PEIYANG CAMPUS: A SPONGE CITY CASE STUDY

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1 ABSTRACT

“Sponge City” is a term that is currently used in China to refer to the urban design of an area based on stormwater management and restoration of ecological processes. Tianjin University’s Peiyang Park Campus was opened in 2015 as a demonstration of the “Sponge City” concept. The campus is one of the first built examples of this concept. This presentation elucidates the “Sponge City” concept by detailing the design of the campus as a case study. The campus is located in the Jinnan District, Haihe Education Park, Tianjin, China. The site is approximately 2.5 km² in area with a complex of waterways, wetlands, and uplands. It was designed to serve 35,000 students and 5,000 faculty and staff. The design goals include: protecting the site’s original ecosystem, using ecological restoration and mitigation to repair damages caused by construction, and using low impact development (LID) practices in design and construction. Essentially, the concept resembles “Resilient Design” with a particular focus on stormwater management. The triangular site of the campus is challenging, with three sides defined by historic canals and a highway system as well as shallow groundwater and saline soil because there is little or no natural storage capacity for water on the site. Agricultural fields have been transformed into 1.55 km² of buildings, 0.15 km² of water and 0.8 km² of restored and designed landscape. The landscape is subdivided into three sub-drainage systems to handle stormwater. The sub-basin that forms an outer ring infiltrates stormwater to groundwater, with excess going to the adjacent canals. Within the inner ring of the campus, there is an integration of green infrastructure within the overall landscape elements through use of concave green spaces, pervious pavers, bioswales, and green roofs. This drops the runoff coefficient for the built up area from 0.9 to 0.5. In this area, there are also water features, such as ponds and wetlands, that collect overflow, and thereby reinforcing the sponge-like function of the area and reducing flow from the campus to surrounding waterways.

1.1 Keywords

Sponge city, Ecological Design, LID, China, Tianjin University
2. INTRODUCTION

Since the 1970s, the United States has proposed "best management practices" (BMPs) (Stern, 1974) for stormwater management; over time these practices have become more ecologically sustainable in the ways they control runoff of rainfall and water quality. Then, on the basis of BMPS, "low impact development" (LiD) was proposed, and stormwater management methods from the source of runoff (Dietz, 2007). In 1999, the United States proposed the concept of a green infrastructure (GI), imitating natural processes to accumulate, delay, infiltrate, transpiration and reuse rainwater runoff. In the 1980s, Germany began to gradually establish and improve rainwater regulation technology, industry standards and regulations. In 1980, Japan's Ministry of Construction encouraged the collection and utilization of rainwater resources by promoting rainwater retention infiltration programs. Committed to conserve groundwater, revive springs and restore river basins.

In addition, Australia has set up the Water Sensitive Urban Design (WSUD) system centered on urban water cycle (Lloyd, 2002). The UK established the Sustainable Urban Drainage System (SUDS) (Spillett, 2005) to manage the run-off of rainfall through science to achieve a virtuous urban water cycle. At the same time, New Zealand also integrated and developed under the concept of LiD and WSUD, and established the "Low Impact Urban Design and Development" (LiUDD) system (Van, 2006). The above ideas all provide strategic support and technical guidance for building a "sponge city."

Like many older cities around the globe, China's largest cities face problems with stormwater management and flooding. Retrofitting older cities can be especially challenging because the upgrading of infrastructure often needs to occur below active streets and buildings. As China has begun to build new cities, many western practices are being tested and incorporated; the ambitious designing and building of new cities creates opportunities for developing new and better stormwater systems.

"Sponge Cities"1, as used in Chinese literature, provide examples of adaptation of low impact development with a strong emphasis on storm water management. In 2003, the concept of "sponge" appeared for the first time in the book titled “The Road to Urban Landscape: Communicating with the Mayor” (Yu 2003). In this book, "sponge" is a metaphor for the function of natural wetlands, especially as they relate to rivers, flood, and drought disaster control in cities. Natural wetlands have been largely disturbed or eliminated around older cities, so this means there is a need for restoration or re-creation of wetlands that can act as sponges for floods and excess nutrients. This is particularly important in moist to wet regions of China, where the majority of rainfall occurs in a few summer months.

During 2011, Liu Bo (as representative of the National People’s Congress) submitted a proposal on “building a sponge city and enhancing the city’s ecological restoration ability”. In April 2012, the concept of “sponge city” was proposed in the “2012 Science and Technology Forum for Low-carbon Cities and Regional Development”. In December 2013, General Secretary Jinping Xi emphasized in his speech at the “Working Conference on Central Urbanization” that “priority should be given to leaving only limited rainwater to enhance urban drainage systems, prioritizing more drainage using natural resources and building natural stockpiles of water by naturally infiltrating, natural purifying in a sponge city “. In October 2014, the Ministry of Housing and Urban-Rural Development officially released “The Guidelines for Construction of a Sponge City - Construction of Low Impact Rainwater System ”(Jian Cheng Han [2014] No. 275) and put forward the concept of sponge city. By the end of 2014 to early 2015 the country elected to produce the first batch of 16 sponge pilot cities and now China's sponge city construction pilot work in full swing. By 2016, the Chinese central government started pilot projects to support sponge city construction.

Sponge city's construction mainly includes three aspects (Wu 2016):
First is to protect the original ecosystem;
the second is to restore and repair the damaged water body and other natural environment;
the third is to use low-impact development measures to build the urban ecological environment.
Sponge city design indicates development and progress of urban stormwater management theory. It creates an ecological city, primarily focused on storm water management ideas and approaches. There is a clear emphasis on the city's resilience to natural hydrological hazards through low-impact integrated management of urban storm water.

2.1 Problem Statement

In 2012, when planning the new Peiyang Campus for Tianjin University, the concept of “sponge campus” was proposed. Specifically, it was proposed that the campus would have the same capacity and
flexibility as a sponge in adapting to environmental changes and handling flood disasters. When it rains, water would be absorbed, stored, and filtered. The Peiyang campus is now open. This paper introduces the campus design as a case study of this approach to urban design based on stormwater management.

2.2 Background

The City of Tianjin is located in the northern coastal region of mainland China, with a population of over 15 million and an area of nearly 12 thousand square kilometers. At one time, it was an imperial port and still serves Beijing as a gateway to the sea. Within the city, Tianjin University (established 1895) is recognized as China's first modern university and is now a national university under the Ministry of Education of China. In 2010, this historic institution launched a plan for a new campus to be created in Haihe Education Park. The planning and design of the campus commenced in 2010 and was led by the Landscape Architecture Studio in Tianjin University Architecture Design and Urban Planning Research Institute. Construction commenced in 2013 and the campus was opened in 2015.

The site is approximately 2.5 km2 in area with a complex of waterways, wetlands, and uplands. The soils are alluvial, saline, and have a high water table, with high salinity and a pH of about 8.0. The Weijin River and Huxiao Canal create the boundaries of the site. Highways dominate the berms that separate the campus from the waterways. The average annual precipitation is 603mm. The highest rainfalls occur in July and August, accounting for nearly 60% of the annual precipitation.

The campus was designed to serve 30,000 students and 5,000 faculty and staff. The design goals include: protecting the site's original ecosystem, using ecological restoration and mitigation to repair damages caused by construction, and using low impact development (LID) practices in design and construction.

3. METHODS

3.1 Design Review

The design of a sponge city begins with the design of the water management system. Therefore, our case study begins with a description and characterization of the water management system. We consider the natural limits of the environment of the building site. Further, we examine how the form of the water management system dictates the campus form. Next, we evaluate how the water management system and campus plan restore ecological forms and functions to the site. Finally, we investigate evidence of the application of low impact design principles.

4 RESULTS

4.1 Water Management System

The construction of “flexible” water management system of Peiyang Campus of Tianjin University is divided into three sub-drainage divisions, which are divided into two sub-drainage divisions: the sub-district and the combination of both inside and out side (Table 1). Within the central sub-basin, water is collected and reused for the landscape. The next ring outward (inner ring) collects run-off from the central basin and stores it in waterways and soil with potential for landscape application in a drought. The inner ring also connects with the outer ring through overflow sites (lake and wetland). This intends to relieve high water build-up on the campus. Finally, the outer ring reduces storm water pressure through release into natural systems. Figure 1 and Table 2 present early conceptual proposals and Figure 2 presents the details of the built system.

The interconnected pathways for water flow create forms that frame and define spaces on the campus (Figure 3). The visual presence of water is ubiquitous – reinforcing the importance of water management throughout the site. The treatment wetland (on west side of Figure 3a) is drawn with a great deal of open water. It is likely that vegetation and sedimentation will close in the wide streams and form a tighter filtration system over time, as indicated in Google Map images.
**Table 1. Three level Stormwater Regulation and Storage System.**

<table>
<thead>
<tr>
<th>Management area level</th>
<th>Rainwater facility components</th>
<th>Function</th>
<th>Runoff direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center Island LID Regulation &amp; Storage Area</td>
<td>The use of the green roof, concave green, planting grass ditch and water-permeable pavement construction and storage area</td>
<td>Source reduction, natural decontamination, accumulation and percolation, and construction of aesthetics and function of the integration of ecological rain management and control system.</td>
<td>Based on the design standards, as far as possible no rainwater drainage outside, over standard runoff overflow to inner ring rainfall collecting area</td>
</tr>
<tr>
<td>Inner Ring Rainfall Collecting Area</td>
<td>Relying on the campus of the center of the lake, the center of the river, overflow Lake and Longyuan wetlands, including the planning of water surface Central rainwater corridor</td>
<td>In the area, rainwater is mainly collected through pipes, combined with green infrastructure to encourage runoff and infiltration. Rainwater from pipelines is periodically raised through pumping stations to supplement landscape water</td>
<td>To accommodate the central island LID regulation &amp; storage area overflow, exceeding the standard flow to the outer ring natural drainage area</td>
</tr>
<tr>
<td>Outer Ring Nature Drainage Area</td>
<td>Relying on the regional ditch and strip protection of green space and other construction of the outer ring of rain corridors</td>
<td>The rainwater in the outer ring rainwater area directly infiltrates into groundwater, or makes full use of the vertical drainage of the site, and the rain water is discharged into the Weijin River and the school river.</td>
<td>To accommodate the Inner ring rainfall collecting area overflow, ultra-standard runoff to Wei River and Huxiao Canal</td>
</tr>
</tbody>
</table>

**Figure 1. Drainage Area Breakdown.** The Outer Ring is a natural drainage area intended to reduce storm season water pressure. The Inner ring combines traditional rainwater pipes and effective utilization of rainwater resources. The Center Island uses LID practices to create a functional integration of ecological flood control system woven into the built landscape. Note that the density of buildings was reduced in the final design.
Figure 2. Water sources and sinks for entire campus. The rectangles on the left indicate sub-basins. Reading from the bottom of the diagram towards the top, we can tack the potential flow of water. In the center campus, there is strong reliance on water collection and infiltration into the soil. With a particularly heavy rain, some runoff overflow to one of the lakes or the pump station. In drought conditions, water can flow from the wetland to the Central Lake and the Inner Lake, or from the pumping station to the Inner Lake. Water leaves the inner sub-basin only by the Overflow Lake to the Weijin River. Excess water collected in the outer sub-basin flows into either of the two adjacent rivers, Weijin and Huxiao.

Table 2. Drainage Area Zones of Peiyang Campus. The Center island ecological rainfall area, the water system of the school, the urban green belt, and the water system around the school make-up the campus core (66.84 ha).

<table>
<thead>
<tr>
<th>Partition name</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer ring drainage area</td>
<td>43.54</td>
</tr>
<tr>
<td>Inner ring pipe rainfall collection area</td>
<td>138.26</td>
</tr>
<tr>
<td>Center island ecological rainfall area</td>
<td>25.55</td>
</tr>
<tr>
<td>Water system of school</td>
<td>15.44</td>
</tr>
<tr>
<td>Urban green belt</td>
<td>11.55</td>
</tr>
<tr>
<td>Water system around the school</td>
<td>14.30</td>
</tr>
<tr>
<td>Total</td>
<td>248.63</td>
</tr>
</tbody>
</table>
4.2 Site Remediation and Enhancement

The site is characterized by shallow groundwater and saline soil, with a high pH. Agricultural fields have been transformed into 1.55 km² of buildings, 0.15 km² of water and 0.8 km² of restored and designed landscape. The landscape is subdivided into three sub-drainage systems to handle stormwater. The sub-basin that forms an outer ring infiltrates stormwater to groundwater, with minimal excess going to the adjacent canal or river. Within the inner ring of the campus, there is an integration of green infrastructure within the overall landscape elements through use of concave green spaces, pervious pavers, bioswales, and green roofs (Figure 3). This drops the runoff coefficient for the built up area from 0.9 to 0.5, greatly reducing the likelihood of overflow from the site to the rivers. In this area, there are also water features, such as ponds and wetlands, that collect overflow, and thereby reinforcing the sponge-like function of the area and reducing flow from the campus to surrounding waterways. The outer ring is referred to as the natural drainage area. The reforestation of the edge extends around most of the triangular site. This area functions both as a buffer and a release valve since excess water will be pumped out of the canals to the adjacent rivers to avoid flooding in the core area (Figure 3a).

In summary, the core area retains and infiltrates water through green infrastructure including bioswales, detention basins, rain gardens and a treatment wetland (Figure 3b and A-D). Excess water is stored in the purification wetland and storage lake. Water from these sources can be pumped back to the campus when needed for landscape plants during a drought. When there is excess water in the purification wetland and storage lake, it is pumped into the canal that forms the outer ring. If there is excess water in the canal, it is pumped into the adjacent rivers.

Figure 3. Green Infrastructure Examples. (a) Forests and wetlands create a buffer between the canals and campus core. (b) Bioswales are distributed throughout the campus, as indicated by green lines in the second image. A-D Detention basins and treatment wetlands collect and filter storm water as it passes from the main campus grounds to the inner ring lake.
4.3 Application of LID Principles

The design of the 2.5 km² campus is dense, when we consider the footprint of the buildings and the size of the population that will work and live there (Figure 4). However, the campus is designed to work as a high-functioning watershed and manages the majority of its storm water on-site as well as managing...
its sewer system on-site. We predict that the stormwater impact of this site on adjacent rivers will be negligible. The landscapes around the buildings and the building themselves are designed using LID elements such as landscape design, green infrastructure, and water management.

Figure 4. Illustrative details of campus design with water system integration. Note the direction of flow of rainwater (blue arrows) to the canals an lake that surround the neter of campus. Also, note the (orange) circulation pump site that moves rainwater circulating around the campus and sewage to the treatment wetland site for purification.

In general, the goals of LID favor restoring a watershed’s hyrologic and ecological functions. The campus core and adjacent buildings reflect several Low Impact Design (LID) principles. Not only are there attempts to minimize impervious surfaces, there is a wetland which recieves and treats storm water. There is an 11.55 ha urban green belt that includes diverse vegetation. In addition to the bioswales and treatment wetlands, green roofs occur on several buildings. There are architectural elements that reduce water use
and the source of some pollutants. Vegetation is planted in gardens and adjacent to building to provide adequate shade and minimize urban heat island effects.

5 Discussion and Conclusions

Peiyang Campus is one of the first examples of application of the Sponge City model to be built in China. The site for the campus had little urban infrastructure, so the storm water, drinking water and sewer systems could be designed to manage all water on site without the expense of removing or updating low functioning systems. The site engineering could be designed and installed before buildings were added. Vegetation could be placed in clean, fresh soil that replaced initial saline soil. The plantings are flourishing on the clean soil and with the water management systems (Figure 5).

Cai (2017), in a review of the 16 pilot designs that were under development in China based on a national Sponge City Policy introduced in 2014, predicts competing forces in selecting sites for this type of development. He points out that economic and ecological objectives often contradict each other, resulting in "Sponge New Districts" being built in urban outskirts rather than in existing cities. The Peiyang Campus example seems to have side-stepped this pattern by occupying an agricultural site that had already been surrounded by the City of Tianjin. Still, the displacement of historic populations can be contentious, and we can find little documentation about the previous residents of the site.

The campus has been occupied for two years now and is hailed as a success by its residents. There has been one major storm, 7/20/2016, that flooded many streets of Tianjin while water failed to collect on the Peiyang Campus walk ways and streets (pers. com). This kind of success is promising for the ongoing adoption of this planning and design theory for the construction of new urban centers in China. Unfortunately, it is difficult to apply in many of the older urban centers.

Figure 5. Campus Core after planting was completed. The photo shows the water feature in the campus core. The lower picture shows a landscaped gathering space that captures and directs stormwater to the wetland area at the west of campus.
Figure 5. Campus Core after planting was completed. The picture shows a landscaped gathering space that captures and directs stormwater to the wetland area at the west of campus. (Continued)

6  ENDNOTES
1. Note that the term Sponge City is also used in Australian planning literature with a very different meaning. Argent and others use the term to refer to cities with the capacity to absorb immigrants. For example, see Argent, N., F. Rolley, J. Walmsley. 2008. “The Sponge City Hypothesis: does it hold water? Australian Geographer 39: 109-130.

7  REFERENCES