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协同合作缓解中国水资源问题

COLLABORATIVE STRATEGIES TO ALLEVIATE CHINA'S WATER RESOURCE PROBLEMS

摘要

我国水资源面临着供需矛盾突出、水旱灾害频发、水污染严重、水生态系统退化等严峻问题。这些问题的解决需要仰赖多学科、多领域的研究合作，以及跨行业、跨部门的协同工作。与水资源研究相关的各个专业应采用协同创新的模式推进彼此间的有效沟通，注重从理论上交互融合、从方法上协作借鉴，深入开展不同学科间的交流。通过对目前广泛开展的海绵城市建设工作进行评述，作者指出应在政策法规、技术标准、体制机制等方面推动海绵城市建设中的协同。

关键词

水资源；海绵城市；协同；生态海绵流域

ABSTRACT

China's water resources are facing serious problems including uneven supply and demand, frequent droughts and floods, severe water pollution, and water ecosystem degradation. To solve these problems, multi-disciplinary and multi-field research cooperation, as well as multi-professional and multi-departmental collaboration are required. The different disciplines that study water resources should adopt new collaborative models that promote effective communication between professionals, and that focus on interactive integration in theory and methodology to achieve disciplinary exchange. A thorough review of Sponge City programs draws attention to policies, regulations, technical standards, and institutional mechanisms needed for this exchange.

KEY WORDS

Water Resources; Sponge City; Collaboration; Ecological Sponge River Basin

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能否请您简要介绍一下我国目前的水资源状况，其所面临的核心问题有哪些？

王浩（以下简称王）：人多水少、水资源时空分布不均、水旱灾害频发广发是我国水资源的基本态势，具体而言，可以概括为以下三个方面：

一是存在先天不足。其一，我国是大陆性季风气候，降雨时空分布不均。在时间上，70%以上的降雨集中在6~9月，其间产生的大量洪水径流，不仅难以利用，而且容易成灾；在空间上，东南地区降雨量多，西北地区降雨量少。其二，人均水资源占有量少。中国是水量丰沛的国家，其水资源总量为$2.84 \times 10^8 m^3$，居世界第六，其中河流山川占90%以上。但由于人口基数大，人均占有量仅有2 070m^3，不足世界人均水资源占有量的1/3，在192个有水资源统计的国家中排在第127位。

二是水资源与社会经济发展不匹配。我国水资源分布不均，南多北少，沿海多内地少，山地多平原少，致使水资源分布与耕地资源匹配性不佳，例如耕地面积占全国64%的长江以北地区水资源仅占19%。而水资源的禀赋条件在一定程度上会影响社会经济发展的速度和格局。随着人口的增长和经济社会的发展，我国水资源分布与社会经济条件不相匹配的问题也愈加突出。加之工程设施体系尚未完善，华北、西北、西南以及沿海城市等地区水资源供需矛盾突出。

三是新老问题交织。其一，随着社会经济的快速发展，传统的洪水、干旱等灾害的风险日益突出；其二，在城镇化背景下，新型水污染、水生态退化等问题有进一步加剧的趋势；其三，在以全球变暖为主要特征的气候变化的影响下，大江大河径流量明显下降，极端降雨事件时有发生，大范围干旱、城镇洪涝等水灾害事件发生频率有所增加。在如上综合性背景下，原来的“水多、水少、水脏、水浑”等老问题又有了新变化。

解决水资源相关问题通常需要多个专业的配合，您能否结合您的学术研究与实践经历，谈一谈如何建立起专业之间的有效沟通？是否有值得推荐的工作框架或方法？

王：现代科学研究靠一个人、一支笔单打独斗已经行不通了，具有重大创新意义的科研成果往往是多学科交叉、大团队协作的结果，这就迫切需要我们协同创新。科学研究并没有金科玉律，协同创新也没有唯一的工作框架或方法，这需要在实践中逐步摸索出适合自己的协调创新模式。这里谈两点个人看法：

1）不同学科的研究理念和范式各不相同，各个学科应该在尊重其他学科研究理念和范式的基础上相互借鉴、虚心学习。如果

墨守陈规，不注重向其他学科学习，则很容易引起不必要的误解。

2）要注意从实际问题出发，提出科研课题、寻找解决方法。科学研究，特别是工程科学研究的出发点和落脚点是要解决实际问题，因此从解决水资源的实际问题出发，无论采用什么方法，只要最终目标一致，就能够促进不同学科殊途同归。

作为水文学家，您对景观设计师有哪些建议？

王：水文模型是对自然水文与社会水文的复合系统的模拟，往往相当复杂。但对于景观设计师而言，仅需要知道和了解一些基本的概念和数据，及模型的结果就可以。重要的是，作为景观设计师应该时刻把水装在大脑里——水是万物的命脉，也是景观的灵魂。水无常态，造就了景观的多样性，也是实现可持续性的重要前提。

水文系统强调尺度，包括空间尺度和时间尺度，在进行景观设计时应该注意与水文系统时空尺度的对应性。在空间尺度上，流域尺度和景观的区域尺度相对应，河流与滨水景观相对应，低影响开发与雨水花园相对应。在时间尺度上，水文系统有上百年的水系循环，也有瞬时的洪峰。把握每一个尺度，也就是把握自然与设计创意之间的平衡。

地表径流、水土流失、面源污染、土壤水分、浅层地下水，以及与之关联的雨量、温度、雨季分布等内容，都是景观设计师在做大尺度项目时应该了然于心的内容。而城市水资源利用、尾水排放量、河流流量、水质等方面的状况也与城市景观系统息息相关。一方面，城市景观系统受限于城市水文循环，而另一方面，其也承担着改善城市水循环的重任。

您能否结合海绵城市建设，谈一谈水系统的跨行业、跨部门协作？

王：在海绵城市建设中，首先要从海绵城市"量、质、用"三大内涵出发，采用分布式城市水文模型对海绵城市三大问题——城市洪涝积水、污染物来源与累积、雨水控制与利用进行系统诊断和评估，以辨别特定城市对海绵城市建设的需求。根据诊断结果与建设需求，可以通过从"量"上消除内涝积水，从"质"上削减污染累积，从"用"上实现供求平衡。最终结果是实现城市水系统"三大平衡"，即水量下泄与滞流分散排放相平衡，污染物产生与削减相平衡，雨水控制与水资源需求平衡。归结起来，海绵城市的基本思想是"一片天对一片地"，即"当地降雨，就地消纳；分片平衡，系统耦合"。

海绵城市建设既基于城市建设水循环的科学基础，又针对我国问题的复杂性和特殊性，整体体现了城市水问题治理的复杂性、综合性和系统性。海绵城市建设具有多层面、多维度的含义，涉及到城市规划、防洪治涝、水资源保护、水污染防治和水生态修复等多个方面，其研究必然需要多学科、多领域合作，其建设亦需要跨行业、跨部门合作。可以从以下几方面着力加强海绵城市建设：1）完善相关政策法规、技术标准，从设计导向上注重不同行业和部门的衔接。2）改革和建立相应的体制机制，从制度上促进不同行业和部门的协作。3）注重发挥政府和市场两大调控作用，从源动力上调控不同行业和部门的交流。

您认为在目前的海绵城市建设工作中，哪些方面有待提升？

王：一是缺乏多部门统筹协调机制和高效权威的统一指挥机制。要协调规划、水利、住建、交通、环保、园林等多部门的合作，着力提高海绵城市建设管理的系统性和综合性，进一步结合流域、区域和城市多个角度，科学论证海绵城市的建设方案。

二是对海绵城市建设的基本内涵和核心思想解读存在偏差。海绵城市建设的本质是一种城市发展方式，核心是对城市水问题的系统治理。它不是单纯的低影响开发，而是具有中国特色、符合中国国情的城市水问题综合治理理念。我们应基于中国城市的实际问题来解读和理解海绵城市建设。

三是碎片化、唯工程化建设。有些建设可以说是"为了海绵而海绵"，存在"大干快上、急于求成"的倾向。有的地区将海绵城市建设分解为多个工程，这种碎片化的建设并不能真正发挥效用；有的地区则不顾当地实际情况，盲目设定指标体系。在海绵城市建设中，我们必须充分认识到我国是一个幅员辽阔的国家，各个地区自然地理和社会经济状况千差万别，必须因地制宜开展建设。

四是政策法规、技术规程、技术标准和技术力量较为欠缺。海绵城市建设政策法规尚不健全，缺乏明确的考核体系和标准，相应的技术规程、技术标准存在空白——已有的标准只针对特定地区，且不具备强制性。结合相关试点城市的调研发现，海绵城市建设还存在科学研究不深入、规划设计人才储备不足、工程技术力量良莠不齐等现象。我们需要进一步加大研究力度，深入开展相关规划设计人才和工程技术人员的培养。

您能否谈一谈您的"生态海绵流域"理念，在这一理念下，实现自然-社会水系统平衡的关键点是什么？

王：生态海绵流域建设以流域多过程水循环为主线，充分发挥流域对水循环的天然调节作用；规范人类水土资源开发活动，减少对自然水循环的扰动；系统布局地表灰色基础设施（水库、堤防、渠系、泵站、水井等）与绿色基础设施（林地、草地、湿地等），建设"土壤水库"和"地下水水库"；融合现代信息技术的新进展，实现地表-土壤-地下多过程、水量-水质-泥沙-水生态的联合调控，系统解决流域水问题。其充分融合了习近平总书记提出的"山水林田湖"生命体理念，遵循生态演变规律和土地适宜性特征，以期建立健全的流域生态服务功能，优化国土空间及绿色基础设施建设。

生态海绵流域充分重视"自然-社会"两大系统的联合调控。在传统水网与水系连通建设中，重点关注的是河流、湖库等面向水循环地表过程的调控，主要通过建设水利工程来实现。不可否认，通过水利工程等人为的社会力量对流域水循环进行调控，对于流域水问题治理具有不可或缺的作用，但应该认识到点尺度的社会力量在流域面尺度的自然力量面前仍然是十分渺小的。在强烈的人类活动作用下，流域水循环呈现"自然-社会"二元特征，流域水问题的系统治理需要"自然-社会"两大系统联合调控、协同作用。

实现自然-社会水系统平衡的关键点在于"去极值化"和"系统治理"。不健康的自然-社会水循环系统即源于自然水循环过程中的极值过程，如洪涝、干旱等，而人类社会对自然水循环的要求是相对坦化的，二者不匹配即会导致灾害产生。建设生态海绵流域就是要充分发挥流域的自然调节能力，整体提升流域的综合调节性能，建设健全的流域综合服务功能，保育"山水林田湖"生命体功能，对流域自然水循环实行"去极值化"调控，实现自然水循环与社会水循环的优化匹配。**LAF**

致谢

感谢中国水利水电科学研究院水资源研究所杨朝晖博士对本次采访的大力协助。

Please briefly introduce the status and core problems facing water resources in China.

Hao WANG (hereinafter referred to as WANG): China's water resource situation can be summarized as simply too many people and not enough water, uneven spatial and time distribution of water resources, and frequent and widespread floods and droughts. To be more specific, the three aspects are as follows:

First, there are inherent deficiencies in China's water resources. With a continental monsoon climate, China's rainfall is unevenly distributed both in space and time. More than 70% of precipitation concentrated between June and September, which causes flooding and can easily lead to water based disasters while hard to be used. Geographically, there is sufficient precipitation in southeastern China, while rain in the northwest is scarce. Another issue is the low per capita water resources. Although China's total amount water resources reaches 2.84×10^8 m^3, ranking sixth in the world, and more than 90 percent of China's water resources are from rivers, the per capita amount is only 2,070 cubic meters, or less than one-third of the world's per capita water resources, lowering China's ranking to 127th out of 192 countries.

Second, water resources often do not match the rate of social and economic development. Water resources in China are distributed disproportionately, with most of the water located in the south, coast and mountains, rather than the north, inland and plains, and where more cultivated land resources are found. For example, in north of Yangtze River, with 64 percent of the total cultivated land of China, but the river system there accounts for only 19 percent of water resources. To some extent, the conditions of water resources affect the speed and patterns of social and economic development. Increases in population and social and economic developments have produced an acute mismatch between social and economic conditions and water resources. Imperfect engineering systems in the north, northwest, southwest and coastal cities have created more serious water supply issues.

Third, new problems arise while old problems remaining. Common natural disasters such as floods and droughts bring higher risks with increased economic and social development. In the context of urbanization, water pollution and water ecological degradation have intensified. Climate change and global warming have reduced river runoff. Extreme rainfall has occurred from time to time. Water disaster events including large-scale drought and urban flooding have increased. In this context, new challenges have born from original problems such as flooding, shortages, pollution, and sediment deposition.

Cooperation among professions is needed to address water-resource issues. Could you share recommendations for effectively establishing communication between professions, based on your academic and practical experiences? Whether there is a recommended work frame or method?

WANG: Working alone is no longer possible in modern research. Scientific research resulting in significant innovation is the result of multi-disciplinary, large team collaborations. It is urgent for us to pursue collaborative innovation, and there is no single working framework or method for collaborative innovation. We should explore suitable and innovative coordination model in practices. My personal position on collaborative research includes the following:

1) Ideas and paradigms of research are different between disciplines. Disciplines should learn from each other while respecting other's research ideas and paradigms. If one sticks to his own subject rules, refusing to learn from other disciplines, it is easy to cause unnecessary misunderstanding.

2) Addressing practical problems should be the starting point for scientific research, especially engineering research. Regardless of methods, if different disciplines share the common goals, cooperation can be realized.

As a hydrologist, what is your advice to landscape architects?

WANG: Hydrological modeling simulates compound systems of natural hydrology and social hydrology, and is often quite complex. Landscape architects need to know and understand only a few basic figures and concepts, as well as the results of the models. For a landscape architect, it is important to always consider water, as it is the lifeblood of all creatures and the soul of the landscape. Water has no fixed form, which creates diversity in the landscape, and is one of the most important factors in achieving sustainability.

Hydrology emphasizes scale, including spatial and time scales. Landscape architects therefore need to pay attention to correspond the design types to the hydrological systems under these two scales. For the spatial scale, the watershed scale corresponds to regional scale of the landscape; the river to the waterfront landscape; the low impact development to the rainwater garden. For the time scale, hydrological system ranges from a hundred years water cycle to instantaneous flood peak. To understand the relationship between these scales is to balance nature with design.

Surface runoff, soil erosion, non-point source pollution, soil moisture, and shallow groundwater, along with associated rainfall, temperature, and rainy season distribution should be understood by landscape architects designing large-scale projects. Water use, discharge, flow and quality, all effect urban landscape systems. Not only are urban landscape systems bounded by the urban hydrological cycle, but they also play an important role in improving urban water cycles.

Taking advantages from sponge city construction, how could we promote multi-professional and multi-departmental collaborations in solving water system problems?

WANG: Distributed urban hydrological models can systematically diagnose and evaluate the three aspects of sponge city programs, including urban flood water, pollutant source and accumulation, and rainwater control and use, and help to identify specific sponge city needs. There are three major ways to realize sponge city construction, depending on diagnosis results and construction needs: eliminate waterlogging for the "quantity," reduce pollution accumulation for the "quality," and achieve supply and demand balance for the "utilization." The result balances three aspects of the urban water system, namely, water capacity discharge and viscous flow evacuation, pollutant generation and reduction, and rainwater control and water demand. In short, the basic idea of a sponge city is to "create a piece of sky parallel to the land," that is, "local rainfall to be consumed locally; balance water in zones, and establish systematical couplings."

Based on urban water circulation science, and the complexity and particularities of China's water problems, sponge city construction generally embodies the complex, comprehensive and systematic urban water problem management. Sponge city construction can include multiple aspects of water management, including urban planning, flood control and water drainage, water resource protection, water pollution control, and ecological restoration. Research and construction requires cooperation. There are several aspects through which we can strengthen sponge city construction. First, improving policies, regulations, and technical standards can highlight the convergences and overlaps of different design profession. Then, reforming and establishing related mechanisms help to promote cooperation between different professions and departments. Finally, a focus on regulatory effects of government and marketing can help to regulate and control the communication between different professions and departments.

How could current sponge city construction improve?

WANG: The current lack of a multi-department coordination and authoritative unified command mechanism needs to be improved. We need to coordinate planning, water, housing and construction, transportation, environmental protection and landscape departments to achieve systematic and comprehensive sponge city construction management. We also need to look at watersheds, regions, and cities to scientifically verify sponge city plans.

There are currently varied understandings of the basic meanings and core ideas of sponge city construction. A sponge city construction is essentially a kind of urban development method where the systematic management of urban water is the most important. Sponge city is better suited to meet China's urban water problems than mere low-impact development, and we should pay attention to the actual water problems of Chinese cities when interpreting and understanding sponge city construction.

Third, fragmentation and engineering-led construction have resulted in green-washing and an anxiousness for quick results. In some cases, sponge city construction has been split into various projects, and as such fragmented construction does not come into play. At other times, local conditions have been neglected while leading to sightless tasks. Sponge city construction requires being fully aware of our country's vastness, and of regional physical geography and local socio-economic situations.

Finally, the lack of policies, regulations, and technical specification, standards, and personnel. Sponge city construction policies and regulations are lack of definite assessment system and standards, and have blank in corresponding technical regulations and standards — some of the existing being merely local and non-mandatory. Our sponge city construction research has shown problems exist at multiple levels, including in scientific research, personnel training in planning and design, and engineering technology. Research efforts need to be intensified to carry out in-depth personnel training in planning and design, and engineering technology.

What is your "ecological sponge watershed" concept? And what is the key to achieving the balance of nature-society water system in this concept?

WANG: Ecological sponge watershed construction takes multi-process water cycle as its main line, gives full play to its natural regulation effect of water cycle. It regulates water and land resources development to reduce disturbances to the natural water cycle. Ecological sponge watershed construction systematically approaches surface gray water infrastructure (reservoir, embankment, channel system, pump stations, and wells) and green water infrastructure (woodlands, grasslands, and wetlands) to build the soil reservoirs and groundwater reservoirs. It integrates new information technology to realize the surface-soil-underground regulation satisfying quantity-quality-sediment-ecology requirement to solve water problems. The ecological sponge river basin concept brings together the ideas of "mountain, water, forest, farmland, lake" as proposed by General Secretary Xi Jinping. It also keeps in harmony with ecological evolution and land suitability, and establishes sound and healthy ecological services in the river basin, which in turn, optimizes the land use and promotes green infrastructure construction.

Ecological sponge watershed pays full attention to the natural-social joint regulation. In the construction of traditional water networks and natural water systems, it focuses on the regulation of rivers, lakes and other surface water cycle through the construction of water conservancy projects. While the effect of such water conservancy projects is undeniable for watershed management, the social forces effecting the watershed scale are still very small. Because of intensive human activities, water system management requires nature-society cooperation.

The key to achieving a balance between nature-society water systems is elimination of hydrological extremes and systematic governance. The current unhealthy nature-society water cycle system is the result of the extreme processes in the natural water cycle, such as floods and droughts. When human requirements do not align with natural water cycles, ecological disasters often result. The construction of ecological sponge watershed is meant to give full play to natural regulation ability, enhance the comprehensive regulation effect of the watershed, and to encourage functioning and healthy watershed while conserving "mountain, water, forest, farmland, lake" community functions, eliminate the hydrological extremes in the basin's natural water cycle, and achieve the optimization of natural-social water cycle. **LAF**

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