Received: 30 October 2022 | Revised: 3 December 2022 | Accepted: 20 January 2023

DOI: 10.1002/rvr2.33

RESEARCH ARTICLE

River IWHR WILEY

Developing a "Sponge Catchment Management Plan (SCMP)" framework at the catchment scale: The case of Guiyang, SW China

Yunfei Qi[1,2] | Faith Ka Shun Chan[1,3,4] | Meili Feng[1] | James Griffiths[5] | Michael Hutchins[6] | Emily O'Donnell[7] | Colin Thorne[7] | Lingyun Liu[2] | Chunguang Zhang[2] | Xinan Li[2]

[1]School of Geographical Sciences, University of Nottingham Ningbo China, Ningbo, China

[2]Guizhou Water & Power Survey—Design Institute Co., Ltd, Guiyang, China

[3]School of Geography, University of Leeds, Leeds, UK

[4]Water@Leeds Research Institute, University of Leeds, Leeds, UK

[5]National Institute of Water & Atmospheric Research (NIWA), Christchurch, New Zealand

[6]UK Centre for Ecology and Hydrology, Oxford, UK

[7]School of Geography, University of Nottingham, Nottingham, UK

Correspondence

Yunfei Qi, Faith Ka Shun Chan and Meili Feng, School of Geographical Sciences, University of Nottingham Ningbo China, Ningbo 315100, China.
Email: yunfei.qi@nottingham.edu.cn; faith.chan@nottingham.edu.cn and meili.feng@nottingham.edu.cn

James Griffiths, National Institute of Water & Atmospheric Research (NIWA), Christchurch 8602, New Zealand.
Email: James.Griffiths@niwa.co.nz

Michael Hutchins, UK Centre for Ecology and Hydrology, Maclean Bldg, Benson Ln, Crowmarsh Gifford, Wallingford, Oxford OX10 8BB, UK.
Email: mihu@ceh.ac.uk

Emily O'Donnell and Colin Thorne, School of Geography, University of Nottingham, Nottingham NG7 2RD, UK.
Email: emily.o'donnell@nottingham.ac.uk and Colin.Thorne@nottingham.ac.uk

Funding information

National Natural Science Foundation of China (NSFC), Grant/Award Number: 41850410497; National Key R&D Program of China, Grant/Award Number: 2019YFC1510400; National Natural Science Foundation of China (NSFC) Youth Project, Grant/Award Number: 51909126; University of Nottingham (UNUK) Project, Grant/Award Number: E01200500006; Institute of Asia Pacific Studies Research Funded for the Environmental Security and Sustainability; Cultural and Creative Industries Research Priority Areas; Faculty of Science and Engineering (FTSE) Postgraduate Research

Abstract

Catchment floods are more challenging due to intensive urbanization and climate change. Enlightened by the Low Impact Development (LID), China initiated the Sponge City Program (SCP) to transform Urban Flood Management (UFM) to be more environmentally friendly in 2013. The China National Government (CNG) has subsidized municipal SCP facilities to enhance urban flood resilience while delivering multiple co-benefits for urban ecosystems and social well-being. Recent floods at Schleiden (Germany), Arizona State (USA), and Zhengzhou (China) in 2021 reflected the necessity of Catchment Flood Management (CFM) to cover the whole catchment scale. The SCP, designed to handle small-scale urban pluvial floods, has brought concerns when facing larger-scale fluvial floods after the Zhengzhou 2021 flood. Indeed, catchment-scale Natural Flood Management (NFM) can manage fluvial floods while improving flood adaptations sustainably from upstream to downstream reaches. This research develops a new framework named the Sponge Catchment Management Plan (SCMP), including structural and Nonstructural elements. On the structural side, the SCMP framework integrates NFM with the SCP and Grey Engineering (GE) for reducing the fluvial flood discharge peaks in the whole-catchment scale. On the nonstructural side, the SCMP encourages collaborative governance, revising technical standards, and improving "bottom-up" participation. This research used Semi-Structured Interviews (SSIs) and a Focus Group Approach (FGA) to explore 62 professional and Non-professional stakeholders' perspectives on the SCMP framework. Some professional respondents did not know much about the NFM and were worried about the effectiveness of this practice. But most interviewees supported the SCMP pilot work and shared the co-benefits from the NFM. This case study at the SW China, Guiyang, could be a lesson to encourage other Chinese cities further implement SCP to improve catchment-scale flood resilience.

Scholarship of University of Nottingham Ningbo China; Guizhou Science and Technology Planning of Project, Grant/Award Number: 20192879

KEYWORDS

Catchment Flood Management (CFM), Catchment Flood Management Plans (CFMPs), Guiyang, Natural Flood Management (NFM), Sponge Catchment Management Plan (SCMP), Sponge City Program (SCP)

1 | INTRODUCTION

1.1 | Uphill challenges of Sponge City Program (SCP) in China

Flooding is one of the most destructive disasters with devastating consequences globally. Flood is a natural process that human beings cannot entirely control but only mitigate (Qi et al., 2020). Flood events can be classified as pluvial, fluvial, groundwater, coastal, and a combination of these processes (Chan et al., 2013a). This research focused on fluvial floods in holistic catchments when a runoff volume caused by intensive rainfall exceeds the catchment-containing capacity. Unfortunately, most of the floodplains' settlements consist of villages, cities, and other urban contexts for industrial and commercial developments (Chan et al., 2013b). It is unrealistic for people to keep all social-economic activities out of flood-prone areas (Antonarakis & Milan, 2020). The development of flood-prone regions increases flood risks to riverside residents, properties, industries, agriculture, and infrastructures (Dadson et al., 2017).

Historically, people widely used human-induced interventions in catchments to partially reduce fluvial flood hazards (Ferguson & Fenner, 2020). By the end of 2019, constructed reservoirs in China reached 98,112, providing a total water storage capacity of 898.3 billion m^3. The river dykes at Grade V or above were 320,000 km in total length, protecting 640 million people and 42 million hectares of farmland nationwide. There were 18,449 drainage water sluices, 8293 flood diversion sluices, 5172 tidal barrages, 57,831 water controlling gates, and 13,830 water diversion intakes for flood management (Ministry of Water Resources of the People's Republic of China, 2019).

Since the early 2000s, China has attempted to integrate ecosystem services into engineered-leading flood management. In 2013, China initiated the Sponge City Program (SCP) in pilot cities, such as Beijing, Shenzhen, Zhengzhou, Wuhan, Ningbo, and Guiyang. This initiative was a signal to promote Low Impact Development (LID) (Li et al., 2019). The SCP was developed to effectively solve the wide-ranging urban flood issues (Li et al., 2017). According to the SCP Guidelines published in 2014, the SCP is designed to enhance the defense ability of urban surface floods up to 1-in-30 years rain-return period (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2014). That said, the SCP practices are only equipped to mitigate the urban flood risks at the site-specific level (or waterlogging issues as they are called in China) (Jia et al., 2017). While recent flood events in many Sponge Cities raised concern about the future development of the SCP, particularly in managing extreme rainstorms (Qi et al., 2021a). One of the devastating examples is the Zhengzhou flood event that happened on July 20, 2021. According to the "*7.20 Investigational Report of Intensive Raining Hazards for Zhengzhou, Henan Province*", the maximum daily rainfall at Zhengzhou National Meteorological Station was 624.1 mm, close to the average annual rainfall of Zhengzhou (640.8 mm). This was 3.4 times the maximum since the station's establishment (189.4 mm, July 20, 1978), reaching about 1-in-1000 years rain-return period. From 8 a.m. 17th to 8 a.m. July 23, 2021, coverage of 2068 km^2 of Zhengzhou and its nearby catchments accumulated rainfall of over 600 mm. As a result, this flood hazard caused over 380 casualties and 40.9 billion RMB in economic losses (Council, 2022). Zhengzhou, as a sponge city, was seriously inundated by floods that came from the upstream catchment. These flood events have severely alarmed the China National Government (CNG) and local governments to rethink current urban flood management strategies in Zhengzhou and other sponge cities that are over-relying on the SCP but lack consideration of a holistic Catchment Flood Management (CFM). It is necessary and urgent to link the SCP with CFM to improve the flood resilience of whole catchments (Cornwall, 2021).

1.2 | Coproduction with the concept of CFMPs and NFM

The European Commission adopted the EU Water Framework Directive (WFD) in 2000, which required member states to improve water management at the catchment scale (European Commission, 2020a). In response to the severe flood events in 2002, the European Commission took the initiative to launch the EU Floods Directive (FD) to help member states reduce flood impacts at the catchment level (European Commission, 2021). Both directives required all member states to meet assessment requirements before 2015 (European Commission, 2020b).

The UK Government pushed this forward with Catchment Flood Management Plans (CFMPs) and Natural Flood Management (NFM). In 2009, the UK Environment Agency (EA) published the CFMPs for 10 major river basins, such as the Anglian River, Dee River, Humber River, and Thames Basins (Environment Agency, 2009a). In the early 2010s, the United Kingdom promoted Natural Flood Management (NFM) as an ecological subset of CFMPs (Bark et al., 2021). The plans encourage cost-effective, environmentally friendly, and sustainable flood management practices under Britain's Flood and Water Management Act (The UK Parliament, 2010). The CFMPs can undertake several types of floods, including pluvial, fluvial, and groundwater floods (Environment Agency, 2012), to increase the protection level from 1-in-30 to 1-in-100 years (Environment Agency, 2009b). The Department for Environment, Food, and Rural Affairs (Defra) and the National Assembly for Wales established the CFMPs in the early 2000s in the United Kingdom (Falconer & Harpin, 2005). NFM applies low-impact hydrological and environmental measures to restore the natural water processes at the upper and middle parts of catchments to reduce flood risk (Holstead et al., 2017), while providing multiple co-benefits to biodiversity, environmental quality, agricultural production, and public health (Iacob et al., 2017). CFMPs have improved policymakers' and stakeholders' understanding of the scale and context of floods before implementing flooding policies within the catchments. NFM has supplemented sustainable solutions to the CFMPs.

There were many successful pilot practices (Ferguson & Fenner, 2020). For instance, the Environment Agency in the United Kingdom published the Working With Natural Processes-Evidence Directory and implemented many pilot NFM projects to set out the evidence of NFM in the last decades (Environment Agency, 2021). These valuable lessons offer global lessons to cities.

1.3 | The Sponge Catchment Management Plan (SCMP) integrating NFM + GE + SCP in the Nanming River Catchment

Guiyang is the capital city of Guizhou province in Southwestern China. The Nanming River runs through Guiyang, which caused significant flooding damage to the catchment in history (Qi et al., 2021a). The constructed Grey Engineering (GE) have improved the flood control ability in the Nanming River. However, reservoirs, floodwalls, and flood channels require extensive construction and operational investment (Qi et al., 2021b). For example, the total investment can be over 1 billion RMB for a 10 million m^3 water storage capacity reservoir in Guiyang. In addition, they negatively impact the nearby landscape and water ecosystem (Qi et al., 2021b).

Although the Guiyang Municipal Government implemented SCP facilities, such as green buildings and sunken gardens, to partly absorb initial rainfall, they can only reduce urban surface water flood risks in the community-scale areas. As a result, the SCP risks becoming a showcase unless it is better connected with broader CFM. Only using GE or SCP is unsuitable for mitigating catchment flood risk in the Nanming River Catchment. (More details of GE and SCP in Guiyang can be found in published papers from the authors (Qi et al., 2021a, 2021b).

Instead, local policymakers need to reconsider the relationship between Guiyang City and the nearby catchment to minimize casualties and damages from catchment flood events. The flood policy needs to be transformed into a larger-scale, more sustainable, and cost-effective CFM (Qi et al., 2021a). The transformed CFM needs to integrate flood management in the upstream, middle stream, and downstream catchments, including urban and rural areas. Most importantly, it should effectively reduce the catchment flood discharge peaks that threaten the downstream people and properties. In addition, it should provide more co-benefits to the residents in the catchment.

This research innovatively proposes the Sponge Catchment Management Plan (SCMP) in an umbrella framework to illustrate the transformational route (Figure 1). The SCMP framework includes horizontal and vertical aspects. In the horizontal part, the SCMP has structural to Nonstructural elements to achieve its objectives. The structural elements (the left side in Figure 1) vertically include NFM, GE, and SCP to mitigate the catchment flood risk. The framework does not follow traditional frameworks that arrange these structural elements following the fluvial flow from upper to middle and lower catchments. The SCMP highlights respecting nature and encouraging the implementation of NFM both in urban and rural areas. In the SCMP framework, NFM is the core part as a natural supplement to GE and SCP. The SCMP also encourages further development of sponge principles in small towns and villages rather than only investing the SCP in large cities and urban communities. In addition, the SCMP does not abandon GE due to its high cost and side effects and continually supports more targeted GE where it is suitable.

Working with the SCMP, the NFM measures can be classified into three primary ways to coproduce the catchment flood mitigation: 1) using hillslope woodland, riverside woodland, wooden barriers, and leaky wooden dams to slow water movement through the landscapes; 2) leaving blue-green spaces via ponds, wetlands, and floodplains to increase water attenuation; 3) conserving natural soil and vegetation to reduce flooding by increasing soil-water infiltration (Environment Agency, 2021). NFM plays a general role (larger than site-specific) in naturally mitigating catchment flood risk up to 1-in-100 years rain-return period. For example, woodland creation can slow water movement significantly depending on the size of the flood and the distribution and amount of planting. The modeling has shown that planting a small catchment (~10 km^2) can reduce flood peaks by an average of 50% and 36% for small and large floods. Combined with leaky wooden dams, the targeted planting along watercourses is predicted to reduce flood peaks by 8%–10% in a approximately 100 km^2 catchment (Parliament, 2011).

Meanwhile, GE, such as reservoirs and flood tunnels, still plays a crucial role in managing rare flood events over 1-in-100 years of rain-return period in the middle and lower reaches. For example, the reservoirs on Nanming River can reduce 70% of mainstream flood peak at 1-in-100 years rain-return period (i.e., the flood standard of Guiyang City). In the SCMP framework, the developing SCP can cope with site-specific flood issues in urban and village catchments. For instance, green roofs and sunken gardens can store the initial rainfall by prolonging the formational process of urban and village surface floods under 1-in-30 years rain-return period.

The nonstructural elements (the right side in Figure 1) vertically include collaborative governance, compatible

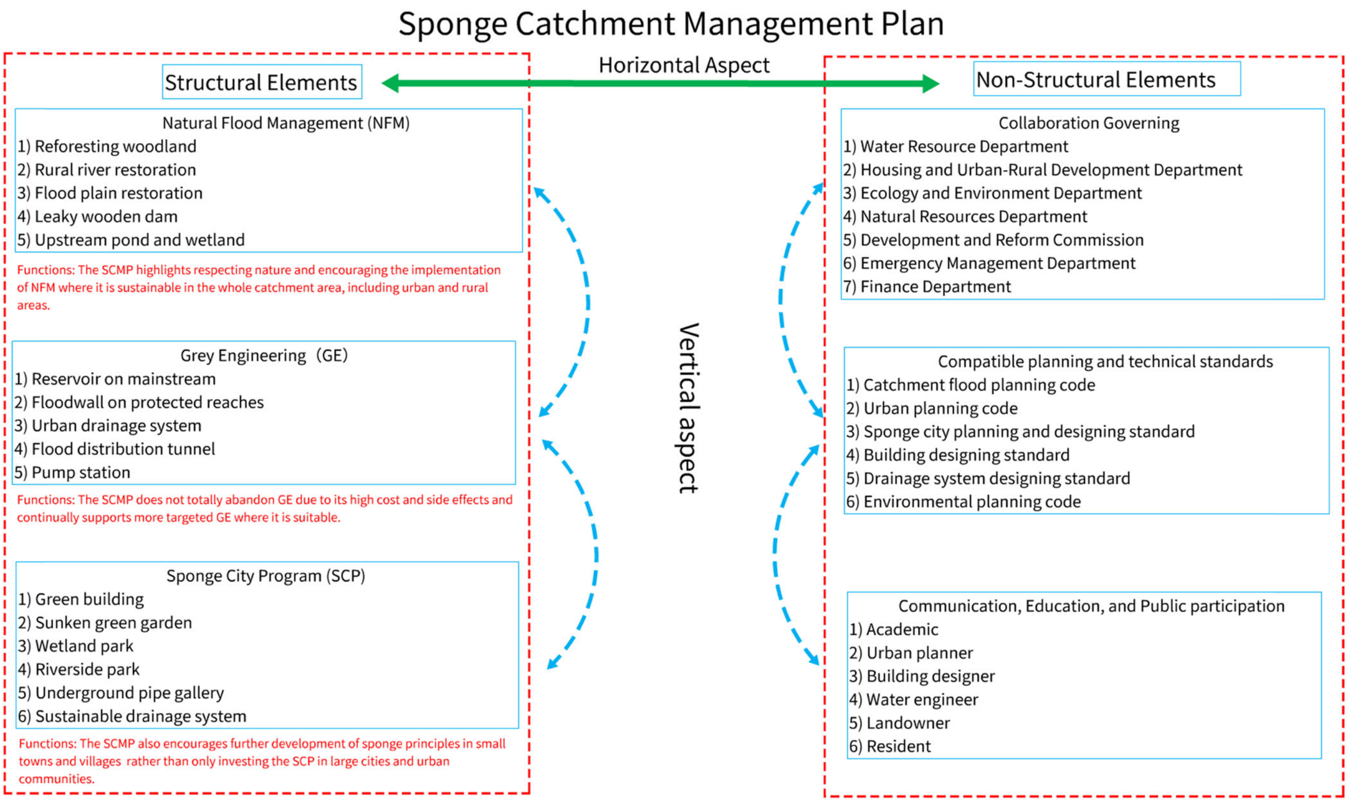

FIGURE 1 The Sponge Catchment Management Plan (SCMP) framework.

standards, communication, education, and public participation. First, the Ministry of Water Resources, Ministry of Housing and Urban-Rural Development, Ministry of Ecology and Environment, Ministry of Natural Resources, National Development and Reform Commission, and Ministry of Finance, have the responsibilities for flooding-related affairs in China. In addition, the arrangement of flood management is top-down and hierarchical, which goes against efficiently implementing SCMP (Holstead et al., 2017). Therefore, it requires collaboration in governing to clarify the responsibilities and break the barriers between different departments. Secondly, NFM is relatively novel in China. The current planning and technical standards do not support NFM. Thus, the framework encourages revising and integrating relative standards to promote SCMP further. Thirdly, early community engagement and stakeholders' support are fundamental to successfully implementing the SCMP.

Generally, the SCMP integrating structural and non-structural elements can effectively and efficiently enhance catchment flood resilience and provide other co-benefits: 1) the SCMP may guide CNG and local governments on plans and projects; 2) inform local authorities and planning companies in spatial planning and emergency rescue works; 3) assist water companies with water-related activities; 4) help landowners, farmers, and land developers operate land for agriculture, 5) conservation, and amenity purposes; 6) enhance the public understanding of flood risk and how it will be addressed (Falconer & Harpin, 2005).

1.4 | Aims and objectives of this study

This research used the Nanming River Catchment of Guiyang, a sponge city in Southwest China, to explore the SCMP. The specific objectives are as follows:

1) to develop the SCMP framework (Introduction);
2) to understand the perspectives of SCMP and its potential role in the Nanming River Catchment (Results);
3) exploring the steps of implementing SCMP by the case study—in the Nanming River Catchment (Discussions).

This research proposes that the SCMP framework could be a lesson for other Chinese cities that will implement the SCP to improve catchment-scale flood resilience further.

2 | RESEARCH AREAS AND METHODOLOGY

2.1 | Research areas

Guiyang is the fast-developing capital city of Guizhou province in Southwest China. The Nanming River stems from the Gui'an New Distinct and runs through the Huaxi Distinct and the Nanming Distinct (Figure 2). In recent years, the fluvial flood risk has increased due to the

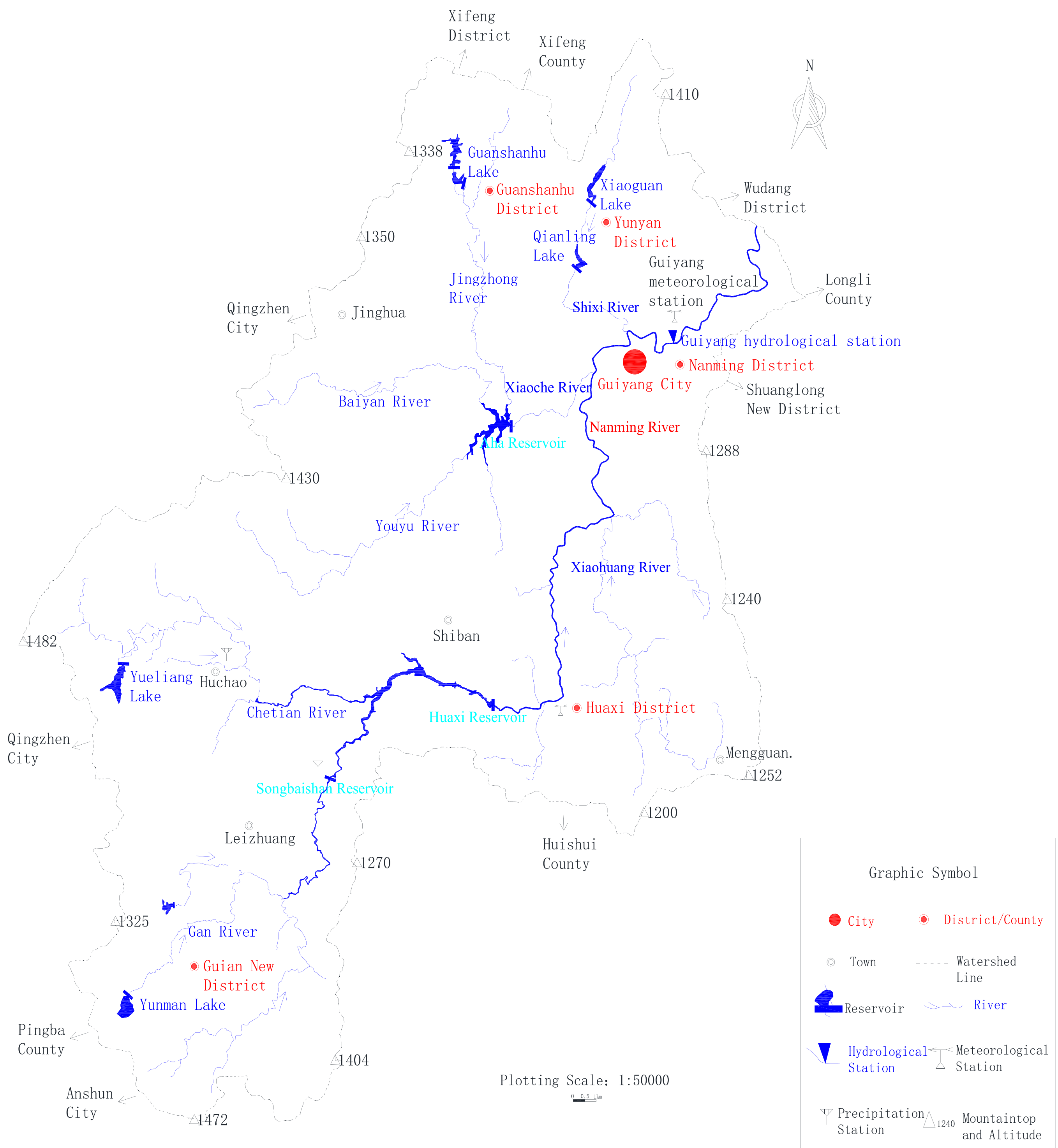

FIGURE 2 The water system map of Naming River Catchment. The authors adopted the figure from Guiyang Emergency Plan for Flood Control and Drought Relief (Guiyang Municipal Government, 2018) and drew the figure.

mountainous topography of the Nanming River Catchment and the rapid economic and population growth of Guiyang (Qi et al., 2021b). The basic principle of current flood management on Nanming River is *"Integration of storage and drainage over the Nanming River Catchment. The priority is quickly draining floods further downstream"* (Guiyang Municipal Government, 2018). The current flood control system of the Nanming River Catchment is based on GE-leading and SCP-additional measures (Figure 2). They include 1) using the Huaxi, Aha, and Songbaishan reservoirs as significant measures to store flood peaks in upper and middle Nanming catchments; 2) keeping floodwater in rivers and lakes confined by floodwalls; 3) building riverside parks as flood detention areas along the middle and lower reaches as additional measures to accommodate excess floodwater; 4) draining flood flow by flood underground channels; 5) implementing SCP to mitigate urban surface flood issues; 6) regulating land use within river lines; 7) building flood forecasting and warning system; 8) enhancing emergency rescue and post-disaster reconstruction (Guiyang Municipal Government, 2020).

2.2 | Methodology and data collection

The research selected Semi-Structured Interviews (SSIs) and a Focus Group Approach (FGA) to identify the perspectives of governmental officials, academics, planners, engineers, developers, landowners, and residents of the Nanming River catchment. Before the interviews, the interviewers explained the SCMP framework and the subset contents, such as the NFM, SCP, and GE, to the interviewees via images (Figure 3). The illustrative process improved the focus and effectiveness of the following interviews. Figure 3a–c labels are, respectively, hillslope woodland, a leaky wooden dam, and a pond, which represent typical NFM measures in upper catchments. Figure 3d is a floodplain, a middle-catchment NFM measure. Figure 3e–i labels are typical SCP measures in urban areas (a mountain forest park, a wetland park, a riverside park, a sunken community garden, and a green building). Figure 3j–l belonged to GE (a concrete reservoir, a floodwall, and an underground flood tunnel).

The authors followed six steps to collect and analyze the data (Table 1). Step one was to identify interviewees. Steps two and three worked on the secondary data, such as official reports and public news, to understand the catchment background and aid the interpretation of the interview data. After that, the interviewees were classified and allocated to the SSIs and FGA in step four. In step five, the authors illustrated the SCMP to interviewees; and recorded, translated, coded, and analyzed the interview data. Finally, this research reflects the issues, challenges, and opportunities to improve the current SCP via the SCMP framework.

A general question guideline for the SSIs was prepared first. The guideline provides a general orientation to help interviewers gather critical and sensitive information from authoritative or professional interviewees in relaxed person-to-person communications (Galletta & Cross, 2013). Through SSIs, the interviewers could deeply explore the interviewees' perspectives (Edwards & Holland, 2013). The authors invited 32 experienced and representative officials,

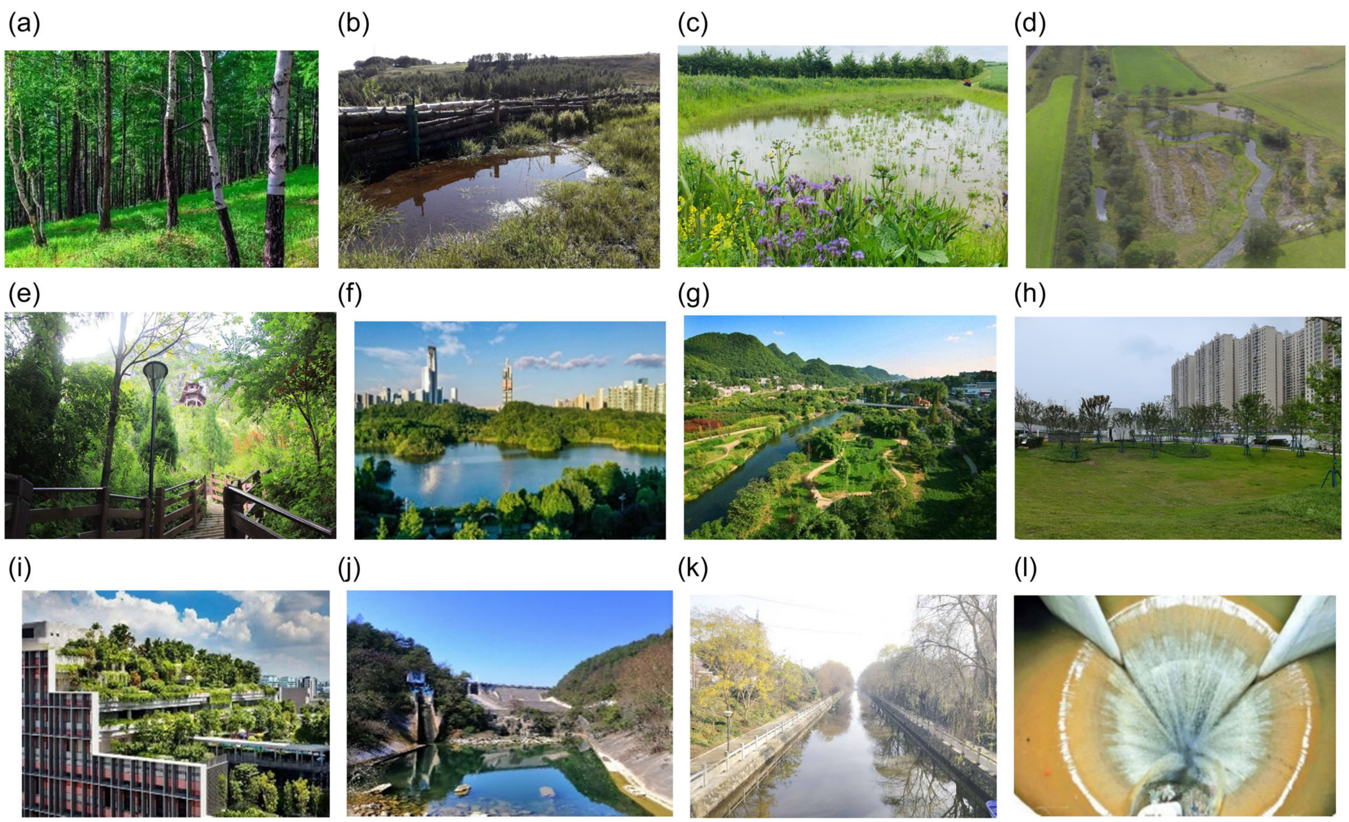

FIGURE 3 (a) Hillslope woodland (NFM); (b) Leaky wood dams (NFM); (c) Pond (NFM); (d) Floodplain (NFM); (e) Mountain forest park (SCP); (f) Wetland park (SCP); (g) Riverside park (SCP); (h) Sunken community garden (SCP); (i) Green building (SCP); (j) Concrete dam (GE); (k) Concrete floodwall (GE); (l) Underground flood tunnel (GE). The authors collected the pictures of (a)–(d) from (Parliament, 2011; Environment Agency, 2021; Environment Agency, 2009b). The authors took photographs of (e)–(l). GE, Grey Engineering; NFM, Natural Flood Management; SCP, Sponge City Program.

TABLE 1 The interview steps, key points, and details.

No.	Steps	Key points	Relationship with the SCMP framework
1	Selection of interviewees	The interviewees need to have a professional background, which helps build trust between interviewers and interviewees.	Identifying experienced interviewees who are familiar with flood management and the SCP.
2	Data collection from governmental reports	Triangulation was used to find relevant secondary data sources from recently published literature, governmental reports, and media information to support and validate the primary data collected from the SSIs and FGA.	Understand current flood management and implementation of the SCP.
3	Data collection from media data		Understand historical flood events in local catchments and the perspectives of public media.
4	Choice of interviewees	The authors invited 32 experienced and representative officials, academics, planners, engineers, and developers to undertake SSIs.	Their perspectives were critical in understanding the current flooding issues and whether or not the SCMP is sustainable for the local catchment.
		The authors targeted 30 specific interviewees, such as landowners and residents settling at the riverside and waterlogging areas, to collect their perspectives using an FGA.	Their perspectives helped the authors understand local flood issues, and which types of NFM are preferable. Their permission is crucial to effectively and efficiently implement the SCMP.
5	Explanation of the SCMP, recording interview data, translating, coding, and analyzing	Setting up coding patterns, undertaking interviews, and translation	Recording details about the SCMP; classifying and underling the critical information to get the research results.
6	Reflecting on the issues, challenges, and opportunities to improve the current SCP via the SCMP framework	Post-data analyses and reflections	Analyzing interview data to determine the reflections and give discussions and suggestions on SCMP

Abbreviations: FGA, Focus Group Approach; NFM, Natural Flood Management; SCMP, Sponge Catchment Management Plan; SCP, Sponge City Program; SSIs, Semi-Structured Interviews.

academics, planners, engineers, and developers in the first category (Professional category). Because the authors participated in many policy consultations and project planning, designing, and construction, some of the professional interviewees knew the authors before the interviews, making it easier to build potential trust. The FGA is a method of group interviews. A host invites targeted people to exchange ideas in group meetings or activities. It allows interviewees to discuss topics with the host and other participants (Catherine et al., 2019). The characteristics of FGA do not necessarily require too many interviewees. Therefore, the authors targeted 30 specific interviewees (nonprofessional category) to collect their perspectives, such as landowners and residents settling at the riverside and waterlogging areas (Table 2).

China has the top construction abilities globally because of the intensive infrastructure investment in the last several decades (Wang et al., 2018). Structural factors are often not the key to limiting infrastructure innovation in China. However, China often lags behind western developed countries in terms of innovative governing, technical standards, and public participation. Nonstructural factors often constrain planning and design innovation in China (Xia et al., 2017). Therefore, the authors mainly coded and analyzed nonstructural elements rather than structural elements in SCMP because the nonstructural aspects may bring more challenges and barriers to further implementation of the SCMP (Table 2 Coding Patterns). When the nonstructural elements are settled, the structural elements can progress well in SCMP.

Due to the Covid-19 pandemic, the authors conducted most interviews using cell phones or popular social online platforms in China, such as QQ and WeChat. Each interview took 30–45 min. The interviews were enjoyed by most participants, who were happy to give deep and honest perspectives. The authors used Mandarin to talk and then translated the results to English for further coding analysis via NVivo software. All participants agreed on the conduction of this research. The interview data was anonymized and appropriately handled and disposed of after completing this research under ethics and privacy compliance.

3 | RESULTS AND DISCUSSIONS

3.1 | The perspectives on NFM, GE, and SCP in the Nanming River Catchment

3.1.1 | The perspectives of residents

The primary goal of SCMP is to provide better living quality for people. Understanding which measure is better for most residents is vital for decision-making, planning, and designing a catchment. As the local government official No.2 (P; Professional) similarly stated follows:

> "*All policies and public infrastructures are to improve people's living convenience and quality. The views of residents cannot be ignored when*

TABLE 2 Basic information on interviewees and coding patterns.

Categories	Interviewees	Department/faculty/professional background	Responsibility or role	Respondent ID	Professional Title	Position	Age	Main topics/coding patterns
Professional category	Officials	Guiyang Municipal Government	Overall management	No. 1(P)	Grade-1 Investigator	Deputy Secretary	42	**1)** Perspectives on NFM, GE, and SCP **2)** Collaboration governing **3)** Compatible planning and technical standards **4)** Communication, education, and public participation **5)** The necessity, urgency, and steps of pushing SCMP in Guiyang on
				No. 2(P)	Grade-2 Investigator	Deputy Secretary	39	
		Water Resources Bureau	Water resources, flood, river, lake, catchment, and water project	No. 3(P)	Grade-1 Investigator	Deputy Bureau Head	46	
				No. 4(P)	Grade-2 Investigator	Chief Engineer	52	
		Housing and Urban-Rural Development Bureau	SCP, road, park, building, and other city construction	No. 5(P)	Grade-2 Investigator	Deputy Bureau Head	42	
				No. 6(P)	Grade-3 Investigator	Chief Engineer	50	
		Ecology and Environment Bureau	Ecology and environment	No. 7(P)	Grade-3 Investigator	Deputy Bureau Head	48	
				No. 8(P)	Grade-4 Investigator	Chief Engineer	42	
		Natural Resources Bureau	City master plan and natural resources (except for water resources)	No. 9(P)	Grade-2 Investigator	Deputy Bureau Head	43	
				No. 10(P)	Grade-3 Investigator	Chief Engineer	48	
		Guiyang Development and Reform Commission	Public investment permission	No. 11(P)	Grade-2 Investigator	Deputy Bureau Head	45	
				No. 12(P)	Grade-3 Investigator	Chief Engineer	53	
		Finance Bureau	Government budget and transferring budget funds	No. 13(P)	Grade-3 Investigator	Deputy Bureau Head	45	
				No. 14(P)	Grade-4 Investigator	Deputy Secretary	38	
	Academics	Hydraulic Engineering	Theoretical research and research	No. 15(P)	Professor	Faculty Head	42	
		Water Engineering		No. 16(P)	Associate Professor	Deputy Faculty Head	43	
		Urban Planning		No. 17(P)	Professor	Deputy Faculty Head	45	
		Building Designing		No. 18(P)	Associate Professor	Deputy Faculty Head	39	
		Environmental Engineering		No. 19(P)	Professor	Faculty Head	58	
	Urban Planners	Urban Planning	Making plans	No. 20(P)	Senior Engineer	Director-General	52	
		Landscape Engineering		No. 21(P)	Senior Engineer	Chief Engineer	58	
		Urban Environmental Engineering		No. 22(P)	Senior Engineer	Project Manager	36	
		Urban Ecological Engineering		No. 23(P)	Senior Engineer	Project Manager	32	
		Urban Economic Engineering		No. 24(P)	Senior Engineer	Project Manager	39	

TABLE 2 (Continued)

Categories	Interviewees	Department/faculty/ professional background	Responsibility or role	Respondent ID	Professional Title	Position	Age	Main topics/coding patterns
	Engineers	Hydraulic Engineering	Designing buildings and public infrastructures	No. 25(P)	Senior Engineer	Director-General	53	
		Hydraulic Structure Engineering		No. 26(P)	Senior Engineer	Chief Engineer	56	
		Water Resource Engineering		No. 27(P)	Senior Engineer	Project Manager	33	
		Water Ecological Engineering		No. 28(P)	Senior Engineer	Project Manager	30	
		Project Cost Engineering		No. 29(P)	Senior Engineer	Project Manager	35	
	Land and housing developers	Architectural Engineering	\	No. 30(P)	Engineer	Manager	45	
		Architectural Engineering		No. 31(P)	Engineer	Deputy Manager	40	
		Architectural Engineering		No. 32(P)	Engineer	Department Manager	35	
Nonprofessional category	Landowners and residents	\	\	No. 1–5(R)	\	\	18–30	
				No. 6–10(R)	\	\	30–40	
				No. 11–15(R)	\	\	40–50	
				No. 16–20(R)	\	\	50–60	
				No. 21–25(R)	\	\	60–70	
				No. 26–30(R)	\	\	70–75	

Abbreviations: GE, Grey Engineering; NFM, Natural Flood Management; P, professional; R, resident; SCMP, Sponge Catchment Management Plan; SCP, Sponge City Program.

planning and designing a program or project. We should understand whether or not the people in the Nanming River Catchment accept the SCMP; and which measure they like."

This section coded the interview results from landowners and residents (nonprofessional category) to analyze their preferences and perspectives on SCMP. The interviewees selected their preferred flood management options from the images in Figure 3. Over 90% of residents selected the NFM and SCP as their favorite pictures. The first impression of parks received the highest welcome from the residents, contrasting with the GE. Respondents No.1 (R; Resident) and No.20 (R) stated, respectively:

"*We like the green pictures. The parks give us happy feelings. We highlight the first impression of things. Green parks and buildings make us relax. Our favorites are the NFM and SCP measures in the SCMP framework you introduced. On the opposite, the grey concrete infrastructures repress our moods.*"

"*The GE gave us pressure emotionally. We feel uncomfortable with the grey pictures. The artificial infrastructures are not compatible with the natural rivers and surrounding landscapes. On the opposite, the green images release us a lot. We can imagine jogging or playing in these parks.*"

The nonprofessional interviewees generally welcomed the green appearance measures. But not all NFM is universally popular among residents. When the authors asked about dredging (an example of river restoration) and leaky wooden dams, resident No.11 (R) and landowner No.21 (R) had similar views as follows:

"*The local government implemented Nanming River Dredging Project about 10 years ago. Many diggers worked in the river to remove tons of mud. Although the river was cleaned up after the project, the effect lasted only three years. Also, the dredging has not mitigated the submergence effects of the floods. The easy flooding river sections were still flooded in rainstorms.*"

"*The leaky wooden dam looks dead. We do not believe a pile of dead trunks can protect us from flood hazards. We cannot take that chance of flooding. At the same time, the picture of the leaky wooden dams seems to have no benefit to the nearby ecosystem and environment. If no one had explained the functions of leaky wooden dams to me, I wouldn't know anything about they can help with flood control. I will consider implementing them on my land only when the government gives us enough subsidies.*"

The green attributes of NFM and the SCP may influence the choice of the image by nonprofessional interviewees. Green infrastructure may hint at some landscape, environmental, biological, and well-being benefits. This finding is consistent with the CNG's efforts to continuously and conspicuously promote green culture to improve people's green awareness. The public appreciation of green infrastructures increases with scientific propagation and green education. When the authors asked about where they had heard about green slogans or programs, resident No.3 (R) gave a representative answer as follows:

"*The TV broadcasts, websites, and cellphone Apps usually propagandize Green and Ecological-Civilization Society, SCP, and Carbon Emission Peak and Neutrality. Even though we are not professionals, we understand that a more natural and greener environment is important for our communities. We strongly support the green and beautiful public facilities shown in the pictures. We also support the proposed SCMP, integrating the NFM and SCP.*"

Most residents identified the compatibility of flood management with the surrounding ecological environment as a critical factor in acceptance. The appearance of green infrastructures rather than flood management efficiency strongly affected residents' selections. Forest, wetlands, gardens, and parks were generally welcome by residents because the green options were considered more esthetically pleasing and environmentally friendly than the GE. Conversely, the residents often commented less on the GE and the parts of NFM without green vegetation. They perceived these to be lifeless measures and eyesores. They linked their preference with the landscape, environmental, biological, and well-being benefits, indicating that the public had started to have stronger green awareness.

Meanwhile, the perspectives were slightly different within different groups. The older interviewees showed a stronger preference for a better living place with good landscapes and medical conditions, indicating that personal age influences their selection. Resident No.17 (R) stated the viewpoint as follows:

"*Because I will retire in 3 years, a more excellent living environment is the first factor when buying a retiring apartment. We do not care too much about the local flood risk. The government and housing developers are responsible for handling it well while planning and designing a community and building. We believe the government and housing developers have the experience and ability to solve it. If we choose a* *community to live in after retirement, we like communities with a better environment and medical treatment, such as park or garden communities*."

Interestingly, the middle-class residents' primary focus is on housing prices and children's education rather than flood management. Only 30% of residents understood that the NFM and SCP, such as hillslope woodland and wetlands, could store rainwater to help flood mitigation. Typical expressions from residents No.6 (R) and No.15 (R) were as follows:

"*When we buy or rent an apartment, the government, developers, and housing lords rarely mention flood risks. We also do not have access to understanding the flood risks to our communities. Over time, we pay less attention to flood risk. We enjoy leisure places provided by parks. It would be perfect if the NFM or SCP could increase the land or housing price I have already bought. However, we do not understand if they can offer benefits for flood management. The stable increase in property pricing is what we care about*."

"*I am a registered lawyer, and my wife is a doctor. We understand that reservoirs, flood tunnels, and floodwalls are essential to protect our city from flood damage. We also understand that the NFM and SCP you mentioned can provide co-benefits to us. However, we are young parents. The flood risk was not a major consideration for our family. We focus on children's education. If the nearby school is highly ranked, we can accept higher housing flood risk. On the other hand, we will not buy or rent a low flooding risk house without great primary and middle schools*."

Housing is the most significant property in Chinese middle-class families. It is reasonable that they are more concerned with housing prices than flood risk. In addition, children's education is the priority in traditional Chinese families. Most young Chinese couples consider their children's education the first factor when selecting houses. On the other hand, young single residents are more sensitive to house rent, job opportunities, and commuting benefits. A young graduate, No.4 (R), answered as follows:

"*We like living near workplaces, subway stations, and bus stations. Even if these places are easily flooded, we still choose to stay there to save commuting time. We need a convenient living place for work and social activities. We also want to have a low flood risk and a better living environment, which the SCMP may provide. Nevertheless, our practical requirements are stable jobs, more income, and enjoyable social networks. In addition, the acceptable house rent is our consideration in selecting an apartment*."

In brief, the most critical factor in supporting or against a strategy varies from age and social roles. The residents and landowners likely connected the preferable flood management measures with their practical requirements. The living environment, children's education, housing prices (or subsidies), job opportunities, and commuting convenience were the primary considerations when supporting or opposing SCMP.

3.1.2 | The perspectives of professionals

In the aspect of perspectives from professional groups, the results were more focused on flood protection rather than external factors. Even though the NFM and SCP are positively associated with the environment and esthetics, GE is still considered the most effective flood management measure on a catchment scale by professionals. Over 75% of interviewees in the professional group favored the flood management efficiency of GE. Although the recent flood events alarmed policymakers and academics to reappraise small-scale SCP and GE limitations, the current challenge is making engineers and planners believe in NFM. They will not be willing to risk using NFM to manage floods unless technical standards strongly support this. This perspective is mainstream among engineers. The experienced water engineers No.25(P) and No.27(P) expressed representative viewpoints as follows:

"*We still recommend GE as the first selection in flood management even though it is costly and has no other co-benefit. The planning and designing standards take reservoirs, flood tunnels, and floodwalls as the recommended options to defend against flood hazards in rare rain return period floods (usually over 1-in-100 years rain-return period). We understand that wetlands, river parks, gardens, leaky dams, and ponds can provide better landscape and environmental, biological, and human well-being benefits. However, the safety of flood management is always our first consideration when planning and designing a catchment*."

"*No one wants to take the risk to alternate all GE with good-looking measures. Maybe, we take the NFM as an additional way to the GE based on securing catchment flood safety. We will use the NFM in catchments only when the basic fluvial flood safety issues are settled. We hope to learn more about the NFM from foreign developed countries' successful experiences on NFM*."

The primary function of GE, such as reservoirs and floodwalls, is to address the flood issue. There is less evidence proving the flood defense ability of NFM in China. Meanwhile, the perspectives of the professional interviewees on dredging (an example of GE-leading river restoration) and leaky wooden dams are similar to no-professional interviewees. The official No.3(P) and engineer No.28(P) respectively expressed as follows:

> "*The dredging is a project under the water and hard to be seen. People do not take it as a long-term solution because the sediment can fill the riverbed after several years of dredging. We have implemented many dredging projects on the Nanming River, which do not have long-term effects on fluvial flood mitigation. In my opinion, the dredging was unsuitable and a waste of money. There also was a corruption risk in dredging projects due to the opaque measurement of project quantity. The government has yet recommended dredging projects in recent years. There are many types of river restoration, such as planting riverside and natural riverbanks; thereinto, dredging may be seen as a more negative method.*"

> "*The leaky wooden dam is constructed with dead logs and tree trunks. There are few successful precedents in using wooden dams in China. We are not sure it can mitigate flood risk as real concrete dams. They show a low flood mitigation ability. We do not dare implement the wooden dams in the Nanming River.*"

Although the professionals understand the co-benefits of the NFM, they will not choose it as the primary flood control measure without the support of technical standards and successful project examples in China. The professional or nonprofessional groups either do not welcome dredging projects and leaky wooden dams. The negative thoughts might relate to the characteristics of unseen work in dredging projects. The leaky wooden dams could be less attractive due to dead vegetation and potentially low flood control ability than concrete dams have. The professional interviewee, No. 19(P), concluded the reasons for this phenomenon as follows:

> "*An easily perceived effectiveness is crucial in getting support when selecting a strategy. The NFM mainly attracts people with its green and sustainable images. But if the NFM measures, such as leaky wooden dams and dredging, seem not fresh and green enough, people will not vote for them. Meanwhile, the NFM is unproven by pilot projects in China. That said, professionals cannot judge it by flood reduction ability. That is why most professional people consider GE effective in flood management.*"

Future research should focus on integrating the a priori experience with Guiyang's specific environmental conditions to understand better the relationship between individual values and flood management preferences. Moving beyond a superficial understanding of flood dynamics to stakeholders' deep values is crucial.

3.2 | Developing collaborative SCMP governance

The Guiyang Municipal Government is the highest authority in managing local bureaus under the existing National Governing Structure mentioned in Section 1.3. The responsible arrangement of local bureaus in flood management is shown in the Governing Responsibility column of Table 2. The overlapping governance may bring down the effectiveness and efficiency of the SCMP. An official, No.5(P), stated the following:

> "*In most cases, authorities can work together on flood management issues. However, there is some overlap between the departments' responsibilities. The overlapping powers may pose a challenge to flood management partnerships. For instance, the Housing and Urban-Rural Development Bureau pays more attention to building construction rather than considering hydrological issues. As a result, the wetland park considers less urban drainage system in its design.*"

The local government needs to overcome the barriers between different bureaus. Collaboration in SCMP governance can improve the effectiveness and efficiency of the SCMP. To achieve this unified SCMP governance, the local government needs to rearrange the responsibilities under the unified management and include the authors' proposed SCMP Commission Office. The SCMP Commission Office can lead all relative bureaus toward one goal to avoid conflicts. Meanwhile, the involved bureaus need to develop their work further to achieve the orders from the SCMP Commission Office. For example, the Natural Resources Bureau should enact mandatory planning laws to reserve natural flood detention areas that are suitable for developing NFM in the holistic catchment. The Water Resources Bureau should consider using more NFM measures, such as hillslope woodland, leaky wood dams, ponds, and floodplain, rather than mainly investing in GE measures. The Housing and Urban-Rural Development Bureau should develop guidelines to control building density and reserve more green space for NFM.

3.3 | Revising planning and technical standards to be more compatible

The interview results showed that the planners and engineers did not dare to risk using NFM due to the lack

TABLE 3 Construction codes and standards of current SCP.

Codes or standards	Serial number
Assessment Standard for Sponge City Construction Effect	GB/T 51345-2018
Code for Vertical Planning on Urban and Rural Development Land	CJJ 83-2016
Code for Design of Outdoor Wastewater Engineering	GB 50014-2006
The standard for Urban Residential Area Planning and Design	GB 50180-2018
Code for Urban Wastewater and Stormwater Engineering Planning	GB 50318-2017
Technical Code for Rainwater Management and Utilization of Building and Subdistrict	GB 50400-2016
Code for Plan of Urban Water System	GB 50513-2009

Abbreviation: SCP, Sponge City Program.

of support from technical standards. The current technical standards are a barrier for planners and engineers choosing NFM measures (Table 3). Meanwhile, the effectiveness of NFM may also differ due to the different characteristics of catchments. The relative importance of multiple factors influencing catchment flooding varies spatially and over time. While implementing pilot SCMP, the technology association should revise the technical standards according to the project evaluation. The revised standards need to recommend locally characteristic NFM measures to address locally specific catchment flood issues.

3.4 | Implementing a "bottom-up" communicational, educational, and participational platform

The different perspectives illustrated by the data show that the preferences and choices of flood risk management infrastructure were different, and controversies existed among various stakeholders. Because flood managers do not easily calculate the co-benefits by currency, the trade-offs usually exist inside a catchment (Garvey & Paavola, 2021). However, the SCMP is a community-sensitive flood management strategy. The SCMP needs to involve a broader range of participants in critical activities through a bottom-up process. An official respondent, No.5(P), expressed similar concerns:

> "*The standpoints are different within different stakeholders when implementing planning or project. Although the CNG has improved public participation in planning and designing, the participation level is still on the surface rather than in essence. For example, the government invites familiar residents but random ones to take advice to get permission more efficiently. Another example is symbolically seeking advice on government websites. It is more like meeting the minimum planning or project review requirement. There are few down-to-earth platforms to communicate with stakeholders in the governing system.*"

Another potential trade-off is land use. The public landowners (local governments) are relatively receptive to SCMP due to its public service attributes. However, land acquisition and housing removal in the private sector usually have issues. Therefore, the support of private landowners and housing owners is essential to success because gaining their permission to site SCMP is critical. The implementation of SCMP needs strong support from them. The developer, No.30(P), raised a similar point:

> "*The law tends to protect private properties. When building new infrastructures, land expropriation and housing demolition are always problems in China. We expect that the implementation of SCMP will have the same challenge. A neighborhood organization may play a role in encouraging private landowners and housing owners to trust that the government can provide fair compensations to them.*"

The authors suggested setting Catchment Flood Groups (CFGs) in communities to identify common values before implementing the SCMP. The CFGs should be a local self-organizing group integrating most stakeholders to narrow the gap among different stakeholders. The CFGs need to be deeply involved in the overall process of the SCMP, including policymaking, planning, designing, construction, risk management, and reconstruction. Setting up CFGs in a catchment can provide a high-level communication platform to encourage stakeholders to engage in SCMP. In this platform, various stakeholders can exchange ideas about SCMP to negotiate a feasible and suitable path. The grassroots can effectively give their messages to policymakers via CFGs.

Because the public easily accepts unofficial information from social networks, the local government needs to endorse an open and third-sector communication path in CFGs. Innovative examples include the creation of catchment-level Apps to monitor the catchment conditions and share them with group members. The Apps can efficiently collect direct feedback from stakeholders and present it to the local authorities. An official respondent, No. 7(P), also noted the bottom-up and creative approaches needed for communications:

> "*The new social technologies are an important way for engaging different groups. Word-of-mouth, social, and alternative media are effective in communication. For instance, more people do not watch TV Programs and Newspapers. They are likely to use cellphone Apps, such as WeChat, QQ, Weibo, and Tik Tok, to get information and express opinions. Cellphone Apps' involvement can allow residents to engage in SCMP actively*."

The interview results of Section 3.1 show that the public has a relatively low-level understanding of the NFM principles because it is novel in China. Knowledge is another crucial issue that needs improvement when implementing the SCPM. It is hard to enable everyone in the catchment to fully understand the principles of the SCPM because of the difference in learning ability, educational level, professional background, and general interest. The professionals in CFGs can act as science communicators to simplify the SCPM principles to ease public understanding of NFM.

In addition, third-party organizations are more convincing when implementing the SCMP. For instance, the CFGs can invite the NGOs to join in to take the implementation of SCMP pilot projects into a short film to help communities understand the principle and benefits of SCMP. The official interviewee, No. 6(P), supplemented as follows:

> "*Many residents did not hear about NFM before. They do not have enough trust in officials. They usually take the authorities as a barrier to public participation. Professionals and NGOs in CFGs can play an important part in explaining the SCMP strategy to win their support*."

The CFGs can better advocate for NFM to involve different stakeholders. The CFGs can be a communicational, educational, and participational platform connecting policymakers, professionals, residents, landowners, and other stakeholders, which makes the SCPM successfully implemented in the Nanming River Catchment.

3.5 | Future foresight—The necessity, urgency, and steps of pushing SCMP in Guiyang

The construction of GE in the past 70 years significantly reduced flooding casualties in the Nanming River Catchment (Guiyang Municipal Government, 2020). As mentioned in 3.1, the current flood management of Guiyang still focuses on the costly and ecological-unfriendly GE. The SCP implementation indeed has partly reduced the urban surface water flood risk below the 1-in-30 years rain-return period; provided co-benefits to the urban ecosystem and residents in Guiyang. However, the SCP implementation is still on the community scale. Nevertheless, the potential economic losses have been growing high, counting the rapid socioeconomic development along the Nanming River, the cost of emergency rescue actions, and post-disaster reconstructions (Guizhou Survey & Design Research Institute for Water Resources and Hydropower, 2016). The current economic losses per unit of land are more than 100 times higher than those in 1954 (Xia & Chen, 2020). In addition, the public's acceptance of flood losses dramatically decreases due to the transparency and timeliness of new social networks (Chan et al., 2021). Using GE or SCP alone is insufficient to mitigate the catchment flood risk in the Nanming River Catchment. Therefore, integrating NFM, GE, and SCP in the SCMP is necessary and urgent. The authors found the same viewpoints from the governmental official No. 3(P) and academic No. 16(P) as follows:

> "*In the past, the authorities focused on the flood management of the Nanming River mainstreams by building reservoirs and floodwalls. The GE-based strategy was defending against the flood rather than living with the flood. As a result, larger reservoirs and higher flood walls were built along the rivers. However, the GE-based strategy was costly and without benefits to the water ecosystem and landscape*."

> "*The flooding tragedies Guiyang (1991, 1996, and 2004) enlighten us that the catchment flood is a major threat to the holistic catchment areas, including cities and rural areas. We understand that only using the GE and small-scale SCP cannot reduce the catchment flood risk to an acceptable extent. To mitigate the catchment flood risk, we should creatively explore more sustainable measures in suburban and rural areas*."

Meanwhile, the current SCP implementation is challenging to be enlarged by scale because the Guiyang Municipal Government's income is highly dependent on land financial revenue, and the urban land price keeps increasing. That means the local government is reluctant to use precious urban land to build large-scale SCP infrastructures like wetland parks. Therefore, there is a contradiction between further developing SCP and urban land sales. Under the condition of urban land shortage, governmental official No. 1(P) agreed with the SCMP idea as follows:

> "*The SCMP integrating with the NFM, GE, and SCP seems feasible to improve the catchment flood resilience further. The SCMP you mentioned is a good idea to connect the UFM with CFM. The NFM in the SCMP framework*

gives a more cost-effective and urban-land-saving way to reduce the discharging flow by naturally storing the floodwater in the suburban and rural catchments."

To push SCMP in Guiyang, the authors suggest implementing the SCMP via further integrating SCP and NFM in Guiyang step by step (Figure 4). The local policymakers may not wholly support the SCMP at the beginning due to the lack of evidence, technical standards, and financial support for SCMP. An initial relatively cheaper SCMP highlighting the main factors will be appropriate to gain their support.

After the initiation of the SCP, the first step is to scope the point of penetration. The local authorities need to support academics in collecting and studying all relative plannings (urban, rural, water resource, flood, SCP, and environmental plannings) and current catchment conditions (hydrological, geographic, ecological, and economic conditions) to find the deficiency of current CFM. Secondly, the authorities need to collect opinions from the stakeholders in the catchment to understand their concerns about catchment flood risk. Thirdly, the local authorities invite planning or water companies to make a feasible report on SCMP. Thereinto, a flood risk map is crucial to identify flooding issues in the catchment. Fourthly, the local government selects a pilot catchment to implement the SCMP. Implementing pilot SCMP projects in sub-catchments are recommended to reduce the initial investment and the potential failure risk. Meanwhile, the SCMP is a dynamic process requiring long-term monitoring feedback from the pilot SCMP projects. In the SCMP pilot stage, planning and designing companies must collect massive data on the pilot catchment to find suitable and practical measures. Fifthly, the local authorities need third-party companies to conduct a post-evaluation of the pilot SCMP projects. Sixthly, according to the post-evaluation, the local government can further decide whether to implement the SCMP in other catchments. After rounds of pilots and adjustments, the SCMP can be more practical, resilient, inexpensive, and easily maintained for the next generations.

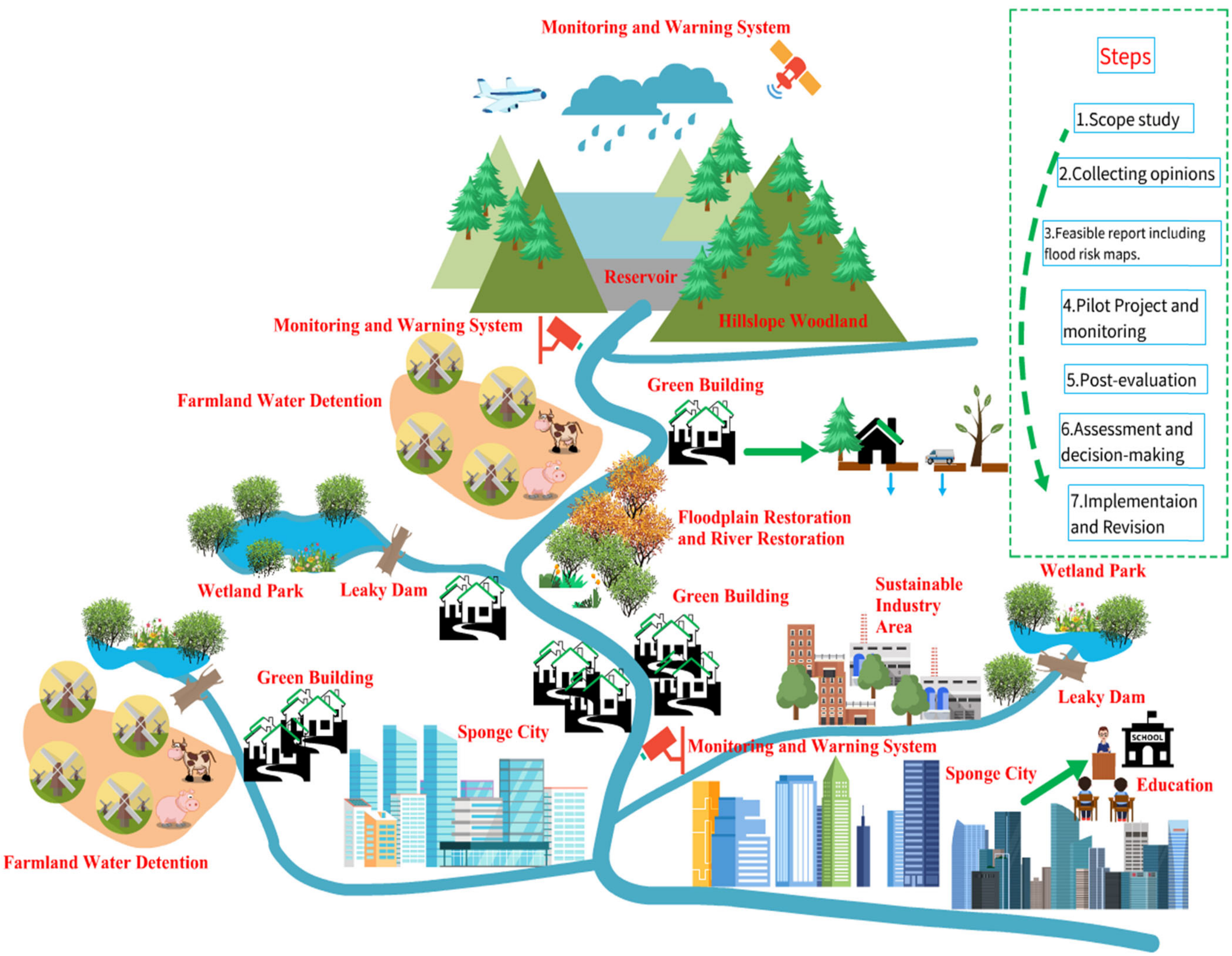

FIGURE 4 A schematic diagram of the SCMP (*Source*: Yunfei Qi). SCMP, Sponge Catchment Management Plan.

4 | CONCLUSIONS

Recent flood events have alarmed the China National Government (CNG) and local governments to rethink the strategy of over-relying on the site-specific Sponge City Program (SCP). Yet, there is a lack of consideration for holistic Catchment Flood Management (CFM) in SCP. Using Grey Engineering (GE) or SCP is insufficient to mitigate catchment flood risk. Therefore, integrating Natural Flood Management (NFM), GE, and SCP in the Sponge Catchment Management Plan (SCMP) is necessary and urgent. The proposed SCMP has structural (NFM + GE + SCP) and nonstructural elements (collaborative governance, compatible planning and technical standards, communication, education, and public participation).

On the structural side, the SCMP framework of integrating NFM with the SCP and GE is designed to extend the current SCP with broader natural catchment solutions. Most importantly, it can effectively reduce the catchment flood discharge peaks that threaten downstream people and properties. In the SCMP framework, NFM is the core part of the holistic catchment as a natural supplement to GE and SCP, aiming to increase the protection level reached from 1-in-30 to 1-in-100 years. GE still plays an important role in defending infrequent flood events over 1-in-100 years rain-return period on mainstreams. Besides investing in the SCP in large cities and urban communities, the SCMP also encourages further development of sponge principles in small towns and villages. Generally, the SCMP can effectively enhance catchment flood resilience and provide other co-benefits.

Based on the interview results, the authors found that support for the SCMP varies with age and social roles. The residents and landowners likely connected the preferable flood management measures with their requirements. The living environment, children's education, housing prices (or subsidies), job opportunities, and commuting convenience were the primary considerations when supporting or opposing SCMP. Meanwhile, the professionals' traditional values still need to be broken as they still doubt the ability of NFM without technical standards and successful project examples in China.

Because there are trade-offs among different stakeholders, the practitioners also need to focus on nonstructural elements. The local government needs to break down barriers between various bureaus. Collaboration in SCMP governing can improve the effectiveness and efficiency of SCMP. To achieve this unified SCMP governance, the local government needs to rearrange the responsibilities under the unified management of the SCMP Commission Office. In addition, the revision for technical standards needs to follow the pilot SCMP process to encourage the planners and engineers to use the NFM in SCMP. Although most residents supported the NFM and SCP because of their green characteristics, they commonly do not understand the principles and importance of SCMP. The SCMP needs to involve a broader range of participants via a bottom-up process in Catchment Flood Groups (CFGs), including different stakeholders, to share information and knowledge and further win their support.

Finally, the authors recommend implementing pilot SCMP projects in sub-catchments at the initiation stage. Based on the pilot project monitoring and post-evaluation, the authorities can assess the effectiveness of SCMP. After that, the CNG can decide whether or not to implement SCMP in more and larger catchments by comparing various pilot SCMP projects.

ACKNOWLEDGMENTS

This research was funded by the National Natural Science Foundation of China (NSFC) (Grant number: 41850410497); National Key R&D Program of China (Grant number: 2019YFC1510400); National Natural Science Foundation of China (NSFC) Youth Project (Grant number: 51909126); University of Nottingham (UNUK) project (Grant number: E01200500006); Institute of Asia Pacific Studies Research Funded for the Environmental Security and Sustainability; Cultural and Creative Industries Research Priority Areas; Faculty of Science and Engineering (FTSE) Postgraduate Research Scholarship of University of Nottingham Ningbo China; and Guizhou Science and Technology Planning of Project (Grant number: 2019 2879).

CONFLICTS OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The authors collected the raw data from all participants. The original data support the results of the paper. Although there is a part of the original data in the paper, the authors will protect the participants' privacy. More inquiries can be directed to the corresponding authors.

ETHICS STATEMENT

None declared.

ORCID

Yunfei Qi http://orcid.org/0000-0003-4505-1314
Faith Ka Shun Chan http://orcid.org/0000-0001-6091-6596

REFERENCES

Antonarakis, A. S., & Milan, D. J. (2020). Uncertainty in parameterizing floodplain forest friction for natural flood management, using remote sensing. *Remote Sensing*, *12*, 1799.

Bark, R. H., Martin-Ortega, J., & Waylen, K. A. (2021). Stakeholders' views on natural flood management: Implications for the nature-based solutions paradigm shift? *Environmental Science & Policy*, *115*, 91–98.

Catherine, S. R., Kirsti, N., & Marie, L. R. (2019). *Conducting the reference interview*. Neal-Schuman.

Chan, F. K. S., Adekola, O. A., Ng, C. N., Mitchell, G., & Mcdonald, A. T. (2013a). Research articles: Coastal flood-risk management practice in Tai O, a town in Hong Kong. *Environmental Practice*, *15*, 201–219.

Chan, F. K. S., Mitchell, G., Cheng, X., Adekola, O., & Mcdonald, A. (2013b). Developing a Sustainable Flood Risk Appraisal (SFRA) framework for the Pearl River Delta. *Environment and Urbanization ASIA*, *4*, 301–323.

Chan, F. K. S., Yang, L. E., Scheffran, J., Mitchell, G., Adekola, O., Griffiths, J., Chen, Y., Li, G., Lu, X., Qi, Y., Li, L., Zheng, H., & Mcdonald, A. (2021). Urban flood risks and emerging challenges in a Chinese delta: The case of the Pearl River Delta. *Environmental Science & Policy*, *122*, 101–115.

Cornwall, W. (2021). Europe's deadly floods leave scientists stunned [Online]. *Science*. https://www.sciencemag.org/news/2021/07/europe-s-deadly-floods-leave-scientists-stunned

Council D. I. T. O. T. S. (2022). 7.20 Investigation Report of Intensive Raining Hazards for Zhengzhou, Henan Province. Beijing China.

Dadson, S. J., Hall, J. W., Murgatroyd, A., Acreman, M., Bates, P., Beven, K., Heathwaite, L., Holden, J., Holman, I. P., Lane, S. N., O'Connell, E., Penning-Rowsell, E., Reynard, N., Sear, D., Thorne, C., & Wilby, R. (2017). A restatement of the natural science evidence concerning catchment-based 'natural' flood management in the UK. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *473*, 20160706.

Edwards, R., & Holland, J. (2013). *What Is Qualitative Interviewing*? . Bloomsbury Academic.

Environment Agency. (2009a). Catchment flood management plans [Online]. https://www.gov.uk/government/collections/catchment-flood-management-plans

Environment Agency. (2009b). Thames Catchment Flood Management Plan. Summary Report December 2009. Reading UK.

Environment Agency. (2012). Exe Catchment Flood Management Plan. Summary Report June (UK).

Environment Agency. (2021). Working with natural processes to reduce flood risk [Online]. https://www.gov.uk/flood-and-coastal-erosion-risk-management-research-reports/working-with-natural-processes-to-reduce-flood-risk

European Commission. (2020a). The EU Water Framework Directive - integrated river basin management for Europe [Online]. https://ec.europa.eu/environment/water/water-framework/index_en.html

European Commission. (2020b). WFD: Timetable for implementation [Online]. https://ec.europa.eu/environment/water/water-framework/info/timetable_en.htm

European Commission. (2021). The EU Floods Directive [Online]. https://ec.europa.eu/environment/water/flood_risk/implem.htm

Falconer, R. A., & Harpin, R. (2005). Catchment flood management. *Water International*, *30*, 5–13.

Ferguson, C., & Fenner, R. (2020). The impact of Natural Flood Management on the performance of surface drainage systems: A case study in the Calder Valley. *Journal of Hydrology*, *590*, 125354.

Galletta, A., & Cross, W. E. (2013). *In mastering the semi-structured interview and beyond: From research design to analysis and publication*. NYU Press.

Garvey, A., & Paavola, J. (2021). Community action on natural flood management and the governance of a catchment-based approach in the UK. *Environmental Policy and Governance*.

Guiyang Municipal Government. (2018). Guiyang Emergency Plan for Flood Control and Drought Relief. Guiyang, China.

Guiyang Municipal Government. (2020). Guiyang Emergency Plan for Flood Control and Drought Relief. Guiyang, China.

Guizhou Survey & Design Research Institute for Water Resources and Hydropower. (2016). Flood control evaluation of Nanming River Regulation Project. Guiyang, China.

Holstead, K. L., Kenyon, W., Rouillard, J. J., Hopkins, J., & Galán-díaz, C. (2017). Natural flood management from the farmer's perspective: criteria that affect uptake: Natural flood management from the farmer's perspective. *Journal of Flood Risk Management*, *10*, 205–218.

Iacob, O., Brown, I., & Rowan, J. (2017). Natural flood management, land use and climate change trade-offs: The case of Tarland catchment, Scotland. *Hydrological Sciences Journal*, *62*, 1931–1948.

Jia, H., Wang, Z., Zhen, X., Clar, M., & Yu, S. L. (2017). China's sponge city construction: A discussion on technical approaches. *Frontiers of Environmental Science & Engineering*, *11*.

Li, H., Ding, L., Ren, M., Li, C., & Wang, H. (2017). Sponge city construction in China: A survey of the challenges and opportunities. *Water*, *9*, 594.

Li, Q., Wang, F., Yu, Y., Huang, Z., Li, M., & Guan, Y. (2019). Comprehensive performance evaluation of LID practices for the sponge city construction: A case study in Guangxi, China. *Journal of Environmental Management*, *231*, 10–20.

Ministry of Housing and Urban-Rural Development of the People's Republic of China. (2014). Technical guidelines for sponge city construction - low-impact development of the stormwater system (trial). Beijing, China.

Ministry of Water Resources of the People's Republic of China. (2019). Statistic Bulletin on China Water Activities. Beijing, China.

Parliament H. O. (2011). Natural Flood Management, UK.

Qi, Y., Chan, F. K. S., O'donnell, E. C., Feng, M., Sang, Y., Thorne, C. R., Griffiths, J., Liu, L., Liu, S., Zhang, C., Li, L., & Thadani, D. (2021a). Exploring the development of the Sponge City Program (SCP): The case of Gui'an New District, Southwest China. *Frontiers in Water*, *3*.

Qi, Y., Chan, F. K. S., Thorne, C., O'donnell, E., Quagliolo, C., Comino, E., Pezzoli, A., Li, L., Griffiths, J., Sang, Y., & Feng, M. (2020). Addressing challenges of urban water management in Chinese Sponge cities via nature-based solutions. *Water*, *12*, 2788.

Qi, Y., Shun Chan, F. K., Griffiths, J., Feng, M., Sang, Y., O'donnell, E., Hutchins, M., Thadani, D. R., Li, G., Shao, M., Xie, L., Liu, S., Zhang, C., Li, X., Liu, L. & Zhong, M. (2021b). Sponge City Program (SCP) and Urban Flood Management (UFM)—The case of Guiyang, SW China. *Water*, *13*.

The UK Parliament. (2010). Flood and Water Management Act 2010 [Online]. https://www.legislation.gov.uk/ukpga/2010/29/contents

Wang, H., Mei, C., Liu, J., & Shao, W. (2018). A new strategy for integrated urban water management in China: Sponge city. *Science China: Technological Sciences*, *61*, 317–329.

Xia, J., & Chen, J. (2020). A new era of flood control strategies from the perspective of managing the 2020 Yangtze River flood. *Science China Earth Sciences*, *64*, 1–9.

Xia, J., Zhang, Y., Xiong, L., He, S., Wang, L., & Yu, Z. (2017). Opportunities and challenges of the Sponge City construction related to urban water issues in China. *Science China Earth Sciences*, *60*, 652–658.

How to cite this article: Qi, Y., Chan, F. K. S., Feng, M., Griffiths, J., Hutchins, M., O'Donnell, E., Thorne, C., Liu, L., Zhang, C., & Li, X. (2023). Developing a "Sponge Catchment Management Plan (SCMP)" framework at the catchment scale: The case of Guiyang, SW China. *River*, 2, 109–125. https://doi.org/10.1002/rvr2.33