Research Narrative

Project name and Track

"Conceptual groundwater models" – TRACK 1

Summary

This project aims to develop a new set of tools and practices for analysis and design of groundwater interventions for drinking water security in rural areas.

Development challenge

For most of the rural households in India, the ordinary dug well, along with borewell, remains the only drinking water source[1]. However, in large areas of Deccan Plateau and certainly within the state of Maharashtra, groundwater is now an increasingly unreliable source. The main reasons being (i) competing use i.e. increasing demands from agriculture as well as industry, (ii) inadequate recharge due to basaltic hard rock terrain and (iii) poor knowledge infrastructure to mediate groundwater use i.e. knowledge deficit.

Given the dependence on groundwater and criticality of drinking water, the Central Ground Water Board (CGWB) in coordination with the state groundwater agencies (Groundwater Survey and Development Agency, GSDA in Maharashtra) carries out groundwater monitoring and assessment at periodic intervals. These studies advise other departments like rural water supply (RWS) or agriculture which depend on the resource. This national level groundwater assessment follows norms recommended by Groundwater Estimation Committee (GEC, last in 1997). Though these norms are considered to be simple and easy to execute, they have very poor statistical validity and frequently underestimate scarcity. *e.g.,* according to the groundwater assessment report of 2008-09, the groundwater utilization or draft in most of the blocks in Thane district is a mere 5% of the total annual groundwater recharge, thus categorizing these blocks as "safe". This is in stark contrast with the severe groundwater stress in many parts of the district as well as with the large number of piped water scheme failures[2] which depend on groundwater sources. This year 99 villages (of 616) of *Shahpur taluka* (block or sub-district) had to depend on tanker water. The current methods used by GEC i.e. rainfall infiltration method and water-level fluctuation method provide an incomplete picture as they do not take into account the impacts due to aquifer characteristics like storage, transmissivity etc. and ignores aquifer boundaries[3].

Apart from groundwater assessment, many national programmes, such as the National Rural Drinking Water Programme (NRDWP), Mahatma Gandhi National Rural Employment Guarantee

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[1] Government of India, 2011 – "Twelfth Five Year Plan of India (2012-2017)" – Planning Commission document – page 154

[2] Mishra, V, Jul 2013 – ""Drinking Water Security" A Conceptual Framework for Policy Assessment tool of Rural Drinking Water Supply Schemes at Taluka level" – unpublished – Masters project work (available at http://www.cse.iitb.ac.in/~ctara/dilproposal/VishalMTP.pdf)

[3] P.S. Vijay Shankar, Kulkarni H., et. al., Jan 2011 – India's groundwater challenge and the way forward – Economic and Political Weekly, Vol. XLVI no. 2, page 41

Scheme (MGNREGS) and Integrated Watershed Management Programme (IWMP), intervene directly to strengthen drinking water sources by increasing groundwater recharge. These programmes have together spent more than Rs. 50,000[4] crores in watershed, groundwater and allied sectors. That said, the outcomes are not commensurate with the investments[5]. The reasons for these are manifold – from policy failure, complicated social dynamics to simply poor technical design. On the technical side, there are indeed no set protocols to represent an intervention plan, or assess impacts of watersheds and other interventions.


Dry well and a Surface Bund

Besides this, a lack of analytic framework also complicates specific tasks such as strengthening drinking water wells, location of check-dams, or of estimating yields and regulating extraction, and so on. This lack of systematic tools in predicting and measuring outcomes leads to poor designs and poor accountability. It has also led to claims and counter claims, so much so that groundwater is now claimed by a few social scientists as having purely social and economic attributes, see e.g., the trajectory of the national watershed program.

Thus, there is indeed an engineering and practice deficit in the sector. While there are a number of studies on groundwater in Indian settings, their objectives are typically purely scientific, e.g., validation of a specific numerical model, or analysis of a particular event. There are no protocols for a systematic representation and analysis of groundwater situations arising in thousands of small watersheds all over the country, and no manpower to execute them.

Approach

The Water group at Centre for Technology Alternatives for Rural Areas (CTARA) has been working on the drinking water problem for the past decade or so, with field work largely in the adjoining districts of *Thane* and *Raigad* of Maharashtra. Our work includes actual interventions, but also design and simulations, failure analyses, modelling, building regional plans and so on (see http://www.cse.iitb.ac.in/~sohoni/water/, also see groundwater modelling related work at http://www.cse.iitb.ac.in/~ctara/dilproposal/). We work in all areas which impact drinking water, i.e., surface and groundwater, schemes, institutions, and policy and economic analysis. Our

4 See "Outcome budget, 2013-14 of Department of Land Resources" by Department of Land Resources, Ministry of Rural Development, GoI and "MGNREGA Sameeksha – An anthology of research studies on Mahatma Gandhi Rural Employment Guarantee Act, 2005, 2006-2012" by Ministry of Rural Development, GoI

5 Belsare H, Jul. 2013 – "Restructuring watershed programmes from water security perspective" – unpublished – Masters project work (available at http://www.cse.iitb.ac.in/~ctara/dilproposal/HemantMTP2.pdf)

stakeholders include local NGOs, people groups, elected representatives, *gram-panchayats* (village level government), *taluka* and district officials and also officials at the state level.

We now outline two interconnected themes which form the core of our proposal. These are (i) development of a conceptual framework for rapid groundwater modelling and (ii) building of complementary knowledge infrastructure to enable it.

In the first theme, we propose to use groundwater models to plan and evaluate typical watershed interventions. This will lead to an understanding of its larger role in addressing the problem of drinking water security. Some preliminary work in this direction is already done. The first case study was done in a small tribal hamlet of *Ikharichapada* in *Mokhada* block of *Thane* district along with a local NGO AROEHAN. The study involved developing of a conceptual groundwater model to evaluate the impact of a watershed intervention (sub-surface bund in this case) on drinking water well. The model in this case showed that the downstream sub-surface bunds were more effective that the upstream bunds[6].

Ikharichapada groundwater model

Another case-study was done in the small tribal hamlet of *Mograj* in *Karjat* block to see how groundwater model could be used to strengthen a drinking water well. The model showed that a simple, low cost intervention like contour trenches in the ridge area of the watershed would raise the water levels of the well and prevent the well from drying in the summer season.

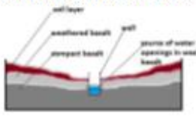
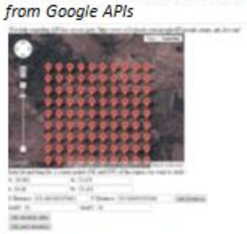
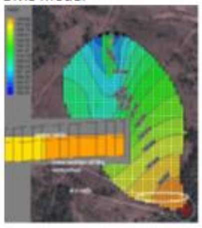
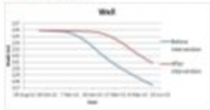
In developing the model, necessary planning practices were followed[7]. These include interacting with the local people, posing their problems correctly, gathering required data through field observations and detailed surveys (like dumpy surveys, geological surveys, trial pits, well-level monitoring etc.), collecting secondary data (like rainfall data, elevation data, geological parameters etc.), modelling and simulating the scenario using tools like MODFLOW and GMS, designing technically correct intervention plan and predicting and validating correct outcomes (see table below). Both case-studies confirm the centrality of both community inputs and model-building for effective intervention design.

It is clear that, in the short term, these planning practices will help in improving the outcomes of the interventions while in long term, they will help in building a strong knowledge base for groundwater related interventions. Thus our first main objective is to build a new conceptual framework for small-community groundwater simulations which will consist of protocols for (i) stakeholder interactions

[6] Belsare H, Nov. 2012 – "Understanding, analyzing and modelling watersheds" – unpublished – Masters Project work (available at http://www.cse.iitb.ac.in/~ctara/dilproposal/HemantMTP1.pdf)

[7] See footnote 5 above

and primary measurements, (ii) model building and validation, (iii) intervention design and simulation of scenarios, and finally (iv) a community based socio-economic cost-benefit analysis.

Step 1 -> **Understanding the needs and site identification**	Step 2 -> **Aquifer characteristics – soil properties, rock properties, layer data**	Step 3 -> **Modelling parameters – boundary conditions, stress periods**	Step 4 -> **Model simulation, calibration and predictions**
Datasets - PRA, Transect Walk, Resource maps, census data, scheme data, discussions with people	Datasets - Rapid geological surveys, trial pits, soil data, soil permeability tests	Datasets – Fetching Google satellite elevation data, doing key topographic surveys, preparing contour maps in GIS, representing watershed in GMS	Tools – MODFLOW, Groundwater Modelling and Simulation Software (GMS)
Meetings with people  *Resource map* 	*Conceptual geological model*  *Trial pit, permeability test*  	*HTML App for fetching elevations from Google APIs*  *3D terrain for delineating watershed boundaries* 	*GMS model*  *Predicting impacts of intervention* 

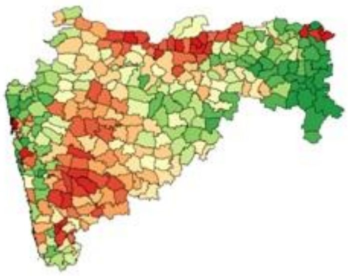
The second theme of our approach is to improve the knowledge and data infrastructure which is to be used in the conceptual framework above. This will guide regime selection, boundary conditions and stress periods, typical demand profiles and so on. It will require a careful analysis of existing data, its classification by granularity, accuracy and use, and building regional and seasonal models for convenient use in the above representation.

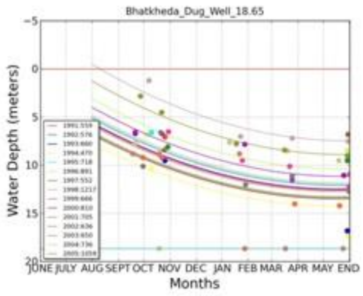
An important part of this is the analysis of the legacy data of GSDA which consists of (i) well levels over 30 years in over 5000 observation wells, and (ii) aquifer depth estimates for watersheds. Much of the GSDA data set is already under analysis and some light-weight regional models are now available. Work is being done currently on the analysis of GEC's groundwater assessment methods and applicability of long term trends in groundwater observation well data in the assessment process.[8]

Other sources of data remain to be mapped. This is largely the irrigation census, soil depth assessments and agricultural data. Along with this, regional groundwater models can be used to predict the natural groundwater discharges, baseflow etc. much more accurately than the current norms-based estimations.

This data infrastructure will enable the easy assembly of a rough-cut model for the community/watershed in question, which will then be refined by structured primary interactions.

[8] Gokhale, Aug. 2013 – "Consideration of recent trends in the method recommended by GEC'97 for categorizing areas according to their potential for future groundwater development" – unpublished – PhD work under Prof. Milind Sohoni – (available at http://www.cse.iitb.ac.in/~rahulbg/pdfs/trends_paper.pdf)





Models showing long term trends in GW levels in observation well data of GSDA

Innovation

Our key innovation will be a conceptual framework and a data infrastructure for small-community groundwater simulations. As a design objective, this framework should be executable by a suitably trained "development" engineer and should eventually lead to better practices within various government agencies such as the IWMP and NRDWP. The framework should also inform NGOs and local self-governments about the ground situation and help them structure their understanding of the various factors which impact drinking water security.

Thus, the framework, besides being an engineering model, should also effectively incorporate sources, community water use practices, community needs and capacity, seasonality and present various options and their costs and benefits.

The second requirement of this framework should be its relative simplicity and executability in a limited time by an engineering graduate. Our target is about 2-4 trained person-months for a regional model-building, simulation and intervention-design cycle for a village covering an area of 4-8 sq.km. Only when this is achieved that the issue of scale will be resolved and good practices and *practitioners* will emerge. This will mean (i) creating a suite of template scenarios and case-studies, (ii) developing protocols for structured community interactions, model building and socio-economic analysis for these templates, and (iii) transmitting these to engineering colleges, NGOs, program offices and implementation agencies

Outcomes

The outcomes can be divided into short-term, mid-term and long-term. Short-term outcomes will be measured in terms of individual case-studies and templates developed for various scenarios of groundwater simulations. These would be the basis of training programs for engineering colleges and also professional employees of government agencies. Mid-term outcomes will include collaborations with local NGOs, local governing bodies like *gram-panchayat* (village-level), *panchayat samiti* (sub-district-level, *zilla parishad* (district-level) etc. so that these practices actually inform the conduct of design and implementation of a wider range of interventions. Long-term outcomes will include the adoption of these practices at the state and national level. It should also contribute to a broader and more robust knowledge and data framework for the country, and a community of practitioners who depend on it and work to improve the drinking water outcomes of our people.

Vision for success

Adoption of protocols based on conceptual groundwater models will bring in more rationality and outcome-oriented thinking in watershed / groundwater augmentation programmes. This will help in creating a strong platform for evolution of good practices and a robust monitoring and evaluation framework for groundwater projects, which will further lead to more accountability and positive results in the sector. This will be the prime success of this project. At the same time, creation of strong knowledge base and data infrastructure in the field of groundwater will trigger more data-driven / measurement-driven studies and analyses. Engaging with engineering colleges on different local situations will help the knowledge database to enter into the academic mainstream and bring subjects of hydrogeology and groundwater closer to ground. This will help generate a price-point for engineers and practitioners working in the field of watersheds who will find gainful opportunities in delivering value in development programmes. This will be the long term goal and achievement of this project.

Relevance

The conceptual models and the templates developed in the project will be used by local implementation agencies (NGOs as well as local government bodies like *gram panchayat*, *panchayat samiti*, *taluka* agricultural office etc.). The models and templates will also be used by development practitioners, researchers and even by private players. Dissemination to local engineering colleges will help engineering students to base their projects on the use of such models in local development situations. To say the least, the outcomes of the project will be beneficial to millions of rural women who have to trek long distances to fetch their daily water.

Project plan

Timeline / Track	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Technical track	Literature review	Expert interactions and preliminary models	Template building and groundwater regimes	Model building and validations on case studies				
Knowledge infrastructure track	Current datasets survey		Data validation	Data architecture design				
Policy analysis track	Policy analysis	Review of government programmes	Template selection					
Field work and intervention track			Identification of case studies	Case studies, interventions			Extended interventions	
Dissemination and outputs track							Interactions and collaborations with local engineering colleges and field implementation agencies	
Deliverables and milestones		Research requirements and tools	Detailed problem specification			Technical outcomes	Peer review of outcomes, stakeholder reviews, publications, policy outcomes	