Risk assessment of flood disaster based on extreme rainstorm transposition in central Beijing

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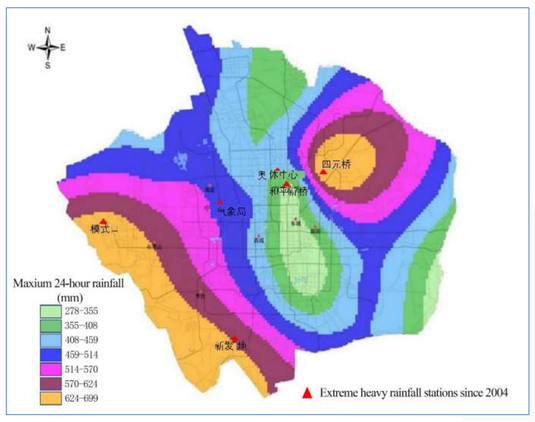
Objectives

The disastrous "7.20" heavy rainstorm in Zhengzhou has brought about fresh challenges to ensuring the safety of operations in the city. Beijing and Zhengzhou share similarities in terms of weather patterns, terrain, topography, and vulnerability to floods. By transferring the rainstorm scenario from Zhengzhou to Beijing, valuable insights can be gained to better manage the impact of extreme flood disasters in the capital.

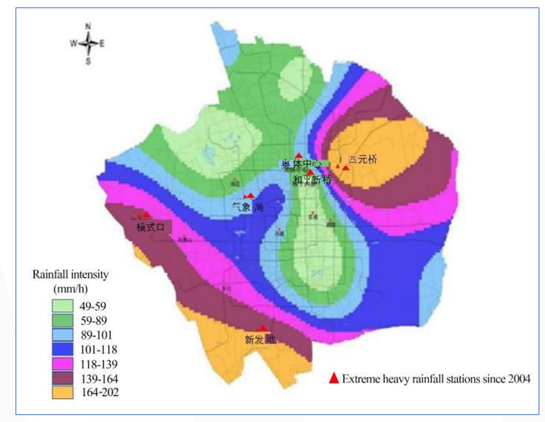
Adopting the concept of "rainstorm transplantation - scenario construction - risk analysis" and guided by the principle of considering the most unfavorable yet plausible scenarios, this research establishes a comprehensive scenario involving urban rainstorms and the discharge of the North Canal. A model is developed to assess the risks associated with urban rainstorms and flood disasters. This model quantifies the level of flood risk during extreme rainstorm scenarios in Beijing, while also pinpointing areas prone to inundation and key zones of heightened risk. The analysis takes into account various factors including subway entrances, low-lying courtyards, population density, economic activities, and road waterlogging. To counter these challenges, the study introduces the "31631" defense strategy and proposes specific preventive measures tailored to the specific circumstances at hand.

Methods

- Transplanting the heavy rainstorm pattern and setting up the combined scenario of urban rainstorm and river discharge.
- Constructing a comprehensive flood model for the central urban area, including rainfall runoff model, river and pipe network confluence model, and surface runoff model.
- Establishing a city flood risk assessment index system based on the framework of "hazard-exposure-vulnerability".



Maximum 24-hour rainfall transplantation results



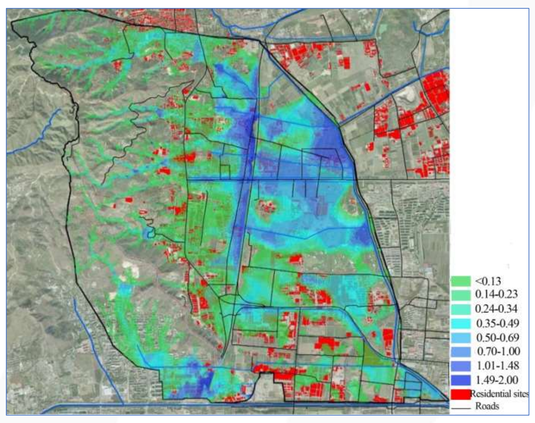
Rainfall intensity transplantation results

Results

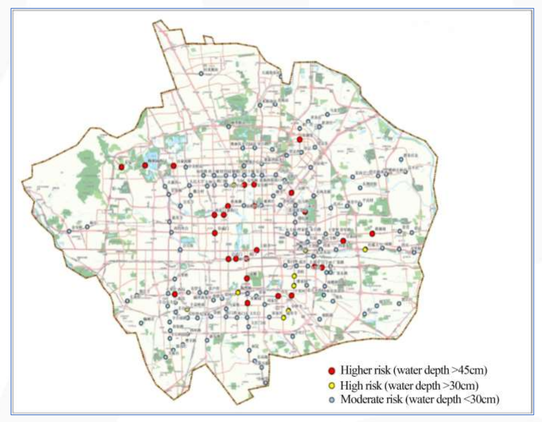
In a worst-case scenario, the challenges posed by flooding from the North Canal, along with the complexities of urban water drainage, are substantial. The most probable situation involves heavy rainfall affecting the city's western, southwestern, and northeastern regions. The North Canal Sand River Sluice has a maximum discharge rate of 1260m³/s, and the city's peak rainfall occurs 12 hours before the peak flood at the Sand River Sluice. This convergence of discharge from the Sand River Sluice and urban floodwaters gives rise to an unprecedented and severe combination scenario of heavy rainfall and flooding.

Within the central urban area, the total flood volume across the four major river basins amounts to 280 million m³, causing varying levels of overflow in different waterways and leading to severe drainage congestion. The West Mountain region witnesses extensive flooding, encompassing an area of 12km² and affecting 34km of roads. In the central urban zone, approximately 27% of the total area experiences inundation, with most areas having water depths of under 0.5m. The impact on roads is substantial, with over 1300km of roads within the central urban area affected. Most of these roads are submerged to depths of less than 0.5m, while 70km of roads are submerged to depths exceeding 1.5m. Notably, 123 subway stations within the New Urban area are situated in high-risk zones.

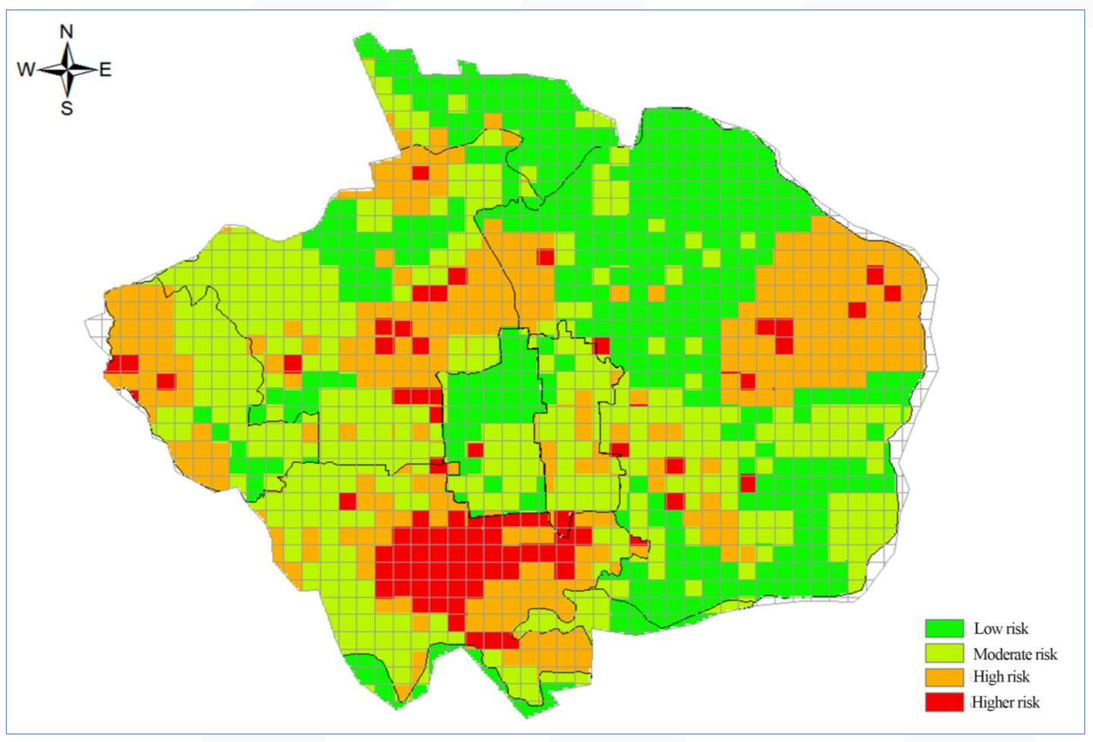
The assessment of flood risk takes into account various indicators, including water depths at subway stations, road water levels, population density, economic indicators based on regional GDP, and the capacity of the pipe network for drainage. Vulnerability indicators encompass factors like susceptibility, recovery capacity, and emergency response capabilities. These include considerations such as the scale of evacuation and resettlement, the number of regional drainage pump stations, and the drainage capacity of emergency response units. The outcomes of the flood risk analysis reveal clear regional patterns of risk levels within the central urban area. Areas with high and moderately high risks are concentrated in the central portions of Fengtai District, the eastern parts of Chaoyang District, and the eastern regions of Haidian District. These patterns are primarily attributed to the elevated hazard levels in the eastern parts of Chaoyang District, central Fengtai District, and eastern Haidian District, as well as the significant exposure in Fengtai and eastern Haidian District.



Flood inundation area under extreme rainfall and open discharge conditions



Spatial distribution map of subway risk levels



Risk level assessment map for Beijing's central urban area

Conclusions

- The combined scenario involves an extremely heavy rainstorm and flood dynamics: the peak of rainfall within the urban area arrives 12 hours ahead of the flood peak at the Shahe Gate on the North Canal. This causes the flood discharged from the Shahe Gate to intersect with the urban area flood.
- Approximately 27% of the central city is submerged, with the western, southwestern, and northeastern sectors of the central area experiencing particularly severe inundation. Additionally, there's a notable risk of backflow impacting 123 subway entrances in this vicinity.
- Accounting for waterlogging concerns in the subway systems, low-lying courtyards, basements, and roads across the central city region, high-risk zones are primarily situated in the eastern part of Chaoyang District. Taking into consideration factors like population density, GDP distribution, and the presence of basic drainage networks, areas of high exposure are prevalent in Fengtai District. Moreover, factoring in the capacity of resettlement sites, the number of regional drainage pumping stations, and the pumping capabilities of emergency response units, the overall vulnerability of the central city area is categorized as high.
- The distribution of risk levels across different regions is notably discernible. Regions with high risk and elevated risk levels are predominantly concentrated in the central areas of Fengtai District, the eastern portions of Chaoyang District, and the eastern parts of Haidian District.