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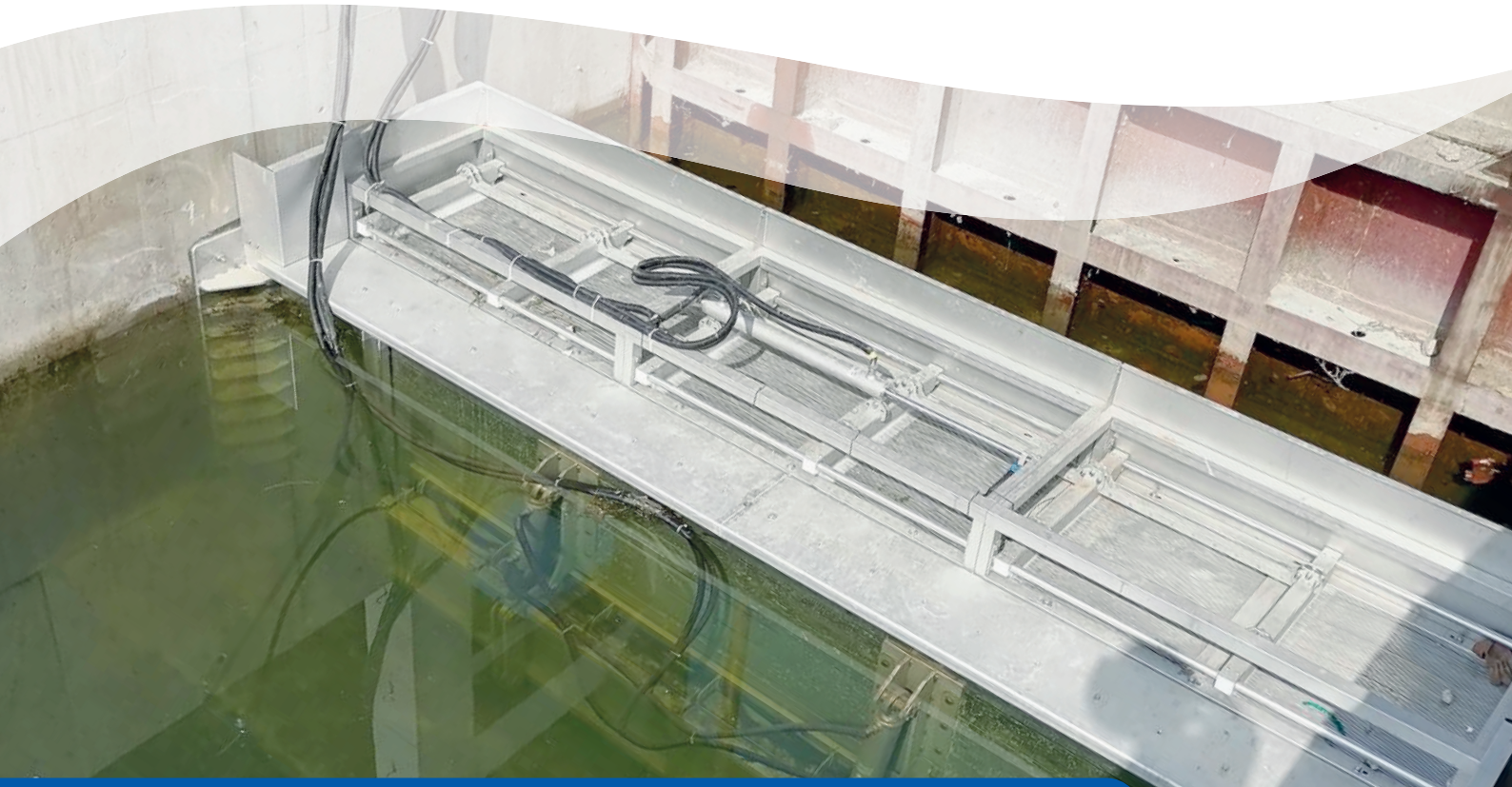

KEYS – DEMONSTRATIONS for a smart Sponge City

海绵城市示范项目

SMART TECHNOLOGIES FOR SUSTAINABLE WATER MANAGEMENT IN URBAN CATCHMENTS AS **KEY** CONTRIBUTION TO **S**PONGE CITY (KEYS)

SINO-GERMAN COOPERATION

中德合作

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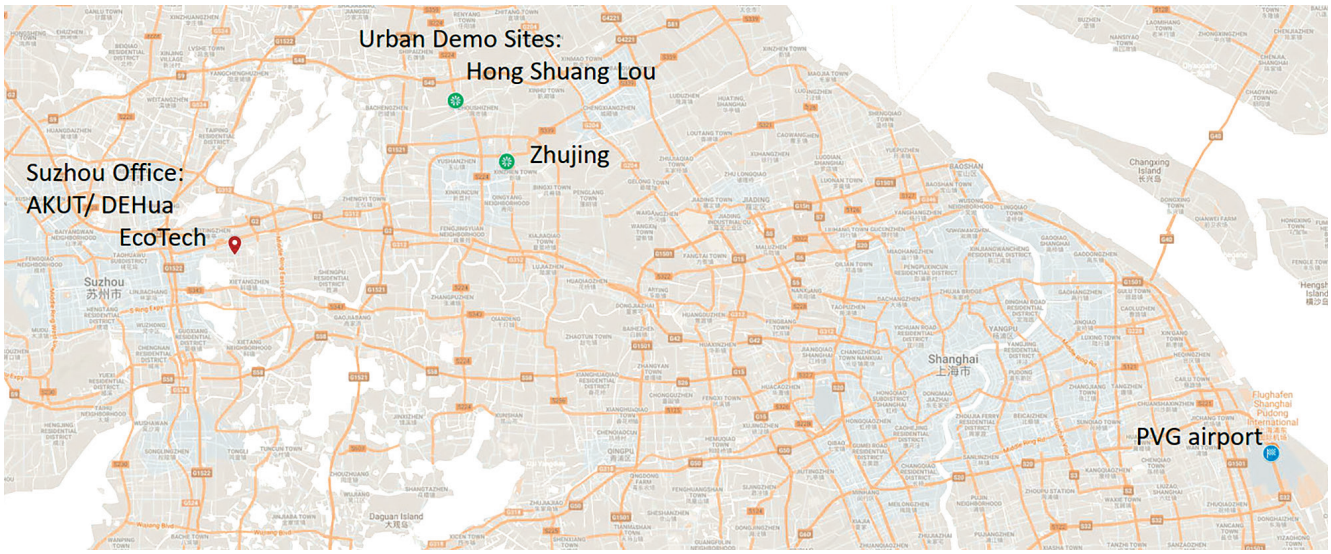
垂直流截留湿地系统在城市地表水管理中的应用–苏州地区成功案例分析



Location (Google Maps) 方位（谷歌地图）

The two project sites in Greater Suzhou, Jiangsu demonstrate the positive effects of filtration wetlands for urban surface water management. Around 10,000 m² treatment wetlands have been installed along each city canal from 2018 to 2020. Both sites revealed typical problems of water quality, odor and ecological structure such as steep walls and lack of riparian vegetation.

位于江苏省苏州区域的两个项目表明，垂直流截留湿地系统有助于改善城市地表水管理。 2018 年至 2020 年期间，在两条城市河道均设置了约 1 万平方米的垂直流截留湿地系统。项目建设前两条河道均面临水质黑臭、垂直驳岸、缺少沿岸植被等典型问题。

Retention and filtration wetlands ensure that rainwater and combined sewer overflows can be collected. By this the water is not only temporarily stored (sponge concept), but also filtered before being released slowly.

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垂直流截留湿地系统能够确保雨水和合流制管网溢流的收集，系统不仅能够临时存储雨污水（海绵的概念），而且能够净化雨污水。

Different filtration wetlands are also used at these sites as an integrated approach. They are adapted to the local situation, depending on space conditions and treatment tasks: Passive

vegetated filter troughs along the channels prevent the untreated inflow of stormwater runoff from adjacent streets and areas. Active filters treat and recirculate surface water that could not be collected by other measures. Aerated soil filters supplement the measures in cases where permanent sewage loads are to be expected.

采用整体性方法，根据不同的空间条件和处理需求，项目中应用了不同的湿地类型：沿河道设置的线性截留湿地可防止相邻街区未经处理的雨水径流直接入河；河水处理湿地能够处理和循环其他措施无法处理的河道地表水；曝气湿地作为补充措施可以处理局部点位持续的污水负荷。

Retention wetlands may be used in humid and also arid climate zones. The sizing differs by regional precipitation rates and connected drained areas. The optimum retention capacity may be modeled by using long term high resolution serial rain data. Annual precipitation rates and serial hourly or even daily rates may be used for estimating feasibility. The total treatment wetland area for canal water mitigation ranges between 0.7 to 1.2 percent of the connected drained urban water shed. Additional surface water treatment and recirculation by retention wetlands protects the wetland biofilm and vegetation from draught (arid climate zones) and enhances water quality and micro climate.

垂直流截留湿地系统可用于气候湿润地区，也可用于气候干旱地区，湿地规模取决于区域降雨量和汇水范围。最佳滞留能力可以通过使用长时间序列高分辨率连续降雨数据建模模拟得到。年降雨量和连续小时降雨量或日降雨量可用于进行可行性评估。用于河道治理的湿地总面积一般约占河道汇水区域面积的 0.7% – 1.2%。垂直流截留湿地系统额外进行地表水处理和循环，可保护湿地生物膜和湿地植物免受干旱（干旱气候地区）影响，同时能够提升水质和调节微气候。

Figure 1 Retention and filtration wetland at Zhu Jing Canal. Two cells of 1,500 m² each installed.

图 1 珠泾中心河河道项目的两个垂直流截留湿地单元（面积各为 1500 平方米）

Figure 2 Hong Shuang Lou 3,000 m² demonstration wetland for CSO retention and filtration

图 2 洪双漊河道项目处理合流制溢流的垂直流截留湿地系统（面积 3000 平方米）

KEYS Project Sites Benefits
KEYS 项目的优势

In all cases, the installation of such green-blue infrastructure has also led to an economic upgrading of the affected neighborhoods.
通常该类蓝绿基础设施的应用也会给周边经济带来升级。

Development of a design approach for the use of retention soil filters in densely populated cities
针对人口稠密城市的垂直流截留湿地系统的设计方法开发

Design of a retention and filtration wetland according to German state of the art
依据德国最先进技术的垂直流截留湿地系统的设计

Investigation of a solution for load-dependent control of soil filters using an online spectrometer probe for the parameter COD
采用在线光谱探头对 COD 参数进行湿地负荷控制解决方案的研究

Introduction of a method for inventorying existing wastewater overflows into water bodies using mobile NIVUS flowmeters
引进 NIVUS 便携式流量计对排口溢流污水量进行测量的方法

Use of a high temporal resolution rain gauge with data logger to record local heavy precipitation for modeling sponge concepts
运用带数据记录器的高分辨率雨量计来记录当地降雨量来服务于海绵概念的模拟

Investigation of the purification potential of retention soil filters
垂直流截留湿地系统的净化潜力研究

2. Conception and Planning of Sponge City Elements and Stormwater Facilities

海绵城市元素及雨水设施的设计与规划

The implementation of the sponge city approach is an important step to make our cities fit for the future. Sponge City elements help to mitigate urban heat island effects and flash floods, to improve groundwater quantity and quality as well as the quality of rivers or the biodiversity within the city grid. They basically follow the natural example and impress with simplicity and efficiency.

海绵城市建设是我们的城市适应未来的重要一步。海绵城市设施有助于减轻城市热岛效应、抵御山洪灾害，改善地下水水质水量，提升河流水质及城市

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Figure 3 Overview of Sponge City Elements (based on Matzinger et al., 2017) 图 3 海绵城市元素概览（基于 Matzinger 等，2017）

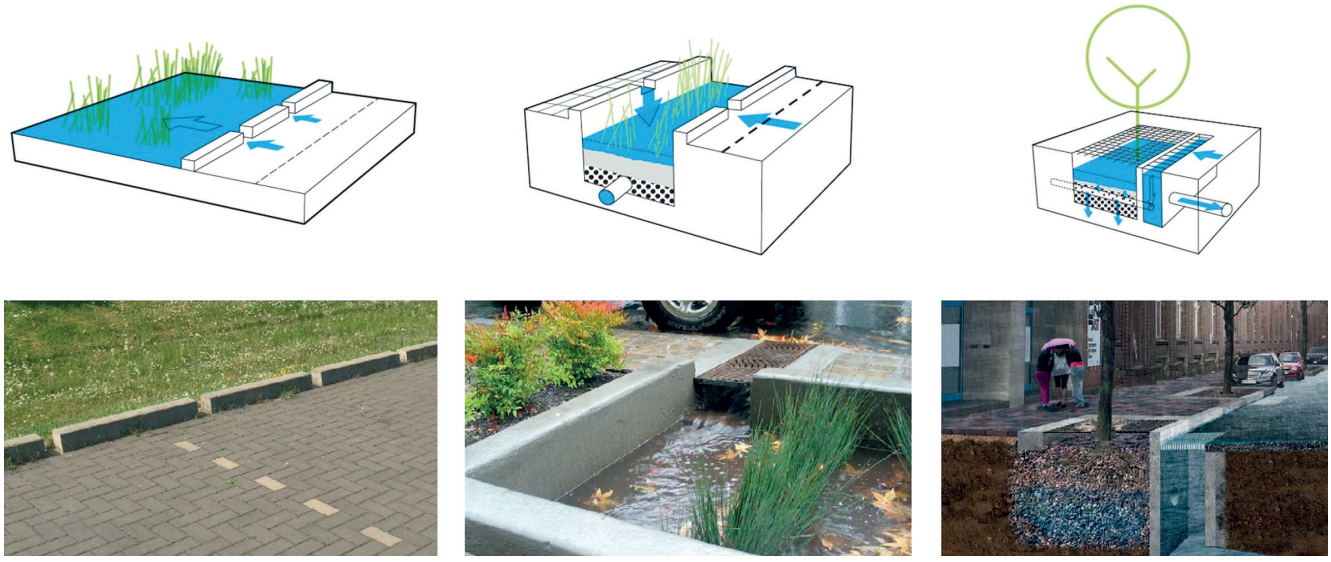


Figure 4 Conventional and innovative Sponge City Elements (Illgen et al., 2018) 图 4 传统和创新海绵城市元素（Illgen 等，2018）

网格内的生物多样性。其具有基本上遵循自然规律，简单并高效的特点。

The Sponge City approach specifically aims to retain as much stormwater runoff as possible and keep it in the natural water balance via infiltration and evaporation. For this purpose, a wealth of elements can be placed on or around buildings, in the neighborhood, and in the catchment area (Fig. 3). Within the last three decades, various elements such as green roofs, cisterns for stormwater reuse, green areas or permeable pavements or various infiltration facilities have been well established in Germany and all over the world (Fig. 4). Nevertheless, even new or innovative elements such as tree pits have been coming up during the last years.

海绵城市建设的具体目标是尽可能多地保留雨水径流，并通过渗透和蒸发将其保持在自然水平衡中。为此，可以在建筑物上或其周围、邻里和集水区放置大量海绵设施（图 3）。在过去的三十年中，各种设施，如绿色屋顶、雨水调蓄池、绿地、透水铺装和各种渗透设施在德国和世界各地都得到了广泛应用（图 4）。尽管如此，在过去几年中，甚至出现了全新或创新设施，例如树池。

According to the national or regional Sponge City design standards, a certain volume capture ratio of annual rainfall (VRR) as to be achieved. The specific values vary over different climatic zones. However, the water balance components of groundwater recharge and evaporation are not explicitly taken into account so far.

根据国家或地方海绵城市设计标准，不同气候条件，年降雨量收集比例指标值不同。然而，目前尚未明确考虑地下水补给和蒸发的水平衡成分。

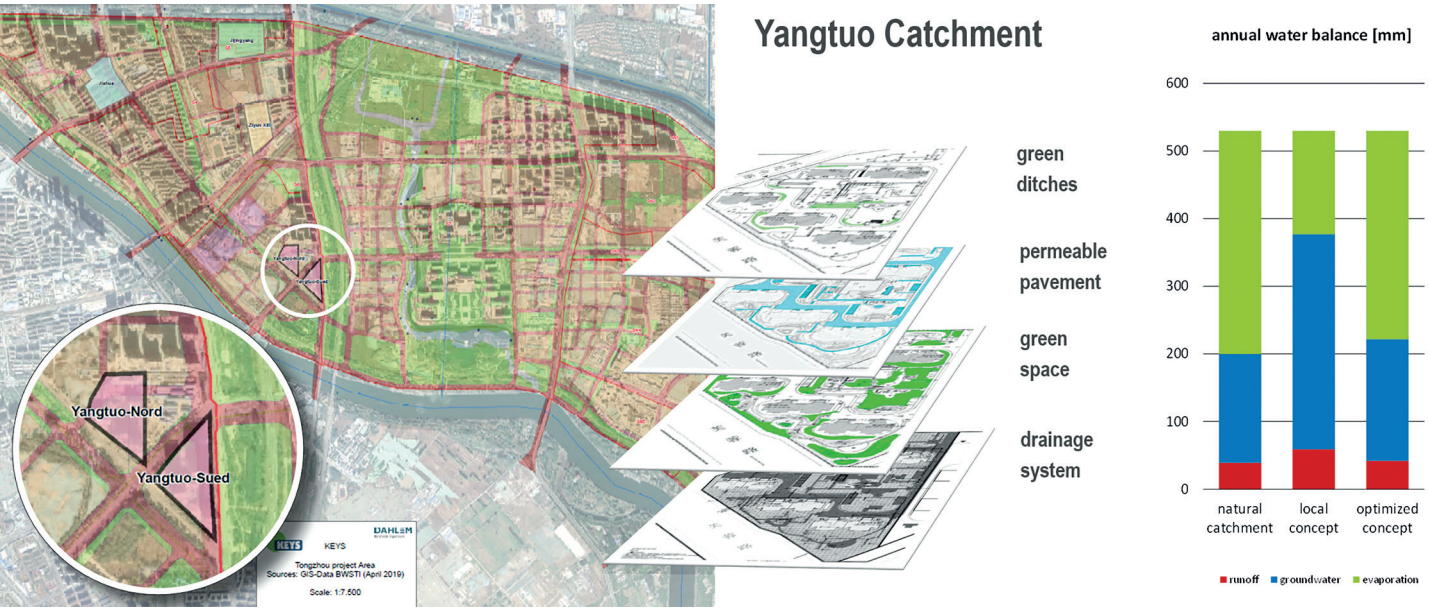
For this reason, one of the KEYS demonstration projects attempted to determine the water balance components for an exemplary catchment in China using a simplified water balance model available in Germany called WaBiLa. The considerations were accomplished for the Yangtuo catchment area in Beijing which is part of the Tongzhou Sponge City project (Fig. 5).

出于这个原因，KEYS 示范项目之一尝试应用在德国被称为 WaBiLa 的简化水平衡模型来确定中国示范流域的水平衡组成部分。杨坨属于北京通州海绵城市建设项目的一部分（图 5）。

The local stormwater concept has been evaluated with the WaBiLa software tool. For all catchment areas and drainage elements, the water balance components runoff, groundwater recharge and evapotranspiration were calculated on an annual basis. Although the calculation tool is not yet optimally adapted to Chinese climate conditions, the results indicate that the local concept is able to reach the intended stormwater runoff retention. Nevertheless, with a high percentage of infiltration elements, groundwater recharge is overemphasized. In contrast, evaporation is significantly lower compared to an undeveloped area. Here, more evaporation-intensive elements such as green roofs, tree pits and especially ponds or other open water surfaces could be applied as the computations for an optimized concept underline.

通过 WaBiLa 软件对当地雨水情况进行了评估。对于所有集水区和排水要素，逐年计算水平衡成分中的径流、地下水补给和蒸发量。尽管该计算工具还未能充分适应中国的气候条件，但结果表明当地的设施能够达到预期的雨水径流滞留量。 然而，由于渗透元素所占比例较高造成了地下水过量补给。与未开发区域相比，蒸发量有效降低。 在这里可以应用更多的蒸发密集型元素，例如绿色屋顶、树池，尤其是池塘或其他开放水面，用以优化设施计算。

Figure 5 Water balance evaluation for Yangtuo catchment in Beijing 图 5 北京杨坨水平衡评估



3. Catalogue of Adapted and Further Developed Sponge City Developments

改编和进一步完善的海绵城市设施手册

For the sustainable implementation of the Sponge City concept, the long-term effectiveness of the implemented infrastructure measures is crucial. KEYS aimed to provide needs-based guidance for the implementation of Sponge Cities by delivering a Sponge City Element Catalogue (Fig. 6). The catalogue includes selected Sponge City elements and thus serves as a planning aid to reduce implementation barriers due to planning uncertainties. The compilation of reliable data and examples of successful implementation with special consideration of local contexts in China should facilitate future Sponge City infrastructure measures.

所应用的基础设施的长期有效性对实现海绵城市理念的可持续性发展具有决定性作用。KEYS 旨在通过海绵城市设施手册（图 6）为海绵城市建设提供以需求为导向的指导。 手册中所选的海绵城市设施作为规划辅助工具能有效降低在实施过程中由于计划不确定性所带来的障碍。该手册基于可靠数据并结合中国实际成功案例，将有助于海绵城市基础设施建设。

The data basis for the catalogue was generated by incorporating available data from measurements, hydrological modeling results, practical experience from the demonstrations in China and implementations in Germany, and comparison with literature values. Based on the Sponge City implementations in China, the elements green roof, permeable pavement, bioretention cells, retention soil filters, cisterns and storage ponds were selected for the catalogue.

手册中的数据是通过现有测量数据、模型模拟结果、中国示范项目的实践经验、德国项目实施及与

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文献值比较生成的。 基于中国海绵城市建设情况，绿色屋顶、透水铺装、生物滞留设施、土壤渗滤、雨水樽和调蓄池被选入该手册。

It synthesizes the function and impact of each element by listing technical details, design parameters, key performance indicators, and operation and maintenance procedures. The hydraulic performance of the individual elements and the operational aspects are adapted to the local climatic conditions. For this purpose, five climate zones were considered for China with correspondingly different stormwater retention requirements. Hydrological modeling in SWMM was used to estimate the hydraulic performance of the Sponge City elements for each climate zone.

手册通过相应的技术细节、设计参数、关键性能指标和运维措施的介绍汇总了各单项设施的功能与作用。每个设施的水力性能和操作方面都考虑到了当地的气候条件。为此，该手册根据不同的雨水滞留需求相应地将中国划分为五个气候区， 并运用暴雨洪水管理模型中的水文模型来评估每个气候带的水力性能。

Figure 6 Sponge City Element Catalogue 图 6 海绵城市设施手册

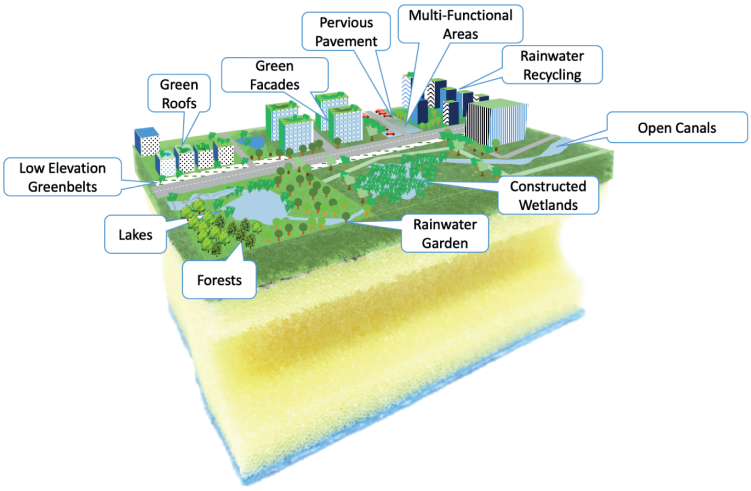
KEYS

SMART TECHNOLOGIES FOR SUSTAINABLE WATER MANAGEMENT IN URBAN CATCMENTS AS **KEY** CONTRIBUTION TO **S**PONGE CITIES

Catalogue

of adapted and further developed LID-System Modules

for Sponge City Development in China



ISAH KOMPETENZZENTRUM WasserBerlin DAHLEM

4. Treatment of Combined Sewer Overflow in Urban Catchment Areas

城市集水区合流排水管网溢流污染控制

Urban Run-off Treatment – Steinhardt Water Technology Systems

城市径流处理 – 水泰和公司

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Background
背景

The Yudai River canal is located in Beijing in the Tongzhou District. Part of the canal, northwest of Liyuan South Street, is culverted and functions as a combined sewer for domestic wastewater from a catchment area of about 3 km² (Figure 7). Drainage towards the wastewater treatment plant is through an outfall about 100 m upstream of the sewer relief structure, which discharges into a main urban collector. The average wastewater volume is approx. 30,000 m³ per day.

玉带河位于北京市通州区。梨园南街西北部的部分河段，约 3 平方公里的合流排水管网（图 7）。平均污水量约为每天 3 万立方米。

The overflow structure of the Yudai River impoundment channel consists of three rectangular outlets that discharge directly into the continuing open part of Yudai River canal and are closed by gates until the start of discharge (Figure 8). While discharging, the middle gate opens first, releasing a defined amount of wastewater through a weir. The two outer gates are additionally opened as needed.

玉带河蓄水沟涵包括三个矩形出水口，直接排入玉带河，平常运行闸门保持关闭（图 8）。降雨过程需要排放溢流污水时中间闸门首先打开，通过溢流堰排放部分污水，根据需要另外两个溢流堰也可开启。

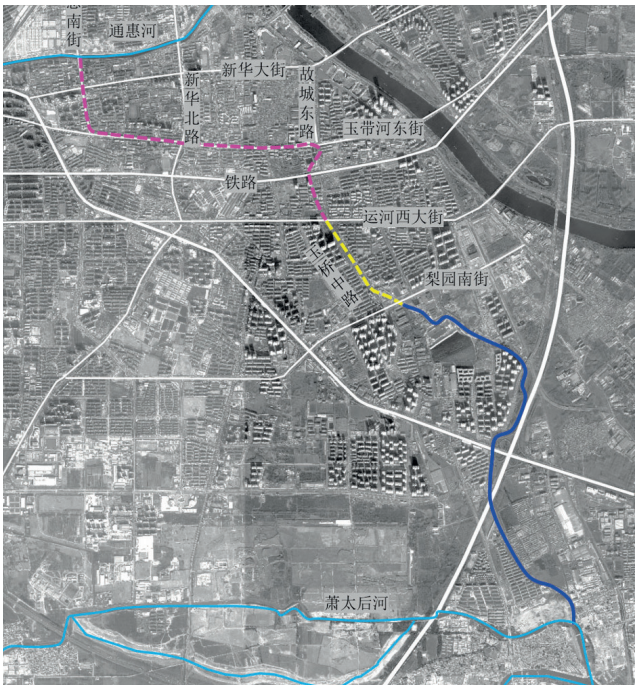

Figure 7 Yudai River with culverted Canal (dotted) in Tongzhou District, Beijing (CN) 图 7 北京市通州区带涵渠（虚线）的玉带河

The problem associated with the Yudai River impoundment channel is, on the one hand, too

Figure 8 Overflow structure Yudai River Channel with gates (old state); overflow weir in the center 图 8 带闸门的玉带河溢流结构（水泰和设备安装前）；溢流堰位于中心

frequent combined sewer discharges during precipitation periods, resulting in aesthetic pollution and eutrophication of the Yudai River. Among other reasons, the excessive rate of discharge is due to insufficient capacity of the outfall from the impoundment channel. Furthermore, there is a continuous odor problem for the residents emanating from the impounding canal, since the canal does not dry out completely after rain events due to the excessively high bottom level of the branching off channel.

降水期间溢流污水排放造成玉带河污染严重和富营养化加剧。蓄水沟涵的排污口容量不足容易导致排放频率过高。

Concept and Design
概念与设计

The operator, Beijing Enterprises Water Group (BEWG), is planning to increase the capacity of the sewer outlets in the direction of the treatment plant and to lower the sewer outlet from the backwater sewer in combination with a suitable flushing sump.
作为运营商的北控水务集团计划增加通向污水处理厂的排放口排放量并结合适当的冲洗池降低回水排水出口。

As a further measure to improve the problem situation, Steinhardt Water Technology Systems does a technical retrofit of the middle section of the spillway with a hydraulically driven rake and flushing system as part of the KEYS project. The objectives are:

为了改善目前的状况，作为 KEYS 子项目之一，水泰和公司应用液压驱动格栅和冲洗系统对溢洪道的中间部分进行了技术改造。目标是：

1. the mechanical treatment of the spillway discharges up to ca. 1,200 l/s
提升溢流口排放能力可高达约 1200 升/秒

2. the possibility of backwashing into the Yudai River impoundment channel in

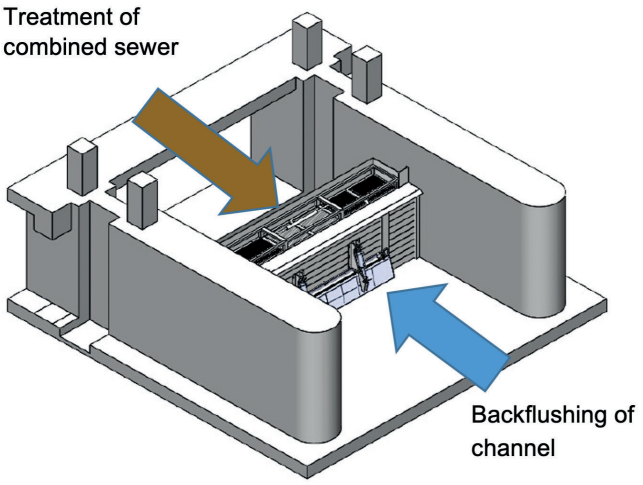

Figure 9 Considered system in the middle part of the spillway structure: automatic raked bar screen for the treatment of combined sewer overflow (CSO) 图 9 溢洪道结构中间部分应用的处理系统：用于处理合流制溢流 (CSO) 的自动格栅系统

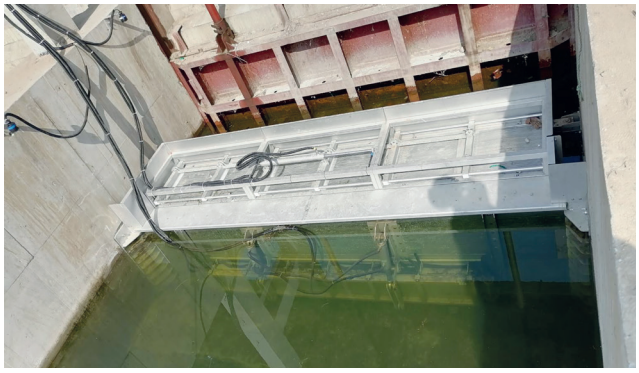

Figure 10 Drainage of the overflow structure and preparing of the assembly (top); finished system consisting of hydraulically driven raked bar screen and flushing gate below waterline (bottom)
图 10 溢流结构的排水和组装准备工作（上）；由液压驱动的格栅系统和位于水位线以下的冲泄闸门组成的成品系统（下）

order to flush back solids deposits at the channel bottom into the newly planned upstream flushing sump.
增加反冲至玉带河蓄水渠，以便将沟涵内的固体沉积物冲回到上游管道排口。

3. the entire system should be removable with lifting equipment.
整个系统可以用起重设备拆卸。

Figure 9 shows the concept of the system, consisting of a hydraulically driven raked bar screen and a flushing gate, which are fixed in combination to a mobile dam beam wall.

图 9 显示了该处理系统的概念，由液压驱动的格栅系统和冲洗闸门组成，它们被组合固定在移动的坝梁侧壁上。

Implementation
安装

The installation of the Steinhardt system took place in early June 2021. The illustrations left (Figure 10) show the preparing of the assembly and the finished system consisting of a hydraulically driven raked bar screen for the treatment of ca. 1,200 l/s and a flushing gate below the waterline.

水泰和系统的安装完成于 2021 年 6 月上旬。图 10 展示了组装和整体系统的安装准备工作，该系统由液压驱动的处理量约达 1200 升/秒的格栅系统和位于水位线以下的冲泄闸门组成。

5. Online-Monitoring

在线监测

Reliable measurement data is the best condition for economic planning, optimum operation and effective water protection.
可靠的测量数据是进行经济规划、优化运行和有效保护水资源的最佳条件。

Whether complex simulation models or simplified assessment methods are used – the crucial point for reliable calculation results is the quality of the data basis. Since very often investments amounting to millions depend on the calculation results it is indispensable to carefully acquire and determine the initial data. Measuring flow, level and substance concentrations within water and wastewater networks is one of the centerpieces of thoroughly obtaining fundamental data. Moreover, it is only possible by collecting and systematically evaluating measurement data to verify whether certain measures work as planned and have the desired effect. Measuring therefore

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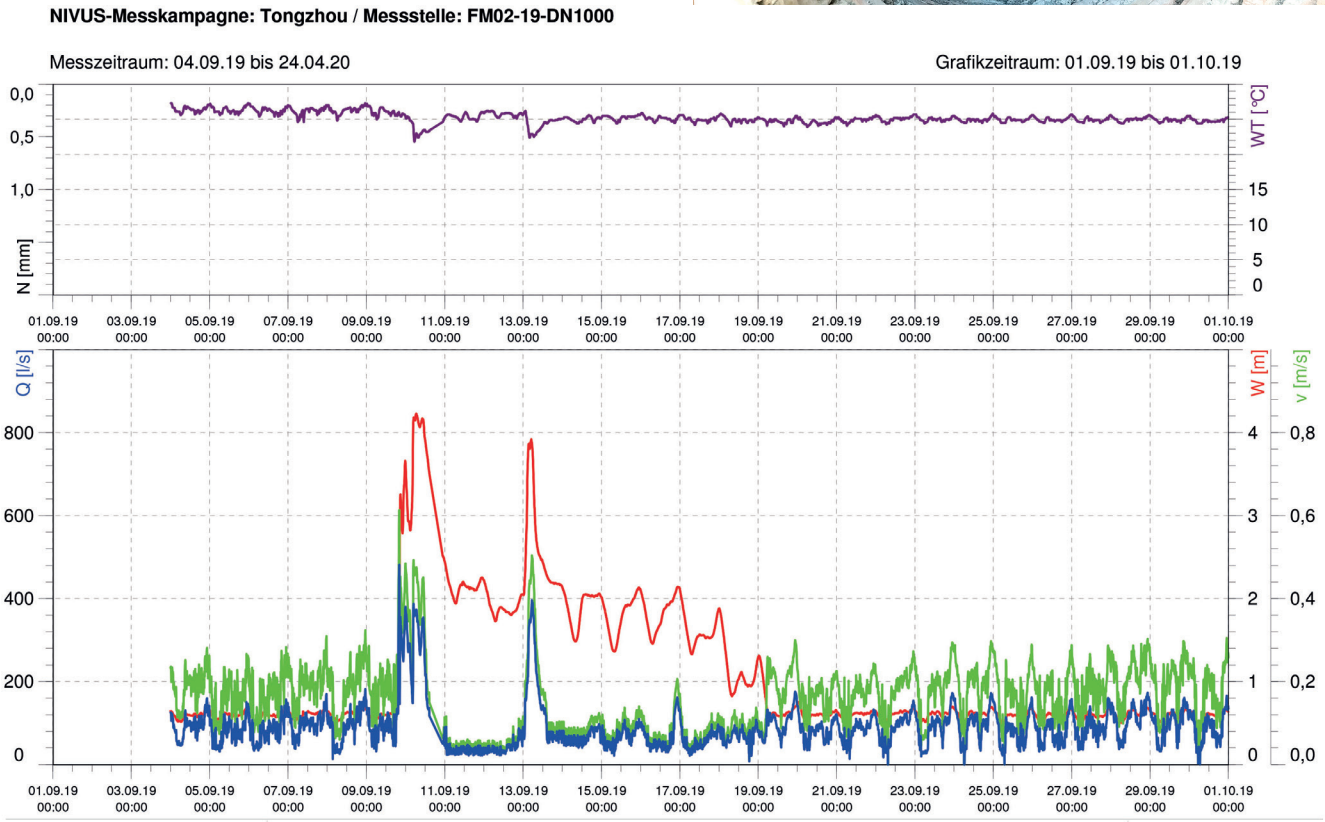
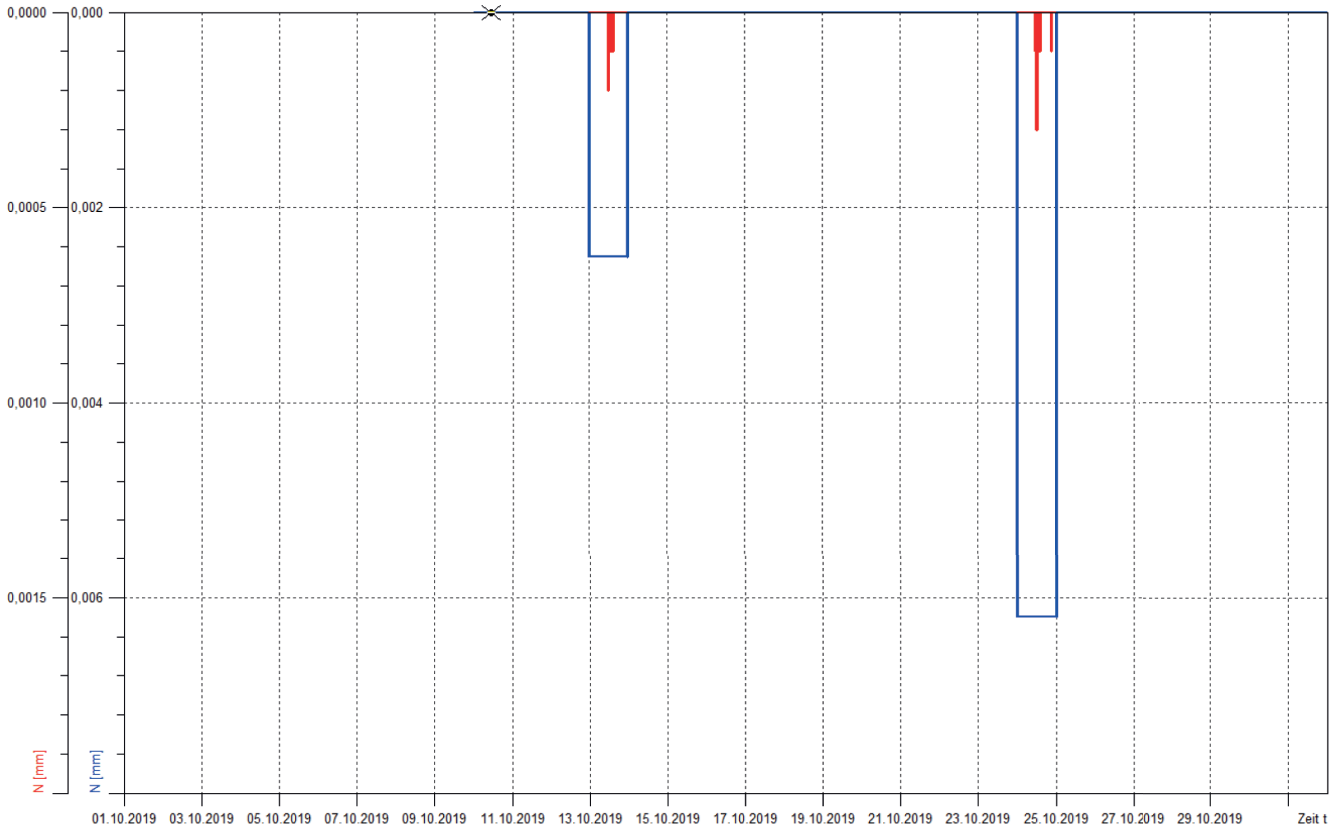


is a substantial element for self-monitoring and success monitoring in the field of urban drainage.

无论是使用复杂的模拟模型还是简化的评估方法 – 计算结果可靠的关键在于数据的质量。数百万的投资通常取决于最终的计算结果，精确地获取和测定初始数据是必不可少的。测量污水流量、水位和物质浓度是获得完整基础数据的关键。此外，只有通过收集和系统评估测量数据，才能验证某些措施是否按计划运作并达到了预期效果。因此，测量是城市排水领域自我监测和成功监测的重要因素。

NIVUS provides a wide range of services within the focus of urban water and wastewater monitoring. Starting with mere equipment rental through the complete planning, implementation and data evaluation carried out by our experienced staff, you are free to choose from various options. Covering a range of 2850 projects our employees have supervised more than 6250 measurement sites. You can easily benefit from this experience. Being integrated into NIVUS GmbH as innovative manufacturer there is always a large number of the latest equipment available. Our measurement solutions are constantly improved in close cooperation with our research department and our department for hardware and software development. This is why we manage to meet even extremely complex requirements. Furthermore we implement special solutions for specific projects.

NIVUS 主要提供城市水体和污水的监测服务，从租赁设备开始到整体规划、安装和数据评估。完成项目共计 2850 个，并监督指导了 6250 多个测量站点。NIVUS 公司不仅拥有最新监测设备，其测量解决方案也通过与研发部门和软硬件开发部的密切合作得到不断改进，为此能够设法满足及其复杂的测量需求，并为项目实施提供特定的解决方案。



Tasks of NIVUS
工作任务

Long term climate data for catchment / region in focus of project (precipitation, temperature etc.)
项目重点流域/地区的长期气候数据（降水、温度等）

Information on planning background of structures of interest in project (applied standards, specific planning decisions due to local constraints, relevant emission limits (volume-/substance flows) etc.)
为项目提供规划背景信息（包括适用标准、由于当地限制导致的具体规划决策、相关排放限制（体积/物质流量）等）

Development of monitoring strategies and implementation of compact and mobile lab for monitoring of emission pathways in cooperation with partner LAR
与合作公司 LAR 共同制定监测策略并实施安装小型移动式监测实验室用于监测排放路径

Hydrological online-monitoring of stormwater treatment trains to provide data for operation, control and performance evaluation
降雨过程获取精准水文在线监测，为运行、控制和性能评估提供数据

Development and implementation of compact mobile lab for monitoring of emission pathways
用于监测排放情况的监测设备的开发和实施

6. Urban Catchment Modeling
城市集水区建模

MODELING FOR SYSTEM IMPROVEMENTS IN URBAN CATCHMENTS
城市集水区系统改进建模

1 – 3 The project catchment area is located on the west bank of the Grand Canal with a combined and hybrid sewer system. The WWTP is located at the southeast end of the catchment. The main facts can be summarized as follows:

项目集水区位于河道西岸，设有合流和混流排水管网系统，污水处理厂位于集水区东南面。主要概况如下：

Catchment area 36.2 km²
集水区面积达 36.2 平方公里

Combined sewer lines 55.69 km
合流管网 55.69 公里

Main trunk sewer and branches 41.89 km
主干管网及支线 41.89 公里

Rain sewer pipes 95.47 km
雨水管道 95.47 公里

Combined sewer ratio 28.85%
合流比例 28.85%

Sewer network density 5.33 km/km², average sewer network density for developed country is 10~15 km/km²
管网密度 5.33 公里/平方公里，发达国家平均管网密度为 10–15 公里/平方公里

An existing sewer model was implemented and updated, requiring some model adjustments and plausibility checks before test calculations were carried out.

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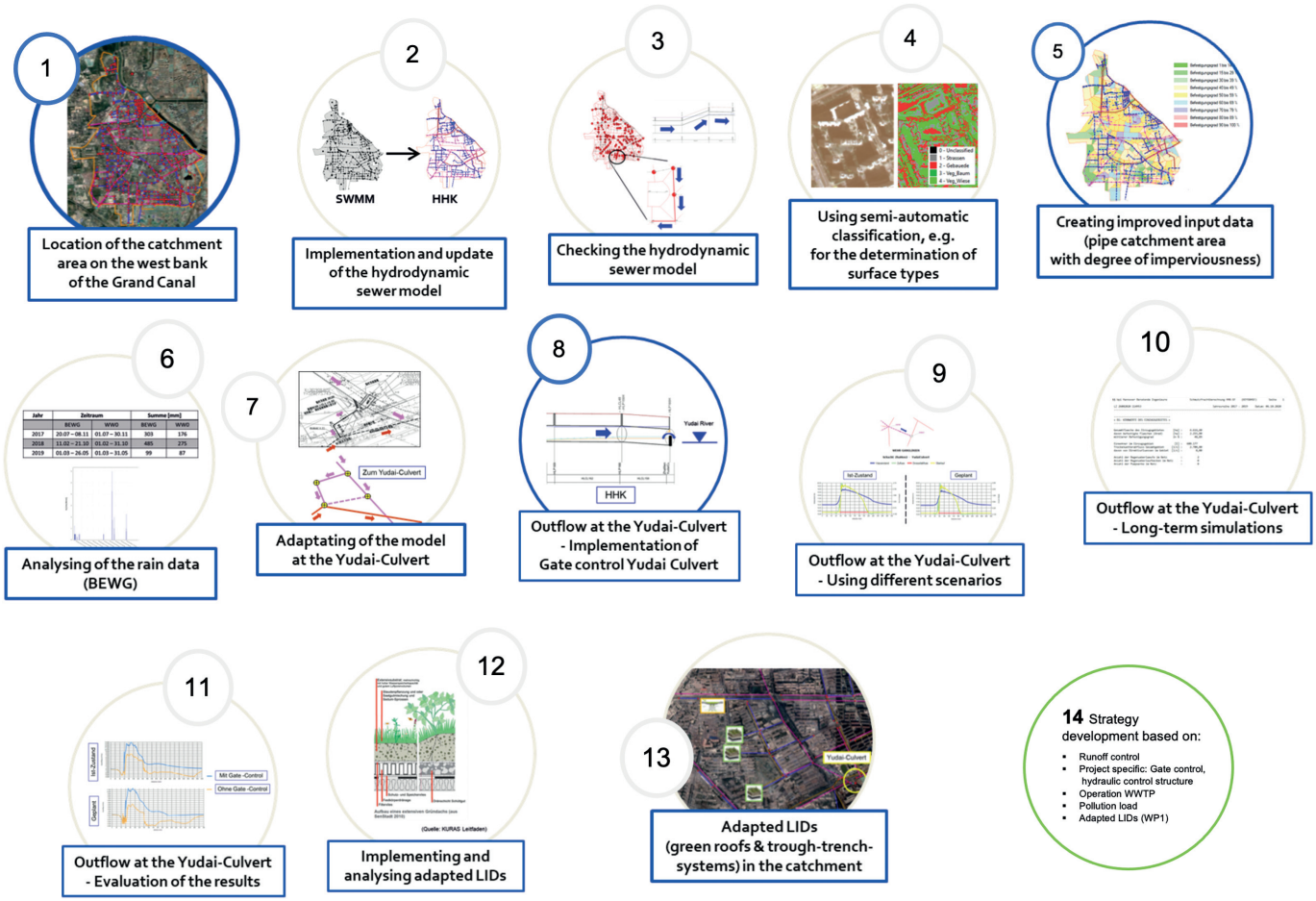
实施并更新了现有管网模型，在进行测试计算之前需要对模型做一些调整和合理性检查。

4 – 6 One focus was on improved input data for the sewer model using automated approaches. Although available aerial images were not ideal in terms of resolution as well as image quality to achieve optimal results in the surface classification, the combination of automated approaches for determining the pipe catchment areas and the automated classification of the paved areas with manual post-processing allowed correspondingly new area data to be transferred to the hydrodynamic model. Thus, an optimization of the input data compared to the existing model was achieved. All available measurement data were checked with regard to their applicability for the hydrodynamic modeling and corresponding events were selected from the BEWG rainfall data.

一个重点是使用自动化方法改进管网模型的输入数据。虽然可用的航拍图像在分辨率和图像质量方面不够理想，无法在表面分类中获得最佳结果，但是管道集水区的自动划分方法与铺装区域的自动分类结合人工处理的方法能够相应地将新的区域数据转



化为水动力模型。因此，与现有模型相比，实现了输入数据的优化。并对现有测量数据在水动力模型中的适用性进行了检查，所应用的降雨数据来自北控水务。

7 With regard to the special structures as well as outfalls in the model area, the project focused on the area of the Yudai-Culvert, but also the inlet area to the wastewater treatment plant.

在示范区的特殊构筑物和排污口方面，本项目以玉带河区域为重点，同时也关注到污水处理厂的进水区域。

8 – 11 With regard to the consideration of the discharge at the Yudai-Culvert, the following work was carried out:

关于玉带河排水管路，开展了以下工作：

Implementation of a weir control (Gate control Yudai Culvert)

在玉带河排水管路安装闸门控制

Scenario comparison with regard to single events

对单一事件进行情景比较

Discharge at the Yudai-Culvert based on long-term simulations

基于长期模拟后通过玉带河管路排放

Evaluation of the results

评估结果

12 – 13 The implementation of adapted LID elements in the catchment was another focus in the project. Selected elements were tested in a subarea of the Yudai-Culvert focusing on the quantification of the impact of the LID elements in relation to the discharge at the Yudai-Culvert.

在集水区应用低影响开发设施是该项目的另一个重点。在玉带河部分区域对所选的低影响开发设施进行了测试，重点是量化低影响开发设施对玉带河管道排放的影响。

7. WWTP Modeling
污水处理厂建模

The wastewater treatment plant (WWTP) Bishui is located in the city center of Tongzhou District, Beijing. It has been in operation since June 2017. The WWTP was built underground. It has a hydraulic capacity of 180,000 m^3/d. The plant is equipped with innovative wastewater treatment technology. Sand is removed by an aerated grit tank and a super-fine screen replaces a primary clarifier. The biological treatment is operated as a multi-stage step-feed process. Furthermore, the wastewater is further treated with membrane filtration and UV irradiation downstream the biological treatment.

碧水污水处理厂位于北京市通州区城市副中心，自 2017 年 6 月开始运营。污水处理厂采用下沉式建设方式，处理规模为 18 万立方米/天。该厂拥有创新的污水处理技术，配备了曝气沉砂池和超细格栅，取代了初沉池，生化处理工艺采用多级 AO 分段进水工艺。此外，在生物处理阶段后采用超滤工艺和紫外线消毒工艺进行深度处理。

The evaluation of the wwtp's influent data showed that the average influent is significantly higher in the summer than in the winter months. The reason for this is the heavier rainfall in the summer months. With regard to the wastewater composition it was found that comparatively low carbon is contained in the wastewater. This leads to a low C/N ratio and thus affects denitrification.

对碧水污水处理厂进水数据的评估显示，平均进水量在夏季月份明显高于冬季月份，其原因是夏季的降雨量较大。此外，在污水的组分上，含有相对较低的 COD。这导致较低的碳氮比例，从而对反硝化产生影响。

In view of the wastewater composition (espc. low C/N ratio) and the wide range of operating possibilities of the step-feed process, the work was concentrated on the model-based optimization of the biological treatment process. A special focus was put on nitrogen elimination. For this purpose, a model for biological treatment was provided in the SIMBA# simulation software, based on the Activated Sludge Model 3 (asm3).

由于污水组分的特征（尤其是低碳氮比）和分段进水工艺运行的灵活性，建模工作集中在基于模型的生化处理过程的优化上，特别是在脱氮方面。为此，在模拟软件 SIMBA# 中建立了生化处理阶段的基于 asm3 的模型。

The calibrated model was used to optimize the biological treatment stage with special regard to nitrogen removal and energy efficiency. Therefore, the optimal settings for the distribution ratio (DR) to the single stages of the step-feed process and the internal recirculation (RC) were determined. The methodology for plant optimization was continuously developed and refined during the project. In particular, the integration of the optimization methodology based on the Nelder-Mead method permits efficient determination of the optimal operating parameters.

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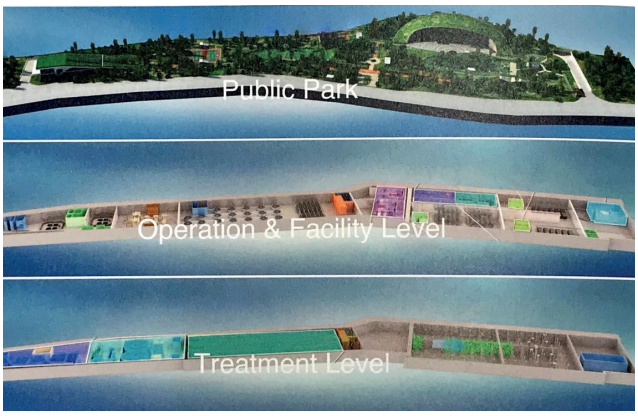
校准的模型已经应用于研究生物处理阶段在脱氮和能源效率方面的优化。因此确定了分段进水比和内部回流的最佳参数设置。在项目期间不断开发优化方法，尤其是基于 Nelder–Mead 算法的优化方法的集成能够有效地确定最佳运行参数。

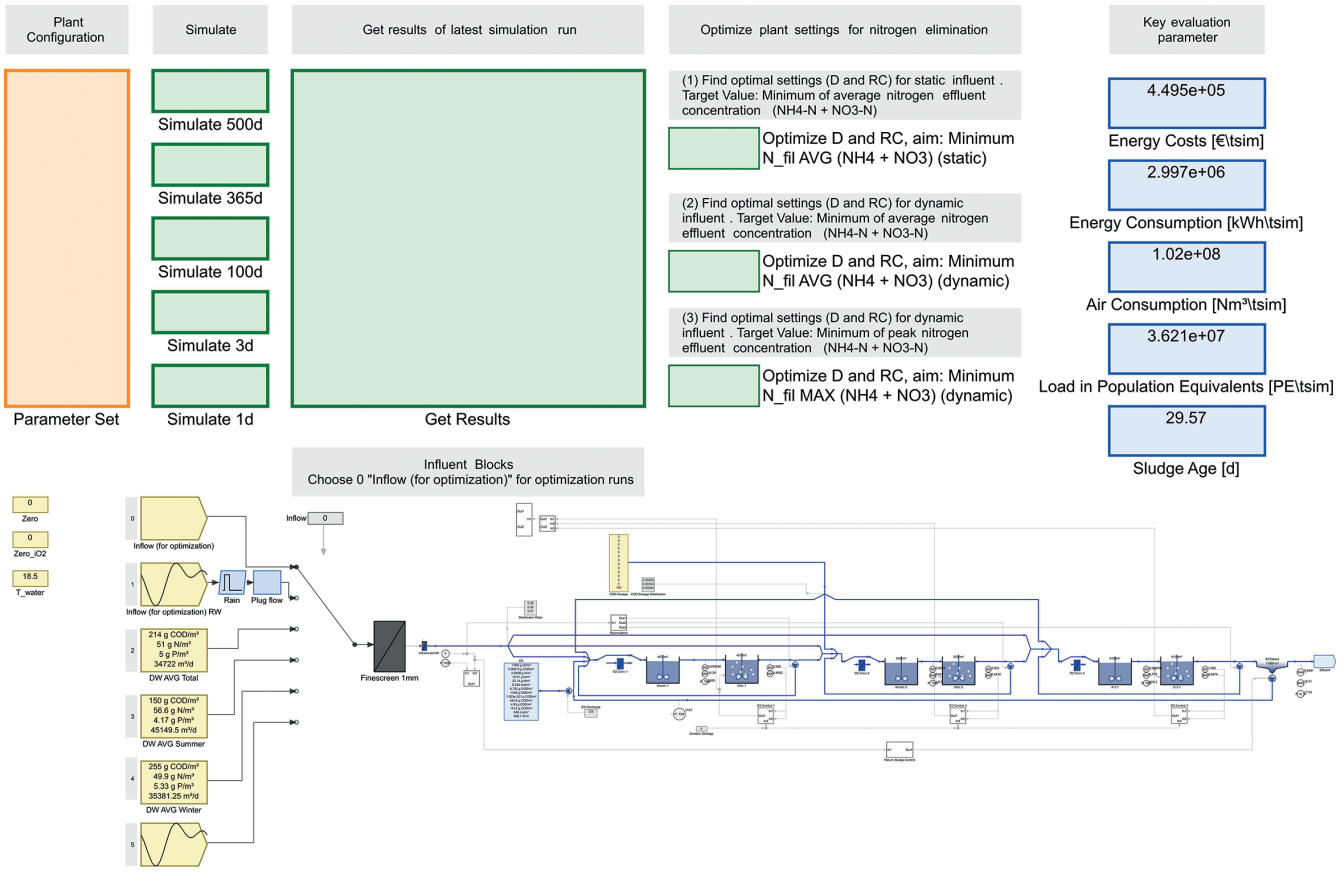
The developed model allows time- and cost-efficient scenario analyses. The impact of adapted operating strategies on wastewater treatment plant operation for current and future inflows and wastewater compositions can be determined. Furthermore, the model is ready to be improved and further developed by the integration of additional measurement data.

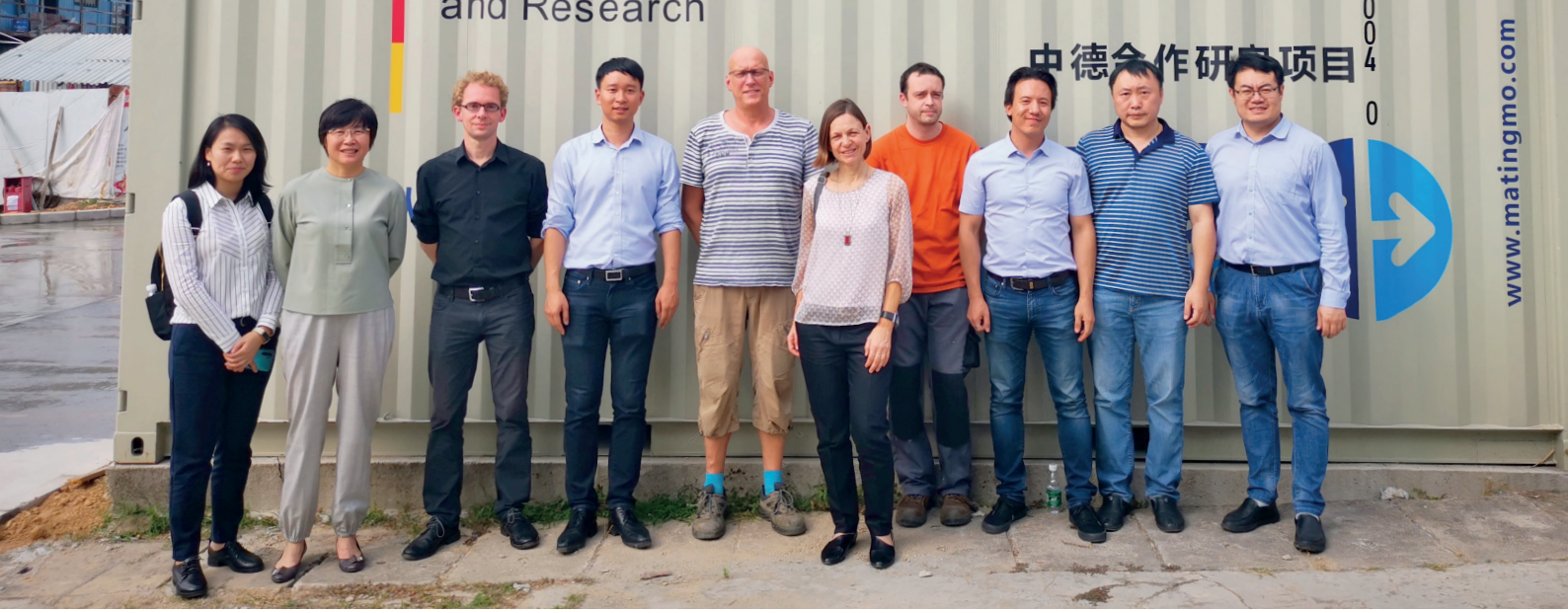
开发的模型允许进行时间和成本效益的情景分析，可以为污水处理厂制定当前和未来进水和污水成分的操作策略。此外，结合其他测量数据可使该模型得到进一步改进和完善。



Project of Water Environment Group Limited 中国水环境集团项目

Project of Water Environment Group Limited 中国水环境集团项目





8. Eco-Friendly Sludge Reduction: Combined System of MBR and Tubificidae-Reactor

生态污泥减量：膜生物反应器和蠕虫床组合工艺

The aim of the membrane bioreactor (MBR) Demonstration in Project KEYS is to promote the demand-based implementation of eco sensitive wastewater treatment and sludge reduction methods. A new approach of MBR processes combined with Tubificidae-reactor as excess sludge treatment was tested on a pilot plant scale at Luofang WWTP in Shenzhen for more than one year.

KEYS 项目中膜生物反应器的示范目的在于实现以需求为导向的生态敏感污水处理和污泥减量方法。基于在深圳罗芳污水处理厂开展的一年多的中试规模试验，应用并测试了一种膜生物反应器结合蠕虫床处理剩余污泥的新工艺。

MARTIN Systems (Berlin, Germany) provided two pilot MBR plants for the demonstration, while, Harbin Institute of Technology (HIT) and Berlin Centre of Competence for Water (KWB) performed the actual on-site testing and scientific evaluation.

马廷膜（柏林，德国）为示范项目提供了两套膜生物反应器设备，哈尔滨工业大学和柏林水研究中心进行了实际的现场测试和科学评估。

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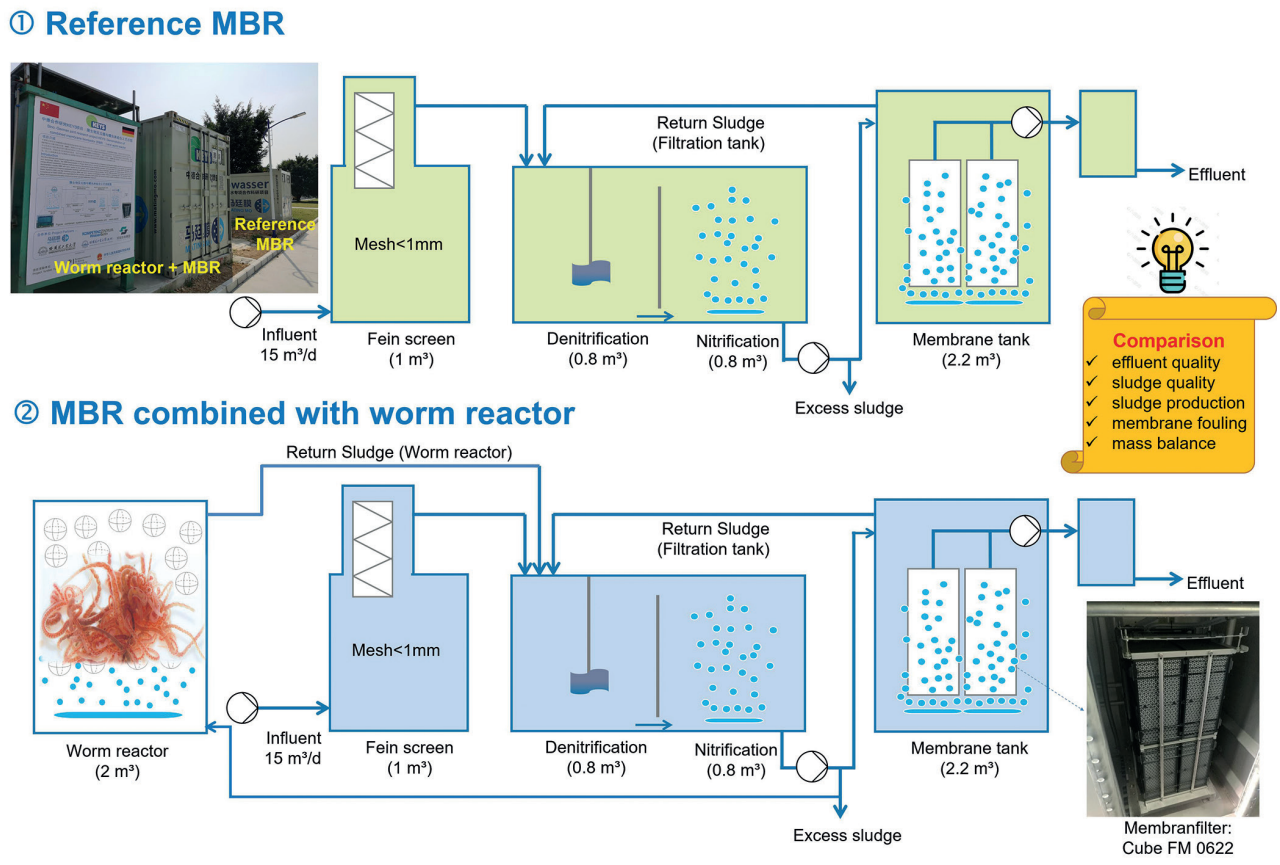
The MBR coupled with the side-stream Tubificidae-reactor was demonstrated over a period of 12 months of continuous operation in Shenzhen. The pilot scale results proved the former lab scale studies of HIT and the combined system indicated excellent sludge reduction efficiency and wastewater treatment performance. The demonstration results show that the sludge yield of the MBR-worm coupling system is reduced by 70%-80% compared with the reference MBR system. A side-stream aerobic treatment of exceeds sludge without worms resulted in 30-40% of sludge reduction. From the results of TMP analysis, the rate of membrane fouling is reduced by more than 50% compared to operation with a side-stream Tubificidae-reactor.

膜生物反应器与测流蠕虫床相结合的示范项目在深圳连续运行了 12 个月。中试测试结果验证了哈尔滨工业大学之前的实验室研究结果，该组合系统显示出了优异的污泥减量效率和污水处理性能。论证结果表明，与膜生物反应器相比，通过膜生物反应器和蠕虫床组合系统处理的污泥量降低了 70%–80%。空蠕虫床侧流处理剩余污泥由好氧稳定化的减量效果在 30%–40%。从跨膜压差分析的结果来看，与使用侧流蠕虫床相比较，膜污染率降低 50% 以上。



Partner: 合作方

KOMPETENZZENTRUM WasserBerlin　MARTIN MEMBRANE SYSTEMS　深圳水务集团 SHENZHEN WATER GROUP　哈爾濱工業大學 Harbin Institute of Technology

9. Rural and Sewage Wastewater Treatment in Beijing
北京市农村污水处理

A number of challenges for treating sewage in rural areas in China have attracted increasing attention in recent years. In 2015, only 11.4 percent of China's villages had access to wastewater treatment facilities. According to the National Development and Reform Commission (NDRC), China will improve sewage water treatment capabilities and enhance the transformation of sewage into resources over the next five years. By 2025, in cities suffering from water shortages, more than 25 percent of the total sewage treated should be used as reclaimed water. For the Beijing-Tianjin-Hebei region in north China, the rate should be over 35 percent.

近年来，中国农村污水处理面临的诸多挑战越来越受到关注。全国只有 11.4% 的行政村对生活污水进行了处理。国家发展和改革委员会表示，未来五年中国将提高污水处理能力，加强污水资源化。到 2025 年，在缺水城市中污水处理总量超过 25% 的部分应作为再生水使用。 对于华北地区的京津冀地区，这一比例应达到 35% 以上。

Partner 合作方

KOMPETENZZENTRUM WasserBerlin

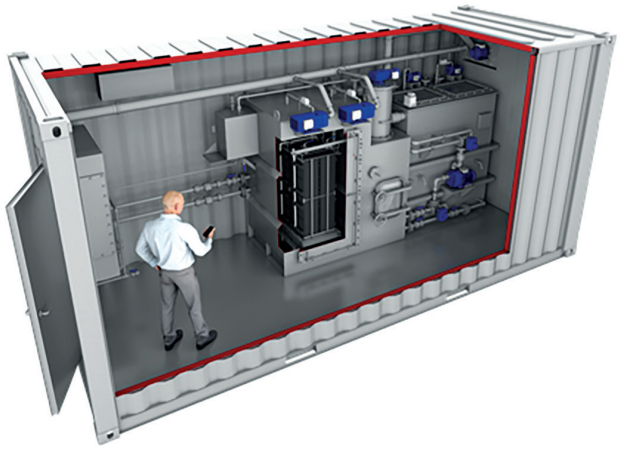
MARTIN MEMBRANE SYSTEMS

BEWG 北控水務

清華大學环境学院 SCHOOL OF ENVIRONMENT, TSINGHUA UNIVERSITY

MBR processes provide a substantially clarified and disinfected effluent of high enough quality to be discharged to sensitive receiving waters and is well positioned to play a critical role in reuse applications. The project partner MARTIN Systems provides a German-engineered and manufactured complete membrane bioreactor systems for the Demonstration in Tongzhou, Beijing. In cooperation with Chinese partners, Tsinghua University and Beijing Enterprises Water Group, the MBR-Demonstration in Project KEYS aims to promote more sustainable and energy efficient wastewater treatment for rural areas. The pilot-scale system was tested and validated at WWTP Zhaijiangou for more than six months. The plant can achieve a high-quality effluent and meet the local discharge standards and effluent limits.

膜生物反应器工艺提供了经过充分净化和消毒的高质量出水，可以排放到敏感水体中去，并且在再利用中发挥了关键作用。项目合作伙伴马廷膜为北京通州的示范项目提供德国设计和制造的整套膜生物反应器系统。与中国合作伙伴清华大学和北控水务集团合作，KEYS 的膜生物反应器示范旨在促进农村地区可持续性、节能的污水处理。该中试系统在污水处理厂翟减沟进行了六个多月的测试和验证。该厂出水可达到高品质，并达到当地排放标准和出水限值。



10. Stormwater Management under Data Scarcity in Tongzhou and Jinxi

通州、金溪数据稀缺下的雨水管理

How to develop sponge city strategies in urban areas where data scarcity is an issue and pollution linked to stormwater runoff is severe? Kompetenzzentrum Wasser Berlin gGmbH (KWB) worked on this question in two cities with different issues, information and boundary conditions: the Tongzhou area in Beijing (climate zone 3) and Jinxi (climate zone 4). Together with the Chinese partners Beijing Enterprises Water Group Limited (BEWG) and Harbin Institute of Technology (HIT) as well as the local stakeholders KWB demonstrated the advantage of using online and open source solutions. Two main tools were developed: 1) a machine learning solution that enables to identify urban surfaces (streets, roofs, green areas) based on satellite images and 2) a simple water balance model (ABIMO), developed in Berlin for urban catchments to calculate the urban runoff and its pollution loads, fed by online climate data. Integrating the results of the Low Impact Development (LID) catalogue from WP1 into the water balance model enabled to compare strategies and support decisions towards sustainable water wise cities. Modeling results (first figure next page) for the Tongzhou demonstration

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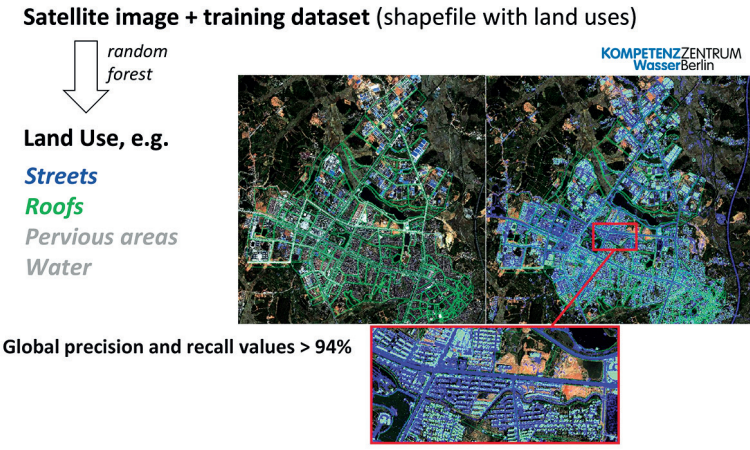
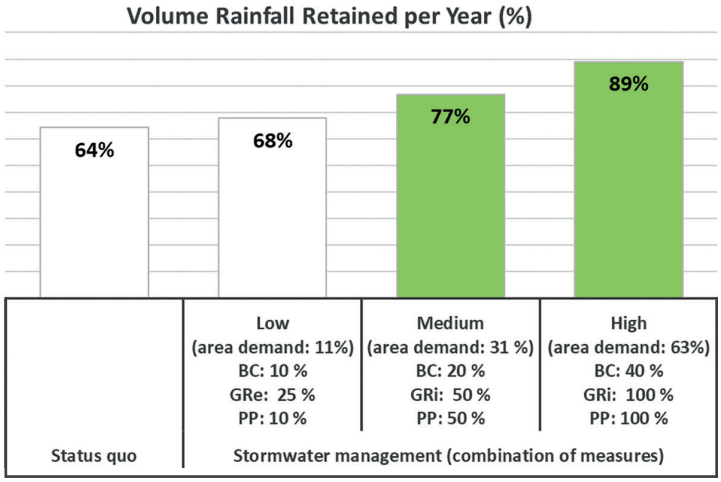


show that a "medium" combination of three LIDs – requiring 31 % of the catchment`s area – is sufficient for satisfying the performance target value of 75 % annual volume rainfall retention according to the Chinese Sponge City Standard for this region.

如何在数据稀缺且雨水径流污染严重的城市地区制定海绵城市战略？ 柏林水研究中心在两个城市对这个问题进行了研究：北京通州地区 (气候带 3) 和金溪 (气候带 4)，这两个城市的关注点、相关信息和边界状况各不相同。柏林水研究中心与中国合作伙伴北控水务和哈尔滨工业大学以及当地有关单位一起示范了应用在线和开源解决方案的优势。该示范开发了两个主要工具：1) 一种机器学习解决方案，能够根据卫星图像识别城市表面 (街道、屋顶、绿地) 2) 一个简单的应用在线气候数据的水平衡模型 (ABIMO)，在柏林开发的用于城市集水区计算城市径流及其污染负荷。将 KEYS 联合项目科研项目工作包 1 的低影响开发手册的结果整合到水平衡模型中去，进行战略对比并为可持续水资源智慧城市提供决策支持。通州示范的建模结果 (右图上) 表明，三个低影响开发设施的“中级”组合需要 31% 的流域面积，能达到本地区对海绵城市径流总量控制率达到 75% 的要求标准。

This methodology can be transferred to other catchments under data scarcity in less time but with similar predictive performance compared to highly parameterized models like SWMM, due to high uncertainties in case of sensitive, but unknown input parameters (i.e. sewer connection degrees).

由于敏感性导致的较高的不确定性及未知的输入参数 (如下水道连接度)，与暴雨洪水管理模型等高度参数化模型相比，该方法可以在更短的时间内转移应用到数据稀缺的其他流域，同时还拥有相似的预测性能。



Partner 合作方

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BEWG 北控水務

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Steinhardt GmbH Wassertechnik, Taunusstein
NIVUS GmbH, Eppingen
MARTIN Systems GmbH, Berlin
AKUT Umweltschutz Ingenieure Burkard und Partner, Berlin
BPI Hannover – Verworn Beratende Ingenieure, Hannover

Project Partners in China

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