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将营养流慢下来
——海口市美舍河凤翔公园生态设计

SLOWING DOWN NUTRIENT FLOWS — ECOLOGICAL DESIGN OF THE FENGXIANG PARK ON THE MEISHE RIVER IN HAIKOU

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摘要

海南省海口市是一座自然风光旖旎的南方滨海旅游城市，在近几十年来的快速城镇化进程中，人们忽视了自然河流作为城市水生态基础设施的重要性，导致城市的生态韧性和安全急剧下降。凤翔公园作为美舍河上的重要生态节点，集中暴露了美舍河流域的各种生态问题。项目设计旨在通过设计生态学途径修复场地的生态系统，系统治理内涝和水质污染问题，为周边居民营造高品质滨水慢生活环境。

借助绿色海绵技术和加强型人工湿地系统的建立，设计最终让场地中的水流及营养流慢了下来，修复了动植物栖息地，提升了生物多样性；多样化慢行系统的引入鼓励了市民及游客的绿色出行，为城市打造了一个全新的旅游、休憩、文化胜地。更为重要的是，在全球日益严峻的水污染和水资源短缺等问题下，项目所采用的设计方法在城市水质治理、防洪以及创造社会文化服务空间等方面具有重要借鉴意义。

关键词
海绵城市；人工湿地系统；生态修复；慢生活；设计生态学

ABSTRACT

Haikou is a coastal tourist city in Hainan Province of South China with beautiful natural landscapes. During the rapid urbanization in the past decades, the role of natural rivers as city's water ecological infrastructure has been long-time neglected, resulting in a sharp deterioration of urban ecological resilience and security. Fengxiang Park, sitting at the middle reaches of the Meishe River, is a key ecological node in the watershed, which however had suffered from severe ecological problems. In this demonstrative project, the site was envisioned as an urban park which mitigates urban flooding and water pollution and provides citizens a quality waterfront with pleasant, slow living environment through a substantial ecosystem improvement with means of Design Ecology.

Techniques of green sponge construction and the reinforced constructed wetland system deployed in the park have effectively slowed down the flow of water and nutrients, restored habitats for fauna and flora, and increased biodiversity; the introduction of a diversity of slow traffic system has brought vitality to the city by encouraging green traffic modes among citizens and tourists, creating a new tourism, recreational, and cultural destination for the city. More importantly, in view of increasingly severe issues such as water pollution and shortage around the globe, this project shows an obvious reference significance to other practices in urban water quality improvement, flooding control, and the creation of public spaces to provide social and cultural services.

KEYWORDS
Sponge City Construction; Constructed Wetland System; Ecological Restoration; Slow Life; Designed Ecology

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1. 美舍河改造前现状照片

1. Meishe River, before the launch of the project.

1 项目背景

海南省海口市是一座自然风光旖旎的南方滨海旅游城市，受季风气候影响显著。在近几十年来的快速城镇化进程中，人们更多地关注城市建设，却忽视了作为城市水生态基础设施的自然河流，导致城市的生态韧性和安全急剧下降。

全长23km的美舍河是海口的母亲河。然而，近几十年来，这条河流却逐渐成为这个城市的噩梦：周边大量污水直接排入河道；为了快速行洪，城市管理者将美舍河裁弯取直、竖起堤坝，将之变为了单一目标的行洪河道，河流生态系统的综合服务能力丧失，传统人水共生的慢生活方式也随之消失。

凤翔公园位于美舍河中游，作为美舍河沿线腹地面积最大的重要生态节点，集中暴露了美舍河流域的生态问题。场地现有行洪河道渠化严重，缺乏韧性，导致雨季内涝频发；旱季缺水，景观效果较差；由于场地所在区域的污水管网尚未完全建成，每天约有3 500吨的生活污水直接排入河道，臭气熏天，为严重污染的劣Ⅴ类水；沿河步道系统缺乏连续性，亲水性差；场地中虽然有乾坤湖和仙人洞这两大当地著名景点，但市民却因为污水和垃圾而无法靠近；原来作为白鹭及鱼类栖息地的乾坤湖也不见白鹭踪影、鱼类大量死亡。

近年来，城市的管理者开展了截污、河床清淤、局部水质处理、建立管理规章等一系列生态修复工作。然而，这些非系统性治理措施往往不能从根本上解决问题。人们向往的人水和谐的“慢生活”如遥不可及的梦。为了推进生态文明建设，海口市以美舍河生态修复为契机掀起了营造新的滨水慢生活方式的浪潮。

2 设计目标

作为美舍河生态修复的示范性节点，凤翔公园场地定位为具有综合功能的城市公园。凤翔公园的设计目标是通过设计生态学途径修复场地的生态系统，系统治理内涝和水质污染问题，为周边居民营造高品质滨水慢生活环境，为城市打造一个全新的旅游、休憩、文化胜地。

项目占地78.52hm^2（包含水域面积），以密林、台地、湿地、浅滩、树岛等大地景观为基底，以20年一遇暴雨防洪标准为行洪排涝要求；构建吸纳城市雨洪、净化生活污水的人工湿地系统；基于白鹭保护区及湿地设置步道系统；通过丰富多彩的活动组织引入慢生活体验。其中，如何应对场地内涝并就地吸纳日均3 500吨的生活污水中的营养物是本次设计需要解决的核心问题。

3 设计策略

设计团队基于以往水生态修复的成功经验和教训，并参考类似案例的使用后评价研究成果[1]-[9]，提出了以下几大设计策略：

3.1 构建让水流与营养流慢下来的绿色海绵系统

3.1.1 绿色海绵系统

场地内地形坡度在0~35° 之间，根据场地雨水径流及排水计算，场地被划分成23个集水分区，用来收集场地内部和部分周边市政道路的雨水径流；经由草沟、下凹绿地、梯级净化湿地等海绵设施，水流得以慢下来，最终汇入美舍河。这可以从根本上解决场地内涝问题，并有效补充地下水。2017年，公园在建成之初便经历了一场暴雨，场地原本的数个易涝点都没有出现内涝，场地内的雨水得到了有效组织和排放，公园的海绵系统经受住了考验。

3.1.2 生态驳岸

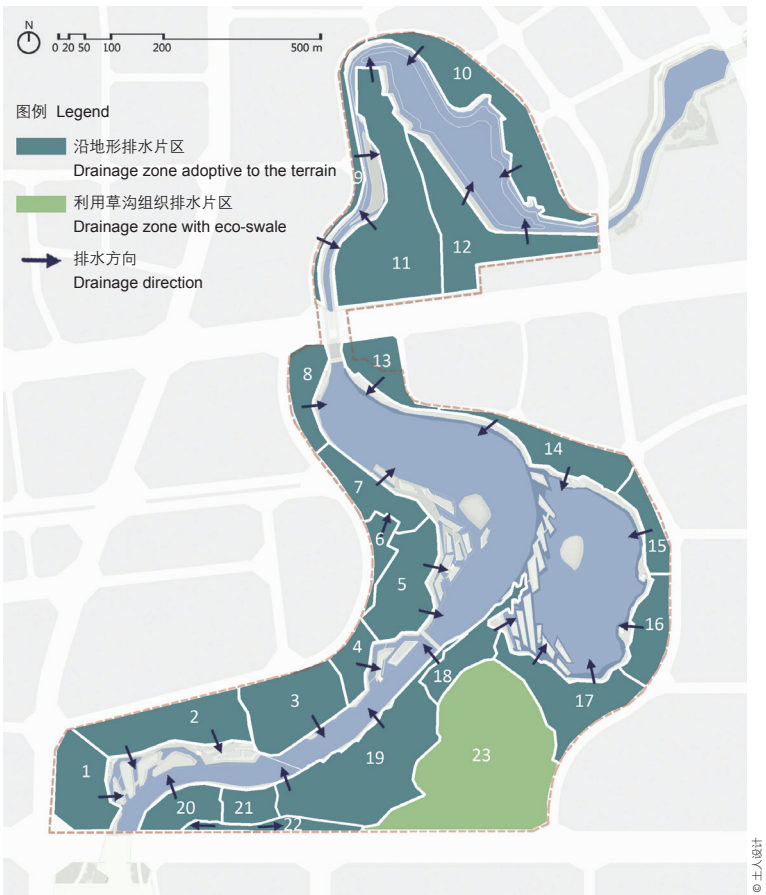
设计最大限度地将灰色防洪堤退还给水域及绿地空间：在不破坏现状市政污水管网的情况下拆除了两岸长达484m的水泥防洪堤，取而代之的是14.82hm^{2}的浅滩湿地，为20年一遇的暴雨提供了可淹没空间。其中，乾坤湖区域驳岸的拆除与重建是设计的亮点：基于现状防洪堤进行就地填挖方，通过最小干预，营造有利于水质改善和栖息地修复的微地形，包括为白鹭创建了专属栖息空间。改造后，原有河道水面得到了扩宽，楔形岛屿与上游水流方向形成了一定的夹角，从而减缓了水流流速——楔形岛屿的特色形状也成为了凤翔公园的标志性景观符号之一。

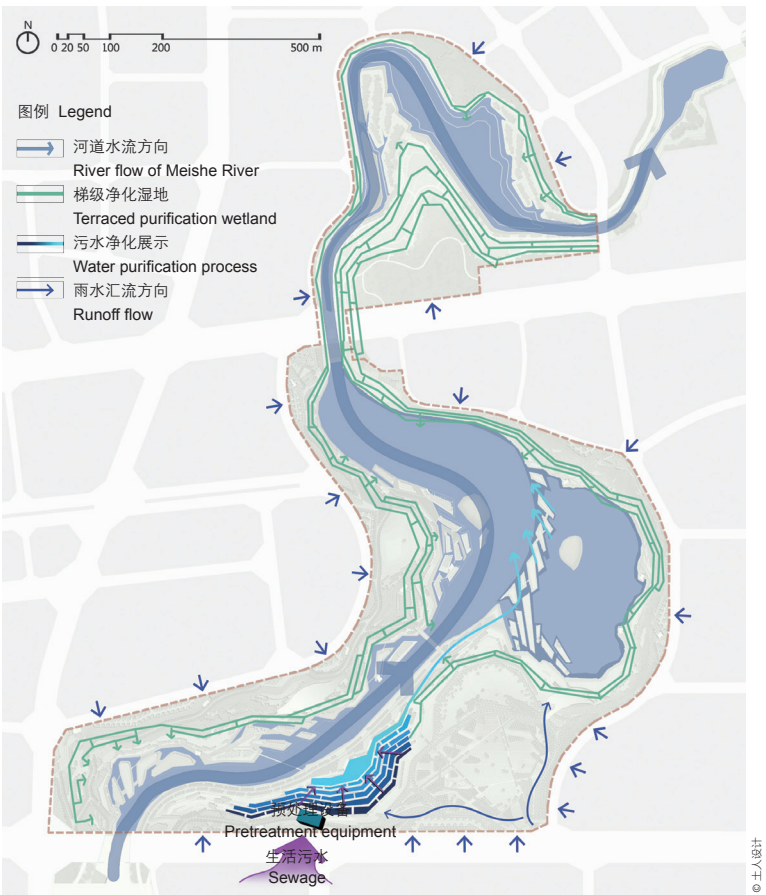
1 © 景帆

3.1.3 梯级净化湿地

为了应对大量生活污水，设计创建了一个梯级净化湿地，采用“灰绿”结合的方式将从生活污水中去除的氮、磷等营养物转变为植物生长的肥料，并通过对植物的定期维护和收割让营养流慢下来。

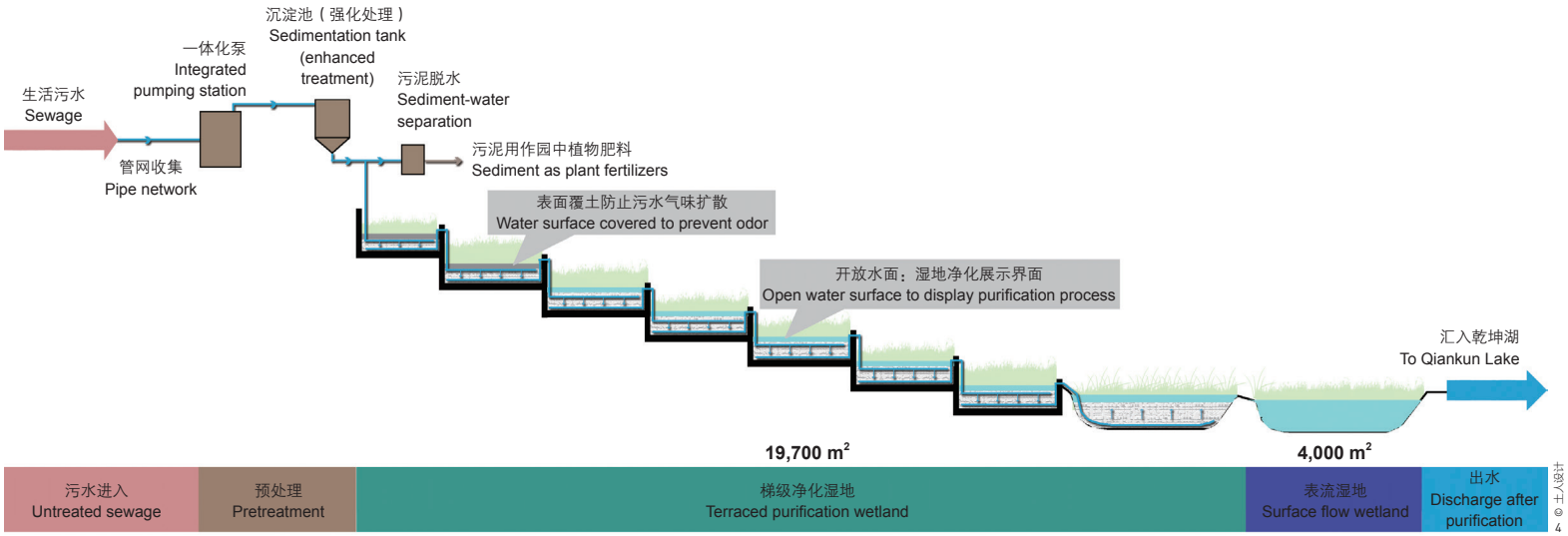
根据要求，梯级净化湿地出水水质需满足《城镇污水处理厂污染物排放标准（GB18918-2002）》中的一级A排放标准，其中污水中的BOD5、TN、TP的去除率需分别达到90%、67%、93%（表1，2）。设计在场地入水口设置了一级处理系统，利用一体化预处理设备来去除污水的气味、重金属以及危害公共健康的病原体。预处理后的污水进



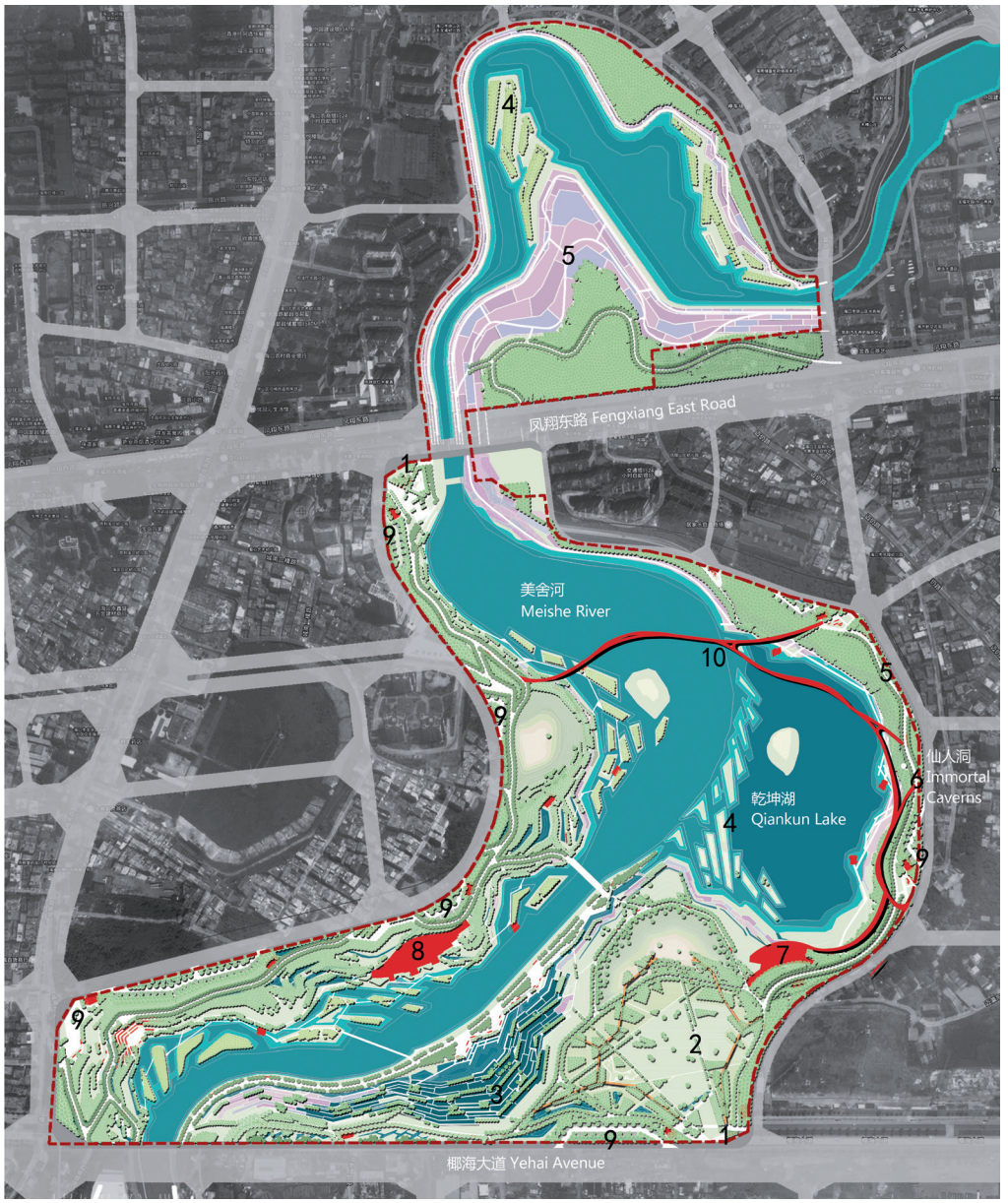


2. 凤翔公园水净化分区图
3. 凤翔公园水流方向分析图
4. 梯级净化湿地流程图
5. 凤翔公园总平面图

2. Water purification zoning plan of the Fengxiang Park
3. Water flow analysis of the Fengxiang Park
4. Diagram of the terraced purification wetland
5. Site plan of the Fengxiang Park



入二级处理系统——加强型人工梯级垂直流湿地系统，其面积约19 700m^2，共设置8层梯级，并以取材于当地的火山岩作为基质；为保证布水均匀、高效发挥湿地的净化作用，将湿地划分为面积均等的10个水净化分区，经过预处理的污水被平均输送至每个湿地分区；经过梯级湿地的层层净化后，出水水质大幅提高。其后，水流进入三级净化系统——河流型表流湿地，面积约4 000m^2，依靠植物根茎的拦截作用去除水中的悬浮颗粒物，并利用根茎生成的生物膜的降解作用净化水体[10]。这一净化系统延长了水流路径、减缓了水流流速，使得污水



1 主入口 Main entrance
2 景观草坪 Grand lawn
3 人工湿地 Constructed wetland
4 景观岛 Green isles
5 台田 Rock terraces
6 自行车道 Bicycle trail
7 服务中心 Service center
8 科普中心 Education center
9 停车场 Parking area
10 观鸟栈道 Birdwatching corridor

N 0 50 100 200m

河道 River
景观岛 Green isle
树岛 Tree island
景观草坪 Lawn
人工湿地 Constructed wetland
台田 Rock terraces
水塘 Pond
广场 Square
空中栈桥 Elevated trail
观鸟栈道 Birdwatching corridor
建筑 Building
景观构筑 Landscape structure
自行车道 Bicycle trail
停车场 Parking area
设计红线 Project boundary

中的营养物得以被充分吸收。最终，经海口桑德美沙环保工程有限公司水质检测中心检测结果显示，水质可达到一级A排放标准，2019年3月湿地的水质更是曾达到了Ⅲ类水的标准，其中NH_3-N、TP、BOD_5、CODcr含量均远远低于Ⅲ类水标准（表3）。梯级净化湿地还串联起了台地、岛屿、浅滩等空间节点，营造出错落有致的湿地景观，在旱季也为美舍河提供了一定的水源补充。

3.2 种植设计与栖息地修复

人工湿地中的水生植物是发挥净化功能的重要载体。水生植物能吸收水中的营养物质，增加水中氧气含量，抑制有害藻类的繁殖和底泥营养盐的释放，利于水体的生态平衡。在水生植物选择上，选取抗性强、代谢生长旺盛、生长周期长、根系发达，并具备一定观赏或经济价值的植物。场地中种植了各类水生植物共19种（表4），其中挺水植物14种、浮水植物2种、沉水植物3种。丰富的植物群落为鸟类栖息提供了良好的环境，公园内鸟类种类和数量明显增加，常见的鸟类包括小白鹭（*Egretta garzetta*）、池鹭（*Ardeola bacchus*）、栗苇鸡（*Ixobrychus cinnamomeus*）等。

3.3 慢行系统与慢生活空间

3.3.1 慢行系统

基于《海口市城市总体规划（2006—2020）》，海口市展开了绿色慢行休闲系统规划，这也是中国首个将全市纳入绿色慢行系统规划的省会城市。依据海口市绿色慢行休闲系统规划选线，美舍河全段在功能上属于自行车和步行相结合的慢行选线，凤翔公园作为海口慢行系统中的重要节点与城市旅游公交慢行环线相衔接。

公园的东西两侧设置了宽4m、总长约1.7km的自行车道，并与外围的城市自行车道相衔接；考虑到公园在城市中的重要角色，以及城市对共享单车需求的日益增加，公园共设置了11处停车场，提供了482个共享单车停车位。紧邻自行车道还设置了总长约1.4km的红色透水混凝土慢跑道，每天清晨与傍晚都能看到众多市民沿着美丽的河景散步或慢跑，为公园注入了活力。自公园建成以来，举办过多次骑行、慢跑、马拉松等绿色出行活动，慢行及慢生活的理念深入人心。

3.3.2 复合栈道系统

设计师在梯级净化湿地之上设计了复合栈道系统，游人可以根据栈道游线参观水质净化的全流程，集科普与休闲于一体。栈道穿梭于不同高度变化的湿地植物群落，创造了从私密到开敞的空间体验；宽1.2~2m的混凝土栈道尺度安全宜人，可满足人们三两成群或者团体出行的要求；人们可以通过扫描栈道标示牌上的二维码来了解不同植被净化水体的生态功能及相关自然生态知识；栈道距离水面仅10cm，人们可以蹲下近距离观察水生植物、昆虫和鱼类，或者干脆把脚伸进水里荡起一阵水花；位于梯级净化湿地末端的将近3 500m^2的荷花池是梯级净化湿地的核心景观，栈道淹没在花海和绿茵中，游人慢行其中，

获得多维度的景观体验；栈道末端的亲水平台更成为了游人与自然对话的舞台，人们在此或就地野餐、或端坐冥想、或在美景中翩翩起舞。梯级净化湿地作为海口最大的人工湿地，在建成不久后受到了社会高度关注及广大市民的喜爱。

3.3.3 观鸟长廊

破堤之后，白鹭的栖息地保护区达4.8hm^2。设计团队通过营造浅滩、湿地、岛屿等地形为白鹭提供觅食区与筑巢地，在不干扰鸟类活动的前提下，在鹭鸟保护区75m（惊飞距离）外设置了长约1km的观鸟长廊（尚未建成）。

3.3.4 空中栈桥

位于入口区的大草坪原为建筑垃圾填埋场，常年的垃圾堆放让场地成为了公园的高地，像“山丘”般矗立在场地中。设计师保留了这一地形特征，将现场表层垃圾清除，并利用就地填挖方的手法将其打造为可眺望对岸城市天际线的最佳观景地；“山丘”上种植了大量的乡土果树，成为了一座“市民果园”。白色简约的空中栈道架设于“山丘”之上，将游人从城市快速引入公园内部；栈道宽约3.5m、全长782m，设有7个出入口，可与大草坪、儿童活动场地、梯级净化湿地等核心节点相连接，在满足人们游憩活动的同时将环境破坏降至最低；游人步入其中，触手可及的榕树（*Ficus microcarpa*）、椰树（*Cocos nucifera*）等植物在带来树荫的同时，也突显了城市的热带气候特色。

4 结语

凤翔公园作为海口市重点项目从立项开始就受到了社会和市民的高度关注，城市管理者及设计师在公园的建设过程中通过媒体采访向市民传播海绵城市建设及绿色出行的理念。经过共同努力，场地的污水问题、洪涝问题得以巧妙解决。绿色海绵技术和加强型人工湿地系统最终让凤翔公园的水流及营养流慢了下来，令动植物栖息地得以修复；多样化慢行系统的引入鼓励了市民及游客的绿色出行，为城市增添了活力。

2018年，海口成为了拉姆萨公约缔约国组织认证的第18个国际湿地城市；2019年1月，中央电视台《焦点访谈》栏目报道了海口美舍河治水治污及景观提升的成功经验。更为重要的是，在全球日益严峻的水污染和水资源短缺等问题下，项目所采用的基于自然的解决方案是可复制的，在城市水质治理、防洪以及创造社会文化服务空间等方面具有重要借鉴意义。[11] LAF

项目信息

项目地址： 中国海南省海口市
项目面积： 78.52hm^2
项目委托： 海口市园林局、海口市水务局
景观设计： 北京土人城市规划设计股份有限公司
首席设计师： 俞孔坚
项目负责人： 张建乔、俞文宇
设计团队： 王欣、林国雄、张喻、拜真、王芳、宋嘉、吴帆、王予非、李飞、边亚光、周洲、董恬祎
设计时间： 2016年12月~2017年6月
施工时间： 2017年3月至今

6. 凤翔公园鸟瞰图

6. A bird's eye view of the Fengxiang Park

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7. 项目设计旨在通过设计生态学途径修复场地的生态系统，为周边居民营造高品质滨水慢生活环境。

7. The site was envisioned as an urban park providing citizens a quality waterfront with pleasant, slow living environment through a substantial ecosystem improvement with means of Designed Ecology.

1 Project Background

Haikou is a coastal tourist city in Hainan Province of South China with beautiful natural landscapes characterized for its typical monsoon climate. Urban construction has been given a high priority during the rapid urbanization in the past decades, while the role of natural rivers as city's water ecological infrastructure has been long-time neglected, resulting in a sharp deterioration of urban ecological resilience and security.

Meishe River, stretching for 23 kilometers, is the mother river that has nourished the growth of the City of Haikou. However, over the decades, the river course became a dump of sewage and waste; for a faster flood drainage, city governors canalized the river and replaced the natural banks with constructed high embankments, destroying its ecosystem services, accompanying with the disappearance of the slow lifestyle honored by the locals through generations.

Fengxiang Park, sitting at the middle reaches of the Meishe River, is a key ecological node in the watershed with the largest hinterland, which however had suffered from severe ecological problems. The canalized watercourse was only used for flood discharge with little environmental resilience, resulting in

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frequent waterlogging in rainy seasons and water shortage during dry months, while ruining the landscape aesthetics; As construction of a sewage pipe network in the surrounding area was not completed, about 3,500 tons of sewage was directly discharged into the watercourse every day, where the water quality declined to the worst level (Class Ⅴ), stinking the site terribly; The walk path system along the river was discontinuous with few accesses to the water; The Qiankun Lake and Immortal Caverns, both high-reputation tourist destinations included within the project territory, no longer served for citizens' recreational opportunities due to the heavy pollution of sewage and waste; In addition, in the Qiankun Lake that previously

8. 设计将原有的防洪堤改造为了楔形岛屿
9. 楔形岛屿鸟瞰图
10. 梯级净化湿地鸟瞰图

8. Wedge-shaped islands transformed from the concrete embankments
9. A bird's eye view of the wedge-shaped islands
10. A bird's eye view of the terraced purification wetland

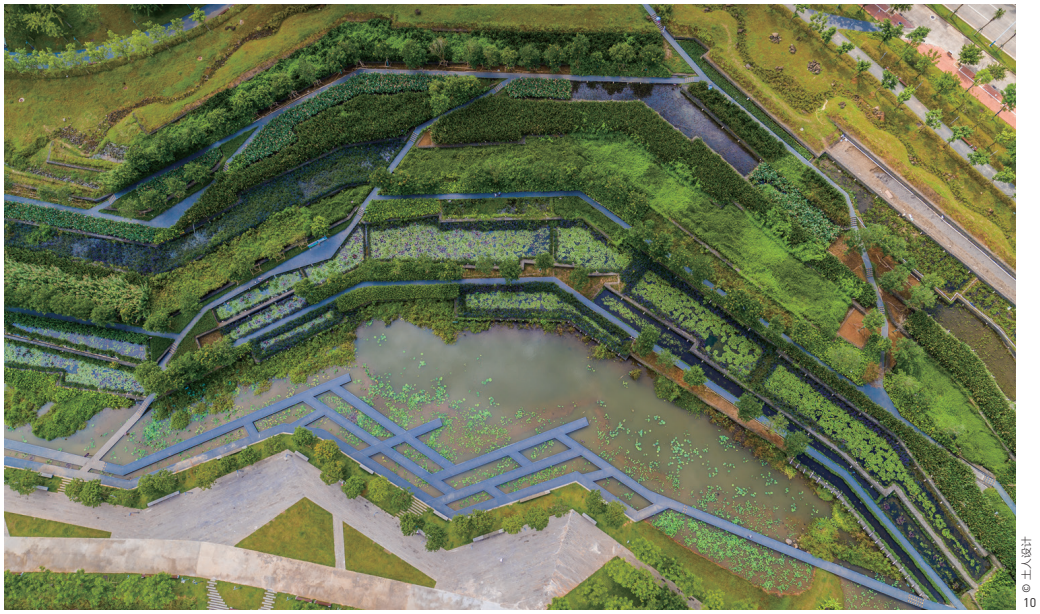

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表1：凤翔公园场地改造前污水水质检测结果（检测时间：2017年3月）
Table 1: Water quality test results on the site of the Fengxiang Park before the launch of project (March, 2017)

检测机构 Test agency	水质指标 Indicators				
	pH	NH_3-N (mg/L)	TP (mg/L)	COD_{Cr} (mg/L)	TN (mg/L)
海口市生态环境保护局 Ecological and Environmental Protection Bureau of Haikou	7.8	13.7	5.11	199	45.7
海口桑德美沙环保工程有限公司 Haikou Sangde Meisha Eco-Protection Engineering Co., Ltd.	-	-	7.11	146	-
中国科学院生态环境研究中心 Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences	7.6	17.1	5.26	138	42.2

注释
海口市生态环境保护局于2019年更名为海口市生态环境局。
NOTE
The Ecological and Environmental Protection Bureau of Haikou was renamed Bureau of Ecology and Environment of Haikou in 2019.

表2：凤翔公园设计进出水水质（单位：mg/L）
Table 2: Design goal of water quality improvement of the Fengxiang Park (mg/L)

	水质指标 Indicators			
	NH_3-N	TP	COD_{Cr}	BOD_5
进水 Inlet	20	7	200	100
出水 Outlet	5	0.5	50	10

表3：凤翔公园人工湿地建成后水质检测结果
Table 3: Water quality test results of the constructed wetland of the Fengxiang Park after completion

检测日期 Date	检测区域 Test location	水质指标 Indicators			检测结果 Result
		NH_3-N	TP	COD_{Cr}	
2019年3月22日 March 22, 2019	一体化预处理系统出水 Outlet of the integrated pretreatment system	6.21	0.14	36.80	满足地表Ⅲ类水标准 满足一级A排放标准 Met the Standard of Surface Water Class Ⅲ and the Discharge Standard of A Level, Class Ⅰ
	梯级净化出水 Outlet of the terraced wetland	0.13	0.01	12.7	
2019年3月24日 March 24, 2019	一体化预处理系统出水 Outlet of the integrated pretreatment system	28.26	1.96	73.6	满足地表Ⅲ类水标准 满足一级A排放标准 Met the Standard of Surface Water Class Ⅲ and the Discharge Standard of A Level, Class Ⅰ
	梯级净化出水 Outlet of the terraced wetland	0.90	0.03	16.8	
2019年3月25日 March 25, 2019	一体化预处理系统出水 Outlet of the integrated pretreatment system	14.11	1.58	166.0	满足地表Ⅲ类水标准 满足一级A排放标准 Met the Standard of Surface Water Class Ⅲ and the Discharge Standard of A Level, Class Ⅰ
	梯级净化出水 Outlet of the terraced wetland	0.90	0.05	17.0	
2019年3月26日 March 26, 2019	一体化预处理系统出水 Outlet of the integrated pretreatment system	6.43	0.59	36.2	满足一级A排放标准 Met the Discharge Standard of A Level, Class Ⅰ
	梯级净化出水 Outlet of the terraced wetland	3.44	0.07	15.1	
2019年3月27日 March 27, 2019	一体化预处理系统出水 Outlet of the integrated pretreatment system	16.35	0.24	17.7	满足一级A排放标准 Met the Discharge Standard of A Level, Class Ⅰ
	梯级净化出水 Outlet of the terraced wetland	2.79	0.08	14.0	
2019年3月30日 March 30, 2019	一体化预处理系统出水 Outlet of the integrated pretreatment system	14.76	0.03	18.3	满足一级A排放标准 Met the Discharge Standard of A Level, Class Ⅰ
	梯级净化出水 Outlet of the terraced wetland	4.96	0.33	17.6	

注释
地表Ⅲ类水标准：NH_3–N≤1，TP≤ 0.2，COD_{Cr}≤20；一级A排放标准：NH_3–N≤5，TP≤ 0.5，COD_{Cr}≤50。
NOTE
Standard of Surface Water Class III: NH_3-N ≤ 1, TP ≤ 0.2, COD_{Cr} ≤ 20; Discharge Standard of A Level, Class Ⅰ: NH_3-N ≤ 5, TP ≤ 0.5, COD_{Cr} ≤ 50.


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11. 梯级净化湿地中使用了种类繁多的水生植物
12. 孩童可以近距离观察水生植物、昆虫和鱼类。
13. 在荷花盛开的夏季，孩子们正与水嬉戏。
14. 白鹭重新回到人们的视线之中

11. A variety of aquatic plants are used in the terraced purification wetland
12. Children have an opportunity to observe aquatic plants, insects, and fish in close.
13. Children playing with the water, surrounding with flowering lotuses.
14. Egrets back to the site

表4：凤翔公园梯级净化湿地植物
Table 4: Plants used at the terraced purification wetland in the Fengxiang Park

类型 Type	常用名 Common name	拉丁名 Latin name
挺水植物 Emerging plants	芦苇 Common reed	*Phragmites communis*
	菖蒲 Sweet flag	*Acorus calamus*
	水生美人蕉 Maraca amarilla	*Canna glauca*
	香蒲 Bulrush	*Typha orientalis*
	姜花 White ginger lily	*Hedychium coronarium*
	慈菇 Arrowhead	*Sagittaria sagittifolia*
	旱伞草 Umbrella papyrus	*Cyperus alternifolius*
	千屈菜 Purple loosestrife	*Lythrum salicaria*
	梭鱼草 Pickerelweed	*Pontederia cordata*
	再力花 Hardy water canna	*Thalia dealbata*
	纸莎草 Paper reed	*Cyperus papyrus*
	花叶芦竹 Striped gant cane	*Arundo donax* var. *versicolor*
	翠芦莉 Mexican petunia	*Ruellia simplex*
	荷花 Lotus	*Nelumbo* spp.
浮水植物 Floating plants	睡莲 Water lily	*Nymphaea* spp.
	水菜花	*Ottelia cordata*
沉水植物 Submerged plants	苦草 Eelgrass	*Vallisneria natans*
	黑藻 Waterthyme	*Hydrilla verticillata*
	菹草 Curly pondweed	*Potamogeton crispus*

inhabited by egrets and various fish species, the birds vanished away and a lot of fish died.

In recent years, city governors carried out a series of ecological restoration projects, ranging from sewage interception, riverbed dredge, pilot water quality control projects to regulation improvement. However, the lack of systematic treatment measures has resulted in inefficiency in addressing those environmental problems — The slow life that people longed for with a harmonious relationship with water seemed like an unreachable dream. To promote the ecological civilization construction, the Haikou City launched an ecological restoration project of the Meishe River, as a waterfront demonstration of the re-establishment of a slow lifestyle.

2 Design Objectives

As a demonstrative node in the entire ecological restoration project, the Fengxiang Park was envisioned as an urban park which mitigates urban flooding and water pollution, provides citizens a quality waterfront with pleasant, slow living environment, and creates a new tourism, recreational, and cultural destination for the

city, through a substantial ecosystem improvement with means of Designed Ecology.

Covering an area of 78.52 hectares (including water areas), the designed topologies on the site include forests, terraces, wetlands, marshes, and tree islands, which were all designed to withstand a 20-year storm event; a constructed wetland system was designed to retain urban floods and purify sewage; a walk path system was planned to encourage pedestrian opportunities while minimizing construction impact on the egret reserve and wetlands; and diverse programs were conceived to invite visitors to experience slow lifestyle. Particularly, the design was expected to address the on-site flooding problem and to absorb the nutrients from the daily 3,500 tons of sewage before it discharges into the river.

3 Design Strategies

Based on their experience from previous practice in water ecological restoration, as well as extensive literature review on recent research of post-occupancy evaluation[1]~[9], the design team proposed the following major design strategies:

3.1 Building a Green Sponge System to Slow down the Flow of Water and Nutrients

3.1.1 Green Sponge System

The site terrain sees a slope gradient from flat to 35°. Calculated according to the runoff flow and drainage capacity, the site was divided into 23 drainage zones which collects on-site rainwater and runoffs from several roads in the surroundings; the flow of water would slow down through sponge measures such as eco-swale, sunken green space, and terraced purification wetland before it joins the Meishe River. Such a green sponge system can radically solve the urban flooding problem and help recharge underground water. In 2017, the park went through a storm upon its completion, but no floods occurred even in the historically vulnerable areas, which proved that park's sponge system effectively works.

3.1.2 Ecological Riverbanks

The design reclaimed the grey embankments into water areas and green spaces to the largest extent: while maintaining the existing civil drainage network, the concrete embankments on both riversides (a total of 484 meters in length) were demolished and replaced with floodable marshes and wetlands, covering an area of 14.82 hectares, which can withstand 20-year storm events. The rebuilding of the revetments of the Qiankun Lake was one of the highlights in the design: For a minimum

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construction impact, on-site cutting-and-filling was conducted adapting to the existing terrain, to create micro-topographies that help improve water quality and restore habitats, including special sanctuaries for egrets. The design increases the water surface and the constructed wedge-shaped islands that form certain angles with water flow and thus can slow it down effectively — The distinctive wedge shape has also become an iconic landscape symbol of the park.

3.1.3 Terraced Purification Wetland

To meet the requirement of dealing with huge amount of domestic sewage, the design conceived a terraced purification wetland which integrates engineering (grey) and ecological (green) treatment measures, to capture nitrogen and phosphorus nutrients from sewage. Such nutrients can be recycled as fertilizers for plants, which would be regularly maintained and

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15. 空中栈桥连接起了园中的各个重要节点
16. 空中栈桥从热带植物群落中穿过

15. Elevated trail linking key landscape nodes in the park
16. Elevated trail passing through topical vegetation communities

harvested so as to slow down the flow of nutrients as well.

The water cleansed by the terraced purification wetland is required to meet the Discharge Standard of A Level, Class I, according to the Standards for Pollutant Discharge by Sewage Treatment Plants in Cities and Towns (GB18918-2002), which stipulates that the removal rates of BOD_5, TN, and TP need to reach 90%, 67%, and 93%, respectively (Table 1, 2). A primary treatment system is employed at the sewage inlet on the site, where an integrated pretreatment equipment is used to remove odor, heavy metals, and pathogens hazardous to public health. After pretreatment, water enters a secondary treatment system — a terraced reinforced vertical flow constructed wetland system, covering an area of about 19,700 square meters, with eight layers of terraces, the bases of which are made with local volcanic rocks. The wetland was divided into 10 subzones of equal size to evenly distribute pretreated water for a higher cleansing efficiency. After purified layer by layer through the terraced wetland, water quality is largely improved. At last, water flows into a river-like surface flow wetland for a further purification. The wetland covers an area of about 4,000 square meters, where suspended particulate matters in water are captured by plant roots and stems and pollutants are removed through the bio-degradation by plants[10]. This whole wetland system extends and slowers the water flow and nutrients are sufficiently absorbed from sewage. Finally, tested by the Water Quality & Testing Center of Haikou Sangde Meisha Eco-Protection Engineering Co., Ltd., water at the outlet of the entire treatment system can meet the Discharge Standard of A Level, Class I — the quality of purified water reached the Class III Standard in March 2019 and the concentrations of NH_3-N, TP, BOD_5, and CODcr were far less than the Standard required (Table 3). The terraced purification wetland also connects a number of spatial nodes such as the terraces, islands, and marshes, creates a resilient wetland landscape that combines a variety of dynamic elements together, and provides water supply for the Meishe River in dry seasons.


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3.2 Planting Design and Habitat Restoration

Aquatic plants in the constructed wetland play an important role in water purification. They can absorb nutrients from sewage, increase oxygen level of water, inhibit the reproduction of hazardous algae, and mitigate the release of nutrients from sediments, which are key to maintaining the water ecological balance. On selection of aquatic plants, specific characteristics were taken into consideration, including strong resistance, vigorous metabolism and growth, long persistency, and robust root system, as well as outstanding ornamental aesthetics or economic values. 19 species of aquatic plants are used on the site (Table 4), including 14 species of emerging plants, two floating plants, and three submerged plants. Sorts of vegetated habitats are well established for wild birds, the observed avian species (including *Egretta garzetta*, *Ardeola bacchus*, and *Ixobrychus cinnamomeus*) and total bird number in the park keep increasing.

3.3 Pedestrian-Cycling System and Spaces for Slow Lifestyle

3.3.1 Pedestrian-Cycling System

Based on Overall Urban Planning of the City of Haikou (2006-2020), the city implemented a planning of a green slow traffic system, becoming the first city-scale project of such planning practices among provincial capitals in China. According to the route planning, the included sections of Meishe River are envisioned to serve citizens' cycling and walking needs, and the Fengxiang Park, as a key node in the slow traffic system, connects with the urban slow traffic loop for tourism and public recreation.

On the east and west sides of the park are bicycle trails, 4 meters in width and nearly 1.7 kilometers in length in total, connecting with city cycling lanes. In consideration of the important role of the park to the city and the growing needs for bike-sharing, 11 parking areas were built in the park, providing 482 parking lots for shared bikes. Adjacent to the bicycle trails, there are jogging trails paved with red pervious concrete, about 1.4 kilometers in length in total, where many residents can be

seen walking or jogging along the beautiful river at dawn and dusk, bringing dynamics and vitality into the park. Since the park's completion, several green traffic events have been held here ranging from cycling, jogging to marathons, popularizing the concepts of slow traffic and slow lifestyle among the public.

3.3.2 Multi-Function Boardwalk System

To integrate educational and recreational opportunities, a boardwalk system was constructed above the terraced purification wetland, along which visitors can observe the whole water purification process. The boardwalk passes across wetland vegetation communities at different heights of plants, creating a unique experience from intimacy to openness; its width of 1.2 to 2 meters not only guarantees visitors' safety but also creates a pleasant landscape experience, meeting the needs of travelling in small or large groups; by scanning QR codes on boardwalk signages, visitors can learn about the ecological roles of different plants in water purification and relevant ecological knowledge; the boardwalk only 10 centimeters above the water surface allows visitors to observe aquatic plants, insects, and fish in close, or to play with the water; the lotus pond at the end of the terraced purification wetland, covering an area of about 3,500 square meters, is a featured landscape in the park, where the boardwalk meanders across the flowers, grasses, and trees, creating a multi-dimensional sightseeing experience for people who walk through; the floating platform at the end of the boardwalk acts as a stage for visitors to appreciate the beauty of nature, have a picnic, meditate or dance in the attractive landscape. As the largest constructed wetland in Haikou, the terraced purification wetland has attracted a great attention from the public after its completion and now becomes a popular destination in the city.

3.3.3 Birdwatching Corridor

The design demolished the concrete embankments and expands the area of egret reserve to 4.8 hectares: Habitats in forms of marshes, wetlands, and islands were created for egrets to forage and nest. On the premise of causing no disturbance to the birds, a birdwatching corridor (not completed yet) about one kilometer in length was designed 75 meters (the observed flight initiation distance of egrets) away from the reserve boundary.

3.3.4 Elevated Trail Network

The site of the grand lawn at the entrance area was previously occupied as a landfill of construction wastes, and a mound was formed due to years of waste dumping. The design made full use of this topographic feature, removed waste on the surface and transformed it into a perfect overlooking spot through on-site cutting-and-filling. The mound, atop which a lot of native fruit trees were planted, has been turned into a "public orchard." A white elevated trail network was set over the mound, leading visitors to the central areas of the park. The trails are about 3.5 meters wide and 782 meters long, with 7 accesses that link up key landscape nodes such as the grand lawn, children's playground, and the terraced purification wetland, offering people an unusual recreational experience while causing minimum impact to the environment. Walking along the trails, visitors can enjoy the lush and shades created

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17. 多样化慢行系统的引入鼓励了市民及游客的绿色出行；自公园建成以来，举办过多次骑行、慢跑、马拉松等绿色出行活动，慢行及慢生活的理念深入人心。

17. The introduction of a diversity of slow traffic system has brought vitality to the city by encouraging green traffic modes. Since its completion, the park has held several green traffic events ranging from cycling, jogging to marathons, popularizing the concepts of slow traffic and slow lifestyle among the public.

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by *Ficus microcarpa* and *Cocos nucifera* trees that highlight tropical climate of the city.

4 Conclusion

Considered an important demonstration project in Haikou, Fengxiang Park has gained a great attention from the society since its launch. During its construction, city governors and designers publicized the ideas of sponge city and green traffic to the public society through all kinds of media communication. Concerted efforts were made to smartly address the problems of sewage and urban flooding on the site. Techniques of green sponge construction and the reinforced constructed wetland system deployed in the park have effectively slowed down the flow of water and nutrients, and restored habitats for fauna and flora; the introduction of a diversity of slow traffic system has brought vitality to the city by encouraging green traffic modes among citizens and tourists.

In 2018, Haikou was honored as the 18th city of Ramsar Convention in the international society; in January 2019, Focus Report of China Central Television reported the success of the Meishe River in water remediation and landscape improvement. More importantly, in view of increasingly severe issues such as water pollution and shortage around the globe, the nature-based solutions adopted by the project shows an obvious reference significance to other practices in urban water quality improvement, flooding control, and the creation of public spaces to provide social and cultural services.[11] **LAF**

PROJECT INFORMATION

LOCATION: Haikou City, Hainan Province, China
AREA (SIZE): 78.52 hm^2
CLIENTS: Landscape Bureau of Haikou City, Water Management Bureau of Haikou City
LANDSCAPE ARCHITECTURE: Turenscape
CHIEF DESIGNER: Yu Kongjian
PROJECT MANAGERS: Zhang Jianqiao, Yu Wenyu
PROJECT TEAM: Wang Xin, Lin Guoxiong, Zhang Yu, Bai Zhen, Wang Fang, Song Jia, Wu Fan, Wang Yufei, Li Fei, Bian Yaguang, Zhou Zhou, Dong Tianyi
DESIGN PERIOD: Decemeber, 2016 ~ June, 2017
CONSTRUCTION PERIOD: March 2017 to present

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