Urban waterfront rehabilitation: can it contribute to environmental improvements in the developing world?

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Abstract
This paper examines urban waterfront rehabilitation as a sustainable development strategy in Chinese cities. Though waterfront rehabilitation is increasingly being employed in developed world cities, the environmental benefits are not always clear. Nonetheless, China, like other developing countries, has shown interest in this strategy, for improving its local water quality, upgrading environmental management, and improving quality of life for urban residents. As developing world cities struggle to break from the traditional model of ‘pollute first, clean up later’, it is critical that they employ strategies which minimize or remediate environmental impacts while still promoting economic development. This paper analyzes three such projects: the Qinhuai River Environmental Improvement Project in Nanjing, the Suzhou Creek Rehabilitation in Shanghai, and the Wuli Lake Rehabilitation in Wuxi. A critical analysis indicates that these projects have served numerous purposes which contribute to the cities’ sustainable development. Though waterways may not be restored to pristine conditions, the incremental improvements appear to be a necessary catalyst for sustainable urban development.

Keywords: urban rivers, remediation, sustainability, China, urban development

1. Introduction
China is undergoing a rapid transformation in terms of economic growth, urbanization, and for better or worse, ecological resources. Its water quality, particularly in and around urban areas, has been a topic of major concern and is now arguably the most urgent environmental issue China confronts. Cities are undertaking ambitious projects aimed at improving quality of life and environmental conditions without compromising economic development; this key tenet of sustainability is put to the test in China, which has enjoyed near double digit annual economic growth perhaps at the expense of its environment. This is compounded by the fact that cities are in competition with one another—leaders are being measured based on their cities’ GDP growth, which is also a key to attracting further investment. The levels of pollution are not dramatically different from what many industrialized country cities experienced earlier in the 20th century; what is unique is the speed at which China is modernizing, and the water constraints it faces (namely, scarcity in the north, and poor quality in the south). Roughly two-thirds of China’s cities experience water shortages, more than half of its major rivers and 70% of its lakes are severely polluted, and 20% of monitored cities did not have drinking water up to standards (SEPA 2007, MEP 2008). This adds urgency to China’s efforts to improve its water quality.

Water quality in China is generally assessed by aggregating measurements of several key pollutants into an index and then reporting quality in terms of Class I (highest) to Class V (lowest)\(^1\). Cities will typically measure approximately 14 pollutants as part of this index, with nitrogen (generally ammonia, [NH3]), chemical oxygen demand (COD), and biological oxygen demand (BOD) being the most important indicators in most urban areas (World Bank 2006). However,

\(^1\) GB3838-2002 Environmental Quality Standards for surface water.
cities rarely report on individual pollutants, and instead rely on
reporting the Class (which is a function of the most prevalent
pollutant).

Recent pollution events like the Songhua River benzene
spill of 2005; the Taihu Lake algal bloom of 2007, and the
Qingdao algal bloom as it prepared to host Olympic
events in 2008 have further highlighted the need for more
comprehensive control of China’s water resources. The
national government now supports numerous projects to
control point and non-point source pollution and control
some of China’s most important water bodies (e.g. the
11th Five Year Plan for Environmental Protection). At
the local level, however, where financial resources are
more constrained and economic development still often takes
precedence over environmental protection, cities have favored
win–win strategies which couple environmental improvements
with development. Much has been made in China of
the ‘environmental Kuznets curve’, that is, the notion that
industrialized countries developed at the expense of the
environment until they reached a certain level of income, at
which point environmental protection emerged as a priority
(e.g. Dasgupta et al 2002). China and other developing
countries recognize that such a trajectory is unlikely to be
environmentally or economically sustainable for the rest of
the world.

One strategy in particular which seeks to change this
trajectory, urban waterfront rehabilitation, is being employed
in some cities and underwritten in part by international
development banks. The goals of these projects are often
pragmatic and begin with removing colors and odors from
the surface water, followed by gradual (one class by China’s
standards) improvements in monitored water quality, with a
long-term goal of phased improvements in quality. What
is unique about the rehabilitation projects is that they are
being used as a catalyst for economic development (a priority
for developing world cities), and are integrated with other
efforts to revitalize waterfront properties, encourage tourism,
provide community amenities, and support further residential
and commercial development.

Historically, cities have developed along waterways,
which provide numerous services, from transportation and
trade to drinking water and sanitation. As urban populations
increased, though, many of these water bodies became
dergraded as a result of nearly unfettered pollution. Numerous
US cities developed along rivers, which are now among the
most impaired waterways in the country (EPA 2001) and
are also the site of many brownfields, former industrial or
contaminated sites, which are no longer in use. Therefore,
urban water bodies offer significant challenges in terms of
rehabilitation, but also opportunities for cities to manage future
development.

It is important to make some distinctions among
rehabilitation, remediation and restoration. Restoration is
typically the most challenging process as this refers to a
complete structural and functional reform to a pre-disturbance
state, while rehabilitation represents a partial reform (NRC
1992). Rhoads et al (1999) propose an alternative, referred
to as ‘naturalization’ in which humans are considered an
integral part of the natural system and therefore must
be considered in strategies to rehabilitate or naturalize an
ecosystem. Findlay and Taylor (2006) take this a step
further and propose that a more appropriate course for urban
ecosystems will be to rehabilitate a degraded ecosystem to
a point, and then remediate the ecosystem further, not with
the goal of full restoration, but an ‘enhanced’ ecosystem.
In nearly all cases, restoration of urban water bodies is not
practicable given the circumstances and therefore some form
of rehabilitation which factors humans into the equation will
be most appropriate.

Numerous cities in the developed world have invested in
waterfront redevelopment projects as a means of attracting
investment, reclaiming marginal land, or revitalizing particular
neighborhoods. One distinction between these projects and
The goals for these projects are not necessarily focused
on environmental concerns, but improved water quality is
a clear precondition to effective waterfront development
(Connor 2005). Such projects are often costly, but it is also
possible to recover these costs, through easily quantifiable
benefits such as real estate development, commercial
opportunities, and increased tourism, to less quantifiable but
nonetheless important benefits to human health and quality of
life.

Deciding to rehabilitate urban ecosystems requires
navigating the conflicting triple bottom line pressures of social,
economic, and environmental factors (Findlay and Taylor
2006). In many of these cases, restoring ecological integrity
may be given a lower priority in order to accommodate other
factors, particularly the fact that these ecosystems also support
human activity. This scenario is arguably even more conflictual
in the developing world, where cities are supporting rapidly
growing populations and are stressed to extend basic services
and foster economic growth, let alone improve or at least
stabilize the urban environment.

Another important challenge in rehabilitating urban
waterfronts is assessing the value of such a project. Setting
commercial interests aside, which are an important factor but
not necessarily derived from the ecosystem, one must look
at the full range of ecosystem services available. Boitsidis
et al (2006) argue that there is a lack of urban-focused
methodologies, and as a result, urban waterways are often
undervalued; if based on water quality alone, they are
generally considered degraded, without having factored in
other intrinsic and economic values. These urban ecosystems
offer a number of services, though, including microclimate
regulation, drainage/flood control, sewage treatment, as well
as recreational and cultural activities (Bolund and Hunhammar
1999). Loomis et al (2000) demonstrated that, if users have
a better understanding of the value of these services, their
willingness to pay increases, an incremental increase which
then fund rehabilitation efforts. Whether or not this holds true in
the developing world remains to be seen, but it does highlight
the importance of education and involving the public. To date,
it appears that calculated economic benefits of these projects in
China have been based mostly on hedonic pricing (e.g. rising
real estate prices) and not on health or other environmental
impacts, which could be substantial.
2. Suzhou Creek: Shanghai

Suzhou Creek is a 125 km stream, 54 km of which pass through urban Shanghai, China’s largest city and a major international port bordering both the Yangtze River and the East China Sea. Suzhou Creek is the principle outlet for Taihu Lake, a large freshwater lake approximately 180 km west of downtown Shanghai. Suzhou Creek is divided into an upper reach (which receives water from Taihu Lake) and the lower reach, which winds through urban Shanghai, joining the Huangpu River and eventually emptying into the Yangtze River before it reaches the sea. Shanghai’s urban areas are densely populated; of the nearly 20 million residents in the municipality, almost 90% live in the urban districts. Nearly 3 million people work and live in the districts along Suzhou Creek, though the area remained relatively underdeveloped (commercially) due to the poor water quality (ADB 1999b). Its main function has been flood relief, but it is also an important navigation channel (up to 3000 barges per day), source for industrial water and agricultural irrigation, and channel for industrial and municipal wastewater (ADB 1999a).

As a consequence of these multiple uses, Suzhou Creek has endured severe pollution for decades. Records dating back to the 1920s document this pollution, and Suzhou Creek has historically been one of the most polluted waterways in China. Its water quality was not even achieving China’s Class V standards, grouping it among the country’s most impaired waterways. Citizens collectively referred to Suzhou Creek’s problem as the ‘black and stink’, a reference to the color of the surface water and the noxious odors emanating from it. Night soil (human waste) and solid waste wharves located along the river contributed to these offenses.

In spite of the poor water quality and visual/odor problems, the area along Suzhou Creek was densely populated, increasing both the domestic wastewater load entering the river and the health risk for a portion of Shanghai’s population. As such, the Shanghai Municipal Government adopted a plan for rehabilitation as part of the February 1996 ‘Economic and Social Development Plan for Shanghai’: rehabilitating Suzhou Creek was made a top priority in order to enable Shanghai to meet its environmental development goals, but also as a means of further developing Shanghai into a global city (ADB 1999b).

At the request of the national and municipal governments, the Asian Development Bank (ADB) became involved in the project to partially finance it and lend technical assistance. The Suzhou Creek Rehabilitation Project is a 12 year project (1998–2010). Total projected costs are $916 million, with $300 million of this being provided by ADB loans (ADB 1999a). Phase I (1999–2003) focused on improving wastewater management (treatment and disposal), introducing water resource management and quality control methods, and providing environmental sanitation and urban renewal. The urban renewal efforts included removing the solid waste and night soil wharves, rehabilitating flood walls, and constructing new green space in the form of parks and boulevards, and these early efforts yielded rapid results. In particular, flow augmentation and daily flushing contributed to noticeable early improvements (WL Delft 2003), though it is less clear what impact these measures might have had further downstream.

As China’s most prosperous city, Shanghai is often considered a window into the future of the country. The rehabilitation of Suzhou Creek is no different; it has been well studied in China, and has also been considered a model for subsequent ADB-funded projects. According to ADB’s assessment, Phase I was highly successful from a water quality standpoint (achieving Class V and IV standards in different reaches of the river ahead of schedule) and an economic standpoint (efficient allocation and high rate of return). The assessment did note that property values along Suzhou Creek have experienced double digit growth outpacing other areas in the city, but even without these figures being included in the valuation of the project, economic benefits were estimated to be in excess of 4.1 billion RMB ($490 million) with a 22% rate of return (ADB 2005a). The subsequent phases are being carried out and fully funded by the municipal government and are focused on further improving water quality to Class IV in the lower reach and Class III in the upper reach, with a goal of restoring aquatic life by 2010 (Tigno 2007).

3. Qinhuai River: Nanjing

Nanjing is the former capital of China and a major city on the Yangtze River, 270 km northwest of Shanghai. The Qinhuai River, known as Nanjing’s ‘Mother River’, covers 110 km, 34 km of which travel through the urban districts. Although Nanjing has been an important city throughout China’s history, rapid urbanization within the city’s limits has been a more recent occurrence. Nanjing’s population was half rural in 1990, but by 2003 this share was cut to 27% as residents moved to the urban districts, which by 2006 were home to approximately 5.1 million residents (NMG 2006). This urban migration has added an additional strain on local water resources. Demands for water for domestic and industrial use are on the rise, as are wastewater loads.

Nanjing suffers from inconsistent rainfall patterns, leading to severe urban flooding following rain events, and stagnation during drier periods. Nanjing’s urban water resources, which include seven rivers and three lakes, are all polluted. The Qinhuai River has been one of the most polluted water bodies—it’s water quality fails to reach Class V standards, often by a significant margin. Most of the pollution comes from industrial and residential wastewater discharged into the river; as of 2005 66% of wastewater was being treated (ADB 2005b), but less than half of wastewater loads were being treated to acceptable standards (NMG 2006). Additionally, some portions of the river, formerly wetlands, became illegal dumping grounds in the 1980s. At present this marginal land has given way to densely-populated squatter settlements without sanitary infrastructure (NMG 2006).
As a result of the rapid urbanization and environmental degradation, the Nanjing Municipal Government has been making investments in infrastructure to address water pollution. Since 1985, the government has invested roughly 600 million RMB (nearly US$90 million) to improve drainage and upgrade sewage treatment, more than half of which was devoted to projects specifically to improve 2.5 km of the inner Qinhuai River, including flood protection, drainage, and waste reduction (UN-Habitat 2006). As of 2002, these projects had been carried out, resulting in significantly improved water quality in stretches of the river (up to Class IV), notably the Fuzimiao section, which is a major commercial, cultural, and tourist area in the city.

Nanjing’s development objectives are to maintain a high rate of GDP growth, improve livelihoods, and reduce poverty, and its objectives for the Qinhuai River are to improve water quality, but also to decrease flooding and health risks (ADB 2005b). In order to link these various goals, the municipal government requested that ADB assist in further projects along the river. Specifically, future efforts would involve:

- extensions to 2 wastewater treatment plants (WWTP);
- 13 sewer subprojects;
- river management (flow augmentation, bank stabilization and erosion control, water replenishing, and urban wetland construction);
- stormwater management (construction and renovation of 7 pumping stations and 80 km of stormwater discharge pipes); and
- sludge management (evaluating treatment options for sludge from WWTPs and dredging).

Based on the ADB experience with Suzhou Creek in Shanghai, as well as similar ongoing projects in other Chinese provinces, the ADB agreed to finance $100 million of the estimated $236 million (2.0 billion RMB) in costs for the project (ADB 2007). In addition, the ADB provided a grant in the form of technical assistance to initiate the project—the municipal government was only responsible for funding 25% of the estimated $800,000. The project was developed to be in line with Nanjing’s development plan through 2010, which set goals of treating 85% of wastewater, reducing waterborne pollution, and reducing the risk of urban flooding, particularly in the Qinhuai catchment.

The project would reclaim marginal land along the river banks and rehabilitate it into urban wetland parks. Nanjing had financed and carried out rehabilitation and remediation of the first 12.5 km of parkland, which is well-utilized by residents, and ADB’s involvement in financing subsequent rehabilitation and remediation was a first for its work in China (NMG 2006). The goal is to remediate 33 hectares of the former wetlands, which would of course involve resettlement of the population currently residing there, along with measures to remediate the land itself. This component is viewed as an opportunity to immediately improve the quality of life for the resettled residents (who currently lack sanitary infrastructure) as well as create opportunities for recreation and education (ADB 2005b). However, this does highlight the fact that residents are being displaced by the projects—this is not without cost, though it appears that these costs may be accounted for since resettlement is specifically identified in the ADB project documents.

Another key component of the ADB loan is capacity building. In addition to improving infrastructure, the ADB is focused on strengthening Nanjing’s local institutions in order to carry out environmental management and monitoring. As such, $100,000 is being devoted to training (NMG 2006). One of the two key outcomes of ADB’s involvement is to improve surface water resource management, and therefore its loan provides for a sludge management study, training programs for managers and staff, and recommendations for institutional arrangements (ADB 2007). Based on the progress Nanjing has made with its prior projects and the success of the ADB-funded project in Suzhou Creek, it is reasonable to assume that Nanjing will experience continued improvements in its water quality. One recent calculation (Luo and Dong 2006) suggested that net benefits of the wetland park alone could be on the order of 780 million RMB (~US$112 million), but in general it seems too early to fully assess the benefits of water quality improvements and related projects.

4. Wuli Lake: Wuxi

Wuli Lake is a perimeter lake located north of China’s largest freshwater lake, Taihu Lake, which was a major target of national investment during the Ninth Five Year Plan (1996–2000). Wuli Lake is a tourist attraction for Wuxi city, located between Shanghai and Nanjing and, until 1998, was the primary source of drinking water for the city. Wuxi, like most other cities in China, is undergoing rapid urbanization—the urban population is now 2.3 million, more than half of the city’s total population. Human activity has impacted the local resources, including Wuli Lake, which in the 1950s was practically transparent and, being a shallow lake, had areas in which the lake bottom was visible (Jin et al 2006).

Severe pollution from wastewater and non-point source pollution has impaired the lake at least since the 1970s, when scientists noted that macrophyte coverage (an indicator of ecosystem health) had severely decreased, a trend that continued on through the 1990s as transparency also decreased and submerged plants virtually disappeared (Li 1996). In 2003 its water quality ranked as Class V or below. Four major rivers entering Wuli Lake seriously exceeded standards for pollutants, particularly nitrogen (ammonia) and phosphates (World Bank 2003). Only about 20% of Wuxi’s industrial and domestic wastewater was being treated as of 2003, and the existing treatment infrastructure is further strained by the growing urban population. Townsend-Small et al (2007) suggest that urban sewage discharge may in fact be the largest source of nitrogen loading in the winter (when agriculture and aquaculture inputs decrease).

Wuli Lake’s banks have been home to small-scale fisheries, and this aquaculture has also been a major source of pollution. Though its total pollutant load is far greater than other sources, its percentage load of COD, TP, and TN is less than that of domestic wastewater (table 1). Thus, rehabilitating
Wuli Lake requires an integrated strategy to address these various pollution sources.

As part of its development strategy, Wuxi has been expanding southward, first by building a university town and a tourist area surrounding Wuli Lake, eventually moving the government offices southward as well (World Bank 2003). This has added to the urgency to address water quality in Wuli Lake, though it is part of a larger strategy intended to enhance quality of life, decrease water degradation, and improve the quality of the urban environment (World Bank 2004b). Beginning with the 10th FYP period (2001–2005), Wuxi began work on projects aimed at improving the water quality of Wuli Lake and rehabilitating the surrounding lakefront. Plans called for dredging 5.6 km² of the lake, dismantling many of the aquaculture fisheries and reclaiming that portion of the lake, and restoring 19.4 km of the lake’s banks for the purposes of tourism (World Bank 2003).

The Wuli Lake subproject was incorporated into a larger regional effort to improve water quality in the Tai Lake basin, since it was traditionally one of the most polluted portions of the basin. Estimated costs of the Wuli Lake subcomponent of the plan (including some improvements to neighboring Meiliang Lake, Wuxi’s current drinking water source) called for 3 billion RMB (>US$440 million) for pollution control, 600 million RMB (US$88 million) for dredging, and 80 million RMB (>US$12 million) for ecological rehabilitation (Jin and Hu 2003). By 2003, the Wuxi government had invested nearly 2 billion RMB focused on expanding wastewater treatment capacity to address point source pollution. In 2003, the World Bank became involved in rehabilitating Wuli Lake, as part of its Tai Basin Urban Environment Project.

The World Bank has been involved in improving urban water resources in China as part of its urban strategy, which focuses on livability, good governance, and bankability (World Bank 2004a). Though cities in the Tai Basin had been working on improving their water quality through increasing point source treatment rates, local governments had been challenged by a lack of investment in treatment plants, coupled with poor enforcement (World Bank 2004b). Therefore, the World Bank became involved in the Tai Basin Urban Environment Project in order to lend technical assistance, improve environmental management, and continue progress with addressing pollution from both point and non-point source pollution.

These projects were developed to complement work already underway in Wuxi and Suzhou. The Wuli Lake project focuses on lakefront rehabilitation, and calls for 10 sluice gates, 1 shiplock, and pilot research in eco-restoration (World Bank 2003). Altogether, it is comprised of six sub-components. The first three—dredging, returning surface water from fisheries to the lake, and water diversion—have been carried out and fully financed by the Wuxi government. The World Bank co-financed the other three components which included pollution control, embankment rehabilitation, and the eco-restoration project, requiring 92 million RMB (US$13.5 million) in World Bank loans and 116 million RMB (US$17.5 million) from Wuxi city (World Bank 2004b).

Dredging has yielded improvements in water quality, reducing organic matter sediment, total nitrogen, and total phosphorous (Jin et al. 2006) and achieving Class III standards (NIGL 2006). Following the dredging, eco-restoration began in the form of macrophyte plantings and aeration measures. It was decided that this would be conducted on a pilot scale, and as water quality improves further it will be possible to scale up the macrophyte plantings and reintroduce fish and benthos (World Bank 2003). Rehabilitating Wuli Lake and the surrounding waterfront has led to reclaimed land and recent commercial and residential development. Reclaimed land has been sold in auctions, yielding 4.12 billion RMB (US$606 million) from sales, 1.65 billion (US$243 million) of which are being reinvested into the project (Gu 2005). Based on land sales alone, this project has yielded benefits much greater than its costs; a full valuation of health and quality of life benefits would certainly reveal additional benefits over costs.

5. Analysis

The three cases presented have been widely hailed within China as model projects, and in the case of Suzhou Creek in Shanghai, an example for subsequent ADB-funded projects. Still, since these environmental remediation projects are sub-components of larger development projects, it is more difficult to assess their contribution to improving water quality. However, it is important to keep in mind that these projects are seeking a balance between economic development and environmental protection; the challenge for Chinese cities as well as all cities in the developing world is to maintain high rates of GDP growth while improving or at least not further compromising environmental quality. As such, the focus is often on incremental water quality improvements rather than dramatic improvements or restoration to pre-disturbance conditions.

One unique intervention in all three cases was the involvement of a development bank. While the banks provide loans and thus have a financial interest in the projects, in the case of China, which likely could have financed these projects on its own, the development banks also provide less tangible benefits. First, in each case the development bank, either ADB or World Bank, provided technical assistance to assess the cities’ needs, and this was often provided at minimal cost to the local governments. Second, both ADB and World Bank require environmental impact assessments (EIA). While China’s environmental agency, the State Environmental Protection Administration (now the Ministry of Environmental

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**Table 1.** Key pollution sources and loads to Wuli Lake. (Note: t: tons, a: annually, COD: chemical oxygen demand, TP: total phosphorous, TN: total nitrogen. Source: Jin et al. 2006.)

| Pollutant source | Pollutant | COD load | TP load | TN load |
|------------------|-----------|----------|---------|---------|
|                  | load (t/a)| (t/a) (%)| (t/a) (%)| (t/a) (%)|
| Industrial waste water | 341 600 | 103.78 (8.2) | 0.38 (2.8) | 7.86 (5.1) |
| Domestic waste water | 1 646 200 | 592.61 (46.9) | 6.58 (48.3) | 65.85 (42.5) |
| Aquaculture | 5 861 100 | 398.73 (31.6) | 3.52 (25.9) | 47.47 (30.7) |
| Other | 562 400 | 168.26 (13.3) | 3.13 (23.0) | 33.60 (21.7) |
| Total | 8 411 300 | 1263.38 | 13.61 | 154.78 |
Project funding is likely to be a major limiting factor if urban waterfront rehabilitation is to be carried out in more developing world cities. However, it is important to note that money is available from various development banks and numerous other international sources. In China, this external assistance is often less than half of the total project funding, and Chinese cities may also make use of other internal funding sources, such as the China Development Bank which funds much of the urban infrastructure in China. Cities have found these initial investments to be cost effective and generally profitable, and better data collection and valuation methods might reveal even more significant benefits (when accounting for other health and environmental impacts). Developing the surrounding waterfront appears to be a key opportunity to catalyze further urban development and generate revenue to offset other costs, particularly if some of the returns on investment (e.g. real estate sales) are reinvested into the project. These developments may guarantee that the ecosystems will not be restored to pre-development conditions, but in an urban context this is an unreasonable expectation. As experiences have shown, modified ecosystems still offer a great deal of value to the urban area.

6. Conclusions

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