

Modular Approach Creating Low-Maintenance Sponge City: Benjakitti Forest Park in Bangkok, Thailand

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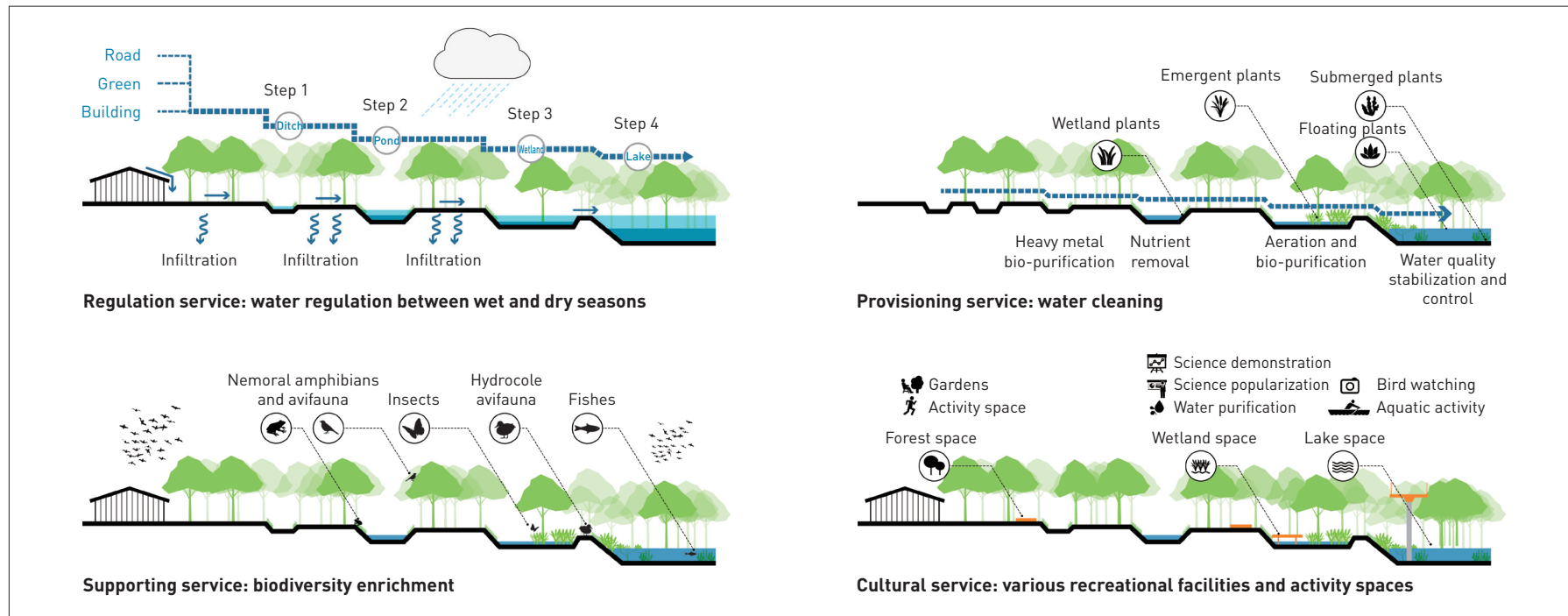
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GRAPHICAL ABSTRACT



HIGHLIGHTS

- The project faced a number of challenges including very limited construction funds and an extremely compressed timeframe (only 18 months)
- The project has become the largest public recreational venue for residents of downtown Bangkok and its environs
- The project offers a low-maintenance, modular approach for worldwide urban public green space design practice

KEYWORDS

Sponge City;
 Modular Landscape;
 Ecological Restoration;
 Low-Maintenance Landscape;
 Pollution Remediation
 Management;
 Urban Recreational Space;
 Ecosystem Services

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In the bustling heart of Bangkok, Thailand, the design team transformed a former tobacco factory into a vibrant new cultural landmark—Benjakitti Forest Park. The project faced a number of challenges including seasonal floods and droughts on the site, severe water pollution in the surroundings, poor accessibility, limited construction funds, and a compressed timeframe (only 18 months). The design has restored the site into an urban park with a resilient ecosystem that intercepts and reduces the destructive force of storm

water, filters contaminated water, and provides much-needed wildlife habitat. Benjakitti Forest Park has not only become the largest public recreational venue for residents of downtown Bangkok and its environs, but also offers a low-maintenance, modular approach for worldwide urban public green space design practice.

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1 Project Background

Located in Khlong Toei District, a central area in the City of Bangkok, Thailand, the project site was formerly a tobacco factory owned by the Ministry of Finance of Thailand. As early as December 1991, the local government approved the relocation of the tobacco factory, and started construction projects of a 20.8 hm² water park (built in 2004) and the 9.8 hm² Benjakitti Forest Park Phase I (built in 2016) on the vacated land. In 2019, the government launched a design competition for Benjakitti Forest Park Phase II, which was scheduled to be completed by June 2021 to celebrate the 90th birthday of Thailand's Queen Sirikit. All the structures would be demolished except for four buildings that would be converted into museum and sports center. The site is surrounded by high-density residential areas, and the Forest Park was envisioned as the largest public green space in the center of Bangkok, serving about 250,000 local residents in the surrounding neighborhoods and thousands of tourists. A total of six international (joint) design teams were invited, and the proposal by the joint design team of Turenscape and Arsomsilp Community and Environmental Architect won the competition.

2 Site Conditions and Challenges

Sitting in the Chao Phraya River Delta, Bangkok is a densely populated city with more than 10.5 million residents^[1]. The

urban area is flat and low-lying, with an average elevation of just 1.5 m or less. The region experiences a monsoon climate (clear dry and rainy seasons) with an average precipitation of about 1,500 mm per year^[1]. Most of the area of the city was originally swampland, which was gradually drained with canals and extensive groundwater pumping for agriculture irrigation; at the same time, the over-extraction of groundwater has caused severe subsidence, which, coupled with the effects of global warming and inadequate municipal drainage infrastructure, has resulted in increased flood risk. In addition, there were only three urban parks open to the public in Bangkok, and urban green spaces are highly fragmented with a low usage. The city's complex urban ecological environment and cultural context posed a number of challenges for the design.

In terms of its location, an urban expressway to the west cut the site off from the adjacent community. There was also an artificial lake to the east and a hospital, hotel, and the Queen Sirikit National Convention Centre to the south. The site is surrounded by a drainage canal to the north, which was contaminated with urban runoff and sewage (Fig. 1).

The site covers an area of about 52.7 hm² and was previously used as a tobacco factory with a history of over 80 years. The southern part was the office, supporting service, and production areas, while the northern part was the stacking and storage areas. The site was densely occupied with single-story warehouses and

^[1] Data source: Thai Meteorological Department.



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1. The northern drainage canal with problems of serious water pollution and poor water quality (Class V)
2. Construction waste left on the site after the demolition
3. Design plan



Legend

- | | | |
|-----------------------|---------------------------|-----------------|
| ① Cascade | ⑧ Skywalk | ⑮ Rice field |
| ② Constructed wetland | ⑨ Amphitheater | ⑯ Museum |
| ③ Plaza | ⑩ Reflection pond | ⑰ Welcome plaza |
| ④ Pond with islets | ⑪ Pedestrian path | ⑱ Parking |
| ⑤ Sports center | ⑫ Board walk | ⑲ Entrance |
| ⑥ Nursery | ⑬ Biking and jogging path | ⑳ Main entrance |
| ⑦ Toilet | ⑭ Picnic area | |

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hard pavements; except for four buildings, all on-site structures were planned to be removed that would leave a large amount of construction waste to be dealt with after demolition (Fig. 2).

Site survey showed that there were 865 trees on the site, including 91 species and dominated by *Ficus benjamina*, *Ficus religiosa*, *Peltophorum pterocarpum*, *Cassia fistula*, *Tamarindus indica*, and *Mangifera indica*; there were 49 trees with a diameter of 1 m or more. Except for some big ones scattered in the eastern part of the site and in-between the single-story warehouses, these trees were mostly found along paths, and many *Ficus benjamina* have grown into the pavement with their robust root system. Therefore, it was a challenge for the design team to preserve the trees and make them a functional feature that is compatible with the plan of the site.

In addition to the challenges of the site itself, the budget for this project was extremely limited (ultimately, it was capped at USD 20/m²), and the project was required to be completed in just 18 months. An extra challenge was that the project was overseen by Royal Thai Army for a fast, efficient construction, but they did not have extensive experience managing landscape projects, so the design had to be easy-to-build. Besides, being costly and using

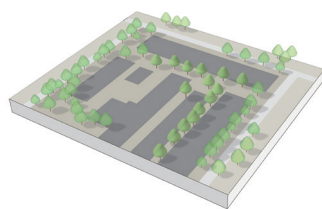
a huge amount of irrigation water, the maintenance of Benjakitti Forest Park Phase I was unsatisfactory, so how to reduce the subsequent maintenance cost became another challenge to the design team.

3 Design Objectives and Strategies

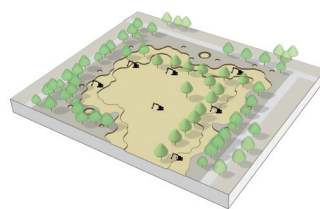
In addressing the multiple challenges of the site and its dense urban surroundings, the project was envisioned as a central park capable of providing holistic ecosystem services to the city



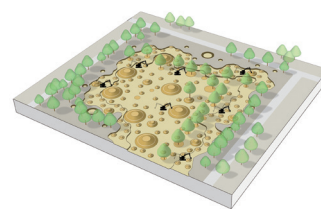
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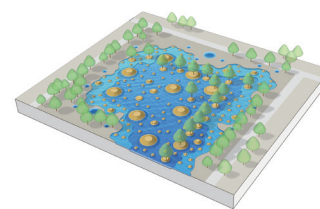
Preserve trees and roads and remove buildings



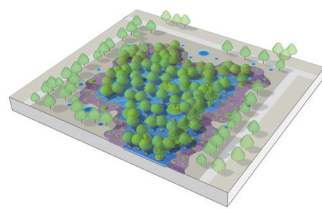
Define wetland boundary



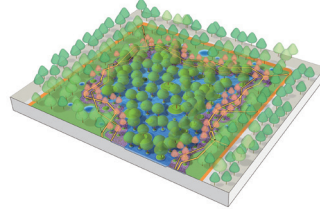
Construct tree islets through *in situ* cutting and filling



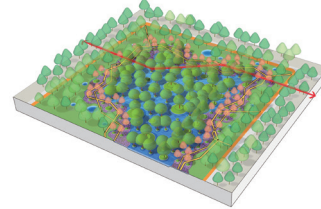
Convey water into the lake area for rainwater storage



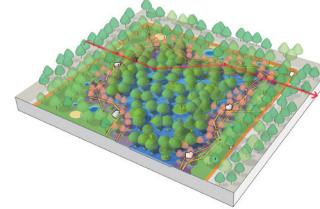
Create a "water forest" and a wetland buffer



Introduce a slow traffic system



Skywalk system



Service nodes and interpretation/signage system

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4. Aerial renderings: the design transforms the former tobacco factory into an oasis in a high-density urban environment.
5. Nature-based solutions responding to the extreme challenges of limited budget and short construction timeframe: through on-site cutting and filling, modular landscape creation, and the introduction of water system, the park allows for an immersive experience for visitors.

(Figs. 3 ~ 5). To improve the site's regulation services to adapt to the changing monsoon climate, the park is designed with a total rainwater retention and storage capacity of 187,500 m³, which allows the park to withstand 10-year rainfall events without draining to the municipal sewer system. To strengthen the site's provisioning services, the park is designed to filter the polluted water from the poorest Class V to Class III. To enhance its supporting services, the design creates an ecosystem composed of forest, grass, and wetland that provides a variety of habitats for native species and wildlife. Also, to increase cultural services, the park is expected to offer badly needed large public recreational space for citizens' daily recreational activities, as visitors as well. Three strategies guided the design to meet these objectives.

3.1 Creating Modular Porous Sponge Wetlands

Wetlands are important life-supporting systems^[3] contributing to flood and drought prevention, soil and water conservation, maintenance of biodiversity, recreation and tourism, etc.^{[4][5]} Highlighting an idea of "porosity," the design creates a resilient, water-island interwoven sponge wetland system under landscape ecology principles^[6].

Firstly, four lakes consisted of hundreds of tree islets (i.e., four constructed wetlands) were built through simple cutting and filling, and each lake was designed with two depths—a shallow, terraced shoreline and a deeper core area. After site investigation, the design team selected the three canopy moduli (6 m, 12 m, and 25 m) that were most frequently found among the existing trees as the island



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6-2

diameters in order to minimize construction impact on the existing vegetation; and then the trees were preserved *in situ* at the center of each island (Fig. 6). Standardized construction transformed the otherwise hard clay surface soil into a series of wet and spongy habitats (Fig. 7), where water acts as a medium to facilitate material and energy flows. The core areas not only serve as storage spaces, but also create diverse aquatic habitats with changing water levels^[3].

The shallow, terraced shoreline is connected to the L-shaped linear purification wetland along the northern and western edges of the park, where the water from the canal is introduced and purified, with a daily purification capacity of 8,152 m³. The purified water

6. Tree islets that are centered with the preserved trees were constructed through modular design. In a short period of 18 months, the constructed wetland system achieved a continuous natural succession.
7. Before and after the project: the site previously occupied with large warehouses was transformed into a porous spongy wetland.
8. Internal implantation of sports fields and eco-pallet islands
9. All existing trees on the site are preserved and integrated into the design, making the park a popular urban public space for residents to enjoy the cool in summer.



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then flows into the lake area, where, according to the “edge effect,” the pattern of scattered tree islets can greatly enhance water purification efficiency and promote biodiversity and community density through the water-land interfaces. This will also increase the activity intensity and productivity of key wetland species such as *Anastomus oscitans*, *Tachybaptus ruficollis*, and *Ardea alba*.^{[7][8]}

After pretreatment, polluted water enters the L-shaped surface flow wetland and subsurface flow wetland, flowing from east to west, from north to south, with the help of elevation difference. After a series of cleansing processes—including the aeration and the purification by emergent and submerged vegetation, microbial degradation, and biological predation—the concentration of pollutants (e.g., BOD, COD, TSS, heavy metal elements) would be largely reduced. The eutrophication substances such as nitrogen and phosphorus in the water can also be absorbed as fertilizers that

help for the growth of wetland plants and agricultural crops on the site, forming a self-sufficient cycle.

Secondly, for the sports center and museum that make use of existing buildings, the idea of porosity was also applied to transform the factory buildings by daylighting portions of the roofs and allowing the living landscape to penetrate through the buildings’ concrete shells, forming refreshing “green walls.” The interiors of some warehouses were redesigned with sports fields and eco-pallet islands (Fig. 8), creating a number of luxuriant “green buildings.”

3.2 Fostering a Low-Budget, Low-Maintenance “Messy Nature”

Considering the limitations in budget and construction period, all kinds of recycled materials on the site were integrated into the design of the park’s landscape: all existing main roads were remained as the skeleton of the new park circulation system; the



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existing trees and understory space were retained to the maximum extent (Fig. 9); and the concrete materials from the demolished structures were used to reinforce the foot and slope of tree islets or the park pavements.^[2] This modular landscape can be easily executed with a single excavator and minimizes dependence on skilled labor (Fig. 10).

In addition, the planting design of the tree islets in this project applied seedlings of native shade tree species at the lowest cost: The modulated landform with diverse micro-environments was sown with seeds and planted with tree seedlings, creating a foundation for the subsequent evolution of a semi-natural plant community. The result is a low-maintenance mosaic of vegetation that will be continually and spontaneously enriched with native species, enhancing biodiversity and community stability^[9] and thus establishing vibrant plant communities (Fig. 11). The porous spongy landscape with integrated water bodies and green spaces is also conducive to reducing maintenance costs. After its completion, the park is expected to retain up to 200,000 m³ of storm water from the surrounding area during the monsoon season, allowing the native plant communities to establish themselves with minimal irrigation or maintenance needed during the dry season.



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10. The large area of concrete pavement on the site was replaced with modular landscape that requires only one excavator to achieve *in situ* filling and excavation, piling up into islands, thus minimizing construction costs.

11. The shaping of landform with diverse micro-environments supports the succession of semi-natural plant communities and enriches the park's ecosystems.



12. An elevated skywalk traverses the forest canopy, linking parcels that were previously cut off away by urban roads. The skywalk will provide space for wildlife and beautiful views of the city's nature and skyline.



13. Before and after the project: the previous carriageway was transformed into a more comfortable slow-traffic system.

3.3 Improving Accessibility and Immersive Recreational Experience

To improve the accessibility of the park and enhance the connection between the park and the surrounding communities and green spaces, a skywalk runs through the tree canopies that ties together the entire park, which for decades was sliced through

by major roads, and creates a unique experience amidst the tropical foliage while reducing the disturbance on wildlife (Fig. 12).

While the major roads were preserved and reused, a cut was made in the middle of each roadway to create a permeable bio-swale and flower bed that separates a bicycle lane and pedestrian path, helping bring a more comfortable scale to what were



Before



After



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originally wide roads designed for heavy truck traffic (Fig. 13). Multiple boardwalks were designed along the edge of the shallow wetlands that allow visitors to have immersive recreational experience of urban nature in the man-made wetlands (Fig. 14). A large lawn and an amphitheater in the core area of the park (Fig. 15), the rice field next to the converted museum (Fig. 16), and a large number of understory spaces were created to provide stages for varied recreational activities of Bangkok's citizens and visitors.

4 After-Completion Performance and Reflection

Despite having been built on an extremely compressed timeframe, the Benjakitti Forest Park project has proven its construction a great success with sound performance in delivering the expected regulation, provisioning, supporting, and cultural services. While much of Bangkok flooded in the summer of 2022, the park and its immediate vicinity did not; the water-quality remediating wetland is performing well and produces enough water to keep the wetland alive through the dry season.^[10] In addition, the park's biodiversity has increased significantly: nearly 100 species of birds have been observed in the park since May

14. Boardwalks are intertwined along the wetland edges, where visitors can have an immersive nature experience.



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2022, and dozens of other wildlife species have taken up residence in the park. A symbiotic ecological interrelationship between fauna and flora is developing, and the “messiness” of the constructed wetland is creating a new, highly dynamic and diverse aesthetic that sharply contrasts with the surrounding urban landscape (Fig. 17). The most striking achievement is that this naturally regenerative system is now the largest park in densely populated central Bangkok and attracts tens of thousands of visitors daily, who use it for a wide variety of activities, including jogging and cycling, family gatherings, school commencements, picnics, dates, art experiences, and wedding photographs.^{[10][11]} It has been celebrated extensively on social media as a new symbol of Thailand’s capital city.

With an extremely low budget and very limited construction timeframe, this project creates a modular landscape that allows nature to do its work, restoring the self-succession of vegetation communities through the use of small-sized seedlings and seed sowing, providing a park that develops with the citizens’ public life of Bangkok. As an overseas project that practices “sponge city” theory and techniques, the construction of the park has innovatively explored a nature-based and nature-driven solution to provide ecosystem services at a lower cost, improving the quality of life to local residents. Its successful experience in low-cost improvement of hardened clay soil, reuse of construction waste, and revitalization of industrial heritage can offer a reference for sustainable park design and construction in Bangkok and other similar cases around the world.

PROJECT INFORMATION

LOCATION: Khlong Toei District, Bangkok, Thailand

AREA (SIZE): 52.7 hm²

CLIENT: The Treasury Department, Ministry of Finance, Thailand

LANDSCAPE DESIGN: Turenscape, Landscape Studio by Arsomsilp
Arsomsilp Community and Environmental Architect Co., Ltd.

PROJECT TEAM: Kongjian Yu, Dong Wang, Wei Liu, Baiqiang Ren, Liang He, Yanjin Bai, Lelai Dai, Defeng Lu, Xiaodong Li, Chang Yang, Xianfeng He, Qiong Zheng

CONTRACTOR: First Development Division, Royal Thai Army

STRUCTURE ENGINEERING: KASEM DESIGN & CONSULTANT CO., LTD.

MECHANICAL AND ELECTRICAL ENGINEERING: Optimology Co., Ltd.

CONSTRUCTION MANAGEMENT: Stonehenge Co., Ltd.

SIGNAGE DESIGN: Plan Motif Co., Ltd.

UNIVERSAL DESIGN: Center of Excellence in Universal Design, Faculty of Architecture, Chulalongkorn University

CONSTRUCTION PERIOD: December, 2019 ~ October, 2022

COMPLETION TIME: March, 2022



15 © Turenscape and Arsomsilp Community and Environmental Architect



Before



After

16 © Turenscape and Arsomsilp Community and Environmental Architect

15. The amphitheater on the west side of a constructed wetland provides a public space where a variety of activities can take place.

16. The loading area outside the warehouse has been transformed into a pleasant rice field.



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17. The “messiness” of the constructed wetlands creates a new, dynamic aesthetic that sharply contrasts with the surrounding urban landscape.

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模式化景观途径营造低维护海绵城市： 泰国曼谷班加科特森林公园

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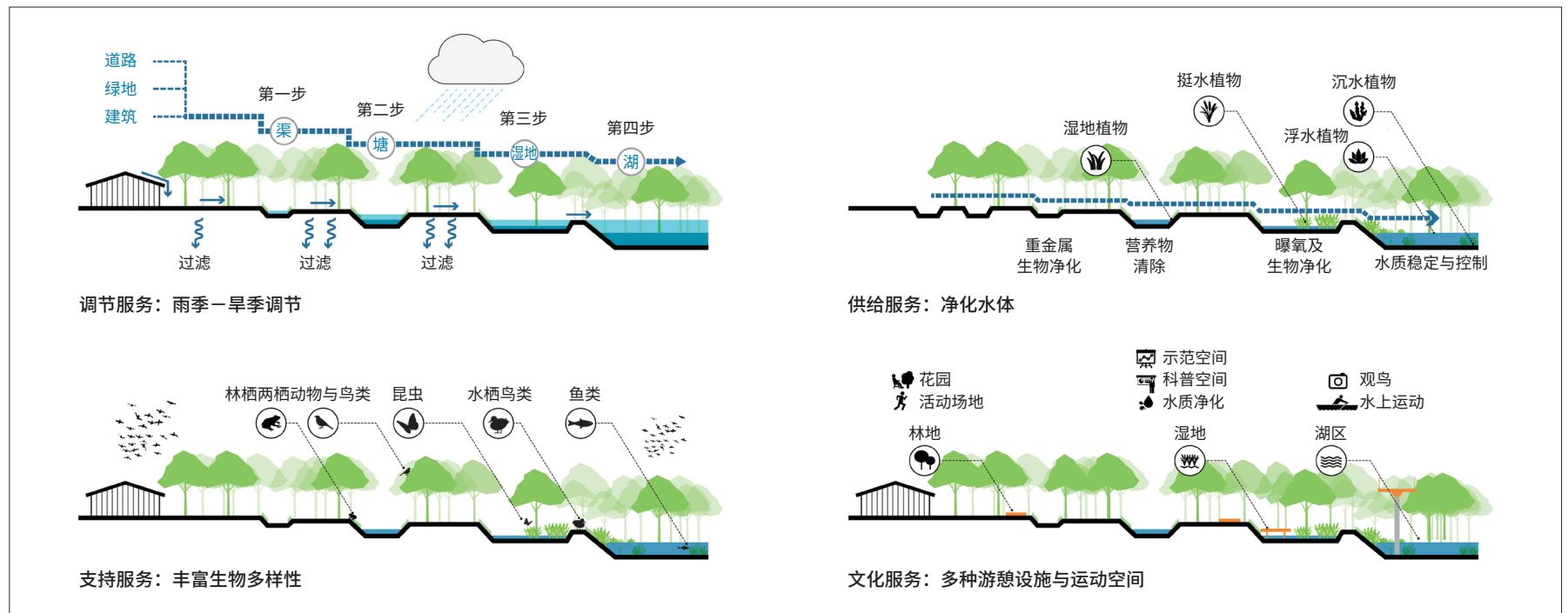
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图文摘要



文章亮点

- 项目面临建设资金极为有限、工期极其紧张（仅18个月）等多重挑战
- 项目为曼谷市中心及其周边地区打造了面积最大的公共游憩空间
- 项目为其他类似城市公共绿地设计实践提供了一种可借鉴的低维护、模式化途径

摘要

在泰国曼谷繁华的城市中心地带，设计团队将一个前烟草工厂转变成了一座活力四射的新文化地标——班加科特森林公园。项目之初，设计团队面临场地上洪涝和干旱交替发生、北侧运河水体污染严重、可达性差、建设资金有限、工期紧张（仅18个月）等多重挑战。通过生态修复手段，设计将场地转变为了可提供全面生态系统服务且富有韧性的生态系统：设计后的公园可以拦截瞬时暴雨积洪并降低其破坏力、净化被污染的水体、调节旱涝，以及为野生动物提供亟需的栖息地。班加科特森林公园不仅成为了曼谷市中心及其周边地区最大的公共游憩空间，也为其他类似城市公共绿地设计实践提供了一种可借鉴的低维护、模式化途径。

关键词

海绵城市；
模式化景观；
生态修复；
低维护景观；
污染治理；
城市游憩空间；
生态系统服务

收稿时间

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1 项目背景

项目场地位于泰国曼谷市中心孔堤区，为泰国财政部所属烟草局工厂的一部分。早在1991年12月，当地政府即批准了烟草工厂搬迁的决议，在腾退出的土地上建设了面积20.8hm²的水公园（2004年）和9.8hm²的班加科特森林公园一期（2016年）。2019年，政府发起森林公园二期设计竞赛，并计划于2021年6月前完工，以庆祝泰国诗丽吉王太后九十岁寿辰；除明确要求保留的四栋建筑外（将改造为博物馆、体育中心等场馆），其余厂房均予以拆除。场地周围为高密度居住区，森林公园建成后将成为曼谷市中心最大的公共绿地，服务周边5km范围内约25万常住人口及曼谷庞大的旅游人群。竞赛共有六支国际（联合）设计团队参加，土人设计与泰国阿颂·信建筑事务所联合设计团队的设计方案最终胜出。

2 场地现状与挑战

曼谷位于湄南河三角洲，是一座人口超1 050万^[1]的发达城市。市区地势平坦且低洼，平均海拔在1.5m以下；属热带季风气候，旱雨两季分明，年平均降水量约为1 500mm^①。曼谷的大部分地区原为沼泽地，后因运河的开挖、地下水的大量抽取，以及粗放的农业灌溉而逐渐干涸；同时，地下水的过度抽取也造成了严重的地面沉降，加之全球气候变暖及城市排水基础设施不足等原因，导致当地市政排水系统无法应对瞬时暴雨产生的城市径流，进而增加了城市洪涝风险。此外，曼谷全市仅有三处城市公园面向公众开放，且城市绿地分散零碎，使用率不高。在复杂的城市生态、文化环境中，设计团队面临着多项挑战。

场地西侧的城市快速路将场地与周边社区割裂，东侧为一座人工湖，南部为医院、酒店和诗丽吉王后国家会议中心，北部曾经的城市运河现已成为排水渠，水质受城市污水直排和城市径流的影响富营养化严重，水体受到严重污染（图1）。

场地面积约52.7hm²，原为一座拥有80余年历史的烟草工厂。南部为办公、配套服务及生产加工区，北部为堆料及仓储区。因烟草生产的特殊性，场地内地面大面积硬化，并紧密排布着单层的厂房。除四座厂房外，其余厂房拆除后遗留下大量建筑垃圾需要处理（图2）。

场地中共有乔木有91个品种、865株，以垂叶榕（*Ficus benjamina*）、菩提树（*Ficus religiosa*）、盾柱木（*Peltophorum pterocarpum*）、腊肠树（*Cassia fistula*）、酸豆（*Tamarindus indica*）、杧果（*Mangifera indica*）为主；胸径1m以上的乔木有49株。除场地东部及单层厂房间散布的一些林荫大树外，这些乔木主要分布于道路两侧，其中榕树发达的根系已经和部分道路融为一体。因此，如何保护这些树木并使其与场地未来功能

① 数据来源：泰国气象局。

规划相契合，就成了摆在设计团队面前的一道难题。

此外，本项目的预算极为有限（上限为20美元/m²），同时在项目工期上要求10个月内建成——后因新型冠状病毒感染疫情，最终要求于18个月内建成。出于建设速度考虑，项目的实施主体确定为本地部队工程兵，因其缺乏景观类项目建设管理经验，需要采取易于施工的设计策略。另外，在本项目之前落成的森林公园一期维护成本较高，在消耗了大量水资源用于灌溉的情况下，树木长势依然堪忧，因此如何降低后续维护成本也成为了本项目的挑战之一。

3 设计目标和策略

为了应对场地面临的多重挑战，项目被构想为一个能够为这座高密度城市提供全面生态系统服务的中央公园（图3~5）：公园需提供生态调节服务，适应旱雨交替的热带季风气候，设计的面积共计187 500m³的雨洪调蓄空间能够保障10年一遇降雨不外排；提供供给服务，将受污染的劣V类水净化为Ⅲ类；提供支持服务，创造林-草-湿地生态系统，为本地野生动物提供多种栖息地；提供文化服务，为城市居民与游客的游憩活动提供亟需的多种休闲设施和大型公共空间。为了实现这些目标，设计团队制定了以下设计策略。

3.1 营造模式化的多孔海绵湿地

湿地是重要的生命支持系统^[3]，并在防洪抗旱、保持水土、维护生物多样性及休闲旅游等方面发挥重要作用^{[4][5]}。设计从景观生态学的角度出发，在充分尊重场地现状的前提下，营造一个基于“多孔”理念的、弹性的、水-岛交织的海绵湿地系统^[6]。

首先通过简单的挖填方技术，建造了4个散布着数百个小岛的湖区（即四大人工湿地），且每个湖都设计为两种不同的深度——较浅的梯级浅水带和较深的核心区域。为了实现对现有植被的最小干预，设计团队通过对场地所有乔木生长信息进行调查统计，选择占比最高的三个冠幅数值作为小岛直径设计参数——6m、12m、25m；然后以原有的树木作为每个岛屿的中心，构筑树岛（图6）。标准化便于施工，同时可将原本坚硬粘滞的表层土壤转变为海绵化生物栖息地（图7），以水作为媒介，疏通物质和能量交换；核心区水位变化提供调蓄空间的同时，可营造条件各异的多样化生境^[3]。

湖区的梯级浅水带与沿公园北部和西部边缘修建的L型线性净化湿地相连，运河河水被引入湿地中并得到净化，每日净化水量可达8 152m³。净化后的水体流经梯级浅水带汇入布满小岛的湖区中，依据“边缘效应”，这里的水质净化效率更高，并可促进这一水陆生境交错带物种多样性和种群密度的提升，包括促进钳嘴鹳（*Anastomus oscitans*）、小鸊鷉（*Tachybaptus ruficollis*）、大白鹭（*Ardea alba*）等重要湿地物种的活

动强度和生产力。^{[7][8]}

污水经预处理后进入L型表流湿地和潜流湿地，借助高差推动水体自东向西、自北向南流动，经过曝氧及挺水与沉水植被的净化过程、微生物降解过程，以及生物捕食过程，水体中污染物（如BOD、COD、TSS、重金属元素等）的含量将大幅降低，水体内的氮磷等富营养化物质也可以转化为场地内湿地植物和农作物的生长肥料，达到循环利用目的。

其次，“多孔”原则也被运用于改建而成的体育中心和博物馆中：部分厂房的屋顶经过改造设计，可将自然光照引入室内，并可使建筑的混凝土外壳逐渐变为生机勃勃的“绿墙”；甚至在有些厂房内部植入运动场地和生态化的垛岛（图8），形成一座座充满活力的“绿色建筑”。

3.2 营造低预算、低维护的“野性自然”

为了满足低预算、短周期的设计要求，场地现有的资源被回收及再利用，融入公园的景观系统设计中。场地的主要道路均予以保留，在此基础上形成新的公园道路系统；减少干预、最大限度地保留现有乔木及林下空间（图9），回收厂房拆除后的混凝土材料，用于构建岛屿的土方基础和边坡加固，同时用作公园的铺装材料。^[2]这种模式化景观仅依靠一台挖掘机即可实现就地填挖、堆地成岛，从而将施工成本降至最低（图10）。

除场地原有的树木外，设计团队在新建岛屿上以最低的成本种植乡土林荫树种幼苗；同时，在具有丰富微环境的人工地形上播撒种子、种植幼苗，为植物群落的自然演替创造基础，以形成一个低维护的植物嵌合体，这将持续、自发地丰富乡土物种，促进动植物共生关系的形成，提升生物多样性和群落稳定性^[9]，从而建立生机勃勃的本土植物群落（图11）。水体与绿地充分交融的海绵状的多孔景观也有利于降低维护成本，公园建成后，雨季最大蓄水量可达20万立方米，足以在整个旱季滋养公园内的所有植被，降低灌溉需求，实现植物群落的自我繁衍。

3.3 提高可达性，创造沉浸式的游憩空间

为提高公园的可达性、增强公园与周边社区及绿地的联系，项目设计了一条空中步道，将多年来被城市快速路分割的地块串联在一起。空中步道降低了对野生动物的干扰，也为游客提供了可以同时欣赏湿地“野性自然”及都市天际线的独特体验（图12）。

公园内部在保留和重新利用主要道路的同时，通过可渗透的生物滞留池和花圃，分隔自行车道与人行道，使原本为重型卡车设计的宽阔道路拥有更加宜人的尺度（图13）。沿着浅水湿地的边缘增设的多条相互交织的栈道可创造慢行的休闲体验，让游客沉浸式地感受人工湿地的自然景观（图14）。公园核心区域的大草坪和户外剧场（图15）、博物馆旁的水稻田（图16）、大量的林下空间等场所旨在创造多样活动的都市乐园，为曼谷市民及游客的各类公共生活提供舞台。

4 建成效果与讨论

尽管班加科特森林公园二期面临各种严苛挑战，但事实证明，它的建造取得了巨大的成功。从生态系统服务的角度评估，公园满足了提供调节服务、供给服务、支持服务和文化服务的设计目标。2022年夏，曼谷再次经历了城市水患，公园及其附近地区并未受灾；水质净化湿地表现良好，如预期般地调蓄了足够的雨水，维系了湿地系统度过旱季，且市民可明显感受到公园的水体变得清澈、无异味。^[10]此外，公园的生物多样性显著提升：自2022年5月至今，公园内已观察到鸟类近百种，数十种其他野生动物在此栖息觅食。作为曼谷市中心最大的城市公园，其所展现出的“野性自然”正在创造一种全新的、高度动态的、多样化的美学，与周围的都市景观形成鲜明对比（图17）。每天有数以万计的游客在园中进行慢跑、骑行、家庭聚会、学校庆典、野餐、艺术交流、约会和婚纱照摄影等活动。^{[10][11]}公园已成为泰国首都的一处新地标，在社交媒体上广受欢迎。

本项目在低预算、短周期的要求下，实施了让自然做功的模式化解决方案，通过采用小规格苗木种植和种子播撒，引入植被的自我演替，为曼谷提供了一座与市民共同成长的公园。作为“海绵城市”理论和技术在海外又一实践项目，该项目的建设创新性地探索了如何在更低成本的前提下，创造一个基于自然、让自然做功的基底，从而提供生态系统服务，为当地居民带来更高的生活品质。其在坚硬粘质土壤的低成本改良、废弃物再利用、工业遗产改造利用等方面均积累了成功经验，可为曼谷和世界其他类似城市的可持续公园建设提供参考。

图 1. 水体污染严重的北部排水渠，水质为劣V类

图 2. 厂房拆除后场地上遗留的建筑垃圾

图 3. 设计平面图

图 4. 场地鸟瞰效果图：设计将前烟草加工厂改造为高密度城市中的绿洲。

图 5. 低预算、短周期、基于自然的解决策略生成过程：通过现场填挖方、模式化景观营建并引入水系，设计为公园游客创造了沉浸式体验。

图 6. 通过模式化设计，以原有树木为中心构筑树岛。短短 18 个月的时间里，人工湿地系统就实现了自然系统持续的自我演替。

图 7. 场地改造前后对比：原有厂房被拆除，硬质场地被改造为多孔海绵湿地。

图 8. 厂房内部植入运动场地和生态化的垛岛

图 9. 场地现状树木得到了保护并整合入设计，使公园成为居民喜爱的躲避炎热夏季的城市公共空间。

图 10. 场地原有地面的大面积水泥硬化铺装。模式化景观只需要一台挖掘机即可实现就地填挖、堆地成岛，从而将施工成本降至最低。

图 11. 多样微环境的地形为半自然植物群落的演替提供了基础，建立了物种丰富的生态系统。

图 12. 一条空中步道穿越林冠，将过去被道路分割的地块串联在一起。空中步道在为野生动物提供空间的同时，也可让人们欣赏城市自然景色和天际线。

图 13. 场地改造前后对比：原有车行道被改造为更为舒适的慢行系统。

图 14. 沿湿地周边增设了相互交织的栈道，游客可以在栈道上享受沉浸式自然体验。

图 15. 四大人工湿地之一西侧的露天剧场提供了可进行多种活动的公共空间。

图 16. 厂房外的卸货区被改造为青葱的水稻田

图 17. 人工湿地的“野性自然”创造了一种新的、动态的美学，与周围的都市景观形成了强烈的对比。