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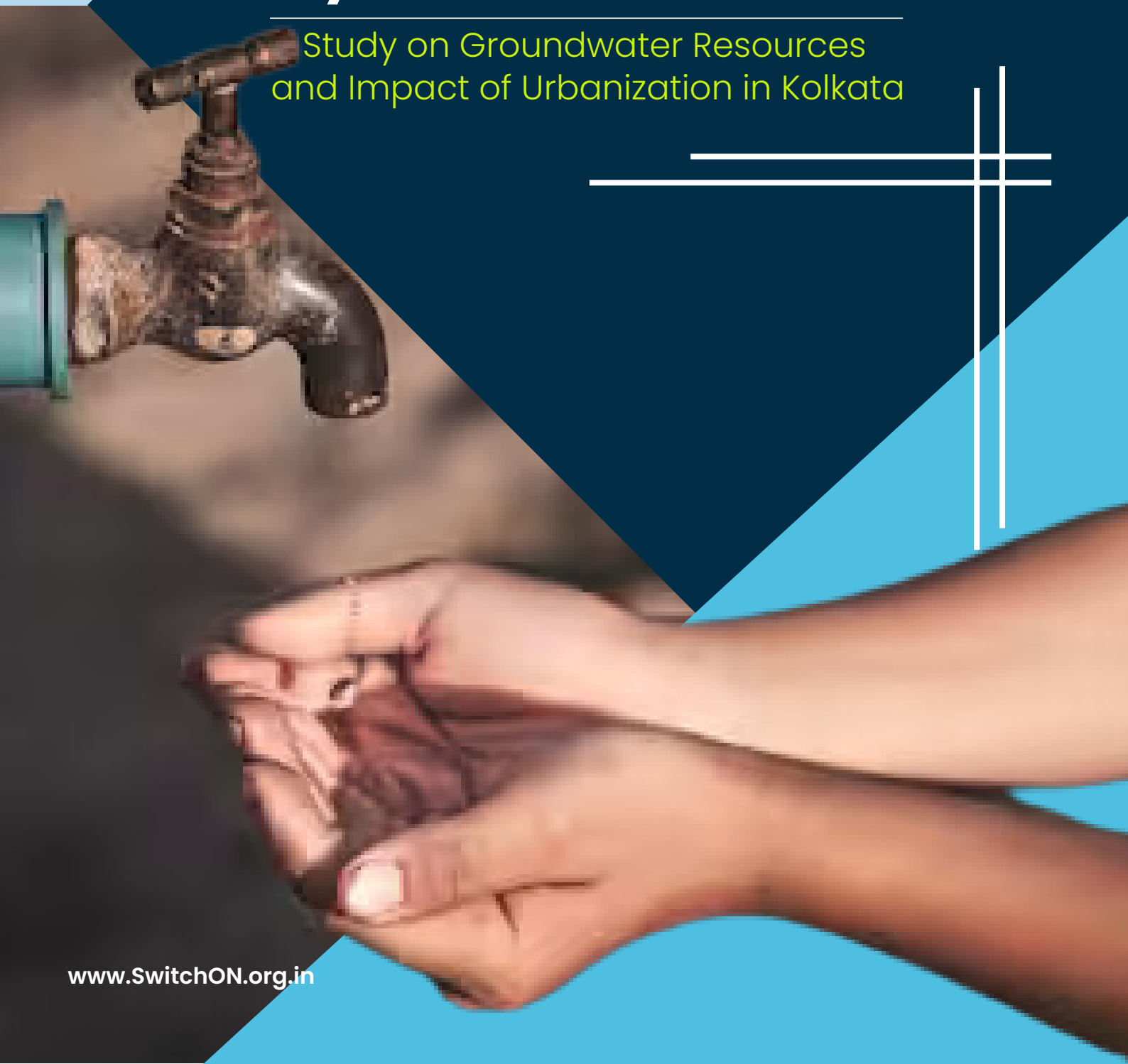
# Groundwater Dynamics of Kolkata

## Study on Groundwater Resources and Impact of Urbanization in Kolkata



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# CONTENT

# Executive Summary

This report provides a comprehensive analysis of Kolkata's groundwater resources, highlighting the critical impact of urban growth, over-extraction, and geomorphological characteristics. The Kolkata Municipal Corporation (KMC) area, spanning 187.33 sq. km., faces significant challenges due to rapid urbanization and rising water demands. Groundwater in KMC is categorized into three risk zones based on depletion trends: **High-Risk Zone** (boroughs VII and VIII), **Medium-Risk Zone** (boroughs IX and X), and **Low-Risk Zone** (the remaining boroughs). The High-Risk Zone, particularly in central and southern Kolkata, shows alarming groundwater decline rates of up to 0.30 m/year due to excessive extraction and land subsidence.

**Urban growth** has historically relied on both surface water from the Hooghly River and groundwater from confined aquifers. With the current population density of 24,000 people per square kilometer, the demand for water has surged, resulting in significant increases in groundwater abstraction. Despite efforts to reduce groundwater dependency and enhance surface water utilization, the East Kolkata Wetlands, crucial for ecological balance, have suffered from urban encroachment and land transformation. This has compounded the pressure on groundwater resources.

Current data indicate that groundwater withdrawal rates rose from 55 million liters per day in 1956 to 144.3 million liters per day in 2006. The recommendations for managing the groundwater are to promote **the 3 R's (Reduce, Reuse, Recycle)** to protect groundwater, which is is essential for sustainable water management, to endure a robust **groundwater monitoring and surveillance system** to detect the change in groundwater level over time, to minimise **the dependency of groundwater** and initiation of surface water-based water supply scheme, and to encourage and foster **participatory groundwater management** to implement a comprehensive strategy that involves and empowers individuals and protects the source. Addressing these issues is essential for balancing urban growth with groundwater conservation and ensuring a resilient water supply for Kolkata's future.

# 1.Introduction

Earth's freshwater constitutes a mere 2.5% of its total water, with 68.7% frozen in glaciers and ice sheets, and 30% residing in groundwater. Groundwater emerges as a sustaining freshwater supply for regions across the globe. In the context of the Kolkata metropolis, a World Bank Report from 2015 highlights its pivotal role, contributing nearly 37.5% to the total water supply. However, the present landscape of groundwater faces challenges amplified by migration trends post-independence, rapid urbanization, and burgeoning population growth. The consequence has been the over-extraction of groundwater, resulting in heightened concerns such as land subsidence, presenting as an environmental hazard for the city.

This study aims to delve into two major themes critical for understanding and addressing the challenges posed by the evolving groundwater scenario in Kolkata. The first theme focuses on unraveling the intricate geomorphological structures of the Kolkata Municipal Corporation (KMC) area, coupled with an exploration of the current groundwater scenarios. The second theme is a comprehensive exploration of urban growth dynamics and the contemporary demand for groundwater in this metropolitan setting. The study branches into key subthemes, such as the historical expansion of the city, present population growth rates, and the evolving water extraction patterns.

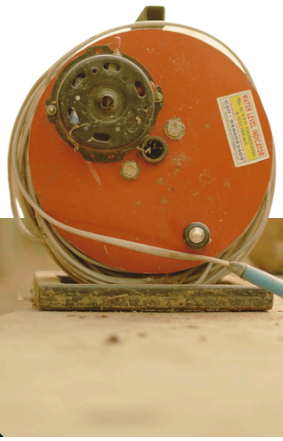
Moreover, including insights into threats concerning the East Kolkata Wetlands provides a holistic perspective. By weaving together these strands of investigation, this study aspires to contribute valuable insights that can inform and guide sustainable water management practices crucial for the well-being and resilience of the Kolkata metropolis in the face of evolving hydrological challenges.

# 2. Study Area

Kolkata is a key hub for water distribution in eastern India because it is situated on the eastern bank of the Ganga and is also known as West Bengal's capital. The city stands at a longitude of 88°36′ E and a latitude of 22° 33' N.


**Figure 1: Study area boundaries**
(Source: Google Maps, 2024)

The main study area is shown in Fig. 1 the Kolkata Municipal (KMC) area occupies approximately 187.33 sq. km., divided into 144 administrative wards or grouped under 16 boroughs (Appendix 1).



# 3. Literature review

## 3.1 Aquifer Characteristics of Kolkata

Kolkata is located in eastern India within the Ganges Delta, spanning an elevation range of 1.5 to 9 meters. The major source of groundwater is rainwater. According to Dasgupta (2017), the whole larger area of Kolkata underlies Quaternary sediment is composed of a sequence of alternations of clay, silty clay, sand, and sand mixed with occasional gravel. A minor aquifer zone exists within a depth span of 20–40 m, and the groundwater arises in both confined and unconfined conditions. Under unconfined conditions, groundwater occurs in a shallow zone. As per Bose, Mazumdar, & Basu, (2020) statement, fresh aquifers are sandwiched between saline/ brackish aquifers. This brackish water underlies an approximately 20–180-meter depth span.

Bose, Mazumdar, & Basu (2020) and John & Das (2020) stated that the KMC area's presence is mainly confined and semi-confined aquifers, and both freshwater and brackish water exist in this zone. In various places like Tollyganj, Dhakuria, Ballyganj, Santoshpur, Garia, Behala, and Thakurpukur, groundwater is found under unconfined conditions in the marshy or swampy lands. For different water availability and taping, the nature of groundwater availability becomes different. However, Sarkar, (2019), stated that the groundwater of the Kolkata region underlies confined conditions. Kasba, Ballygunj, and Dhakuria regions come under shallow aquifers.

## 3.2 Groundwater Quantity in different places of Kolkata

In Kolkata, the major source of groundwater is rainwater. Currently, groundwater faces issues of overpumping, land subsidence, and contamination. According to, Sikdar, Banerjee, & Chakraborty, (2022), about 93% of the available groundwater is abstracted. As a result, the piezometric surface is declining at a rate of 13–37 cm/year, and the groundwater trough in Kolkata is expanding at a rate of 8.60 km2/year.

Dasgupta, (2017) and Sarkar, (2019) both stated that the Ballyganj, Dhakuria, and Kasba areas, come under unconfined conditions, and this shallow aquifer occurs within 12 m below ground level. As the amount of groundwater Sarkar, (2019) stated, freshwater aquifers exist in the northern part of Kolkata, and the depth range is from 40 to 100m. Similarly, freshwater aquifers exist at 60–160 m in the central part and 180–300 m in the southwestern parts of KMC.

According to Dasgupta, (2017), in the Kalighat to Garia area, freshwater aquifers exist in 60–100 m thicknesses below a clay-slit horizon. Brackish water aquifers occur from a top to a drilled depth of 200 m below ground level in the Kashipur region of the Dumdum area. A similar situation is shown in the Santoshpur area, where brackish water aquifers occur from a top to a drilled depth of 300 m below ground level.

## 3.3 Impact of Land Subsidence and Rapid Urbanization on Kolkata's Groundwater Resilience

Groundwater is primarily used for drinking, agricultural, and industrial purposes, which are currently increasing due to rapid urbanization. According to Bose, Mazumdar, & Basu, (2020), due to the over-extraction of groundwater, land subsidence varies between 1.12 - 43.8 mm/year. The area's sustainable ecology is also negatively affected by rapid urbanization. Roy *et al.*, (2021), stated that, from 1989 to 2019, the total built-up area increased as well as agricultural area by approximately 33.33%. The author worried that the balance of the groundwater table negatively affected townships and infrastructure in the present time. Ghosh *et al.*, (2018), portray massive degradation of wetlands in the east Kolkata zone due to rapid urbanization, which enhances land subsidence probability. The changing land use and land cover patterns and other development activities significantly reduced the species diversity that is connected with water bodies.

## 3.4 Present Situation of Groundwater in KMC

At this present time, groundwater provides approximately 25% of the city's water supply. Most of the groundwater is withdrawn by industry-operated motorized wells, housing estates, and highrise apartments. Bose, Mazumdar, & Basu, (2020) stated that, during the pre-monsoon period, the Piezo metric level ranges between 10.92 & 19.03 mbgl and during the post-monsoon period between 8.08 and 17.74 mbgl. In the major part of the city, the piezometric level generally varies from 14.50–16.50 mbgl. This amount of groundwater depends on the flow of urbanization and the huge withdrawal of groundwater for domestic and industrial uses.

According to, Sikdar, Banerjee, & Chakraborty, (2022), in 1956, the estimated groundwater abstraction from the tubewell owned by Kolkata Municipal Corporation (KMC) was about 55 million l/day (mld), which jumped to about 182 mld in 1989 and 219 mld in 1992. In 2006, the groundwater abstraction was reduced to 144.3 mld (CGWB, 2006) due to the introduction of a surface water supply.

# 4. Objectives

This report aims to perform a comprehensive analysis of Kolkata's groundwater resources, highlighting the critical impact of urban growth, over-extraction, and geomorphological characteristics

- To analyze the influence of urbanization on groundwater levels in Kolkata by studying trends and variations of groundwater level.

- To comprehensively examine the groundwater resources in Kolkata, including an in-depth analysis of aquifer properties.

# 5. Methodology

This cross-sectional study relies on secondary data obtained from journal-conference articles and scientific reports sourced from ResearchGate, Academia, and Google Scholar. The primary focus of this study is on the observation of secondary groundwater data. Utilizing an inductive research approach and the data gathered, specific trends related to groundwater are identified in this research.

# 6. Groundwater Resources in the KMC area

## 6.1 Geomorphological Structure

Kolkata is located on the lower deltaic plain, which was developed in the Quaternary era by river-flowing sediments such as clay, silt, different grades of sand, and mixed gravel (CGWB, 2018).

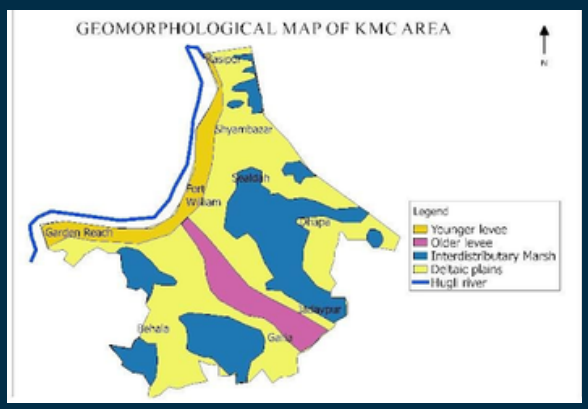



**Figure 2: Geomorphological Maps of the KMC area**
(Source: Bose, Mazumdar, & Basu, 2020)

This quaternary sediment is the most essential ingredient for groundwater development in Kolkata. According to Fig. 2, marshlands and younger levee depositions can easily be identified. It is also able to provide a brief idea about the groundwater presence in the KMC region. The groundwater in the KMC area is mostly located under confined conditions in aquifers, although in some parts of the city, groundwater is present under semi-confined conditions.

## 6.2 Present Groundwater Scenarios

Due to the over-extraction of groundwater in different areas of Kolkata, the piezometric level is remarkably deep. In the pre-monsoon period, under confined conditions, groundwater ranged between 1.59 - 20.67 mbgl, and during the post-monsoon period, groundwater ranged between 1.37 - 20.08 mbgl (CGWB, 2018).

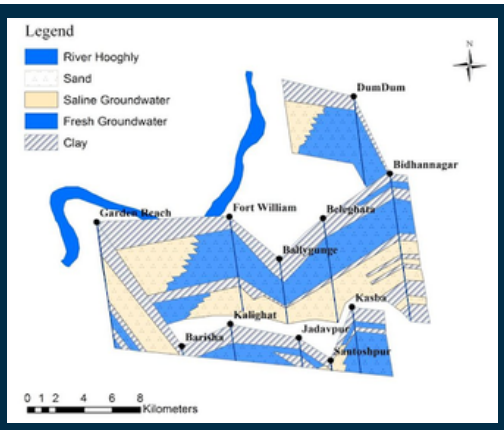



**Figure 3: Aquifers maps in Kolkata**
(Source: John & Das, 2020)

As per Fig. 3, the presence of fresh groundwater and brackish water can easily be shown in unconfined conditions. According to figs. 2 and 3, the Garia, Behala, and Kasba areas are covered by marshy lands, and major brackish water is present in Fort William to Kalighat and some areas in Dumdum where freshwater is present below (John & Das, 2020).

In the present time (2010–2018), major spatial differences have been noticed in numerous parts of Kolkata city. For geological characteristics, the southern parts of the city have higher levels of groundwater than the northern parts compared to any deltaic lowland area. Around the Garia region, the groundwater level ranges from 7 to 13 mbgl (John & Das, 2020).

# 7. Urban growth and demand for Groundwater

## 7.1 Historical expansion:

Since historical times, population expectations have been constant in the urban region of Kolkata for easily available surface water from the Hooghly River and groundwater from a quaternary confined aquifer (Sikdar, Banerjee, & Chakraborty, 2022).

The main city area structure is a bit complicated because it is divided into three major categories, which are Old Kolkata, New Kolkata, and Greater Kolkata. The old Kolkata represented by fig. 4, is divided into three villages called Sutanuti (Chitpur, Baghbazar, Sobhabazar, & Hatkhola), Kolkata (Dharmatala, Bowbazar, Simla, and Janbazar), and Gobindapur (Hastings, Maidan, & Bhowanipur) (KMCGOV, 2024).

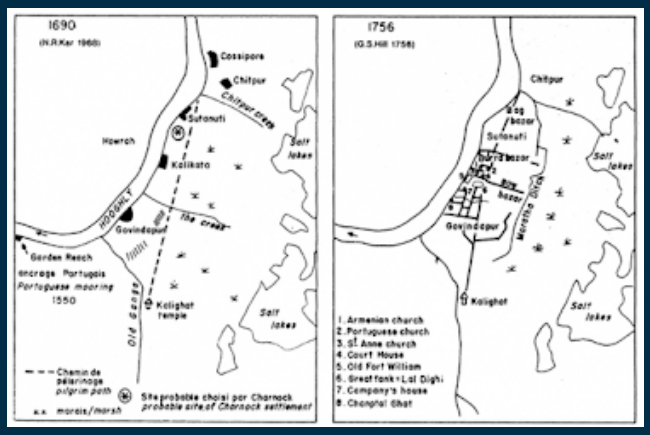



Figure 4: Old Kolkata 1690 - 1756
(Source: Munsi, 1990)

The new kolkata is divided into four parts, which are North, South, East, and West. The northern parts consist of Sinthi, Cossipore, and Gughudanga; the southern part consists of Tollygunge, Khidderpore, and Behala; the eastern part consists of Salt Lake, Beliaghata, and Topshia; and the western boundaries are made by the Hoogly River. Fig. 2 clearly depicts the new Kolkata boundaries. At this present time, KMCGOV, 2024, declared the greater Kolkata boundaries,where the government where the government added Baruipur to Bansbebria and Kalyani to Budge Budge.

## 7.2 Population growth in Kolkata

Currently, the Kolkata region's estimated population is 15,570,786 with a 1.55% growth rate. With the help of Fig. 5, it can be identified that, in 1950, the estimated population was 4.6 million. The city indicates a very high population density of 24,000 people per square kilometer or 63,000 per square mile (World Population Review, 2024).

By occupying wetlands and vegetation covers, Kolkata build-up expansions enhanced 100 to 162 km2. and during 1985–2016, estimated urbanization growth was 0.80% per year (Sikdar, Banerjee, & Chakraborty, 2022). The population of Kolkata, Salt Lake, and Howrah uses groundwater for drinking and domestic purposes.

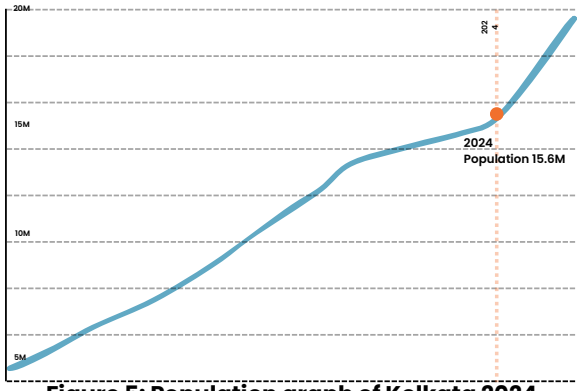



**Figure 5: Population graph of Kolkata 2024**
(Source: WORLD POPULATION REVIEW, 2024)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## 7.3 Water Demand and extractions rates in the KMC area

The main city's water supply crucially depends on surface water (from the Hoogly River) and groundwater sources from different places. In 1956, the estimated groundwater abstraction rate was 55 million liters per day (Sikdar, Banerjee, & Chakraborty, 2022). The KMC 2016 report stated that in 1986 they extracted 121.5 million liters per day (mld) of water, and this amount increased to 209.7 mld in 1998, which continued until 2004. In 2005, KMC started to increase surface water resource utilization, and in 2006, KMC withdrew 144.30 million liters per day (mld) of groundwater (Sarkar, 2019).

## 7.4 Threats regarding East Kolkata Wetlands

The East Kolkata wetlands used to be called the 'Kidney' of Kolkata City, which faces major negative ecological impacts due to rapid urbanization. Since the last 20 years, due to huge population growth and economic demand, urbanization has taken place in the East Kolkata Wetlands. As per fig. 6, total wetlands shrinkage amounts are visually represented, and a major part of the wetland's land transformations occurred in the northeast, north-west, and southern portions (Ghosh *et al.*, 2018).

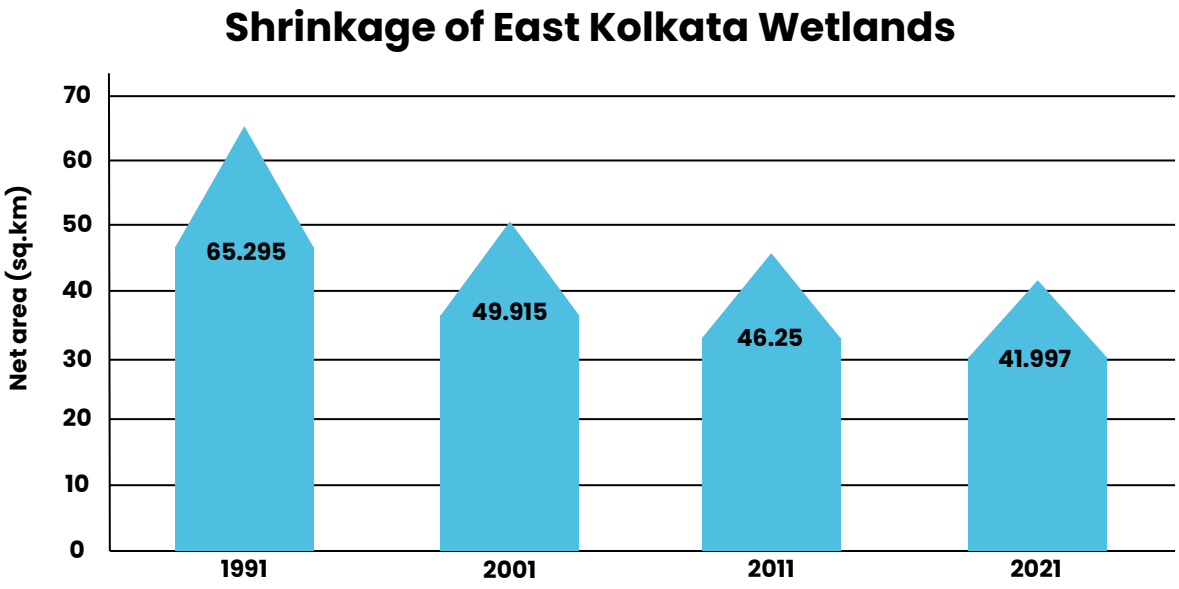
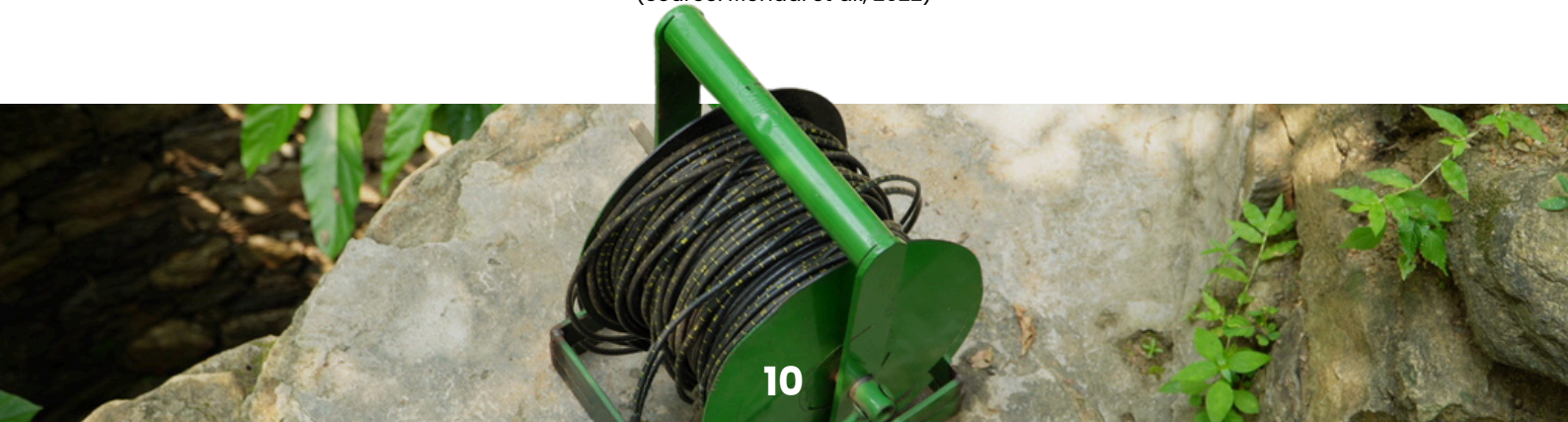



**Figure 6: Shrinkage of East Kolkata Wetlands**
(Source: Mondal *et al.*, 2022)



As per 1991–2021 data on wetlands, it can be identified that this has gradually decreased. In 1991, the total wetlands area was 65,298 km2, and it decreased by 15% between 2001 and From 2001 to 2011, the amount of shrinking was 4%, and from 2011 to 2021, the shrinking amount was 3% (wetlands shrinking: Appendix 4). Four main reasons are behind wetland shrinkage: extensions of build-up area, agricultural lands, populations, and aquaculture land transformations. Annexure 4. represents the surface water area reductions, and from fig. 7 the year-wise changes in water bodies are visualized.

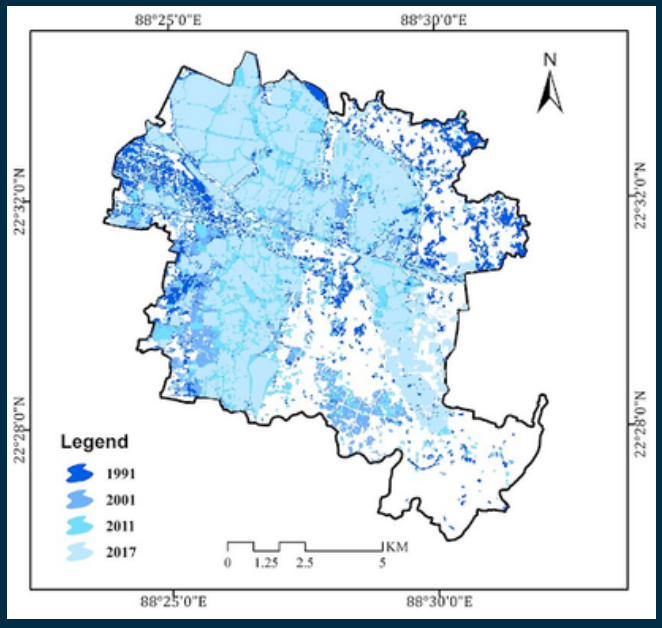



**Figure 7: Year-wise water body changing**
(Source: Ghosh *et al.*, 2018)

Apart from enhancing agricultural activity and expanding build-up cases, aquacultural land expansions are also responsible. In the last decades, this transformation has directly changed the hydrological perimeter of wetlands (Ghosh *et al.*, 2018). This unsustainable usage has negative impacts on groundwater levels in eastern Kolkata.

# 8. Risk Zones in the KMC ward

As a result of urbanization and over-extractions of groundwater the piezometric levels decreased. With the help of Table 1, aquifer depth and its declining trends are shown.

Table. 1: Borughwise Groundwater Potential, Kolkata (Annexure: 1)

| Borough No. | Depth to groundwater aquifers (mbgl) | Trends of the decline of groundwater level |
|---|---|---|
| I | <= 170; 200 in Kashipur region | @0.11m/year |
| II | <=160 | @0.11 - 0.12 m/year |
| III - V | <=160 | @0.11 - 0.15 m/year |
| VI | <=160 | @0.13 - 0.18 m/year |
| VII | <=160 | @0.30 m/year |
| VIII | <=160 | @0.20 m/year |
| IX - X | <160 | @0.13 - 0.16 m/year |
| XI - XII | <=150 | @0.11 - 0.13 m/year |
| XIII | <160 | @0.11 - 0.13 m/year |
| XIV | <160 | @0.11 m/year |
| XV | <150 | @0.11 m/year |

(Source: Sarkar, 2019)

As per table 1. the whole KMC borough is divided into three major risk zones on basis of present groundwater utilization.

## Zone 1: High-Risk Zone

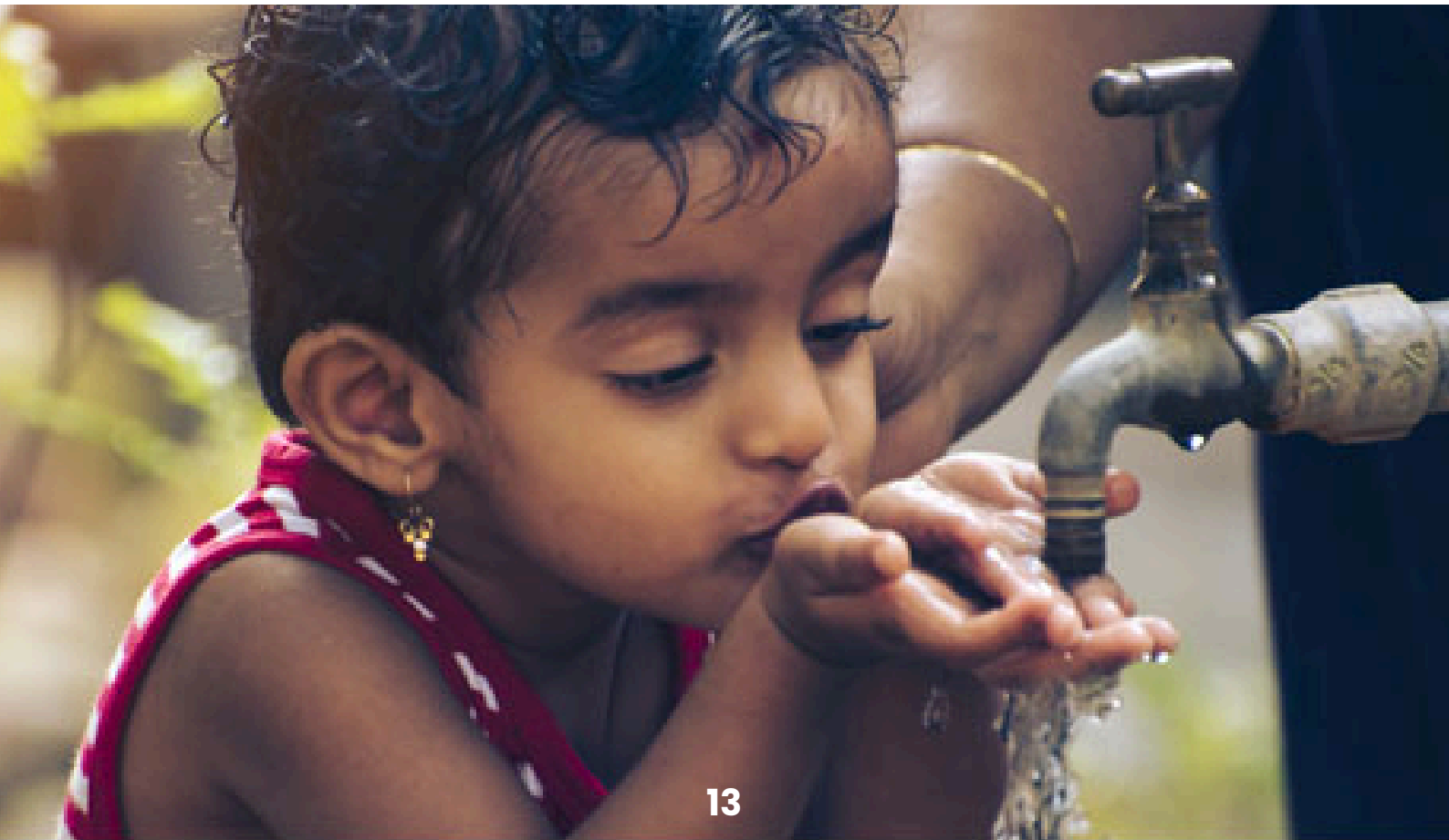
This zone covers VII and VIII boroughs and some parts of borough I. Borough VII covers the central part of the KMC area, with declining trends over 0.30 m/year. Borough VIII covers some of south Kolkata's parts, such as the Kalighat, Hazra, and Poddopukur areas, with 0.30 m/year water level declining trends. Uncontrollable groundwater withdrawal is the key reason for entering a high-risk zone. The maximum subsidence rate is 12 mm per year in various parts of the city, such as the Tiljala-Tangra area, Park Circus, and Belghata area.

## Zone 2: Medium-Risk Zone

This zone covers borough IX (New Alipur and Garden Reach area) and X (Jadavpur, Prince Anwarshah Road, Tollygunj, Bansdroni-Ranikuthi in the south of the study area). Within this zone, groundwater declining trends are mostly 0.13–0.16 m/year. However, in some areas, groundwater declines by 0.15–0.20 m/year.

## Zone 3: Low-risk Zone

This zone includes most of the boroughs, such as I, II, III, IV, V, XI, XII, XIV, and XV. The northern parts of the city, such as Bagbaza, Hedua, Shyam Bazar, and Maniktala, come under this zone. In the southwestern parts of the city, such as Sarsuna, and Thakurpukur; the south-eastern parts, such as Garia, come under this zone. The ground-decreasing trend is less than 0.15 m/year. The pre-monsoon water table shows a declining trend, but the post-monsoon trend is either rising or maintaining equilibrium with that of the pre-monsoon period.



# Conclusion

The groundwater of the Kolkata Municipal Corporation (KMC) area heavily depends on the city's geomorphological structure, which predominantly developed on Quaternary-era river-flowing sediments. Both confined and unconfined aquifers play a vital role in sustaining groundwater levels. However, presently, urbanization and the trend of over-extraction due to high population growth have negative impacts on piezometric levels.

Urban growth and demand for groundwater have historical roots, with the city's expansion influenced by the availability of surface water from the Hooghly River and groundwater from the Quaternary confined aquifer. At this present time, the Kolkata region's current population density is 24,000 people per square kilometer, which is a prominent reason for water demand. Not only build-up expansions, agricultural and aquaculture transformations are also reasons for the East Kolkata Wetlands, which pose challenges to groundwater levels.

KMC identified three types of risk zones all over Kolkata with their subsidence rates. This data may be valuable for the proper water management process to mitigate the adverse impacts of urbanization and over-extraction on Kolkata's groundwater resources. This will be carried out as a comprehensive approach to maintaining balance for growing water demands and its final preservation through groundwater reservoirs.

# Recommendations

- **Promoting the 3 R's (Reduce, Reuse, Recycle)** in the context of groundwater protection is essential for sustainable water management.
- Enduring a robust **groundwater monitoring and surveillance system** to detect the change in groundwater level over time.
- **Minimise the dependency of groundwater** and initiation of surface water-based water supply scheme.
- Encourage and foster **participatory groundwater management** to implement a comprehensive strategy that involves and empowers individuals and protects the source.

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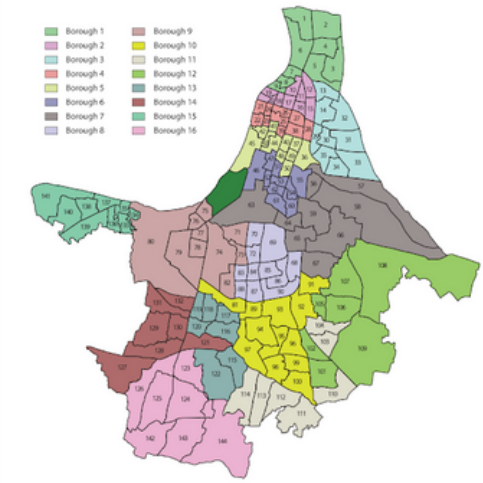
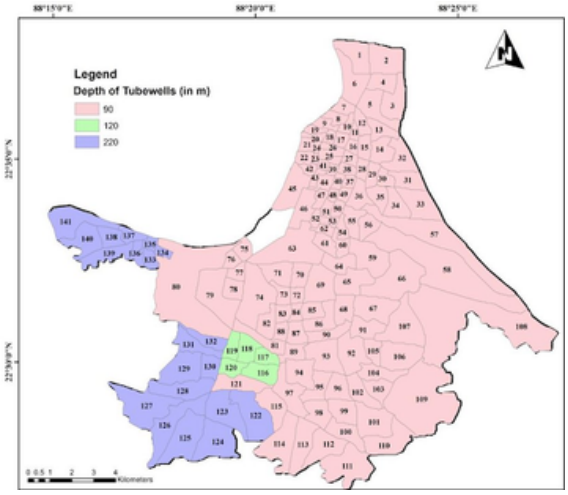
# Appendices

Appendix 1:
Figure name: **Administrative wards and boroughs maps**



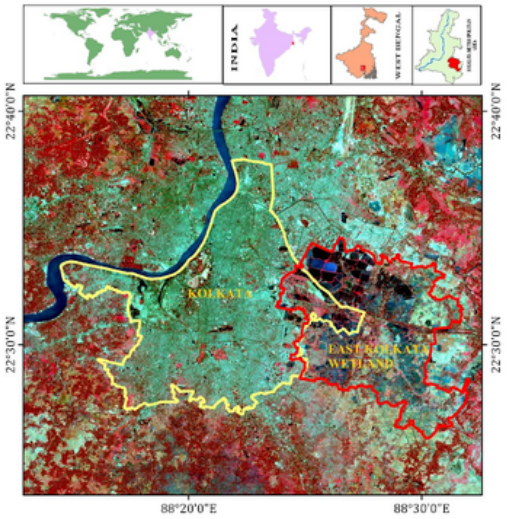
(Source:https://en.wikipedia.org/wiki/Wards_of_Kolkata_Municipal_Corporation#)

Appendix 2:
Figure name: **The depth of tube-wells for groundwater withdrawal in different wards of Kolkata**.



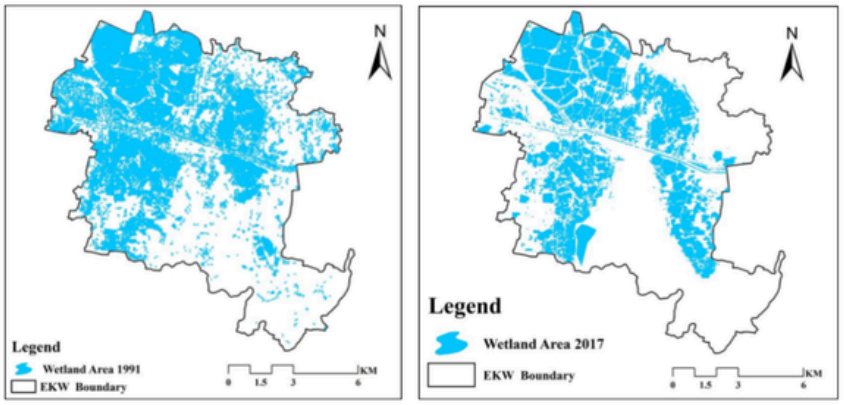

(Source:https://www.researchgate.net/figure/The-depth-of-tubewells-for-groundwater-withdrawal-in-different-wards-of-Kolkata_fig3_343048208#:~:text=...%20to%20the%20presence%20of,m%20(source%3A%20KMC))

Appendix 3:
Figure name: **East Kolkata wetlands**




(Source:https://www.researchgate.net_East_Kolkata_Wetland_India)

Appendix 4:
Figure name: **Surface water reduction from east kolkata wetlands**




(Source:https://www.researchgate.net/publication/327226504_Analyzing_risk_factors_for_shrinkage_and_transformation_of_East_Kolkata_Wetland_India)