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RESTORATION AND REJUVENATION OF WATER BODIES ACROSS DELHI-NCR - AN OVERVIEW

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Abstract

In India, National Capital Region (NCR) – Delhi, has various forms of water bodies. However, it is either encroached, highly polluted, or silted over the decades, thereby resulting in less functional status, especially for activities like groundwater recharge, etc. Out of the total of more than 1000 water bodies of comparatively lower size area either completely encroached (18%), converted into the park (9%), non-traceable (4%), or filled with dirty water (11%), etc. By mapping the coordinates of these water bodies, restoration and rejuvenation can be planned which includes community participation, a self-supporting system, etc. for effective and sustainable management of individual water body. This paper briefly discusses the current situation of the surface water availability in Delhi (NCR) that is deprived of water, especially in the post-monsoon season. The present study also suggests the usage of Geographical Information System (GIS) and Remote Sensing (RS) technology, for the identification, mapping, etc. that can also be linked with surface water as a continuous resource. This will help in analyzing the catchment area as well as understanding the storage capacity to a certain possible extent. This study also emphasizes the synchronization of government policy with associate laws and their implementation with appropriate and effective management and action of concerned regulatory authority.

Keywords*: Water bodies; Restoration; Rejuvenation; Water pollution; Government efforts*

Introduction

Ancient India has witnessed river valley civilization where human settlements flourished near flowing water. This is because the dependency on water was high for agricultural activity. In a healthy ecosystem for surface water, the dependency is not only with the quantity of water, but it has a direct relation with the quantity, quality, and timing of water available for sustainable use by living beings. Likewise, for groundwater, the quantity, quality as well as the location of water plays an important role [1, 2].

Nowadays, rapid urbanization, increasing infrastructure projects, and anthropogenic activities have modified the surface as well as groundwater from its original state. Alteration to the natural movement of the surface as well as groundwater impacts the ecosystem adversely. This not only has an impact on water quantity but also has an adverse impact on its quality in turn health impact on various living species having a dependency on the same [2-4]. The Abstraction of water changes the natural system significantly. Overexploitation of water from a

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single source can reduce the groundwater infiltration that may further reduce the groundwater table. The natural health of all such water bodies is very much required and important to sustain a wide range of social and economic benefits and values. Various social, cultural, and economic values can be sustained if water bodies can be protected or restored in their natural environment [5-15].

Surface water bodies like lakes and ponds, reservoirs, tanks play a vital role in bridging the gap between the demand for groundwater and its natural availability by storage of rainwater, river flow water, etc. Water bodies are quite abundant in rural areas as well as in urban areas. However, due to poor management, the count of the water bodies is getting reduced or their capacity to store water is getting reduced. This results in low penetration of water to the ground led to the depletion of the groundwater table. If we identify the specific water requirement for a healthy ecosystem in its original form, then effective management of water can be planned. This can be done by the restoration of lakes, ponds, tanks by increasing their water storage capacity, regular cleaning, maintaining the source of water throughout the year. Once restoration gets completed then planning the volume of water abstraction for domestic, industrial, and agricultural purposes without impacting on the natural course of the water system can be done [16-20].

Status of surface water resources available- Delhi

Earth covers 71% of its surface area like water. However, its 97% volume comprises salty ocean water, 2.5% freshwater locked in glaciers. Water is precious as only 0.5% of the earth's water is available as fresh water for use. In India, we are blessed with 4% of the world's water resources and can be considered a rich country (India-WRIS wiki 2015). Rapidly increasing population and infrastructure results in a rise in demand and thus changes the characteristics of water in India. Surface water bodies have been adversely affected and thus groundwater is more depleted and less available whereas surface water is getting more and more polluted. For a healthy ecosystem and human health, good water quality is essential. However, it appears as a challenge across various parts of India [21].

Effective management of water is one of the important aspects of overall growth for society as well as the nation. The water is precious and scarcity of the same with relation to the increasing population is well known in Delhi as well as other parts of India. An effective water management plan is needed which ensures the availability of water for drinking as well as other purposes to households and industries without affecting its current source. It includes the management of quality as well as quantity of the water. The exploitation of surface, as well as groundwater, needs to be balanced with the groundwater recharge for its quantity, and treatment of wastewater before releasing into the environment to maintain the ecosystem. Major challenges lie with the effective management of water by maintaining a consistent supply and good quality over time to sustain the increasing population without affecting the environment. The development activities must be allowed up to the carrying capacity of existing environmental resources. Overexploitation of natural resources such as groundwater, surface water, and a load of pollution due to domestic as well as industrial wastewater, agricultural chemicals decline the quality of water [22, 23]. Increasing demand for water in Delhi NCR – has a high dependency on Surface water which comes from the only river in the state i.e., the Yamuna, which is a lifeline for Delhi as its water is being used from both of its costs for domestic, industrial as well as irrigation purposes. From the origin of the river Yamuna, it crosses through Punjab and Haryana before reaches to Delhi. The flow of water in the river is not constant throughout the year as a major proportion of the water comes through interstate agreements. As per Delhi Jal Board, the major volume of the surface flow into the river (75.6%) is received during the 4 monsoon months i.e., from July to October. The percentage share of water received in the Yamuna is 80% from July to October, 9% from November to February, and 11% from March to June. Snowmelt accounts for only 25-30% of the water while the rest comes from rainwater [24].

Other than the river Yamuna, Delhi also gets water from Bhakra storage (Himachal Pradesh) and upper Ganga canal (Uttar Pradesh) as mentioned in figure 1. Economic Survey report of Delhi suggests that dependency on Yamuna water in the last 20 years has increased

considerably. In 2001 the water usage from the Yamuna was 210 MGD (Mega Gallon per Day) whereas in 2019 it has increased to 380 MGD. The utilization of the Bhakra barrage is similar however exploitation of water from Ganga has also increased by 250% in the past 20 years [2-4].

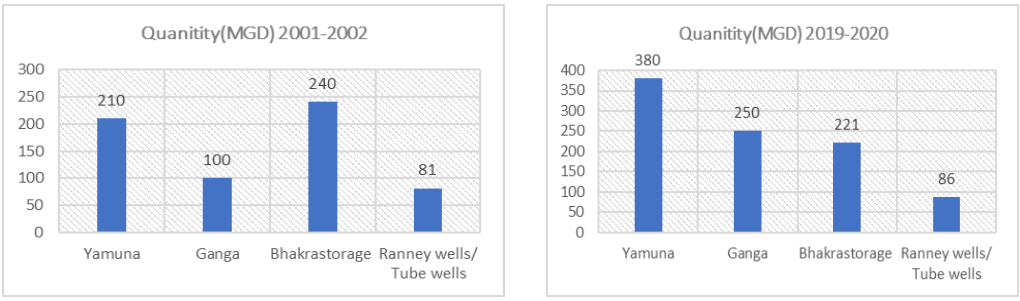

Fig. 1. Source of water in Delhi as per economic survey report for the year 2001-2002 and 2019-2020

Status of groundwater

To meet the increasing demand groundwater exploitation is also being done by more than 5000 Ranney wells or tube wells operated by the government. However due to overexploitation of water as compared with its natural recharge the quality of water has deteriorated significantly in past years. The dependency on irrigation is also high on groundwater only. The report published by Central Groundwater Board (2017-2018) states that approx. 6% of the land area in Delhi is available for cultivation which has a high dependency on groundwater for irrigation. This results in a decreasing groundwater table at various locations in Delhi. The water table across Delhi is varying from 2 meters in areas of the Yamuna flood plain to 78 meters across other areas in Delhi. The thickness of freshwater sediments below the ground is thin in a major part of Delhi. Whereas the very next layer of saline water has high thickness. This is the reason why groundwater available for use across Delhi is not fit for direct use in domestic purposes and requires treatment [25, 26].

Status of natural water bodies

As per the report published by the census of India (the Year 2011), the total land surface area of Delhi is 1484 SQKMs whereas as per a report published by "Delhi Parks and Gardens Society" on their website the total count of water bodies is 1009 (Table 1, Updated Aug 2020). Most of the water bodies lie under rural areas (village ponds) with small catchments having a dependency on rainwater as a primary source. Other water bodies are lakes and marshes that lie near flood plain and have a dependency on rainwater as well as the seasonal flow of water from flood plains [26]. The decreasing water bodies are a major concern and maybe a potential threat to the natural ecosystem. The catchment area is getting reduced day by day due to rapid urbanization, siltation as well as illegal encroachments. Approx. 180 Water bodies (Fig. 2) have encroached partly or completely across all the districts of Delhi. Likewise, 89 water bodies were overlooked for their importance and converted into a park. The waterbody in Pochanpur village as shown in figure 3 has changed to a park to add recreational value. Although there is a catchment for water storage however there is no source of water. Waterbody present in Dwarka Sector 23-B can be seen in figure 4 where all measures have been taken to protect the water body however the source of water is not available. Changes in water bodies to park result in the overflow of water during the rainy season and quick dry of the water bodies in case of deprivation of monsoon. The absence of water throughout the year results in dirty and muddy water appearance (Fig. 5) and can be the reason for visual negligence by common people. Approx. 40% of such water bodies are either filled with dirty water or encroached or converted into a park by locals or authorities. This has an adverse impact on the ecosystem supported by water bodies such as fish, birds, migratory birds, etc. There are four distinct water bodies identified in Delhi such as well, lakes, marshes, and village ponds. In Delhi, most of the wells

are either step wells or artesian wells such as Baoli in Tuglakabad fort. These water bodies are primarily taken care of by the Archaeological Survey of India due to their historical importance. The presence of natural freshwater lakes in Delhi is less as compared to its geographical area. However, DDA has developed an artificial lake (Sanjay Lake) in Trilokpuri which is spread over 42 acres. Marshes are a type of wetland usually developed along with the source of water such as lakes, rivers. Delhi has its largest water body in the form of marshes within the floodplain embankment in Jahangirpuri. In the agricultural farmlands, there ~~are~~ is several small water bodies (ponds) that store rainwater during the rainy season and dry when deprived of Monsoon.

Table 1. Summary of the total number of water bodies, non-traceable water bodies, water bodies with dirty water, water bodies encroached, waterbodies converted into park and water bodies near the Yamuna (Delhi Parks and Gardens Society, 2020)

S. No	District	Total No of Waterbodies	No of Non-Traceable Water Bodies	No of water bodies with Dirty Water	No of water Bodies Encroached	No of Water Bodies converted into Park	Water Bodies Near Yamuna
1	East	54	3	16	3	8	17
2	North East	48	2	1	2	8	17
3	North	164	5	14	50	7	21
4	North West	154	1	14	28	21	1
5	South	131	5	11	29	13	2
6	South East	37	9	1	2	2	10
7	South West	260	6	30	37	13	
8	West	72	4	16	18	9	4
9	New Delhi	61	3	3	8	5	1
10	Central	28	2	4	3	3	3
		1009	40	110	180	89	76

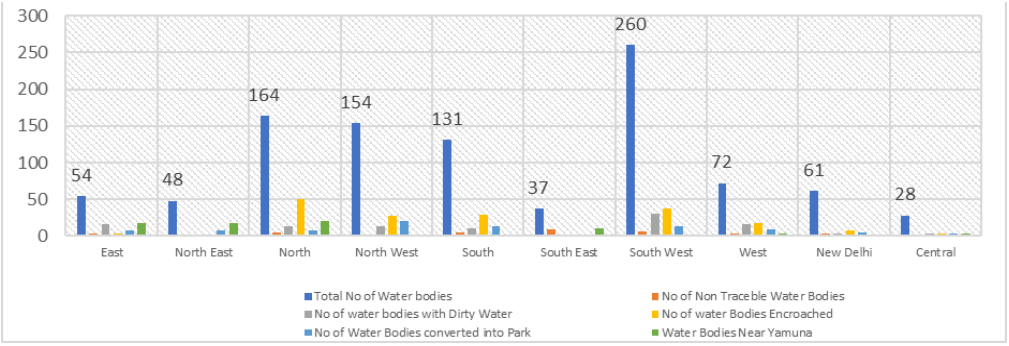

Fig. 2. Water bodies across various districts of Delhi

Fig. 3. Pochanpur Village, Delhi, water body converted into a park

Fig. 4. Waterbody in Dwarka Sector-23B, Delhi, Dried due to deprived of Monsoon and in absence of a source of water

Fig. 5. Dwarka Sector-23, Delhi, Lack of water throughout the year results in the dirty and muddy appearance

The existing water quality status

Surface water, as well as groundwater available in Delhi, is not suitable to use directly for domestic purposes. The quality of river water is getting deteriorated due to the release of untreated effluents at several places across the NCR region. Other anthropogenic activities such as dumping of waste, animal skins, and carcasses, religious activities like the dumping of tazia, the immersion of idols, cattle baths, etc are further deteriorating its quality. Dependency on the water from the Yamuna is increasing for agricultural as well as industrial purposes. However, with rapid urbanization and anthropogenic activity, the course of only the river "Yamuna" in Delhi is limiting itself in space. Encroachment of the Yamuna flood plain/ embankments and lack of natural flow of water is the major reason for poor water quality [27].

Currently, groundwater is being exploited across the NCR region for miscellaneous activity (Fig. 6) Overexploitation of groundwater has an adverse impact on the depletion of the water table as well as also created a gap in the water table recharged due to rainwater Vs water exploitation. The gap in exploitation vs recharge also has a cascading impact on the quality of water due to high salinity. In its original state, the groundwater quality across the NCR is saline and not suitable for drinking purposes without treatment [3].

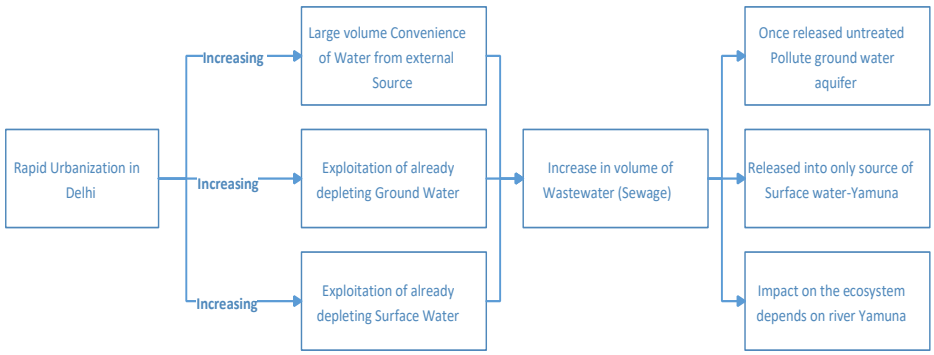

Fig. 6. Urbanization and increasing demand for water Vs Impact on water quality

Rapid urbanization causes increasing use of water for domestic as well as industrial purposes resulting in overall exploitation of already depleting groundwater as well as surface water (Fig. 6.) and an increase in the volume of wastewater. Once these effluents are released into the river Yamuna or on open ground, pollute the groundwater aquifer and have an adverse impact on the ecosystem supported by river Yamuna. The CPCB's annual report 2018 indicates the grievous situation of the river Yamuna in Delhi. Central Pollution Control Board is regularly monitoring about 40km. long Delhi stretch of Yamuna River from Palla to downstream of Okhla barrage at 4 locations i.e., Palla, Nizamuddin Bridge, Okhla at Kalindi Kunj (Okhla U/s), and Okhla D/s on monthly basis. Dissolved Oxygen for the year 2018 reflects that the level of this parameter was well above the prescribed limit 0f 4.0mg/L at Palla and is in the range from 4.9 – 10.5mg/L with an annual mean of 7.4mg/L [28, 29].

Methodology to improve quality of the existing water bodies

Rejuvenation of the flood plains

In general, the flood plain along the river has various advantages (Fig. 7), as these are the flat area along the river which normally overflows during the rainy season. It creates good agricultural land, and their agricultural productivity is high as they carry sediments along with overflowing flood water. These are the topsoils that are rich in nutrients. Delhi has a flood plain across the only river the Yamuna spread across both east (Shahdara) and west riverbank (Ring Road).

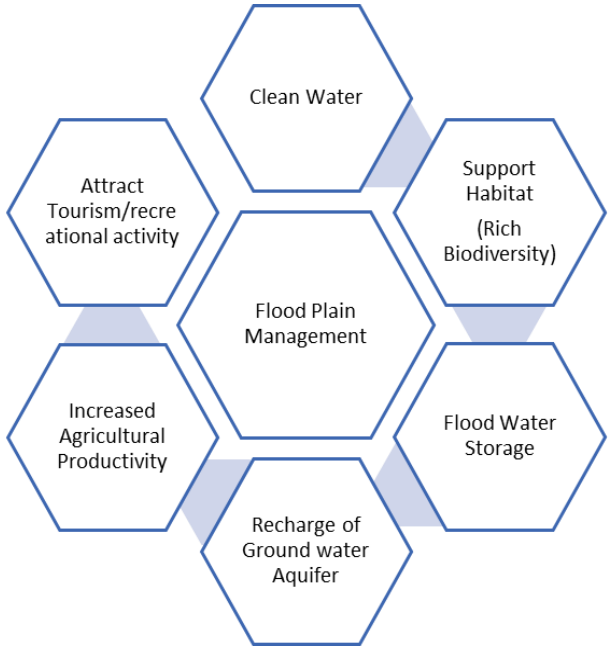

Fig. 7. Benefits of Flood Plain Management

The ecosystem along the bank also gets suffered adversely. The flood plain can be rejuvenated by the following approach.

- By initiating a massive campaign among the people especially settlements across the riverbank to make them understand the importance of flood plain
- Encroachment across the riverbank to be removed so that overflow water can spread to the maximum possible extent to recharge the aquifers

- Anthropogenic activities including farm practices need to be restricted along with the 500-meter buffer of the riverbank
- Outside the buffer area a green zone of maximum possible extent can be created to support the native flora and fauna of that area
- Dumping of solid waste if any can be strictly prohibited
- Mythological practices If any can be done in a controlled environment i.e. without impacting the health of the riverine ecosystem
- Water bodies across the riverbank at a certain interval can be created throughout the stretch to store water
- Flow of wastewater without treatment can be strictly prohibited. Currently, the only purpose of wastewater treatment is to drain it into the river. Hence treated wastewater can be utilized for other activity
- Exploitation of water through tube well along the riverbank can be strictly banned

From figure 7, the following benefits can be obtained post rejuvenation of flood plain

- **Clean Water:** Rejuvenation results in cleaner water in a flood plain as it eliminates/reduces all possible sources of pollution and allows only treated water to flow
- **Support Habitat:** Clean water and green environment across the flood plains support the river ecosystem and may attract various species across such as migratory birds
- **Flood Water storage:** Water spillage due to heavy rain or flood water can be reduced to a greater extent once the course of the river flood plain gets increased. It can help in the recharge of water aquifers thus helping in increasing the groundwater table
- **Increase in Agricultural Productivity:** Flood water carries the topsoil which has maximum nitrogen content and increases the agricultural productivity
- **Attract Tourism:** Rejuvenated water bodies along with the development of the green area can attract local tourism

Developing wetlands/water bodies

It is important to protect wetland across the river as it supports an ecosystem that not only protects the river but also recharges groundwater aquifer, prevents flooding. It also helps in nourishing the ecological diversity for various flora and fauna such as migrating birds etc. The protection of existing water bodies and the development of wetlands in Delhi is very much required to rejuvenate the only river Yamuna. Other than marshes or wetlands across the river, Delhi has three distinct types of water bodies such as village ponds, lakes, and artesian wells. Village pond comprises natural or man-made water bodies having a very small catchment area.

The main source of water is rainfall. Delhi has a few lakes as well where the major source of water is rainfall. The third type of water body is an artesian well, which is created for the extraction of water for drinking purposes, as briefly mentioned in figure 8.

Other than artesian wells the effective management of wetlands, lakes, and village ponds can be done by the following measures.

- Identification and mapping of water bodies across the state of Delhi
- Measurement of the catchment area and identification of the source of water such as rainfall or river water
- Possibility of linking waterbodies through river water sources can be mapped
- All possible sources of pollution and encroachment to be identified

Once water bodies are identified and mapped, the following measures can help them for complete rejuvenation:

- Removal of encroachment if any and strengthen of bunds such as fencing/ boundary wall across the water body
- In situ measures of water body cleaning such as de-silting, de-weeding, bioremediation, aeration
- Inlet and outlet of the water body to be identified or created for smooth flow of water
- Rainwater harvesting from nearby urban infrastructure is possible
- Plantation across the 50-100-meter buffer across the catchment area (Figs. 9 and 10) to maintain a healthy ecosystem. It may attract migratory birds and increase local tourism as well

- Awareness among residents or villagers about the importance of water bodies
- Training of stakeholders/local stakeholders in urban and rural areas
- A separate and dedicated place can be built for religious practice without disturbing the natural water body
- After the implementation of the above, monitoring at regular intervals needs to be done
- Linking of water bodies to river Yamuna or other canals is possible. This can be done by preparing a drainage map of Delhi (Fig. 11) to understand the natural flow of water from the River Yamuna from its course to canals, drainage. All the water bodies across these drainages can be linked to the Yamuna water which can get river overflow as a source of water after treatment

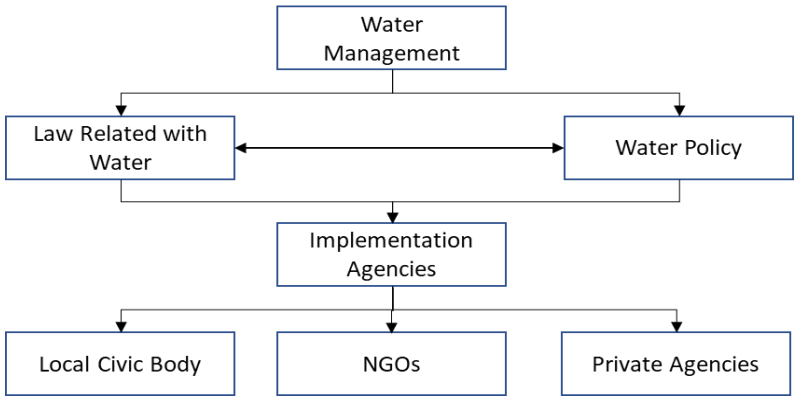

Fig. 8. Implementation of policies in coordination with laws

Fig. 9. Hauz Khas Lake, Delhi, buffered with green area and supports flora and fauna

Fig. 10. Prasad Nagar lake, Delhi, buffered with green area and supports flora and fauna

Public participation for water bodies management

In the **United Nations Conference** held in **Rio De Janeiro (1992),** it was emphasized that "Environmental issues are best handled with participation of all concerned citizens, at the

relevant level". Until it becomes the worst of its environmental stage, gaining attention from the public to participate in conservation or effective environmental management has always been a challenge. However public participation can help in the conservation of water bodies and supporting ecosystems to align the economic, social, and environmental needs of that area. This may bridge the gap between the mitigation actions implemented by the government and that required.

At the regional level, people can have appropriate information about environmental challenges such as degrading or depleting water bodies in their respective areas and possible impacts in the future. The awareness about the possible cause and impact with mitigation options can gradually increase the public participation towards effective management of water bodies. Conservation of water bodies requires a collaborative effort; it includes public awareness, scientific as well as the political will to a greater extent. The extinction of water bodies is an environmental threat that can further enhance the risk of the freshwater ecosystem. Hence it is essential to conserve the water bodies through desiltation, cleaning, and natural methods like rainwater harvesting. To implement this effectively local people must collaborate with the government for the successful implementation of a planned strategy for the conservation of water bodies.

The case of public participation typically focuses on three things, objective, and functional gains to the government by managing water bodies, planning for fair implementation of objective and third is individual and social fulfillment of needs. Integrating local people makes environmental governance easier, with considerably less opposition to potential plans. Locals know better about the area, source of pollution, flora, fauna, and can bring value to the decision-making process with unique knowledge of water bodies for that region. Therefore, the participatory approach raises the alarm or public voice and helps the government in environmental management with more strength [27, 28].

The objective of the government initiative needs to be clearly stated to the public along with the implementation plan. A massive awareness program amongst the locals can be launched to make them understand what benefit they will get by effective management of water bodies.

The public can participate as per the following.

- Volunteer the implementation of government initiatives in their respective areas
- Create awareness about the importance of water and water bodies amongst each other
- Raise alarm to the respective authority regarding the sources of pollution and encroachment with water bodies if any
- Participate in training provided by the government and arrange the same for students and others
- Based on the local climate, increase plantation across the water bodies to support flora and fauna

Synchronization of government policy on a water body with laws and implementation

Freshwater availability concerning the location of demand is a challenge across the world. Hence exploitation of groundwater or utilization of surface water requires a regulatory framework that must be abiding by the state policy for sharing and distribution for various purposes. Environment management is one of the sectors in India which largely depends upon the Non-Government Organisation or local civic body for its implementation.

There are various laws related to water however supporting government policy is not available. When the government design some policy then there are no supporting laws for that policy. When both Policies and laws are available then there is failure or willingness of implementation agencies to implement the same. Hence most of the new initiatives for environment management struggle with a policy without law and law without policy [28].

Conservation of water bodies such as lakes and wetlands are presently not covered by any specific laws. It is being monitored using several legislations enacted to Date. These acts applied partly to the lakes and wetlands such as The Wildlife act 1972, The water Act 1974, Forest conservation act 1980, and The Environment Protection act 1986. The National Environmental Policy 2006 comes up with setting up a legally enforceable regulatory

mechanism for lakes and wetlands to prevent their degradation. NEP-2006 suggests setting up a legally enforceable regulatory mechanism for identified valuable wetlands, to prevent their degradation and enhance their conservation. It is also suggested that to develop a national inventory of such wetlands. The environmental policy may remain wishful thinking if it will be not linked with a law that will ensure the implementation in a definite timeline. The existing laws related to water bodies can be modified according to the prepared policy for implementation (Fig. 8) where the implementation agency can complete the identified task in a defined timeline with the help of the local body, NGOs, and private agencies (Public-private partnership) for the betterment of water bodies [26].

Participation of local governing bodies

Delhi State has spread across 1483 SQKMs (Census, 2011), where the rural comprises 25% of the total area and urban comprises 75% of the total area. The local governing in rural and urban areas has been classified into two distinct forms. Nagarpalika derives their power from state government and takes care of urban localities whereas Panchayati raj takes care of the rural localities. The role of local governing bodies is very important in decision-making as well as the implementation of new projects as they have a better understanding of local areas regarding the problem and required resolution [25].

In India, most of the laws related to water come under state jurisdiction. State and Central government regulations help in protecting water bodies however they alone are not able to do the complete job. Hence local governing bodies have an important role to play such as preventive actions required for water bodies. Local governing bodies fill the gap in various regulations and frameworks identified by State and Central governments for maintaining and monitoring water quality [23, 24].

In Delhi, the water bodies are spread across both urban as well as rural areas. The responsibility to create, maintain, restore, and rejuvenate lies with different stakeholders as mentioned in Table 2.

Table 2. Summary of Water bodies comes under the ownership of different governing bodies (Delhi Parks and Gardens Society (Aug 2020)

		MCD									ASI		Forest							
S.No	District	DDA	BDO/Rev	EDMC	North MCD	SDMC	DJB	PWD	CPWD	Delhi Circle	Mini Circle	Delhi Arch.Dept	South Forest DIV	WEST Forest DIV	Wakf Board	DUSIB	DSIIDC	JNU	IIT	Total Count
1	East	49		3			2													54
2	North East	41	5				2													48
3	North	132	27		3						2									164
4	North West	133	15		1		1									1	3			154
5	South	94	6			3			1	9			13		1			3	1	131
6	South East	37																		37
7	South West	172	77			7	1	1		1		1								260
8	West	69	1											2						72
9	New Delhi	54				3					1			3						61
10	Central	20	1		1				4	1	1									28
Total Count		801	132	3	5	13	6	1	5	11	4	1	13	5	1	1	3	3	1	1009

Here both the local governing bodies for rural as well as urban can play a vital role like:

- Detailed Identification of water bodies along with coordinates for proper tagging
- Prepare the development plan for water bodies of their respective area
- Coordinate with state stakeholders for funding and implementation of the development or rejuvenation plan of water bodies
- Training and awareness of the people regarding the importance of water bodies for their respective areas

Change detection and preparation of drainage map which relates to the Yamuna

The riverbank has reduced in size in the recent past as can be seen in figure 11, showing the course of river Yamuna due to various development activities and encroachment. During the rainy season or high monsoon, the riverbank is unable to occupy and transport floodwater downstream due to reducing catchment. This results in less recharge of aquifers and wetlands along its bank as compared to the availability of water. The Yamuna is the only source of Surface water in Delhi whose course is changing in past years due to encroachment from both sides of the coast, this results in seasonal flooding of the river. Using GIS and remote sensing analysis can be done using Landsat Imagery (given in Fig. 11) for the past 30 years to understand the original river course of Yamuna and the course present today. This will help in the temporal analysis of satellite imagery to understand the change in Landuse due to encroachment. Likewise, the Drainage Map of Delhi can be prepared and used to understand the surface flow of water, connectivity of Drainage from the Yamuna. A drainage map (Fig. 12) of Delhi can be helpful to plan the connectivity of water bodies across the drainage. This will also help in providing natural sources of water to dying water bodies and stop flooding the river course of Yamuna [25, 26].

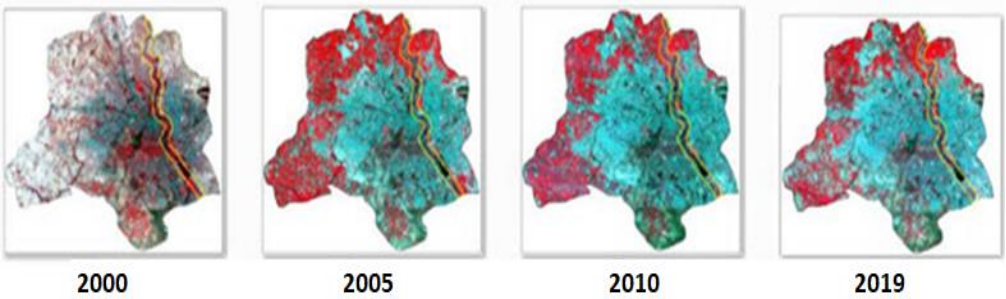

Fig. 11. Landsat Imagery displaying changing course of Yamuna River in Delhi

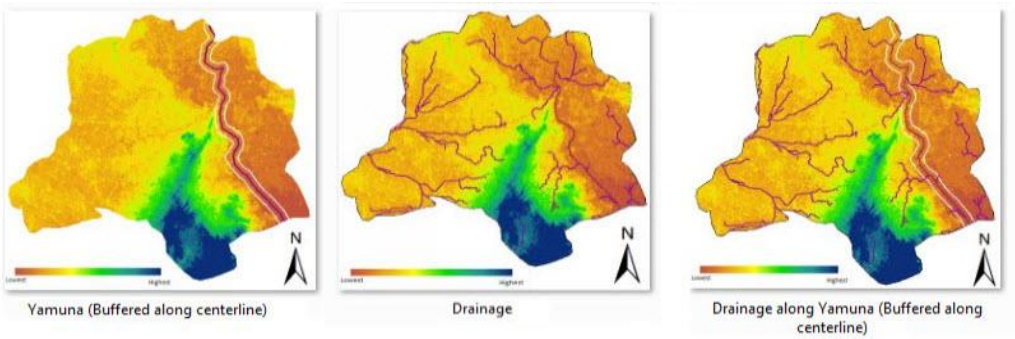

Fig. 12. Drainage Map of Delhi

NGT's monitoring committee on restoration– and rejuvenation of water bodies in Delhi NCR

National Green Tribunal (NGT) is looking into the expeditious disposal of cases related to burning environmental issues since its inception in the year 2010 under the National green

tribunal act 2010. An article appeared in the Hindustan Times dated 19.6.2015 on the topic entitled Dirty flows your drinking water emphasizing the level of contamination of groundwater in the various parts of Delhi. Based on information published in the article, NGT on its motion vide application number OA 496 of 2016 instructed Delhi Jal Board to share a status report on contaminated groundwater which is not potable for drinking purposes across various areas in Delhi.

Consumption of such contaminated water adversely affects the health of the consumers. It is because no regular water supply was available in the areas. Out of 979 samples collected by Delhi Jal Board, 473 samples were found unsatisfactory. Considering the above NGT has constituted a committee headed by Secretary, Environment National Capital Territory (NCT) of Delhi along with representative from Central Pollution Control board CPCB), Delhi Pollution Control Committee (DPCC), Delhi Development Authority (DDA), and Central Groundwater Authority (CGWA) to identify the area where water is contaminated across Delhi and take necessary steps towards its prevention and control.

The Central Ground Water Board publishes the Yearbook where they present the status of groundwater quality using various surveyed statistics and Maps. On 30th January 2018 referring to the Ground Water Yearbook-2015-2016, the tribunal suggested Delhi Jal board survey the area where electrical conductivity was identified as high (37 locations) and classified in red (3000-5000 Micro Siemens) and violet zone (>5000 Micro Siemens). The electrical conductivity (EC) of water is measured to get an idea about the extent of the mineralization of groundwater. It also gives an idea of total dissolved salts in a water sample. Considering the criticality of the situation, measure was taken such as the closing of borewell in the affected area, not issuing borewell licenses, and a compressive plan to recharge the groundwater so that the quality of the water gets improved. The tribunal also observed the urgent need for three upstream storage of River Yamuna and its tributaries in a time-bound manner to reduce dependence on groundwater and emphasized the urgent need for a comprehensive management plan. The tribunal had given due emphasis on revival- and rejuvenation of water bodies.

Tribunal suggested for the use of treated effluent for groundwater recharge through surface storage, rejuvenation of existing water bodies, creation of new water bodies, and use of treated effluent of less than 10/10 BOD/SS can also be used for horticulture and other non-potable uses that can also include the following.

- Installation of rainwater harvesting system mandatory for all buildings carrying out business activity having rooftop size more than 500 Square meter
- Utilization of treated effluents as a source of raw water for various usages such as for park and horticultural purposes
- Modification of building by-laws to include provision for rainwater harvesting
- Management of flood plains by removing encroachment to increase surface area for groundwater recharge

Satellite imagery examples of water bodies lying in Delhi NCR

In Optical Remote Sensing, sensors sense the amount of radiance, i.e., the amount of light the sensor sees from the object being observed and measures the reflection of sunlight [30]. Sunlight is the portion of the electromagnetic spectrum that constitutes the visible, infra-red regions and ultraviolet regions. Optical remote sensors mounted on earth observation satellites are designed and constructed to measure sunlight in visible and infra-red regions. Images obtained from the visible region (Red, Green, Blue) resemble those seen by our naked eyes. Remote sensing and GIS (Geographical Information System) techniques have been used in India by various researchers to calculate the numbers and areas of water bodies. Identified location on satellite imagery (google earth) of some of the water bodies are briefly explained here:

Badkhal Lake. Locating at the coordinate of 28°24'55.82"N, 77°16'33.49"E Badkhal lake is one among the tourist attraction of Faridabad in the state of Haryana. This is an artificial lake, and it was created in village Badkhal which is surrounded by Aravalli Range. The only source of water for this lake was seasonal rainwater flowing from the Aravalli range that use to store in its catchment area. Rapid urbanization, deforestation, and changing rainfall patterns

across the area results in the drying of this lake in the 1980s to finally dying stage now as can be seen from figure 13.

Fig. 13. Google historical Imagery of Badkhal Lake, Faridabad (NCR), dried gradually from 2003 till 2020

Roshanara lake: Like Badkhal Lake the Roshanara lake is located at the coordinate of 28°40'26.57"N 77°11'58.75" in Shakti Nagar, Delhi. Lake was built by daughter Roshanara of Mugal Emperor Sah Jahan, with losing its historical glory as can be seen in figure 14, is now completely dried in last few decades due to lack of proper source of water. During interactions with locals, it was known that in the initial time, it was full of beautiful scenic appearance and plenty of fresh water in it. The surrounding of the catchment of this lake was full of healthy vegetation which is supporting migratory birds during winter and was having a continuous source of water in this lake can further strengthen the ecosystem.

Fig.14: Google historical Imagery of Roshanara Lake, Shakti Nagar Delhi, dried gradually from 2002 till 2020

Satpula Lake: Another important lake which is also disappeared is Satpula Lake. It was located to the East of Khirki Masjid at the coordinate of 28°31'55.66"N 77°13'25.94" Satpula Lake as can be seen in figure 15. It is one of the best architectural representations of traditional scientific water management. The structure has seven arched barrages, and it was built by emperor Muhammad Bin Tuglaq as a water harvesting dam. Losing its historical tale, the water catchment area is completely dried with no visible traces of surface water. By linking the dried catchment area with continuous sources of water such as the river Yamuna the revival of the lake can be planned towards a healthy freshwater ecosystem surrounded by rich flora and fauna.

Fig. 15. Google historical Imagery of Satpula Lake, Khirki Masjid, Dried Lake converted into a park

Conclusion

Water bodies are dying in Delhi-NCR, many of them are on verge of extinction. Proactive measures are required to be taken to preserve these water bodies not only in Delhi but across the country. Using the GIS and Remote sensing technology these water bodies can be identified and mapped. This will help in analyzing the catchment of the water bodies as well as to understand the tank storage capacity to a probable extent. Temporal analysis of water bodies using high-resolution satellite imagery for pre-and post-monsoon can be done to understand the availability of a source of water in tanks, ponds, lakes due to rainfall, or due to some other sources such as flooded water from the canal, water from Rainwater harvesting channel, etc. In parallel with that, the water quality analysis can be done using a comprehensive field visit. Temporal analysis of water bodies with information on water quality can further be analyzed to understand the volume of water present across the year as well as its impact on the quality of water. The second step can be to identify the probable source of pollution. This information can be used for prioritizing the water bodies for rejuvenation. Public participation by mass awareness campaigns led towards the behavioral changes in society and this can be the core of the conservation plan.

The existing laws related to water bodies can include polluter pay principal and implementation of the same should be done more stringently. These regulations should not confine to Delhi-NCR, but also a similar stringent regulation should be put into action in the whole country without further delay. As per the report published by Delhi Parks and Gardens Society, most of the ponds in Delhi have been reduced in the area due to encroachment, siltation, dumping of garbage, and depleted sources of water. Similar issues can be identified across the country as most of the cities identified under the Smart City initiative are already experiencing water scarcity. Hence it is essential to map the coordinates of all water bodies in a single platform to monitor, control, and prevent pollution and in parallel make the people aware to protect these water bodies locally from getting the same extinct. Healthy water bodies, wetlands help the ecosystem get rich in biodiversity.

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