the bed load and moves it along the tube to an outlet at the downstream end of the structure (Munir, 2011).

2.6.4. Soil conservation practice

Increasing the roughness of land surface, changing the micro relief of land slope and improving vegetation cover can foster soil and water conservation and improve soil texture (Hudson,1981).It is sometimes assumed that the introduction of soil conservation programmers in river catchments will rapidly reduce river sediment loads, and thus sedimentation problems in downstream irrigation canals. The information that is available suggests that this is not the case over the lifetime of typical irrigation structures, except for schemes supplied from very small catchments. The principle reason is that in semi-arid regions the vast store of sediments available for remobilization in catchments that have suffered from high rates of soil erosion in the past, continue to contribute to downstream sediment yields for long periods, decades or even centuries, even if catchment wide conservation was possible. Soil and water conservation programmers will not usually provide significant short-term reductions in canal sedimentation in irrigation systems. However, construction of series of low check dams can provide some benefit. Although the storage provided by check dams soon fills with coarse sediments, the reduction in and control of river bed gradients provided by check dams can reduce bed and bank scour during floods (Lawrence, 2008).

2.7. The Role of Sediment Transport in the Design of Irrigation Canals.

The design of irrigation canals for sediment-laden water should consider aspects related to the conveyance of irrigation water as well as the transport of sediments. The need to convey different quantities of water to meet the irrigation requirements at the required water level is the main criterion for canal design. Furthermore, the design must be compatible with a particular sediment load in order to avoid silting and/or scouring (Lawrence, 1990 and 1993). The diverted discharge should meet the irrigation requirements and at the same time it should result in the least deposition and/or erosion in the canal network.

According to FAO (1981), the objective of a canal design is to select the proper bottom slope and geometry of the cross section so that during a certain period the sediment flowing in is equal to the sediment flowing out of the canal. Chang (1985) suggested that in view of these sediment problems, the bottom slope and the canal geometry must be interrelated in order to maintain the best possible sediment transport equilibrium. He stated that the sediment problem can be controlled by maintaining the continuity in sediment transport in the irrigation canals during the design stage. Dahmen (1994) pointed out that an irrigation network should be designed and operated in such a way that the required flow passes at the design water level, no erosion of the canal bottom and banks occurs, no deposition of sediment in the canal takes place.

2.8. Measurement of Sediment Load

The data needed to check sediment transporting capacity and to design sediment control structures will depend on the severity of the sediment problem, and the methods chosen for its measurement. For the wash load, which is mainly composed of fine sediment that is uniformly vertically distributed, the mean sediment concentration obtained by conventional sampling methods should represent satisfactorily the true mean value. However, for the bed material load, especially particles coarser than fine sand, a considerable part is concentrated near the streambed, and it is not included in the results of suspended sediment sampling. The suspended sediment yield is the main parameter for hydrological studies and has spatial and temporal variability depending on many factors such as the hydraulic characteristic of the stream, geomorphologic conditions of the catchments, and the climatic regime of the area and the presence of vegetation. Correct measurement of amount of sediment load is crucial in the design and management of water resources projects for determining the economic life of the facilities. Transportation of sediment load not only causes decrease in economic life of facilities but also harm agricultural areas (Ramazanet al., 2008).

2.8.1. Measuring sediment using bottle samplers

Despite a large number of methods for measuring sediment transport rates, most hydrological studies use one or another of the “standard” bottle sampling techniques. In this method of sampling, bottles are lowered from a cable way in to the flow and if depth integrating samplers are used moved to the channel bed and back at constant rates. In high velocity flows, counter weights have to be used. At high flows it is usually impossible to get the bottle to the near bed zone with weights of a practical size. Hence, very little sediment data is collected with bottle samplers during the important high flow periods (FAO, 1981). Generally, conventional bottle sampling techniques are difficult to use in high flows. A further objection to bottle sampling techniques is, that the samples are too small to be analysed to yield size grading curves of the suspended material (Bolton, 1985).

2.8.2. Measuring sediment using pump samplers

Because of the limitations of bottle sampling Hydraulics Research has used pump sampling techniques for many years. In this method, a number of nozzles can be fixed to a rigid mast mounted in the river bed. Alternatively, nozzles can be suspended from a cableway. Where stream velocities are very large, nozzles can be bolted to rock outcrops or on to small purpose built concrete structures. Water is pumped from each nozzle, in turn, through a 63 micron filter to remove wash load which can be sampled at the filter out let if required. Normally at least 10 litres of water should be pumped, depending on the application. Sampling at each nozzle lasts several minute, providing some temporal averaging. More importantly, at least in perennial rivers where sediment concentrations are usually low, enough bed material sediment can be collected to enable individual samples to be size graded (Lawrence, 1986a and 1986b).

Pumping samplers collect a sample from a "fixed" intake point in the water column, and the resulting point samples are normally biased when compared with the mean concentration of sediment in the cross-section at the time of sampling. Pump sampler bias is due to several factors including, efficiency of sampler intake (especially with the sand fraction), non-is kinetic nature of intake region, and changing relative position of fixed-position intake with varying flow depth (Edwards and Glysson, 1999).

2.8.3. Measuring sediment using integrating samplers

There are two general types of integrating samplers for is kinetic sampling: those with a fixed open intake, and those with a controlled intake. The former, called a depth-integrating sampler, is used to collect a specimen of the water-sediment mixture in a vertical in which the concentrations at different depth are averaged. The latter, called a point-integrating sampler, is used to collect a specimen at a point at which the momentary fluctuations in sediment concentration are averaged. The intake nozzle and the air exhaust tube of an integrating sampler are separated in order to avoid disturbances to the inflow as the container is being filled (Tilerm, 1997).Because of its size, a suspended load sampler is designed to exclude the main zone of bed load transport close to the bed. Also, the bed load is well outside the scope of suspended load sampling. This type of sampler is the one that has been used in the present study.

2.9. Sediment Size Analysis, Canal Water Flow Measurement

2.9.1. The entrance of different sediment size along the canal

Due to the fact that the sediments entering irrigation canals are from external sources (for instance, rivers), the particle size of the sediment is usually different from the parent bed material. The incoming particle size depends on the operation of the sediment trap or intake structure at the head of the canal network. Normally the sediments entering into the irrigation canals are in the range of fine sand, silt and clay (Worapansopak, 1992).Larger particles are preferably excluded from entering the canal system by a careful skimming of the water at the intake or have been allowed to settle in a sediment trap in the first reach of the canal system (Dahmen, 1994). In view of these provisions at the head of an irrigation network, the sediment sizes are assumed to be in the range of $0.05\text{mm} < d50 < 0.5$ mm. It is also assumed that only non-cohesive material will be present in the irrigation system, despite some degree of cohesion that is present for the smaller particle sizes.

Particles transported as a bed load and suspended load are dependent on particle size distribution and the local flow strength. Particles might be carried as bed load in one reach and as suspended load in other section, where the flow conditions are different (Richardson, 1998; Saeyni, 2002).Particle size distribution effects on the trapping efficiency of a settling basin are reflected primarily by particle fall velocity or settling velocities which will be affected by the size, shape, and density of sediment particles. In turn, these settling velocities affect sediment transport rates and the point where particles are deposited (Haan*et al.,* 1994). Settled particles require more energy for start movement than keep on moving when already in motion. Clay particles require high velocities when compacted because of the cohesive nature of clay sediments. Sediment transport computation carried out to design sediment control structures are based on canal bed sediment size distribution (Lawrence, 2009).Sampling of bed material in coarse-grained channels requires a very large sample size to represent the sediment distribution accurately. When the surface layer consists mostly of gravel cobbles and boulders a randomized point counting method of the bed material can be used as alternative to sieving.

2.9.1. Canal water flow measurement and water distribution uniformity

To estimate actual water delivery and conveyance on main canal, actual water level and mean flow velocity will be measured using current meter, tape meter and staff gauges and, canal flow discharge will be computed from the known cross sections of the canal using velocity area method. The measurement will be conducted three times to minimize errors (Kieffer and Huck, 2008).

2.9.2. Sprinkler Irrigation water distribution uniformity

Uniformity of water application is necessary for more efficient use of the available water, to maximize crop returns and to reduce deep percolation (Mateos, 1997). Sprinkler irrigation systems are typically gauged by the uniformity of application above the crop canopy. The performance of a sprinkler irrigation system is often evaluated based on water uniformity coefficients collected in an array of measuring devices called rain-gauges or catch cans (Topak*et al.,* 2005). Such system requires a minimum value of uniformity to be considered as acceptable by the end users. Keller and Bliesner (1990), classified the irrigation uniformity in solid set systems as “low” when the Christiansen’s coefficient of uniformity was below 84%. A sprinkler water distribution pattern depends on the system design parameters such as: the sprinkler spacing, operating pressure, nozzle diameter, and environmental variables such as: wind speed and direction.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Location

The study area, Finchaa Sugar Estate, is located in Oromia Regional State, Horro Guduru Wollega Zone, at 9°30' to 10°00' North latitude and 37°15' to 37°30'Eastlongitude. It is found about 340 km North West of Addis Ababa and has an altitude range of 1350-1650 meter above sea level. The Finchaa River divides the project area in to Western and Eastern banks. Irrigation method of the estate is drag line sprinkler irrigation system and water for irrigation is supplied from Neashie and Finchaa reservoir. Neashie diversion system supply water for Neashie farms while Finchaa river supplies water for both West bank and East bank canals after generating hydroelectric power. The valley progressively widens from the South to the North where eventually, the Finchaa River is joined by the Amerti Neashie River before the combined rivers finally enter Abay River, main tributary of Blue Nile (Adinew, 2001).

Currently, more than 20,000 hectare of land is cultivated and out of this, 7,000 hectare is irrigated on East bank estate. The main objective of the scheme is growing sugar cane crop for white sugar and ethanol production.

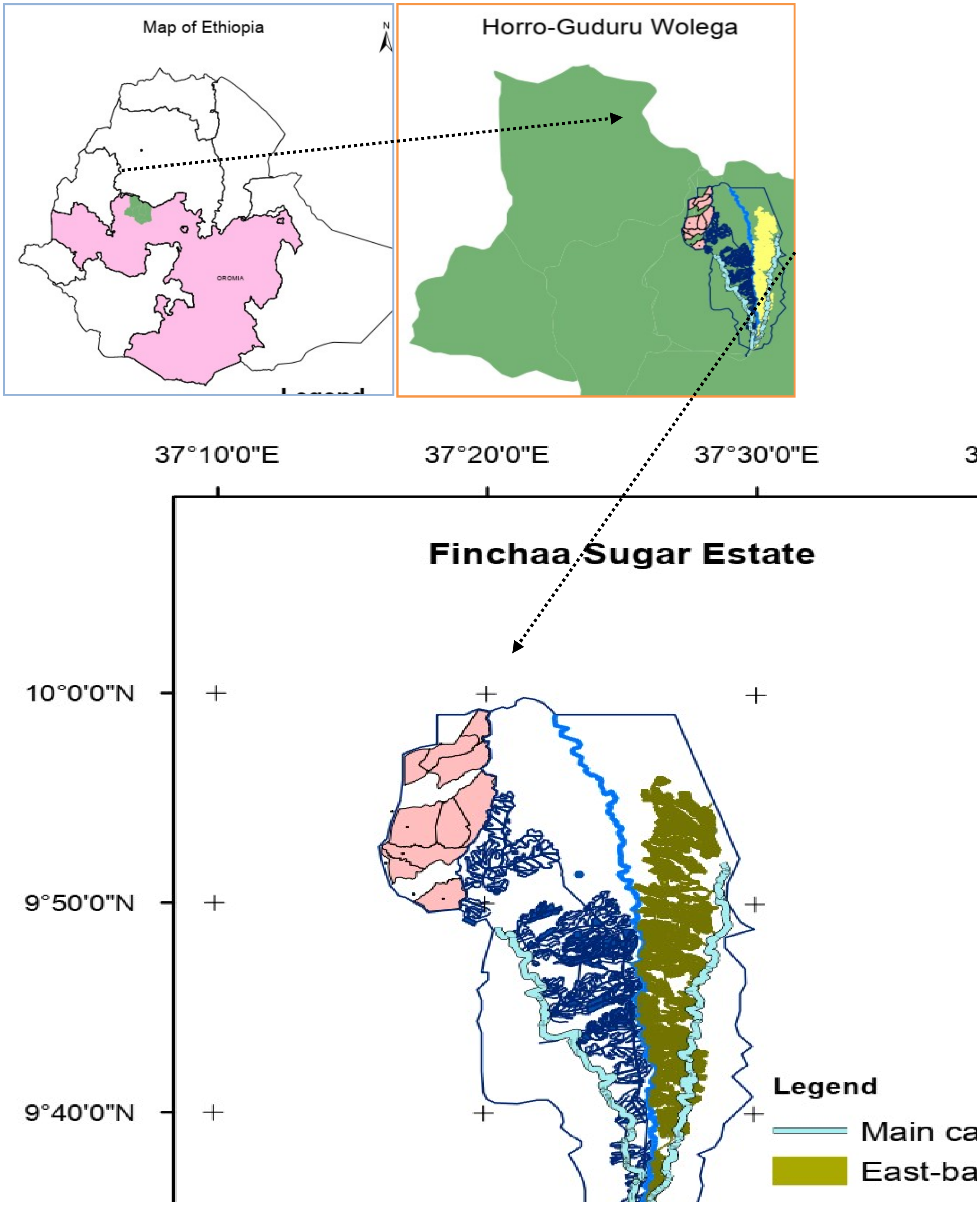

Figure 3. : Location Map of Finchaa Sugar Estate, East Bank

3.1.2. Climate

The long years (1999-2018)analysis of the annual rainfall of the area reaches about 1308.22 mm and the average monthly rainfall of the area reaches about 109.02 mm. Maximum and minimum daily temperatures of the area were 31.9°C and 15.1°C, respectively and the highest(36.7°C) and lowest (26°C).The 20 years (1999-2018) monthly average maximum and minimum mean of temperatures were31.45°C and14.86°C.The 20 years (1999-2018) monthly average highest and lowest relative humidity values are 84% and 43%, respectively. The 21 years (1990-2010) daily average sunshine is 7.66 hr (Anonymous, 2011).

The mean daily wind speed at Finchaa Valley of 20 years data (1999-2018) is about 2.1 km/hr at 2 m height, which is low and, therefore desirable for sprinkler irrigation system. The wind speed is insignificant to affect the distribution pattern of sprinkler spray.In general; the valley has a bi-modal rainfall distribution pattern with alternate wet and dry seasons with the major rain falling from May to October while being dry throughout the rest of the months. As a result, irrigation is not required from June to September because of sufficient amount of rainfall for cane growth. During the dry season water is applied to cane fields using a dragline sprinkler irrigation system (Worku, 1995).

3.1.3. Soil Types

There are two main soil types in Finchaa sugar estate. These are: Reddish Brown (Chromic, Hepallic and Gleyic) Luvisol and Black Clay Eutric Vertisols. The ratio of Luvisol to Vertisol in Finchaa cane plantation is about 3:1 (i.e., 27% Vertisol and 73% Luvisol) (Girma, 1995).

3.1.4. Crop types

The major crop grown in the area is sugar cane crop. Currently, more than 20,000 ha of the estate area is covered by sugar cane crop at Finchaa sugar estate. There are a number of sugar cane varieties introduced to the estate farm from different countries with some varieties emerged from local estates.

3.1.5. Irrigation practice

The Finchaa Sugar Estate irrigation scheme diverts its water from Finchaa River, at some 3 km downstream of the Finchaa Hydroelectric Power plantby the help of a diversion weir. The water is obtained from the Finchaa multipurpose reservoir after satisfying the non-consumptive hydroelectric power generation (Olmana, 2004).The Finchaa hydropower dam was constructed at the outlet of the Finchaa watershed. The dam has a 340 m crest length and reaches 20 m above the lowest foundation level (HARZA, 1975). The canal is designed to convey a gross discharge of 7.01m^3/s. The settling basin is located at about 10 km from the weir. Within the settling reach the velocity of flow is reduced from a peak of 1.5 m/s to 0.3 m/s to induce settling of fine particles. At the Estate, water is applied to sugar cane crop by semi-portable dragline sprinklers in the form of spray. The sprinklers operate under both gravity and pumped systems (centrifugal type). In the pumped sprinkler irrigation system, there are seven pump stations situated along the canal. Different number of pumps is being used on each pump stations depending on the total area to be irrigated (Booker Tate, 1994).

In addition to this, there are eight gravity off-takes along the canal, with different capacities to abstract water to areas that operate by gravity. Water is distributed to the cane fields via buried pipe systems and surface laid lateral pipes. The overhead irrigation equipment comprises the sprinkler lateral and the hose, tripod and sprinkler assembly. The application depth of the sprinkler is 5.6 mm per hour. The irrigation system is designed to give a gross application of 134.5 mm per cycle. The field efficiency is estimated to be 75% giving a net application of 100 mm. The system is designed to operate on a 15-day cycle with a 24 hour set time. Each sprinkler serves 15 positions on an 18 m x 18 m grid; with a 24 hour set time with sprinkler nozzle size was 2.4 mm by 4.4 mm. One sprinkler serves an area of 90 m x 54 m or 0.486 ha. This area is known as the irrigation module (Booker Tate, 1994).

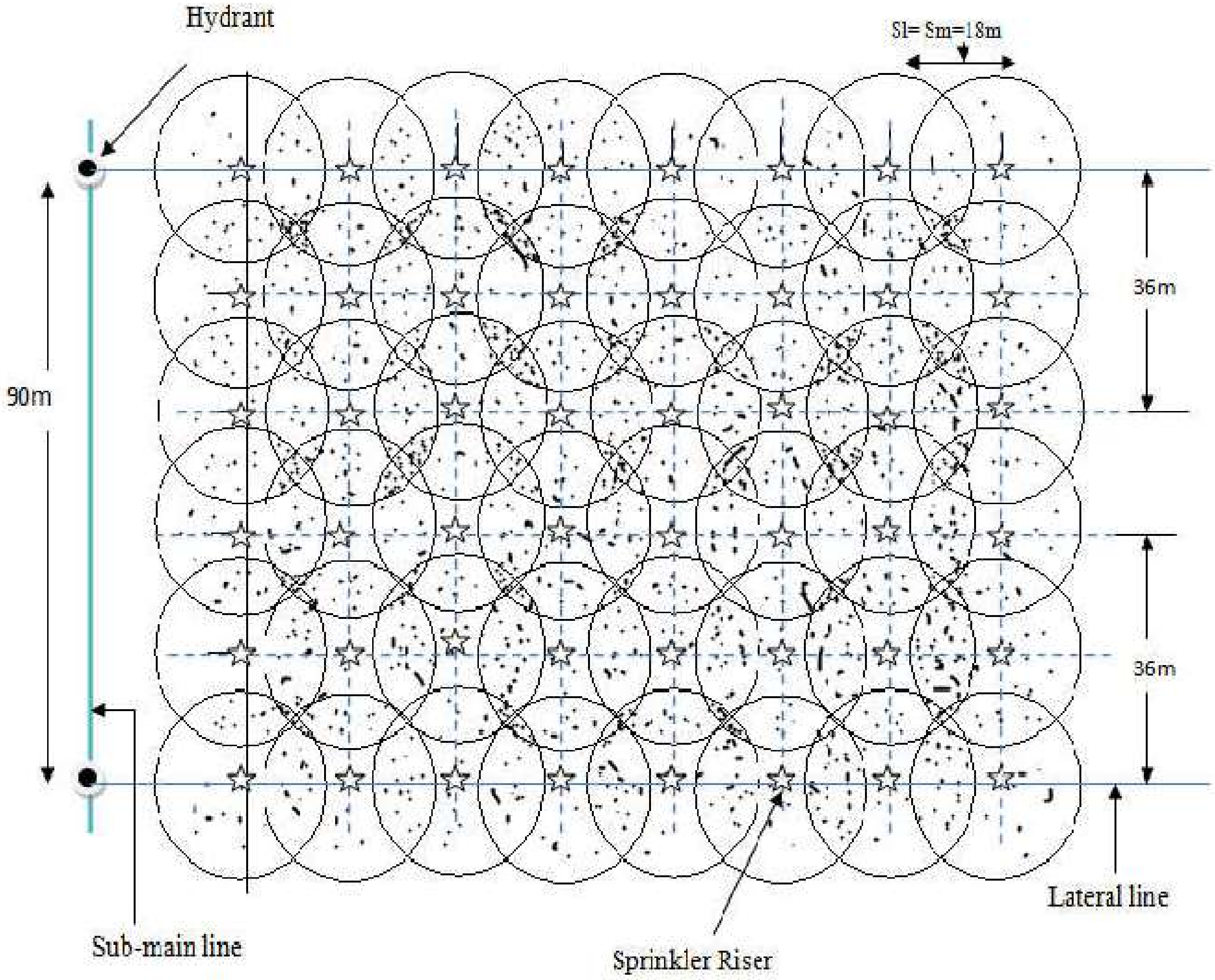

Figure 3., Layout of Operating Sprinkler Irrigation System at Finchaa Sugar Estate

3.2. Data Collection and Analysis

3.2.1. Materials to be used

Materials that were used during field data collections include: Sediment sampler, Current meter, Staff gauge, Measuring tape, Stop Watch, Catch-can, Sprinkler Assembly and Pressure Gauge. US D-74 Suspended Sediment Sampler with all of its accessories was used to collect sediment samples from different sampling points along the canal.USGS Type AA- Model 6200 current meter was used to measure the flow velocity during sampling. A staff gauge fixed on a wooden plate and measuring tape was used to measure the flow depth and width of flow cross section in the canal respectively. A digital stop watch was used to measure the time taken during transit. Additionally, different types of wrenches were used for assembling the sediment sampling equipment and the current meter during the test.

Plastic type standard catch-cans with capacity of 50 ml were used to collect water during the uniformity test and the amount of water collect at each point was measured using a graduated cylinder. Sprinkler heads was fit with different nozzles which have 2.4*4.4mm size. Additionally, plastic hoses of different diameter were used to collect water discharge from the nozzles. Pressure gauge was used to measure the operating pressure at the hydrant and at different points along the hydrant during the test, Wooden pegs was used to make the layout.

3.2.2. Data collection technique

Primary data required include data for canal flow measurement and sprinkler water application tests. Field water application measurement include: sprinkler nozzle discharge, water application depth and sprinkler operating pressures. Representative Fields which was one from upstream, one from downstream parts of the canal and canal sections were selected for data collection from different locations as it was not feasible to collect data for the entire system. To select the representative locations, field observations were first made to see the status of the fields and canal sections before starting data collection. Two fields were selected from pump stations from the entire East Bank sugar cane estate at different locations andsampling points along the canal was taken at six representative points out of total 40.8km length.

3.2.3. Sampling location along the canal and different canal structures

Sampling points were selected and located along the canal based on their suitability for data collection. For the case of this study, it was remarked as above settling basin (points 5 and 6) was selected as upstream old and the area covered below settling basin (points 1- 4) selected as downstream old, and with this concept the analysis have done. Figure 3.3 show detail sampling points along the canal.

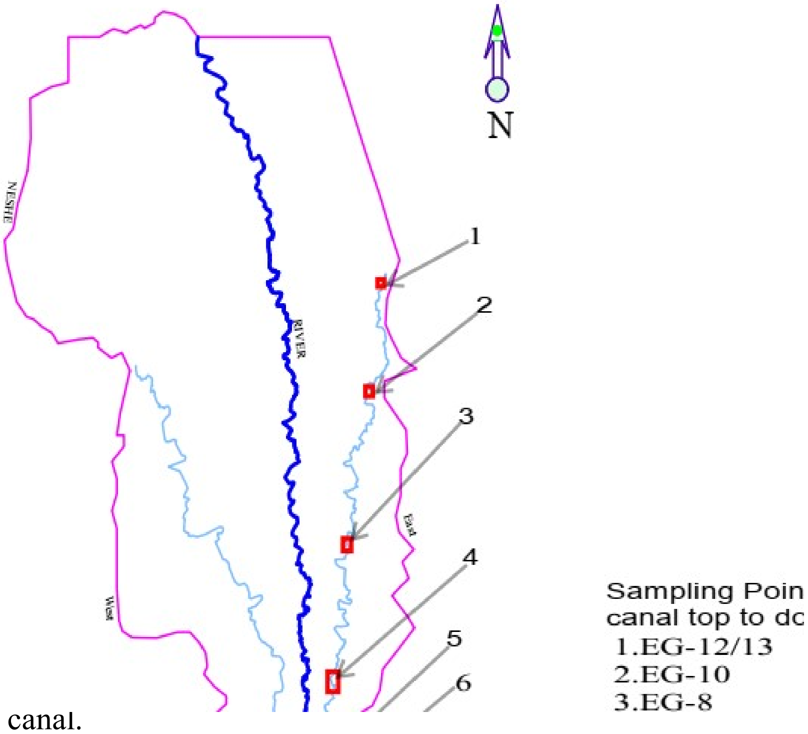

Figure 3. : Sampling points along the canal.

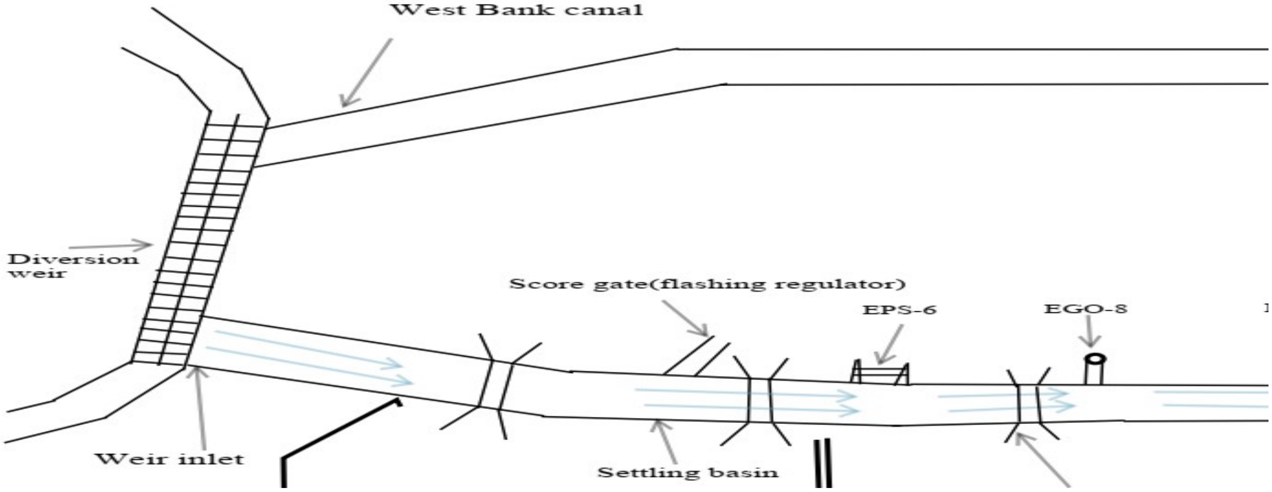

Figure 3. : The Schematic Diagram Locations of Sampling Points along the Canal

Figure 3. : Diversion Weir and Manual Removal of Sediments from Settling Basin

Figure 3. : Data collecting byUS D-74 Suspended Sediment Sampler.

3.2.4. Discharge measurement in canals

Velocity measurements was done using USGS Type AA- Model 6200 current meter commonly known as the Price-type current meter together with USGS Model 4020 Sounding Weights and USGS Model 4049 Hunger bar and Pins. These commonly used current meters express flow velocity in terms of rotations. Conventional meters are of two general types: the propeller type with horizontal axis of rotation and the conical cup type with vertical axis. The latter type was used in this study.

The discharge was computed using the velocity-area method making use of (Rickly, 1997) equation:

$$Q = \sum A_i V_i \qquad [3.1]$$

Where, Q = the discharge (m^3/s)

V_i= the flow velocity in sub-section (m/s)

A_i = cross sectional area of the canal sub-section (m^2)

3.2.5. Determination of sediment load and Sediment discharge

The US D-74 Cable-Suspended Sampler was used to take the suspended sediment samples. USGS B-56 Model Sounding Reel was used to position the sample collecting equipment in the water (Rickly, 1997). US D-74 was depth integrating instrument, designed for use in streams not more than about 4.5 meters in depth. The depth of the canal was not more than 1.75 meters and that was why this sampler was used in this study.

Then, sediment concentration (C_s) in parts per million (ppm) was computed by dividing the oven dry weight of the sample to the net weight of sediment water mixture and multiplied by one million (Dendy *et al.,* 1979; Line and White, 2001).

$$C_s = \frac{\text{Wieght of sediment}}{\text{Wieght of water sediment mixture}} \times 10^6 \qquad [3.2]$$

where, C_s = Sediment concentration in (ppm)

Then, the rates of sediment discharge were computed using the equation (Kidane, 1987):

$$Q_s = kQ_wC_s \qquad [3.3]$$

Where, Q_s= sediment discharge, 1000 kg/day or ton/day

Q_w= water discharge (m3 s^{-1})

k = conversion factor which is equal to 0.0864 or 86.4

C_s = Sediment Concentration (ppm) or (g l^{-1})

3.2.6. Measuring sprinkler uniformity

The (CU_C) Christiansen Uniformity Coefficient (Christiansen, 1941) is the coefficient widely used by researches on the global scale and has been applied as a proven criterion to define water distribution uniformity (Topak*et al.,* 2005). It is commonly used in agricultural sprinkler uniformity assessment and is expressed as:

$$\mathrm{CUC} = 100\left[1 - \frac{\sum_{i=1}^{n}|V_i - \overline{V}|}{\sum_{i=1}^{n} V_i}\right] \qquad [3.4]$$

Other methods to calculate the uniformity coefficients were given by (Wilcox and Swailes, 1947), (Merriam and Keller, 1978), (Burt *et al.,* 1997) and (IA, 2005). Another common measurement of variability in water application include the low quarter distribution uniformity (DU_{lq}),

$$\mathrm{DU_{lq}} = \frac{\overline{V}_{lq}}{\overline{V}_{tot}} \qquad [3.5]$$

To distinguish between a measure of uniformity and efficiency, DU_{lq} shall be expressed as a decimal as suggested by (Buret*et al.,* 1997).This method emphasizes the areas which receive the least irrigation by focusing on the low quarter. The lower half distribution uniformity can be calculated from lower quarter distribution uniformity as follows (IA, 2005).

$$\mathrm{DU_{lh}} = 0.386 + \left(0.614 \times \mathrm{DU_{lq}}\right) \qquad [3.6]$$

The uniformity coefficient according to (Wilcox and Swailes, 1947) is given by (CUWS),

$$\mathrm{CUWS} = 100(1 - C_V) \qquad [3.7]$$

The (C_v), in application volume was computed as the standard deviation of all catch can measurements divided by the average catch can volume for a test. IA (2012) suggested different schematic layouts of catch can such as radial, circular and square to assess point test. ButRegan (1987) and Dabbous (1962) suggested square patterns of catch can test for water distribution uniformity measurement with different sprinklers spacing.

3.2.7. Sediment size analysis along the canal

In addition to determining the rate of sediment discharge, the sediment size analysis was carried out to know the relative proportion of different particles (sand, silt, and clay) in the sediment sample.Since adequate amount of sediment usually in the order of 50 to 100 gram (for hydrometer method) was required for particle size analysis, individual flow weighted samples were collected together after their sediment content was determined. Since the sediment content in the flow weighted samples was very minimum and measured in milligrams (mg) additional samples were taken along the canal for particle size analysis. Moreover, sediment samples were collected from diversion weir at the entrance to the canal, settling basin out let, Pump stations-4,6,8 and9,gravity off take-10,11,2 and 13 in order to analyze the amount of sediment transport and particle size distribution of the sediment along the canal.

The particle size analysis was done using the hydrometer method following the standard procedures recommended (Line and White, 2001; Foth, 1990). 100 gm of dry sediment was weighed and 100 ml of dispersing reagent, 40 gm of sodium-hexane taphosphate ($NaPO_3$) and 10 gm of sodium carbonate (Na_2CO_3) added in distilled water and shacked for three hours using oscillatory shaker and then stirred for 5 minutes. After transferring the dispersed soil suspension in to the sedimentation cylinder, distilled water was added such that the final volume of the specimen and the solution becomes one liter. Then, the solution was stirred again thoroughly with a plunger and a hydrometer and temperature readings were taken at interval of 40 second after the cylinder is set down. This reading measures the % of silt and clay in suspension.

This reading was subtracted from the sample weight to know the weight of sand. After 2 hrs, second hydrometer reading was taken, which determined percent weight of clay fraction. To estimate the silt content, the percent weight of the sand and clay was added and the sum was subtracted from 100%. Results obtained as such were corrected for a temperature at 20°C before final computation as recommended (Line and White, 2001; Foth, 1990).

3.2.8. Uniformity and sprinkler discharge measurement

In order to evaluate the effects of sediment on the uniformity of the sprinkler irrigation, uniformity evaluation and discharge measurement of the irrigation system was carried out on field number EGO, 920. In order to get more accurate result in terms of pressure variation, three different hydrant pressures of 4.0 bar, 4.5 bars and 5 bars were used for the test.For all the tests, sprinkler nozzles of 2.4 mm*4.4 mm size have been used. The tests were conducted on a lateral having 387 m length and 21 riser positions.

The old sprinkler nozzles used for this trial were randomly selected from two areas and additionally a new sprinkler nozzle was also used for the test as a control. The first nozzle was selected from a command area that was found upstream of the canal on field number (EPS, 208) and in this study named as "upstream old nozzle" whereas, the second nozzle was selected from a command area that was located downstream of the canal on field number (EPS,618) and named as "downstream old nozzle". Both nozzles were selected from second Raton (R2) fields. From the plantation field history and irrigation operation reports, the age of the sprinkler selected from (EPs,208) was 31 months whereas, the age of the second nozzle selected from (EPs, 618) was 33 months. Hence, the nozzles selected for comparison have nearest to similar age but newly installed.

The catch can uniformity test was performed on EGO-920 for new, upstream old and downstream old nozzles with each at 4.0, 4.5 and 5.0 bar operating pressures. The test was carried out using four sprinkler methods. For the uniformity measurement thirty-six plastic pegs were installed between the squares bound by four sprinklers in square grid patterns of 3 meter interval as indicated in Figure 3.6. Then graduated catch cans were placed at the top of each peg and the sprinkler was allowed to operate for two hours. After two hours, the water collected in the catch cans was measured using a graduated cylinder. During the uniformity test, the evaporation loss was also approximately determined by placing a graduated catch can of known volume around the test site for the same duration as that of the uniformity test.

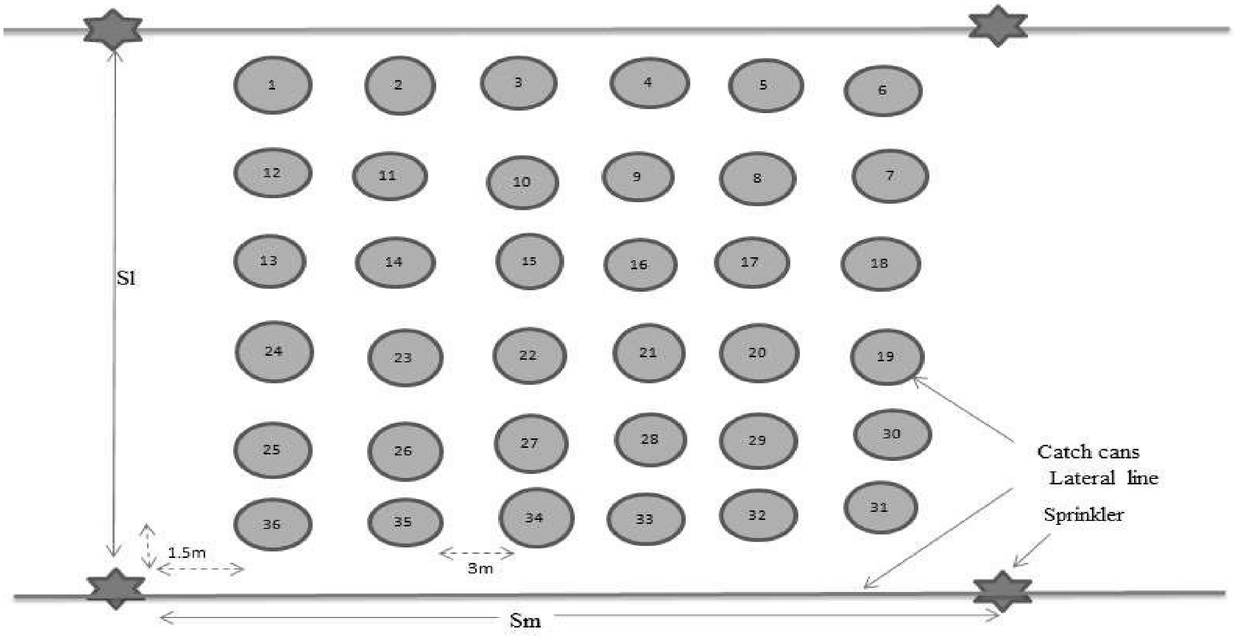

Figure 3. : Catch Can Arrangements for Uniformity Measurement at a field

The coefficient of uniformity was calculated using Christiansen Uniformity Coefficient (Christiansen, 1941) equation. The discharge rate for all sprinkler nozzles: new, upstream old and downstream old was also measured on field EGO-920 on a lateral having a length of 387 meters and 21 riser positions with two replications at the considered hydrant pressures. The test was carried out at three points along the lateral: beginning (1st riser), middle (11th riser) and end (21th riser) by connecting flexible hoses to both the 4.4 mm and 2.4 mm nozzles, and allowing water to fill a known volume of barrel (230 lit) for a measured period of time. The discharges from the two nozzles were collected in to the same container. The pressures were also measured at the hydrant and at the three test points along the lateral (Olmana, 2004). The discharge from the sprinkler was calculated by (Cuenca, 1989):

$$\text{Discharge}(q) = \frac{\text{Volume of water collected(lit)}}{\text{Test period(sec)}} \qquad [3.8]$$

From the measured discharge and given sprinkler spacing the application rate (Ra) can be computed using the relation given by (Cuenca, 1989) as:

$$\text{Application rate } R_a = \frac{\text{Sprinkler Discharge (lit/hr)}}{S_l \times S_m} \qquad [3.9]$$

4. RESULTS AND DISCUSSIONS

4.1. Sediment Particle Size Analysis

The size and distribution of sand silt and clay fractions were determined by hydrometer methods. The grain size distribution was estimated for the bed load ,the primary grain size class in transport was sand.The particle size analysis result was described in Table 4.1 below and it shows 43.12%, 35.01%and 21.87% for sand, clay and silt respectively.

Table 4. : Particle Size Analysis Result of Sediment Samples

S/n.	Sampling Location	% Sand	% Silt	% Clay
1	Diversion weir	39	37	31
2	Settling reach out let	41	33	26
3	EPS-4	25	45	30
4	EPS-8	33	43	24
5	EPS-9	49	39	12
6	EGO-10	46	33	21
7	EGO-11	50	30	20
8	EGO-12/13	62	27	11

From this result, it can be concluded that an increase in percentage of the sand and clay particles may be due to two reasons. The first one was there could be bank and bed scouring in the diversion weir section (between the weir and the power house) since it comprises of mainly black cotton soil or vertisol with significantly higher clay content.

Secondly, settling down of coarse particle (sand) could have increased its proportion because the canal design and its alignment was approached and parallel to the chain mountains which exist above its surrounding and deforestation for agricultural practices by community result in soil erosion and it was the main causes for the increased in the values of sands

4.2 The Effect of Sediment along the Canal

4.2.1. Sediment measurement in the canal

Sediment measurement in irrigation canal was done per average distance of eight kilometres along the canal, so that the results vary at each point depending up on cross sectional location, flow velocity and flow discharge. Accordingly, the measurement gathered data were described in Table 4.2 below. The values of sediment data measurement for weight of sample were 43.33to 26.67(mg), average flow discharge from 7.94 to 1.97m^3/s, sediment concentration from 99.37to 65.75 (ppm), rate of sediment dischargefrom 68.17to 15.52 tone/day and critical velocity from 1.47 to 0.41m/s diversion weir inlet to end of the canal.

Table 4.2.showed that both weight of sediment sample taken and sediment concentration in different canal sections decreased from diversion weir up to settling reach of the canal, then it was going again at an increasing rate to the end of the canal and at the same time,sediment rate, flow velocity and flow discharge decreases until end of canal. From this result, it can be concluded that, rate of sediment discharge (Qs) was directly proportional with flow discharge along the canal.Larger particle have been allowed to settle in a sediment trap in the settling reach, some amount of the sediment passes through the canal again. After the middle distance of the canal, the amount of sediment entrance increased because of three different problems. During the operation time, because of the high peak demand of electric power to the country, Finchaa power house was generating more power, so that more water flashed from the dam. For this reason, there was more detachment of sediment particles from the dam and there was the chance for the entrance of sediment to the river and diversion weir.

The second case was there could be bank and bed scouring in the diversion weir section between the weir and the power house comprising of mainly black cotton soil or vertisol with significantly higher sand content. The third point was because of cultural farming practices and deforestation by the local community, the surrounding chain of mountains was contributing for the increment of erosion and the canal sediment entrance increases. So that, there was more sediment ten trance to the canal at the beginning until it reaches settling reach.

After that, larger particles have been trapped by settling reach, the remaining particles was flow with water to settle in different parts of the canal.Sediment concentration and sediment discharge will increase during the rainy season. This may be due to the reason that, the erosion rate and consequently the sediment yield increases due to an increase in both detachments by rain drop and transport of detached sediment material by runoff (Foster, 1982).

Larger particles are preferably excluded from entering the canal system by a careful skimming of the water at the intake or have been allowed to settle in a sediment trap in the first reach of the canal system (Dahmen, 1994).The particle size analysis of flow at the settling basin outlet and at pump station four, (found 12 km downstream of the basin) indicated that, during the flow of water from the outlet of the basin to pump station (4), the coarse sized particle sand has settled down further (62.5%) resulting in an increase of silt and clay proportion in the flow (Olmana and Chemeda, 2011).

During sediment data measurement, velocity and flow discharge at the sampling point was measured to compare with the actual design document parameters specially velocity and flow discharge. The result shows that there was a little difference, because the values of both parameters was taken from the design document for full capacity of the canal but the actual measurement was done when the canal water flow was at a normal condition, so it made a little difference. Even though there was a little difference up on both velocity and flow discharge between the actual measured values and data from canal designed document for velocity and flow discharge, the values from designed document parameters have had no input for the result done, more it was used for comparative aspect.

The result obtained during the study showed that, the average sediment concentration (C_s) along the canal was571.67ppm and the average rate of sediment discharge (Q_s) was found to be 256.47ton/day. From these results, it can be concluded that the amount of sediment transport through the canal cross section were significantly affect canal and canal structures at the same time it affects the existing irrigation pumps. Sedimentation reduces canal conveyance efficiency leading to inadequacy and inequity in water distribution to crops. In addition, sedimentation may lead to increased risk of canal breach due to a reduction in freeboard and water logging. Sediment deposition in irrigation canals results in rising canal bed levels, reduced canal capacities, and problems in supplying the required amounts of water to some or all parts of the irrigated area (Chancellor *et al.,* 1996).Within the same study area, a study doneby (Olmana andchemeda, 2011) showed that, the average silt concentration (C_s) at the inlet of the settling basin was 313.8 ppm and the average sediment discharge (Q_s) was found to be 196.4 ton/day. At the outlet of the settling basin, the sediment concentration and the silt discharge were, 234.7 ppm and 146.5 ton/day, respectively.

Study done by (Habtamu, 2010), in Awash Basin on sediment yield found suspended sediment load ranges of 600-700 ppm at Hombole and 300-400 ppm at Kunture gauging stations respectively.

Table 4. : Sediment measurement along the canal.

S/no.	Sampling locations	Weight of sample (mg)	Sediment conc., C_s (ppm)	Sediment rate, Q_s (tone/day)	Average Actual Velocity at a point in (m/s)	Designed Velocity at a point in (m/s)	Average actual Flow discharge $Q(m^3/s)$	Designed Flow discharge $Q(m^3/s)$
1.	Weir outlet	43.33	99.37	68.17	1.47	1.52	7.94	8.02
2.	Settling reach outlet	26.67	65.75	39.71	0.73	0.78	6.99	7.66
3.	East bank pump station (EPS -6)	30.00	75.00	30.84	0.69	0.72	5.82	6.11
4.	Gravity off take-8	33.33	80.22	24.61	0.65	0.70	4.94	5.73
5.	Gravity off take-10	36.67	88.40	17.87	0.59	0.61	2.89	3.94
6.	Gravity off take-12/13	40.00	91.23	15.52	0.41	0.48	1.97	2.09

4.3. The Effect of Sediment on Application uniformity of sprinkler irrigation system

4.3.1. Sprinkler discharge and application rate

The specific discharges and application rates for the test nozzles were also determined from the field measurement. The results are summarized in Table 4.3below for the three operating pressure and test nozzle combinations. The specific discharge obtained at the test was between 0.49 and 0.78 lit/sec for the considered combination of operating pressures and nozzles. The values vary between 0.49 and 0.67 lit/sec, between 0.58 and 0.72 lit/sec and between 0.60 and 0.78 lit/sec for the new, downstream old and upstream old nozzles, respectively.

Table 4. : Discharge and Application Rate

Nozzle description	Hydrant pressure (bar)	Specific discharge (lit/sec)	Application rate (mm/hr)
Upstream old nozzle	4	0.60	6.68
	4.5	0.73	8.11
	5	0.78	8.69
Downstream old nozzle	4	0.58	6.44
	4.5	0.65	7.22
	5	0.72	8.02
New nozzle	4	0.49	5.48
	4.5	0.51	5.67
	5	0.67	7.46

The average depth applied by the sprinkler nozzles was 6.20 mm/hr for the new, 7.83 mm/hr for upstream old and 7.23 mm/hr for downstream old nozzle (Table 4.3).From this result, it was evident that the upstream old nozzle was giving the highest discharge and application rates followed by the downstream old nozzle at all operating pressures, because of increase in nozzles diameter of for upstream and downstream. This increased discharge could be due to wear and tear of nozzles by the abrasive effect of sediment in irrigation water. Since the discharge through the nozzle is a function of nozzle diameter and operating pressure, the upstream old nozzles gave higher discharges at all operating pressures.At this junction, it is worth to mention that the upstream old nozzle has performed better than its counterpart downstream old nozzle in terms of discharge and application rate. This could be explained by the fact that the settling basin has trapped some of the sediments and the amount of sediment passing via the settling reach was relatively small and its abrasive effect on the downstream old nozzle was minimal. Hence, the sediment has affected the performance of the sprinkler nozzles found at upstream and downstream of the basin at a varying degree.

From this result, one can understand that improving the sediment trapping efficiency of the settling basin, frequent cleaning of sediment from diversion weir to end canal could help to improve the performance of the sprinkler nozzles found in the command area. For an average sprinkler discharge rates the result obtained by (Habib and Girma, 2006) and (Olumana,2004) have had almost similar with this study for 4.0,4.5 and 5.0 pressure bars.

In addition, Olumana and Chemeda, (2011), found the specific discharge obtained at the test was between 0.49 and 0.76 lit/sec for the considered combination of operating pressures and nozzles. The values vary between 0.49 and 0.57 lit/sec for the new, between 0.58 and 0.67 lit/sec downstream old and between 0.66 and 0.76 lit/sec for upstream old nozzles, respectively at operating pressures of 4.0, 4.5 and 5.0 bars which were similar with the previous study results.

4.3.2. Surface uniformity

The surface uniformity of water application/distribution was determined from the catch can observation data and the results were tabulated in Table 4.4 below. The obtained CUC at the test ranges between 87.60 and 89.43%, for the new nozzles, between 79.65and 81.28%, for the upstream old nozzles and between 84.32and 85.54%, for the downstream old nozzles. Here, it can be observed that, the CUC for the new nozzles is greater than the minimum recommended value of 85% (Michael, 2008). The CUC obtained for the upstream old nozzle is below the range indicating non uniform water application by the nozzles. The result obtained for the downstream old nozzle indicates that, though not as good as, the CUC obtained for the new, it has performed better than the upstream old nozzles in terms of uniformity. It can be concluded that the new nozzles have better uniformity of water distribution than both upstream and downstream old nozzles. Next to new nozzles, downstream nozzles have better water uniformity than upstream old nozzles. The conclusion can be described as, the selection of sampled nozzles were collected from two different fields that were served for 31 and 33 months respectively. Sprinkler nozzles diameter ranges from 2.4mm for the small one to 4.4mm for the largest nozzles, so that when diluted sediment with water distributed to the plants for long period of time, the sediment causes wear and tear up on the nozzles diameter by increasing their sizes, as a result, there was an increase in discharge flow of water through the nozzles, but the increase in discharge and nozzles diameter, decreases the pressure for upstream old nozzles and less effect for downstream old nozzles, because of the decrease in pressure could decrease the rotations of nozzles over a time and decrease the coverage of water distribution by minimizing a radius of nozzles coverage from standard of9m to 8m.

Therefore the new nozzles do not affected by sediment in the water for the test period and have better uniformity of water distribution than both upstream and downstream old nozzles.

Table 4.: Surface CUC and DU Result

Nozzle description	Hydrant pressure (bar)	Surface uniformity (%)	
		CUC	DU
Upstream old nozzle	4.0	81.28	60.85
	4.5	79.65	68.48
	5.0	80.90	69.04
Downstream old nozzle	4.0	85.54	82.08
	4.5	84.32	76.89
	5.0	85.35	81.05
New nozzle	4.0	87.60	80.24
	4.5	89.43	83.92
	5.0	88.48	82.95

The value obtained during the test indicates that, for the new nozzle, DU ranges from 80.24 to 83.92%. For the upstream old nozzle the value was between 60.85 and 69.04%, for the downstream old nozzle it ranges from 76.89 to 82.08%. From this it can be concluded that, the DU value for the new sprinkler nozzle was above the minimum recommended value of 80% at all considered hydrant pressures (Michael, 2008). DU for the upstream old nozzle was by far below the recommended minimum value of 80% at all pressures. This poor distribution could be due to the reason that the sprinkler nozzles were worn out because of the action of abrasion by the sediments.

The DU for the downstream old nozzle was within the acceptable range that shows that even if the downstream old nozzle was relatively affected by sediment, the wear caused by the sediment is not as severe as that of the upstream old nozzle. There was better uniformity of water application at 4.5, 4.0 and 5.0 bar hydrant pressure for the new, old downand old upstream sprinkler nozzles. The higher uniformity at optimum or designed hydrant pressure of 4.5 bars for the new nozzle could be explained by the fact that, when the pressure rises to 5.0 bars the stream is broken up into excessively small droplets and the water does not carry to the extent of the design wetted diameter and excessive amount of water are instead deposited in the vicinity of the nozzle and hence resulting in poor uniformity.

Generally, it can be concluded that the obtained values of CUC % andDU % at the test for new nozzle were greater than the minimum recommended value and by (Michael, 2008), downstream old nozzle was within the acceptable range that shows that even if the downstream old nozzle was relatively affected by sediment, the wear caused by the sediment is not as severe as that of the upstream old nozzle. So that the degree of wear and tear severity caused by sediment was significantly affect the water distribution at different pressure bars.
Olumana, (2004) investigated, on application performance at Finchaa irrigation system found CUC 95.6%, 89.6% and 89.0% at hydrant pressures of 4.0, 4.5, and 5.0 bars respectively. The values of DU found were at his test 93%, 87% and 83% at the respective operating pressures. These results indicated that both CUC and DU increased with an increase in pressure which was contrary to the result of the present study. The reason may be due to the nozzle selected for the test. The nozzles were randomly selected from the field irrespective of their age.

Olumana and Chemeda, (2011)investigated on sprinkler uniformity at Finchaa irrigation system found CUC 87.01%, 90.64% and 89.46% at hydrant pressures of 4.0, 4.5, and 5.0 bars respectively. The values of DU found at the test were 79.88%, 87% and 82.67% at the respective operating pressures. In his study both CUC and DU achieve a maximum value of uniformity at an optimum pressure of 4.5 bars. The reason may be due to the nozzle he selected for the test, the nozzles were selected from the field with respective of their service age and selective command area in which the same result and approach to this findings. In agreement with the present result, Cuenca (1989) found a decrease in uniformity due to an increase or decrease of pressure from the design optimum value as discussed above.

The above results indicate that there is a loss of 17.63%, 33.87% and 20% for the new, upstream old and downstream old nozzles, respectively. In regard to this (Habib and Girma, 2006) have found an average loss of about 20% in their study. From this result, one can conclude that, the upstream old nozzle in addition to its poor performance in terms of uniformity and discharge it also has the highest water loss. The above result indicates that, both the upstream and downstream old nozzles used in the trial were supplying water in excess of the designed crop water requirement (CWR).

Studies indicate that, in addition to causing loss of water and energy non uniform water application could also have an adverse impact on yield. Hence, to overcome the problem, replacement of old nozzles have to be carried out based on cost benefit analysis for the cost of nozzle replacement and return from water and energy saving as well as yield increment obtained from better application uniformity.Usually, more efficient sprinkler systems achieve higher economic returns and use less water (Cuenca, 1989).

As presented in (Table 4.5), a maximum depth of average catch as well as lower quarter for the new sprinkler nozzle was obtained at an operating pressure of 5.0 bars. This indicates that, the application rate of the nozzle decreases as the pressure increases or decreases from an optimum value. For both the upstream and downstream old nozzles, a higher application rate in terms of average catch and lower quarter was obtained at the maximum operating pressure (or 5 bars).

The amount of water actually discharged from the sprinklers andcollectedby the catch cans was different due to losses such as wind drift, evaporation and others.

During the study, the average amount of water received by catch cans at each an operating pressure of 4.0, 4.5 and 5.0 bars(the average catchreceived)was found by the new, upstream and downstream old nozzle was 3.64 mm/hr, 4.5 mm/hr and 4.43 mm/hr respectively (Table 4.5).

Table 4. : Average Catch and Lower Quarter Received

Nozzle description	Hyd. Pressure (Bars)	Avg. catch received (mm/hr)	Avg. Lower quarter (mm/hr)
New nozzle	4.0	3.88	2.89
	4.5	3.44	2.99
	5.0	3.6	3.11
Upstream old nozzle	4.0	4.25	3.39
	4.5	4.41	3.51
	5.0	4.81	3.95
Downstream old nozzle	4.0	4.21	3.29
	4.5	4.48	3.49
	5.0	4.63	3.55

However, from Table 4.5 it can be seen that, the average catch as well as the average lower quarter received by both of the old nozzles were higher than that of the new nozzle at all pressures. This result reveal that, the operating pressure being equal with the new the higher discharge obtained by the old nozzles may be due to an increase in nozzle diameter from wear caused by sediments. This result agrees with the fact that discharge is a function of operating pressure and nozzle diameter (Cuenca, 1989).

In the study of (Habib and Girma 2006), irrigation interval and efficiency at Finchaa Sugar Estate, found that the average catch can receive ranged from 3.68 mm/hr to 5.7 mm/hr with an average value of 4.6 mm/hr for test pressures of 2.5, 3.5, 4 and 4.5 bars. This result is in agreement with the outcome of the present study which has values of the average catch received by the new, upstream and downstream old nozzle was 3.64 mm/hr, 4.5 mm/hr and 4.43 mm/hr respectively.Similar result was obtained by(Olumana,2004); found average catch can depths of 3.89 mm/hr, 4.66 mm/hr and 4.78 mm/hr at respective operating pressures of 4, 4.5 and 5 bars.

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary

This study assessed the impact of sediment transport on irrigation canal and its effect on application uniformity of sprinkler irrigation system on East bank canal. The study was carried out by analyzingapplication uniformity of sprinkler irrigation system and analysis of sediment transport along the canal. Application Uniformity was done by measuring Sprinkler discharge, application rate and surface uniformity of the system. Analysis of sediment along the canal was carried out by determining measuring the amount of Sediment in different canal sections and Sediment particle size analysis flow through the canal from diversion weir to all canal sections.

Sprinkler discharge and application rate of the system was done for the three operating pressure namely 4.0, 4.5 and 5.0 bar and test nozzle combinations. The values vary between 0.49 and 0.67 lit/sec, between 0.58 and 0.72 lit/sec and between 0.60 and 0.78 lit/sec for the new, downstream old and upstream old nozzles, respectively. From this result, it was evident that the upstream old nozzle was giving the highest discharge and application rates followed by the downstream old nozzle at all operating pressures. This increased discharge could be due to wear and tear of nozzles by abrasive effect of sediment in irrigation water. Since the discharge through the nozzle is a function of nozzle diameter and operating pressure, the upstream old nozzles gave higher discharges at all operating pressures.

The surface uniformity of water application/distribution was determined from the catch can observation data and the results were tabulated in Table 4.5 above. The obtained CUC at the test ranges between 87.60 and 89.43%, for the new nozzles, between 79.65 and 81.28%, for the upstream old nozzles and between 84.32 and 85.54%, for the downstream old nozzles. Here, it can be observed that, the CUC for the new nozzles is greater than the minimum recommended value 85% (Michael, 2008). The CUC obtained for the upstream old nozzle is below the range indicating non uniform water application by the nozzles. The result obtained for the downstream old nozzle indicates that, though not as good as, the CUC obtained for the new, it has performed better than the upstream old nozzles in terms of uniformity.

The value obtained during the test indicates that, for the new nozzle, DU ranges from 80.24 to 83.92%. For the upstream old nozzle the value was between 60.85 and 69.04%, for the downstream old nozzle it ranges from 76.89 to 82.08%. From this, it can be concluded that, the DU value for the new sprinkler nozzle was above the minimum recommended value of 80% at all considered hydrant pressures (Michael, 2008). DU for the upstream old nozzle was by far below the recommended minimum value of 80% at all pressures. This poor distribution could be due to the reason that the sprinkler nozzles were worn out because of abrasion by the sediments. The DU for the downstream old nozzle was within the acceptable range that shows that even if the downstream old nozzle was relatively affected by sediment, the wear caused by the sediment is not as severe as that of the upstream old nozzle.

The effect of sediment along the canal was analyzed by measuring the amount of Sediment in different canal sections at an average of eight kilometres far apart. Accordingly, the measured data was described in table 4.2 above. The values of sediment data measurement for Weight of sampled sediment in (mg), average flow discharge, sediment concentration, rate of sediment discharge and velocity from diversion weir inlet to end of the canal was 43.33 to 26.67 (mg), from 7.94 to 1.97m^3/s, from 99.37 to 65.75 (ppm), from 68.17to 15.52tone/day and from 14.7 m/s to 0.41m/s respectively along the canal section.

Larger particles have been allowed to settle in a sediment trap in the settling reach, some amount of the sediment passes through the canal again. The result obtained during the study showed that, the average sediment concentration (C_s) along the canal was 571.67(ppm) and the average rate of sediment discharge (Q_s) was found to be 256.47ton/day. Study done within the same study area by (Olmana and Chemeda, 2011) showed that, the average silt concentration (C_s) at inlet of the basin was 313.8 ppm and the average sediment discharge (Q_s) was found to be 196.4 ton/day. At the outlet, the sediment concentration and the silt discharge were, 234.7 ppm and 146.5 ton/day, respectively. In the study of (Habtamu, 2010) during his study in Awash Basin on sediment yield found suspended sediment load ranges of 600-700 ppm at Hombole and 300-400 ppm at Kunture gauging stations respectively and those study shows the same result to the present study.

The study shows average particle size analysis in values was 43.12%, 35.01% and 21.87% for sand, clay and silt respectively. From this result it can be concluded that, increase in percentage of the sand and clay sized particles may be due to two reasons firstly, there could be bank and bed scouring in the diversion weir section between the weir and the power house comprising of mainly black cotton soil or verti soil with significantly higher clay content. Secondly, settling down of coarse sized particle (sand) could have increased its proportion because the canal design and its alignment was approached and parallel to the chain mountains which exist above its surrounding and deforestation for agricultural practices by community result in the detachment of sand soils from rocks and other parent minerals and it was the main causes for the increased in the values of sands and also thirdly, there was more detachment of sediment particles from the upstream dam and there was the chance for the entrance of sediment to the river and diversion weir.

5.2. Conclusions

The analysis was done using primary and secondary data collected from the entire system at selected locations. The following conclusions were drawn from this study.

- Sediment deposition in irrigation canals results in rising canal bed levels, reduced canal capacities, and problems in supplying the required amounts of water to some or all parts of the irrigated area.
- There was a high over flowing of water occurring in the conveyance system at the end of the canal due to the accumulation of sediment in the canal.
- The sprinklers water distribution uniformity indicators (CU & DU) were lower than the recommended values given by (Michael, 2008), for bothupstream and downstream old nozzles, indicating poor water distribution uniformity that shows wear and tear severity caused by sediment up on the nozzles were significantly affect the water distribution uniformity.

5.3. Recommendations

Based on the results of study, the following recommendations have been made:

- During irrigation operation period, whenever a highly sediment laden water comes to the weir, weir attendants shall close the intake and wait the flash flow to pass. During off-season, both the scouring sluice at the weir and the flashing gate at the settling basin shall be left open to allow the bottom sediment laden water flash out.

- The canal, the headwork and side ditches should be regularly cleaned to minimize the entrance and depositions of sediment in the canal.
- During operation period, action plan shall be made to remove and clean at the settling basin and end of canal without interruption of operation in order to reduce accumulation of sediment in the canal.
- Replacement of the sprinkler nozzles should be carried out based on efficiency as well as cost benefit analysis as using nozzles that were worn out will cause non uniform water distribution, loss of water and energy and may sometimes cause ecological problems like erosion, leaching and water logging.
- Drain valves should have to be installed at the end of buried underground pipe so that the sediment can drain out through the valves.
- The drain valves (sediment passing gate) installed at the end of canal shall be taking into correction and should have to be operational for removal of sediment accumulation.
- Trash screens shall be cleaned regularly to reduce the entrance of trash and sediments that can be blocked and wear the nozzles.
- Sediment excluder shall be installed at the upstream intake of the canal/weir.

6. REFERENCES

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7. APPENDICES

7.1. Appendix Tables

Tables 7.: Maximum Air Temperature ^{0}C at 0.5m above Ground Level

	Months											
years	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**August**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
1999	32.2	35.0	35.2	35.2	33.3	30.7	26.0	26.6	28.9	28.4	29.7	30.8
2000	32.7	34.1	35.5	32.3	33.3	31.0	27.3	27.0	29.0	29.6	30.0	31.1
2001	31.8	33.9	32.4	34.3	32.8	28.9	26.9	26.9	29.3	30.6	31.3	32.1
2002	32.0	34.4	34.2	34.8	35.2	31.4	28.7	28.0	29.6	32.1	33.1	32.4
2003	33.5	34.7	34.6	35.1	36.5	31.1	27.5	27.8	28.5	30.9	31.9	32.3
2004	33.9	34.6	34.8	33.9	35.3	30.3	27.7	27.7	28.7	30.1	31.6	32.8
2005	33.0	35.7	34.5	35.0	34.4	31.3	27.3	27.8	29.0	30.2	31.1	32.4
2006	33.4	35.1	35.0	34.5	33.1	30.7	27.9	26.6	28.1	30.7	31.3	32.2
2007	33.1	34.0	35.6	34.3	33.5	30.2	27.9	27.6	28.6	30.5	31.9	32.6
2008	33.8	34.6	36.3	34.1	31.5	30.0	27.7	27.4	29.3	30.8	30.6	32.1
2009	33.5	35.0	35.9	36.0	35.6	33.4	27.6	28.2	29.9	31.4	32.8	32.5
2010	33.6	35.2	35.8	36.1	33.3	31.6	28.7	27.3	29.6	31.8	32.2	31.9
2011	32.5	34.7	33.6	35.4	32.6	30.0	27.9	27.9	29.6	32	31.4	32.1
2012	33.3	35	35.5	35.6	35.5	32.3	28.7	28.3	29. 0	31.4	31.7	31.8
2013	33.5	35.5	36.2	37.1	33.3	29.2	27.2	26.4	29.9	29.5	31.5	31.9
2014	33.1	34.2	35.2	35	32.3	31.2	29.3	27.4	27.6	29	32.2	32.1
2015	32.4	34.2	35.2	36.7	33.9	31.3	30.7	29.9	30.1	33.0	32.4	32.5
2016	34.0	36.1	36.6	35.7	31.6	30.8	28.5	28.5	29.6	31.1	31.8	32.3
2017	33.9	34.7	36.6	35.7	32.3	32.0	28.6	28.2	29.6	31.0	32.1	32.8
2018	33.2	35.2	35.7	35.2	35.1	30.0	28.1	28.1	30.5	31.5	31.4	33.5

Tables 7.: Minimum Air Temperature ^{0}C at 0.5m above Ground Level

	Months											
Years	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**August**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
1999	12.0	13.0	15.1	18.2	17.1	15.9	15.6	15.7	15.2	15.5	11.1	12.1
2000	11.9	13.1	15.9	16.9	17.0	15.8	15.7	15.9	15.4	15.4	13.0	11.7
2001	11.1	14.6	16.5	17.8	17.4	16.4	16.1	16.6	15.6	15.3	13.2	13.1
2002	13.9	14.4	17.0	16.8	18.2	16.8	16.3	16.0	15.4	14.1	13.5	13.7
2003	13.3	15.1	17.2	17.3	18.2	16.5	16.6	16.6	15.7	13.7	12.9	11.8
2004	13.5	13.9	17.3	17.9	17.7	17.1	15.9	16.0	15.8	13.8	13.1	13.1
2005	12.3	14.8	16.4	18.3	17.2	16.3	16.3	15.9	15.9	14.4	12.5	10.1
2006	11.8	14.9	16.7	17.4	17.1	16.3	16.6	16.1	15.6	15.6	14.4	13.3
2007	13.6	14.8	16.7	17.3	17.8	16.6	16.2	15.7	15.7	12.3	12.0	10.2
2008	11.9	14	15.6	16.8	16.5	16.7	16	16	15.6	14.7	13.6	12.7
2009	13.4	15.8	16.9	17.6	17.3	16.9	16.5	16.5	15.8	14.6	12.5	14.2
2010	13.8	16.5	17.4	18.9	18.5	17.1	16.6	16.4	16	14.5	13.8	13.2
2011	13.9	13.1	15.6	16.6	16.7	16.4	15.7	16.1	15.8	13.6	14	12.3
2012	12.2	13	15.8	17.5	17.7	16.2	15.5	16.1	15.6	13.1	13.9	13.9
2013	13.1	14.5	16.1	16.1	16.2	16.2	16.3	16.2	15.3	15.94	14.5	11.4
2014	13.6	14	16.2	16.4	16.2	16.3	15.9	15.7	15.6	14.6	13.7	13.3
2015	13.5	15.4	17.1	19.6	17.1	15.0	14.1	9.8	11.7	12.8	12.6	12.5
2016	11.4	12.0	14.7	16.4	15.0	14.3	14.7	13.8	13.2	12.7	9.8	9.0
2017	7.3	13.3	15	14.9	15.7	17.1	16.5	16.7	16.4	15.7	13.8	11.9
2018	12.8	16.0	16.2	16.8	18.0	16.9	16.3	16.9	15.1	15.1	14.2	14.2

Tables 7.: Long Year Monthly Average Rain Fall (mm)

Years	Month											
	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
1999	17.9	0.0	1.0	63.7	78.5	322.3	248.8	333.2	148.8	305.1	0.4	12.0
2000	0.0	0.0	0.9	115.2	73.0	355.1	262.1	271.7	293.4	212.0	6.4	9.0
2001	0.0	0.4	66.3	46.1	115.7	263.2	295.6	283.6	111.0	60.4	1.6	4.1
2002	6.4	2.7	33.8	42.0	46.6	239.3	320.1	221.0	156.7	12.3	0.0	18.6
2003	1.5	24.9	52.7	11.5	5.0	292.7	294.3	271.6	217.7	11.6	5.5	4.0
2004	0.4	0.4	2.3	56.6	36.6	251.9	295.4	272.2	194.7	42.1	4.9	0.0
2005	9.6	0.0	112.1	30.5	53.8	418.7	351.8	232.1	244.3	77.0	15.7	0.0
2006	0.0	1.0	27.7	13.7	115.9	185.8	465.4	290.8	253.0	73.9	3.3	22.6
2007	3.5	38.2	36.6	36.4	126.1	259.4	273.9	237.5	192.8	61.9	0.0	0.0
2008	0.0	0.0	0.0	55.1	174.8	161.9	477.6	280.8	170.5	58.3	76.2	5.7
2009	0.1	11.7	14.7	43.1	16.6	200.8	304.2	431.6	98.1	137.7	0.0	4.1
2010	3.5	2.9	0.0	23.4	180.2	66.7	486.9	360.0	156.0	27.0	8.2	0.0
2011	9.5	0.0	48.6	46.3	196.9	23.8	238.9	203.5	253.3	0.0	66.9	0.0
2012	0.0	0.0	21.8	4.2	29.0	143.6	315.6	337.5	370.3	17.5	0.0	0.0
2013	0.0	0.0	2.6	13.4	157.3	301.5	310.0	363.6	128.4	111.5	43.0	0.0
2014	0.0	1.4	43.9	59.3	296.8	145.5	265.1	263.3	153.1	173.2	7.6	3.9
2015	0.0	0.0	22.3	0.0	210.9	160.4	215.9	199	153.1	3.6	69.4	15.4
2016	0.0	2.7	20.9	53.5	255.7	153.4	298.2	163.5	172.6	87.6	0.0	0.0
2017	0.0	12.1	17.7	49.0	191.6	116.8	340.9	324.9	270.5	102	15.7	0.0
2018	0.0	7.8	7.5	21.4	92.8	184.5	385.1	208	174.6	46.8	33.0	0.0

7.2 Appendix Figuers

Figure 7. : USGS Model 6200 Current Meter

Figure 7. :US D-74 Suspended Sediment Sampler While Taking the Sediment Sample

Figure 7. : Removal of Sediment Deposition from Settling Basin

Figure 7. : Cultural Farming Process and Its Ill- Effect on the Canal

Figure 7. : Catch CanArrangement for Uniformity Test

Figure 7. : Samples under Laboratory Analysis

Figure 7. : Diversion weir on Finchaa River