INVESTIGATION STUDY TO MEASURE SEEPAGE LOSSES BETWEEN MASITAWALI (HANUMANGARH) HEAD TO BRIDHWAL HEAD (SHRI GANGA NAGAR) AT A LIMITED SECTION OF INDIRA GANDHI NAHAR PROJECT

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Abstract—The preservation of irrigation water is often of primary importance to the agriculture development of a country. The reduction or eliminate of seepage losses in irrigation canals by means of linings assures better utilization of the conveyed water and an improved economic situation, seepage losses from earthen irrigation channels depend on a number of factors and vary from (30 to 50) percent of the discharge available at the head of an irrigation system. The main focus of the study was to determine the seepage losses through lined canal. The studies on estimation and measurement of seepage losses were of much interest to the irrigation scientist. The research workers have done lot of work on the seepage aspect of the irrigation water management. The main objective of this investigation study is to measure seepage losses between Masitawali (Hanumangarh) head to Bridhwal head (Shri Ganga Nagar), to determine the rate of conveyance losses at a limited section of Indira Gandhi Nahar Project, the comparison of measurement of water losses with inflow-outflow and ponding method, to check out the conveyance efficiency of earthen watercourse and to determine the total quantity of water lost from earthen water course with seepage alone.

Index Terms—Conveyance Losses, Evaporation Data, Indira Gandhi Nahar Project, Seepage Losses

I. INTRODUCTION

Water is one of the most valuable natural resources in the world. With the increase of population, the development and management of water resources have become essential for sustainable use of water resources for domestic, industrial and irrigation purpose throughout the world. Conservation of water supplies is becoming increasingly important as the demand continues to increase and new sources of supply became harder to find. The time is rapidly approaching when the only additional water supplies available will be the saving from those now being lost through canal seepage and field losses. The Principles of conservation require that full use be made of our water supplies, and the greatest results probably can be accomplished on most irrigation projects by a reduction of seepage from canals up to the farmer's fields. An open channel may be lined or unlined section. Unlined channels lose a substantial part of the usable water through the seepage. Seepage loss results not in depleted freshwater resources but also causes water logging, salinization, and ground water contamination. Canals are lined for slowing the seepage loss. A perfect lining would prevent all the seepage loss, but canal lining deteriorates with time. Cracks in the lining may develop anywhere on the perimeter of the canal due to settlement of the subgrade, weed growth in the canal, construction defects and use of inferior quality lining materials, weathering, etc.

Seepage from canals occurs due to a combined effect of gravitational force and water tension gradients (Hansen et al. 1980). When the water is first turned into a dry canal, the force of water tension is usually greater than that of gravity, but as the soil approaches saturation, these forces reverse in importance. This high initial loss rate soon decreases and is governed mainly by the percolation of water through the voids in the soil forming the canal bed and banks, and seepage rates eventually stabilize. The key factor affecting seepage is the depth of water in the canal. If the groundwater level is above the design water surface of the canal, water will seep into the canal.

On the other hand, if the groundwater level is below the water surface of the canal then water in the canal will continue to seep out of canal until the groundwater level reaches equilibrium with the canal. Canals are lined to control the seepage. But canal lining deteriorates with time and hence, significant amount of seepage losses continue to occur from a lined canal. Therefore, seepage loss must be considered in the design of a canal section. Providing perfect lining can prevent seepage loss from canals, but cracks in lining develop due to several reasons and performance of canal lining deteriorates with time. In the present study studied the seepage losses through channel lining materials is calculated.

Seepage is the downward lateral movement of water into soil or substrata from a source of supply such as reservoir or irrigation canal. Seepage losses depend up on the time for which the channel runs type of soil i.e. capacity of soil to conduct water, wetted perimeter, length of channel, operation policies and methods of construction and embankment material, Atmospheric temperature, microbial activity, type of lining growth of aquatic weeds etc.

The loss of water due to percolation seriously affects surface irrigation. The seriousness of such loss is keenly felt in arid and semi-arid region where the demand for water far exceeds the availability. Different research workers reported the loss and estimated that on an average seepage losses were 15 to 20 percent in conveyance. Because of excessive seepage losses there is substantial gap between irrigation potential and its utilization. Excessive seepage losses contribute to water logging of lands and salt and alkali concentration in soils. These constitute a serious economic waste and are also associated with problems of leaching of nutrients. Aeration in agricultural fields which deteriorates soil and lead to lower crop productivity. It is common observation that the major seepage losses occur in the field where the channels are not properly lined. lining irrigation canals is the simplest and most effective method of saving both water and land in irrigated area. Although costly it is likely to be cheaper than developing additional water. Irrigation canals are lined for the purpose of decreasing the conveyance and seepage losses by providing safety against branches, Preventing weed growth, retarding moss growth, decreasing the capacity to convey water.

Total loss in the watercourse is taken as criterion for deciding on the lining. Importance of lining channels has been in context overall storage of water resources. It has been estimated that due to lining the area under irrigation may be increased by 20 per cent.

Prevention of seepage losses from field channels will enable the farmers to irrigate more area and to avoid severe water logging problems. In order to induce farmers to line the field channels the information about various lining material in respect of their relative effectiveness and economics is required to be made available to the farmers.

Factor Affecting the Seepage Loss

Many factors can affect seepage and total water losses in canals. Documenting and recording these factors can help in selecting canals.

- Soil type - texture, compaction and permeability (or infiltration rate).
- Type and condition of lining material - permeability, condition (size and number of cracks), erosion, construction methods etc.
- Control structures - leaks through wooden gates and rusty or broken steel valves.
- Wildlife - holes and erosion caused by animal traffic and rodents.
- Shallow groundwater table - depth to groundwater.
- Sedimentation - Silting can help seal the canal bottom, but breaking the silt seal on unlined canals during reshaping and routine maintenance increases seepage.
- Evaporation - temperature, wind speed, relative humidity, wind blocks and sun shine hours etc.
- Trees and plants - Roots can crack a canal lining and create holes through canal levees. Plant transpiration accounts for some loss.
- Routine maintenance - Cleaning out and reshaping unlined canals can often break the seal caused by sedimentation. Heavy machinery used to clean out lined canals can crack the concrete.
- Length of time the canal has been in operation before testing - level of saturation and absorption of water into canal walls.
- Depth of water in canal - Generally, if the higher the water level, then higher the losses.

Keeping in view the practicability, the losses through lined IGNP Canal under the command area of Hanumangarh and Shri Ganga Nagar project was undertaken with following objectives.

II. INVESTIGATION DATA & METHODOLOGY

Study Area

Rajasthan the second largest state of India, located in the north- west of Indian union, lying between 69.30 to 84.17East and latitude 23.03 to 30.12 north. Rajasthan state has land potential of 34.23 million ha. Out of which 27.65 million ha is cultivable. Only 3.72 million ha is irrigated that is about 13.34% of cultivable area, enjoys the benefit of assured irrigation. Land generally lie fallow due to non-availability of water in the form of rain or irrigation. With limited water resources including interstate share, the ultimate irrigation potential in the state would be 5.15million hectare. Indira Gandhi Nahar project is one of the most ambitious and gigantic project of the world aiming at transforming vast desert land of western Rajasthan into granary by utilizing surplus Ravi-Beas water. It is brought out that under interstate agreement 1981 between Punjab, Haryana and Rajasthan, 8.60 MAF Ravi-Beas water has been allocated to the state of Rajasthan out of which 7.59MFA water has been proposed to be utilized in Indira Gandhi Nahar project. A Canal network for utilizing 7.59MFA surplus of Ravi-Beas water planned by constructing a head works at the influence of Beas-Sutlej River at Harike presently known as Harike Head Works.

The Indira Gandhi Nahar project originally known as Rajasthan canal project is a very typical multipurpose project. With aim of providing irrigation facility and drinking water to the area located in the districts of Shri Ganga Nagar and Hanumangarh, churu, Bikaner, Jodhpur, Jaisalmer, Barmer and to provide drinking water to en-route cities, town and villages. The Indira Gandhi Nahar project was started in 1958 and envisages to provide irrigation facilities to about two million hectare of land with annual irrigation to about 15.17lac.ha due to acquisition of land by army in Shahgarh Manoeuvres range and Desert National Park, the net CCA has reduced to 18.78lac.ha. Through final phase are still under construction, the actual (maximum) irrigation achieved from the project is 9.80lac.ha. i.e. about 60% of envisaged irrigation, giving annual production of food grain worth Rs. 17.50 billion. The Indira Gandhi Nahar covers a total distance of 649km from its origin point. i.e. Harike barrage to tail, located near Mohangarh in Jaislamer district. The work of Indira Gandhi feeder and main canal has already been completed. For purpose of administrative convenience the project has been divided into two parts.

Stage-I: - The work on Indira Gandhi Nahar project stage-I was taken up in 1958 and the work of stage-I was almost completed by March, 1992.

Stage-II: - The work on Indira Gandhi Nahar project stage –II was taken up in 1972 and separate project estimate of stage-II was finalized and approved by central water commission during 1970 with estimated cost of Rs. 89.12 crore for a CCA of 6.08 lac.ha the project estimates for stage-II has been revised from time to time due to inclusion of six number new lift scheme which changed the scope of project. The latest revised and approved estimate by the central water commission is for Rs. 2267.00 crore at 1993 price level with a CCA of 13.16 lac.ha. The CCA of stage –II has been further increased to 14.10 lac.ha. During 1997 due to inclusion of 0.94lac.ha. Area under Sahwa lift canal. Subsequently, due to acquisition of land by army in Shahgarh Manoeuvres Range and Desert National Park, the net CCA of stage-II has reduced to 13.32lac.ha.The salient features of the Indira Gandhi Nahar Project is given here under:-

Table 1 Silent Feature of IGNP

S.N.	ITEM	UNIT	STAGE-I	STAGE-II	DEDUCT FOR SHAHGARH	TOTAL
A	CANAL WORKS					
1	CCA					
(a)	Under flow	000 ha	484	873	78	1279
(b)	Under lift	000 ha	62	537	-	599
2	Irrigation Potential	000 ha	553	964	62	1455
3	Canal					
(a)	Feeder	km	204	-	-	204
(b)	Main Canal	km	189	296	-	445
B	CAD WORKS					
1	Water course lining	000 ha	546	1410	78	1878
2	Roads	km	1066	1177	-	2243
3	Sanitary doggies	Nos.	314	533	-	817

(Source: IGNP Regulation Dept).

Rainfall

There is a great variation in rainfall from year to year and that too is very unevenly disturbed. The average rainfall in the area of Sri Ganga Nagar and hanumangarh districts varies from 200 to 300mm. the general trend of isohytal line during rainy season, is from north-east to south west. The rainfall occurs mainly during south west monsoon season (July- September) which commence in 1st week of July. The number of rainy days varies from 16 to 18 in Sri Ganga Nagar. The daily intensity of rainfall also varies and up to 250 mm per day has occurred in Sri Ganga Nagar.

Temperature

The hottest months are from April to September with the peak temperature being mostly in the month of May when the mean maximum temperature varies from 41.5 to 42.0 C. the mean minimum temperature is normally recorded in the month of January and varies from 4.7 to 7.9C

Relative humidity

The relative humidity during the monsoon months is high. It is highest in the month of august. Which is wettest month. Humidity in winter is moderately law.

Wind

The general wind direction in the region is south-west. The wind speed remains highest in Jaisalmer. Maximum number of dust storms occurs in June. Due to poor rainfall, humidity, in this area is extremely low.

Evapotranspiration

The mean annual potential evapotranspiration in Sri Ganga Nagar and Hanumangarh is 1622.2mm. The peak evapotranspiration in the month of June.

Population

The population in the command area especially stage-II of Indira Gandhi Nahar Project is 45,207(1971 census) giving an overall density of 3 persons per seq. km. the overall density of population of Rajasthan is 75 and that of India is 173 persons per sq.km. The density of lift areas (except Sahwa) is 24 people per sq.km. And lift area is better populated when compared with flow area.

Geology

Sand stone, shales and lime stone crop out from the beneath the sand, Gypsum is found in patched at many place.

IGNP Data

The primary objective of the present work is to analyze the seepage loss from IGNP Canal between "Masitawali Head (Hanumangarh) and Bridhwal Head (Shri Ganga Nagar)". It also analyses the seepage & evaporation losses monthly variations. The five year IGNP daily discharge data (2010-2015) has been used for the study which has been taken from IGNP Regulation Department Hanumangarh district of Rajasthan. Details of the data, its properties and pre-processing of monthly discharge have been studied.

Evaporation Data

The evaporation losses have been calculated by the "CROPWAT". CROPWAT 8.0 for Windows is a computer program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data. In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. CROPWAT 8.0 can also be used to evaluate farmers' irrigation practices and to estimate crop performance under both rain fed and irrigated conditions. All calculation procedures used in CROPWAT 8.0 are based on the two FAO publications of the Irrigation and Drainage Series, namely, No. 56 "Crop Evapotranspiration - Guidelines for computing crop water requirements" and No. 33 titled "Yield response to water". CROPWAT 8.0 is a Windows program based on the previous DOS versions. Apart from a completely redesigned user interface, CROPWAT 8.0 for Windows includes a host of updated and new features, including:

- Monthly, decade and daily input of climatic data for calculation of reference evapotranspiration (ETo).
- Backward compatibility to allow use of data from CLIMWAT database.
- Possibility to estimate climatic data in the absence of measured values.
- Decade and daily calculation of crop water requirements based on updated calculation algorithms including adjustment of crop-coefficient values.
- Calculation of crop water requirements and irrigation scheduling for paddy & upland rice, using a newly developed procedure to calculate water requirements including the land preparation period.
- Interactive user adjustable irrigation schedules.
- Daily soil water balance output tables.
- Easy saving and retrieval of sessions and of user-defined irrigation schedules.
- Graphical presentations of input data, crop water requirements and irrigation schedules.
- Easy import/export of data and graphics through clipboard or ASCII text files.
- Extensive printing routines, supporting all windows-based printers.

For calculation of evaporation by the CROPWAT 8.0, the different parameters are used like minimum temperature, maximum temperature, wind speed, relative humidity 7sunshine hours. These data download from site of "The National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR)". This website allows to download daily CFSR data (precipitation, wind, relative humidity, and solar) in SWAT file format for a given location and time period. The evaporation data of five year (2010- 2014) are studied.

Methodology

Seepage is the most dominant processes by which water is lost in the canal. Thus, for the effective operational planning and management of an irrigation system, a dependable forecasting of the seepage is very important. Seepage rates are obtainable either by direct measurement or by estimation. The exact analysis of seepage loss from the canals is quite complex. The following methods to measure the seepage from canals:

(1) Inflow-outflow method
(2) Ponding method
(3) Constant and variable head permeameters
(4) Seepage meter

In the present study simple water budget equation (Inflow- Outflow) were adopted to calculate the seepage loss from IGNP Main Canal. The inflow outflow method involves the measuring of the flow into a certain section, and the flow out of the section, the difference representing the losses by seepage after subtraction of evaporation.

The daily discharge at different- different head is measured by instrument is called skada. It gives the discharge reading in cubic feet per second. We have used this method for measuring the seepage losses. This method involves measuring the amount of water flows into a channel at inlet of the section and amount which flows out at the tail and amount of water flow into the distributaries and evaporation losses. The loss is the difference between inflow and outflow.

The seepage loss is calculate by following equation-

$Q_s = Q_i - Q_o - Q_e$

Where:-

Q_s = seepage loss in cumecs (m^3/s)

Q_i = Inflow discharge in cumecs (m^3/s)

Q_e = Evaporation losses in cumecs (m^3/s)

Q_o = Outflow discharge in cumecs (m^3/s)

This equation uses the principles of conservation of mass. All the variables in the budgets were measured except seepage, which was computed as a residual. Seepage rates were computed for as many different stages as possible. In water budget equation discharge is in cumecs, which is calculated from the daily gauge reading which is in cubic feet per second.

Q (cumecs) = Q (feet^3/s) / 0.0283

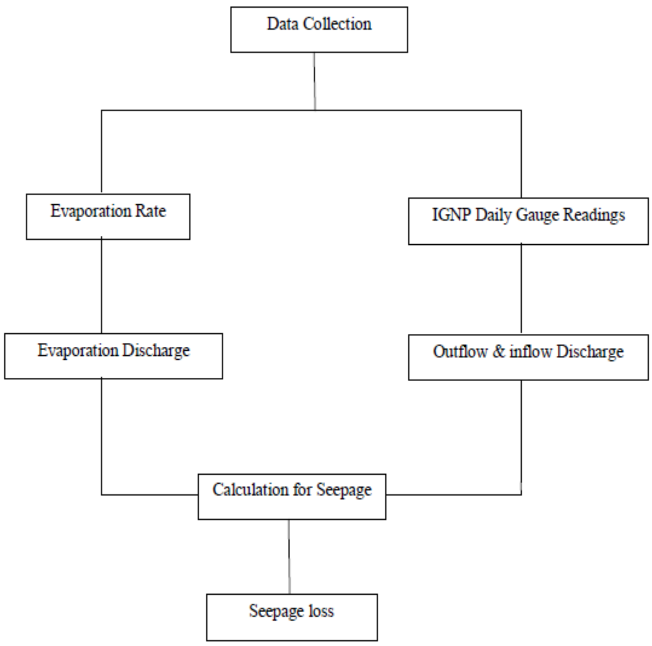
The evaporation rate is calculated from the CROPWAT 8.0. This is in mm per day.

Actually CROPWAT 8.0 is used for calculation of evapotranspiration but in present study we assume evapotranspiration as evaporation because there is very small difference between evapotranspiration & evaporation.

Q_e = (Evaporation rate) x Canal area

In the present study for the analysis of seepage the length of the Indira Gandhi Main Canal is taken 73km. and the width of the canal is changed at Lakhuwali Head (Hanumangarh) 40 to 37m. Total surface area of the IGNP between Masitawali Head and Bridhwal head is 2764000m^2.

Flow Chart



III. RESULTS AND DISCUSSION

Prevention of seepage losses from field channels will enable the farmers to irrigate more area and to avoid severe water logging problems. In order to induce farmers to line the field channels the information about various lining material in respect of their relative effectiveness and economics is required to be made available to the farmers.

Canals are lined to control the seepage. But canal lining deteriorates with time and hence, significant seepage losses continue to occur from a lined canal. Therefore, seepage loss must be considered in the design of a canal section. Providing perfect lining can prevent seepage loss from canals, but cracks in lining develop due to several reasons and performance of canal lining deteriorates with time. In this study studied the seepage losses through channel lining materials is calculated. When the water is first turned into a dry canal, the force of water tension is usually greater than that of gravity, but as the soil approaches saturation, these forces reverse in importance. This high initial loss rate soon decreases and is governed mainly by the percolation of water through the voids in the soil forming the canal bed and banks, and seepage rates eventually stabilize. The key factor affecting seepage is the depth of water in the canal. If the groundwater level is above the design water surface of the canal, water will seep into the canal. On the other hand, if the groundwater level is below the water surface of the canal, water in the canal will continue to seep out of the canal until the groundwater level reaches equilibrium with the canal.

The seepage losses through selected sections of lined canal and was measured by adopting the water budget equation. The present chapter includes the data collected. Their analysis and interpretation in light with the literature reviewed. Present study indicates that the average seepage through the IGNP canal section between Masitawali head and Bridhwal head is 11.785 Cumecs or 6.163%. The evaporation losses varying between 0.110 cumec and 0.392 cumec in 2010 to 2014 in Hanumangarh and Sri ganga nagar

The results are shown in tables as below:-

Table: 2 Monthly evaporation & Seepage losses (2010)

S.N.	Date	Evaporation (Cumec)	ET_0 Mm/day	Seepage (Cumec)	Seepage %
1	January 10	0.1182	3.5	7.1419	3.86
2	February 10	0.1618	4.79	8.5824	4.63
3	March 10	0.213	6.33	13.50	6.42
4	April 10	0.278	8.23	6.747	8.18
5	May 10	0.223	9.59	5.768	4.54
6	June 10	0.392	12.26	13.751	8.44
7	July 10	0.316	9.89	15.596	7.08
8	August 10	0.238	7.45	10.037	5.16
9	September 10	0.261	8.15	9.6	4.48
10	October 10	0.193	6.03	7.648	5.00
11	November 10	0.148	4.40	14.28	8.09
12	December 10	0.130	4.06	5.762	3.35

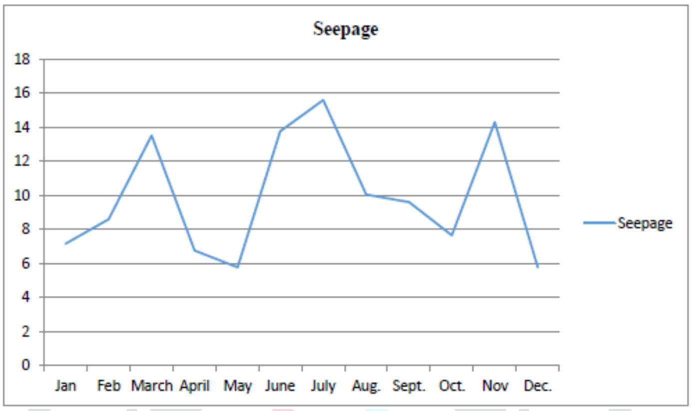


Figure: 1 Monthly variation of seepage (2010)

Table: 3 Monthly evaporation & Seepage losses (2011)

S.N.	Date	Evaporation (Cumec)	ET_0 Mm/day	Seepage (Cumec)	Seepage %
1	January 11	0.110	3.28	13.257	7.32
2	February 11	0.1429	4.23	22.443	9.55
3	March 11	0.226	6.70	13.50	6.42
4	April 11	0.229	8.86	6.747	8.18
5	May 11	0.355	10.53	7.97	7.84
6	June 11	0.348	10.31	7.418	4.11
7	July 11	0.284	8.42	23.46	9.76
8	August 11	0.209	6.19	9.187	4.08
9	September 11	0.189	5.60	17.478	7.10
10	October 11	0.219	6.48	15.256	6.40
11	November 11	0.177	5.26	23.569	8.60
12	December 11	0.138	4.11	13.859	5.62

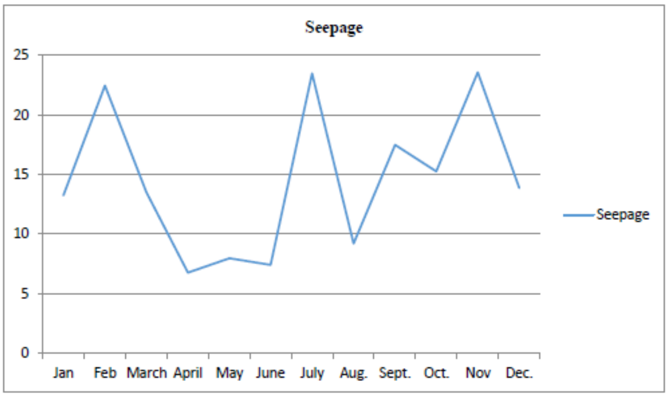


Figure: 2 Monthly variation of seepage (2011)

Table: 4 Monthly evaporation & Seepage losses (2012)

S.N.	Date	Evaporation (Cumec)	ET_0 Mm/day	Seepage (Cumec)	Seepage %
1	January 12	0.125	3.71	8.078	4.02
2	February 12	0.160	4.74	10.744	5.65
3	March 12	0.261	7.73	13.50	6.42
4	April 12	0.272	8.06	6.747	8.18
5	May 12	0.351	10.41	6.115	4.29
6	June 12	0.377	11.18	7.418	4.11
7	July 12	0.353	10.47	23.46	9.76
8	August 12	0.254	7.54	9.187	4.08
9	September 12	0.265	7.85	17.478	7.10
10	October 12	0.220	6.53	15.256	6.4
11	November 12	0.148	4.40	14.28	8.09
12	December 12	0.128	3.81	5.895	3.44

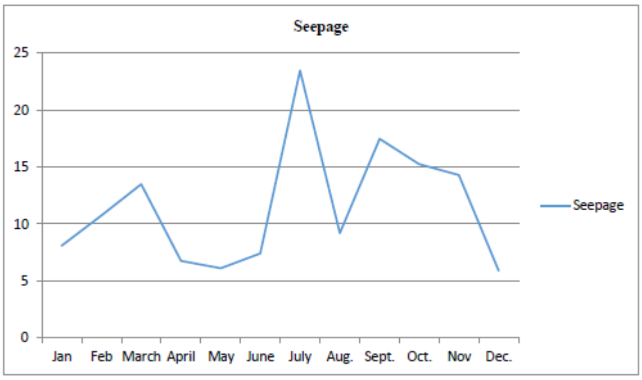


Figure: 3 Monthly variation of seepage (2012)

Table: 5 Monthly evaporation & Seepage losses (2013)

S.N.	Date	Evaporation (Cumec)	ET_0 Mm/day	Seepage (Cumec)	Seepage %
1	January 13	0.121	3.6	4.275	2.56
2	February 13	0.134	3.98	20.837	8.83
3	March 13	0.213	6.33	13.50	6.42
4	April 13	0.278	8.23	6.747	8.18
5	May 13	0.380	11.25	7.97	7.84
6	June 13	0.387	11.48	7.418	4.11
7	July 13	0.324	9.59	23.46	9.76
8	August 13	0.252	7.47	9.187	4.08
9	September 13	0.275	8.15	17.478	7.10
10	October 13	0.203	6.03	15.256	6.4
11	November 13	0.156	4.64	23.569	8.61
12	December 13	0.138	4.09	13.859	5.64

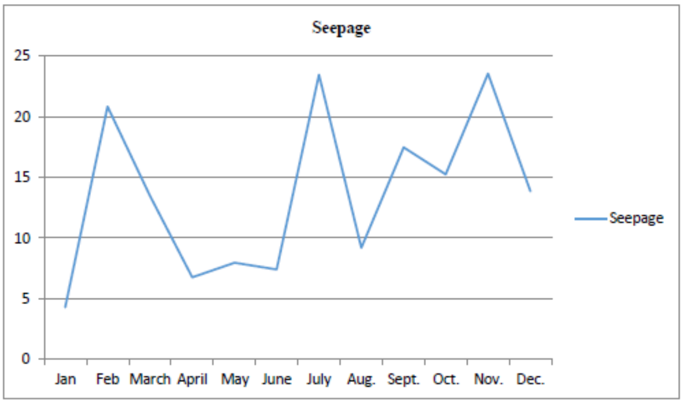


Figure: 4 Monthly variation of seepage (2013)

Table: 6 Monthly evaporation & Seepage losses (2014)

S.N.	Date	Evaporation (Cumec)	ET_0 Mm/day	Seepage (Cumec)	Seepage %
1	January 14	0.1182	3.5	7.1419	3.86
2	February 14	0.1618	4.79	8.5824	4.63
3	March 14	0.2173	6.43	17.019	6.82
4	April 14	0.2889	8.55	7.195	7.34
5	May 14	0.223	9.59	5.768	4.54
6	June 14	0.392	12.26	13.751	8.44
7	July 14	0.316	9.89	15.596	7.08
8	August 14	0.238	7.45	10.037	5.16
9	September 14	0.261	8.15	9.6	4.48
10	October 14	0.193	6.03	7.648	5.00
11	November 14	0.148	4.64	6.88	3.85
12	December 14	0.13	4.06	5.762	3.35

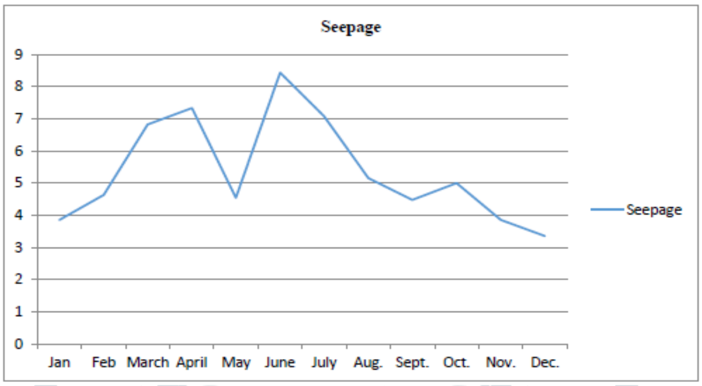


Figure: 5 Monthly variation of seepage (2014)

IV. Conclusions

As the lining is to be provided on existing canal which is unlined canal, the velocity of water in the canal will increase as the surface of the canal will be smooth due to rugosity coefficient is improved. This will increase the discharge carrying capacity of the existing canals. As a result of proposed lining of the canal, seepage losses, water logging, silting and maintenance cost of canal can be significantly decreased. Whatever quantity of water saved can be used for irrigation. Average seepage losses in Brick lined canal is 6.16%.

Followings conclusion could be drawn from the findings of the present study:

1. Maximum seepage loss was found to be 23.46 cumec and minimum seepage loss was found to be 4.275 cumec in section of IGNP canal from 2010 to2014.
2. Average seepage losses between Masitawalihead and bridhwal head from 2010 to 2014 are 11.785 cumec.
3. Average evaporation loss was found to be 0.251 cumec in 2010 to 2014.

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