Final Draft: A Feasibility Study of the Hangzhou Tangxi Canal Restoration

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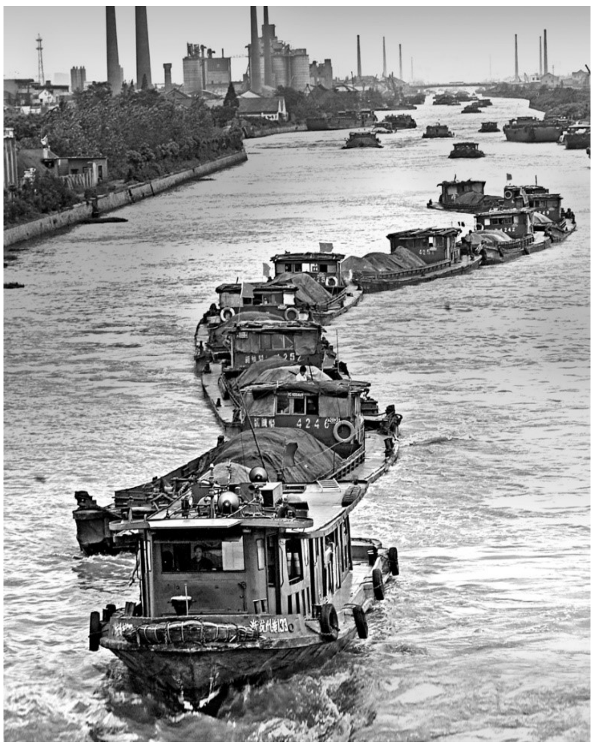

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Abstract

I provide this feasibility study for the future restoration of Tangxi Canal (Hangzhou, Zhejiang, China) to explore whether the canal district can become a social-interactive urban space with healthy environmental conditions and sustained connectivity with the canal waters. Overall, the Tangxi Canal District faces two challenges: first, pollution from fuel leaks from motorboats and stormwater runoff; and second, a lack of sociocultural interaction between residents and the canal. Therefore, the restoration of the Tangxi Canal area requires the following: (a) providing more green spaces and public spaces; (b) addressing environmental problems; and (c) providing more urban amenities.

Introduction

China's urbanization occurred primarily along the Grand Canal during the dynastic periods, incubating unique socio-urban cultural identities in various canal cities, such as the Tangxi District in Hangzhou at the south terminal of the canal (see Fig. 00 A–B). The Tangxi canal segment includes a 5 km stretch of the canal and its surroundings (see Fig. 1), located on the north side of downtown Hangzhou and extending north from Gongchen Bridge to Tangxi District, a municipality that includes danwei housing, industrial sectors, unregulated brownfields, heritage areas, existing or planned housing settlements, and a proposed central business district.

Methods

I made a standard for this feasibility study stating that the restoration of healthy environmental conditions in the Tangxi Canal area requires the following actions: (a) enhancing social connectivity between humans and water; (b) addressing environmental problems; and (c) sustaining the canal culture. My study includes the following:

1. I synthesized current studies on pollution that describe motorboat leaks, heavy metal distribution, and stormwater runoff from Tangxi's north to south end. I have visualized these data on maps.
2. I identified and mapped out current canal-front typologies, which include land use and planned future developments consisting of commercial, institutional, residential, and industrial structures, as well as brownfields.
3. I conducted an urban proximity study covering the entire Tangxi District, identifying existing locations of heritage areas, public spaces, and other facilities (e.g., restaurants and coffee shops). I have also mapped these features.
4. I analyzed and mapped out of transportation circulation routes (within Tangxi District), comprising a major road network, existing trail routes, boat routes, and ports.

5. Review of the Shanghai sponge-city guidelines[1], which show that the unit absorption rate of a sponge green space is 30% in the southern Yangtze Delta (Shanghai Ministry of Construction, 2016, p. 56).

Documenting the current condition requires first discerning how the structures and uses of the study area relate to the canal, and second, how some of these uses could be changed to bring people to the waterfront and how the hydrological processes could be modified to reduce stormwater runoff and improve its quality, creating green spaces for human use in the process. (All mapping studies use ArcGIS 11.6 for the base layer, Baidu Professional for the urban information layer, and data provided by Hangzhou Canal Association as content layers. Additionally, I created a 3D digital model for spatial analysis.) I have documented six typical canal-front conditions, overlaying existing canal-front conditions with potential conditions after applying sponge city green spaces. These sectional conditions include, first, a generic prototype that graphically explains major components of a sponge-city green space and its construction codes, and second, another five sub-prototypes that explain specific urban conditions: (a) where sponge space meets heritage sites; (b) where sponge space meets residential sites; (c) where sponge space meets commercial sites; and (d) where sponge space meets an open area of brownfields.

1. ANALYSIS

1.1 Mapping pollution data

1.1.1 Fuel leaks from boats

Due to pollution, the urban area of Tangxi remains underdeveloped (see Fig. 2). Most of Tangxi Canal's water pollution comes from fuel leaks from motorboats, and Tangxi's high volume of water traffic stems from the high density of industrial plants along the water, which require frequent cargo services. By the end of 2014, the waterway of the Grand Canal in Hangzhou reached its peak level of motorboat traffic,

[1] Hangzhou has no sponge city guidelines, but the Shanghai guidelines can be used, as they pertain to the same climate zone (Shanghai sits 200 km away from Tangxi).

which allows for full navigation for 2,000 boats per day. Reaching peak traffic levels in the Tangxi section of the canal brought particularly serious effects because this section has both cargo boats (usually 1,000 tons, 63 m) and tour boats (usually 750 tons, 50 m). A total of 455,704 boats dock at the ports along the waterway, and the number of boats passing through this section totaled 1,401,999 in 2014 (Cao et al., 2018, p. 499).

Two factors lead to water pollution from fuel leaks. First, when a ship carries a low-weight load (less than 20% load; Cao et al., 2018, p. 504), the fuel efficiency of the engine decreases and the engine-oil consumption increases in turn, leading to a rise in lubricating oil leaks. Major fuel pollutants include NOx, HC, CO, PM, SO2, and CO2 (Cao et al., 2018, p. 505). Second, ships carrying increased engine loads experience higher leaks of octanes that affect the environment[2] (Truchan, 2021). Additionally, rapid urbanization has increased tourist visitation to the area over the past three decades, which increased water traffic on the canal. Leaks from this traffic have degraded the water quality of the canal waters (Truchan, 2021).

The city of Hangzhou hired the StoryMaps[3] to provide data on water samples from 11 industrial sites in the Tangxi Canal. I identified their names as: Hangzhou Zuoer, Qianjiabang, Kedi Mechanical Inc., Shouqu Limited, Lianhua Global, Yuangang Steels, Qianchao Energy, Qianchao Concrete, Xixi Gu sectors 001 and 002, Debang Oil, Shangliyang Port, and Nanyang Bridge port. Except for Qianchao, Lichua Global, and Kedi, the industrial sites have been abandoned and their cargo ports have been converted to tour-boat ports.

These 11 industrial sites are close to major ports. All water samples contain high levels of petrol wastes in (higher than 0.5 mg/L of water). In general, engine oil and petroleum cause ecological and sanitary issues

[2] High-load boats were built before the 1990s, and they have an older version of a transmitter in their engines. The oil pump in these transmitters does not have a well-developed air lock, causing oil leaks when the boats carry heavy loads.

[3] StoryMaps is a global third-party agency with environmental scientists that are usually hired by government agencies to analyze environmental data and create diagrams on specific environmental issues of a particular place.

in Tangxi because it will decrease the oxygen concentration in water (Truchan, 2021). In peak seasons (July and August), the concentrations of petrol substances rise above 0.8 mg/L. I have mapped these data in Figure 4.

In Figure 4, the brown color indicates the worst condition: over or equal to 0.5 mg of petrol pollutants in 1 liter of water. The blue color indicates the least serious condition: less than or equal to 0.1 mg of petrol waste in 1 liter of water. Additionally, there are potential health and ecological risks from contaminants called persistent organic pollutants in the canal—the undegradable oils (Zhang, Q., Wang, X., Zhu, J., Li, Z., & Wang, Y, 2018).

1.1.2 Heavy metals from adjacent industrial sites, brownfields, and stormwater runoff

Heavy metal pollutants in the canal water mainly flow from adjacent brownfields (where industries are located) due to stormwater runoff. Hangzhou sits at the southeast corner of the Yangtze Basin, on the mouth of Hangzhou Bay, where cold air from the inner land meets seasonal warm air from the Pacific Ocean, causing storms in the summer. Hangzhou also sits in an alluvial plain of the east Qiantang River—one of the largest floodplains in China (see Fig. 41).

According to typographical information, canal-front brownfields start to slope to the canal side at about 20-120 meters from the banks. In Figure 3, I mapped the study result from the StoryMaps data showing heavy metal pollution from 11 different brownfields[4] along the Tangxi Canal from north to south, compared to conditions in their adjacent waters. Total concentrations of heavy metals in the soil (mg/kg) and in water (mmg/L) increase from north to south. If we compare these findings in an 11-cornered diagram (see Fig. 3; orange represents heavy metal concentration in brownfields and gray represents

[4] 11 sites follow an order of 21,3, 13, 19, 15, 17, 7, 9, 1, 5 from north to south. There are 11 sites only and the actual number are names only and does not represent the actual counts.

heavy metal concentration in water), we can see that heavy metal pollution in the land has a proportional effect on the adjacent water.

Canal-front typological studies

The land use in Tangxi District will play a significant role in the future (Cervero & Landis, 1997). Thus, I performed an urban typological study (see figures 6–7 and 11), for which I have presented results in a figure-ground diagram for Tangxi District and identified major urban types within a one-block (500–1,200 m, on average) area from both banks. Existing urban typologies include (a) commercial areas (red) such as wet markets and supermarkets (see Fig. 9); (b) institutional entities (blue) such as Tangxi People's Hospital, community centers, a primary school (see Fig. 10), and a community middle school; (c) existing housing settlements (brown), such as 150 condo buildings each containing 24–36 units and an existing danwei housing[5] community (yellow) including 5,724 workers' units, left over from the 1950s (Fig. 8); (d) existing industrial sectors (dark gray) and abandoned sectors (pink), as mentioned in the above sections; and (e) 11 existing canal-front brownfields (figures 13–14) totaling 1,306,343.16 square meters and (f)an heritage area (green); these features intersect with water surface and urban grids, extending through neighborhoods (see Fig. 12).

There is also a government initiated future development includes 280 condo buildings with 36–48 units apiece and a new central business district (CBD) area (figures 11, 15; CBD: 1,800,000 sqm, with an average building height of 120 meters) at the northeast mouth of the canal (City of Hangzhou, Tangxi District,

[5] A work unit, or danwei (simplified Chinese: 单位; traditional Chinese: 單位; pinyin: dān wèi), is the name given to a place of employment in the People's Republic of China. The term remains in use today, as people still use it to refer to their workplace. However, it is more appropriate to use *danwei* to refer to a place of employment during the period when the Chinese economy was not as developed and was more heavily reliant on welfare for access to long-term urban workers, or in the context of state-owned enterprises. Prior to Deng Xiaoping's economic reforms, a work unit served as the first step of a multi-tiered hierarchy linking everyone with the central Communist Party infrastructure. Work units were the principal method of implementing party policy. The work unit provided lifetime employment and extensive socioeconomic welfare—"a significant feature of socialism and a historic right won through the Chinese Revolution" (Bjorklund, 1986; Fig. 9B).

2019). The study revealed that first, a variety of urban typologies exist in Tangxi District, and second, future developments will double the local population while the new CBD will bring more business into the area. (Hangzhou City Department of Housing, 2022) Both factors will catalyze an increase in human-canal engagement.

1.2 Urban proximity studies

The magnitude, determinants, rate, and spatial distribution of urban growth pose major concerns for policymakers. Accessibility, neighborhood interactions, and spatial policies arguably act as the most influential factors in contemporary land use change (Verburg et al., 2004). Meyer's (2008) "sustained beauty theory" suggests that we must consider urban amenities when addressing the social-cultural landscape. Thus, I conducted an urban proximity study covering an area of 750 meters away from both banks (T. Wang, personal communication, October 22, 2022) to understand the accessibility to urban amenities and public spaces within the area. In this research, I analyzed seven main components of the area, including restaurants, tour ports, sightseeing locations, coffee shops, shopping places, public spaces such as squares, and family leisure areas, as well as other amenities, by mapping their locations on the map, with the aim of determining the accessibility of these elements of Tangxi's canal-front neighborhoods. The results (see Fig. 16) show that inadequate urban amenities exist in the canal-front area. In addition, the area contains no green spaces, so the city should work to add more green spaces to these neighborhoods. In most cases, newly added public spaces should complement existing amenities, such as the three existing kayaking clubs that need more spaces (see Fig. 17).

1.3 Traffic routes

"Transport infrastructure [can] stimulate and guide urban growth via the improvement of accessibility," assert Anas et al. (1998)—an assumption demonstrated in a long tradition of policies in Hangzhou intended to catalyze urban growth by investing in transport infrastructure. This urbanization primarily took place near water, as illustrated by the complex water routes and ports (see figures 20–21) developed along the canal and over 14.58 km of trails adjacent to it (see figures 21–22), as well as existing (including some planned) road networks that penetrate the canal neighborhoods (see Fig. 18).

2. SUGGESTIONS

2.1 Sponge-city-based green spaces and social interactivity: Cultural and social amendments

The sponge city theory, developed by Kongjian Yu (2015), makes use of green spaces to control pollution and other hazards caused by stormwater. "Sponge city," a metaphorical expression, provides a theoretical model of building green spaces for flood control that embeds complex ecological functions. The term "sponge" refers to the city as a membrane that can absorb precipitation, store water, handle seepage, and enable water purification. On certain occasions, the sponge will "squeeze out" stored rainwater for civil uses. In general, a sponge city has six elements: "infiltration, retention, storage, purification, use, and drainage" (Hangzhou City Department of Housing & Suburban Development, 2015; see figures 23 and 25), and its construction path includes the protection of the original urban ecosystem, ecological restoration and rehabilitation, and low-impact development (General Office of the State Council of China, 2015).

A sponge city entails an organic combination of restoration technology and social, environmental, and human factors. I recommend considering implementation of a sponge city design in Tangxi District for three reasons:

- The rapid urbanization of the Tangxi Canal, the rise of urban clusters, and the construction of urban facilities have led to the hardening of the subsurface, with 70–80% of rainfall forming surface runoff and only 20–30% penetrating underground (Shanghai Ministry of Construction, 2016, p. 5), resulting in stormwater runoff in summers.
- The foul smell of the canal has caused the surrounding residents to lose interest in riverfront activities.

- Water pollution, flooding, and loss of aquatic habitat in Tangxi are systemic and comprehensive problems that require systematic solutions, and the sponge city theory employs a systematic approach. In general, the annual average runoff ranges from 60–85 mm in the lower Yangtze, and the design of sponge green spaces could decrease it to 12.4–33.4 mm. Since Hangzhou continuously records precipitation levels (see Fig. 26 for annual precipitation in Hangzhou), sufficient reliable data exist for determining how much sponge city space the study areas need to adequately absorb stormwaters.
- I suggest converting existing canal-front brownfields in Tangxi into public spaces with parks and bicycle routes (see Fig. 27), creating a ring-shaped green space system (Fig. 28) that contains native vegetation and connects existing trails and sightseeing locations. According to the Shanghai Ministry of Construction (2016, p. 5), one unit of a green sponge space will absorb another 20–30% of precipitation in proportion to an equal amount of square footage, simultaneously storing another 10–20% of rainwater, leaving only 40% of excess stormwater (see Fig. 24). Therefore, I suggest installing a ring of sloped (15% on the canal side and 10% on the urban side)[6] green space in between the bank and the adjacent area (see Fig. 20; Shanghai Ministry of Construction, 2016). The width of the green space should total 20 meters on average (different urban conditions require different potential modifications; Shanghai Ministry of Construction, 2016). In addition, I also suggest installing a ring of low-lying drainage space within the green belt to achieve better performance of rainwater drainage and storage. The width of the drainage space should total 0.75–1.25 meters on average (Shanghai Ministry of Construction, 2016, p10).
- In conditions where buildings sit close to the canal, such as in the heritage area and danwei housing area, I suggest adding another green space in between the building and the water. This

[6] Some areas can have a 5% slope if it has existing green spaces beside it.

will allow rainwater to flow from the roofs to fall directly onto the belt before entering the sponge, thereby reducing the possibility that it will overflow into the canal.[7]

- According to the City of Hangzhou, no major development should happen along the canal (T. Wang, personal communication, October 22, 2022). Therefore, I suggest adding more urban amenities and civil facilities such as locations for street vendors, areas for street music activities, outdoor restaurants, and public areas with wireless internet services. According to Fu and Jin (2020), these urban amenities should be included at every major intersection (Fig. 39).
- I recommend adding more educational features such as boards that show local plants, animals, and hydrological processes.
- I suggest relocating running factories to other areas to transform the canal into a place for wellbeing (e.g., an area of leisure activities, public spaces, and green spaces).
- I recommend using electric-powered or self-pedaled boats to allow for more human-water engagement and reduce the number of ports.

Additional supplementations—sectional studies

Studying typical sections of the Tangxi Canal provides basic site characteristics for designers to consider in planning waterfront spaces with the aim of attracting more social activities to the canal front. The findings of this research will assist planners in considering linear spatial expansion, a means of catalyzing human-water interactions. (Prominski et al., 2012)

[7] In the southern Yangtze Delta, 1 cm of rain in a 100 sqm roof produces 2,271.25 L of runoff per year. The average rainfall totals 145 cm in Tangxi. One danwei house roof is 150 sqm, and 150 x 22.71 x 145 is 493,942.50 L—the total runoff/danwei house/year. This is 75% after vaporization: 370,456.87 L of the polluted stormwater runoff from the roof flows into the canal per year (Ballo et al., 2009).

The continuous brownfield space along the canal is underdeveloped, and all areas of this space slope toward the water. Turning them into public spaces and green spaces provides a viable option that would expand the linear space in Tangxi's canal-front area.

According to *River, space, design: Planning strategies, methods and projects for urban rivers*, linear expansion along waterways—in terms of the magnitude, determinants, rate, and spatial distribution of urban growth or urbanization—poses major concerns for policymakers. By incorporating these principles, this design strategy presents a possibility for improving the riverbank while at the same time widening the canal slightly. This reconfiguration of the riverbank allows the urban infrastructure to be directly interwoven with the water space and can thus elevate formerly insignificant or degraded watercourses as a prominent component of the urban landscape and make them accessible again. Further, this approach facilitates direct contact with the water through activities such as swimming or canoeing (Prominski, M., Stokman, A., Zeller, S. 2012, p.52) (See Fig. 40). I documented sections of the canal spanning different urban conditions. These sections are visual references professionals who will work on Tangxi's restoration.

2.2 Sectional studies on different conditions

To provide further understanding, I performed six sectional studies on how a sponge green space could function in Tangxi. The sectional study in Figure 21 shows the baseline condition. According to the Shanghai Ministry of Construction's (2016) guidelines for sponge city construction, one unit of a sponge green space includes, first, a 3-meter-wide sponge space between the road and the sidewalk, which drains rainwater away from the road. Second, it includes a 20-meter-wide sponge green belt between the sidewalk and the canal bank (the slope percentage on the street side varies according to different conditions; the canal side has a constant slope of 15%). Further, I suggest re-sloping an existing boardwalk along the canal to 5% inward to direct water away from the canal; adding a drainage slot in between the boardwalk and canal serves as another option. The surface of the sponge layer includes five layers, as follows (from top to bottom): the top vegetation layer, membrane soils for absorbing water, a gravel layer, a drainage pipe layer, and the earth. Storage pipes are implanted every 5 meters under the second layer to store rainwater (Shanghai Ministry of Construction, 2016). I do not suggest changing the material of the ripraps if heritage stone forms the existing portion. However, most areas in the Tangxi section of the canal consist of earth exposed directly to water, so I suggest constructing a concrete layer there to prevent further erosion.

2.2.1 Heritage conditions

The Qinghe region is a heritage area with various examples of Qing and Ming dynasty architecture (see Fig. 30). It contains a Ming dynasty heritage street with various tourist spots (see Fig. 31). According to the sectional study for which results are displayed in Figure 32, heritage buildings sit very close to the water. I suggest reducing the width of the existing canal-front boardwalk, which would leave five meters of space for installing a sponge space between the canal and the heritage area, thereby directing water away from the canal and extended bridge area.

2.2.2 Large open areas of brownfield

Two types of brownfield exist in the study area. In the first condition, the brownfield has a low height, and in this case, I suggest extending the width of the sponge green space. This choice will allow for another 10% of slope reduction (Shanghai Ministry of Construction, 2016) because the tree area in the parks will absorb more rainwater, which will reduce the performance pressure of the proposed sponge space (see Fig. 34). In the second condition, the brownfields meet the ports. The two existing port areas in Tangxi Canal sit only one meter above the water surface. In this case, I suggest re-sloping the green space to a 10% steeper grade and raising the street plane outside of the field by about 15 meters (see Fig. 35; the average height of a tour boat is 15 meters), which will achieve the 20% absorption advised by the Shanghai Ministry of Construction's (2016) guidelines for sponge city construction.

2.2.3 Housing condition

Most of Tangxi's danwei housing flats were built from 1950 through the 1970s and generally sit close to the canal—about 50 meters away on average, with some areas reaching 10 meters from the canal. After the demolition of two neighborhoods in the 2000s, the remaining properties are now mainly concentrated in the southeast of the Tangxi Canal area. These houses require maintenance due to their poor condition, but because of their historical value, demolition is not currently recommended (T. Wang, personal communication, October 22, 2022). Three aspects of these flats have a detrimental effect on the canal:

- Due to the technical limitations of the 1950s, most of the roofs have poor drainage, and a large amount of precipitation likely slides down from the eaves and flows directly into the canal.
- Not all flats were included in the state-run urban planning that occurred after implementation of the reform policies, so their drainage features have not been updated, leading to excess stormwater runoff that carries pollutants during typhoon seasons. In extreme weather conditions, as shown in figures 29 and 30, floods fill the entire residential area, posing a great risk to the canal environment.
- The neighborhoods were built during the Communist era, which usually had little regard for greenery, leading to a great need for green infrastructure in these danwei complexes.

Therefore, I propose the following solutions to address this situation (see Fig. 36): (a) Remove the road along the canal side of the flats and replace it with a pedestrian path to increase public space in the neighborhood; (b) keep the existing pedestrian path along the canal and re-slope it to 5% away from the water; (c) add a sponge green belt between the river walkway and the neighborhood walkway, ensuring this green belt retains a common 20 m width (in some situations, 30 m is recommended) and a common slope; (d) add a two-meter-wide sponge green belt with a drainage ditch between the walkway and the flats, which will lead rainwater from the roof into the ditch; (e) since Hangzhou uses a lot of ginkgo trees as street trees, use another native tree species in the area—the camphor tree—because ginkgo trees drop a lot of pulp in the spring, which clings to the road surface, causing pollutants to accumulate. During spring, the time of high tide in the canal, pollutants are easily carried into the water. Further, the fast growth of camphor trees, which can form a cluster of trees in 5–10 years, can prevent soil erosion in a short period of time (Shanghai Ministry of Construction, 2016).

2.2.4 CBD business district condition and condo neighborhood condition

In 2030, the planned central business district (CBD), with high-rise buildings as well as a newly built high-rise residential area, will sit 100–150 meters away from the canal, a suitable distance for building public spaces. I offer the following suggestions for accommodating this planned development (see Fig. 37): (a) Keep the street on the canal side of the high-rise. This will extend the canal tour bus line from downtown Hangzhou to the Tangxi section; (b) add a two-meter-wide sponge green belt on the high-rise side of the street, which would function similarly to measures taken in the danwei area; (c) because of the width between the office buildings and the canal, install a widened sponge green belt between the street and the canal, as the green space can function as a public space within the new commercial center in the future to enhance canal culture and social interaction; and (d) change the bank material from traditional rock to concrete. The CBD area generally sits 10 m above water level, which will prevent flooding; thus, the sponge here serves to prevent further erosion of rock banks, ensuring the stability of the bank (Shanghai Ministry of Construction, 2016).

I have also provided 3D drawings of these conditions for reference (see Fig. 38).

Conclusion

In summary, it is feasible to transform the Tangxi Canal district into a dynamic urban space with good environmental conditions while simultaneously enhancing and sustaining human-water interactions. The restoration plan for Tangxi Canal requires a healthy canal water body and a well-developed canal front with good accessibility to urban amenities and public spaces. In particular, adding more public spaces and green areas will address pollution and increase the Tangxi Canal's ecological performance, while at the same time rebuilding the socio-cultural structure of Tangxi.

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Figures

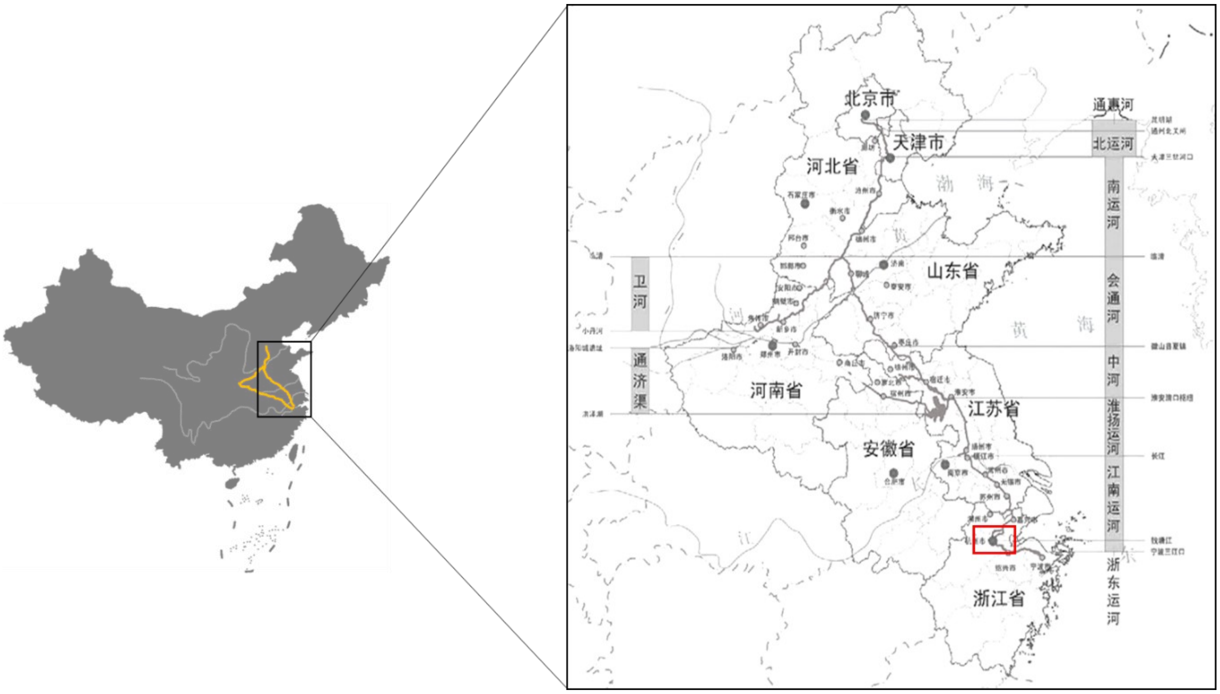


Fig 00 A – the location of Hangzhou in China and its canal section - created by author

Fig 00 B – the location of the Tangxi area in Hangzhou, - created by author

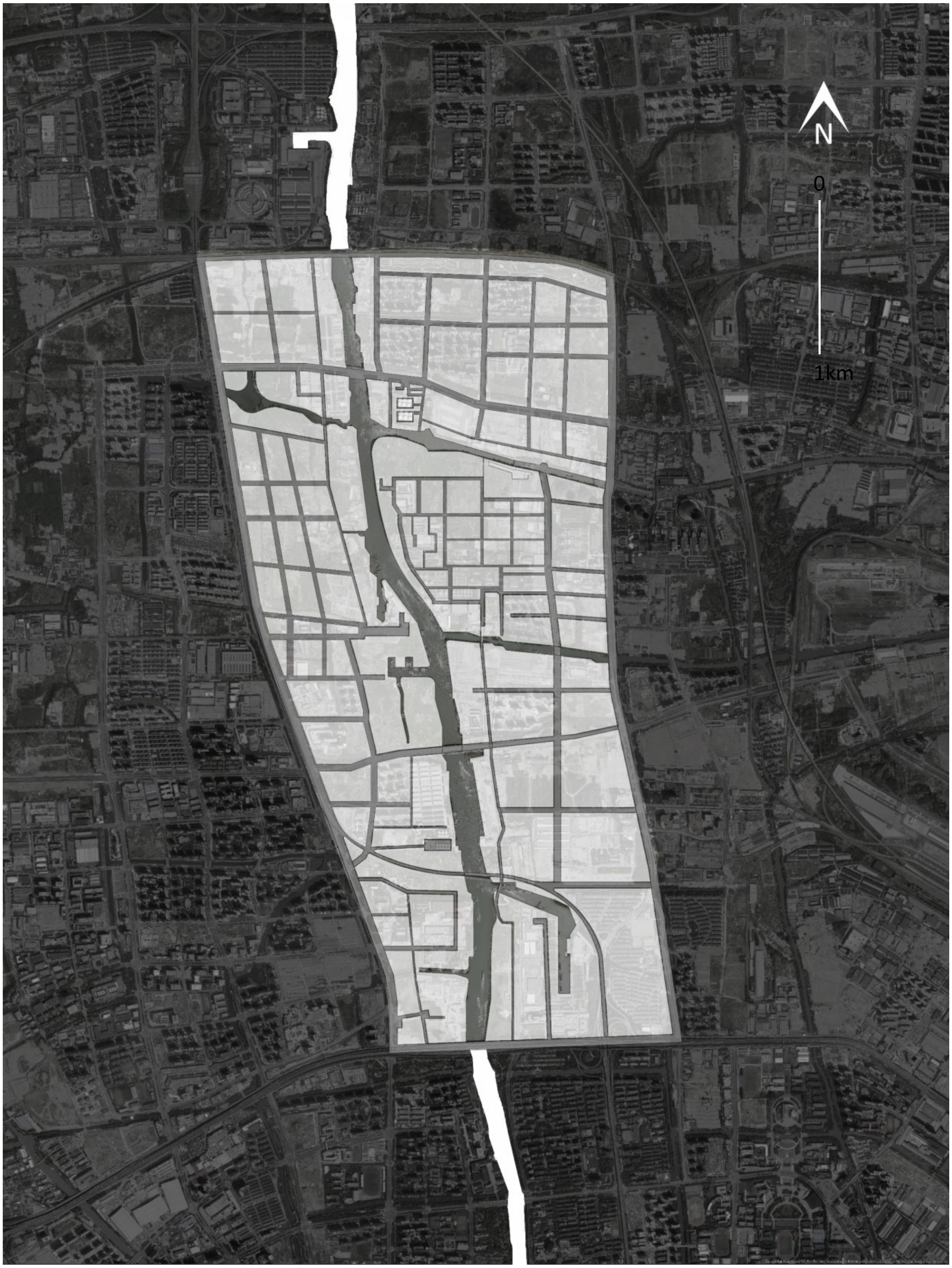


Fig 1 – the location of the studied area, - the Tangxi Canal and surroundings, urban blocks - created by author

Fig 2 – Mid-Tangxi Canal region - provided by the city of Hangzhou, 2022

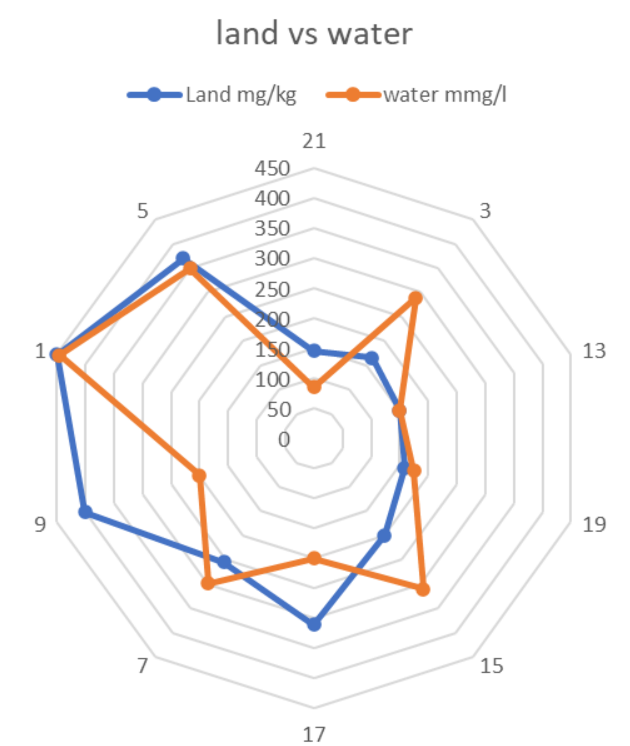


Fig 3 - Truchan, E. (2021). *Conditions of heavy metal pollution from 11 different sites along the Tangxi from north to south.* The Grand Canal's sustainability. ArcGIS Story Maps.

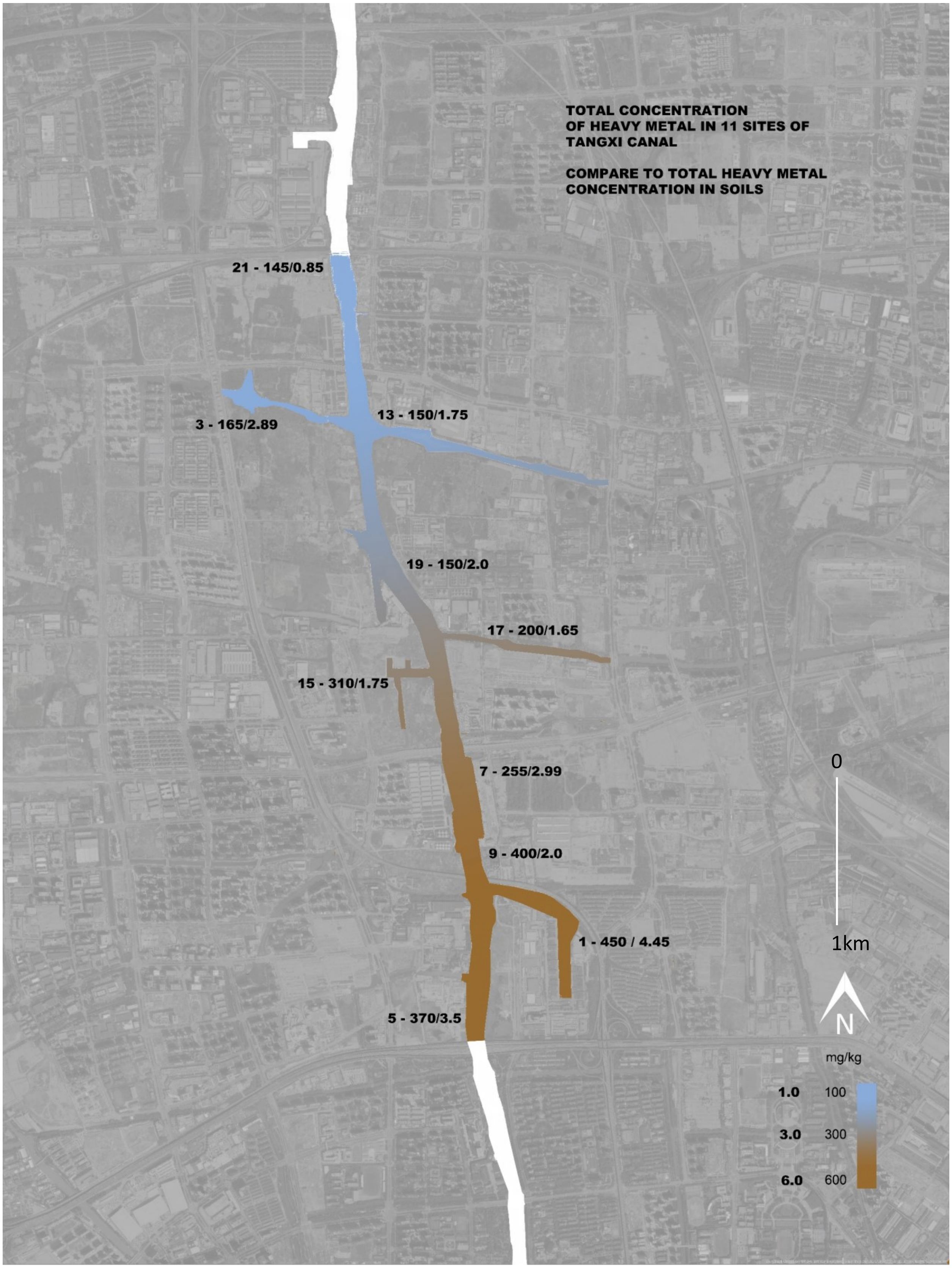


Fig 4 – Mapping study, created by the author, data provided by the City of Hangzhou, 2022

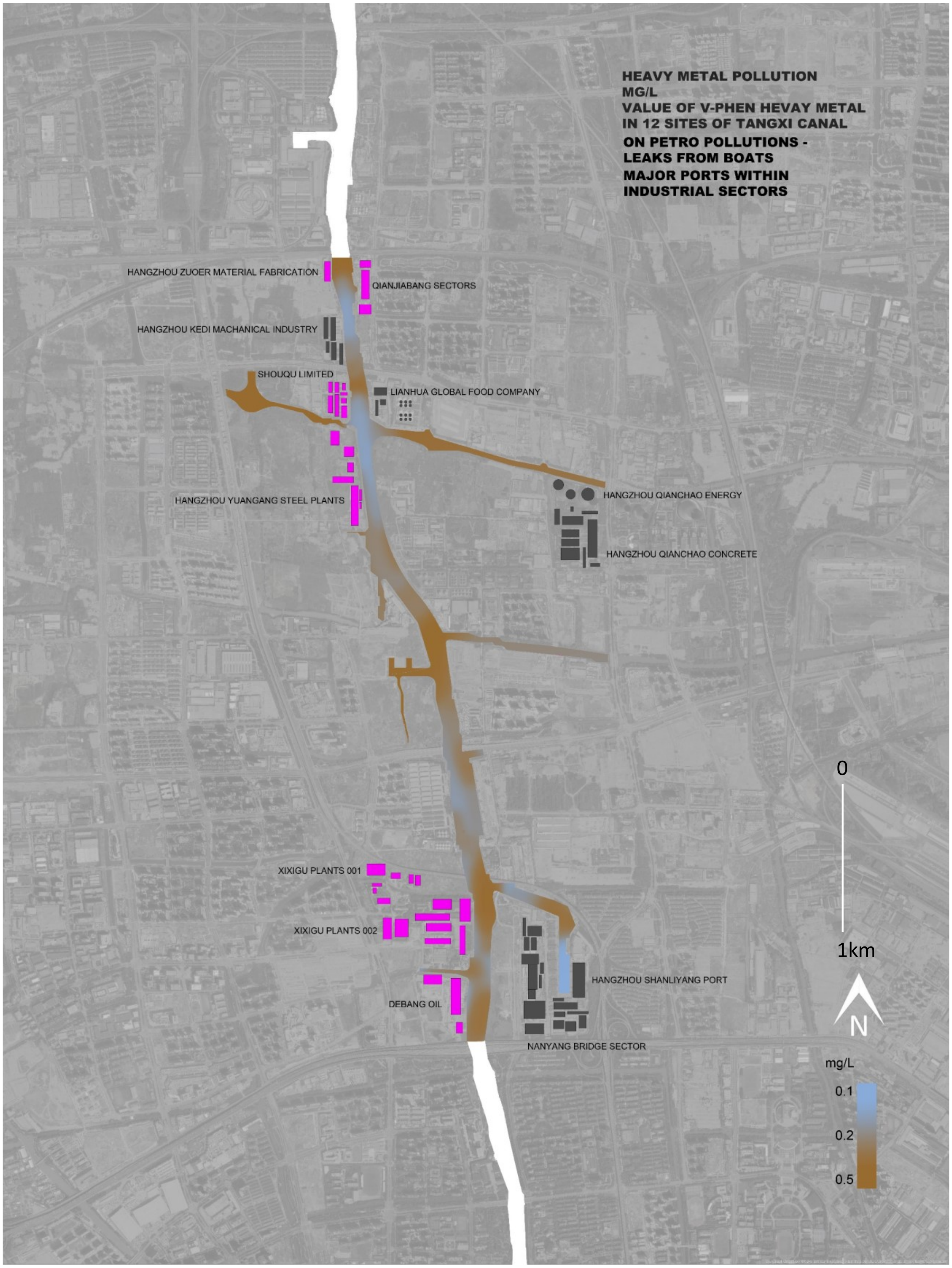


Fig 5 – Mapping study, created by the author, data provided by the City of Hangzhou, 2022

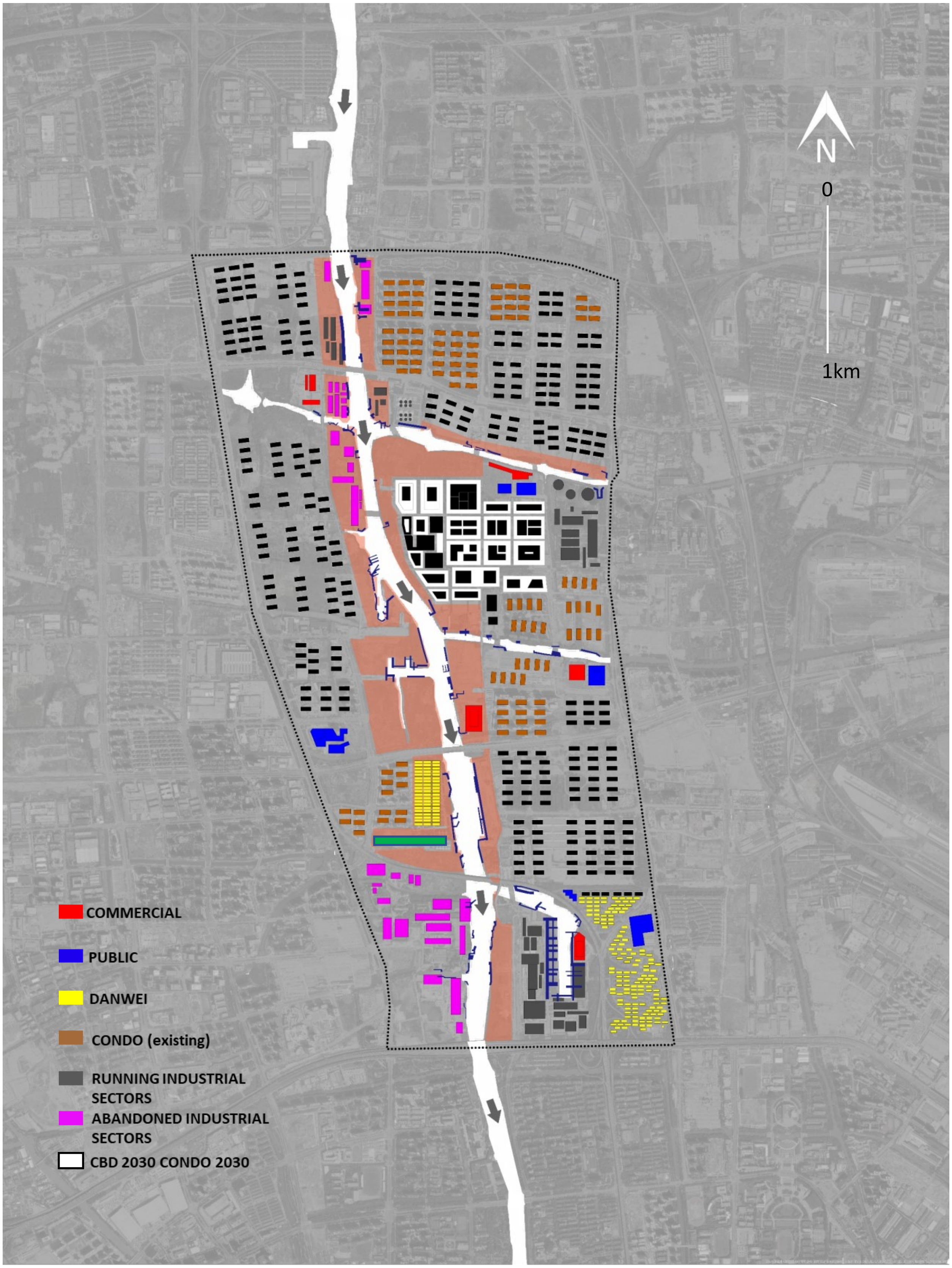


Fig 6 – Mapping - urban typologies, created by author data provided by the City of Hangzhou, 2022

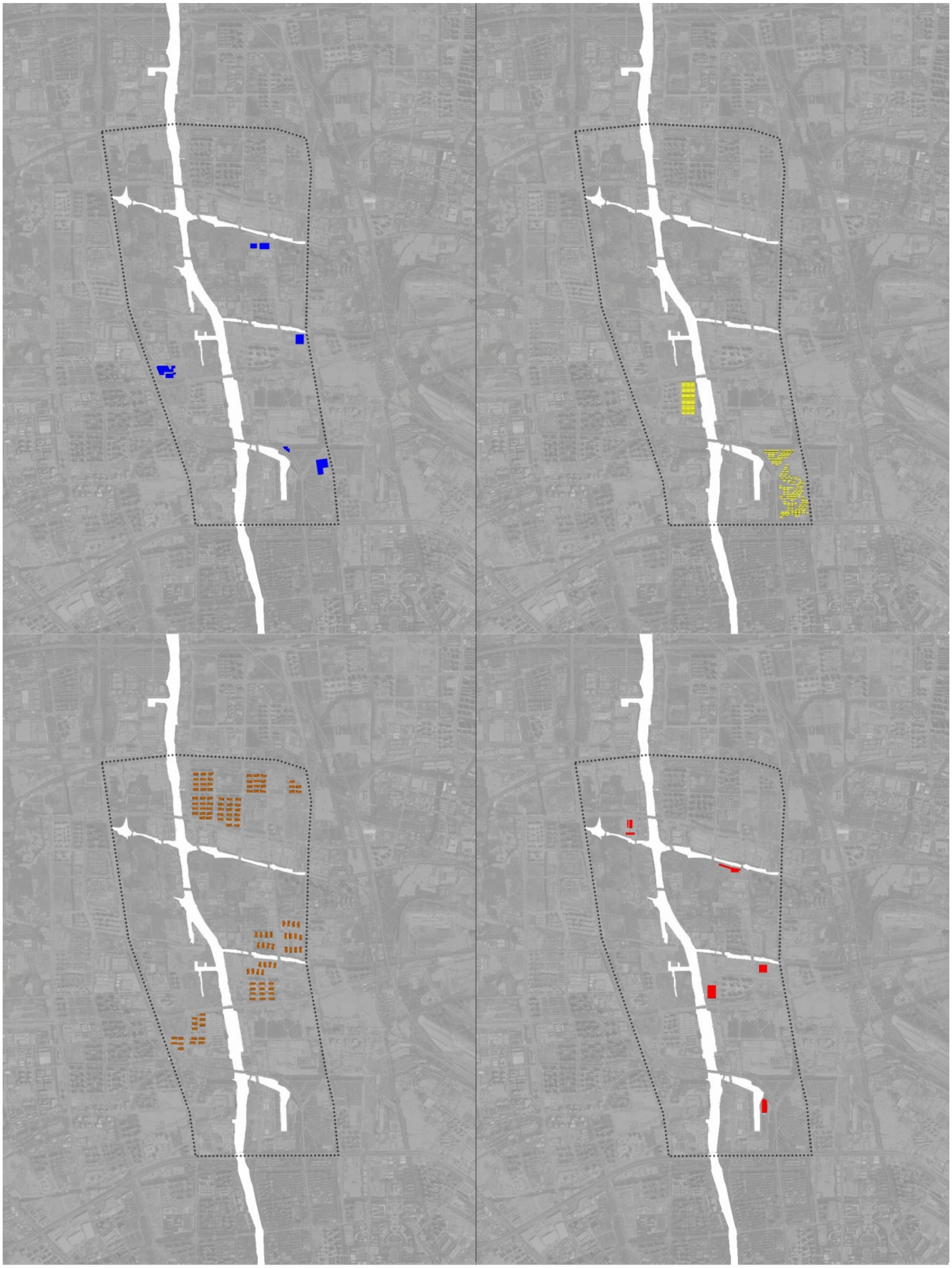


Fig 7 – Mapping – typologies separated, data provided by the City of Hangzhou, 2022

Fig 8 – Canal side Danwei Housing – photo was taken by the author in 2010

Fig 9 – Canal side wet market and street vendors – photo taken by the author in 2015

Fig 10 – Primary School students joining activities in urban farming and new campus – Qianjiang News, 2016

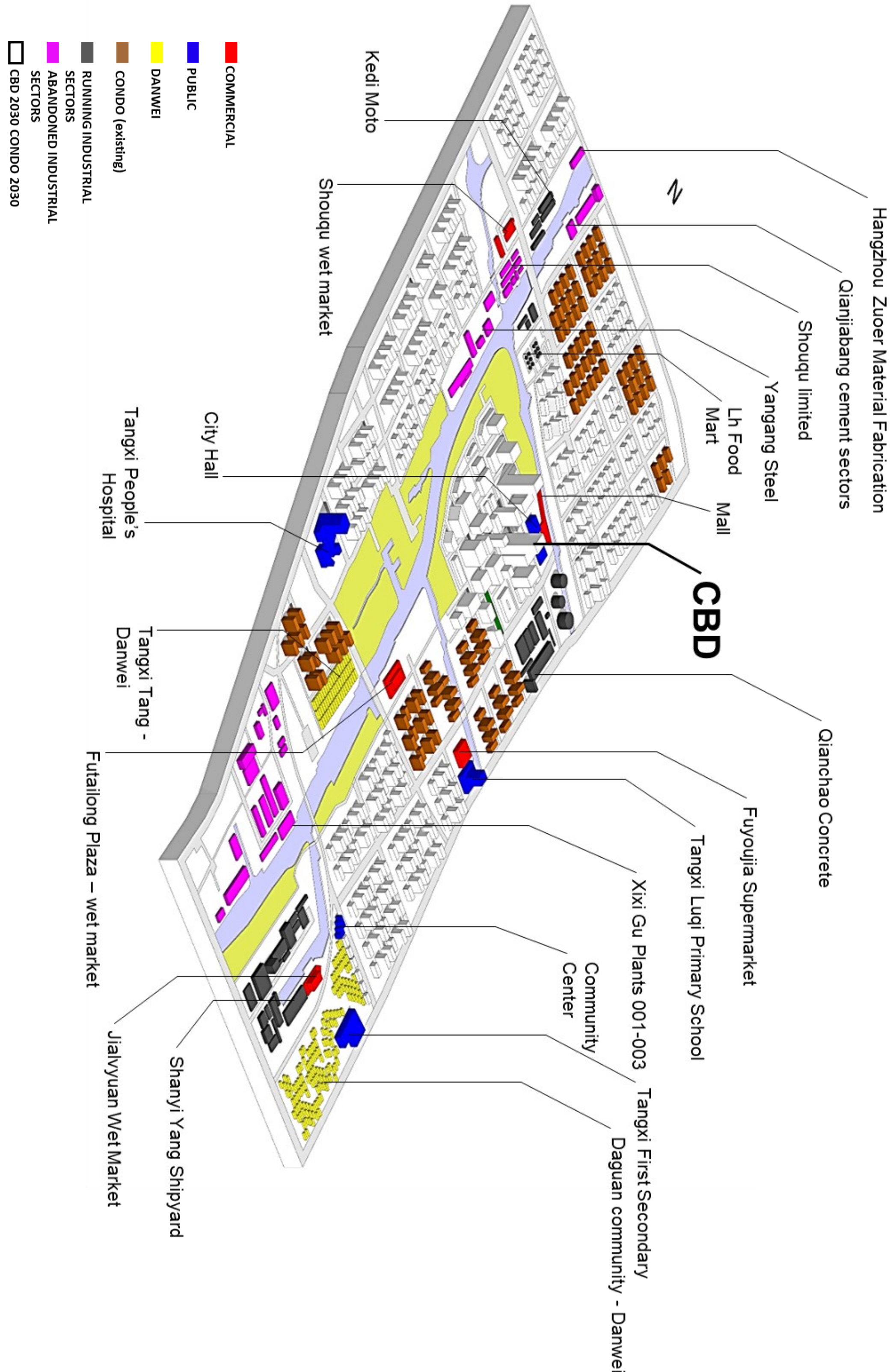


Fig 11 – Urban typologies, 3D

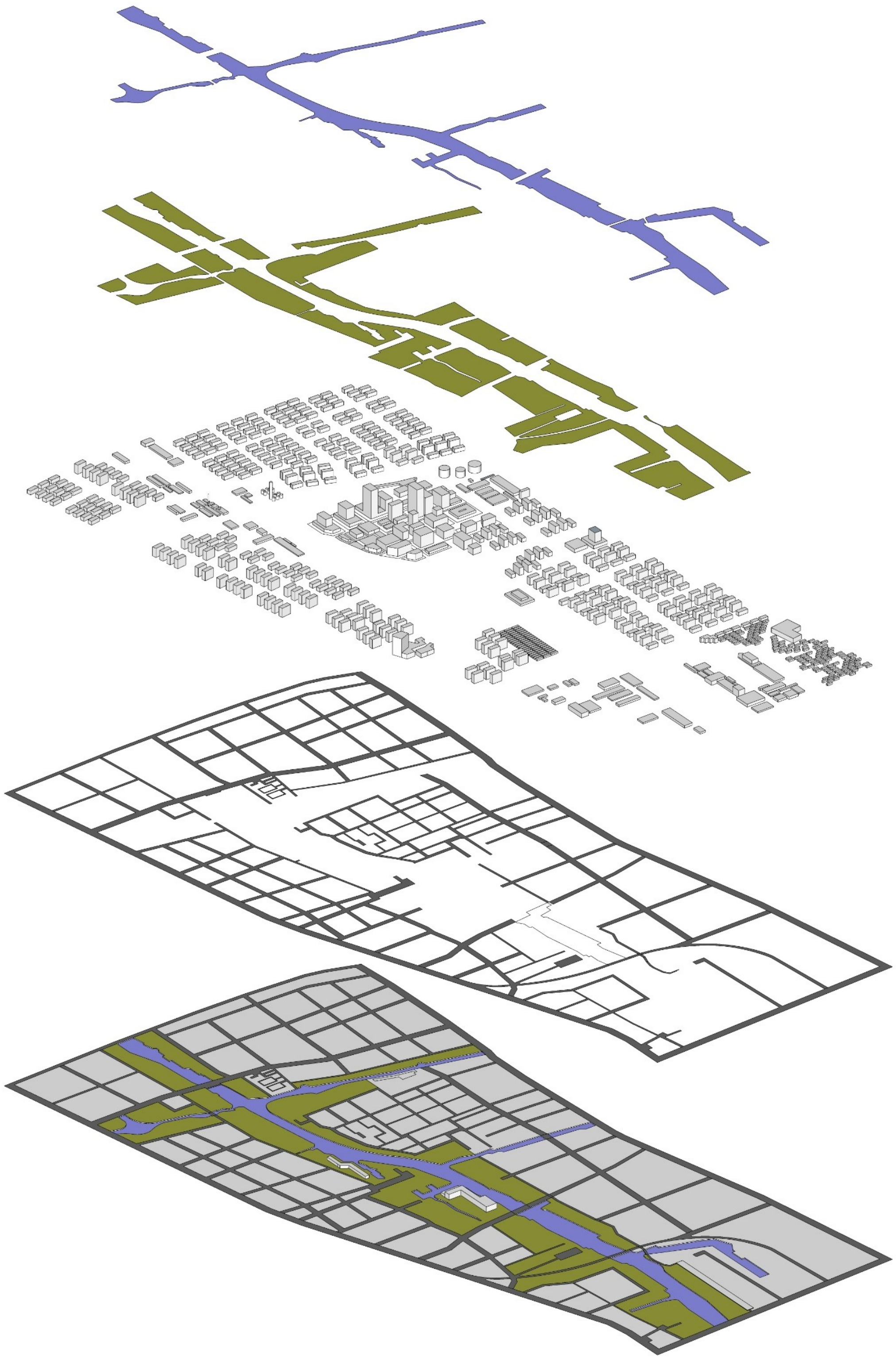


Fig 12 – 3D study, brownfield and its relation to the canal and urban grid

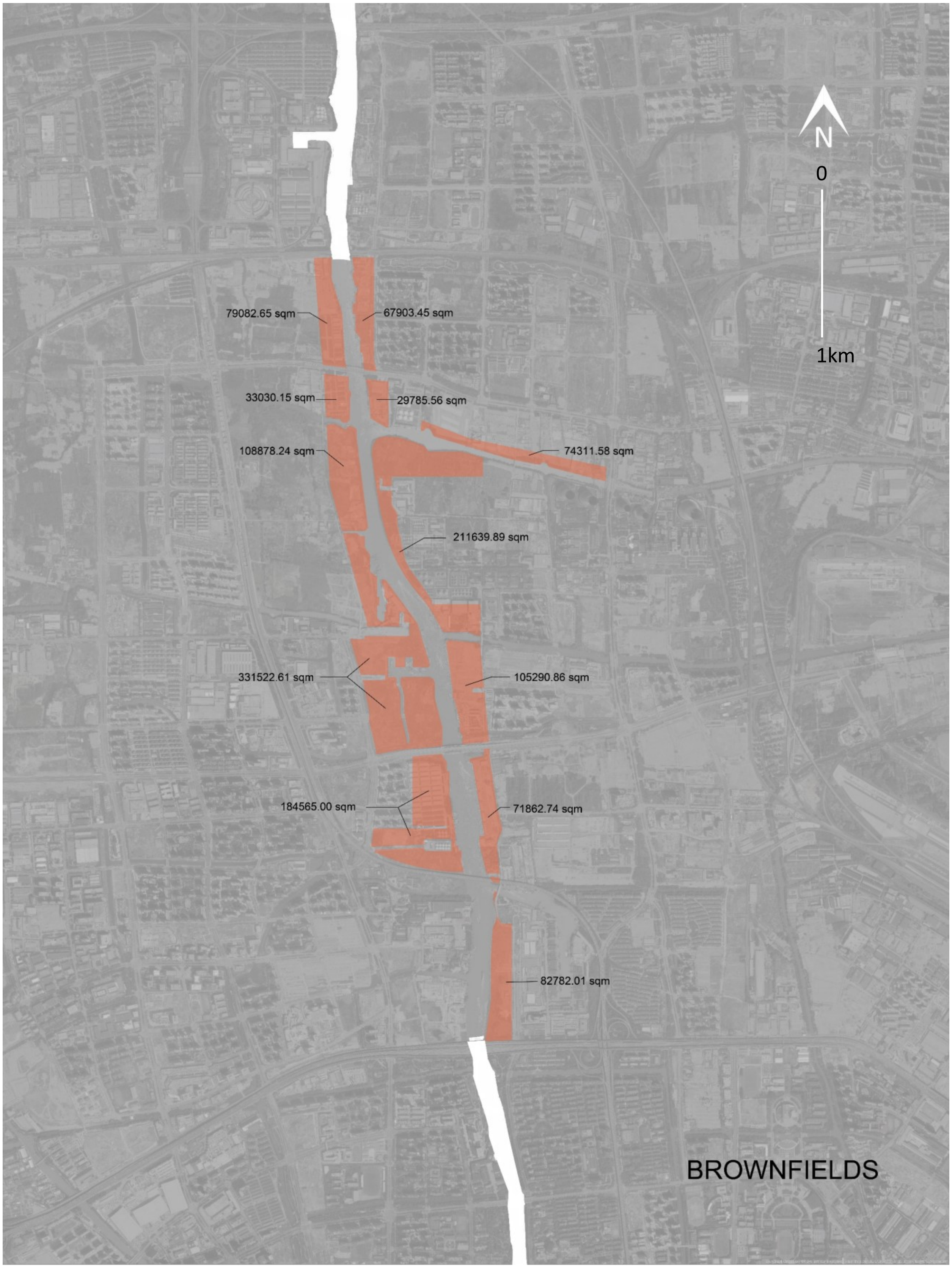


Fig 13 – Mapping study, created by the author, data provided by the City of Hangzhou, 2022

Fig 14 – Tangxi Canal front Brownfield, Public domain

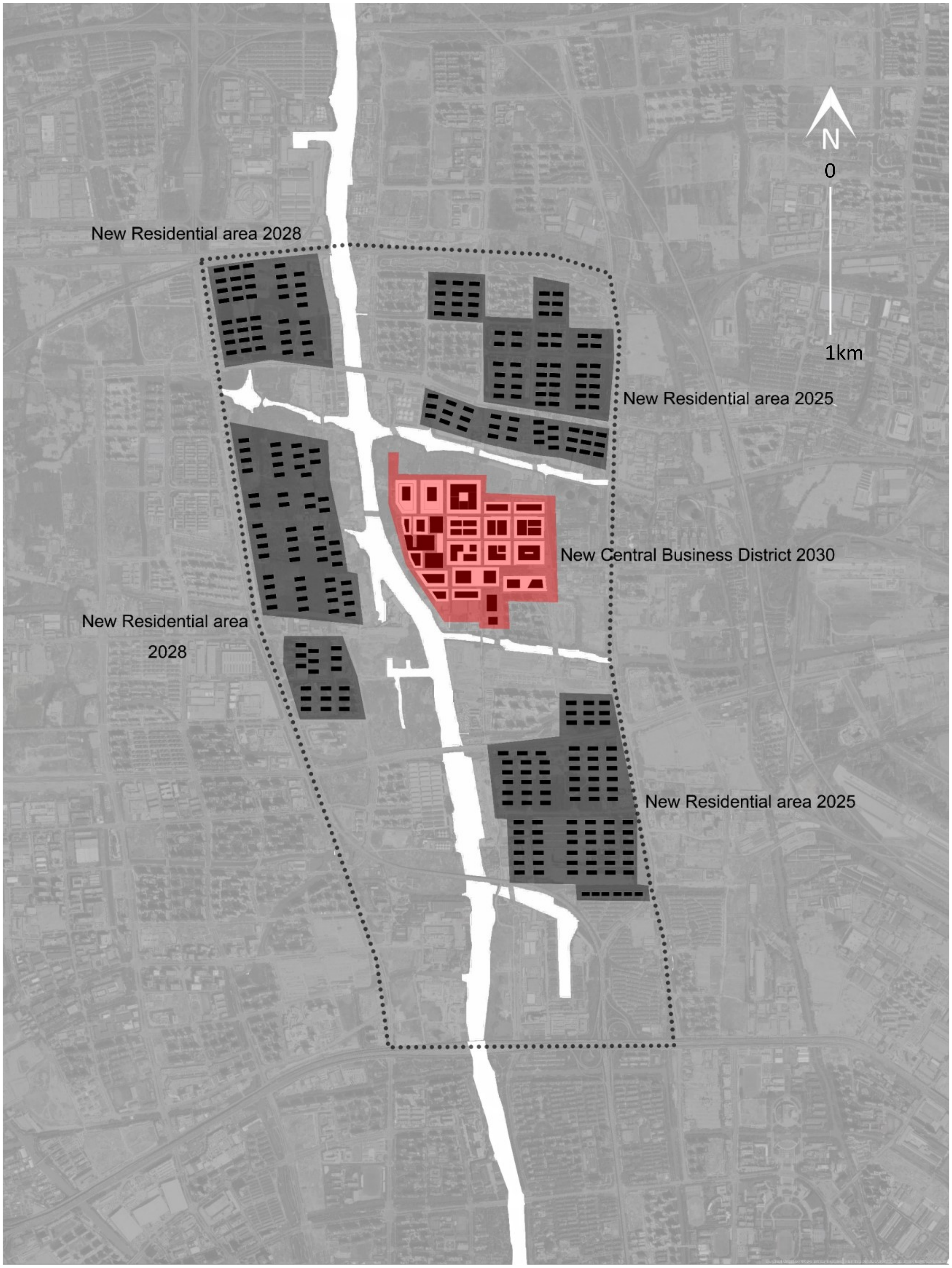


Fig 15 – Mapping study, created by the author, data provided by the City of Hangzhou, 2022

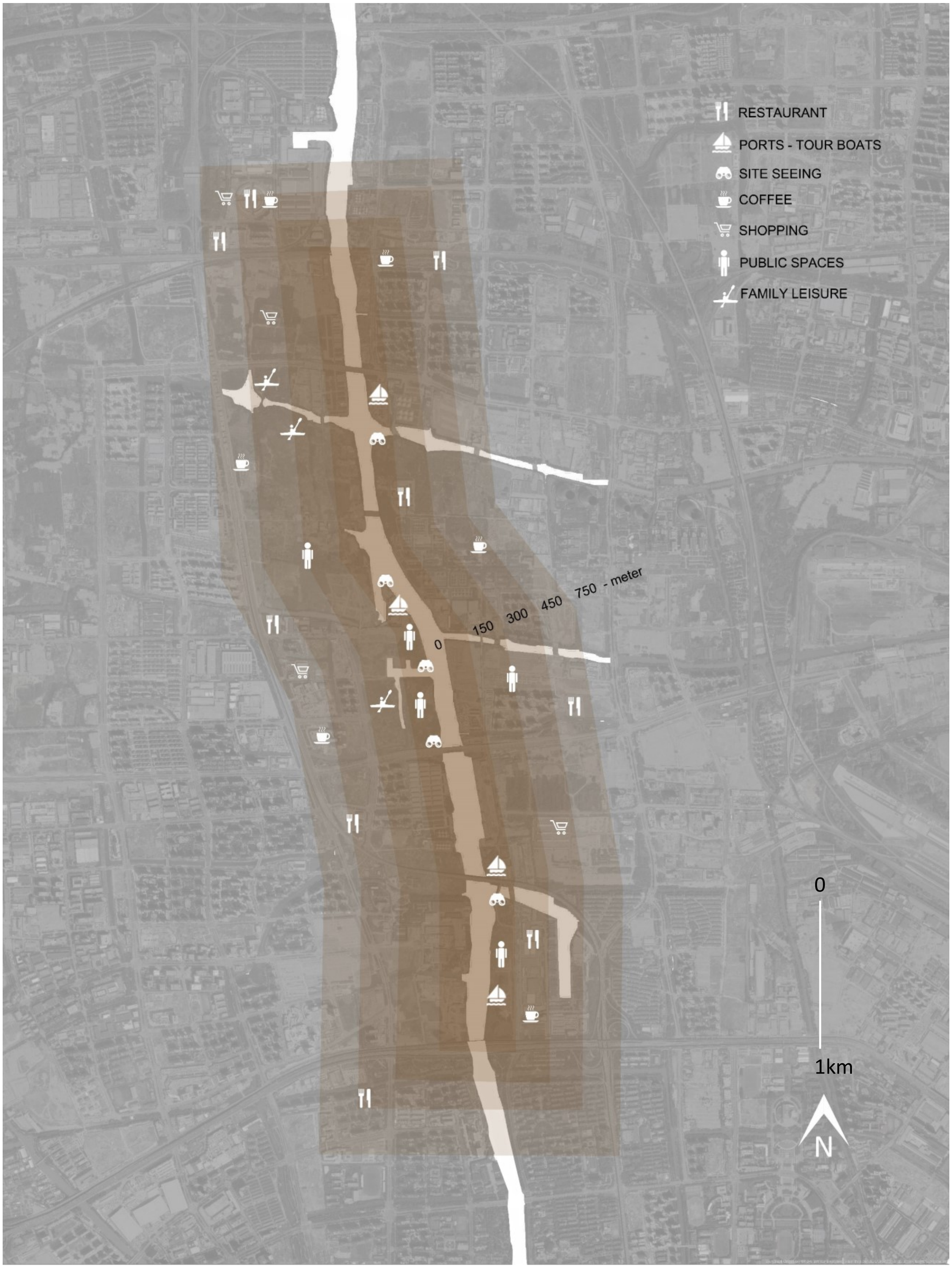


Fig 16 – Mapping study, created by the author, data provided by the City of Hangzhou, 2022

Fig – 17 – Kayak Club – Hangzhou City News 2018

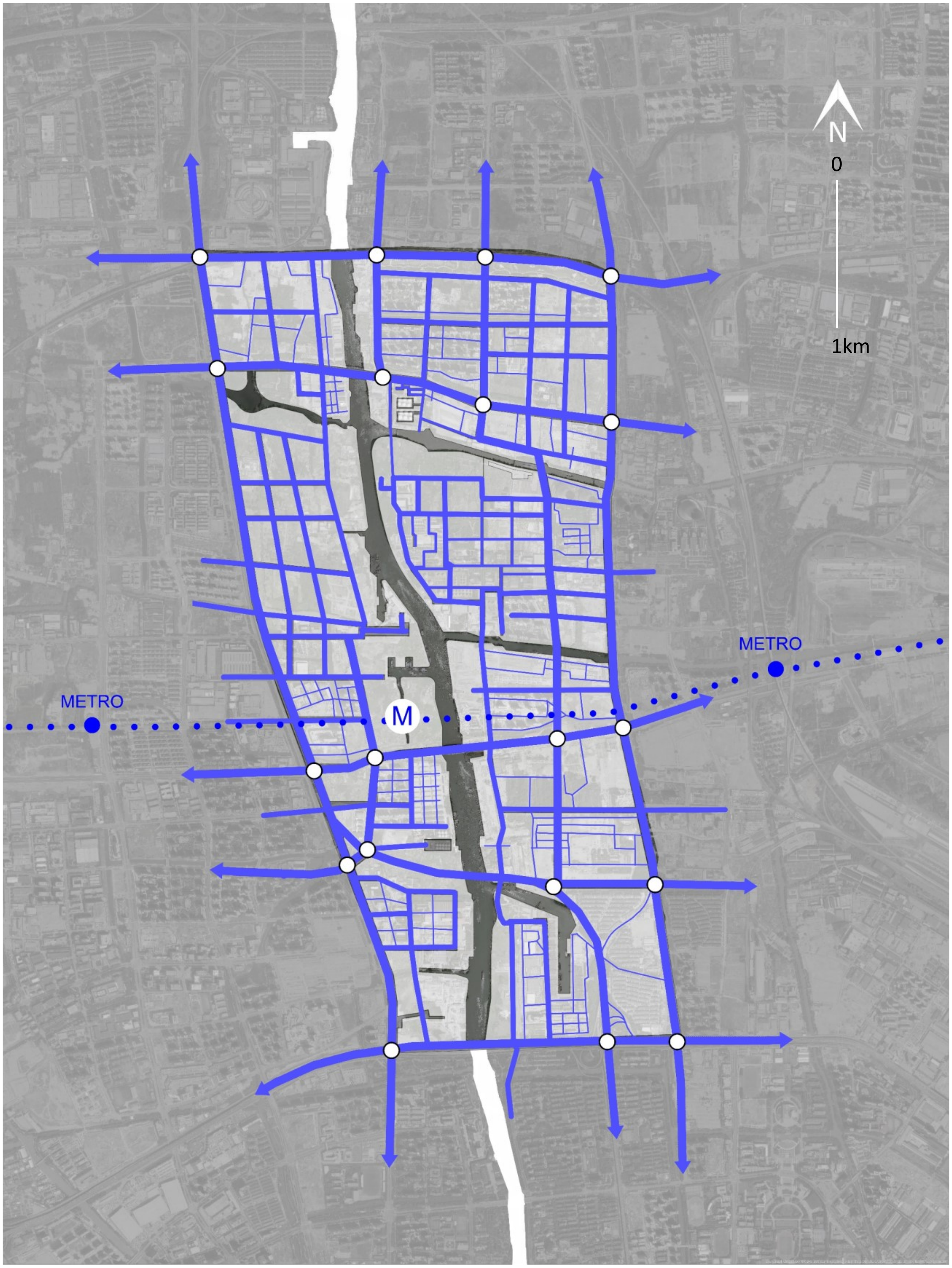


Fig 18 – Mapping study, created by the author, data provided by the City of Hangzhou, 2022

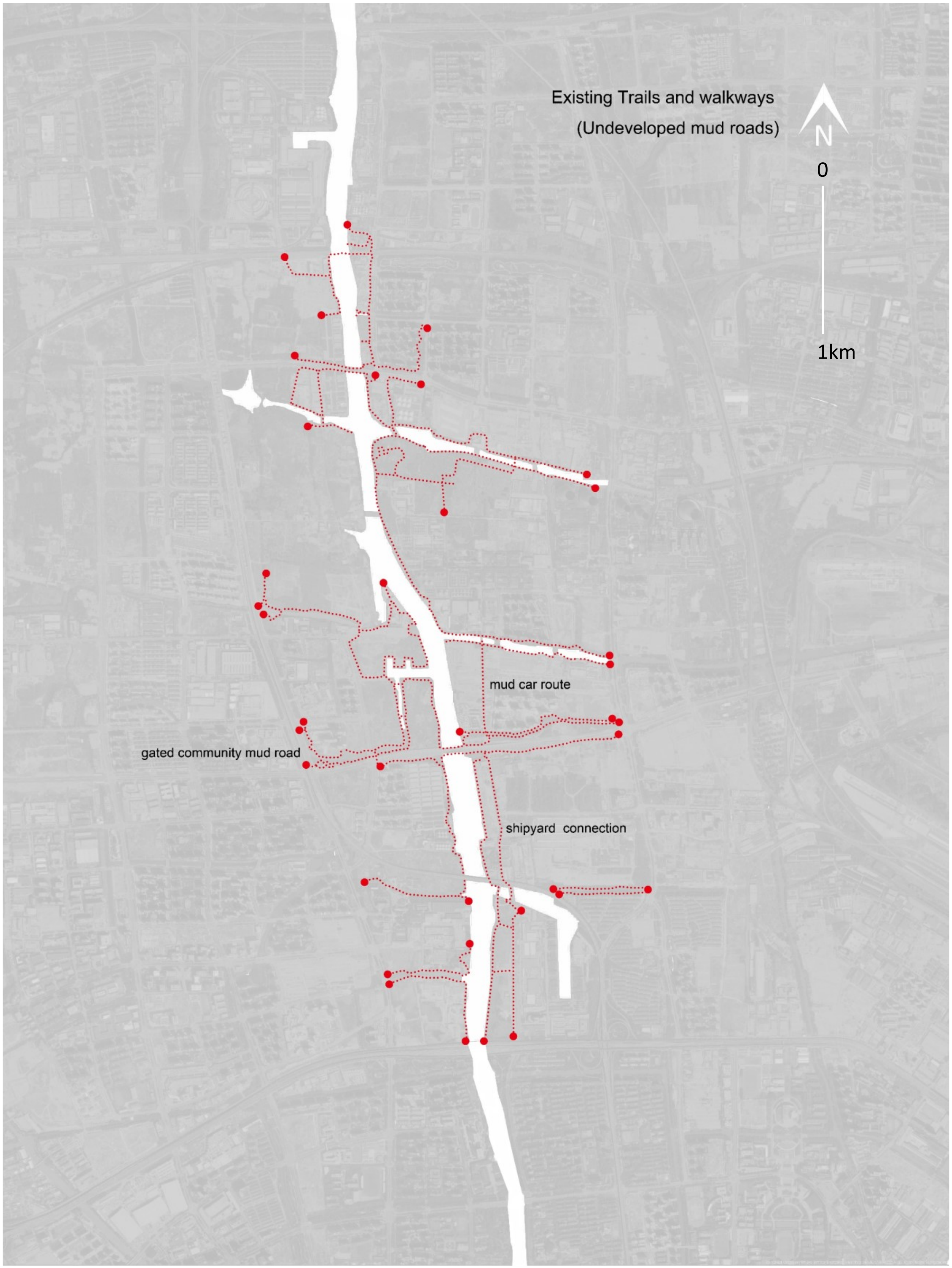


Fig 19 – Mapping study, created by the author, data provided by the City of Hangzhou, 2022

Fig 20 – Trails – Hangzhou Daily, 2018

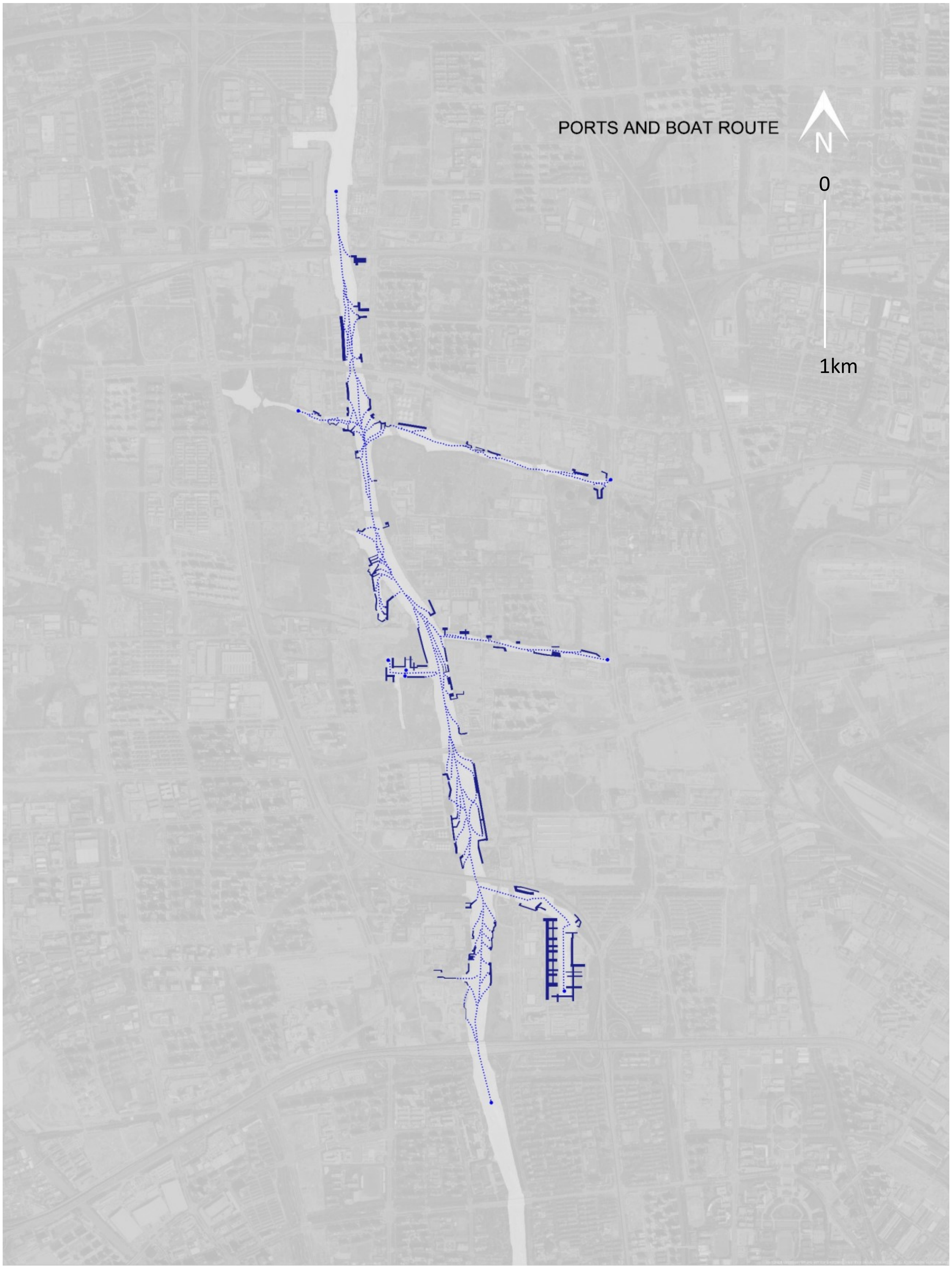


Fig 21 – Mapping study, created by the author, data provided by the City of Hangzhou, 2022

Fig 22 – Boat route – Hangzhou Three Rainbows collection and Feng Shen News - 1998

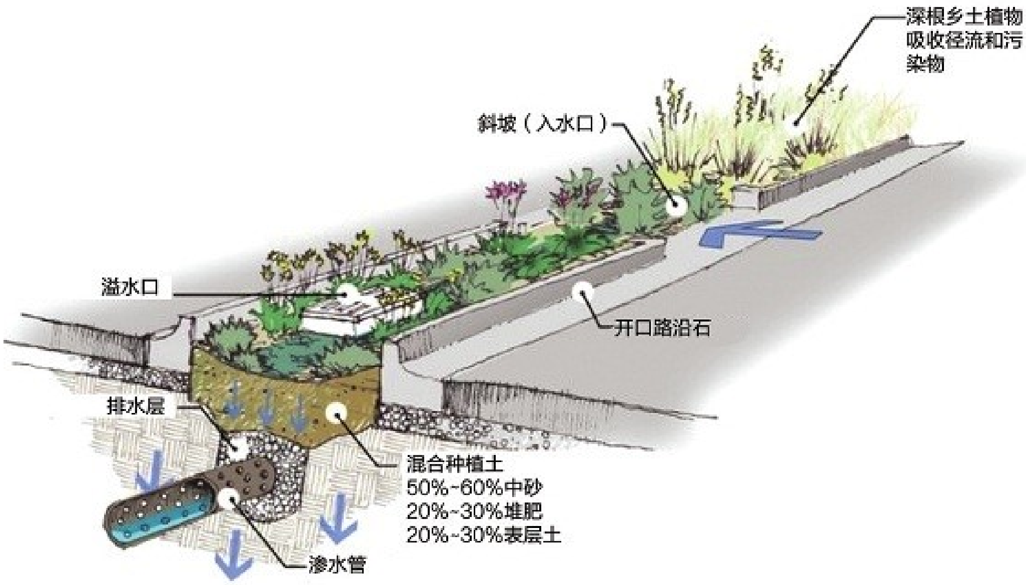


Fig 23 - 住房城乡建设部 (Hangzhou City Department of Housing & Suburban Development). (2015). 海绵城市建设技术指南——低影响开发雨水系统构建 (Sponge city guide). Hangzhou, China.

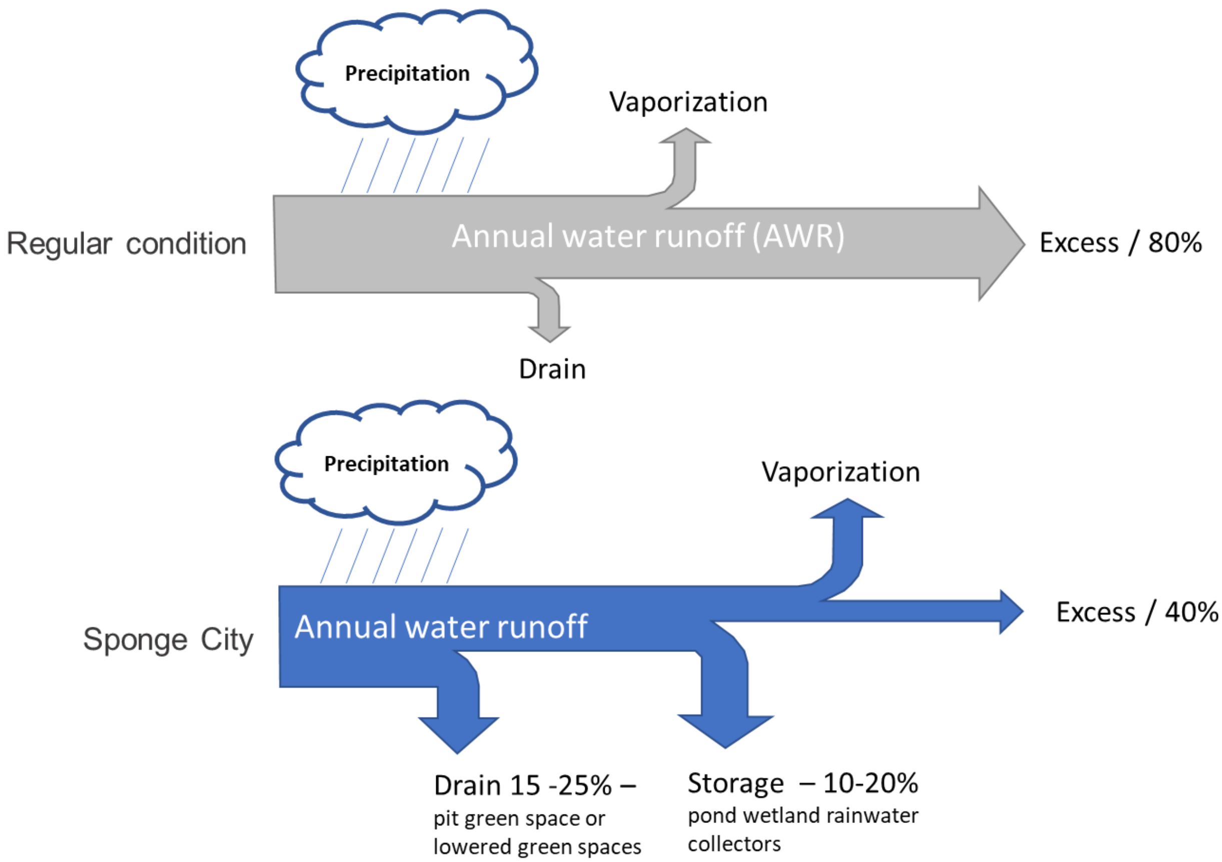


Fig 24 – Diagram of Sponge City Data, The city of Shanghai, Ministry of Construction (2016) Sponge City Construction Guideline. Congress of Shanghai presents

Fig 25 – Explanation of Sponge City, The city of Shanghai, Ministry of Construction (2016) Sponge City Construction Guideline. The Congress of Shanghai presents

平均降水量 mm（英寸）	79.8 (3.14)	86.1 (3.39)	143.7 (5.66)	122.5 (4.82)	128.2 (5.05)	211.8 (8.34)	180.3 (7.10)	156.1 (6.15)	130.1 (5.12)	78.6 (3.09)	72.3 (2.85)	48.6 (1.91)	1,438.1 (56.62)
平均降水天数（≥ 0.1 mm）	12.4	12.1	15.3	14.5	13.8	14.6	12.4	13.8	11.7	9.0	9.3	8.5	147.4
平均相对湿度（%）	75	75	75	74	74	80	76	78	79	76	74	72	76
月均日照时数	102.0	97.2	116.4	140.6	164.7	136.6	212.7	193.0	143.9	144.6	129.0	128.7	1,709.4

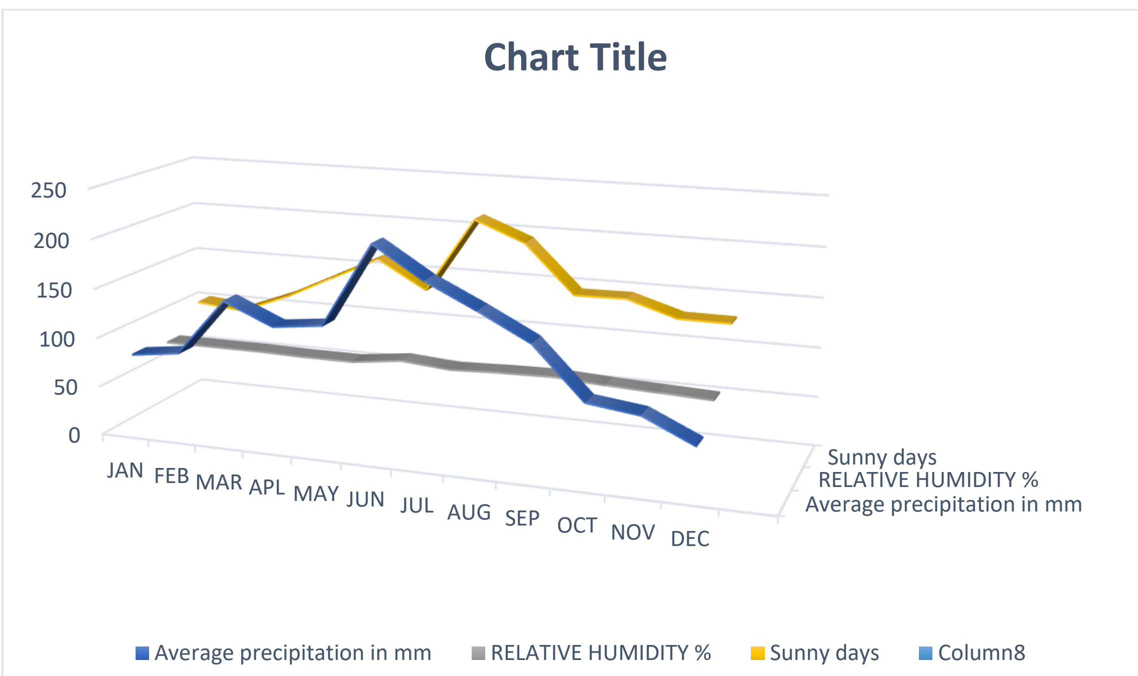


Fig 26 - China Meteorological Administration. (2020). Hangzhou precipitation data, Beijing

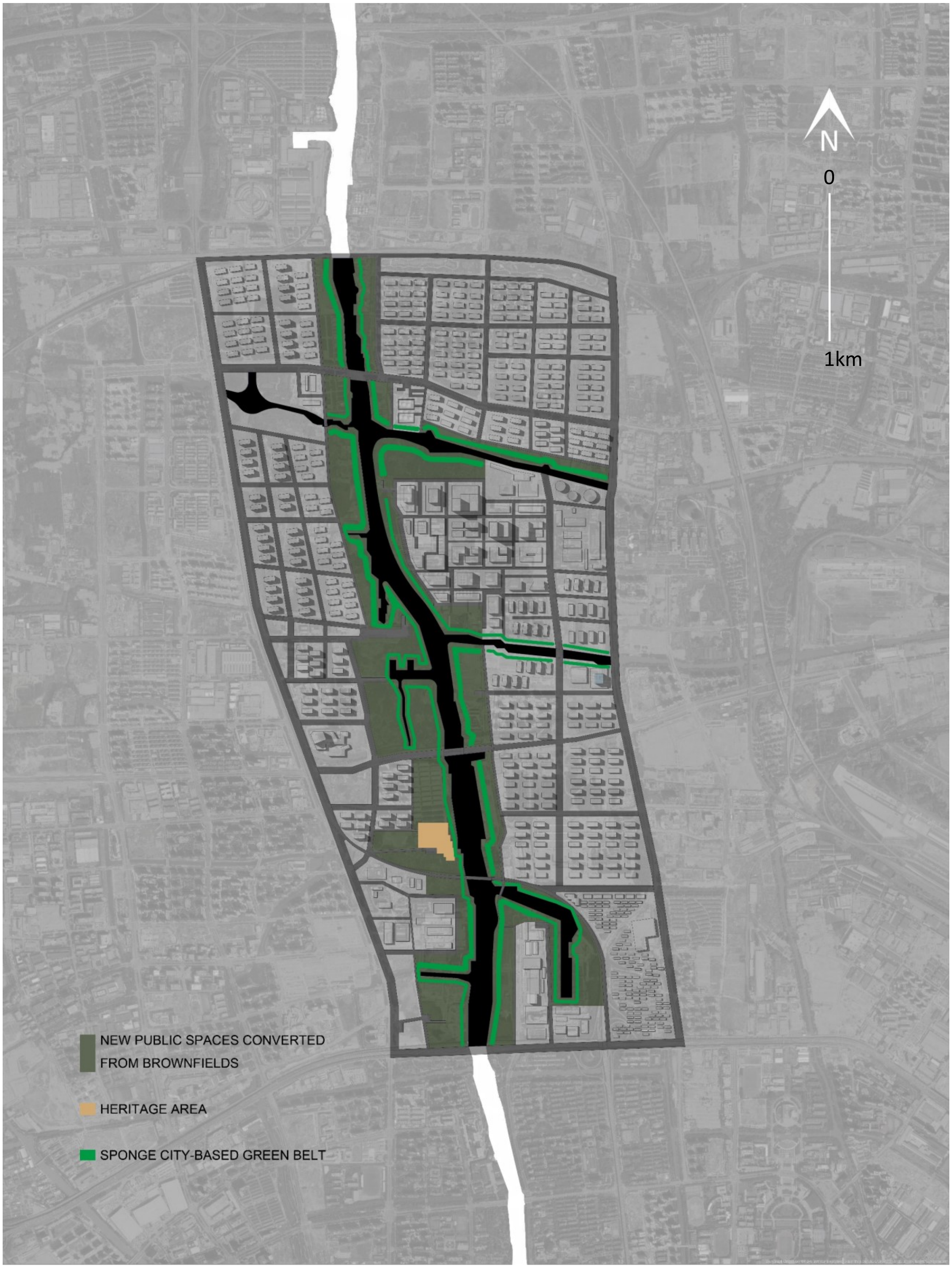


Fig 27 – green infrastructure study by the author

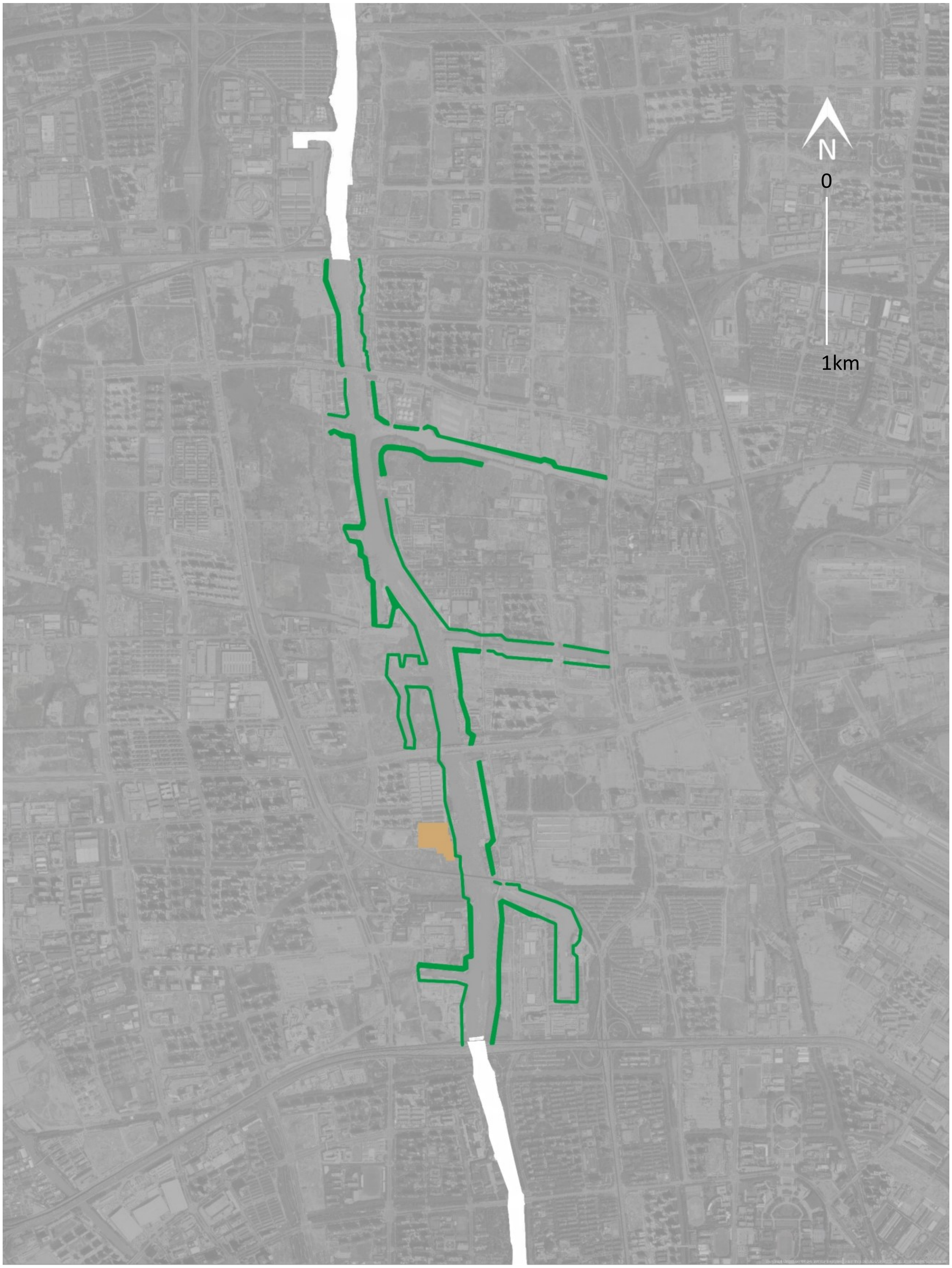


Fig 28 – green sponge space planning draft by the author

Fig 29 – Sectional study – generic – studied by the author - The city of Shanghai, Ministry of Construction (2016) Sponge City Construction Guideline.

Fig 30 – Yong Village 01, flooding day, provided by the City of Hangzhou, 2022

Fig 31 – Yong Village 02, canal bridge and heritage building, public domain

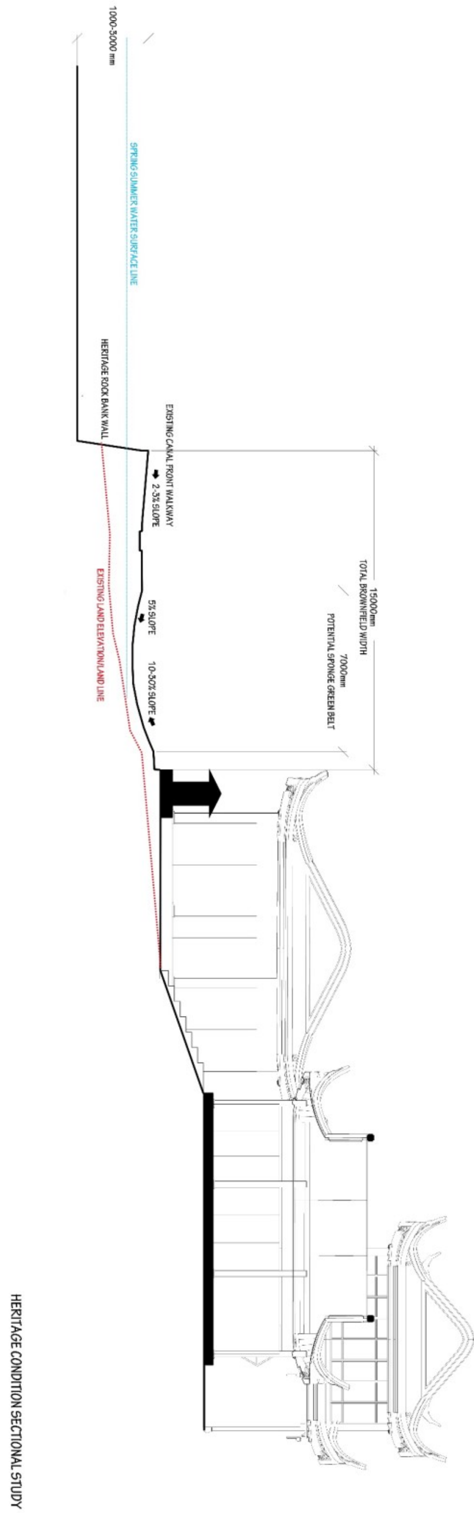


Fig 32 – Heritage condition, sectional study, created by the author - The city of Shanghai, Ministry of Construction (2016) Sponge City Construction Guideline.

Fig 33 – A brown field along the Tangxi Canal, bird-eye photo provided by the City of Hangzhou, 2022

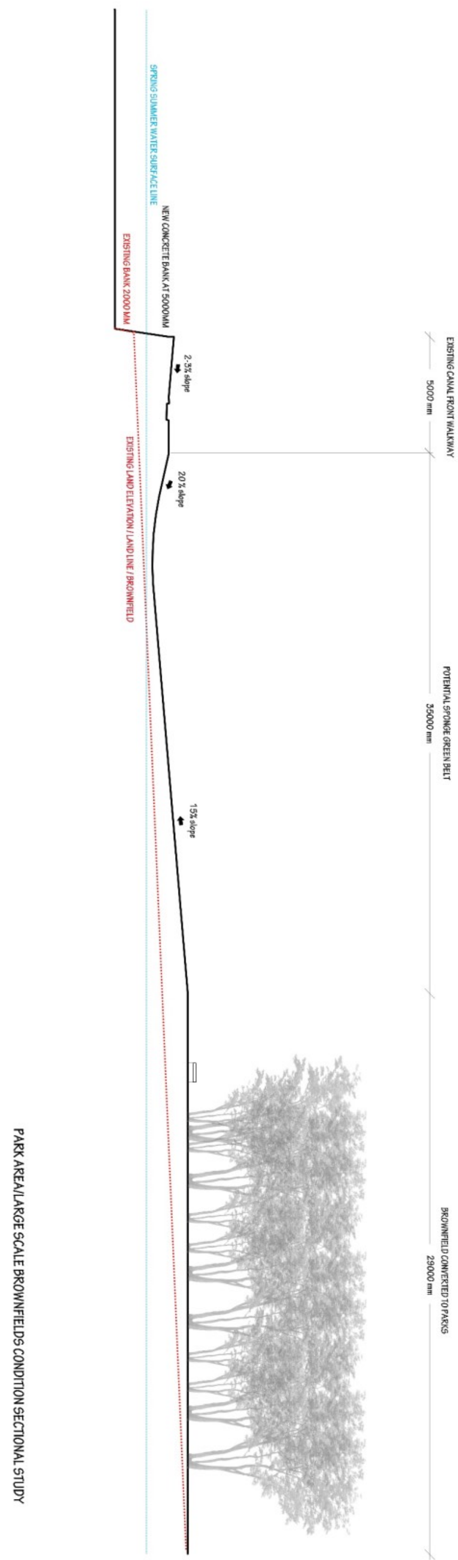


Fig 34 - Park Condition, the sectional study created by the author - The city of Shanghai, Ministry of Construction (2016) Sponge City Construction Guideline.

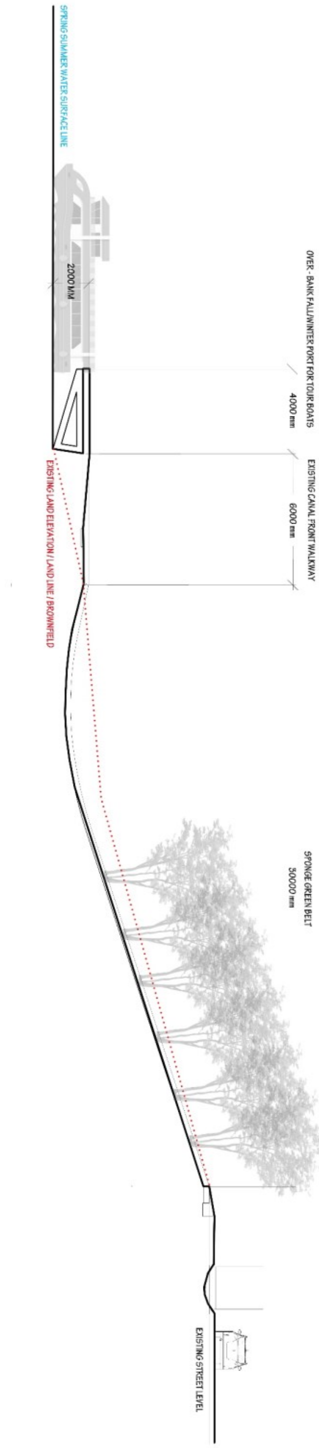


Fig 35 – Boat dock condition, the sectional study created by the author - The city of Shanghai, Ministry of Construction (2016) Sponge City Construction Guideline.

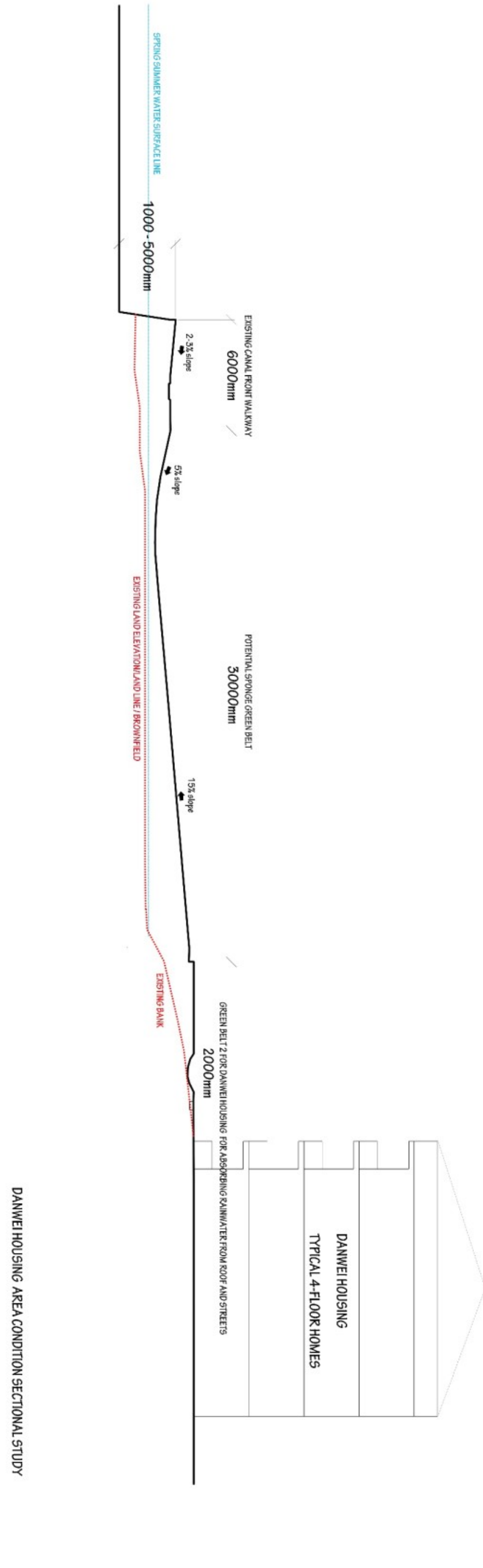


Fig 36 – Housing condition, the sectional study created by the author - The city of Shanghai, Ministry of Construction (2016) Sponge City Construction Guideline.

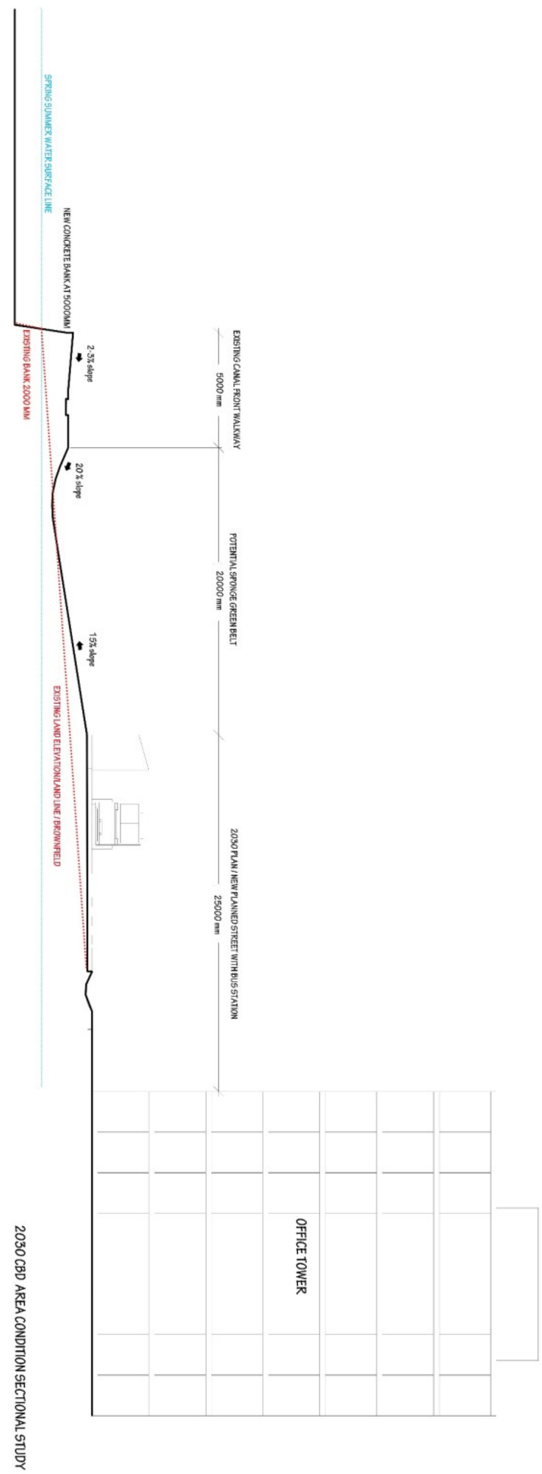
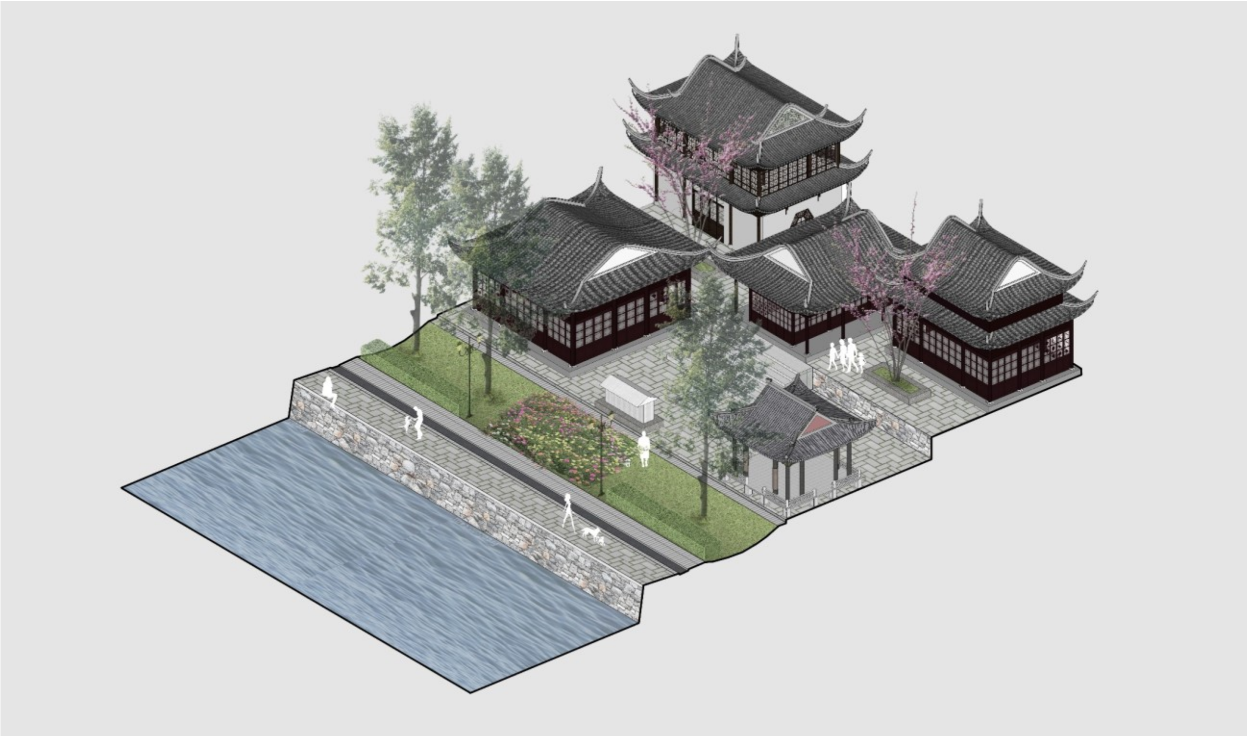
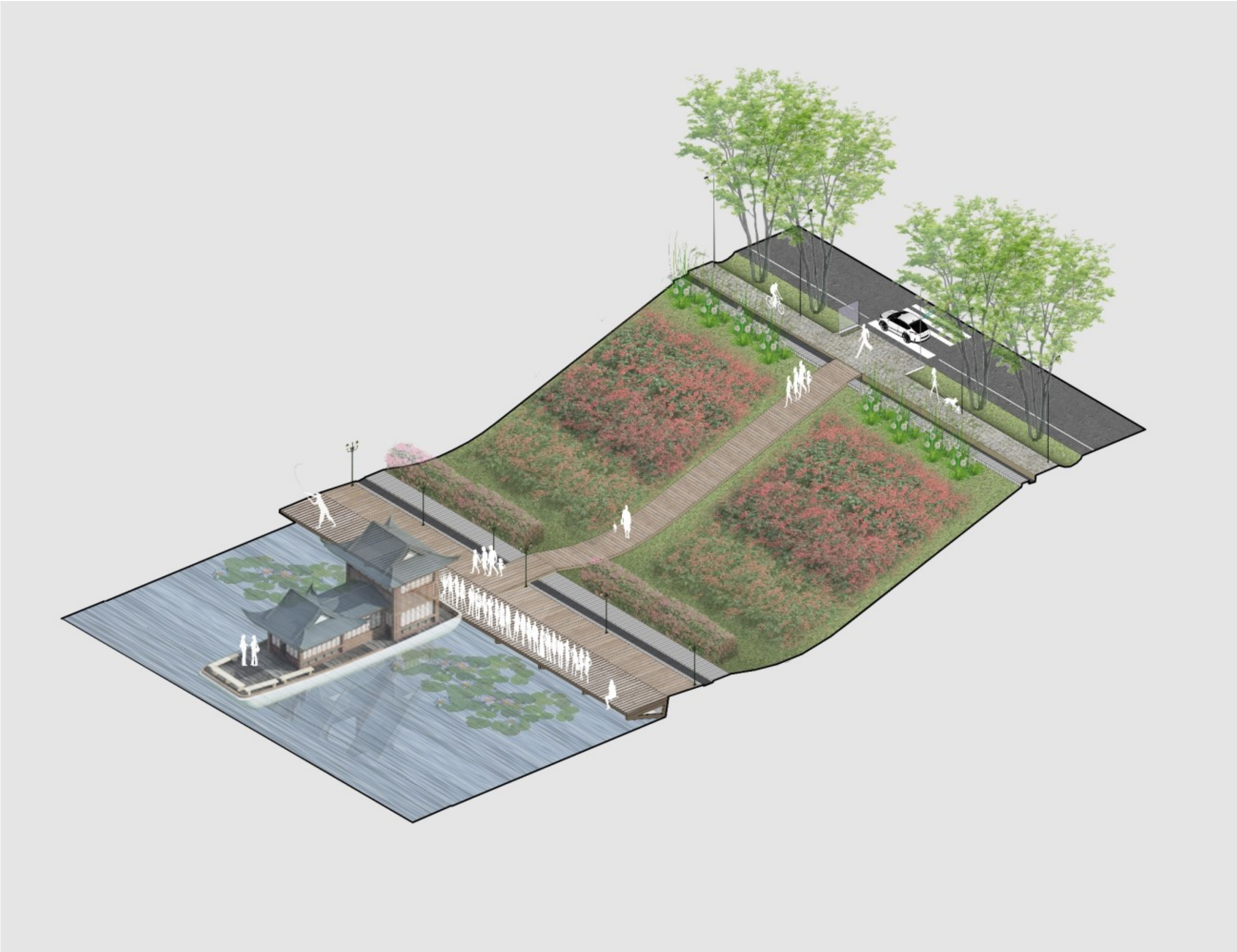


Fig 37 – CBD business area condition, the sectional study created by the author - The city of Shanghai, Ministry of Construction (2016) Sponge City Construction Guideline.





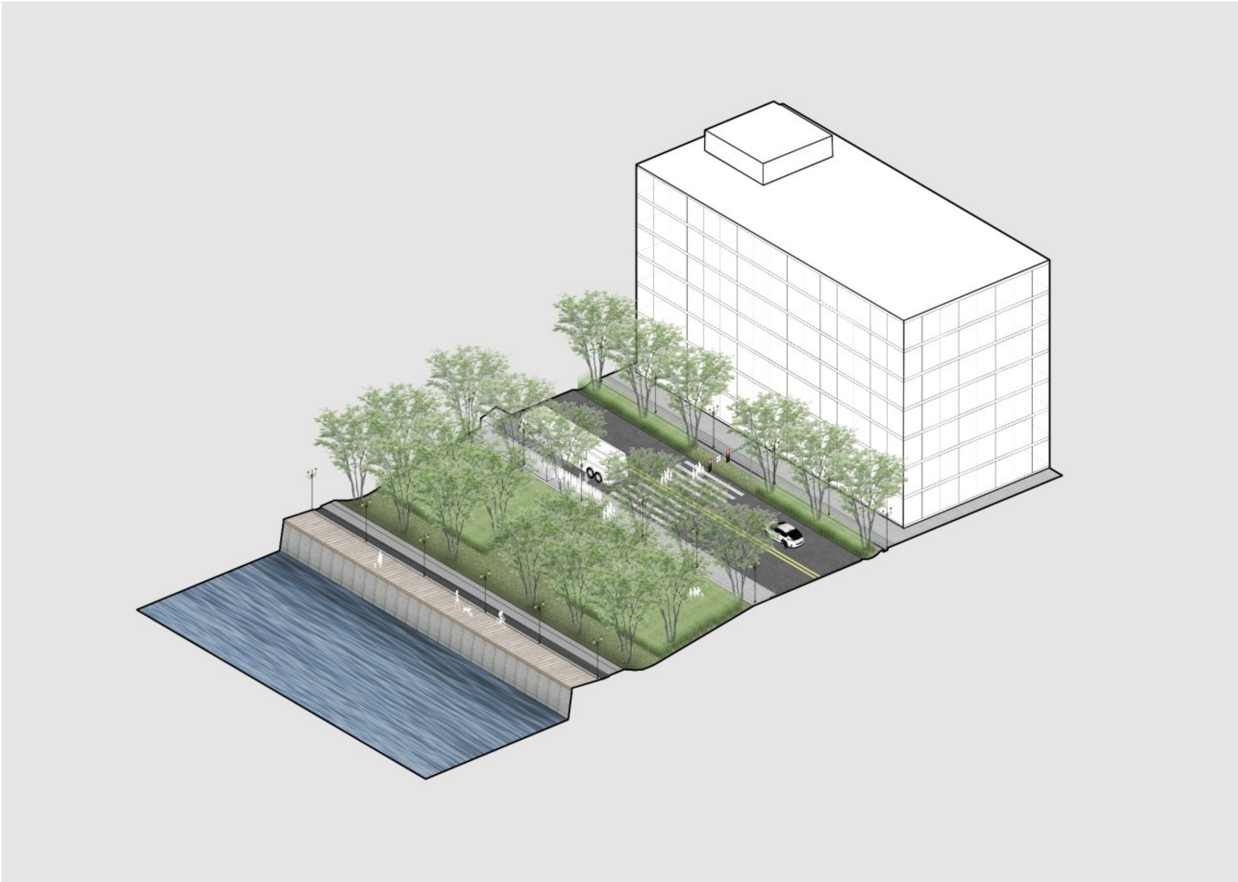


Fig 38 – 3D section studies of four conditions – created by the author

Fig 39 - SOCIAL INTERACTIVITY + LINEAR EXPANSION + RIVER SPACE DESIGN

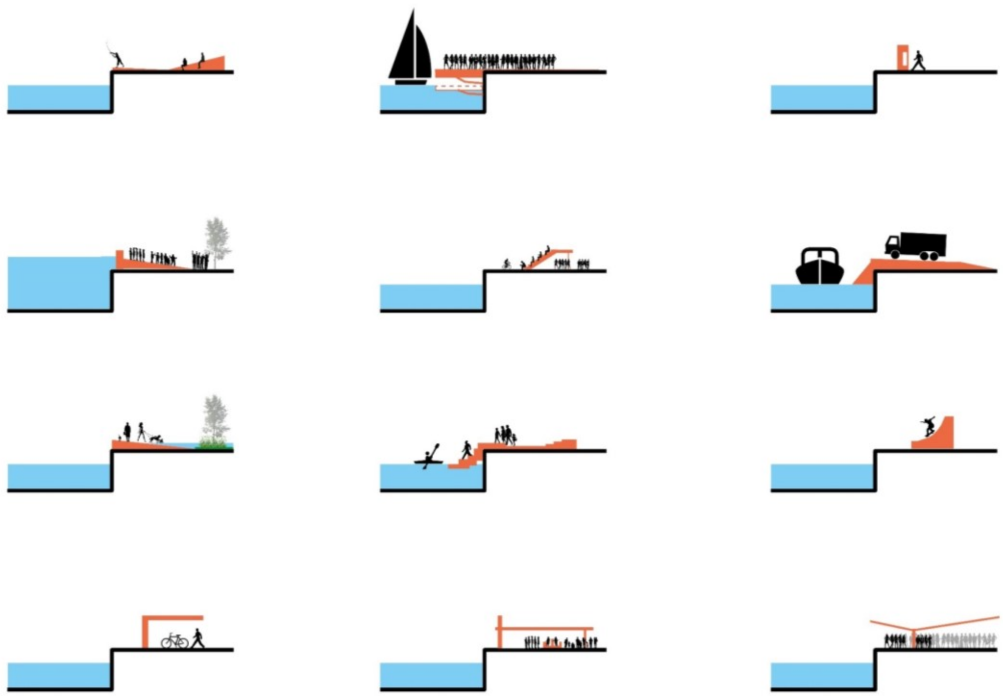


Fig.40 – Linear expansion – created by author

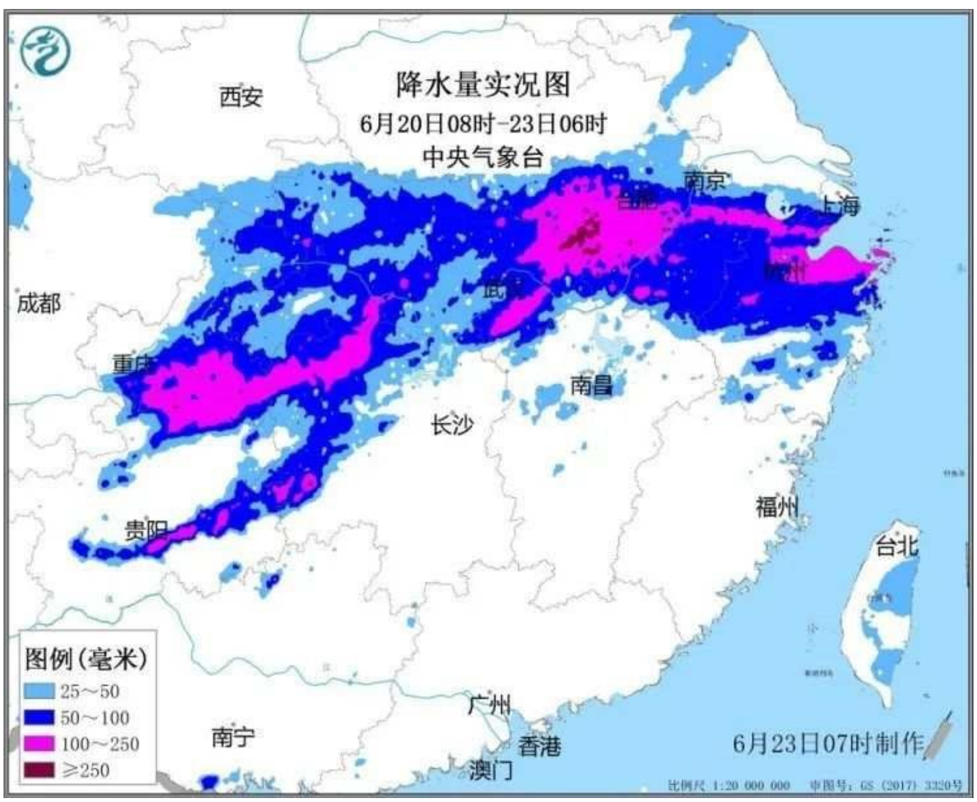


Fig 41 – the alluvial plain down at the east Qiantang River – Beijing daily 2020-06-23 14:13