A National Vision for Flood Protection and Stormwater Resilience: Integrated, Sustainable, and Future-Ready Urban Infrastructure in the Kingdom of Saudi Arabia

1. Abstract

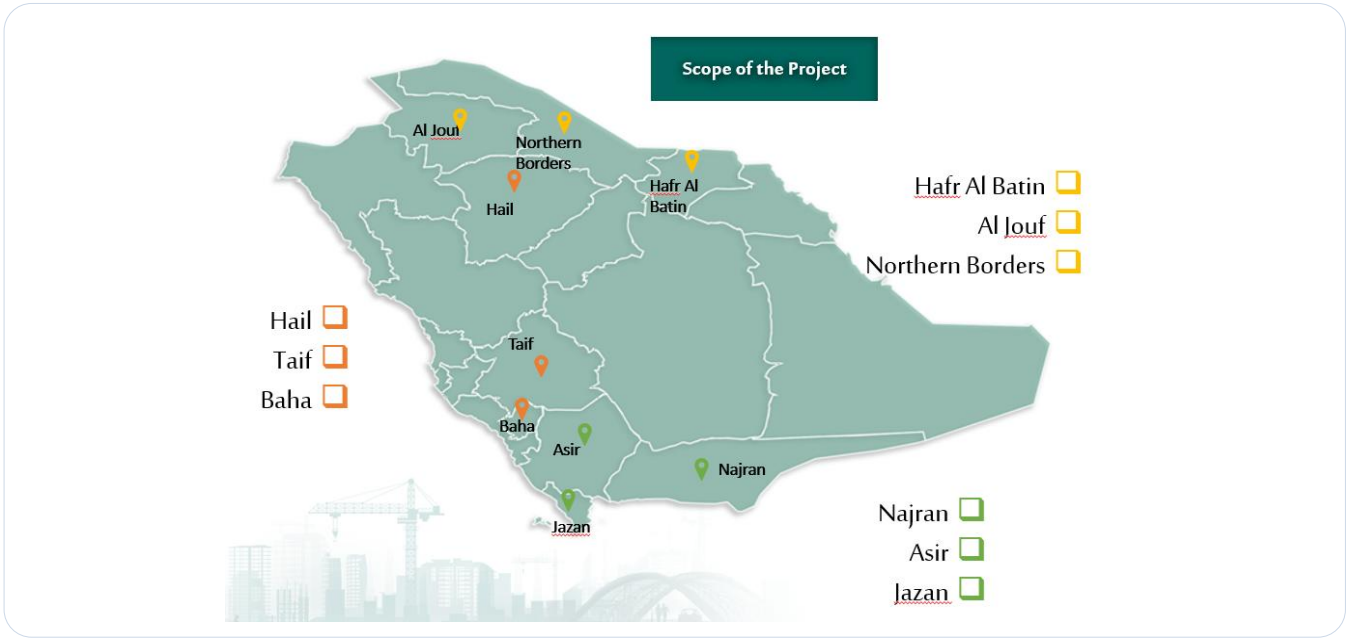
In alignment with Saudi Vision 2030, the Kingdom of Saudi Arabia has launched a comprehensive national project under the leadership of the Ministry of Municipalities and Housing (MOMAH) to strengthen flood protection and stormwater drainage systems and enhance the resilience of municipal assets against climate change and extreme weather events. The project represents a strategic shift toward proactive risk management and sustainable urban infrastructure, focusing on the preparation of detailed engineering designs supported by integrated master planning, advanced hydrological and hydraulic modeling, and the adoption of nature-based solutions.

2. Initiative Strategic Objectives

The initiative seeks to reduce flood risks in urban and peri-urban areas, protect critical infrastructure, and ensure the continuity of municipal services during extreme rainfall events. By improving stormwater drainage efficiency and enhancing flood prevention measures, the project supports quality of life, public safety, and environmental security while establishing unified national standards for flood mitigation and infrastructure delivery across municipalities.

3. Project Strategic Objectives

The project aims to provide detailed designs for flood mitigation and rainwater drainage projects within 8 municipalities, in addition to the scope of work of Hafr Al-Batin in the Kingdom of Saudi Arabia.



4. Integrated Planning and Risk Assessment

A data-driven and risk-based planning approach underpins the project, beginning with the identification and prioritization of high-risk and flood-prone locations, particularly in densely populated and strategically important areas. This process includes assessing vulnerabilities within existing infrastructure, developing early warning and emergency response frameworks, and evaluating residual flood risks to ensure that mitigation measures address both immediate and long-term challenges. Two-dimensional hydrodynamic modeling is employed to accurately define flood extents, wadi boundaries, and natural flow paths, enabling informed design decisions and precise delineation of flood protection corridors.

5. Sustainable Urban Drainage and Environmental Integration

Environmental sustainability is embedded within the engineering framework through the integration of Sustainable Urban Drainage Systems (SUDS). These systems include permeable pavements and roofs, rain gardens, vegetated detention basins, and green drainage corridors that work collectively to reduce surface runoff, enhance infiltration, support groundwater recharge, and improve urban microclimates. By adopting nature-based solutions alongside conventional infrastructure, the project balances flood risk reduction with ecological preservation and urban livability.

6. Stormwater Drainage and Flood Protection Infrastructure

The project involves the design of more than 10,000 km of stormwater drainage networks that serve as essential urban infrastructure for the rapid conveyance of surface runoff and the prevention of water accumulation in low-lying and flood-prone areas. Complementing these networks, flood protection channels and regulated wadi systems exceeding 5,000 km in length are designed to enhance the natural drainage capacity of valleys and reduce flood risks within urbanized zones. Artificial lakes and retention ponds are also incorporated as multi-functional elements, providing temporary stormwater storage during peak rainfall events, alleviating pressure on drainage systems, supporting non-potable water reuse such as irrigation, enhancing groundwater recharge, and contributing to ecological balance. In parallel, road-related flood mitigation measures—including culverts, bridges, spillways, and pumping stations—are designed to ensure traffic continuity, protect transportation infrastructure, and enable efficient drainage from vulnerable areas during flood events.

7. Phased Implementation and Budget-Aligned Tendering Strategy

To ensure financial sustainability and effective execution, municipalities adopt a phased implementation strategy aligned with municipal budget capacities and funding cycles. Initial phases focus on high-risk and critical areas where flood impacts are most severe and where early intervention can deliver immediate risk reduction and tangible community benefits. Subsequent phases expand coverage

coverage to secondary urban areas, integrating drainage and flood protection works with planned road and urban development projects to optimize costs and minimize disruptions. Long-term phases address future growth areas, ensuring infrastructure readiness and alignment with land-use planning and climate adaptation strategies. This approach allows municipalities to implement projects progressively, based on available resources, while maintaining consistent technical standards nationwide through the provision of ready-to-issue tender documents.

8. Municipal-Level Impact and Benefits

At the municipal level, the project enables faster implementation by providing standardized engineering designs and tender documents, allowing municipalities to directly initiate construction without delays associated with design procurement. The initiative directly benefits approximately 9.9 million citizens across nine municipalities, serving more than 15 km^2 of critical urban areas and resolving over 1,000 previously identified flood-prone locations. These interventions significantly improve public safety, infrastructure reliability, and urban resilience.

9. Knowledge Transfer and National Capacity Building

A core pillar of the initiative is the systematic transfer of knowledge and technical expertise to newly graduated Saudi engineers, recognizing human capital development as a strategic national priority for the Kingdom. The project is designed not only as an infrastructure delivery program, but also as a large-scale professional development platform that exposes young engineers to advanced hydrological modeling, flood risk assessment, sustainable drainage design, and international best practices in urban resilience. Through structured on-the-job training, mentorship by experienced specialists, and direct involvement in real projects across multiple municipalities, recent graduates gain practical, field-tested skills that bridge the gap between academic education and professional practice. This knowledge transfer strengthens national engineering capabilities, reduces long-term reliance on external expertise, and supports the localization of technical competencies in line with Vision 2030 objectives. By investing in the next generation of Saudi engineers, the project ensures the sustainability of infrastructure programs, fosters innovation, and builds a resilient national workforce capable of leading future urban and environmental initiatives.

10. Anticipated Outcomes

The anticipated outcomes of the project include measurable improvements in flood prevention performance indicators, enhanced stormwater drainage efficiency, reduced emergency response times, and increased resilience of urban environments. Overall, the initiative represents a significant contribution to achieving Vision 2030 objectives related to sustainability, environmental protection, infrastructure security, and improved quality of life across the Kingdom.

11. Conclusion

This national flood protection and stormwater drainage initiative represents a transformative step in strengthening urban resilience and safeguarding municipal infrastructure across the Kingdom. By combining advanced engineering design, sustainable and nature-based solutions, phased implementation aligned with municipal budgets, and digital enablement, the project delivers an integrated and future-ready approach to flood risk management. Beyond its physical infrastructure impact, the initiative establishes unified national standards, accelerates municipal readiness, and embeds knowledge transfer to empower the next generation of Saudi engineers. Collectively, these elements position the project as a strategic enabler of Vision 2030, enhancing quality of life, environmental security, and institutional capacity while ensuring that cities across the Kingdom are better prepared to withstand climate challenges and support sustainable growth.

12. Biography

Dr Ahmed Lotfy is PhD holder in Hydrology and Water Resources with more than 20 years of combined academic, research, and professional experience. He has established a strong scientific foundation complemented by extensive hands-on expertise in hydrological analysis and water resources engineering, gained through addressing complex engineering challenges across diverse regions, including Egypt, Nile Basin countries, Europe, and the Kingdom of Saudi Arabia.

His PhD research focused on reducing uncertainty in runoff estimation using rainfall data, contributing to improved reliability in hydrological modeling. He developed an innovative Python-based methodology for the optimal design of rainfall monitoring networks in arid regions where ground-based observations are limited. He earned his M.Sc. degree from Newcastle University (UK) and has also developed web-based software and an online database for hydrometric systems.

His professional experience encompasses advanced hydrological data analysis, hydrologic and hydraulic modeling, flood mitigation planning, and stormwater drainage network design in arid and semi-arid environments. He has led and contributed to flood risk assessment and management studies, as well as the structural design and site supervision of water-related infrastructure projects.

In addition to his technical expertise, he demonstrates strong communication and interpersonal skills, enabling effective collaboration with multidisciplinary teams and stakeholders at all organizational levels and across diverse cultural and professional backgrounds. His qualifications and adaptability allow him to perform efficiently in complex and demanding engineering roles