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North Eastern Coastal Sand Aquifer in Trincomalee District

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All geologists and other staff of Water Resources Board are thanked for their help given in the different stages of the study. We would also like to register our gratitude to the staff of the Integrated Food Security Programme Trincomalee for their dedicated and competent support provided during the field activities, which were carried out under difficult ground conditions.

Finally, our sincere thanks are to settlers of the Nilaveli – Kumpurruppiddi area for their valuable participation during the field activities.

CONTENTS

Figures

Tables

Annex

1. Introduction

Water constitutes the basic resource for life. The water resources of the north eastern coastal aquifer are predominantly used for irrigation and domestic purposes. The ever increasing extraction of water poses a threat to the aquifer and ultimately to the livelihood of communities living along the north eastern coast of Sri Lanka. No reliable longer-term data are available for the quantity of water generated by the aquifer nor for the possible change of the water quality. Intensive irrigation and a comparatively dense habitat may result in an over extraction of water and a deterioration of the water quality over time. Since IFSP is has a focus on improving the conditions for nutrition and health of the local communities the availability of water of good quality for human consumption and sufficient water for cultivation has become an important issue.

IFSP-GTZ has initiated a combined survey[1] aiming at

- Monitoring the quality and quantity of water of the north eastern coastal aquifer and arriving at conclusions for better water management and possible health threats
- Inventorising all agro-wells and common wells north of Trincomalee
- Estimating the safe yield of the aquifer and establishing a water balance.

1.1 Background

Agricultural activities are dominant and highly concentrated along the eastern coastal belt from Nilaveli to Kumpurruppiddi in Trincomalee district. The water for the irrigation agriculture is obtained from the coastal sand aquifer from shallow agro-wells. Almost all of these agro-wells are pumped daily. Some of the farmers pump their agro-wells twice a day during the cropping period. The density of the agro-wells is very high, regardless of the conflict induced scattered and uneven settlement pattern.

The groundwater potential and the thickness of the fresh water column of the coastal sand aquifer are limited due to the low rainfall through out the year. Since most of the agro-wells are not operated in any systematic manner a depletion of the groundwater table and an intrusion of saline water to the fresh water body may occur. Assuming normal ground conditions and the return of internally displaced families to the region, an intensification of the use of ground water from agro-wells and other shallow wells could be expected. An expansion and intensification of vegetable cultivation combined with an additional demand for domestic water use could pose a serious threat to the aquifer. The survey team considers the design and introduction of a regulatory framework for the operation of the agro-wells essential.

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[1] IFSP Technical Paper 16, Water Quality Monitoring in the Coastal Area of Trincomalee District. Results of Phase I July 2000 - July 2001, Authors: C.R. Panabokke, S.R.K. Pathirana, Trincomalee & Colombo, May 2002
IFSP Technical Paper 17, Well Inventory in the Nilaveli-Kuchchaveli Area, Author: K. Nadarajah, Trincomalee, May 2002
IFSP Technical Paper 18, North Eastern Coastal Sand Aquifer in Trincomalee District, Authors: K. A. W. Kodituwakku, S.R.K. Pathirana, Trincomalee. Colombo, May 2002
IFSP Technical Paper 8, Monitoring of Agro-wells in the Sandy Regosol Area between Nilaveli and Kuchchaveli. First Seasonal Results, Authors: C.R. Panabokke, K.A.W. Kodituwaku, S.R.K. Pathirana, Trincomalee & Colombo, February 2001

A detail hydrogeological survey of the 'North Eastern Coastal Sand Aquifer in Trincomalee District' was carried out with the aim to evaluate the safe yield of this sand aquifer. An estimate for a water balance was done. This report summarises the findings and recommendations.

1.2 Objectives

The objectives of the survey are:

- Carry out a water balance study for the sand aquifer
- Determination of the safe yield of the aquifer
- Estimation of a water budget for the aquifer
- Recommend a regulatory framework for the operation of agro-wells

1.3 Methodology

The study was executed in to two phases.

Phase 1 - Data collection and field activities:

- Collect and collate all existing available data
- Conducting pumping and infiltration tests
- Carrying out geophysical investigations
- Measurement of rainfall

Phase 2 – Data interpretation and desk studies

- Determination of infiltration rates
- Determination of aquifer properties and dimensions
- Evaluation the groundwater flow, groundwater recharge and evapotranspiration
- Carrying out a water balance study
- Determination of the safe yield of the aquifer
- Estimation of a water balance
- Recommend a regulatory framework for the operation of agro-wells

The flow diagram of the working procedure of the survey is shown in figure 1.

2. Study area

2.1 Description

The survey area is located along the north eastern coastal belt, from Nilaveli to Kumpurruppidi in Trincomalee district. The extent of the area is about 25 km^2. kilometres. The survey area begins at Nilaveli about 10 km north of Trincomalee town along the Trincomalee – Kuchchaveli road and it extends up to Errakkandi and Kumpurruppidi. The location map of the survey area is shown in map 1.

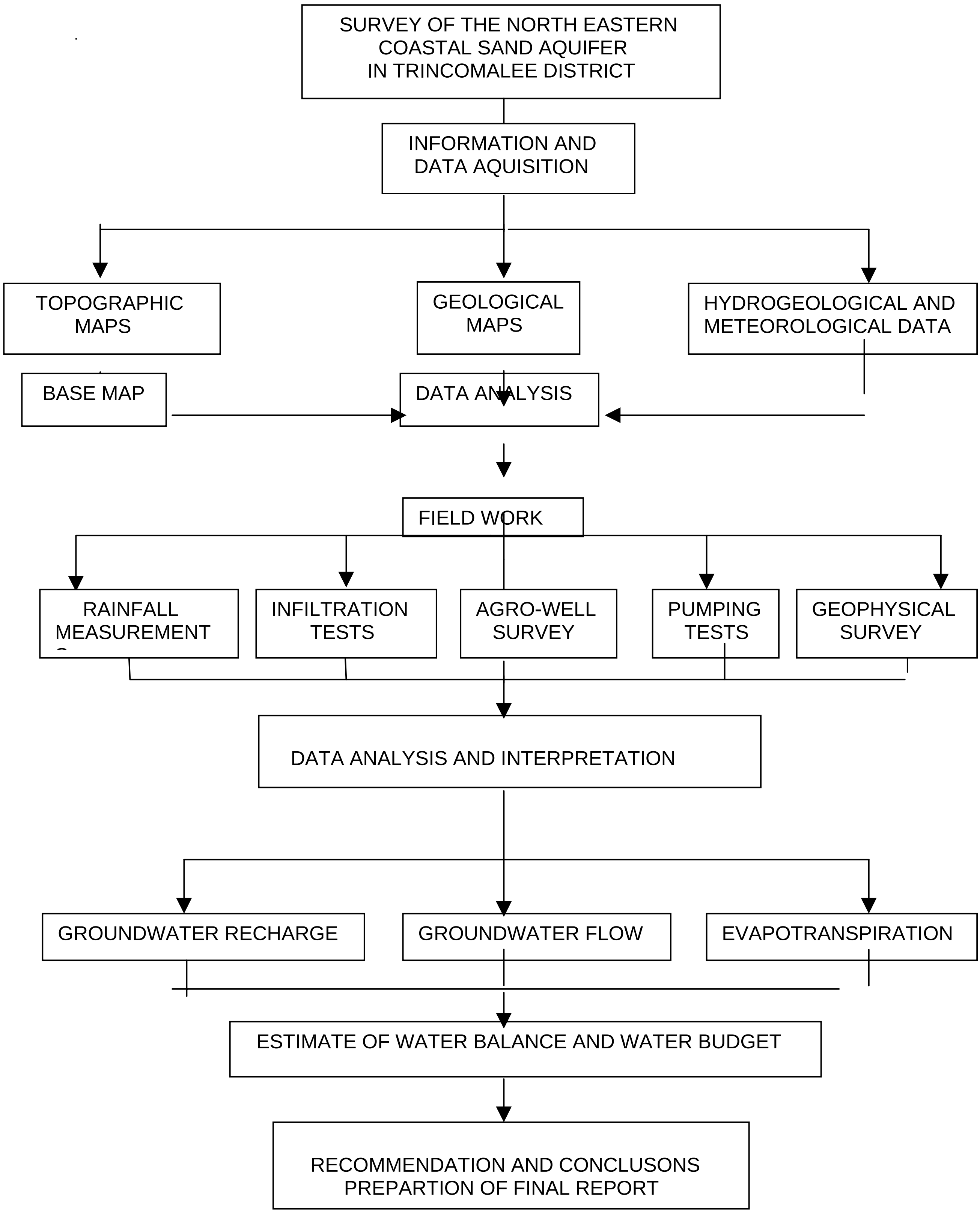

Figure 1: Flow diagram of survey

The area falls within the agro ecological and soil sub classes of dry low land DL_{1C} with a 75% probability of the annual precipitation of <900 mm. The major precipitation is received from the north east monsoons and occurs from October to January with the highest average in November and December. The lowest rainfall is received during June and March. Figure 1 shows the variation of the 75% probability of the monthly precipitation for the north eastern coastal area in the district of Trincomalee.

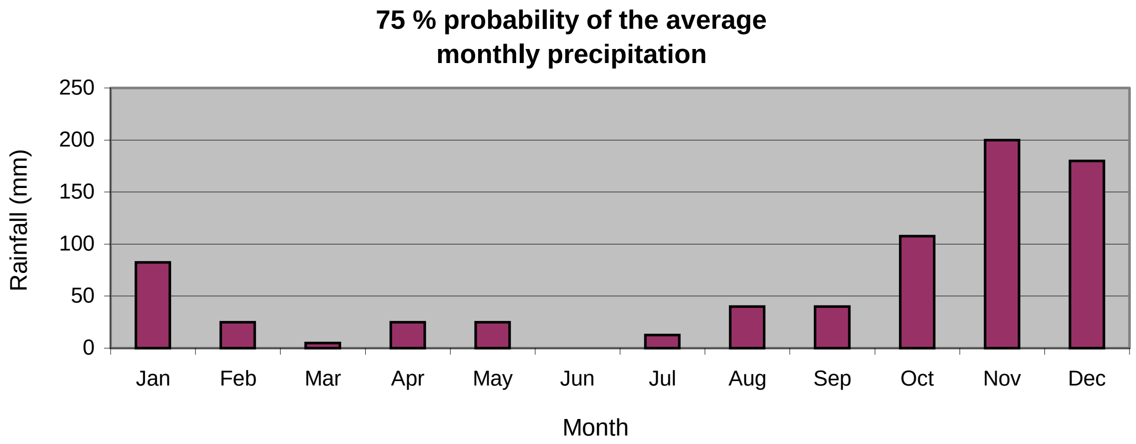

Figure 2: Average monthly rainfall

The mean monthly average temperature varies within the range of 25.6^{0}C to >30^{0}C. For the months of June and July a higher average temperature is recorded. The lowest temperature is recorded for December and January. However, there is no significant variation of the mean average monthly temperature. Figure 3 shows the variation of the mean monthly temperature at the Trincomalee meteorological station.

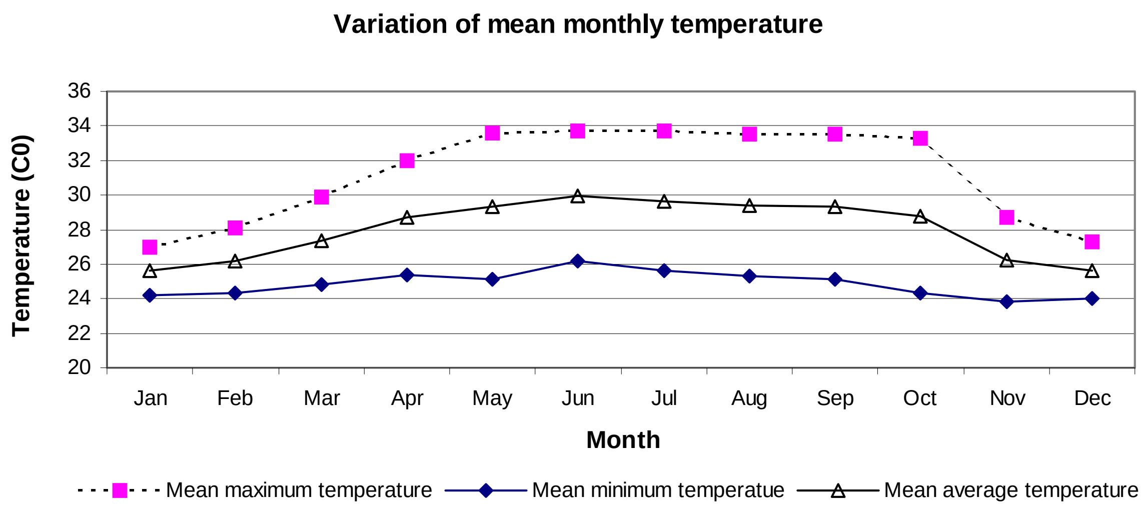

Figure 3: Variation of mean monthly temperature

2.2 Geology and topography

The survey area is made up of semi-recent coastal sands termed as “Sandy Regosols”. The centre part of the area along the coastal belt is elevated slightly higher. The area gently slopes towards the direction of the sea and the lagoon sides.

2.2 Hydrogeology

The major aquifer unit is of coastal sands overlying a coral basement. The infiltration rate, porosity and the permeability of this sand formation are very high. More than 90% of the water percolates with the rains which results in building up the fresh water body. However, since the aquifer unit is connected with both the sea and the lagoon, which are contained with saline water, a boundary exists between the saline and the fresh water bodies within the aquifer. This boundary is referred to as the saline fresh water interface. The interface occurs at a very shallow depth, close to both the lagoon and the sea with a gentle increase towards the centre of the land. The result is a fresh water lens.

During the rainy season the water level is closer to the ground surface and significantly drops with the beginning of the dry season. The groundwater flow is mainly directed to both the sea and the lagoon sides from the centre part of the survey area.

2.3 Agricultural activities

The predominant crop cultivated in the area are red onions. Other crops are vegetables, e.g. egg plants, cabbage and commercial crops such as chewing tobaccos, groundnuts and chillies etc. Two onion crop seasons are practising from January to March and May to July. Some of the farmers grow a third onion crop from July to September. Subject to availability of water and capital, an increasing number of farmers have started the cultivation of a fourth onion crop.

For irrigation farmers take water from the sand aquifer through shallow agro-wells. At most of the agro-wells in operation by 2” centrifugal pumps with an average rate of about 250 litres per minute are installed. Farmers practice a furrow basin method of on-farm irrigation with a stream size of around three litres per second. In general, the pumping period is about six to eight hours per day and per acre. Pumping is done daily throughout the cropping period.

3. Field tests and surveys

3.1 Measurement of rainfall

To establish a longer term information base for the seasonal rainfall a collector type rain gauge was installed at Gopalapuram Tamil School on February 2001. A school boy and a girl were trained to measure and record the rainfall on a daily basis. The recorded monthly rainfall is shown in figure 4.

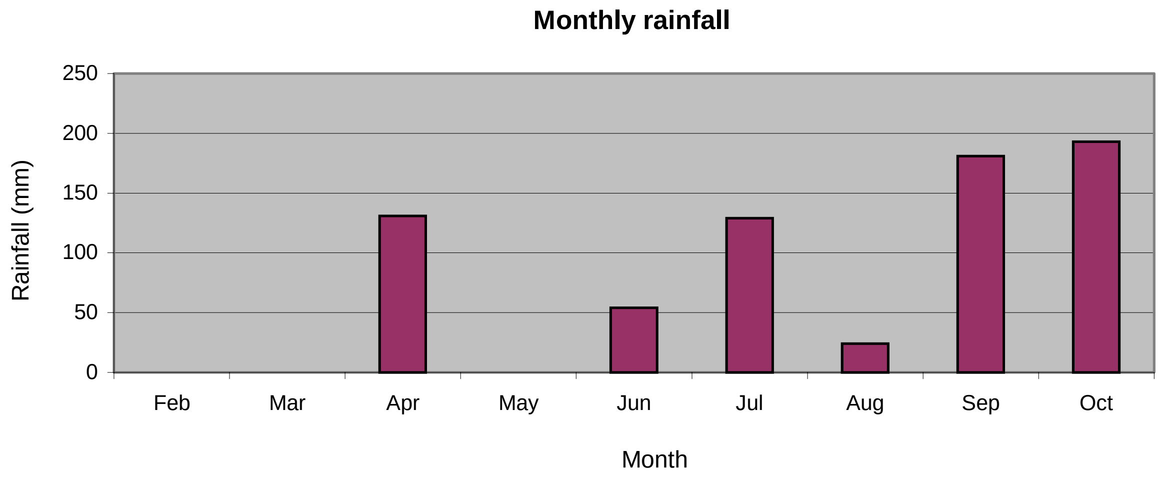

Figure 4: Rainfall at Gopalapuram Tamil School in 2001

3.2 Infiltration tests

Water from rainfall or irrigation reaching the land surface infiltrates into the soil. Soils have a definite capacity to absorb water. This is called the “infiltration rate”. The infiltration rate of a soil depends on a number of factors.

- Type of soil
- The depth of ponding of water on the surface
- Moisture condition of the soil
- Land cover
- Inclination and the roughness of the surface
- Chemical characteristics of the soil surface
- Physical and chemical properties of the soil

The infiltration rate plays a major role in the groundwater recharge mechanism. It is essential to measure the infiltration rate of different types of soils under various conditions to obtain reliable results of the water balance of an aquifers. Six infiltration tests were carried out in the survey area by using a double ring infiltrometer. The results are given in table 1.

Owner's Name	*Village/G.S. Division*	*Location*	*Initial infiltration rate (cm/hour)*	*Stabilised infiltration rate (cm/hour)*
P. Sivalingam	Kumpurruppidi	Close to sea	70	42
Itlas Pillai	Kumpurruppidi	Centre of the area	70	36
S. Arulanadan	Kumpurruppidi	Close to lagoon	52	20
R.M. Theresa	Errakkandi	Close to sea	65	38
S. Darmalingam	Nilaveli	Centre of the area	55	28
S. Sundaralingam	Nilaveli	Close to lagoon	50	22

Table 1: Results of the infiltration tests

The average initial infiltration rate of this area is 60 mm/hour and the average stabilised infiltration rate is 32 mm/hour. The results of the infiltration tests clearly indicate that the infiltration rate is higher at locations close to the sea area and lower in the lagoon areas. The observed differences are due to the different percentages of sand in the soil.

3.3 Pumping tests

The outflow or inflow of groundwater is one of the major components of water balance studies. To evaluate the groundwater outflow or inflow the aquifer properties such as hydraulic conductivity, specific yield etc. have to be determined. Pumping tests are one of the best methods to obtain reliable data for flow values. Eight pumping tests were carried out at the existing agro-wells. The selection of wells for the pumping tests was based on:

- Sand percentage of the soil
- Intensity of the agricultural activities
- Location of the well
- Nitrate concentration of groundwater

During the tests, the test wells were pumped on a constant discharge rate for a period of four to six hours continuously and the draw down of the wells was taken. The discharge lines were placed well away from the pumping well. The water levels of the adjacent wells were measured during the pumping period. No significant changes of the water levels of the adjacent wells were observed.

After a pumping time of four to six hours, the water levels of the pumping wells stabilised. Once the pumping stopped, the recovery of wells were recorded. All wells fully recovered within two to four hours. The results of the pumping test were analysed according to the Boultion and Streltsova curve fitting method. The results are given in table 2.

Owner's name	*Village/G.S. Division*	*Hydraulic conductivity (m/day)*	*Specific yield*
P. Sivalingam	Kumpurruppidi	11.5	0.56
Itlas Pillai	Kumpurruppidi	8.2	0.50
S. Arulanadan	Kumpurruppidi	7.8	0.62
R.M. Theresa	Errakkandi	12.4	0.60
S. Darmalingam	Nilaveli	9.3	0.52
S. Sanmuganathan	Nilaveli	10.4	0.48
V. Subramuniyam	Gopalapuram	9.2	0.52
S. Sivalingam	Nilaveli	7.6	0.46

Table 2: Results of the pumping tests

Considering the results of the pumping tests, the hydraulic conductivity and the specific yield of the aquifer is comparatively high. The average value of the hydraulic conductivity is 9.6 m/day. The average value of the specific yield is 0.53.

3.4 Geophysical surveys

To evaluate the groundwater flow, aquifer dimensions are needed. Geophysical surveys are suitable methods to assess the aquifer dimensions. Hence, the resistivity method according to the Slumberger electrode configuration was applied. Three cross profiles from the sea side to the lagoon were conducted as AB, CD & EF lines and the elevations of all of the sounding points were taken with respect to the mean sea level. The water levels of the wells closer to the sounding points were measured.

The quantity of the work performed for geophysical surveys is given in table 3 and the resistivity sounding curves for three different locations are shown in figures 5 to 7.

Line	*Area*	*Distance of the line (km)*	*No. of sounding points*
AB	Nilaveli	1.5	12
CD	Valaiuthu	1.5	12
EF	Kumpurruppiddi	1.6	16

Table 3: Quantity of the work performed for the geophysical surveys

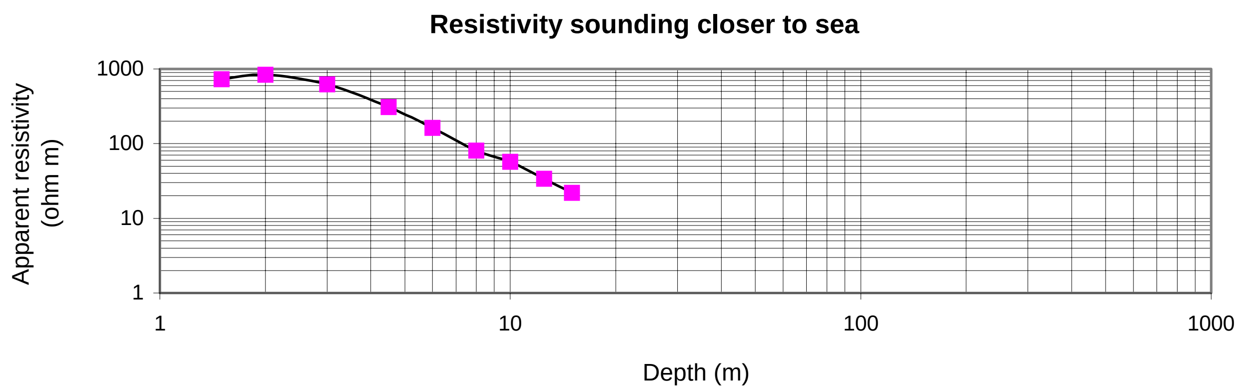

Figure 5: Resistivity sounding closer to sea

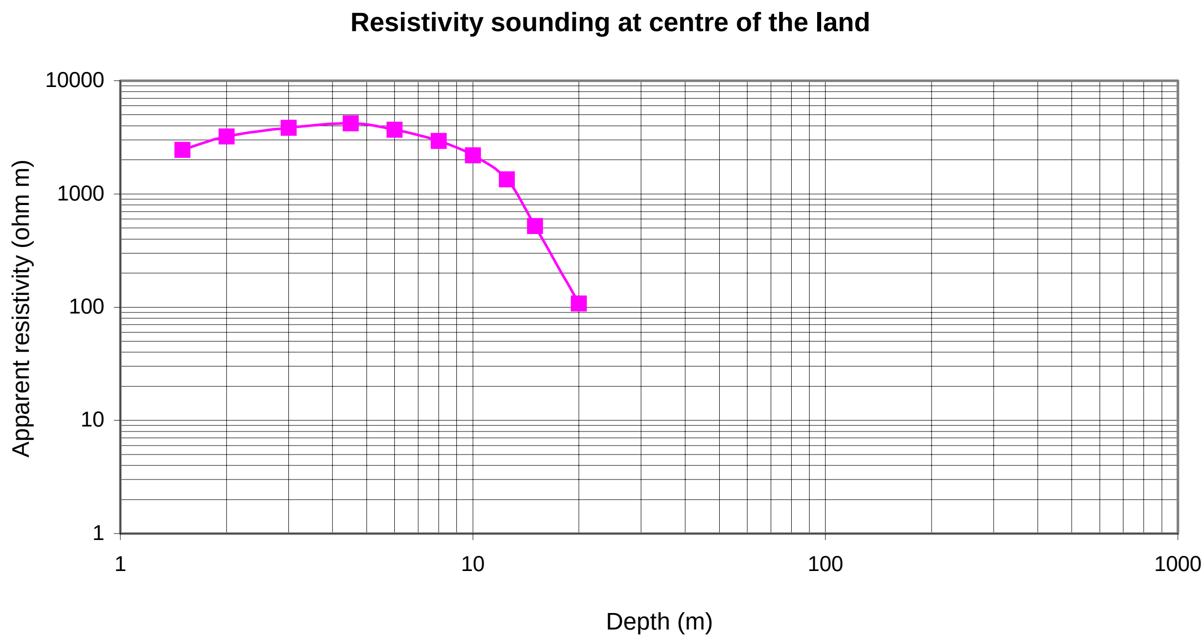

Figure 6: Resistivity sounding at centre of the land

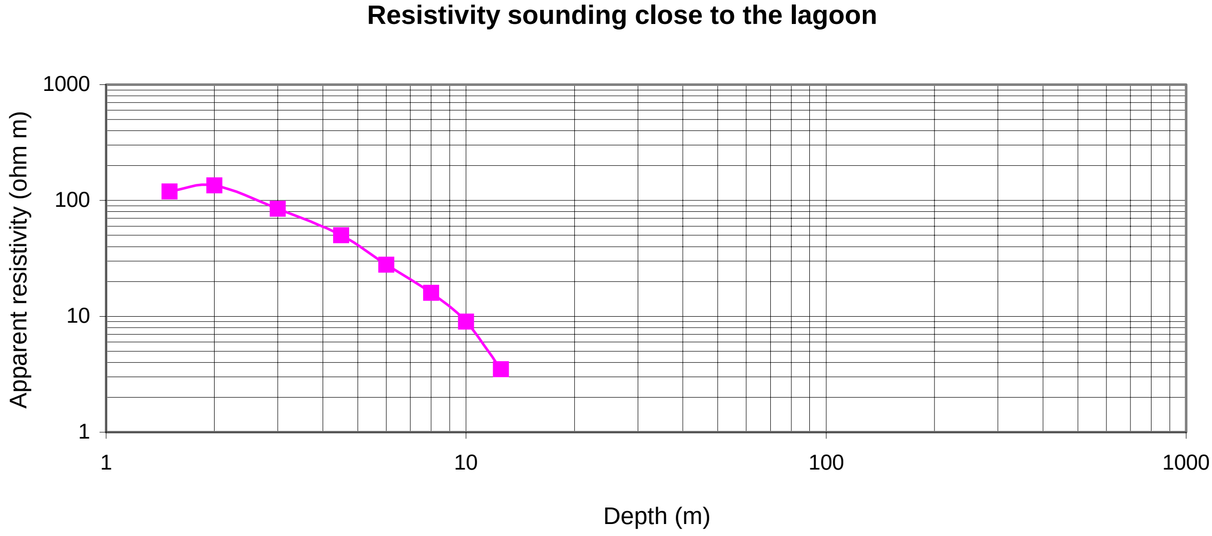

Figure 7: Resistivity sounding close to the lagoon

The geophysical data were analysed to determine the depth/distance to the saline to fresh water interface. Elevations and water levels and cross sections of the fresh water body were calculated and are shown in the annex.

3.5 Agro-well survey

During the field studies 30 agro-wells were surveyed in detail. The summarised and averaged results of the agro-well survey are given in table 4.

Parameter	*Results*
Average depth	4.5 m below ground level
Average pumping rate	300 litres per minute
Average cultivation area per well	1.5 acres
Average pumping period per day	6 hours
Average pumping interval	daily
Average pumping days per year	120 days

Table 4: Results of the agro well survey

4. Analysis

As described in chapter 2, the survey area stretches from Nilaveli in the south to Kumpurruppiddi in the north. The area is separated by a lagoon river at Erakkandi. For this reason the analysis of the groundwater flow, the water balance, the safe yield and the estimation of the water budget were carried out separately for the Nilaveli - Errakkandi area and the Kumpuruppiddi area.

4.1 Groundwater flow

According to the Darcy Law, the quantity of flow from a known section is given by:

Q = KAI

where Q = Groundwater flow
K = Hydraulic conductivity
A = Cross section area
I = Hydraulic gradient

The hydraulic conductivity is obtained from the pumping test results. The cross section area is obtained from the sections made based on the geophysical surveys and levelling. The hydraulic gradient is calculated by using monthly monitoring results. The whole groundwater regime is assumed as a steady state in a closed system.

Based on the above assumptions and parameters, the average groundwater flow was calculated on a monthly basis separately for both of the above areas. The highest groundwater flow occurs in the months of December and January and the lowest in July and August.

The results are given in table 5 and the variation of the monthly average groundwater flow and the average monthly precipitation is given in figure 8.

Month	*Average groundwater flow (m^3)*	
	Kumpurruppiddi area	*Nilaveli to Errakkandi area*
January	52,886	101,376
February	41,440	82,944
March	36,952	66,816
April	33,300	58,060
May	29,326	52,992
June	23,400	45,776
July	19,096	35,712
August	17,856	33,331
September	22,800	34,104
October	31,556	76,185
November	53,040	99,072
December	56,110	104,755
Total	*417,762*	*788,123*

Table 5: Average calculated monthly groundwater flow

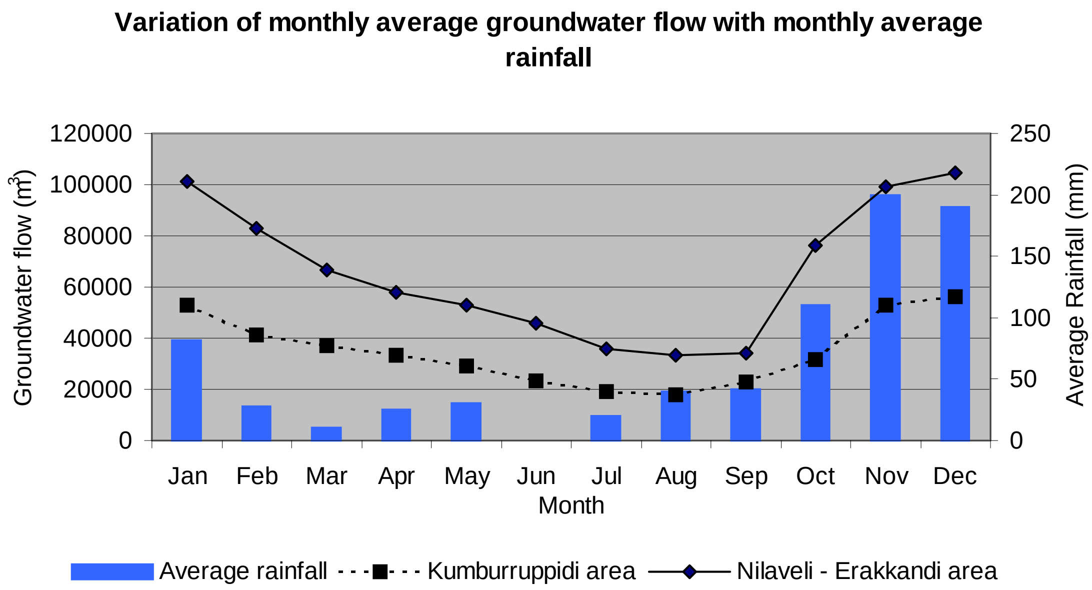

Figure 8: Variation of monthly average groundwater flow and monthly average rainfall

4.2 Water balance

The general equation for the groundwater balance (C.W. Fetter) is:

Input = Output +/- Groundwater Recharge

where Input = Rainfall

Output = Run off

Groundwater flow

Evapotranspiration

Rainfall: Average annual rainfall was calculated using the monthly rainfall data obtained from the meteorological department.

Run off: Since the infiltration rate and the permeability of sand formation are high, the run off is assumed at about 20% of the rainfall.

Groundwater flow: Calculation was done by using geophysical data, monthly monitoring data and pumping test data.

Evapotranspiration: The available meteorological data limit the calculation of the evapotranspiration. An assumption was made that about 40% of the rainfall will evaporate and be transported.

Based on the above, the calculated average annual groundwater recharge of the aquifer is as follows:

- Nilaveli - Errakkandi area 4.05 MCM
- Kumpuruppiddi area 2.36 MCM

4.3 Safe yield

From the water balance survey, the average annual recharge of the aquifer was calculated. However, the actual yearly groundwater recharge values are greater or smaller than the average values due to the variation of climatic conditions such as rainfall, temperature, wind velocity and humidity. It could be justified that the safe yield of this aquifer is assumed at about 60% of the average annual groundwater recharge. This figure is applied to avoid over extraction of the aquifer.

The safe yield of the coastal sand aquifer is about double the estimated annual recharge:

Nilaveli - Errakkandi Area	2.43 MCM
Kumpuruppiddi Area	1.42 MCM

4.4 Estimation of water budget

Kumpuruppiddi area

No. of agro wells:	226
Average pumping rate:	0.30 m^3/min
Average pumping period:	06 hours/day
Average pumping duration:	120 days/year
Groundwater abstraction per well:	12,960 m^3/year
Total groundwater abstraction:	2.93 MCM/year

Considering the average initial and average stabilised infiltration rates it can be assumed that the return flow from agricultural irrigation to the aquifer is about 30%.

Actual groundwater abstraction per well:	3,888 m^3/year
Total actual groundwater abstraction for this area:	0.88 MCM/year

The results of the estimation indicate that about 0.54 MCM of additional groundwater could be made available for irrigation purposes. That would mean that not more than 140 additional agro wells could be established.

Nilaveli - Errakkandi area

No. of agro wells:	706
Average pumping rate:	0.30 m^3/min
Average pumping period:	06 hours/day
Average pumping duration:	120 days/year
Groundwater abstraction per well:	12,960 m^3/year
Total groundwater abstraction:	9.15 MCM/year

Actual groundwater abstraction per well:	3,888 m^3/year
Total actual groundwater abstraction for this area:	2.74 MCM/year

An over abstraction of about 0.30 MCM of groundwater per year is estimated for this area.

4.5 Regulatory framework for agro-well operation

All the existing agro wells in the study area have partially penetrated this sand aquifer. The lateral flow lines while pumping of the well is shown in figure 9.

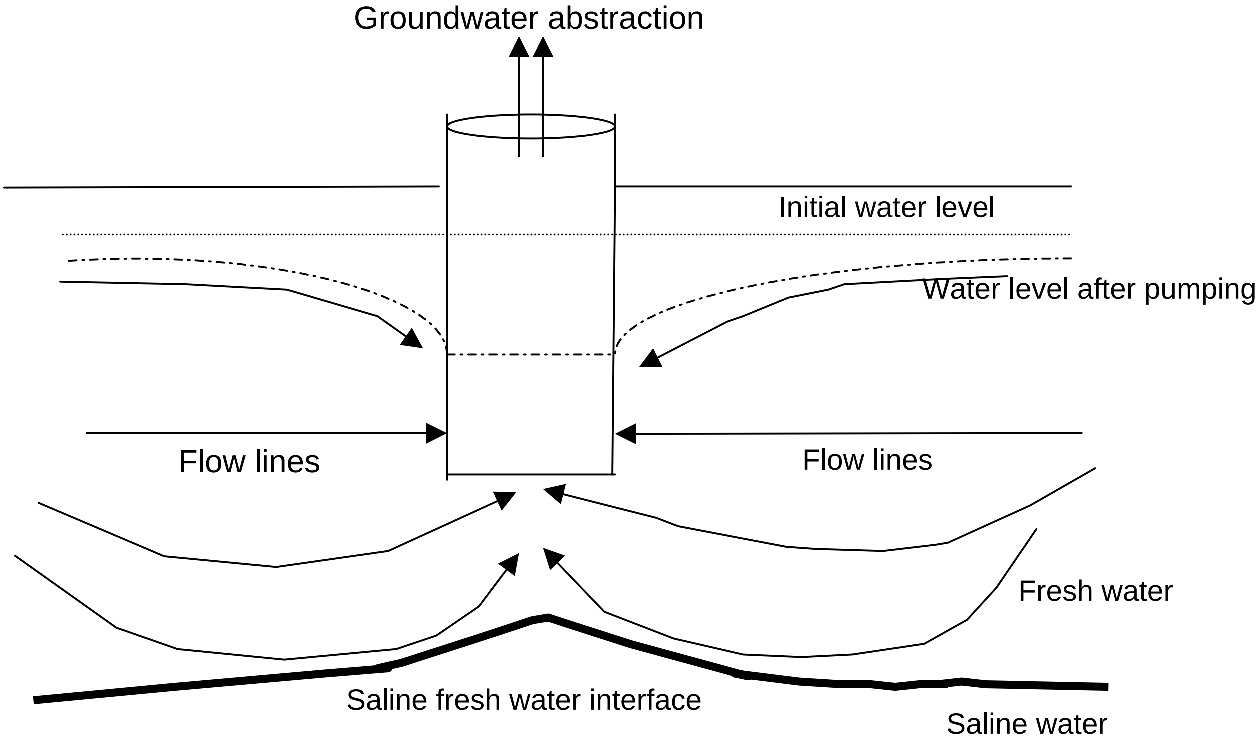

Figure 9: Flow lines while pumping of a well

At present, most farmers extract water from their agro-wells for a period of six to eight hours continuously. This practice may result in saline water/brackish water entering the fresh water lens and also in an uplifting of saline water at certain locations. If salt water intrusions was to happen for a longer period then this water could spoil the aquifer. It is quite obvious that the average pumping rates are at present far too high.

To protect the north eastern coastal sand aquifer water extraction is suggested as follows:

Safe pumping rate	250 litres per minute
Pumping period	6 hours per day

A regulatory framework for the operation of agro-wells should be introduced. It is recommended to keep a two hours break after pumping for two hours continuously. This would result in a recovery of the well. At the same time the flow of saline water from deeper zones into the aquifer will be interrupted. It is also necessary to stop pumping from the adjacent closer wells while pumping of the other wells continues. Once the pumping has stopped at the first wells, the other wells could operate for two hours. This procedure has to be followed for the rest of the day for a maximum pumping time of six hours.

5. Recommendations and conclusions

For the Kumpuruppiddi area a total of <0.54 MCM of additional groundwater per year would be available for irrigation purposes. About 140 additional agro-wells could be constructed. However, these wells should only be constructed in the low agro-well density areas, i.e. in locations which show a rather low agricultural and domestic intensity. Before construction of additional wells commences, it is recommended to conduct a survey for identifying suitable locations, depths of wells and well spaces.

The estimated water balance shows that over extraction of groundwater occurs in the Nilaveli - Errakkandi area. This area includes the G.S. Divisions of Nilaveli, Gopalapuram, Valaiuthu and Errakkandi. The agro-well density is very high in the Nilaveli and Gopalapuaram G.S. Divisions and the well spacing is rather close. In the Errakkandi G.S. Division a low agro-well density was observed, whereas a moderate density was recorded in the Valaiuthu G.S. Division.

Comparing the electrical conductivity of water from agro-wells in the Erakkandi and Valaiuthu area, the conductivity of the water is higher in the Nilaveli and Gopalapuram are. Over extraction of groundwater mainly occurs in these two G.S. Divisions. These two G.S. Divisions would be the initial locations which may endanger the coastal aquifer.

To protect and further develop the coastal sand aquifer on a long term base would require a number of initiatives:

- Convince the farming community about the importance and protection of the aquifer; cooperation between the Agricultural Department, Irrigation Department, Divisional Secretariats and Farmer Organisations would be essential. Crop rotation and alternative crops need to be introduced.

- Introduce a regulatory framework for the establishment and operation of agro-wells. All agro-wells and common wells need to be registered and licensed. A water abstraction model should be introduced. Finally, a regional water policy with emphasis to ensuring the safe yield of the aquifer, to protect the water quality and to introduce a balanced model for water uses for irrigation and domestic purposes.

- The groundwater abstraction in the Nilaveli and Gopalapuram areas should be limited as soon as possible. This could be achieved by decreasing the agricultural area per agro-well and introducing the regulated system for the agro-well operation.

- Since a considerable amount of groundwater is wasted due to the prevailing furrow irrigation system, it is important to improve the irrigation efficiency.

- Most farmers grow exclusively red onion in two or three crop seasons per year. Lately, four onion crops are grown. The return of IDPs will result in an additional stress on the coastal aquifer. Onion cultivation requires constant irrigation, the application of fertilisers and pesticides. The prevailing cultivation practice has a negative long-tem effect on the aquifer. The Department of Agriculture is advised to actively introduce alternative crops. Mixed cropping according to an environmental maximisation strategy should be introduced.

- Farmers are used to construct their agro-wells in an unsystematic manner. This results in low spacing between the wells. The safe distance between new and additional agro-wells should be determined. A hydrological survey should to be conducted.

- The present groundwater monitoring network done by IFSP-GTZ is to be continued and expanded over a longer time period to obtain reliable time series data. A provincial institution is to be charged with monitoring.

- A systematic groundwater model for future predictions uses of the north eastern coastal aquifer should be developed.

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