Role of scientific studies in managing urban groundwater '*quantity aspects*' – the experience with Mulbagal, Karnataka

Prof. M. Sekhar
Department of Civil Engineering
Indian Institute of Science
Bangalore
http://civil.iisc.ernet.in/~muddu

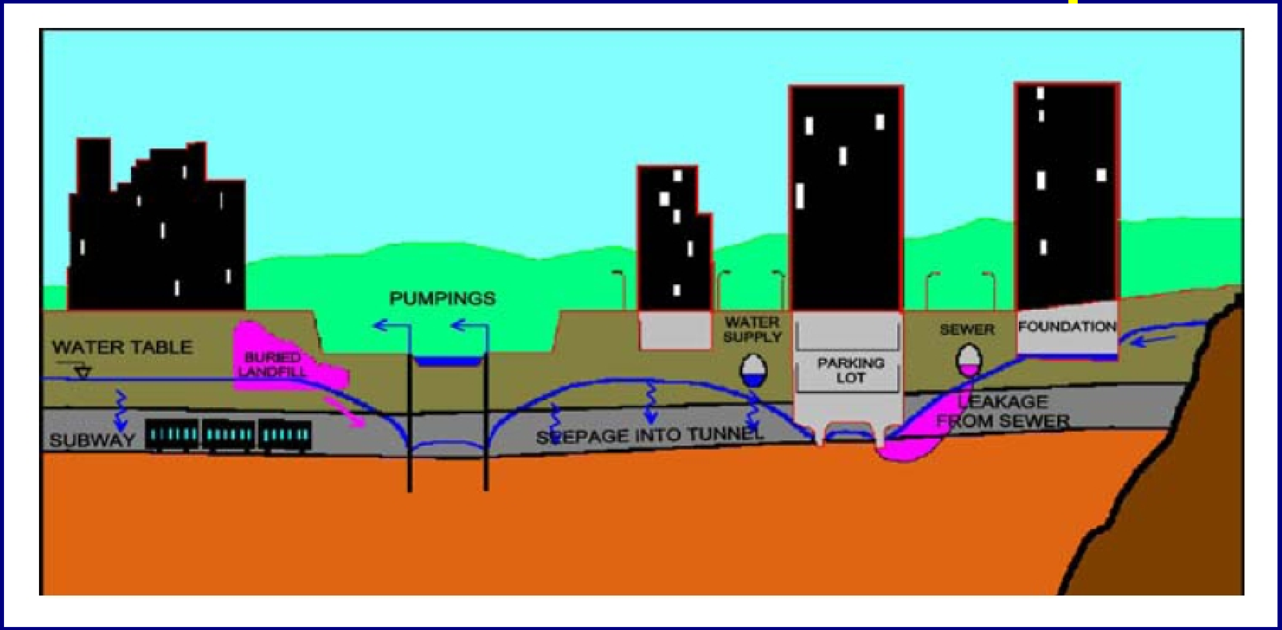
IUC 2011: 18th November 2011

Groundwater use in urban water

- Several towns and cities have used groundwater and then moved on to surface water sources
  - due to issues of sustainability of groundwater resource within the urban areas.
  - or due to poor groundwater quality resulting from inadequately-controlled urban pollution, especially wastewater handling, or disposal.

Foster et al. (2010)

Urban Groundwater – Complex setting



- Rainfall Recharge (conventional & alterations).
- Leakage from water supply & sewage pipelines.
- Recharge from harvesting operations.
- Groundwater pumping (24x7 – much different from agricultural demands).
- Impacts to Infrastructure & Effect of Infrastructure

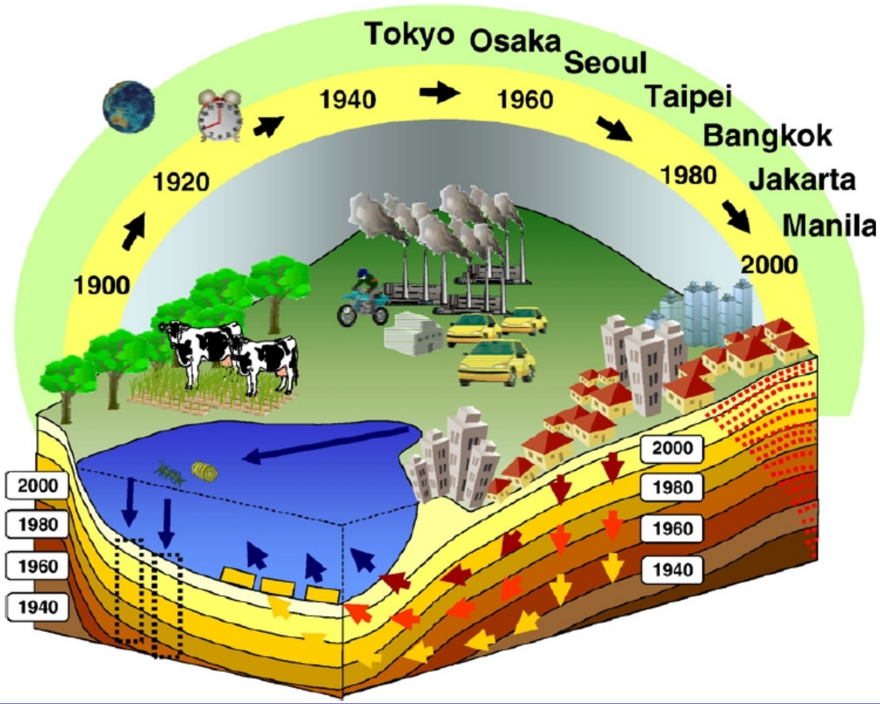
Urban Groundwater – Impacts

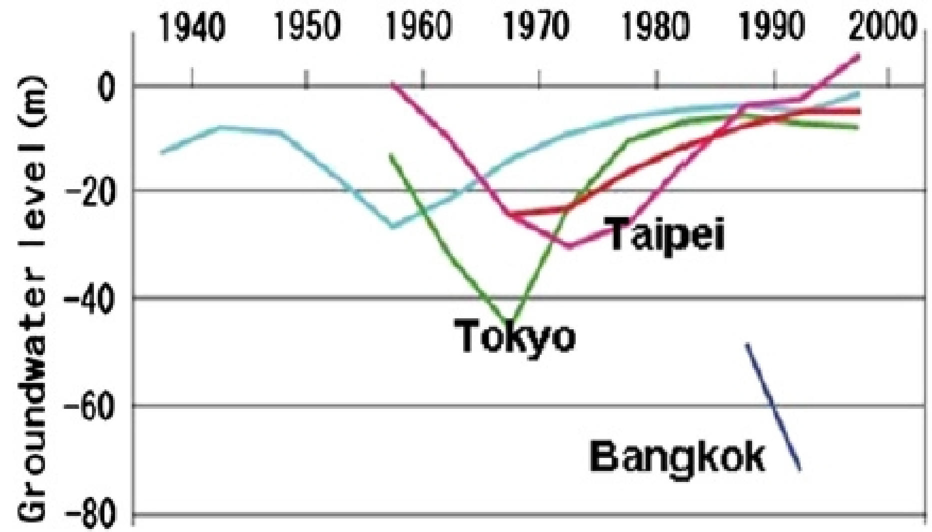
- Urbanization modifies local hydrology, often extensively.

  - Changes in land cover will often reduce recharge amounts and change recharge distributions; increased flood hazard.

  - Groundwater abstraction will lower piezometric surfaces: reduced well, reduce baseflows (river yields).

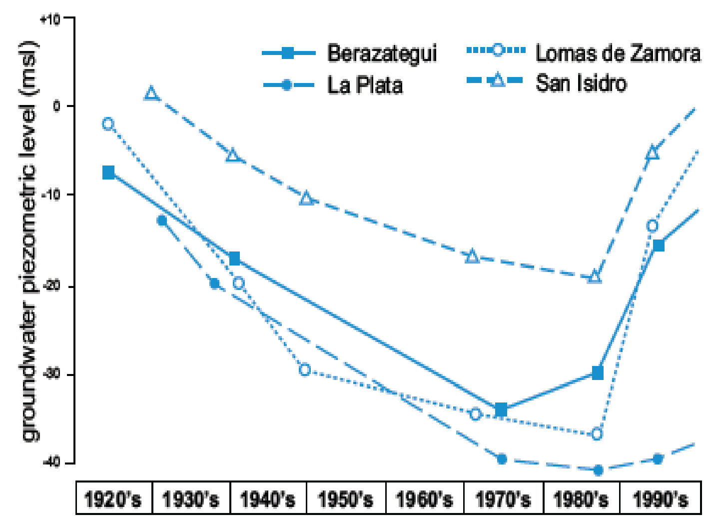
  - Deterioration in quality of groundwater; salinization (water logging), migration of polluted urban groundwater into surrounding rural areas.





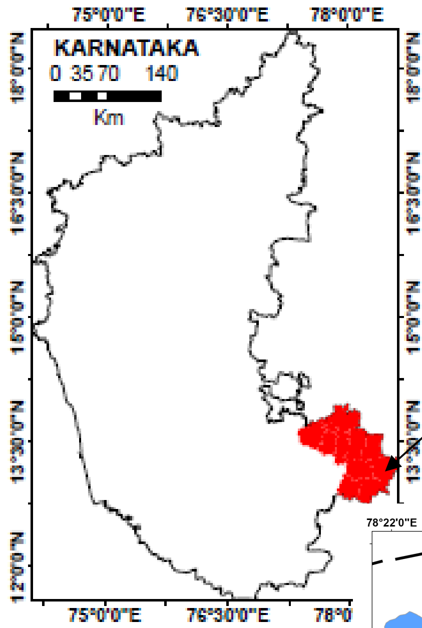
Taniguchi (2008)

- Few Asian cities - monitored.
- Groundwater development → depletion of levels
- Surface water imported → rising of levels→ urban flooding, impacts on underground projects



Foster et al. 2010

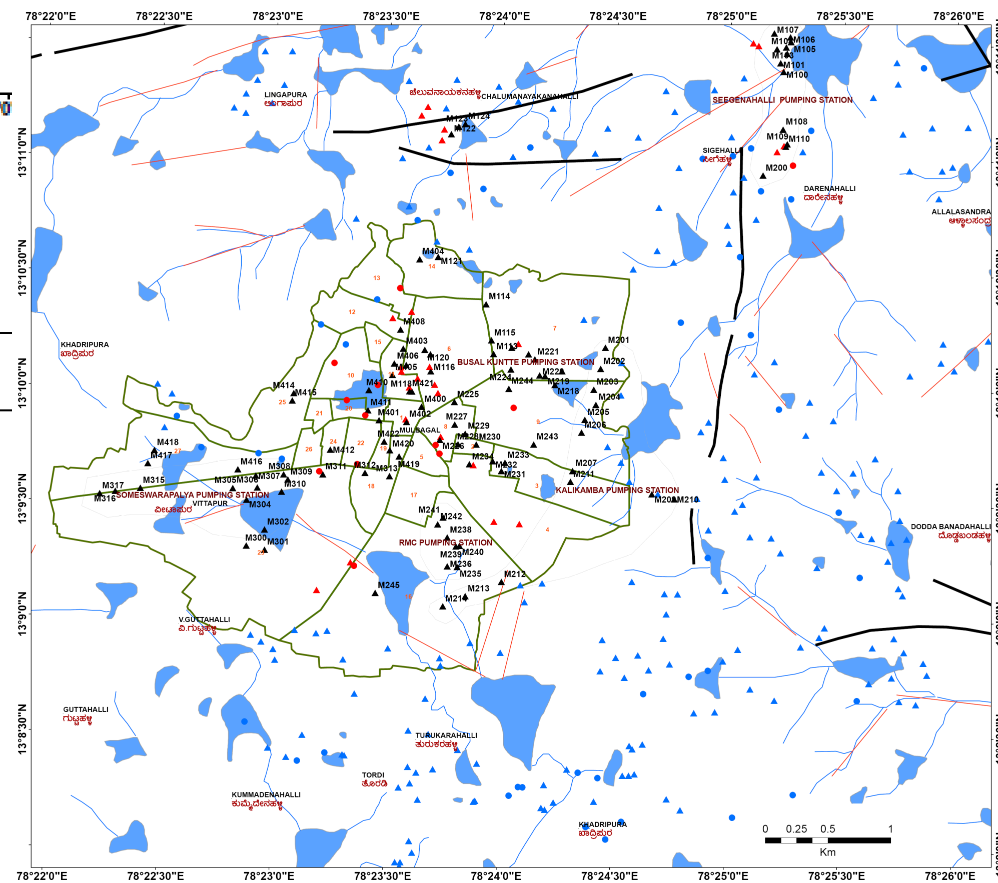
Groundwater Management under IUWM



Mulbagal Town

Karnataka State

Bangalore



Case Study

Scientific Query

- How are the inter-annual variations in the groundwater regime with respect to its use and inter-year variations in rainfall ?
- Recharge, groundwater balance and their spatial variations in peninsular urban catchments.
- What factors control the sustainable groundwater use ?

Background & Methodology

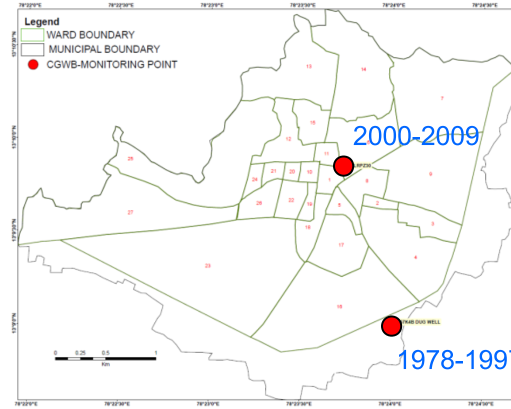
- The population is 60,000 and supply is ~ 5 MLD and entirely through GW.
- To help develop a sustainable water management plan towards the future needs. To efficiently manage the groundwater resources.

- Hydrological & hydrogeological survey (monitoring of groundwater levels) over 3 years (2008-2011).
- Analysis of urban groundwater system behavior.
- Hydrological Models were developed to use as diagnostic tools for current setting and future scenarios.

Focus of studies

- Temporal variations of groundwater regime (Jul 2008 – Jun 2011)
- Aquifer tests (Short and long duration pump tests; recovery tests) – performance of well.
- Variogram analysis - comparison between urban and agricultural catchments.
- Development of lumped models- Spatial variations of groundwater stock for various pumping stations (e.g. recharge and storage changes).
- Numerical model development – Cal/Val; Analysis of groundwater behavior under various scenarios of management.

Recharge Modeling (1978-1996)



Mean Annual

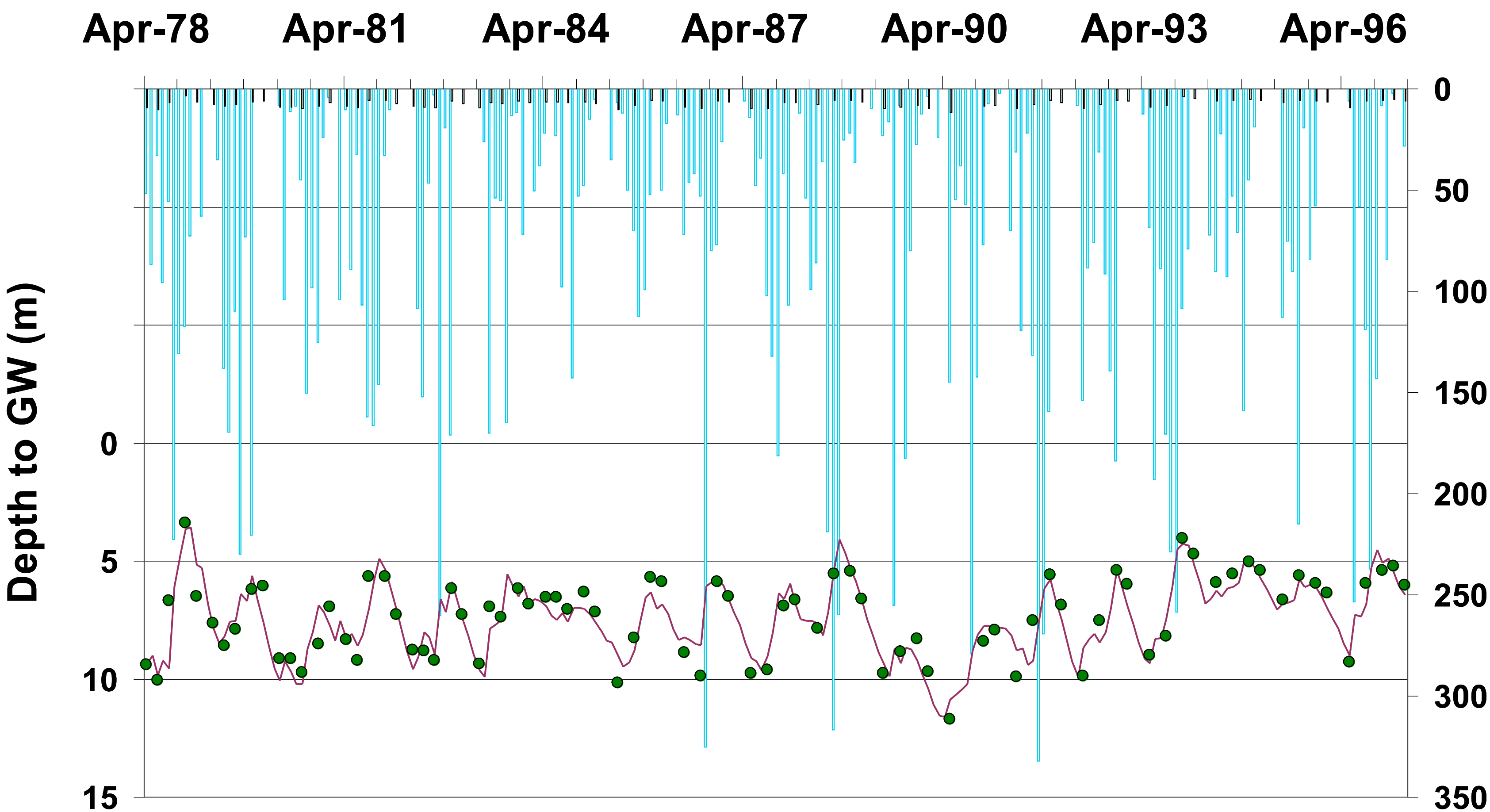
Rainfall = 790.23 mm

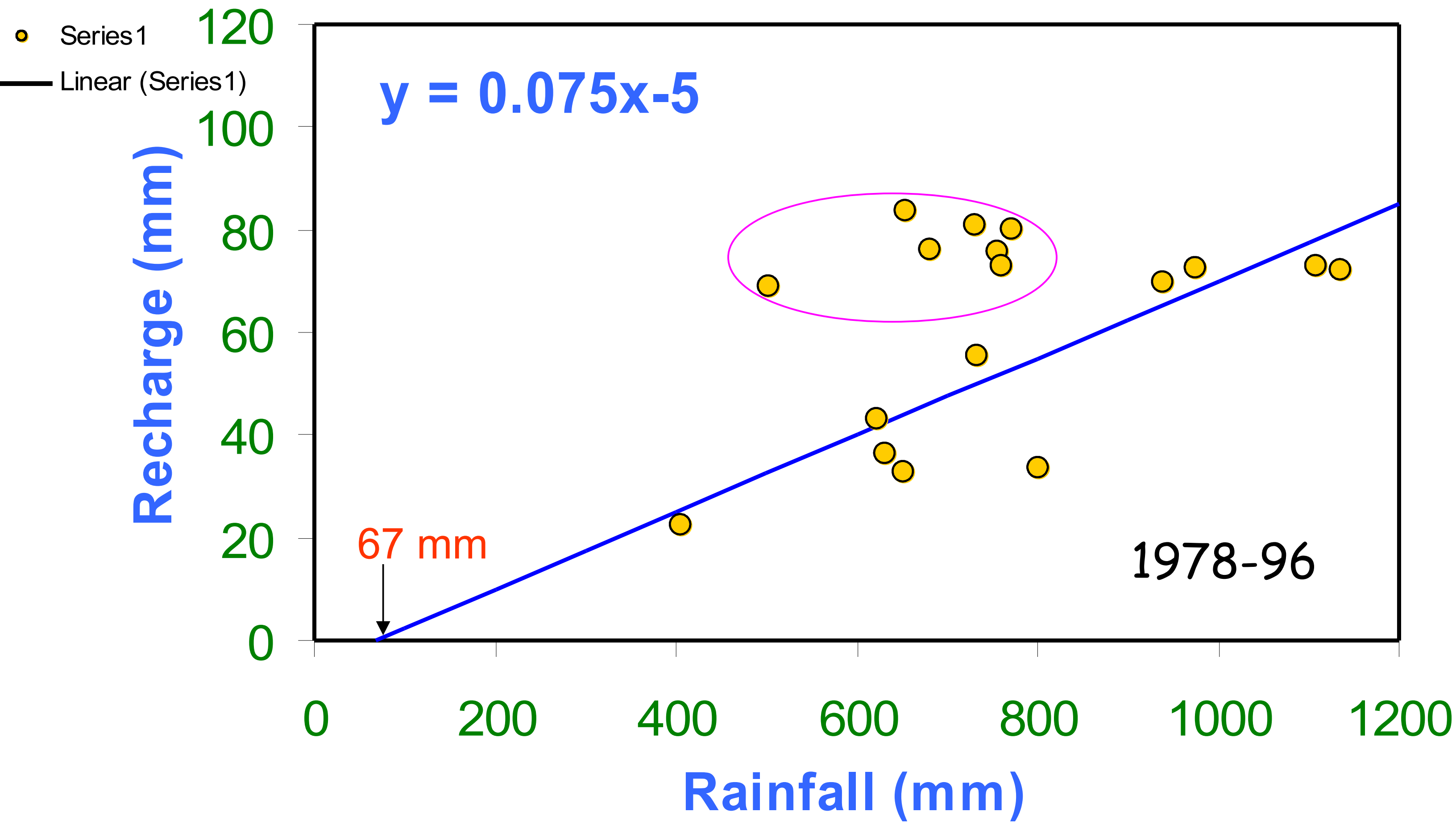
COV = 27%

Recharge = 68.64 mm

COV = 45%

Modeling of Groundwater levels 1978-1996





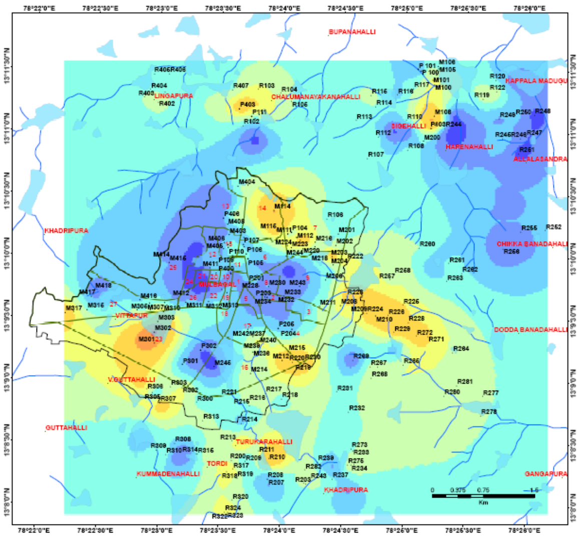
Mean Annual

Rainfall = 790.23 mm

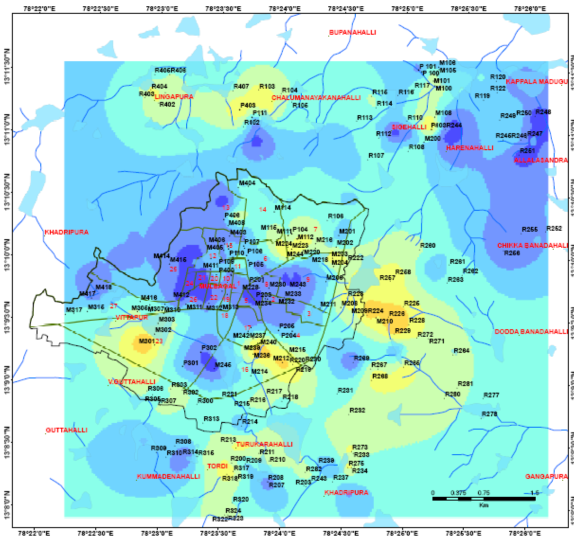
COV = 27%

Recharge = 68.64 mm

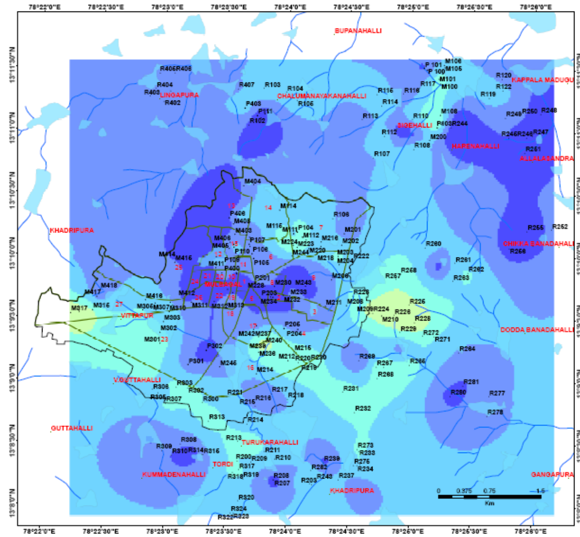
COV = 45%



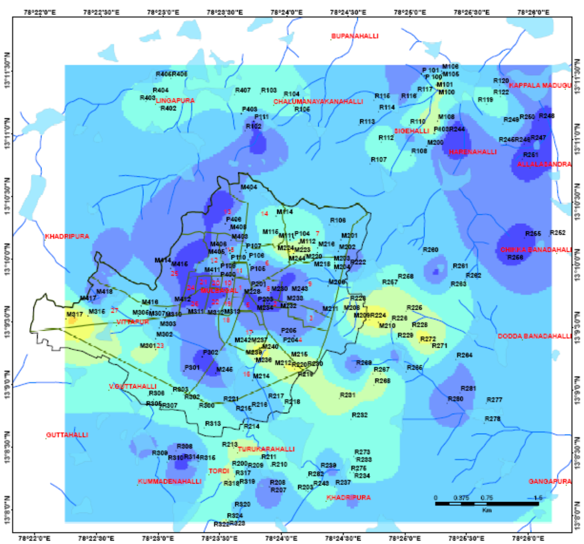
August 2008



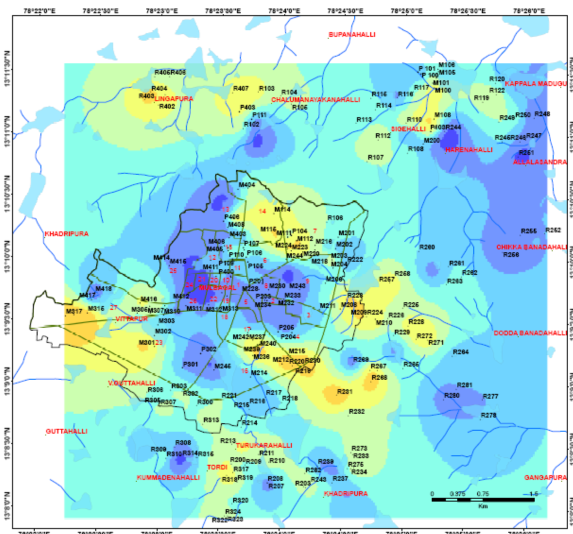
October 2008



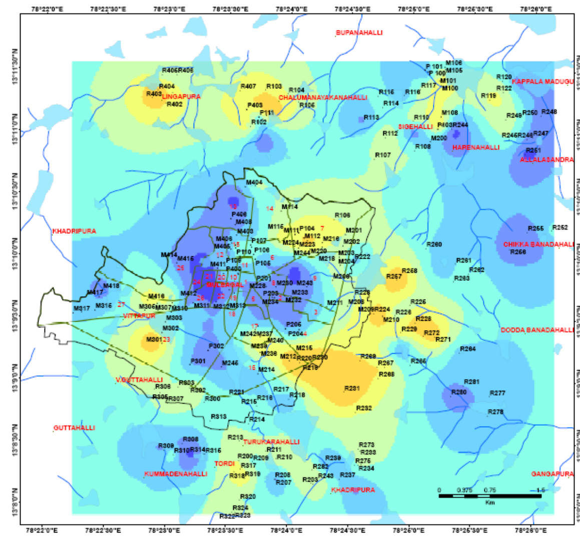
November 2008



January 2009



April 2009



July 2009

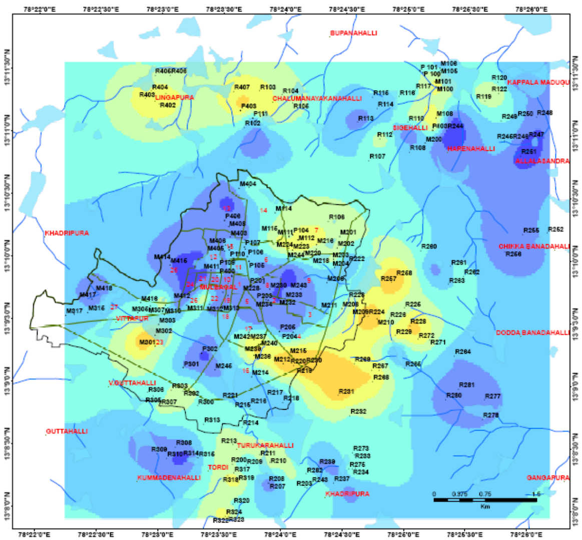
Depth to GW (m)

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 55

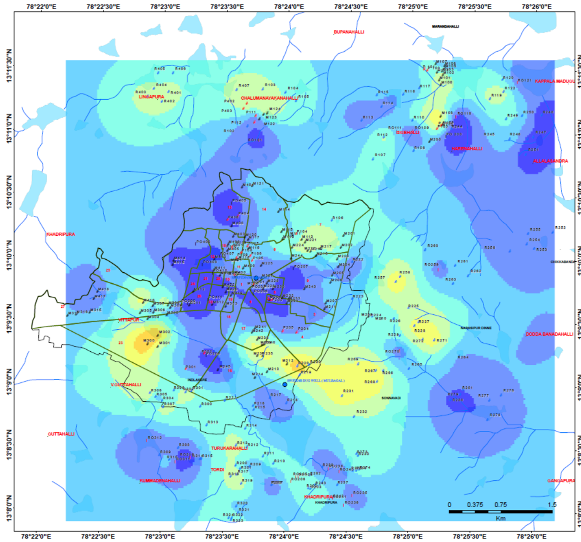
Legend

- WARD BOUNDARY
- MUNICIPAL BOUNDARY
- BORE WELL

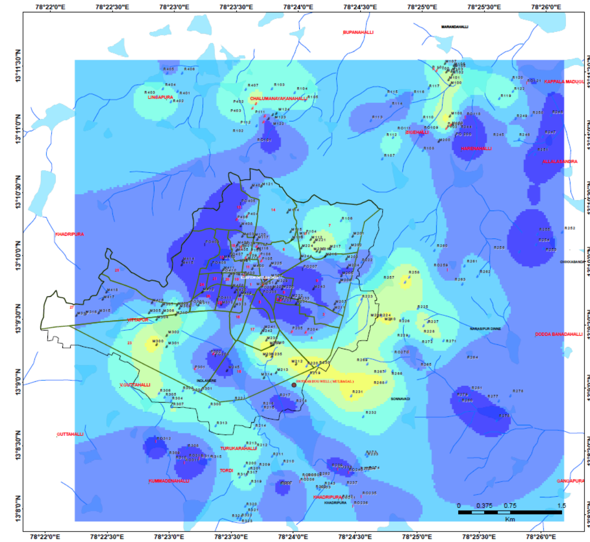
Shallow GWL in the core areas of the town



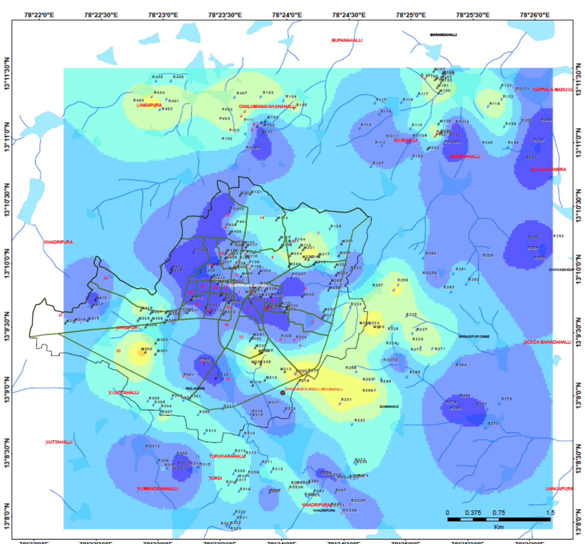
August 2009



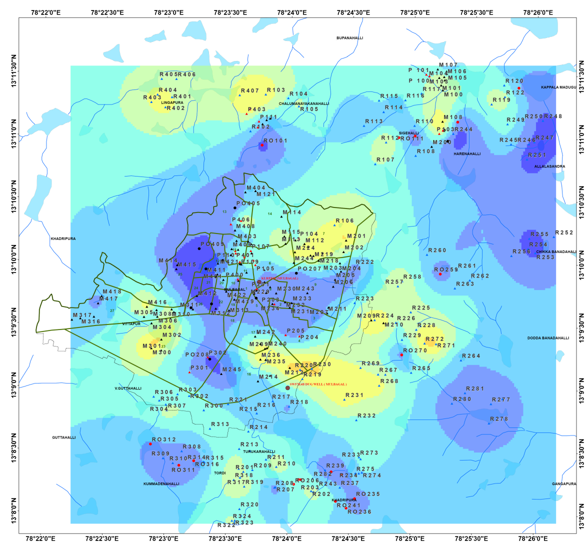
October 2009



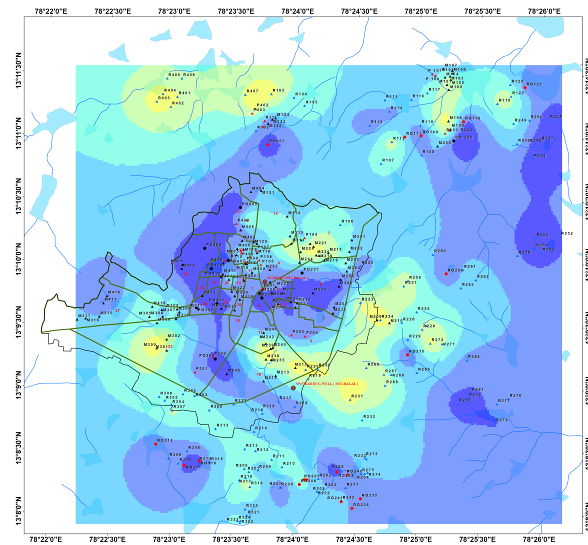
November 2009



January 2010



May 2010



July 2010

Depth to GW (m)

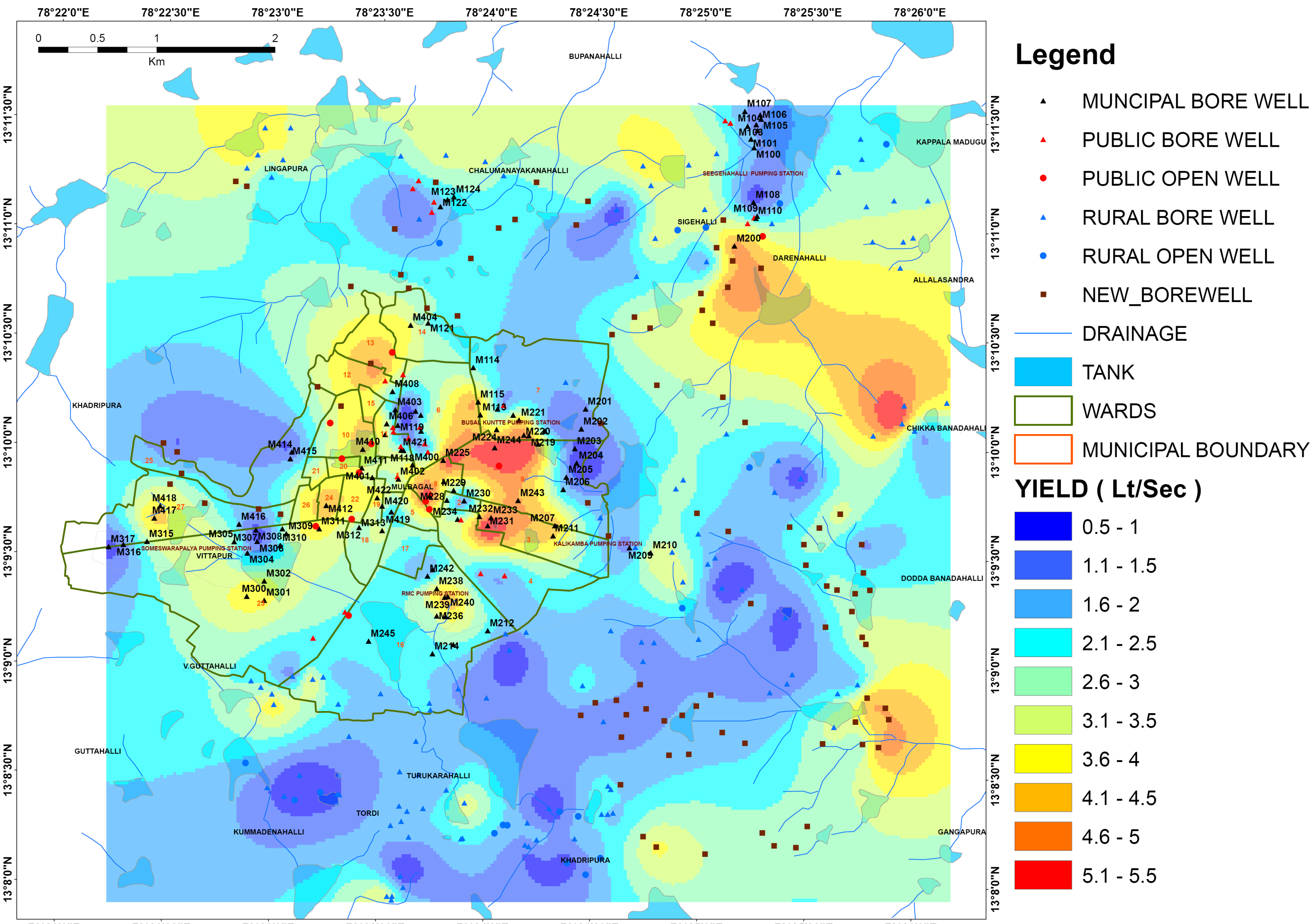
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 55

Legend

- WARD BOUNDARY
- MUNICIPAL BOUNDARY
- BORE WELL

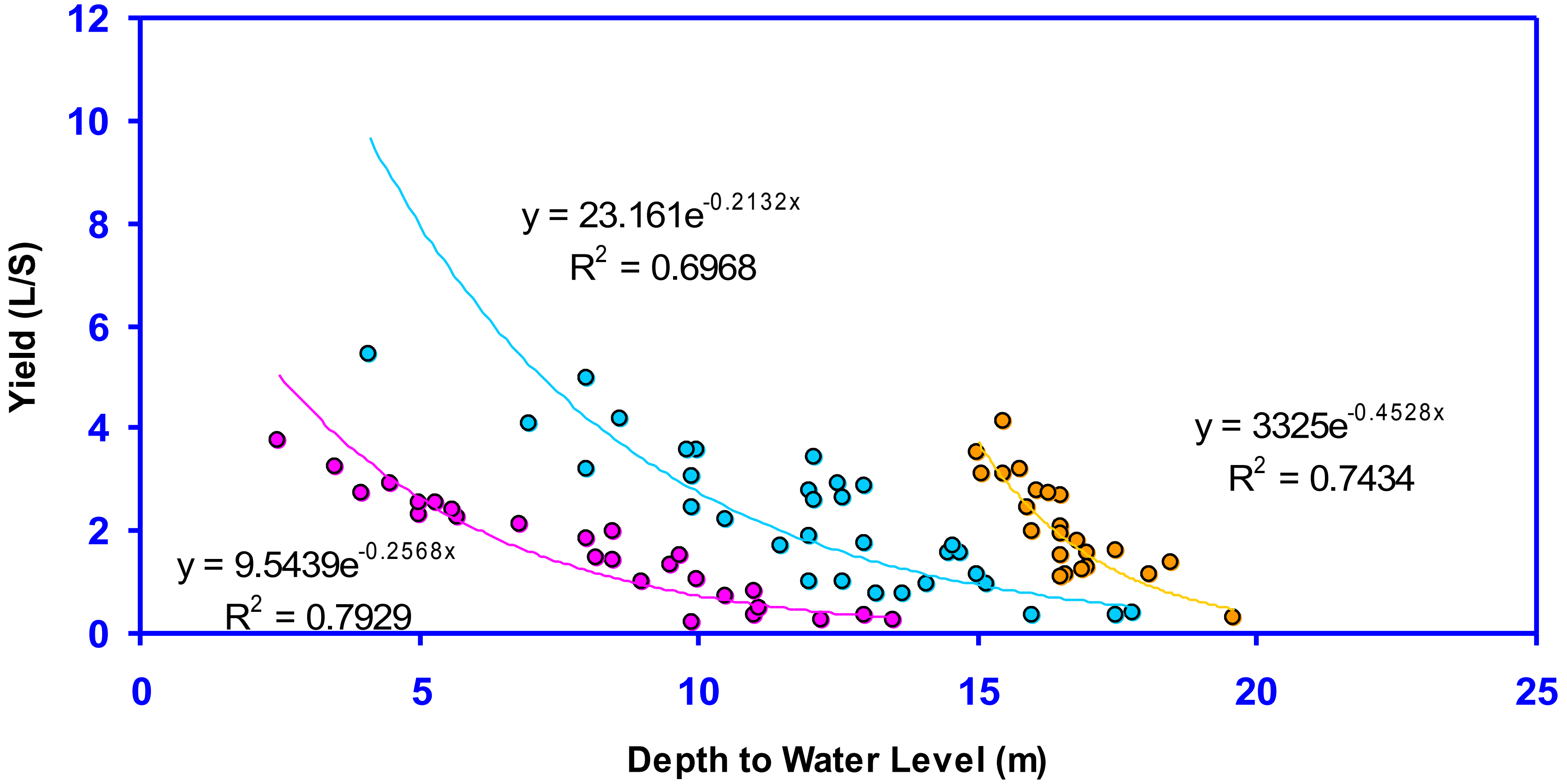
Shallow GWL in the core areas of the town

Groundwater Yield Map



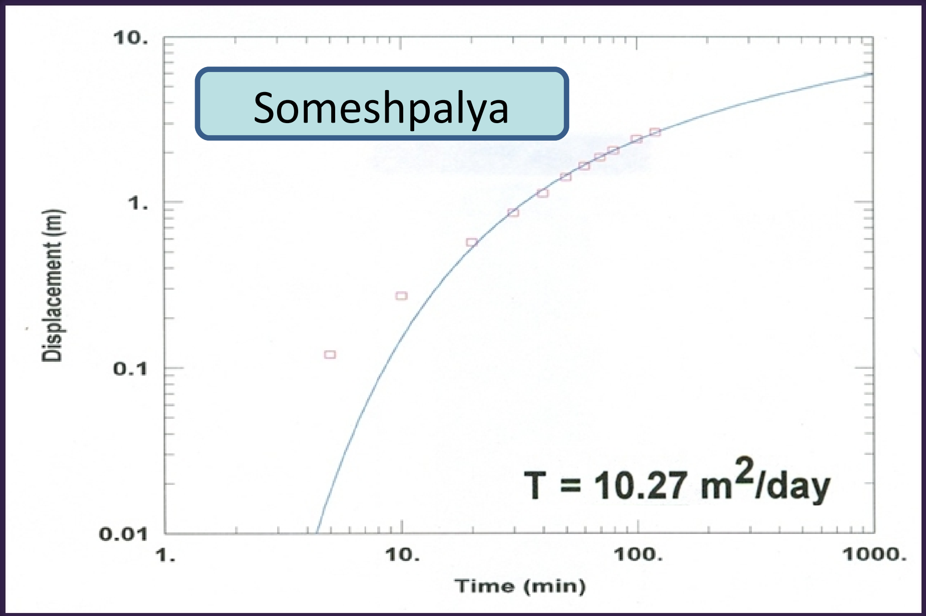
Based on Field measurements of water yield from wells

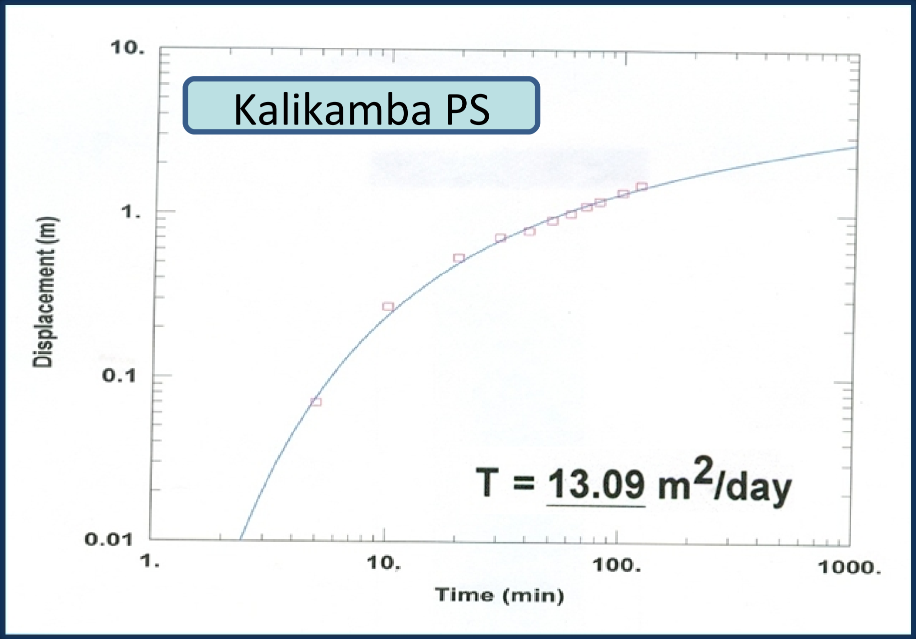
Relationship of Water yield with depth to groundwater level

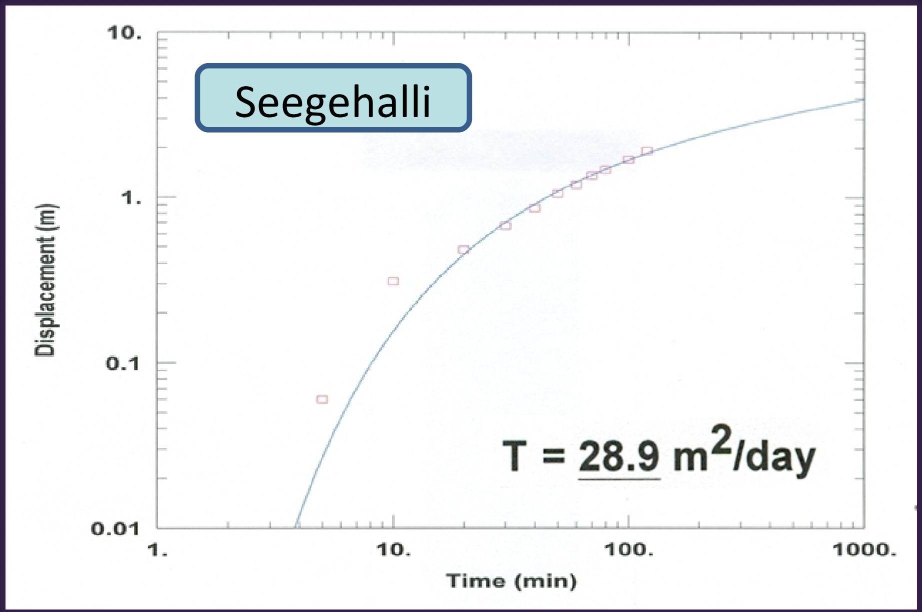


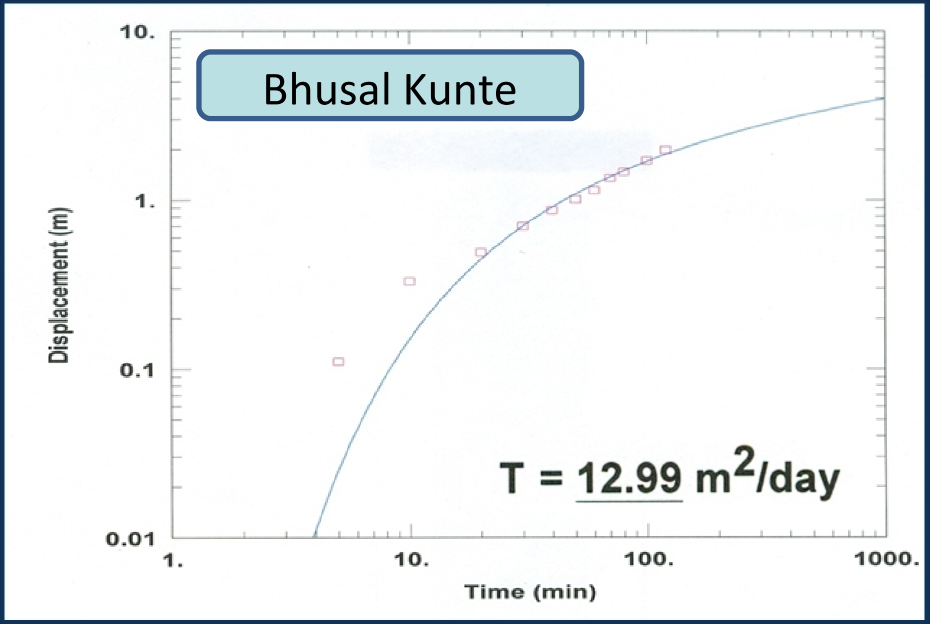
The water yield with depth is found to have the above relationships especially for the shallow wells indicating the applicability for the weathered zone.

Transmissivity Estimates – Short duration pump tests

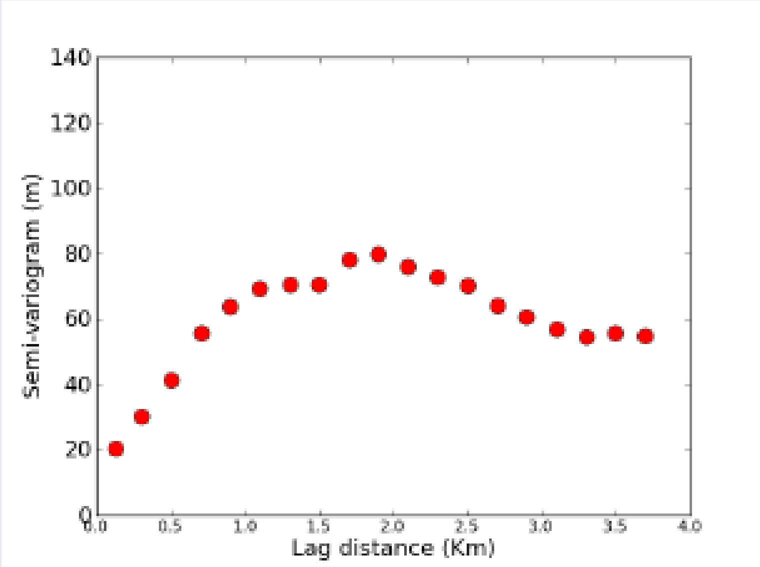




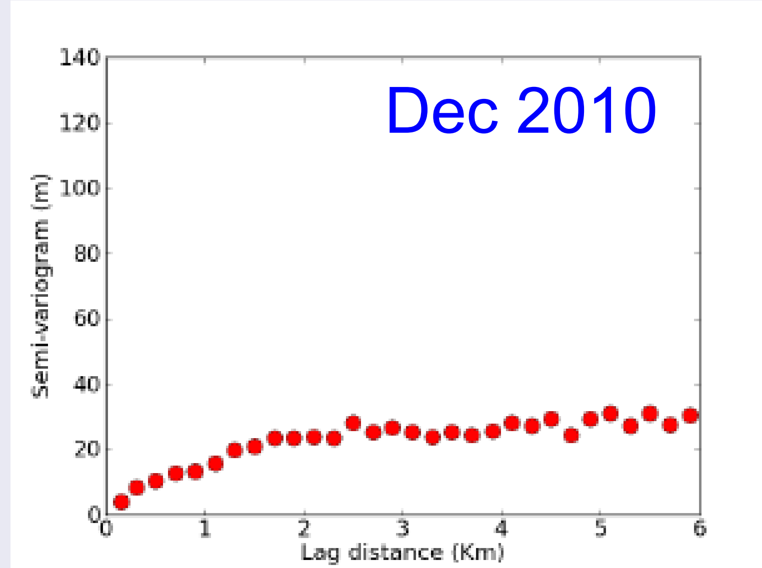




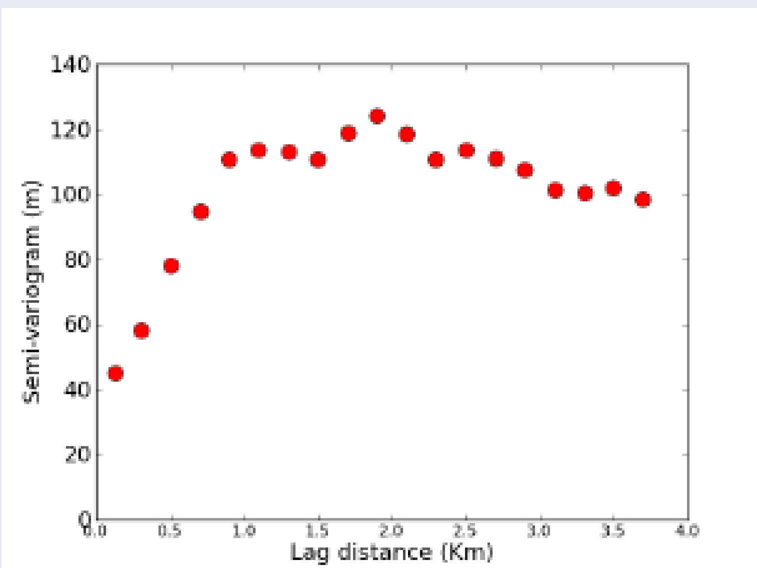
Mulbagal



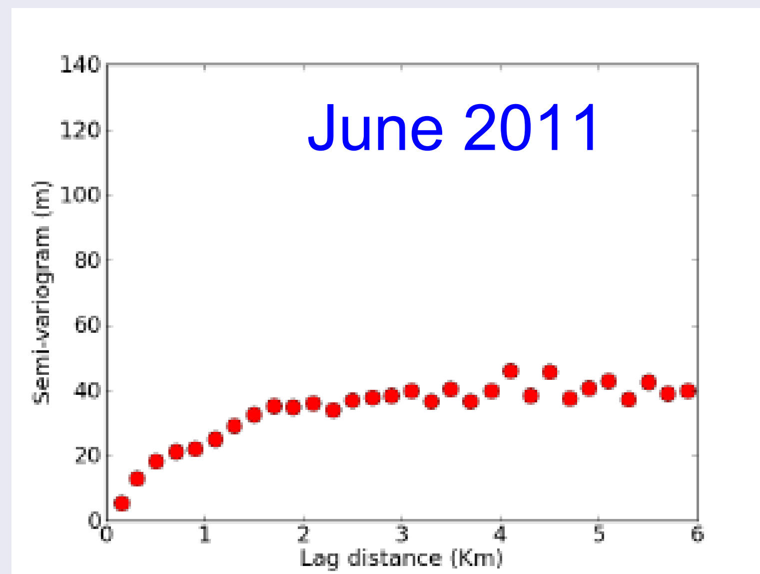
Berambadi



Mulbagal

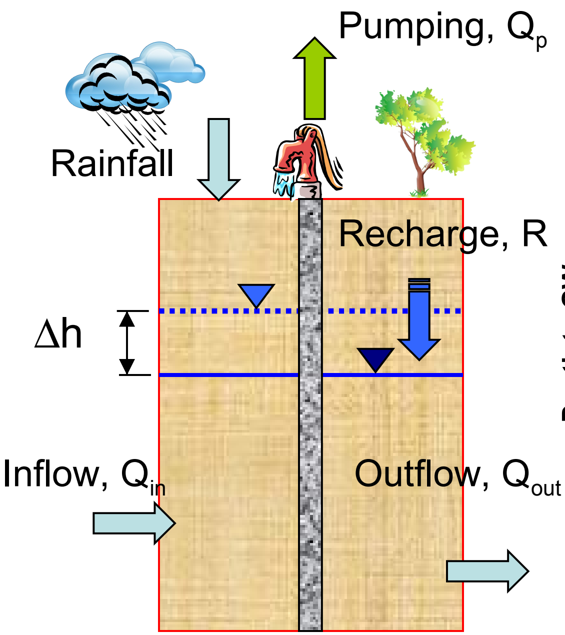


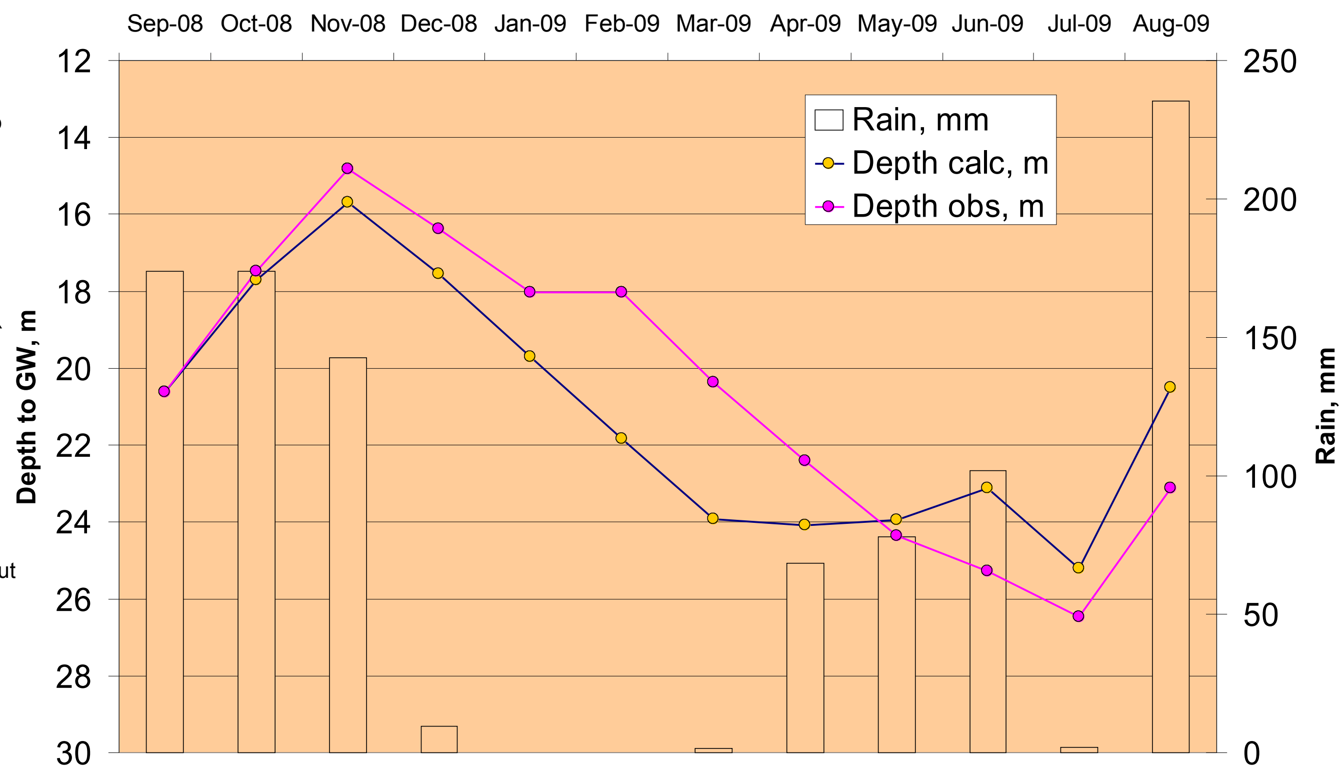
Berambadi



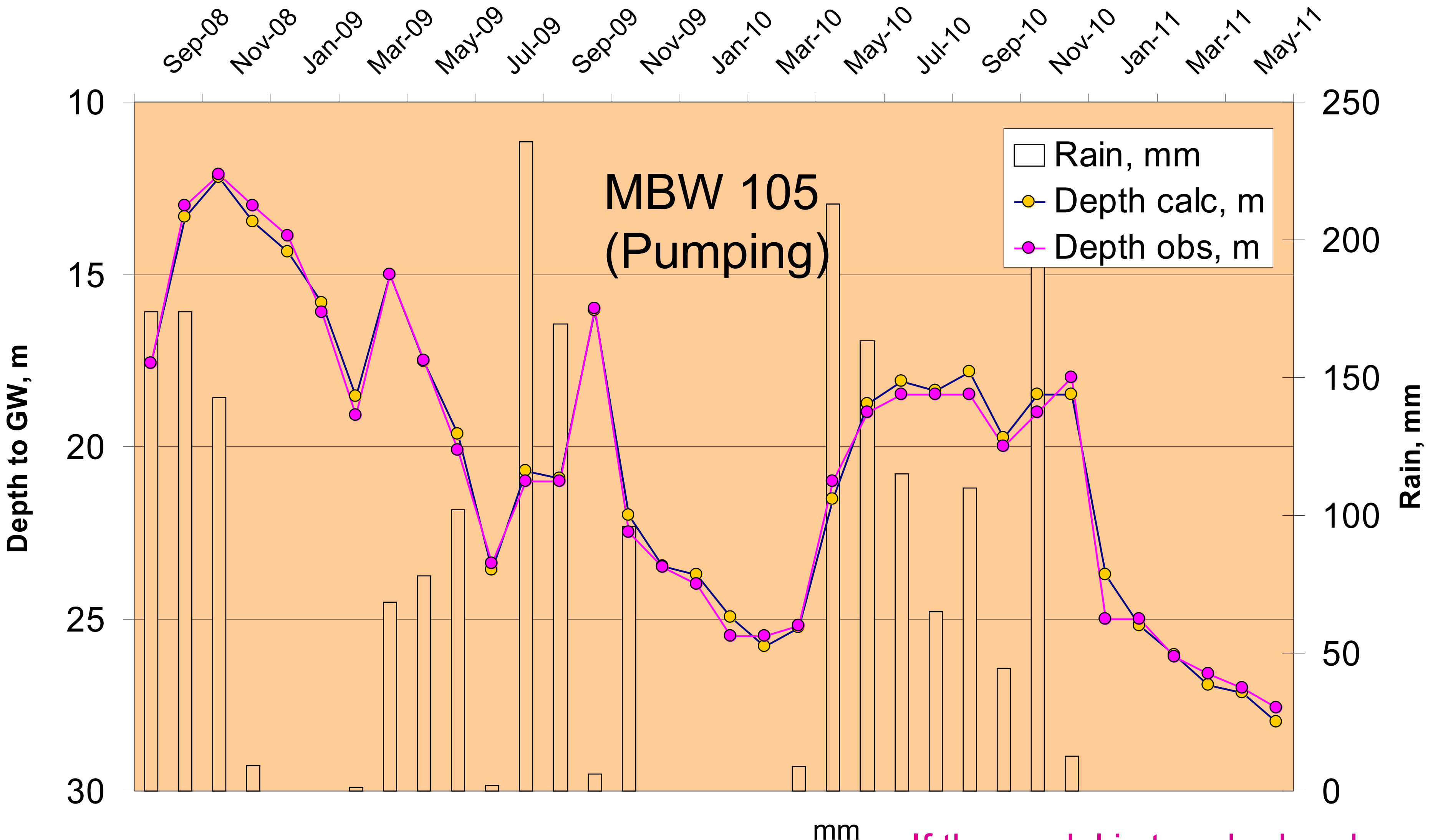
Groundwater Model at well field scale

Example:Sigehalli PS





- Lumped well field scale model for the cluster of municipal wells at a pumping station (PS) indicates that it is feasible to capture the recharge-discharge trends. However interesting departures exist between model and observations. Groundwater modeling using rainfall recharge is not adequate to model the levels. The presence of recharge from other sources dampens the groundwater decline especially during the non-rainy season.



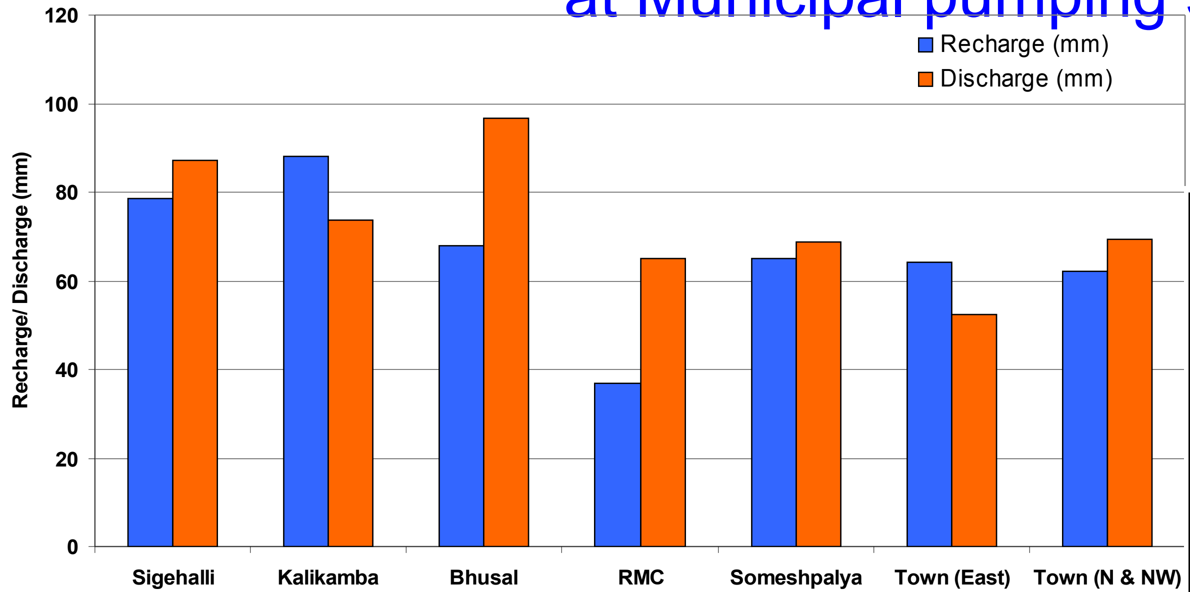
Recharge

2008 – 65 mm; 2009 – 50 mm;

2010 – 70 mm *Recharge from other sources = ~ 75 mm/year*

If the model is tweaked and fitted it gives us the recharge occurring in the dry season from the lakes surrounding the wells and the fraction of recharge from other sources.

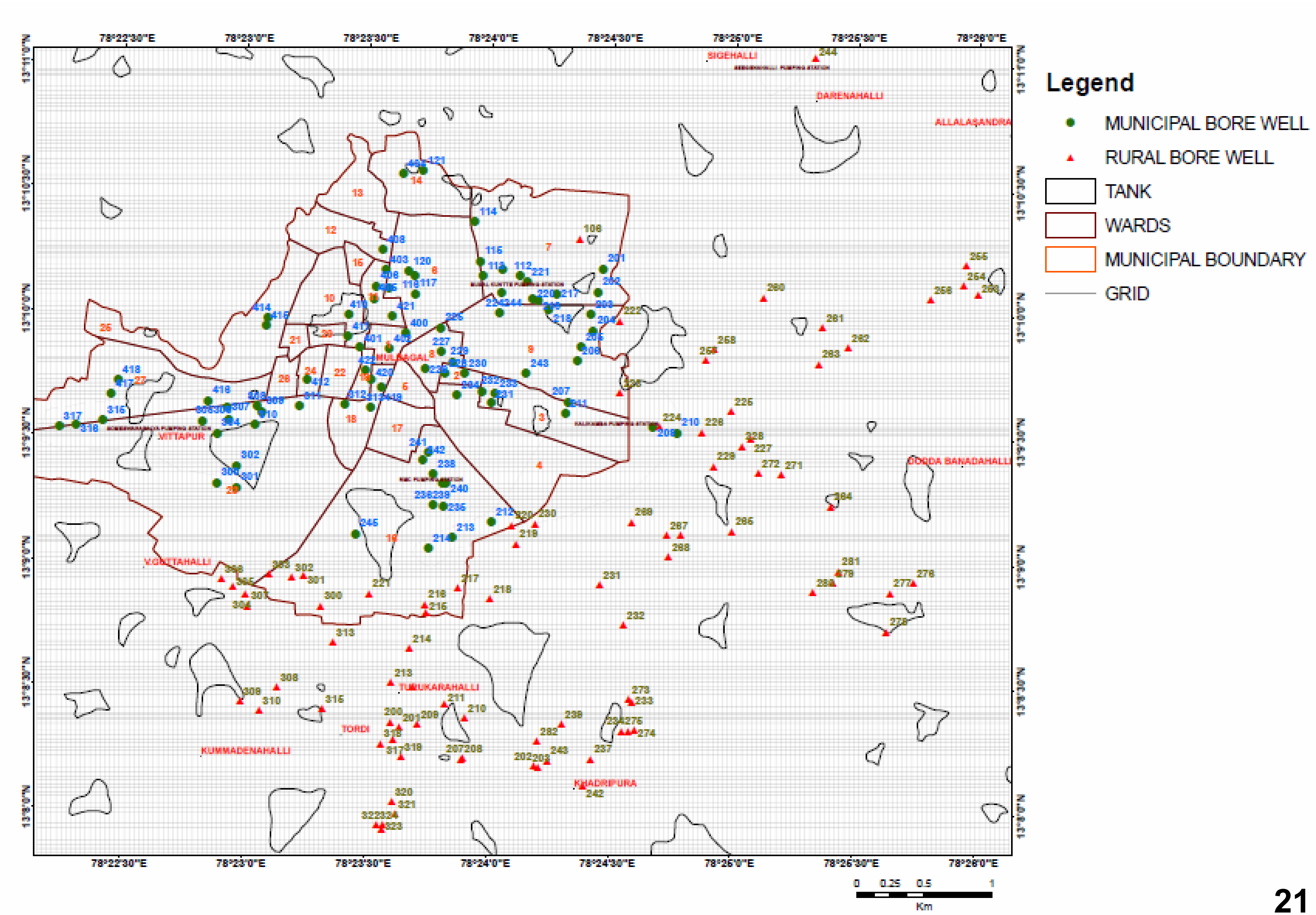
Summary of spatial variations of groundwater balance at Municipal pumping stations (2008-2009)



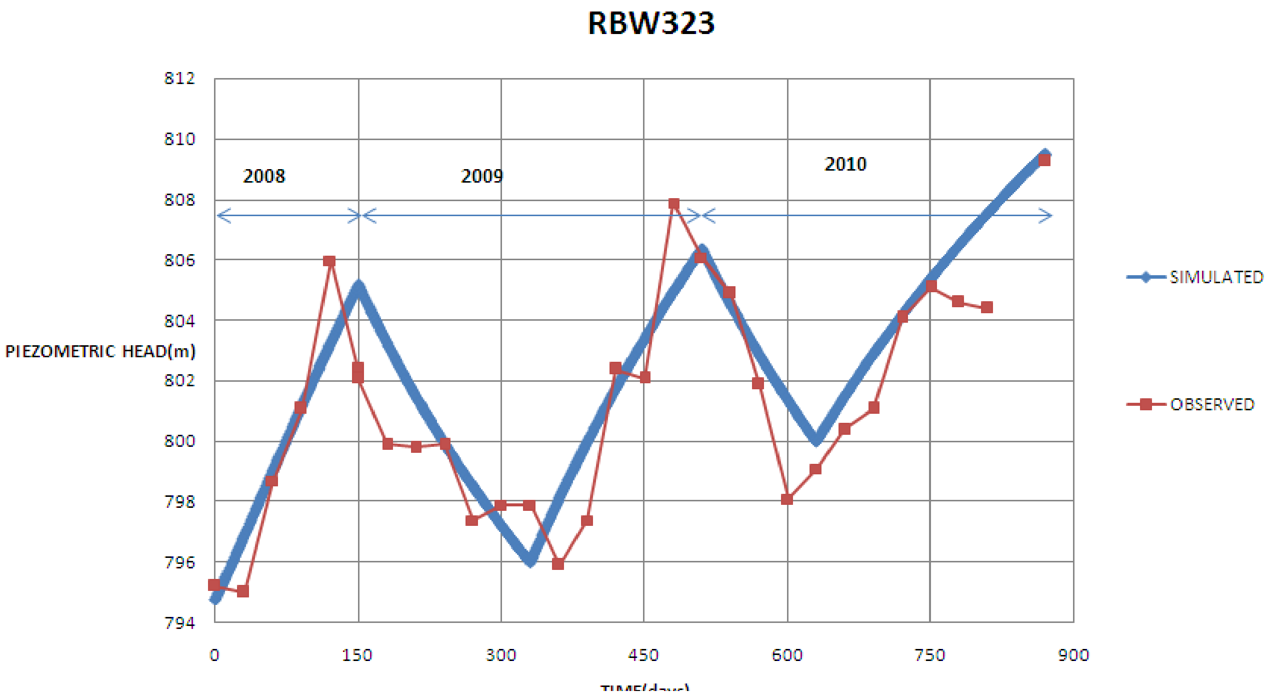
Pumping stations	Total Water pumped per day kL
Seegenahalli	569
Kalikamba temple	455
Busalkunte	364
RMC yard	273
Someshwara palaya	614
Total	**2275**

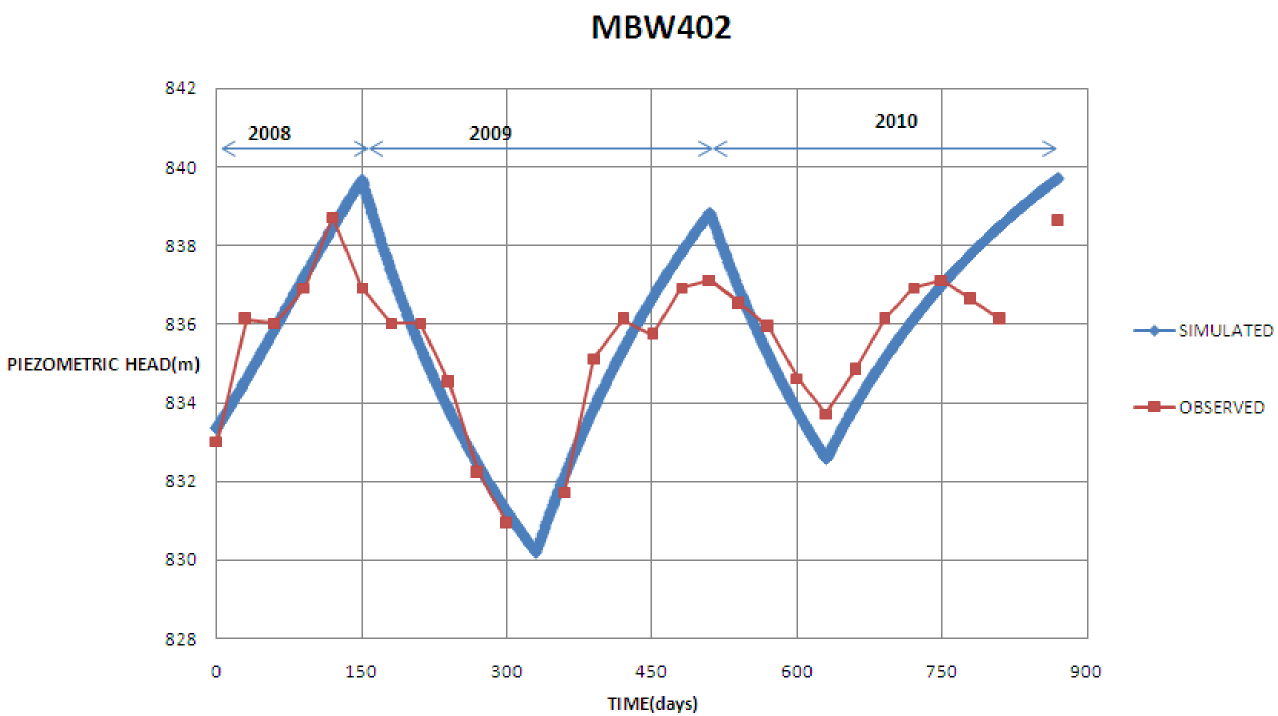
Location	Storage Increase (recharge) mm	Storage decrease (discharge) mm
Sigehalli	78.51	87.23
Kalikamba	88.05	73.80
Bhusal	67.82	96.56
RMC	36.92	65.16
Someshpalya	65.11	68.85
Town (East)	64.12	52.50
Town (N & NW)	62.20	69.30

Numerical Modeling

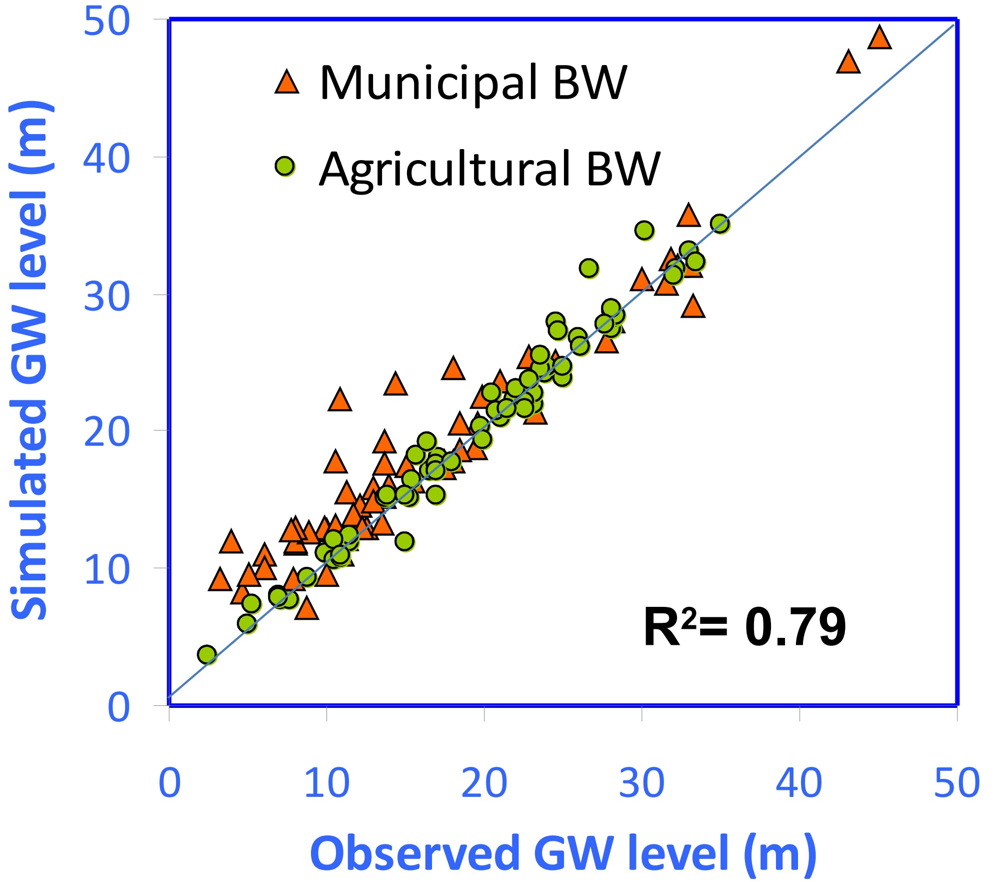


Model Validation





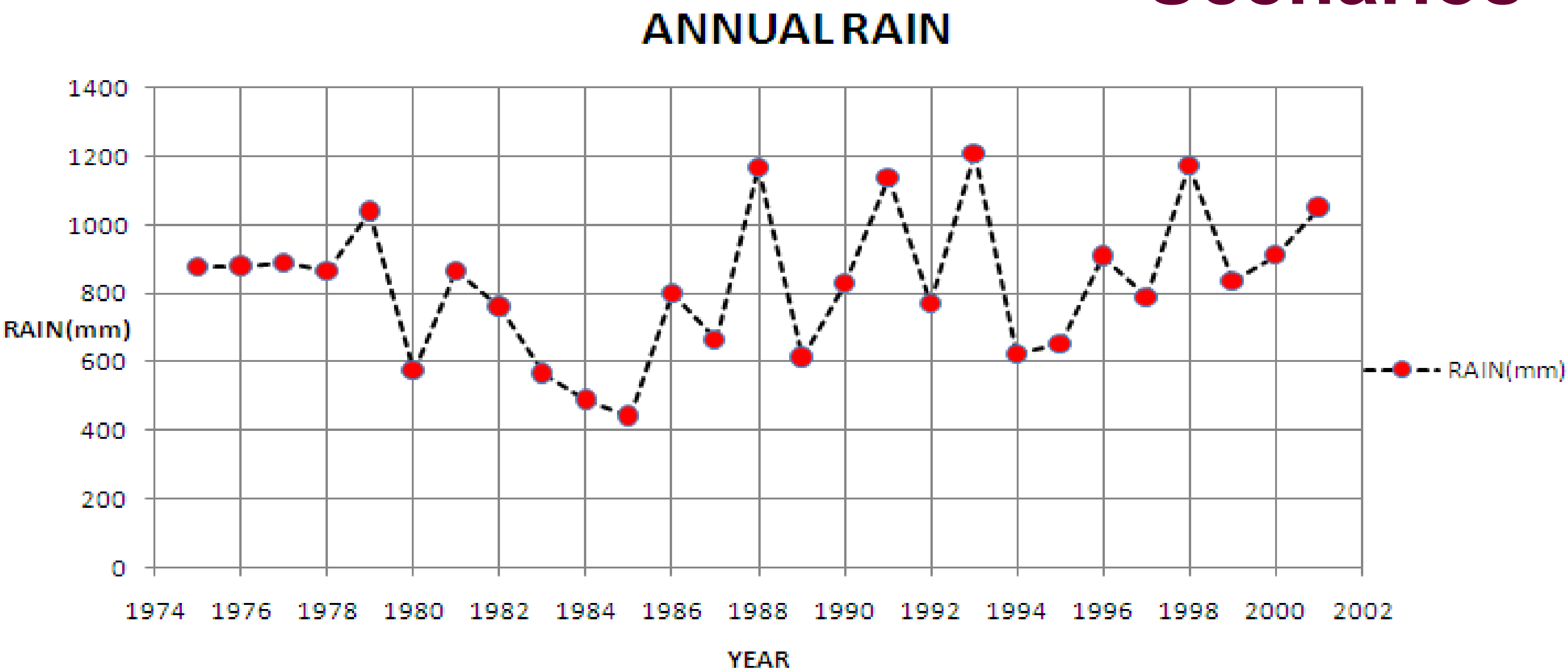
Municipal wells – Non Monsoon period



The simulations indicate that observation wells in the town show a consistent deviations from measured values during the non-rainy season.

- **indicating the role of recharge during non-rainy period.**
- **Fitting the model helps in obtaining recharge in dry period.**

Scenarios



Case A: Lower rainfall

Case B: Lakes/ Tanks not filling up to good extent @ PS wells

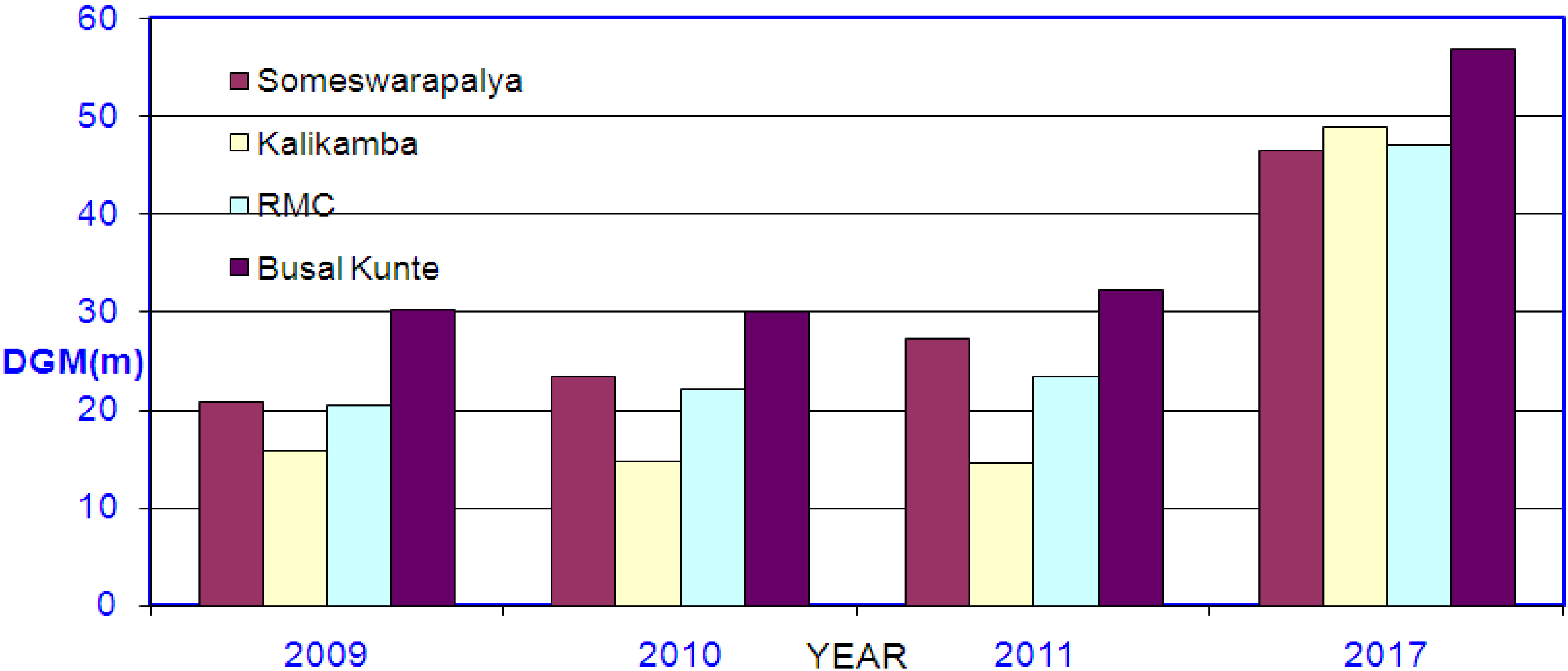
Case C: Increased pumping

Case D: Reduced leakage from waste water due to UGD

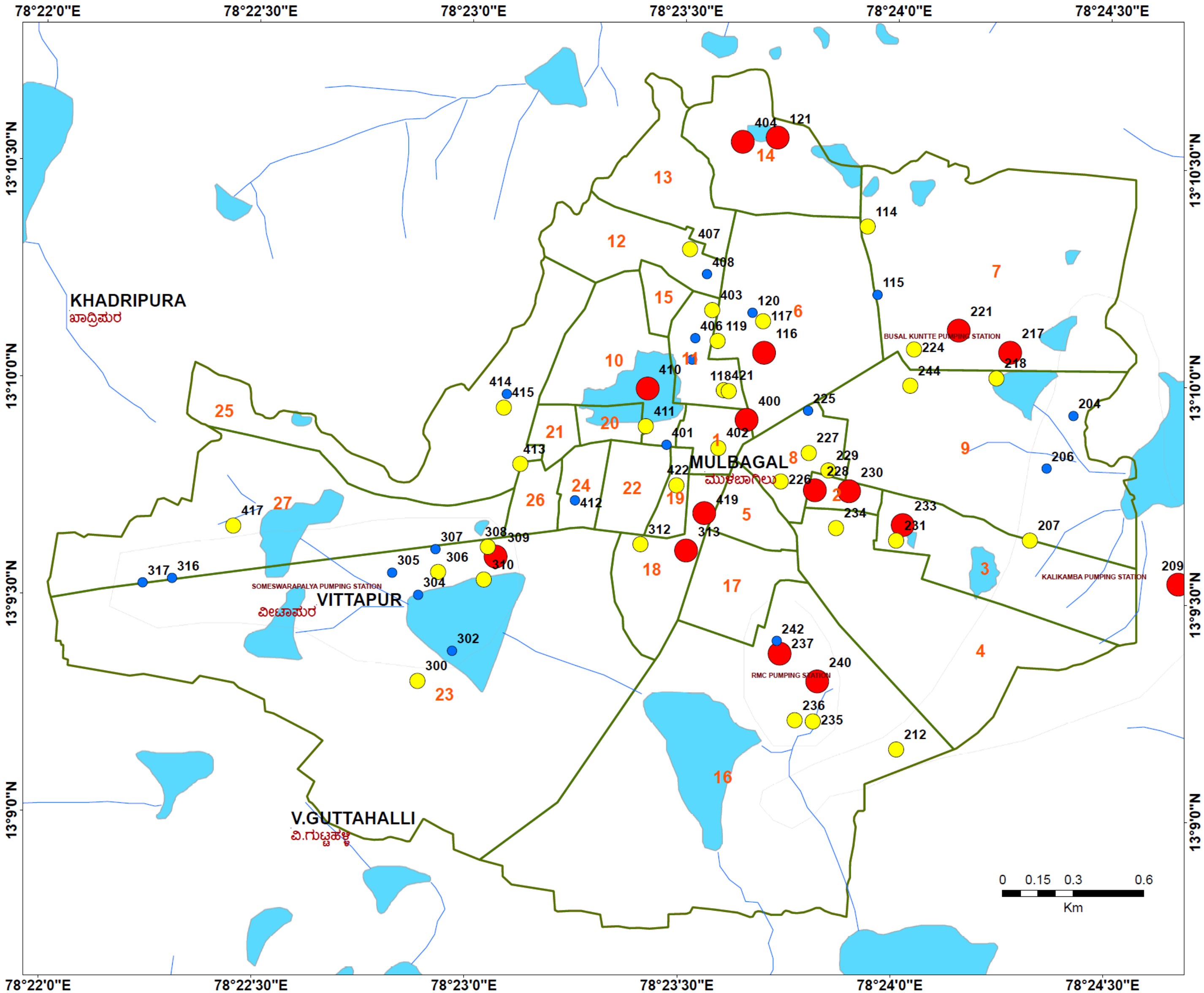
Case E: Combination of Cases B and D

Case F: Combination of Cases B, C and D – Critical case

CASE F Scenario – GWLs at PS wells



Groundwater pumping – Energy nexus



Conclusions

1. It is required to scientifically understand groundwater system in urban towns/cities using a comprehensive database at a proper spatial scale using hydrogeological models for assessing future resource availability for various scenarios. IUWM approaches should use the inputs from such studies.

2. The approach developed for groundwater level monitoring demonstrated and captured the spatio-temporal variations in the regime. A framework for monitoring network in cities/towns to be formulated to understand the groundwater regime behavior at the relevant scale. Moreover such networks should be continuous to capture the evolving groundwater conditions.

Conclusions

3. Recharge from other sources is substantial in urban catchments and hence studies are needed to estimate this component under various configurations (urban/peri-urban, nature of water supply source & wastewater collections systems).

4. Surface water sources alone to cities and towns may not be sufficient to manage the urban water demands and groundwater may be required to be used in a conjunctive manner. A planned and well managed groundwater development & use is a good buffer and an adaptation strategy to confront the challenge of climate change.

Conclusions

5. Numerical aquifer models are required to be constructed for towns and cities which depend substantially on groundwater. These models have to be calibrated with historic groundwater abstraction and groundwater level data and used for evaluation of various scenarios (increased rates of abstraction, extended drought).

6. Sound basis to be developed for future expansion of municipal water-supply while taking into account efficient water well design, aquifer recharge and water well source protection areas.

7. Strengthening of institutions (manpower & training) for better management of urban groundwater resource.

Thank You