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Availability Study of Groundwater in Jaffna Peninsula of Northern Sri Lanka

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Abstract –

The Jaffna Peninsula lie in the northern-most part of Sri Lanka. It is separated from the mainland by two external lagoons. The Jaffna Peninsula depends for its water on the rainfall which percolates and stored in lime stone aquifers. The average annual rainfall is 1284 mm/year and the potential vapour transpiration is 1858.8 mm. The Jaffna Peninsula is struggling to meet the water demand and quality of available ground water also threatened by pollutants. The major aquifers within Jaffna Peninsula located in Valikamam, Vadamaradchchi and Thenmaradchchi area. From 1966 several surveys and investigations were carried out to find out the water usage pattern, required water and available water, etc. The studies which are carried out in different periods on deriving possible "Safe Yield" from the aquifers of Jaffna Peninsula are showing inconsistent results for the same aquifers. In last few decades the ground water is exposed for the pollution due to over extraction for irrigation lead for sea water intrusion, heavy usage of agro chemicals lead to increase the Nitrate concentration beyond the limit and discharging industrial waste in to ground lead to the contamination of petroleum components.The studies done so far on estimating the availability of groundwater in Jaffna Peninsula have been carried out to certain extent and derived recommendations for "Safe Yield" as well. But the findings are varying with the time period for a specific aquifer. Also the carrying capacity of the aquifers are not clearly studied in detail as the groundwater in Jaffna Peninsula is stored in fractured weak limestone aquifers. Therefore the over storage of groundwater in the aquifers beyond their capacity may cause adverse impact to the environment.Based on the past studies, the recommended total "Safe Yield" from the aquifers in Jaffna Peninsula is 13,100 m^3 per day in dry season and 34,600 m^3 per day in wet season while having a basic water requirement for domestic need of 31,500 m^3 per day. Further available annual water resources is 718 m^3 per day per person which is less than the recommended amount in the World Water Development Report of the United Nations. These are indicating that the Jaffna Peninsula is facing the water scarcity.The availability of groundwater and the possible additional recharge shall be studied with correlation to the carrying capacity of the aquifer to ensure and improve the available water resources in a sustainable manner. This paper is analysed and summarised the past studies on groundwater in Jaffna Peninsula.

Index Terms— Groundwater, Aquifers, Yield, Capacity, Jaffna Peninsula

1 Introduction

The availability of groundwater refers to the groundwater available to fulfil all the requirements of people such as for domestic and irrigation and for environmental conservation with appropriate quality or required standards.

The Water Scarcity or Water Stress in a place shall be defined or analysed in several ways or methods. The most common indicator for water stress or scarcity is per capita renewable water per year. As per the Falkenmark Indicator [9], an area shall face "Water Stress" when annual water resources fall below 1,700m^3 per capita. If the annual water resources fall below 1,000m^3 per capita, the area will face "Water Scarcity" and the area will face "Absolute Scarcity" if the annual water resources fall below 500m^3 per capita [39]. Further the "Benchmark Indicator" [9] of 1000m^3 per capita per year is a generally accepted standard to define the status of water scarcity.

Internationally recommended basic water requirement per person per day would be minimum 50 litres. This amount includes the basic minimum water requirement for drinking (5 litres), food preparation (10 litres), bathing (15 litres) and sanitation (20 litres) [32].

The Jaffna Peninsula lie in the northern-most part of Sri Lanka. It is separated from the mainland by two external lagoons namely the Elephant Pass lagoon and the Jaffna lagoon. The Peninsula is narrow and elongated. The topography of the peninsula is flat with a maximum elevation of about 10 m above MSL. The land area is about of 1000 km^2 and it has the coastline of 160 km [27]. Due to this flat topography, there are no large water storage bodies or streams within the peninsula. But it includes two internal lagoons namely the Upparu lagoon and the Vadamaradchchi lagoon (Figure 1). These lagoons are having an area of 26km^2 and 78 km^2 and catchment area of 220 km^2 and 298 km^2 respectively [20]. The rain water harvested by these lagoons drains finally to the sea.

The Jaffna peninsula is underlain by the pre-Paleozoic basement rocks, the Mannar Sandstone and the Jaffna Limestone. The pre-Paleozoic basement rocks found at a depth of 240 m. This basement rocks are overlain by the Mannar Sandstone for a thickness of 130 m. The Jaffna Limestone is overlaying the Mannar Sandstone for a thickness of 90 m. The soil

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layer on top of the limestone is varying in thickness from no cover to 15m [15].

The Peninsula is receiving an average annual rainfall of 1284 mm/year. The rainfall data from 1960 to 2015 show the annual variation of rainfall ranges from a low of 569 mm in 1968 to high of 1909 mm in 1993 [8]. The major portion of the annual rainfall is receiving in North East monsoon period. The monsoon rains are of high intensity and unreliable. The annual potential vapour transpiration is 1858.8 mm [8].

The Jaffna Peninsula depends for its water on the rainfall which percolates and stored in aquifers. The recharge of the aquifers mainly occurs in the wet season in North East monsoon period from October to December [8]. From the ancient the groundwater in the aquifer is extracted via dug wells for the domestic and agriculture need of the people.

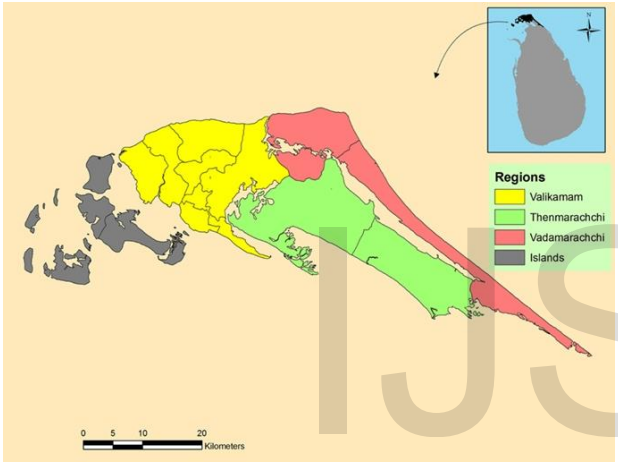

Fig. 1. Jaffna Peninsula and Internal Lagoons

2 Groundwater Source

Groundwater is the prime source for the domestic and agriculture needs in Jaffna Peninsula and it is extracted via dug wells. The extraction pattern is changed from drawing water manually by using pulley to use high-lift motorised pumps.

The behaviour of aquifers in Jaffna Peninsula is simulating the Ghyben – Herzberg principle. The difference in densities between sea water (1.025 mg/cm^3) and fresh water (1.0 mg/cm^3) allows the fresh water to float as a lense on sea water and results in a depth of 40m of fresh water below sea level for every metre above sea level [42].

There are two major type of aquifers in Jaffna Peninsula: limestone and sand dune aquifer. Both aquifers are responding to the Ghyben – Herzberg principle as same. Even though in wet season the Ghyben – Herzberg heads change only slightly while the water table change rapidly over a wider range [6].

Generally the limestone aquifers are exposed for chemical reaction with groundwater as it is an active weathering agent, especially the groundwater which forms from direct rainfall. The dissolution may cause cavities in limestone aquifers and it may lead to form caves or caverns [5].

The major aquifers are located in Valikamam, Thenmaradchchi and Vadamaradchchi area within Jaffna Peninsula (Figure 2). The limestone formation with the cover of thin sand layers are functioning as aquifers. The aquifers are recharged by direct infiltration of rainfall. Due to the fractured limestone, the permeability is high and it leads to rapid ground water movement. The studies are showing that 30 to 50 percent of rainfall would be the recharge to groundwater and of which 15 to 50 percent shall be lost to sea as sub – surface flow [8].

As the Jaffna Peninsula is receiving an average annual rainfall of 1284 mm in the area of 1000km^2; the annual water resources available after the losses such as runoff, evapotranspiration and sub-surface flow to sea would be 450 million m^3 [7]. The population in Jaffna Peninsula (2014) is 626,564. Therefore the available annual water resources is 718 m^3 per capita. According to the "Falkenmark Indicator" this is indicating that the region is facing "Water Scarcity".

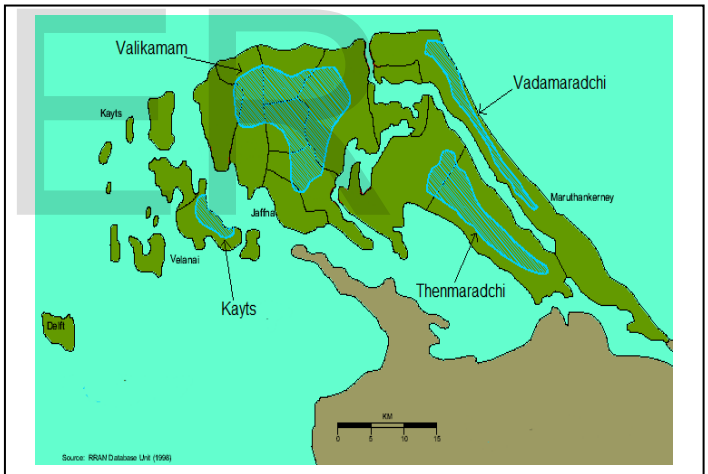

Fig. 2. Major Aquifers in Jaffna Peninsula

The incidence of saline infiltration was experienced in early sixties. Then from 1966 several surveys and investigations were carried out to find out the water usage pattern, required water and available water, etc. [18]

Generally groundwater systems are complex and difficult to study and analyse. The study on groundwater needs simplifications on defining boundaries and linearising the equations of groundwater flow[1]. Also such simplifications may fail to predict future behaviour. To overcome this problem, physical and numerical models shall be used. In simulating real aquifer behaviour in to physical model is difficult while the numerical modelling is preferred as it accommodates heterogeneities and non isotropism. In numerical models the aquifer shall divide into arrays / cells / nodes and the properties of the aquifer shall be assigned to each arrays / cells / nodes. But numerical

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models need reliable data record for a long period.

The aquifers in Jaffna peninsula are unconfined and the upper and lower boundaries of the aquifer are unstable as it may vary with the water balance.

The outcomes of two recent studies on estimating the "Safe Yield" of groundwater from the aquifers are summarised below in Table 1. The proposed total possible "Safe Yield" from the aquifers of Jaffna Peninsula by these two studies are inconsistent. Also these studies are recommending for further studies on estimating the available groundwater and continuous monitoring to confirm and update the studies.

Further a study which was carried out based on water balance shows that total average annual withdrawal from the limestone aquifer in the study area is exceeded the total average annual recharge which leads to unsustainable withdrawal [40].

TABLE 1
SAFE YIELD FROM AQUIFERS

Location of Aquifers in Jaffna Peninsula	Market Town Water Supply Jaffna Project, Engineering Science, 1984		Jaffna Peninsula Water Supply and Sanitation Feasibility Study, 2006	
	Safe Yield (m^3/day)		Safe Yield (m^3/day)	
	Minimum	Maximum	Minimum	Maximum
Valikamam	4,000	4,000	5,000	19,200
Thenmaradchchi	17,000	26,000	3,600	6,600
Vadamaradchchi	19,000	34,000	4,500	8,800
Total	40,000	64,000	13,100	34,600

Beyond the direct infiltration of rainfall to the aquifers, studies on influence of the lagoons in recharging the aquifers also done in the past. Based on the inflow-outflow analysis and the salinity data, the lagoons could not be used as a fresh water source due to high rate of evaporation and percolation which results insufficient quantity of water to be retained in the lagoon and the salinity of the water increases in dry season more than the sea water[1].

Instead of converting the lagoon in to fresh water source the productivity of the adjacent area of the lagoons could be improved[15]. Further by maintain the water level in the lagoons at 0.3m above mean sea level may result in an excess of 10 Mm^3 of fresh water available to Jaffna Peninsula [41].

3 WATER DEMAND

The agriculture of Jaffna Peninsula is mainly depend on groundwater in addition to direct rain fed cultivation during North East monsoon period.

The estimated total extraction of ground water per annum in 1981 was 290 million m^3 which includes domestic demand of 16 million m^3 and other demands for irrigation, home garden and deep rooted trees. The population in 1981 was 738,791 [18].

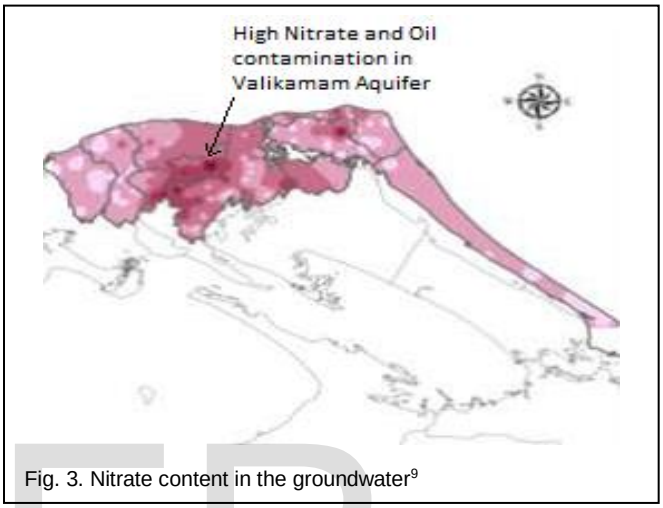

Fig. 3. Nitrate content in the groundwater[9]

The population in Jaffna Peninsula at present (2014) is 626,564. The water demand for basic needs excluding irrigation would be 31,500 m^3/day i.e. 11.5 million m^3 per annum.

Even though the population decreased as at now compared to 1981, the Jaffna Peninsula is struggling to meet the required day to day water demand. Further population growth, resettlement after water and industrial activities will induce the scarcity for water in future.

4 WATER QUALITY

There are several studies and surveys done on the quality of groundwater in the aquifers of Jaffna Peninsula. In last few decades the ground water is exposed for the pollution due to over extraction for irrigation lead for sea water intrusion, heavy usage of agro chemicals lead to increase the Nitrate concentration beyond the limit and discharging industrial waste in to ground lead to the contamination of petroleum components.

The water in the major aquifer which is located in Valikamam area is content of high Nitrate due to the excess usage of fertilisers, pesticides and weedicides. Further a recent study shows that this aquifer is contaminated by waste oil as well[10].

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The groundwater within the Jaffna city limit is contaminated due to uncontrolled poor sanitation system[11]. The Figure 3 shows the level of faecal contamination within the densely populated area of the Jaffna city.

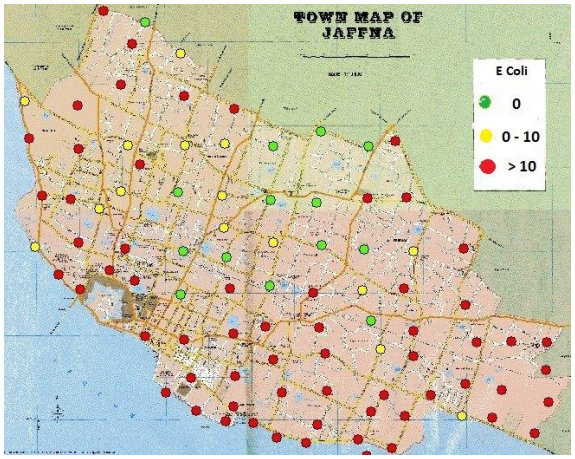

Fig. 4. Fecal Contamination in Jaffna City[11]

5 Research Methodology

There were several studies carried out in past few decades to find the solution for proper water management and provide safe potable water to the public. Those studies have the following limitations on their findings;

1. Lack of reliable data to develop the accurate groundwater model [42].
2. The solute transport is not considered into groundwater model [42].
3. Findings of the studies / prediction for future extraction are practically not achievable.
4. The influence of pollutants such as nitrate and faecal contaminations are not considered into the model.
5. Carrying capacity of the aquifers are not considered in the studies especially in the case of artificial recharge.
6. Direct influence of lagoon schemes to aquifers to be studied further as the past records shows that storing water in lagoon for full year cycle is impractical.

Based on the basis and findings of the past studies in developing a groundwater model; following research methodology has been formulated;

1. Defining study area: Jaffna city and suburbs
2. Collecting satellite image, contour map of the study area
3. Collecting rainfall data
4. Collecting groundwater quality and groundwater level with seasonal variations
5. Developing water usage pattern / demand.
6. Developing proper groundwater model by considering aquifer properties and solute transport.

6 Conclusion

The present situation of the Jaffna Peninsula clearly shows that some parts of the Peninsula are suffering without adequate water while the some areas are not having the guarantee for the safe potable water. Based on ongoing development activities and resettlements, need for safe potable water may drastically increase and the aquifers may not be able to fulfil the demand.

The studies are done so far on estimating the availability of groundwater in Jaffna Peninsula have been carried out to certain extent and derived recommendations for "Safe Yield" as well. But the findings are varying with the time period for the same aquifer. Also the carrying capacity of the aquifers are not clearly studied in detail as the groundwater in Jaffna Peninsula is stored in fractured weak limestone aquifers. Therefore the over storage of groundwater in the aquifers beyond their capacity may cause adverse impact to the environment.

Based on the recent study, the recommended total "Safe Yield" from the aquifers in Jaffna Peninsula is 13,100 m^3 per day in dry season and 34,600 m^3 per day in wet season while having a minimum basic water requirement of 31,500 m^3 per day for domestic need only. Further available annual water resources is 718 m^3/day. These are indicating that the Jaffna Peninsula is facing the water scarcity.

The carrying capacity of the limestone aquifer shall play a major role in additional recharge as the limestone aquifers shall have caves or caverns which may weak in strength and also the fractures in the limestone aquifer may cause leak and waeter may flow to sea. Further the artificial recharge may weaken or damge the limestone aquifer if the property or behaviour of the limestone aquifer is not clearly incorporated.

The availability of groundwater, water resource management and the possible additional recharge shall be studied with correlation to the carrying capacity of the aquifer and temporal behaviour of the aquifer to ensure and improve the available water resources in a sustainable manner.

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