

Water steps

Reviving the Bagmati River in the Kathmandu Valley

Maozhu Zhang 5531829
Landscape Architecture

Water steps
Reviving the Bagmati River in the Kathmandu Valley

Maozhu Zhang

Flowscape studio-Circular water stories
MSc Landscape Architecture
Faculty of Architecture and the Built Environment
Delft University of Technology

This thesis has been produced with the guidance of the

First mentor
Dr. Ir. Inge Bobbink

Second Mentor
Dr. Ir. Esther Gramsbergen

P5 report
June, 2023

TU Delft

ACKNOWLEDGEMENT

First of all, I would like to express my sincere thanks to my mentors, Dr. Ir. Inge Bobbink and Dr. Ir. Esther Gramsbergen, for their patience and guidance in the past year. Their help and encourage enable me to explore the different design directions and possibilities of the site under the main topic of water. I encountered problems from time to time throughout the process, and their critical comments and inspiring suggestions always helped me get out of trouble. I really enjoyed the moments of exchanging design ideas with them, and I benefit a lot from the process.

I would also like to thank my family for their financial and spiritual support. They always encourage me unconditionally and help me eliminate a lot of stress and negative emotions.

Thanks to my friends to often share interesting stories with me to relieve my stress and give me mental encouragement and support.

Finally, I would like to thank all the professors, mentors, colleagues and friends that I met at Delft University of Technology. With their help and companionship, I had a pleasant two years.

Preface

Introduction

Part I Research for design

Chapter 1 Bagmati River in the Kathmandu Valley
1.1 Kathmandu Valley
1.1.1 Geography
1.1.2 Nature
1.2 Bagmati River
1.2.1 Context
1.2.2 Culture
1.2.3 Nature
1.2.4 Daily activity
1.2.5 Scenes of life
1.3 City expansion
1.4 Water pollution
1.4.1 Source of pollution through time
1.4.2 WWTP
1.5 Solid waste
1.5.1 Garbage littered space
1.5.2 Poor garbage management system
1.5.3 Growing concern
1.6 Pollution from riverbank squatter settlements
1.6.1 Squatter settlements
1.6.2 Squatter settlements during monsoon season
1.7 Declining groundwater level
1.7.1 Natural recharge
1.7.2 Water recharge and extraction
1.8 Lost connection with Bagmati River
1.9 Living quality decline

Chapter 2 Problem statement and research question
2.1 Problem statement
2.2 Research question

Chapter 3 Project theoretical framework
3.1 Urban catalyst
3.1.1 Introduction
3.1.2 Operation Mechanism
3.2 Project application
3.2.1 Selection of intervention area
3.2.2 Chain development

Chapter 4 Intervention area
4.1 Overview
4.2 River bank typology
4.3 Religious monuments
4.4 Transfer station
4.5 Squatter settlement
4.6 The problematic site

CONTENT

Part II Research through design

Chapter 5 Design theoretical framework

5.1 Urban metabolism
5.2 Spatial design strategies
5.4 Concept

Chapter 6 Formation of catalyst

6.1 Master plan
6.2 Sustainable transfer station
6.2.1 Master plan
6.2.2 Increase capacity through segregation
6.2.3 Diversified waste collection ways
6.2.4 Involvement of Squatters
6.2.5 Involvement of Squatters - Water circularity of the new settlements
6.2.6 Involvement of Squatters - Application of units on site
6.3 Landscape approach to WWTP
6.3.1 Water purification
6.3.2 Fishery park design
6.3.3 Fishery hut design
6.3.4 Strolling through the fishery park
6.4 Sustainable water retention
6.4.1 Seasonal river bank
6.4.2 #1 Water retention ponds
6.4.3 #1 Water retention ponds - seasonal changes
6.4.4 #2 Stepped water retention riverbank
6.4.5 #2 Stepped water retention riverbank - the growth cycle of bamboo

Chapter 7 Chain development

Part III Conclusion and Reflection

Chapter 8 Conclusion

Chapter 9 Reflection

Appendix

References

PREFACE

The spirit of the project is from my tour in Nepal in 2012. I was born in a river-fed plain in China, and until I arrived in Kathmandu, I never imagined that the capital of a country next to China would face such severe water pollution: the water coming out of the taps is always cloudy, and the only drinkable water is the bottled water sold in stores. The concern about Bagmati came from the reports I read later on the internet. The Kathmandu Valley is a place with a deep cultural and historical heritage, its rich religious heritage attracts a large number of tourists, and Bagmati is the origin of these cultures, but it is now filled with sewage and garbage, becoming a huge open sewer in the Kathmandu Valley. Therefore, people never introduce the river to tourists, and only a few of the monuments along the river will be visited by tourists, and it is these relics that attract them, not the river itself. Tourists come here to experience the culture, but they know nothing about the origin of the culture – Bagmati River, and some are not even aware of the existence of the river after the trip is ended. Even the local inhabitants of the Kathmandu Valley are moving away from the river, even though it was destroyed by them. The connection between the people and the river is gradually being broken, although the river is the origin of urbanization and civilization in the Kathmandu Valley.
So, I started to think about what landscape architects can do to rebuild the relationship between people and river?

INTRODUCTION

The civilization and urbanization of Kathmandu Valley started with the Bagmati River but rapid urban expansion in the 21st century has brought many problems-the direct discharge of wastewater, solid waste in the river, encroachment of riverbanks by squatter settlements, and declining groundwater levels, they together contributed to the decline of this sacred river. It resulted in a loss of connection between people and it, which ultimately led to a decline in living quality for the people who live in the Kathmandu Valley. The government is currently taking several separate technique measures to address these issues. But these measurements alone are not enough. They don't work together. More efforts need to put into the 'process of change' to improve the living quality of the Kathmandu Valley.

This project explores the role of landscape architectural means to integrate the separated, mainly technical measures, as part of a spatial design that rebuild the connection between people and Bagmati and achieve the improvement in living quality in the Kathmandu Valley. As a large region with complex environmental issues, it is difficult to achieve all changes at once. The concept of an "Urban Catalyst" is chosen as the framework of the project through a slow landscape transformation guided by phasing and involvement of inhabitants to gradually make the river livable. The theory "Urban metabolism" helps to form spatial strategies which in the theory of "Urban Catalyst" is called catalyst point to transform the linear and unsustainable flows into circular and sustainable flows to restore the ecological condition of Bagmati River. With the intervention of the catalytic points, the Bagmati River will slowly be restored, from the intervention area to the entire river system, reconnecting people to it and ultimately impacting the valley and improving the quality of life of its inhabitants.

RESEARCH FOR DESIGN

01 BAGMATI RIVER IN THE KATHMANDU VALLEY

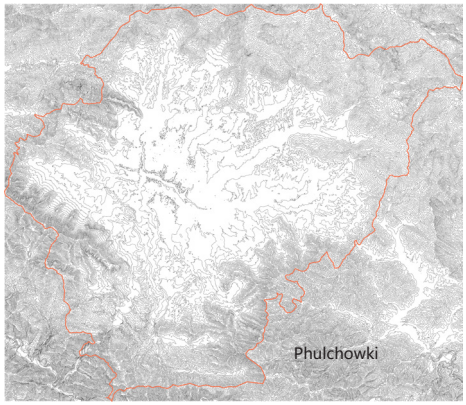


The study area, the Kathmandu Valley, is a basin located in Nepal. It is the most developed urban area in Nepal and is also one of the fastest growing metropolitan areas in South Asia (Prasad, T. N., Anushiya, S., Prasad, P. D., & Rachana, U., 2020). With a rich cultural heritage, including numerous Hindu and Buddhist shrines, the Kathmandu Valley attracts a large number of devotees and tourists every year (Khanal, A., 2023). The main water system flowing through the Kathmandu Valley is the Bagmati River system, which is considered to be the origin of civilization and urbanization in the Kathmandu Valley. (Mishra, T. 2005).

Figure 1-1. Kathmandu Valley in country scale (Lamichhane, S., & Shakya, N. M., 2019), Redrawn by author

KATHMANDU VALLEY
Geography







The Kathmandu Valley is located in the central part of Nepal in the Lesser Himalayas, with an east-west axis 30 km long and a north-south axis about 25 km wide at its widest point (Shigefuji, M., Takai, N., Bijukchhen, S., Ichiyanagi, M., Rajaure, S., Dhital, M. R., Paudel, L. P., & Sasatani, T., 2022). The most important river in the valley - Bagmati River runs through the center of the valley, separating the two main cities in the valley, Kathmandu and Patan (Jana, C. M., 2022). All the tributaries join along the way and it finally leaves the valley in a southwestern direction.

Figure 1-2. Kathmandu valley scene (Devkota, A. R., 2009)
Figure 1-3. Elevation map of Kathmandu Valley, drawn by author
Figure 1-4. Bagmati river system (Chitrakar, R., & Shrestha, B., 2020), Redrawn by author



Figure 1-5. Kathmandu valley green system, drawn by author

As a fast-growing metropolitan area, the Kathmandu Valley has most of its land devoted to construction, especially in the central area where Kathmandu and Patan are located, with only scattered and fragmented green spaces. Most of these green spaces are man-made small urban parks. Some are recreation-oriented, such as the UN Park on the bank of the Bagmati River, where people go to experience nature (OnlineKhabar., 2021). Some are religion-oriented, such as Swayambhu Buddha Park, which is located at the foot of the Swayambhunath Stupa, a UNESCO World Heritage Site in Kathmandu, and has not only beautiful gardens but also great stupas and large prayer wheels. (OnlineKhabar., 2021). Large natural forests are located in the border areas of the valley, especially in the southeast. These areas usually have a high level of biodiversity, such as Suryabinayak Forest, which is home to 99 species of birds, makes it a famous bird watching and tourist destination (Suryabinayak Municipality., 2023).

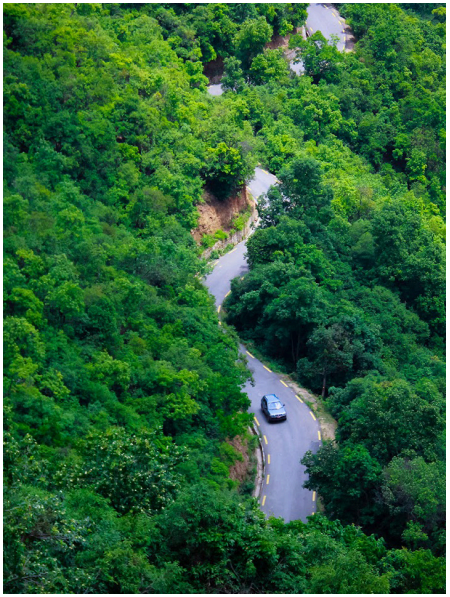
KATHMANDU VALLEY
Nature



UN Park



Swayambhu Buddha Park



Suryabinayak Forest

Figure 1-6. UN park (Basnet, S., 2016)
Figure 1-7. Swayambhu Buddha Park (Durganand., 2022)
Figure 1-8. Suryabinayak Forest (Ojha, A., & Dhimal, M., 2017)



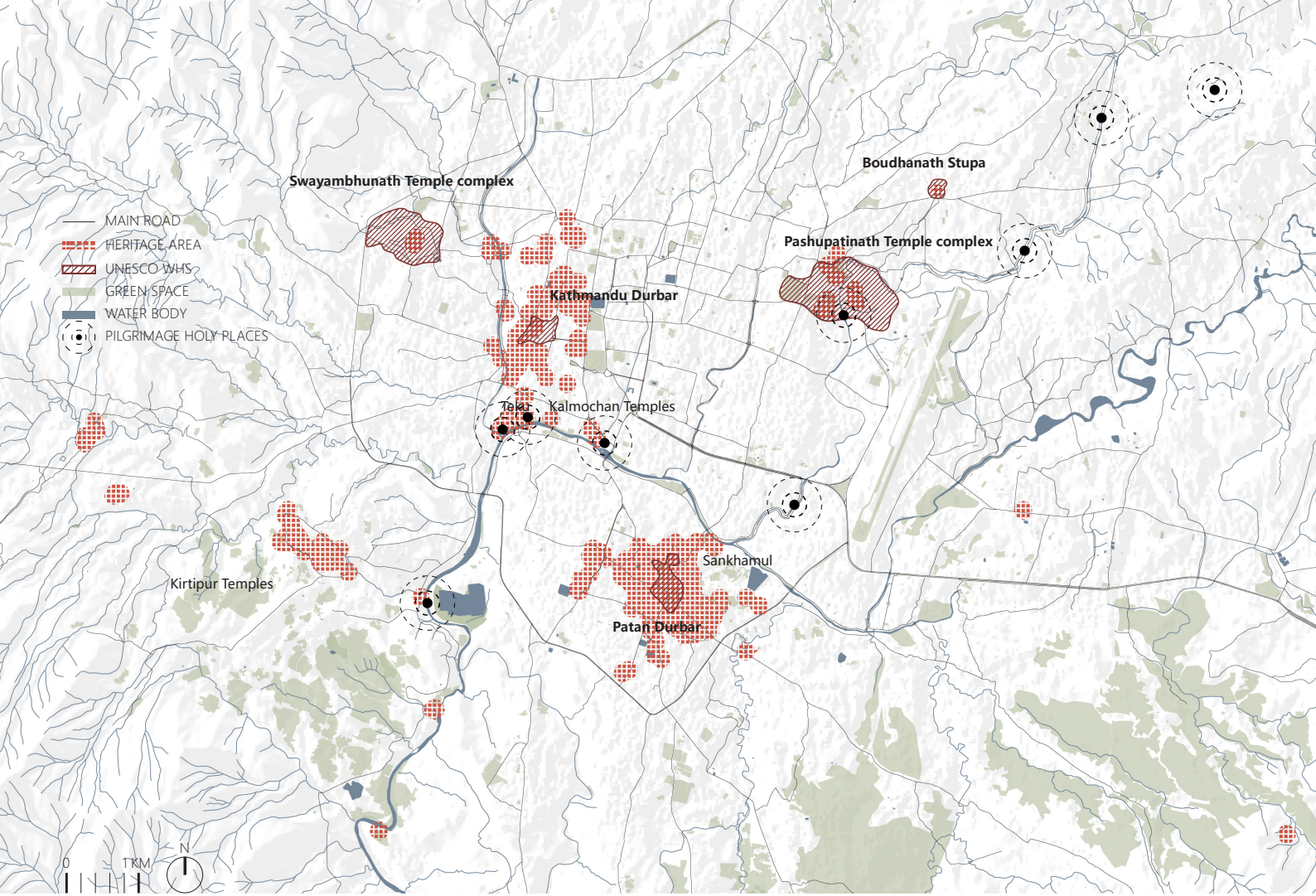




BAGMATI RIVER
Context

The Bagmati River, as the most important river in the Kathmandu Valley, has both cultural and natural significance. It originates at the Bāghdwār Falls (Fisher, J. F., 1998) and flows through villages and cities, with tributaries feeding into it along the way, eventually leaving the Kathmandu valley and joining the Ganges system (Tuladhar, D., Dewan, A., Kuhn, M., & Corner, R. J., 2019). The major urban clusters of the Kathmandu Valley have developed around the Bagmati and its tributaries since the Licchivi (400-750 AD) dynasty. The river has shaped the history, culture, religion and urban landmarks of the Kathmandu Valley. For a long time in the past, it irrigates agriculture, provides drinking water, and its banks are used to celebrate various cultural events and perform religious rituals (Pudasaini, S. P., 2019). People in the Kathmandu Valley have long worshipped Bagmati River.

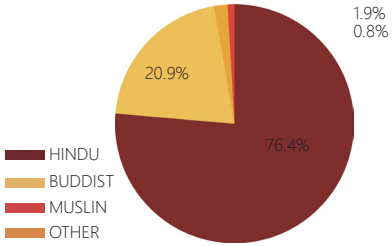
Figure 1-9. Perspective view of Bagmati river in 1972 (Feary, S., 2019)
Figure 1-10. Perspective view of Bagmati river in 2022 (Gurung, N. B., 2022)



The Kathmandu Valley is a place of rich cultural heritage and numerous religions, the highest percentage of which are Hinduism and Buddhism. (Office of international religious freedom., 2021). As the origin of the urbanization and civilization of Kathmandu Valley, there are many sacred places for Hinduism and Buddhism along Bagmati River. These religious buildings are mostly made of red bricks and wooden structures, but the architectural styles are not exactly the same. Although they vary in form and religion, they are all closely connected to the Bagmati River through the ghat, which refers to the series of steps leading down to the spiritual river.

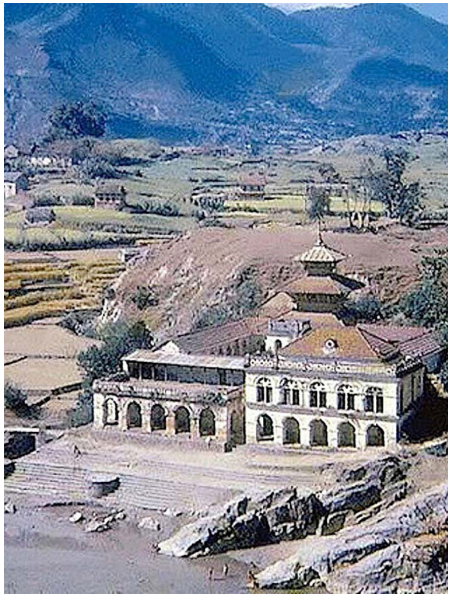
Figure 1-11. Heritage map of Kathmandu Valley (NHDP, 2022)

Figure 1-12. Distribution of religion in Kathmandu Valley (Gurung, H.B., Khanal, N., Pradhan, P, & Ghimire, P.K., 2008)

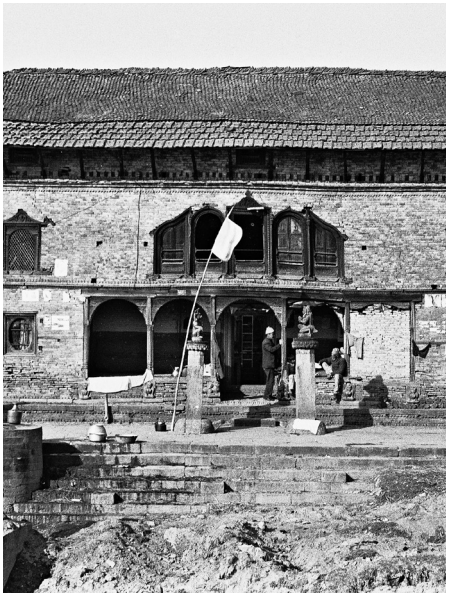




Radhakrishna Temple



Jalavināyaka Mandira temple



Sattal at Purohit Ghat

The Radhakrishna Temple has a unique mixture of styles; its tower is supported by an inner sanctum, with carved pillars and beams of wood construction and a tiled roof (Michaels, A., Maharjan, B., Schrom, T., Awal, P., Tamrakar, A., & Timalsina, R., 2021). Jalavināyaka Mandira temple is one of the four major Ganeśa temples in the Kathmandu Valley, and the Jalavināyaka Satah South, built around it, was reconstructed in 1877 AD in a neoclassical style, with a façade decorated with carved windows (Brosius, C., Maharjan, B., Schrom, T., Rajbhandari, S., & Khatiwoda, R., 2021). The Sattal at Purohit Ghat, built in 1883, is a Hindu building in the traditional Nepalese newari house architectural style. It has a unique carved wooden façade, including an oval window on the ground floor and a uniquely shaped five-bay window on the first floor (Brosius, C., Maharjan, B., Schrom, T., Joshi, S., Michaels, A., & Timalsina, R., 2021).

Figure 1-13. Radhakrishna Temple in 1974 (Pruscha, C., 2015)
Figure 1-14. Jalavināyaka Mandira temple in 1967 (Chase, P, 2022)
Figure 1-15. Sattal at Purohit Ghat in 1983 (Gutschow, N., 2022)

BAGMATI RIVER
Culture



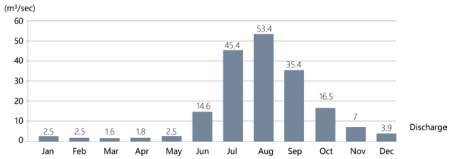
Devotees take bath-1905

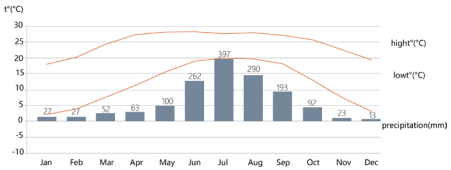


Bala Chaturdashi- 2016

With its spiritual significance and the large number of religious buildings along its banks, the Bagmati River has always been an essential part of the religious life of the inhabitants of the Kathmandu Valley. They consider Bagmati to be sacred and they worship it as a deity. Some consider the river to be a sacred home, while others pray for its life-giving power. Traditional rituals and ceremonies associated with Bagmati throughout history have continued to reinforce this belief (Nepali Times, 2020). This river has played an important role in the continuation and development of religion in the Kathmandu Valley.

Figure 1-16. Devotees take bath-1905 (Rana, B. N., 2013)
Figure 1-17. Bala Chaturdashi- 2016 (EPA., 2016)







Monsoon

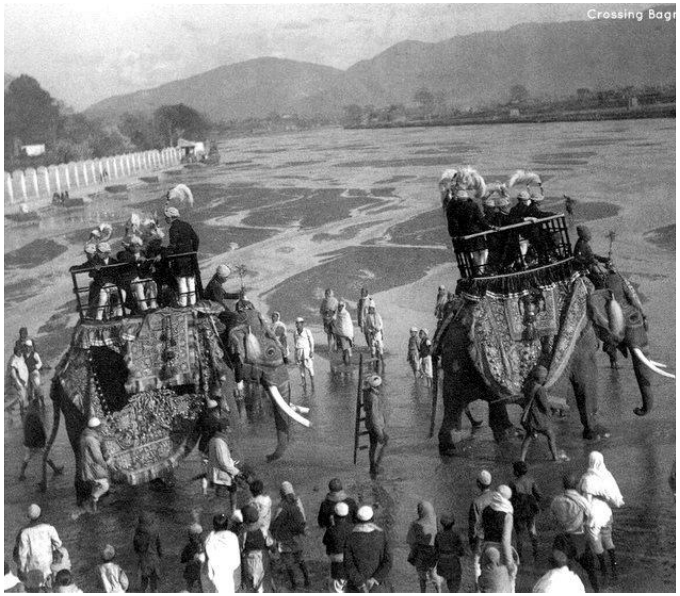


Dry season

Without the snow to feed it, the flow of the Bagmati River system is largely dependent on rainfall. Due to the uneven annual precipitation which concentrated between June and September, the flow of the Bagmati is lowest during the dry hot season (January to April) and then peaks during the monsoon season (July to mid-August) (Tuladhar, D., Dewan, A., Kuhn, M., & Corner, R. J., 2019). The water level in Bagmati varies significantly during the year, with a general difference of 3.5 meters between the highest and lowest levels (minimum around 1.5 meters and maximum around 5 meters at Balkumari Hydrological Station) (Himalayan News Service., 2020). With global warming, the discrepancy between dry and rainy season water levels is likely to be greater in the future.

Figure 1-18. Average monthly Discharge of Bagmati River at Chovar (Sharma, S., & Bremer, M. H., 2009), Redrawn by author
Figure 1-19. Annual precipitation in Kathmandu, Nepal (Weather-and-climate., 2023), Redrawn by author
Figure 1-20. Bagmati river during the monsoon season (Khabar, M., 2021)
Figure 1-21. Bagmati River during the dry season (Shrestha, S., 2021)

BAGMATI RIVER
Daily activity in the past



Wedding Ceremony-1948



Gathering-1926

In the past, the Bagmati River is a very important part of the daily life of the Nepalese people. It can assume the function of transportation, as people can ride elephants or even walk across the Bagmati River to another city during the non-monsoon season. In addition to this it can also perform a recreational function, for example, the ghat on the riverbank provides a social place for the inhabitants of Nepal to meet and gather on a daily basis.

Figure 1-22. Wedding Ceremony-1948 (Images of the Century., 2013)
Figure 1-23. Gathering-1926 (Images of the Century., 2012)

BAGMATI RIVER
Daily activity in the past



Grain drying and clothes washing-1971



Cowherding-1968

In the old days, the water of Bagmati also provides much convenience to the residents. The clean river allowed people to bathe, wash, swim, and even collect drinking water. It also served as a source of drinking water for cattle and there used to be many herders grazing their cattle along the Bagmati River.

Figure 1-24. Grain drying and clothes washing-1971 (Letson, P., 1971)
Figure 1-25. Cowherding-1968 (Reinhard, J., 1968)



Figure 1-26. Scenes of life along the Bagmati River in the past (Sharma, H. P, 2016)


BAGMATI RIVER
Scenes of life along the Bagmati River in the past
Childhood memory of Bagmati River
by Hari Prasad Sharma
Duku Dyo Puja Celebration
Holy dips
Make offerings

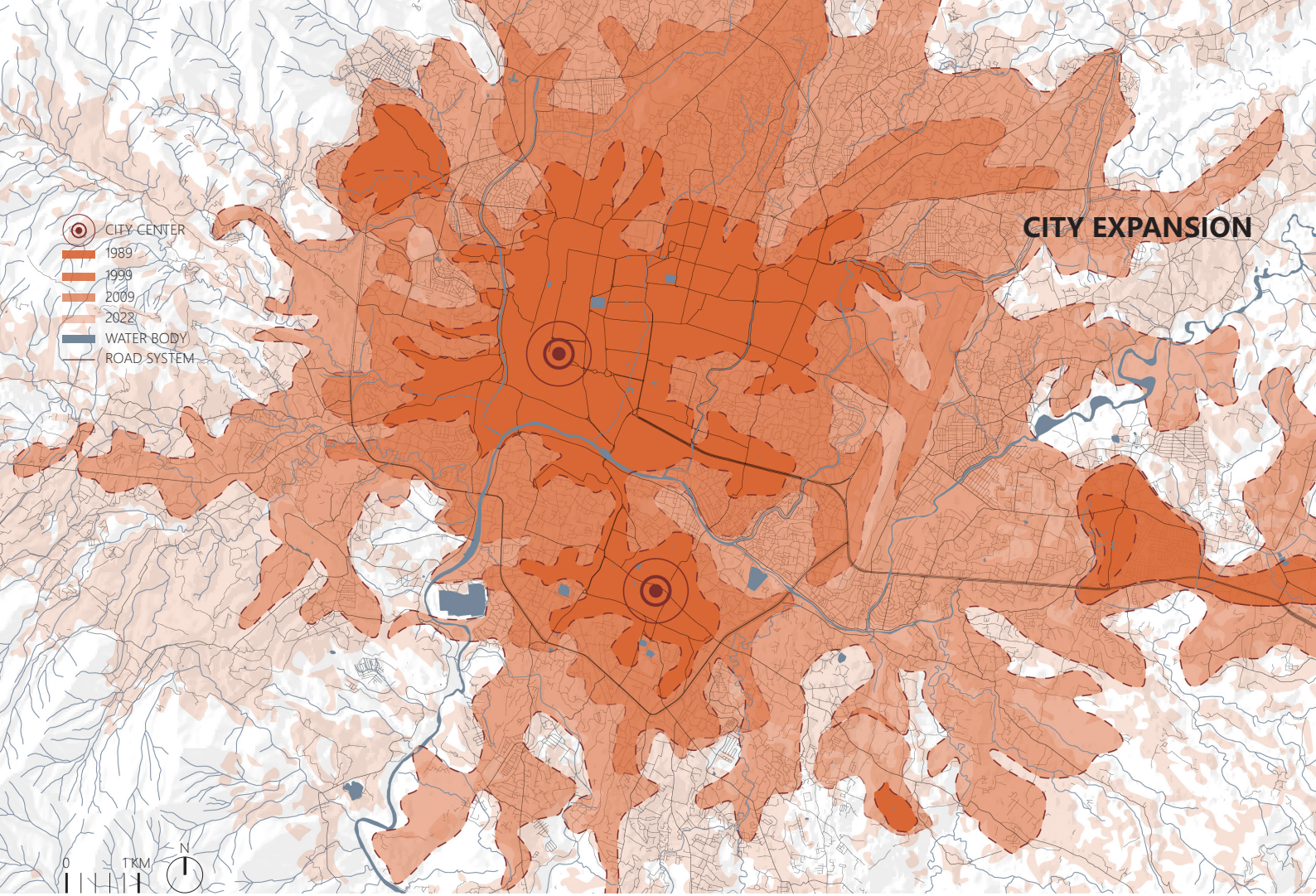


Figure 1-27. City expansion map of Kathmandu Valley (Shrestha, M., & Chhetri, N., 2017), Redrawn by author

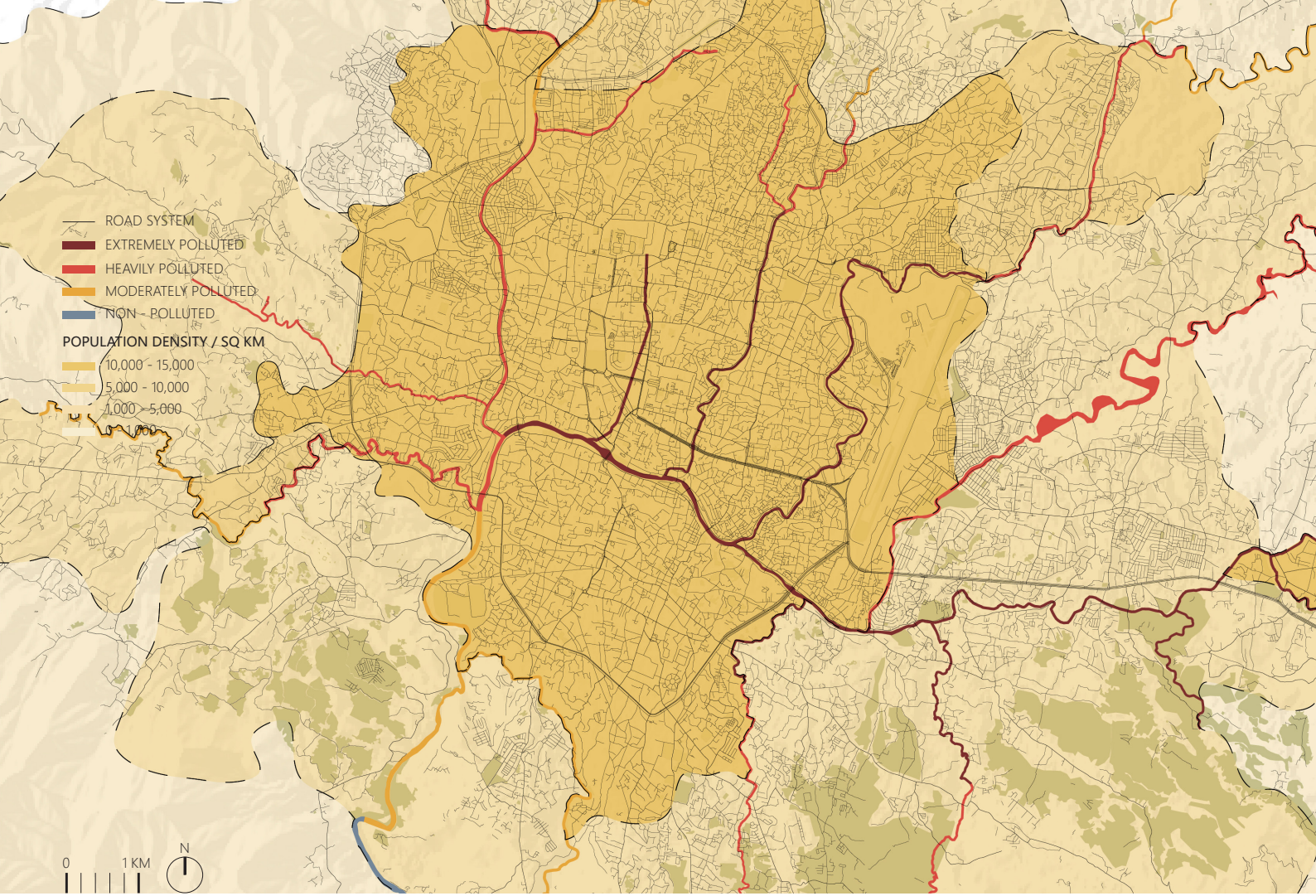
Nowadays, due to the rapid expansion of the city, the sacred river-Bagmati has suffered a decline. Since the 1990s, the Kathmandu Valley has begun to grow rapidly (Ishtiaque, A., Shrestha, M., & Chhetri, N., 2017). At that time, many people moved to the Kathmandu Valley in search of job opportunities. This population boom resulted in rapid urbanization. Between 1989 and 1999 alone, the built-up area of the city increased by approximately 120%. In total, the built-up area has increased by 412% over the past three decades. (Ishtiaque, A., Shrestha, M., & Chhetri, N., 2017). Currently, the population of the Kathmandu Valley continues to grow at a rate of 6.5% per year, making it one of the fastest growing urban areas in South Asia. (Prasad, T. N., Anushiya, S., Prasad, P. D., & Rachana, U., 2020). There is a growing demand for public infrastructure such as water supply facilities, sewage treatment facilities, and waste management facilities.



Figure 1-28. Polluted Bagmati River (Ecohub., n.d.)
Figure 1-29. The polluted Bagmati River in the religious area (Cleanwaterwave., n.d.)

QUICK CITY EXPANSION CAUSE THE DECLINE OF BAGMATI

But while the city has grown rapidly, public infrastructure in the Kathmandu Valley has not developed in tandem, which has led to a series of environmental problems, the most severely affected of which is the sacred river-Bagmati River. The slum-encroached riverbanks, direct discharged untreated sewage, accumulated garbage and decreasing groundwater level led to the decline of the Bagmati River.



The pollution of the Bagmati River began in the 1980s when a large number of carpet factories were built along the river bank. All the waste generated was discharged directly into the river. By the 1990s, more and more people were coming to the Kathmandu Valley in search of jobs, which led to rapid urban growth, and large amounts of domestic sewage began to be discharged into the Bagmati River (Mohan, M., 2022). In recent decades, based on the report of International Center for Integrated Mountain Development, **the main source of pollution in Bagmati River has changed from industrial pollution to domestic sewage, which accounts for about 93% of the total** (ICIMOD, MOEST/GON and UNEP., 2007).

Figure 1-30. Pollution map of Bagmati River (Baniya, B., Bhattarai, B., Bhatta, R., Dhital, Y. P, Sharma, S., Baniya, H., Ghimire, S. K., & Khadka, N., 2019), Redrawn by author

WATER POLLUTION
Source of pollution through time

Proliferation of carpet factories

1980s

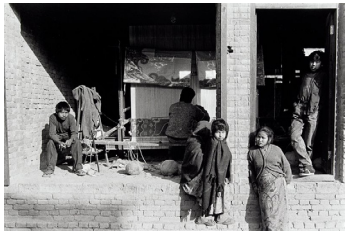
Industries began to proliferate

1990s

Domestic sources contribute the majority of pollution

2007

NOW



The Beginning of Bagmati's Decline

There were a lot of carpet factories, and they were mostly located along the riverbanks. So all the waste generated - either liquid or solid - were directly discharged into the river.



Bagmati River Pollution Increases

As the years rolled on, more people moved to Kathmandu in search of job opportunities. The mushrooming population meant rapid urbanisation and heavy industrial activity. Untreated sewage started flowing directly into the river.

Wastewater Production the Municipal Areas of Kathmandu Valley in 2007

	Kathmandu	Patan	Bhaktapur	Kirtipur	Madhyapur Thimi
Volume of Domestic Wastewater Generated (MLD)	64.497	15.647	5.971	3.920	3.069
Volume of Industrial Wastewater Generated (MLD)	4.515	1.095	0.418	0.274	0.215
Total Wastewater Generated (MLD)	69.012	16.742	6.389	4.95	3.284
Total Wastewater Collected (MLD)	34.506	8.371	3.195	2.097	1.642

Figure 1-31. Carpet Factory in 1993, Kathmandu, Nepal (Parker, D., 1993)
Figure 1-32. Brick kiln, in Bisahariya, Saptari (Himalayan News Service. ,2016)
Figure 1-33. Wastewater Production the Municipal Areas of Kathmandu Valley in 2007 (Shukla, A., Jha, B. C., & Timilsina, U. R., n.d.)

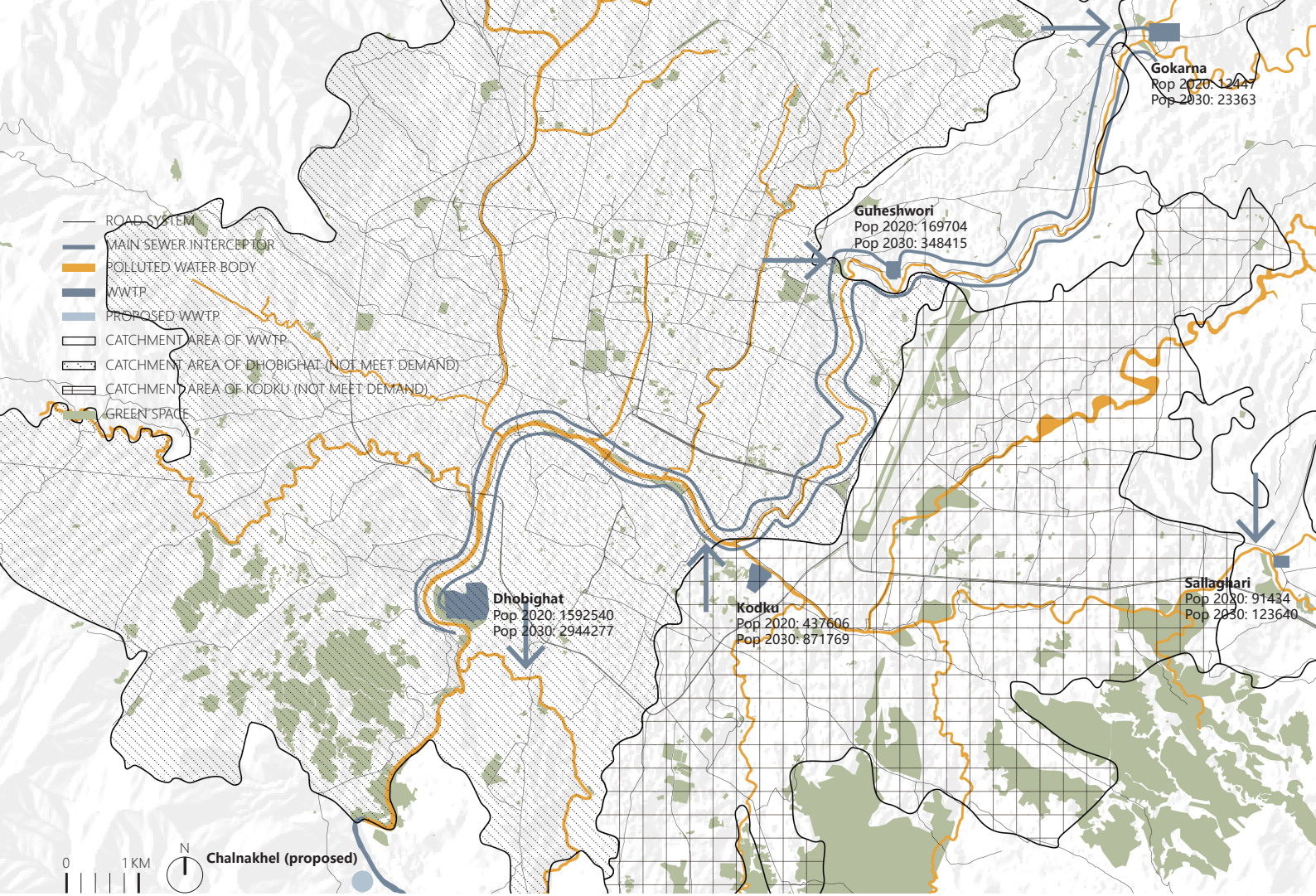


Figure 1-34. WWTP map of Kathmandu Valley (Rana, S. B., 2017), Redrawn by author

As the most urbanized area in the country, the Kathmandu Valley is expected to produce about 200 million liters of wastewater per day after the Melamchi Water Supply Project is completed (Ramtel, P., Tamang, T., Pokhrel, N., Mainali, B., & Paudel, S. R., 2021), 30 percent of which could not be collected by the sewerage network (Japan International Cooperation Agency (JICA), & Japan International Cooperation Agency (JICA)., 2019). Only one of the five existing sewage treatment plants built 30 years ago is still working due to lack of timely repair and maintenance (Rana, S. B., 2017), therefore, **even if the sewage is collected by the sewage treatment system, most of it cannot be purified and they are discharged directly into the Bagmati River.**

	Discharge	Capacity (2022)	Capacity (2023)	Surplus Cap.	Estimated Discharge (2030)	Proposed Capacity
Gokarna	0.8 MLD	0 MLD	0 MLD	-0.8 MLD	2.0 MLD	3 MLD
Guheshwori	10.3 MLD	16.2 MLD	32.4 MLD	5.9 MLD	30.2 MLD	34.2 MLD
Sallaghari	5.6 MLD	0 MLD	14.2 MLD	8.6 MLD	10.7 MLD	14.2 MLD
Kodku	26.6 MLD	0 MLD	17.5 MLD	-9.1 MLD	75.6 MLD	35 MLD
Dhobighat	96.8 MLD	0 MLD	74 MLD	-22.8 MLD	255.6 MLD	110 MLD
Khokana	/	/	/	/	/	approx. 300 MLD
Total	140 MLD	16.2 MLD	138.1 MLD	-1.9 MLD	374.1 MLD	496.4 MLD

Figure 1-35. Capacity of WWTP in Kathmandu Valley, drawn by author

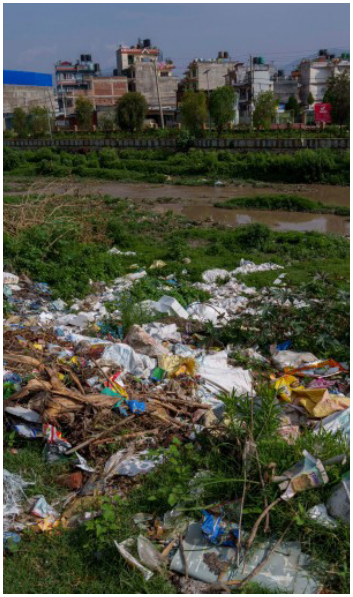
According to the Environmental Monitoring Report 2022, the government now plans to rehabilitate some existing wastewater treatment plants and build more along the river system to reach a capacity of 138.1 million liters per day in recent years (Kathmandu Valley Wastewater Management Project., 2022). However, by comparing the volume of wastewater generated within the service area of a wastewater treatment plant (Rana, S. B., 2017) and its capacity to treat it (Kathmandu Valley Wastewater Management Project., 2022), **there are still some wastewater treatment plants that are unable to meet the wastewater treatment demand within their service area after upgrading.**

SOILD WASTE
Garbage littered space

In the river



Riverbank



Near religious site





In addition to sewage, there is a large amount of solid waste in the Bagmati River channel. The Kathmandu Valley generates more than 1,200 tons of solid waste per day, but only about 67% is transported to landfills, meanwhile, waste collection services are often interrupted for various reasons (Pathak, D. R., 2021). **With inefficient waste management in the valley, Nepalis dump their household waste in urban open spaces, including the Bagmati River.** Although many rules have been put in place to stop people from dumping trash in the river, some people still sneak household trash into the river at midnight via motorcycles or large vehicles (Mohan, M., 2022).

Figure 1-36. Polluted Bagmati River (Ecohub., n.d.)
Figure 1-37. Polluted Bagmati riverbank (FP Staff, 2022)
Figure 1-38. The polluted Bagmati River in the religious area (Cleanwaterwave., n.d.)
Figure 1-39. People throwing garbage into the Bagmati River (The Kathmandu post., 2017)
Figure 1-40. Bancharedanda Waste Landfill Site (A., 2022)
Figure 1-41. Trucks carrying waste from Kathmandu to the Bancharedanda landfill site (Onlinekhabar., 2022)
Figure 1-42. Sisdol Waste LandPll Site (Sanvaadadaata, L., n.d.)
Figure 1-43. Muddy road to the landfill in monsoon (Karki, S., 2021)
Figure 1-44. Garbage on narrow city road (The Kathmandu post., 2022)
Figure 1-45. Map of roads from Kathmandu to landfill sites, drawn by author

SOILD WASTE

Poor garbage management system

Banchare Danda Waste Landfill Site



New landfill that will accommodate the waste in the valley for about 25 years

TRUCK
LANDFILL SITE
TRANSFER STATION
GREEN SPACE



The road to the new landfill is still a mountain road



Sisdol had almost reached its full capacity

Sisdol Waste Landfill site



The only mountain road to the landfill in monsoon

0 1 KM

N

The accumulation of garbage in Bagmati River and the open spaces in Kathmandu Valley is due to the poor garbage management. There is only one government-operated transfer station in the whole Kathmandu Valley, the Teku Transfer Station, whose capacity is far from adequate for the temporary storage and transfer of unsorted waste throughout the whole Valley. (Kathmandu Metropolitan City., 2005). Therefore, the coverage of waste collection services at the Teku transfer station is far less than the demand. Residents outside the collection area dump their garbage on city open space, including Bagmati River. This situation is exacerbated during the rainy season, when heavy rains damage the dirt roads leading to the landfill, the accumulated garbage cannot be removed in time, and the transfer station quickly reaches its maximum capacity, at which point the garbage trucks stop collecting garbage in the city resulting in a rapid accumulation of garbage in the rivers and streets. This usually lasts for a week (Taylor, M., 2021). At the same time, the dense and narrow network of urban roads in the Kathmandu Valley makes it difficult for garbage trucks to pass through, further increasing the difficulty of garbage collection (Sharma, R., 2016). Together, these problems have led to the indiscriminate dumping of garbage in the Bagmati river channel.



Narrow city roads do not allow for garbage trucks

Teku Transfer station

SOLID WASTE

Growing concern - Bagmati River Clean-up Mega Campaign



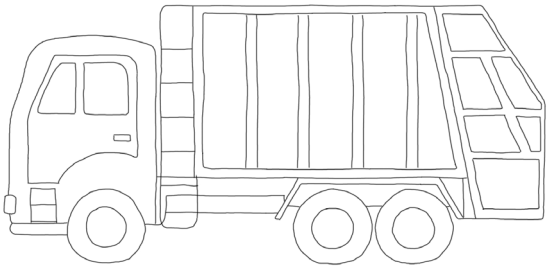


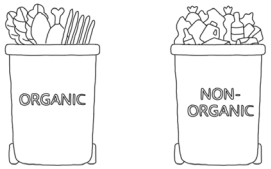
Figure 1-46, 1-47. Volunteers collect garbage in the Bagmati River (Kandel, Y. K., 2016)

For the past nine years, volunteers and the government have been working to clean up the river. Every Saturday, hundreds of volunteers gather at the Bagmati River to clean up the trash in the water and on the riverbank. However, their efforts do not achieve the best results, as garbage continues to be dumped in the Bagmati River due to poor garbage management and frequent interruptions of garbage collection services during the rainy season. As a result, some people have taken a negative view of this approach to manage pollution in the Bagmati River:

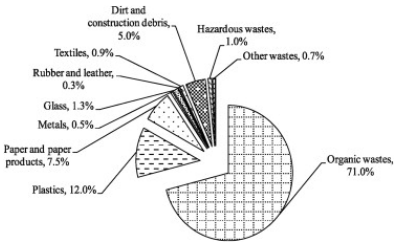
"Not that there has not been any efforts, there have been several cleaning campaigns, but there are more people dirtying it. People are the problem." (Associated Press., 2022).

SOILD WASTE
Growing concern - Government attention





GARBAGE COMPOSITION



The government is currently trying to increase the efficiency of waste management and the amount of waste that can be managed by using waste segregation. They hope that this more sustainable solid waste management system will address the problem of waste being dumped in the Bagmati River and on open urban land. Kathmandu Metropolitan City requires its residents to separate biodegradable and non-biodegradable waste at the source of origin. They have also set different collection times for these two types of waste. However, problems and challenges remain due to the insufficient implementation of these measures. One is that although biodegradable and non-biodegradable wastes are collected separately, some waste collectors use the same truck to transport them to the Teku transfer station. Another is the main reason why the current waste segregation initiative is not working: there is no place in the Kathmandu Valley to convert organic waste into fertilizer. All sorted waste ends up in landfills, where it is dumped together, which has the same result as not implementing the waste segregation policy (Ojha, A., 2022). **This new waste management method is not as efficient and sustainable as it was expected to be, and it did not increase the total amount of waste that can be handled.** Thus, although residents separate their waste, the purpose of this measure has not been achieved and the problem remains the same.

Figure 1-48. Waste segregation in Kathmandu Valley, drawn by author
Figure 1-49. Garbage composition in Kathmandu Valley (Dangi, M. B., Reddy, J. M., Gerow, K. G., Urynowicz, M. A., & Pretz, C. R., 2011)



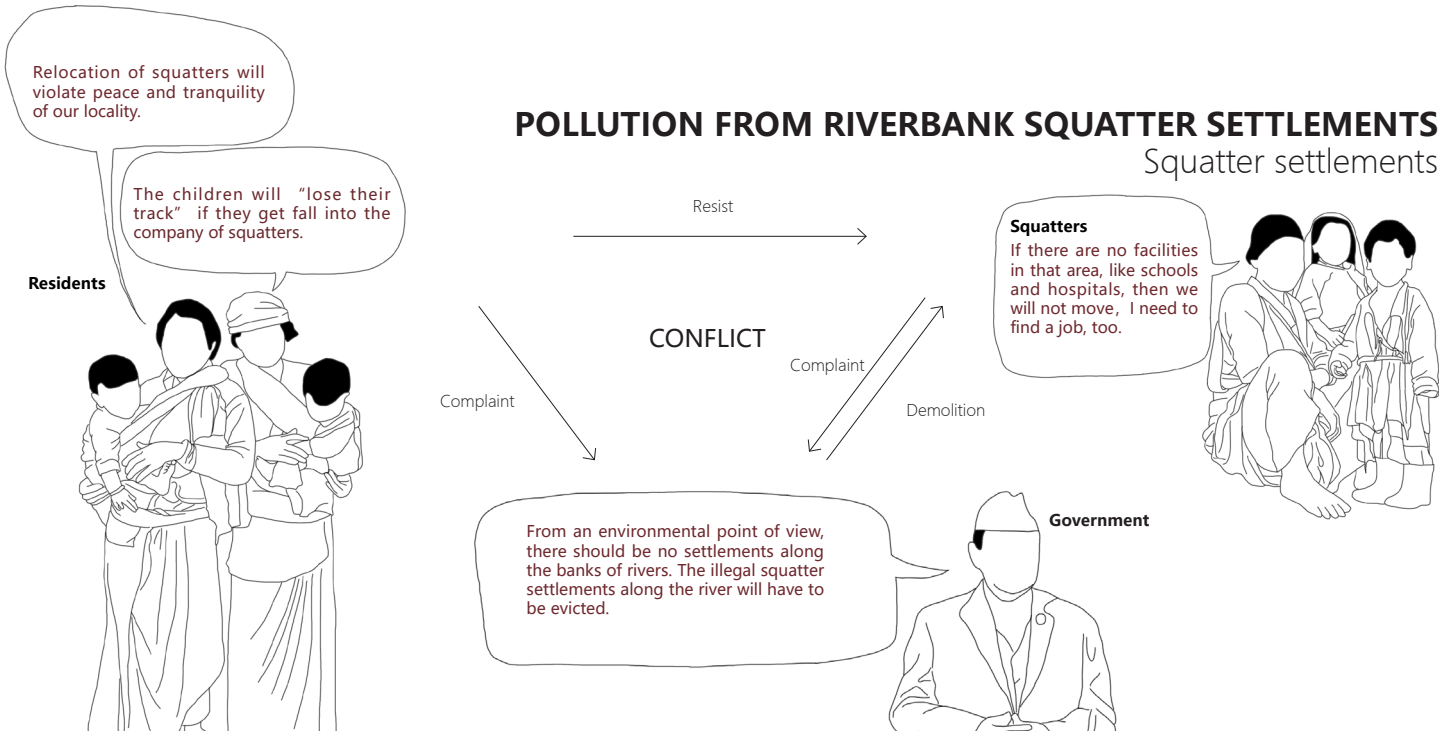






The squatter settlements along the Bagmati make the pollution worse. According to a report from a government workgroup, a total of 3,496 squatters in the Kathmandu Valley live in 20 districts and 27 settlements in Kathmandu, Lalitpur and Bhaktapur (Republica, 2022). The majority of the squatter settlements are located along the riverbank (Shrestha, P., 2022), most of which are at risk of flooding during the monsoon, and floods would carry waste from the river banks and residential areas into the river, leading to pollution. In addition, some squatters would pile garbage on the riverbank or throw it directly into the river, and some even built sewers to discharge domestic sewage directly into the river (Kainulainen, S., Khanal, A., Voima, K., & Kivelä, S., 2016), which aggravates the pollution of the Bagmati River.

Figure 1-50. Distribution of squatter settlements in Kathmandu Valley (Shrestha, P, 2022), Redrawn by author



POLLUTION FROM RIVERBANK SQUATTER SETTLEMENTS

Squatter settlements

For the environmental reasons, the government has been trying to evict illegal squatter settlements along the river. And this is not an easy job. In the past they have taken the approach of forced demolition, but with little success. While some chose to leave the settlements after accepting the compensation offered by the government, there were still many residents who chose to stay even after their houses were demolished because they had nowhere else to go. As a result, within a short period of time, new squatter settlements reappeared in the same places, as those who continued to stay built temporary huts out of timber and plastic sheeting (Manandhar, S., 2014). The government is also working to provide alternative housing for the remaining squatter families, and the Ministry of Urban Development began constructing apartments for these squatter families in the village of Ichangu Narayan in Kathmandu in 2012 to accommodate 300 families (Republica., 2022). But this is still not a good strategy for most of them. They moved from their old home to live along the Bagmati River in the center of the valley in order to seek more job opportunities, and most of them worked as daily wage workers. The new residence was located in the suburbs, with few job opportunities nearby, and they could not afford to take the bus to the city every day to look for work. Therefore, relocation makes no sense to them, and they would still choose to try to stay alongside the riverbank. Some residents are also concerned about the availability of public facilities such as schools and hospitals around the new residential area (Manandhar, S., 2014). At the same time, squatters moving to new settlements may face some resistance. This is because the neighboring residents are very resistant to their arrival. They believed that these squatters would disturb the peace and tranquility of the area (Sharma, N., 2014).

Figure 1-51. Drawing of the indigenous people in the relocation site, drawn by author
Figure 1-52. Drawing of government representative, drawn by author
Figure 1-53. Drawing of squatters, drawn by author

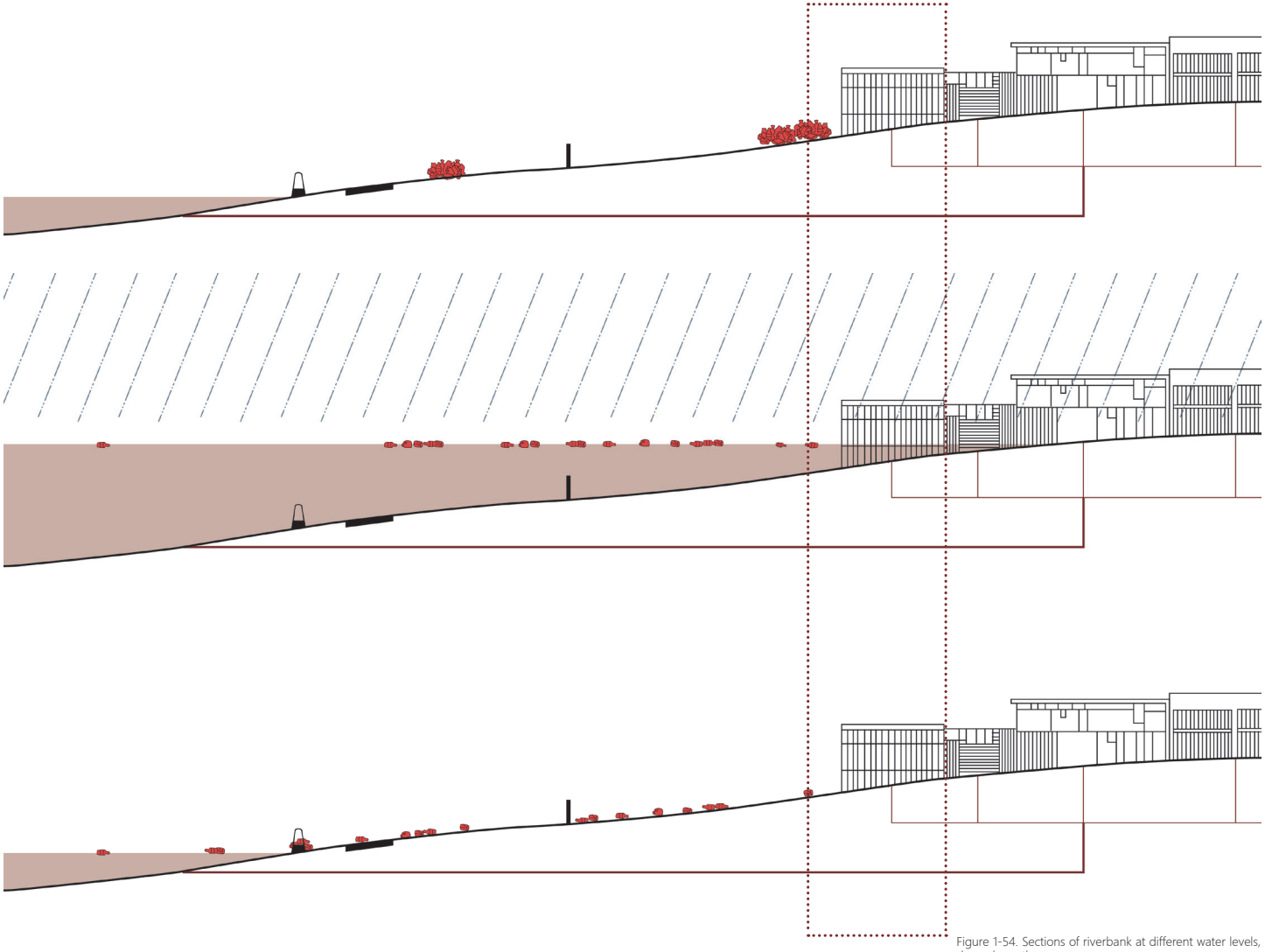


Figure 1-54. Sections of riverbank at different water levels, drawn by author

POLLUTION FROM RIVERBANK SQUATTER SETTLEMENTS

Squatter settlements during monsoon season

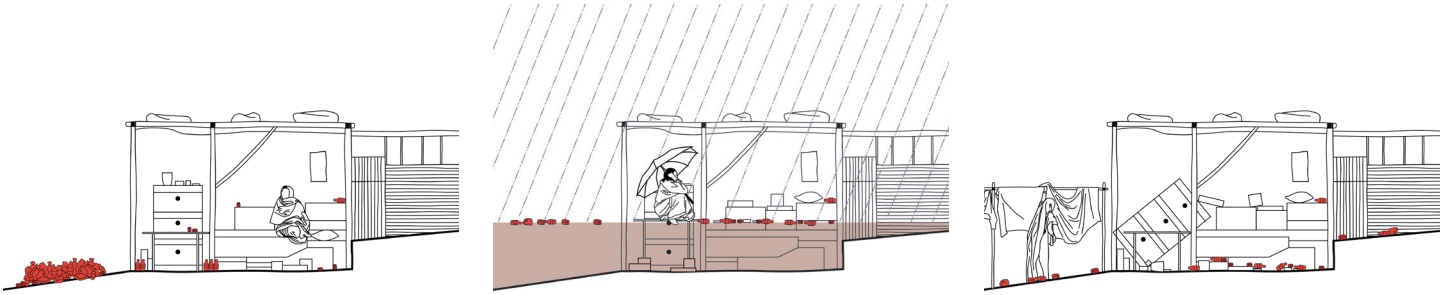


Figure 1-55. Sections of squatter settlement in the monsoon season, drawn by author

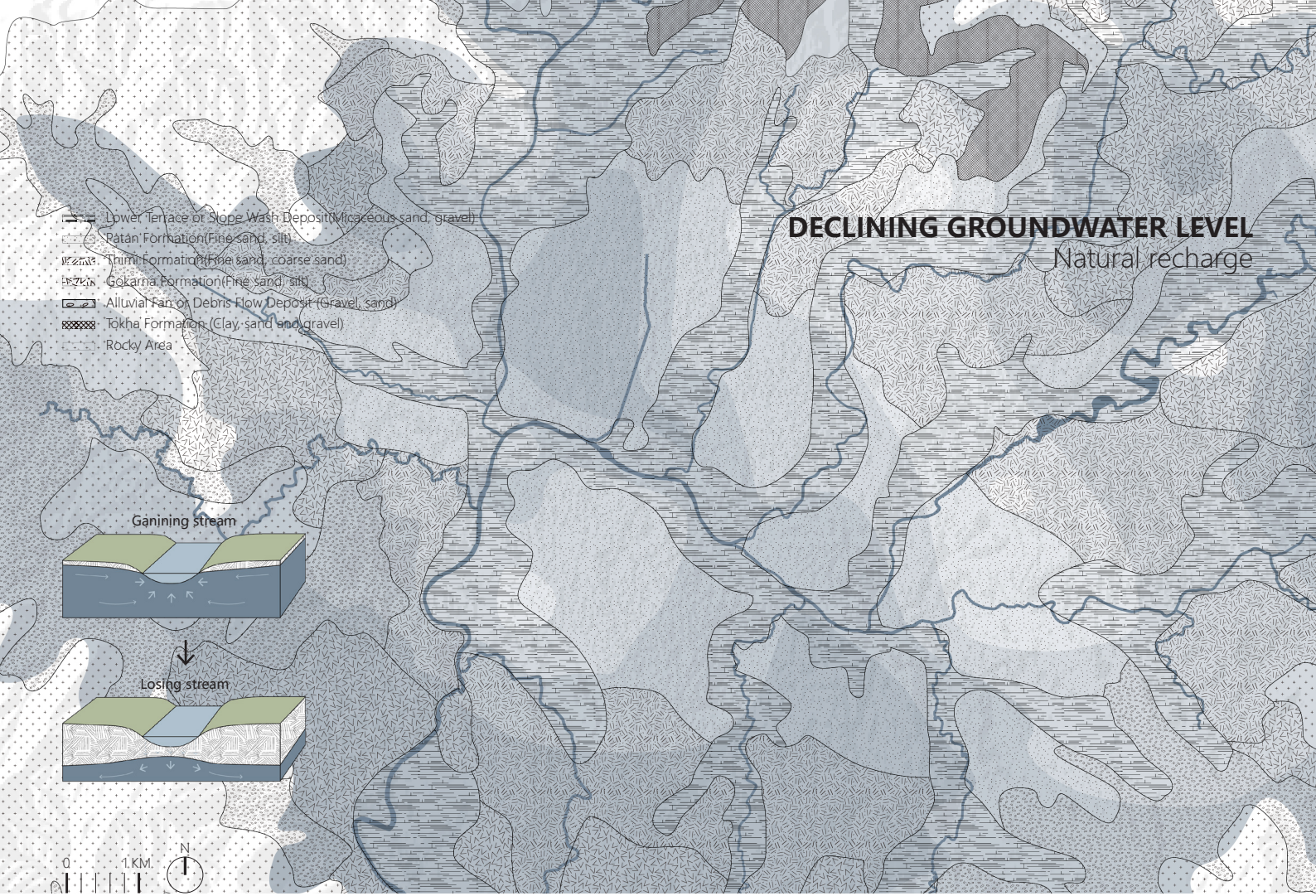
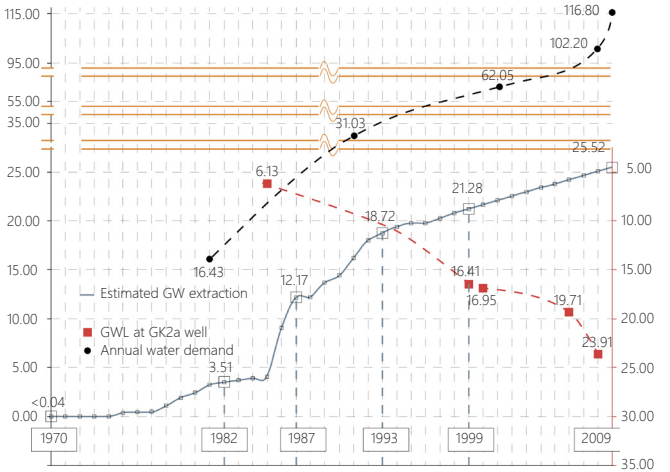
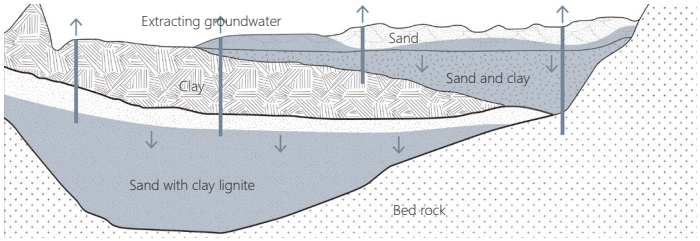


Figure 1-56. Soil map of Kathmandu Valley (Bajracharya, R., Tamrakar, N. K., & Shrestha, M., 2018), Redrawn by author
Figure 1-57. Interaction of groundwater and surface water (Whymap., n.d.), Redrawn by author

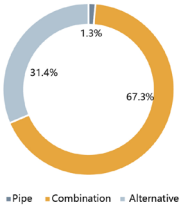
The influence of urban expansion on underground water recharge makes the pollution worse. The Bagmati River is supplied with water from both rainfall and groundwater (Taylor, M., 2018). Rain is the main source of water in the Bagmati River, but most of the rainfall is concentrated during the monsoon period (Tuladhar, D., Dewan, A., Kuhn, M., & Corner, R. J., 2019) and the long dry season relies mainly on groundwater for recharge (Asia News Network., 2022). The soil composition of Kathmandu valley is mostly sand and silt (Bajracharya, R., Tamrakar, N. K., & Shrestha, M., 2018), which has good permeability, therefore, **in the past, the rainwater during the monsoon season could penetrate the soil and be stored in the aquifer in large quantities. When the dry season arrives, the water from the aquifer will flow back into the river, ensuring that the river is able to continue to flow. This process has now mostly disappeared** (Mohan, M., 2022). Due to urban expansion, eighty percent of the valley's soil has been covered with concrete, making it difficult for rainwater to infiltrate and recharge the groundwater (Asia News Network., 2022). Flow is reduced during the dry season, making it difficult for pollutants to be discharged, they remain in the river channel, polluting the riverbed (Taylor, M., 2018).

DECLINING GROUNDWATER LEVEL
Water recharge and extraction





Private well



Stone spoute



Private well



Rain water



Tanker water



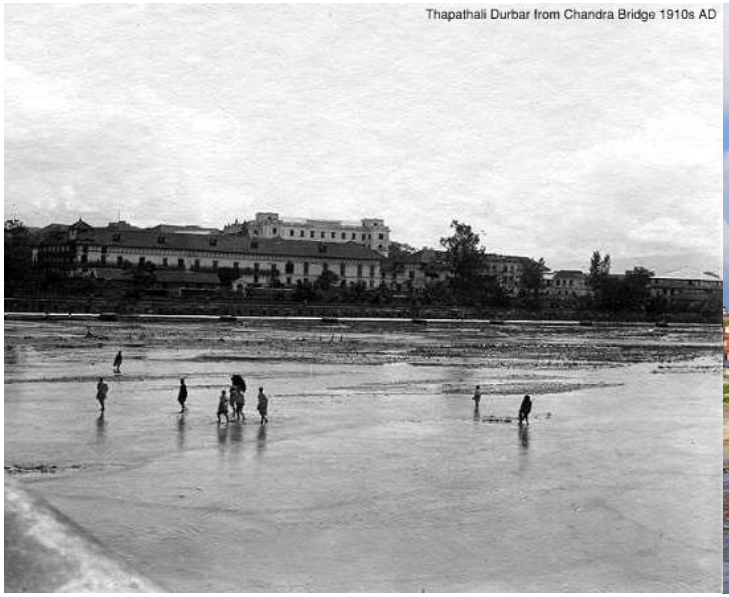
At the same time, groundwater extraction by people has further led to a rapid decline in groundwater levels. The Kathmandu Valley is facing severe water shortage due to rapid population growth. Currently, people in the Kathmandu Valley use two sources to meet their water needs: a direct water supply by Kathmandu Upatyaka Khanepani Limited (KUKL) and groundwater. Of these, groundwater accounts for nearly 50% (Taylor, M., 2018). The population is still growing and more and more wells are being excavated to pump water from the ground. **The amount of water being extracted is far more than the natural recharge, accelerating the depletion of the aquifer, and the groundwater level is decreasing rapidly** (Pandey, V. P., Shrestha, S., & Kazama, F., 2012). **Currently, the Bagmati River suffers from a significant reduction in runoff during the dry season due to the water level decline** (Asia News Network., 2022)**, which leads to long-term retention of pollutants and exacerbates the pollution of the Bagmati River.**

Figure 1-58. Groundwater level changes over the years (Pandey, P. V., Kazama, F., & Shrestha, S., 2012), Redrawn by author
Figure 1-59. Conceptual cross-section of groundwater system in the Kathmandu Valley Basin (Davids, J., 2019)
Figure 1-60. Daily water composition in Kathmandu Valley, drawn by author
Figure 1-61. Stone spoute (Sasimoto., 2019)
Figure 1-62. Private well (Methodology Centre for Environment Assessment., 2018)
Figure 1-63. Rain water (Budhathoki, B., 2021)
Figure 1-64. Tanker water (Himalayan News Service., 2017)

All the problems together lead to the decline of Bagmati civilisation.
Now, **people** living in Kathmandu **are disconnected from the Bagmati River,**
resulting in **a decline in the quality of life** in Kathmandu Valley.

LOST CONNECTION WITH BAGMATI RIVER

Thapathali(Patan) from Thapathali bridge





1918

People used walk through Bagmati

2023

Bagmati is chocked with Sewage and trash which is no longer safe for people to get close

Figure 1-65. Thapathali (Patan) from Thapathali bridge in 1918 (Regmi, A., 2013)
Figure 1-66. Thapathali (Patan) from Thapathali bridge in 2023 (Subedi, U., 2022)

Sankhamul Ghat



1920

A pleasant gathering space

2016

Home to scavenging animals and birds

Figure 1-67. Sankhamul Ghat in 1920 (Storymaps., 1920)
Figure 1-68. Sankhamul Ghat in 2016 (Wei, L. Y., 2016)

LOST CONNECTION WITH BAGMATI RIVER

River bank of Thapathali in rainy season



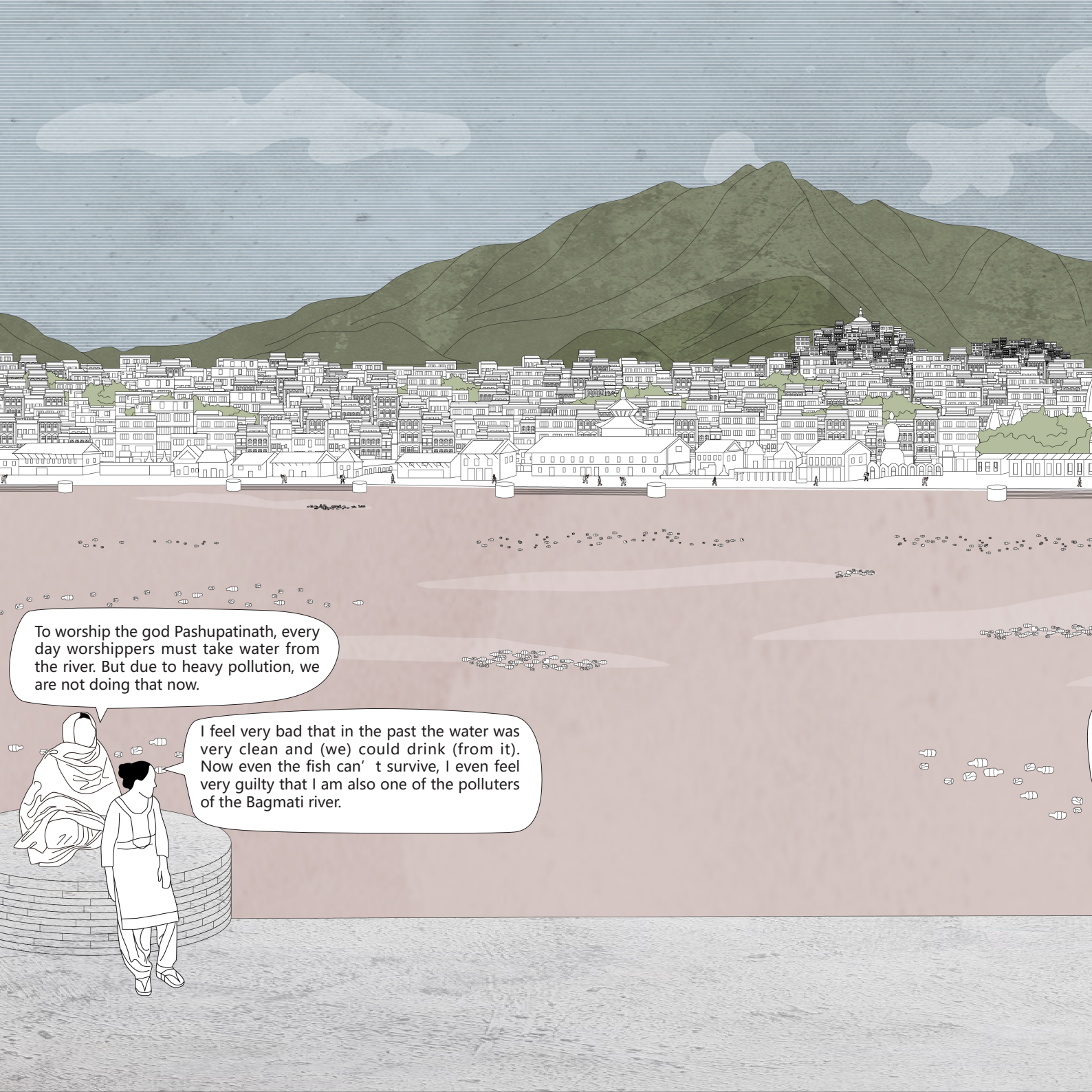
1926

Swimming during monsoon

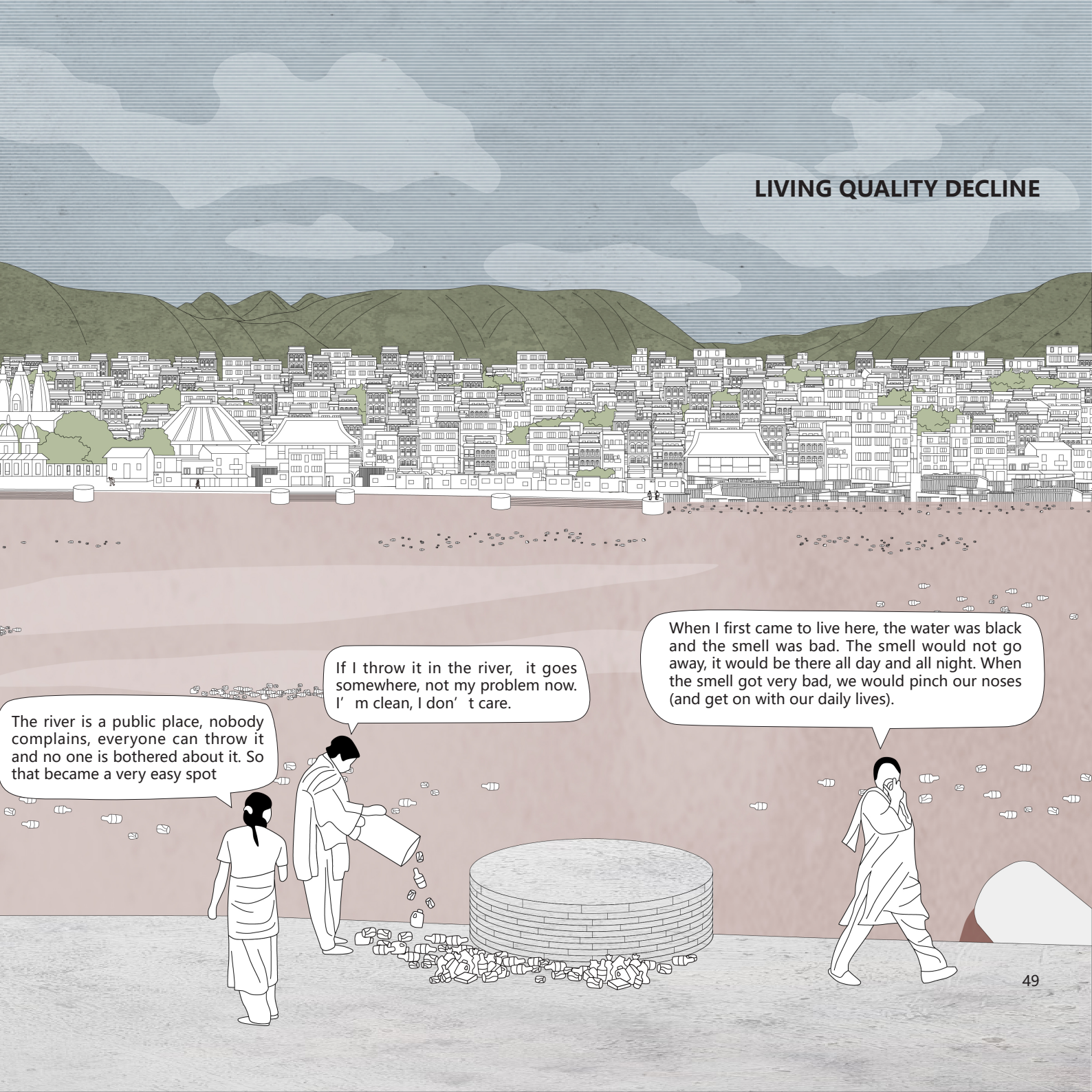
2021

Water of Bagmati is too dirty for swimming inside

Figure 1-69. River bank of Thapathali in rainy season in 1926 (Storymaps., 1920)
Figure 1-70. River bank of Thapathali in rainy season in 2021 (Poudel, P, 2021)


To worship the god Pashupatinath, every day worshippers must take water from the river. But due to heavy pollution, we are not doing that now.
I feel very bad that in the past the water was very clean and (we) could drink (from it). Now even the fish can' t survive, I even feel very guilty that I am also one of the polluters of the Bagmati river.

LIVING QUALITY DECLINE



02 PROBLEM STATEMENT AND RESEARCH QUESTION

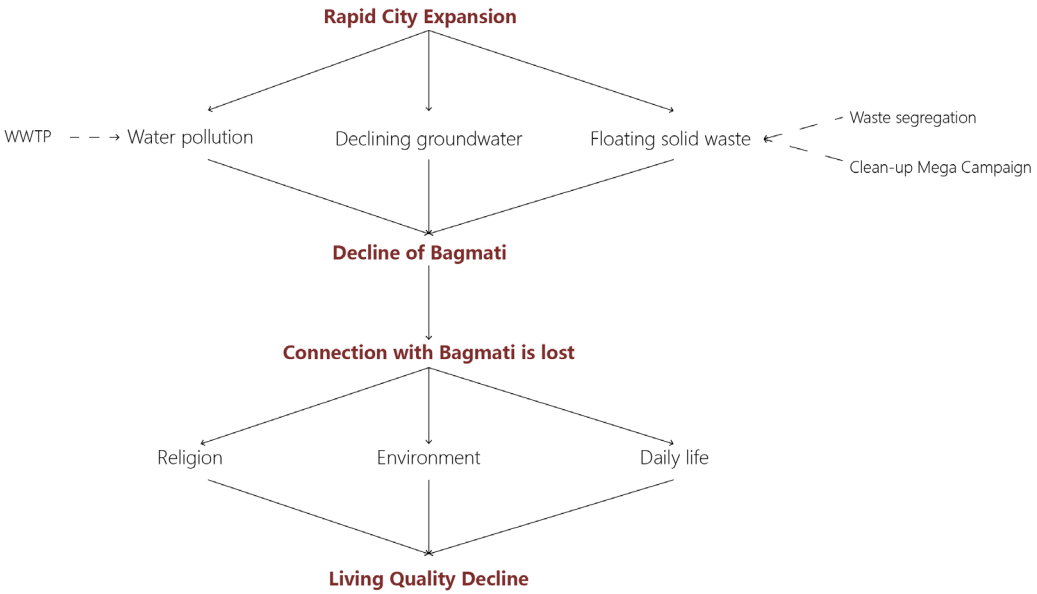


Figure 2-1. Problem statement diagram, drawn by author

PROBLEM STATEMENT

Rapid urban expansion in the 21st century has brought many problems to the Kathmandu Valley, and one of the most severely affected is the sacred river, the Bagmati. The direct discharge of wastewater, solid waste in the river, encroachment of riverbanks by squatter settlements, and declining groundwater levels have all contributed to the decline of this sacred river. It resulted in a loss of connection between people and it, which ultimately led to a decline in living quality for the people who live in the Kathmandu Valley.

The government is currently taking several separate measures to address these issues. But these measurements alone are not enough. They don' t work together- the upgraded sewage treatment plant still has insufficient capacity, large amounts of wastewater remain untreated, people continue to throw garbage into the river despite the rules and demolished squatter settlements reappeared within a short period of time etc. As a large region with complex environmental issues, it is difficult to achieve all changes at once. Therefore, more efforts need to put into the 'process of change' to improve the living quality of the Kathmandu Valley. This project will explore the role of landscape architectural means to integrate the separated, mainly technical measures, as part of a spatial design that rebuild the connection between people and Bagmati and achieve the improvement in living quality in the Kathmandu Valley.

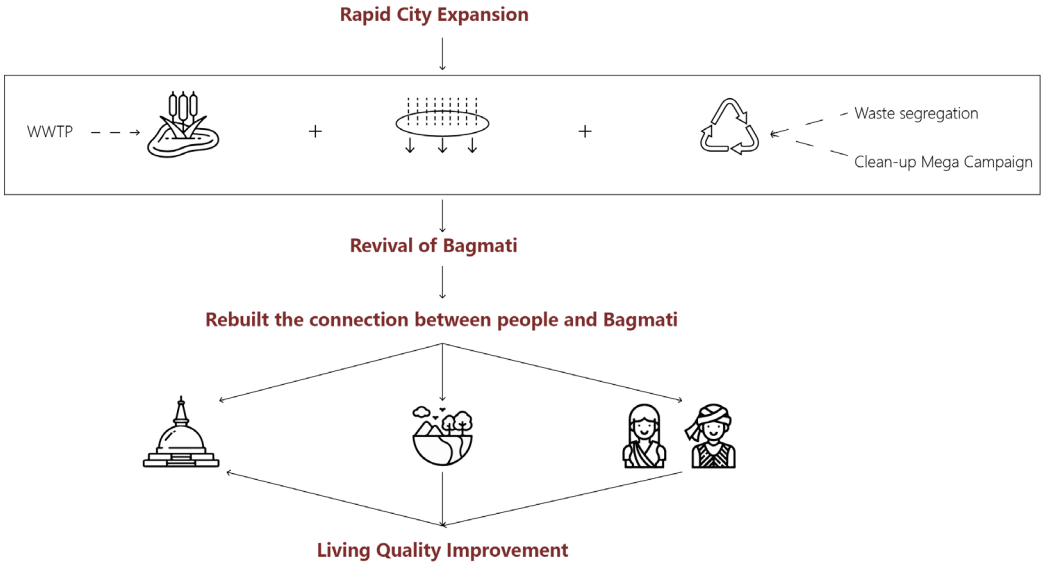


Figure 2-2. Research question diagram, drawn by author

RESEARCH QUESTION
The role of landscape architecture

Can an integrated and comprehensive landscape architectonic (spatial) design of the Bagmati River reconnect people to the river and enhance the living quality in the Kathmandu Valley?

MAIN ELEMENTS	SUB-QUESTION
Can an integrated and comprehensive landscape architectonic (spatial) design	How to integrate the separated technique measures and landscape (spatial) interventions to form integrated and comprehensive landscape architectonic (spatial) design?
of the Bagmati River	What is needed to revive Bagmati River to restore its culture and nature?
reconnect people to the river and enhance the living quality in the Kathmandu Valley?	What steps need to be taken to implement change to reconnect people to the river and enhance the living quality in the Kathmandu Valley?

03 PROJECT THEORETICAL FRAMEWORK

In this research, I will investigate the role of landscape architecture to integrate the separated technique measures with the landscape spatial design to accelerate the living quality improvement process. To make the place livable, a slow landscape transformation guided by phasing and involvement of inhabitants might be a good approach. Therefore, the concept of an "Urban Catalyst" is chosen as the framework of the project. With the intervention of catalyst point - which in landscape design are spatial designs to promote positive changes and chain effect to the surroundings beyond the boundary of the intervention area to regenerate the area (Aitani, K., & Arima, T., 2014) – we can slowly start to restore Bagmati River. Through the landscape approach, the transformation will take place step by step, from the scale of the intervention area to the entire river system, to reconnect people with the Bagmati River, ultimately impacting the valley and improving the quality of life of its inhabitants.

URBAN CATALYST
Introduction

The concept of Urban Catalyst was developed by Wayne Atton and Donna Logan in their book American Urban Architecture: Catalysts in the design of Cities. They brought the concept of catalyst from the field of chemistry to the field of architecture. The theory holds that there are chain reactions in urban development similar to a chemical reaction, and that a catalyst with a positive catalytic effect will bring about a positive impact on urban development (Aitani, K., & Arima, T., 2014). This theory was later applied to the field of urban planning, which Koichiro and Takafumi defined it as a catalyst promoting the chain development and regeneration in the city. It is not the end result, but the beginning of a series of designs which promotes positive changes and chain effect to the surroundings beyond the boundary of the intervention area and most likely regenerate the area (Aitani, K., & Arima, T., 2014). Urban catalyst theory had been later applied to landscape design as well. There are various types of things that can be used as catalysts in different fields. A building, a square, or a commercial street (Atton, W., & Logan, D. 1989) or even an event can be a catalyst (Jie, C., 2019) and the way they affect larger areas is also different. But all catalysts share the same characteristics(王欣宜 ., 2020):

1.Associativity：In the process of catalytic reaction should always pay attention to the connection between the catalytic elements and the surrounding.

2.Progressivity：Catalyst intervention at the site is a gradual, step-by-step process. The influence of the catalyst also plays a step-by-step role.

3.Continuity: The impact process of urban catalysts is continuous, not only the continuity of the renewal process, but also the continuity of the impact of the catalyst on more distant areas through inspire and guide the subsequent design.

URBAN CATALYST
Operation Mechanism

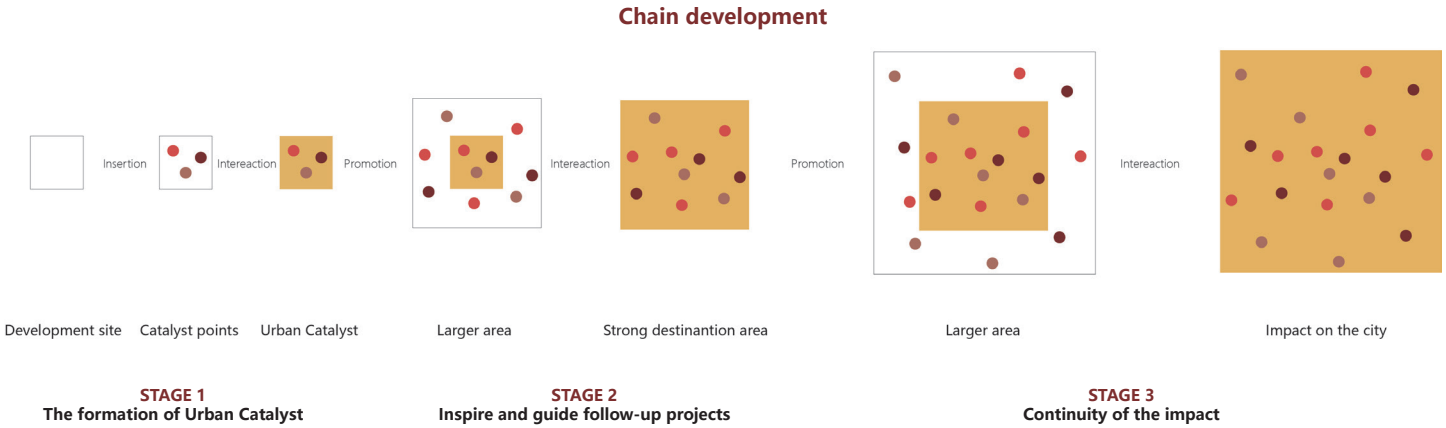
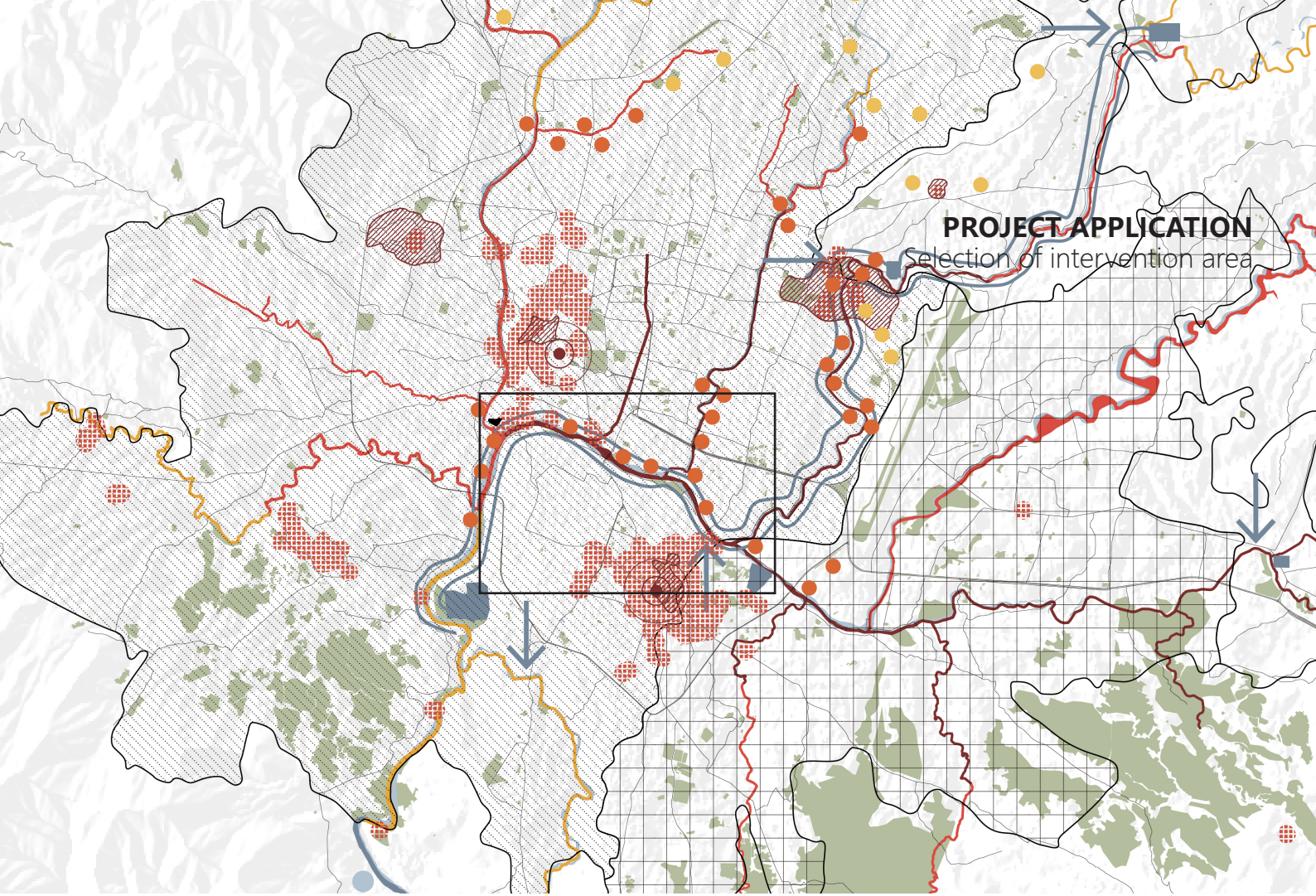


Figure 3-1. Operation Mechanism of Urban Catalyst, drawn by author

According to the understanding of the theoretical mechanisms of the Urban Catalyst theory, its operation mechanism in landscape design can be summarized in the following three stages (徐 云 曦 ., (2012)). The first stage is the formation of urban catalyst through the intervention of catalytic points in the intervention area, which in landscape design are spatial designs. After the urban catalyst is formed, in the second stage, it is necessary to continue to guide the continuation of the catalytic reaction to transform the entire destination area by inspiring and guiding follow-up projects to create a more lasting impact in the larger region. In the last stage, the impact can continue, influencing larger area at the city scale.



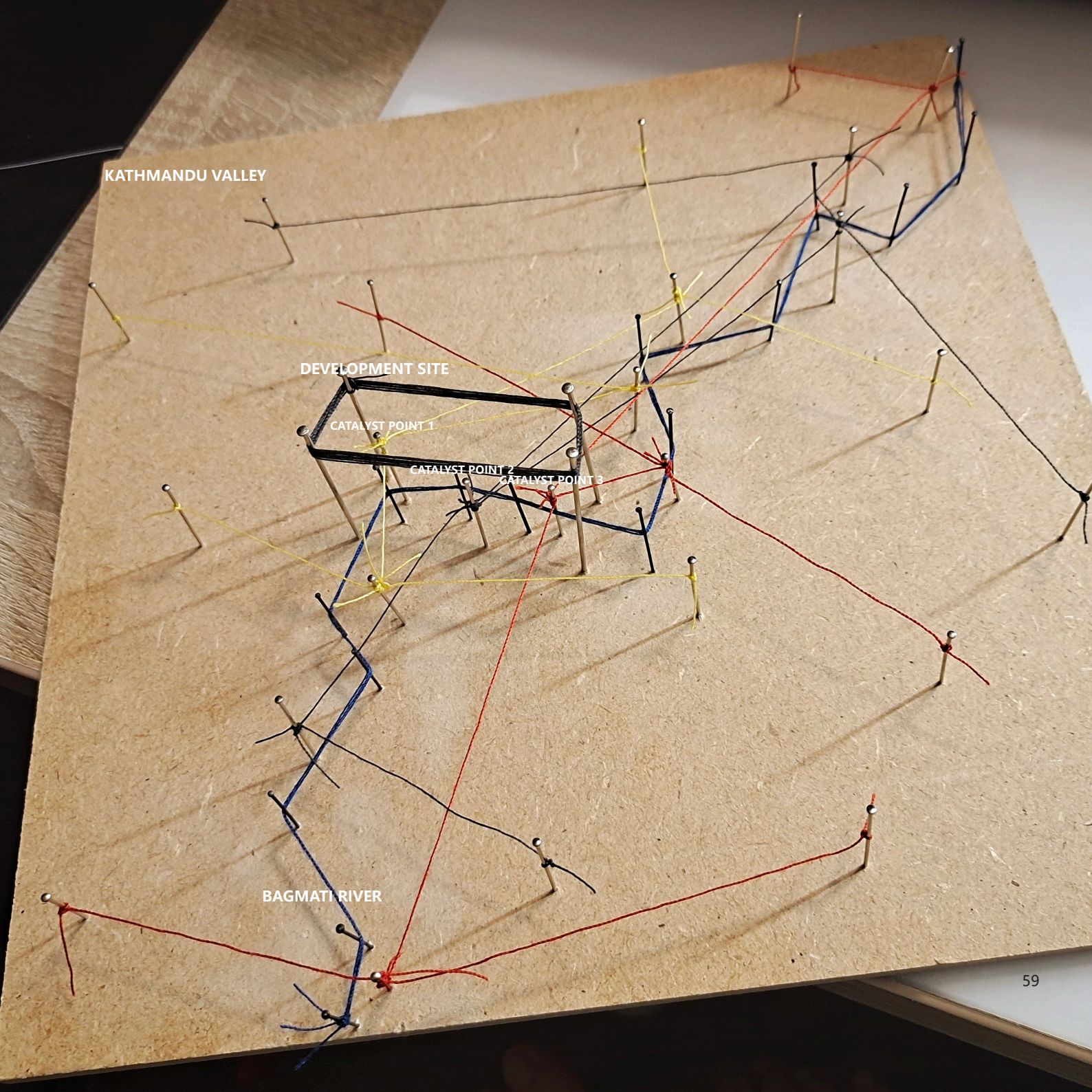
The application of Urban Catalyst theory on the project is start from the selection of intervention area that based on the overlaid challenge maps. The place with all the challenges is chosen to be the intervention area. It is the miniature of the problematic Bagmati River system. Therefore, the design of this area can be the Urban Catalyst to inspire and guide the following environmental improvement projects in other sections of the Bagmati River through the implementation of the catalyst points which in this project is the spatial design interventions during the chain development phase to restore the whole Bagmati River system. And some of these catalyst points can continue to be applied in larger area with similar problems to have impact on a wider area of the Kathmandu Valley.

Figure 3-2. Overlaid problem map of Kathmandu Valley, drawn by author

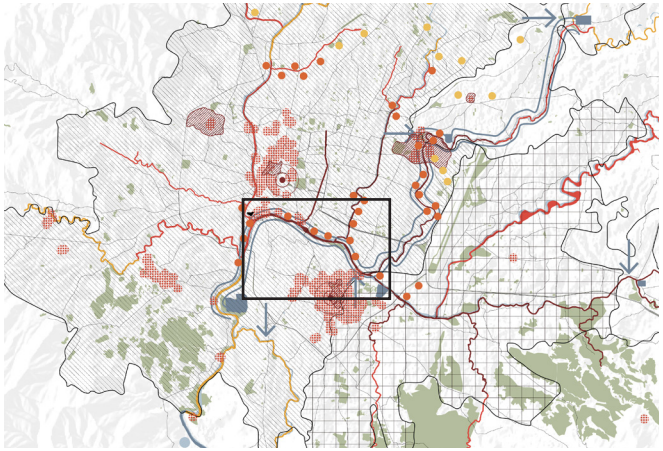
PROJECT APPLICATION
Chain development

The concept model shows the chain development of the Bagmati revival project. The first stage is the formation of Urban Catalyst-the design implementations in the intervention area, it is the main part of this project, several spatial design interventions (catalyst points) will be generated in this phase. In the second stage, the catalyst points will be applied to the entire Bagmati River Basin to achieve the goal of improving the ecological condition of Bagmati River. But the influence of the project will not end at this scale. In the final stage, in the larger region of the Kathmandu Valley, some interventions could also be continued in places with similar problems. With these three stages, the entire Bagmati River system will be revived and the quality of life in the entire Kathmandu Valley will be improved to some extent.

Figure 3-3. Model of the application of Urban Catalyst theory to the study site, taken by author

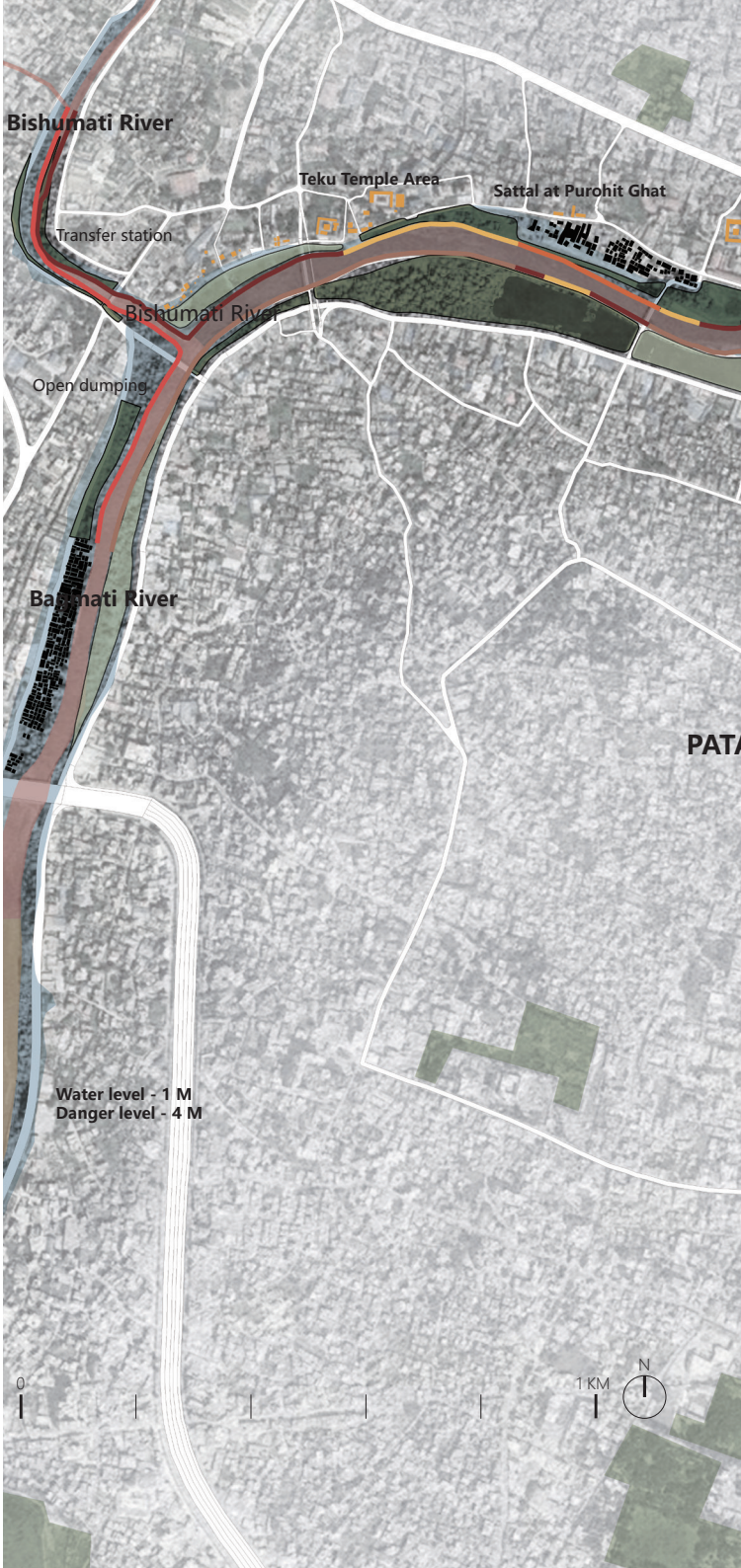

KATHMANDU VALLEY
DEVELOPMENT SITE
CATALYST POINT 1
CATALYST POINT 2
CATALYST POINT 3
BAGMATI RIVER

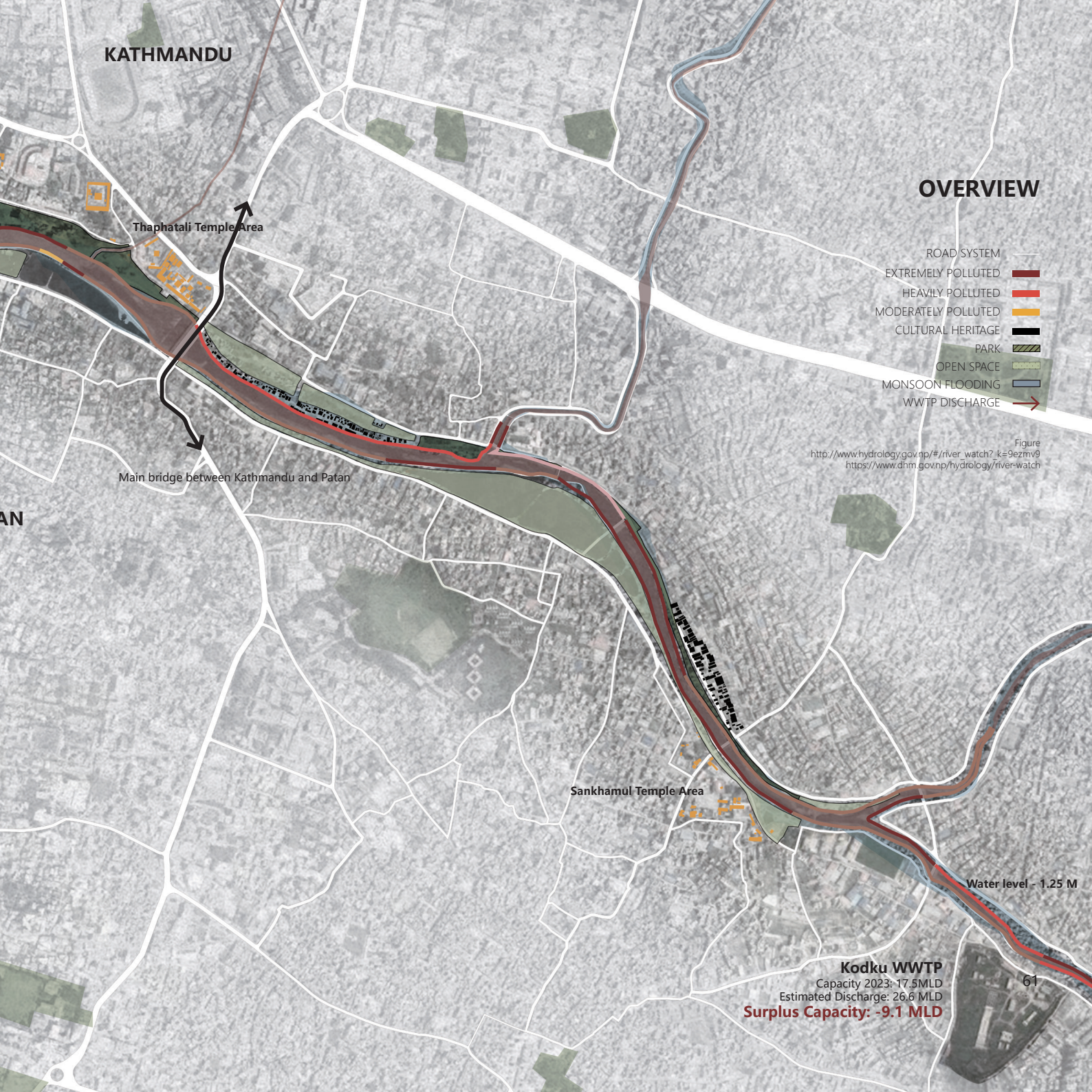
04 INTERVENTION AREA



The intervention area is the miniature of the problematic Bagmati River system. It is located between the two main cities of Kathmandu Valley-Kathmandu and Patan. Several bridges across the river connect the two cities. The banks of the river are mostly open spaces and parks, except for very few government facilities and four squatter settlement areas. The cultural monuments are mostly located on the north side of the river. The only transfer station-Teku transfer station in Kathmandu Valley is located at the junction area of Bishumati River and Bagmati River. It has a capacity of 100 tons per day (Kathmandu Metropolitan City., 2005) far from adequate to meet the waste management needs of the Kathmandu Valley. The wastewater treatment plant in this area will continue to discharge 9.1 million liters of untreated wastewater per day after the upgrade.

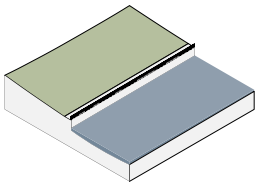
Figure 4-1. Overlaid problem map of Kathmandu Valley, drawn by author
Figure 4-2. Overview map of existing situation of the intervention area, drawn by author

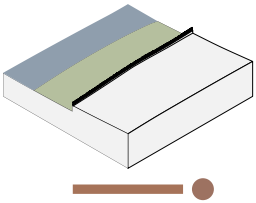



KATHMANDU
Thaphatali Temple Area
Main bridge between Kathmandu and Patan
AN
Sankhamul Temple Area
Water level - 1.25 M
OVERVIEW
ROAD SYSTEM
EXTREMELY POLLUTED
HEAVILY POLLUTED
MODERATELY POLLUTED
CULTURAL HERITAGE
PARK
OPEN SPACE
MONSOON FLOODING
WWTP DISCHARGE
Figure
http://www.hydrology.gov.np/#/river_watch?_k=9ezmv9
https://www.dhm.gov.np/hydrology/river-watch
Kodku WWTP
Capacity 2023: 17.5MLD
Estimated Discharge: 26.6 MLD
Surplus Capacity: -9.1 MLD

Most of the existing river banks in the intervention area are covered by hard pavement which prevents the rain water from recharging the aquifer. As for the more natural banks, they allow for aquifer recharge, but most of them are nearly flat, which makes it difficult to collect and store rainwater, therefore greatly reduces the amount of water that can later recharge the aquifer.

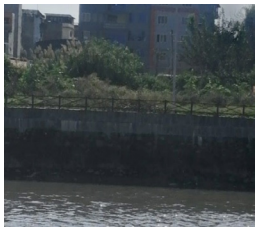
Hard Riverbank



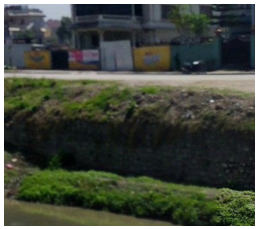






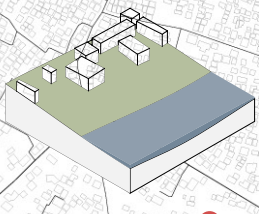








Soft Riverbank







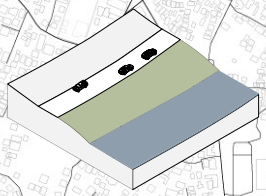






RIVER BANK TYPOLOGY

ROAD SYSTEM
WATER BODY
MONSOON FLOODING
SQUATTER SETTLEMENT
CULTURAL HERITAGE





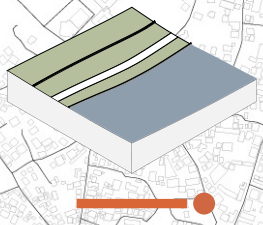




Figure 4-3. Map of riverbank typology of intervention area, drawn by author
Figure 4-4. Axonometric diagram of riverbank typology of intervention area, drawn by author
Figure 4-5. Images of different types of riverbanks in the intervention area (Googlemap., n.d.)

0 1 KM N

Figure 4-6. Teku Temple Area in 1993 (Trapp, H., 2020)
Figure 4-7. Sattal at Purohit Ghat in 1983 (Gutschow, N., 2022)
Figure 4-8. Thaphatali Temple Area in 1960 (Chitrakar, G. M., 2022)
Figure 4-9. Sankhamul Ghat in 1920 (Storymaps., 1920)
Figure 4-10. Teku Temple Area in 2021 (Kayastha, R. R., 2021)
Figure 4-11. Sattal at Purohit Ghat in 2017 (Khattri, P., 2017)
Figure 4-12. Thaphatali Temple Area in 2022 (Voice, A., 2022)
Figure 4-13. Sankhamul Ghat in 2016 (Wei, L. Y., 2016)

Most of the cultural remains in the area are located on the north bank of the river. The south bank has only one temple complex - Sankhamul temple area, near the east side, while the north bank has two temple complexes - Teku temple area and Thaphatali temple area, with some monuments scattered on the river bank. In the past, these religious buildings were directly connected to Bagmati through ghat, but now, for a number of reasons, this connection is gradually being lost.

For the Teku Temple area, an open space was built between the monument and the Bagmati River, which replaced the old ghat. Although a new ghat is built on the riverbank, but the accumulated trash, sand and stones and temporary structures on the open space greatly diminishes this connection. For the Sattal at Purohit Ghat, the old ghat was preserved, but the river bank was encroached upon by squatter settlements, resulting in the loss of the connection with the Bagmati River. The situations in the Sankhamul Temple area and Thaphatali Temple area are quite similar to the Teku Temple area, but Thaphatali Temple area is now fenced off from the Bagmati River.

Teku Temple Area



1993





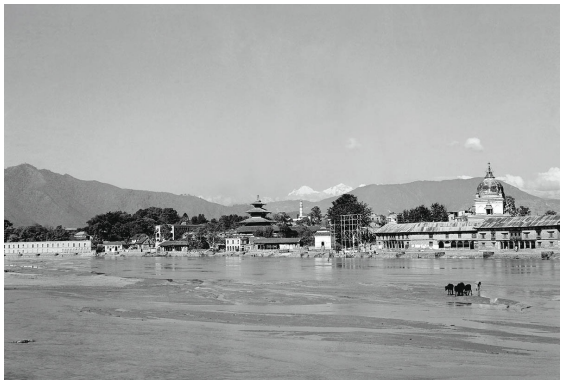
RELIGIOUS MONUMENTS

attal at Purohit Ghat



1983

Thaphatali Temple Area



1960

Sankhamul Temple Area

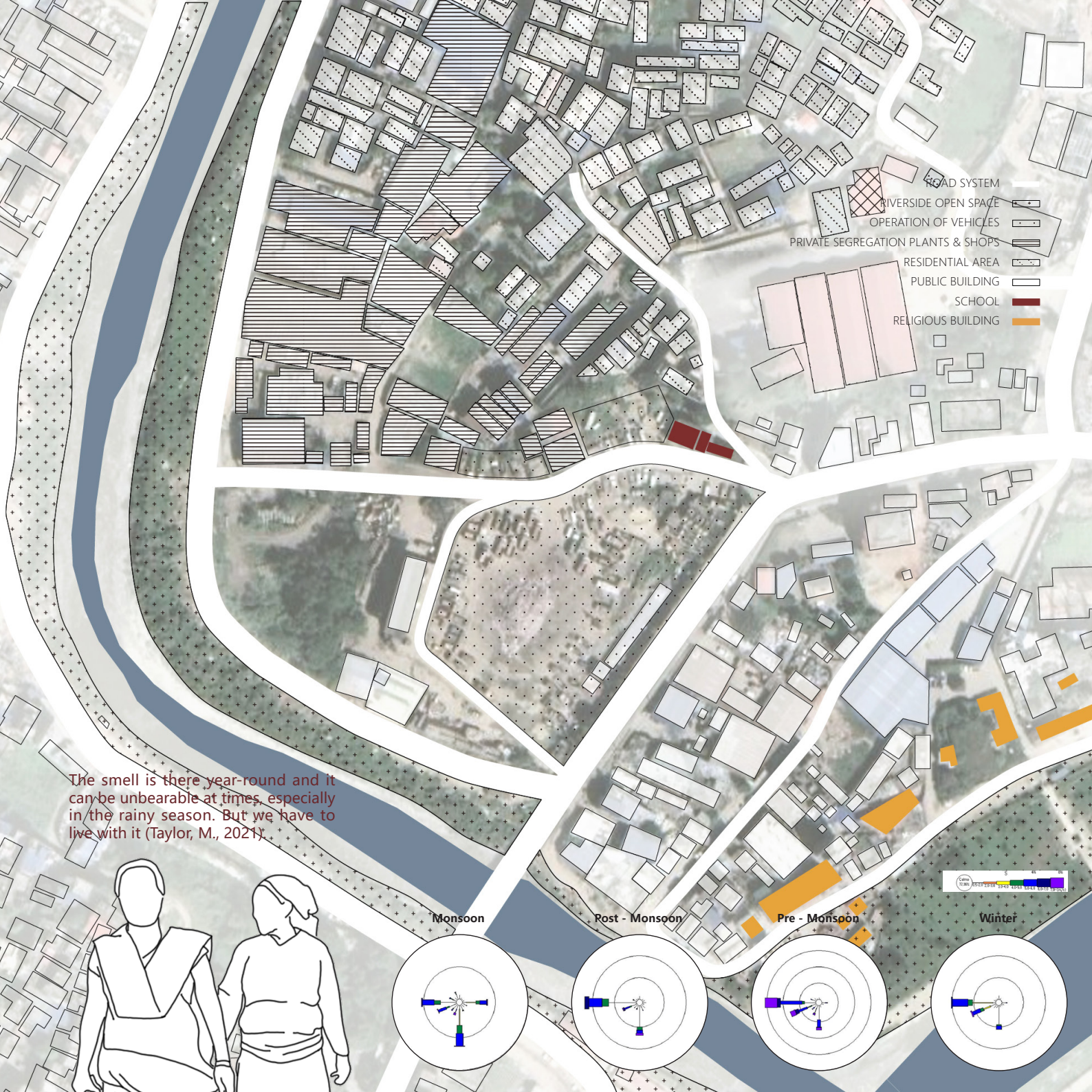


1920








ROAD SYSTEM
RIVERSIDE OPEN SPACE
OPERATION OF VEHICLES
PRIVATE SEGREGATION PLANTS & SHOPS
RESIDENTIAL AREA
PUBLIC BUILDING
SCHOOL
RELIGIOUS BUILDING
The smell is there year-round and it can be unbearable at times, especially in the rainy season. But we have to live with it (Taylor, M., 2021).
Monsoon
Post - Monsoon
Pre - Monsoon
Winter

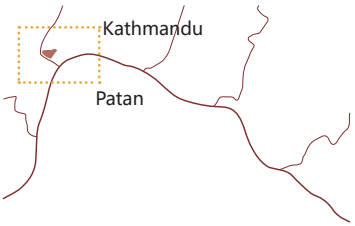
TRANSFER STATION



The transfer station is surrounded by the many private segregation shops. Recyclable waste, such as plastic bottles, is bought from private waste collection organizations and sold to India from here. (Pandey, G. G., 2016). Some stores and construction material warehouses are also located in this area. The private segregation shops, warehouses and shops are all mainly built of red bricks and timber with steel roof.

Besides these facilities, there are a large number of residences located a little further away. Although the residence adjacent to the transfer station is located upwind, and the residence downwind is separated from the transfer station by the river (Aryal, R., Lee, B. K., Karki, R., & Gurung, A., 2008), the residents here are still sometimes plagued by odors. The first reason is the garbage that transported to the transfer station are all dumped outside (Kathmandu Metropolitan City., 2005). The second reason is the inefficient waste disposal method, it leads to the accumulation of waste in the transfer station. This situation is especially serious during the rainy season (Taylor, M., 2021).

Figure 4-14. Map of exisiting transfer station, drawn by author
Figure 4-15. Wind speed and direction in four seasons in Kathmandu Valley (Aryal, R. K., Giri, N., Sharma, S., Pathak, B. K., Kandasamy, J., Gurung, A., Karki, R., & Lee, B.-K., 2008)
Figure 4-16. Map of the surrounding condition of the transfer station (Googlemap., n.d.)
Figure 4-17. Location map of transfer station, drawn by author



TRANSFER STATION

PRIVATE SEGREGATION PLANTS & SHOPS







CONSTRUCTION MATERIAL WAREHOUSE

STORES







RESIDENTIAL AREA





Figure 4-18, 4-19, 4-20. Image of private segregation plants & shops (Googlemap., n.d.)
Figure 4-21, 4-22. Image of construction material warehouse (Googlemap., n.d.)
Figure 4-23. Image of stores (Googlemap., n.d.)
Figure 4-24, 4-25. Image of residential area (Googlemap., n.d.)

TRANSFER STATION

DRY SEASON





MONSOON





BIOMETHANATION PLANT





BRIDGE



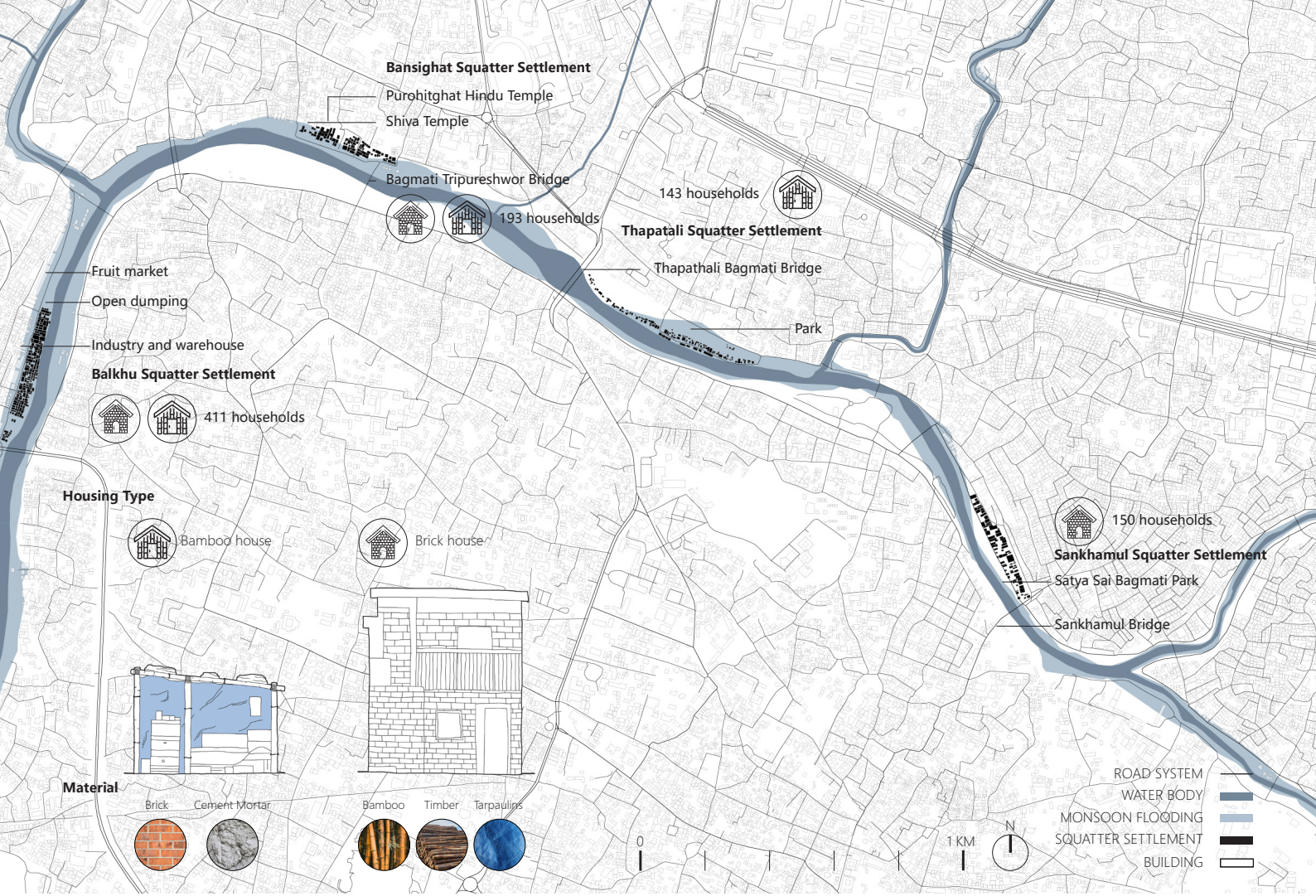


THE PROBLEMS OF THE EXISTING TRANSFER STATION

1. The infrastructure is poor, solid waste collection is difficult and disposal services remain insufficient. Teku T/S only allows access to garbage collected by truck. But many roads are too narrow for garbage trucks, therefore, **garbage from the dense and narrow city roads cannot be collected** (Sharma, R., 2016).
2. Since Teku T/S has a **limited capacity** - 100 tons per day (Kathmandu Metropolitan City., 2005) - and the Kathmandu Valley generates 1,200 tons per day (Pathak, D. R., 2021), it can only collect garbage in a **limited service area**, although it is the only transfer station in the Kathmandu Valley.
3. **Manpower is lack** due to the caste. Most Nepalis believe that **managing garbage cannot be honorable work** (Sharma, R., 2016). Municipal garbage collectors traditionally belonged to marginalised Dalit communities. Street children and scavengers (kabbadis) make their living by collecting and sorting waste.

These three main causes lead to the accumulation of garbage in the Bagmati River and city streets.

Figure 4-26. Image of transfer station in dry season (Pandey, G. G., 2016)
Figure 4-27. Image of transfer station in dry season (Sh, F., 2017)
Figure 4-28. Image of transfer station in dry season (Shrestha, D., 2021)
Figure 4-29. Image of transfer station during monsoon (Ojha, A., 2022)
Figure 4-30. Image of biomethanation plant (Me, I. A., 2018)
Figure 4-31. Image of biomethanation plant (Onlinekhabar., 2017)
Figure 4-32. Image of bridge of transfer station (Panday, P., 2020)
Figure 4-33. Image of bridge of transfer station (Environment Audit Report., 2015)



There are about nine hundred people living in four squatter settlements in this area (Republica, 2022), and these squatter settlements and Bagmati negatively affect each other. Three of these four settlements are at risk of flooding. Most of the settlements here are not very structurally stable, which increases the vulnerability of squatters living in these areas to flooding. On the other hand, the dumping of garbage and direct discharge of sewage by squatters make the pollution of Bagmati worse.

Figure 4-34. Map of squatter settlements in intervention area, drawn by author
Figure 4-35. Images of the existing situation of squatter settlements in intervention area (Google., n.d.)

SQUATTER SETTLEMENT

HOUSE TYPE

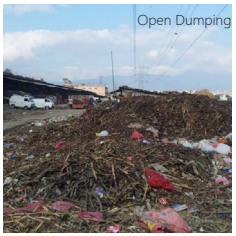
SURROUNDING

Balkhu SS











Bansighat SS











Thapatali SS











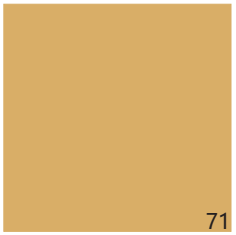
Sankhamul SS

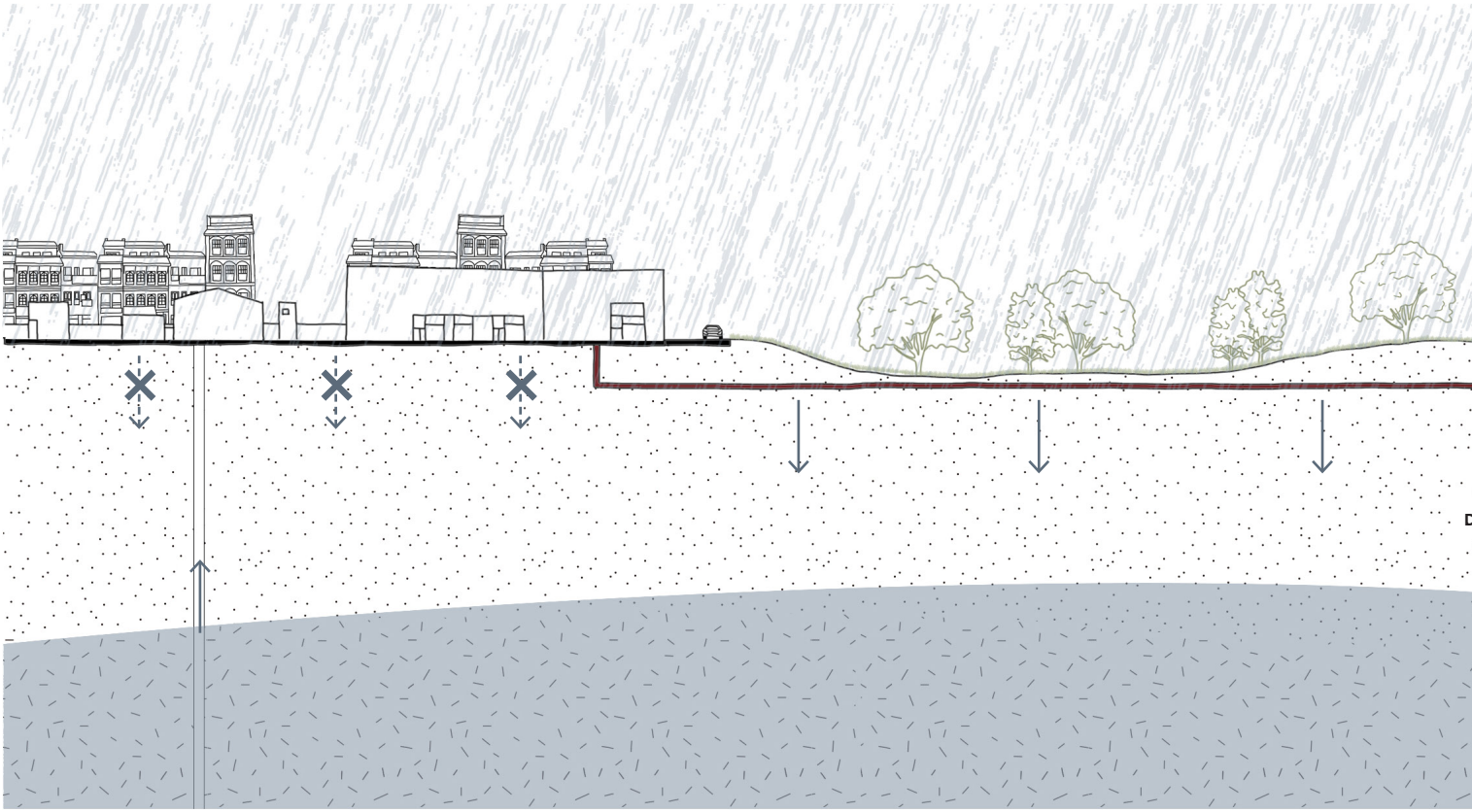












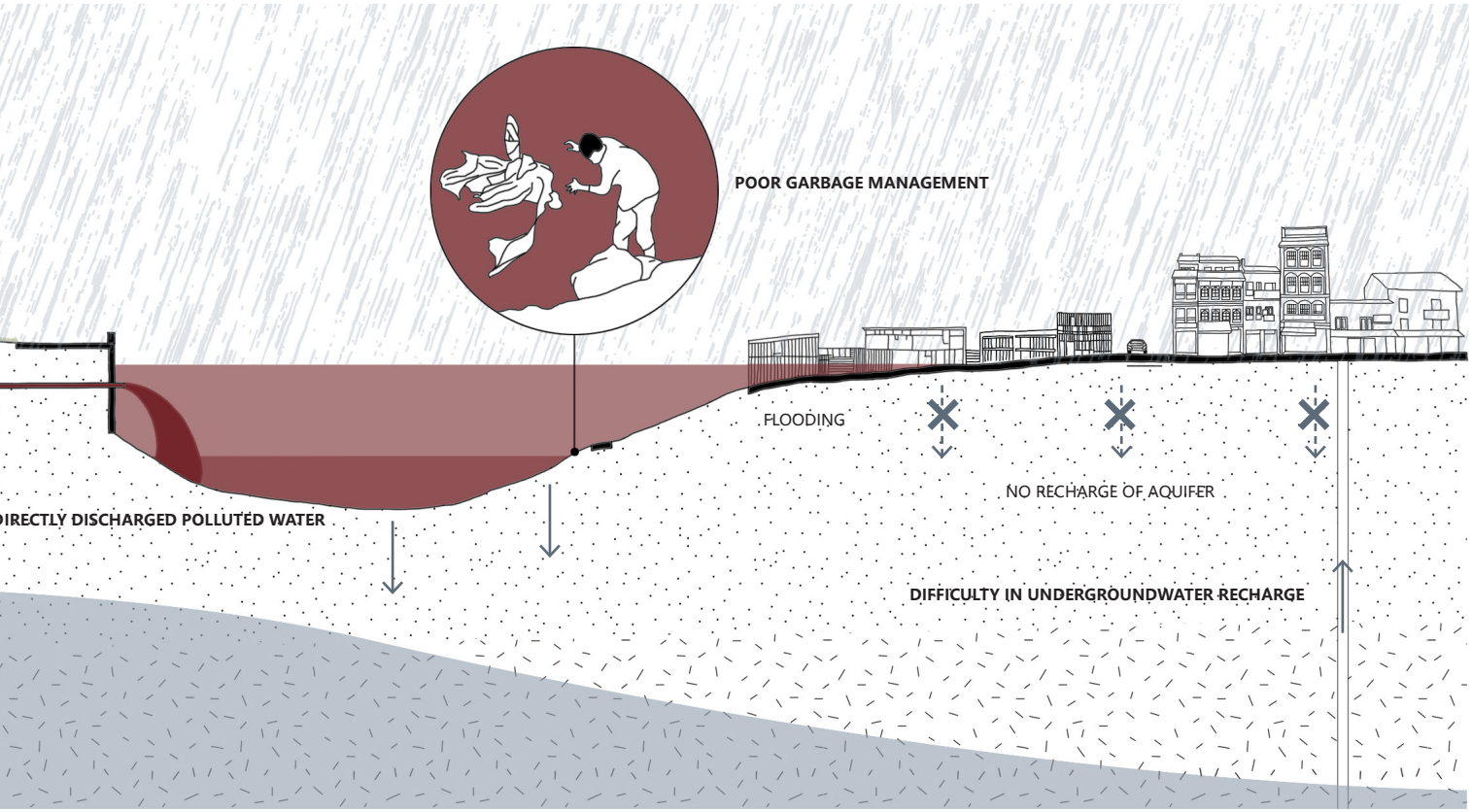


Figure 4-36. Conceptual section of the problematic intervention area, drawn by author

RESEARCH THROUGH DESIGN

05 DESIGN THEORETICAL FRAMEWORK

Figure 5-1. Conceptual drawing of existing urban metabolic flows in the intervention area, drawn by author
Figure 5-2. Conceptual drawing of proposed urban metabolic flows in the intervention area, drawn by author

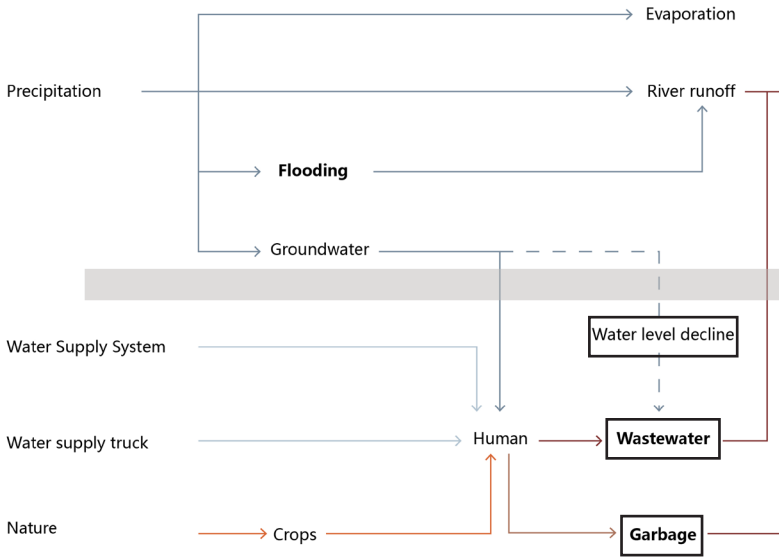
There are currently many contradictions within the site, which together contribute to the continuous deterioration of pollution in Bagmati. In order to clarify the reasons for the existence of these contradictions and the mechanism of their operation and how they act to cause pollution in Bagmati to find an optimal way to resolve the contradictions and restore the ecological condition of Bagmati, urban metabolism was chosen as the theoretical basis for spatial design.

The concept of Urban Metabolism was first introduced by Wolman in 1965, and by analogy with natural metabolic processes, it can be defined as the complete process of material and energy input to the city and product and waste output from the city, which indicates the basic way of material and energy flow and reveals the impact of the city on the external environment (Wolman, A., 1965).

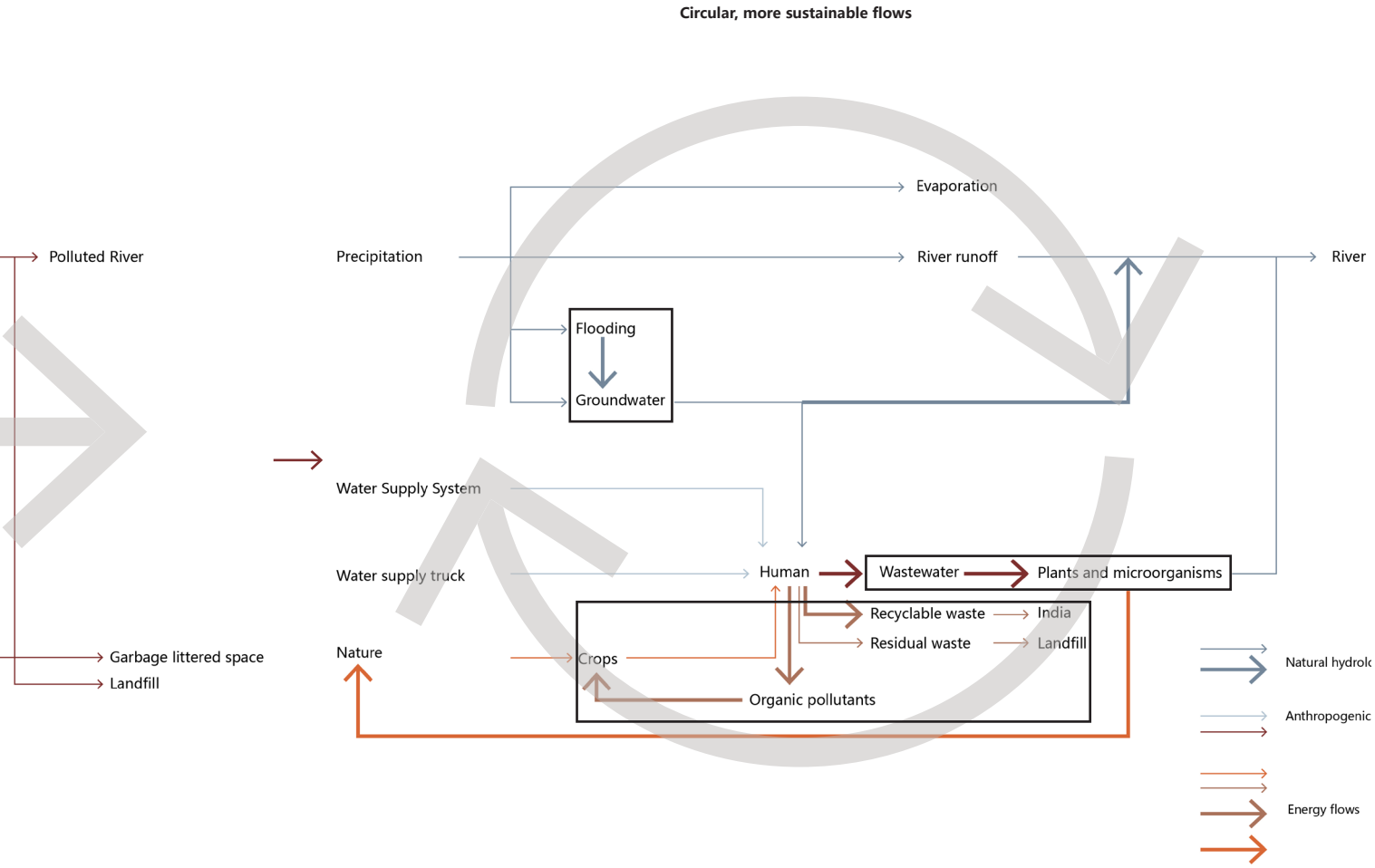
Urban metabolic theory provides a new perspective for solving urban ecological problems. It provides a research basis for finding the key to maintaining a functioning ecosystem by exploring the metabolic mechanisms and flow processes within a site (Lu, Y., & Chen, B., 2015).

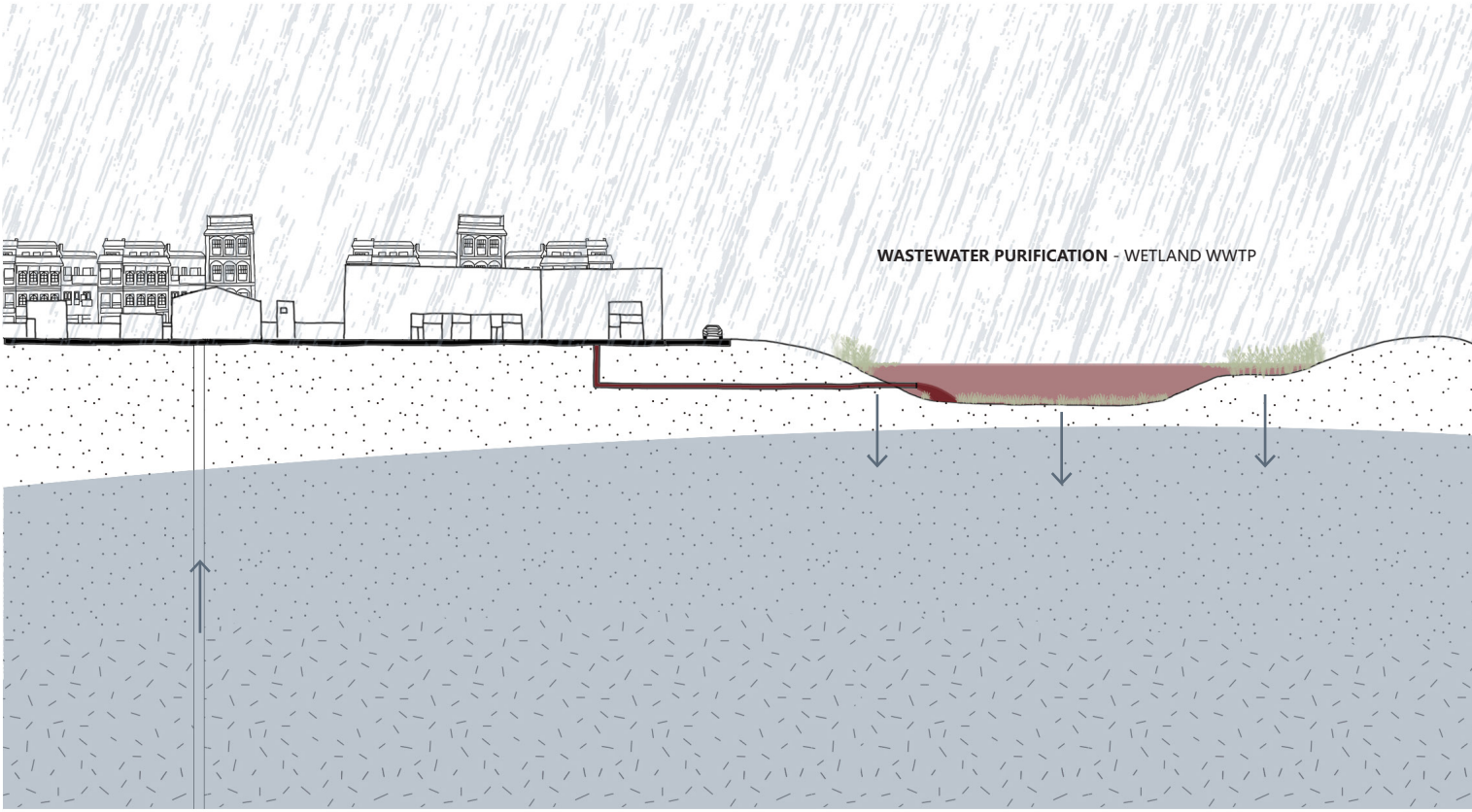
Based on the urban metabolism flow analysis shown in the figure on the right, three spatial design strategies are proposed: effective garbage management, wastewater purification and sustainable water retention to form a circular and more sustainable flow to have a clean river and better living quality.

Linear, inefficient unsustainable flows



URBAN METABOLISM




WASTEWATER PURIFICATION - WETLAND WWTP

SPATIAL DESIGN STRATEGIES

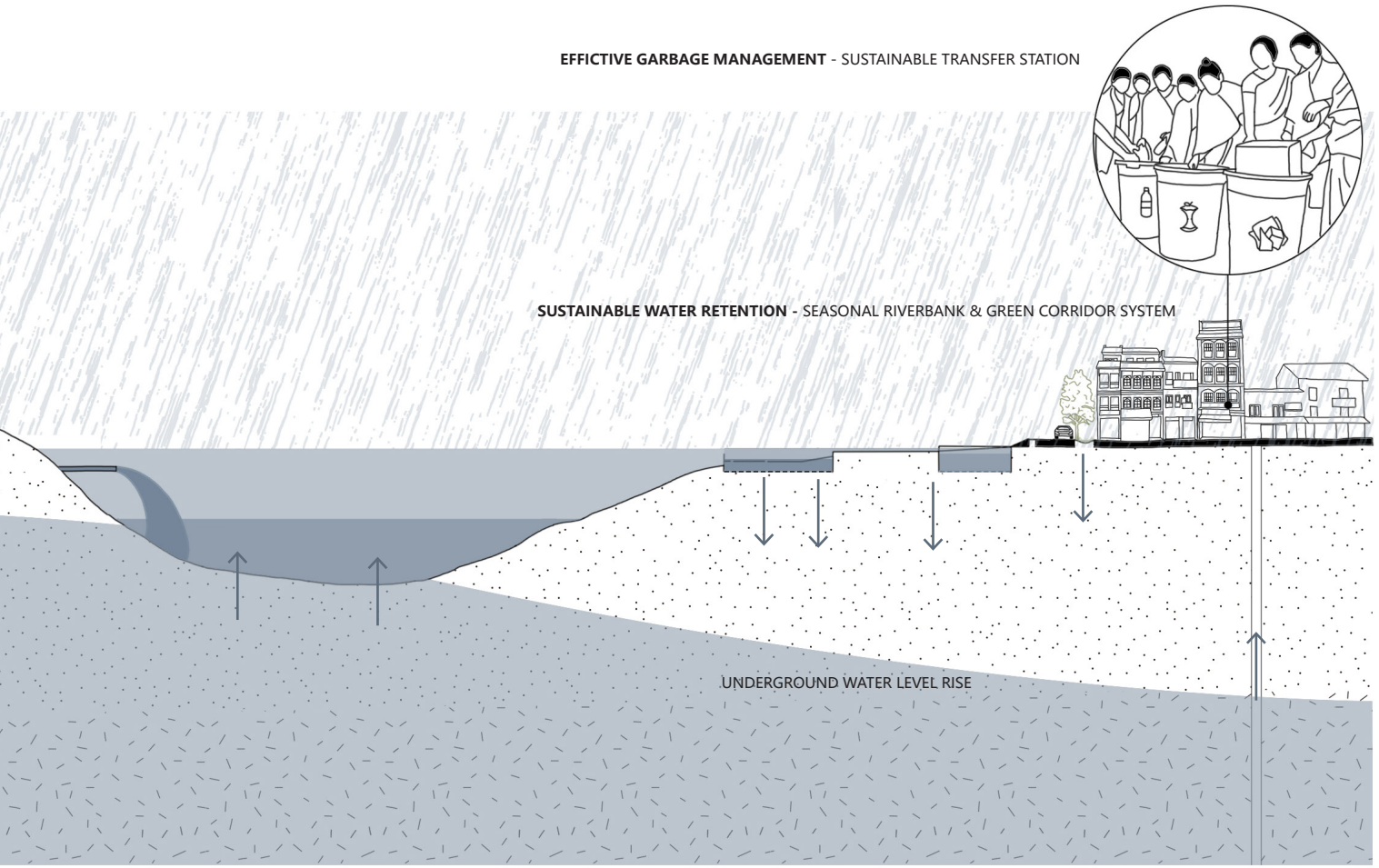
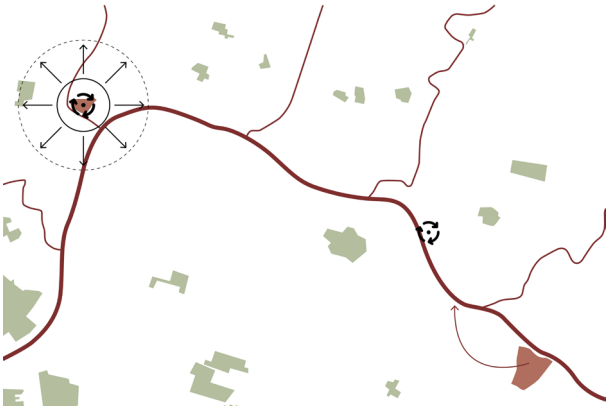


Figure 5-3. Conceptual section of the strategies of the intervention area, drawn by author

Stage1-Reduce the source of pollution

EFFICTIVE GARBAGE MANAGEMENT - SUSTAINABLE TRANSFER STATION



HUMAN EFFORT



Residents



Squatters



Government

WASTEWATER PURIFICATIO



HUMAN EFFORT AN



Residents



Squat

Stage2-Cleaning up already existing pollutants

N - LANDSCAPE APPROACH TO WWTP



ND BAGMATI RIVER



ters



Government

SUSTAINABLE WATER RETENTION - SEASONAL RIVERBANK & GREEN CORRIDOR SYSTEM



BAGMATI RIVER



Government

Figure 5-4. Conceptual maps of the strategies of the intervention area, drawn by author

06 FORMATION OF CATALYST

1.Sustainable transfer station
2.Ritual pond
3.Purification pond
4.Stepped pond
5.Anaerobic pond
6.Facultative pond
7.Water purification channel
8.Fish pond
9.Seasonal farmland
10.Orchard
11.Wetland
12.Teku temple area
13.Sattal at Purohit ghat
14.Thaphatali temple area
15.Sankhamul temple area
16.Kodku WWTP



Figure 6-1. Master plan, drawn by author

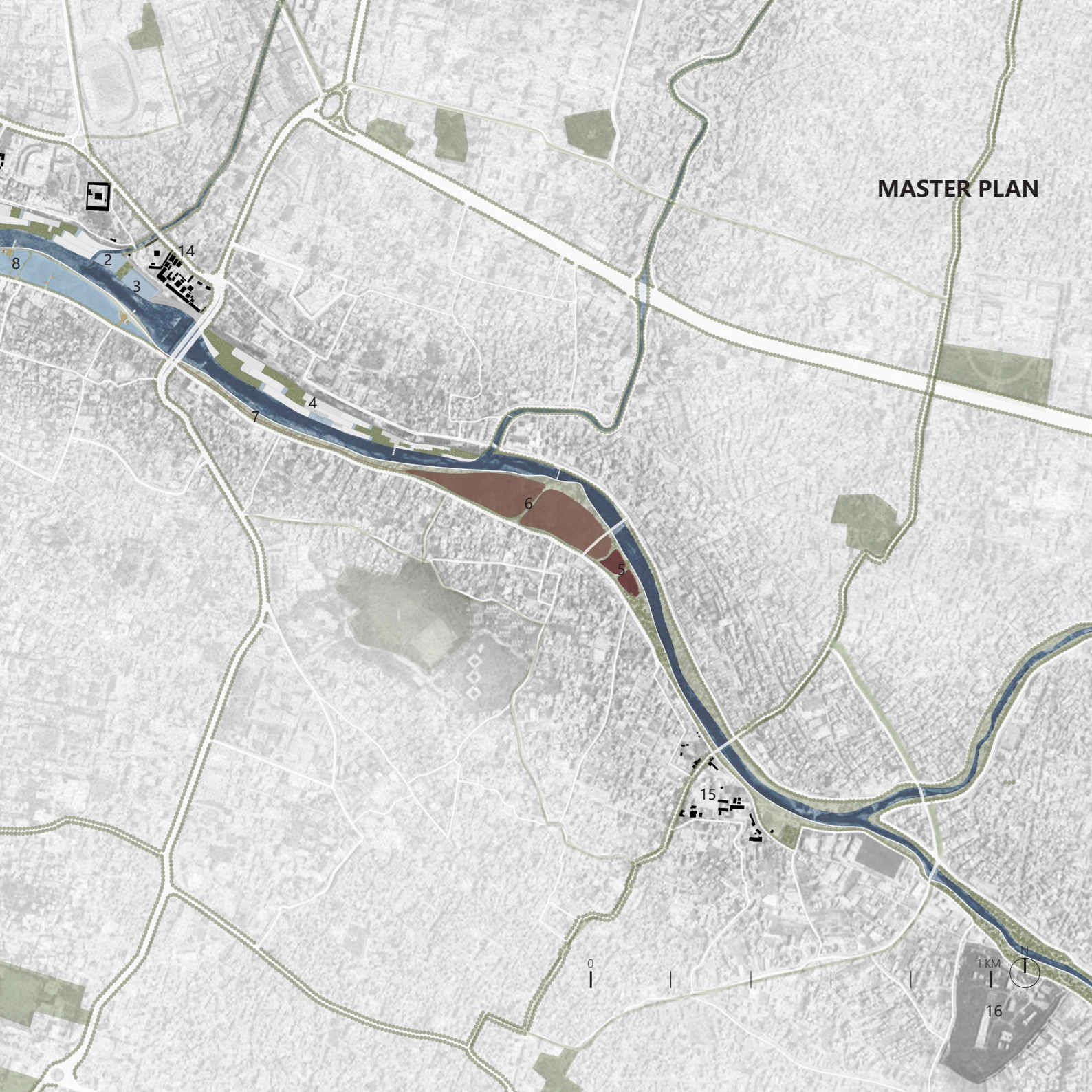

MASTER PLAN
2
14
8
3
4
7
6
5
15
0
1 KM
N
16



Figure 6-2. Master plan of transfer station, drawn by author

1.Sustainable transfer station
2.New squatter settlement

SUSTAINABLE TRANSFER STATION
Master plan

The main strategies of effective garbage management are based on problem:

1. Limited capacity cause limited service area → **Improve capacity through garbage segregation.**
2. Garbage from the dense and narrow city roads cannot be collected → **More ways to collect garbage to transfer station.**
3. Manpower is lack due to the caste → **Involving squatters in the waste management process**

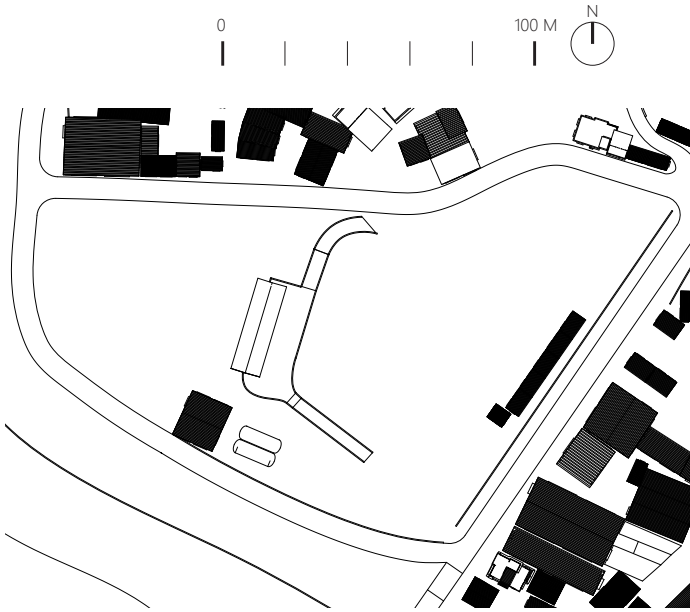
Figure 6-2. Location map of transfer station, drawn by author



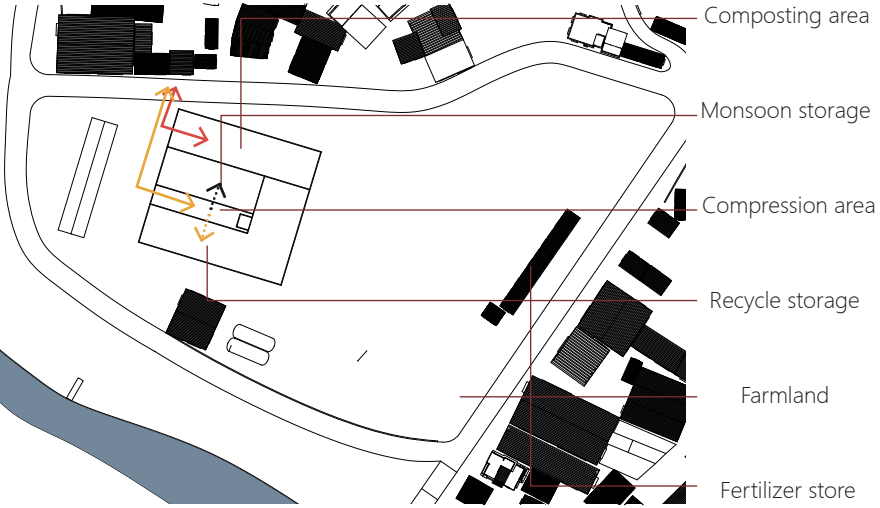
Figure 6-4. Current situation map of existing transfer station, drawn by author
Figure 6-5. 0 Floor map of sustainable transfer station, drawn by author
Figure 6-6. 1 Floor map of sustainable transfer station, drawn by author

Traffic flow

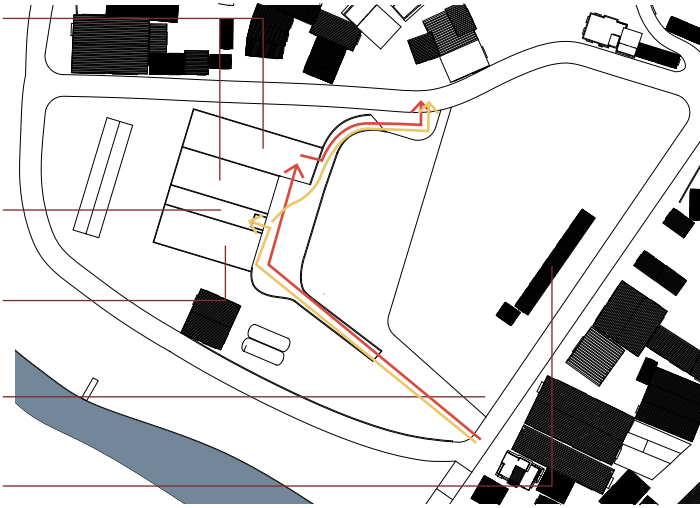
- Organic waste truck
- Non-organic waste truck
- Compressed waste truck
- Recyclable waste
- Residual waste in monsoon season



Existing situation



0 Floor



1 Floor

SUSTAINABLE TRANSFER STATION
Increase capacity through segregation

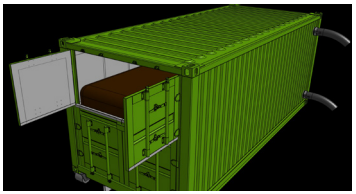
The first design goal of this new transfer station is to **increase its waste treatment capacity to handle all the waste generated by** the two largest cities in the Kathmandu Valley - **Kathmandu and Patan** the place where this transfer station located. Now, Kathmandu generates around 346 tons of garbage per day and Patan generates around 44 tons (Worldometer, 2023). Of this, 273 tons are organic waste that can be composted through composting facilities to produce fertilizer for farming and sale. 100 tons of waste is recyclable and can be temporarily stored and sold to India. The remaining 27 tons are residual waste that can be compacted and then transferred to a landfill (Dangi, M. B., Pretz, C. R., Urynowicz, M. A., Gerow, K. G., & Reddy, J. M., 2011).

Therefore, the functional area of this transfer station should including-**1. Compression area 2. Composting area 3. Store to sell fertilizer 4. Farmland that can use organic waste fertilizer for food production and provided garbage reuse education 5. Storage area for recyclable waste 6. Storage area for residual waste during monsoon.**

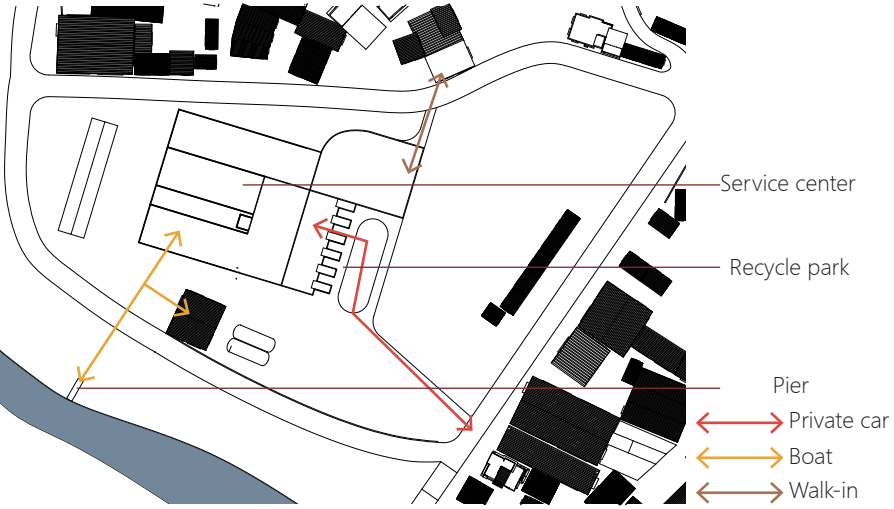
A small garbage compactor can have a capacity of 80 tons per day, therefore one is enough for this transfer station. A belt will be added in front of the compactor to further separate the recycled garbage from the remaining garbage, since now the residents only divide the garbage into organic and non-organic garbage. The existing bridge was retained, the garbage compacting area is designed to be right behind the bridge, so that the garbage truck can still use the bridge to easily dump the garbage into the garbage receiving area below and then be sent to the conveyor belt for sorting. And for garbage composting, as the Intermodal Containerized Compost System (IM-CCS) has a daily organic waste treatment capacity of 56 tons and need 2 weeks for composting, to meet the daily capacity of 273 tons of organic waste (Green Mountain Technologies, 2022), 70 IM-CCS are required, covering an area of at least 1050 square meters. It will occupy two floors, the first floor can be reached by the original bridge. The existing energy bin is remained to produce energy and small amount of fertilizer from 3 tons of organic waste per day. Around 1320 square meters and 410 square meters of space are provided for the storage of recyclable waste and residual waste during monsoon. It is located on both sides of the trash compacting area so that it can be easily transported or stored after sorting and compacting. The area next to the main road now used for open dumping will be turned into farmland, while the existing brick houses along the road will be turned into fertilizer stores. Farmers can buy cheap fertilizer here very quickly, and they can also enter the site to learn the cycle from waste to fertilizer to crop to fertilizer.

Figure 6-7. Image of Intermodal Containerized Compost System (IM-CCS) (Green montain technologies., n.d)

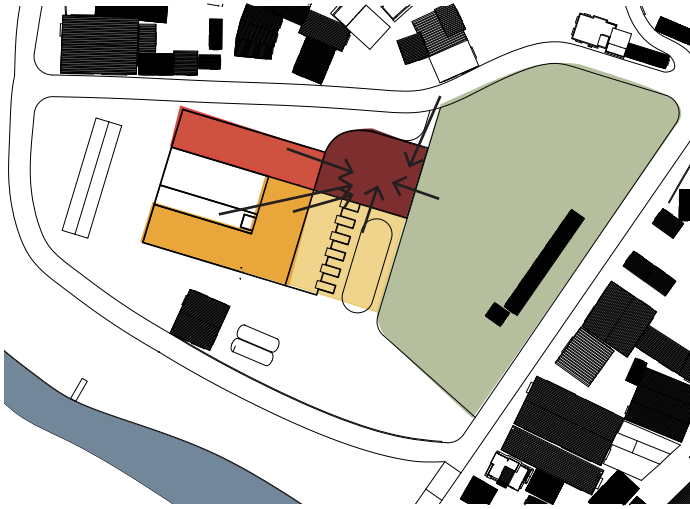
Intermodal Containerized Compost System (IM-CCS)



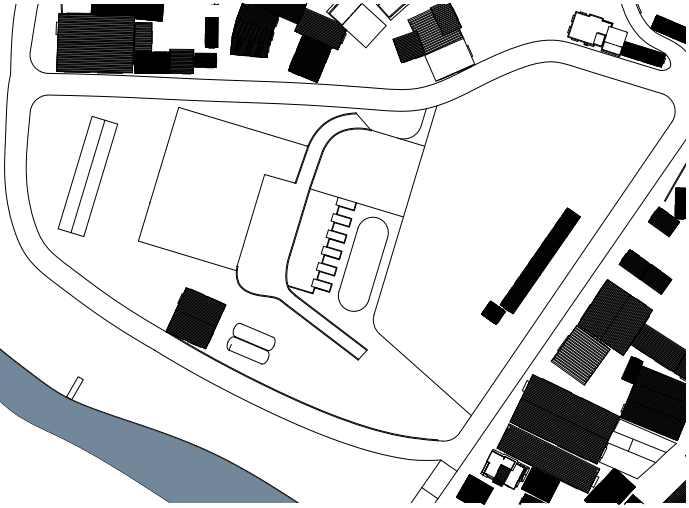
Capacity	56 tons/day
Composting cycle	2 weeks (14days)
Production	25 tons
Size	2.5m*6m
Prize	$ 25,000- $ 35,000



Traffic flows for different types of waste collection



Relation map



Master plan of sustainable transfer station

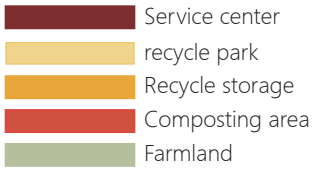


Figure 6-8. Traffic flows for different types of waste collection, drawn by author
Figure 6-9. Relation map of sustainable transfer station, drawn by author
Figure 6-10. Master plan of sustainable transfer station, drawn by author



SUSTAINABLE TRANSFER STATION

Diversified waste collection ways

The second design goal of this new transfer station is to have more ways to collect garbage. In addition to garbage collection via garbage trucks, smaller vehicles such as tricycles and trolleys will be used for garbage collection in order to accommodate the narrow city roads. Also, since the residents of Kathmandu Valley throw their garbage into the river, additional garbage collection stations will be added along the river banks and then the garbage will be transported to the transfer station by boat. A pier will be set up at the river near the transfer station. In addition to garbage disposal through the above government garbage collection, the new transfer station will also allow residents to drive or walk to it for recyclable garbage disposal by themselves after making an appointment.

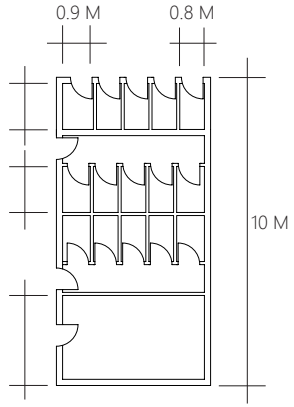
Therefore, more functional areas are added including: 1. recycle park for private cars 2. service center for workers and people who walk in.

The space under the existing bridge was converted into a recyclable waste storage area. The recycle park was designed in front of the bridge so that the storage area will be centrally located to receive recyclable waste from private vehicles and those separated from truck collections. The service center is the heart of the transfer station. It includes offices, restaurants and rest areas for workers, it is also partially open to residents to recycle the recyclable waste they bring in, as well as educational areas to educate them on the process and benefits of waste separation and reuse. So, it is located at the central area that connect composting area, recycle park and farmland and it is also have easy access to the two storage areas. Its entrance is on the secondary road which is safer for people who walk in.

Also, as a basic functional area, a car wash and parking area is set up behind the transfer station main building.

Unit for 35-45 families





Public facility

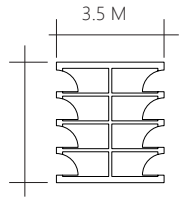
Toilet

x5

Bathroom

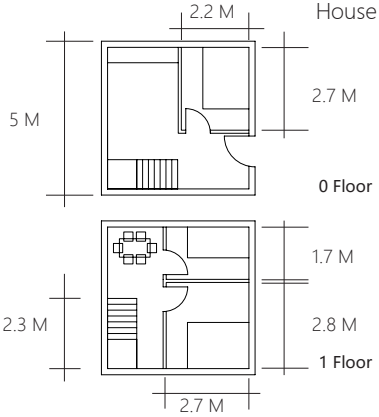
x5 x5

Laundry

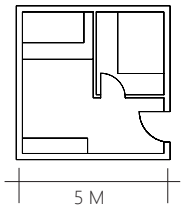


Toliet

House for family of five



House for family of three



SUSTAINABLE TRANSFER STATION
Involvment of Squatters

The third design goal is to involve squatters in the garbage management, many of whom are now make a living by collecting garbage. So, the idea is to relocated the squatters along the river to prevent the pollution from squatter settlements and settle them in the area of existing recycle shops which was demolished and combined in the transfer station with low rent or in the apartment that government previously built with higher rent. And some job opportunities will be provided to them in the transfer station. The new designed transfer station has the capacity to deal with 390 tons of garbage per day. Due to the poor traffic condition, almost half of them need to be collected by tricycles, trolleys and boats. And there is still solid waste in the river, where squatters are also needed. As these small transport vehicles have a capacity of 0.3- 1 tons, about 350 new job opportunities will be provided. The crops grow in the farmland at the transfer station can provide food for the squatters.

The design of the new settlements is to create several units. In order to save space and have more efficient way to manage water, all the houses in the unit share toilet, bathroom and laundry room. So, every unit has a central public facility. A unit is designed to accommodates 35-45 families, they share 20 toilets (Up to six people should have a toilet), 10 bathroom and a laundry room. The rainwater will be collected during monsoon to provide water for shower and washing cloth (Clean water systems will also be connected, as the collected rainwater may have run out by the end of the long dry season), then be used for toilet and finally go to WWTP through sewage system. And the grey water from settlements will be used for food production in the farmland in transfer station. The housing area for a family of three is 25 square meters with two bed rooms, a living room and a kitchen. The house for a family of five is on two stories. As this residential area is designed to meet basic residential needs, the distance between houses and the width of walkways in each unit meet minimum standards.

Now, there are around 900 squatter families living in this area and the government building can only accommodate 300 families (Republica., 2022). The new settlements around the transfer station can provide house for around 320 families. As the place where Sankhamul squatter settlement located do not face the threat of flood, this place will be transformed into another assemble with residential area for 320 squatter families, farmland and community composting area.

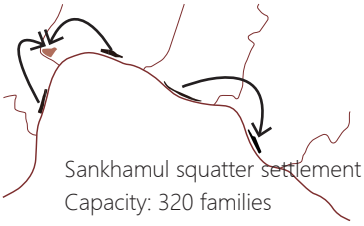
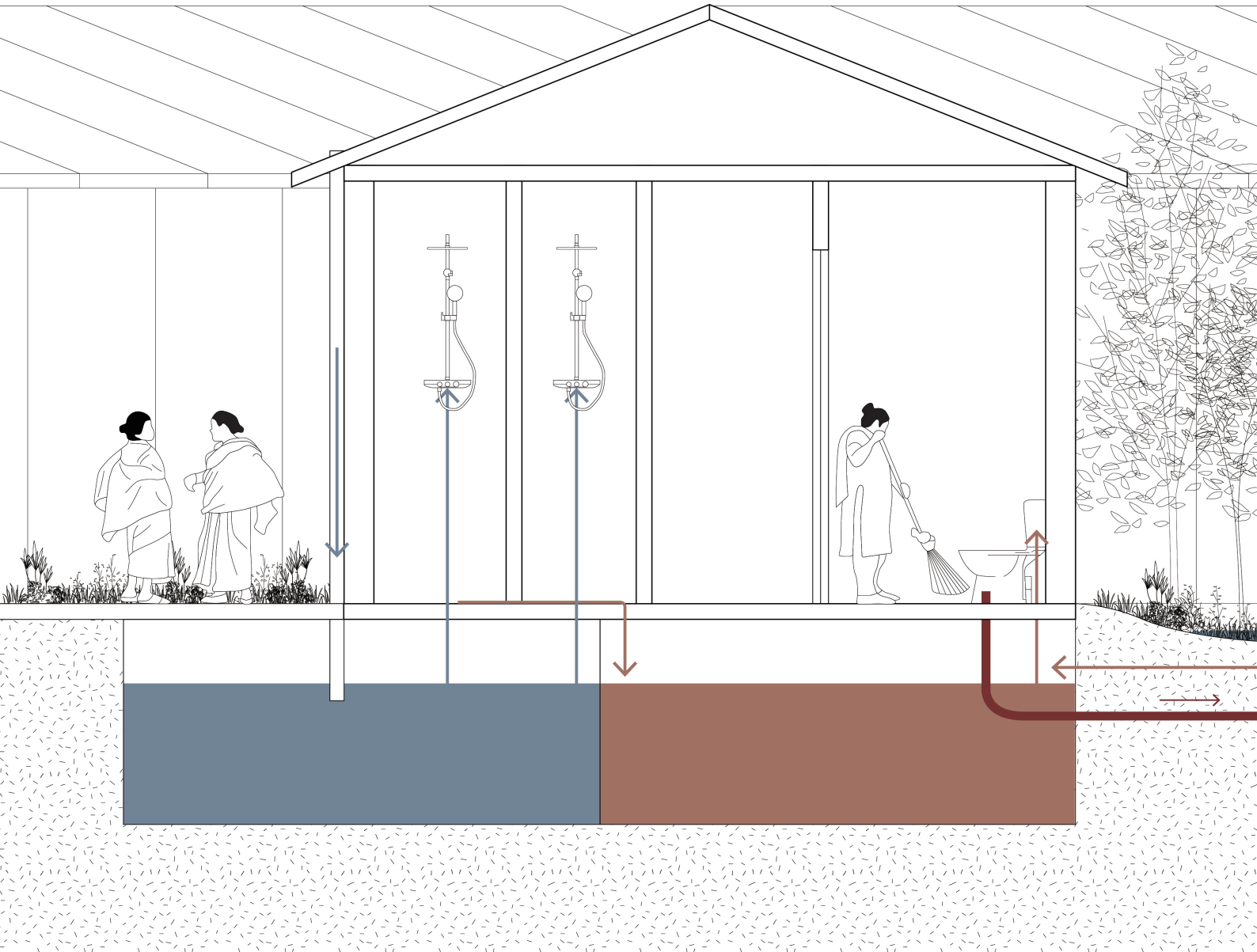


Figure 6-11. Map of the Unit for 35-45 families, drawn by author
Figure 6-12. Map of Public facility, drawn by author
Figure 6-13. Map of toilet
Figure 6-14, 6-15. Map of house for family of five, drawn by author
Figure 6-16. Map of house for family of three
Figure 6-17. Map of the relocation of squatters



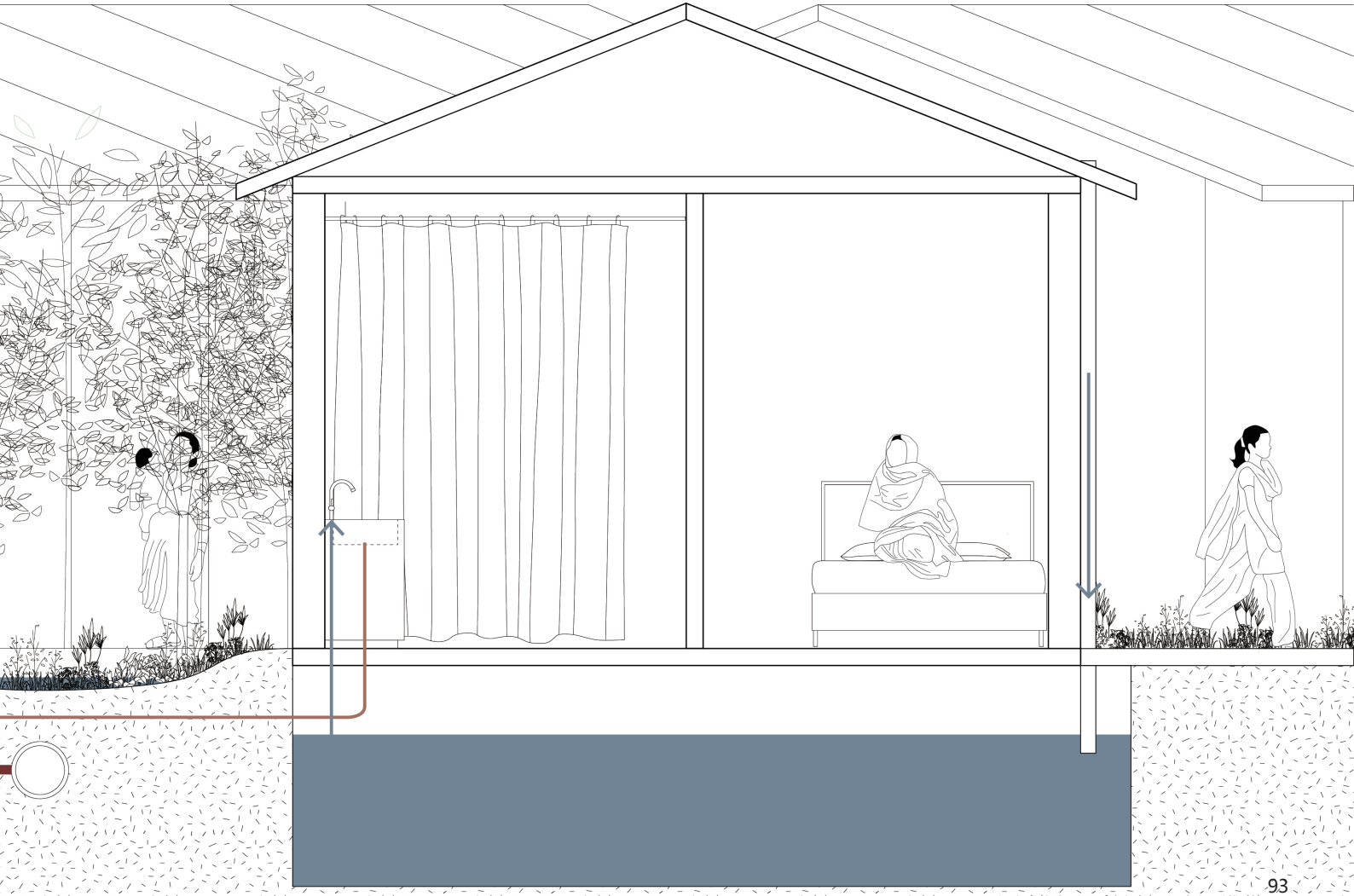


Figure 6-18 Section of the water circularity within the new settlement, drawn by author

Figure 6-19. Map of site selection of new residential area, drawn by author
Figure 6-20. Map of the existing situation of the transfer station and its surrounding, drawn by author
Figure 6-21. Map of the layout of unit, drawn by author
Figure 6-22. Map of the structure of new residential area, drawn by author

Site selection - connection with transfer station



Vegetation bufffer zone

Recyclable waste storage

Transfer station

Residential area

As the main design purpose of this residential area is to provide living space to the squatters who will join the garbage management job, therefore the connection and accessibility between the transfer station and the residential area is the primary consideration. So, this new settlement area is located around the transfer station and separated some distance by vegetation buffer zone to reduce the smell and visual influence.

Existing situation



Structure of the demolished house



Types of demolished houses

Private garbage shop

Kiosk

Warehouse

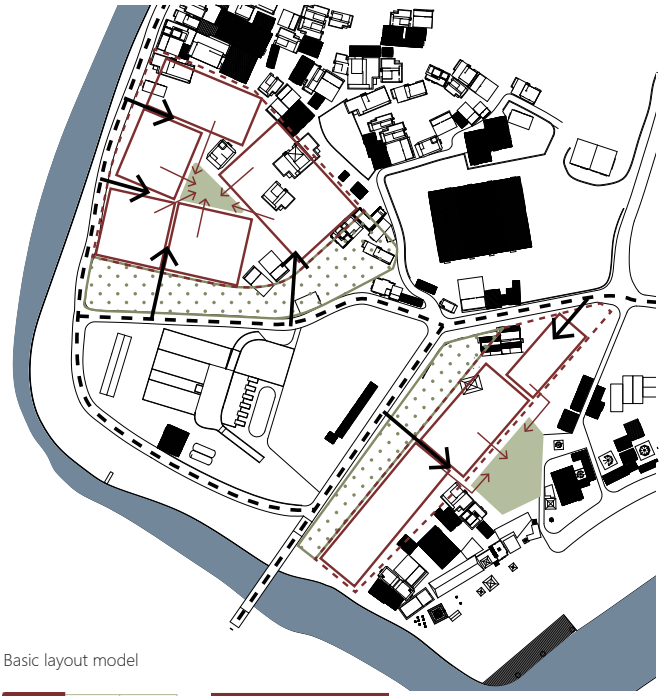
move to other vacant land

To save space for the construction of new settlement, some existing building will be relocated and demolished. These buildings are all simple structured brick house which mostly used for storage of recycle garbage that collected privately which will be combined in the transfer station. The rest is some shops and warehouses which need to be relocated to other vacant land.

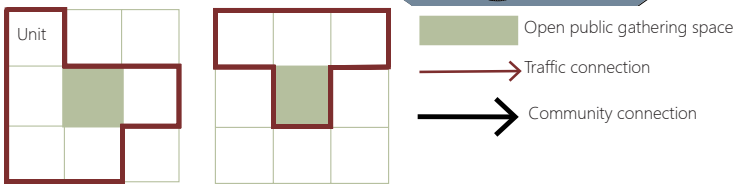
SUSTAINABLE TRANSFER STATION

Involvment of Squatters - Application of units on site

Units layout - community and traffic connection



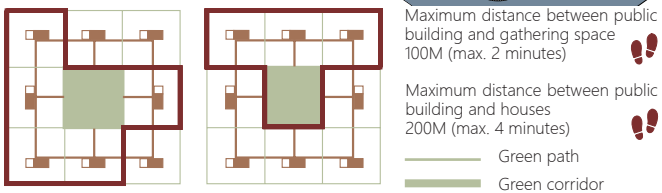
Basic layout model



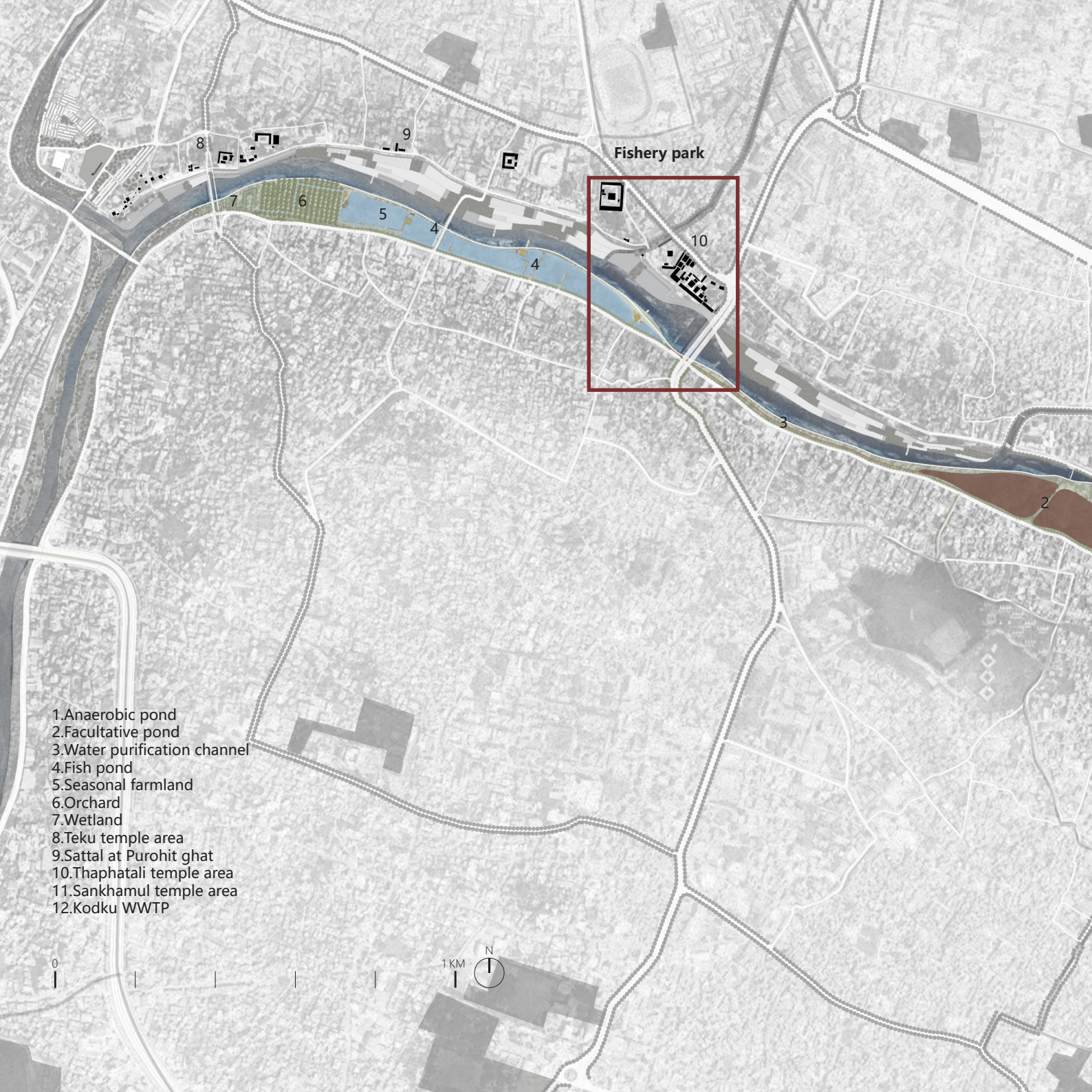
Every unit has a public facility which also act as a public gathering space. As a big community composed of several units, a big public gathering green space with good accessibility is also need. And every unit also need to have direct connection with main city roads to have a good traffic accessibility. Therefore, the basic layout is that units are distributed on the boundary and shares a central green space. There will be two communities, their layout all base on the basic layout model.

Structure





The overall structure of the units meets the two-minute maximum walking distance from the public building to the central gathering space and four-minute maximum walking distance from the house. The public buildings are connected together to generate a secondary public gathering cycle and it connect with the central big open gathering space to form the open space system of the community. The open space systems of two communities are all connected with the farmland to create a bigger open space system.


Fishery park
1.Anaerobic pond
2.Facultative pond
3.Water purification channel
4.Fish pond
5.Seasonal farmland
6.Orchard
7.Wetland
8.Teku temple area
9.Sattal at Purohit ghat
10.Thaphatali temple area
11.Sankhamul temple area
12.Kodku WWTP
0
1 KM
N

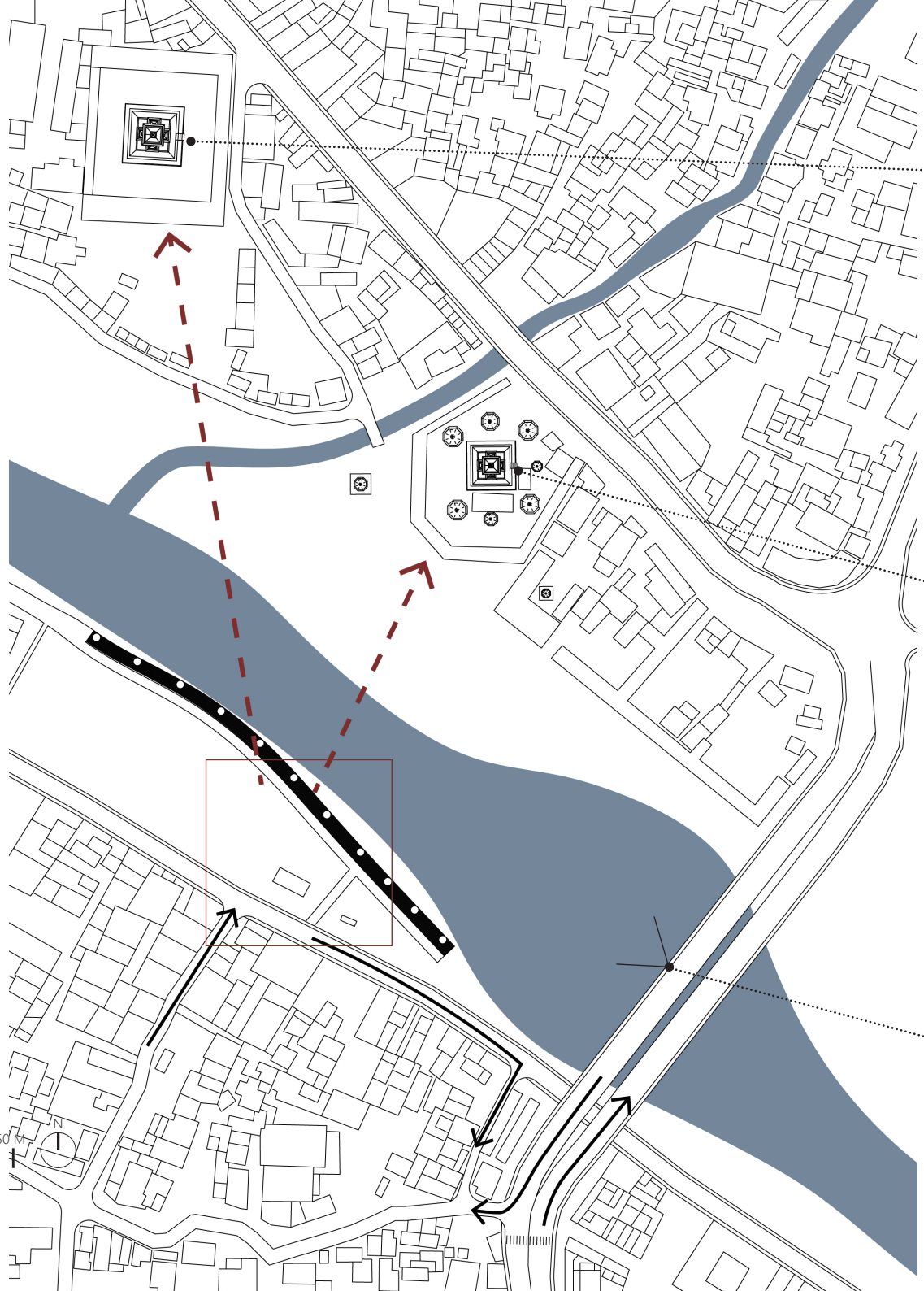


LANDSCAPE APPROACH TO WWTP
Water purification

Figure 6-22. Map of landscape approach to WWTP, drawn by author

Sustainable transfer stations help to better manage waste and can significantly reduce the amount of solid waste being thrown into the river and with the effort of squatters who cleaned up the garbage that was already being thrown into the river, this solid waste will no longer be a threat that causes pollution in the Bagmati River. But due to the discharge of untreated water from WWTP, more efforts need to be done to improve the water quality of Bagmati River. As 4.6 million people are still food insecure although the food shortage situation has improved recent years, the wastewater management design intend to integrate water purification with aquaculture and food production.

The work flow and scale of the 8 MLD sewage-fed aquaculture facility is taken as the reference to generate the design of agricultural WWTP (Appendix1). The 9.2 MLD untreated wastewater from Kodku WWTP which be discharged directly into Bagmati will be guide to anaerobic pond through a underground pipe. Here oxygen is excluded to promote the growth of algae to reduces organic load in wastewater and removes approximately 60 percent of the BOD from the water. The next stage is facultative pond to further removal of BOD through natural diffusion, wind and algae-driven photosynthesis. Then the water will be channeled to maturation ponds through underground pipes where the fishes are raised. It is the shallowest of a series of ponds to ensure sunlight penetration and promote photosynthetic release of oxygen by algae, while contributing to the growth of plankton populations, a process further facilitated by the remaining organic matter in the wastewater. These plankton and algae can provide food for fish, allowing for low-cost fish farming. The water will then flow through the farmland via the zig-zag waterway, which can be used for food production as there are still nutrients left in the water. One piece of the farmland will be used as water retention area in the monsoon season to prevent the overflow of water from fish ponds. The last step is a water purification wetland to completely purify the water before it reaches Bagmati.


0
50 M
N









Tripureshwor Mahadev Mandir



Kalmochan Mahadev Temple



View from Thapathali Bagmati Bridge

LANDSCAPE APPROACH TO WWTP
Fishery park design

Figure 6-23. Map of existing situation and surrounding context of the selected fishery park site, drawn by author
Figure 6-24. Image of Tripureshwor Mahadev Mandir (Dhungana, R., 2021)
Figure 6-25. Image of Kalmochan Mahadev Temple (K., 2014)
Figure 6-26. Image of view from Thapathali Bagmati Bridge (Voice, A., 2022)

Each fish pond needs at least two fishermen to manage it on a daily basis. The fishery hub next to the pond provides them with a place to store their fishing gear and to rest. As the fish pond is located in a section with a good view of the heritage on the other side of the river and is adjacent to the bridge across Bagmati, the fish pond is not only a workplace for fishermen but also a destination for people who stay here to rest and resonate with the religious monuments on the other side of the river in Thaphatali Temple area, especially the Tripureshwor Mahadev Mandir and Kalmochan Mahadev Temple with their unique architectural shapes and religious overtones, enhancing the connectivity between the two sides of the Bagmati River and improving the connection between people and Bagmati.
The wastewater purification system of the fishery hut will be shown here. By demonstrating the flow of wastewater from the hut to anaerobic ponds, through the facultative pond and then to the fish pond and the multiple uses of wastewater in the fish pond for fish and crop production, the place will also have an educational function for environmental protection.


1.Pier
2.Fisherman hut
3.Farmland
4.Water platform
5.Anaerobic pond
6.Facultative pond
7.Fish pond
8.Bagmati river
0
10 M
N

LANDSCAPE APPROACH TO WWTP
Fishery park design

A bamboo platform connects the the fishery hut and riverbank to the entrance. It can also be used as a pier for tourists and fishermen. A large recreational platform which will also be made of bamboo was designed to the north of the fishery hut, giving a good view of the cultural monuments on the other side of the river. There is a small farm next to the platform, and the water in the fish pond makes crops grow well, which can be offered to fishermen or be made into food and sold to tourists in the fishery hut.

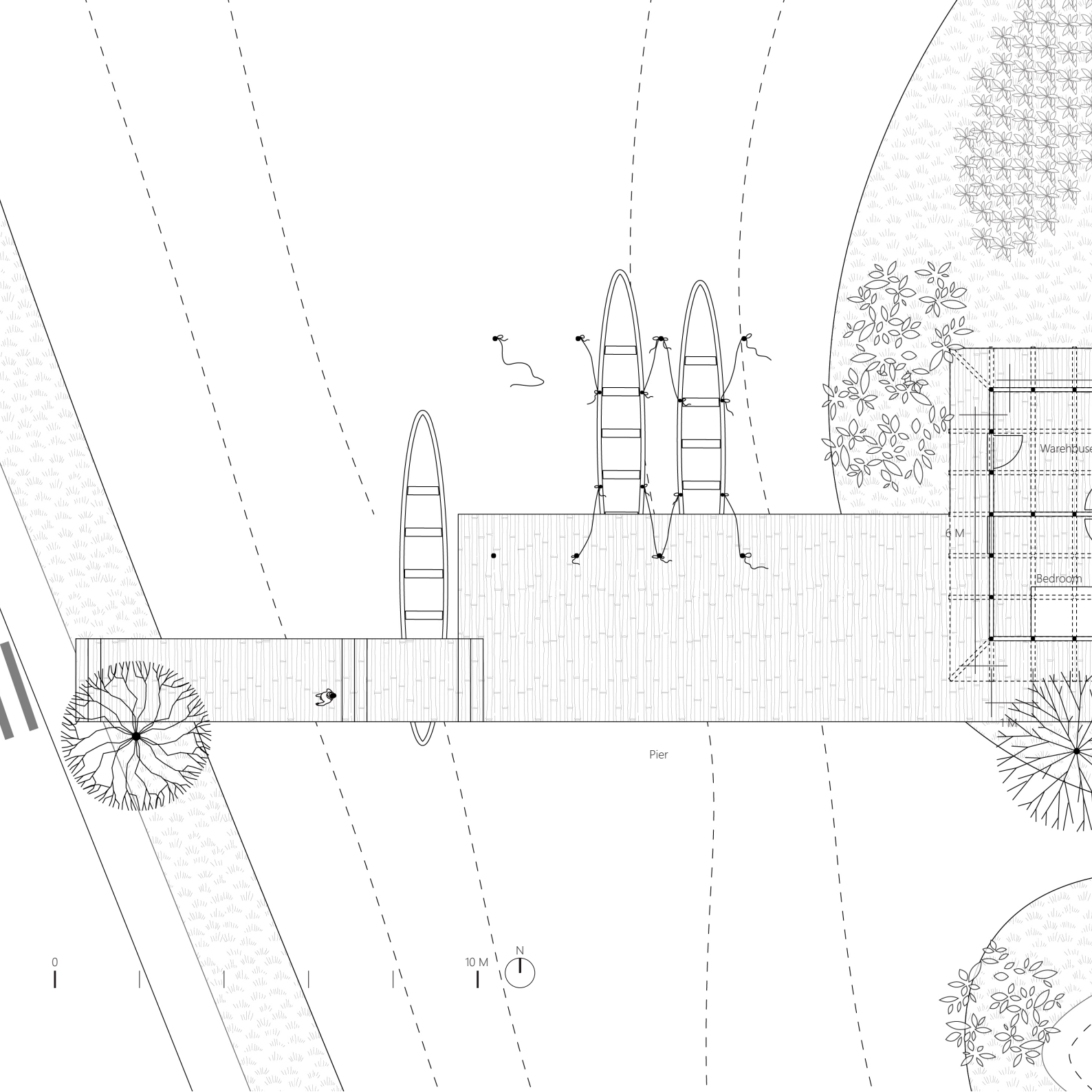
Along the riverbank, the existing brick ghat will be maintained. A strip of brick platform was designed that extends into the Bagmati River, providing a broader view of the river landscape while allowing users to get closer to the river and make stronger connections.

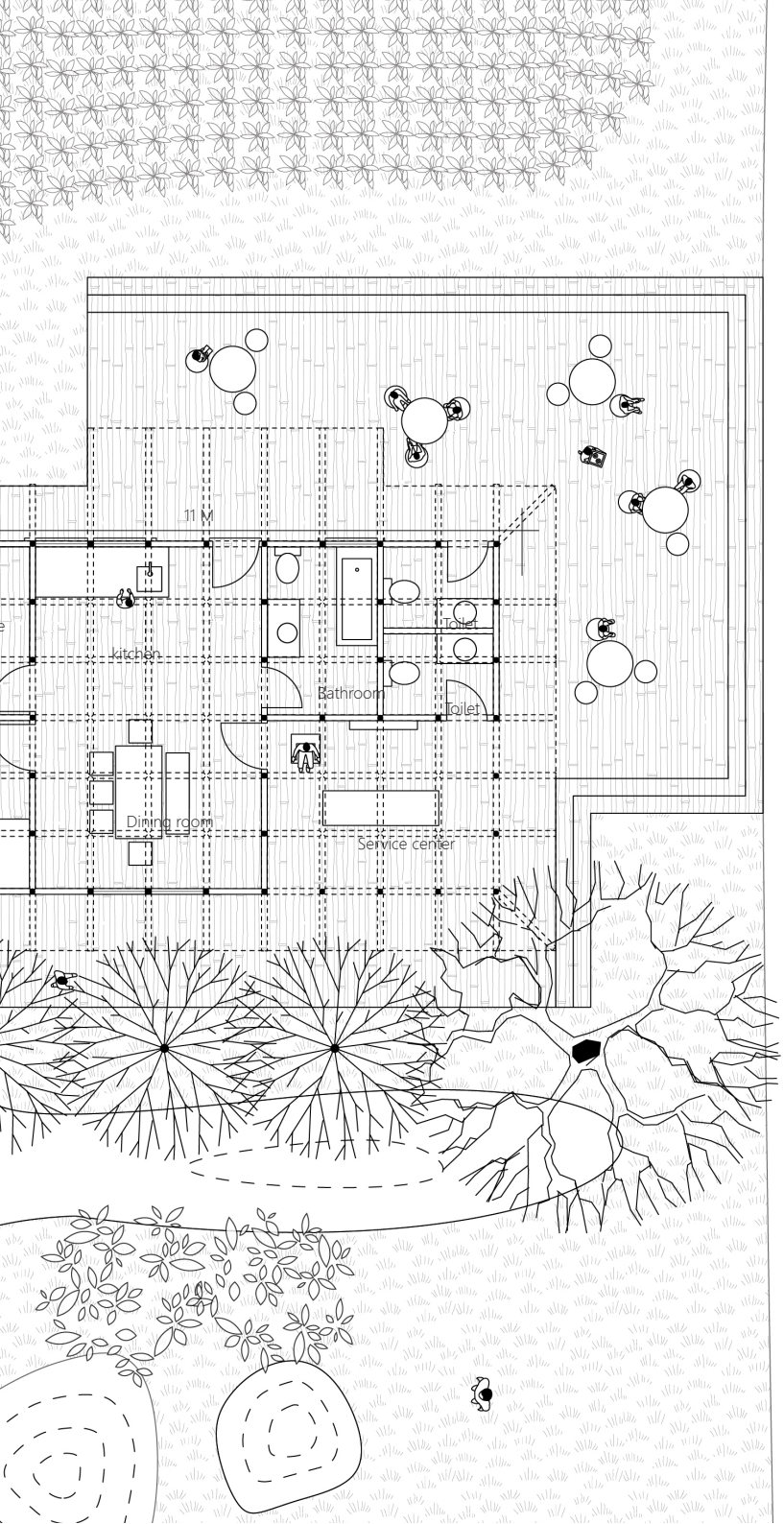
An attractive landscaped pathway will be formed from the entrance to the water platform, providing a variety of spatial experiences for users. The view to the river bank at the entrance is largely blocked by the fishery hut. With its architectural form and carved wooden façade characteristic of traditional Newari architecture (Appendix 2), the fishery hut draws users across the bamboo platform to a narrow orientation space formed by the building wall and tree line, guiding their attention continuously forward. When reaching the end of this space, users will see a water platform leading into the Bagmati River. At the same time, the blockage of building disappears, the view becomes open, and the scenery of the river bank and the religious relics on the other side of the river enter the view of the users, attracting them to continue forward into the water platform. At the end of the entire walking stream - the water platform - users will have the most open view. This platform is located in the river, providing users with a unique spatial experience that is different from the riverbank.

The walkway parallel to the riverbank also offers a fascinating landscape experience. Walking along the river from south to north, visitors can not only enjoy the historical monuments on the other side of the river, but also discover and learn about the wastewater purification system of the fishery hut in the bamboo forest, or fish on the bank of the fish pond, or bird watch near the small bamboo platform.

Figure 6-27. Master plan of fishery park, drawn by author
Figure 6-28. Image of existing brick ghat




Warehouse
6 M
Bedroom
1 M
Pier
0
10 M
N

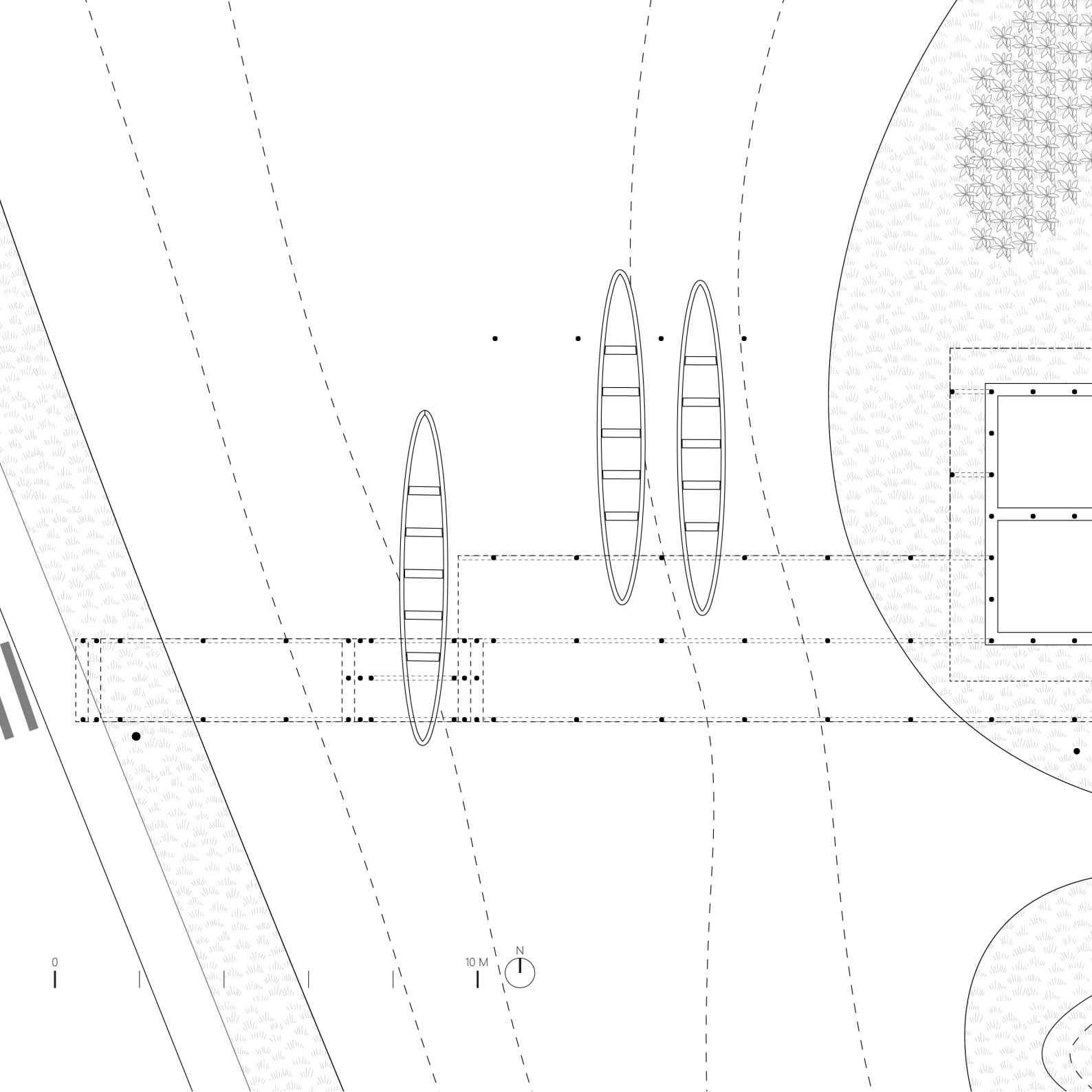


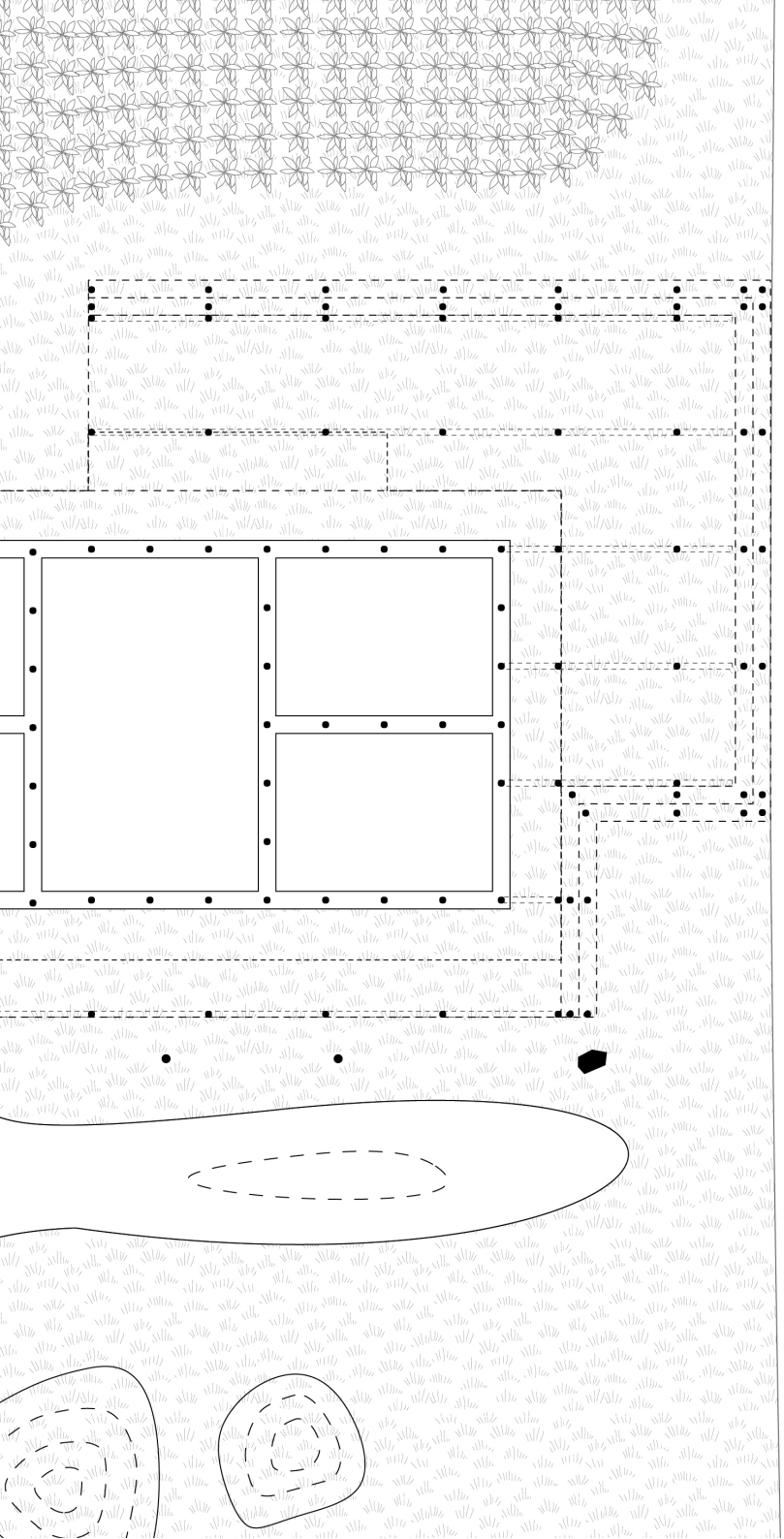
LANDSCAPE APPROACH TO WWTP

Fishery hut design

Figure 6-29. Master plan of fishery hut with roof structure, drawn by author

The fishery hut is mainly used as a working place for fishermen, but there are also some spaces available for visitors to use. The semi-open space connecting the river bank and the entrance platform serves as a service center for visitors to rest, talk with fishermen, learn about the wastewater purification system, etc. And the kitchen window faces the recreation platform, visitors can order food and drinks there.


0
10 M
N



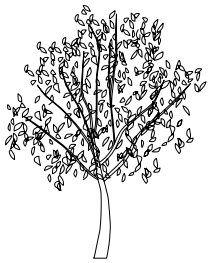
LANDSCAPE APPROACH TO WWTP
Fishery hut design

Figure 6-30. Fundation map of fishery hut and platform, drawn by author

The structure design of the fishery hut is based on the way the Nepalese build bamboo huts today (Appendix 3). With a stable stone foundation with cement mortar and bamboo pillars and beams, the load-bearing structure of the fishery hut forms. The main structure of the wall is also made of bamboo. The inner support structure of the wall is made of woven bamboo pieces, and then the outside is covered with clay to form the wall.
The platform around the fishery hut is made entirely of bamboo, with bamboo structures and bamboo floors.



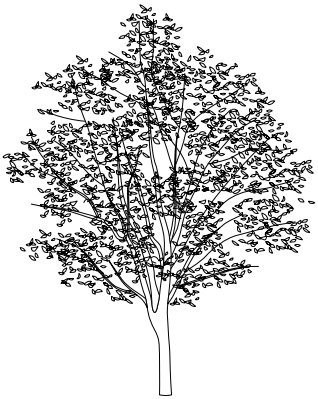
June-August
Crepe Myrtle
Lagerstroemia indica L.



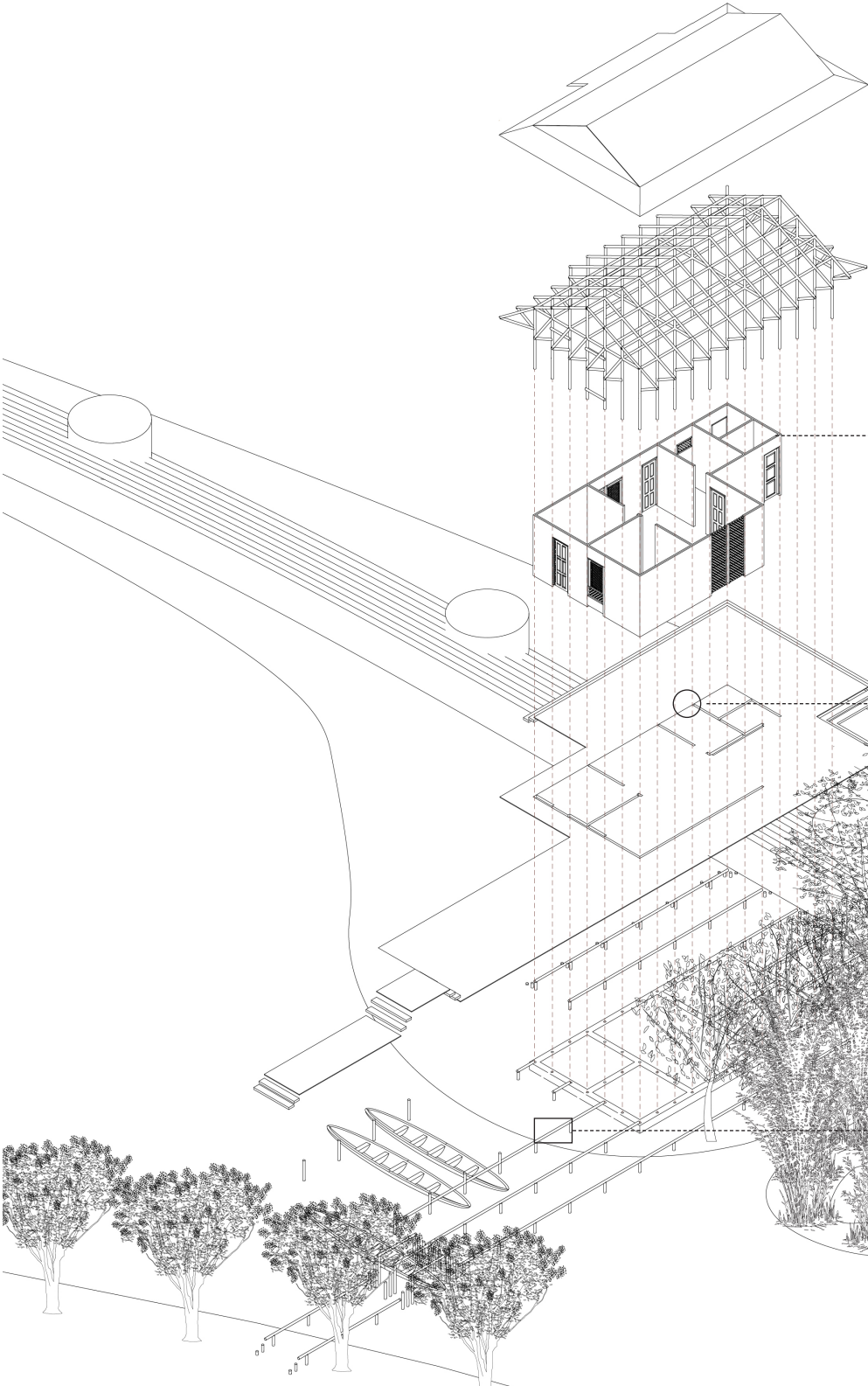
Bead Tree
Elaeocarpus angustifolius Bl.



Bamboo
Bambusa vulgaris

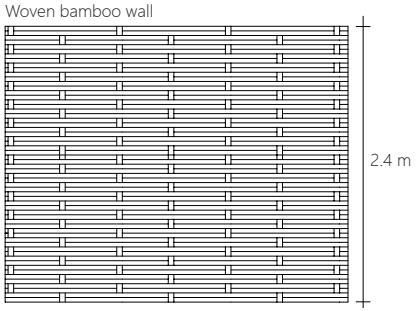


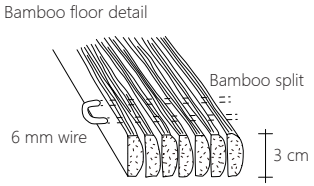
March-April
Coraltree
Erythrina stricta Roxb.

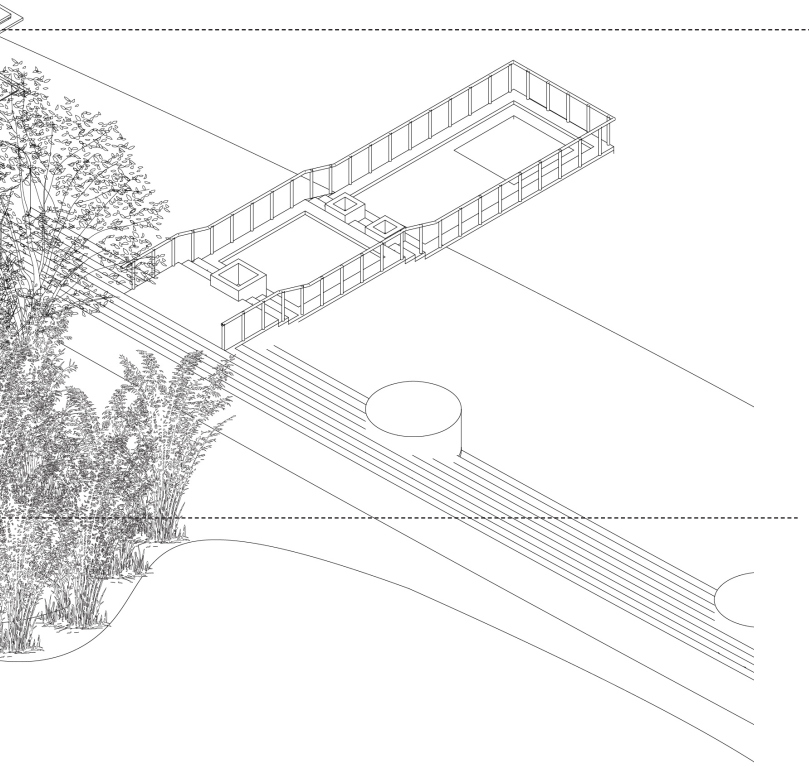


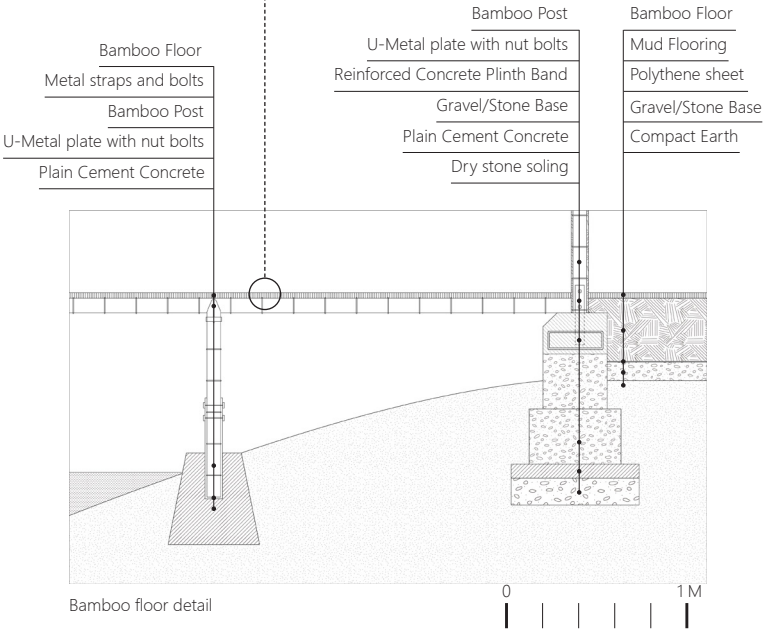
LANDSCAPE APPROACH TO WWTP
Fishery hut design

Figure 6-31. Planting species, drawn by author
Figure 6-32. Fishery hut exploded axonometric diagram, drawn by author
Figure 6-33. Fishery hut foundation detail design, drawn by author









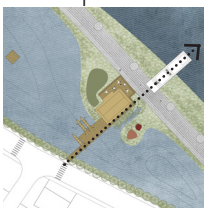
Bamboo floor detail

Figure 6-34. Fishery pond perspective drawing, drawn by author



LANDSCAPE APPROACH TO WWTP

Strolling from entrance to water platform



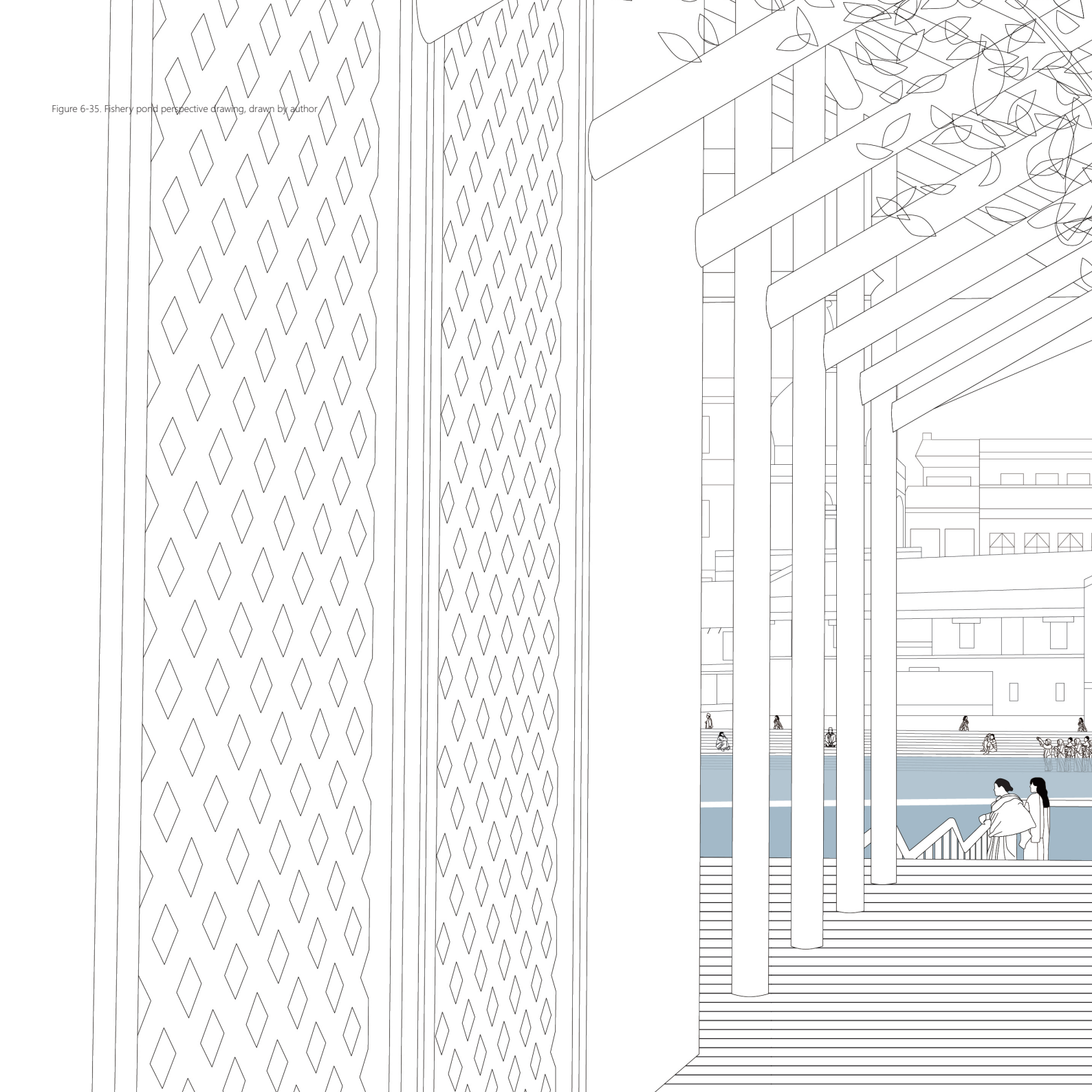
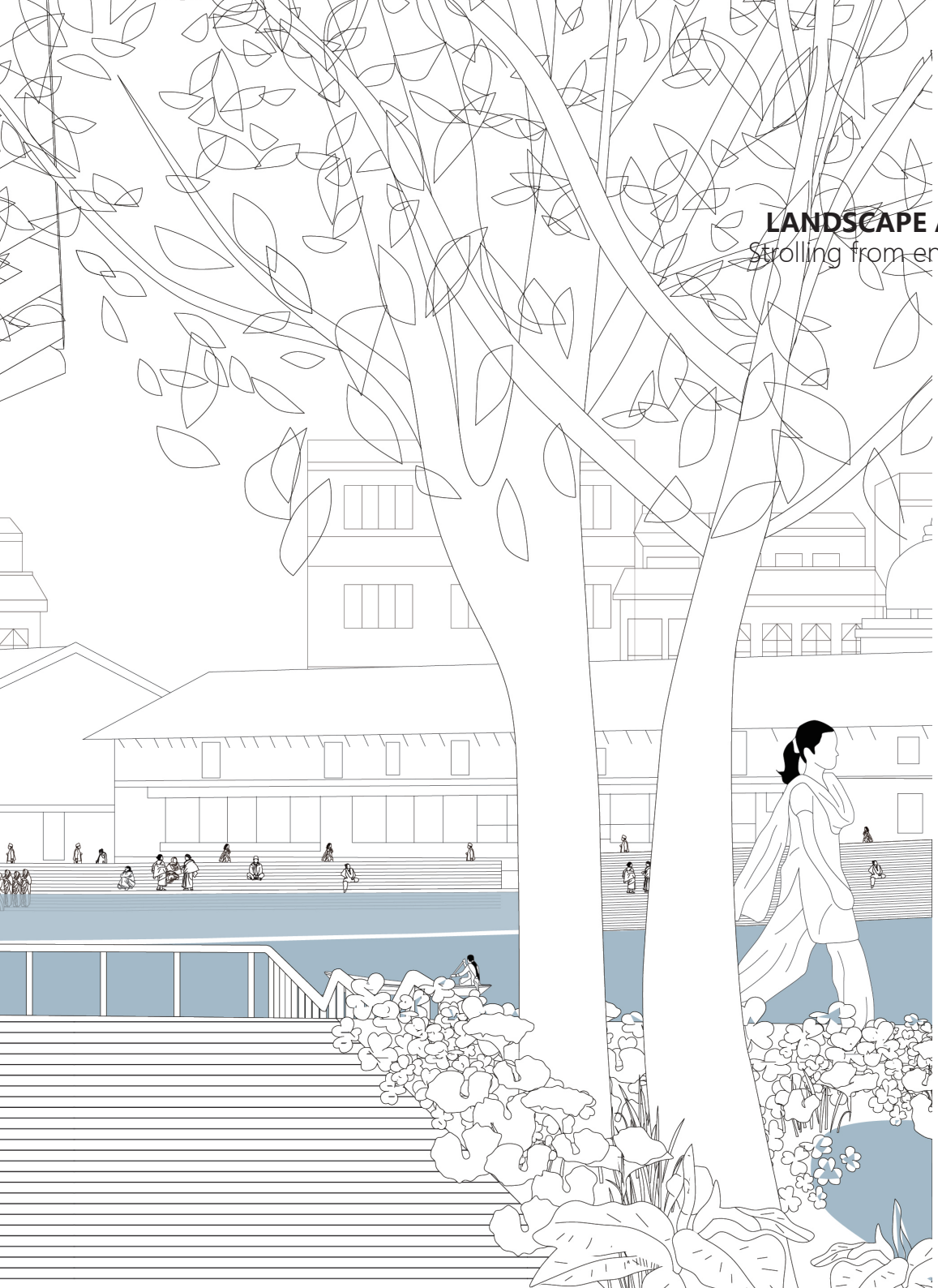
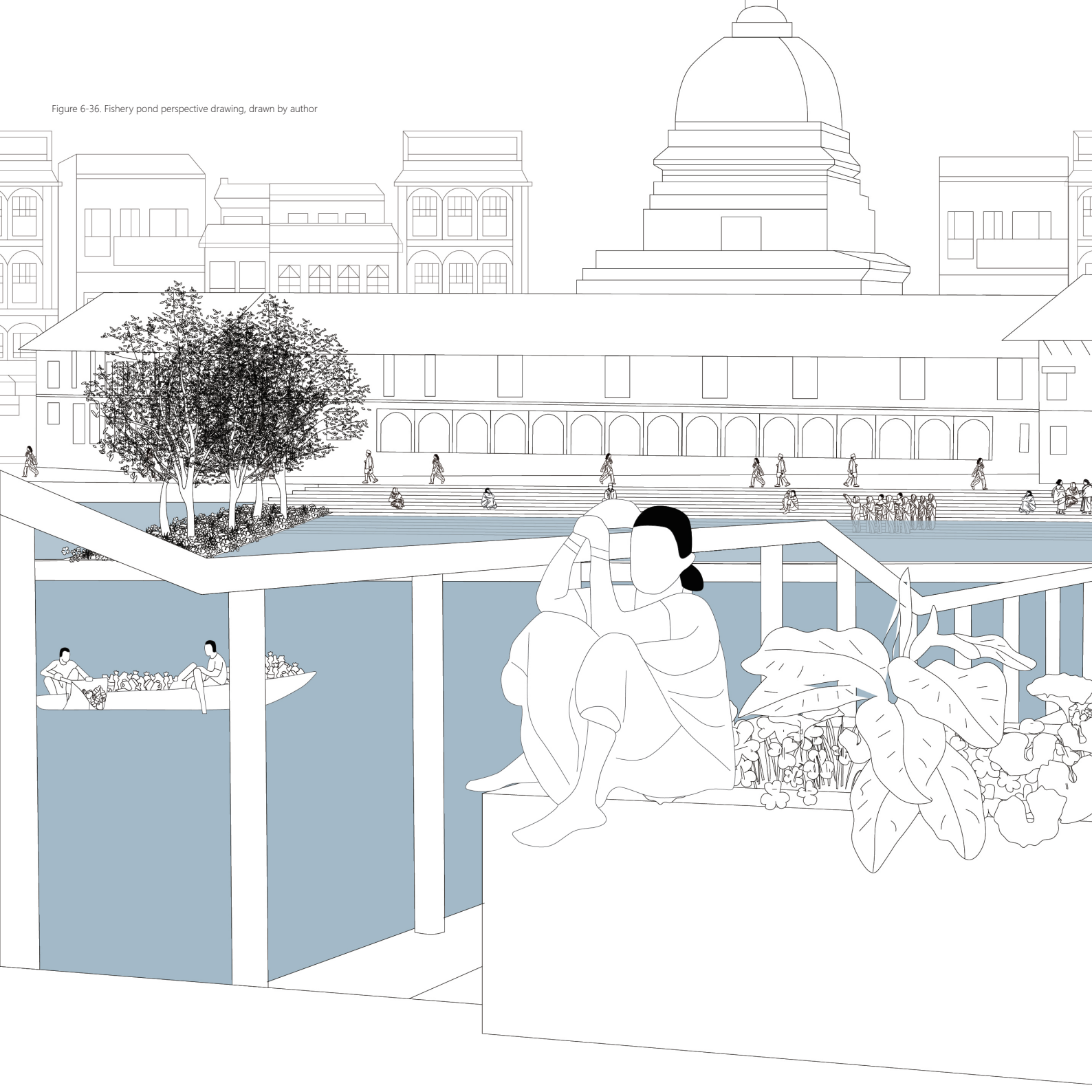


Figure 6-35. Fishery pond perspective drawing, drawn by author



LANDSCAPE APPROACH TO WWTP
Strolling from entrance to water platform

Figure 6-36. Fishery pond perspective drawing, drawn by author

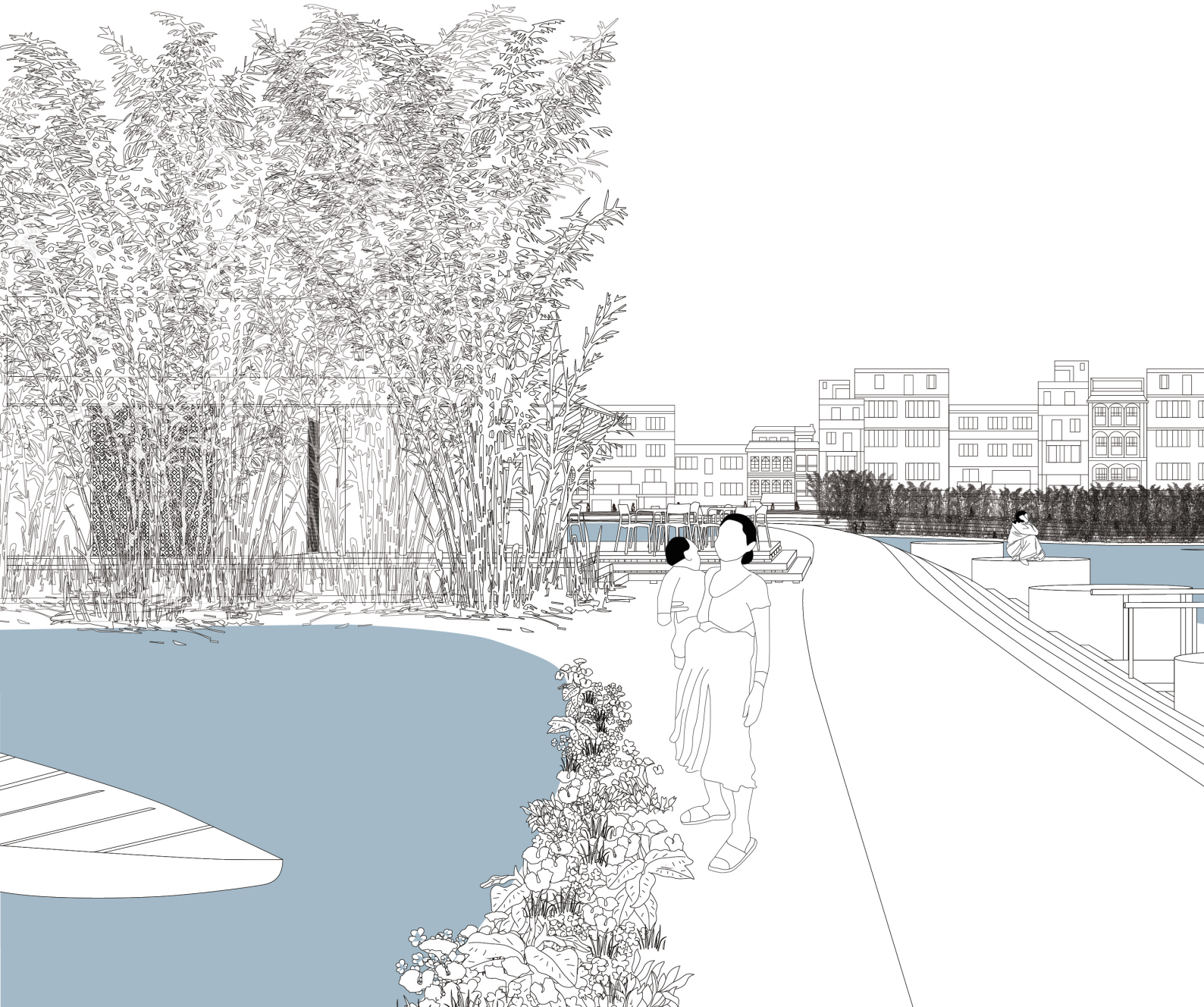


LANDSCAPE APPROACH TO WWTP

Strolling from entrance to water platform

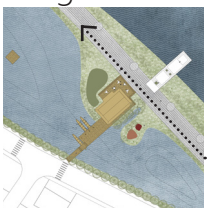


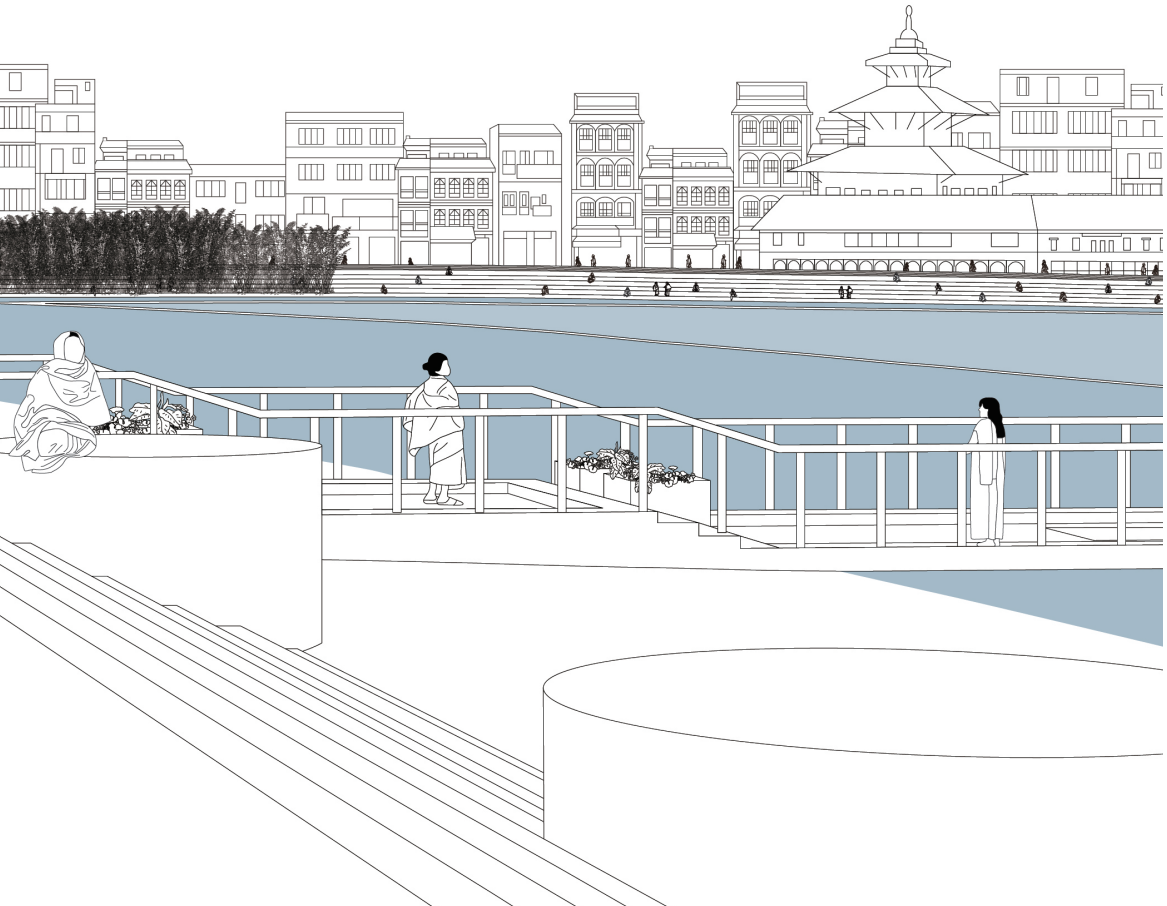
Figure 6-37. Fishery pond perspective drawing, drawn by author



LANDSCAPE APPROACH TO WWTP

Strolling along the river





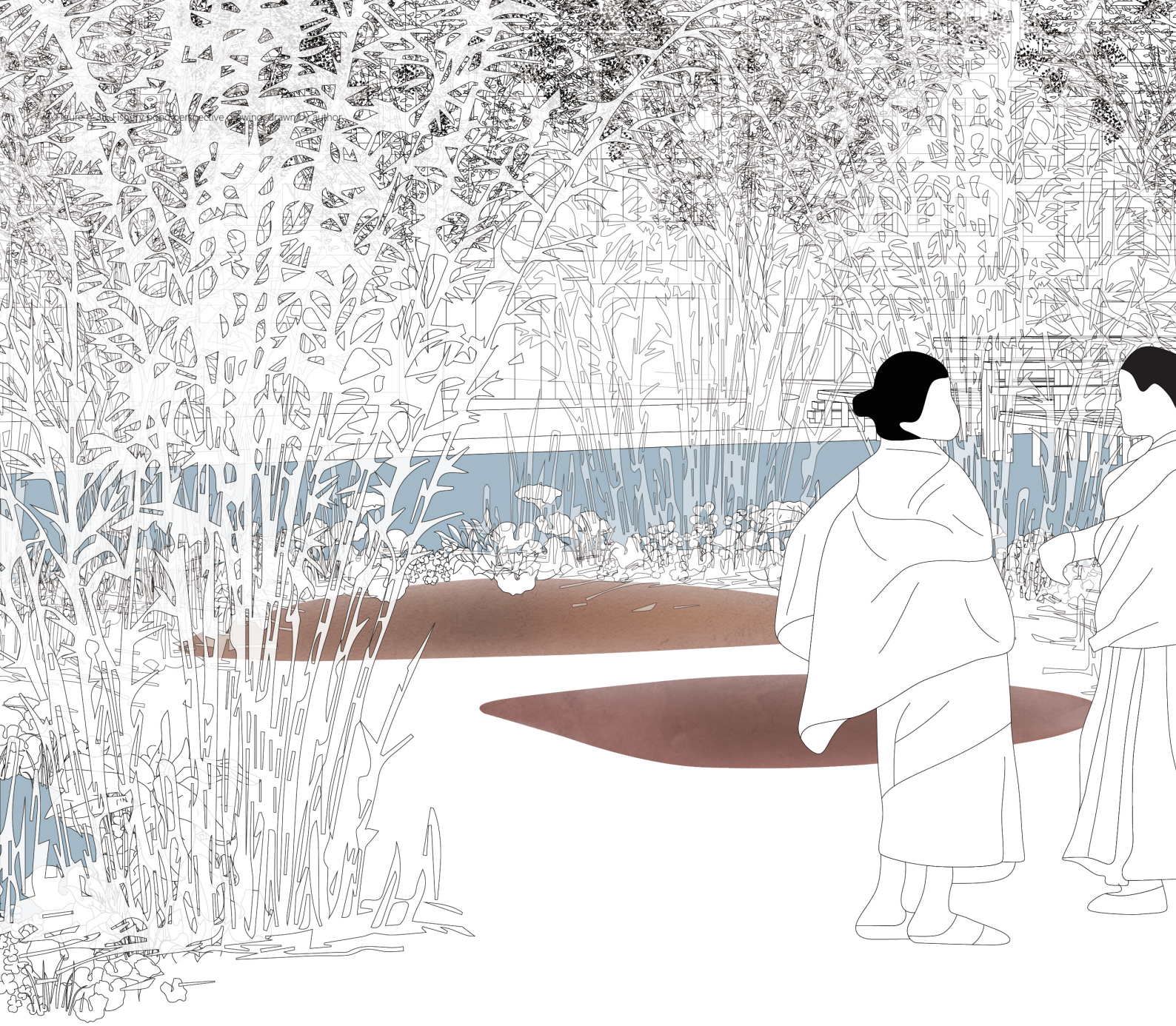


Figure 6.3 Final perspective drawing (drawn by author)



LANDSCAPE APPROACH TO WWTP

Strolling along the river

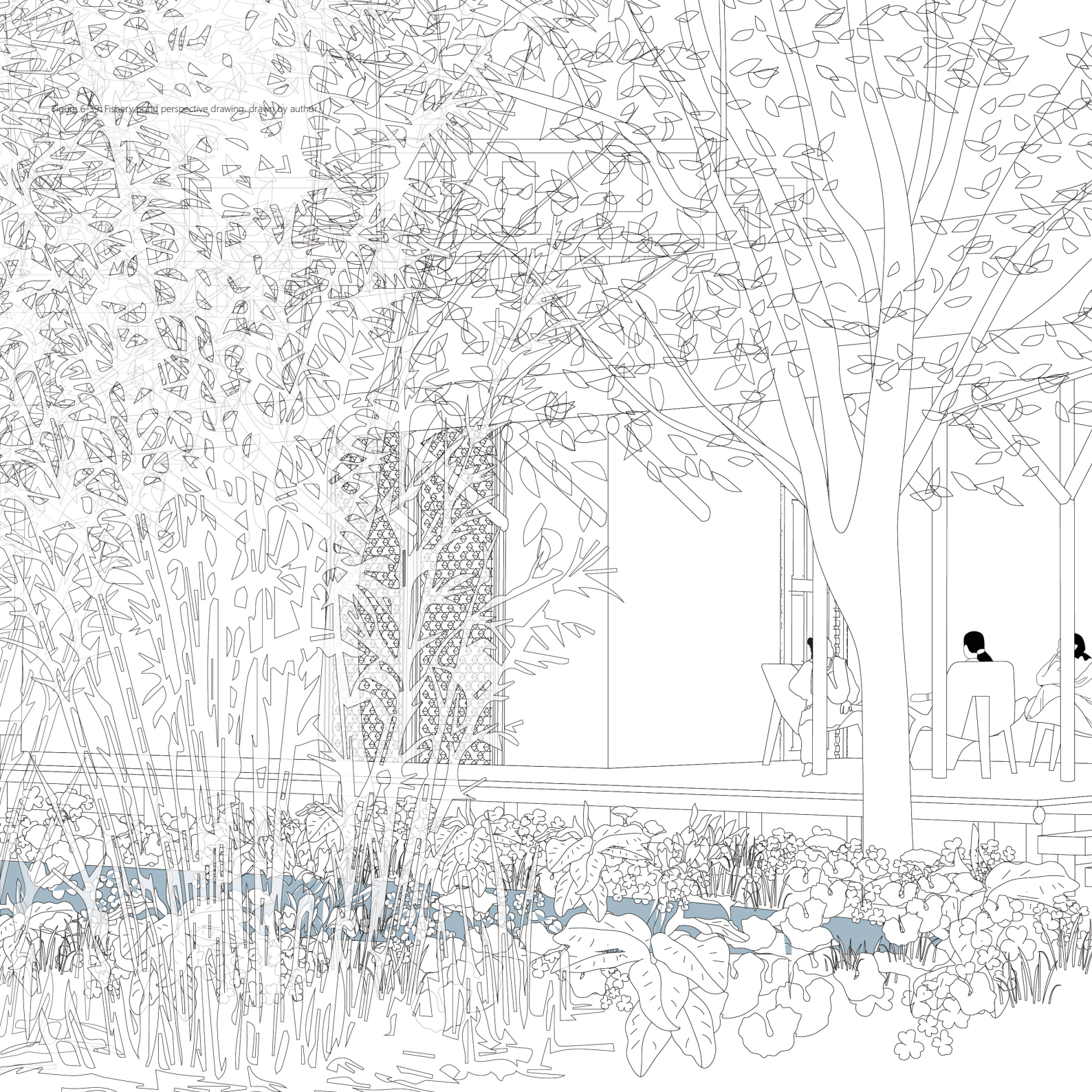
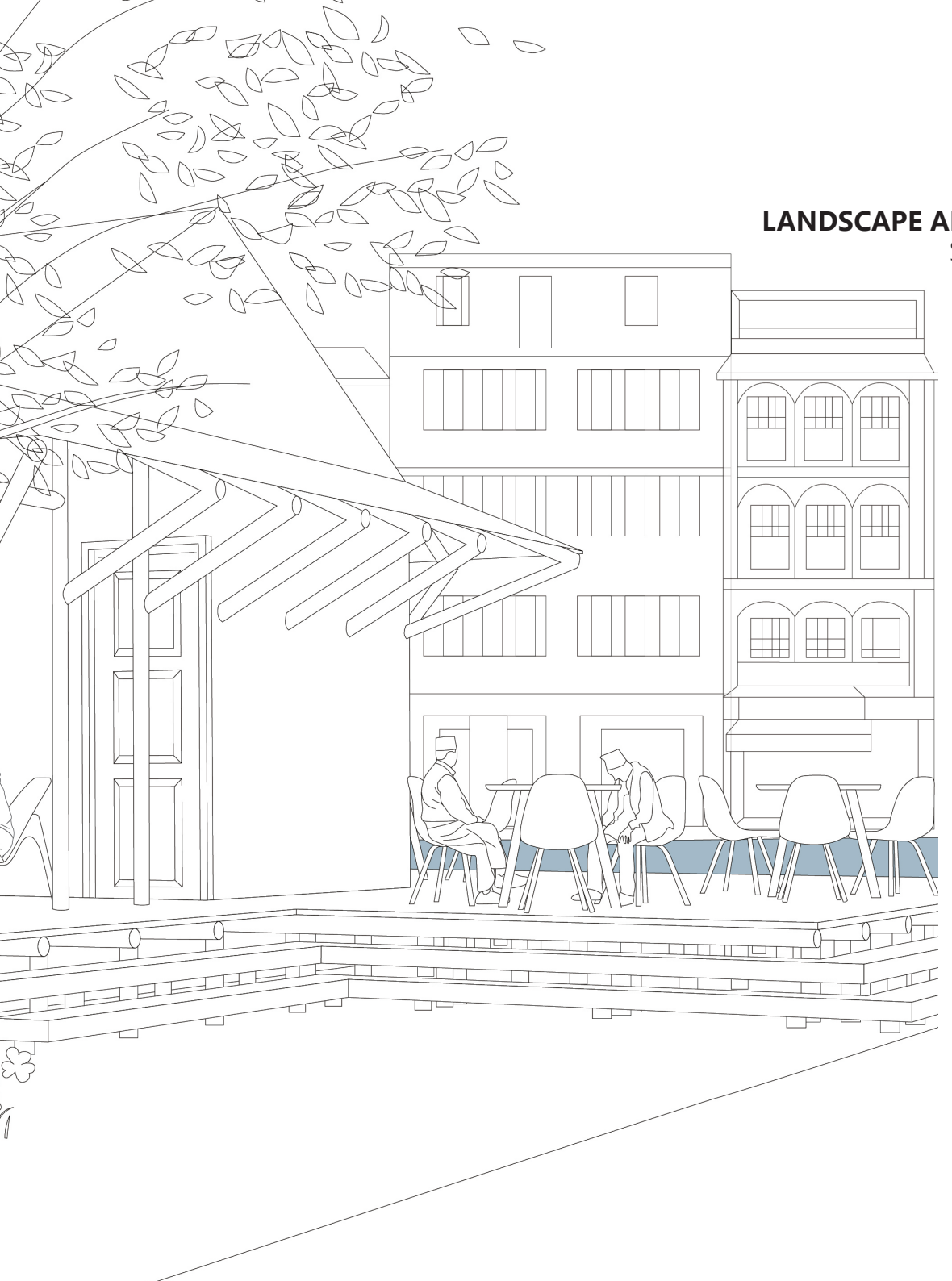


Figure 6-39 Fishery pond perspective drawing, drawn by author



LANDSCAPE APPROACH TO WWTP

Strolling along the river



Figure 6.20 Fisherly Wood perspective drawing, drawn by author

LANDSCAPE APPROACH TO WWTP

Strolling along the river



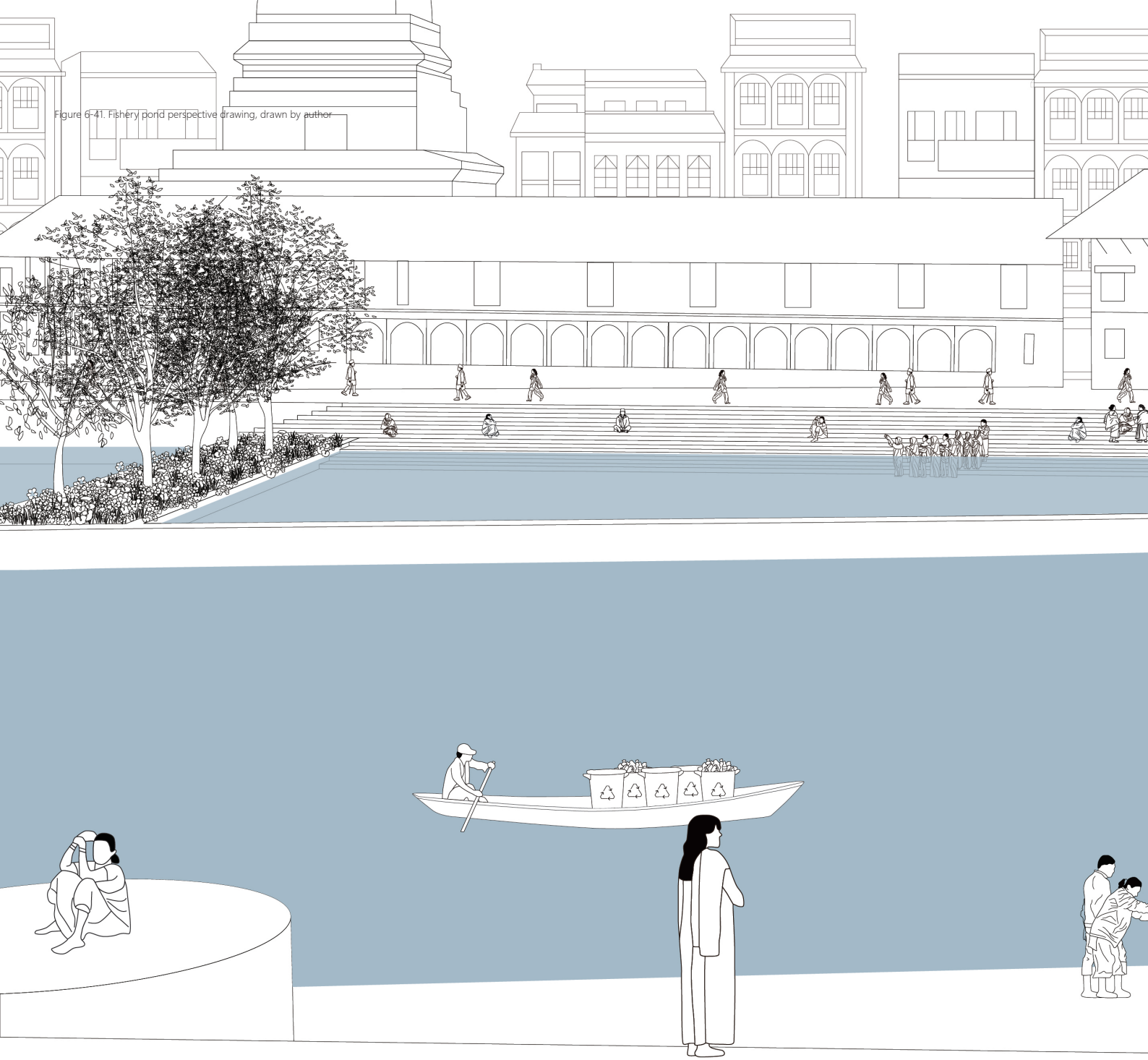
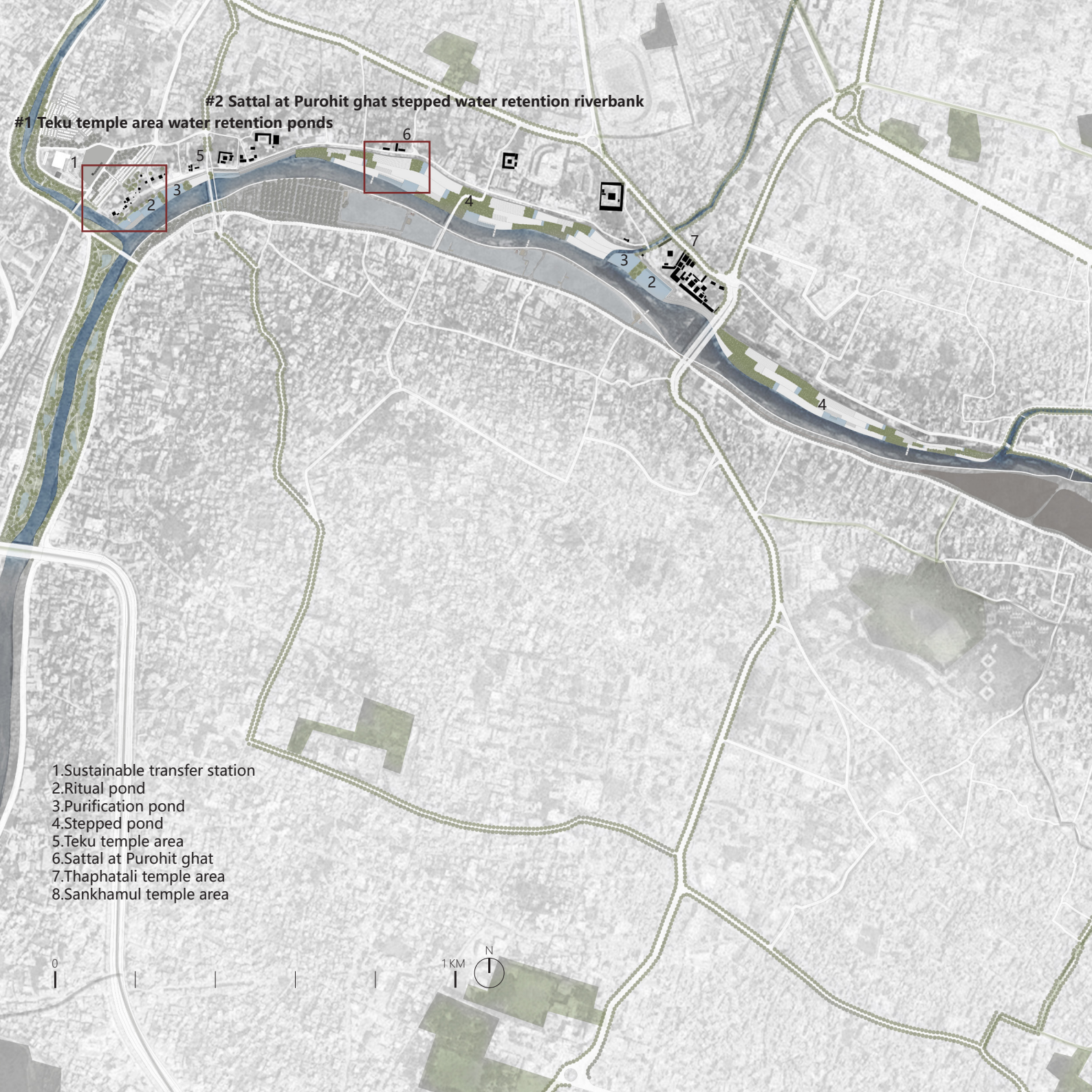


Figure 6-41. Fishery pond perspective drawing, drawn by author



LANDSCAPE APPROACH TO WWTP

Strolling along the river


#2 Sattal at Purohit ghat stepped water retention riverbank
#1 Teku temple area water retention ponds
1
2
3
5
6
4
3
2
7
4
1.Sustainable transfer station
2.Ritual pond
3.Purification pond
4.Stepped pond
5.Teku temple area
6.Sattal at Purohit ghat
7.Thaphatali temple area
8.Sankhamul temple area
0
1 KM
N

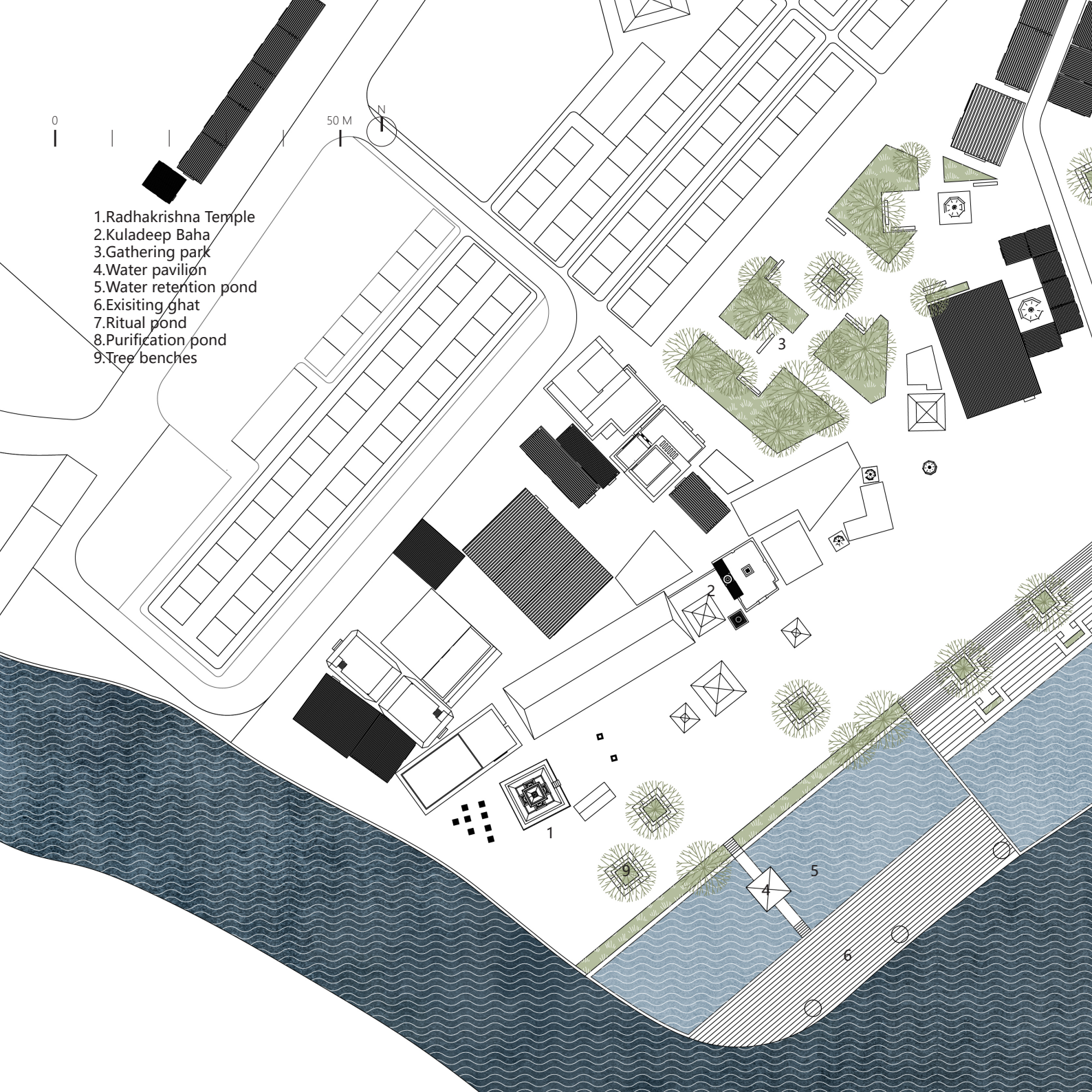


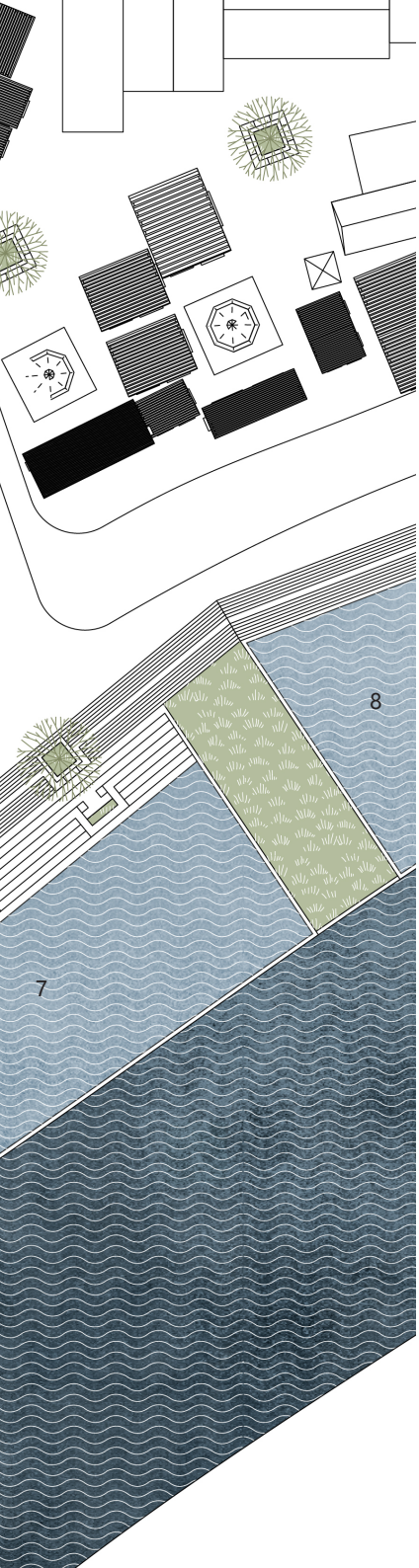
SUSTAINABLE WATER RETENTION
Seasonal riverbank

Figure 6-42. Map of seasonal water retention riverbank, drawn by author

In addition to reducing the sources of pollution to combat pollution in Bagmati, raising the groundwater level by collecting flood water and rainwater to replenish it so that it can enter the Bagmati River to flush the already polluted river can further help deal with the pollution of Bagmati.

Much of the open space on the south bank has been used to purify the domestic sewage discharged from the WWTP, so the storage of rainwater and monsoon flood water is in the open space on the north bank. As there are many religious monuments on the north bank-the Teku temple area and Thaphatali temple area as well as some scattered monuments like Sattal at Purohit Ghat, the design of these water catchment areas has been divided into two types depending on the size of the open space and the density of the heritages.

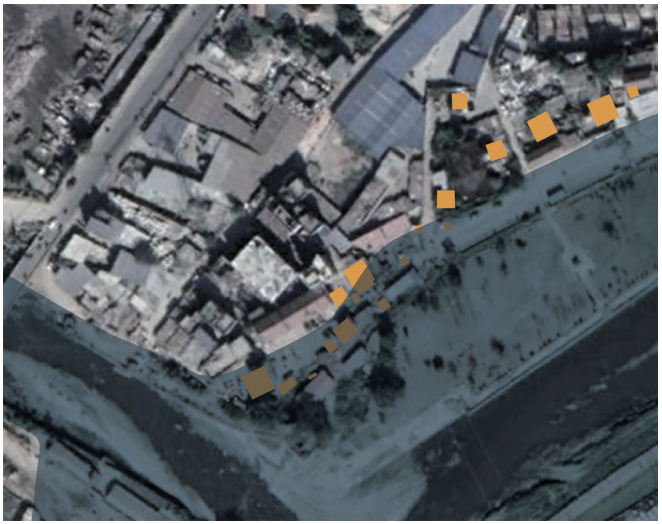

0
50 M
N
1.Radhakrishna Temple
2.Kuladeep Baha
3.Gathering park
4.Water pavilion
5.Water retention pond
6.Exisiting ghat
7.Ritual pond
8.Purification pond
9.Tree benches
1
2
3
4
5
6
9



SUSTAINABLE WATER RETENTION

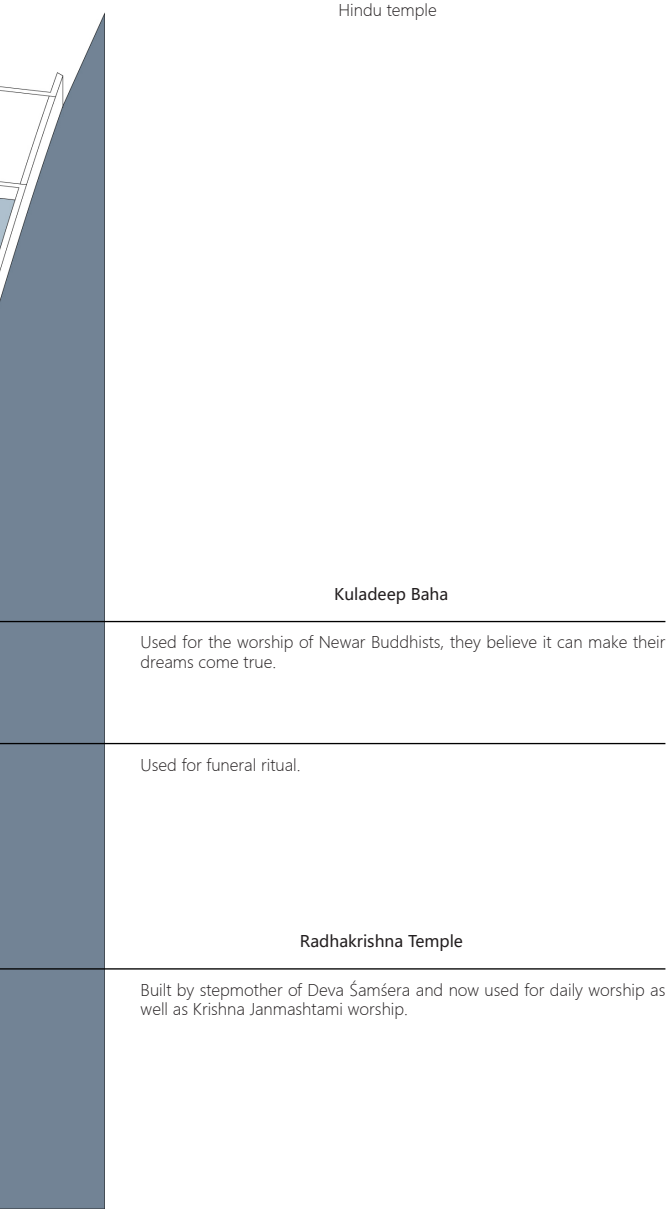
#1 Teku temple area water retention ponds

Figure 6-43. Map of Teku temple area water retention ponds, drawn by author
Figure 6-44. Map of existing situation of Teku temple area, drawn by author



The first type is the heritage intensive area, which refers to the two temple areas with only narrow open spaces along the river. The design of the pond is derived from the traditional pond (Appendix 4) of the valley, with a regular geometric form and hard material, and a brick bottom, through which water enters the soil and finally penetrates into the shallow aquifer. These ponds along the river have a similar form but different functions.





SUSTAINABLE WATER RETENTION

#1 Teku temple area water retention ponds

Figure 6-45. Axonometric diagram of Teku temple area water retention ponds, drawn by author

The main function of some of the reservoirs is to provide recreational space, connecting the existing near-river steps through a pavilion, providing a place for visitors to relax and enjoy the view, and enhancing the connection between people and cultural heritage and Bagmati.

Some of the ponds have been designed to accommodate religious rituals. In the past, during daily or festival ceremonies, devotees would step directly into the Bagmati River and sacrifice offerings, which, although religiously significant, still made the Bagmati River more polluted, and the already heavily polluted Bagmati was not good for the health of those who stepped into it. Therefore, some of the reservoirs were designed to be accessible by downward steps as an alternative to the place where the rituals was held. These reservoirs collect rainwater which with good quality is good for people to go inside. The offerings that are scattered into the water will be fished out after the festival to prevent the overflow from entering the Bagmati when the rain is too heavy. Also, this type of reservoir will be connected to a waterlily planted reservoir to ensure that the overflow is purified before entering Bagmati.

Due to the low topography of this area, there is a risk of flooding in the monsoon season, so behind the pond, there is a dike parallel to the direction of the river to protect the heritage from being flooded, part of the dike is designed as a staircase for people to stay and rest and see the view.

The main attraction of the area is the existing heritages. The temples and ghat on the banks of the river are where people go for their daily worship and some also for funeral ritual, believing that the sacred Bagmati River has the power to heal everything. Therefore, the open spaces in the site are designed to provide different spaces for devotees to gather after the worship, and for visitors to better experience the heritage and history of the site. In terms of spatial experience, the tree benches are the main element of the design, providing a gathering place for visitors and also serving as a guide for the tour of the heritages.

SUSTAINABLE WATER RETENTION

#1 Water retention ponds - seasonal changes

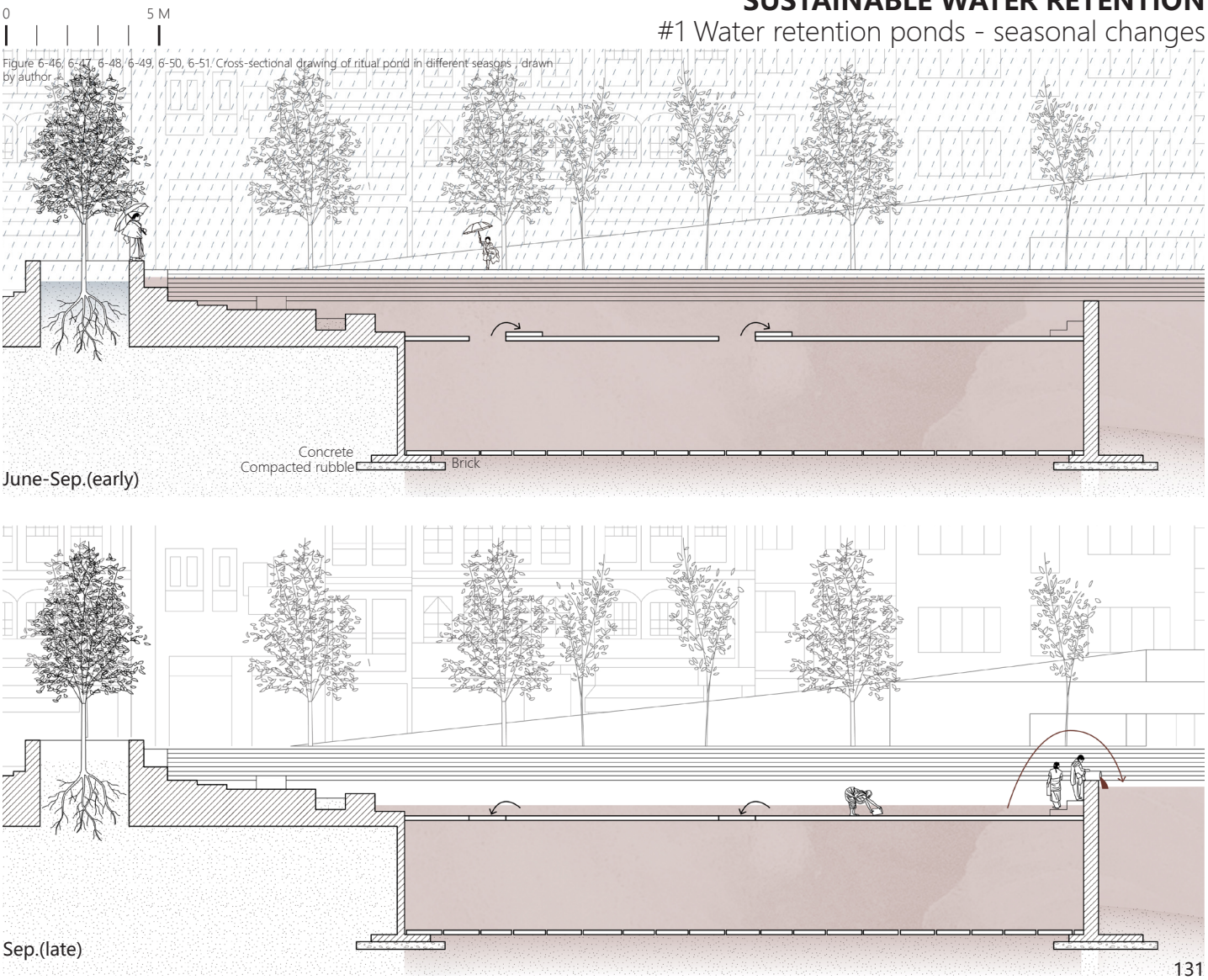
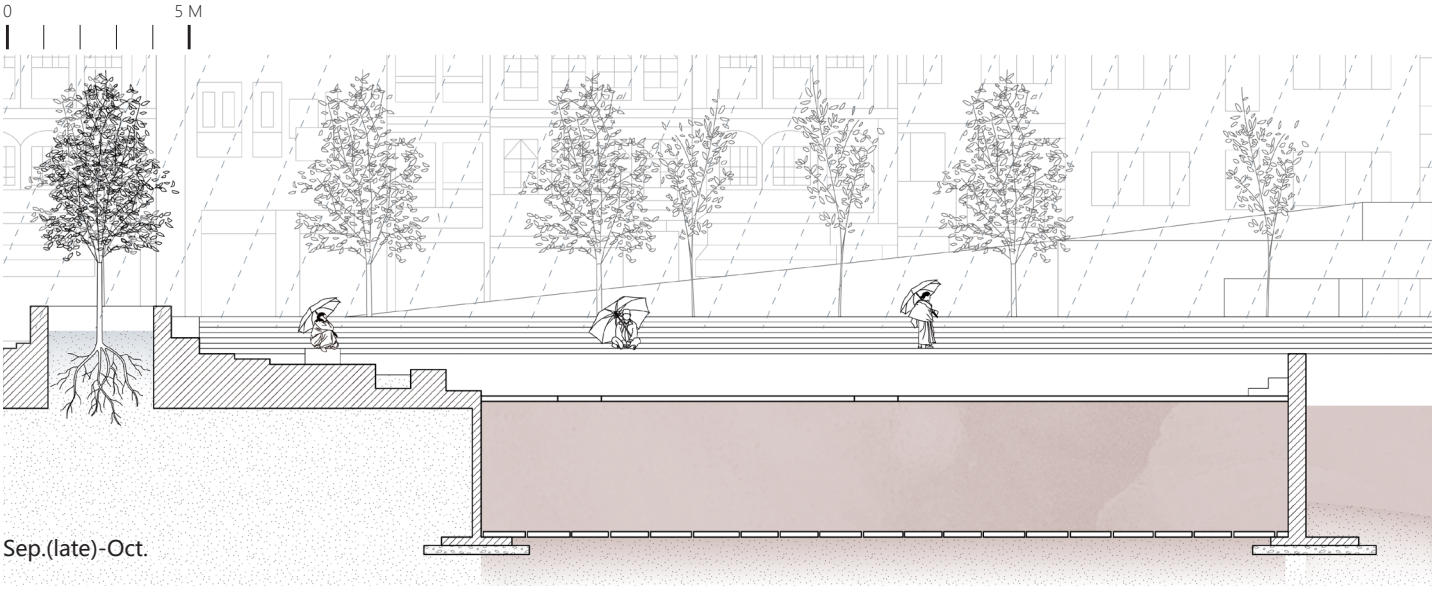
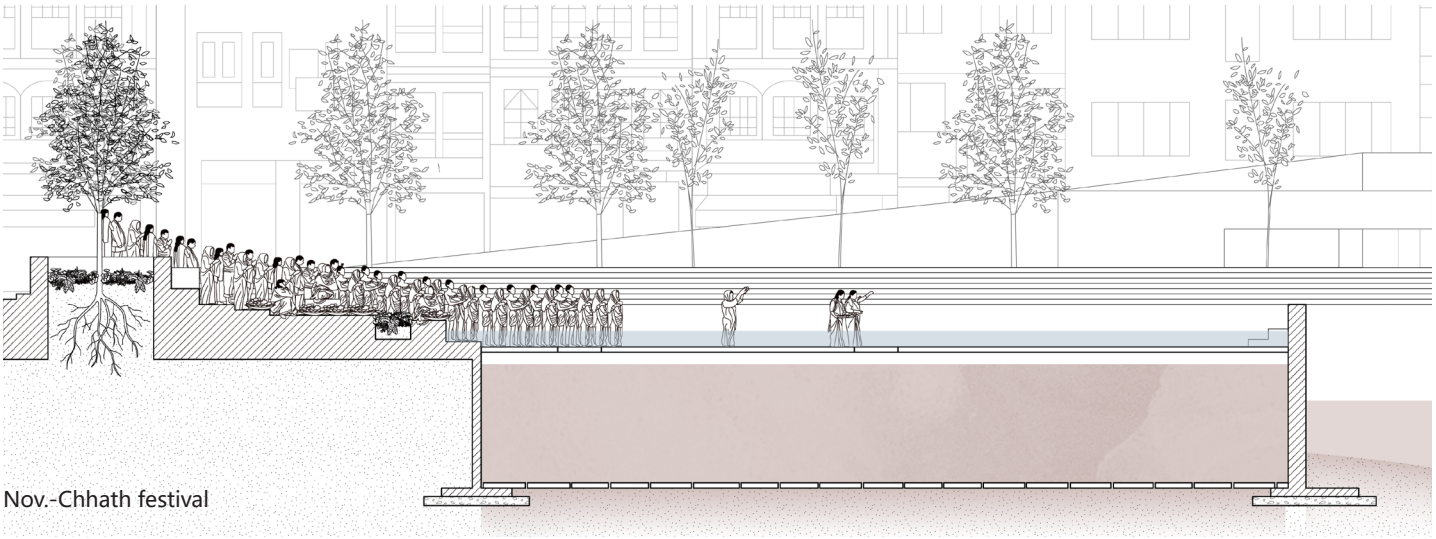


Figure 6-46, 6-47, 6-48, 6-49, 6-50, 6-51. Cross-sectional drawing of ritual pond in different seasons , drawn by author

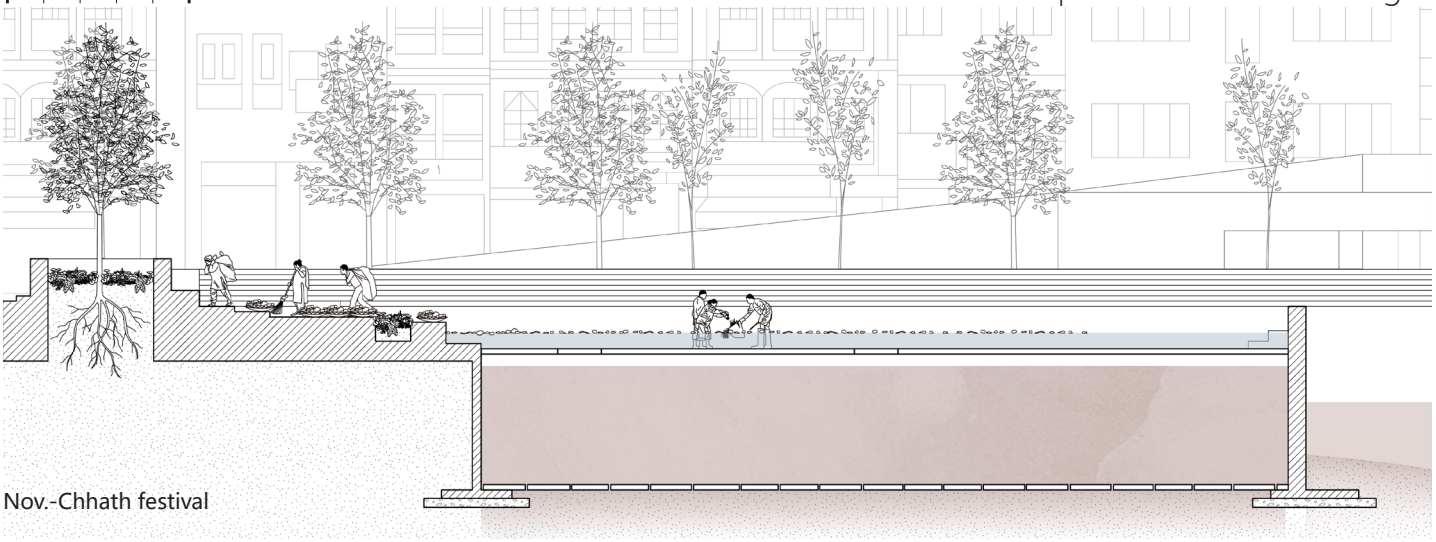

0
5 M
Sep.(late)-Oct.


Nov.-Chhath festival

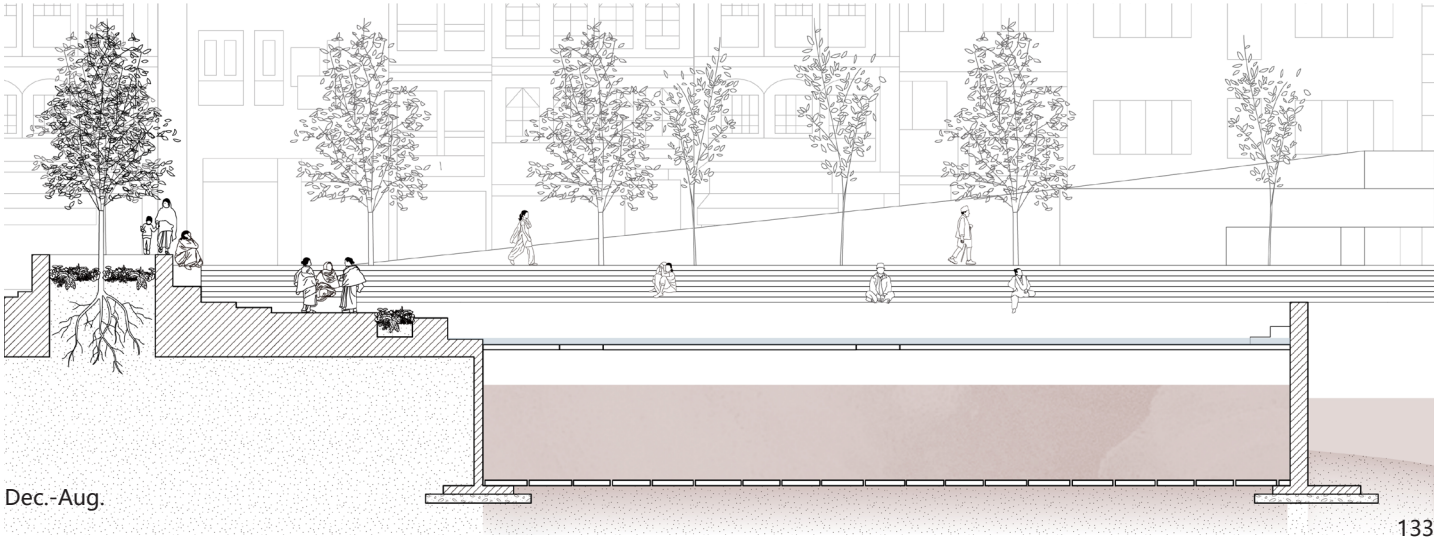
SUSTAINABLE WATER RETENTION

#1 Water retention ponds - seasonal changes

0 5 M



Nov.-Chhath festival



Dec.-Aug.

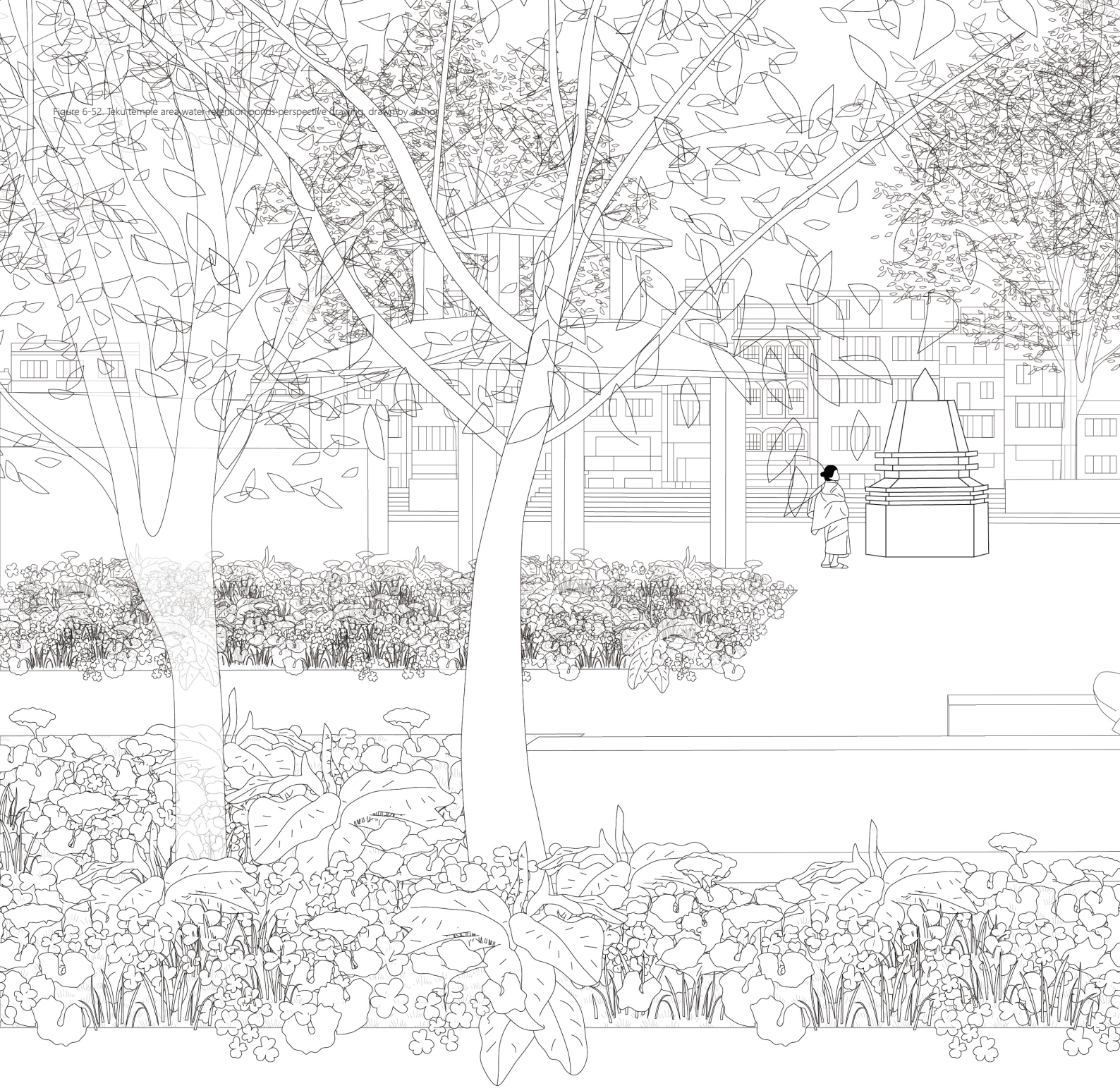


Figure 6-52. Teku temple area water reception ponds perspective drawing, drawn by author

SUSTAINABLE WATER RETENTION
Strolling through the monuments





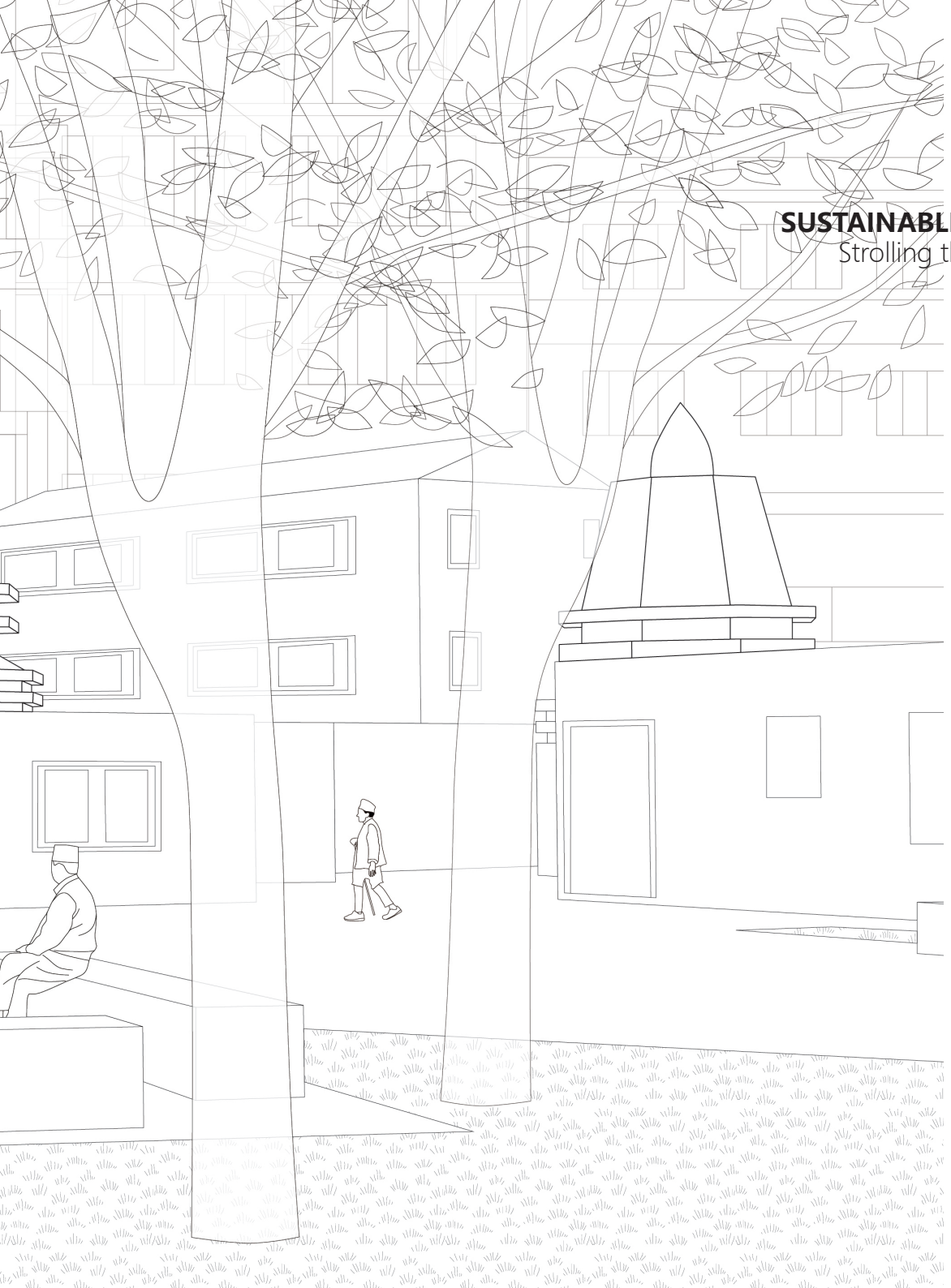
Figure 6-53 Teku temple area water retention ponds perspective drawing, drawn by author



SUSTAINABLE WATER RETENTION
Strolling through the monuments

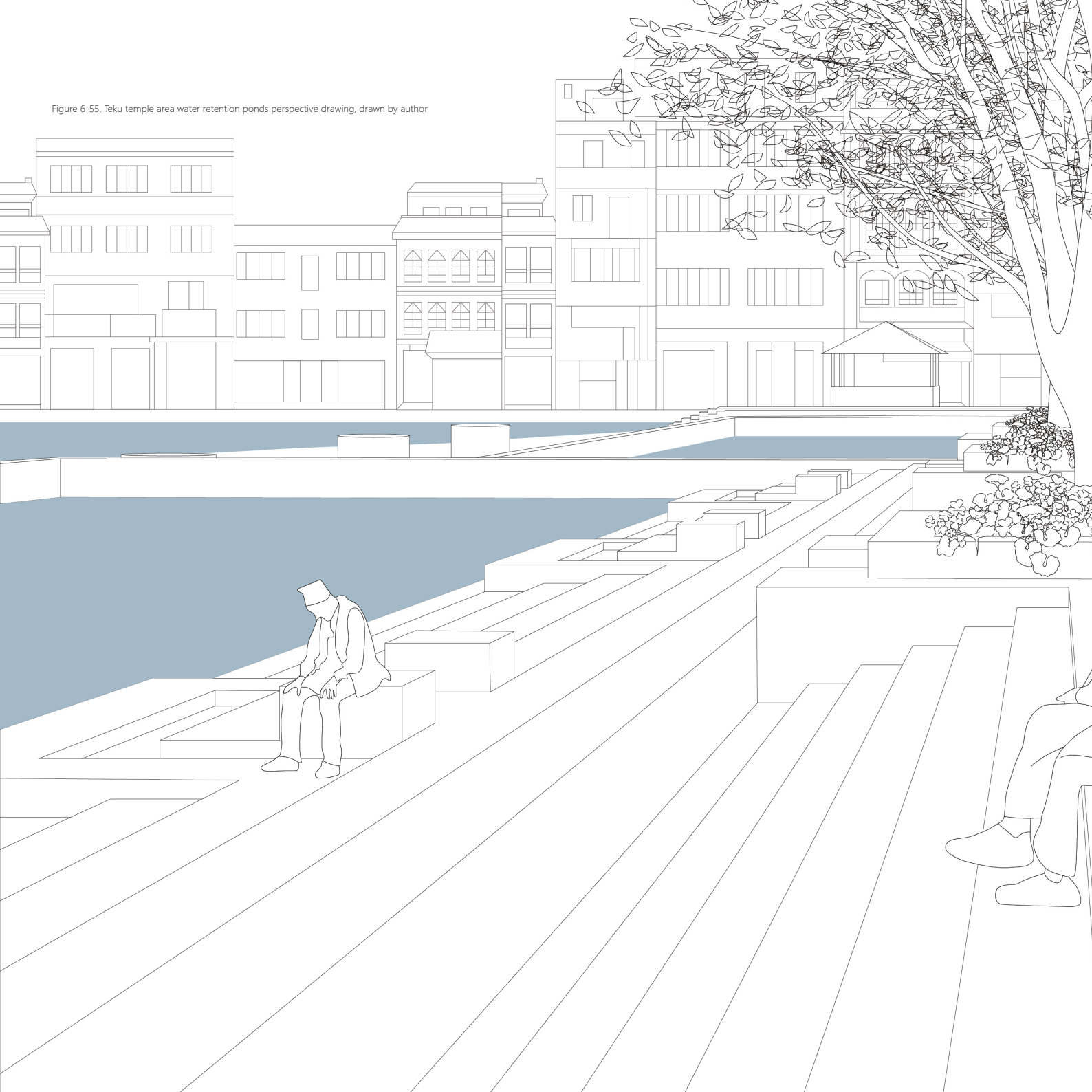


Figure 6-54 Teli Temple area water detention ponds perspective drawing (drawn by author)



SUSTAINABLE WATER RETENTION
Strolling through the monuments

Figure 6-55. Teku temple area water retention ponds perspective drawing, drawn by author



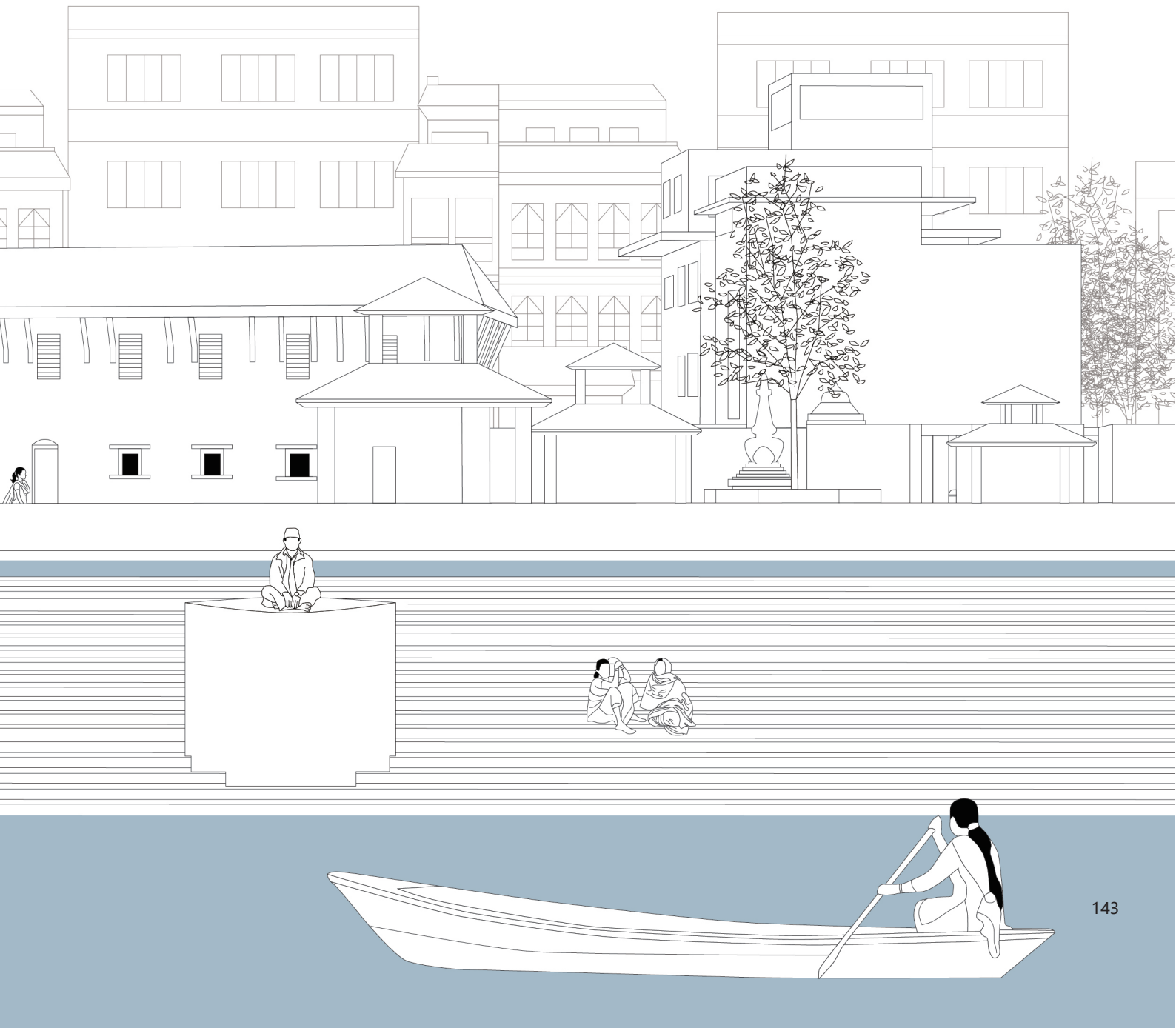
SUSTAINABLE WATER RETENTION

Strolling along the river



Figure 6-56. Teku temple area water retention ponds perspective drawing, drawn by author





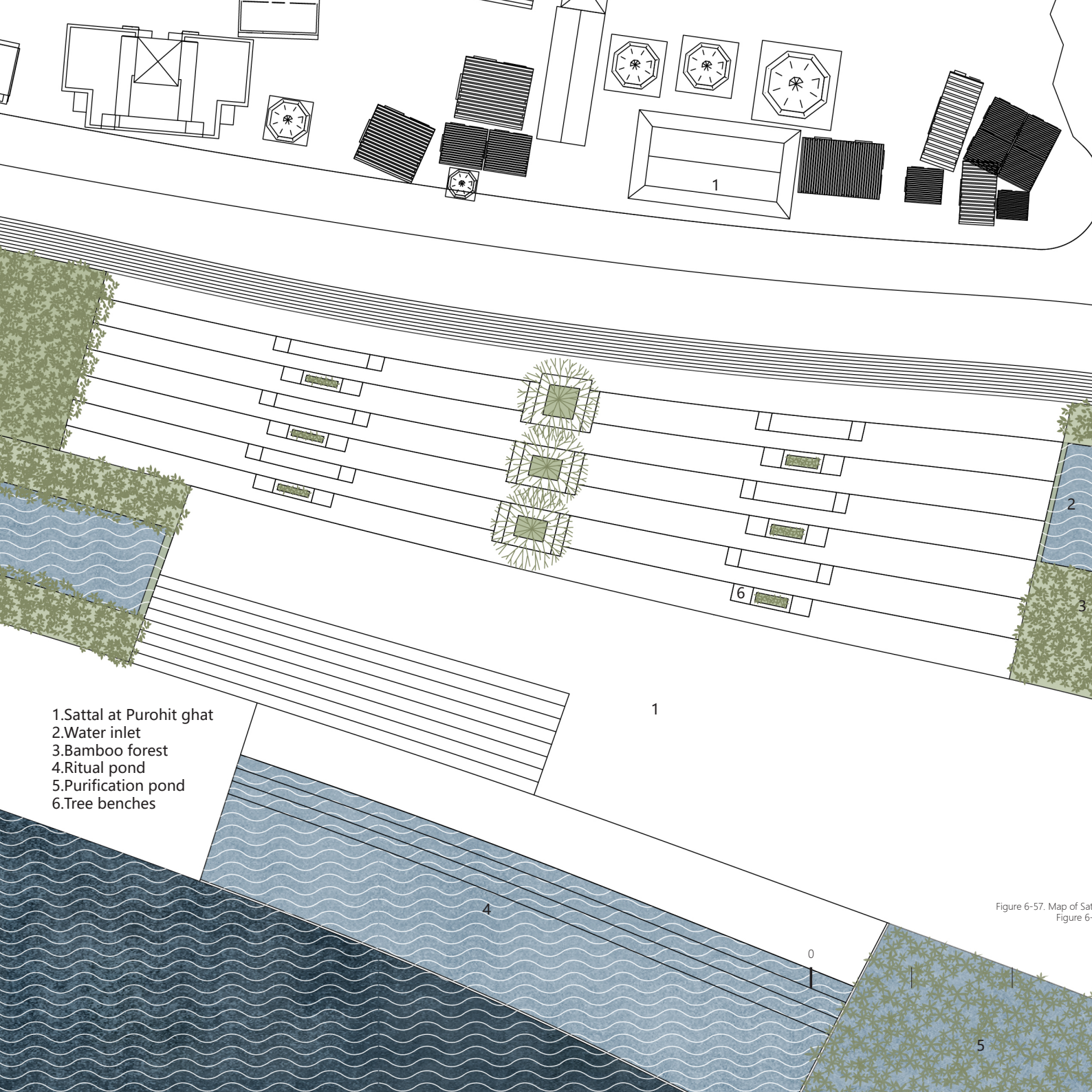
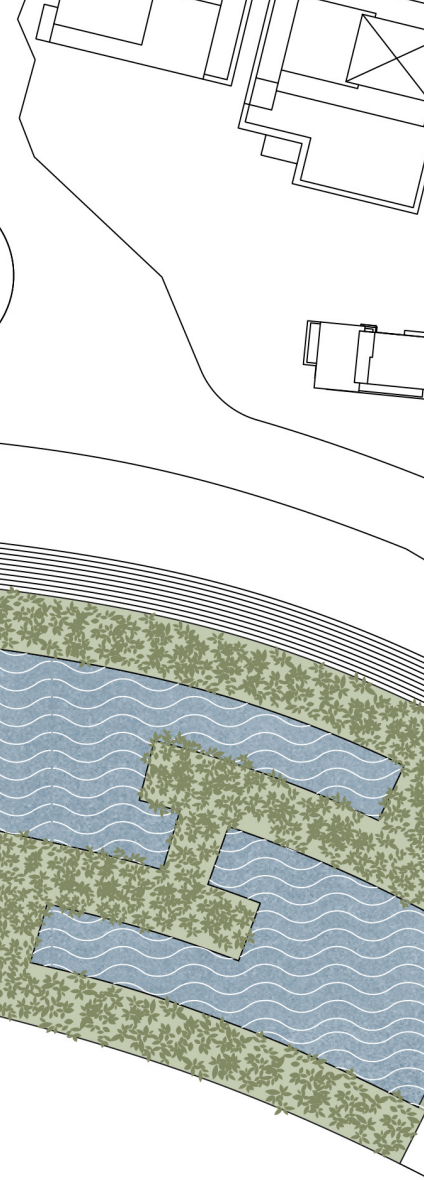
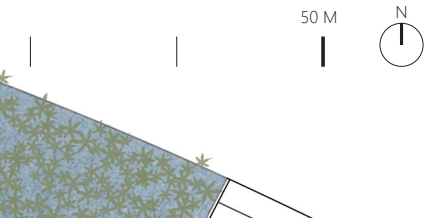


Figure 6-57. Map of Sat
Figure 6-

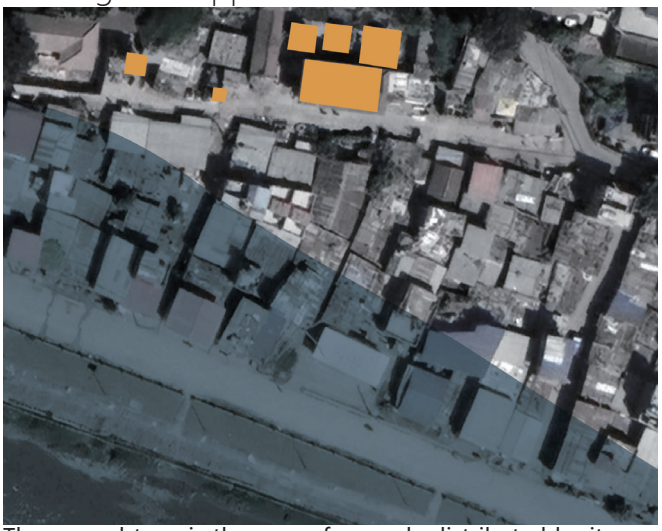


ttal at Purohit ghat stepped water retention riverbank, drawn by author
-58. Map of existing situation of Sattal at Purohit ghat, drawn by author



SUSTAINABLE WATER RETENTION

#2 Sattal at Purohit ghat stepped water retention riverbank



The second type is the area of sparsely distributed heritages, with a large open space between the heritages and the river, which used to be the squatter settlements area. The design of this area is derived from the traditional riverbank-ghat. The change in the height difference of the terraces can to some degree prevent the reappearance of squatter settlements. And the terraced topography also facilitates the storage of flood water as the area is often flooded to varying degrees during the monsoon season due to the changing water levels in Bagmati.

In order to reduce evaporation of the stored water, most of the water surface is covered by hard pavement, leaving only the inlet open. A bamboo forest was planted around the inlet to create shade, further reducing evaporation and providing shade for people who stay and rest here.

In addition to water storage, these terraces also serve other functions. Since there are still some temples along the river, during some festivals, devotees will step into Bagmati to continue their rituals after finishing the rituals in the temple, therefore, some areas of the terraces that near the river are designed to be reservoirs for religious rituals and purification to meet the religious needs which is the same as the first type.

And in some areas, these large terraces are subdivided into smaller steps, with platforms of different heights and vegetation, to provide recreational areas for residents and visitors.

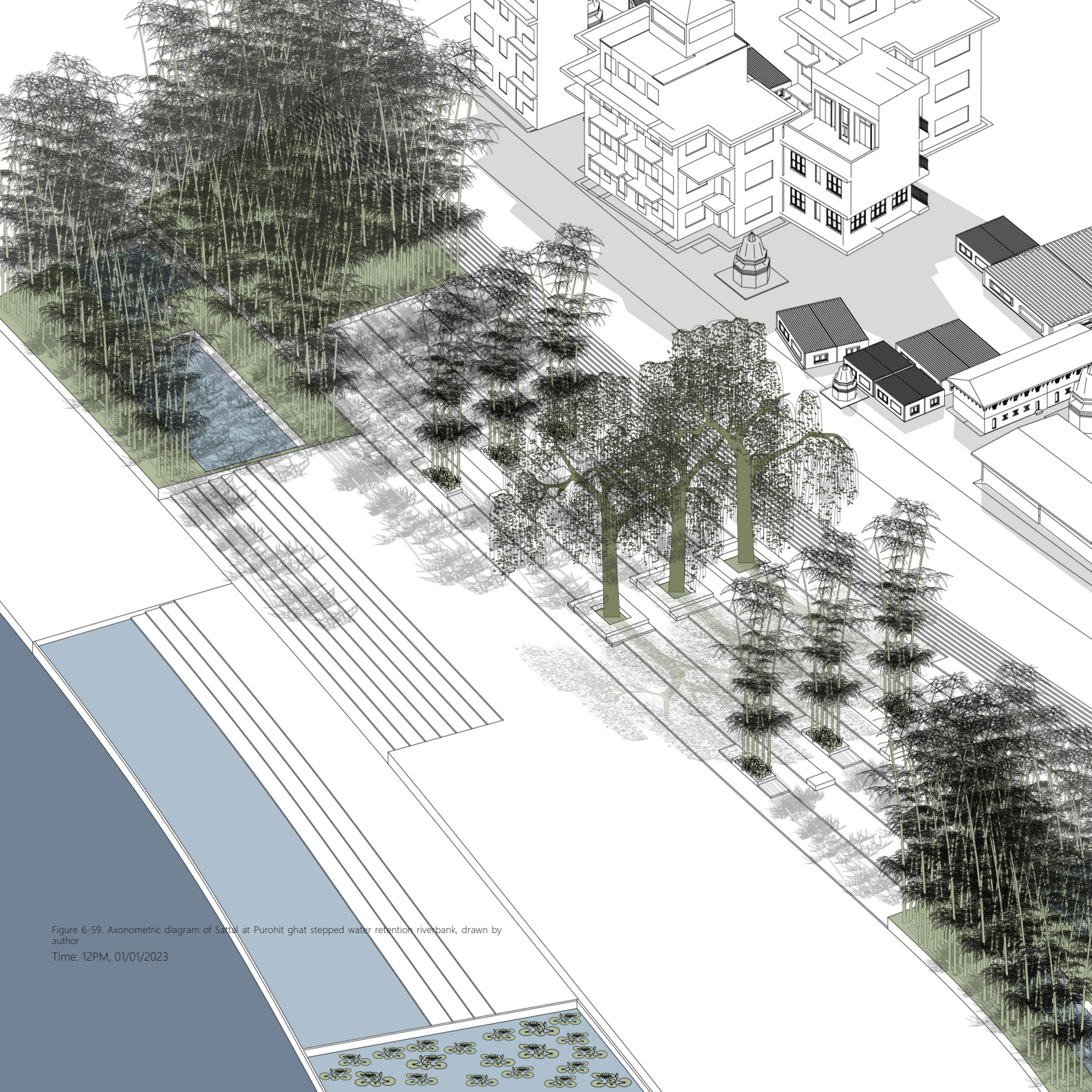


Figure 6-59. Axonometric diagram of Sattal at Purohit ghat stepped water retention riverbank, drawn by author

Time: 12PM, 01/01/2023

SUSTAINABLE WATER RETENTION

#2 Sattal at Purohit ghat stepped water retention riverbank



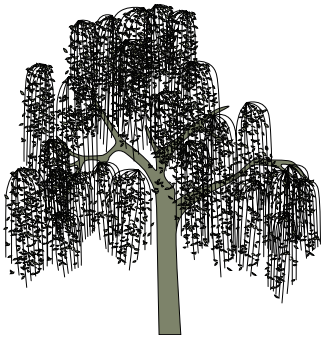
1983



Now



Bamboo



Willow



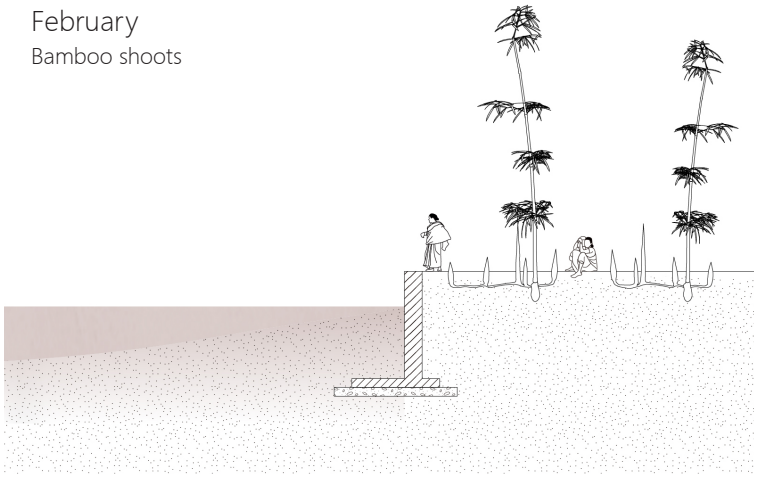
Figure 6-60 In the bamboo forest, drawn by author.



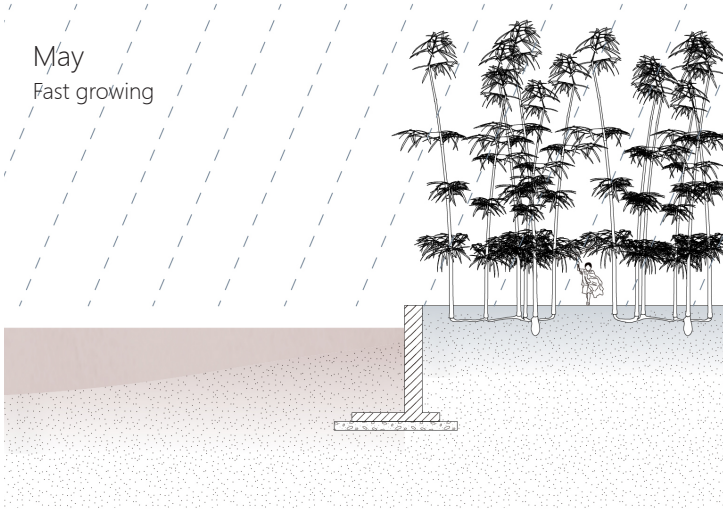
SUSTAINABLE WATER RETENTION

In the bamboo forest

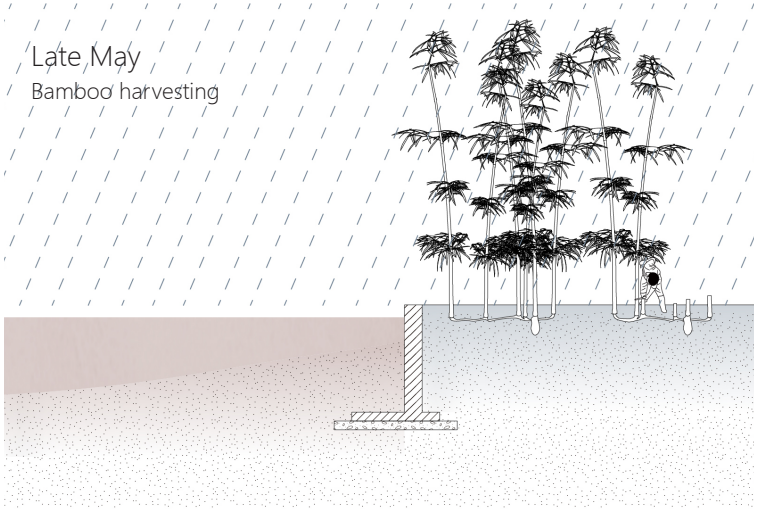
February
Bamboo shoots



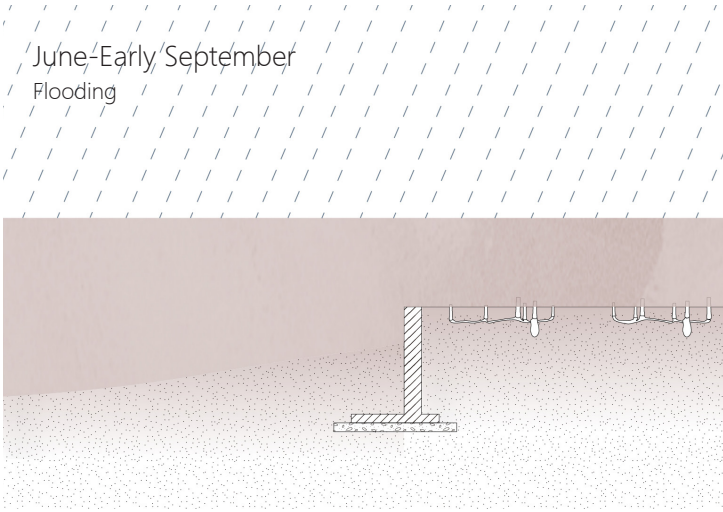
May
Fast growing



Late May
Bamboo harvesting



June-Early September
Flooding



SUSTAINABLE WATER RETENTION

#2 Sattal at Purohit ghat stepped water retention riverbank - the growth cycle of bamboo

October.

Bamboo planting

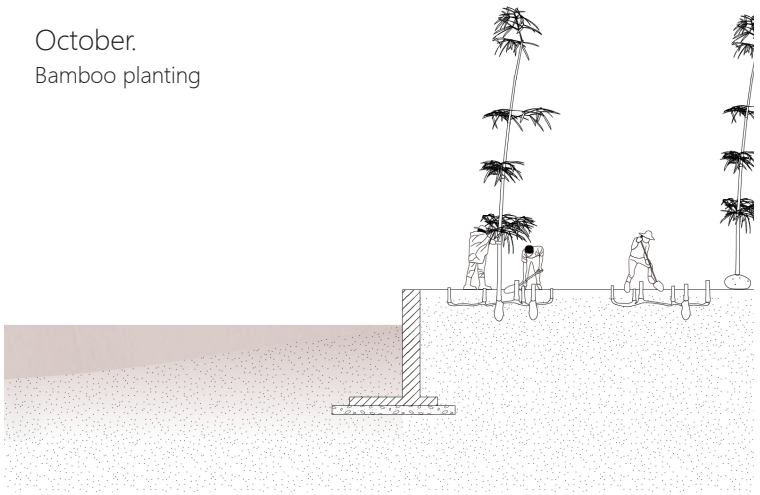


Figure 6-61. Growth cycle of bamboo, drawn by author

Bamboo is one of the important native plant species in Nepal. It was chosen to be planted here because the area is seasonally flooded, as other large trees are perennial and therefore do not survive, while bamboo has a short growth cycle. The bamboo is transplanted here after the monsoon season, and after germination in the spring and rapid growth in the early summer, the bamboo can be harvested before the area is flooded, and the harvested bamboo can be used to make handicrafts. Bamboo is therefore the most suitable native species for this condition.



Figure 6-62. Street side water retention green space, drawn by author
Figure 6-63. Map of green system, drawn by author

SUSTAINABLE WATER RETENTION

Green system



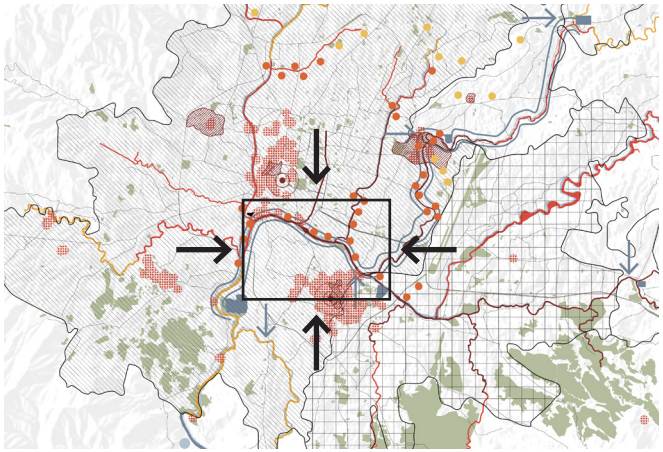
In order to store as much rainwater as possible to recharge the aquifers, not only riverbanks but also green areas in urban areas can be transformed into water retention areas.

With climate change, there will be more rain during the monsoon season and more heat and drought during the dry season. This green network that stores water, in addition to supplementing so that more rainwater can be stored into the aquifer, also helps maintain the water balance. During the rainy season, it stores excess surface runoff to prevent flooding of streets and residences, while during the dry season, the stored surface water helps to create a cooler climate in dense urban areas.

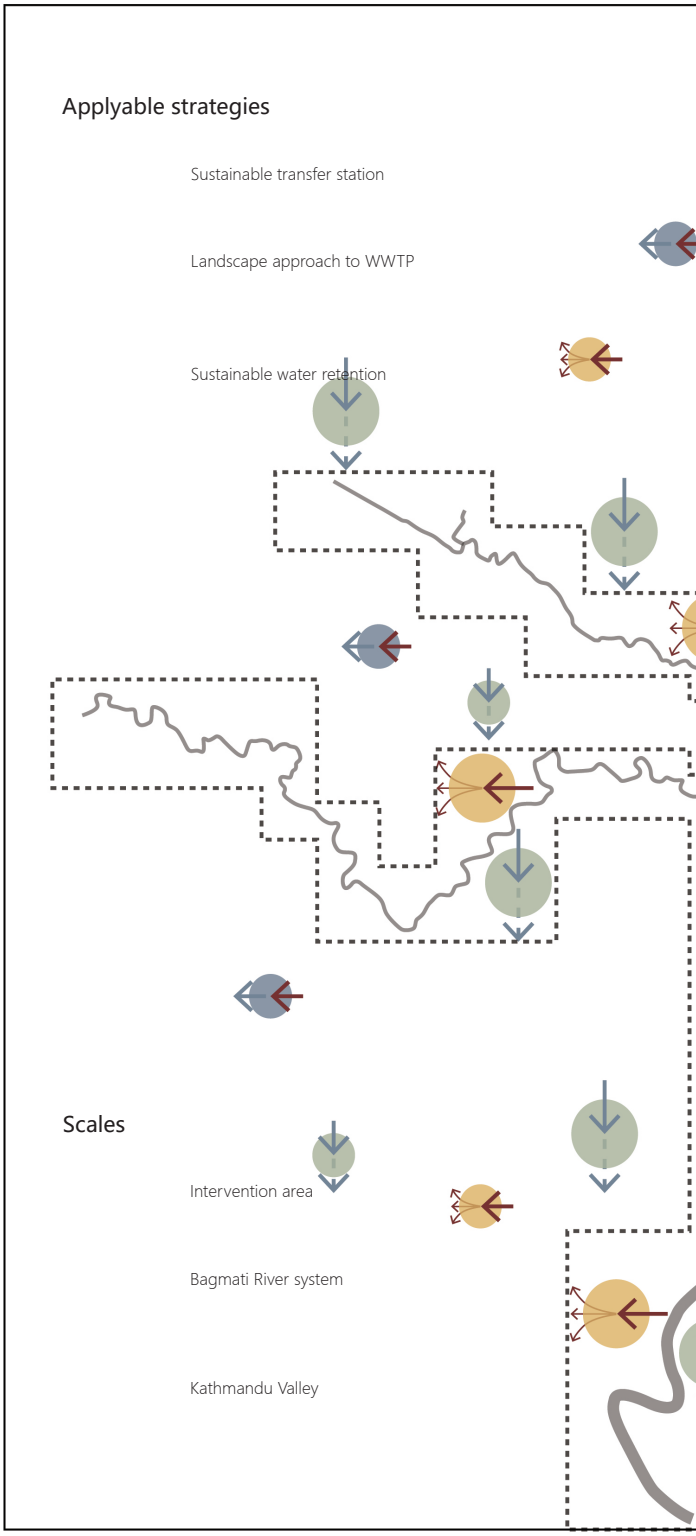
The formation of this green network is based on the existing scattered patches of green space within the site. These green spaces are converted into water storage areas that can still be used as recreational spaces for residents. These green patches are connected by greenways, which are strips of green space with wadi that are near the main urban roads. The entire sustainable water storage system greatly enhances groundwater recharge while improving the resilience of the city to climate change and improving the living quality of residents.

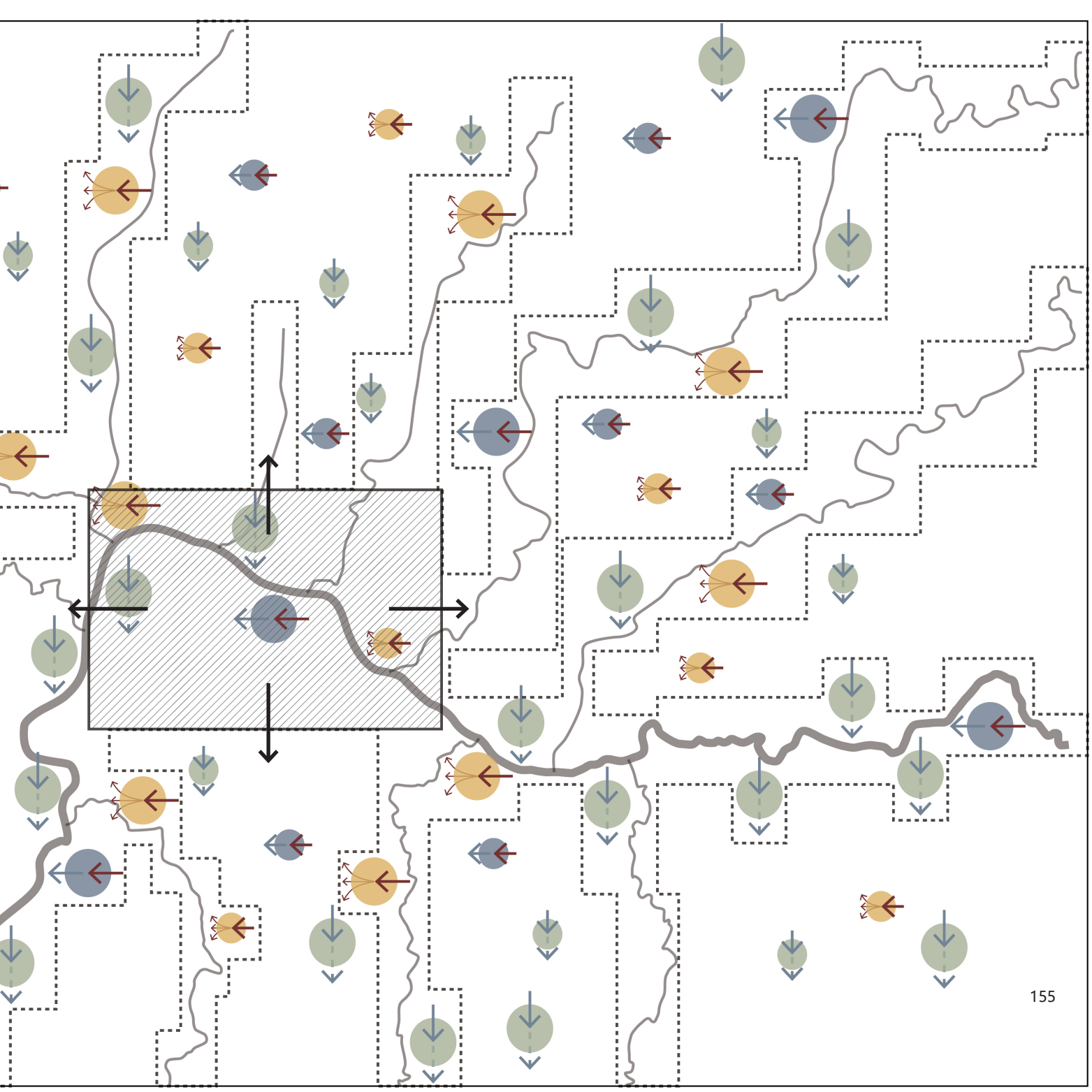
07 CHAIN DEVELOPMENT

Figure 7-1. Overlaid challenge map, drawn by author
Figure 7-2. Map of chain development, drawn by author



Through the three proposed strategies, the ecological condition of the Bagmati River will be improved. However, the revival of the entire Bagmati River system requires more efforts over time through the application of these strategies on a larger scale.
In the following phases, these strategies will first be applied to the entire Bagmati River Basin. Then, in the larger region of the Kathmandu Valley, some interventions can continue in places with similar problems. Through all of these phases, the goal of reviving the entire Bagmati River system and improving the quality of life throughout the Kathmandu Valley will be achieved.









CONCLUSION AND REFLECTION

08 CONCLUSION

After the research through design and research by design process, the problems of research question can be answered.

How to integrate the separated technique measures and landscape (spatial) interventions to form integrated and comprehensive landscape architectonic (spatial) design?

The first principle of integration is to propose landscape interventions based on existing technical measures. In terms of wastewater purification, the existing WWTP in the intervention area could not meet the demand, resulting in the destruction of the entire wastewater treatment system. The landscape approach to WWTP helps purify wastewater that exceeds the capacity of the existing WWTP to ensure that the wastewater treatment system can function well and that all wastewater can be purified before being discharged into the Bagmati River. For waste management, a sustainable transfer station will be proposed based on the existing waste segregation policy to increase the service area for waste collection. The second principle of integration is to consider the problems as a whole and find the point where the contradictions of these problems can be balanced. Sometimes a problem could be transformed into an opportunity when searching for a solution to another problem. The landscape approach to WWTP and sustainable transfer stations faces a lack of labor, especially at transfer station, because many Nepalese do not consider waste management an honorable job and are reluctant to get involved. At the same time, the problem with relocating squatter settlements is that squatters cannot afford to pay rent for new houses and they need jobs. In this case, an integrated intervention could be proposed to provide permanent housing to squatters, who could serve as laborers for waste management and fishermen for wastewater treatment, for whom a small salary would be sufficient. All problems can be easily solved through this integrated intervention. The riverbank squatter areas can then be transformed into sustainable water retention areas for groundwater recharge. Through these two principles, separated technical measures can be integrated with the landscape (spatial) design to form a comprehensive landscape architectonic (spatial) design for the restoration of the Bagmati River.

What is needed to revive Bagmati River to restore its culture and nature?

The direct cause of the decline of the Bagmati River is the encroachment of pollutants caused by the direct discharge of sewage, poor garbage management and the declining water table. The squatter settlements along the riverbank exacerbated this pollution. But the root cause is the attitude of

people towards Bagmati River. In the past, there was a strong spiritual connection between people and Bagmati River. People revered Bagmati River, built various religious sites along it, and showed their worship of this river in their daily rituals and festival ceremonies, and the Bagmati River was an important part of their daily and religious life. As the city expands, this relationship is weakening, people no longer revere the sacred river, it is polluted, and this further weakens the connection between people and the river. This creates a negative cycle that continues to erode the connection between people and the Bagmati River, ultimately leading to its decline. Therefore, in order to revive the culture and nature of Bagmati River, it is important to rebuild the connection between people and the river, in addition to directly addressing the problems that lead to pollution through the landscape approach to WWTP, sustainable transfer station and sustainable water retention areas. Several interventions are proposed to rebuild the connection. The design involves the squatters in the process of enhancing the ecological condition of the Bagmati River. The whole process of wastewater purification and water retention is then integrated into the environment and shown to the residents through the transformation of the Bagmati riverbank through landscape spatial design approaches, while the riverbank also creates public spaces that can be used for daily recreation and religious festivals according to the needs of the residents. This participation in environmental management, the environmental education and the more frequent use of the riverbank space by people has created a new connection between people and the river: people know they should make effort to revive and protect Bagmati River and they put it into action, and at the same time the Bagmati River provides them with different spaces based on their needs and the river will once again become an important part of the life of the inhabitants. Throughout the process, the connection between people and Bagmati River will be continually reinforced and the reverence that people have for the Bagmati River will be rebuilt.

What steps need to be taken to implement change to reconnect people to the river and enhance the living quality in the Kathmandu Valley?

The first stage is the formation of Urban Catalyst-the design implementations in the intervention area to generate several spatial design interventions. In the second stage, the spatial design interventions will be applied to the entire Bagmati River Basin to achieve the goal of reviving the whole Bagmati River system and reconnect people with it. In the final stage, in the larger region of the Kathmandu Valley, some interventions could also be continued in places with similar problems. To some degree improve the living quality in the whole Kathmandu Valley.

09 REFLECTION

This document is the reflection of the project: "Reviving the Bagmati River in the Kathmandu Valley" . This project will be reflected on from six aspects.

Reflecting through the relationship to Flowscapes studio

The project is part of Circular Water Stories Lab in Flowscapes studio. The main topic of Flowscapes studio is the flows and the Circular Water Stories Lab focuses on one of the most important flows in landscape-water. It began with the study and analysis of a traditional water system. These analytical studies help to understand the historical changes in the relationship between people and water within the design site, which is an indispensable beginning to the final design project, as it facilitates reflection on changes over time, thus forming the overall context of the graduation project. The graduation project focuses on a polluted sacred river-Bagmati River. The project starting with the historical relationship between people and the river. In the past, there was a strong spiritual connection between people and the river, people revered it. As the city expands, this relationship is weakening, people no longer revere the sacred river, it is polluted, and this further weakens the connection between people and the river. Eventually, Bagmati declined, the connection between people and the river was lost, and the quality of life of the people seriously deteriorated as a result. Interventions are then proposed from the perspective of landscape spatial design, responding to historical relationship to create a new human-river relationship based on current environmental challenges: With people working to restore and protect the Bagmati River, and the Bagmati River providing them with different spaces according to their needs, the river will once again become an important part of the lives of its inhabitants, and spiritual connections will be established at the same time. This relationship is sustainable and it helps to improve the ecological condition of the river and the quality of life of people, creating a better living environment.

Reflecting through the relationship between research and design

Research and design are the primary methods during each phase of the graduation project, and the weight and way in which they are used and the role they play will vary from phase to phase.
The first phase: Site analysis is mainly achieved through research methods, such as mapping, literature review etc. And design provides direction on what elements should be researched. The design of the project is related to river pollution and the relationship between people and river, so when conducting the research, the main focus is on the history and current status of the river and the relationship between people and it.
The second phase is to find the theoretical basis for design, using design as a starting point to select theories that may be suitable, further studying these theories through literature review and other research methods, and then judging the results of the research through design to clarify whether these theories are instructive for design. In this phase, this process from design to research to design will be repeated, and finally find a theoretical framework that can guide design.

REFLECTION

The first two phases are led by research, after entering the third phase: design, design is the main method of this phase, at this time research assists the progression of design. The first and second phase of research is carried out at a large scale, after entering the design phase, there is still a need for continuous research on some details, and the conclusions obtained through the research will promote the formation of the design. In this phase, a lot of reference projects research is also necessary, they can contribute to the formation of design ideas, and is also one of the important bases to prove the implementability of the design. Therefore, this phase is completed through the continuous feedback and revision from design to research to design.
Research and design are two methods that work together in different ways at different phases, but they are complementary throughout each phase of the project and together contribute to the completion of the project.

Reflecting through the outcome

The main proposal of the project is to restore the Bagmati River, re-establish its connection with its inhabitants and improve the quality of life of its inhabitants. Due to the complex environmental issues and large scale of the Bagmati River system, the framework of the project follows the Urban Catalyst theory to proposes design implementations at different scales. Within the scale of the intervention area, three main strategies are proposed and detailed design interventions are elaborated with the consideration of the social, cultural and natural elements within the site to solve the problems that lead to the decline of Bagmati River and achieve the design proposal. However, the revival of the entire Bagmati River system requires more efforts in the follow-up chain development phase through the application of these strategies and interventions on a larger scale.
In this project, the application of these interventions in a larger area is conceptually presented. In the next step, for more specific designs at this scale, such as where to apply these interventions and how to apply them, should involve people from other disciplines, such as urban planners, since at a larger scale, most areas are urban areas. Their knowledge can help enable these interventions to work systematically at the urban scale.

Ethical dilemmas

The design involves the relocation of squatters which requires consideration of a number of ethical issues, including the needs of the people who live there, the intentions of the government, and also the problems that arise after the relocation, such as the acceptance of this squatter group by the surrounding indigenous people. The requirements of these three groups are often in conflict with each other. Instead of balancing these conflicts from the single perspective of any of these three groups, which often leads to inequity, the design looks for balance from the perspective of the environment. The revival of Bagmati requires a lot of labor to participate in waste management. By involving squatters into the process, squatters can have jobs and a place to live, the government has

cheap labor to reduce the cost of waste management, and the quality of living environment of the indigenous people is improved, increasing their acceptance of squatters.

Limitations

The most difficult part of the project was the data collection. At the beginning of the project, due to the travel restrictions of Covid-19, it was not possible to conduct on-site research in Nepal, and since the last visit to Nepal was almost ten years ago, the photographic data was not current at that time, so the information collection had to rely on the internet.
Most of the information on the Internet is fragmented, so the only way to gather the required information is through extensive reading, especially since this project involves squatter settlements and few studies have been published about these areas, the relevant information is difficult to collect, and the images are vague.
Although the data collection process was time-consuming and much of the information ended up not being used, in the process, a deeper understanding of the design site itself was gained: its customs, history and culture. This information made the spatial design of the project more site-specific. Since a field trip to Nepal is now possible, the next step could be a field trip to help deepen the understanding of the site and revise the details of the design interventions, after gaining knowledge of the design site through the research and design process.

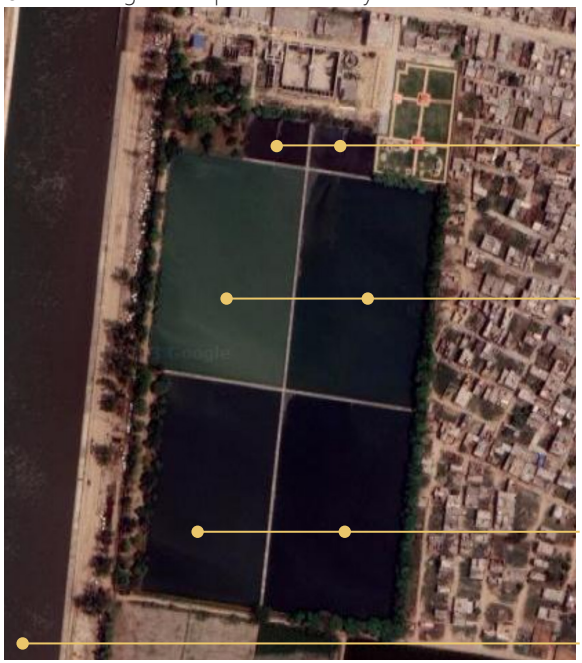
Relevance in the larger social, professional and scientific framework

The project reasonably considers the responsibilities of landscape architects in urban environmental improvement projects related to rivers. In a series of chain designs, the landscape architect is primarily responsible for the design of the urban catalyst that serves as the starting point, which is usually the restoration design of the most impacted section of the river, as it epitomizes the environmental issues. Some of these strategies and interventions will stimulate and guide subsequent, larger-scale urban design projects.
The design frameworks, principles and interventions can be informative when applied to other countries with similar problems. Many countries are facing similar challenges as Nepal, especially developing countries. Rapid urban development brings problems that end up destroying culture and nature, and the area suffers most are always the important rivers, which become muddy and full of garbage. For example, the Ganges River in India, the Majia River in Heilongjiang Province of China, the Pasig River in the Philippines, the Citarum River in Indonesia, the Mekong River in Myanmar, etc. The similar problems and causes, as well as the similar results, make the design framework, design principles and strategies used in this project highly informative when doing environmental improvement projects in these cities.

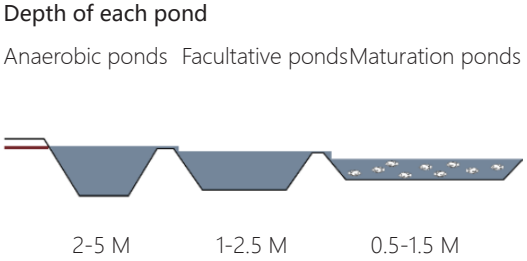
APPENDIX 1

Reference project - Effluent-fed aquaculture wastewater management

8 MLD sewage-fed aquaculture facility



Depth of each pond

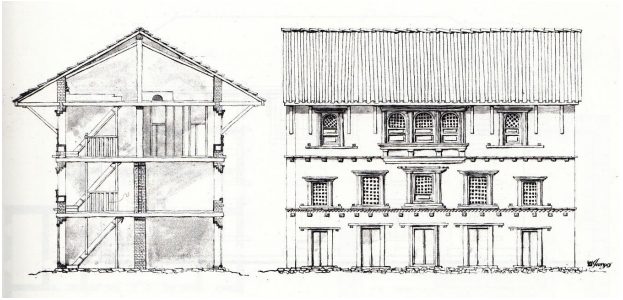


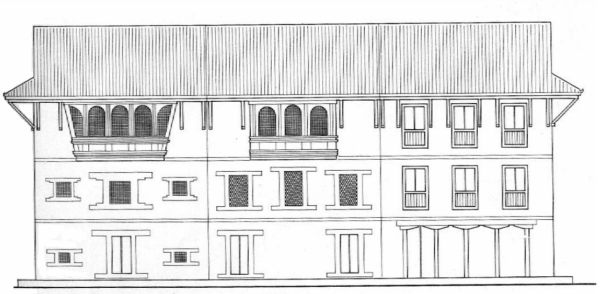
Some places in India have integrated effluent-fed aquaculture with wastewater management in practice. This system is used to treat domestic sewage and the nutrients contained in the sewage can sustain fish farms and agriculture.

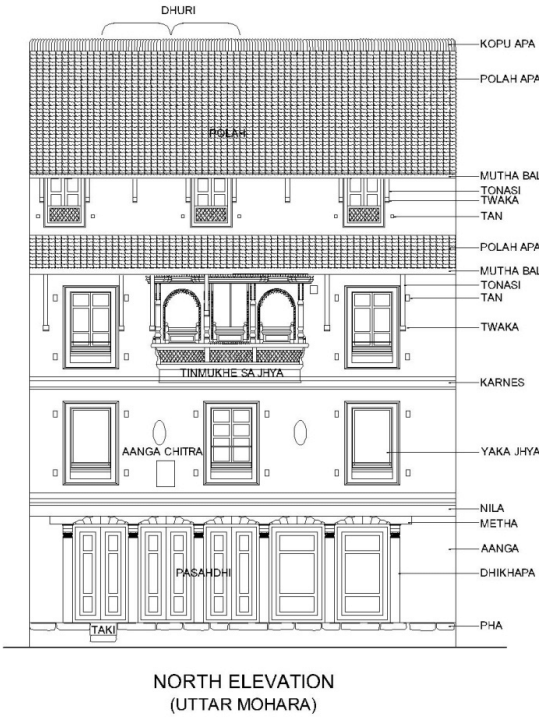
The reference project showing there is located in Karnal, the northern Indian state of Haryana (Poswal, D., Chaturvedi, M. K. M., Sharma, S., & Asolekar, S. R., 2015). Domestic wastewater from the city of Karnal is collected here and treated in a waste stabilization tank facility with a capacity of 8 million liters. The treatment unit consists of a series of ponds, i.e. anaerobic ponds, followed by facultative pond and maturation ponds. The maturation ponds are used for fish farming and the treated effluent can immediately be used for irrigation without any disinfection treatment.

Fish fed by domestic wastewater can be used for food, while the organic content of the wastewater can be reduced by about eighty percent. The treated wastewater k can continue to be used for agricultural cultivation. This system not only purifies the wastewater, but also provides cheap food and vegetables and some work opportunities.

APPENDIX 2
Reference project - Newari architecture







NORTH ELEVATION
(UTTAR MOHARA)

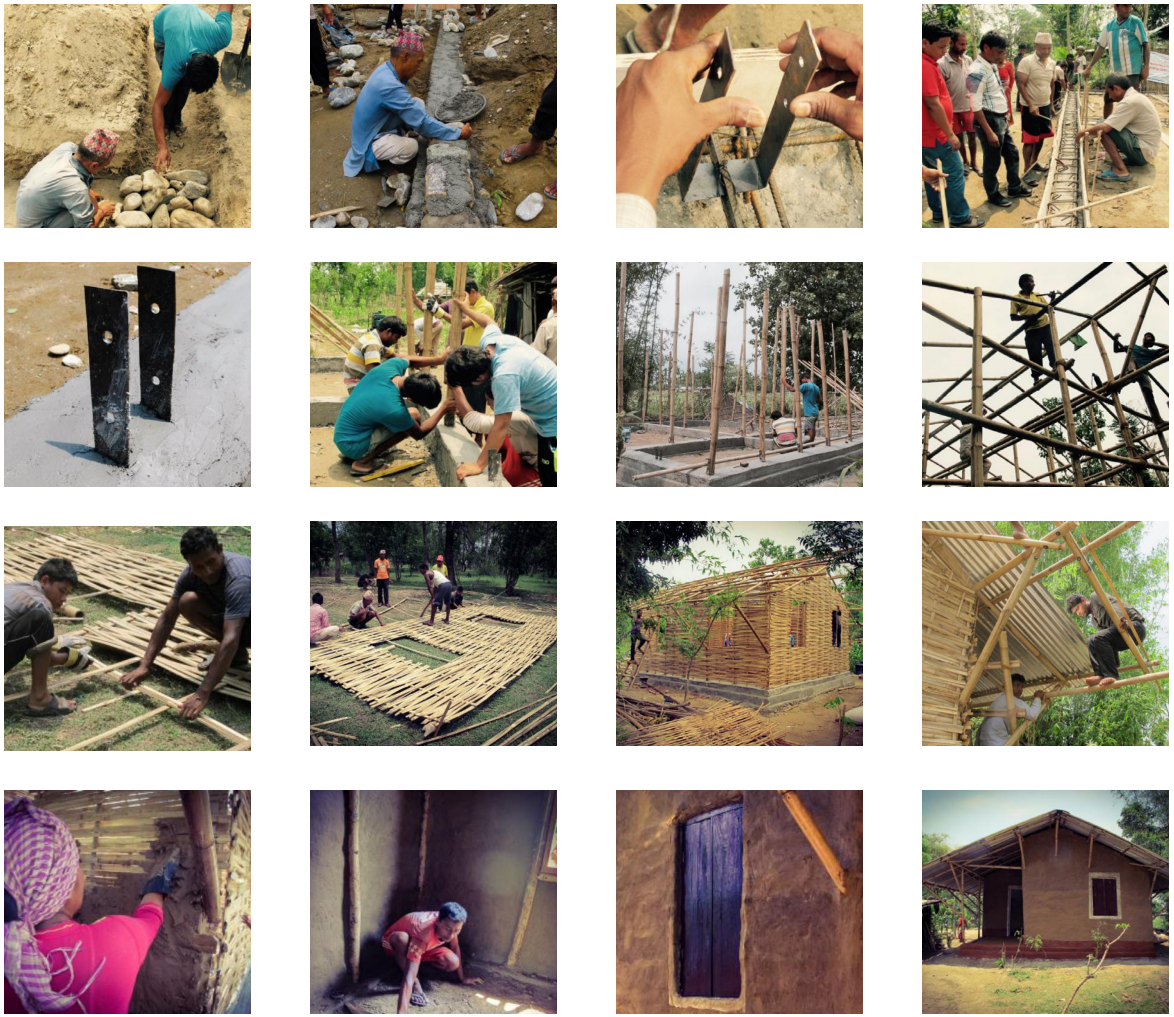
Figure. Traditional Newari House
Source: https://www.bhaktapur.com/a-closer-insight-into-typical-traditional-newari-house/

Figure. Fenestration of a Newar house
Source: http://conference.ioe.edu.np/ioegc10/papers/ioegc-10-054-10074.pdf

Figure. Elevation of a traditional Newari Building with terminologies of the elements at different levels
Source: https://www.researchgate.net/Þgure/Elevation-of-a-traditional-Newari-Building-with-terminologies-of-the-elements-at_fig2_354543758

APPENDIX 3
Reference project - Construction manual of bamboo house

Figure. Construction process of bamboo house in Nepal
Source: https://habitatnepal.org/wp-content/uploads/2019/10/Habitat-for-Humanity-Bamboo-House-Manual-in-English-Web.pdf



APPENDIX 4
Reference project - Traditional pond

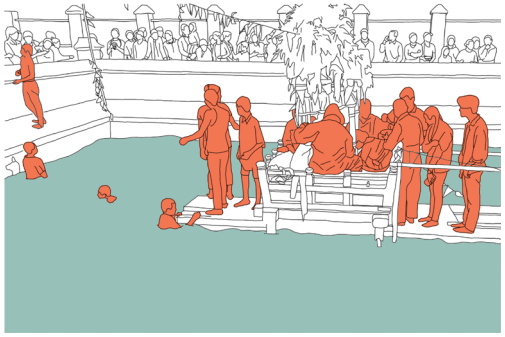
Figure. Ancient pond at Patan Durbar Square premises in Kathmandu, Nepal.
Source: https://www.dreamstime.com/ancient-pond-patan-durbar-square-premises-kathmandu-nepal-unesco-world-heritage-site-ancient-pond-patan-durbar-square-image157719715

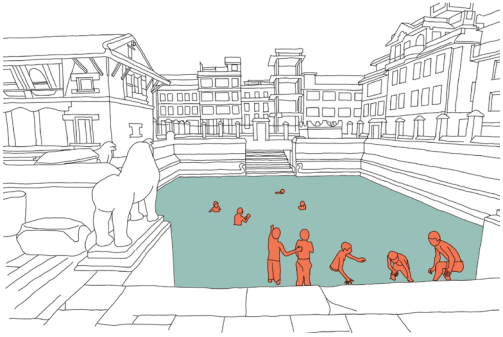
Figure. Pimbahal pond
Source: https://danam.cats.uni-heidelberg.de/heritage-focus-area-pimbahal/

Figure. Kumbeshwar Pokhari, Patan, Nepal, drawn by author
Figure. Kumbeshwar Pokhari, Patan, Nepal, drawn by author









Adhikari, M. (2015). Scampering Spaces: A heterotopic reading of Hanumandhoka Durbar Square. Central Department of English. Retrieved from https://www.academia.edu/87420132/Scampering_Spaces_A_Heterotopic_Reading_of_Hanumandhoka_Durbar_Square

Aitani, K., & Arima, T. (2014). Urban catalyst: Regeneration of downtown area through Community Development. Association of Collegiate Schools of Architecture. Retrieved from https://www.acsa-arch.org/chapter/urban-catalyst-regeneration-of-downtownarea-through-community-development/

Aryal, R., Lee, B. K., Karki, R., & Gurung, A. (2008). Seasonal PM10 dynamics in Kathmandu Valley. ResearchGate. Retrieved from https://www.researchgate.net/publication/229391683_Seasonal_PM10_dynamics_in_Kathmandu_Valley

Associated Press. (2022). Sewage and trash clog Nepal's Holy Bagmati River. NBCNews.com. Retrieved from https://www.nbcnews.com/news/world/nepal-holy-bagmati-river-sewage-trash-environment-kathmandu-rcna43471

Asia News Network. (2022). Why Nepal, rich in water resources, is facing water stress today. The Kathmandu Post. Retrieved from https://kathmandupost.com/national/2022/06/28/why-nepal-rich-in-water-resources-is-facing-water-stress-today

Atton, W., & Logan, D. (1992). American Urban Architecture: Catalysts in the design of Cities. University of California Press.

Bajracharya, R., Tamrakar, N. K., & Shrestha, M. (2018). Status of shallow wells along major rivers of the Kathmandu Valley, Central Nepal. ResearchGate. Retrieved from https://www.researchgate.net/publication/327261909_Status_of_shallow_wells_along_major_rivers_of_the_Kathmandu_Valley_Central_Nepal

Brosius, C., Maharjan, B., Schrom, T., Joshi, S., Michaels, A., & Timalsina, R. (2021). Monument - Satah at Purohitaghāta (1883 CE) || पुरोहतिघाटको सतः || KAT2731. NHDP. Retrieved from https://danam.cats.uni-heidelberg.de/report/ca7dd19e-f7af-11e9-8649-0242ac130002

Brosius, C., Maharjan, B., Schrom, T., Rajbhandari, S., & Khatiwoda, R. (2021). Monument - Jalavināyaka Satah South (1877 CE) || जनवनिायक सत: दक्षणि || CHO4020. NHDP. Retrieved from https://danam.cats.uni-heidelberg.de/report/bb58b263-f53c-45f6-9e1c-d9a3e5a68856

Dangi, M. B., Pretz, C. R., Urynowicz, M. A., Gerow, K. G., & Reddy, J. M. (2011). Municipal solid waste generation in Kathmandu, Nepal. ScienceDirect. Retrieved from https://doi.org/10.1016/j.jenvman.2010.09.005

Fisher, J. F. (1998). In Living Martyrs: Individuals and revolution in Nepal (p. 220). essay, Oxford University Press.

Green Mountain Technologies (2022) Intermodal containerized compost system, Green Mountain Technologies. Available at: https://www.compostingtechnology.com/in-vessel-composting-systems/containerized-compost-systems/intermodal-containerized-compost-system/.

Himalayan News Service. (2020). Flood alert issued inside Kathmandu Valley. The Himalayan Times. Retrieved from https://thehimalayantimes.com/kathmandu/flood-alert-issued-inside-kathmandu-valley

Ishtiaque, A., Shrestha, M., & Chhetri, N. (2017). Rapid urban growth in the Kathmandu Valley, Nepal: Monitoring land use land cover dynamics of a Himalayan city with landsat imageries. MDPI. Retrieved from https://doi.org/10.3390/environments4040072

ICIMOD, MOEST/GON and UNEP. (2007). Kathmandu Valley Environmental Outlook. International Center for Integrated Mountain Development (ICIMOD), Ministry of Environment Science and Technology of Government of Nepal (MOEST/GON) and United Nations Environmental Program (UNEP).

Japan International Cooperation Agency (JICA), & Japan International Cooperation Agency (JICA). (2019). Federal Democratic Republic of Nepal Data Collection Survey on Water Supply and Waste Water Sector in Nepal. openjicareport. Retrieved from https://openjicareport.jica.go.jp/pdf/12326708_01.pdf

REFERENCES

Jana, C. M. (2022). Bagmati River - location, map, origin, mouth, length, depth, basin features, course, and more. RiversGraphy. Retrieved from https://www.riversgraphy.com/bagmati-river/

Jie, C. (2019). Literature Review of Urban Catalyst Theory. 城市建筑, 16.

Kainulainen, S., Khanal, A., Voima, K., & Kivelä, S. (2016). (PDF) quality of life in a Kathmandu slum - researchgate. ResearchGate. Retrieved from https://www.researchgate.net/publication/323358365_Quality_of_life_in_a_Kathmandu_slum

Kathmandu Metropolitan City. (2005). Action Plan on Solid Waste Management. Openjicareport. Retrieved from https://openjicareport.jica.go.jp/pdf/11808672.pdf

Kathmandu Valley Wastewater Management Project. (2022). Nepal: Kathmandu Valley Wastewater Management Project. Asian Development Bank. Retrieved from https://www.adb.org/sites/default/files/project-documents/43524/43524-014-emr-en_9.pdf

Khanal, A. (2023). About Kathmandu: Discover the Rich History, Culture, and Tourism of Nepal's Capital City. nepaldatabase. Retrieved from https://www.nepaldatabase.com/about-kathmandu-discover-the-rich-history-culture-and-tourism-of-nepals-capital-city

Lu, Y., & Chen, B. (2015). A review on urban metabolism: connotation and methodology. Acta Ecologica Sinica, 35(8), 2435–2451.

Manandhar, S. (2014). Evicted once, Nepali squatters living in the ruins of a Razed River settlement fear a recurring nightmare. Global Press Journal. Retrieved from https://globalpressjournal.com/asia/nepal/evicted-once-nepali-squatters-living-in-the-ruins-of-a-razed-river-settlement-fear-a-recurring-nightmare/

Michaels, A., Maharjan, B., Schrom, T., Awal, P., Tamrakar, A., & Timalsina, R. (2021). Monument - Rādhākrsna Mandira (1887 CE) || राधाकृष्ण मन्दरि || KAT2600. NHDP. Retrieved from https://danam.cats.uni-heidelberg.de/report/a0771bce-eb36-11e9-8bc4-0242ac130002

Mishra, T. (2005). 'नेपाली वास्तु र वास्तुग्रन्थको संक्षिप्त परचिय. प्राचीननेपाल, 159. https://himalaya.socanth.cam.ac.uk/collections/journals/ancientnepal/pdf/ancient_nepal_159_02.pdf

Mohan, M. (2022). In focus: From life-giving source to murky brown water, is there hope for Nepal's Bagmati River? CNA. Retrieved from https://www.channelnewsasia.com/asia/nepal-bagmati-river-kathmandu-rubbish-dirty-water-2763851

Nepali Times. (2020). How the Bagmati Civilisation is becoming uncivilised. Nepali Times. Retrieved from https://www.nepalitimes.com/here-now/how-the-bagmati-civilisation-is-becoming-uncivilised

Nyaupane, P. (2019). Cultural heritage tourism management in Pashupatinath area. Nepalese Culture, 13, 95-106.

Office of international religious freedom. (2021). 2020 Report on International Religious Freedom: Nepal. U.S. department of state. Retrieved from https://www.state.gov/reports/2020-report-on-international-religious-freedom/

Ojha, A. (2022). Households segregating waste as requested but KMC Mixing It up again. The Kathmandu Post. Retrieved from https://kathmandupost.com/valley/2022/09/22/households-segregating-waste-as-requested-but-kmc-mixing-it-up-again

OnlineKhabar. (2021). 10 public parks in Kathmandu that take you away from Concrete Jungle. OnlineKhabar English News. Retrieved from https://english.onlinekhabar.com/public-parks-in-kathmandu.html

Pandey, G. G. (2016). Waste management in Kathmandu 1.04 - teku transfer station. ganeshgpks.blogspot. Retrieved from https://ganeshgpks.blogspot.com/2016/08/waste-management-in-kathmandu-104-teku.html

Pandey, V. P., Shrestha, S., & Kazama, F. (2012). Groundwater in the Kathmandu Valley: Development dynamics, consequences and prospects for sustainable management. ResearchGate. Retrieved from https://www.researchgate.net/publication/292026833_Groundwater_in_the_Kathmandu_Valley_Development_dynamics_consequences_and_prospects_for_sustainable_management

Pathak, D. R. (2021). Resolving Kathmandu Valley's solid waste problems. My Republica. Retrieved from https://myrepublica.nagariknetwork.com/news/resolving-kathmandu-valley-s-solid-waste-problems/

Poswal, D., Chaturvedi, M. K. M., Sharma, S., & Asolekar, S. R. (2015). Sewage-fed aquaculture: a sustainable approach for wastewater treatment and reuse. ResearchGate. Retrieved from https://www.researchgate.net/publication/282511814_Sewage-fed_aquaculture_a_sustainable_approach_for_wastewater_treatment_and_reuse

Prasad, T. N., Anushiya, S., Prasad, P. D., & Rachana, U. (2020). Trend of urban growth in Nepal with a focus in Kathmandu Valley: A review of processes and drivers of change. Tomorrow's Cities. Retrieved from https://tomorrowscities.org/sites/default/files/resources/2020-11/Tomorrow%27s%20Cities%20Working%20Paper%20%231.pdf

Pudasaini, S. P. (2019). Bagmati River Civilization And Spiritual Salvation. Spotlight, 12. https://doi.org/584/074-75

Ramtel, P., Tamang, T., Pokhrel, N., Mainali, B., & Paudel, S. R. (2021). Wastewater and bio-gas production in Kathmandu Valley, Nepal ... ResearchGate. Retrieved from https://www.researchgate.net/publication/344250882_Wastewater_and_Bio-gas_Production_in_Kathmandu_Valley_Nepal_Challenges_and_Opportunities

Rana, S. B. (2017). State of Urbanization, Water and Wastewater Facilities in Kathmandu Valley and Other Parts of Nepal. Escape. Retrieved from https://www.unescap.org/sites/default/files/2.%20Sanjeev%20KVWSMB.pdf

Republica. (2022). Over 3,500 squatters of Kathmandu to be moved to Ichangu Narayan. My Republica. Retrieved from https://myrepublica.nagariknetwork.com/news/over-3-500-squatters-of-kathmandu-to-be-moved-in-ichangu-narayan/?categoryId=81

Shah, R. (1990). Ancient and Medieval Nepal. Ratna Pustak Bhandar.

Sharma, N. (2014). Voice from slum. Retrieved from https://unhabitat.org.np/featured_news_detail/voice-from-slum

Sharma, R. (2016). Living amidst filth. D+C - Development + Cooperation. Retrieved from https://www.dandc.eu/en/article/waste-management-has-not-kept-kathmandus-fast-growth

Shigefuji, M., Takai, N., Bijukchhen, S., Ichiyanagi, M., Rajaure, S., Dhital, M. R., Paudel, L. P., & Sasatani, T. (2022). Strong Ground Motion Data of the 2015 gorkha Nepal earthquake sequence in the Kathmandu Valley. Nature News. Retrieved from https://doi.org/10.1038/s41597-022-01634-6

Shrestha, P. (2022). (In)formal Land Delivery Processes: Relational Perspectives on Squatter Settlements in Kathmandu. In: Marinic, G., Meninato, P. (eds) Informality and the City. Springer, Cham. https://doi.org/10.1007/978-3-030-99926-1_29

Suryabinayak Municipality. (2023). Brief introduction: Suryabinayak municipality. Brief Introduction | Suryabinayak Municipality. Retrieved from https://suryabinayakmun.gov.np/en/node/4

Taylor, M. (2021). Living with garbage. The Record. Retrieved from https://www.recordnepal.com/living-with-garbage

REFERENCES

Taylor, M. (2018). The Bagmati is dead-and there's nothing we can do about it. The Kathmandu Post. Retrieved from https://kathmandupost.com/climate-environment/2018/12/01/can-we-bring-the-bagmati-back

Tuladhar, D., Dewan, A., Kuhn, M., & Corner, R. J. (2019). The influence of rainfall and land use/land cover changes on river discharge variability in the mountainous catchment of the Bagmati River. MDPI. Retrieved from https://www.mdpi.com/2073-4441/11/12/2444

UNESCO. (2021). Kathmandu Valley. UNESCO. Retrieved from https://en.unesco.org/node/317587

Wolman, A. (1965). The metabolism of Cities. Scientific American, 213(3), 178–190. https://doi.org/10.1038/scientificamerican0965-178

Worldometer (2023) Nepal population, Worldometer. Available at: https://www.worldometers.info/world-population/nepal-population/.

王欣宜 . (2020). 基于城市触媒理论下的大事件对城市的影响 . 现代园艺 , 07.

徐云曦 . (2012) “触媒式” 旧城改造与更新的实践探索——以四川宜宾中国酒都特色街区南区规划为例 . 重庆 : 重庆大学 .

A. (2022). Bancharedanda Waste Landfill Site [Digital image]. Retrieved from https://himalsanchar.com/garbage-disposal-started-under-police-protection-in-bancharedanda/

Aryal, R. K., Giri, N., Sharma, S., Pathak, B. K., Kandasamy, J., Gurung, A., Karki, R., & Lee, B.-K. (2008). Wind speed and direction in four seasons in Kathmandu Valley [Digital image]. Retrieved from https://doi.org/10.1016/j.atmosenv.2008.08.016.

Bajracharya, R., Tamrakar, N. K., & Shrestha, M. (2018). Soil map of Kathmandu Valley [Digital image]. Retrieved from https://www.researchgate.net/publication/327261909_Status_of_shallow_wells_along_major_rivers_of_the_Kathmandu_Valley_Central_Nepal

Baniya, B., Bhattarai, B., Bhatta, R., Dhital, Y. P., Sharma, S., Baniya, H., Ghimire, S. K., & Khadka, N. (2019). Pollution map of Bagmati River [Digital image]. Retrieved from https://doi.org/10.3126/njes.v7i0.34314.

Basnet, S. (2016). Un Park [Digital image]. nepalitimes. Retrieved from http://archive.nepalitimes.com/article/Nepali-Times-Buzz/wide-open-spaces-Kathmandu,3181.

Budhathoki, B. (2021). Rain water [Digital image]. Retrieved from https://english.onlinekhabar.com/rainwater-harvesting-kathmandu.html

Chase, P. (2022). Jalavināyaka Mandira temple in 1967 [Digital image]. Retrieved from https://danam.cats.uni-heidelberg.de/report/bb58b263-f53c-45f6-9e1c-d9a3e5a68856

Chitrakar, G. M. (2022). Thaphatali Temple Area in1960 [Digital image]. Retrieved from https://www.nepalitimes.com/banner/the-way-we-were

Chitrakar, R., & Shrestha, B. (2020). Bagmati river system [Digital image]. Retrieved from https://www.researchgate.net/publication/344550558_Revisiting_Kathmandu_Valley's_Public_Realm_Some_Insights_into_Understanding_and_Managing_Its_Public_Spaces.

Cleanwaterwave. (n.d.). The polluted Bagmati River in the religious area [Digital image]. Retrieved from https://cleanwaterwave.com/raising-awareness-save-bagmati-river/

Dangi, M. B., Reddy, J. M., Gerow, K. G., Urynowicz, M. A., & Pretz, C. R. (2011). Garbage composition in Kathmandu Valley [Digital image]. Retrieved from https://doi.org/10.1016/j.jenvman.2010.09.005

Davids, J. (2019). Conceptual cross-section of groundwater system in the Kathmandu Valley Basin [Digital image]. Retrieved from https://www.researchgate.net/publication/333172243_Mobilizing_Young_Researchers_Citizen_Scientists_and_Mobile_Technology_to_Close_Water_Data_Gaps_Methods_Development_and_Initial_Results_in_the_Kathmandu_Valley_Nepal

Devkota, A. R. (2009). Kathmandu valley scene [Digital image]. Retrieved from https://en.wikivoyage.org/wiki/File:Kathmandu_valley_scene_Shivapuri_Nagarjun.JPG

Dhungana, R. (2021). Image of Tripureshwor Mahadev Mandir [Digital image]. Retrieved from https://commons.wikimedia.org/wiki/File:Tripureshwor_Mahadev_Tripureshwor_Kathmandu,_Nepal_Rajesh_Dhungana_%288%29.jpg

Durganand. (2022). Swayambhu Buddha Park [Digital image]. Retrieved from https://www.google.com/maps/place/Swayambhu+Buddha+Park/@27.716145,85.2838866,3a,75y,90t/data=!3m8!1e2!3m6!1sAF1QipP5r_aNWFnxUkL0sjYaY7aoqB30JWm5hL7VEO1J!2e10!3e12!6shttps:%2F%2Flh5.googleusercontent.com%2Fp%2FAF1QipP5r_aNWFnxUkL0sjYaY7aoqB30JWm5hL7VEO1J%3Dw203-h270-k-no!7i3000!8i4000!4m11!1m2!2m1!1sAmideva+Buddha+Park!3m7!1s0x39eb189021984781:0xc02431dabe5b419d!8m2!3d27.716145!4d85.2838866!10e5!15sChNBbWlkZXZhIEJ1ZGRoYSBQYXJrgEEcGFya-ABAA!16s%2Fg%2F1thwyvwj.

Ecohub. (n.d.). Polluted Bagmati River [Digital image]. Retrieved from https://www.ecohubmap.com/hot-spot/sewage-and-rubbish-choke-nepal%E2%80%99s-holy-bagmati-river/cr4aml8ein3ov

IMAGE REFERENCES

Environment Audit Report. (2015). Image of bridge of transfer station [Digital image]. Retrieved from https://nepalindata.com/media/resources/bulkuploaded/Enviroment_Audit_2071_eng_may_17.pdf

EPA. (2016). Bala Chaturdashi- 2016 [Digital image]. Retrieved from https://www.straitstimes.com/multimedia/photos/in-pictures-the-bala-chaturdashi-festival-in-nepal

Feary, S. (2019). Perspective view of Bagmati river in 1972 [Digital image]. Retrieved from https://www.facebook.com/oldphotosnepal/photos/a.838382796328065/1204800766352931/

FP Staff. (2022). Polluted Bagmati riverbank [Digital image]. Retrieved from https://www.firstpost.com/photos/sewage-and-trash-choke-nepals-holy-bagmati-river-11069401.html

Google. (n.d.). Images of the existing situation of squatter settlements in intervention area [Digital image]. Retrieved from https://www.google.com/search?q=squatter+settlements+pollution+kathmandu+valley&tbm=isch&ved=2ahUKEwjB5sjzht7-AhWJgv0HHcHuBOoQ2-cCegQIABAA&oq=squatter+settlements+pollution+kathmandu+valley&gs_lcp=CgNpbWcQA1DGBljZE2D3FWgAcAB4AIABP4gBugSSAQIxMZgBAKABAaoBC2d3cy13aXotaW1nwAEB&sclient=img&ei=u-VUZIGdJomF9u8Pwd2T0A4&bih=1027&biw=1897#imgrc=LN8VAXirZPYkgM

Googlemap. (n.d.). Images of different types of riverbanks in the intervention area [Digital image]. Retrieved from https://www.google.com/maps/place/Thapathali+Bagmati+Bridge/@27.692258,85.309098,2170m/data=!3m1!1e3!4m15!1m8!3m7!1s0x39eb19b9f4c8754b:0x5b73ef603bef6a2c!2sRosebud+School!8m2!3d27.6873363!4d85.3251394!10e5!16s%2Fm%2F076fpw8!3m5!1s0x39eb19b3bcdce271:0x9e96fcf9d7b0a5aa!8m2!3d27.6894329!4d85.3169234!16s%2Fg%2F11c2kjdpsq

Green montain technologies. (n.d.). Image of Intermodal Containerized Compost System (IM-CCS) [Digital image]. Retrieved from https://www.compostingtechnology.com/in-vessel-composting-systems/containerized-compost-systems/intermodal-containerized-compost-system/

Gurung, H.B., Khanal, N., Pradhan, P., & Ghimire, P.K. (2008). Distribution of religion in Kathmandu Valley [Digital image]. Retrieved from http:// iskconeducationalservices.org/HoH/practice/504.htm

Gurung, N. B. (2022). Perspective view of Bagmati river in 2022 [Digital image]. Retrieved from https://en.setopati.com/social/158841

Gutschow, N. (2022). Sattal at Purohit Ghat in 1983 [Digital image]. Retrieved from https://danam.cats.uni-heidelberg.de/report/ca7dd19e-f7af-11e9-8649-0242ac130002

Himalayan News Service. (2016). Brick kiln, in Bisahariya, Saptari [Digital image]. Retrieved from https://thehimalayantimes.com/nepal/brick-kilns-told-furnish-registration-tax-clearance-documents

Himalayan News Service. (2017). Tanker water [Digital image]. Retrieved from https://english.onlinekhabar.com/rainwater-harvesting-kathmandu.html

Images of the Century. (2012). Gathering-1926 [Digital image]. Retrieved from https://www.facebook.com/photo/?fbid=374858702553372&set=a.155001071205804

Images of the Century. (2013). Wedding Ceremony-1948 [Digital image]. Retrieved from https://www.facebook.com/photo/?fbid=497355063637068&set=a.155001071205804

K. (2014). Image of Kalmochan Mahadev Temple [Digital image]. Retrieved from https://commons.wikimedia.org/wiki/File:Kalmochanghat.jpg

Kandel, Y. K. (2016). Volunteers collect garbage in the Bagmati River [Digital image]. Retrieved from https://globalpressjournal.com/asia/nepal/cleanup-kathmandus-bagmati-river-makes-strides-help-volunteers/ers/

Karki, S. (2021). Muddy road to the landfill in monsoon [Digital image]. Retrieved from https://english.khabarhub.com/2021/01/206343/

Kayastha, R. R. (2021). Teku Temple Area in 2021 [Digital image]. Retrieved from https://www.google.com/maps/place/Teku+Dobhan/@27.6917985,85.3023476,3a,75y,90t/data=!3m8!1e2!3m6!1sAF1QipNzPEANbz4BzI4OlLI0w6oMivSeaEZ6DX67GT0-!2e10!3e12!6shttps:%2F%2Flh5.googleusercontent.com%2Fp%2FAF1QipNzPEANbz4BzI4OlLI0w6oMivSeaEZ6DX67GT0-%3Dw203-h152-k-no!7i4000!8i3000!4m16!1m8!3m7!1s0x39eb19b9f4c8754b:0x5b73ef603bef6a2c!2sRosebud+School!8m2!3d27.6873363!4d85.3251394!10e5!16s%2Fm%2F076fpw8!3m6!1s0x39eb19f0204b915d:0x78865ea391f61812!8m2!3d27.6917985!4d85.3023476!10e5!16s%2Fg%2F11h7c_5065

Khabar, M. (2021). Bagmati river during the monsoon season [Digital image]. Retrieved from https://english.makalukhabar.com/2021/09/22022/

Khattri, P. (2017). Sattal at Purohit Ghat in 2017 [Digital image]. Retrieved from https://www.google.com/maps/@27.6935631,85.3091909,3a,75y,14.92h,90t/data=!3m8!1e1!3m6!1sAF1QipPPpkCZg1S0oeKZr7WzQDPK5fDSMeZX67WKrpZE!2e10!3e11!6shttps:%2F%2Flh5.googleusercontent.com%2Fp%2FAF1QipPPpkCZg1S0oeKZr7WzQDPK5fDSMeZX67WKrpZE%3Dw203-h100-k-no-pi-0-ya299.2786-ro-0-fo100!7i8704!8i4352

Lamichhane, S., & Shakya, N. M. (2019). Kathmandu Valley in country scale [Digital image]. Retrieved from https://www.mdpi.com/2073-4441/11/10/2059

Letson, P. (1971). Grain drying and clothes washing-1971 [Digital image]. Retrieved from https://roundsimaging.com/galleries/nepal-peace-corp-photos/individual-contributors/perry-letson/PCL106-single.php

Me, I. A. (2018). Image of biomethanation plant [Digital image]. Retrieved from https://www.google.com/maps/place/Bishnumati+Kuleshwor+Bridge/@27.692387,85.3010709,3a,75y,90t/data=!3m8!1e2!3m6!1sAF1QipM7rUNmDoTRHuU9NW2cE-WfX_cKGWYjz1GBGufU!2e10!3e12!6shttps:%2F%2Flh5.googleusercontent.com%2Fp%2FAF1QipM7rUNmDoTRHuU9NW2cE-WfX_cKGWYjz1GBGufU%3Dw203-h114-k-no!7i4160!8i2340!4m10!1m2!2m1!1sbagmati+river!3m6!1s0x39eb18452f44e699:0xb76c3f6085fc673f!8m2!3d27.692387!4d85.3010709!10e5!16s%2Fg%2F11b6grr6d4

Methodology Centre for Environment Assessment. (2018). Private well [Digital image]. Retrieved from https://www.metcenas.cz/en/kathmandu

NHDP (2022). Heritage map of Kathmandu Valley [Digital image]. Retrieved from https://danam.cats.uni-heidelberg.de/search?paging-filter=1&tiles=true

Ojha, A. (2022). Image of transfer station during monsoon [Digital image]. Retrieved from https://nepalindata.com/ne/City-covers-waste-pile-in-plastic-after-rains-damage-road-to-Banchare-Danda/

Ojha, A., & Dhimal, M. (2017). Suryabinayak Forest [Digital image]. Retrieved from https://wondervibes.blogspot.com/2017/06/hike-to-lakuribhanjyang.html

Onlinekhabar. (2017). Image of biomethanation plant [Digital image]. Retrieved from https://english.onlinekhabar.com/kathmandu-will-produce-14-kw-power-from-waste-everyday.html

Onlinekhabar. (2022). Trucks carrying waste from Kathmandu to the Bancharedanda landfill site [Digital image]. Retrieved from https://english.onlinekhabar.com/locals-bar-bancharedanda-landfill.html

Pandey, G. G. (2016). Image of transfer station in dry season [Digital image]. Retrieved from https://ganeshgpks.blogspot.com/2016/08/waste-management-in-kathmandu-104-teku.html

IMAGE REFERENCES

Panday, P. (2020). Image of bridge of transfer station [Digital image]. Retrieved from https://www.google.com/maps/place/Bishnumatil+Kuleshwor+Bridge/@27.692387,85.3010709,3a,75y,90t/data=!3m8!1e2!3m6!1sAF1QipOi2EEeM4Fl1R6AbNPeiYnqT6wFhpp4yNXA4Ryz!2e10!3e12!6shttps:%2F%2Flh5.googleusercontent.com%2Fp%2FAF1QipOi2EEeM4Fl1R6AbNPeiYnqT6wFhpp4yNXA4Ryz%3Dw203-h114-k-no!7i4128!8i2322!4m10!1m2!2m1!1sbagmati+river!3m6!1s0x39eb18452f44e699:0xb76c3f6085fc673f!8m2!3d27.692387!4d85.3010709!10e5!16s%2Fg%2F11b6grr6d4

Pandey, P. V., Kazama, F., & Shrestha, S. (2012). Groundwater level changes over the years [Digital image]. Retrieved from https://www.ewra.net/ew/pdf/EW_2012_37_01.pdf

Parker, D. (1993). Carpet Factory in 1993, Kathmandu, Nepal [Digital image]. Retrieved from https://collections.artsmia.org/art/32192/carpet-factory-david-parker

Poudel, P. (2021). River bank of Thapathali in rainy season in 2021 [Digital image]. Retrieved from https://www.google.com/maps/place/Thapathali+Bagmati+Bridge/@27.6894329,85.3169234,3a,75y,90t/data=!3m8!1e2!3m6!1sAF1QipNNe18J1cWP7MQsxqiEd90zEHkHZnCWaZXRMojg!2e10!3e12!6shttps:%2F%2Flh5.googleusercontent.com%2Fp%2FAF1QipNNe18J1cWP7MQsxqiEd90zEHkHZnCWaZXRMojg%3Dw205-h100-k-no!7i4032!8i1960!4m17!1m7!3m6!1s0x39eb19b9f4c8754b:0x5b73ef603bef6a2c!2sRosebud+School!8m2!3d27.6873363!4d85.3251394!16s%2Fm%2F076fpw8!3m8!1s0x39eb19b3bcdce271:0x9e96fcf9d7b0a5aa!8m2!3d27.6894329!4d85.3169234!10e5!14m1!1BCgwKCC9tLzA2Y25wMAE!16s%2Fg%2F11c2kjdpsq

Pruscha, C. (2015). Radhakrishna Temple in 1974 [Digital image]. Retrieved from https://primo.getty.edu/primo-explore/fulldisplay/GETTY_ALMA21182169840001551/GRI

Rana, B. N. (2013). Devotees take bath-1960s [Digital image]. Retrieved from https://www.facebook.com/photo/?fbid=460722777300297&set=a.154993321206579

Rana, S. B. (2017). WWTP map of Kathmandu Valley [Digital image]. Retrieved from https://www.unescap.org/sites/default/files/2.%20Sanjeev%20KVWSMB.pdf

Regmi, A. (2013). Thapathali (Patan) from Thapathali bridge in 1918 [Digital image]. Retrieved from https://www.facebook.com/oldnepal/photos/a.155001071205804/519778578061383/?type=3

Reinhard, J. (1968). Cowherding-1968 [Digital image]. Retrieved from https://www.archivenepal.org/search?current=n_10_n&q=Bagmati%20river&size=n_20_n

Sanvaadadaata, L. (n.d.). Sisdol Waste Landfill Site [Digital image]. Retrieved from https://www.lokpath.com/story/211414

Sasimoto. (2019). Stone spoute [Digital image]. Retrieved from https://kathmandupost.com/lalitpur/2019/08/17/kathmandu-valley-s-stone-spouts-were-once-gushing-with-water-now-they-re-slowly-disappearing?fbclid=IwAR0i-cbsGXF_Y_oD3HncY1bkAujhjXbBthoj93SPsXCeN-jLpjAy27JfKAs

Sh, F. (2017). Image of transfer station in dry season [Digital image]. Retrieved from https://www.google.com/maps/place/Environment+Management+Department,+Transfer+Station,+Teku/@27.6931721,85.3016926,3a,75y,90t/data=!3m8!1e2!3m6!1sAF1QipM0kd_3Jgyv2M8MGbGfSvYvYzK3r0cKB1TpWtA-!2e10!3e12!6shttps:%2F%2Flh5.googleusercontent.com%2Fp%2FAF1QipM0kd_3Jgyv2M8MGbGfSvYvYzK3r0cKB1TpWtA-%3Dw203-h114-k-no!7i3264!8i1836!4m10!1m2!2m1!1sbagmati+river!3m6!1s0x39eb185acdbb9abb:0x1ce74ca9ba013358!8m2!3d27.6933211!4d85.3014457!10e5!16s%2Fg%2F11dybd5mzt

Sharma, H. P. (2016). Scenes of life along the Bagmati River in the past [Digital image]. Retrieved from https://m.facebook.com/artisthariprasadsharma/photos/bagmati-this-painting-of-bagmati-river-based-on-the-artists-childhood-memories-d/1676021335996850/

Sharma, S., & Bremer, M. H. (2009). Average monthly Discharge of Bagmati River at Chovar [Digital image]. Retrieved from https://www.researchgate.net/figure/Average-monthly-Discharge-of-Bagmati-River-at-Chovar-Source-Environment-Impact_fig2_266160578

Shrestha, D. (2021). Image of transfer station in dry season [Digital image]. Retrieved from https://www.recordnepal.com/living-with-garbage

Shrestha, M., & Chhetri, N. (2017). City expansion map of Kathmandu Valley [Digital image]. Retrieved from https://www.mdpi.com/2076-3298/4/4/72

Shrestha, P. (2022). Distribution of squatter settlements in Kathmandu Valley [Digital image]. Retrieved from https://link.springer.com/chapter/10.1007/978-3-030-99926-1_29

Shrestha, S. (2021). Bagmati River during the dry season [Digital image]. Retrieved from https://www.google.com/maps/@27.6931519,85.3080973,3a,75y,286.73h,81.74t/data=!3m8!1e1!3m6!1sAF1QipNFYR203tT3X9tz-lJQ6HD4oBvFTiYjlfQBbCYQ!2e10!3e11!6shttps:%2F%2Flh5.googleusercontent.com%2Fp%2FAF1QipNFYR203tT3X9tz-lJQ6HD4oBvFTiYjlfQBbCYQ%3Dw203-h100-k-no-pi-0-ya90.41879-ro-0-fo100!7i10240!8i5120?hl=zh-CN

Shukla, A., Jha, B. C., & Timilsina, U. R. (n.d.). Wastewater Production the Municipal Areas of Kathmandu Valley in 2007 [Digital image]. Retrieved from https://www.ais.unwater.org/ais/pluginfile.php/232/mod_page/content/134/Nepal_CountryPaper.pdf

Storymaps. (1920). Sankhamul Ghat in 1920 [Digital image]. Retrieved from https://storymaps.arcgis.com/stories/22fc532ba6024dd783d7d63641787b5d

Subedi, U. (2022). Thapathali (Patan) from Thapathali bridge in 2023 [Digital image]. Retrieved from https://www.google.com/maps/place/Thapathali+Bagmati+Bridge/@27.6894329,85.3169234,3a,75y,90t/data=!3m8!1e2!3m6!1sAF1QipPkDNt7V9BChZBxTXFOBnJfa98HMAFHrYO7P5Pv!2e10!3e12!6shttps:%2F%2Flh5.googleusercontent.com%2Fp%2FAF1QipPkDNt7V9BChZBxTXFOBnJfa98HMAFHrYO7P5Pv%3Dw152-h86-k-no!7i4032!8i2268!4m16!1m8!3m7!1s0x39eb198a307baabf:0xb5137c1bf18db1ea!2z5bC85rOK5bCU5Yqg5b635ruh6YO96YKu5pS_57yW56CBOiA0NDYwMA!3b1!8m2!3d27.7172453!4d85.3239605!16zL20vMDRjeDU!3m6!1s0x39eb19b3bcdce271:0x9e96fcf9d7b0a5aa!8m2!3d27.6894329!4d85.3169234!10e5!16s%2Fg%2F11c2kjdpsq?hl=zh-CN

The Kathmandu post. (2017). People throwing garbage into the Bagmati River [Digital image]. Retrieved from https://kathmandupost.com/valley/2017/01/07/five-litterbugs-dumping-trash-in-bagmati-booked-rs-20000-fined

The Kathmandu post. (2022). Garbage on narrow city road [Digital image]. Retrieved from https://kathmandupost.com/editorial/2022/05/17/a-city-that-stinks

Trapp, H. (2020). Teku Temple Area in 1993 [Digital image]. Retrieved from https://www.google.com/maps/place/Radha+Krishna+Temple/@27.6922636,85.302249,3a,78.8y,90t/data=!3m8!1e2!3m6!1sAF1QipMSbTlkExWZ75qn-yZfOynetSs8YuWmm0qp6V1e!2e10!3e12!6shttps:%2F%2Flh5.googleusercontent.com%2Fp%2FAF1QipMSbTlkExWZ75qn-yZfOynetSs8YuWmm0qp6V1e%3Dw203-h143-k-no!7i1476!8i1044!4m16!1m8!3m7!1s0x39eb19b9f4c8754b:0x5b73ef603bef6a2c!2sRosebud+School!8m2!3d27.6873363!4d85.3251394!10e5!16s%2Fm%2F076fpw8!3m6!1s0x39eb19c88c59054f:0x65b909d03cece8cc!8m2!3d27.692209!4d85.3023075!10e5!16s%2Fg%2F11fl984kvv

IMAGE REFERENCES

Voice, A. (2022). Image of view from Thapathali Bagmati Bridge [Digital image]. Retrieved from https://www.google.com/maps/place/Bridge+(Bagamati)/@27.6893996,85.3168461,3a,75y,90t/data=!3m8!1e2!3m6!1sAF1QipNaTK6SpwCy8xYd9dGaGCkC4c8VUkRUApcm616j!2e10!3e12!6shttps:%2F%2Flh5.googleusercontent.com%2Fp%2FAF1QipNaTK6SpwCy8xYd9dGaGCkC4c8VUkRUApcm616j%3Dw217-h100-k-no!7i3264!8i1504!4m16!1m8!3m7!1s0x39eb1b9bb3d4ce59:0x496bc7559b3a3af6!2zR29rYXJuZXNod29yLCDlsLzms4rlsJQ!3b1!8m2!3d27.7668123!4d85.4066!16s%2Fg%2F11bwdvh45r!3m6!1s0x39eb19b3a32aee97:0x7ddfcd3ed172149b!8m2!3d27.6894982!4d85.3167578!10e5!16s%2Fg%2F11c1rfjg1t

Voice, A. (2022). Thaphatali Temple Area in 2022 [Digital image]. Retrieved from https://www.google.com/maps/place/Bridge+(Bagamati)/@27.6893996,85.3168461,3a,75y,90t/data=!3m8!1e2!3m6!1sAF1QipOko46UAEhY7fi4pru7jpRhfexFGIyerjJuoaGY!2e10!3e12!6shttps:%2F%2Flh5.googleusercontent.com%2Fp%2FAF1QipOko46UAEhY7fi4pru7jpRhfexFGIyerjJuoaGY%3Dw216-h100-k-no!7i4000!8i1844!4m16!1m8!3m7!1s0x39eb19b9f4c8754b:0x5b73ef603bef6a2c!2sRosebud+School!8m2!3d27.6873363!4d85.3251394!10e5!16s%2Fm%2F076fpw8!3m6!1s0x39eb19b3a32aee97:0x7ddfcd3ed172149b!8m2!3d27.6894982!4d85.3167578!10e5!16s%2Fg%2F11c1rfjg1t

Weather-and-climate. (2023). Annual precipitation in Kathmandu, Nepal [Digital image]. Retrieved from https://weather-and-climate.com/average-monthly-precipitation-Rainfall,kathmandu,Nepal.

Wei, L. Y. (2016). Sankhamul Ghat in 2016 [Digital image]. Retrieved from https://www.thinglink.com/scene/749168059998011394

Whymap. (n.d.). Interaction of groundwater and surface water [Digital image]. Retrieved from https://www.whymap.org/whymap/EN/Maps_Data/Rgwb/rgwb_node_en.html