

Supporting Materials

Appendix A - Calibration results and model validation outcomes

To calibrate the parameters, rainfall data and initial parameters are inputted into the model, followed by altering each parameter by + 10%, + 20%, -10%, and -20% sequentially. The changes in the objective function are observed to select the parameter setting that optimizes the function's performance. This process of adjusting the parameter by + 10%, + 20%, -10%, and -20% is continued until the objective function reaches its optimum with respect to that parameter. Subsequently, the same method is applied for adjusting the next parameter. The final values of the hydrology and hydraulics parameters determined through calibration are presented in Table A.1, and the final values of the water quality parameters are shown in Table A.2.

Table A.1 Final values of hydrology and hydraulics parameters.

Modules	Symbols	Parameter Name	Initial Value	Final Value
Hydrology	N-imperv	Impervious area Manning's roughness coefficient	0.013	0.015
	N-perv	Pervious area Manning's roughness coefficient	0.42	0.7
	Destore-imperv	Impervious area depression storage	1.5	1
	Destore-perv	Pervious area depression storage	6.5	7.0
	MaxRate	Horton maximum infiltration rate	55	50
	MinRate	Horton minimum infiltration rate	5	7.0
Hydrodynamic	Con-roughness	Pipe Manning's coefficient	0.017	0.022

Table A.2 Final values of water quality parameters.

Pollutant Type	Surface Type	COD			SS		
		Road	Roof	Grass	Road	Roof	Grass
Maximum Accumulation	Initial Value	50	50	50	250	250	250
	Final Value	70	55	44	80	70	40
Accumulation Constant	Initial Value	1.05	1.05	1.05	1.05	1.05	1.05
	Final Value	1.05	1.05	1.05	1.05	1.05	1.05
Erosion Coefficient	Initial Value	0.1	0.1	0.1	0.1	0.1	0.1
	Final Value	0.018	0.013	0.012	0.01	0.008	0.005
Erosion Index	Initial Value	1.25	1.25	1.25	1.25	1.25	1.25
	Final Value	1.35	1.35	1.25	1.32	1.3	1.25

Appendix B – Designation and selection of green infrastructure scenarios

B.1 Selection of typical year

As the study area is situated within Beijing’s urban sub-center, where rainfall variation is minimal, we analyzed annual rainfall data for Beijing spanning nearly 40 years (1978–2018), as illustrated in Fig. B.1. The average rainfall during this period is 547 mm, with a median of 541 mm, closely aligning with the precipitation recorded in the study area in 2013. Consequently, 2013 was selected as the representative year for analysis.

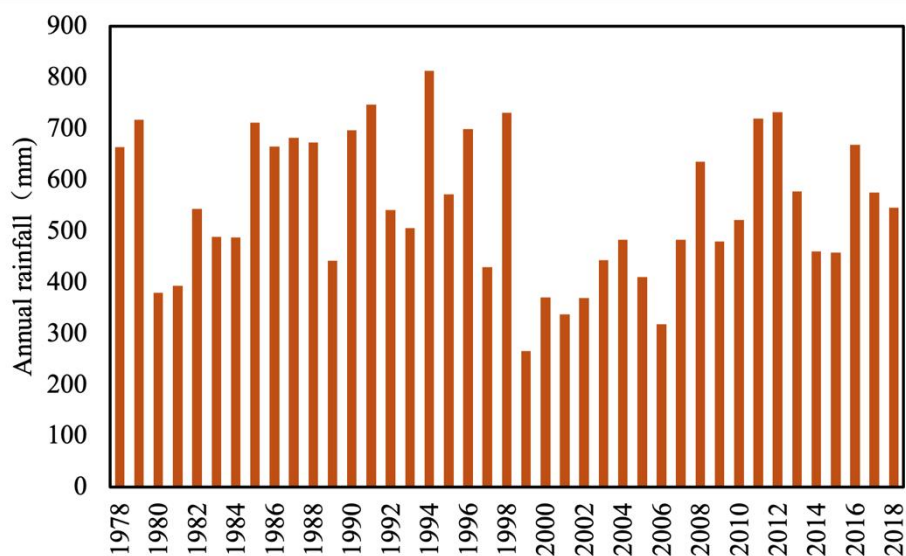


Fig. B.1 Annual rainfall statistics of Beijing from 1978 to 2018.

B.2 Designation and selection of green infrastructure scenarios

Gray infrastructure in the study area primarily comprises reservoirs and levees for flood control, stormwater drainage networks, flood-control pump stations, flood channels, sewage collection pipelines, and various engineering pipelines. Data on these gray infrastructure components were collected from municipal records, encompassing information on their dimensions, capacities, and geographic distribution within the study area.

The administrative zone under investigation boasts a substantial green cover, yet a notable trend has emerged where newly established green spaces are constructed at elevated levels (Tongzhou Water Bureau, 2018). This elevation restricts their capacity to effectively mitigate runoff during rainfall events. Consequently, the scenario planning prioritizes the transformation of green areas within administrative office zones into BRCs. Given the land use distribution within the study area, approximately 30% of the total area comprises green spaces. Assuming an 80% conversion rate from green fields to BRCs, this study estimates that a maximum of 24% of the study area could potentially be transformed into BRCs, thereby enhancing its resilience against stormwater runoff.

To elaborate, the scenarios for deploying BRC in the study area encompass high, medium, and low deployment ratios, corresponding to converting 24%, 16%, and 8% of the total area, respectively. Based on the data from the Tongzhou Water Bureau (2018), which outlines the study region's 16 catchment areas spanning a total of 1516 ha, the specific areas targeted for conversion under each scenario have been calculated. Under the high deployment scenario, 364 ha would be converted, while 244 ha and 121 ha would be converted under the medium and low scenarios, respectively.

WPs are typically designed to incorporate an inlet, a forebay, a sedimentation zone, an embankment, and an outlet. These ponds serve to detain runoff during rainfall events, thereby attenuating peak flows in stormwater conveyance systems and mitigating flood risks. Additionally, the water retained in WPs can be repurposed for irrigation, reuse, and as a source for ecological landscaping, thus enhancing the efficiency of rainwater utilization. Given the substantial area required for a single WP and the constraints posed by limited construction space, the high, medium, and low deployment ratio scenarios for WP have been devised to cover 10%, 6.7%, and 3.3% of the total study area, respectively. This translates to total construction areas of 152 ha, 102 ha, and 50.3 ha. Adhering to the ‘Sponge City Construction Technical Guidelines’ and accounting for additional height for storage capacity, the depth of WP in this study is set at 3 m. Regarding the geographical placement of WP, they should be strategically interconnected with the stormwater drainage system and adjacent water bodies. In this study, WP construction is primarily focused on the terminus of the stormwater network, in proximity to water bodies. This arrangement allows WP to manage runoff during rainy seasons and, during dry periods, draw water from nearby water bodies to replenish pond levels. Based on the above description, the detailed designation scenarios are presented in the Section 2.2.

Employing the SWMM mentioned in the Section 3.1 to simulate the aggregate drainage outflow from the various outlets, the simulation results pertaining to the annual runoff control rate of 15 different scenarios were shown in Table B.1.

Table B.1 Scenario simulation water control results.

Construction Scenarios	Annual Runoff Control Rate (%)	Reach the Standard or not
S1	81.0	NO
S2	80.1	NO
S3	79.4	NO
S4	89.9	YES
S5	88.7	YES
S6	87.3	YES
S7	88.4	YES
S8	86.9	YES
S9	85.2	YES
S10	89.1	YES
S11	87.8	YES
S12	86.3	YES
S13	81.6	NO
S14	82.7	NO
S15	84.0	YES

Appendix C - Pollutant removal efficiency and pollutant concentration

Table C.1 Pollutant removal efficiency of different GI types for various pollutants.

GI Type	Pollutant Removal Efficiency				Data Source
	COD	NH ₃ -N	TN	TP	
WP	78.5%	23.7%	26.4%	51.2%	(Li et al., 2017; Xu, 2020; Zhou et al., 2020)
BRC	59.1%	65.5%	73.9%	72%	(Xu, 2020)

This table presents the removal efficiencies of various pollutants—COD, NH₃-N, TN, and TP—by two types of GI: WP and BRC. The values indicate the percentage of each pollutant removed by each GI type, with higher percentages representing greater removal effectiveness.

Table C.2 Pollutants concentration under different surfaces types.

Surface Type	Pollutant Concentration (mg/L)				Data Source
	COD	NH ₃ -N	TN	TP	
Road	142	4.4	13.7	0.37	(Zhu et al., 2023)
Roof	53	3.1	3.9	0.42	
Grass	25	2.2	2.5	0.42	

This table presents the concentrations of four pollutants—COD, NH₃-N, TN, and TP—measured in milligrams per liter (mg/L) on three types of surfaces: Road, Roof, and Grass.

References

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