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Study of Salinity Intrusion through the Estuaries of Periyar River using an Emperical Model

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***Abstract*— The salinity distributions of estuaries exhibit unique characteristics due to the effects of various external forces including freshwater discharges and topographic effects. To identify the salinity distribution of Periyar River Estuary, Kerala the surface salinity of Aluva Head works area were observed from 2008 to 2010. Variations in the salinity were clearly correlated in month wise with all other fluctuations. Furthermore, the salinity strongly decreased when additional freshwater was discharged relative to the dry period. The characteristics of the salinity distribution in the Periyar River were studied using data from the Water Resources Department and Central Water Commission, and the length of the salinity intrusion relative to the amount of freshwater discharge, and topographic effects were expressed using an empirical equation. A correlation between the saltwater intrusion limit at the Periyar River the freshwater discharge rate was also expressed using an empirical equation. Based on this simple analytical approach, it can believe that the structural characteristics of the salinity distribution in estuarian rivers vary not only due to freshwater discharge but also due to topographic effects.**

Keywords*— *Discharge; Empirical Model; Estuaries; Intrusion Length; Periyar River; Salinity Intrusion

I. INTRODUCTION

The study salinity intrusion processes of estuaries are dominantly governed by the amount of fresh water discharge and the estuarine salinity concentration. At the same time the depth governing geometrical factors and the velocity of fresh water discharge also plays active roles in the salinity intrusion process. Due to this fact, it is decided to study the salinity intrusion length also in the salinity intrusion processes.

Estuaries, where fresh water from rivers mixes with salt water from the oceans, are among the most productive environments on Earth. The estuary is not a part of the coast but is a coastal feature with a continuous exchange of water between land and the sea [1]. The intrusion of seawater in estuaries is an interesting phenomenon which occurs naturally and affects the quality of the water for different purposes [2]. In addition to morphological characteristics of an estuary, salinity intrusion depends strongly on the salinity difference between sea and river water and the amount of riverine flow [3], [4]. Combinations of above factors determine the mixing mechanism in an estuary and the salinity intrusion length [2]. Salinity intrusion may decrease the estuarine water quality so that its water becomes unsuitable for some uses such as drinking and agricultural purposes. Therefore determination of the salinity distribution along an estuary is a main interest for water engineers in coastal regions. Since the physical modelling of seawater intrusion in an estuary is time-consuming and expensive, it is preferred to use tools like empirical models [2]. This Chapter deals with such an attempt of Periyar estuaries in Kerala. The Periyar estuaries have free connections with the Arabian Sea is the most important water resource for Kochi City, the commercial capital of Kerala. Along this estuary some intake stations have been made to supply various water needs and it is important to keep the water salinity below a certain level at these intake stations. Here for Kochi City, the intake point situates at Aluva.

The initial studies for this work have been carried out using both Numerical Analysis and Harleman Emperical Model. This was explained vide previous Chapters. The aims of this paper are: (1) the determination of riverine flow discharge for different salinity concentrations, to keep the salinity under a certain level at the intake station that is located about 20 km from the estuaries, and (2) Evaluation of Byung II Yoon Model to assess the suitability of Periyar River Estuaries to predict the Salinity intrusion length [7].

To achieve these aims, a one-dimensional model prepared by J.Parsha et,al (2007) based on an established model of the famous researcher Savanaji(1993) to calculate the salinity intrusion length was used [5]. The model established by Byung II Yoon and Seung-Buhm Woo is also used to compute the salinity intrusion length of Periyar River estuaries. After calibration of the model using field data, it was verified using another set of field data. The verified model was then used for computing of salinity intrusion in this estuary at different conditions. In addition, an emperical model is formulated to predict the salinity intrusion lengths in the same conditions and which was also tested using regression analysis.

II. STUDY AREA

Periyar River estuaries, located in the central-west of Kerala are one of the main inland waterways in Kerala. The back water of this portion is known as Venbanad Kayal. It has a length of 96.5km and 14km width with an average area of 2033 Sq.Km. The first upstream dam of the estuary is

Bhoothathankettu. The averaged cross-sectional area, width and depth of Periyar estuary are about 3980 m2, 920 m and 4.2 m respectively. The annual average discharge through the estuaries is noted as 206 m^3/sec. During dry season, usually in summer, when the Periyar discharge is very low, the salinity intrusion influences the drinking water production, even though the intake is more than 20 km upstream of the estuary. However, under different riverine flow, depth of water and salinity concentrations, water surface elevation and water quality of Periyar River along its entire course are strongly affected. As the salinity in Periyar River estuaries is high in its initial portions, it is not suitable for agricultural use and also affecting the intake of drinking water source at 20 Km upstream. The salinity of the Periyar estuaries varies between 2000 and 4500 mg/l, with maximum salinity of 4500mg/l**.**

A detailed monthly mass balance study has been carried out and the flow for the selected stations for ten years was worked out. The obtained flow was compared with the actual flow recorded in the selected stations, which was already established [8].

In Salinity intrusion studies, the minimum discharge required through the estuaries is found out so as to maintain the quality of source for an uninterrupted Water Supply to Kochi. In this regard, a work on flow optimization has been carried out by keeping the water quality standards insisted by the CPHEEO. The work has been carried out using Harleman's Empirical Model [6]. It reveals the minimum discharge required for controlling salinity intrusion and also a better resource management.

III. METHOD OF STUDY

An estuarine researcher, named Mr.Byung II Yoon, in 2013 has developed a relationship between the salinity intrusion length and river discharges through the estuaries. It is noticed that a Relationship between fresh water discharges through the estuary and the salinity intrusion length is established by Byung II Yoon and Seung - Buhum Woo through their research work on Han River Estuary, South Korea. The study revealed that its Correlation coefficient, obtained is 0.89, a very good relation between the coefficients.

The Byung II Model, find the Salt Water Intrusion Length given as,

$$L = 234.6\ Q^{(-1.6/10)} \text{ –(1) for 2 ppm}$$

Here, L is the salt water intrusion in km and Q is the fresh water discharge in m^3/sec

Mr. Byung II, has given an indication of flexibility in using the relationship for other estuaries that by refixing the constant value of 234.6 and the power value to suit the river under selection if required.

Keeping these limitations and other constraints of power values, in our studies for Periyar River estuaries a detailed iteration work has been carried out to reach the values of constants and the power values. The iteration works revealed that a constant of 80 during summer (December to May) and 63 during monsoon (June to November); and a power value of (-1.7/10) throughout the year are the most suitable emperical values. The summer relationship and monsoon relationship has been separately worked out. During iteration works for finding the Emperical constants, the values used for Byung has been tested initially. But there was no consistency for the output and the constants used above a 'value 100' was going away from the consistency. Finally, the best consistency results were obtained for 80 during summer and 63 during monsoon seasons. Similar iteration works have been carried out for obtaining the power values also. The optimum and best results are obtained with consistency for a power value of (-1.7/10) throughout the year.

IV. RESULTS AND DISCUSSIONS

As discussed earlier, the intrusion length using both methods has been worked out for 3 years and computed the relationship. It is found that Byung II Model is more easy, workable and dependable. As such the work was completed and an empirical relationship has been developed for the study.

Salt Water Intrusion Length was further obtained using the empirical relationship developed based on the Byung II Model for Han River Estuary.

Salt Water Intrusion Length, $L = 80\ Q^{(-1.7/10)}$ for summer season ; and , $L = 63\ Q^{(-1.7/10)}$ for monsoon season

As explained, the Discharge verses Salinity intrusion length for the year 2008, 2009 and 2010 were computed and tabulated in table 1.

TABLE 1 Computation of Salinity Intrusion Length for Periyar Estuaries using the Empirical Relationship - on the basis of Byung-II

2008		2009		2010	
Discharge, Q in m^3/sec	Intru. Length, L in Km	Discharge , Q in m^3/sec	Intru. Length, L in Km	Discharge , Q in m3/sec	Intru. Length, L in Km
13.24	51.57	3.48	64.72	18.66	48.64
6.76	57.81	6.00	58.99	20.93	47.70
13.42	51.45	3.70	64.05	26.38	45.86
31.91	44.40	20.57	47.85	23.17	46.89
68.84	38.96	36.05	43.49	35.78	43.55
212.96	25.32	402.44	22.73	353.18	23.24
475.88	22.09	1660.8	17.86	511.99	21.82
489.34	21.98	994.38	19.49	422.89	22.54
1069.9	19.25	1879.0	17.49	329.60	23.51
303.12	23.85	308.85	23.77	597.44	21.25
256.17	24.54	214.07	25.30	375.39	23.00
15.61	50.15	46.00	41.73	149.32	34.16

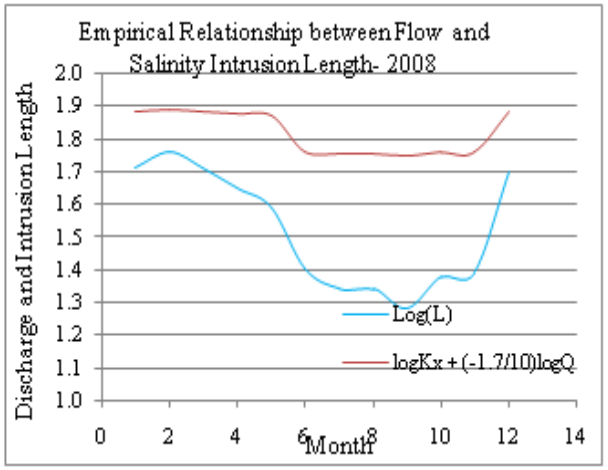

Fig 1 Byung II Emperical Relationship of Flow and Salinity Intrusion Length – 2008

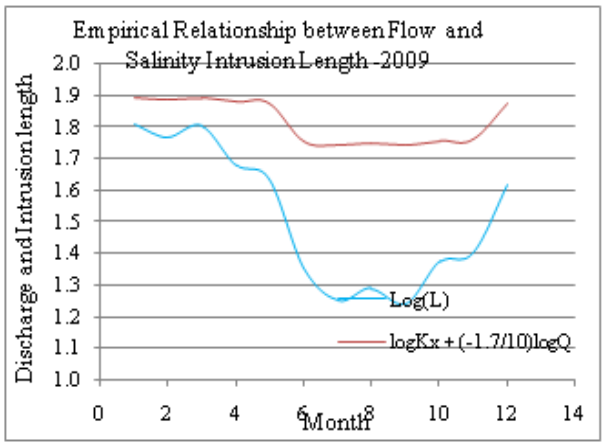

Fig 2 Byung II Emperical Relationship of Flow and Salinity Intrusion Length- 2009

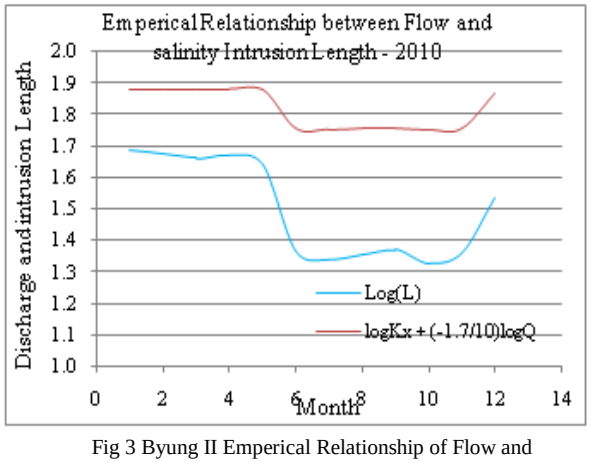

Fig 3 Byung II Emperical Relationship of Flow and Salinity Intrusion Length - 2010

The salinity intrusion length was worked out using Byung II Model vide Table 1 for the years 2008, 2009 and 2010. It is also revealed that the salinity intrusion length is inversely proportional to the fresh water discharges through the estuaries, which is depicted through the Fig. 1 Fig 2 and Fig 3 given below. To verify the strength of the linear relationship, graphs are plotted using logarithmic values. The coefficient of correlation found as more than 0.9 in all cases except during monsoon, which is not considered in this study on practical point of view.

V. CONCLUSION

1. The Salinity Intrusion length was computed using Byung II Model and found that the intrusion length is inversily proportional to the estuarine river discharges.
2. The Byung II Model was tested using the measured Salinity to obtain the Salinity Intrusion Length.
3. The intrusion lengths obtained by the Byung II model are assisting to predict the salinity concentration at Head Works, Aluva.
4. The study results will assist for a better flow control so as to maintain the water supply scheme uninterrupted.
5. The study results will assist for the betterment of other water users like agricultural and industrial purposes.

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