Status Report

on

Ground Water Potential and Use in Trivandrum District with Special Emphasis on Trivandrum City

By

Dr. K. Soman

Report Prepared for
RULSG

Centre for Development Studies
Thiruvananthapuram

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Figures

Tables

Executive Summary

Recent reports on the prospect of ground water availability within Thiruvananthapuram district by the Central Ground Water Board (CGWB) with the participation of the State Ground Water Department indicate that availability of ground water in the capital district is at around 270 litres per person per day (CGWB, 2014) as against the daily urban requirement of 150 litres per person per day. Total annual ground water recharge in March, 2004 was 308.51 Million Cubic Metres (MCM), and net ground water availability, after providing for natural discharges, was shown as 278.03 MCM. As on March, 2011, these figures were 355.96 MCM and 328.71 MCM respectively (CGWB, 2014), indicating an increase in ground water recharge in spite of a general trend of declining water table over the years, erratic monsoon and higher ambient temperature levels experienced. Computations for the capital city also showed most of the areas having sufficient ground water resources.

On the practical side, summer months in the district witness drying up of wells/drastic drop of water level in many parts, water shortage and misery to the people. The city's elevated areas and coastal stretches also witness water shortage. The predominant water level trend is seen skewed towards level decrease. Water level shows decrease in 47 wells (out of 62) during NE monsoon period during the observation years. The reported ground water recharge/availability figures appear contradictory to ground reality.

Perusal of the reports prepared based on the guidelines issued by the Ground Water Estimation Committee (GEC, 1997) and the related literature on the choice of the methodology by the Central Ground water Board (CGWB) indicate that ground water recharge/storage was calculated using essentially the Ground Water Fluctuation method, which is generally applied for local-scale, short term calculations in unconsolidated strata. Further, this methodology is oblivious to important factors such as temperature variabilty, evapo-transpiration rates, urbanization factors/land use etc. While applying this methodology in a highly undulating hard rock/laterite terrain like Kerala, omissions of certain guideline factors such as slope in the case of Thiruvananthapuram district happened. 'Specific yield' value application also appears faulted in the case of some assessment blocks. These resulted in escalated recharge figures. Absence of well archived/ tested data and lack of coordination among institutions engaged in comparable activities and data sharing appear the other causative factors.

Considering the complexities involved in ground water estimation, application of multiple techniques with varying uncertainties is generally accepted globally. In order for us to achieve this goal, serious capacity building efforts including re-training of the existing personnel in the water sector and creation of new institutions are needed.

Quality of ground water in the city is termed as *potable* in the CGWB report, though the harmful (from a public health perception angle) NO_3 upper values exceed the acceptable limits. The Environmental Monitoring Programme report amplifies the acidic nature of water samples, and mentions about microbial contamination, though the latter data sets are not included in the report. Perusal of the parametric mix in both the reports indicates inadequacy, calling for devising a monitoring design to accommodate spatial and temporal variations of the hydrological net works, point and diffuse sources of pollution, standardized analytical requirements etc

Inadequacy in availability of reliable data bases needs to addressed, and the data generated through public funding shall be preserved well and placed in the public domain. Legal and administrative measures are needed in regulating commercial scale ground water extraction and ground water trading that are bound to envelope the social domain in the context of global warming and attendant water shortage.

Available feedback from different sources and field observation inputs indicate the presence of extractable good quality ground water resources in many parts of TUA. The high yielding open wells at Pachallur and Vailur are two of the prominent examples. Interface of the coastal plains and the low lands shall be ideal sites for extracting good ground water sources.

Ground water to the tune of 1.35 MLD is under exploitation by the KWA in the city. Total ground water potential of the sedimentary sequence within the TUA needs to be ascertained and the strata need to be protected from excavations.

Status report

on

Ground Water Potential and Use in Trivandrum District with special emphasis on Trivandrum City

1.0 INTRODUCTION

"Water is life". It is how water has been characterized in the European Union (EU) Water Policy document. Such characterization is apt, as life on Earth had its origin in water, and life is not possible without water.

The world's water resources are locked in to the hydrologic cycle, whereby evaporation of ocean water becomes entrained in to the atmosphere. Precipitation provides water to the lakes, streams and wetlands (surface water). Further, part of the precipitation infiltrates in to the ground and becomes groundwater (sub surface water). Ultimately, all these continental waters flow back to the ocean and become recycled again. Oceans with 97.2% of all waters dominate the hydrosphere. There is less than 1% of water that is possibly available to mankind for its various uses. Riverine sources are a meager part of the above. Because of the limited nature of fresh water availability and the increasing demand for various purposes, besides resource depletion due to pollution, water resource estimation had become a major concern of Governments in the developed countries for national planning. Surface water evaluation is relatively easy, whereas ground water recharge estimation requires application of multiple techniques to increase reliability of recharge estimate (Scanlon et al, 2002). Global warming and climate change have all the ingredients to add to the woes of recharge estimation that can offset the water resource projections, affecting life and economy of nations.

A glance at the global water resource position and various components of the global water budget, its distribution and residence time indicate that ground water resources far exceed the instantaneous volume of riverine resources, and have longer residence time because of the long period of accumulation (Table 1). Today ground water is the source of about one third of global water withdrawals and provides drinking water for a large portion of global population ((Kundrewicz and Doll, 2009). Further, ground water resources are continuously recharged under favourable geo-climatic conditions, and are considered safe storage for use in difficult times.

Growth of Thiruvananthapuram, the capital of the of the erstwhile kingdom of Travancore (and present day Kerala) as a prosperous urban centre prompted the Travancore rulers to establish a piped water supply scheme way back in the 1930s. Water was drawn from the middle reaches of Karamana river at Aruvikkara. Commensurate with further growth of the city, the water supply scheme was augmented with storage enhancement by constructing another dam in the upper reaches of the river at Peppara. During a couple of drought years, even the enhanced storage seemed inadequate to meet the water requirements of the city water supply. Even today, the city water supply is not able to cater to the total demand of the population, and many city wards suffer supply shortage exceeding 41% of the demand. Available data on river run off from Kerala also substantiate the general declining trend in riverine surface sources of water. Fast expansion of the city and mounting deficiency in normal rainfall due to erratic monsoons as a consequence of global climatic change cast inhibitions on the desirability of total dependence on surface water as the only source of water supply in the city. The thought of ground water as a supplementary source assumes significance in this context. It has two advantages: (1) ground water resources are natural storage within the soil/substrata from the hydrologic cycle inputs, and can be nurtured by human efforts, and (2) ground water extraction can be managed in a decentralized manner by the needy local community.

Keeping this in view, a project on “City River Restoration” to clean up the river stretches passing through the city, which is key to ensuring clean ground water storage was initiated by the Centre for Development Studies (CDS), and a study was commissioned to report on the “Ground Water Potential and Use in Trivandrum District with special emphasis on Trivandrum City” with the following ToR:

- Ground water resource of Trivandrum district-present use, problems and future prospects
- Fluctuation of ground water
- Quality of ground water
- Adequacy/inadequacy of the institutions involved in ground water management in the matter of data gathering, analysis and dissemination
- Governance of ground water-role of government and Local Self Government Institutions (LSGIs)
- Any other issue that you feel necessary for the project

Table. 1 Distribution and residence time of various components of the global water budget

Water Item	Volume (Km^3)	Percentage	Residence time (yr)
Supply			
World ocean	1,370,000,000	97.2	40000
Icecaps and glaciers	29,200,000	2.13	10000
Ground water to depth of 4000 meters	8,350,000	0.59	5000
Fresh-water lakes	125,000	0.0089	100
Saline lakes and inland seas	104,000	0.0074	100
Soil moisture and vadose water	67,000	0.00475	1
Atmosphere	13,000	0.00092	0.1
Rivers (Average instantaneous volume)	1,250	0.00009	1
Total, all items	**1,410,000,000**	**100**	
BUDGET			
Annual evaporation from world ocean	350,000	0.026	
Annual evaporation from land areas	70,000	0.005	
Total annual evaporation	**420,000**	**0.031**	
Annual precipitation on world ocean	320,000	0.024	
Annual precipitation on land areas	100,000	0.007	
Total annual precipitation	**420,000**	**0.031**	
Annual runoff to oceans from rivers and icecaps	32,000	0.003	
Annual ground-water outflow to oceans	1,600	0.0001	
Total annual runoff and outflow	**33,600**	**0.0031**	

Source: U. S. Geological Survey, New Release, August 13, 1972.

The present report attempts to collate the available data on ground water resources of Thiruvananthapuram district and to evaluate the veracity of the available ground water estimates for Thiruvananthapuram district and the city bounds, which is vital while deciding on using these as supplementary sources. Adequacy/inadequacy of data availability and institutional mechanisms in ground water management and related governance issues are also touched upon in order to have a dependable dossier on this vital resource that can be tapped as a supplementary source, as well as a source in the event of emergencies.

2. 0 GROUND WATER ESTIMATION- UNDERLYING FACTORS AND CHOICE OF METHODOLOGY

Before attempting to elucidate the ground water situation in the district, it is contextual to examine the underlying factors that control ground water storage, recharge and the choice of estimation methods in any given territory.

Sub-surface water, or groundwater, is fresh water located in the pore space of soils and rocks. It is also the water that is confined within aquifers below the water table (Fig. 1). It can be thought of in the same terms as surface water with inputs, outputs and storage. The critical difference is that due to its slow rate of turnover, sub-surface water storage is generally much larger compared to inputs than it is for surface water. Predominance of ground water storage over surface water is amplified in the global water budget as well (ref. Table 1). In other words, it is easy for humans to use sub-surface water for a long time, if nurtured and used meticulously. Occurrence and storage of ground water are facilitated by a number of factors (hydrogeologic factors) influencing the infiltration and permeability rates, such as:

(1) Geology (rock type, texture, structure and tectonics, rock/soil properties). Unconsolidated sand, silt and boulders for example have a very high cumulative permeability rate. If there is substantial clay content within it, the permeability rate will be lesser. Depending on the extent of consolidation and facies change within sedimentary rocks, as is the case in large sedimentary basins such as the Indo-Gangetic plains, the infiltration rates will differ. Hard rocks such as granite, gneiss, khondalite, charnockite etc have generally low infiltration rates. Foliated and fractured/faulted rocks have higher water infiltration rates. Foliation angle of metamorphic rocks also exerts influence on the infiltration rates. In weathered rocks, parent rock structures and composition have influence on infiltration/permeability rates.

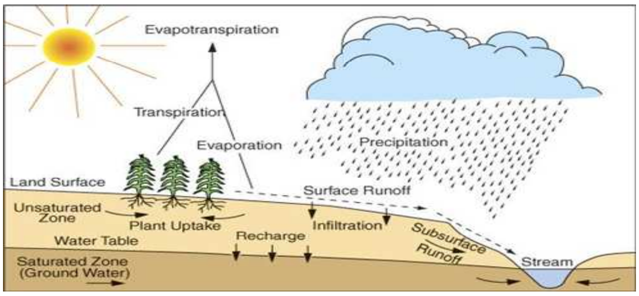

Fig. 1. Components of the hydrologic cycle. Water table above the saturated zone (Phreatic zone) is shown.

(2) Geomorphological/terrain features (elevation, slope, aspect and extent of weathering). These are closely interwoven with geologic, tectonic, and climatic factors and influenced by the vegetation type. Terrain elevation and slope are determinants in the runoff/infiltraton rates (Krishnamurthy and Srinivas, 1995). Laterite and lateritic soils have variable permeability depending on the source rock character, porosity and extent of induration. Nudging the areas of semi-arid climate, laterites become very hard resulting in very low infiltration rates, as in parts of Kasaragod district.

(3) Human interference with the land use and landscape (deforestation, mining, damming, overdraft , urbanization etc). All these activities have a negative impact on the ground water potential. Deforestation affects ambient temperatures, evaporation and infiltration rates. Mining, especially open cast mining usurps the top soil/strata conditions and dissects the phreatic zone (zone of saturation). Damming results in deprivation of water for the downstream, affecting infiltration rates. Over draft can choke the ground water reservoir. Urbanisation reduces areas of infiltration and increases ambient temperatures, adversely affecting ground water recharge.

(4) Climate (rainfall amount, annual distribution, intensity etc). Rainfall amount and seasonality are important in water saturation of strata. Sporadic, off season rainfall may not be as good as sustained rainfall in the infiltration scenario. Annual distribution is important as the prevailing temperature will determine the percentage of evapo-transipration, percolation and runoff. Intensity of rainfall influences runoff and percolation. Climate change has offset the prevailing rhythm, and the adverse impacts on the water front are yet to be assessed in India.

(5) Pollutant disposal has a determinant role in the quality of ground water, and hence in its availability.

Over the long term, the average rate of seepage above a sub-surface water source is the upper limit for average consumption of water from the ground water source. This upper limit is continuously constrained due to anthropogenic interventions such as land use change, landscape alterations and urbanization that restrict the seepage rates. Climate change induced erratic rainfall pattern, higher ambient temperatures and winds further reduce water availability for infiltration. Subsurface microbial pollution due to pit latrines also constrains ground water utility.

Groundwater recharge is a critical part of the overall water budget and is one of the most difficult components to quantify. The reliability of recharge estimates and mapping of the spatial and temporal variability of recharge remains a topic of great interest. Improved knowledge of this variability would help water managers to better assess water availability and protect vulnerable aquifers under stresses from expanding urbanization or drought. Recharge estimates should be detailed enough to resolve local variability while also providing accurate regional values needed to manage a regional ground water system (Scanlon et al, 2002).

A number of methods are applied in ground water recharge estimation based on physical parameters, chemical and isotopic techniques, numerical modeling and empirical methods. The most important among them relate to (1) Water Budget, (2) Base Flow measurements, (3) Darcian Methods, (4) Lysimeters, (5) Water Table Fluctuation (WTF), (6) Cumulative Rainfall Departure (CRD), (7) Temperature Measurements, (8) Electrical Resistivity Measurements, (9) Stable Isotopes of Hydrogen and Oxygen, (10) Ground Water Dating, (11) Chloride Mass Balance, (12) Run Off Modeling etc and recently through application of NASA’s Gravity Recovery and Climate Experiment (GRACE) satellite data integrating with other observations and using a sophisticated numerical model of land surface water and energy processes.

Because the actual recharge rate is never known with 100% certainty at a given location, use of multiple recharge estimation methods is beneficial. No single method can be termed the ‘‘best’’ at estimating recharge due to: (1) spatial and temporal variability in the various independent variables ; (2) inherent limitations for each method; (3) limitations on the availability of input data in a given area; and (4) variability in the uses or applications of the recharge estimates (Delin et al, 2007). Application of such a wide range of methods in ground water recharge estimations testifies to the complexities and uncertainties involved in the estimation process and their global acceptance.

In India, the premier ground water investigating agency, namely the Central Ground Water Board (CGWB) opted to adopt the unitary Water Level Fluctuation (WLF) method to assess ground water recharge. Justification for the choice is that the WLF has been by far the most commonly used method in all the water balance projects undertaken in India with international support (Rana Chatterjee, 2011; Rana Chateerjee and Ranjan Ray, 2014). This method is based on the premise that rise in ground water levels in unconfined aquifers is due to recharge/water arriving at the water table. It is further presumed that the fluctuation in water table indicates changes in ground water storage. Using notionally derived *specific yield* factors, the quantum of ground water recharge has been estimated based on this method, though this method is best applied over short time periods in regions having shallow water tables that display **sharp rises and declines** in water levels, i.e. in very porous and permeable strata. This methodology has been the choice by the CGWB for the entire country with disparate hydro geological settings and climatic zones. Difficulties in applying this method are related to determining representative value for specific yield and ensuring that fluctuations in water level are due to recharge, and not the result of changes in atmospheric pressure, the presence of entrapped air, or other phenomena such as pumping (Scanlon et al, 2002). In spite of such ambiguities and uncertainties, India's ground water resources remain estimated through the above method only.

3. 0 RELEVANCE OF SELECTION OF THE STUDY AREA

Thiruvananthapuram is the southernmost district of Kerala with a geographical area of 2186 km^2 (Kerala Gazetteer). It is bounded to east and south by the districts of Tamil Nadu, and bordered to the west by the Arabian Sea (Fig.2). Besides hosting the capital city of Kerala, the district is home to many attractive world class tourist destinations, a sprawling IT industry in the vicinity of the capital city itself, international airport, and an upcoming transshipment terminal at Vizhinjam, installations of the Vikram Sarabhai Space Centre (VSSC), many institutions of higher learning, research and medicare. Traditionally, known as an agricultural district, the industry in the district is limited, and essentially concentrated within the city bounds. Growth of urban centres is more prominent in the district. All these add to the demand on water on an urban requirement scale. 24X7 water supply system of Thiruvananthapuram city has been under severe stress for quite some time. It is in this background that an appraisal of the water resource situation in the district, especially its city bounds becomes relevant.

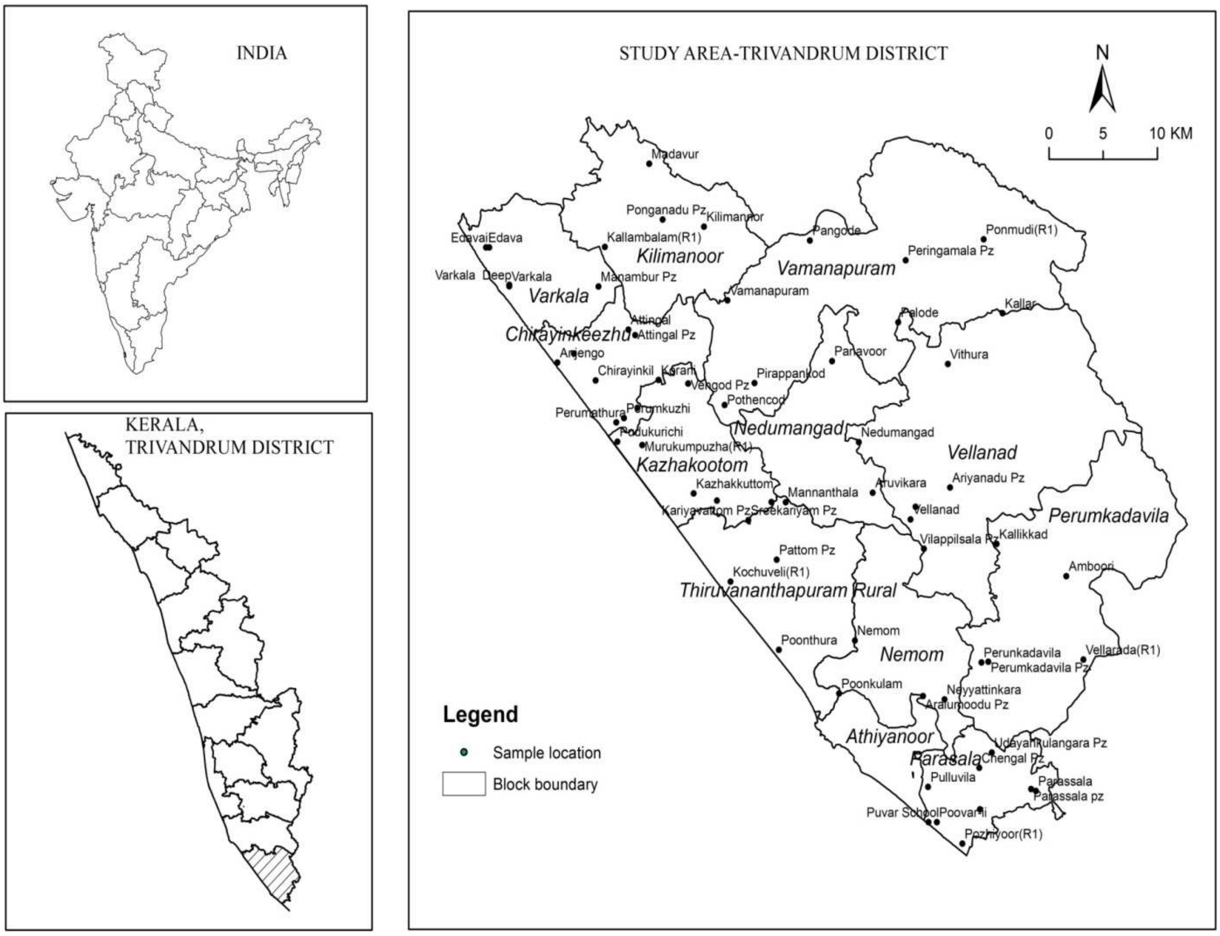

Fig. 2. Location map showing assessment blocks

4.0 HYDROMETEOROLOGIC AND HYDROGEOLOGIC SETTING OF THIRUVANANTHAPURAM DISTRICT

Climate:

Thiruvananthapuram district experiences tropical warm and humid climate. Being on the windward side of the Western Ghats, rainfall in the district is reasonably high. The north eastern portion of the district, comprising the Ghats and the neighbourhood receives much more rainfall. Owing to its position near the south western end of the Indian peninsula, the district benefits from the south west monsoon and to a lesser extent from north east monsoon. By analyzing the rainfall trend in the district, the following three seasons are identified (CESS Report 1996):

South-west monsoon-(June to September)

North-east monsoon -(October to December)

Other than monsoon-(January to May).

This is also in tune with the climate season projections in Attri and Tyagi (2010).

Isohyets for the three seasons are given in Fig. 3, 4 and 5. Mean rainfall varies from less than 200 cm to more than 300 cm. Rainfall increases towards the Ghats region. The north western part of the district receives rainfall ranging from 100 cm to 150 cm. Analysis of long term meteorological data indicates that the district receives most of the rainfall during south-west monsoon. Available daily precipitation data for the period 1994-2004 indicate a shift of peak rainfall from June to October when compared to the long term average (Jennerjahn et al. 2008). During north-east monsoon, the rainfall is low varying from 60 to 80 cm and the foothills of the northern part of the district receive more of it. Rainfall during January-May is scattered and in the range of 30-50 cm (CESS Report, 1996). A decreasing trend in rainfall for the Kerala region has been projected in the Climate profile of India , and the all- India increase in annual mean temperature has been placed at 0.56^{o} C with increasing trend both in the maximum and minimum temperature across the country (Attri and Tyagi, 2010). Data on Trivandrum district-specific rainfall deficiency and temperature/evaporation increase, parameters very vital in water resource evaluation, are not readily available, and not factored in the CGWB estimates. Because of the rainfall variability and terrain characteristics, infiltration, percolation, evaporation and runoff rates in various parts of the district are bound to be different. Recent climate data available with the State Ground Water Department is priced, and hence could not be accessed for use in this report.

Physiography and drainage:

Fluvio-denudational and marine-estuarine geological processes have been mainly responsible for shaping the terrain system of the district. Aeolian process had also been operative in part of the coastal stretch. Based on relief features and break in slope, the district can be divided into five physiographic divisions, viz. (a) coastal plains (0-10m), (b) lowland (10-100m), (c) midland (100-300m), (d) foothill region (300-600m) and (e) high ranges of the Western Ghats (Fig. 6). Slope parameters and morphogenetic attributes permit identification of 11 terrain units excluding water bodies. They are shown in Table 2. Over 31% of the area has slope categories in the range of 31-54%.

Neyyar, Karamana and Vamanapuram are the major drainage basins of the district. Drainage density and broad soil types pertaining to the terrain units are also shown in Table 6.

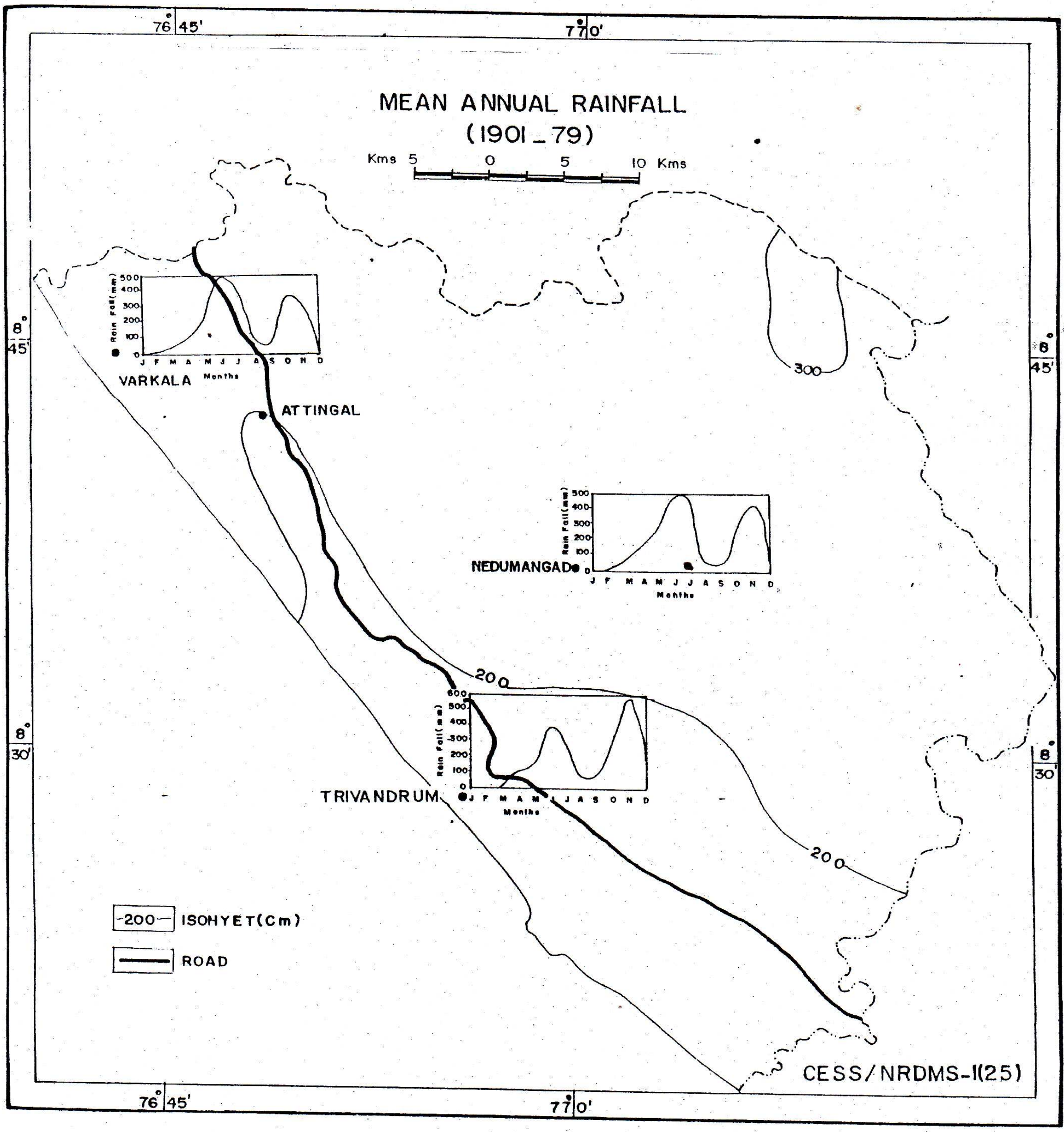

Fig. 3 Isohyets showing mean annual rainfall during 1901-1979 period. Rainfall graphs from Trivandrum, Nedumangad and Varkala stations are shown

Source: CESS Report, 1996

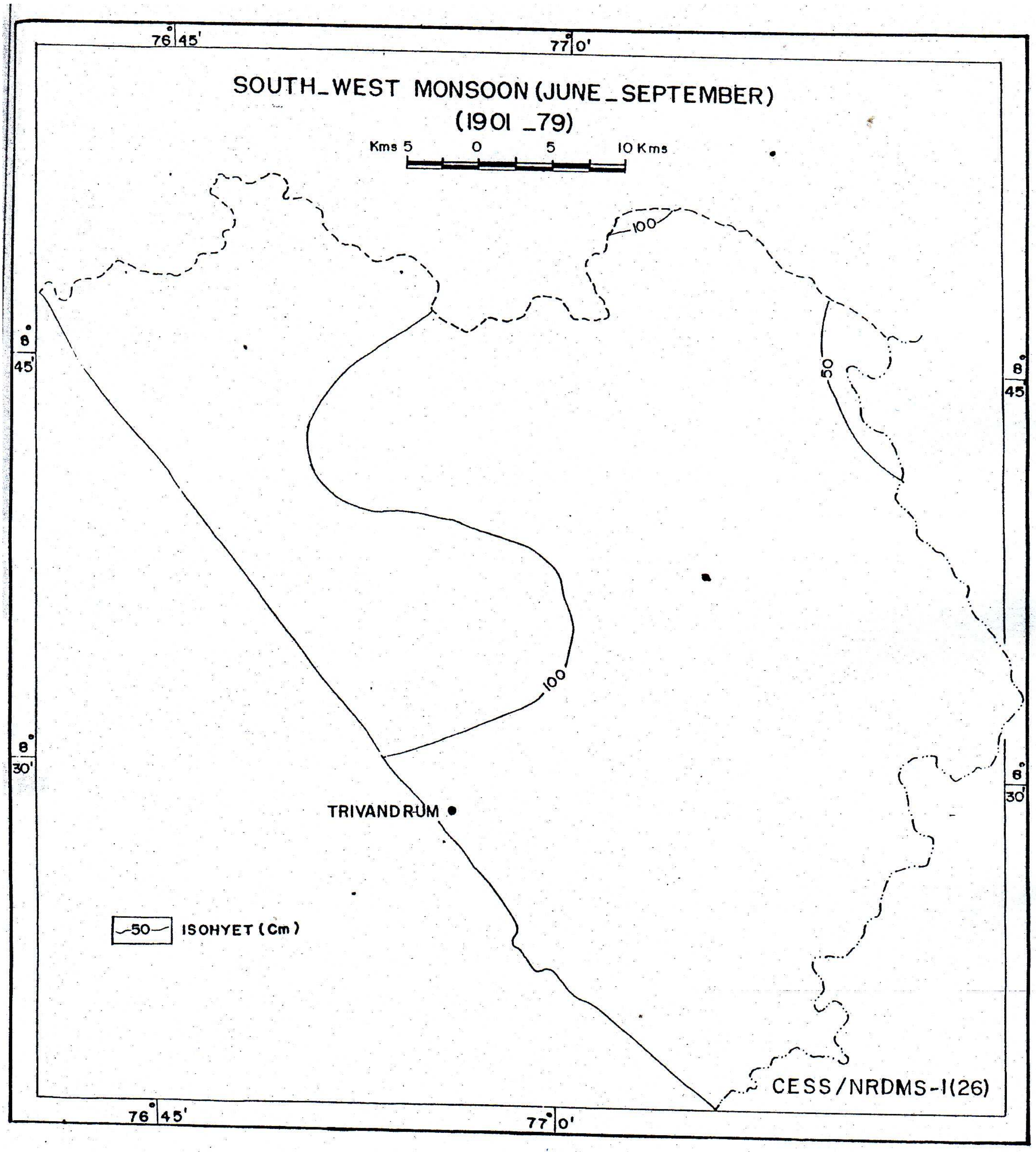

Fig. 4. Isohyets showing rainfall during SW monsoon, 1901-1979 period.

Source: CESS Report, 1996

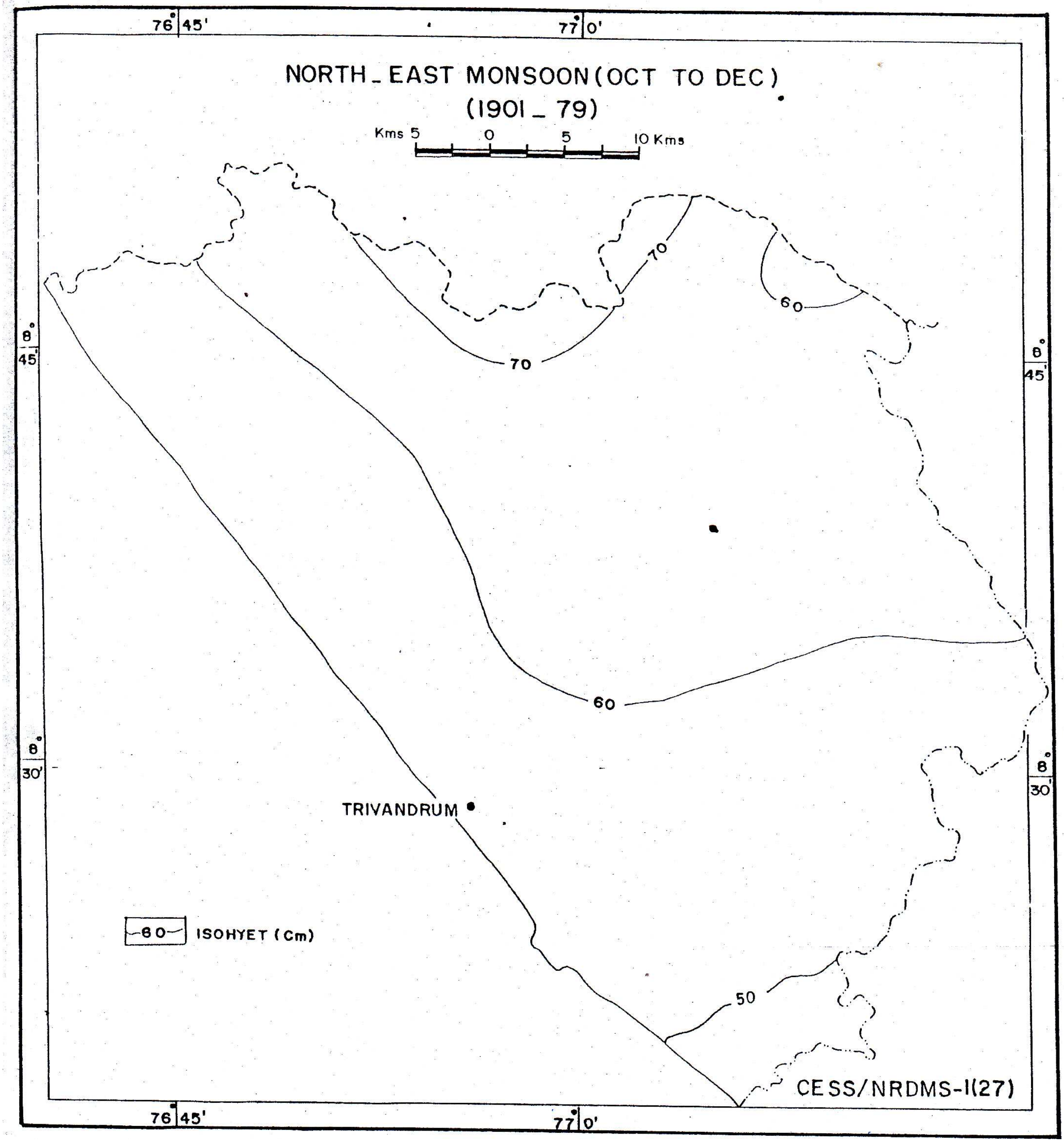

Fig. 5. Isohyets showing rainfall during NE monsoon, 1901-1979 period.

Source: CESS Report, 1996

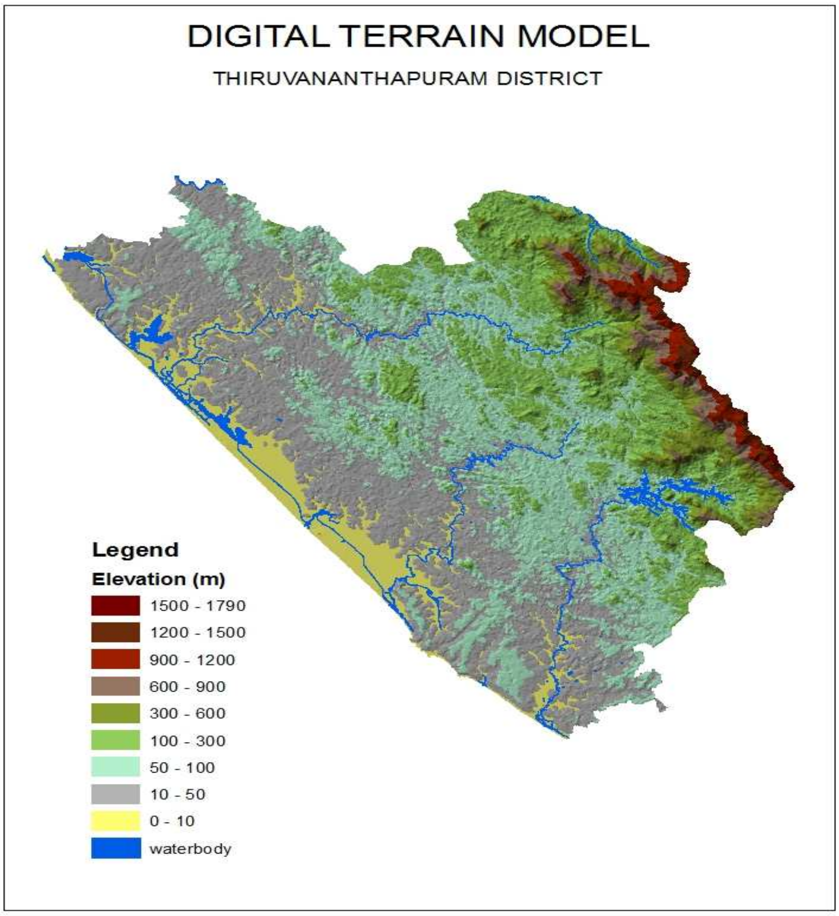

Fig. 6. Digital Terrain Model, Thiruvananthapuram district

Geological setting:

Geological features of the terrain influence physiography, drainage pattern, soil characteristics, extent and depth of weathering profile development and hence the water availability. Bulk of the rock types encountered within the territory of Thiruvananthapuram district belongs to the Precambrian basement complex, comprising products of granulite facies metamorphism . These are identified with the khondalite and charnockite suites of rocks. The khondalite suite of rocks consists of garnet-biotite gneiss with discontinuous bands of garnet-sillimanite-graphite gneiss (khondalite *sensu-stricto*). Charnockite occurs as large patches extending for scores of metres and as enclaves within garnet-quartz-feldspar neosome. The enclaves show evidence of retrogression at their contact with the neosome. Charnockite can also be found as later, arrested development in a number of quarry exposures. Outcrops of augen gneiss occur to the north east of Thiruvananthapuram city. Early Paleozoic granites and pegmatites and Tertiary dolerite dykes intrude the Precanbrian rocks. Regional foliation and secondary compositional banding in the rocks trend NW-SE with moderate dips. Towards the west, dip angles become moderate to gentle. Fractures and joints aligned in NW-SE, N-S and WNW-ESE directions traverse the terrain. The western fringe of the district exposes outcrops of sedimentary formations belonging to the Warkallai formation (Mio-Pliocene age), overlain by Quaternary age sands and Teri sands. Rocks of the Warkallai formation and the Precambrian rocks are seen lateritised to various depths (Photo 1) depending on rock structure and geomorphic setting (Soman et al, 1995).

Table 2. Terrain system, Thiruvananthapuram – attribute data

Unit Name	Map Symbol	Area (%)	Relative relief (m)	Slope (%)	Drainage density km/km^2	Broad soil Type	Land use
Beach	C1	0.77	-	-	-	Sandy	-
Coastal Cliff	C2	0.12	28	14	1.4	Rocky/laterite	Mixed trees
Coastal Plain	C3	5.58	13	5	0.5	Sandy	Settlement/cultivable land
Coastal Plain-lateritic	C4	1.17	28	18	0.5	Lateritic	Settlement with trees
Flood Plain – valley fills	F1	2.1	15	7	1.5	Alluvium	Seasonal crops including paddy and settlement with trees
Low rolling plain	D1	42.78	20	8	0.9	Alluvium/lateritic	---Do---
Moderately undulating plain	D2	13.53	62	22	2	Lateritic/red loam	Seasonal crops including paddy & rubber settlement with trees
Highly undulating terrain	D3	10.01	95	35	2	Lateritic	Mixed crops, dispersed settlements, scrubs
Hilly area	D4	19.86	150	32	4	Forest loam	Forest plantation
Isolated hills	D5	1.13	60	31	2.6	Laterite/residual	Plantations, mixed trees, settlements
Scarp slope	D6	0.12	500	54	5.3	Barren rock/Forest loam	Forest and plantation
Water bodies	-	2.82	-	-	-	-	-

Source: Chattopadhyay S and Mahamaya Chattopadhyay (1995)

Laterite developed over metamorphic rocks is more enriched in iron compared to the iron content in laterite profiles over sedimentary rocks (Soman and Slukin, 1987), with implications on their physico-mechanical and infiltration properties and ground water recharge potential. Further, laterite profile development is deeper in the gneissic rocks than in the massive charnockite. Weathering of quartzo-feldspathic bands and pegmatitic veins within the genisses give rise to kaolin beds that obstruct permeation of seepage waters deeper and across, and rather facilitate their discharge in to the surface water system through the foliation planes (Photo 1).

Photo 1. Impermeable layers of china clay beds (white in colour) in the laterite zone, Thonnakkal, Thiruvananthapuram district.

Land use

Trivandrum is essentially an agricultural district. As per 1996 data, agricultural land occupied around 77% of the district, and forests around 18%. Water bodies occupied 2.53% of the area. Built up area was 0.44%. Hard rock out crop category has also been shown recorded. This scenario has changed much since then. Large parts of the low lying areas have been reclaimed, and lateritic hillocks leveled for extracting soil as filling material, affecting ground water recharge potential.

5.0 WATER RESOURCE POTENTIAL OF THIRUVANANTHAPURAM DISTRICT

5.1 Surface water sources

Taking into account the annual rainfall figure of 2.14 m used in the CGWB computations, the district of Thiruvananthapuram receives 4.68 Billion Cubic Metres (BCM) of water annually. The district is drained by Neyyar, Karamana Ar, Vamanapuram Ar and Mamam thodu. Together they provide an annual runoff of about 3.4 BCM, if to rely on the 1974 estimates. Dams, water diversion and abstraction projects, climate variability and increase in evaporation rates are bound to offset the above figure.

5.2 Ground water resources

Ground water resources of the District were computed by the CGWB, based on water level fluctuation data from 142 observation wells (64 of the CGWB and 78 of the Ground Water Department) in the District.

Prospect of ground water availability within the district, as reported by the Central Ground Water Board (CGWB) with the participation of the State Ground Water Department, is promising and indicative of sufficiently large quantities of ground water that can support the needs of the entire population of the District (CGWB, 2008 and 2014).

Total annual ground water recharge in March, 2004 was 308.51 MCM, and net ground water availability was shown as 278.03 Million Cubic Metre (MCM) (CGWB, 2008) spread over 12 assessment blocks in the District. Out of these, 7 blocks were characterized as "safe", two as "semi critical", two as "critical" and one as "over exploited[1]".

As on March, 2011, annual ground water recharge and net ground water availability figures were 355.96 MCM and 328.71 MCM respectively (CGWB, 2014), indicating an increase in ground water recharge in spite of a general trend of declining water table over the years and higher ambient temperature levels experienced. Assessment blocks were 11, out of which 8 were termed "safe" and 3 as "semi critical".

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[1] "Safe" blocks constitute areas which have ground water potential for development.
"Semi critical" blocks consist of areas where cautious ground water development is recommended "Critical" and "over exploited" blocks denote areas where there should be intensive monitoring and evaluation and future ground water development be linked with water conservation measures and micro level studies (Dynamic Ground Water Resources of Kerala, 2014).

District’s ground water availability computed by the CGWB as of March, 2004 and March 2011 (CGWB 2008, 2014) are given in Tables 3 & 4.

For the population in the district per census data 2001, it amounted to about 235 litres/day of ground water availability per person during 2004. 2011 figures are a bit higher with ground water availability at around 270 litres/day per person.

5.3 Situation on the Ground

On the practical side, summer months in the district witness drying up of wells/drastic drop of water level in many parts, water shortage and misery to the people. Parts of the city are also not exception, especially its elevated areas and coastal stretches. The available ground water recharge/ net availability figures appear contradictory to ground reality. Unplanned growth of the city has resulted in large scale reclamation of the wetlands, marshes and ponds that used to be the flood-cushioning areas, as well as recharge sources of ground water. Inadequate sanitation and waste management measures adversely affect water quality and hence water resource availability. As there is an urgent need to provide safe water to the population of the city’s coastal wards, wards in the elevated terrain segments, city periphery and in the slum areas, a thought process is on whether the ground water potential could be put to effective use. However, the mismatch between the projected ground water recharge/net ground water availability figures and the ground truth, calls for a check on the veracity of the projected figures.

Table 3. Block wise net ground water availability as on 31st March 2004, Thiruvananthapuram District (in MCM) (CGWB, 2008)

Sl. No.	Assessment Unit/Block	Command/non-Command/Total	Recharge from rainfall during monsoon season	Recharge from other sources during monsoon season	Recharge from rainfall during non-monsoon season	Recharge from other sources during non-monsoon season	Total Annual Ground Water Recharge (4+5+6+7)	Natural Discharge during non-monsoon season	Net Annual Ground Water Availability (8-9)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	Varkala	Non-Command	11.31	Nil	7.15	2.00	20.46	2.05	18.41
2	Kilimanoor	Non-Command	10.41	Ni	11.70	4.00	26.11	2.61	23.5
3	Vamanapuram	Non-Command	24.37	Ni	27.34	3.00	54.71	5.47	49.24
4	Chirayinkil	Non-Command	8.08	Ni	7.65	3.4	19.13	1.85	17.28
5	Kazhakkoottam	Non-Command	11.56	Ni	9.53	2.34	23.43	3.34	20.09
6	Nedumangad	Non-Command	7.11	Ni	9.98	1.23	18.32	1.77	16.55
7	Vellanad	Non-Command	21.35	Ni	29.94	1.62	52.91	5.1	47.81
8	Thiruvananthapuram	Non-Command	8.71	Ni	7.17	0.70	16.58	1.68	14.90
9	Nemom	Non-Command	9.71	Ni	8.76	1.00	19.47	1.95	17.52
10	Perumkadavila	Non-Command	3.57	Ni	19.57	8.5	31.64	3.16	28.48
11	Athiyannur	Non-Command	6.04	Ni	4.99	0.83	11.86	0.73	11.13
12	Parassala	Non-Command	5.96	Ni	6.33	1.6	13.89	0.77	13.12
Total			**128.18**	**Nil**	**150.11**	**30.22**	**308.51**	**30.48**	**278.03**

Table 4. Block-wise net ground water availability as on 31st March 2011, Thiruvananthapuram District (CGWB, 2014)

Sl. No.	Assessment Unit/District	Command/non-Command/Total	Recharge from rainfall during monsoon season	Recharge from other sources during monsoon season	Recharge from rainfall during non-monsoon season	Recharge from other sources during non-monsoon season	Total Annual Ground Water Recharge [(4)+(5)+(6)+(7)]	Provision for Natural Discharges	Net Annual Ground Water Availability [(8)-(9)]
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	Athiyannur	Non-Command	1219.21	36.51	436.24	83.00	1774.97	88.75	1686.22
2	Chirayinkeezhu	Non-Command	1041.42	6.68	370.85	340.00	1758.95	87.95	1671.00
3	Kilimanoor	Non-Command	2353.98	13.57	599.83	400.00	3367.38	336.74	3030.64
4	Nedumangad	Non-Command	2297.39	9.38	585.41	198.00	3090.18	309.02	2781.17
5	Nemom	Non-Command	3264.56	34.75	927.92	100.00	4327.23	216.36	4110.87
6	Parassala	Non-Command	1317.57	45.31	335.74	152.55	1851.17	185.12	1666.05
7	Perumkadavila	Non-Command	2294.69	26.39	877.09	850.00	4048.16	404.82	3643.35
8	Pothencode	Non-Command	1430.59	31.64	373.76	234.00	2069.99	103.50	1966.49
9	Vamanapuram	Non-Command	5084.86	26.06	1361.85	300.00	6772.76	338.64	6434.13
10	Varkala	Non-Command	1440.11	16.95	366.96	200.00	2024.02	202.40	1821.62
11	Vellanad	Non-Command	3147.24	37.56	1202.95	123.27	4511.03	451.10	4059.93
	Total (ha.m)	**Non-Command**	**24891.61**	**284.81**	**7438.6**	**2980.82**	**35595.85**	**2724.39**	**32871.46**
	Total (MCM)	**Non-Command**	**248.92**	**2.85**	**74.39**	**29.81**	**355.96**	**27.24**	**328.71**

5.4 Depth to Water Table and Water Level Fluctuation

In view of the discrepancy between ground water recharge estimates and the ground reality, it was thought rational to look in to the water level fluctuation data, being the base of the estimation method adopted in the reports.

Depth to water table and water level fluctuation in the district have been examined based on the data from 64 observation wells maintained by the Central Ground Water Board (CGWB) and used in the recharge estimates. Observation period ranged from 2004 to 2014-2015. Data from Ground Water Department, GoK could not be accessed for the scrutiny. List of the CGWB observation wells with the coordinates is given in Table 5.

Table 5. Location of CGWB observation wells , Thiruvananthapuram District

1. ATHIYANNOOR BLOCK				
SL. No.	**LATITUDE**	**LONGITUDE**	**LOCATION**	**WELL TYPE**
1	8°24'50" N	77°3'45" E	Aralumoodu	Bore well
2	8°25'45" N	76°59'0" E	Poonkulam	Dug well
2. CHIRAYINKEEZHU				
Sl. No.	**LATITUDE**	**LONGITUDE**	**LOCATION**	**WELL TYPE**
1	8°40'20" N	76°45'25" E	Anjengo	Dug well
2	8°41'50" N	76°49'0" E	Attingal	Dug well
3	8°41'35" N	76°49'20" E	Attingal	Bore well
4	8°39'30" N	76°47'20" E	Chirayinkil	Dug well
5	8°40'45" N	76°46'15" E	Kadakkavur	Dug well
6	8°37'33" N	76°48'22" E	Perumathura	Dug well
7	8°37'45" N	76°48'45" E	Perumkuzhi	Dug well
3. KAZHAKKOOTAM				
Sl. No.	**LATITUDE**	**LONGITUDE**	**LOCATION**	**WELL TYPE**
1	8°33'55" N	76°53'25" E	Kariyavattom	Bore well
2	8°34'15" N	76°52'15" E	Kazhakkoottom	Dug well
3	8°39'30" N	76°50'30" E	Korani	Dug well
4	8°19'35" N	77°6'35" E	Kulathoor	Bore well
5	8°38'28" N	76°50'2" E	Mangalapuram	Bore well
6	8°36'30" N	76°49'40" E	Murukumpuzha	Dug well
7	8°38'20" N	76°53'50" E	Pothencod	Dug well
8	8°36'40" N	76°48'25" E	Pudukurichi	Dug well
9	8°33'0" N	76°55'0" E	Sreekariyam	Dug well
10	8°39'20" N	76°52'0" E	Vengod	Bore well
4. KILIMANOOR				
Sl. No.	**LATITUDE**	**LONGITUDE**	**LOCATION**	**WELL TYPE**
1	8°46'35" N	76°52'50" E	Kilimannor	Dug well
2	8°49'30" N	76°50'5" E	Madavur	Dug well
3	8°46'55" N	76°50'45" E	Ponganadu	Bore well

4	8°45'40" N	76°47'50" E	Kallambalam	Dug well
5. NEDUMANGAD				
Sl. No.	**LATITUDE**	**LONGITUDE**	**LOCATION**	**WELL TYPE**
1	8°34'10" N	77°1'10" E	Aruvikara	Dug well
2	8°36'35" N	77°0'35" E	Nedumangad	Dug well
3	8°40'20" N	76°59'15" E	Panavoor	Dug well
6. NEMOM				
Sl. No.	**LATITUDE**	**LONGITUDE**	**LOCATION**	**WELL TYPE**
1	8°27'25" N	77°0'20" E	Nemom	Dug well
2	8°24'40" N	77°4'50" E	Neyyattinkara	Dug well
7. PARASSALA				
Sl. No.	**LATITUDE**	**LONGITUDE**	**LOCATION**	**WELL TYPE**
1	8°21'30" N	77°6'34" E	Chengal	Bore well
2	8°20'25" N	77°9'25" E	Parassala	Dug well
3	8°20'30" N	77°9'10" E	Parassala	Bore well
4	8°27'0" N	76°56'30" E	Poonthura	Dug well
5	8°19'0" N	77°4'25" E	Poovar	Dug well
6	8°18'0" N	77°5'42" E	Pozhiyoor	Dug well
7	8°20'40" N	77°3'8" E	Pulluvila	Dug well
8	8°19'0" N	77°4'0" E	Puvar School	Dug well
9	8°22'45" N	77°7'29" E	Udayankulangara	Bore well
8. PERUMKADAVILA				
Sl. No.	**LATITUDE**	**LONGITUDE**	**LOCATION**	**WELL TYPE**
1	8°30'20" N	77°11'0" E	Amboori	Dug well
2	8°31'50" N	77°7'30" E	Kallikkad	Dug well
3	8°26'24" N	77°7'3" E	Perumkadavila	Bore well
4	8°26'22" N	77°6'42" E	Perunkadavila	Dug well
5	8°26'28" N	77°11'50" E	Vellarada	Dug well
9.TRIVANDRUM RURAL				
Sl. No.	**LATITUDE**	**LONGITUDE**	**LOCATION**	**WELL TYPE**
1	8°30'10" N	76°54'5" E	Kochuveli	Dug well
2	8°34'10" N	76°57'0" E	Mannanthala	Dug well
3	8°33'20" N	76°56'35" E	Mannanthala	Bore well
4	8°45'55" N	76°58'10" E	Pangode	Dug well
5	8°31'10" N	76°56'25" E	Pattom	Bore well
10. VAMANAPURAM				
Sl. No.	**LATITUDE**	**LONGITUDE**	**LOCATION**	**WELL TYPE**
1	8°43'40" N	77°2'50" E	Peringamala	Bore well
2	8°39'20" N	76°55'20" E	Pirappankod	Dug well
3	8°43'10" N	76°54'0" E	Vamanapuram	Dug well
11. VARKALA				
Sl. No.	**LATITUDE**	**LONGITUDE**	**LOCATION**	**WELL TYPE**
1	8°45'40" N	76°41'50" E	Edava	Tube well
2	8°45'40" N	76°42'0" E	Edavai	Dug well
3	8°43'50" N	76°47'30" E	Manambur	Bore well
4	8°43'52" N	76°43'0" E	Varkala	Dug well
5	8°43'56" N	76°43'0" E	Varkala Deep	Tube well

12. VELLANAD				
Sl. No.	LATITUDE	LONGITUDE	LOCATION	WELL TYPE
1	8°34'50" N	77°5'10" E	Ariyanadu	Bore well
2	8°42'30" N	77°7'51" E	Kallar	Dug well
3	8°33'35" N	77°3'25" E	Mithranikethan	Bore well
4	8°43'15" N	77°1'55" E	Palode	Dug well
5	8°44'45" N	77°7'32" E	Ponmudi	Dug well
6	8°33'0" N	77°3'10" E	Vellanad	Dug well
7	8°31'25" N	77°2'30" E	Vilappilsala	Bore well
8	8°40'10" N	77°5'5" E	Vithura	Dug well

Spatial distribution of the observation wells is given in Fig. 7. Water level data projected on to transect profiles along and across river basins of the district have also been examined. Histograms of water level during dry season along the transects 1-6 are given in Fig. 8, and those of water level in the cross-transect are shown in Fig. 9.

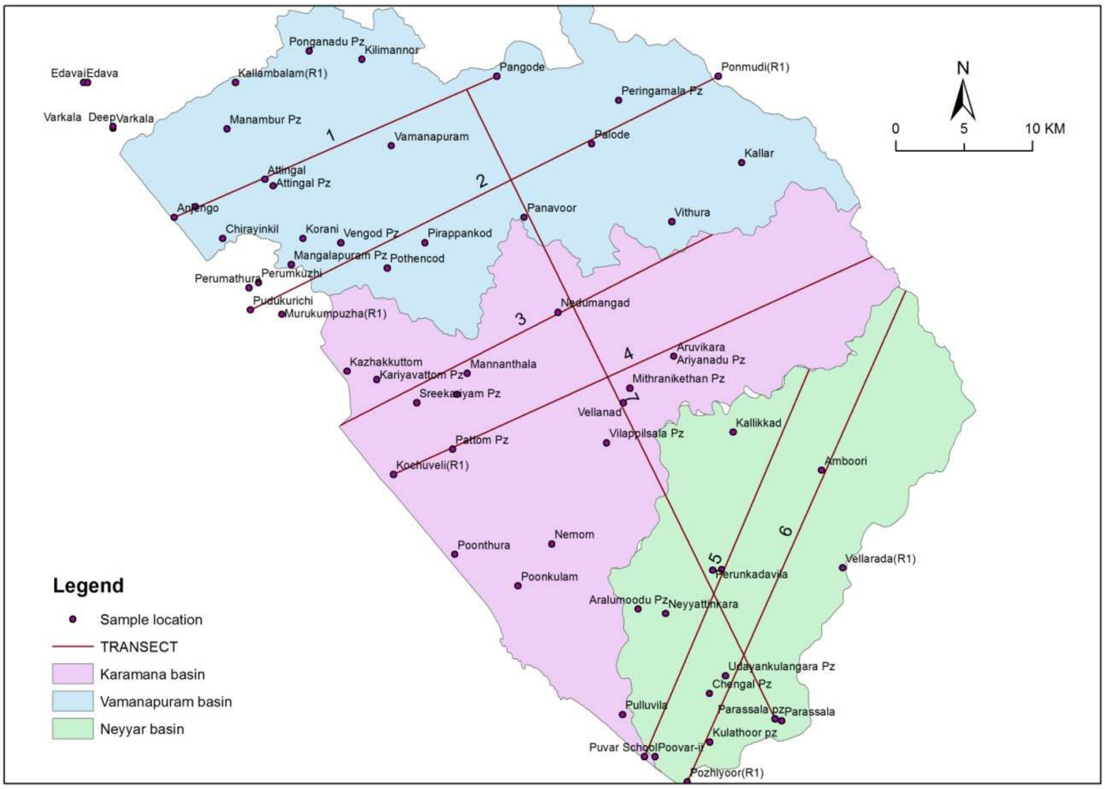


Fig. 7. Spatial distribution of Observation wells with transect locations 1-7 and River basin boundaries, Thiruvananthapuram District.

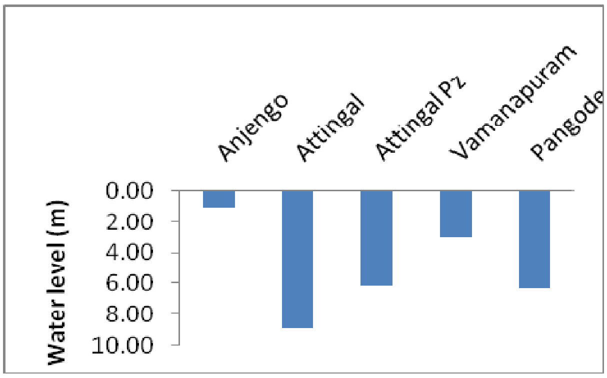
Transects 1 and 2 are within the Vamanapuram River basin, 3 and 4 within the Karamana River basin and 5 and 6 within the Neyyar catchment.

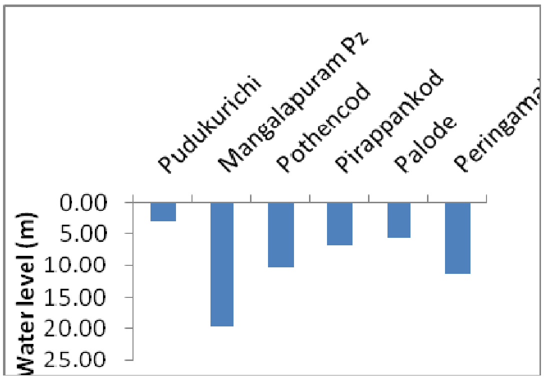
Water Table in wells within the Vamanapuram River basin is on an average below 10 m below ground level (bgl), with the exception of well in the Mangalapuram area, which forms part of an elevated coast parallel ridge.

Water table appears a bit deeper in the Karamana basin (10-12m bgl) with the deeper wells on the elevated ridge line passing through Kariavattom-Pattom etc.

Water table within the Neyyar catchment is the deepest, exceeding 12 m on an average.

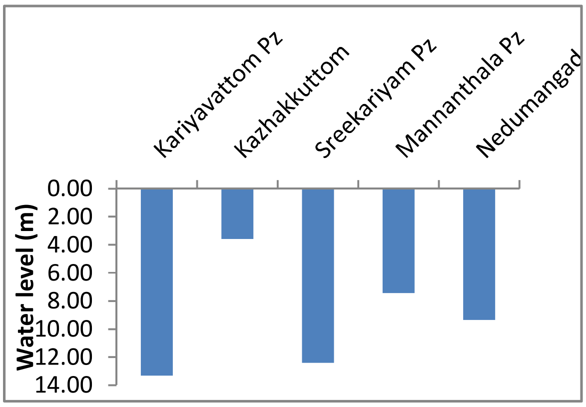
Histogram of water table in cross- transect (Fig.9) further testifies to the above observation. Causative factors for such a zonation needs to be analyzed to find out whether it is due to geologic factors, ground water draft regime or due to alterations in land use/land cover and landscape alterations involving sand and clay mining.

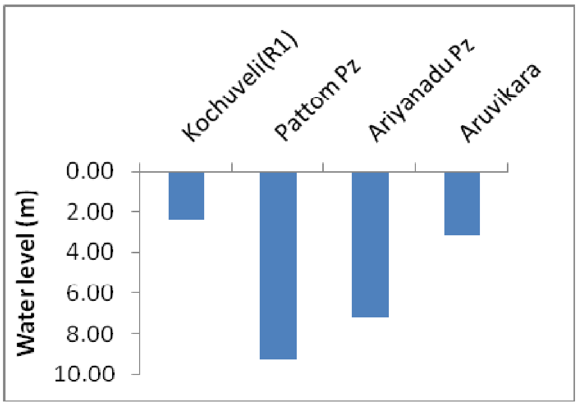




Transect 1

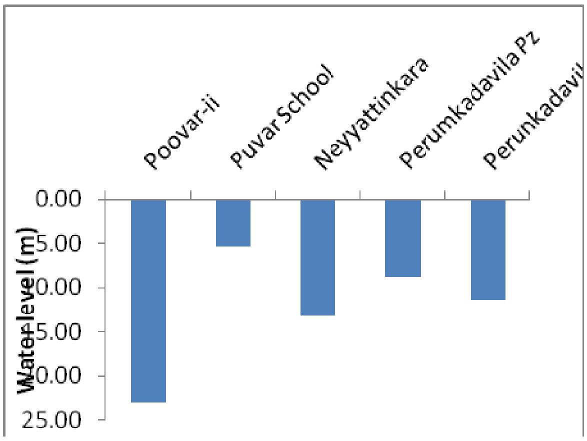
Transect 2

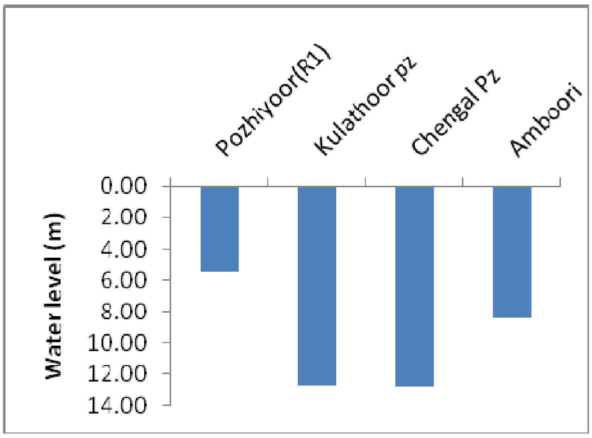




Transect 3

Transect 4





Transect 5

Transect 6

Fig. 8. Histograms of water level in transects during dry season

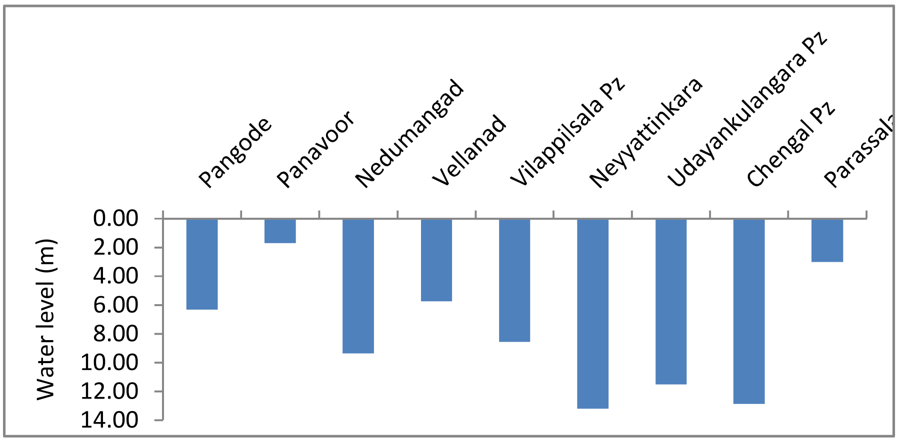


Fig. 9. Histogram of water level in wells projected on to cross-transect 7- Dry season

Histograms with statistical parameters of water table fluctuation trends of 62 wells out of 64 for different seasons and years are given in Annexure 1. Perusal of water level fluctuation trends from histograms is indicative of three trends: (A) **increasing** water level during all the seasons (Pre monsoon, Monsoon and Post monsoon). It is confined only to three out of the 62 wells, (B) **decreasing** water level fluctuation trend during all the seasons was discernible in 20 wells and (C) **mixed** trends predominate in the remaining 39 wells. Summary of water level fluctuation trends is given in Table 6.

Table 6. Summarized Water Table Fluctuation Trends, CGWB Observation wells, Thiruvananthapuram District

Assessment Block	Location, Well type, Period	Fluctuation trend			Remarks
		Dry Season	SW Monsoon	NE Monsoon	
Athiyannur	Aralummoodu, Bore well 2007-2012	Decrease	Decrease	Decrease	Drop of about 2 m over the years. Water Table (WT) depth 10-12 m.
	Poonkulam, Dug well, 2004-2015	Increase	Increase	Increase	Increase of 2 to 4 m, WT 15-20 m
Chirayinkeezhu	Anjengo, Dug well, 2004-15	Increase	Increase	Decrease	Increase 0.50-1 m, decrease about 1 m, very shallow coastal well
	Attingal , Dug well, 2004-15	Decrease	Decrease	Decrease	Decrease of about 2-2.5m, 10-15 m deep well
	Attingal , Bore well,2007-15	Decrease	Decrease	Decrease	Decrease of about 2-3 m, WT depth 4-7 m
	Chirayinkil, Dug well,2004-15	Steady	Decrease	Decrease	Decrease 0.5-1.5 m, 10-15 m deep well
	Kadakkavur, Dug well,2007-15	Steady	Steady to Decrease	Decrease	shallow well, 5-6 m deep
	Perumathura, Dug well, 2004-14	Steady	Decrease	Decrease	Shallow well, decrease to the tune of 0.4-0.7 m
	Perumkuzhi, Dug well, 2004-14	Decrease	Decrease	Decrease	Shallow well, decrease to the tune of 0.2-0.8 m
Kilimanoor	Kilimannor, Dug well, 2004-15	Increase	Increase	Decrease	6-8 m deep well
	Madvur, Dug well, 2004-14	Decrease	Increase	Decrease	14-15 deep well, drop to the tune of ~3 m during dry season, rise to the tune of ~1 m
	Ponganadu, Bore well, 2004-14	Decrease	Decrease	Increase	Drop of about 1.00 - 1.50 m, increase of about 0.8 m, WT depth 2.5 -8.5 m
	Kallambalam, Dug well, 2007-15	Decrease	Increase	Decrease	Drop 0.80 -1.20 m, rise ~2.0 m, Wt depth 4-9.5 m
Nedumangad	Aruvikkara, Dug well, 2004-15	Decrease	Increase	Decrease	Drop 0.60-1.50 m, rise ~1.00 m shallow well

	Nedumangad, Dug well, 2004-14	Decrease	Decrease	Decrease	Drop of 1.00 -1.50 m, 10-12 m deep well
	Panavur, Dug well, 2004-12	Increase	Increase	Increase	Rise 0.10-0.60 m, shallow well
Nemom	Nemom, Dug well, 2004-15	Decrease	Decrease	Decrease	Shallow well, drop ~ 3.00 m
	Neyyattinkara, Dug well, 2004-15	Marginal Increase	Decrease	Decrease	Rise marginal, drop to the tune of ~1.50 m, 14-15 m deep well
Parassala	Chengal, Bore well, 2004-15	Decrease	Decrease	Decrease	Drop ~ 3.0-6.0 m, WT depth 9-17 m
	Parassala, Dug well, 2004-15	Increase	Increase	Decrease	Shallow well, rise ~ 0.30-6.0 m, drop ~0.50 m
	Parassala, Bore well	Decrease	Decrease	Decrease	Drop ~ 0.30-2.0 m, WT ~ 2-5 m
	Poonthura, Dug well, 2004-15	Decrease	Decrease	Decrease	Shallow well, drop ~ 0.50-1.10 m
	Poovar, Dug well, 2004-15	Decrease	Increase	Decrease	28-30 m deep well, drop ~ 3.0-6.0 m, rise ~ 5.0 m
	Pozhiyoor, Dug well, 2004-15	Decrease	Decrease	Decrease	8-10 m deep well, drop ~ 1.0-3.50 m
	Pullivila, Dug well, 2004-15	Decrease	Decrease	Decrease	Drop ~ 0.30-1.50 m
	Poovar School, Dug well, 2004-14	Decrease	Decrease	Decrease	Drop ~ 0.30-1.50 m, 6.00-8.00 m deep well
	Udayankulangara, Bore well, 2004-14	Decrease	Decrease	Decrease	Drop 0.20-1.00 m , WT ~ 9.0-14.0 m deep
Perumkadavila	Kallikkad, Dug well, 2004-15	Increase	Decrease	Decrease	Shallow well, rise ~ 0.30 m, drop ~ 1.40-0.60 m
	Amboori, Dug well, 2004-15	Steady	Increase	Steady	WT ~ 5-10 m deep, rise ~ 1.00m
	Perumkadavila, Bore well, 2004-15	Decrease	Increase	Steady	WT~7-12 m deep, rise ~ 0.50 M, drop ~ 2.0 m

	Perumkadavila, Dug well, 2004-14	Decrease	Decrease	Decrease	Drop ~ 3.50 -5.50 m, 15-17 m deep well
	Vellarada, Dug well, 2004-15	Increase	Steady		7-10 m deep well
Trivandrum Rural	Kochuveli, Dug well, 2004-15	Steady	Steady	Decrease	Shallow well, drop ~ 1.00m
	Mannanthala, Dug well, 2004-14	Decrease	Steady	Decrease	Drop ~ 0.50-1.00 m , > 9.00 m deep well
	Mannanthala, Bore well, 2004-15	Increase	Increase	Increase	Rise ~0.80-1.20 m, WT 5-8 m deep
	Pangode, Dug well, 2004-15	Decrease	Slight Increase	Decrease	Rise ~ 0.20 m, drop ~ 0.60-1.20 m, > 8.0 m deep well
	Pattom, Bore well, 2007-15	Increase	Increase	Steady	Rise ~ 1.50 m, WT ~ 6-14 m bgl
Vamanapuram	Peringammala, Bore well, 2004-15	Decrease	Increase	Increase	Drop ~ 1.0m, rise ~ 1.20-1.50 m, WT ~ 9-12 m bgl
	Pirappancode, Dug well, 2004-15	Steady to decrease	Steady	Steady	WT ~ 4-9 m bgl
	Vamanapuram, Dug well, 2004-14	Decrease	Decrease	Decrease	Shallow well, drop ~ 0.20-1.40 m
Varkala	Edava, Tube well, 2004-14	Steady	Increase	Decrease	Rise ~ 1.0 m, Drop ~ 2.0 m, WT ~ 12-19 m bgl
	Edava, Dug well, 2004-14	Decrease	Increase	Decrease	Rise ~ 0.50 m, drop 0.80-2.0 m, WT ~ 8-14 m bgl
	Manabur, Bore well, 2007-15	Decrease	Steady	Decrease	Drop ~ 1.0 m, WT ~ 10-15 m bgl
	Varkala, Dug well, 2004-14	Steady	Increase	Steady	Rise ~ 1.0m, WT ~ 11-16 m bgl
	Varkala, Tube well, 2004-14	Decrease	Decrease	Decrease	Drop ~ 0.40 -5.0 m, WT ~ 19-29 m bgl
Vellanad	Aryanad, Bore well, 2004-14	Steady-Slight decrease	Increase	Steady	Rise ~ 1.30 m, WT ~ 3-10 m bgl

	Kallar, Dug well, 2004-15	Decrease	Increase	Decrease	Drop ~ 0.60 m, Rise 0.70 m, WT ~ 2-6 m bgl
	Mithranikethan, Bore well, 2004-15	Steady	Decrease	Decrease	Drop ~ 2-3 m, WT ~ 8-13 m bgl
	Palode, Dug well, 2004-14	Steady, Oscillating	Increase	Increase	Rise ~ 2.50-3.0 m, WT ~ 2-10 m bgl
	Ponmudi, Dug well	Steady	Increase	Decrease	Rise ~ 0.30 m, drop ~ 0.40 m WT ~ 3-4 m bgl
	Vilappilasala, Bore well, 2004-15	Decrease	Steady	Decrease	Drop ~ 0.50 -1.0 m, WT ~ 6-10 m bgl
	Vithura, Dug well, 2004-14	Slight Decrease	Increase	Decrease	Drop ~ 0.30-1.80 m, rise ~ 0.50 m, WT ~ 5-10 m bgl
Kazhakkoottam	Kariyavattom, Bore well 2007-13	Decrease	Steady	Decrease	Drop ~ 2-3 m, WT ~ 12-17 m bgl
	Kazhakoottam, Dug well, 2004-15	Increase	Steady	Increase	Rise ~ 0.30 -0.60 m, WT ~ 2.5-4.0 m bgl
	Korani				
	Kulathur, Bore well, 2007-14	Decrease	Decrease	Decrease	Drop ~ 1.20-3.0 m, WT ~ 10-17 m bgl
	Mangalapuram, Bore well, 2004-14	Decrease	Steady	Decrease	Drop ~ 2.0-2.50 m, WT ~ 14-22 m bgl
	Murukkumpuzha, Dug well, 2004-15	Decrease	Decrease	Decrease	Shallow well, Drop ~ 0.80-2.0 m, WT ~ 1-3.5 m bgl
	Pothencode, Dug well, 2004-15	Steady	Slight Decrease	Decrease	Drop ~ 1.0-1.20 m, WT ~ 7-11 m bgl
	Puthukurichi, Dug well, 2004-15	Steady	Increase	Decrease	Shallow well, rise ~ 0.40 m, drop ~ 0.80 m, WT ~ 2.4 m bgl
	Sreekariyam, Dug well, 2004-15	Decrease	Increase	Steady	Drop ~ 1.0 m, rise 0.8 m, WT ~ 9-14 m bgl
	Vengode, Bore well, 2007-15	Steady	?	?	WT ~ 5-9 m bgl

Based on water table depth, the observation wells can be broadly categorized as shallow (water table /well depth up to 5-7 m bgl, medium depth wells (up to 10-12 m) and deep wells (above 12 m bgl). Wells in the coastal stretches, wetlands and valleys are shallow throughout the District.

Increasing water level fluctuation trends covering all seasons and observation years (category A wells) were discerned only in three out of the 62 wells. These wells are located in the valley/wetland areas of Nedumangad block (Panavur-shallow well), Trivandrum Rural block (Mannanthala bore well with 5-8 m deep water table) and in a deep well in Athiyannur block (Poonkulam-dug well).

Decreasing water level trends (category B wells) were observed in 20 wells spread over the assessment blocks of Athiyannur (Aralummoodu bore well), Chirayinkeezhu (Attingal dug well, Attingal bore well, Chirayinkil dug well, Perumkuzhi dug well), Nedumangad (Nedumangad dug well), Nemom (Nemom dug well), Parassala (Chengal bore well, Parassala bore well, Poonthura dug well, Pozhiyoor dug well, Pulluvila dug well, Poovar school dug well, Udayankulangara bore well), Perumkadavila (Perumkadavila dug well), Trivandrum Rural (Mannanthala dug well), Vamanapuram (Vamanapuram dug well), Varkala (Varkala tube well) and Kazhakoottam (Kulathur bore well, Murukkumpuzha dug well). Parassala and Chirayinkeezhu assessment blocks have more observation wells with all season decreasing water level trends. Further, as a whole , deep or medium depth wells display the decreasing trend, though occasional shallow wells in Nemom, Vamanapuram, Parassala, Chirayinkeezhu and Kazhakoottam blocks also show all season decreasing trends (Also ref. Annexure 1).

39 wells with mixed trends (category C wells), consisting of **decreasing, increasing** and **steady** water level fluctuation patterns over seasons and observation years have been further categorized as follows:

Wells with **decreasing** water level			Wells with **steady** water level			Wells with **increasing** water level		
Dry season	SW monsoon	NE monsoon	Dry season	SW monsoon	NE monsoon	Dry season	SW monsoon	NE monsoon
18	8	27	13	9	7	7	22	4

Note: In the case of one well, data for two seasons were not available.

Amongst the mixed water level fluctuation pattern group of observation wells, level decrease is observed in 18 wells, level increase in 7 wells and steady levels in 13 wells during dry season. Level decrease is less during SW monsoon (8 wells), but more during NE monsoon (27 wells). Water level increase among this group is discernible in 22 wells during SW monsoon and in 4 wells during NE monsoon. Of the 7 wells that displayed water level increase during dry season, four wells belong to the shallow depth category and three to the medium depth category. Steady water levels persisted in 9 wells during SW monsoon and in 7 wells during NE monsoon.

As a whole, water level fluctuation trends appear complex, and difficult to explain in simple terms. It can be surmised that the predominant water level fluctuation trend is skewed towards level decrease. This is more glaring in Parassala (Neyyar catchment) and Chirayinkeezhu (Vamanapuram catchment) blocks. No definite trend can be attributed to the wells in Athiyannur and Nemom assessment blocks, where one well each out of the two under observation displays opposite trends.

Reasons for water level decrease in 47 wells (20 in category B and 27 in category C wells) during NE monsoon need to be analysed specifically to find out whether it is due to hydrometeorologic reasons, excess draft or due to increased natural discharges consequent on continuous rainfall incidence and the resultant soaking of the strata and opening up of subsurface channels. Such exercises would require detailed inputs on geologic and geomorphic setting, surface material characteristics, empirical determination of percolation rates and transmissivity regime, ground water flow assay using isotopes/tracers, watershed based hydrometeorologic inputs etc.

5.5 Why the mismatch?

Ground water availability in many parts of the district and the projections in the reports do not match. Simple analysis of available water level fluctuation data indicates that water levels in wells and hence water availability are controlled by complex hydrogeologic and hydrometeorologic factors. A cursory look in to the ground water availability within a one hectare of undulating plot with sufficiently thick soil/laterite cover in a terrain similar to the one in Thiruvananthapuram district would confirm that water availability and water table depth vary substantially, even certain lacations in the plot may yield dry wells. Terrain, slope, strata and soil characteristics, vegetation cover, proximity to canals, water bodies, water draft, seepage, human interferences etc are factors influencing such a complex water level/water availability behavior, under given hydrometeorologic regime. In the present case, observation well coverage is one well for about 15 km^2 of area with non uniform terrain and strata characteristics, hindering uniform hydraulic conductivity. Incidence of rainfall, run off, vegetation cover and ambient atmospheric temperatures are also different, affecting natural uniform recharge. The mismatch between the projected ground water availability in the district and the not so promising ground reality may be contrasted with the above.

It appears that the mismatch stems essentially from (1) the simple methodology adopted for the estimation of ground water resources of a relatively complex terrain, and (2) its further "over simplified" adoption.

Methodology adopted by the CGWB (GEC, 1997 with periodic modifications) in the computations is as follows:

Monsoon recharge R= (h x Sy x A) + DG, where

h - The rise in water level in the monsoon season

A- Area for computation of recharge

Sy- specific yield, and

DG- gross ground water draft

In simple terms, the formula would mean that water level rise in a well is applicable for the entire area of its influence with the observed surface strata near the well. Only constraining factor is the percolation/yield value. Or notionally, it argues that there exists a water pool/water layer at depths with thickness corresponding to the water level rise/fluctuation. Had it been so, a well dug in any part of the terrain would yield ground water with appropriate projected yield. This, however, is not the ground reality.

The change in storage/recharge has been computed by multiplying water level fluctuations between pre and post monsoon periods with the area of assessment and specific yield of the formation. Though the guidelines suggested that hilly areas with more than 20% slope shall be excluded from recharge computation, only 10 km^2 of area is seen excluded in Perumkadavila block, of Thiruvananthapuram district. Perusal of collated data in Table 2 indicates that about 30%f the district has slope values exceeding 30%, a factor not finding any place in the reported computations.

The applied specific yield factor has been seen ranging from 0.03 to 0.09 in various assessment blocks with average water level fluctuation varying from 0.70 m (Pothencode block) to 5.59 m (Athiyannur block). Rainfall Infiltration Factor (RIF) has been shown as varying from 0.07 to 0.09. Though the average water level fluctuation in Pothencode block was only 0.70 m, the specific yield factor applied was 0.08. In the case of Athiyannur block with the maximum average fluctuation, specific yield factor applied was 0.07. In Parassala block with average fluctuation of 2.44 m, the factor applied was 0.09. It was 0.03 in Vamanapuram block with average fluctuation of 3.47 m. Rationale behind such an arbitrary application of specific yield parameters is not seen explained in the report, although it is known that in reality Sy varies as a function of depth to the water table and it also varies over time in response to the wetting and draining history (Childs, 1960). This has been done against the suggested values of 0.02 to 0.05 applicable for laterites (CGWB, 2014, page 13). This might have also contributed to the escalated ground water recharge estimates.

Rainfall, though not having any direct significance in the scheme of computation in the report, has been taken as 2140.80 mm for all the assessment blocks in the district, though the collated data on hydrometeorology of the district give a different picture (Also refer Chapter 4).

Non Monsoon recharge: During non monsoon, rainfall recharge has been computed by using Rainfall Infiltration Factor (RIF) method. Recharge from other sources is then added to get total non monsoon recharge. In both the cases, absence of empirical data is glaringly visible.

Total ground water resource of the area has been obtained as the sum of monsoon and non monsoon recharge. An allowance of 5%, in the event of water level fluctuation method (WLF), and 10% in the event of RIF is deducted for natural discharge during non monsoon season from the annual replenishable resource.

Net ground water availability= Total ground water resource-Natural discharge during non monsoon season.

Perusal of relevant literature indicates that Water Level Fluctuation (WLF) method is best applied over short time periods in regions having shallow water tables that display **sharp rises and declines** in water levels i.e. in very porous and permeable strata. Application of it in a terrain with less porous strata and complex hydrogeologic conditions has resulted in such a mismatch. Application of this method for the sandy layers of large basins would have resulted in a coherent and congruent estimate. At best, certain segments of the undisturbed sandy flood plains of Bharathapuzha basin in Kerala would have given a realistic estimate of ground water recharge and storage through application of this method. Complexities involved in ground water estimation and the commonly applied methods are described in Chapter 2.

As such, application of a very simplified methodology which is more apt for recharge calculation in fluvial plain settings and its over simplified adoption in a hydro geologically complex terrain have resulted in exaggerated ground water resource estimates. In other words, a very complex process was approached very lightly.

5.6 Ground water draft

Gross ground water draft for domestic and industrial water supply and irrigation in the district had been estimated at 185.79 MCM during 2004 (CGWB, 2008). Draft was more in Chirayinkeezhu (20.73 MCM), Kilimanoor (18.47 MCM), Kazhakoottam (16.92 MCM), Vamanapuram (16.69 MCM), Perumkadavila (16.52 MCM) and Nemom (16.52) assessment blocks. Athiyannur block with an overall draft of 12.56 MCM had been termed “over exploited”, whereas, Chirayinkeezhu and Parassala with 20.73 and 14.03 MCM draft respectively (CGWB, 2008, page 59) were characterized as “critical” and Kilimanoor and Nemom blocks with overall draft of 18.47 and 16.07 MCM respectively as “semi critical”.

In 2011 computations (CGWB, 2014), gross ground water draft for all uses in the district has been shown as 173.01 MCM. It is 12.78 MCM less than the 2004 figure. Draft has been shown more in Nedumangad and Nemom blocks. Athiyannur block with a total water draft of 14.77 MCM, which is over 2 MCM more than in 2004 has been recategorized as “semi critical” (CGWB, 2014 page 160) an upgradation from “over exploited’ category (CGWB, 2008 page 79). Though water draft figures were similar for Parassala block during both the estimation periods, its position was also upgraded to “semi critical” in 2011 computations (CGWB, 2014, page 138). Status of Chirayinkeezhu, Kilimanoor and Nemom blocks was upgraded to “safe” category based on the stage of ground water development. Factors behind lower draft in the later computation have not been elaborated. Ambiguities associated with the recharge estimates may as well have contributed to the uncertainties in recategorisation of assessment blocks. Block-wise data on ground water draft, future utilization and stage of ground water development during the two computation periods are given in Tables 7 & 8.

Table 7. Block wise ground water draft, future utilization, stage of ground water development (in MCM), 2004

District – Thiruvananthapuram (CGWB, 2008)

Sl. No.	Assessment block	Command/non-Command/Total	Net Annual Ground water Availability	Existing Gross Groundwater Draft for Irrigation	Existing Gross Groundwater Draft for Domestic and Industrial water supply	Existing Gross Ground water Draft for all uses	Allocation for domestic and Industrial requirement supply up to next 25 years	Net Groundwater availability for future irrigation development (10-11-14)	Stage of Ground water development {(13/10)*100} (%)
1	**2**	**3**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	Varkala	Non-Command	18.41	8.96	5.91	14.87	7.50	1.95	80.76
2	Kilimanoor	Non-Command	23.50	10.65	7.82	18.47	9.99	2.86	78.60
3	Vamanapuram	Non-Command	49.24	8.41	8.28	16.69	10.80	30.03	33.90
4	Chirayinkeezhu	Non-Command	17.28	13.71	7.02	20.73	8.84	0.00	119.97
5	Kazhakoottam	Non-Command	20.09	6.73	10.19	16.92	12.68	0.68	84.22
6	Nedumangad	Non-Command	16.55	5.81	6.33	12.14	7.96	2.78	73.35
7	Vellanad	Non-Command	47.81	7.01	8.55	15.56	11.07	29.73	32.55
8	Thiruvananthapuram	Non-Command	14.90	2.94	8.29	11.23	10.12	1.84	75.37
9	Nemom	Non-Command	17.52	6.76	9.31	16.07	10.18	0.58	91.70
10	Perumkadavila	Non-Command	28.48	8.57	7.95	16.52	9.68	10.23	57.99
11	Athiyannur	Non-Command	11.13	5.63	6.93	12.56	8.72	0.00	112.80
12	Parassala	Non-Command	13.12	6.88	7.15	14.03	8.98	0.00	106.90
Total			**278.03**	**92.06**	**93.73**	**185.79**	**116.52**	**80.68**	**66.82**

Table 8. Block wise ground water draft, future utilization, stage of ground water development, 2011

District – Thiruvananthapuram (CGWB, 2014)

Sl. No.	Assessment Unit/District	Command/non-Command	Net Annual Ground water Availability	Existing Gross Ground water Draft for Irrigation	Existing Gross Groundwater Draft for Domestic and Industrial water supply	Existing Gross Groundwater Draft for all uses (11+12)	Provision for domestic and Industrial requirement supply in 2025	Net Groundwater availability for future irrigation development (10-11-14)	Stage of Groundwater development {(13/10)*100} (%)
1	**2**	**3**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	Athiyannur	Non-Command	1686.22	464.86	1012.18	1477.04	1138.62	82.74	87.59
2	Chirayinkeezhu	Non-Command	1671.00	184.45	1070.44	1254.90	1178.36	308.19	75.10
3	Kilimanoor	Non-Command	3030.64	219.11	1126.68	1345.79	1240.37	1571.16	44.41
4	Nedumangad	Non-Command	2781.17	228.79	2191.57	2420.35	2412.72	139.66	87.03
5	Nemom	Non-Command	4110.87	441.78	1688.88	2130.65	1859.30	1809.79	51.83
6	Parassala	Non-Command	1666.05	566.28	857.63	1423.91	944.18	155.59	85.47
7	Perumkadavila	Non-Command	3643.35	361.81	1282.65	1644.46	1412.08	1869.46	45.14
8	Pothencode	Non-Command	1966.49	421.08	1103.78	1524.86	1212.78	332.63	77.54
9	Vamanapuram	Non-Command	6434.13	364.72	1130.89	1495.61	1245.01	4824.40	23.24
10	Varkala	Non-Command	1821.62	236.65	952.57	1189.21	1048.69	536.29	65.28
11	Vellanad	Non-Command	4059.93	495.47	898.44	1393.91	1007.08	2557.38	34.33
	Total (ha.m)	**Non-Command**	**32871.46**	**3984.99**	**13315.72**	**17300.71**	**14699.19**	**14187.28**	**52.63**
	Total (MCM)	**Non-Command**	**328.71**	**39.85**	**133.16**	**173.01**	**146.99**	**141.87**	**52.63**

6.0 GROUND WATER POTENTIAL OF TRIVANDRUM URBAN AREA (TUA)

Trivandrum Urban Area covers 215.86 $km^{2.}$ It extends from south of Vizhinjam in the south to the south of Kaniyapuram-Andurkonam in the north. The north eastern boundary extends from east of Paudikonam through Mukkola-Kudappanakunnu to Randamada in the east. The eastern boundary is confined to the west of the north-south course of Karamana river from Randamada till it takes a U-turn to the north before its meandering course within the city bounds, and further south in the same direction till the intersection with the National Highway-47. From this point, the boundary line turns west through the wetlands of Vellayani and then follows a zig-zag course bordering Kalliyoor panchayat up to the south of Kovalam. From there, the boundary turns east up to the north of Venganur, then south east up to Uchhakkada before it takes a south-westerly course till the coast (Fig. 10). In administrative terms, TUA comprises the capital city and the adjoining erstwhile panchayats of Kazhakkoottam, Sreekariyam, Kudappanakunnu, Vattiyoorkavu and Vizhinjam.

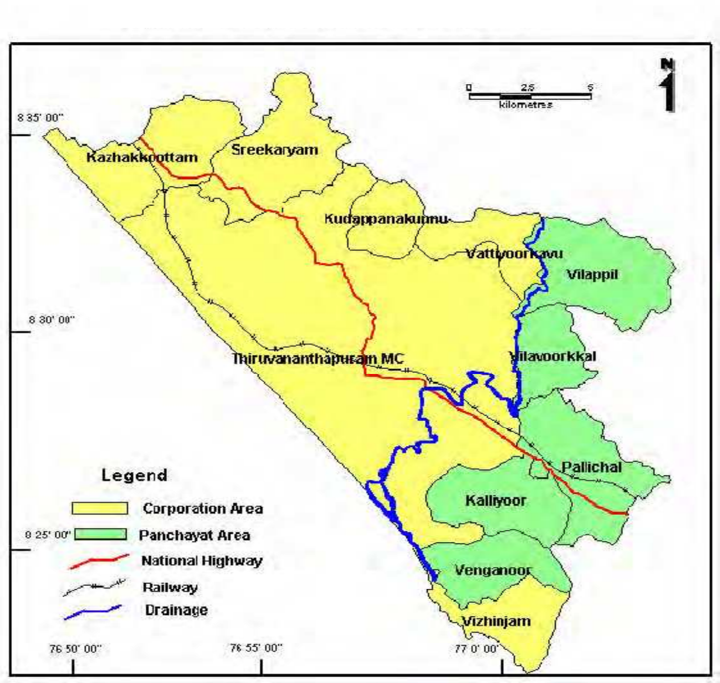


Fig. 10. Thiruvananthapuram Urban Area

6.1 Physiography

The TUA comprises (1) the western Coastal plains (0-10 m altitudinal range), consisting of areas adjacent to the coastline, (2) the Lowlands (10-100 m), formed of laterite ridges and crystalline rock exposures (inselbergs) forming part of a low level planation surface with a general westerly slope, and (3) Midland areas with elevation above 100 m. The latter is confined to the northern and north eastern parts of TUA (Fig. 11). A massive charnockitic hillock falling within the Midlands near Pachallur had been quarried out long back.

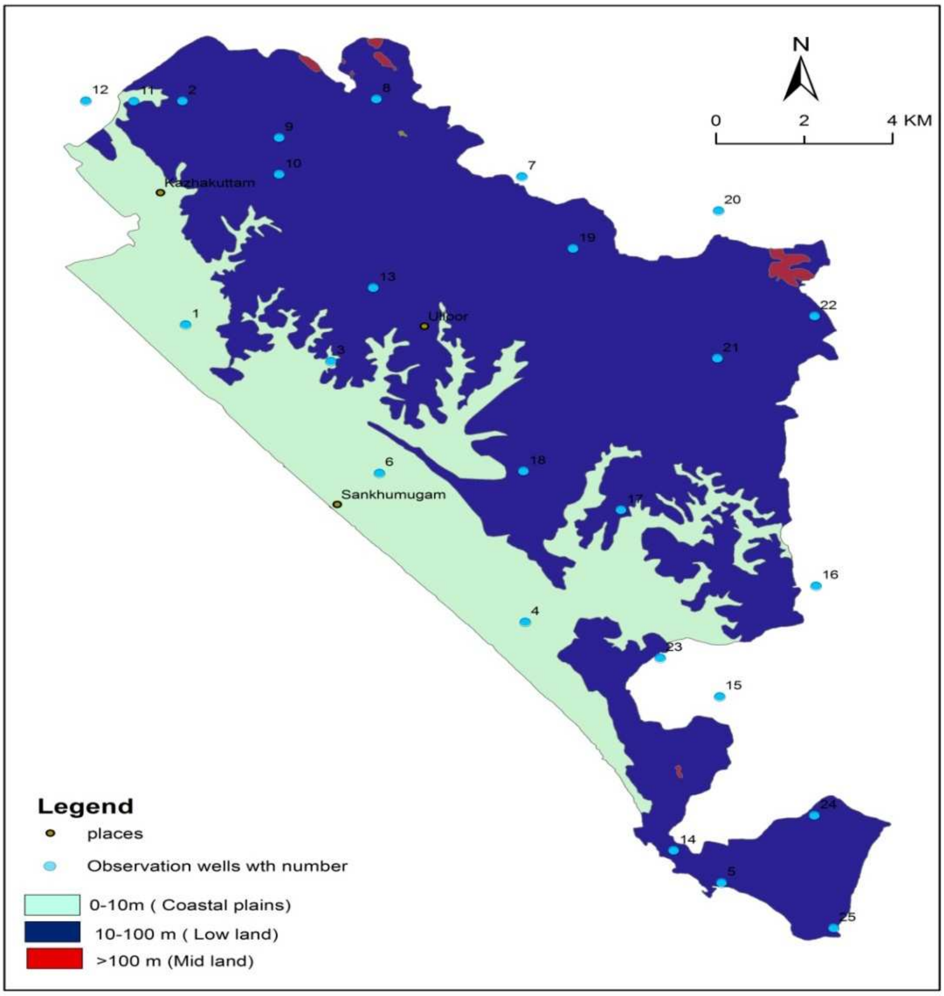


Fig. 11 Physiographic divisions within TUA

6.2 Drainage

TUA falls broadly within the Karamana-Killi Ar drainage. Kulathur thodu and Ullur thodu drain in to Akkulam lake. In the south, Vizhinjam thodu also drains part of the TUA (Fig. 12). Predominant drainage pattern is trellis that follows coast parallel and coast perpendicular directions. East of the coast parallel ridge passing through Melethonnakkal- Mangalapuram – Kariyavattom- Sreekariam-Pattom, drainage takes initially a north easterly course before breaching the ridge line and flowing in the south-west direction. Many of the smaller order drainage channels had been filled up and non-existent now, adversely affecting smooth drainage, and water resource potential.

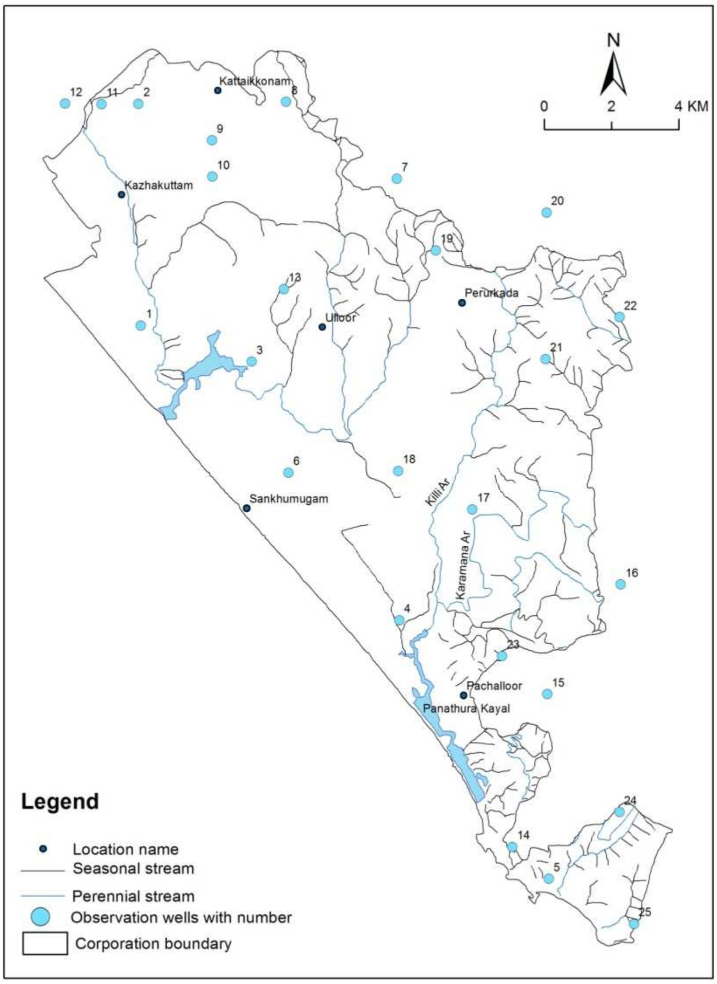


Fig. 12 Drainage map of TUA Area

6.3 Geology

Geological formations of the coastal plains consist of coastal and riverine alluvium, clays of the wetlands and coastal marshes (mostly reclaimed), underlain in many places by rocks of the Warkalli formation. In places, the alluvial deposits rest directly on hard crystalline rocks. East ward extension of the coastal-alluvial deposits is visible up to the east of Vellayani, East Fort in the city centre and up to the west of the Sainik school in the Kazhakoottam area. Very fine coastal sands are seen in the eastern sides of the elevated Sainik school campus also. South of Kazhakoottam and up to Akkulam lake and further south, coastal plains narrow down up to the west banks of Kulathur thodu, before it merges with the relatively wider fluvial plains of River Karamana. As per Rani et al (2011), maximum thickness of the alluvium is 18 m at Chakkai.

Coastal plains are bordered to the sides by a dissected arcuate laterite ridge developed over rocks of the Warkalli formation, as well as over Precambrian rocks with occasional rock exposures (inselbergs). Occurrence of this ridge at an altitudinal range of 20-35 m in various segments of the TUA, and at 60-65 m within the Vellayani lake catchment is indicative of differential uplift history underwent by the terrain. Clayey sand and sandy clay layers are characteristic of the Warkallis in this stretch, and the depth of their occurrence is variable. Towards the north of the TUA area, precisely near Thonnakkal/Melethonnakkal, such layers are at depths ranging from 22 to 48-60 m below ground level, depending on the uplift history of the area and have good ground water potential. Local water supply schemes like the one at Vailur are supported by such sources. Weathering profiles developed over Precambrian rocks, as in the Life Science Park at Thonnakkal or those underlying the sedimentaries do not normally host sizeable ground water storage. In other words, relatively larger occurrence of ground water is expected in areas within the coastal alluvial deposits underlain by the Warkallis or interfacing them, as in the case of Pachallur and Vailur areas.

The eastern parts of TUA, broadly east of the National Highway-47 alignment belong to the khondalite provenance, with variable thickness of weathering ptofile development (Some areas to the west of the highway also have khondalite provenance) . As per Rani et al (2011), aquifers in khondalites in the depth range of 60-200 m below ground level have 2-3 aquifer groups, and discharge ranges from 12 to 90 lpm.

Absence of reliable subsurface data/lithologs of both the observation wells as well as scores of wells drilled by the departments is a major constraint in delineating subsurface geology that determines the ground water potential in areas within TUA for their protection, exploitation and replenishment.

6.4 Ground water potential

Ground water potential of TUA, comprising the capital city and the adjoining erstwhile panchayats of Kazhakkoottam, Sreekariyam, Kudappanakunnu, Vattiyoorkavu and Vizhinjam has been deliberated in a paper by Rani et al (2011) based on 26 observation wells (21 in the erstwhile municipal area and 5 in Vizhinjam and Kalliyoor panchayats) and largely leaning on water resource potential of the Thiruvananthapuram rural block as calculated by CGWB (2008). Water fluctuation data for 22 of the wells pertaining to 2007-2009 years (dry and NE monsoon seasons) have been accessed. Five of the wells are beyond the boundary of TUA. Five out of the remaining 20 wells are within coastal alluvium/marshy deposits and the remaining are located on laterite ridges/slopes developed either over Warkalli sediments or on Precambrian rocks. Lithologic and geomorphic setting of the 25 wells, reconstructed from locational and geologic considerations has been summarized and given in Table 9.

The available data on water table of wells within TUA for the period 2007-2009 indicate that water level recedes in all the observation wells irrespective of strata and season. Maximum drop was to the tune of 2.5-3.0 m during NE monsoon. The only exceptions were: (1) increase of about 1.0m water level during dry season in the well in Vizhinjam, (2) increase of about 8-10 cm during April and November in the well in Chakkai and (3), increase of 1.50-1.60 m water level in Chantavila and Nemom wells during NE monsoon over the observation years. Of these, Vizhinjam and Chakkai wells are located in the marshy-alluvial strata and Chantavila well possibly on the interface of alluvium and Warkalli sediments. Histograms showing water level fluctuation trends of TUA observation wells are given in Annexure 2.

Considering a gross draft of 11.23 MCM out of a total estimated net ground water availability of 14.90 MCM, the stage of development of ground water in Thiruvananthapuram rural block was estimated at 75.37% (CGWB, 2008). With the perceived further ground water development potential of Kazhakoottam, and the over-exploited nature of ground water in and around Vizhinjam area, Rani et al (2011) have proposed the following classification of the area as shown in Fig. 13.

Table 9. Reconstructed Geomorphic and Lithological Setting of the Observation wells, TUA

Observation Well No.	Location	Geomorphic Characteristics	Lithology
1	East of Thumba	Coastal plains, well on the bank of T S canal	Coastal alluvium
2	East of Chantavila	Low land region, altitude ~ 40m above msl	Laterite, possibly over Tertiary sediments
3	Eastern fringe of Akkulam lake	Interface of coastal plains and lowland, altitude<20m	Alluvium and detrital laterite
4	SW of Ambalathara	Interface of coastal plains and marsh	Alluvium
5	Vizhinjam	Narrow valley surrounded by laterite mounds	Limited alluvial provenance
6	Chakkai	Coastal plains	Marshy alluvium
7	Mannanthala	Valley head within lowland-midland transition zone	Laterite + alluvium
8	Karikuzhy	Down slope of a laterite ridge(low land)	Laterite
9	Chengottukonam (near Thundathil)	Lowland part of a laterite planation surface	Laterite
10	East of Kariyavattom junction	Low land part of a laterite planation surface	Laterite Warkalli sediments(?)
11	Chantavila	Low land slope of a laterite planation surface	Laterite over Warkalli sediments (?)
12	SE of Pallippuram	Low land valley	Laterite and alluvium
13	SWS of Sreekaryam junction	U-shaped valley head surrounded by low land laterite mounds	Alluvium within the valley
14	SW of Kovalam	Valley flat	Laterite over Precambrian rocks
15	Vellayani Agri. College Campus	Laterite ridge	Laterite over Warkalli sediments
16	NW of Edakkad	Slope of a low land laterite mound	Laterite
17	NW of Karamana bridge	River bed	Alluvium
18	East of Kunnumpuram (Ayurveda College)	Slope of a low land laterite terrace	Laterite
19	South of Kudappanakunnu	Lowland laterite ridge	Laterite over Precambrian rocks
20	ESE of Karakulam	Valley within low land	Laterite over Precambrian rocks
21	Vattiyoorkavu	Valley head on low level laterite ridge	Laterite and alluvium
22	Vallekadavu	Flood plain of Karamana river	Alluvium
23	Vellayani	Interface of laterite ridge slope and flood plain	Laterite over Tertiaries
24	North of Venganoor(west of Uchakkada)	Low land (~ 20 m altitude) close to canal	Laterite
25	South of Mukkola	Elevated coastal flat (low land)	Lateritised Teri sands (?)

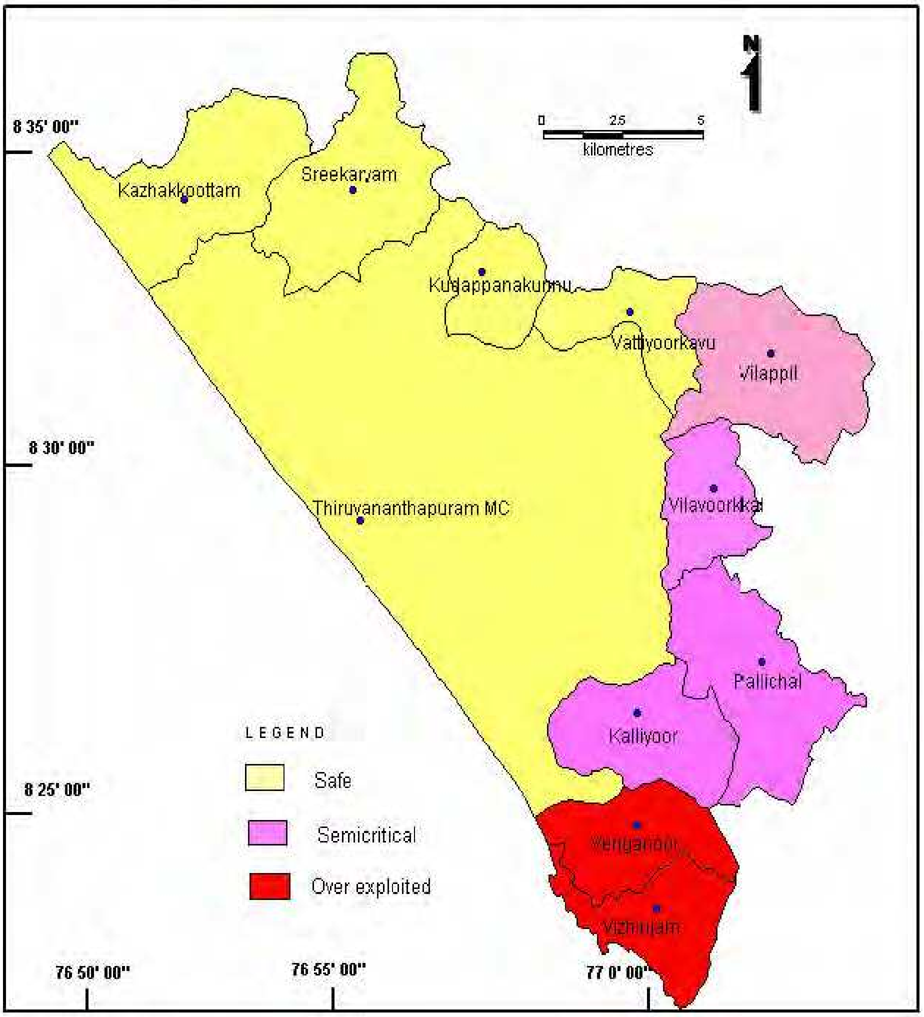


Fig. 13 Categorization of TUA based on ground water potential (After Rani et al, 2011)

The map indicates that all the area within TUA belongs to the ‘safe’ category, except Vizhinjam which is the only block categorized as “over exploited”. This would mean that the TUA area is rich in ground water resources with potential for exploitation.

6.5 Water scarcity in wards of Thiruvananthapuram Corporation

Draft City Master Plan projections, however, depicts a picture of chronic water shortage. Many parts of the city area have disrupted supplies and the dependence on wells and tanker services are on the increase. Wards such as Valiyasala, Thampanoor, Poojappura, Nalanchira, Vanchiyoor, Ulloor, Sreekariyam, Estate wards, Chala market area and the coastal wards experience water deficiency more than 41% of water supply. In geomorphological and spatial terms, these areas can be identified as coastal stretches, elevated areas and peripheral regions of the city Corporation. Water scarcity area is depicted in Fig.14 (ref. Draft master Plan document). This is besides the periodic disruptions due to pipe bursts, both in the main and distributor arteries.

6.6 Possibility of ground water extraction

Such a scenario also prompts to look in to the possibility of utilizing the ground water resources as a supplementary source in the event of emergencies. Available feedback from different sources such as the hydrogeology narration in Environmental Impact Assessment (EIA) reports pertaining to high rise buildings in the city bounds, inputs from KWA sources and field observation inputs indicate the presence of extractable good quality ground water resources in many parts of the city. The high yielding open wells at Pachallur and Vailur are two of the prominent examples. Rani et al (2011) have stated that the most potential aquifer within the city bounds is confined to the alluvial deposits composed of sands and clays at shallow depths (2-6 m bgl depth range) with average yield of about 10-60 m^3 per day. Unplanned nature of the city development has resulted in large scale reclamation of the coastal plains and valleys, fragmenting the water resource base of the strata. Pit latrines and waste disposal have rendered the available resources unsafe for potable purposes.

On a safer plane, it is still possible to tap the alluvial aquifer potential at the interface of alluvial deposits with the sediments of Warkalli formation as in the case of Pachallur and Veilur. Such locations are on either side of the elevated ridge that passes through the eastern side of the coastal plain. Sedimentary strata in the north eastern part of the city also contains water holding strata at depths ranging from 22-48 m bgl. Demarcation of more of such area requires sub surface investigations through geophysical means and collation of data from reliable secondary sources including the lithologs of wells drilled by the State Ground Water Department.

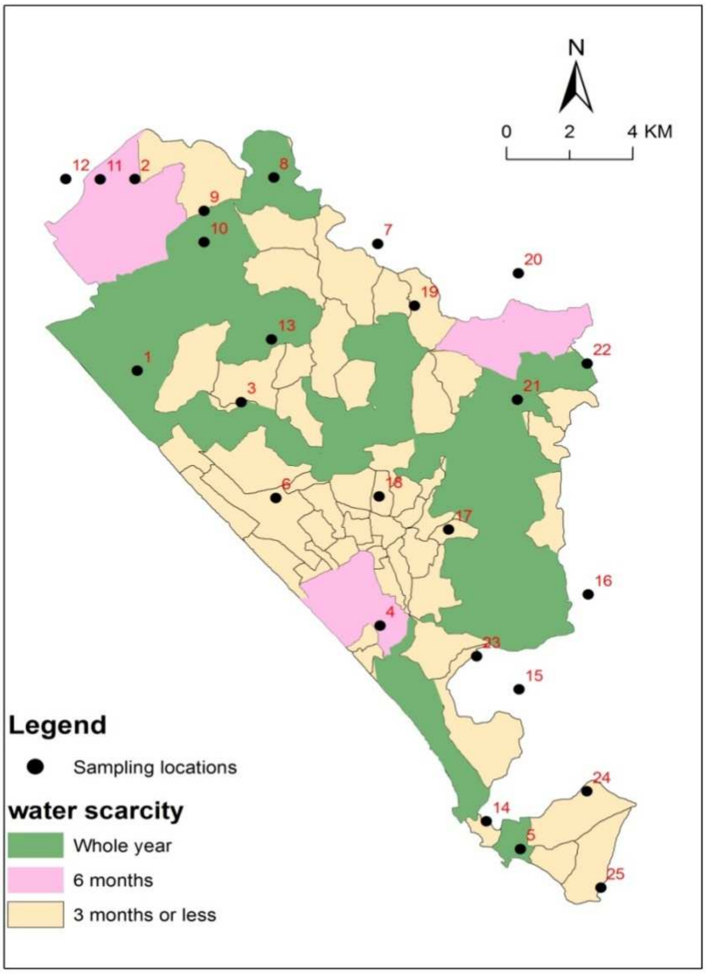


Fig. 14 Water Scarcity areas in the city (After Master Draft Plan)

6.7 Constraints in tapping ground water potential

As the water situation is bound to deteriorate on account of the climate change uncertainties and increasing demand position, it is time to think about plans to supplement the sources. Naturally, ground water is the immediate supplementary source. The available CGWB projections on ground water potential appear exaggerated, and are far from ground reality. Absence of reliable dossiers on subsurface geology of bore wells drilled by the official agencies further constrain the scope of identifying potential ground water sites within the coastal sedimentary tract. Conversion of existing open wells as latrine pits, the present day design of "septic" tanks leading to bacterial and nitrogen contamination of ground water, dumping of waste in to water bodies and sewage discharge in to the stream/drainage network have added to the quality woes of ground water. Large scale landscape alterations and change in land use have very adversely affected the ground water potential. All these aspects need to be addressed, if we aim to tap ground water as a supplementary source.

7.0 QUALITY OF GROUND WATER

Quality of ground water shall determine its utilization as a supplementary source. Water quality can be thought of as a measure of the suitability of water for a particular use based on selected physical, chemical and biological characteristics. Drinking water quality parameters such as colour, conductivity, dissolved oxygen (DO), electrical conductivity (EC), hardness, pH, salinity and turbidity, and contaminants and pollutants such as nitrogen, phosphorus, pesticides, bacteria, harmful trace metals etc emanating from runoff, strata, sewage overflows/effluents and waste disposal are generally determined.

Ground water quality data pertaining to the district is scanty in the public domain, and the available material is summarized below. Chemical data on water quality from TUA is given in Table. 10. Wide variation in pH, beyond the acceptable limit of 6.5-8.5 as per revised BIS (IS 10500-2012) norms is discerned in the results. Nitrate (NO_3) values range from 2.1 to 152 mg/L. Acceptable limit of NO_3 as per revised BIS is 45 mg/L only, whereas it is 10 mg/L as per Environmental Protection Agency (EPA), USA, which is likely to be further reduced. High nitrate concentrations in groundwater can have adverse health impacts. For example, Methemoglobinemia (blue baby disease) in infants is a potentially fatal disease and results from low oxygen levels in the blood caused by ingestion of high nitrate groundwater (Spalding and Exner, 1993). Nitrate concentrations ≥ 2 mg/l in groundwater are considered to be impacted by human activities *.

Table 10 Chemical quality if ground water in TUA (After Rani et al, 2011)

Constituents	Minimum	Maximum
pH	4.15	9.90
EC	93.00	1294
Total Hardness mg/l	14.00	2582
Ca2+	4.20	89
Mg2+	1.50	7.30
Na+	5.70	140
Cl-	11.0	337
NO^3	2.10	152
F	0.00	0.50

Potential sources of nitrate contamination in groundwater include atmospheric deposition, natural sources, inorganic fertilizer, organic fertilizer or manure, septic tanks, and leaking sewer systems. In the case of TUA, septic tanks and disposal of raw sewage in to the river can be the potential sources of NO_3 in ground water, driving a link between ground water quality and sanitation. Relatively high concentrations of NO_3 in the Karamana river recorded in all the sampling seasons of 2007-2008 also needs to be researched to establish the source of nitrogen in the surface water. Very high E.Coli content was reported from the sample near Vilappilsala.

*Note:

Nitrate is highly soluble in water and is not prone to ion exchange (Stumm and Morgan, 1996 in Scanlon et al, 2009). The anionic form of nitrate does not sorb onto clay particles which are also negatively charged under normal pH conditions. Nitrate also cannot be lost through volatilization because it is nonvolatile. The high solubility and mobility of nitrate results in nitrate being readily leached through the soil zone to underlying aquifers. Nitrate is not affected by chlorination, the most common method of treating most public water. It can be removed from water by reverse osmosis, although this is an expensive process. Additional treatment technologies include ion exchange and denitrification (Kapoor and Viraraghavan, 1997 in Scanlon et al, 2009).

As part of the Environmental Monitoring Programme on Water Quality by the Kerala State Council for Science, Technology and Environment (KSCSTE) and Centre for Water Resources Development and Management (CWRDM), 41 ground water samples during post monsoon and 57 samples during pre monsoon and monsoon seasons from Karamana basin were collected during 2007-2008 period. Out of theses, 8 were samples from the city corporation area and 16 from the constituent panchayats of TUA. Analysis indicated that the water samples were highly acidic during post monsoon season with the lowest pH value of 3.9 noticed from Vizhinjam. During pre monsoon, pH values ranged from 3.62 to 8.27, with the lowest value recorded from Vattiyoorkavu. pH in monsoon season samples varied from 3 to 8.4, with the lowest value noticed in the Vattiyoorkavu sample again. EC was relatively high in almost all samples. The highest value was noticed in the sample from Vizhinjam. Colour index was reported normal for most samples, except two samples from the city Corporation area and one sample from Vizhinjam. Total hardness ranged from 4 to 380 mg/l, the latter from Vizhinjam exceeding desirable limits but within permissible limits as per Bureau of Indian Standards (BIS). Chloride value from a sample from the Corporation area and one from Vizhinjam exceeded the desirable limit by BIS. A well sample in close proximity to the Parvathy Puthanar showed relatively high PO_4-P (1.31 mg/l during post monsoon sampling, and lower values were detected in a sample from the city corporation and another from Vizhinjam.). During pre-monsoon sampling, phosphorus values were lower, and highest in the season was recorded from Vizhinjam (0.37 mg/l). This report is silent on NO_3 in the ground water samples. Similarly, E.Coli has not been estimated.

8.0 DISCUSSION AND CONCLUSIONS

There is mismatch between the projected ground water availability in the district and the not so promising ground water availability. Similar is the case in the city bounds. The CGWB calculations based on GEC 1997 methodology did not factor some of the important determinant factors in ground water recharge estimations. Specifically, climatic variations and terrain conditions were not factored. This was because the adopted methodology did not factor them, though there was separate specific suggestion to factor the terrain data. Perusal of relevant literature indicates that Water Level Fluctuation (WLF) method is best applied over short time periods in regions having shallow water tables that display **sharp rises and declines** in water levels i.e. in very porous and permeable strata. Application of this methodology in a terrain with less porous strata and complex hydro geologic conditions has resulted in such a mismatch. Micro level terrain features such as slope and aspect, together with strata conditions determine the *micro provenance* of each well and its ground water storage potential in an undulating laterite terrain. Rainfall variability, that impacts specific yield, within the district has not been factored appropriately. Temperature variability due to climate change is bound to increase the evaporation and evapo-transpiration rates affecting specific yield factor. Further, 'specific yield' factor, though capable of assimilating part of the 'strata' considerations was applied without any locally relevant empirical findings.

As stated elsewhere, laterites of the district belong to more than one genetic type with different physico-chemical and mechanical properties. Laterite horizon is the aquifer stratum in most part of the district. Depending on the parent rock characteristics, thickness of laterite column varies considerably. This is bound to impact the seepage rates and quantum of storage. 'Specific yield' factor as applied for average low water level fluctuation and high water level fluctuation blocks e.g. Pothencode (Sy 0.08) and Athiyannur (Sy 0.07) respectively, adds to the confusion. Occurrence of china clay deposits in areas adjoining the city within the Tertiary sediments diminishes ground water prospects. Prospects of ground water within the Tertiary sediments and the coastal alluvium have not been fully evaluated.

Although the GEC (1997) guidelines insisted on considering the assessment units and recharge calculations aquifer/micro-watershed based with due weightage for lithology (hard rock, alluvial beds etc) and terrain features, the published estimates did not seem to have considered slope factors, lithological variations etc. From the terrain data included in this report, it is clear that about one third area of the district has slope parameters exceeding 30%. Even as per GEC (97) guidelines, that much area should have been excluded from the estimation, reflecting a lesser annual recharge figure. In nutshell, the methodology adopted for ground water estimation of the district could not adopt certain ingredient recharge factors, besides the methodology itself being oblivious to important factors such as temperature variability, evapo-transpiration rates, urbanization factors/land use etc.

Such situations arising in ground water recharge estimation efforts have prompted experts world over to adhere to application of multiple recharge estimation techniques with variable reliability. Techniques based on surface water and unsaturated zone data , for example, provide estimates of potential recharge, whereas those based on ground water generally provide estimates of actual recharge, if applied in appropriate geo-hydrological context. Uncertainties in each approach to estimating recharge underscore the need for application of multiple techniques to increase reliability of recharge estimates (Scanlon et al, 2002). A recent study in the Karamana basin in Thiruvananthapuram district substantiates the above, and amplifies the complexities involved. Natural ground water recharge as % of precipitation using water balance method for various time scales yielded results varying from 11.37 to 6.65%. The recharge shows a decreasing trend with increase in built up area. By base flow index method that does not incorporate any effect of land use on recharge, the figures varied from 11.09 to 8.2% (Divya Bhoopesh and Joisy, 2012). Considering the possibility of ground water discharges on account of the sloping nature of the basins, it is necessary to evaluate the discharges through tracer tests and so on also in order to make ground water estimates more dependable.

The whole idea of adoption of a very simplified methodology for water recharge estimations that is mostly applied in short-term, local scale, easy to use with low data needs and its mandatory application for the whole nation with disparate physiography, climatic zones, aquifer stratigraphy and land use practices can be attributed to part of an escapist mindset prevailing in the high echelons of decision making in matters of natural resources evaluation in the country. More importantly, it speaks of the absence of expertise to apply multiple, complex methodologies in ground water estimation in the country. Recent recommendations of Mihir Shah Committee Report to the Government of India to revamp the management structure on water related matters testify to the inadequacies/expertise- deficit existing in water resource management agencies in the country. Capacity building in this complex field has been under neglect for long, and it is high time that we address the issue. Though the 2002 National Water Policy document contained a number of suggestions to remedy this issue, as usual, nothing tangible emerged.

Water quality in the wells is termed as *potable* in the CGWB report, though NO_3 upper values exceed the acceptable limits. The Environmental Monitoring Programme report amplifies the acidic nature of water samples, and mentions about microbial contamination, though the latter data sets were not included in the report. Full set of data were not reproduced in both the reports. In sum, it can be said that the parametric mix and spatial and temporal scales adopted for sampling surface and ground water need to be refined for more reliable results from a public health angle.

Available feedback from different sources and field observation inputs indicate the presence of extractable good quality ground water resources in many parts of TUA. The high yielding open wells at Pachallur and Vailur are two of the prominent examples. Rani et al (2011) have stated that the most potential aquifer within the city bounds is confined to the alluvial deposits composed of sands and clays at shallow depths (2-6 m bgl depth range) with average yield of about 10-60 m^3 per day. Interface of the coastal plains and the low lands shall be ideal sites for extracting good ground water sources. Absence of reliable dossiers on subsurface geology of bore wells drilled by the official agencies make the task of locating future wells very arduous. It is also to be noted that unplanned nature of the city development has resulted in large scale reclamation of the coastal plains and valleys, fragmenting the ground water resource base of the strata. Conversion of existing open wells as latrine pits, the present day design of “septic” tanks leading to bacterial and nitrogen contamination of ground water, dumping of waste in to water bodies and sewage discharge in to the stream/drainage network have added to the quality woes of ground water within TUA.

9.0 ADEQUACY/INADEQUACY OF INSTITUTIONS INVOLVED IN GROUND WATER MANAGEMENT & RECOMMENDATIONS

A number of agencies are involved in the field of ground water monitoring/exploitation and use in the State. CGWB (Govt. of India), Ground Water Department, Kerala Water Authority, Jalanidhi, CWRDM and Minor Irrigation Department are the prominent among them. There is no coordination among them in their activities, except the interactions between the CGWB and the State Ground Water Department.

Bore wells are drilled, but no efforts are made to meticulously store the subsurface data. By this act we miss valuable subsurface information, which is important not only for ground water management, but also for various other development and conservation programmes.

Water management demands the support of a robust meteorological data base. Meteorological data sources are shrinking over the years. Data bases available with various agencies (IMD, Irrigation Department, Univesity of Agriculture/Research stations, Airports, Research Institutions in the State, Ground water Department and private operators in large estates need to be collated and brought under a central dissemination system for use in water management schemes.

Installation of more meteorological stations capable of monitoring temperature and evaporation rates are also needed for ground water management. River basin-wise installations would be desirable. Considering the importance of ground water in the life and economy of nations in the coming years, there is an urgency to initiate capacity building and skill acquisition in various aspects of geo-hydrology and application of modern techniques in ground water estimation. National water Policy document of 2002 had some suggestions in this regard. The policy documents advocated creation of well developed information system for water related data in its entirety at the national / state level for resource planning. It also emphasized the need for a standardized national information system established with a network of data banks and data bases, integrating and strengthening the existing Central and State level agencies and improving the quality of data and the processing capabilities. Exhortations included pushing forward of the frontier knowledge in several directions by intensifying research efforts in various areas, including in hydrometeorology, snow and lake hydrology, surface and ground water hydrology, river morphology and hydraulics, assessment of water resources, water harvesting and ground water recharge, water quality etc among others.

2012 National Water Policy document also advocated giving adequate grants to the States to update technology, design practices, planning and management practices, preparation of annual water balances and accounts for the site and basin, preparation of hydrologic balances for water systems, benchmarking and performance evaluation citing the advances in information technology and analytical capabilities in the advanced countries. A re-training and quality improvement programme for water planners and managers at all levels in India, both in private and public sectors was also recommended, including institution building.

Quality characterization is very important. Going by the quality assay reports, it appears that we need to initiate long term state-scale monitoring programmes of both surface and ground water with preparation of a monitoring design to accommodate spatial and temporal variations of the hydrological net works, point and diffuse sources of pollution, land use, soil characteristics, analytical requirements and their standardization. Recent findings on Dissolved Nitrogen , far exceeding the NO_3 values and Ammonium being the largest contributors of nutrient loading in the temple segment of the intensely human impacted Pamba river (Shilly et al, 2016) also reiterate the need for devising a better analytical design (than the one contained in the Environmental Monitoring Programme) for water quality monitoring in our rivers and water sources. This is contextual in the case of Thiruvananthapuram district., as sewage disposal in to the Killi ar, and sewage treatment tailing waters in to Parvathy Puthanar pose severe health hazards. Considering the fact that even in the US, it took many years to put in place a national net work programme on river quality monitoring (Smith et al, 1987), it is imperative on our part to initiate at least the thinking process in this respect.

Judging by the current state of affairs in this field, a lot needs to be done in the water sector, especially in the context of spiraling demand on water and the dwindling resources. Kerala's dossier on surface water resources remain the same as in 1974, and the state of knowledge on ground water resources (both on quantity and quality) is inadequate.

Though there is no dearth of institutions/departments in the water sector, new institutions, contextual to the current demands and capable of addressing all the issues related to this sector are needed. Proposed provisions of grants by the National Water Policy documents may be availed for the same and setting up of an **institute for studies on ground water and training/retraining of water managers** may be a viable suggestion.

Ground water extraction is also an important issue to be tackled legally and administratively. The draft 2012 Water Policy document contained recommendation from the Confederation of Indian Industry to make ground water a national asset, delinking it from the provisions of the 1882 Easement Act which vested ground water right with the ownership of the land. In the evolving scenario of global warming, demand on water will be on the increase, prompting many to trade in ground water using deep bore wells. Such activity, if carried out in large scale, will definitely deprive the neighbourhood's water prospects, leading to social tension. Thought on instituting judicious institutional mechanisms to tackle such issues is also the need of the hour.

Acknowledgements

Critical review of investigation reports, especially by Government departments in the realm of important natural resources such as water is a rare phenomenon in our country. As a result, we are mostly groping on the veracity of many a report, and the plan projections based on most of them often go awry. It was the friendly persuasion by Prof. K N Harilal and Dr. Srikumar Chattopadhyay that made me agree to undertake the present unpleasant task of looking in to the veracity of the ground water projections by the Central Ground Water Board (CGWB) pertaining to Thiruvananthapuram district. Mild observations, highly critical if read between lines, are contained in the report, warranting serious efforts to revisit the subject after meaningful capacity building efforts in this filed. I am thankful to Prof. Harilal and Dr. Chattopadhyay for the support extended during the work. Support, including preparation of histograms and maps by Dr. Vandana M is gratefully acknowledged. Ms. Resmi P S has attended to data collection from various departments and extended secretarial assistance during preparation of the report. Fruitful discussions were held with Dr. P. Nandakumaran, Regional Director, CGWB, Thiruvananthapuram and his colleagues at CGWB on the topic. Further, I was also benefitted by the discourse on the subject at the Semiar held at CDS on August 14, 2015. Reference facilities were extended by CGWB and Geological Survey of Inida's regional circle office. I extend my heartfelt thanks to all of them.

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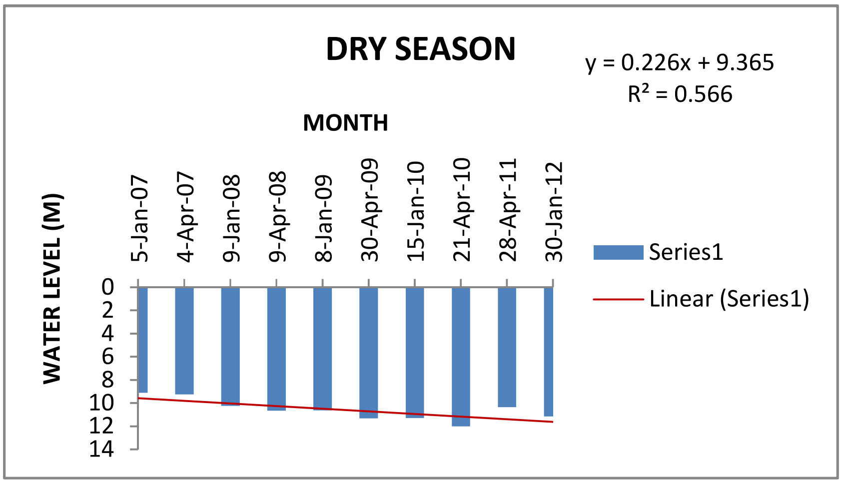
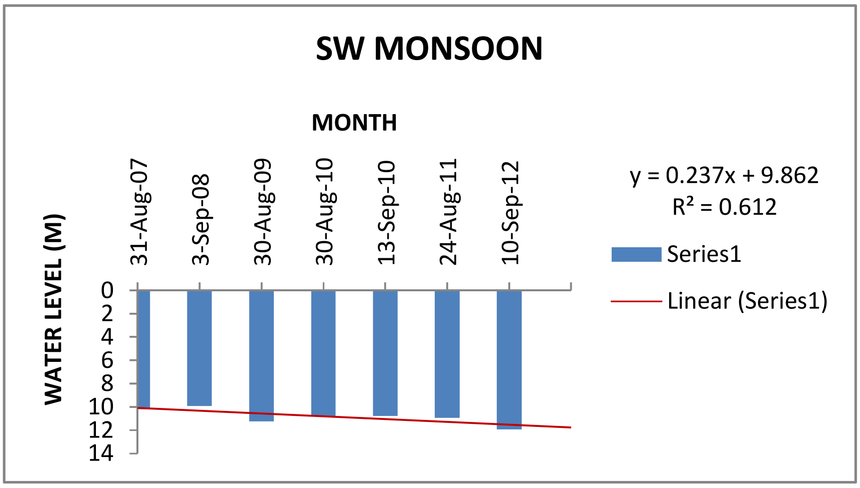
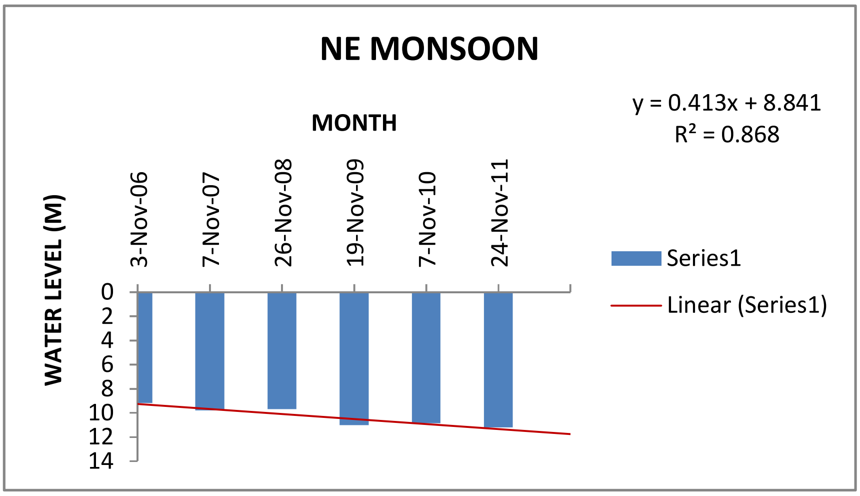
Annexure 1 Histograms of Water Table fluctuation trends, Thiruvananthapuram district



DRY SEASON	
5-Jan-07	9.11
4-Apr-07	9.27
9-Jan-08	10.25
9-Apr-08	10.67
8-Jan-09	10.65
30-Apr-09	11.35
15-Jan-10	11.3
21-Apr-10	12
28-Apr-11	10.37
30-Jan-12	11.15

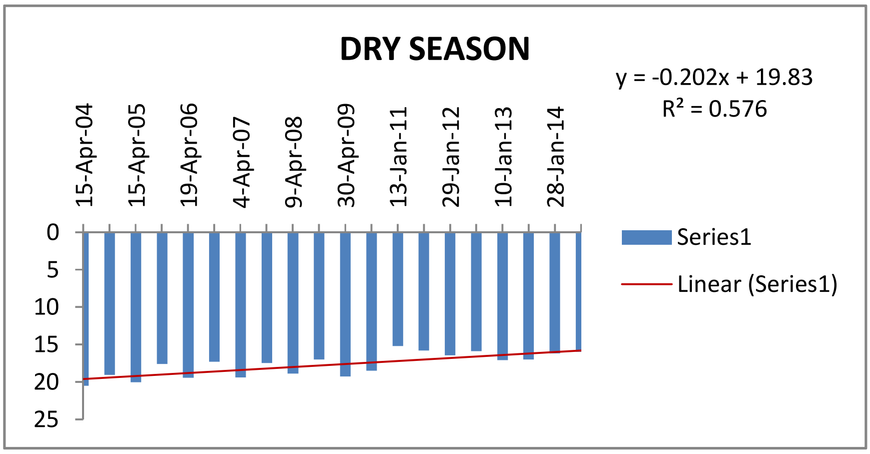


SW MONSOON	
31-Aug-07	10.2
3-Sep-08	9.91
30-Aug-09	11.25
30-Aug-10	10.75
13-Sep-10	10.75
24-Aug-11	10.94
10-Sep-12	11.9



NE MONSOON	
3-Nov-06	9.2
7-Nov-07	9.8
26-Nov-08	9.68
19-Nov-09	11
7-Nov-10	10.85
24-Nov-11	11.2

Histogram showing depth to water table (bgl), Bore well at Aralumoodu



DRY SEASON	
15-Apr-04	20.51
7-Jan-05	19.1
15-Apr-05	20.05
3-Jan-06	17.61
19-Apr-06	19.44
5-Jan-07	17.3
4-Apr-07	19.43
9-Jan-08	17.48
9-Apr-08	18.87
8-Jan-09	16.99
30-Apr-09	19.3
15-Jan-10	18.5
13-Jan-11	15.19
28-Apr-11	15.79
29-Jan-12	16.45
6-Apr-12	15.92
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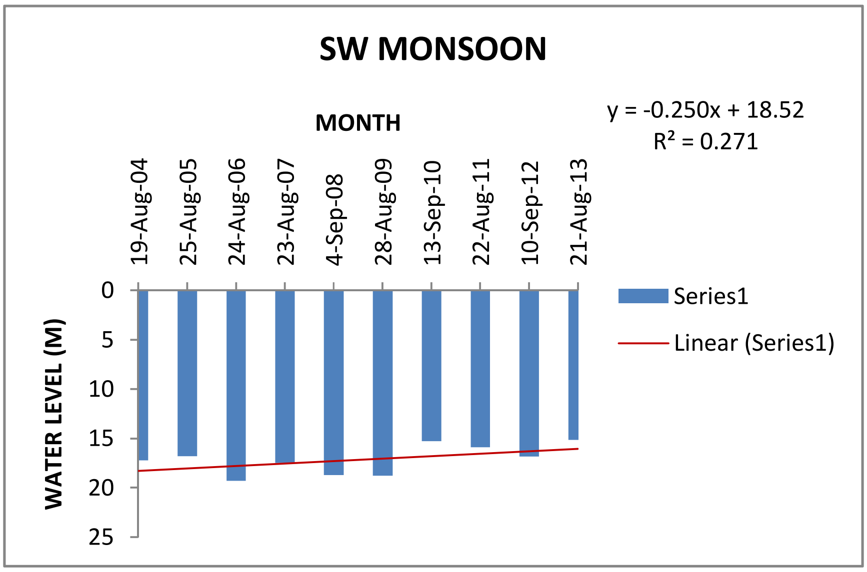
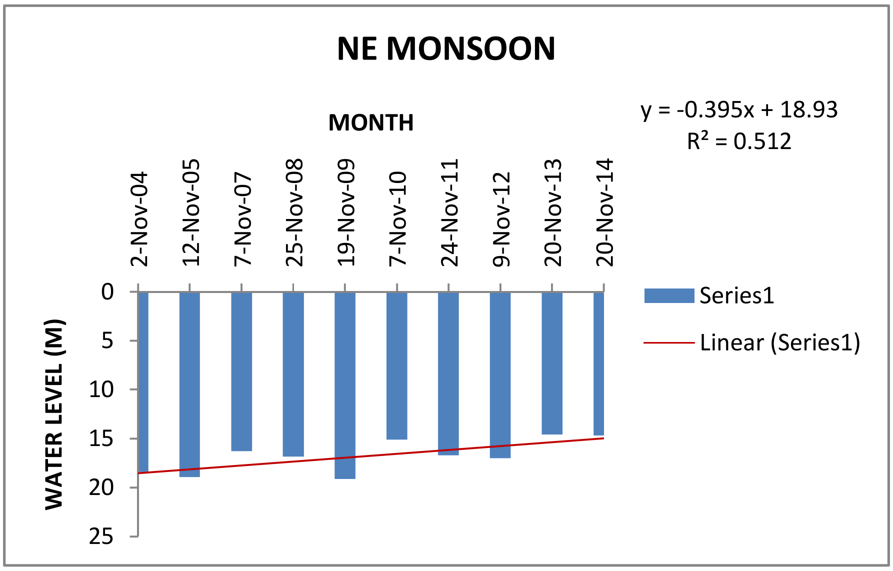
28-Jan-14	16.2
9-Jan-15	16

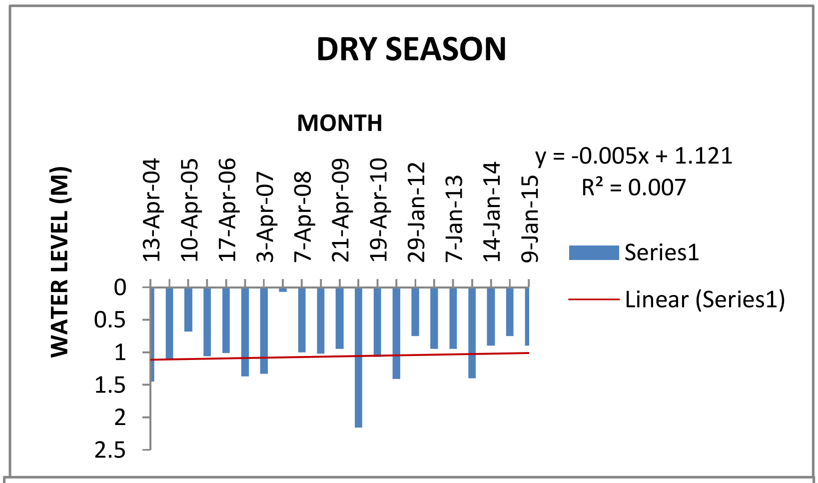


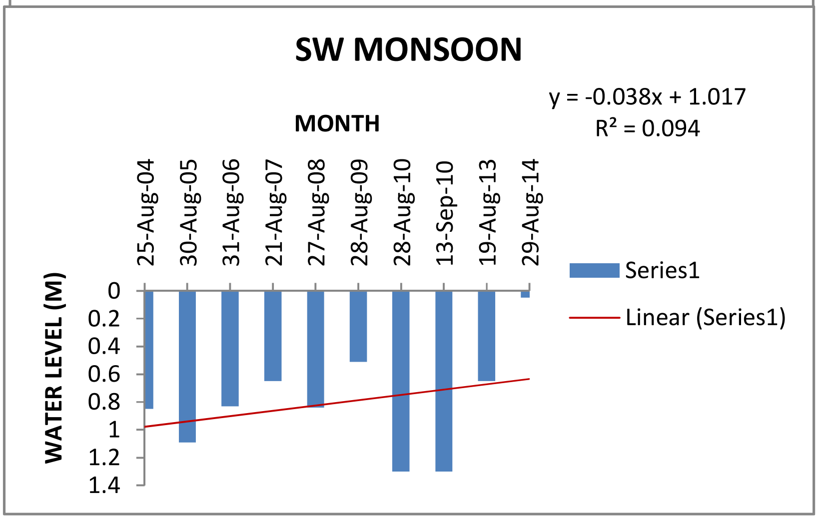
SW MONSOON	
19-Aug-04	17.21
25-Aug-05	16.8
24-Aug-06	19.28
23-Aug-07	17.45
4-Sep-08	18.74
28-Aug-09	18.8
13-Sep-10	15.28
22-Aug-11	15.9
10-Sep-12	16.85
21-Aug-13	15.17

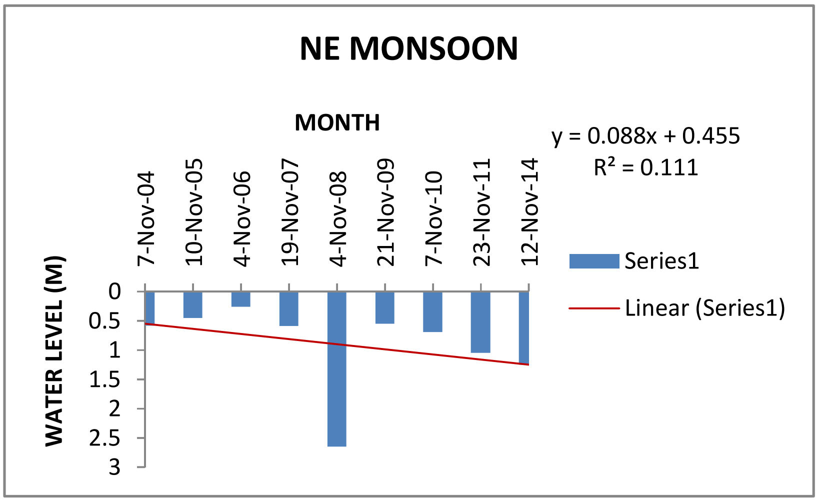


NE MONSOON	
2-Nov-04	18.42
12-Nov-05	18.94
7-Nov-07	16.28
25-Nov-08	16.81
19-Nov-09	19.1
7-Nov-10	15.12
24-Nov-11	16.7
9-Nov-12	16.97
20-Nov-13	14.56
20-Nov-14	14.68

Histogram showing depth to water table (bgl), Dug well at Poonkulam





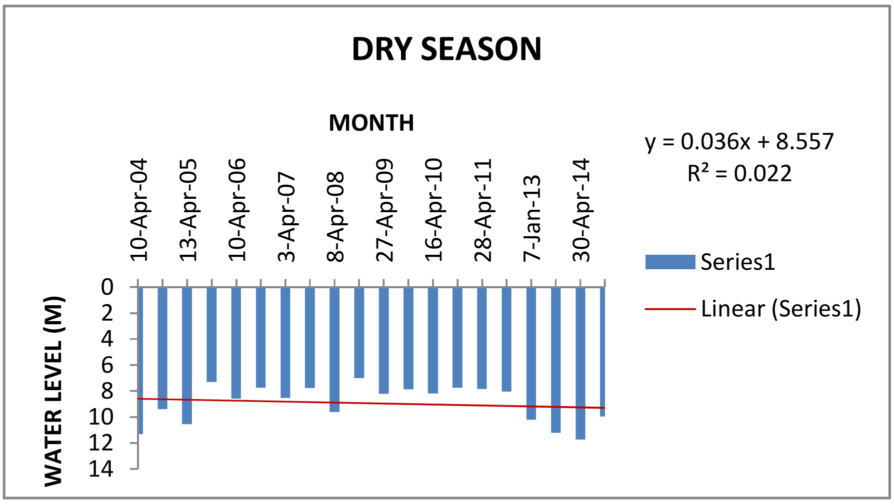


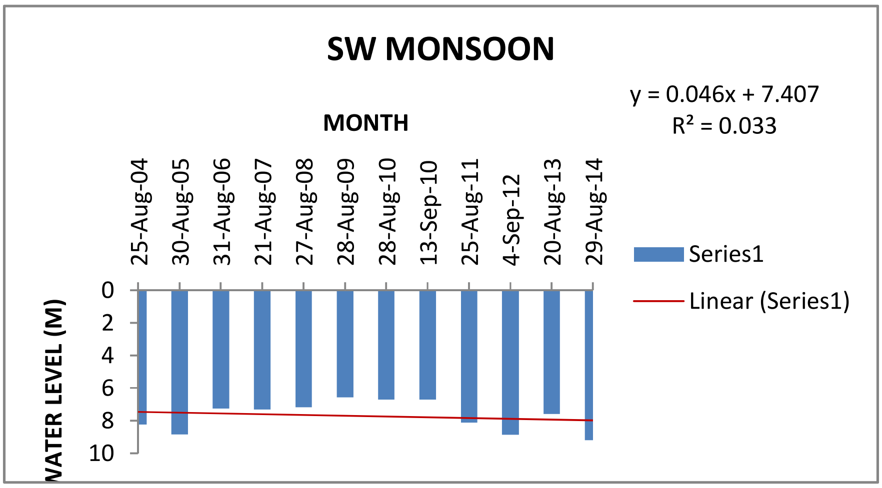
DRY SEASON	
13-Apr-04	1.45
7-Jan-05	1.12
10-Apr-05	0.68
18-Jan-06	1.06
17-Apr-06	1.01
9-Jan-07	1.37
3-Apr-07	1.33
7-Jan-08	0.07
7-Apr-08	1
5-Jan-09	1.02
21-Apr-09	0.95
9-Jan-10	2.16
19-Apr-10	1.07
10-Jan-11	1.41
29-Jan-12	0.75
14-Apr-12	0.95
7-Jan-13	0.95
11-Apr-13	1.4
14-Jan-14	0.9
16-Apr-14	0.75
9-Jan-15	0.9

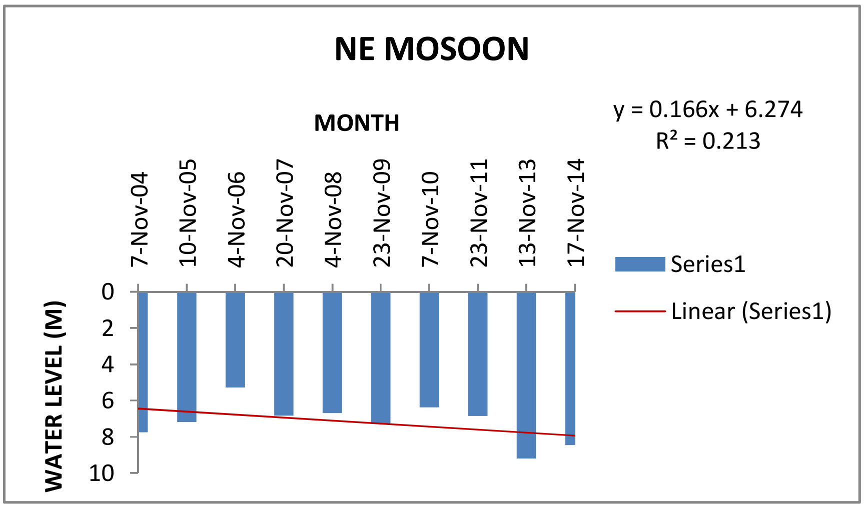
SW MONSOON	
25-Aug-04	0.85
30-Aug-05	1.09
31-Aug-06	0.83
21-Aug-07	0.65
27-Aug-08	0.84
28-Aug-09	0.51
28-Aug-10	1.3
13-Sep-10	1.3
19-Aug-13	0.65
29-Aug-14	0.05

NE MONSOON	
7-Nov-04	0.58
10-Nov-05	0.45
4-Nov-06	0.26
19-Nov-07	0.59
4-Nov-08	2.65
21-Nov-09	0.55
7-Nov-10	0.69
23-Nov-11	1.05
12-Nov-14	1.25

Histogram showing depth to water table (bgl), Dug well at Anjengo

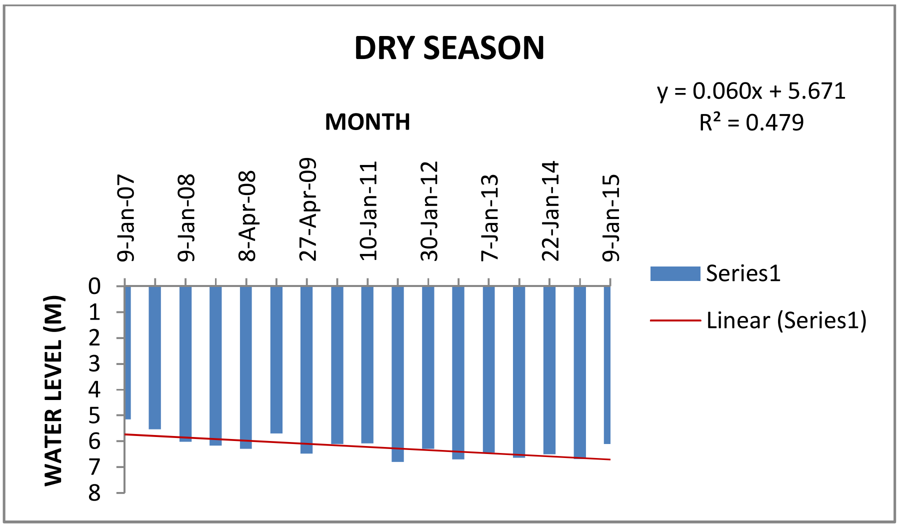


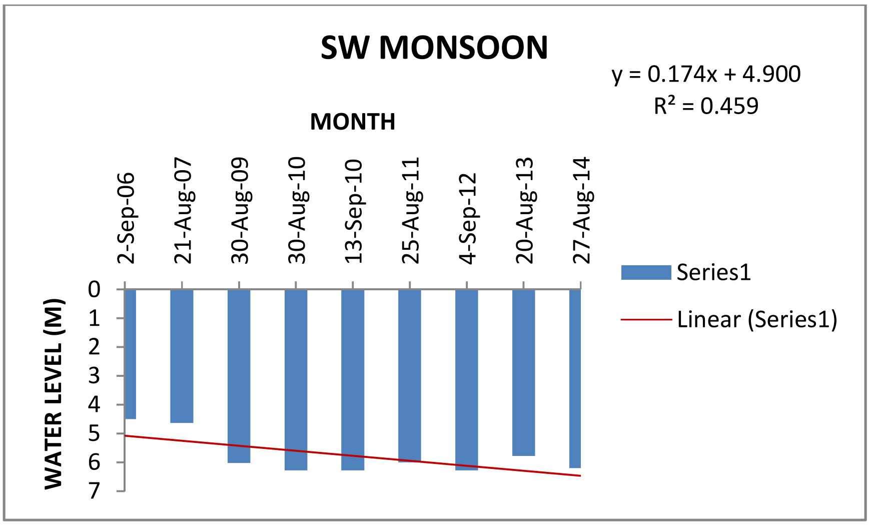


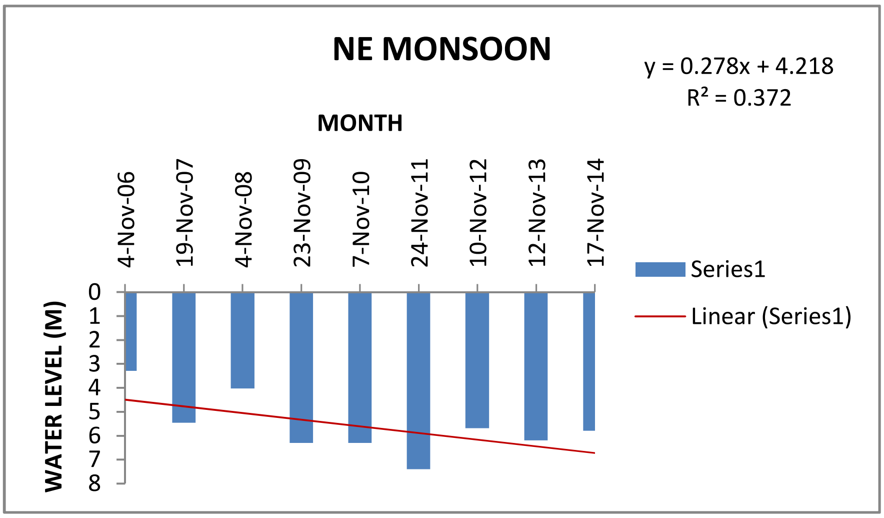


DRY SEASON	
10-Apr-04	11.31
3-Jan-05	9.39
13-Apr-05	10.55
18-Jan-06	7.29
10-Apr-06	8.59
9-Jan-07	7.75
3-Apr-07	8.55
7-Jan-08	7.78
8-Apr-08	9.63
5-Jan-09	7.01
27-Apr-09	8.21
15-Jan-10	7.87
16-Apr-10	8.19
10-Jan-11	7.75
28-Apr-11	7.86
29-Jan-12	8.05
7-Jan-13	10.2
11-Apr-13	11.19
30-Apr-14	11.73
9-Jan-15	9.95
SW MONSOON	
25-Aug-04	8.25
30-Aug-05	8.83
31-Aug-06	7.25
21-Aug-07	7.3
27-Aug-08	7.17
28-Aug-09	6.57
28-Aug-10	6.69
13-Sep-10	6.69
25-Aug-11	8.12
4-Sep-12	8.85
20-Aug-13	7.59
29-Aug-14	9.2
NE MONSOON	
7-Nov-04	7.75
10-Nov-05	7.19
4-Nov-06	5.28
20-Nov-07	6.83
4-Nov-08	6.7
23-Nov-09	7.26
7-Nov-10	6.38
23-Nov-11	6.86
13-Nov-13	9.2
17-Nov-14	8.45

Histogram showing depth to water table (bgl), Dug well at Attingal





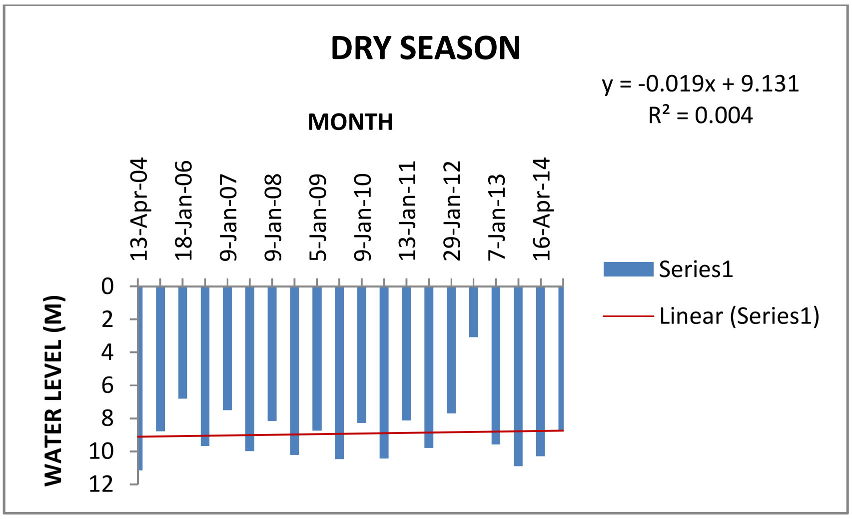


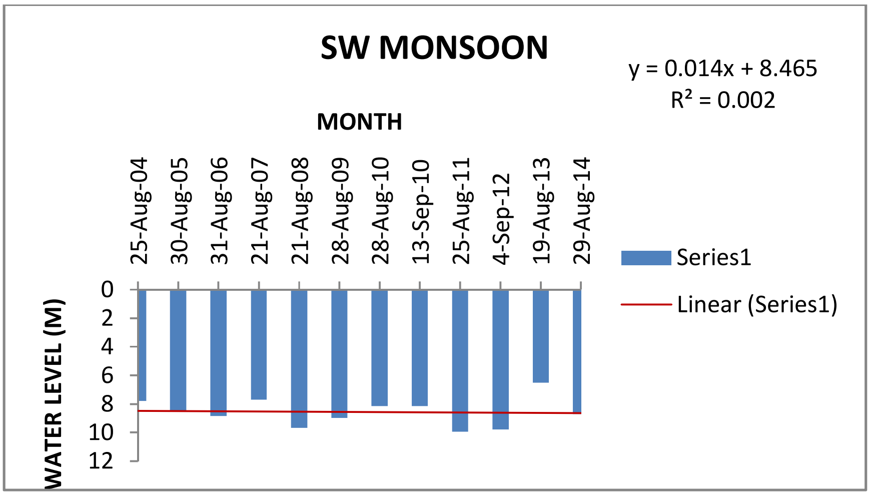
Histogram showing depth to water table (bgl), Bore well at Attingal

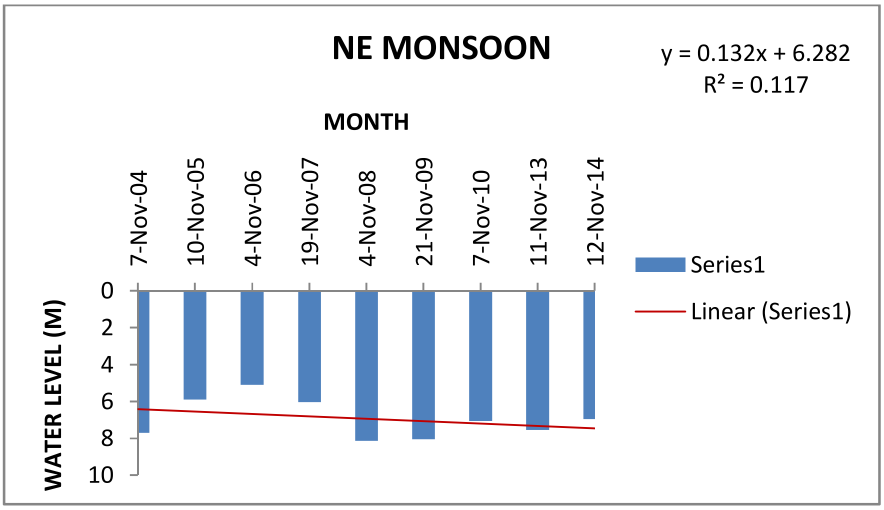
DRY SEASON	
9-Jan-07	5.15
3-Apr-07	5.54
9-Jan-08	6.02
27-Jan-08	6.17
8-Apr-08	6.3
5-Jan-09	5.7
27-Apr-09	6.48
16-Jan-10	6.1
10-Jan-11	6.08
28-Apr-11	6.8
30-Jan-12	6.3
14-Apr-12	6.7
7-Jan-13	6.44
13-Apr-13	6.64
22-Jan-14	6.5
30-Apr-14	6.69
9-Jan-15	6.1

SW MONSOON	
2-Sep-06	4.5
21-Aug-07	4.63
30-Aug-09	6.03
30-Aug-10	6.27
13-Sep-10	6.27
25-Aug-11	6
4-Sep-12	6.27
20-Aug-13	5.78
27-Aug-14	6.2

NE MONSOON	
4-Nov-06	3.3
19-Nov-07	5.46
4-Nov-08	4.02
23-Nov-09	6.3
7-Nov-10	6.3
24-Nov-11	7.4
10-Nov-12	5.7
12-Nov-13	6.2
17-Nov-14	5.8





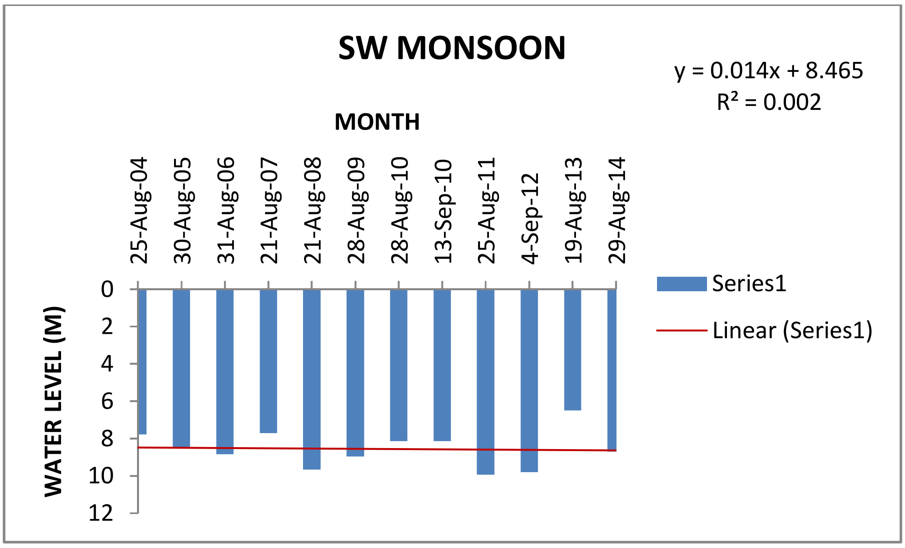


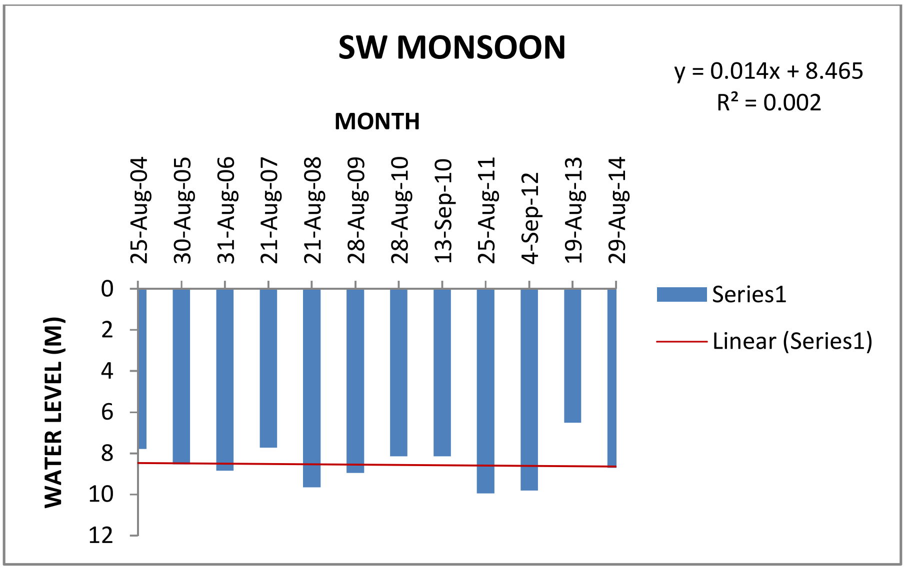
DRY SEASON	
13-Apr-04	11.16
7-Jan-05	8.78
18-Jan-06	6.82
17-Apr-06	9.68
9-Jan-07	7.51
3-Apr-07	9.99
9-Jan-08	8.17
7-Apr-08	10.21
5-Jan-09	8.74
21-Apr-09	10.48
9-Jan-10	8.29
16-Apr-10	10.43
13-Jan-11	8.14
28-Apr-11	9.8
29-Jan-12	7.7
14-Apr-12	3.07
7-Jan-13	9.59
11-Apr-13	10.89
16-Apr-14	10.3
9-Jan-15	8.7

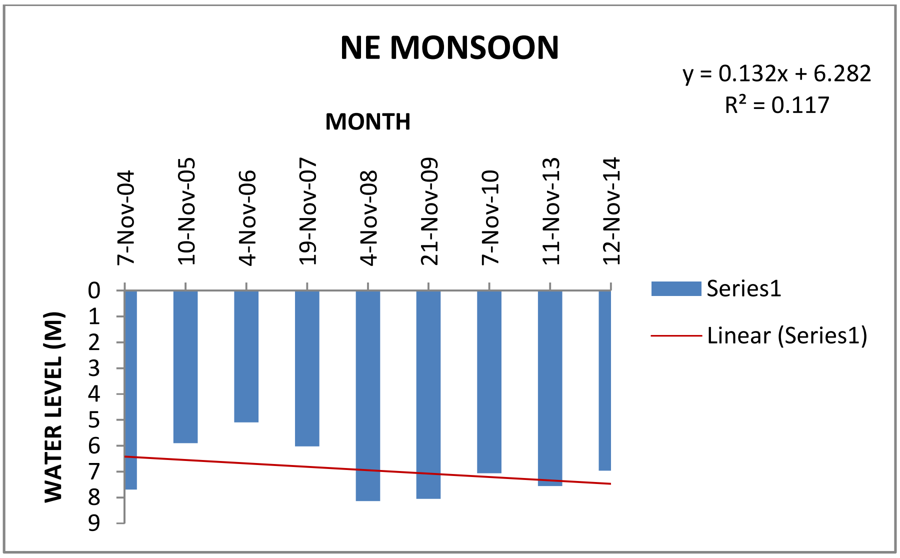
SW MONSOON	
25-Aug-04	7.79
30-Aug-05	8.54
31-Aug-06	8.84
21-Aug-07	7.71
21-Aug-08	9.66
28-Aug-09	8.96
28-Aug-10	8.14
13-Sep-10	8.14
25-Aug-11	9.94
4-Sep-12	9.8
19-Aug-13	6.5
29-Aug-14	8.7

NE MONSOON	
7-Nov-04	7.7
10-Nov-05	5.9
4-Nov-06	5.1
19-Nov-07	6.03
4-Nov-08	8.14
21-Nov-09	8.05
7-Nov-10	7.06
11-Nov-13	7.55
12-Nov-14	6.96

Histogram showing depth to water table (bgl),B well at Chirayinkil

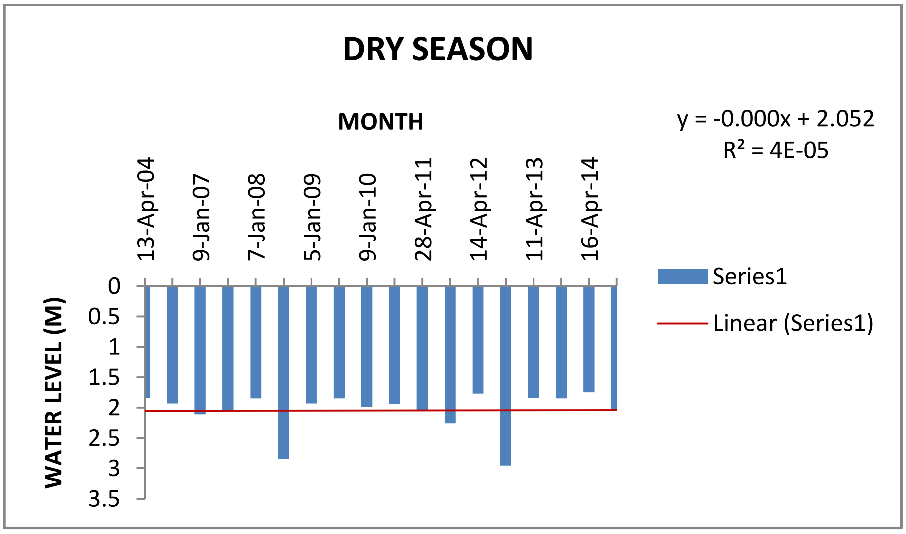


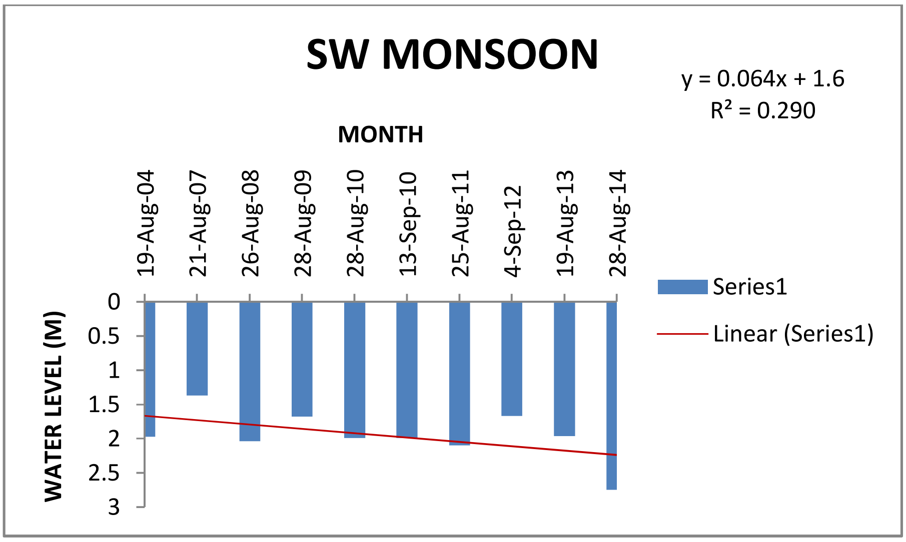


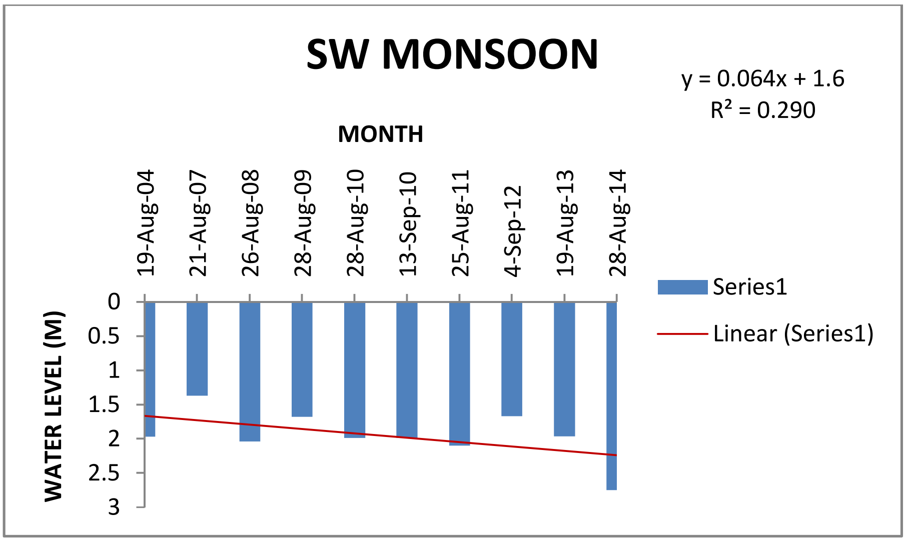


DRY SEASON	
13-Apr-04	11.16
7-Jan-05	8.78
18-Jan-06	6.82
17-Apr-06	9.68
9-Jan-07	7.51
3-Apr-07	9.99
9-Jan-08	8.17
7-Apr-08	10.21
5-Jan-09	8.74
21-Apr-09	10.48
9-Jan-10	8.29
16-Apr-10	10.43
13-Jan-11	8.14
28-Apr-11	9.8
29-Jan-12	7.7
14-Apr-12	3.07
7-Jan-13	9.59
11-Apr-13	10.89
16-Apr-14	10.3
9-Jan-15	8.7
SW MONSOON	
25-Aug-04	7.79
30-Aug-05	8.54
31-Aug-06	8.84
21-Aug-07	7.71
21-Aug-08	9.66
28-Aug-09	8.96
28-Aug-10	8.14
13-Sep-10	8.14
25-Aug-11	9.94
4-Sep-12	9.8
19-Aug-13	6.5
29-Aug-14	8.7
NE MONSOON	
7-Nov-04	7.7
10-Nov-05	5.9
4-Nov-06	5.1
19-Nov-07	6.03
4-Nov-08	8.14
21-Nov-09	8.05
7-Nov-10	7.06
11-Nov-13	7.55
12-Nov-14	6.96

Histogram showing depth to water table (bgl), Dug well at Kadakkavur

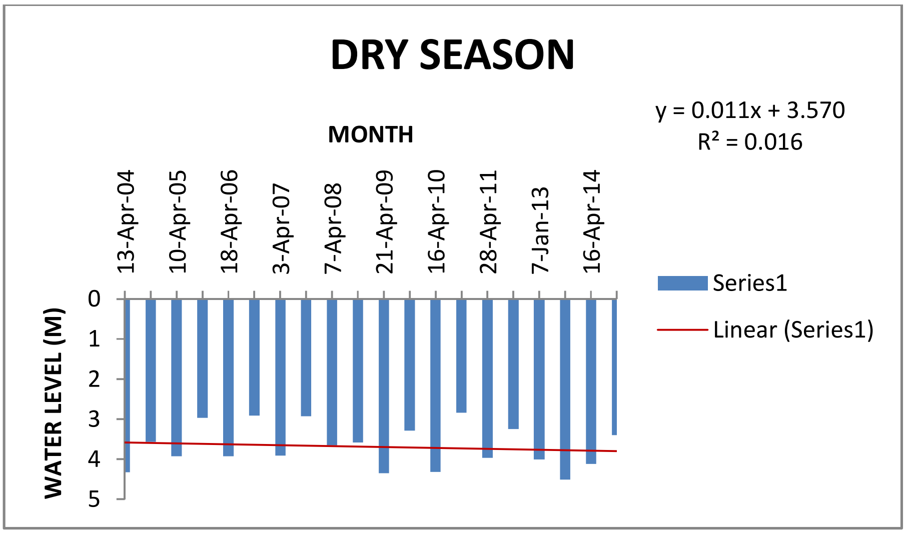


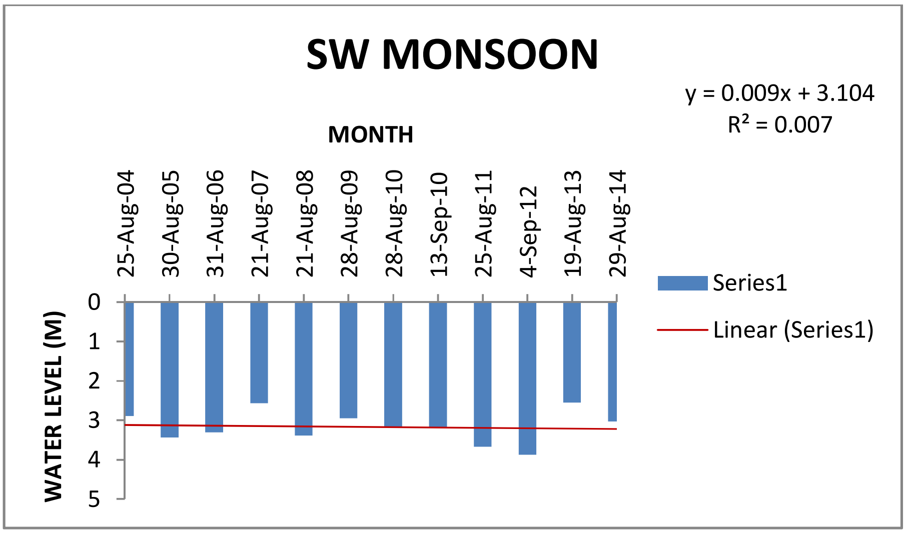


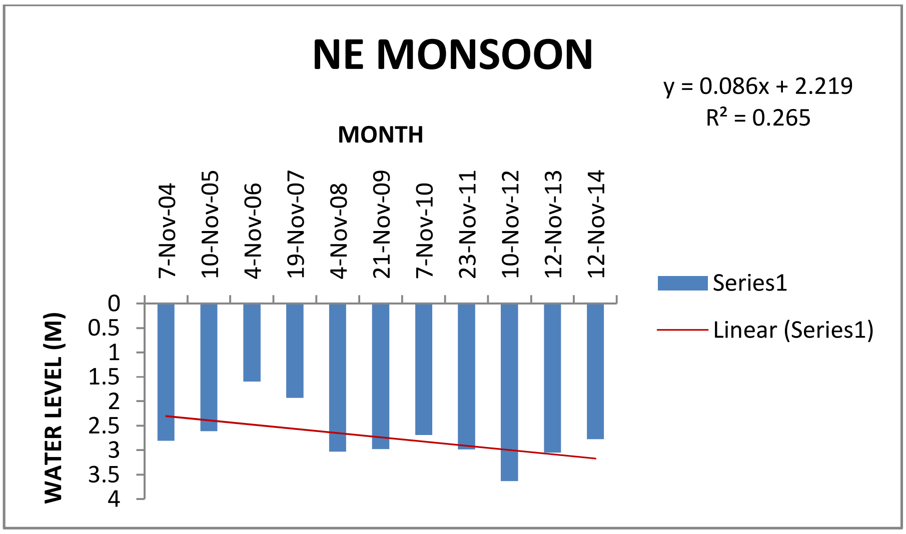


DRY SEASON	
13-Apr-04	1.84
7-Jan-05	1.93
9-Jan-07	2.11
3-Apr-07	2.06
7-Jan-08	1.85
7-Apr-08	2.85
5-Jan-09	1.93
21-Apr-09	1.85
9-Jan-10	1.99
13-Jan-11	1.94
28-Apr-11	2.05
29-Jan-12	2.26
14-Apr-12	1.77
7-Jan-13	2.95
11-Apr-13	1.84
14-Jan-14	1.85
16-Apr-14	1.75
9-Jan-15	2.05
SW MONSOON	
19-Aug-04	1.97
21-Aug-07	1.37
26-Aug-08	2.04
28-Aug-09	1.68
28-Aug-10	1.99
13-Sep-10	1.99
25-Aug-11	2.1
4-Sep-12	1.67
19-Aug-13	1.96
28-Aug-14	2.75
NE MONSOON	
5-Nov-04	1.85
19-Nov-07	1.65
4-Nov-08	1.85
21-Nov-09	1.68
7-Nov-10	1.89
23-Nov-11	1.63
10-Nov-12	1.68
12-Nov-13	2.03
12-Nov-14	1.87

Histogram showing depth to water table (bgl), Dug well at Perumathura

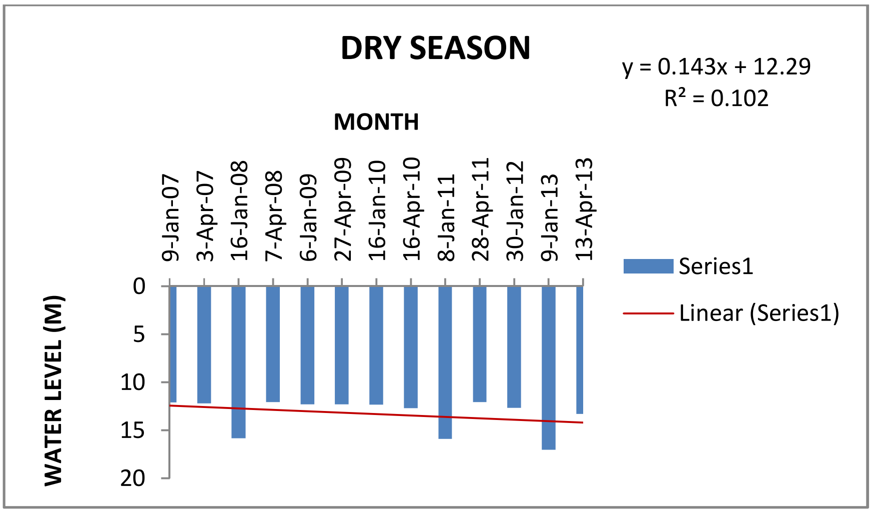




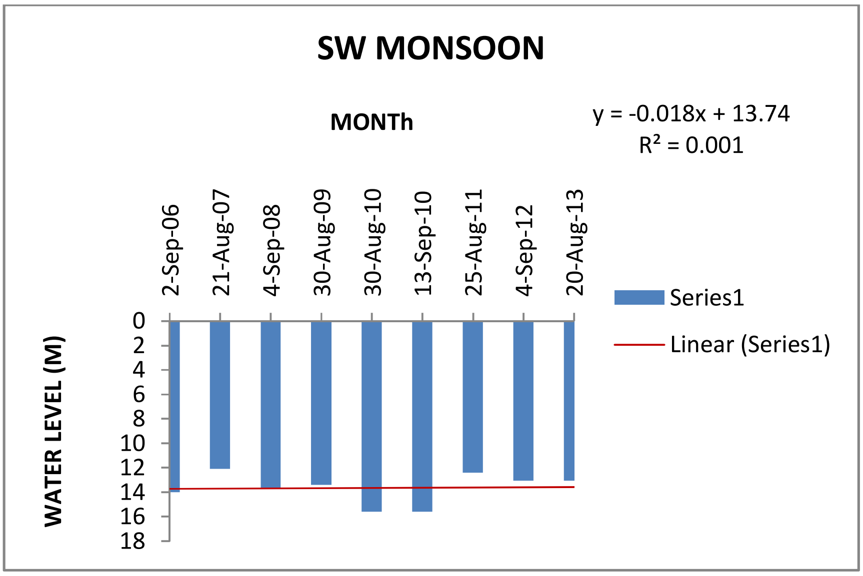


DRY SEASON	
13-Apr-04	4.33
7-Jan-05	3.57
10-Apr-05	3.93
18-Jan-06	2.97
18-Apr-06	3.93
9-Jan-07	2.91
3-Apr-07	3.92
7-Jan-08	2.93
7-Apr-08	3.66
5-Jan-09	3.58
21-Apr-09	4.35
9-Jan-10	3.29
16-Apr-10	4.32
13-Jan-11	2.84
28-Apr-11	3.97
29-Jan-12	3.25
7-Jan-13	4.01
11-Apr-13	4.52
16-Apr-14	4.12
9-Jan-15	3.4
SW MONSOON	
25-Aug-04	2.89
30-Aug-05	3.43
31-Aug-06	3.31
21-Aug-07	2.56
21-Aug-08	3.39
28-Aug-09	2.95
28-Aug-10	3.17
13-Sep-10	3.17
25-Aug-11	3.67
4-Sep-12	3.88
19-Aug-13	2.55
29-Aug-14	3.03
NE MONSOON	
7-Nov-04	2.81
10-Nov-05	2.61
4-Nov-06	1.6
19-Nov-07	1.93
4-Nov-08	3.03
21-Nov-09	2.98
7-Nov-10	2.69
23-Nov-11	2.99
10-Nov-12	3.63
12-Nov-13	3.05
12-Nov-14	2.78

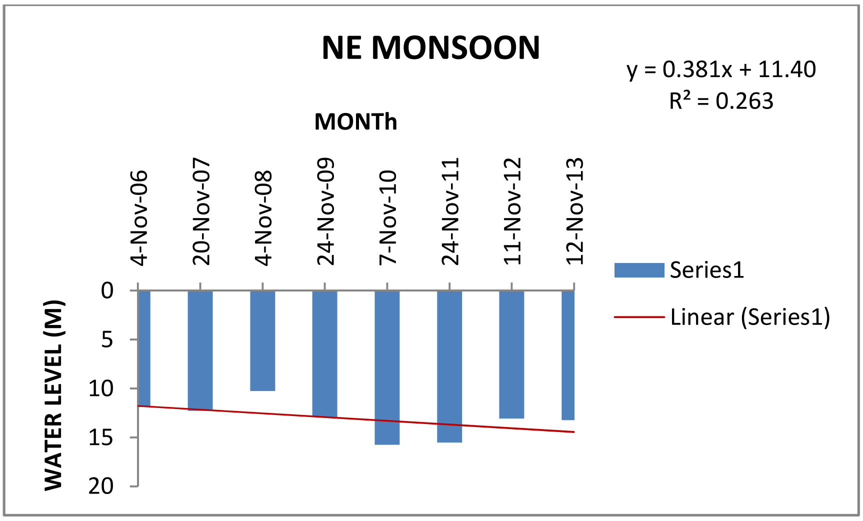
Histogram showing depth to water table (bgl), Dug well at Perumkuzhi



Dry Season	
9-Jan-07	12.1
3-Apr-07	12.22
16-Jan-08	15.85
7-Apr-08	12.08
6-Jan-09	12.32
27-Apr-09	12.32
16-Jan-10	12.35
16-Apr-10	12.68
8-Jan-11	15.9
28-Apr-11	12.08
30-Jan-12	12.66
9-Jan-13	17.06
13-Apr-13	13.3

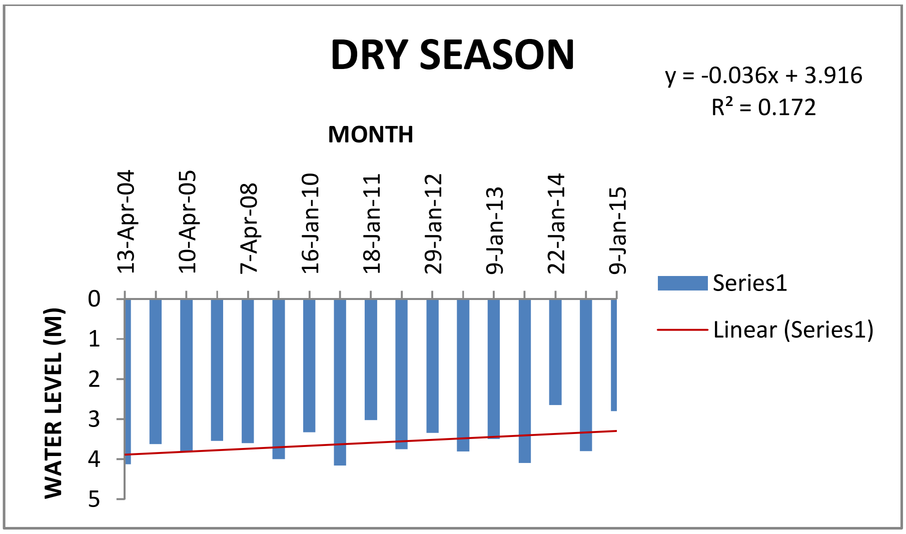


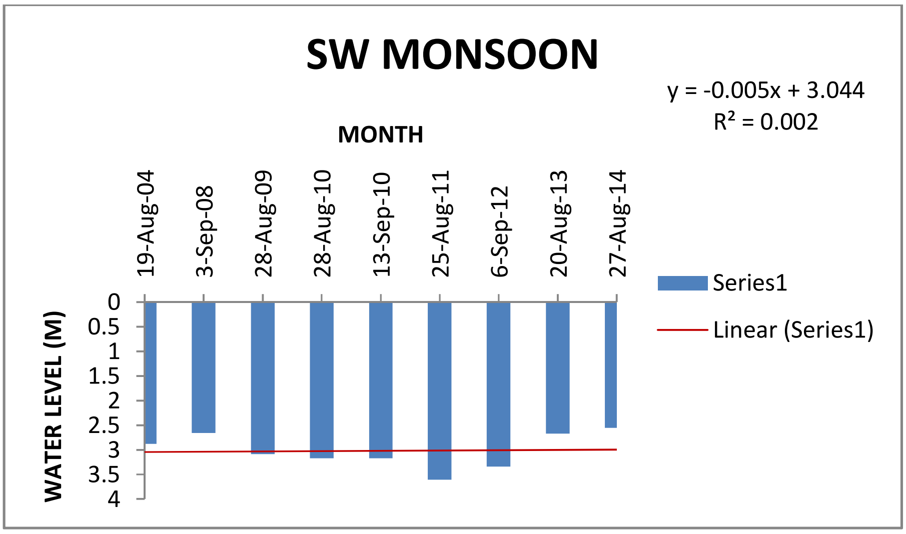
SW Monsoon	
2-Sep-06	14
21-Aug-07	12.09
4-Sep-08	13.63
30-Aug-09	13.4
30-Aug-10	15.6
13-Sep-10	15.6
25-Aug-11	12.4
4-Sep-12	13.05
20-Aug-13	13.07

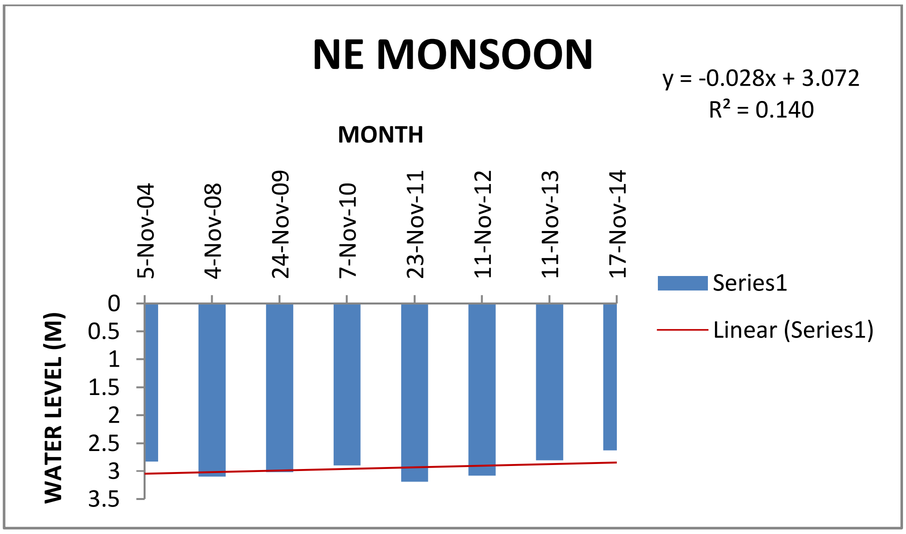


NE Monsoon	
4-Nov-06	11.9
20-Nov-07	12.28
4-Nov-08	10.27
24-Nov-09	12.9
7-Nov-10	15.75
24-Nov-11	15.55
11-Nov-12	13.08
12-Nov-13	13.24

Histogram showing depth to water table (bgl), bore well at Kariyavattom

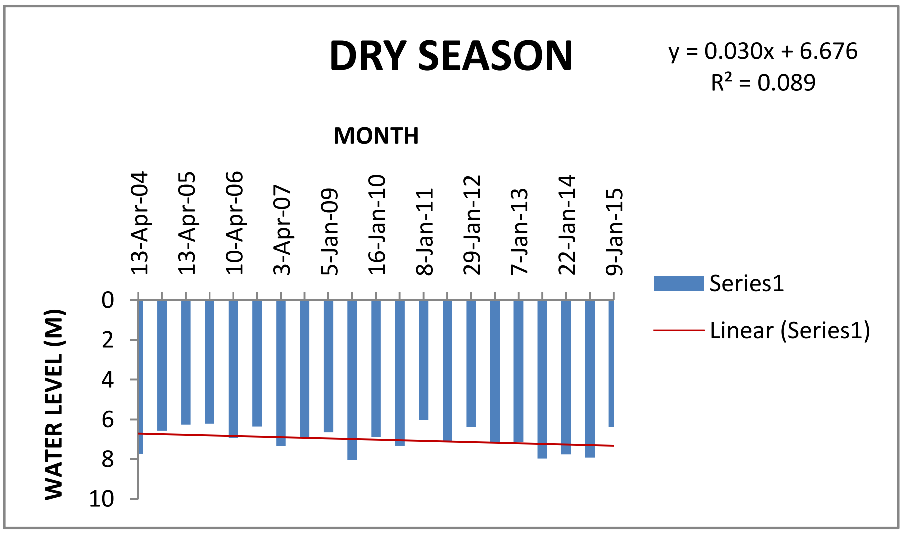


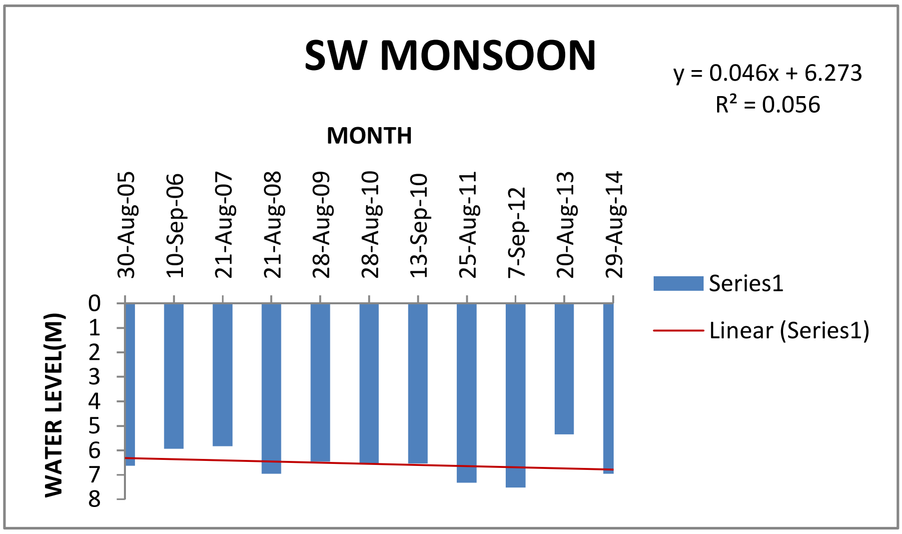


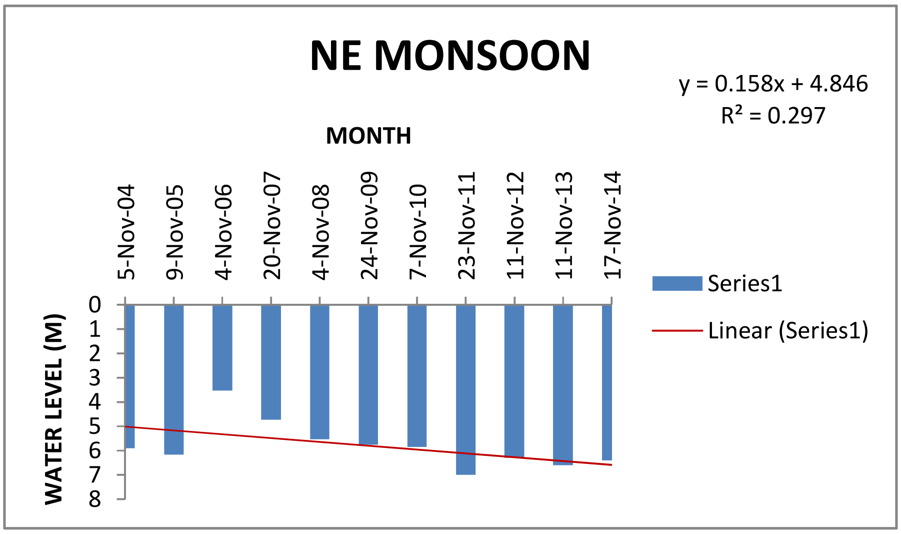


DRY SEASON	
13-Apr-04	4.13
3-Jan-05	3.63
10-Apr-05	3.81
16-Jan-08	3.54
7-Apr-08	3.6
27-Apr-09	4
16-Jan-10	3.33
16-Apr-10	4.16
18-Jan-11	3.02
28-Apr-11	3.75
29-Jan-12	3.35
15-Apr-12	3.81
9-Jan-13	3.5
13-Apr-13	4.1
22-Jan-14	2.65
30-Apr-14	3.8
9-Jan-15	2.8
SW MONSOON	
19-Aug-04	2.88
3-Sep-08	2.66
28-Aug-09	3.09
28-Aug-10	3.17
13-Sep-10	3.17
25-Aug-11	3.61
6-Sep-12	3.34
20-Aug-13	2.67
27-Aug-14	2.55
NE MONSOON	
5-Nov-04	2.83
4-Nov-08	3.1
24-Nov-09	3.02
7-Nov-10	2.9
23-Nov-11	3.19
11-Nov-12	3.08
11-Nov-13	2.81
17-Nov-14	2.63

Histogram showing depth to water table (bgl), Dug well at Kazhakkoottam

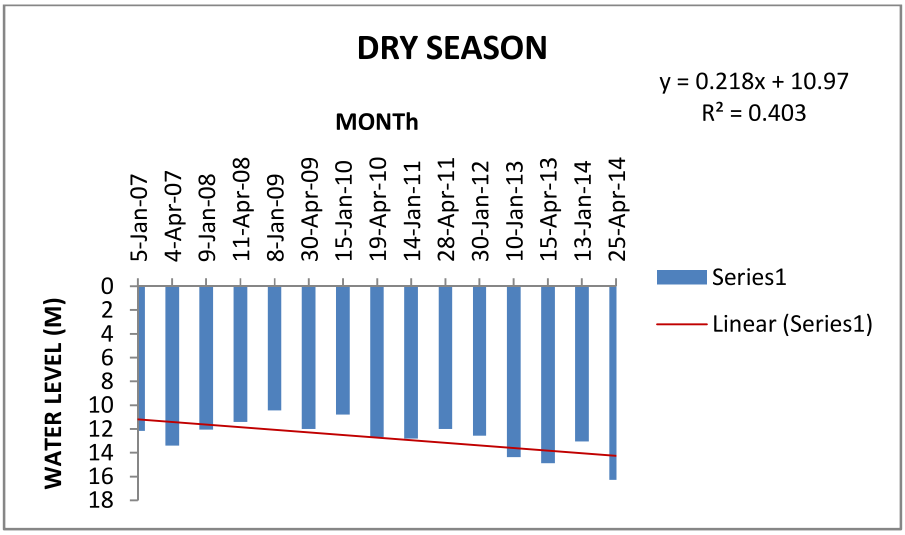




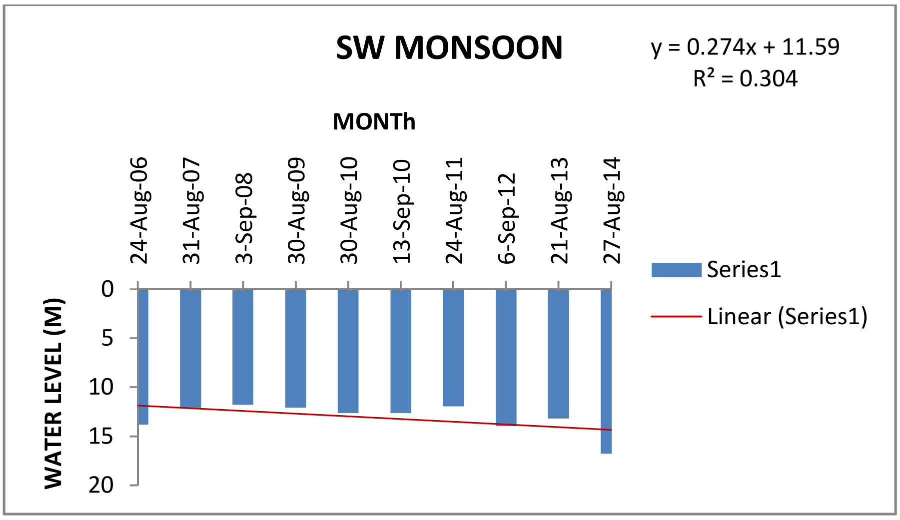


Histogram showing depth to water table (bgl), Dug well at Korani

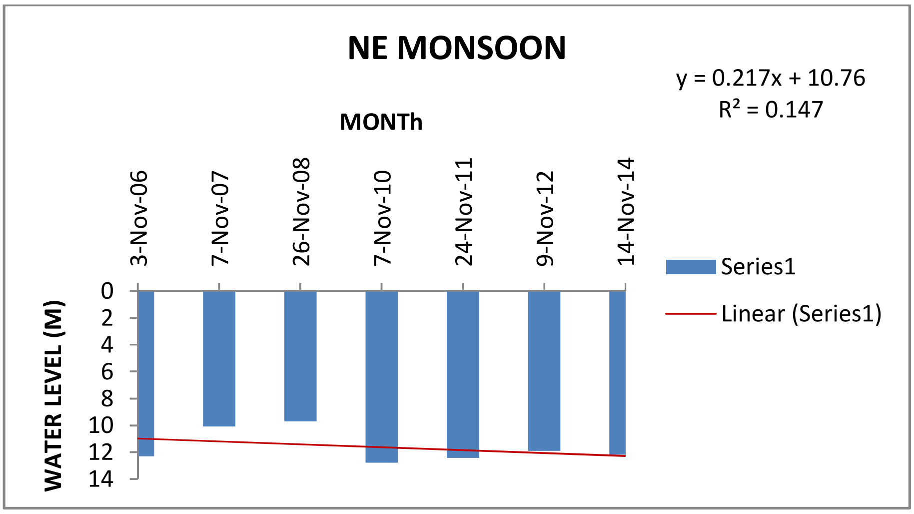
DRY SEASON	
13-Apr-04	7.72
3-Jan-05	6.57
13-Apr-05	6.27
18-Jan-06	6.22
10-Apr-06	6.94
9-Jan-07	6.37
3-Apr-07	7.34
8-Apr-08	6.9
5-Jan-09	6.65
27-Apr-09	8.06
16-Jan-10	6.9
16-Apr-10	7.32
8-Jan-11	6.02
28-Apr-11	7.13
29-Jan-12	6.4
14-Apr-12	7.2
7-Jan-13	7.15
13-Apr-13	7.97
22-Jan-14	7.76
30-Apr-14	7.92
9-Jan-15	6.38
SW MONSOON	
25-Aug-04	5.96
30-Aug-05	6.64
10-Sep-06	5.93
21-Aug-07	5.84
21-Aug-08	6.96
28-Aug-09	6.46
28-Aug-10	6.55
13-Sep-10	6.55
25-Aug-11	7.33
7-Sep-12	7.53
20-Aug-13	5.35
29-Aug-14	6.95
NE MONSOON	
5-Nov-04	5.9
9-Nov-05	6.17
4-Nov-06	3.52
20-Nov-07	4.73
4-Nov-08	5.54
24-Nov-09	5.75
7-Nov-10	5.84
23-Nov-11	7
11-Nov-12	6.3
11-Nov-13	6.6
17-Nov-14	6.4



DRY SEASON	
5-Jan-07	12.16
4-Apr-07	13.4
9-Jan-08	12.04
11-Apr-08	11.4
8-Jan-09	10.44
30-Apr-09	11.99
15-Jan-10	10.8
19-Apr-10	12.67
14-Jan-11	12.8
28-Apr-11	12
30-Jan-12	12.54
10-Jan-13	14.37
15-Apr-13	14.89
13-Jan-14	13.06
25-Apr-14	16.26

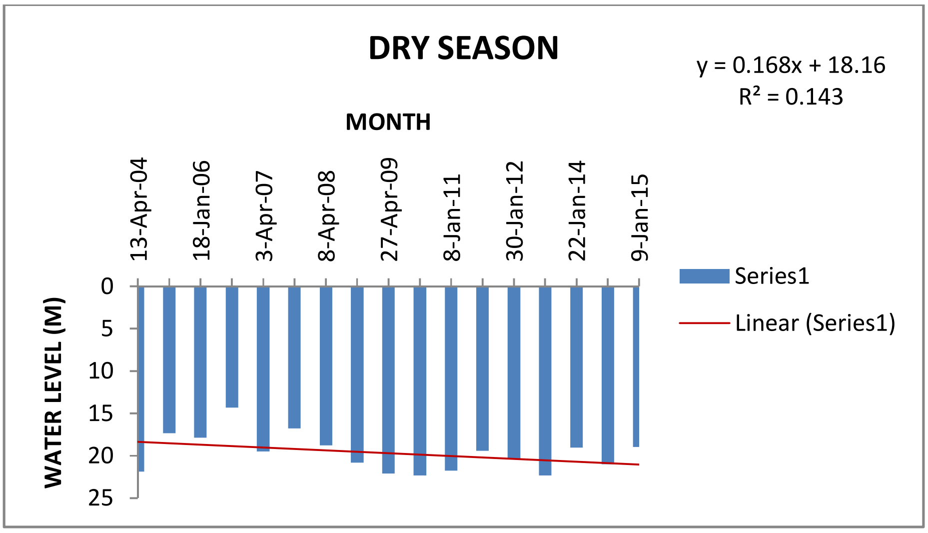


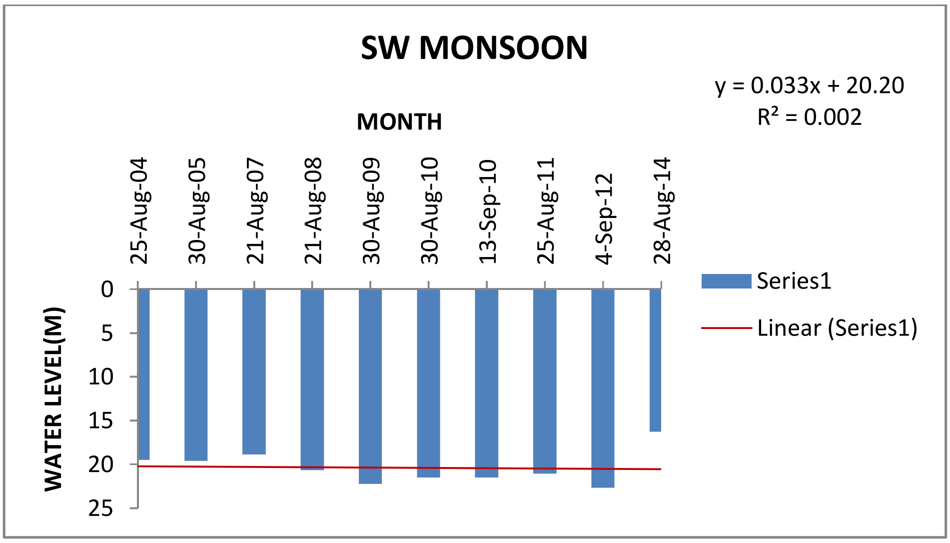
SW MONSOON	
24-Aug-06	13.8
31-Aug-07	12.1
3-Sep-08	11.77
30-Aug-09	12.1
30-Aug-10	12.65
13-Sep-10	12.65
24-Aug-11	11.96
6-Sep-12	13.98
21-Aug-13	13.2
27-Aug-14	16.8

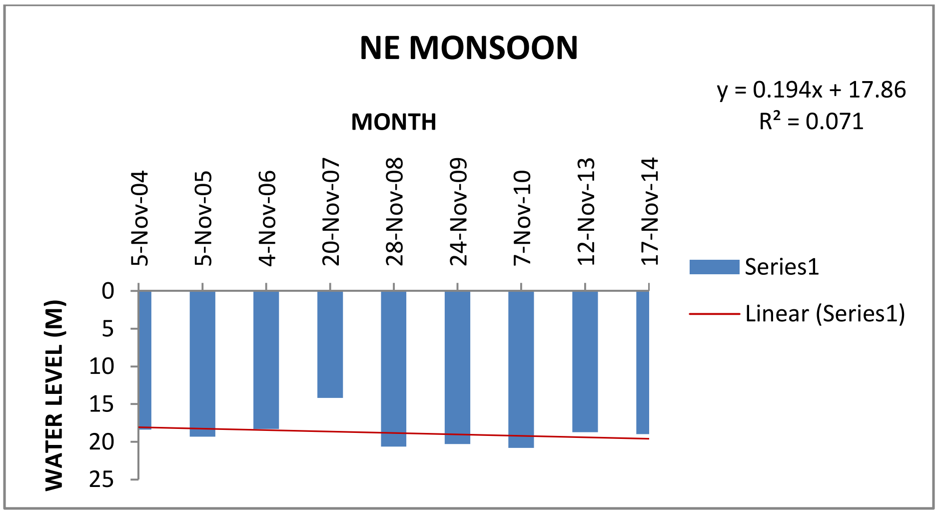


NE MONSOON	
3-Nov-06	12.3
7-Nov-07	10.08
26-Nov-08	9.7
7-Nov-10	12.8
24-Nov-11	12.41
9-Nov-12	11.92
14-Nov-14	12.2

Histogram showing depth to water table (bgl), Bore well at Kulathoor





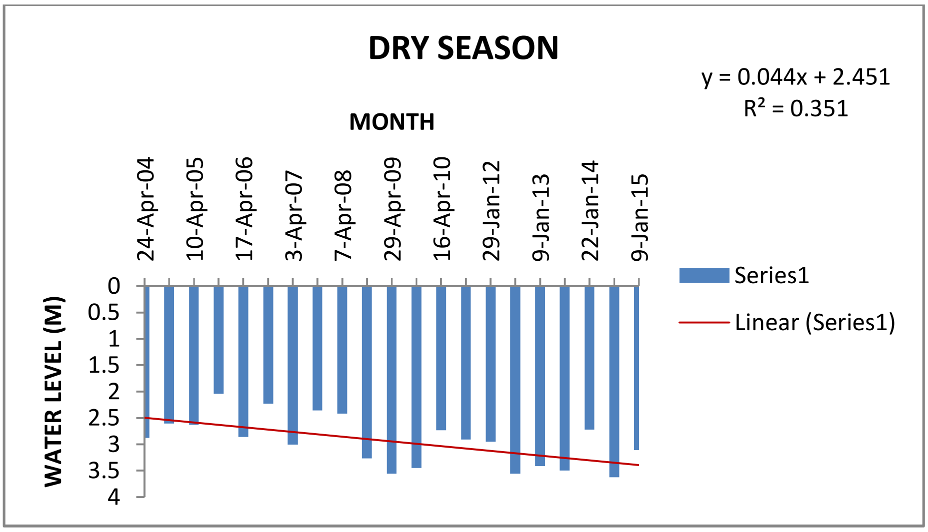


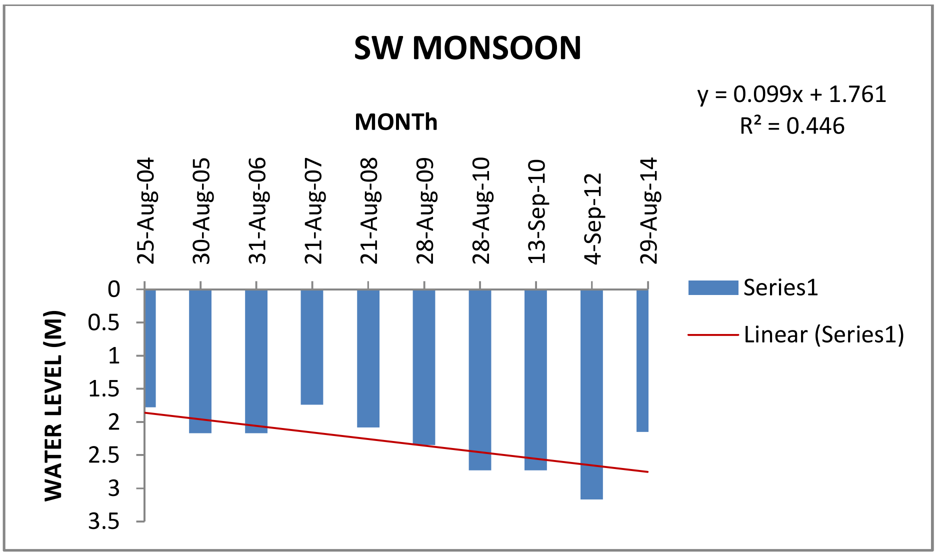
DRY SEASON	
13-Apr-04	21.86
3-Jan-05	17.34
18-Jan-06	17.88
9-Jan-07	14.3
3-Apr-07	19.5
16-Jan-08	16.75
8-Apr-08	18.8
6-Jan-09	20.8
27-Apr-09	22.1
16-Apr-10	22.31
8-Jan-11	21.75
28-Apr-11	19.4
30-Jan-12	20.4
9-Jan-13	22.33
22-Jan-14	19.03
26-Apr-14	21
9-Jan-15	18.98

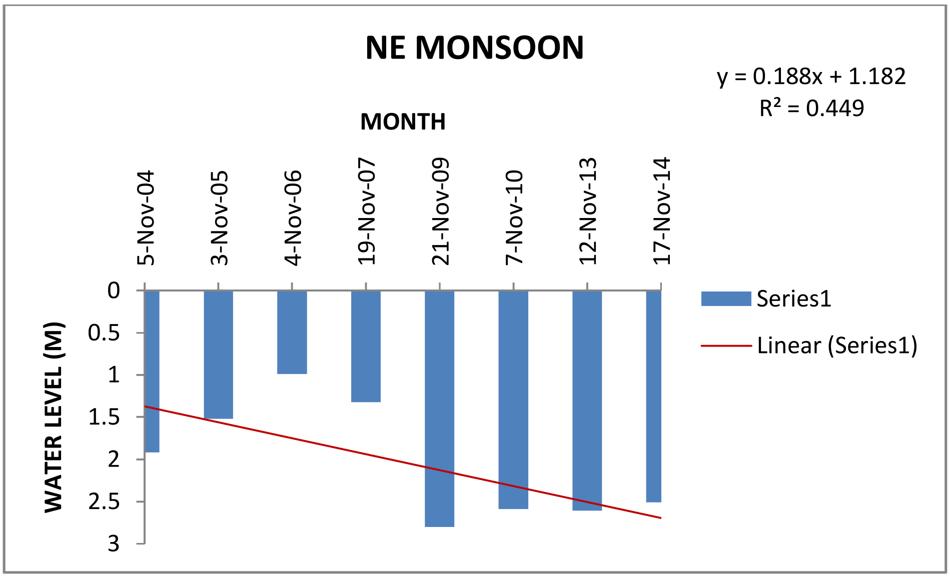
SW MONSOON	
25-Aug-04	19.48
30-Aug-05	19.6
21-Aug-07	18.9
21-Aug-08	20.65
30-Aug-09	22.21
30-Aug-10	21.5
13-Sep-10	21.5
25-Aug-11	21.05
4-Sep-12	22.68
28-Aug-14	16.3

NE MONSOON	
5-Nov-04	18.38
5-Nov-05	19.28
4-Nov-06	18.3
20-Nov-07	14.18
28-Nov-08	20.6
24-Nov-09	20.3
7-Nov-10	20.8
12-Nov-13	18.7
17-Nov-14	18.95

Histogram showing depth to water table (bgl), bore well at Mangalapuram





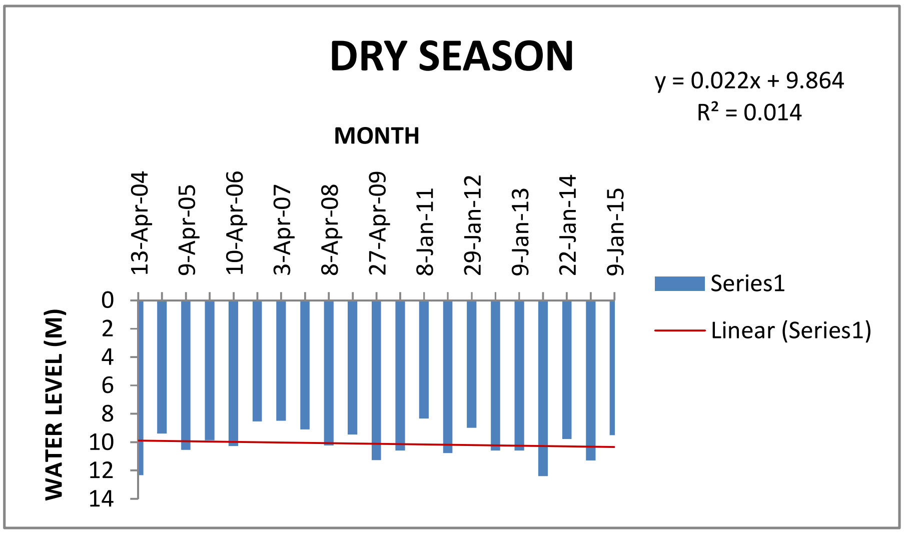


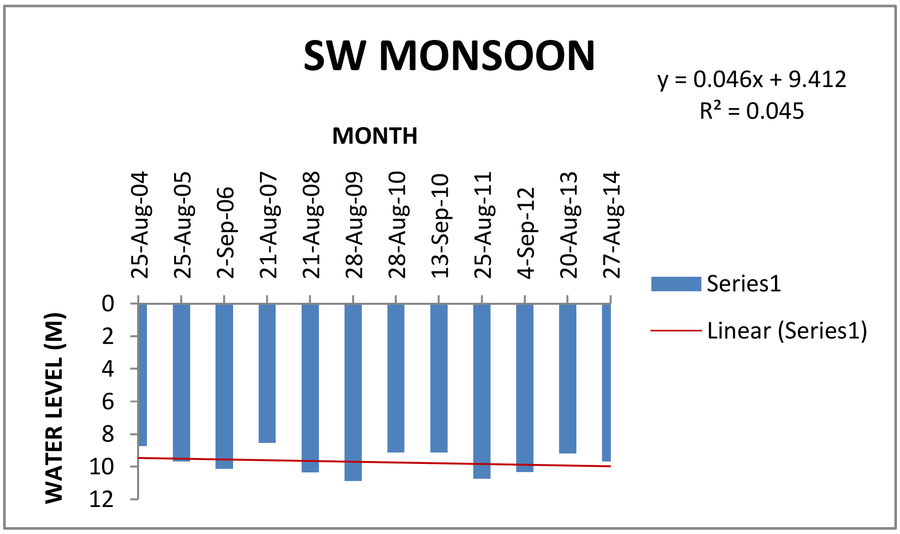
DRY SEASON	
24-Apr-04	2.88
7-Jan-05	2.61
10-Apr-05	2.63
18-Jan-06	2.04
17-Apr-06	2.86
9-Jan-07	2.23
3-Apr-07	3.01
16-Jan-08	2.36
7-Apr-08	2.42
5-Jan-09	3.27
29-Apr-09	3.56
9-Jan-10	3.45
16-Apr-10	2.73
8-Jan-11	2.91
29-Jan-12	2.95
15-Apr-12	3.56
9-Jan-13	3.41
13-Apr-13	3.5
22-Jan-14	2.72
26-Apr-14	3.62
9-Jan-15	3.11

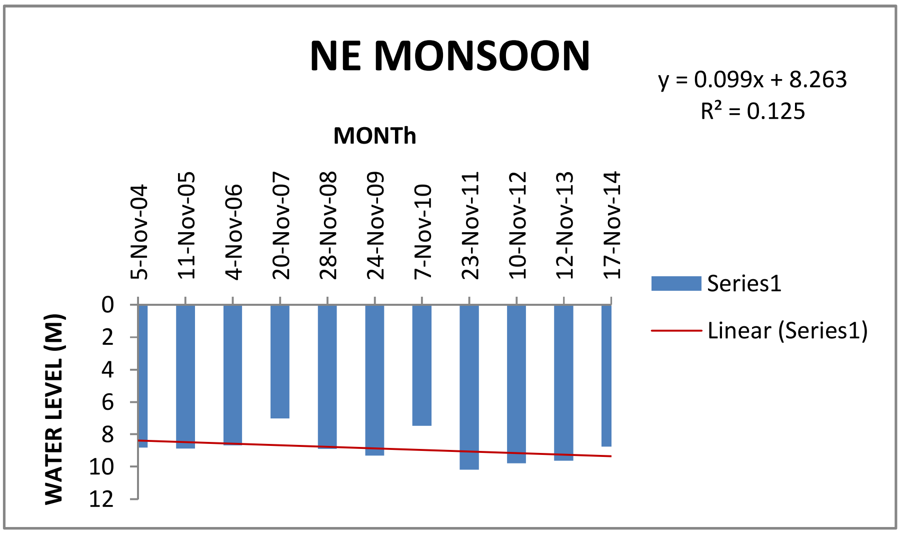
SW MONSOON	
25-Aug-04	1.78
30-Aug-05	2.17
31-Aug-06	2.17
21-Aug-07	1.74
21-Aug-08	2.08
28-Aug-09	2.35
28-Aug-10	2.73
13-Sep-10	2.73
4-Sep-12	3.17
29-Aug-14	2.15

NE MONSOON	
5-Nov-04	1.92
3-Nov-05	1.52
4-Nov-06	0.99
19-Nov-07	1.32
21-Nov-09	2.8
7-Nov-10	2.59
12-Nov-13	2.61
17-Nov-14	2.51

Histogram showing depth to water table (bgl), dug well at Murukumpuzha

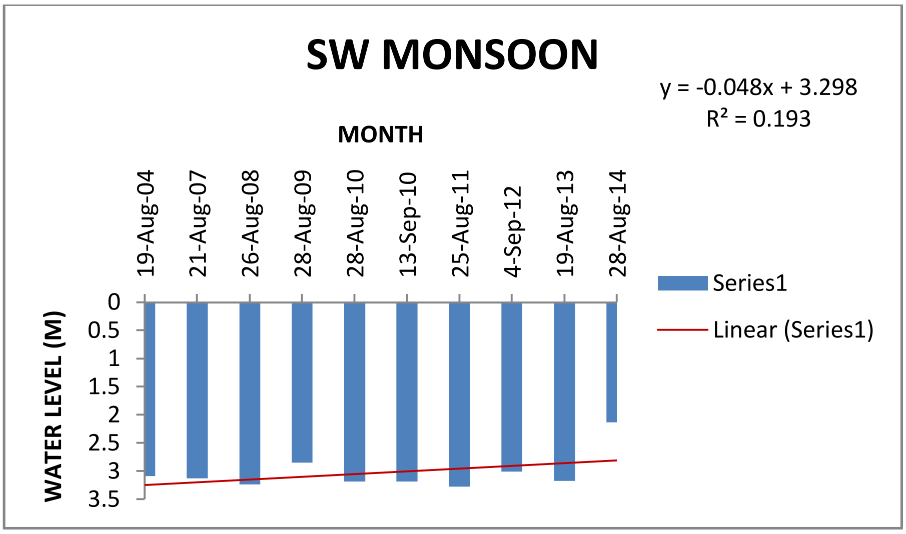


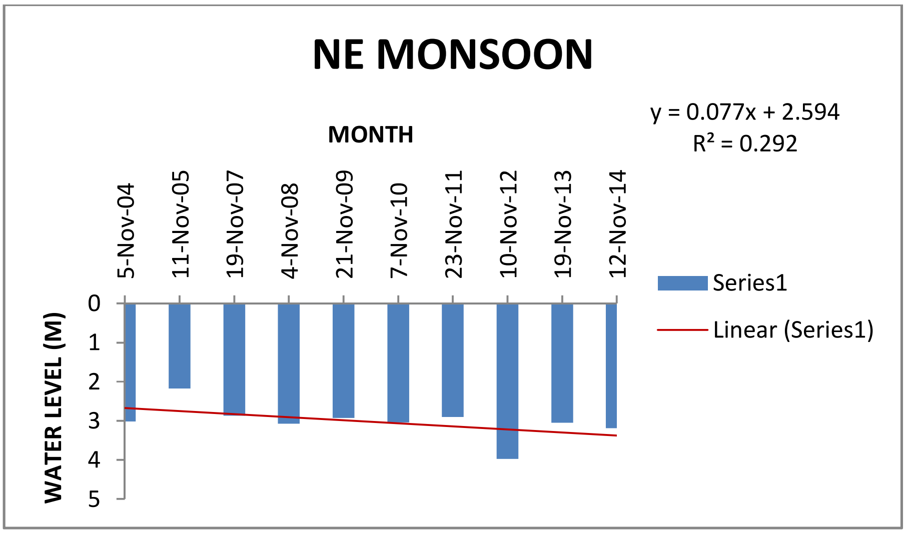


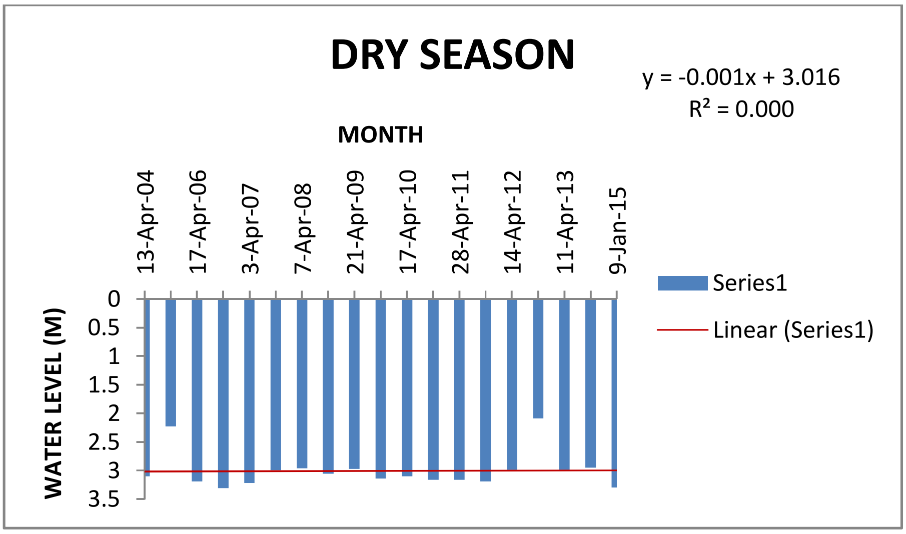


DRY SEASON	
13-Apr-04	12.32
7-Jan-05	9.4
9-Apr-05	10.54
16-Jan-06	9.86
10-Apr-06	10.28
9-Jan-07	8.53
3-Apr-07	8.48
16-Jan-08	9.09
8-Apr-08	10.24
6-Jan-09	9.48
27-Apr-09	11.28
16-Jan-10	10.6
8-Jan-11	8.32
28-Apr-11	10.78
29-Jan-12	8.98
14-Apr-12	10.6
9-Jan-13	10.6
13-Apr-13	12.4
22-Jan-14	9.78
26-Apr-14	11.3
9-Jan-15	9.52
SW MONSOON	
25-Aug-04	8.73
25-Aug-05	9.68
2-Sep-06	10.12
21-Aug-07	8.55
21-Aug-08	10.36
28-Aug-09	10.88
28-Aug-10	9.13
13-Sep-10	9.13
25-Aug-11	10.74
4-Sep-12	10.34
20-Aug-13	9.2
27-Aug-14	9.68
NE MONSOON	
5-Nov-04	8.83
11-Nov-05	8.87
4-Nov-06	8.68
20-Nov-07	7.03
28-Nov-08	8.89
24-Nov-09	9.33
7-Nov-10	7.48
23-Nov-11	10.18
10-Nov-12	9.78
12-Nov-13	9.64
17-Nov-14	8.77

Histogram showing depth to water table (bgl), Dug well at Pothencode

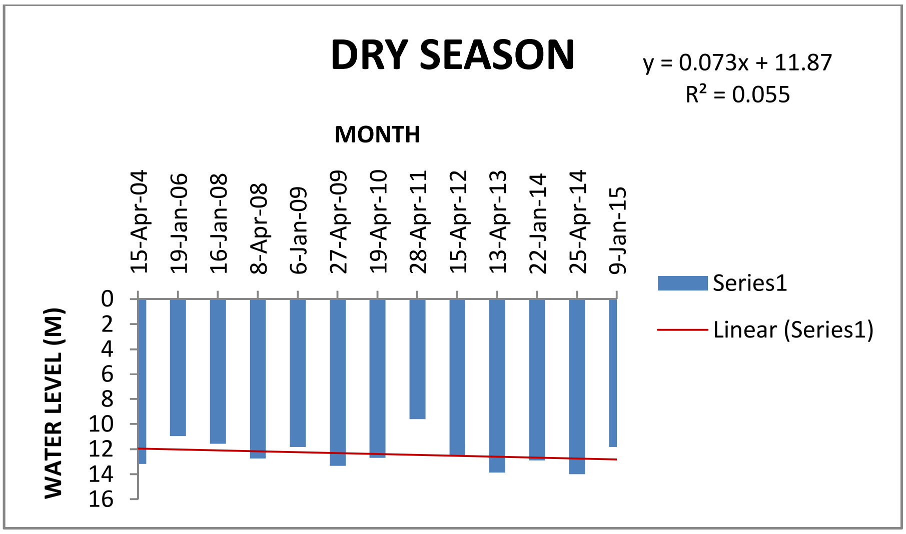


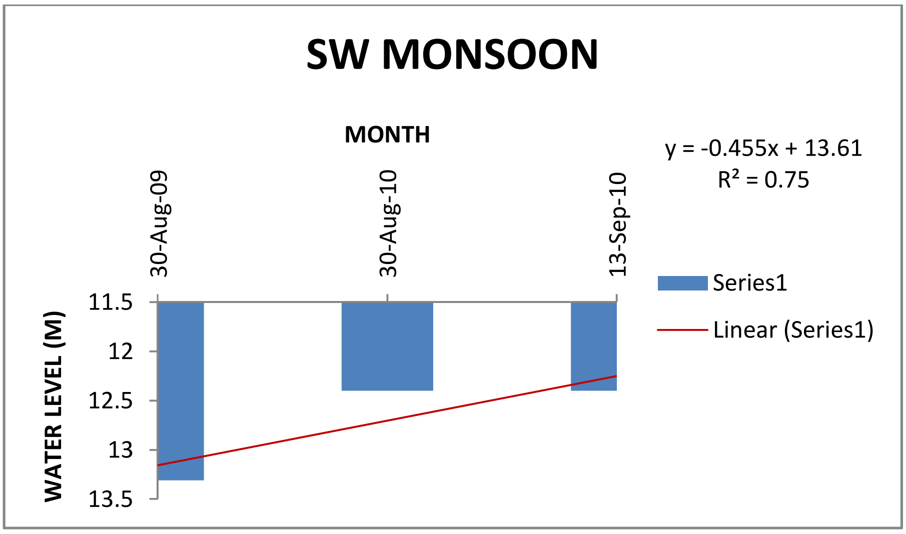


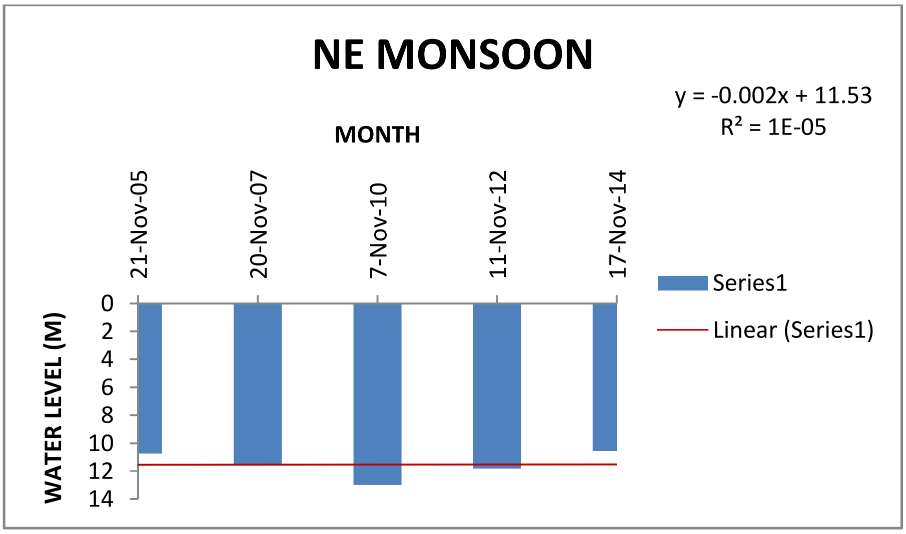


Histogram showing depth to water table (bgl), Dug well at Pudukurichi

DRY SEASON	
13-Apr-04	3.1
18-Jan-06	2.23
17-Apr-06	3.19
9-Jan-07	3.31
3-Apr-07	3.22
7-Jan-08	3
7-Apr-08	2.96
5-Jan-09	3.06
21-Apr-09	2.97
9-Jan-10	3.14
17-Apr-10	3.1
13-Jan-11	3.16
28-Apr-11	3.16
29-Jan-12	3.19
14-Apr-12	2.99
7-Jan-13	2.09
11-Apr-13	2.99
16-Apr-14	2.95
9-Jan-15	3.3
SW MONSOON	
19-Aug-04	3.09
21-Aug-07	3.13
26-Aug-08	3.24
28-Aug-09	2.85
28-Aug-10	3.19
13-Sep-10	3.19
25-Aug-11	3.28
4-Sep-12	3.01
19-Aug-13	3.18
28-Aug-14	2.14
NE MONSOON	
5-Nov-04	3.02
11-Nov-05	2.17
19-Nov-07	2.87
4-Nov-08	3.07
21-Nov-09	2.93
7-Nov-10	3.04
23-Nov-11	2.91
10-Nov-12	3.97
19-Nov-13	3.05
12-Nov-14	3.19

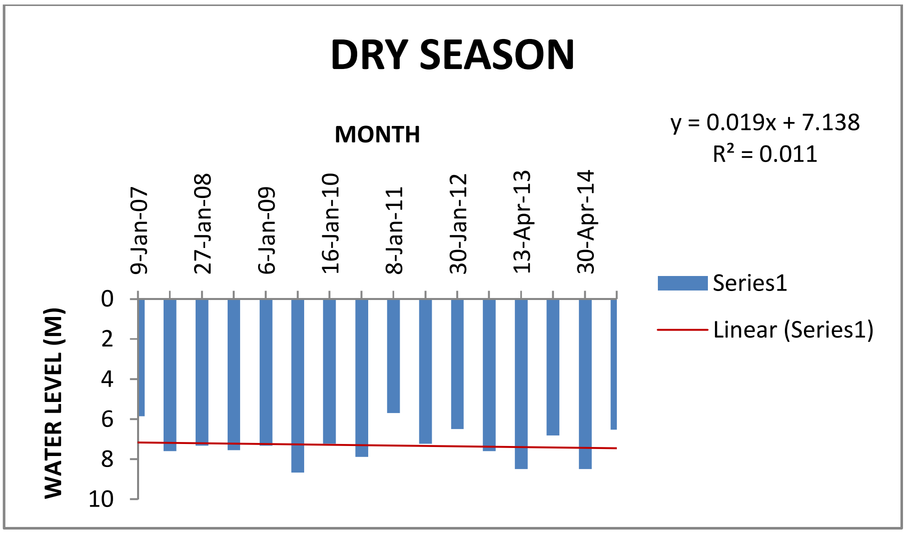


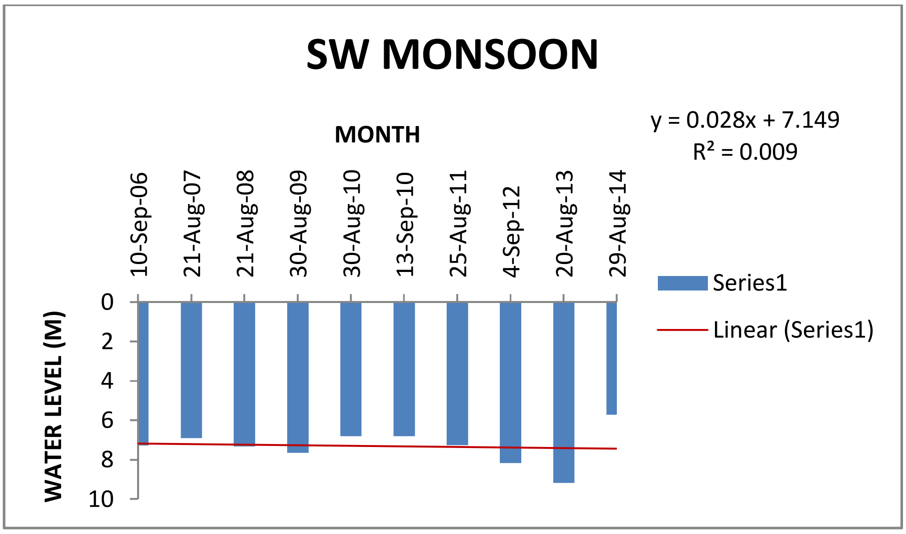


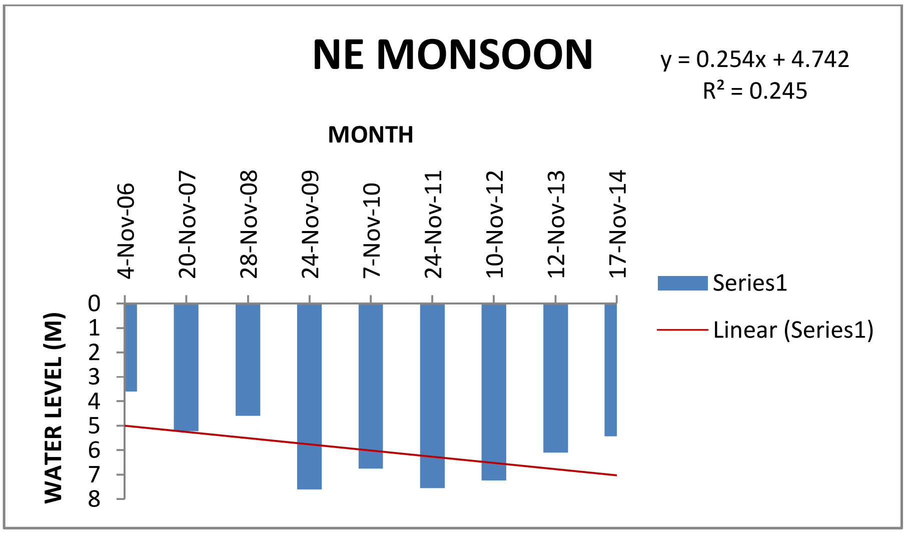


DRY SEASON	
15-Apr-04	13.18
19-Jan-06	10.96
16-Jan-08	11.6
8-Apr-08	12.75
6-Jan-09	11.85
27-Apr-09	13.33
19-Apr-10	12.7
28-Apr-11	9.6
15-Apr-12	12.5
13-Apr-13	13.88
22-Jan-14	12.9
25-Apr-14	14
9-Jan-15	11.85
SW MONSOON	
30-Aug-09	13.31
30-Aug-10	12.4
13-Sep-10	12.4
NE MONSOON	
21-Nov-05	10.74
20-Nov-07	11.5
7-Nov-10	13
11-Nov-12	11.82
17-Nov-14	10.57

Histogram showing depth to water table (bgl), Dug well at Sreekariyam

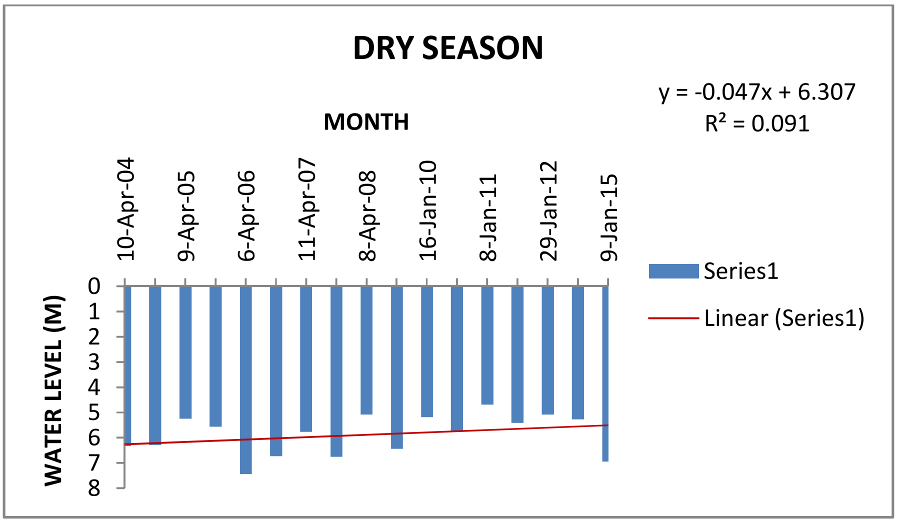


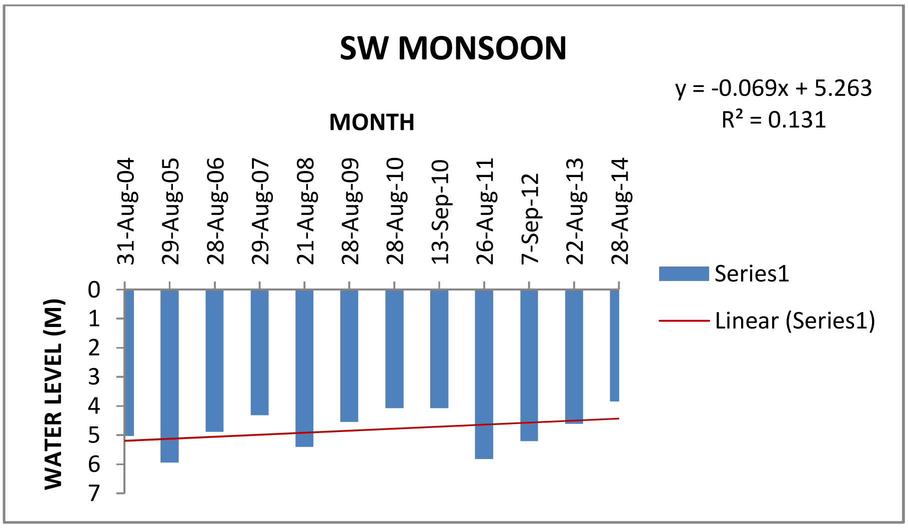


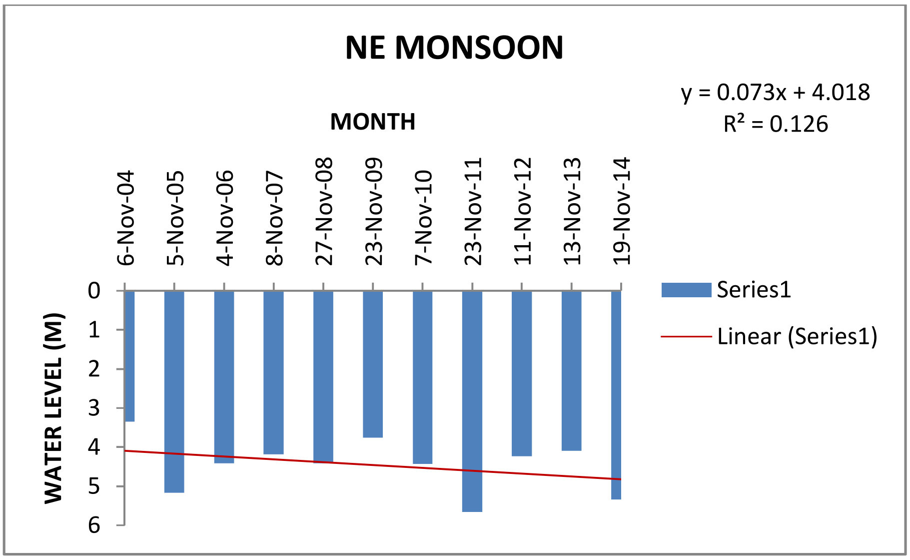


DRY SEASON	
9-Jan-07	5.86
3-Apr-07	7.6
27-Jan-08	7.33
8-Apr-08	7.56
6-Jan-09	7.34
27-Apr-09	8.67
16-Jan-10	7.25
16-Apr-10	7.89
8-Jan-11	5.7
28-Apr-11	7.23
30-Jan-12	6.5
14-Apr-12	7.6
13-Apr-13	8.5
22-Jan-14	6.82
30-Apr-14	8.51
9-Jan-15	6.52
SW MONSOON	
10-Sep-06	7.28
21-Aug-07	6.9
21-Aug-08	7.33
30-Aug-09	7.66
30-Aug-10	6.8
13-Sep-10	6.8
25-Aug-11	7.26
4-Sep-12	8.17
20-Aug-13	9.17
29-Aug-14	5.71
NE MONSOON	
4-Nov-06	3.6
20-Nov-07	5.22
28-Nov-08	4.6
24-Nov-09	7.6
7-Nov-10	6.75
24-Nov-11	7.56
10-Nov-12	7.24
12-Nov-13	6.1
17-Nov-14	5.44

Histogram showing depth to water table (bgl), Bore well at Vengod

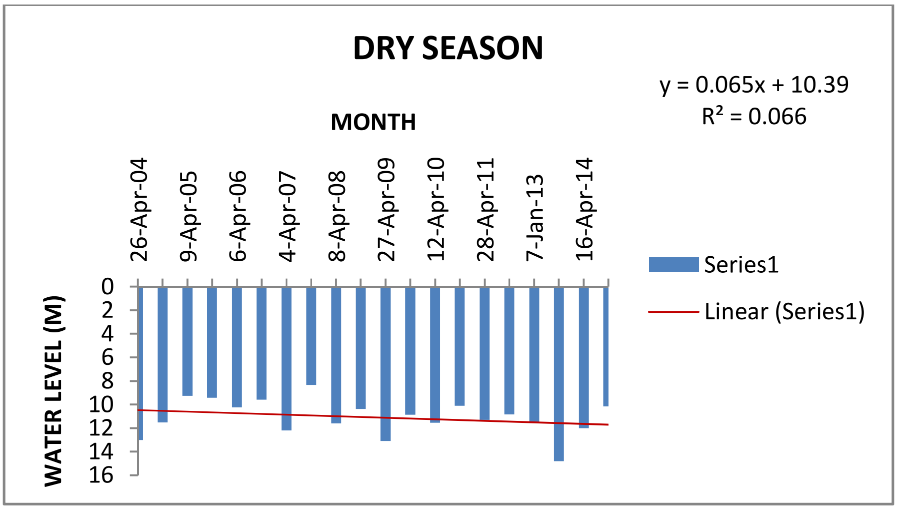


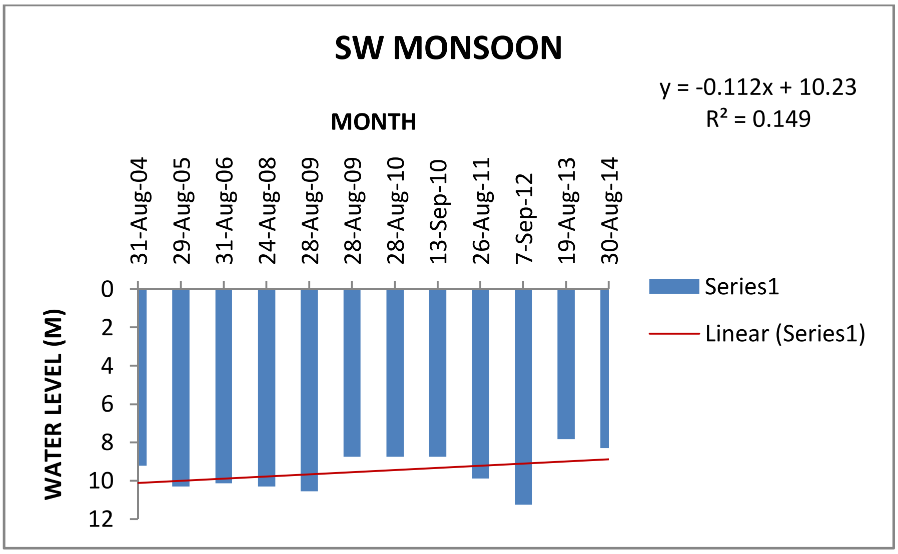


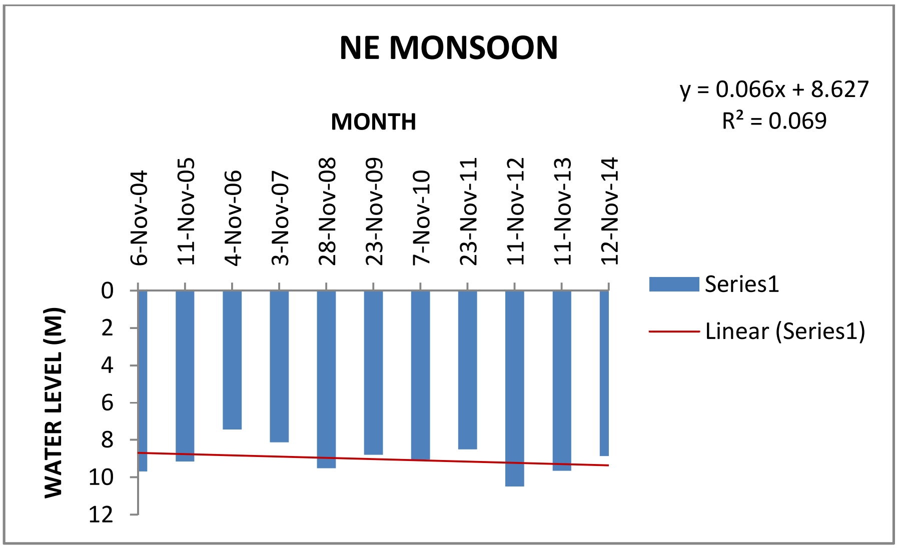


DRY SEASON	
10-Apr-04	6.32
6-Jan-05	6.29
9-Apr-05	5.25
16-Jan-06	5.57
6-Apr-06	7.44
9-Jan-07	6.73
11-Apr-07	5.77
8-Jan-08	6.75
8-Apr-08	5.09
6-Jan-09	6.44
16-Jan-10	5.19
17-Apr-10	5.74
8-Jan-11	4.69
28-Apr-11	5.41
29-Jan-12	5.09
21-Jan-14	5.27
9-Jan-15	6.95
SW MONSOON	
31-Aug-04	5.03
29-Aug-05	5.94
28-Aug-06	4.89
29-Aug-07	4.31
21-Aug-08	5.41
28-Aug-09	4.55
28-Aug-10	4.08
13-Sep-10	4.08
26-Aug-11	5.82
7-Sep-12	5.2
22-Aug-13	4.61
28-Aug-14	3.84
NE MONSOON	
6-Nov-04	3.35
5-Nov-05	5.17
4-Nov-06	4.41
8-Nov-07	4.19
27-Nov-08	4.41
23-Nov-09	3.76
7-Nov-10	4.43
23-Nov-11	5.66
11-Nov-12	4.24
13-Nov-13	4.09
19-Nov-14	5.34

Histogram showing depth to water table (bgl), Dug well at Kilimanur

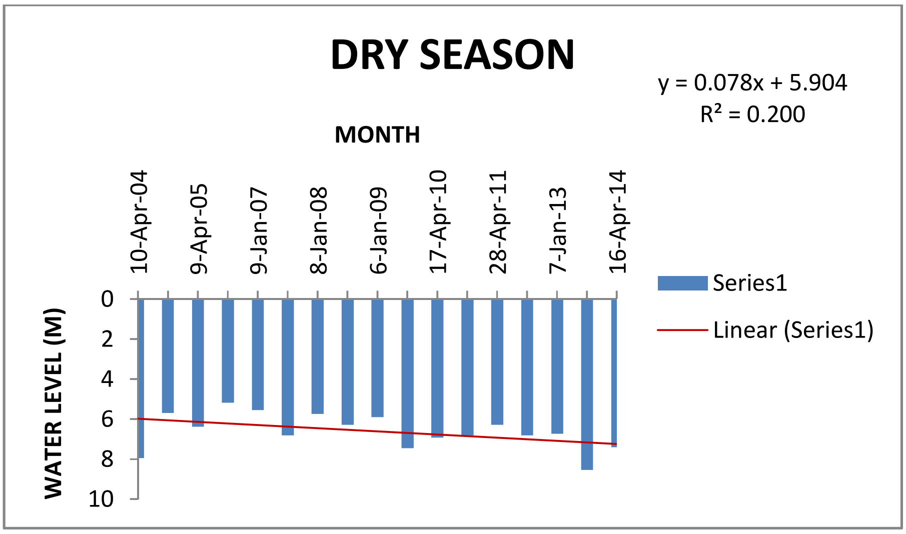


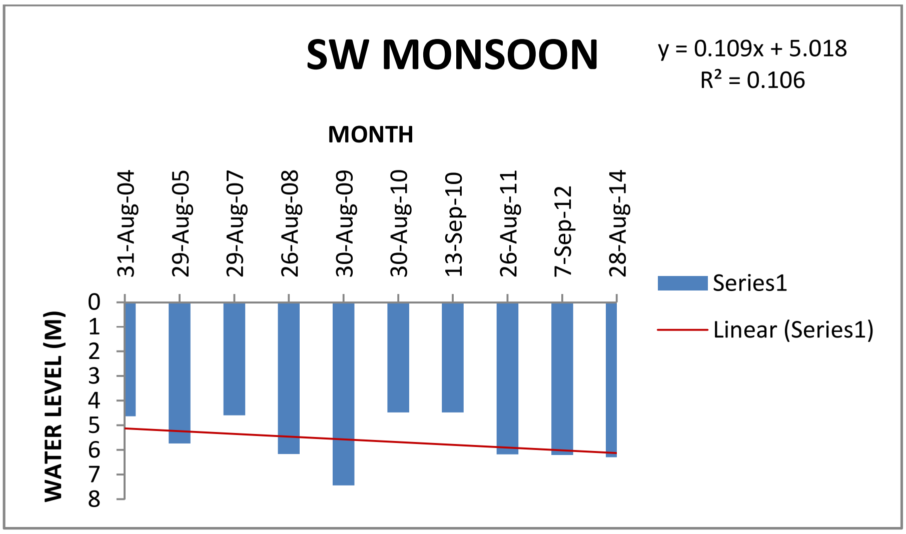


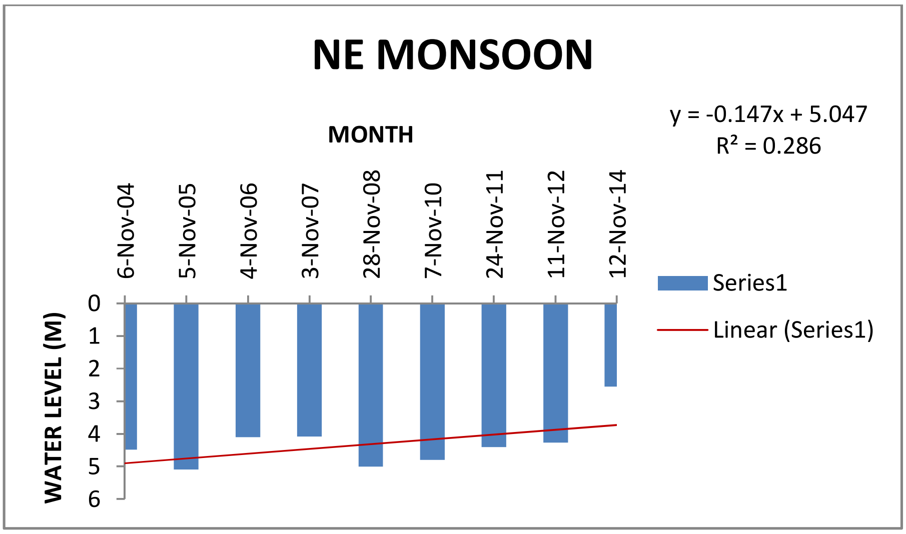


DRY SEASON	
26-Apr-04	13.01
7-Jan-05	11.54
9-Apr-05	9.25
16-Jan-06	9.43
6-Apr-06	10.24
9-Jan-07	9.59
4-Apr-07	12.2
8-Jan-08	8.34
8-Apr-08	11.6
6-Jan-09	10.38
27-Apr-09	13.1
16-Jan-10	10.87
12-Apr-10	11.55
15-Jan-11	10.1
28-Apr-11	11.28
29-Jan-12	10.85
7-Jan-13	11.5
11-Apr-13	14.8
16-Apr-14	12.01
9-Jan-15	10.15
SW MONSOON	
31-Aug-04	9.23
29-Aug-05	10.3
31-Aug-06	10.13
24-Aug-08	10.3
28-Aug-09	10.56
28-Aug-09	8.75
28-Aug-10	8.75
13-Sep-10	8.75
26-Aug-11	9.89
7-Sep-12	11.26
19-Aug-13	7.83
30-Aug-14	8.3
NE MONSOON	
6-Nov-04	9.68
11-Nov-05	9.16
4-Nov-06	7.45
3-Nov-07	8.12
28-Nov-08	9.51
23-Nov-09	8.8
7-Nov-10	9.04
23-Nov-11	8.5
11-Nov-12	10.5
11-Nov-13	9.64
12-Nov-14	8.86

Histogram showing depth to water table (bgl), Dug well at Madavur

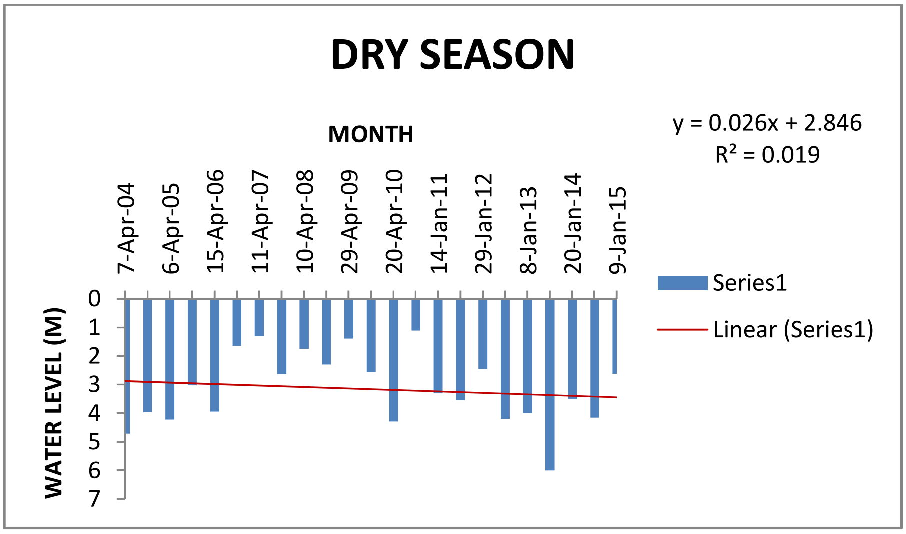


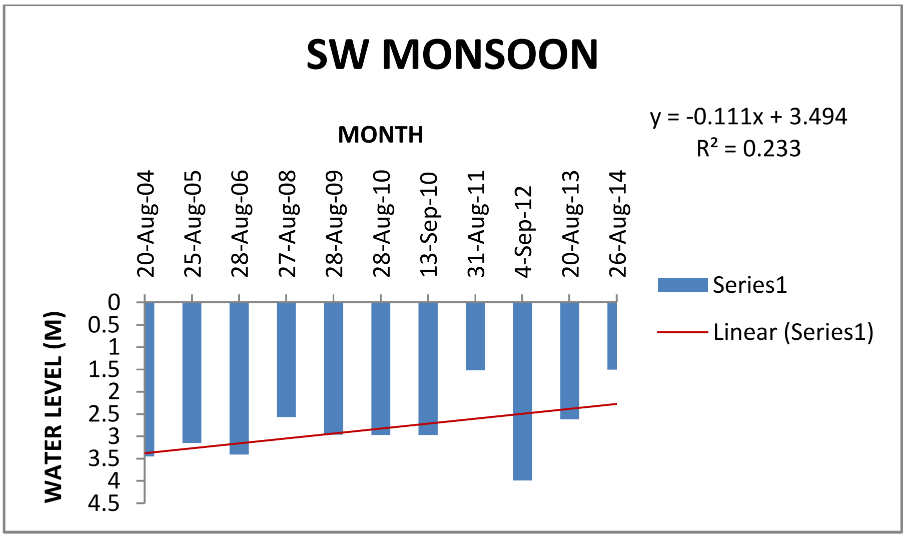


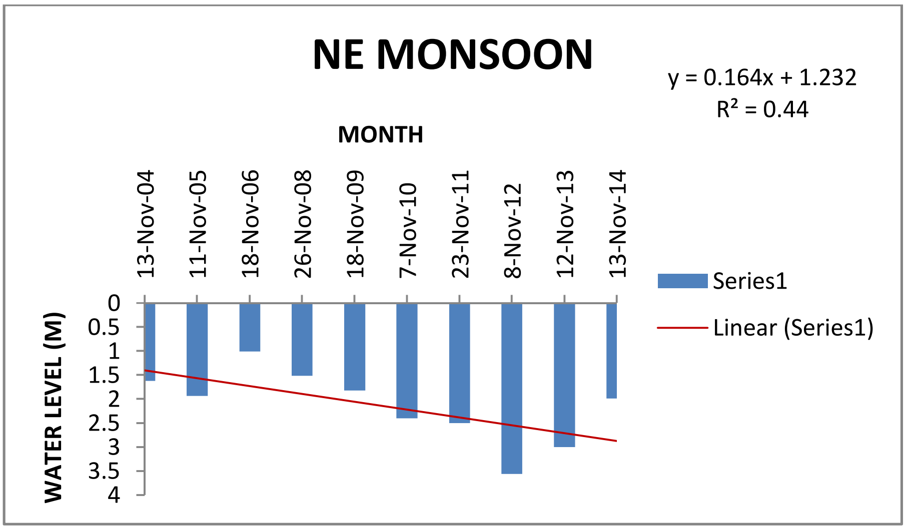


DRY SEASON	
10-Apr-04	7.95
7-Jan-05	5.7
9-Apr-05	6.38
16-Jan-06	5.18
9-Jan-07	5.55
4-Apr-07	6.8
8-Jan-08	5.75
8-Apr-08	6.28
6-Jan-09	5.9
27-Apr-09	7.44
17-Apr-10	6.93
8-Jan-11	6.8
28-Apr-11	6.28
30-Jan-12	6.8
7-Jan-13	6.73
11-Apr-13	8.53
16-Apr-14	7.4
SW MONSOON	
31-Aug-04	4.63
29-Aug-05	5.74
29-Aug-07	4.6
26-Aug-08	6.17
30-Aug-09	7.44
30-Aug-10	4.48
13-Sep-10	4.48
26-Aug-11	6.18
7-Sep-12	6.2
28-Aug-14	6.3
NE MONSOON	
6-Nov-04	4.48
5-Nov-05	5.09
4-Nov-06	4.1
3-Nov-07	4.08
28-Nov-08	5.01
7-Nov-10	4.8
24-Nov-11	4.4
11-Nov-12	4.27
12-Nov-14	2.55

Histogram showing depth to water table (bgl), Bore well at Ponganadu

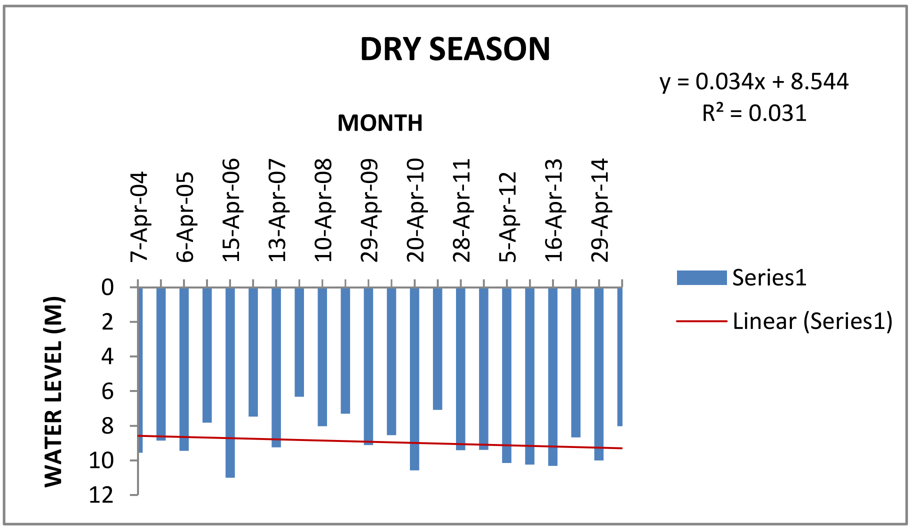


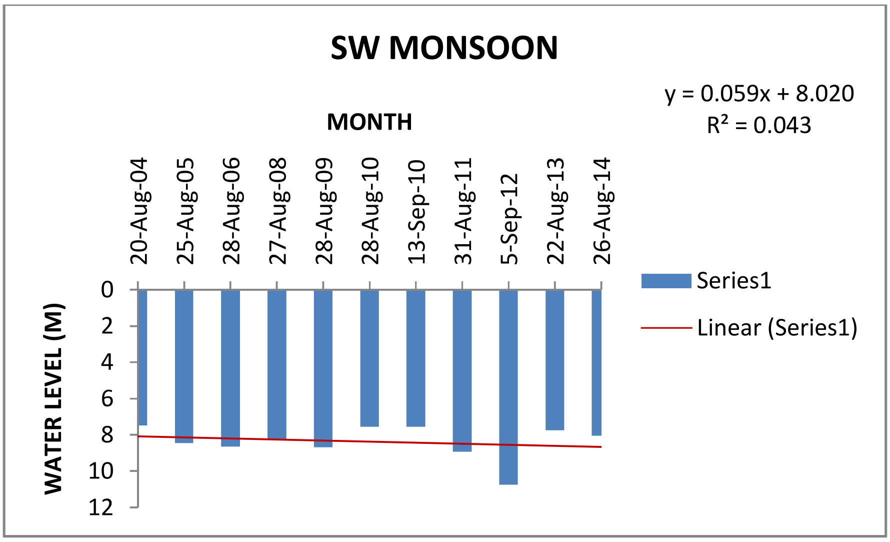


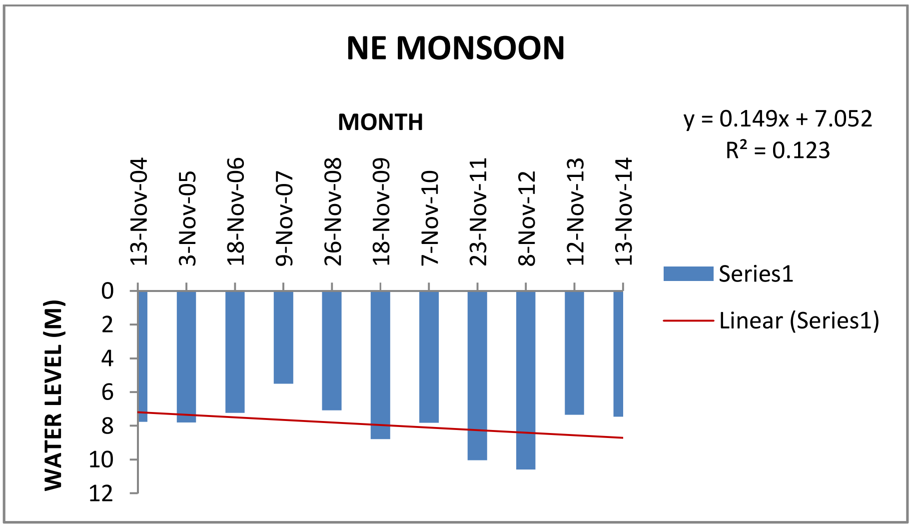


DRY SEASON	
7-Apr-04	4.72
8-Jan-05	3.97
6-Apr-05	4.22
2-Jan-06	3.03
15-Apr-06	3.95
10-Jan-07	1.65
11-Apr-07	1.3
8-Jan-08	2.64
10-Apr-08	1.74
7-Jan-09	2.3
29-Apr-09	1.4
14-Jan-10	2.55
20-Apr-10	4.3
10-Jan-11	1.11
14-Jan-11	3.3
28-Apr-11	3.54
29-Jan-12	2.45
14-Apr-12	4.2
8-Jan-13	4
12-Apr-13	6.01
20-Jan-14	3.5
28-Apr-14	4.15
9-Jan-15	2.63
SW MONSOON	
20-Aug-04	3.45
25-Aug-05	3.15
28-Aug-06	3.41
27-Aug-08	2.57
28-Aug-09	2.96
28-Aug-10	2.97
13-Sep-10	2.97
31-Aug-11	1.52
4-Sep-12	3.99
20-Aug-13	2.62
26-Aug-14	1.5
NE MONSOON	
13-Nov-04	1.62
11-Nov-05	1.93
18-Nov-06	1.01
26-Nov-08	1.52
18-Nov-09	1.82
7-Nov-10	2.4
23-Nov-11	2.5
8-Nov-12	3.56
12-Nov-13	3
13-Nov-14	1.99

Histogram showing depth to water table (bgl), Dug well at Aruvikkara

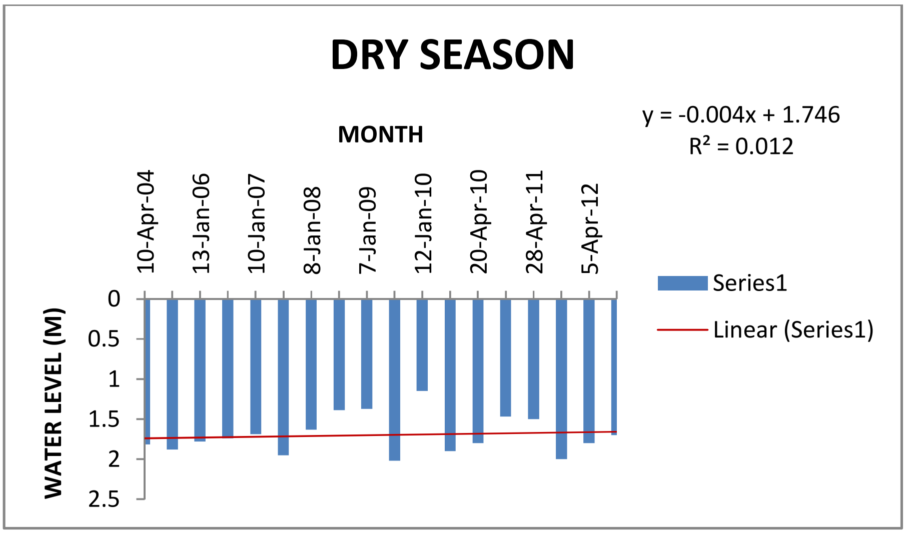


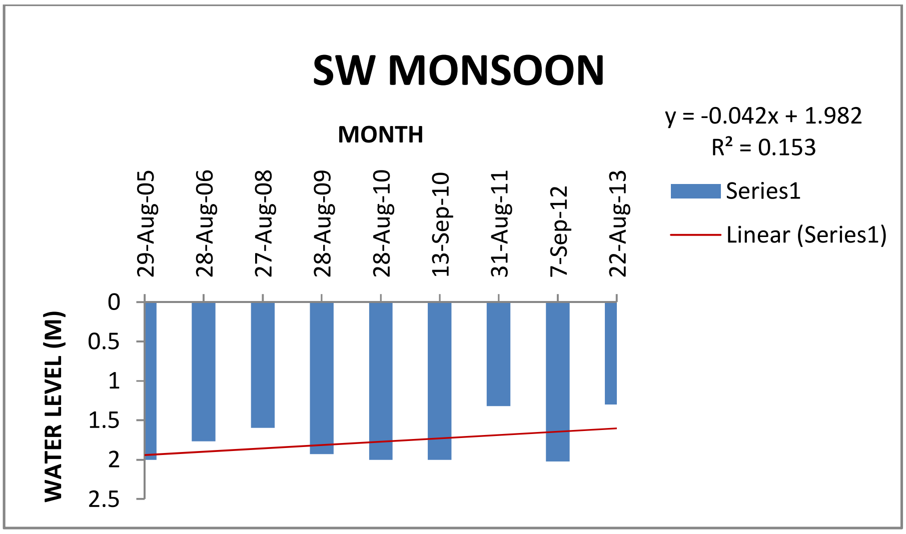


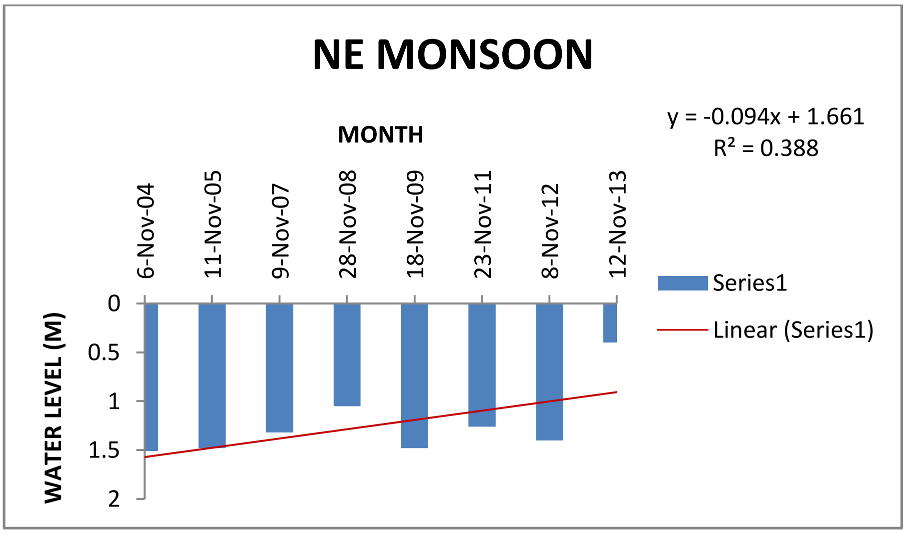


DRY SEASON	
7-Apr-04	9.56
8-Jan-05	8.86
6-Apr-05	9.45
4-Jan-06	7.82
15-Apr-06	11
10-Jan-07	7.47
13-Apr-07	9.25
8-Jan-08	6.32
10-Apr-08	8.03
7-Jan-09	7.31
29-Apr-09	9.13
12-Jan-10	8.55
20-Apr-10	10.57
14-Jan-11	7.09
28-Apr-11	9.41
29-Jan-12	9.4
5-Apr-12	10.15
8-Jan-13	10.23
16-Apr-13	10.31
21-Jan-14	8.67
29-Apr-14	10
9-Jan-15	8.02
SW MONSOON	
20-Aug-04	7.49
25-Aug-05	8.45
28-Aug-06	8.65
27-Aug-08	8.27
28-Aug-09	8.68
28-Aug-10	7.55
13-Sep-10	7.55
31-Aug-11	8.93
5-Sep-12	10.75
22-Aug-13	7.75
26-Aug-14	8.05
NE MONSOON	
13-Nov-04	7.77
3-Nov-05	7.81
18-Nov-06	7.23
9-Nov-07	5.51
26-Nov-08	7.09
18-Nov-09	8.78
7-Nov-10	7.83
23-Nov-11	10.05
8-Nov-12	10.6
12-Nov-13	7.35
13-Nov-14	7.45

Histogram showing depth to water table (bgl), Dug well at Nedumangad

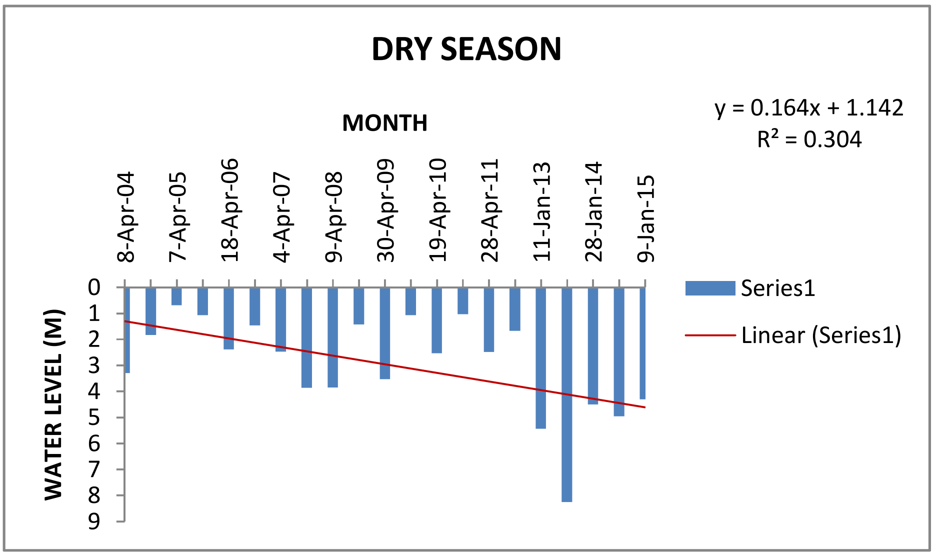


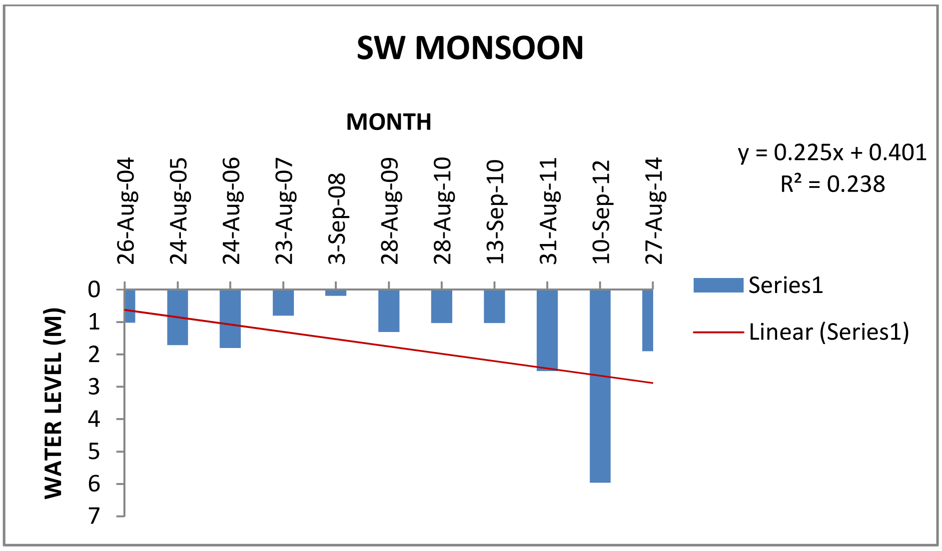


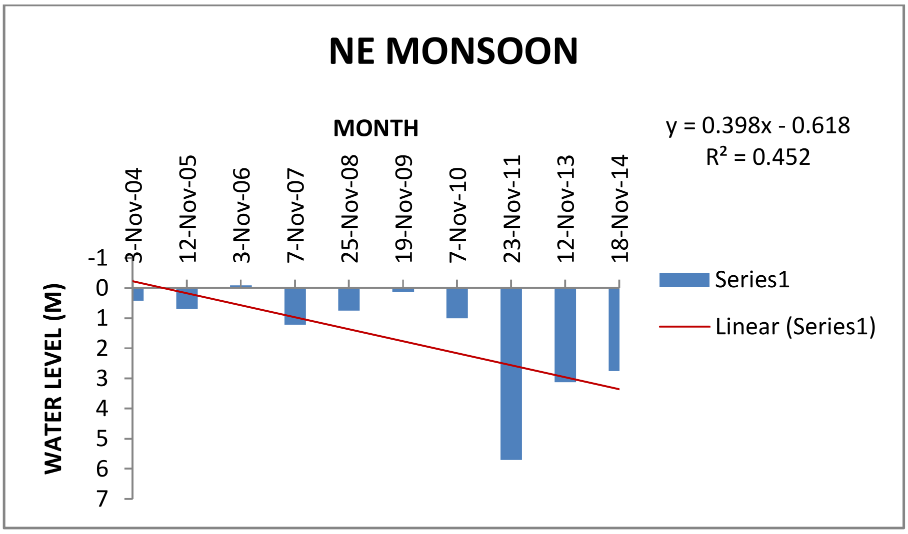


DRY SEASON	
10-Apr-04	1.82
8-Apr-05	1.88
13-Jan-06	1.78
12-Apr-06	1.74
10-Jan-07	1.69
4-Apr-07	1.95
8-Jan-08	1.63
10-Apr-08	1.39
7-Jan-09	1.37
29-Apr-09	2.02
12-Jan-10	1.15
7-Feb-10	1.9
20-Apr-10	1.8
14-Jan-11	1.47
28-Apr-11	1.5
29-Jan-12	2
5-Apr-12	1.8
8-Jan-13	1.7
SW MONSOON	
29-Aug-05	2
28-Aug-06	1.77
27-Aug-08	1.6
28-Aug-09	1.93
28-Aug-10	2
13-Sep-10	2
31-Aug-11	1.32
7-Sep-12	2.02
22-Aug-13	1.3
NE MONSOON	
6-Nov-04	1.51
11-Nov-05	1.48
9-Nov-07	1.32
28-Nov-08	1.05
18-Nov-09	1.48
23-Nov-11	1.26
8-Nov-12	1.4
12-Nov-13	0.4

Histogram showing depth to water table (bgl), Dug well at Panavoor

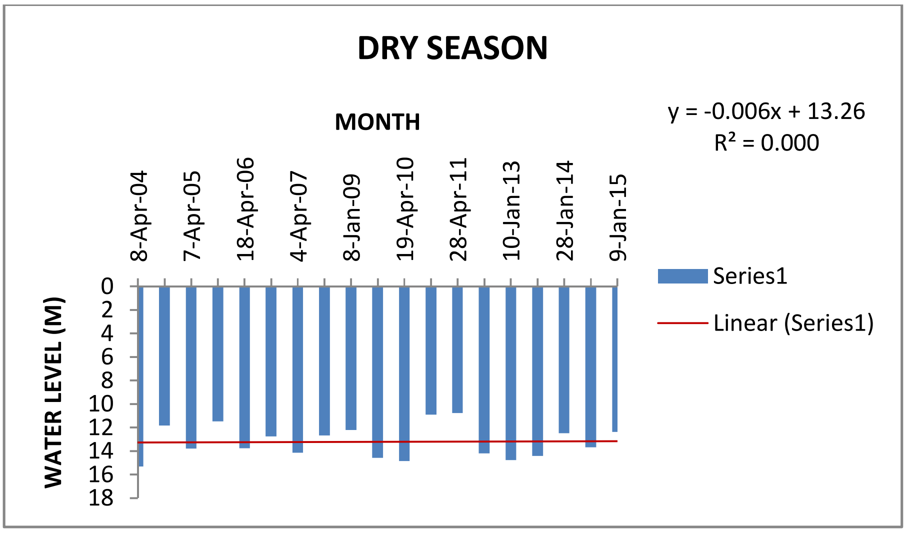


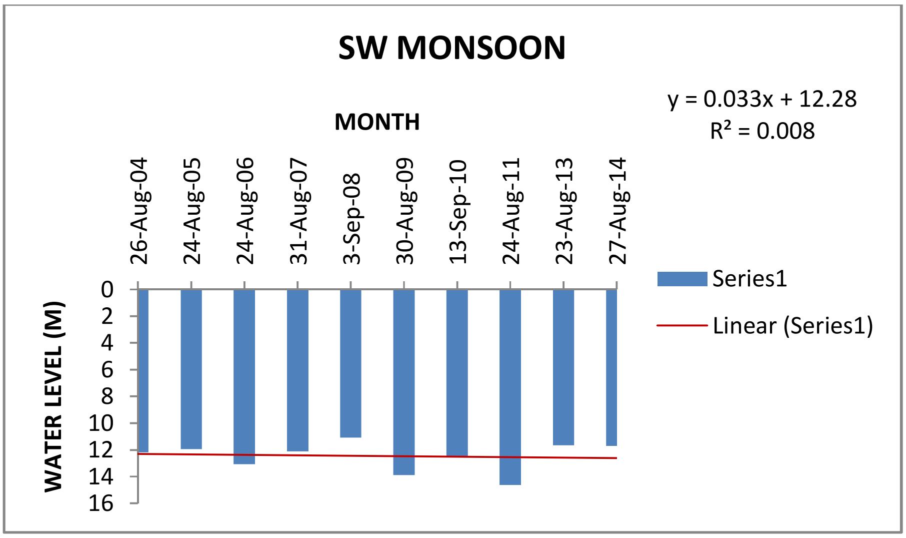


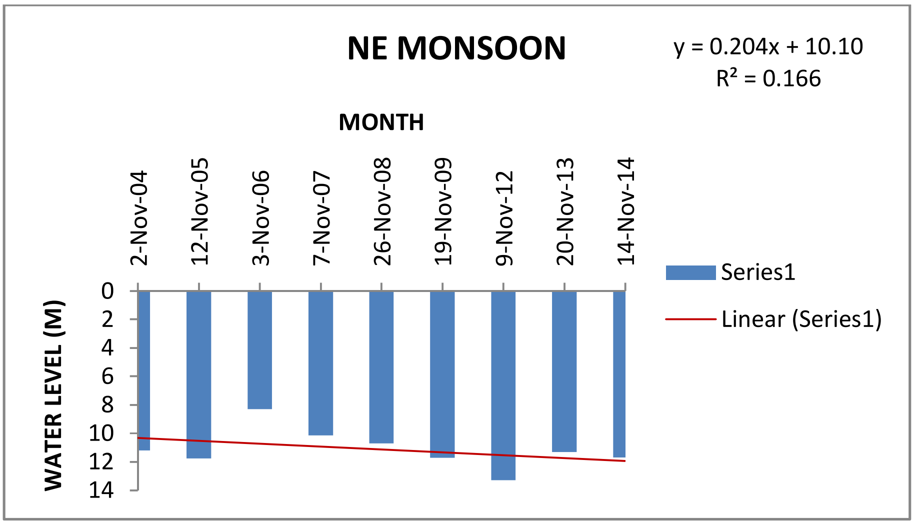


DRY SEASON	
8-Apr-04	3.29
12-Jan-05	1.83
7-Apr-05	0.69
3-Jan-06	1.06
18-Apr-06	2.38
5-Jan-07	1.46
4-Apr-07	2.48
9-Jan-08	3.86
9-Apr-08	3.85
8-Jan-09	1.43
30-Apr-09	3.53
15-Jan-10	1.06
19-Apr-10	2.54
14-Jan-11	1.03
28-Apr-11	2.49
29-Jan-12	1.67
11-Jan-13	5.43
16-Apr-13	8.25
28-Jan-14	4.5
25-Apr-14	4.95
9-Jan-15	4.31
SW MONSOON	
26-Aug-04	1.02
24-Aug-05	1.71
24-Aug-06	1.81
23-Aug-07	0.81
3-Sep-08	0.19
28-Aug-09	1.31
28-Aug-10	1.03
13-Sep-10	1.03
31-Aug-11	2.51
10-Sep-12	5.96
27-Aug-14	1.9
NE MONSOON	
3-Nov-04	0.42
12-Nov-05	0.7
3-Nov-06	-0.09
7-Nov-07	1.21
25-Nov-08	0.75
19-Nov-09	0.14
7-Nov-10	1.01
23-Nov-11	5.71
12-Nov-13	3.12
18-Nov-14	2.75

Histogram showing depth to water table (bgl), Dug well at Nemom

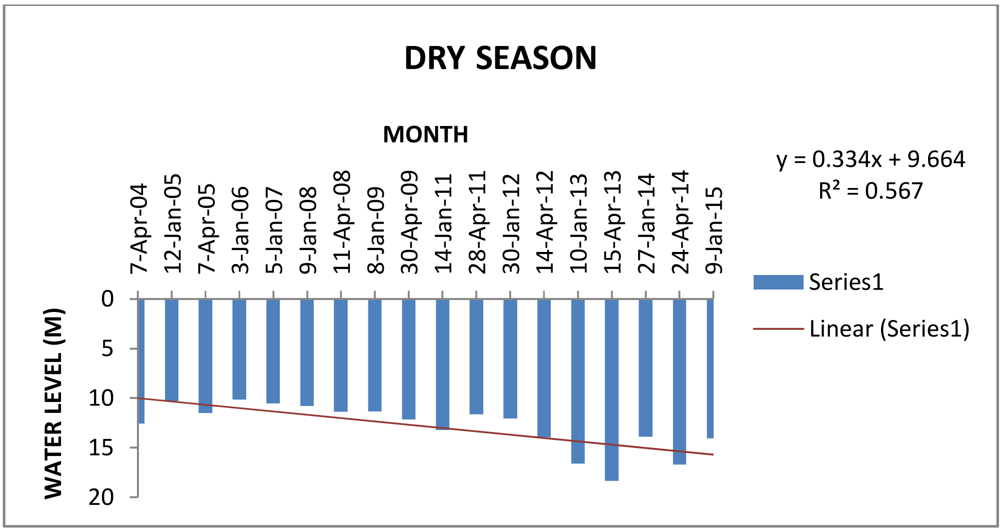


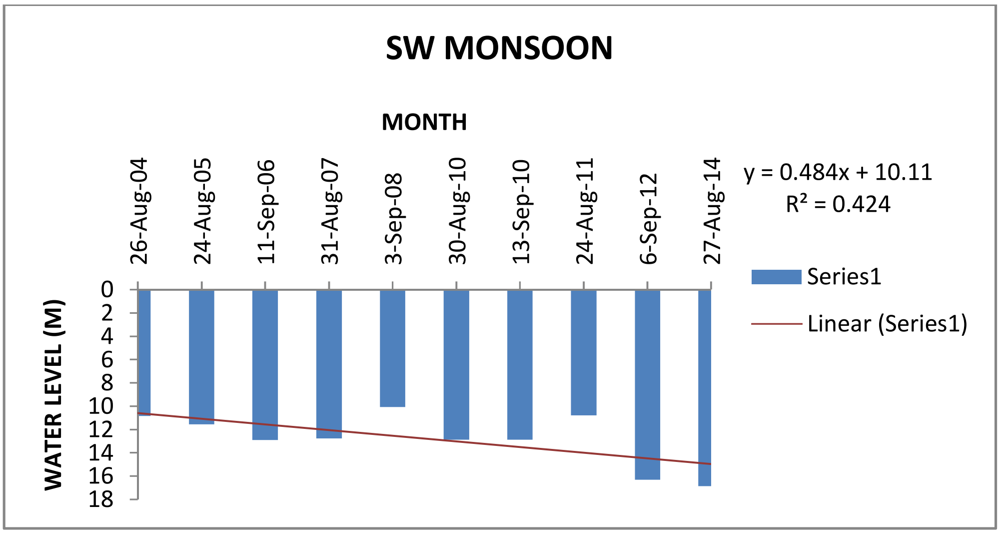


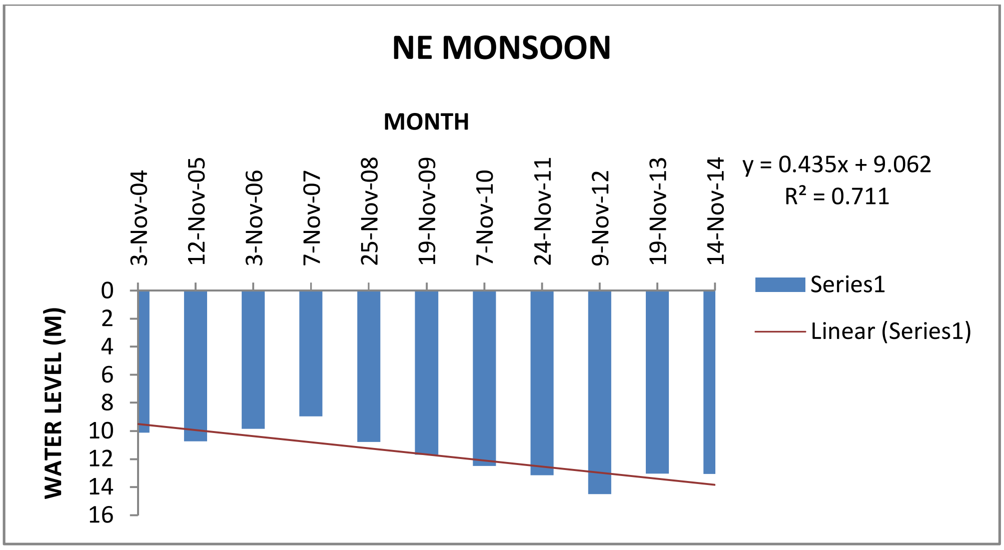


DRY SEASON	
8-Apr-04	15.3
12-Jan-05	11.84
7-Apr-05	13.8
3-Jan-06	11.48
18-Apr-06	13.76
5-Jan-07	12.75
4-Apr-07	14.13
9-Jan-08	12.69
8-Jan-09	12.2
30-Apr-09	14.58
19-Apr-10	14.84
13-Jan-11	10.9
28-Apr-11	10.78
6-Apr-12	14.2
10-Jan-13	14.77
15-Apr-13	14.43
28-Jan-14	12.49
24-Apr-14	13.68
9-Jan-15	12.35
SW MONSOON	
26-Aug-04	12.17
24-Aug-05	11.95
24-Aug-06	13.06
31-Aug-07	12.1
3-Sep-08	11.07
30-Aug-09	13.87
13-Sep-10	12.48
24-Aug-11	14.63
23-Aug-13	11.67
27-Aug-14	11.7
NE MONSOON	
2-Nov-04	11.19
12-Nov-05	11.77
3-Nov-06	8.3
7-Nov-07	10.16
26-Nov-08	10.69
19-Nov-09	11.72
9-Nov-12	13.31
20-Nov-13	11.3
14-Nov-14	11.71

Histogram showing depth to water table (bgl), Dug well at Neyyattinkara

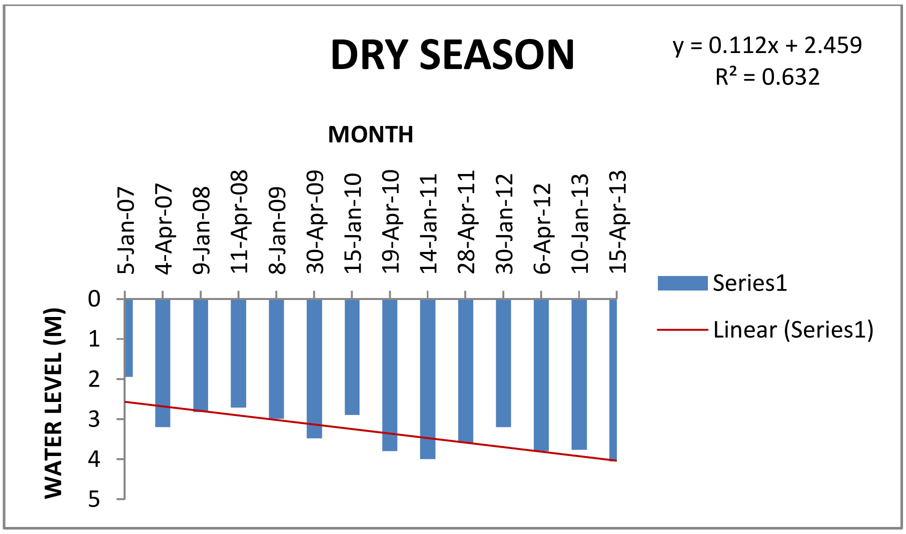


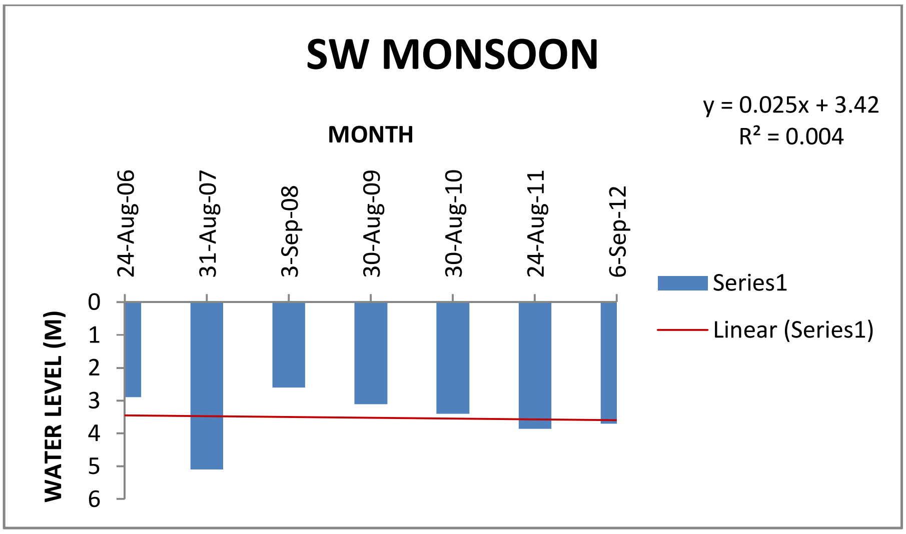


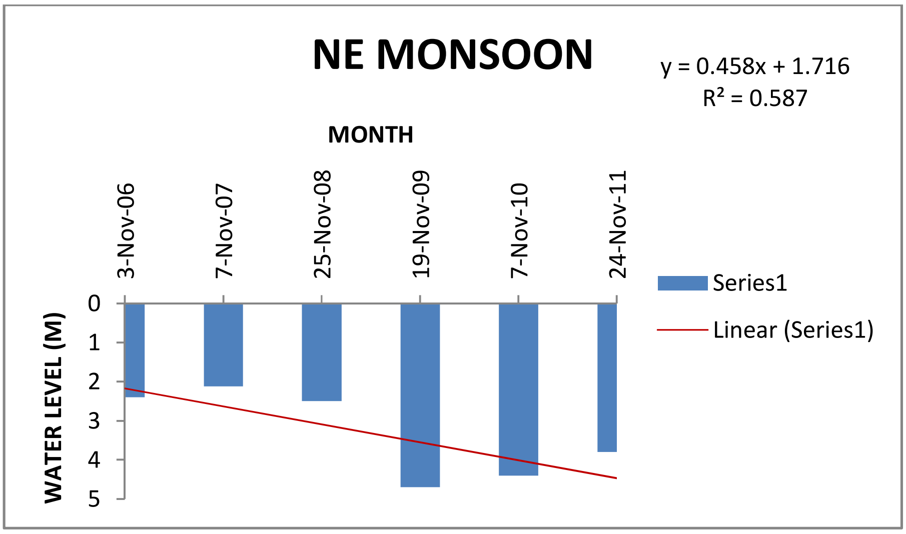


DRY SEASON	
8-Apr-04	14.8
12-Jan-05	5.79
7-Apr-05	7.15
3-Jan-06	1.59
18-Apr-06	3.45
5-Jan-07	2.13
4-Apr-07	3
9-Jan-08	1.68
11-Apr-08	1.52
8-Jan-09	1.18
30-Apr-09	1.3
15-Jan-10	1.17
14-Jan-11	1.28
28-Apr-11	1.26
29-Jan-12	1.55
5-Apr-12	2.3
24-Apr-14	1.49
9-Jan-15	1.35
SW MONSOON	
26-Aug-04	1.68
24-Aug-05	2.62
24-Aug-06	2.55
31-Aug-07	1.56
3-Sep-08	0.97
28-Aug-09	1.15
13-Sep-10	1.21
24-Aug-11	1.39
6-Sep-12	1.48
21-Aug-13	2.06
27-Aug-14	2.05
NE MOONSOON	
3-Nov-04	1.27
2-Nov-05	1.56
3-Nov-06	1.2
7-Nov-07	1.23
25-Nov-08	1.02
19-Nov-09	1.02
7-Nov-10	1.07
23-Nov-11	1.15
9-Nov-12	1.25
19-Nov-13	1.59
18-Nov-14	2.15

Histogram showing depth to water table (bgl), Bore well at Chengal

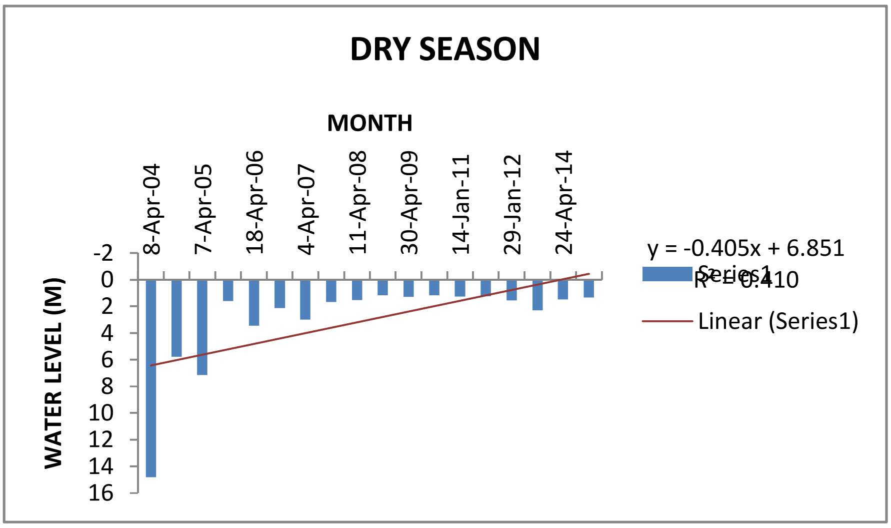


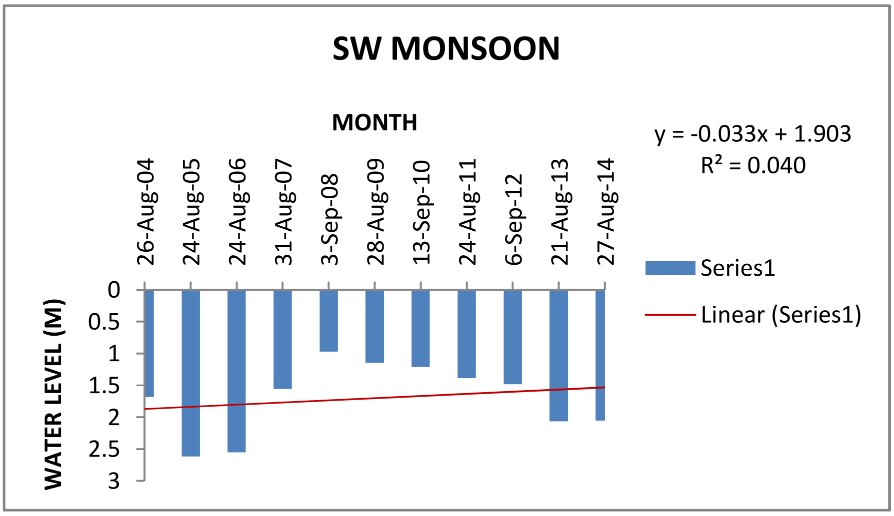


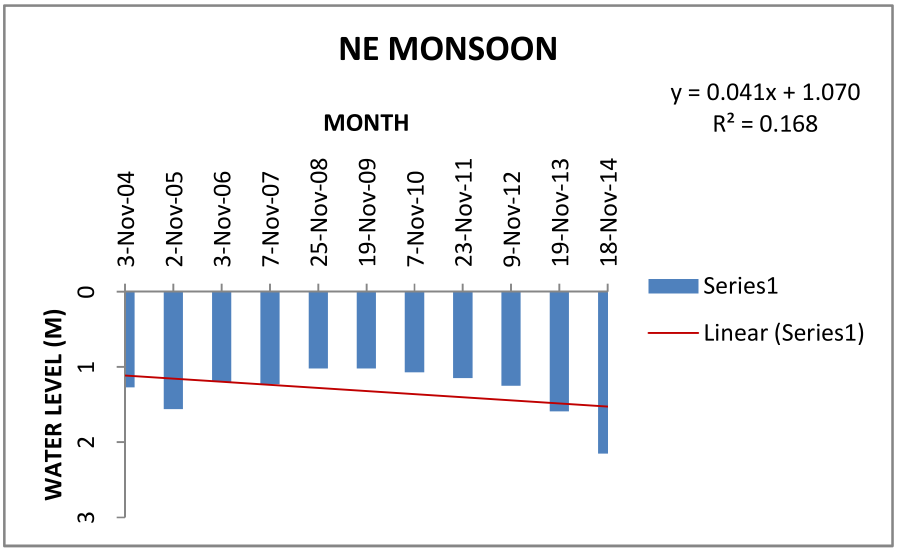


DRY SEASON	
5-Jan-07	1.95
4-Apr-07	3.2
9-Jan-08	2.83
11-Apr-08	2.71
8-Jan-09	2.99
30-Apr-09	3.48
15-Jan-10	2.9
19-Apr-10	3.8
14-Jan-11	4
28-Apr-11	3.58
30-Jan-12	3.2
6-Apr-12	3.8
10-Jan-13	3.77
15-Apr-13	4.06
SW MONSOON	
24-Aug-06	2.9
31-Aug-07	5.1
3-Sep-08	2.6
30-Aug-09	3.1
30-Aug-10	3.4
24-Aug-11	3.86
6-Sep-12	3.7
NE MONSOON	
3-Nov-06	2.4
7-Nov-07	2.12
25-Nov-08	2.5
19-Nov-09	4.7
7-Nov-10	4.4
24-Nov-11	3.8

Histogram showing depth to water table (bgl), Bore well at Parassala





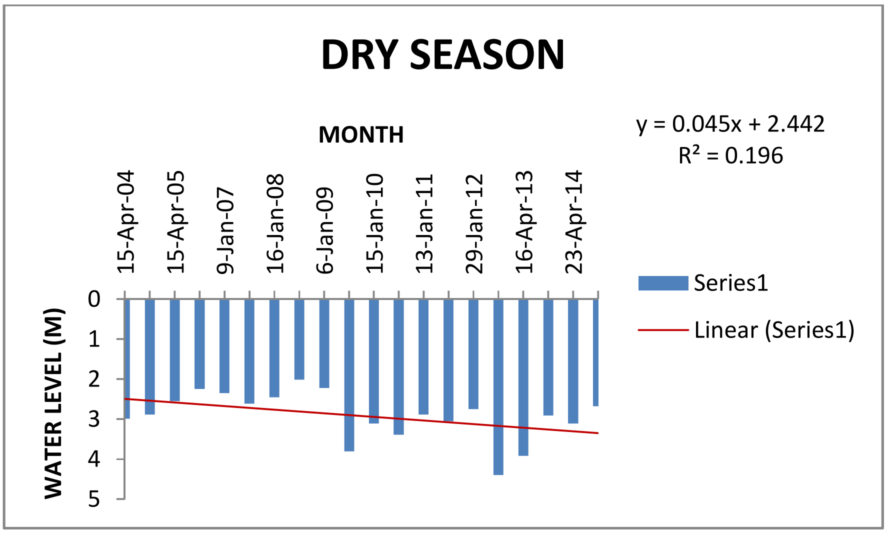


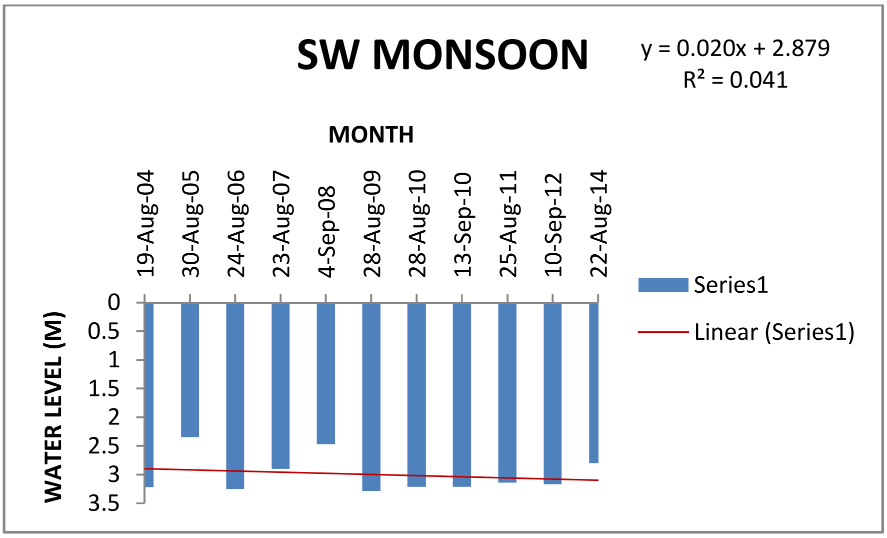
DRY SEASON	
10-Apr-04	8.8
12-Jan-05	8.48
7-Apr-05	9.07
2-Jan-06	6.91
19-Apr-06	8.85
5-Jan-07	7.77
4-Apr-07	9.6
15-Apr-08	8.03
9-Jan-09	6.98
30-Apr-09	7.77
14-Jan-11	6.95
10-Jan-13	11.55
15-Apr-13	11.38
27-Jan-14	10.83
24-Apr-14	10.41
9-Jan-15	7.65

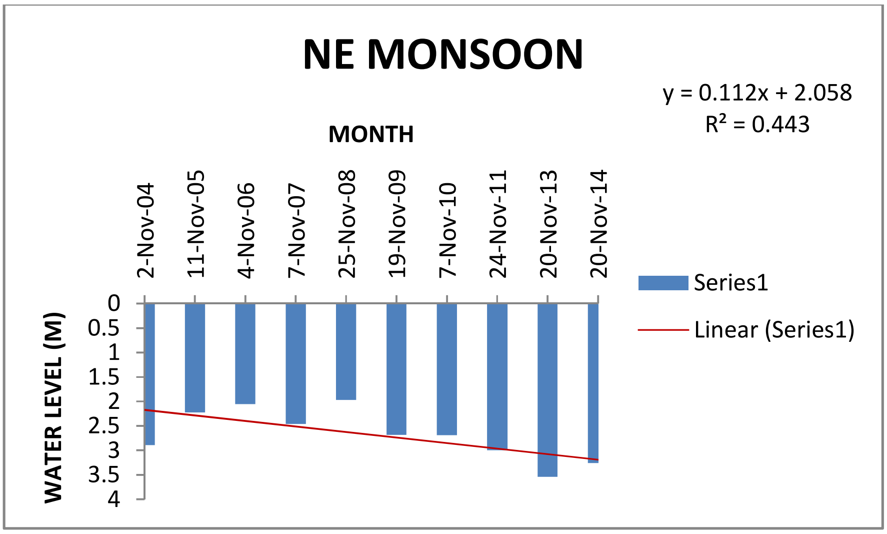
SW MONSOON	
26-Aug-04	8.29
24-Aug-06	9.37
31-Aug-07	8.75
3-Sep-08	8.3
30-Aug-09	8.11

NE MONSOON	
3-Nov-04	7.82
7-Nov-05	7.41
3-Nov-06	7.32
8-Nov-07	6.15
9-Nov-12	8.63
14-Nov-14	7.72

Histogram showing depth to water table (bgl), Dug well at Parassala

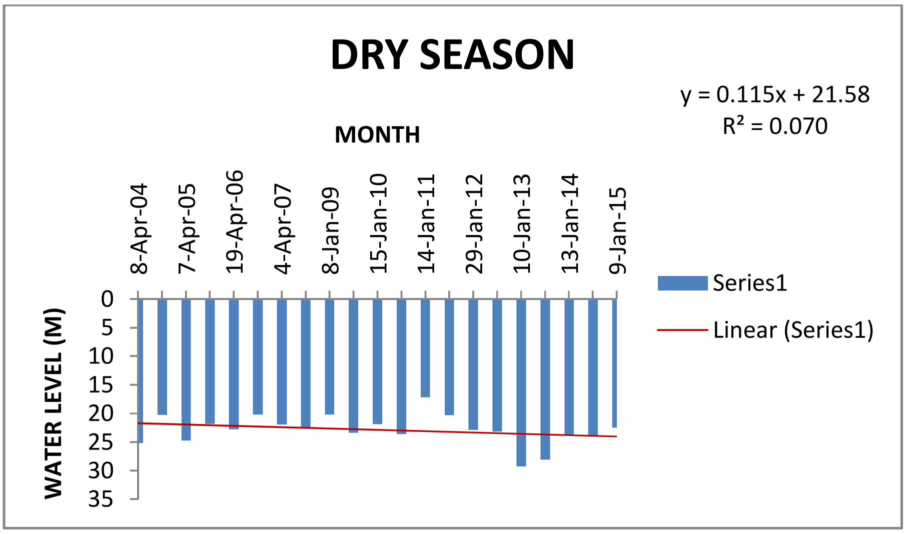


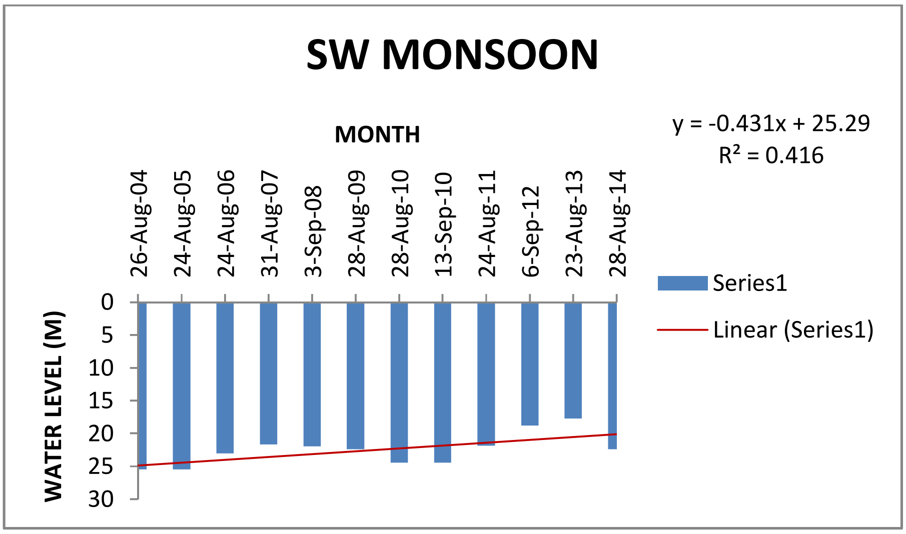


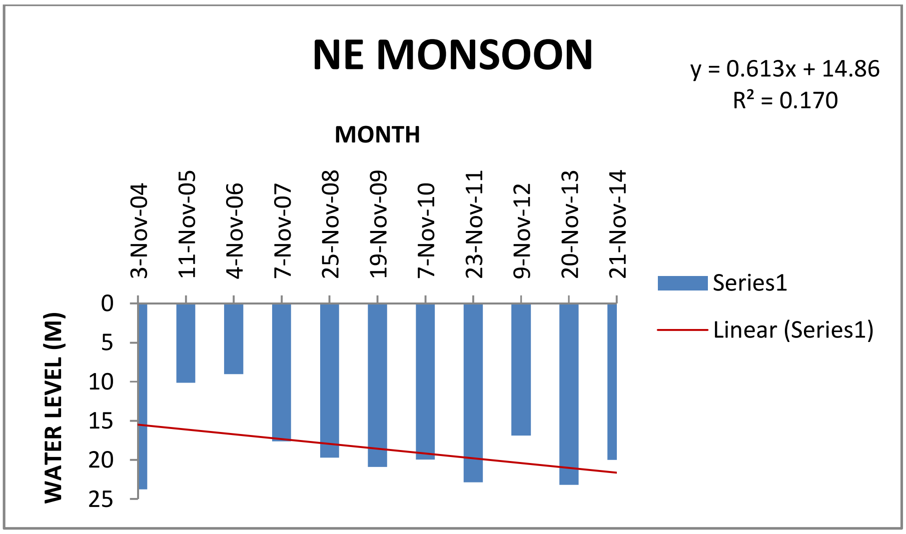


DRY SEASON	
15-Apr-04	2.99
7-Jan-05	2.89
15-Apr-05	2.55
3-Jan-06	2.24
9-Jan-07	2.35
4-Apr-07	2.62
16-Jan-08	2.45
7-Apr-08	2.02
6-Jan-09	2.22
29-Apr-09	3.81
15-Jan-10	3.11
21-Apr-10	3.39
13-Jan-11	2.89
28-Apr-11	3.05
29-Jan-12	2.75
10-Jan-13	4.4
16-Apr-13	3.92
28-Jan-14	2.91
23-Apr-14	3.11
9-Jan-15	2.68
SW MONSOON	
19-Aug-04	3.22
30-Aug-05	2.35
24-Aug-06	3.25
23-Aug-07	2.9
4-Sep-08	2.47
28-Aug-09	3.28
28-Aug-10	3.21
13-Sep-10	3.21
25-Aug-11	3.14
10-Sep-12	3.17
22-Aug-14	2.8
NE MONSOON	
2-Nov-04	2.89
11-Nov-05	2.23
4-Nov-06	2.06
7-Nov-07	2.46
25-Nov-08	1.97
19-Nov-09	2.68
7-Nov-10	2.69
24-Nov-11	3
20-Nov-13	3.54
20-Nov-14	3.26

Histogram showing depth to water table (bgl), Dug well at Poonthura

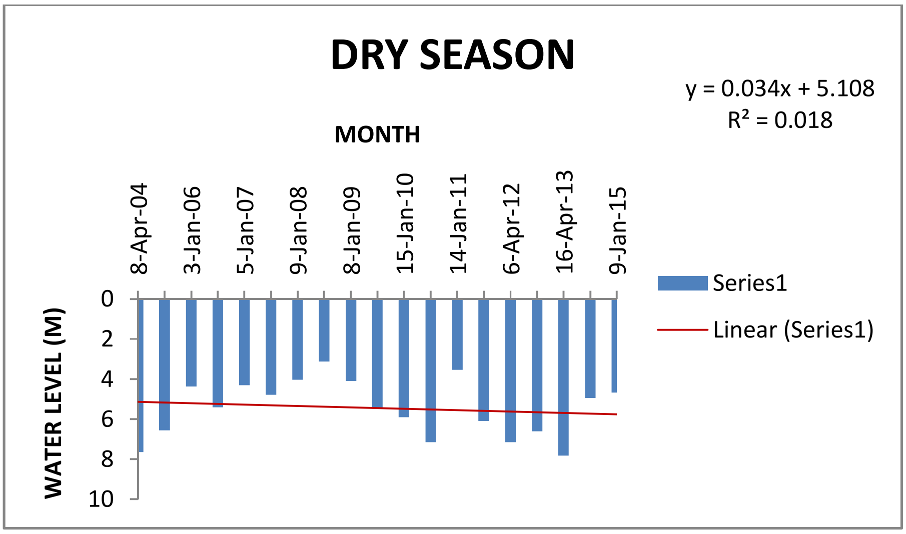


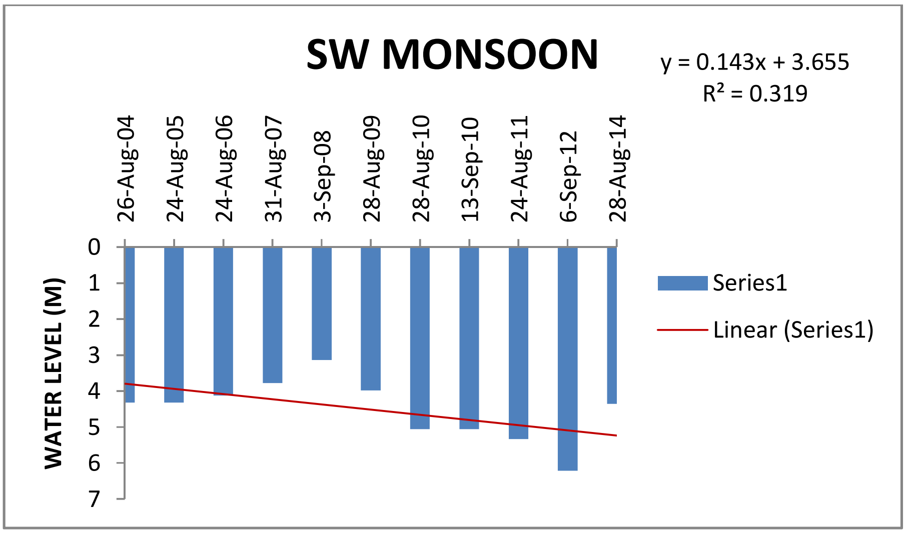


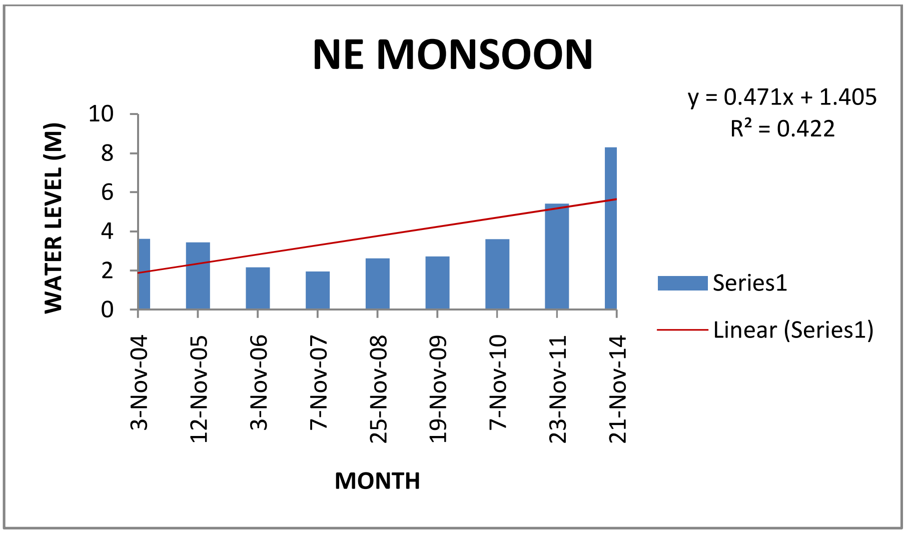


DRY SEASON	
8-Apr-04	25.2
12-Jan-05	20.3
7-Apr-05	24.75
3-Jan-06	21.78
19-Apr-06	22.8
5-Jan-07	20.2
4-Apr-07	21.9
15-Apr-08	22.52
8-Jan-09	20.22
30-Apr-09	23.4
15-Jan-10	21.85
19-Apr-10	23.62
14-Jan-11	17.2
28-Apr-11	20.34
29-Jan-12	22.9
6-Apr-12	23.15
10-Jan-13	29.3
15-Apr-13	28.15
13-Jan-14	23.8
25-Apr-14	24
9-Jan-15	22.5
SW MONSOON	
26-Aug-04	25.5
24-Aug-05	25.5
24-Aug-06	23.04
31-Aug-07	21.7
3-Sep-08	21.98
28-Aug-09	22.42
28-Aug-10	24.46
13-Sep-10	24.46
24-Aug-11	21.9
6-Sep-12	18.8
23-Aug-13	17.7
28-Aug-14	22.4
NE MONSOON	
3-Nov-04	23.78
11-Nov-05	10.14
4-Nov-06	9.02
7-Nov-07	17.65
25-Nov-08	19.7
19-Nov-09	20.9
7-Nov-10	19.94
23-Nov-11	22.86
9-Nov-12	16.89
20-Nov-13	23.17
21-Nov-14	20

Histogram showing depth to water table (bgl), Dug well at Poovar

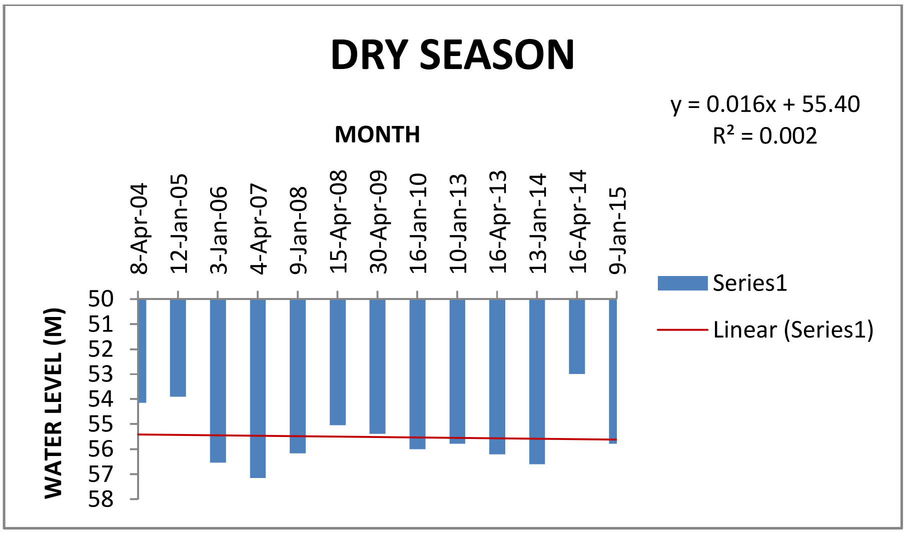


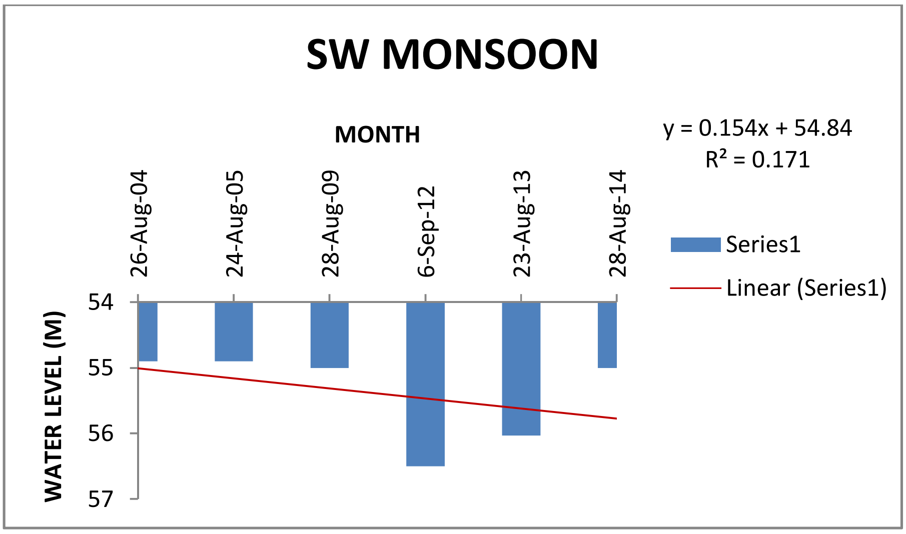


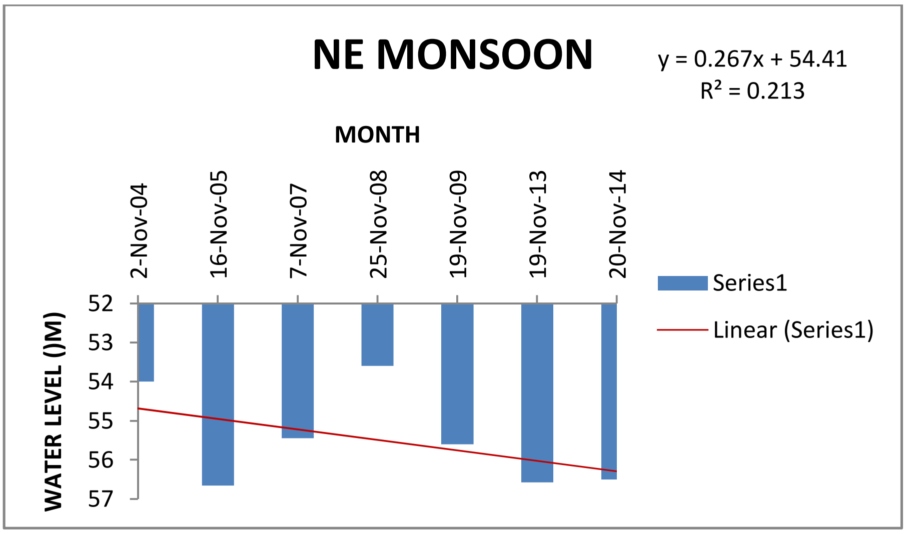


DRY SEASON	
8-Apr-04	7.65
7-Apr-05	6.55
3-Jan-06	4.37
18-Apr-06	5.4
5-Jan-07	4.3
4-Apr-07	4.78
9-Jan-08	4.03
11-Apr-08	3.11
8-Jan-09	4.1
30-Apr-09	5.47
15-Jan-10	5.9
19-Apr-10	7.15
14-Jan-11	3.53
29-Jan-12	6.1
6-Apr-12	7.15
10-Jan-13	6.6
16-Apr-13	7.82
13-Jan-14	4.96
9-Jan-15	4.67
SW MONSOON	
26-Aug-04	4.32
24-Aug-05	4.32
24-Aug-06	4.13
31-Aug-07	3.78
3-Sep-08	3.14
28-Aug-09	3.98
28-Aug-10	5.06
13-Sep-10	5.06
24-Aug-11	5.33
6-Sep-12	6.21
28-Aug-14	4.35
NE MONSOON	
3-Nov-04	3.62
12-Nov-05	3.44
3-Nov-06	2.16
7-Nov-07	1.96
25-Nov-08	2.63
19-Nov-09	2.73
7-Nov-10	3.6
23-Nov-11	5.42
21-Nov-14	8.29

Histogram showing depth to water table (bgl), Dug well at Pozhiyoor

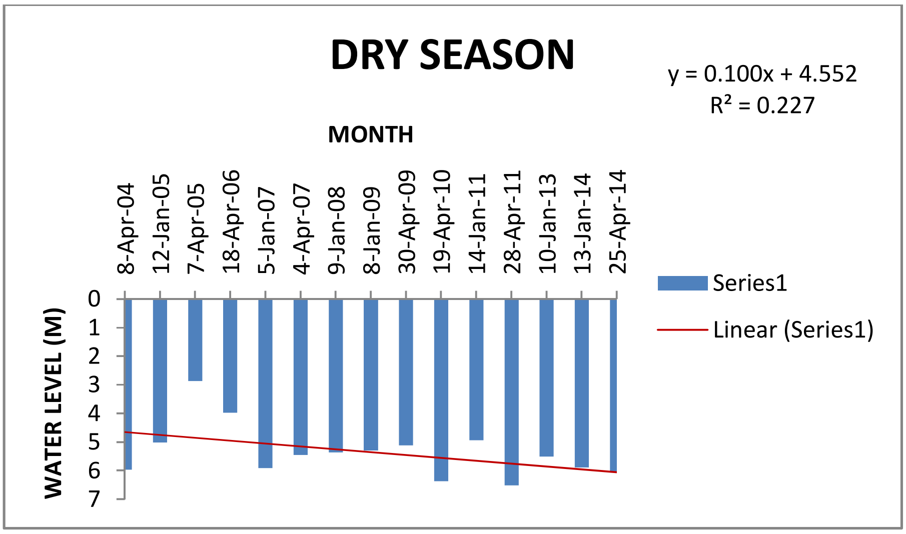


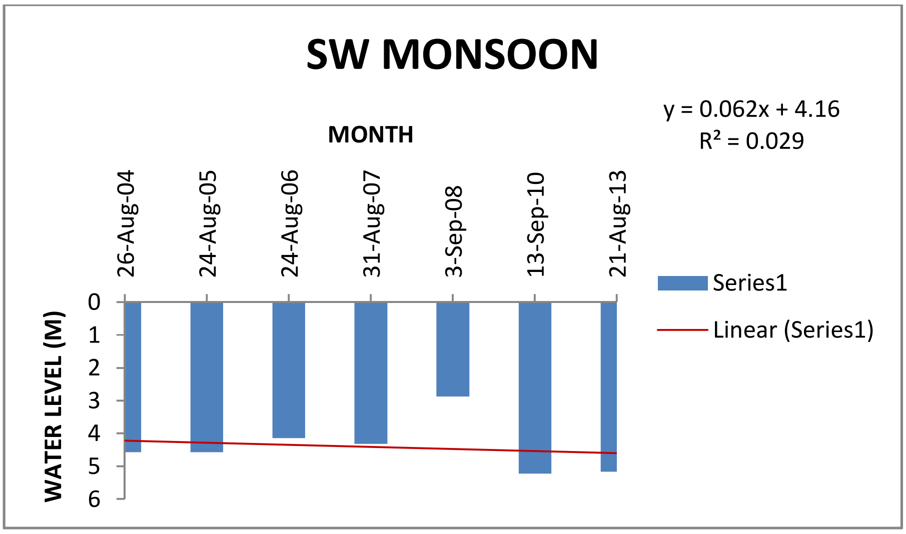


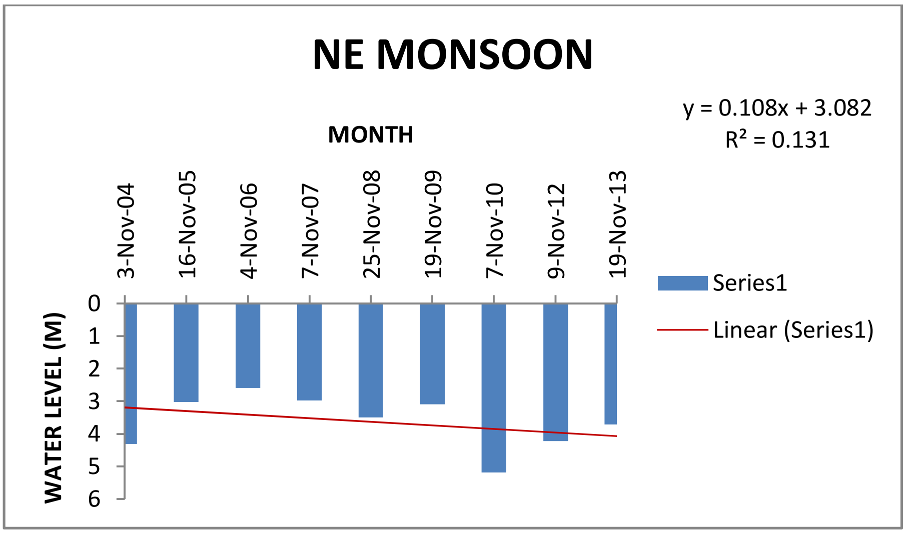


DRY SEASON	
8-Apr-04	54.15
12-Jan-05	53.9
3-Jan-06	56.54
4-Apr-07	57.15
9-Jan-08	56.17
15-Apr-08	55.05
30-Apr-09	55.4
16-Jan-10	56
10-Jan-13	55.8
16-Apr-13	56.2
13-Jan-14	56.6
16-Apr-14	53
9-Jan-15	55.8
SW MONSOON	
26-Aug-04	54.9
24-Aug-05	54.9
28-Aug-09	55
6-Sep-12	56.5
23-Aug-13	56.03
28-Aug-14	55
NE MONSOON	
2-Nov-04	54
16-Nov-05	56.66
7-Nov-07	55.45
25-Nov-08	53.6
19-Nov-09	55.6
19-Nov-13	56.58
20-Nov-14	56.5

Histogram showing depth to water table (bgl), Dug well at Pulluvila

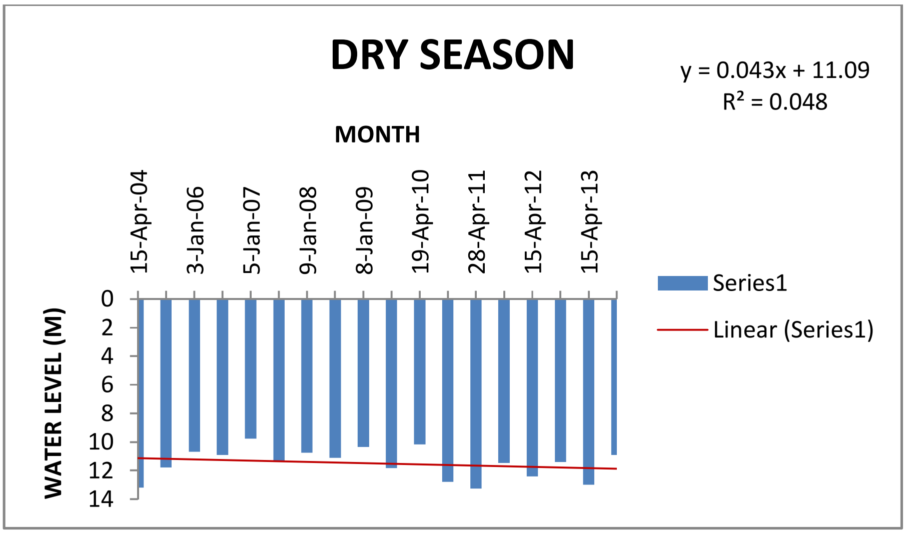


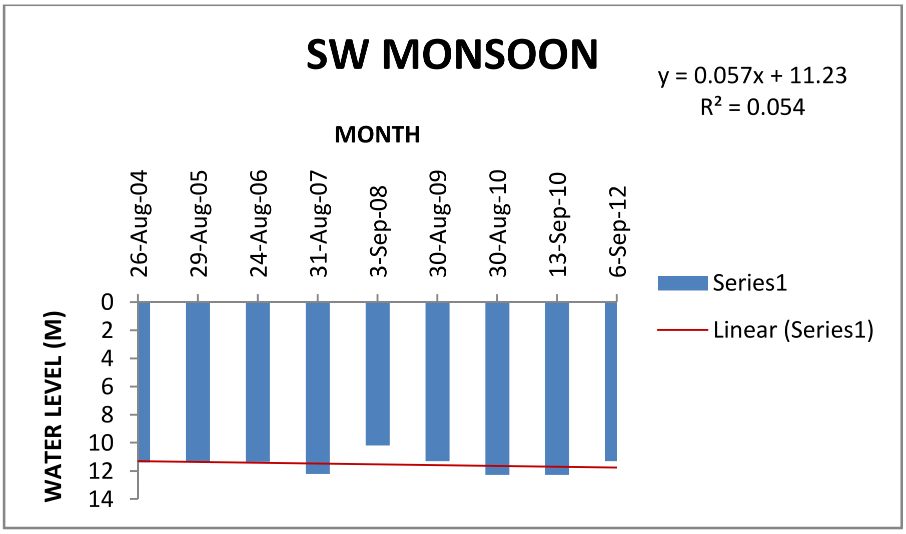


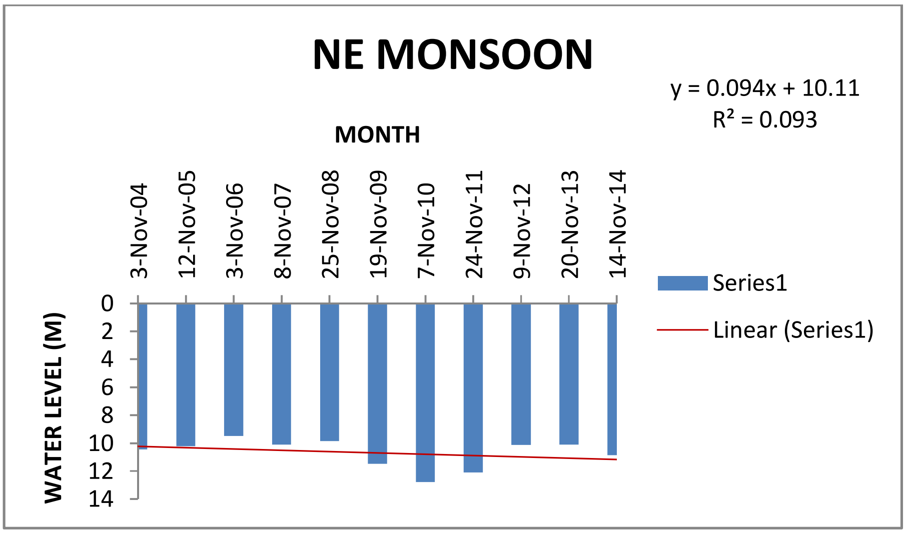


DRY SEASON	
8-Apr-04	5.97
12-Jan-05	5.02
7-Apr-05	2.87
18-Apr-06	3.98
5-Jan-07	5.92
4-Apr-07	5.45
9-Jan-08	5.36
8-Jan-09	5.3
30-Apr-09	5.12
19-Apr-10	6.38
14-Jan-11	4.94
28-Apr-11	6.52
10-Jan-13	5.52
13-Jan-14	5.9
25-Apr-14	6.07
SW MONSOON	
26-Aug-04	4.58
24-Aug-05	4.58
24-Aug-06	4.14
31-Aug-07	4.32
3-Sep-08	2.88
13-Sep-10	5.22
21-Aug-13	5.16
NE MONSOON	
3-Nov-04	4.31
16-Nov-05	3.03
4-Nov-06	2.59
7-Nov-07	2.98
25-Nov-08	3.5
19-Nov-09	3.1
7-Nov-10	5.19
9-Nov-12	4.22
19-Nov-13	3.72

Histogram showing depth to water table (bgl), Dug well at Puvar School

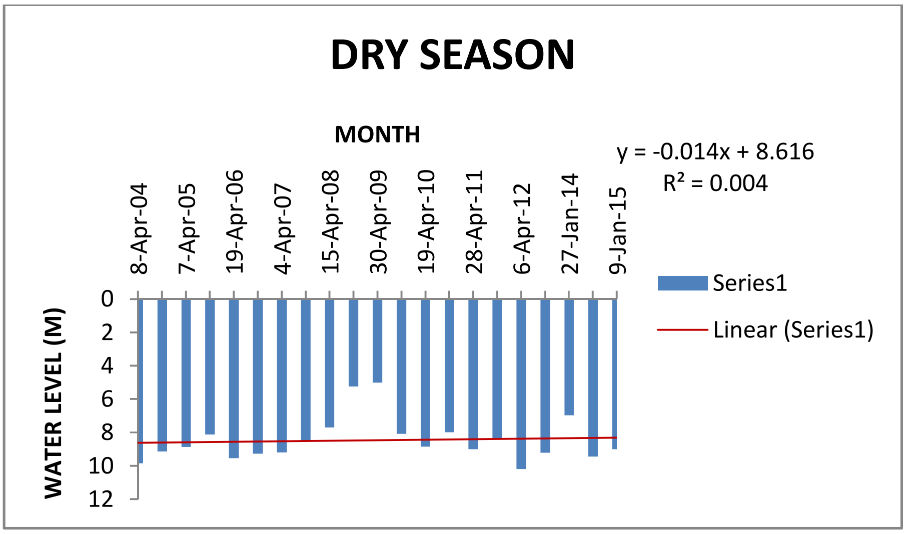


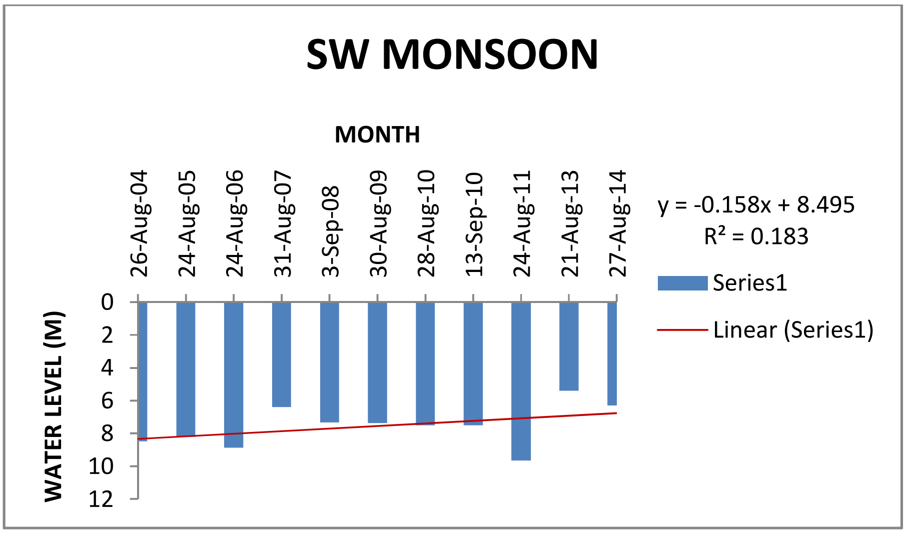


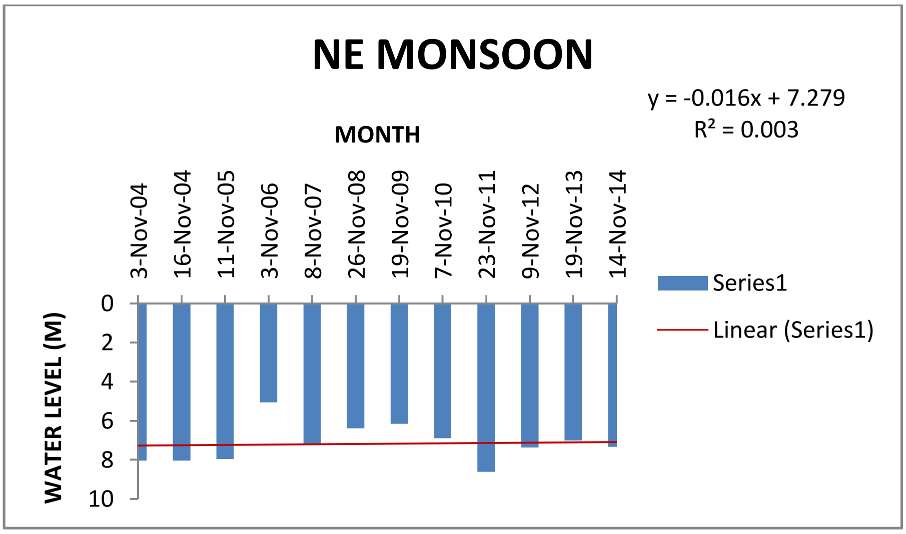


Histogram showing depth to water table (bgl), Bore well at Udiyankulangara

DRY SEASON	
15-Apr-04	13.2
7-Apr-05	11.77
3-Jan-06	10.68
18-Apr-06	10.9
5-Jan-07	9.78
4-Apr-07	11.41
9-Jan-08	10.74
11-Apr-08	11.13
8-Jan-09	10.35
30-Apr-09	11.84
19-Apr-10	10.19
14-Jan-11	12.8
28-Apr-11	13.25
30-Jan-12	11.46
15-Apr-12	12.4
10-Jan-13	11.4
15-Apr-13	12.99
9-Jan-15	10.9
SW MONSOON	
26-Aug-04	11.38
29-Aug-05	11.38
24-Aug-06	11.34
31-Aug-07	12.2
3-Sep-08	10.18
30-Aug-09	11.3
30-Aug-10	12.3
13-Sep-10	12.3
6-Sep-12	11.3
NE MONSOON	
3-Nov-04	10.45
12-Nov-05	10.2
3-Nov-06	9.5
8-Nov-07	10.1
25-Nov-08	9.85
19-Nov-09	11.48
7-Nov-10	12.8
24-Nov-11	12.1
9-Nov-12	10.12
20-Nov-13	10.1
14-Nov-14	10.85

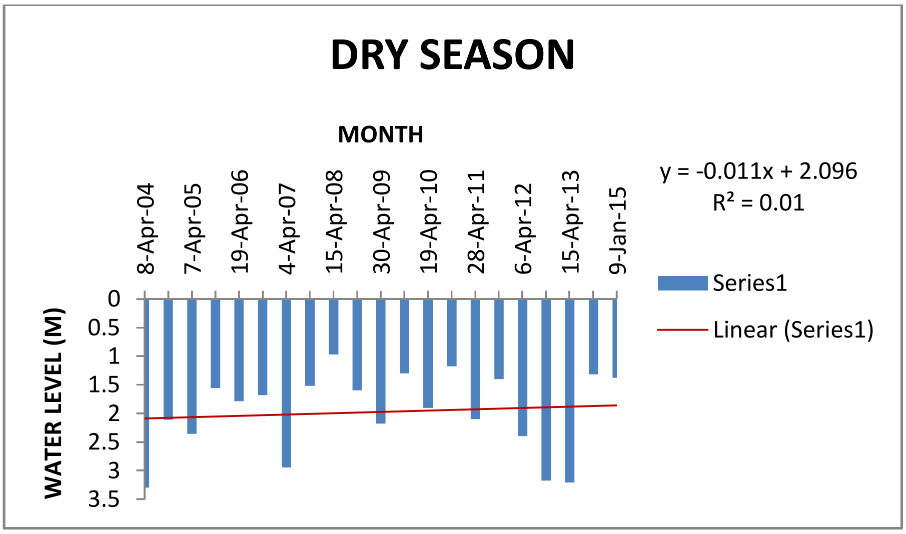


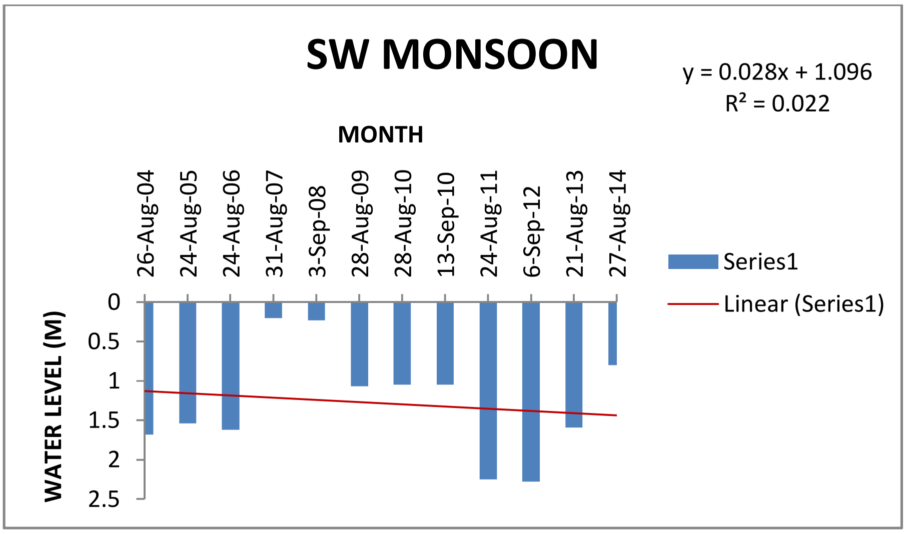


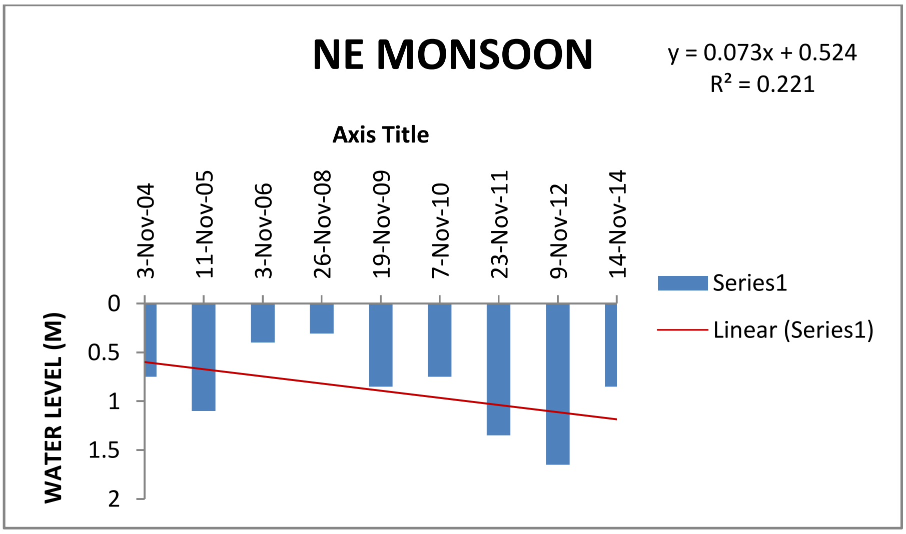


Histogram showing depth to water table (bgl), Dug well at Amboori

DRY SEASON	
8-Apr-04	9.85
9-Jan-05	9.14
7-Apr-05	8.87
2-Jan-06	8.14
19-Apr-06	9.55
5-Jan-07	9.27
4-Apr-07	9.2
9-Jan-08	8.5
15-Apr-08	7.7
9-Jan-09	5.26
30-Apr-09	5
15-Jan-10	8.09
19-Apr-10	8.86
14-Jan-11	8
28-Apr-11	9.01
29-Jan-12	8.38
6-Apr-12	10.2
10-Jan-13	9.22
27-Jan-14	6.98
24-Apr-14	9.45
9-Jan-15	9
SW MONSOON	
26-Aug-04	8.48
24-Aug-05	8.21
24-Aug-06	8.87
31-Aug-07	6.4
3-Sep-08	7.32
30-Aug-09	7.37
28-Aug-10	7.5
13-Sep-10	7.5
24-Aug-11	9.65
21-Aug-13	5.4
27-Aug-14	6.3
NE MONSOON	
3-Nov-04	8.04
16-Nov-04	8.04
11-Nov-05	7.96
3-Nov-06	5.07
8-Nov-07	7.2
26-Nov-08	6.38
19-Nov-09	6.17
7-Nov-10	6.89
23-Nov-11	8.62
9-Nov-12	7.37
19-Nov-13	7
14-Nov-14	7.33

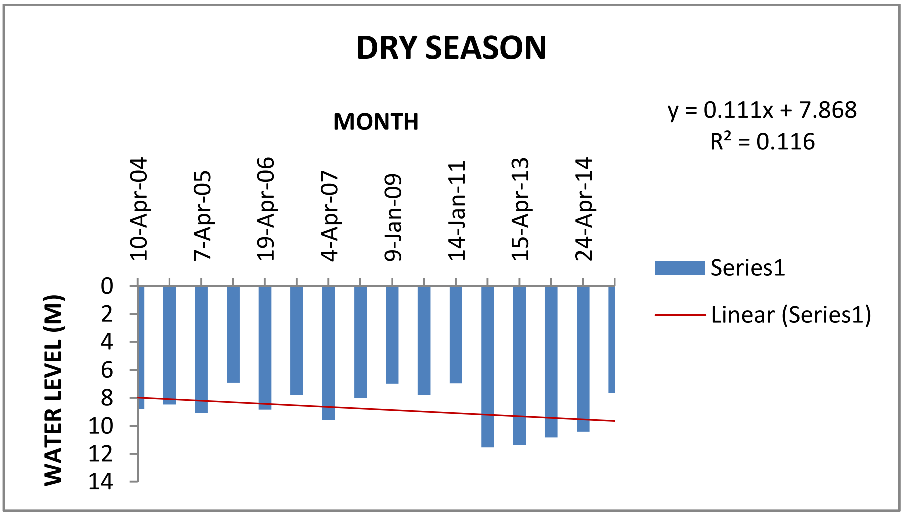


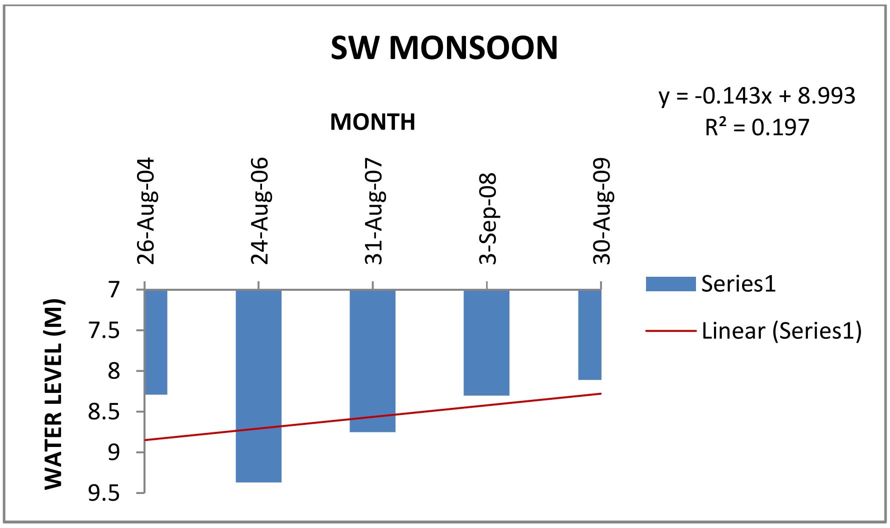


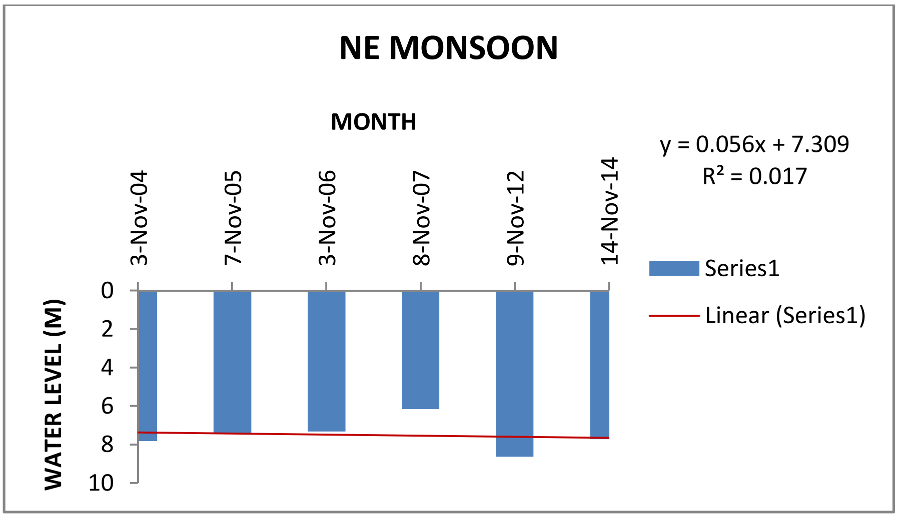


DRY SEASON	
8-Apr-04	3.3
12-Jan-05	2.11
7-Apr-05	2.36
2-Jan-06	1.56
19-Apr-06	1.79
5-Jan-07	1.68
4-Apr-07	2.95
9-Jan-08	1.52
15-Apr-08	0.97
9-Jan-09	1.6
30-Apr-09	2.18
15-Jan-10	1.3
19-Apr-10	1.9
14-Jan-11	1.18
28-Apr-11	2.1
29-Jan-12	1.4
6-Apr-12	2.4
10-Jan-13	3.18
15-Apr-13	3.21
24-Apr-14	1.32
9-Jan-15	1.38
SW MONSOON	
26-Aug-04	1.68
24-Aug-05	1.54
24-Aug-06	1.62
31-Aug-07	0.2
3-Sep-08	0.23
28-Aug-09	1.07
28-Aug-10	1.05
13-Sep-10	1.05
24-Aug-11	2.25
6-Sep-12	2.28
21-Aug-13	1.59
27-Aug-14	0.8
NE MONSOON	
3-Nov-04	0.75
11-Nov-05	1.1
3-Nov-06	0.4
26-Nov-08	0.31
19-Nov-09	0.85
7-Nov-10	0.75
23-Nov-11	1.35
9-Nov-12	1.65
14-Nov-14	0.85

Histogram showing depth to water table (bgl), Dug well at Kallikkad

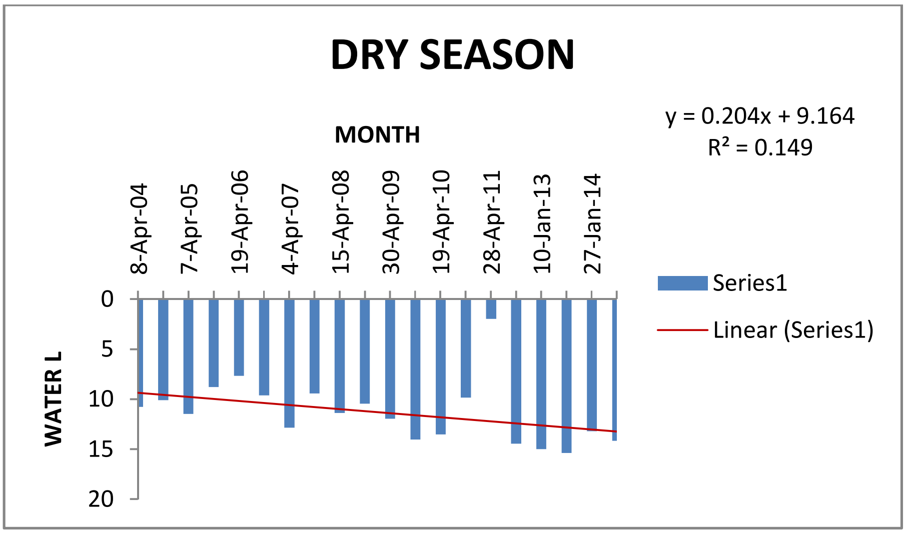


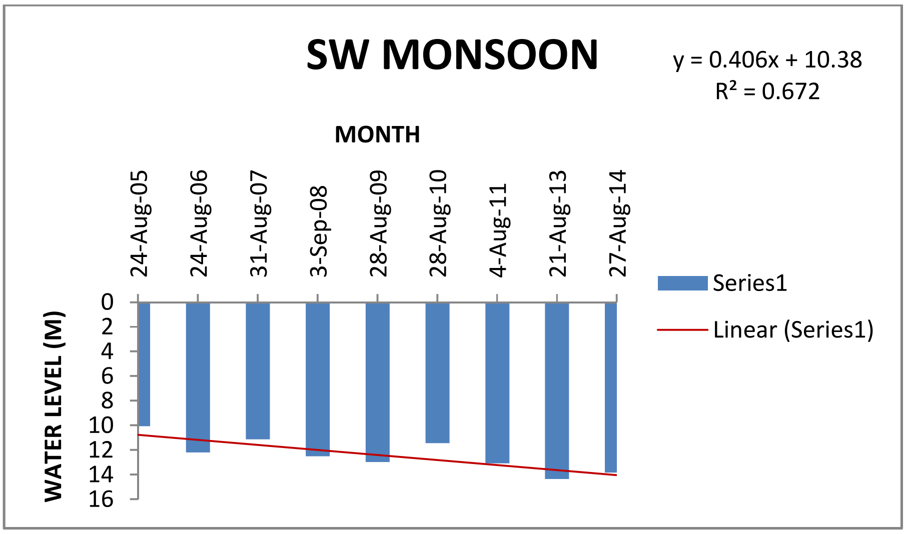


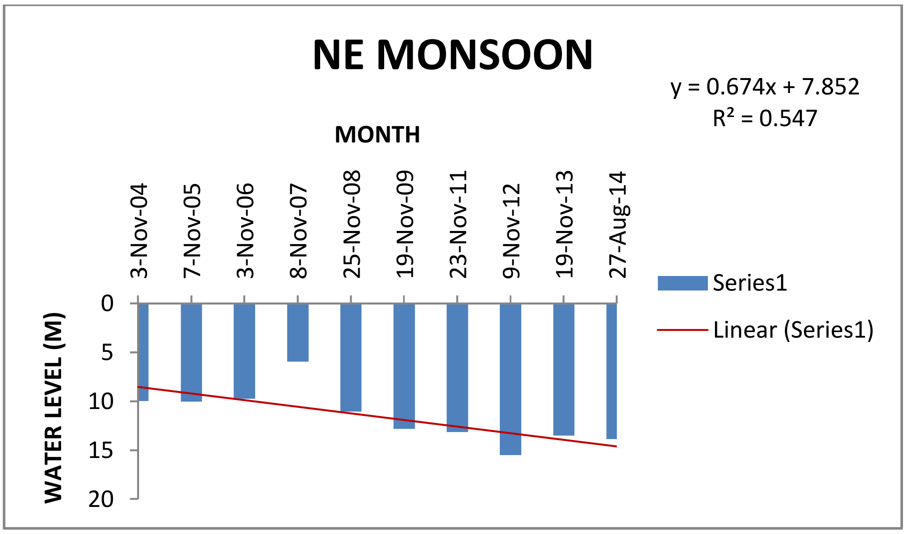


DRY SEASON	
7-Apr-04	12.57
12-Jan-05	10.32
7-Apr-05	11.52
3-Jan-06	10.16
5-Jan-07	10.54
9-Jan-08	10.78
11-Apr-08	11.37
8-Jan-09	11.34
30-Apr-09	12.14
14-Jan-11	13.2
28-Apr-11	11.62
30-Jan-12	12.05
14-Apr-12	13.95
10-Jan-13	16.61
15-Apr-13	18.38
27-Jan-14	13.89
24-Apr-14	16.71
9-Jan-15	14.05
SW MONSOON	
26-Aug-04	10.83
24-Aug-05	11.55
11-Sep-06	12.9
31-Aug-07	12.75
3-Sep-08	10.08
30-Aug-10	12.87
13-Sep-10	12.87
24-Aug-11	10.77
6-Sep-12	16.31
27-Aug-14	16.85
NE MONSOON	
3-Nov-04	10.13
12-Nov-05	10.75
3-Nov-06	9.85
7-Nov-07	8.96
25-Nov-08	10.78
19-Nov-09	11.7
7-Nov-10	12.5
24-Nov-11	13.15
9-Nov-12	14.48
19-Nov-13	13.05
14-Nov-14	13.07

Histogram showing depth to water table (bgl), Bore well at Perumkadavila

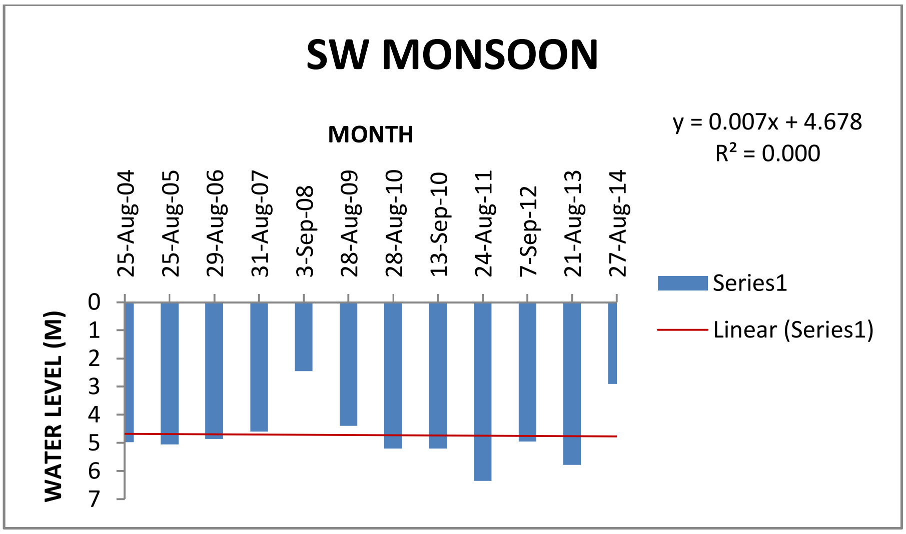


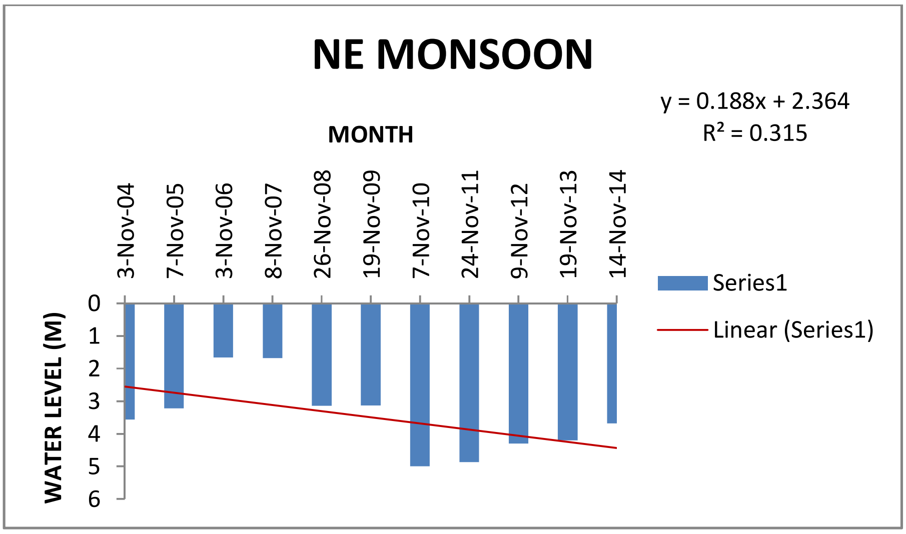


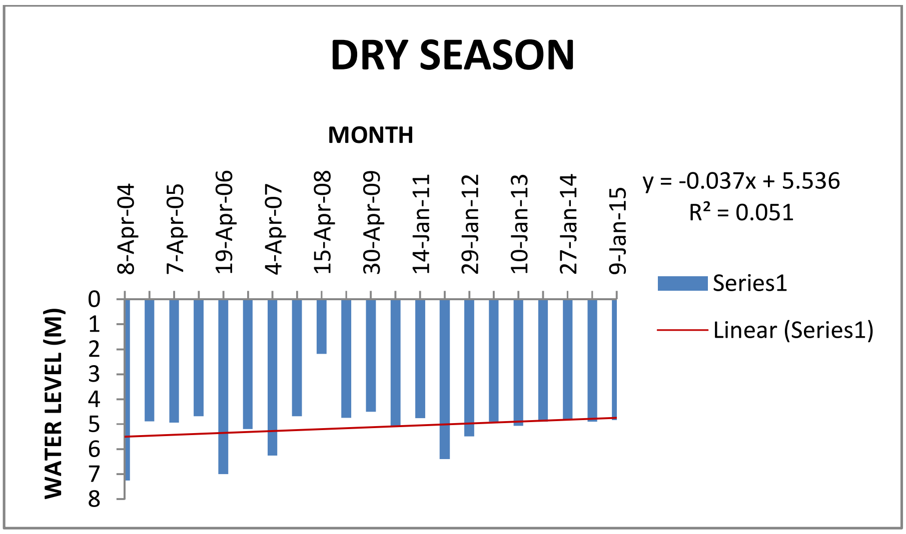


DRY SEASON	
8-Apr-04	10.78
12-Jan-05	10.08
7-Apr-05	11.5
2-Jan-06	8.77
19-Apr-06	7.65
5-Jan-07	9.64
4-Apr-07	12.87
9-Jan-08	9.44
15-Apr-08	11.39
9-Jan-09	10.48
30-Apr-09	11.95
15-Jan-10	14.05
19-Apr-10	13.51
14-Jan-11	9.85
28-Apr-11	1.95
29-Jan-12	14.45
10-Jan-13	15.03
15-Apr-13	15.39
27-Jan-14	13.21
24-Apr-14	14.16
SW MONSOON	
24-Aug-05	10.07
24-Aug-06	12.21
31-Aug-07	11.15
3-Sep-08	12.54
28-Aug-09	12.99
28-Aug-10	11.45
4-Aug-11	13.1
21-Aug-13	14.36
27-Aug-14	13.85
NE MONSOON	
3-Nov-04	9.97
7-Nov-05	10.04
3-Nov-06	9.75
8-Nov-07	5.95
25-Nov-08	11.06
19-Nov-09	12.85
23-Nov-11	13.16
9-Nov-12	15.51
19-Nov-13	13.5
27-Aug-14	13.85

Histogram showing depth to water table (bgl), Dug well at Perumkadavila

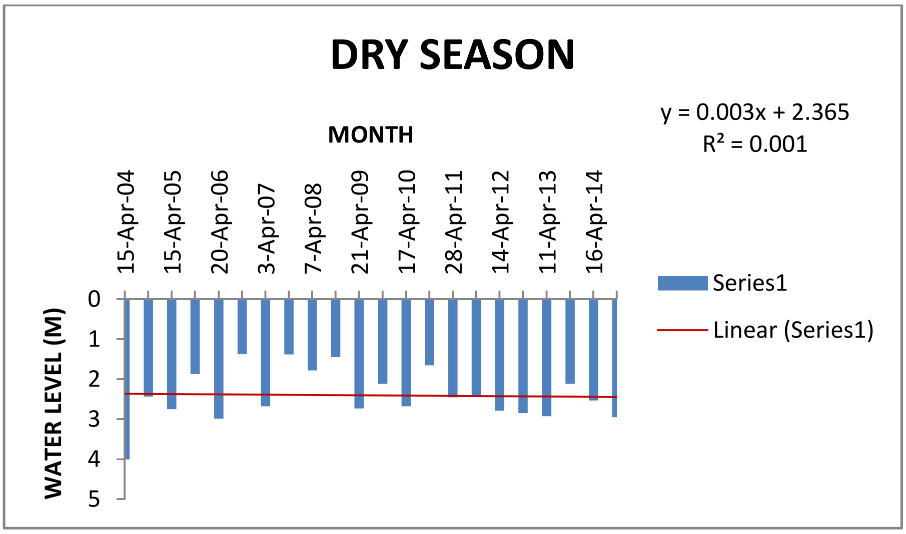


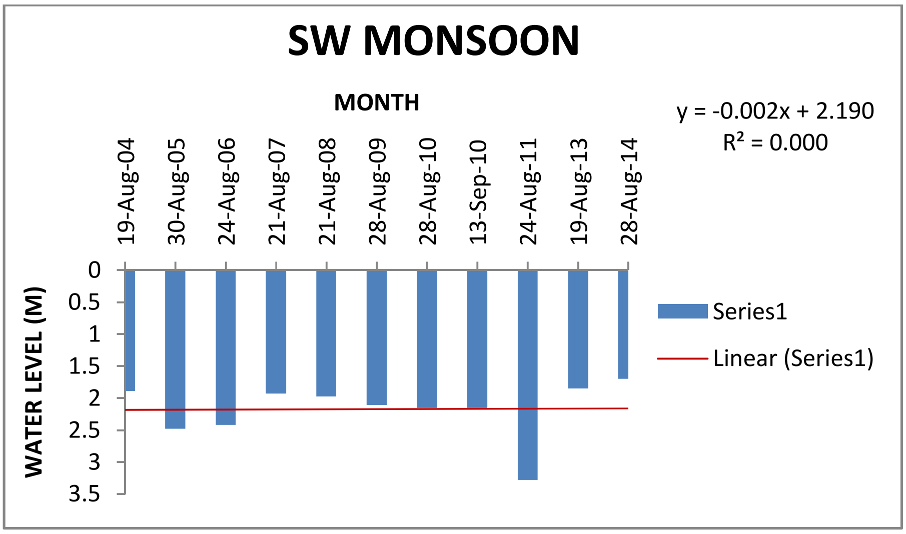


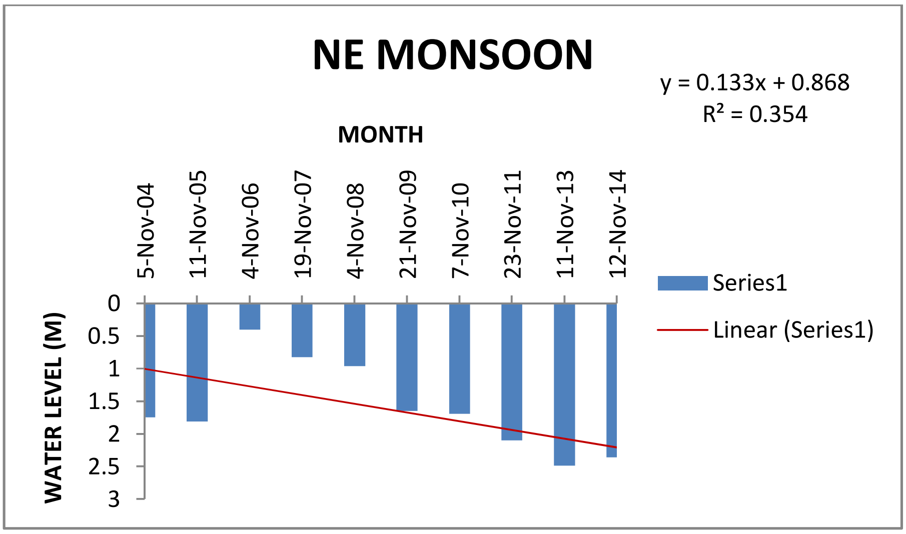


DRY SEASON	
8-Apr-04	7.25
12-Jan-05	4.89
7-Apr-05	4.94
2-Jan-06	4.69
19-Apr-06	7
5-Jan-07	5.2
4-Apr-07	6.25
9-Jan-08	4.69
15-Apr-08	2.19
9-Jan-09	4.75
30-Apr-09	4.5
19-Apr-10	5.12
14-Jan-11	4.76
28-Apr-11	6.4
29-Jan-12	5.5
6-Apr-12	4.9
10-Jan-13	5.07
15-Apr-13	4.9
27-Jan-14	4.82
24-Apr-14	4.9
9-Jan-15	4.83
SW MONSOON	
25-Aug-04	4.97
25-Aug-05	5.06
29-Aug-06	4.86
31-Aug-07	4.6
3-Sep-08	2.45
28-Aug-09	4.4
28-Aug-10	5.21
13-Sep-10	5.21
24-Aug-11	6.36
7-Sep-12	4.95
21-Aug-13	5.78
27-Aug-14	2.9
NE MONSOON	
3-Nov-04	3.56
7-Nov-05	3.22
3-Nov-06	1.65
8-Nov-07	1.68
26-Nov-08	3.14
19-Nov-09	3.13
7-Nov-10	5
24-Nov-11	4.86
9-Nov-12	4.3
19-Nov-13	4.2
14-Nov-14	3.68

Histogram showing depth to water table (bgl), Dug well at Vellarada

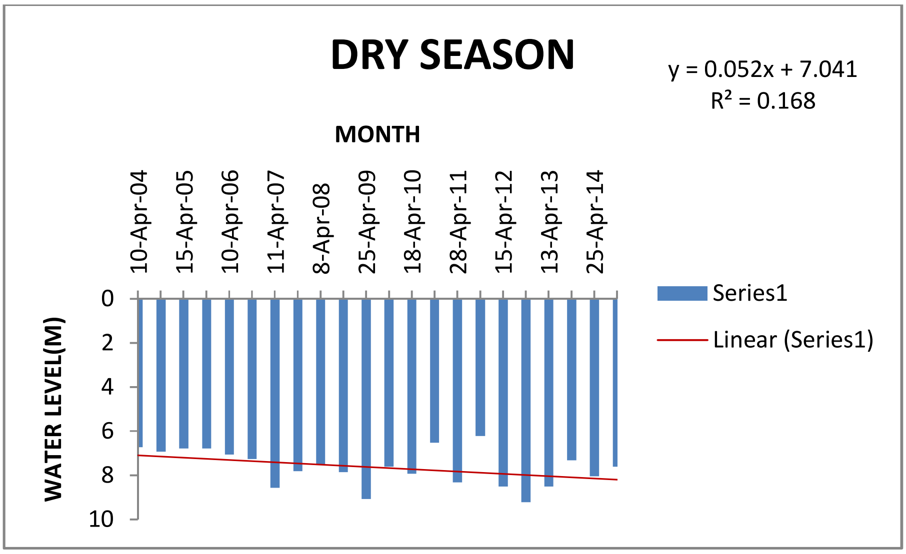


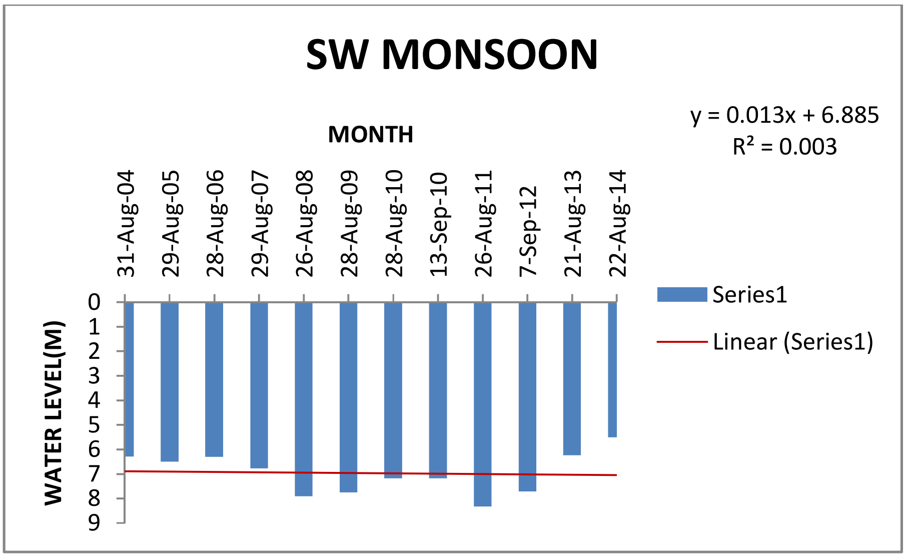


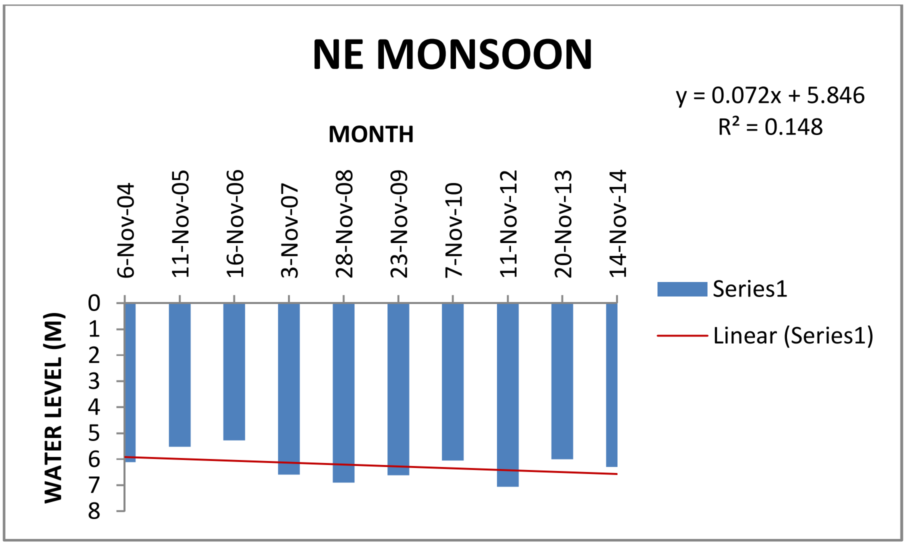


Histogram showing depth to water table (bgl), Dug well at Kochuveli

DRY SEASON	
15-Apr-04	4
7-Jan-05	2.44
15-Apr-05	2.75
18-Jan-06	1.87
20-Apr-06	2.99
9-Jan-07	1.37
3-Apr-07	2.68
7-Jan-08	1.38
7-Apr-08	1.78
5-Jan-09	1.45
21-Apr-09	2.73
9-Jan-10	2.12
17-Apr-10	2.68
13-Jan-11	1.65
28-Apr-11	2.45
29-Jan-12	2.4
14-Apr-12	2.79
7-Jan-13	2.85
11-Apr-13	2.93
14-Jan-14	2.12
16-Apr-14	2.53
9-Jan-15	2.95
SW MONSOON	
19-Aug-04	1.89
30-Aug-05	2.48
24-Aug-06	2.42
21-Aug-07	1.93
21-Aug-08	1.97
28-Aug-09	2.11
28-Aug-10	2.15
13-Sep-10	2.15
24-Aug-11	3.28
19-Aug-13	1.85
28-Aug-14	1.7
NE MONSOON	
5-Nov-04	1.75
11-Nov-05	1.81
4-Nov-06	0.4
19-Nov-07	0.82
4-Nov-08	0.96
21-Nov-09	1.65
7-Nov-10	1.69
23-Nov-11	2.1
11-Nov-13	2.49
12-Nov-14	2.36

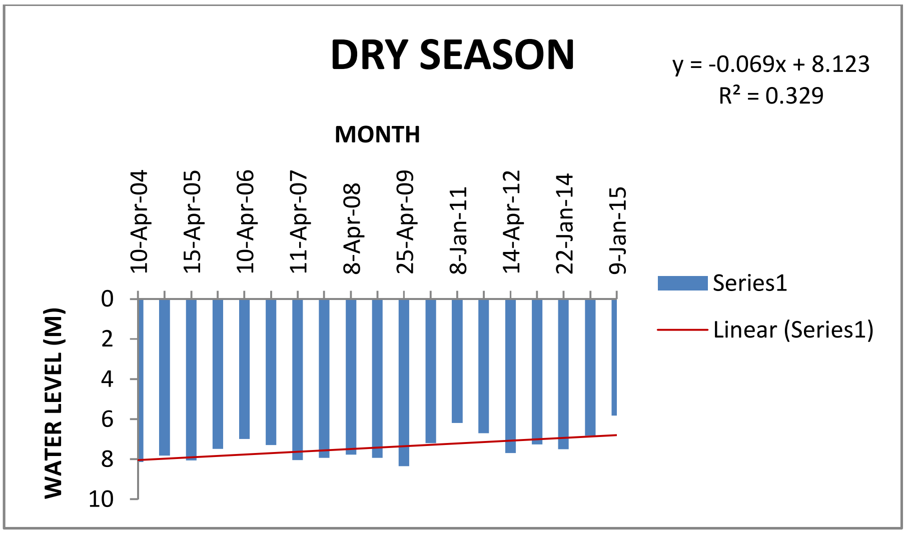


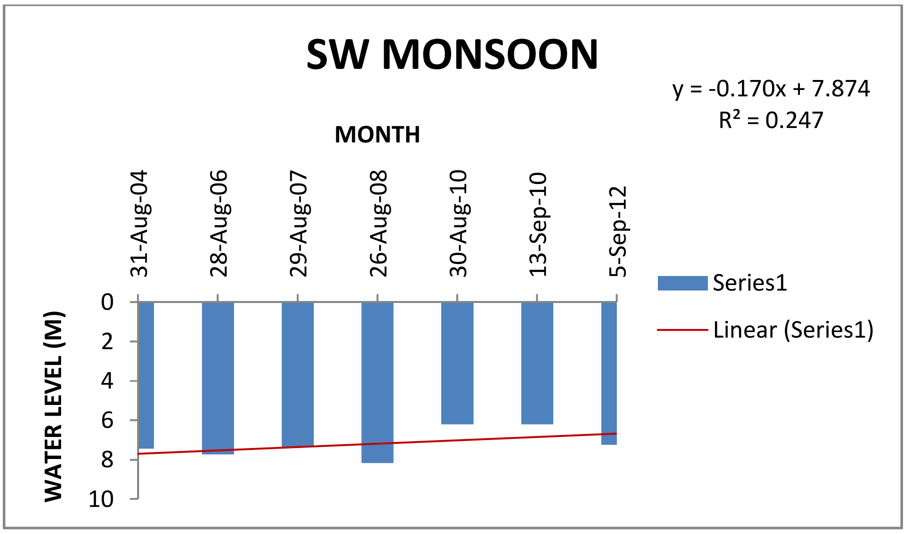


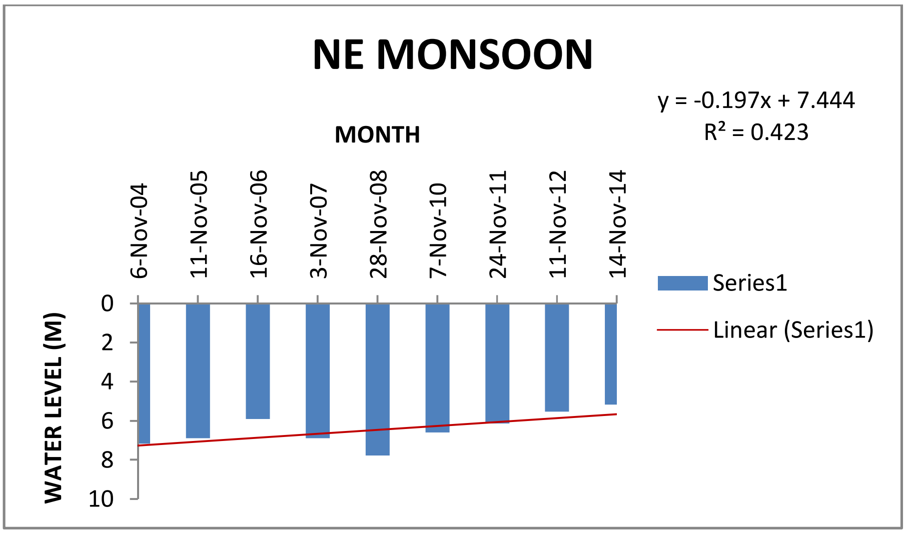


DRY SEASON	
10-Apr-04	6.73
6-Jan-05	6.92
15-Apr-05	6.78
19-Jan-06	6.78
10-Apr-06	7.05
9-Jan-07	7.27
11-Apr-07	8.56
16-Jan-08	7.82
8-Apr-08	7.53
6-Jan-09	7.85
25-Apr-09	9.07
16-Jan-10	7.6
18-Apr-10	7.93
8-Jan-11	6.52
28-Apr-11	8.32
29-Jan-12	6.22
15-Apr-12	8.5
9-Jan-13	9.23
13-Apr-13	8.5
21-Jan-14	7.32
25-Apr-14	8.04
9-Jan-15	7.6
SW MONSOON	
31-Aug-04	6.29
29-Aug-05	6.5
28-Aug-06	6.3
29-Aug-07	6.78
26-Aug-08	7.91
28-Aug-09	7.75
28-Aug-10	7.18
13-Sep-10	7.18
26-Aug-11	8.32
7-Sep-12	7.72
21-Aug-13	6.24
22-Aug-14	5.5
NE MONSOON	
6-Nov-04	6.12
11-Nov-05	5.52
16-Nov-06	5.28
3-Nov-07	6.6
28-Nov-08	6.9
23-Nov-09	6.62
7-Nov-10	6.06
11-Nov-12	7.06
20-Nov-13	6
14-Nov-14	6.3

Histogram showing depth to water table (bgl), Dug well at Mannanthala

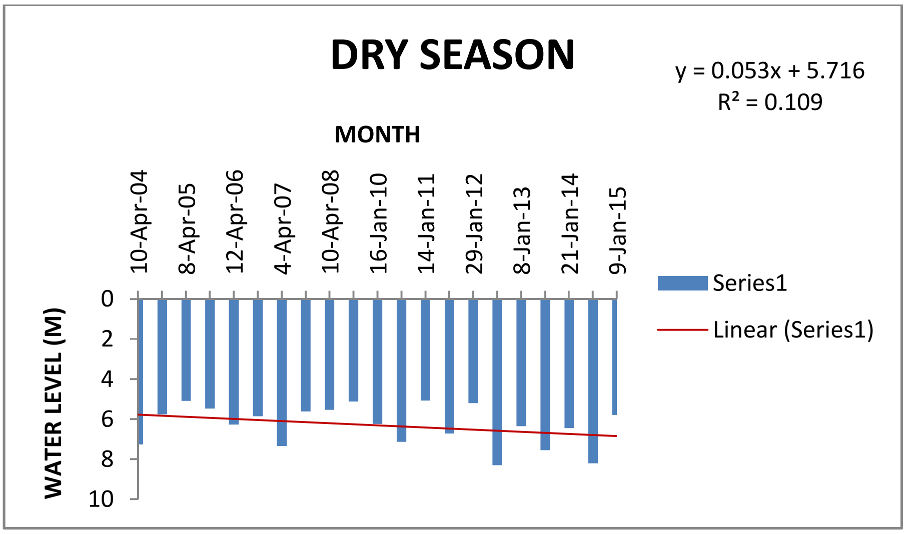


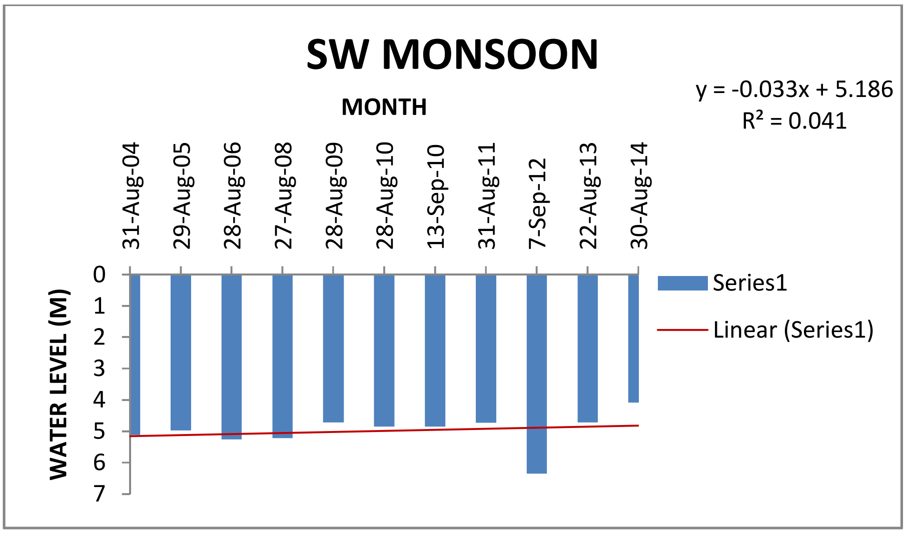


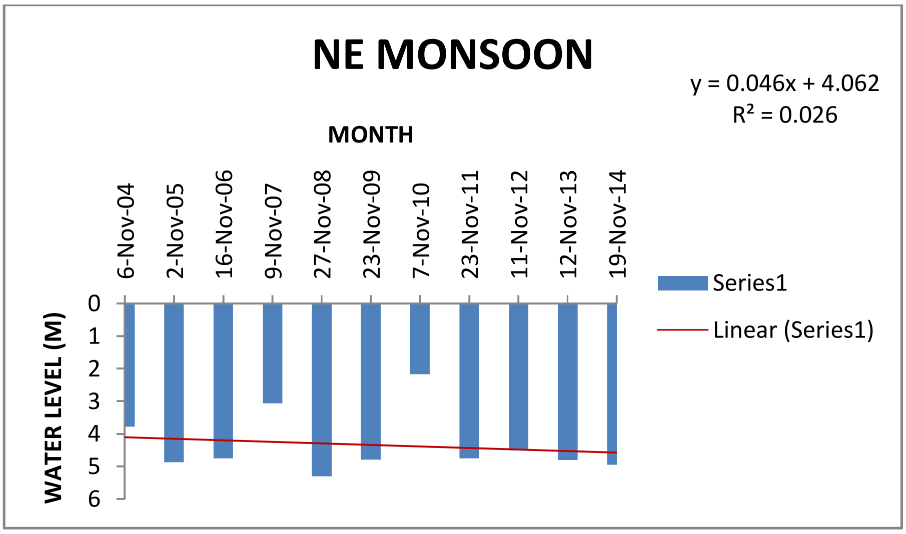


DRY SEASON	
10-Apr-04	8.15
6-Jan-05	7.83
15-Apr-05	8.07
19-Jan-06	7.49
10-Apr-06	7
9-Jan-07	7.31
11-Apr-07	8.06
16-Jan-08	7.95
8-Apr-08	7.77
6-Jan-09	7.95
25-Apr-09	8.35
17-Apr-10	7.2
8-Jan-11	6.2
30-Jan-12	6.71
14-Apr-12	7.7
11-Jan-13	7.28
22-Jan-14	7.5
30-Apr-14	6.84
9-Jan-15	5.83
SW MONSOON	
31-Aug-04	7.44
28-Aug-06	7.73
29-Aug-07	7.35
26-Aug-08	8.17
30-Aug-10	6.2
13-Sep-10	6.2
5-Sep-12	7.25
NE MONSOON	
6-Nov-04	7.17
11-Nov-05	6.9
16-Nov-06	5.9
3-Nov-07	6.9
28-Nov-08	7.77
7-Nov-10	6.6
24-Nov-11	6.15
11-Nov-12	5.53
14-Nov-14	5.18

Histogram showing depth to water table (bgl), Bore well at Mannanthala

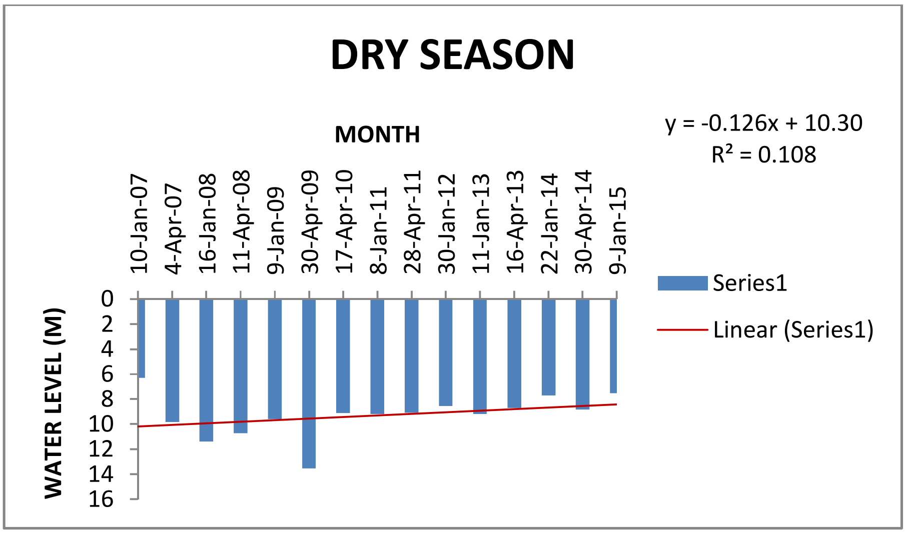


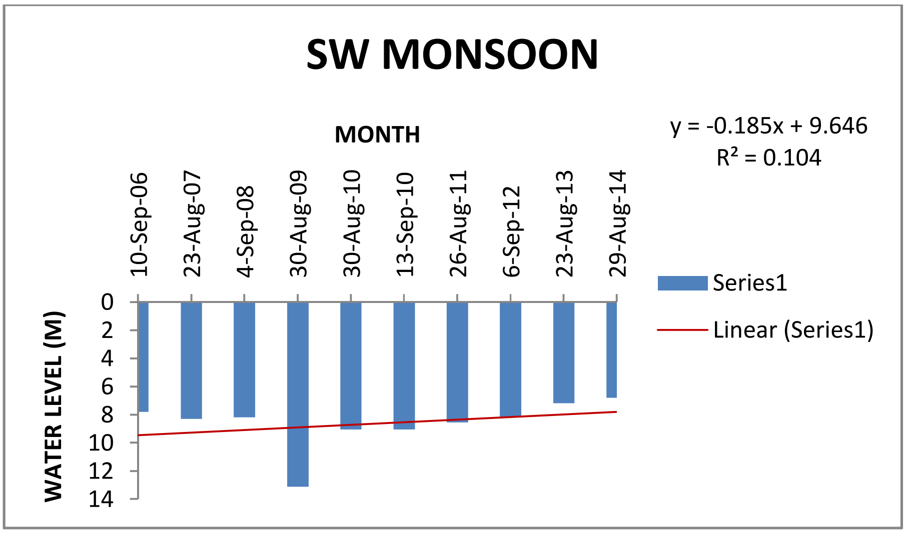


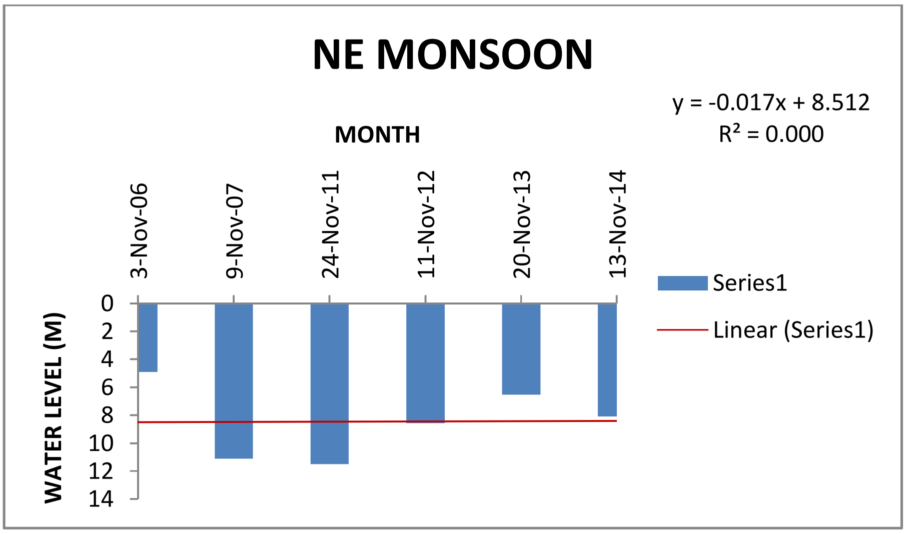


DRY SEASON	
10-Apr-04	7.28
8-Jan-05	5.76
8-Apr-05	5.1
13-Jan-06	5.46
12-Apr-06	6.27
10-Jan-07	5.85
4-Apr-07	7.35
8-Jan-08	5.62
10-Apr-08	5.55
7-Jan-09	5.12
16-Jan-10	6.25
17-Apr-10	7.14
14-Jan-11	5.08
28-Apr-11	6.73
29-Jan-12	5.21
5-Apr-12	8.3
8-Jan-13	6.35
12-Apr-13	7.56
21-Jan-14	6.45
29-Apr-14	8.21
9-Jan-15	5.8
SW MONSOON	
31-Aug-04	5.11
29-Aug-05	4.97
28-Aug-06	5.25
27-Aug-08	5.21
28-Aug-09	4.72
28-Aug-10	4.85
13-Sep-10	4.85
31-Aug-11	4.73
7-Sep-12	6.34
22-Aug-13	4.72
30-Aug-14	4.08
NE MONSOON	
6-Nov-04	3.78
2-Nov-05	4.87
16-Nov-06	4.75
9-Nov-07	3.07
27-Nov-08	5.3
23-Nov-09	4.8
7-Nov-10	2.17
23-Nov-11	4.75
11-Nov-12	4.51
12-Nov-13	4.81
19-Nov-14	4.95

Histogram showing depth to water table (bgl), Dug well at Pangode

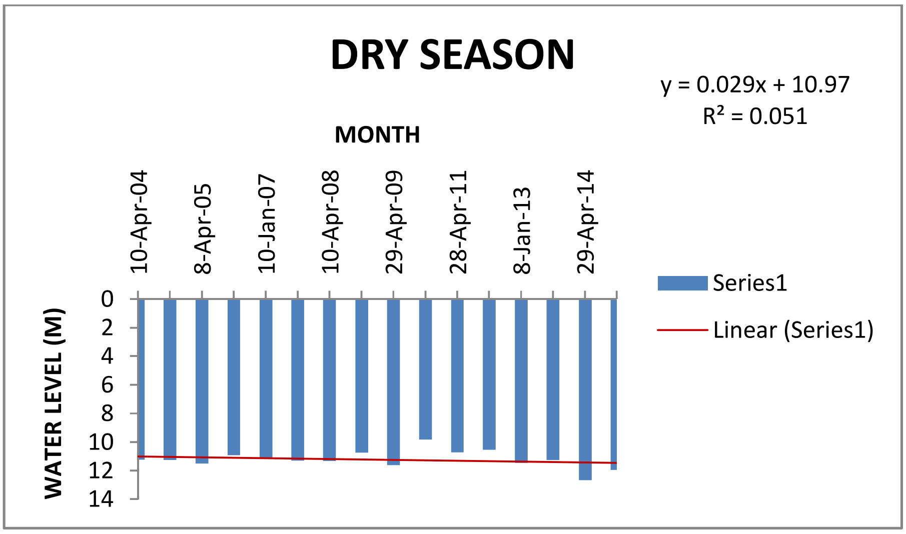


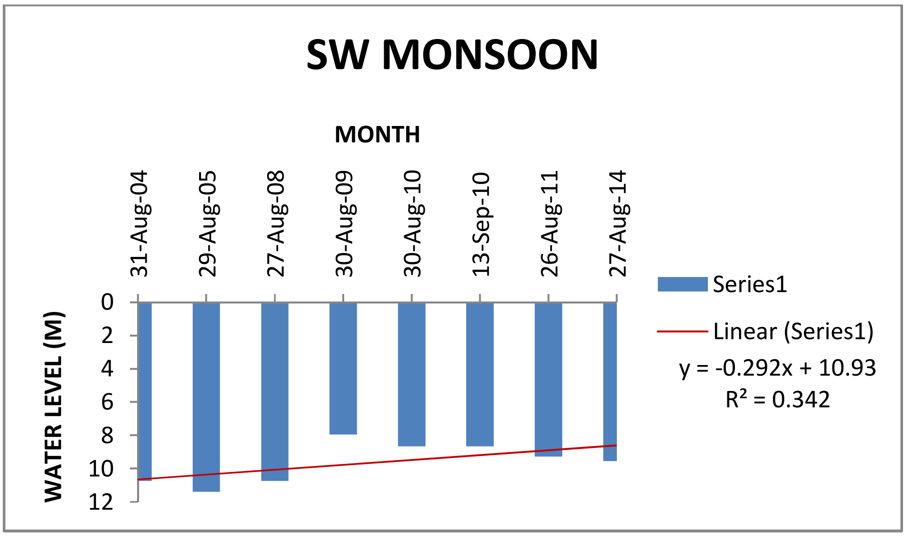


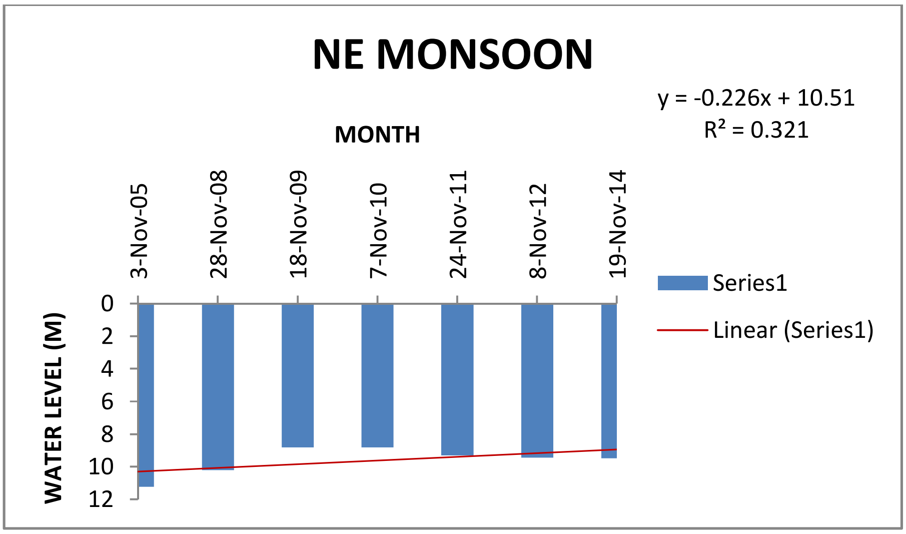


DRY SEASON	
10-Jan-07	6.3
4-Apr-07	9.85
16-Jan-08	11.4
11-Apr-08	10.74
9-Jan-09	9.6
30-Apr-09	13.56
17-Apr-10	9.11
8-Jan-11	9.2
28-Apr-11	9.1
30-Jan-12	8.55
11-Jan-13	9.2
16-Apr-13	8.7
22-Jan-14	7.7
30-Apr-14	8.84
9-Jan-15	7.53
SW MONSOON	
10-Sep-06	7.8
23-Aug-07	8.3
4-Sep-08	8.2
30-Aug-09	13.13
30-Aug-10	9.05
13-Sep-10	9.05
26-Aug-11	8.56
6-Sep-12	8.2
23-Aug-13	7.17
29-Aug-14	6.8
NE MONSOON	
3-Nov-06	4.9
9-Nov-07	11.1
24-Nov-11	11.5
11-Nov-12	8.56
20-Nov-13	6.54
13-Nov-14	8.1

Histogram showing depth to water table (bgl), Dug well at Pattom

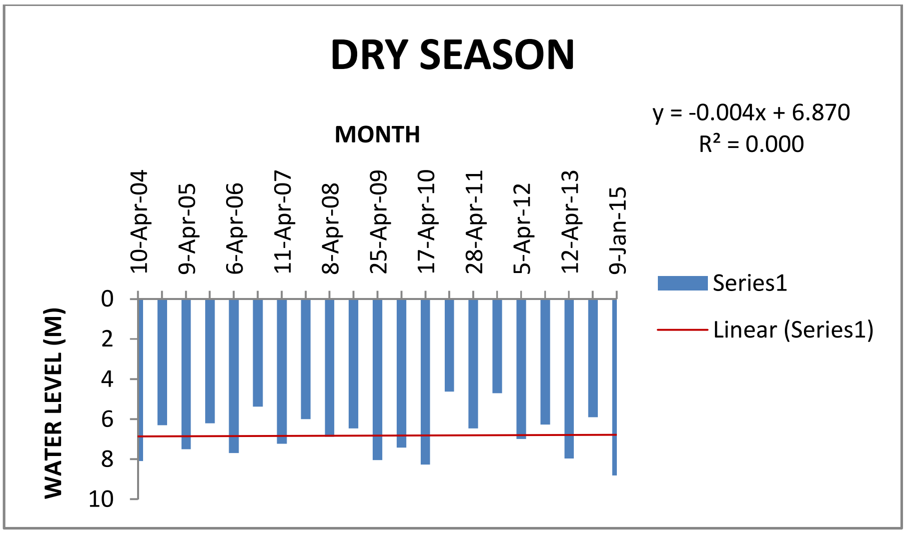


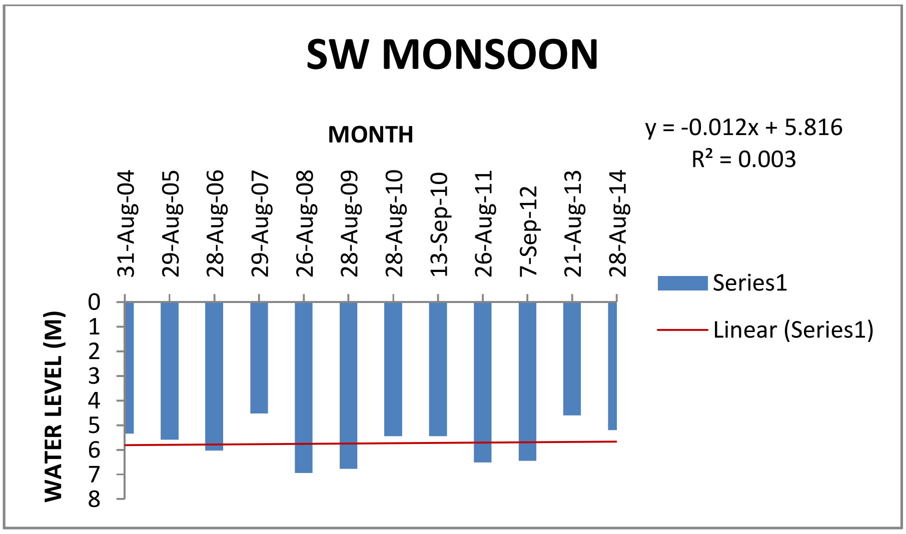




DRY SEASON	
10-Apr-04	11.25
8-Jan-05	11.28
8-Apr-05	11.51
13-Jan-06	10.92
10-Jan-07	11.15
8-Jan-08	11.32
10-Apr-08	11.33
7-Jan-09	10.75
29-Apr-09	11.63
15-Jan-11	9.84
28-Apr-11	10.72
30-Jan-12	10.56
8-Jan-13	11.48
21-Jan-14	11.28
29-Apr-14	12.67
9-Jan-15	11.95
SW MONSOON	
31-Aug-04	10.75
29-Aug-05	11.4
27-Aug-08	10.74
30-Aug-09	7.95
30-Aug-10	8.66
13-Sep-10	8.66
26-Aug-11	9.28
27-Aug-14	9.55
NE MONSOON	
3-Nov-05	11.24
28-Nov-08	10.2
18-Nov-09	8.8
7-Nov-10	8.8
24-Nov-11	9.31
8-Nov-12	9.43
19-Nov-14	9.47

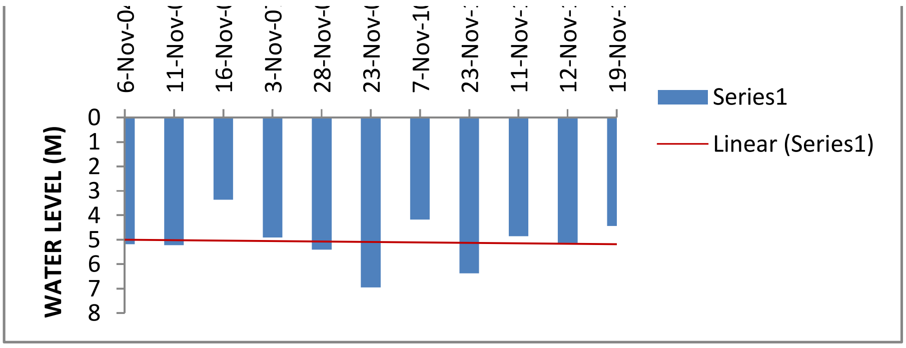
Histogram showing depth to water table (bgl), Bore well at Peringamala



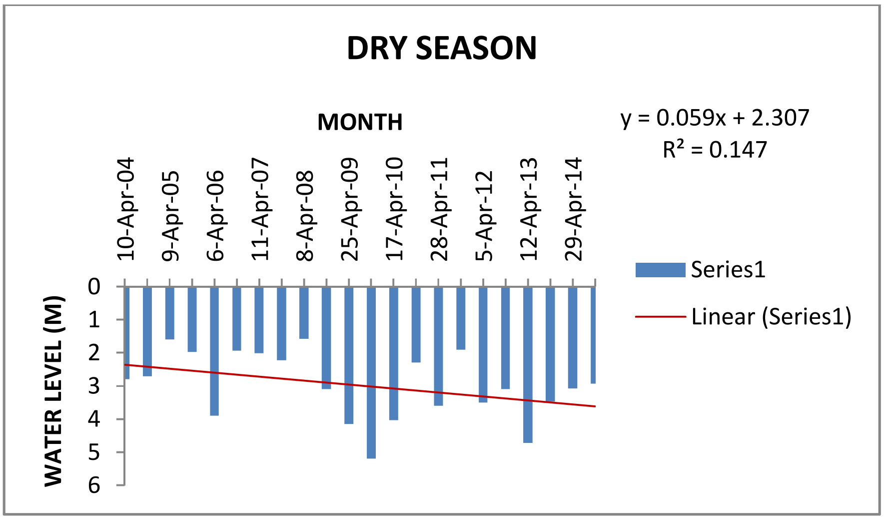


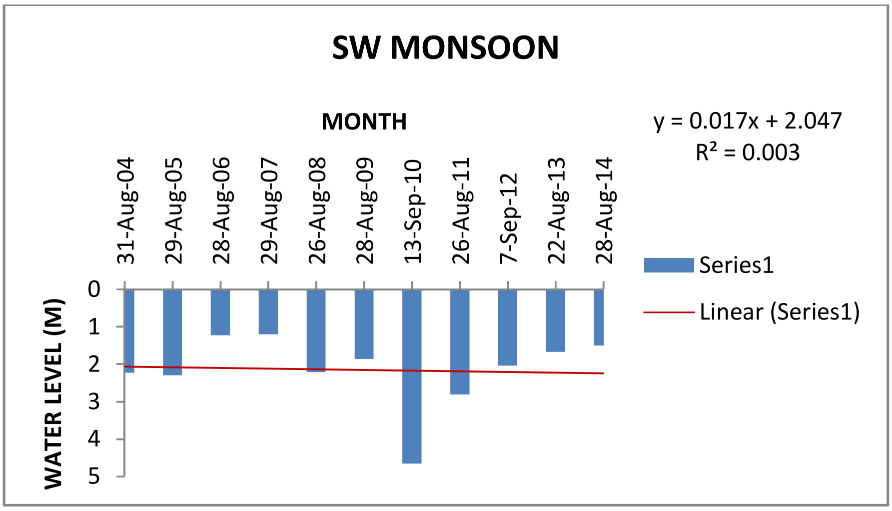
Histogram showing depth to water table (bgl), Dug well at Pirappancode

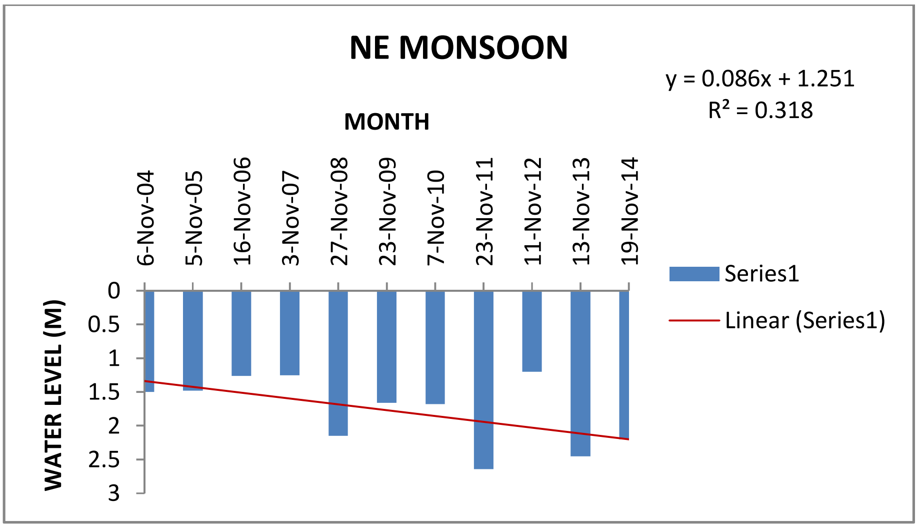
xlviii



DRY SEASON	
10-Apr-04	8.1
6-Jan-05	6.31
9-Apr-05	7.5
16-Jan-06	6.22
6-Apr-06	7.7
9-Jan-07	5.37
11-Apr-07	7.23
16-Jan-08	6
8-Apr-08	6.89
6-Jan-09	6.47
25-Apr-09	8.05
16-Jan-10	7.43
17-Apr-10	8.27
8-Jan-11	4.62
28-Apr-11	6.46
29-Jan-12	4.7
5-Apr-12	7
9-Jan-13	6.28
12-Apr-13	7.98
21-Jan-14	5.9
9-Jan-15	8.82
SW MONSOON	
31-Aug-04	5.34
29-Aug-05	5.6
28-Aug-06	6.03
29-Aug-07	4.52
26-Aug-08	6.94
28-Aug-09	6.77
28-Aug-10	5.44
13-Sep-10	5.44
26-Aug-11	6.51
7-Sep-12	6.44
21-Aug-13	4.6
28-Aug-14	5.2
NE MONSOON	
6-Nov-04	5.19
11-Nov-05	5.22
16-Nov-06	3.36
3-Nov-07	4.9
28-Nov-08	5.42
23-Nov-09	6.95
7-Nov-10	4.18
23-Nov-11	6.38
11-Nov-12	4.85
12-Nov-13	5.13
19-Nov-14	4.43

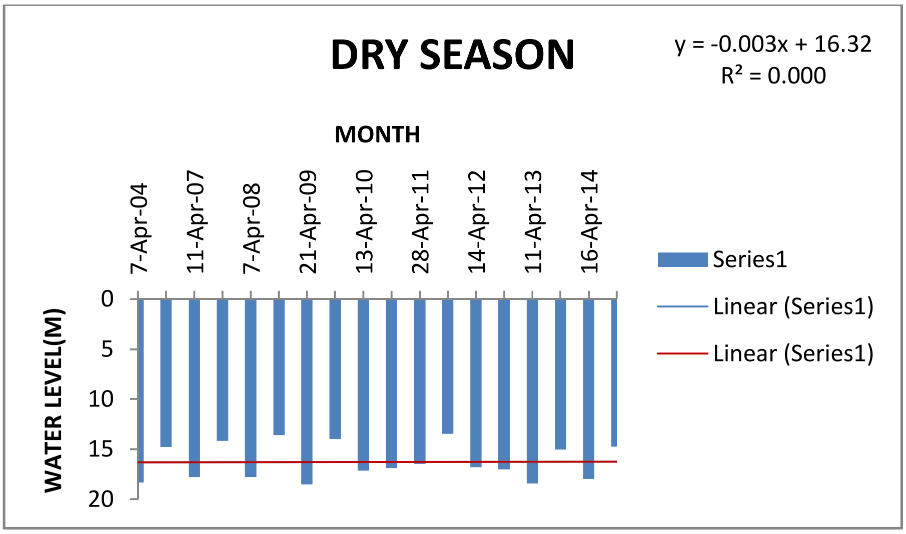


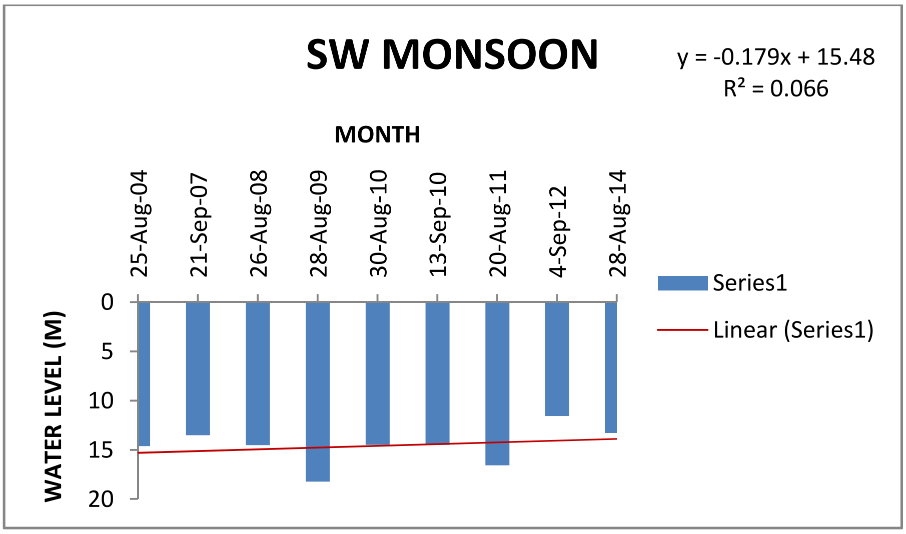


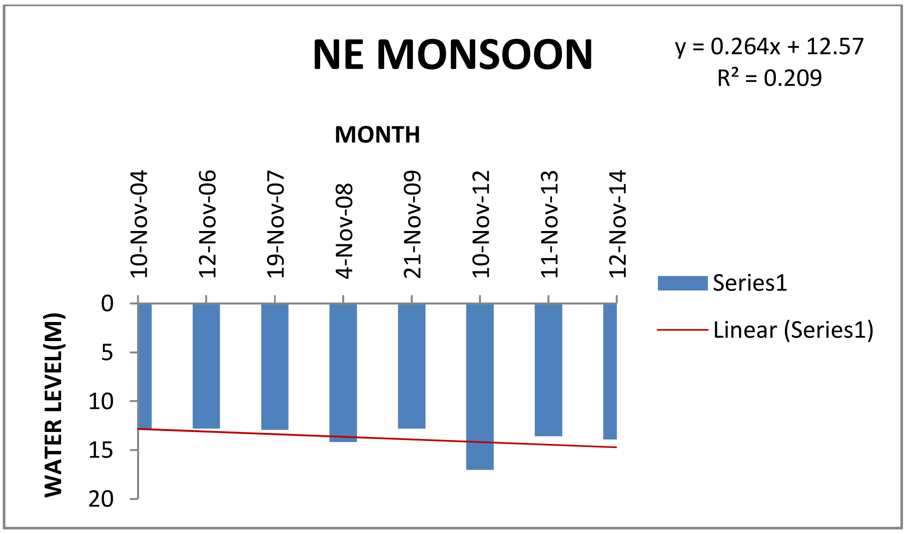


DRY SEASON	
10-Apr-04	2.8
6-Jan-05	2.71
9-Apr-05	1.6
16-Jan-06	1.98
6-Apr-06	3.9
9-Jan-07	1.94
11-Apr-07	2.02
8-Jan-08	2.22
8-Apr-08	1.58
6-Jan-09	3.1
25-Apr-09	4.15
16-Jan-10	5.2
17-Apr-10	4.03
8-Jan-11	2.3
28-Apr-11	3.6
29-Jan-12	1.9
5-Apr-12	3.5
9-Jan-13	3.1
12-Apr-13	4.72
21-Jan-14	3.48
29-Apr-14	3.08
9-Jan-15	2.93
SW MONSOON	
31-Aug-04	2.23
29-Aug-05	2.3
28-Aug-06	1.22
29-Aug-07	1.2
26-Aug-08	2.21
28-Aug-09	1.86
13-Sep-10	4.65
26-Aug-11	2.81
7-Sep-12	2.04
22-Aug-13	1.67
28-Aug-14	1.5
NE MONSOON	
6-Nov-04	1.5
5-Nov-05	1.48
16-Nov-06	1.26
3-Nov-07	1.25
27-Nov-08	2.15
23-Nov-09	1.66
7-Nov-10	1.68
23-Nov-11	2.64
11-Nov-12	1.2
13-Nov-13	2.45
19-Nov-14	2.2

Histogram showing depth to water table (bgl),Dug well at Vamanapuram

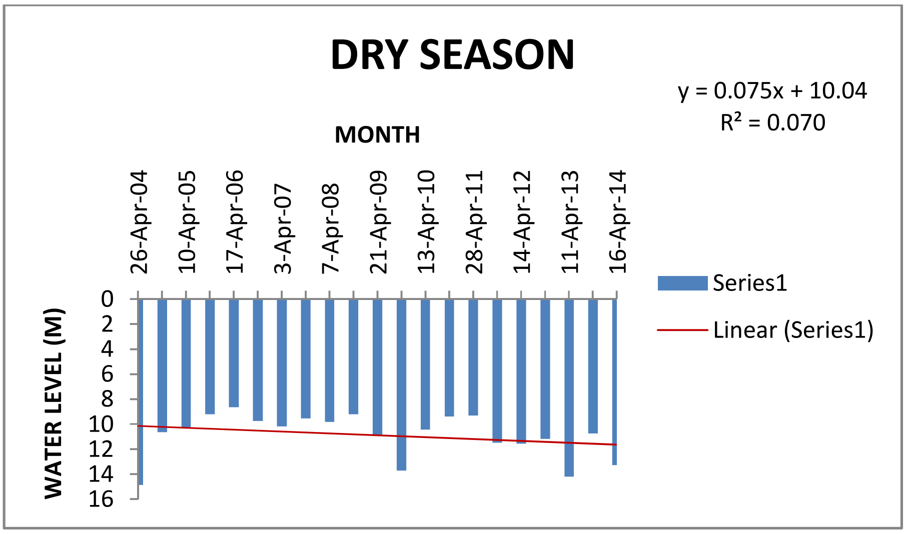


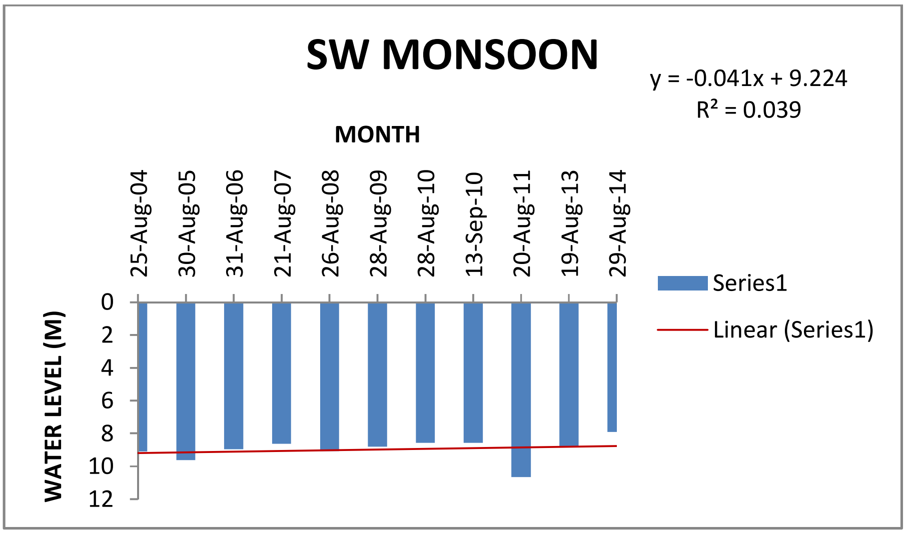


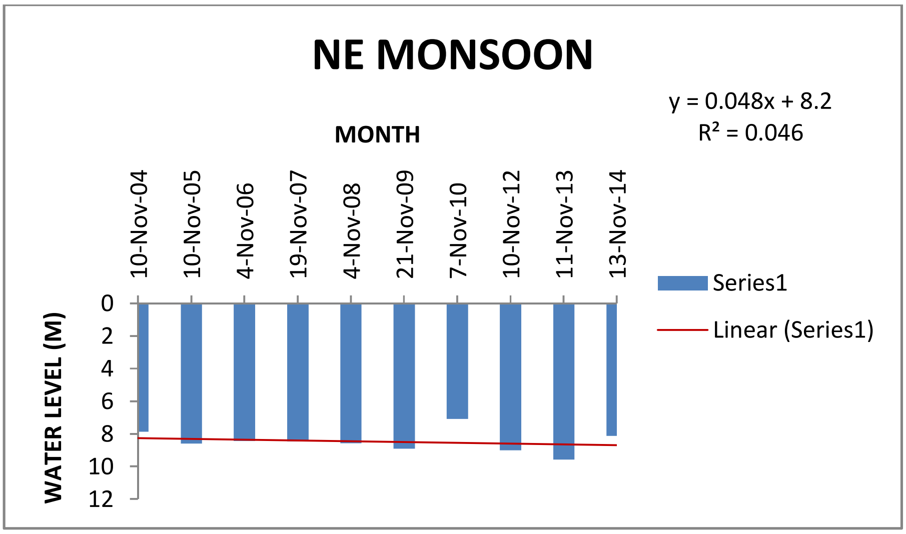


DRY SEASON	
7-Apr-04	18.35
8-Jan-07	14.81
11-Apr-07	17.78
7-Jan-08	14.16
7-Apr-08	17.8
5-Jan-09	13.6
21-Apr-09	18.54
9-Jan-10	14
13-Apr-10	17.16
12-Jan-11	16.92
28-Apr-11	16.47
31-Jan-12	13.5
14-Apr-12	16.8
7-Jan-13	17.05
11-Apr-13	18.45
14-Jan-14	15.05
16-Apr-14	18
9-Jan-15	14.77
SW MONSOON	
25-Aug-04	14.61
21-Sep-07	13.5
26-Aug-08	14.52
28-Aug-09	18.22
30-Aug-10	14.5
13-Sep-10	14.5
20-Aug-11	16.57
4-Sep-12	11.56
28-Aug-14	13.28
NE MONSOON	
10-Nov-04	12.87
12-Nov-06	12.8
19-Nov-07	12.93
4-Nov-08	14.16
21-Nov-09	12.8
10-Nov-12	17
11-Nov-13	13.6
12-Nov-14	13.92

Histogram showing depth to water table (bgl), Tube well at Edava

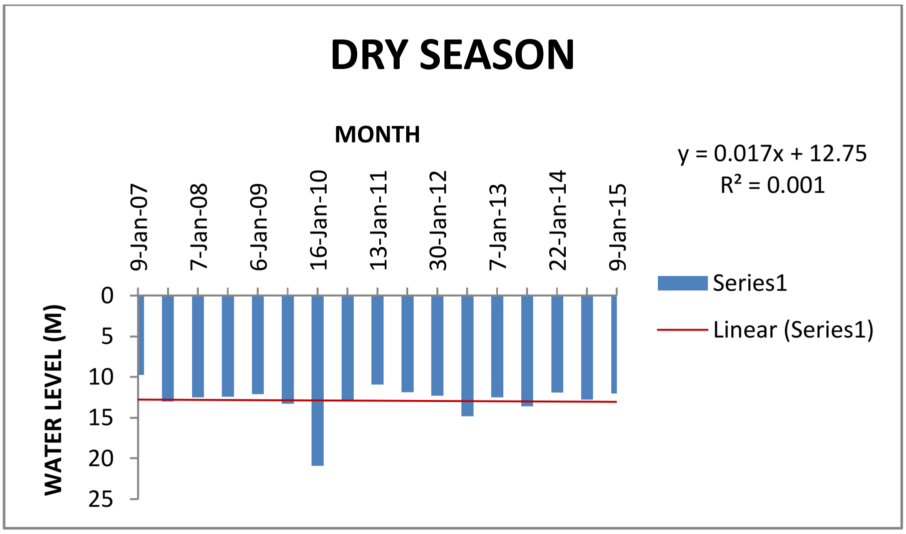


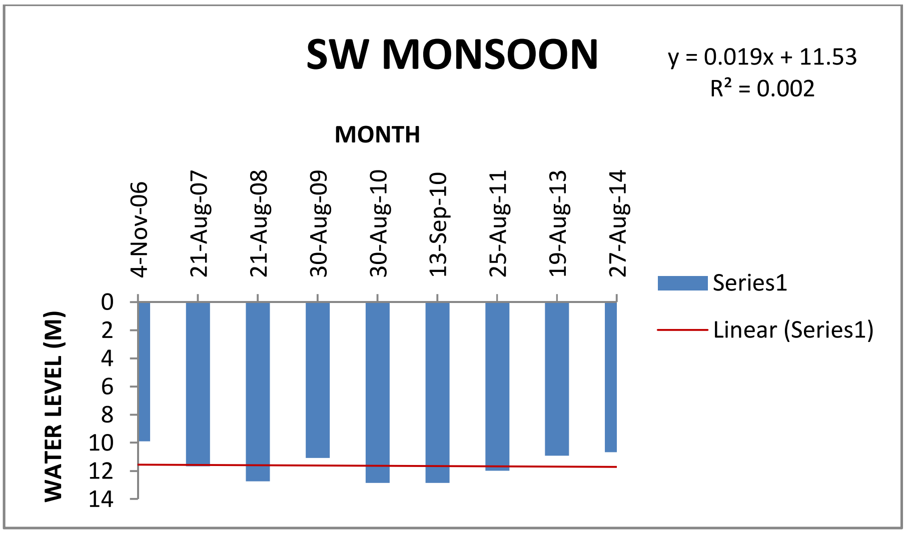


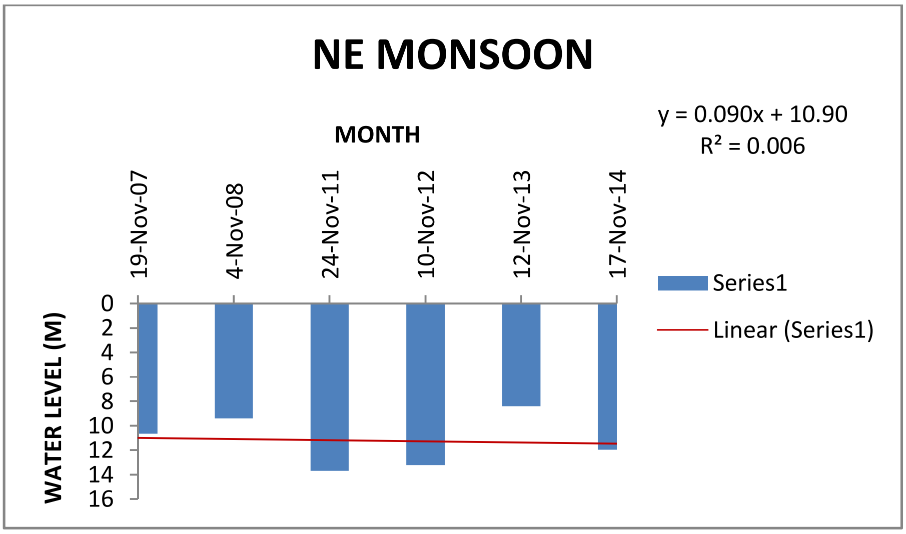


DRY SEASON	
26-Apr-04	14.89
7-Jan-05	10.63
10-Apr-05	10.26
18-Jan-06	9.22
17-Apr-06	8.66
8-Jan-07	9.75
3-Apr-07	10.2
7-Jan-08	9.54
7-Apr-08	9.82
5-Jan-09	9.22
21-Apr-09	10.95
9-Jan-10	13.7
13-Apr-10	10.45
12-Jan-11	9.4
28-Apr-11	9.32
29-Jan-12	11.5
14-Apr-12	11.57
7-Jan-13	11.2
11-Apr-13	14.2
14-Jan-14	10.73
16-Apr-14	13.28
SW MONSOON	
25-Aug-04	9.09
30-Aug-05	9.62
31-Aug-06	8.96
21-Aug-07	8.62
26-Aug-08	9.08
28-Aug-09	8.81
28-Aug-10	8.56
13-Sep-10	8.56
20-Aug-11	10.66
19-Aug-13	8.84
29-Aug-14	7.9
NE MONSOON	
10-Nov-04	7.88
10-Nov-05	8.59
4-Nov-06	8.45
19-Nov-07	8.47
4-Nov-08	8.58
21-Nov-09	8.9
7-Nov-10	7.08
10-Nov-12	9
11-Nov-13	9.57
13-Nov-14	8.12

Histogram showing depth to water table (bgl), Dug well at Edavai

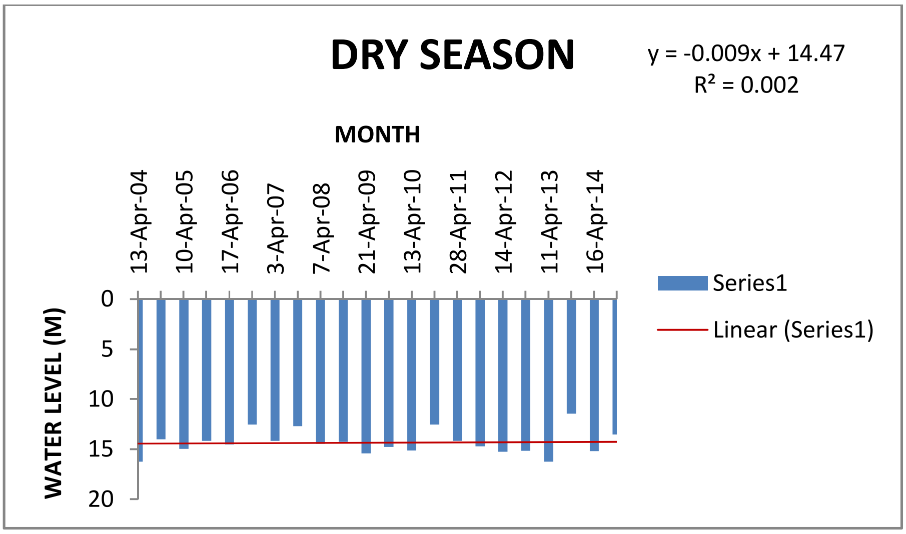


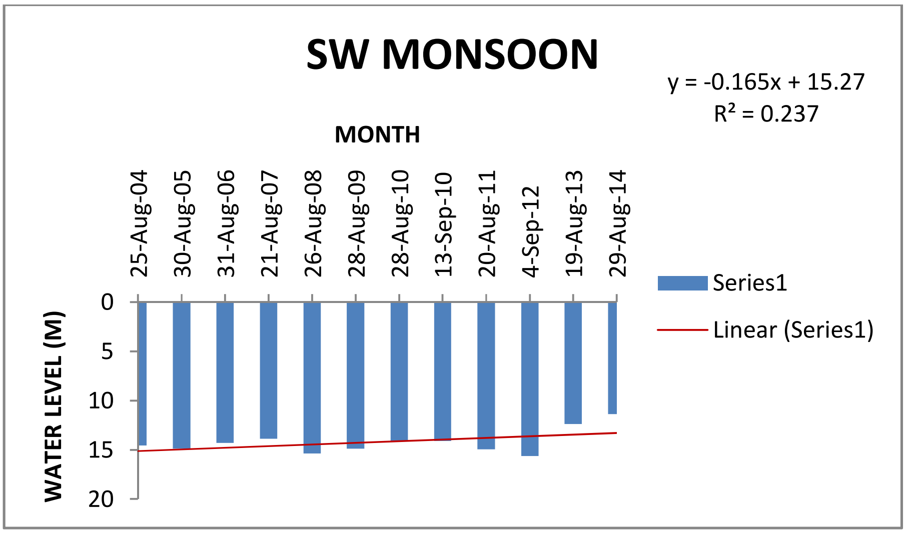


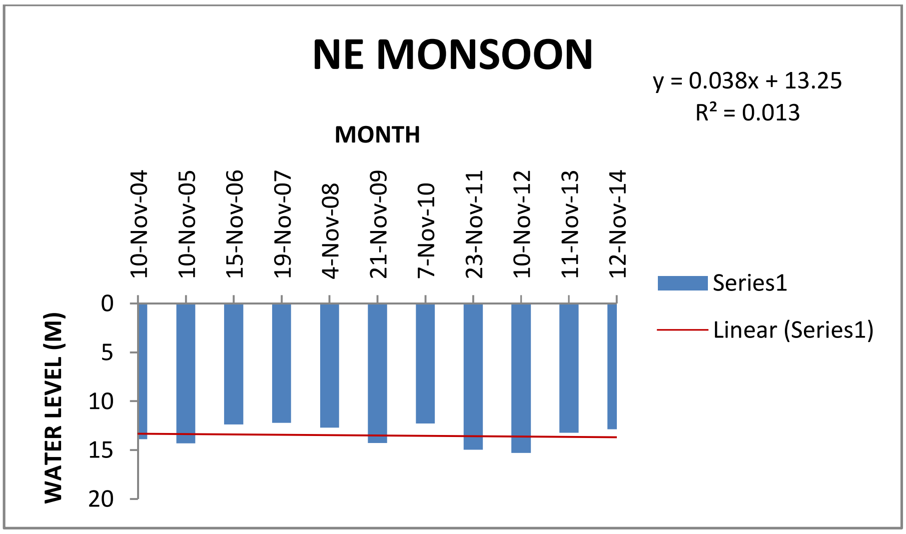


DRY SEASON	
9-Jan-07	9.75
3-Apr-07	13
7-Jan-08	12.51
8-Apr-08	12.4
6-Jan-09	12.08
27-Apr-09	13.28
16-Jan-10	20.9
19-Apr-10	12.84
13-Jan-11	10.9
28-Apr-11	11.86
30-Jan-12	12.3
14-Apr-12	14.8
7-Jan-13	12.5
11-Apr-13	13.6
22-Jan-14	11.9
30-Apr-14	12.78
9-Jan-15	12.02
SW MONSOON	
4-Nov-06	9.9
21-Aug-07	11.68
21-Aug-08	12.73
30-Aug-09	11.08
30-Aug-10	12.84
13-Sep-10	12.84
25-Aug-11	11.99
19-Aug-13	10.93
27-Aug-14	10.68
NE MONSOON	
19-Nov-07	10.64
4-Nov-08	9.4
24-Nov-11	13.7
10-Nov-12	13.23
12-Nov-13	8.4
17-Nov-14	11.97

Histogram showing depth to water table (bgl), Bore well at Manambur

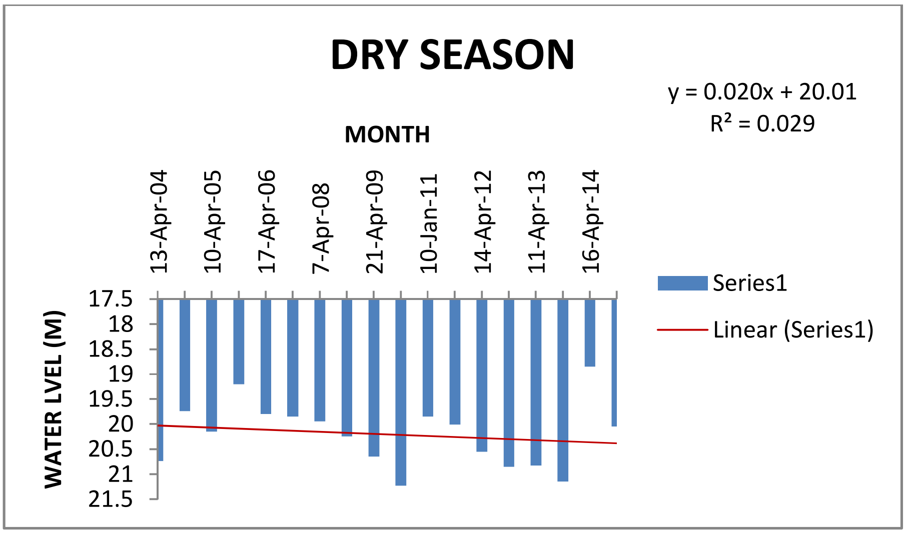


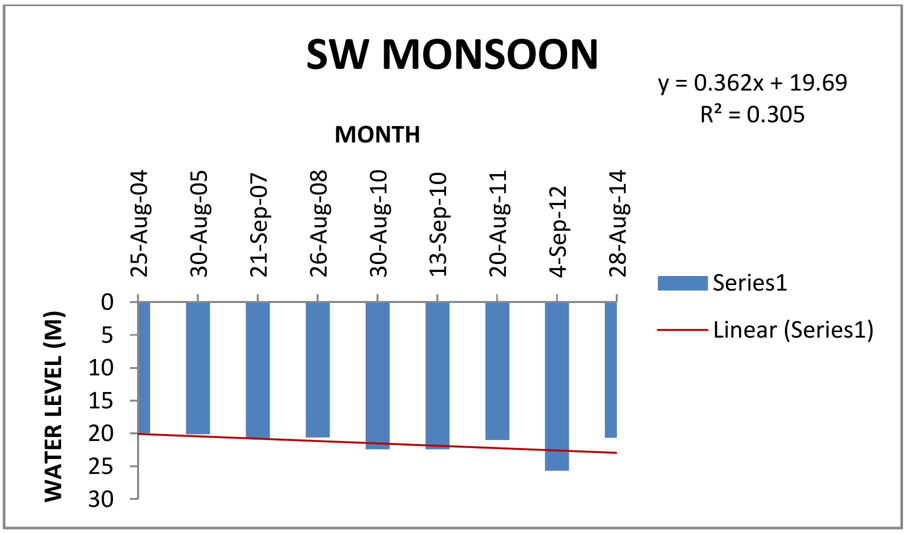


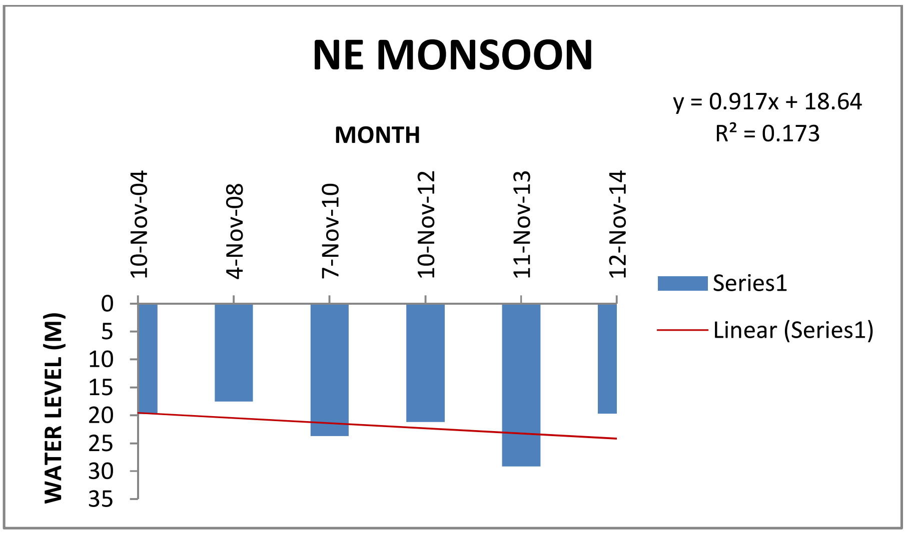


DRY SEASON	
13-Apr-04	16.26
7-Jan-05	14.01
10-Apr-05	14.99
18-Jan-06	14.16
17-Apr-06	14.56
8-Jan-07	12.55
3-Apr-07	14.16
9-Jan-08	12.7
7-Apr-08	14.48
5-Jan-09	14.27
21-Apr-09	15.43
9-Jan-10	14.81
13-Apr-10	15.15
12-Jan-11	12.54
28-Apr-11	14.16
29-Jan-12	14.73
14-Apr-12	15.26
7-Jan-13	15.16
11-Apr-13	16.26
14-Jan-14	11.46
16-Apr-14	15.21
9-Jan-15	13.54
SW MONSOON	
25-Aug-04	14.56
30-Aug-05	14.86
31-Aug-06	14.29
21-Aug-07	13.86
26-Aug-08	15.38
28-Aug-09	14.86
28-Aug-10	14.11
13-Sep-10	14.11
20-Aug-11	14.95
4-Sep-12	15.63
19-Aug-13	12.36
29-Aug-14	11.36
NE MONSOON	
10-Nov-04	13.88
10-Nov-05	14.3
15-Nov-06	12.4
19-Nov-07	12.2
4-Nov-08	12.7
21-Nov-09	14.26
7-Nov-10	12.27
23-Nov-11	14.96
10-Nov-12	15.28
11-Nov-13	13.21
12-Nov-14	12.86

Histogram showing depth to water table (bgl), Dug well at Varkala

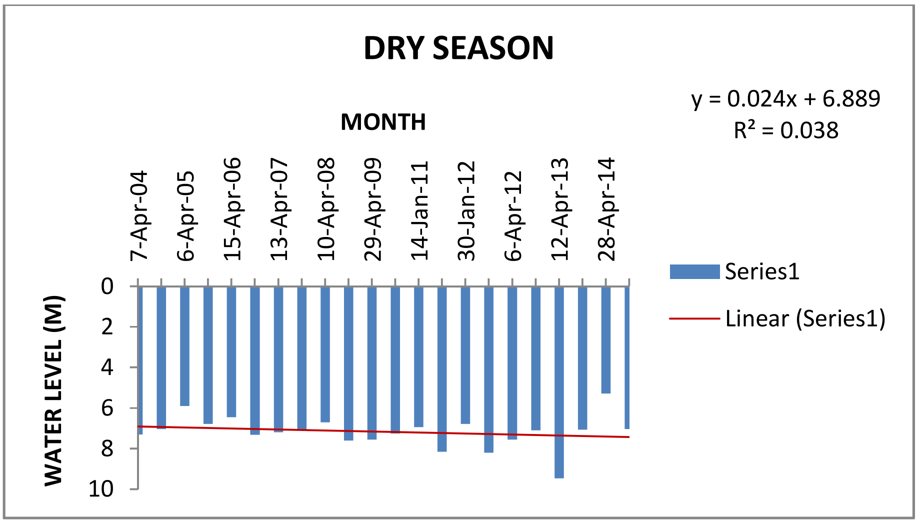


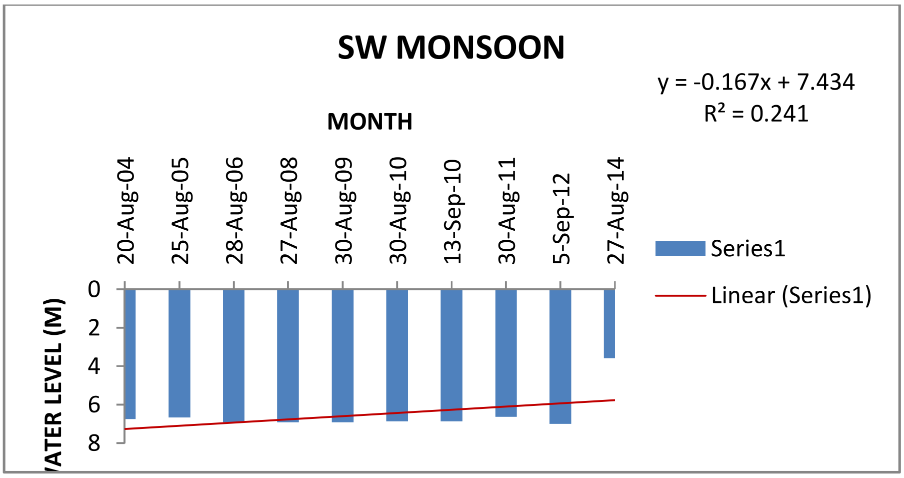


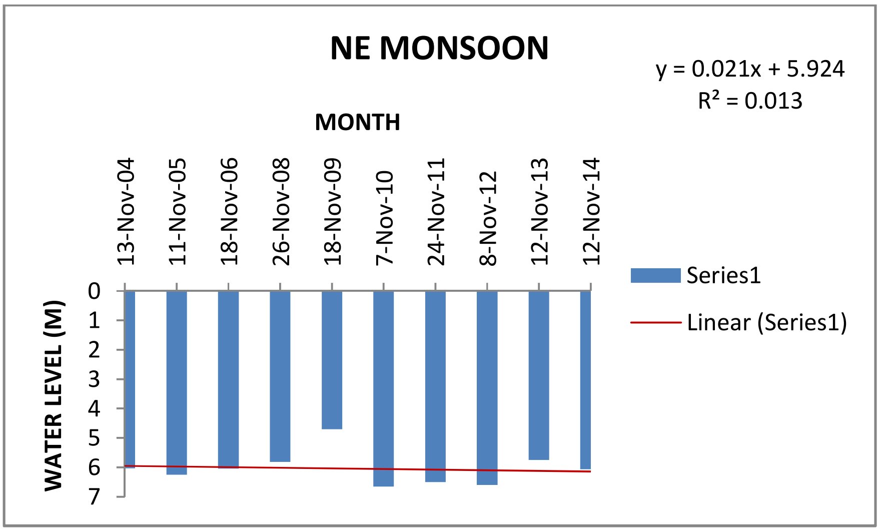


Histogram showing depth to water table (bgl), Tube well at Varkala Deep

DRY SEASON	
13-Apr-04	20.74
7-Jan-05	19.74
10-Apr-05	20.15
18-Jan-06	19.2
17-Apr-06	19.8
3-Apr-07	19.85
7-Apr-08	19.95
5-Jan-09	20.25
21-Apr-09	20.65
13-Apr-10	21.23
10-Jan-11	19.85
28-Apr-11	20.01
14-Apr-12	20.55
7-Jan-13	20.85
11-Apr-13	20.83
14-Jan-14	21.15
16-Apr-14	18.85
9-Jan-15	20.05
SW MONSOON	
25-Aug-04	20
30-Aug-05	20.12
21-Sep-07	20.72
26-Aug-08	20.58
30-Aug-10	22.4
13-Sep-10	22.4
20-Aug-11	21.02
4-Sep-12	25.69
28-Aug-14	20.65
NE MONSOON	
10-Nov-04	19.78
4-Nov-08	17.53
7-Nov-10	23.75
10-Nov-12	21.16
11-Nov-13	29.15
12-Nov-14	19.75





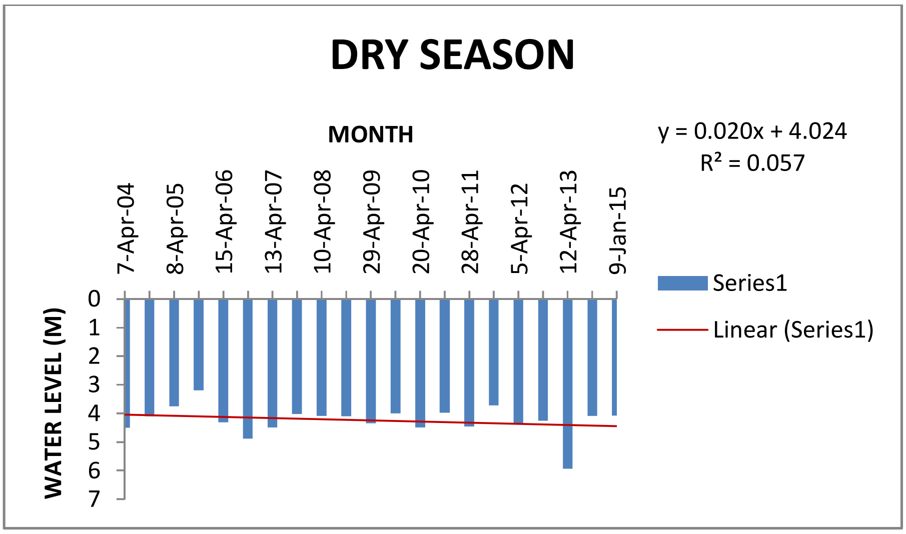


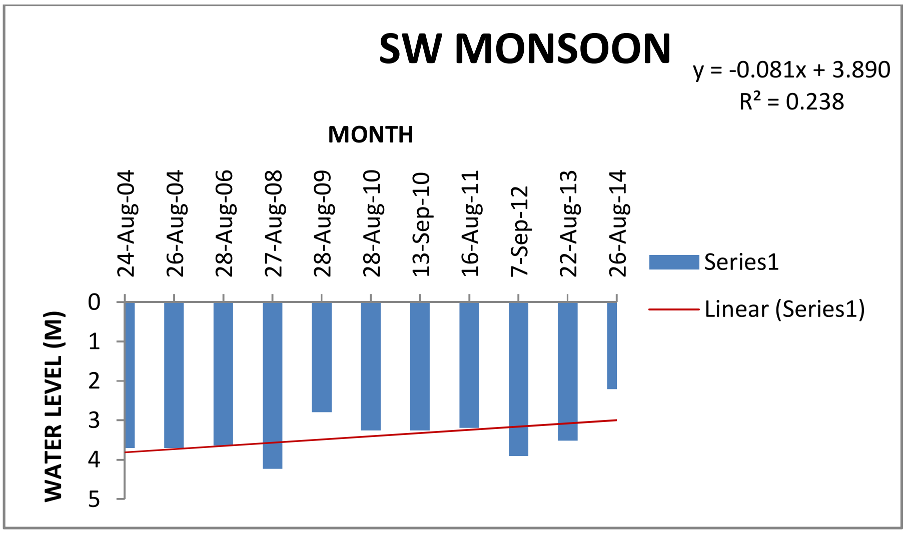
DRY SEASON	
7-Apr-04	7.31
12-Jan-05	7.03
6-Apr-05	5.9
2-Jan-06	6.79
15-Apr-06	6.45
10-Jan-07	7.32
13-Apr-07	7.2
8-Jan-08	7.08
10-Apr-08	6.72
7-Jan-09	7.6
29-Apr-09	7.55
20-Apr-10	7.27
14-Jan-11	6.95
28-Apr-11	8.15
30-Jan-12	6.79
5-Apr-12	8.2
6-Apr-12	7.55
8-Jan-13	7.1
12-Apr-13	9.46
14-Jan-14	7.07
28-Apr-14	5.28
9-Jan-15	7.03

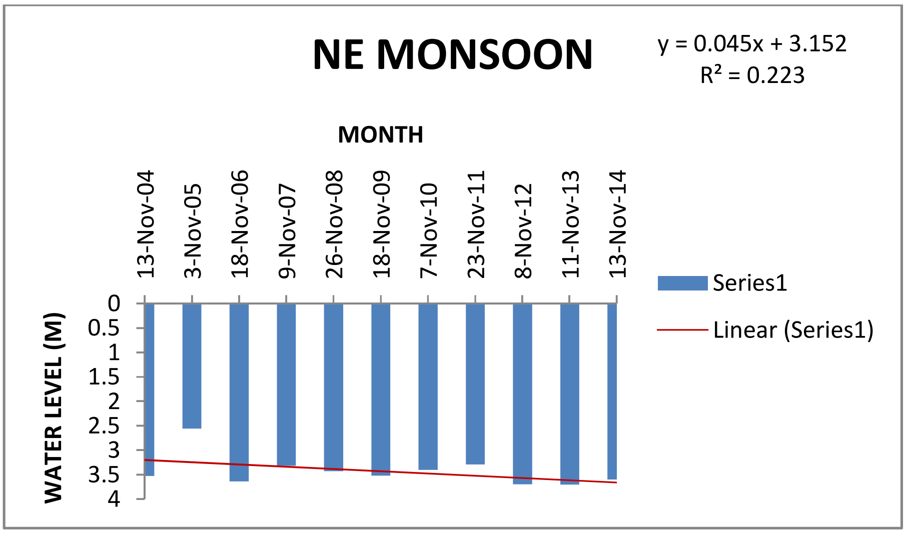
SW MONSOON	
20-Aug-04	6.75
25-Aug-05	6.67
28-Aug-06	6.91
27-Aug-08	6.91
30-Aug-09	6.91
30-Aug-10	6.87
13-Sep-10	6.87
30-Aug-11	6.63
5-Sep-12	7
27-Aug-14	3.59

NE MONSOON	
13-Nov-04	6.04
11-Nov-05	6.25
18-Nov-06	6.05
26-Nov-08	5.81
18-Nov-09	4.7
7-Nov-10	6.65
24-Nov-11	6.5
8-Nov-12	6.6
12-Nov-13	5.75
12-Nov-14	6.07

Histogram showing depth to water table (bgl),Bore well at Ariyanadu

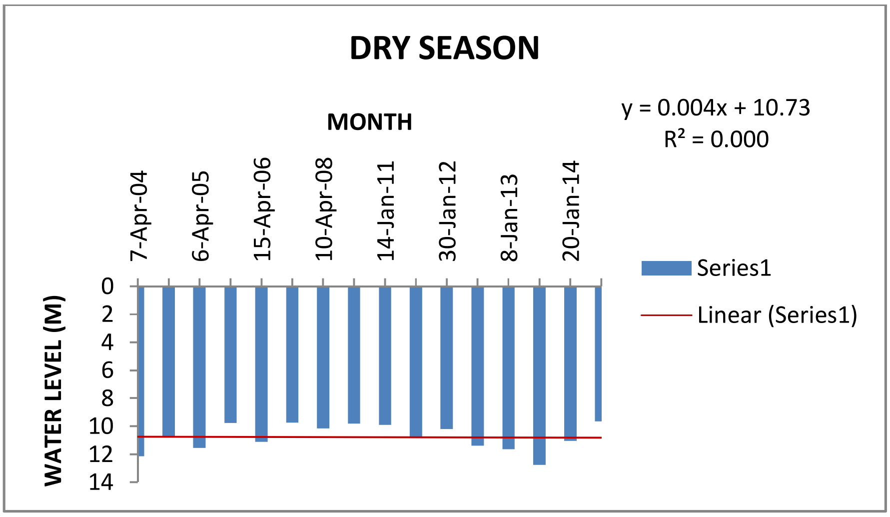


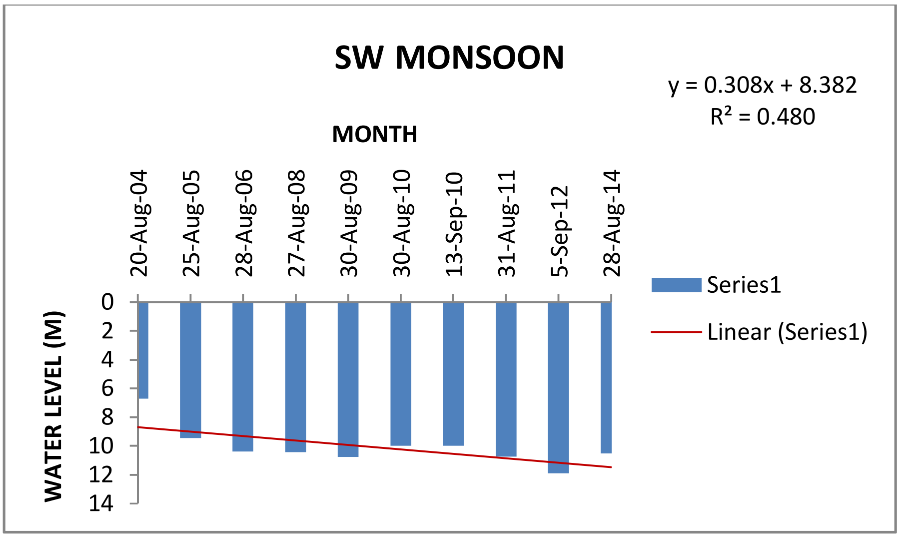


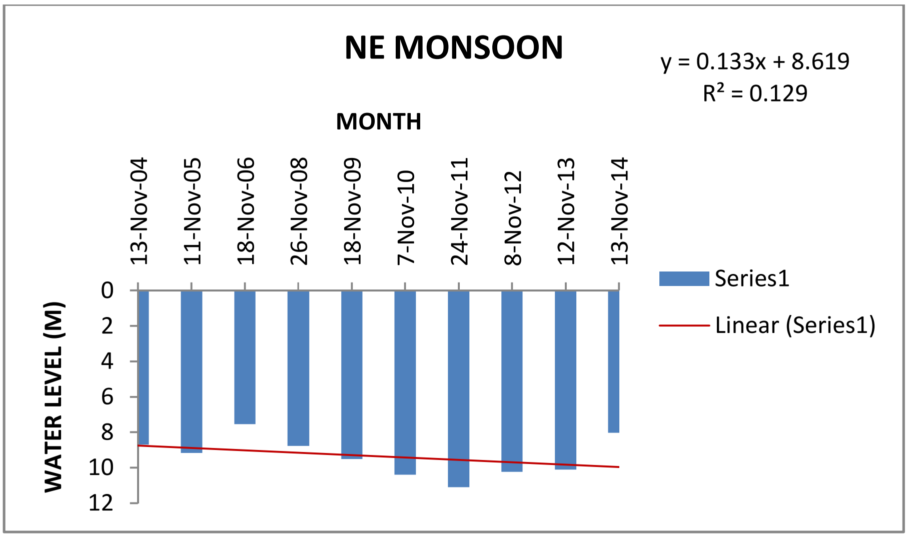


Histogram showing depth to water table (bgl), Dug well at Kallar

DRY SEASON	
7-Apr-04	4.5
8-Jan-05	4.1
8-Apr-05	3.75
4-Jan-06	3.2
15-Apr-06	4.32
10-Jan-07	4.88
13-Apr-07	4.49
8-Jan-08	4.02
10-Apr-08	4.09
7-Jan-09	4.1
29-Apr-09	4.35
14-Jan-10	4
20-Apr-10	4.49
14-Jan-11	3.98
28-Apr-11	4.46
29-Jan-12	3.72
5-Apr-12	4.36
8-Jan-13	4.26
12-Apr-13	5.94
20-Jan-14	4.09
9-Jan-15	4.08
SW MONSOON	
24-Aug-04	3.7
26-Aug-04	3.7
28-Aug-06	3.64
27-Aug-08	4.23
28-Aug-09	2.79
28-Aug-10	3.26
13-Sep-10	3.26
16-Aug-11	3.19
7-Sep-12	3.91
22-Aug-13	3.52
26-Aug-14	2.21
NE MONSOON	
13-Nov-04	3.53
3-Nov-05	2.56
18-Nov-06	3.64
9-Nov-07	3.32
26-Nov-08	3.43
18-Nov-09	3.52
7-Nov-10	3.4
23-Nov-11	3.29
8-Nov-12	3.7
11-Nov-13	3.71
13-Nov-14	3.6





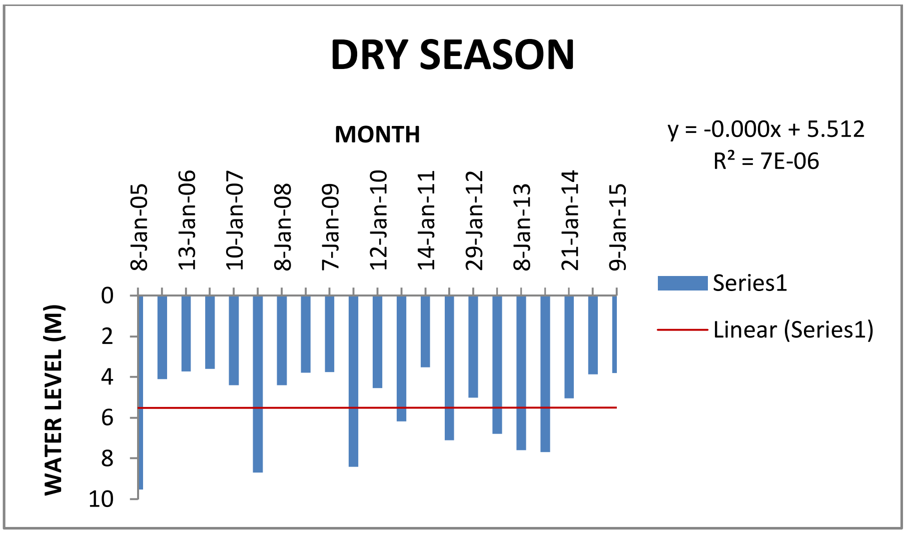


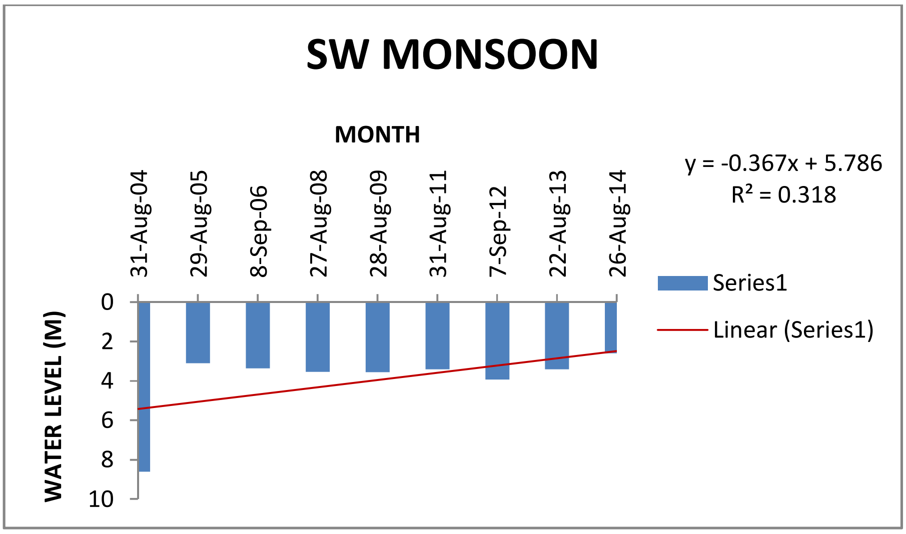
Histogram showing depth to water table (bgl), Bore well at Mithranikethan

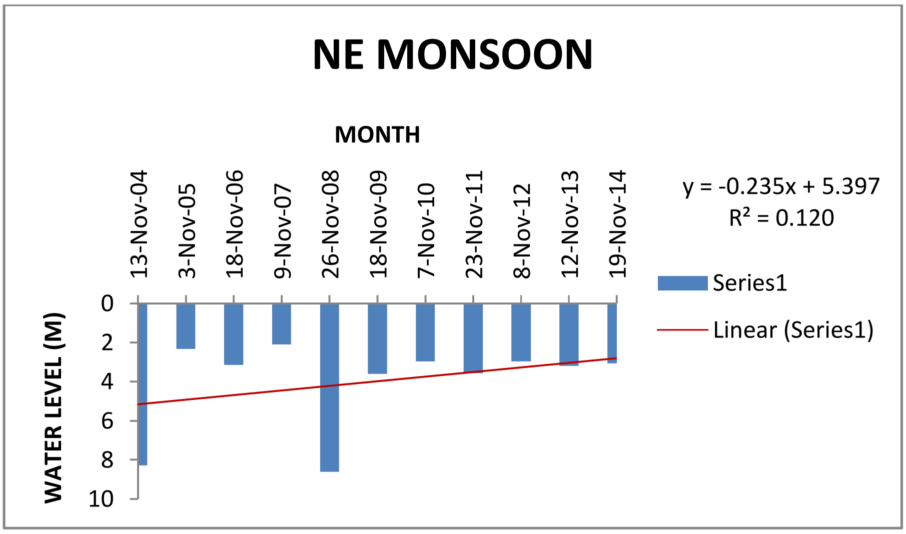
DRY SEASON	
7-Apr-04	12.16
8-Jan-05	10.71
6-Apr-05	11.55
2-Jan-06	9.77
15-Apr-06	11.1
10-Jan-07	9.75
10-Apr-08	10.14
7-Jan-09	9.82
14-Jan-11	9.9
28-Apr-11	10.8
30-Jan-12	10.2
14-Apr-12	11.4
8-Jan-13	11.64
12-Apr-13	12.75
20-Jan-14	11.05
9-Jan-15	9.66

SW MONSOON	
20-Aug-04	6.71
25-Aug-05	9.44
28-Aug-06	10.38
27-Aug-08	10.42
30-Aug-09	10.77
30-Aug-10	9.98
13-Sep-10	9.98
31-Aug-11	10.72
5-Sep-12	11.9
28-Aug-14	10.5

NE MONSOON	
13-Nov-04	8.7
11-Nov-05	9.17
18-Nov-06	7.53
26-Nov-08	8.76
18-Nov-09	9.5
7-Nov-10	10.4
24-Nov-11	11.1
8-Nov-12	10.25
12-Nov-13	10.11
13-Nov-14	8.03

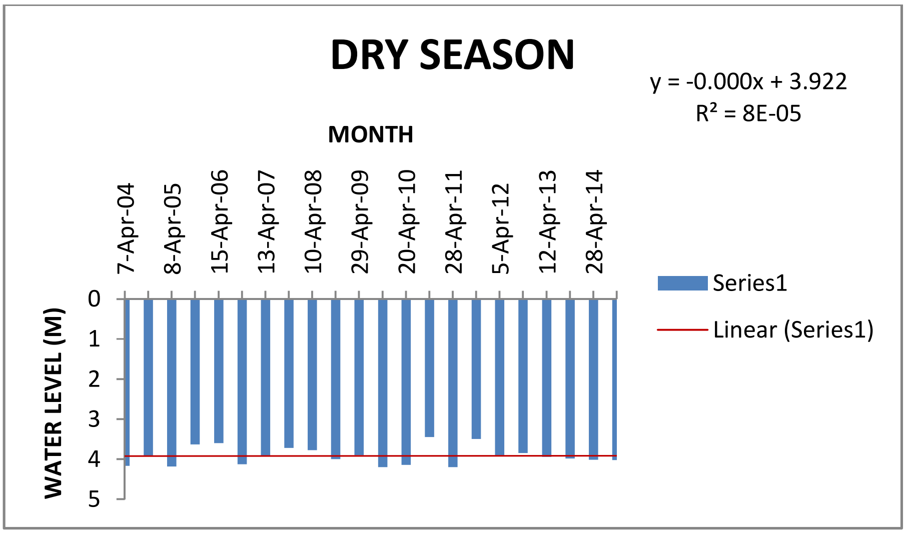


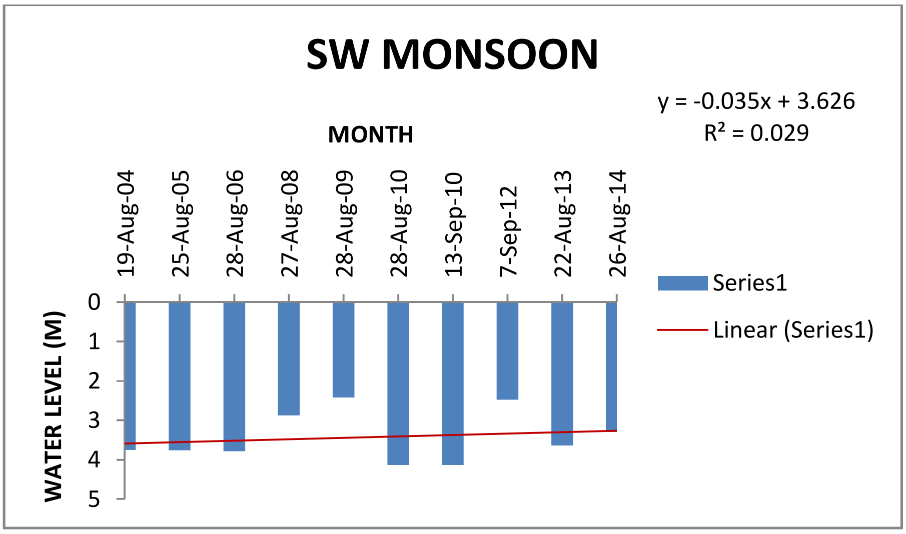


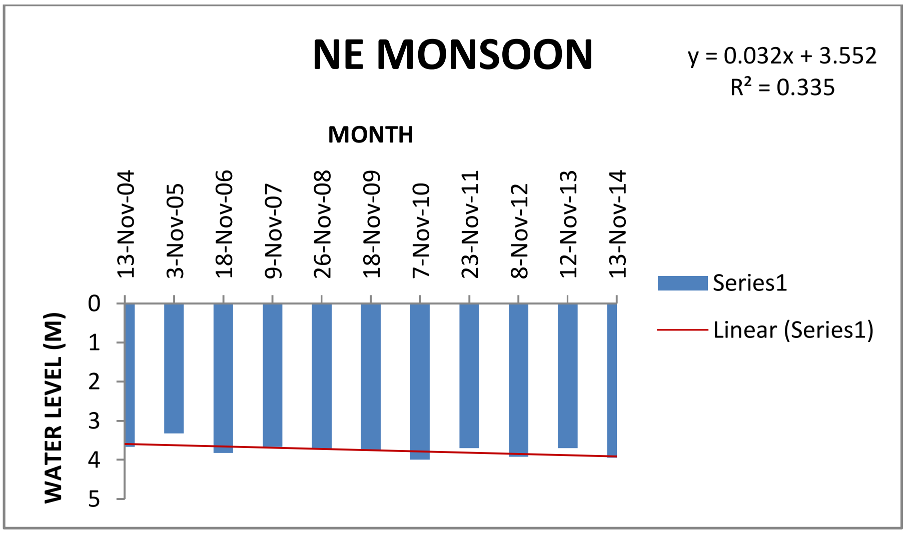


DRY SEASON	
8-Jan-05	9.52
8-Apr-05	4.1
13-Jan-06	3.72
15-Apr-06	3.6
10-Jan-07	4.4
11-Apr-07	8.7
8-Jan-08	4.41
10-Apr-08	3.78
7-Jan-09	3.75
29-Apr-09	8.41
12-Jan-10	4.55
20-Apr-10	6.19
14-Jan-11	3.52
28-Apr-11	7.1
29-Jan-12	5.02
5-Apr-12	6.8
8-Jan-13	7.6
12-Apr-13	7.68
21-Jan-14	5.05
29-Apr-14	3.87
9-Jan-15	3.8
SW MONSOON	
31-Aug-04	8.61
29-Aug-05	3.1
8-Sep-06	3.35
27-Aug-08	3.55
28-Aug-09	3.56
31-Aug-11	3.42
7-Sep-12	3.92
22-Aug-13	3.42
26-Aug-14	2.6
NE MONSOON	
13-Nov-04	8.28
3-Nov-05	2.32
18-Nov-06	3.16
9-Nov-07	2.1
26-Nov-08	8.61
18-Nov-09	3.6
7-Nov-10	2.96
23-Nov-11	3.57
8-Nov-12	2.96
12-Nov-13	3.2
19-Nov-14	3.05

Histogram showing depth to water table (bgl), Dug well at Palode

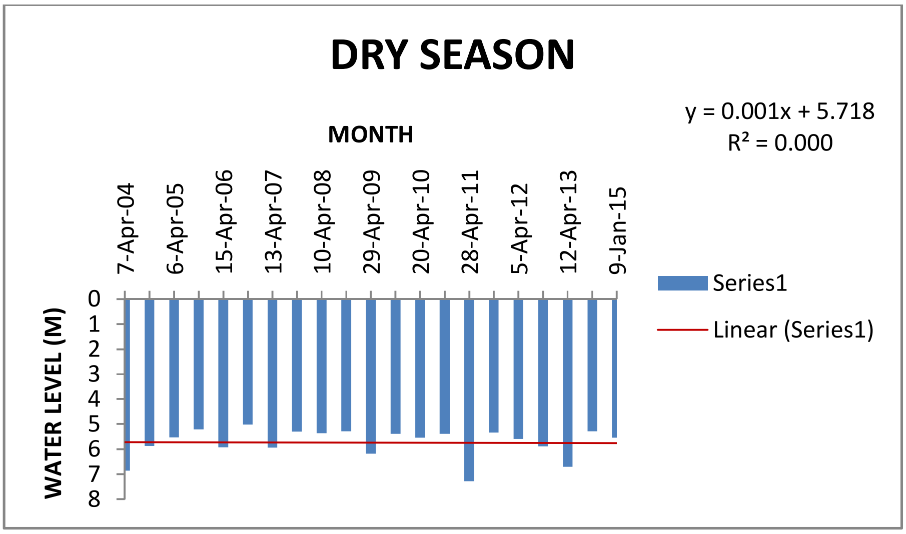


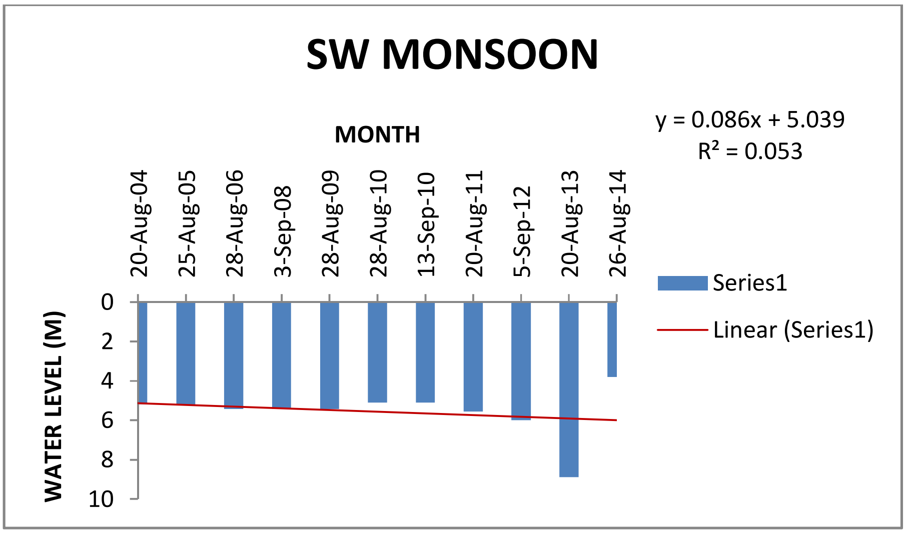


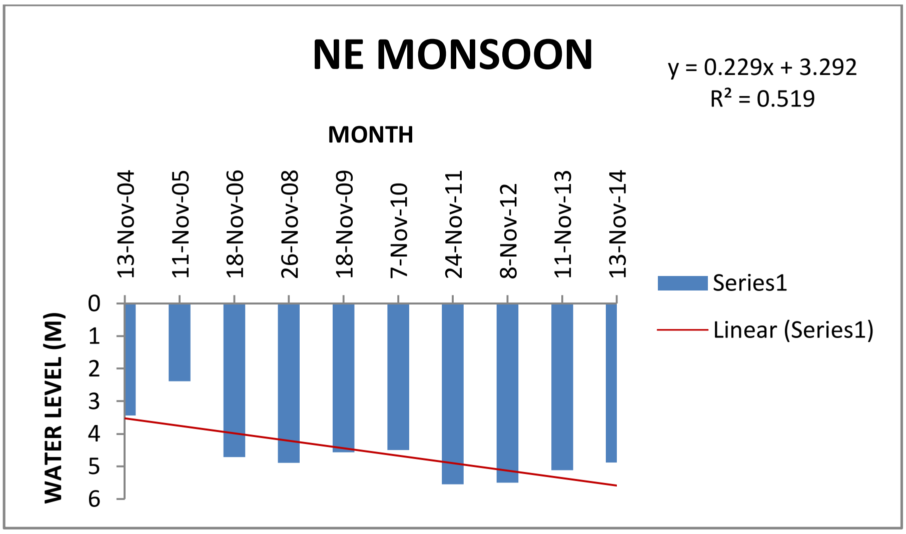


Histogram showing depth to water table (bgl), Dug well at Ponmudi

DRY SEASON	
7-Apr-04	4.17
8-Jan-05	3.93
8-Apr-05	4.18
4-Jan-06	3.64
15-Apr-06	3.6
10-Jan-07	4.13
13-Apr-07	3.93
8-Jan-08	3.72
10-Apr-08	3.78
7-Jan-09	4
29-Apr-09	3.9
14-Jan-10	4.2
20-Apr-10	4.14
15-Jan-11	3.45
28-Apr-11	4.2
29-Jan-12	3.5
5-Apr-12	3.9
8-Jan-13	3.85
12-Apr-13	3.95
20-Jan-14	3.99
28-Apr-14	4.02
9-Jan-15	4.03
SW MONSOON	
19-Aug-04	3.75
25-Aug-05	3.76
28-Aug-06	3.79
27-Aug-08	2.87
28-Aug-09	2.42
28-Aug-10	4.14
13-Sep-10	4.14
7-Sep-12	2.48
22-Aug-13	3.64
26-Aug-14	3.3
NE MONSOON	
13-Nov-04	3.67
3-Nov-05	3.32
18-Nov-06	3.82
9-Nov-07	3.66
26-Nov-08	3.72
18-Nov-09	3.75
7-Nov-10	4
23-Nov-11	3.7
8-Nov-12	3.92
12-Nov-13	3.7
13-Nov-14	3.94

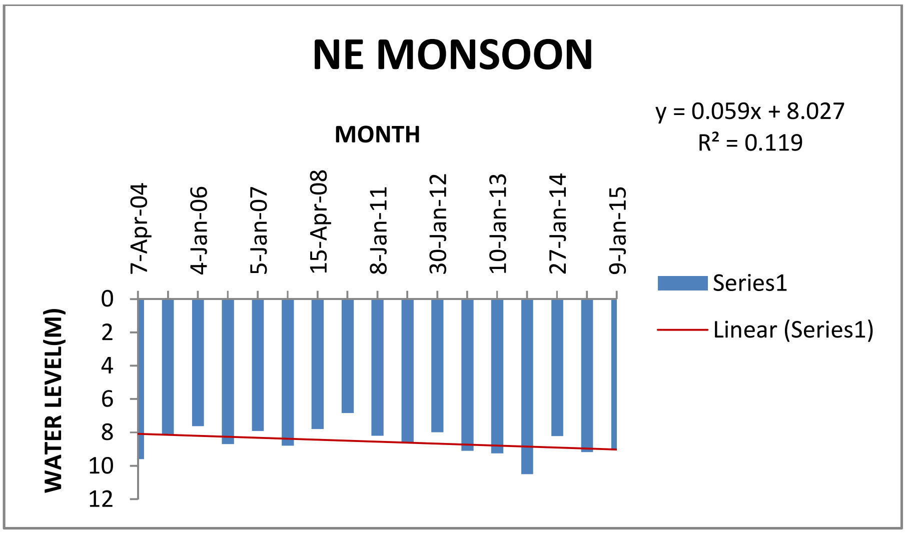


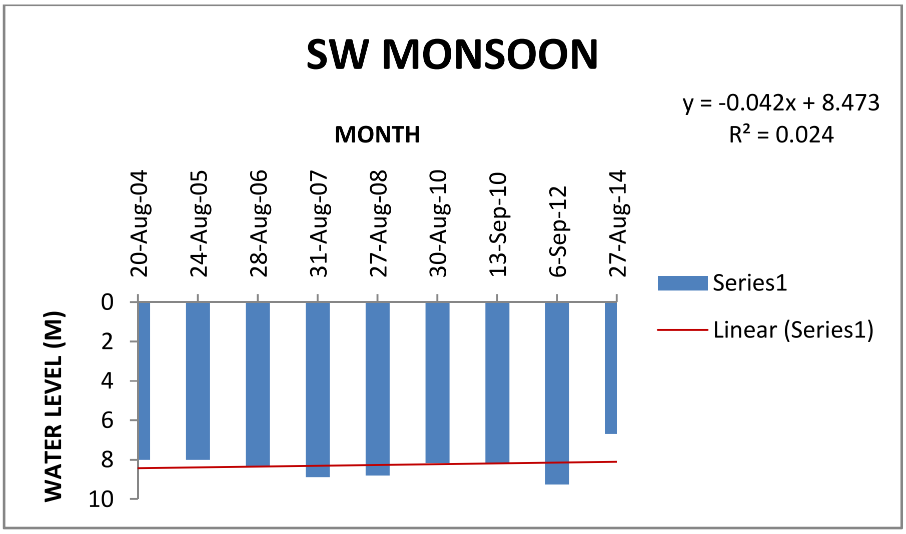


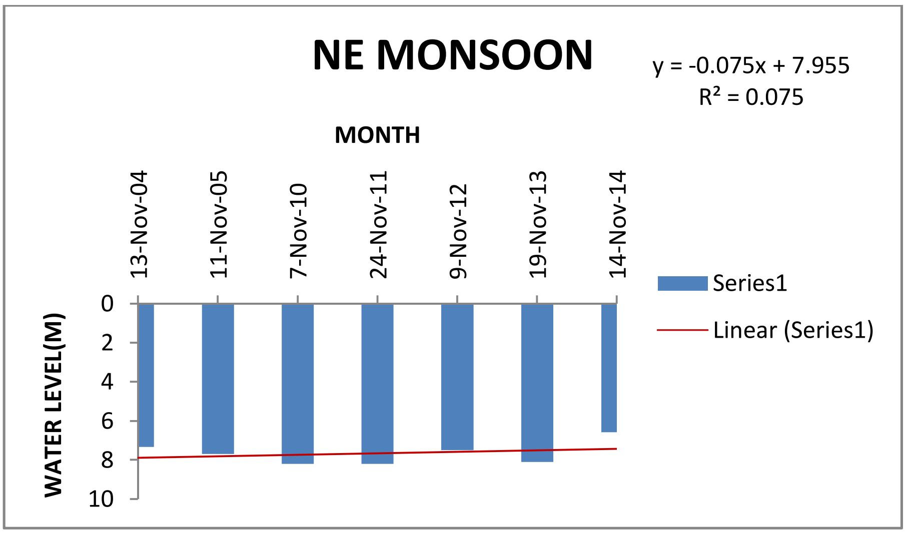


DRY SEASON	
7-Apr-04	6.87
8-Jan-05	5.88
6-Apr-05	5.53
2-Jan-06	5.21
15-Apr-06	5.93
10-Jan-07	5.02
13-Apr-07	5.94
8-Jan-08	5.3
10-Apr-08	5.37
7-Jan-09	5.28
29-Apr-09	6.18
14-Jan-10	5.4
20-Apr-10	5.54
14-Jan-11	5.4
28-Apr-11	7.29
29-Jan-12	5.35
5-Apr-12	5.6
8-Jan-13	5.9
12-Apr-13	6.7
20-Jan-14	5.28
9-Jan-15	5.55
SW MONSOON	
20-Aug-04	5.18
25-Aug-05	5.22
28-Aug-06	5.42
3-Sep-08	5.43
28-Aug-09	5.42
28-Aug-10	5.1
13-Sep-10	5.1
20-Aug-11	5.55
5-Sep-12	6
20-Aug-13	8.9
26-Aug-14	3.8
NE MONSOON	
13-Nov-04	3.44
11-Nov-05	2.39
18-Nov-06	4.71
26-Nov-08	4.89
18-Nov-09	4.57
7-Nov-10	4.5
24-Nov-11	5.55
8-Nov-12	5.5
11-Nov-13	5.11
13-Nov-14	4.88

Histogram showing depth to water table (bgl), Dug well at Vellanad

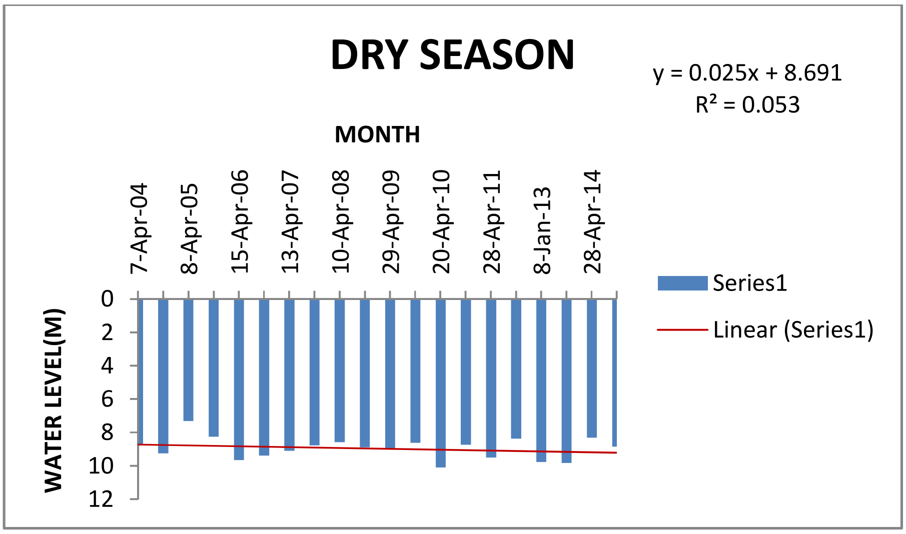


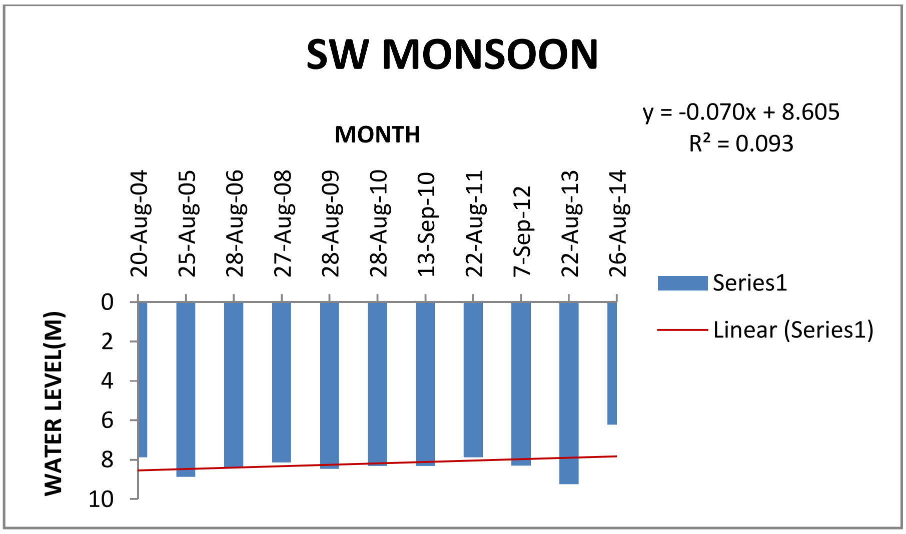


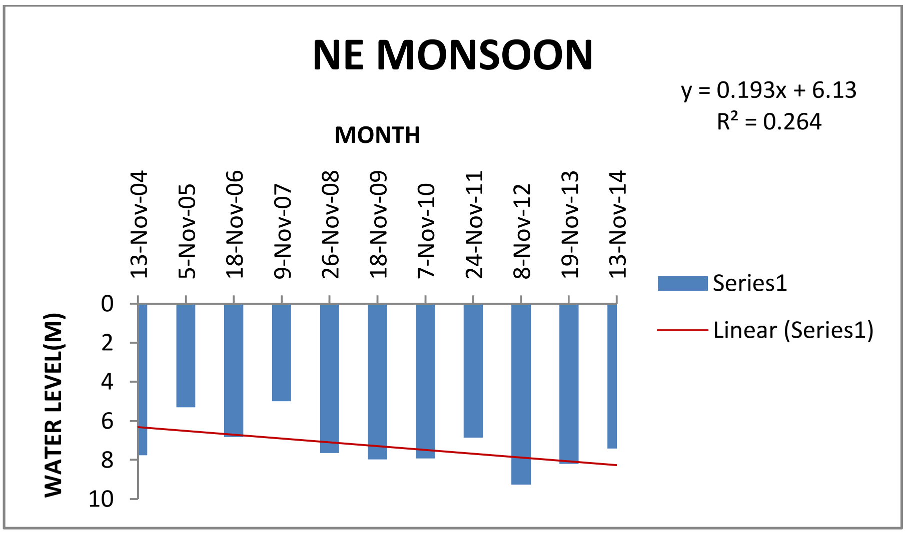


DRY SEASON	
7-Apr-04	9.6
8-Jan-05	8.13
4-Jan-06	7.62
15-Apr-06	8.71
5-Jan-07	7.9
11-Apr-07	8.8
15-Apr-08	7.79
9-Jan-09	6.85
8-Jan-11	8.2
28-Apr-11	8.58
30-Jan-12	8
14-Apr-12	9.1
10-Jan-13	9.26
15-Apr-13	10.5
27-Jan-14	8.22
24-Apr-14	9.17
9-Jan-15	9.07
SW MONSOON	
20-Aug-04	8
24-Aug-05	8
28-Aug-06	8.34
31-Aug-07	8.9
27-Aug-08	8.82
30-Aug-10	8.18
13-Sep-10	8.18
6-Sep-12	9.25
27-Aug-14	6.69
NE MONSOON	
13-Nov-04	7.32
11-Nov-05	7.69
7-Nov-10	8.2
24-Nov-11	8.2
9-Nov-12	7.5
19-Nov-13	8.1
14-Nov-14	6.58

Histogram showing depth to water table (bgl), Bore well at Vilappilsala



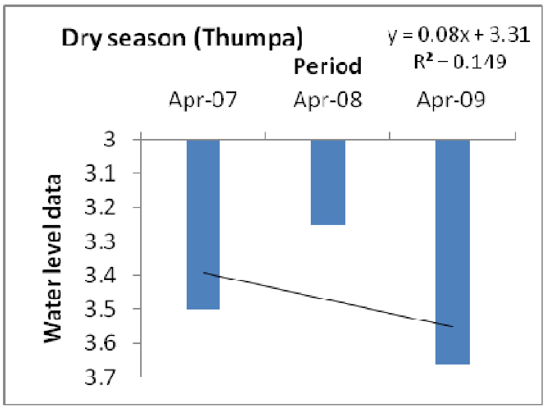


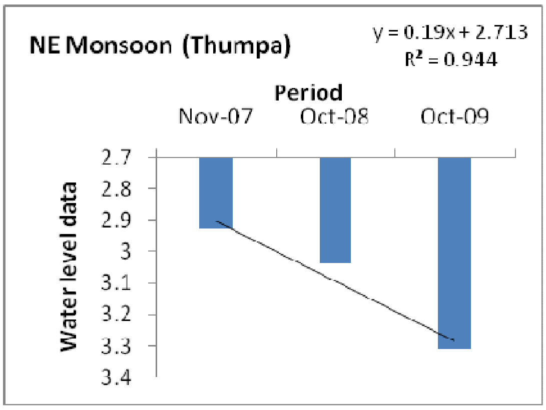


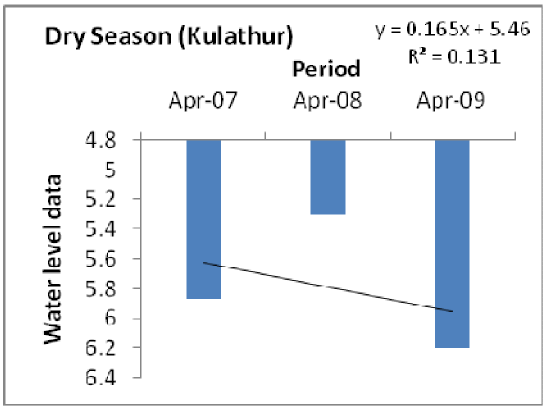
DRY SEASON	
7-Apr-04	8.78
8-Jan-05	9.26
8-Apr-05	7.32
4-Jan-06	8.26
15-Apr-06	9.67
10-Jan-07	9.39
13-Apr-07	9.11
8-Jan-08	8.79
10-Apr-08	8.58
7-Jan-09	8.89
29-Apr-09	9.01
14-Jan-10	8.62
20-Apr-10	10.1
13-Jan-11	8.74
28-Apr-11	9.52
29-Jan-12	8.38
8-Jan-13	9.77
20-Jan-14	9.83
28-Apr-14	8.32
9-Jan-15	8.86
SW MONSOON	
20-Aug-04	7.88
25-Aug-05	8.87
28-Aug-06	8.39
27-Aug-08	8.14
28-Aug-09	8.46
28-Aug-10	8.32
13-Sep-10	8.32
22-Aug-11	7.88
7-Sep-12	8.31
22-Aug-13	9.24
26-Aug-14	6.22
NE MONSOON	
13-Nov-04	7.75
5-Nov-05	5.31
18-Nov-06	6.83
9-Nov-07	5
26-Nov-08	7.64
18-Nov-09	7.97
7-Nov-10	7.92
24-Nov-11	6.87
8-Nov-12	9.27
19-Nov-13	8.2
13-Nov-14	7.42

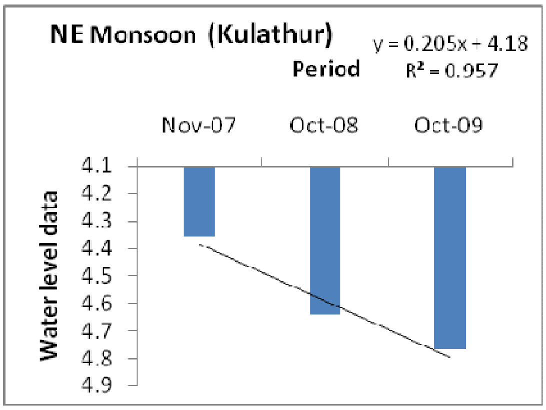
Histogram showing depth to water table (bgl), Dug well at Vithura

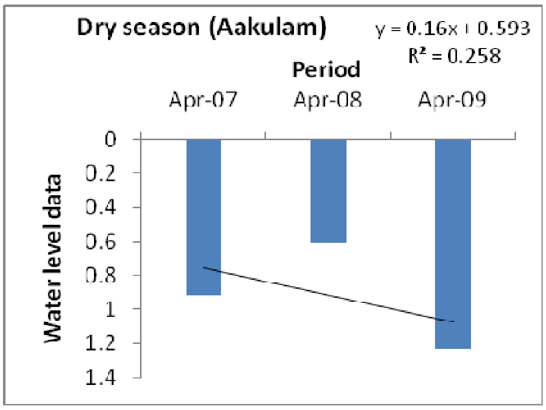
Annexure 2 **Histograms of Water Table fluctuation trends, TUA**

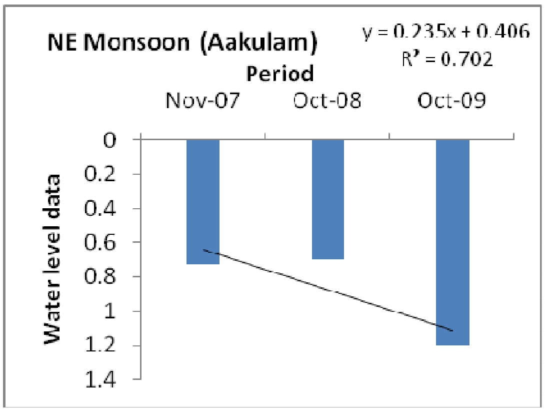


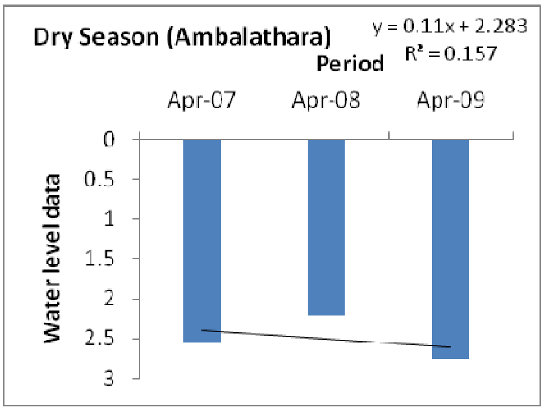


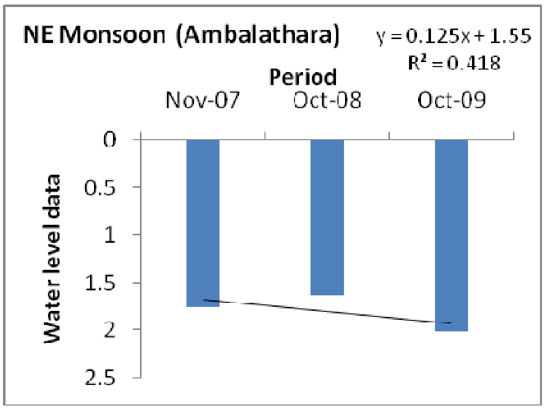




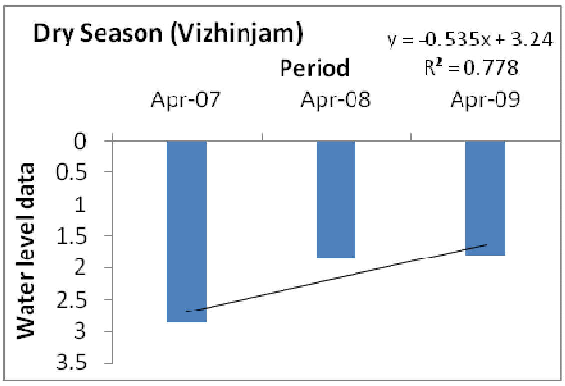


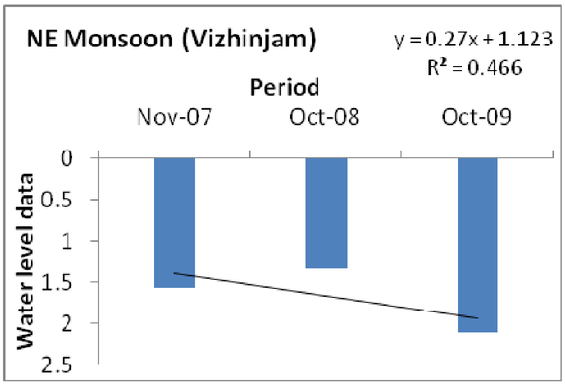


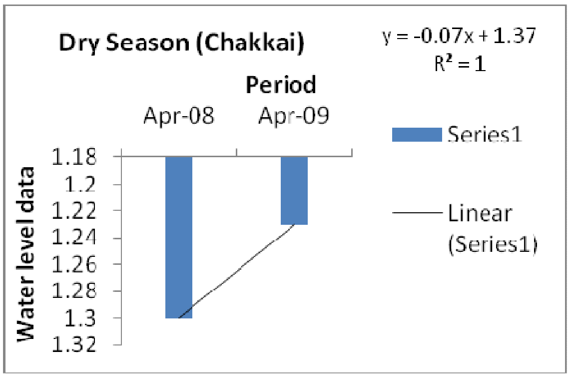


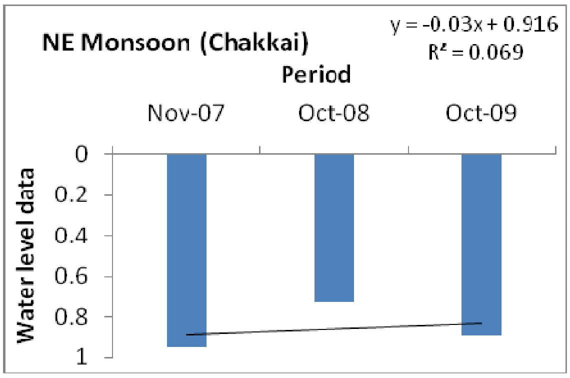


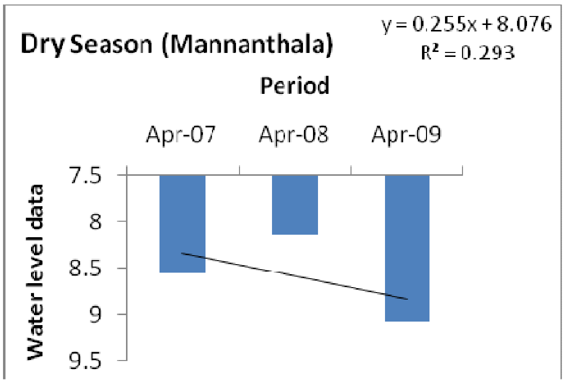
Dry Season (Thumpa)	
Apr-07	3.5
Apr-08	3.25
Apr-09	3.66
NE Monsoon	
Nov-07	2.93
Oct-08	3.04
Oct-09	3.31
Dry Season (Kulathur)	
Apr-07	5.87
Apr-08	5.3
Apr-09	6.2
NE Monsoon	
Nov-07	4.36
Oct-08	4.64
Oct-09	4.77
Dry Season (Aakulam)	
Apr-07	0.91
Apr-08	0.6
Apr-09	1.23
NE Monsoon	
Nov-07	0.73
Oct-08	0.7
Oct-09	1.2
Dry Season (Ambalathara)	
Apr-07	2.54
Apr-08	2.21
Apr-09	2.76
NE Monsoon	
Nov-07	1.76
Oct-08	1.63
Oct-09	2.01

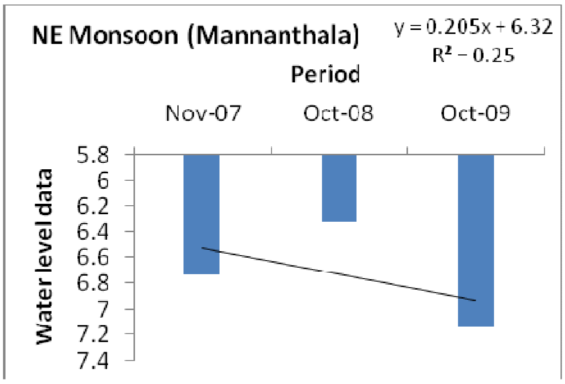


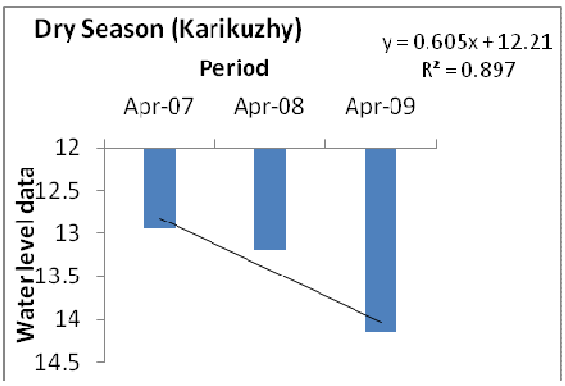


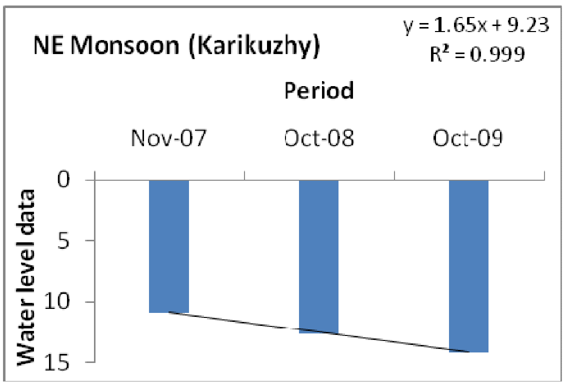




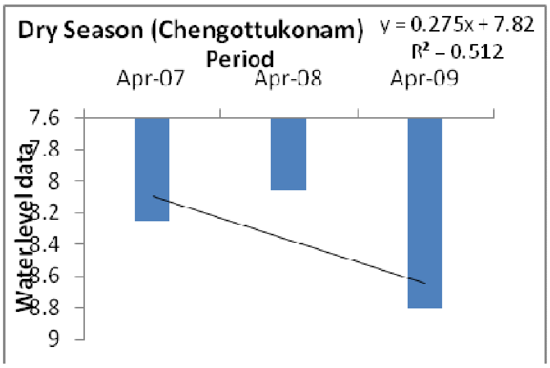


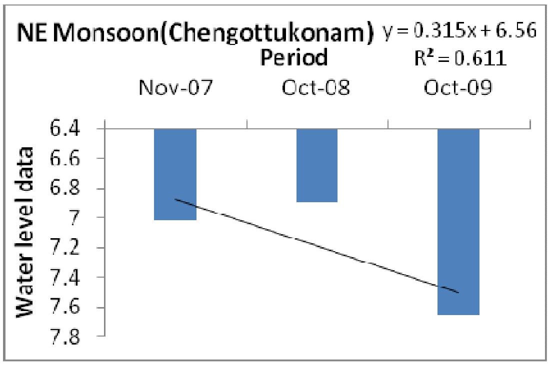


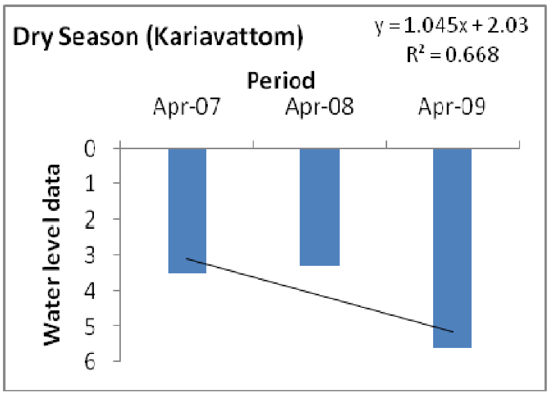


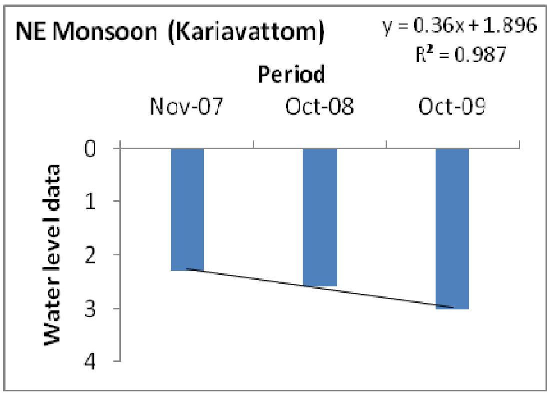


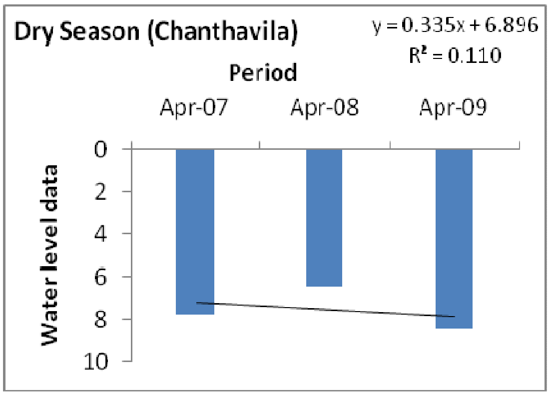
Dry Season (Vizhinjam)	
Apr-07	2.87
Apr-08	1.84
Apr-09	1.8
NE Monsoon	
Nov-07	1.56
Oct-08	1.33
Oct-09	2.1
Dry Season (Chakkai)	
Apr-08	1.3
Apr-09	1.23
NE Monsoon	
Nov-07	0.95
Oct-08	0.73
Oct-09	0.89
Dry Season (Mannanthala)	
Apr-07	8.56
Apr-08	8.13
Apr-09	9.07
NE Monsoon	
Nov-07	6.73
Oct-08	6.32
Oct-09	7.14
Dry Season (Karikuzhy)	
Apr-07	12.94
Apr-08	13.19
Apr-09	14.15
NE Monsoon	
Nov-07	10.85
Oct-08	12.59
Oct-09	14.15

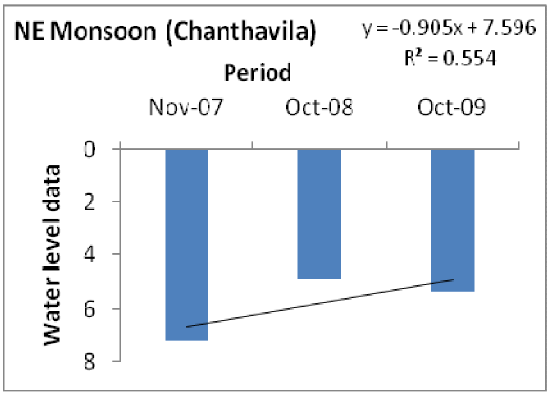


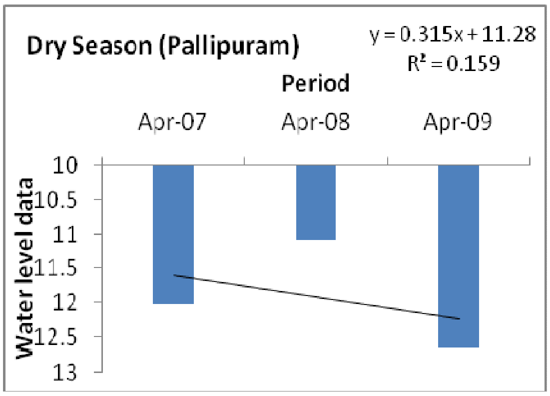


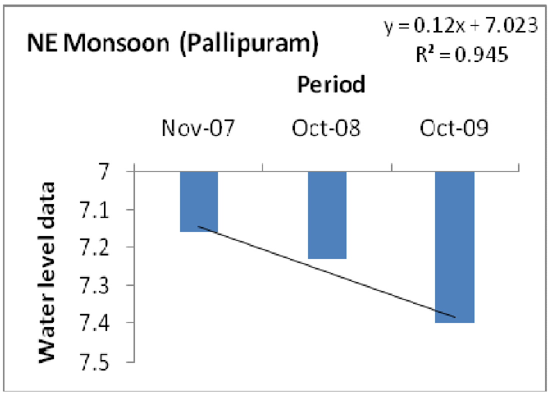




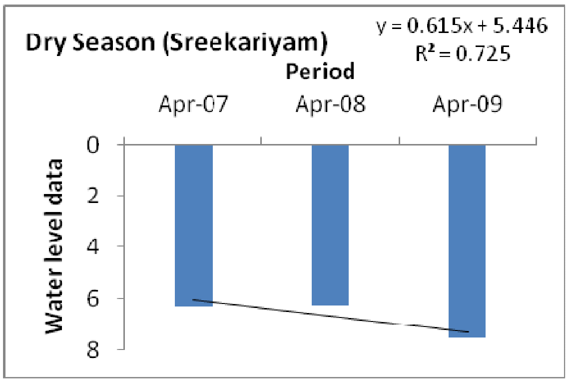


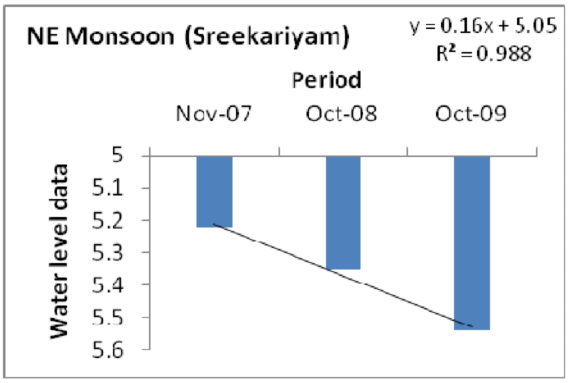


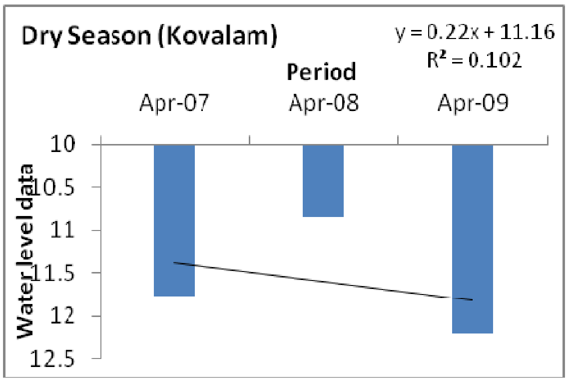


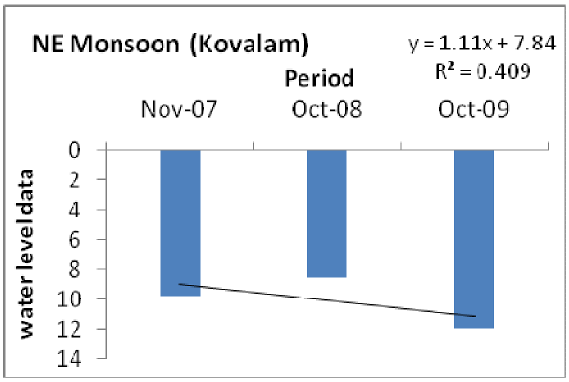


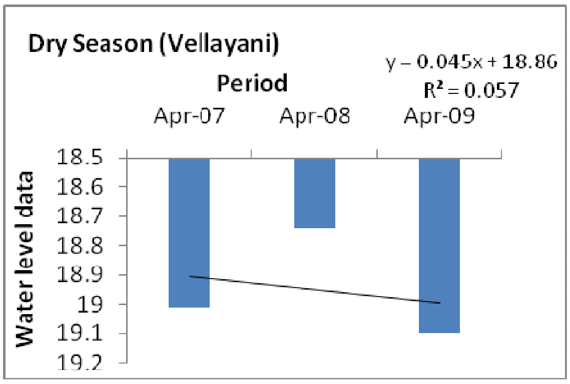
Dry Season (Chengottukonam)	
Apr-07	8.3
Apr-08	8.1
Apr-09	8.8
NE Monsoon	
Nov-07	7
Oct-08	6.9
Oct-09	7.7
Dry Season (Kariyavattom)	
Apr-07	3.5
Apr-08	3.3
Apr-09	5.6
NE Monsoon	
Nov-07	2.3
Oct-08	2.6
Oct-09	3
Dry Season (Chanthavila)	
Apr-07	7.8
Apr-08	6.5
Apr-09	8.5
NE Monsoon	
Nov-07	7.2
Oct-08	4.9
Oct-09	5.4
Dry Season Pallipuram)	
Apr-07	12
Apr-08	11
Apr-09	12.7
NE Monsoon	
Nov-07	7.2
Oct-08	7.2
Oct-09	7.4

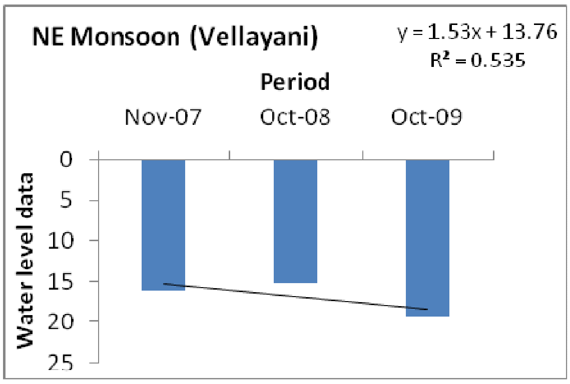


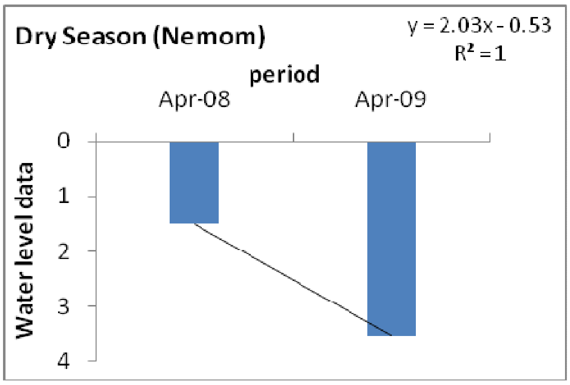


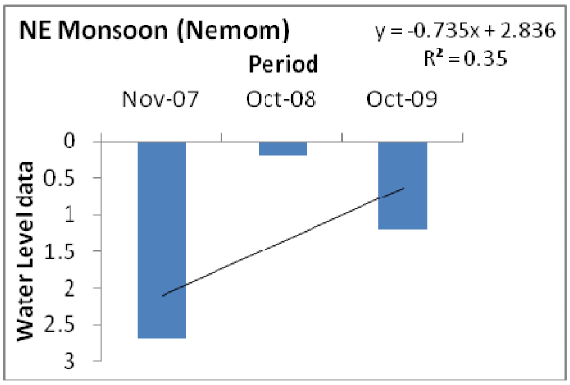




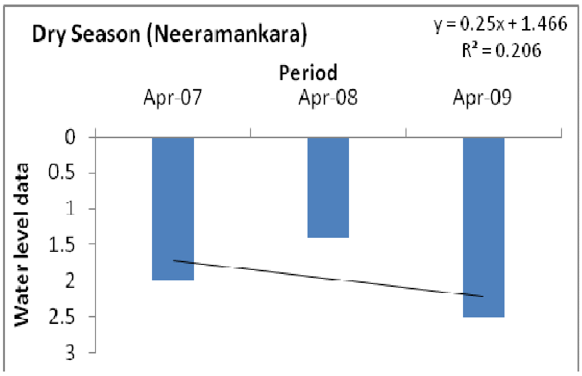


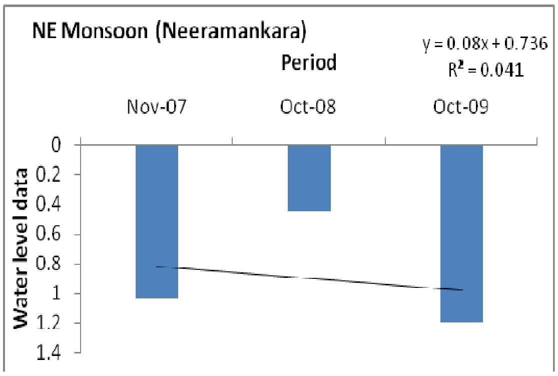


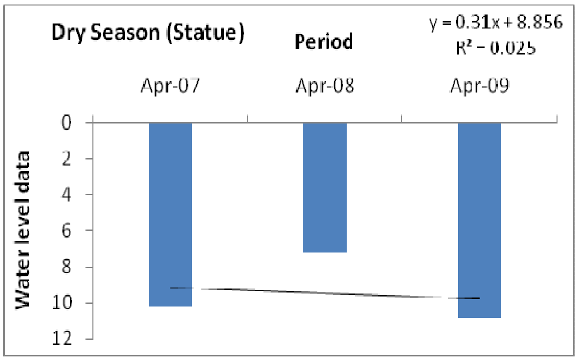


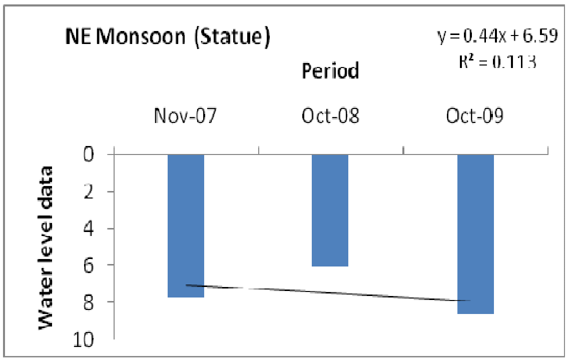


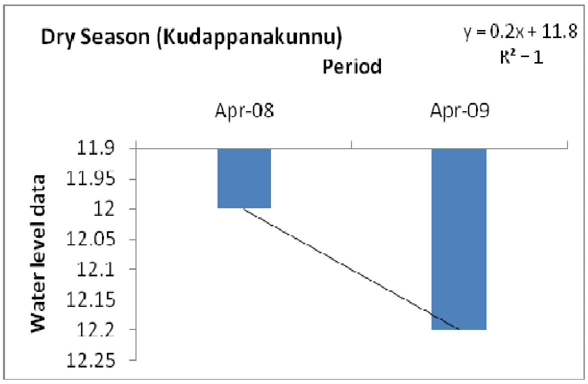
Dry Season (Sreekariyam)	
Apr-07	6.3
Apr-08	6.2
Apr-09	7.5
NE Monsoon	
Nov-07	5.2
Oct-08	5.4
Oct-09	5.5
Dry Season (Kovalam)	
Apr-07	11.8
Apr-08	10.9
Apr-09	12.2
NE Monsoon	
Nov-07	9.7
Oct-08	8.5
Oct-09	12
Dry Season (Vellayani)	
Apr-07	19.01
Apr-08	18.74
Apr-09	19.1
NE Monsoon	
Nov-07	16.12
Oct-08	15.18
Oct-09	19.18
Dry Season (Nemom)	
Apr-08	1.5
Apr-09	3.53
NE Monsoon	
Nov-07	2.68
Oct-08	0.21
Oct-09	1.21

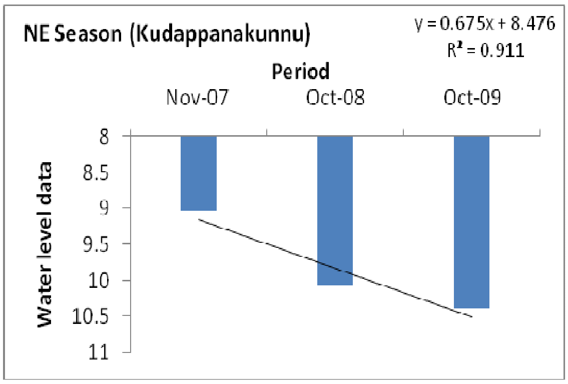


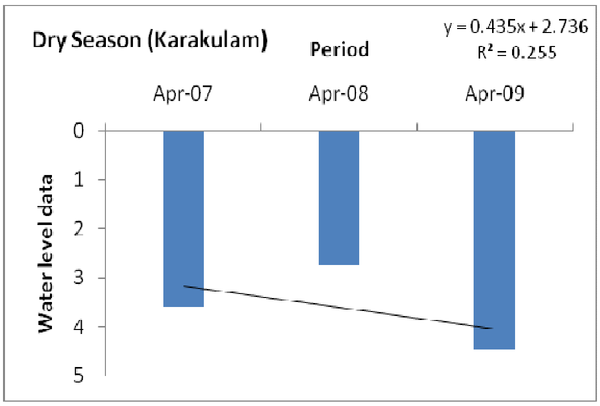


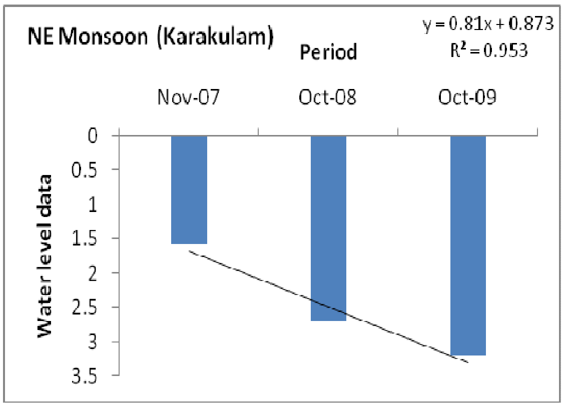




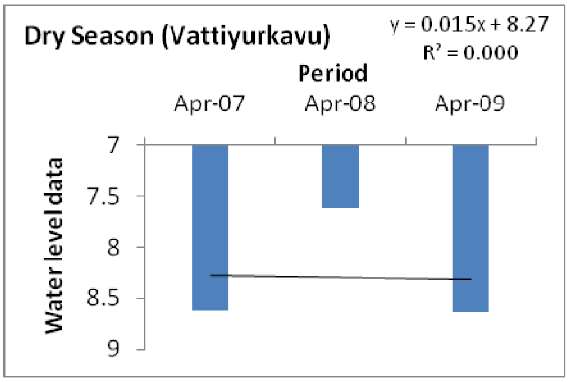


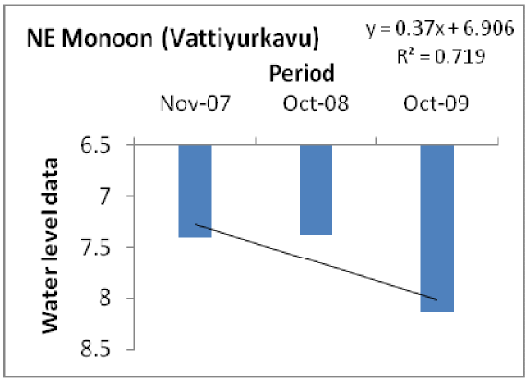


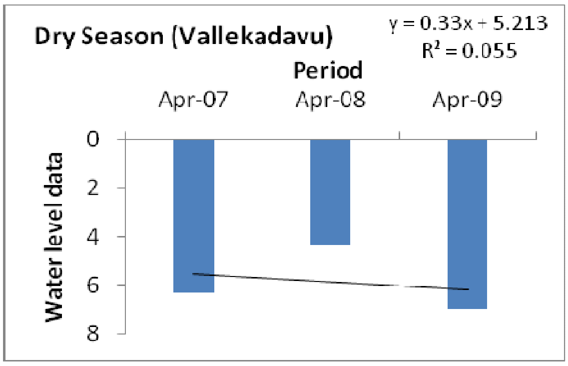


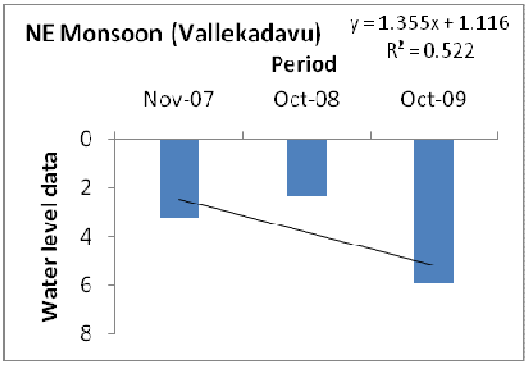


Dry Season (Neeramankara)	
Apr-07	2
Apr-08	1.4
Apr-09	2.5
NE Monsoon	
Nov-07	1
Oct-08	0.5
Oct-09	1.2
Dry Season (Statue)	
Apr-07	10.3
Apr-08	7.3
Apr-09	11
NE Monsoon	
Nov-07	7.7
Oct-08	6.1
Oct-09	8.6
Dry Season (Kudappanakunnu)	
Apr-08	12
Apr-09	12.2
NE Monsoon	
Nov-07	9
Oct-08	10
Oct-09	10.4
Dry Season (Karakulam)	
Apr-07	3.6
Apr-08	2.8
Apr-09	4.5
NE Monsoon	
Nov-07	1.6
Oct-08	2.7
Oct-09	3.2









Dry Season (Vattiyurkavu)	
Apr-07	8.6
Apr-08	7.6
Apr-09	8.7
NE Monsoon	
Nov-07	7.4
Oct-08	7.4
Oct-09	8.2
Dry Season (Vallekadavu)	
Apr-07	6.3
Apr-08	4.3
Apr-09	7
NE Monsoon	
Nov-07	3.2
Oct-08	2.3
Oct-09	6.0

Annexure-3 Water resources of India

India started harnessing its water resources in a big way after independence for agricultural and industrial development. As per the Government of India's Water Policy (1987) document, total volume of water resources of the country was estimated at 4000 Billion Cubic Metres (BCM), considering an average annual rainfall of 1170 mm and the inputs from snow fall and glacier melts. Water availability after evaporation and evapotranspiration was estimated at 1780 BCM. It was also suggested that 50% of it could be put to beneficial use. Ground water component was put at 420 BCM. Water Policy was revised in 2002 and in 2012. Water resource estimates, however, remained the same as in a revised (from 1987 figures) 1993 estimate, placing the total water potential at 4000 BCM. Aavailable water resource after evaporation and evapotranspiration was 1989 BCM and the utilizable resource 1123 BCM as per the draft 2012 water policy notification. The latter was split into 690 BCM of surface water resources and 433 BCM of replenishable ground water resources (These figures were contained in the draft policy document circulated in 2012). Though the Water Policy (2012) was stated to be necessitated by the emerging scenarios of climate change, among others, no effort seems to have been made to reassess the water scenario in the country in the light of the global climate change, erratic monsoons, large scale water diversion/abstraction projects commissioned since 1993, rampant land use/land cover changes, landscape alterations etc. The challenges on the water front were, however, succinctly summarized thus," India has more than 18 % of the world's population, but has only 4% of world's renewable water resources and 2.4% of world's land area. There are further limits on utilizable quantities of water owing to uneven distribution over time and space. In addition, there are challenges of frequent floods and droughts in one or the other part of the country. With a growing population and rising needs of a fast developing nation as well as the given indications of the impact of climate change, availability of utilizable water will be under further strain in future with the possibility of deepening water conflicts among different user groups".

Annexure – 4 Water resources of Kerala

Situated entirely on the western side of the Western Ghats, the territory of Kerala is endowed with copious rainfall received in two monsoon spells, humid tropical climate, very rich and diverse vegetation and bewitching natural beauty. The coastal seas receiving fresh waters and nutrients from 41 west flowing rivers are home to a very rich fisheries resource base.

Total volume of water that Kerala receives a year can be estimated at 116.59 BCM or about 2.9% of the national figure, considering a normal annual rainfall of 3060 mm (Dynamic Ground Water Resources of Kerala, 2014) and a geographical area of 38883 km^2, This would give an impression that Kerala with just about 1.2 % surface area of India and about 2.75% of its population is endowed with a relatively larger percentage of water. Runoff from 41 west flowing rivers of Kerala was estimated at 72,000 Million Cubic Metres (MCM)/year (Water Resources of Kerala, 1974) or about 62% of the total rainfall. Recent reports are suggestive of a declining trend in the runoff, as innumerable check dams and water abstraction points find their place in the Highland and Midland regions of the State. The Kerala Development Report published by the Planning Commission , Government of India in 2008, for example, states that the total surface water availability per annum after evaporation, evapotranspiration and diversions is about 35 BCM, and indicates a surplus of about 8 BCM over demand. Net ground water availability had been projected as 6.23 BCM, as on Mach 2004, and as 6.07 as on March 2011 by the Central Ground Water Board (Dynamic ground Water Resources of Kerala, 2008, 2014). This would indicate that per capita ground water availability in Kerala as on 2011 is around 500 litres per day. This has also reflection in the Planning Commission’s report cited above, where it is stated that ground water resources of Kerala are rich and numerous, except around the back waters and the congested coastal areas. It further states that ground water resources are concentrated in the coastal sedimentary formations. The CGWB figures and the Planning Commission observations are, however, not in consonance with the ground reality. In many parts of the State acute water shortage is felt during dry season. Elevated, steeply sloping areas as well as locations within coarse grained sedimentary strata of the Warkallai formation behave alike in this respect. Very hard lateritic terrain, as in Kasaragode district is also water deficient. It emerges that the CGWB estimates and the projections miss the subtle geological and physiographic context and the climate variability factor with rising temperatures.