The Application of Ecological Cycle Theory in Waterfront Area Design

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Abstract. Waterfront area is one of the most important interact area between human activities and natural processes. As its multifunction attribute such as agricultural producing, leisure and recreation, ecological conservation et al., high efficient and synthetic utilization of land resources has become a crucial challenge in waterfront area planning. Most of the recent studies about landscape construction of waterfront area have focused on the spatial pattern of landscape elements. However, the issue of organic integration of landscape elements still has not been resolved effectively. In our study, a case study has been carried out in waterfront area along the Pihe River in Yaodu town, Qingbaijiang district, Chengdu. The principles of ecological cycle theory have been introduced in landscape design, for optimizing landscape pattern and promoting material circulation as well as energy flow among patches, in order to achieve organic integration and effective use of different land use types.

1. Introduction
Waterfront area is one of the most important interactive areas between human activities and natural processes [1]. As an open space between land and waters, waterfront area has always been a hotspot in the landscape design field [2]. At present, the strategy of landscape planning and design for waterfront area mainly takes two perspectives as follows: 1. the overall image of waterfront area is shaped on the basis of urban design theory while taking into account waterfront landscape area, landscape axis and landscape node to create the spatial and environmental arts of waterfront area; 2. the basic pattern for protection and construction of waterfront landscape is put forth under the support of landscape ecology and ecological design to protect and restore the ecosystem of rivers, protect and construct the patches and corridors for biodiversity protection, and combine the landscape ecological strategies for overall natural and cultural design [3-7]. Generally, most of landscape designs for waterfront area address how diverse spatial elements are morphologically combined to achieve their unification and integration, but there is not any effective way to realize the organic integration of heterogeneous elements. With the focus on Pihe River in Yaodu Town, Qingbaijiang District, Chengdu City, this paper preliminarily explores and studies the ideas of landscape design and overall planning for waterfront area of Pihe River, so as to organically integrate different types of land in the waterfront area, enhance the utilization...
efficiency of land resources in small towns, and provide a new approach to effectively eliminate the conflict between land consumptions for production and ecological purpose.

2. Overview of the Research Area

2.1. Current Conditions
Pihe River is a third-level tributary of Tuojiang River. Originated from Minjiang River, water flows from Naxi River in Guangming District into the territory of Yaodu Town, and heads east across Yaodu Town. Along Tuocun Village in Xiushui Township, it joins the water from Xiuchuan River and Changliu River on the left side, flows towards Zhaozhen Town, and then converges into Tuojiang River. Pihe River is not only a watercourse for irrigation and drainage in the Dujiangyan channel system, but also one of main flood relief channels on the Chengdu Plain. Due to gentle stream gradient and sediment deposition in flood period, its banks are dominated by point bars, and its water level fluctuates dramatically. The average flow rate of Pihe River is approximately 27m³/s. The riverbed is irregular due to excessive sand mining in the past. Along both banks of the river, agriculture is the leading industry together with a few agritainment resorts and small factories.

Yaodu Town (N 30°42′, E 104°19′) situates approximately 10km away from the downtown in the southeast of Qingpaijiang District, Chengdu City. It abuts Jintang County in the east, is bordered by Xijiang River in the west, extends to Qingbai River in Qingquan Town in the south and meets Pihe River in the north. Pihe River extends by 3.2km within the territory of Yaodu Town. The watercourse is wide, straight and shallow. The average width of the river is 108m and the depth is 3.5m (Fig. 1). This research area is formed by the intersection of Pihe River and Shilongyan channel, and accommodates Yaodu Town. It has a total area of 1.2km². The waterfront area has a natural gentle slope on its north bank, while its south bank is intermittently provided with artificial embankment. On the whole, the area has a gentle terrain, but the bank close to the town is steep.

2.2. Existing Problems
According to field survey and sorted data, the waterfront area of Pihe River in Yaodu Town faces four major problems as follows:

(1) Severely damaged natural shape of watercourse

![Figure 1. Location of the waterfront of Pihe River in Yaodu town](image)
Yaodu Town locates on the south bank of Pihe River, so it faces very heavy burden of flood prevention and control during every rainy season. In recent years, Yaodu Town Government has gradually repaired and solidified the watercourse, which straightens the natural bends of watercourse and gradually increases the proportion of hardened bank. For this reason, the wandering and changing natural shape of watercourse has disappeared, while the vegetations on the buffer zone of bank decrease to lower the biodiversity of wetland and cause ecological unbalance.

(2) Common water pollution of river
At present, Yaodu Town has relatively backward drainage facilities, and some farms and residential communities along the river directly discharge their domestic sewage into Pihe River without treatment. On the other hand, agricultural production is managed extensively along the banks, and rural non-point source pollution control does not achieve the desired results. Since fertilizer and pesticide residues flow into Pihe River together with the water for irrigation, they lower the content of dissolved oxygen in water body, and undermine the self-purification capability of waters.

(3) Poor effect of landscape on both banks
Along the town area, buildings are not arranged in an orderly manner, and landscape structures in different blocks are not coordinated. New and old buildings exist with different styles, while it is very common to see illegal floors on houses in residential communities. The roads in town area have not been built systematically, so many roads end abruptly. Moreover, the roads are provided with insufficient greening, which does not form a network or system. The whole appearance of landscape in the town area is not satisfying.

(4) Insufficient land use management
As revealed in the field survey, farmers often occupy the arable land illegally for house construction in the research area, so they convert the shoals or green space into farmland without permission, and even grow crops on the isle in the middle of the river. Additionally, some riverside sections with good view have been illegally occupied for agritainment. Hence, the supervision and management of urban planning and land use should be further strengthened.

3. Problem Analysis and Landscape Design Objectives
As the most important landscape resource in the world, waterfront area assumes a variety of functions such as transportation, safety, production and ecological protection for human beings. All the above problems must be rooted in its attribute of multiple functions, which conflicts with the demand for land and the low efficiency of land resource allocation in waterfront area at present. Ecological cycle means to take the food chain as a link to organically combine the constituents of ecosystem at all nutritive levels, so as to considerably improve the utilization rate of resources in each constituent, and achieve the favourable ecological and economic benefits. At present, the theory has been widely applied in social, economic, production and environmental protection fields. This project is designed to realize the efficient and comprehensive utilization of land resource, and introduces the ecological cycle theory into the waterfront landscape design to realize the organic combination of different types of land in the energy flow and material circulation. Equal attention is paid to the production and ecological functions to facilitate the growth of local agriculture and industry and reinforce the role of the river as a natural ecological barrier. While satisfying the requirements for the function of flood prevention and control, the design can provide a waterfront ecological recreation experience place for people. By creating the safe, stable and healthy waterfront ecological landscape, it can facilitate the harmonious relationship between human and the nature.

4. Strategy and Method

4.1. Efficient and Sustainable Utilization of Land Resources
Waterfront area is a transition area between land and water ecosystems, making it a typical ecotone. Since it controls the circulation of energy, mass and information between water and land ecosystems, waterfront area plays a significant role in ecological protection. For this reason, land use planning for
The waterfront area should be oriented to improve ecological benefits, and abandon the practice of aiming at the increase of land for construction while ignoring the resources and environment. With regard to urban construction, the principle of reduction should be followed to determine the minimum quota of per-capita land for construction, and economize the use of land for residence, commerce and industry as intensively as possible. The surface hardening of land should be strictly controlled, while the green space should not be lower than 60% of total area to facilitate the water-vapor circulation between land and waters. On the basis of farmland and environmental protection, the land can be developed properly according to local conditions, while its use and maintenance are coordinated to achieve cyclic and sustainable utilization. Sufficient land for ecological protection should be reserved in the waterfront area.

4.2. Cyclic Water System and Green Path Network
Ecological treatment is provided for Shilongyan channel to connect it with Pihe River at the south and north ends, so as to form a circular water cycle. The rainwater drainage system and agricultural irrigation channels inside the town area are improved to form an integrated water network and system with “a cycle and multiple channels”. The green space ecological system is constructed to improve the ecological functions of urban waterfront area. First of all, the ecological revetments of Pihe River are repaired to form a main riverside green corridor, while green corridor is also created along Shilongyan channel, so as to form two main east-west horizontal green axes in the waterfront area. The greening for roads inside the town area, such as Sitong Road, Wenhui Road and Chengtai Road, is improved to create three south-north green roads for connecting Pihe River and Shilongyan. The greening in Yaodushangjie Street and Yaoduxiajie Street is solidified at every corner. Inside the town area, public green space and park are created to strengthen the protection and conservation of ancient and precious trees. In the end, a networked ecological green space system can be formed with “two horizontal and three vertical” green spaces. Trees are often grown in the green spaces, and organically combined with shrubs and grass to highlight the features of local plants, which can create the seasonal landscape with profound cultural implications in these plants. The construction of this “water artery and green network” can facilitate the exchange and circulation of river water and groundwater and protect the self-regulating function of the river on one hand, while the continuous and smooth development space formed by waterway and green path can facilitate the circular airflow and form a great microclimate in the waterfront area.

Moreover, waterside treatment is carried out for Pihe River and Shilongyan to construct the banks of varying gradient and levelness while maintaining the original natural shape of riverbank. Diverse treatments are conducted to simulate the natural shape of riverbank and reconnect the disrupted natural water corridor, so as to create the natural revetment with good accessibility to waterscape (Fig. 2).

![Figure 2. The ecological revetment in waterfront area](image-url)
4.3. Function Partitions and Integration

According to the degree of development allowed, waterfront area can be divided into three function partitions, i.e. ecological conservation zone, ecological agriculture zone and town center zone (Fig. 3).

Ecological conservation zone is mainly created for ecological protection and conservation. The existing forestland and wetland resources are utilized to create the habitats for migratory birds and water birds, while the plant communities are arranged in consideration of habitat conditions for birds. Meanwhile, the zone is reasonably designed considering the requirements of different species for environment and the principles of competition and symbiosis between species, so as to achieve the optimal productivity. On the other hand, the aesthetical requirements for landscape are taken into account to achieve the seasonal variation of plants in the layout.

Town center zone can be divided into residential community and recreational & commercial center. First of all, integrated land consolidation is organized within the scope of waterfront area, and scattered farmers are encouraged to move to the centralized residential community, so that ecological residential community can be constructed under the guidance of “holism, coordination, circulation and recycle” theories and with the objective of sustainable development. The green space system in the residential community is optimized to improve the microclimate in the residential community and its vicinal areas, and realize the natural ventilation and lighting for the residential community. Several systems are constructed including rainwater and sewage separate drainage system, centralized sewage treatment system, reclaimed water recycling system and garbage collection and treatment system. Domestic garbage and wastes can be taken as the raw materials for the production of biogas to provide the clean energy for public service facilities. Domestic sewage can be used for irrigation and agricultural production after being treated, while sludge can be used as fertilizer in agriculture. The residential community is arranged in the “enclosed” and people-oriented manner on the whole, while the traditional places for social activities in the neighbourhood are created to satisfy the needs of social life. Buildings are constructed with green materials and techniques to conserve energy and resources, and reduce pollution and wastes. Recreational & commercial center is formed with Yaodushangjie Street and Yaoduxiajie Street as the axis, while the appearance of buildings on the streets is renovated on the whole to create the Hakka style in West Sichuan, and develop the recreational & commercial pedestrian streets with strong local cultural characteristics, so as to satisfy the needs of residents for recreation, shopping, foods and entertainment.

Ecological agriculture zone focuses on the development of ecological agriculture, recycling agriculture and stereoscopic agriculture. The agricultural landscape elements such as farmlands, forestlands, roads and ditches are optimized on the basis of landscape ecology, while the protection forests between farmlands are utilized to enhance the farmland protection against disasters and epidemics, conserve the water and soil, and improve the value of agricultural landscape for appreciation, so as to create an efficient, healthy and wonderful ecological agriculture zone. As a transition between ecological conservation zone and town center zone, ecological agriculture zone should attach importance to the connection with the neighboring function partitions. On its west border with ecological conservation zone, fruit woods can be developed for agricultural economy, while small animal husbandry can be properly developed between forests to extend the forest resource into the ecological agricultural zone while enhancing the land yield. At its transition to the residential community in the east, facility agriculture can be arranged together with farms and biogas digesters to provide fresh vegetables, meats, poultries and eggs, etc. for residents in the residential community and the recreational & commercial zone, while it can be also converted into a place for resource-based and comprehensive utilization of domestic and agricultural wastes to provide clean energy for the residential community and organic fertilizers for the ecological agriculture zone.
5. Conclusion
As a typical transition area between land and water ecosystems, waterfront area is of great strategic significance to the safety of regional ecology, and also becomes a key area for development by human beings owing to its abundant ecological resources. In the landscape planning and design of waterfront area, efforts must be made to resolve the conflict of production, ecology, development and protection within the limited space. In the landscape planning and design of waterfront area in Pihe River, the ecological cycle theory is taken as the basis for organic integration of function partitions to enhance the efficiency of land utilization, realize the efficient utilization of resources, facilitate the material circulation and energy flow of ecosystem and effectively protect the ecological functions of waterfront area.

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