Urban lakes and wetlands: opportunities and challenges in Indian cities - Case study of Delhi

Ritu Singh, Manu Bhatnagar

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Ritu SINGH and Manu BHATNAGAR

Natural Heritage Division, Indian National Trust for Art and Cultural Heritage, 71, Lodhi Estate, New Delhi, India
(Email: sinh.ritu@gmail.com)

Abstract

In India, urban water bodies commonly become cesspools due to lack of sanitation facilities. Delhi is continually urbanizing at a rapid pace that has affected the condition of water bodies. To identify water resource available within Delhi, an extensive field survey and remote sensing based mapping was carried out in Delhi to map all the water bodies including groundwater recharge sites – 44 lakes and 355 village ponds. Hauz Khas, a historical tank and important recharge site, was restored by sourcing secondary treated wastewater and further improving water quality through ecological methods including bio-remediation that are cost effective. Water quality, water recharge and avian diversity data was collected to record improvement. The water table rose by more than 6 m, biological oxygen demand decreased from 50 to 15 mg/L in 21 days, the number of resident and migratory birds increased with two resident water bird species breeding in the lake.

Keywords

urban lakes; Delhi; restoration; water quality; ecosystem services

INTRODUCTION

Lakes are perceived as vast expanse of water in a pristine landscape where one goes for recreation. It is a place of experiencing nature by way of boating, camping, fishing, swimming, bird watching, etc. however, when one mentions ‘urban lakes’ the picture is soon demystified. While urban lakes are different from the common perception of lakes in general they too have value and functions, both ecosystem functions and social values.

There is no specific definition for Lakes in India. The word “Lake” is used loosely to describe many types of water bodies – natural, manmade and ephemeral including wetlands. Many of them are euphemistically called Lakes more by convention and a desire to be grandiose rather than by application of an accepted definition. Vice versa, many lakes are categorized as wetlands while reporting under Ramsar Convention.

India abounds in water bodies, a preponderance of them manmade, typical of the tropics. The manmade (artificial) water bodies are generally called Reservoirs, Ponds and Tanks though it is not unusual for some of them to be referred to as lakes. Ponds and tanks are small in size compared to lakes and reservoirs.

In a recent initiative the Ministry of Environment and Forest (MoEF) has mapped wetland on a 1:50,000 scale, however, the mapping for Delhi was carried out at 1:25,000 scale under the National Wetland Inventory and Assessment project. The inventory identifies and maps 15260572 ha area under natural and manmade lakes but small wetlands (< 2.25 ha) are mapped as point features (3.64 %). While it is difficult to date the natural lakes, most of the manmade water bodies like ponds and tanks are historical. The large reservoirs are all of recent origin. The water bodies across India have suffered environmental degradation, the degree of degradation differs. The degradation itself is a result of lack of public awareness and governmental indifference. The local city authorities responsible for management of stormwater and solid waste do not look at urban lakes as resources that should be conserved, rather consider it a 'waste land'. The situation is changing but slowly. Environmental activism and legal interventions have put sustainability of lakes in the vanguard of environmental issues.

Case of Urban Lakes

Humanity is increasingly urban, but continues to depend on Nature for its survival. Cities are dependent on the ecosystems beyond the city limits, but also benefit from internal urban ecosystems. The numerous effects of urbanization on hydrology, geomorphology, and ecology make wetlands in urban regions function differently from wetlands in non-urban lands. Furthermore, wetlands in urban regions may take on human-related values that they lack in non-urban areas, as they provide some contact with nature, and some opportunities for recreations that are otherwise rare in the urban landscape. Natural water bodies tend to get absorbed in urban expansion and their catchment is disturbed as a result of development. In Delhi in the Yamuna floodplain, the once river fed water bodies are disconnected from the river because of embankments.

Impact of Urbanization

The biodiversity of lake and pond ecosystems is currently threatened by a number of human disturbances, of which the most important include increased nutrient load, contamination, acidification, and invasion of exotic species (Bronmark & Hansson, 2002).

Hydrologic change is the most visible impact of urbanization. Hydrology concerns the quality, duration, rates, frequency and other properties of water flow. Urbanization typically increases runoff peak flows and total flow volumes and damages water quality and aesthetics. Pollutants reach wetlands mainly through runoff. Urbanized watersheds generate large amounts of pollutants, including eroded soil from construction sites, toxic metals and petroleum from roadways, industrial and commercial areas, and nutrients and bacteria from residential areas. By volume, sediment is the most important non-point pollutant. At the same time that urbanization produces large quantities of pollutants, it reduces water infiltration capacity, yielding more surface runoff. Pollutants from urban land uses are, therefore, more vulnerable to transport by surface runoff than pollutants from other land uses.

Likely effects of urbanization on wetland hydrology and geomorphology

<u>Hydrology</u>

- Decreased surface storage of storm water results in increased surface runoff
- Increased storm water discharge relative to base flow discharge results in increased erosive force within stream channels, which results in increased sediment input to recipient waters
- Changes occur in water quality (increased turbidity, increased nutrients, metals, organic pollutants, decreased O_2 etc.)
- Decreased groundwater recharge results in decreased groundwater flow, which reduces base flow and may eliminate dry season flow
- Increased floodwater frequency and magnitude result in ,or scour of wetland surface, physical disturbance of vegetation

- Increase in range of flow rates (low flows are diminished high flows are augmented) may deprive wetlands of water during dry weather

Geomorphology

- Decreased sinuosity of wetland / upland edge reduces amount of ecotones habitat
- Decreased sinuosity of stream and river channels results in increased velocity of stream water discharge to receiving wetlands
- Alterations in shape of slopes(e.g., convexity) affects water gathering or water disseminating properties

Likely effects of urbanization on wetland ecology

Vegetation

- Large number of exotic species present; large and continuous sources of re-invasion
- Restricted pool of pollinators and fruit dispersers
- Chemical changes and physical impediments to growth associated with the presence of trash
- Small remnant patches of habitat not connected to other natural vegetation
- Human enhanced dispersal of some species
- Trampling along wetland edges and periodically unfloodded areas.

Fauna

- Species with small home ranges, high reproductive rates, high dispersal rates favoured
- ‘edge’ species favoured over forest-interior species
- Absence of upland habitat adjacent to wetlands
- Absence of wetland/upland ecotones
- Human presence disruptive of normal behaviour.

(source: Ehrenfeld, 2000)

Bolund & Hunhammar (1999) in a study of Stockholm, Sweden, analyzed the ecosystem services generated by ecosystems within the urban area. ‘Ecosystem services’ refers to the benefits human populations derive from ecosystems. Seven different urban ecosystems have been identified: street trees; lawns/parks; urban forests; cultivated land; wetlands; lakes/ sea; and streams. These systems generate a range of ecosystem services, including, air filtration, micro climate regulation, noise reduction, rainwater drainage, sewage treatment, and recreational and cultural values. Findings of this study indicate that wetlands perform all six ecosystem services while other habitats lagged on one or more of these services.

Urban lakes and wetlands provide habitat for biodiversity conservation. Birds are known to be useful biological indicators of health of an ecosystem as they respond to secondary changes resulting from primary causes. Because of their high mobility birds react very rapidly to any change in their habitat. Urban development is one such change which often affects the population and diversity of terrestrial as well as water birds. In a comparative study of sub-urban wetland and irrigation reservoir it was demonstrated that the natural sub-urban lake supported resident species of birds while the reservoir supported migratory species (Rathod and Padate, 2008). Similarly Mohan & Gaur (2008) observed sixty two species of birds in Jajiwal pond, a natural wetland on the outskirts of Jodhpur city in Rajasthan, India. At Udaipur, Rajasthan, India, 32 bird species belonging to 18 families were observed during two year study period, 2004-2006. Of these 20 were resident, two summer migrants and 10 winter migrants. It was suggested that better habitat management would increase species diversity of the area.

Loss of wetland habitat results in threat to species dependent on it, in a study conducted during 2002- 2005, Gopakumar and Kimal (2008) showed that population of white breasted water hen *Amaurornis phoenicurus phoenicurus* was declining due to clearing of wild vegetation, filling of water bodies, change in land use pattern and construction activities. The study proved that wetlands are inevitable for breeding of this species. Loss of wetlands was responsible for its decline and if it continues at current level, it was feared that this bird may become a threatened species in the immediate future. Effective management of existing wetland habitats is crucial for conservation of this species.

The condition of urban lakes and water bodies in India is so dismal that the people have now filed a number of public interest litigation (PIL) to put pressure on government agencies to take action for their conservation. Citizens having realised that this important natural resource is key to sustenance of habitations and source of potable water need immediate conservation. Many cases have been documented, Dal Lake in Kashmir, Delhi's Waterbodies, Kurpa Tal, Naini Tal, Bhimtal, Naukuchia Tal and Sattal in Uttaranchal, Charkop, Thanne lake, Powai and Eksar Lakes in Mumbai, Hussain Sagar, Saroo Nagar lake, Kolleru wetlands in Andhra Pradesh, Vembanad wetlands in Kerala, Bangalore lakes, Bellandur lake in Karnataka etc. There are many more instances where citizens have come forward to conserve the wetlands and lake in light of government apathy.

The city of Hyderabad, in the last 50 years of its growth, has witnessed large scale destruction of this physical heritage of Hyderabad. It is estimated that there were 932 tanks in 1973 in and around Hyderabad which came down to 834 in 1996. Consequently the area under water bodies got reduced from 118 to110 km^2. About 18 water bodies of over 10 hectare size and 80 tanks of below 10-hectare size were lost during that period in the Hyderabad Urban Development Authority area.

MATERIALS AND METHOD

The study area Delhi, the capital city, spread over an area of 1483 km^2, has grown at a phenomenal rate, having a population of over 10 million. Data was accessed from the National Wetland Inventory and Assessment (http://moef.nic.in/modules/others/?f=wetlands-atlases), survey of India topographical sheets (scale 1:50,000) were referred. The Blueprint for Water Augmentation in Delhi, which is the only comprehensive source so far for information on water bodies in Delhi was used as primary reference.

In Delhi, the national inventory of MoEF identifies total wetland area estimated is 2556 ha that is around 0.86 % of the geographic area (Table 1). The major wetland types are river/stream (1116 ha), tanks/ponds (518 ha), waterlogged (natural/man-made) accounting for 23.2 percent of the wetlands (577 ha) and reservoirs (230 ha). It identifies 11 natural lakes and 352 manmade ponds/tanks in a total of 573 lakes / wetlands in Delhi.

Table 1: Area estimates of wetlands in the Delhi area in hectares

#	Wetland category	Number of wetlands	Total wetland area	% of wetland area	Open water	
					Post-monsoon area	Pre-monsoon area
	Inland wetlands - Natural					
1	Lakes/Ponds	11	106	4.15	100	60
2	Ox-bow lakes/ Cut-off meanders	-	-	-	-	-
3	High altitude wetlands	-	-	-	-	-
4	Riverine wetlands	5	15	0.59	13	14
5	Waterlogged	10	86	3.36	54	65
6	River/Stream	26	1116	43.66	826	845
	Inland wetlands -Man-made					
7	Reservoirs/Barrages	8	230	9.00	124	153
8	Tanks/Ponds	352	466	18.23	441	418
9	Waterlogged	29	471	18.43	85	145
10	Salt pans	-	-	-	-	-

INTACH's blueprint for water augmentation mapped all water resources as well as possible groundwater recharge sites such as paleo-channels and lineaments. It identified 44 lakes and 355 village ponds as major sites for water storage and recharge locations. A few of these are water bodies constructed by Delhi rulers in the past that have become defunct with time. When revived they can be used for storage of rainwater and groundwater that will aid in recharging the groundwater in the associated aquifers, in addition to providing habitat for biodiversity.

Survey of Lakes in Delhi

During 2010-11 the status of these 44 lakes of Delhi was re-ascertained. With the use of Google Earth application change in last 10 years was also recorded. It was recorded that 21 of 44 lakes / depressions have either been encroached or were permanently dry. The water bodies that were part of parks or protected areas had survived; however, the water quality was generally poor.

The wetlands surviving in heavily developed areas are highly degraded by the complex of stressors associated with urban development. However, some wetland functions can persist despite urban challenges. Wetland functions result from interactions among plants soils, and water. Urban residents use wetlands for passive recreation. While ecologists value wetlands for their biodiversity support function, which help maintain overall species richness in the landscape, people living near wetlands may value the provision of bird habitat or pleasing scenery, or have a general sense of ethical "good" associated with natural habitat (Erhenfeld, 2005).

Restoration of Hauz Khas lake, Delhi, India

Restoration of wetland hydrology is the single most important need for urban wetlands, but also the most challenging. Most of the wetlands are now located in places where adjacent land use cannot be changed. This then calls for innovative restoration techniques. Secondly, adjoining land use is an important factor in protecting biotic integrity of urban wetlands, densely vegetated forest edges helps protect these sites from exotic invasion.

Less than a decade ago, Hauz Khas Lake suffered from a fallen water table; its bed was dry and partly concretized. Surface water was not available for restoration. Storm water from 125 ha. catchment area and treated effluent from Vasant Kunj Sewage Treatment Plant was directed to Hauz Khas through a series of five check dams in Sanjay Van as per the INTACH proposal.

From the large check dam, a 3 km pipeline was laid in storm water drain to Hauz Khas ensuring gravity flow. The restored Lake is now a popular destination for tourists and Delhi citizens.

Objectives of restoration were:

- Enrich the local ground water regime
- Offer a bio-diversity habitat for aquatic life and avian visitors
- Enable sustained tube well operations in the area
- Substantially add to the visual attraction of the area
- Cool the micro-climate
- Offer recreational possibilities
- Increase soil moisture to support enhanced vegetation growth in the localized area

Database

The lake is situated in a district park of urban south Delhi and has a water spread of 6 hectares. The catchment of this lake has undergone rapid urbanization The Hauz has an area of 58,515 m^2, an average depth of 2.20 m [the bed is in slope with a difference of 1.5 m between the highest and lowest levels] and a storage capacity of 128,000 m^3. It has a perimeter of 1 km.

The bed of the Hauz was concretized with a 50 mm thick layer of lean concrete in 1968 with a view to stop the tremendous percolation losses. Over a period of time the layer has crumbled and is completely ineffective. Several trees had taken root in shallow mud pockets in the bed and several more have been planted along the 1 km. long edge. From the lake management point of view this vegetation is a nightmare as it multiplies the *in situ* organic load through decay and leaf fall. The littoral zone is also steep with stone-pitched banks and little vegetation. There is an island of 0.40 ha with steep banks but thick vegetation.

The stratum is extremely porous and makes it difficult to retain surface water. The water table was encountered at 19 mbgl (metres below ground level) in 2002. The depth to bedrock in the area is 60 -112 mbgl and the shallow aquifer occurs from 26 – 35 mbgl

The catchment area was estimated at 10 km^2. draining through 3 storm water channels [now carriers of sewage] and these are now diverted away from the Hauz (MAP 1). The groundwater contained high levels of nitrates (> 20 mg/l), chlorides (90 mg/l), and total dissolved solids (TDS) were 400-500 mg/l.

Resources in the Catchment

A sewage treatment plant exists in the catchment discharging 2.5 million gallons of treated effluent. The effluent quality of this STP that was available for sourcing water to Hauz Khas lake is given in table below.

Table 2: Vasant Kunj STP effluent quality

	pH	Total alkanity	Cl	TS	SS	DS	BOD	COD	Oil	Grease
January	7.8	403	171	895	16	879	12	96	1	
February	7.7	415	126	889	12	877	14			
March	7.7	448	182	936	19	917	13	46	2	
April	7.7	472	184	904	77	882	14	47	1	27.9
May	7.7	470	167	892	19	873	14	39	1	28.2
June	7.8	329	176	881	13	868		26	1	31.1
July	8.1	399	171	886	15	871	11	27		

August	8.1	348	166	773	14	739	10	29	1	
September	8	432	155	783	16	267	11	31	2.5	4.2
October	8.1	486	178	820	26	794	13	54	1	
November	7.9	439	151	754	21	733	12	40	2	
December										

Source : DJB , Note : One day from every month of 2002 values of all parameters in mg/l except for pH.

The parameters of effluent were fairly consistent and the effluent quality meets the Ministry of Environment & Forests [MoEF] standards for discharge into surface streams [< 20mg/l BOD, <30 mg/l SS, > 100mg/l COD].

Catchment Area

Three storm water channels lie on the upstream side of the Hauz. None of them were directly flowing into the Hauz in the natural course. These channels emerge south of the Hauz from the southern ridge area and serve a catchment of approximately 10 km^2. These channels are carrying wastewaters/sewage from unsewered areas of heavily urbanized catchment, the annual storm water runoff generated was about 700,000 - 900,000 m^3 annually, in a year of average rainfall.

Storm water drainage channels

The drainage channels of the southern ridge which are relevant to the Hauz emerge, one from Jawaharlal Nehru University (JNU) and two from north of JNU passing through Sanjay Van and thereafter through Indian Institute of Technology (IIT), Delhi. As mentioned earlier the storm waters were contaminated by the sewage load carried by these channels. The south-easternmost of these channels also carried the treated effluent of the Vasant Kunj STP. The channel has a series of 5 check dams in the Sanjay Van area which have served to recharge the aquifer and bring up the water table in that area. The treated effluent discharge flow rate of STP available at the check dam no. 3 are given below.

Table 3: Treated effluent discharge at check dam no.3 in Sanjay Van.

Time (h)	**Discharge** (m^3)
0800	0.055
0900	0.06
1000	0.085
1200	0.04
1400	0.066
1600	0.073
1800	0.072
1900	0.065

Source: Field Observations (February, 2003)

Map 1: Revivals of Hauz Khas lake in Delhi: storm water channels in Hauz Khas catchment

Rainfall

The average annual rainfall in Delhi is 610 mm/y, direct precipitation over the Hauz reservoir area annually amounted to 35,110 m^3.

Evaporation

Evaporation losses from lake were considered and water management system devised accordingly.

Operational Concept

On analysing the data base assembled above it emerges that:

- given the current state of the storm water channels [which have become carriers of polluted urban flows],
- the erratic nature of the rainfall [80 % of annual precipitation occurs during July to September],
- the deep water table combined with the porous sub-stratum which no longer supports the surface spread.

It would not have been possible to fill up the Hauz with clean storm water and sustain the lakes water spread to beyond even October. Nor, in an above average rainfall year, would it be possible to store sufficient water so as to maintain the water body beyond October.

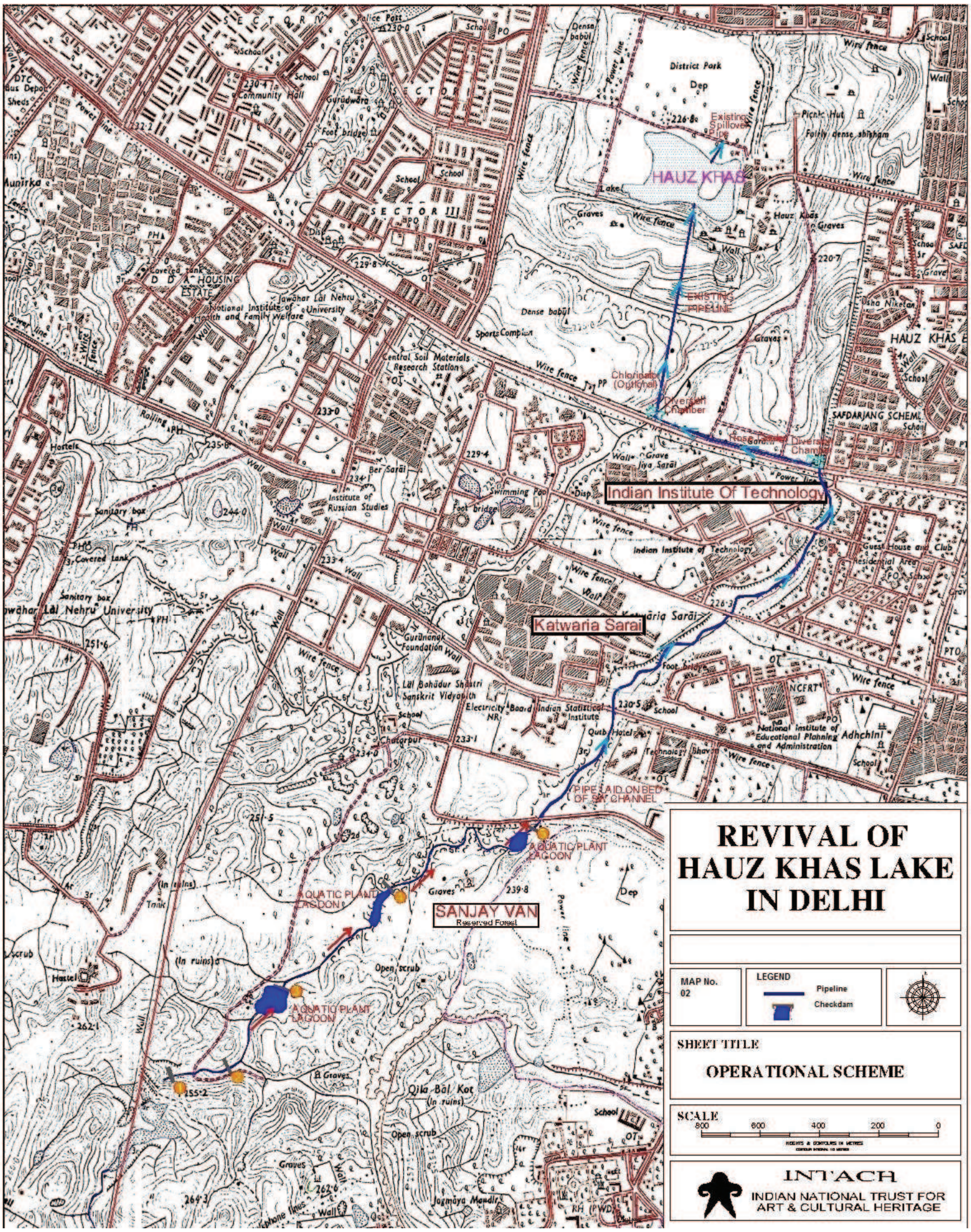
To revive the Hauz presently there was no option but to utilize the treated effluent water from Vasant Kunj which is the only reliable regular source of water. The following scheme was followed:

a) One MGD (Million Gallon per Day) treated effluent from Vasant Kunj STP was utilized for filling the lake after further treatment with duckweeds (*Spirodella, Lemna, Wolffia*) in the water retained in existing check dams in the catchment. The objective was to bring the BOD from 12 mg/l [at STP outlet] to < 5 mg/l with 2 days retention time.
b) The treated water is conveyed from check dam through a system of pipes (600 mm ø) and chambers. The pipes are laid on the bed of the storm water channel to ensure that non-point pollution does not affect the water quality en route.
c) The entire flow is accomplished with gravity.
d) Based on the flow regime the average flow is estimated at 2000 m^3/d (cubic meters per day) after accounting for diversions upstream of Sanjay Van, seepage losses in Sanjay Van, trans-evaporation by the plant community in the aquatic plants lagoon in Sanjay Van and removals in IIT campus.
e) After filling the Hauz to full capacity the losses on account of evaporation and percolation have to be made up. The percolation losses are assumed as a stable constant whereas the evaporation losses would vary with the seasons. The losses are estimated between a high of 940 m^3/d in May to a low of 600 m^3/d in December – January.
f) After filling the Hauz appropriate fish species have been introduced in the reservoir. [Populations: Indian Carps – 120,000, Grass Carps - 50,000, Gambussia – 10,000 no.s]. The plankton, which feed upon the organic load in the water are consumed by the fish. Bottom feeder fish feed upon the detritus of dead matter floating down towards the bed of the reservoir. The fish would attract fish eating birds and thus the organic matter would be removed from the water through a natural food chain.
g) Bioremediation: Facultative anaerobic bacterial consortium was introduced in surface waters to reduce biological oxygen demand, reduce nitrates and to improve the levels of dissolved oxygen. This formed basis for restoration of water quality and aquatic ecosystem to the lake.

Map 2 shows operational scheme.

RESULTS AND DISCUSSION

A number of tangible benefits have been achieved. There is a rise in the localized water table of 5 meters over a span of 3 years as a result of which dry hand pumps in neighbouring areas have regained functionality. The yield from surrounding tube wells has increased thereby reducing operational time and consequently reducing energy consumption.



Map 2: Revivals of Hauz Khas lake in Delhi: operational scheme.

Rain water, to the tune of 500 million litres, has been harvested to date. Due to the high percolation rate this has all been recharged to the aquifer. Overall the groundwater quality has improved as shown by post-project groundwater tests.

Analyses of the groundwater samples [2004 and 2007] have shown improvement in a number of parameters. pH reduced to 7.1, biological oxygen demand reduced from 3 mg/L to 1 mg/L, nitrates fell from 20 to 1.14 mg/L. The estimated volume of this recharge is 3500 million litres. Thus, the total recharge affected through this project is 4000 million litres to date.

Bioremediation of lake water ensured that the BOD in lake water fell from 50 to 15 mg/L. visual water quality drastically improved within a month and turbidity level improved as well. This process was instrumental in controlling algal blooms. The table below details water quality improvement in lake waters

Table 4: Water Quality analysis of lake water during bioremediation process

Week	pH		Turbidity (FNU)		Conductivity (µmhos/cm)		BOD (mg/L)	
	Spot 1	Spot 2	Spot 1	Spot 2	Spot 1	Spot 2	Spot 1	Spot 2
First Week (13 – 19 July 2007)	9.57	9.25	102	174	800	797	50	70
Second Week (20 – 26 July 2007)	9.07	9.13	52	158	787	787	17	34
Third Week (27 July-02 August 2007)	8.82	9.02	50	131	761	748	15	28

The lake has steadily acquired the characteristics of a natural eco-system. While fish have been introduced into it, some resident water birds have habited by themselves. Several wild ducks have been attracted here and have also been breeding as is evident by the large number of ducklings. Thus 12 species of birds have been observed here, amongst them, Northern Shovellers from Central Asia. The observed species include spotbill ducks, black-winged stilts, pond herons, garganey duck, gadwall duck, pied kingfisher, white-breasted kingfisher, plovers, coots, water hens. In the winter of 2006-2007 the bird count reached 500. Spot-billed duck, Indian moorhen and White-breasted water hen are resident water birds that regularly breed in the lake.

The recreation of an environmental asset and its transformation into a natural habitat with pleasing visual characteristics is beginning to attract citizens to the area as well as to the nearby markets. The historical monuments on the southern corner now have an original water foreground to reflect them.

Given Delhi's large number of water bodies, it has potential to house natural restored wetlands. While a large number of water bodies- 21 out of 44 surveyed have gone dry, it is due to rapid urbanization and falling groundwater tables. These were smaller depression that were not protected, however, those water bodies that were either larger in size or were part of city greens/ institutional areas have survived. The survey shows immediate need to preserve remaining water bodies and restoring the ones that have gone dry.

It is demonstrated by restoration of Hauz Khas lake, the water bodies in urban areas can not only be restored but develop into functional ecosystems. Restoration of ecosystem services garners public support. Such restoration efforts could be extended to other lakes in Delhi as also to urban water bodies across the country.

Even in the face of encroaching development, urban wetlands can retain an impressive amount of integrity. Despite their need for restoration and management, urban wetlands remain functional and diverse ecosystems. It is important that urban wetlands as well as forests be accessible to people, though it may be argued by ecologists (purist) as source of disturbance, therefore, a threat to ecosystem.
Some challenges pertain to the established paradigm of engineered solution. In a country like India we can ill afford the cost intensive and energy intensive engineered solution. The low confidence in ecosystem approach to restoration of lakes and control of pollution needs a change. It also stems from a root cause that ecologists and environmentalists are not part of decision making and planning process. Time has come to look at the issues of urban environment in landscape context rather than isolated project.

CONCLUSION

An effort towards restoration of urban lakes through innovative measures has been demonstrated by INTACH through its project on Hauz Khas. Other similar innovative endeavours are required. Further, instead of a project based approach conservation of urban lakes needs to be part of master plans. Lest proactive measures are taken the remaining water bodies of Delhi will disappear as many have.

Lastly, urban environment research in the India is limited to pollution abatement in the conventional way. The need now is to identify and accept that there are 'natural' areas within urban areas. That there are several ecosystems including wetlands/ lakes and forest that are functional ecosystems; that these are in need of conservation and that the urban wetland and lakes add to the quality-of-life. Research in urban forestry, urban wetlands and urban lakes is required to establish their role in provision of ecosystem services, as wildlife habitats, as carbon sinks, as climate ameliorators, as controllers of pollution, and for their position in hydrology.

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