CAPITAL UNIVERSITY OF SCIENCE AND TECHNOLOGY, ISLAMABAD

Evaluation of Water Losses in Unlined Canal: A Case Study of Malik Branch Canal, Bahawalnager, Pakistan

by

Adnan Ahmad Khan

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This effort is devoted to my respected and cherishing parents, who helped me through each troublesome of my life and yielded every one of the comforts of their lives for my brilliant future. This is likewise a tribute to my best teachers who guided me to go up against the troubles of presence with ingenuity and boldness, and who made me what I am today.

CERTIFICATE OF APPROVAL

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Abstract

Water is an essential component of nature for the survival of life on planet earth. It is the most valued reserve of nature. But supply of water on earth is not identical on all parts of globe. Also its characteristics and quality is changing in different areas. In the case of some areas it is not usable for drinking purposes as well as for irrigation. The two main source of water are surface water and ground water. Surface water has its uses as domestic and for irrigation supply. It is diverted from rivers to the irrigation systems such as canals and water courses with aim to irrigate fields. Now-a-days, with an increasing demand of water, due to the gradual increase in population, it is becoming a scared source from an abundant resource. Due to this increase in demand and scarcity in supply, it is being prominent to decrease water losses to make irrigation systems more and more efficient. This study undergoes to estimates the water losses in unlined canal with a purpose of providing estimation of water losses. Canal is used for supply of water from one location to other. In canal, different types of losses take place. Seepage and evaporation are the major water losses in an irrigation channel. The losses from canals need to be reduced to ensure the efficient performance of irrigation system and effective utilization of water. Seepage losses are main problem in earthen canal. There are methods to calculate these water losses. In this case, study the seepage losses & evaporation losses are determined also investigated the rate of water losses. There is a dire need to identify and prioritize the cause of losses in unlined canals so that rehabilitation and maintenance can be done accordingly. The Inflow and Outflow method was adopted to estimate the water losses on four sections of the selected canal. Average total water loss rate is calculated for four sections which is 1.74 x $10^{-}3$ cusecs/ft, whereas contribution of evaporation losses (during September to December) in total water losses is 1.22%. The amount of evaporation increases with the increase in temperature. It is observed from this research that there is 13.38% difference in water discharge between upstream and downstream of canal which badly affects the proper availability of water to irrigation lands at the tail, hence causes water scarcity.

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Abbreviations

BRB Canal	Bambawli-Ravi Bedian Canal
BWN	Bahawalnagar
Cs	Cusecs
Cumecs	Cubic Meters per Second
Cusecs	Cubic Feet per Second
IBIS	Indus Basin Irrigation System
KBr	Potassium Bromide
Lps	Liter per Second
m/sec	Meter per Second
MAF	Million Acre Feet
NaCl	Sodium Chloride
OFWM	Own Form Water Management
PIPIP	Punjab Irrigated Productivity Improvement Project
PIDA	Punjab Irrigation and Drainage Authority
PMD	Pakistan Meteorological Department

Chapter 1

Introduction And Background

1.1 Background

Water is the most important resource of the world, necessarily utilized by living things for survival and also has a lot of uses in different industrial processes. The existence of life on planet earth is directly relying on the availability of this natural resource. It is equally important for animals and plant life on earth. Water is a primary source for food production by facilitating the plants growth. Proper provision of water to field may cause a successful cropping while its deficiency may result a failure in crop production. According to Food & Agriculture Organization of United State (FAO, 2011) the number of crops grown in one year is increased from one to two hence increased water demands. The vast amount water which covers 71% of the blue planet out of which 2.5% is fresh water and only one third of this fresh water is can be economically available for human use. The competing demand of this finite resource is gradually increasing for drinking, hygiene, agriculture and industry in a world of 9 billion people. It quickly becomes clear that without proper water management now a days, the world is headed a crises of water scarcity that will affect every aspect of life. In regards of the above discussion it is realized that water saving has become the need of time. About 70% of total water(125/175 Bm3) consumed for irrigation, and rest of water around 35 Bm3 in wasted in to Arabian Sea [1].

Indus Basin Irrigation system about 74 percent of mean annual river flow (140 MAF) is taken to canal networks and 19% flows to Arabian Sea and remaining 7% is water losses. Productivity of canal networks is tremendously low, as 53% of water (55 MAF) is disappeared during conveyance through canals, and water courses. So there is only 47% of conveyance efficiency in canal irrigation system. This disappearance in discharge having a volume of 55 MAF is estimated as a financial loss Rs.55 billion per year [2]. The conveyance losses in channels are due to seepage, evaporation, spillage, vegetation, rodent holes and operational inefficiencies, out of this seepage, operational and spillage are the major losses. These water losses must be minimized so that the efficiency of the system may increase and also to meet the future demands of irrigation water. This efficiency can only be enhanced by efficient irrigation water supply practices. Conveyance losses of channels can be controlled through lining may diminish the drainage requirement and lead towards better irrigation efficiency. A brief study has been carried out to provide an appropriate estimation of water losses in earthen canal which will be beneficial to take precautionary measures to minimize these water losses.

1.2 Research Motivation

Pakistan is running extremely low in water availability in major reservoirs and approaching the scarcity threshold for water. Researchers predict that Pakistan is on its way to becoming the most water-stressed country in the region. The PMD has issued a drought alert due to high deficiency of water. The PMD stated that the shortage appeared mainly due to severe deficient in rainfall during last winter in 2018. Water scarcity condition may worsen if the rainfall remains scare during summer. This dry condition was observed in southern parts of the country during the past years. According to PMD report, severe drought is prevailing in barani areas of Punjab, lower Khyber Pakhtunkhwa (KPK), south Punjab, southwest Balochistan and southeast Sindh which may cause water stress for Kharif crops in the agriculture areas of the country. In this regard, stakeholders are advised to establish an immediate water management strategy by the PMD as the water shortfall could adversely affect the energy, agriculture and can distress the economy. Pakistan is among the top countries severely threatened by the global climate change [3]. This change is resulting in extreme deficient in rainfall or untimely rainfall, fast approaching droughts, unpredictable season's conditions and other weather calamities. Water scarcity in Pakistan is accompanied by less rainfall and high temperatures. According to researchers and experts, the scale of the impact of water scarcity may not be gauge able, but the situation calls for a water emergency in the country, and a water management policy. The motivation of this research is to make maximum and effective use of accessible water by pointing the areas of water losses along with causes in irrigation sector. Figure 1.1 shows the drought alert situation in different areas of Pakistan. The understudy area lies in severe drought alert.

1.3 Problem Statement

Water losses are more and well pronounced in the area of consideration due to many reasons including characteristics of soil. The conservation of water is going to be more important as the demand for this vital natural resource is increasing rapidly and the availability of new sources of water supply is limited. Thus, there are growing concerns over water losses in agricultural system and studies for the conservation of this natural resource along with its wide applications are under special considerations.

The water losses disturb the operational function and preservation of canal in the way that the water taken for consumers is misplaced from conveyance system. This lost water might produce piping, can erode the bank of the canal etc. The portion of this misplaced water absorbed by soil causes excessive saturation in the soil and

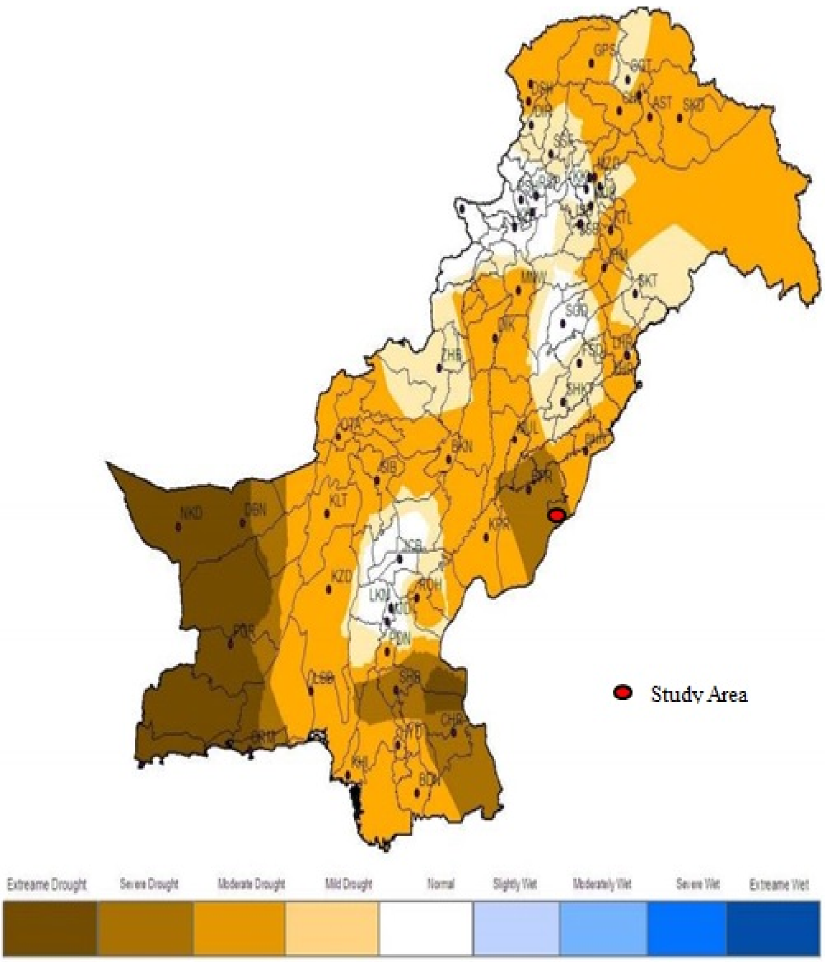

FIGURE 1.1: Drought Condition of Pakistan 2018, (afterDROUGHT ALERT, PMD,2018)

creates an uplift pressure. So there is a necessity to evaluate the percentage of water losses in any canal specially unlined canal, to overcome these problems.

1.4 Research Objectives

The general objective of the study is to point out the different types of water losses occurring in canals and to help the measures which may undertake to increase the water efficiency in canals for irrigation purposes. Along with there is a purpose to highlight the water losses occurring in canals which causes a scarcity to provide efficient water supply to irrigators especially at tale of the canal. It is often observed that mostly the fields at the tale of canals not receive proper supply of water which severely affects the crop production in such areas. It would help to make necessary measurements to minimize water losses in canals in a better way.

1.5 Limitations of Study

There are no specific instruments installed or available at selected study area for measurement of seepage losses. Hence, seepage losses were calculated by balance flow concept of inflow-outflow discharge. Cross section of canal is non-uniform throughout the length of the canal so there were variations in the flow velocity at different sections. Evaporating pan was installed outside the canal for estimating evaporation loss. No arrangements are available to calculate seepage losses, hence these are indirectly calculated.

1.6 Organization of Research Project

The layout of research project comprises of main five chapters. These are:

Chapter 1: It is titled as introduction. It explains the background of water losses, research motivation, problem statement, research objective, limitation of study organization of research project.

Chapter 2: It explains the literature review related to previous researches on losses. It consists of background, history of losses studies, water losses measuring techniques and summary of chapter 2.

Chapter 3: It is named as study area, data and methodology. It consists of background, it also explains about the study area and data set. It also covers methodology, flow chart of methodology and summary of chapter 3.

Chapter 4: It covers background, total water loss rate in each section. It also contains results evaporation losses, seepage losses and losses rate with respect to length of the channel and summary of chapter 4.

Chapter 5: It consists of conclusion, benefits of study and future recommendations.

References

Chapter 2

Literature Review

2.1 Background

Heavy water losses are detected in irrigation systems which are providing water to agriculture fields, especially in IBIS system in Pakistan. The measurement of percentage of water losses is different in rivers, canals, minors and watercourses. The water losses in canals are predominant; the reason behind this is the negligence of water preservation measurements in this fragment of irrigation system as compared to watercourses, where irrigators do their best to decrease water losses. Some of the basic reasons of water loses in canals may be seepage, evaporation, spillage, poor maintenance or unlined sections of canals. The losses in irrigation canals are mainly, seepage losses, Evaporation losses, Absorption losses and Transpiration losses [4].

2.2 History of Studies on Conveyance Losses

Ashfaque [5] stated that a huge amount of irrigation water is misplaced from the canal in the form of seepage from banks and bed of the canal. It is estimated that 40% to 50% of water is lost between the canal head works to the farm-gate. He further stated that lining of canal decreases seepage losses from 40% to 50%, consequently water logging becomes negligible. Conveyance efficiency increases from 70% to 90% resulting into significant increase in cropping concentration. Alam and Bhutta [6] measured the canal seepage rate varying from 9.76 to 20.39 cm/day. Lining of irrigation channels are widely accomplished in the world for controlling seepage losses and for enhancing delivery efficiency. Kahlown and Kemper [7] suggested the cost benefit analysis of different lining options and observed that seepage losses around 0.29 m^3/hour and 0.05 m^3/hour were obtained for the unlined and lined canals respectively. Ahuchaogu, I. et al. [8] found that seepage losses in earthen canal are 82.8% higher than seepage losses in lined canal. Sayed & Hossain,[9] found that conveyance losses of the existing earthen canal of the selected study schemes ranged from 6.9 to 8.2 lps/100m.

Roshni Patel & Sanhal, [4] disclose that as the canal water is exposed to the atmosphere at the surface, loss due to evaporation is obvious. But in most of the cases evaporation loss is not remarkable as compared to the seepage losses. It may range from 0.25 - 1 % of the total canal discharge. Saha [10] studied the water losses in canal and concluded that seepage loss in the irrigation canal accounts for the major portion of water conveyance loss (98.37%) while approximately 1.3% of the total stream is lost due to evaporation. The lining of an irrigation canal has the advantages of reduction in seepage losses from canals reaching water table and raising it resulting in waterlogging and reduction in yield, reduction in losses thereby making more water available for extension of irrigation to new areas and improvement of irrigation facilities in the areas already under irrigation. P. B. Jadhav et al. [11] determined seepage losses rate (mm3) and Conveyance Loss (m^3/m) and the values of seepage losses, evaporation losses and total losses are given in Table 2.1.

Alam and Bhutta [12] examined the seepage losses in canal with the help of physical measuring technique. The purpose of the study was to decrease the irrigation system losses. The seepage losses varied from 9.76 to 17.54 cm/day. Table 2.2 shows seepage rate (cm/day) for discharge and seepage rate in different canals. In this table, it is noted that seepage rate increased with the decrease in discharge,

TABLE 2.1: Conveyance Losses (mm^3) from unlined canal sections and overall conveyance efficiency (%) by P. B. Jadhav et al. [11]

Section (m)	**Seepage Losses (mm^3)**			**Conveyance Loss (m^3/m) Canal length**	**Over All Canal Efficiency (%)**
	Seepage Loss	**Evaporation Loss**	**Total Loss**		
41 – 280	0.32	5.39×10^{-4}	0.32	1333	-
481 – 630	0.14	2.57×10^{-4}	0.14	933	-
721 – 1000	0.15	5.54×10^{-4}	0.15	536	51.1
Total	0.61	1.34×10^{-3}	0.61	-	-

but there is no perfect correlation seen between the discharge and seepage rate. It occurred due to velocity and large wetted perimeter.

TABLE 2.2: Loss rate and discharge by Alam and Bhutta [12]

Channel name	**Discharge (cumec)**	**Seepage rate (cm per day)**
Daulat	4.36	8.83
Mohar	0.95	7.34
Phogan	0.81	23.16
Soda	2.2	19.01
Fordwah	4.74	5.53

Table 2.3 shows The Conveyance losses of existing earthen canal reached from 6.9 to 8.2 lps per 100m. The conveyance losses of improved earthen canals reached 3.0 to 4.5 lps per 100m. The conveyance losses of pre cost canals reached 2.5 to 2.9 lps per 100m [9].

TABLE 2.3: Water Losses Conveyance Loss (lps) from earthen, improved earthen and pre-cast canal by [9]

Schemes	**Conveyance Losses in Earthen Canal/100m**				**Conveyance Losses in improved Earthen Canal/100m**				**Conveyance Losses in Pre-Cast Canal/100m**	
	lps	**Avg.**	**% of Discharge**	**Avg.**	**Lps**	**Avg.**	**% of Discharge**	**Avg.**	**lps**	**% of Discharge**
M_1	7.2	7.7	44	41	4.3	3.7	24	-	-	-
	8.2		38		3.7		17	18	2.6	12
					3.3		14	-	-	-
M_1	7.6	7.4	53	48	3.0	3.6	23	-	-	-
	7.2		43		3.3		14	21	2.5	11
					4.5		26	-	-	-
D	6.9	7.5	53	45	3.3	3.4	24	-	-	-
	8.2		37		4.0		25	24	2.9	13
					3.0		23	-	-	-

2.3 Water Losses Measurement Techniques

Water losses from canals can be predicted by the physical procedures or by empirical formulization. In physical methods losses are directly calculated by evaluating the difference between the discharge ($Q = \frac{A}{V}$) at inflow and outflow of the sections. Empirical formulae designate the relationship of water loss rates with channel parameters; these perimeters also obtained physically.

2.3.1 Ponding Method

This method includes separation of a segment of any canal by means of temporary cross bunds. The bounded area is filled with water and the reduction in the volume after a definite duration of time is noted. This reduction in volume is then used to compute the rate of water loss. Amount of rainwater and evaporation loss is also catered for in this approach. The canal cannot be used for operational purposes during the period of tests. The variation in water level is examined over 24 to 48 hours. Ponding tests are categorized as either “seepage loss tests” or “over-all loss tests” depending on the appearances of the canal section and the presence of leaky stopcocks, gateways and other structures. In seepage loss test small canal sections are frequently adopted to avoid stopcocks, gateways or other structures that can cause leakage. Therefore, all water loss is owed to seepage through bottom and sides of the canal.

Overall loss tests method are associated with canal sections that hold stopcocks, gateways and other structures. It may be significant to account for losses from leaky regulator structures, but these kinds of leaks are frequently difficult to find and challenging to measure distinctly from canal seepage. Staff gauges are positioned in the canal test section to find the fall in water height during the test. At least three staff gauges are installed equally all over the test section, or place one at midpoint and two at the finishes. The longest the test section, more will be no of staff gauges are needed. Using numerous staff gauges will help to match and assess readings and will minimize mistakes in the event, as a staff gauge may fall or misplaced. To assess the changes in water level, staff gauges are read manually or by using electronic water level sensors. The staff gauge delivers a quick and informal optical indicator of water height and is frequently more consistent than electronic sensors.

Subsequently the staff gauge standpoint is set; a small bubble level may be used to level the staff gauge. The amount of rainfall is subtracted from the staff gauge readings and evaporation is also considered in final calculations. Figure 2.1 & 2.2 describe the survey method and schematic diagram for ponding method of water losses measurement. Staff gauge is fixed at the point where is less disturbance in water level due to external factors such as wind.

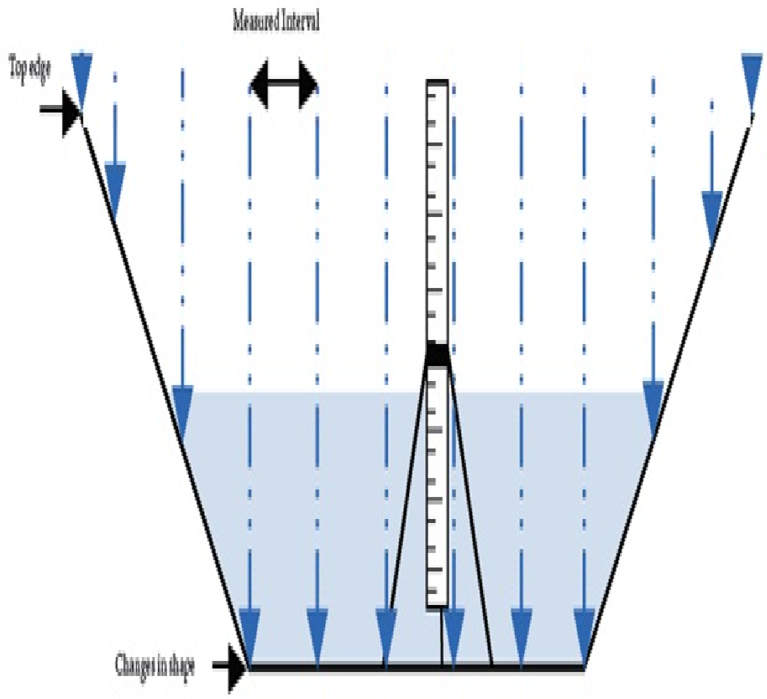

FIGURE 2.1: A basic survey method for determining the shape of the cross section by measuring the depth at marked intervals (after Eric and Guy, 2009)

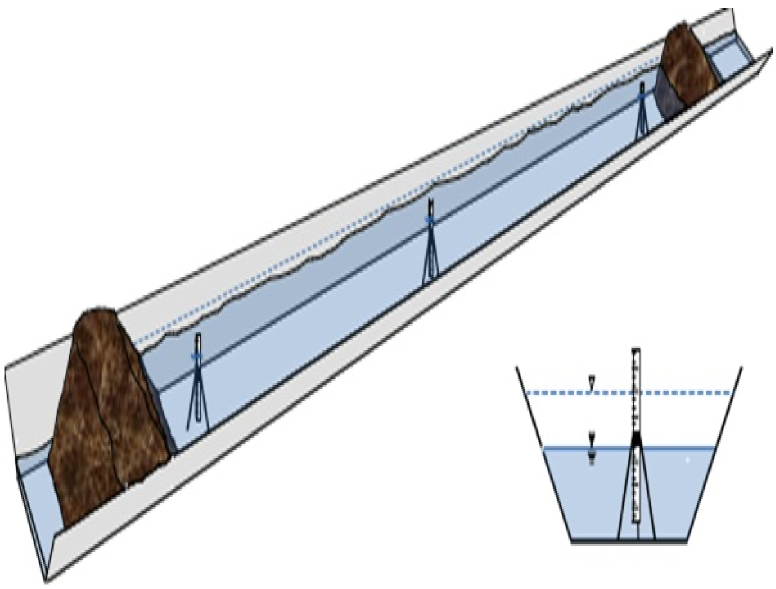

FIGURE 2.2: Schematic diagram of ponding loss method (after Eric and Guy, 2009)

After the physical installation of complete assembly readings are noted and judged based on empirical formula which is described as below:

$$Q = \frac{\Delta A x \Delta H x 1}{\Delta t} + \frac{EpLT}{\Delta t} + \frac{Ra}{\Delta t} \tag{2.1}$$

Where,

Q = Avg. loss rate

ΔA = Change in cross sectional are with respect time

ΔH = Change in water height

l = Selected length

Ep = Evaporation

L = Selected length

Δt = Change in time

Ra = Rain fall or precipitation

2.3.2 Inflow-Outflow Method

The inflow-outflow method for determination of water losses is extremely favor able as the losses can actuality measured even during the normal working condition of the canal. The canal is subdivided into suitable number of section according to length of the canal. Cross-regulators alongside a canal or branch canal may define the borderline between two sections. Then, the doorways at each cross-regulator may be adjusted in order to establish a discharge ranking for every flow control section along with each distributary head regulator splitting in each section. In inflow-outflow method the flow is measured at the heads of the section to find any alternation in the water amount entering in the canal; the water stages are observed after appropriate intervals to promise the steady-state flow circumstances. After this water stages are noted at each section in a comparatively small time duration of one or 2 hours. If steady-state flow situations continued during the duration of the test then the outcomes are acknowledged; if not, the test is made again until this steady-state flow situation is gained. The flow speed is tangibly examined by the assistance of current meter or flume. During the investigation, flow rate of the water is retained constant. Figure 2.3 the actual working of inflow & outflow method describing all parameters involved in water losses measurement.

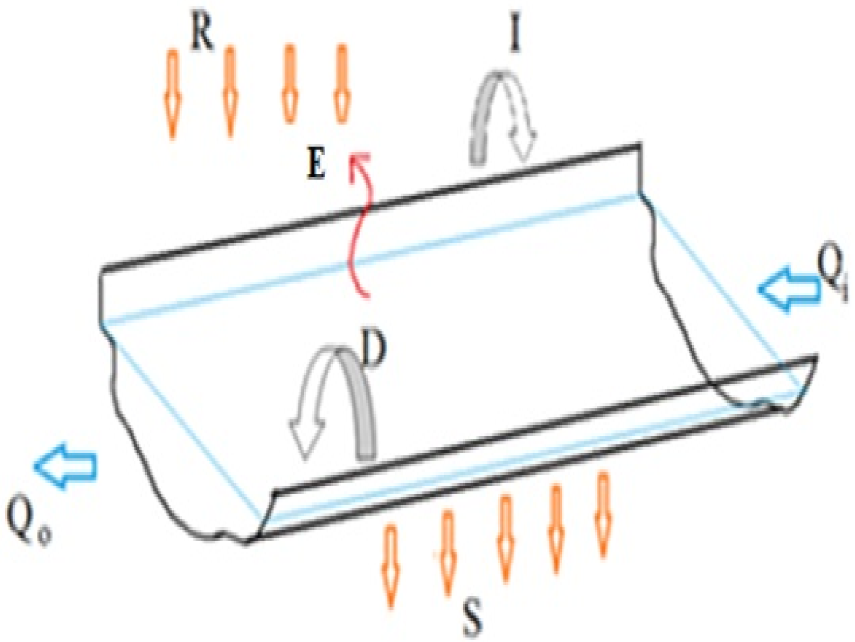

FIGURE 2.3: Schematic diagram of Inflow-Outflow method, (after Roshni & Saneha, 2016)

This inflow-outflow technique is based on the water balance method. It includes the straight measurement of the water passing into and out of canal. Evaporation pans are installed at the site to measure the evaporation losses and also rainwater and precipitation are considered during the experiments. In this method, the following formula is used to estimate water carriage loss in prescribed canal sections of adequate length.

Determination of water losses

$$S = Qt - Qo + R - D + I - E \tag{2.2}$$

Where,

S = Seepage loss in canal section

Qt = Total discharge of water at inlet

Qo = Discharge at outlet

R = Direct rainfall

D = Flow diverted along the reach

I = Inflow along the reach

E = Evaporation

2.3.3 Tracer Techniques

The tracer-dilution method is applicable for determining both open channel and closed channel flow. However, imaginable tracer losses might be an additional problem in open channel flow. Either salts or dyes may be used as tracers. The tracer-dilution method contains the addition of an identified, high concentrated tracer solution, Tracer method was used for seepage measurement for both lined and earthen canals and waterways by the Irrigation Research Institute [12]. The mechanism follows the norm of determining the velocities of outflows of flow path initiating from the canals. Dilution proportion of vaccinated tracer gives the velocity of flow outlines. These evaluations are measured on the both sides of canal at an equal pause. Everyday salts like NaCl and KBr etc. may be used. The velocity of the seepage flow is determined by the equation.

$$C - C_i = (C_o - C_i)_{exp} \frac{8V.\ r_1^2\ .\ \ r_2^2\ .\ t/v_o}{\frac{k}{k^*}\ \ (r_1^2 -\ \ r_2^2) + r_1^2 +\ \ r_2^2} \tag{2.3}$$

Where,

C = tracer conductivity and is equal to electrical resistance of the saline column, at a given horizon in the screened well at time t;

C_o = Initial conductivity of the groundwater flowing in and out of the screened well before the addition of the tracer;

V_o = constant volume of water in the screened well per unit of its length;

V = un-perturbed horizontal velocity in the aquifer;

r_1 = outer radius of the shrouding;

r_2 = inner radius of the strainer pipe;

k = permeability of the aquifer; and

k^* = permeability of the compound unit consisting or strainer and shrouding

A study of water losses at BRB link canal was undertaken using this technique by Irrigation Research Institute Lahore. It has been experiential that this is a complex technique and minor seepage determination is possible by this technique. It is also experiential that this gives acceptable outcomes only for small velocities as 0.001 ft/sec. The basic limitation of this method is to describe the flow direction and divergence of seepage and groundwater flow, due to this, the outcomes may not symbolize the true picture of loss percentage.

2.3.4 Seepage Meter Method

A seepage meter contain on a restricting cylinder pressed into the side or bottom of a canal to calculate the penetrability ratio on a small separate location. Seepage loss valuation depends on the quantity of tests executed and averaged above the span and boundary of a canal segment. Drawbacks are that it is usually restricted to be used in less than 2 feet of water depth [13] and can merely be applied on earthen canals. The basic function of this method is to separate the small area at the bed or side of the canal. A metal bell support is placed underneath the bed material and the water droplet above the bell support is observed. The rate of droplet is linked to the loss rate. There are two types of seepage meters: constant head seepage meter and falling head seepage meter [14].

The basics of seepage meter method are fairly alike to ponding method but the lone alteration among the two is that seepage meter method is functional without closing flows in canal. Its apparatus is capable for determining local seepage loss rates in the canal. The apparatus can be simply and rapidly fixed and deliver sensible results. The restriction of using this method is that velocities should not higher than 2 ft/s and movable bed should not be adapted for measurement. The apparatus is delicate and vulnerable to give very inaccurate results [14] inspected the loss rate with seepage meter. The stated loss rates were found 23 to 58 % extra in contrast to ponding method; this was because of the needless disturbance of the subsoil, pushing the bell into the bottom of the canal.

According to Planning and Development [15,] WAPDA made numerous preliminary tests on minor canals and watercourses in the IBIS. The results developed were not acceptable due to miscalculations coming from different integral sources throughout the measurements.

2.3.5 Empirical Formulas

Empirical formulas are adapted where straight dimensions of canals are not reachable or useful. These formulas are established on affiliations observed between water losses and the hydraulic situations. Few formulas are established for very precise, restricted situations, and others guesstimate more comprehensive situations (i.e. unlined or lined canals); others involve canal discharge or velocity or the waterlogged penetrability of the canal soils [16]. The Davis-Wilson formula: connects seepage losses straight to the cube root of the water elevation in the canal, and supposed infiltration to be equivalent everywhere in the saturated boundary. This Davis-Wilson was the single formula quoted for approximating seepage losses for lined canals and also recommended constant values for a range of soil types. The square root of the mean canal velocity is considered to be inversely proportional.

$$S = C \times \frac{WP \times L}{4 \times 10^6 + 2000\sqrt{V}} \times H_W^{l/3} \tag{2.4}$$

Where,

S = seepage losses (ft^3 per second per length of canal);

L = length of canal (ft);

WP = wetted perimeter (ft);

Hw = mean water depth in the canal (ft);

V = is the velocity of flow in the canal (ft/sec);

C = constant values depending on lining of canal (ranging from 1 for concrete and maximum value of 70 for coarse sand-unlined respectively)

The Molesworth-Yennidumia principle [17] was used by the Egyptian Irrigation Department is formulized as:

$$S = C \times L \times WP \times \sqrt{R} \tag{2.5}$$

Where,

S = conveyance losses (ft^3/sec per length of canal)

L = is the length of canal (ft)

WP = is the wetted perimeter (ft)

R = is the hydraulic mean depth (ft)

C = is coefficients for soil type (stiff clay = 0.00271; very sandy = 0.00542)

The outcomes revealed that the Molesworth-Yennidumia empirical formula, along with the critical formulas, had good settlement with the test outcomes. The coefficients of experimental formulas for a collection of soil textures and vegetation densities of small earth canals linked with measured seepage ratios using the inflow-outflow technique in the north zone of Isfahan Province, Iran. They originate that the coefficients required to be enlarged about 8 times to appropriately guesstimate seepage losses, and established that the improved Davis-Wilson and Molesworth-Yennidumia formulas were the finest two formulations for the study area.

The Moritz formula [16] was suggested by the USBR for estimating seepage damages per mile of earthen canal is given as:

$$S = 0.2 \times C \times \sqrt{Q N} \tag{2.6}$$

Where,

S = seepage losses (ft^3/sec/mi)

Q = the discharge (ft3/sec)

V = the velocity of flow in the canal (ft/sec)

C = constant values depending on soil type, details are available in literature and values ranging from 0.34 to 2.20

Akkuzu [18] calculated both the Moritz and David-Wilson equations and linked it with inflow-outflow experiments on lined canals. Akkuzu realized that the seepage loss estimated by both formulas were meaningfully beneath the experienced values and determined that this was because of the poor settings of the concrete canals. Akkuza used a metric form of the Moritz equation, using a constant value of (C) of 0.1 for concrete lined canals.

The Muskat formula was resultant by for canals with similar, isotropic lands and deep water benches

$$q = \frac{K(B + 2H)}{WP} \tag{2.7}$$

Where,

q = seepage rate (ft^3/ft^2/day)

K = permeability (ft/day)

B = the width of water surface (ft)

H = depth of water (ft)

WP = wetted perimeter (ft)

The USBR estimated Muskat's formula in combination with seepage loss tests executed on earthen canals in Wyoming and Nebraska. They originate it to be unpredictable in forecasting seepage rates owing to the fact that the canal earths were mainly dissimilar and anisotropic.

2.4 Summary

All the above discussed techniques are useable to determine the water losses occurring in canals, but also have their limitations. As ponding method is not applicable in working condition of canal. Tracer technique has also a limitation as it is only applicable to a channel having depth less than or equal to 2ft. Moreover, seepage meter method has a limitation that it is not applicable to the channel having velocity more than 2 ft/sec. While in contrast, inflow-outflow method is capable of measuring water losses even when the canal is functional and is more useful to determine the water losses of selected channel. As the selected canal has average depth of 6.5ft with average flow velocity of about 3 ft/sec, hence, inflow-outflow method is more suitable to measure the water losses.

Chapter 3

Study Area, Data And Methodology

3.1 Background

The water losses in canals has significant diverse effect on the efficient water supply to fields as it is a basic element of irrigation system so there is a need to be aware of these water losses and take necessary precautions to overcome these losses. According to the rules Punjab irrigation department 10% of extra discharge is added in design discharge to compensate these water losses. Also annual desilting works are conducted to keep canal in its best operational condition and to decrease water losses. It is a forecast that Pakistan may face a severe water deficiency conditions in near future and also presently some of its area are facing this water scarcity situation. The purpose of this case is to provide awareness about the water which is being lost in our irrigation channels because it has become essential to overcome these losses to have an efficient irrigation system. In this chapter, study area, data set and methodology used for water losses estimation in irrigation canals will be discussed.

3.2 Study Area

Malik branch canal located in district Bahawalnagar, province Punjab is selected for this research work. The coordinates of Bahawalnager district are 30.0025N 73.2412E having an elevation of 163 meters from mean sea level. Most of the district lies in cholistan region. River Sutlej passes from the northern side of the district at a distance about 9 km. Most of soil is sandy, rest of the portion consist of sandy loam and clayey loam. Most of the area is undulated having the sand dunes. The temperature ranges from 0 C to more than 50 C. Mean annual rain fall is quite less and ranges from 150mm to 200mm. Sixty percent of total annual rainfall occur in monsoon season. District is mainly irrigated by Eastern Sadiqia canal, which is perennial canal off takes from Sulaimanke barrage. The Malik branch canal is located at a distance of 15 km from District headquarters in Bahawalnager Tehsil. The length of canal is 35640 meter (35.6 Km). Cotton, wheat, sugarcane and rice are the major crop grown in the area. The line diagram of the canal is given in figure 3.1 the canal is off taking from Eastern Sadiqia Canal and has five distributaries.

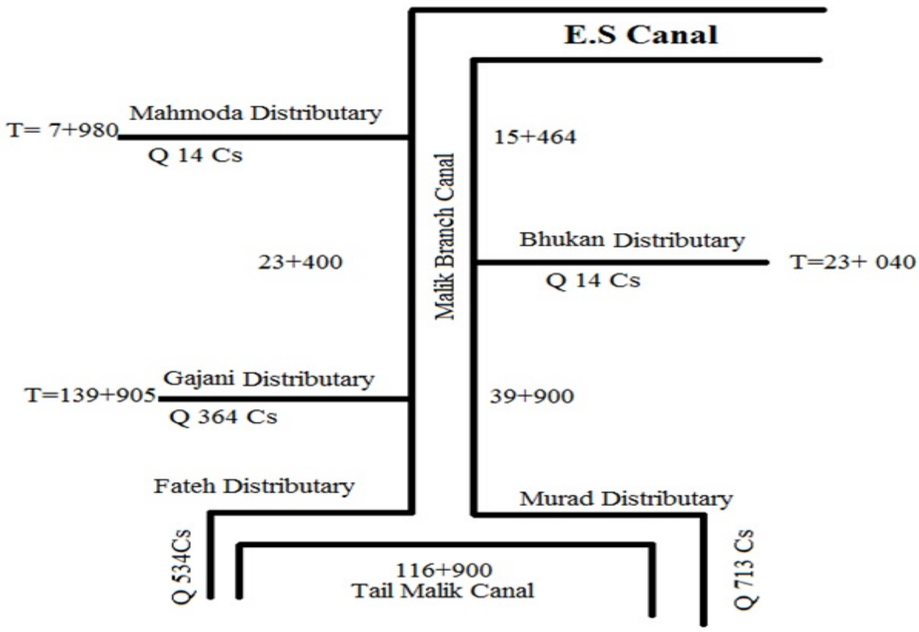

FIGURE 3.1: Line Diagram of Malik Branch Canal

3.3 Study Area

The channel was divided into four sections according to the installed discharge measuring gauges. All parameters of channel were obtained from Punjab irrigation department. Evaporation measuring pan is installed in the center of the channel to evaluate evaporation loss. Temperature, humidity, precipitation, wind speed and wind direction values were also taken from internet source. It was made sure that there would be no spillage from any side or bottom of the channel with in the channel. Figure 3.2 shows the schematic diagram of district Bahawalnager irrigation system network and Malik Branch canal is also heighted to show its irrigated area.

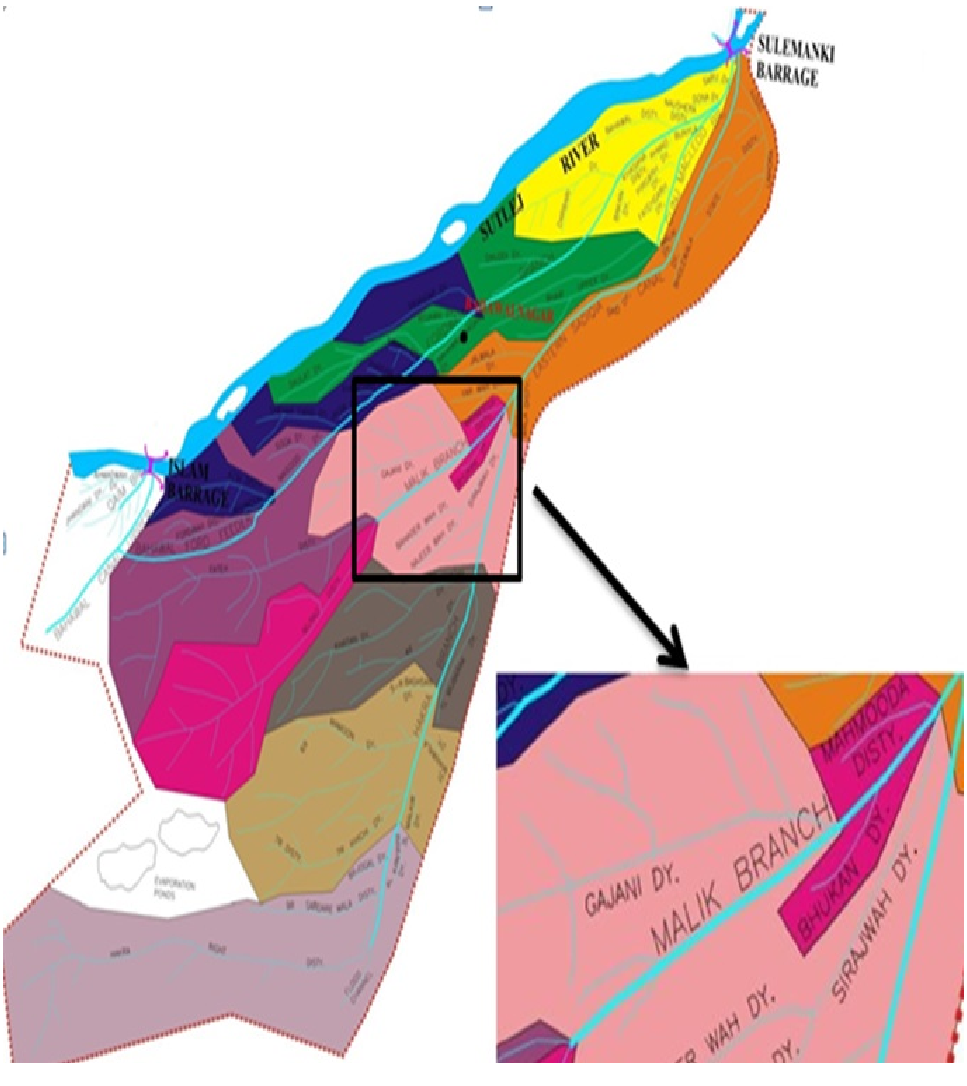

FIGURE 3.2: Schematic diagram of Bahawalnager irrigation system including Malik branch canal, after PIDA

3.4 Methodology

Inflow-outflow method is adopted to find the amount of water losses in total discharge from inlet to outlet and the factors responsible these water losses are considered as seepage losses, evaporation losses, leakage losses, over topping and canal erosion. Current meter is used for the determination of water losses in discharge. The inflow-outflow technique offers direct measurement of water losses with disturbing the operation functions of the canal. This technique is based on determining the proportions of water flowing in and out from a nominated section of canal. The alteration in discharge between inflow-outflow is recognized as water losses. The inflow-outflow technique is a useful approach and it performs well under undulating situations of flow. Further, nonstop measurements can be executed without any inter looping in the system process [19]. Correctness in the results depends on accurateness of inflow and outflow measurements. Inflow-outflow technique gives the loss occurring throughout water passage in the open canals without hindering the regular irrigation process of the certain canal, at the similar time allow precise calculations. Table 3.1 describes different parameters of the canal involving it length, sloe and maximum design discharge.

FIGURE 3.3: Evaporation Pan

TABLE 3.1: Basic Parameters of Malik branch canal

Sr. Number	Parameters	Description
1	Type	Unlined
2	Length	116900ft
3	Canal Bed Width	100ft
4	Full Supply Depth	6.80 ft
5	Slope	0.11%
6	Design Discharge (cusecs)	1866 Cusecs
7	Maximum Observed Discharge	1729 Cusecs
8	No of No Distributaries	5
9	No of Outlets	45

The canal selected for study is an unlined canal having no provisions (bricks, concrete work etc.) on it cross section. The Inflow-Out flow method overcome a widespread variety of losses and is assumed to be the most superior method for determining the losses in the Canals. Table 3.2 predicts the assessment of diverse factors disturbing losses in several approaches [15]. It reveals that inflow-outflow technique is the solitary method that computes for all the factors involved in water losses. Others methods mainly discourse just seepage, excluding ponding method which also considers evaporation losses.

Discharges at the start and end of section of the canal were determined agreeing to the velocity-area flow measurement method. The cross-section of the canal at the data collecting points was first distributed into sub-sections, and velocities were checked for both sub-sections according to the two-point method. Discharge velocity at the data collecting points was measured in relative to the revolutions of an Ott-type current meter completing duration of 60 seconds. Discharge velocity was measured by using the succeeding equation:

$$V = 0.2451\ n + 0.014 \tag{3.1}$$

TABLE 3.2: Comparison of Losses in various methods [15]

Factor Affecting Losses	**Tracer Method**	**Ponding Method**	**Inflow-Out Flow Method**	**Empirical Method**
Seepage	Yes	Yes	Yes	Yes
Evaporation		Yes	Yes	
Spillage			Yes	
Rodent Holes			Yes	
Breaches/Cuts			Yes	
Dead storage			Yes	
Infiltration			Yes	
Operational			Yes	

Where:

0.2541= the coefficient of the propeller type

0.014 = the coefficient of the friction of the propeller, found by calibration

n = is the number of revolutions per second of the propeller

V = the flow velocity of the water (m/s)

While following the two-point method, the discharge velocity was calculated at two upright points, 0.2 (20%) and 0.8 (80%) depths, correspondingly, from the topmost of the water superficial. The discharges at these two heights were then averaged to obtain a single value. Velocity should usually be higher at the 0.2 depth, but should not be greater than double of the velocity of the 0.8 depths. In case the velocity at the 0.2 depths was not greater than the 0.8 depths or if it was two times as higher as at 0.8 depths, then a supplementary reading was engaged at the 0.6 depths. This 0.6 depth was average of the 0.8 and 0.2 means. Evaporation loss (E) was measured through evaporation pan. Moreover, the precipitation was not consider due to limitations that no flow was considered into the segment from outside (I), or distracted from the segment (D), both values were assumed zero. Evaporation pans are installed, a cylinder with a diameter of 47.5 in (120.7 cm) that has a depth of 10 in (25 cm). Following mathematical relations are used to measure total water losses, evaporation losses, seepage losses, water losses rate respectively. Determination of total water losses

$$Totalwaterlosses = Qt - Qo - D + I \tag{3.2}$$

Where:

Qt = Total discharge of water at inlet of section

Qo = Discharge at outlet of section

D = Flow diverted along the reach

I = Inflow along the reach

$$Evaporation\, losses\, (in\ cusecs) = \left(\frac{Drop\ in\ evaporation\ pan\ in\ inches\ \ x\ Surface\ area\ in\ feet}{Average\ day\ light\ in\ hours\ \ x\ 3600\ x\ 12}\right) \tag{3.3}$$

$$Seepage\ losses(in\ cusecs) = Total\ water\ losses -\ \ Evaoration\ losses \tag{3.4}$$

$$\text{Water losses rate incusecs/ftx}10^3 = \left(\frac{Total\ water\ losses\ in\ cusecs\ X\ 1000}{Length\ of\ canal\ section}\right) \tag{3.5}$$

Evaporation is measured on daily basis as the depth of water (in inches) evaporates from the pan at the site to measure the evaporation losses and also rainwater and precipitation are not considered during the data collection. The time duration for determination of evaporation is only considered average day light hours.

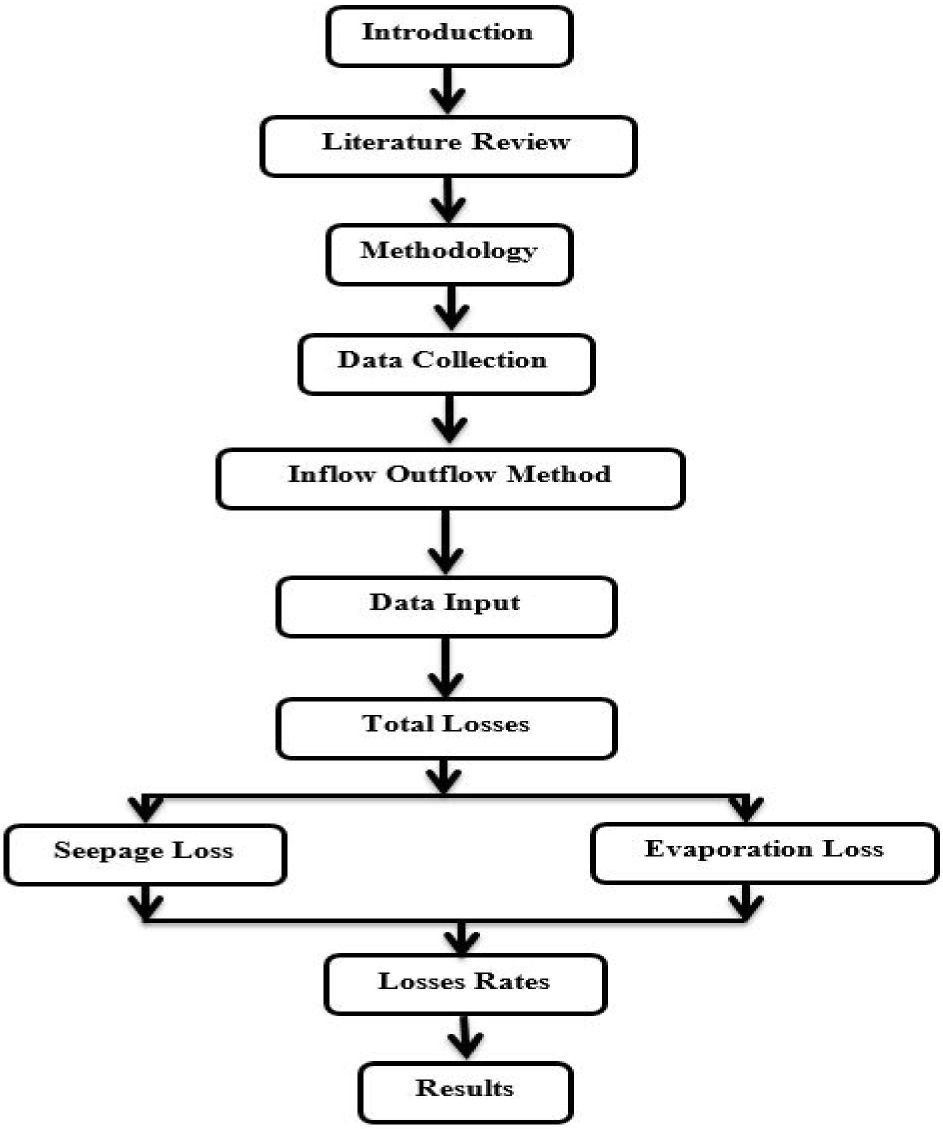

FIGURE 3.4: Flow Chart of study

In selecting the canal to be examined and the engaging of the segments, the subsequent conditions were taken into account, the discharge should be the normal working situation of the canal, there should be no fluctuation in water height during measurement, there should be no disturbance of the cross-sectional geometry of the segment where the measurement was taken and there should be nothing to avoid the flows. The evaporation pan installed for field test in given in figure 3.3.

The flow chart given in figure 3.4 describes the methodology followed during the research work.

3.5 Summary

The channel was divided into four sections according to the preinstalled discharge measuring gauges. Inflow outflow method was used for measuring water losses in the channel. The discharge table is prepared from already installed gauges and then the values were verified by current meter at each point. Discharge at inlet and outlet is measured than difference of discharge along with deduction of outflows discharges gives the total water losses in the section. Additionally to segregate evaporation losses from the total losses, evaporation measuring pan was installed in the center of the channel. Only day light hours are taken to determine the evaporation losses rate.

Chapter 4

Results And Analysis

4.1 Background

The particular study area is deliberated in preceding chapter. In which different methods for determination of losses have also been discussed. Inflow-outflow has been adopted due it suitability of implication for given parameters of understudy canal. Average losses were measured due seepage and evaporation also the percentage losses due to each factor have been determined. Total water losses rates have been determined with respect to net head discharge in section of the channel. This chapter is related to the discussion and the results achieved by using methodology discussed in chapter 3.

4.2 Losses Rate in Canal

The loss rate was measured through inflow outflow method for canal and given in the table 4.5. The losses are determined in cusecs & percentage losses with respect to total discharge are determined. The readings of discharge between 22-Oct-2018 to 02-Nov-2018 were not measured due short closure period of canal. Thirty nine readings for discharge are taken at each section with one day interval.

Tale 4.1 gives the total water losses in canal at four sections and also percentage losses with respect to head discharge of the canal. It shows the Average water Losses 196 cusecs from head to tail of the channel. Also average water Losses percentage with respect to Head Discharge is 13.38%.

TABLE 4.1: Total Water Losses in cusecs

Date	**Head Discharge (Cusecs)**	**Total Water Losses in Cusecs**				**Total losses from head to tail**	**Losses % w.r.t Head Discharge**
		RD 0+000 TO RD 23+400	**RD 23+400 TO RD 38+900**	**RD 38+900 TO RD 95+900**	**RD 95+900 TO RD 116+900**		
16-Sep	1721	40	36	112	28	216	12.55
18-Sep	1713	44	30	96	41	211	12.32
20-Sep	1700	42	33	106	31	212	12.47
22-Sep	1411	46	38	91	41	216	15.31
24-Sep	1280	47	38	81	29	195	15.23
26-Sep	1298	40	36	90	37	203	15.64
28-Sep	1577	47	29	106	38	220	13.95
30-Sep	1721	46	24	89	42	201	11.68
2-Oct	1721	46	40	73	42	201	11.68
4-Oct	1721	40	30	106	39	215	12.49
6-Oct	1713	38	32	109	34	213	12.43
8-Oct	1605	39	33	94	34	200	12.46
10-Oct	1565	45	38	105	34	222	14.19
12-Oct	1072	35	28	75	30	168	15.67
14-Oct	1038	39	19	75	29	162	15.61

Date	Head Discharge (Cusecs)	Total Water Losses in Cusecs				Total losses from head to tail	Losses % w.r.t Head Discharge
		RD 0+000 TO RD 23+400	**RD 23+400 TO RD 38+900**	**RD 38+900 TO RD 95+900**	**RD 95+900 TO RD 116+900**		
16-Oct	1729	48	36	106	30	220	12.72
18-Oct	1577	44	31	107	35	217	13.76
20-Oct	1343	41	35	99	30	205	15.26
3-Nov	1362	50	51	73	33	207	15.2
5-Nov	1541	30	46	73	33	182	11.81
7-Nov	1462	44	36	62	46	188	12.86
9-Nov	1680	43	40	74	30	187	11.13
11-Nov	1521	41	37	63	42	183	12.03
13-Nov	1525	33	37	93	30	193	12.66
15-Nov	1600	46	24	76	37	183	11.44
17-Nov	1679	51	38	74	39	202	12.03
19-Nov	1721	49	38	71	49	207	12.03
21-Nov	1721	56	44	71	36	207	12.03
23-Nov	1721	59	37	71	36	203	11.08
25-Nov	1597	34	32	91	31	188	11.77
27-Nov	1597	28	32	91	35	176	11.02
29-Nov	1295	42	38	98	27	205	15.83
1-Dec	1638	37	39	59	45	180	10.99
3-Dec	1400	40	46	83	30	199	14.21
5-Dec	1041	39	36	60	29	164	15.75

Date	Head Discharge (Cusecs)	Total Water Losses in Cusecs				Total losses from head to tail	Losses % w.r.t Head Discharge
		RD 0+000 TO RD 23+400	RD 23+400 TO RD 38+900	RD 38+900 TO RD 95+900	RD 95+900 TO RD 116+900		
7-Dec	1072	30	28	58	38	154	14.37
9-Dec	932	26	30	62	31	149	15.99
11-Dec	1214	36	24	85	29	174	14.33
13-Dec	1232	30	24	98	29	181	14.69
Average	**1489**	**41**	**32**	**90**	**33**	**196**	**13.38**

Table 4.2: Evaporation Losses in Inch/Hour with Temperature, Humidity, Wind Speed and Direction

Date	Drop in Evaporation pan	Evaporation Losses (Inch/Hour)	Temperature		Humidity	Wind	
			Min.	Max.		Speed	Dir.
16-Sep	0.188	0.0158	23	38	41%	11	NE
20-Sep	0.188	0.0158	22	38	42%	8	SW
24-Sep	0.188	0.0158	22	38	54%	10	NW
26-Sep	0.125	0.0105	22	37	70%	18	SW

Date	**Drop in Evaporation pan**	**Evaporation Losses (Inch/Hour)**	**Temperature**		**Humidity**	**Wind**	
			Min.	**Max.**		**Speed**	**Dir.**
2-Oct	0.125	0.0105	22	36	59%	8	E
6-Oct	0.187	0.0157	22	37	38%	10	NW
8-Oct	0.125	0.0105	19	37	24%	24	S
12-Oct	0.125	0.0105	18	34	48%	6	S
18-Oct	0.125	0.0113	17	33	45%	10	SE
3-Nov	0.125	0.0113	13	31	55%	13	SE
9-Nov	0.0625	0.0056	13	28	54%	8	N
15-Nov	0.0625	0.0056	13	28	67%	11	S
19-Nov	0.0625	0.0060	13	28	64%	11	S
25-Nov	0.0625	0.0060	11	29	59%	5	W
1-Dec	0.0625	0.0060	11	27	60%	8	NE
7-Dec	0.0625	0.0060	7	23	67%	12	NE
13-Dec	0.0625	0.0060	6	20	75%	9	NW

Table 4.2 shows the detail of Seepage losses in each section of the canal and Average seepage Losses 193.14 cusecs from head to tail of the channel. Also average seepage Losses percentage with respect to total losses is 98.78%.

Table 4.3 shows the detail of Evaporation losses in each section of the canal and Average evaporation Losses is 2.43 cusecs from head to tail of the channel. Also average evaporation Losses percentage with respect to Total losses is 1.22%. Table 4.4 shows the detail of Evaporation data, which indicates that when maximum temperature of a day becomes less than 30^{o}C and the minimum temperature of that day becomes less than 15^{o}C the daily evaporation nearly become constant. Only day light hours are taken to determine the evaporation losses.

Table 4.3: Evaporation Losses in Cusecs

Date	**Evaporation Losses (Inch/Hour)**	**Evaporation Losses in Cusecs**				**Total Evapo-ration losses**	**Eva Losses % w.r.t Total Losses**
		RD 0+000 TO RD 23+400	**RD 23+400 TO RD 38+900**	**RD 38+900 TO RD 95+900**	**RD 95+900 TO RD 116+900**		
16-Sep	0.0158	0.856	0.55	1.745	0.622	3.772	1.75
18-Sep	0.0158	0.856	0.55	1.745	0.622	3.772	1.79
20-Sep	0.0158	0.856	0.55	1.745	0.622	3.772	1.78
22-Sep	0.0158	0.856	0.55	1.745	0.622	3.772	1.75
24-Sep	0.0158	0.856	0.55	1.745	0.622	3.772	1.93
26-Sep	0.0105	0.569	0.366	1.16	0.414	2.508	1.24
28-Sep	0.0105	0.569	0.366	1.16	0.414	2.508	1.14
30-Sep	0.0158	0.856	0.55	1.745	0.622	3.772	1.88
2-Oct	0.0105	0.569	0.366	1.16	0.414	2.508	1.25
4-Oct	0.0105	0.569	0.366	1.16	0.414	2.508	1.17
6-Oct	0.0157	0.851	0.547	1.735	0.619	3.752	1.76
8-Oct	0.0105	0.569	0.366	1.16	0.414	2.508	1.25
10-Oct	0.0157	0.851	0.547	1.735	0.619	3.752	1.69
12-Oct	0.0105	0.569	0.366	1.16	0.414	2.508	1.49
14-Oct	0.0105	0.569	0.366	1.16	0.414	2.508	1.55
16-Oct	0.0169	0.917	0.589	1.87	0.667	4.044	1.84
18-Oct	0.0113	0.61	0.392	1.244	0.443	2.689	1.24
20-Oct	0.0113	0.61	0.392	1.244	0.443	2.689	1.31
3-Nov	0.0113	0.61	0.392	1.244	0.443	2.689	1.3
5-Nov	0.0113	0.61	0.392	1.244	0.443	2.689	1.48
7-Nov	0.0113	0.61	0.392	1.244	0.443	2.689	1.43
9-Nov	0.0056	0.305	0.196	0.622	0.222	1.344	0.72
11-Nov	0.0113	0.61	0.392	1.244	0.443	2.689	1.47
13-Nov	0.0113	0.61	0.392	1.244	0.443	2.689	1.39
15-Nov	0.0056	0.305	0.196	0.622	0.222	1.344	0.73

Date	Evaporation Losses (Inch/Hour)	Evaporation Losses in Cusecs				Total Evapo-ration losses	Eva Losses % w.r.t Total Losses
		RD 0+000 TO RD 23+400	RD 23+400 TO RD 38+900	RD 38+900 TO RD 95+900	RD 95+900 TO RD 116+900		
17-Nov	0.006	0.323	0.208	0.659	0.235	1.424	0.7
19-Nov	0.006	0.323	0.208	0.659	0.235	1.424	0.69
21-Nov	0.0119	0.646	0.415	1.317	0.47	2.848	1.38
23-Nov	0.006	0.323	0.208	0.659	0.235	1.424	0.7
25-Nov	0.006	0.323	0.208	0.659	0.235	1.424	0.76
27-Nov	0.006	0.323	0.208	0.659	0.235	1.424	0.81
29-Nov	0.006	0.323	0.208	0.659	0.235	1.424	0.69
1-Dec	0.006	0.323	0.208	0.659	0.235	1.424	0.79
3-Dec	0.006	0.323	0.208	0.659	0.235	1.424	0.72
5-Dec	0.006	0.323	0.208	0.659	0.235	1.424	0.87
7-Dec	0.006	0.323	0.208	0.659	0.235	1.424	0.92
9-Dec	0.006	0.323	0.208	0.659	0.235	1.424	0.96
11-Dec	0.006	0.323	0.208	0.659	0.235	1.424	0.82
13-Dec	0.006	0.323	0.208	0.659	0.235	1.424	0.79
Average	**0.0102**	**0.55**	**0.35**	**1.12**	**0.4**	**2.43**	**1.22**

The amount of evaporation increases with increase in temperature also humidity has an inverse effect on evaporation as with increase in humidity evaporation decreases. Wind speed and wind direction has no significant effect on evaporation.

Table 4.5 shows the detail of Water Losses in cusecs/ft x 10^3 with percentage Difference According to Average losses in each section of the canal and Average Losses rate are 1.74 in cusecs/ft x 10^3. Also the 2^{nd} section RD 23400 to 39900 shows maximum value of average loss rate 2.07 with 18.9% Difference According to Average losses.

Table 4.4: Seepage Losses in Cusecs

Date	Head Discharge (Cusecs)	Seepage Losses in Cusecs				Total losses from head to tail	Losses % w.r.t Head Discharge
		RD 0+000 TO RD 23+400	RD 23+400 TO RD 38+900	RD 38+900 TO RD 95+900	RD 95+900 TO RD 116+900		
16-Sep	1721	39.14	35.45	110.26	27.38	212.23	98.25
18-Sep	1713	43.14	29.45	94.26	40.38	207.23	98.21
20-Sep	1700	41.14	32.45	104.26	30.38	208.23	98.22
22-Sep	1411	45.14	37.45	89.26	40.38	212.23	98.25
24-Sep	1280	46.14	37.45	79.26	28.38	191.23	98.07
26-Sep	1298	39.43	35.63	88.84	36.59	200.49	98.76
28-Sep	1577	46.43	28.63	104.84	37.59	217.49	98.86
30-Sep	1721	45.14	23.45	87.26	41.38	197.23	98.12
2-Oct	1721	45.43	39.63	71.84	41.59	198.49	98.75
4-Oct	1721	39.43	29.63	104.84	38.59	212.49	98.83
6-Oct	1713	37.15	31.45	107.26	33.38	209.25	98.24
8-Oct	1605	38.43	32.63	92.84	33.59	197.49	98.75
10-Oct	1565	44.15	37.45	103.26	33.38	218.25	98.31
12-Oct	1072	34.43	27.63	73.84	29.59	165.49	98.51
14-Oct	1038	38.43	18.63	73.84	28.59	159.49	98.45
16-Oct	1729	47.08	35.41	104.13	29.33	215.96	98.16
18-Oct	1577	43.39	30.61	105.76	34.56	214.31	98.76
20-Oct	1343	40.39	34.61	97.76	29.56	202.31	98.69
3-Nov	1362	49.39	50.61	71.76	32.56	204.31	98.7
5-Nov	1541	29.39	45.61	71.76	32.56	179.31	98.52
7-Nov	1462	43.39	35.61	60.76	45.56	185.31	98.57
9-Nov	1680	42.7	39.8	73.38	29.78	185.66	99.28
11-Nov	1521	40.39	36.61	61.76	41.56	180.31	98.53
13-Nov	1525	32.39	36.61	91.76	29.56	190.31	98.61
15-Nov	1600	45.7	23.8	75.38	36.78	181.66	99.27

Date	Head Discharge (Cusecs)	Seepage Losses in Cusecs				Total losses from head to tail	Losses % w.r.t Head Discharge
		RD 0+000 TO RD 23+400	RD 23+400 TO RD 38+900	RD 38+900 TO RD 95+900	RD 95+900 TO RD 116+900		
17-Nov	1679	50.68	37.79	73.34	38.77	200.58	99.3
19-Nov	1721	48.68	37.79	70.34	48.77	205.58	99.31
21-Nov	1721	55.35	43.58	69.68	35.53	204.15	98.62
23-Nov	1721	58.68	36.79	70.34	35.77	201.58	99.30
25-Nov	1597	33.68	31.79	90.34	30.77	186.58	99.24
27-Nov	1597	27.68	21.79	90.34	34.77	174.58	99.19
29-Nov	1295	41.68	37.79	97.34	26.77	203.58	99.31
1-Dec	1638	36.68	38.79	58.34	44.77	178.58	99.21
3-Dec	1400	39.68	45.79	82.34	29.77	197.58	99.28
5-Dec	1041	38.68	35.79	59.34	28.77	162.58	99.13
7-Dec	1072	29.68	27.79	57.34	37.77	152.58	99.08
9-Dec	932	25.68	29.79	61.34	30.77	147.58	99.04
11-Dec	1214	35.68	23.79	84.34	28.77	172.58	99.18
13-Dec	1232	29.68	23.79	97.34	28.77	179.58	99.21
Average	**1489**	**40.07**	**31.8**	**88.39**	**32.88**	**193.14**	**98.78**

Table 4.5: Water Losses in cusecs/ft x 10^3 with percentage Difference According to Average losses

Date	Water losses rate in cusecs/ft x10^3 (% Difference According to Average losses)				Total losses from head to tail	Average
	RD 0+000 TO RD 23+400	RD 23+400 TO RD 39+900	RD 39+900 TO RD 95+900	RD 95+900 TO RD 116+900		
16-Sep	1.71 (-6.7)	2.32 (-26.7)	1.96 (-7.2)	1.33 (-27.2)	1.85 (-0.8)	1.83

Date	Water losses rate in cusecs/ft x10^3 (% Difference According to Average losses)				Total losses from head to tail	Average
	RD 0+000 TO RD 23+400	RD 23+400 TO RD 39+900	RD 39+900 TO RD 95+900	RD 95+900 TO RD 116+900		
18-Sep	1.88 (-0.9)	1.94 (-3.9)	1.68 (-9.6)	1.95 (-4.)8	1.8 (-3.1)	1.86
20-Sep	1.79 (-1.1)	2.13 (-17.3)	1.86 (-2.5)	1.48 (-18.7)	1.81 (0)	1.81
22-Sep	1.97 (-1.3)	2.45 -23.1	1.6 (-19.8)	1.95 (-2.0)	1.85 (-7.2)	1.99
24-Sep	2.01 (-12.8)	2.26 (-26.8)	1.47 (-17.2)	1.38 (-22.4)	1.67 (-6.3)	1.78
26-Sep	1.71 (-7.3)	2.32 (-26)	1.58 (-14.3)	1.76 (-4.4)	1.74 (-5.8)	1.84
28-Sep	2.01 (-6.4)	1.87 (-0.9)	1.86 (-1.5)	1.81 (-4.1)	1.88 (-0.3)	1.89
30-Sep	1.97 (-11.1)	1.55 (-12.5)	1.56 (-11.7)	2 -13.1	1.72 (-2.8)	1.77
2-Oct	1.97 (-4.2)	2.19 (-16.3)	1.39 (-26.5)	2 -6	1.72 (-8.8)	1.89
4-Oct	1.71 (-7.1)	1.94 (-5.2)	1.86 (-1)	1.86 (-0.9)	1.84 0	1.84
6-Oct	1.62 (-10.0)	2.06 (-14.4)	1.91 (-5.9)	1.62 (-10.3)	1.82 (-0.9)	1.8
8-Oct	1.67 (-5.6)	2.13 (-20.6)	1.65 (-6.6)	1.62 (-8.3)	1.71 (-3.1)	1.77
10-Oct	1.92 (-1.8)	2.45 (-25.1)	1.84 (-6.0)	1.62 (-17.4)	1.9 (-3.1)	1.96
12-Oct	1.5 (-1.1)	1.81 (-19.5)	1.32 (-13.0)	1.43 (-5.5)	1.44 (-4.9)	1.51
14-Oct	1.67 (-14)	1.48 (-1.5)	1.32 (-10.0)	1.38 (-5.5)	1.42 (-2.9)	1.46
16-Oct	2.05 (-7.1)	2.32 (-21.3)	1.86 (-2.9)	1.43 (-25.4)	1.88 (-1.8)	1.92
18-Oct	1.88	2	1.88	1.67	1.86	1.86

Date	Water losses rate in cusecs/ft x10^3 (% Difference According to Average losses)				Total losses from head to tail	Average
	RD 0+000 TO RD 23+400	RD 23+400 TO RD 39+900	RD 39+900 TO RD 95+900	RD 95+900 TO RD 116+900		
	(-1.3)	(-7.8)	(-1.1)	(-10.2)	0	
20-Oct	1.75	2.26	1.74	1.43	1.75	1.79
	(-2.3)	(-25.9)	(-3.2)	(-20.4)	(-2.2)	
3-Nov	1.97	2.26	1.56	1.57	1.74	1.84
	(-6.9)	(-22.8)	(-15.1)	(-14.6)	(-5.6)	
5-Nov	1.45	1.94	1.56	1.57	1.59	1.63
	(-10.9)	(-18.7)	(-4.2)	(-3.6)	(-2.4)	
7-Nov	1.88	2.32	1.26	1.43	1.56	1.72
	(-9.1)	(-34.7)	(-26.7)	(-17.1)	(-9.7)	
9-Nov	1.84	2.39	1.35	1.43	1.6	1.75
	(-4.9)	(-36.3)	(-22.9)	(-18.4)	(-8.6)	
11-Nov	1.75	2.39	1.16	1.86	1.57	1.79
	(-2.0)	-33.5	(-35.3)	(-3.8)	(-12.5)	
13-Nov	1.41	2.39	1.63	1.43	1.65	1.71
	(-17.7)	(-39.2)	(-4.8)	(-16.7)	(-3.7)	
15-Nov	1.97	1.55	1.33	1.76	1.57	1.65
	(-19)	(-6.3)	(-19.3)	-6.6	(-5.3)	
17-Nov	1.97	2.45	1.3	1.86	1.69	1.89
	(-3.8)	(-29.5)	(-31.4)	(-1.9)	(-11.0)	
19-Nov	1.62	2.19	1.72	1.52	1.73	1.77
	(-8.0)	(-24.3)	(-2.6)	(-13.7)	(-2.1)	
21-Nov	1.79	2.45	1.6	1.71	1.77	1.89
	(-5.0)	(-29.8)	(-15.5)	(-9.3)	(-6.3)	
23-Nov	1.97	2.45	1.42	1.71	1.72	1.89
	(-4.1)	(-29.8)	(-24.7)	(-9.2)	(-8.9)	
25-Nov	1.45	2.06	1.6	1.48	1.61	1.65
	(-11.8)	(-25.3)	(-3.1)	(-10.4)	(-2.4)	
27-Nov	1.2	1.42	1.6	1.67	1.51	1.47
	(-18.6)	(-3.4)	(-8.6)	(-13.4)	(-2.4)	
29-Nov	1.79	2.06	1.72	1.29	1.7	1.72
	(-4.6)	(-20.3)	(0)	(-25.1)	(-0.8)	

Date	Water losses rate in cusecs/ft x10^3 (% Difference According to Average losses)				Total losses from head to tail	Average
	RD 0+000 TO RD 23+400	**RD 23+400 TO RD 39+900**	**RD 39+900 TO RD 95+900**	**RD 95+900 TO RD 116+900**		
1-Dec	1.58 (-4.2)	2.13 (-29)	1.37 (-17.1)	1.52 (-7.7)	1.54 (-6.7)	1.65
3-Dec	1.71 (-1.1)	2.19 (-27.0)	1.58 (-8.6)	1.43 (-17.3)	1.66 (-3.9)	1.73
5-Dec	1.67 (-4.7)	1.94 (-21.6)	1.39 (-13.0)	1.38 (-13.3)	1.51 (-4.9)	1.59
7-Dec	1.58 (-5.4)	1.81 (-20.4)	1.28 (-14.6)	1.33 (-11.1)	1.42 (-5.4)	1.5
9-Dec	1.5 (-1.8)	1.94 (-27.1)	1.28 (-15.9)	1.38 (-9.3)	1.43 (-6.2)	1.52
11-Dec	1.54 (-3.3)	1.55 (-3.9)	1.49 (0)	1.38 (-7.3)	1.49 (0)	1.49
13-Dec	1.28 (-13.5)	1.55 -4.4	1.72 -16	1.38 (-6.9)	1.55 (-4.4)	1.48
Average	**1.74 (-0.4)**	**2.07 -18.9**	**1.57 (-9.6)**	**1.58 (-8.9)**	**1.67 (-3.9)**	**1.74**

4.3 Summary

The data of total water losses, seepage losses and evaporation losses of each section of the canal are analyzed and discussed in this chapter. The results predict average 13.38% water losses with respect to the total discharge of the canal which has an average amount of 196 cusecs. The average contribution of evaporation losses is 1.22% of total losses in canal.

Chapter 5

Conclusions And Recommendations

5.1 Conclusions

The case study, conducted for an earthen canal in district Bahawalnager aims at finding the water losses in unlined canal. Inflow outflow method is applied to determine water losses by splitting the canal in four sections. The difference in inflow and outflow discharge gives the amount of water lost during conveyance process and also indicates the efficiency of the channel. The results of the study highlight the need of safety precautions to avoid water losses and to meet water needs in irrigation sector.

The usual values of water conveyance loss in the study area canal were higher than the provision of extra discharge in design. The surplus in conveyance loss demonstrate that there is no proper restoration work, was accompanied on conveyance canal during land consolidation, maintenance and repair work done are not done by the Punjab Irrigation which is the major reason for this increased water loss situation. Furthermore this study may help the Punjab Irrigation Department to nominate the critical sections of the canal and to carry rehabilitation work on priority bases.

Seepage and evaporation losses occurring in canal cause deficiency in water supply to fields especially at the tail of the canal and causes huge financial problems. In order to avoid such difficulties, certain actions should be taken. The results predict an overall 13.38% water losses with respect to the total discharge of the canal which has an average amount of 196 cusecs. Average evaporation Losses percentage with respect to total losses is 1.22%.

5.2 Benefits of Study

Inflow outflow method is preferably applicable method for evaluating water losses in canals. The study provides a guide for similar studies in study area as there are no proper prior studies about water losses in the relevant study area. The alarming condition of water losses may urge stake-holders to take necessary steps to overcome these losses. Thus, the concerned officials can securely use the results for future water budgeting and planning. The same idea can also be functional in other parts of the country.

5.3 Future Recommendations

Losses can be mitigated by proper renovation work of the canal and there should be no obstruction in the canal or algae which may decrease the velocity of flow, so that seepage and water losses can be decreased at maximum possible level. The application of suitable technical measures is crucial to decrease water conveyance loss in the network. For this reason, the following actions may be recommended as a start:

1. Install lining at sections where seepage losses are prominent.
2. Grow proper plants on both sides of canal which may shelter the canal against evaporation losses as the temperature of the region is high for a long portion of year.

3. Some more accurate future technique should be adopted to determine more appropriate results for water losses.

Bibliography

[1] Qureshi, Asad Sarwar. (2011). Water Management in the Indus Basin in Pakistan: Challenges and Opportunities. Mountain Research and Development 31 (3), 25260.

[2] Sufi, A.B., Hussain, Z., Sultan, J.S., & Tariq, I. (2011). Integrated water resource development in Pakistan. WRM Publications, WAPDA, Lahore.

[3] DROUGHT ALERT, (2018) National Drought Monitoring Centre Pakistan Meteorological Department

[4] Roshni Patel & Sanhal Patel, (2016). Water Losses in Canal Networking (Narmada Canal Section Near Gandhinagar-Ahmedabad. International Journal of Science Technology & Engineering, 2349-784X.

[5] Ashfaque A. Memon et al. (2013). Design and Evaluation of Dadu Canal Lining for Sustainable Water Saving Journal of Water Resource and Protection, 5,689-698.

[6] Alam, M. M. and Bhutta, M. N. (2004). Comparative evaluation of canal seepage investigation techniques. Agricultural Water Management, 66(1), 65-76.

[7] Kahlown, M. A. & Kemper, W. D. (2004). Reducing water losses from channels using linings: Cost and benefits in Pakistan. Agricultural Water Management, 74, 57-76.

[8] Ahuchaogu, et al. (2015). Evaluation of Seepage Losses in Earthen Lined Canal. International Journal of Engineering Sciences & Management Research, ISSN: 2349-6193.

[9] Sayed A., and Hossain M. A. (2014). Impact of Lined Canal on Shallow Tube-well Irrigation and Their Acceptability by the Farmers. A Scientific Journal of Krishi Foundation. The Agriculturists 12(2): 116-125(2014)

[10] Saha, B. (2015). A critical study of water loss in canals and its reduction measure. International Journal of engineering research and application, 5(3), 53-56.

[11] Jadhav P. B., et al. (2014). Conveyance Efficiency Improvement through Canal Lining and Yield Increment By Adopting Drip Irrigation in Command Area. International Journal of Innovative Research in Science, Engineering and Technology. 2319 8753.

[12] Irrigation Research Institute, (1992). Studies on water losses from water-courses and their lining measures. Lahore, Pakistan.

[13] Brockway and Worstell, (1968). Field Evaluation of Seepage Measurement Methods. In Proceedings of the Second Seepage Symposium 121-127. Phoenix, Arizona: USDA, Agricultural Research Services.

[14] Awan, M. et al. (1978). Watercourse cleaning and maintenance program Annual report, CSU, 394-426.

[15] Planning & Development, (1988). Report on water losses. Technical committee, Lahore, Pakistan.

[16] Kraatz, D. B. (1977). Irrigation Canal Lining. Rome New York: Food and Agriculture Organization of the United Nations.

[17] Dhillon, G. S. (1967). Estimation of Seepage Losses from Lined Channels. Indian Journal of Power and River Valley Development, 17, 16-20.

[18] Akkuzu, E. (2012). Usefulness of Empirical Equations in Assessing Canal Losses through Seepage in Concrete-Lined Canal. Journal of Irrigation and Drainage, 138, 455-460.

[19] Arshad, et al. (2009). Comparison of Water Losses Between Unlined and Lined Watercourses in Indus Basin of Pakistan. Pakistan Journal Agricultural Science, 46(2), 280-284.