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Research On Environment Management for Flood Control in Kolkata City

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***Abstract*- The objective of this study is to evaluate the importance and severity of city flooding in Kolkata with special attention to the jurisdiction of the Municipal Corporation. Till around nineties the rail approach to Kolkata, the Howrah Station in heavy rains trains could not enter platforms. The author was doing PhD on project management and met the Railway authorities and suggested to drill inclined boreholes down to the adjacent Hooghly River and the problem was solved. But, many regions of Kolkata used to be clogged with rain water.**

Later, as Director, Project & Environment Consultants, with collaboration of Central Mechanical Research Institute, research was taken up using hydraulic and GIS-based models to map flood situations below extraordinary eventualities. Data resources consist of ancient rainfall data as well as maps, and data on municipal drainage structures. Research revealed areas of excessive flood threat, insufficient drainage as well as excessive population and low-lying geographical features. Targeted and effective flood control strategies were developed with dredging of streams and rivulets in Kolkata to quicken outflow and use the dredged sludge for urban use in Parks and gardens in Kolkata. This study contributes to the improvement of broader city flood management for other towns dealing with similar challenges.

***Keywords*-- Flood dynamics, Flood intensity, Municipal Corporation, Flood management strategies, Drainage infrastructure, GIS-based flood mapping, Community-based initiatives.**

I. Introduction

Urban flooding is a global issue which is exacerbated by weather change as well as rapid population growth with insufficient infrastructure. Kolkata is particularly vulnerable in low-mendacity regions specific to the Hooghly River. Rapid city development, as well as outdated culverts, and poor flood control strategies, contribute to the frequency and severity of floods. Managing urban flooding in Kolkata needs intensive expertise in its dynamics. There is also a need for the implementation of powerful mitigation techniques to shield citizens and infrastructure.

The geographical region of Kolkata influences the risk of flood extensively. The metropolis is situated on the banks of the Hooghly River and there are numerous low-mendacity areas. This obviously has a tendency to build up water. Expanding roads and buildings as well as reduces natural drainage, and runoff, resulting in flood threats**.** Urban enlargement has destroyed the natural drainage system by encroaching on natural waterways and wetlands.

Understanding flood patterns and their reasons helps to enable the development of effective techniques as well as beautify urban resilience and make certain sustainable development. This permits the identity of high-risk areas as well as reporting on infrastructure improvements and further helps to guide the planning policies of the urban. Figure No -1 shows major drainage systems in Kolkata city.

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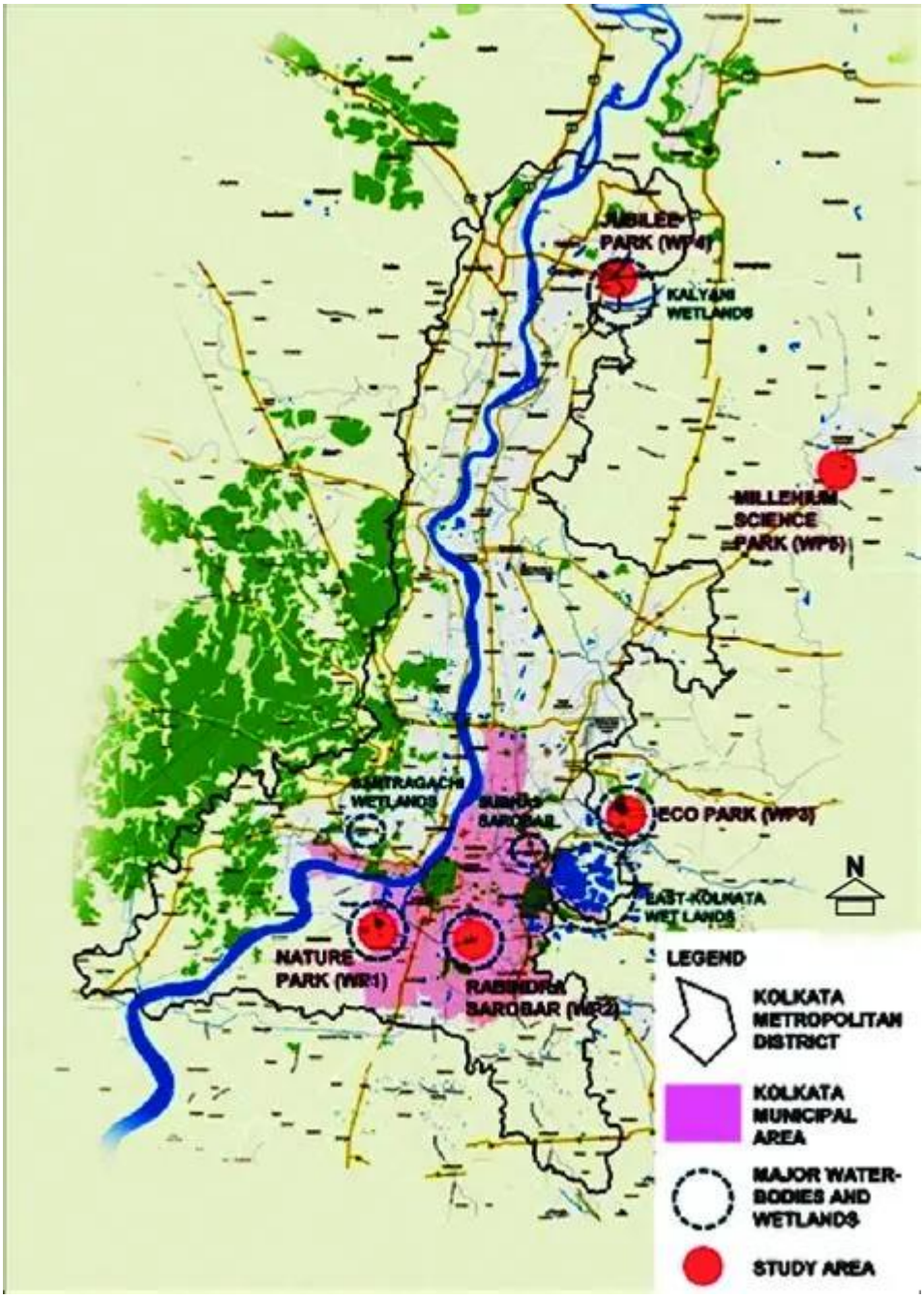

FIGURE NO-1: KOLKATA DRAINAGE MAP

The city is located at 22O30' North Latitude, 88O30' East Longitude, and is the main port of entry in North Eastern India. This study makes a speciality of assessing the significance and intensity of city flooding in Kolkata which is mainly in the jurisdiction of the Municipal Corporation.

The most important objectives are to become aware of the main reasons for flooding as well as determine the effectiveness of current flood control structures and further suggest recommendations for enhancing flood control. The study seeks to provide actionable insights to city planners and the makers of the policy.

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This is done to assist them broaden targeted interventions to decrease flood risks and shield metropolis residents and infrastructure from future flooding.

II. Background

The entire CMC area is divided into 8 (eight) major drainage basins. (KMDA, 1990) with many canals, channels and tributaries. The Hooghly river in the more recent past used to flow along a braided course of the 'Adi Ganga' stretched from the vicinity of Hastings into the Hooghly River, The important drainage channels serving the Kolkata Metropolitan District Area are as follows: 1.Dankuni Drainage Channel, 2.Howrah Drainage Channel, 3.Rajpur Drainage Channel, 4. Barajola Drainage Channel, 5. Beghar Khal, 6. Naui Khal, 7.Tolly's Nullah, 8. Boat Canal, 9. Bagjola Khal, 10.Krishnapur Canal, 11. Kolkata Outfall Channel, 12. Beliaghata Canal, 13.Circular Canal, 14. Panchanna gram Khal. The urban planning has to be done to reduce future flood risks.

The natural landform characteristics of Calcutta make the city's drainage problem inevitably problematic. The land is more elevated towards the west and is gradually tilted towards the eastern marshy land which has been partly reclaimed and developed into the present Salt Lake City. Kolkata lies on the land that slopes towards the east, i.e. away from the river Hooghly. The area is very flat and low, with a saucer-line shape, with scattered local low pockets. The period from July to September is the rainiest when the city receives as much as 1000 to 1200 mm of rainfall due to intensive monsoon activity. During these three months the city receives nearly three fourth of its average annual precipitations.

Kolkata experiences widespread flooding and water stagnation, particularly in low-lying areas. Some key challenges include:

- Severe Waterlogging in Low-Lying Areas – Locations like Salt Lake, Behala, New Alipore, and Rajarhat face prolonged water stagnation due to poor drainage.
- Outdated & Clogged Drainage Systems – The old underground drainage network in North and Central Kolkata struggles to handle heavy rainfall, leading to urban flooding.
- High Groundwater Table & Seepage Issues – In regions like Tollygunge, Jadavpur, and Garden Reach, excessive groundwater levels contribute to structural damage and road collapses.
- River & Tidal Flooding from Hooghly River – Areas near Howrah, Kidderpore, and Kalighat experience overflow from the Hooghly River, leading to additional flood risks.
- Climate Change & Unpredictable Rainfall Patterns – Increasing heavy rainfall events and rising sea levels have worsened the flood situation, particularly in South Kolkata and Sundarbans.

Storm Water Flow Channel (SWF Channel) and Dry Weather Flow channel (DWF Channel) that CMC excavated between 1937 and 1939. This system also serves some rural areas stretching along its flow line from the city to the outfall covering an area of about 150 km^2. Such outfalls play a vital role in Kolkata system, but after deluge, but Kshudiram Pally, Green Park, Adarsha Nagar, Mahendra Banerjee Road, Motilal Gupta Road, Hemanta Mukherjee Road, Subhas Marg, Airport Road, Pally Sree, Anandanagar and Joyrampur etc are very flood prone.

The pumping stations located at discrete locations of the city become the life-line of the city during the floods. An important report released regularly by the KMC authorities relates to ameliorative measures, particularly with reference to the draining out of flood waters through the operations of the pumping stations located in different parts of the city. The situation of the pumping stations as these were being operated at different location must improve. Precautionary measures through installation of extra submersible pumps have to be taken to prevent water logging within the water supply generating stations as well as the booster pumping stations.

III. Growth Problems

The city expanded over time and the sewer network and out of the 141 Wards of the city, there is vulnerability to floods is the considerable human and infrastructure costs. Additionally, insufficient drainage infrastructure is prone to frequent and severe flooding, resulting in many economic and social disruptions.

The city does not have any conventional facility for wastewater treatment. There are a total of 815 km of sewer, of which there are about 645 km of pipe sewer and about 170 km of brick sewer. About 88 km of the brick sewer is man-entry sewer, i.e. sewers above 42-in in diameters.

The two of the most important tools used in the analysis and management of urban flood risks are Hydrological modeling and flood mapping, which is based on a Geographic Information System (GIS). This further helps in planning and decision-making. They analysed the current flood pathways and pinpointed the metropolitan areas that were at risk by examining optical and radar satellite pictures.

Urban Flood Risk Mitigation (InVEST-UFRM) model for the city Kolkata was used to estimate the flood-like situation after consecutive rainfall for 2 h with different rainfall depths and find possible mitigation measures.

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The result finds Kolkata is covered up with 75% impervious surface where more than 80% of the rain water transforms into runoff after 2 h of rainfall and northern portion of Kolkata is extremely vulnerable to flooding.

Locations in Kolkata predominant are in Paikpara and Dum Dum Road area of Bagjola basin; Maniktala and Khanna area of Maniktala Basin; Chitpur, Bidhan Sarani, Central Avenue and Barabazar area of Town System; Park Street, Camac Street, Chowringee Road and Rabindra Sadan region of Suburban System; Tangra, Topsia and Ruby Park area of Topsia-Tangra Basin; Behala, Silpara, Sursuna, Thakurpukur area of Churial basin and Garden Reach and Khidirpore area of Hoogly Basin. Among all these, maximum increase in waterlogged areas has been recorded in the Churial, Hoogly and Topsia-Tangra Basins.

IV. Methodology Of The Study

Discussions were held with the Director of CMERI and a Scientist was allotted to help Project & Environment Consultants for the research. Many meetings were held with the Commissioner of Kolkata Municipal Corporation and concerned officials. This study collected quantitative data including historical data on rainfall and present maps and surveys of urban flooding in Kolkata. Rainfall data was collected with information on drainage systems including the ability and circumstance of current drainage systems is accumulated from urban reviews and urban planning files.

It was suggested that vehicle travelling in flooded area should be using new technology offerings like a real-time GPS vehicle tracking system via a smartphone, tablet or PC remotely, and dynamically manage their rescue. Enterprise Risk Management (ERM) solution set. It is a planning and preparation tool to document, approve and test an organization's response plans for ensuring business continuity in the face of various emergencies like flood, The enforcement tools range from remote sensing (using satellite imagery, drones and radar) and real- time monitoring, through use of big data analytics.

Conduct root cause analysis was suggested for both long and short-term improvements occur. This analysis tool is ideal for teasing out the root cause of complex problems and finding a timely and workable resolution. This important concept allows corrections to be introduced preventing its recurrence in the future. Risk management and mitigation are key quality functions, and especially important in emergency planning.

To improve your organizational response to events, it is critical to define precisely how an organization will react during an emergency KMC authorities, Kolkata Environment Improvement Program, Kolkata Metropolitan Development Authority, KMWSA, I&W Dept. were consulted on their major primarily serving areas. Due to excessive sedimentation canals could not play an effective role at the time of excessive storm water flow, one of the main constraints to effective drainage of the canals. There is no regular maintenance, resulting in a gradual reduction in hydraulic capacity. The accumulation of silt throughout the years which is caused by the encroachment that makes the canal becomes ineffective.

V. Reseach Instrumentation

GIS mapping is a critical tool for visualizing and assessing flood risks, providing spatially detailed information on flood hazards, exposure, and climate change impacts. Flood risk mapping in GIS combines hydrological and hydrodynamic models with spatial data such as elevation, land use, and flood protection infrastructure. QGIS software is, available free of charge if downloaded from QGIS.org. QGIS meets their specific needs or to contribute to and accelerate the huge social impact that is realised by making a tool such as QGIS freely available.

Mobile version is also available. Flood susceptibility maps can be produced by using Geographic Information System (GIS)-based Multi-Criteria Decision Analysis (MCDA) Analytical Hierarchy Process (AHP) and Bivariate Statistical Frequency Ratio (FR) models. This study analyses twelve Hydro-geomorphological flood conditioning factors selected based on the scale and characteristics of the study area. These factors include elevation, slope, distance from the river, rainfall, drainage density, Land Use Land Cover (LULC), Topographic Wetness Index (TWI), Height Above Nearest Drainage (HAND).

The location and weather of Kolkata make it flood-prone area, very close to the River Hooghly. The drainage system of the city is old and it is unable to manage the situation of heavy rains. The development of urban areas has added more concrete and asphalt surfaces in the city, with high population density. Inadequate maintenance of drainage systems and delays in flood management projects make the situation worse for the people of Kolkata during the rainy season. Sedimentation over many years after floods on the nullahs, channel and canals minimise outflow during heavy rains. Figure No -2 shows various utilizations of GIS system for flood control.

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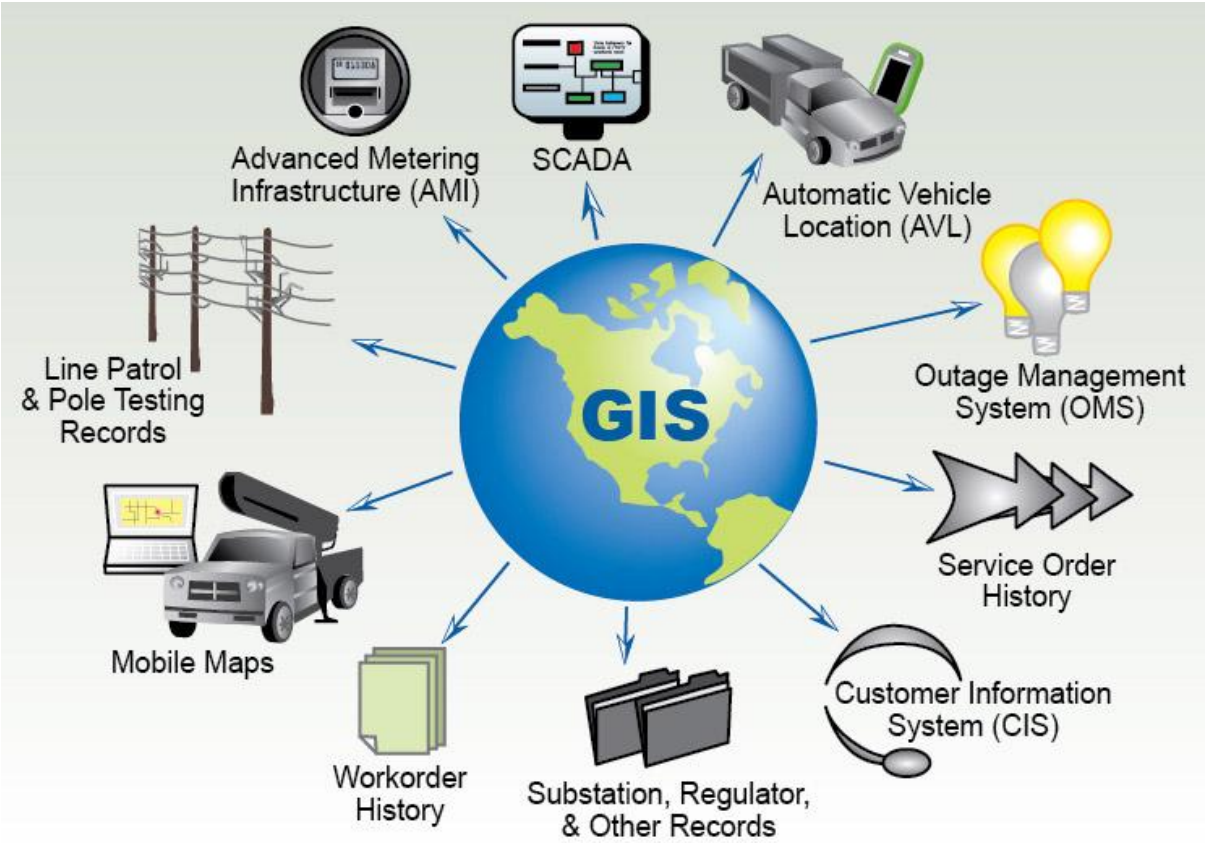

FIGURE NO-2: GIS SERVICES FOR FLOOD CONTROL

VI. IMPLEMENTATION

A judicious combination of structural and non-structural responses, including institutional, economic, financial, and social efforts were considered. Engineering Centre's River Analysis System (HEC-RAS) and Storm Water Management Model (SWMM) and others were taken into consideration due to their robustness in simulating flood conditions. The effectiveness of flood management is evaluated via metrics including flood frequency along with the duration and effect on inclined areas.

The early warning system has also been set up, which has improved the preparedness and the response.

Kolkata is situated in the Low-lying Ganges delta near the Hooghly River There are many areas in Kolkata that still utilize the drainage system of the colonial era. Controlling floods becomes difficult because of the crowded neighbourhoods that have very small open spaces.Research was done and it is recommended that easy dredging can be done by wheel mounted backhoe from the side of a canal. The sludge can be loaded into dump trucks for taking to low-lying areas for backfilling or utilizing in parks and gardens. Canal Dredging machine type suggested from the banks to load for carrying away for utilization is shown in Figure No-3

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FIGURE NO-3: CANAL DREDGING MACHINE RECOMMENDED

Building new drains and pumping stations to improve drainage system are the appropriate solution for Kolkata to mitigate the issue of Urban Flooding. Biological reclamation should include filling up of low-lying areas with sediments obtained from dredging of canals and channels. All outflows should go into Hooghly river and then flood waters will recede fast.

Multiple Linear Regression Method (OLS) with histogram of the residual distribution, which is ideally symmetric around zero. Symmetry and mild curvature propose approximate normality with minor deviations. It was shown that some statistics on the dataset, exploratory data analysis for showing the relationship demonstration among the variables, correlation table for finding the highest correlation among the variables, OLS method.

VII. Conclusions

The survey reveals good-sized variability within the importance and depth of flooding across Kolkata, with more extreme flooding in some regions because of an aggregate of heavy rainfall as well as low soil and bad drainage. The findings highlight the pressing need for comprehensive city flood management in Kolkata. Effective flood control requires an integrated technique that mixes infrastructure upgrades with policy adjustments and community engagement.

1) Upgrade and extend existing drains to increase capacity and performance.
2) Implement inexperienced infrastructure solutions such as tired sidewalks as well as green roofs and rain gardens to beautify natural drainage.

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3) Restore and guard natural waterways and wetlands to improve the city's natural drainage system.
4) Stricter legal guidelines on land use and improvement could be introduced to save encroachment on water-susceptible regions.
5) Design and put in force complete city flood control plans including early warning structures and emergency control.
6) Flood risk tests need to be included inside the city making plans technique to make sure that new developments can resist flooding.
7) Increasing public cognizance of flood chance and community participation in flood preparedness and response sports is advocated.
8) Develop a plan primarily based on neighbourhood tracking and remediation for neighbourhood drains and watersheds.
9) Encourage partnerships among authorities agencies, NGOs and nearby groups to increase flood manipulate.

Implementing adaptive management techniques advanced with the converting environment will ensure lengthy-term flood resilience in Kolkata. Regularly updating flood management plans and resource assessments will help to control rising flood risks as well as safeguard the future of the city.

Flooding Solutions in Kolkata, tackling the city's persistent waterlogging, poor drainage, and monsoon-related urban flooding. With increasing climate change impact, rapid urbanization, and outdated drainage infrastructure, Kolkata faces severe flooding risks, especially during the monsoon season. Our advanced flood mitigation strategies, including stormwater management, drainage optimization, and groundwater recharge, help protect industries, residential areas, and municipal bodies from flood damage.

Tarutium system, supported by ADB, is leading the development of a comprehensive flood early warning system in Kolkata to address urban flooding issues. The IoT-powered system provides real-time forecasts on rainfall and inundation levels, climate, and environmental data, strengthening city resilience. The flood forecasting and early warning system is India's first-ever comprehensive city-level early warning system, designed to provide forecasts and real-time updates from sensor nodes. The system is singular in that it is accompanied by environmental and weather sensors for year-round environmental monitoring, providing information on temperature, humidity, and air quality across the city.

The ultrasonic sensors fixed at key points across the city, such as hot spots identified as vulnerable to inundation during flood events, canals, pumping stations, traffic junctions, and schools, will send real-time data to a cloud-based dashboard. The input will be automatically analyzed using Kolkata's global information system data. Risk information will then be shared with citizens and community groups through mobile alerts and radio/television messaging to help them plan their daily activities, such as commuting, based on early warning and real-time inundation status. Tarutium has also developed a web platform and app to collect and analyse the data, available at https://www.kflood.in.

The Kolkata Municipal Corporation (KMC) has launched a major drainage upgrade project for north and central Kolkata, including refurbishment of the 148-year-old underground sewer line from Moulali to Palmer Bridge and installation of high-capacity pumps at drainage pumping stations. This project aims to protect over 10 lakh residents across 30 wards from monsoon flooding

To address recurring waterlogging, Kolkata is exploring IoT-enabled smart drainage systems. These systems integrate sensors, automated sluice gates, predictive analytics, and SCADA dashboards to monitor water levels, prevent tidal ingress, and optimize pumping operations. Pilot projects in the Behala–Taratala corridor have demonstrated up to **80% reduction in waterlogging duration**, with potential socio-economic savings of ₹50–80 crores annually if scaled city-wide.

VIII. Recommendations

On the basis of research undertaken, the following points are recommended mainly for quick results: -

1) *Stormwater Drainage Optimization* – Upgrading existing drainage infrastructure to enhance water flow and prevent blockages.
2) *Flood-Resistant Infrastructure Planning* – Implementing flood-resilient urban planning strategies, including elevated roads and flood-proof construction.
3) *Groundwater Recharge & Rainwater Harvesting* – Reducing waterlogging by promoting sustainable rainwater infiltration techniques.
4) *Tidal & River Flood Protection Measures* – Designing embankments, levees, and flood barriers to prevent Hooghly River overflow.
5) *Smart Flood Monitoring Systems* – Installing real-time flood tracking sensors and AI-based early warning systems.

6) *Wetland & Green Infrastructure Solutions* – Restoring natural drainage systems and urban wetlands to absorb excess floodwaters.

Flood control in Kolkata also involves **flood-resistant urban planning**, including elevated roads, flood-proof construction, and zoning regulations. Restoration of urban wetlands is emphasized as a natural buffer to absorb excess rainfall before it overwhelms drainage systems. Proper land use planning, water harvesting, and flood insurance are additional measures to reduce vulnerability.

Effective flood management requires **inter-agency proper coordination** among municipalities, electricity boards, and disaster management authorities. Community-based climate literacy programs are being promoted to educate residents on flood preparedness, response.

The two examples of the structural measures that make up the approach taken by the city of Bangkok, Thailand, are the retention basins and floodwalls. Furthermore, So Paulo, a city in Brazil, has embraced the stormwater management approach. This focuses on improving the quality of the water and preventing floods, river restoration projects, and stricter land use regulations were implemented in the flood protection strategy of So Paulo.

Moreover, the land use and the urban planning emphasize the land-use regulations and flood-proofing measures. The use of remote sensing and GIS as experienced in Egypt could help Kolkata to a great extent in managing the flood.

Kolkata's flood control strategy should combine **structural measures** (drainage upgrades, pumping stations, flood-resilient infrastructure), **technological solutions** (smart drains, real-time monitoring), and **non-structural measures** (urban planning, community engagement, wetland restoration) to reduce flooding risks, protect residents, and improve urban resilience during monsoon seasons.

In 2025 The Asian Development Bank (ADB) has approved a $200 million loan to enhance the development of climate- and disaster-resilient sewerage and drainage infrastructure in Kolkata, aiming to improve the city's life. ADB's 25-year partnership with the Kolkata Municipal Corporation (KMC), working to make Kolkata a more liveable city through phased, integrated investments to improve urban services, operational efficiency, institutional effectiveness, and long-term sustainability.

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