Water sensitive development in Kunshan, China

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Abstract:
The *UN HABITAT 2010 Scroll of Honour Award Winner* City of Kunshan is one of the fastest growing areas in terms of economic development in China. The Kunshan City Construction Investment and Development Company (KCID) have embarked on applying a water sensitive approach to its new developments which shall be designed with ecological landscape for stormwater management. The first of its projects is the demonstration of WSUD in the development of Kunshan Culture & Arts precinct where a series of constructed wetlands are smartly integrated into the public realm landscape setting. These sculptural and functional urban wetlands demonstrate the integrated design response by a multi-disciplinary team consisting of engineers, ecologists and landscape designers from early project planning, to project conception stage and through to implementation. The project was finished in February 2013. Some preliminary water quality results will be presented in this paper.

1. Introduction

The *UN HABITAT 2010 Scroll of Honour Award Winner* City of Kunshan has been regarded as one of the most economically successful county-level administrations in China within the greater Suzhou region. Just 50km out of Shanghai, the city is bursting with water. One thousand km of waterways in total lengths are the urban fabric of this beautiful water town.

The rapid economic growth and urban development in the recent decades present a great challenge to its water environment and the water quality is inevitably degrading. In addition to its effort to sewer all its municipal wastewater to centralised treatment system, the City also realises that managing its stormwater to reduce diffuse pollutant loads into receiving water is equally important to preserve and sustain its unique water environment.

The construction arm of the city Kunshan City Construction Investment and Development Company (KCID) have therefore embarked on applying a water sensitive approach to its new developments whereby development parcel looks after its own footprint in terms of stormwater management using ecological landscape. One of the first projects to demonstrate this concept is the development of Kunshan Culture & Arts precinct where a series of constructed wetlands are integrated into the public realm landscape setting and function to both clean stormwater generated on site and maintaining the water quality and quantity of a large ornamental water pool through re-circulation.

2. Overall design response

Kunshan Culture & Art Center is a government financed construction and is built to raise the level of urban culture. This precinct consists of an art center, an architectural piece inspired by Kun Opera, one of the oldest extant forms of Chinese opera that has evolved from the Kunshan melody, and dominated Chinese theatre from the 16th to the 18th centuries. Kun Opera is listed as one of the masterpieces of the Oral and Intangible Heritage of Humanity by UNESCO since 2001. The precinct also includes a public plaza that integrates the new icon building with the joining waterway and existing sports facilities. Central to this plaza is the constructed wetland system (refer to Figure 1) which has been integrated within contemporary landscape character of the plaza to deliver visual, recreational and educational amenity.

The constructed wetland was proposed to function as an ecological landscape that not only provides (vegetation) biodiversity that is usually lost in the highly urbanized development area but also forms a green infrastructure that delivers multiple benefits to the precinct on top of its aesthetic and landscape value.

Figure 1 completed constructed wetlands

The constructed wetland system consists of 3 inter-connected stormwater wetland cells which are designed to demonstrate a number of functions:

- Stormwater treatment : Approximately one third of the site area drains its stormwater runoff into the wetland for cleansing before being released into the external waterways to the east of site to ensure that external waterway is protected from further stormwater pollution from the precinct (refer to left diagram in Figure 2) .
- Landscape pool water quality management: During dry weather conditions, the shallow water (0.3m deep) in the landscape pool could have periods of poor water circulation and subject to risks of poor water quality, particularly occurrences of algal blooms that are prevalent in so many of Chinese constructed waterscapes. Therefore a looped system is incorporated between the wetland and pool systems to allow re-circulation of water at a relatively low pumping rate. The re-circulation operation doesn't just improve the hydrodynamic condition in the pool but also at the same time constantly improves the water quality through wetland treatment and maintain a healthy water environment to meet landscape and recreational objective. (refer to central diagram in Figure 2)
- Landscape pool water recharge: The landscape pool has a relatively large surface area of 10000 m^2 and subject to loss through evaporation. A small pump is incorporated to allow water from the adjoining external waterway to be extracted into wetland system for treatment and injected into the pool to compensate for evaporative loss (refer to right diagram in Figure 2).

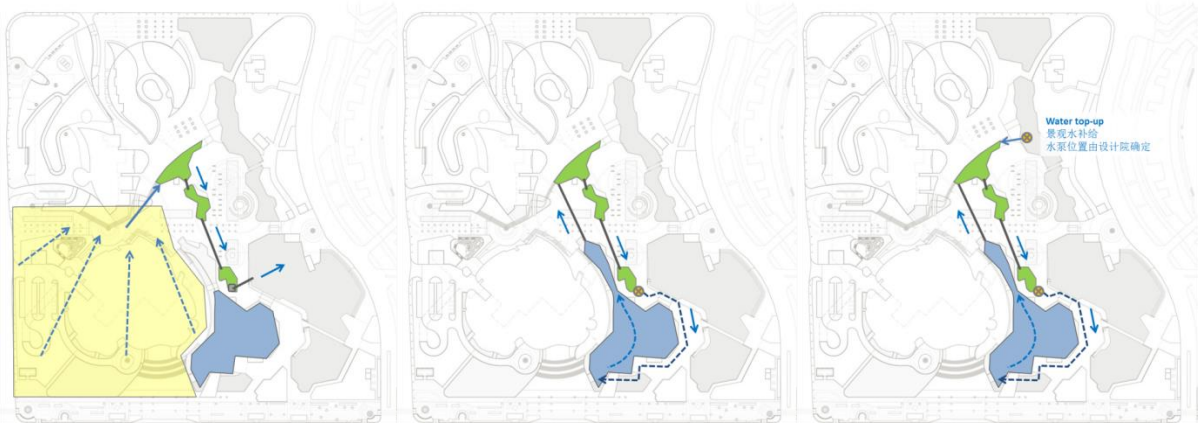

Figure 2 Operating regimes for wetland

3. System design

The design methodology was based on a strong integration of water engineering, ecology, landscape architecture and the collaboration between these professions together with the civil and landscape construction professions. The wetland area, retention time, bathymetry and hydraulic structures have been configured in accordance to guidelines of Wong and Breen (2002) and Melbourne Water (2005) to provide effective water-vegetation interaction to enhance stormwater quality treatment performance and maximise efficiency. The key parameters and considerations in system design are documented in the following sub-sections.

Retention time and sizing

The average annual rainfall in Kunshan is about 1285 mm/year over the period of 2006-2010 and average annual evaporation of 885mm/year is recorded over 2009-2011(refer to Figure 3 below). In order to effectively manage the water quality in the ornamental pool, the wetland is designed to have a retention time of 5 days under re-circulation scheme and the turnover in the pool is about 30 days. Based on this relationship, wetland size adopted is approximately 1000 m^2 for the given size of the ornamental pool. Preliminary hydrologic modeling with daily rainfall data over the 5 years period was then carried out to understand the maximum contributing impervious catchment area can be treated by the wetland of 1000 m^2 to achieve best practice outcome and subsequently to inform the drainage design for the site.

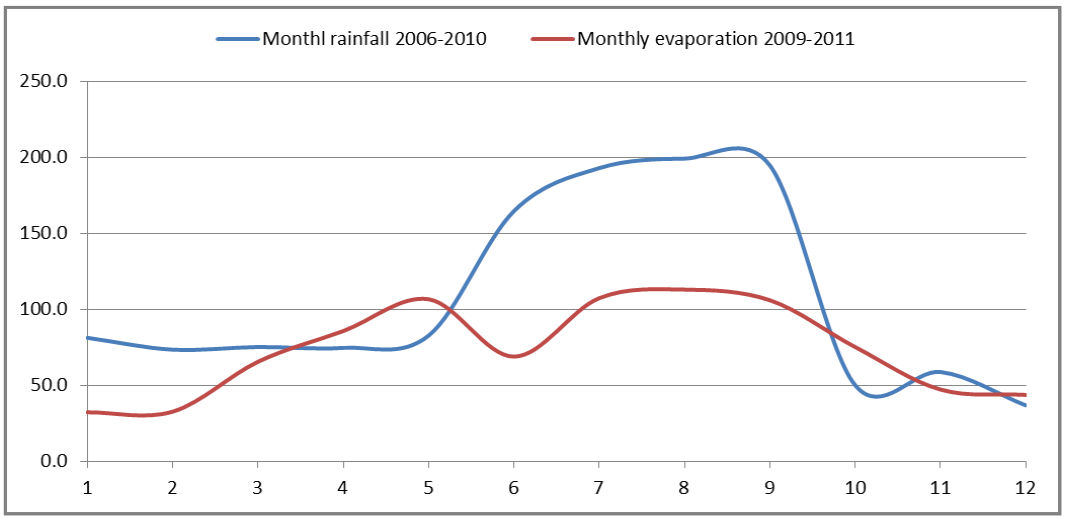

Figure 3 Rainfall and evaporation monthly distribution in Kunshan

Vertical profile

The vertical profile of wetland consists of a 300mm layer of planting soil and an average water inundation depth of 300mm. The bathymetry varies at a longitudinal direction to allow for different water depth and therefore different aquatic species to be established throughout the system. At maximum there will be up to 400mm of water above the soil layer and it tappers out at the littoral zone. Extended detention depth during stormwater inflow is limited to 200mm and inflows when this condition is reached bypass the macrophyte via an overflow pit incorporated into the sedimentation zone.

Sedimentation zone

A sedimentation zone is adopted as part of the first wetland cell to trap sediment before water flows into macrophyte zone (refer to Figure 4 below). The sedimentation zone is approximately 2m deep with a curvilinear shape framing one side of the first wetland cell. Due to safety reasons, the sedimentation zone is covered with a metal grating mesh and with lightings mounted underneath to create a night time landscape feature. Because of the curvilinear shape of sedimentation zone, the interface between sedimentation zone and macrophyte zone is very long and therefore might pose a challenge to the construction of a constant level across the entire length as a broad weir to convey water from sedimentation zone into macrophyte zone. In response, a porous gabion wall is adopted to separate the sediment zone and vegetated area in the first cell. The inflow enters into sediment zone via a submerged pipe at one end and an overflow pit setting the maximum detention depth level in the wetland is placed at the other end to safely move excessive flows into municipal drainage network during major events.

Figure 4 sediment zone and first wetland cell

Hydraulic connections

A 300mm horizontal submerged pipes with grating on either side are used to hydraulically connect the wetland cells (refer to Figure 5 below). The water in the third wetland cell is conveyed to an outlet pit where an orifice plate is deployed to control the retention time during wet weather. In dry weather conditions when the recirculation scheme is operational, treated water will be transferred at the outlet pit via submerged pump into the ornamental landscape pool and thence back to the first cell via a 250mm gravity pipe to complete the circulation operation as shown in Figure 2 (right photo).

Figure 5 first wetland cell connected with second cell via underground pipe

4. Landscape response

The extensive river networks throughout the city fabric have been such an integral part of Kunshan's urban and cultural development and the landscape design response sets out to tell the story of water with the application of dry fountains, reflective pools and functional wetland, as well as retaining part of an existing connecting river channel for the design concept of Cultural and Arts Center. This concept is also the key strategy to align with the notion of prioritising the public realm as part of a larger open space system within this newly developed urban area beyond the existing site boundary and not typically serving as only the green backdrop of the main building.

In addition to the environmental benefits where their size and shape of the 3 wetland cells are well considered together with the eco-engineer's requirement, their organic configurations are also extremely critical to break down the scale and formality of the otherwise commonly over-scaled public plazas in China. Together, they provide such focal dynamics in providing the spatial intimacy and seasonal interests to the grand gesture of the plaza.

The reflective pool fronting the Center can be considered as both an architecture and landscape feature. Due to its relatively large size, it is imperative that there is water maintained within this system even during dry and/ or cold conditions when most cities in China will drain the water leaving an empty pool. In this regard, the wetland cells that supplements clean water becomes an extremely important feature to ensure a consistent project identity.

5. Ecology consideration

Apart from the varying depth of water throughout the wetland system, the concrete grids over the wetland present a great opportunity to create a number of ecological patches each of which colonized by one aquatic species creating a patchwork effect. This allows for a nice and neat delineation of a variety of aquatic plants to co-exist in the same system but in an integrated way with the grids. The grid also absorbs winter sun and helps mitigate harsh temperatures during the plant establishment phase. The system was planted in May 2013. During the first summer no poor water quality issues were observed. When the system was inspected in August and September 2013 many dragonflies were observed in the wetland suggesting the system was being colonized and will act as habitat in the future.

Table 1 lists a number of design species for the wetland system and they are all native plants selected for easy maintenance and quick establishment. Swamp Cyprus are planted at the southern edge of each wetland cell to enhance biodiversity and add a nice vertical touch to spatially expand ecological dimension. Figure 6 shows the established conditions of plants that are approximately 5 month old since planting. Species were selected to both enhance water quality treatment and support epiphytic biofilms and also for their landscape and aesthetic values.

Table 1 list of wetland plants for various zones

Littoral zone	Ephemeral	Shallow marsh	Submerged marsh
Iris pseudacorus	ludwigia prostrata	Eleocharis dulcis	Vallisneria natans Hara
Lythrum salicaria	Cyperus alternifolius	Sagittaria sagittifolia	Nymphoides peltatum
Polygonum capitatum	Alisma plantago-aquatica/Alisma sp.	Acorus calamus/Acorus sp.	Nymphaea alba
Juncus dastrophanthus	Pontederia cordata	Phragmites australis	Myriophyllu mspicafum
Canna glauca	Juncus effusus/Juncus sp.	Zizania latifolia	Trapa incisa

Figure 6 Some aquatic species in the wetland

6. Construction

The project construction was initiated in August 2012 and completed in February 2013. The surrounding landscape work was finished in April 2013 with planting work commenced in May 2013. Construction of small buildings for food and beverage to activate the plaza and finishing touches for landscape works continue during the writing of this paper. Some of the photos recorded during the construction and establishment phase are presented in Figure 7.

Figure 7 Collection of construction photographs

7. Water quality monitoring

The system was commissioned in June 2013 and subsequently water quality in the ornamental landscape pond was monitored twice with one sample taken in June 2013 and the other in September 2013. Table 2 summarises the key performance data that show:

- The water quality in the landscape pool maintained by the wetland re-circulation scheme satisfies the Chinese Water Quality Guidelines for Ornamental Waters (secondary contact)
- The low TSS value shows the water is of good clarity and therefore good aesthetic value
- Despite the shallowness of water and hot summer, the low TP value indicates the water is at low risk of developing nuisance algal blooms. The re-circulation system has proven to be very effective with no occurrence of algal blooms throughout the summer of 2013.
- The microbiological results while below the guideline suggest some contamination by birds which is a common feature of such constructed urban waterbodies.

Table 2 water quality results for 2 sampling events since operation against local guidelines

	Sample (1)	Sample (2)	Chinese water quality guidelines for ornamental use *
Sampling date	2013/06/20	2013/09/10	GB/T 18921-2002
Total Suspended Solids	3	9	≤10
Total Nitrogen	1.51	1.96	≤15
Total Phosphorus	0.08	0.02	≤0.5
BOD5	3.3	2.2	≤6
Fecal Coliform	200	110	≤2000
*Guideline includes the use of treated recycled wastewater			

8. Conclusion and future application

The City of Kunshan has a unique water environment framed by an extensive network of canals and hydrologically behaves as a series of inter-connected polders through a system of gates and pumps. Water quality of the canals, especially the smaller canals are often affected by a combination of catchment pollution and poor water circulation. The overarching concept of diffuse source control of stormwater and sullage through WSUD features to maintain higher levels of inflow water quality to this canals coupled with a polder-wide recirculation of canal water through regional and precinct-scale wetlands provides a city-wide strategy for the City of Kunshan to sustain its unique water environment and for the city to be transformed into a water sensitive city.

Although further monitoring is required to assess the performance of stormwater treatment by this particular wetland, the concept and application of this first demonstration of water sensitive approach to stormwater management has a significant effect on the attitude and organizational responses to future projects undertaken by the KCID. The collaborative and consultative approach adopted had meant that the concept of ecological landscapes shall be adopted for all future new or retrofitting development undertaken by KCID to capture the opportunities presented and progressively transform the catchment management practice within the City of Kunshan.

The initial water quality results show that the effectiveness of a wetland based re-circulation system for maintaining healthy landscape water. This demonstrated how public open space can be designed to carry ecological functional and provides eco-system service beyond their traditional amenity values to the urban environment. The key proof-of-concept moment was when an adjoining ornamental waterbody within the same precinct experienced deteriorating water quality and occurrence of algal blooms during the summer of 2013 compared with a largely clear waterbody connected to the constructed wetland system. The concept of ecological landscape can be further applied at a larger scale to convert local parks into multi-functional infrastructure for water quality management, micro-climate enhancement, biodiversity support and flood detention and conveyance. The concept is relatively new but this demonstration project has seeded an appetite for exploration and trail of water sensitive urban design for such an iconic water city.

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9. Reference

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