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Exploration of Sponge System Design in Wetland Parks Based on Rainwater and Flood Control: A Case Study of Southern Anhui Province

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Abstract Based on the background that wetland resources in China are under threat and urgently need to be protected, a series of rainwater and flood problems caused by urban construction is analyzed comprehensively, and the design and planning methods of wetland parks in response to rainwater and flood disasters caused by floods and heavy rainfall are explored. Southern Anhui with complex and variable terrain and frequent rainfall and flood disasters is selected as the research area, with Xuanzhou District of Xuancheng City as the main research object. The relationship between municipal drainage of urban park and water conservancy drainage is investigated from different sample selection, design samples, and design flow rates. Based on literature review and model building methods, an urban storm flood model suitable for typical wetland parks in southern Anhui is constructed after processing the survey data using Arc GIS, SWMM (storm water management model). On this basis, a methodology and principles for designing a sponge system of wetland park based on rainwater and flood control are proposed, including technical measures such as rainwater collection, retention, and purification. This paper provides certain research results in design schemes, effect evaluations, ecological and social benefits, and useful suggestions and solutions for urban stormwater management and resilience development.

Keywords Wetland park, Rainwater and flood control, Sponge city, Resilient mountain landscape

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With the gradual development of urbanization construction in recent years, the area covered by reinforced concrete on the land has become increasingly large. High-speed urbanization has caused a series of climate change problems, and cities are more prone to rainstorm and waterlogging, and serious urban heat island effect also needs to be solved. It needs to conduct in-depth literature review to understand and study the relevant theories, methods, and latest research achievements of rainwater and flood control. Relevant theoretical frameworks in the field of rainwater and flood control are incorporated into the research[1]. It is of great significance for the sustainable development of urban ecological economy by adapting measures to local conditions to alleviate urban flood disasters, and solving problems such as waterlogging, groundwater scarcity, and river pollution[2].

1 Research background

On October 22, 2014, the *Technical Guidelines for Sponge City Construction* (*Trial Edition*) was officially released. From 2015 to 2016, 30 national-level pilot sponge cities conducted a three-year sponge city pilot project[3]. In recent years, some cities have developed smart rainwater and flood management systems, and various imaging technologies are integrated to form a brand new three-dimensional digital baseboard, visualizing information such as rainfall and water level, and making it easier for management personnel to allocate resources. The Qinhan New City Smart City Management Center in Xixian New Area of Shaanxi Province has reasonably added big data technology to the "Smart Rainwater and Flood" management platform, providing a lot of help for flood season prevention and control work. In addition to regulation, sponge cities focus on the resource utilization of rainwater, and there are many discussions related to the transformation of such a rainwater management concept (especially from the perspective of architectural planning)[4].

1.1 Causes of rain and flood disasters

1.1.1 Natural cause.

(1) The research area is located in southern Anhui (the south of the Yangtze River in Anhui Province, including Wuhu, Ma'anshan, Xuancheng, Chizhou, Tongling, and Huangshan). The hilly area of southern Anhui is located at the intersection of cold and warm air currents from north to south. Due to its proximity to the ocean, the region has entered the rainy season first, with large rainfall, wide coverage, and long duration. The annual precipitation is higher than other areas, with an average annual rainfall of over 1,400 mm. At the same time, due to the uplift effect of the peak, there has been an increase in heavy precipitation, with precipitation exceeding 900 mm during the flood peak period. The annual precipitation in the surrounding areas of Xuancheng City is about 1,300 mm, and the precipitation during flood period is about 70% of the annual precipitation. During the flood, the precipitation also reached over 800 mm. During Meiyu season, precipitation is abundant and concentrated, which can easily lead to floods and landslides. Fig.1 shows the monthly rainfall of Xuancheng City in recent years. Using official data from China Meteorological Network, and collecting the required years, the software Origin 2021 is used for mapping. It clearly explains the precipitation in each month of different years, which has not changed significantly in recent years, but the precipitation period is relatively concentrated.

(2) The large surface runoff but short collection time in the southern Anhui region is caused by geographical factor. There are many mountainous areas in southern Anhui, and the rivers and streams are mostly closed small watersheds. The geometric characteristic values of the watercourse are relatively large, and rainfall in a short period of time is easy to form flood peaks.

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1.1.2 Human factor. Table 1 provides a comprehensive analysis and summary of human factors through research, literature review, and news organization[5].

1.2 Drainage system

In the process of rapid urbanization in China, the infrastructure and planning and design of pipe network of urban drainage system cannot adapt to the growing runoff, which easily leads to urban waterlogging in rainstorm. Fig.2 is rainwater zoning planning of Xuancheng City. The increase in runoff can be explained from two aspects: firstly, the microclimate change caused by urbanization and the decrease in canopy interception caused by vegetation reduction; the decrease in infiltration caused by the increase in surface impermeability; secondly, the increase in flow velocity caused by the decrease in roughness of flow channels and pipelines[6]. The drainage system of Xuancheng City is taken as the research object, and the drainage system planning of Xuancheng City is shown in Fig.2. Based on terrain and watershed, the water system planning area of the Shuiyang River into ten major zones is divided into: Chengdong Lianwei, Qingxi River, Tongzigang River, Guantang River, Jingtingwei, Daocha River, Meixi River, Baima River, Baima River low discharge area, Shuangqiao Lianwei; the water system planning area of the Qingyi River is divided into two major zones: Xijing River and Changqiao River; there are a total of 12 major divisions mentioned above.

Regarding the calculation of water conservancy pipeline networks, simple hydraulic pipeline network calculations only involve the application of relevant formulas and specifications. There are detailed methods in design institutes and other units, and at most, local hydraulic models are added to simulate important parts. For the calculation of control and storage capacity of low-impact development facilities, the *Technical Guidelines for Sponge City Construction* (*Trial Edition*) only provides rough estimation methods such as volume method, which is also widely used in pilot construction of many places. In addition to the methods given in the guide, the calculation of water conservancy pipe network can also use SWMM (storm water management model) for calculating. Some of its models include the so-called LID (low impact development) module, whose calculation principle essentially emphasizes the effect of the region on rainwater retention[7]. The LID concept mostly relies on low impact development facilities such as retention zones, rainwater gardens, and permeable pavements to play a role, and enhance the source, which is more suitable for small and medium-sized rainfall events. Compared to this, the regulation of the source is quite limited. In pilot construction of many sponge cities in China, they tend to adopt the LID concept to achieve the goal of "not accumulating water by light rain", and it is also easier to achieve results[8].

1.3 Current situation of flood disasters

Due to its unique geographical location and weather environment, water disasters in the southern Anhui region present three major characteristics. ① High frequency of occurrence. On average, one to two major floods occur every year. ② Widespread impact of disasters. There are certain flood disasters in various cities of the southern Anhui region. ③ The damage caused after a disaster is enormous. People have a traditional habit of choosing water to live in. Most of the cultivated land and properties are located on both sides of the river and near reservoirs. Therefore, half of the population's life and property safety are highly susceptible to flooding. To solve the relationship between people and the environment, it is necessary to improve the scientific level of flood prevention and disaster reduction.

2 Research methods

Data collection and analysis: data and information related to the research topic are collected. Necessary measurement work is performed, such as measuring the ground elevation, water level, and capacity of rainwater collection facilities in the park. This may include rainfall data, historic records of flood, rainfall patterns, water quality monitoring data, etc. Through data collection, it can gain a deeper understanding of rainfall conditions, flood risks, and water resource conditions. Precipitation data, rainfall patterns, historic records of flood, water quality monitoring data, etc. should be reasonably utilized. Using statistical analysis, geographic information system (GIS) analysis, model simulation and other methods, the design effectiveness of existing sponge system is evaluated, and the rainfall situation, flood risk, and water resource situation in southern Anhui are deeply understood, extracting valuable insights and conclusions from them[9].

Public research and interviews: go to the selected wetland park for on-site investigation. This includes observing and recording the geographical environment, topography, hydrological characteristics, and existing rainwater and flood control facilities of the wetland park. Field investigation can provide intuitive information and data, helping to understand the actual situation and problems. Interviews and exchanges are conducted with management departments, designers, engineers, and relevant experts of wetland parks. Through communication with relevant personnel, the current status of rainwater and flood control facilities in wetland parks can be obtained.

3 Case application: southern Anhui region

3.1 Overview of the study area

Southern Anhui refers to the area in the south of the Yangtze River in Anhui Province, including Xuancheng, Chizhou, Huangshan, and other cities. The southern Anhui region is mainly mountainous and hilly, and Fig.3 shows an overview of the southern Anhui region. The annual average precipitation is 1,100−2,500 mm, and annual average temperature is 15.5−16.3 ℃, making it the main transition zone from subtropical to temperate regions. Xuancheng City is located in the southeast of Anhui Province. As a resource-based city with mountains and rivers, three major mountains converge here, and there are also five major water systems within its territory[10].

Xuancheng City belongs to the subtropical monsoon humid climate zone. Fig.4 is a geographical overview of Xuancheng area. The northern part of the territory is relatively flat, with many water systems. There are more hills in the south, high in the south and low in the north,

Table 1 Influence of human factors

Influence factor	Surface phenomena	Root cause
Economic factor	Water conservancy facilities are insufficient to resist disasters, and most of the existing flood control facilities are outdated	Water conservancy construction has not been given sufficient attention, and governments at all levels lack funding support
Ecological environment factor	Soil erosion causes the riverbed to be raised, and the water level is affected during both dry and wet seasons	The interception of rainwater decreases, causing rainwater to wash the ground and carry sediment, to form flash floods
River occupation factor	Multiple factors occupy the river channel, and surface runoff cannot play a role, which can easily lead to greater disasters	Natural rivers and lakes at all levels are destroyed, and flood regulation capacity is weakened

with abundant rainfall. In spring, the temperature rises but is not stable. Due to the influence of Meiyu, the rainfall is relatively concentrated, often accompanied by floods. In summer, it is often accompanied by high temperature and drought.

3.2 Anhui Xuancheng Wanling Lake Provincial Wetland Park

The research object is Wanling Lake Provincial Wetland Park, located in the southeast of Xuancheng City, with an area of approximately 268 hm^2. It is a typical freshwater lake wetland[11]. Xuancheng City, located in the southern Anhui region, is mainly mountainous and hilly, with vegetation mostly ranging from tropical to subtropical components. The average annual temperature is 15.0−16.4 ˚C, and the average annual precipitation is 1,200−2,600 mm. It is a transitional area from subtropical to temperate regions. Based on the protection and restoration of wetlands, its three basic functions are exerted: ecological protection, science education, and ecotourism. The habitats of rare birds are protected, and humanity and nature are showed in a landscape manner. It can be used for tourism, sports, leisure, and science education, and built into a provincial-level wetland park.

3.3 Specific analysis of the research area

(1) Parks can be roughly divided into reasonable utilization, management services, restoration and reconstruction, and education and display. From the micro regulatory mechanism to the macro level of rainwater management, afforestation and greening of the lake island are conducted, and wetland plants are planted. Water seepage and purification capacity is improved, and environmental conditions are repaired, and an ecological bird island is built.

(2) The restoration and reconstruction area has an island in the center of the lake, surrounded by aquatic plants such as reeds, calamus, and black algae. It should minimize development impact as much as possible. Through the comprehensive use of physical, biological, and ecological methods, the area is gradually restored, creating a sponge system to restore the ecological and natural environment[12].

(3) According to the terrain characteristics, there are small hills of varying heights distributed around the current site, which can be seen as a buffer zone separating the city and gardens, with a certain rainfall purification function. At the same time, there are also supporting waterfront leisure spaces such as wooden boardwalks, elevated boardwalks, and riverside landscape platforms. They combine with moist vegetation for flood resistance to form a waterfront leisure activity space, enhancing the water absorption and storage capacity of the land. Fig.5 is a photo obtained from field investigation.

(4) Faced with the threat of rainstorm and flood, the park lacks the equipment for rainwater

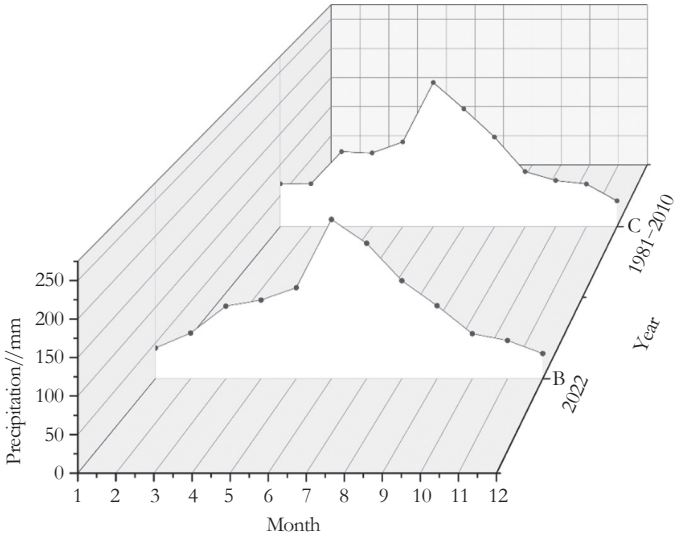

Fig.1 Monthly precipitation in Xuancheng City

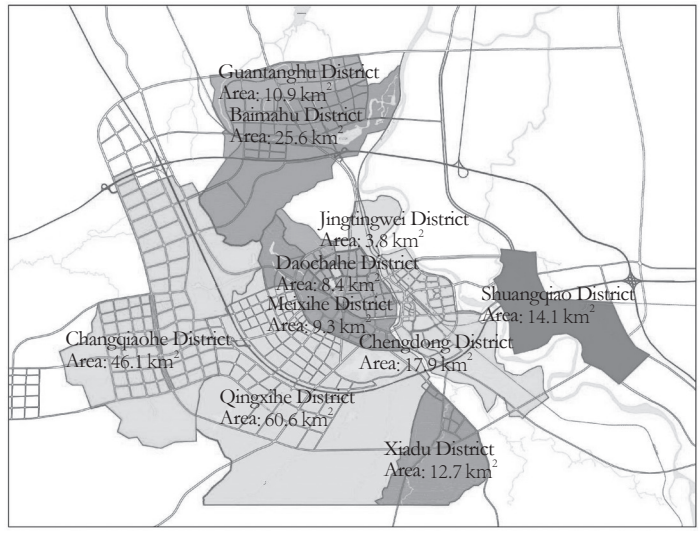

Fig.2 Rainwater zoning planning in Xuancheng City

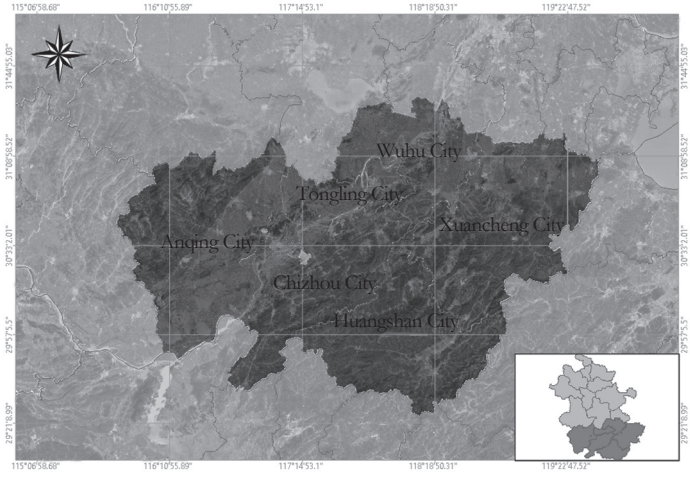

Fig.3 Geographical overview of southern Anhui region

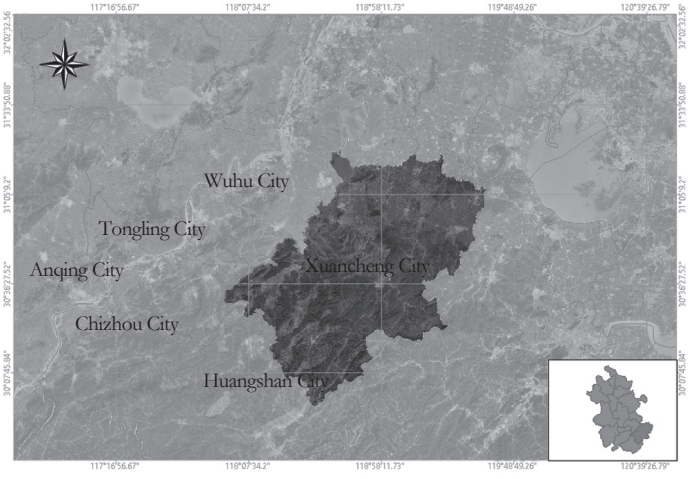

Fig.4 Geographical overview of Xuancheng City

utilization, detention and collection, which leads to the rainwater of the park being directly discharged into municipal engineers outside the park without sufficient water supply, resulting in a gradual reduction in the area of the water body. In multiple important links of sponge city, there is a need for updates and upgrades in order to achieve better results[13].

3.4 Design concept

(1) Based on the degree and height of submergence, the protection circle of the wetland is graded and divided. Based on the main surface runoff, the catchment zone and its area are determined and planned. At the same time, artificial wetlands can also be used to store water and replenish water sources.

(2) As shown in Fig.6, during the design process, a mathematical model of elevation change is established through the analysis of elevation data, and the range of water level change is determined, and the water level change is quantified to determine the normal and maximum storage capacity of the site. Buffer zone is a barrier between a city and a wetland park. The buffer zone not only effectively protects the ecological environment of wetland, but also plays a certain role in urban development to a certain extent.

(3) The elevated piers, sightseeing towers, and observation platforms set up in wetland parks can minimize the intervention of natural wetlands and form the internal tourism system of the park. It meets the basic demands of surrounding residents for recreation and water friendliness, without disturbing the ecological environment.

Fig.5 Ecological slope protection landscape in the park

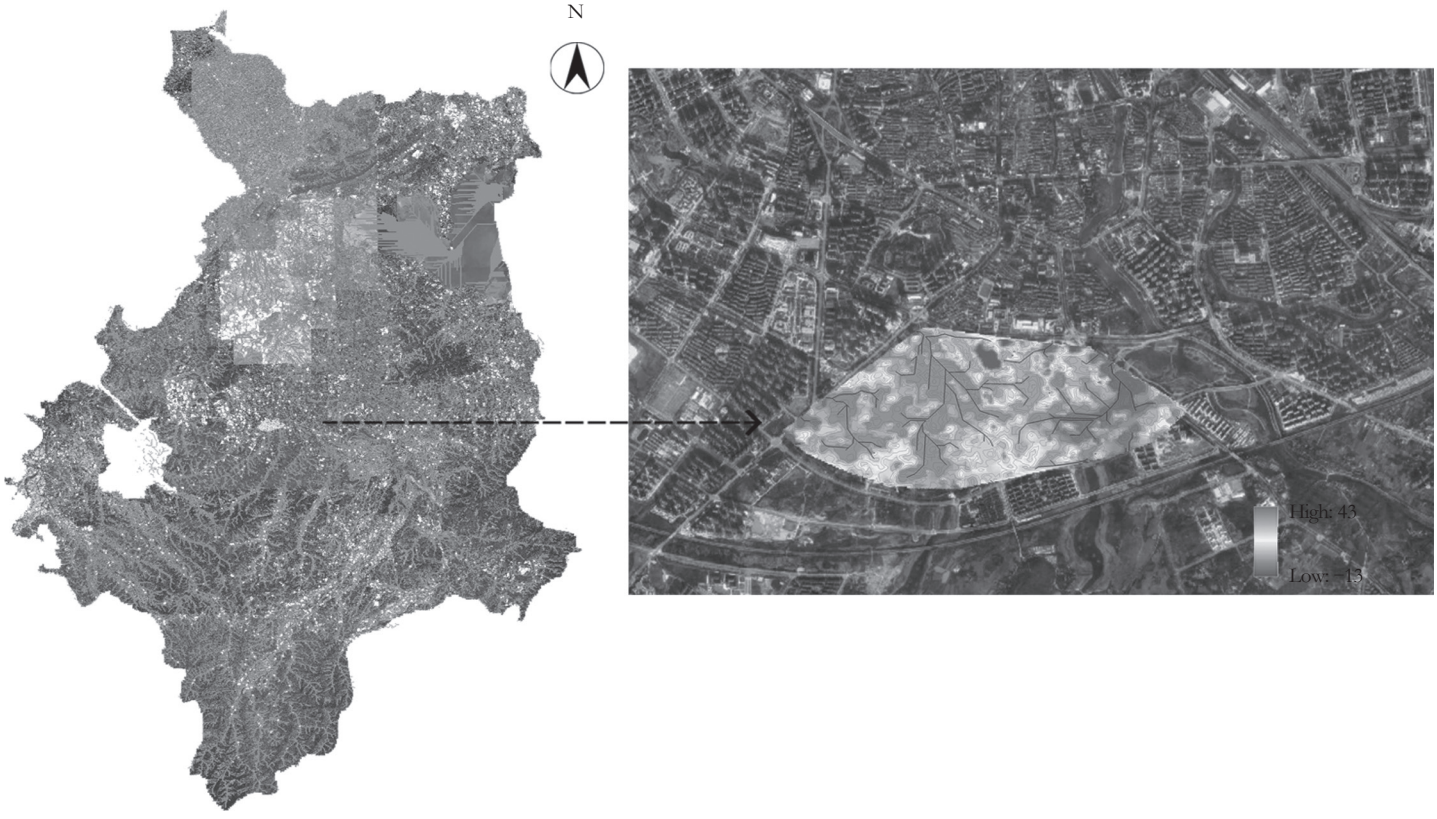

Fig.6 Surface runoff simulation of Yuanling Lake

Table 2 Scheduling of spatial scale

Spatial scale	Optimization measure	How to schedule scientifically
Macro-scale (city)	Governments at all levels and expert teams should conduct site selection and scale research for water conservancy projects; strive to create a good rainwater and flood management model for mountainous small towns	At the design level, it should comprehensively consider the rainfall and flood situation over the years for planning and interdisciplinary communication; conclusion on certain measures could be obtained after the sensitivity evaluation and analysis of sponge ecology
Meso-scale (town)	Scientifically schedule water conservancy projects; utilizing the intercepted rainwater and flood, combining with measures such as water purification	Manage and dispatch water conservancy projects at all levels, and draw certain conclusions on measures after simulating hydrological processes in space
Micro-scale (site)	Site should be adjusted according to local conditions, and it should make reasonable use of the various current conditions of the site	Making good use of rainwater and flood resources; based on the simulation of surface runoff process, the design and planning ideas are derived through analysis and derivation

(4) On this basis, by constructing flood water level landscapes with multiple repeated cycles, the construction of "easily flooded areas", "difficultly flooded areas", and "safest recreational areas" relative to the areas with different degrees of flooding can be achieved, enhancing the resilience of urban water systems.

4 How to improve the current situation

4.1 Plan first and scientifically draw a blueprint for prevention and control

The problem of flooding is almost impossible to completely avoid, and it requires scientific and rational layout and planning. At present, some wetland parks are fully considered in the design, such as Fenghe Wetland Park. Based on this, a micro terrain landscape system has been established using methods such as earthwork excavation and backfilling. Based on this, a landscape with sponge function has been shaped. During the dry season, rainwater gardens, artificial wetlands, and blocky retention ponds are used to collect rainwater and alleviate water scarcity issues. In terms of purifying water sources, the existing water source pumping stations are used to discharge unpurified water sources, which are organically combined with artificial ecological wetlands for multi-level purification, so that their water quality meets the requirements of park construction.

4.2 Optimizing and improving, and doing a good job in regulating rain–water and flood

In the hilly areas of southern Anhui, it is crucial to make rational use of rainwater and flood. Interception of rainwater and flood can effectively prevent floods and make rational use of water sources, achieving a virtuous hydrological cycle in the city. The terrain and landforms of mountainous small towns are complex and varied. The characteristics of rainfall and flood disasters exhibit unique attributes, and the mechanism of their occurrence involves the influence of multi-scale and multi-regional factors. Based on theoretical research on urban resilience and sponge cities, a rainwater and flood management model for mountainous small towns is constructed, and quantitative and visual simulation analysis methods are used[14]. From Table 2, it can be seen that rainwater and flood management is a multi-scale system. It should establish a multi-scale system, and conduct coordination and connection at various scales. This project takes small towns in mountainous areas as the research object. With the help of some suitable evaluation model tools, combined with theoretical foundations such as analytic hierarchy process and runoff curve model, hydrological processes in macro-scale and meso-scale space are simulated, and hydrological characteristics in small towns of mountainous areas and the mechanism of rainfall and flood disasters are analyzed in micro-scale space. By simulating hydrological processes at three scales: macro space, meso space, and micro space, rain and flood management measures and strategies for sponge safety pattern construction, catchment network layout, and sponge facility regulation are derived.

5 Summary

5.1 Conclusions

(1) Enhancing flood resistance. By observing and recording the geographical environment, topography, and hydrological characteristics of wetland parks, the current flood risk can be assessed. Based on data, appropriate rainwater and flood control facilities could be designed to improve the flood resistance of wetland parks and surrounding areas. A certain level of resilience can be increased to better cope with possible extreme rainfall events.

(2) Protecting ecosystem services. Wetland parks generally have good conditions and provide a variety of ecosystem services. By observing and recording wetland vegetation, water conditions, etc., the current situation can be evaluated, and corresponding measures can be designed to better protect and enhance it.

(3) Promoting community participation and sharing. During the field research process, it should collaborate and exchange with local community residents, government agencies, and relevant stakeholders to collect perspectives, opinions, and needs. It could promote community participation and sharing, jointly participate in the design and decision-making process, and establish a more inclusive and sustainable wetland park sponge system.

(4) Long-term monitoring and flexible adjustment. In field research, a long-term monitoring system can be established to collect data and conduct regular evaluations. It could identify issues and changes, make adjustments, and optimize the design. Through continuous and flexible adjustments, the sponge system of wetland parks can be ensured to remain resilient and sustainable in the face of constantly changing environmental pressures and demands.

5.2 Prospect

(1) It should evaluate the flood response capacity and water resource utilization of wetland parks under rainfall and flood events through more sufficient data analysis and more comprehensive model simulations. A more practical design plan for rainwater and flood control facilities is proposed.

(2) The correlation between rain and flood control and urban resilience: exploring the interrelationship between rain and flood control and urban resilience, interacting in multiple directions, and analyzing the impact of rain and flood control on urban resilience. Multi disciplinary communication and integration are conducted. The role of rain and flood control in improving urban flood resistance, ensuring water resource supply, and improving environmental quality, and its impact on social and economic development are studied.

By implementing the above measures, research can be aligned with rainfall and flood control, making it more relevant to practical applications. Through case studies, rainfall and flood control measures and methods at various scales can be derived, forming a multi-level and systematic framework system for resilient rainfall and flood management in mountainous areas. Because most of the data and parameters require approval from relevant departments, if set based solely on experience, the simulated

evaluation results may have some deviation. For the long-term process of rainwater and flood management, a long-term rainfall management monitoring mechanism is adopted to verify the accuracy of the model. On the basis of the preliminary work, this project plans to further carry out research on relevant theories and methods to provide reliable theoretical basis for further improving the accuracy of the model. On this basis, the accuracy of the model will be further improved through interdisciplinary integration.

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quality and level. On the other hand, the current consumption in the cultural and tourism industry market is constantly upgrading, and people are constantly pursuing new consumption trends. Therefore, Yannanfei Tea Field Resort needs to develop distinctive cultural and tourism new formats based on new market demands and its own resource advantages. It could timely develop starry sky accommodation, tent accommodation, and wild luxury vacation format in tea field; carry out customized tea cultivation, harvesting, production, and supply to high-end customers through the form of tea field crowdfunding.

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