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## 基于自然过程的人工干预下的水系统生态设计 Ecological Water System Design under Human Intervention Based on Natural Processes



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### Abstract

Ecological water system design is an approach to ecological engineering that intervenes natural processes and regulates the living environment through human intervention. This article discusses the scope of ecological water system design and the relationships between water systems at different scales. Citing several built projects, this paper illustrates how to construct ecological water systems, while also analyzing the instructive significance of ancient water management to current methods of ecological water system design.

### Key words

Water System; Ecological Design; Human Intervention; Ancient Water Management Concept

### 摘要

水系统生态设计是一种利用人工干预的方式，介入自然过程、调节人居环境的工程化的生态处理方式。本文探讨了水系统生态设计的内涵、不同尺度的水系统之间的关联，并结合具体项目说明如何进行水系统生态设计与建设，以及古代水管理对于当代水系统生态设计的借鉴意义。

### 关键词

水系统；生态设计；人工干预；古代水管理理念

### 您如何理解“水系统生态设计”这一主题？

郑曦（以下简称郑）：作为生态系统中的重要组成部分，从古至今，水系统都是人类在其生存环境相互作用的过程中，塑造理想人居环境的最重要的自然对象。在我的理解中，水系统生态设计是一种利用人工干预的方式，介入自然过程、调节人居环境的工程化的生态处理方式。

在人与自然相互适应的过程中，人工干预对于区域景观演变与生态系统完善至关重要。如4 000多年前大禹治水中的“决九川距四海，浚赋治距川”，2 200多年前李冰父子修筑都江堰时的“深淘滩，低作堰”等，都是人类通过工程手段梳理区域水系统、干预自然过程，形成理想的生态人居环境的典范。如今，世界上发达的城市（群）大多位于河流三角洲或冲积扇地区。这些地区的繁荣与城市发达的水系统密不可分，看上去如同自然形成的水环境实际上是千百年来人类秉承着对生态法则的尊重，通过人工水利工程对自然进行改造、利用和干预的结果；是物质环境与人类社会之间最为持久的联系的一种体现。

当前提出的生态设计，主要是为了应对自20世纪以来，城市建设为追求更高的技术效率而建造的经工程化、标准化处理的功能单一的基础设施（如城市河道的渠道化、规模/数量庞大的水坝建设等）所导致的一系列城市问题。这些无处不在的城市环境元素仅仅是从技术标准层面进行考量与评估，几乎完全忽视了其在社会、美学和生态方面的功能。

因此，生态设计的提出实际上是一种回归，一种通过设计这一人工干预手段使人居环境恢复其应有的自然生态系统功能的思维方式。生态设计可以成为探索自然过程与城市人工构建之间关系的有效途径。

### 您对于不同尺度的水系统（如城市中的水景观、区域中的江河系统等）以及它们之间的关联有着怎样的理解？

郑：水系统是大的循环体系，其包括降水、地表径流、地表水下渗、蒸发，以及浇灌、污水处理等。

区域尺度的水系统对生态环境具有显著的影响。由于我

### How do you understand Ecological Water System Design?

**Xi ZHENG (ZHENG hereafter):** As an important component of ecosystems, water system has always been essential to creating ideal living environments in the interaction process between human and the living environment since ancient times. “Ecological Water System Design” is an engineering method that intervenes and regulates the natural environment through human intervention.

Human intervention is essential to the evolution of regional landscapes and the improvement of ecosystem. For example, more than 4,000 years ago, stories say that Dayu “dredged all the rivers of the country to make the water flood into four seas and dredged channels on farmland to direct water flow into rivers”, and more than 2,200 years ago, Bing Li and his son repaired Dujiang Dam by “deeply dredging beaches and keeping the dams low”. These historic examples illustrate a deep understanding of the regional water system and the necessity for intervening with natural processes through engineering to construct ideal ecological environments. Today, most of the world’s developed cities (or megalopolis) are located in deltas or alluvial fan areas, and the prosperity of these areas is inseparable from their urban water systems. The “natural” waterways of these cities are actually the results of hydraulic projects that have intervened with the nature following ecological principals over thousands of years. The highly constructed nature of urban water systems reflects the most lasting bond between the physical environment and human society.

Since the 20th century, the pursuit of higher technique efficiency in urban areas resulted in the construction of engineered and standardized single-function infrastructure, such as the channelization of urban river systems and excessive construction of dams. The shift towards “eco-design” is mainly a response to the issues created by single function urban infrastructure. Currently, these ubiquitous urban environment elements have been only considered and assessed from standard technical levels, and almost completely ignore their social, aesthetic, and ecological functions.

Therefore, eco-design is actually a return — a return to a way of design thinking that restores the built environment to its natural ecosystem through design, the human interventional device. Eco-design can be an effective way to explore the relationship between natural processes and the urban built environment.

### How do you understand water systems of different scales, such as urban waterscape, and regional river systems and watersheds, and the relationships between them?

**ZHENG:** The water cycle is a large circulating system. For instance, precipitation, surface runoff, surface water infiltration, evaporation, and wastewater and sewage treatment are all part of the urban water cycle.

The regional-scale water system has significant impacts on the ecological context. For instance, as a result of the reckless construction of upstream dams, water flow at the estuaries of China’s major rivers has been reduced and the flow speed has slowed. Most importantly, the dams retain nutrient-rich sediment from upstream flow. This cuts off the material and energy exchange, and directly leads to seawater intrusion, land salinization, and freshwater erosion. These problems continue to deteriorate the state-scale ecological environment. However, this does not mean that all dam construction goes against natural processes. The Yellow River Xiaolangdi Water Control Project, for example, regulates water storage and helps to “tame” the Yellow River. Therefore, one of the key aspects to explore in water system eco-design is how human intervention and hydrologic natural processes can be balanced.

At the urban-scale water systems and waterscapes also need to be addressed as infrastructures through eco-design in order to prevent urban waterlogging and flooding, as well as increasing ecological functions in the urban environment. The State Council recently issued six key tasks for “Strengthening Urban Infrastructure Construction”, including strengthening ecological environmental construction, improving urban green space as sites of stormwater retention and detention, and recharging groundwater. One of the difficult topics is how to take advantage of eco-design tools in order to solve these problems and to build water system infrastructure based on urban security.

Eco-design should also be applied to the microcirculation of water bodies in landscape planning and design projects. Issues that need to be taken into consideration at the site scale include increasing rainwater collection, using surface runoff to recharge groundwater, water source awareness, irrigation, wastewater treatment, and municipal inter-cooperation. The eco-design of microcirculation systems should emphasize incorporation into larger municipal



1. 烟台植物园水系统图  
 2. 建设中的烟台植物园：连接山地汇水区与湖区的道路涵洞桥。  
 3. 建设中的烟台植物园：设计将汇水冲积区保留的蓄水池和新建设的主湖区连接在一起。  
 1. Water system of Yantai Botanical Garden  
 2. Yantai Botanical Garden under construction: the road culvert bridge connects the mountain watersheds and the lake area.  
 3. Yantai Botanical Garden under construction: the reserved reservoir in the alluvial watersheds combined with the newly-built main lake.

国主要河流的上游无节制地筑坝，河流入海口的水流量不断减少，流速减缓，更为关键的是，由上游水流带来的富含大量营养物质的泥沙被水坝拦阻，切断了物质与能量交换，从而直接导致了海水倒灌、土地盐碱化、淡水水源地受到侵蚀等现象，使得国土尺度的生态环境不断恶化。但并不是说人工构筑的水坝都是违背自然进程的，如黄河小浪底水利枢纽工程具有调蓄水量的功能，对于黄河治理起到了重要的作用。因此如何平衡人工干预与水体自然过程之间的关系是水系统生态设计需要重点探索的内容。

城市尺度的水系统和水景观需要生态设计，使其作为基础设施来解决城市内涝与防洪问题，并发挥生态效能，服务于城市生态环境。在国务院刚刚颁布的“加强城市基础设施建设”的六大重点任务中，提出要加强生态环境建设，提升城市绿地蓄洪排涝、补充地下水等功能。如何利用生态设计的手段解决这些问题，构建基于城市安全的水系统基础设施是其中的热点和难点。

景观规划设计项目中的水体微循环系统也需要纳入生态设计范畴，应在场地中考虑雨水收集、地下水补给、水源保障、

灌溉，以及污水处理、市政对接等问题。应强调水系统与市政基础设施的对接，而不仅仅是发挥示范作用。

综上所述，水系统的生态设计是跨越尺度的，每一种尺度的项目都需要考虑这一循环系统的各个环节。

请结合您参与的实践项目谈一谈如何在设计中统筹水系统与其他系统之间的关系？

郑：在实践项目中考虑并统筹水系统与其他系统的关系是需要重点解决的问题。以本人参与设计的烟台植物园为例（图1），如何梳理现有场地的水资源是需要解决的首要任务。项目场地东侧为连绵的山体，以西地势逐步降低。山地的谷地在南北各形成一条排水冲沟，疏导山地汇水并引导水流自东向西汇聚。当地居民在西侧的南北汇水区，各修筑了两个用于灌溉的土坝蓄水池。由于常年的冲刷，雨水将山体表层的泥沙冲刷到西侧的区域，冲沟内的土质变得肥沃。随着城市化的推进，场地中央修建了一条南北向的交通干道。这个交通基础设施并未考虑原有场地东西两侧的水体与能量流动之间的生态联系，阻断了汇水沟，使得山地汇水淤积在道路东侧，而道路西侧无法承接汇水，导致现有小型蓄水池的水量日益萎缩。

设计团队首先建议甲方调整新修道路，在原有汇水冲沟处设置涵洞桥，使山区的汇水与西部的湖区相贯通，进而也恢复了原有的能量流动。其次，依据地形地势疏导整个区域的水系统，因为“水本无形，因器成之”。设计本着最大化地吸收地表径流，特别是山地汇水的原则，连通了原有的两条汇水冲沟；同时在南侧小蓄水池以西，利用由雨水冲积而成的冲积扇区形成一个较大的湖体，作为植物园的中心主湖和全园标高的最低区域（图2，3）。

由此，全园水系统在充分利用原有地形地势的基础上，实现了贯通和循环。最后通过工程的适度介入，完成了园区水系统的构建，并实现了最小工程量和最少人工干预的原则。

您认为古人的“理水”理念应该如何与当代的水系统“生态设计”结合？

郑：古人在理水、治水方面有许多非常值得借鉴的理念。前文提到的大禹治水即是通过疏水泄洪、堆土筑山，以安置居民的经典范例；李冰父子主持修筑的都江堰使得饱受水患的成都成为了天府之国。

许多古城依水而生，因水而变。例如西湖与杭州的“湖—

infrastructure, rather than just play a demonstration role for water system.

In summary, the eco-design of water systems should work across scales. Projects should consider all aspects of this circulation system in the design process, regardless of scale.

Within your own practice, how have you managed the relationship between water system and other ecological systems?

ZHENG: In practice, considering and coordinating the relationship between water and other systems is key. Take my participation in the design of the Yantai Botanical Garden as an example (Fig. 1). The primary task was to sort out the existing water resources. East of the project site were continuous mountains, the elevation of which gradually decreases towards the west. The valleys in the north and the south created a drainage spillway. The spillways directed water from the mountains, causing it to flow from east to west. Local residents built two dirt dam reservoirs for irrigation on the west sides of the south and north reservoirs. Year after year, rainwater pushed the topsoil of the mountains to the west side of the reservoir causing the soil off the spillways to become rich with nutrients. A north-south traffic artery, which did not consider the flow of water or soil movement between the east and west, was constructed at the base of valley. The road blocked the spillways, leaving water to accumulate on the east side of the road. With water no longer flowing to the west side of the road, the existing reservoir began to shrink.

The design proposes realigning the new road and building the Hanqiao Bridge at the former catchment spillway location in order to reconnect the surface water from the mountains to the west reservoir. This change in direction would restore the original energy flow. Secondly, the design works with existing topography to direct the regional water system. In a landscape where “water has no shape, only shaped by its containers”, the design is dedicated to maximizing the capture of runoff water, especially dedicated to the “mountain collects water” principal. At the same time, it connects the two original catchment spillways and uses the alluvial fan area to form a larger lake at the west end of the south reservoir. This lake, along with being the lowest water body in the garden system, is also the main lake for the botanic garden (Fig. 2, 3).

The entire water system of the garden makes full use of the existing topography, maximizing connectivity and circulation throughout the garden. Finally, through considerate engineering intervention, the water system was constructed, and the goal of minimizing engineering quantities and human intervention was achieved.

How should the ancient “Water Management” be combined with the contemporary ecological water system design?

ZHENG: Our ancestors had a lot of concepts worth learning from in terms of water management and flood control. As I previously mentioned, Dayu diverted water through spillways for water management and resettled residents in mountainous highlands. Bing Li and his son built the Dujiang Dam and turned the flood-inflicted Chengdu region into a land of abundance.

Many ancient cities have always been built around water, and therefore challenged and changed by water, such as the symbiotic “Lake-City” relationship between West Lake and Hangzhou. In the constructing and dredging processes of West Lake, for example, a moderate amount of human intervention ensured the lasting prosperity of the West Lake landscape and the city of Hangzhou.



城”共生关系，在西湖从未间断的营造和疏浚过程中，为顺应自然而进行的适度人工干预，保证了西湖景观与杭州城持久的繁荣。又如开封市的“四水灌都”，城市内引入的四条水系与黄河、淮河连通，同时承担着漕运、商业、公共空间等多种功能。

以上这些古人的理水筑城案例对于当代的水系统生态设计具有重要的借鉴意义。将“理水”理念与城市的防洪、蓄水、交通、文化发展等相结合，再加上持续适度的人工介入，将对区域景观产生深刻影响，并使其成为景观基础设施和孕育繁荣文化的载体。

将“理水”理念与城市的防洪、蓄水、交通、文化发展等相结合，再加上持续适度的人工介入，将对区域景观产生深刻影响，并使其成为景观基础设施和孕育繁荣文化的载体。

#### 作为一名景观教育者，您在教学过程中是如何安排生态设计的教学工作的？

郑：我在学校主要教授设计课程，教学计划中安排了较多与生态和设计相关的专业课程。设计课的主要任务是培养学生综合应用包括生态学知识在内的所学知识，解决项目实际问题的能力。所以在课堂上并不会专门详细地介绍生态设计，而是将引导学生探索和分析设计中场地所面临的各个层面的问题，以及可能的相关解决方式作为教学重点。

#### 您认为生态的思想应用于实践存在哪些困难？

郑：开发者的经济利益考量和缺少以量化数据支撑生态设计发挥生态效能的评估体系是当前生态思想应用于实践中存在的较大问题。生态并不一定代表投资减少，相反可能会增加投资，而增加的部分大多是在“看不见”的地方。如何通过有效的评估体系对生态设计做出评价，并据此说服开发者支持生态设计的实践，是我们目前面临的主要困难。LAF

Another example is Kaifeng City, where “four rivers pour into the city”. Here the city introduced four new rivers to connect the Yellow River and Huai River. The new canals took on a variety of functions, such as transportation, and commercial and public space.

These water management and city-making examples come with significant lessons and principles that can be applied to contemporary water system design. Applying the ancient concept of “water management” in flood control, water storage, transportation, and culture development, combined with the continuous, moderate human interventions will have a profound impact on regional landscape, serving as a base that builds landscape infrastructures and nurtures prosperous cultures.

#### As a landscape educator, how do you teach students eco-design?

ZHENG: I mainly teach design classes. The syllabus includes some professional courses in ecology and general design. The main purpose of the design courses is to develop the students' ability to apply their own knowledge (including knowledge of ecology) to site issues. I do not specifically teach eco-design in the classroom. I focus on guiding them to explore and analyze design problems at the project site and develop possible solutions.

#### What are the difficulties of incorporating ecological ideas into design practice?

ZHENG: It depends on the client. Developers are concerned with economics, so making an argument for the monetary value of ecological design is one challenge. The lack of quantified data, which is needed to evaluate the effectiveness of eco-design is another major issue of applying ecological thinking to design practice. A focus on ecology is not necessarily equal to a reduced investment. On the contrary, it may increase the initial money spent, while most of the return is seen in “invisible” places. How to evaluate eco-design with an effective evaluation system and how to convince developers to support the practice of eco-design are the major difficulties we are currently facing. LAF

## 人性化的城市雨水景观设计对策 People-oriented Design Solutions in Urban Rainwater Landscapes



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#### 摘要

城市雨洪综合利用的根本目的在于促进地方水文的良性循环，解决地方水问题。城市是人类活动的集中地区，城市中的大多数工程设施都无可避免地要考虑人的使用需求，然而这一点却常常为传统的工程设计所忽视。本文提出了两种人性化的城市雨洪综合利用对策——弹性对策以及防御对策，并归纳总结了针对不同策略的设计手法，以期进一步促进雨洪综合利用在城市中的推广，从而构建城市中的“人水和谐”。

#### 关键词

人类活动；景观设计；城市水文；雨洪利用

#### Abstract

The fundamental purpose of the comprehensive utilization of urban stormwater is to improve the cycle of local hydrology, and respond to local water issues. Most of urban engineering facilities cannot avoid considering human uses and needs, because a city is a concentrated area of human activities. However, this point is often overlooked by the traditional design in engineering. In this paper, two people-oriented design strategies of comprehensive stormwater utilization are proposed: adaptive strategy and protective strategy. Moreover, it summarizes the design solutions for different strategies to further promote the comprehensive stormwater utilization in cities to establish a harmonious relationship between human and water.

#### Key words

Human Activities; Landscape Design; Urban Hydrology; Stormwater Utilization

近年来，旱涝灾害频繁、饮用水匮乏、地下水位降低以及河流污染等水问题一直困扰着中国城市的发展<sup>[1]</sup>。为了应对这些问题，中国于21世纪开始逐步展开对城市雨洪综合利用的研究，目前已在北京<sup>[2-4]</sup>、上海<sup>[5]</sup>、深圳<sup>[1]</sup>等城市出现诸多试点建设工程。城市作为人口高度密集的地区，是人类生产、生活的基本场所，因此，城市雨水利用需要考虑怎样能够在实现合理利用的同时兼顾人的使用与需要。人性化的城市雨水景观设计正是基于此提出的。本文概括出两大策略：弹性对策以及防御对策（表1），并针对不同对策归纳总结了一些国内外的设计途径，以期完善人性化的雨水景观设计方法，促进雨洪综合利用在城市中的进一步推广。

In recent years, water issues such as frequent droughts and floods, shortage of drinking water, lowering of underground water level and river pollution, have been besetting urban development in China<sup>[1]</sup>. To address these problems, China has gradually begun the study of comprehensive utilization of urban stormwater since the beginning of the 21st century. Currently, many pilot projects have already been launched in China's cities like Beijing<sup>[2-4]</sup>, Shanghai<sup>[5]</sup>, and Shenzhen<sup>[1]</sup>. Cities are highly populated areas, and primary places for human production and living. Thus, how to reasonably use the stormwater while fulfilling the human needs should be taken into consideration