Freshwater Cultivation by Continuous Flushing of River Water through Elephant Pass Lagoon to Vadamarachchi Lagoon in Northern Sri Lanka

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Abstract— Elephant pass lagoon which is located between the mainland and the Jaffna peninsula is fed by the larger catchment. Sea water intrusion caused the lagoon water more brackish. *Further ground water quality in Jaffna peninsula is getting worse due to the high contamination of nitrates, bacteria-coliforms and oil. Posibility of converting the lagoon water to fresh water lake can be an alternative solution to reduce the water demand of pipe born water in the current situation in northern Sri Lanka. It can improve the agricultural land and reduce the salinity around the periphery of lagoons, presently abandoned due to salinity. This study is being carried out to analyze the water balance in Elephant pass lagoon and study the possibility of flushing the vadamarachchi lagoon by the excess water in elephant lagoon. Numerical rainfall runoff model was developed and the results were analyzed by changing the crest level in eastern spill crest of elephant pass lagoon and sill level of the northern outlet of elephant lagoon to take water to Mandalai canal to flush saline water of vadamarachchi lagoon. Preliminary study indicate water availability but the insufficient driving head in "mandalai" canal to take excess water from elephant pass lagoon to vadamarachchi lagoon. Alternate possibilities are being studied by changing the crest level of eastern spill crest and sill of northern outlet of elephant pass lagoon.*

Index Terms— Elephant pass lagoon, Rainfall-Runoff model, Salinity, Brackish water, Vadamarachchi lagoon, Mandalai canal.

1 INTRODUCTION

One of the uprising problem in the world is sustainably managing the limited amount of fresh water sources. Failure in managing these freshwater sources adversely affects the country's economy and the society living nearby it. When there is a lack of freshwater sources, cultivating fresh water from water bodies such as lagoons will be a promising one. Jaffna peninsula is surrounded by sea on all 3 sides. Limestone aquifers has been used for all the water needs of Jaffna peninsula. Increasing extraction of water from the aquifer resulted in breeching of sea water into the aquifer. So recharging these aquifers plays an important role. Recharging is done through percolation of rainfall only. So when recharge from rainfall decreases the salinity of the underground reservoirs seems to be increased. Recharging the ground water reservoirs and protecting them from salt water intrusion are important for Jaffna peninsula. Jaffna peninsula has two internal lagoons namely Vadamaradchy and Upparu. External lagoon is the Elephant pass lagoon and it separates the peninsula from main land. Elephant pass lagoon which has a catchment area of 940km². Elephant Pass lagoon is fed by the larger catchment in the main land and receives much more supply of water. The construction of Elephant Pass lagoon scheme commenced in the year 1962 with the construction of a bund cum spill across the east at Chundikulam and another bund in the west at A9 highway to seal the entry of sea water into the lagoon. A map showing Elephant pass lagoon and Jaffna lagoons are shown in Fig 1.1. Constructing barrages and flushing out the salinity of the lagoons repeatedly over a period of years with fresh water runoff needs a plentiful supply of rain water and it will require over years to washout the salt that deposited in lagoon bed. In addition to this if the catchment area draining into the lagoon is limited then the flushing out will be a more slow process. Elephant pass lagoon has a larger catchment area and receives more supply of water. Table 1.1 shows the river basins and reservoirs from which the inflow to the Elephant pass lagoon is considered.

Water balance calculation done by Irrigation Departmeny, they consider spill crest level at 1 m & 1.2 m MSL. This crest level was proposed by the irrigation department studies in 1976. Unfortunately due to natural phenomena the constructed bund was collapsed. The bund was constructed without correctly observing the behavioral patterns of the Indian

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International Journal of Scientific & Engineering Research, Volume 8, Issue 2, February-2017 706
ISSN 2229-5518

Ocean. Later due to civil war and other internal problems there was no further development in reconstructing the eastern bund. Due to this collapse, the water turned more brackish because of the sea water intrusion. This intrusion affected the nearby agricultural lands and wells. Agricultural lands were turned to barren lands and well waters became saline. While the seasonal rainfall exhibits a definite rhythmic pattern, there is a considerable variation in it from year to year. This variability of rainfall has always been a major hazard for agricultural development. At the end of the month of August, water table is generally at the lowest and the salinity of water at its highest.

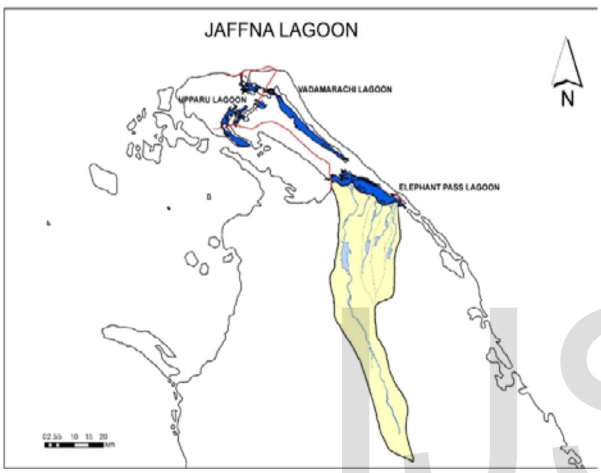

Figure: 1.1 - Map of Elephant pass lagoon and catchment

Runoff is low due to the relatively flat topographical nature of the area and its geological structure, the surface drainage of the peninsula under normal rainfall is meagre. Heavy runoff and flooding however takes place after heavy and abnormal rains, through the drainage courses.

In order to resolve the issues studies are being carried out. Studies made in the last year deals with the water balance and contamination of ground water in Jaffna peninsula. Hypothesis of Cultivating Productive Water from Lagoons of Northern Sri Lanka deals with the water balance checking in Upparu lagoon, Vadamaradchy lagoon and Elephant pass lagoon. But the crest level for eastern bund was assumed as 1.2m and studies were done. And in this study water availability in Elephant pass lagoon was also not done. In the research, water problems in the Jaffna peninsula deals with the groundwater problem in Jaffna and suggest some ideas to overcome those problems.

Our research is to check the water availability in Elephant pass lagoon and thereby proposing a proper crest level to Eastern bund by modelling in the spreadsheet. Furthermore we assumed the runoff coefficient as 0.3 and we used pan evaporation coefficient in order to calculate the evaporation loss.

Table: 1.1 - River basin and reservoirs

River basin	Catchment area (km2)		Reservoir capacity (MCM)
Kanakarayan aru			
Chemamamadu	37.4		3.2
Kanakarayan kulam	9.1		1.4
Iranamadu tank	587.9		131.3
Nethali aru			
Kalmadu tank	83		11.3
Peramanthal aru			
Visvamadu kulam	33.2		3.7
Piramanthal aru	67.3		3.9
Theruvil aru			
Udayarkaddu kulam	61.5		7.9

2 Literature Review

One of the main reasons for lagoon water salinity is salt water intrusion from sea. Saline water contamination is a wide threat nowadays. It pollutes the main land and unconfined aquifers by many ways. A research by Environmental Science department in Venice proved the saline water contamination within the main land by using the geophysical and geochemical tools. Conductivity logs and vertical electrical sounding were used in all over the area of Venice lagoon to detect ground water and rivers. He concluded that this water is not suitable for agricultural purposes because of the high saline content.

Ground water quality depends on different factors such as geology, lithology properties of aquifer, land use, the physical conditions of boundaries etc. From the research findings groundwater in Jaffna peninsula is highly polluted due to the improper usage of ground water. Over pumping the ground water for agricultural purposes, contamination of wastage from the industries and salt water intrusion are the major reasons for the ground water pollution in Elephant pass lagoon.

Research by Reza Jahanzahi defined that water with high TDS is found in wells near the lagoon areas, while fresh water are far from the lake. And also study of the relation between salinity and depth of the sampling points reveals that saline water is located in the depth of the area. For this analysis fifty duplicate water samples were collected for hydro chemical analysis from Maharlon Lake and were stored in acid washed poly ethylene bottles.

From the research by Navaretnarajah, he pointed about the nitrate-nitrogen level increase in the wells near the agricultural lands in Elephant pass lagoon due to the excess urea in the agricultural lands and the location of soaking pits of toilets near the wells in town areas. In his review he mentioned that the flushing out of salt water in the natural manner with the monsoon rains over a period of time is the best way of consideration about salinity reduction. The best way to analyze the salinity reduction in elephant pass lagoon is to study the water balance of the lagoon down streams of the reservoirs of the four regulated river basins considered as local catchments to the elephant pass lagoons.

The simulation model done by Kunanesan and Sivakumar says that the 70% of inflow of the total evaporates directly from the lagoon.

From the research by Shanmugarajah we can observe that there were some projects started from 1942 by irrigation department in Northern Province to reduce the salt water intrusion from the sea. Two barrages across Thondamanaru and Upparu, a bund cum spill across the east end of Elephant pass lagoon at Chundikulam and western end of Elephant pass lagoon were built according to the projects done.

3 Methodology

For the water bodies water balance equation consist of inflow, outflow and change in water storage of the volume considered. The simplified reservoir operation can be written as

$$S_{t+1} = S_t + I_t - O_t$$

Where

S_{t+1}= storage at the end of time step
S_t= Storage at the beginning of time step
I_t= Inflow to the reservoir during time step
O_t= Outflow to the reservoir during the time step

3.1 Inflow

Inflow to the lagoon was calculated considering the daily rainfall data and upstream spilling data. Daily rainfall data were collected from Kilinochchi Irrigation department. Upstream spills were from Iranamadu, Kalmadu, Visvamadu, Udayarkaddu and spilling data were obtained from their relative irrigation departments.

3.2 Outflow

This goes from percolation of the water stored in the lagoon, spillage from eastern proposed spill of elephant pass lagoon, evaporation from water body and the release at inlet of Mandalai cannel.

3.2.1 Percolation

Due to larger lagoon area percolation will be high and the value was estimated as 2% of initial reservoir volume.

3.2.2 Spill/Release

Due to collapse of eastern bund, there is not much detail for spill data. In this study stimulation was done with spill crest levels varying from 1m MSL to 1.5 m MSL and spill volumes were computed.

3.2.3 Evaporation loss

Evaporation losses were estimated using the pan evaporation data. Table 3.1 below shows monthly evaporation values were taken from the book Design of Irrigation Headworks by A.P.J.Ponrajah. They were observed for a long period and corrected with the pan coefficient of 0.8.

Table 3.1 - Pan Evaporation value for each month

Month	Pan evaporation (mm/month)
October	76.2
November	82.9
December	110.6
January	102.7
February	117.0
March	127.4
April	126.8
May	123.4
June	122.5
July	97.5
August	69.2
September	67.4

3.3 Mandalai Canal

ISSN 2229-5518

Trace of Mandalai canal can be observed in the northern side of the Elephant pass lagoon which was constructed 30 years back. Mandalai canal connects the Thondamanaru lagoon and Elephant pass lagoon. Simulation was done to find the flow through this canal for different crest level of eastern spill of elephant pass lagoon and sill level of inlet canal of mandalai canal.

4 Results

For the year 2012/13 simulation was done and losses of spill, evaporation, percolation were found. Crest level of the eastern bund was changed from 1 m MSL to 1.5 m MSL and corresponding spilling data were plotted. It can be seen that spill was considerably high when compared with evaporation loss and percolation.

Table 4.1 shows the canal parameters taken to calculate the canal flow through the Northern side of the Elephant pass lagoon. Manning's equation is used to find out the flow through the canal.

Table 4.1 Canal parameters

Sill level (m MSL)	1
Roughness (n)	0.025
Length (km)	7
Width (m)	5
Channel slope	0.000143

Different crest levels for the Eastern bund were taken and for those crest levels different sill levels were too assigned to calculate the Spill and canal flows. Table 4.2 shows the simulated results for various crest levels and sill levels. When the crest level and sill levels were increased the spill volume decreases. For the maximum crest level of 2.1 m and sill level of 0.6 m it is observed that a canal flow of 53.10 MCM for the year of 2012-2013. Canal flow is observed throughout the year but it needs a driving force to drive it through the canal towards the Thondamanaru lagoon. Driving force can be utilized either from solar energy or fuel. But for the crest level of 2.1 m, canal flow is high and it doesn't need a driving force. 2.1 m crest level has a risk of flooding the nearby areas. So study need to be carried out to find out the possibility of flooding.

Table 4.2 Simulated results for various crest levels and sill levels.

Crest level (m)	Sill level (m)	Spill (MCM)	Canal flow (MCM)
1	0.6	502	5.25
	0.8	504	2.06
	1	506	0.33
1.5	0.6	427	25.43
	0.8	431	19.40
	1	435	12.73
2.1	0.6	336	53.10
	0.8	340	46.80
	1	345	38.35

Table 4.3 shows the simulated results for the year of 2012-2013. Canal flow is observed throughout the year. For the months of June, July, August, and September there were no spilling observed.

Table 4.3 Simulated annual water balance computations

Year	Month	Total runoff (MCM)	Evaporation (MCM)	Percolation (MCM)	Spill (MCM)	Canal Flow(MCM)
2012	Oct	111	6	0	0	0
	Nov	66	8	3	0	1
	Dec	182	7	4	144	4
2013	Jan	52	8	4	44	5
	Feb	125	9	4	107	4
	Mar	30	12	4	14	4
	Apr	63	11	4	29	4
	May	10	12	4	7	4
	Jun	0	14	4	0	4
	Jul	0	14	3	0	3
	Aug	20	13	3	0	2
	Sep	15	13	3	0	2

Figure 4:1 shows the simulated water balance components for the year of 2012-2013.

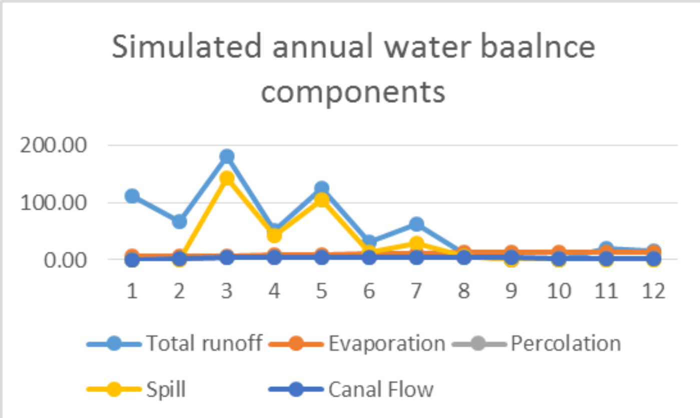

Figure 4:1 simulated annual water balance components

5 Conclusion

Test simulation was done to calculate the spill from Elephant pass lagoon and mandalai canal flow in north side of lagoon. Yearly canal release of 12.73 MCM is available and the canal release is possible throughout the year. Spilling is observed for 7month of the year. Hence flushing the lagoon water in these months can be carried out. From this study it is significant that substantial amount of water is available and lagoon water can be flushed out by utilizing this water if the driving head in Mandalai canal is sufficient.

This can be done by adding an energy lift at the inlet of mandalai canal just downstream of the northern outlet of elephant pass lagoon.

Further research can be proceed utilizing HEC - HMS (Hydraulic Modeling System of Hydraulic Engineering Centre) with real time data to get a fine tuned results.

Acknowledgment

The valuable thanks goes to Department of Civil Engineering, University of Jaffna, Sri Lanka and Irrigation Department of Northern Province Sri Lanka for the support in carrying out this research and WaSo project of University of Jaffna for guidance and other support.

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