Ground Water Data Analysis

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Outline

- Computing Variance
- Polynomial Model
- Spatial Models
- Krigging Interpolation
- Database and Geo Server Demo
- Future Work

Computing Variance

- Variance

$$\sigma = \left\{ \frac{\sum_{i=1}^{n} (y_i - \mu)^2}{n} \right\}^{\frac{1}{2}}$$

- Objective: Separation of variance causes
- Current Models and its variance

$$\sigma = \left\{ \frac{\sum_{i=1}^{n} (y_i - \mu_i)^2}{n} \right\}^{\frac{1}{2}}$$

Table: Top 5 Bore wells with high variance

Well_name	Variance	Depth
Mandawa	12.561928	30
Tokavde	10.591332	24
Safale	4.466477	25.9
Kudan	4.302190	30
Sakharshet_chalatwad	,3.640198	22.5

Variance

Table: Top 5 Dug wells with high variance

Well_name	Variance	depth
Washind_1	6.396629	7
Talasari	5.252879	7
Mangrul	3.221694	7.6
Satiwali	3.102799	7.2
Dahisar	3.084735	9.5

Variance

Figure: Behavior of Mandawa Bore Well

Variance

Figure: Behavioor of Washind1 DugWell

Normalized Variance

Table: Variance Vs Discrepancy for Bore Well

Village	Normalized variance	Depth(m)	Discrepancy_count
Tokavde	0.135601	24.000	1
Mandawa	0.118143	30.000	2
Gokhiware	0.090139	18.000	4
Satiwali	0.033998	18.000	23
Bhatsai	0.050426	18.000	17

Table: Variance Vs Discrepancy for Dug Well

Village	Normalized variance	Depth(m)	Discrepancy_count
Washind_1	0.361308	7.000	7
Talasari	0.286490	8.000	5
Satiwali	0.244649	7.200	15
Dapode	0.208616	5.250	7
Titwala	0.150577	7.000	10

Bore Well Characteristics

Bore well data general behavior.

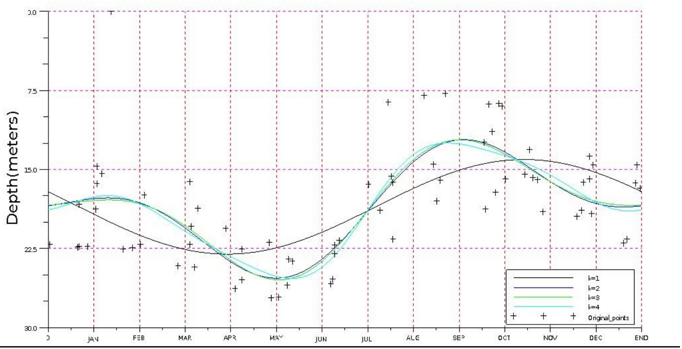


Figure: Periodic model of Mandawa bore well

Bore Well Characteristics

- AGRAR case study of Kolwan valley,Pune,Maharashtra
- Chikhalgaon Water shed with shallow aquifer(20m)
- 8 Dug wells, 8 Bore wells
- Shallow and deep bore well recharge

Bore Well Characteristics

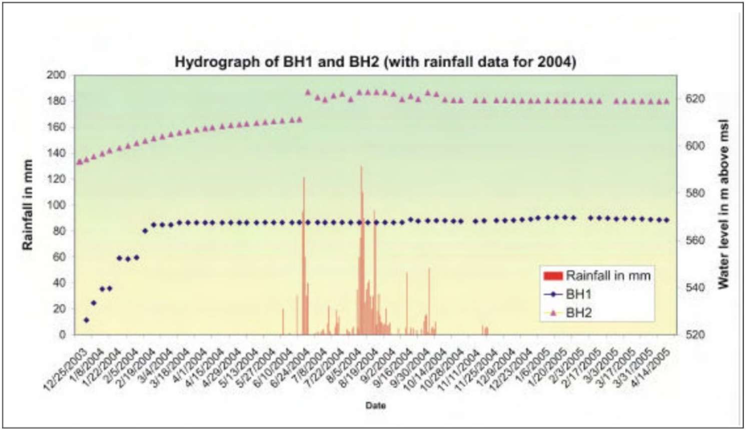


Figure 44: Hydrograph showing water levels in BH2, plotted along with the rainfall and water levels for BH1. *Note: The initial rise of water levels in both boreholes is the effect of slow recovery in the shallow and deep aquifers due to low transmissivities.*

Figure: Image Taken from AGRAR report

Bore Well Characteristics

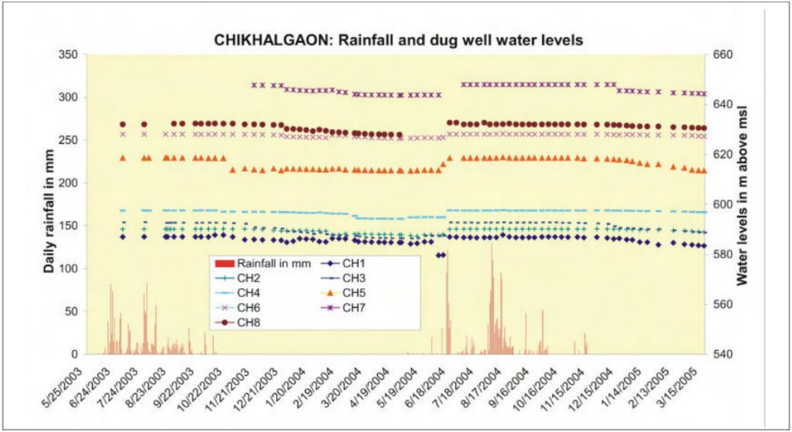


Figure 42: Hydrograph showing weekly water levels in dug wells from Chikhalgaon watershed, along with rainfall for the two seasons.
Data from May 2003 to March 2005.

Figure: Image taken from AGRAR report

Bore Well Characteristics

Discontinuity of old model

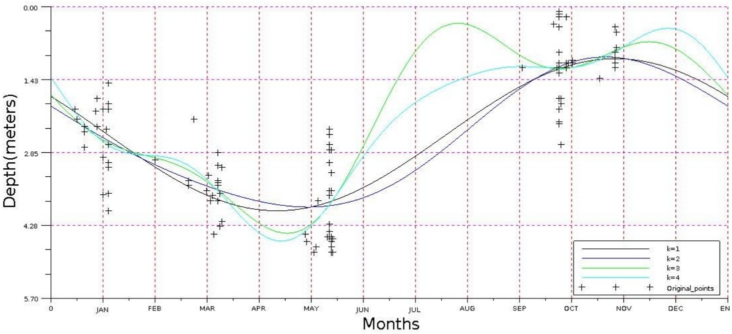


Figure: Periodic model of Chahad Dug Well

Polynomial Model

Polynomial model

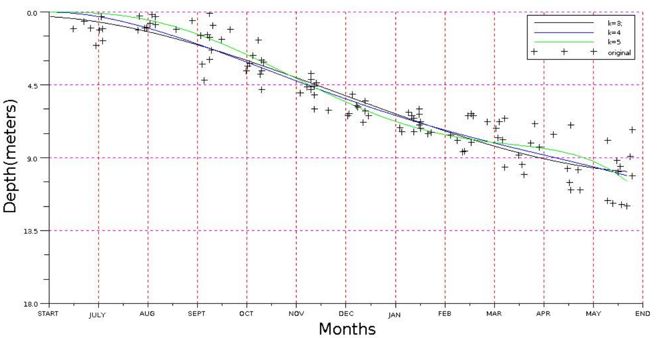
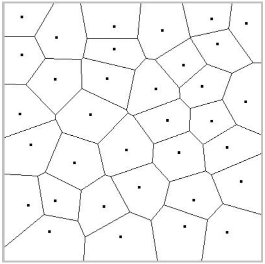


Figure: Polynomial model of Gokhiware bore well

Spatial Models

- Spatial Model
- Voronoi Diagrams



Spatial Correlation Between Rainfall Data

22.5	5	5	3	4	5	5	4	5
21.5	5	2	3	4	4	4	5	5
20.5	5	0	3	3	3	4	4	4
19.5	4	1	3	3	3	3	3	3
18.5	4	0	0	0	2	2	3	2
17.5	0	0	1	0	0	1	1	4
16.5	0	0		1	0	1	1	1
15.5	R	0	0	0	1	1	1	1
Latitude Longitude	73.5	74.5	75.5	76.5	77.5	78.5	79.5	80.5

Spatial Correlation Between Rainfall Data

22.5	2	1	1	1	1	0	0	5
21.5	2	1	1	1	0	0	0	0
20.5	1	1	1	0	0	0	0	0
19.5	1	1	0	0	R	0	0	-1
18.5	1	0	0	0	0	0	0	-1
17.5	0	0	1	0	0	0	-1	-1
16.5	0	1	0	-1	-1	-1	-1	-1
15.5	-3	-2	-2	-2	-2	-4	-1	-1
Latitude Longitude	73.5	74.5	75.5	76.5	77.5	78.5	79.5	80.5

Spatial Correlation Between Rainfall Data

22.5	2	1	1	1	1	0	0	R
21.5	2	1	1	1	0	0	0	0
20.5	2	-5	-5	0	0	0	0	0
19.5	-4	-5	-5	-5	-5	0	-1	-1
18.5	-5	-5	-5	-5	-5	-5	-1	-1
17.5	-4	-5	-5	-5	-5	-5	-5	-5
16.5	-5	-5	-5	-5	-5	-5	-5	-3
15.5	-5	0	-3	-5	-5	5	-3	-3
Latitude Longitude	73.5	74.5	75.5	76.5	77.5	78.5	79.5	80.5

Krigging Interpolation

- Krigging Interpolation
- Stationary model.
  - $E[Z(x_i)] = \mu \ i = 1, 2, ..n$
  - $R(\|x - x^{'}\|) = R(h) = E[(Z(x) - \mu)(Z(x^{'}) - \mu)]$, where $\|x - x^{'}\|$ is the distance between $x, x^{'}$
- Given n measurements of Z, at different locations $x_1, x_2, ...x_n$, Estimated value of Z at x_0 is

$$\hat{Z}_0 = \sum_{i=1}^{n} \lambda_i Z(x_i)$$

- Estimation error

$$\hat{Z}_0 - Z(x_0) \quad = (\sum_{i=1}^{n} \lambda_i Z(x_i)) - Z(x_0)$$

Krigging Interpolation

- Requirements for good estimator.
- Unbiasedness:

$$E[\hat{Z}_0 - Z(x_0)] \quad = \textstyle\sum_{i=1}^{n} \lambda_i \mu - \mu \quad = (\sum_{i=1}^{n} \lambda_i - 1)\mu \quad = 0$$

$$\textstyle\sum_{i=1}^{n} \lambda_i = 1$$

- Minimum Variance:

$$\begin{aligned} E[(\hat{Z}_0 - Z(x_0))^2] &= -\textstyle\sum_i^n \sum_j^n \lambda_i \lambda_j \gamma(\|x_i - x_j\|) + 2\sum_i^n \lambda_i \gamma(\|x_i - x_0\|) \\ \gamma(\|x - x'\|) &= \frac{1}{2} E[(\hat{Z}(x) - Z(x'))^2] \end{aligned}$$

Kriging Interpolation

Lagrange multiplier system: $Ax = b$

$$-\sum_{j=1}^{n} \lambda_j \gamma(\|x_i - x_j\|) + v \quad = -\gamma(\|x_i - x_0\|) i = 1, 2, ..n$$

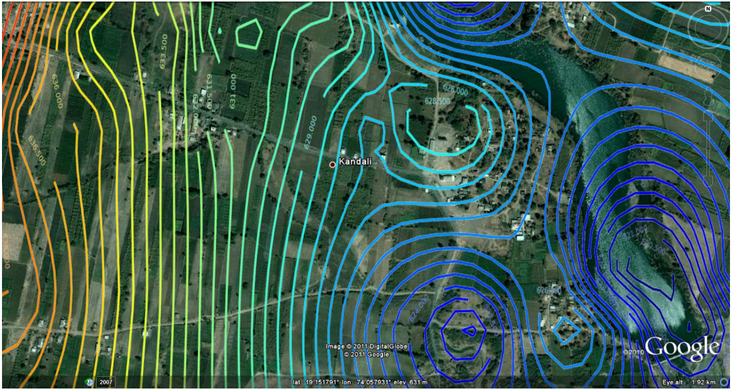
$$\sum_{j=1}^{n} \lambda_j = 1$$

$$A = \begin{bmatrix} 0 & -\gamma(\|x_1 - x_2\|) & \cdots & -\gamma(\|x_1 - x_n\|) & 1 \\ -\gamma(\|x_2 - x_1\|) & 0 & \cdots & -\gamma(\|x_2 - x_n\|) & 1 \\ \vdots & \vdots & & \vdots & \vdots \\ -\gamma(\|x_n - x_1\|) & -\gamma(\|x_n - x_2\|) & \cdots & 0 & 1 \\ 1 & 1 & \cdots & 1 & 0 \end{bmatrix}$$

$$x = \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \vdots \\ \lambda_n \\ 1 \end{bmatrix} \qquad b = \begin{bmatrix} -\gamma(\|x_1 - x_0\|) \\ -\gamma(\|x_2 - x_0\|) \\ \vdots \\ -\gamma(\|x_n - x_0\|) \\ 1 \end{bmatrix}$$

Kriging Interpolation

Altitude contour map generated using krigging interpolation.



Kriging Interpolation

- Sample Problem
- Key assumptions
- Validity of assumptions
- Use of soil Properties

Database and Geoserver demo

- Postgres
- Post Gis
- Geo Server

Future Work

- Survey of national and international experience
- Groundwater data for a different district
- District level water budget
- Using additional geological data
- Developing a regime for groundwater monitoring