Emergency services and drainage system improvement under urban flooding

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XVIII WORLD WATER CONGRESS

Beijing, China

Sep 14, 2023

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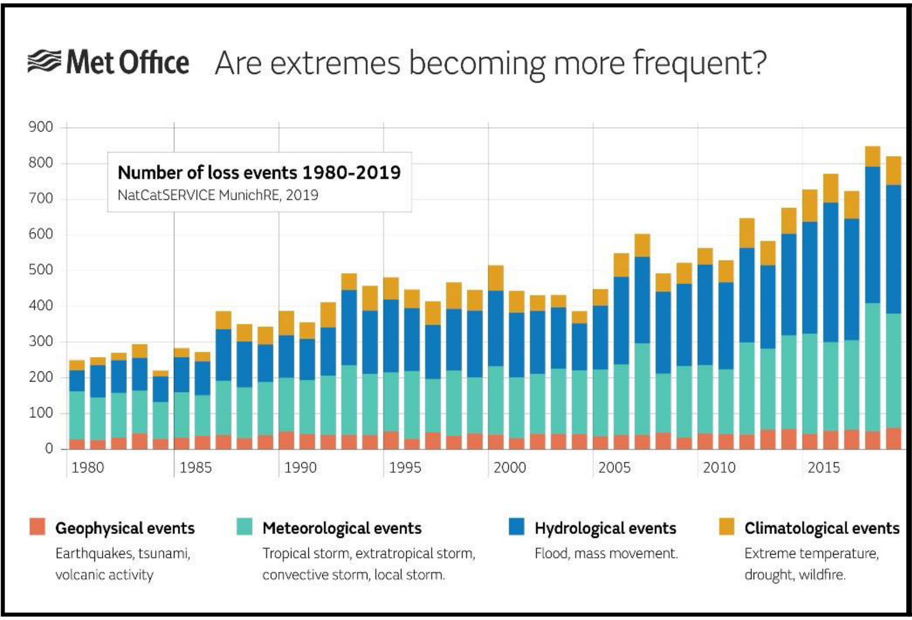
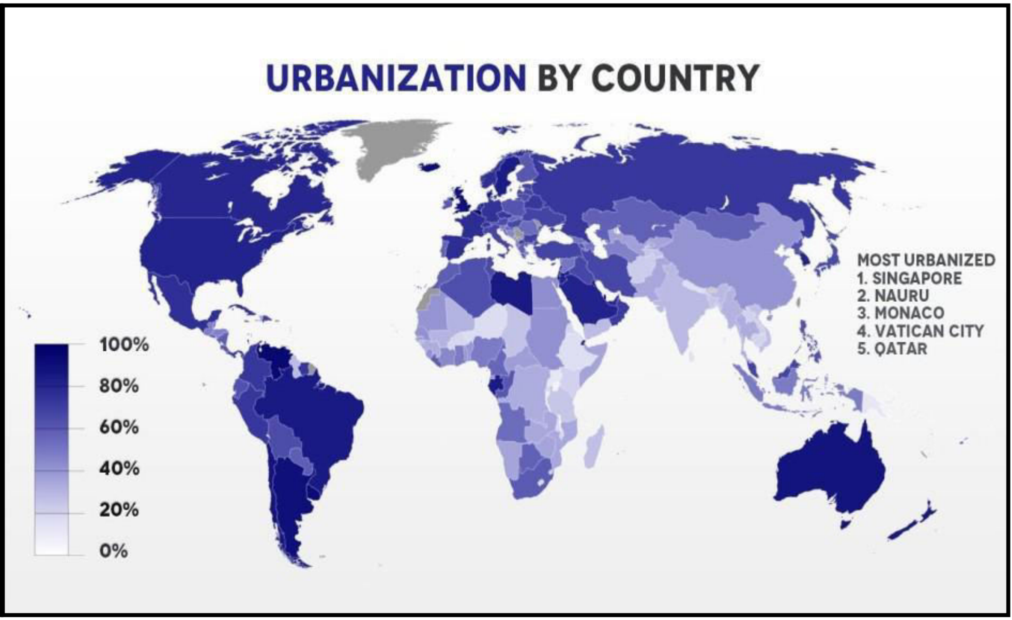
Background

Background



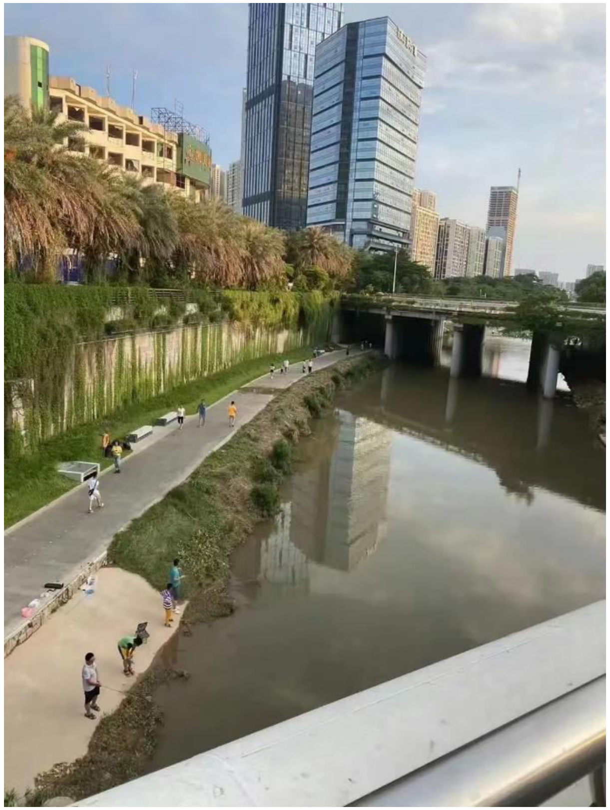


https://www.metoffice.gov.uk/weather/climate/climate-and-extreme-weather

https://en.Wikipedia.org/wiki/urbanization_by_country

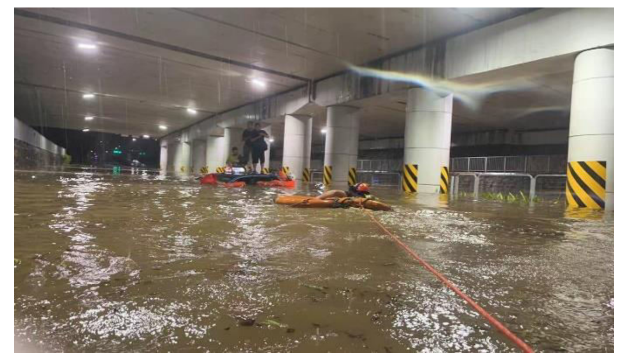
Urban flooding resulting from extreme rainfall events has emerged as a pressing concern necessitating immediate attention, within the context of sustainable urban development, attributable to the effects of climate change

Serious flooding problem in Shenzhen



River view before September 7

River condition on September 7



Citizens trapped on roof of car

The issue of traffic congestion due to flooding has perennially posed a significant issue plaguing the lives of the residents of Shenzhen.

Two critical issues

Emergency response capacity needs strengthening

Drainage system needs improving

The "soft" power of urban emergency response → **Coupling** ← The "hard" power of basic urban drainage system

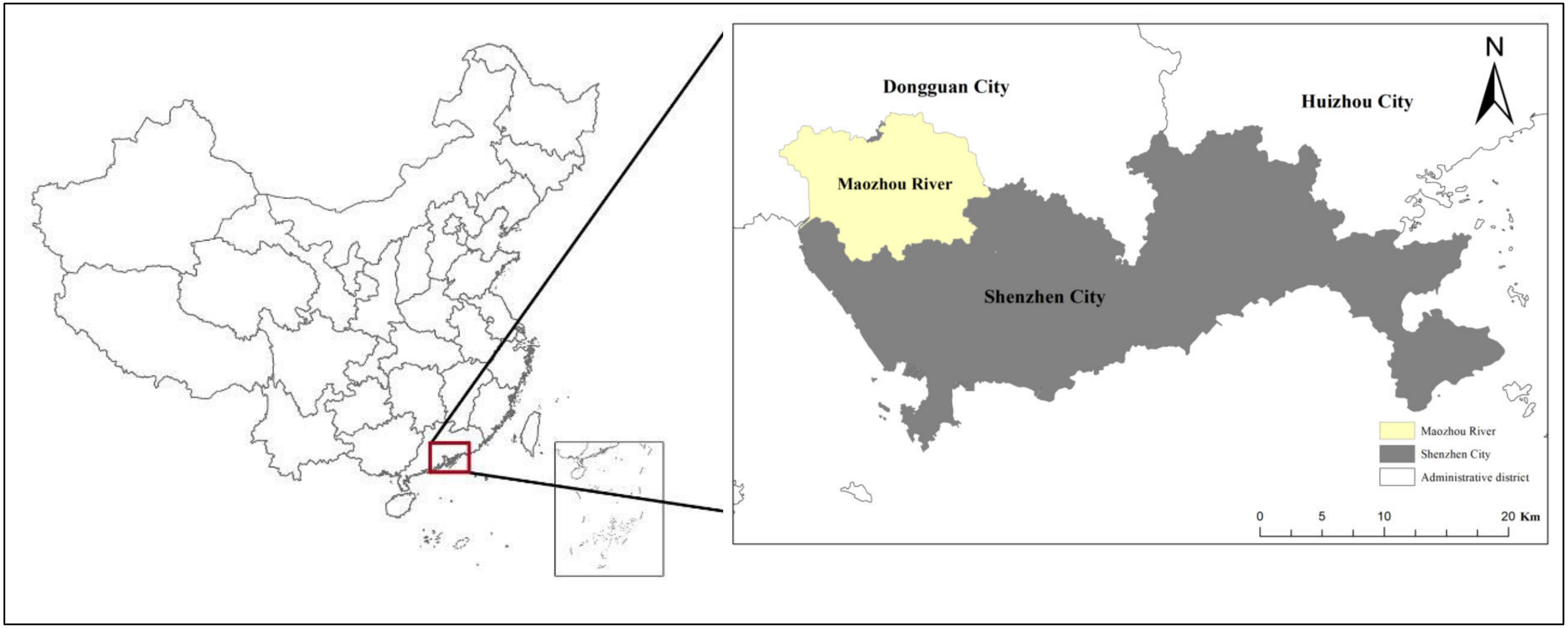
Blending "software" and "Hardware" for advancing urban flood resilience is imperative!

2

Drainage Network Optimization

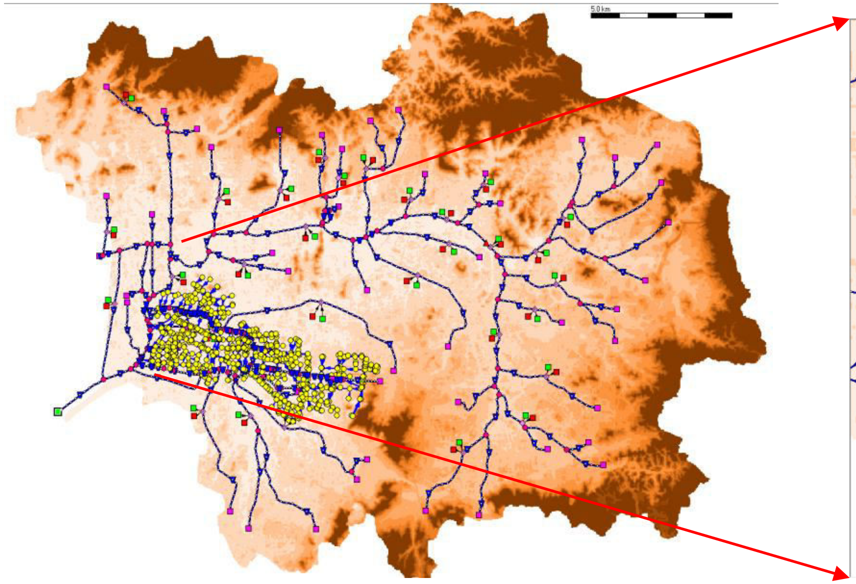
Study area

- **The Maozhou River basin is located in the northwestern region of Shenzhen.**
- **It experiences a notable disparity in both spatial and temporal rainfall distribution, rendering it particularly susceptible to intense summer rainfall and subsequent flooding events.**

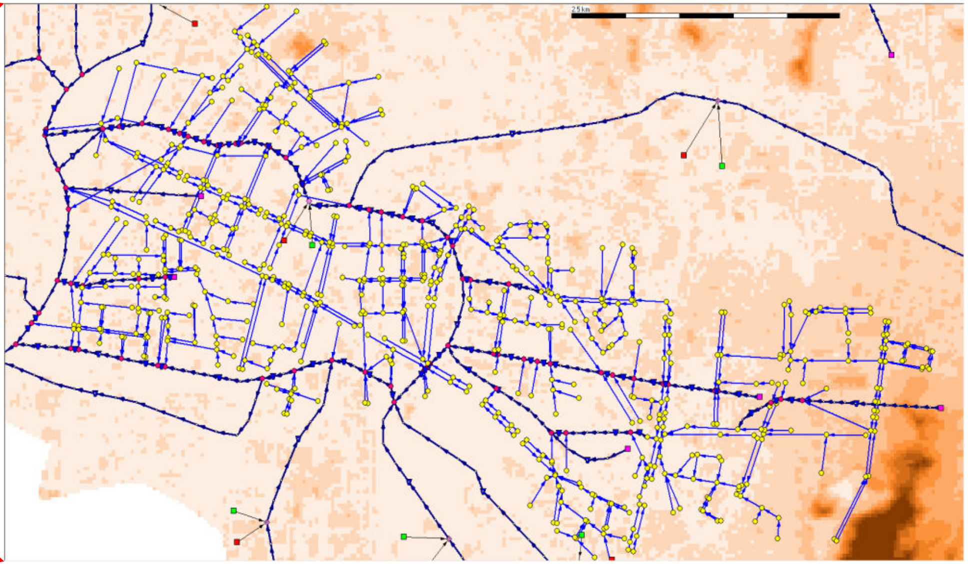


Shajing drainage network model

- The area of the Shajing drainage basin is ~1,590 hectares, exhibiting a notably high building density and coupling with predominantly low-lying topography.
- The rainwater pipe network coverage rate is about 4.24 km/km2. A significant shortfall in drainage capacity is due to the following reasons: extended duration and non-optimal design standard.



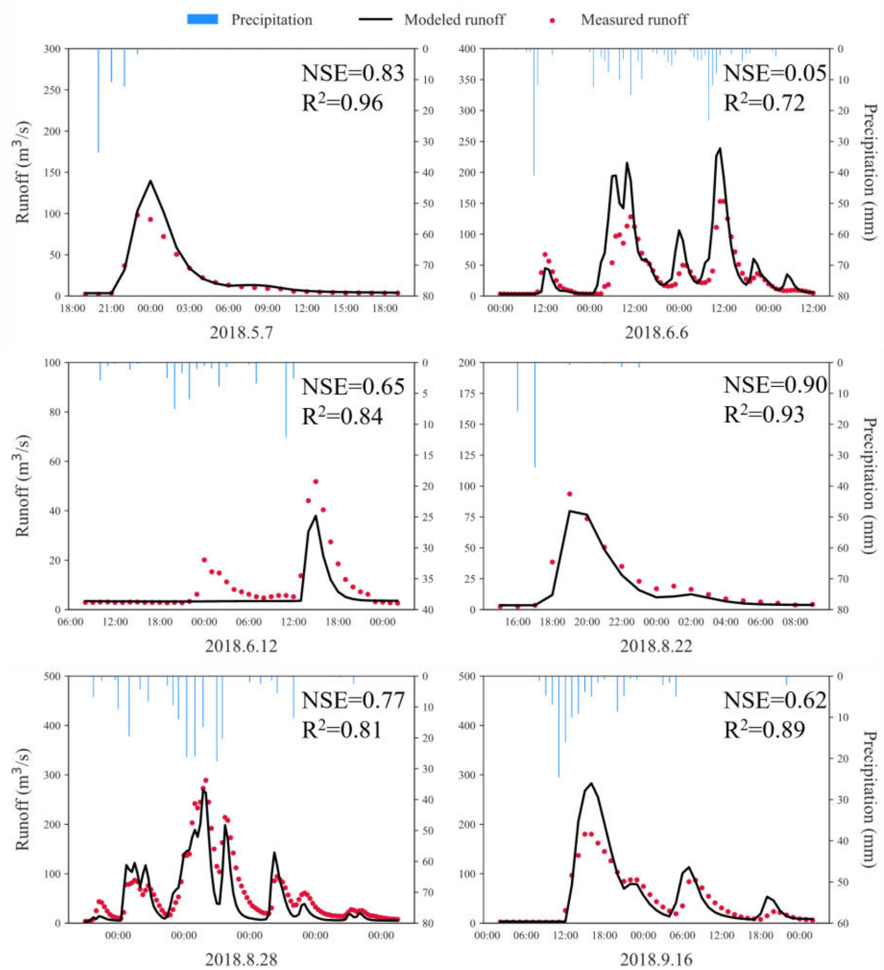
SOBEK hydrological model



Rainfall pipe network in Shajing drainage basin

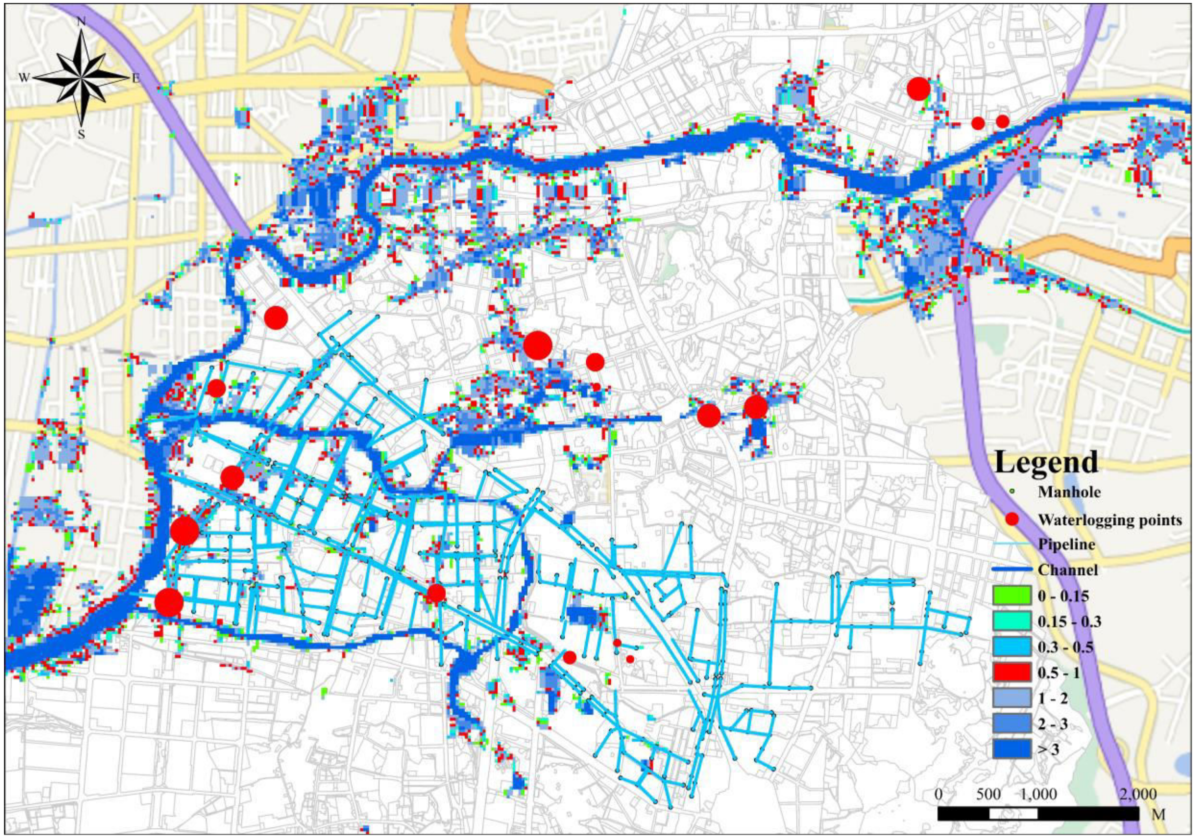
Discharge simulation result

- ◆ **The model exhibits commendable simulated discharge, after calibration using measured discharge data**



Simulation of event on August 28, 2018

- All internal waterlogging points within the Shajing drainage basin are situated within the submerged range predicted by the model.
- The simulated water depth closely matches the measured water depth.

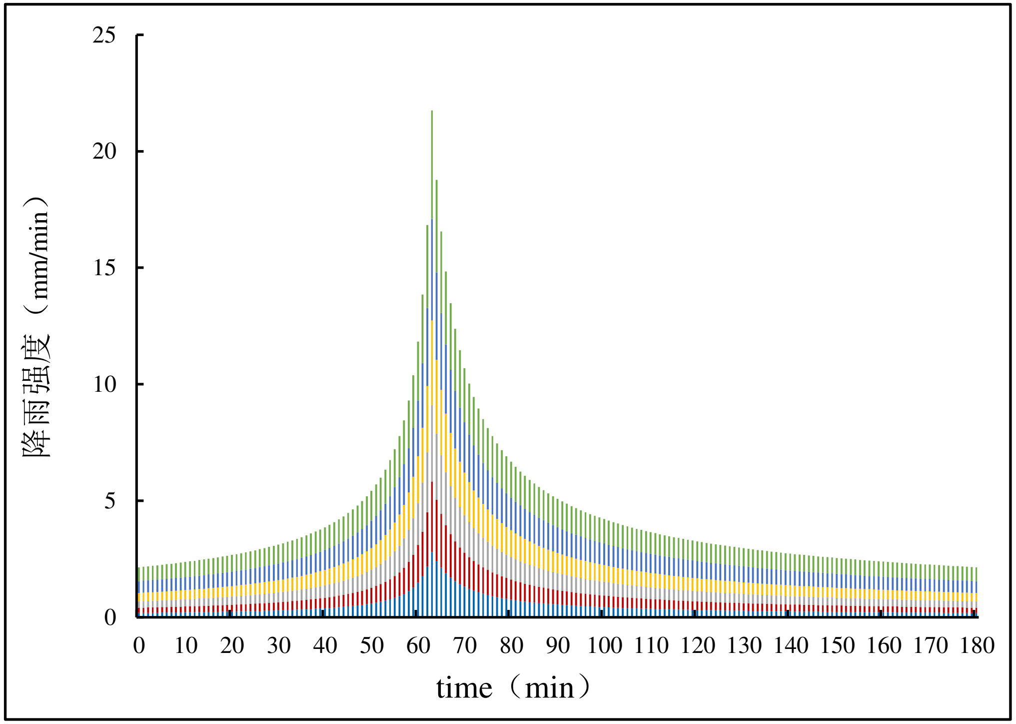


Waterlogging	Measured	Observed
Verification point 1	1.2m	1~2m
Verification point 2	1.4m	1~2m
Verification point 3	0.3m	0.3~0.5m
Verification point 4	0.8m	0.5~1m
Verification point 5	0.4m	0.3~0.5m
Verification point 6	0.6m	0.3~0.5m

Designed rainfall scenarios

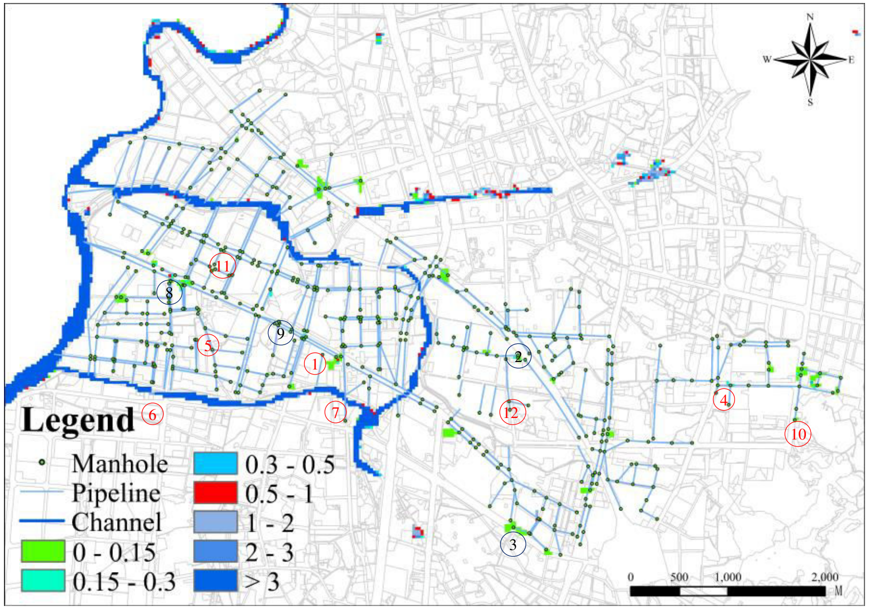
◆ **The duration of the rainfall event was configured to span 3 hours, employing a temporal resolution of 1 minute, and incorporating a rainfall peak location factor of 0.35.**

rainfall return period	unit：mm/min
2	14.768/(t+12.688)0.654
3	14.839/(t+12.544)0.629
5	14.914/(t+12.388)0.602
10	14.004/(t+11.305)0.557
50	13.007/(t+9.068)0.495
100	12.587/(t+8.298)0.47

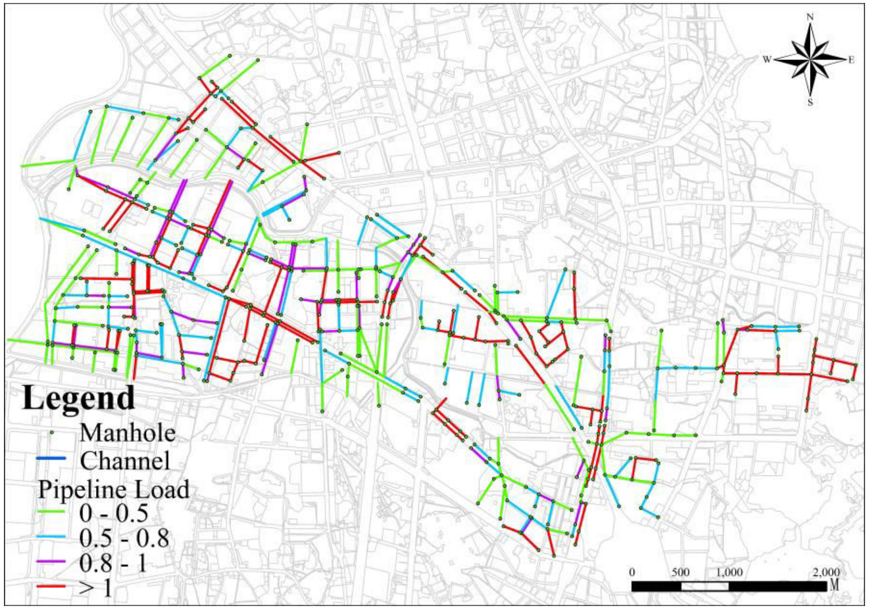


5-year waterlogging simulation

- At waterlogging points designated as No. 1, 4, 5, 6, 7, 10, 11, and 12, the adjacent pipelines are operating at full capacity, leading to overflow of inspection wells.
- Locations No. 2, 3, 6, 8, and 9 exhibit lower elevations, rendering them susceptible to fluctuations in river water levels. This vulnerability results in the backflow of river water into the pipe network, submerging inspection wells and causing outflows.



Waterlogging location



Rainwater pipe network load

Optimization schemes

Pipeline's name	Section Type	Cross section size	Optimize
Pipe_102_Pipe_103	Circle	0.6m	0.8m
Pipe_113_Pipe_114	Circle	0.5m	0.6m
Pipe_115_Pipe_116	Circle	0.6m	0.8m
Pipe_116_Pipe_117	Circle	0.8m	1.0m
Pipe_118_Pipe_120	Circle	0.6m	0.8m
Pipe_121_Pipe_122	Circle	0.8m	1.0m
Pipe_150_134_82	Circle	1.6m	1.8m
Pipe_152_Pipe_150	Circle	1.6m	1.8m
Pipe_153_Pipe_152	Circle	1.5m	1.6m
Pipe_159_Pipe_150	Circle	0.8m	1.0m
Pipe_160_Pipe_152	Circle	1.0m	1.2m
Pipe_162_Pipe_622	Circle	1.6m	1.8m
Pipe_165_Pipe_352	Circle	1.0m	1.2m
Pipe_168_Pipe_171	Circle	1.0m	1.2m
Pipe_473_Pipe_474	Rectangle	Width=1.5m Height=1.7m	Width=2m Height=2m

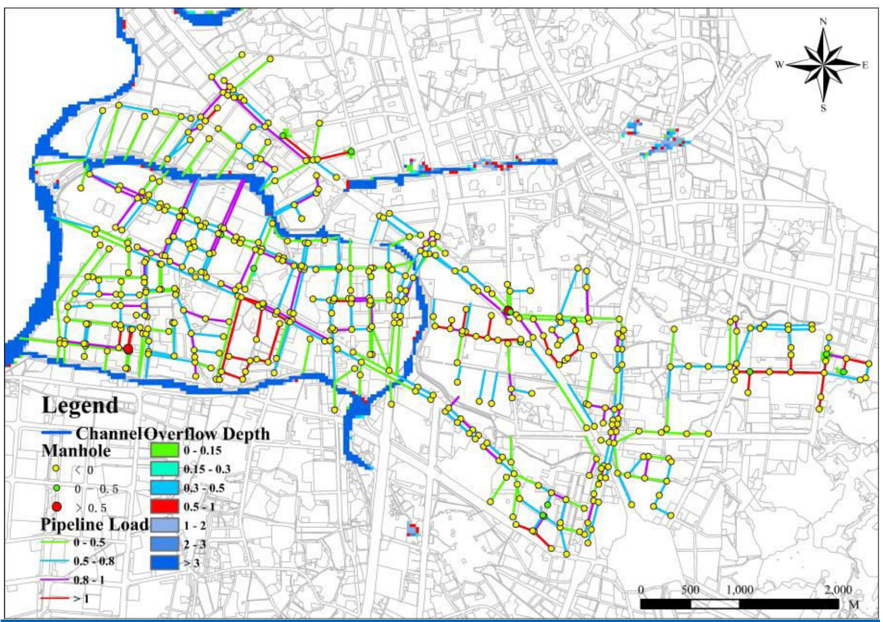
Grey schemes

Area type	Intensive	Gentle slope	Steeper slope
Closed paved with a slope	0.018	0.045	0.054
Stretched, closed paved area	0.072	0.045	0.018
Flat, closed paved area	0	0	0.018
Open paved with a slope	0.072	0.18	0.216
Stretched, open paved area	0.288	0.18	0.072
Flat, open paved area	0	0	0.072
Roof area with a slope	0.04	0.1	0.12
Stretched roof area	0.16	0.1	0.04
Flat roof area	0	0	0.04
Unpaved with a slope	0.07	0.175	0.21
Stretched, unpaved area	0.28	0.175	0.07
Flat, unpaved area	0	0	0.07

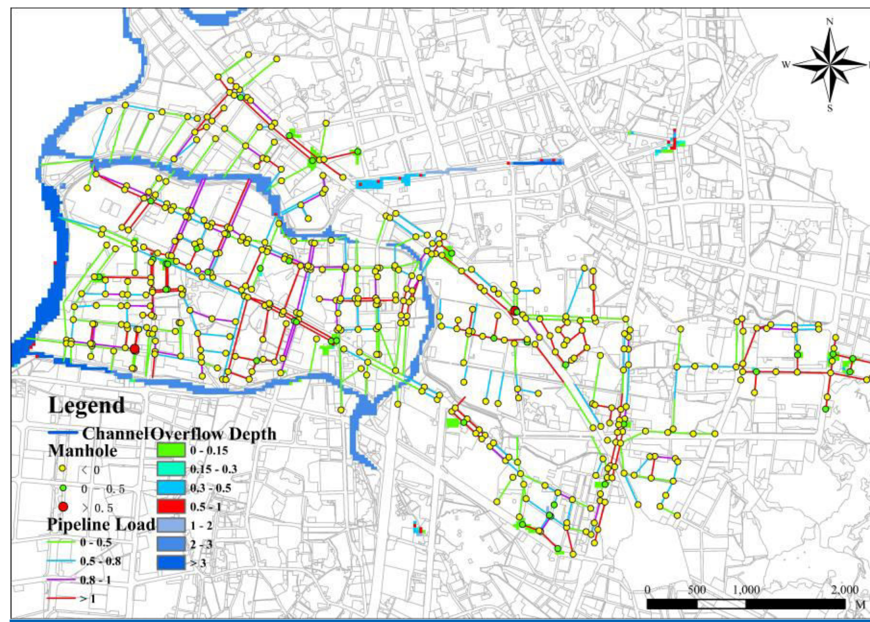
Green schemes

Optimization schemes

- ◆ **Within Scheme #1, the optimization of the drainage system entails the enlargement of select pipe diameters, which necessitates reforming a total of 215 pipes within the existing rainwater pipe network.**
- ◆ **Scheme #2 incorporates the implementation of green roofs and permeable pavements. Specifically, the green roof area constitutes 60% of the overall roof area, while the permeable pavement area encompasses 40% of the total road area.**



Scheme #1



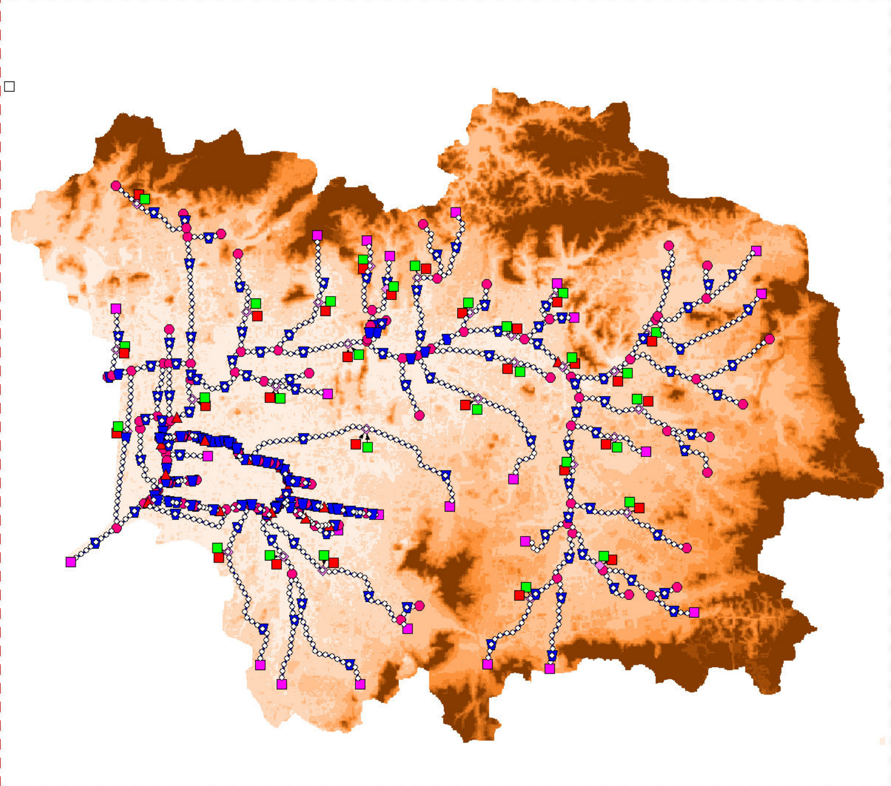
Scheme #2

3

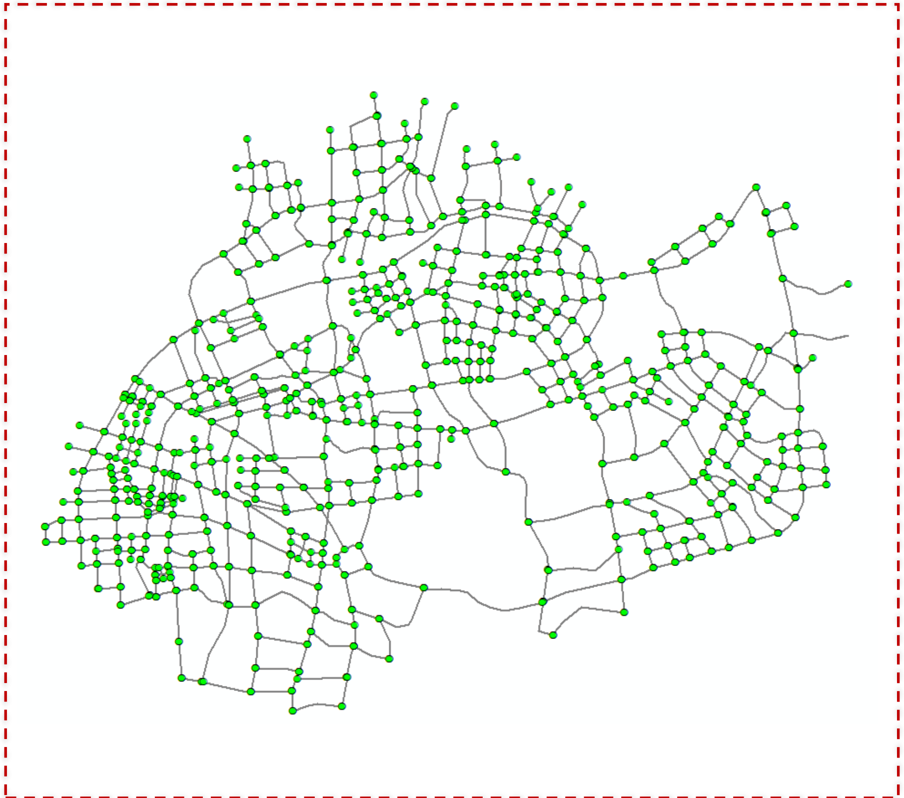
Emergency Services Optimization

Model development

- Developing a coupled one-dimensional and two-dimensional hydrological and hydraulic model
- Establishing the primary transport network in Shenzhen through integration of OpenStreetMap (OSM) data and satellite imagery



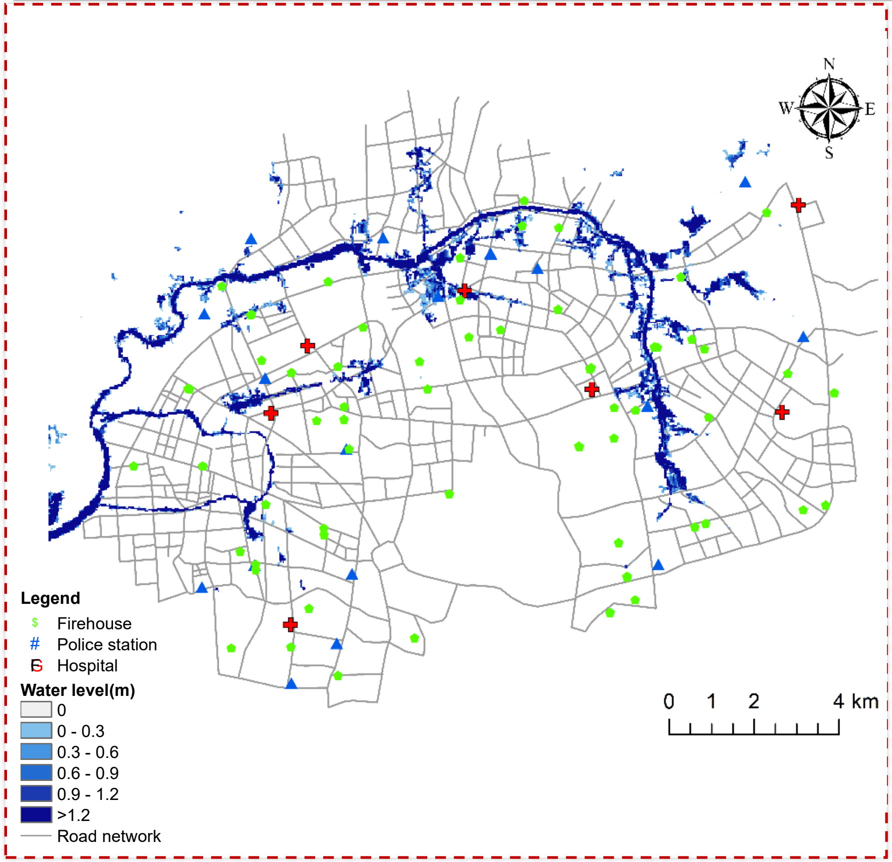
SOBEK model



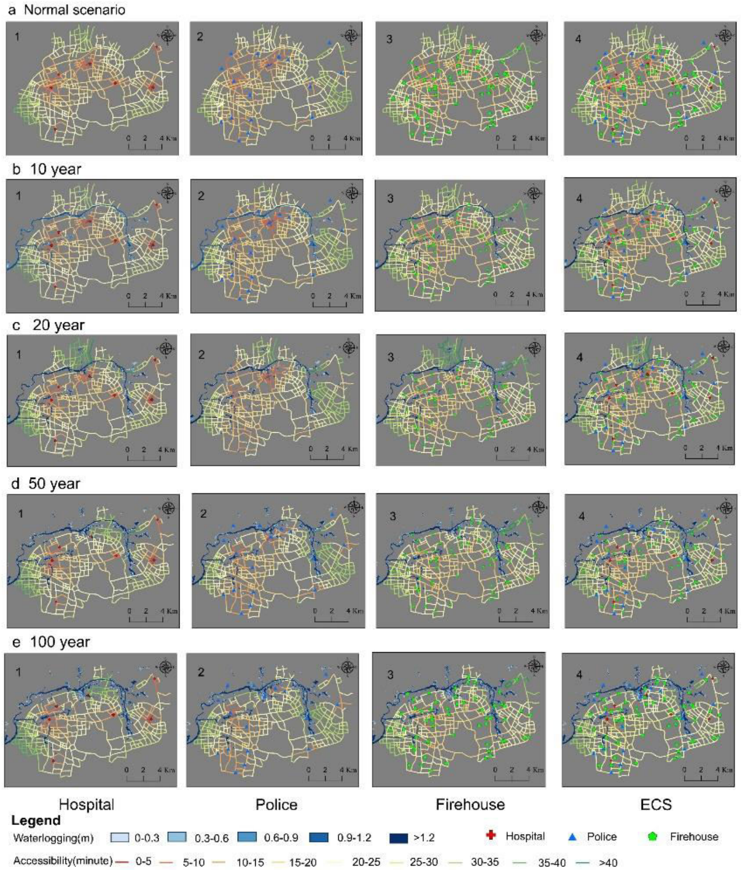
Transport network

Spatial and temporal distribution of emergency accessibility

◆ **Hospitals and police stations have distinct centres of accessibility and firefighting accessibility is more evenly distributed**



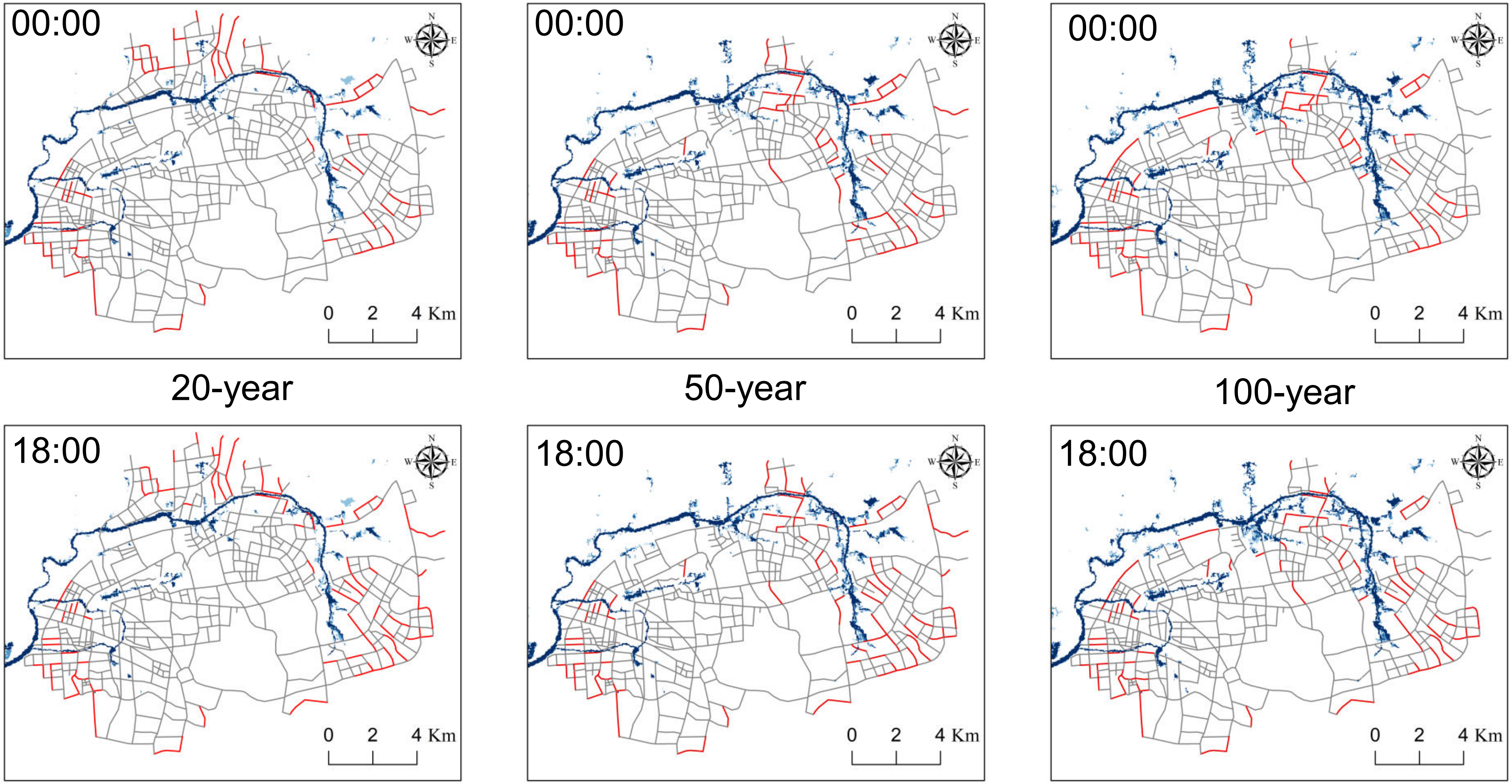
100-year rainfall triggers river flooding



Spatial distribution of emergency accessibility

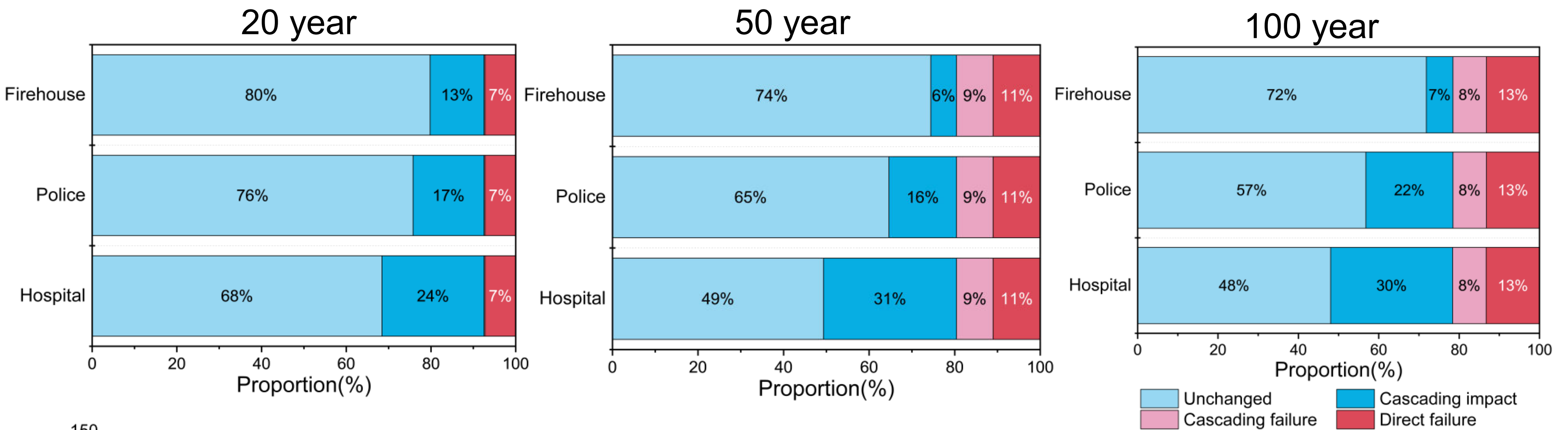
Vulnerable road segments

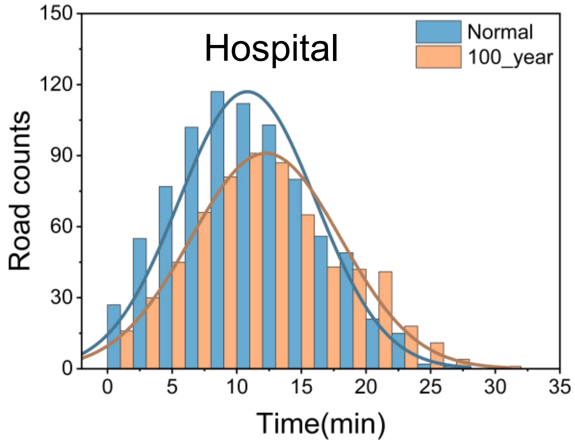
- ◆ **The larger the rainfall return period, the closer the vulnerable segments are to the channel, and the higher the count of vulnerable segments during the evening peak period.**

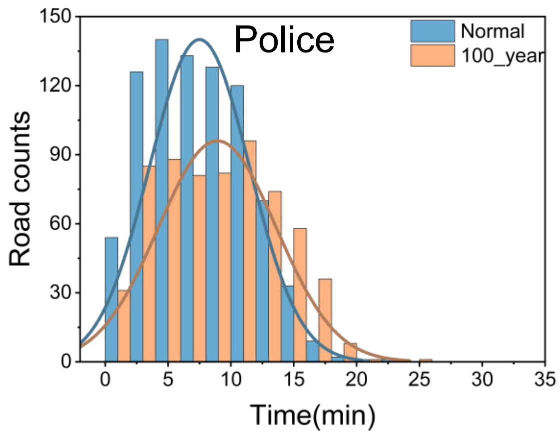


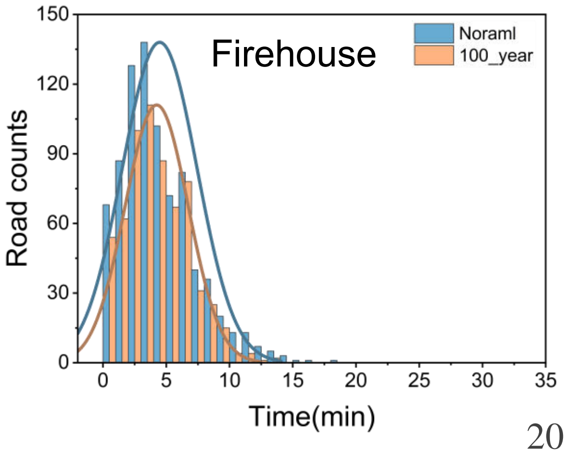
Flood resilience of emergency services

- With the escalation of the rainfall return period, the count of traffic sections with consistent minimum travel times diminishes.
- Firehouse has the highest resilience to river flooding.



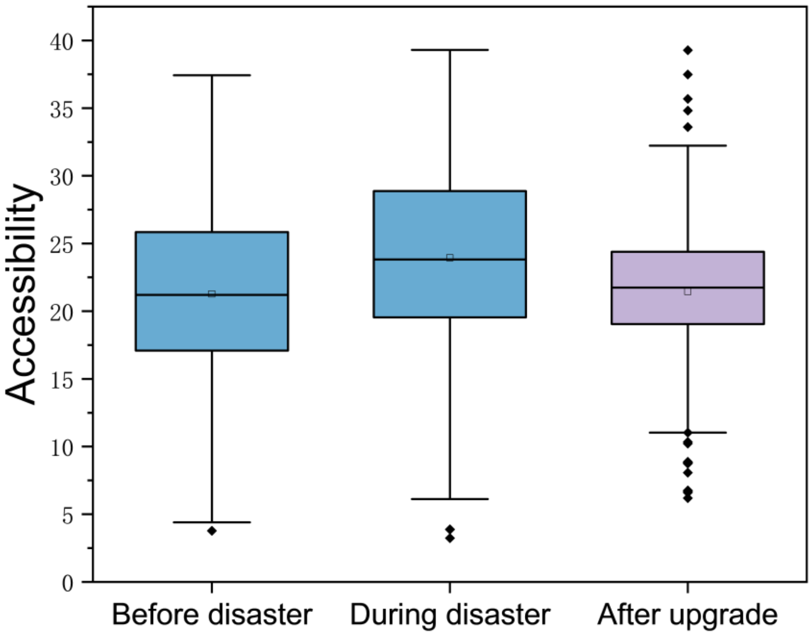




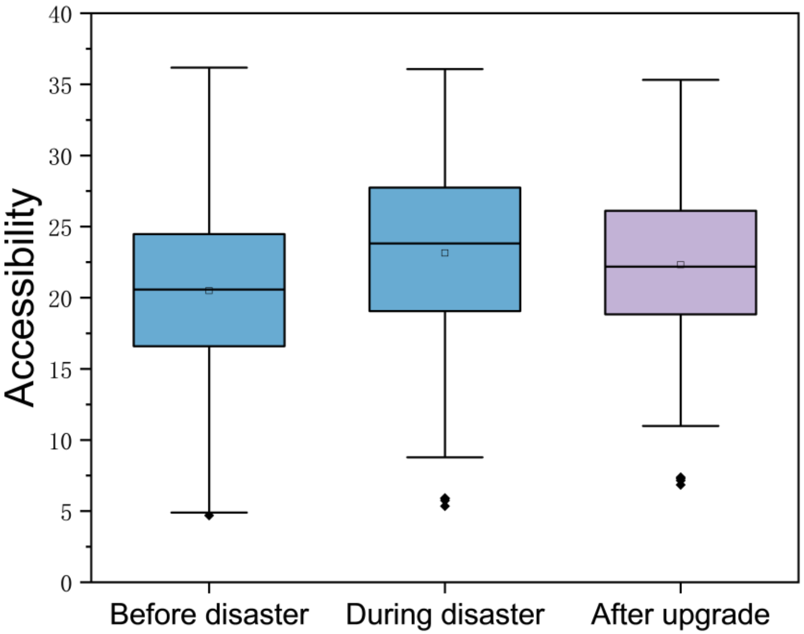


Optimization schemes

- The hospital needs a minimum of 6 temporary supplementary locations.
- The police station needs a minimum of 4 temporary supplementary locations.



Hospital enhancement



Police station enhancement

Conclusion

- **Under the 5-year-return-period scenario, 12 waterlogging points are identified in the study area. Waterlogging points 1, 4, 5, 6, 7, 10, 11, and 12 experience waterlogging primarily due to insufficient drainage capacity within the pipeline network.**
- **To address the challenges, two (grey and green) schemes have been devised: enlarging pipe diameters and implementing Low Impact Development (LID) measures. The grey scheme results in a significant improvement in urban waterlogging prevention and control; the green scheme aims to reduce surface water accumulation by bolstering urban surface infiltration capacity.**
- **In terms of emergency services in the Maui River Basin, the fire service demonstrates good resilience to river flooding events when they occur, and the medical emergency services are the most sensitive to river flooding.**
- **To enhance the level of emergency services in the Study Area, we propose to add at least six temporary hospital emergency points and four police stations to ensure that three types of emergency services can be provided within 15 minutes, even in the face of an 100 year rainfall event.**

Thanks For Your Attention!