Hydrology
2025, Vol. 13, No. 2, pp. 126-133
https://doi.org/10.11648/j.hyd.20251302.14

Research Article

Hydraulic Performance Evaluation of Irrigation and Drainage Infrastructure Serving Ahero Irrigation Scheme in Kenya

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Abstract

The hydraulic performance of irrigation and drainage infrastructure in irrigation schemes in many developing countries like in Ahero Irrigation Scheme in Kenya is poor. The scheme grows rice under irrigation. It is important to evaluate the scheme to come up with measures that will assist the scheme's managers to better understand the system they control to bring about improvements. The main objective of this research study was to evaluate the hydraulic performance of the irrigation and drainage infrastructure serving Ahero Irrigation Scheme in Kenya. The conveyance efficiency of the earthen main canal and the pumps' performance efficiencies were researched. The research study employed both quantitative and qualitative research designs. The primary and secondary data types were collected. Specialized software was used in data analysis. The irrigation water conveyance efficiency of the earthen main canal of length 14.3km was measured and found to be 83.2%. The pumps' average performance efficiency was measured as 47.05%. The conveyance losses along the earthen main canal were caused by the; infiltration losses of irrigation water from the canal's bed, invasion of aquatic weeds in the canal, and failure of some of the water control structures along the earthen main canal to effectively control irrigation water in the canal. The pumps had low performance efficiencies because the pumps required maintenance and the pumps were at the end of their utility life and were due for replacement. This study recommends; the earthen main canal be lined with impermeable lining preferably by concrete, water control structures be rehabilitated, and the pumps be maintained or replaced with new ones.

Keywords

Hydraulic Performance Evaluation, Hydraulic Performance Assessment, Irrigation and Drainage Evaluation, Conveyance Efficiency, Pumps Efficiency, Ahero Irrigation Scheme

1. Introduction

Developing countries like Kenya are currently experiencing rapid population increase [1]. Population increase comes with unemployment challenges and increased need for food, clean water, and energy to meet the demands of the growing population. This population increase puts pressure on available natural resources and there is need to utilize these resources sustainably. Water, food, and energy form a nexus that greatly influence sustainable development [2].

Irrigation schemes in Kenya and in many developing

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Received: 10 May 2025; **Accepted:** 9 June 2025; **Published:** 30 June 2025

countries are currently performing poorly. The irrigation and drainage infrastructure established in these schemes are in poor conditions incapable of serving the schemes sufficiently. This has led to; poor utilization of scarce irrigation water resources, high cost of operation and maintenance, and low crop productivity [3, 4].

The irrigation and drainage infrastructure established in these schemes greatly influence the hydraulic performance of the irrigation systems [5]. Some of the irrigation and drainage infrastructure that influence performance of irrigation systems in these schemes include; i) canals and their conditions, ii) pumps and their efficiencies, and iii) conditions of the water control structures along the canals.

Efficiency can be defined or expressed as a ratio of output to the input. Conveyance efficiency relates the quantity of irrigation water delivered to the irrigated fields through the transport systems to the quantity of water diverted from an abstraction point [6]. Earthen canals have low conveyance efficiencies because they are associated with high infiltration losses. The indicative conveyance efficiencies of canals made of clay soils and ones lined with concrete are 80% and 95% respectively for the canals longer than 2000 meters [7].

Canals invaded with aquatic weeds have low conveyance efficiencies. The aquatic weeds growing in the canals' transport systems are opportunistic as they use the water intended to irrigate the crops for their own transpiration. The floating and submerged aquatic weeds also increase the retention time of flowing water in the canals by reducing the flow velocity [8]. The reduction in flow velocities causes more water to be lost through infiltration and promotes deposition of sediments onto the canals' bed. The aquatic weeds also reduce the canals' capacities and cause blockages [9]. The sedimentation in canals is mainly caused by the reduction of the canal's water current as a result of poor maintenance or lack of it [10].

Pump efficiency is determined by comparing the pump's actual discharge rate as it operates in the field in relation to the manufactured discharge capacity of the same pump. Pump efficiencies reduce with time due to wear and tear of its parts. The presence of sediment particles in pumped irrigation water cause abrasion effect on the surfaces of parts in a pump that leads to wear and tear due to erosion. This reduces efficiency and shortens the operational life of a pump [11].

When the water pressure in a pump falls below the vapour pressure during suction, air bubbles are created that later implode with high energy on the surface of impellers located in a high-pressure delivery side of a centrifugal pump. This phenomenon is called cavitation and it leads to wear and tear of impellers [12]. Cavitation reduces the efficiencies of pumps.

The water control structures are infrastructure put in place along a canal to convey water, divert flow direction, and to maintain appropriate water surface elevation in a canal [13]. Some of the water control structures include; division boxes, culverts, sluice gates, weir etc. Vandalized water control structures hinder effective irrigation water resource management practices in the field and contributes to conveyance losses along a canal [14].

It is important to evaluate hydraulic performance of irrigation and drainage infrastructure in poorly performing irrigation schemes to inform the scheme's managers on areas of improvement. The main objective of this research study is to evaluate the hydraulic performance of irrigation and drainage infrastructure serving Ahero Irrigation Scheme in Kenya. The conveyance efficiency of the earthen main canal and the pumps' efficiency will be researched.

2. Research Methods

2.1. Study Area

Ahero Irrigation Scheme is located in Kisumu County in the western part of Kenya, see Figure 1. The area falls within the tropics and can be referenced using GPS coordinates as follows; Latitude ($0^0$07'30" S to 0°10'30" S) and longitude ($34^0$58'30" E to $34^0$54'18" E). The irrigation scheme is further subdivided into various irrigable blocks namely; A, B, C, D, F, G, K, L, M, N, O, P, and R, see Figure 2. The water used for irrigation is abstracted from river Nyando by use of several electric pumps. The abstracted water is then delivered into the earthen main canal for conveyance to the field for irrigation. The water flows through gravity in the earthen main canal from the abstraction point (pumping station) to be field to irrigate the crop. The rice crop is grown in irrigation basins. The scheme practices surface irrigation method. The scheme uses the fully supply irrigation method to apply water to the crop [15].

2.2. Earthen Main Canal Conveyance Efficiency

The earthen main canal conveyance efficiency (CE) was calculated by dividing the total volume of irrigation water delivered to the field to irrigate the rice crop in a year (m^3) by the total volume of irrigation water supplied into the irrigation scheme from the abstraction point in a year (m^3). Equation 1 will be applied when calculating the conveyance efficiency of the earthen main canal.

$$CE = \frac{\text{Volume of irrigation water delivered}}{\text{Volume of irrigation water supplied}} \quad (1)$$

2.2.1. Volume of Irrigation Water Delivered

The volume of irrigation water delivered is the amount of water drawn from the earthen main canal used by farmers to irrigate the rice crop. The total volume of irrigation water delivered in a year (m^3) was measured at various points where the irrigation water exited the earthen main canal (outlet points). The outlet points (A, B, C, D, F, G, K, L, M, N, O, P, and R) are graphically illustrated in Figure 2. The volume of irrigation water exiting at various points along the earthen main canal were later summed together to get the cumulative volume of irrigation water delivered to the entire irrigation scheme. The latitude and longitude coordinates of these outlet points are outlined in Table 1.

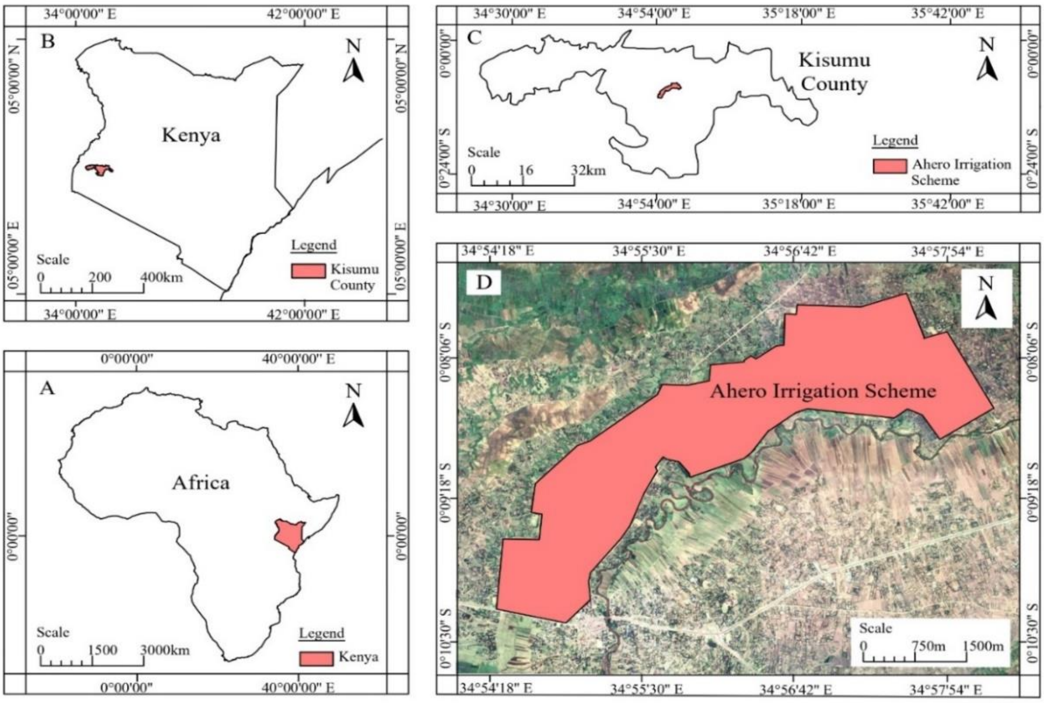

Figure 1. Arial satellite imagery of Ahero Irrigation Scheme (Source; Google Earth, 2025).

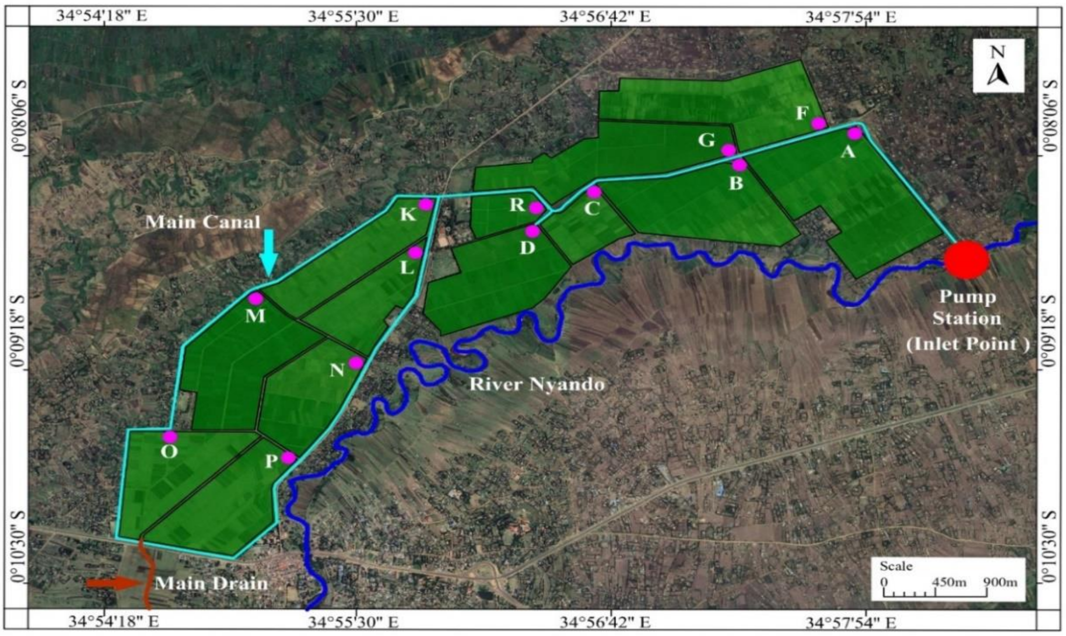

Figure 2. Irrigated blocks in Ahero Irrigation Scheme (Source; Google Earth, 2025).

Table 1. Latitude and longitude coordinates for discharge measurement locations.

	Location	Latitude (S)	Longitude (E)	Description
1	Pump Station	-0.144213	34.972498	Inlet point
2	A	-0.132191	34.963703	Outlet point

	Location	Latitude (S)	Longitude (E)	Description
3	B and C1	-0.135160	34.954868	Outlet point
4	C2	-0.140501	34.940128	Outlet point
5	D	-0.140519	34.940073	Outlet point
6	F	-0.132139	34.963663	Outlet point
7	G	-0.135089	34.954777	Outlet point
8	K, Feeder 1	-0.139290	34.930535	Outlet point
9	K, Feeder 2	-0.139394	34.930522	Outlet point
10	L	-0.142711	34.930353	Outlet point
11	M	-0.147705	34.916849	Outlet point
12	N	-0.154155	34.925645	Outlet point
13	O, Feeder 1	-0.160839	34.909869	Outlet point
14	O, Feeder 2	-0.160934	34.909716	Outlet point
15	P	-0.163482	34.920149	Outlet point
16	R	-0.140455	34.940066	Outlet point

The discharge measurement equipment was used to quantify the volume of irrigation water drawn from the exit points along the earthen main canal. The velocity-area method was used to calculate the amount of discharge passing through the exit points. An electromagnetic current meter was used in flow velocity measurements. The staff gauges were used to measure the depths of water in the canal. The rating curves were later developed to help quantify continuous discharge passing through the exit points along the earthen main canal at various water depths. The continuous discharge exiting the earthen main canal through the sluice gate was quantified by multiplying the duration in which the sluice gates were opened and the corresponding discharge rates drawn from the rating curves at specific gauge readings, see Table 2.

2.2.2. Volume of Irrigation Water Supplied

The volume of irrigation water supplied was the amount of water diverted into the earthen main canal from River Nyando at the abstraction point (inlet point) by the help of electric pumps. The total volume of irrigation water supplied in a year (m^3) was measured at the pumping station by finding the product of the pumping duration and the pumps' operating discharge rates, see Table 3. The latitude and longitude coordinates of this inlet point is as shown in Table 1. This inlet point is graphically illustrated in Figure 2.

2.3. Pumps Performance Efficiency

The pump's performance efficiency (PE) was determined by dividing the measured discharge rate of a pump as it operates in the field by the capacity discharge rate of the same pump specified by the manufacturer. The irrigation scheme had four electric pumps installed at the pumping station. The average performance efficiency of the pumps was computed by finding the mean of the performance efficiencies of the four pumps, see Table 4. Equation 2 will be applied when calculating the pumps' performance efficiency.

$$\text{PE} = \frac{\text{Measured discharge rate}}{\text{Capacity discharge rate}} \tag{2}$$

2.3.1. Measured Discharge Rate

The discharge measurement equipment (current meters and staff gauges) helped in quantifying the discharge rates of each pump by measuring their actual discharge in the canal when each pump was operating alone. The measured discharge rates of the four pumps were quantified as outlined in Table 4.

2.3.2. Capacity Discharge Rate

The capacity discharge rate of the four pumps were drawn from the manufacturers' equipment operation manuals that outlined each equipment performance specifications. The capacity discharge rates of the four pumps are outlined in Table 4.

3. Results

3.1. Computation of Conveyance Efficiency

The value of the total annual volume of irrigation water delivered (m^3) was drawn from Table 2 as 11,572,188.36 m^3 and the value of the total annual volume of irrigation water supplied (m^3) was drawn from Table 3 as 13,908,174.84 m^3. The conveyance efficiency was calculated by dividing the value of the total annual volume of irrigation water delivered by the value of the total annual volume of irrigation water supplied. The computation of the conveyance efficiency (CE) of the earth main canal was found to be 83.2% as shown in equation 3.

$$CE = \frac{11{,}572{,}188.36}{13{,}908{,}174.84} = 83.2\% \quad (3)$$

Table 2. Total annual volume of irrigation water delivered (m^3).

No.	Irrigated Blocks	Duration of water delivery in a season (Hrs)	Gauge Readings (decimeter)	Discharge rate from rating curves (m^3/s)	Volume of water delivered per irrigated block (m^3)
1	Block A	3240	7	0.19	2,216,160.00
2	Block F	3240	4	0.16	1,866,240.00
3	Block B and C1	3240	6	0.14	1,632,960.00
4	Block G	3240	1.75	0.12	1,399,680.00
5	Block P	3240	2.5	0.09	1,049,760.00
6	Block N	3240	3	0.06	699,840.00
7	Block D	3240	5	0.06	699,840.00
8	Block K, Feeder 1	3240	2	0.024	279,936.00
9	Block K, Feeder 2	3240	4	0.023129	269,772.36
10	Block L	3240	3	0.05	583,200.00
11	Block M	3240	4	0.015	174,960.00
12	Block C2	3240	3	0.01	116,640.00
13	Block O, Feeder 1	3240	3	0.01	116,640.00
14	Block O, Feeder 2	3240	2.5	0.01	116,640.00
15	Block R	3240	4	0.03	349,920.00
Total					11,572,188.36

Table 3. Total annual volume of irrigation water supplied (m^3).

Pump Name	Discharge Rate (m^3/s)	Duration (Hrs)	Volume of Pumped Water (m^3)
Pump 1	0.3492	3769	4,738,085.28
Pump 2	0.5287	3743	7,124,126.76
Pump 3	0.425	0	0
Pump 4	0.291	1953	2,045,962.80
Total			13,908,174.84

3.2. Computation of Pumps' Performance Efficiency

The performance efficiency of each pump was calculated as by dividing the value of the measured discharge rate of each pump when it was operating in the field alone by its value of the capacity discharge rate specified by the manufacturer drawn from the pump's equipment operation manual. The average performance efficiency of the four pumps was calculated by finding the mean of the performance efficiencies of the four pumps. The computation of the pumps' performance efficiency is as shown in Table 4.

Table 4. Performance efficiencies of the pumps.

	Capacity	Measured	Efficiency
Pump 1	1100 l/s	349 l/s	31.7%
Pump 2	1100 l/s	528 l/s	48.0%
Pump 3	660 l/s	425 l/s	64.4%
Pump 4	660 l/s	291 l/s	44.1%
Average			47.05%

4. Discussion

4.1. Earthen Main Canal Conveyance Efficiency

There was a significant reduction of amount of irrigation water exiting the earthen main canal at various exit points quantified as 11,572,188.36 m^3 compared to the amount of irrigation water diverted into the start of the earthen main canal at an inlet point (pump station) quantified as 13,908,174.84 m^3. This was an indication that the earthen main canal was associated with high conveyance losses. The earthen main canal conveyance system efficiency was calculated as 83.2% as shown in equation 3. The measured length of the earthen main canal was 14.3 km. The earthen main canal length was long because the area to be irrigated was fairly large, 2,183 acres. This level of conveyance efficiency was found to be insufficient compared to the indicative conveyance efficiency of 95% for the canals lined with concrete longer than 2,000 meters [7, 14]. This level of conveyance efficiency was low because of; infiltration losses from the earth main canal's bed, evapotranspiration losses caused by aquatic weeds, and losses caused by faulty water control structures that could not control irrigation water in the canal effectively.

During the research period it was observed that the earthen main canal was invaded by aquatic weeds, see Figure 3. The aquatic weeds hindered conveyance of irrigation water in the canal, promoted irrigation water loss through infiltration from the canal's bed and the deposition of sediments onto the canal's bed [10]. The aquatic weeds in the canals were opportunistic because they used the water intended to irrigate the rice crop for their own transpiration. The aquatic weeds also caused blockages in the canals [9]. The invasion of aquatic weeds in the canal was attributed to poor maintenance or lack of it.

Figure 3. *Poorly maintained irrigation canal invaded with aquatic weeds.*

During the research period it was observed that some of the water control structures along the earthen main canal were not functioning properly. Figure 4 is a picture of a failing division box that has its wing wall leaning and collapsing towards the earthen main canal hindering the operation of the sluice gate. Figure 5 is a picture of a faulty sluice gate. The sluice gate is fully closed but still water passes downstream of the gate. The failing water control structures affected the ability to manage the canal water effectively. The inadequate provision of maintenance and vandalism caused by water users promoted deterioration of hydraulic structures along the earthen main canal [14]

Figure 4. *Failing water control structure – Division box.*

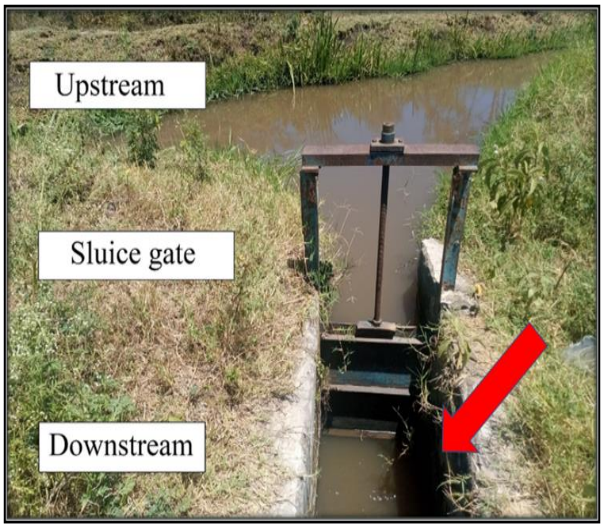

Figure 5. *Failing water control structure – Sluice gate.*

Based on the findings of this research study, the conveyance efficiency of the earthen main canal will improve if the earthen main canal's bed is lined with impermeable lining. The preferable lining is concrete. The concrete will limit infiltration losses and growth of aquatic weeds. The geometric design of the proposed lined canal should have a trapezoidal cross-section for efficient water conveyance [16]. As a cheaper alternative before lining the earthen main canal with concrete, regular maintenance activities should be done on the earthen main canal such as desilting, reshaping of the canal's embarkment, and removal of aquatic weeds to improve the conveyance efficiency of the earthen main canal. The failing water control structures should be rehabilitated to prevent losses of irrigation water in the earthen main canal.

4.2. Pumps Performance Efficiency

The average performance efficiency of the four pumps serving the scheme was calculated an found to be 47.05% as shown in Table 4. The average pumps' performance efficiency was below average. The average performance efficiency of the four pumps was low because the pumps were at the end of their utility life and were due for replacement. The low performance efficiencies of the pumps were also attributed to the wear and tear of their parts. The movable parts of the pumps were eroded by the sediments carried by pumped irrigation water [17]. Cavitation also promoted the wear and tear of the movable parts of the pumps serving the scheme [18]. The level of performance efficiency of the four pumps was low and similar compared to other pumps serving in developing countries like Pakistan that were powered by electricity and diesel that had overall performance efficiency in the range of 48% to 54% [18].

Based on the findings of this research study, the efficiency of pumping irrigation water will be improved if the old pumps that are at the end of their utility life are replaced with new ones. The scheme should do regular maintenance of the pumps to improve the pumps' performance efficiency as a cheaper alternative before buying the new ones.

5. Conclusion

A substantial amount of irrigation water was lost as conveyance losses in the earthen main canal of the irrigation scheme. The conveyance efficiency of the earthen main canal was low. Some of the water control structures along the earthen main canal were not functioning properly compromising their ability to control the irrigation water along the earthen main canal effectively. There was invasion of aquatic weeds in the earthen main canal.

The scheme had four electric pumps that were not operating optimally. The electric pumps had low performance efficiencies. The pumps were at the end of their utility life and were due for replacement. Cavitation and abrasion caused by sediments carried by pumped irrigation water caused wear and tear of parts in the electric pumps serving the scheme.

The scheme will benefit if its earthen main canal is lined with impermeable lining. The preferable lining is concrete. The lined canal will limit infiltration losses and growth of aquatic weeds. The failing water control structures should be rehabilitated occasionally.

The pumps that are at the end of their utility life should be replaced with new ones. The scheme's management should do regular maintenance of the pumps to ensure their performance is improved.

Abbreviations

CE	Conveyance Efficiency
PE	Pump Performance Efficiency

Acknowledgments

The authors are grateful to Ahero Irrigation Research Station of the National Irrigation Authority for providing permission, resources and a conducive environment that made it possible to undertake research activities within the irrigation scheme.

Authors Contributions

Marita Nickson Kenyoru: Methodology, Data curation, Formal analysis, manuscript drafting, Manuscript review and editing.

Emmanuel Chessum Kipkorir: Conceptualization, Methodology, Supervision, and Formal analysis.

Kibiiy Joel: Methodology, Supervision, and Formal analysis

Ooro Charlotte: Conceptualization, and Data curation

Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] KNBS. Kenya population and housing census - Analytical report on population projections - Volume XVI, Kenya, Nairobi. 2019.

[2] Belaud, G., Mateos, L., Aliod, R., Buisson, M. C., Faci, E., Gendre, S., Ghinassi, G., Gonzales Perea, R., Lejars, C., Maruejols, F. and Zapata, N. Irrigation and energy: issues and challenges, Irrigation and Drainage. 2020, 69(S1), 177-185. https://doi.org/10.1002/ird.2343

[3] Muema, F. M., Home, P. G., & Raude, J. M. Application of benchmarking and principal component analysis in measuring performance of public irrigation schemes in Kenya. Agriculture. 2018, 8(10), 162.

[4] Bwambale, E., Home, P. G., Raude, J. M., & Wanyama, J. Hydraulic performance evaluation of the water conveyance system of Doho Rice Irrigation Scheme in Uganda. Journal of Sustainable Research in Engineering. 2019, 5(2), 101-112. https://doi.org/10.3390/agriculture8100162

[5] Shumye, A., and Singh, P. Evaluation of canal water conveyance and on-farm water application for a small-scale irrigation scheme in Ethiopia. International Journal of Water Resources and Environmental Engineering. 2018, 10(8), 100-110. https://doi.org/10.5897/IJWREE2018.0800

[6] Gidey, G., & Siri, H. Conveyance efficiency and maintenance performance evaluation of canals at serenta irrigation scheme, Northern Ethiopia. Fluid Mechanics. 2021, 7(2), 29-34. https://doi.org/10.11648/j.fm.20210702.12

[7] FAO. Annex I: Irrigation efficiencies 1989. Available from: https://www.fao.org/3/t7202e/t7202e08.htm (Accessed 1 December 2023).

[8] Pitlo, R. H., & Dawson, F. H. Flow-resistance of aquatic weeds, Oxford University Press: Oxford. 1990, 74-85.

[9] Sytsma, M., & Parker, M. Aquatic vegetation in irrigation canals. 1999.

[10] Agunwamba, J. C., Dike, C. C., Ogarekpe, N. M., and Dike, B. U. Analysis of sedimentation of canals. International Journal of Development and Sustainability. 2013, 2(1), 306-332.

[11] Bandi, S., Banka, J., Kumar, A., & Rai, A. K. Effects of sediment properties on abrasive erosion of a centrifugal pump. Chemical Engineering Science. 2023, 277, 118873. https://doi.org/10.1016/j.ces.2023.118873

[12] Glovatskiy, O., Ergashev, R., Rashidov, J., Nasyrova, N., and Kholbutaev, B. Experimental and theoretical studies of pumps of irrigation pumping stations. In E3S Web of Conferences; EDP Sciences. 2021, 263, pp. 02030. https://doi.org/10.1051/e3sconf/202126302030

[13] Rampano, B. Water control structures: Designs for natural resource management on coastal floodplains. Sydney: NSW Department of Industry and Investment. 2009.

[14] Legesse, T., & Tadesse, A. Evaluation of water delivery performance and conveyance efficiency in Gatto small-scale irrigation scheme, Southern, Ethiopia. Journal of Water Resources and Ocean Science. 2021, 10(5), 139-154. https://doi.org/10.11648/j.wros.20211005.16

[15] NIA. Ahero Irrigation Scheme, 2024. Available from: https://irrigation.go.ke (Accessed 1 December 2023).

[16] El-Hazek, A. N. Design charts and design equations for trapezoidal earthen open channels. Sumerianz Journal of Scientific Research. 2019, 2(12), 166-182. https://doi.org/10.13140/RG.2.2.31984.38406

[17] Serrano, R. O., Castro, A. L. D., Rico, E. A., Pinto, M. A., Viana, E. M. D. F. and Martinez, C. B. Abrasive effects of sediments on impellers of pumps used for catching raw water. Revista Brasileira de Engenharia Agrícola e Ambiental. 2018, 22(9), 591-596. https://doi.org/10.1590/1807-1929/agriambi.v22n9p519-596

[18] Reinemann, D. J., Khalid, M., Kah, G. F. and Saqib, G. S. Irrigation pumpset efficiency in developing countries: field measurements in Pakistan. 1993, 9(1), 141-14.