PERFORMANCE EVALUATION OF WATER CONVEYANCE SYSTEM OF KESEM IRRIGATION SCHEME: AFAR REGION, ETHIOPIA

Selamawit Ketema Aklilu

A Thesis Submitted to the Department of Water Resources Engineering, School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Water Resources Engineering (Specialization in Irrigation Engineering)

Office of Graduate Studies

Adama Science and Technology University

June, 2021

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DECLARATION

I hereby declare that this Master Thesis entitled *"Performance Evaluation of Water Conveyance System of Kesem Irrigation Scheme: Afar Region, Ethiopia* " is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Selamawit Ketema Aklilu	____________________	________________
Name of the student	Signature	Date

RECOMMENDATION

We, the advisors of this thesis, hereby certify that we have read the revised version of the thesis entitled "*Performance Evaluation of Water Conveyance System of Kesem Irrigation Scheme: Afar Region, Ethiopia*" prepared under our guidance by Selamawit Ketema Aklilu submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Water Resources Engineering (Specialization in Irrigation Engineering).

Therefore, we recommend the submission of revised version of the thesis to the Department following the applicable procedures.

Dr. Keredin Temam Siraj	________________________	________________
Major Advisor	Signature	Date
Dr. Boja Mekonen	________________________	________________
Co-advisor	Signature	Date

APPROVAL PAGE OF M.SC THESIS

We, the advisors of the thesis entitled "*Performance Evaluation of Water Conveyance System of Kesem Irrigation Scheme: Afar Region, Ethiopia*" and developed by Selamawit Ketema Aklilu, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Selamawit Ketema Aklilu have read and evaluated the thesis entitled "*Performance Evaluation of Water Conveyance System of Kesem Irrigation Scheme: Afar Region, Ethiopia*" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Water Resources Engineering (Specialization in Irrigation Engineering).

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LIST OF ACRONYMS AND ABBREVATIONS

AIA	Actual, Irrigated Area
CWR	Crop Water Requirement
DIA	Designed Irrigated Area.
Ec	Conveyance Efficiency
EI	Effectiveness of Infrastructure
ETo	Reference Evapo-transpiration
ETC	Crop evapotranspiration
FSL	Water at Full Supply Level
GPS	Global Positioning System
Ha	Hectare
IE	Irrigation Efficiency
IWD	Irrigation Water Demand
Kc	Crop Coefficient
Mha	Million hectares
M.a.s.l	Meter above sea level
NFS	Number of Functioning Structures
PA	Adequacy of Performance Indicators
PD	Dependability of Performance Indicators
PE	Equity of Performance Indicators
PF	Efficiency of Performance Indicators
QD	The amount of Discharge Delivered
QR	The amount of Discharge Required
R	Represents the sub-region of the system
SIA	Sustainability Irrigation Area
SSC	Southern Secondary Canal
T	Represents the period in month
TNSII	Total Number of Structures Initially Installed
WDR	Water Delivery Ratio
WSER	Water Surface Elevation Ratio

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ABSTRACTS

Irrigation development is one of the most key factors considered in many developing countries like Ethiopia to alleviate the poverty and improve the livelihood of the community both in the urban and rural area. Irrigation development in the country, especially where the availability of irrigation water supply is sufficient helps to fulfil the food self-sufficiency by producing more crops than rain fed production of one time per year. Like in Ethiopia, in which the irrigation development is very infant even if the availability of the irrigation water is sufficient, the benefit from the irrigation development is very low due to high loss of irrigation water from the main conveyance of the irrigation canal to the field application area in many irrigation schemes like Kesem irrigation scheme. In line with this the main purpose of the current study was to evaluate the water conveyance system of Kesem irrigation scheme, which was operational since 2009.In the evaluation of the irrigation scheme, different irrigation performance indicators were used for the irrigation canal section from October 2020 to January 2021 G.C.To determine the crop water requirement, crop coefficient at growth stage of crop and reference evapotranspiration water determined by the Penman Monteith Method (CROPWAT 8.0 Model) using climatic data collected from Melka Werer Metrological Station. The irrigation water flow in the main and three secondary canals were measured at different sections of the canals using Current meter. The performance indicators used in this evaluation were water delivery performance, which includes adequacy, equity, dependability and efficiency, and maintenance performance includes water surface elevation ratio, effectiveness of infrastructure, water delivery ratio and sustainability of irrigated area. The result of this study indicated that, the adequacy, performance indicators of the secondary canals-1, 2 and 3were fair at the head section(0.81- 0.91, 0.80-0.89 and 0.81-0.91)respectively, and poor at the tail section of the three secondary canals(0.67- 0.79, 0.70-0.79 and 0.68-0.79) the entire system, respectively. The equity performance of the three secondary canals were ranges from good (0.05-0.09) to fair (0.13-0.14) at head and tail section of the canals. But the maintenance indicators considered in this study indicate as the scheme requires continuous maintenance to improve the overall performance of the irrigation scheme. Therefore, it is recommended to undertake appropriate maintenance activities of conveyance structures of the irrigation scheme that improve the overall performance of the irrigation scheme and that may help for the sustainability of the scheme.

Keyword: *Crop water requirement, Irrigation water demand, irrigation water supply, water delivery performance indicators.*

CHAPTER ONE

INTRODUCTION

1.1. Background

Irrigation development has gained significant importance across the globe because of its potential to improve food security and reduce poverty. The contribution of irrigation towards agricultural production is enormous. Particularly for least developed countries irrigation development and use is a backbone to the extent that it is responsible for the nations' feeding most of their population. Despite the fast economic growth experienced along the last two decades by many Sub-Saharan African (SSA) countries, half of its population currently remains under the poverty line (Cambaza et al.,2020).

Ethiopia is one of few African countries endowed with abundant rainfall and water resource, but its agricultural system does not yet fully benefit from the technologies of water management and irrigation as (Awulachew *et al.,* 2010).cited by (Efriem and Mekonen, 2017). The country has 12 river basins with an annual runoff volume of 124-billion-meter cube (BMC) of water and an estimated range of 2.6 to 30 BMC ground water potential (Awulachew *et al.,* 2010). According to those authors, even though Ethiopia has abundant rainfall and water resources, its agricultural system does not yet fully benefit from the technologies of water management and irrigation. Because the finding revealed that at global level, 60% of the diverted fresh water for agriculture does not contribute directly to food production. It was described by World Agriculture Forum (2009) cited by Dejen (2015) only about 40% global fresh water abstracted for irrigation is being effectively used for consumptive use in agriculture. Much amount of irrigation water diverted is lost because of poor water control, inefficient irrigation systems with leaky conveyance and distribution, poor on-farm water management practices.

According to MoWIE report currently in Ethiopia the total irrigated area is 1.2 million ha. Water distribution supplies to the mentioned irrigated land 93% of its water resources, leaving 6% to the domestic sector and 1% to the industrial one (Nemera, 2013). Expansion and new irrigation development is one of the best alternatives to consider for reliable and sustainable food security on various scales through river diversion, constructing micro dams and water harvesting structures (Ngigi, 2002).

Water loss is a major constraint to agricultural production and there is a need for increase in the productivity of irrigation schemes and the overall performance of schemes would have to improve. Therefore, performance of irrigation schemes should be evaluated to minimize the losses of water, improve the irrigation water use efficiency, and improve scheme performance accordingly (Evans and Sadler, 2008). There is a need to optimally utilize the resource. This can be achieved through several structures that include sustainable river catchment management, proper design of water canal, hydraulic structure operational and maintenance of the systems. The achievement of irrigation water management can be measured by how well water delivery meets crops demand in time and space (Gorantiwar and Smout, 2005). Hence, analysing the current condition of water conveyance system of irrigation scheme and evaluating the level of the objective that can be achieved are necessary, and measure can be taken to reduce the gap between the potential and actual performance of the irrigation scheme.

Conveyance losses are defined as the losses that occur from the time water is released from the reservoir to when it is delivered to the farm gate. Water conveyance structures are the main part of any irrigation system to transporting water with minimum losses and increasing irrigation efficiency as the main task of these structures. Water conveyance efficiency is affected by several factors such as cracks, percolation seepage and physical damage of the canals. The water delivery and performance in conveying irrigation water of many irrigation schemes are significantly below their potential (Ali , 2011).

The purpose of performance evaluation is to achieve an efficient and effective use of resources by providing relevant feedback to the scheme management at all levels. Poor design and lack of suitable criteria for irrigation systems are generally responsible for uneven irrigation, leading to wastage of water, water logging and salinity problems (Shonka ,2017).The Irrigation performance was evaluated to identify the gap related to water conveyance efficiency by using different hydraulic performance indicators like adequacy, efficiency, dependability, and equity. These indicators could be evaluated for a single off-take, a group of off-takes in a sub system or for a whole irrigation scheme. Adequacy is an indicator for a water delivery system whether it attained a target or required water delivery over a certain period. The time frame to be considered could be daily, per irrigation turn, monthly or annually as required (Dejen et al.,2012).

Efficiency is an indicator for water conservation property of an off-take or a system. It is an inverse (opposite) of adequacy (relative delivery). Dependability is the temporal uniformity of the ratio of delivered amount of water to the required or scheduled amount over a region. Equity implies the fairness of water delivery to different parts of an irrigation system. It indicates the spatial distribution of a water delivery. In large scale gravity irrigation systems with manual operation of structures, ensuring equity is a major challenge for operators.

Kesem irrigation scheme is one of the large-scale irrigation schemes which require evaluating its performance to prove whether it is as per designed objective or not. There were no previous studies conducted and documented on the performance evaluation of the scheme for checking the efficiency and effectiveness of water conveyance system of the study area. In line with this, the current study was undertaken to evaluate the performance of water conveyance system of the Kesem irrigation scheme.

1.2. Statement of the Problem

The challenges related to inefficient use of water resource in the agricultural production have become a major issue in the world. Many large-scale irrigation schemes in least developed countries are typically manually operated gravity systems and their operation is often complex and tedious. Performance evaluation is a practical tool to assess the successes of irrigation management at the scheme to meet growing challenges, increasing demand for irrigation to meet the growing food demands of the population, the competition for water allocation from high priority non-agricultural sectors and technical infeasibility. Irrigation performance indicators are the advantages that used to measure performance and it describes the level of actual goal in respect of one of the objectives of irrigation. Indicators are used to simplify the otherwise complex internal and external factors affecting the performance of irrigation schemes (Adane, 2020).

Performance of many irrigation schemes is significantly below their potential due to a number of shortcomings, including poor design, construction, operation, maintenance and ineffective water control and measurement structure (Taye, 2016). According to this author, a number of irrigation projects have been constructed in Ethiopia for reliable water supply for agriculture. In most cases people believe that irrigation scheme with modern system will have high performance but use of modern method of field application alone not guarantees of high performance.

Many irrigation schemes are characterized by a low level of overall performance. This requires continuous monitoring and evaluation of structures and flows to make sure that the water delivery is demand responsive. The problem experienced at Kesem irrigation scheme regarding water conveyance efficiency is water continuously diverted into the main canal but at the bottom end of the system does not know level of performance.

Therefore, to identify and suggest possible solution to overcome the problems, the current study was conducted to evaluate the water conveyance system performance of Kesem irrigation scheme.

1.3. General Objective

The main objective of this study was to evaluate the performance of the water conveyance system of Kesem irrigation scheme.

1.3.1. Specific Objective

The specific objectives of the study were:

- ✓ To evaluate water delivery performance of the Kesem irrigation scheme water conveyance system using indicators
- ✓ To assess the performance of the scheme conveyance system related to maintenance needs.
- ✓ To identify the performance gaps and suggest remedial measures.

1.4. Research Question

- ✓ Is the Water delivery performance of Kesem irrigation scheme adequate?
- ✓ Does the scheme suffer from any performance challenges related to maintenance?
- ✓ What are the performance gaps and possible solutions for the scheme improvement of water conveyance?

1.5. Significance of the Study

Evaluating the performance of Kesem irrigation scheme water conveyance system and checking the efficiency of main and secondary canals of the scheme was assessed by using performance indicators. The performance evaluation of water conveyance of Kesem irrigation scheme was assessed to evaluate the overall performance of the scheme. Evaluating the current situation and identifying the main causes affecting the performance of the scheme has great contribution for managers and policy makers. The result of this study could be used at institutional and operational water management levels that ensure better irrigation service and sustainability of the scheme. Since there were no documented studies on the scheme before, this study will be used as a baseline information for the improvement of the irrigation schemes.

1.6. Scope of the Study

The study was focused on the water conveyance performance evaluation of Kesem irrigation scheme. The performance evaluation of the scheme covers from the conveyance system which takes place from inlet of southern primary canal to off take of three secondary canals that are currently using for sugarcane plantation. The evaluation includes the conveyance losses occur along the distribution canals, water balance analysis by considering canal inflow and outflows to evaluate the current operation rules in terms of matching supply and demand throughout the water delivery system. Based on the results of the evaluation, alternative operational rules that would enhance water delivery performance and sustainability of the scheme has been proposed as compared to the performance indicators standards.

1.7. The Thesis Organization

The thesis is organized in to five chapters. Chapter one is introduction which includes background, statement of the problem, objectives, research questions, significance of the study, and scope of the study. Chapter two contains the detailed literature review part related to the study. Chapter three focused on material and methods which includes description of the study areas, data collection methods and data analysis techniques. Chapter four contains the result and discussion of the study finding while chapter five includes conclusion and recommendation of the findings of the study.

CHAPTER TWO
LITERATURE REVIEW

2.1. Global and National Perspectives of Irrigation Development

Irrigation is the supply of water to agricultural crops by artificial means, designed to permit farming in arid regions and to offset the effect of drought in semi-arid regions. Since the beginning of crop cultivation, irrigation has been used to reduce crop drought stress by compensating for low precipitation. Even in areas where total seasonal rainfall is adequate on average, it may be poorly distributed during the year and variable from year to year (Siebert *et al.,* 2015).The world total irrigated area is around 324 million ha, of which 280 million ha (86 %) is irrigated by surface irrigation. In Africa, the irrigation potential is massively unexploited as only 5.8 % of the cultivated lands are irrigated. Ethiopia has a huge cultivable land covering about 30 - 70 million ha but only about 15 million ha is presently cultivated with recent irrigation schemes covering about 1.2 million ha (MoWIE, 2020).

Water crisis has drawn worldwide attention to the urgency of achieving a more efficient use of water resources, particularly in agriculture, to increase crop production and achieve world food security pointed out that, at least 40 % of the water does not reach the fields due to the water loss along the conveyance (Adane, 2020). Considering that a major share of the world`s water resource issued in agriculture and that food requirements are increasing while global water resources are limiting irrigated agriculture and therefore, the role of efficient irrigation systems and techniques have recently assumed greater importance in increasing food production (Teshome, 2003).

To maximize the benefits of surface irrigation systems, water conveyance efficiency is one of the key factors to be improved. Irrigation management normally consists of key aspects through which the irrigation can be appraised water balance between water resources and crops water requirement, institutional system, conveyance system and delivered water service (Cambaza *et al.,*2020).

2.2. Performance Evaluation of Irrigation Scheme

Performance evaluation of irrigation scheme is defined as the degree of measurement how far the goals and objectives set forth at the time of project formulation of the system have been achieved, therefore it is essential to measure and evaluate their success or failure of objectively and identifies specific areas in need of improvement (Cakmak *et al.,* 2010).

According to Tebebal and Ayana, (2015).the performance of irrigation schemes in Ethiopia observed that low due to poor operation and maintenance services, improper planning and design, and lack of incentive for proper management of water in state run projects. Basically, Performance evaluation is essential to ensure all activities proceed smoothly as planned towards achieving those objectives and that system managers are alerted easily to potential threats to crop and production system performances and react in time to avoid or overcome the situation when it occurs. Specially, some of the major roles of performance assessment and evaluation are to ensure for accurate supply demand matching, water savings and to alert potential crisis event. This is a tool to provide necessary feedback for improving the systems management by initiating remedial measures (Dejen , 2015).

Irrigation scheme performance studies being used increasing frequency to promote the objective of sustainability, thereby helping to improve the system operation, assess the general health of the system, evaluate the impact of intervention, diagnosis constraint, better understanding determinants of performance and compare its performance with others or within the same system over the time (Ho *et al.*,2016). According to those findings, an important and active field of research during last few decades, several approaches and methodologies have been developed for assessing irrigation performance from different perspectives with limited water and land resources availability.

Efficient operation and management for irrigation system plays an important role in the sustainability of irrigated agriculture. Hence, irrigation project performance studies are being used with increasing frequency to encourage this objective. Furthermore, performance analysis is an essential part of management, it is needed to target and monitor actual achievements in the operation and take appropriate actions if required (De Alwis and Wijesekera, 2011).

Performance of an irrigation system could be assessed for several reasons, some of needs are to evaluate impact of water delivery service on the whole performance of the agricultural sector, to recognize cost effectiveness and financial viability of the system and for comparison of one with other irrigation systems. Frequently evaluation on the irrigation scheme have become more important in diagnosing and improving the performance of irrigation schemes in order to achieve optimal productivity in the context of increasing food demand, open global market, and competition for limited freshwater resource (Mancosu *et al.*, 2015).

Many scholars emphasized the importance of performance evaluation for an irrigation system. Much of the work to date in irrigation performance assessment has been focused on both external and internal processes of irrigation systems. These process indicators relate performance to management targets such as timing, duration and flow rate of water, effective irrigation management requires reliable performance assessment (Efriem and Mekonen, 2017). Irrigation scheme performance indicators are useful tools to understand the internal operational processes that affect water distribution and delivery, hence assist in finding ways to enhance the water delivery process. It also assists in determining whether the performance is acceptable and if not, it suggests that which and where remedial actions to be taken for improving the performance of the scheme. This is required to provide information for the managers and planners doing more in productive and efficient approach. These indicators examine the technical performance of conveyance structure of scheme by measuring how the water is conveyed through the canals (Adane, 2020) .

According to Shenkut (2015), irrigation system performance includes efficiencies of various components like storage efficiency, conveyance efficiency of canals, application efficiency, and field efficiency, among others. In turn, three main standards could be used to evaluate the performance of irrigation systems, these are: the physical condition of the infrastructure, water delivery services, and agricultural production. The effects of challenges on water conveyance system performance were determined using performance indicators namely adequacy, equity, efficiency, and dependability were used to evaluate the performance of the conveyance system as Bos MG. (2005), cited by (Tebebal and Ayana, 2015).

As those authors stated, water delivery system that is not adequate, dependable, equitable or efficient can have adverse effect on crop productivity in the irrigation scheme. Timely information on performance related is required by the operational managers to make relevant decision based on the efficiency of the scheme performance.

2.2.1. Conveyance efficiency

Conveyance efficiency is defined as the ratio of the amount of water that reaches the field to the total amount of water diverted into the irrigation system as percentage. According to (Brower and Heilbloem, 2011), the conveyance efficiency mainly depends on the length of the canals and the soil permeability of the canal bank. Losses of irrigation water in the conveyance system can be a major component of the overall water losses particularly for farms located at significant distances from water sources where the main canals are long and unlined. Significant volume of water is lost by the network of the canals due to evaporation, seepage depending on the nature of the soil and agro climatic zone in which the canals are located, on quality of operation, maintenance, and the nature of the soil that affects the seepage rate.

2.2.2. Effectiveness of infrastructure

The effectiveness of infrastructure focuses on the physical structures in irrigation system components, including the spillway and weir. Effectiveness of infrastructure (EI) is the ratio of functional to total number of structures initially installed. The effectiveness of infrastructure is computed as the ratio of number of functional structures to the total number of functional structures initially installed (Mamuye and Mekonen, 2015)**.** As the deviation of EI ratio more than 5% would signal the need for maintenance or rehabilitation of the physical structures.

2.3. Performance Gaps in Irrigation System

Performance is assessed for a variety of reasons: to improve system operation and to assess progress against strategic goals. as an integral part of performance-oriented management, to assess the general health of a system; to assess impacts of interventions; to diagnose constraints; to better understand determinants of performance; and to compare the performance of a system with others or with the same system over time. The type of performance measures chosen depends on the purpose of the performance assessment activity.

There are four potential kinds of performance gaps that can occur with irrigation systems (Cakmak *et al.,* 2010).The first is a technological performance gap. This is when the infrastructure of irrigation system lacks the capacity to deliver a given hydraulic performance standard. The normal solution to technology performance gaps is to change the type, design, or condition of physical infrastructure.

The second kind of performance gap is when a difference arises between how management procedures are supposed to be implemented and how they are implemented. This includes such problems as how people adjust gates, maintain canals and report information. This can be called a gap in implementation performance. A problem of this kind requires changes in procedures, supervision, or training.

The third kind of performance gap is a difference between management targets and actual achievements. Examples of management targets are the size of area served by irrigation in each season, cropping intensity, irrigation efficiency, water delivery schedules and water fee collection rates. This can be called a gap in achievement. Such problems are addressed either by changing the objectives especially simplifying them or increasing the capacity of management to achieve them such as through increasing the resources available or reforming organizations. The fourth type of performance problem concerns impacts of management. This is a difference between what people think should be the ultimate effects of irrigation and what actual results. These are gaps in impact performance and include such measures as agricultural and economic.

2.4. Performance Indicators of Irrigation scheme

Performance is measured using indicators, for which data are collected and recorded. The analysis of the indicators then informs us on the level of performance. Performance measures relative to water delivery in the system defined as four objectives adequacy, efficiency, dependability, and equity. Indicators appropriate to address the performance of the system with reference to target of water supply efficiency to the irrigated area. Indicators appropriately addressed the performance of the system with reference to targets of equitable, adequate, timely and reliable water supply to the farm was used to assess the water delivery performance (Ho *et al.*, 2016).

2.4.1. Water Delivery Performance Indicators

Evaluation the property of water delivery canals of irrigation system will be assessed using spatial and temporal water delivery performance indicators. The spatial performance indicators are intended for the water delivery performance over a region, while the temporal indicators are for the water delivery performance in time. Therefore, temporal values of performance indicators will be evaluated for adequacy, efficiency, and dependability, whereas spatial values of indicators also evaluated for adequacy, efficiency, and equity (Zeleke, 2015).The hydraulic performance of the canal will be evaluating at head, middle and tail reaches of the system. To evaluate canal water delivery performance, four basic internal parameters used are such as Adequacy indicator (PA), equity indicator (PE), dependability indicator (PD) and efficiency indicator (PF).

2.4.1.1. Adequacy indicator

Adequacy determined for an irrigation system as a whole or for subsystems. It is a measure of performance relative to the objective for a region or sub region system or water delivery structure to meet the required irrigation water. When the amount delivered Q_D exceeded the amount required Q_R, the amount delivered is accepted as adequate.

2.4.1.2. Equity indicator

Equity is defined as spatial uniformity of the ratio of water delivered to the water required. An appropriate measure of the performance related to equity would be the average related spatial variation of the ratio of the amount delivered to the amount required over the period of interest. Equity expresses the degree of variability in relative water delivery from point to point over the irrigated area. Excess water results in inequity, water logging and salinity problems (Kakar, 2010).An equity value of zero (PE=0) indicates perfect equity or fair distribution of water, hence water delivery structures distribute water fairly for each system.

2.4.1.3. Dependability Indicator

Dependability is the degree of temporal variability in the ratio of the amount delivered to the amount required over a region. In performance measurement it indicates the uniformity of QD/QR over time. Dependability expresses the ability to find water at the time desired and in the place desired in the system.

2.4.1.4. Efficiency indicator

Efficiency refers to the water conservation property of the irrigation system. The ratio of required to delivered flows (QR/QD) indicates the off-take efficiency. Efficiency is the measure of the excess of water delivered in comparison with the requirements, where PF is an efficiency indicator over an area R and the time period T and PF is an efficiency indicator at a point for a specific time. It represents the ability to conserve water by matching the water deliveries with water requirements.

Table 2. 1 Standards for Water delivery performance indicators (Source: Molden and Gates, (1990)

Indicators	Performance status		
	Poor	Fair	Good
PA	< 0.80	0.80-0.89	0.90-1.00
PE	> 0.25	0.11-0.25	0.00-0.10
PD	> 0.20	0.11-0.20	0.00-0.10
PF	< 0.70	0.70-0.84	0.85-1.00

2.4.2. Maintenance Indicators

2.4.2.1. Water surface elevation ratio

The value of WSER is equal to or close to 1.00, the main canal is keeping of water level in good working condition and the main canal is free of sediment accumulation and not affected by erosion. A value of WSER greater than one indicates an erosion problem. A value of WSER is less than one, shows a probability of increasing canal bad level due to siltation and weed incidence in a canal (Boss *et al.,* 1993).

2.4.2.2. Effectiveness of Infrastructure

The physical structures in its operational condition were categorized as operative, nearly operative, nearly inoperative and inoperative. If at least one of the following conditions are in effect, broken and damaging of the structure, change of canal cross-section, scouring of canal section, missing of flow control, and measuring structures, sedimentation and weed growth. Generally, a deviation of more than 5% would signal that need for maintenance or rehabilitation of the physical structures as (Bos *et al.*, 2005).

2.4.2.3. Water Delivery Ratio

Delivery Performance Ratio is the simplest and probably the most important operational performance indicator. The average monthly measured discharge for each outlet has been compared with intended (design) discharge. As this ratio increase above one that is mean the outlet delivers more than the intended discharge and a reveres situation occur when the WDR value become less than one. The performance of outlet considered excessive when the WDR values exceed 0.9 classified as in adequacy as (Wahaj, 1995).

2.4.2.4. Sustainability of Irrigated Area

Sustainability of irrigated area is a useful indicator for assessing the sustainability of irrigated agriculture. Lower values of this indicator would mean abandonment of lands which were initially irrigated; and hence, indicate contraction of irrigated area over time. On the other hand, values higher than unity indicate expansion of irrigated (Dejen , 2015).

CHAPTER THREE

MATERIALS AND METHODS

3.1. Description of the Study Area

Kesem river catchment is found in the middle part of the Awash River basin which is in the eastern part of Ethiopia. The Kesem irrigation scheme is one of the newly established schemes in 2009 in the middle Awash basin to irrigate 20,000 ha in southern and northern project which covers 10,000 ha in both locations using a furrow irrigation method. The irrigation scheme has a main canal length of 8.5 km and three secondary canals with 1 km, 0.8km and 2km length respectively. Before sugarcane plantations in 2009, most parts of the Kesem scheme did not have any irrigation or rain fed cultivation history. The storage capacity of Kesem dam is 0.5 billion cubic of water is supplied by means of a weir conveyed to open earthen main and secondary canal and then hydro flume discharge the water to field. Currently the irrigated area of the scheme is only 3000 ha, in which 2900 ha irrigated area from southern and 100 ha is north project part. The topography of the area is irregular which means that there are hilly and flatter parts. All these are the result of different geological activities through long period of time and other exogenous processes like erosion. The scheme is located at 250 km North East of Addis Ababa in Afar regional state at left bank of the river in the middle Awash section of the northern rift valley. It is traversed by three significant perennial tributaries of Awash namely, Kebena, Kesem and Filwh river. The study area is located between 9°23’ 10’’to 9°50’N and 39°30’to 40°10’ E at the elevation of the area ranges from 820 meter above sea level at the diversion site to 785 meter above sea level at Awash in North Kebena.

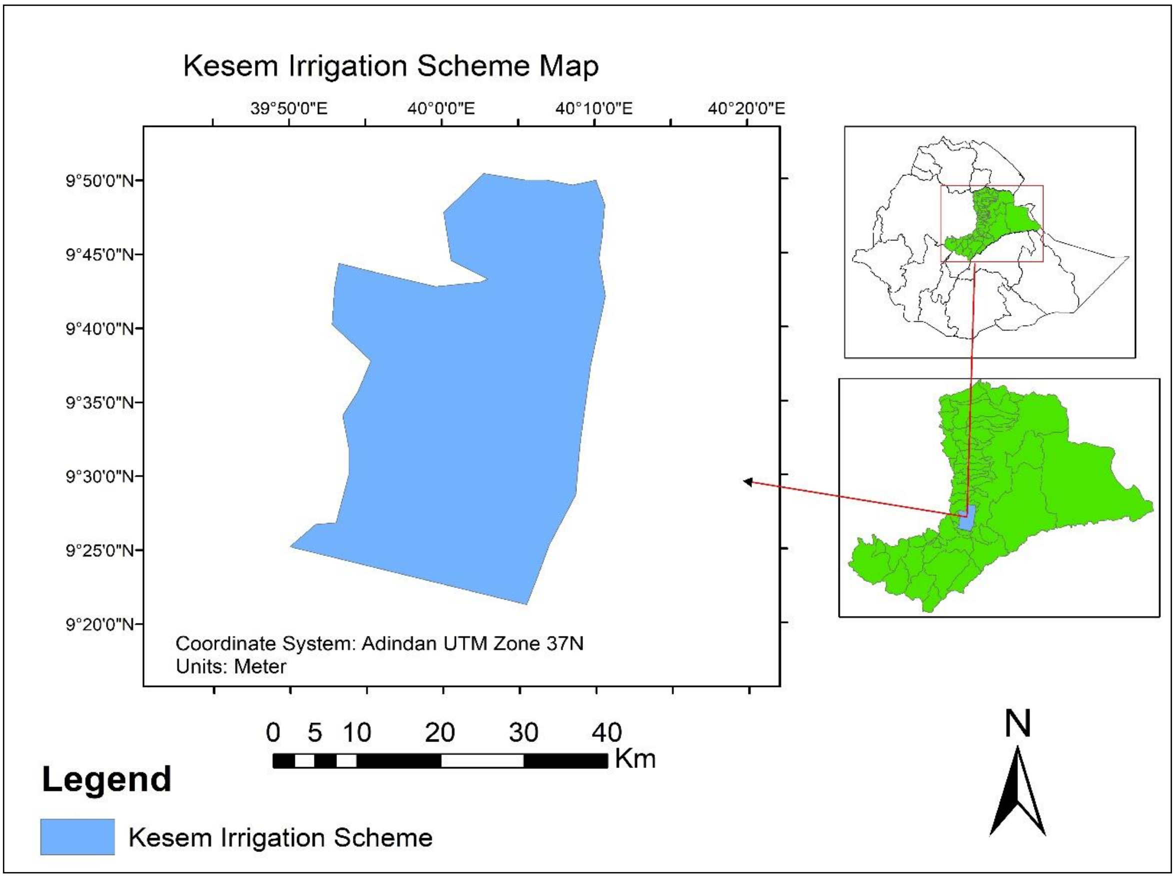

Figure 3. 1: Map of the study area

3.1.2. Climate

The mean annual minimum and maximum temperature is 18°C and 34.85°C, respectively. Mean annual rainfall is about 626.45 mm and annual evapotranspiration in the area has been estimated at 1,800 mm. The climatic condition of the area is classified under arid which characterized by much losses of water through evapotranspiration and crop water requirement is very high. Due to this condition, even if water from dam is conveyed through primary open canal to tertiary canals, then it distributed to each furrow using hydro flumes.

3.1.3. Land use

The project area is covered with vegetative growth which open grass land and light bush to densely planted wood area particularly on the eastern part of Kesem-Kebena of Awash River. The slopes area ranges from 2% at upper part of the area and decreasing to 0.1% in the lower eastern part. The soil textures of the area are heterogeneous which vary from clay loam to sandy loam.

3.2. Materials

The lists of materials used were current meter, Staff gauge, Stakes, measuring tapes, GPS, and Stopwatch. In addition to those materials, CROPWAT 8.0 model was used to compute the reference evapotranspiration.

3.3. Data sources and methods of data collection

The study was conducted one sugarcane irrigation season from October 2020 to January 2021. During this period, both primary and secondary data were collected. The primary data were collected from field by direct measurement and field observation of irrigation infrastructures. Whereas secondary data were obtained from Kesem irrigation development office, Melka Werer Metrological Station and related journal and FAO published document.

3.3.1. Primary data

The primary data were collected directly from the field, the activities including discharge measurements and field observations.

3.3.1.1. Flow measurement

Propeller type current meter was used for measurement of water flow for main and secondary canals. The main and secondary canals are trapezoidal shape it was lined with geo membrane initially, but currently the liner was taken away and destroyed in both main and all secondary canals. The tertiary canals constructed by hydro flume (a plastic pipe with outlets).

Flow measurement was one of the main activities of data collection for this study. It helped to know the conveyance efficiency. The measurement has been taken using a current meter at main and three secondary canals which were conveyed water to sugar plantation and off takes. The discharge was measured along the main canal and secondary at each offtake located at the head, middle and tail ends and at each offtake. Measured discharge average value has been taken for a total of 12 days for four months (three days/month) from October, 2020 to January 2021.It was measured to evaluate the water conveyance efficiency and water delivery performance indicators(Figure 3.2). The current meter was mounted on a rod and moved vertically to measure the velocity at different points. The speed of rotation of cups depends on the velocity of flow. The instrument has an automatic counter with which the number of revolutions per second and the minimum measurements were taken for 40 seconds at each measured points and water flow velocity determined using (Eq. 2).

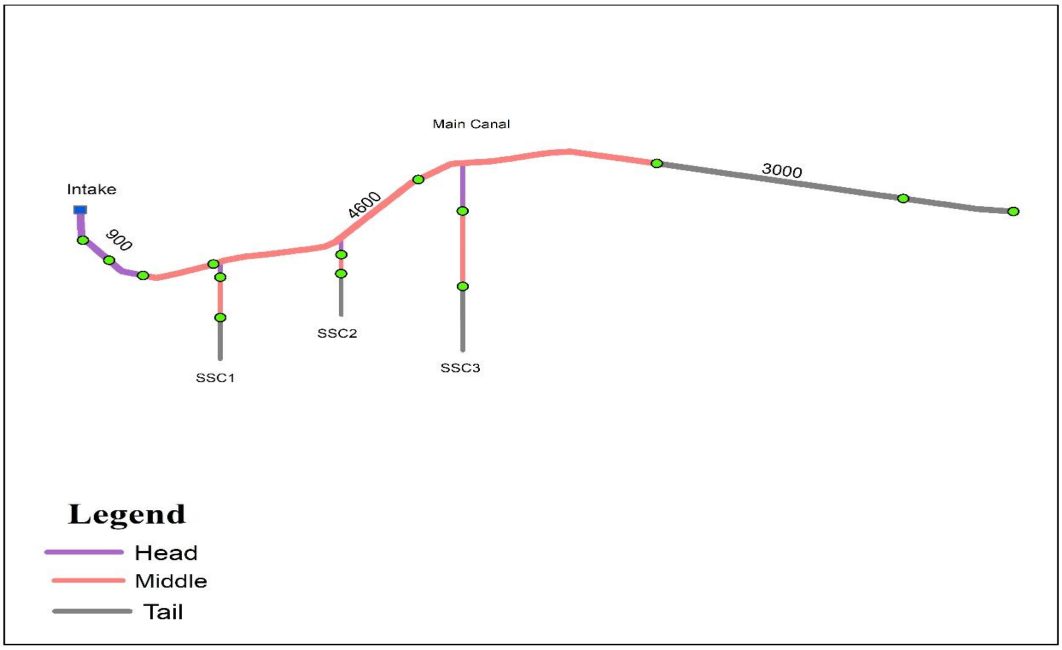

Figure 3. 2 Layout of Kesem Scheme water flow rate measurement points (m)

The delivered discharge conveyed at each control point was calculated multiplying cross-sectional area by the flow velocity using (Eq.3).Cross sectional area of the canal computed was measuring water depths at a series of points across the canal and multiplying by the width within each segment represented by the depth measurement. Therefore, the cross-sectional area of the section is the areas are summed to determine the entire cross-sectional area (Donald W. Meals and Steven A. Dressing. ,2008).

The flow velocities distribution in vertical is close to the regular form then it can be assumed that the mean velocity occurs at 0.6 of the depth (D) from the surface i.e., one point (0.6D) and two point (0.2D & 0.8D) method are adequate for most routine fieldwork for the depth less than 1 m and greater than 1 m respectively (Srivastava, 2016).

The discharge was computed using the following equation (Eq. 2)

$$Q = A * V \tag{2}$$

Where: A = Cross sectional area subsection (m^2)

V = Average velocity of water at that sub cross-sectional area (m/s) using current meter standard table

$$V = (2.2048 * R + 0.0178) * 0.3048 \quad (3)$$

Where: R = Revolutions per second,

V = Flow velocity of the water, in m/s.

Therefore, the cross-sectional area of the canal was computed in the following equation (Eq. 4).

$$A = \Sigma\,[\ (w1 * h1) + (w2 * h2) + ..\ (wi * hi)\ ] \quad (4)$$

Where: h= Water depth at a series of points across the canal (m)

w= Width of the canal at each segment (m)

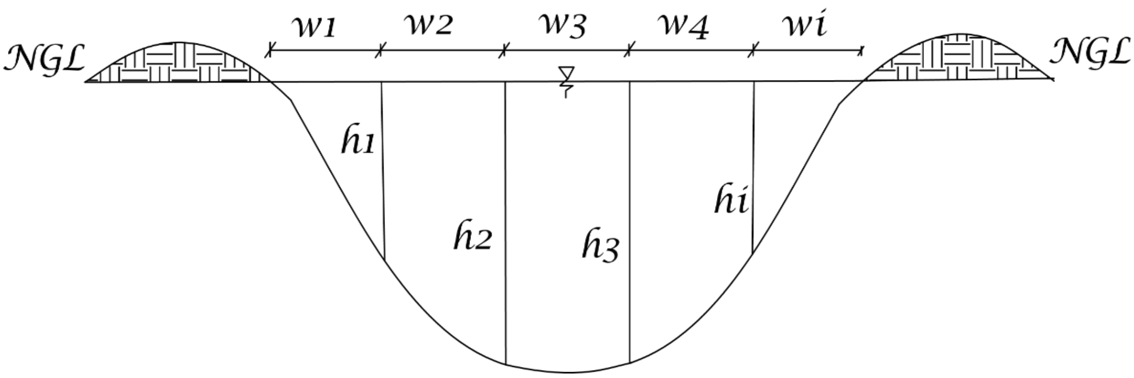

Figure 3. 3: Canal section

Figure 3. 4: Discharge measurement using Current meter

3.3.1.2. Field observation

In this study frequent field observation were conducted to understand the conditions of existing irrigation structures, current water delivery system, method of irrigation and the management system. During field observation the overall operational activities, overall water conveyance structure, water distribution at secondary, tertiary, and field canals were observed. Field visit enables to visualize and identify the three secondary canals which is currently water conveying to sugar cane plantation and others visible factors which affect the performance of the scheme. After careful selection of the measuring section of the canal, water flow velocity, water depth and canal width of the main and secondary canals were measured and compared to the intended /planned.

The primary data collected for the study were:

- Delivered discharge at each selected point of main and secondary canals.
- Depth of water flow at each selected point.

3.3.2. Secondary data

Secondary data included study area related reports, design document, studies and other useful written materials were collected from different sources. The design document and layout of the scheme were obtained from Kesem irrigation development project office and climatic data were collected from the Melka Werer Metrological Station.

3.4. Data Analysis

In this study field observation and performance of conveyance system were done at the point where measurements are carried out to determine water delivery performance and maintenance indicators at head, middle and tail reach of main and secondary canal.The flow depth was used to calculate the delivered amount of water (QD) to check elevation difference. Similarly, for estimation of water conveyance efficiency measurements were taken.

3.4.1. Determination of irrigation demand and supply

Since, CWR includes the amount of available effective rain fall which was computed from observed total rainfall using the modeland crop evapotranspiration. Therefore, reference crop evapotranspiration (ETo) were computed using CROPWAT 8.0 model.The required climate data for determination of reference crop evapotranspiration (ETO) such as radiation, air temperature, air humidity and wind speed were used for 25 years (1994 -

2018) collected from Melka Were Metrological Station. The mean values of the climate data were analysed and presented in Appendix Table 5.

Crop coefficient (Kc) is the factor that relates the actual crop water use to reference crop evapotranspiration. According to Doorenbos and Puritt (1996), growth stage of sugarcane can be classified to four stages. Thus (i.e., the duration of initial stage, development stage, mid stage, and late stage). Then, crop evapotranspiration was determined by multiplying the crop coefficient (Kc) and the reference crop evapotranspiration as expressed in (Eq. 1).

$$ET_C = ET_O * K_c \tag{1}$$

Where: ET_C = Crop evapotranspiration

ET_O = Reference crop evapotranspiration

K_C = Crop coefficient

3.4.2. Estimation of water conveyance efficiency

The water conveyance efficiency and water losses from main and secondary were estimated by measuring inflow and outflow at the canals reaches. Conveyance losses refer to the fraction that is lost when irrigation water travels from its source to the field through the conveyance network, including losses due to seepage, leakage, evaporation and over topping. The inflow and outflow were measured at monitoring points for main canal and secondary canal. The average values of inflow and outflows for all measurements for each of the canal segments were used for the estimation of water conveyance losses and water conveyance efficiency using the following equation (Eq. 5).

$$E_C = \left(\frac{Q_{outflow}}{Q_{inflow}}\right) * 100 \tag{5}$$

Where: Ec = Water conveyance efficiency (%),

$Q_{outflow}$ = amount of water outflow (m^3/s)

Q_{inflow} = amount of water inflow (m^3/s)

3.4.3. Water delivery performance indicators

The water delivery performance parameters like adequacy, equity, dependability, and efficiency have been proposed by Molden and Gates (1990) was used as a standard comparison of the current study. According to Molden and Gates (1990), the performance of the water delivery performance system was classified as good, fair, and poor.

3.4.3.1. Adequacy performance indicator

Adequacy displays the extent to which the total water deliveries are sufficient to fulfil the needs of the crops in a specific growing season.Adequacy is the ratio of actual amount of water delivered by the system to the amount of water required (Molden, D.J., and Gates, T.L. 1990).This indicator was determined after actual amount of the discharge delivered measured and required amount of discharge was computed (Eq. 6).

$$PA = \frac{1}{T}\sum_{T}\left(\frac{1}{S}\sum_{S}\frac{Q_D}{Q_R}\right) \tag{6}$$

Where: T = period of consideration,

S = the site where canals are located

Q_D = actual amount of water delivered (m^3/s)

QR = Required discharge (m^3/s)

3.4.3.2. Equity performance indicator

Equity as related to the water delivery system can be defined as the delivery of the fair shares of water to the field throughout the system. An appropriate measure of the performance of the system with equity would be the average relative spatial variability of the ratio of amount delivered to the amount required over the period of interest computed by (Eq. 7).

$$P_E = \frac{1}{T}\sum_{T} CV_R\left(\frac{Q_D}{Q_R}\right) \tag{7}$$

Where: CV_R= special coefficient of variation of the ratio of delivered water to required Water over the region

T = the period.

3.4.3.3. Dependability performance indicator

According to Gorantiwat & Smout (2005) and Won-Ho Nam et al., (2016) dependability states that the ability to find water at the time desired and in the place desired in the systemin which actual delivered amount of water measured and required amount of the water computed over the given area within the scheduled period (Eq. 8).

$$P_D = \frac{1}{S}\sum_{S} CV_T\left(\frac{Q_D}{Q_R}\right) \tag{8}$$

Where: CV_T is temporal coefficient of variation of the ratio QD/QR over a region S in time period T

$$CV_T = \frac{SD}{Mean}$$

SD = Standard Deviation

3.4.3.4. Efficiency performance indicator

Efficiency is defined as the ratio of the volume of water required for a specific purpose to the volume of water delivered (W.H.Nam, E.M. Hong, and J.Y.Choi ,2016). It is commonly interpreted ability to conserve water by matching the water deliveries with water requirements at predetermined station on the canal (Eq. 9)

$$P_F = \frac{1}{T}\sum_{T=1}^{T}\left(\frac{1}{R}\sum_{R=1}^{R} P_f\right) \ with \ P_f = {Q_R}/{Q_D} \qquad (9)$$

If QR ≤ QD and PF = 1

Where:

T = represents the period (month) in which the system performance was determined

R = represents the secondary canals of the system, the performance of which was to be determined.

3.4.4. Maintenance indicators

Maintenance performance inspection of the irrigation scheme would provide to insight the feature of maintenance situations. Hydraulic performance of the scheme was also evaluated with maintenance performance indicators. It was estimated through the indicators recommended by (Bos*et al.*, 2005). Maintenance requirements of the system were observed according to the maintenance indicators of water surface elevation ratio, effectiveness of infrastructure, water delivery ratio and sustainability of irrigable area.

3.4.4.1. Water surface elevation ratio

Water surface elevation ratio indicator provides to predict the impact of sedimentation and erosion problems on the physical irrigation system. To compute these indicators, actual water surface elevation was measured at each point of the predetermined station of a long the main canal and the intended surface water elevation was taken from the Kesem irrigation development office (Eq. 10)

$$\mathrm{WSER} = \frac{\text{Actual water surface elevation}}{\text{Intended water surface elevation}} \qquad (10)$$

3.4.4.2. Effectiveness of Infrastructure

Regular maintenance of irrigation system component is needed to keep the system in operational condition. The ratio of effectiveness of infrastructure indicates the extent to which the system manager is able to control water. To compute this indicator, the number of structures properly functioned during the study period was recorded and the total number of structures initially installed was taken from the office (Eq. 11).

$$\mathrm{EI} = \frac{\mathrm{NFS}}{\mathrm{TNSII}} \qquad (11)$$

Where: NFS = Number of Functioning Structures

TNSII = Total Number of Structures Initially Installed

3.4.4.3. Water Delivery Ratio

The water delivery ratio in irrigation system indicates the problems related to sediment deposits, erosion, and vegetation of some water conveyance structures. The water delivery ratio is both maintenance and water utility performance indicators and it is described as the ratio of actual and intended supply. The actual discharge was measured at selected stations along the canal in which measurements the average value. and the intended discharge taken from the Kesem irrigation scheme development office that computed using (Eq. 12)

$$WDR = \frac{\frac{1}{n}\sum_{i=1}^{n} Q_A}{Q_d} \qquad (12)$$

Where: Q_A = Actual discharges based on daily water level measurement for n days, (m^3/s)

Q_d = Intended discharges of irrigation water (m^3/s)

n = number of monitoring period

3.4.4.4. Sustainability of Irrigated area

Sustainability is the performance measure related to upgrading, maintaining, and degrading the environment in the irrigation scheme. Sustainability of irrigated area refers to the percentage of change in irrigated area over the period of years. Sustainability of irrigated area (SIA) is computed as the ratio of existing area under irrigation to the planned irrigated area. The actual irrigated area during the study periods and designed irrigated area was taken from the Kesem irrigation development office to compute this indicator using (Eq. 13).

$$\mathrm{SIA} = \frac{\mathrm{AIA}}{\mathrm{DIA}} \tag{13}$$

Where: AIA = Actual irrigated area during the study period

DIA = Designed irrigated area at the establishment of the scheme

CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.1. Determination of crop Water Requirement

The reference evapotranspiration of the area was computed by using the CROPWAT 8.0 model. The climate data required was taken from the Melka Werer Metrological Station and the crop coefficient was taken from the FAO recommendation at each growth stage. After those parameters computed and obtained, the sugarcane water requirement for the entire growing period was computed using Eq 1. The reference evapotranspiration computed by CROPWAT 8.0 model was from 4.32 to 5.05 mm/day during the study period presented Appendix Table 5. The crop evapotranspiration was determined multiplying of reference evapotranspiration and crop coefficient from 4.1 to 4.8 mm/day (Appendix Table 6). The result of the current study was similar with the result of (Win *et al.*,2014)on the determination of sugarcane water requirement which varies from time to time. The other finding (Dingre and Gorantiwar ,2020) also indicates similar result as the sugarcane water requirement vary from time to time based on the climatic condition and crop growth stages.

4.2. Determination of Irrigation Demand and Supply

The water requirement (Q_R) was computed on the main canal and secondary canal using equation 3. In all canal sections, the delivered discharge throughout the measured time was less than the required discharge. The measured delivered discharge and required discharge in all canal sections were presented in (Table 2, 3, and 4) for secondary canal one, two and three, respectively.

Table 4. 1: The required and delivered discharge (m^3/s) from the secondary canal one

Discharge	canal section	Months			
		October	November	December	January
Required	Head	0.46	0.43	0.46	0.45
	Middle	0.36	0.26	0.34	0.25
	Tail	0.19	0.13	0.15	0.12
Delivered	Head	0.42	0.36	0.40	0.35
	Middle	0.27	0.20	0.27	0.21
	Tail	0.13	0.10	0.11	0.12

Table 4. 2: The required and delivered discharge from the secondary canal two

Discharge	Canal Section	Months			
		October	November	December	January
Required	Head	0.6	0.62	0.56	0.51
	Middle	0.54	0.53	0.44	0.42
	Tail	0.3	0.25	0.24	0.19
Delivered	Head	0.48	0.53	0.46	0.45
	Middle	0.4	0.43	0.34	0.32
	Tail	0.21	0.2	0.19	0.14

Table 4. 3: The required and delivered discharge from the secondary canal three.

Discharge	Canal Section	Months			
		October	November	December	January
Required	Head	0.450	0.415	0.477	0.460
	Middle	0.211	0.210	0.160	0.660
	Tail	0.071	0.080	0.042	0.050
Delivered	Head	0.365	0.335	0.365	0.400
	Middle	0.163	0.167	0.113	0.140
	Tail	0.049	0.062	0.029	0.036

4.3. Water Conveyance Efficiency and Conveyance Losses

The water conveyance efficiency of the irrigation scheme was estimated using Equation 5 for each measurement at each selected location along the main and secondary canals. But the measurement was not taken from the tertiary canals because the tertiary canals almost all with hydro flumes and there are no significant losses expected. The conveyance efficiency of the main canal was computed from the average value of inflow, and outflow for different eight sections of the main canal.

Table 4. 4 Water conveyance efficiency of the Kesem irrigation scheme from the main canal during the study period

Reach	Canal section head (m)	Replication (mean value)	Qinflow (m3/s)	Qoutflow (m3/s)	Conveyance loss (m3/s)	Ec
Head	0 - 300	M1	2.97	2.85	0.12	1.0
		M2	3.22	3.11	0.11	1.0
		M3	3.44	3.18	0.26	0.9
		M4	4.26	4.08	0.18	1.0
		Mean	**3.47**	**3.31**	**0.1675**	**1.0**
	300 - 600	M1	2.85	2.77	0.08	1.0
		M2	3.11	2.82	0.29	0.9
		M3	3.18	2.93	0.25	0.9
		M4	4.08	3.73	0.35	0.9
		Mean	**3.31**	**3.0625**	**0.2425**	**0.9**
	600 -900	M1	2.77	2.13	0.64	0.8
		M2	2.82	2.22	0.6	0.8
		M3	2.93	2.38	0.55	0.8
		M4	3.73	3.11	0.62	0.8
		Mean	**3.063**	**2.460**	**0.603**	**0.8**
Middle	900 - 1500	M1	2.13	1.48	0.65	0.7
		M2	2.22	1.52	0.7	0.7
		M3	2.38	1.83	0.55	0.8
		M4	3.11	2.35	0.76	0.8
		Mean	**2.46**	**1.795**	**0.665**	**0.7**
	1500 - 3500	M1	1.48	0.86	0.62	0.6
		M2	1.52	0.78	0.74	0.5
		M3	1.83	0.92	0.91	0.5
		M4	2.35	1.62	0.73	0.7
		Mean	**1.795**	**1.045**	**0.750**	0.6
	3500 - 5500	M1	0.86	0.72	0.14	0.8
		M2	0.78	0.54	0.24	0.7
		M3	0.92	0.31	0.61	0.3
		M4	1.62	0.97	0.65	0.6
		Mean	**1.045**	**0.635**	**0.41**	0.6
Tail	5500 - 7500	M1	0.72	0.55	0.17	0.8
		M2	0.54	0.35	0.19	0.6
		M3	0.31	0.17	0.14	0.5
		M4	0.97	0.64	0.33	0.66
		Mean	**0.635**	**0.4275**	**0.2075**	**0.7**
	7500 - 8500	M1	0.55	0.44	0.11	0.80
		M2	0.35	0.27	0.08	0.77

		M3	0.17	0.14	0.03	0.82
		M4	0.64	0.48	0.16	0.75
		Mean	0.4275	**0.3325**	**0.095**	**0.79**

The water conveyance efficiency of the main canal varied from 57.16 to 95.19% with an average value of 75.45%. The values of conveyance efficiency were different for each canal section from the head to the tail. The water conveyance losses per 300 m length varied from 0.17 to 0.6 $m^3/s/300$ m with an average value equal to 0.34 $m^3/s/300$ m at the head of the canal. The water conveyance losses at the middle canal per 1500 m length varied from 0.41 to 0.75 $m^3/s/1500$ m with an average value equal to 0.61 $m^3/s/1500$ m and finally, at the tail of the canal, the water conveyance losses were lower than the head and the middle canal which ranges from 0.1 to 0.21m3/s with an average of 0.18m^3/s.

The conveyance efficiency of the secondary canal one was computed from the average value of inflow, and outflow for different five sections of the canal. The water conveyance efficiency for secondary canal one varied from 51.3 to 91.3% with an average value of 60.23%.

Table 4. 5 Water conveyance efficiency of the Kesem irrigation scheme from the secondary canal one during the study period

Reach	Canal section (m)	Replication (mean value)	Qinflow (m3/s)	Qoutflow (m3/s)	Conveyance loss (m3/s/)	Ec (%)
Head	0 - 200	M1	0.46	0.42	0.04	0.9
		M2	0.41	0.36	0.05	0.9
		M3	0.49	0.4	0.09	0.8
		M4	0.38	0.35	0.03	0.9
		Mean	**0.44**	**0.38**	**0.0525**	**0.9**
Middle	200 - 400	M1	0.42	0.31	0.11	0.7
		M2	0.36	0.26	0.1	0.7
		M3	0.4	0.32	0.08	0.8
		M4	0.35	0.24	0.11	0.7
		Mean	**0.38**	**0.2825**	**0.1**	**0.7**
	400 - 600	M1	0.31	0.23	0.08	0.7
		M2	0.26	0.16	0.1	0.6
		M3	0.32	0.22	0.1	0.7
		M4	0.24	0.17	0.07	0.7
		Mean	**0.283**	**0.195**	**0.088**	**0.7**
Tail	600 -800	M1	0.23	0.17	0.06	0.7
		M2	0.16	0.12	0.04	0.8
		M3	0.22	0.15	0.07	0.7

	M4	0.17	0.11	0.06	0.6
	Mean	**0.20**	**0.138**	**0.058**	**0.7**
800 - 1000	M1	0.17	0.09	0.08	0.5
	M2	0.12	0.08	0.04	0.7
	M3	0.15	0.077	0.073	0.5
	M4	0.11	0.08	0.03	0.7
	Mean	**0.138**	**0.082**	**0.056**	0.6

The values of conveyance efficiency were different for each canal section from the head to the tail. The water conveyance losses per 200 m length varied from 0.03 to 0.11 m^3/s/200 m with an average value equal to 0.08 m^3/s/200 m at the head of the secondary canal one. The water conveyance losses at the middle, secondary canal one per 200 m length varied from 0.04 to 0.1 m^3/s/200 m with an average value equal to 0.07 m^3/s/200 m and finally, at the tail of the secondary canal-1, the water conveyance losses were lower than the head and the middle canal which ranges from 0.03 to 0.08m^3/s with an average of 0.06m^3/s.

The conveyance efficiency of the secondary canal two was computed from the average value of inflow, and outflow for different five sections of the canal. The water conveyance efficiency for secondary canal two varied from 71.1 to 91.8% with an average value of 82.44%.

Table 4. 6 Water conveyance efficiency of the Kesem irrigation scheme from the secondary canal-2 during the study period

Reach	**Canal section (m)**	**Replication (mean)**	**Qinflow (m3/s)**	**Qoutflow (m3/s)**	**Conveyance loss (m3/s/)**	**Ec (%)**
Head	0 - 200	M1	0.57	0.48	0.09	0.8
		M2	0.61	0.53	0.08	0.9
		M3	0.53	0.46	0.07	0.9
		M4	0.49	0.45	0.04	0.9
		Mean	**0.55**	**0.48**	**0.07**	**0.9**
Middle	200 - 400	M1	0.48	0.4	0.08	0.8
		M2	0.53	0.43	0.1	0.8
		M3	0.46	0.34	0.12	0.7
		M4	0.45	0.32	0.13	0.7
		Mean	**0.48**	**0.3725**	**0.1075**	**0.8**
Tail	400 - 600	M1	0.4	0.25	0.15	0.6
		M2	0.43	0.26	0.17	0.6
		M3	0.34	0.22	0.12	0.6
		M4	0.32	0.17	0.15	0.5
		Mean	**0.373**	**0.225**	**0.148**	**0.6**

	600 -800	M1	0.25	0.17	0.08	0.7
		M2	0.26	0.14	0.12	0.5
		M3	0.22	0.15	0.07	0.7
		M4	0.17	0.11	0.06	0.6
		Mean	**0.23**	**0.143**	**0.083**	**0.6**

The values of conveyance efficiency were different for each canal section from the head to the tail. The water conveyance losses per 200 m length varied from 0.04 to 0.13 $m^3/s/200$ m with an average value equal to 0.09 $m^3/s/200$ m at the head of the secondary canal two. The water conveyance losses at the middle, secondary canal two per 200 m length varied from 0.12 to 0.17 $m^3/s/200$ m with an average value equal to 0.15 $m^3/s/200$ m and finally, at the tail of the secondary canal two, the water conveyance losses were lower than the head and the middle canal similar to the secondary canal three which ranges from 0.06 to $0.12m^3/s$ with an average of $0.08m^3/s$.

The conveyance efficiency of the secondary canal three was computed from the average value of inflow, and outflow for different eight sections of the canal. The water conveyance efficiency for secondary canal three varied from 90.9 to 55.6% with an average value of 70.4%.

Table 4. 7 Water conveyance efficiency of the Kesem irrigation scheme from the secondary canal three during the study period

Reach	Canal section (m)	Replication (mean value)	Qinflow (m3/s)	Qoutflow (m3/s)	Conveyance loss (m3/s/)	Ec (%)
Head	0 - 250	M1	0.44	0.4	0.04	0.9
		M2	0.51	0.38	0.13	0.7
		M3	0.57	0.46	0.11	0.8
		M4	0.61	0.48	0.13	0.8
		Mean	**0.53**	**0.43**	**0.1025**	**0.8**
	250 - 500	M1	0.4	0.33	0.07	0.8
		M2	0.38	0.29	0.09	0.8
		M3	0.46	0.27	0.19	0.6
		M4	0.48	0.32	0.16	0.7
		Mean	**0.43**	**0.3025**	**0.1275**	**0.7**
Middle	500 - 750	M1	0.33	0.22	0.11	0.7
		M2	0.29	0.2	0.09	0.7
		M3	0.27	0.15	0.12	0.6
		M4	0.32	0.21	0.11	0.7

		Mean	**0.303**	**0.195**	**0.108**	**0.6**
	750 -1000	M1	0.22	0.16	0.06	0.7
		M2	0.2	0.17	0.03	0.9
		M3	0.15	0.11	0.04	0.7
		M4	0.21	0.12	0.09	0.6
		Mean	**0.20**	**0.140**	**0.055**	**0.7**
	1000 - 1250	M1	0.16	0.110	0.050	0.7
		M2	0.17	0.130	0.040	0.8
		M3	0.11	0.080	0.030	0.7
		M4	0.12	0.090	0.030	0.8
		Mean	**0.14**	**0.103**	**0.038**	**0.7**
Tail	1250 - 1500	M1	0.110	0.067	0.043	0.6
		M2	0.130	0.082	0.048	0.6
		M3	0.080	0.044	0.036	0.6
		M4	0.090	0.053	0.037	0.6
		Mean	**0.10**	**0.062**	**0.041**	**0.6**
	1500 - 1750	M1	0.067	0.043	0.024	0.6
		M2	0.082	0.055	0.027	0.7
		M3	0.044	0.026	0.018	0.6
		M4	0.053	0.031	0.022	0.6
		Mean	**0.06**	**0.039**	**0.023**	**0.6**
	1750 - 2000	M1	0.043	0.038	0.005	0.9
		M2	0.055	0.048	0.007	0.9
		M3	0.026	0.018	0.008	0.7
		M4	0.031	0.023	0.008	0.7
		Mean	**0.04**	**0.032**	**0.007**	**0.8**

The values of conveyance efficiency were different for each canal section from the head to the tail. The water conveyance losses per 250 m length varied from 0.004 to 0.19 m^3/s/250 m with an average value equal to 0.11 m^3/s/250 m at the head of the secondary canal three. The water conveyance losses at the middle, secondary canal three per 250 m length varied from 0.03 to 0.09 m^3/s/250 m with an average value of 0.04 m^3/s/250 m and finally, at the tail of the secondary canal three, the water conveyance losses were lower than the head and the middle canal similar to the secondary canal one and two which ranges from 0.01 to 0.03 m^3/s with an average of 0.01m^3/s. The average conveyance efficiency of the irrigation scheme is 72.13%.Therefore, the estimated conveyance efficiency values of each reach as well as the average values Kesem irrigation scheme were below the recommended value (80 %) for earth canals (FAO, 1989).

Table 4. 8: Summary conveyance efficiency and loss in the canals

Canal	Reach	Conveyance loss (m3/s/)	Ec
Main canal	Head	0.34	0.89
	Middle	0.61	0.64
	Tail	0.15	0.72
	Mean	0.37	0.75
SSC1	Head	0.053	0.9
	Middle	0.09	0.71
	Tail	0.06	0.66
	Mean	0.068	0.76
SSC2	Head	0.07	0.870
	Middle	0.11	0.770
	Tail	0.12	0.620
	Mean	0.10	0.753
SSC3	Head	0.12	0.760
	Middle	0.07	0.700
	Tail	0.02	0.670
	Mean	0.07	0.710

4.4. Performance Indicators of Irrigation Canals

The performance indicators considered in this study were water delivery performance indicators and maintenance performance indicators mainly focused on the selected secondary canals. To evaluate the Kesem irrigation scheme, all required data were collected, analysed, and interpreted separately in the following section.

4.4.1. Water Delivery Performance Indicators

The water delivery performance indicators of the canal such as adequacy, equity, dependability, and efficiency were computed for four successive months (October, November, December, and January).To estimate these indicators, the values of water delivered (QD) and required (QR) of the irrigation scheme were taken as basic variables for a given period over the irrigation region. The average irrigation water supply was measured from three secondary canals and at the offtake from the main canal and the irrigation water required for each secondary canal was computed. After all, those required data obtained the water delivery performance were analysed.

4.4.1.1. Adequacy performance indicator

Adequacy is an important parameter which indicates the extent to which total irrigation water delivered sufficiently satisfy the crop water needs during the crop growing periods over the command area. The adequacy performance indicators from the three secondary canals of the Kesem irrigation scheme indicates fair for secondary canal one, two and three with average values of 0.81, 0.80 and 0.80,respectively. The adequacy, performance indicator for the three secondary canals considered in this study was presented in (Figure 4.1, 4.2, 4.3).

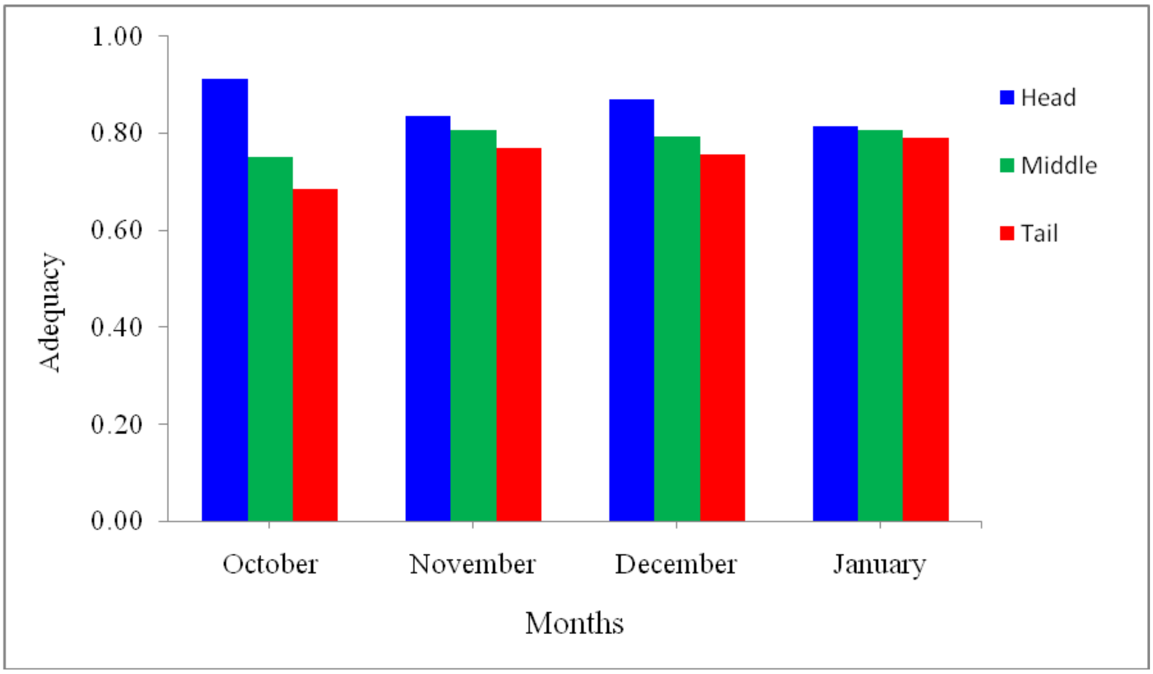

Figure 4. 1: Adequacy performance indicators for secondary canal one

The average adequacy at the head of the canal was good at the head during October and fair at all other months, at middle fair in the November and January months and poor in October and December months, and poor at the tail of the secondary canal one in all months.

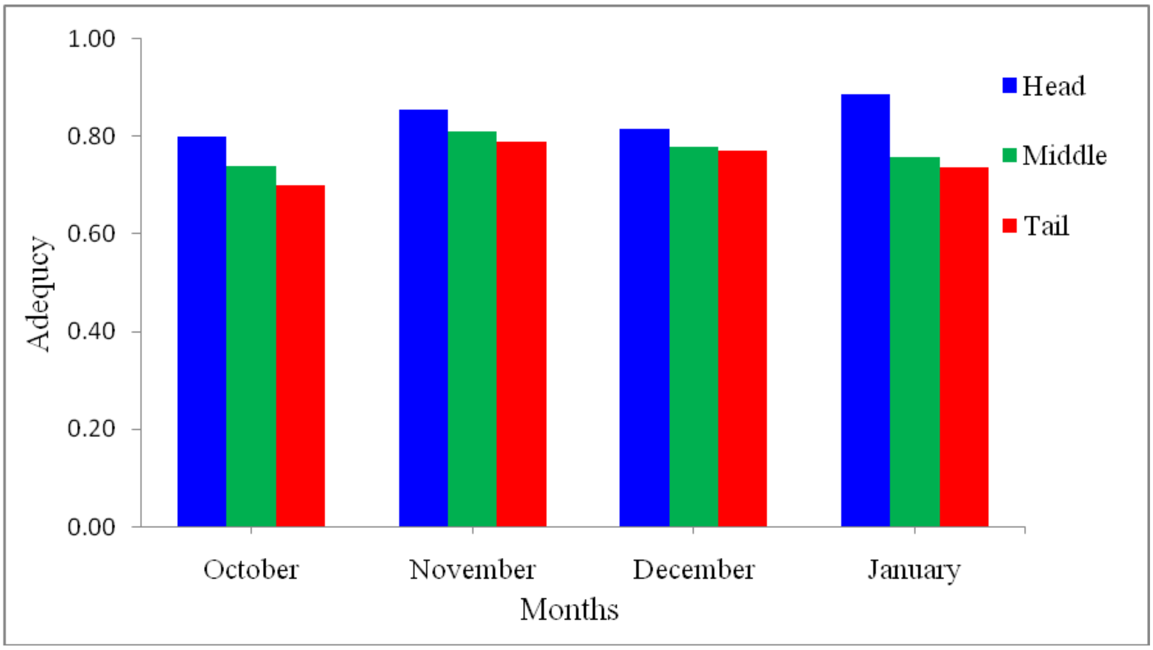

Figure 4. 2: Adequacy performance indicators for secondary canal two

The average value of adequacy at the head of the secondary canal two was fair, at middle poor except for November month, which was fair and poor in all months at the tail of the secondary canal two during the study period.

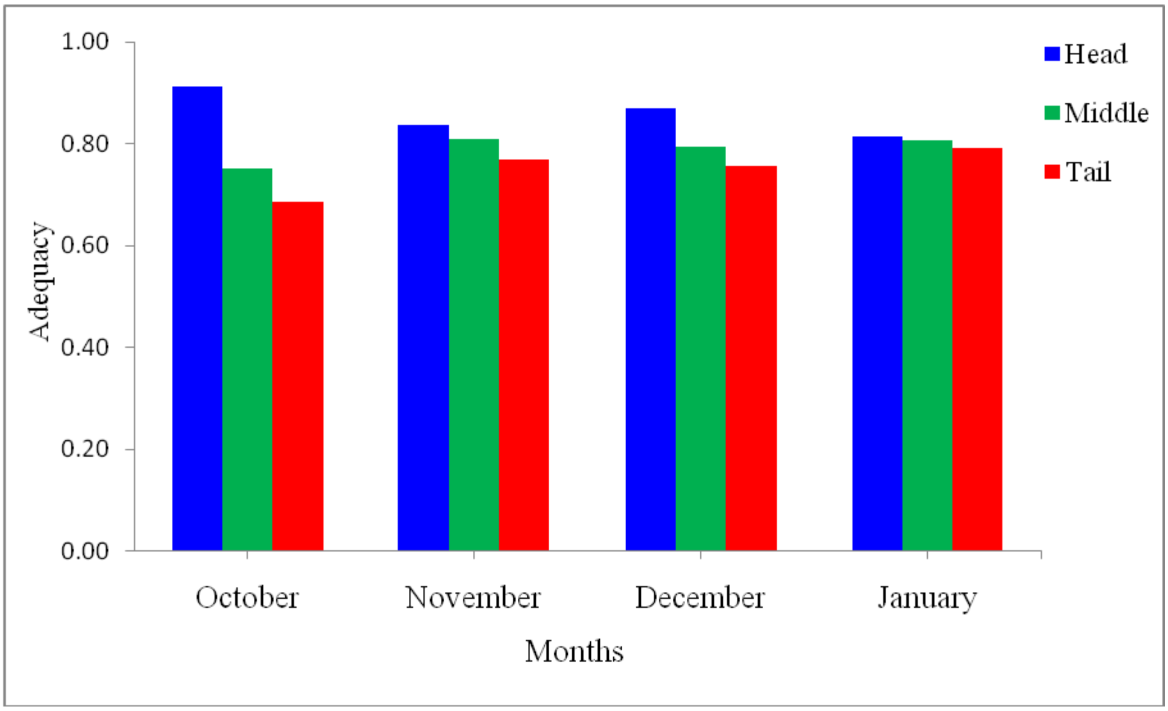

Figure 4. 3: Adequacy performance indicators for secondary canal three

The average adequacy at the head of the canal was good at October and fair at all other months, fair at middle in November and January, and finally, at tail of the secondary canal three poor in all months. The adequacy performance indicator indicated that the irrigation water delivered in the canal is sufficient or not to fulfil the crop water requirement.

According to Molden and Gate (1990), the adequacy of irrigation canal rated as good (0.9-1), fair (0.8-0.89) and poor (<0.80).The result of the current study indicated that the overall adequacy of the three secondary canals considered was indicated that a fair performance of adequacy at the head and middle location but shows poor at tail location. In general, the adequacy performance indicator of this irrigation scheme was fair at the head and partially at the middle reach of the scheme but poor at tail reach of the scheme. The result of the study conducted by (Tebebal and Ayana 2015), revealed that the overall adequacy performance of the irrigation canal was poor. Similarly, the findings of study conducted by Efriem and Mekonen (2017) indicated that the adequacy performance of the overall irrigation canal was fair.

4.4.1.2. Equity performance indicator

Equity indicates the fairness of water delivered to different parts of an irrigation system or delivery of the fair shares of water to the users throughout the system. In the current study, equity was computed from the data on secondary canal water delivered and water required in each canal. Because the performance of the secondary canals more indicative than the whole scheme about the performance from both water supply and demand of the individual fields from that canal since all the tertiary canals were hydro flumes.

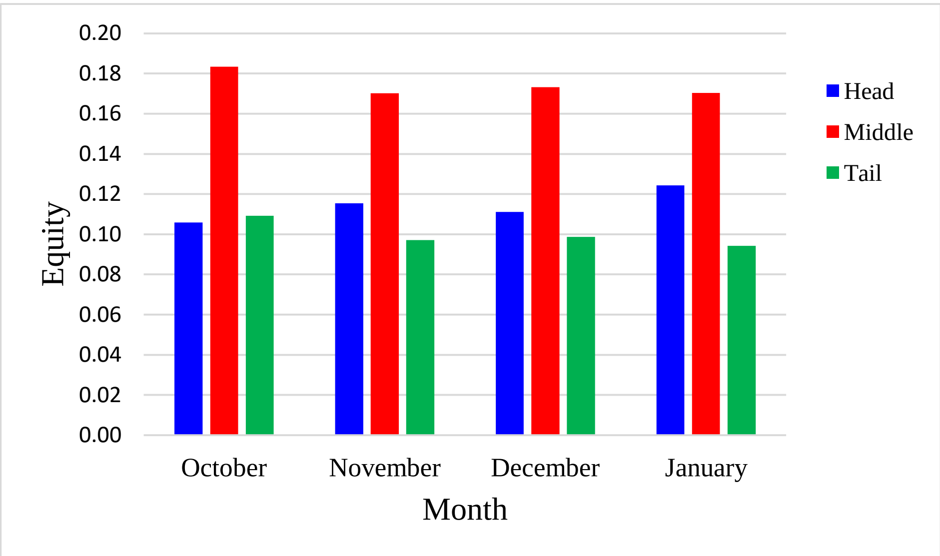

Figure 4. 4: Equity performance indicator for secondary canal one

According to the Molden and Gate (1990) the equity performance is ranged as good (0.00-0.1), fair (0.1-0.25) and poor if it is (> 0.25). The result of the current study of the equity performance indicators were 0.1 to 0.12 at head, 0.17 to 0.18 at middle and 0.09-0.11 at the tail reaches of the secondary canal one. The equity performance indicator of the canal indicates as it was good at head and tail. However, the result shown that equity of water distribution throughout the evaluation period at middle reach fair. Therefore, the spatial coefficient of variation of adequacy between the three reaches (head, middle and tail) reaches was not uniform of the water deliveries.

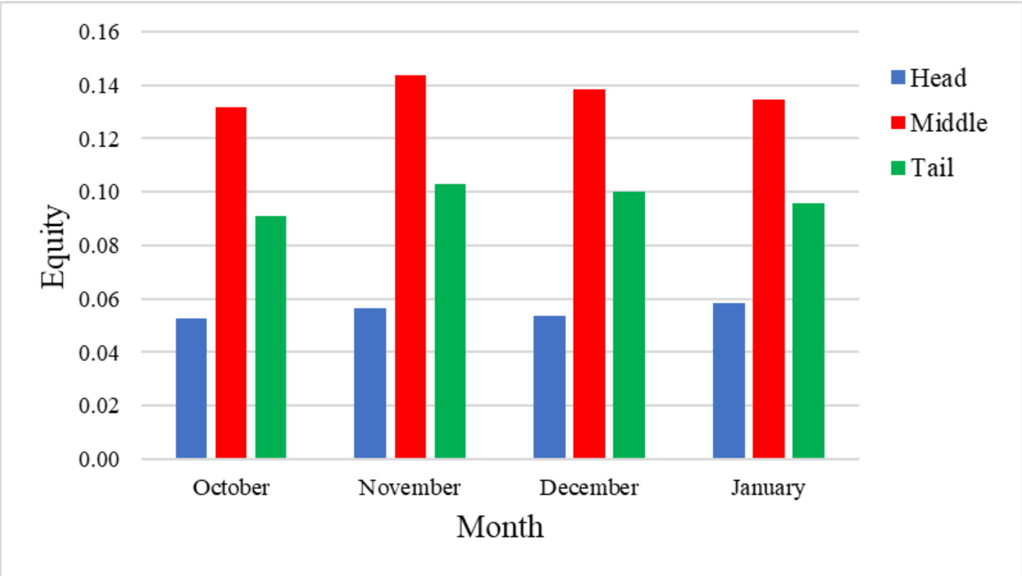

Figure 4. 5: Equity performance indicator for secondary canal two

The result of the current study of the equity performance indicators were 0.5 to 0.06 at head, 0.13 to 0.14 at middle and 0.09 to 0.10 at the tail reaches of the secondary canal two. The equity performance indicator of the canal generally indicates good at head, fair at middle and tail of the canal which indicates the water distribution to the secondary canal two out outreach was practically fair distribution.

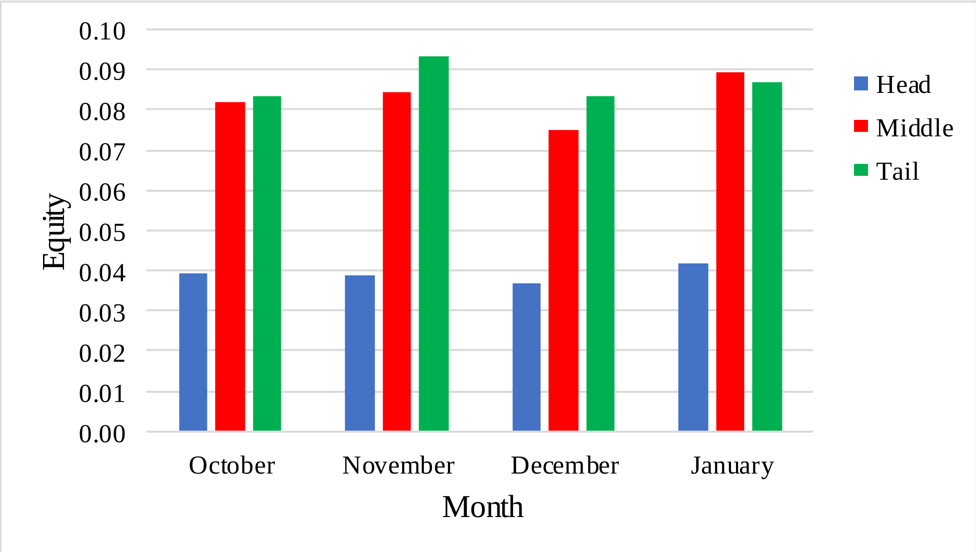

Figure 4. 6: Equity performance indictor for secondary canal three

The result of the current study of the equity performance indicators was 0.04 at head, 0.07 to 0.09 at middle and 0.08 to 0.09 at the tail reaches of the secondary canal three. The equity performance indicator of the canal generally indicates good at all sections of the canal and the water distribution from the main canal reach to the secondary canal three outreach was good.

Similar to the current study, the result of the study conducted by (Efriem and Mekonen, 2017) indicated that the equity performance indicator showed the overall irrigation scheme was ranged from good to fair at different irrigation periods. The other study conducted by Bitew (2017). revealed that the equity performance indictor of the irrigation canal was ranged from good and fair. Similarly, the other result of the study conducted by Gebremedhn and Singh (2020) revealed the overall good equity performance indicator.

4.4.1.3. Dependability performance indicator

Dependability of water delivery is an indicator for the degree of conformity of water deliveries to prior expectations. It implies the achievement of temporal uniformity of the relative water delivery over a region R. Dependability of the three secondary canals were calculated and shown in the figures at each reach (head, middle and tail).

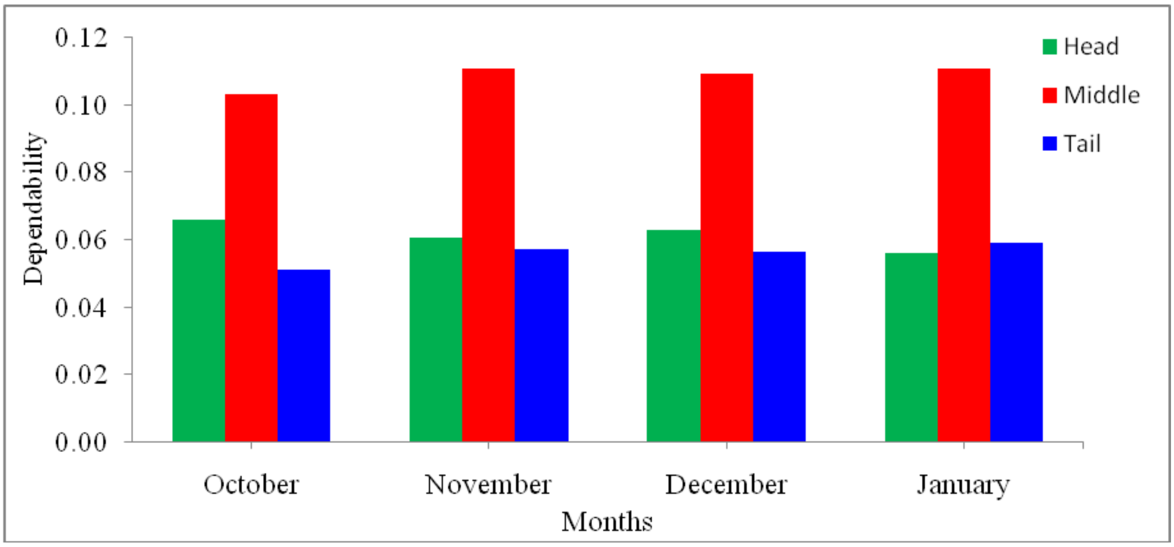

Figure 4. 7: Dependability performance indicator of secondary canal one

According to the Molden and Gate (1990) the dependability performance is ranged as good (0.00-0.1), fair (0.11-0.20) and poor if it is (> 0.20). As shown from the result presented figure 4.7 temporal coefficient of variation at the head, middle and tail reach of secondary canal one was 0.06 to 0.07 at head, 0.1 to 0.11 at middle and 0.05 to 0.06 at tail reaches. Compared with the standard the average value of dependability at head and tail reach was good and fair at Middle. The result indicated that the reliability of flow was somehow lower at middle reach during the evaluation period.

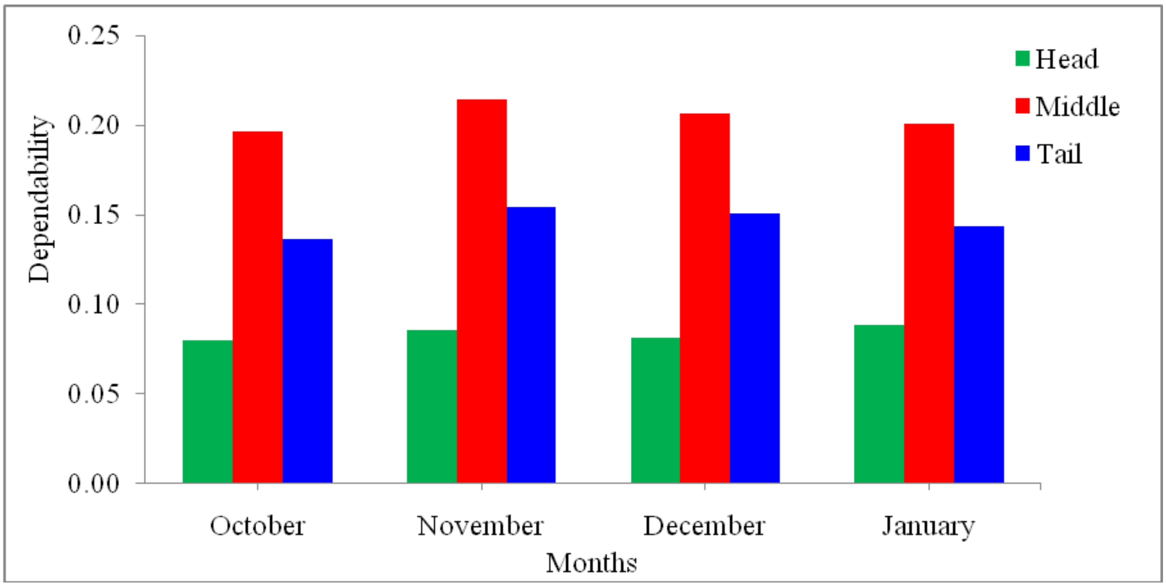

Figure 4. 8: Dependability performance indictor of secondary canal two

The result of the current study on the dependability, performance indicators were 0.08 to 0.09 at head, 0.20 to 0.21 at the middle and 0.14 to 0.15 at the tail reaches of the secondary canal two. The dependability, performance indicator of the canal generally indicates, good for the secondary canal two at the head and the tail of the canal and fair in the middle of the canal, which indicates the water distribution in canal outreach was within the desired time.

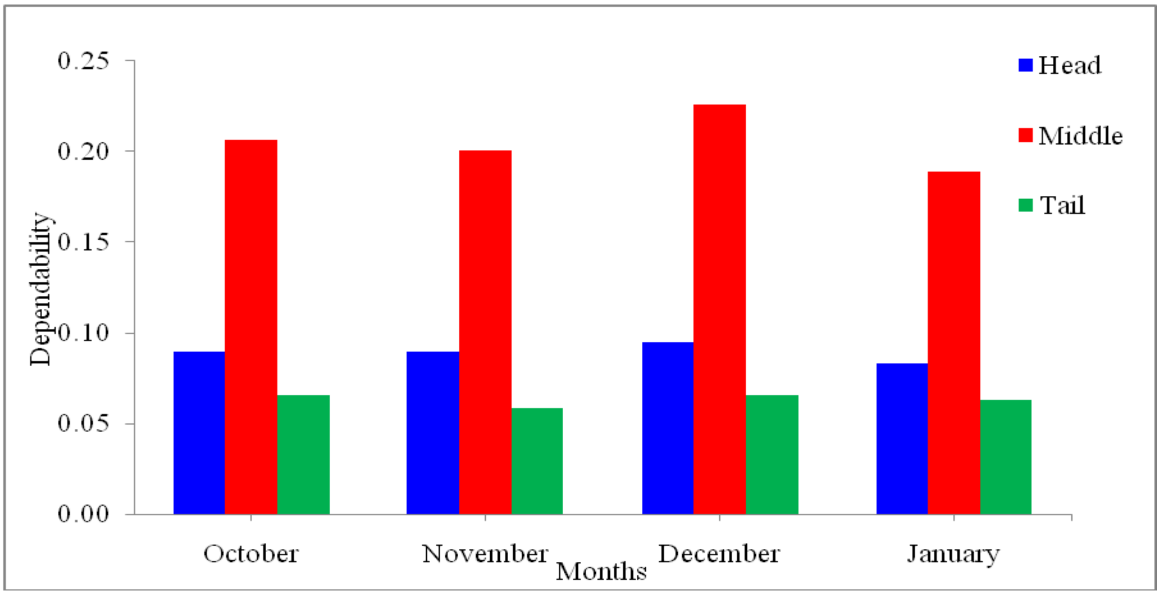

Figure 4. 9: Dependability performance indicator of secondary canal three

The result of the current study on the dependability, performance indicators were 0.08 to 0.09 at head, 0.19 to 0.23 in the middle and 0.06 to 0.07 at the tail reaches of the secondary canal three. The dependability, performance indicator of the canal generally indicated that good for the secondary canal three at the head and the tail reach and fair at middle in the month of November and January. But temporal uniformity water deliveries poor in the month of October and December was poor at middle section of the canal. Which indicates the water distribution at the middle of the secondary canal three were not consistency within the desired duration.

The study findings conducted by Gebremedhn and Singh (2020) showed that the water delivery performance of the irrigation schemes was with the requirement in the different location of the canal with respect to the time of evaluation. In opposite to this study, the study result conducted by Yeshi (2018), indicated that the water delivery performance of the irrigation canal was rated as poor as compared to the standards.

4.4.1.4. Efficiency performance indicator

The performance, efficiency indicator is the measure of the excess of water delivered in comparison with the requirements. It is indicated over an area R and the time period T at a point in a specific time. Efficiency expresses the capacity to preserve water by matching water requirement with water delivery.

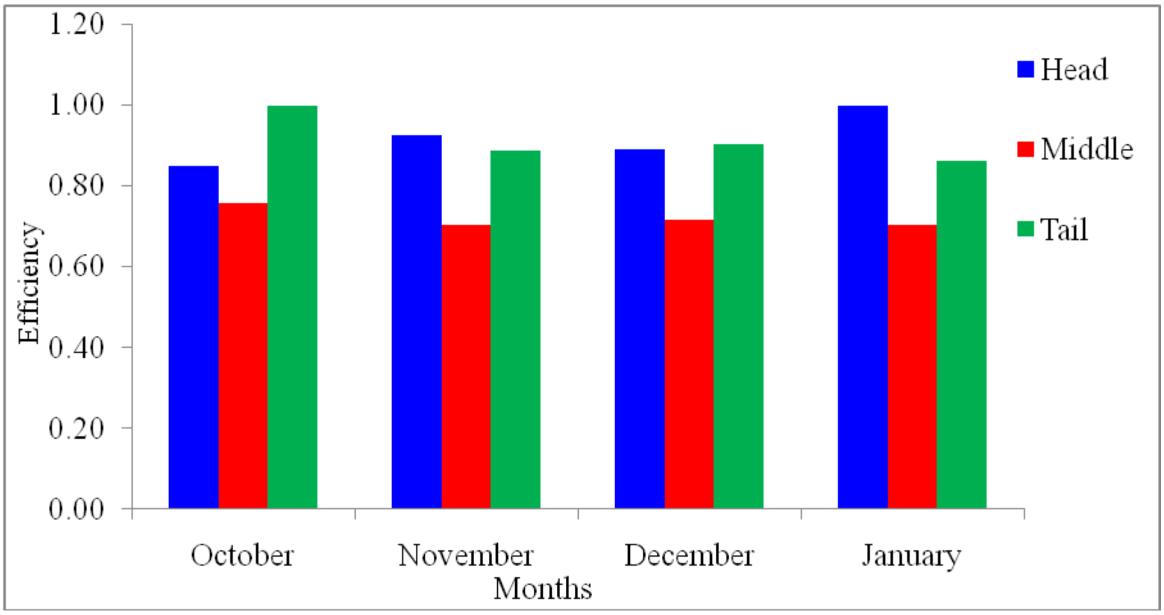

Figure 4. 10: Efficiency performance indicator of secondary canal one

According to the Molden and Gate 1990) the efficiency of the irrigation rated as good (0.85- 1.0), fair (0.7- 0.84) and poor (0.7). The current study finding as shown (Figure 12), the overall irrigation efficiency performance indicator of secondary canal one was good at head and middle reach of canal section and fair at the tail of the canal section in all months of consideration.

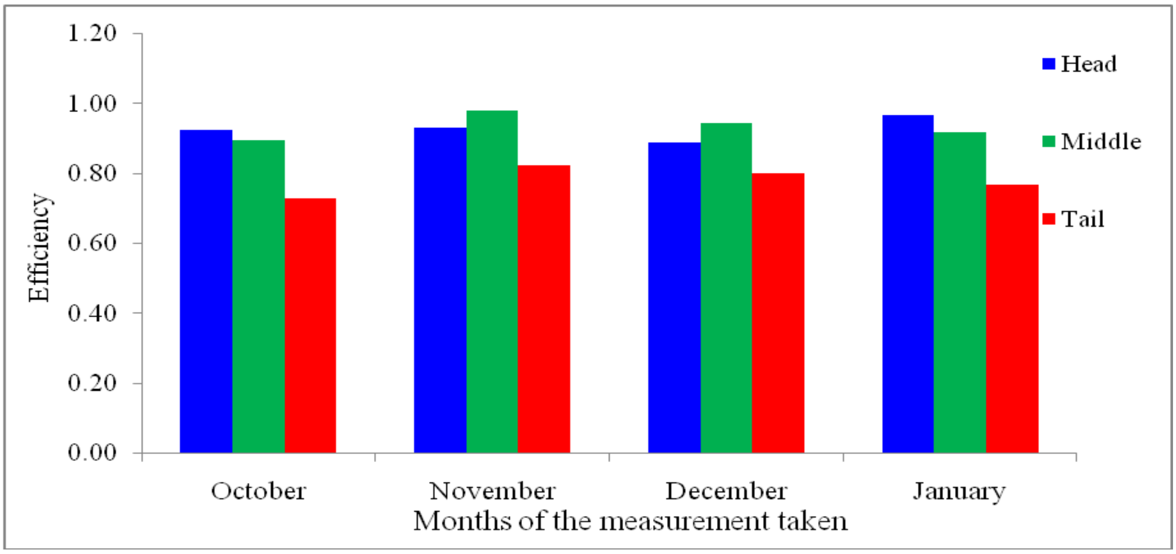

Figure 4. 11: Efficiency performance indictor of the secondary canal two

The efficiency of the secondary canal two was rated as good in all sections of the canal at head and middle reaches of the canal section in all months of the study but fair at the tail of the canal. This indicated that the water delivered through the canal two meet in comparison with requirement.

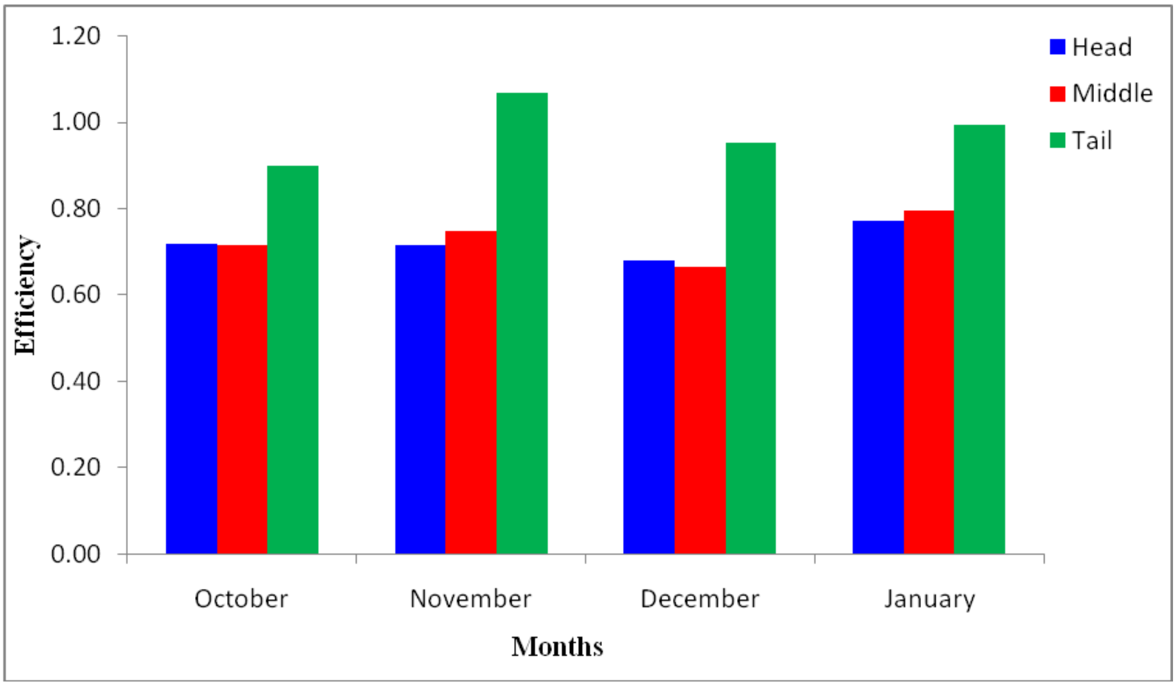

Figure 4. 12: Efficiency performance indicator of the secondary canal three

Similar to the secondary canal one and two in secondary canal three, the efficiency of the secondary canal-three was also rated as fair at head and middle reach of all sections of the canal in all months of the study, and good at the tail reach of the whole canal sections. This indicated that the amount of irrigation water delivered was effectively used in the application area.

4.4.2. Maintenance Performance Indicators

Maintenance performance inspection of irrigation scheme would provide an insight to the feature of maintenance situations. The main objectives of maintenance indicators are to keep the system in proper operating conditions, to maximize the life of the system's facilities, and to prevent interruptions in water deliveries. Therefore, maintenance study helps to reflect the management performance of an irrigation scheme.

4.4.2.1. Water surface elevation ratio

Water surface elevation ratio indicator provides to predict the impact of sedimentation and erosion problems on the physical conveyance irrigation system. In this study the inspection was made at the head, middle and tail reach of the main canal. The water surface elevation ratio was computed by taking the actual water depth from the canal bed on different measurement points in each individual inspection location and compared with the intended water depth at the same position in the main canal. The parameter was estimated based on the measurements taken 5 inspection points from each location at head, middle and tail reach a total of 15 points. The result was based on mean level measurement of water depth at inspection points of the main canal cross sections.

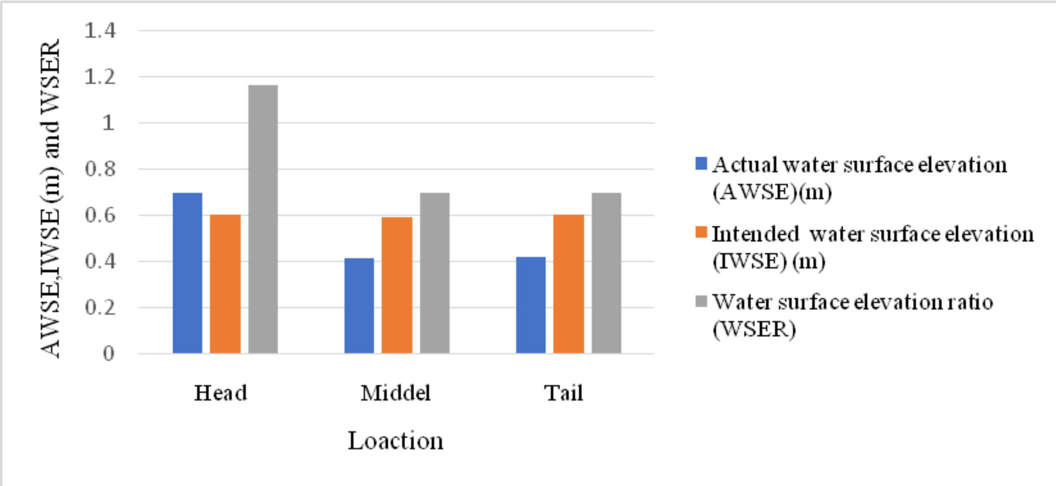

Figure 4. 13: Average water Surface elevation of the main canal

Water surface elevation ratio (WSER) of the main canal was found 1.2 m, 0.7m, and 0.7 m at head, middle and tail reaches respectively (Figure 4.16). This indicates that in the main canal at head there is scouring, on the other side sedimentation and weed was occurred at middle and tail reach. The overall average WSER of the main canal during the monitoring period was less than one, the overall value indicated that the main canal was ineffective by weed and sedimentation problems.

The current study result is similar with the result of the study conducted by Eshetie (2017) revealed that the water elevation ratio was 0.78 at FSL. Similarly, the result of other study by Bitew (2017) also showed the WSER at FSL was reduced due to the deposition of silt and lack of canal maintenance which is similar to the current study.

4.4.2.2. Effectiveness of infrastructure

This parameter focussed on flow control gates at intake and offtake in main and secondary canal. According to the design document, total numbers of structures initial installed in the scheme were 29, however only 19 structures are currently functional. The effectiveness of infrastructure of the scheme was computed as the ratio of currently functioned structure to the initially installed considered. The result of the current study showed that, only 65.5% of the initially installed structures were functional according to the design. This indicated that as the maintenance of the structures were very poor.

The result of the study conducted by Tebebal and Ayana (2015) indicated that the overall main and secondary canals of the irrigation scheme demonstrated showed nearly no functionally operative. This is similar to the current study in which 25.5% of the initially installed structures were not functional only from intake and offtake of the main and secondary canals. In opposite to the current study, the finding of Habtamu (2017) indicated that almost all structure installed (71.8%) were not functional and finally the irrigation scheme may be collapsed in a short period of time unless critical consideration is not given by the concerned body. Like this, when the overall irrigation scheme considered, the functionality of the structures across the scheme were not good since it is large scale irrigation it requires critical maintenance considerations.

4.4.2.3. Water Delivery ratio

The delivery performance ratio is the ratio of actual discharge of allowed (maximum design or intended) discharge during the design of the irrigation scheme. The water delivery ratio of the scheme was computed on the three sample secondary canals at offtake point using Eq 12. The indictor was evaluated whether the supply of water meets as per design or not at each monitoring point. This parameter computed the ratio of average actual flow to the design discharge at offtake points from secondary to hydro flume head. It is a useful comparative indictor which was investigated three times per month for four months using current meter. The average value range of water deliver ratio of the three canals was from 0.5 to 0.9. The highest WDR value found at SSC2 and the lowest is at SSC3. The lower values of this indicator which is less than one this means water is not delivered as per the required.

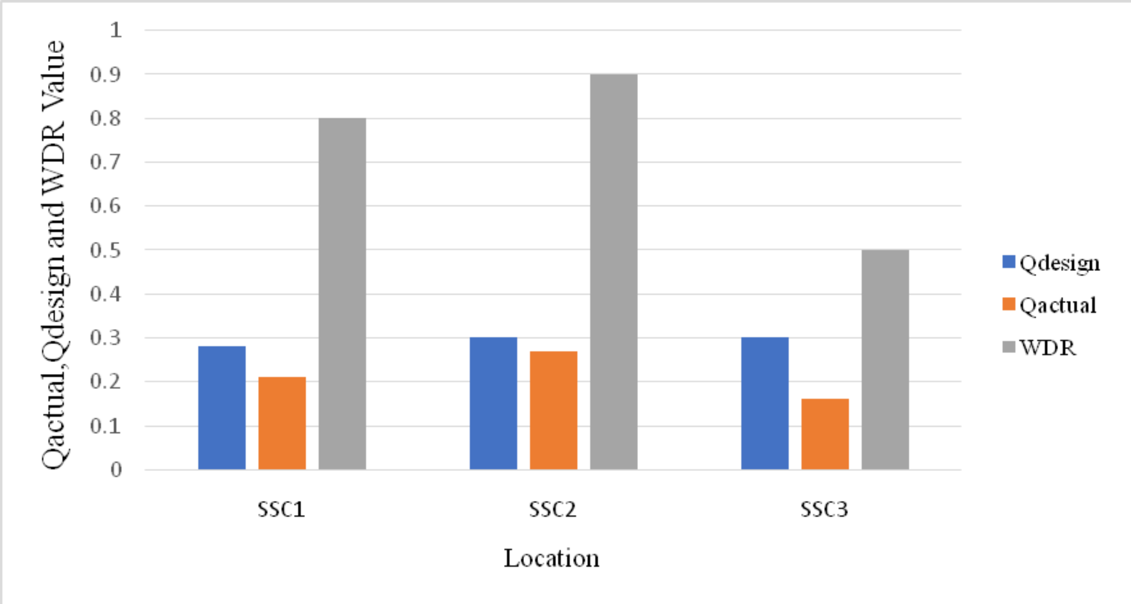

Figure 4. 14: Water delivery ratio of secondary canals

This result shows that the actual water delivery at the main offtake to branched canals was remain between 0.5 and 0.9 for the three monitored locations. Therefore, it concludes that the three monitored canals SSC1, SSC2 and SSC3 were lost, 20, 10 and 50% of discharge compared with the design value, respectively. It was happening since high water losses in the main and secondary canal. This occurred due to the accumulation of sediments and poor maintenance. Maintenance of the irrigation scheme required based on the maintenance indicators of the scheme. In consideration of the water delivery ratio, the maintenance required if it is greater than 5%. Therefore, in this irrigation scheme, in all secondary canals considered the water delivery ratio was greater than 5% which requires maintenance.

The result of the study conducted by Efriem and Mekonen (2017) indicated that the water delivery ratio during the study period was greater than 5% in all canal section which requires the critical maintenance of the scheme. This is similar to the current study in which the scheme requires maintenance by considering this indicator.

4.4.2.4. Sustainability of Irrigated Area

Sustainability of the scheme was investigated to identify the change in the area of actually irrigated against the planned. As per design document the proposed command area that the scheme potential that could irrigate is 10,000ha. However, the overall actual irrigated area of the scheme is 2900ha. Hence sustainability of the overall scheme is found 29% this result indicted that sustainability of irrigated area of the scheme is very poor as per standard. Major factor contributed for the poor performance of the scheme was less attention given related to the completeness of facilities and given less attention for expansion of the irrigated area as per initially design.

Moreover, the sustainability of irrigated area for three secondary canals namely SSC1, SSC2 and SSC3 were computed compared with the planned and illustrated (Figure 4.18).

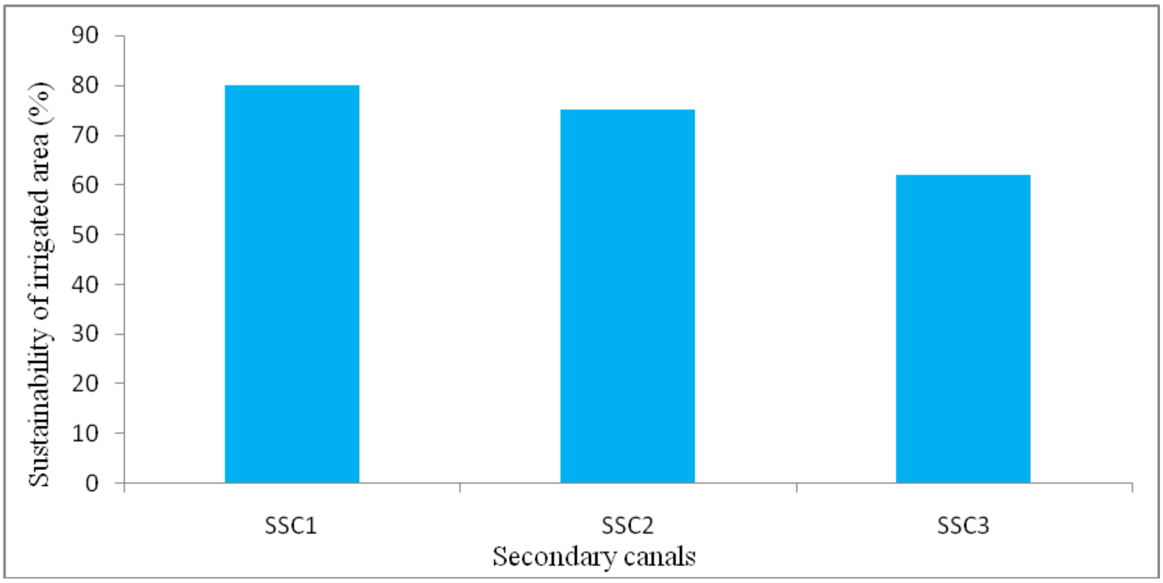

Figure 4. 15: Sustainability of irrigated area under secondary canal

From this study finding, the current irrigated area is reduced as compared with the design of each canals target irrigated area. The computed values of sustainability of each canal were 80, 75 and 62% respectively. The reduction of command area was due to very poor maintenance activities for the three secondary canals.

The current study result was similar with the study findings by Tebebal and Ayana (2015)in which the overall sustainability of the scheme considered was 85% which considered as good. The result of the study findings by Habtamu (2017) showed that the sustainability of the irrigation scheme considered was very good in which around 98% of the designed irrigated area actually irrigated during the study period.

4.5. Identified Performance Gaps and Suggested Corrective Measures.

Based on the result of the study, the main problems and limits that reduced the existing performance of the scheme are mismatches between irrigation water supply with irrigation water demand, and miss understanding of the role of maintenance to improve the performance of the irrigation scheme. The main gaps identified during the study period were, the conveyance efficiency of the irrigation scheme is somewhat low, water delivery performance of the canal is fair for the head of the canal section and decreased the tail of the canal reaches, and maintenance of the irrigation schemes in almost all indicators revealed as poor. Therefore, based on the result of the current study the following corrective actions should be undertaken to improve the overall performance of the irrigation scheme. It is observed that there was shortage supply of water in some portion of the canals in different times to overcome this problem the irrigation water delivered should be in line with the crop water requirement considering the climatic condition during the irrigation time as well as crop growth stages.

The improvement of the water delivery performance in the irrigation scheme is related to the water supply and demand relation during the crop growing period. The irrigation water delivery from the main canal to field should be maintain as much as possible to meet the water demand the plantation, through reducing the water losses of the system by providing proper maintenance of the structures pre and post irrigation. Because there was a clear observation of the silt deposited and development of plants leaves in the irrigation canals. There is also a great variation between irrigation water delivered from the head to the tail section of the canals in which some area more supplied but in the other area less water supplied across the irrigation scheme. In general, to improve the efficiency of the irrigation scheme all aspects of the irrigation water management should be improved throughout the scheme reaches.

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusion

Irrigation development, particularly in developing countries is a backbone to the extent that it is responsible for the nation's poverty reduction and fulfilling the food self-sufficiency for the most incredibly increasing population from time to time. But currently irrigation development in the developing countries are constrained by many factors. The main factors which affect like Ethiopia are improper operation and scheme management, luck maintenance and mismatch the irrigation water to deliver into the application area compare with the design. There are high losses of irrigation water from the source of water to the field due to lack of irrigation structure maintenance and lack of scheme management. As it is known, the main purpose of evaluation is to know the level of performance. Poor design and lack of suitable criteria for irrigation systems are generally responsible for uneven irrigation, leading to wastage of water, water logging and salinity problems. In line with this the current study was undertaken to evaluate the conveyance performance of the Kesem irrigation scheme, which is in the Afar regional state, Ethiopia.

To evaluate the performance evaluation of a water conveyance system of the Kesem irrigation scheme, different performance indicators were considered. The performance indicators considered in this study were water delivery performance indicators which include adequacy, equity, dependability, and efficiency. The other performance indicator used was maintenance indicator which also includes water surface elevation ratio, water delivery ratio, effectiveness of the infrastructure and sustainability of the irrigated area as compared to the design. All required data for this performance evaluation were collected from the field and concerned offices. After, all required data for the performance obtained, the analysis was performed to check whether the irrigation scheme is at good performance or not. The performance was evaluated from main canal and three secondary canals with respect to all indicators considered for this evaluation.

The average water conveyance efficiency of the main canal 75.45% in which the values of conveyance efficiency varied from the head to the tail section of the canal. Similar to the main canal the conveyance efficiency of the secondary canal considered were varied from the head to the tail section, but the average values were 60.23, 82.44 and 70.4% from secondary canal one, two and three, respectively. The conveyance efficiency of those canals was poor, good, and fair for secondary canal one, two and three respectively, according to the FAO irrigation and drainage paper 33 recommendations for surface irrigation.

The water delivery performance was fair as compared to the maintenance performance indicators in the secondary canals. But the overall performance of the main canal of the irrigation scheme was poor, which requires a serious amendment of the structural and managerial activities. The adequacy, performance indicators in three secondary canals were fair at the head section of the canals, but poor at the tail reach of the canal. In the case of equity performance, throughout canal reaches it was fair and the dependability indicators in all secondary canals considered in all sections showed that it was good.

The overall maintenance performance indicators in the irrigation scheme were poorone of the reason that aggravates scouring and sedimentation occurred was due to the damaged initially installed geo membrane which increasing the possibility of canal bank collapsing and difficult for maintenance of the canal.
The sustainability of the irrigation scheme was at a critical level in which 71% of the overall irrigation designed is not currently irrigated. In the other hand, this leads to less benefit from the expected output of the irrigation. Finally, many gaps which lead to the low performance of the irrigation scheme was identified and require correction accordingly. If the remedial action is not taken after some time the irrigation scheme may become more deteriorated due to the factors that identified as the performance gap in this study.

5.2. Recommendation

Based on the results of the current study on the conveyance performance evaluation of the Kesem irrigation scheme, the following recommendations are forward to improve the overall performance of the scheme.

- Supply of irrigation water should be improved by continuous maintenance of main and secondary canals to keep them free from plant leaves, debris, sedimentation throwing into the canal, and construct canal bank protection.
- Appropriate irrigation water management should be adopted to reduce the conveyance water loss during the irrigation processes.
- Water losses are comparatively more in earthen canals; efforts should be made to Re-install the geo- membrane liner in both main and secondary canals to improve canal conveyance efficiency.
- A considerable number of sluice gates at the off take were not functional and are not effective yet. and now needs sustainable solution through provide proper maintenance to improve the performance of the irrigation scheme.
- In accordance with government policy the project has to be sustainable irrigable land which could be explained by the expansion of irrigated areas in this site from what has been designed initially.
- Finally, it is recommended that addition study should be undertaken for wider period that may covers at least one growing period of the crop. Sugarcane is the mono crop produced by this irrigation scheme and it takes more time be harvested, which is not easily managed with such like short time study.

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APPENDIXES

Appendix Table: 4.1: Reference evapotranspiration of the study area for each month of a year (CROPWAT 8.0 model) Mean value of 25 years (1994– 2018)

Station: Kesem Altitude: 785m Latitude: 9.7^{0}N Longitude: 39.9^{0}E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	15.4	31.6	56	153	7.8	18.9	4.54
February	16.7	33.9	50	166	8.4	21.0	5.38
March	19.5	35.3	51	179	7.8	21.3	5.84
April	20.5	36.3	51	183	7.6	21.2	6.05
May	21.2	37.7	46	192	7.6	20.8	6.40
June	23.3	38.3	43	235	7.9	20.8	7.16
July	21.4	35.0	57	293	6.8	19.3	6.40
August	20.9	33.5	60	220	5.7	18.1	5.33
September	20.8	34.5	56	184	5.8	18.2	5.35
October	17.8	34.1	51	138	6.9	19.0	5.05
November	15.5	32.6	52	129	7.9	19.3	4.66
December	14.5	31.5	53	133	7.6	18.1	4.32
Average	18.9	34.5	52	184	7.3	19.7	5.54

Appendix Table: 4.2: Crop water requirement of the study area for each growth stages

Month	ETo (mm/day)	ETc (mm/day)			
		0 to 3	3 to 6	6 to 12	Above 12
January	4.54	3.06	4.31	4.65	3.18
February	5.38	3.63	5.11	5.51	3.77
March	5.84	3.94	5.55	5.99	4.09
April	6.05	4.08	5.75	6.2	4.24
May	6.4	4.32	6.08	6.56	4.48
June	7.16	4.83	6.8	7.34	5.01
July	6.4	4.32	6.08	6.56	4.48
August	5.33	3.6	5.06	5.46	3.73
September	5.35	3.61	5.08	5.48	3.75
October	5.05	3.41	4.8	5.18	3.54
November	4.66	3.15	4.43	4.78	3.26
December	4.32	2.92	4.1	4.43	3.02
Average	5.54	3.74	5.26	5.68	3.88

Appendixes Table 4.3 Measured discharge data of the main canal for the month of October

Initial point (m)	**Width (m)**	**Depth (m)**	**Revolution**	**Time(sec)**	**velocity (m/s)**	**Area (m2)**	**Discharge (m3/sec)**
0.00	0.4						
0.80	0.4	0.5	15	46	0.225	0.2	0.045
1.20	0.4	0.59	20	44	0.311	0.236	0.073396
1.60	0.4	0.6	40	46	0.59	0.24	0.1416
2.00	0.4	0.95	50	47	0.72	0.38	0.23351
			30	41	0.509		
2.40	0.4	1.37	20	52	0.264	0.548	0.303866
			50	40	0.845		
2.80	0.4	1.5	50	49	0.691	0.6	0.4548
			50	41	0.825	0	
3.20	0.4	1.53	40	42	0.645	0.612	0.438192
			50	43	0.787	0	
3.60	0.4	1.5	40	44	0.616	0.6	0.3696
			40	44	0.616	0	
4.00	0.4	1.47	30	43	0.447	0.588	0.2793
			40	54	0.503	0	
4.40	0.4	1.45	30	57	0.359	0.58	0.24476
			30	42	0.485	0	
4.8	0.4	0.6	30	42	0.485	0.24	0.1164
5.2	0.4	0.6	30	47	0.434	0.24	0.10416
5.6	0.4	0.5	25	44	0.387	0.2	0.0774
6	0.4	0.6	20	54	0.254	0.24	0.06096
6.4	0.4	0.56	7	43	0.115	0.224	0.02576
							2.97

Appendixes Table 4.4 Measured discharge data of the main canal for the month of November

Initial point (m)	Width (m)	Depth (m)	Revolution	Time(sec)	velocity (m/s)	Area (m2)	Discharge (m3/sec)
0.00	0.4						
0.80	0.4	0.5	20	40	0.341	0.2	0.0682
1.20	0.4	0.59	25	40	0.425	0.236	0.1003
1.60	0.4	0.6	30	40	0.509	0.24	0.12216
2.00	0.4	0.95	40	40	0.677	0.38	0.25726
			50	40	0.845		0
2.40	0.4	1.37	40	45	0.616	0.548	0.337568
			50	40	0.845		0
2.80	0.4	1.5	50	40	0.845	0.6	0.507
			50	41	0.825	0	0
3.20	0.4	1.53	60	45	0.922	0.612	0.564264
			50	42	0.805	0	0
3.60	0.4	1.5	40	44	0.631	0.6	0.3786
			40	45	0.616	0	0
4.00	0.4	1.47	30	43	0.485	0.588	0.28518
			40	54	0.503	0	0
4.40	0.4	1.45	30	57	0.359	0.58	0.20822
			30	42	0.485	0	0
4.8	0.4	0.6	30	42	0.485	0.24	0.1164
5.2	0.4	0.6	30	47	0.434	0.24	0.10416
5.6	0.4	0.5	25	44	0.396	0.2	0.0792
6	0.4	0.6	20	54	0.254	0.24	0.06096
6.4	0.4	0.56	10	45	0.155	0.224	0.03472
							3.22

Appendixes Table 4.5 Measured discharge data of the main canal for the month of December

Initial point (m)	Width (m)	Depth (m)	Revolution	Time(sec)	velocity (m/s)	Area (m2)	Discharge (m3/sec)
0.00	0.4						
0.80	0.4	0.5	15	40	0.257	0.2	0.0514
1.20	0.4	0.59	20	42	0.335	0.236	0.07906
1.60	0.4	0.6	20	40	0.341	0.24	0.08184
2.00	0.4	0.95	40	40	0.677	0.38	0.25726
			40	45	0.616		0
2.40	0.4	1.37	50	45	0.752	0.548	0.412096
			50	48	0.705		0
2.80	0.4	1.5	50	40	0.845	0.6	0.507
			50	41	0.825	0	0
3.20	0.4	1.53	50	40	0.845	0.612	0.51714
			50	42	0.965	0	0
3.60	0.4	1.5	50	40	0.845	0.6	0.507
			50	45	0.752	0	0
4.00	0.4	1.47	50	48	0.72	0.588	0.42336
			50	45	0.736	0	0
4.40	0.4	1.45	40	40	0.677	0.58	0.39266
			40	45	0.616	0	0
4.8	0.4	0.6	15	40	0.257	0.24	0.06168
5.2	0.4	0.6	15	42	0.245	0.24	0.0588
5.6	0.4	0.5	10	45	0.155	0.2	0.031
6	0.4	0.6	10	45	0.155	0.24	0.0372
6.4	0.4	0.56	7	47	0.115	0.224	0.02576
							3.44

Appendixes Table 4.6 Measured discharge data of the main canal for the month of January

Initial point (m)	Width (m)	Depth (m)	Revolution	Time(sec)	velocity (m/s)	Area (m2)	Discharge (m3/sec)
0.00	0.4						
0.80	0.4	0.5	25	42	0.425	0.2	0.085
1.20	0.4	0.59	30	40	0.509	0.236	0.120124
1.60	0.4	0.6	40	40	0.677	0.24	0.16248
2.00	0.4	0.95	50	40	0.845	0.38	0.3211
			40	40	0.677		0
2.40	0.4	1.37	50	45	0.769	0.548	0.421412
			50	40	0.845		0
2.80	0.4	1.5	60	40	1.013	0.6	0.6078
			50	40	0.845	0	0
3.20	0.4	1.53	50	40	0.845	0.612	0.51714
			50	40	0.845	0	0
3.60	0.4	1.5	60	40	1.013	0.6	0.6078
			40	45	0.616	0	0
4.00	0.4	1.48	40	40	0.677	0.592	0.400784
			40	45	0.616	0	0
4.40	0.4	1.45	40	40	0.677	0.58	0.39266
			40	41	0.661	0	0
4.8	0.4	0.62	40	40	0.677	0.248	0.167896
5.2	0.4	0.62	30	40	0.509	0.248	0.126232
5.6	0.4	0.6	30	40	0.509	0.24	0.12216
6	0.4	0.6	30	45	0.464	0.24	0.11136
6.4	0.4	0.58	25	40	0.425	0.232	0.0986
							4.26

Appendixes Table 4.7 Measured discharge data of the main canal for the month of October at 300m

Initial point (m)	**Width (m)**	**Depth (m)**	**Revolution**	**Time(sec)**	**velocity (m/s)**	**Area (m2)**	**Discharge (m3/sec)**
0.00	0.4						
0.80	0.4	0.5	15	40	0.257	0.2	0.0514
1.20	0.4	0.59	20	45	0.304	0.236	0.071744
1.60	0.4	0.6	30	47	0.434	0.24	0.10416
2.00	0.4	0.95	35	45	0.603	0.38	0.21128
			30	40	0.509		
2.40	0.4	1.2	40	40	0.677	0.48	0.26616
			40	45	0.603		
2.80	0.4	1.33	50	40	0.845	0.532	0.403256
			40	46	0.603	0	
3.20	0.4	1.6	50	40	0.845	0.64	0.45824
			50	43	0.787	0	
3.60	0.4	1.45	40	44	0.616	0.58	0.35728
			40	45	0.603	0	
4.00	0.4	1.2	30	43	0.474	0.48	0.228
			40	48	0.577	0	
4.40	0.4	1.4	30	41	0.497	0.56	0.26908
			30	44	0.464	0	
4.8	0.4	0.6	30	47	0.444	0.24	0.10656
5.2	0.4	0.6	30	47	0.444	0.24	0.10656
5.6	0.4	0.5	25	44	0.387	0.2	0.0774
6	0.4	0.6	20	40	0.341	0.24	0.08184
6.4	0.4	0.56	15	40	0.257	0.224	0.057568
							2.85

Appendixes Table 4.8 Measured discharge data of the main canal for the month of November at 300m

Initial point (m)	Width (m)	Depth (m)	Revolution	Time(sec)	velocity (m/s)	Area (m2)	Discharge (m3/sec)
0.00	0.4						
0.80	0.4	0.5	15	40	0.257	0.2	0.0514
1.20	0.4	0.6	20	45	0.311	0.24	0.07464
1.60	0.4	0.6	30	40	0.509	0.24	0.12216
2.00	0.4	1.2	40	40	0.677	0.48	0.32496
			40	45	0.603		0
2.40	0.4	1.3	50	45	0.769	0.52	0.39988
			50	44	0.769		0
2.80	0.4	1.35	50	40	0.845	0.54	0.4563
			50	43	0.787	0	0
3.20	0.4	1.4	50	40	0.845	0.56	0.4732
			50	40	0.845	0	0
3.60	0.4	1.4	50	40	0.845	0.56	0.4732
			40	40	0.677	0	0
4.00	0.4	1.3	50	45	0.752	0.52	0.39104
			50	45	0.752	0	0
4.40	0.4	1.2	30	40	0.509	0.48	0.24432
			30	40	0.509	0	0
4.8	0.4	0.6	15	40	0.257	0.24	0.06168
5.2	0.4	0.6	10	40	0.173	0.24	0.04152
							3.11

Appendixes Table 4.9 Measured discharge data of the main canal for the month of December at 300m

Initial point (m)	Width (m)	Depth (m)	Revolution	Time(sec)	velocity (m/s)	Area (m2)	Discharge (m3/sec)
0.00	0.4						
0.80	0.4	0.5	20	40	0.257	0.2	0.0514
1.20	0.4	0.6	25	45	0.425	0.24	0.102
1.60	0.4	0.6	30	40	0.509	0.24	0.12216
2.00	0.4	1.35	40	40	0.677	0.54	0.36558
			40	45	0.603		0
2.40	0.4	1.5	50	45	0.752	0.6	0.4512
			50	44	0.769		0
2.80	0.4	1.5	50	40	0.845	0.6	0.507
			50	45	0.752	0	0
3.20	0.4	1.44	50	40	0.845	0.576	0.48672
			50	45	0.752	0	0
3.60	0.4	1.09	50	40	0.845	0.436	0.36842
			40	44	0.616	0	0
4.00	0.4	1.35	50	40	0.845	0.54	0.4563
			50	43	0.787	0	0
4.40	0.4	1.12	30	45	0.453	0.448	0.202944
			30	42	0.485	0	0
4.8	0.4	0.6	10	40	0.173	0.24	0.04152
5.2	0.4	0.6	7	40	0.123	0.24	0.02952
							3.18

Appendixes Table 4.10 Measured discharge data of the main canal for the month of January a

Initial point (m)	Width (m)	Depth (m)	Revolution	Time(sec)	velocity (m/s)	Area (m2)	Discharge (m3/sec)
0.00	0.4						
0.80	0.4	0.5	20	40	0.257	0.2	0.0514
1.20	0.4	0.6	30	45	0.453	0.24	0.10872
1.60	0.4	0.6	30	40	0.509	0.24	0.12216
2.00	0.4	1.45	40	40	0.677	0.58	0.39266
			40	45	0.603		0
2.40	0.4	1.51	50	45	0.752	0.604	0.454208
			50	44	0.769		0
2.80	0.4	1.63	50	40	0.845	0.652	0.55094
			50	46	0.736	0	0
3.20	0.4	1.65	50	40	0.845	0.66	0.5577
			50	45	0.752	0	0
3.60	0.4	1.68	50	40	0.845	0.672	0.56784
			50	48	0.705	0	0
4.00	0.4	1.68	60	40	1.013	0.672	0.680736
			50	40	0.845	0	0
4.40	0.4	1.5	40	45	0.603	0.6	0.3618
			40	40	0.677	0	0
4.8	0.4	0.6	15	40	0.257	0.24	0.06168
5.2	0.4	0.6	15	45	0.229	0.24	0.05496
5.6	0.4	0.6	10	40	0.173	0.24	0.04152
6	0.4	0.6	10	40	0.173	0.24	0.04152
6.4	0.4	0.6	7	44	0.123	0.24	0.02952
							4.08

300m

Appendixes Table 4.11 Measured discharge data of the main canal for the month of October at 600m

Initial point (m)	Width (m)	Depth (m)	Revolution	Time(sec)	velocity (m/s)	Area (m2)	Discharge (m3/sec)
0.00	0.4						
0.80	0.4	0.5	15	40	0.257	0.2	0.0514
1.20	0.4	0.5	25	45	0.379	0.2	0.0758
1.60	0.4	0.6	25	40	0.425	0.24	0.102
2.00	0.4	0.8	30	40	0.509	0.32	0.16288
			30	42	0.509		
2.40	0.4	1.2	40	40	0.677	0.48	0.26616
			40	44	0.616		
2.80	0.4	1.5	50	40	0.845	0.6	0.4548
			50	45	0.752	0	
3.20	0.4	1.45	50	42	0.805	0.58	0.41528
			50	45	0.752	0	
3.60	0.4	1.45	40	43	0.631	0.58	0.35728
			40	45	0.603	0	
4.00	0.4	1.4	40	45	0.603	0.56	0.266
			40	48	0.565	0	
4.40	0.4	1.32	40	41	0.661	0.528	0.337128
			40	44	0.616	0	
4.8	0.4	0.6	30	45	0.453	0.24	0.10872
5.2	0.4	0.6	30	50	0.409	0.24	0.09816
5.6	0.4	0.5	25	45	0.379	0.2	0.0758
							2.77

Appendixes Table 4. 12 Measured discharge data of the main canal for the month of November at 600m

Initial point (m)	Width (m)	Depth (m)	Revolution	Time(sec)	velocity (m/s)	Area (m2)	Discharge (m3/sec)
0.00	0.4						
0.80	0.4	0.5	15	40	0.257	0.2	0.0514
1.20	0.4	0.5	25	45	0.379	0.2	0.0758
1.60	0.4	0.6	30	40	0.509	0.24	0.12216
2.00	0.4	0.8	30	40	0.509	0.32	0.16288
			30	42	0.509		
2.40	0.4	1.2	50	40	0.845	0.48	0.26616
			50	44	0.769		
2.80	0.4	1.5	50	40	0.845	0.6	0.4548
			50	45	0.752	0	
3.20	0.4	1.45	60	40	1.013	0.58	0.41528
			60	45	0.901	0	
3.60	0.4	1.45	60	40	1.03	0.58	0.35728
			60	45	0.901	0	
4.00	0.4	1.4	50	45	0.752	0.56	0.266
			50	48	0.705	0	
4.40	0.4	1.32	40	40	0.661	0.528	0.353232
			40	44	0.677	0	
4.8	0.4	0.6	30	40	0.474	0.24	0.11376
5.2	0.4	0.6	30	45	0.453	0.24	0.10872
5.6	0.4	0.5	25	45	0.379	0.2	0.0758
							2.82

Appendixes Table 4.13 Measured discharge data of the main canal for the month of December at 600m

Initial point (m)	Width (m)	Depth (m)	Revolution	Time(sec)	velocity (m/s)	Area (m2)	Discharge (m3/sec)
0.00	0.4						
0.80	0.4	0.5	10	45	0.155	0.2	0.031
1.20	0.4	0.59	15	40	0.257	0.236	0.060652
1.60	0.4	0.6	20	45	0.304	0.24	0.07296
2.00	0.4	0.95	25	50	0.345	0.38	0.14402
			25	55	0.379		
2.40	0.4	1.37	30	45	0.317	0.548	0.292632
			30	47	0.434		
2.80	0.4	1.5	40	55	0.503	0.6	0.4449
			40	58	0.477	0	
3.20	0.4	1.53	40	45	0.603	0.612	0.541926
			40	48	0.565	0	
3.60	0.4	1.5	40	57	0.477	0.6	0.4245
			40	60	0.461	0	
4.00	0.4	1.47	40	55	0.503	0.49	0.363335
			40	57	0.477	0	
4.40	0.4	1.45	30	40	0.509	0.58	0.42659
			30	45	0.453	0	
4.8	0.4	0.6	15	40	0.257	0.24	0.06168
5.2	0.4	0.6	10	40	0.173	0.24	0.04152
5.6	0.4	0.5	7	40	0.123	0.2	0.0246
							2.93

Appendixes Table 1.14 Measured discharge data of the main canal for the month of January at 600m

Initial point (m)	Width (m)	Depth (m)	Revolution	Time(sec)	velocity (m/s)	Area (m2)	Discharge (m3/sec)
0.00	0.4						
0.80	0.4	0.5	15	45	0.229	0.2	0.0458
1.20	0.4	0.59	20	40	0.341	0.236	0.080476
1.60	0.4	0.6	25	45	0.379	0.24	0.09096
2.00	0.4	0.95	30	45	0.453	0.38	0.18886
			30	41	0.497		
2.40	0.4	1.37	40	40	0.677	0.548	0.553206
			40	42	0.665		
2.80	0.4	1.5	50	48	0.59	0.6	0.5613
			50	50	0.691	0	
3.20	0.4	1.53	40	40	0.677	0.612	0.60741
			40	43	0.631	0	
3.60	0.4	1.5	40	45	0.603	0.6	0.5349
			40	48	0.577	0	
4.00	0.4	1.47	40	48	0.577	0.56	0.47516
			40	51	0.543	0	
4.40	0.4	1.45	30	40	0.509	0.58	0.43587
			30	42	0.485	0	
4.8	0.4	0.6	20	45	0.304	0.24	0.07296
5.2	0.4	0.6	15	47	0.229	0.24	0.05496
5.6	0.4	0.5	10	44	0.158	0.2	0.0316
							3.73

Figure 1.1: Main, Secondary and Tertiary canal respectively

Figure 1.2: Main Canal

Figure 1.3: Secondary and main canal flow control point