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CLIMATE-RESILIENT URBAN FLOOD MANAGEMENT AND WATER RESOURCE INTERVENTIONS IN THE UPPER KRISHNA BASIN, MAHARASHTRA

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ABSTRACT:

Rapid urbanization coupled with severe climate vulnerability has exponentially increased the frequency of extreme flooding events within Maharashtra, India. This paper evaluates the structural and non-structural interventions proposed under the Maharashtra Resilience Development Project (MRDP), a US$ 400 million joint initiative funded by the World Bank and the Government of Maharashtra. Focusing on the critical urban centers of Kolhapur and Sangli-Miraj-Kupwad (SMKMC) in the Upper Krishna Basin, this study examines advanced hydraulic re-validation methods, infrastructure modifications designed to prevent involuntary resettlement, and the regional concept of inter-basin water channeling to mitigate flood-and-drought dualities.

Keywords: *Flood Management, Urbanization, Climate Resilience, Inter-Basin Water Channeling, Hydro-Modeling.*

1. INTRODUCTION:

Maharashtra stands as one of India's primary economic engines, yet it faces rising socio-economic disruptions due to climate-induced hazards, notably severe flooding. The catastrophic floods of 2019 resulted in economic losses of INR 4,287 Crores, with the state paying INR 641 Crores in community compensations. This was closely followed by the 2021 floods, which incurred damages worth INR 1,178 Crores.

Urban catchments within the flood-prone districts of Kolhapur and Sangli have demonstrated severe infrastructure deficiencies. Aging drainage systems, rapid expansion of impervious surfaces, and structural encroachments on natural waterways (nallas) have heavily exacerbated local flooding risks. Operating on the premise that historical climate baselines are no longer reliable predictors for future disaster risks, the Government of Maharashtra launched the MRDP (World Bank Operation ID: P506340). The project objectives encompass re-validating stormwater drainage master plans, executing structural urban upgrades under the strict condition of minimizing displacement, and establishing state-wide digital risk frameworks.

2. METHODOLOGY AND APPROACH:

To develop engineering interventions adaptive to future extreme hazards, a multi-faceted hydrological and empirical methodology was implemented:

1. **Meteorological and Gauge Data Analysis:**
   A comprehensive 39-year dataset from the India Meteorological Department (IMD) was extracted to formulate rainfall Intensity-Duration-Frequency (IDF) curves. Real-time runoff modeling was cross-calibrated using daily gauge and discharge metrics obtained from Water Resources Department (WRD) monitoring stations along the Krishna and Panchganga rivers.
2. **Topographical Spatial Modeling:**
   High-resolution Digital Elevation Models (DEMs), including TessaDEM for Kolhapur, were utilized alongside satellite imagery and localized Lidar data. This enabled spatial watershed delineation, precise sub-catchment mapping, and the simulation of urban flood inundation boundaries.
3. **Climate Change Scaling:**
   Following the mandates of the 2019 Expert Study Committee Report, a forward-looking 20% safety factor was integrated across all design rainfall intensities to account for climate-induced extreme precipitation shifts.
4. **Stakeholder and Community Consultations:**
   Participatory workshops and field assessments targeted highly vulnerable demographics—including local residents, women entrepreneurs, gig workers, and transit operators—to align engineering interventions with community protection needs.

3. URBAN FLOOD MANAGEMENT IN KOLHAPUR:

Kolhapur City is uniquely vulnerable due to its location inside the Panchganga River basin, facing backwater effects when river gauges approach danger thresholds.

3.1 Existing Vulnerabilities:

Field inspections verified that municipal drainage capacity has dropped significantly. This impairment stems directly from heavy siltation, uncontrolled solid waste dumping, and systemic bottlenecks where underground infrastructure meets aging trunk lines.

3.2 Engineering Interventions and Social Safeguards:

To augment capacity without causing urban displacement, hydraulic models optimized targeted interventions:

- **Strategic Pipe Upgrades:** Existing 800mm diameter stormwater pipes at critical bottlenecks are designated to be replaced with 1m diameter Reinforced Cement Concrete (RCC) drainage lines.
- **Avoidance of Resettlement:** The choice of a 1m diameter threshold was strategically modeled to expand flow capacity sufficiently while avoiding structural impacts on neighboring commercial establishments. This precluded the necessity for a separate, disruptive Resettlement Action Plan (RAP), satisfying strict social safeguard parameters.
- **Blue-Green-Grey Infrastructure (BGGI):** Structural modifications are coupled with sustainable 'Sponge City' techniques, combining regular mechanical desilting, channelization, and nature-based solutions to optimize gravity flow and groundwater infiltration.

4. URBAN FLOOD MANAGEMENT IN SANGLI-MIRAJ-KUPWAD (SMKMC):

The SMKMC urban zone, located directly within the main Krishna River basin, experiences chronic inundation caused by combined riverine overflows and low-lying terrain vulnerabilities.

4.1 Diagnostic Network Assessment:

The drainage infrastructure is a fragmented, mixed network composed of natural open streams (nallas) connected to secondary open drains and tertiary piped systems. Proximity to the Krishna River subjects the entire internal system to intense backwater pressures during upstream reservoir discharge events.

4.2 Mitigation Framework:

The MRDP deploys a parallel, rigorous approach for SMKMC:

- **Structural Stream Regularization:** Interventions prioritize clearing major open channels, building retaining walls, and constructing upgraded culverts with wider waterway openings to eliminate severe backwater pooling.
- **Environmental and Social Mitigation:** Every modification strictly adheres to World Bank environmental frameworks. Alignment vectors utilize existing municipal rights-of-way to minimize land acquisition. A transparent Grievance Redress Mechanism (GRM) and specialized livelihood restoration programs are built directly into the project execution budget to safeguard informal workers and roadside vendors.

5. REGIONAL CLIMATE-INFORMED RISK FRAMEWORKS:

Moving past isolated municipal engineering, the project addresses regional watershed vulnerabilities through coordinated structural and digital management systems.

5.1 Advanced Real-Time Early Warning Systems (EWS):

To enhance temporary shelter readiness and emergency deployments, the MRDP integrates an automated forecasting architecture:

- **Real-Time Data Acquisition Systems (RTDAS):** Automated sensors and river gauges across the Krishna basin track live precipitation and reservoir inflows.
- **Satellite Nowcasting:** Live radar and Global Precipitation Measurement (GPM) satellite data are integrated to capture real-time wide-area storm developments over data-sparse catchment zones.
- **Hydraulic Prediction Integration:** Collected telemetry feeds directly into predictive software (such as PCSWMM), allowing authorities to simulate inundation boundaries up to 72 hours in advance and coordinate proactive reservoir pre-releases to establish flood-moderating cushions.

5.2 Inter-Basin Water Channeling: Kolhapur/Sangli to Marathwada (Solapur Region):

As a long-term macro strategy, the framework explores an innovative Inter-Basin Water Transfer Scheme:

- **The Dual-Benefit Logic:** The framework seeks to channel excess floodwater from high-volume, disaster-prone basins (such as the Panchganga and Krishna systems in Kolhapur and Sangli) and redirect it toward chronically drought-prone, water-scarce zones within Marathwada and the broader Solapur region.
- **Engineering and Administrative Challenges:** While highly promising for state-wide water stabilization, the execution barriers include technical complexities in maintaining sustained cross-terrain gravity or lift channels, extended environmental clearance timelines due to regional ecological adjustments, and substantial long-term financing requirements to sustain major pump and conduit operations.

6. FINANCIAL AND OPERATIONAL ANALYSIS:

The financial structure leverages public funds to optimize climate-resilient operations without leaving investment deficits:

Table 1: Project Financial Architecture

Project Parameter	**Financial Allocation / Metric**
Total Project Operation Cost	US$ 400.00 Million
World Bank (IBRD/IDA) Contribution	US$ 280.00 Million (70% of total)
Government of Maharashtra Funding	US$ 120.00 Million (30% of total)
Financing Deficit / Gap	US$ 0.00 (Fully funded)

Project Parameter	**Financial Allocation / Metric**
Primary Valuation Parameters	DSR 2022-23 rates with material adjustments

Project implementation tasks are systematically divided among core state departments to guarantee localized expertise:

- *Component 1 (Climate-Informed Management):* Managed by the Maharashtra Krishna Valley Development Corporation (MKVDC).
- *Component 2 & 3 (Resilient Urban Infrastructure & Emergency Capacities):* Supervised by local Municipal Corporations and the Disaster Management Relief and Rehabilitation (R&R) Department.
- *Component 4 & 5 (Private Capital Mobilization & Knowledge Databases):* Governed by the Maharashtra Institution for Transformation (MITRA), serving as the central Project Management Unit (PMU).

7. CONCLUSION:

The Maharashtra Resilience Development Project indicates a critical shift from reactive crisis control to proactive, climate-informed urban engineering. By integrating a 20% climate escalation factor into hydraulic models, upgrading critical urban drainage channels while strictly preventing residential displacement, and leveraging real-time RTDAS/GPM telemetry, the framework provides a comprehensive model for urban flood mitigation. Scaling these local solutions into macro-level regional strategies, such as inter-basin water transfers to Marathwada, offers a path toward true climate adaptation and long-term resource security across the state.

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