Temporal Models for Groundwater Level Prediction in Regions of Maharashtra

Dissertation Report

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by

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Dissertation Approval

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Declaration

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Abstract

In this project work we perform analysis of groundwater level data in three districts of Maharashtra - Thane, Latur and Sangli. We have analyzed this data for more than 100 observation wells in each of these districts and developed seasonal models to represent the groundwater behavior. Three different type of models were developed-periodic, polynomial and rainfall models. While periodic and polynomial models capture trends on water levels in observation wells, the rainfall model explores the correlation between the rainfall levels and water levels. The periodic and polynomial models are developed only using the groundwater level data of observation wells while the rainfall model also uses the rainfall data. All the data and the models developed with a summary of analysis is available at [1]. The larger aim is to build these models to predict temporal changes in water level to aid local water management decisions and also give region specific input to Government planning authorities e.g. Groundwater Survey and Development Agency to flag water status with more information.

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Chapter 1

Introduction

Water below the land surface appears in two zones - saturated and the unsaturated zone. When rainfall occurs, a part of it infiltrates into the ground. Some amount of this infiltrated rain is held up by the upper layer of soil in its pore spaces. This layer is immediately below the land surface and contains both air and water and is known as the unsaturated zone. When all the soil pores are completely filled with water, then water seeps further down through the fractures in the rock. After a certain depth all pores in the soil are completely filled with water, this part forms the saturated zone. The top of saturated zone is known as the water table and water in this zone is called the groundwater. Figure 1.1 shows the saturated and unsaturated zone.

1.1 Groundwater as a Resource

In the last two decades urbanization, population, industrialization and groundwater dependent irrigation have increased quite significantly. All this have directly or in directly resulted in increased demands of water with agriculture sector forming a major portion of the demands. Places where surface water is easily accessible it is seen as the first choice to fulfill these demands. But in places where surface water is not easily accessible or is not sufficient enough, which is the situation in most cases, groundwater has emerged as the next best alternative. As per [2], in Maharashtra the net groundwater irrigated area increased by 507640 hectares from 1988 to 1997 and it accounted for 60% of the total irrigated area. Dug wells, bore wells and pumping are the main medium through which groundwater is extracted. The number of wells in India stood at 100,000 in 1960 which increased to 12 million by 2006 [3]. Such a sharp increase in number of wells has led to over-extraction of groundwater. Excessive withdrawal of groundwater led to the drying up of many drinking water wells. [2]The water table has dropped by as much as 300 feet in some locations of Maharashtra. Over extraction can also cause problem such as sinking of land and water quality issues such as fluoride and arsenic.

To make better utilization of such an important resource in future, its sustainable development is required. We believe that quantitative estimates of groundwater availability both temporally and spatially along with analysis of present situation with respect to socio-economic conditions

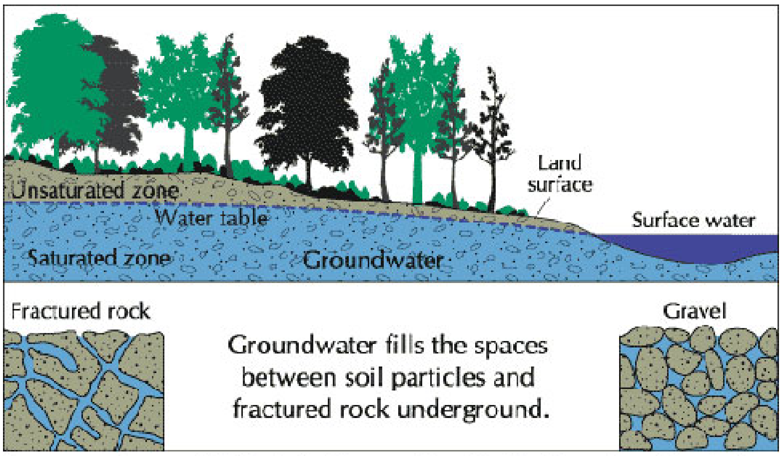


Figure 1.1: A picture showing groundwater in ecosystem
Source : U.S Geological Survey

will play a key role in sustainable development of groundwater. These groundwater estimates would help planners and policy makers to prepare strategies for the long-term management of groundwater. Understanding socio-economic conditions will allow administrators to come up with new rules, regulation and conflict resolution mechanism. Understanding dynamics of groundwater movement and storage is complex as it depends on many factors such as geology, hydro-geology and human involvement. In this project we focus on quantitative estimates of groundwater temporally. We use a data centric approach to make these estimates. We analyze last 20-30 years of groundwater level data to come up with yearly seasonal models which would help in understanding the regime of groundwater at an observation well. Observation wells are dedicated monitoring wells which are measured periodically to know the changes in water level and water quality. These wells are not meant to be used for irrigation purposes. The water level in an observation well is measured as the depth to water from the top of the well. On similar lines the depth of the well is measured as length from the top of the well to the base of the well.

1.2 Societal Objectives and their Partition as Technical Objectives

In general there are many societally important questions which may be asked of any groundwater data system. These questions could be specific or general, in time or space, relate to the withdrawal and recharge of water and about the quality of water. Our project's main motivation comes from the drinking water regime. Here, societally important questions would be to predict groundwater levels for the whole year knowing the rainfall for that season, or specific limits of groundwater withdrawal in a particular area. Currently, Groundwater Survey and Development Agency (GSDA's) role covers many such functions. This work and [4], breaks up the question into two parts, viz., the single well site specific questions, and the across-wells regional questions.

1.2.1 Single-Well and Regional Objectives

In this project we focus on the availability of groundwater both temporally and spatially. Some very specific questions which we want to answer pertaining to both are listed below. This report focuses on the temporal part of groundwater availability i.e. questions 1-5.

1. Given the past groundwater level data for an observation well, what will be the water levels in that well in the coming season?
2. Will an increase in the frequency of collecting observation data help in answering the above question?
3. Does using previous years rainfall data along with groundwater level data, helps us to make better predictions?
4. What additional information is needed to make the predictions at an acceptable confidence level?
5. When an observation well is dry, what is the actual groundwater level?
6. Given the water level in an observation well , what will be the water level in wells located in nearby areas.
7. Do, the observation wells located in a watershed, show similar groundwater behavior?
8. Do, observation wells at the same elevation and slope have some similar water availability characteristics ?

1.3 GSDA Groundwater and Rainfall Datasets

To achieve our objectives we use a data centric approach. We have used datasets pertaining to groundwater and rainfall. The datasets are discussed in detail in following subsections.

1.3.1 GSDA Groundwater Dataset

Groundwater Survey and Development agency (GSDA) is an agency of Government of Maharashtra established in 1972. Its headquarter is in Pune. It deals with groundwater exploration, monitoring, development and management. Few important tasks done by them are as follows-:

- Periodic collection of groundwater level and groundwater quality data in Maharashtra so as to assess the groundwater potential and quality affected areas.
- Carrying out watershed development under various projects such as Hariyali.

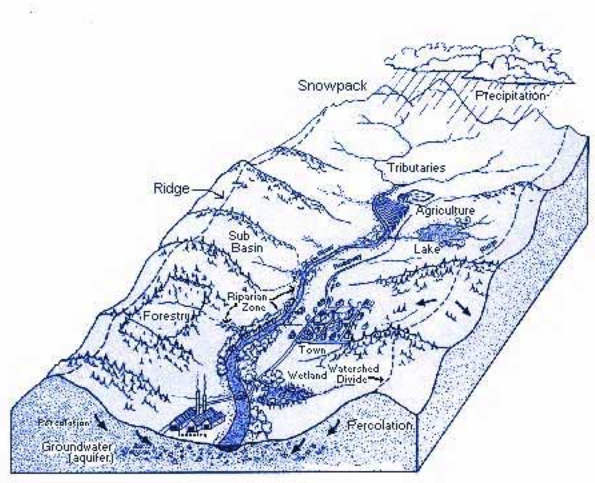


Figure 1.2: Pictorial display of Watershed
Produced by Lane council of Governments

The Groundwater level dataset was received from Groundwater Survey and Development Agency (GSDA), Pune for the entire state of Maharashtra. From this dataset, we have used data of only Thane, Latur and Sangli districts for our study. Initially we had worked on a subset of data, for wells in Thane district, and at later stage Latur and Sangli were included. Data showed the water levels i.e. depth to water from the top of well, at an observation well over the years. The various attributes in the dataset are following-:

1. District, Taluka and Village-: The district, taluka and the village in which the observation well is located.

2. Watershed-: Indicates the watershed in which the observation well is located. A watershed is an area of land enclosed within mountain ridges from which water drains to a particular point along a stream. An image of watershed is shown in Figure 1.2

3. Site_ID-: An unique ID assigned to each observation well. It is created by concatenating the latitude and the longitude at which the observation well is located.

4. Site_type-: Indicates whether the observation well is a dug well or bore well.

5. Depth-: The depth of the observation well in meters.

6. Elevation-: The elevation from mean sea level at which the observation well is located.

7. Wls_date-: The date at which the water level is measured.

8. Wls-: Measured water level in an observation well.

Following points[1] were observed about the groundwater data-:

- Data is collected from as early as 1975.
- Initially till about 1983-84 the water level in dug wells was measured 2 times a year in the months of May and October. Later this increased to 4 times a year as January and March were also included.
- Bore wells are observed from 1997 onwards and an observation is measured every month.
- 3-5 observation wells are located in a watershed.

Table 1.1 shows the number of observations, bore wells, dug wells and watersheds in these 3 districts.

Table 1.1: Dataset Summary

District	**Total observations**	**Dug wells**	**Bore wells**	**Watersheds**
Thane	11682	92	28	34
Latur	12576	115	21	48
Sangli	17054	116	30	38

1.3.2 Rainfall Datasets

For our study we have taken daily rainfall data from three different sources. Two rainfall datasets were available at granularity 0.5°and 1.0°interval in latitude and longitude. Third dataset had the rainfall measurement at the taluka level. The rainfall points for each dataset are shown in Figures 1.3 and 1.4. The geographical area covered and the year for which data was available was also not the same. A table summarizing these aspects of rainfall datasets is shown below in Table 1.2.

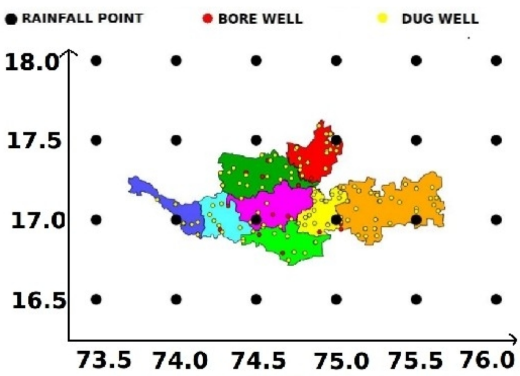
1.4 Discrepancy Analysis of Groundwater Data

From observation wells data we initially removed some implicit error and then performed discrepancy analysis of the remaining observations.

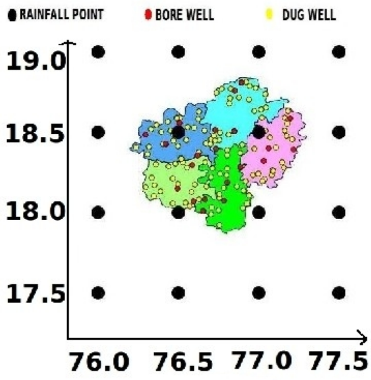
1.4.1 Implicit Errors

In the initial analysis certain very obvious errors were seen in the data. Following are the types of errors found-:

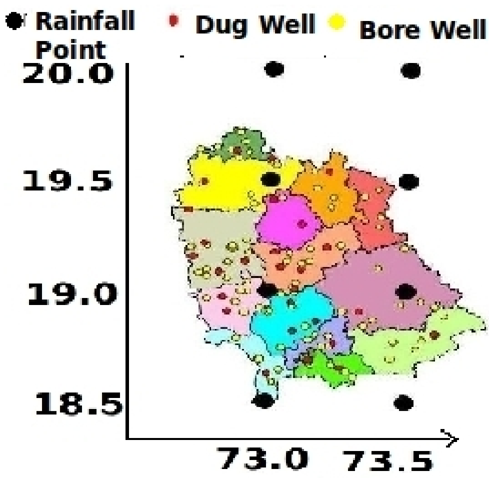
[1]Based on data of only Thane district



(a) Sangli



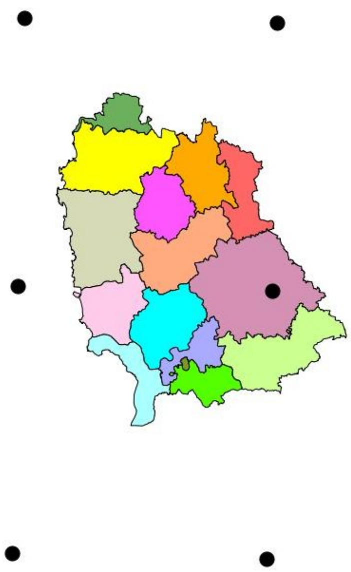
(b) Latur



(c) Thane

Figure 1.3: Rainfall grid points at 0.5°interval in latitude and longitude

- **Duplicate Entries-:** There were two entries of water level for an observation well on the same date. Most of them also showed the same water level. From the two entries the second one was retained and first one was deleted. A total of 366 entries were deleted by this approach in Thane. For Sangli this count was 57 and for Latur it was 0.
- **Negative Depth-:** There were 12 entries which showed negative depth of water in Thane. These entries were also deleted from the data. For Latur and Sangli there was no such observation.
- **Water Level greater than Depth-:** Two entries in the data for Thane showed that depth of water(water level) is greater than depth of the well. For Latur this count was 0 and for Sangli 31.



(a) Rainfall grid points for Thane at 1.0°interval in latitude and longitude

(b) Rain gauge in Taluka's of Thane

Figure 1.4: Rainfall points in Thane

Table 1.2: Summary of 3 Rainfall Datasets

Attributes	Type-1	Type-2	Type-3
Name	0.5°Grid Data	1.0°Grid Data	Rain gauge Data
Source	Prof. Subimal Ghosh, IIT Bombay	GISE Lab, IIT Bombay	GSDA, Pune
Spatial granularity	0.5°interval	1.0°interval	Taluka Level
Availability Period	1972-2005	1989-2007	1992-2009
Temporal granularity	Daily	Daily	Yearly
Spatial Availability	India	Thane	Thane, Latur
Calculated By	Interpolation	Interpolation	Measurement

1.4.2 Flagging Errors

Before using the data for making mathematical models or doing some sort of analysis , it was necessary to identify the errors in the data. The following two types of discrepancies were flagged in the data set.

1. **Gaps in Reading-:**The observations are supposed to be taken while maintaining the intervals between them as decided by GSDA. There were certain observation which were found violating these constraints. We had flagged these observations. Readings which were taken more than 210 days apart were marked.

2. **More Increase/Decrease-:**A normal trend for observation well is that water level should increase(depth decrease) in monsoon period and decrease (depth increase) in non-monsoon period. We decided to flag all those readings which were not in accordance with it. We assumed the monsoon period starts from June 01 and ends at October 31. Now if an observation in non-monsoon shows decrease in depth of water as compared to their preceding observation respectively then these observations were flagged. e.g. consider the observations shown in Table 1.3 In the above two observations the second observation is in the month of May so the depth of water indicated by this observation should be more than the preceding observation. But instead the depth of water indicated by the observation is less than the preceding observation, therefore it is flagged. Similarly if any observation showed decrease in depth in monsoon period as compared to preceding observation then that observation was also flagged. Sample of such flagging is shown in Table 1.4. A total of 1230 observations out of 11302 observations were flagged.Out of these 697 were in monsoon period and remaining 533 are in non-monsoon period.

Table 1.3: Flagging example in non-monsoon

Village	Site_Type	Wls_Date	Wls	Depth	Flag
Khodala	Dug Well	2000-04-06	5	5.8	0
Khodala	Dug Well	2000-05-25	2.6	5.8	1

Table 1.4: Flagging example in monsoon

Village	Site_Type	Wls_Date	Wls	Depth	Flag
Saravali	Bore Well	2006-07-24	1	24	0
Saravali	Bore Well	2006-08-22	2.1	24	1

The above approach of flagging discrepancy was found to be not so good. The approach had the following problems:

- An observation was being compared to its preceding observation irrespective of the gap between the two readings.
- The hard deadline for the start and end of monsoon was not the correct approach. Suppose we had an observation on June,01 then according to our assumption this observation is in monsoon, so it should have less depth(more water) as compared to preceding observation. But being on June,01 it is not necessary that rain would have happened on that day.

After this task one more set of observations were deleted[2]. These were those observations which showed water at depth 0(well is full) in non-monsoon period. There were 36 such observations

[2]They are used again in analysis ahead as the scenario is not impossible and we did not want to lose data when sparsity of data is a problem

in Thane. For the discrepancy analysis it was not correct to mark readings across the monsoon period as we had done previously because there was no information about the rain. Hence we decide to flag the observations only in non-monsoon(Nov-May) period. Let an observation be denoted as O_i and the observation immediately preceding O_i in time is called O_{i-1}. Any observation O_i in the period November to May should show increase in water depth(as no rains) as compared to its preceding observation O_{i-1} provided the O_{i-1} is not before October. A total of 471 observations which violated this were flagged in Thane. The observations flagged by this new approach were checked against the 1.0°rainfall data [3]. The rainfall data was taken for points shown in Figure 1.4a. The count of such discrepancy in Latur and Sangli when later used for analysis is found to be 142 and 292[4] respectively.

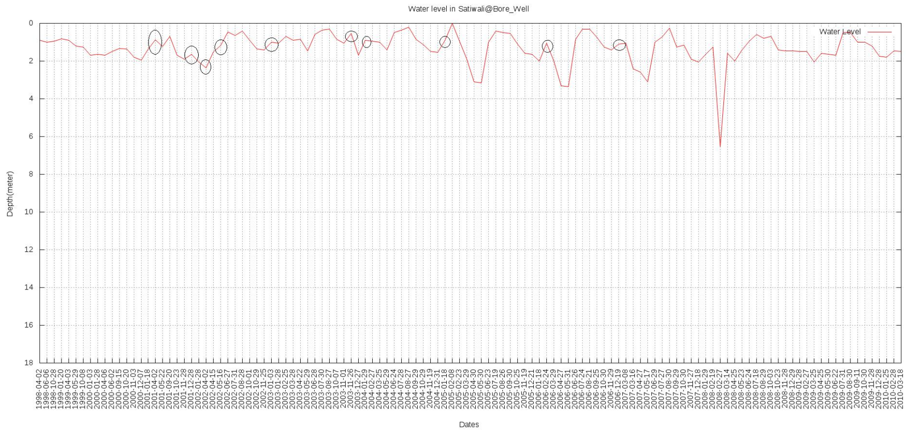
Discrepancies only for Thane till year 2007 (373 out of 471) was checked against rainfall, as rainfall data was available only till year 2007. The total rainfall as per the rain gauge nearest to observation well for days between observation O_i and O_{i-1} was calculated. After analysis we found that out of 373 observation marked for increase in water, 102 had non-zero rainfall whereas there was no rainfall for other 271 observation. If we neglect changes smaller than 0.2m then out of these 271 observation, 189 showed increased level of water by 0.2m or more. The observation well which occurs maximum number of time in these 189 observation are Satiwali_Bore_Well(10), Ghol_Dug_Well(9), Vasar_Bore_Well(8). Plots showing the groundwater level over the years for these wells is shown below in Figures 1.5a, 1.5b and 1.5c. The circles on the graph indicates the discrepant readings. These wells should be looked into as they show increase in water level quite a few times even when there is no rain. A table showing top ten increases in water level in non-monsoon is shown in Table 1.5.

There were observation in data which showed huge variation in few days. To flag these errors slope was used. The rate of change of groundwater depth per day was plotted between two observations. Now the observation with huge variation in few days had very high value and were the outliers in slope values. The graph for two villages indicating slopes is shown in Figures 1.6a and 1.6b. The peak in Figure 1.6a is an outlier whereas the graph in Figure 1.6b has no such observation. The values due to which their is an peak are last 3 rows of Table 1.6.

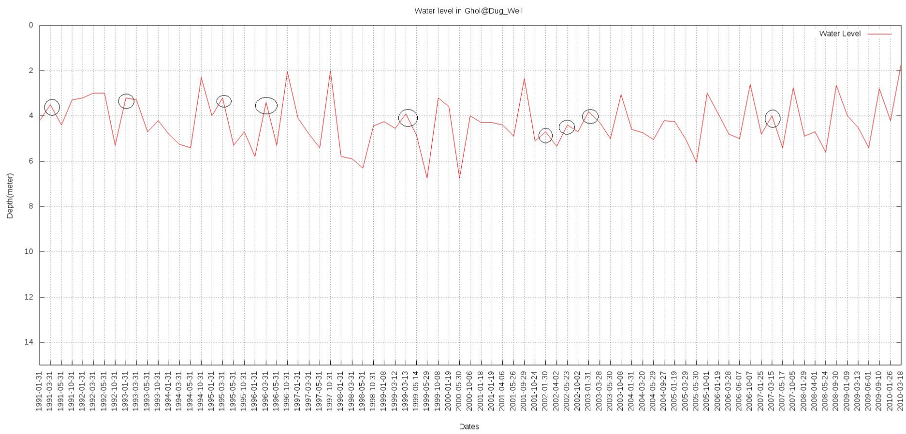
To detect such outliers in the slope values the interquartile range was used. If Q_1 and Q_3 are the lower and upper quartiles then any observation outside the range [Q_1-k(Q_3-Q_1),Q_3+k(Q_3-Q_1)] was decided as an outlier where Q_1 is the lowest 25% values of the data and Q_3 is the highest 25% values of the data and k is the constant. In our case the k was chosen to be 3 by hit and trial, as with k=3 all the extreme outliers were rejected. The observation for which outlier was detected were flagged. These flagged entries were discarded for making mathematical models using splines, which would be explained in Chapter 2. This analysis is not performed for Latur and Sangli because the models for which the result is used were not developed for them.

[3]Other rainfall data was received later so only this was available

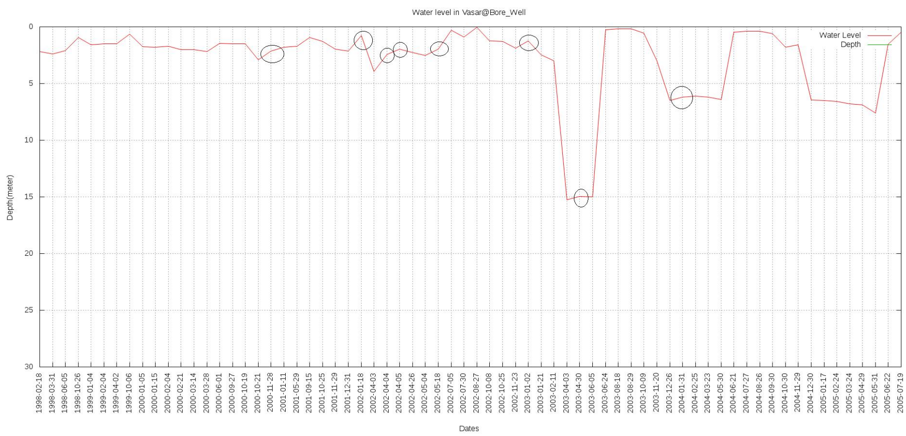
[4]These were not checked against rainfall as from analysis from Thane did not reveal much and in long term this did not seem to help us.



(a) Satiwali Bore Wells

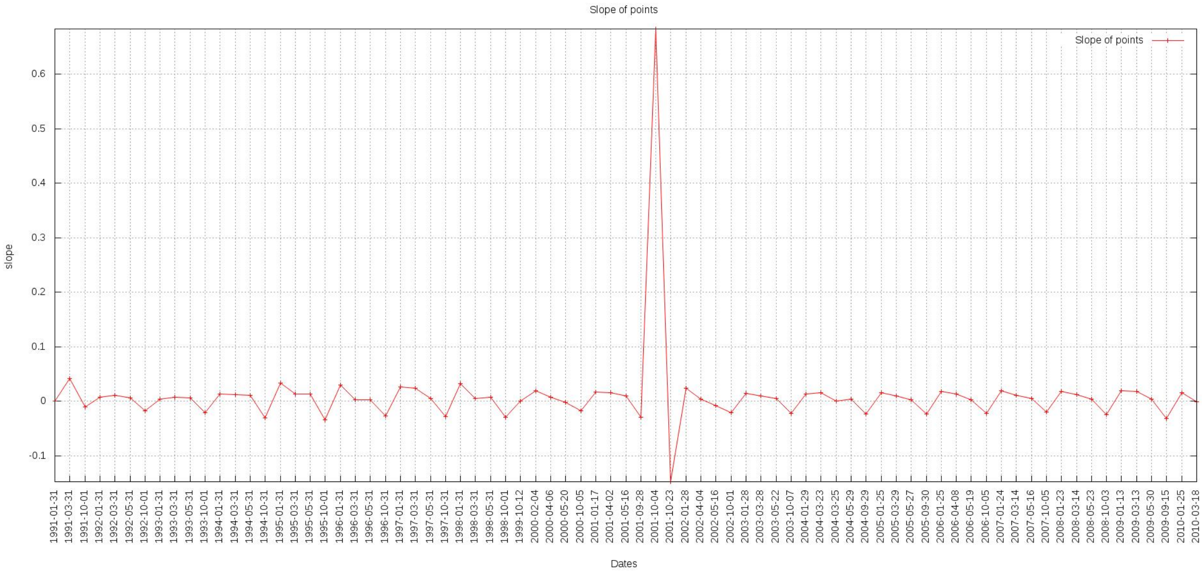


(b) Ghol Dug Wells

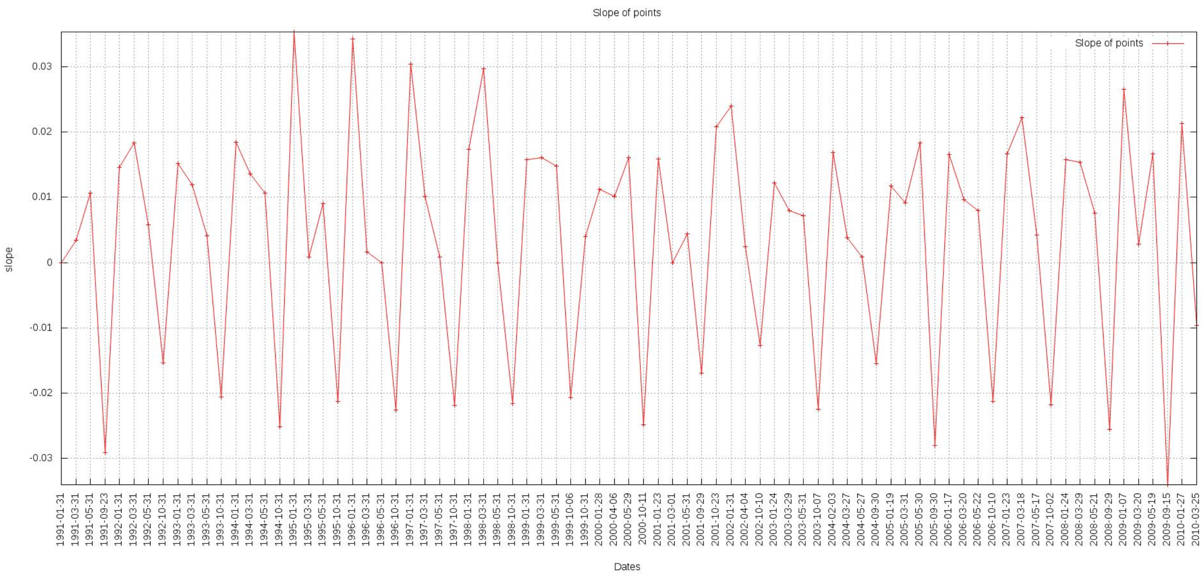


(c) Vasar Bore Wells

Figure 1.5: Observation wells with marked discrepancy



(a) Well with outlier



(b) Well with no outlier

Figure 1.6: Rate of Change in water levels between observation dates

Table 1.5: Observation readings comparison with rainfall.

Village	Well Depth	Rain-Gauge Distance	Previous Date	Previous Depth	Observation Date	wls	Difference	Rain
Kudan	30	42.492	2002-05-03	13.68	2002-05-22	3.75	-9.93	0
Kajali	14	40.377	2003-10-08	7	2004-01-31	1.4	-5.6	1
Talasari	8	40.672	1988-05-03	8	1988-05-30	2.6	-5.4	0
Awale	7.35	38.117	1988-01-30	7.35	1988-02-03	2.1	-5.25	0
Talasarimal	8.2	49.393	2001-04-06	8	2001-05-30	3.1	-4.9	0
Zhari	7.4	39.333	1997-10-31	6.4	1998-01-31	2	-4.4	69
Mahim	20	25.001	2002-04-02	9.55	2002-04-03	5.18	-4.37	0
Safale	25.9	28.896	2000-10-03	10	2000-12-13	5.69	-4.31	25
Palghar Kolgaon	30	31.751	2007-12-18	7.15	2007-12-28	3.2	-3.95	0
Veyour	10.1	31.586	1988-04-22	7.7	1988-05-30	4.15	-3.55	0

Table 1.6: Sample value showing high slope

village	site_type	depth	wls_date	wls
Agashi_Boling	Dug Well	10	2001-01-17	3.1
Agashi_Boling	Dug Well	10	2001-04-02	4.3
Agashi_Boling	Dug Well	10	2001-05-16	4.75
Agashi_Boling	Dug Well	10	2001-09-28	0.9
Agashi_Boling	Dug Well	10	2001-10-04	5
Agashi_Boling	Dug Well	10	2001-10-23	2.2

1.5 Literature Review

We started with study of some basic hydrology, which we would need to understand the domain of groundwater. Various concepts in hydrology and geology such as conductance, watershed, aquifer, water table, specific yield etc. were studied. Then we looked at literature for existing work done in groundwater modelling. An integrated groundwater/surface water hydrological model on 1 km^2 grid has been constructed for Denmark which covers an area of 43,000 km^2. Denmark was divided into 11 areas , each covered by a hydrological model. The work in [5] describes the modelling process used for construction, calibration and validation of hydrological model for the 7330 km^2 island of Sjealland, which is one among the 11 areas. They had used geological data to develop a 3D geological map of Sjealland and had also used soil conductivity for creating the model. They had also used hydrological process such as snow fall, river flows, groundwater flow and levels etc. to achieve accurate simulations of groundwater flow. For simulating groundwater flow system the MIKE SHE code was used by them.

There have been some work in forecasting groundwater levels using artificial neural networks. In [6] comparison of different artificial neural networks for groundwater level forecasting is done. The study is carried out in Messara valley, at southern part of the island of Crete in Greece. Datasets used by them were well water depth, monthly precipitation, evapotranspiration, runoff and temperature. They use 3 artificial neural network which are (i)Feed forward neural network(FNN) (ii)Recurrent neural network(RNN) (iii)Radial Basis function Network(RBF). They use 3 training algorithms to train the network which are (i) Gradient descent with momentum and adaptive learning rate back-propagation (GDX) (ii)Levenberg-Marquardt(LM) (iii)Bayesian regularization. In total have used 7 combination of ANN-algorithms to see which gives the best result. The best performance is achieved by FNN trained with LM algorithm. The best performance is the one whose accuracy diminishes with least rate for the predictions ahead. Similar work is presented in [7], where they do groundwater level forecasting in shallow aquifers using artificial neural networks. The study area is a part of river Godavri delta system in East Godavri district of Andhra Pradesh. They have used multi layer perception network trained with back propagation algorithm for forecasting water levels. The datasets used by them are observation data from 3 wells, monthly averages of rainfall and canal releases.

In [8] an empirical statistical model is proposed to predict changes in groundwater behavior in response to different climate conditions. This model is a combination of a water flow model and water budget model. The water flow model is use to reflect that pattern in groundwater level variation is similar to the fluctuations observed in recharge. The water budget model is used to get estimates of precipitation and temperature. The proposed empirical model is tested using dataset from 80 observation wells in carbonate rock aquifer, southern Manitoba, Canada. In predicting the water level in 82 wells a correlation of 0.93 was there between the observed value and the predicted value.

1.6 Outline

The remaining portion of the report is structured into 4 chapters. In Chapter 2, we initially present the expected model and its mathematical formulation. Then we have presented the first series of model i.e. periodic models and discussed some issues with them. In Chapter 3, the next series of models i.e. the polynomial model is presented. A comparison of polynomial model with periodic models and across districts is also discussed. Chapter 4 deals with the rainfall model, as the name suggest, they are developed using rainfall along with observation well data. The performance of both rainfall model with polynomial model and their behavior across districts is also highlighted. Finally in Chapter 5 we present our conclusions and discuss some of the future objectives.

Chapter 2

Elements of the Single Well Model

2.1 Expected Model and Metrics for Measurement of Fit

Our aim is to understand the temporal availability of groundwater in districts of Maharashtra. To achieve our aim we develop seasonal models for observation wells in these districts. These models would show the variation in groundwater levels throughout the year in the observation wells. A dummy model showing groundwater variation throughout the year is shown in Figure 2.1. An ideal model would show exact variation of groundwater level. The models would use observation well data and/or the rainfall data as input. These models would enable us to predict the water level in an observation well at a given date. To create these models we will fit different functions to the dataset, to come up with the desired model. The metric we will use to measure the fit is the R^2 value i.e Quality of fit. The R^2 is given by formula shown in Equation 2.1 where y_i is the observed water level, m_i is the model value of water level and μ_Y is the mean of observation values. The closer R^2 is to 1, the better is the fit. There may be variations in the behavior of groundwater even in the models having almost same R^2 values. These variations can be attributed to following reasons-:

$$R^2 = 1 - \frac{\sum_i (y_i - m_i)^2}{\sum_i (y_i - \mu_Y)^2} \tag{2.1}$$

1. Variable Rainfall-: The amount of rainfall may vary across time, space or both, causing fluctuations in groundwater water level. Figure 2.2 show the yearly rainfall in some locations of Thane. We can see there is considerable amount of variation both in time and space.

2. Extraction Pattern-: Even if the rainfall pattern are same, but if wells in vicinity of an observation wells are being used for drinking purpose only while wells in vicinity of other observation well are being used for irrigation then such variation in pattern of extraction would cause the models to behave differently.

3. Land use-: The total irrigation land in the area in which observation well is located might

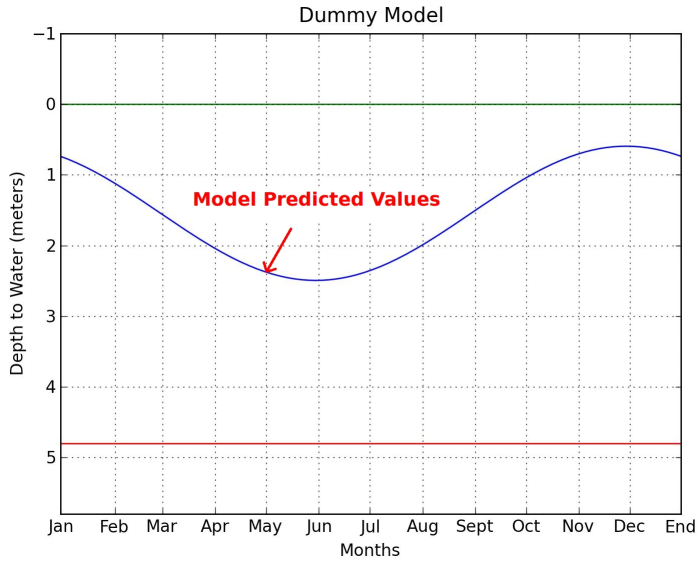


Figure 2.1: Dummy Model for an observation well

also effect the groundwater level. This is again related to extraction pattern as more irrigation land would imply more groundwater is needed.

4. Geological Factors-: The difference in geological properties such as conductivity, storativity, rock type, fractures in rock and aquifer depth can cause the variations in the model.

5. Observation Errors-: The actual behavior of models could be different from what we actually observe, because the observation data using which we developed our model was erroneous.

2.1.1 Behavioral Aspect of Seasonal Model

To model the groundwater behavior in observation wells we have tried different model space. In our first attempt as described in detail, later in Section 2.3, we have chosen periodic model to show the groundwater behavior. This sought to describe the groundwater as a periodic continuous function. These models, however, have certain limitations. In our next attempt as described in Chapter 3 we chose polynomial functions to model the groundwater behavior. In this approach we model for the period June-May to show the decaying water levels from post monsoon to premonsoon. After developing the model we saw this was not true for all observation wells. Later we also used rainfall in our polynomial models to predict the groundwater behavior.

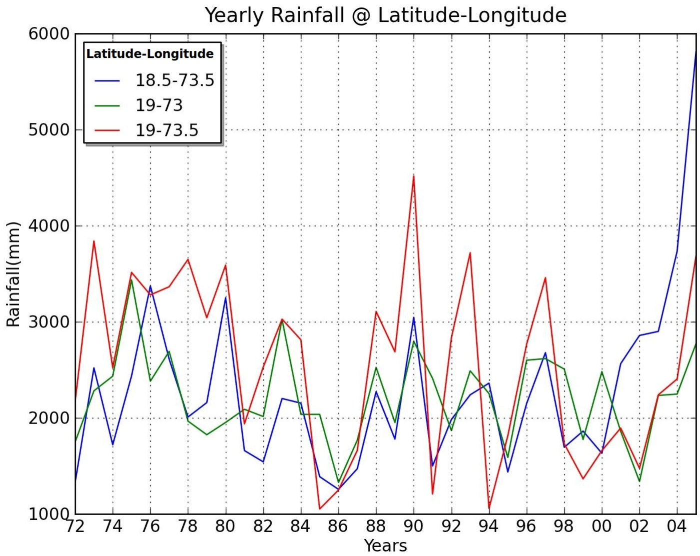


Figure 2.2: Rainfall Pattern in Thane

2.2 Mathematical Formulation of Models

Our basic assumption is that extraction levels over the years are stable . If they are not model will result in an error. In order to develop the first seasonal model for an observation well we use the observation data for that well. This data is in the form of water level and date on water level is measured. Since we want to make a yearly model we fold all the years data into a single year. For this we drop the year part from the dates and convert the dates in to the day of the year value, so January1st is value 1, May 31st is value 151, December 31st is value 365 and so on. Now all observation have a day value varying from 1 to 365. Thus we have scaled down the 30 years of data into a single year.

We know groundwater level is a function of many environmental factors. For simplicity we assume that groundwater level y is a function of the day of the year x. Let the function be F i.e $y = F(x)$ where $F(x) = a_1 f_1(x) + a_2 f_2(x) + \cdots + a_n f_n(x)$. Here function involves n constants. We find the estimate of these n constants as the values which minimize the sum of the squares between the measured value and the model i.e the error value. This method is know as least square fit. This amounts to minimizing the expression shown in Equation 2.2

$$\begin{aligned}
(y-F(x))^2 &= \sum_{i=1}^{n}(y_i - F(x_i))^2 \\
error &= \sum_{i=1}^{n}(y_i - F(x_i))^2 \\
&= \sum_{i=1}^{n}((y_i - a_1 f_1(x_i) - a_2 f_2(x_i) \cdots - a_n f_n(x_i))^2
\end{aligned} \tag{2.2}$$

If the above expression is to be minimized then :

$$\frac{\partial(error)}{\partial(a_r)} = 0; r = 1, 2, \cdots n. \tag{2.3}$$

On performing the above operation we get the following Equations:

$$\begin{aligned}
&\sum_{i=1}^{n}((y_i - a_1 f_1(x_i) - a_2 f_2(x_i) \cdots - a_n f_n(x_i)).f_1(x_i)) = 0 \\
&\sum_{i=1}^{n}((y_i - a_1 f_1(x_i) - a_2 f_2(x_i) \cdots - a_n f_n(x_i)).f_2(x_i)) = 0 \\
&\vdots \\
&\sum_{i=1}^{n}((y_i - a_1 f_1(x_i) - a_2 f_2(x_i) \cdots - a_n f_n(x_i)).f_n(x_i)) = 0
\end{aligned}$$

Expanding the above expression and writing it in matrix notation as shown in Equation 2.4 we solve the system of Equations and get the constants $a_1, a_2 \cdots a_n$ which minimizes the error in fitting the above function $F(x)$. Now using these constants we can probe the model to get the water level at a given day x.

$$\begin{bmatrix}
\sum_i (f_1(x_i))^2 & \sum_i f_1(x_i) f_2(x_i) & \cdots & \sum_i f_1(x_i) f_n(x_i) \\
\sum_i f_2(x_i) f_1(x_i) & \sum_i (f_2(x_i))^2 & \cdots & \sum_i f_2(x_i) f_n(x_i) \\
\vdots & \vdots & \cdots & \vdots \\
\sum_i f_n(x_i) f_1(x_i) & \sum_i f_n(x_i) f_2(x_i) & \cdots & \sum_i (f_n(x_i))^2
\end{bmatrix}
\begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_n \end{bmatrix}
=
\begin{bmatrix} \sum_i y_i f_1(x_i) \\ \sum_i y_i f_2(x_i) \\ \vdots \\ \sum_i y_i f_n(x_i) \end{bmatrix} \tag{2.4}$$

2.3 The Basic Model

In this section we actually present the models developed by fitting functions to the data. The models shown in this section are developed only for observation wells in Thane district. We assume that groundwater behavior in a year is periodic because it is seasonal in nature. We choose periodic function consisting of sines and cosines to model the groundwater behavior. The function we chosen is $F_1(x) = a_0 + a_1 sin(x) + a_2 cos(x)$. Using the method described in

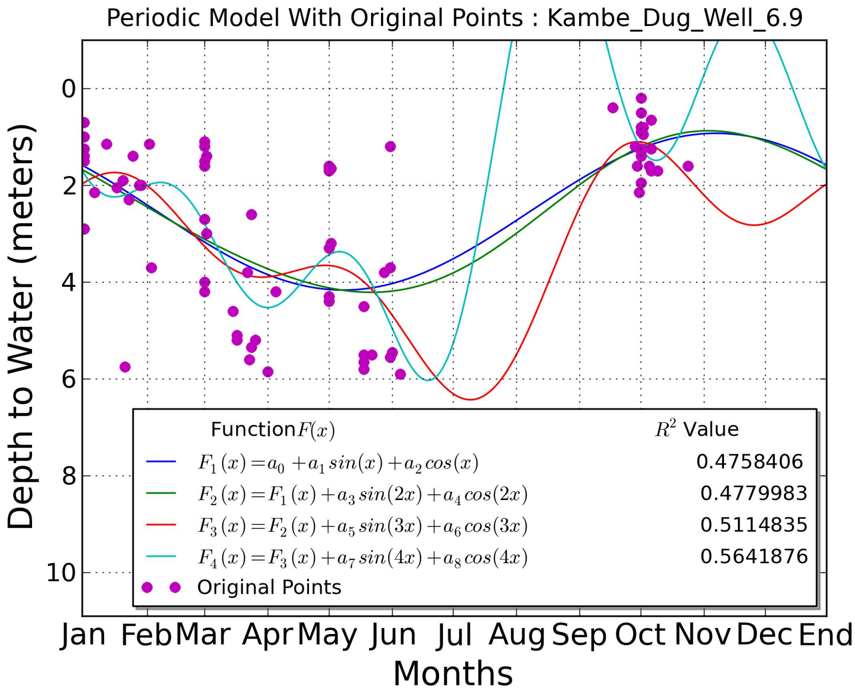


Figure 2.3: Periodic Model developed using original points for a Thane Village

subsection 2.2 we perform a least square fit using this function to our folded data points. Since these are sine and cosine terms we have converted our day of the year i.e. x from range 1-365 to 0-2π. On applying the least square fit we get system of Equations shown in Equation 2.5.

$$\begin{bmatrix} \sum_i 1 & sin(x_i) & \sum_i cos(x_i) \\ \sum_i sin(x_i) & \sum_i sin(x_i)^2 & \sum_i sin(x_i)cos(x_i) \\ \sum_i cos(x_i) & \sum_i cos(x_i)sin(x_i) & \sum_i cos(x_i)^2 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} \sum_i y_i \\ \sum_i y_i sin(x_i) \\ \sum_i y_i cos(x_i) \end{bmatrix} \tag{2.5}$$

On solving these equations we get constants a_0, a_1 and a_2. Now we substitute these in our function $F_1(x)$ to plot our seasonal model. We had also tried function with more sines and cosine terms to see which gives a better result. The other functions which were tried are shown in Equations 2.6 to 2.8. Models developed with different functions for an observation well in Thane is shown in Figure 2.3. The R^2 for each function is shown in graph. The complete lists of R^2 values for observation wells in Thane is shown in Table A.1 on page 53.

$$F_2(x) = F_1(x) + a_3 sin(2x) + a_4 cos(2x) \tag{2.6}$$
$$F_3(x) = F_2(x) + a_5 sin(3x) + a_6 cos(3x) \tag{2.7}$$
$$F_4(x) = F_3(x) + a_7 sin(4x) + a_8 cos(4x) \tag{2.8}$$

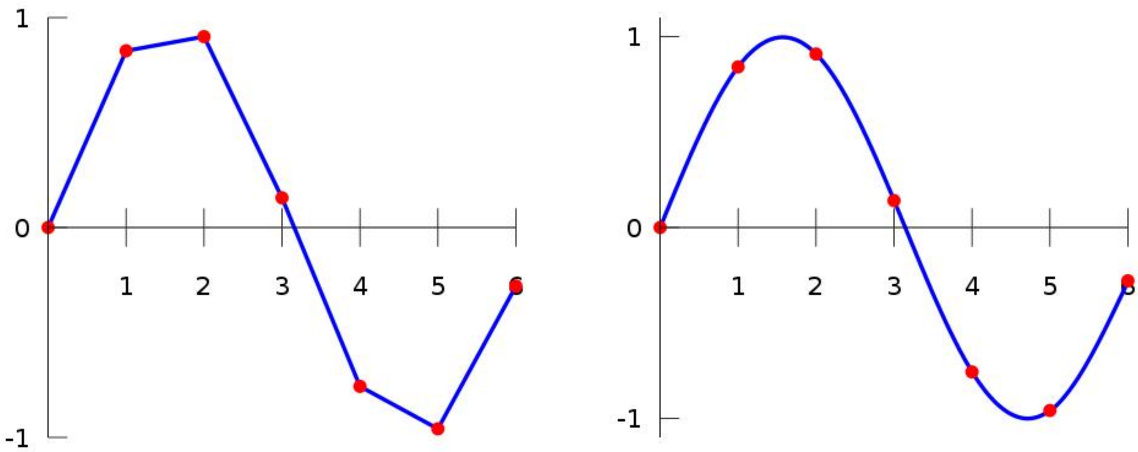
We observed in the model that they show bad behavior in some months. The reason for this is the large gap between sampling points and high density at some points. This is because a lot of our sample data is collected in months of January, March, May and October. Very few readings are taken in remaining months. The clusters of dots in Figure 2.3 shows this. To overcome the limitation of absence of data points we resorted to interpolation. Interpolation is the technique of constructing new data points within the range of a discrete set of known data points. We have used two types of interpolation which are discussed in the subsections ahead.

2.3.1 Linear Interpolation Models

For a given set of data points say $(x_1, y_1) \cdots (x_n, y_n)$ linear interpolation connects two consecutive data points (x_a, y_a) and (x_{a+1}, y_{a+1}) where $\{x_a, x_{a+1}\} \in \{x_1 \cdots x_n\}$ and $\{y_a, y_{a+1}\} \in \{y_1 \cdots y_n\}$ using a straight line as shown in Figure 2.4a. Then the value of interpolant y at any x in the interval (x_a, x_{a+1}) is given by Equation 2.9

$$y = y_a + (y_{a+1} - y_a)\frac{(x - x_a)}{(x_{a+1} - x_a)} \tag{2.9}$$

Using this approach we linearly interpolated water levels between two observation dates at 15



(a) Linear Interpolation

(b) Spline Interpolation

Figure 2.4: Interpolation Techniques

days interval. Now again we folded all the data into a single year as done previously. With this we had a large set of sample data distributed evenly over the months. To develop the model we performed a least square fit of the functions $F_1(x)$, $F_2(x)$,$F_3(x)$ and $F_4(x)$ as done in the case of previous model. A model developed using linearly interpolated points for observation well in Thane is shown in Figure 2.5 with R^2 values indicated on it. The complete list of R^2 values for linearly interpolated models of observation wells in Thane is shown in Table A.2 on page 57.

The models developed using linearly interpolated points do not show sudden bad behavior as in the case of models developed using only original points. But how truly they show groundwater behavior at an observation well is a question that cannot be answered with much confidence. We have used linear interpolation to get water level values on dates in between two actual observation dates. We have taken the groundwater variation between two observation dates to be represented by a straight line, which is a rare case. Hence the method of linear interpolation to get water level does not make sense in our case. We need a better interpolation technique which would reflect the groundwater variation in a better way.

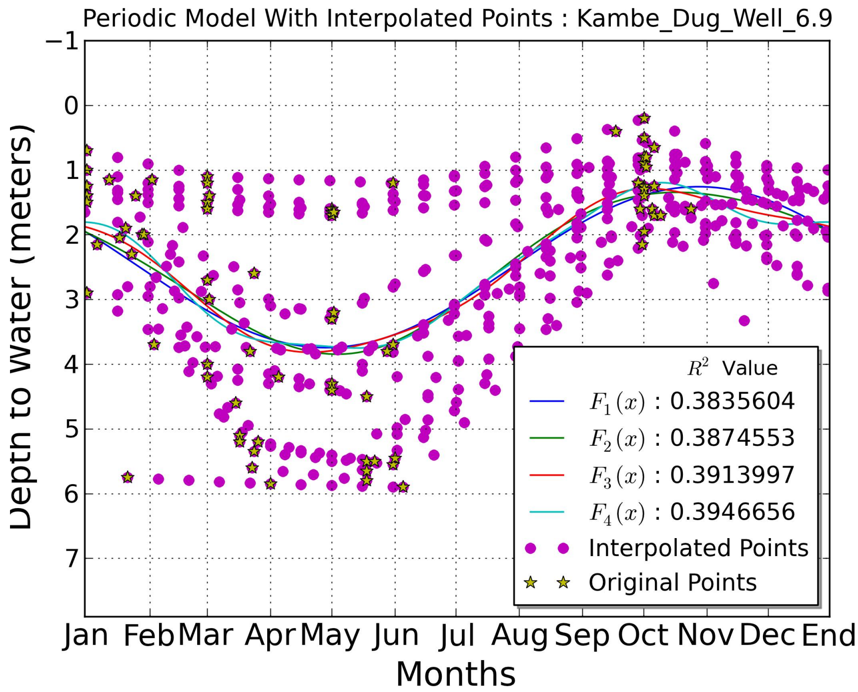


Figure 2.5: Periodic Model developed using linearly interpolated points for a Thane Village

2.3.2 Spline Interpolation Models

As an alternative to linear interpolation we have used spline interpolation to generate data points [6]. In spline interpolation for n interval of data points, we fit piecewise polynomial between two points (x_a, y_a) and (x_{a+1}, y_{a+1}) with constraints at joins to ensure smoothness. For smoothness first and second derivatives are made equal across the point of joining i.e. for n intervals we fit n polynomials and get a smooth curve fitting the n points. The function representing this curve is called the spline. Figure 2.4b show a spline fitted to data points. The most popularly used spline for interpolation is the cubic spline. Cubic spline fits degree 3 polynomial between two points successive points (x_a, y_a), (x_{a+1}, y_{a+1}), the spline function $S(x)$ is given by Equation 2.10.

$$S(x) = \left\{ \begin{array}{lll} S_1(x) & if & x_1 \leq x < x_2 \\ S_2(x) & if & x_2 \leq x < x_3 \\ \vdots & & \\ S_n(x) & if & x_{n-1} \leq x < x_n \end{array} \right\} \tag{2.10}$$

where S_x is degree 3 polynomial given by Equation 2.11.

$$S_i(x) = a_i(x - x_i)^3 + b_i(x - x_i)^2 + c_i(x - x_i) + d_i \tag{2.11}$$

Before using the cubic spline to get interpolated points, we divide our data points into subsets. The division is done at those data points which indicate rising in water level during non-monsoon period or there is a gap of more than 180 days between two data points. For example if we have n data points as $(x_1, y_1) \cdots (x_n, y_n)$ and y_6 and y_{13} are observation showing rise in water level, then we break our data as $(x_1, y_1) \cdots (x_5, y_5)$, $(x_7, y_7) \cdots (x_{12}, y_{12})$ and $(x_{14}, y_{14}) \cdots (x_n, y_n)$. We fit a separate cubic spline to each subset of data. Figure 2.6 shows cubic splines fitted to data points. Using these splines we get our interpolated values, these values are then folded into a single year as done previously. Then a least square fit of functions $F_1(x)$, $F_2(x)$,$F_3(x)$ and $F_4(x)$ is done to these points as explained in Section 2.3 . A model developed using interpolated points from cubic splines is show in Figure 2.7 with R^2 values indicated on it. The complete list of R^2 values for spline interpolated models of observation wells in Thane is shown in Table A.3 on page 61.

2.3.3 Issues With Periodic Model

During the course of developing the various type of periodic models a number of issues were brought out. The sparsity of data across a year is a major drawback for modeling, due to this sparsity the model behaves unpredictably in portions where there is no data. When we model using linearly interpolated points or spline interpolated points then we are creating a lot of synthetic data. Using this created data to model groundwater behavior is not a very good idea. The observations post monsoon show very high water level due to heavy rainfall. When we model the groundwater behavior as periodic from January to December then the observations post monsoon are like a sudden break in the periodic behavior, it causes the model to rise very steeply or in some cases even before the monsoon. When we model the groundwater behavior we are not trying to model the response of water level to heavy rains, instead we are focusing on the pattern in the complete year. Hence this choice of modeling period from January to December is not very convincing. A better choice is to model from June to May of next year, where the behavior is much more smooth.

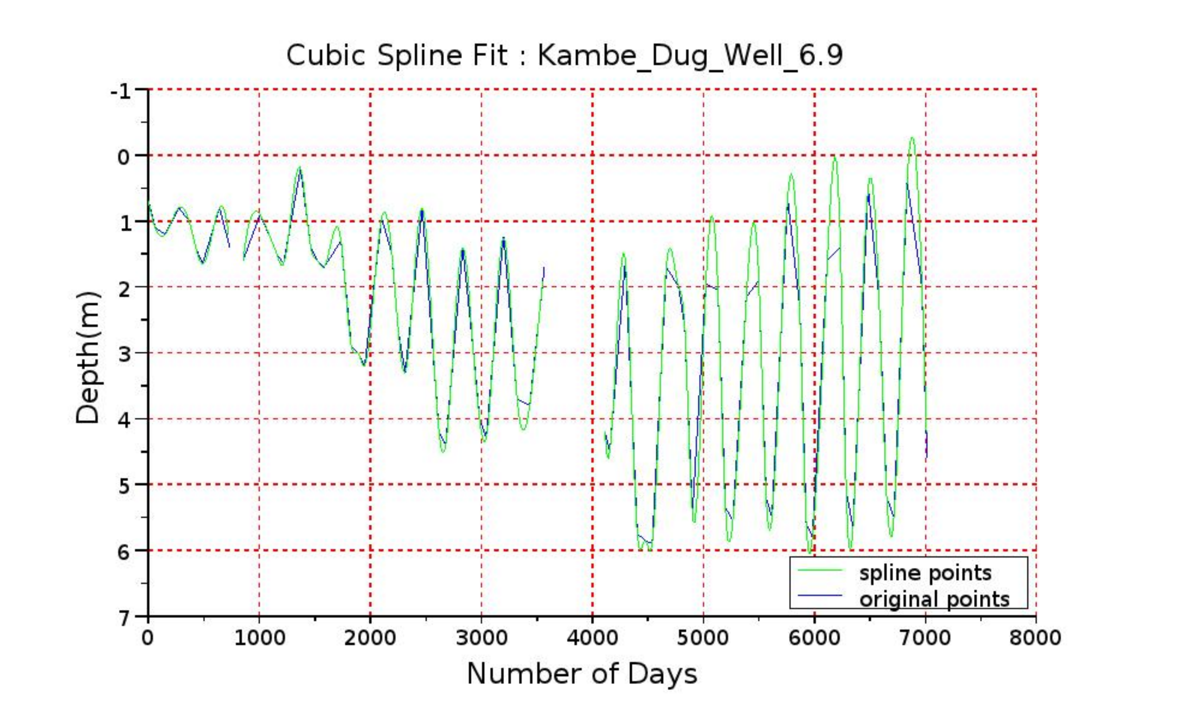


Figure 2.6: Cubic splines fitted to data sequence

2.4 Summary

- Three types of periodic models were developed-using original points, linearly interpolated points and spline interpolated points.
- Periodic models developed with original point shows unpredictable behavior at times when no data is present
- Modeling from January to December is a bad choice of model, as modeling the sudden rise in water level after monsoon is difficult.
- Using synthetic data generated to overcome the problem of sparsity does not help much and moreover is not a true reflection of the water levels.

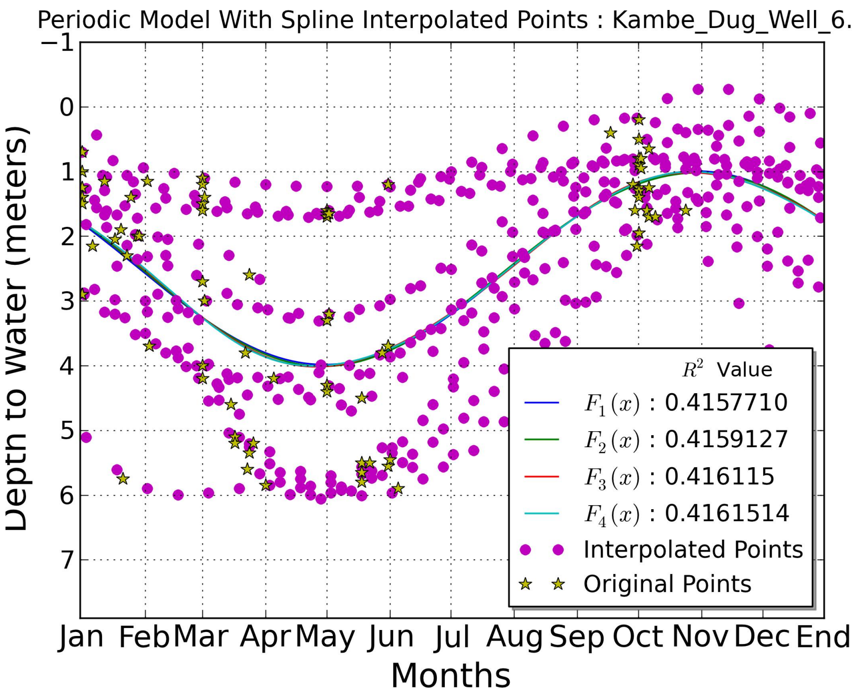


Figure 2.7: Periodic Model developed using spline interpolated points for a Thane Village

Chapter 3

Polynomial Model

In Chapter 2 we had seen the first series of seasonal models, the periodic models. As discussed in subsection 2.3.3 it has some problems. An attempt has been made to overcome those problems in the next series of models. We call them the basic polynomial model and the rainfall model.

3.1 Basic Polynomial Model

After the heavy rains in June-September we expect the water levels in observation wells to drop continuously till the next monsoon. In polynomial model we try to capture this monotonically decreasing behavior of water level in an observation well using the observation well data. In these models we have discared observation from the month of June because observations in June being immediately after the rain are more of a resultant of rainfall then resultant of factors affecting groundwater level. So these models would show how the water in an observation well behaves from July, to May of next year. We drop the continuity requirement at May 31-June 1. In these models we shift our model year from January-December to June-May. That is 1^{st} June and 31^{st} May of consecutive year are now day 1 and day 365 of model-year respectively. All the observation dates of an observation well are changed into day of the year value and then shifted to map into the model-year. For example 1989-10-27 is 300^{th} day of the year and 1991-05-28 is 148^{th} day of year, they are mapped into June-May year as day 149 and day 362 respectively. With this shifting all the observation dates of an observation well are mapped to June-May year. These shifted values of dates form the x_i's input for model and water level measured on these dates is the y_i input for model. Now we perform a least square fit to the data points using polynomial function shown in Equation 3.1 $\forall$k$\in\{2,3,4\}$ where k is the degree of polynomial.

$$f(x) = a_0 + a_1 x + \cdots + a_{k-1}x^{k-1} + a_k x^k \tag{3.1}$$

To perform least square fit we solve the system of linear Equations shown in Equation 3.2 $\forall$ k $\in$ $\{2,3,4\}$ and get the values of constants $a_0, a_1, \cdots, a_k$ $\forall$ k. We also compute the goodness of fit i.e. the R^2 value in each case.

$$\begin{bmatrix} \sum_i 1 & \sum_i x_i & \cdots & \sum_i {x_i}^k \\ \sum_i x_i & \sum_i x_i^2 & \cdots & \sum_i {x_i}^{k+1} \\ \vdots & \vdots & \cdots & \vdots \\ \sum_i {x_i}^k & \sum_i {x_i}^{k+1} & \cdots & \sum_i {x_i}^{2k} \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ \vdots \\ a_k \end{bmatrix} = \begin{bmatrix} \sum_i y_i \\ \sum_i y_i x_i \\ \vdots \\ \sum_i y_i {x_i}^k \end{bmatrix} \tag{3.2}$$

Now using these constants we plot the model for observation well. Since we have discarded the observation in June if any, so we plot our models from July onwards and in case of dug wells in Thane there are no observations in July too, so for them models are plotted from August onwards. Fig 3.1 shows a polynomial model with R^2 values shown $\forall$ k. The complete list of R^2 value for Thane, Latur and Sangli district is shown in Tables B.1, B.2 and B.3 respectively in the appendix.

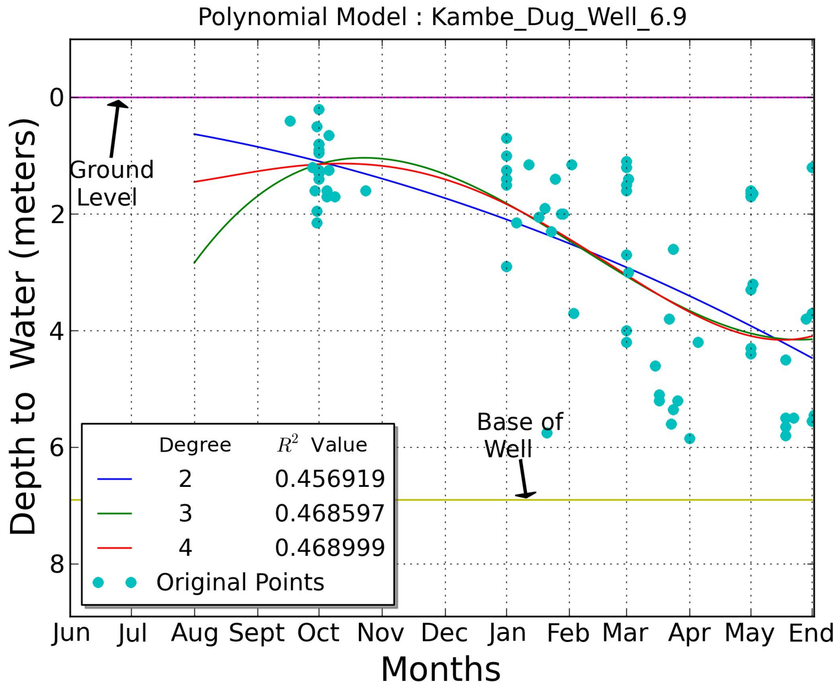


Figure 3.1: Polynomial Model of observation well in Kambe village of Thane district

3.2 Polynomial Model Performance

Initially we compare polynomial models with the periodic models and then we discuss the performance of polynomial models across districts.

3.2.1 Comparison with Periodic Models

The comparison with periodic model is done only for Thane because as mentioned in Section2.3 periodic models are developed only for Thane. When we compare polynomial models to the periodic models, doing so makes sense, only when the comparison is done with periodic model developed using only the original points (i.e. no interpolated points are used), as the other periodic models are developed using synthetic data. The comparison of R^2 values should be made in cases when degree of freedom is same for both the models. On comparing R^2 values of periodic model with function $F1(x)$ to R^2 values of polynomial model with degree 2 (both have 3 degrees of freedom) we observe the following points-:

- The R^2 value increases for **all bore wells** in case of polynomial model.
- Out of 92 dug wells the R^2 value increases in 70 dug wells in case of polynomial model.
- The average increase in R^2 values for bore wells is 0.1891.
- The average increase and decrease in R^2 value for dug wells is 0.0313 and 0.0139 respectively.

From these observation we conclude that polynomial model are better than the periodic model. Table 3.1 shows the R^2 values for some observation wells in both the models.

Table 3.1: Comparison between R^2 values of periodic and polynomial model

S.No	Village	Periodic Model	Polynomial Model	Difference
1	Agashi_Boling_Dug_Well_10	0.6785	0.6725	-0.0060
2	Ambiste_kh_Bore_Well_17	0.6577	0.8746	0.2169
3	Badlapur_Bore_Well_30	0.3493	0.5026	0.1533
4	Chavindra_Bore_Well_13.5	0.6155	0.8682	0.2527
5	Chndansar_Bore_Well_24	0.6535	0.7515	0.0980
6	Govade_Dug_Well_6.6	0.7562	0.7716	0.0154
7	Goveli_Bore_Well_17.25	0.4628	0.6459	0.1831
8	Inde_Dug_Well_7.8	0.6138	0.6332	0.0194
9	Jawhar_Dug_Well_7.65	0.4446	0.4467	0.0021
10	Kajali_Dug_Well_14	0.3919	0.4257	0.0338
11	Kambe_Dug_Well_6.9	0.4758	0.4569	-0.0188
12	Karav_Dug_Well_8	0.2238	0.2211	-0.0026

3.2.2 Behavior and Performance Across Districts

Now coming to performance of the polynomial models across districts. Polynomial model for almost all dug wells and bore wells in Thane district generally show a monotonic decrease in groundwater level from the month of August to next years May. This pattern can be observed in

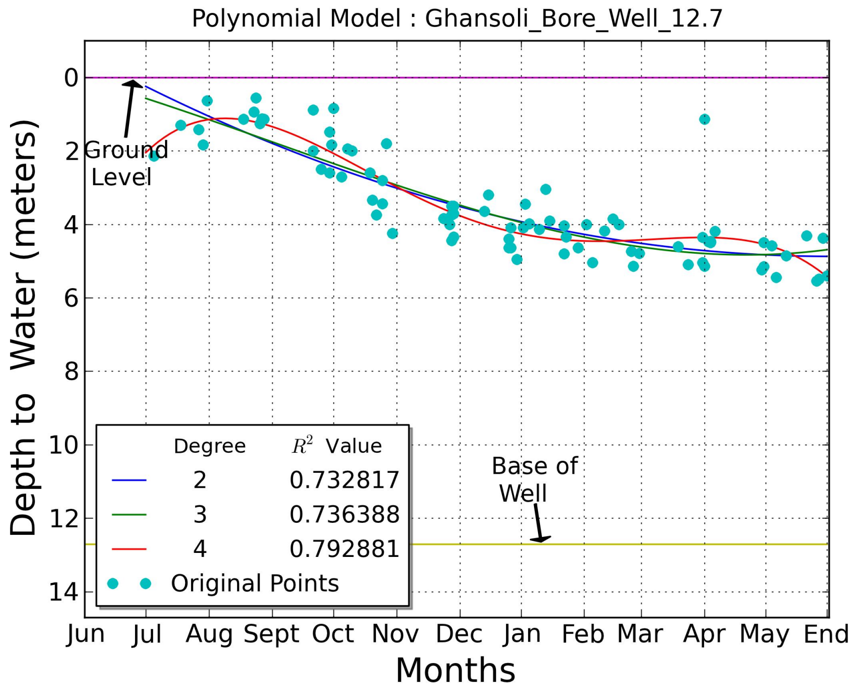


Figure 3.2: Polynomial Model of Bore well in Ghansoli village of Thane district showing a monotonic decline in water level

the polynomial model shown in Figure 3.2. In Latur district similar pattern is observed for dug wells, but not for the the bore wells. Here the bore wells showed an increase in water level till about mid October to starting of November. This pattern can be observed in the two models in Figures 3.3 and 3.4 respectively. We observe such a pattern due to the fact that, aquifers in Latur district are deeper as compared to Thane, so bore wells which are very deep, tap these aquifers and recharge in them takes place for a longer duration. Whereas the aquifers in Thane are very shallow, they fill up very quickly during the rains, and then the rainfall just runs off. In Sangli district, both dug wells and bore wells have observation throughout the year. Here both dug well and bore well show increase in water level post monsoon till about mid October to starting of November. A model for dug well and bore well is show in Figures 3.5 and 3.6 respectively. The average R^2 values for dug wells and bore wells in all three district is shown in Table 3.2.

Table 3.2: Average R^2 comparison for 3 districts

Well Type	Dug Well			Bore Well		
Degree	2	3	4	2	3	4
Thane	0.6492	0.6581	0.6638	0.7300	0.7362	0.7458
Latur	0.4862	0.5004	0.5061	0.2909	0.3158	0.3226
Sangli	0.3102	0.3460	0.3551	0.1595	0.1810	0.1937

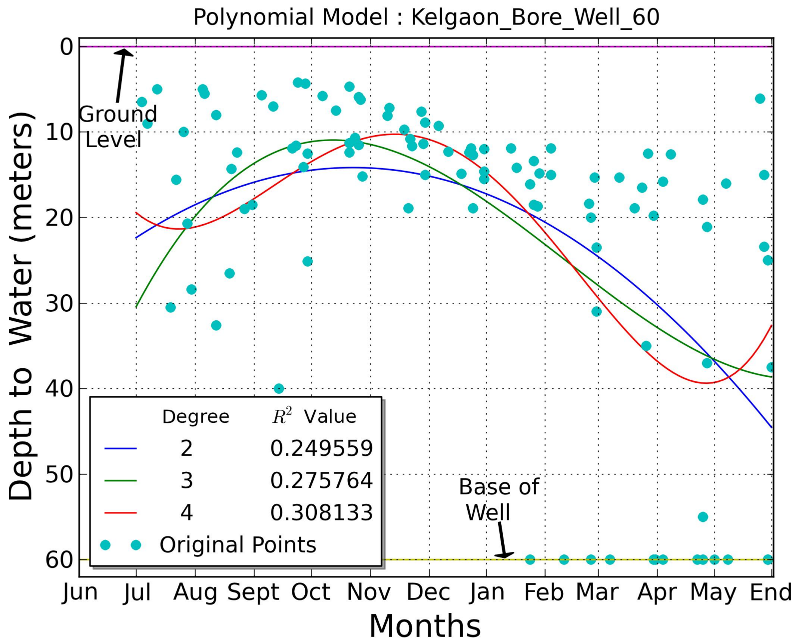


Figure 3.3: Polynomial Model of Bore well in Kelgaon village of Latur district showing rise in water level till start of November

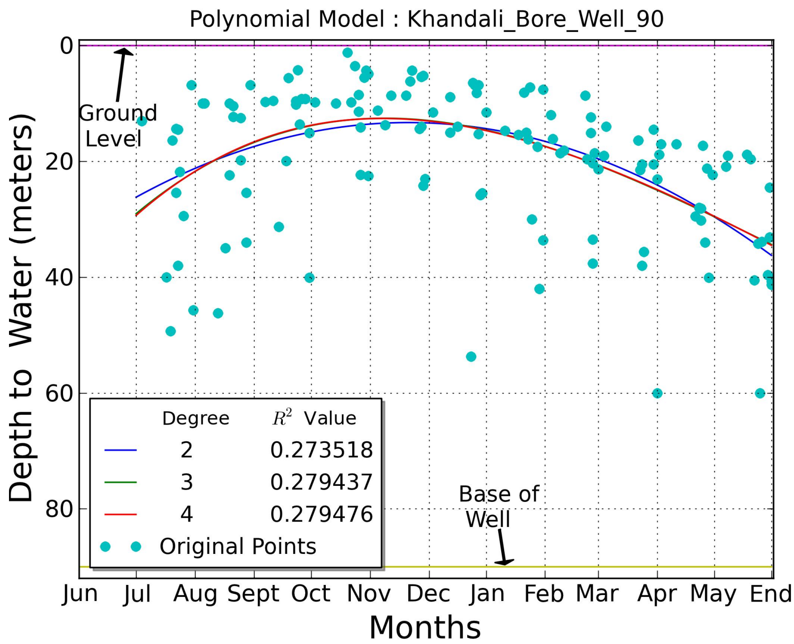


Figure 3.4: Polynomial Model of Dug well in Khandali village of Latur district showing rise in water level till start of December

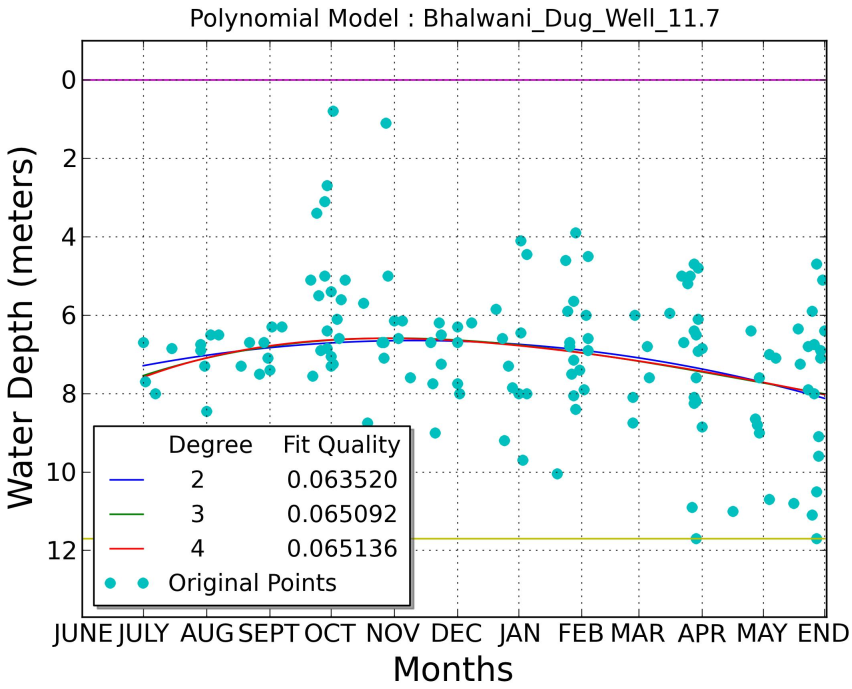


Figure 3.5: Polynomial Model of Dug well in Bhalwani village of Sangli district showing rise in water level till start of December

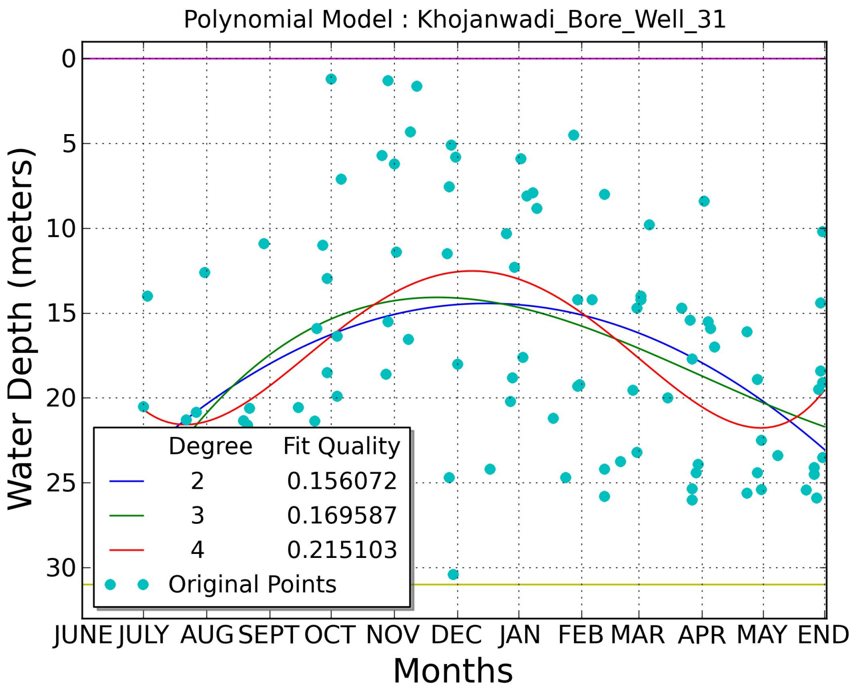


Figure 3.6: Polynomial Model of Bore well in Khojanwadi village of Sangli district

3.3 Summary

- Polynomial model for all three district were developed.
- The polynomial models were better than polynomial model.
- Choice of modeling for the period June to May is a better approach.
- Wells in Thane generally show a monotonically decreasing water levels.
- Latur bore wells initially show rise in water level before declining.
- The value of R^2 improves in all bore wells and it increases by 0.2 in some cases.

Chapter 4

Rainfall Model

4.1 Basic Rainfall Model

For developing our initial polynomial models we have only used observation well data. These were the time stationary model. In the next model i.e. the rainfall model, along with observation well data we have used the rainfall data for developing the models. These models are developed using only those year data in which both rainfall data and observation well data is available. The model year for the rainfall model is same as the polynomial model i.e June-May. For developing the rainfall model we have taken observation well data as degree 2 polynomial and rainfall as linear. The observation well data is folded into single year and mapped to June-May period as done in the case of polynomial model. From this folding and mapping we have x_i and y_i input for model where x_i is the value of date mapped in June-May year and y_i is the water level on that date. The amount of rainfall at an observation well over the years in the months June-September is used as input to develop the model for that observation well. This rainfall is calculated from 0.5°gridded rainfall data. Four rainfall grid points inside which an observation well is located as shown in Figure 4.1 are chosen for every observation well. Let the distance of the 4 grid

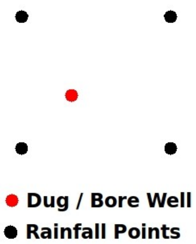


Figure 4.1: Well inside 4 grid rainfall points

points from observation well be d_1, d_2, d_3 and d_4. Let the rainfall at the 4 grid points in months June-September in a year t be $r_{1,t}$, $r_{2,t}$, $r_{3,t}$ and$r_{4,t}$. Then the rainfall at the observation well for the months June-September in the year t i.e r_t is calculated using distance weighted estimator (DWE). DWE is a special case of weighted mean where weighting coefficient for each data point is computed as the inverse mean distance between this data point and the other data points. The value of r_t is by DWE is given as shown by Equation 4.1. Now we have the rainfall input r_t for the rainfall model. Now we do a least square fit of function show in Equation 4.2 to the observation well data i.e x_i, y_i and the rainfall data r_t.

$$r_t = \frac{\frac{r_{1,t}}{d_1} + \frac{r_{2,t}}{d_2} + \frac{r_{3,t}}{d_3} + \frac{r_{4,t}}{d_4}}{\frac{1}{d_1} + \frac{1}{d_2} + \frac{1}{d_3} + \frac{1}{d_4}} \tag{4.1}$$

$$f(x,r) = a_0 + a_1 r_t + a_2 x + a_3 r_t x + a_4 x^2 + a_5 r_t x^2 \tag{4.2}$$

To perform least square fit we solve the system of linear Equations shown in Equation 4.3 and get the values of constants $a_0, a_1, \cdots, a_5$. We also compute the goodness of fit i.e. the R^2 value. Now using these constants we plot the rainfall model for an observation well. These models are plotted for all three districts. A rainfall model for an observation well in Thane is shown in Figure 4.2a with R^2 values shown on it. The complete list of R^2 values for all districts is attached in the appendix. Same method is followed for developing models using the 1.0°gridded data. Since this data set is available only for Thane, models using this dataset are developed only for observation wells in Thane. Figure 4.2b shows such a model.

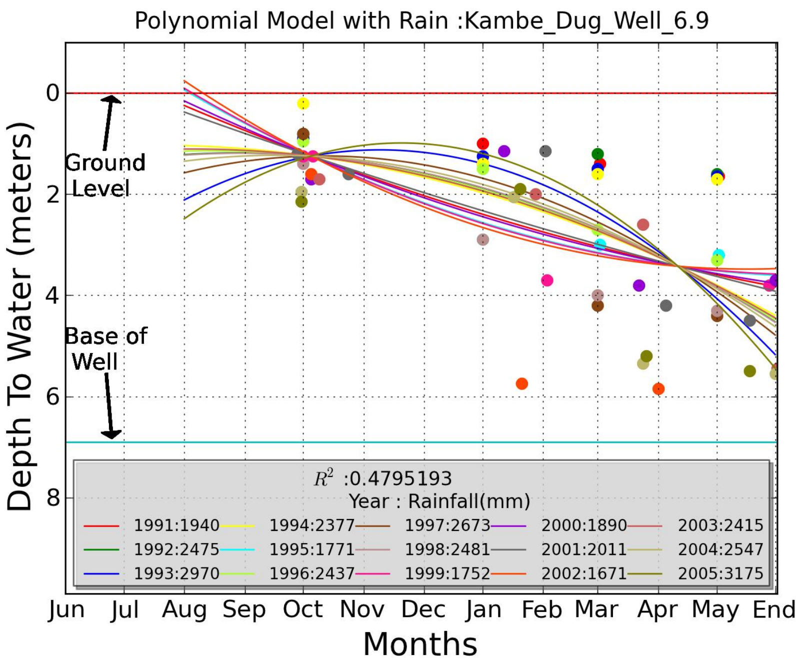
$$\begin{bmatrix} \sum_i 1 & \sum_i r_t & \sum_i x & \sum_i r_t x & \sum_i x^2 & \sum_i r_t x^2 \\ \sum_i r_t & \sum_i r_t^2 & \sum_i r_t x & \sum_i r_t^2 x & \sum_i r_t x^2 & \sum_i r_t^2 x^2 \\ \sum_i x & \sum_i r_t x & \sum_i x^2 & \sum_i r_t x^2 & \sum_i x^3 & \sum_i r_t x^3 \\ \sum_i r_t x & \sum_i r_t^2 x & \sum_i r_t x^2 & \sum_i r_t^2 x^2 & \sum_i r_t x^3 & \sum_i r_t^2 x^3 \\ \sum_i x^2 & \sum_i r_t x^2 & \sum_i x^3 & \sum_i r_t x^3 & \sum_i x^4 & \sum_i r_t x^4 \\ \sum_i r_t x^2 & \sum_i r_t^2 x^2 & \sum_i r_t x^3 & \sum_i r_t^2 x^3 & \sum_i r_t x^4 & \sum_i r_t^2 x^4 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} = \begin{bmatrix} \sum_i y_i \\ \sum_i y_i r_t \\ \sum_i y_i x \\ \sum_i y_i r_t x \\ \sum_i y_i x^2 \\ \sum_i y_i r_t x^2 \end{bmatrix} \tag{4.3}$$

We also had the rainfall data measured at rain-gauge stations in Thane and Latur. We developed rainfall models using this dataset too. The rainfall at an observation well in the months June-September in a year t i.e. r_t was calculated differently in this case. Each taluka in a district would have a rain-gauge station. All the observation wells in a taluka 'T' were assigned the rainfall measured in the months June-September at rain-gauge station located in taluka 'T'. Hence all observation wells in a taluka were assigned the same rainfall. Now as with the gridded rainfall data, same procedure is followed ahead to develop the models. Models with this data are developed for observation wells in Thane and Latur. A model of observation well in Latur developed using this data is shown in Figure 4.3

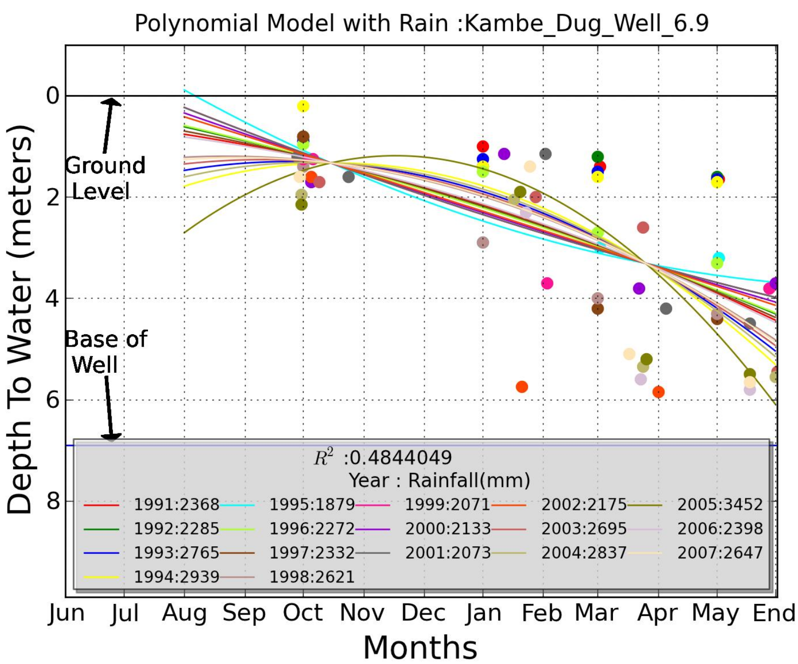
4.2 Rainfall Model Performance

4.2.1 Comparison With Polynomial Model

After developing the rainfall model we compare its performance with the polynomial model in all districts. This comparison is done with rainfall models developed using 0.5°grid data as it



(a) Rainfall Model with 0.5°rainfall data for observation well in Kambe village of Thane district



(b) Rainfall Model with 1.0°rainfall data for observation well in Kambe village of Thane district

Figure 4.2: Rainfall Models

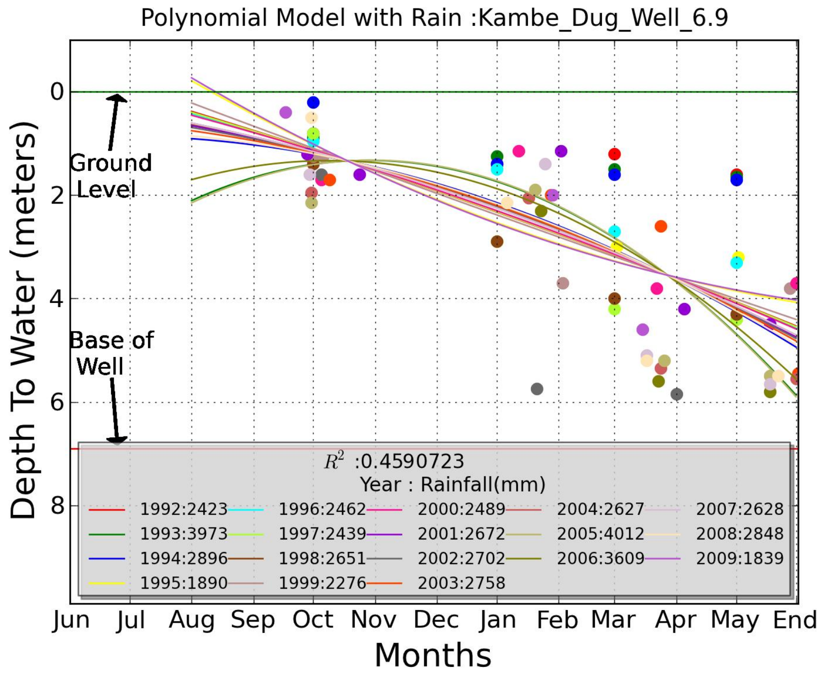


Figure 4.3: Rainfall Model with rain-gauge rainfall data for observation well in Kambe village of Thane district

was available for all the three districts. Since the rainfall data was available only till the year 2005, so for comparison polynomial models were also developed with data up to the year 2006 May [1]. The value of R^2 for polynomial and rainfall models for wells in Thane, Latur and Sangli is show in Tables 4.1, 4.2 and 4.3 respectively. The Table 4.4 shows comparison of R^2 values in different cases in three districts.

Table 4.1: Comparison of R^2 values of Polynomial and rainfall model for some wells in Thane

THANE		
Village	Polynomial	Rainfall
Inde_Dug_Well_7.8	0.6057	0.6109
Jawhar_Dug_Well_7.65	0.4094	0.4171
Kajali_Dug_Well_14	0.4299	0.4422
Kalamdevi_Dug_Well_5.5	0.6076	0.6358
Kambe_Dug_Well_6.9	0.4445	0.4795
Kanchad_Bore_Well_18	0.8645	0.8885

From the Table 4.4 we observe that improvement in R^2 values for Latur and Sangli both in case of dug wells and bore wells is much more that what we get in Thane. Hence adding rainfall to our model helps in Latur and Sangli but not so much in Thane. From this we say that rainfall

[1] Rainfall in 2005 Monsoon is used for observation till 2006 May

Table 4.2: Comparison of R^2 values of Polynomial and rainfall model for some wells in Latur

LATUR		
Village	Polynomial	Rainfall
Gadwad_Dug_Well_12.5	0.3494	0.4855
Gangahipparga_Dug_Well_10.5	0.5065	0.5512
Gangapur_Dug_Well_11.5	0.4499	0.6349
Ganjoor_Dug_Well_19.25	0.2328	0.3773
Garsuli_Dug_Well_10.2	0.6199	0.6800
Gategoan_Dug_Well_13.8	0.2292	0.5040

Table 4.3: Comparison of R^2 values of Polynomial and rainfall model for some wells in Sangli

SANGLI		
Village	Polynomial	Rainfall
Deshing_Dug_Well_9.8	0.1440	0.3680
Devnal_Bore_Well_36.5	0.0780	0.1655
Devnal_Dug_Well_11.75	0.3174	0.3297
Dhavadwadi_Dug_Well_12.3	0.6087	0.7668
Dhavadwadi_Dug_Well_5.7	0.1738	0.2204
Dhavadwadi_Dug_Well_6	0.2574	0.3121

Table 4.4: Comparison of average R^2 value of polynomial and rainfall model in Thane, Latur and Sangli

Model	Polynomial Model		Rainfall Model	
Well	Dug Well	Bore Well	Dug Well	Bore Well
Thane	0.6442	0.7046	0.6636	0.7512
Sangli	0.3186	0.1781	0.4467	0.3517
Latur	0.4649	0.3189	0.5775	0.4798

plays a more prominent role in Latur and Sangli then it does in Thane.

4.2.2 Performance Across Districts

We have developed rainfall models with different rainfall dataset. But using different rainfall datasets did not make a very significant change to the behavior of rainfall models. One can observe this in Figures 4.2a, 4.2b and 4.3 which show rainfall model developed using different rainfall datasets for an observation well. As far as R^2 values obtained with different rainfall datasets are concerned, they also did not change very significantly and neither all increased/decreased from one rainfall model to the other rainfall model. In text ahead when we refer to rainfall model we mean rainfall model developed using 0.5°rainfall data, unless mentioned explicitly otherwise. The average R^2 values of observation wells in Thane, Latur and Sangli obtained by using

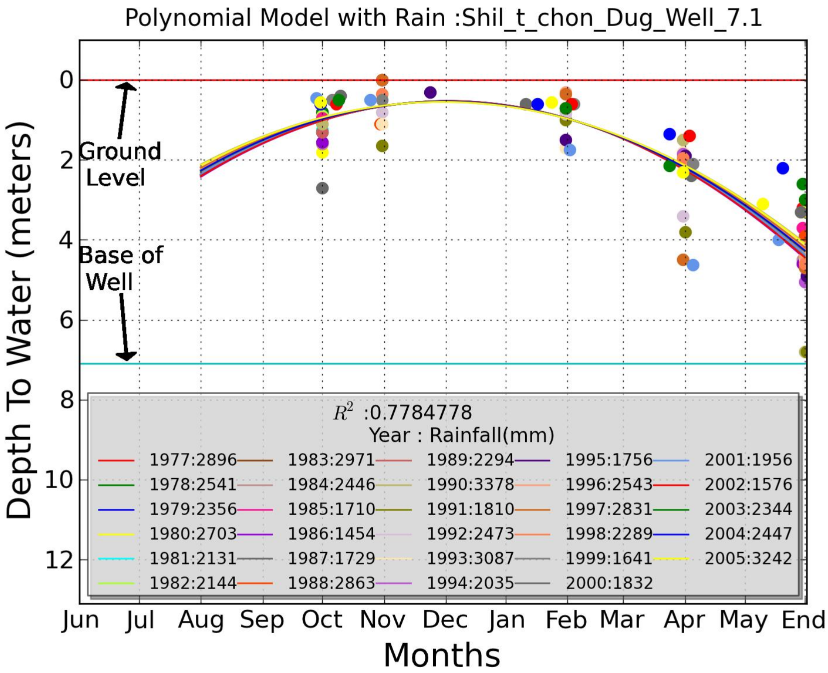


Figure 4.4: Rainfall Model with 0.5°rainfall data for dug well in ShiltChon village of Thane district showing rise in water level till about December

different rainfall datasets are shown in Table 4.5. In Thane, the rainfall models for almost all observation wells, showed decreasing water levels from August to May in all years. There are some exceptions of observation wells which behave differently, as they show some rise in water levels till about Nov-Dec. Model for such an observation well is shown in Figure 4.4. In Latur a very similar behavior was observed for dug wells, but as in the case of polynomial model, the bore wells in Latur showed significant rise in water levels till about Nov-Dec. A model showing such a pattern is shown in Figure 4.5. In Sangli both dug wells and bore wells show rise in water levels till about the month of December.

Table 4.5: Average R^2 values for models developed using different rainfall dataset

Rain Data	**0.5 Degree Grid Data**		**1.0°Grid Data**		**Raingauge Data**	
Well	Dug Well	Bore Well	Dug Well	Bore Well	Dug Well	Bore Well
Thane	0.6636	0.7512	0.6888	0.7531	0.6820	0.7370
Latur	0.5775	0.4798	-	-	0.5090	0.3837
Sangli	0.4467	0.3517	-	-	-	-

4.2.3 Cross Validation of Rainfall Model

To quantify how good/bad is our rainfall model we perform cross validation of our model. Through cross validation we check how well our model is able to predict the water levels in

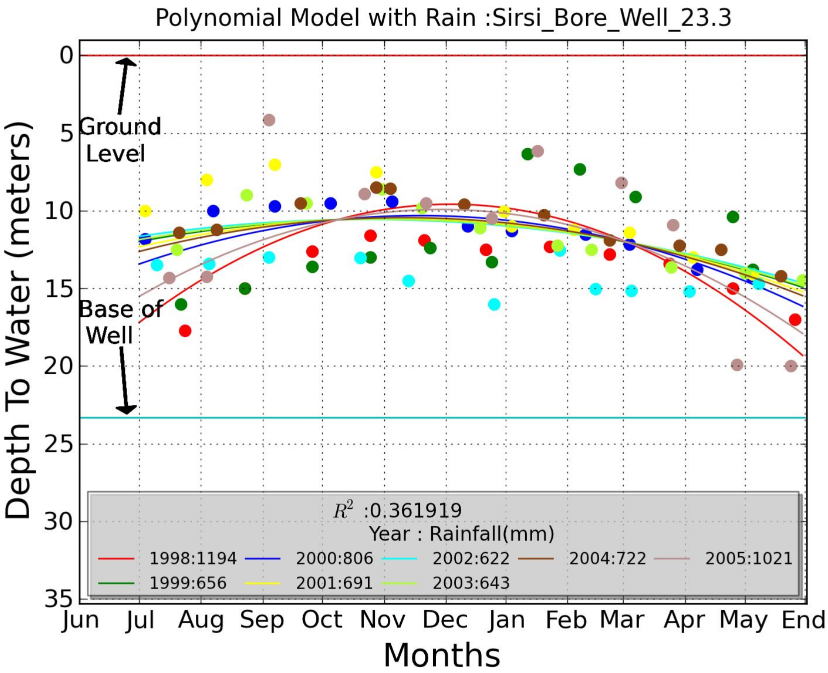


Figure 4.5: Rainfall Model with 0.5°rainfall data for Bore well in Sirsi village of Latur district showing rise in water level till about December

the observation well. This cross validation is done only for rainfall models of dug wells, because the bore wells do not have sufficient data to perform this cross validation. We have performed this cross validation **only for rainfall models developed using 0.5°rainfall data**. The cross validation procedure performed is as follows. Let Y={ Y_1, Y_2,Y_3,$\cdots\cdots$,Y_n} be the set of n years for which both observation well data and rainfall data is available. For us such a set for all district was Y ={ Y_{1991},Y_{1992},$\cdots\cdots$,Y_{2005}}. We randomly choose 5 years from the set Y. Let the set of chosen years be Y', for Latur district we got Y'={ Y'_{1994},Y'_{1997},Y'_{1998},Y'_{1999},Y'_{2003}} . Now we develop rainfall models for the observation well by only using the data from the years in the set $Y - Y'$. We call this rainfall model as sub-rainfall model. In simple words , we have developed a rainfall model using the subset of available data. Now using the rainfall in the year y' as input, where $y' \in Y'$ we plot the groundwater pattern for that year in the observation well. We then probe the model on days at which actual observation are taken in year y', to get the predicted water level. Finally we compare the models predicted value with the actual measured values in the year y'. The metric which we have chosen to quantify the difference is, Root Mean Square Error (RMSE) between the measured values and the predicted values. Let the actual measured values in the year y' be a_1,a_2,$\cdots\cdots$,a_n and the values predicted by sub-rainfall model be p_1,p_2,$\cdots\cdots$,p_n, then the RMSE is given by Equation 4.4

$$RMSE = \sqrt{\frac{\sum_i^n (p_i - a_i)^2}{n}} \tag{4.4}$$

Groundwater pattern predicted using the sub-rainfall model for an observation well in Latur, with low RMSE value for each year y' is shown in Figure 4.6. Another model highlighting the case where the RMSE in high is shown in Figure 4.7 The complete table showing the RMSE error for each dug well is shown attached in appendix

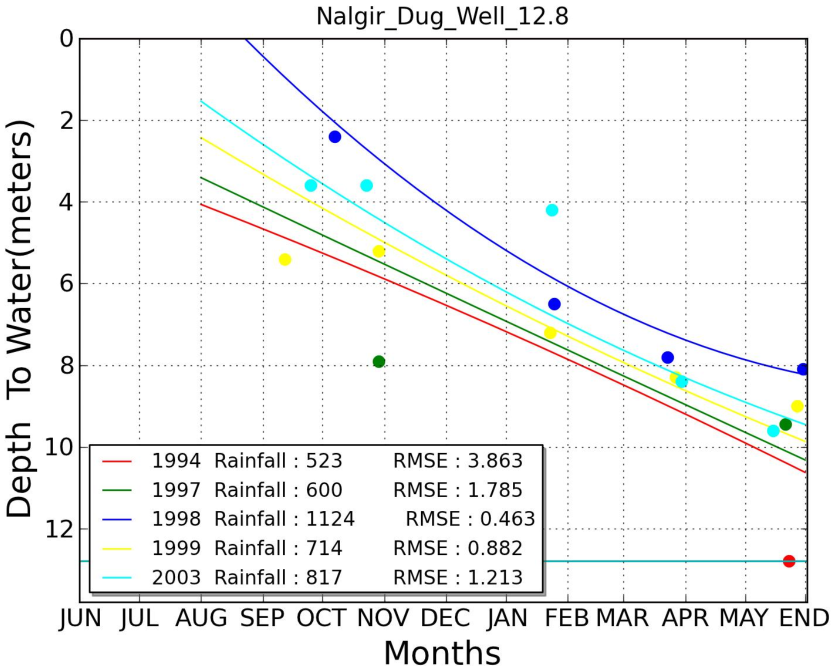


Figure 4.6: Low RMSE Value : Predicted water level and Measured water level observation well in Nalgir village of Latur district.

4.2.4 Performance with Time Weighted Rain

In the rainfall models developed, the rainfall at the observation well for a year y i.e. r_y is calculated as the sum of rain on each day in the period June to September i.e equal weightage is given to rain on all days. But recent and heavier rainfalls are expected to have more impact on groundwater levels than past rainfall. We test this argument with our rainfall model. We develop rainfall model with time weighted rain where lighter rains in past are assigned less weightage whereas heavy rains are considered to have full affect. To calculate time weighted rainfall for a year i.e r'_y, we assign a weight W_d to each day in the period June to September, where W_d is given by Equation 4.5, δ is a constant ≤ 1 and d is count of days starting from 1 at the end of the month September i.e. d is 1 on 30^{th} September, 2 on 29^{th} September, 3 on 28^{th} September and so on till 1^{st} June.

$$W_i = \delta^d \tag{4.5}$$

After the rainfall not all rain infiltrates into the ground. Some amount of rain just runs-off. We define an upper limit U_L on the heavy rain infiltrating into the ground in a day. Now the time

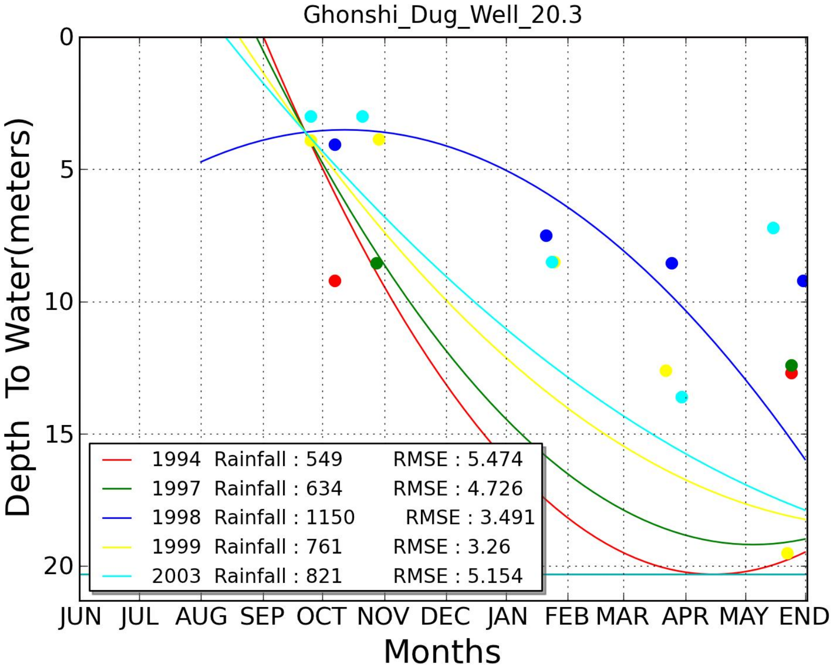


Figure 4.7: High RMSE Value : Predicted water level and Measured water level observation well in Ghansoli village of Latur district.

weighted rainfall for the year i.e. r'_y is calculated as given by Equation 4.6

$$r'_y = \sum_d r'_d \tag{4.6}$$

where r'_d is the weighted rain on day d given by 4.7 and r_d is the rain [2]on day d. For different values of U_L and δ the weighted rainfall was calculated, using which rainfall model were developed. and their quality of fit i.e.R^2 value was calculated. Tables 4.6 and 4.7 shows the R^2 values at different U_L's and δ's for an observation well in Thane and Latur districts respectively. Currently this analysis has not been done for Sangli.

$$r'_d = \begin{cases} U_L & if \quad r_d \geq U_L \\ r_d * W_d & otherwise \end{cases} \tag{4.7}$$

Let each cell be represented by $R^2_{U_L,\delta}$.The entry in the top left most corner of the Tables 4.6 and 4.7 represent the scenario in which we simply sum up the daily rain to get yearly rain. To show comparison of R^2 in this case with cases where weighted rainfall is used we have assigned colours to cells on the basis of following rules-:

[2]The rain on day d is calculated from four grid points using distance weighted estimator as described in 4

Table 4.6: R^2 Values for time weighted rain with different values of U_L and δ for dug well in Thane

U_L/δ	1	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.9
∞	0.4556	0.4569	0.4604	0.4667	0.4738	0.4798	0.4837	0.4857	0.4859	0.4847	0.4825
100	0.4517	0.4622	0.4785	0.4866	0.4885	0.4880	0.4867	0.4854	0.4843	0.4833	0.4825
95	0.4517	0.4617	0.4807	0.4926	0.4968	0.4972	0.4962	0.4948	0.4934	0.4922	0.4912
90	0.4517	0.4618	0.4803	0.4914	0.4950	0.4952	0.4942	0.4930	0.4919	0.4909	0.4901
85	0.4516	0.4581	0.4702	0.4775	0.4799	0.4801	0.4794	0.4785	0.4777	0.4770	0.4764
80	0.4516	0.4586	0.4705	0.4768	0.4785	0.4783	0.4775	0.4767	0.4759	0.4753	0.4748
75	0.4517	0.4569	0.4638	0.4662	0.4662	0.4654	0.4645	0.4638	0.4632	0.4627	0.4623
70	0.4516	0.4551	0.4596	0.4610	0.4607	0.4600	0.4593	0.4588	0.4584	0.4580	0.4578
65	0.4516	0.4556	0.4627	0.4662	0.4672	0.4671	0.4667	0.4663	0.4659	0.4655	0.4653
60	0.4516	0.4543	0.4574	0.4583	0.4583	0.4580	0.4578	0.4577	0.4575	0.4575	0.4574
55	0.4515	0.4539	0.4563	0.4578	0.4588	0.4595	0.4599	0.4603	0.4606	0.4608	0.4609
50	0.4514	0.4530	0.4542	0.4549	0.4553	0.4555	0.4557	0.4559	0.4560	0.4560	0.4561

Table 4.7: R^2 Values for time weighted rain with different values of U_L and δ for dug well in Latur

U_L/δ	1	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.9
∞	0.6248	0.6397	0.6401	0.6315	0.6230	0.6191	0.6201	0.6249	0.6323	0.6413	0.6506
100	0.6268	0.6142	0.6117	0.7232	0.8628	0.9030	0.9164	0.9219	0.9245	0.9258	0.9265
95	0.6294	0.6284	0.6090	0.5998	0.6067	0.6206	0.6345	0.6458	0.6544	0.6606	0.6650
90	0.6317	0.6320	0.6118	0.6000	0.6049	0.6179	0.6317	0.6433	0.6522	0.6588	0.6635
85	0.6341	0.6360	0.6150	0.6006	0.6032	0.6152	0.6287	0.6405	0.6497	0.6567	0.6619
80	0.6367	0.6402	0.6188	0.6017	0.6018	0.6124	0.6256	0.6374	0.6470	0.6544	0.6599
75	0.6394	0.6448	0.6232	0.6035	0.6007	0.6097	0.6223	0.6341	0.6440	0.6518	0.6577
70	0.6423	0.6497	0.6282	0.6059	0.6000	0.6071	0.6189	0.6306	0.6407	0.6488	0.6551
65	0.6452	0.6550	0.6339	0.6092	0.5998	0.6046	0.6154	0.6268	0.6370	0.6454	0.6522
60	0.6483	0.6606	0.6403	0.6134	0.6004	0.6025	0.6118	0.6228	0.6330	0.6416	0.6487
55	0.6499	0.7044	0.7233	0.7212	0.7110	0.6999	0.6905	0.6836	0.6786	0.6751	0.6726
50	0.6480	0.6819	0.6986	0.7018	0.6981	0.6921	0.6863	0.6815	0.6777	0.6749	0.6728

- **Red**: If $R^2_{U_L,\delta} \leq R^2_{\infty,1}$, where $U_L \neq \bigwedge \delta \neq 1$
- **Blue**: If $R^2_{U_L,\delta} > R^2_{\infty,1} <$, where $U_L \neq \bigwedge \delta \neq 1$
- **Green**: The maximum value in the table.

We have observed that in Thane the quality of fit improves, although marginally, for a very large section of villages at many values of U_L and δ. In Latur also the quality of fit improves with many values of U_L and δ and the increase is more than Thane. In some cases R^2 increases by 0.3.

4.3 Dug wells Vs Bore wells

The numbers and depth of dug wells and bore wells vary in all three district. Table 4.8 summarizes these numbers. Figures 4.8 and 4.9 show the R^2 values Vs Well Depth graphs for polynomial models and rainfall model respectively for all districts. Few points to remember before proceeding are: (i) Dug wells in Thane and Latur are sampled 4 times a year, whereas this is not true for Sangli. In Sangli observation from dug wells are also collected monthly. (ii)Bore wells in all three districts are sampled monthly.

Table 4.8: Count and Average Depth of Wells

Well	Dug Wells		Bore Wells	
District	Count	Average Depth	Count	Average Depth
Thane	92	7.18	28	24.10
Latur	115	13.61	21	55.8
Sangli	116	10.65	30	57.40

4.3.1 Observation Frequency Issue

In Latur and Thane dug wells are sampled less frequently as compared to bore wells. So will increasing the frequency of sampling improve the models for dug wells ? To answer this question we consider Sangli as there dug wells are sampled at the same frequency as the bore wells. In Tables 3.2 and 4.5 we observe that quality of fits for dug wells in Sangli is less compared to Thane and Latur, both in polynomial models and rainfall models. In addition to this the R^2 value for bore wells is also very less compared to Thane and Latur. In essence, in case of dug wells with higher frequency and bore wells with same frequency the models are poor compared to Thane and Latur. On this basis we say that increasing the frequency of observation will not improve the polynomial and rainfall model.

The depth of dug wells is in the range of 5-20 meters in all the three districts. The bore wells are much shallower in Thane with a maximum depth of 30 meters whereas in Latur and Sangli bore wells are much deeper. In Figures 4.8 and 4.9 the R^2 value from both polynomial model and rainfall model is plotted Vs Depth of well for all three districts. We make the following observations from these figures.

- In Thane no major contrast is seen in the R^2 values of dug wells and bore wells in polynomial model. And same is the case for rainfall model.
- In Latur, bore wells have poorer fit i.e less R^2 value when compared to dug wells. At this point we don't know the exact reasons but one pointer is the fact that bore wells are much deeper, and their recharge would take more time than the dug wells.
- Overall in Sangli both dug wells and bore wells have a low R^2 value. With rainfall model deeper bore wells (>80 meters) show a relatively higher increase in R^2 values as compared to other bore wells.

4.4 Pending Mathematical Issues

4.4.1 Dry Readings Formulation

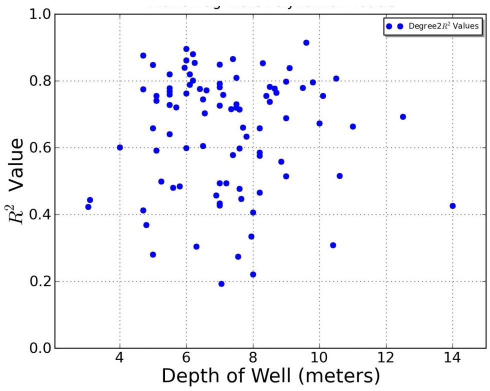
In developing our various model we have perform least square fit of functions to the data points i.e we calculate values of a_i's such that the term e in Equation 4.8 is minimized.

$$e = \sum_i \left(y_i - \sum_k a_k f_k(x_i) \right)^2 \tag{4.8}$$

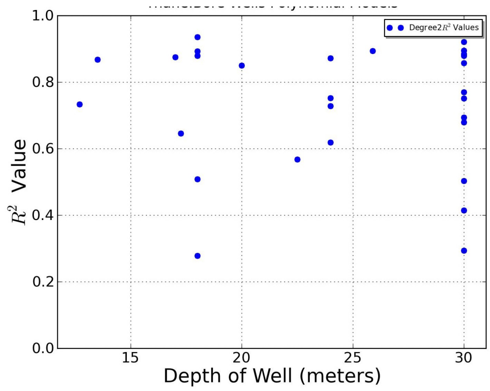
In cases where observation is recorded as dry i.e. if the actual water level is y' and dry well depth is y then it is known that $y' > y$. In such a situation we would consider the term on R.H.S of Equation 4.8 in calculation of error if and only if $y_i > \sum_k a_k f_k(x_i)$ i.e. the fit has a lower value then the well depth, which we know is certainly false. Now following is the approach we used by applying constraint. Now the formulation in Equation 4.9 is a quadratic program. When we perform the fit of functions with the constraints then we found that the models in all cases were same as the previous models. There was only case in which the new model was different. Figure 4.10 shows the model. The reason for this was this observation well had 42 dry readings whereas as the other observation wells had only 3-4 dry readings.

$$\text{Minimize } \sum_i s_i^2 \text{ such that}$$

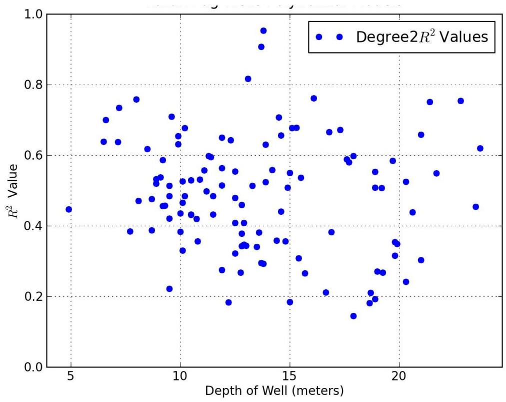
$$\begin{aligned} \sum_k a_k f_k(x_i) + s_i = y_i \qquad & \forall i \in D; \quad D = \{DryReadings\} \\ \sum_k a_k f_k(x_i) + s_i > y_i \qquad & \forall i \in W; \quad W = \{WetReadings\} \end{aligned} \tag{4.9}$$



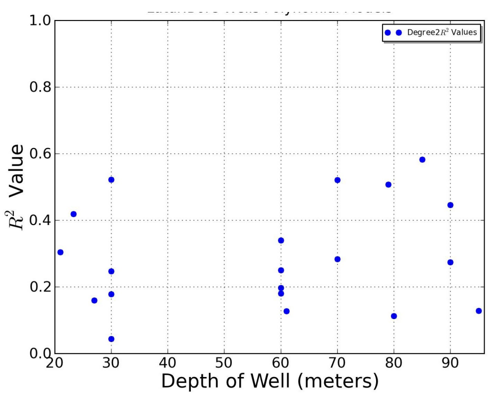
(a) Thane Dug Wells



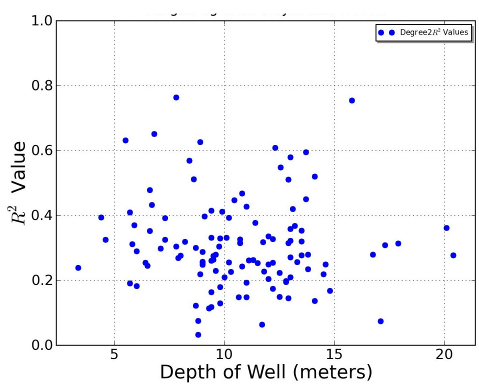
(b) Thane Bore Wells



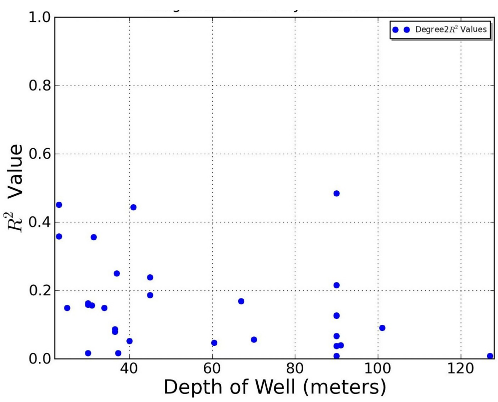
(c) Latur Dug Wells



(d) Latur Bore Wells



(e) Sangli Dug Wells

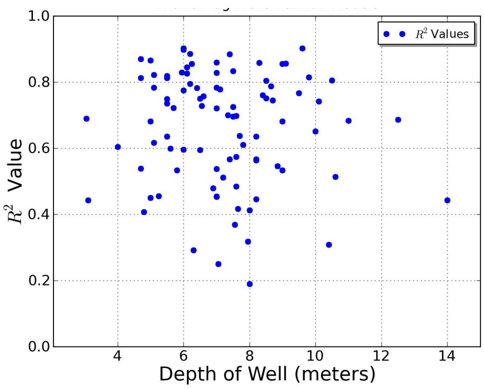


(f) Sangli Bore Wells

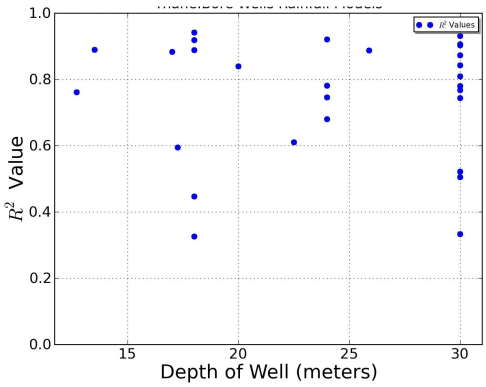
Figure 4.8: R^2 Values of Polynomial Model Vs Depth

4.4.2 MLE for Dry Readings

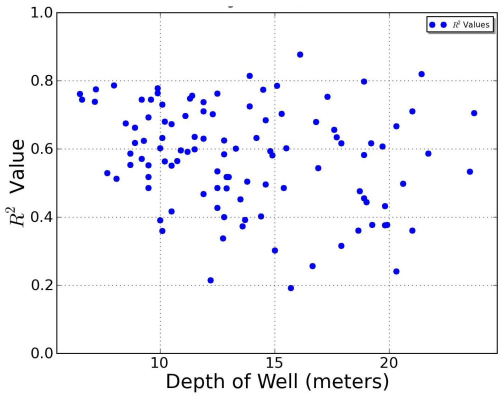
In developing our models we have assumed that the observation values are normally distributed with some unknown mean and variance. The likelihood that mean has value m for the given



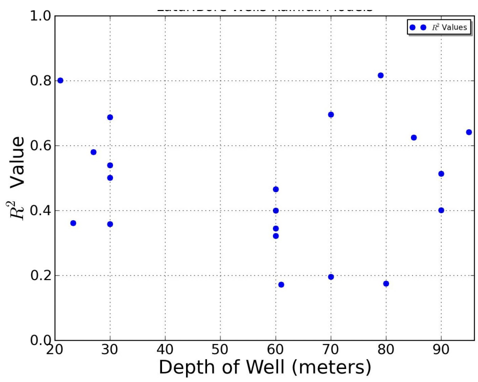
(a) Thane Dug Wells



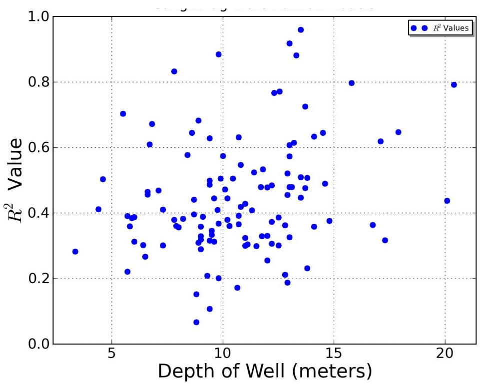
(b) Thane Bore Wells



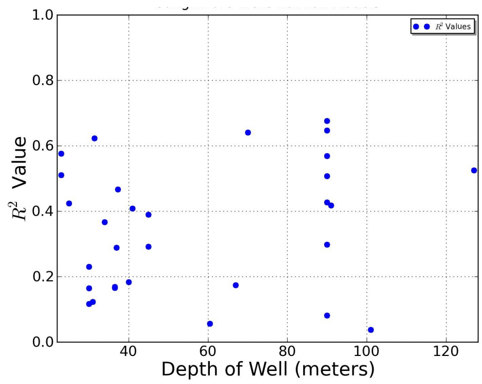
(c) Latur Dug Wells



(d) Latur Bore Wells



(e) Sangli Dug Wells



(f) Sangli Bore Wells

Figure 4.9: R^2 Values of Rainfall Model Vs Depth

sample data is defined to be the probability of getting those sample observations if the mean value is m. MLE for the given sample set of observations is that value of m which maximizes this likelihood. The procedure to calculate this MLE turns out to be the same as that required for calculating the least square fit where we minimize the sum of squared errors. But when we

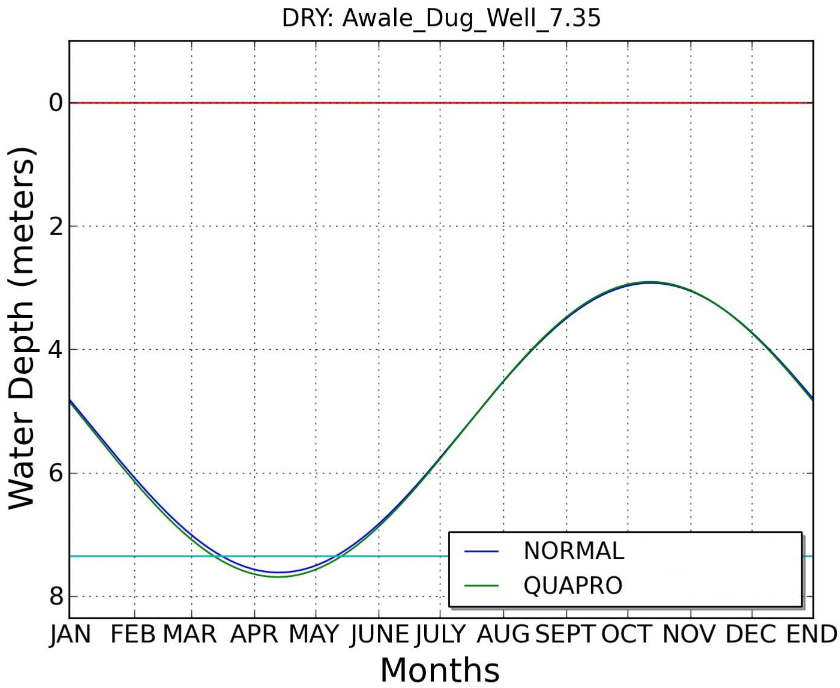


Figure 4.10: Model without constraint(Normal) and with constraint(QUAPRO)

consider a sample set with dry reading, then these observations are not normally distributed as the dry readings are truncated at the value equal to depth of well. The probability of getting an observation this 'depth' value will be higher and hence the likelihood definition will then change. Then in this case the Maximum likelihood estimation procedure will not be the same as the one for ordinary least squared fit. MLE calculations in truncated observations case are a bit cumbersome. It can be probed whether a slight variation in the ordinary least squared fit procedure can be equivalent to the truncated-case MLE. In the worst case, the MLE calculations for the case of truncated observations can be carried out using some numerical optimization procedure.

4.4.3 First Readings

In the classification of years as good bad in [4] we observed that, if the first observation of the year June-May is above the model i.e it indicates higher water level than model, then the subsequent observations in that year are also above the model and vice-versa is true for first observation below the model. This implies that first reading of the year gives a good indication of the water levels in the remaining part of the year.

4.4.4 Rainfall Level in Previous Years

In developing these rainfall models we have just considered that water level in a year is dependent on the rainfall in the current year. But after talking to groundwater experts we realized that this may not be true and water levels may depend on this current year rain as well as previous years rain. Simple scenario to illustrate this is, consider a well in a location where there has been very scarce rainfall in the last 2 years , but a good amount of rainfall this year. In such a scenario the groundwater levels may not immediately show expected amount of increase in levels. For modeling this aspect of rainfall main issue which needs to be looked into is the fact that from how many years should one consider the rainfall.

4.5 Summary

- Rainfall from different datasets did not did not cause a significant difference to the R^2 values of the models. So we choose 0.5°interval data to perform analysis ahead, as it was available for all the years and districts.
- Compared to polynomial models the average R^2 values improved more in Latur and Sangli as compared to Thane. So Thane seems to be not much effected by rain.
- The R^2 values in Sangli is very less compared to Thane and Latur.
- In cross validation of rainfall models, the results were not very conclusive as root mean square error was less in some case more in others.
- Using time weighted rain showed marginal improvement in Thane but values were poorer in case of Thane.

Chapter 5

Conclusion

In Maharashtra groundwater remains a critical component of policies dealing with water management, distribution and various other schemes. Correct estimation of the resource both temporally and spatially under various extraction pattern and recharge regimes is an important objective. This will aid, not only sustainable use, but also used for formulation of new legislation and regulation governing to water sector.

5.1 Conclusions

The thesis began with the GSDA observation well data set. Initially a very preliminary study regarding the number of wells, observation frequency, observation periods and spatial distribution of wells was done. As a part of this preliminary study we also pointed out certain common errors and exceptions in the dataset. Next, we developed the single well models, first as periodic and then as polynomial functions by using only the observation well data. The we developed models using polynomial functions which take into account the rainfall for that year. This was done for Thane, Latur and Sangli districts. Our conclusions are as follows.

- The quality of fit improves as we move from the periodic model to the polynomial model. The improvement is more significant in case of bore wells as compared to dug wells. This is reasonable since the bore wells have observations in monsoon period, and monsoon is a fairly dramatic recharge event which is not easily modeled.
- Next, we see that using the rainfall for the year again improves the quality of fit. On an average the increase in R^2 value is 0.12-0.16 in case on Latur and Sangli , but only 0.02-0.05 in case of Thane. This led us to conclude that rain has a more prominent role in Latur and Sangli and not so much in Thane.
- The R^2 values after rainfall is used ranges from roughly 0.7 for Thane to around 0.4 for Sangli, which in itself is not good enough. This indicates that other than rain there are several other parameters affecting the well levels, which needs to be accounted to get better fits. This could be the groundwater discharge from wells within the area or from the observation well itself.

- We also observed that bore wells and dug wells do behave differently, especially in the deeper aquifer areas, where the recharge is slower and takes more time. This is evident especially in Latur. On the other hand, this effect is subdued in Thane where presumably the aquifers are shallow.

- The bore wells and dug wells have different sampling frequency in Thane and Latur , but in Sangli both of them are sampled monthly. Yet the quality of fit is poorest in Sangli. So, it is not clear that increasing the frequency of observation will actually lead to better models in Thane and Latur, unless other factors which seem to influence levels are well understood.

- We have tested out model for prediction as described in Section4.2.3. For some wells the results were good i.e root mean square error was less, but for others the results were not so impressive. So the current rainfall models are not as good as we want.

- Overall, in our opinion, our single well model is an important first step in the analysis of groundwater. Getting the R^2 values to 0.8 will require us to understand many factors which are related to geology and hydrology.

- These models will play a crucial role in building spatial models which will have a greatly enhanced predictive value than our models. As of now, the models are more indicative of the trend than of exact levels and can help in addressing some of the broader predictive needs of GSDA.

5.2 Future Objectives

In this work we have made an attempt to understand groundwater from observation samples and rainfall data. Future work in this area will perhaps need more hydro-geological understanding. We made an initial attempt by using the weighted rain approach as described in Section 4.2.4 Some of the objectives for the future work are following-:

- Predict the water level in a well when it is dry, this was a part of current work but could not be done

- Use the aquifer properties - storativity and transimissivity in the models.

- Currently, models are developed using rainfall from current year, but previous year rain may also have influence on groundwater levels. In future this aspect can be explored to see if including previous years rain have an impact or not.

- Instead of using rainfall, use infiltration to model groundwater, but this would require accurate estimate of rainfall, evapotranspiration, runoff which is not easily available.

Appendix A

Periodic Model R^2 Values

Table A.1: Periodic Model with Original Points R^2 values-THANE

S.No	Village	$F_1(x)$	$F_2(x)$	$F_3(x)$	$F_4(x)$
1	Agashi_Boling_Dug_Well_10	0.6785	0.6940	0.6992	0.7336
2	Akoli_Dug_Well_5.5	0.7123	0.7759	0.7840	0.7984
3	Ambiste_kh_Bore_Well_17	0.6577	0.8103	0.8511	0.8566
4	Awale_Dug_Well_7.35	0.6892	0.7365	0.7457	0.7623
5	Badlapur_Bore_Well_30	0.3493	0.4343	0.4550	0.4923
6	Badlapur_Dug_Well_7.95	0.3360	0.3374	0.3497	0.3516
7	Bapgaon_Dug_Well_7.4	0.8290	0.8799	0.8809	0.8910
8	Bhatsai_Bore_Well_18	0.3154	0.5491	0.5590	0.5637
9	Bhinar_Dug_Well_6.25	0.8250	0.8543	0.8641	0.8679
10	Borivali_T_Padgha_Dug_Well_10.6	0.4869	0.5370	0.5565	0.5586
11	Bursunge_Dug_Well_8.65	0.7113	0.7892	0.7956	0.8011
12	Chahade_Dug_Well_5.7	0.7377	0.7440	0.7507	0.7516
13	Chavindra_Bore_Well_13.5	0.6155	0.7894	0.8094	0.8154
14	Chndansar_Bore_Well_24	0.6535	0.7426	0.7769	0.7778
15	Dahisar_Dug_Well_9.5	0.7332	0.7919	0.8017	0.8049
16	Dapode_Dug_Well_5.25	0.4645	0.4821	0.4898	0.4958
17	Deoli_Dug_Well_6.2	0.7840	0.8110	0.8253	0.8557
18	Dhanivri_Dug_Well_5.5	0.7010	0.7569	0.7805	0.7811
19	Dhanoshi_Dug_Well_6.5	0.7373	0.7830	0.7842	0.7904
20	Dhuktan_Dug_Well_6.1	0.7544	0.7903	0.8024	0.8098
21	Dolhare_Dug_Well_5.5	0.8215	0.8393	0.8400	0.8407
22	Durves_Dug_Well_9.6	0.8578	0.9196	0.9200	0.9206
23	Gates_Bk_Dug_Well_7.5	0.6938	0.7321	0.7382	0.7505
24	Ghansoli_Bore_Well_12.7	0.5482	0.6746	0.6844	0.6929

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S.No	Village	$F_1(x)$	$F_2(x)$	$F_3(x)$	$F_4(x)$
25	Ghodbandar_Dug_Well_8.2	0.5587	0.5920	0.5979	0.6164
26	Ghol_Dug_Well_10.4	0.2426	0.3554	0.3649	0.3683
27	Gokhiware_Bore_Well_18	0.7016	0.8408	0.8712	0.8781
28	Gokhiware_Dug_Well_5.5	0.6598	0.7270	0.7474	0.7665
29	Govade_Dug_Well_6.6	0.7562	0.7748	0.7943	0.8059
30	Goveli_Bore_Well_17.25	0.4628	0.6522	0.6716	0.6739
31	Inde_Dug_Well_7.8	0.6138	0.6473	0.6475	0.6748
32	Jawhar_Dug_Well_7.65	0.4446	0.4769	0.4834	0.5390
33	Kajali_Dug_Well_14	0.3919	0.4323	0.4649	0.5180
34	Kalamdevi_Dug_Well_5.5	0.6123	0.6263	0.6759	0.6892
35	Kambe_Dug_Well_6.9	0.4758	0.4780	0.5115	0.5642
36	Kanchad_Bore_Well_18	0.6263	0.8266	0.8508	0.8682
37	Kanchad_Dug_Well_7.5	0.7687	0.8413	0.8425	0.8559
38	Kanhor_Dug_Well_8.5	0.6955	0.7326	0.7374	0.7552
39	Karav_Dug_Well_8	0.2238	0.2347	0.2373	0.4968
40	Karvele_Dug_Well_6.3	0.2734	0.3008	0.3078	0.4015
41	Kasa_bk_Dug_Well_6.5	0.5978	0.6124	0.6296	0.6626
42	Katrap_Dug_Well_3.1	0.3747	0.3973	0.4022	0.4112
43	Khaniwade_Dug_Well_5	0.8013	0.8503	0.8505	0.8577
44	Kharade_Dug_Well_8.2	0.5188	0.5927	0.5968	0.6033
45	Khodala_Dug_Well_5.8	0.4863	0.5026	0.5263	0.5263
46	Kogde_Dug_Well_7	0.8007	0.8154	0.8180	0.8248
47	Kopar_Karane_Dug_Well_4.7	0.3908	0.4101	0.4191	0.4481
48	Kopari_Dug_Well_7.55	0.2954	0.2966	0.3129	0.3335
49	Kudan_Bore_Well_30	0.5937	0.6645	0.6659	0.6744
50	Kudus_Dug_Well_6	0.7589	0.7819	0.7961	0.8027
51	Lalthan_Dug_Well_6.4	0.7198	0.7858	0.7984	0.8185
52	Mahim_Bore_Well_20	0.6796	0.8444	0.8615	0.8621
53	Makunsar_Dug_Well_9.8	0.7556	0.8036	0.8043	0.8429
54	Mandawa_Bore_Well_30	0.3500	0.5030	0.5038	0.5087
55	Mandvi_Dug_Well_9.1	0.8189	0.8507	0.8554	0.8684
56	Mangrul_Dug_Well_7.6	0.4950	0.5026	0.5175	0.5336
57	Manor_Dug_Well_7	0.4412	0.4855	0.5222	0.5498
58	Met_Dug_Well_8.3	0.8079	0.8650	0.8718	0.8831
59	Mokhada_Dug_Well_9	0.7041	0.7112	0.7389	0.7474
60	Morhande_Dug_Well_5.1	0.7485	0.7765	0.7887	0.7904
61	Musarne_Dug_Well_6	0.8285	0.8745	0.8807	0.8833
62	Nare_Bore_Well_18	0.7375	0.8519	0.8871	0.9033
63	Neharoli_Bore_Well_24	0.3701	0.5992	0.6312	0.6319

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S.No	Village	$F_1(x)$	$F_2(x)$	$F_3(x)$	$F_4(x)$
64	Newale_Dug_Well_8.2	0.5559	0.5888	0.5925	0.5957
65	Nihe_Dug_Well_7	0.7412	0.8009	0.8195	0.8328
66	Nimbavali_Bore_Well_30	0.4452	0.5532	0.5924	0.6298
67	Padgha_Bore_Well_30	0.5897	0.7319	0.7479	0.7584
68	Palghar_kolgaon_Bore_Well_30	0.7062	0.8589	0.8705	0.8759
69	Pali_Dug_Well_6	0.8925	0.9118	0.9119	0.9165
70	Parli_Dug_Well_5.1	0.5639	0.6090	0.6107	0.6188
71	Pawane_Dug_Well_5	0.2763	0.2909	0.2936	0.3118
72	Pelhar_Dug_Well_7	0.6950	0.7248	0.7283	0.7353
73	Pimpalas_Dug_Well_6.55	0.6785	0.7271	0.7373	0.7839
74	Pimpalshet_Dug_Well_8.5	0.7026	0.7417	0.7453	0.7541
75	Rayta_Dug_Well_4	0.6137	0.6202	0.6205	0.6228
76	Safala_Dug_Well_10.5	0.8018	0.8145	0.8257	0.8354
77	Safale_Bore_Well_25.9	0.6563	0.8317	0.8733	0.8848
78	Sakharshet_chalatwad_Bore_Well_22.5	0.3670	0.5494	0.5647	0.5964
79	Sakwar_Dug_Well_6	0.5228	0.6005	0.6222	0.6516
80	Sange_Dug_Well_4.7	0.8375	0.8874	0.8877	0.8884
81	Saravali_Bore_Well_24	0.5187	0.6983	0.7221	0.7247
82	Sasne_Dug_Well_8.85	0.5561	0.5692	0.5791	0.6057
83	Satiwali_Bore_Well_18	0.1827	0.2929	0.3039	0.3128
84	Satiwali_Dug_Well_7.2	0.4394	0.5682	0.5917	0.5931
85	Sawta_Dug_Well_8.4	0.6719	0.7366	0.7650	0.7740
86	Shelonde_Dug_Well_12.5	0.6780	0.7151	0.7388	0.7433
87	Shendrun_Dug_Well_4.7	0.7505	0.7831	0.7861	0.7874
88	Shil_t_chon_Dug_Well_7.1	0.7080	0.7166	0.7179	0.7212
89	Shilphata_Dug_Well_4.8	0.3720	0.4128	0.4832	0.4910
90	Shirgaon_Dug_Well_9	0.7924	0.8116	0.8259	0.8407
91	Shivale_Dug_Well_11	0.6512	0.6762	0.6772	0.6982
92	Suksale_Bore_Well_30	0.4842	0.6564	0.7171	0.7321
93	Talasari_Dug_Well_8	0.4578	0.4613	0.4789	0.4882
94	Talasarimal_Dug_Well_8.2	0.4947	0.4986	0.5024	0.5099
95	Talegaon_Dug_Well_6.1	0.8323	0.8458	0.8509	0.8551
96	Talwada_Bore_Well_30	0.6600	0.7982	0.8353	0.8435
97	Tembhare_Dug_Well_5.5	0.7485	0.7972	0.8108	0.8134
98	Thane_Dug_Well_7.05	0.2035	0.2035	0.2921	0.2956
99	Thilher_Dug_Well_6.2	0.8470	0.8868	0.8876	0.8922
100	Thunepada_Dug_Well_5.95	0.7820	0.8501	0.8540	0.8572
101	Titwala_Dug_Well_7	0.4221	0.4682	0.4901	0.4977
102	Tokavde_Bore_Well_24	0.7104	0.8062	0.8161	0.8287

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S.No	Village	$F_1(x)$	$F_2(x)$	$F_3(x)$	$F_4(x)$
103	Tokawade_Dug_Well_5	0.6774	0.6854	0.6867	0.6990
104	Udawa_Bore_Well_30	0.6305	0.8312	0.8698	0.8866
105	Vadoli_Dug_Well_5.6	0.4517	0.5106	0.5378	0.5403
106	Varaskol_Dug_Well_7	0.8673	0.8790	0.8814	0.8830
107	Vasar_Bore_Well_30	0.2033	0.2560	0.2678	0.2729
108	Vedhi_Dug_Well_8.7	0.7041	0.7686	0.7743	0.8114
109	Vehaloli_Dug_Well_5.1	0.7517	0.7795	0.7919	0.7945
110	Vevaji_Dug_Well_7.6	0.5461	0.6211	0.6384	0.6999
111	Veyour_Dug_Well_10.1	0.7599	0.7735	0.7885	0.7912
112	Vihigaon_Dug_Well_7.5	0.6851	0.7246	0.7551	0.7858
113	Wada_Dug_Well_9	0.5124	0.5170	0.5289	0.5488
114	Waret_Bore_Well_30	0.6412	0.7945	0.8519	0.8558
115	Warwade_Dug_Well_7.6	0.6622	0.7244	0.7460	0.7499
116	Washind_Dug_Well_3.05	0.4328	0.4437	0.4586	0.5280
117	Washind_Dug_Well_7	0.4182	0.4721	0.5119	0.5238
118	Zhai_Dug_Well_7.7	0.6105	0.6562	0.7003	0.7122
119	Zhari_Bore_Well_30	0.6882	0.8349	0.8903	0.9076
120	Zhari_Dug_Well_7.4	0.5688	0.5919	0.5943	0.5980

-End of Table A.1

Table A.2: Periodic Model with Linearlly Interpolated Points R^2 values-THANE

S.No	Village	$F_1(x)$	$F_2(x)$	$F_3(x)$	$F_4(x)$
1	Agashi_Boling_Dug_Well_10	0.7363	0.7557	0.7571	0.7577
2	Akoli_Dug_Well_5.5	0.7581	0.7889	0.7907	0.7940
3	Ambiste_kh_Bore_Well_17	0.6639	0.7711	0.7866	0.7877
4	Awale_Dug_Well_7.35	0.6430	0.6727	0.6755	0.6767
5	Badlapur_Bore_Well_30	0.3298	0.3738	0.3794	0.3854
6	Badlapur_Dug_Well_7.95	0.3156	0.3188	0.3210	0.3230
7	Bapgaon_Dug_Well_7.4	0.8406	0.8648	0.8675	0.8693
8	Bhatsai_Bore_Well_18	0.3732	0.5165	0.5202	0.5227
9	Bhinar_Dug_Well_6.25	0.7213	0.7620	0.7625	0.7672
10	Borivali_T_Padgha_Dug_Well_10.6	0.3950	0.4146	0.4155	0.4177
11	Bursunge_Dug_Well_8.65	0.7626	0.7952	0.7970	0.7992
12	Chahade_Dug_Well_5.7	0.7116	0.7219	0.7248	0.7272
13	Chavindra_Bore_Well_13.5	0.6091	0.7285	0.7400	0.7418
14	Chndansar_Bore_Well_24	0.6130	0.6460	0.6578	0.6582
15	Dahisar_Dug_Well_9.5	0.5894	0.6077	0.6091	0.6104
16	Dapode_Dug_Well_5.25	0.2876	0.3015	0.3026	0.3047
17	Deoli_Dug_Well_6.2	0.8190	0.8324	0.8329	0.8366
18	Dhanivri_Dug_Well_5.5	0.6786	0.7065	0.7084	0.7137
19	Dhanoshi_Dug_Well_6.5	0.7084	0.7207	0.7244	0.7252
20	Dhuktan_Dug_Well_6.1	0.7485	0.7695	0.7710	0.7748
21	Dolhare_Dug_Well_5.5	0.8263	0.8367	0.8375	0.8393
22	Durves_Dug_Well_9.6	0.8304	0.8521	0.8534	0.8556
23	Gates_Bk_Dug_Well_7.5	0.7043	0.7215	0.7230	0.7263
24	Ghansoli_Bore_Well_12.7	0.4981	0.5843	0.5871	0.5913
25	Ghodbandar_Dug_Well_8.2	0.6312	0.6425	0.6453	0.6488
26	Ghol_Dug_Well_10.4	0.2827	0.3246	0.3265	0.3284
27	Gokhiware_Bore_Well_18	0.7445	0.8348	0.8457	0.8479
28	Gokhiware_Dug_Well_5.5	0.6212	0.6435	0.6459	0.6498
29	Govade_Dug_Well_6.6	0.8003	0.8104	0.8106	0.8150
30	Goveli_Bore_Well_17.25	0.5025	0.6660	0.6753	0.6758
31	Inde_Dug_Well_7.8	0.5857	0.6023	0.6041	0.6061
32	Jawhar_Dug_Well_7.65	0.3861	0.4064	0.4074	0.4084
33	Kajali_Dug_Well_14	0.4934	0.5116	0.5138	0.5175
34	Kalamdevi_Dug_Well_5.5	0.5409	0.5487	0.5491	0.5516
35	Kambe_Dug_Well_6.9	0.3836	0.3875	0.3914	0.3947
36	Kanchad_Bore_Well_18	0.6398	0.7291	0.7358	0.7426
37	Kanchad_Dug_Well_7.5	0.6411	0.6668	0.6751	0.6765

-Table A.2 continued on next page

-Table A.2 continued from previous page

S.No	Village	$F_1(x)$	$F_2(x)$	$F_3(x)$	$F_4(x)$
38	Kanhor_Dug_Well_8.5	0.6783	0.7005	0.7040	0.7065
39	Karav_Dug_Well_8	0.2522	0.2660	0.2683	0.2710
40	Karvele_Dug_Well_6.3	0.2415	0.2495	0.2509	0.2519
41	Kasa_bk_Dug_Well_6.5	0.4539	0.4780	0.4793	0.4828
42	Katrap_Dug_Well_3.1	0.3438	0.3560	0.3568	0.3574
43	Khaniwade_Dug_Well_5	0.7712	0.8068	0.8079	0.8113
44	Kharade_Dug_Well_8.2	0.5023	0.5309	0.5364	0.5394
45	Khodala_Dug_Well_5.8	0.4954	0.5063	0.5084	0.5087
46	Kogde_Dug_Well_7	0.8033	0.8135	0.8160	0.8171
47	Kopar_Karane_Dug_Well_4.7	0.3435	0.3539	0.3544	0.3550
48	Kopari_Dug_Well_7.55	0.2039	0.2163	0.2200	0.2200
49	Kudan_Bore_Well_30	0.6341	0.6633	0.6638	0.6647
50	Kudus_Dug_Well_6	0.7231	0.7323	0.7346	0.7356
51	Lalthan_Dug_Well_6.4	0.7916	0.8193	0.8209	0.8251
52	Mahim_Bore_Well_20	0.7144	0.8236	0.8292	0.8307
53	Makunsar_Dug_Well_9.8	0.7213	0.7386	0.7404	0.7418
54	Mandawa_Bore_Well_30	0.3867	0.4875	0.4889	0.4936
55	Mandvi_Dug_Well_9.1	0.8150	0.8331	0.8362	0.8375
56	Mangrul_Dug_Well_7.6	0.4663	0.4721	0.4738	0.4741
57	Manor_Dug_Well_7	0.3414	0.3843	0.3866	0.3931
58	Met_Dug_Well_8.3	0.7946	0.8212	0.8237	0.8248
59	Mokhada_Dug_Well_9	0.6643	0.6799	0.6813	0.6823
60	Morhande_Dug_Well_5.1	0.7178	0.7315	0.7337	0.7347
61	Musarne_Dug_Well_6	0.7691	0.7869	0.7887	0.7906
62	Nare_Bore_Well_18	0.7326	0.7795	0.7908	0.7969
63	Neharoli_Bore_Well_24	0.4120	0.5692	0.5794	0.5811
64	Newale_Dug_Well_8.2	0.5116	0.5258	0.5273	0.5279
65	Nihe_Dug_Well_7	0.7230	0.7470	0.7501	0.7530
66	Nimbavali_Bore_Well_30	0.4811	0.5448	0.5596	0.5760
67	Padgha_Bore_Well_30	0.5820	0.7031	0.7055	0.7100
68	Palghar_kolgaon_Bore_Well_30	0.7406	0.8691	0.8745	0.8764
69	Pali_Dug_Well_6	0.8727	0.8824	0.8840	0.8854
70	Parli_Dug_Well_5.1	0.5266	0.5374	0.5400	0.5412
71	Pawane_Dug_Well_5	0.2371	0.2432	0.2448	0.2466
72	Pelhar_Dug_Well_7	0.6154	0.6369	0.6387	0.6429
73	Pimpalas_Dug_Well_6.55	0.6250	0.6459	0.6482	0.6496
74	Pimpalshet_Dug_Well_8.5	0.6915	0.7092	0.7109	0.7129
75	Rayta_Dug_Well_4	0.5928	0.5970	0.5979	0.5991
76	Safala_Dug_Well_10.5	0.7562	0.7746	0.7759	0.7788

-Table A.2 continued on next page

-Table A.2 continued from previous page

S.No	Village	$F_1(x)$	$F_2(x)$	$F_3(x)$	$F_4(x)$
77	Safale_Bore_Well_25.9	0.6662	0.7869	0.7971	0.8033
78	Sakharshet_chalatwad_Bore_Well_22.5	0.3656	0.4654	0.4731	0.4796
79	Sakwar_Dug_Well_6	0.4086	0.4379	0.4390	0.4440
80	Sange_Dug_Well_4.7	0.8184	0.8435	0.8458	0.8480
81	Saravali_Bore_Well_24	0.5421	0.6884	0.7008	0.7014
82	Sasne_Dug_Well_8.85	0.6086	0.6191	0.6202	0.6224
83	Satiwali_Bore_Well_18	0.2026	0.3033	0.3055	0.3091
84	Satiwali_Dug_Well_7.2	0.2169	0.3282	0.3315	0.3364
85	Sawta_Dug_Well_8.4	0.6404	0.6624	0.6650	0.6660
86	Shelonde_Dug_Well_12.5	0.6885	0.7055	0.7092	0.7096
87	Shendrun_Dug_Well_4.7	0.7453	0.7684	0.7701	0.7731
88	Shil_t_chon_Dug_Well_7.1	0.5162	0.5628	0.5672	0.5704
89	Shilphata_Dug_Well_4.8	0.2077	0.2291	0.2294	0.2331
90	Shirgaon_Dug_Well_9	0.7808	0.7935	0.7944	0.7967
91	Shivale_Dug_Well_11	0.5856	0.6104	0.6115	0.6129
92	Suksale_Bore_Well_30	0.4957	0.6086	0.6343	0.6382
93	Talasari_Dug_Well_8	0.4381	0.4418	0.4432	0.4503
94	Talasarimal_Dug_Well_8.2	0.5660	0.5708	0.5744	0.5749
95	Talegaon_Dug_Well_6.1	0.8326	0.8406	0.8425	0.8438
96	Talwada_Bore_Well_30	0.6921	0.7718	0.7857	0.7895
97	Tembhare_Dug_Well_5.5	0.7752	0.8059	0.8097	0.8119
98	Thane_Dug_Well_7.05	0.1252	0.1376	0.1438	0.1438
99	Thilher_Dug_Well_6.2	0.7700	0.7883	0.7903	0.7919
100	Thunepada_Dug_Well_5.95	0.7632	0.7957	0.7996	0.8016
101	Titwala_Dug_Well_7	0.2568	0.2897	0.2898	0.2964
102	Tokavde_Bore_Well_24	0.7382	0.7913	0.7937	0.7967
103	Tokawade_Dug_Well_5	0.5941	0.6133	0.6152	0.6166
104	Udawa_Bore_Well_30	0.6173	0.7120	0.7215	0.7261
105	Vadoli_Dug_Well_5.6	0.4591	0.4888	0.4937	0.4944
106	Varaskol_Dug_Well_7	0.8631	0.8739	0.8754	0.8774
107	Vasar_Bore_Well_30	0.2112	0.2456	0.2526	0.2562
108	Vedhi_Dug_Well_8.7	0.7491	0.7752	0.7762	0.7796
109	Vehaloli_Dug_Well_5.1	0.7389	0.7543	0.7568	0.7580
110	Vevaji_Dug_Well_7.6	0.5232	0.5440	0.5444	0.5478
111	Veyour_Dug_Well_10.1	0.7491	0.7554	0.7570	0.7587
112	Vihigaon_Dug_Well_7.5	0.7704	0.7866	0.7869	0.7914
113	Wada_Dug_Well_9	0.3704	0.3869	0.3880	0.3924
114	Waret_Bore_Well_30	0.6659	0.7549	0.7703	0.7717
115	Warwade_Dug_Well_7.6	0.7253	0.7526	0.7539	0.7569

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-Table A.2 continued from previous page

S.No	Village	$F_1(x)$	$F_2(x)$	$F_3(x)$	$F_4(x)$
116	Washind_Dug_Well_3.05	0.3741	0.3787	0.3794	0.3820
117	Washind_Dug_Well_7	0.1801	0.2182	0.2194	0.2245
118	Zhai_Dug_Well_7.7	0.6607	0.6940	0.6952	0.7001
119	Zhari_Bore_Well_30	0.6988	0.7918	0.8151	0.8225
120	Zhari_Dug_Well_7.4	0.5439	0.5536	0.5540	0.5551

-End of Table A.2

Table A.3: Periodic Model with Spline Interpolated Points R^2 values-THANE

S.No	Village	$F_1(x)$	$F_2(x)$	$F_3(x)$	$F_4(x)$
1	Agashi_Boling_Dug_Well_10	0.7601	0.7842	0.7842	0.7845
2	Akoli_Dug_Well_5.5	0.8047	0.8306	0.8319	0.8320
3	Ambiste_kh_Bore_Well_17	0.6357	0.7969	0.8229	0.8249
4	Awale_Dug_Well_7.35	0.5863	0.6032	0.6050	0.6051
5	Badlapur_Bore_Well_30	0.2873	0.3086	0.3105	0.3150
6	Badlapur_Dug_Well_7.95	0.2547	0.2623	0.2625	0.2628
7	Bapgaon_Dug_Well_7.4	0.8274	0.8492	0.8503	0.8504
8	Bhatsai_Bore_Well_18	0.4840	0.5956	0.6139	0.6153
9	Bhinar_Dug_Well_6.25	0.7837	0.7911	0.7914	0.7915
10	Borivali_T_Padgha_Dug_Well_10.6	0.4789	0.4859	0.4862	0.4865
11	Bursunge_Dug_Well_8.65	0.7961	0.8258	0.8288	0.8289
12	Chahade_Dug_Well_5.7	0.6246	0.6363	0.6365	0.6366
13	Chavindra_Bore_Well_13.5	0.6146	0.7390	0.7568	0.7612
14	Chndansar_Bore_Well_24	0.6542	0.6764	0.6854	0.6871
15	Dahisar_Dug_Well_9.5	0.6351	0.6466	0.6477	0.6479
16	Dapode_Dug_Well_5.25	0.4594	0.4615	0.4617	0.4618
17	Deoli_Dug_Well_6.2	0.8822	0.8927	0.8931	0.8931
18	Dhanivri_Dug_Well_5.5	0.7220	0.7516	0.7528	0.7529
19	Dhanoshi_Dug_Well_6.5	0.6858	0.7009	0.7013	0.7013
20	Dhuktan_Dug_Well_6.1	0.7540	0.7702	0.7709	0.7709
21	Dolhare_Dug_Well_5.5	0.7671	0.7740	0.7742	0.7742
22	Durves_Dug_Well_9.6	0.7703	0.8020	0.8027	0.8028
23	Gates_Bk_Dug_Well_7.5	0.7084	0.7267	0.7275	0.7275
24	Ghansoli_Bore_Well_12.7	0.6047	0.7453	0.7537	0.7581
25	Ghodbandar_Dug_Well_8.2	0.7342	0.7415	0.7430	0.7431
26	Ghol_Dug_Well_10.4	0.4185	0.4313	0.4346	0.4348
27	Gokhiware_Bore_Well_18	0.7594	0.8619	0.8768	0.8780
28	Gokhiware_Dug_Well_5.5	0.6295	0.6487	0.6492	0.6494
29	Govade_Dug_Well_6.6	0.8335	0.8393	0.8395	0.8395
30	Goveli_Bore_Well_17.25	0.5877	0.7436	0.7645	0.7651
31	Inde_Dug_Well_7.8	0.5999	0.6325	0.6335	0.6338
32	Jawhar_Dug_Well_7.65	0.4164	0.4269	0.4276	0.4276
33	Kajali_Dug_Well_14	0.6743	0.6861	0.6879	0.6880
34	Kalamdevi_Dug_Well_5.5	0.6409	0.6513	0.6518	0.6518
35	Kambe_Dug_Well_6.9	0.4158	0.4159	0.4161	0.4162
36	Kanchad_Bore_Well_18	0.6600	0.7833	0.7995	0.8034
37	Kanchad_Dug_Well_7.5	0.6480	0.6532	0.6534	0.6535

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S.No	Village	$F_1(x)$	$F_2(x)$	$F_3(x)$	$F_4(x)$
38	Kanhor_Dug_Well_8.5	0.7415	0.7593	0.7605	0.7607
39	Karav_Dug_Well_8	0.3264	0.3318	0.3325	0.3325
40	Karvele_Dug_Well_6.3	0.2861	0.3117	0.3156	0.3161
41	Kasa_bk_Dug_Well_6.5	0.5187	0.5293	0.5296	0.5297
42	Katrap_Dug_Well_3.1	0.4225	0.4319	0.4326	0.4328
43	Khaniwade_Dug_Well_5	0.7388	0.7463	0.7467	0.7467
44	Kharade_Dug_Well_8.2	0.5709	0.5812	0.5833	0.5836
45	Khodala_Dug_Well_5.8	0.5284	0.5477	0.5479	0.5480
46	Kogde_Dug_Well_7	0.8285	0.8364	0.8365	0.8365
47	Kopar_Karane_Dug_Well_4.7	0.3625	0.3683	0.3694	0.3694
48	Kopari_Dug_Well_7.55	0.2758	0.2782	0.2784	0.2787
49	Kudan_Bore_Well_30	0.7237	0.7768	0.7789	0.7792
50	Kudus_Dug_Well_6	0.5901	0.5955	0.5955	0.5957
51	Lalthan_Dug_Well_6.4	0.8016	0.8375	0.8383	0.8386
52	Mahim_Bore_Well_20	0.7022	0.8356	0.8442	0.8457
53	Makunsar_Dug_Well_9.8	0.6550	0.6768	0.6776	0.6778
54	Mandawa_Bore_Well_30	0.4363	0.5790	0.5866	0.5913
55	Mandvi_Dug_Well_9.1	0.7847	0.8068	0.8076	0.8076
56	Mangrul_Dug_Well_7.6	0.4995	0.5081	0.5081	0.5082
57	Manor_Dug_Well_7	0.4330	0.4411	0.4419	0.4422
58	Met_Dug_Well_8.3	0.7814	0.8079	0.8090	0.8091
59	Mokhada_Dug_Well_9	0.6372	0.6441	0.6443	0.6443
60	Morhande_Dug_Well_5.1	0.7038	0.7108	0.7127	0.7128
61	Musarne_Dug_Well_6	0.7077	0.7263	0.7270	0.7270
62	Nare_Bore_Well_18	0.5845	0.7013	0.7306	0.7320
63	Neharoli_Bore_Well_24	0.4996	0.6846	0.7167	0.7197
64	Newale_Dug_Well_8.2	0.5590	0.5808	0.5818	0.5822
65	Nihe_Dug_Well_7	0.7007	0.7395	0.7414	0.7417
66	Nimbavali_Bore_Well_30	0.4201	0.5253	0.5603	0.5691
67	Padgha_Bore_Well_30	0.6360	0.8098	0.8333	0.8425
68	Palghar_kolgaon_Bore_Well_30	0.7304	0.8822	0.8908	0.8919
69	Pali_Dug_Well_6	0.8777	0.8931	0.8933	0.8933
70	Parli_Dug_Well_5.1	0.5557	0.5596	0.5605	0.5606
71	Pawane_Dug_Well_5	0.3995	0.3999	0.4018	0.4018
72	Pelhar_Dug_Well_7	0.5097	0.5292	0.5297	0.5298
73	Pimpalas_Dug_Well_6.55	0.5328	0.5520	0.5550	0.5550
74	Pimpalshet_Dug_Well_8.5	0.6793	0.6977	0.6992	0.6995
75	Rayta_Dug_Well_4	0.6492	0.6554	0.6555	0.6556
76	Safala_Dug_Well_10.5	0.7137	0.7227	0.7231	0.7232

-Table A.3 continued on next page

-Table A.3 continued from previous page

S.No	Village	$F_1(x)$	$F_2(x)$	$F_3(x)$	$F_4(x)$
77	Safale_Bore_Well_25.9	0.7302	0.9083	0.9431	0.9540
78	Sakharshet_chalatwad_Bore_Well_22.5	0.4492	0.5555	0.5606	0.5669
79	Sakwar_Dug_Well_6	0.4228	0.4519	0.4528	0.4530
80	Sange_Dug_Well_4.7	0.8169	0.8539	0.8549	0.8551
81	Saravali_Bore_Well_24	0.5279	0.7027	0.7238	0.7294
82	Sasne_Dug_Well_8.85	0.6249	0.6297	0.6298	0.6300
83	Satiwali_Bore_Well_18	0.2940	0.4179	0.4487	0.4581
84	Satiwali_Dug_Well_7.2	0.1969	0.2015	0.2025	0.2032
85	Sawta_Dug_Well_8.4	0.6619	0.6883	0.6901	0.6904
86	Shelonde_Dug_Well_12.5	0.7030	0.7295	0.7306	0.7306
87	Shendrun_Dug_Well_4.7	0.7818	0.7909	0.7913	0.7913
88	Shil_t_chon_Dug_Well_7.1	0.5084	0.5115	0.5117	0.5117
89	Shilphata_Dug_Well_4.8	0.3028	0.3067	0.3068	0.3069
90	Shirgaon_Dug_Well_9	0.7828	0.8008	0.8012	0.8013
91	Shivale_Dug_Well_11	0.6989	0.7138	0.7144	0.7146
92	Suksale_Bore_Well_30	0.4850	0.6075	0.6362	0.6401
93	Talasari_Dug_Well_8	0.1858	0.1897	0.1898	0.1899
94	Talasarimal_Dug_Well_8.2	0.4445	0.4476	0.4479	0.4483
95	Talegaon_Dug_Well_6.1	0.8384	0.8579	0.8581	0.8583
96	Talwada_Bore_Well_30	0.6934	0.7796	0.7978	0.8022
97	Tembhare_Dug_Well_5.5	0.8166	0.8457	0.8469	0.8471
98	Thane_Dug_Well_7.05	0.1389	0.1420	0.1420	0.1424
99	Thilher_Dug_Well_6.2	0.7670	0.7895	0.7900	0.7902
100	Thunepada_Dug_Well_5.95	0.7395	0.7530	0.7545	0.7546
101	Titwala_Dug_Well_7	0.3717	0.3727	0.3728	0.3730
102	Tokavde_Bore_Well_24	0.7140	0.7921	0.7975	0.8014
103	Tokawade_Dug_Well_5	0.5800	0.5879	0.5880	0.5881
104	Udawa_Bore_Well_30	0.5953	0.7489	0.7618	0.7695
105	Vadoli_Dug_Well_5.6	0.5393	0.5621	0.5633	0.5634
106	Varaskol_Dug_Well_7	0.8657	0.8692	0.8693	0.8693
107	Vasar_Bore_Well_30	0.4617	0.4628	0.4700	0.4893
108	Vedhi_Dug_Well_8.7	0.6998	0.7191	0.7204	0.7204
109	Vehaloli_Dug_Well_5.1	0.7831	0.8005	0.8011	0.8012
110	Vevaji_Dug_Well_7.6	0.5362	0.5542	0.5549	0.5552
111	Veyour_Dug_Well_10.1	0.7044	0.7144	0.7148	0.7149
112	Vihigaon_Dug_Well_7.5	0.8410	0.8587	0.8589	0.8590
113	Wada_Dug_Well_9	0.4582	0.4598	0.4600	0.4601
114	Waret_Bore_Well_30	0.6828	0.7913	0.8068	0.8090
115	Warwade_Dug_Well_7.6	0.7606	0.7876	0.7891	0.7893

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S.No	Village	$F_1(x)$	$F_2(x)$	$F_3(x)$	$F_4(x)$
116	Washind_Dug_Well_3.05	0.5265	0.5280	0.5281	0.5282
117	Washind_Dug_Well_7	0.1179	0.1197	0.1204	0.1206
118	Zhai_Dug_Well_7.7	0.5810	0.6002	0.6016	0.6018
119	Zhari_Bore_Well_30	0.6816	0.7740	0.7982	0.8034
120	Zhari_Dug_Well_7.4	0.5670	0.5712	0.5721	0.5721

-End of Table A.3

Appendix B

Polynomial Model R^2 Values

Table B.1: Polynomial Model R^2 values-THANE

S.NO	Village	Degree=2	Degree=3	Degree=4
1	Agashi_Boling_Dug_Well_10	0.6724683	0.6859742	0.6910189
2	Akoli_Dug_Well_5.5	0.7685363	0.7686576	0.7823175
3	Ambiste_kh_Bore_Well_17	0.8746249	0.8759907	0.8810790
4	Awale_Dug_Well_7.35	0.7151274	0.7158759	0.7295504
5	Badlapur_Bore_Well_30	0.5026095	0.5046002	0.5110555
6	Badlapur_Dug_Well_7.95	0.3340341	0.3452366	0.3453612
7	Bapgaon_Dug_Well_7.4	0.8660606	0.8686051	0.8730206
8	Bhatsai_Bore_Well_18	0.5087187	0.5197588	0.5357880
9	Bhinar_Dug_Well_6.25	0.8540722	0.8564639	0.8594002
10	Borivali_T_Padgha_Dug_Well_10.6	0.5155574	0.5169714	0.5389700
11	Bursunge_Dug_Well_8.65	0.7770269	0.7785728	0.7892314
12	Chahade_Dug_Well_5.7	0.7208796	0.7423330	0.7430528
13	Chavindra_Bore_Well_13.5	0.8682229	0.8688223	0.8698469
14	Chndansar_Bore_Well_24	0.7515912	0.7743186	0.7967375
15	Dahisar_Dug_Well_9.5	0.7795532	0.7803996	0.7842591
16	Dapode_Dug_Well_5.25	0.4994760	0.4996998	0.5053345
17	Deoli_Dug_Well_6.2	0.8008918	0.8090283	0.8163254
18	Dhanivri_Dug_Well_5.5	0.7592019	0.7593168	0.7603777
19	Dhanoshi_Dug_Well_6.5	0.7447349	0.7619579	0.7744725
20	Dhuktan_Dug_Well_6.1	0.7883844	0.7911710	0.7911905
21	Dolhare_Dug_Well_5.5	0.8194093	0.8343903	0.8367217
22	Durves_Dug_Well_9.6	0.9141511	0.9147320	0.9171770
23	Gates_Bk_Dug_Well_7.5	0.7303206	0.7321606	0.7367774
24	Ghansoli_Bore_Well_12.7	0.7328172	0.7363877	0.7928813

-Table B.1 continued on next page

-Table B.1 continued from previous page

S.No	Village	Degree=2	Degree=3	Degree=4
25	Ghodbandar_Dug_Well_8.2	0.6578494	0.6582299	0.6769570
26	Ghol_Dug_Well_10.4	0.3082767	0.3410620	0.3449936
27	Gokhiware_Bore_Well_18	0.8929069	0.8992407	0.9086193
28	Gokhiware_Dug_Well_5.5	0.7279937	0.7290904	0.7393346
29	Govade_Dug_Well_6.6	0.7716586	0.7790359	0.7798411
30	Goveli_Bore_Well_17.25	0.6459019	0.6460492	0.6742977
31	Inde_Dug_Well_7.8	0.6332361	0.6419154	0.6458772
32	Jawhar_Dug_Well_7.65	0.4467368	0.4548124	0.465771
33	Kajali_Dug_Well_14	0.4257920	0.4262242	0.432043
34	Kalamdevi_Dug_Well_5.5	0.6405671	0.6431484	0.6431895
35	Kambe_Dug_Well_6.9	0.4569189	0.4685966	0.4689995
36	Kanchad_Bore_Well_18	0.8790922	0.8790972	0.8796252
37	Kanchad_Dug_Well_7.5	0.8092767	0.8102482	0.8166031
38	Kanhor_Dug_Well_8.5	0.7820306	0.7840992	0.7906560
39	Karav_Dug_Well_8	0.2211756	0.2281150	0.2520142
40	Karvele_Dug_Well_6.3	0.3040230	0.3046993	0.3063572
41	Kasa_bk_Dug_Well_6.5	0.6051489	0.6092733	0.6096078
42	Katrap_Dug_Well_3.1	0.4440864	0.4440869	0.4440920
43	Khaniwade_Dug_Well_5	0.8484009	0.8508900	0.8513407
44	Kharade_Dug_Well_8.2	0.585539	0.5903198	0.5966344
45	Khodala_Dug_Well_5.8	0.4838876	0.4913240	0.4914418
46	Kogde_Dug_Well_7	0.7810134	0.8072878	0.8106083
47	Kopar_Karane_Dug_Well_4.7	0.4127595	0.4138056	0.4204308
48	Kopari_Dug_Well_7.55	0.2734619	0.2968947	0.3020077
49	Kudan_Bore_Well_30	0.6795729	0.7266182	0.7433658
50	Kudus_Dug_Well_6	0.7622097	0.7717028	0.7807359
51	Lalthan_Dug_Well_6.4	0.7760517	0.7761171	0.7917866
52	Mahim_Bore_Well_20	0.8500376	0.8527414	0.852903
53	Makunsar_Dug_Well_9.8	0.7958914	0.7972029	0.8054913
54	Mandawa_Bore_Well_30	0.4150167	0.4181722	0.4396234
55	Mandvi_Dug_Well_9.1	0.8388851	0.8451526	0.8459265
56	Mangrul_Dug_Well_7.6	0.4775209	0.4962337	0.4966658
57	Manor_Dug_Well_7	0.4934992	0.4949182	0.5013864
58	Met_Dug_Well_8.3	0.8528434	0.8535909	0.8592522
59	Mokhada_Dug_Well_9	0.6888190	0.7081084	0.7208008
60	Morhande_Dug_Well_5.1	0.7407865	0.7724334	0.7769685
61	Musarne_Dug_Well_6	0.8612418	0.8649382	0.8734912
62	Nare_Bore_Well_18	0.9358606	0.9438107	0.9445257
63	Neharoli_Bore_Well_24	0.6183300	0.6328432	0.6437067

-Table B.1 continued on next page

-Table B.1 continued from previous page

S.No	Village	Degree=2	Degree=3	Degree=4
64	Newale_Dug_Well_8.2	0.5762578	0.5781545	0.5799412
65	Nihe_Dug_Well_7	0.7914288	0.7921227	0.7957829
66	Nimbavali_Bore_Well_30	0.6934121	0.6944532	0.7114496
67	Padgha_Bore_Well_30	0.7693946	0.7710139	0.7718806
68	Palghar_kolgaon_Bore_Well_30	0.8574799	0.8755069	0.8930478
69	Pali_Dug_Well_6	0.8962738	0.9096527	0.9120143
70	Parli_Dug_Well_5.1	0.5914702	0.5956143	0.6021187
71	Pawane_Dug_Well_5	0.2806342	0.2854520	0.2947392
72	Pelhar_Dug_Well_7	0.7259266	0.7269637	0.7271012
73	Pimpalas_Dug_Well_6.55	0.7033289	0.7053607	0.7222981
74	Pimpalshet_Dug_Well_8.5	0.7377782	0.7383372	0.7451284
75	Rayta_Dug_Well_4	0.6011700	0.6200771	0.6228527
76	Safala_Dug_Well_10.5	0.8069575	0.8190859	0.8197707
77	Safale_Bore_Well_25.9	0.8937619	0.8948843	0.8983920
78	Sakharshet_chalatwad_Bore_Well_22.5	0.5675834	0.5705269	0.5762585
79	Sakwar_Dug_Well_6	0.5991173	0.6041093	0.6184817
80	Sange_Dug_Well_4.7	0.8759230	0.8778477	0.8878653
81	Saravali_Bore_Well_24	0.7284291	0.7288982	0.7300592
82	Sasne_Dug_Well_8.85	0.5580999	0.5651418	0.5656369
83	Satiwali_Bore_Well_18	0.2778613	0.2850851	0.2898433
84	Satiwali_Dug_Well_7.2	0.4940856	0.5779982	0.5798769
85	Sawta_Dug_Well_8.4	0.7547057	0.7549353	0.7550123
86	Shelonde_Dug_Well_12.5	0.6922928	0.6993484	0.7041929
87	Shendrun_Dug_Well_4.7	0.7753063	0.7774277	0.7791707
88	Shil_t_chon_Dug_Well_7.1	0.7586228	0.7622184	0.7622536
89	Shilphata_Dug_Well_4.8	0.3683917	0.3712120	0.3865806
90	Shirgaon_Dug_Well_9	0.7975303	0.8100876	0.8119710
91	Shivale_Dug_Well_11	0.6638872	0.6686958	0.6728660
92	Suksale_Bore_Well_30	0.7507526	0.7568284	0.7615571
93	Talasari_Dug_Well_8	0.4064812	0.4689271	0.4690928
94	Talasarimal_Dug_Well_8.2	0.4658898	0.4995668	0.5041104
95	Talegaon_Dug_Well_6.1	0.8194583	0.8455885	0.8456588
96	Talwada_Bore_Well_30	0.8945895	0.8946327	0.8957620
97	Tembhare_Dug_Well_5.5	0.7786077	0.7812469	0.7820385
98	Thane_Dug_Well_7.05	0.1924458	0.2290827	0.2316175
99	Thilher_Dug_Well_6.2	0.8799083	0.8827472	0.8874184
100	Thunepada_Dug_Well_5.95	0.8393681	0.8393765	0.8399762
101	Titwala_Dug_Well_7	0.4268063	0.4298987	0.4425565
102	Tokavde_Bore_Well_24	0.8723757	0.8803747	0.8888952

-Table B.1 continued on next page

-Table B.1 continued from previous page

S.No	Village	Degree=2	Degree=3	Degree=4
103	Tokawade_Dug_Well_5	0.6578848	0.6782234	0.6786148
104	Udawa_Bore_Well_30	0.8839166	0.8842009	0.8868274
105	Vadoli_Dug_Well_5.6	0.4801193	0.4802667	0.4855688
106	Varaskol_Dug_Well_7	0.8488178	0.8732595	0.8778791
107	Vasar_Bore_Well_30	0.2941200	0.2973931	0.2977362
108	Vedhi_Dug_Well_8.7	0.7643007	0.7643493	0.7708361
109	Vehaloli_Dug_Well_5.1	0.7548609	0.7691481	0.7710990
110	Vevaji_Dug_Well_7.6	0.5978966	0.5994172	0.6130517
111	Veyour_Dug_Well_10.1	0.7549733	0.7753831	0.7759393
112	Vihigaon_Dug_Well_7.5	0.7195096	0.7207480	0.7304631
113	Wada_Dug_Well_9	0.5144082	0.5205461	0.5211624
114	Waret_Bore_Well_30	0.8790074	0.8790555	0.8833378
115	Warwade_Dug_Well_7.6	0.7144598	0.7146178	0.7353199
116	Washind_Dug_Well_3.05	0.4234091	0.4385938	0.4387285
117	Washind_Dug_Well_7	0.4330514	0.4331322	0.4512697
118	Zhai_Dug_Well_7.7	0.6605041	0.6609836	0.6610942
119	Zhari_Bore_Well_30	0.9206437	0.9234192	0.9234658
120	Zhari_Dug_Well_7.4	0.5781240	0.5838758	0.5901991

-End of Table B.1

Table B.2: Polynomial Model R^2 values-LATUR

S.NO	Village	Degree=2	Degree=3	Degree=4
1	Aashiv_Dug_Well_15	0.1843813	0.2334716	0.3411036
2	Achola_Dug_Well_12.3	0.6427375	0.6460334	0.6601434
3	Ahmadpur_Dug_Well_15.1	0.6768526	0.6808887	0.6815389
4	Almala_Dug_Well_9.5	0.2219546	0.2712117	0.2717843
5	Ambanagar_Dug_Well_6.5	0.6383853	0.6530792	0.6533275
6	Ambulga_Dug_Well_10.5	0.4316561	0.432021	0.4322378
7	Ambulga_Dug_Well_12.9	0.3469963	0.3507531	0.3516753
8	Andhori_Dug_Well_16.1	0.7618815	0.7726391	0.7730658
9	Arasnal_Bore_Well_60	0.1964458	0.1967713	0.1975244
10	Ashta_Dug_Well_9.9	0.6537919	0.657422	0.6803061
11	Aurad_shahjani_Dug_Well_8.1	0.4706288	0.5095822	0.5100525
12	Ausa_Dug_Well_19.9	0.3486765	0.3502676	0.3527269
13	Babalgoan_Dug_Well_19.7	0.5844846	0.5856765	0.5920609
14	Barmachiwadi_Dug_Well_16.9	0.3819389	0.3931483	0.3934724
15	Bhadi_Dug_Well_11.3	0.5975915	0.5996886	0.6004598
16	Bhatkheda_Dug_Well_18.65	0.1814941	0.1843564	0.1877872
17	Bhuisamudraga_Dug_Well_16.65	0.2117101	0.2167833	0.2169167
18	Borfal_Dug_Well_8.5	0.6178529	0.6480971	0.6519193
19	Borgaon_bk_Dug_Well_10.8	0.3561195	0.3641566	0.3754004
20	Borgaon_n_Dug_Well_12.5	0.3218183	0.3405359	0.3413156
21	Budhada_Dug_Well_23.5	0.4541945	0.4560341	0.456079
22	Chikurda_Bore_Well_27	0.1598801	0.1734842	0.1763831
23	Dangewadi_Dug_Well_17.7	0.580236	0.5873605	0.5912019
24	Dapegaon_Bore_Well_30	0.178296	0.1808857	0.1811731
25	Dawangaon_Dug_Well_7.15	0.6375083	0.6568523	0.6578617
26	Deokara_Dug_Well_21.4	0.751142	0.7540696	0.7614641
27	Deoni_bk_Dug_Well_18.9	0.5531765	0.5534737	0.5535199
28	Deoni_kh_Dug_Well_17.9	0.597774	0.5977783	0.6045425
29	Dhalegaon_Bore_Well_90	0.445517	0.510466	0.5110779
30	Dhanegaon_Dug_Well_15.7	0.2655877	0.2777708	0.2983814
31	Dighol_deshmukh_Dug_Well_11.9	0.2754046	0.2808133	0.2819653
32	Gadwad_Dug_Well_12.5	0.4085935	0.4223708	0.4273441
33	Gangahipparga_Dug_Well_10.5	0.4325301	0.4325781	0.4358106
34	Gangapur_Dug_Well_11.5	0.4317939	0.4384671	0.4387552
35	Ganjoor_Dug_Well_19.25	0.2677067	0.2677308	0.2687902
36	Garsuli_Dug_Well_10.2	0.6771387	0.6784164	0.6857432
37	Gategoan_Dug_Well_13.8	0.2927563	0.3206665	0.3218072

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-Table B.2 continued from previous page

S.No	Village	Degree=2	Degree=3	Degree=4
38	Gaur_Dug_Well_13.9	0.5240789	0.5602627	0.5702312
39	Gharni_Dug_Well_9.6	0.7090575	0.7093754	0.7130684
40	Ghonshi_Dug_Well_20.3	0.5253523	0.5257689	0.5267498
41	Hadolti_Dug_Well_12.8	0.3778337	0.380311	0.3838285
42	Haibatpur_Bore_Well_60	0.179839	0.1815805	0.1880232
43	Halsi_t_Dug_Well_14.4	0.3585698	0.4145073	0.4147027
44	Hanchnal_Dug_Well_21.7	0.5486969	0.5541985	0.5875276
45	Harangul_bk_Dug_Well_10	0.4351584	0.4561185	0.4562899
46	Hipparga_kopdev_Dug_Well_18.9	0.5080994	0.5081582	0.5085889
47	Hisamabad_ujed_Dug_Well_15.4	0.3078316	0.3233699	0.3235153
48	Hosur_Dug_Well_8.9	0.5196109	0.5450899	0.5453132
49	Ismailpur_Dug_Well_17.6	0.5884741	0.5900255	0.6131441
50	Jalkot_Dug_Well_19.2	0.5075574	0.5760279	0.577172
51	Jawala_bk_Dug_Well_19.8	0.3158806	0.3452944	0.3617088
52	Jawali_Dug_Well_15	0.5501258	0.5741839	0.577151
53	Kabansangvi_Dug_Well_11.2	0.4984072	0.5009086	0.5009883
54	Karadkhel_Dug_Well_14.9	0.5084818	0.5224507	0.5241974
55	Karla_Dug_Well_9.3	0.4568331	0.4972711	0.4976473
56	Karsa_Dug_Well_8.7	0.4764119	0.5280088	0.5281055
57	Kasarshirshi_Dug_Well_11.9	0.5143512	0.5151288	0.515607
58	Kelgaon_Bore_Well_60	0.2495586	0.2757639	0.3081333
59	Kelgaon_Dug_Well_15.5	0.5367058	0.5559487	0.5606196
60	Khandali_Bore_Well_90	0.2735178	0.2794373	0.279476
61	Khandali_Dug_Well_9.2	0.586056	0.5937756	0.5965218
62	Kharola_Dug_Well_11.5	0.4845191	0.5023274	0.5045169
63	Kharosa_Dug_Well_23.7	0.6194946	0.6198819	0.6213339
64	Khuntegaon_Bore_Well_95	0.1280524	0.1619761	0.1623207
65	Killari_Dug_Well_18.7	0.2099869	0.2156124	0.2175248
66	Kiniyalladevi_Dug_Well_21	0.6579839	0.6597258	0.6597535
67	Kodli_Dug_Well_8.7	0.3878344	0.3950763	0.3955146
68	Kolnoor_Dug_Well_10.9	0.5316162	0.5320601	0.5339195
69	Kolwadi_Dug_Well_15.3	0.6776244	0.681625	0.6816567
70	Kumbhari_Bore_Well_30	0.5216726	0.5760491	0.5831556
71	Kumtha_Bore_Well_21	0.303883	0.306595	0.3079838
72	Lakhan_Gaon_Dug_Well_13.1	0.816655	0.8755997	0.9054328
73	Lambota_Dug_Well_12.8	0.3424727	0.343385	0.344386
74	Lamjana_Dug_Well_17.3	0.6722881	0.6788658	0.6789226
75	Latur_road_Bore_Well_80	0.112023	0.1272801	0.1573565
76	Latur_road_Dug_Well_13.3	0.5137055	0.5181312	0.5210716

-Table B.2 continued on next page

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S.No	Village	Degree=2	Degree=3	Degree=4
77	Lodga_Dug_Well_22.8	0.7538598	0.7542669	0.7565666
78	Madansuri_Dug_Well_10.2	0.4840383	0.4967428	0.4971954
79	Mahalangra_Dug_Well_14.5	0.707043	0.7261187	0.7261219
80	Mal_hipparga_Bore_Well_85	0.5824321	0.587647	0.5941328
81	Mamdapur_Dug_Well_11.1	0.5571466	0.5678676	0.5683567
82	Mankhed_Dug_Well_13.9	0.6299265	0.6374982	0.6375351
83	Mannatpur_Dug_Well_10.1	0.5262589	0.5820694	0.5824169
84	Mogha_Dug_Well_20.6	0.4388058	0.4749253	0.4824926
85	Murdhav_Dug_Well_12.2	0.1828663	0.2283237	0.236339
86	Murud_bk_Dug_Well_21	0.3034374	0.3300094	0.3300407
87	Nagzari_Dug_Well_4.9	0.4473264	0.4997785	0.5117021
88	Nalgir_Dug_Well_12.8	0.4593726	0.4595248	0.4600318
89	Nandgaon_Dug_Well_7.7	0.3839577	0.3907091	0.39298
90	Nandgaon_Dug_Well_9.9	0.631183	0.6514279	0.6530654
91	Nandurga_Dug_Well_17.9	0.1444754	0.1591026	0.1611575
92	Neoli_Dug_Well_14.6	0.4405427	0.44856	0.44856
93	Nilanga_Dug_Well_14.8	0.356054	0.3617036	0.3677067
94	Pakharsangvi_Dug_Well_13.5	0.3408147	0.3566096	0.3568356
95	Palshi_Dug_Well_6.6	0.6995398	0.7229836	0.72447
96	Pangaon_Dug_Well_10.75	0.4200609	0.4202665	0.4220803
97	Patoda_kh_Dug_Well_10.1	0.330098	0.3315425	0.3315811
98	Rapka_Dug_Well_19.8	0.3546128	0.3553575	0.3554313
99	Renapur_Dug_Well_13	0.3434076	0.3453962	0.3458226
100	Sakol_Bore_Well_30	0.0434807	0.0757683	0.0815255
101	Sakol_Dug_Well_19	0.2712734	0.2966621	0.3366819
102	Samsapur_Dug_Well_11.4	0.5952551	0.6294466	0.631198
103	Sangvi_s_Dug_Well_12.9	0.4086649	0.4095388	0.4095822
104	Sarwadi_Bore_Well_30	0.2468871	0.2471377	0.2645205
105	Selu_Dug_Well_8.9	0.532385	0.561423	0.5623021
106	Shelgi_Dug_Well_11.9	0.6495104	0.6495192	0.6502422
107	Shirur_tajband_Dug_Well_12.5	0.4789924	0.4791124	0.4836428
108	Shivankhed_Bore_Well_70	0.2832236	0.2923815	0.294315
109	Shivni_kothal_Dug_Well_9.1	0.5377935	0.5727421	0.5792013
110	Shivpur_Dug_Well_9.5	0.484657	0.4877804	0.4907023
111	Sindgi_bk_Dug_Well_14.2	0.5582371	0.5584928	0.5631547
112	Sindgoan_Dug_Well_10.1	0.4657704	0.4659219	0.4694215
113	Sindkhed_Bore_Well_61	0.1268193	0.1294034	0.1322423
114	Sirsi_Bore_Well_23.3	0.4182891	0.4342057	0.4342057
115	Somnathpur_Dug_Well_7.2	0.7343164	0.7379548	0.7390138

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S.No	Village	Degree=2	Degree=3	Degree=4
116	Sugaon_Bore_Well_60	0.3395944	0.3538331	0.3539378
117	Tajpur_Dug_Well_11.9	0.5634498	0.5845306	0.5958201
118	Taka_Dug_Well_10	0.3829413	0.3889276	0.3938632
119	Taka_Dug_Well_13.7	0.2951603	0.2989092	0.3070223
120	Takli_Dug_Well_12.75	0.2673802	0.3130716	0.3155095
121	Talni_Dug_Well_18.9	0.1929407	0.1978559	0.2069459
122	Tambatsangvi_Dug_Well_20.3	0.2414253	0.2495304	0.2619552
123	Tattapur_Dug_Well_8	0.7587747	0.7880028	0.7933384
124	Tavashi_Tad_Dug_Well_13.8	0.9527176	0.9652834	0.9998916
125	Tiruka_Dug_Well_14.6	0.6564469	0.6564712	0.6608927
126	Togari_Dug_Well_9.5	0.5130545	0.5185343	0.5206416
127	Udgir_Bore_Well_70	0.5206102	0.5544856	0.5547617
128	Wadmurumbi_Dug_Well_13.6	0.3814343	0.4068797	0.4121431
129	Waigaon_Dug_Well_10.5	0.5294547	0.5295123	0.5357122
130	Walandi_Dug_Well_9.2	0.4564974	0.4579205	0.4589098
131	Walsangi_Dug_Well_12.5	0.5537801	0.55647	0.5576565
132	Wanjarkheda_Dug_Well_9.5	0.4212835	0.4711533	0.4928061
133	Yekambi_Dug_Well_13.7	0.9075872	0.9282037	0.9363537
134	Yelwat_Bore_Well_79	0.507555	0.6698601	0.6893775
135	Yerol_Dug_Well_16.8	0.6656801	0.6708142	0.6866636

-End of Table B.2

Table B.3: Polynomial Model R^2 values-SANGLI

S.No	Village	Degree2	Degree3	Degree 4
1	Akkalawadi_Dug_Well_7.8	0.7630209	0.8289085	0.8297439
2	Alkud_M_Dug_Well_10.7	0.3145819	0.4034443	0.4040606
3	Antral_Dug_Well_12.2	0.3273694	0.3360413	0.3367161
4	Arag_Dug_Well_12.5	0.2225792	0.2498701	0.2523031
5	Ashta_Dug_Well_12	0.3353807	0.3368679	0.3369362
6	Atpadi_Bore_Well_45	0.2384127	0.3402977	0.3426988
7	Atpadi_Dug_Well_10.2	0.3927474	0.4715417	0.4763276
8	Atpadi_Dug_Well_6.7	0.4318228	0.4324791	0.4428014
9	Bagewadi_Dug_Well_9.1	0.3968214	0.445782	0.4462016
10	Balvadi_Dug_Well_10.7	0.3261789	0.3277073	0.3511343
11	Basargi_Dug_Well_4.6	0.3246237	0.3595879	0.365961
12	Bedag_Dug_Well_13.7	0.5951261	0.6915809	0.6925991
13	Bedag_Dug_Well_9.4	0.2607694	0.2766922	0.2788084
14	Belanki_Bore_Well_31.4	0.3567003	0.4008441	0.4223583
15	Belanki_Dug_Well_8.7	0.1217662	0.1218454	0.1399329
16	Bevanur_Dug_Well_9.5	0.2631112	0.2932924	0.2942906
17	Bhalwani_Dug_Well_11.7	0.0635202	0.0650916	0.0651361
18	Bhaurayachiwadi_Dug_Well_11.1	0.2609897	0.2670142	0.2803726
19	Bhilwadi_Bore_Well_37	0.250392	0.308309	0.3228736
20	Bhilwadi_Dug_Well_7.3	0.3913801	0.4036005	0.4047369
21	Bhood_Dug_Well_9.9	0.4109595	0.4426929	0.4427211
22	Bilashi_Dug_Well_13.8	0.2340302	0.2349333	0.2495278
23	Bilur_Bore_Well_90	0.0664454	0.0699903	0.0993783
24	Bilur_Dug_Well_13.5	0.3195853	0.3616808	0.370153
25	Biur_Dug_Well_8.6	0.5118202	0.5432734	0.5452765
26	Bombewadi_Dug_Well_5.7	0.4094428	0.5668458	0.5681719
27	Borgaon_Bore_Well_36.5	0.08601	0.0915149	0.100152
28	Borgi_bk_Dug_Well_9	0.2545215	0.2960553	0.2977527
29	Chorochi_Dug_Well_7.3	0.3250586	0.3344198	0.3344314
30	Dafalapur_Dug_Well_12.8	0.1942739	0.2283918	0.2296568
31	Deshing_Dug_Well_9.8	0.1287998	0.1356705	0.1357981
32	Devnal_Bore_Well_36.5	0.079223	0.1026385	0.1027953
33	Devnal_Dug_Well_11.75	0.3174467	0.424298	0.4244151
34	Dhavadwadi_Dug_Well_12.3	0.6087256	0.8935281	0.9686896
35	Dhavadwadi_Dug_Well_5.7	0.1910823	0.1953331	0.2077296
36	Dhavadwadi_Dug_Well_6	0.2896818	0.2948413	0.2966511
37	Dudhebhavi_Dug_Well_9.8	0.1790606	0.239785	0.2408417

-Table B.3 continued on next page

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S.No	Village	Degree=2	Degree=3	Degree=4
38	Dudhgaon_Dug_Well_10.65	0.1483629	0.1518564	0.1646453
39	Ghanand_Dug_Well_12	0.20434	0.2200938	0.2287218
40	Ghatnandre_Dug_Well_13.3	0.2558078	0.2558618	0.2697101
41	Ghoti_kh_Dug_Well_10.45	0.446439	0.4892154	0.489313
42	Halli_Dug_Well_9.6	0.2790724	0.3829822	0.3834471
43	Hanmant_Vadiye_Bore_Well_37.3	0.016323	0.0425127	0.0435266
44	Hanmantvadiye_Dug_Well_9.6	0.2296116	0.2313956	0.2313976
45	Hingangaon_Dug_Well_13	0.2096136	0.2267071	0.2340709
46	Hivtad_Bore_Well_90	0.0370402	0.0371004	0.041817
47	Hubalwadi_Dug_Well_8.2	0.3184354	0.324628	0.3268812
48	Itakare_Dug_Well_9.5	0.2749834	0.275671	0.2782054
49	Jadraboblad_Dug_Well_12	0.2486505	0.3500052	0.4777024
50	Jadraboblad_Dug_Well_8.7	0.3000997	0.3984189	0.3996284
51	Kadegaon_Dug_Well_13.8	0.2791211	0.3188914	0.3221374
52	Kalambi_Dug_Well_12.8	0.1983314	0.2303789	0.2313633
53	Karanje_Bore_Well_70	0.0560219	0.0619301	0.0622727
54	Karve_Dug_Well_11.8	0.2269434	0.2418035	0.2467008
55	Kasbe_Digraj_Bore_Well_30	0.1629852	0.1748985	0.1798971
56	Kaslingwadi_Bore_Well_30	0.0163413	0.0237222	0.0405794
57	Kaslingwadi_Dug_Well_6	0.1824053	0.1966245	0.2095047
58	Kavalapur_Dug_Well_20.1	0.361763	0.4001254	0.4005311
59	Kerewadi_Dug_Well_8.8	0.0318284	0.0340485	0.0340592
60	Khambale_Aundh_Dug_Well_14.1	0.5199906	0.5268361	0.5282434
61	Khanapur_Dug_Well_6.6	0.3525361	0.3971827	0.4071271
62	Kharsundi_Dug_Well_16.75	0.2796661	0.3104915	0.310567
63	Khojanwadi_Bore_Well_31	0.1560717	0.1695872	0.2151031
64	Khojanwadi_Dug_Well_9.4	0.163866	0.2074219	0.2077289
65	Kokale_Dug_Well_6.4	0.2541558	0.261507	0.3130867
66	Kokale_Dug_Well_9.4	0.3307849	0.3397741	0.3500752
67	Kuchi_Dug_Well_11	0.1926086	0.2027708	0.2035645
68	Kudnur_Bore_Well_40	0.0523677	0.0539913	0.0793174
69	Kumathe_Dug_Well_13	0.3586612	0.3958081	0.3960459
70	Kumbhargaon_Dug_Well_9.4	0.4143466	0.4310092	0.4310587
71	Kundlapur_Dug_Well_6.5	0.2445869	0.2476391	0.2522158
72	Landgewadi_Dug_Well_11	0.1475999	0.206365	0.2103417
73	Lavanga_Dug_Well_6.6	0.4786187	0.5622837	0.5624304
74	Mahuli_Dug_Well_12.9	0.3148632	0.3453824	0.346039
75	Mandur_Dug_Well_4.4	0.3942291	0.3945399	0.3981964
76	Manerajuri_Bore_Well_127	0.007872	0.0081932	0.0098859

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S.No	Village	Degree=2	Degree=3	Degree=4
77	Mangle_Bore_Well_41	0.4440994	0.4707105	0.4732608
78	Mangle_Dug_Well_8.4	0.5690774	0.5694596	0.601633
79	Mhaisal_Dug_Well_13	0.5791455	0.6014953	0.6077732
80	Mitki_Dug_Well_12.2	0.1738925	0.2054454	0.2250776
81	Morbagi_Dug_Well_7.1	0.2982177	0.3787334	0.3833629
82	Muchandi_Dug_Well_11.5	0.2535911	0.2618249	0.2622029
83	Nagaj_Dug_Well_12.2	0.2545368	0.2931125	0.2941394
84	Nandre_Dug_Well_17.3	0.3082167	0.3820027	0.3867261
85	Nelkaranji_Dug_Well_8	0.275594	0.3107086	0.3359014
86	Nerle_Dug_Well_13.1	0.4193623	0.4464108	0.4503763
87	Nigadi_Kh_Dug_Well_9.8	0.3290055	0.3561319	0.3561341
88	Nigadi_kh_Dug_Well_5.9	0.3702723	0.3754024	0.4352345
89	Nimaj_Dug_Well_8.8	0.0751828	0.0925535	0.0983055
90	Pandharewadi_Dug_Well_20.4	0.277432	0.2932446	0.3338889
91	Parekarwadi_Dug_Well_9.75	0.3041728	0.332076	0.3538309
92	Pimpari_Kh_Dug_Well_7.8	0.3042724	0.3881006	0.3888555
93	Pujarwadi_Dug_Well_3.35	0.2380246	0.2761413	0.3128486
94	Rajewadi_Dug_Well_9.4	0.1176797	0.1765469	0.1765474
95	Ranjani_Bore_Well_67	0.1684685	0.1690691	0.2011615
96	Ranjani_Dug_Well_12.9	0.1448485	0.1500562	0.164234
97	Rethare_Dharan_Dug_Well_8.9	0.6257044	0.6551488	0.6553781
98	Rile_Bore_Well_25	0.1494497	0.1512098	0.1524354
99	Rile_Dug_Well_5.8	0.311563	0.3199124	0.3210951
100	Saholi_Bore_Well_90	0.0086535	0.0140896	0.0143045
101	Saholi_Dug_Well_14.6	0.2492139	0.299158	0.3041158
102	Sanamadi_Dug_Well_9	0.2572652	0.3106435	0.3109645
103	Sankh_Dug_Well_11.3	0.2629691	0.3015641	0.3108947
104	Sankh_Dug_Well_13	0.3217374	0.3310462	0.335148
105	Sarati_Bore_Well_45	0.1861712	0.1884196	0.2211762
106	Sarati_Bore_Well_91	0.0392975	0.0457993	0.0857933
107	Sawalwadi_Dug_Well_12.55	0.5484096	0.5484584	0.5540876
108	Sawantwadi_Dug_Well_5.5	0.6311225	0.6508706	0.6565684
109	Shetphale_Dug_Well_9	0.2479232	0.2621962	0.2649796
110	Shirala_Dug_Well_15.8	0.7536721	0.7986218	0.8040073
111	Shirdhon_Dug_Well_10.2	0.25512	0.3266634	0.3386989
112	Shirdhon_Dug_Well_17.9	0.3137749	0.3238845	0.3478629
113	Shirgaon_Visapur_Dug_Well_13	0.270914	0.3277529	0.3334373
114	Shivpuri_Dug_Well_6.8	0.6507023	0.6750139	0.6774599
115	Singnapur_Bore_Well_101	0.090789	0.0924985	0.1222721

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S.No	Village	Degree=2	Degree=3	Degree=4
116	Sonsal_Dug_Well_10.8	0.4682279	0.4685788	0.4730544
117	Sonsal_Dug_Well_17.1	0.074098	0.1720026	0.2533388
118	Sulewadi_Dug_Well_10.1	0.3311137	0.3625293	0.3631613
119	Tandulwadi_Dug_Well_13.7	0.4503811	0.4645854	0.4658984
120	Tasgaon_Bore_Well_34	0.149057	0.1493516	0.1495304
121	Tisangi_Dug_Well_9	0.2877018	0.3135453	0.3149483
122	Tung_Bore_Well_23	0.4508137	0.4511868	0.4540492
123	Tung_Dug_Well_12.9	0.5105044	0.537872	0.5388505
124	Umarani_Dug_Well_10.7	0.3160412	0.3613234	0.3613491
125	Umbargaon_Dug_Well_11	0.4267705	0.4588885	0.4592904
126	Utagi_Bore_Well_90	0.4844837	0.5518901	0.5778146
127	Utagi_Dug_Well_10.3	0.2261656	0.3119542	0.3144414
128	Vaddi_Bore_Well_23	0.358187	0.4589321	0.4643785
129	Vajrawad_Dug_Well_14.5	0.2188345	0.2301517	0.2309997
130	Vejegaon_Dug_Well_13.5	0.3532501	0.4644739	0.4727834
131	Vejegaon_Dug_Well_14.1	0.1368013	0.1376585	0.1377651
132	Vhaspeth_Dug_Well_8.9	0.2182729	0.3892541	0.3997509
133	Vita_Bore_Well_90	0.1264378	0.1270182	0.1274624
134	Vithalapur_Dug_Well_9.3	0.1137988	0.1442757	0.1716654
135	Waifal_Dug_Well_13.2	0.3680023	0.3680725	0.4158834
136	Waifal_Dug_Well_7.9	0.268321	0.3453146	0.3453512
137	Walekhindi_Dug_Well_10	0.2094486	0.2447763	0.2494058
138	Walkhad_Bore_Well_90	0.2154138	0.2312802	0.2443053
139	Wangi_Dug_Well_13.5	0.2767861	0.2935888	0.2939462
140	Wasgade_Bore_Well_30	0.1581667	0.244654	0.2506872
141	Wasgade_Dug_Well_11.4	0.3768428	0.397693	0.4070118
142	Yelavi_Dug_Well_14.8	0.1671899	0.1678298	0.1680127
143	Yelur_Bore_Well_60.5	0.0473176	0.0610706	0.0705592
144	Yogewadi_Dug_Well_12.5	0.1488411	0.148974	0.1516948
145	Zare_Bore_Well_90	0.1268473	0.136022	0.1379323
146	Zare_Dug_Well_10.8	0.2428703	0.2686283	0.2711038

-End of Table B.3

Appendix C

Rainfall Model R^2 Values

Table C.1: Rainfall Models R^2 values-Thane

S.No	Village	0.5 Degree Rain(Start-2006)	1.0 Degree Rain (start-2007)	Raingauge Rain (1992-2009)
1	Agashi_Boling_Dug_Well_10	0.6510139	0.6652037	0.6331151
2	Akoli_Dug_Well_5.5	0.7358774	0.7568838	0.7372691
3	Ambiste_kh_Bore_Well_17	0.8835335	0.874912	0.8748821
4	Awale_Dug_Well_7.35	0.7004422	0.8074496	0.8400209
5	Badlapur_Bore_Well_30	0.5221814	0.5220431	0.517144
6	Badlapur_Dug_Well_7.95	0.3176229	0.4392369	0.3911277
7	Bapgaon_Dug_Well_7.4	0.8845438	0.8786999	0.8785858
8	Bhatsai_Bore_Well_18	0.3260892	0.3937095	0.3198313
9	Bhinar_Dug_Well_6.25	0.8552908	0.8528219	0.8443564
10	Borivali_T_Padgha_Dug_Well_10.6	0.5134245	0.5503818	0.5191051
11	Bursunge_Dug_Well_8.65	0.7874082	0.7950966	0.759359
12	Chahade_Dug_Well_5.7	0.7221748	0.8699245	0.8738729
13	Chavindra_Bore_Well_13.5	0.889361	0.8835861	0.8725602
14	Chndansar_Bore_Well_24	0.781102	0.7748481	0.7614372
15	Dahisar_Dug_Well_9.5	0.7664238	0.7773528	0.7698761
16	Dapode_Dug_Well_5.25	0.45563	0.5869822	0.5564777
17	Deoli_Dug_Well_6.2	0.795212	0.8047705	0.7912022
18	Dhanivri_Dug_Well_5.5	0.8134596	0.835511	0.8272588
19	Dhanoshi_Dug_Well_6.5	0.7500653	0.7732262	0.7749636
20	Dhuktan_Dug_Well_6.1	0.8447702	0.8409324	0.8292091
21	Dolhare_Dug_Well_5.5	0.8128984	0.8140879	0.8182395

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S.No	Village	0.5 Degree Rain(Start-2006)	1.0 Degree Rain (start-2007)	Raingauge Rain (1992-2009)
22	Durves_Dug_Well_9.6	0.9021983	0.9111539	0.9061525
23	Gates_Bk_Dug_Well_7.5	0.7249018	0.7390241	0.6994636
24	Ghansoli_Bore_Well_12.7	0.7617074	0.7561767	0.736619
25	Ghodbandar_Dug_Well_8.2	0.6353988	0.6569866	0.6336609
26	Ghol_Dug_Well_10.4	0.3080064	0.3236722	0.3070447
27	Gokhiware_Bore_Well_18	0.9186675	0.9234957	0.9203984
28	Gokhiware_Dug_Well_5.5	0.7494071	0.7338667	0.7180314
29	Govade_Dug_Well_6.6	0.7570237	0.7735623	0.7582633
30	Goveli_Bore_Well_17.25	0.5943489	0.6286854	0.5693634
31	Inde_Dug_Well_7.8	0.6109089	0.6226149	0.6428992
32	Jawhar_Dug_Well_7.65	0.417063	0.528335	0.5093286
33	Kajali_Dug_Well_14	0.4422432	0.3815451	0.3608966
34	Kalamdevi_Dug_Well_5.5	0.6357514	0.6392599	0.641227
35	Kambe_Dug_Well_6.9	0.4795193	0.4844049	0.4590723
36	Kanchad_Bore_Well_18	0.8885406	0.8849725	0.8814217
37	Kanchad_Dug_Well_7.5	0.8329024	0.8597892	0.8978615
38	Kanhor_Dug_Well_8.5	0.8042779	0.8256942	0.8092083
39	Karav_Dug_Well_8	0.1895069	0.1868721	0.17395
40	Karvele_Dug_Well_6.3	0.2917039	0.3421522	0.3159953
41	Kasa_bk_Dug_Well_6.5	0.5949006	0.7770563	0.7747274
42	Katrap_Dug_Well_3.1	0.442862	0.4548667	0.4734711
43	Khaniwade_Dug_Well_5	0.8656651	0.8994667	0.9019864
44	Kharade_Dug_Well_8.2	0.5639737	0.5900478	0.5661326
45	Khodala_Dug_Well_5.8	0.5328543	0.5465752	0.5196818
46	Kogde_Dug_Well_7	0.8284839	0.838156	0.8327635
47	Kopar_Karane_Dug_Well_4.7	0.5387726	0.5104838	0.5473869
48	Kopari_Dug_Well_7.55	0.3692445	0.3405021	0.3536081
49	Kudan_Bore_Well_30	0.7433341	0.7256617	0.7328432
50	Kudus_Dug_Well_6	0.7746448	0.8541037	0.8520267
51	Lalthan_Dug_Well_6.4	0.7827106	0.7903451	0.7739695
52	Mahim_Bore_Well_20	0.8395158	0.8433199	0.8356859
53	Makunsar_Dug_Well_9.8	0.8147035	0.8174292	0.8147599
54	Mandawa_Bore_Well_30	0.5051498	0.4803988	0.4116657
55	Mandvi_Dug_Well_9.1	0.8560269	0.8609808	0.8673714
56	Mangrul_Dug_Well_7.6	0.4843877	0.4726156	0.4744037
57	Manor_Dug_Well_7	0.5372022	0.5156388	0.4707417

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S.No	Village	0.5 Degree Rain(Start-2006)	1.0 Degree Rain (start-2007)	Raingauge Rain (1992-2009)
58	Met_Dug_Well_8.3	0.8583244	0.8595582	0.8578304
59	Mokhada_Dug_Well_9	0.6812283	0.7370204	0.7069277
60	Morhande_Dug_Well_5.1	0.7832691	0.7735717	0.7714072
61	Musarne_Dug_Well_6	0.8978713	0.8951847	0.8829329
62	Nare_Bore_Well_18	0.942	0.9366252	0.9403947
63	Neharoli_Bore_Well_24	0.6806413	0.6453606	0.5541415
64	Newale_Dug_Well_8.2	0.5664686	0.5828445	0.5657912
65	Nihe_Dug_Well_7	0.7836614	0.7813013	0.7620461
66	Nimbavali_Bore_Well_30	0.7675683	0.7954848	0.7190905
67	Padgha_Bore_Well_30	0.7797427	0.7865357	0.7780311
68	Palghar_kolgaon_Bore_Well_30	0.8733791	0.8566523	0.8811919
69	Pali_Dug_Well_6	0.9022613	0.9047187	0.8999879
70	Parli_Dug_Well_5.1	0.6162533	0.6236001	0.6111547
71	Pawane_Dug_Well_5	0.4498261	0.4615822	0.4540399
72	Pelhar_Dug_Well_7	0.7212839	0.800033	0.7804812
73	Pimpalas_Dug_Well_6.55	0.7281179	0.7288998	0.7185053
74	Pimpalshet_Dug_Well_8.5	0.7515184	0.7551294	0.7535057
75	Rayta_Dug_Well_4	0.6044533	0.6162191	0.6071121
76	Safala_Dug_Well_10.5	0.8050718	0.8158182	0.8283017
77	Safale_Bore_Well_25.9	0.8876111	0.8901143	0.8835427
78	Sakharshet_chalatwad_Bore_Well_22.5	0.6105416	0.6053023	0.5849818
79	Sakwar_Dug_Well_6	0.595954	0.6088914	0.6076456
80	Sange_Dug_Well_4.7	0.8694652	0.8720333	0.8806663
81	Saravali_Bore_Well_24	0.7455786	0.7372011	0.6843486
82	Sasne_Dug_Well_8.85	0.5459075	0.552562	0.540197
83	Satiwali_Bore_Well_18	0.446877	0.4715276	0.2880985
84	Satiwali_Dug_Well_7.2	0.511242	0.3864317	0.4089973
85	Sawta_Dug_Well_8.4	0.7608951	0.7654755	0.7590192
86	Shelonde_Dug_Well_12.5	0.6865479	0.696641	0.6929729
87	Shendrun_Dug_Well_4.7	0.8129365	0.8344643	0.808041
88	Shil_t_chon_Dug_Well_7.1	0.7784778	0.7866394	0.7848066
89	Shilphata_Dug_Well_4.8	0.407066	0.4916883	0.4978516
90	Shirgaon_Dug_Well_9	0.8549223	0.8285075	0.807368
91	Shivale_Dug_Well_11	0.6833161	0.658188	0.6659769
92	Suksale_Bore_Well_30	0.8092644	0.7774523	0.790856
93	Talasari_Dug_Well_8	0.4123234	0.7871129	0.7973123

-Table C.1 continued on next page

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S.No	Village	0.5 Degree Rain(Start-2006)	1.0 Degree Rain (start-2007)	Raingauge Rain (1992-2009)
94	Talasarimal_Dug_Well_8.2	0.4462978	0.6190188	0.6547334
95	Talegaon_Dug_Well_6.1	0.8258078	0.8275124	0.825286
96	Talwada_Bore_Well_30	0.9315646	0.9264553	0.9289107
97	Tembhare_Dug_Well_5.5	0.8189154	0.8121089	0.8100869
98	Thane_Dug_Well_7.05	0.249603	0.3654138	0.3862716
99	Thilher_Dug_Well_6.2	0.8856092	0.8813909	0.8651082
100	Thunepada_Dug_Well_5.95	0.8289057	0.84183	0.8350897
101	Titwala_Dug_Well_7	0.4536793	0.5127631	0.3901818
102	Tokavde_Bore_Well_24	0.9206414	0.9030754	0.9131701
103	Tokawade_Dug_Well_5	0.6817294	0.6787909	0.6762035
104	Udawa_Bore_Well_30	0.9034096	0.9007817	0.8807363
105	Vadoli_Dug_Well_5.6	0.5987547	0.6028518	0.6218372
106	Varaskol_Dug_Well_7	0.8596181	0.8629385	0.8559823
107	Vasar_Bore_Well_30	0.333441	0.3923779	0.61272
108	Vedhi_Dug_Well_8.7	0.7446964	0.7554035	0.7452259
109	Vehaloli_Dug_Well_5.1	0.821921	0.8301012	0.8242601
110	Vevaji_Dug_Well_7.6	0.5744005	0.6028129	0.6837548
111	Veyour_Dug_Well_10.1	0.7413705	0.8109697	0.8040656
112	Vihigaon_Dug_Well_7.5	0.6961868	0.7119633	0.6967913
113	Wada_Dug_Well_9	0.533454	0.6646302	0.6776726
114	Waret_Bore_Well_30	0.8425024	0.8570683	0.8421273
115	Warwade_Dug_Well_7.6	0.698345	0.7146286	0.7018021
116	Washind_Dug_Well_3.05	0.6898296	0.5269989	0.7192495
117	Washind_Dug_Well_7	0.4528959	0.5760242	0.4389685
118	Zhai_Dug_Well_7.7	0.6375898	0.6602398	0.6377981
119	Zhari_Bore_Well_30	0.9059797	0.9153721	0.918625
120	Zhari_Dug_Well_7.4	0.5662066	0.5812451	0.5413716

-End of Table C.1

Table C.2: Rainfall Models R^2 values-Latur

S.No	Village	0.5 Degree Rain (Start-2005)	Raingauge Rain (1992-2009)
1	Aashiv_Dug_Well_15	0.3018352	0.3530664
2	Achola_Dug_Well_12.3	0.7019446	0.6362778
3	Ahmadpur_Dug_Well_15.1	0.7849394	0.7270889
4	Almala_Dug_Well_9.5	0.485419	0.3887059
5	Ambanagar_Dug_Well_6.5	0.7611721	0.6679871
6	Ambulga_Dug_Well_10.5	0.4164717	0.4222369
7	Ambulga_Dug_Well_12.9	0.5181035	0.3583963
8	Andhori_Dug_Well_16.1	0.8772779	0.8165858
9	Arasnal_Bore_Well_60	0.399788	0.2128165
10	Ashta_Dug_Well_9.9	0.7636629	0.6543039
11	Aurad_shahjani_Dug_Well_8.1	0.5122739	0.5346077
12	Ausa_Dug_Well_19.9	0.3768038	0.3649117
13	Babalgoan_Dug_Well_19.7	0.6076666	0.6364421
14	Barmachiwadi_Dug_Well_16.9	0.5432535	0.4279665
15	Bhadi_Dug_Well_11.3	0.7477869	0.6164076
16	Bhatkheda_Dug_Well_18.65	0.3603843	0.2599832
17	Bhuisamudraga_Dug_Well_16.65	0.2561898	0.24922
18	Borfal_Dug_Well_8.5	0.6748787	0.6304473
19	Borgaon_n_Dug_Well_12.5	0.4273558	0.2819464
20	Budhada_Dug_Well_23.5	0.5334786	0.5614287
21	Chikurda_Bore_Well_27	0.5802016	0.2447753
22	Dangewadi_Dug_Well_17.7	0.6342324	0.6426629
23	Dapegaon_Bore_Well_30	0.5399494	0.2629118
24	Dawangaon_Dug_Well_7.15	0.7384095	0.660568
25	Deokara_Dug_Well_21.4	0.8194479	0.6975779
26	Deoni_bk_Dug_Well_18.9	0.7975737	0.6593662
27	Deoni_kh_Dug_Well_17.9	0.6164912	0.5099255
28	Dhalegaon_Bore_Well_90	0.5131821	0.5500976
29	Dhanegaon_Dug_Well_15.7	0.1918787	0.3041185
30	Dighol_deshmukh_Dug_Well_11.9	0.4678987	0.3301049
31	Gadwad_Dug_Well_12.5	0.4854713	0.398759
32	Gangahipparga_Dug_Well_10.5	0.551233	0.486331
33	Gangapur_Dug_Well_11.5	0.6349133	0.4909334
34	Ganjoor_Dug_Well_19.25	0.3772608	0.270225
35	Garsuli_Dug_Well_10.2	0.679973	0.6730084

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S.No	Village	0.5 Degree Rain(Start-2006)	Raingauge Rain (1992-2009)
36	Gategoan_Dug_Well_13.8	0.5040251	0.3934277
37	Gaur_Dug_Well_13.9	0.7252298	0.5435777
38	Gharni_Dug_Well_9.6	0.744408	0.7199441
39	Ghonshi_Dug_Well_20.3	0.6668534	0.5097912
40	Hadolti_Dug_Well_12.8	0.3996959	0.4661518
41	Haibatpur_Bore_Well_60	0.3223553	0.2244802
42	Halsi_t_Dug_Well_14.4	0.4023315	0.3585689
43	Hanchnal_Dug_Well_21.7	0.5863508	0.6500744
44	Harangul_bk_Dug_Well_10	0.6016359	0.4111658
45	Hipparga_kopdev_Dug_Well_18.9	0.581923	0.5380001
46	Hisamabad_ujed_Dug_Well_15.4	0.484998	0.2884091
47	Hosur_Dug_Well_8.9	0.6620122	0.5028903
48	Ismailpur_Dug_Well_17.6	0.6562607	0.6557105
49	Jalkot_Dug_Well_19.2	0.6168463	0.6045647
50	Jawala_bk_Dug_Well_19.8	0.3757536	0.3475164
51	Kabansangvi_Dug_Well_11.2	0.5911811	0.5414069
52	Karadkhel_Dug_Well_14.9	0.581607	0.5240333
53	Karla_Dug_Well_9.3	0.6237141	0.5677311
54	Karsa_Dug_Well_8.7	0.5534075	0.567322
55	Kasarshirshi_Dug_Well_11.9	0.6306712	0.5831854
56	Kelgaon_Bore_Well_60	0.4658574	0.3404882
57	Kelgaon_Dug_Well_15.5	0.6021998	0.546241
58	Khandali_Bore_Well_90	0.4006174	0.378912
59	Khandali_Dug_Well_9.2	0.7449761	0.6474477
60	Kharola_Dug_Well_11.5	0.5988744	0.6083875
61	Kharosa_Dug_Well_23.7	0.7056582	0.5612489
62	Khuntegaon_Bore_Well_95	0.6412344	0.1832502
63	Killari_Dug_Well_18.7	0.4763135	0.2277131
64	Kiniyalladevi_Dug_Well_21	0.7103363	0.7626753
65	Kodli_Dug_Well_8.7	0.5862902	0.509158
66	Kolnoor_Dug_Well_10.9	0.595641	0.6139195
67	Kolwadi_Dug_Well_15.3	0.7033582	0.6928198
68	Kumbhari_Bore_Well_30	0.687208	0.5789082
69	Kumtha_Bore_Well_21	0.8013583	0.389142
70	Lambota_Dug_Well_12.8	0.5842181	0.365983
71	Lamjana_Dug_Well_17.3	0.7530829	0.7517306
72	Latur_road_Bore_Well_80	0.1752429	0.1730181

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S.No	Village	0.5 Degree Rain(Start-2006)	Raingauge Rain (1992-2009)
73	Latur_road_Dug_Well_13.3	0.601315	0.4739625
74	Madansuri_Dug_Well_10.2	0.5633788	0.5158853
75	Mahalangra_Dug_Well_14.5	0.7741988	0.7428621
76	Mal_hipparga_Bore_Well_85	0.6247956	0.7836097
77	Mamdapur_Dug_Well_11.1	0.6972688	0.5723193
78	Mankhed_Dug_Well_13.9	0.8147229	0.6347209
79	Mannatpur_Dug_Well_10.1	0.6320027	0.7362533
80	Mogha_Dug_Well_20.6	0.4977609	0.6607421
81	Murdhav_Dug_Well_12.2	0.2150953	0.3013702
82	Murud_bk_Dug_Well_21	0.3604705	0.2247595
83	Nalgir_Dug_Well_12.8	0.6244839	0.5470255
84	Nandgaon_Dug_Well_7.7	0.5296643	0.4540179
85	Nandgaon_Dug_Well_9.9	0.7777447	0.7100457
86	Nandurga_Dug_Well_17.9	0.3156062	0.2419815
87	Neoli_Dug_Well_14.6	0.495695	0.4236564
88	Nilanga_Dug_Well_14.8	0.5941196	0.3456777
89	Pakharsangvi_Dug_Well_13.5	0.4520316	0.342322
90	Palshi_Dug_Well_6.6	0.7447	0.7336289
91	Pangaon_Dug_Well_10.75	0.564071	0.4214618
92	Patoda_kh_Dug_Well_10.1	0.3598288	0.4415259
93	Rapka_Dug_Well_19.8	0.4321257	0.3403687
94	Renapur_Dug_Well_13	0.517958	0.4270271
95	Sakol_Bore_Well_30	0.5009932	0.6010544
96	Sakol_Dug_Well_19	0.4442124	0.2577544
97	Samsapur_Dug_Well_11.4	0.7566073	0.6727696
98	Sangvi_s_Dug_Well_12.9	0.4841817	0.4021498
99	Sarwadi_Bore_Well_30	0.358524	0.3026102
100	Selu_Dug_Well_8.9	0.6179186	0.5835363
101	Shelgi_Dug_Well_11.9	0.7373361	0.6293679
102	Shirur_tajband_Dug_Well_12.5	0.5347222	0.3901821
103	Shivankhed_Bore_Well_70	0.1958358	0.3128577
104	Shivpur_Dug_Well_9.5	0.5518007	0.4656821
105	Sindgi_bk_Dug_Well_14.2	0.6327537	0.6162577
106	Sindgoan_Dug_Well_10.1	0.7306547	0.5116928
107	Sindkhed_Bore_Well_61	0.1714149	0.1965281
108	Sirsi_Bore_Well_23.3	0.361919	0.4125388
109	Somnathpur_Dug_Well_7.2	0.7754367	0.7347958

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S.No	Village	0.5 Degree Rain(Start-2006)	Raingauge Rain (1992-2009)
110	Sugaon_Bore_Well_60	0.3443079	0.3280675
111	Tajpur_Dug_Well_11.9	0.7099054	0.5664062
112	Taka_Dug_Well_10	0.3908977	0.3655431
113	Taka_Dug_Well_13.7	0.3917898	0.3209084
114	Takli_Dug_Well_12.75	0.3372344	0.2952985
115	Talni_Dug_Well_18.9	0.4553244	0.1590735
116	Tambatsangvi_Dug_Well_20.3	0.2411084	0.2736626
117	Tattapur_Dug_Well_8	0.7867837	0.7605718
118	Tiruka_Dug_Well_14.6	0.6845035	0.7101425
119	Togari_Dug_Well_9.5	0.6923136	0.5770099
120	Udgir_Bore_Well_70	0.6955167	0.5939478
121	Wadmurumbi_Dug_Well_13.6	0.3726725	0.4190889
122	Waigaon_Dug_Well_10.5	0.6726919	0.5232456
123	Walandi_Dug_Well_9.2	0.5703561	0.4060736
124	Walsangi_Dug_Well_12.5	0.7628355	0.6116566
125	Wanjarkheda_Dug_Well_9.5	0.517315	0.503103
126	Yelwat_Bore_Well_79	0.8163918	0.6030651
127	Yerol_Dug_Well_16.8	0.6794862	0.6420093

-End of Table C.2

Table C.3: Rainfall Models R^2 values-Sangli

S.No	Village	0.5 Degree Rain (start-2005)
1	Akkalawadi_Dug_Well_7.8	0.8326353
2	Alkud_M_Dug_Well_10.7	0.3919118
3	Antral_Dug_Well_12.2	0.3729012
4	Arag_Dug_Well_12.5	0.3864056
5	Ashta_Dug_Well_12	0.3307121
6	Atpadi_Bore_Well_45	0.2916324
7	Atpadi_Dug_Well_10.2	0.4452552
8	Atpadi_Dug_Well_6.7	0.6093163
9	Bagewadi_Dug_Well_9.1	0.3885881
10	Balvadi_Dug_Well_10.7	0.630914
11	Basargi_Dug_Well_4.6	0.5030435

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S.No	Village	0.5 Degree Rain(Start-2006)
12	Bedag_Dug_Well_13.7	0.7248826
13	Bedag_Dug_Well_9.4	0.4865537
14	Belanki_Bore_Well_31.4	0.6225039
15	Belanki_Dug_Well_8.7	0.3954559
16	Bevanur_Dug_Well_9.5	0.3463488
17	Bhalwani_Dug_Well_11.7	0.4792143
18	Bhaurayachiwadi_Dug_Well_11.1	0.3037362
19	Bhilwadi_Bore_Well_37	0.2880332
20	Bhilwadi_Dug_Well_7.3	0.4106102
21	Bhood_Dug_Well_9.9	0.5052274
22	Bilashi_Dug_Well_13.8	0.2314214
23	Bilur_Bore_Well_90	0.2977786
24	Bilur_Dug_Well_13.5	0.5092808
25	Biur_Dug_Well_8.6	0.6448927
26	Bombewadi_Dug_Well_5.7	0.3910684
27	Borgaon_Bore_Well_36.5	0.168301
28	Borgi_bk_Dug_Well_9	0.3183424
29	Chorochi_Dug_Well_7.3	0.3014903
30	Dafalapur_Dug_Well_12.8	0.2117847
31	Deshing_Dug_Well_9.8	0.3680158
32	Devnal_Bore_Well_36.5	0.1654711
33	Devnal_Dug_Well_11.75	0.3296606
34	Dhavadwadi_Dug_Well_12.3	0.7667723
35	Dhavadwadi_Dug_Well_5.7	0.2203937
36	Dhavadwadi_Dug_Well_6	0.3121287
37	Dudhebhavi_Dug_Well_9.8	0.2010039
38	Dudhgaon_Dug_Well_10.65	0.171902
39	Ghanand_Dug_Well_12	0.2549954
40	Ghatnandre_Dug_Well_13.3	0.8815416
41	Ghoti_kh_Dug_Well_10.45	0.5050377
42	Halli_Dug_Well_9.6	0.3123592
43	Hanmant_Vadiye_Bore_Well_37.3	0.4668485
44	Hanmantvadiye_Dug_Well_9.6	0.4442716
45	Hingangaon_Dug_Well_13	0.3263111
46	Hivtad_Bore_Well_90	0.4273391
47	Hubalwadi_Dug_Well_8.2	0.3822319
48	Itakare_Dug_Well_9.5	0.3329101

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S.No	Village	0.5 Degree Rain(Start-2006)
49	Jadraboblad_Dug_Well_12	0.4785995
50	Jadraboblad_Dug_Well_8.7	0.4403604
51	Kadegaon_Dug_Well_13.8	0.5071267
52	Kalambi_Dug_Well_12.8	0.3629388
53	Karanje_Bore_Well_70	0.6402713
54	Karve_Dug_Well_11.8	0.5335648
55	Kasbe_Digraj_Bore_Well_30	0.117068
56	Kaslingwadi_Bore_Well_30	0.1643791
57	Kaslingwadi_Dug_Well_6	0.3876019
58	Kavalapur_Dug_Well_20.1	0.4376601
59	Kerewadi_Dug_Well_8.8	0.0665644
60	Khambale_Aundh_Dug_Well_14.1	0.6330892
61	Khanapur_Dug_Well_6.6	0.4645197
62	Kharsundi_Dug_Well_16.75	0.3634861
63	Khojanwadi_Bore_Well_31	0.1232543
64	Khojanwadi_Dug_Well_9.4	0.4988551
65	Kokale_Dug_Well_6.4	0.3022721
66	Kokale_Dug_Well_9.4	0.316019
67	Kuchi_Dug_Well_11	0.2997406
68	Kudnur_Bore_Well_40	0.1838428
69	Kumathe_Dug_Well_13	0.5727884
70	Kumbhargaon_Dug_Well_9.4	0.6283295
71	Kundlapur_Dug_Well_6.5	0.2670624
72	Landgewadi_Dug_Well_11	0.3243051
73	Lavanga_Dug_Well_6.6	0.4559293
74	Mahuli_Dug_Well_12.9	0.4555234
75	Mandur_Dug_Well_4.4	0.411956
76	Manerajuri_Bore_Well_127	0.5245385
77	Mangle_Bore_Well_41	0.4083391
78	Mangle_Dug_Well_8.4	0.5772012
79	Mhaisal_Dug_Well_13	0.6071928
80	Mitki_Dug_Well_12.2	0.4841936
81	Morbagi_Dug_Well_7.1	0.4688504
82	Muchandi_Dug_Well_11.5	0.2990197
83	Nagaj_Dug_Well_12.2	0.3065605
84	Nandre_Dug_Well_17.3	0.316864
85	Nelkaranji_Dug_Well_8	0.3565636

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S.No	Village	0.5 Degree Rain(Start-2006)
86	Nerle_Dug_Well_13.1	0.4787417
87	Nigadi_kh_Dug_Well_5.9	0.3842534
88	Nigadi_kh_Dug_Well_9.8	0.884224
89	Nimaj_Dug_Well_8.8	0.1517092
90	Pandharewadi_Dug_Well_20.4	0.7920133
91	Parekarwadi_Dug_Well_9.75	0.4097291
92	Pimpari_kh_Dug_Well_7.8	0.3790622
93	Pujarwadi_Dug_Well_3.35	0.282277
94	Rajewadi_Dug_Well_9.4	0.1076558
95	Ranjani_Bore_Well_67	0.1740534
96	Ranjani_Dug_Well_12.9	0.187328
97	Rethare_Dharan_Dug_Well_8.9	0.6820801
98	Rile_Bore_Well_25	0.4240211
99	Rile_Dug_Well_5.8	0.3593061
100	Saholi_Bore_Well_90	0.675694
101	Saholi_Dug_Well_14.6	0.489898
102	Sanamadi_Dug_Well_9	0.3295397
103	Sankh_Dug_Well_11.3	0.4082914
104	Sankh_Dug_Well_13	0.9175976
105	Sarati_Bore_Well_45	0.3890987
106	Sarati_Bore_Well_91	0.4176918
107	Sawalwadi_Dug_Well_12.55	0.7704986
108	Sawantwadi_Dug_Well_5.5	0.7034286
109	Shetphale_Dug_Well_9	0.2900444
110	Shirala_Dug_Well_15.8	0.7967645
111	Shirdhon_Dug_Well_10.2	0.3787052
112	Shirdhon_Dug_Well_17.9	0.6466869
113	Shirgaon_Visapur_Dug_Well_13	0.4793034
114	Shivpuri_Dug_Well_6.8	0.672005
115	Singnapur_Bore_Well_101	0.0374592
116	Sonsal_Dug_Well_10.8	0.5473023
117	Sonsal_Dug_Well_17.1	0.6187006
118	Sulewadi_Dug_Well_10.1	0.4721598
119	Tandulwadi_Dug_Well_13.7	0.476095
120	Tasgaon_Bore_Well_34	0.3669901
121	Tisangi_Dug_Well_9	0.357864
122	Tung_Bore_Well_23	0.5760037

-Table C.3 continued on next page

-Table C.3 continued from previous page

S.No	Village	0.5 Degree Rain(Start-2006)
123	Tung_Dug_Well_12.9	0.52051
124	Umarani_Dug_Well_10.7	0.3656862
125	Umbargaon_Dug_Well_11	0.4284175
126	Utagi_Bore_Well_90	0.569057
127	Utagi_Dug_Well_10.3	0.360871
128	Vaddi_Bore_Well_23	0.5104669
129	Vajrawad_Dug_Well_14.5	0.6450838
130	Vejegaon_Dug_Well_13.5	0.9593859
131	Vejegaon_Dug_Well_14.1	0.3583458
132	Vhaspeth_Dug_Well_8.9	0.3098033
133	Vita_Bore_Well_90	0.6463972
134	Vithalapur_Dug_Well_9.3	0.2081819
135	Waifal_Dug_Well_13.2	0.6142298
136	Waifal_Dug_Well_7.9	0.3608922
137	Walekhindi_Dug_Well_10	0.5740743
138	Walkhad_Bore_Well_90	0.5069489
139	Wangi_Dug_Well_13.5	0.4471252
140	Wasgade_Bore_Well_30	0.2300388
141	Wasgade_Dug_Well_11.4	0.524128
142	Yelavi_Dug_Well_14.8	0.3756937
143	Yelur_Bore_Well_60.5	0.0562955
144	Yogewadi_Dug_Well_12.5	0.3006538
145	Zare_Bore_Well_90	0.0815099
146	Zare_Dug_Well_10.8	0.4192037

-End of Table C.3

Appendix D

Root Mean Square Error Values

Table D.1: Root Mean Square Error in Prediction-Thane [1]

S.No	Village	1991	1999	2000	2002	2003
1	Agashi_Boling_Dug_Well_10	3.416	3.087	3.499	3.268	2.695
2	Akoli_Dug_Well_5.5	4.397	4.257	4.497	4.87	3.062
3	Awale_Dug_Well_7.35	4.5	4.774	4.764	4.686	4.956
4	Badlapur_Dug_Well_7.95	2.875	1.691	2.582	2.315	2.098
5	Bapgaon_Dug_Well_7.4	6.458	6.598	7.437	7.969	6.823
6	Bhinar_Dug_Well_6.25	3.141	1.878	2.232	2.446	2.733
7	Borivali_T_Padgha_Dug_Well_10.6	2.93	2.684	2.623	2.284	2.177
8	Bursunge_Dug_Well_8.65	9.636	9.306	10.214	11.001	6.657
9	Chahade_Dug_Well_5.7	3.506	3.201	3.483	3.754	2.776
10	Dahisar_Dug_Well_9.5	8.168	7.283	9.466	9.069	
11	Dapode_Dug_Well_5.25	2.224	1.608	1.318	1.39	1.316
12	Deoli_Dug_Well_6.2	5.816	4.648	4.746	5.505	4.021
13	Dhanivri_Dug_Well_5.5	3.285	2.64	2.974	2.709	
14	Dhanoshi_Dug_Well_6.5	4.013	2.707	3.248	3.747	3.764
15	Dhuktan_Dug_Well_6.1	4.928	4.661	5.058	5.262	4.089
16	Dolhare_Dug_Well_5.5	4.962	4.579	5.967	5.548	4.472
17	Durves_Dug_Well_9.6	8.506	7.27	7.717	8.335	7.925
18	Gates_Bk_Dug_Well_7.5	8.746	6.355	6.443	7.603	5.057
19	Ghodbandar_Dug_Well_8.2	5.028	4.712	4.811	4.358	3.122
20	Ghol_Dug_Well_10.4	0.928	2.043	1.672	1.05	1.555
21	Gokhiware_Dug_Well_5.5	2.172	1.407	2.312	2.272	1.903
22	Govade_Dug_Well_6.6	5.029	4.772	5.02	5.242	3.653

-Table D.1 continued on next page

[1] Missing Value Means no observation data is available for the year

-Table D.1 continued from previous page

S.No	Village	1991	1999	2000	2002	2003
23	Inde_Dug_Well_7.8	3.816	3.17	3.509	4.32	2.732
24	Jawhar_Dug_Well_7.65	1.962	2.781	3.725	4.411	4.295
25	Kajali_Dug_Well_14	5.059	4.254	4.486	5.897	
26	Kalamdevi_Dug_Well_5.5	3.123	3.52	3.371	3.43	3.54
27	Kambe_Dug_Well_6.9	1.214	2.481	2.125	4.707	2.324
28	Kanchad_Dug_Well_7.5	4.707	3.598	4.256	4.001	3.351
29	Kanhor_Dug_Well_8.5	6.696	4.854	4.183	4.845	4.814
30	Karav_Dug_Well_8	9.001	7.116	4.016	4.171	3.457
31	Karvele_Dug_Well_6.3	5.164	2.354	2.304	2.172	1.782
32	Kasa_bk_Dug_Well_6.5	2.418	2.08	2.305	3.426	2.973
33	Katrap_Dug_Well_3.1	1.445	1.545	2.21	2.099	0.95
34	Khaniwade_Dug_Well_5	2.719	2.918	3.103	3.448	2.663
35	Kharade_Dug_Well_8.2	4.894	2.713	2.415	2.807	1.62
36	Khodala_Dug_Well_5.8	1.862	3.478	2.96	3.05	3.108
37	Kogde_Dug_Well_7	6.935	6.088	6.02	7.442	7.105
38	Kopar_Karane_Dug_Well_4.7	1.559	1.576	1.916	1.807	1.12
39	Kopari_Dug_Well_7.55	1.452	1.282	0.499	1.077	0.388
40	Kudus_Dug_Well_6	4.377	5.201	4.516	4.169	3.37
41	Lalthan_Dug_Well_6.4	4.154	4.393	3.914	4.453	3.915
42	Makunsar_Dug_Well_9.8	7.816	8.862	8.111	7.532	7.323
43	Mandvi_Dug_Well_9.1	9.003	8.392	8.887	9.843	6.891
44	Mangrul_Dug_Well_7.6	4.888	7.594	9.121	10.273	7.478
45	Manor_Dug_Well_7	1.82	1.137	0.895	0.815	0.937
46	Met_Dug_Well_8.3	5.095	5.179	5.687	5.446	5.802
47	Mokhada_Dug_Well_9	3.353	2.505	3.252	3.535	2.559
48	Morhande_Dug_Well_5.1	4.792	3.752	5.284	4.79	3.471
49	Musarne_Dug_Well_6	5.457	5.966	6.277	5.682	
50	Newale_Dug_Well_8.2	4.91	6.63	7.512	7.208	4.855
51	Nihe_Dug_Well_7	5.225	4.805	4.901	5.691	4.078
52	Pali_Dug_Well_6	6.148	5.575	5.613	5.87	5.742
53	Parli_Dug_Well_5.1	1.752	1.501	2.272	2.457	1.765
54	Pawane_Dug_Well_5	2.409	2.481	1.71	2.803	1.247
55	Pelhar_Dug_Well_7	4.836	3.325	3.586	3.467	4.049
56	Pimpalas_Dug_Well_6.55	5.215	4.141	4.11	5.914	5.803
57	Pimpalshet_Dug_Well_8.5	6.133	6.257	4.676	5.72	6.622
58	Rayta_Dug_Well_4	3.425	3.204	3.575	4.539	2.526
59	Safala_Dug_Well_10.5	6.046	6.218	6.229	6.829	6.92
60	Sakwar_Dug_Well_6	3.688	3.066	2.951	2.352	2.51
61	Sange_Dug_Well_4.7	5.215	5.007	4.956	6.517	5.273

-Table D.1 continued on next page

-Table D.1 continued from previous page

S.No	Village	1991	1999	2000	2002	2003
62	Sasne_Dug_Well_8.85	7.461	4.705	5.435	6.69	4.337
63	Satiwali_Dug_Well_7.2	3.812	3.775	4.24	4.147	2.731
64	Sawta_Dug_Well_8.4	5.474	4.265	5.496	5.114	4.899
65	Shelonde_Dug_Well_12.5	4.983	5.41	4.592	5.447	6.379
66	Shendrun_Dug_Well_4.7	3.123	2.254	2.8	2.678	1.49
67	Shil_t_chon_Dug_Well_7.1	3.406	1.684	2.256	1.633	1.821
68	Shilphata_Dug_Well_4.8	1.122	1.286	1.001	1.094	0.926
69	Shirgaon_Dug_Well_9	4.639	5.522	5.174	5.257	4.622
70	Shivale_Dug_Well_11	7.565	4.082	7.627	6.481	7.507
71	Talasari_Dug_Well_8	6.869	6.617	8.649	7.163	5.963
72	Talasarimal_Dug_Well_8.2	2.572	1.991	4.179	3.086	3.881
73	Talegaon_Dug_Well_6.1	5.325	5.295	6.722	6.701	4.686
74	Tembhare_Dug_Well_5.5	3.335	3.192	3.597	3.009	3.282
75	Thane_Dug_Well_7.05	1.106	1.068	0.622	0.497	0.28
76	Thilher_Dug_Well_6.2	6.44	7.55	7.729	6.365	
77	Thunepada_Dug_Well_5.95	4.254	3.922	3.789	3.949	2.794
78	Titwala_Dug_Well_7	1.224	0.713	0.702	0.929	0.836
79	Tokawade_Dug_Well_5	2.842	2.309	2.139	1.747	2.304
80	Vadoli_Dug_Well_5.6	2.224	2.791	3.22	2.949	2.467
81	Varaskol_Dug_Well_7	4.671	3.737	3.814	4.318	3.428
82	Vedhi_Dug_Well_8.7	6.565	5.427	5.938	6.855	6.26
83	Vehaloli_Dug_Well_5.1	4.062	2.915	3.75	4.668	4.01
84	Vevaji_Dug_Well_7.6	3.658	3.048	2.577	2.245	2.709
85	Veyour_Dug_Well_10.1	6.149	5.749	7.234	7.878	6.901
86	Vihigaon_Dug_Well_7.5	6.392	5.01	5.938	6.41	4.809
87	Wada_Dug_Well_9	0.975	1.621	1.131	0.933	0.668
88	Warwade_Dug_Well_7.6	5.736	5.36	5.776	5.517	5.065
89	Washind_Dug_Well_3.05	0.956	0.923			
90	Washind_Dug_Well_7	2.061	2.518	2.407	1.26	
91	Zhai_Dug_Well_7.7	4.064	3.578	3.647	4.532	2.149
92	Zhari_Dug_Well_7.4	2.444	3.633	3.263	2.262	

-End of Table D.1

Table D.2: Root Mean Square Error in Prediction-Latur

S.No	Village	1994	1997	1998	1999	2003
1	Aashiv_Dug_Well_15	1.676	1.978	3.237	3.69	
2	Achola_Dug_Well_12.3	5.588	1.269	5.689	0.345	2.646
3	Ahmadpur_Dug_Well_15.1	3.151	3.268	2.889	2.037	1.133
4	Almala_Dug_Well_9.5	0.545	0.515	1.737	2.119	2.358
5	Ambanagar_Dug_Well_6.5	2.404	1.731	0.919	0.431	1.226
6	Ambulga_Dug_Well_10.5	1.921	1.914	2.4	5.806	1.491
7	Ambulga_Dug_Well_12.9	2.043	4.618	5.351	3.929	3.1
8	Andhori_Dug_Well_16.1	1.756	1.79	2.913	2.329	0.778
9	Ashta_Dug_Well_9.9	2.479	1.198	2.052	1.333	1.302
10	Aurad_shahjani_Dug_Well_8.1	1.024	1.144	0.869	1.052	1.724
11	Ausa_Dug_Well_19.9	1.974	3.45	0.735	1.909	5.062
12	Babalgoan_Dug_Well_19.7	1.535	11.381	10.956	9.189	5.696
13	Barmachiwadi_Dug_Well_16.9	4.297	3.067	3.048	2.861	2.468
14	Bhadi_Dug_Well_11.3	2.488	0.148	1.663	2.392	1.656
15	Bhatkheda_Dug_Well_18.65	4.296	3.484	2.602	2.466	4.703
16	Bhuisamudraga_Dug_Well_16.65	3.209	2.055	9.516	3.877	4.218
17	Borfal_Dug_Well_8.5	1.205	0.866	3.373	1.241	2.43
18	Borgaon_n_Dug_Well_12.5	2.063	2.128	3.061	1.111	1.992
19	Budhada_Dug_Well_23.5	1.104	1.098	1.873	4.218	6.013
20	Dangewadi_Dug_Well_17.7	7.822	1.889	3.815	5.549	2.269
21	Dawangaon_Dug_Well_7.15	0.684	0.758	1.238	1.305	0.839
22	Deokara_Dug_Well_21.4	6.327	1.719	5.979	3.163	5.627
23	Deoni_bk_Dug_Well_18.9	1.909	5.133	0.682	3.401	2.333
24	Deoni_kh_Dug_Well_17.9	3.66	2.161	3.51	1.59	2.786
25	Dhanegaon_Dug_Well_15.7	2.28	1.393	4.285	1.969	1.398
26	Dighol_deshmukh_Dug_Well_11.9	3.266	0.19	4.729	3.845	1.176
27	Gadwad_Dug_Well_12.5	1.003	1.293	8.774	1.433	1.898
28	Gangahipparga_Dug_Well_10.5	2.109	1.141	4.115	2.101	1.464
29	Gangapur_Dug_Well_11.5	0.378	1.179	1.78	1.195	2.284
30	Ganjoor_Dug_Well_19.25	2.613	2.65	4.589	5.488	4.152
31	Garsuli_Dug_Well_10.2	1.375	3.599	4.965	2.405	1.719
32	Gategoan_Dug_Well_13.8	2.047	2.625	1.138	2.246	2.337
33	Gaur_Dug_Well_13.9	1.921	2.24	4.422	3.67	0.944
34	Gharni_Dug_Well_9.6	1.161	2.389	0.797	1.016	1.028
35	Ghonshi_Dug_Well_20.3	5.474	4.726	3.491	3.26	5.154
36	Hadolti_Dug_Well_12.8	5.295	0.45	1.442	3.77	0.991
37	Halsi_t_Dug_Well_14.4	2.805	3.51	4.182	3.757	4.18

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S.No	Village	1994	1997	1998	1999	2003
38	Hanchnal_Dug_Well_21.7	10.572	2.048	4.388	3.18	5.265
39	Harangul_bk_Dug_Well_10	1.603	1.515	4.507	1.992	1.179
40	Hipparga_kopdev_Dug_Well_18.9	5.294	9.982	1.042	2.623	5.135
41	Hisamabad_ujed_Dug_Well_15.4	0.779	0.571	1.548	2.852	1.548
42	Hosur_Dug_Well_8.9	1.304	0.863	0.706	1.531	1.055
43	Ismailpur_Dug_Well_17.6	2.505	2.541	1.109	3.87	3.717
44	Jalkot_Dug_Well_19.2	2.802	3.554	3.01	3.371	5.84
45	Jawala_bk_Dug_Well_19.8	4.838	2.322	1.672	5.831	3.35
46	Kabansangvi_Dug_Well_11.2	0.711	0.9		1.523	1.523
47	Karadkhel_Dug_Well_14.9	0.638	0.367	3.186	2.943	3.955
48	Karla_Dug_Well_9.3	2.423	0.771	1.174	1.933	1.325
49	Karsa_Dug_Well_8.7	1.774	0.783	1.309	1.107	0.909
50	Kasarshirshi_Dug_Well_11.9	2.728	2.455	3.185	2.054	2.251
51	Kelgaon_Dug_Well_15.5	4.848	0.989	2.831	2.944	3.478
52	Khandali_Dug_Well_9.2	1.145	0.944	1.668	1.389	2.449
53	Kharola_Dug_Well_11.5	1.9	0.824	1.309	2.586	0.962
54	Kharosa_Dug_Well_23.7		1.427	6.57	4.356	6.173
55	Killari_Dug_Well_18.7	1.318	0.789	3.278	3.029	0.831
56	Kiniyalladevi_Dug_Well_21	1.261	4.463	3.405	3.563	2.84
57	Kodli_Dug_Well_8.7	0.577	1.634	2.017	0.965	2.05
58	Kolnoor_Dug_Well_10.9	0.266	1.882	1.202	0.349	1.189
59	Kolwadi_Dug_Well_15.3	1.388	3.252	5.477	3.784	2.365
60	Lambota_Dug_Well_12.8	1.168	1.038	5.029	3.006	1.904
61	Lamjana_Dug_Well_17.3	2.233	3.62	3.089	1.893	1.747
62	Latur_road_Dug_Well_13.3	1.033	2.099	3.276	2.749	3.4
63	Madansuri_Dug_Well_10.2	0.962	1.758	1.286	1.884	2.452
64	Mahalangra_Dug_Well_14.5	5.329	1.063	3.338	2.298	1.925
65	Mamdapur_Dug_Well_11.1	2.166	1.196	1.632	2.471	1.566
66	Mankhed_Dug_Well_13.9	2.15	6.065	3.367	2.264	3.096
67	Mannatpur_Dug_Well_10.1	1.52	1.545	3.346	1.518	2.508
68	Mogha_Dug_Well_20.6	4.605	3.125	2.752	2.759	3.731
69	Murdhav_Dug_Well_12.2	1.28	0.674	2.048	1.472	0.492
70	Murud_bk_Dug_Well_21	2.529	3.578	4.779	1.177	7.345
71	Nalgir_Dug_Well_12.8	3.863	1.785	0.463	0.882	1.213
72	Nandgaon_Dug_Well_7.7	0.831	0.41	2.191	1.663	1.424
73	Nandgaon_Dug_Well_9.9	2.284	1.385	0.92	1.041	0.749
74	Nandurga_Dug_Well_17.9	2.13	2.174	6.84	3.854	6.706
75	Neoli_Dug_Well_14.6	1.464	4.297	1.406	4.169	0.751
76	Nilanga_Dug_Well_14.8	1.317	1.256	3.011	2.746	2.332

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S.No	Village	1994	1997	1998	1999	2003
77	Pakharsangvi_Dug_Well_13.5	0.977	1.244	5.28	3.847	2.353
78	Palshi_Dug_Well_6.6	0.882	1.505	0.829	1.085	0.857
79	Pangaon_Dug_Well_10.75	1.801	3.573	1.424	2.124	2.658
80	Patoda_kh_Dug_Well_10.1	1.532	3.711	2.654	1.931	1.087
81	Rapka_Dug_Well_19.8	1.65	2.45	3.658	3.698	2.564
82	Renapur_Dug_Well_13	0.888	0.467	2.328	1.978	1.191
83	Sakol_Dug_Well_19	2.437	5.08	4.253	3.405	0.947
84	Samsapur_Dug_Well_11.4	4.199	3.247	1.416	1.944	2.473
85	Sangvi_s_Dug_Well_12.9	0.586	1.241	2.271	1.745	2.117
86	Selu_Dug_Well_8.9	1.395	0.993	3.638	1.771	4.026
87	Shelgi_Dug_Well_11.9	2.675	1.343	2.952	2.009	3.168
88	Shirur_tajband_Dug_Well_12.5	5.093	4.063	4.591	2.756	3.223
89	Shivpur_Dug_Well_9.5	2.515	1.269	2.716	2.631	2.834
90	Sindgi_bk_Dug_Well_14.2	1.192	0.811	1.759	1.974	0.552
91	Sindgoan_Dug_Well_10.1	1.642	1.415	2.341	1.992	1.074
92	Somnathpur_Dug_Well_7.2	2.047	0.384	0.791	0.411	1.479
93	Tajpur_Dug_Well_11.9	2.254	2.489	3.969	3.073	1.165
94	Taka_Dug_Well_10	1.072	0.967	5.597	2.362	3.5
95	Taka_Dug_Well_13.7	3.26	3.462	9.769	4.251	3.173
96	Takli_Dug_Well_12.75	2.864	0.846	1.291	3.213	3.363
97	Talni_Dug_Well_18.9	1.282	0.795	4.388	3.068	1.363
98	Tambatsangvi_Dug_Well_20.3	5.414	4.108	1.675	5.403	3.191
99	Tattapur_Dug_Well_8	0.46	0.234	1.696	1.361	1.397
100	Tiruka_Dug_Well_14.6	4.97	5.605	1.257	2.609	0.613
101	Togari_Dug_Well_9.5	2.064	0.921	0.738	1.686	0.995
102	Wadmurumbi_Dug_Well_13.6	1.316	1.265	1.356	2.413	1.523
103	Waigaon_Dug_Well_10.5	1.12	2.746	0.617	0.653	1.14
104	Walandi_Dug_Well_9.2	0.846	1.969	2.138	1.41	1.591
105	Walsangi_Dug_Well_12.5	2.809	2.082	1.967	1.237	1.634
106	Wanjarkheda_Dug_Well_9.5	2.512	2.154	1.162	1.836	2.387
107	Yerol_Dug_Well_16.8	0.88	4.594	4.754	3.233	2.226

-End of Table D.2

Table D.3: Root Mean Square Error in Prediction-Sangli

S.No	Village	1991	1994	1998	2000	2005
1	Alkud_M_Dug_Well_10.7	2.989	1.669	1.308	1.14	2.488
2	Antral_Dug_Well_12.2	2.005	1.567	1.46	1.217	1.012
3	Arag_Dug_Well_12.5	2.621	1.299	2.275	1.345	6.698
4	Ashta_Dug_Well_12	2.513	3.319	1.634	2.425	1.47
5	Atpadi_Dug_Well_10.2	1.407	1.904	0.903	0.427	
6	Atpadi_Dug_Well_6.7	7.71				
7	Bagewadi_Dug_Well_9.1	3.351	2.748	1.759	1.213	3.534
8	Balvadi_Dug_Well_10.7	7.859				
9	Basargi_Dug_Well_4.6	0.712	0.94	1.422	0.626	
10	Bedag_Dug_Well_13.7	22.897				
11	Bedag_Dug_Well_9.4	1.248	2.016	0.533	1.931	
12	Belanki_Dug_Well_8.7	0.907	0.717	1.099	0.934	4.633
13	Bevanur_Dug_Well_9.5	0.903	1.168	0.616	0.432	2.101
14	Bhalwani_Dug_Well_11.7	0.704	2.775	2.182		
15	Bhaurayachiwadi_Dug_Well_11.1	3.062	3.894	2.928	0.505	6.454
16	Bhilwadi_Dug_Well_7.3	1.973	0.36	2.72		
17	Bhood_Dug_Well_9.9	1.298	1.038	0.27	1.18	2.542
18	Bilashi_Dug_Well_13.8	3.406	1.512	0.736	0.774	0.506
19	Bilur_Dug_Well_13.5	1.557	1.267	0.965	3.538	
20	Biur_Dug_Well_8.6	1.273	1.557	1.21	1.583	1.176
21	Bombewadi_Dug_Well_5.7	1.407	1.599	0.868	1.982	
22	Borgi_bk_Dug_Well_9	1.608	1.444	0.947	2.585	3.922
23	Chorochi_Dug_Well_7.3	0.813	1.351	0.386	1.042	3.826
24	Dafalapur_Dug_Well_12.8	0.896	1.623	3.509	7.037	
25	Deshing_Dug_Well_9.8	1.544	1.285	1.113	1.258	4.285
26	Devnal_Dug_Well_11.75	2.877				
27	Dhavadwadi_Dug_Well_5.7	1.729	1.407	0.461	0.901	5.434
28	Dhavadwadi_Dug_Well_6	1.488	2.17	0.339	1.008	4.104
29	Dudhebhavi_Dug_Well_9.8	2.313	1.082	1.276	1.249	7.138
30	Dudhgaon_Dug_Well_10.65	2.347	3.723	0.417	2.584	
31	Ghanand_Dug_Well_12	1.848	1.265	2.808	5.065	
32	Ghatnandre_Dug_Well_13.3	8.213				
33	Ghoti_kh_Dug_Well_10.45	3.209	1.348	3.625	2.791	8.213
34	Halli_Dug_Well_9.6	1.741	2.82	3.27	1.808	3.744
35	Hanmantvadiye_Dug_Well_9.6	2.461	1.31	1.194	1.444	1.627
36	Hingangaon_Dug_Well_13	4.049	0.859	2.133	0.956	2.353
37	Hubalwadi_Dug_Well_8.2	2.404	0.442	0.271		

-Table D.3 continued on next page

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S.No	Village	1991	1994	1998	2000	2005
38	Itakare_Dug_Well_9.5	2.562	3.399	1.114	2.278	2.313
39	Jadraboblad_Dug_Well_12	3.078				
40	Jadraboblad_Dug_Well_8.7	2.979	2.228	1.358	1.619	
41	Kadegaon_Dug_Well_13.8	1.24	0.787	1.693	1.187	2.428
42	Kalambi_Dug_Well_12.8	2.613	4.458	3.017	2.867	
43	Karve_Dug_Well_11.8	2.437	2.054	1.701	2.765	6.563
44	Kaslingwadi_Dug_Well_6	0.365	0.508	0.265	0.996	
45	Kavalapur_Dug_Well_20.1	2.876	2.195	1.178	2.056	
46	Kerewadi_Dug_Well_8.8	0.604	0.921	0.775	0.672	8.108
47	Khambale_Aundh_Dug_Well_14.1	3.46	2.307	1.568	2.132	7.709
48	Khanapur_Dug_Well_6.6	1.262	0.805	1.03	0.859	
49	Kharsundi_Dug_Well_16.75	3.285	3.813	2.039	1.581	5.968
50	Khojanwadi_Dug_Well_9.4	1.378	0.763	1.64	1.874	
51	Kokale_Dug_Well_6.4	0.317	1.239	1.231	0.879	
52	Kokale_Dug_Well_9.4	5.261				
53	Kuchi_Dug_Well_11	2.034	2.296	0.708	1.651	6.544
54	Kumathe_Dug_Well_13	4.513	2.436	0.278	3.531	5.343
55	Kumbhargaon_Dug_Well_9.4	0.796	0.371	0.36	0.585	0.887
56	Kundlapur_Dug_Well_6.5	1.762	3.111	1.509	1.332	2.85
57	Landgewadi_Dug_Well_11	2.123	2.324	1.405	1.818	2.208
58	Lavanga_Dug_Well_6.6	1.055	1.706	1.547	0.832	3.269
59	Mahuli_Dug_Well_12.9	2.841	3.168	2.616	4.017	6.307
60	Mandur_Dug_Well_4.4	0.691	0.359	0.913	1.099	0.365
61	Mangle_Dug_Well_8.4	0.428	0.97	1.114		
62	Mhaisal_Dug_Well_13	0.622	0.641	0.776	0.966	2.978
63	Mitki_Dug_Well_12.2	14.757				
64	Morbagi_Dug_Well_7.1	0.737	0.257	0.979	0.579	1.049
65	Muchandi_Dug_Well_11.5	1.268	1.628	2.482	1.589	5.588
66	Nagaj_Dug_Well_12.2	0.664	1.535	0.721	0.86	2.419
67	Nandre_Dug_Well_17.3	2.468	5.889			
68	Nelkaranji_Dug_Well_8	0.77	1.556			
69	Nerle_Dug_Well_13.1	0.722	0.919	0.492	0.568	0.515
70	Nigadi_kh_Dug_Well_5.9	0.952	0.719	0.874	0.758	3.198
71	Nimaj_Dug_Well_8.8	2.802	2.152	0.764	1.522	7.838
72	Pandharewadi_Dug_Well_20.4	6.361				
73	Parekarwadi_Dug_Well_9.75	1.171	4.07	0.964	1.169	4.042
74	Pimpari_kh_Dug_Well_7.8	1.625	3.184	0.481	4.178	
75	Pujarwadi_Dug_Well_3.35	1.696	1.62	0.363		
76	Rajewadi_Dug_Well_9.4	2.033	2.055	1.658	4.279	

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S.No	Village	1991	1994	1998	2000	2005
77	Ranjani_Dug_Well_12.9	3.112	1.506	1.002	1.359	8.081
78	Rethare_Dharan_Dug_Well_8.9	1.044	1.879	0.196	0.381	1.376
79	Rile_Dug_Well_5.8	1.304	1.18	1.263	0.874	1.749
80	Saholi_Dug_Well_14.6	1.576	1.517	2.069	4.384	
81	Sanamadi_Dug_Well_9	0.874	1.973	1.401	0.613	3.719
82	Sankh_Dug_Well_11.3	1.04	1.005	1.515	1.092	
83	Sankh_Dug_Well_13	1.611				
84	Sawalwadi_Dug_Well_12.55	1.094				
85	Sawantwadi_Dug_Well_5.5	0.455	0.67	1.159	1.63	1.565
86	Shetphale_Dug_Well_9	3.743	5.727	1.329	5.75	5.739
87	Shirala_Dug_Well_15.8	1.285	1.317	1.101	1.117	3.297
88	Shirdhon_Dug_Well_10.2	0.593	2.016	0.403	3.627	
89	Shirdhon_Dug_Well_17.9	15.24				
90	Shirgaon_Visapur_Dug_Well_13	2.009	2.284	0.465	1.748	3.502
91	Shivpuri_Dug_Well_6.8	1.162	2.248	0.928	1.559	0.897
92	Sonsal_Dug_Well_10.8	2.478	0.585	0.63	3.472	
93	Sonsal_Dug_Well_17.1	13.356				
94	Sulewadi_Dug_Well_10.1	0.946	0.883	1.184	0.463	1.685
95	Tandulwadi_Dug_Well_13.7	2.115	2.829	1.406	1.195	1.79
96	Tisangi_Dug_Well_9	1.53	3.363	1.171	0.764	
97	Tung_Dug_Well_12.9	1.039	1.709	0.523		
98	Umarani_Dug_Well_10.7	2.537	3.108	2.476	1.805	4.42
99	Umbargaon_Dug_Well_11	2.844	4.729	0.789	3.888	3.316
100	Utagi_Dug_Well_10.3	1.283	1.603	0.866	1.359	2.496
101	Vajrawad_Dug_Well_14.5	13.089				
102	Vejegaon_Dug_Well_14.1	2.813	2.483	0.643	2.049	5.764
103	Vhaspeth_Dug_Well_8.9	1.454	0.719	2.07	1.142	3.101
104	Vithalapur_Dug_Well_9.3	1.929	3.599	1.885	2.062	5.313
105	Waifal_Dug_Well_13.2	6.072				
106	Waifal_Dug_Well_7.9	0.719	1.701	2.99		
107	Walekhindi_Dug_Well_10	1.014	0.395	1.988	1.275	2.853
108	Wangi_Dug_Well_13.5	1.938	1.718	0.912	2.118	1.613
109	Wasgade_Dug_Well_11.4	2.235	0.488			
110	Yelavi_Dug_Well_14.8	1.399	1.907	1.994	0.715	2.138
111	Yogewadi_Dug_Well_12.5	2.499	1.165	4.019	0.821	7.456
112	Zare_Dug_Well_10.8	1.143	1.651	0.382	1.142	2.813

-End of Table D.3

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