

Shaping Waterside City Form in Hangzhou through Water-Oriented Ecological Infrastructure

1 Introduction: Background and problems in Hangzhou

There used to be many famous waterside cities in Chinese history. The harmony between people and water was just like what is showed in *Riverside Scene at Qingming Festival* (Fig.1), a fantastic painting work highly praised by many scholars.



Fig. 1 Riverside Scene at Qingming Festival by Zhang Zeduan

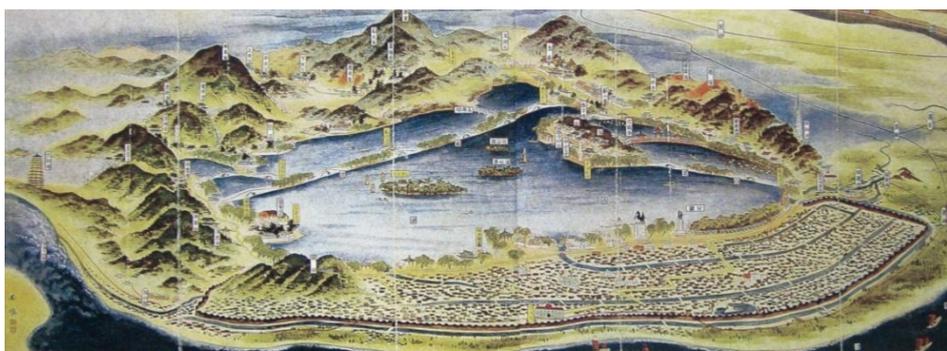


Fig. 2 Harmony of City and Water in Hangzhou,1920 (source: Old Map of Hangzhou by Archive of Hangzhou)

With nearly 300 crisscrossing canals, including the Grand Canal considered as the greatest canal in ancient China, Hangzhou used to be the typical Chinese waterside city. With well-known West Lake in city, Hangzhou was figured as a model of harmonious relationship between people and water (Fig.2).

In old times, it was canals that play a significant role of transportation. Besides, riparian areas of canals played the equally important role of communicating, trading, as well as carrying daily-life activities. Since modernization and urbanization took place, roads for cars were taking the place of canals. As a result, values of canal network was getting neglected and wrongly cognized. Water pollution and unsustainable engineering methods made people accustomed to keep distant from canals, either living or walking. Hangzhou, consequently, is facing five crises that Chinese waterside cities are suffering nowadays:

1) Unsustainable urban developing mode makes the city sprawl disorderly oriented by roads, which leads the disappearance of numerous area that used to be wetlands (Fig.5);

2) Natural processes taking place on canals are obstructed because of stuffing or blocking for city development, which seriously disturbs environmental self-regulating and causes

frequent waterlogging and flooding.

3) Cultural experiencing processes connected by canals and streams are destroyed by construction, especially by roads;

4) Traditional fabric and character of waterside city are disappearing, which result in seldom perceiving of canal network identity by public (Fig.3,4);

5) People-water relationship, as well as city-water relationship, is alienating.



Fig. 3(left) Samples of Perception Investigation that shows merely roads can be perceived (perception investigation is supported by 99 effective maps)

Fig. 4 (right) Fabric Changing (resource: Archive of Hangzhou)

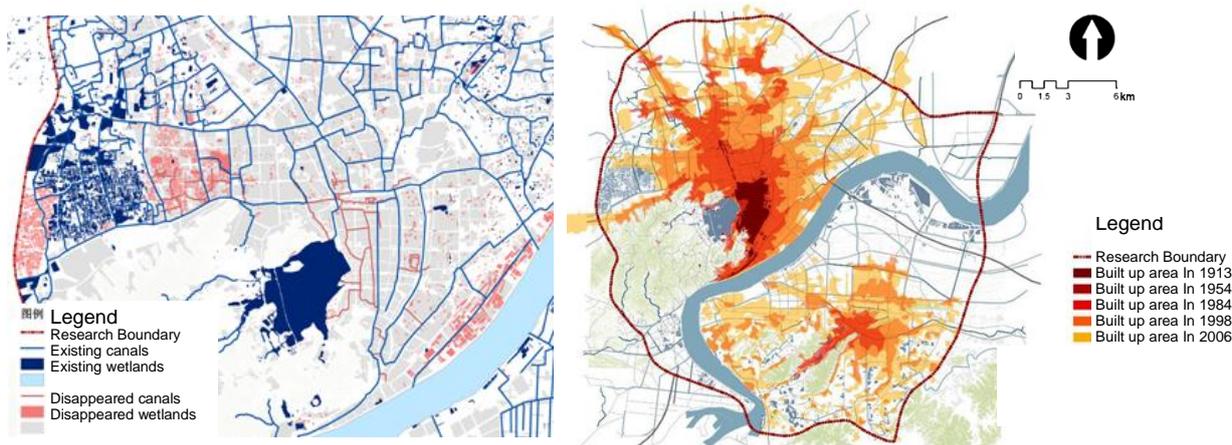


Fig. 5 Expanding of Hangzhou City

2 Objective, Value and Methodology

2.1 Objective and Value

Objective has been emerging obviously. That is to reshape the form of Hangzhou city so that the city can be sustainable developed without disorderly sprawling, and returned to waterside.

Knowing that all the problems mentioned above are resulted from misunderstanding of the value, clear and correct values of canals is to be required. However, what kind of values should be taken as criteria to evaluate the water system of Hangzhou?

Ecosystem services (ES) are the benefits people obtain from ecosystems (MA, 2005). It also can be regarded as the contribution and supporting provided by ecosystems. ES include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as biological diversity

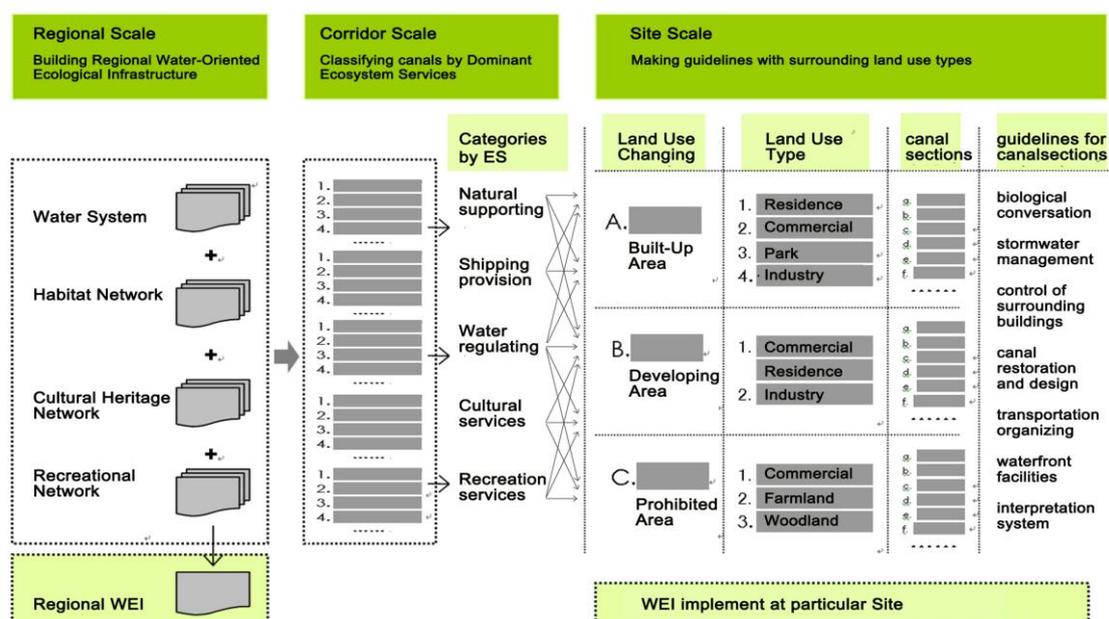
maintaining, soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefits.

Regarding ES as value criteria helps to comprehensively understand functions and roles of water network in Hangzhou. ES of water ecosystem contains provisioning services such as shipping and fresh water, regulating services such as flood and waterlog, supporting services such as biological diversity, cultural services such as cultural and recreational benefits,

2.2 Methodology

As an effective tool for defining urban growth pattern in advance, Ecological Infrastructure (EI) that is composed of critical landscape patterns identified to secure the regional natural system, is an essential structure for city and citizen to acquire Ecological Services. It means that EI is the physical ecological network carrying conceptual Ecological Services. Structure of EI should be distinguished due to different region and city. It can be oriented by the most critical pattern which is the identity of particular area. In Hangzhou case, because water network is the most outstanding and critical pattern, Water-Oriented Ecological Infrastructure (WEI) is adapted.

Therefore, through building WEI which is mainly composed of water network that are strategically planned and designed to safeguard various natural, biological, cultural and recreational processes across the landscape at three scales, ideal form of waterside city and harmonious people-water relationship can be achieved in Hangzhou. At the regional scale, regional WEI was built to ensure the integrity and connectivity of various processes on the land. At the medium scale, five categories of canals were classified according to prior Ecological Service of each canal. At the site scale, guidelines for each canal section were established after further classification due to the surrounding land use type.



Tab. 1 Framework

3 Building Regional Water-Oriented Ecological Infrastructure

At regional scale (landscape scale), research was carried out with abiological, biological, cultural, as well as recreational processes. Regional EI oriented by water security pattern is established afterwards to secure natural and cultural processes in regional area. Consequently, based on WEI, smart growth form of the city was defined and city-water relationship was reestablished.

3.1 Water System and Stormwater Management Strategies

Locating in the Yangtze River delta, Hangzhou is a typical city that has dense plain canal network. Because of the city development and urbanization in recent decades, enormous canals has been stuffed or blocked up and many wetlands, such as ponds and low-lying lands, have been also filled up. Furthermore, process of surface runoff has been changed because of changing of land use and increasing of impermeable urbanized area. As a result, waterlog is getting more frequent and serious during the rainy season in Hangzhou.

Stormwater management strategies are based on water security pattern, which play a primary role of water regulation. In Hangzhou, strategies were proposed for different type of land use.

In built-up area which refers to the old city, small wetlands should be integrated with green space in blocks. It is strongly suggested to restore or reclaim the canal network, as well as the ponds, wetlands and canals that disappeared already, in order to maintain connectivity and integrity of water ecosystem.

In developing area where new city will be constructed and developed in 5-10 years according to Master Plan of Hangzhou, existing water network and all ponds and wetlands at critical positions must be preserved from urbanization. And also, restoration of disappeared canals and wetlands should be carried on while the moment of new city constructing. If necessary, new wetlands and canals should be planned for stagnating, storing and draining storm water.

In prohibited area where land use will not much change in future, water network and all ponds and wetlands must be strictly preserved and controlled.

Adapting to these three areas, some guidelines and indexes, such as green space ratio, seepage ratio and water surface ratio, are used for controlling construction. Efforts and endeavors are made to ensure the minimum disturbance to runoff and permeation processes. In particular, areas where water logging frequently happened are strategic points, which existed in hillside outside city, low-lying lands within city, confluence of canals. Focusing on these critical points, specific guidelines are made.

3.2 Habitat Network

Habitats in Hangzhou mainly consist of woodlands and wetlands, which include various types, such as ponds, paddy fields, lakes, tidal flats, reservoirs, rivers, streams, as well as canals. Wetlands are the most significant habitat of the region, accounting for nearly one thirds of the total land area of Hangzhou. In recent decades, integrity of habitat system has been disturbed, which embodied in greatly reducing of canals and wetlands.

Patches for inhabiting and corridors for migrating and foraging in landscape are critical

pattern for biological conservation (Yu,1996). Accordingly, In order to build strategic biological network, critical biological habitats and corridors, which could be indicated by various Indicator species, have to be identified in priority. By selecting Little Egrets (*Egretta garzetta*), Black-Crowned Night-Heron (*Nycticorax nycticorax*), pheasants (*Phasianus colchicus*), Oriental Green Heron (*Ardeola greenheron*), Ornamented Pygmy Frog (*Microhyla ornata*) as the indicator species which indicate diverse habitat, critical positions, patches and corridors were identified respectively and biological security patterns of each species were established. Through overlaying the separate SPs, biological network was established ultimately.

Large habitat patches outside city (wetlands, woodlands, mountains and fields), small patches at inner city (lakes, ponds and green spaces), as well as corridors (canals and streams) are considered as the most critical structures connecting all patches, constituting the biological conservation network.

As most significant connective components of the network, biological corridors were constructed mainly along canals and streams because of the prominence of water structure in Hangzhou.

Large habitat patches outside city, such as mountains, woodlands, were preserved strictly. Small habitat patches at inner city, such as lakes, ponds and green spaces were restored or reclaimed at strategic positions.

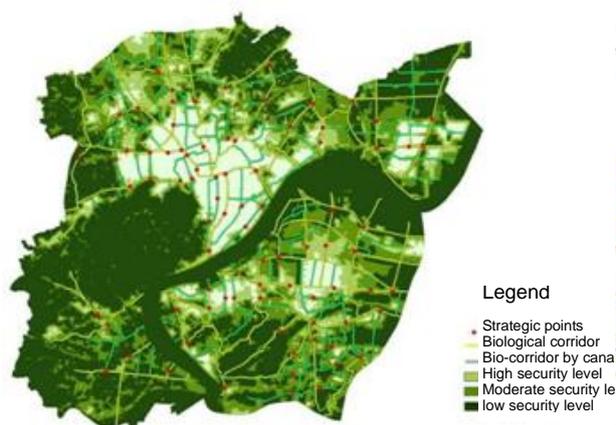


Fig. 6 Habitat Network



Fig. 7 Cultural Heritage Network

3.3 Cultural Heritage Network

Hangzhou is a historical city, having numerous cultural heritages, which include historical heritages and vernacular heritages. Those heritage that have been identified and conserved by government, such as West lake and surrounding temples, historical districts and buildings, are typical historical heritage. The landscape that is adaptive to nature and local land, belonging to local people, functioning for daily producing or living activities are vernacular heritage, productive wetlands, traditional water facilities, industry buildings, for instance.

Reviewing the history, development of Hangzhou city had close relation to water. For instance, west lake, on which origination and evolution of the city depended, was surrounded by the city and bearing a lot of historical and cultural information. Canals and riparian spaces, which use to be the place of daily life, interlaced densely inside the city. Water system of great importance is a component of heritages.

A variety of heritages scattered in the city as isolated points without integration. It is neither favorable to experience, nor to conservation. Although the government is focusing on units of cultural relic and historic districts composed of historic buildings and streets, enormous of vernacular landscape and heritages are neglected.

Heritage corridor, corresponding to concept of greenway, is an approach of heritage area conservation that originated in US heritage area. Similar idea was accepted internationally (Wang, 2001). Based on the character of dense crisscrossed canals in Hangzhou, It is suggested to construct heritage network that is mainly composed of canals taken as heritage corridors.

Security Patterns of cultural heritage that consist of critical heritage points and corridors is aimed to protect human experiencing and perceiving processes, which is considered as the core of cultural heritage conservation. Heritage points mainly are historic buildings, industry buildings, classical gardens and temples, productive wetlands. Heritage corridors are constitute of canals and streets which played a connecting role of the pattern.

3.4 Recreation Network

West Lake, which has more than one thousand years history, is almost the first open space for public recreation in China. With the attractive and peaceful west lake, and 80% open spaces locating by water, Hangzhou is a traditional city that is marked by its leisure and romantic characteristic. However, problems still exist. First, being lack of open space in high dense population areas results in uneven accessibility. Second, recreational uses of hiking, cycling or jogging are discontinuous because open spaces network for recreation have not been formed.

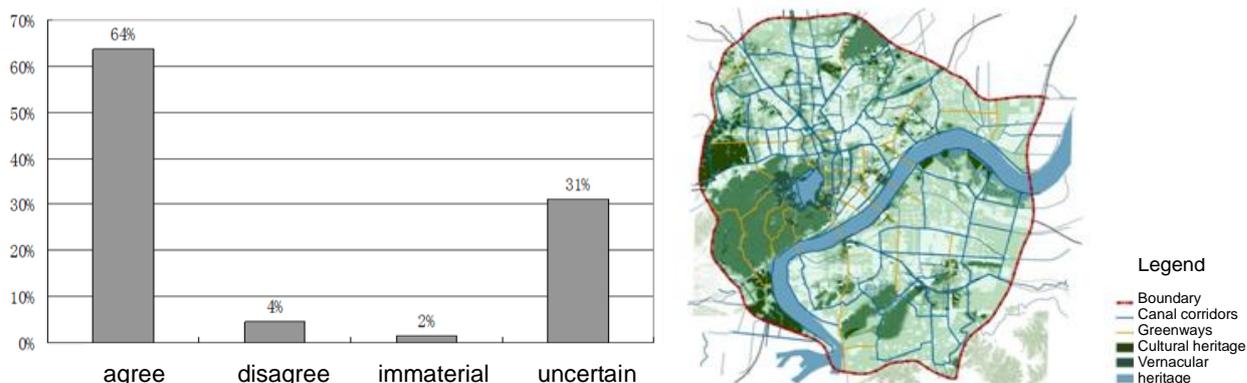


Fig. 8 Attitude towards Building Special Cycling Way and Walking Way along Canals

Recreation network is to safeguard recreation and experience process of people. According to questionnaire supported by 379 effective ones, citizens had strong willing to build biking and walking paths (Fig.8) Holistic and continuous non-motorized vehicle paths along riparian area, which integrated with pedestrian, are going to be built as greenways both for weekdays commuting and weekend hiking and cycling. Based on non-motorized vehicle paths which are along water and taken as linkage of open spaces and other recreational resources either inner or outside city, recreation network is established.

3.5 Regional Water-Oriented Ecological Infrastructure

Overlaying all the networks above that mainly integrated with canals, water-oriented Ecological Infrastructure was holistically established, carrying multifunction of biological conservation, water regulating, cultural heritage preservation, recreational services, as well as shipping provision that existed formerly. It is a rigid control of city development and sprawl in the regional scale.

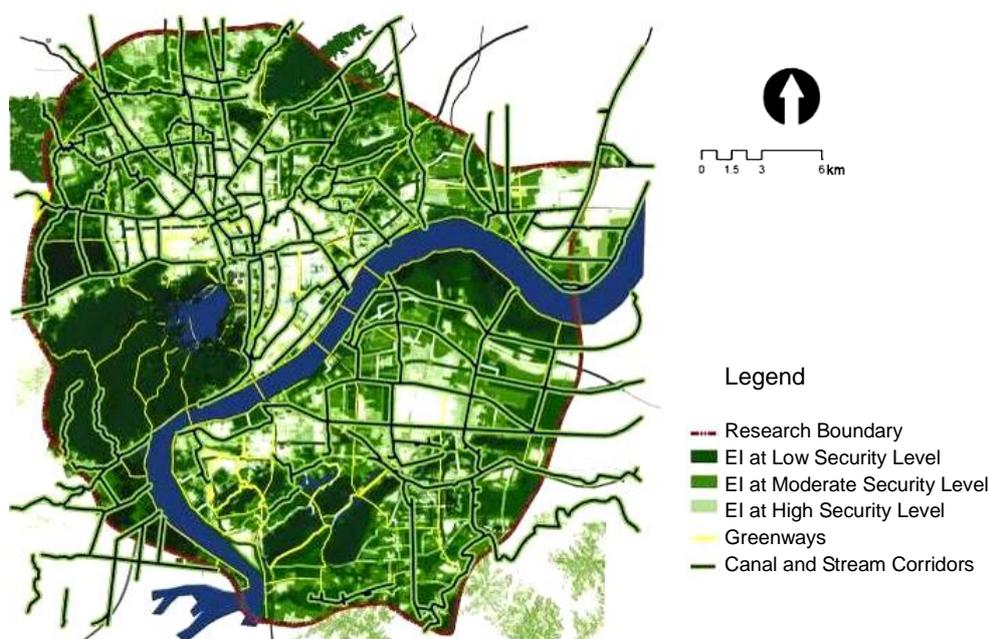


Fig. 9 Regional Water-Oriented Ecological Infrastructure

4 Classifying canals by Dominant Ecosystem Services

In order to implement the regional EI and make it effective in practice, intensive guidelines have to be made. Hangzhou has a complex water-oriented EI network with more than three hundred canals. Deservedly, systematical classification of canals based on ecological services as a guarantee of EI's function should be given the priority. In this step, studies are focusing on corridor scale of individual canal.

4.1 Defining Dominant Ecosystem Services of Canals in Hangzhou

Dominant Ecosystem Service was used to better conclude the categories of canals. Ecosystem in different region has different contribution to human. And also, the benefits from ecosystem are unequal in particular region (Wang, 2005). It means that some ecosystem services are of greater importance than others under particular natural and cultural circumstance.

To classify canals in Hangzhou, it is reasonable to conclude dominant ecosystem services from four aspects: provisioning, regulating, cultural, and supporting services. Known for historic and cultural city, as well as leisure attribute, Hangzhou has a greater requirement of cultural and recreational functions supplied from WEI. In addition, shipping provision is an essential function of canal network. Furthermore, biological habitat supporting, as well as

flood and waterlog regulating is the contribution of water-ecosystem. Accordingly, five dominant ecosystem services were defined. They were natural supporting, cultural services, recreational services, water regulating, and shipping provision (Tab.2).

Tab. 2 table of Dominant Ecosystem Services corresponding to Ecosystem Services

Ecosystem Services		Dominant Ecosystem Services
Supporting Services	Birds	Natural supporting
	Small animals	
	Amphibian	
	Nutrient cycling	--
Provisioning Services	Shipping	Shipping provision
	Fresh water	--
	Food	--
Regulating Services	Flood	Water regulating
	waterlog	
	Climate	--
	Water purification	--
Cultural Services	Environment education	Cultural services
	Cultural experiencing	
	Vernacular experiencing	
	Daily recreation	Recreation services
	Assembly and ceremony	
	Excuse and outing	

4.2 Classification following Dominant Ecosystem Services

Classification of canals was following dominant ecosystem services. Using Delphi method, experts were asked to evaluate ecosystem services of each canal. And the weight of each ecosystem services, which is the key for recognizing and classifying, was defined based on public cognition which is reflected by questionnaires. Eventually, dominant service of each canal was calculated by fuzzy recognition system, a method of Fuzzy mathematics (Guo, 2008). Consequently, categories of all canals were defined (Tab.3).

5 Making guidelines with surrounding land use types

At the site scale (reach scale), based on the five categories concluded already, further classification which divides individual canal into sections is carried out according to surrounding land use type. Design guidelines, containing strategically method such as reclamation, rehabilitation, and preservation for different section, are made so that healthy city form, as well as harmonious relationship between human being and water which existed in historical time can be achieved in particular site again.

Tab. 3 Sample of Dominant Ecosystem Services for Each Canal

number	name	Ecosystem services													Dominant Ecosystem Services	Suggestion width
		Provisioning		regulating		supporting			cultural							
		Fresh water	shipping	flood	waterlog	Birds	Small animals	Amphibian	Environment education	Cultural experiencing	Vernacular experiencing	Daily recreation	Assembly and ceremony	Excuse and outing		
1	Zhong Canal	--	--	●	●	●	--	--	●	●	--	●	--	--	C	6-30m
.....																
4	The Great Canal	--	●	--	--	●	--	--	●	●	●	--	--	●	S	80-100 m
.....																
8	Yu Hang Tang Canal	--	●	●	●	●	--	●	●	--	--	●	--	--	R	0—30m
.....																
53	Ying Er Canal	--	--	●	--	●	●	●	●	--	--	●	--	--	N	12-30m
.....																
108	Hu Tang Canal	--	--	●	--	●	--	--	--	--	--	●	--	●	W	12-60m

Abbreviations for Dominant Ecosystem Services:

S: Shipping provision; C: Cultural services; W: Water regulating;

N: Natural supporting; R: Recreation services

5.1 Three General-Guideline Areas according to Land Use Changing

According to the change of land use in the next 5-10 years showed by the Master Plan of Hangzhou city, three areas are divided, including built-up area, developing area and prohibition area, and general guidelines for each have already been set up.

Notably, there are 15 further categories when 3 general-guideline areas multiplying 5 categories of canal corridors that have been classified. General guidelines for each subcategory are made, considering the function, buffering width, strategies, but omitted here.

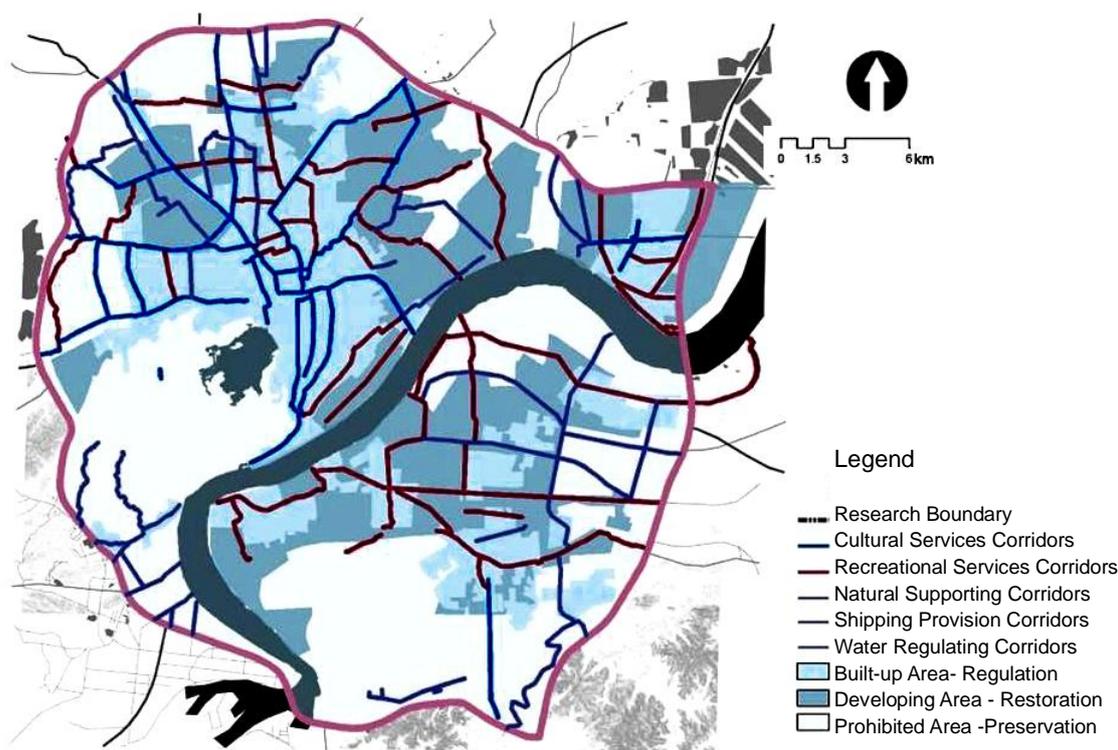


Fig. 10 Three General-Guideline Areas according to Land Use Changing

5.1.1 Regulation in Built-Up Area

Regulation and Moderate rehabilitation of canal corridors should be applied in built-up area where the land use will seldom change in the future with narrow space along the water. It was unreasonable to give accordant buffering width of the corridors. General speaking, canals in built-up area had the narrowest space, the buffering width was 6m to 30m generally.

5.1.2 Restoration in Developing Area

It is suggested that restoration, which includes rehabilitation and reclamation, should be acted to the network in developing area where new towns will be constructed and developed in the next 5-10 years according to the Master Plan of Hangzhou city. It is treasured opportunity to do some restoration and ecological design while constructing and land-use changing.

5.1.3 Preservation in Prohibited Area

In prohibited area where land use will not much change in the future, rigid preservation

was demanded. Network in prohibited area should be controlled much broader, wider than 80m, if possible.

5.2 Further Sectional Classification According to the Current Land Use Surrounded

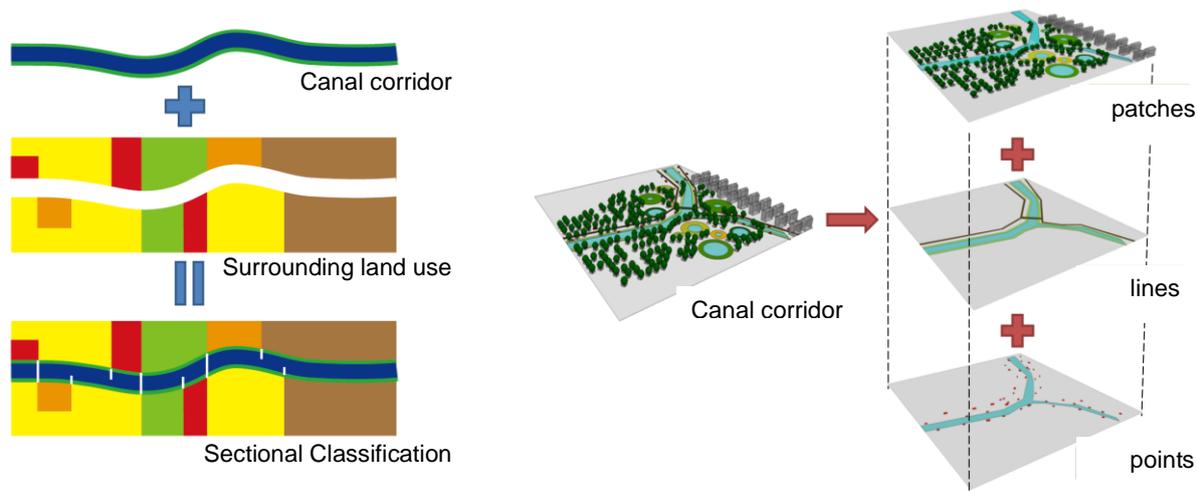


Fig. 11 Scheme of Further Sectional Classification **Fig. 12 Diagram of Section Component**

Based on the current land use surrounded, each canal corridor is divided into several sections. Further classification is accomplished accordingly. For instance, a recreational corridor might be matched with residential area, commercial area, official area, and parks. Each surrounding land use was treated as a type. Nearly 50 types in total are emerged after classification.

5.3 Detail-Guidelines for Each Canal Section

This step, which is the last but not the least, makes water-oriented ecological infrastructure effective in practice to reshape the city form and rebuild people-water relations. For each section of corridor, components and elements are shown as patches, points and lines. It is considered to make specific guidelines for each section with these structural characters. Factors of guidelines which determine what should be controlled are defined. They are factors of biological conversation, stormwater management, control of surrounding buildings, canal restoration and design, transportation organizing, waterfront facilities and interpretation system. To be better illustrated, structural plan and section are presented.



Fig. 13 Sample of plan and section of each canal section

6 Conclusions and Discussions

It is proposed that WEI as an effective approach is capable to reshape the city form that

helps to rebuild relationship between city and water, as well as people and water, in Hangzhou.

Conclusions have been reached as follows:

- 1) Ecosystem services are comprehensive criteria for recognizing and utilizing water system.
- 2) Water-oriented ecological infrastructure in Hangzhou is mainly composed of canal network, carrying ecosystem services such as biological habitat maintaining, water regulating, cultural services, recreational services, as well as shipping provision.
- 3) WEI is established holistically from regional scale to site scale. It helps to radically control the city form. Regional WEI network secures natural and cultural processes in large-scale system. Classification of individual corridors following dominant ES is the guarantee of the implement of WEI. Guidelines for canal sections are made ultimately to control and induct in particular site.
- 4) The ultimate layout of WEI is figured as a operational and practical manual, which is able to induct the city development of Hangzhou under the comprehensive value.

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