Case study: Rainwater harvesting in very high rainfall area

Goa University Campus, Taleigao (Goa)

Objective
The key objective of the RWH project in Goa University is to arrest declining groundwater levels and recharge the aquifers to reduce dependence on the overstretched municipal water supply for a more sustainable water supply on the campus.

Location
Goa city is located along the western coast of India (*see Map 5: Location map of Goa University in Taleigao, Goa*) and the university campus is located on the outskirts of Panaji (the capital city) spread over nearly 173 hectares on the Taleigao plateau overlooking the Zuari river joining the Arabian Sea. The campus is located on a plateau in the island of Tiswadi and has unique geological features. The area has hard laterite rock of variable thickness on the top (*see Diagram 5: Geological cross-section of the study area*) followed by a thick sequence of clays, and fractured and weathered basement rocks forming deep seated confined aquifers.[24]

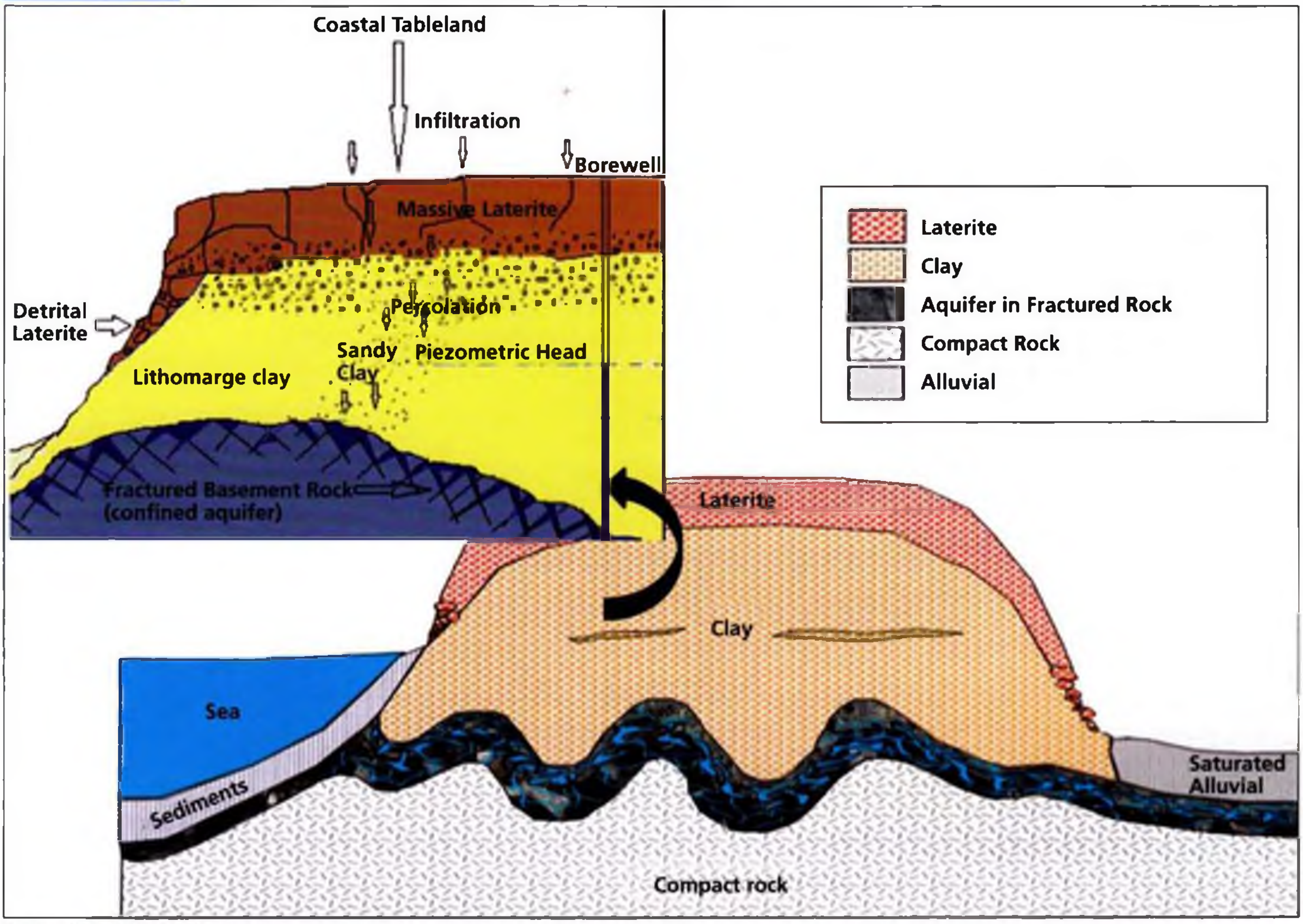
Hard laterite on the surface in Goa University

Climate profile
Goa is known for its tropical climate. The area has mild and pleasant weather entire year due to its location along the coast. There is very less fluctuation in weather with maximum temperature rise to 35°C in April and May months. The

MAP 5 Location map of Goa University in Taleigao, Goa

Source: *Google Map Image*, 2014

DIAGRAM 5 Geological cross-section of the study area



Source: *AG Chachadi, 2013*

monsoon period begins in the month of June and remains till September. Rainfall is heaviest at the mountain ranges and on its western slopes, which gradually reduces towards the coastal plains. The rainfall is very heavy and the strong winds are experienced during the rainy season in Goa.[25] The region receives very high rainfall around 250 cm per annum in the coastal belt and 400 cm per annum in the vegetated regions. The average rainfall of Goa is approximately 320 cm per annum.[26]

Water scenario

There are not enough water supply facilities to meet increasing water usage due to growth of population, increase in number of tourists, and rise in living standards, resulting in serious imbalance in supply and demand of water in Goa. The current water supply is dependent on both groundwater and surface water. The groundwater contributes to over 33 per cent of the water supply in Goa and is considered as safe.

The depth to water level depends on the nature of aquifer. In shallow unconfined aquifer the water levels are less than 10 mbgl but in confined deeper aquifers the water levels are in range of 15-85 mbgl depending on the undulating nature of the basement rock and seasonal fluctuation.[24] Due to steep hydraulic gradient and highly permeable phreatic aquifers, the dynamic ground water resource in and around campus gets depleted quickly rendering scarcity even for drinking water during summer months.

The university has around 1500 staff and student population. The existing water demand of university is around 0.45 million litres per day.[24] Around 50 per cent of the water supply depends on public water supply and remaining from the existing twelve bore wells on the campus. During summer the public water supply is further reduced by almost 50 per cent. This results overexploitation of groundwater and has resulted in drying up of few bore wells on the campus.

"Goa receives high rainfall but because of its geological characteristics, most of the water is drained into the sea. Since, Goa has large plateaus and they act as a sponge to store water, it is beneficial that we have RWH"

— Sujeet Dongre, Programme Coordinator
Centre for Environment Education, Goa

Rainwater harvesting system

In 2007 the Goa University initiated the plan to develop RWH system for recharging the fast depleting aquifers. Keeping in mind the vast potential of harvesting rainwater on the campus a RWH system has been implemented at the university under supervision of Prof. AG Chachadi, Department of Earth Sciences, Goa University.

The existing rainwater system has two main structures – one main structure for harvesting surface runoff constructed in year 2007 with a catchment of 1.5 hectare mainly unpaved area and second, rooftop harvesting system constructed in year 2008 for harvesting the runoff mainly from built up area on campus (*see Table 6: Salient features of the RWH system at Goa University*).

The project is good example of private sector engagement. According to Prof. Chachadi RWH system of university was funded partly from his research fund and remaining generous contributions from – Sociedade de Fomento Industrial Pvt Ltd; Bhagavathi Ana Labs Ltd; Timblo Pvt Ltd; V M Salgaocar & Bro Pvt Ltd, Vasco (Goa) and Mineral Engineering Services and Coca Cola Ltd.

Technical specifications and design of the RWH system

Goa University area is located on confined aquifer with layers of impermeable material above and below them. The depth to aquifer in the Goa University campus varies from 65m to 110m below ground. The topography of the basement rock is fractured and weathered water bearing zone is undulating in nature.[24,27] The RWH at university was designed keeping the site characteristics. The detailed technical specification of the implemented RWH is discussed in the following section.

Site 1: Surface runoff harvesting

Catchment area and conveyance system

The total catchment area contributing to runoff for the surface runoff RWH structure is 1.5 hectare to the natural depression – a pond (*see Photograph: Surface runoff catchment area of the RWH structure*).

In the beginning before creating RWH structure, the site was de-silted and leveled. To maintain clean and contaminant runoff recharging the aquifers a protective rubble wall was built around this natural depression pond as the pond receives mainly runoff from the unpaved surrounding catchment. A deep trench (dimension 20m x 10m and 2m) is built at the centre of the pond and a retention concrete wall of 0.5m height was built around this trench to prevent direct entry of the pond water. The runoff water passes into the deep trench ensuring the suspended particles settle down before water enters into the sand filter (dimension 3m x 3m x 3m). Finally after getting through the sand filter the water enters the main recharge well trench (dimension 3m x 3m x 4m size).

The deep bore well is perforated both at the surface as well as at the bottom where it is exposed to the aquifer. The runoff water enters through these perforations wrapped with nylon cloth and directly enters into the aquifers at deeper levels.[24,28]

The bore well is drilled to a depth of 89m below ground and has tapped an aquifer at 65m depth. In the well water enters through the top 5m length of the slotted casing pipe. Inside the bore, water is released to the aquifer between 65m and 89m depth through a slotted casing pipe. Between 89m and 65m depth range the bore well is cased with blank pipe as the geological layer in this depth range is made up of clay (*see Diagram 6: Cross sectional view of surface runoff – RWH system).*

TABLE 6 Salient features of the RWH system at Goa University

Parameters	Details of the RWH system
Total catchment area	173 hectares
RWH structure (2 no.s)	Recharge trench in natural depression/pond Recharge bore well for rooftop water harvesting
Total volume of recharge (in year 2010)	39 million litres (38 million litres surface water from and 0.9 million from roof top run off)
Cost of system (in Rs)	0.16 million
Savings per annum (in Rs)	4.4 million per annum
Year of implementation of the RWH system	2007, 2008

Source: *AG Chachadi, 2013*

AG CHACHADI

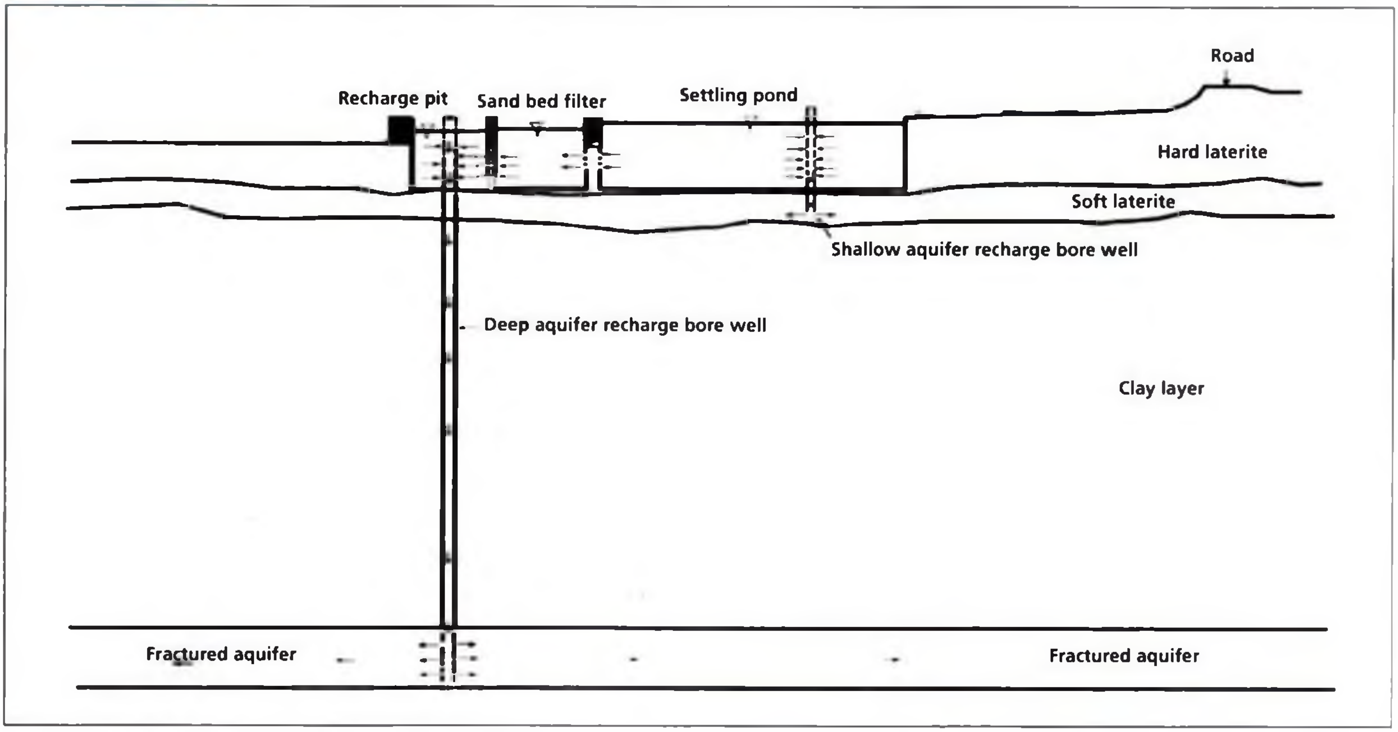
RWH structures – deep trench, sand filter and recharge well


AG CHACHADI

Deep recharge bore well

Surface runoff catchment area of the RWH structure

DIAGRAM 6 Cross sectional view of surface runoff – RWH system



Source: *AG Chachadi,* 2013

Plan showing the roof water harvesting catchment and structure

Site 2: Roof water harvesting

Catchment area and conveyance system

The roof areas of about 400 m^2 form presently the catchment for the RWH structure at this site. At present the conveyance for the runoff from the rooftop from boy's hostel and the electronic building is complete and feeds to the existing recharge. The rooftop of the girl's hostel, men's hostel and remaining department buildings will be connected in next phase and work is under progress *(see Photograph: Plan showing the roof water harvesting catchment and structure)*.

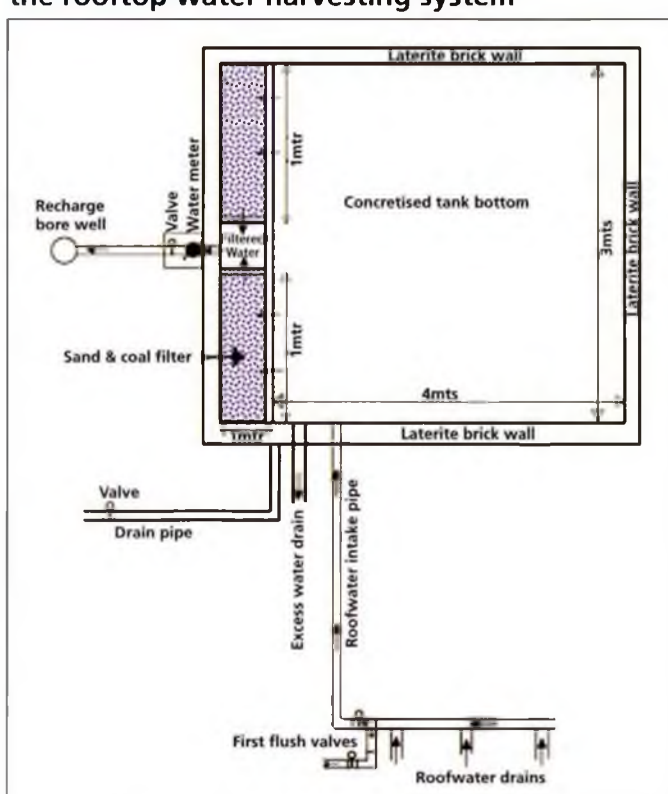
The diagram gives the detailed structural design of the roof top RWH structure at the university (*see Diagram 7: Structural design and layout of the rooftop water harvesting system*).

The rooftop water intake pipes bring water to the storage tank made of concrete base and laterite brick wall. The rooftop runoff storage tank has capacity of 100,000 litres. The rooftop runoff passes through a sand and coal filter. After filtration the water is taken to the nearby recharge bore well feeding aquifer at 100 mbgl depth. To avoid any pollutants from rooftop entering the aquifer first 15 minute rainfall is flushed away using the manually operated flush valve. The photographs on next page shows the PVC pipes used to collect rooftop rainwater and the first flush valve.[27,28]

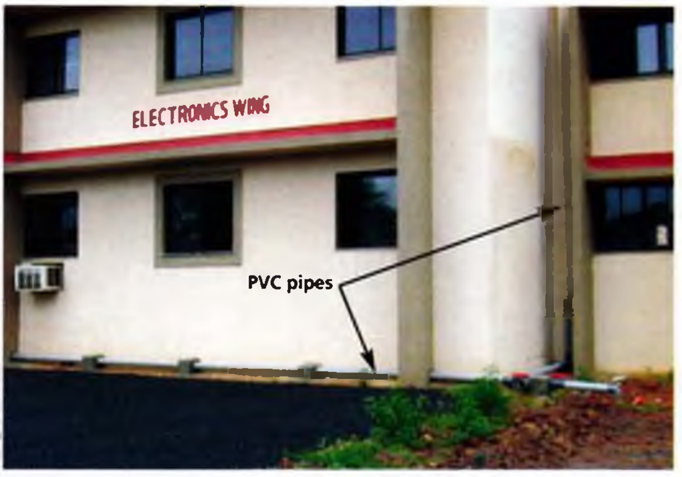
Operation and maintenance

Every year the system and catchment areas are cleaned twice before and after monsoon. The first flush system has been

DIAGRAM 7 Structural design and layout of the rooftop water harvesting system



Source: *AG Chachadi*, 2013



AG CHACHADI

Roof water conveyance system – PVC pipes

AG CHACHADI

First flush device in use in the roof top RWH site on campus

provided to avoid first one or two spells of season rainfall and has to be operated manually. The manual de-silting of settlement tank is also undertaken twice pre and post monsoon for better efficiency of the RWH system. Due to regular O&M no mosquito breeding case has been reported. The annual maintenance for both the systems costs Rs. 8,000 to 10,000 per year.[24] In addition the water quality is tested at periodic interval to ensure good quality runoff is recharging the aquifer.

Socio–economic and environmental benefits

The university caters to water supply for 1500 both resident and non-resident staff as well as students. The estimated demand for water supply is 0.45 million litres per day to meet water requirements of the administrative blocks, teaching blocks, hostels, residential quarters and landscaping. The total groundwater recharge during 2010 from both the structures was 39 million litres. In 2010, Site 1 estimated recharge was 38 million litres (*see Table 7: Recharge per year from surface runoff RWH structure (Site 1)*).

The roof area for the Site 2 is about of about 400 m^2. The site received a record recharge in the year 2010 due to heavy rainfall of 3.7 m.[24] The performance of the system in terms of water harvested and recharged into the groundwater through bore well during last three year (2008 to 2010) is given in the table (*see Table 8: Performance of rooftop RWH structure (Site 2)*).

The RWH has been contributing considerably in recharge of the local aquifer resulting in improved yield and sustainable extraction of groundwater. The water is now provided on sustainable basis particularly during summer when the public water supply also decreases to less than 50 per cent of the supply. As a result since 2007-08 the water supply has not been interrupted or dependent on any alternate source of water supply. In terms of water availability the volume of groundwater recharged during 2010 can meet about 78 days of campus water supply.[24]

TABLE 7 Recharge per year from surface runoff RWH structure (Site 1)

Sl. No.	Item	Details
1.	Total drainage area contributing surface runoff	15,000 m^2
2.	Monsoon rainfall year 2010	3.7 m
3.	Surface runoff collected	55.5 million litres
4.	Estimated recharge (70%) to sub surface through recharge bore well	38 million litres

Source: *AG Chachadi, 2013*

TABLE 8 Performance of rooftop RWH structure (Site 2)

Year	Water recharged (litres)
2008	2,60,000
2009	1,80,000
2010	9,00,000

Source: *AG Chachadi, 2013*

Economic benefits

The basic aim of the implemented RWH system at university was not to bring down the water bill but to recharge the aquifers that contribute more than 50 per cent of water supply. With increasing constraints in public water supply and the university authorities had to depend on groundwater extraction in summer to meet the public water demand – supply gap. But each unit of water conserved through RWH will have the

"The system has contributed towards convenience/ease in water accessibility and usage to some extent as the groundwater storage has been augmented and decline in water levels is arrested. In the absence of this augmentation the wells would have gone dry by now and we would have to relocate our pumping well systems elsewhere in inconvenient locations"

— Prof. AG Chachadi, Department of Earth Science, Goa University, Goa

CSE TEAM

Green area at the Goa University campus

corresponding saving on the water bill. In fact the capital cost incurred for RWH system at Site 1 involving surface water harvesting has been recovered in just 5 years. Site 2 involving rooftop harvesting payback of capital cost is projected to be recovered in next 5-6 years if one works out the unit cost of public supply water at the delivery end in Goa.[29]

The RWH system at university has resulted substantial increase in the aquifer yields is confirmed from the well yield tests carried out on two bore wells located in close proximity of the recharge structure during May 2009. Within one year of operation of the first recharge structure well yields have increased by 13 per cent to 15 per cent showing the recovery in the groundwater levels.[24] The improved yields also mean less electricity usage for pumping groundwater and savings in costs.

A water tanker of 10000 litres capacity costs around Rs. 800-1000/-. In economic terms the RWH system has resulted estimated Rs. 2.8 million per year savings to university that would otherwise be required to arrange water supply from water tankers.

"As neighbor within 3 kms from the site and as expert the RWH in the Goa campus is set up as an example for other institutes and commercial entities to show the benefits of RWH"
— Pradip Sarmokadam, Director, Lila Digital & Environmental Solutions Pvt Ltd, Goa

"The system as devised by Goa University, with or without modifications/alterations as per site conditions would go a long way in decreasing the load on the treated water supply and improve the water development scenario in Goa"
— Sandeep T Nadkarni, Chief Engineer & Ex-Officio Addl Secretary to Govt. of Goa, Water Resources Department, Goa

"The RWH system in Goa University campus has brought about a change in the state. This has been serving as a place of learning on resource conservation especially by the high school students and individuals. Besides this, the Government of Goa after seeing the success of these experiments has made RWH a mandatory for industries, housing colonies and institutions in the state"
— Prof. AG Chachadi, Department of Earth Science, Goa University, Goa

AG CHACHADI

School student group at RWH site

Environmental benefits

The reduced pressure on the public water supply system and improved recharge has a positive environmental impact. At small scale, the system contributes toward the resource conservation. This activity can also earn carbon credit in terms of energy conservation for in-situ water augmentation on Campus instead of sourcing water from distant sources of water supply.[29] The increase in availability of water has also contributed university maintain its lush green landscape round the year and improvement in the micro climate.

Social impact

The RWH system implemented on the campus has become a platform of creating awareness, information dissemination, and learning about groundwater conservation methods. Various stakeholders NGOs, government officers, school children, and citizens), industry representatives, researchers regularly visit the site.

Prof. Chachadi and team have developed a module of teaching for the villagers and other stake holders and organise workshops at panchayat and school levels to disseminate the experience and create awareness about water and its quality.[24,29]

The International Centre, Goa located adjacent to university has also installed RWH systems after the success at University. The centre harvests 2.5 million litre rainwater.[30] The university RWH has influenced and encouraged several institutes and industries in Goa to implement of RWH structures.

Implications and Conclusion

The modern water management relies heavily on the cost intensive long distance transfer of water to meet the widening demand-supply including overexploitation of in-situ groundwater resources. The sustainable water management requires understanding the value of rain, and to make optimum use of rainwater at the place where it falls. With rapid urbanisation and greater areas coming under roofs and concrete structures the water utilities have focused on augmentation and failed to combine traditional wisdom with modern engineering.

The report discusses both case studies with over arching framework of different rainfall agro-climatic region – low / scanty and very high rainfall and defines type of RWH implemented within context. In both cases it is clearly evident that the selection of system is site and context specific. For planning and delivery of any RWH the information and data to be considered include: geological boundaries; hydraulic boundaries; inflow and outflow of waters; storage capacity; porosity; water resources available for recharge, natural recharge; water balance; depth of aquifer and tectonic boundaries that may vary from site to site.

The framework presented in the report is drawn on geographical focus and variation of rainfall in different regions. But the framework presented in this report with help of case studies may not be applicable in all cases, and there may be other more specific context for particular cases.

The report with the help of case studies seek to encourage discussion within ULBs or water management organisations on potential of mainstreaming RWH about what they are doing at present and raising questions about what they want to do in the future.

It is time that municipal and other government bodies make determined efforts to mainstream RWH. The sustainable water management requires understanding the value of rain, and to make optimum use of rainwater at the place where it falls.

Each town / city should value each raindrop and need to understand that unless we are prudent, indeed frugal, with our use of this precious resource, there will never be enough water for all in town and cities.

REFERENCES

1. UNICEF *et al* 2013 'Water in India: Situation and prospects'

2. Shankar *et al* 2011, 'India's groundwater challenge and the way forward', Economic & Political Weekly, 46(2011), 37

3. JnNURM, 'JawaharLal National Urban Renewal Mission. Primer: 03- Revision of byelaws to make rainwater harvesting mandatory: Optional reform under JNNURM,' 2005, http://jnnurm.nic.in/wp-content/uploads/2011/01/Optional_Primer_primer.rainwater.pdf

4. Grant Thornton 2011, 'Appraisal of Jawaharlal Nehru National Urban Renewal Mission (JnNURM)'. (Vol. 1)

5. Neale *et al* 2006, 'Preparing a case study: A guide for designing and conducting a case study for evaluation input', Pathfinder International

6. RK Yin 2009, 'Case study research: Design and methods (Vol. 5)'. California: Sage publications.

7. John Creswell 2003, 'Research design: Qualitative, quantitative, and mixed method approaches'. Second Edition. Thousand Oaks: Sage Publications, Inc.

8. HJ Rubin and IS Rubin 2005, 'Qualitative interviewing: The art of hearing data'. Second Edition. Thousand Oaks: Sage Publications, Inc.

9. Environmental Protection Agency 2002, 'Community culture and the environment: A guide to understanding a sense of place' U.S. EPA (EPA 842-B-01-003), Office of Water, Washington D.C.

10. Interview with A Mridul, principal architect, *Birkha Bawari*, Jodhpur, September 19, 2013

11. PC Chatterji and S Singh 1980 'S. Proceedings of Indian National Science Academy', in Geology Hydrogeomorphology Geomorphological Studies for exploration of ground water in Rajasthan desert No. 5, 509-518

12. Sunita Narain and RK Srinivasan 2012, 'Excreta Matters: 71 cities- a survey', Centre for Science and Environment

13. NIH 'Annual Report 2011-2012', National Institute of Hydrology. Central Ground Water Board. Ministry of Water Resources, Government of India. New Delhi, 2012

14. Interview with OP Poonia, central ground water board, Jodhpur, January 7, 2014

15. Interview with A Khan, architect and supervisor, Umaid Heritage, Jodhpur, January 6, 2014

16. Interview with A Mridul, principal architect, *Birkha Bawari*, Jodhpur, January 6, 2014

17. Devyani Jayakar 2012, '*Birkha Bawari*- a modern stepwell', Inside Outside, September (2012) 134-142

18. A Mridul 2012, '*Birkha Bawari*', Indian Architect & Builder, November 2012

19. A Mridul 2012, 'A linear step well', Architecture + Design, December (2012)117-124

20. Interview with K Jain, resident, Umaid Heritage, Jodhpur, January 6, 2014

21. Interview with CV Arora, charatered accountant, Umaid Heritage, Jodhpur, January 6, 2014

22. Interview with A Mathur, marketing manager and resident, Umaid Heritage, Jodhpur, January 6, 2014

23. Interview with Dr. Bharadwaj, resident, Umaid Heritage, Jodhpur, January 7, 2014

24. Interview with Professor A Chachadi, Goa University, Goa, September 4, 2013; November 11, 2013; October 30, 2013; December 11, 2013

25. Goa Weather, http://www.goaweather.co.in/, accessed on September 24, 2013

26. Interview with ST Nadkarni, Chief Engineer & Ex-Officio Addl Secretary to Govt. of Goa, Goa water resources, January 6, 2014

27. N Kamat, 'Unique rainwater harvesting project at Goa University', 2007, http://lists.goanet.org/pipermail/goanet-goanet.org/2007-June/144337.html, accessed on September 24, 2013

28. AG Chachadi 2009, 'Hydrogeology and water availability status in the State of Goa' in Natural Resources of Goa: A Geological Perspective, (eds) A Mascarenhas and G Kalavampara, Geological Society of Goa, India, 119-147

29. Interview with Professor A Chachadi, Goa University, Goa, January 14, 2014

30. Interview with KA Zickriya, assistant general manager, The International Centre Goa, January 2, 2014