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Bridging Water Demand and Supply in Delhi: The Potential of Rainwater Harvesting

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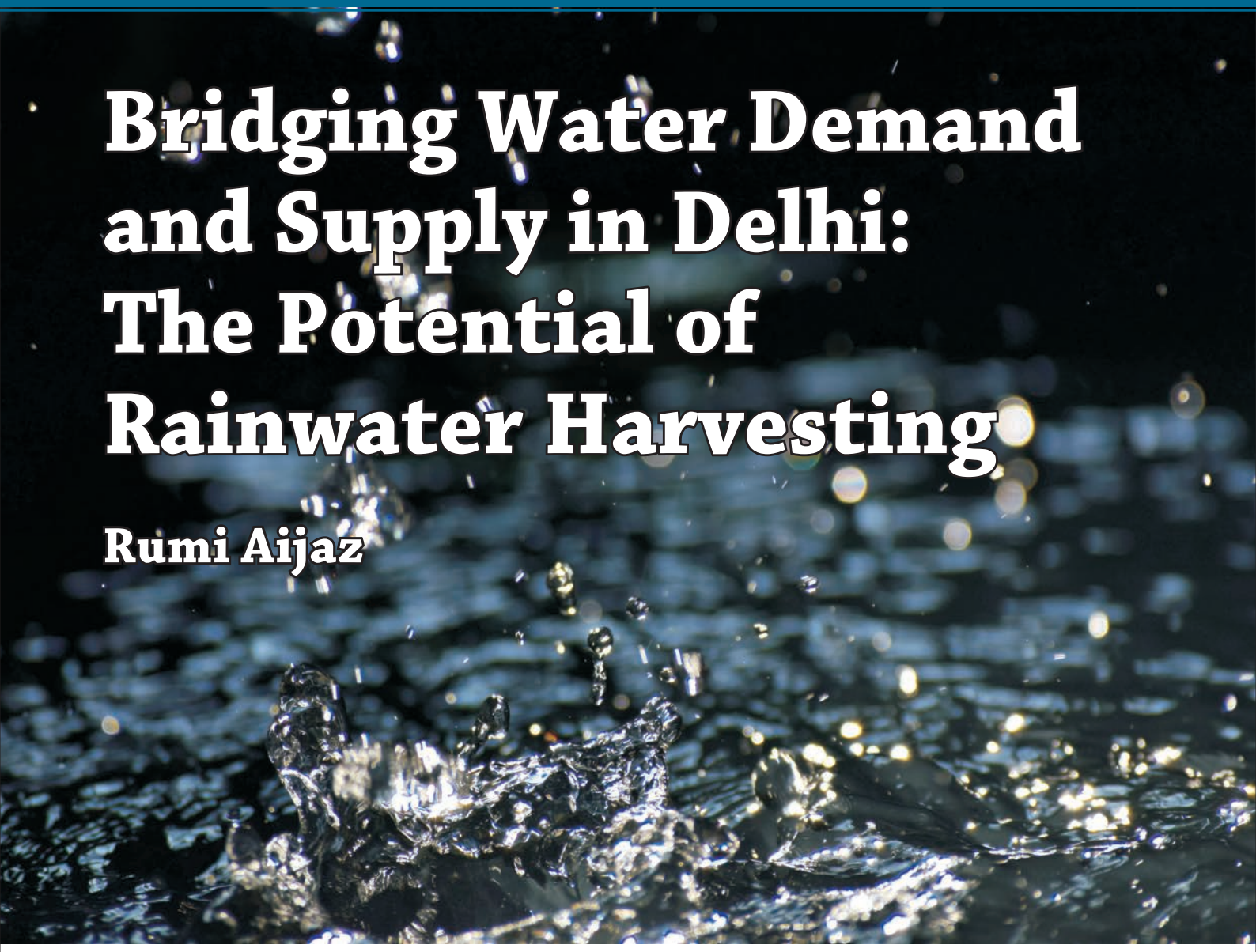

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ABSTRACT

The Delhi government is facing numerous challenges in managing water demand and supply in the capital, primary of which are water shortages and declining groundwater levels. One of the strategies that are being employed to address these issues is the promotion of rainwater harvesting (RWH). This report provides an account of the growth and development of Delhi's RWH sector. The analysis shows that while the programme has met with some success, its progress is hampered by various factors. The report recommends the proper positioning of institutional, governance and technical factors responsible for implementing the RWH policy, and a shift in focus from individual to neighbourhood-level systems.

WATER IN DELHI: AN OVERVIEW

Delhi, India's capital city, has a large population of about 20 million,[1] and demand for infrastructure and services is steep. One of the areas in which resources are stretched thinly is water—many households are either not receiving their required quantity through municipal pipelines, or are not connected to a piped network at all. Data shows that water demand is at 1,260 million gallons per day (mgd) and supply is at 937 mgd; this means that about 25 percent of the demand (or 323 mgd) is not being met.[2] Indeed, 17 percent of households do not have access to piped supply, and 13 percent of unauthorised colonies are not covered by any piped network.[3] Without sufficient access to water, large proportions of Delhi's population are adversely affected in their various water-dependent activities, such as sanitation, domestic activities, and horticulture, as well as construction, irrigation, and industry.

The Delhi Jal Board (DJB)—the city's water supply agency under the Delhi government—is making efforts to augment water production by obtaining greater volumes of raw water from surface water sources in the region. The DJB is also engaging in different strategies including wastewater recycling, restoration of water bodies, groundwater conservation, reduction of water losses, and rainwater harvesting. However, the DJB is constrained in its functions by many factors,[4] and its performance is sub-par. There are two fundamental issues:

1. The city has limited surface water resources (i.e., rivers, lakes, and canals) in its jurisdiction, and is dependent on water-abundant neighbouring states[a] for meeting nearly 50 percent of its raw water needs.[5] Sometimes these states curtail their supply to Delhi, leading to a crisis situation in the

a These are primarily Haryana, Himachal Pradesh, and Uttar Pradesh.

capital. On one occasion, Haryana did not release the full supply as its government wanted the Delhi government to withdraw all cases related to a water dispute filed in Delhi high court and the National Green Tribunal.[6]

2. Inadequate supply of water by DJB is leading to illegal extraction/ overexploitation of groundwater (GW). The current rate of GW extraction is higher than that of natural recharge, resulting in a decline in the water table levels in some parts of Delhi. Further, GW recharge is also affected by construction of concrete structures and encroachments that block the flow of rainwater to natural depressions.

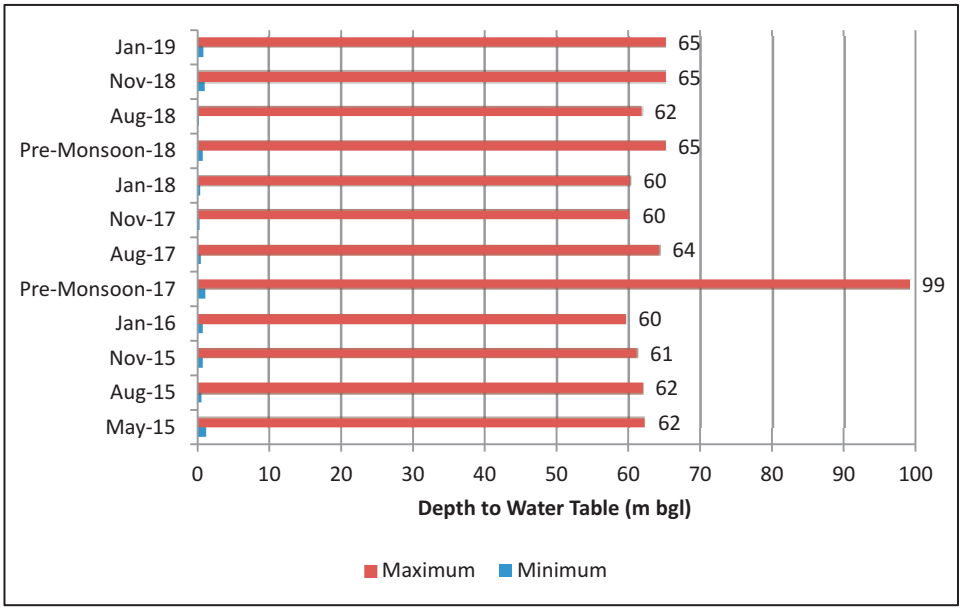
Data on GW utilisation show that DJB extracts 86 mgd (or nine percent of total water produced).[7] Further, many registered borewells are operational in lands owned by farmers. In addition to regulated use of GW, about 5,000 illegal borewells are operational.[8] Moreover, there are private water tanker truck operators that illegally extract GW for supply in areas that are not covered by piped networks to increase their profits. Therefore, groundwater in the city is overexploited and has reached a critical state.

The Central Ground Water Board (CGWB)[b] reports that annual groundwater extraction in Delhi was more than 100 percent during 2017.[9] The depth of water level in various parts of the city ranges from a minimum of 0.80 to a maximum of 65 metres below ground level (m bgl) in January 2019 (See Figure 1). City-level data show an increasing trend in maximum depth by three metres from 62 m bgl in May 2015 to 65 m bgl in January 2019 (See Figure 1).

District-wise analysis of data for the period May 2015 to January 2016 reveals that groundwater is available at a maximum depth of nearly 60 m bgl in the south and southwest districts of Delhi, and about 30 m bgl in the west and New Delhi districts (See Figure 2). Over a three-month period (November 2015 and January 2016), the central, east, new Delhi, northeast, and southwest districts recorded a fall in their water table levels. Meanwhile, the north, northwest, south, and west districts recorded a rise.

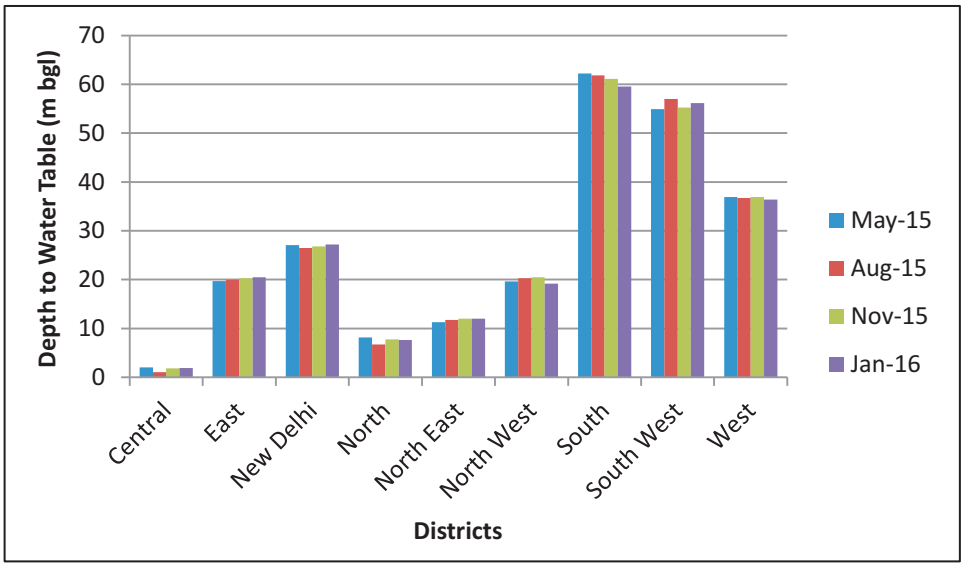
b CGWB, a national apex agency, under the Indian government's Ministry of Jal Shakti, is responsible for providing scientific inputs on management and regulation of groundwater resources in the country.

Figure 1: Depth of Water Table in Delhi



Sources: (i) Central Ground Water Board, Ground Water Year Book 2015-16, NCT Delhi (Delhi: State Unit Office, 2016); (ii) Central Ground Water Board, Ground Water Year Book India 2017-18 and 2018-19 (Faridabad: Government of India), 49.

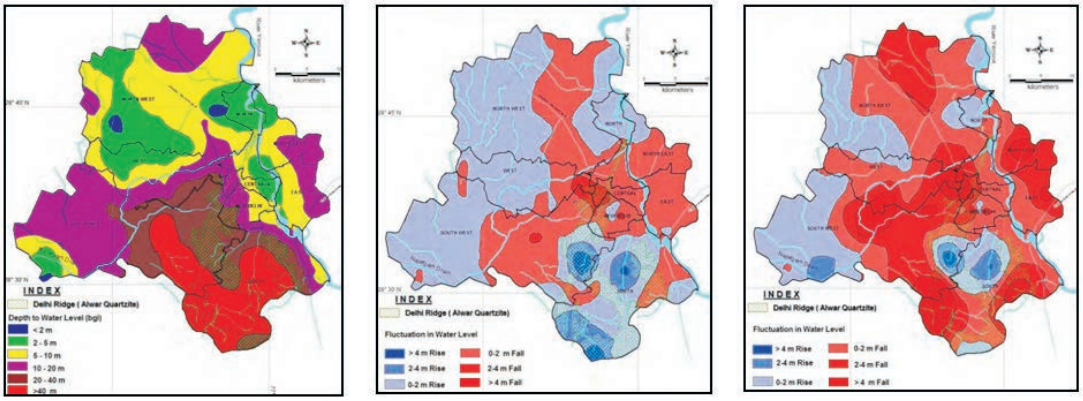
Figure 2: Maximum Depth of Water Table in Districts of Delhi



Source: Central Ground Water Board, Ground Water Year Book 2015-16, NCT Delhi (Delhi: State Unit Office, 2016).

The three maps (Figure 3) show depth of water level in January 2016, and fluctuations in water level over one-year (2015-16) and ten-year (2006-16) periods.[10] The depth of water level in January 2016 was recorded at maximum (above 55 m bgl) in the southern and south-western parts of Delhi. An analysis of annual fluctuation of water level between January 2015 and January 2016 reveals falling water levels by up to four metres in New Delhi, northwest, south and southwest districts. A comparison of January 2016 data with the 10-year mean (January 2006 to January 2015) shows a depletion of water table in most districts.

Figure 3: Water Level Depth and Fluctuation in Delhi



January 2016 | **Jan 2015 to Jan 2016** | **Mean (Jan 2006 to Jan 2015) – January 2016**

Source: Central Ground Water Board, Ground Water Year Book 2015-16, NCT Delhi (Delhi: State Unit Office, 2016).

The issue of groundwater depletion requires urgent attention as it brings various risks. These include the drying up of wells; reduction of water in streams and lakes; land subsidence (due to removal of subsurface water); increased costs for the user in lifting water from greater depths; and deterioration of water quality.[11]

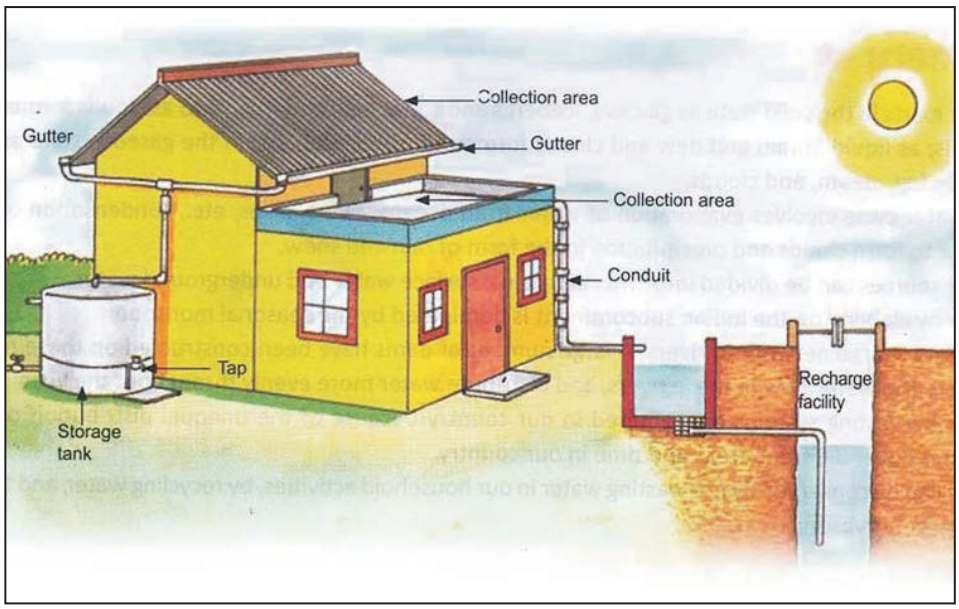
RAINWATER HARVESTING AS RESPONSE

Rainwater harvesting (RWH) is the collection of rainwater from rooftops of buildings or from the Earth's surface and its storage in tanks for use or for groundwater recharge. It is one method that can help in addressing the issue of water scarcity (See Figure 4). This practice also prevents runoff from going into sewer or storm water drains, and reduces flooding.

Of the total rainfall that Delhi receives in a year, about 81 percent occur during the monsoon season (in the three months of July, August and September); the remaining is received during the winter season or when thunderstorms occur at various times during the year.[12] The rainfall patterns are highly variable and characterised by short spells and high intensity. There are dry spells in-between the monsoon season, when rainfall does not occur for several days. Moreover, there are notable deviations (surplus/deficit) from normal rainfall, as well as evaporation losses.

The average annual precipitation amounts to about 800 mm.[13] However, the city received 544 mm[14] (31 percent below normal) annual rainfall in 2018, and in the following year, 680 mm[15] (11 percent below normal). It is estimated that the city's annual RWH potential[16] is 900 billion litres (or 2,500 million

Figure 4: Components of Rainwater Harvesting System



Source: Veerendra, "What is water conservation," AplusTopper, September 20, 2016, https://www.aplustopper.com/what-is-water-conservation/.

litres per day (mld)/550 mgd), while potential for rooftop RWH is assessed at 27 mld (or 6 mgd).[17] However, as will be discussed in a latter section of this report, due to inadequate arrangements for RWH at many places in the city, most of the rainwater ends up going to waste. The city government therefore needs to tap this potential in a significant manner.

The aims of this analysis are threefold:

(i) To describe steps taken by the Delhi government in promoting RWH, and the progress achieved;

(ii) To understand the difficulties in tapping greater RWH potential;

(iii) To give suggestions for the growth of Delhi's RWH sector.

NATIONAL/STATE GOVERNMENT INITIATIVES FOR RWH

Recognising the significance of RWH in water conservation and groundwater recharge, the Ministry of Urban Development and Poverty Alleviation issued a notification on 28 July 2001 for provision of RWH systems on plots of all newly planned buildings measuring 100 sq m and above. The Delhi government, too, announced a financial assistance scheme in December 2002 to support installation of RWH structures. Under the scheme, grants-in-aid up to 50 percent of the total cost of RWH structure or INR 50,000, whichever is less, is

given to eligible groups, such as registered Resident Welfare Associations (RWAs), Cooperative Group Housing Societies, recognised private and government schools, hospitals, charitable institutions, and NGOs.

An evaluation study of the scheme for the period 2002-03 to 2005-06 reveals that 90 RWH structures were completed by 2005-06.[18] Ten structures were surveyed, and the evaluators found: irregularities in maintenance – presence of soil in recharge pits which would result in clogging of filter media and slots of bore pipe; groundwater level maintained and no further deepening of tubewells; and groundwater used for non-potable purposes, i.e., watering plants and cleaning.

To achieve the goals of Jal Shakti Abhiyan, a water conservation campaign launched on 1 July 2019, the Ministry of Housing and Urban Affairs (MoHUA) has issued guidelines for urban water conservation through RWH (See Box 1).

Box 1: MoHUA Guidelines for Rainwater Harvesting

(i) Enforcement of building by-laws

RWH needs to be implemented as per provisions of Model Building Bye-laws (MBBL), 2016 shared with all states/UTs. Cities need to ensure that RWH provisions are incorporated in city/state BBLs. Thereafter, an enforcement mechanism should be put in place for providing RWH structures in all buildings.

(ii) Establishment of RWH cell

Urban Local Bodies (ULBs) should constitute a RWH cell which will be responsible for effective monitoring of RWH in the city. The cell should monitor the extent of groundwater extraction and groundwater aquifer recharge. The information should be displayed at prominent locations for public awareness.

(iii) Specific measures during Jal Shakti Abhiyan

- ULBs should ensure that all government buildings, public buildings (educational institutions, commercial establishments, hospitals), group housing societies have RWH structures.
- ULBs should ensure that building permissions are granted and occupancy-cum-completion certificates are issued after RWH structures are incorporated.

- ULBs should undertake de-concretising of pavements around trees for allowing water to percolate into the ground.

Source: Ministry of Housing and Urban Affairs, Guidelines for Urban Water Conservation (Delhi: MoHUA, 2019), 4-6.

Finally, provision for RWH was incorporated in Building By-laws for Delhi of 1983. Subsequently, Delhi Water & Sewer (Tariff and Metering) Regulations of 2012[19] were amended and approved by DJB on 19 August 2019. This is a significant legislative measure. Regulation 50 calls for mandatory provision of RWH structures in existing and new properties/buildings. In this regard, a rebate of 10 percent on water bills is given as an incentive to owners complying with the provision; non-compliance invites a penalty equivalent to 50 percent of the total water bill amount. The rebate is given only to those consumers who design their RWH structures as per DJB guidelines for RWH, and receive an adequacy/installation certificate from DJB. For installed structures, property owners are required to provide a functionality certificate issued by zonal engineers, which is renewed every two years. Consumers unable to install RWH system due to reasons such as property located on rocky ground or on banks of River Yamuna, or where groundwater levels are shallower than 5 metres, are exempted.

A period of one year (i.e., until 25 September 2020) from the date of issue of public notice is given for installation of RWH systems in properties constructed prior to 28 July2001, while those constructed after this date are required to do so by 31 March 2020. In view of the Covid-19 pandemic, a fresh deadline is being considered.

Implementation Mechanism

The responsibility for implementation of RWH scheme lies with Delhi Jal Board (DJB). A RWH Cell was established by DJB in 2002 to generate awareness among people on water conservation and benefits of RWH, and to provide technical assistance for installation of RWH systems. Three RWH Centres were also set up by DJB in residential areas of R.K. Puram, Dwarka, and Lajpat Nagar in 2016 in partnership with the NGO 'FORCE' (Forum for Organised Resource Conservation and Enhancement) to assist the public on questions regarding setting up RWH systems and costs involved. The work performance of these centres declined after withdrawal of the NGO, due to non-renewal of partnership contract.[20] Information available in early July 2020 reveals that DJB has addressed this issue by establishing one central rain

centre at DJB headquarters, and one district rain centre in each of the 11 districts of Delhi. To facilitate implementation (i.e., consultancy, design and construction), eight agencies having expertise in RWH are empanelled and registered with DJB. Citizens can avail services of these agencies to establish RWH structures, or have the option of setting up structures through their own arrangements. In both cases, DJB guidelines for RWH are to be followed so as to ensure that the installed structures function in an optimal manner (Box 2).[21]

Box 2: DJB Guidelines for Rainwater Harvesting

- RWH systems should be designed in such a way that: even if it rains with high intensity continuously for 1 hour, the system should be able to store and recharge the runoff that flows into it; it is safe, easy to make and easy to maintain; it complies with DJB guidelines so that people are able to avail rebate.
- Water holding capacity (in cubic metres or kilolitres) of pit to be build to be calculated by using the following formula:

  Rooftop area* (in sq m) X

  0.8** (runoff coefficient for rooftop/concrete area) X

  0.025*** (average maximum rainfall intensity in metres per hour)
- To arrest silt in rain runoff generated from catchments before its percolation into natural soil strata, instead of filter media, residents may use multiple layers of jute mats in recharge chambers/modular filters in rainwater pipes from rooftops.
- No waste water should be allowed to enter recharge structures. Only non-polluted rainwater from rooftops and other catchment areas should be directed to recharge structures.
- A mesh (*jali*) is to be provided at the mouth of inlet pipes connected to recharge structures.
- Depth of recharge structures should be 1 – 4 metres.
- Recharge systems should be located at a safe distance away from buildings/foundations.
- Runoff coefficient for bituminous roads/paved areas and open/green areas without steep slopes should be 0.6 and 0.1 respectively.
- All catchment areas, rainwater conveyance system and recharge

structures should be cleaned (including removal, washing and topping of filter media layers) before onset of monsoon to avoid any contamination.

- An overflow pipe in recharge structures should be provided leading out/falling into municipal storm water drains/open areas. Under no circumstances should they be connected to the sewer.

- By-pass arrangements may be provided before the recharge chambers to divert the first rain runoff directly into municipal drain.

- Recharge structures with requisite structural soundness must be implemented and adhered to all construction and structural norms. The structure should not pose any danger to people and building. The design should be based on soil type and land use. Thickness of RCC cover slabs and reinforcement shall be dependent on structural loads.

- Filter media consisting of brick aggregates/charcoal and activated carbon/coarse sand/geo textile membrane ought to be provided. For membrane even thick blankets can be used.

- Recharge structures are to be cleaned after every 2 rainfalls during the rainy season.

- Post monsoon cleaning and maintenance of recharge chambers shall be carried out.

- Roof should not be painted since most paints contain toxic substances and may peel off.

- Chemicals, rusting iron, manure or detergent should not be stored on the roof.

- Terraces should not be used for toilets either by human beings or pets.

- Polluted water should not be used to recharge groundwater.

- Rainwater should not be harvested where post monsoon groundwater levels are less than 5 metres.

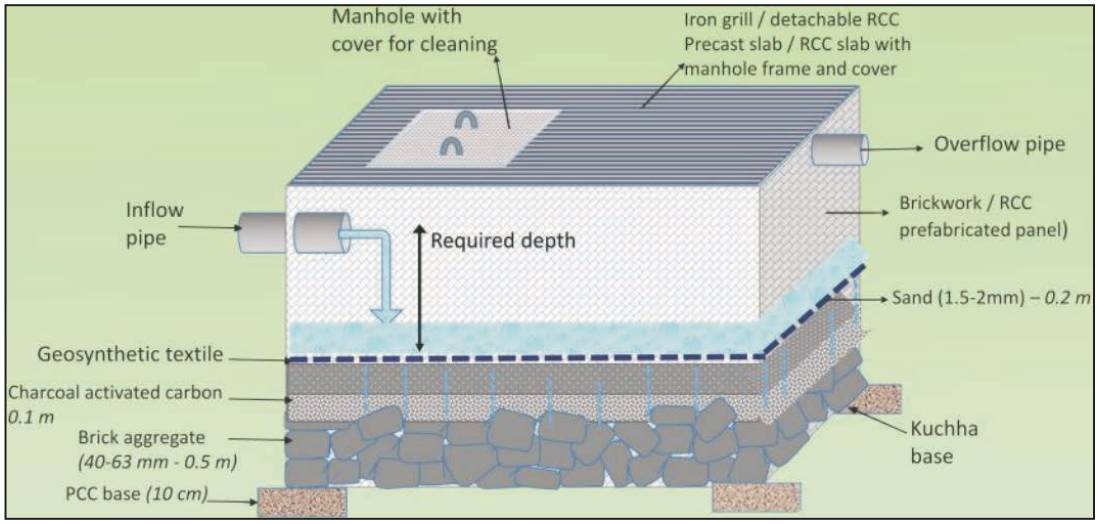
Source: Delhi Jal Board, Rain Water Harvesting Guidelines (Delhi: DJB, 2016).

Notes: * Rooftop area: This is the total area of the rooftop of the building.

** Approx 20 % of the rainwater that falls on a rooftop evaporates or is absorbed by the concrete. The balance 80 % flows as runoff. Hence, 0.8 is taken as the coefficient of recharge for rooftops.

*** 0.025 metre or 25 millimetres is the average rainfall that falls in an hour over 1 metre square area in Delhi.

Figure 5: Storage Chamber Specifications for Rainwater Harvesting



Source: Delhi Jal Board, Rain Water Harvesting Guidelines (Delhi: DJB, 2016), 5.

DJB conducts surveys to ascertain the implementation and functional status of RWH systems in government and private building premises. In addition, the public is sensitised through various means – print, electronic, workshops, and exhibitions.

PROGRESS OF RWH SCHEME

Following the July 2001 notification of the urban development ministry, and the directive on mandatory installation of RWH structures from August 2019 onwards, the Delhi government and its water agency (DJB) have taken several steps to ensure implementation of the scheme. Table 1 shows actuals and estimates of grant-in aid for RWH and expenses for the period 2016-17 to 2019-20. It is noted that after 2017-18, grant-in-aid has been hiked six times.

Table 1: Grant-in-aid for Rainwater Harvesting and Expenditure
(in INR million)

Head of Accounts	2016-17 (Actuals)	2017-18 (Actuals)	2018-19 (Revised Estimates)	2019-20 (Budget Estimates)
Grant-in-aid	5.00	5.00	30.00	30.00
Expenditure	7.41	4.57	30.00	30.00

Source: Delhi Jal Board, Budget 2018-19 and 2019-20 (Delhi: Government of NCT of Delhi).

Available data and information on physical progress show that RWH structures have been established in several government and private

properties/buildings, including offices, hospitals, schools and colleges,[22] universities and research institutes, and residential colonies (Figure 6).

Figure 6: RWH Recharge Structures

Location: Park in Chhatarpur

Location: Shastri Park Depot, DMRC

Source: (i) Delhi Jal Board, Action Taken Report on Jal Shakti Abhiyan (Delhi: DJB, 2019); (ii) DMRC, "Rainwater harvesting," 2017, http://www.delhimetrorail.com/watermanage.html.

A record is kept of properties yet to install RWH structures, rebate given and penalty imposed (See Table 2). For example, DJB has installed the structures at 47 percent of its properties, while the Delhi Metro Rail Corporation (DMRC) has installed such structures at 78 percent of its locations including elevated stations, viaducts, depots, and staff colonies, that have a total water capacity of over 11,203 cubic metres.[23, 24] Many educational and health institutions, and residential areas are yet to initiate steps in this regard. A total rebate of INR 325.7 million was provided by DJB to consumers reporting functional RWH systems, while an amount of INR 567.1 million was generated as penalty from those without the structures.

Table 2: Installation Status of RWH Structures, Rebate Given and Penalty Imposed

S. No.	Category	Status	Source
1.	Number of DJB installations* with RWH systems	368 out of 785 (47%)**	*Economic Survey of Delhi 2019-20*, 244; *Action Taken Report on Jal Shakti Abhiyan*, 2019, 27
2.	Number of schools and colleges with RWH systems	3,595 out of 4,805 (75%)	*Economic Survey of Delhi 2019-20*, 244
3.	Number of private schools with RWH systems	901 out of 1,600 (56%)	*The Week*, April 4, 2020
4.	Number of government schools with RWH systems	528 out of 742 (71%)	*The Week*, April 4, 2020
5.	Number of housing societies with RWH systems	221 out of 1,000 +	*The New Indian Express*, January 5, 2020

6.	Number of DMRC locations with RWH systems	185 out of 236 (78%)	DMRC, "Rainwater harvesting," 2017
7.	Number of hospitals (having 100 beds or more) with RWH systems	70 out of 100 (70%)	Delhi government, 2014
8.	Number of RWAs with RWH systems***	22 out of 2,206	Delhi government, 2014
9.	Cost of setting up RWH system (approx.)	Rs. 500,000 – 700,000	*The New Indian Express*, January 5, 2020
10.	Number of consumers provided 10 % rebate & total rebate	1,559; Rs. 325.7 million	*Action Taken Report on Jal Shakti Abhiyan*, 2019, 8; *Economic Survey of Delhi 2019-20*, 244
11.	Number of consumers penalised & penalty imposed (500 sq m +)	11,958; Rs. 567.1 million	*Action Taken Report on Jal Shakti Abhiyan*, 2019, 8

Sources: (i) Planning Department, Economic Survey of Delhi 2019-20, (Delhi: Government of NCT of Delhi); (ii) Delhi Jal Board, Action Taken Report on Jal Shakti Abhiyan (Delhi: DJB, 2019); (iii) Somrita Ghosh, "Housing societies in Delhi miss NGT deadline to set up rainwater harvesting," The New Indian Express, January 5, 2020, https://www.newindianexpress.com/thesundaystandard/2020/jan/05/housing-societies-in-delhi-miss-ngt-deadline-to-set-up-rainwater-harvesting-2085146.html; (iv) "NGT slams Delhi govt over rainwater harvesting in schools colleges," The Week, April 4, 2020, https://www.theweek.in/wire-updates/national/2019/01/23/lgd13-green-rainwater.html; (v) DMRC, "Rainwater harvesting," 2017, http://www.delhimetrorail.com/watermanage.html; (vi) "Additional compliance affidavit on behalf of government of NCT of and Delhi Pollution Control Committee, 2014, http://www.indiaenvironmentportal.org.in/files/rainwater%20harvesting%20systems%20Delhi%20NGT.pdf.

Notes: (i) * Installation implies plots with underground reservoirs, booster pumping stations, tube wells, water/sewer stores, pump houses, offices, flats, community centre and dispensary; (ii) ** RWH systems are not installed on plots having area of less than 100 sq m or where post-monsoon groundwater level is shallower than 5 m; (iii) *** Each RWA has one or several RWH structures.

Table 3 provides details on the quantity of rainwater harvested, capital and O&M costs incurred, and benefits achieved from RWH. The Centre for Science and Environment (CSE), Jamia Hamdard University, and Nizamuddin East locality have maintained groundwater levels in their area, and the method has helped in attending to the problem of waterlogging.

Table 3: Impact of Functional RWH Systems

Location	Area (sq m)	Operational Since	Rainwater Harvested Annually (litres)	Capital Cost (INR)	O & M Cost (INR)	Benefits
Centre for Science & Environment, Tughlakabad Institutional Area[25]	1,000	1999	366,600 (about 1,000 litres per day)	36,000	5,000	Groundwater level maintained at 65 m
Jamia Hamdard University, Hamdard Nagar[26]	315,380	2002	67,444,000	652,000	N.A.	Groundwater level maintained at 39 m
Nizamuddin East[27]	200,916	2004	48,513,149	174,000	N.A.	Groundwater recharge, Reduction in water logging

Source: Centre for Science and Environment.

RWH is also practiced at the international airport in Delhi, where over 300 wells have been built for recharging groundwater/aquifers.[28] It is estimated that about 4.5 million litres of water is consumed at the airport every day, and water conservation measures help airport authorities in meeting the demand, and thus reduce dependence on the city's already overburdened water supply agency.[29]

In a further boost to the RWH strategy, the Delhi government launched in August 2019 a pilot project in the floodplains of river Yamuna that will aim to recharge groundwater, and the river naturally. For this purpose, land in Yamuna floodplains is leased from farmers, where one-metre-deep artificial reservoirs have been created for collecting rain/floodwater.

DJB is also planning to store water in underground aquifers, especially for use during periods of shortage.[30] A project involving the creation of 80 Aquifer Storage and Recharge (ASR) wells, designed by WAPCOS, a consultancy organisation and public sector undertaking under Ministry of Jal Shakti, is considered for implementation. Under the project, excess (raw) water in river Yamuna, as well as storm water runoff, will be harvested. Raw water will first be collected in tanks and then treated before injecting into aquifers. DJB also plans to initiate the collection of surface runoff along road stretches and flyovers in modular tanks installed below the ground.

Findings of the Study

1. Delhi, India's capital city, is facing problems of inadequate availability of water for production and supply, and overexploitation of groundwater.

Lack of access to water creates difficulties, and adversely affects operation of various water-dependent activities.

2. The national government of India and the Delhi government have taken steps to address the issue of water supply in Delhi. One initiative is rainwater harvesting (RWH), to judiciously tap and utilise rain received during monsoons.

3. To support the RWH initiative and for its effective implementation, legislative, financial, and institutional measures have been introduced. Further, guidelines outlining the specification of RWH structures have been formulated.

4. Since 2019, it has been mandatory for owners of all existing and new properties measuring 100 sq m and above in Delhi to install RWH structures, and to ensure that installed structures are properly maintained. To achieve this objective, a system of rebate (10 percent on water bill) and penalty (equivalent to 50 percent of the total water bill amount) is in place.

5. For implementation, a RWH cell and 12 RWH centres have been set up, and eight agencies having expertise in RWH are empanelled to support installation of structures. The implementation and functional status of RWH systems is assessed by DJB through regular field surveys. Moreover, public sensitisation campaigns are organised occasionally.

6. In 2018-19, a six-fold hike in grants-in-aid for RWH is observed over the previous period 2017-18 from INR 5 million to INR 30 million.

7. RWH structures have been established in several government and private properties / buildings, including offices, hospitals, schools and colleges, universities and research institutes, residential colonies, and housing societies. Benefits are seen in the form of use of stored rainwater for non-potable purposes, stable groundwater levels in the surrounding area, and reduced waterlogging. However, many properties are still without RWH structures.

8. DJB provided a total rebate of INR 325.7 million to consumers reporting functional RWH structures, while an amount of INR 567.1 million was collected as penalty from those without the structures.

RECOMMENDATIONS

This study finds that the RWH sector in Delhi has achieved little growth. Many government departments and bungalows, institutions and residential societies have either not installed RWH systems or have systems which are non-functional. The issues prevailing in Delhi's RWH sector have been highlighted in available literature.

The National Green Tribunal (NGT) is concerned about the progress of the RWH scheme. In its order issued on 6 May 2014, the NGT directed the Delhi government to seek reply from all hospitals and RWAs on the status of RWH system installation, and their condition. Again on 16 November 2017, NGT directed the Delhi government to ensure that RWH systems are installed in all schools and colleges within two months.[31] In 2020, NGT asked the DJB to recover a fine of INR 500,000 from institutions (such as Delhi Development Authority, Public Works Department, Delhi Metro Rail Corporation) that have failed to install RWH systems in their properties.[32]

A survey conducted by DJB has revealed that out of 771 buildings, other than those of DJB, as many as 559 building premises[33] are without RWH systems.[34]

It is necessary to understand the difficulties involved in tapping greater RWH potential, and urgently address these for further development of the sector. The following are some aspects requiring attention.

- The corporate community interested in installation of RWH structures faces hurdles in obtaining permissions from government departments at multiple levels.[35] Such procedures need to be simplified.

- Harvesting of rainwater is mostly being done for groundwater recharge, and less for non-potable use. While groundwater recharge is important, if some rainwater is also stored in tanks, it can be used in gardens, water coolers, or for washing cars and driveways. It is estimated that up to 40 percent of water supplied to households is for non-potable use.[36] If stored rainwater is used, there can be significant savings of potable water supplied by the water agency.

- There is insufficient evidence of harvested water being used for potable/drinking purposes. There are impurities in the atmosphere (such as air pollution) and on rooftops of buildings and catchment areas (such as dust, bird and animal droppings, insects and garbage) as well as sediments that need to be prevented from entering drain pipes, storage tanks and

pits. Moreover, there is scope for entry of zinc and lead in stored rainwater, which is caused by leaching from metal roofs/pipes/tanks. There can be serious health problems if water with impurities is used for drinking. The World Health Organization (WHO) points out that "higher microbial concentrations are generally found in the first flush of rainwater, and the level of contamination reduces as the rain continues; uncovered storage tanks on the other hand are ideal places for breeding of mosquitoes."[37] For making rainwater drinkable, necessary arrangements are to be made so that stored water is free from contaminants. These include regular cleaning of tanks and disinfection with chlorine to kill algae, bacteria and viruses, use of non-toxic materials in tanks, and maintaining healthy standards of acidity[38] (i.e., pH value of 7), installation of downpipe diverter[39] and bio-mineral cartridges.[40] Such measures can help make rainwater available for various uses, and reduce consumer dependence entirely on supply from water agency.

- Despite RWH being made mandatory by a law passed in August 2019, many people/institutions are yet to install RWH structures in their properties. This is due to a number of reasons. Generally, people prefer to meet their requirements with whatever quantity of water is received through the piped network laid down by the water agency, as this is convenient and economical. Due to investment of time and expenses, they are not interested in installation of RWH structures that can cost from INR 500,000 to INR 700,000. Moreover, it costs INR 40,000 for annual maintenance of a pit/tank. Availability of sufficient vacant space within every property for building a rainwater pit is another issue. Besides, people do not like the idea of getting annual functionality certificates from the authority to obtain rebate in their water bills. Rather, many do not mind paying the penalty for not installing the structures. However, entirely depending on piped municipal supply amounts to significant wastage of treated water. Further, this is not a sustainable solution to the problem. There are only a handful of people who are genuinely concerned about water conservation and have laid down the infrastructure for RWH.

- Residents of slums and unauthorised colonies in Delhi face severe water shortages as they are yet to be covered by piped municipal supply. Installation of RWH structures near informal settlements can help meet their water requirements.

- Every year during monsoon, several parts of the city get flooded. This year too, for instance on 19 July, several areas of Delhi, including colonies,

underpasses, road intersections were heavily inundated. Flooding of this nature can be controlled by identifying all areas in the city prone to flooding and ensuring provision of proper drainage and RWH systems.

The effective implementation of the RWH policy will depend on a number of parameters, including managerial and financial capability of government; level of engagement with the civil society, experts, and specialised private sector entities; awareness amongst citizens on the environmental and economic benefits of RWH; up-to-date database on number of installed RWH units and their condition; identification and installation of RWH systems in potential RWH areas in the city; and proper arrangements in the three main components of the system, i.e., catchments (rooftops), pipes and gutters, and storage tanks. Specialised companies recommend up to eight steps for successful RWH, i.e., limit sources of contamination, plan for storage volume, filter leaves and debris, divert the first flush of rainwater, secure tanks with screens and covers and install an air gap to prevent stormwater backflow, manage standing water in tanks, use a filter to reduce sediment, and monitor water level (in tanks) and its use.[41]

The question that the Delhi government needs to examine is whether it has ensured that these essential parameters are properly positioned. The Delhi government should also review its current policy of compulsory installation of RWH structures by owners of residential properties (as it is proving to be a challenge), or indeed if a shift in focus from individual to neighbourhood-level systems is required. In this arrangement, instead of asking every household to create RWH pits within their premises, large pits/tanks can be created at the neighbourhood level. Rainwater falling on rooftops of a cluster of houses can be brought to these pits through a network of pipes. The responsibility for maintaining rooftops and water entry points of pipes installed for transporting water could lie on residents, whereas the neighbourhood level pits can be maintained by the Resident Welfare Association or a private entity hired for such purpose. The water collected in neighbourhood level pits can be utilised by residents as and when required. Equity in water use can be ensured by installing water meters.

CONCLUSION

The Delhi government has been making efforts to promote the practice of rainwater harvesting so that the growing water needs of the capital's citizens are suitably met and groundwater levels are maintained. Following the truism,

"catch the rain where it falls", this work is being done in two ways: (i) rooftop harvesting, i.e., owners of all properties (including residential, commercial, institutional, industrial) measuring 100 sq m and above are required to install RWH structures within their premises; and (ii) RWH pits/artificial reservoirs have been created where potential for RWH exists, such as the Yamuna river floodplain, as well as parks. There are also plans to collect surface runoff along roads and flyovers, and to dig wells for storing rainwater in aquifers.

This analysis finds that rainwater harvesting has occurred in a limited manner and some benefits have been derived—the use of stored rainwater for non-potable purposes, and stable groundwater levels in the area where RWH is practiced. However, progress in this regard has been unsatisfactory as many properties have not installed RWH systems, and many installed systems lie in a neglected state. The previous section briefly describes Delhi-specific institutional problems, citizen concerns, and some ideas to overcome the challenges in the RWH sector. Therefore, it may be said that the full potential of RWH remains untapped. Further development of the RWH sector in Delhi is needed to bridge the widening water demand and supply gap, and to ensure reliable supply of water to communities living in informal and peri-urban areas that remain uncovered by piped networks. ORF

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