Learning from Agri-Aquaculture for Multiscale Water-Sensitive Design in the Pearl River Delta

Sun, Chuanzhi; Nijhuis, Steffen; Bracken, Gregory

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风景园林
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本期主题
韧性景观
09 / 2019 170 VOL. 26

风景园林
Landscape Architecture

变迁中的岛屿——韧性城市形态
An Island in Transition: Adaptation of Urban From

专题・SPECIAL
韧性景观
Resilient Landscape

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基于基塘系统的珠江三角洲多尺度水敏设计研究

Learning from Agri-Aquaculture for Multiscale Water-Sensitive Design in the Pearl River Delta

孙传致 （荷）斯特芬・奈豪斯 （英）格雷戈里・布拉肯
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孙传致 / 男 / 代尔夫特理工大学在读硕士研究生 / 研究方向为多尺度视角下，基于对西江泛洪平原基塘及生态水利系统的理论方法研究，探索珠江三角洲雨洪韧性城市景观设计的开发策略以及设计原则
SUN Chuanzhi, is a master student in the Delft University of Technology. His research focuses on the water management methods in the flood plains of the West River through multi-scale, and the exploration of strategies/design principles for water resilient urban landscape development based on dike-pond system..

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(NLD) Steffen Nijhuis, Ph.D., is the head of Landscape Architecture Research, director of the European Post-master in Urbanism (EMU) and associate professor at the Faculty of Architecture and the Built Environment at Delft University of Technology. His research focuses on sustainable urban and landscape development, water-sensitive and socio-ecologically inclusive urban planning and design.

（英）格雷戈里・布拉肯 / 男 / 博士 / 代尔夫特理工大学建筑与建成环境学院副教授、城市规划与空间规划主席 / 研究方向为可持续发展、空间规划、可持续建筑和城市规划
(GBR) Gregory Bracken, Ph.D., an associate professor of landscape architecture at the Faculty of Architecture and the Built Environment, Delft University of Technology. His research focuses on the sustainable development, spatial planning, sustainable architecture, and urban planning.

摘要：珠江三角洲是位于中国东南部以河流为主导的洪泛平原。由于堤防建设、河流渠化和城市化带来纳水空间的减少，珠江三角洲地区的河流、雨水和海洋所引起的洪水风险增加。为了防范洪水风险，需要采取更具适应性的城市化战略，在考虑多尺度研究视角的同时，重视珠江三角洲传统水利方法（即生态农业），例如利用传统水管理方法的基塘系统。确定基于该地区传统水陆混合农业实践的多尺度水敏设计的景观设计原则。顺德地区地处珠江三角洲西江和北江之间洪水易发的低地，这种传统水陆混合农业系统已经有着悠久的历史并促使其形成了与水共生的传统。通过学习传统的水陆混合农业实践，发现新的设计原则，从而减轻洪水风险，同时促进可持续的城市化。这种新的方法将不仅服务于顺德区，而且包括整个珠江三角洲，以增加对于洪水的适应性。
关键词：风景园林；适应性城市转型；水敏设计；多尺度策略；基塘系统；景观设计原则
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Abstract: The Pearl River Delta (PRD) is a river dominated floodplain in southeast China. Decreasing space for water, through dike-ring construction, channelization, and urbanization, has led to increased flood risk from river, rain, and sea. To protect from flood risk, a more adaptive urbanization strategy is required; one takes into account a multiscale approach while investigating agri-aquaculture, i.e. ecological agriculture, for example, the dike-pond system which makes use of traditional water-management methods. The objective of this article is to identify landscape architecture principles for multiscale water-sensitive design based on traditional agri-aquacultural practices in the region. In the Shunde district (a flood prone lowland located between the West and North rivers of the PRD) there is a centuries' old tradition of working with water via integrated agri-aquaculture systems. By learning from traditional agri-aquacultural practices, new design principles can be developed to mitigate flood risk while allowing for increased but sustainable urbanization, not just for the Shunde district, but also for the PRD, so that these areas can be more resilient to floods in the future.
Keywords: landscape architecture; adaptive urban transformation; water-sensitive design; multiscale strategy; dike-pond system; landscape design principles
Fund Item: NSFC, NWO, and the EPSRC Joint Research Project: Adaptive Urban Transformation (AUT) (No. ALWSD 2016.013 sustainable delta program)

珠江三角洲（简称珠三角）是世界上城市化最快的三角洲之一，具有潜力的同时也面临着挑战：如洪水风险增加、生态和社会价值的丧失等。珠三角位于中国东南沿海地区，西江、北江和东江是其主要的河流动脉，经历了 1 000 多年的自然过程，如淤积和沉积[1]，珠三角形成了 2 个次级三角洲以及一个河口的地形地貌特点。由于土壤肥沃，珠

三角长期以来一直非常适合农业生产。人类干预始于大约 1 000 年前，通过开发一种被称为基塘系统的综合水陆农业养殖模式 [2]13，逐渐将珠三角转变为中国最富裕的农业区之一。这种基于基塘所形成的独特的景观是水利、农业、生态、工业和居住聚落之间历史悠久而错综复杂的关系的结果（图 1）。西江次级三角洲——顺德区域，位于易发洪水的低地，在该地这种景观清晰可见，是当地人们长达几个世纪解决洪水和暴雨内涝问题、通过实践取得的成果。然而，长时间的筑堤围垦、硬化河道以及城市化所带来的传统基塘大量消失，不仅导致了蓄洪能力的丧失和洪水风险的增加，更威胁到了整个三角洲的水安全问题。为了解决这些问题，急需一种更具适应性的城市化战略：一种以社会生态介入、更具水敏感性和包容性的多尺度方法 [3]。为了总结这一方法，须重点研究传统的区域特定水陆农业实践以及历史水管理方法，以便得出可以为当代空间发展战略提供帮助的设计和规划原则。

笔者通过对顺德传统基塘系统的分析，结合该地区多尺度的生态水利系统的历史发展与进化，发掘隐藏在这一独特景观表象之下的丰富设计原则。由于这些原则是基于该地区悠久的历史与独特的水文、生态与人文社会结构总结而出，它们有极大的潜力成为未来适应性城市规划和设计的工具。随后，这些原则将以设计规划实践的形式被应用于改善当代的雨洪消纳能力、修复河道生态以及重塑和凸显城市的独特文化个性。最后，本文笔者将讨论该研究在珠三角其他地区应用的适应性与普遍性，以建立更广泛的联系。

1 综合水陆农业养殖实践

西江和北江之间的农业低地在雨季期间容易发生洪水，造成上游河流排水达到峰值。洪水主要发生在 6—8 月，往往雨洪同期发生，因此内部积水由于外江水位较高而无法排放到外河。这种自然的水文环境孕育了肥沃的土壤，从而形成一种特殊类型的水陆农业养殖模式——基塘系统，作为当地经济生产的基础（图 2、3）[2]30。

基塘系统发展于 14 世纪，由堤坝上种植的果树及中心鱼塘组成，是当地居民在易发洪水的自然条件下发明的一种独特的农渔混合耕种模式。17 世纪初，这一系统变成了桑树与鱼塘中四大家鱼的组合，形成了丝绸综合渔业的经济模式。从那时起，这种农业水产养殖模式继续繁荣发展，直到 20 世纪 20 年代达到顶峰。在此之后，全球丝绸市场的萧条以及日本侵略极大地打击了珠三角地区的生丝市场，丝绸价格急剧下跌，最终人们不得不寻求其他替代丝绸的基塘作物组合（香蕉、甘蔗）。基塘系统因其拥有能量和物质合理循环的优点而享誉世界，它不仅是一种自足且高效的土地利用方式，也体现了对该地区特殊地貌的有效利用（图 4）。人们利用从池塘中挖出来的塘泥来建造周围的堤坝，并在堤坝上种植桑树以养蚕，蛹以及吃剩的叶子和蚕粪是非常好的饲料，可以被回收以喂鱼。塘中，鱼吃剩的饲料与鱼粪富含有机物，这些有机物被塘内微生物分解落到池塘底部增加了塘泥的肥力。最后，人们通过每年挖掘塘泥并将其堆回堤坝，又增加了土壤肥力从而为桑树提供营养。然而，这个综合系统直到 1350 年左右 [4]66 才被开发出来。随着水利系统的发明，在古代河口周围的河岸地区已经开始建设堤坝，以保护低于河岸低地的农业地区。由于其优良的抗洪能力和高产能力，这种土地利用方法集中在西江和北江之间易发洪水的低地。此后，基塘系统遍布珠三角，并成为综合水利系统中重要元素之一。因此，我们需要了解整个系统才能正确理解这种特殊的农业水产养殖模式如何起到防洪的作用。

2 多尺度的水利系统

珠三角历史悠久，形成于 6 000 多年前，在当时，顺德仍然是南海的一部分。到了宋代（960—1279 年），三角洲中心的大部分由于沉积作用已逐渐形成。此时西江的分流加快了土地围垦的速度，形成了顺德西南的杏坛、均安等地 [5]32。1450 年，清代建立顺德县，以防止富农和贫困渔民之间由于稀缺土地资源而产生冲突。土地持续开垦导致渔民逐渐失去生存空间，而富农希望进一步加速开垦以获利。因此，顺德县政府的成立平衡了这一矛盾，

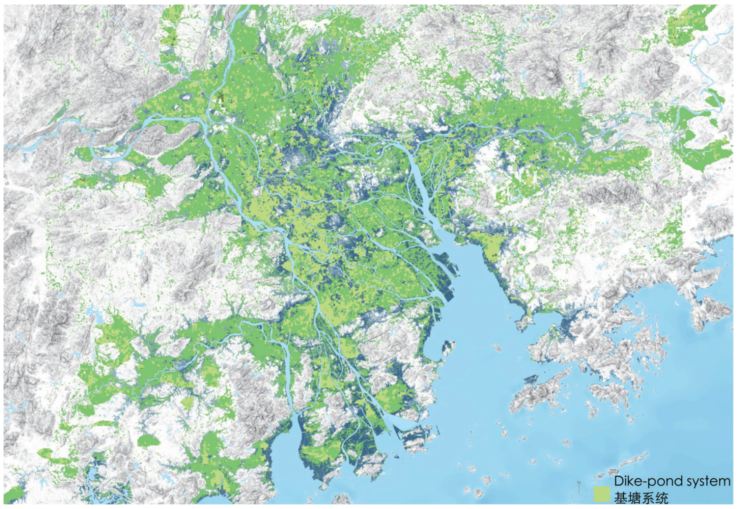
1 基塘景观展示了水利、农业、生态、工业和居民点之间错综复杂的关系

Dike-pond landscape showcasing the intricate relationships between water management, agriculture, ecology, industry, and settlements

同时也保护了整个区域的农业免受洪水侵害，建立了各乡各堡的合作原则。该地区的行政区划以水利防洪为基础，倡导包括 40 个县和 297 个村的通力协作 [6]。通过来自不同县、村和部族人们的共同努力，保护河岸及其腹地免受洪水侵袭，这种以合作为导向的区划体系帮助建立了跨区域、系统性的水利管理方法。该水利系统包含 4 个级别的防洪干预：区域、县、村和建筑（图 5）。这 4 个尺度彼此之间有着密切的关系，并共同发展形成一个整体系统，起到防洪、促进居住区建立、发展农业生产和形成社会结构的作用。因此，理解不同的水管理原则以及它们如何通过这些尺度相互关联非常重要。

2.1 区域尺度的水敏设计

区域规模包括 40 个县，297 个村庄。每个县有 20%~50% 的边界毗邻西江或北江 [5]24，每个县的县界都以平衡优势与分摊泛洪风险为原则，即平衡沿河的生产和运输利益，同时分担水利措施建设以保护整个区域免受洪水的危险。几个世纪以来，洪水一直是顺德区的主要威胁。明清两代（分别为 1368—1644 年和 1644—1912 年）平均每年记录在册的有 3 次洪水，不包括季风季节（4—9 月）几乎每月发生的小洪水。堤防建设一经发明



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3

2 顺德区：珠三角西江和北江之间的一个易发洪水的低地，拥有数百年的传统，通过综合农业水产养殖系统与水为生
Shunde district: a flood prone lowland between the PRD's West and North rivers with a centuries' old tradition of working with water via integrated agri-aquaculture systems

3 典型的带有农舍的堤坝结构，2019 年
Typical dike-pond structure with farmhouses, 2019

便成为该地区防洪的主要措施之一。然而，由于缺乏技术和人力资源，当时的大型堤坝建设不仅需要县或村内进行合作，而且需要长期的努力（图 6）[7]。

从宋代开始一直到清代，区域堤防建设逐渐发展出了几个防洪原则。在宋代近 3 个世纪中，人们在西、北、东江沿岸建造了大量的堤坝（共 28 个）[8]39，特别是在西江，桑园围是当时最大的堤围系统 [4]32。堤防的主要功能是保护定居点免受河流洪水的影响，其主要原则如下 [5]45：利用自然地形（使其成为堤坝的一部分，利用上游和下游之间的高度差进行排水）；2）保持堤围与河流的足够距离；3）在堤坝完成后，于其旁边修建寺庙（纪念和作为未来治水、议会的场所）。

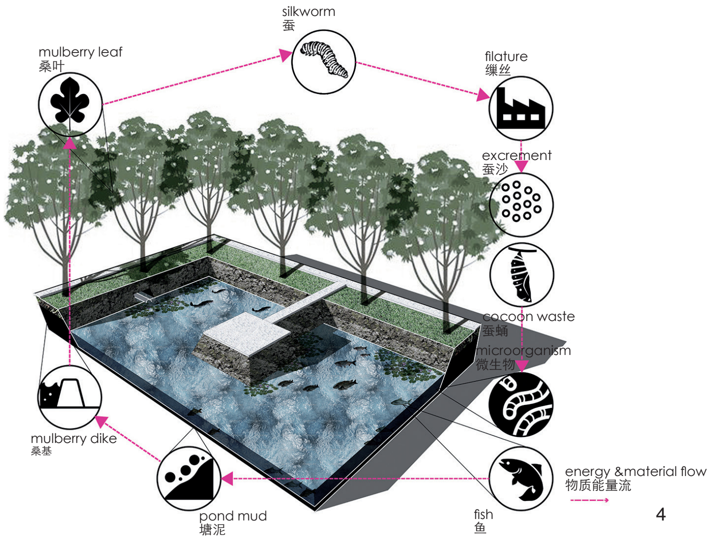
在元代（1271—1368 年），旧堤坝的高度被增加并加固，包含 11 个县的西江沿岸继续新建堤防，最终形成 34 个新堤围 [8]13。然而，由于下游河口的延伸和淤积加剧了上游的洪水堵塞，施工往往集中在河流的上游岸线部分。同时，通过使用石制水闸和堤坝，施工技术也得到了改善。

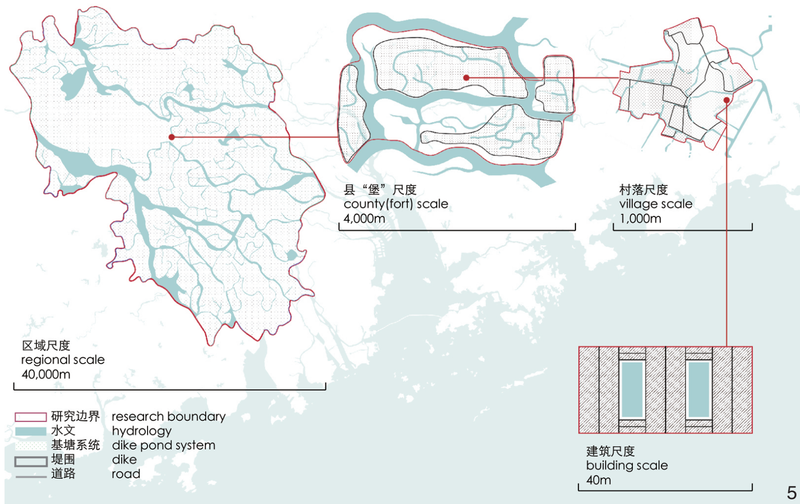
明代人口与经济的繁荣意味着这一时期堤防建设和土地围垦达到了顶峰。人口和经济空前繁荣，对土地的需求也剧烈增加，而同时人们发现堤防建设有利于促进自然淤积从而形成陆地，于是人们利用这种方法开始进行大规模的围垦。历朝历代都主要采用线性堤防，在岛屿的西部和东部建造以防止洪水，但在明朝期间，由于开垦和淤积导致海水倒灌，人们不得不寻求新的堤围修建方法。因此，修建原则从开口堤围建设以防止河水泛滥，变成了封闭的堤防系统以防止海潮泛滥，例如明代初期通过在东南部增加堤坝而关闭了桑园围 [5]55。然而，这一系列的封闭式堤防结构加剧了腹地的洪水问题，特别是在强降雨无法有效排放时的季风季节。正是在此期间，基塘系统被发明出来，并且作为一种特殊的农业用地，通过吸纳多余雨洪缓解这一内涝问题。

这种在明代末期出现的基塘系统一直繁荣发展到清代中期 [8]36。农业的蓬勃发展鼓励了更多的土地围垦、堤防建设。然而，由于河道渠化导致河床空间大量减少，从而导致大型堤围内的河流容易在雨季发生更严重的洪水。因此，人们开始在较大的堤坝内部建造小的堤围以保护村庄免受内部洪水的影响，最终形成了嵌套的环状布局。与此同时，为了防御来自外部河流的洪水，不同的堤坝被连接起来形成更大、更坚固和更安全的堤围，并在其中建造水闸以控制排水。最终，形成了一个环环相套的整合式水利基础设施，由一个大型的堤围和内部较小的堤围组成。反思通过漫长过程逐步建立的区域水利系统时，研究了解到以下关于水敏设计的原则：1）水利系统需要协同合作：防洪系统只有通过不同层级的政府机构（乡—堡—都—围）和学科团队合作，并从区域角度共同规划、设计和建设时才能卓有成效；2）在对当地水文的理解中，要认清每种水资源（例如海水、河水和雨水）都有各自随时间的动态变化规律（例如，整个季节的排水量不断变化），并且对于水利的方法有特定的要求；3）通过对当地水文的增量学习，当地人发现为雨水和洪水消纳提供足够的空间是非常重要的：通过引入天然水流和水体来为洪水提供更大的缓冲空间；在筑堤时需要和河流之间保持一定距离；利用自然地形建造堤防并分配布置排水（灌溉）的沟渠和运河。

2.2 县（堡）尺度的水敏设计

区域范围内的水利系统涉及外部洪水的管理与疏导，而县（堡）尺度干预措施则侧重于调节内部水患。“堡”这一行政区划仅在顺德区被发现使用，它是一个基本的治水单位，其防御的两个主要威胁分别为洪水和海盗 [9]。堡内的水利设施由 3 个部分组成，形成有效的





4 基塘的循环系统
Circular system of dike-fishponds

5 4 种尺度的水利措施
Scheme showing four scales of water management

系统：堤围、水网和不同的连接通道（图 7），这 3 个要素密切相关。传统的水利单位划分可归纳为“外海、外堤、内河、海湾、运河、沟渠、排水系统”[10]。

堡尺度的水利系统包括汛期的排水和旱季的蓄水，与每日和每月的水量变化密切配合。例如，在汛期，沿着主要河道建造的大型堤坝将防止来自外部河流或海洋的洪水，而大雨引起的内部洪水可暂时存储在内河、运河、小溪、海湾和基塘中。在退潮期间，当外部水位降低时，这些水可以通过排水孔从基塘排入沟渠与运河，然后流入内河、小溪中。最后，随着外堤上水闸的打开，多余的洪水可以排入外河。在干旱季节，这个系统可以反过来用于储存雨水以及农业灌溉。有了这个可以随时调整的双向系统，堡内的定居点和农业能够积极地应对洪水和干旱。因此，该水利系统不仅能够防洪，还能够进行灌溉和运输，为农业提供了灌溉用水和有机土壤，同时建立了便捷的交通。

基于以上理解，可以总结得出关于水敏设计的原则：1）通过建立庞大的供水网络以缓冲和临时储存洪水：不同的水要素连接在一起形成一个网络，为临时储存雨洪提供足够的空间，并可以用于灌溉和排水；2）堡尺度水网的多层次结构可以通过不同水体之间的动态控制实现自适应性的雨洪管理，从而可以随时调节水位，其中排水孔、沟渠、运河和水闸等调节系统都在整个系统中起着至关重要的作用；3）需要形成一个完整且多功能的水利系统：洪水防御、蓄水、农业和交通都被认为是系统的组成部分，为农业生产发展、定居点发展以及加强社会交往提供了条件。

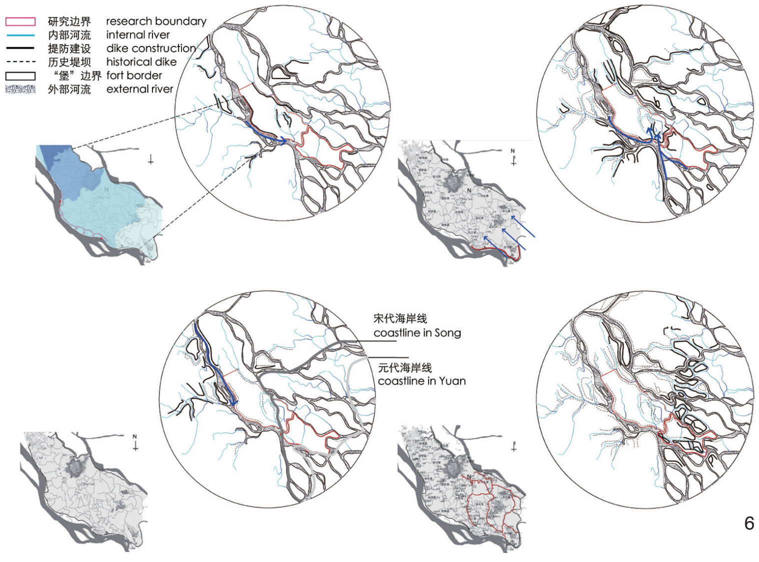
2.3 村庄尺度的水敏设计

除了保护整个堡免受洪水侵袭的水利系统外，村庄也拥有与防洪相关的选址、布局和建筑技术原则。这些原则不仅有助于降低洪水风险，而且形成了与水为生和以水为邻的特殊范式，并侧重于不同地理条件下的村庄布局，蓄水和排水方法以及社会结构等方面。首先，本文确定了两种主要的村庄类型，其名称来自其地理条件：依山村落和平原村落。

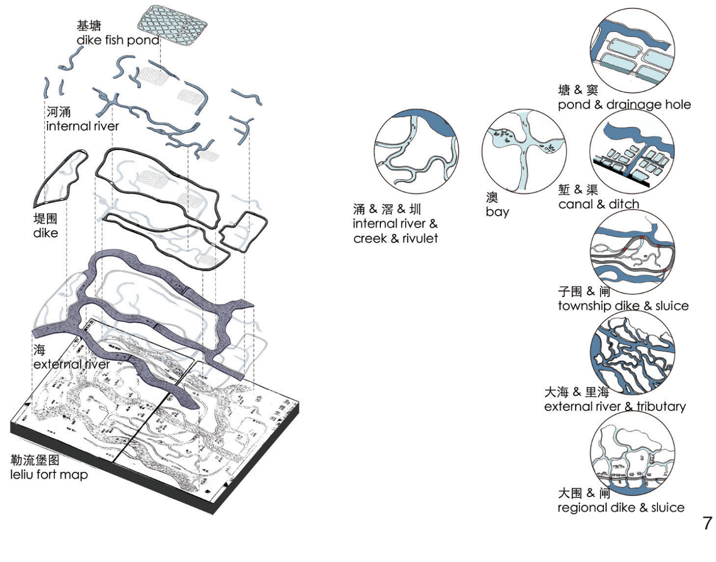
依山村落通常垂直于等高线布置，以利用高低差地形进行排水和集水（图 8）。此外，垂直排布于建筑之间的排水通道，被称为“冷巷”，促进通过空气压力差而进行的冷暖空间循环。这个原则产生了“梳式”布局[11]，其中主要的排水渠通过小巷中的沟渠连接垂直于它们布置的房屋，有助于快速排水。这些排水通道有时也与公共建筑物（如寺庙、学院和学校）前面的池塘相连，称为“风水”池塘。该类池塘不仅用于收集雨水，还象征着财富和祝福。此外，这些池塘周围还设有公共空间（如小广场），为集会、交流和传统节日提供场所。从这个意义上讲，该类池塘具有储水和促进社交联系的多种功能。除了风水池塘外，在山地村落周围还发现了基塘，通过排水孔与运河或河流相连。池塘内的水可以通过下部排水孔轻易地排入运河或河流中，同时，水也可以通过上部排水孔从运河河流中注入池塘。用于农业生产和住宅的小屋位于池塘堤坝上，为灌溉、施肥和收获提供便利。村庄内部的运河大多渠化，并作为交通、社会交流和防洪的重要骨架。市场、港口和周围的寺庙都分布于这些运河沿岸。

平原村落也遵循这些关于布局、排水和社会结构的原则。然而，与山地村落有 2 个重要的区别：1）水网通常更密集，有时在村边界挖掘运河，以防止洪水和海盗；2）在平原村庄内有更多的风水池塘和基塘紧邻建筑用于收集多余的雨水（而在山地村落中，基塘通常都与定居点分开设置，图 9）。

根据这些信息，可以从村庄尺度的研究中得出以下经验教训：1）基于地形的定居点组织与开发，其中自然地形作为建筑环境的分配和布局的基础，包括排水、蓄水和农业；2）公共建筑和公共空间与主要水体有关，例如运河或风水池塘，以刺激社会交流与互动。



6 不同朝代的堤防建设过程
Process of dike construction in different dynasties



7 县（堡）尺度水利系统要素的解构
Deconstruction of water-management element at the county scale

2.4 建筑尺度的水敏设计

寺庙、民居和农舍是3种典型的建筑类型，在该地区的整体水利系统中发挥着重要作用。虽然它们具有不同的功能，但有相似的排水和储水原则。寺庙通常位于运河旁或风水池塘后面（图10）。这样的布局有很大的排洪优势：从建筑物中排出的雨水能够便捷快速地流入运河或被储存在风水池塘中供日常灌溉等使用。内部庭院作为雨水排蓄缓冲区，通常低于建筑平面以收集从屋顶（釉面瓷砖覆盖）落入其中的雨水。民居通常有一个较小的庭院，中间有一个水箱，可以收集雨水以供日常使用（图11）。云母制成的天窗可以自由开关，有利于引入日光同时可以有效防雨。通常在建筑物之间布置排水沟以收集雨水，将其输送到较大的沟渠或运河。农舍用于与农业生产相关的活动，通常修建在基塘上，靠近运河，以利用运输资源。建筑材料也取自在基塘上种植的作物，如桑树的枝条或稻壳。此外，屋顶的雨水和生活污水可以直接排入池塘进行灌溉和施肥。建筑尺度的水敏设计原则：1）建筑物的分配、定位、布局和材料基于对气候模式（降水量 / 蒸发强度，风力强弱和温度高低）以及水利的深刻理解，以通过储存在不同形式（包括蓄水池、庭院池或吸水的材料）中的水体提供降温效果和淡水供应；2）水是循环自给自足系统的一部分（例如饮用水、冷却水、污水处理、象征 / 宗教用水等）。

3 水敏感规划设计的特点

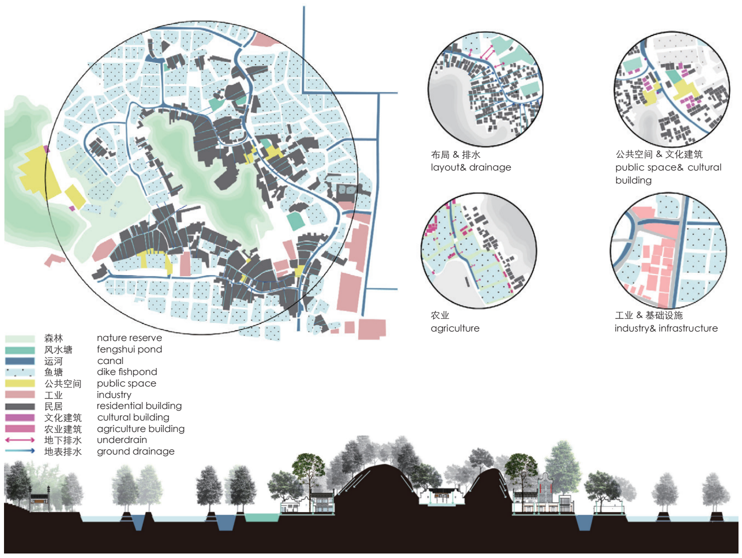
通过解读隐藏在顺德区典型水陆农业景观中的知识，归纳总结出不同尺度的设计原则，这些原则共同协作从而使整个系统成功运作。基于对该地区传统水利和水陆农业养殖实践的理解，可以确定水敏规划和设计的某些关键特点。这些特点可以被提取，并作为减轻洪水风险的基础原则，同时也可以促进可持续的城市化建设。这些原则不仅能被运用于顺德区，而且能服务于整个珠三角。

3.1 长期发展过程

其中一个关键特征是水敏感景观是长期发展所形成的结果。如上所述，顺德区的水利系统是上千年不断累积的试验和观察的结果，这一特点使其成为现今和未来水敏城市建设的宝贵水利系统模范，并能从中提取适应雨洪的地方性基础知识。然而，当代的水利措施主要集中在水利工程解决方案方面，这些系统通常在短时间内，建立并且完全依赖于人造的、单功能的城市排水网络和堤防建设。事实证明，这种方法是无效的，随着近年来洪水事件的频频发生，这种完全摒弃旧有的历史水利系统而用与其无关的城市肌理取而代之的建设模式带来了更多麻烦而非利益。从这个意义上讲，考虑景观的长期发展过程应该被予以足够的重视，因为在这一原则中，景观被视为一个多层级且含有不同过程的系统，这些过程不仅具有不同的自我变化动态，更相互影响、相互作用[12]。在珠三角，由于自然沉积和侵蚀等力量，以及通过水利和农业的人为干预不断地改变景观，景观动态和转变成为景观研究和设计的关键问题[13]。

3.2 多尺度视角

另一个特征是水敏景观的发展强调多尺度的干预，这些不同尺度一起构成互补系统。这一点可以通过“堡”中的系统组成和防洪机制很好地说明：堡规模的水利系统是具有不同水体的密集水网络。该系统通过在2个方向（即排水和储存）中调节河流、运河和基塘中的水，使其对洪水具有弹性与适应性。此外，它通过将大型堤围与内部较小的堤防相结合，提供多层级的防洪保护，因此可以保护人们免受外部和内部洪水的侵害。通过将水系统和堤防系统划分为较小的系统，以减轻特定的洪水危险（例如外堤围防河洪、内堤围防雨洪），这个原则将珠三角的水利系统视为一个复杂的问题，因此我们不应该通过一个单一的解决方案来解决每一个要素（河流、溪流、海湾、基塘）的问题。这使得多尺度的视角不仅在



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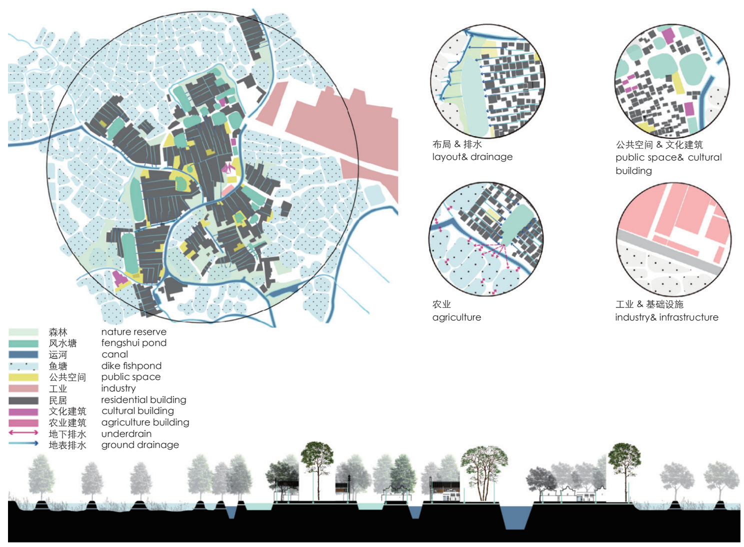

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8 山地村落水利系统
Water management in mountain village

9 平原村落水利系统
Water management in plain village

防洪方面发挥着重要作用，而且在提供更大的灵活性方面也起着重要作用（如储水和保留洪水区）。现代实践中常常看到的建造一个单一巨大的水利工程堤防以保护整个县的做法是失败的，相反，一个多尺度协调合作、对不同雨洪问题更有针对性的水利系统不仅更有效，而且对于建设适应性的城市景观规划至关重要。

3.3 协同作用

正如顺德区的案例所示，水敏感规划设计需要当局、专家和其他利益相关者之间协作，与不同的堡或村庄共同合作努力，这对区域范围内的水敏设计也是至关重要的，当涉及整个地区的洪水时，单个县或村庄做出的单独决定是不够的。其原因在于整个地区中，河流、潮汐、沉积物以及其他需要区域共识和宏观层面决策的能源或物质密切相关，因此需要从全局的角度出发才能解决问题。区域战略必须由不同的地方政府共同制定，以便根据当地的不同情况进行调整，并将措施付诸实践。这需要多个学科，当局和其他利益相关方的合作，以便为更具弹性的水利系统制定共同的理解和战略。

3.4 了解地形条件

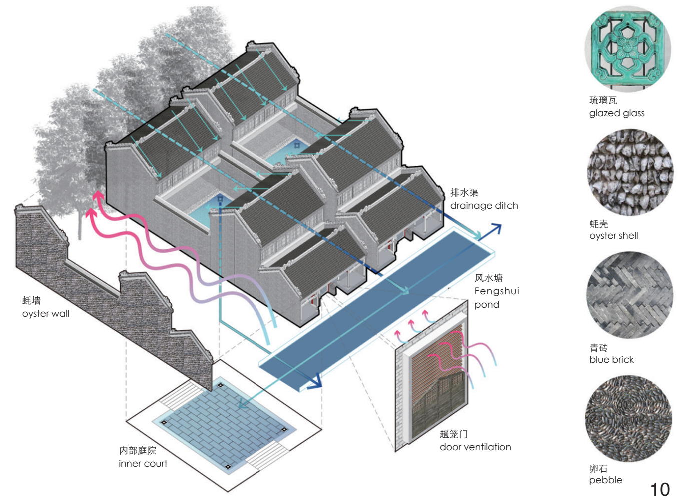
如上所述，地形条件，如地形、水文和土壤决定了定居点的分配和布局。这些特点决定了场地是否容易发生洪水。因此，传统村庄通常位于丘陵或山脉的山脚下、天然河堤上或基塘系统的堤坝上。这些地点可以保证定居点免受洪水侵袭，同时还可以提供足够的水资源。该布局不仅提供了一种有效的排水方式，并且创造了小气候效益，例如引进风和水蒸发带来的冷却效果。然而，现代的开发实践中通常以发展基础设施（交通运输）为优先，其他的开发则依从于这一交通框架，因为该框架带来了便利的运输和外部资源。这种开发方法有利于快速发展，但忽略了自然地形和特定布局，使得其往往不能够抵御雨水和河流引起的洪水。通过重新确定由交通优先转变为地形或水网络发展优先的战略，未来将在远离洪水风险的更安全地区发展。

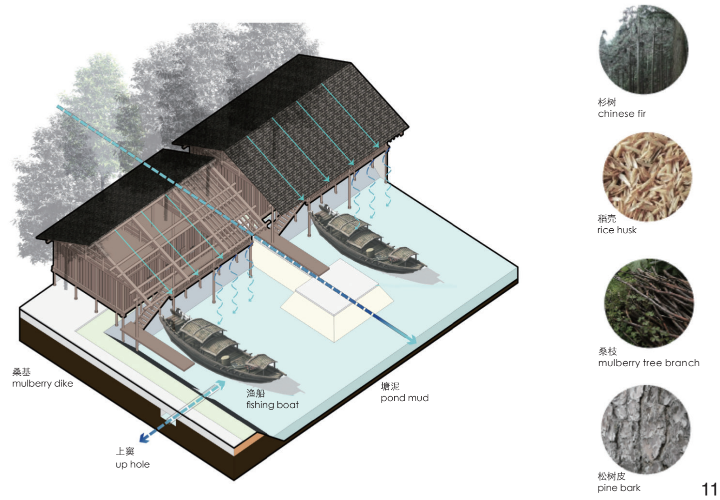
3.5 自然做功以及纳水滞洪空间

了解景观系统及其水文和生态过程是水敏感规划设计的另一个重要特征。由于水和植被有其自身的发展动态，并遵循一定的发展过程和周期，因此在不同的时间尺度（日、月、年）为其提供生长发展、演替变化的机会以及灵活弹性的空间是很重要的。为水位消涨、河流和生态系统创造更多自我消纳与修复的空间将缓解整个水利系统的防洪压力，同时还可以增加生物多样性，刺激肥沃土壤的沉积以利于农业发展，并且创造更多自然环境以满足人们的娱乐休闲需求，最后，还为发展特定地点（不同的地形、土壤和水位消落环境）的住房类型提供了合适条件。然而，旨在严格控制水位变化以达到防洪目的的现代水利工程方法限制了水和自然的动态变化，并且使得水利（堤坝、渠道）局限于单一的功能，这一系列的做法最终增加了洪水风险并加剧了生态破坏。与水相关的自然过程需要开放和包容的设计策略，而不是制定一个蓝图式的设计策略。相反，提供一个可调整并尊重自然和水文过程的框架指导开发，将为适应性开发和规划设计未来的水敏感（城市）景观创造极好的条件。

3.6 多功能水利系统

顺德地区历史水利系统的另一个重要特征在于多功能性。顺德区的水利系统不只用于防洪，同时集防御、商业、社会交流、农业和城市发展于一体。这样一个庞大的供水网络还促成了一个广泛连接的交通网络，提供不同村庄之间的交通运输和交易。市场往往设置在水闸或堤坝旁，以利用其运输优势。这一原则不只将防洪和水资源管理问题视为一种威胁或者是工程措施，而是将其视为一种为人们提供新的水上生活、水上通勤、与水为乐的范例。因此，这些不同功能之间相互促进，为人们提供了三角洲生活的全新体验。在动态使用公共空





10 寺庙的水利系统
Scheme of water management in temples

11 农舍的水利系统
Scheme of water management in cottages

间的做法中我们也能看到关于多功能使用的考虑，如风水池塘和私人庭院空间不同状态（雨、旱）的利用。多功能使用的做法还考虑了天气和季节的变化，并将这些变化转变为多功能使用公共、半公共空间的优势。这种做法将社交、娱乐和其他公共生活或活动等与排水和储水相结合，使对洪水消长的利用成为人们日常生活的一部分，为人们带来了景观和水位的季节性变化。不仅为人们提供了景观的美丽动态变化，还警示人们：洪水的风险就在身边。在这方面，规划者和设计者应利用水利措施与其他开发的整合，以鼓励多功能使用并提供更多的适应性。

3.7 再生和循环

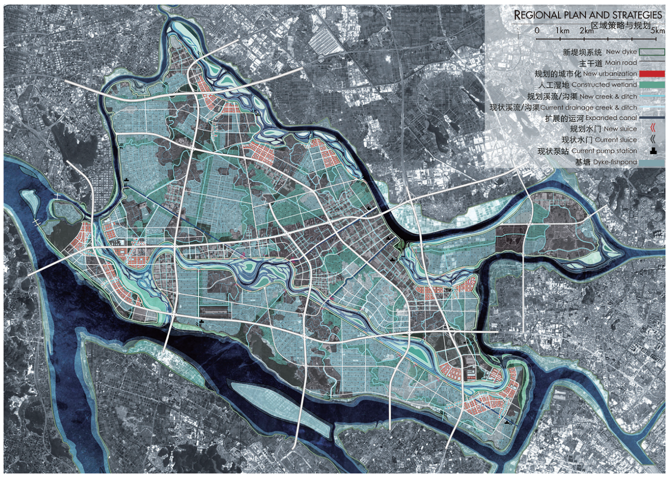
传统上，基塘景观是再生和循环利用的典范。循环原理在于重新使用灰水和黑水进行净化、灌溉、施肥和其他用途。以基塘系统作为循环中心，来自庭院或屋顶的雨水以及河水可以成为池塘补给水的来源，而这些池塘中的水也可以用来灌溉基塘上的作物。来自房屋的污水也可以流入鱼塘作为肥料。之后，经过一系列生物降解过程，营养物质将被植被或水中的微生物吸收并净化。这种循环原理不仅可以成为一系列雨水收集和净化系统的设计原则，而且可以在不同季节充分利用雨水。

综上所述，分析得到的水敏规划和设计方法特点有：1）长期发展过程：将景观理解为具有不同动态的长期过程；2）协作：政府以及具有不同学科背景的专家和其他利益相关者共同努力，为更具弹性的水系统制定协同战略；3）多尺度的景观设计：从区域尺度到建筑尺度的防洪集水解决方案；4）了解地形条件：景观系统及其地形条件是村庄、建筑和土地利用的分配、组织和布局的基础；5）自然做功以及纳水滞洪空间：修复河流与降雨的系统并恢复其自然的生态过程，如演替、沉积和侵蚀等；6）多功能水利系统：不仅关注水利，还包括规划设计中的生态、社会、文化和经济方面；7）再利用和循环：促进水循环的发展，在建筑、村庄、县和地区的尺度上推动雨洪的收集和再利用。

这些特征是综合水利系统的基础，水利系统不仅起到防洪的作用，而且还是生态发展、循环、交通、农业生产、聚落、社会联系和政府管理的驱动力。从这个角度来看，水成为增长和繁荣的主要条件；通过水敏规划设计，水成为文化性和地方性的催化剂。这一设计理念不仅汲取了历史“技术”的经验教训，而且还具有构成珠三角强大区域特征即地方性和适应性的内在文化品质。

3.8 水敏原理在顺德规划设计中的应用

通过对历史水利和生态堤防——基塘系统的研究所学到的水敏原理将被应用于杏坛县，以实现更具弹性的城市景观设计。运用上述原则，该设计中构建了一个强大的水网系统，可以引导过量洪水，并且通过一系列雨洪调控将其储存起来，通过净化过程实现再利用，并将修复一条历史溪流，改造成新的中央洪泛平原，以帮助消纳该县内运河和小溪带来的过量雨洪（图 12）。此外，通过恢复河流的自然涨落动态和泥沙沉积过程，修复了其生态功能，加速自然界物质能量循环并增加了生物多样性（图 13）。因此，这些天然泥沙沉积物可用于加强该地区的农业。作为新洪泛平原的一部分，该方案还提出了一个多功能的水利基础设施，包括现有的道路系统：新的公共交通、自行车道和人行道。这个新的交通体系不仅是连接所有村庄、城镇和其他主要道路或高速公路的主干道路系统，同时也作为新型堤防住宅的交通基础。通过扩展基础设施并逐渐发展新的“交通分支”，这一生长的交通体系还为两栖住宅（可建于洪泛平原）和漂浮住宅增加了可达性，并利用现有的农业水产养殖模式进行水循环和减轻洪水威胁（图 14）。总之，该方法为珠三角地区的城市发展提供了崭新的视角，利用从生态基塘和水利方法中提取的原则，将其转化为现代规划和设计语言以进行实践。



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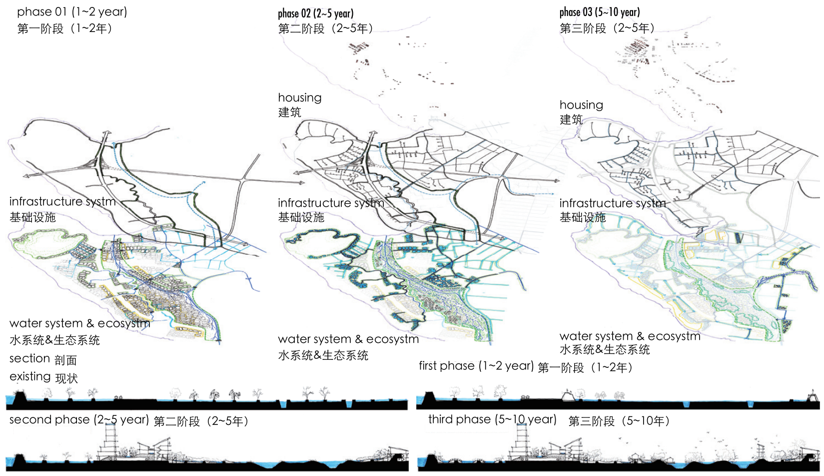

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12 新的杏坛综合区域计划（宏观尺度），该计划基于可持续的水利和基础设施框架，考虑水系统，新基础设施，生态系统，农业和住房的发展

A new integrated regional plan that takes the development of the water system, new infrastructure, ecosystem, agriculture, and housing into consideration based on a sustainable water and infrastructure framework

13 中观尺度水敏景观的时序规划。这一注重过程性的规划着重于恢复水动态并建立一个弹性生长的基础设施系统

Phasing Plan of water-sensitive landscape development in middle scale. This process-oriented plan focuses on restoration of the water dynamics as well as building up a growing system of flexible infrastructure

此外，这一方法探索了城市化新的可能性：使我们有可能将传统的水陆农业养殖模式转变成为具有适应性和弹性的景观基础设施并能够促进可持续的城市化发展。

4 结论

本研究最重要的贡献是提供在珠三角地区城市化实践的崭新视角，将传统的水陆农业养殖（基塘）系统知识与未来城市发展联系起来，架构了地方性、历史性设计原则与现代雨洪城市设计的桥梁。在这种可持续转型发展的视角之下，景观被视为空间战略和干预的基础。由于一些地方历史地图的不准确性（即在某些情况下缺乏原始数据），这项研究面临着资料不完整的困难。然而，该研究确实为更加注重动态雨洪防范的方法提供了新的思路：其中包括上面列出的水敏规划方法特征。通过学习传统的水陆农业养殖实践，可以开发出水敏规划设计的新原则，这些原则可以减轻洪水风险，同时也可以促进可持续的城市化和农业发展。这些方法将不仅仅能够被应用于顺德区，而且可以扩展至整个珠三角。这种观点需要规划者正确理解景观及其背后的设计规划原理，并以此为基础制定发展战略，而不是应用中国近现代城市化进程中出现的“白纸式”的发展模式（与这种方法相关的问题也是如此）。总之，恰如其分地应用和适应上述原则和特征不仅可以为城市景观发展提供崭新的视角，而且还可以为规划和设计更具弹性和适应性的珠三角提供新的范例。

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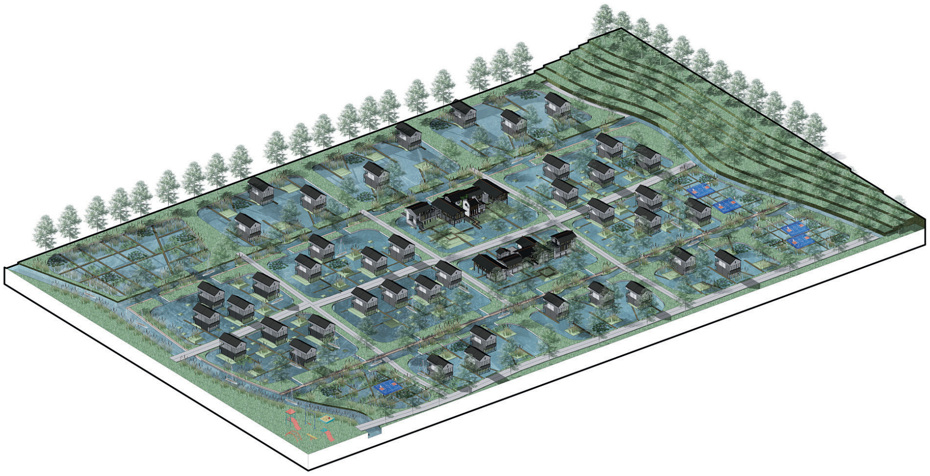
图片来源：

图 1 由招力行摄；图 2 由斯特芬 · 奈豪斯绘；图 3 由孙传致摄；图 4、5、8~14 由孙传致绘；图 6 由孙传致基于参考文献 [7] 绘；图 7 由孙传致基于《顺德县志》绘。

（编辑 / 王亚莺）



14

14 基于杏坛基塘系统转型而成的水敏社区阐释了一种新的与水而生的范式，同时结合了公共空间，湿地与新的住房类型
Elaboration of a new water-sensitive community transformed from the dike-fishpond pattern in Xingtan County that implies a new paradigm of water life with public space, wetland, and new housing typologies

The Pearl River Delta (PRD) is one of the world's fastest urbanizing deltas, with all the related challenges and potentials that this entails (e.g. increasing flood risk, loss of ecological and social values, etc.). The PRD is located in the southeast coastal region of China, with the West, North, and East rivers being its main riverine arteries. This river-dominated delta has been formed by natural processes, such as siltation and deposition, for more than a millennium[1]. The resulting lowland is characterized by two sub-deltas (North river/West river) and an estuary. The PRD is an area that has long been well suited to agriculture because of its rich soil. Human intervention, which began around 1,000 years ago, gradually transformed the delta into one of the richest agricultural regions in China by developing an integrated agri-aquaculture, known as the dike-pond system[2]13. This unique landscape is the result of an historic and intricate relationship between water management, agriculture, ecology, industry, and settlement (Fig. 1). In the sub-delta of the West river, a flood prone lowland near Shunde, this is clearly visible via its centuries' old tradition of coping with river floods and excessive rainwater. However, the ongoing process of dike-ring construction and the channelization of watercourses, as well as the partial disappearance of the dike-pond system due to urbanization, has led to a dramatic decrease in flood storage capacity and has seriously increased flood risk from rivers and rain water, not only in this region, but in the PRD as a whole. In order to address these issues a more adaptive urbanization strategy is required: a multiscale approach that is more water sensitive and inclusive in a socio-ecological way[3]. In order to develop such an approach, it is important to study traditional region-specific agricultural practices as well as historical water-management methods in order to derive design and planning principles that can inform contemporary spatial development strategies.

The objective of this paper is to identify landscape architecture principles for multiscale water-sensitive design based on traditional agri-aqucultural practices and historical development of ecological water management in the sub-delta of the West river (in particular the dike-pond system) in order to increase flood storage. Since these systems were formed gradually and refined by residents through practical lessons learned over centuries, there is wealth of accumulative knowledge hidden in the landscape that can be used for flood protection, ecology, and the cultural formation of contemporary urban development. After that, this tacit knowledge which is as yet largely unexplored but proven useful, would be applied for adaptive urban planning and design in order to illustrate how these principles can be put into practice in contemporary situations. Finally, the link between this research and its possible application in the PRD will be discussed, while connecting it to a wider context.

1 Integrated Agri-aquaculture Practice

The agricultural lowlands of the area between the West and North rivers is flood prone due to heavy rain which causes a peak river discharge from upper parts of the river basins. Floods occur mainly between June and August, a time when these two flood dangers happen at the same time, causing internal floods that cannot be discharged to the outer river due to the higher level of the water. This natural hydrological circumstance resulted in a fertile soil which in turn led to a particular type of agri-aquaculture known as the dike-pond system, which became the basis for local economic production (Fig. 2, 3)[2]30.

The dike-pond system developed in the 14th century with fruit trees being planted on dikes around fish ponds at their centre. This changed in the early 17th century into a combination of mulberry and four major fish species, creating a local silk and fisheries economy. Since then, this agri-aquaculture pattern continued to grow and prosper until it hit a peak around the 1920s. After this time, the worldwide depression, and later Japanese aggression, led to market changes with other alternatives being explored and developed. The dike-pond system had been well-known as a self-sufficient and productive use of land because of its closed energy and material circulation (Fig. 4). It makes use of soil dug from the pond to build the surrounding dikes, on which the mulberry was planted to feed silkworms. After the worms had been reared, their chrysalis, along with the leaves and silkworm excrement, were returned to feed the fish, providing very good forage. The forage that was left then combined with fish manure and other rich organic matter, which was decomposed by microorganisms and fell to the bottom of the pond as fertilizer. By the digging the organically enriched mud two to three times a year and putting it back onto the dike it also offered nutrients to the mulberry trees.

However, this integrated system was not fully developed until around 1350[4]66, by which time water-management methods were in place and dike construction already begun in riparian areas around the old estuary to reclaim the low tidal flat for agriculture. Because of its excellent flood tolerance and high productive capacity, land use was concentrated in the flood-prone lowland between the West and North rivers. Later it sprawled all over the PRD as a result of the region's water-management system and also became one of the most important elements in an integrated water-management system. A look at the whole system is required to properly understand how this special agri-aquaculture pattern functioned as a flood-protection system.

2 Multiscale Water-management System

The Pearl River Delta is ancient, having been formed more than 6,000 years ago, a time when Shunde was still part of the South China Sea. By the Song dynasty (960—1279), a large amount of the central part of the delta had been formed very gradually from sedimentation. The diversion of the West river at this time accelerated the speed of land reclamation, forming Xingtan, Junan, and other places to the southwest of Shunde[5]32. In 1450, the Qing dynasty established Shunde county partly in an effort to prevent conflict over scarce land resources between rich farmers and poor fishermen, which had resulted from the continuous land reclamation, but also to protect agriculture from flooding, thereby establishing a principle of cooperative flood defence. As a result, the administrative divisions were based on cooperation for water management and included 40 counties and 297 villages[6]. This classification system helped build up a systematic water-management system thanks to the joint efforts of people from the different counties, villages, and clans to protect both the waterfront and its hinterland from flooding. This historical water-management system contains interventions at four levels of scale: regional, county, village, and building (Fig. 5). These four scales have a strong relationship with each other and developed together to form an integral system that functions as a flood defence, as well as for settlement establishment, agricultural production, and social structure. It is, thus, very important to understand the different water-management principles, and how they are interrelated through these scales.

2.1 Water-sensitive Design at the Regional Level

The regional scale includes 40 counties, which manage 297 villages. Each county has 20 to 50 percent of its boundary abutting either the West or the North river[5]24, and each tries to balance profit with danger, i.e. balance production and transportation along the river while protecting from the danger of flooding. Flood has been a major threat in the Shunde district for centuries. Floods were recorded on average three times a year during the Ming and Qing Dynasties (1368—1644 and 1644—1912 respectively), and this did not include the frequent small floods that happening nearly monthly during the monsoon season (usually April to September). Once invented, dike construction became one of the main measures against flooding. However, due to a lack of technique and human resource at the time, the building of large dikes required cooperation not only within a county or village, but also their joint efforts over a long time period (Fig. 6)[7].

Regional dike construction evolved several flood-defence principles, starting in the Song Dynasty and continuing through the Qing Dynasty. During the nearly three centuries of the Song Dynasty, people built a large number of dikes (28 in total) along the banks of the West, North, and East rivers[8]39 particularly along the West river, where the Sangyuan dike was the largest at that time[4]32. The main function of the dike was to protect settlements from river floods using three main principles[5]45 : 1) Utilize natural topography (i.e. make it part of the dike to make use of height difference between upstream and downstream for drainage); 2) Keep enough distance from the river; 3) Build temples besides the dikes (for commemoration and as places of deliberation).

In the Yuan Dynasty (1271—1368), old dikes had their heights raised and were reinforced, and new construction of dikes continued along the West river in 11 counties, resulting in 34 new dikes[8]13. At this time construction tended to focus on the upstream parts of the river due to the more serious floods caused by the extension and siltation of the estuary downstream. Construction techniques were also improved by using stone for the sluices and dikes.

The flourishing of both population and economy during the Ming Dynasty meant that this period saw the largest extent of dike construction and land reclamation. Population and economy were witnessing a prosperity which led to an increased demand for land, thus reclamation was widely carried out using dike construction to capture natural sediment. While in former dynasties the dikes were mainly linear, constructed on the west and east sides of islands to protect from river floods, during the Ming this was inverted because reclamation and siltation had caused tidal water infusion from the sea. Thus, the principle changed from open dike construction, to prevent river flooding, to a closed dike-ring system against sea flooding, for example, the Sangyuan dike was closed in the early Ming dynasty by adding dikes on its southeast[5]55. However, this series of closed dike-ring constructions caused further flooding problems in the hinterland, especially during the monsoon season, when heavy rainfall could not be discharged effectively. It was at this time that the dike-pond system was invented as a special agricultural land use to mitigate this problem by providing capacity for extra excess water.

This dike-pond system, which appeared in the late Ming Dynasty, prospered into the middle of Qing dynasty[8]36. The burgeoning of agriculture in this period encouraged more land reclamation downstream, which required more dike construction and connections. However, this caused more serious flooding from the river inside the large dike rings because there was less space for water. As a result, smaller dike rings were constructed inside the large ones to protect settlements from internal floods, which led to a nested loop-like layout. At the same time, to defend from floods from the external river, different dikes were connected to form large stronger and safer dike rings, and sluices were built in them to control drainage. Finally, the whole water-management system was formed into an infrastructure of large connected dike rings with smaller dike rings inside them.

While reflecting on the long-term development of the regional water-management system, the following lessons for water-sensitive design can be learned: 1) Water management is a collaborative effort: flood defence can only be effective when different authorities and disciplines team up and jointly plan, design, and construct the water-management system from a regional perspective; 2) It is important to acknowledge that each water source (e.g. sea, river, and rain water) has its own temporal dynamic in the amount of water in each (e.g. changing levels of discharge throughout the seasons) and have specific requirements for water management; 3) As a result of an incremental learning process in this region it was considered important to provide enough space for water and flood storage by incorporating natural water streams and water bodies, have a certain distance between dike and river, and utilize natural topography to build dikes and allocate and orient drainage/irrigation ditches and canals.

2.2 Water-sensitive Design at the County (Fort) Scale

Water management at the regional scale deals with external water; at the county scale (also known as the Fort scale) interventions focus on regulating internal water. The name "Fort" for a county is used only in Shunde district and highlights a basic unit of division which is strongly related to defence from the two main enemies: flood and pirates[9]. Water management inside a Fort consists of three main components in order to form an effective system: dikes, rivers, and connectors (Fig. 7). These three elements were closely interrelated. The traditional division of the water management can be summarized as "external river, outer dike, internal river, bay, canal, ditch, drainage system"[10].

The water-management system at the Fort scale consists of drainage in the flood season and water storage in the dry season, which also works closely with the daily and monthly tidal change. For example, in the flood season, floods from the external river or the sea will be prevented by the large dikes constructed along the main river course, while the internal flood waters caused by heavy rain can be temporarily stored in internal rivers, canals, creeks, bays, and dike-ponds. During low tide, when the outer water table is lower, this water can be drained from the ponds through drainage holes into canals and thence to internal rivers, creeks, or rivulets. Finally, with the opening of sluices on the outer dikes, it can be drained into the outer rivers. In the dry season this system works conversely to store rain water, using it and river water for irrigation. With this double-sided and regular system, that could be adjusted at any time, the settlements and agriculture inside the Fort were able to deal with both flood and drought. As a result, this water system was not only capable of flood protection, but also of irrigation and transportation. It provided agriculture with water as well as rich sediment and convenient transportation.

Based on this understanding the following lessons can be learned for water-sensitive design: 1) Buffering and storing water through a water network: water elements are connected and form a network that provides enough space for temporary storage of rain and river water for irrigation and drainage; 2) The hierarchy in the water network enables adaptive water management through dynamic control between different water bodies enabling the regulation of the water table at any time; the drainage holes, ditches, canals, and sluices all play key important roles in the whole system; 3) Water management requires an integral approach; the water system is multifunctional: flood defence, water storage, agriculture, and transportation are all considered integral to the system and provide conditions for the development of agricultural production, settlement development, as well as enhancing social communication.

2.3 Water-sensitive design at the village scale

Besides the water-management system that protects the whole Fort from flood risk, the village also has its principles of site selection, layout, and building techniques related to flood protection. These principles not only help people reduce flood risk, but also form a special paradigm for living and interacting with water, and focus on aspects such as the layout of villages in different geographical conditions, methods of water storage and drainage, as well as social structure. First, two main village types are identified in this article, taking their names from their geographical conditions: the mountain village and the plain village.

The mountain village is usually arranged perpendicular to the contours of the terrain to make use of it for drainage and catchment (Fig. 8). In addition, small alleys are reserved as drainage aisles between perpendicular rows of buildings, which are called "cold alleys" since they aid the circulation of cool air from the water body thanks to differences in air pressure. This principle results in what is known as a "tomb" layout[11] where a main drainage canal is connected to a number of perpendicular houses via the ditches in the alleys that help drain water quickly. Sometimes these drainage aisles are also linked to ponds in front of public buildings like temples, colleges, and schools. These are known as "fengshui" ponds. This type of pond is used not only for rain water collection but also symbolizes wealth and blessings. In addition, public spaces (e.g. small plazas) are arranged around these ponds, offering a place for assembly, communication, and traditional festivals.

In that sense they have the multifunctional purpose of storing water and allowing for social connection. Besides the fengshui pond, dike-fishponds are also found surrounding the mountain villages and are connected to canals or rivers via drainage holes. The water inside these ponds can be easily drained into the canals or rivers through the lower drainage hole and, conversely, water can also be poured into the ponds via an upper drainage hole. Cottages for agricultural production, as well as dwelling, are located on pond dikes which offer convenience for irrigation, fertilization, and harvesting. The canals in the village are always channelized and regarded as an important framework for transportation, social communication, and flood prevention as can be seen by the markets, ports, and temples surrounding them.

The plain villages also follow these principles regarding layout, drainage, and social structure. However, there are two crucial differences with the mountain village: first, the water network is usually denser and sometimes a canal was excavated around the village boundary to protect against flooding and pirates; second, there are more fengshui ponds and dike-fishponds inside the plain villages for the collecting of excess water (in mountain villages, dike-fishponds are usually separated from the settlements, Fig. 9).

Based on this information the following lessons can be derived from the village scale: 1) Terrain-sensitive organization and development of settlements, where the natural terrain serves as the basis for the allocation and layout of the built environment, including drainage, water storage, and agriculture; 2) Public buildings and public spaces are related to the main water bodies, e.g. canals or fengshui ponds, which stimulate social interaction.

2.4 Water-sensitive design at the building scale

Temples, folk houses, and cottages are three of the typical building types that play a significant role in the integral water management of the region. Though they have different functions, they share principles of water drainage and storage. Temples are usually located besides canals or behind fengshui ponds (Fig. 10). This helps the rain water that runs off the building to be easily drained into the canal or stored in fengshui pond for daily irrigation use. The inner court serves as a water buffer zone, with a lower-level surface to collect rainwater that drops into it from the roof (which is covered in glazed ceramic tiles). Folk houses usually have a smaller courtyard with a water tank in the middle to collect rain water for daily use (Fig. 11). Skylights made of mica can be opened or closed to let in sunlight or keep out rain. A drainage ditch is usually laid out between the buildings to collect water and deliver it to a larger ditch or canal. Cottages are typically buildings used for activities related to agricultural production and are usually built besides the dike-ponds and canals to prioritize transportation. Their building materials are also taken from the crops grown on the dikes, like the branches of mulberry tree or rice husks. In addition, the rainwater from the roof and domestic sewage can be drained directly into ponds for irrigation and fertilization.

Lessons for water-sensitive design at the building level: 1) Allocation, orientation, layout, and materialization of buildings are based on a deep understanding of climate patterns (precipitation/evaporation, wind, and temperature) as well as water management to provide for cooling effects and fresh water supply via water storage in many different forms, ranging from cisterns, pools in courtyards, or to materials that absorb water; 2) Water is part of a circular, self-sufficient system (e.g. drinking water, cooling water, sewage treatment, symbolic/religious water, etc.).

3 Characteristics of Water-sensitive Planning and Design

By interpreting the accumulative knowledge hidden in the typical agri-aquaculture landscape of Shunde district, design principles can be identified for each scale that, working together, make them collaborate successfully. Based on an understanding of traditional water-management and agri-aquacultural practices in this district, certain key characteristics of water-sensitive planning and design can be identified. These characteristics could serve as a basis for mitigating flood risk while also allowing for increased but sustainable urbanization, not only in the Shunde district but also for the Pearl River Delta as a whole.

3.1 Long-term development process

One of the key characteristics is that a water-sensitive landscape is the result of a long-term development process. As has been shown above, the water-management system of Shunde district was the result of incremental experimentation and observation over a millennium, which makes it a valuable basis on which to build for today and the future. However, current practice is focused on fixed engineering solutions, often built in a short time frame and depending exclusively on manmade mono-functional urban-drainage networks and dike construction. This approach has proved to be ineffective, as illustrated by increased flooding events in recent times. In fact, it has brought more trouble than benefits by demolishing the historical water-management pattern, replacing it with an urban texture that has no relation with the existing water network. In that sense, taking into account the long-term development process is vital because it regards the current landscape as a layered entity where different processes and systems influence each other and have a different dynamic of change[12]. In the PRD, natural forces like sedimentation and erosion, along with human intervention through water management and agriculture, have constantly changed the landscape, which makes landscape dynamics and transformation a key issue in landscape research and design[13].

3.2 Multiscale Approach

Another characteristic is that the development of a water-sensitive landscape addresses multiple scale levels that, taken together, make for a complementary system. This might best be illustrated by the following: the water-management system at the Fort scale is a dense water network with different water bodies. This system, by regulating water in rivers, canals, and dike-ponds in both directions (e.g. drainage and storage) makes the settlement more resilient to flooding. In addition, it offers multiple flood defences by combining the large dike ring with the smaller dikes inside, so they protect people from both external and internal flooding. By dividing the water system and the dike system into smaller systems that work to mitigate specific flood dangers (e.g. the outer dike for river flooding, the inner against rain flooding), this principle see water management in the PRD as a complicated issue that should not be addressed by one single solution. Every single element (river, rivulet, bay, dike-fishpond) plays an important role not only in flood defence but also in accommodating greater flexibility (for things like water storage and reserved flood zones). Thus, instead of modern practices which see the construction of one single dike to protect a whole county, which has proved subject to failure, a water system that addresses multiple scales is not only more effective, but is vital for adaptive urban-landscape planning.

3.3 Collaborative Effort

As illustrated by the Shunde district case, a water-sensitive approach requires a collaborative effort between authorities, experts, and other stakeholders. Their joint efforts, by working together with the different Forts or villages, is also crucial in the regional scale because it reminds us that separate decisions taken by a single county or village will not be enough when it comes to floods in the whole region. The reason for this is that the whole region is closely connected by rivers, tides, sediment, and other energy or material flows which require regional consensus and decisions taken at the macro level. Regional strategies have to be formulated by different local governments working together to put things into practice depending on their different local situations. This requires a collaboration of multiple disciplines, authorities, and other stakeholders to develop common understandings and strategies for a more resilient water system.

3.4 Understanding Terrain Conditions

As highlighted above, terrain conditions such as topography, water courses, and soil determine the allocation and layout of settlements. As a result, the site determines if a settlement is prone to flooding. Traditional villages were therefore usually located at the foot of hills or mountains, on natural river levees, or on the dikes of an agri-aquaculture system. These locations keep the settlements safe from flooding, but at the same time provided access to water, which acted as an effective way of draining rainwater and provided microclimatic benefits, such as the cooling effects of wind and evaporation. However, modern practice usually privileges transportation in its development framework, since this brings convenience and external resources. This approach is beneficial for rapid development but ignores the natural terrain and the specific layout that makes it resilient to flooding caused by rain and river. By reprioritising from a traffic- to a terrain- or water-network-development strategy, future development will have the advantage of being located in places that are safer from flooding.

3.5 Working with Nature and Space for Water

Understanding the landscape system and its hydrological and ecological processes is another important characteristic of water-sensitive planning and design. Since water and vegetation have their own dynamics of development, and follow their own processes and cycles, it is important to provide space for development, change, and flexibility in different temporal scales (diurnal, monthly, yearly, etc.). Space for fluctuating water levels, room for rivers, and the development of ecosystems will ease pressure on the water system as a whole, increase biodiversity, stimulate sedimentation of fertile soil for agriculture, create possibilities for recreation, and open up opportunities for the development of site-specific housing typologies. However, modern engineering methods that aim at making strict controls limit the dynamic of water and nature and result in a mono-functional system that contributes to increasing flood risk and ecological damage. Working with natural processes connected to water demands open and inclusive design strategies, not blueprint designs, aimed at guiding development and creating conditions for a more adaptive and water-sensitive (urban) landscape.

3.6 Multifunctional Water Management

Another important characteristic lies in multifunctionality. The water system of Shunde district integrated defence, business, social communication, agriculture, and urban development and was, thus, not merely used for water protection. The water network also contributed to a widely connected transportation network for communication and trading between different villages. Markets were arranged beside sluices or on dikes to make use of their transportation advantages. This principle regarded the issues of flood protection and water management not only as a threat or an engineering problem, it also saw it as an opportunity to offer a new paradigm of living with water, commuting with water, and generally enjoying life with water. As a result, these combined functions promoted each other to provide people with a new experience of delta life. Multifunctionality was also visible in the dynamic use of public spaces, like the fengshui ponds and the private courtyard spaces. It also took fluctuation of weather and seasons into consideration, transforming these into advantages for multiple uses. It combined activities like social communication, recreation, and other public life or events with water drainage and storage and made it part of people's daily life. It brought the seasonal changes in landscape and water to the people, which not only warned them of possible flooding but also provided beautiful scenery. In that respect, the integration of water management with other developments should be utilized by planners and designers to encourage multifunctional use and accommodate more adaptation.

3.7 Re-use and Circularity

The agri-aquacultural landscape was traditionally one of re-use and circularity. The circulation principle lies in the re-use of grey and black water for irrigation, fertilization, and other purposes. Taking the dike-pond system as the circulation centre, rain water from the courtyard or roof, as well as river water, could be a source of water replenishment for the ponds while the water in these ponds could also be used to irrigate crops on the dike. Sewer water from houses could also flow into the dike-fishpond to act as fertilizer. Later, after a series of bio-degradation processes, nutrients would be absorbed by vegetation or by microbes in the water and purified. This circulation principle could be the inspiration for a series of water collection and purification systems that make the best use of water during the dry season today.

To sum up, a water-sensitive planning and design approach is characterized by: 1) Long-term development process: understanding the landscape as a long-term process with different dynamics; 2) Collaboration: collaborative efforts of authorities, multiple experts with different disciplinary backgrounds, and other stakeholders to develop a common understanding and strategies for a more resilient water system; 3) Multiple scale levels: complementary water solutions ranging from the regional scale to the building scale; 4) Understanding terrain conditions: the landscape system and its terrain conditions are the basis for the allocation, organization, and layout of settlements, buildings, and land use; 5) Working with nature and space for water: employing natural river and rain-water systems and processes, and also make use of natural processes such as ecological succession, sedimentation, and erosion, etc; 6) Multifunctional water management: not only focused on water management but also includes ecological, social, cultural, and economic aspects in planning and design; 7) Re-use and circularity: stimulating the development of closed loops of water, re-use of water at the levels of scale of building, village, county, and region.

These characteristics are the basis for an integrated water system that not only functions as flood defence but also serves as a driving force for ecological development, circularity, transportation, agricultural production, settlement advancement, social connection, and governance. From this perspective, water becomes the main condition for growth and prosperity; it boosts culture through water-sensitive planning and design, because not only does it apply "technical" lessons learned but also carries the intrinsic cultural qualities of local adaptations that make up the strong regional identity of the PRD.

3.8 Application of Water-sensitive Principles in Shunde

By applying the water-sensitive principles learned through the study of historical water-management and the ecological dike-fishpond system to Xingtan county for a more resilient urban landscape design, this approach creates a robust water network that could allow excessive water to be guided, stored, and purified through a series of processes and controls. It is proposed that a historical creek will be renovated as a new central flood plain that could help absorb heavy rainwater brought by canals and rivulets inside the county (Fig. 13). In addition, by bringing water fluctuation and sedimentation back to the river, this intervention also restores its ecological function, like circulation and biodiversity, through natural processes (Fig. 12). As a result, this sediment could be utilized for enhancing agriculture in this region. A multifunctional water infrastructure which consists of existing road systems, new public transportation, as well as biking and pedestrian paths is also proposed as part of the new flood plain. This not only serves as an arterial road system that connects all the villages, towns, and other main roads or highways, but it is also the basis for a new type of dike house. By extending the infrastructure and creating new "branches" through this development process, it also offers accessibility to the amphibious houses, terp houses, and floating houses that make use of the existing agri-aquacultural pattern for water circulation and flood mitigation (Fig. 14). In conclusion, this approach offers a transformative perspective that makes use of the principles extracted from the ecological dike-fishpond and water-management methods and converts them into practice with modern planning and design language. In addition, the exploration provides us with a possibility of transforming and adapting the traditional agri-aquaculture into a more resilient and sustainable urban landscape.

4 Conclusion

The most vital contribution of this paper is to build a bridge between traditional practices in agri-aquaculture and future urban development to offer a transformative perspective that takes landscape as the basis for spatial strategies and interventions. The difficulty with this research consists in the incompleteness of some of its information due to the inaccuracy of some local historical maps (even a lack of these in some cases). However, the research does provide clues for a more water-sensitive approach that includes the characteristics listed above. By learning from traditional agri-aquacultural practices new principles for water-sensitive planning and design can be developed which can mitigate flood risk while also allowing for increased but sustainable urbanization and agricultural development, not just for the Shunde district but the PRD as a whole. This perspective requires a proper understanding of landscape, and the principles behind it, to build on such a system, instead of taking a tabula rasa-development model, which can be seen everywhere in China's recent urbanization (as can the problems associated with this approach). In conclusion, a proper application and adaptation of the above-mentioned principles and characteristics would not only provide a transformative perspective for urban landscape development but would also offer a new paradigm for planning and designing for a more resilient and adaptive Pearl River Delta.

Sources of Figures:

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(Editor / WANG Yaying)