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Hydraulic Performance Evaluation of Diversion Weir and Canal Structures: Case Study of Basaka Small Scale Irrigation Scheme, Wayu Tuka, East Wallaga, Oromia, Ethiopia

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Abstract: Hydraulic Performance evaluation of the irrigation system is important to conserve scarce water resources by improving the performance of the existing irrigation structure. However, there was no study in the past performance evaluation of the Basaka scheme, which is used for irrigation purposes. This study was to evaluate the hydraulic performance of the diversion weir and the canal structures by using hydraulic performance indicators, conveyance indicators, and maintenance indicators. The primary data collected were direct field measurements in the canals and direct field observations of function & mal-function structures. The secondary data was also taken from the designed document scheme and the journals. The study was carried out during the one irrigation season from February to April 2023. The data collected was analyzed using empirical equations. A diversion weir structure is unsafe for the passage of high floods because the discharge capacity of the weir (227.8m^3/s) is relatively lower than the peak design discharge (234m^3/s) that is generated from catchment areas. The current intake gate water withdrawal to the main canal was 97%. The discharge measurement was performed at three measuring stations at the head, middle, and tail on the main and secondary canals respectively by using the area-velocity method. Also, the velocity of discharge flow through both canals was examined by using floating material (tennis ball). The causes of malfunctioning structures were investigated through field observation. And also, there is a sedimentation problem in the diversion weir due to the under-sluice gate structure is not constructed at diversion head-work, whereas seepage problems in the main and secondary canals due to the many parts of the canals are unlined. The overall average main and secondary canal's conveyance efficiency was 57% & 59%, and water conveyance loss was 43% and 41% respectively, which is below recommended values. This conveyance efficiency is reduced due to breakage occurring on the main canal, seepage, siltation and vegetation growth within the canal interfere. The maintenance indicators investigation of the scheme was examined. This means that; the value of the effectiveness of infrastructure was 58%, the sustainability of the irrigated area was 71%, the delivery duration ratio was 200%, and the water surface elevation ratio (58% for MC and 62% for SC) respectively. Based on the results of the maintenance and conveyance indicators, Basaka small irrigation scheme requires a high level of maintenance.

Keywords: Hydraulic Performance, Maintenance Indicators, Conveyance Indicators

1. Introduction

Irrigation is the artificial application of water to the soil to provide an environment that is optimized for crop production. Irrigation enhances access to nutritious food, generates job prospects, enhances upkeep, and brings about good health in a nation [1]. One of the best ways to consider reliable and sustainable food security is to expand the new irrigation development. Population growth with higher agricultural intensities, increased calculation of the various sectors for water allocation and environmental concerns put pressure on water resources [2]. Irrigation expansion is a crucial instrument to stimulate economic expansion and rural progress, and it is regarded as a foundation of food safety and alleviation of poverty in Ethiopia. Irrigation is one method through which agricultural output can be enhanced to fulfill the increasing food requirements in the country [3]. Currently, the government has undertaken the development of several new irrigation projects to improve coverage. But there is less focus on improving the performance of existing irrigation systems [4].

Performance is gauged through the use of indicators, which are numerical representations of the degree of attainment of an irrigation system objective [5].

The performance of many irrigation systems is significantly below their potential due to several limitations including poor design, construction, operation, maintenance, and ineffective water control and measurement structure installation [6]. In many of these schemes, water management activities are achieved by the farmers themselves, however, they lack technical expertise to manage their water effectively. The lack of water management makes implementation and monitoring of irrigation efficiencies difficult and inadequate [7]. The deprived performance of the small scale irrigation schemes that existed in Ethiopia; however frequent assessment is not common, and also resource management challenges are often observed in small-scale irrigation system [8].

The evaluation of the irrigation system has been conducted for various objectives, such as comprehending the efficiency of irrigation and overall irrigation patterns, as well as contrasting the effectiveness of one irrigation scheme with another [9].

Basaka small-scale irrigation scheme is one of the modern small-scale irrigation projects in Ethiopia which is developed by government investment. The sustainability of the Basaka irrigation scheme is questionable due to diversion weir and canal structures affected by many problems during field visits. And also, the problems of malfunctioning structures those reduce the performance of the scheme, the illegality of abstraction water, conveyance system, maintenance and poor management of the scheme during the field study. Therefore, the aim of this study was to evaluate the current hydraulic performance of the Basaka diversion weir and canal structures using different indicators.

2. Materials and Methods

2.1. Location and Description of the Study Area

The study was conducted at Basaka small-scale irrigation scheme which is located in Gida Basaka Kebele, Wayu Tuka Woreda, East Wallaga zone, Oromia region, Ethiopia.

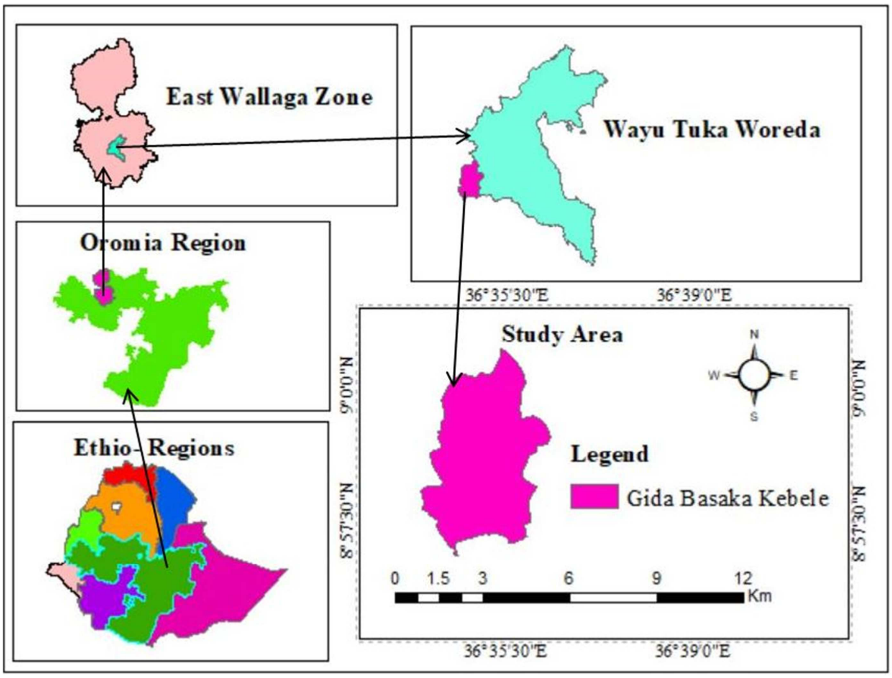

Figure 1. *Location map of the study area.*

Wayu Tuka woreda is located about 324km from West of Finfinnee (Addis Ababa city) at maximum and minimum altitudes of 2200m and 1700m a.m.s.l respectively. The geographical location of the study area is sited at latitude 8°57′30"N to 9°0′0"N and longitude of 36°35′30" E to 36°39′ 0" E as shown in Figure 1.

2.2. General Description of the Scheme

This scheme was constructed on the Basaka main River in 1990 E. C. for 281 beneficiaries. This weir is a broad crest concrete weir type with a vertical upstream wall and 14.5m elongated. The catchment area is 58km^2 and the plan was designed for a command area of 60 ha and currently uses 42.45 ha of command area (Source: Own survey February, March, and April 2023). This scheme contains one main canal & one secondary canal. The main canal has a 4km length out of this 1.2km lined masonry trapezoidal and rectangular concrete canal and 2.8km unlined trapezoidal section. Also, the secondary canal has a 1.8km length and all of them are unlined trapezoidal sections.

2.3. Data Collection

The data were collected from two sources, which are primary and secondary data sources.

2.3.1. Primary Data

The primary data were collected by direct field observations and field measurements in the field. This activity including concerning the functionality and non-functionality of structures, deposition of sediment in head-work, and siltation problems in the main & secondary canal, measuring discharge through the river, and canal by using the area-velocity method, measuring water surface elevation at the canals by using a tape meter, and determination of discharge through the intake pipe of the canals by numerical formula and other relevant data were observed in the field survey of this irrigation scheme.

2.3.2. Secondary Data Collection

The secondary data were collected from the East Wallaga zone irrigation development office for the design document report of the Basaka irrigation project and different journals.

2.4. Materials and Soft Wares Used

Materials and soft wares used during this study, Smartphone camera: to take photos of the constructed structure, Stopwatch: to know the time taken by a tennis ball to reach the second marked point, Tennis ball: this is used to determine the velocity of discharge passing in the canals, Tape meter: used to measure the wetted depth and wetted width of canal structures, Basaka design document: to collect required data relating to discharge flow & structure dimension, ArcGIS10.8: was used to a delineate location map of the study area, and Excel software: to use the estimation of mathematical equations.

2.5. Discharge Flow Measurements

In this study, the area-velocity method was used for measuring discharge flow through the canals which is used for agricultural activity [10]. The discharge measurement was conducted at three different positions (head position, middle position, and tail position) of the distribution canals. Floating material (tennis ball) was put on the upper end of the canal section and the time it took to reach the marked section of the same canals was registered. This floating material aims to determine discharge velocity through the canal. This test was replicated three times and the average time it took was taken to calculate the discharges. The cross-sectional area of the canal was also estimated by measuring the average depth of water and the width of water in the canal section by using a tape meter. The times at which the tennis ball passes each section was observed by stopwatch.

$$A = b*h \tag{1}$$

Where A: is the area of the wetted canal (m^2), b: is the top wetted width of the canal (m), and h: is the depth of water in the canal (m).

The average flow velocity, V (m/s) was calculated as

$$V = \frac{L}{T} \tag{2}$$

Where L: is the length of the canal but it must be straight and flow laminar (for this study take 15m at each section), and T is the time taken for the floating material (tennis ball) to reach the end section.

Since the measurement was taken at the surface due to the external factors that affect the tennis ball like wind and wave action, a correction factor 0.85 was taken for safety factors, and finally, the flow rate, Q (m^3/s) in that canals was calculated by using equation 3 below:

$$Q = 0.85*V*A \tag{3}$$

Figure 2. *Discharge measurement by area-velocity method.*

2.6. Water Surface Elevation Measurement

Water surface elevation of the main and secondary canal was measured in the reaches at the head, middle, and tail [6]. The current water surface depth from the canals bottom was measured by using a tape meter in 100m intervals.

The first measurement of current WSE data was taken from 40 measuring stations sub-divided into three segments with a 4km length of the main canal.

The second measurement of current WSE data was taken from 18 measuring stations sub-divided into three segments with a 1.8km length of the secondary canal at an interval of 100m. Generally, current WSE data were taken on 40 and 18 review stations along the main and secondary respectively at head, middle, and tail reaches.

Figure 3. *Water surface elevation measurement.*

2.7. Hydraulic Performance Analysis of the Basaka Diversion Weir

2.7.1. Passage of Sediment

Sand particles start moving when the force of flowing water exceeds the limit of attractive force. The design has to allow free movements of the bed-load materials through sluiceways so that there may not be any damage caused to the head-work structures. In the Basaka diversion weir upstream reservoir there is sedimentation from construction time up to now. Due to this; there is a change or rise in elevation of the river bed or approaching channel and canal head regulators due to sediment accumulation were determined by measuring the existing elevation of the structures using leveling or tape meter as shown in Figure 4, and designed elevation from design document of the scheme [5].

Figure 4. *Current measurement of sediment accumulation.*

2.7.2. Passage of Flood Capacity

The capacity for passage of peak flood of the diversion weir has been done using equation 4 which is recommended by [11]. The equation can be represented as:

$$Q = Cd*(L-Kn*He)*He^{1.5} \tag{4}$$

Where:-

Q = Discharge over the weir

Cd = Coefficient of discharge for broad crest

He = is total head over the weir (m) including velocity head

n = Number of end contractions (twice the number of gated bays)

L = Net length of the weir (m)

K = Coefficient of end contraction ≈ 0.1

2.7.3. Water Withdrawal Evaluation

The performance of the withdrawal of water through the head regulator has been done using a submerged orifice flow equation, which describes the rate of flow of liquid through an orifice. Field measurements of the existing opening sectional area of intake structures and water driving head (depth of water in the intake pipe) have been done and equation (5) recommended by was used to calculate the current water withdrawal capacity of the intake of the main canal and secondary canal structures.

$$Q = Cd*A*\sqrt{2gh} \tag{5}$$

Where,

Q = Flow rate (m^{3}/s)

Cd = Coefficient of discharge (0.62)

A = Area of orifice (m^2)

g = Acceleration from gravity (9.81 m/s^2)

h = Current water depth in the intake pipe (m)

2.8. Conveyance Indicators Analysis of the Canal Structure

2.8.1. Canal Conveyance Efficiency

Conveyance efficiency is normally the amount of water to be delivered to the field, which depends on the characteristics of the canal. In the process of transporting water from the source to the farmland, there is water loss through evaporation, transpiration, percolation, and spills. For the determination of conveyance efficiency in the main and secondary canal area-velocity method was used. Floater (tennis ball) was used and the time taken to travel 15m canal length was recorded using a stopwatch. CE is assessed by measuring the inflow and outflow of selected canal reaches and calculated using equation (6) recommended by [12]. Therefore, the CE is calculated as;

$$CE = \frac{Qout}{Qin} * 100\% \tag{6}$$

Where CE - is the conveyance efficiency expressed as a percentage [%], Q_{in} - is the total water flowing into a specific section of the canal (m^3/s), and Q_{out} - is the total water flowing out of a specific section of the canal (m^3/s).

2.8.2. Canal Conveyance Loss

It measures the efficiency of the canal system during conveying water by losing water over a given travel distance. A water conveyance loss ratio can be calculated for each section of the main & secondary canal using equation (7) recommended by [13]. Therefore, the CL is calculated as;

$$CL = \frac{(Q_{in} - Q_{out})}{Q_{in}} * 100\% \quad (7)$$

Where CL - is the water conveyance loss expressed as a percentage [%], and Q_{in} & Q_{out} - is the total water flowing into and out of a specific section of the canal (m^3/s).

2.9. Maintenance Indicators Analysis of the Basaka Scheme

The maintenance performance measure allows for identifying performance gaps between current and desired performance and provides an indication of progress toward closing the gaps [14]. The purposes 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 [15]. The hydraulic performance of the scheme was evaluated with maintenance performance indicators; the performance was estimated through the indicators recommended by [14].

2.9.1. Effectiveness of Infrastructure

The study was focused on all components of the diversion head-work and canal structures. The effectiveness of infrastructure is computing by the ratio of the number of functioning structures to the total number of structures initially installed. If so, the deviation of the computed result of the effectiveness of infrastructures of more than 5% would signal the need for maintenance or rehabilitation of flow control structures [15]. The effectiveness of infrastructure (EI) can be calculated as:

$$EI = \frac{\text{Number of functioning structures}}{\text{Total number of structures initially installed}} \quad (8)$$

According to [16] cited by [14] the effectiveness of infrastructure determine based on the following conditions:

1) If EI > 5%, the need for maintenance or rehabilitation of the physical structures
2) If SIA < 5%, there is no need for maintenance or rehabilitation of the physical structures

2.9.2. Water Surface Elevation Ratio

The water surface elevation ratio (WSER) is an important indicator that aims at assessing the impact of sedimentation and erosion problems on the main and secondary canal of the irrigation scheme [14]. The water surface elevation ratio (WSER) can be calculated as:

$$WSER = \frac{\text{Current water surface elevation at FSL}}{\text{Required water surface elevation at FSL}} \quad (9)$$

According to [16] cited by [17] the water surface elevation ratio determine based on the following conditions:

1) If WSER = 1, shows that the canals are in good working condition;
2) If WSER > 1, indicates that there is an erosion problem in the canals;
3) If WSER <1, indicates that there is a deposition problem in the canals;

2.9.3. Sustainability of Irrigated Area

The sustainability of irrigated areas is the ratio of the current irrigated area to the initially irrigated area when designed [6]. The sustainability of irrigated area (SIA) can be calculated as:

$$SIA = \frac{\text{Current irrigated area}}{\text{Required irrigated area}} \quad (10)$$

According to [16] cited by [17] the sustainability of irrigated area determine based on the following conditions:

1) If the value of SIA = 1, indicates the irrigated area is at its design state;
2) If SIA > 1, improvement in conveyance and distribution system is required to irrigated the expanded command area;
3) If SIA < 1, then the irrigated area is reduced as compared to the area to be irrigated when designed therefore, rehabilitation or repair is required for the scheme

2.9.4. Delivery Duration Ratio

This parameter is estimated as the ratio of the duration of current irrigation water delivered to the required duration of water delivery. The delivery duration ratio (DDR) can be calculated as:

$$DDR = \frac{\text{Current duration supply}}{\text{Required duration supply}} \quad (11)$$

According to [6] the delivery duration ratio determine based on the following conditions:

1) If current DDR < required DDR, showing the water distribution system is dependable and the system maintenance is sufficient
2) If current DDR > required DDR, showing the water distribution system is not dependable and the system maintenance is insufficient

3. Results and Discussions

3.1. Hydraulic Performance Analysis Result of Basaka Diversion Weir

3.1.1. Sediment Flash out Analysis Result

During field observation, the Basaka diversion weir was constructed without under sluice gate structure. Due to the lack of this structure, there is deposition of sedimentation in the upstream reservoir diversion weir. The result from the measured bed level of the river in the diversion weir and around the head regulator using a tape meter were presented in Table 1.

Table 1. *Prevalence of sediment analysis result.*

Changed river bed level due to silt deposited			
S/n	**Parameters**	**Units**	**Elevation**
1	Original ground level	m	1795
2	Weir crest level	m	1794.75
3	Constructed weir height	m	1.5
4	Original u/s river bed level	m	1793.25
5	Current u/s river bed level	m	1794

The result presented in Table 1 indicated that 0.75m height of the silt is deposited in the Basaka diversion head-work structure at the upstream reservoir. This is increasing the river bed level due to sedimentation. Sedimentation on this bed level comes from the catchment area and is stored in the upstream reservoir due to the lack of under sluice gate structure on this weir. Therefore, the weir height was reduced from 1.5m to 0.75m. This sediment deposited in the upstream reservoir causes the failure of the weir & clogging of intake gate water withdrawal after a few years and discontinuing the agricultural process.

3.1.2. Passage of Flood Analysis Result

The diversion head-work structures must be designed in a way that they will withstand the maximum flood occurrence is unquestionable because the unexpected maximum floods occurring in the area will cause danger to the structure.

But, currently, the components of the Basaka irrigation scheme diversion head-work structure have been found to perform under the design capacity in passages of the flood.

Table 2. *Performance capacity of flood passage.*

S/n	Parameters	Units	Intake
1	Discharge capacity of weir	m^3/s	227.8
2	Peak discharge	m^3/s	234

The result in Table 2 hydraulic performance analysis indicated that the discharge capacity of the weir is relatively lower than the peak discharge generated once in 50 years (i.e. $227.8m^3/s$ which is calculated by using equation (4) is less than peak discharge ($234m^3/s$) taken from design document. This result implies that this diversion weir structure is unsafe against the passage of high flood. Therefore, when designing a head-work structure it has to be considered the flood magnitude against which this structure was designed just to be safe. It can neither use a very high nor may a very low value because a very high value needs much more implementation cost and that very low-value causes damages to the structure [11].

3.1.3. Water Withdrawal Analysis Result

The canal head regulator should be designed to deliver at least river lean flow during the dry season to meet the demands of the command area through the intake gate.

The quantity of average required intake capacity of water withdrawal & current water withdrawal in three months (Feb-Mar-Apr) were presented in Table 3.

Table 3. *Water withdrawal performance analysis result.*

S/n	Parameters	Units	Intake
1	Required aver. water withdrawal	l/s	381
2	Current aver. water withdrawal	l/s	370

As indicated in Table 3 above, the intake gate withdrawal water to the main canal was 97% of the required amount of water from the Basaka diversion weir structure, which shows that it relatively to meet the required demand. On the other hand, the intake structure of main canal is existent on good performance in the case of current delivering water based on the required delivering water.

3.2. Hydraulic Performance Analysis Results of Basaka Scheme Canal Structure

3.2.1. Main Canal Conveyance Efficiency & Conveyance Loss

The conveyance efficiency of the system was computed using equation (6) by considering the total flow delivered by the conveyance system to the total inflow into the system. And also, water conveyance loss was calculated by using the equation (7). Therefore, the conveyance efficiency & conveyance loss of the unlined and lined main canal was computed based on the data represented in Table 4.

Table 4. *Conveyance efficiency & conveyance loss at canal.*

Inflow and outflow discharge in the main canal							
Distance	**m**	**750**	**1500**	**2250**	**3000**	**3750**	**4000**
Inflow	l/s	370	308	184	154	73	30
Outflow	l/s	308	184	154	73	30	8
CE	%	83	60	84	47	41	27
Ave. CE	%			57			
CL	%	17	40	16	53	59	73
Ave.CL	%	43					

Table 4 above shows that, the average conveyance efficiency and conveyance loss of both lined and unlined Basaka main canal was 57% ($0.171m^3/s$) & 43% ($0.129m^3/s$) respectively based on the distance of 750m at each section.

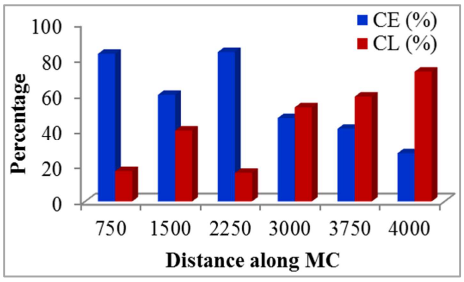

Figure 5. *Conveyance efficiency & conveyance loss at MC.*

Siltation, breakage of canal, seepage, evaporation, and vegetation growth within the canal interfere with water flow, reducing the conveyance efficiency of the main canal from the required discharge which is $0.3m^3/s$ as shown in Figure 5. According to the FAO guideline cited by [18], the indicative conveyance efficiency of adequately maintained earth canals with loam soils should be not less than 75%.

3.2.2. Secondary Canal Conveyance & Conveyance Loss

Table 5. *Conveyance efficiency & conveyance loss at canal.*

Inflow and outflow discharge in the secondary canal							
Distance	**m**	**300**	**600**	**900**	**1200**	**1500**	**1800**
Inflow	l/s	70	52	41	29	18	7
Outflow	l/s	52	41	29	18	7	2
CE	%	74	79	71	62	39	29
Aver.CE	%				59		
CL	%	26	21	29	38	61	71
Aver.CL	%	41					

Table 5 shows above the average conveyance efficiency and conveyance loss of all unlined Basaka secondary canals which are 59% (0.024m^3/s) & 41% (0.016m^3/s) respectively; based on the distance of 300m at each section.

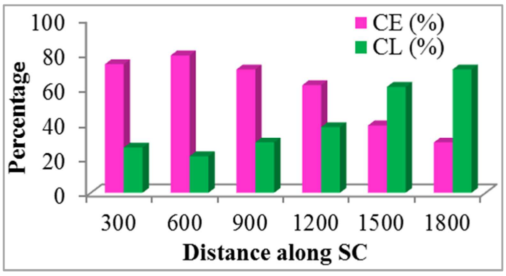

Figure 6. *Conveyance efficiency & conveyance loss at SC.*

Siltation, seepage, and vegetation growth within the canal interfere with water flow, reducing the conveyance efficiency of the secondary canal from the required discharge which is 0.04m^3/s as shown in Figure 6.

Generally, the amount of average water lost in the total measured length of main canal which is 4km was 60l/s (5184m^3/day), and secondary canal which is 1.8km was 11lit/s (950.4m^3/day). This showed that 43% and 41% the loss of water occurred in the main and secondary canals respectively as shown in Table 4 & 5 respectively. [13] About 10 to 15% of loss of water in the canal is accepted, when the result was compared to this, it not to be in the acceptable range. So, a large amount of water was lost, which could have irrigated more land. The problems of canal conveyance losses come from the occurrence of breakage of the canal, seepage through unlined canals, & climatic change.

3.3. Assessment of Maintenance Performance of the Basaka Scheme

3.3.1. Effectiveness of Infrastructures

Based on the layout design document & field study, the full measure of the scheme that had been, to begin with, built-in Basaka small-scale irrigation scheme become 31 as shown in Table 6; but 18 of the structures are presently practically giving service. Hence, the value of effectiveness infrastructure becomes 58% for the Basaka scheme. This value indicates that 42% of initially installed structures were non-functional and the physical irrigation infrastructure in this system has deteriorated over time. This result can be agreed with [14] which are 38.36% for Golina small-scale irrigation scheme, and [16] which 39.35% for Tahtay Tsalit small-scale irrigation scheme greater than 5%; a result renovation or rehabilitation for the infrastructures should be required.

Table 6. *Existing structures at Basaka irrigation scheme.*

Status of existing structures in number			
Total Installed	**Function**	**Mal-function**	**EI (%)**
31	18	13	58

Source: design document & current field visit in 2023 G.C.

3.3.2. Water Surface Elevation Ratio

This parameter is also called canal water level ratio, which is focused on different sections of the main canal and secondary canal. As per the design document shown in Table 7; the required water level depth in the main & secondary canals from the bottom was 0.8m & 0.5m at full supply level. The current average water surface elevation at full supply level was found to be 58% (0.46m) for main canal and 62% (0.31m) for secondary canal section by using equation (9) respectively. This shows a 42% and 38% of WSE at FSL was reduced from the required water depth of the main & secondary canal as shown in Table 7. Therefore, the average WSER through the head, middle, and tail reaches was less than one. In general, the main and secondary canal systems of the Basaka irrigation scheme did not have a maintenance schedule to remove sediment buildup and weed incidence.

Table 7. *Overall average WSER in the canals.*

Type of canal	Required	Current	WSER
	m	**m**	**%**
Main canal	0.8	0.46	58
Secondary canal	0.5	0.31	62

3.3.3. Sustainability of Irrigated Area

The sustainability of irrigated areas is used to show whether or not the command areas required for irrigation are adequately serviced. Despite the fact that the current irrigated area and required command area during the irrigation season were explained in Table 8, As a result, the SIA using equation (10) was 71%. The computed values of the sustainability irrigated area of the Basaka scheme were below one, which indicated that the current irrigated area was below the proposed values during the construction period of the irrigation scheme. The reduction of the Basaka command area was due to water scarcity and poor maintenance activity of the scheme.

Table 8. *Environmental sustainability of Basaka scheme.*

Basaka irrigation command area	Unit	Extent
Required irrigated area	ha	60
Current irrigated area	ha	42.45
Sustainability of irrigated area	%	71

3.3.4. Delivery Duration Ratio

Water delivery is neither timely nor reliable because the current duration of water delivery is extended as indicated in Table 9 due to the silting up of the canal system, malfunctioning of the control structure, defective of the main canal, and due to water shortages primarily for tail end beneficiaries. The DDR value was calculated by using equation (11), which is 200%. Due to this, the system needs further maintenance requirements.

Table 9. *Required & current delivery duration ratio of irrigation scheme.*

	Required	Current	DDR
	hr	**Hr**	**%**
Deliver duration	12	24	200

3.4. Identification of the Components of the Scheme That Reduce the Performance of the Basaka Irrigation Scheme

This research work problem identification of Basaka small-scale irrigation diversion head-work was carried out by the researcher through field visits and investigations made during the stay on the field. In conjunction with this, the problem identification made in this part will help for the next objectives as an input to deal with it and to elaborate it further aiding with numerical values. The problems which were observed practically on Basaka diversion head-work and canal structure components which reduced its performance have been discussed below. Those are:-

1) Lack of under-sluice gate structure
2) Occurrence of breakage at main canal
3) High seepage in the canal
4) Clogging of turnouts
5) Night storage problem

3.4.1. Lack of Under Sluice Gate Structure

In the case of Basaka diversion head-work, under sluices were not constructed because the river has sediment on my site observation accumulation of bolder and enhancing conflict between users of downstream and upstream of diversion head-work due to no water cannot pass to for downstream during winter season rather than a rainy season (during overflow) as shown in Figure 7. Due to the lack of under-sluice structure, it is difficult to remove the silt from this headwork without human power. Therefore, due to the improper design, this scheme is affected by a sedimentation problem that comes from the watershed area and is deposited in the reservoir of the diversion weir.

Figure 7. *Lack of under sluice gate.*

3.4.2. Occurrence of Breakage at the Main Canal

The main canal is a structure that served to transport water from the diversion head-work to the command area. Due to the rupture occurring around the intake structure and on other parts of the command area, it will reduce the efficiency of the scheme. The main cause of this breakage is the conflict between users who getting service from this river based on the required water for downstream. Now, users use this canal by maintaining locally available materials like soil, boulders, and other materials during farming activities year to year as indicated in Figure 8. But those farmers whose daily activity is depending on this agriculture are asked many times for maintenance to go to the Wayu Tuka woreda agriculture and development office. Still, now, there is no maintenance on this scheme.

Figure 8. *Breakage of the main canal.*

3.4.3. High Seepage in the Canal

Currently; there is a seepage problem in the main canal and secondary canal structures at the Basaka irrigation scheme. It is difficult to prevent leakage through the main and secondary canals because they are unlined earth canals as indicated in Figure 9. During this time, the researchers recommend that the canals be converted to lined canals for reducing seepage problems by participating both government and beneficiaries from the scheme. If this is difficult; another option is plastering this canal with clay soil before starting the agricultural activity.

Figure 9. *Highly seepage due to the unlined canal.*

3.4.4. Clogging of Turnouts

Turnout is the most quintessential phase of canal shape which is used for the divert water to the farming area. Due to this in the Basaka canals structure half of the constructed turnouts are no longer used for the motive they want for construction as indicated in Figure 10.

The scarcity of water occurs throughout the irrigation season and water level cannot attain the hole of turnout which passes water to the agricultural area. At this time half of the farmers use water from the canal by the method of making illegal turnout for serving water for the crops as indicated in Figure 10. But this method is after a few years destructive to this canal if immediately protection can't reach it.

Figure 10. *Clogging of turnout structure.*

3.4.5. Night Storage Problem

Night storage is a structure used to store water at night and release water for the users downstream of the command area for farming practices like upstream users' command area. But this structure due to the shortage of water the structure does not give the service for which constructed. The scarcity of water problem comes from breakage on the lined main canal around the outlet of the intake structure and seepage problems in the unlined main canal as shown in Figure 11.

The scarcity of water occurs only after the outlet of the intake structure. These indicate that water diverted from the river is to meet the demand of the command area. These issues decrease the performance of the Basaka diversion scheme. Therefore, to enhance the performance of the scheme must maintain the breakage lined-main canal with concrete or masonry and convert all parts of the unlined canal to the lined canal to minimize seepage through the canal totally by considering evaporation loss.

Figure 11. *Night storage problem due to scarcity of water.*

4. Conclusion

Based on the field study and observations Basaka diversion weir and canal structure faced unexpected serious problems and most of the components failed before the finished design period or to fulfill the function for which they were required. Diversion head-work sedimentation, clogged turnout, lack of under sluice gate, breakage at the main canal, breakage at head regulator valve, lack of trash rack, night storage problem, and breakage of pavement structure are some problems that happen at the Basaka irrigation scheme constructed for irrigation purpose.

The total discharge passage capacity of the existing overall waterway 227.8m^3/s of the scheme is relatively lower than the peak discharge of the catchment area which is 234m^3/s. This indicated that the diversion head work structure is unsafe against the passage of high flood.

The average conveyance efficiency in the main canal and secondary canal was 57% & 59% respectively, which is less than 70% for loam soil at main canal and 75% for loam soil at secondary canal. According to FAO, 1989 guidelines, it was not recommended for unlined earthen canals with more than 2000m for main canal which is 4000m, and for less than 2000m at secondary canal length which is 1800m. However, the conveyance efficiency varied spatially in the scheme. It was concluded that conveyance efficiency was higher at the head-end to middle-middle reach because the canal section at the head-end to middle-middle reach was still whole and had stable banks with no seepage problem due rectangular concrete canal at the main canal.

Still, it was lower in the tail-reaches due to siltation and vegetation growth within the canal interfering with water flow reducing the conveyance efficiency, and poor maintenance reducing canal capacity. The main and secondary canals need maintenance to minimize water losses through seepage in each of the canal sections.

Maintenance performance indicators used in this study were the effectiveness of infrastructures, water surface elevation ratio, sustainability of the irrigated area, and delivery duration ratio.

The performance of the scheme related to maintenance has been unacceptable. On average, the mean level of surface water for the main canal and secondary canal has been reduced by 48% and 38% respectively from the full supply level. From the gross planned command area of the irrigation scheme, 17.55ha was not covered by crop which means the total required area was reduced by 29%. Also, the effectiveness of infrastructure is reduced compared to the total installed structures by 42%. A number of the structures are affected by sedimentation, weed growth, erosion, and breakage problems. Therefore the number of functional structures initially installed has been becoming nonfunctional.

The delivery duration ratio of the scheme is extended by 200% from design capacity due to a shortage of water. These all parameters of maintenance performance indicators call for maintenance in the scheme is very short.

Generally, poor performance of the irrigation system is due to the following factors such as unreliable water deliveries, poorly control and distribution system, inflexible irrigation planning, lack of supportive training for irrigation water application and management, inadequate frequent maintenance, sediment accumulation, improper operation of water delivery system, and malfunctioning of flow control structures. Therefore, the result focuses on the government and other stakeholders in identifying suitable improvement lines.

Data Availability

All information provided to this publication is presented in the full document.

Conflict of Interest

The author declares that they have no conflicts of interest.

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