Electronic Supplementary Material

The development of roadside green swales in the Chinese Sponge City Program (SCP): Challenges and opportunities

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Table S1 Pollutant removal rates with green swales worldwide

Type	Details with swales	Removal rates with green swales			References
		TSS	TN	TP	
Grass swale	Located in Taiwan, China. The experiment was conducted in an agricultural testing ground.	48%–86%	14%–24%	29%–77%	Yu et al. (2001)
Grass swale	Located in Xikeng Reservoir Basin, Shenzhen, China. A separate swale has also been built on the site.	50%–90%	−10%–35% (NH_3-N)	25%–70%	Zhang et al. (2009)
Grass swale	Located in Beijing, China. The grassy-swale simulation device was 8 m in length and 1.8 m in height.	98%	32%–57%	13%–20%	Yuan et al. (2019)
Wet swale	Located in Hefei, China. The wet swale was constructed in 2010 and was 120 m long and planted with a mix of 90% Typha latifolia linen and 10% Scirpus validus.	70%–85%	54%	52%	Tang et al. (2016)
Grass swale	The site is monitored in the MoPac Expressway at Walnut Creek (Austin, Texas, USA). Centerline length: 1055 m; Width: 15.5–16.2 m; Average side slope: 9.4%; Average centerline slope: 1.7%.	85%	44%	34%	Barrett et al. (1998)
Grass swale	Located in Brisbane, Australia. The swale was 65 m long, with a longitudinal slope of 1.6%, a top width of 4 m and batter slopes of approximately 1:13. The vegetation was a mix of winter rye and couch grass, with an average aerial cover of 67%.	69%	56%	46%	Deletic and Fletcher (2006)
Grass swale	Located on MD Route 32, a four-lane limited access highway near Savage, Maryland, USA. Both swales have identical cross-sections (side slopes of 3:1 (33%) and 4:1 (25%) on either side of the swale), with a 0.61 m bottom width and approximately 1.4% longitudinal slope.	63%	56%	59%	Stagge et al. (2012)
Grass swale	Located in the Piedmont region of North Carolina, USA. Three swales with dimensions of 42.9 m × 1.2 m, 99.5 m × 1.6 m, and 29.3 m × 1.6 m.	77%	65%	60%	Wu and Allan (2018)
Grass swale	Located in the Cul-de-Sac catchment area on the Island of Sint Maarten in the Caribbean. The vegetative swale model surface area was designed as 15% of the contributing impervious drainage area with a depth of 1.3 m (under a five-year return period).	40%	45%	41%	Dutta et al. (2021)

Table S2 Rainwater pipe channel design with rainfall return period (unit: year)

City type & different areas	Central general areas	Central important areas	The underground passageway and sunken plaza	Non-central areas	References
Megacities	3–5	5–10	30–50	2–3	ODDS-2021
Large cities	2–5	5–10	20–30	2–3	ODDS-2021
Medium-small cities	2–3	3–5	10–20	2–3	ODDS-2021

Notes: A megacity refers to a city with a permanent resident population of more than 5 million. A large city refers to a city with a permanent resident population of more than 1 million but less than 5 million. A medium-sized city refers to a city with a permanent resident population of more than 500000 but less than 1 million. A small city refers to a city with a permanent resident population of less than 500000.

Table S3 Guidelines with the purpose of water quality improvement

Guidelines	Purpose of water quality improvement	Connections with SCP	Challenges/Limitations	Citations
Action Plan for Water Pollution Prevention and Control	The quality of the aquatic environment will increase by 2030. The ecological and environmental quality of the nation should be higher by 2050, and the ecosystem should accomplish a virtuous cycle.	The document has a robust and proactive policy that highlights the contribution that banks and other financial institutions can make to advancing green credit. Green finance in sponge cities is closely related to this.	The document outlines some significant objectives but provides few details.	The State Council of the People's Republic of China (2015) (http://www.gov.cn/zhengce/content/2015-04/16/content_9613.htm)
Water Pollution Prevention and Control Plan for Key Watershed (2016–2020)	The Action Plan for Water Pollution Prevention and Control's goals are being implemented with details in this document.	SCP will be supported by making full use of environmental spaces such as rivers, lakes, wetlands, cultivated land, woodlands, and grasslands.	There are currently no quantitative indicators to support the construction of roadside sponge city facilities.	MEE, NDRC and MWR (2017) (http://www.gov.cn/xinwen/2017-10/27/content_5234917.htm)
Code for the planning of urban drainage engineering	Stormwater runoff pollution control should include source reduction, process control, and system treatment.	It is compatible with SCCTG with a variety of techniques during construction, including source reduction, midway transmission, terminal regulation, and storage.	This document does not plan available urban land for SCP.	MHURD (2017) (https://www.mohurd.gov.cn/gongkai/fdzdgknr/tzgg/201703/20170302_231227.html)
Outdoor drainage design standard	The design standard for outdoor drainage quality of urban sewage has been formulated.	The drainage engineering design is based on the planning of the sponge city.	It does not address designing drainage projects with green infrastructure, such as green swales.	MHURD (2021) (https://www.mohurd.gov.cn/gongkai/fdzdgknr/tzgg/202105/20210520_250183.html)
Code for an urban and rural drainage project	In places with significant surface runoff pollution, it is prohibited to build infiltration facilities at the source; instead, the area's rainwater runoff must be gathered and treated separately.	The code, which is founded on the concept of SCP, strives to enhance the aquatic environment, guarantee the security of drainage, and encourage the use of water resources.	A solution for the construction's financial constraints for green infrastructure construction is not mentioned in this document.	MHURD (2022) (https://www.mohurd.gov.cn/gongkai/fdzdgknr/zfhcxjsbwj/202204/20220412_765619.html)
Technical Guide for Monitoring Surface Water Pollution Intensity in Flood Season	To direct nationwide scientific monitoring and analysis of the level of pollution during the flood season and assist in finding solutions to the country's main non-point source pollution issues.	Sponge City facilities play an important role in controlling pollution during flood season.	There are some restrictions and no quantification of the impact of sponge city infrastructures on flood season pollution control.	MEE (2022) (http://www.cnemc.cn/jcdt/202210/P020221028660854084768.pdf)
Ningbo Water Pollution Prevention Action Plan	Control the discharge of water pollutants and promote the prevention of agricultural rural pollution and industrial pollution.	This document proposes to promote the related tasks of water environment governance in key river basins, which has become one of the goals for the effectiveness of SCP.	The lack of information directly relates to the SCP in Ningbo City.	Ningbo Municipal People's Government (2016) (http://sthjj.ningbo.gov.cn/art/2016/11/16/art_1229051402_1440212.html)
Ningbo Sponge City Planning and Design Guidelines	To lessen the effect of the initial rainwater on the ecology of the green space and sponge facilities, the initial rainwater entering the green space needs to be processed or discarded.	This document serves as the guideline for SCP in Ningbo, including typical sponge facilities and their evaluation.	There are no specific requirements for controlling stormwater runoff pollution.	Ningbo Housing and Urban-Rural Development Bureau (2019) (http://zjw.ningbo.gov.cn/art/2019/5/27/art_1229325543_1524967.html)
Five-year Action Plan for Sewage Treatment in Ningbo Central City (2019–2023)	By 2023, the municipal rainwater and sewage confluence pipes will be separated and the mixed drainage pipes on roads will be eliminated.	The road renovation mentioned in the document is an opportunity for SCP, but it has not been closely associated with the SCP.	There are currently no quantitative indicators to support the construction of roadside sponge city facilities.	Ningbo Municipal Water Resources Bureau (2019) (http://slj.ningbo.gov.cn/art/2019/8/9/art_1229051278_36863.html)

Notes: The Ministry of Ecology and Environment of the People's Republic of China (MEE), the National Development and Reform Commission of the People's Republic of China (NDRC), the Ministry of Water Resources of the People's Republic of China (MWR) and the Ministry of Housing and Urban-Rural Development of the People's Republic of China (MHURD).

Table S4 Estimated prices of different Low Impact Development (LID) facilities in Beijing, China (2014)

Type of facilities	Construction cost (yuan/m^2)	Maintenance cost (percentage of construction cost/%)
Permeable pavement	60–200	1
Green roof	100–300	6
Sunken green space	40–50	/
Bioretention	150–800	6
Wet pond	400–600	4
Rainwater wetland	500–700	4
Reservoir	800–1200	/
Regulating pond	200–400	/
Grass swale	30–200	6
Artificial soil infiltration	800–1200	/

Note: Construction costs of each LID facility were indicative values that may differ in different areas (source: SCCTG and Li et al. (2021)).

References

Barrett M E, Walsh P M, Malina J F, Charbeneau R J (1998). Performance of vegetative controls for treating highway runoff. Journal of Environmental Engineering, 124(11): 1121-1128

Dutta A, Torres A S, Vojinovic Z (2021). Evaluation of pollutant removal efficiency by small-scale nature-based solutions focusing on bio-retention cells, vegetative swale and porous pavement. Water, 13(17): 2361

Deletic A, Fletcher T D (2006). Performance of grass filters used for stormwater treatment: A field and modelling study. Journal of Hydrology, 317(3-4): 261-275

Li F Z, Chen J Q, Engel B A, Liu Y Z, Wang S Z, Sun H (2021). Assessing the effectiveness and cost efficiency of green infrastructure practices on surface runoff reduction at an urban watershed in China. Water, 13(1): 24

Stagge J H, Davis A P, Jamil E, Kim H (2012). Performance of grass swales for improving water quality from highway runoff. Water Research, 46(20): 6731-6742

Tang N Y, Li T, Ge J (2016). Assessing the ability of a wet swale to manage road runoff: A case study in Hefei, China. Journal of Central South University, 23(6): 1353-1362

Wu J S, Allan C (2018). Vegetated swales for managing stormwater runoff from secondary roads. Journal of Environmental Engineering, 144(10): 04018097

Yuan D H, He J W, Li C W, Guo X J, Xiong Y, Yan C L (2019). Insights into the pollutant-removal performance and DOM characteristics of stormwater runoff during grassy-swales treatment. Environmental Technology, 40(4): 441-450

Yu S L, Kuo J T, Fassman E A, Pan H (2001). Field test of grassed-swale performance in removing runoff pollution. Journal of Water Resources Planning and Management, 127(3): 168-171

Zhang R, Zhou W B, Field R, Tafuri A, Yu S L, Jin K L (2009). Field test of best management practice pollutant removal efficiencies in Shenzhen, China. Frontiers of Environmental Science & Engineering in China, 3: 354-363