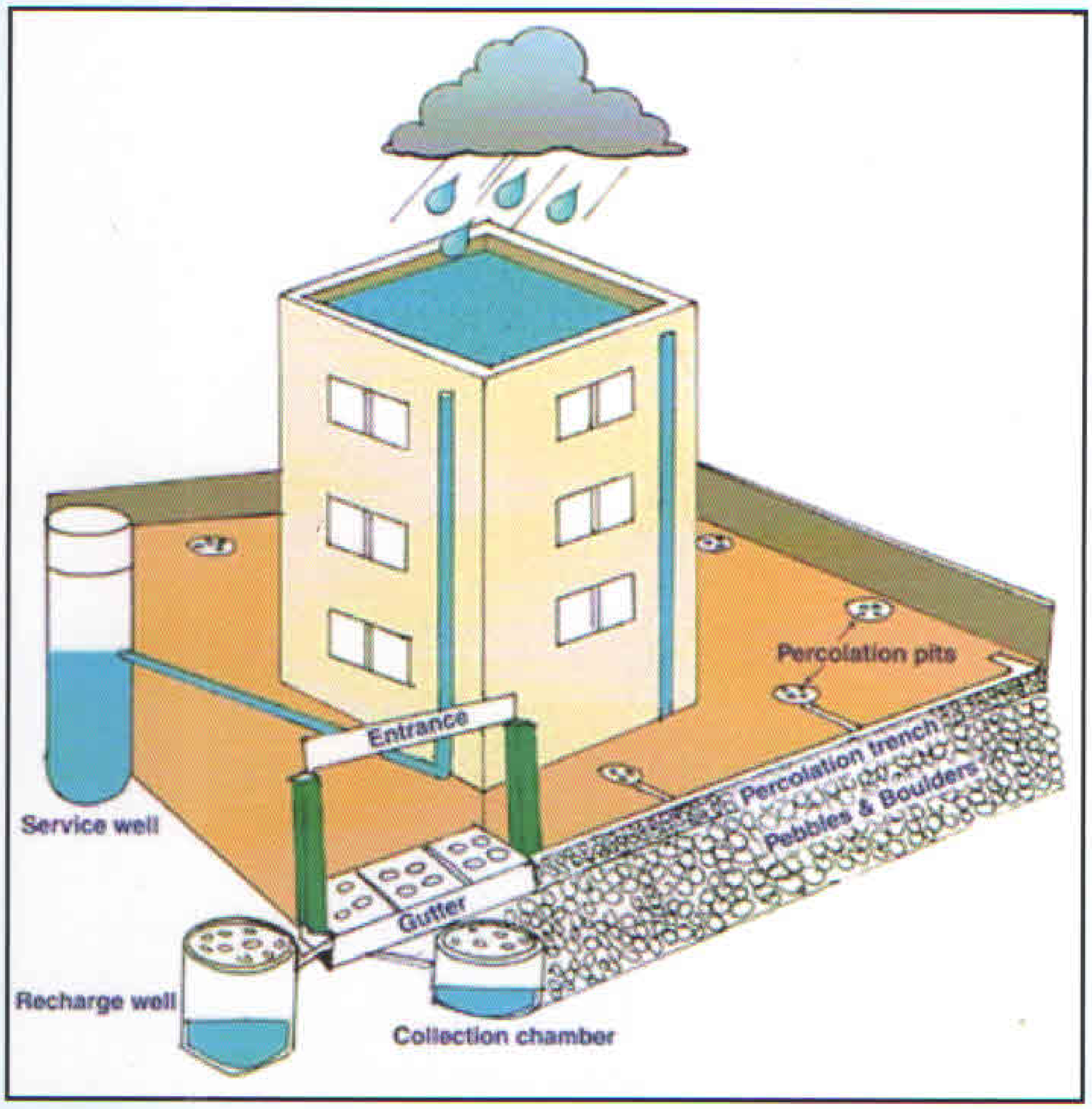
WORKSHOP ON WATER CONSERVATION AND SUSTAINABLE MANAGEMENT OF GROUND WATER IN NATIONAL CAPITAL REGION



Edited By

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New Delhi
March 2014

WORKSHOP ON WATER CONSERVATION AND SUSTAINABLE MANAGEMENT OF GROUND WATER IN NATIONAL CAPITAL REGION

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सुशील गुप्ता
अध्यक्ष
केन्द्रीय भूमि जल बोर्ड
जल संसाधन मंत्रालय
भारत सरकार
नई दिल्ली

सत्यमेव जयते

Sushil Gupta
Chairman
Central Ground Water Board
Ministry of Water Resources
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New Delhi

MESSAGE

Water resource development including ground water in the country is at cross roads. The sustainability of water resources has been endangered by vagaries of rainfall and over-development. The rapid increase in industrialisation, urbanisation and agricultural development coupled with burgeoning population have posed stress on the available water resources. In order to ensure the availability of water on sustainable basis, it would be essential to adopt suitable water conservation strategies. Besides judiciously managing and regulating the development of ground water resources, there is utmost need to adopt measures to augment ground water resources.

I am glad to note that Central Ground Water Board, State Unit Office, Delhi is organizing a Regional Workshop on "Water Conservation and Sustainable Management of Ground Water in National Capital Region" on 25th March, 2014 at New Delhi. The prime objective of this workshop is to create a platform for dissemination of information and sharing of knowledge amongst Central and State Government Organizations, Non Government Organizations and Academicians. I hope that the deliberations of this workshop would culminate in bringing out recommendations which will provide useful inputs to policy makers, resource managers and users.

I would like to appreciate the efforts of Dr. Uma Kapoor, Officer In charge, State Unit Office, Delhi and her team of officers and staff for successful organization of the event.

(SUSHIL GUPTA)

New Delhi

21st March, 2014

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ADVANCEMENT IN RAIN WATER HARVESTING SYSTEMS

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Abstract:

Development in different areas of the country has not been uniform. Highly intensive development in certain areas has resulted in over exploitation of traditional sources of water, leading to decline in the ground water table and sea water intrusion in coastal areas. Ironically majority of industrial hubs in India are largely dependent on groundwater (GW). In order to augment the depleting ground water resources, it is pivotal to strategically adopt advanced and more efficient systems, ensure proper functioning of the systems after implementation, and modular technology is certainly an exceptional solution at the moment.

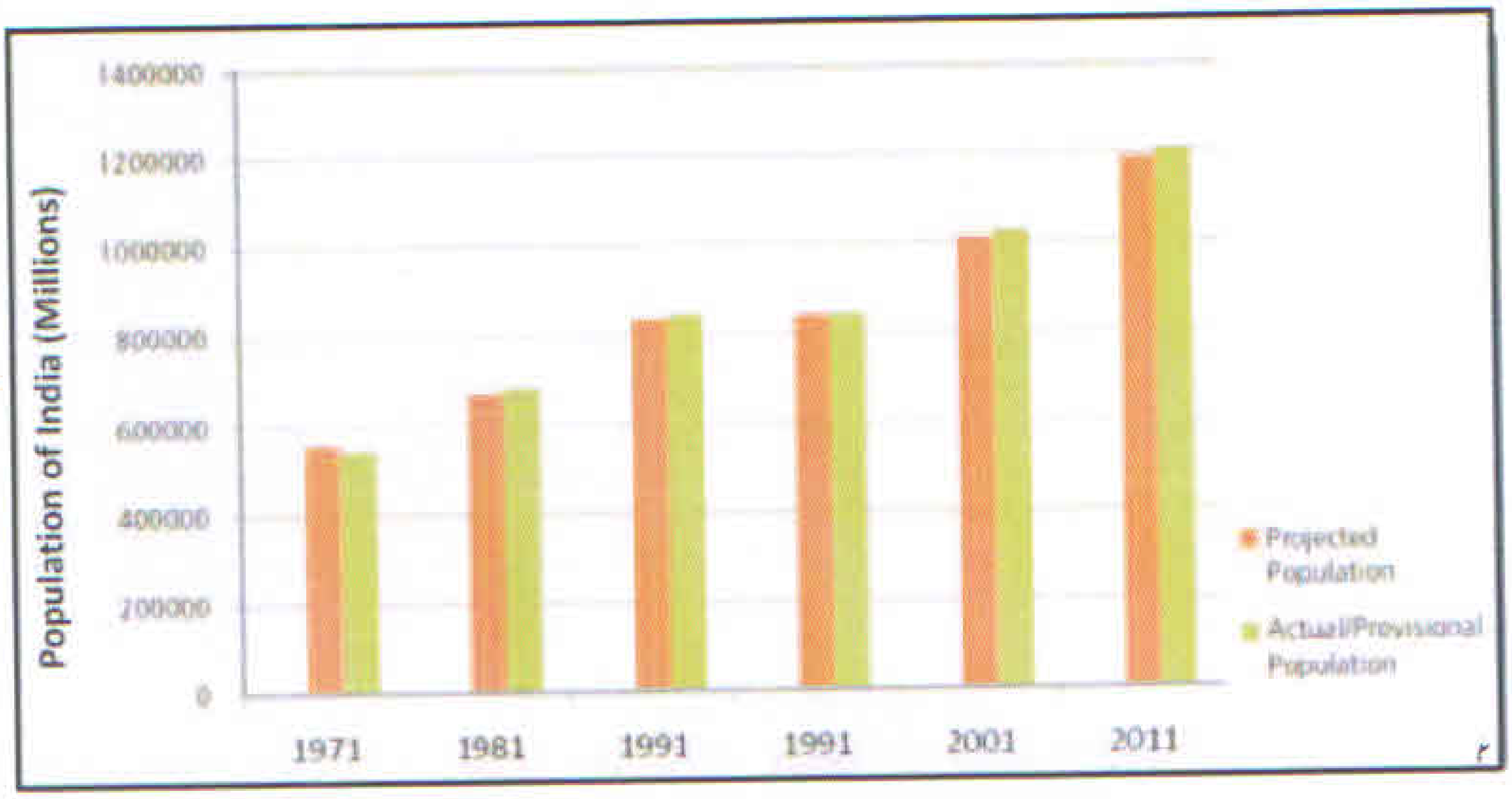
Over the past decade, conventional recharge structures like recharge pits and trenches, constructed with brick, stone or concrete and using gravel and sand as filter media, have been adopted due to their low initial cost. Although these structures are ideal for impoverished regions where efficiency is not a priority, their application in water intensive urban areas should be strongly contested as they clog frequently and fail to meet their intended purpose, as commonly observed. This is no longer acceptable, considering that GW abstraction is permitted in high stress areas based on adoption of equivalent GW recharge measures. Insufficient recharge would lead to unsustainable abstraction eventually resulting in dry-wells. This would mark the absolute disaster and a point of no return. Hence for sustainable practice, it is crucial to keep pace with advancement in technology and embrace only the most efficient designs available to ensure that initiatives taken yield optimum results long term.

In this paper, we present and compare benefits and disadvantages of currently adopted rainwater harvesting (RWH) and GW recharge structures with an innovative and advanced Modular Technology. Working of the modular system is presented along with test results and data from projects completed in India and Japan.Based on several years of research, test results, and performances of currently installed structures, modular technology is recommended to replace conventional methods of RWH and GW recharge in water stressed regions and industrial hubs.

Introduction:

The earth's population is projected to double from the present 5.6 billion to about 10 billion by the year 2050 (State of World Population Report, 1993, U.N. Population Fund). Most of this increase will occur in the Third World; where close to 90% of the world population will then live. Also, people will continue to migrate from rural areas to cities and already by the end of this century, there will be 22 mega cities (population more than 10 million), 18 of which will be in the Third World. Such cities have mega water needs, produce mega sewage flows, and will have mega problems. Already now, it is estimated that half the people in theThird World have no access to safe drinking water, that one billion get sick every year from waterborne diseases, and that 12 million die, 80% of which are children. Also, more water will be needed for irrigation of crops to provide enough food for the expanding population.

The reality of water crisis cannot be ignored. India has been notorious of being poor in its management of water resources. The demand for water is already outstripping the supply. Majority of the population in the cities today are groundwater (GW) dependent. In spite of the municipal water supply, it is not surprising to find people using private tube wells to supplement their daily water needs. As a result, the GW table is falling at an alarming rate. Extraction of GW is being done unplanned and uncontrolled. This has resulted in:



Years

Fig 1. Population of India 1971 – 2011(Source: Census of India 2011).

1. Hydrological imbalance

2. Deterioration in water quality

3. Rise in energy requirements for pumping

A study carried out by NASA collecting data over a period of six years found that GW levels have been declining by an average of one meter every three years (one foot per year). More than 109cubic km (26cubic miles) of GW disappeared between 2002 and 2008 – double the capacity of India's largest surface reservoir, the Upper Waingangâ, and triple that if Lake Mead, the largest man-made reservoir in the United States. The loss is particularly alarming because it occurred when there were no unusual trends in rainfall. In fact, rainfall was slightly above normal for the period.

The northern Indian states of Rajasthan, Punjab, and Haryana have all of the ingredients for GW depletion: staggering population growth, rapid economic development and water-hungry farms, which account for about 95% of GW use in the region. Figure 3 shows the status of GW development in the tri-state region (www.nasa.gov).

Uncontrolled disposal of industrial effluents and sewage of cities into rivers and other water bodies has also resulted in contamination of GW. Hence, immediate remedial actions need to be undertaken to avoid a national water crisis.

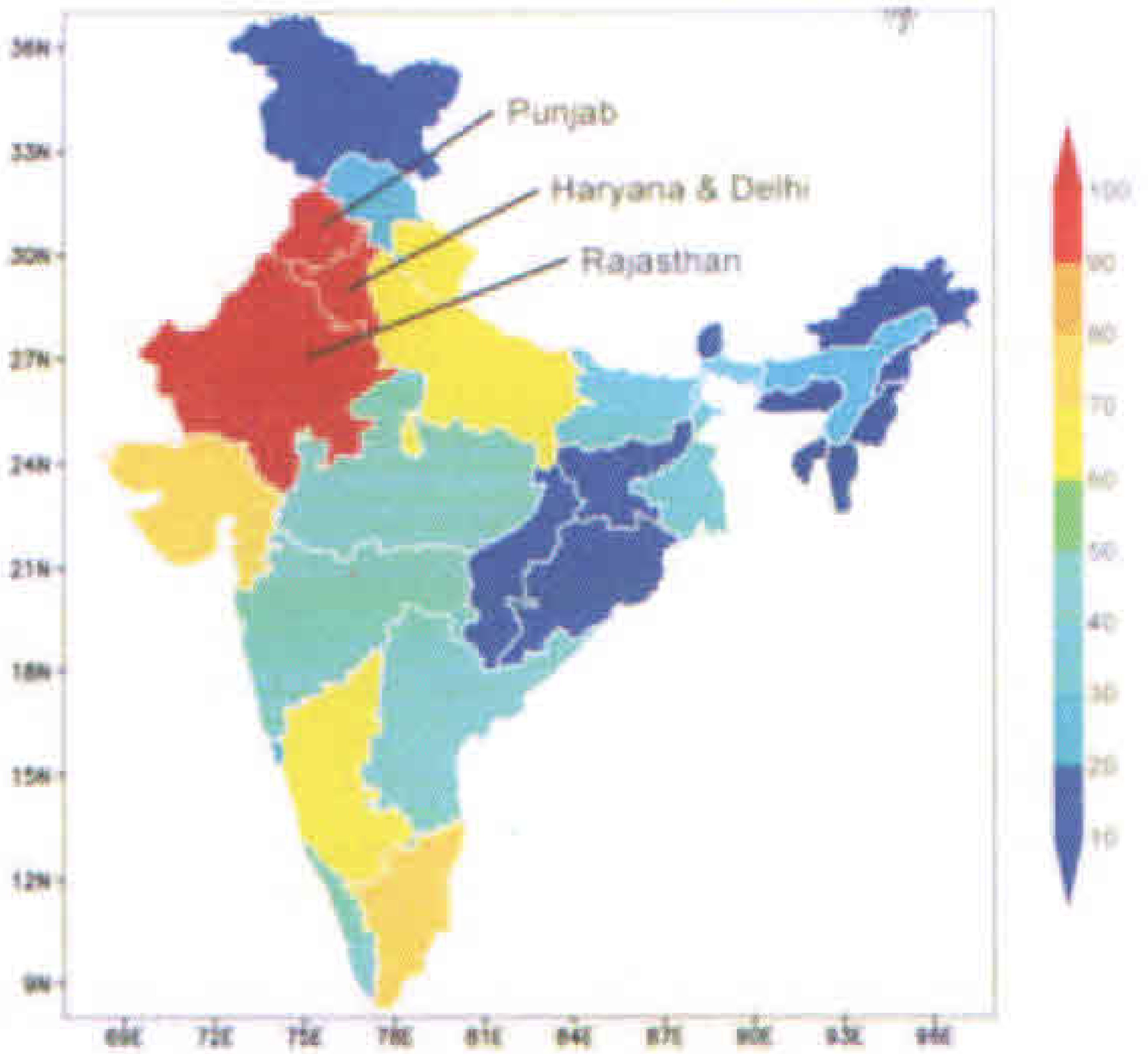


Figure 2: Shows groundwater withdrawal as a percentage of groundwater recharge based on state-level estimates of annual withdrawals and recharge reported by India's Ministry of Water Resources. Source: www.nasa.org

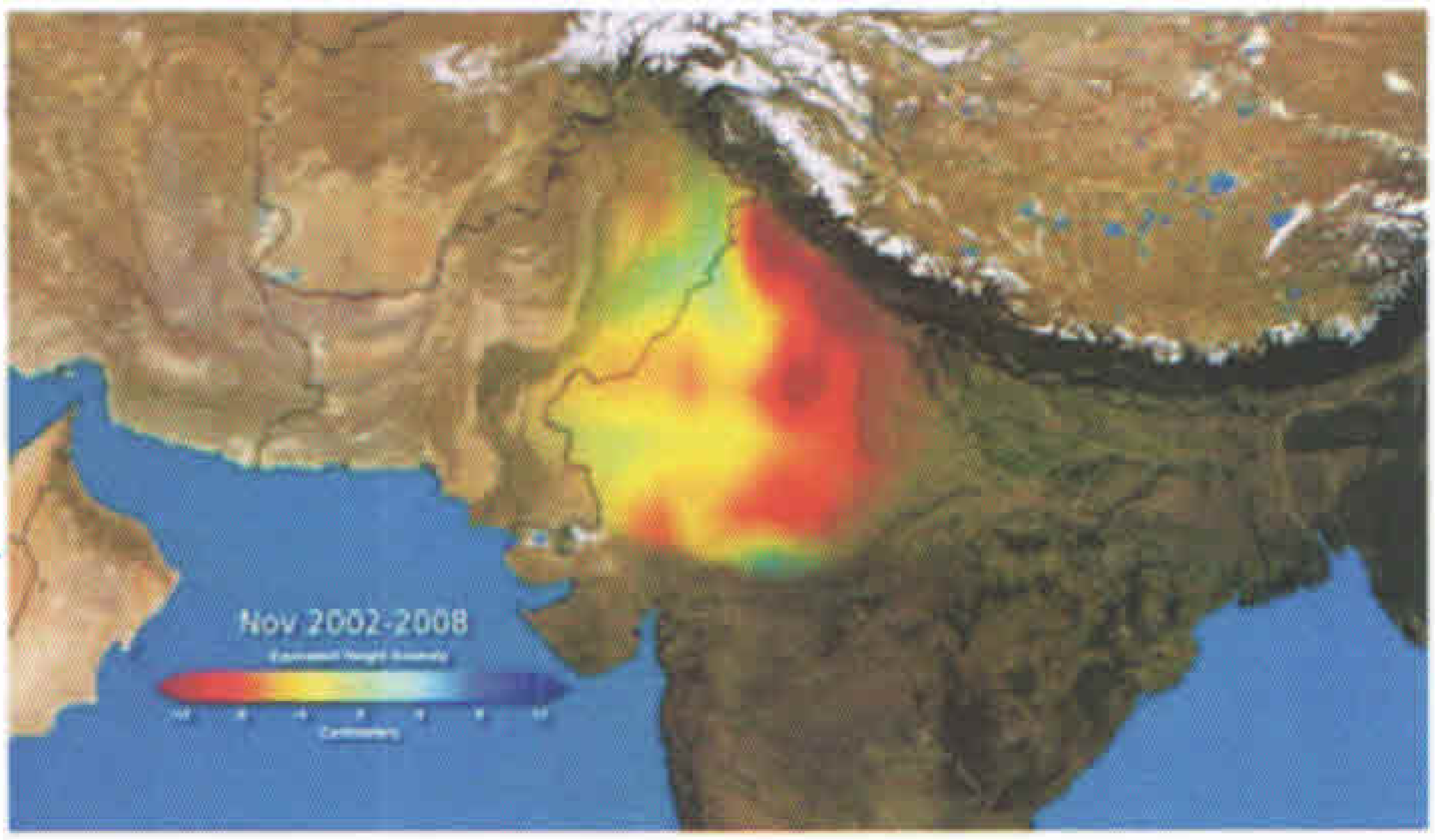


Figure 3: As animated here, groundwater storage varied in northwestern India between 2002 and 2008, relative to the mean for the period. These deviations from the mean are expressed as the height of an equivalent layer of water, ranging from -12 cm (deep red) to 12 cm (dark blue). Source: www.nasa.org

Rain Water Harvesting in the Urban Environment

Rain Water Harvesting (RWH) techniques have been utilized throughout time as some irrigation methods have been used by the people of Ur (present Iraq) around 4500 BC and are even at present used in India (Khadin structures). Today RWH is being used worldwide for drinking (human and livestock) and agricultural purposes. Although RWH has been practiced for generations, the concept of recharging harvested rainwater to GW has received very little consideration, but recently, with the increasing pressure on available water resources, renewed interest has emerged.

Traditional Approach for GWRecharge

The storage of rain water on surface is a traditional technique and structures used were underground tanks, ponds, check dams, weirs, etc. Recharge to ground water is a fairly new concept (past decade or so) of RWH and the structures generally used are

Pits: - Recharge pits are constructed for recharging the shallow aquifers. These are constructed 1 to 2 m. wide and 2 to 3 m. deep which are back filled with boulders, gravels & coarse sand.

Trenches: - These are constructed when the permeable strata is available at shallow depths. Trench may be 0.5 to 1 m. wide, 1 to 1.5 m. deep and 10 to 20 m. long depending upon availability of water. These are back filled with filter materials.

Dug wells: - Existing dug wells may be utilised as recharge structure and water should pass through filter media before putting into dug well.

Recharge wells:- Recharge wells of 100 to 300 mm. diameter are generally constructed for recharging the deeper aquifers and water is passed through filter media to avoid choking of recharge wells.

Recharge Shafts:- For recharging the shallow aquifers which are located below clayey surface, recharge shafts of 0.5 to 3 m. diameter and 10 to 15 m. deep are constructed and back filled with boulders, gravels & coarse sand.

Spreading techniques: - When a permeable stratum starts from top then this technique is used. Spread the water in streams/Nalas by making check dams, nala bunds, cement plugs, gabion structures or a percolation pond may be constructed.

Conventional Recharge Structures

A typical conventional recharge structure consists of an excavated pit lined with a brick/stone/concrete wall and refilled with porous media like pebbles, boulders or broken bricks, and river sand, which act as the "filter media"andcovered with perforated concrete slabs wherever necessary.Size of the tanks may vary as per the amount of runoff expected. The recharge tanks should be periodically cleaned of accumulated debris to maintain the intake capacity. In terms of recharge rates, these are relatively less effective since the soil strata at a depth of about 1.5 metres, is generally less permeable. In order to facilitate speedy recharge, boreholes are drilled at regular intervals in this trench. A schematic of a typical conventional recharge structure is shown in Figure 4.

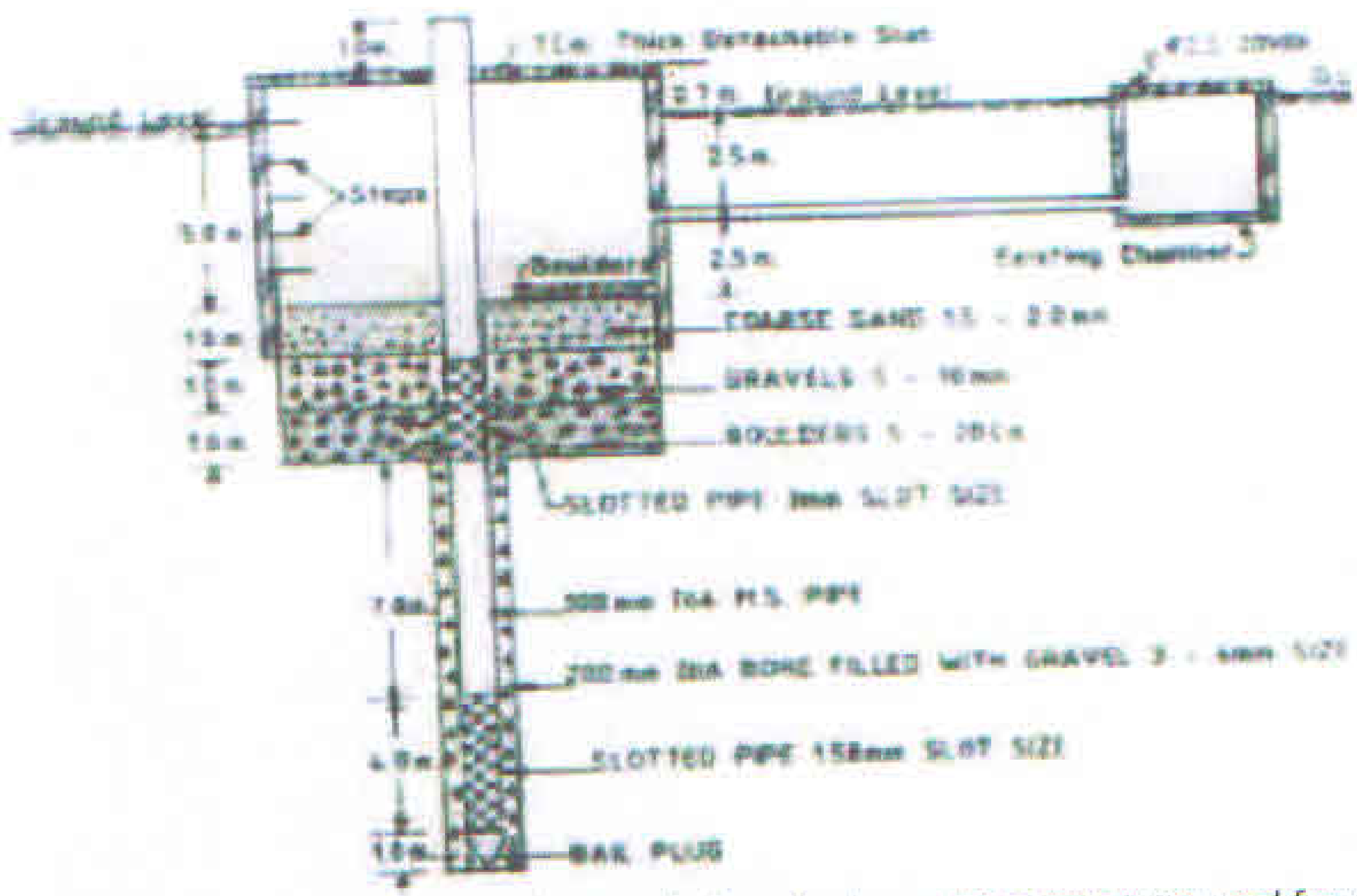


Figure 5: Schematic diagram of a typical conventional rainwater harvesting structure used for groundwater recharge

Conventional systems are predominantly adopted in India owing to their relatively low cost of construction and simplistic design. They are ideal for harvesting small quantities of rainwater from rooftops of residential buildings and in remote impoverished regions where efficiency is not a priority. However, these are highly susceptible to clogging due to vertically settling impurities in water and floating matters which occupy the pores within the top layer. As the top layer gets chocked, the rate of percolation of water to the well reduces rapidly severely affecting the efficiency of the system.Some of the major advantages and disadvantages of conventional systems used for recharging GW are presented in the following section.

Advantages

- Locally available materials are used for construction
- Skilled workers are not necessary
- Lower initial cost
- Ideal where efficiency is not a criteria

Disadvantages

- Inefficient: clogs frequently owing to internal filtration media
- Large foot print: Filter media occupies 30-40% volume of the tank, andempty space above standing water up to ground level

- Accumulation of foul gases: Due to deterioration of organic matter in the standing water
- Accident prone:Due to hollow structure
- Maintenance is tedious, time consuming and expensive: Sludge and filtration media needs to be completely removed and flushed,
- Standing water – poor quality, mosquito breeding ground

In the absence of financial incentives, laws, or other regulations to encourage landowners to maintain RWH or GW recharge structures adequately, the wells may fall into disrepair and ultimately fail to serve their purpose. Although this may not have significant impacts in regions with ample water resources, it would pose devastating consequence on future development or even sustenance of population at areas dependent on GW.It should be noted that many of the Indian states are classified as either "Critical" or "Overexploited" in terms of GW use. Categorization of different blocks of Indian states into these segments is presented in Table 2.It is crucial to envisionthe economical and social ramifications of continued unsustainable abstraction of GW in these areas, and imperative to take preventive measures to avert agitation and colossal distress.

Sustainable Development

Most of the major drawbacks of conventional methods of artificial recharge to GW may be minimized or eliminated, simply by adopting more advanced technologies specifically designed for achieving significantly higher efficiency. Modular technology is one of the latest innovations in effective water management that has been implemented around the globe over the past 11 years and proven for efficiency, water quality, and for its unison with sustainable development. Following sections provide working of a typical modular system, its various components, results of tests, and their benefits in detail.

Table 2:

CATEGORIZATION OF BLOCKS/ MANDALS/ TALUKAS IN INDIA

Sl. No.	States / Union Territories	Total No. of Assessed Units	Safe		Semi-critical		Critical		Over-exploited		Remarks
			Nos.	%	Nos.	%	Nos.	%	Nos.	%	
	States										
1	Andhra Pradesh	1231	760	62	175	14	77	6	219	18	-
2	Arunachal Pradesh	13	13	100	0	0	0	0	0	0	-
3	Assam	23	23	100	0	0	0	0	0	0	-
4	Bihar	515	515	100	0	0	0	0	0	0	-
5	Chattisgarh	146	138	95	8	5	0	0	0	0	-
6	Delhi	9	2	22	0	0	0	0	7	78	-
7	Goa	11	11	100	0	0	0	0	0	0	-
8	Gujarat	223	97	43	69	31	12	5	31	14	Rest 14 talukas- Saline
9	Haryana	113	42	37	5	4	11	10	55	49	-
10	Himachal Pradesh	5	5	100	0	0	0	0	0	0	-
11	Jammu & Kashmir	8	8	100	0	0	0	0	0	0	-
12	Jharkhand	208	208	100	0	0	0	0	0	0	-
13	Karnataka	175	93	53	14	8	3	2	65	37	-
14	Kerala	151	101	67	30	20	15	10	5	3	-
15	Madhya Pradesh	312	264	85	19	6	5	2	24	8	-
16	Maharashtra	318	287	90	23	7	1	0	7	2	-
17	Manipur	7	7	100	0	0	0	0	0	0	-
18	Meghalaya	7	7	100	0	0	0	0	0	0	-
19	Mizoram	22	22	100	0	0	0	0	0	0	-
20	Nagaland	7	7	100	0	0	0	0	0	0	-
21	Orissa	314	308	98	0	0	0	0	0	0	Rest 6 blocks- Saline
22	Punjab	137	25	18	4	3	5	4	103	75	-
23	Rajasthan	237	32	14	14	6	50	21	140	59	Rest 1 block- Saline
24	Sikkim	1	1	100	0	0	0	0	0	0	-
25	Tamil Nadu	385	145	38	57	15	33	9	142	37	Rest 8 blocks- Saline
26	Tripura	38	38	100	0	0	0	0	0	0	-
27	Uttar Pradesh	803	665	83	88	11	13	2	37	5	-
28	Uttaranchal	17	12	71	3	18	0	0	2	12	-
29	West Bengal	269	231	86	37	14	1	0	0	0	-
	Total States	**5705**	**4067**	**71**	**546**	**10**	**226**	**4**	**837**	**15**	**-**
	Union Territories										
1	Andaman & Nicobar	1	1	100	0	0	0	0	0	0	-
2	Chandigarh	1	1	100	0	0	0	0	0	0	-
3	Dadra & Nagar Haveli	1	1	100	0	0	0	0	0	0	-
4	Daman & Diu	2	0	0	1	50	0	0	1	50	-
5	Lakshdweep	9	6	67	3	33	0	0	0	0	-
6	Pondicherry	4	2	50	0	0	0	0	1	25	Rest 1 Region- Saline
	Total Uts	**18**	**11**	**61**	**4**	**22**	**0**	**0**	**2**	**11**	**-**
	Grand Total	**5723**	**4078**	**71**	**550**	**10**	**226**	**4**	**839**	**15**	**-**

Methodology

Modular systems are designed to be very flexible and hence can be adopted according to the site conditions and circumstances. Since the tank is built by joining numerous small standard sized modules, the tank could be built in various shape and size, and to accommodate any volume of water without any challenges in construction. Modules could be designed to act in three different ways through slight variations in basic components such as 1) Storage and Reuse, 2) Percolation, 3) RWH and GW recharge.

Components involved in the installation of modular structures are presented in the following section,

- **First flush diverters, roof washers, drainage screens:** These are provided to prevent large volume of suspended solids carried along with runoff following the first rainfall event, and large floating material like leaves, rags, twigs, plastic trash, etc respectively.
- **Recharge wells (only in case of aquifer recharge):**Similar to conventional practice, recharge wells are installed to increase the rate of percolation of water into the aquifers. (Picture 2)
- **External filtration units:** In-house research and effort to address large volumes of suspended solids in runoff without compromising the efficiency of the recharge structure has led to the development of **"Pure Rain - Silt and Oil Filter"** designed specific to Indian urban conditions, which works on the basic principle of strainers and lamellar settling and incorporates innovative modifications to achieve clog-free and efficient removal of silt and oil from the collected rainwater. Additionally, a patented **"micro filter"** with long fiber foam is provided to eliminate finer particulate matter up to 300microns in size, prior to diverting the water into Modular Tanks.
- **Geotextile:**These are permeable fabrics which have the ability to separate and filter particulate matter, reinforce and protect the modular tank, or act as a drain. Thesearemade of strong material with micro pores (two layers creates a microne porosity of 80 micron) for preventing impurities and soil from entering into the tank as well as to provide stability to the structure. Modules are wrapped and sealed with geotextile and together they form the "Modular Tank".
- **Water-proof liner (only in case of Storage and Reuse):**Modular percolation pit could be easily converted into a storage tank simply by providing a water-proof liner manufactured from the latest technology resin, which is both tough and durable, and sandwiched between two layers of geotextile. This composite layer is then wrapped around the modules to form a "storage tank" which may be used as a detention tank or for reuse.
- **Modules:** Modules make up the core of the structure;manufactured using 85% recycled Co-polypropylene. Available in 2 different sizes and various load bearing matrrix allowing heavy vehicular movement, these may be arranged in any shape or size depending on the site conditions and space availability. As the modules are manufactured offsite (In **India** also to qualify for Green Building rating) and does not involve any masonry or concrete work, installation time is phenomenally lesser than conventional structures. Under ideal conditions installation of a 100cum capacity tank may take 3-4 days in comparison to over a month for conventional methods.Recent installation in DLF Okhla Prime tower, India of a 60 cum capacity tank in October 2013 was completed in 48 hours.
- **Observation Wells:** Since the modular tanks are designed to be maintenance free, observation wells are installed to ensure the quality of stored water, proper functioning of the system, and to act as air vents, (**Proudly Developed In India**) Recently we installed a fire water holding tank to be fed by Rainwater as well at Berger Paints Nagpur.

Working of a typical Modular Structure used for RWH and GW recharge

Water inflow to the Cross Wave occurs in two ways. 1) Polymer Modules are wrapped completely with geotextile with high porosity but very small pore size. This unit is overlain by fine sand. Runoff flowing over the tank seeps through the sand and only relatively pure water reaches the tank. 2) Pipes from the catchment areas are diverted to external filtration units to remove all impurities and relatively pure water is allowed to flow into the tank. Typical working of a modular structure is presented in Figure 6 along with images of installations (Picture 1).

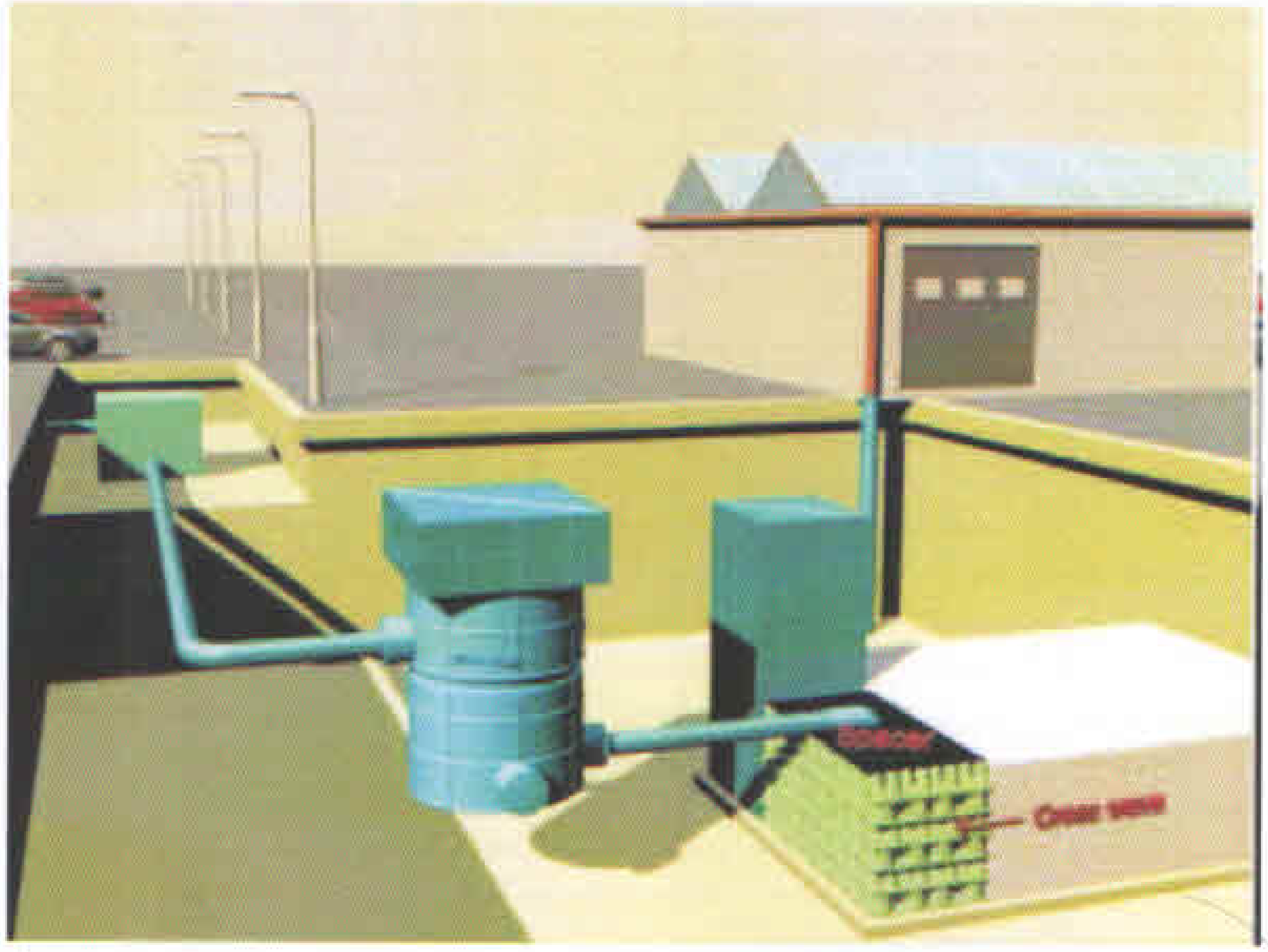
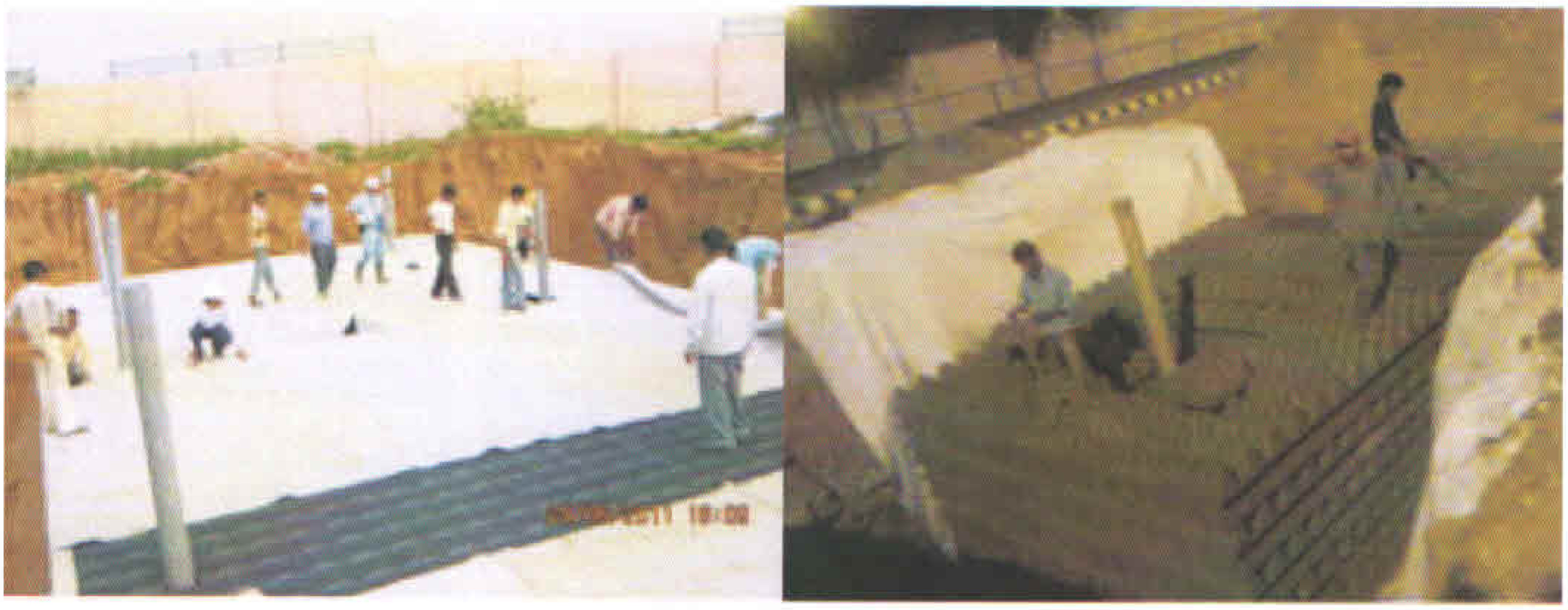


Figure 6: Schematic diagram showing cross sectional view of a typical modular RWH system and flow paths into the tank and to the groundwater

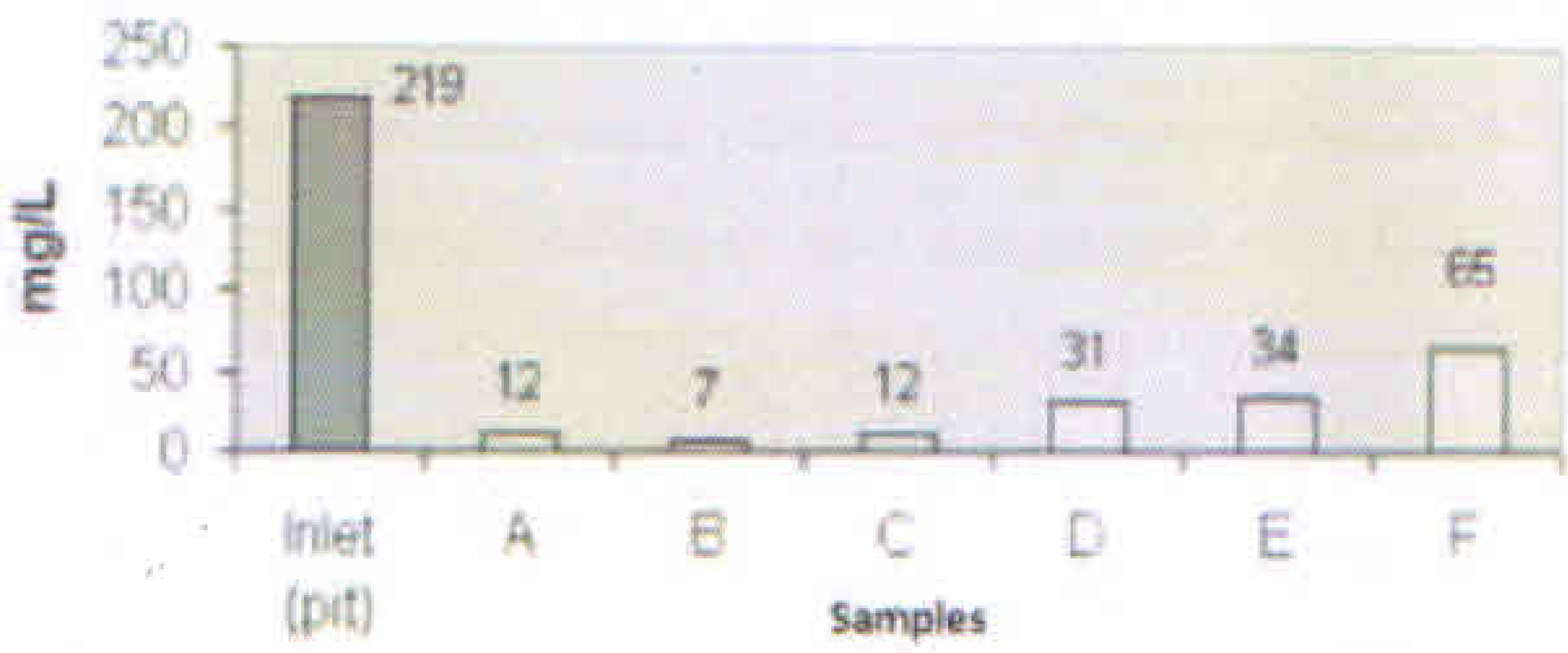


Picture 1: Showing installation of modular tanks at Honda Scooters and Motercycles In Tapukra, Rajasthan and Bangaluru and Metro Rail Delhi.

Test Results

One of the studies on the efficiency of modular structures to remove suspended particulate matter in the runoff is presented below -

The objective of this undertaking was to measure the quality of water stored in the modular tank or recharged into the GW. The system was designed to accept raw storm water runoff from a curb gutter. Received runoff was allowed to percolate through amended soil layer into designated modular percolation tanks. Water from these percolation tanks was collected and analyzed in comparison with the influent runoff. Results are shown in Figure 5. Evidently quality of water stored within the modular tanks is effectively free of turbidity. Through the adoption of "external" filtration which prevents deposition of organic suspended solids inside the tank, degradation will be substantially reduced improving the quality of stored or recharged water.



The soil profiles of each pit tested are as follows

A = existing soil
B = cleaned washed sand
C = existing soil with 5% Zeolite
D = existing soil with 10% Zeolite
E = existing soil with 5% Zeolite and bacterial agents
F = existing soil with 10% Zeolite and bacterial agents

Figure 7: Depicting quality of water stored within the modular tanks.

Size Comparison of Modular and Conventional recharge structures

One of the major drawbacks of conventional systems is the large footprint. Filter media generally used are pebbles, boulders or broken bricks, and river sand (**Mining of the same on large scale is also posing threat to the environment**) with a void ratio of 50-60%, which implies that as much volume is unaccountable for storage capacity. Additionally, it is a common practice to provide a free board of 0.5m which is unused for storage throughout the lifespan of the structure. These are addressed in Modular design which eliminates free board and has upto 95.6% void ratio. Advanced design enables the modular structures to have significantly smaller footprintto accommodate equivalent volume of runoff. Following table provides comparison of the actual sizes of tanks installed in Rajasthan, India using conventional and modular design to accommodate 1,200cum volume of rainwater. Owing to the innovative design of modular structure, footprint was reduced by nearly 40% as compared to conventional recharge trench.

Table 3: Comparison of tank sizes of structures designed for RWH and GW recharge and installed at Honda Motorcycle & Scooter India Pvt Ltd.

Recharge Pit Location	Proposed Artificial Structures using Conventional Method		Installed Artificial Recharge Structures using Cross Wave	
	Dimensions	No. of recharge wells	Dimensions	No. of Recharge Wells
Area Pit - 1	78m x 7.5m x 5.8m	18	32m x 7m x 2.07m	18
Area Pit - 2	58m x 7.5m x 5.8m	14	24m x 7m x 2.07m	14
Area Pit - 3	45m x 7.5m x 5.8m	10	19m x 7m x 2.07m	10
Area Pit - 4	29m x 7.5m x 5.8m	6	12m x 7m x 2.07m	6

Advantages

- **Clog-free function:** Owing to external filtration units and specific function of geotextile
- **Higher quality of stored or recharged water:** Owing to continuous movement of water within the structure with capilary action in geotextile and sand.
- **Economical to maintain:** No maintenance cost for the structure; as little as 10% of conventional methods for cleaning external filtration units
- **Easy and less labour intensive maintenance:** Designed to be cleaned by 1 person in 1-2 hours
- **Compact design:**up to 40% smaller footprint owing to 95% void ratio and elimination of unused space above inlet pipe.
- **Fast installation:** up to 75% shorter time of installation relative to conventional methods. A 100cum capacity tank may be installed in 3-4days as opposed to 4-8 weeks in case of conventional systems
- **Safer:** No hollow space or removable parts in the main tank. Hence confined space entry challenges of ISO 18000: OSHAS can be avaided.
- **Efficient land use:** Design allows for use of space above the structure for recreation, gardening, vehicle parking, etc.
- **Eco-friendly:** 85% post industrial used recycled material.

Disadvantages

- Requires skilled labour for installation of geotextile and modules
- Some of the materials need to be sourced from outside the country
- Supervision by a qualified person is required throughout the installation
- Initial cost may be slightly higher relative to conventional systems for small structures

Conclusion

Certain parts of India are experiencing tremendous development in terms of industries, infrastructure, and groundwater use. These developments are subjecting unprecedented stress on traditional sources of water, specifically groundwater, leading to severe depletion of GW table. Although there are limited water resources which are currently "over-exploited", abstraction of GW is being permitted primarily based on GW recharge measures adopted by the involved party, since development is an essential part of continued prosperity. Even though rainwater harvesting is implemented per the mandate by Central Ground Water Board, it is commonly observed that conventional systems used for GW recharge turn inefficientover a short period and fails to serve its crucial purpose.

Considering the state of GW depletion, inefficiency is unacceptable. Prolonged and unsustainable GW development in severely water stressed regions and industrial hubs may lead to dramatic decrease in GW quality as well as possibility of aquifers running dry, in which case, it is essential to foresee the incomprehensible cost of inefficiency. Vast numbers of advanced technologies are available to minimize or eliminate most of the major drawbacks associated with conventional systems. Several years of research on developing systems specific to Indian conditions have led to adoption of external filtration developed in-house in conjunction with Modular Technology, as the most effective system available for harvesting rainwater. Successful implementation of these systems around the globe(More than 3500 Installations in Japan) including more than 50 structutres in India over the past 10 years along with extremely positive test results provide sufficient level of confidence to replace conventional methods of RWH and GW recharge, until the emergence of more efficient technologies.

Being stewards of the environment, we understand that it is our responsibility to take the initiative to identify best available practices, recommend their adoption, and assist regulatory agencies to keep pace with advancement in technologies. Willingness to accept new innovations and a strong focus to achieve sustainable development should be our objective.

Additionally, mass movements where every individual, every society and urban settlements need to take responsibility in conserving the rain water and put an envelope on water use along the footsteps of best practices followed by the water scarce society of Rajasthan (Mishra, Anupam (1993): Aaj Bhi Khare Hai Talaband Mishra, Anupam (1995): Rajasthan ki Rajat boondey).In order to compliment the water conservation efforts,industries need to adopt zero discharge and its adoption must not be limitedtodesign.It should also be achieved in practice along with prompt and regular maintenance work.