

Hydrological Enclaves: Adaptive Management of Non-Water Supply Reservoirs in Shenzhen, China

Shuyang SUN*

Division of Landscape Architecture, Faculty of Architecture, The University of Hong Kong, Hong Kong 999077, China

***CORRESPONDING AUTHOR**
Address: Knowles Building, The University of Hong Kong, Pokfulam Road, Hong Kong 999077, China
Email: shuyang98@connect.hku.hk

ABSTRACT

This research focuses on Shenzhen’s “urban waters,” particularly small-sized reservoirs that are undergoing rapid transformations due to the cross-municipality water supply centralization project launched in 2019, which includes the expansion of trans-basin water transfer capacity, the completion of Shenzhen’s first-ever two large-sized reservoirs, and the decommissioning of small-sized reservoirs. Applying an iterative design-research process, this project focuses on a chain of small reservoirs located along the northwestern foothills of Tanglang Mountain and uses the term “Hydrological Enclaves” to reveal the three interconnected realities of these soon-to-be decommissioned small-sized reservoirs in Shenzhen. First, it indicates their unique morphology of being surrounded by dense urban fabric; second, it refers to the fact that these small-sized reservoirs have long been “out of sight, out of mind” for that their existence is rarely known by the public; and third, it reveals the complex hydrosocial relationships between reservoirs and the larger landscape system of which they are part. This project aims to adapt these soon-to-be decommissioned small-sized reservoirs into decentralized off-grid water sources to increase local water resiliency. Simultaneously, the proposed water infrastructure also plays a much-needed educational role where visual and tactile experiences are curated to exhibit landscape performance and its critical connection with water security.

KEYWORDS

Water Security;
Water Supply Reservoir;
Non-Water Supply Reservoir;
Water Infrastructure;
Educational Infrastructure;
Shenzhen

HIGHLIGHTS

- Positions decommissioned water supply reservoirs in Shenzhen as a unique urban heritage
- Identifies socio-ecological risks and functional opportunities of non-water supply reservoirs
- Reveals the complex hydro-social relationships between reservoirs and the larger landscape system
- Curates visual and tactile experiences to communicate ecological and hydrological processes in the landscape
- Encourages multi-stakeholder collaboration to improve landscape stewardship and water security

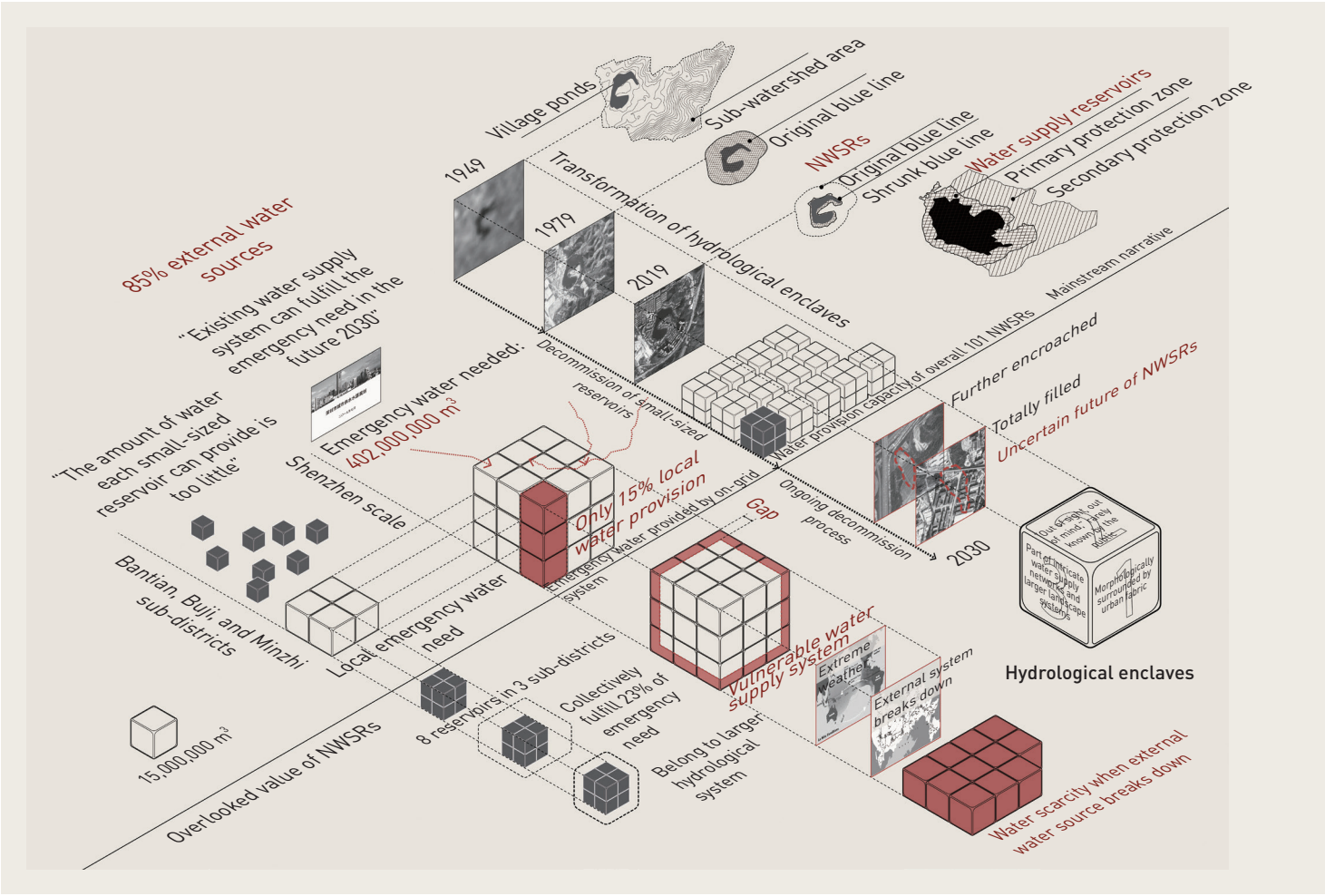
EDITED BY
Ying WANG, Yuting GAO

1 Design Context

There are several key components of the ongoing water supply centralization in Shenzhen, China. The first is the expansion of water transfer capacity between basins, namely importing water from Xijiang River to increase the amount of water of the city currently imported from Dongjiang River. The second is the construction of two first-ever large-sized reservoirs in Shenzhen, over 100 million cubic meters each in storage capacity. And the last is the decommissioning of small-sized reservoirs, which are deemed superfluous in a centralized and efficient water supply management system^[1]. The decommissioning process is carried out through changing reservoirs' status from water supply reservoirs to non-water supply reservoirs (NWSRs), leaving them subject to a range of socio-economic and environmental challenges. According to the 2019 Shenzhen Urban Water Supply Planning, the number of water supply reservoirs would be reduced from 68 to 29^[2].

Currently, water diverted from Dongjiang River, an extra-municipal water source, accounts for more than 85% of the

yearly fresh water supply in Shenzhen^[3]. Eliminating small-sized reservoirs from the water supply system will further decrease the percentage of water sourced locally, exposing Shenzhen to huge risk in light of potential disruption of trans-basin water supply system currently connected to Dongjiang River, and to Xijiang River in the near future. In the ideal scenario outlined in the official report, medium- and large-sized reservoirs with full reservoir level could fulfill 402 million cubic meters of emergency water need of Shenzhen^[4]. However, realities such as the recorded water levels hitting all-time lows and getting dangerously close to becoming a “dead pool” in these reservoirs challenge the mainstream narrative of water security^[5]. Also, while the Water Authority of Shenzhen Municipality argues that the amount of water of each small-sized reservoir could barely fulfill a fraction of need, a detailed calculation reveals how collectively they formed a sizable system able to serve the need in the face of emergency situations such as droughts and interrupted water supply from Dongjiang River and Xijiang River at the local level (Fig. 1). For example, there is a chain of eight small-sized reservoirs located along the northwestern foothill of



1. Overview of ongoing water supply centralization in Shenzhen

Tanglang Mountain that spans Bantian, Buji, and Minzhi Sub-districts of Shenzhen. Collectively, they have the capacity to store a significant amount of water for emergency use, fulfilling 23% of the total need of the three subdistricts. This project foregrounds the overlooked value and potential of small-sized reservoirs undergoing rapid transformations due to the municipal-wide water supply centralization project launched in 2019 (Fig. 1).

2 Design Proposition

Titled “Hydrological Enclaves,” it highlights three interconnected realities of these soon-to-be decommissioned reservoirs, while simultaneously sheds light on possible locations for design intervention.

First, Hydrological Enclaves indicates the unique morphology where small-sized reservoirs are surrounded by densely built urban context. Initially constructed for irrigating surrounding farmlands, these reservoirs went through rapid transformations since the late 1970s as Shenzhen’s major water usage shifted from rural to urban and industrial, and surrounding farmlands were gradually replaced by urban development.^[6] This project positions small-sized reservoirs as a unique urban heritage and argues that interventions are urgently needed to avoid the loss of these valuable social and ecological assets. Shenzhen’s demand for urban development land and the lack of strict regulations protecting the NWSRs could result in the encroachment of buildings right up to the very edge of the reservoirs, and even entire “reclamation” of the reservoirs, as shown in the analysis of satellite images (Fig. 1).

Second, Hydrological Enclaves refers to the fact that these small-sized reservoirs have long been “out of sight, out of mind.” Despite that they are embedded within the urban fabric, their existence is rarely known by the public. Water infrastructures, including urban reservoirs in Shenzhen, are under strict control and completely fenced off to prohibit public access. With this in mind, this project recognizes small-sized reservoirs as important public amenities and identifies the ongoing decommissioning process as an opportunity to increase public access to these much-needed urban recreational spaces as well as promote public awareness of the socio-environmental values of these urban water infrastructures.

Third, Hydrological Enclaves points out the lack of understanding of how small-sized reservoirs are part of an intricate network of water supply and situated within larger ecological and hydrological systems. Closely related to the previous two interpretations, this third interpretation of Hydrological

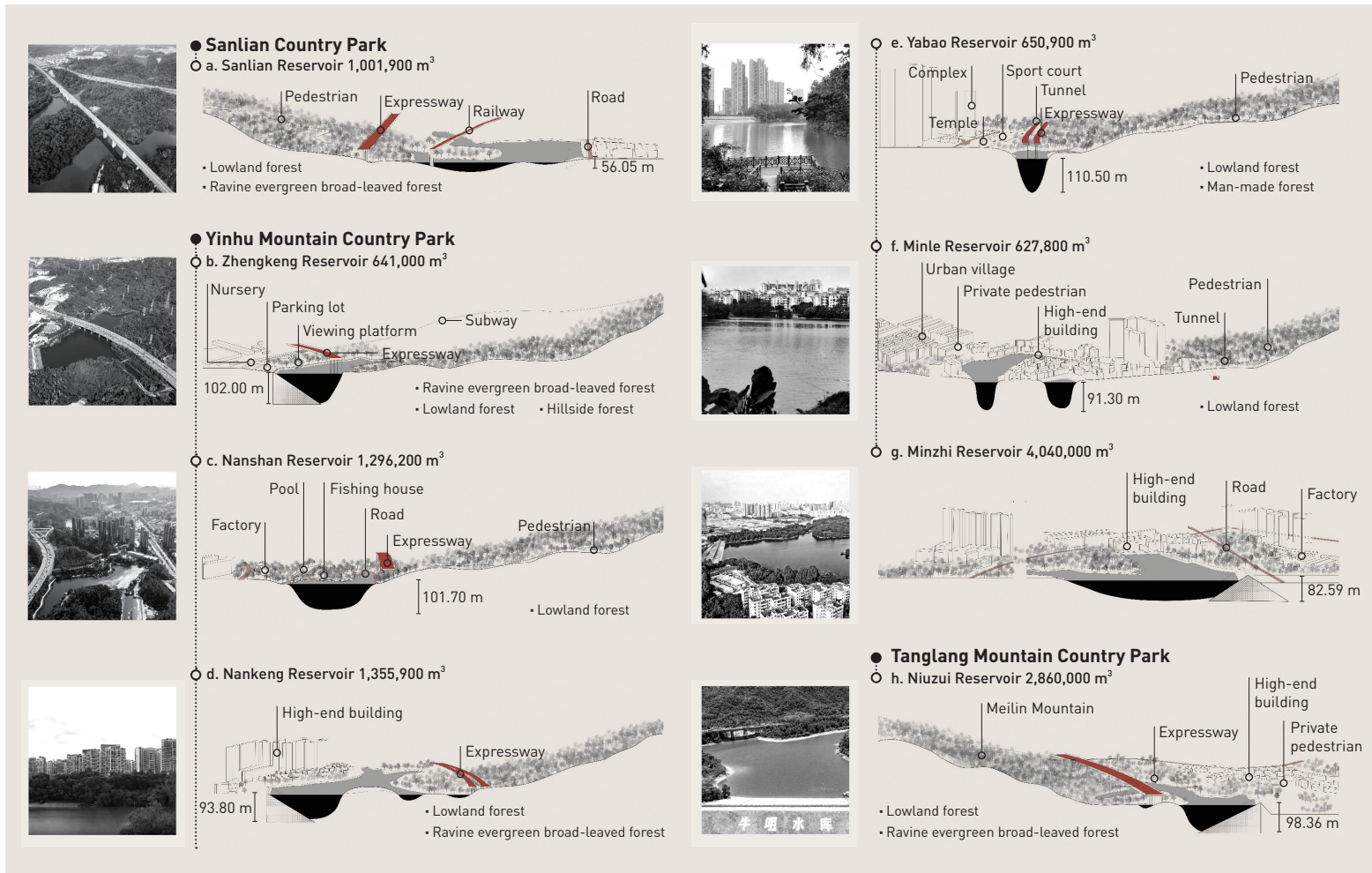
Enclaves specifies directions of landscape interventions. First and foremost, this project aims to adapt these soon-to-be decommissioned small-sized reservoirs into decentralized off-grid water sources to increase local water resiliency. Simultaneously, transforming them from on-grid to off-grid water infrastructure necessitates an alternative sub-watershed management scheme to ensure the preferable quantities and qualities of water collected and stored for emergency water supply. Last but not least, it aims to create a resilient water infrastructure that simultaneously serves as a much-needed educational infrastructure where the performance of the landscape system and its critical connections with water security is communicated to the public through spatial and material approaches. A chain of small-sized reservoirs located along the northwestern foothill of Tanglang Mountain is used to test these interconnected propositions.

3 Site Construction

3.1 Landscape Transects

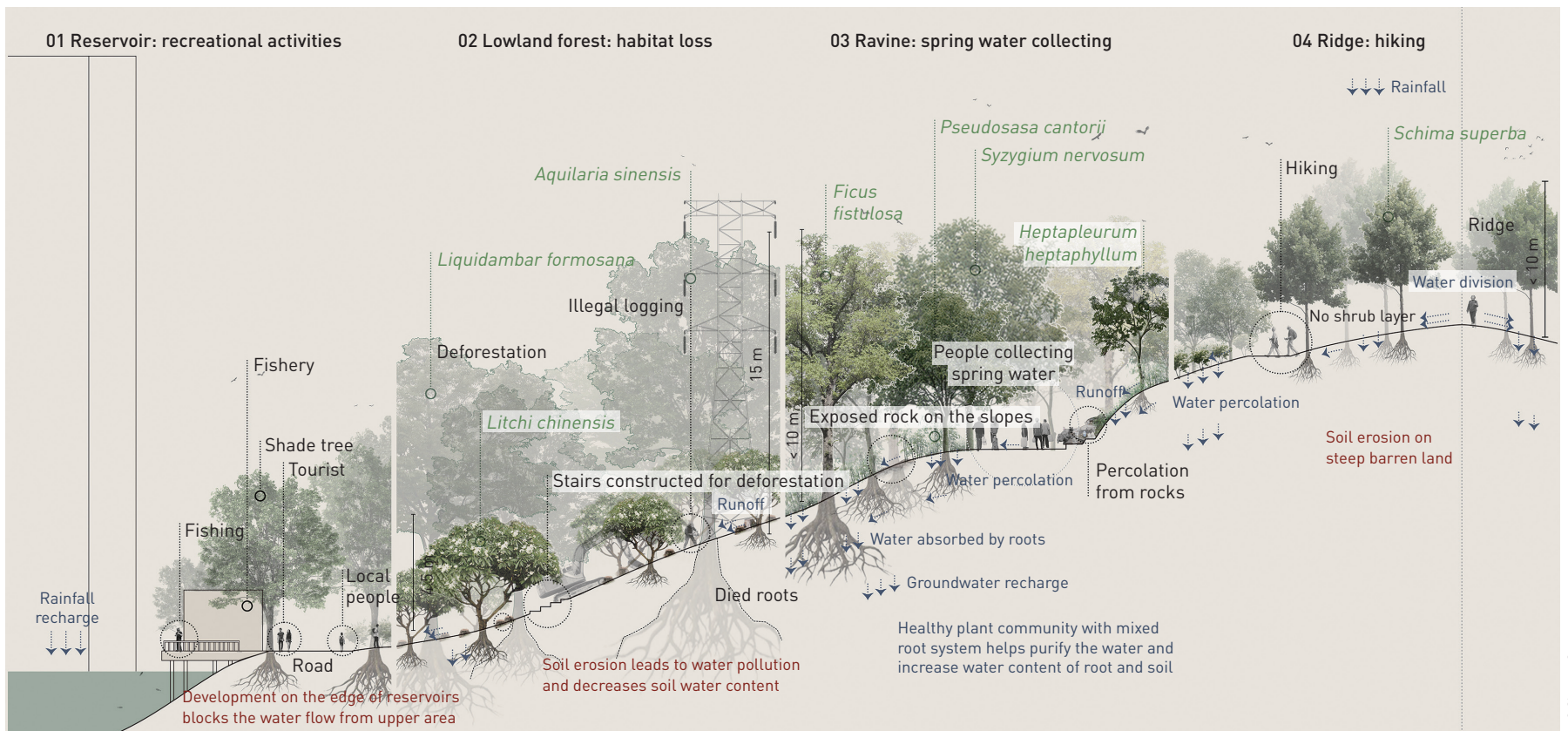
This project adopts an iterative design-research process. First, it uses landscape transects to facilitate information gathering and synthesis. Based on information extracted from various local news media over the past two decades, a sequence of landscape transects of Tanglang Mountain have been constructed. These transects reveal hydrological impacts of major infrastructure projects such as Nanping Expressway. They also show more nuanced and dynamic human activities in the landscape and how human-induced landscape transformations in the sub-watersheds greatly impact the quantity and quality of water in the downstream reservoirs. For example, situated along the edge of the reservoirs, recreational facilities such as private fishing centers interrupt and contaminate runoff from upstream. Illegal logging, firebreak maintenance, and other human activities in the upstream lead to soil erosion and reduction of water holding capacity in the root zone, consequently resulting in negative impacts on the quantity and quality of water feeding into the reservoirs.^[7]

These transects also highlight often overlooked ecological and cultural processes embedded in the landscape to identify possible locations for intervention. For example, different vegetation species, with different water holding and water purification capacities, collectively define the hydrological function within the watershed. As a cultural practice, local people have long been collecting natural spring water while hiking in the country parks as they believe the water from Tanglang Mountain is more natural and healthier (Figs. 2, 3).

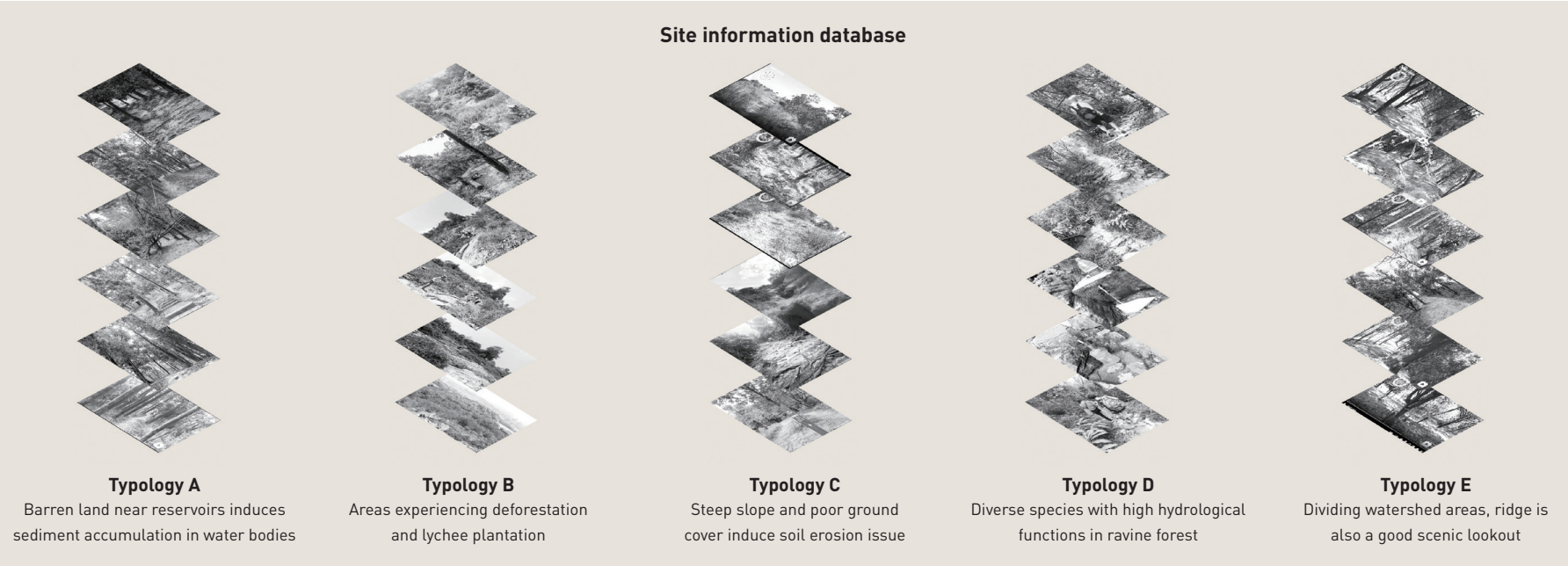


2. A chain of 8 small-sized reservoirs located along the northwestern foothill of Tanglang Mountain
3. A diagrammatic transect of Yinhu Mountain Country Park, one of the three country parks in Tanglang Mountain.

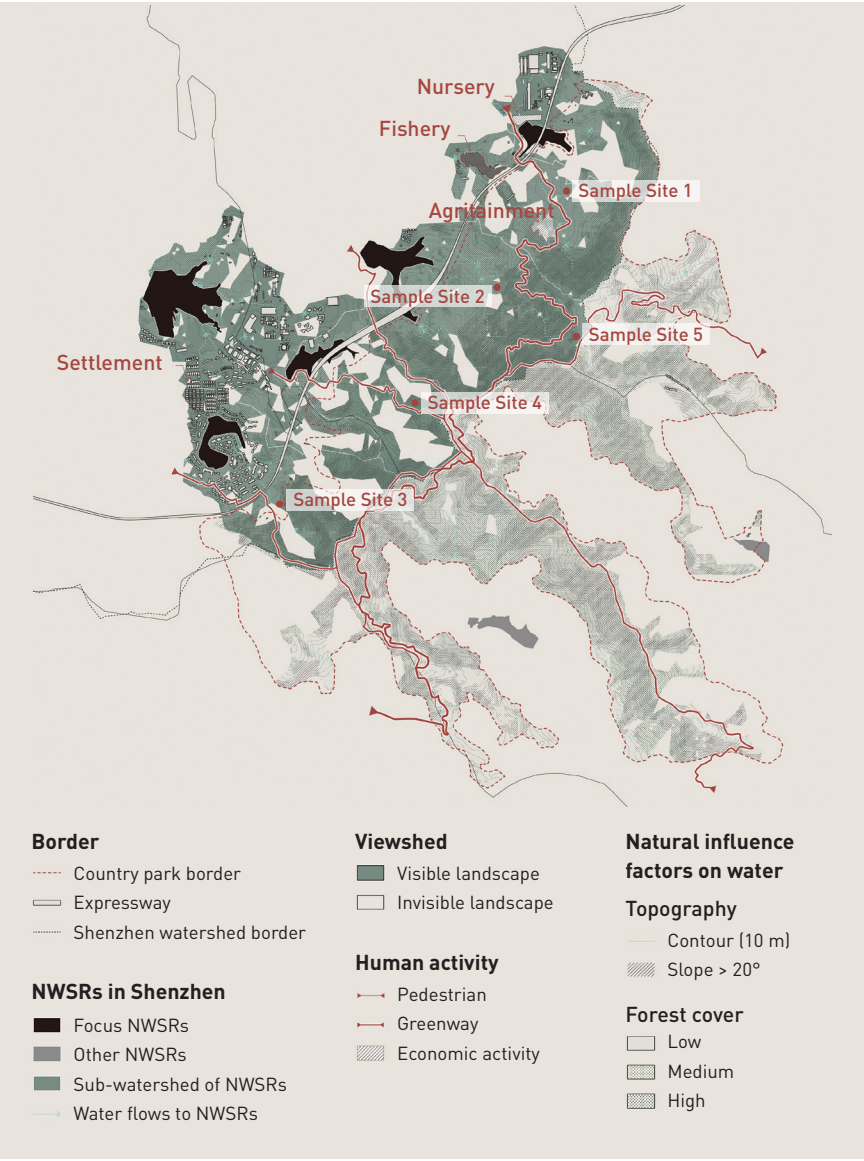
© Shuyang Sun



© Shuyang Sun



© Shuyang Sun
4-1



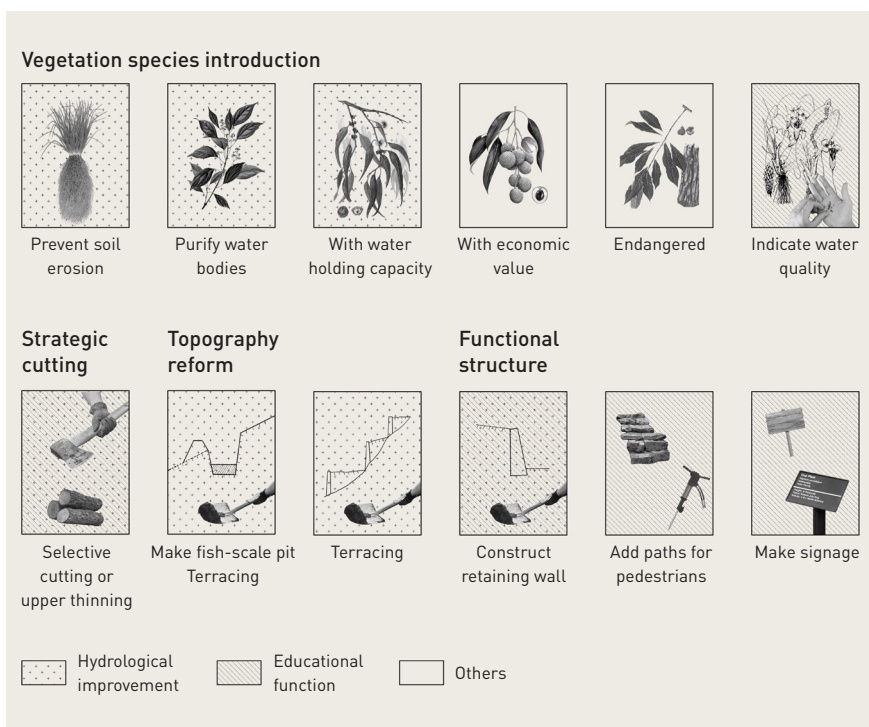
© Shuyang Sun
4-2

4. A ground truthing process: site information validation and landscape typologies identification

3.2 Ground Truthing

To better understand people's perception of the existing landscape and identify potential space for intervention, a virtual ground truthing process is deployed to construct the conceptual dimension of the sub-watershed area of 6 small-sized reservoirs that located on the foot of Yinhu Mountain Country Park. This ground truthing process allows to compare and crosscheck information constructed in GIS, including a viewshed that delineates area visible from existing major trails in the Yinhu Mountain Country Park, and those extracted from hiking apps and social media (e.g., Bilibili, Xiaohongshu, Sina Weibo) that reveal the materiality of the landscape as well as spatial and temporal dimension of visitors' grounded experience. Five major landscape typologies are identified through this process of site construction. Major socio-ecological risks and functional opportunities are displayed for each typology (Fig. 4).

A landscape intervention toolkit is created in response to the risks and functions identified. Strategies in the toolkit include three major types, namely strategic planting and clearing, changes in topography, and micro-infrastructure upgrades. Collectively, they strengthen the capacity of the landscape within each watershed to serve as a water infrastructure with improved



© Shuyang Sun
5-1

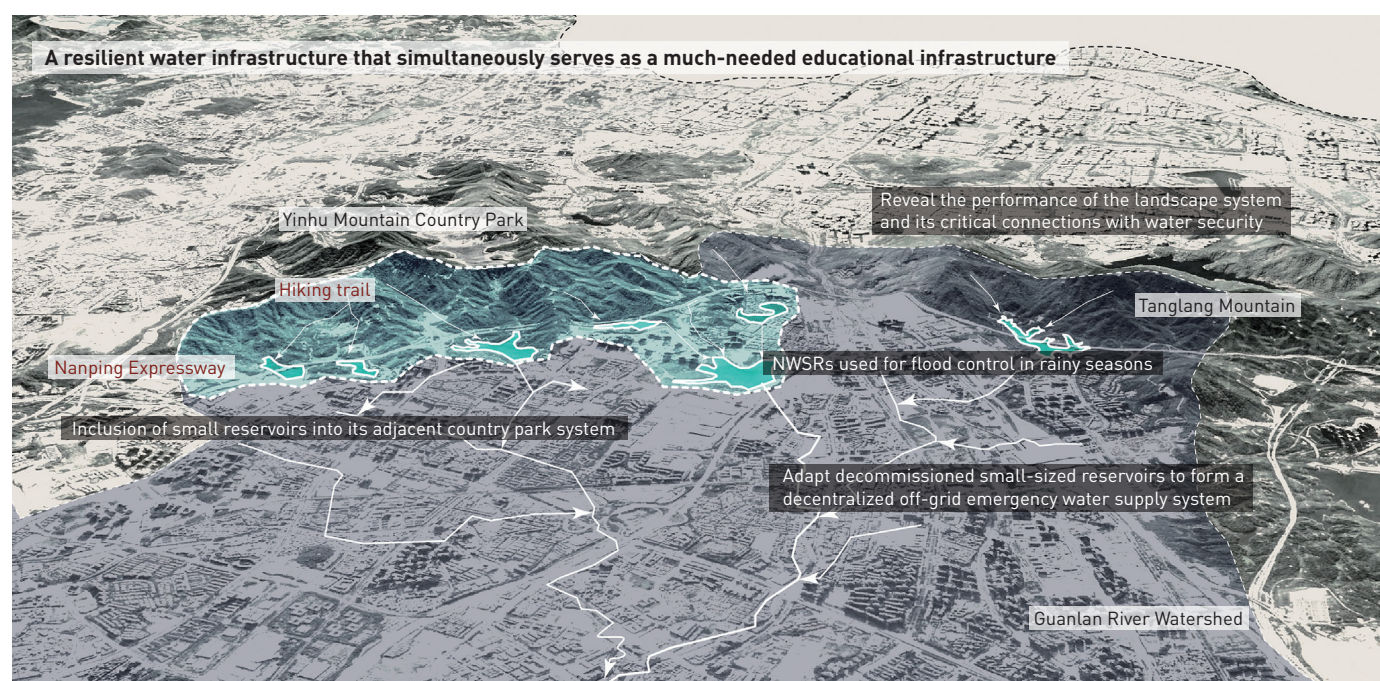
ecological and hydrological functions. Simultaneously, they enrich visitors' visual and tactile experiences in the country park, while communicating the functionality of the landscape and the intricate interrelationships between reservoirs downstream and hiking trails navigating upstream (Fig. 5).

4 Design Speculation

A sequence of sections and eye-level perspectives illustrate how diverse strategies using the proposed landscape intervention toolkit can be combined and applied to five major landscape typologies identified in the ground truthing process. Collectively, the implementation of selected strategies at five sample sites aims to strengthen ecological and hydrological functions at the sub-watershed scale, as well as communicate landscape system performance and its intricate connections with water security to the public.

4.1 Sample Site 1: Reducing Sediment Accumulation in Reservoirs

Located in the upper reaches of the sub-watershed of Nanshan Reservoir, Sample Site 1 represents a typical site condition within the Yinhu Mountain Country Park characterized by steep slopes and degraded vegetation cover. To reduce sediment accumulation downstream in the Nanshan Reservoir, major strategies applied at Sample Site 1 include the construction of multi-functional small-scale retaining walls and restoration of vegetation cover. The system of retaining walls established at strategic locations serves the following functions. First, they help block sediments eroding from the higher slopes. Second, they provide a way of measuring and communicating to the public the amount of sediments accumulated. Third, sediment collected can be used as a growing medium for



© Shuyang Sun
5-2

5. Major strategies in the landscape intervention toolkit

restoring vegetation cover. Notably, since sediment accumulation greatly impacts the burgeoning private fishing centers established around Nanshan Reservoir, this intervention seeks to establish collaboration between fishing center owners and the country park manager in the landscape intervention process (Fig. 6).

4.2 Sample Site 2: Balancing Ecological and Economic Values of Landscape

Located in the upper reaches of the sub-watershed of Zhengkeng Reservoir, Sample Site 2 represents a typical site condition within the Yinhu Mountain country park that is characterized by dominant monocultures. The site first witnessed the rapid expansion of lychee orchards in the 1960s. Although the price of lychees is relatively low, orchards remain and have even expanded over the last two decades. Local villagers practice this kind of monoculture as a means to occupying land in anticipation of getting compensation from future conservation and development projects. Such land speculation leads to extensive deforestation, particularly the loss of old and valuable trees. The major strategies applied at Sample

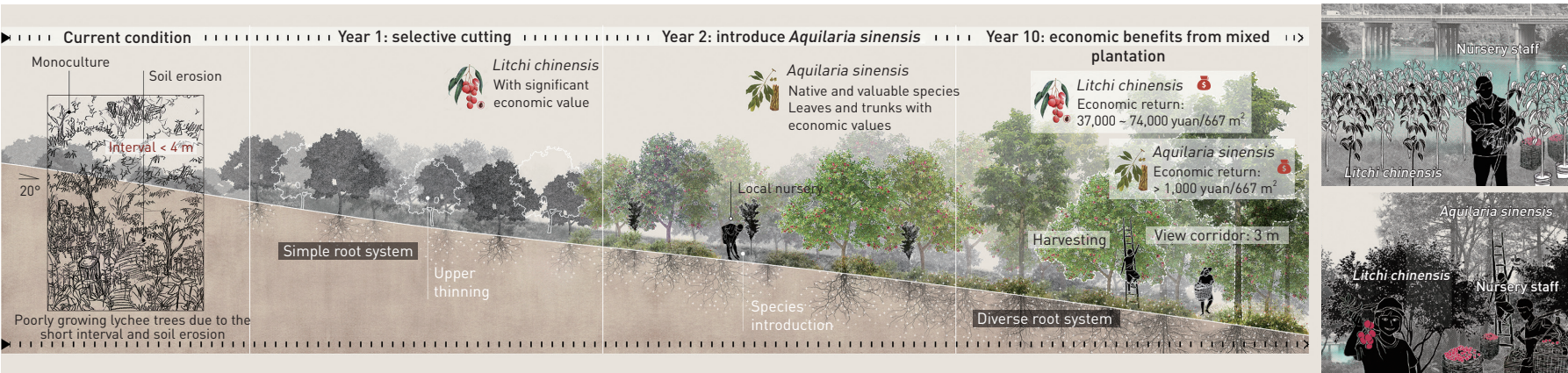
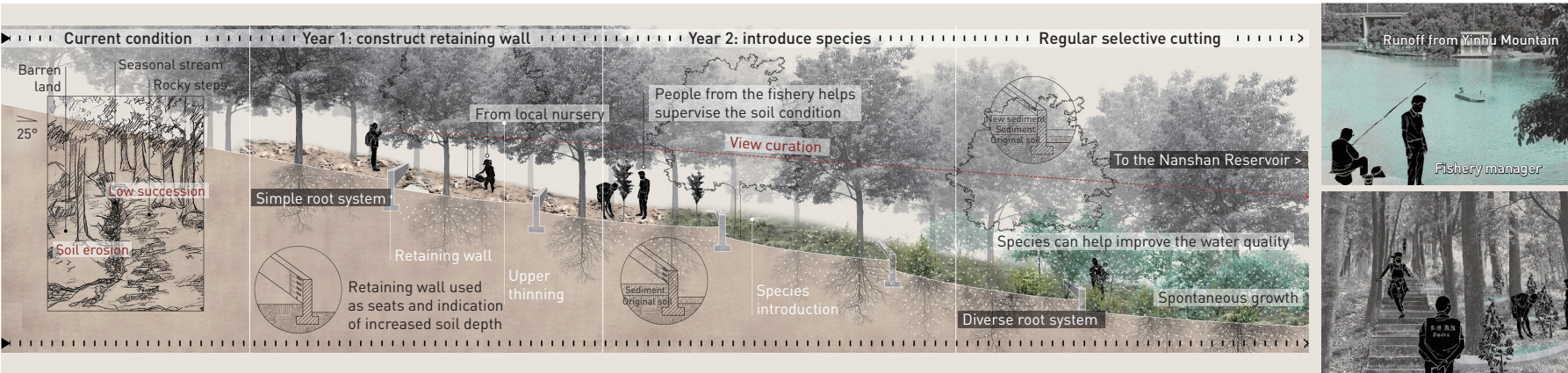
Site 2 serve to mitigate conflicts between conservation and development, and balance the ecological and economic values of the landscape. They include strategic cutting and clearing and the re-introduction of valuable native species (e.g., *Aquilaria sinensis*). This intervention aims to establish collaboration with orchard owners and diversify their income sources through establishing alternative forms of conservation and education programs^[8] (Fig. 7).

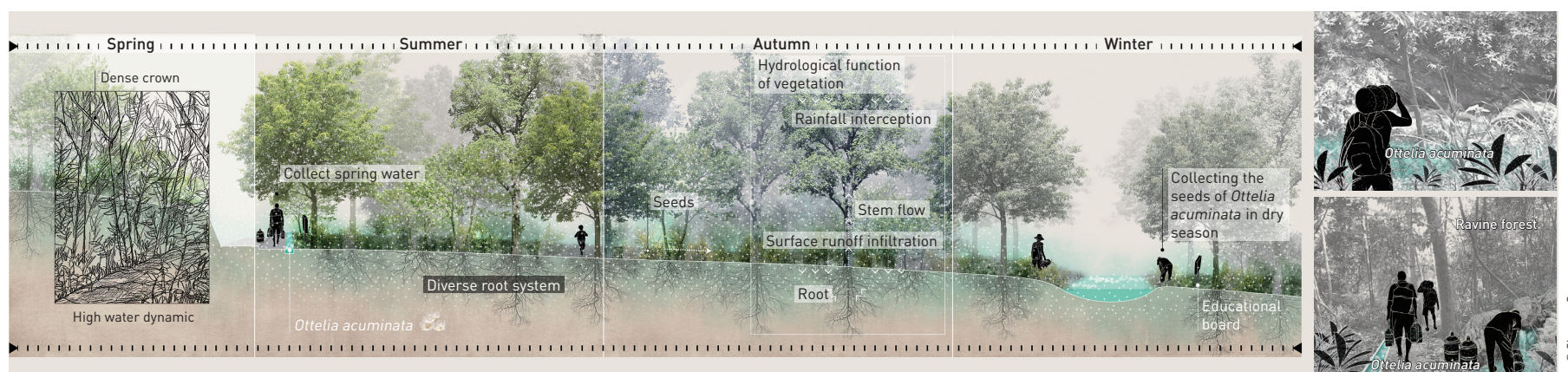
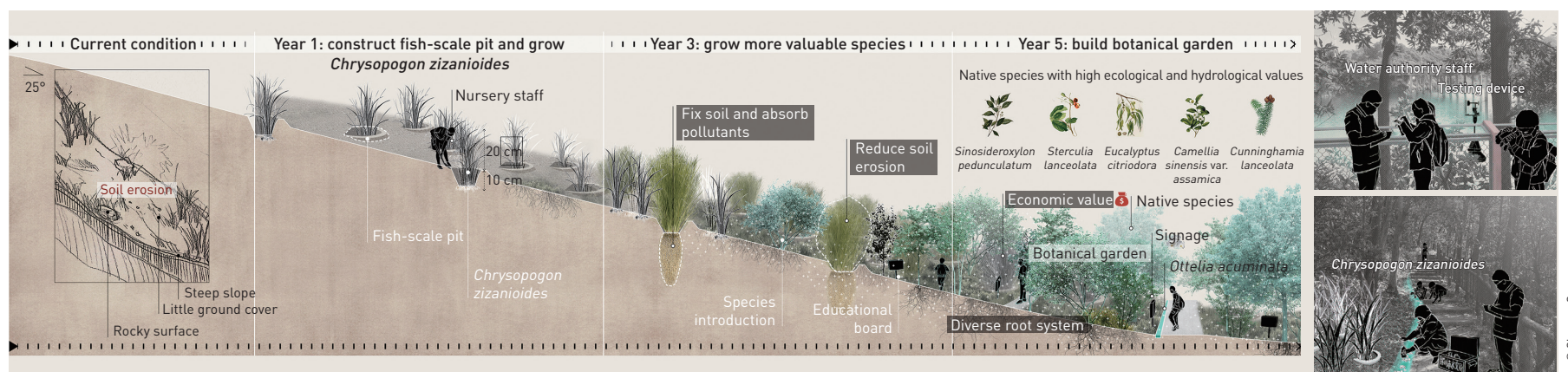
4.3 Sample Site 3: Mitigating Water Pollution and Soil Erosion

Located in the upper reaches of the sub-watershed of Minle Reservoir, Sample Site 3 represents a typical site condition within the Yinhu Mountain country park where large-scale infrastructure projects impact the quality and quantity of runoff. To prevent water pollution and soil erosion caused by the elevated Nanping Expressway, major strategies applied at Sample Site 3 include constructing “fish-scale” planting pits and introducing plant species that help protect against soil erosion. In phase one, perennial bunchgrass such as vetiver grass (*Chrysopogon zizanioides*) will be introduced to stabilize the soil against concentrated flow

6. Landscape strategies for reducing sediment accumulation in downstream reservoirs

7. Landscape strategies for balancing ecological and economic value of landscape





8. Landscape strategies for mitigating water pollution and soil erosion

9. Landscape strategies for visualizing hydrological performance

erosion, and filter polluted runoff from the elevated highway. In phase two, additional pollution tolerant species are introduced to strengthen the ecological and hydrological function of the site. This intervention focuses on enabling collaboration between the Water Authority of Shenzhen Municipality and the Shenzhen Expressway Group through a joint bio-remediation and soil stabilization program to mitigate the adverse impacts of different infrastructure projects (Fig. 8).

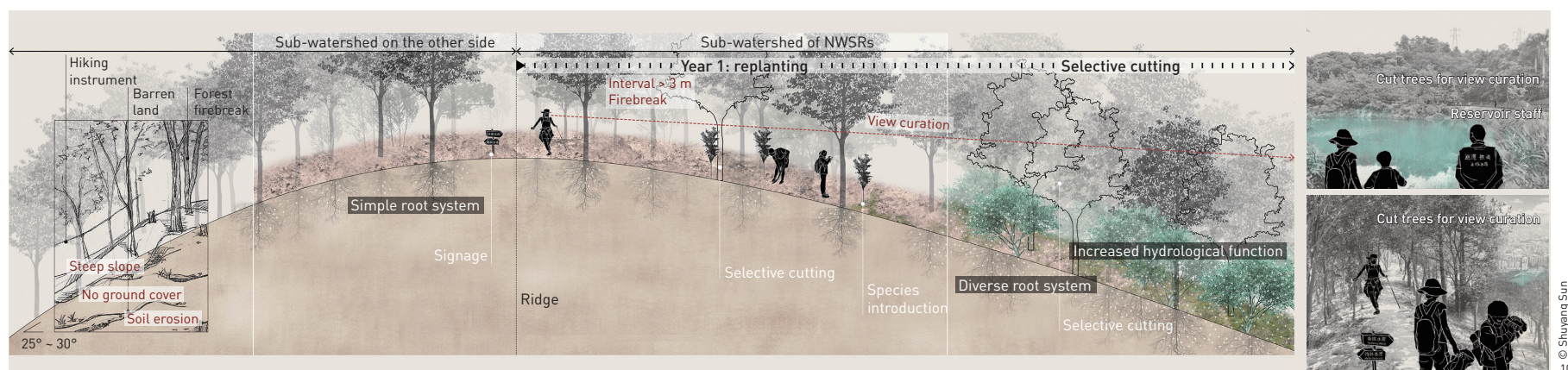
4.4 Sample Site 4: Visualizing Hydrological Performance

Located in the upper reaches of the sub-watershed of Yabao Reservoir, Sample Site 4 represents a typical site condition found in the Yinhu Mountain Country Park where natural springs flow close to the trails. While natural springs are generally believed to be beneficial in terms of health, there is no spring water quality monitoring system in place. Taking advantage of the existing cultural practice of collecting water from natural springs, this intervention introduces a specific species of aquatic plant to improve the performance of the hydrological system and enable

a grassroots and community-based monitoring system. In collaboration with a nursery that is adjacent to and relies on water from the Yabao Reservoir, *Ottelia acuminata*, an aquatic plant with low tolerance for pollutants is planted near the springs, in retention ponds on the slope, and in designated locations within the reservoir downstream near the trailhead. When hiking along the trail, particularly in summer, people can admire the *Ottelia acuminata*'s delicate white flowers at different locations along the trails in the knowledge that the plant is also a positive indicator of water quality (Fig. 9).

4.5 Sample Site 5: Curating an Upstream-downstream View Corridor

Located in the upper reaches of the sub-watershed of Nankeng Reservoir, Sample Site 5 represents a typical site condition within the Yinhu Mountain Country Park where firebreaks are constructed and maintained near the ridge crest.^[9] This intervention takes advantage of, and expands the scope and scale of existing firebreak management. Given that the ridges are at the highest edges of the



10. Landscape strategies for curating an upstream-downstream view corridor

watersheds, they have the potential to be connected to strategic locations in the lower reaches of any given watershed visually and conceptually. Rather than following a 3-meter standardized width along the ridge to fulfill the functional purpose of fire prevention, the orientation and shape of the firebreaks can be strategically delineated to serve as view corridors, from ridge to reservoir for example. Moreover, rather than maintaining permanent strips of bare land following existing firebreak practice, this intervention envisages a more dynamic system of temporary strips. Such an arrangement helps replace non-native trees with natives that are more ecologically desirable, while opening up views and vistas of locations where various watershed management interventions in Tanglang Mountain can be observed for educational purposes (Fig. 10).

5 Conclusions

This project focuses on small-sized reservoirs that are undergoing rapid transformations due to the cross-municipality water supply centralization project. It positions small-sized reservoirs as a unique urban heritage, identifying the ongoing decommissioning process as an opportunity to reflect on both the challenges inherent in an increasingly centralized water supply system, as well as a lack of public awareness of the connection between water infrastructure and the larger landscape they inhabit. Through strategic landscape interventions, decommissioned small-sized reservoirs can serve as off-grid emergency water supply resources strengthening urban water resilience. Alternative sub-watershed management schemes can nurture public awareness of the crucial importance of urban water cycles and water security.

REFERENCES

- [1] Lu, X. (2022). Reservoir Urbanism in Shenzhen. In: Y. Yang, & A. Taufen (Eds.), *The Routledge Handbook of Sustainable Cities and Landscapes in the Pacific Rim* (pp. 336–349). Routledge.
- [2] Water Authority of Shenzhen Municipality. (2019). *Shenzhen urban water supply planning* (p. 113).
- [3] Bureau of Water Resources of Shenzhen Municipality. (2020). *Shenzhen water situation*.
- [4] Water Authority of Shenzhen Municipality. (2019). *Shenzhen urban water supply planning* (p. 32).
- [5] Wu, L. (2021, December 14). *Why is Shenzhen a water-stressed city?* National Business Daily.
- [6] Dou, P., & Chen, Y. (2017). Dynamic monitoring of land-use/land-cover change and urban expansion in Shenzhen using Landsat imagery from 1988 to 2015. *International Journal of Remote Sensing*, 38(19), 5388–5407.
- [7] Xie, C., Cai, S., Yu, B., Yan, L., Liang, A., & Che, S. (2020). The effects of tree root density on water infiltration in urban soil based on a Ground Penetrating Radar in Shanghai, China. *Urban Forestry & Urban Greening*, (50), 126648.
- [8] He, W., Liao, J., & Xie, X. (2015). Analysis on the mixed forests of *Aquilaria sinensis* and *Litchi chinensis*. *Chinese Horticulture Abstracts*, (6), 71–73.
- [9] Lan, W., Zeng, S., Long, D., Deng, X., Yang, Y., & Lin, S. (2016). Vegetation diversity and colorful gardening in the Yinhu Mountain Country Park. *Modern Horticulture*, (8), 20–23.

水文飞地： 深圳非供水水库的适应性管理

孙曙阳*

香港大学建筑学院园境建筑学部，香港 999077，中国

*通讯作者邮箱：shuyang98@connect.hku.hk

摘要

本文重点关注深圳的城市水域，尤其是自2019年跨城区集中化供水工程启动以来正在经历快速转变的小型水库。该供水工程的任务包括提升深圳市的跨流域调水能力（西江引水）、建设两个储水量超过1亿立方米的大型水库，以及推动废弃小型水库的退役。水库的退役过程是指将无法支持供水管理系统集中高效运作的小型水库从饮用水源供水水库改造为非饮用水源供水水库，随之降级的水源保护政策使小型水库极易受到城市发展的威胁，进而引发一系列生态和社会经济问题。

“水文飞地”一词揭示了深圳即将退役的小型水库背后三个相互关联的现实：首先，这些水库被高密度城市环境所包围，形成了独特的形态；其次，它们的存在长期不为公众知晓与关注；第三，它们与所属的更大尺度的景观系统之间存在复杂的水文社会关系，暗示了潜在的景观干预空间。本项目建议将这类小型水库作为分散的离网供水系统水源，以期提高当地的供水韧性。与此同时，从并网水基础设施向离网水基础设施的转变需要借助新的分流域管理方案来确保水源的储量与质量。

本文呈现了一个迭代的设计 - 研究过程，重点关注位于深圳市塘朗山西北山脚的一系列小型水库。在探究场地复杂生态水文关系及景观所蕴含机遇与挑战的同时，也对银湖山郊野公园将这些非饮用水源供水水库排除在管理边界之外的现状提出了质疑。项目提出的水利基础设施同时可发挥必要的教育功能，通过策划的视觉和触觉体验向人们展示景观性能及其与水安全之间的重要联系。

文章亮点

- 将深圳境内即将退役的供水水库视为一种重要的城市遗产
- 指出非供水水库面临的社会 - 生态性威胁及其功能性潜力
- 揭示了单体水库和更大尺度的景观系统之间复杂的水文 - 社会关系
- 营造了视觉和多感官体验以传达景观中的生态及水文过程
- 提倡通过多方利益相关者合作来提升景观管理及水安全

关键词

水安全；
供水水库；
非供水水库；
水利基础设施；
教育设施；
深圳

编辑 王颖，高雨婷