BEFORE THE NATIONAL GREEN TRIBUNAL
PRINCIPAL BENCH, NEW DELHI

Original Application No. 927 of 2024

IN THE MATTER OF:

Society for Protection of Culture, Heritage, Environment, Traditions and Promotion of National Awareness (Regd.) Also known as [SP-CHETNA] **.... Appellant**

Versus

Delhi Development Authority & Ors. **.... Respondents**

INDEX

For S P CHETNA
Hony President

APPLICANT

THROUGH

NEW DELHI
DATED: 10-06-2025

Madhumita

MADHUMITA SINGH, SAMEER SOOD

(ADVOCATES)

[(D/4778/2016) & (D/3229/2017)]
A 414-415, SOMDUTT CHAMBERS-1,
5, BHIKAJI CAMA PLACE, NEW DELHI – 110066
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SHORT REPLY ON BEHALF OF APPLICANT BY WAY OF AN AFFIDAVIT TO COUNTER AFFIDAVIT FILED BY RESPONDENT NO. 1 i.e., DELHI DEVELOPMENT AUTHORITY (DDA)

I, Anil Sood, a senior citizen, S/o Late Sh. M.C Sood, aged about 69 yrs., R/o C-1/1056, Vasant Kunj, New Delhi-110070, do hereby solemnly affirm and state as under:

That I am the President of the Applicant Society and am well acquainted with the facts and circumstances of the present case and as such, competent to make and affirm the present short affidavit. I have gone through the affidavits filed by Respondent No. 1 and a short reply to the same is as under:

NOTARY PUBLIC SANDEEP SHARMA REGN. NO. 1186/98 EXP DT. 02-04-2026 GOVT OF INDIA

MOST RESPECTFULLY SHOWETH:

1. The Applicant had filed Original Application 927/2024 highlighting the pathetic state of Water Body in Master Amir Chand Park - Vasant Kunj, New Delhi, Machli Talab in Samriti Van, Vasant Kunj, New Delhi and Kitchner

Lake - a Master Plan Lake under control of Respondent No.1, but had restricted present OA only to Kitchener Lake.

2. That the Respondent No.1 in para 4 (i) of its short affidavit as *Annexure-A-2 (colly),* has placed on record the test reports dated 11.01.2025, 06.02.2025, 06.03.2025 and 10.05.2025 issued by the *CATTS Labs and Research Private Limited, an ISO 9001-2015 Certified MoEF recognised Govt approved test house.*

3. Applicant respectfully submits that on 18th February 2025, applicant had visited the lake and taken photographs, which have been uploaded on NGT Portal. In view of the status of water on that day, the test reports dated 11.01.2025, 06.02.2025 raise a serious question on the conduct of the Respondent No. 1. While placing on record the test Reports, Respondent No.1 has not placed on record work order placed on the Laboratory, name and designation of the officer who accompanied the Test Lab staff to pick up the sample, geo tagged photographs evidencing picking up of sample from which part of the lake the sample was picked up and how it was picked which was carried to the lab for the purpose of testing. Therefore, the test report cannot be relied upon in absence of aforesaid details and also in view of the status of the lake on 18-02-2025 as evidenced by photographs, that were sent through email on 21.05.2025 and uploaded on NGT Portal on 05.06.2025. The copies of the email dated 21.06.20025 and the Photographs dated 18.02.2025 of Kitchner Lake are annexed herewith as **Annexure A-1 (Colly).**

4. That it is further respectfully submitted that Respondent No. 1 (DDA) in para 4 (ii) of its affidavit submitted that it has been coordinating with the Military Engineer Services (MES) Department to obtain water from STP installed at RR base hospital, located adjacent to the Jheel Park, Dhaula

Kuan. However, no documents have been placed on record about the quality of water in the lake and whether it is suitable for the revival of lake.

5. That the Respondent no. 1 in para 4 (ii) placed on record the correspondence letter dated 29.01.2025 as ***Annexure-3*** in which it is submitted that MES Department has proposed take off point for treating water to facilitate the revival of Kitchner Lake. However, the Respondent No.1 is blowing hot and cold in same breath as in the matter of ***Delhi Development Authority vs Society for Protection of Culture, Heritage, Environment, Traditions and Promotion of National Awareness (CHETNA) and Others with Civil Appeal No. 4238-4239 of 2022*** filed before the Hon'ble Supreme Court by the Respondent No. 1 (Appellant in the before Apex Court) challenging the order dated 05.10.2017 in OA No. 289/2017 and review order dated 25.03.2022 in Review Application No. 05/2022 in OA no. 289/2017 passed by the Hon'ble National Green Tribunal in which Respondent No.1 was directed to adopt stone pitching instead of Ethylene Propylene Diene Monomer (EPDM) which is not environment friendly while developing artificial lakes at its Qutub Golf Course.

6. Hon'ble Supreme Court in the aforementioned matter had directed IIT Roorkee to submit its opinion/report as to the methods that can be applied or adopted for the construction of an environmental friendly water body that would ensure groundwater recharge. The IIT Roorkee placed on record two reports first on 11.08.2022 and second on 20.11.2023, wherein the use of treated water for recharging the groundwater resources of the area has been discouraged as treated water would contaminate ground water. The relevant text paras of the aforementioned reports are reproduced below:

NOTARY PUBLIC
SANDEEP SHARMA
REGN. NO. 1186/98
EXP. DT. 02-04-2026
GOVT OF INDIA

i. **Report dated 11.08.2022 in terms of order dated 20-05-2022 (at internal page No. 18 of the report at page no. 34 of the paper book)**

> ***8.0 Concluding remarks***
>
> .....
>
> *3. The treated wastewater used for irrigating the Golf course contains relatively high level of some trace elements, and is therefore, not recommended for recharging the groundwater resources of the area. However, harvested rainwater during the monsoon season shall continue to be recharged using the existing recharging structures after discarding some initial volume of water.*
>
> *4. Emerging pollutants like personal care products, pharmaceuticals, metabolites etc. which are not analysed in this study may also be present in traces in the treated waste water used in the Golf course and should be avoided for recharging aquifers to check quality degradation of the groundwater of the area.*

ii. **Report dated 20.11.2023 – [at internal page No. 17 of the report] (at 59 page no. of the paper book) submitted by the IIT Roorkee after revisiting the Golf Course, in view of suggestions by Hon'ble Supreme Court during the hearing dated 12-09-2023**:

> ***9. Concluding Remarks***
>
> .....
>
> *2. Samples of the treated wastewater used for irrigating the Golf course were collected again for analysing its quality. It was observed that the samples still exhibit elevated concentration of some pollutants and thus, the utilization of treated water for groundwater recharge is discouraged.*

The reports dated 11.08.2022 and 20.11.2023 submitted by the IIT Roorkee before the Hon'ble Supreme Court of India are annexed herewith as **'Annexure-A 2 (Colly)'.**

NOTARY PUBLIC
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7. That, therefore, in view of the report submitted by the IIT Roorkee, it is evidently clear that the treated water cannot be used for the revival of Kitchner Lake because once the lake is revived with treated water, the same shall be percolated and consequently contaminate the ground water, which would be an ecological disaster. Therefore, Respondent No.1 be directed to place on record the quality of water after treatment which is likely to be used for reviving lake in view of two reports already placed on record before Hon'ble Supreme Court.

8. Applicant seeks liberty of this Hon'ble Tribunal to submit a detailed response, once Respondent No.1 places on record the detailed affidavit.

DEPONENT

VERIFICATION:

Verified at New Delhi on this the 10th day of June 2025 that the contents of the above application are true and correct to the best of my knowledge and belief and no part of it is false and nothing material has been concealed therefrom.

Date: 10.06.2025

Place: New Delhi

NOTARY PUBLIC
SANDEEP SHARMA
REGN. NO. 1186/98
EXP. DT. 02-04-2026
GOVT OF INDIA

DEPONENT

IDENTIFIED BY

ATTESTED
NOTARY PUBLIC
DELHI (INDIA)
10 JUN 2025

Outlook

Re: Photographs dated 18-02-2025 - Kitchnere Lake No work on ground

From Madhumita Singh <madhumita@casassociates.in>
Date Wed 5/21/2025 12:02 PM
To न्यायिक अनुभाग Judicial Section <judicial-ngt@gov.in>
Cc Anil Sood <anilsood@spchetna.com>; Anil Sood <anilsood@casassociates.in>

18 attachments (5 MB)

IMG-20250218-WA0017.jpg; IMG-20250218-WA0019.jpg; IMG-20250218-WA0022.jpg; IMG-20250218-WA0020.jpg; IMG-20250218-WA0018.jpg; IMG-20250218-WA0023.jpg; IMG-20250218-WA0025.jpg; IMG-20250218-WA0024.jpg; IMG-20250218-WA0026.jpg; IMG-20250218-WA0027.jpg; IMG-20250218-WA0028.jpg; IMG-20250218-WA0029.jpg; IMG-20250218-WA0032.jpg; IMG-20250218-WA0030.jpg; IMG-20250218-WA0031.jpg; IMG-20250218-WA0033.jpg; IMG-20250218-WA0035.jpg; IMG-20250218-WA0034.jpg;

Dear Sir,
Good afternoon!

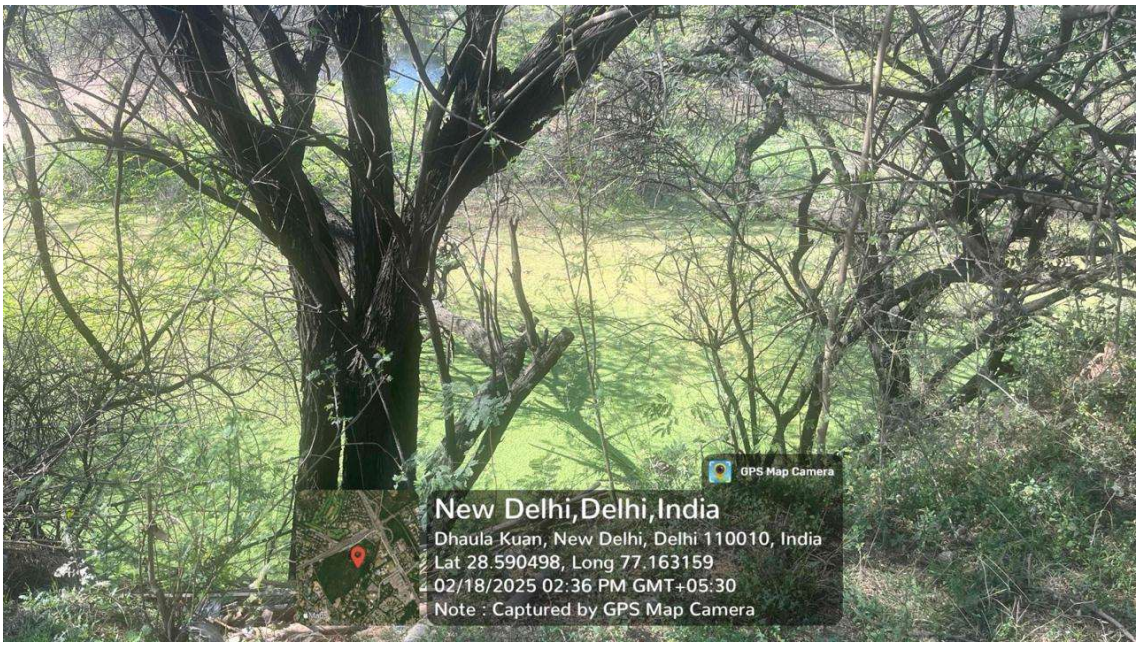
Request you to place these photographs before the Hon'ble Bench when item 18 is called out. Due to paucity of time the same could not be filed in the registry.

As per affidavit test reports dated 11-01-2025, 06-02-2025, 06-03-2025 and 10-05-2025 , Kitchener Lake Water is being tested for drinking purposes.

Learned Counsel had made a statement before this Hon'ble Tribunal that a lot of work has been done, whereas on 18-02-2025, as per photographs nothing was done.

As per the photographs dated 18-02-2025 the test reports dated 11-01-2025 and 06-02-2025 appear to be of some other site and cannot be of Kitchener Lake.

Regards,
Madhumita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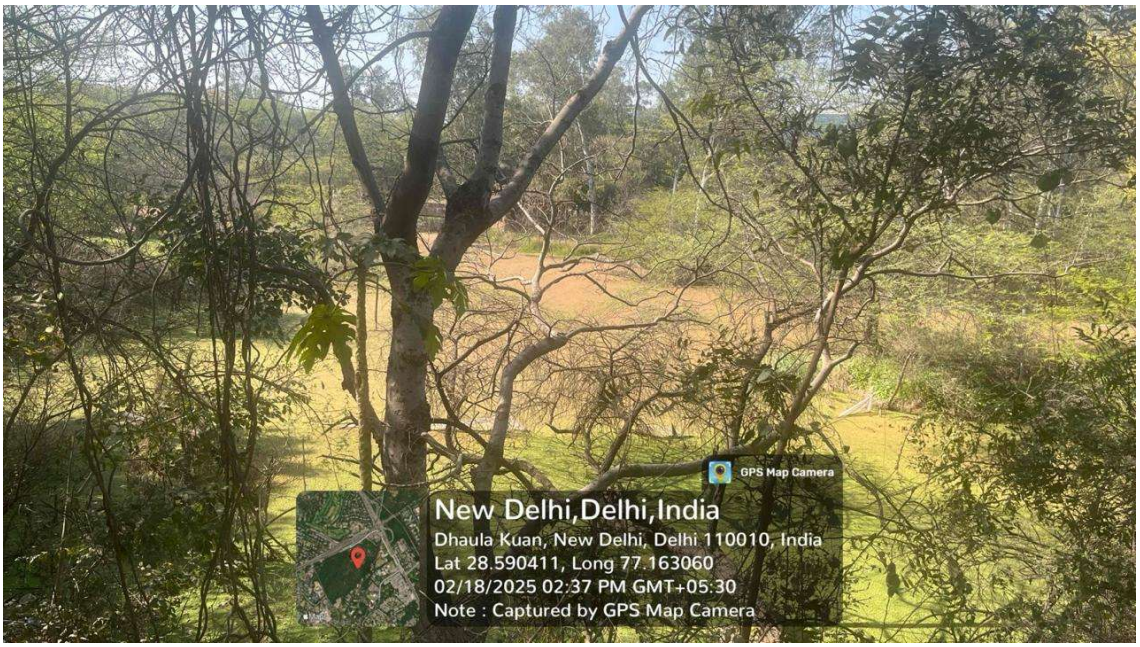
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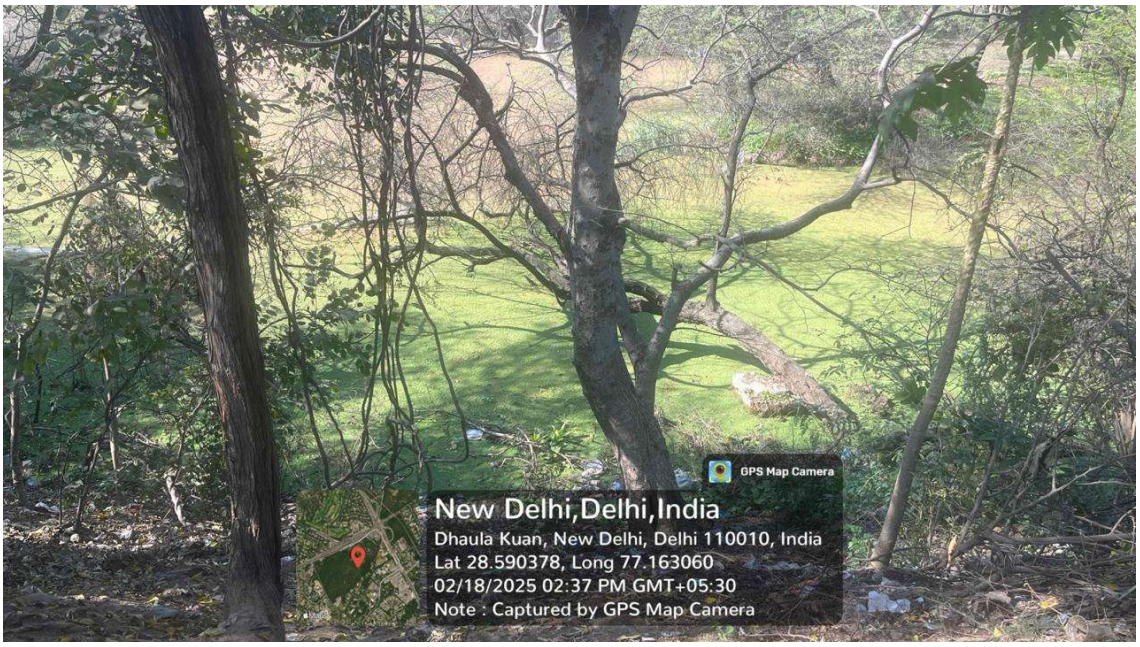
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दिल्ली विकास प्राधिकरण
DELHI DEVELOPMENT AUTHORITY
चेतावनी
• यहाँ पर पानी गहरा है, पानी में नीचे उतरना मना है।
• यह पानी पीने एवं नहाने योग्य नही है।
• यहाँ पर कचरा ना फैलाए, पार्क को स्वच्छ बनाएं।
• डीडीए किसी भी दुर्घटना एवं चोट की जिम्मेवारी स्वीकार नही करता है।
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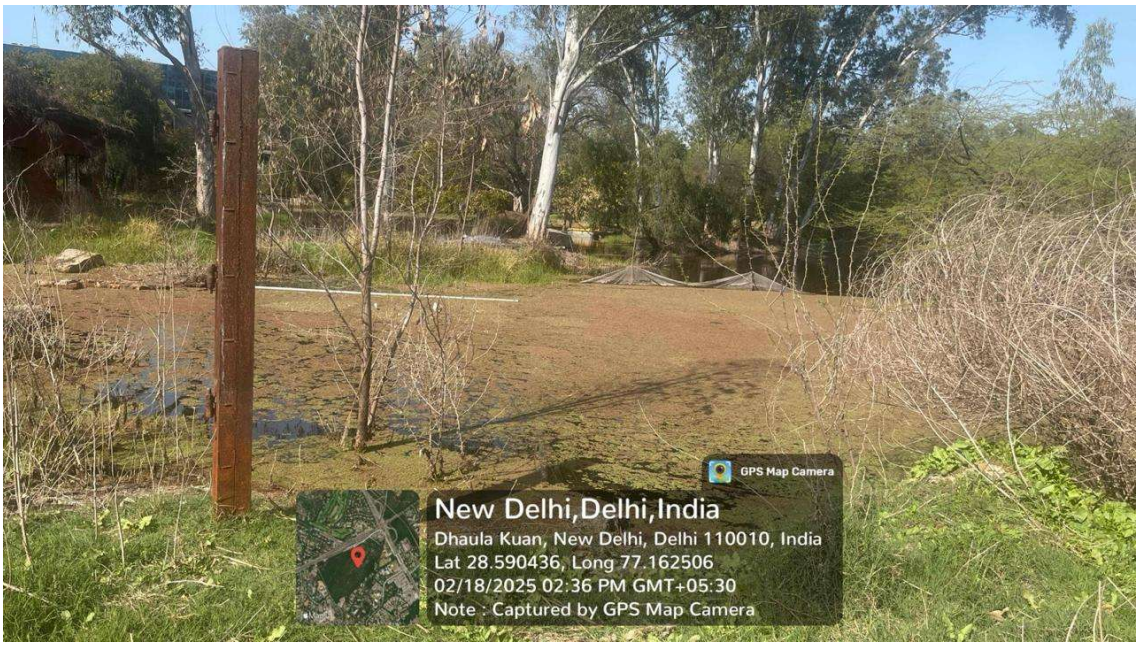
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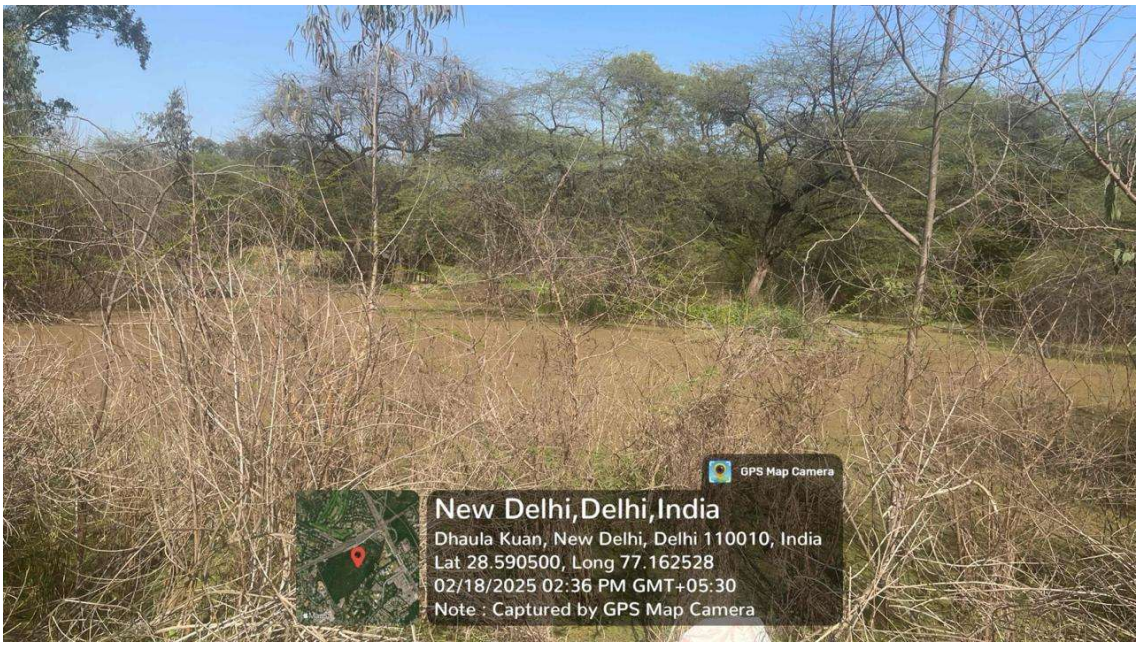
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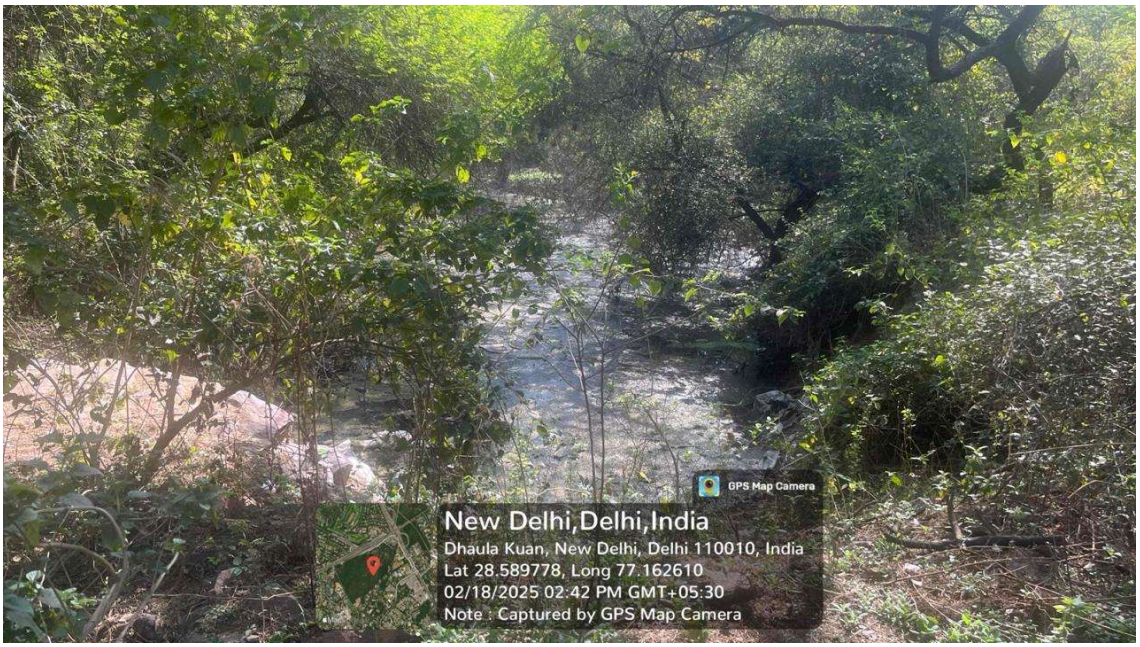
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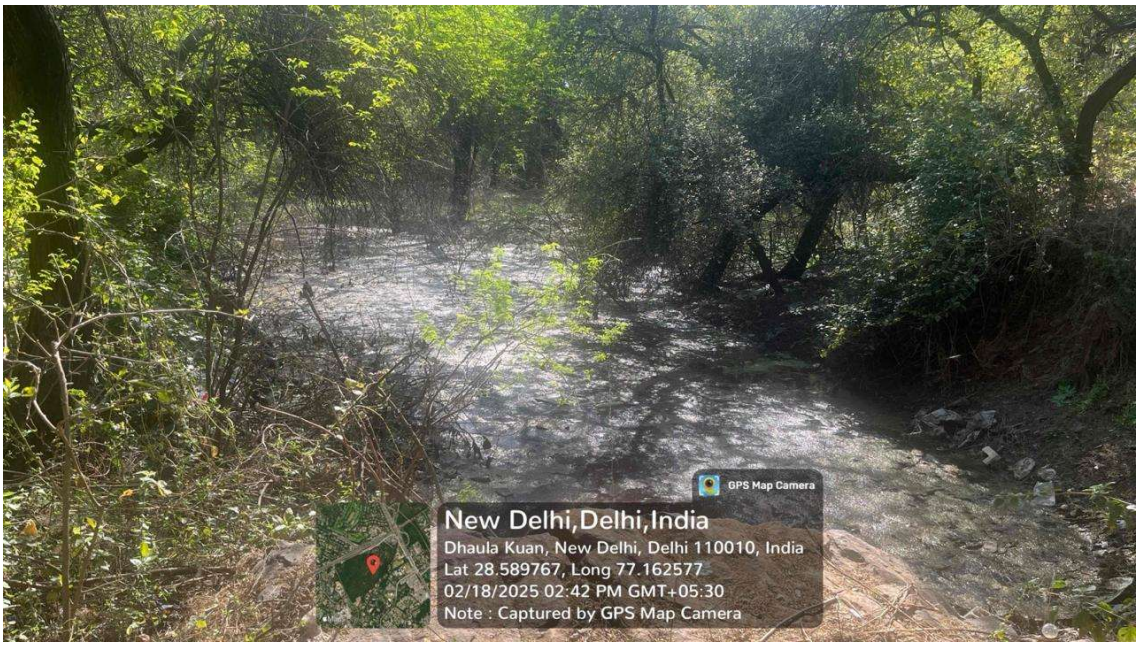
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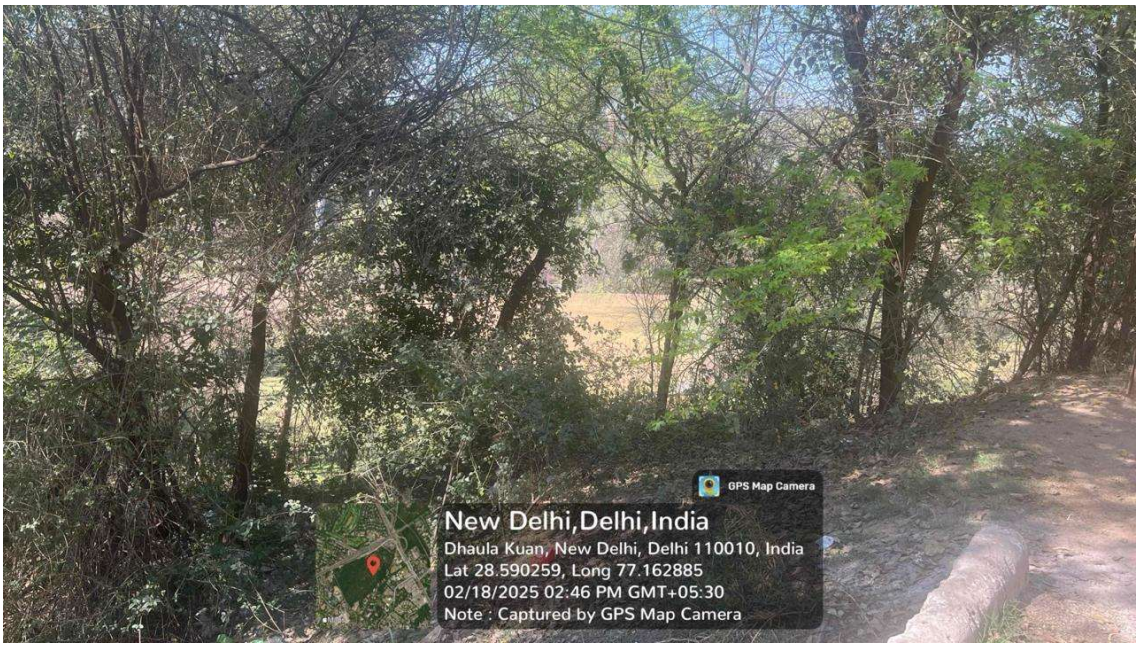
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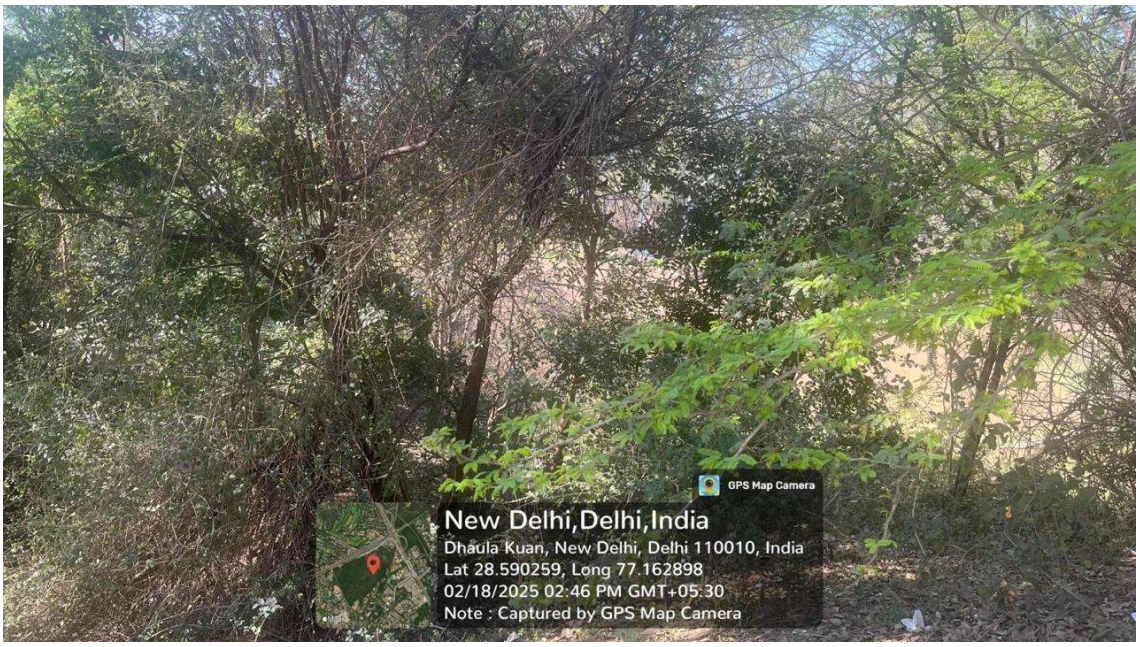
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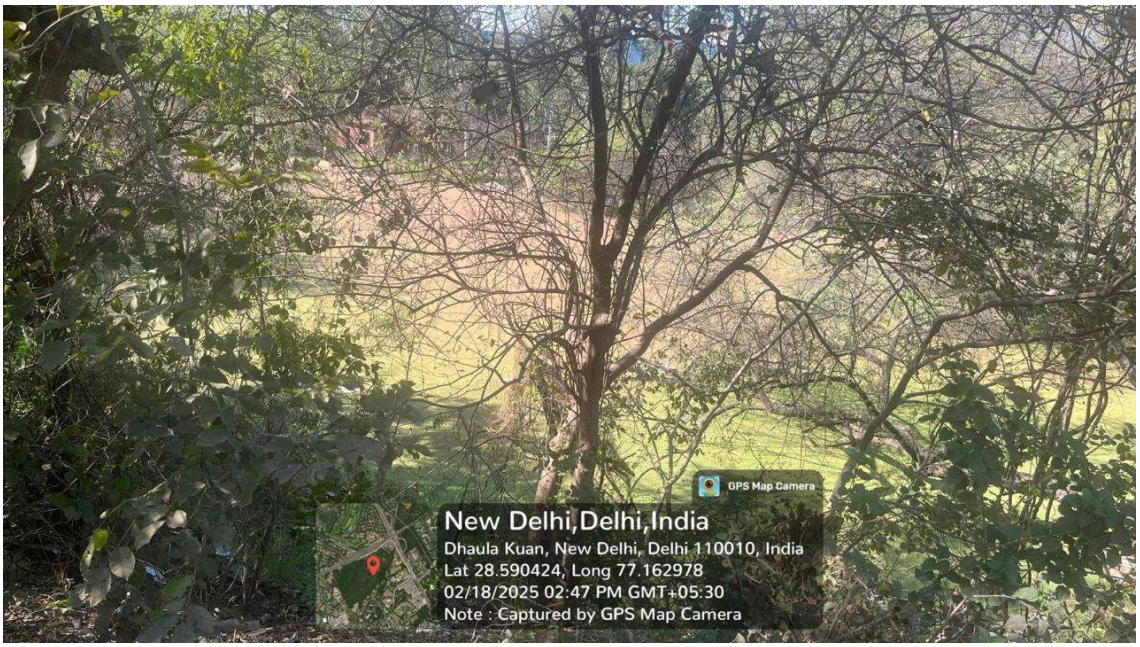
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DELHI DEVELOPMENT AUTHORITY
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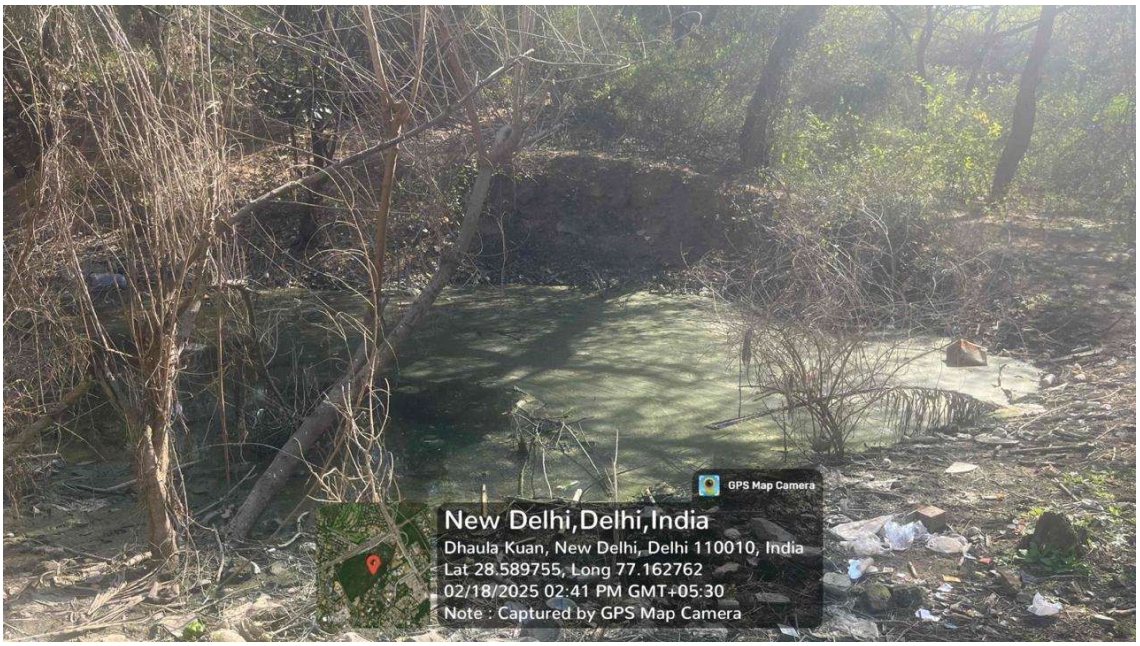
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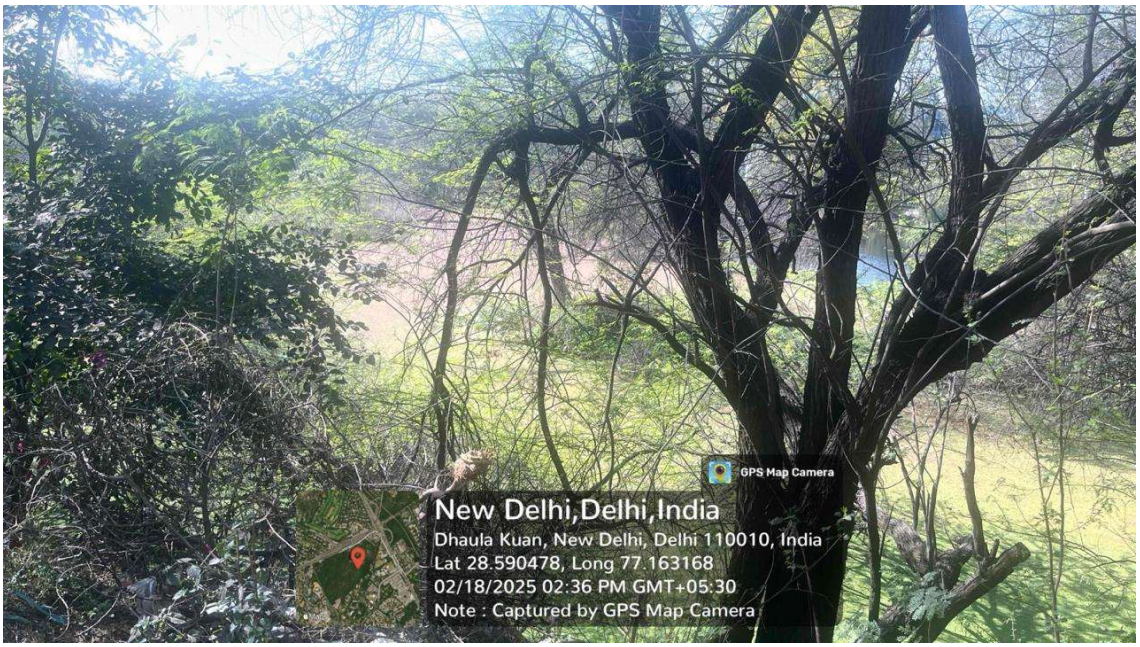
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ANNEXURE-A2 (COLLY) 16

"IT IS NOT A CERTIFIED COPY"

IN THE SUPREME COURT OF INDIA
CIVIL APPELLATE JURISDICTION
CIVIL APPEAL NO. 004238-004239 OF 2022

IN THE MATTER OF:

DELHI DEVELOPMENT AUTHORITY ...APPELLANT

VERSUS

SOCIETY FOR PROTECTION OF CULTURE, HERITAGE, ENVIRONMENT, TRADITION AND PROMOTION OF NATIONAL AWARENESS (CHETNA) & ORS ...RESPONDENTS

INDEX

APPELLANT - DDA

THROUGH

NITIN MISHRA
ADVOCATE-ON-RECORD
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MAYUR VIHAR PHASE – I
DELHI – 110091
(M) 9810070377
(E) advocatenitin@gmail.com

PLACE: NEW DELHI
DATE: 11/08/2022

Final Report on

Hydro-Geological Study of the Qutub Golf Course, New Delhi for Construction of Environmentally benign Water Bodies

by

Dr. Brijesh K. Yadav (Professor), Hydrology
Dr. Pramod K. Sharma (Associate Professor), Civil Engg

Indian Institute of Technology Roorkee

Submitted to

DDA New Delhi

[July, 2022]

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1.0 Introduction

A survey team comprised of Prof. Brijesh Kumar Yadav (Department of Hydrology), Prof. Pramod Kumar Sharma (Department of Civil Engineering), Dr. Uttam Singh (Research Associate), Mr. Subham Tiwari (Research Scholar), and Mr. Deepak (Research Scholar) from IIT Roorkee visited at Qutub Golf Course, New Delhi at 29/06/2022 to conduct Two-dimensional electrical resistivity tomography (ERT) survey and for conducting infiltration tests. Samples of water used in maintaining the landscape of the Golf course along with the groundwater of the area were also collected and analysed during the field work. Shri Sandeep Dubey (Ex Engineer, sports division) and Shri. P. K. Jain (Assistant Engineer) of Delhi Development Authority (DDA) joined the Team IIT Roorkee during the entire field work.

2.0 Study area

The area of this study, Qutub Golf Course, situated in south Delhi. The South Delhi is divided into three subdivisions, Saket, Hauz Khas and Mehrauli and is bounded by the Yamuna river to the East. The Qutub golf is the first public golf course in India which is designed and developed by the Delhi Development authority (DDA) and established in 2000. It is located at Lado Sarai, Mehrauli area of South Delhi and covering a geographical area of approximately 110 acres of Delhi state. The Golf course lies between latitudes $28^0$31'16.92'' N to $28^0$31'52.90''N and East Longitude $77^0$11'34.21'' to $77^0$12'01.33''. The Golf course contains six artificial lakes for providing world class Golf infrastructure.

The average annual rainfall of the study area is 794 mm and about 81% of the annual rainfall is received during the monsoon months of July, August, and September. The rest of the rainfall is received during pre and post monsoon periods. The variation of rainfall from year to year is quite large. On an average, rainfall of 2.5mm or more falls on 27 days in a year including 19 days during the monsoon months. The climate of the study area is humid subtropical to semiarid with generally dry winters extending from November to January (Sarkar et al. 2016). The hot and humid summer period from April to July is followed by the monsoon season in July and August, characterized by heavy rainfall with winds blowing from Arabian Sea. The average temperature of the area varies from 25^0C to 45^0C from April to July and drops from 22^0C to 5^0C in December and January. April and May are the driest months with relative humidity of about 30% in the morning and less than 20% in the afternoons. The average annual relative humidity of the area is reported as 54%.

Geomorphologically the upland area of Southern Delhi is characterized by strike ridges, dissected hills, badlands with rills and ravines and also exposed by Quartzitic rocks (Kaul and Pandit 2004). These isolated rocks are visible in the Golf course premise. The Stratigraphic succession in and around the New Delhi lies on hills and ridges consist of Alwar quartzities. The southern part of the Delhi containing the Golf course is occupied by quartzite interbedded with Mica Schist belonging to the Delhi Super Group, uncomfortably overlain by unconsolidated quaternary to recent sediments. The Quartzite are grey to brownish grey in colour with thin to massively thick bedding, doubly plunging towards northeast and southwest as coaxially refolded regional (GSI, 1997). The area is dominated by clay, silt and fine to medium sand types of soil which is mostly calcareous in nature. A substantial amount of Kankar is also admixed with the clayey-silt below 20m depth.

The Quartzite ridges in and around the Qutub area rise to 225 to 275 m above mean sea level (CGWB, 2006a). The groundwater is controlled by hydrogeomorphic units in the region such as rocky tracts of the ridge, pediments, alluvial uplands, valley fill and floodplains (Bajpai, 2011). Amongst these, the alluvial floodplain of Yamuna is the most proficient area of subsurface fresh water resources in the city. In the floodplains of the Yamuna, the freshwater aquifer ranges from 30 to 70 mbgl. Based on aquifer material and its depth, the groundwater system of alluvial plains can be categorised into three groups: (i) Group I, which is unconfined in nature and extends up to 60 mbgl from the surface; (ii) Group II, which is confined or semiconfined in nature, and comprises sandy horizons between 65 mbgl and 200 mbgl; and (iii) Group III, which is confined in nature and found in horizons between 200 mbgl and >300 mbgl (CGWB, 2012a). Shekhar and Rao (2010) suggested high transmissivity and discharge for the unconfined formations having transmissibility and specific yield of around 1371 m^2/day and 0.24, respectively. Particularly in the study area, the aquifers with alluvial deposits are lying above the bedrock consisted of fractured and weathered quartzite hard rock (Bajpai, 2011). Wells sunk in the weathered and fractured aquifers of hard rock generally penetrate down to 80 mbgl but in some places they reach up to 150 mbgl (CGWB, 2012a). The Fresh and saline water varies in 50-70 mbgl in southern part of Delhi (Shekar and Rao, 2010).

Tree ERT surveys were conducted based on the availability of the spread length for the electrodes to map the subsurface of the Golf course during this study. Infiltration test were also conducted at four locations nearby to the water bodies to get an idea of the influx rate of the applied water or rainfall taking over the grass turf (Fig. 1). Also, surface and groundwater

samples were collected from the study area to analyse their current state of quality. Few water quality parameters were measured in-situ during the field visits and the remaining parameters were obtained by analysing water samples brought from the study area in the laboratories of the Department of Hydrology and Institute Instrumentation Centre (IIC) of IIT Roorkee.

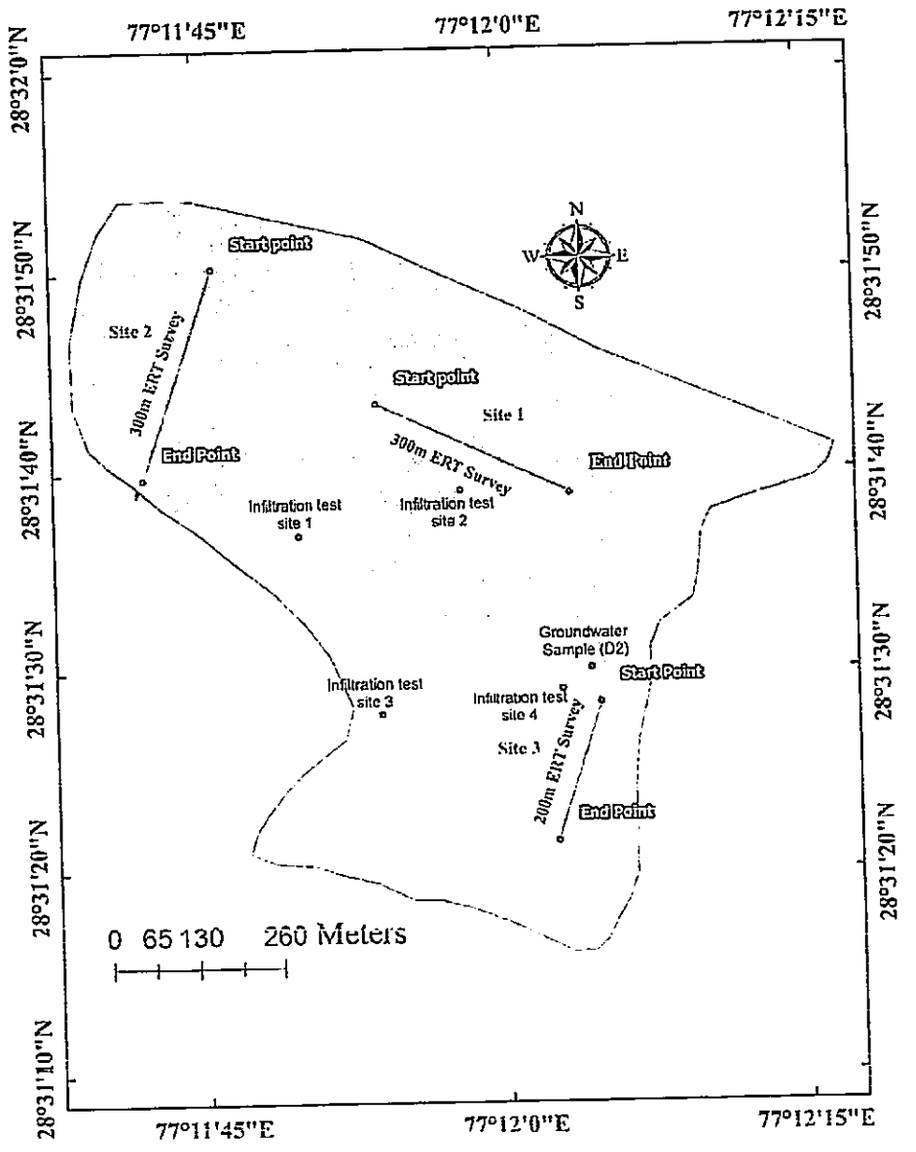

Fig. 1: Locations of ERT surveys, infiltration test, groundwater sample in the study area.

3.0 Electrical resistivity tomography (ERT)

The earth resistivity meter is a 4-point light 10W high precision instrument for determination of soil resistivity. The electrical resistivity allows determination of the water content in the soil and of the types of soils and rock. It can be used for groundwater prospecting, mining, and other environmental investigations (Stummer et al. 2004). The phase shift between output current and voltage provides information about the induced polarization (IP). The accuracy of the instrument is about 0.1 % with a resolution of max. 100 nV. From the current I, the voltage U and a geometric configuration factor the specific electrical resistivity rho (Ohm-m) is calculated. The receiver of the instrument is highly selective and only records voltages at the set frequency. However, noise at the measurement frequency degrades the quality of the measurement and should be suppressed. Major reasons for noise may include Mains (electric) interferences, magnetic interferences, wind, rain, and mechanical instability of the electrodes. Three field ERT surveys were carried out over the Golf course during this study on June 29, 2022. The resistivity values obtained by Earth resistivity meter is interpolated in lithological formations using Palacky (1988).

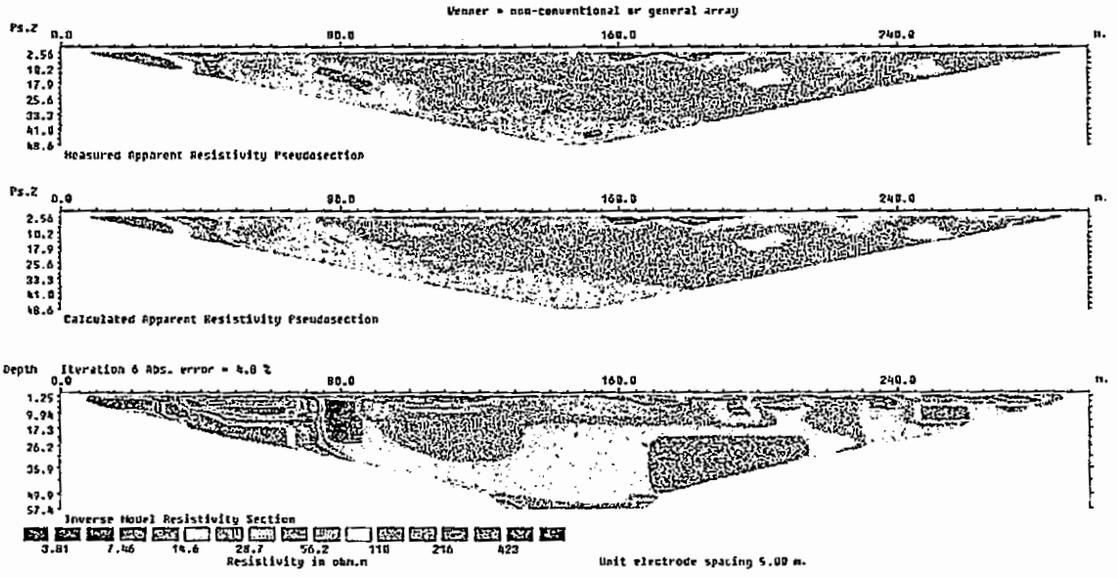

Fig. 2: The 300m length Two-dimensional ERT subsurface resistivity profile using the Wenner array configuration at Site 1.

A 300m ERT survey was carried out at site 1 in Golf Course (near the water body 1&2). The co-ordinates of the start and end point of the survey are $28^{\circ}31'43.3''N, 77^{\circ}11'53.8''E$, and $28^{\circ}31'38.8''N$, $77^{\circ}12'3.4''E$, respectively as marked in Fig. 1. The contact between the ground and electrode was good at survey site, and images are quite clear. The obtained ERT subsurface profile is presented in Fig. 2 and probable subsurface lithology is mentioned in Table 1.

Table 1 Subsurface characterization and probable lithology at Site 1 of the gold course.

Depth of Investigation (m)	ERT test	
	Average resistivity (Ohm-m)	Probable lithology
1-10	164	Mixture of clay, sand, and sandstone with low water content
10-20	72	Mixture of clay, sand and Kankar with relatively high-water content as compared to the above depth
20-30	52	
30-40	51	
40-50	15	
50-57.4	42	

Another 300m length ERT survey was carried out at site 2 in Golf Course (at 9 number green ground). The co-ordinates of the start and end point of the survey are $28^{\circ}31'50.2''N$, $77^{\circ}11'45.8''E$, and $28^{\circ}31'39.72''N, 77^{\circ}11'42.3''E$, respectively. The contact between the ground and electrode was maintained firmly at survey site, and the images of the subsurface is quite promising. The ERT subsurface profile is represented in the Fig. 3 and probable subsurface lithology is provided in Table 2.

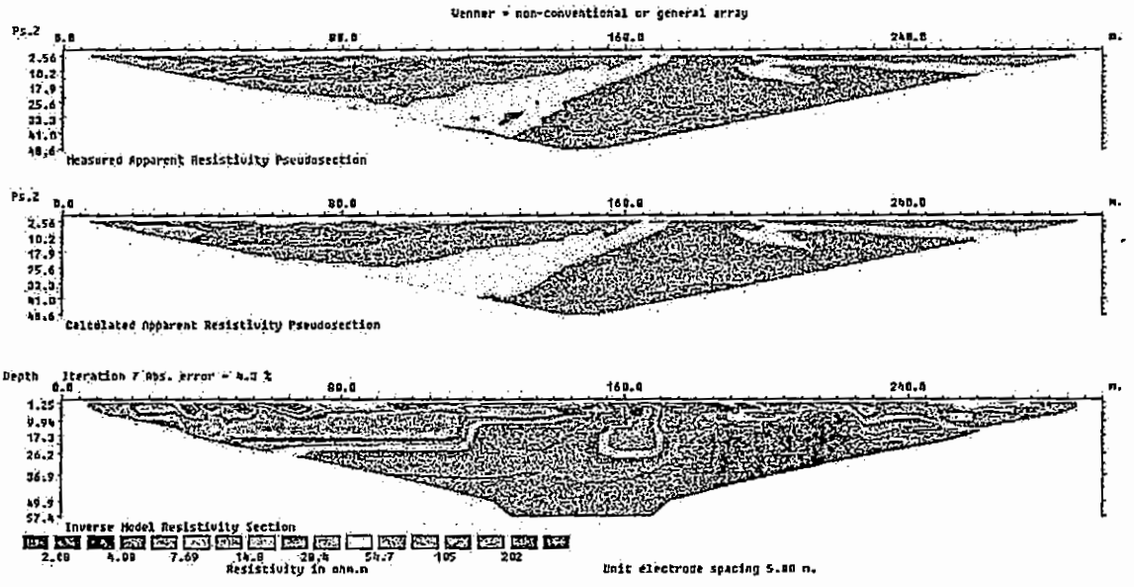

Fig. 3: The 300m length Two-dimensional ERT subsurface resistivity profile using Wenner array configuration at Site 2.

Table 2 Subsurface Characterization and probable lithology at Site 2.

Depth of Investigation (m)	ERT test	
	Average resistivity (Ohm-m)	Probable lithology
1-10	58	Mixture of clay, sand, and sandstone with low water content
10-20	38	
20-30	98	Mixture of clay and sand with low water content
30-40	120	
40-50	153	
50-57.4	105	

A 200m ERT survey was carried out at site 3 having co-ordinates of the start and end point of the survey are $28^{\circ}31'28.3''N$ $77^{\circ}12'4.8''E$, and $28^{\circ}31'43.3''N, 77^{\circ}12'32.52''E$, respectively. The contact between the ground and electrode was good at survey site, and results are looks quite clear. The ERT subsurface profile is represented in the Fig. 4 and probable subsurface lithology is given in the table 3.

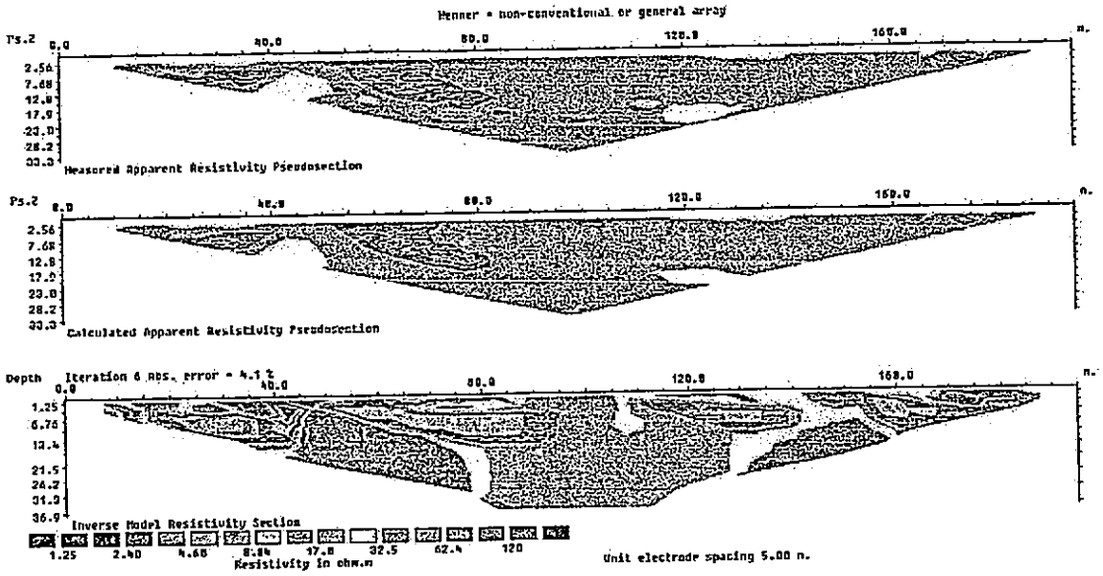

Fig. 4: A 200m length Two-dimensional ERT subsurface resistivity profile using Wenner array configuration at Site 3.

Table 3 Subsurface Characterization and probable lithology at Site 3.

Depth of Investigation (m)	ERT test	
	Average resistivity (Ohm-m)	Probable lithology
0-10	35	Mixture of clay and sand with water content
10-20	25	
20-30	37	
30-37	24	

The subsurface lithology obtained from these three nearby ERT survey sites shows that subsurface formation is quite similar with respect to depth. The third site is showing little high-water content as compared to the initial two sites. This seems due to the lower site elevation of this site-3 and moist soil conditions was observed during the ERT survey. Change in resistivity with lateral and in longitudinal directions in all three ERT inversion images shows the strong heterogeneity present in the subsurface formation of the Golf course. The main cause of this heterogeneity could be due to the presence of Kankar or weathered rock mixed with sand/clay.

4.0 Water Quality Analysis

Water samples were analysed at site for measuring the pH, TDS (Total dissolved solids), EC (Electrical Conductivity), DO (Dissolved Oxygen), and ORP (oxidation reduction potential) concentration using the multi-meter electrode. The obtained results are listed in Table 4. Collected water samples were brought to the laboratory of IIT Roorkee for ex-situ analysis and examined using inductively coupled plasma mass spectrometry (ICP MS) for finding the concentration of heavy metals (Cr, Fe, Cu, Zn, As, Se, Cd and Pb). All the samples were first acid digested, diluted to a suitable degree, filtered through a 0.45-micron filter, and then proceed for ICP-MS analysis. The purpose of acid digestion was to destroy the matrix, which otherwise interferes during atomization. Also, digestion converts all forms of metal into a single oxidation state. The results are listed in Table 5 and are compared with Bureau of Indian Standards (BIS) code IS 10500:2012 to check their fitness.

Table 4 Mean values of pH, EC, TDS, DO, and ORP obtained in the water samples from In-situ analysis.

S. No	Code	Latitude (N)	Longitude (E)	Detail of Sample	pH	EC (mS/cm)	TDS (ppm)	DO (mg/L)	ORP (mV)
1	D2	28°31′30″	77°12′4.32″	Bore well near Hole 5	7.17	1802	865	6.39	154
2	D4	28°31′33.6″	77°12′7.2″	Delhi Jal board water for irrigation	7.66	1395	685	4.92	181
3	D6	28°31′44.4″	77°11′49.2″	Self-treated waste water	7.26	3104	1511	2.08	26
BIS Limits (IS 10500:2012)				AL	6.5-8.5	NS	500	NS	NS
				PL			2000		

Notations: AL-acceptable limit, PL- permissible limit; NS-not specified

The pH concentration in D2 (groundwater) is found 7.17. Likewise, other parameters such as EC, TDS, DO and ORP values are observed as 1802 (mS/cm), 865 ppm, 6.39 mg/L and 154 mV, respectively in the groundwater (D2). In contrast, the treated water samples i.e., D4 (Delhi jal board) and D6 (Self treated water) has 7.66 and 7.26 pH values. The ORP values of groundwater and Self treated water samples are found as 181 mV and 26 mV, respectively. Low ORP indicates that the chemical reactions about to occur and it is mostly caused by reducing agents or contaminants present in water. Comparatively high NO3- concentration has

been observed in groundwater sample which seems due to continuous recharge of nitrate containing water from the existing water bodies where percolating water from the grass root zone is collected through the subsurface drainage network. Winter and Dillon (2005) also reported the similar results in groundwater of Golf course area.

The concentration of heavy metals such as Cu, Zn, As, Se, Cd and Pb are within the limits of BIS in the groundwater. However, the sample collected from D4 (Irrigation water used in the Golf course) shows marginally high concentration of Cr i.e., 0.11 ppm. Also, elevated concentration Cd is observed in treated water as compared with the groundwater. In general, the quality of groundwater is better in comparison to the treated water (D4) used for irrigating the Golf course. This little high concentration of some trace metals in the irrigation water is the main cause of concern for using the lake water for recharging the underlying groundwater resources. A high level of nitrate concentration in the groundwater shows the excess fertilizers recharge to the underlying aquifer from the water bodies collecting the return flow from the vadose zone of the Golf course.

Table 5 Mean concentration of heavy metals, and NO_3, Cl, K, Mg obtained in the water samples and its comparison with BIS limits of IS 10500:2012.

Parameter	Sample			BIS standard	
	D-2	D-4	D-6	AL	PL
Chromium (Cr)	ND	0.11	ND	0.05	NR
Iron (Fe)	0.160	4.422*	3.953*	0.3	NR
Copper (Cu)	0.133	0.127	0.107	0.05	1.5
Zinc (Zn)	2.552	2.810	2.058	5	15
Arsenic (As)	0.002	0.041	0.037	0.01	0.05
Selenium (Se)	0.008	ND	0.002	0.01	NR
Cadmium (Cd)	ND	0.002	ND	0.003	NR
Lead (Pb)	ND	0.007	ND	0.01	NR
Nitrate (NO3)	462	33.3	25.73	45	NR
Chloride (Cl)	283.6	255.24	357.77	250	1000
Potassium (K)	41.15	67.46	98.94	NS	
Magnesium (Mg)	184.97	170.78	157.97	30	100

Notations: AL-acceptable limit, PL- permissible limit, concentration in mg/L, *High level of Fe seems due to collection of the stagnant water from the iron pipe

5.0 Infiltration Tests

Infiltration rate is a measure of the rate at which soil is able to absorb rainfall or irrigation water. The measure of infiltration of water through the grass covered soil surface of the Golf course is an important parameter, which can help in planning groundwater recharge interventions. The Mini Disk infiltrometer, having two chambers, is used here for measuring of infiltration rate. The top chamber (or bubble chamber) controls the suction and the lower chamber contains a volume of water that infiltrates into the soil at a rate determined by the soil suction. The lower chamber is labelled like a graduated cylinder with volume shown in mL. The bottom of the Infiltrometer has a porous sintered stainless-steel disk that does not allow water to leak. The small diameter of the disk allows for undisturbed measurements on relatively level soil surfaces as compared to the double ring infiltrometer. The calculations were performed by the method proposed by Zhang (1997). These infiltration experiments were conducted at 4 locations as marked in Fig. 1 and is also listed in Table 6. Low to moderate infiltration rate is observed in all four locations dominated by clayey sand cover.

Table 6. Measured infiltration rate of different site in the Qutab golf course.

Site name	Latitude	Longitude	Infiltration (cm/hr)	Site Description
Site 1	28°31′39″N	77°11′57.84″E	1.04	Near water body 1 & 2. hole 1 & 2
Site 2	28°31′28.92″	77°12′2.88″E	1.06	Near water body 3 & 4. hole 4 & 7
Site 3	28°31′36.84″	77°11′49.92″E	1.09	Near water body 5. hole 8
Site 4	28°31′27.84″	77°11′53.88″E	1.34	Near water body 6. hole 14

6.0 Importance of Water in Golf course

Water is precious resource that ties together all of the elements of the golf Course. Most of the criticisms that have been raised concerning golf course impacts upon the environment have dealt with water quality degradation and excessive water use. Therefore, it is important to identify any possible water quality impacts of the water used in the Golf course for better

management of the surface and groundwater resources of the area. Most common strategy that has been used for water conservation is the design of golf courses with internal collection of rainwater and irrigation runoff into holding ponds for reuse. This decreases the demand for fresh water for irrigation of the course and decreases the likelihood of off-site transport of nutrients and chemicals from turfgrass area. The use of treated effluent water is another option that has been implemented in several courses in the U.S. (Frye, 1994; Salvesen, 1996; Poellot, 1992) and seems useful for golf courses situated in water scarce areas. However, the use of treated waste water in the golf course particularly for groundwater augmentation purpose can be allowed after thoroughly monitoring the water quality parameters.

7.0 Construction of water bodies in Golf course

The Golf course consists of a series of holes, each consisting of a tee box, water bodies a fairway, the rough and other hazards, and a green with a cylindrical hole in the ground, known as a "cup". The artificial water bodies are constructed in arbitrary shapes and size by excavating of the ground material. Lining provisions are available to check the seepage of water to the underlying strata and aquifer as mentioned in the following sections.

Sodium bentonite lining: Sodium bentonite is popular liner for water bodies. It is a naturally occurring clay with specific properties that make it especially effective for lining ponds (Fig. 5a). Correctly installed, it can absorb several times its weight in water and expand up to 15 times its original volume, until it has formed an exceptionally dense, watertight seal. Because of its elastic properties, bentonite can handle a small amount of ground movement and can self-heal small cracks or other minor damage (Naka et al. 2019). On the downside, bentonite must always be kept wet. Any shrinkage due to reduced water level associated will result in cracking/crumbling of the liner. However, Bentonite cannot be installed on steeply sloped sides because over time it will slump down to the pond bottom and leave the sides uncovered. It can also take exceptionally large amounts of bentonite to seal even a small pond, depending on the soil type.

Geosynthetic clay liners (GCL): The GCLs are a combination of bentonite clay and synthetic lining that aim to capture the advantages of each while mitigating their respective disadvantages (Naka et al. 2019). Sometimes called clay blanket or bentonite mat, the liner consists of some sort of geotextile membrane fabricated to hold small amounts of bentonite clay within sealed pockets (Fig. 5b). This design helps in keeping the bentonite evenly distributed and allows for installation on steeper slopes. On the downside, GCLs are relatively

thin, which makes them more vulnerable to punctures than ordinary clay, especially during installation. They are also susceptible to friction damage where the liner meets other materials, and since much less bentonite is involved, increased hydraulic permeability can become a problem.

Polyvinyl chloride (PVC) liner: PVC liners are a type of geotextile and are relatively cheaper option, but they suffer from some disadvantages. The PVC can include trace amounts of arsenic and other toxins in the water bodies which may ultimately pollute the surrounding soil-water system (Fig. 5c). Also, PVC liners are vulnerable to splits and cracks, are not suitable for cold climates, and will quickly degrade when exposed to sunlight (Akovali 2012). To maintain flexibility, PVC is combined with plasticizers, which are often toxic and can leach into stored water. Plasticizers have been linked to significant pollution and environmental damage.

Reinforced polyethylene (RPE) liners: RPE is highly resistant to punctures and tears, are thinner and more flexible than other types, and are lighter and substantially easier to install. Three times stronger than EPDM and ⅓ the weight, RPE is considered the most durable liner available, does not require a protective underlayment (Fig. 5d). RPE liners can last for decades and some types are manufactured with coatings that make them virtually impervious to UV exposure. This liner may bot last longer for soil strata having Kankar and other sharp objects.

Ethylene propylene diene monomer (EPDM) lining: EPDM liners are essentially a synthetic rubber, which makes them soft and very flexible, but they are the least puncture resistant of the geotextile options and always require underlayment (Fig. 5e). While EPDM is safe for aquatic life, it is also the heaviest liner type, which may be difficult in shipping and installation in large water bodies. EPDM lining is relatively considered safer as compared with the sodium bentonite, PVC, GCL, and HPE and may be allowed to DDA for lining the Golf course water bodies.

Stone pitching: This technique involves large interlocking of stones, with their flattest side up to create small irregular steps that blend into the landscape. This method is particularly useful on slopes with a massive seepage. The stones subjected to the marked deterioration by water or weather are not suitable for stone pitching. Preparation of sound slope before laying the rocks is required along with an even surface for its stability (Fig. 5f). This type of lining is recommended for allowing the pondage water to recharge the underlying groundwater

resources. However, the quality of the water used in these water bodies must be free from pollutants to avoid degradation of the groundwater quality.

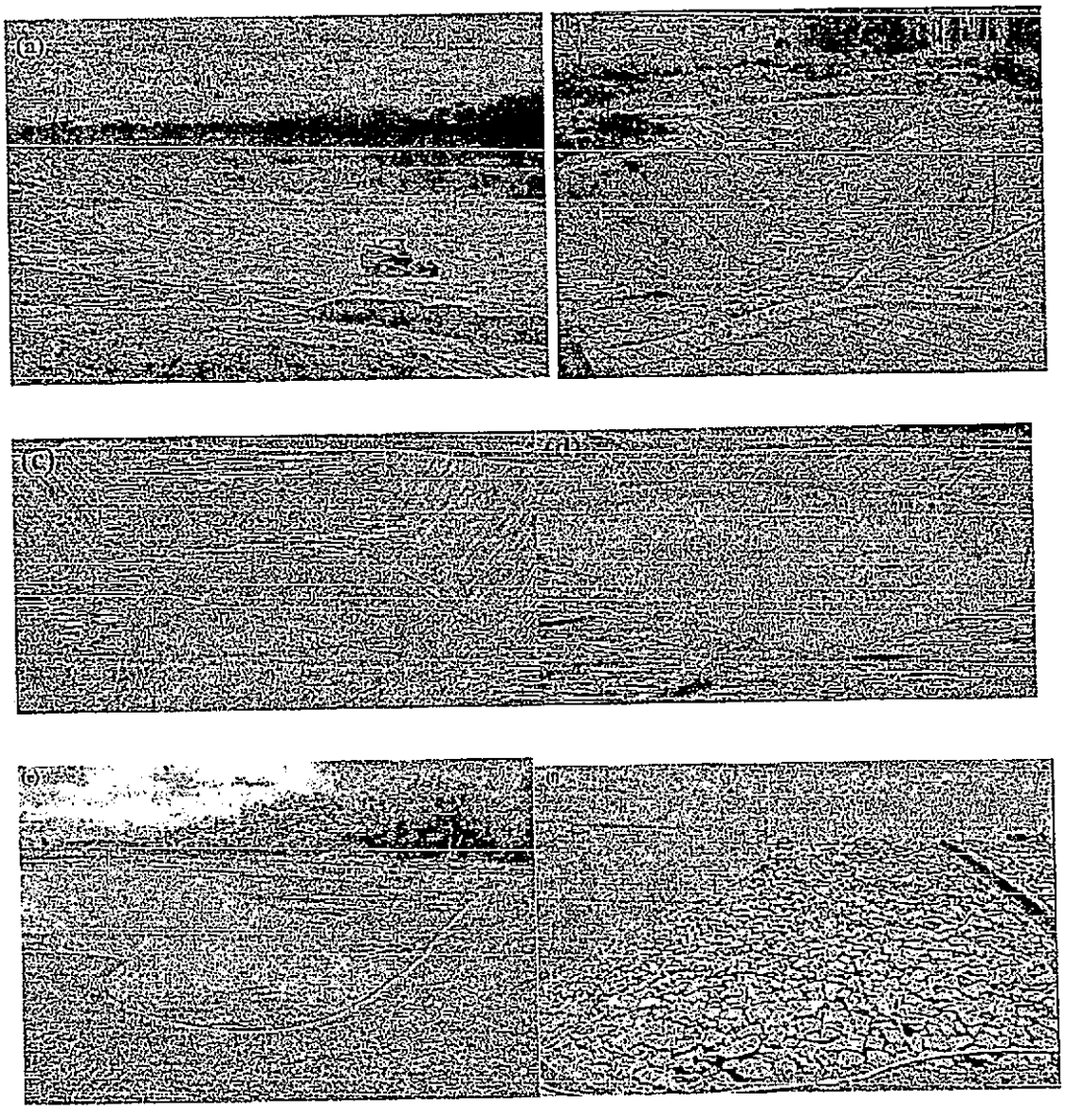

Fig. 5: (a) Sodium bentonite, (b) PVC, (c) GCL, (d) RPE, (e) EPDM, and (f) Stone pitching in the artificial water body.

The above lining material such as sodium bentonite, GCL, PVC, EPDM, and RPE are significantly make bottom of artificial water body impervious. Also, sodium bentonite, PVC, GCL, and RPE linings are not environment friendly as compared to the EPMD liner (Surya et al. 2021).

8.0 Concluding Remarks

Based of the above study concluding remarks are as follows:

1. Golf course greens at Qutub site are constructed using a sand base for maintaining the well drainage conditions of the root zone. The underlying groundwater resources of the area is susceptible to contamination due to deep percolating water (containing excess nutrients and pesticides) generated from the permeable vadose zone of the Golf course. Therefore, arresting the seepage water from the vadose zone using the existing subsurface drainage network of the Golf course is crucial. The outlets of the subsurface drainage network of the Golf course is currently connected to the existing water bodies and this water should be avoided for groundwater recharging purpose.
2. The subsurface strata of the study domain are comprised of clay and sand material with significant heterogeneity that can allow preferential flow paths for water stored in Golf course lakes to the underlying groundwater. Due to this preferential flow, the time of residence for self-cleaning the percolating water from water bodies seems inadequate and the water bodies should be lined using appropriate impervious barrier.
3. The treated wastewater used for irrigating the Golf course contains relatively high level of some trace elements, and is therefore, not recommended for recharging the groundwater resources of the area. However, harvested rainwater during the monsoon season shall continue to be recharged using the existing recharging structures after discarding some initial volume of water.
4. Emerging pollutants like personal care products, pharmaceuticals, metabolites etc. which are not analysed in this study may also be present in traces in the treated waste water used in the Golf course and should be avoided for recharging aquifers to check quality degradation of the groundwater of the area.
5. Periodic water quality monitoring of the water used in irrigating the Golf course is needed to ensure the effective long-term management of the soil and groundwater resources of the area. DDA may think of having pervious material (like stone-pitching) in water bodies only when the stored water in lakes is fit for recharging the groundwater.
6. The lining materials such as sodium bentonite, GCL, PVC, EPDM, and RPE make the bottom of artificial water body almost impervious. Amongst these, EPDM liner seems more environment friendly and may be allowed to DDA for its use.
7. It is also recommended that the evaporation losses of the Golf course should be controlled so that optimum use of surface water is ensured in maintaining the landscape.

To sum-up, considering the current situation of available irrigation water to DDA, it is recommended to have the water bodies with impervious barrier for checking the groundwater contamination. Rainwater harvesting and recharging structures are recommended to be continued for rejuvenating the underlying aquifer. Measures may be taken by DDA to check the excessive evaporation losses from the existing water bodies for optimising the water use in the golf course area. Periodic water quality monitoring of the water used in irrigating the Golf course is strongly recommended to ensure the better management of the soil and groundwater resources of the Golf course area and its surrounding zones.

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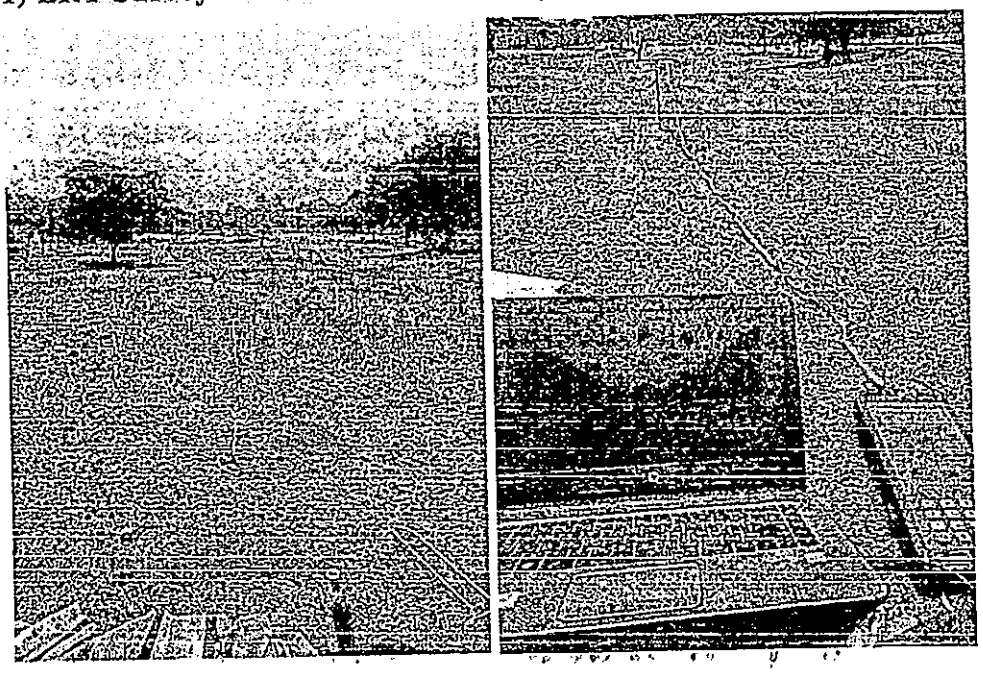
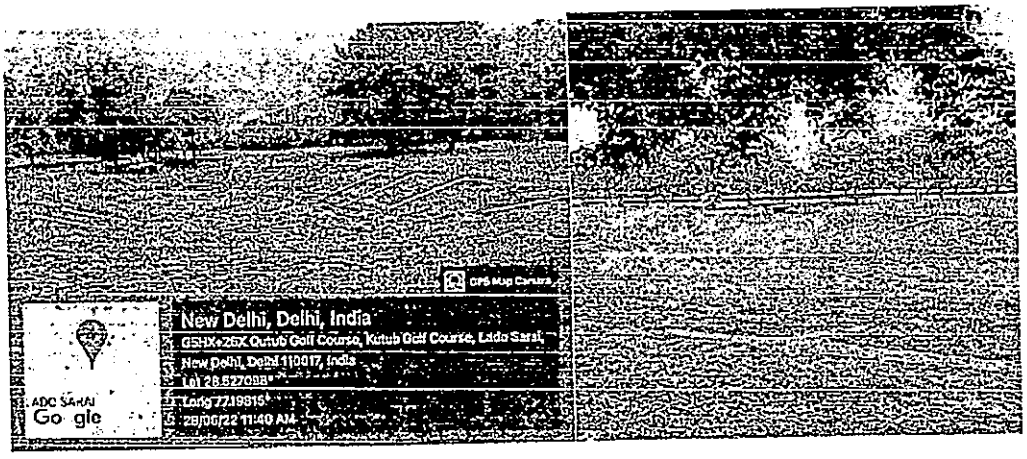
Appendix

(Some pictures of the Hydro-Geological Study of the Qutub Golf Course, New Delhi)

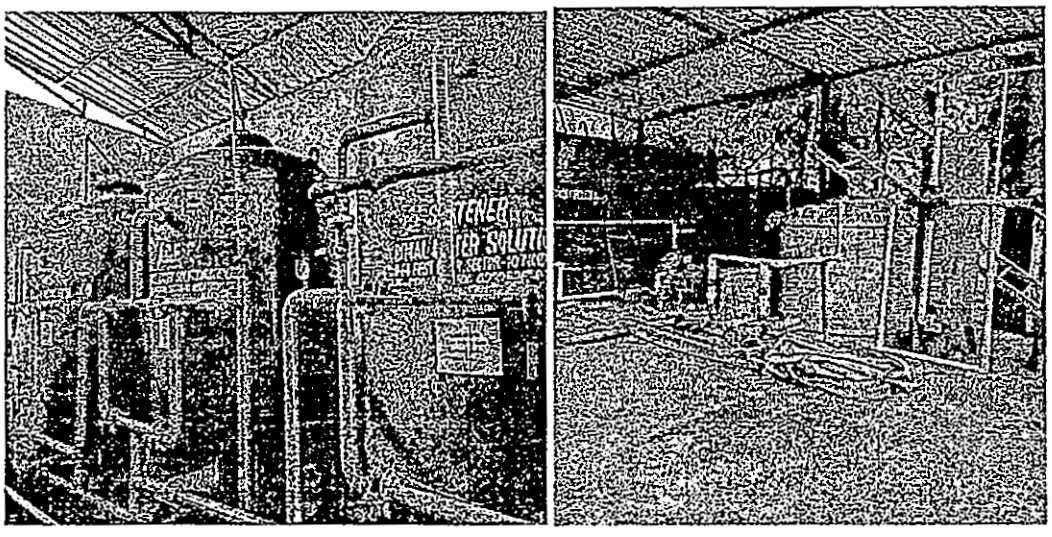
1) ERT Survey conducted in the Golf course



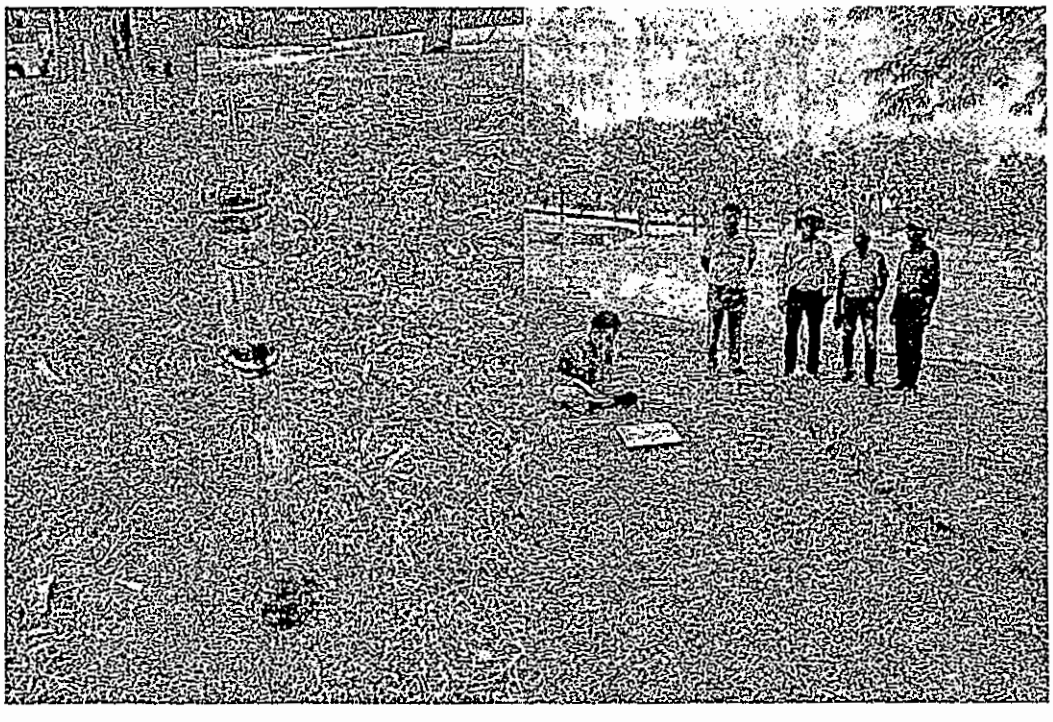
2) Existing water bodies in the Qutub Golf course



3) Filtering unit of the Irrigation water and treatment unit used in the Golf course



4) Disc Infiltrometer experiments in the Golf course



Executive Summary for recommendations of environmentally benign water bodies in Qutub Golf course, New Delhi

by

Department of Hydrology, IIT Roorkee

Chief Engineer (Sports), Shri N N Atey, from Delhi Development Authority (DDA) approached Director, IIT Roorkee, for getting technical help related to the construction of environmentally benign water bodies in Qutub Golf course, New Delhi related to the Honourable Supreme court's order. IIT Roorkee deputed Dr. Brijesh Kumar Yadav, Professor and Head, Department of Hydrology for providing the expert opinion on this matter. Thereafter, a survey team led by Prof. Brijesh Kumar Yadav (Hydrology) and Prof. P. K. Sharma (Civil Engineering) along with their students Dr. Uttam Singh (Research Associate), Mr. Deepak Tripathi (Research Scholar), and Mr. Shubham Tiwari (Senior Research Scholar) visited to the Qutub Golf course on June 29, 2022 for conducting electrical resistivity tomography (ERT) surveys for characterization of subsurface. Infiltration tests and water quality analysis of the irrigation water used by DDA were performed along with the groundwater quality checking of the area. Sh. Sandeep Dubey (Executive Engineer, sports division) and Sh. P. K. Jain (Assistant Engineer) of Delhi Development Authority (DDA) joined the Team IIT Roorkee during the field work. Total three ERT surveys were conducted at different locations in the study area. Four infiltration tests were also conducted at locations near the artificial water bodies. Some water quality parameters were measured in-situ during the field visit and the remaining parameters were obtained by analysing water samples brought from the study area in the laboratories of the Department of Hydrology and Institute Instrumentation Centre (IIC) of IIT Roorkee. Based on this study, suggestions and recommendations are provided below.

1. Golf course greens at Qutub site are constructed using a sand base for maintaining the well drainage conditions of the root zone. The underlying groundwater resources of the area is susceptible to contamination due to deep percolating water (containing excess nutrients and pesticides) generated from the permeable vadose zone of the Golf course. Therefore, arresting the seepage water from the vadose zone using the existing subsurface drainage network of the Golf course is crucial. The outlets of the subsurface drainage network of the Golf course is currently connected to the existing water bodies and this water should be avoided for groundwater recharging purpose.

2. The subsurface strata of the study domain are comprised of clay and sand material with significant heterogeneity that can allow preferential flow paths for water stored in Golf course lakes to the underlying groundwater. Due to this preferential flow, the time of residence for self-cleaning the percolating water from water bodies seems inadequate and the water bodies should be lined using appropriate impervious barrier.
3. The treated wastewater used for irrigating the Golf course contains relatively high level of some trace elements, and is therefore, not recommended for recharging the groundwater resources. However, harvested rainwater shall continue to be used for recharging the groundwater using the existing structures.
4. Emerging pollutants like personal care products, pharmaceuticals, metabolites etc. which are not analysed in this study may also be present in traces in the treated waste water used in the Golf course and should be avoided for recharging aquifers to check quality degradation of the groundwater of the area.
5. Periodic water quality monitoring of the water used in irrigating the Golf course is needed to ensure the effective long-term management of the soil and groundwater resources of the area. DDA may think of having pervious material (like stone-pitching) in water bodies only when the stored water in lakes is fit for recharging the groundwater.
6. The lining materials such as sodium bentonite, GCL, PVC, EPDM, and RPE make the bottom of artificial water body almost impervious. Amongst these, EPDM liner seems more environment friendly and may be allowed to DDA for its use.
7. It is also recommended that the evaporation losses of the Golf course should be controlled so that optimum use of surface water is ensured in maintaining the landscape.

To sum-up, considering the current situation of available irrigation water to DDA, it is recommended to have the water bodies with impervious barrier for checking the groundwater contamination. Rainwater harvesting and recharging structures are recommended to be continued for rejuvenating the underlying aquifer. Measures may be taken by DDA to check the excessive evaporation losses from the existing water bodies for optimising the water use in the golf course area. Periodic water quality monitoring of the water used in irrigating the Golf course is strongly recommended to ensure the better management of the soil and groundwater resources of the Golf course area and its surrounding zones.

A2-No 334
Urgent Fee: Rs 5/-
No. of Folio 25 Rs 25
Total Cost Rs 30
(a) application filed on :- 7-11-22
(b) the date given to receive copy :- 10-11-22
(c) date on which copy is made ready :- 10-11-22
(d) the date on which the copy is received by the applicant or sent to the applicant :-

Branch Officer
Supreme Court of India

IN THE SUPREME COURT OF INDIA
CIVIL APPELLATE JURISDICTION
CIVIL APPEAL NO. 004238-004239 OF 2022

IN THE MATTER OF:

DELHI DEVELOPMENT AUTHORITY …APPELLANT

VERSUS

SOCIETY FOR PROTECTION OF CULTURE,
HERITAGE, ENVIRONMENT, TRADITION
AND PROMOTION OF NATIONAL AWARENESS
(CHETNA) & ORS …RESPONDENTS

INDEX

PETITIONER - DDA

THROUGH

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PLACE: NEW DELHI
DATE: 20/11/2023

Report on

Assessment of water budget and rainwater harvesting infrastructure of the Qutub golf course, New Delhi

Submitted to

Delhi Development Authority
New Delhi

Submitted by the

Department of Hydrology

Indian Institute of Technology Roorkee

ROORKEE – 247667

November 2023

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Disclaimer

This report on the assessment of water budget and rainwater harvesting infrastructure of the Qutub Golf Course, New Delhi, has been compiled by IIT Roorkee for the Delhi Development Authority. The findings and recommendations are based on available data gathered from various sources and its analysis, but the accuracy and completeness of the information cannot be guaranteed. IIT Roorkee is not liable for any losses or damages resulting from its interpretation.

1. Executive Summary

In accordance with the directives issued by the Honorable Supreme Court of India, a survey team from IIT Roorkee, including Dr. Apoorv Verma (Project Associate-I), Mr. Deepak Tripathi (Research Scholar), Mr. Sonu Singh (Research Associate), and Mr. Rupesh Kumar (JLA), visited the Qutub Golf Course in New Delhi on October 03, 2023. The team's objective was to perform essential survey and gather information from the officials of Delhi Development Authority (DDA). During their visit, the team had a discussion with Shri. P. K. Jain, (Assistant Engineer) from the DDA. A comprehensive survey of the entire golf course was conducted to assess the existing water harvesting and groundwater recharging structures. Additionally, the team carried out two-dimensional Electrical Resistivity Tomography (ERT) survey at two locations for a more detailed characterization of the subsurface formation. Samples of water used for maintaining the golf course's landscape were collected, along with groundwater samples from the surrounding area during this fieldwork. Some water quality parameters were assessed on-site during their visit, while other parameters were analyzed at the laboratories of the Department of Hydrology and the Institute Instrumentation Centre (IIC) at IIT Roorkee.

2. Study area

The Qutub Golf Course is situated in South Delhi, specifically in the Lado Sarai, Mehrauli area, covering approximately 98 acres. The area experiences a humid subtropical to semiarid climate with a significant monsoon season from July to September, contributing to about 81% of the average annual rainfall of 753 mm. The temperature ranges from 25°C to 45°C from April to July and drops to 22°C to 5°C in December and January. The study area is characterized by strike ridges, dissected hills, badlands with rills, and ravines, and is predominantly composed of quartzitic rocks.

The region's geology comprises the Alwar quartzite of the Delhi Super Group, with the southern part occupied by quartzite interbedded with Mica Schist. The predominant soil types are clay, silt, and fine to medium sand, which are often calcareous, with some Kankar below 20m depth. The topography is marked by ridges rising to 225-275 m above mean sea level, and the groundwater systems are influenced by various hydrogeomorphic units, including rocky tracts, pediments, alluvial uplands, valley fills, and floodplains, with the Yamuna floodplain serving as a crucial source of subsurface freshwater resources.

Aquifers are categorized into three groups: unconfined, confined, or semi-confined, with varying depths ranging from 30 to >300 mbgl. The unconfined formations exhibit high transmissivity and discharge, with transmissibility and specific yields averaging approximately 1371 m^2/day and 0.24, respectively. Freshwater and saline water were found at depths of 50-70 mbgl in southern Delhi.

3. Electrical Resistivity Tomography

Electrical Resistivity Tomography (ERT) is a geophysical imaging technique used to investigate subsurface properties of soil and rock. It functions by measuring the electrical resistivity of the subsurface at various points through the transmission of electrical current into the ground and measuring the resulting voltage. ERT is valuable for various applications including environmental studies, geological surveys, and groundwater exploration. By analyzing the resistivity data collected from different locations, ERT can create detailed images and cross-sectional profiles of the subsurface, aiding in the identification of underground structures, anomalies, and variations in geological or environmental properties.

The first ERT survey (ERT-01) of 200 m was conducted at a site near the boundary of the Golf Course. The initial and final electrode coordinates for the linear survey line are shown in Figure 3, where the first electrode is situated at 28.5259°N, 77.1973°E and the last electrode is located at 28.5245°N, 77.1989°E. Throughout the survey, the contact resistance between the ground and electrodes remained favourable. However, the resistivity values obtained for most points were remarkably low and negative, indicating the presence of noise in the data, which was likely caused by underground features such as electrical cable lines, conductive pipes, and fencing. After data processing and noise removal, the determined depth was found to be 21.5 meters. In certain areas, the obtained resistivity value was less than 0.2 ohm-m, probably indicative of saltwater content in the soil. The resulting ERT subsurface profile is shown in Figure 1, and the subsurface resistivity is listed in Table 1.

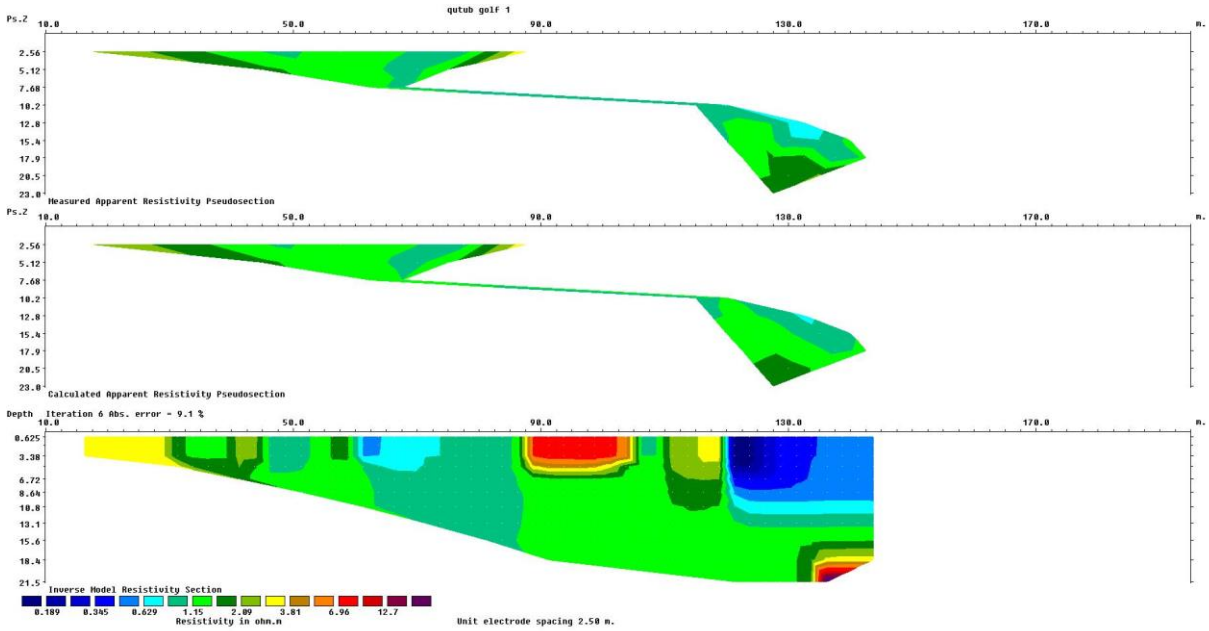

Figure 1. The 200m length Two-dimensional ERT subsurface resistivity profile using Wenner array configuration.

Table 1 Subsurface characterization and probable lithology using ERT-01.

Depth of Investigation (m)	ERT-01
	Average resistivity (Ohm-m)
0-5	2.10
5-10	1.09
10-15	1.14
>15	2.02

Another 200m ERT survey (ERT-02) was conducted within the golf course. The initial and final electrode coordinates for the linear survey line were recorded as 28.52848°N, 77.20063°E and 28.5295°N, 77.19885°E. Upon processing and eliminating the noise from the data, the determined depth was found to be 26.2 m. Notably, beyond a lateral distance of 100 m from the first electrode, the soil is likely to be dry and consolidated, resulting in higher resistivity compared to the rest of the section. The resulting ERT subsurface profile is shown in Figure 2 and the observed subsurface resistivity is listed in Table 2.

Table 2 Subsurface characterization and probable lithology using ERT-02 of the Golf course.

Depth of Investigation (m)	ERT-02
	Average resistivity (Ohm-m)
0-5	21.23
5-10	9.28
10-15	4.08
15-20	2.13
>20	3.62

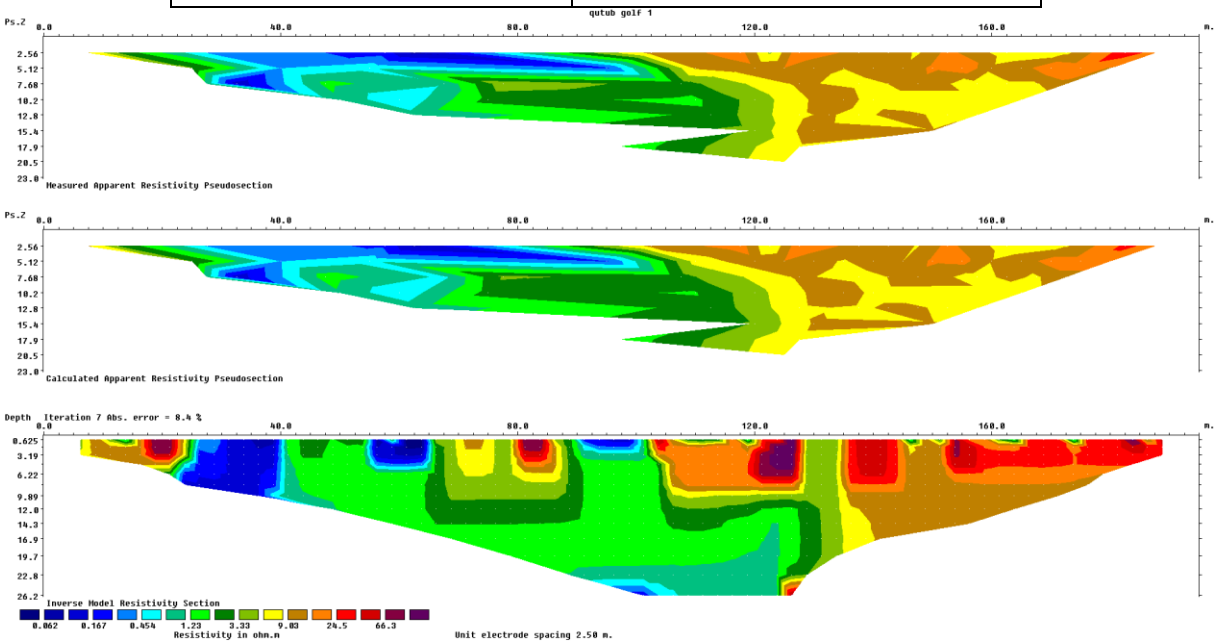

Figure 2. The 200m length Two-dimensional ERT subsurface resistivity profile.

Figure 3. Locations of Electrical Resistivity Tomography (ERT) surveys within the Golf course premise

4. Water Quality Analysis

Golf courses often use significant amounts of water for irrigation, and the fertilizers used for grass maintenance can seep into the water supply, leading to pollution. Regular water quality analysis helps identify contaminants and allows for timely remediation, thus preventing harm to the environment and surrounding ecosystems. Water samples were analyzed at the site to

measure the pH, total dissolved solids (TDS), Electrical Conductivity (EC), and Dissolved Oxygen (DO) level using a multimeter electrode as presented in Table 3. The collected water samples were brought to the laboratory of IIT Roorkee for ex-situ analysis and examined using inductively coupled plasma mass spectrometry (ICP-MS) for finding the concentration of heavy metals. All the samples were first acid-digested, diluted to a suitable degree, filtered through a 0.45-micron filter, and then subjected to ICP-MS analysis. The purpose of acid digestion is to destroy the matrix, which otherwise interferes with atomization. In addition, digestion converts all metal forms into a single oxidation state. The results are listed in Table 4 and compared with the Bureau of Indian Standards (BIS) code IS 10500:2012 to check their fitness.

Table 3. Mean values of pH, EC, and TDS were obtained in the water samples from In-situ analysis.

S. No	Code	Latitude (N)	Longitude (E)	Detail of Sample	pH	EC (mS/cm)	TDS (ppm)
1	D2	$28^0 31' 30''$	$77^0 12' 4.32''$	Bore well near Hole 5	5.34	1710	850
2	D4	$28^0 31' 33.6''$	$77^0 12' 7.2''$	Delhi Jal board water for irrigation	6.28	1120	560
3	D6	$28^0 31' 44.4''$	$77^0 11' 49.2''$	Self-treated wastewater	6.2	1070	530
BIS Limits (IS 10500:2012)				AL	6.5-8.5	NS	500
				PL			2000

Notations: AL-acceptable limit, PL- permissible limit; NS-not specified

The pH values in samples D2, D4, and D6 were 5.34, 6.28, and 6.2 respectively, during the post-monsoon period of 2023. The concentrations of EC in samples D2, D4, and D6 were 1710, 1120, and 1070 mS/cm, respectively, while the TDS concentrations were 850, 560, and 530 ppm, respectively. The concentrations of heavy metals, Cu, Zn, As, Se, Cd, and Pb, were within the limits of the BIS in the groundwater. However, the samples collected from D2, D4, and D6 showed marginally higher concentrations of Cr and Fe. The concentration of nitrate in sample D2 was found to be 148.86 ppm while in sample D4 and D6 it was found to be 121.12 and 99.9 ppm, respectively. The high nitrate concentrations on golf courses can be attributed to several factors. One possible reason is the use of fertilizers, including nitrogen-based ones, to maintain the lush and green appearance of fairways and greens. The chloride concentration was within the BIS limit for all samples.

Table 4. Mean concentration of heavy metals, and other elements measured in the water samples and its comparison with BIS limits of IS 10500:2012.

Parameter	Sample			BIS standard	
	D-2	D-4	D-6	AL	PL
Chromium (Cr)	0.25	0.28	0.22	0.05	NR
Iron (Fe)	0.61	0.86	2.48	0.3	NR
Copper (Cu)	0.01	0.01	0.22	0.05	1.5
Zinc (Zn)	0.12	0.02	1.76	5	15
Arsenic (As)	ND	ND	ND	0.01	0.05
Selenium (Se)	0.01	ND	ND	0.01	NR
Cadmium (Cd)	0.003	ND	ND	0.003	NR
Lead (Pb)	ND	ND	0.01	0.01	NR
Nitrate (NO_3)	148.86	121	47.17	45	NR
Chloride (Cl)	155.02	121.12	99.9	250	1000
Potassium (K)	8.97	44.72	52.13	NS	
Magnesium (Mg)	70.46	33.15	36.66	30	100

Notations: AL-acceptable limit, PL-permissible limit, NS-not specified by BIS, NR-No relaxation; all concentrations in ppm.

5. Water Budget and rainfall recharge

Water budgeting serves as a quantitative framework to assess the availability and sustainability of water resources in the study area. A thorough comprehension of water budget and underlying hydrological processes forms the basis for informed decision making in water resources planning and management. By analyzing the observed alterations in water budget over time, it is possible to gauge the impacts of both climate variability and anthropogenic activities on local water resources. This quantitative approach to water resource assessment empowers researchers, policymakers, and stakeholders with essential data to optimize water utilization and safeguard the environment.

Human activity has a significant impact on the natural hydrological cycle through various mechanisms. Land alterations, such as impermeable ground surfaces and the implementation of drainage and irrigation systems, introduce changes that impact key hydrological processes. These modifications can disrupt natural equilibrium by affecting factors such as infiltration, runoff, evaporation, and plant transpiration rates. Essentially, they can accelerate/hinder the movement of water through subsurface of an area.

The water budget equation, also known as the water balance equation, is a fundamental concept in hydrology used to quantify the movement of water within a study area. This provides a

simple and adaptable framework for understanding the dynamics of water flow. The water balance equation for a small area can be expressed as:

$$P + I + Q_{in} = ET + R + \Delta S + Q_{out} \quad \ldots(1)$$

where P =Precipitation, I = Irrigation, R = Runoff, Q_{in} = Water flow into the region, ET = Evapotranspiration, ΔS = Change in water storage, and Q_{out} =Water flow out of the region.

The equation essentially states that the total input of water (precipitation and external inflow) must be balanced by the sum of water losses (evapotranspiration) and changes in water storage as well as the outflow of water from the study area. It is a fundamental hydrological tool for assessing water availability, understanding the water cycle, and managing water resources within a specific geographic area. In the case of golf courses, grass is irrigated to meet the evapotranspiration needs; hence, irrigation can be considered equal to ET in a conservative side. Furthermore, one can consider the inflow into the region equal to the outflow from the region. Thus, the recharge of groundwater can be estimated using the Rainfall Infiltration Factor method.

For computing groundwater recharge, precipitation data for the years 2015-2022 for the region were obtained from the Climate Engine (2023) as listed in Table 5. The total area of golf course A is 98.57 acres, which is equivalent to 398,898.64 m^2. The annual average rainfall for the period 2015-2022 in the golf course region is observed as 752.9 mm. The monsoon rainfall from June to September amounts to 597.51 mm. To estimate the recharge from rainfall during the monsoon season using the following Rainfall Infiltration factor method (GEC, 2015), is applied.

$$R = f \times A \times \text{Normal rainfall in the monsoon season} \quad \ldots(2)$$

where, R represents the estimated recharge, f is the rainfall infiltration factor, and A is the area considered for recharge computation. The infiltration factor (f) for the aquifer type in Delhi is taken as 0.2 (CGWB, 2022). Thus, the runoff R = 0.2 x 597.51 mm x 398,898.64 m^2 = 47,669.19 m^3

The recharge during the non-monsoon season was estimated using the Rainfall Infiltration factor method only when the non-monsoon season rainfall exceeded 10% of the normal annual rainfall. From Table 5, it is evident that the rainfall in December is less than 10% of the normal annual rainfall; therefore, this month is excluded from consideration. The sum of the non-monsoon month rainfall is 151.51 mm. Hence, the recharge during the non-monsoon period is estimated as 12,087.4 m^3. Making the total recharge in of area as 59756.6 (approx. 60000) m^3.

Table 5. Monthly precipitation in the study area, (mm) during 2015-2022

Month	2015	2016	2017	2018	2019	2020	2021	2022	Average
Jan	26	1	29	5	31	65	32	69	32.25
Feb	3	2	5	1	25	32	3	13	10.5
Mar	53	25	10	2	12	71	6	3	22.75
Apr	20	4	16	6	21	10	3	1	10.13
May	3	15	22	9	6	26	53	19	19.13
Jun	43	28	96	46	10	16	18	50	38.38
Jul	242	322	207	251	223	117	269	181	226.5
Aug	192	164	175	248	232	249	152	117	191.13
Sep	35	76	168	185	111	68	268	221	141.5
Oct	3	10	0	2	11	0	109	247	47.75
Nov	2	2	9	12	23	19	0	5	9
Dec	1	3	2	7	9	1	8	0	3.88
	623	**652**	**739**	**774**	**714**	**674**	**921**	**926**	**752.9**

As the infiltrated rainfall water primarily flows into the golf course's drainage network, it does not contribute much to the replenishment of the underlying groundwater of the golf course. Therefore, the total volume that needs to be percolated into the groundwater using water harvesting structures is about 60,000 m^3.

6. Suggesting the number and location of rainwater harvesting structure inside Qutub golf course premises

When designing rainwater harvesting structures, the primary objective is to capture rainfall and runoff for local use. This runoff shall be directed into storage tanks for direct use or for recharging to the groundwater system through filtration and injection well network. Rainwater harvesting is a vital and enduring solution to enhance water availability. Given these considerations, rainwater harvesting structures are essential for collecting rainwater from the

runoff generated in the Golf course area. The design process considers factors such as average annual rainfall, peak rainfall intensity, and the infiltration capacity of the land surface.

The recharge structure should be designed to store runoff water originating from its surrounding catchment area (CPWD, 2019). The five existing recharge structures in the golf course are of the lateral trench cum borewell type. The dimensions of the structures are 6 m length x 3 m width x 3.3 m depth (inner dimension), as shown in Figure 4 and Figure 5. The runoff coefficient of the golf course is taken as 0.2 (Davis, 2015) for calculating the recharge amount. The average rainfall during monsoon month is 597.51 mm. Considering rainfall occurs for an hour a day during monsoon season with 120 days, the average intensity of rainfall = 597.51/120 = 4.98 mm/h.

To account for first flush wastage, evaporation, and spillage the effective runoff volume generated in the area can be taken as 85%. Thus, total runoff generated from the entire golf course = 398898.64 *0.2*4. 98/1000 * 0.85 = 337.6 m^3/h.

Volume of water within freeboard of recharge structure (refer to Figure 4 & Figure 5) = 6*3*2.4 m^3 = 43.2 m^3

The volume of water in the gravel-filled part considering the porosity to be 35% (refer to Figures 4 & Figure 5) = 6*3*0.9*0.35 = 5.67 m^3.

The average infiltration capacity of the soil in the study region is taken as 20 mm/h (CGWB, 2016), thus the volume of water that will infiltrate through each recharge structure is 0.02 * 6*3 = 0.36 m^3/h.

Thus, the total volume that can be accommodated by individual structure will be = 43.2+5.67+0.36 = 49.23 m^3/h

Hence, total volume that could be accommodated by five existing rainwater harvesting structures = 246.15 m^3/h.

Number of additional structures required = (337.6-246.5)/49.23 ≈ 2.

Hence, to effectively manage the excess rainfall during the peak monsoon season, it is advised to install two additional rainwater harvesting structures.

Moreover, in accordance with the Rainwater harvesting and conservation manual by CPWD, New Delhi (2019), the diameter of the recharge shaft should be within the range of 500 mm to

3000 mm, considering the water availability. Therefore, it is advisable to expand the diameter of the existing recharge shafts to the specified range of 500–3000 mm to facilitate efficient groundwater recharge.

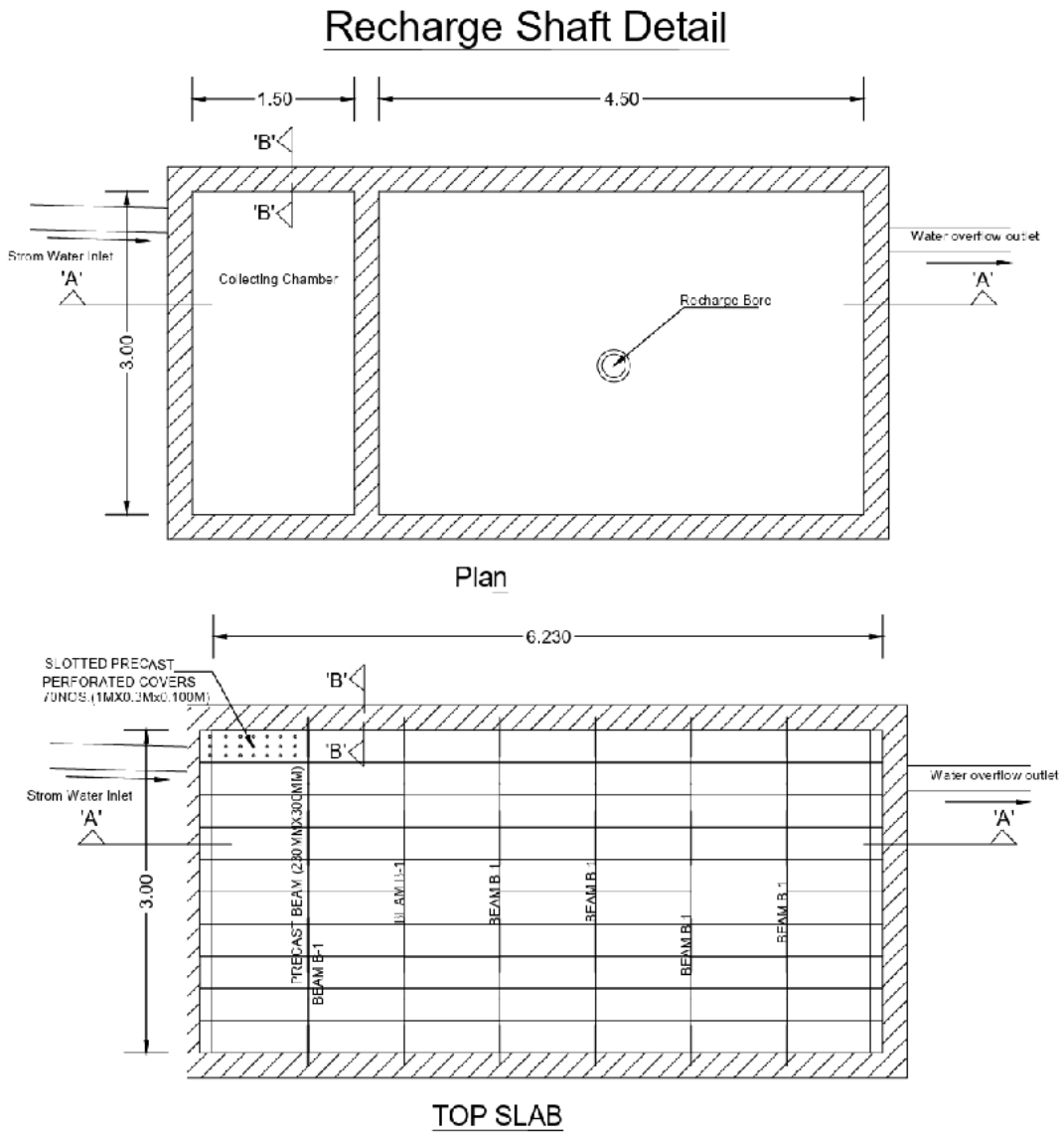

Figure 4. Top view of the recharging shaft with borewell provided at the Golf Course.

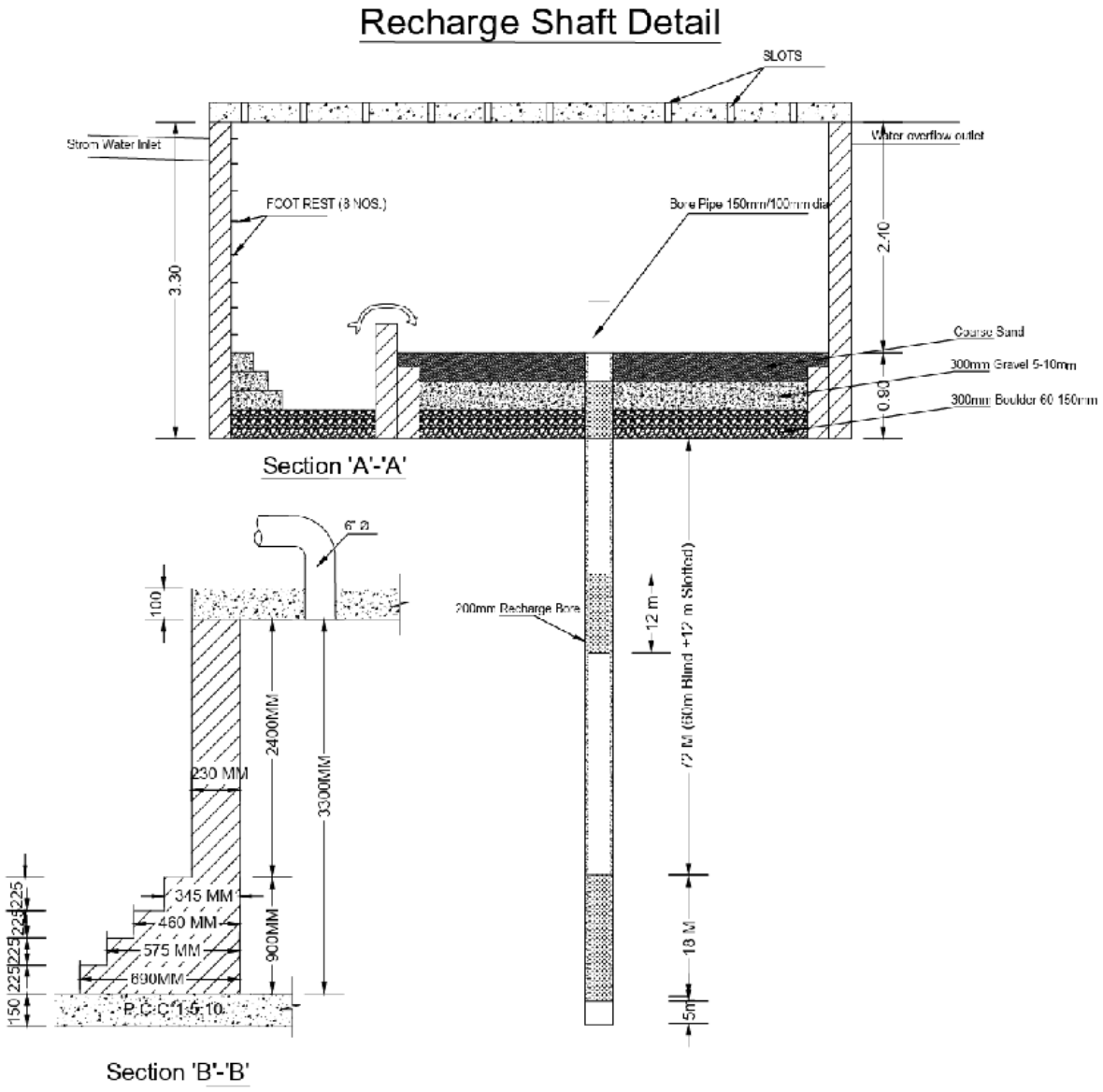

Figure 5. Existing section plan of the recharging shaft with borewell provided in the Golf Course.

The filter bed may clog owing to the recharge of rainwater, as the runoff may contain fine particles of sand and silt. The filter bed should be cleaned annually, preferably by scraping the top layer of sand and refilling the bed timely. The silt deposited on the filter bed may reduce recharge efficiency hence, it should be periodically removed or scrapped.

7. Sustainable Solutions for Enhanced Ground Impermeability and Water Protection

To render the water bodies of the golf course impermeable, a pond liner material that can prevent water leakage and withstand environmental factors is required. EPDM, which is an ethylene propylene diene monomer, is a suitable option. It is a synthetic rubber material known for its flexibility and lightweight nature, making it easy to install and mold the pond shape. Additionally, EPDM is resistant to UV rays, ozone, and weathering, ensuring long-term durability without cracking or degradation. However, it is not highly resilient to punctures or strong impacts from sharp objects or animals.

On the other hand, HDPE (high-density polyethylene), offers strength and rigidity, making it highly resistant to tearing and puncturing. HDPE's chemical resistance is advantageous for its use in environments where high exposure to fertilizers and pesticides is expected. Its ability to be welded allows for seamless joint creation, reducing the likelihood of leaks. However, due to its weight and rigidity, installing HDPE can be challenging, often requiring specialized machinery. The material's lack of flexibility may also pose challenges in conforming to the shape of the pond and adapting to changes in temperature or water levels.

Considering these comparisons, EPDM is a better choice for constructing impermeable and long-lasting liners for golf course water bodies, primarily due to its ability to withstand UV rays and weathering. However, precautions need to be taken to protect it from damage by sharp objects. On the other hand, HDPE though a cost-effective option, providing chemical resistance and efficient leak prevention but its rigidity can complicate the installation process (Chris G, 2023). It is also advisable to direct the initial rainfall towards the existing water bodies within the golf course instead of routing it to the recharging structures.

8. Supreme Court's Suggestions

- To visit the Golf course to carry out necessary tests and interact and get details/information from the officers of the Delhi Development Authority (DDA).
- To point out deficiencies, suggest measures including those necessary for groundwater recharge and to control/stop contamination of groundwater due to percolation of treated wastewater or surface water and examine, recommend relocation and construction of new rainwater harvesting pits in the Golf course and optimum use of water.

9. Concluding Remarks

1. In compliance with the orders of the Honourable Supreme Court of India, a team from the Department of Hydrology, IIT Roorkee, conducted a survey of the Delhi Development Authority (DDA) Qutub Golf course in South Delhi. The survey revealed the existence of 05 rainwater harvesting cum recharge structures within the Golf course area. A detailed discussion was held with DDA officials to assess the functionality and status of these structures.

2. Samples of the treated wastewater used for irrigating the Golf course were collected again for analysing its quality. It was observed that the samples still exhibit elevated concentration of some pollutants and thus, the utilization of treated water for groundwater recharge is discouraged.

3. Based on the hydrological data of the site and the existing drainage network of the Golf course, a comprehensive water balance study was performed to quantify the required volume of groundwater replenishment. It is found that the existing water harvesting setup of the Gold course need additional structures to augment the underlying groundwater aquifer system of the area.

4. We recommend the construction of two new water harvesting structures, considering the extreme rainfall events and intake capacity of the existing recharge structures. Furthermore, the refurbishment of existing structures is imperative to ensure effective groundwater replenishment. Relocation of the existing rainwater harvesting structures in the Golf course is not required.

5. It has been observed that the diameter of the recharge bore currently measures 100-150 mm. To optimize groundwater recharge efficiency, it is advisable to either increase the diameter of the recharge bore to a minimum of 500 mm or consider the provision of additional recharge bore in the existing recharging structures.

6. To control contamination of groundwater due to percolation of treated wastewater, the water bodies should be impervious in nature. The DDA should ensure that water bodies remain impermeable by suitable installation of the proposed EPDM liner. The EPDM seems a suitable linear for the Golf water bodies due to its flexibility and UV resistance.

7. It is advisable to direct the initial rainfall towards the existing water bodies within the golf course instead of routing it to the recharging structures to avoid entrance of pollutants to the recharging structures.

8. Periodic water quality monitoring of the water used in irrigating the Golf course is recommended to ensure the better management of the soil and groundwater resources of the Golf course area and its surrounding zones.

9. It is also recommended that sprinklers of the Golf course should be operated in early morning and in late evening particularly during the summer times to avoid excessive evaporation losses taking place during the fertigation events of the Golf course.

10. Measures should be taken by DDA to check the excessive evaporation losses from the existing water bodies for optimizing the water use in the golf course area. Suitable floats are recommended for use in the water bodies to reduce the direct exposure area of the water bodied to control the evaporation losses.

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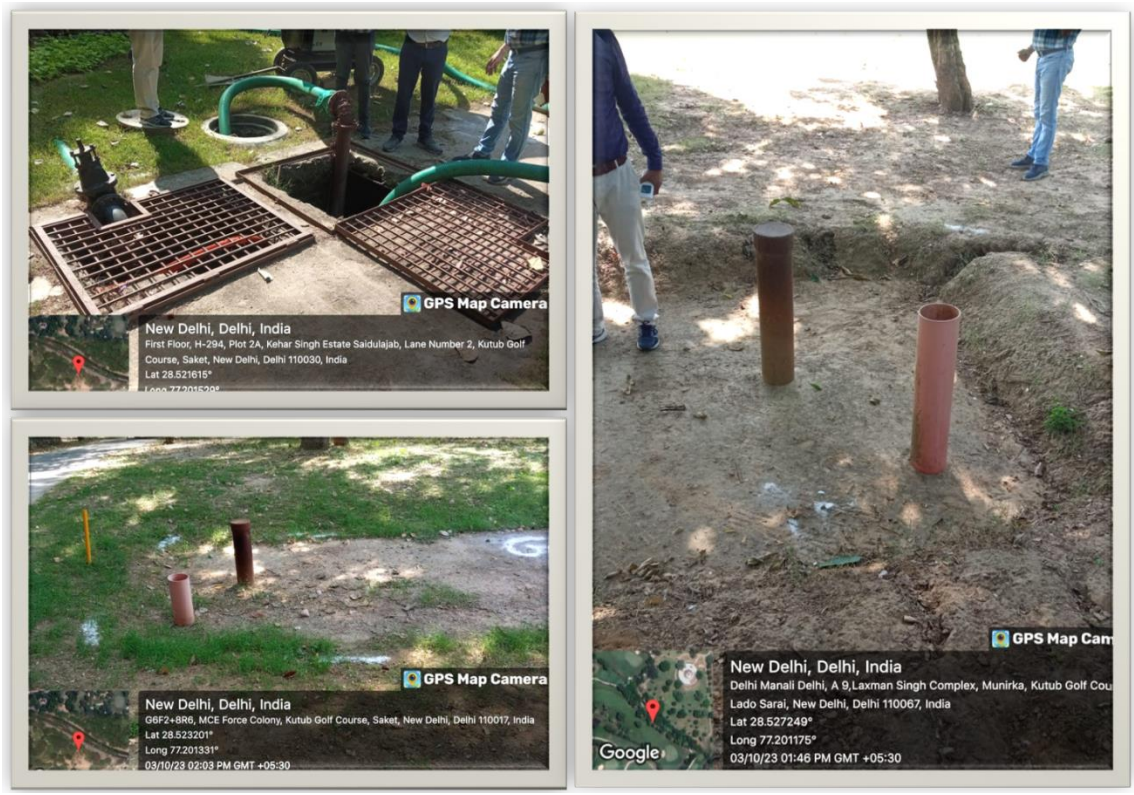
Appendix

(Some pictures of the Hydro-Geological Study and site survey of the Qutub Golf Course, New Delhi)

1. **ERT Survey**

2. **Existing recharging structures in the golf course area**



BEFORE THE NATIONAL GREEN TRIBUNAL,

PRINCIPAL BENCH, NEW DELHI

MEMORANDUM OF APPLICATION

[Under Section 18(1) Read with Section 14 & 15 of the National Green Tribunal Act, 2010]

Original Application No. 927 of 2024

IN THE MATTER OF:

Society for Protection of Culture, Heritage, Environment, Traditions and Promotion of National Awareness (Regd.)
Also known as [SP-CHETNA] **.... Appellant**

Versus

Delhi Development Authority & Ors. **.... Respondents**

AFFIDAVIT OF SERVICE

I, Anil Sood a Senior Citizen, S/o Sh. M.C. Sood, R/o.- C-1/1056, Vasant Kunj, New Delhi-110070, aged about 69 years, do hereby solemnly affirm and state as under:

1. That I am the President of the Applicant in the above-mentioned case. The present affidavit of service is being affirmed by me in such capacity on behalf of the Applicant.

2. I state that I have sent e-mail dated: 10th June 2025 from my official e-mail address anilsood@spchetna.com to the Respondents as well as their counsels, in the present case and have duly served on them an advance copy of the short reply on behalf of the Applicant by way of an affidavit to

NOTARY PUBLIC SANDEEP SHARMA REGN. NO. 1186/98 EXP DT 02-04-2026 GOVT OF INDIA

the counter affidavit filed by Respondent No.1. The particulars and e-mail address of the Respondents on whom service has been affected are as under:

Description of Recipient	**E-mail Adress**	**Date of e-mail**
Delhi Development Authority **(Respondent No. 1)**	Vcdda@dda.org.in	10th June 2025
Chief Secretary, GNCT of Delhi **(Respondent No. 2)**	csdelhi@nic.in	10th June 2025
Secretary, Ministry of Environment, Forest & Climate Change **(Respondent No. 3)**	Secy-moef@nic.in	10th June 2025
Secretary, Wetland Authority of Delhi, Delhi Parks and Gardens Society **(Respondent No. 4)**	ceodpgsenv.delhi@nic.in senv@nic.in	10th June 2025

Description of Respondents	**Counsel for Respondents**	**E-mail Address**	**Status**	**Date of e-mail**
Delhi Development Authority **(Respondent No.1)**	Prabhsahay Kaur	sahayk@gmail.com	Served	10th June 2025
Secretary, Ministry of Environment, Forest & Climate Change **(Respondent No. 3)**	Prasenjeet Mohapatra	prasenjeetmohapatra@gmail.com	Served	10th June 2025

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SANDEEP SHARMA
REGN. NO. 1186/98
EXP. DT. 02-04-2026
GOVT OF INDIA

Secretary, Wetland Authority of Delhi, Delhi Parks and Gardens Society **(Respondent No. 4)**	Jyoti Mendiratta	jmalawoffices@gmail.com	Served	10th June 2025

DEPONENT

VERIFICATION

I, the Deponent above named do hereby verify that the contents of my above affidavit are true and correct to my knowledge, no part of it is false and nothing material has been concealed therefrom.

Verified at New Delhi on this 10th June 2025.

DEPONENT

IDENTIFIED BY

NOTARY PUBLIC
SANDEEP SHARMA
REGN. NO. 1186/98
EXP. DT. 02-04-2026
GOVT OF INDIA

ATTESTED
NOTARY PUBLIC
DELHI (INDIA)

10 JUN 2025

Gmail

Anil Sood <anilsood@spchetna.com>

Short Reply to Affidavit filed by R-1 - DDA OA 927/2024

1 message

Anil Sood <anilsood@spchetna.com> Tue, Jun 10, 2025 at 1:08 PM
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Dear All

Attached is the short reply to the Short Counter affidavit filed by DDA.

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With best wishes & kind regards

Anil Sood
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Short reply to counter affidavit of R1.pdf
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