FEASIBILITY STUDY ON NEAR NATURE CONTROL OF WATERFRONT RESTORATION IN THE PEARL RIVER ESTUARY AREA

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1 ABSTRACT

The Pearl River estuary is one of the typical coastal wetland types in Southern China, which has significant value in both ecological and economic aspects. Over the past 30 years, large numbers of river bank hardening projects, such as reclamation, river levee and wharf, have directly changed the hydrodynamic environment characteristics of the Pearl River estuary area, which has led to a chain of ecological environment deterioration problems. The crucial concept of near natural control is to reconstruct the environmental basement near the original or natural state in the damaged area by artificial means, so as to gradually restore the sustainable ecosystem and create a rich local landscape. This paper focuses on the near natural control spatial restoration of the hard engineering waterfront with low ecological function in the Pearl River estuary area. Based on the realistic regional hydrological characteristics of the Pearl River estuary area, we design a series of spatial waterfront modes according to the conditions and the needs of different surrounding land use. These spatial modes are constructed by waterfront slope reconstruction, soil matrix improvement, mangrove and associated plant community replanting, and other ecological engineering methods of varieties for spatial units. On the basis of meeting the functional requirements such as irrigation, freight transport and flood control, this research assesses whether near nature control is a feasible way to restore the natural material and energy flow of the Pearl River estuary waterfront effectively, and gradually restore the diversity of its ecosystem.

1.1 Keywords

landscape planning, near nature control, waterfront restoration, pearl river estuary , hydrological characteristics

2 INTRODUCTION

At Guangdong in southeast China, the Pearl River is an extensive river system with rich natural resource that take a significant role in hydropower, shipping, irrigation and so on. For thousands of years, under the period alternately movement between light water and salt water, soil with variety biological resources accumulates at the area where the Pearl River flows into South China Sea, forms the rich estuary delta.

Located in the south central part of Guangdong Province, the Pearl River estuary is a complex tidal delta (22°02′～23°8′N，112°35′～113°57′E) which size in about 160km in North-South and 120km in East-West (Zhang Sheng-cai, 1994). According to the form of the water, the spatial form of the Pearl River estuary can be divided into two zones——the river network zone and the estuary bay zone (Figure 1). The convergence of the runoff from the three rivers (Xi jiang, Beijiang, Dongjiang), and the tide form the South China Sea, makes the Pearl River estuary one of the most complex river estuaries in the world (in hydrological activities).

Under the combined effect of Subtropical oceanic monsoon climatic conditions, the estuarine ecosystem was formed with water as its core and varies in biological diversity. As the interface between land and water, the waterfront is the most intense area of land and ocean interaction in the region of the estuary. Sediments and nutrients transported by the large river continue to accumulate in this area, and form large-scale tidal flats with great biological diversity.

As for economic and social development, the tidal flat is a great potential land use resource. People in the estuary region often use the means of reclamation to transform these perennial or non-periodically flooded wetlands into usable land. The Pearl River estuary area has a long history of reclamation. Continuous reclamation provides space for agriculture, industry and urban construction.

In the period of agricultural society, the major land use form of the waterfront space in the Pearl River estuary was farming. Restricted by the level of productivity development, it would take about 10 to 15 years for people to transform the tidal flats into cultivated land by reclamation (Xian Jian-ming and Wang Li-wa, 2005). After entering the period of industrial society development, the construction of waterfront in the Pearl River estuary area became mainly focused on industry, urban construction, and port traffic.

In the last three decades of reform, construction of water conservancy projects, such as the construction of sluices, rivers and embankments, port terminals, and so on, has been maintained at a high level. The coastline and entrances (also, mouth) are advancing rapidly to the sea, and have changed greatly in shape (Li Ying, et al., 2008) (Figure 1). Since the reform, urban construction in the Pearl River Delta has developed rapidly. Magnanimous and high intensity waterfront construction has seriously threatened the natural ecological environment of the estuary. However, the process of urbanization has had dire biological effects, and the ecological environment is in need of urgent repair. To coordinate the contradiction between human social development and environmental carrying capacity, waterfront construction in the Pearl River estuary region, the center of economic development, needs to introduce a new pattern of spatial organization.

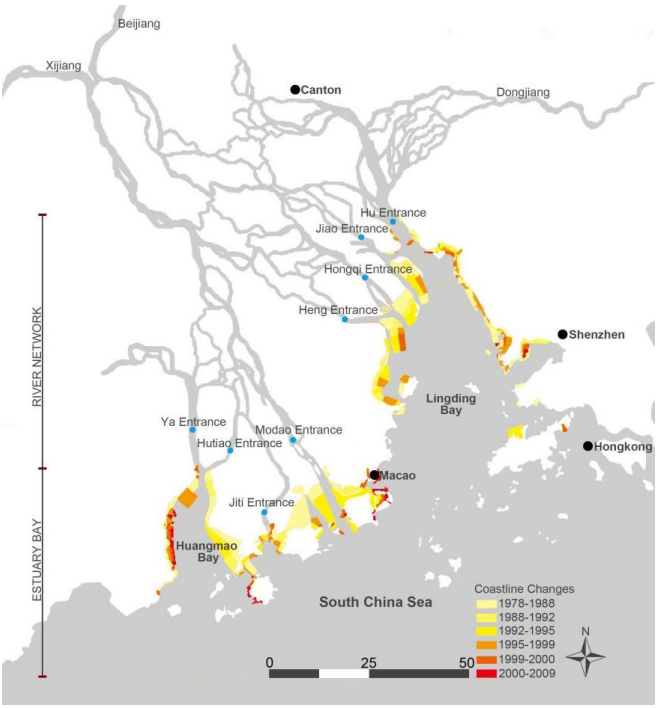

Figure 1. Spatial Pattern and Coastline change of the Pearl River estuary.

3 INADEQUATCES & PROBLEMS

The river and with the surrounding floodplain is an ecosystem. In natural conditions, water quality is maintained by flow. The flow of the water washes the sediment of the shore and the bottom of the river, and the riverbed is relatively stable under the condition of natural erosion and deposition. Overall, the scouring and silting interaction between soil and water, and the interaction between animals and plants, provide a balance in the natural river. The river landscape presents an obvious lateral and vertical continuity.

Because of the strong influence of human activities and its accumulation in recent decades, the characteristics of the riverbed evolution and the spatial distribution and correlation of the runoff and tidal dynamics in the Pearl River Estuary area have changed sharply compared to the previous natural state.

The hardening of the waterfront blocks the interaction between the river water and the soil. This formed the vertical section which led to an intensive rapid reclamation that changed the shape of the river bank sharply. This hardening also led to the variation of water and sediment distribution, leading to the alienation of the geographical environment (Yun Cai-xing, 2010). As a result of its geographic and the climatic condition, the Pearl River estuary area suffers a great many natural disasters such as flood, drought saltwater intrusion and storm (mainly typhoon). Among them, the biggest natural disturbance factors are flood and storm.

In the time scale of ten years to several hundred years, the effects of human disturbance like waterfront reclamation, urban and port development in the Pearl River estuary area has been running neck and neck with natural disturbance. The influence of natural disturbance on the estuary area has been exacerbated by the interference of human disturbance.The following section describes, in depth, the major ecological and environmental problems in the region.

3.1 Ecological resource degradation

The reclamation, fill Bay Bridge construction, and other projects continue to occupy a large area of wetland resources and significantly reduce the availability of the waterfront wet land. Mangrove resources are rapidly shrinking (Zhan Guo-qiang, 2008 and simplification of species is aggravated and amplified.

3.2 Aggravated water pollution caused by increased rain pollution hazards

At this stage, due to the dense population and booming in economy, large amounts of domestic

sewage and industrial waste water drain into the estuary water body without proper disposal. Also caused by urbanization, impervious areas have increased rapidly which has led to the change of surface hydrological processes change. Abundant rainfall gathers pollutants on the impervious surface (like roof and pavement), which is turned into contaminated runoff flow by the hard-engineering waterfront into the river.

3.3 Increased risk of flooding

In recent years, the frequency of extraordinary flooding in the Pearl River estuary area has grown. Located at the edge between the river and the sea, the Pearl River estuary area plays a significant role in the flood drainage of the Pearl River Basin (Chen Wen-long, et al., 2014). Affected by the strong influence of human activities and its accumulation, the regulation capacity of flood discharge in the lateral branch channel of the Pearl River estuary has been weakened, as well as the reduction of flood storage space. More and more flood runoff is also flowing into the main channel (Yun Cai-xing, 2010).

From a spatial point of view, river bed deformation of the split entrances in the lower part of the estuary area (estuary bay zone) have not changed much. Under the impact of tidal lockup, the flood transportation from river to sea is still blocked, but the return period of the flood is basically unchanged. The flooding from upper river, together with the tide from estuary bay, have formed a two-way extrusion at the upper part of the estuary area (river network zone), and this has caused the water level to rise abnormally high. The return period of flooding has shortened significantly, and this has increased the threat of flooding (Yun Cai-xing, 2010).

3.4 Salt tide disaster intensified

In recent years, saline water intrusion in the Pearl River estuary area has become more frequent, longer in duration, shows a wider range of effects, has increased intensity, and tends to be more serious. Severe salinity intrusion occurred in the years between 1998-1999, 2003-2004, 2004-2005, and 2005-2006. Increased salinity intrusion frequency resulted in the degradation of wetland types. An increase in tidal flat soil salt content can affect or even destroy the growth of reeds and other various wetland vegetation (Guo Zheng-ren, Yuan Li-rong, 2012).

4 NEAR NATURE CONTROL

The concept of “near natural control” was first proposed by Alwin Seifert, a German landscape architect. In the 1950s, the school of near natural river management engineering was formally established in Germany, and proposed that the river regulation should be consistent with the principle of plant and life. By the 1980s, the European engineering field began to reflect the construction concept of a water conservancy project, and realized that river management should not only conform to the principle of engineering design, but also be in accord with the principles of ecology. In 1990s, the river ecological control projects in Europe proved to be successes, and this brought out a series of theory and technology on ecological river control engineering.

In 1991, Japan began to promote a river construction method that focused on creating waterfront environments with habitat variety increases; this was called Multi-Natural River Construction. By recovering soil and planting vegetation, this construction method effectively promoted the infiltration of groundwater and a virtuous cycle of water system. After nearly a century of research and practice, the concept of near nature control has been widely accepted by the field of water conservancy and has been numerously applied in middle and small size river restoration projects in suburbs or cities (Wu Dan-zi, 2015). However, due to the complexity of hydrology and socio-economic infrastructure constraints, research and practice of ecological landscape restoration planning on *near nature control* in large size river is still in the initial stage.

Near nature control, is a systematic engineering theory that comprised modern hydraulic engineering, landscape ecology, environmental science, biological science, aesthetics and other disciplines together as a theoretical support. On the premise of protecting the living environment of the river system and creating a harmonious natural landscape, as well as ensuring the safety of flood control and full consideration of the ecological effect. The aim of near nature control is to transform hard-impermeable waterfront spaces into a soft-permeable spaces of which three systems (water system, soil system and bio system) mutually interact in balance.

In essence, *near nature river control* is an artificial river construction method based on the simulation of natural river characteristics (Table 1). The crucial concept of *near natural control* is to reconstruct the

environmental base near the original or natural state of the damaged area by artificial means, so as to gradually restore the sustainable ecosystem and create a rich local characteristics landscape. Restoration of natural the soil and water interaction process contributes to the success of environmental base reconstruction.

Table 1. Comparison of natural and artificial river.

	Nature River	Artificial River
Characteristic	High water quality	improve water quality
	Water body circulation	artificial measures
	Water corridor effect take place	levee withdrew
	water-soil interaction	vertical anti-seepage
	Rich animal and plant resources	artificial community construction

In ecological river landscape planning at the basin scale, the major guiding principle is to realize the natural circulation of water; this has become a global approach. Therefore, the relationship between the river and the groundwater must first be improved, in order to create a complimentary relaitonship (Figure 2). Specific measures include:

(a) River channel adjustment.

(b) Dig a deep channel in the upstream to reduce the bed height and increase the interaction of the water and soil by excavating a braided channel.

(c) In the middle reaches of the river, determine the width of the river according to the flood flow, then set the dam at both sides. The river then flows along the artificial channel by the continuous self-adjustment, and the adapted river bed is formed to create a more natural river.

(d) In the downstream, take parts of the farmland as a flood-relief area to avoid a flood disaster.

The Pearl River estuary area restoration is a large complex social system of engineering projects involving many disciplines. Due to high population density and the high land utilization rate, numerous organizations are involved. It is unrealistic to develop a basin-scale *near nature control* plan that fully restores the natural ecological state back to the time before the high intensive construction.

The border interface of land and water, compared to the river base, is an easier space to be used and transformed. Here the scenery changes are more intuitive. Also, the change in the riparian morphology directly affects the activities of the water and sediment within the river, and therefore influence the operation of the whole river ecosystem. Accordingly, combined with bank construction opportunities, the realistic regional hydrological characteristics, and the practical application needs, the reconstruction of the waterfront space on the concept of *near natural control* is a feasible method to restore the ecological environment quality of the Pearl River estuary area.

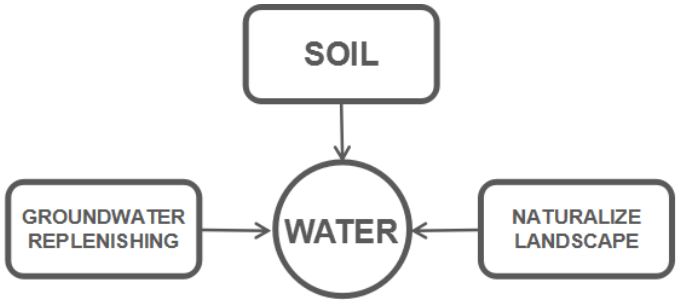

Figure 2. Water oriented near mature control approach.

5 STRATEGY

According to region environmental problems and development needs, like flood control and channel construction, the spatial structure of the *near nature control* model of the waterfront in the Pear River estuary area consists three basic levels—Level 1: Decontamination and interception; Level 2: Retard and retention; and Level 3: Purify and salt solution (Figure 3).

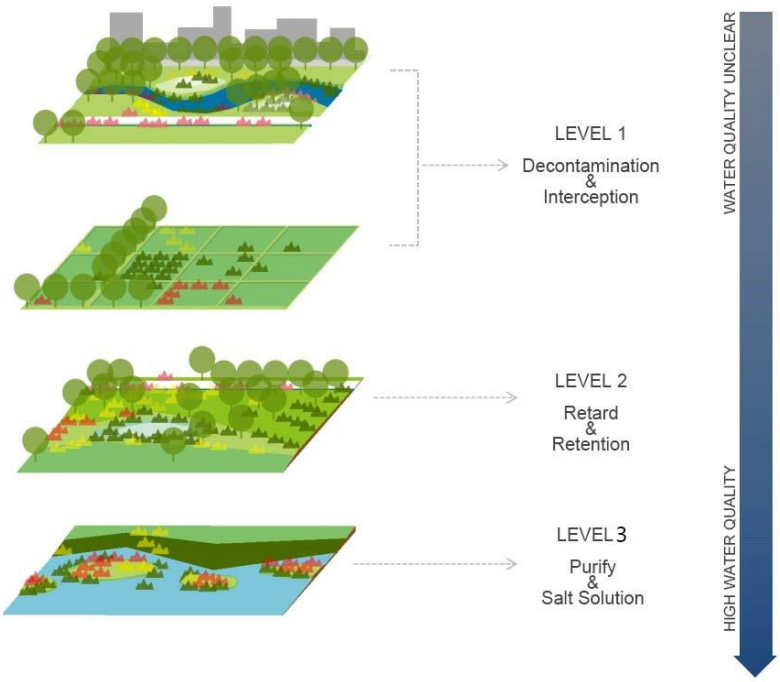

Figure 3 Spatial structure of natural waterfront in the Pearl River Estuary.

As a transitional space unit, according to the different surrounding land use, our research focuses on two major types of waterfront spatial units.

5.1 Urban Interface

Shoal and tidal flats would be restored by the means of earthwork. On this basis, the river drainage ditches, slope-detention ponds and swamps would be designed to form the three defense lines to ensure the quality of the estuarine waters and provide maintenance to the river corridor ecosystem (Figure 4).

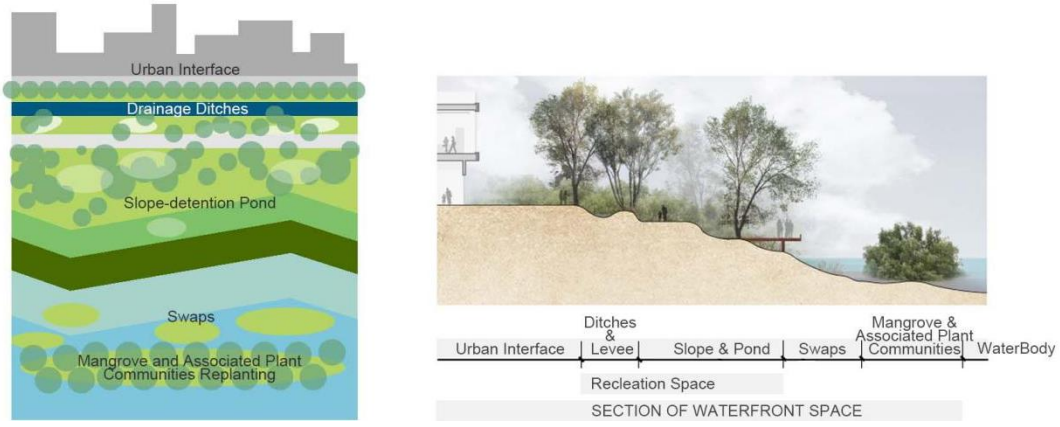

Figure 4 Urban Interface Model.

5.2 Agriculture and forestry interface

Agriculture and forestry interfaces include: conform to the texture of the farmland and woodland, plant moderately so as to modified the skyline. Modify the planting intensity, in order to gradually reduce the intensity of crop planting towards the river. Draw back the original levee, and form soft-permeable grass revetment with serious shoal wetland which slopes directly into water. Set up a ditch along the road sides as well as replant the swamp between the shoals and mangroves in order to intercept runoff containing pesticides (Figure 5).

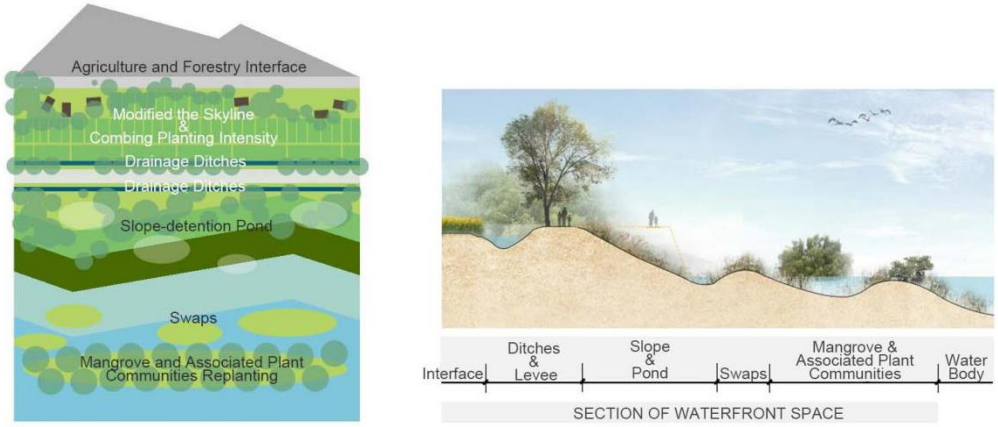

Figure 5 Agriculture and Forestry Interface Model.

6 MEASURES

The main measures involved in the above space units are as follows:

6.1 Waterfront slope reconstruction

The major goal of this measure is to simulate the river profile under natural condition, to increase the capacity to absorb floodwater and tidal salts. Simultaneously, the contact surface between the soil and water would be increased to allow the formation of natural material circulation. On the other hand, by the reconstruction of slopes, a series of sub water environments with different water depths can be set up, providing habitat for different plants. By utilizing the variation of water flows, a series of submerged spaces could tentatively be development into recreation open space for people to have a more intuitive feeling of the ebb and flow of river, and more obvious touch with its natural beauty.

6.2 Soil matrix improvement

Large amounts of discarded soil from urban subway construction provides the possibility to improve the saline alkali soil. Inland soils which are rich in fresh water nutrient substances could be used to improve the soil salinity, and slow down the impact of the salt tide in the groundwater. At the same time, a natural gap of these soils can enrich the hydrological process of the waterfront.

6.3 Mangrove and associated plant communities replanting

Large, stable mangrove and associated plant communities have performed great functions in preventing wind erosion, temperature adjustment and purifying the environment. They provide a magnificence value for the provision of food and habitat for terrestrial and aquatic organisms. Also, the mangrove and its associated communities has the ecological effects of decomposing salt. Restoration of mangrove vegetation along the Pearl River estuary area can slow down the erosion of groundwater by salt tide.

7 REFLECTION

The design of spatial units in this paper is based on the general problems of the whole basin of the Pearl River estuary on the macro level. It's more like a hypothesized model depends on the case study of

near nature control. The Pearl River estuary is a complex estuary which hydrological characteristics with changes in different reaches on the meso level. In this paper, as lack of data and the design of waterfront spatial models did not provide numerical data. The suitability of the method is still on practicing. In future research, we hope to continue to study this issue, hoping to develop a more specific and adaptable landscape spatial models for different sections of the Pearl River estuary on the concept of *near nature control.*

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