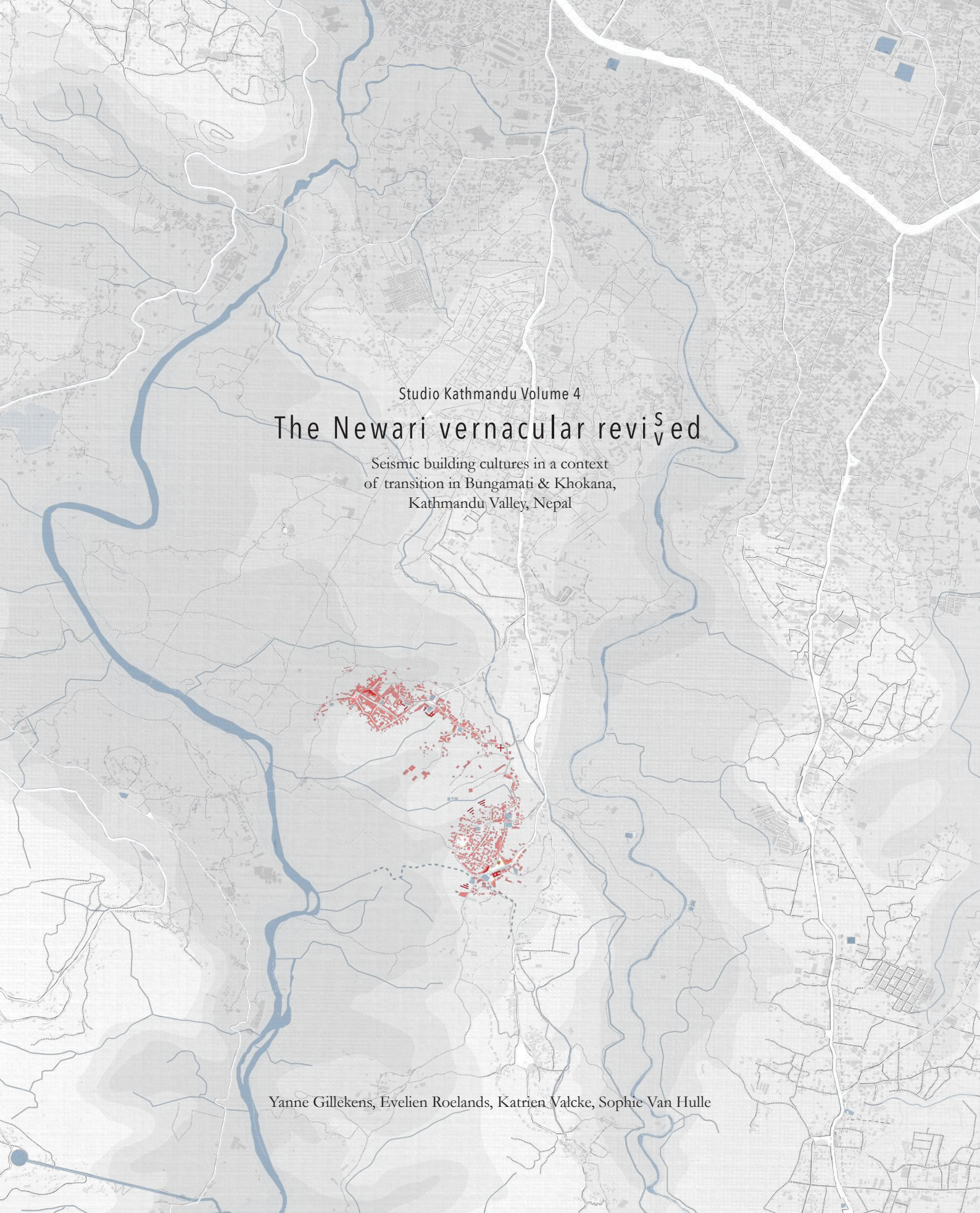




Studio Kathmandu Volume 4

The Newari vernacular revisited

Seismic building cultures in a context
of transition in Bungamati & Khokana,
Kathmandu Valley, Nepal

Yanne Gillekens, Evelyn Roelands, Katrien Valcke, Sophie Van Hulle

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Thesis submitted to obtain
the degree of Master of
Engineering: Architecture

Promotors:

Bruno De Meulder
Viviana d'Auria

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Academic Year 2016-2017

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Master's Thesis file

Students: Yanne Gillekens
Evelien Roelands
Katrien Valcke
Sophie Van Hulle

Title: **The Newari vernacular revisited**
Seismic building cultures in a context of transition in
Bungamati & Khokana, Kathmandu Valley, Nepal

Abstract:

Two years after a 7.8 magnitude earthquake struck Nepal, a major reconstruction task still lies ahead of the country. Urban sprawl and temporary shelters threaten the vernacular seismic building culture of the Newars. The question rises how the reconstruction process will take these contemporary challenges into account, while preserving the values of the Newari vernacular architecture. In 2015 and 2016 respectively, two teams from KU Leuven researched two traditional settlements, Bungamati and Khokana, in the Kathmandu Valley and published three books as a result. This thesis is the continuation of the series and aims to revive the Newari traditions, and simultaneously to revise them, in order to meet the contemporary needs of the Twin Villages.

Promoters: Bruno De Meulder (KU Leuven)
Viviana d'Auria (KU Leuven)

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Annelies De Nijs, Stefanie Dens & Guido Geenen

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Our genuine gratitude goes to all the people of Bungamati and Khokana, for their hospitality, kindness and help, despite the language barriers we were facing. For offering us food and water during hot days, for allowing us to enter and measure their private homes and for participating in our interviews. We want to thank Gopal and his family, for making our house into a real home, for all the efforts to make our stay more comfortable and for making us feel welcome and safe.

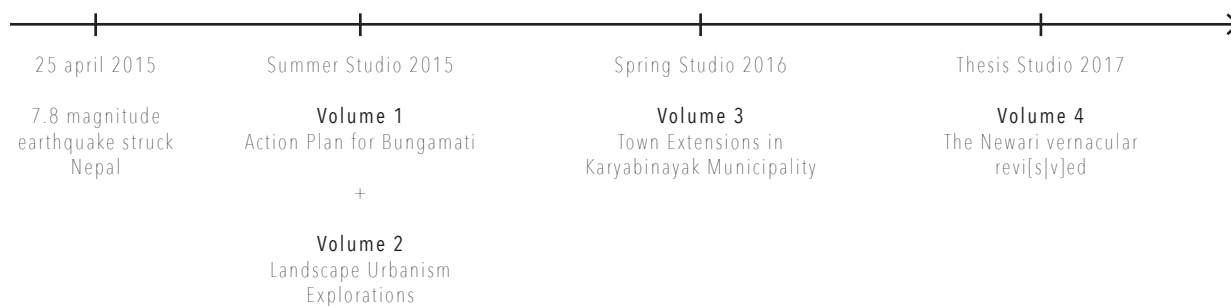
A very warm thank you to Anil Tuladhar and Anatta Shresthacharya, for answering every question we had, for helping us cross this language barrier and most importantly for being our first friends in Nepal. Thank you for always being there for us. We would also like to thank Pink-key and Sudip, two students of the Tribhuvan University, for helping us conduct various interviews with the inhabitants.

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Preface

In 2015, a research team from KU Leuven went to Kathmandu, Nepal in the aftermath of the earthquake on 25 April. In close cooperation with UN Habitat and the Tribhuvan University, they researched two traditional settlements in the southern fringe of the Kathmandu Valley. This resulted in a first book, in the form of an action plan for Bungamati. A second book followed and explored Landscape Urbanism in this area. In 2016, a new team went to the Valley to continue this research. A third book about Town Extensions was published.

This thesis is the continuation of the research and forms the fourth book in the series. This time the focus is more on the traditional Newari architecture of both Bungamati and Khokana.





Collapsed house in Bungamati, 2016



Women cleaning rubble from building that broke down in Khokana, 2016



Excavating the treasures underneath the Mashhindranath temple, Bungamati, 2016



*Courtyard filled with construction materials
from collapsed buildings, Khokana, 2016*



*New construction of peti in front of the
Rudrayanee temple, Khokana, 2016*



*Entrance building of the main square in
Bungamati, 2016*

Hypothesis

On 25 April 2015, an earthquake with a 7.8 magnitude on the Richter scale struck Nepal, followed by several aftershocks. Countless houses have collapsed entirely and many more were severely damaged. Two years later, an enormous reconstruction task still lies ahead of the country. At the same time, the Kathmandu Valley is developing rapidly and urban sprawl is emerging, threatening the Newari vernacular architecture. These Newari settlements have a unique seismic building culture that developed over centuries, focusing on public spaces with life centred around a traditional water system. However, much of the knowledge has faded. The temporary shelters, that were built as an emergency relief, are still scattered in between and at the edges of the existing tissue, further increasing the pressure on the vernacular settlements. The question now rises: how can the reconstruction process take these challenges of urban pressure into account, while preserving the values of the Newari vernacular architecture? The reconstruction after the earthquake offers an opportunity to reinterpret the tradition while meeting the contemporary needs of the settlements.



Methodology

This thesis is a research by design. The book is divided in two main parts, that are intertwined: the analysis and the design. The analysis builds further on the work of the previous teams and is based on a literature study and a field study. The design is an investigation on how two traditional settlements in Nepal can be reconstructed after the earthquake of 2015 and its many aftershocks.

On 17 August 2016, an intensive eight-week field study commenced in the Kathmandu Valley. While the mapping of the settlements and measuring of the houses was divided between Khokana and Bungamati, the interviews were usually done as one team. Existing maps were used as a base to make more detailed versions. The everyday life of the inhabitants, public spaces, traditions, vegetation, local building techniques and much more were all included in the study by making photos and observations. The existing maps were completed and entirely new maps were created.

Furthermore, the fieldwork consisted of several interviews. With the help of local translators, the inhabitants of both settlements were able to tell their story. At the same time, interviews with experts took place as well. Several professors of the Tribhuvan University of Nepal, Red Cross, UN-Habitat, the municipality and local NGOs all contributed to the information that was needed for the analysis. Additionally, local architecture students shared their personal view on the reconstruction process.

The field study finally ended on 14 October 2016. A thorough literature study built further on these experiences to further expand the analysis. Ultimately, the analysis ended in a design proposal. Since it is a research by design, the analysis and design have strongly influenced one another. While the design brought along new questions that required a deeper look into the analysis, it is at the same time a conclusion and answer to the problems and discussions raised by the analysis.

Content

Master's Thesis file	9
Acknowledgements	11
Preface	13
Hypothesis	17
Methodology	19

PART ONE TRADITIONAL NEWARI SETTLEMENTS AT THE VERGE OF RAPID CHANGE

I.	Framing the Kathmandu Valley	25
	The Kathmandu Valley	
	The Newars	
	Bungamati & Khokana	
II.	Topographical foundations & landscape logics	43
	Concentric patterns in the landscape	
	Hazards determining the use of land	
	The topography of Bungamati & Khokana	
III.	Water management in development	53
	Traditional water system	
	Wastewater management	
	Cultural heritage	
	Modern water supply	
IV.	Specificities of the urban tissue	69
	The founding legends	
	The Newari social structure & its spatial reflection	
	A hybridified caste system	
	The guthi system	
	The maze of open spaces	
V.	The Newari seismic building culture challenged	121
	Traditional Newari building culture & appropriations	
	Modern building culture	
	Earthquake response	
VI.	Conclusion	232

PART TWO DESIGN STRATEGIES FOR A REINTERPRETED
SEISMIC BUILDING CULTURE

I.	Strategy for the Twin Villages	239
	Recycle bank	
II.	Bungamati: rethinking water cycle	251
	Introduction	
	Wastewater treatment	
	Maximizing water collection	
	Public space shaped by water	
III.	Khokana: extending the streetscape	341
	The street as connecting factor	
	Site 1 Reconstruction & housing	
	Site 2 Reconstruction & restaurant	
	Site 3 Densification & carpenter's atelier	
	Site 4 Expansion & guesthouse	
	 Newari vocabulary	 436
	Bibliography	438
	Interviews	444
	Image credits	445



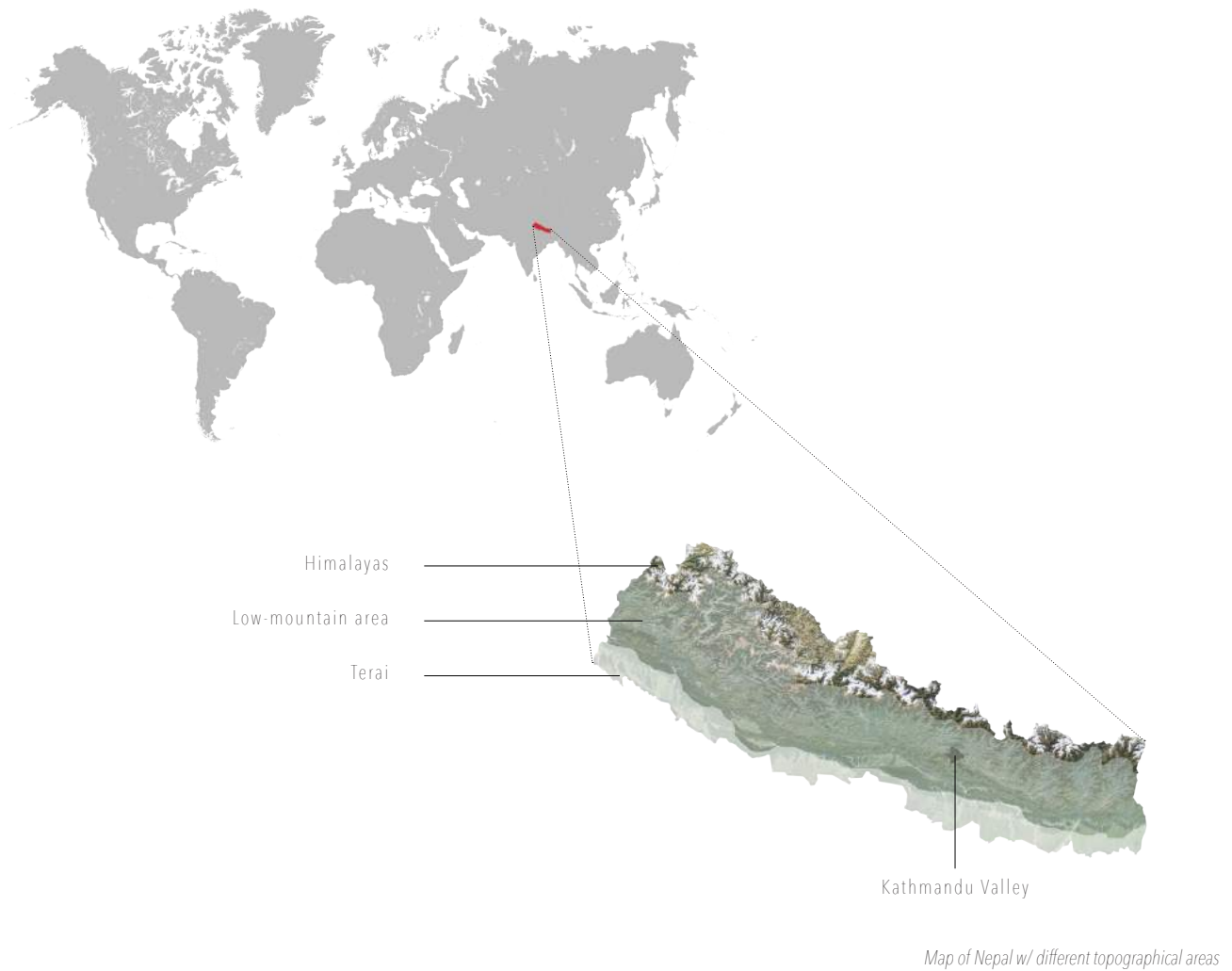


I.

Framing the Kathmandu Valley

The Kathmandu Valley is situated in Nepal, South-East Asia. Its first inhabitants, called the Newars, know a turbulent history of earthquakes and civil wars. Bungamati and Khokana, two vernacular settlements, are located in the Kathmandu Valley.

View over the Kathmandu Valley from the Swayambhunath Stupa.



The Kathmandu Valley

Nepal borders on China and the Tibetan plateau in the north and on India in the south. It can be divided into three geographical areas: the plains of the Terai in the south, the High-Mountain area of the Himalayas in the north (sometimes referred to as Khumbu-Himal) and the hills or Low-Mountain area in between (Ives & Messerli, 1981).

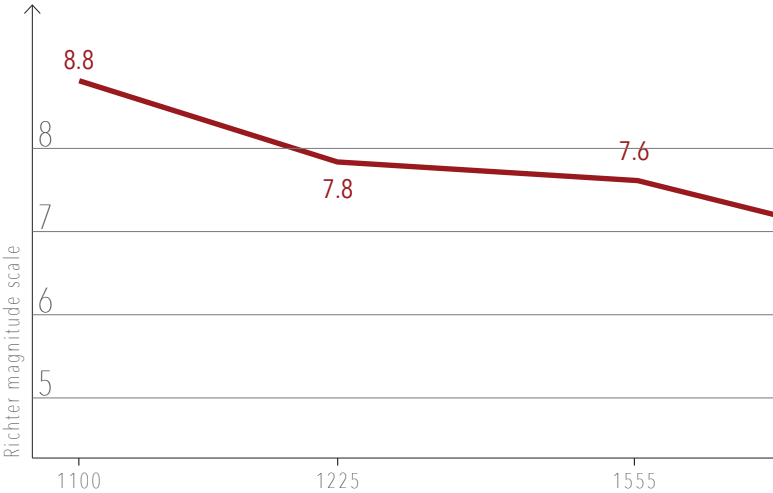
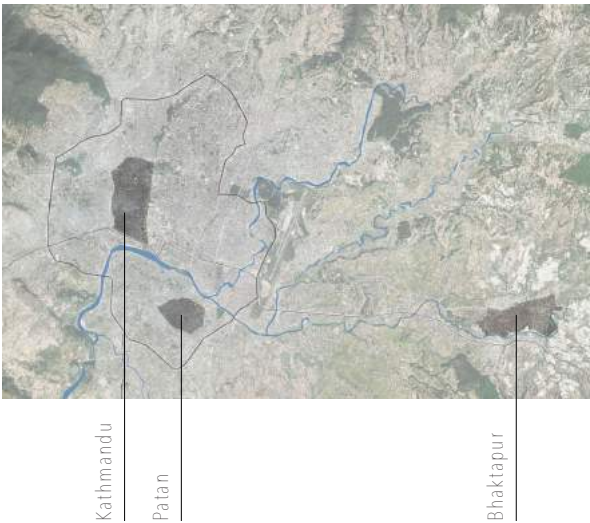
The Kathmandu Valley is situated in the latter and has the highest population density of Nepal. Several rivers flow through the Valley and all of them flow out to the Bagmati river, which ultimately ends in the Ganges.



Map of the Kathmandu Valley,
© Esri, 2017



The three Kingdoms



566 B.C.

Kirata

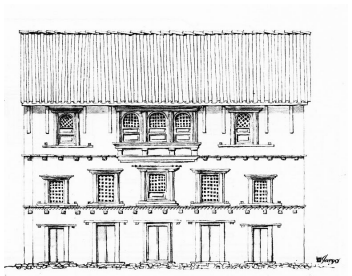
The birth of Buddha in Lumbini, South-Nepal (Rose et al., 2002).

300

Licchavi

The Licchavi was a Hindu-Indian dynasty which gained political control over the first settlements in the Kathmandu Valley around the fourth century, but never extended their rule over the hill areas (Rose et al., 2002). In this era Nepal was divided in small ethnic groups, with the Newars as most important community.

The origins of the Newari architecture can probably be found in the architecture of their neighbours (Sengupta & Upadhyaya, 2016). It was the Gupta architecture of India which influenced the houses from the Licchavi dynasty. Houses from this period were built of stone and already showed some decorations.



Typical Newari house.
Source: Shilpakar S., 2015

1200

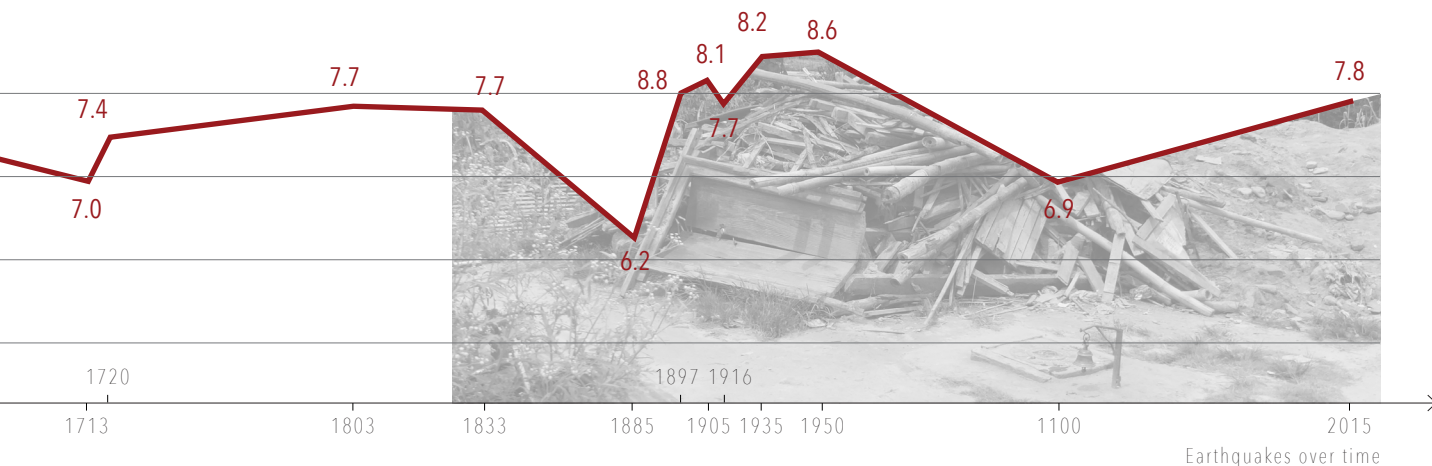
Malla

High-caste Hindu families, fleeing from a Muslim invasion in India, settled in the western hill area of Nepal (Rose et al., 2002). This new elite gradually took over political control in the small hill principalities. The Kathmandu Valley was divided into three independent kingdoms – Kantipur (Kathmandu), Lalitpur (Patan) and Bhadgaon (Bhaktapur) - during this period (Sharma P., 1989). Jayasthiti Malla, one of the most popular kings in the Malla period, introduced the caste system.

The Newari architecture reached its peak during this dynasty (Ranjitkar, 2006). Most noticeable is the symmetrical facade of the houses and its beautiful woodcarvings. Whenever possible, an uneven number of windows was built per storey.

It was during the Malla reign that the rules about urban planning in relation to caste were implemented (Sengupta & Upadhyaya, 2016). The houses of lower castes were thus restricted to the fringes of the settlements, which also immediately decreased their value. Often they were also less decorated.

The rivalry between the three kingdoms definitely stimulated the Newari architecture. Palaces and temples were regarded as the highest in status and were thus ideal to communicate power and enforce status. The art and design of the rest of the cities automatically followed.



Graphic timeline, Source:Thakur, 2006

1769

Shah

Prithvi Narayan Shah unified the different principalities and founded the kingdom of Nepal (Thapa et al., 2008). From then on Kathmandu, capital of the newly founded kingdom, was the seat of political, economic and social power. During this period the Rana dynasty took over the authority for one century, but in the end their regime was overthrown by the Shah rule again (Shrestha B.K., 2011; Rose et al., 2002). Eventually a constitutional monarchy, with a democratically chosen parliament, was established by king Birendra, but the Maoists did not agree with this new political structure and caused the Nepalese civil war (Rose et al., 2002).

Houses from the Shah period mainly have the same characteristics as the Malla period (Ranjitkar, 2006). However, these buildings were generally larger than their ancestors. The typical triple window remained, but it was less decorated. During the later years of this period, the Shah houses also gained inspiration from India, this time probably from the Mughal architecture. They introduced them to the idea of plastered facades, which were now seen for the first time.

Rana

The Ranas, an elite family, increased their influence in the government and eventually took over the power from the Shahs in the second half of the 19th century (Rose et al., 2002). The regime had close ties with the British imperial government in India and many Nepalese men were recruited as Gurkha units into the British Indian Army. However, after WWII, their authority decreased and a few years later the Ranas were overthrown.

With the relations with the British, colonial influences came to Nepal (Sengupta & Upadhyaya, 2016). The Newari houses got lighter and larger windows with less details (Ranjitkar, 2006). Very often these houses had neoclassical or even baroque influences, with columns and plastered facades (Sengupta & Upadhyaya, 2016).



Gaddi Baithak. © Sommer, 2015

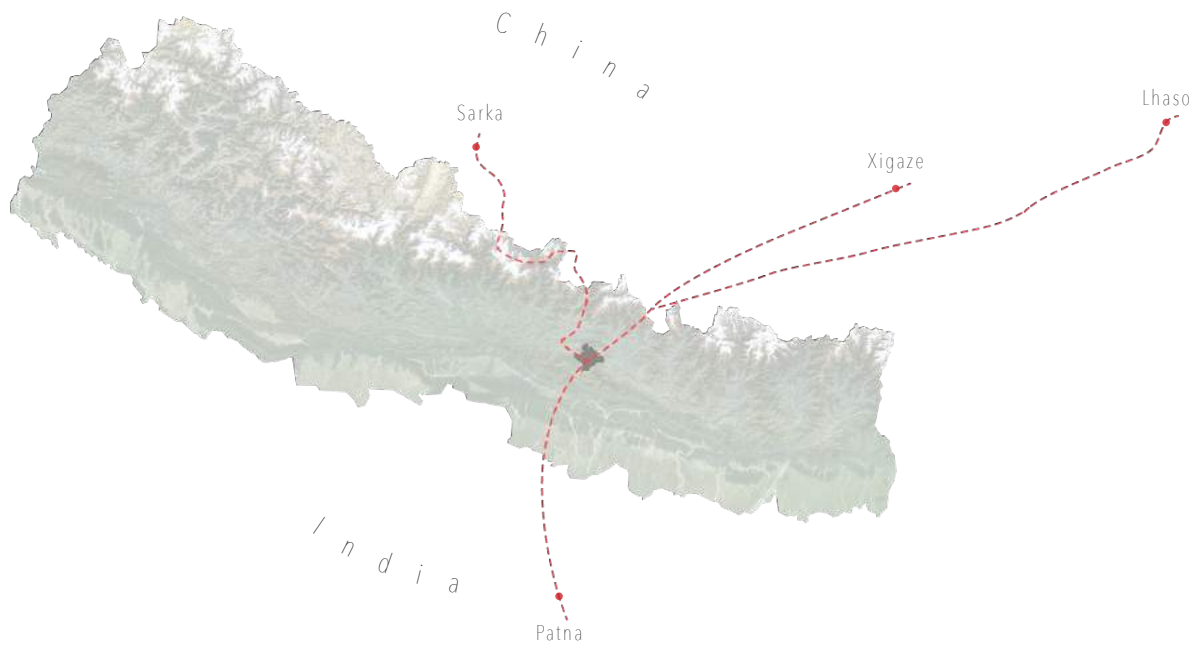
2007

Republic

After a decade of violence and uncertainty, the Comprehensive Peace Accord was signed in 2006, leading to the declaration of the Federal Republic of Nepal in 2007 (Britannica Academic, 2017).

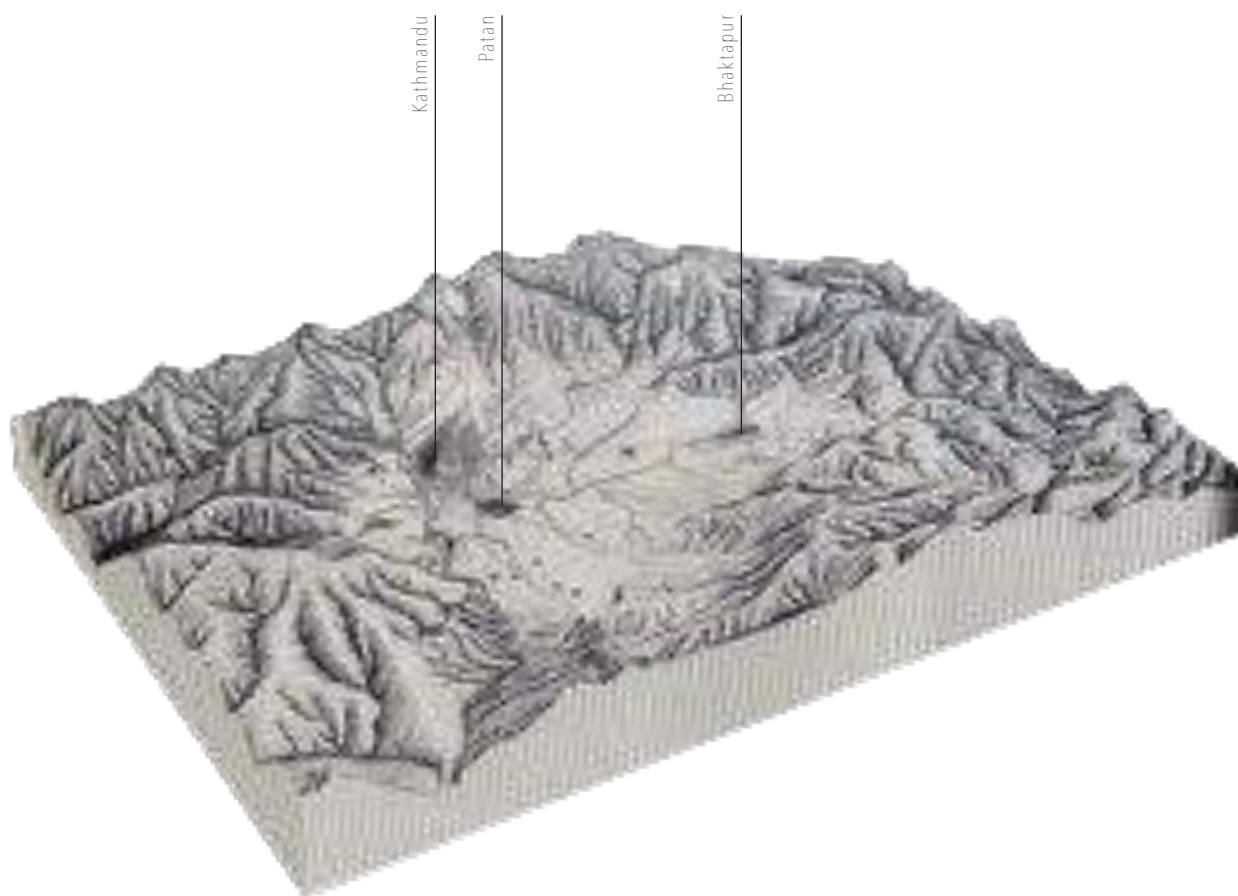
2015 "New constitution"

In 2015, the Second Constituent Assembly implemented a new constitution, following the temporary constitution that was set up in 2007 (Devare, 2015). However, immediately after that, India proposed an amendment that would be beneficial for the Madhesi people, a group of Terai-inhabitants with Indian origins (Pathak, 2015). When Nepal did not include this amendment in its new constitution, India blocked the borders with Nepal, causing an unofficial stop of all trade between the countries. At the same time, the borders with China were blocked by landslides caused by the earthquake of April 2015. This caused an enormous delay in the reconstruction process. After 4,5 months, the embargo was finally lifted (Khanal, 2016). Nevertheless Nepal was left with an enormous gasoline and oil shortage, causing people to start cooking on firewood again.



*Trade routes through the Kathmandu Valley, Nepal.
Adapted from: Wessels, 1924*

In prehistorical times, the Kathmandu Valley was a lake (Hosken, 1974). Over time the lake drained and a very fertile soil was left behind. In the 5th century B.C., the main trade route between Tibet, China and India was formed (Sen, 1971). Because it ran through Kathmandu, the city soon completely controlled the trade between these countries. In the 16th century, during the Malla dynasty, this trade route brought an additional boost to the economy of the country (Hosken, 1974). It was not until the 18th century, when the Shahs took the power from the Malla reign and conquered more land, that Nepal became more than just the Kathmandu Valley and came to exist as it is known today. Nevertheless Kathmandu remains the largest and most important city of the country.



The Kathmandu Valley. Source: Toffin, 1984



120.000 years ago

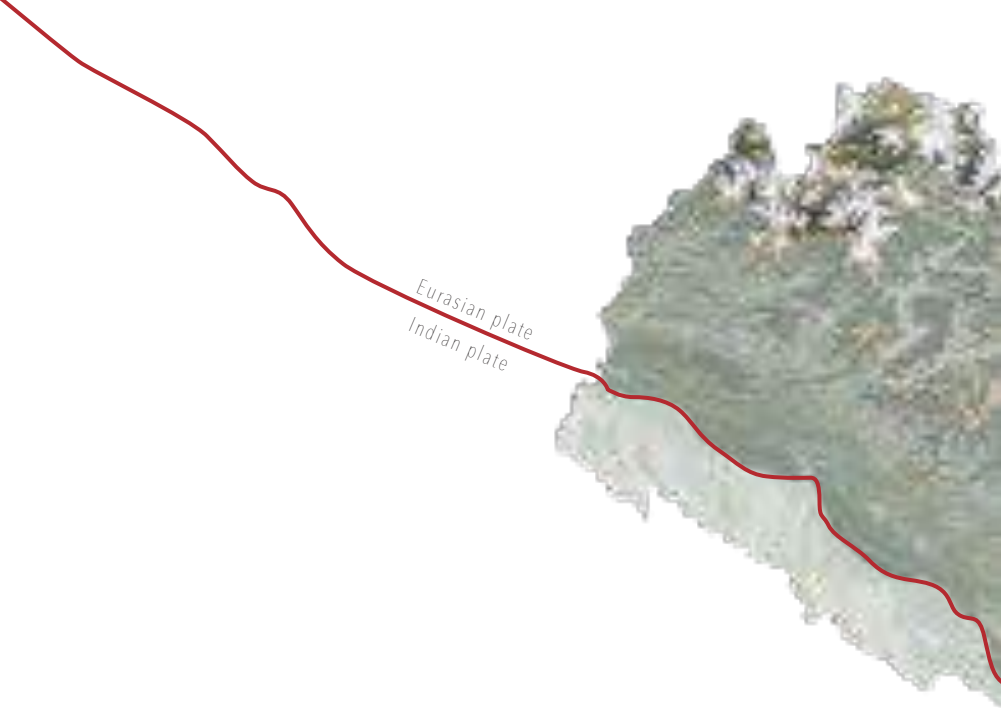


30.000 years ago



5.000 years ago

*Water evolution in the Kathmandu Valley.
Adapted from: Amaya Marin et al., 2015*



Eurasian plate
Indian plate

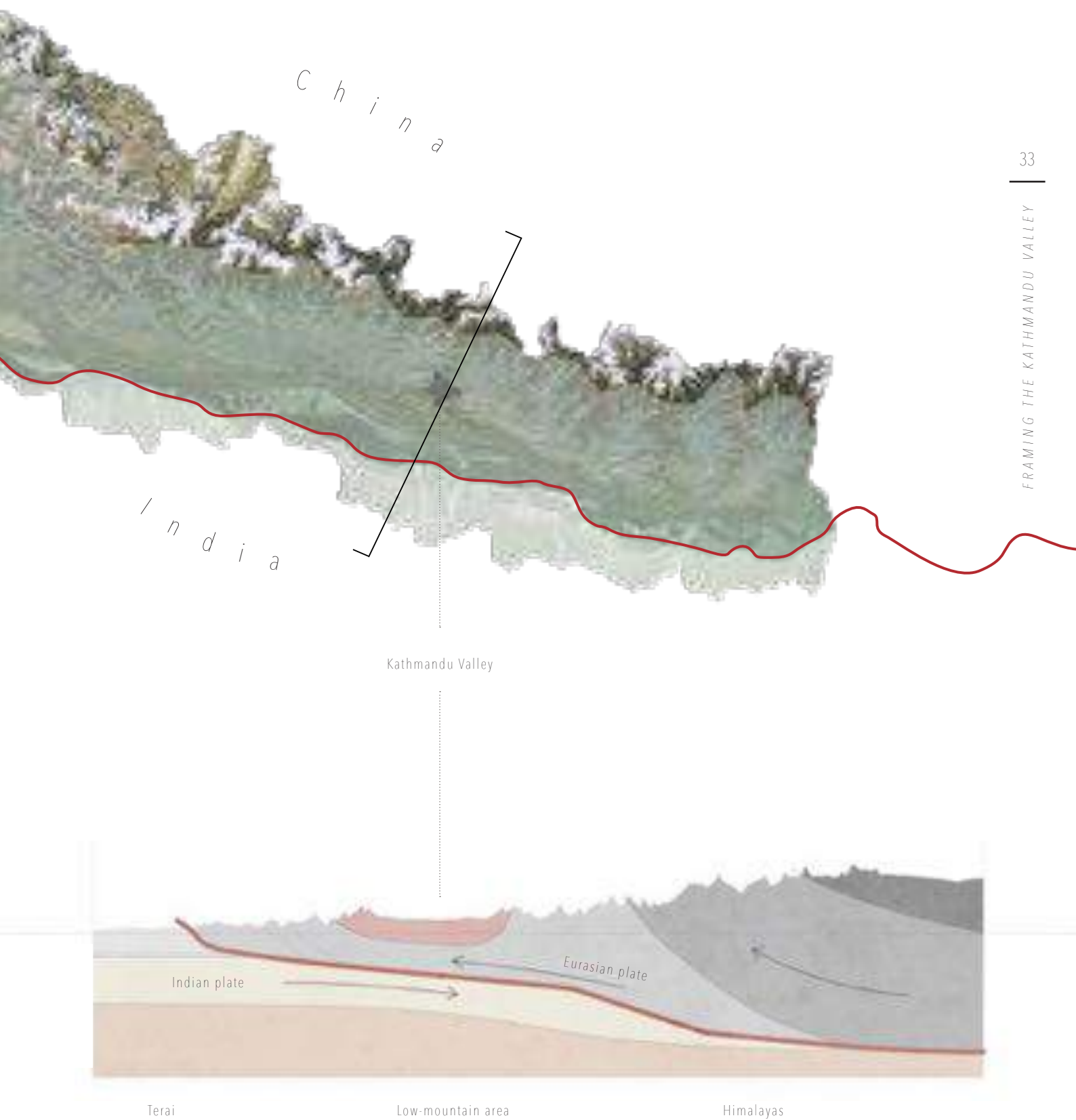
The combination of the Himalayan tectonic belt and the collision of the Eurasian with the Indian Ocean tectonic plate make Nepal extremely vulnerable to earthquakes (Zhao, 2016). The 8.1 magnitude earthquake in 1934 and the 7.8 in 2015 caused great damage to large parts of Nepal. In particular the vernacular patrimony suffered from these seismic shocks, resulting in the erasure of almost entire settlements.



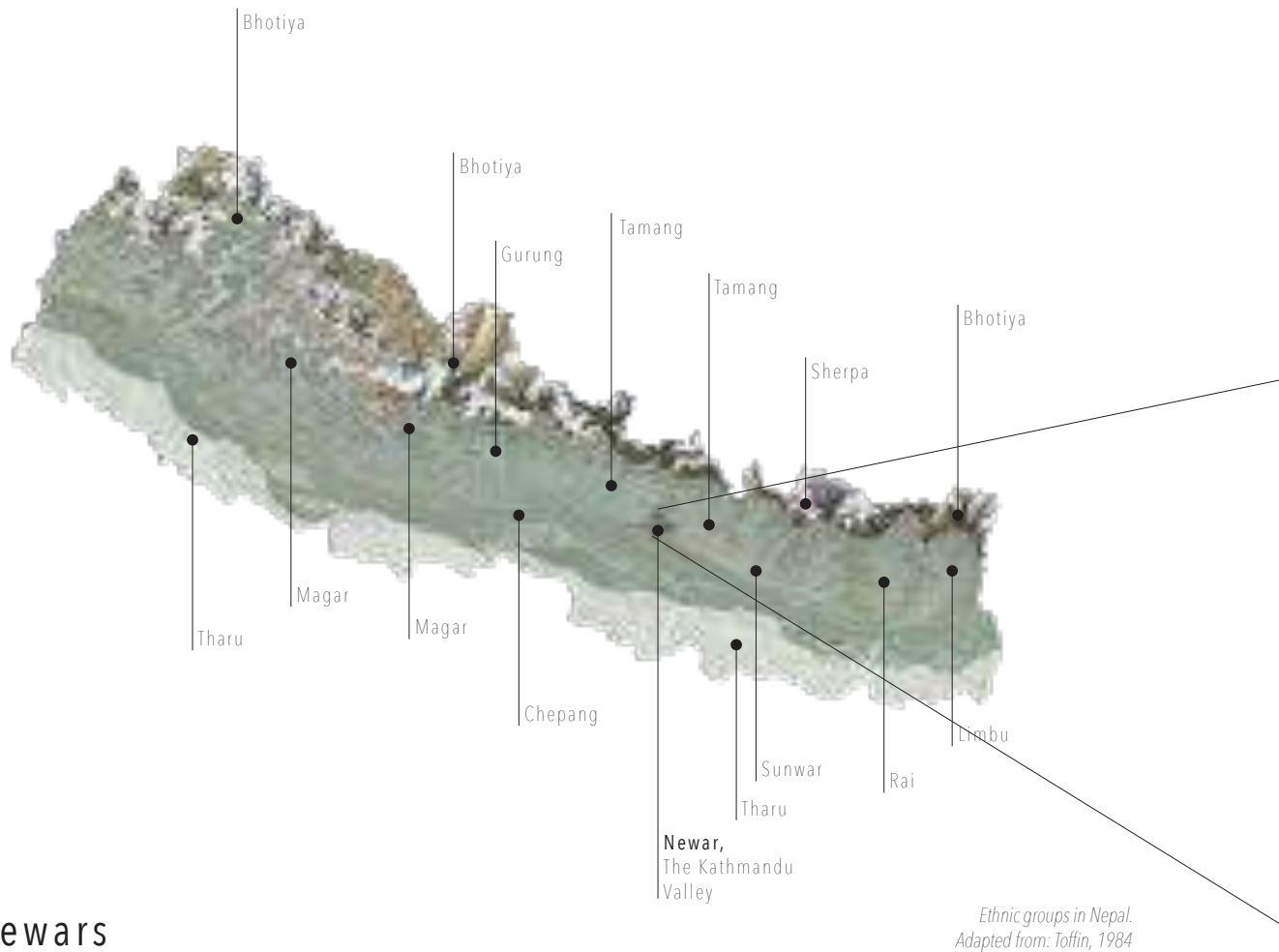
Damaged house in Bungamati, 2016



Damaged housing block in Khokana, 2016



Faultline underneath the Kathmandu Valley.
Adapted from: Searle et al., 2016

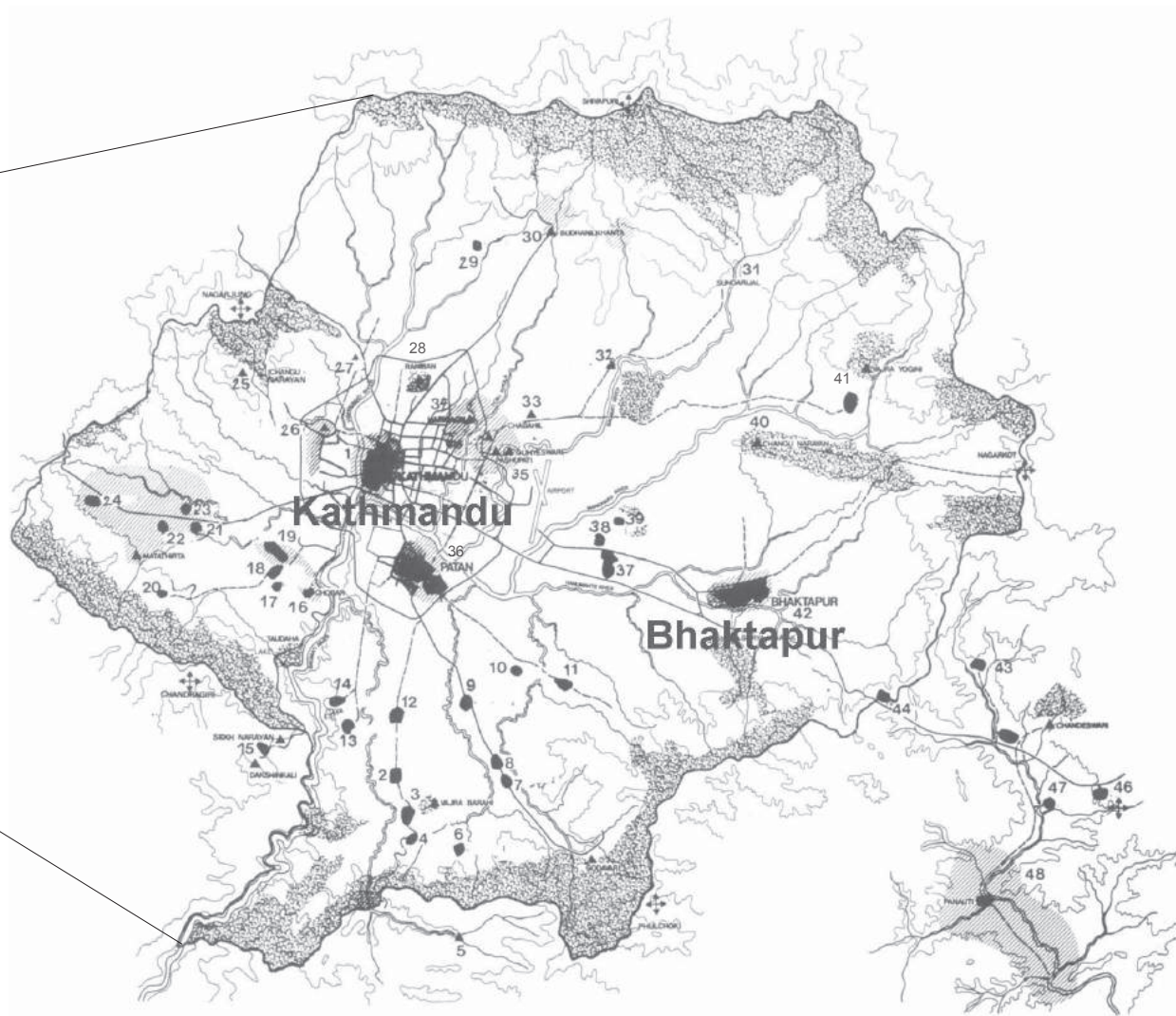


The Newars

There are over 60 different ethnicities in Nepal (Niroula, 1998). More than two third of these originate from the Hill area. The first inhabitants of the Kathmandu Valley and thus of Nepal were called the Newars (Gellner, 1986). Today they represent about 5% of the Nepalese population and still mainly live in the Valley. The Newars are either Hindus or Buddhists, but this distinction is not always clear (Charpentier, 1973). Most people attend festivals of both religions and some people even claim to be Hindu and Buddhist at the same time (Gellner, 1986).

The Newars live according to a caste system, which simultaneously defines their occupation (Gellner, 1986). Almost all of them occupy a job in agriculture, crafts or trade. More than that, almost all of the craftsmen in Nepal are from Newari origin. They also have their own language, Newari, originating from their Tibeto-Burman tradition (von Fürer-Haimendorf, 1957).

The Malla dynasty was Newari, so until 1768, when the Shahs took the power, the Newars were the ruling ethnic group. Their architecture is therefore widely spread all over the Valley in the form of houses, temples and palaces.



- | | | | | | | | |
|--------------|---------------|---------------|-----------------|-------------------|-------------------|-------------------|---------------|
| 1. Kathmandu | 7. Badagaon | 13. Bungamati | 19. Kirtipur | 25. Deochok | 31. Sundaryal | 37. Thimi | 43. Nala |
| 2. Thecho | 8. Thaira | 14. Khokana | 20. Chandragiri | 26. Swayambhunath | 32. Gokarna | 38. Nakadesa | 44. Sanga |
| 3. Chapagaun | 9. Harisiddhi | 15. Pharping | 21. Satungal | 27. Darmathali | 33. Boddhnath | 39. Buday | 45. Banepa |
| 4. Balu | 10. Sanagoan | 16. Chobar | 22. Kisipidi | 28. Ranban | 34. Harigaon | 40. Changunarayan | 46. Dhulikhel |
| 5. Leke | 11. Lubhu | 17. Panga | 23. Balambu | 29. Thokha | 35. Pashupatinath | 41. Sankhu | 47. Chaukot |
| 6. Pyangaun | 12. Sonagutti | 18. Nagaun | 24. Thankot | 30. Budanilkantha | 36. Patan | 42. Bhaktapur | 48. Panauti |



Kathmandu

Patan

Prithvi Highway

Bagmati River

Manohara River

Hanumante River

Ring Road

Nakhu River

Khokana

Bungamati



Bhaktapur

Araniko Highway

⊙ + 0,8 km +

Kathmandu Valley with indication of the 3 kingdoms and
Bungamati & Khokana. © Esri, 2017.



*Urban growth evolution around Bungamati & Khokana.
Source: Bruneel et al., 2016*

Bungamati & Khokana

Bungamati and Khokana are two traditional Newari settlements and are referred to as the twin villages. They are situated approximately 8 km south of Kathmandu. The Newari culture and architecture is very present in these agricultural settlements. Both villages are framed by the Bagmati river in the west and the Nakkhu river in the east (Gurung, 2000). There are cremation sites at the riverbank of the Bagmati river near each village. Khokana and Bungamati are part of the Karyabinayak Municipality in the Lalitpur District (Gurung, 2000). The 2015 earthquake destroyed over 200 houses in the twin villages alone, and again twice as many were heavily damaged.

Bungamati is approximately 0,23 square kilometres large and in 2011 it had a population of 5 966 people (Webb & Bajracharya, 2016; Bista, 2014). Most families own or rent a piece of agricultural land, although it is mainly for personal use and not meant to sell the crops. Furthermore Bungamati is famous for its woodcarving, which is, apart from agriculture, the main source of income for the village.

Khokana is one of the most traditional settlements in the Kathmandu Valley. It still maintains its agricultural based existence and is widely known for its mustard oil mills. Although Khokana is smaller than Bungamati, it still had 4297 inhabitants in 2011 (Bista, 2014). The settlement is very dense, resulting in a lively atmosphere. In 1996, Khokana was submitted for the UNESCO Tentative List (UNESCO, 1996).

In the last few decades, these settlements have faced the changes brought by urban expansion (Bruneel et al., 2016). Even though most expansion takes place at the edge of town and alongside the road to Kathmandu, urban sprawl is still spreading rapidly and putting pressure on the historical cores.

⊙ + 4 km +

Aerial view of Bungamati & Khokana



Road to Patan

Nakhu River

Bagmati River

Khokana

Armature road

Karyabinayak temple

Bungamati

New
development
by real estat
developers



View on the main street in Khokana, 2016



*View on the main square in Bungamati where the
Machhindranath temple once stood, 2016*



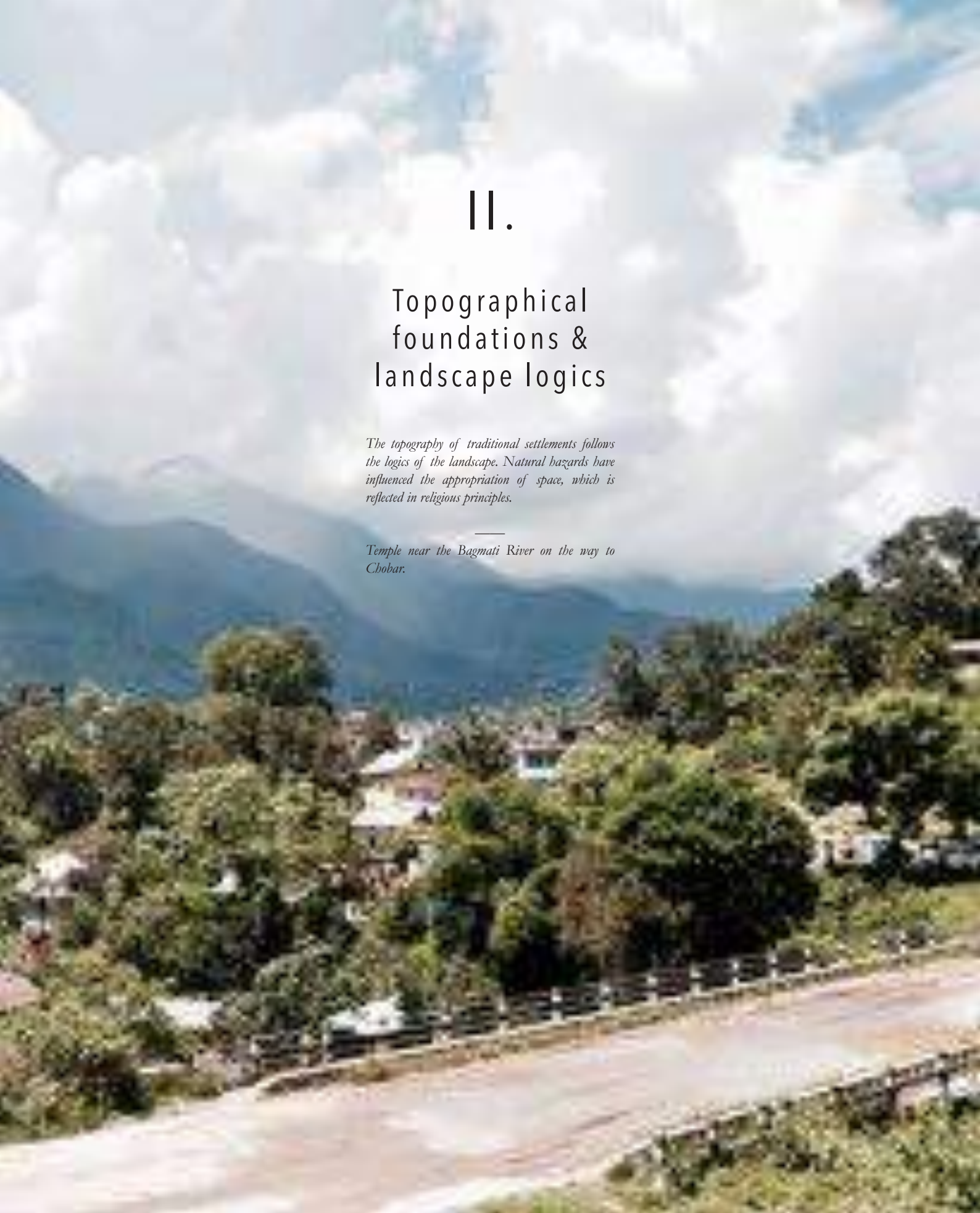


II.

Topographical foundations & landscape logics

The topography of traditional settlements follows the logics of the landscape. Natural hazards have influenced the appropriation of space, which is reflected in religious principles.

Temple near the Bagmati River on the way to Chobar.





Mandala made of food during festival in Bungamati, 2016

Concentric patterns in the landscape

The Kathmandu Valley has a fertile clay soil because it used to be a lake (Hosken, 1974). Therefore, the main use of land has been agriculture for centuries. Most traditional settlements are thus agriculture-based settlements.

Many of the traditional towns of the Kathmandu Valley were formed nearby the riverbanks alongside the ancient trade routes between India and Tibet (Sen, 1971). The main streets of these villages are often remaining parts of the original roads.

Because most traditional settlements are agriculture-based, they are built on higher land where no crops can grow. In this way they leave as much of the lower area as possible free for cultivation (Hosken, 1974). Apart from that, a hilltop also implies less risk of flooding during the monsoon (Korn, 2007). This has led to very dense settlements with clear boundaries, in order to avoid expansion and thus losing fertile land.

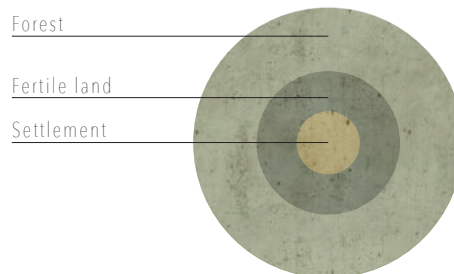
All construction in Nepal, from single houses to entire settlements, follows an ancient Indian principle that is over 2000 years old: *vaastu-vidya*, the “science of dwelling” (MacFadyen & Vogt, 1977). This spiritual principle clarifies the link between earth and the universe.

Vaastu-vidya also defines the spatial organisation of the settlements. They are all similarly shaped according to the form of a *Mandala*. In general, a *Mandala* is a circular pattern, regularly used by priests to represent a deity (Gurung, 2000). *Mandalas* are often multi-coloured and made out of sand or powder. Sometimes, for example during festivals, the food is also presented in such a shape.

Translated into the form of the settlements, there are three elements that can be observed in the Newari towns and that refer to the *Mandala*: the centre of the town is important, the city is not infinite (it is bounded) and there is a form of hierarchy.

Most of the traditional towns have a concentric structure, with a temple or palace to mark the centre (MacFadyen & Vogt, 1977). The temple or palace and the rest of the settlement form the boundary of the first inner circle, until the edge of the town. Everything inside this circle is considered sacred and in need of protection. The second part built around this inner circle consists of the agricultural fields. They often take the form of terraces on the steep hillsides of the higher situated town. The third circle is usually a wider area of forest. In the past, especially during the Malla period, these forests offered extra protection against possible invasions, either by wild animals or hostile kingdoms. Some of the older settlements were even walled.

These features can directly or indirectly be found in every Newari town that was founded in the Malla period, whether it is a large city close to Kathmandu or a small settlement in the outskirts of the Valley. While the concentric principles have a spiritual meaning, they clearly reflect the topography on which the settlements were based.



Patterns in the landscape



Hazards determining the use of land

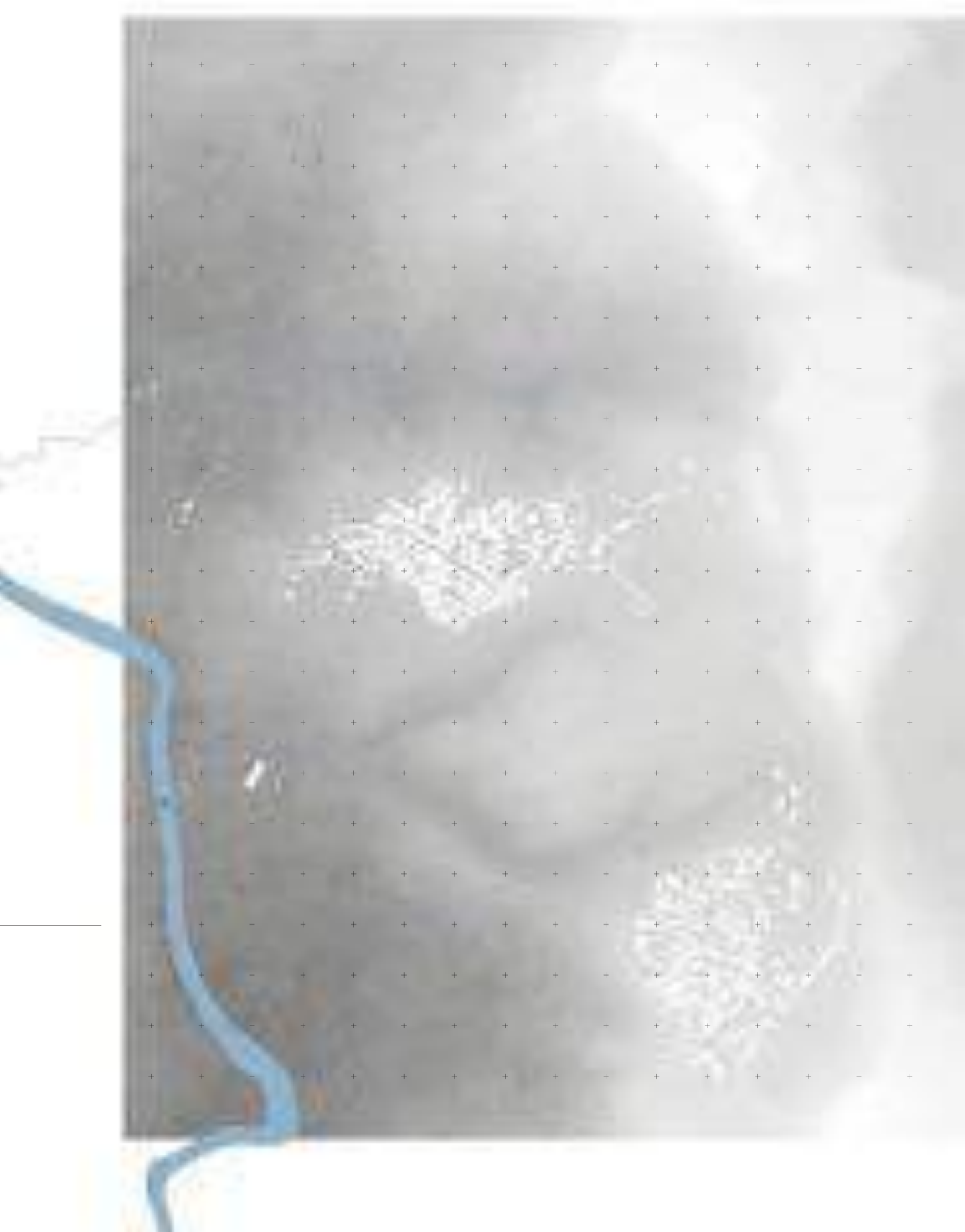
The middle section of the *Mandala*-shaped landscape can further be subdivided, based on the use of its land (Johnson et al., 1982). The inhabitants of the Valley categorise it as either wet or dry terrace, grazing land for farm animals, or untilled land. Including the inner circle or settlement, and the outer circle or forest, this creates six types of land use. The wet terraces are mainly used to cultivate rice and wheat, and are close to irrigation sources. The dry terraces are usually on higher and steeper hillsides. The exact cultivation of the fields depends on the season.

The use of land is in line with the hierarchy of the *Mandala*: inside the middle section there is still a differentiation in value. Wet terraces are often considered most valuable, followed by dry terraces and finally grazing land. This hierarchy is also reflected in how much labour is required for each activity: the lower the value, the lower the required efforts. Nevertheless, these uses are all still seen as hierarchically ranking higher than forest land, as they are in the middle section of the *Mandala*.

⊙ + 9 km +

Topographical view of Bungamati
& Khokana



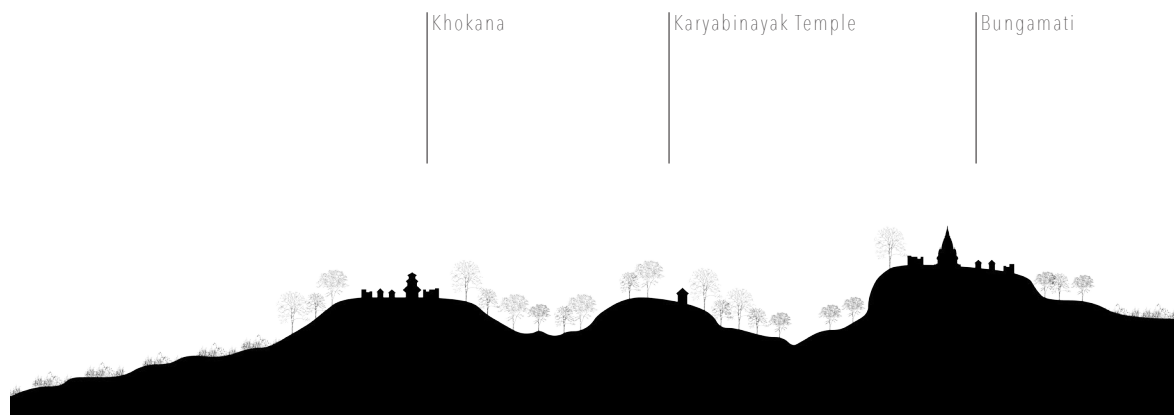


The agricultural land and settlements are liable to different threats (Johnson et al., 1982). Most issues occur with landslides, floods and erosion, all of which can be caused by earthquakes. The terraces have thoroughly maintained walls, made of stone and turf, to help protect the fertile areas against these threats. Information about the hazards of a certain area is passed on through generations in order to minimize the risks. Flooding of an irrigation canal forms a threat in itself, so the canals are carefully checked on cracks or possible flooding zones. Another way in which the owners protect their land is by planting trees on strategic locations. Trees help to prevent erosion and landslides. Sometimes bamboo walls are constructed alongside the riverbanks in order to protect agricultural land against flooding. However, this needs to be done in a proper way and in consent with all farmers, because it will affect the irrigation of the entire farmland.

The value of an area strongly determines how much effort is put into the protection against these hazards (Johnson et al., 1982). Wet or dry terraces and housing thus receive the most attention, although people realise that a threat on a different location can easily spread and still affect their higher-valued land. This works both ways: when a farmer realises that a certain area is more vulnerable to a hazard, he will “de-intensify” the use of this land, at least for a while. For example, wet terraces can become dry terraces for a while, and dry terraces can become grazing area, when the risk of landslides or floods is too high. To a lesser extent, land that is deemed too exposed to hazards for any agricultural activity, can become a reforestation zone. That way the use of land and thus the boundaries of the circles may shift over time. Hence, the presence of hazards strongly determines whether or not certain land is used to live on, and clarifies why most traditional settlements are located on higher land, surrounded by agricultural fields on the hillsides and forest on the lower land.

*Wall in between rice fields to
protect the landscape from
landslides, 2016*





Section through Khokana & Bungamati

The topography of Bungamati & Khokana

The *Mandala* concept can also be seen in the twin villages. There is a clear hierarchy in the width of the streets, and in case of Bungamati, in the location of the different castes.

The main temple of Khokana is located almost exactly in the middle of the village at the centre of the swastika symbol, but for Bungamati the importance of the centre can be seen in a less literal way (Gurung, 2000). In this case the centre is the former location of the main temple. Although it is not in the geographical middle of the village, it forms the most lively place of the entire town. Both villages are surrounded by rice- and cornfields (wet terraces) and have the remains of a forest at their edges.

⌚ + 50 m +

Vegetation map of Bungamati & Khokana

- Forest tree
- Large/tall tree
- Small tree
- Fruit tree
- Bushes/weeds
- Flowers
- Rice fields
- Cornfields
- Kitchen garden





III.

Water management in development

In the past, providing water for settlements situated on higher land required a sophisticated combination of different waterbodies that worked together as one system. Ever since the rise of the modern water supply, this traditional system got neglected and inhabitants are depending on the rationed amounts of water supplied through pipelines.

Naa Pukbu, one of the ponds in Bungamati.



Dhobi Khola River

Ichu Nadi

Bishnumati River

Bagmati River

Kodaku River

Nakhu River

Bagmati River

Manohara River

Kasan River

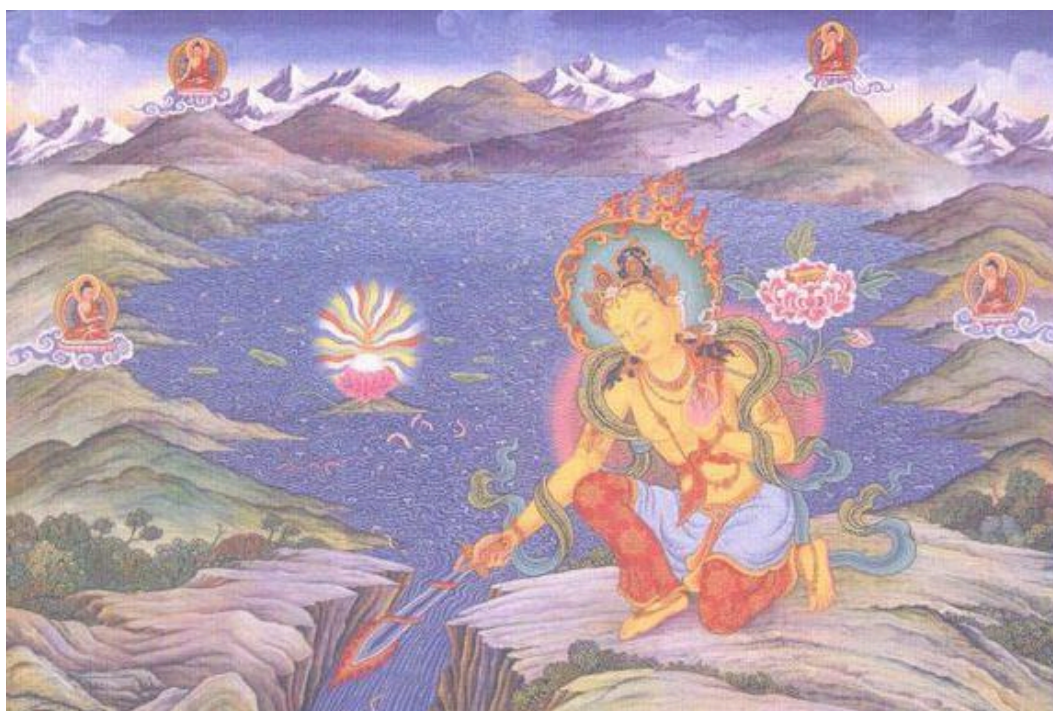
Hanumante River

Godawari River

Lubhu Khola



Pond in Bungamati in 1968.
Source: Danish architect students, 2015



Founding legend of the Kathmandu Valley, draining of the valley.
Source: KVDA, 2015

+ 2,5 km + 

River network in the
Kathmandu Valley.
Source: Amaya Marin
et al., 2015

- Bungamati & Khokana



Bagmati river, 2016

Traditional water system

In the past, the various water providing structures were perfectly adapted to the physical conditions of the terrain. The basis of the traditional water system is a closed cycle of various waterbodies, depending on the *Rajkulo* or royal canal. Every one of the three former kingdoms of the Kathmandu Valley, Kathmandu, Bhaktapur and Patan, had its own *Rajkulo* leading the river water to their cities, thus guaranteeing a regular water supply. (Becker-Ritterspach, 1995). However, these canals were not only transporters, but also water collectors, that way minimizing the water loss (Bisht, 2011). They used to irrigate numerous agricultural fields where they passed. In this way the king was able to meet the needs of his people and keep them satisfied. Following the definition of Karl Wittfogel, these kingdoms can be seen as 'hydraulic civilizations', since the dependence on this canal to irrigate the fields could be used to suppress the people too (Brittanica Academic, 2017; Pariyar B., 2010). In Bungamati and Khokana a tributary of the royal canal contributes to the water supply and irrigates the surrounding rice fields.

ⓘ + 250 m +

Map of Rajkulo with side canals.
© Esri, 2017
Adapted from: Aryal, 2005

- Rajkulo
- Rivers
- Bungamati & Khokana



The traditional water system is composed of various waterbodies, which are directly connected to one another. This cycle keeps the water flowing, providing clear water through ash filtering inside the pipelines that connect the waterbodies. The main supply of water derives from groundwater resources. In the Kathmandu Valley two aquifers, separated by a less permeable layer of clay, provide the bulk of the water needed to meet the demand (Pandey et al., 2010). The traditional water systems, often not able to reach the deep aquifer, depend mainly on the shallow aquifer. However, the water extracted from the shallow aquifer is nowadays polluted (Cresswell et al., 2001). Water of the deep aquifer is of significantly better quality, but is recharged even slower than the shallow aquifer. Therefore, the recharge of groundwater both in shallow and deep aquifers is very important for maintaining this traditional water system.

The main waterbodies of the settlements are the ponds, or *pukhus*, which are supplied by the *Rajkulo*. They also serve as reservoirs of rainwater and they recharge the groundwater. Nowadays villagers are enclosing the ponds by building small walls around them. This prevents rainwater from flowing into the ponds, leading to less refill. Whereas the ponds recharge the groundwater, the stone spouts and the wells extract groundwater of the shallow aquifer. Stone spouts are stepwells, often constructed in depressions of the terrain. The stepwell or the *biti* is dug under the groundwater table of the shallow aquifer and water is provided by gravity flow through a channel (Amaya Marin et al., 2015; UN-Habitat, 2008). To guarantee a continuous supply throughout the year, some stone spouts are connected to a nearby underground porous brick chamber by channels of brick, timber or clay (UNEP-IETC et al., 1998). The water is then guided to vessels with filtering media, upstream of the spout. These vessels are mostly working as a sand filter, a settling basin or both.

Another important waterbody that extracts groundwater is the well. Though wells mostly derive the water from the shallow aquifer, there are two deep wells in Bungamati and Khokana, excavated to the level of the deep aquifer. Wells are usually built with the image of a serpent around them, since these are the saints of the water.

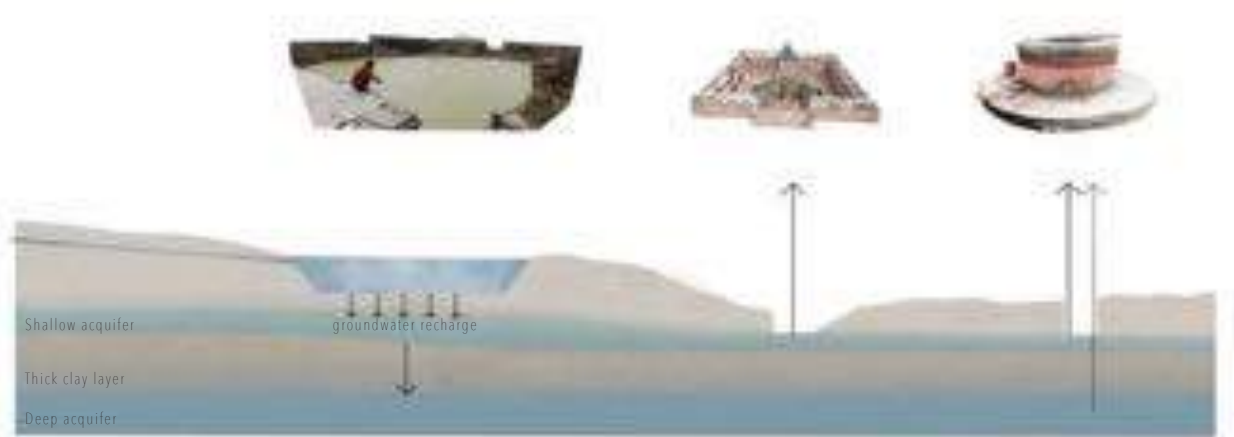


Royal Bath with spout in Bhaktapur, 2016

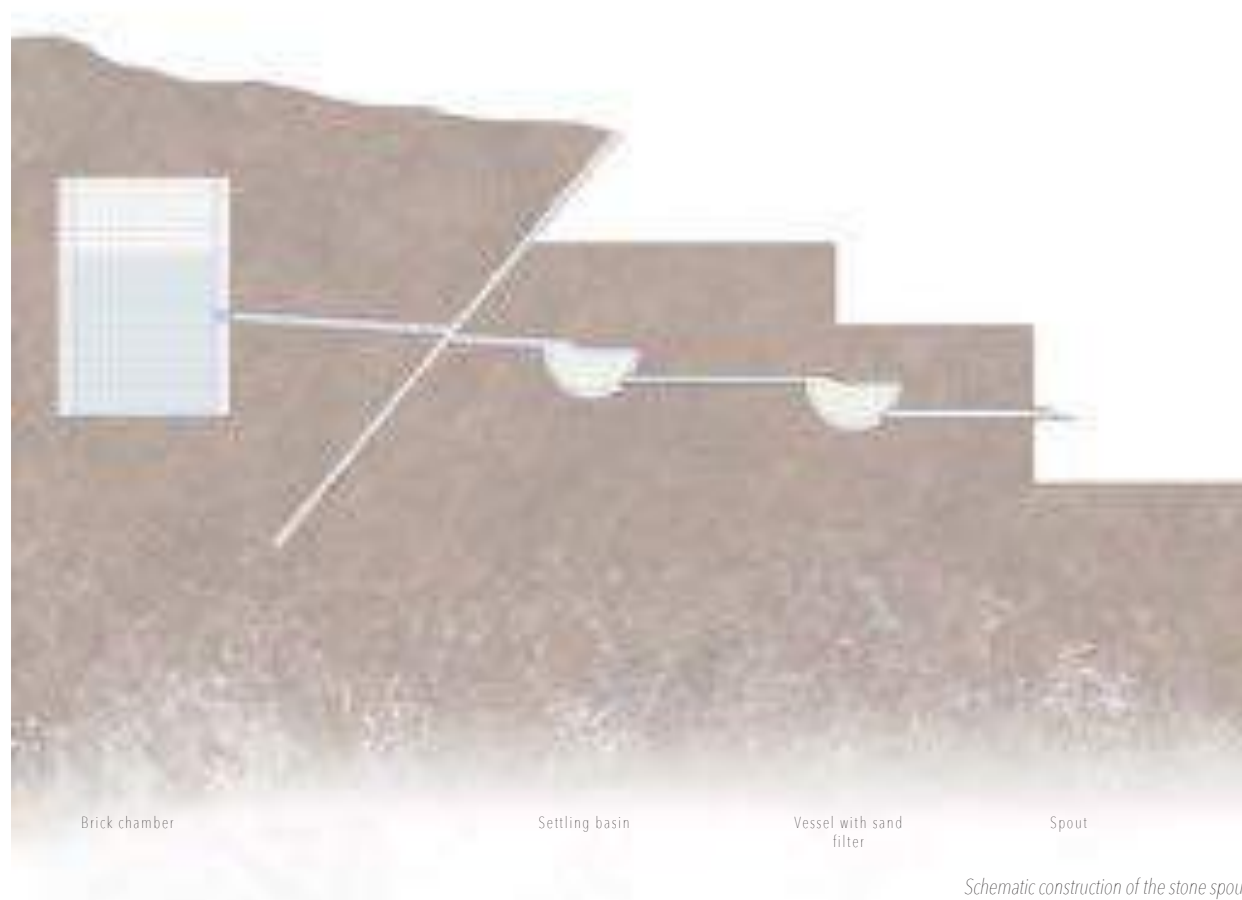
PONDS
(*pukhus*)

STONE SPOUTS
(*hitis*)

WELLS
(*kuva*)



System of the traditional waterbodies



*Schematic construction of the stone spout.
Adapted from: UNEP - ETC et al., 1998*

The irrigation system is composed of various canals. There are permanent stone canals and secondary mud canals, dug by the local farmers. The water used for irrigating the fields is later on directed towards the river. Because Bungamati and Khokana are located downstream, they do not get much water from the canal, especially in the dry season. As a result, wastewater is increasingly used for additional irrigation of the fields.

The fast urban expansion of Kathmandu is destroying the *Rajkulo* since houses are being built on it. Nowadays, the royal canal is very deteriorated and provides less water than it used to, leading to a shortage of water. The shortage of water, combined with the increasing demand, is being solved by extracting groundwater in unsustainable ways. Since the *Rajkulo* is no longer able to supply the ponds, they are in their turn unable to recharge the ground water, leading to an even bigger shortage of water. However, the Environment and Heritage Conservation Nepal is planning to restore the royal canals of both Patan and Bhaktapur, with the financial support of the Indian Government (Aryal, 2005). When the canals are fully reconstructed, 8 million litres of water will flow to Patan every day and irrigate hundreds of hectares of field along the way (Bisht, 2011; Aryal, 2005). The tributaries of the royal canal will again supply the traditional water system of Bungamati and Khokana.

Because of the abovementioned expansion, the natural infiltration of rainwater is dramatically decreasing. More houses are covering the permeable soil, preventing water from infiltrating into the ground. In addition, the houses of reinforced concrete are characterized by a flat roof, equipped with a water pipeline directing the rainwater straight to the drainage system. This prevents the water from permeating the ground, resulting in the inability to recharge the groundwater. A possible solution to these problems could come from harvesting rainwater by collecting the rainfall on the roofs and leading it to the ponds or to other recharge areas.

Formerly, the traditional water supply system worked perfectly, providing clean water for the various settlements. However, nowadays we see that the water transported through the old pipelines is very polluted. This is the result of the increasing problem of (solid) waste. The terracotta pipelines are deteriorated because when new houses are constructed, their foundations damage the pipelines. Theoretically inhabitants are supposed to report to the Municipality when they find an ancient pipeline underneath their construction site. However, because they are afraid they will not obtain their building permit, they conceal this discovery and build the house anyway, thereby breaking the pipelines. On top of that, all kinds of chemicals are passing through them as a result of an increasing use of washing products. Since the pipelines are broken, the dirt and sewage water easily enter the water supply. Because of the highly polluted condition of the water from the traditional system, it is no longer used as drinking water, but rather for washing clothes and doing the dishes.



Irrigation canal between the rice fields, 2016



Wastewater directed to the streets, 2016

Wastewater management

Wastewater is collected in individual septic tanks, usually situated in a courtyard. Following professor Suresh Das Shrestha, professor at the department of geology at the Tribhuvan University, there was no wastewater system in the past, so the inhabitants did not know what to do once their septic tanks were full (Shrestha S. Personal interview. 2016, October 6). Therefore, many septic tanks were badly constructed on purpose. That way they would leak continuously and the owners would not have to deal with the problem of emptying their tank. This has caused severe pollution of the soil and thus of the groundwater all over the Kathmandu Valley.

The Newari settlements have three models of wastewater management: the standalone system where the villagers are individually responsible for the transportation of the wastewater, the community system which uses the wastewater for irrigation of the fields, and finally another community system where the wastewater is transported to the ponds (Shukla et al., 2012). A serious disadvantage of transporting wastewater to the ponds is that once the water in the ponds is contaminated, it feeds the weeds, resulting in even worse pollution.

A potential solution might arise from the multi-use of greywater. This greywater could be used for irrigation of the fields, kitchen gardens and so on. In addition there could be a wastewater treatment system.



Deopokhari Festival in Khokana.

© AFP, 2014

Cultural heritage

The traditional water system, with all its components, did not only shape the urban fabric of the settlements, it also played a fundamental role in the cultural and socio-economic activities (Feyen et al., 2008). Water has great symbolic value in the Newari culture. Most settlements are constructed near a river or stream, often with a cremation site at their riverbanks (Gurung, 2000). The cremation sites in turn usually have a temple nearby.

Many people prefer to be cremated near the holy Bagmati river. The river served two purposes. The water of the river was used to bathe people in the last hour before they died, but since this river is so polluted nowadays, bottled water is poured on their feet. Additionally, ashes are scattered into the river after the cremation. In Bungamati and Khokana too, cremation sites are located at the banks of the Bagmati river.

The Deopokhari Festival is another example of the religious activities connected to waterbodies. This unique festival takes place at the main pond, or *De Pukhu*, of Khokana. The ceremony represents a 900 year old tradition, derived from the belief that the medieval gods used to drown children in this pond. During the festival, the villagers bring a goat to the pond and the animal is sacrificed there. The man who can eventually kill the goat, is the leader of the following procession. By sacrificing a goat every year the gods will be assuaged.

The most important festival of Bungamati, the *Machhindranath Jatra*, is celebrated for one month each year during spring, or in other words, before monsoon (Webb & Bajracharya, 2016; Hosken, 1974) and is as such also related to water. *Machhindranath*, the god of rain and fertility, is one of the most important gods in an agricultural based community, since he has power over the monsoon rains (Hosken, 1974). In the chapter 'specificities of the urban tissue' this festival is discussed in more detail.

Sitbinakha is the most common day to do maintenance works on the water system (UN-Habitat, 2008). On that day there are no caste restrictions for the maintenance of the waterbodies. However, nowadays the maintenance of the traditional water bodies seems to be fading.

In the past, also a significant part of the social life took place around the ponds and spouts. The women would come there in the morning to wash their children, clothes and do the dishes. This turned the water sites into the most vibrant places in the traditional towns. Reconstructing this traditional water system could therefore not only contribute to the solution for the present water shortage, it will revive an important part of the cultural heritage of the Kathmandu Valley.



Cremation site of Khokana near the Bagmati river, 2016



Women washing themselves in Bungamati, 2016



Women collecting water by a concrete tank in Bungamati, 2016

Modern water supply

The first modern water supply, providing water through pipes, dates from the end of the 19th century (Juuti, 2007; Maharjan, 2014). These pipelines brought water to the palaces of the ruling Rana dynasty. In the 1960's *Pani Goswara*, the former water work office, started distributing private taps in Patan (UN-Habitat, 2008). Around the same period the “Development Plans”, plans with goals for the next five years, were made to modernize Nepal. The Eighth Five Year Plan (1992-1997) strived for 72% coverage of drinking water supply, but at the end of the Ninth Plan (2001-2002) this goal was not yet achieved (Maharjan, 2014).

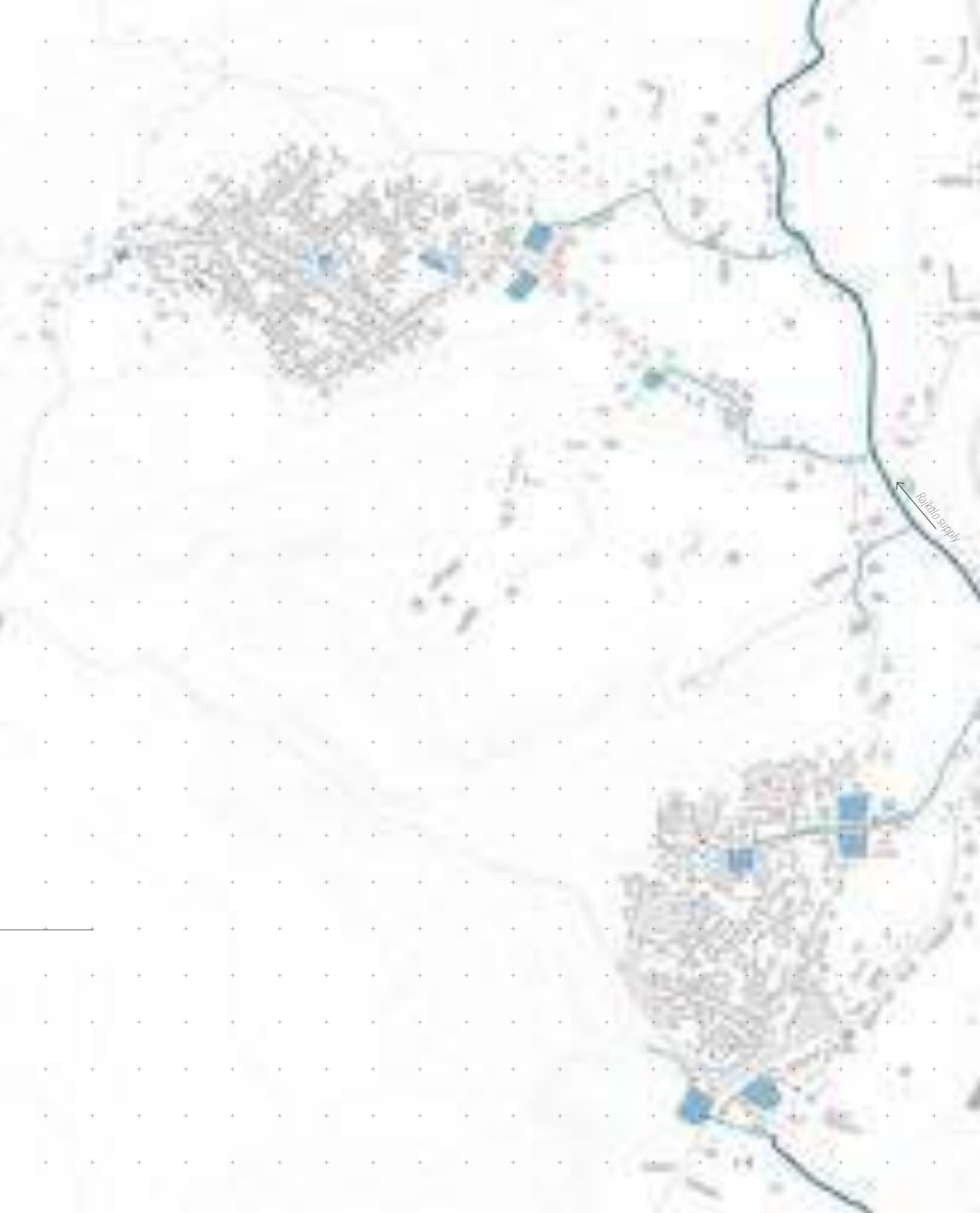
Bungamati and Khokana are connected to the modern water supply system, but the rapid urban growth comes with an increasing demand for drinking water, which has resulted in the rationing of water. The current water demand in Kathmandu is approximately 320 million litres of water per day (MLD), where the providing service, Kathmandu Upatyaka Khanepani Limited (KUKL), can only supply 155 MLD during wet season and 100 MLD during dry season (Shrestha et al., 2014).

Inhabitants of Bungamati and Khokana with a private connection to the water supply only receive water during two hours a day, five days a week. On these moments, all villagers tap water at the same time and store it in plastic containers for future use. This plastic tanks have a volume of approximately 700 to 1000 litres and are placed on the upper floors. Consequently, these floors have to carry an enormous additional weight, which may be disastrous during an earthquake. Inhabitants who are less fortunate and do not have a private connection to the water supply system have to rely on the communal water tanks, big concrete reservoirs that are supplied with the same frequency.

⊙ + 50 m +

Permanent waterbodies in
Bungamati & Khokana

- Pond
- Stone spout
- Well
- Concrete tanks





Neglected pond in Bungamati, 2016

According to the Nepalese government, the Melamchi Water Supply Project (MWSP) should offer the solution (Shrestha, 2014). The project aims to bring 170 MLD of water from the Melamchi river to a water treatment plant in Sundarimal, where the water could be distributed over several reservoirs in the Kathmandu Valley (Grad, 2016). For future expansion, two upstream rivers, Yangri River and Larke River, are being investigated (Shrestha, 2014). Connecting these rivers to the project can bring an additional 340 MLD. The Melamchi project is divided in two smaller sub-projects (Shrestha, 2014). The first subproject is the construction of a 26,5 km long tunnel and water treatment plant and is coordinated by the Melamchi Water Supply Development Board. The second subproject consists of the construction of several reservoirs spread over the Kathmandu Valley and the distribution pipelines from the treatment plant to these reservoirs. It is authorized by the KUKL. The whole project was supposed to be completed in 2008, but has experienced serious delays due to political instability (Shrestha, 2014; Government of Nepal, 2016).

The introduction of the modern water supply has made daily life of many villagers easier, but it has also had other consequences (Hoek, 2016). Over the years, the dependence of the traditional water system has decreased and the vernacular water bodies, once the most vivid places in daily life, have become neglected.



Melamchi water supply project
in the Kathmandu Valley
© Esri, 2017
Adapted from: Shrestha, 2014

- Tunnel
- Distribution pipelines
- Water reservoir
- Water treatment plant
- ... Possible expansion



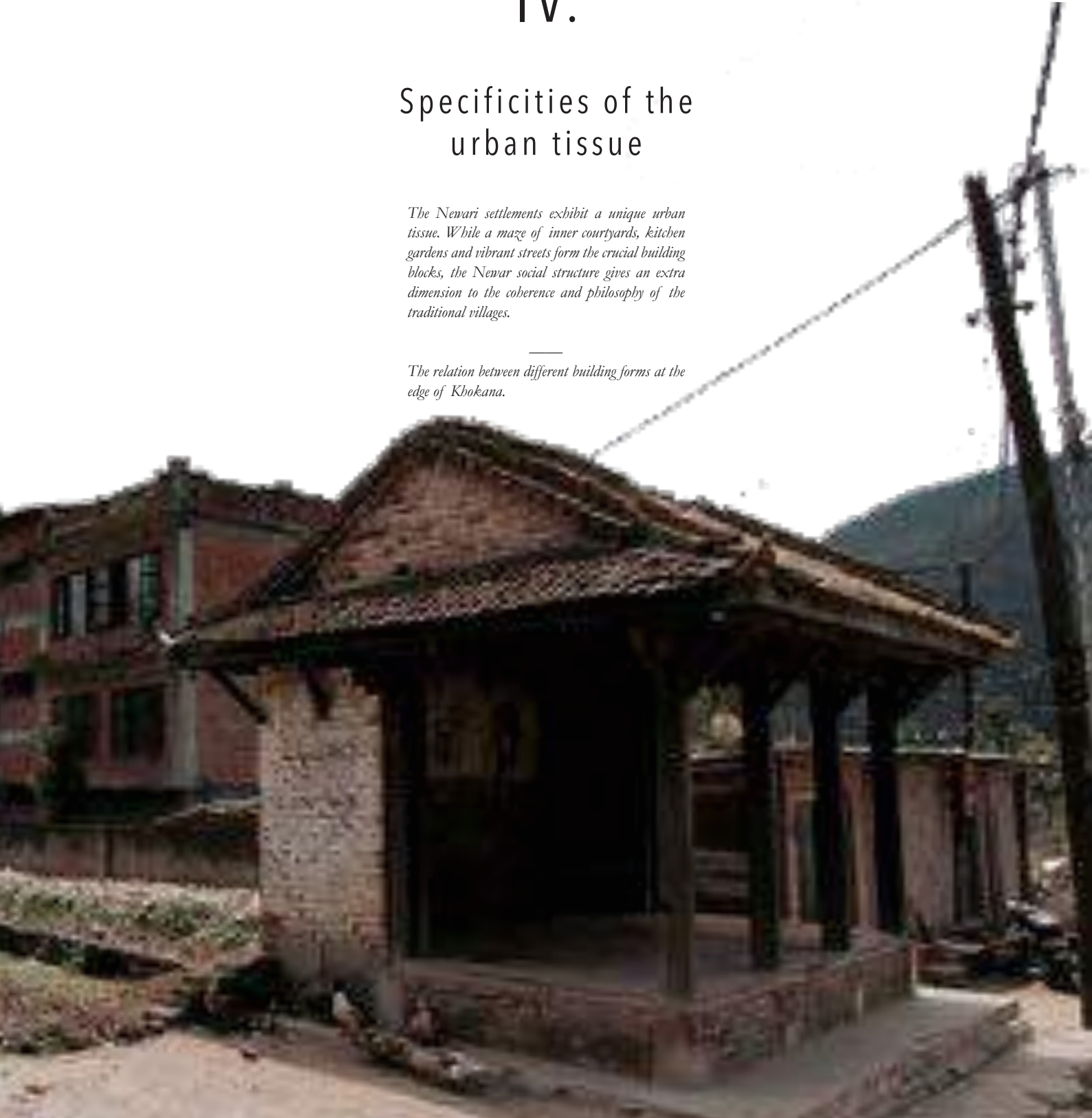


IV.

Specificities of the urban tissue

The Newari settlements exhibit a unique urban tissue. While a maze of inner courtyards, kitchen gardens and vibrant streets form the crucial building blocks, the Newar social structure gives an extra dimension to the coherence and philosophy of the traditional villages.

The relation between different building forms at the edge of Khokana.





The Newari settlements are dominated by a *Mandala* principle in order to protect the core of the settlements from various threats. When zooming in on the inner circle of this *Mandala*, a typical Newari fabric, formed by vibrant streets and a network of courtyards, can be observed. However, the formation of the villages was not purely guided by topography. The daily life of the villagers as well as various principles contributing to the social system lie at the basis of their development (Shrestha & Shrestha, 2008). That way, every settlement is unique, as it is based on the social structure that is present in that village. The basis of the formation of every settlement can be found in its founding legends, narrating the story of how the village was established.



Illustration of the founding legend of Bungamati

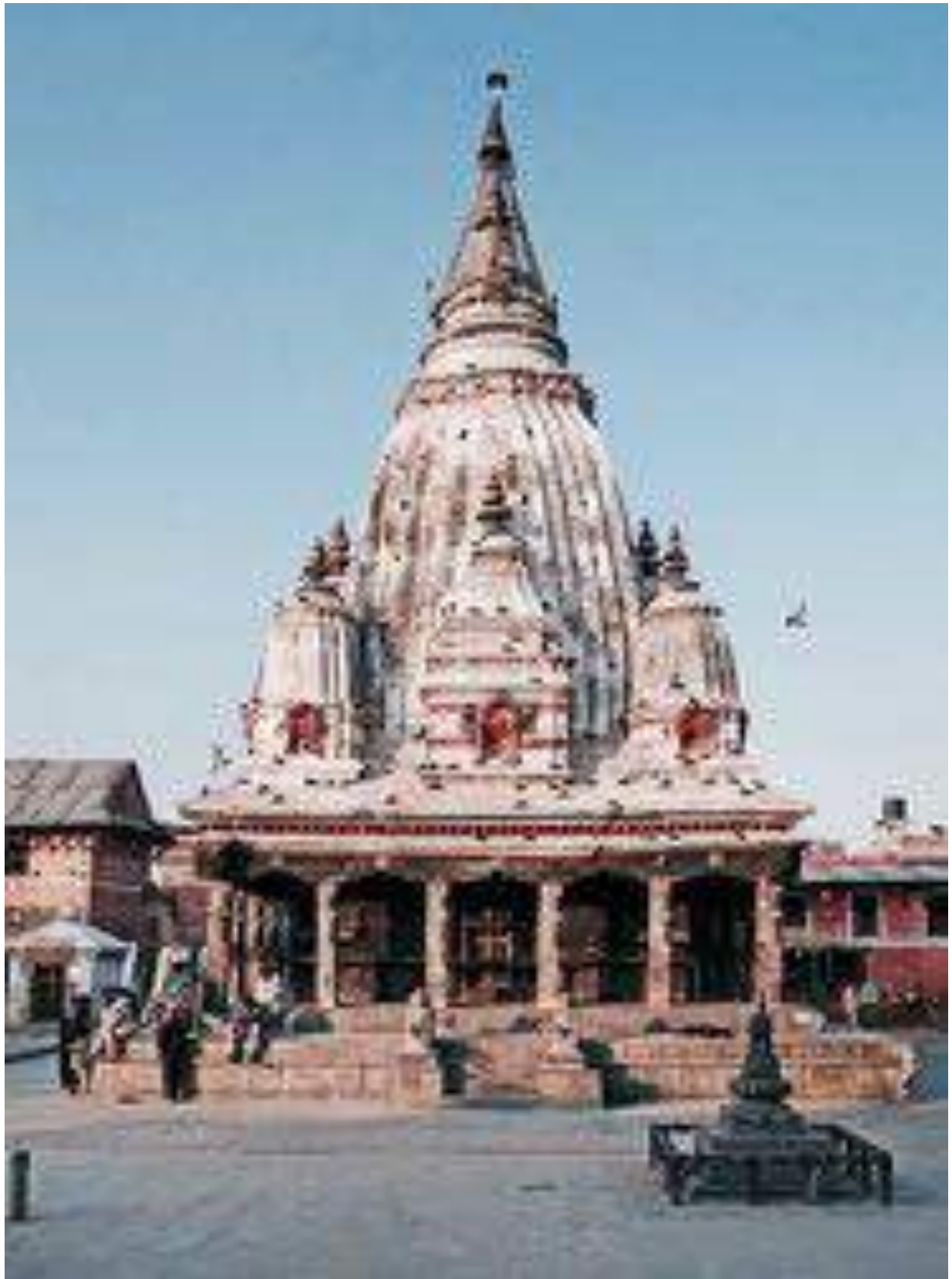
The founding legends

Bungamati

The name Bungamati originates from the words '*buga yumi grama*', which means "god of water resources" and was first mentioned in the year 605 (Gurung, 2000). The founding legend as written in Medieval chronicles can be summarized as follows (Gurung, 2000). For two hundred years, there had been a draught in the kingdom of Kathmandu. Desperate to solve this problem, the king went to a priest for help. The priest told him that a saint had collected all the serpents of the Kathmandu valley, made a seat out of them and had gone into meditation sitting on it. To stop the draught, the serpents needed to be set free, because they are the symbol of water. However, to do so, the saint had to be woken up first and the only one who could do that was his master, *Machhindranath*.

In that time, there were three important settlements in the Kathmandu valley: Bhaktapur, Kantipur (Kathmandu) and Lalitpur (Patan). The king of Bhaktapur, a priest from Kantipur and a farmer from Lalitpur together went on a quest to bring *Machhindranath* to the valley. It was an adventurous route, but eventually they succeeded in bringing the master to the saint. The saint woke up and the serpents were set free, whereupon it finally started to rain again in the Kathmandu Valley.

However, the king, the priest and the farmer were now facing another problem: where would they keep this master? Of course, all three wanted to let him stay in their own settlement, but finally they came to an agreement. They decided to build a new temple for the master, on a new location. The king then brought a hundred families from each of the three settlements to live around this new *Machhindranath* temple, and thus the village of Bungamati came to exist.



The Machhindranath temple of Bungamati
© Dalbéra, 2013



The Rudrayanee temple of Khokana, 2016



Location of Sikali Lawn & old Khokana

Khokana

Khokana is believed to be derived from the word '*Khona*', which means 'telling while weeping/crying'. The legend tells a story about a very sick *Maharjan* priest who fainted because of a high fever. His family believed he was dead, so they decided to take his body to the banks of the Bagmati River to cremate him. By tradition, it was intended to cremate the wife alive together with her dead husband. But when a storm came up, people ran away in order to seek shelter. The man suddenly woke up again and the couple got out of the fire. Because the villagers feared what they just witnessed, nobody wanted the couple to live in their neighbourhood. The couple ran away crying and they settled at a place nearby Sikali Lawn, which is located south-west of Khokana. Later, they moved to a place situated on higher grounds in order to be safe from harassing villagers and floods, and so Khokana was founded.

The Newari social structure & its spatial reflection

The social life of the Newars is strongly guided by the *guthi* system, which, in its turn, is linked to the well-known caste system representing the social status. These social arrangements create a socio-hierarchical structure, strongly influencing the shape of the urban tissue (Müller-Böker, 1988). Therefore, people from the same social group tend to build their houses in close proximity to each other, creating a variety of neighbourhoods, or *tole*. Various *toles* compose a village, like Bungamati and Khokana. These settlements used to belong to a VDC (Village Development Committee), but nowadays are part of bigger whole, called a municipality. Both Bungamati and Khokana are part of the Karyabinayak municipality.

ⓘ + 0,4 km +

Karyabinayak municipality
© Esri, 2017
Adapted from: Brinkhoff
(Population) & LGCDP (Map)



Sainbu

Village: Bhaisepati

Population: 2001 8,337
2011 19,721
(+8.93%/year)

Area: 4.12 km²

Khokana

Village: Khokana

Population: 2001 4,542
2011 4,927
(+0.81%/year)

Area: 3.17 km²

Bungamati

Village: Bungamati

Population: 2001 5,667
2011 5,966
(+0.51%/year)

Area: 3.89 km²

Chhampi

Village: Salyantar

Population: 2001 4,192
2011 4,753
(+1.26%/year)

Area: 5.52 km²

Dukuchhap

Village: Dukuchhap

Population: 2001 2,501
2011 2,669
(+0.65%/year)

Area: 4.91 km²

A hybridified caste system

The caste system, implementing a socio-religious hierarchy, is a well-known principle dominating a lot of different countries (Pant & Funo, 2007). This system originated in the Hindu society, but is widely known for influencing various religions. As Bal Gopal Shrestha said in 2012:

“The main root of the caste system in South Asia is the Hindu *Varnasrama* system, which divides the whole of Hindu society into four social categories.”

However, the caste system keeps expanding. In 1991, sixty caste and ethnic groups were registered, while in 2011 this number had risen to 125, according to the Nepal Population Report 2016.

The Newar caste system represents a hybrid structure, since these settlements are a co-existence of two religions, namely Hinduism and Buddhism.

The structure of the urban tissue as well as the entire social network inside the settlements is dominated by this system. The occupancy of the villagers is strongly linked to the caste system, leading people from the same caste to have the same profession. People from the same caste tend to live close to each other, since this increases the work efficiency (Shrestha & Shrestha, 2008). In addition, “purity” is a leading factor in the relation between various people and the caste system creates a hierarchy of people who are equally or less pure, or even impure (Gray, 2009). Therefore, certain activities cannot be performed with people from other castes, like eating or marrying, resulting in people from the same caste gathering in clusters. By building their houses in each other’s proximity, the social structure and bonds are strengthened. This building in clusters can also be observed in the location of the temporary shelters. Tiny neighbourhoods are created by big families or members from the same caste.

According to the founding legends, the dominant castes living inside a settlement are generally the first ones that inhabited the village. Furthermore, it can be observed that people of higher castes live in the close proximity of the temple, thus in the very centre of the town, while lower castes commonly live in the periphery (Shrestha, 2011). In the past, this hierarchy was very strict, leading to social rules, for example forbidding the butchers’ caste to live within the boundaries of the towns (Gutschow, 2011).

On an architectural level, the houses of the higher castes are generally more decorated since the house represents an important status symbol and there is the tendency to distinguish oneself. Before, there were still other architectural implications: the butchers’ caste was for instance prohibited to build brick houses higher than one story (Gutschow, 2011).

Although the influence of the caste system has diminished over the centuries, it is important to understand its concepts.

BUDDHIST

HINDU

Priest caste

Brahmin

Vajracharya (Guvaju)
Shakya (Bare)

Merchant caste

noble, ruling position

Shrestha

Tuladhar (Uraye)



Farmer caste

servant status

Maharjan
Dangol
Jyapu
Mali

Artisan & service caste

unclear

Malakhar (florist)
Nau (barber)Yogi (death specialist): Kusle & Kapali
Khadgi & Shahi (butchers)
Kasai (Nyae) (muslim)

Untouchable castes (sweepers)



The Kumari of Bungamati playing with a friend, 2016

Bungamati & Khokana

All the illustrated castes are present in Bungamati, however, the three most dominant castes, and thus professions, are *Shakya* (priests), *Tuladhar/Shrestha* (merchants and craftsmen) and *Maharjan* (farmers owning agricultural land) (Gurung, 2000). According to the legend on the origin of the town, these three castes were the first that came to live in Bungamati from Kantipur, Bhaktapur and Lalitpur respectively. The three main ponds of the town, combined with three large open spaces, mark these distinctive communities: *Bhunna*, *Guanna* and *Khanna*. In the overall plan of the town, this distinction is still visible.

Within the highest caste of Bungamati, a special deity is present: one of the ten living goddesses or *Kumaris* inside the Kathmandu Valley lives in the settlement (Allen, 1976). The *Kumari* is the daughter of a single *Vajracharya* family and represents the destroyer of male demons. This *Kumari* is worshipped by all clean castes inside Bungamati.

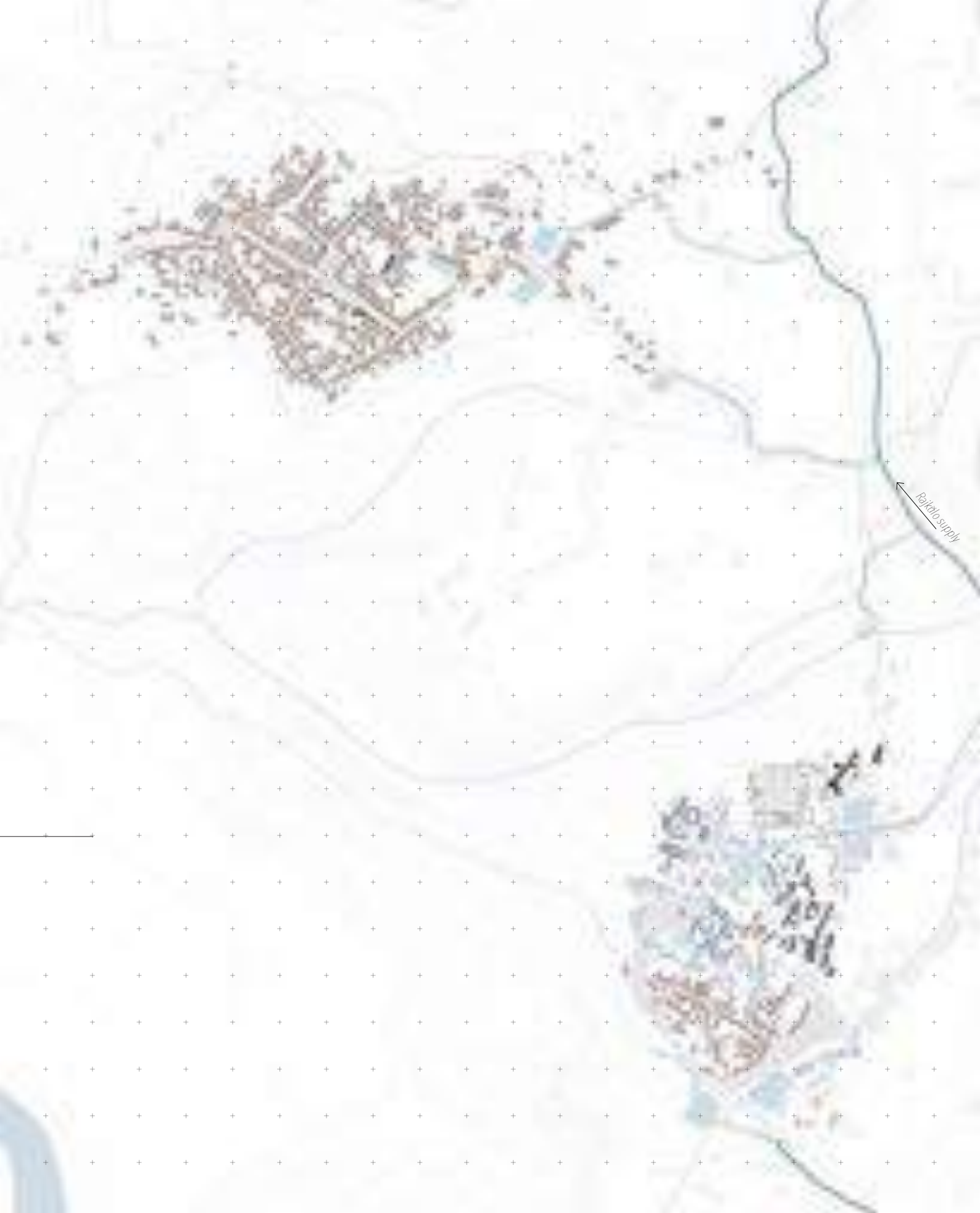
In comparison with Bungamati, the caste system in Khokana is noticeably different. In this tiny settlement 98% of the inhabitants are from the same caste, namely the *Maharjan/Dangol* or farmer's caste (Müller-Böker, 1988).

This caste system also has a clear reflection in means of water management. Both traditional settlements are fed by the royal canal, or *Rajkulo* (Aryal, 2005). However, Bungamati receives water from the *Rajkulo* first. This can be related to the fact that the majority of the people of Bungamati are from higher castes in comparison with Khokana. In addition, within Bungamati, another distinction is visible. The higher castes receive water first, making sure they receive water of higher quality. Furthermore, this makes sure that in times of water scarcity, the higher castes are sure to receive water, while the members of the lower caste have to survive with less or even no water supply.

🕒 + 50 m +

Caste system of Bungamati & Khokana

- Brahmin
- Shakya (Bare)
- Malakhar
- Vajracharya (Guvaju)
- Maharjan, Dangol (Jyapu)
- Kapali
- Kasai (Nyae)
- Shrestha
- Tuladhar (Uraye)
- Unsurveyed





Inside an oilmill in Khokana, 2016

As a reflection of the caste system, the population is mainly composed of farmers, craftsmen and priests. The large number of priests can be explained by the presence of the *Machhindranath* temple, an important deity for the entire Kathmandu Valley.

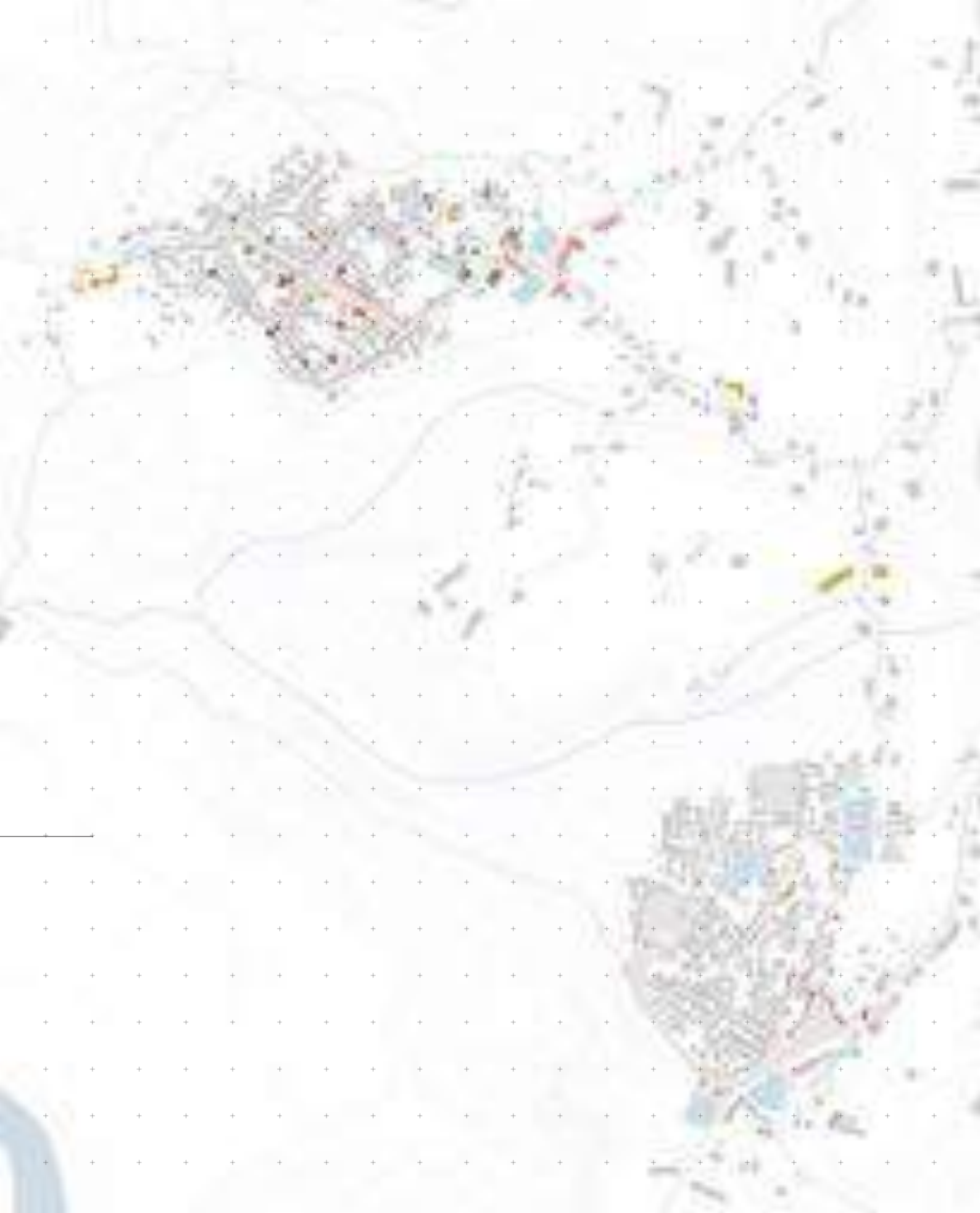
In general, there is a lot of economic activity in Bungamati. It is considered to be a self-sufficient town, where products fabricated within the village are also consumed there (Pandey, 1969). Throughout history, Khokana has always been a centre of economic activity, partly because it is located on a trade route to India (Pandey, 1969). Because almost everyone belongs to the *Maharjan/Dangol* caste in Khokana, its economy is mainly based on agriculture. Every family in Khokana owns approximately two to three Ropani¹ for cultivation.. Another important occupation influences the overall economy of this settlement, namely the oil pressing industry. Khokana is known for its oil mills, using traditional wooden machines to press the mustard seeds. The ancient town used to own four oil mills spread over the settlement, applying an intensive, both manual and electric process in order to provide the finest quality of mustard oil. However, due to the earthquake, only two of the original oil mills are still in use. Nowadays there is little commercial activity, leading to a considerable amount of import and export with the bigger cities.

¹ 1 Ropani = 508 m²

⌚ + 50 m +

Different functions in
Bungamati & Khokana

- Shop
- Restaurant / Café
- Meatshop
- Crafts Atelier
- Sewing Atelier
- Weaving
- Metal Atelier
- Barber shop / Hairdresser
- School
- Oil Mills





A farmer maintaining his land, 2016

Traditional structures on the move

Being a farmer does not only entail agricultural activities. Farmer families often have several family members who take up another profession to earn some extra money (Gellner, 1986). These side jobs are necessary for families to survive because the land they own, an average between one to three Ropani¹, is hardly enough to provide them with food during half of the year. In addition, the various crops that they harvest do not cover an entire year, meaning that the rest of the year they need to have an additional income. Therefore, the grandparents often work in the fields and harvest the crops, while the parents have a job in the city. Examples of these secondary jobs are handicrafts, wool spinning, running a shop or catering service, ... The last mentioned arises during the holidays or festivals, when wealthy people from the capital or larger cities want to invite their entire family for a festive meal. Sometimes farmers then provide a catering service, so that the people organising the feast do not have to worry about cooking.

While in the past people would stay inside their settlement for both living and working, nowadays there is a transition towards more people travelling to the bigger cities for their jobs.

¹ 1 Ropani = 508 m²



Men playing chess in front of a wooden craft shop



Man working in his sewing atelier



A woman spinning wool on a peti in front of her house



A woman working in her craft shop



Women weaving a carpet inside a weaving atelier

Extension of the house

Living area

Shop area
(linked to the
profession)



Building block on the bus park of Bungamati with shops on the ground floors and housing on the upper floors, 2016

The woodcarvers and other craftsmen, such as metal workers or weavers, can be divided into two categories: those who have their own shop, and those who do not. The people that do not own a shop usually have an arrangement with a shop-owner somewhere in the city. They get all the necessary materials and tools for free and can work in their own house. These craftsmen working inside the door opening of their house, represent a charming characteristic of the Newari settlements. It is a typical aspect of the vernacular architecture that the house provides space for both the domestic and working life of the inhabitants. In general, the ground floor is linked to the profession, while the other floors are preserved for daily life. Due to this, walking through the streets immediately gives a glimpse of the various occupancies that are present inside the settlement. However, people in this situation are often being exploited as cheap labour forces. They get paid per produced piece, where the salary depends on how large and detailed the final product is. Nevertheless, the money they earn by finishing a product is far less than the actual value for which it is sold in the city. Therefore, most woodcarvers would prefer to have their own shop, but they often cannot afford it.

The weavers' profession is dominated by women. They often go to a large atelier, usually located in the outskirts of the town, where they can work together with other weavers. They also get paid per piece they make.

People owning a shop either have a room at the ground floor of their house, transformed into a shop and atelier, or they rent a room somewhere else.



Shop on the ground floor of a house in Khokana, 2016



*Weaving atelier on the armature road between
Khokana & Bungamati, 2016*



Ritual performed for the Sikali festival on the main square in Khokana, 2016

The guthi system

The main social structure leading the traditional settlements is the *guthi* system, dating back from the Licchavi period (Pant & Funo, 2007). As Vajracharya explains: “The meaning of the word ‘*guthi*’ is derived from the Sanskrit ‘*Gosthi*’ meaning an ‘association’ or an ‘assembly’” (Vajracharya, 1998).

It refers to a group of people within a community or town, based on territorial proximity or religious association (Pant & Funo, 2007). The *guthis* are strongly intertwined with the caste system, meaning you get born into a *guthi*. This results in several *guthis* with their own rituals and rules of worshipping. They take the responsibility of organizing common activities and bring specific rules to the community to achieve a common objective (Pandey, 1969). It is a well-functioning structure, based on solidarity where every member is part of the association and has his own liability in order to succeed in living together as a group.

Nowadays, three different kinds of *guthis* can be distinguished (Quigley, 1985). Firstly, there are the *de guthis*, who are responsible for the festival rituals. They take care of the maintenance of religious monuments and the organization of a festival with money they earn from the harvest of their agricultural land. Every *de guthi* assembles once a year to worship the deity representing the ancestors. These *guthis* own individual buildings that are used once a year for a feast.

Secondly, the *si guthis*, are responsible for the funerary rituals. When a member of a *si guthi* dies, at least one representative of every family belonging to that *guthi* has to be present at the funeral. If not, they must pay a fine that will be used for the maintenance of the *guthi*. If such absence repeated, expulsion from the *guthi* will be requested (Quigley, 1985).

Becoming a member of a *si guthi* is very strict and happens through family (Gurung, 2000). If a father is already part of a *si guthi*, his children will be a member of this *si guthi* to in the future. In general, only the head of a household is inscribed in a *si guthi* (Quigley, 1985). Once a family splits up, for example when there are two sons who each start their own family, there needs to be a member from each new family in the *guthi*. It is possible to join a different *guthi* than the one your family used to be part of, however, this is highly unusual. In this case, a fee must be paid and a feast for the existing members should be organised in order to merit your position within the *guthi*. The most important criterion for entering a different *guthi* is the caste someone belongs to. People from a lower caste can exceptionally join a *guthi* from a higher caste, but sometimes this leads to internal problems and it will be very expensive. In Bungamati, *guthis* have been split up because for example a *Maharjan* joined a *guthi* of *Tuladbars*.

The *si guthis* have a strong spatial reflection and therefore have an impact on the development of the urban tissue. Members from a *si guthi* tend to live closely to one another, since this is more expedient when handling corpses.

The third kind of *guthi*, the *temple/festival guthi*, is more of voluntary kind and generally carries the name of the deity to whom a temple of the settlement is dedicated (Quigley, 1985). These *guthis* organise and fund an annual festival to worship the deity of which they carry the name. In addition, they are responsible for the maintenance of the temple.

Every household has to be part of both a *de guthi* and a *si guthi*. If this is not the case, a household will be considered exiled.



Morning rituals on the main square in Bungamati, 2016



The god Pegasus during Dashain in Bungamati, 2016



The *guthi* system in Bungamati is rather extensive. Most *guthis* are linked to a specific caste, but for the *si guthis*, there are often multiple *guthis* per caste. For the *de guthis*, the system is slightly different (Gurung, 2000).

Usually, every *guthi* owns land, but in general the *de guthis* own more land than the *si guthis*. The *si guthis* only own land if it is donated by a rich member, whereas the *de guthis* need land so they can use the income it generates to pay for worshipping rituals. In Bungamati there are several *de guthis*, most of which own large parts of collective land, all in showing important differences, as can be derived from the below details. The *Falcha guthi* is a rather exceptional *guthi*, because it does not own any land, only funds. It is a *guthi* from the Shrestha community. The *Bhairav guthi* then, owns 1 200 Ropani¹ of land. This covers an entire hill in the south of Bungamati. Further, the *Paneju Khandi guthi* owns 365 Ropani¹ of land in the northern part of Bungamati, known as *Nakkei Port*. It is a part of the land that is linked to the *Machhindranath* temple. This *guthi* in particular is responsible for the *Red Machhindranath* festival. The *Wasi guthi* owns 144 Ropani¹ of land. This parcel also belongs to the *Machhindranath* land, as do the 12 Ropani¹ belonging to the *Kurle guthi*. Finally, the *Damara* and the *Praja* own 12 and 64 Ropani¹ respectively.

The fact that the *guthis* own agricultural land sometimes led to problems in the past. This is because occasionally, the land of a *guthi* can be used by the members of the *guthi* to cultivate their crops, and over time the users of the land start to claim it as their own. This has led to loss of property for several *guthis*.

¹ 1 Ropani = 508 m²

⌚ + 50 m +
Map of Khokana with the different *guthis*

- Rudrayanee *guthi*
- Ta *guthi*
- Salan *guthi*
- Ja *guthi*
- Si *guthi*



Khokana

The majority of the inhabitants of Khokana belong to the same caste, so there is no differentiation within the various *guthis* and their caste. There is also no clear pattern in the localization of the members of one *guthi*; they are scattered around the entire settlement.

In Khokana there are three de *guthis*: the *Ta guthi* (the largest one), the *Salan guthi* and the *Ja guthi*. The buildings of the de *guthis* are all centred around the same public square, namely the Kwe Lachhi. This square, as well as the *guthi* system, plays an important role in the religious rituals.

For the death rituals, the inhabitants have five associations instead of three. The *si guthis* that are present in Khokana are the *Ta guthi*, the *Salan guthi*, the *Ja guthi*, the *Tami guthi* and the *Nbugu guthi*. These *si guthis* only have two buildings, which are used collectively.



Symbols of the Ja guthi, Salan guthi & Ta guthi



Inside the Salan guthi



Square surrounded by the guthi buildings in Khokana



Two of the living gods of Khokana on the Sikali jatra, 2016

Khokana also has a festival *guthi*, the *Rudrayanee guthi*, named after the deity worshipped in the main temple of Khokana. This *guthi* consists of 46 (male) members, who are the living gods of Khokana. Within this group, there are 14 masked gods, who are the living representation of the following gods: *Bhairav*, *Kumari*, *Shakti*, *Brahma*, *Vishnu*, *Mahadev*, *Barahi*, *Kali*, *Kumar*, *Ganesh*, *Hunaman*, *Indrayani*, *Rudrayani* and *Mahalaxmi*. Out of these gods, only *Bhairav*, *Kumari*, *Barahi* and *Kali* can drink blood from offered animals. Furthermore, there is one unique unmasked god, the trembling god, that is allowed to drink blood as well. Understandably this *guthi* plays an important role in the organization of different festivals.

If someone of the *Rudrayanee guthi* dies, the spirit of that god along with his task is transferred to the son. When becoming a god, it is mandatory to organize a big feast for all the members (*Rudrayanee guthi*. Personal interview. 2016, October 10). Within the *guthi*, there is a smaller group, called the *Mahankel*. This group consists of five members who are responsible for the management of the festivals.

The *Rudrayanee guthi* used to own a hundred Ropani of land outside of Khokana in between the Rudrayanee School and the Sikali Lawn, but half of its property was sold because it faced a small economic crisis. The grain that they get out of this land is used for common feasts and festivals.

One of the masked gods performing a ritual dance during the Sikali festival, 2016





Connection
circulation through settlement

Shadow
community space (gathering,
resting, washing, playing..)

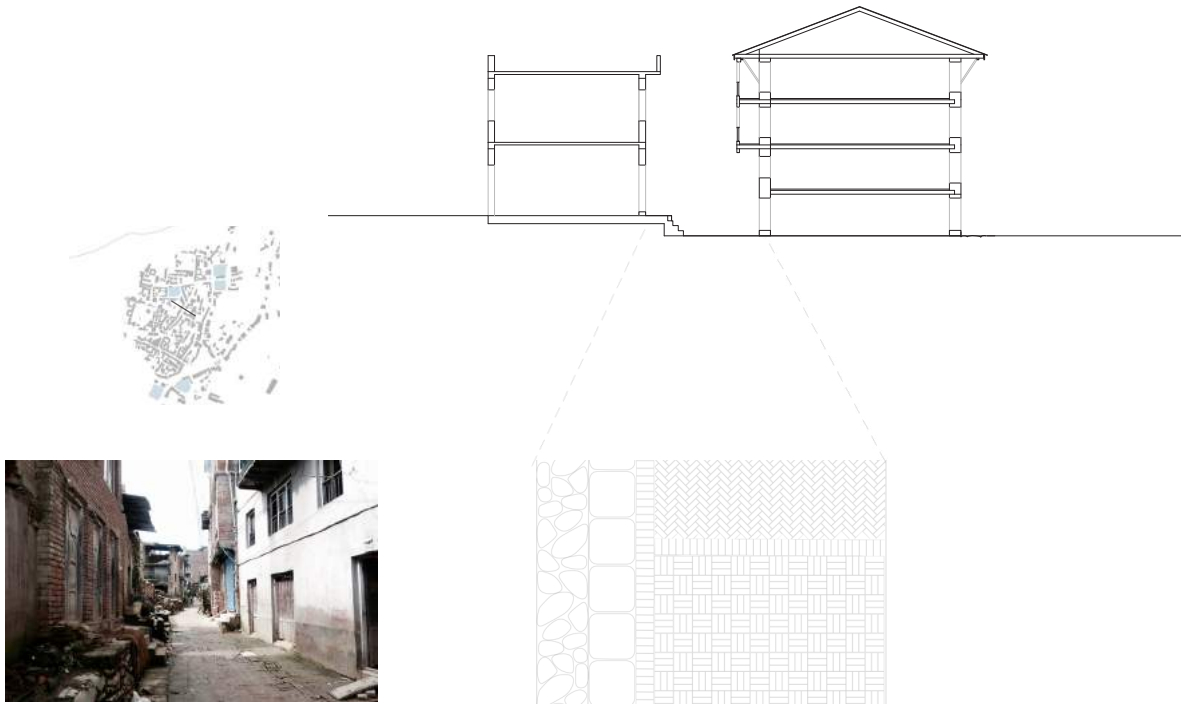
The maze of open spaces

The urban tissue of the towns is defined by two key elements, forming the backbone of Newari settlements and reflecting a varying degree of privacy. First, there are blocks of closely built Newari houses, commonly bundled around inner courtyards and kitchen gardens. Secondly, the public squares, connected by a network of streets, unite the various building blocks (Shrestha, 2011). The various open spaces, ranging from the maze of private kitchen gardens and courtyards to public open spaces create a unique urban tissue that results in a productive village answering the needs of every household (Manandhar & Parajuli, 2015). The inhabitants of the settlements behave as a real community and their daily life is primarily taking place in the open air. Therefore, open spaces play an important role for the daily activities. In order to optimize their use, the design is strongly linked to climate, either by natural or architectural elements. The different dimensions are based on the principle of shadow, generated both by surrounding houses and trees.

⊙ + 50 m +

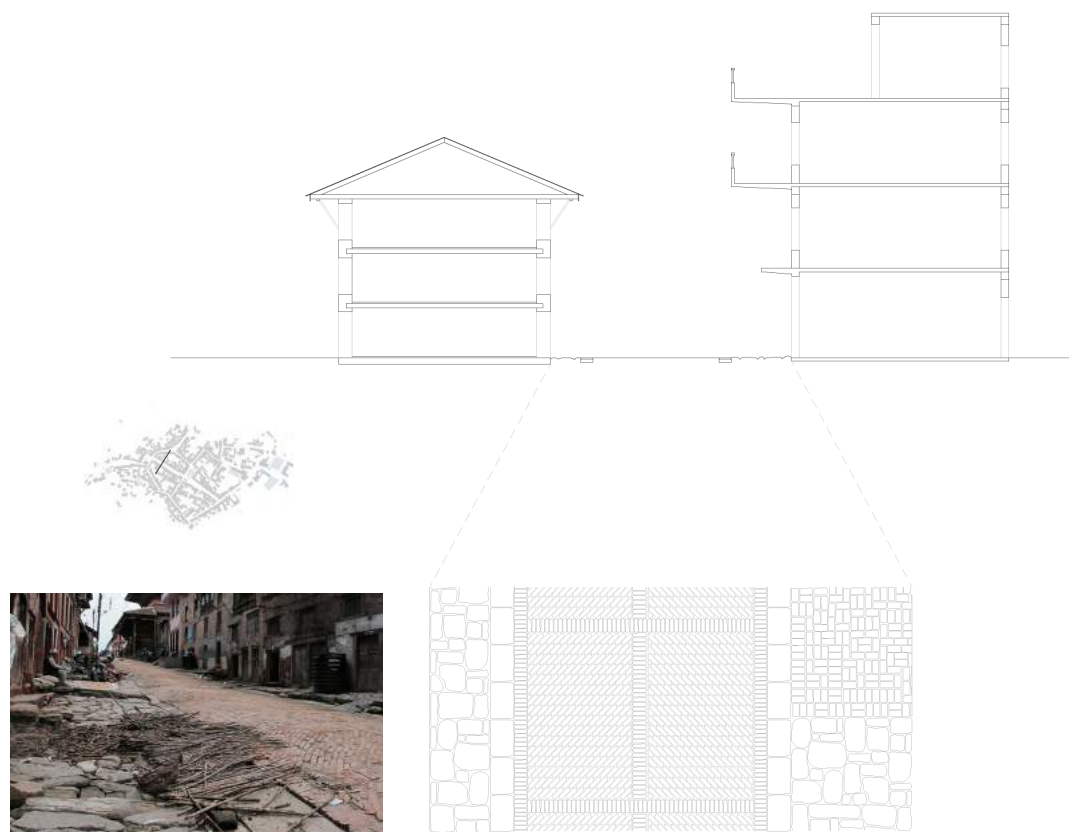
*Open spaces in Bungamati &
Khokana*





The street network forms an important part of the open space, serving both as connector and community space for a variety of social and religious events. In this concept, the division between street and building is not as strict as seen in the western part of the world. Between the streets and the buildings, there is a certain transition zone or threshold, shaped by a different kind of pavement or even an elevated plinth, or *peti*. These *petis* are always crowded with people, creating a lively atmosphere. The *peti* also has a constructional significance: by elevating the entrance of the houses, they are better protected against floods.

The street network shows an obvious hierarchy. It is based on the order in which they came into being and is indicated by the width of the streets as well as the presence of some sort of pavement. The main streets, which are wider and commonly located at the centre of the historical town, indicate the original structure of the traditional town. Different opinions arise regarding the question whether traditional settlements were planned or the result of organic growth. However, when looking at the plan of both Patan and Khokana, the swastika, a typical Buddhist symbol, is clearly noticeable. This leads to the conclusion that there must have been some sort of planning principle. The main, traditional roads are commonly paved either with bricks or (modern or ancient) flagstones. Within one street a variety of pavement is visible, marking the boundaries between private and public spaces.



Old flagstones



Brick



Modern flagstone



Concrete surface



Sand

Historical core area

Latest expansion



Dug gutter around shelter



Lowered part of the road



Gutter of inclined bricks



Fully covered sewage system

The other type of streets were influenced by a later expansion of the settlement due to urban growth. When the settlements started to expand, farmer routes were widened, resulting in rather organic pathways. These secondary roads can be divided into two types. The streets alongside the core area have been paved over the years with bricks or flagstones, while the streets accessible by cars are usually covered with a concrete surface. The narrower streets, a result of more recent expansion, and thus generally located at the edges of the settlements, are rarely paved, which results in sandy or muddy lanes.

The various types of pavement and the water management within the settlement are strongly related. The sandy lanes are perfectly permeable, allowing infiltration of water when it rains. This water infiltration in its turn, results in ground water recharge which is crucial for the water provision of the settlement. However, the roads that are surfaced by man, influence the behaviour of the water. The paved roads are less permeable, preventing to some extent the process of infiltration. In case of roads paved with flagstone or bricks, the infiltration can still occur in the mud joints between the pavement. So, the bigger the joints, the more water can infiltrate for groundwater recharge. Conversely, the more recent, modern roads which are covered with concrete do not allow infiltration and make the water flow down according to the topography.

In addition, paved streets usually have a gutter, in order to lead abundant water away from the street network. The water is generally transported to the ponds of the settlements, or through the rice fields to the rivers situated on lower lands. In the existing situation, the sewage water as well as the clean rainwater are transported together.

Various constructions of gutters can be observed: fully covered sewage systems, to prohibit waste from getting in, or gutters existing of just a small, lowered part of the road. The unpaved streets, located next to houses or temporary shelters come with more rudimentary, dug gutters.

⊙ + 50 m +

*Bungamati & Khokana with
indication of different pavements
& waterflow*

- Flag stones
- Red bricks
- Concrete
- Unpaved





Festival route in Khokana with a part of the old pavement preserved, 2016

This hierarchy of pavement as well as the width of the streets is also strongly based on religion. The wider roads represent certain routes related to processions, where gods have to be able to travel, whereas roads merely used by humans are narrower (Singh S. Personal interview. 2016, August 21). In the Newari tradition two fixed routes are defined, the festival route and the funeral route, followed during a festival and funeral respectively. In Khokana the significance of these routes is clearly expressed, the festival route being paved with traditional flagstone. When the town decided to renew the pavement, the middle strip of the street was preserved in traditional flagstone, while the outer parts were replaced by modern flagstones. These religious routes are remarkably important in case of a natural hazard (Manandhar & Parajuli, 2015). By following these routes when participating in festivals, the inhabitants become familiar with the network of open spaces and streets. In this way, they know their options and escape routes in case of a natural disaster. In addition, the highest priority is assigned to cleaning up these roads after an earthquake.

⊙ + 200 m +

Funeral routes (brown) & festival routes (red) in Bungamati & Khokana. Source: Tomoda, 2016



Road to Patan

Sikali temple

Shikali temple

Cremation site

Bagmati River

Nakhu River

Rudrayanee temple

Cremation site

Karyabinayak temple

Machhindranath temple

Cremation site



Chariot of the Rato Machhindranath
© Joshi, 2008



Ritual dance on the Sikali jatra performed by a member of the Rudrayanee guthi, 2016

Rato Machhindranath Jatra | main festival of Bungamati

A “*jatra*” is a festival devoted to a specific deity. *Rato Machhindranath* or “*Red Machhindranath*” is the god of rainfall (Pujari, 2014), therefore this *jatra* takes place before the monsoon, between April and May. The entire festival lasts about a month, but the final day is the most important one.

Machhindranath has several temples in the Kathmandu Valley and one of the most important ones lies in Bungamati, where in the past this festival was held every year. The image of *Macchinadranath* was put on a chariot and carried around the town. Nowadays the *jatra* has shifted to Patan, where the celebrations still take place once a year. The chariot is carried all the way to Jawalakhel and on four different locations animals are sacrificed. Afterwards, the deity is brought to Bungamati to rest there for six months. Around November or December, he is brought back to Patan (Gurung, 2000). He thus lives half of a year in Bungamati and the other half in Patan. It is only every twelve years that the original festival is held in Bungamati as it used to be. On this occasion, the chariot is built in Bungamati and then carried all the way to Patan, to be brought back again to Bungamati at the end of the festival. The chariot is then demolished, except for one part: a curved shaft that is seen as sacred and kept by the *Paneju Khandi*, which is the *guthi* responsible for the *Machhindranath* festival.

The chariot in its totality is constructed by the villagers themselves, where every caste is responsible for the construction of a specific part of the chariot.

The Sikali Festival | main festival of Khokana

One week before the Nepali *Dashain* festival, the people of Khokana celebrate their own unique five-day festival; the *Sikali Jatra* which is short for *Siddhikali*, a representation of Parvati (Pruscha, 1975). This festival is based on the principles of tantric Hinduism, more specific the legend of lord *Shiva*. The various *de guthis* are all present at the festival, with their own worshipping rituals. The *Rudrayanee guthi* plays a fundamental role in this festival.

On the evening of the first day of the festival three buffalos are sacrificed, one by each *de guthi*. The intestines of these buffalos are conserved in order to use them as necklace for the god Bhairav.

The second day of the festival is called *chholabu*. On this day, every *guthi* prepares the meat from the offered buffalos to have a big feast.

On the third day, the goddess *Rudrayanee* descends from the temple to the palanquin. Another buffalo is sacrificed by one of the living gods of Khokana. After this ceremony there is a concert on the Kwe Lachhi.

On the fourth and most important day of the festival, the procession of the *Rudrayanee* goddess to Sikali Lawn is carried out. Sikali Lawn, which is situated at the west of Khokana, is the place for ancestral worshipping. Once the goddess has arrived there, all the inhabitants worship her in the Sikali temple. In the afternoon, the fourteen masked gods perform dances, which are based upon the story of *Shakti* and lord *Shiva*.

Later that day the shrine of *Rudrayanee* is brought back to the settlement and is placed inside the temple of the Kwe Lachhi. The 46 gods walk around Khokana to worship various houses of the town by offering ducks in front of them.

On the fifth and last day of the festival, the living gods dance around the festival route inside the settlement. To conclude the day, the last dances are performed on the Kwe Lachhi.





Gods being carried through the streets of Khokana during
Sikali festival, 2016

Shiva and Shakti are husband and wife, but the father of Shakti is not pleased, because Shiva is not a normal man. He is a god, who does not wear clothes and scrubs his skin with ashes. In an attempt to break up the marriage, the father creates another god, Mahadev. When the relationship effectively breaks up, Shakti commits suicide. Mahadev is so shocked that he decides to console Shiva with the help of the other gods. (Rudrayanee guthi. Personal interview. 2016, October 10)



Nowadays, streets usually represent a means for transportation and traffic. However, the core of the villages emerged long before the existence of vehicular transport, resulting in traffic-free roads. Narrow streets and, in the case of Bungamati, several stairs make the core of the settlements almost inaccessible for cars. The only form of motorized transport observed in these rural settlements consists in motorcycles, and occasionally some cars, minimizing its impact on street life. In order to cope with the advent of vehicular traffic, both Khokana and Bungamati have a bus park located at the edges of the villages.



Vehicles using the streets in Khokana, 2016



Bus park Khokana, 2016



Main road in Bungamati towards the Machhindranath temple, 2016



Private courtyard in Khokana, 2016



Kitchen garden in Bungamati, 2016

In traditional Newari settlements, the urban fabric of streets and squares is typically refined by the presence of a network of inner courtyards and kitchen gardens. Both Khokana and Bungamati can be categorized as ‘courtyard villages’. The network usually consists of narrow alleys and small corridors, often hidden behind an entrance door of a house, leading to a diversity of courtyards and kitchen gardens. These courtyards are very important in the daily life of the inhabitants and serve many purposes. In general, two types of courtyards can be distinguished: the open courtyards, or *nani*, and closed courtyards, or *babil* (Shrestha, 2011). The public spaces as well as both types of courtyards form an important extension of the street network.

⌚ + 50 m +

Vegetation vs openspace
Bungamati & Khokana

- Forest tree
- Large/tall tree
- Small tree
- Fruit tree
- Bushes/weeds
- Flowers
- Rice fields
- Cornfields
- Kitchen garden



Private courtyard

Kitchen garden



Collective courtyard in Bungamati, 2016



A maze of public spaces in Khokana, 2016

One of the main advantages of a settlement with courtyard houses is the ability to create a denser urban fabric (Rapoport, 2007). Looking at the inverse map of both Bungamati and Khokana, there is a noticeable difference in the urban tissue of the twin villages. Khokana clearly has a more advanced network of little courtyards, allowing a more efficient use of space and the optimal preservation of agricultural land (Mathema, 1999). As a result, this smaller village counts almost as many inhabitants as Bungamati. Bungamati in its turn has a less extensive network of courtyards and a larger variety of large open spaces in combination with an abundance of small kitchen gardens. This difference could be explained by the fact that the degree of privacy is status related. Khokana is primarily inhabited by the *Maharjan* caste, while Bungamati is composed of relatively higher castes. People from higher castes can afford a larger degree of privacy, resulting in bigger private courtyards. On the other hand, the lower castes are more likely to share a courtyard with various neighbours. In addition, the higher castes are more likely to invest in proper, individual vegetable gardens, which is clearly tangible in Bungamati.

Because the entrances of the courtyards are to some extent hidden, passers-by do not immediately notice a lot of the inner courtyards. Although the corridors leading to the courtyards are never locked and therefore accessible for everyone, the small access routes give them a more private atmosphere. As a result, the boundaries between private and public properties are vague, leading to interesting subzones.

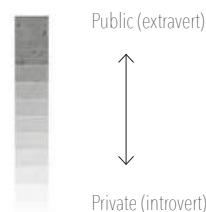
Another significant value of the courtyards is the fact that they offer a certain degree of protection in these areas vulnerable to earthquakes. As has been shown worldwide, the open spaces between buildings play an essential role both during and after the earthquake (Allan & Bryant, 2010). In courtyard villages, the courtyards are connected by numerous passages, creating numerous escape routes even if some of them are obstructed. Therefore, every household immediately has access to an open space in order to get away from collapsing buildings. This open space not only acts as a refuge, but also as a temporary home, as can be seen in Bungamati. Plenty of day to day activities are arising from the emergency situation, creating what can be called a 'second city'.

For the further discussion of these open spaces we work with a division in five categories (public, semi-public, semi-private, collective and private).



⊙ + 50 m +

Privacy gradient in Bungamati & Khokana







temple



stupa



pati



chaitya

Elements that define the public courtyards

The public courtyards can be defined as larger public spaces or squares and are usually designed with a view to shadow. Squares form the fundamental basis for the settlements. They were originally built in close relationship to chariot processions, as they form fixed locations where the procession begins, pauses or ends (Shrestha, 2011). The strong link between spaces and religion is also marked by the fact that the majority of the squares contain an image of a deity and are used to perform religious dances during the festivals on the square platforms, or *dabali*. These public spaces, in addition to the streets, form an important location for the collective life inside the settlements, connecting a diversity of activities. They are used by every inhabitant of the settlement, hosting different groups at different times during the day.

As mentioned before, Bungamati comprises more of this type of courtyards. They are often characterized by a Buddhist *chaitya*, a little Buddhist temple or a *stupa* where people can pray and perform their daily rituals. Every morning and evening, women go to the temples and *chaityas* to offer rice, flowers or food. Furthermore, these courtyards are used for collective water supply, since not every house is connected to the municipal water pipeline. The tanks, spouts or wells at the sides of the courtyard are used by the inhabitants every morning to wash themselves and to fill the household cans with water. Also during the day women often jointly wash clothes at the courtyards. Another important use of the courtyards takes place during the harvest. Since most of the villagers farm their own agricultural land, there is need for a place to dry the crops during harvest season. Not every house has its own garden or private courtyard, so the crops can dry in the public and shared courtyards too. In the aftermath of the earthquake, the courtyards have also been used for the storage of recyclable building materials.



Flow of people in Khokana, 2016

- Public space
- Buildings
- Ponds
- 4 Wheelers
- 2 Wheelers
- Concentration of people



Flow of people in Bungamati
Source: Amir, 2015



Morning rituals in Bungamati, 2016



Morning market in Khokana, 2016



Although the larger public spaces are discussed as one type, both settlements have an obvious main square. These squares are commonly marked with an impressive temple, but the *Machhindranath* temple in Bungamati collapsed during the earthquake of 2015. Given the importance of this building, the whole community is intensively working to rebuild their monument.

The main square forms the lively centre of the settlement and is generally very crowded, especially in the morning and evening because offering rituals are performed at the main temple. In addition, in the case of Khokana, a fruit and vegetable market is organized. Particularly during the festival period, the square is crowded with people sitting together to sing or make music.

⊙ + 3,5 m +

Map of the main square of Bungamati with detailed pavement





The semi-public courtyards are accessible by everyone, but they differ from the public spaces because they are only accessible by a small corridor underneath the first floor of the houses, marked by a door opening. Therefore, they are only frequently used by villagers living nearby or by people who need to be there for a specific reason. They often have a *chaiya* where the morning rituals take place and a water tap or tank to provide water for the nearest houses. Since most of these courtyards have a considerable width, they are also frequently used as a storage place for building materials.



Semi-public courtyard in Bungamati, 2016

Semi-private courtyards are like the semi-public ones, except that they are smaller in size. And even though entering them happens in the same way, the feeling to be intruding is stronger when accessing them. In some cases, they are less easy to access because they lie beneath street level and are thus more hidden from people passing by, or there is an actual door to offer some privacy.



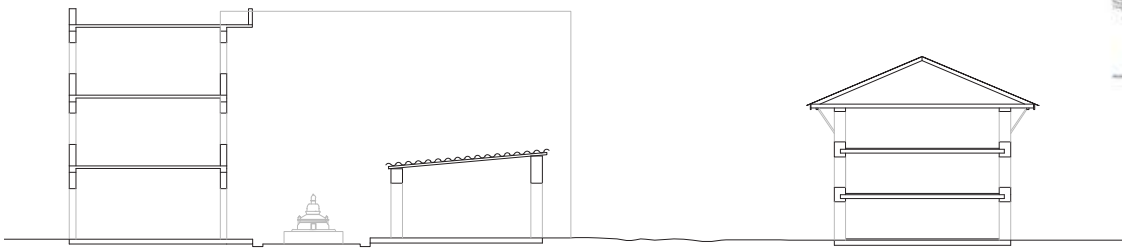
Semi-private courtyard in Khokana, 2016

All of the above described courtyards can be categorized as open courtyards, or *babil*, while the following ones rather are closed courtyards, or *nani* (Shrestha, 2011). The collective and private courtyards are courtyards which are linked to one or several specific houses and function more as introvert spaces. They are only accessible by the inhabitants living directly around them, be it one family or a group of families sharing a collective courtyard, since the access to the courtyard crosses their houses. These courtyards are often characterized by little cupboards for the shoes, a water tap or tank and dishes collected on the ground.

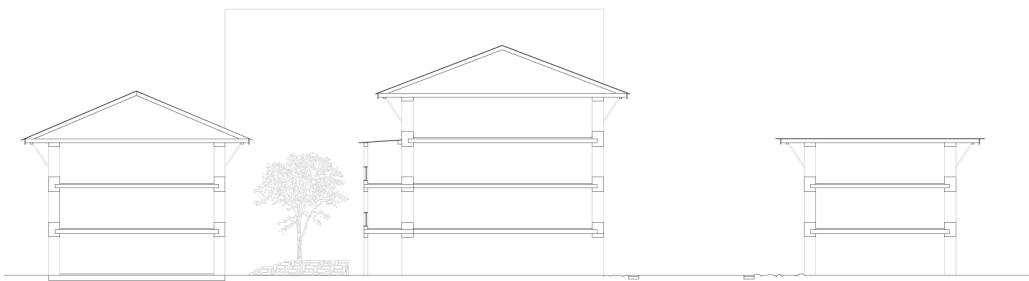
The private courtyards can also occur in the form of courtyards inside the houses. This housing typology used to be owned by wealthier families in the past, but nowadays it has almost entirely vanished.



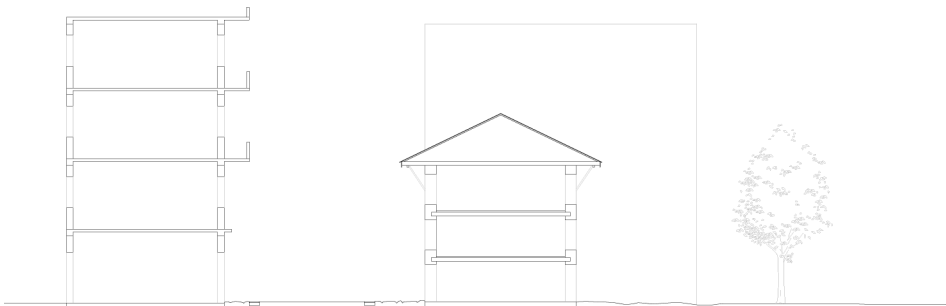
Closed courtyard in Khokana, 2016



+ 3 m +
Section through semi-public courtyard



+ 3 m +
Section through semi-private courtyard



+ 3 m +
Section through closed courtyard





Kitchen garden in Khokana, 2016

However, it is the combination of the diversified natural environment and the man-made environment that expresses the exceptional value of the Kathmandu Valley's settlements (Pruscha, 1975). At the outskirts of the village forests and vegetable gardens alternate. Further away, the settlements are surrounded by large surfaces of agricultural fields, used for planting rice or mustard according to the season and representing an important share of the economic value of the towns. The hillocks used to be fully covered with forest trees, however a lot of these forests were replaced by manmade structures. The remains of the forest now surround the settlement and offer a certain degree of protection (Thapa & Murayama, 2010). However, plants are not limited to the surroundings of the settlement. Within the urban tissue, behind and in between numerous Newari houses lie the kitchen gardens. Their crops are used for cooking as well as the morning rituals and offerings. These crops form a large part of the planting and create some openness in the dense tissue. However, the amount of kitchen gardens is decreasing noticeably because after the earthquake the space is being used as a building plot for the temporary shelters.



⌚ + 50 m +

Vegetation map of Bungamati & Khokana

- Forest tree
- Large/tall tree
- Small tree
- Fruit tree
- Bushes/weeds
- Flowers
- Rice fields
- Cornfields
- Kitchen garden





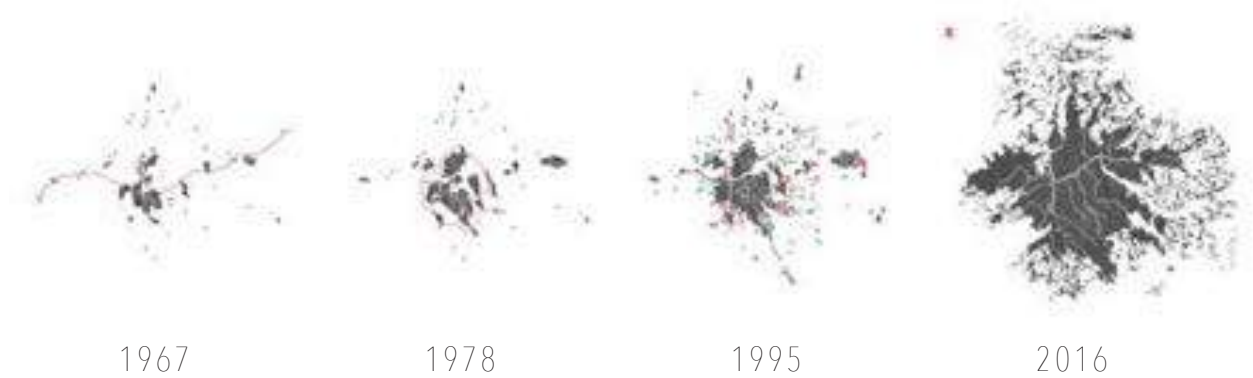
V.

The Newari seismic building culture challenged

Urban trends have caused a rise of new typologies, complementing the traditional Newari architecture. At the same time, earthquakes and the response to this natural disaster have drastically changed the urban tissue. This has led to heterogenous streetscapes with a variety of indigenous building forms such as the numerous temples, patis, water spouts, ... in addition to modern buildings and temporary structures.

Main road of Khokana showing the mixture of architectural typologies.





*Urban growth evolution Kathmandu Valley.
Source: Amaya Marin et al., 2015*

Urban sprawl & typologies

Transformation of the urban tissue

The revolution of 1951, and the ending of the Rana dynasty, led to several political and socio-economic changes that contributed to the commercialisation and modernisation of Kathmandu (Chitrakar et al., 2016; Jigyasu, 2002). The Kathmandu Valley started to expand rapidly, which also reflected in the population growth. From 1952 to 2001 the population grew with more than 500% (Singh & Pawel, 2016). The expansion of infrastructure networks and increasing migration played key roles in this matter (Chitrakar et al., 2016).

While urban growth puts much pressure on the larger cities, it also influences the rural landscape and the fringes of the cities. A strong need for more houses spread out towards the traditional settlements (Thapa & Murayama, 2010). The result was a rise of sprawl in between the existing tissue during the second half of the 20th century. While in the Malla and Shah period the traditional settlements showed a very isomorphic landscape, this has changed since the borders opened to the western world (Gallagher, 1992). It was during the Rana dynasty that Nepal first gained western influences in its architecture, and this trend drastically increased when the borders opened and the country became acquainted with reinforced concrete (Sengupta & Upadhyaya, 2016).

*View over the Kathmandu Valley,
2016*





*New development next to Bungamati
by real estate developers*

These elements have clearly altered the urban fabric of the traditional settlements over the years. The new houses no longer follow the traditional building practice of streets, houses and courtyards. Sometimes the contemporary architecture is placed amidst the existing houses, but much more often a whole new area or street is formed, expanding and transforming the former borders of the Mandala to a more fragmented shape. In the larger cities, so-called gated communities exist as well. Larger houses that are not a part of the gated communities usually have a fence or a wall. In the smaller, traditional settlements or the historical part of the larger cities, this trend is not so prominent.



Urban growth evolution around Bungamati & Khokana.
Source: Bruneel et al., 2016



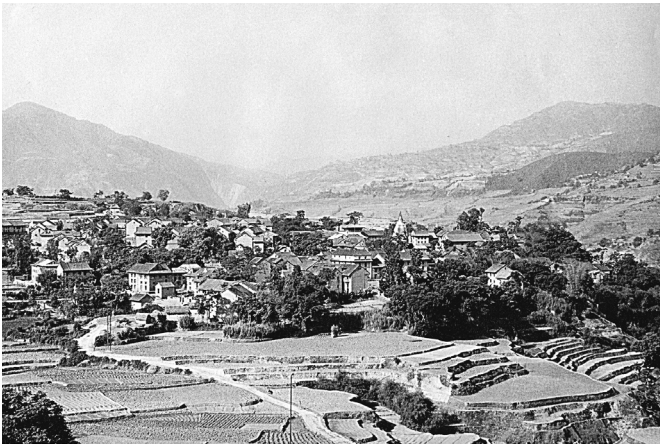
Sprawl alongside the armature road between
Bungamati & Khokana, 2016



Panorama of Khokana 1968. Source: Danish architect students, 2015



Panorama of Khokana, 2016



Panorama of Bungamati 1968. Source: Danish architect students, 2015



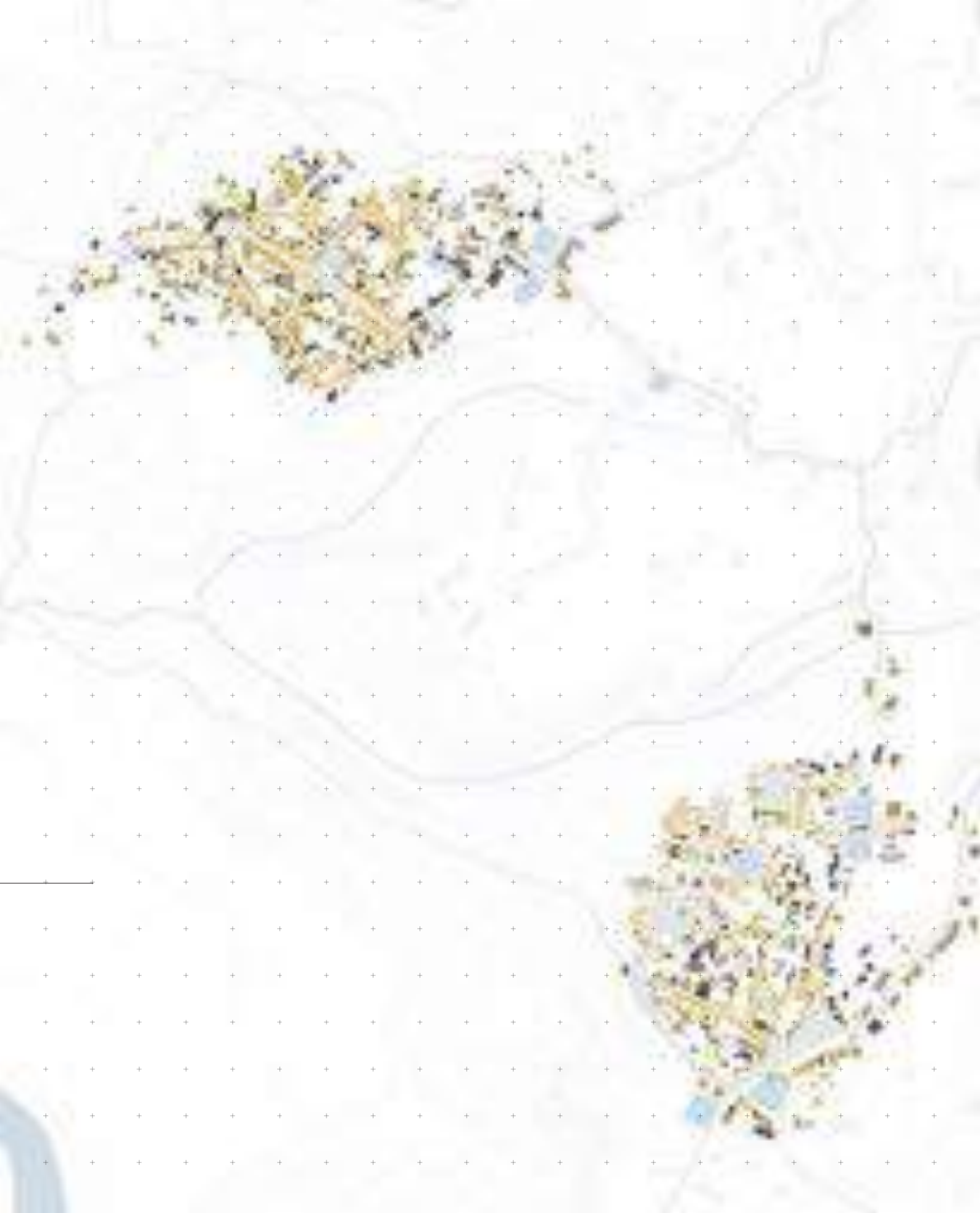
Panorama of Bungamati, 2016

The Newari settlements are described as historical centres, characterised by many building forms, like temples, *patis* and a traditional water supply, typical for the traditional Newari architecture (Jigyasu, 2002). Nowadays the villages are composed of a mixture of both modern and traditional buildings, representing a multi layered settlement. However, the traditional architecture clearly forms the basis of the settlements.

⌚ + 50 m +

Different typologies in
Bungamati & Khokana

- Traditional Newari
- Traditional Newari w/ extension
- RCC w/ masonry in frame
- RCC w/ masonry before frame
- RCC w/ plastered facade
- Namaste
- Modern w/ loadbearing masonry
- Unsurveyed



Overview of the various typologies

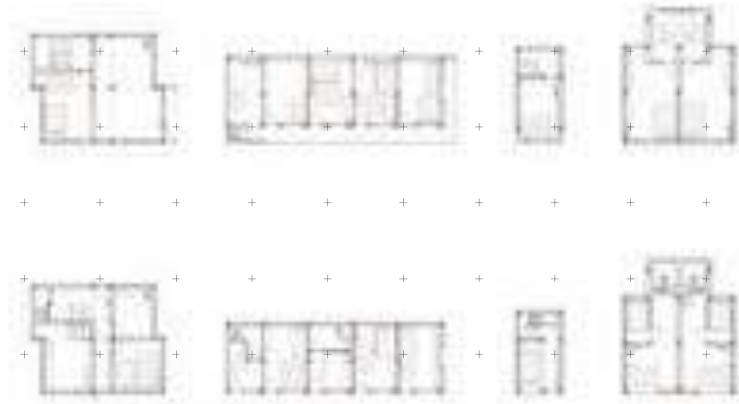
PART 1

Traditional Newari

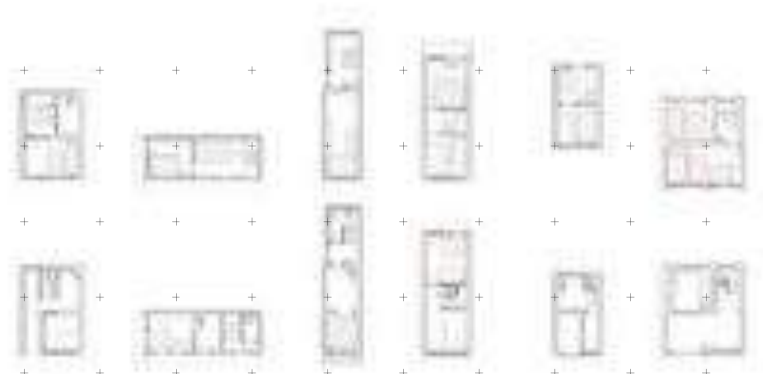


PART 2

RCC
Masonry in frame



Loadbearing masonry



PART 3

Shelters



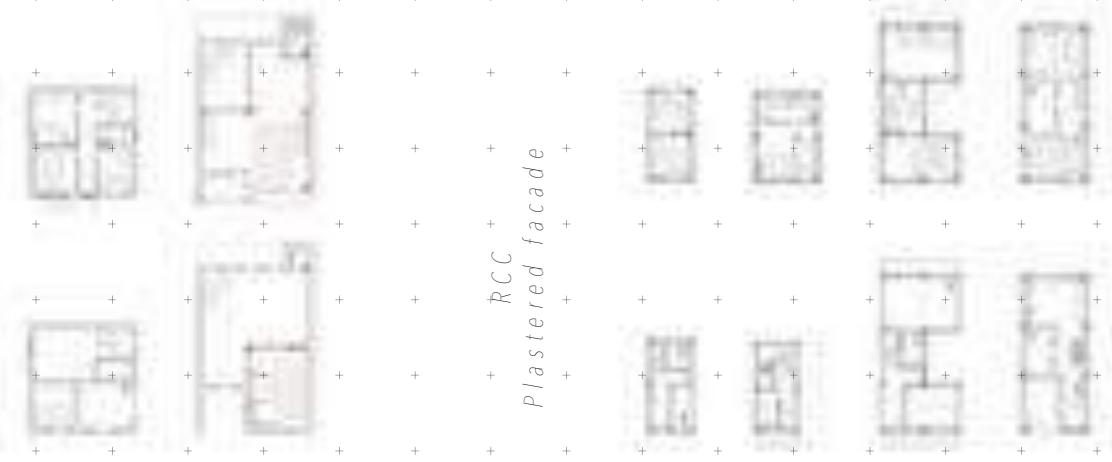
*Traditional Newari
w/ modern extension*



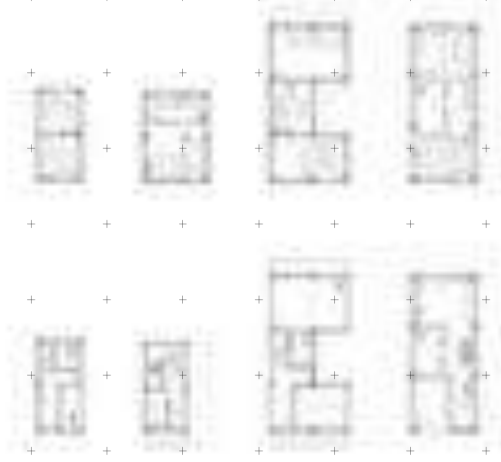
*RCC
Masonry in front of frame*



*RCC
Namaste*



*RCC
Plastered facade*



5 m





1.

Traditional Newari building culture &
appropriations



The facade and second floor of a traditional Newari house in Bungamati, 2016

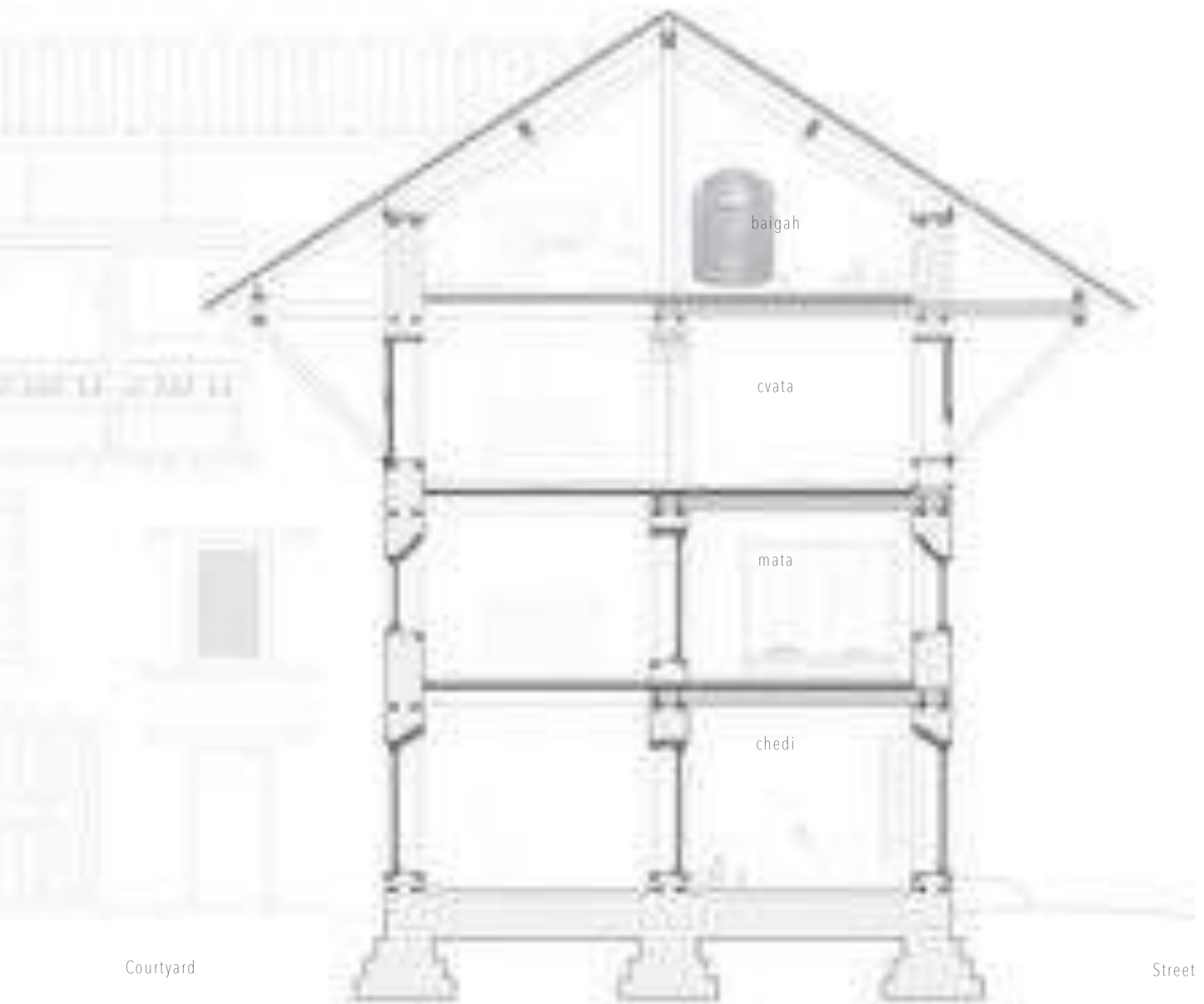


Typologies

Traditional Newari house

In general, Newari houses are all organised in a similar way (Jigyasu, 2002). The ground floor or *chedi* is used as a storage room or a workshop, according to the occupancy of the inhabitants. Given its function, it serves as a damping room for the vapour coming from the soil. In addition, it provides a thermal buffer for the rest of the house (Bodach et al., 2014).

The bedroom and living room are located respectively on the first and second floor (called *mata* and *vrata*), and the attic or *baigah* contains the kitchen and some overall storage space. Most Newari houses do not have a bathroom, because people used to wash themselves at the ponds, spouts or wells and they would simply go to the fields for sanitary needs. In the past, people sometimes used a pile of ashes in the storage room as a toilet, because the faeces could serve as a fertilizer for their fields and the ashes would soften the smell (Rupakheti, 2013). Nowadays many owners of a Newari house have built a separate restroom in their backyard, or on their courtyard to share with the neighbours.



Level 3: Kitchen area
with extension

Level 2: Living area
big window openings

Level 1: Sleeping area
small window openings

Level 0: Shop/storage
no window openings



Window openings differ in each floor, 2016

privacy & purity

The arrangement of a Newari house is based on a privacy gradient. Various degrees of privacy are obtained throughout the different storeys by changing the type of windows facing the street (Toffin, 1991). The facade usually directly communicates the rooms that lie behind it and therefore defines their relation to the public life outside.

The ground floor is characterised by a minimum of openings, primarily out of construction reasons. The carpentry has a lower level of detail, with a simple front door and, in case of the shops, a larger window or an open entrance. The doors of a Newari house are remarkably low. In that way, a person entering the house is obliged to bow down, which is considered as a sign of respect towards the house and the deities.

The first floor, where the bedrooms are located, requires a large degree of privacy. Therefore it has smaller windows with a wooden screen built in their frame, called lattice windows. They provide light in the room and a view to the outer world, but they do not allow people to look inside the house.

The second floor has one of the most striking elements of the Newari carpentry: the triple window. These three-parted windows are extremely detailed, sometimes with religious symbols integrated in them. This floor contains the living room and is the interior equivalent of a public space. In order to enhance the communication between the street and the living room, this triple window often inclines towards the street. In addition, the interior window-sills are often large enough to provide a place to sit. In older times, these windows represented an element of status: the richer the detailing, the richer the inhabitants. As the Nepalese people told us during interviews, there even used to be a saying in the Newari culture: “do not let your daughter marry a man that lives in a house without a triple window”.



Kitchen in model house of Mr. Puri in Bhaktapur, 2016

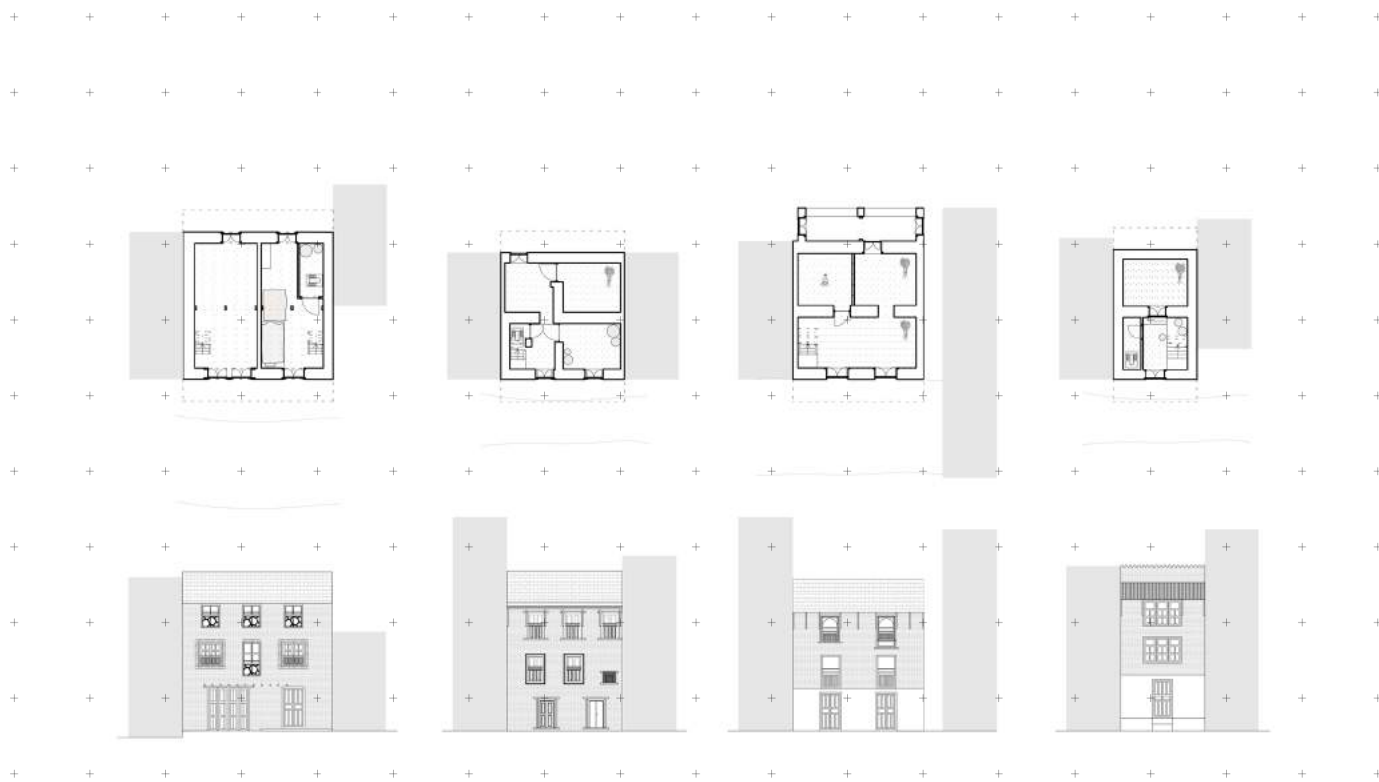


Detailed woodcarving on the door of a Vajracharya family in Bungamati, 2016

The caste system shows an apparent influence on the Newari architecture. People from higher castes not only live closer to the centre of the village (and as such closer to the temple), they also live in bigger and taller houses. People from the lower castes usually live in simple one-storeyed houses (Gutschow, 2011). Until the mid-20th century, people from sub-castes were even prohibited to build houses with a tiled roof. The Newari houses are especially famous for their amazing carpentry details. In this way too, buildings play an important role in translating the caste system to the outer world: the facades of higher caste families are real artworks, making the hierarchical system even more tangible (Sengupta and Upadhyaya, 2016).

The tradition to put the kitchen at the attic has two explanations. One is purely based on considerations regarding safety. It derives from a lack of chimneys: by simply positioning the kitchen on the top floor, the smoke from the cooking fire can escape without damaging the rest of the house (Ranjitkar, 2006). The other explanation is more socially based and takes into account purity and impurity. Eating and cooking are practices that cause impurity, since food gets contaminated with saliva (Gray, 2009). In addition, the caste system defines people from lower castes as being less pure or even impure, creating a hierarchy of people from whom you can or cannot eat food or accept water. Therefore, inhabitants tend to protect their kitchen and food from people of lower castes. By locating it on the top floor, the kitchen becomes a private space, only allowing the presence of the more intimate family members.

Since religion is so intertwined with the daily life of the Newars, it is only logical that it also has a place in their homes. The richer households have a separate worshipping room, while the more modest houses have a small area that is devoted to worshipping the gods in a room with a different main purpose (Sengupta & Upadhyaya, 2016). For the same reason - keeping impurity out - these rooms are generally located on the higher floors of the house.



Maharjan

Dangol

Maharjan

Maharjan

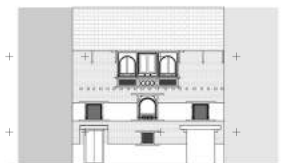
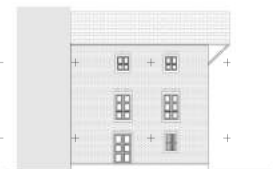
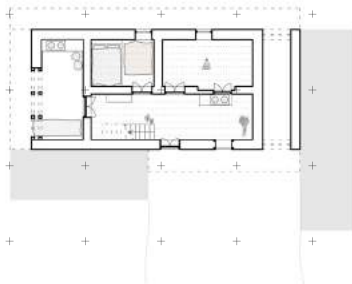


1

2

3

4



3,5 m #
Newari typologies

Vajracharya

Guvaju

Tuladhar

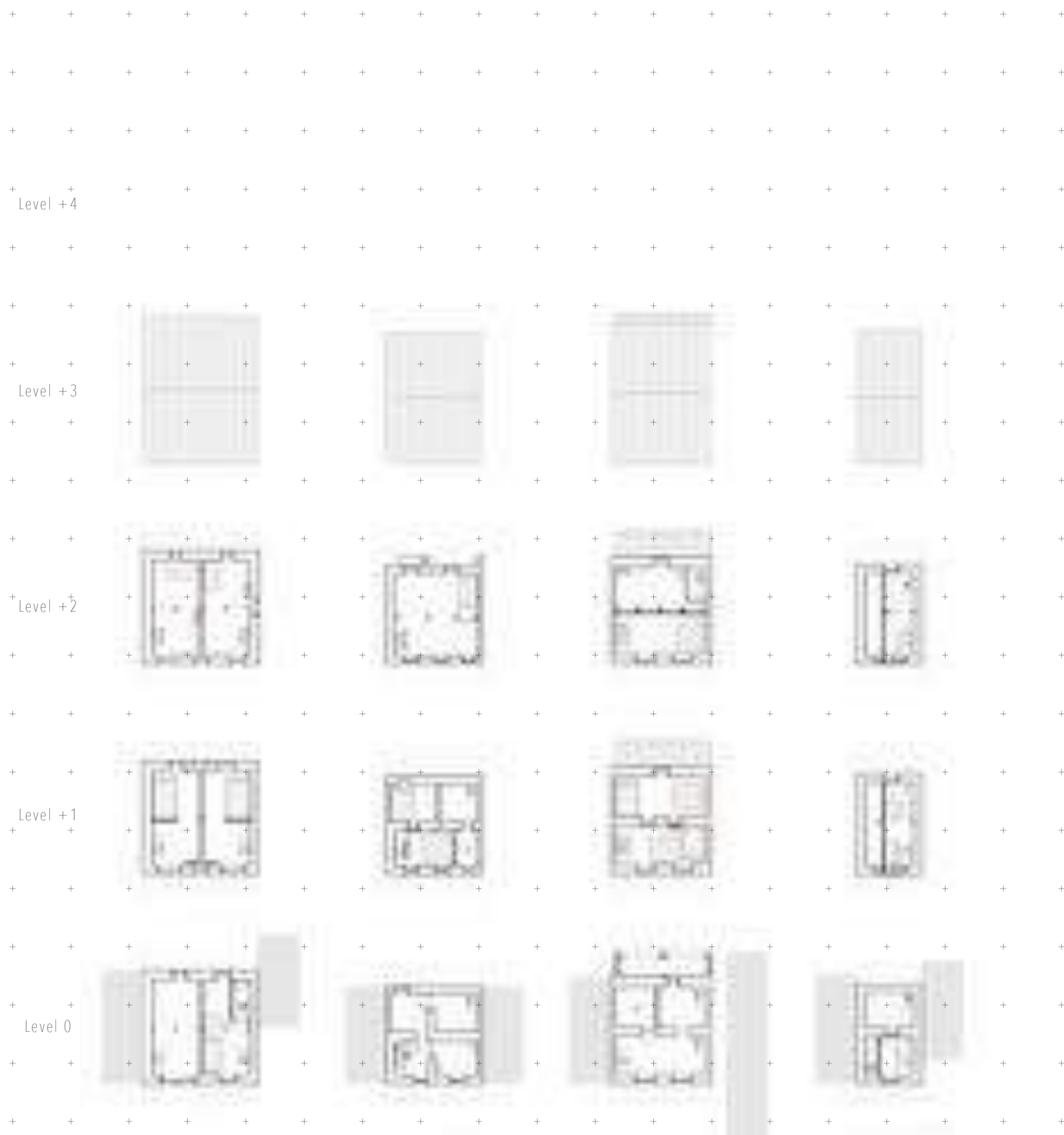


5

6

7

 # people living in the house







Inside the Newari house



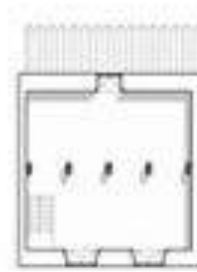
Level 0



Level +1



Level +2



Level +3



Roof plan

Scale: 1/250

Floor plans of the house





roof:
clay roof tiles
finishing layer of mud
timber planks (softwood)
3 layers of constructive beams (hardwood)



traditional Newari carpentry
(hardwood)



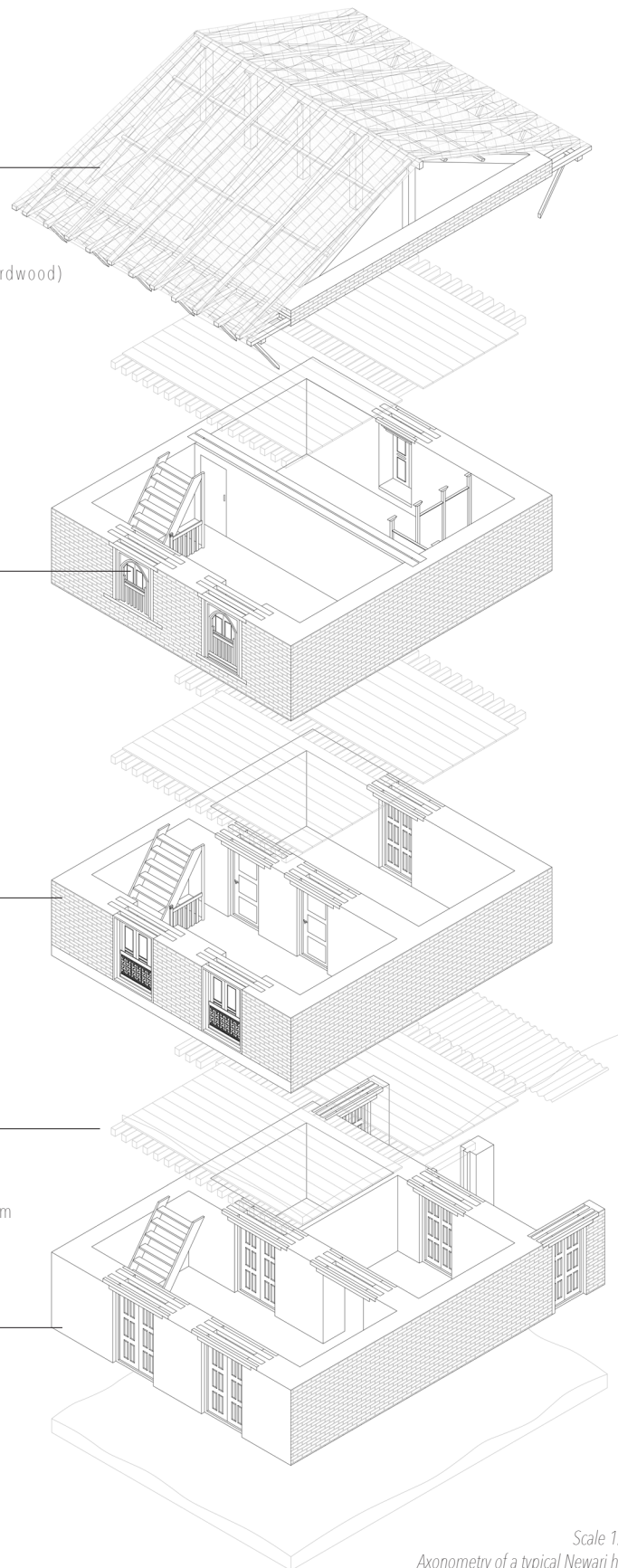
masonry wall (45 cm)



floor:
finishing layer of mud
timber planks (softwood)
constructive beams $\pm 14 \times 16$ cm
(hardwood)



plastered masonry wall (45 cm)



Scale 1/150
Axonometry of a typical Newari house



Divided traditional house, Khokana. One part was replaced by a new, modern house, 2016



Traditional door remains useless after division in Bungamati, 2016



Traditional Newari house with extension

A special characteristic of the Newari house is that it tends to change over time in order to answer to the needs of its inhabitants, which in Nepal means the increasing number of its inhabitants. In most cases, an entire family, ranging from grandparents to grandchildren, lives in one larger traditional house. The Nepalese tradition has it that sons live in their parents' house and daughters move in with their husband. This results in the division of a house over the various sons of the original home owner (Ranjitkar, 2006). Therefore, many houses seem like one house from the outside, but are internally divided into several compartments. This division has implications for the interior of the house: there is need for an additional staircase, which means extra openings in the floor and less room for other purposes. Sometimes it even influences the facade, when the house is split exactly in the middle and a door or window gets cut in two.





Roof plan

Level +3

Level +2

Level +1

Level 0

The original house

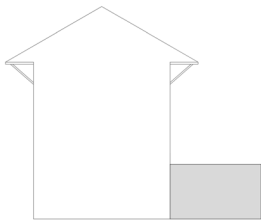
The house split in two

+ 3,5 m +
The original Newari house and its division between two brothers.



*Newari house with modern extension on top on main road
in Khokana, 2016*

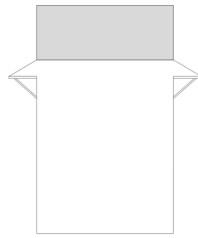
As a consequence, dividing the house decreases the available space. This often leads to expanding the house in various forms. To keep a dense urban fabric, expansions of Newari houses during the Malla period and the later Middle Ages were almost always vertical (Gallagher, 1992). However, in the second half of the 20th century, trends changed and horizontal expansions also occurred more frequently.



- ✓ Safer in terms of earthquake resistance

Not visible from the street

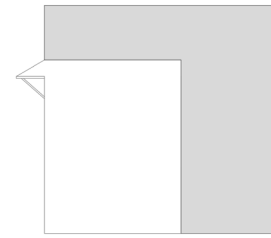
- ✗ Consumption of open space



- ✓ Creating higher density without consuming open space

- ✗ Original foundations are in general too weak for a vertical expansion

Prominent influence on the facade of the building



- ✓ Maximum extra space

- ✗ Original foundations are in general too weak for a vertical expansion

Influence on the facade of the building

Different building forms have different seismic characteristics and will damage each other

Different forms of extension



Dangol



Maharjan



Tuladhar



Khadgi

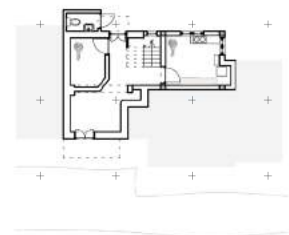


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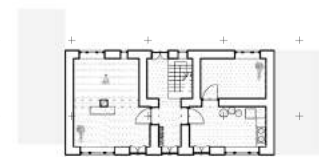
4



Dangol



Shahi



Malakhar



4 m
Different Newari with modern extension typologies measured in
Bungamati & Khokana



5



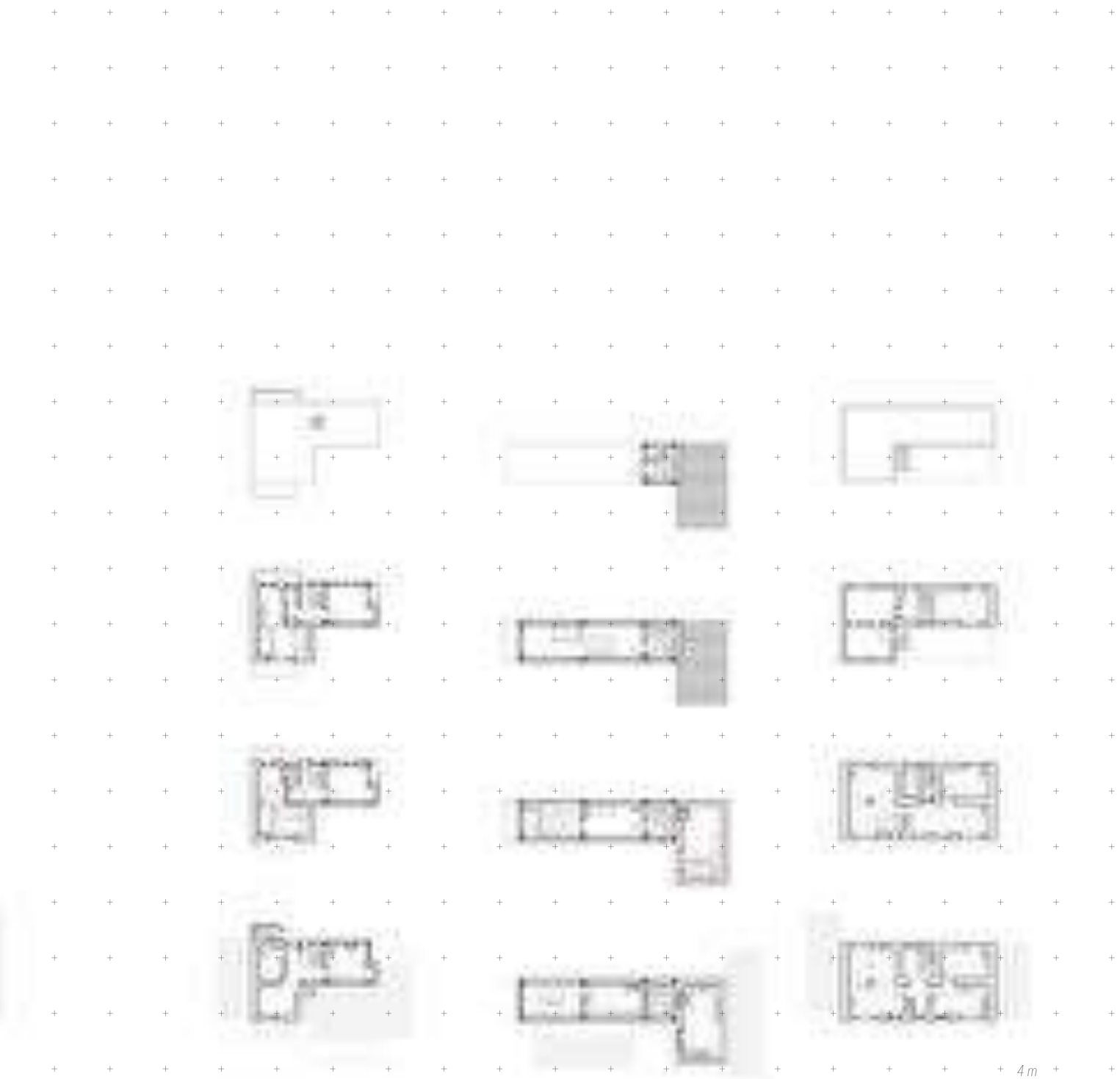
6



7

people living in the house

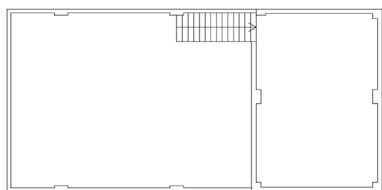




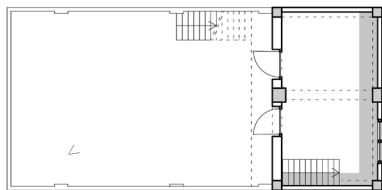
Different Newari with modern extension typologies measured in Bungamati & Khokana



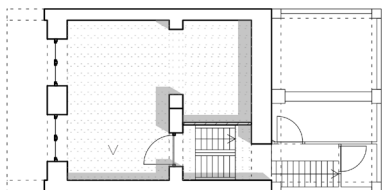
Roof plan



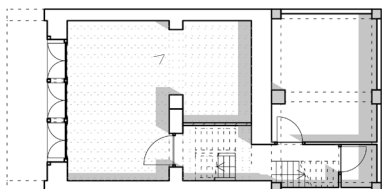
Level +4



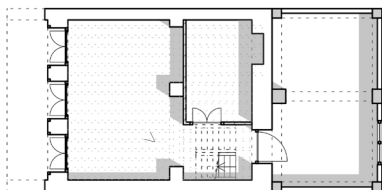
Level +3



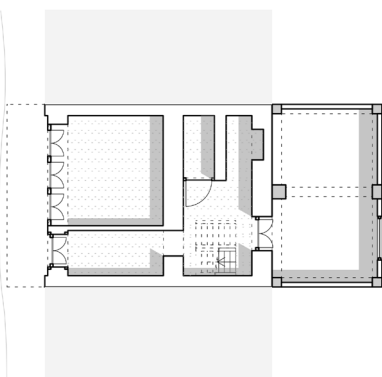
Level +2



Level +1



Level 0



Level +4



Level +3



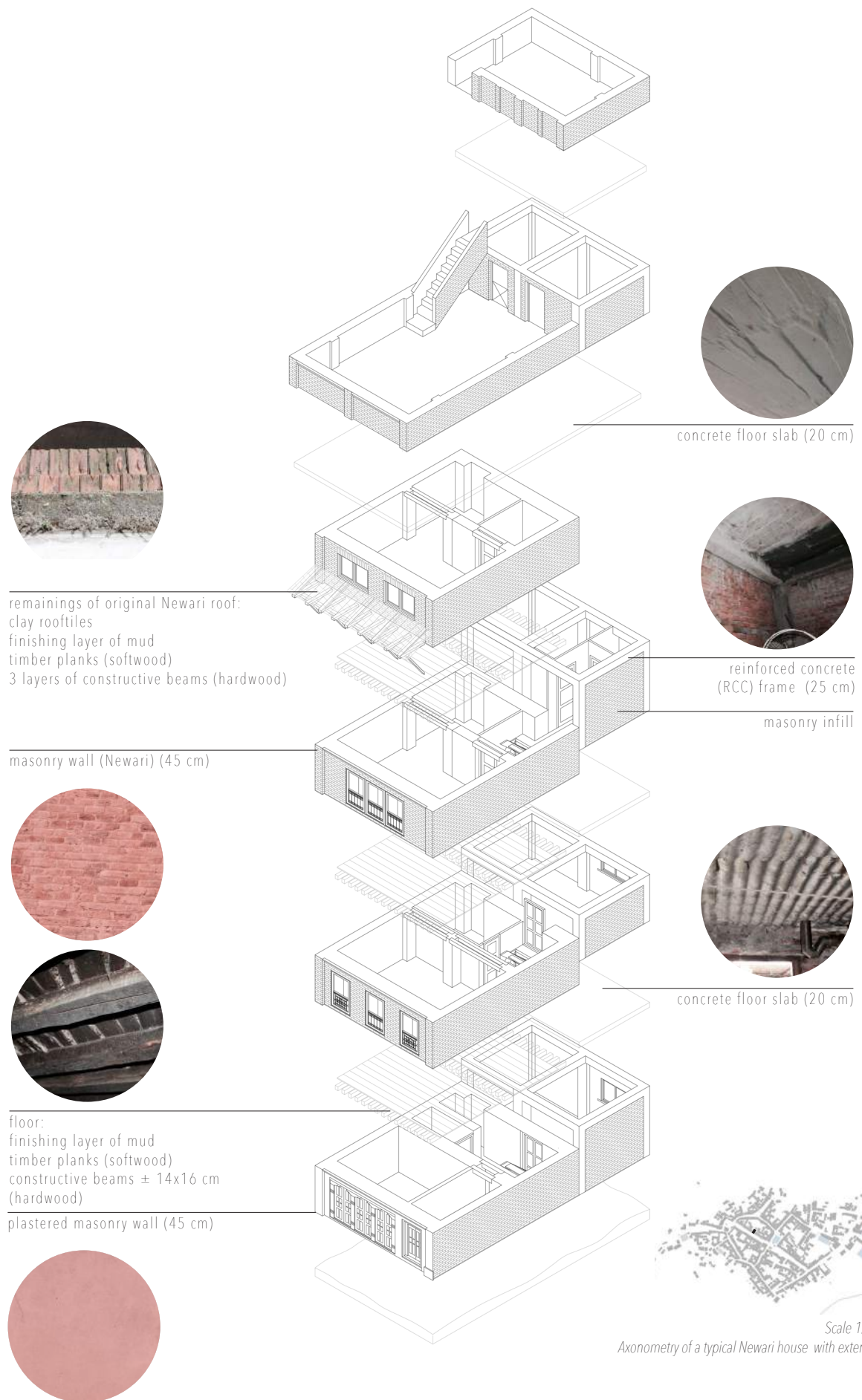
Level +2



Level +1



Facade





*Entire row of Newari houses with removed upper floor in
Khokana, 2016*

Earthquake implications

Due to the 2015 earthquake, many houses now only have one or two storeys left, because the top floors are either too heavily damaged or removed to avoid further collapse. This has resulted in a new way of living, improvised within the remaining space. Often the inhabitants now have only one or two bedrooms left and an improvised kitchen on one of the remaining floors. The kitchen is then also used for storage and the bedrooms play the role of a living room.

In addition, many houses are still removing their upper floor in order to prevent the entire house from collapsing. In many cases this means they have replaced their sloped roof with horizontal corrugated iron sheets. The result is not only acoustically unpleasant when it rains, it also is far less insulating than the original wooden beams with mud and tiles. Additionally, the houses are less protected against heavy rainfall.



Traditional house with extension, August 2016

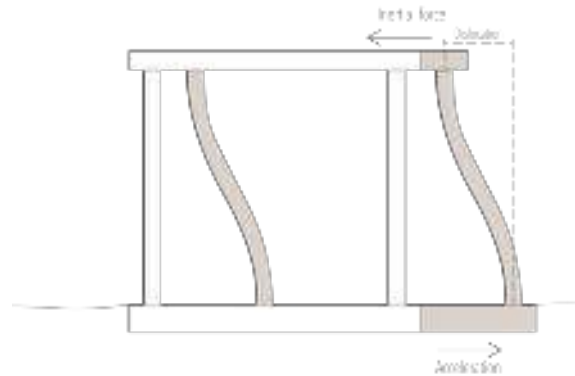


Upper floor of traditional house with extension has been removed for safety reasons, October 2016





House still standing but the displacements are clearly visible, 2016



*Forces and displacements during an earthquake.
Adapted from: Murty, 2005*

Seismic detailing & materiality

Since earthquakes play an important role in the life of the inhabitants, the Newari architecture is consequentially based on a seismic building culture. The architecture has developed over centuries of time on a trial-and-error basis in order to provide resilient structures which are able to survive earthquakes (Marahatta, 2008).

Earthquakes cause seismic waves which move the soil (Murty, 2005). Both horizontal and vertical forces are generated, provoking motion in the base of the building. In most cases, the vertical forces cause no problems, but the horizontal forces do: when the foundations are laterally accelerated, the inertia at the top of the building will cause a displacement “u” between the horizontal elements of the construction, being the different floors and the roof. This displacement generates forces and strains in the construction. The higher the stiffness of the structure, the higher these forces. The vertical elements of a construction, walls and columns, are thus essential in transferring the inertia forces between the horizontal parts.



Collapsed house during the fieldwork in Khokana, 2016

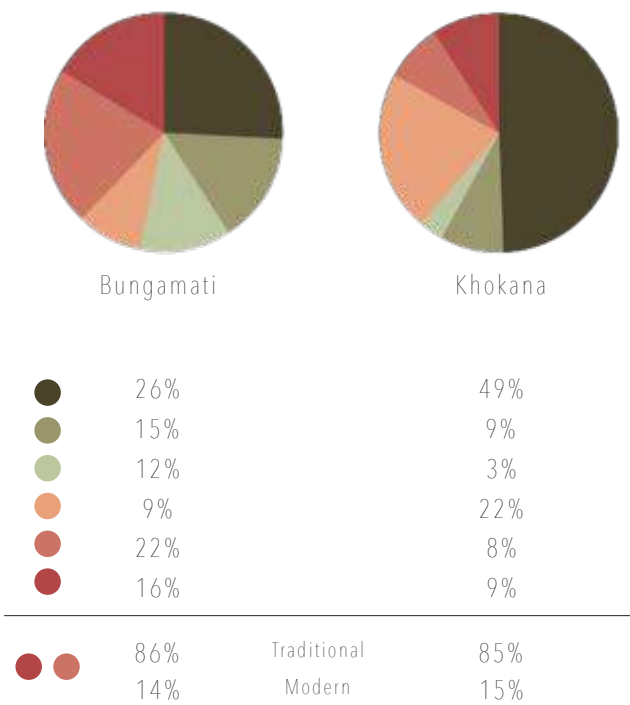


Collapsed house during the fieldwork in Bungamati, 2016





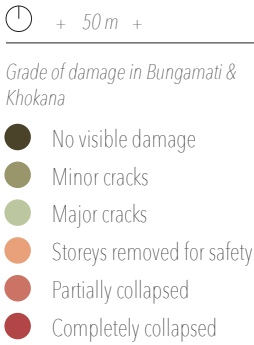
Collapsed building in Bungamati, 2016

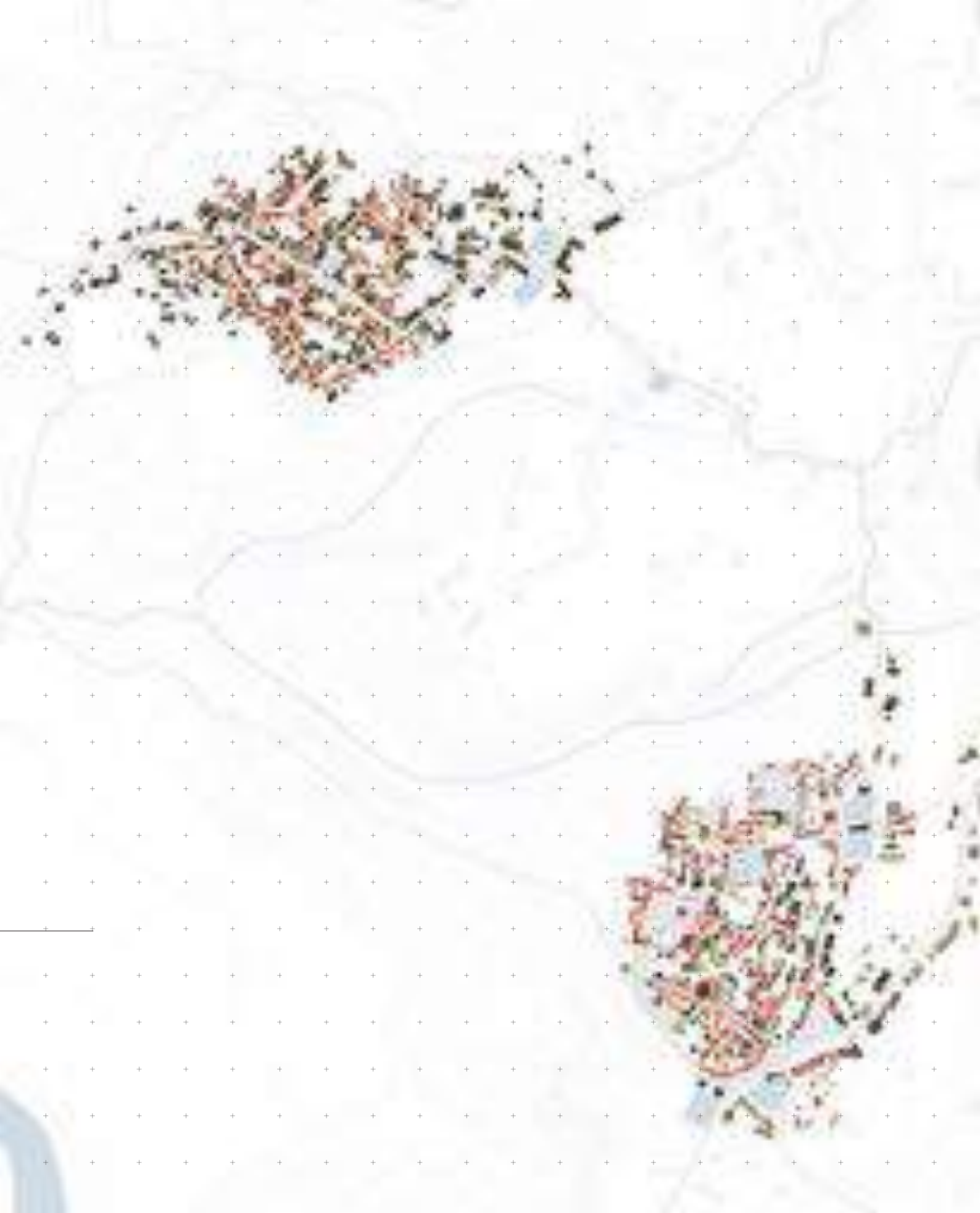


Seismic detailing - building guidelines

Observing the damage caused by the earthquake of April 2015, noticeably more traditional than modern buildings have collapsed, leading the inhabitants to believe that concrete, modern buildings are more earthquake resilient. However, this is not necessarily true.

The main reason for the traditional Newari houses to collapse is the fact that people started to leave out important parts of the building to save money (Joshi P., Pesonal interview, 2016, August 29). The ancient building knowledge, which provides resilient buildings, is primarily tacit because of the lack of written documents. Consequently, since people are not fully aware of the structural importance of various building parts, they did not know that leaving them out could cause this kind of damage. In addition, the houses were not maintained as they should, resulting in degraded structural parts of the buildings. Another important reason for the houses to be heavily damaged, is that the inhabitants started building extra floors on top of their house in order to increase their space. However, the builders of the original foundations did not anticipate this kind of extension, leading to insufficient stability when an earthquake hits.





In 1988, after yet another important earthquake had struck Nepal, the country realised there was a need for more attention to construction details. This resulted in the National Building Code (NBC) of Nepal in 1994 (NBC 204:1994; NBC 105:1994...). The entire NBC consists of many different parts, including a separate chapter designated to seismic design.

It is of fundamental importance that the inhabitants have comprehensive guidance in how to properly build a resilient house. In order to optimize the seismic behaviour of the buildings, the next paragraphs propose a set of written and graphical building guidelines, complementing the NBC, while respecting and revitalising the Newari architecture. Traditional building materials and techniques are implemented in order to preserve the Newari building culture. Traditional materials are preferred since these are the ones which are locally available. In addition, traditional techniques should be used considering the inhabitants are familiar with these techniques.

10

6.3 Foundations on Sloping Sites

No building shall be built on land steeper than 20° (1:3, Vertical : Horizontal). Stepped strip footings shall be made for foundations on sloping land. The minimum depth of a foundation shall be measured from the existing ground level on the filled part and from the finished ground level on the cut part, and this shall not be less than 750 mm. Each step shall not be narrower than two times the wall thickness at the base of the superstructure, as shown in Figure 6.2.

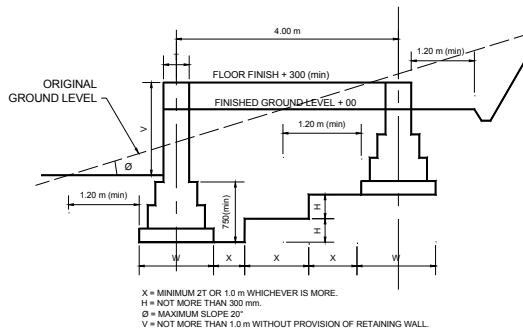


Figure 6.2 : Foundation on Sloping Land

21

Each post shall have a properly connected *Meth* (capital) on its top end. The minimum dimensions of such capitals shall be as given in Figure 9.3.

Alternatively, the capitals may be replaced by struts well-connected to the posts and beams, as shown in Figure 9.4.

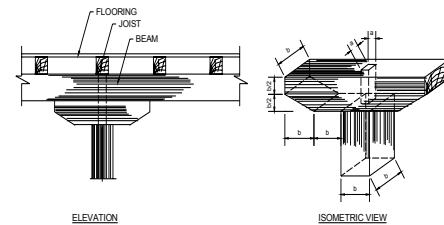


Figure 9.3 : Details of Fixing Capitals on the Posts

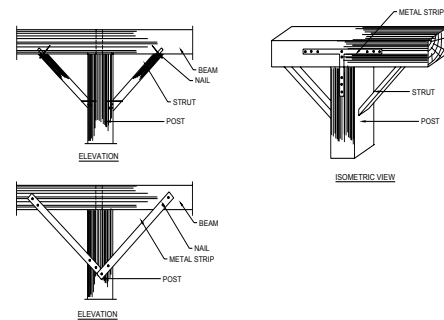


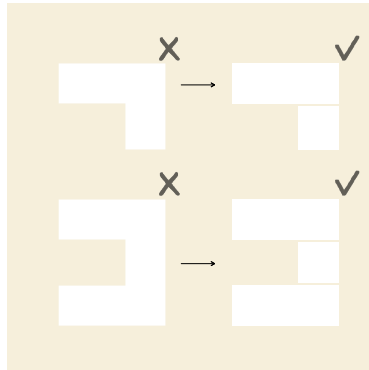
Figure 9.4 : Alternative Details for Fixing Struts on Posts and Beams

Resilient layout & appropriate planning

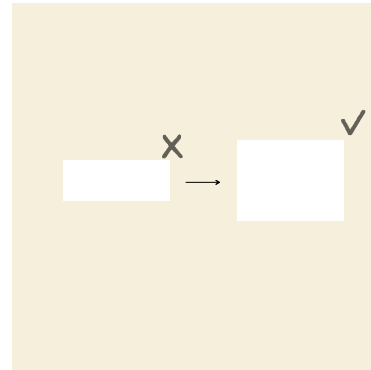
The evolution of the Newari architecture has led to approximately rectangular floor plans, parallel to the street (Toffin 1991). A simple floor plan, that is not substantially larger in one specific direction, is preferred since it is more resistant to earthquakes than irregularly shaped buildings (Murty, 2005). This can be explained by the fact that torsion can occur in buildings with an asymmetrical plan, since the focus of the building will not correspond with its middle point. In means of proportion, the rule ‘width < 3 x depth’ should be respected at all times (Government of Nepal, 1994). The openings in the walls, namely their size and localisation, are also of importance when thinking about earthquake resilience. Large openings on the ground floor are to be avoided, since they induce a soft-storey effect, meaning the ground floor, and therefore the whole building, is more likely to collapse.

In general, Newari houses have three storeys and one extra storey underneath the sloped roof. Building higher is not recommended for reasons of earthquake safety. However, an additional incentive is used to prevent villagers from building higher, namely legends claiming that houses should never be taller than the temple, in order to respect the gods.

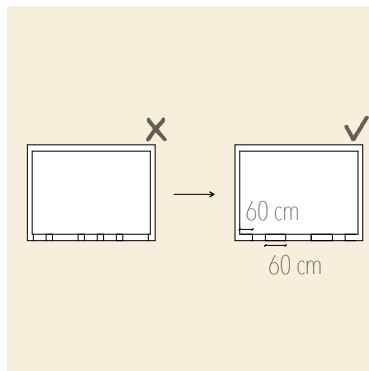
As to the relation between various houses, it can be observed that houses are either standing alone or built wall-to-wall (Jigyasu, 2002). However, most traditional residences are wall-to-wall constructions, either as a row house or as built around a courtyard, since these configurations have better seismic behaviour due to a larger redundancy (van Wijnbergen, 2016). This also implies that buildings are preferably built with matching storey heights, reducing the chance that they will damage one another: parts of the roof of the higher building may fall on the lower building. When two buildings are built close to each other, but without touching, mutual damage of the adjacent buildings can occur as a consequence of pounding (Murty, 2005).



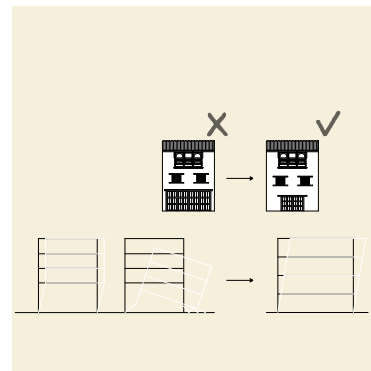
preference of regular plans



width < 3 x depth

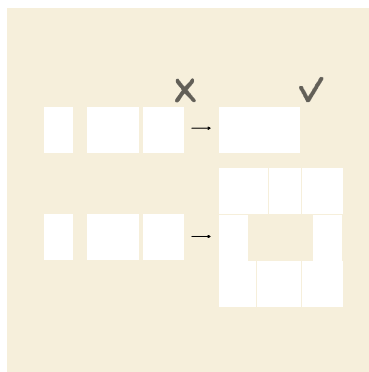


size of openings

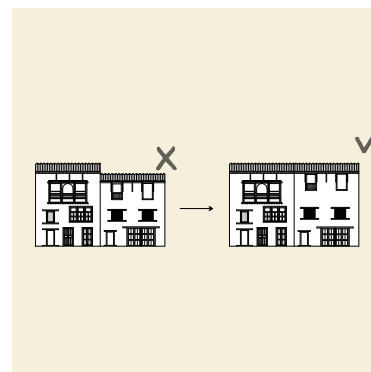


avoid the soft-storey effect

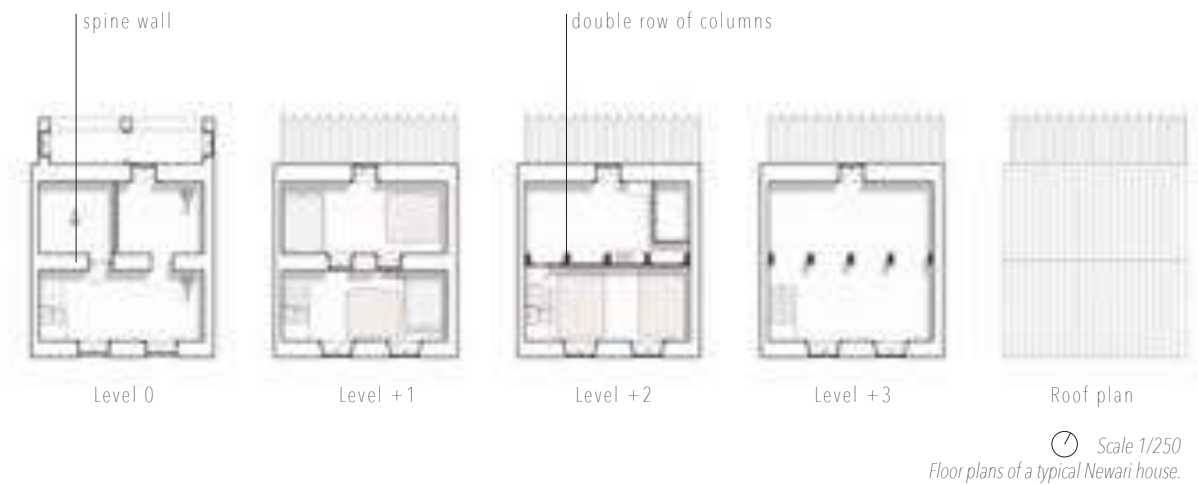
Adapted from: de Stoppelaar et al., 2015



building in clusters



matching storey heights



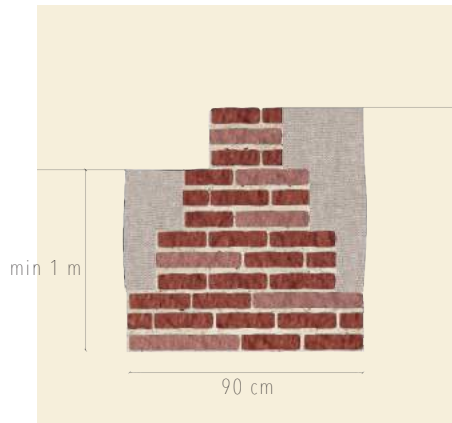
Foundations & walls

The walls represent the basis of a building, separating the exterior from the interior. But they should, in their turn, have a firm basis, namely the foundations (Government of Nepal, 1994). These foundations are traditionally constructed out of a step-like masonry structure or a simple wooden pin in a stone. This joint between wood and stone makes sure there is some space for movement, without resulting in breaking. In this way part of the energy from the earthquake can be dissipated.

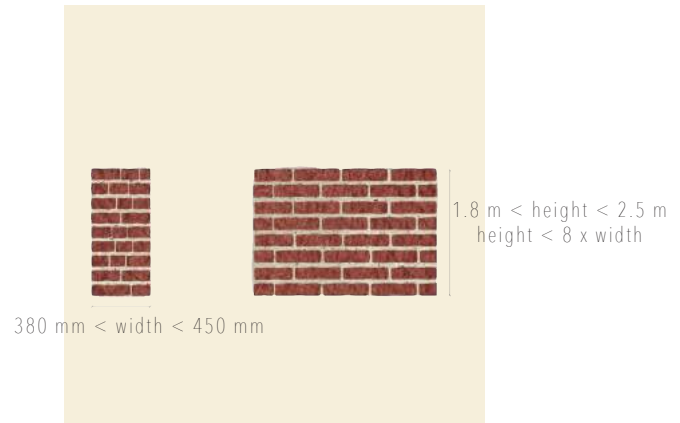
On top of these foundations, heavy masonry walls are erected. A typical Newari house has a rectangular plan divided in two parts by a longitudinal wall, called the spine wall. Combined with the two parallel facades, there are three main loadbearing walls. These thick masonry walls combined with natural mortar provide a high thermal mass (Bodach et al., 2014), resulting in rather good insulation in winter and a cool house in summer (Ranjitkar, 2006).

The adobe walls have relatively large dimensions in order to optimize their structural performance and thermal inertia. Adobe walls tend to have better seismic characteristics when right proportions are applied. Therefore, bigger stones, with a larger overlap should be preferred over small ones (Government of Nepal, Ministry of Urban Development & Shelter Cluster Nepal, 2015). In addition, the mortar joints between the bricks should be well proportioned.

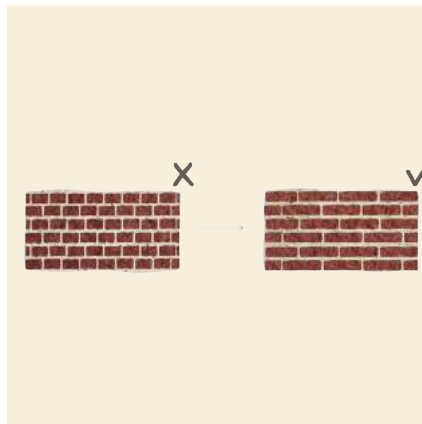
Traditionally Newari walls are built in multiple wythes (D'Ayala, 2003), reducing the coherence of the wall. In order to prevent them from cracking in the middle, walls should be constructed as whole walls, preventing mortar accumulation in the centre of the wall (Government of Nepal, 1994). Another element which improves the coherence of the wall during earthquakes is the use of through-stones (Government of Nepal, Ministry of Urban Development & Shelter Cluster Nepal, 2015). These connections make sure that the wall will work as a whole, preventing it from collapsing easily. The connections could be realised as stones or as wooden dowels, while keeping in mind to use hardwood for important structural elements. These through-stones should be implemented every 60 cm vertically and 1,2 m horizontally.



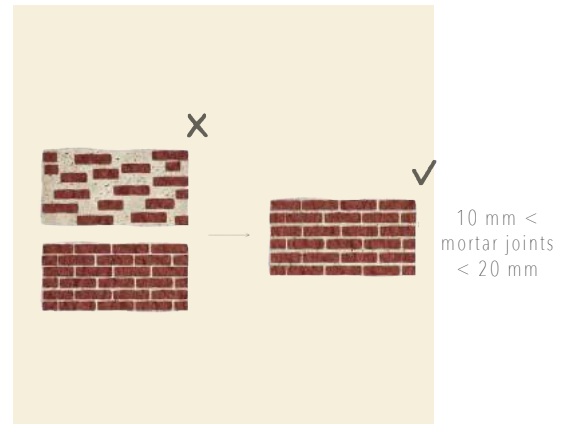
foundations



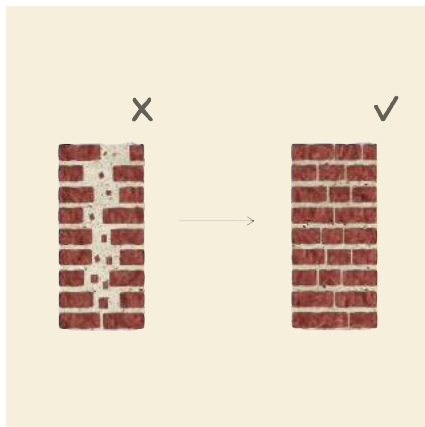
dimensions of the walls



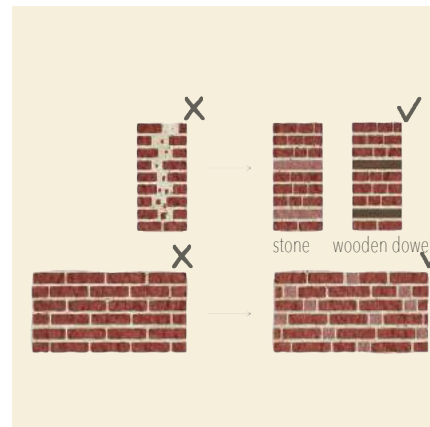
bigger stones, bigger overlap



mortar joints



avoid building walls in multiple wythes



through-stones

Adapted from: Government of Nepal, 2015



Stacking of bricks on the side of the armature road, 2016



Woman cleaning bricks from demolished house for reuse in Bungamati, 2016

The masonry walls consist out of bricks and mortar. Various types of both bricks and mortar are available, but careful consideration should be given to their compositions. In the Newari architecture mud based mortar is most common. In general, it is preferable to use a mortar that is weaker than the masonry. Cracking of the wall during an earthquake usually happens in the weak link of the wall. Since mortar is more easy to replace, cracks should happen in the mortar instead of the bricks. Therefore, mud mortar stabilised with lime, in case of adobe, and lime mortar, in case of burnt bricks, are good choices (Michiels T. Personal interview. 2017, April 20). When using a mud based mortar, the quality of the mud plays an important role in its performance. Therefore the mud mortar should be free from pebbles and the amount of sand should not exceed 30% of the total volume in order to maximize the cohesiveness (Government of Nepal, 1994). In mud mortar stabilised with lime, the amount of lime should be limited to 2-5% (Michiels T. Personal interview. 2017, April 20).

The bricks are made of clay and are either burnt bricks (from the brick kiln) or sun-dried bricks (Toffin, 1991). The latter are stacked with a layer of straw on top and left to dry in the sun for three days. This type of bricks is often used for interior walls or the inner row of an outside wall (creating a composite wall), protected against the weather. However, some parts of a construction require more solid materials. For these parts, for example the outside parts of walls, the more expensive burnt bricks are used. They are piled up and then baked in the kiln for 48 hours. All bricks vary in size between 24 x 12 x 7 cm and 21 x 14 x 5,5 cm. However, in general it can be observed that sun-dried bricks are often more irregular in shape than burnt bricks (Toffin, 1991). Sun dried bricks cost approximately 3 rupees per piece, while the burnt bricks are more expensive: 10-20 rupees per piece, depending on the quality (Puri R. Personal interview. 2016, September 26).

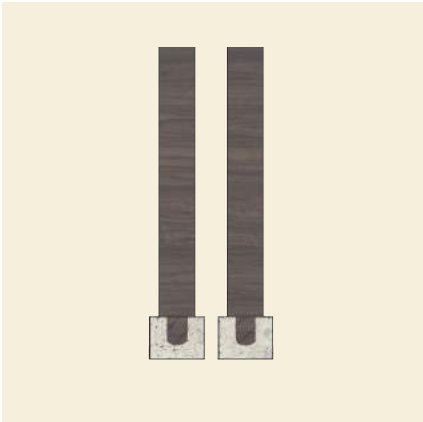
⊙ + 0,4 km +

Brick kilns in the surroundings
© Esri, 2017
Adapted from: Amaya Marin
et al., 2015



Khokana

Bungamati



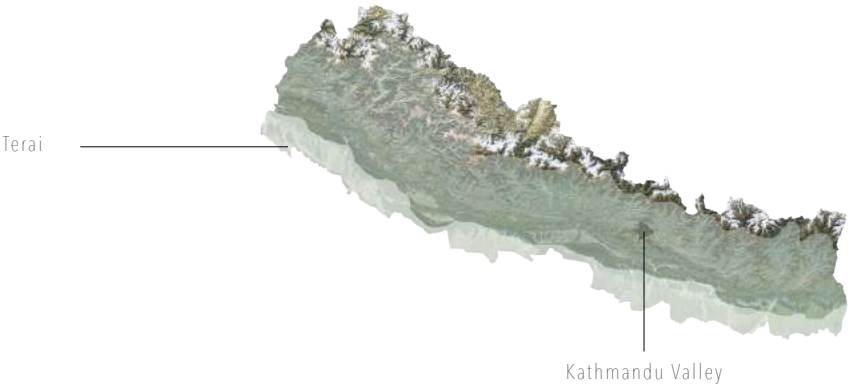
connection post and floor beam (bottom)



connection post and floor beam (top)



interlocking of two beams





Carpenter working in atelier, Bungamati, 2016



Carpenters working on reconstruction of the main temple in Khokana, 2016

On the higher storeys, the spine wall is often replaced with a row of wooden columns. Usually this row is doubled in order to use smaller (and thus cheaper) sections of wood.

Because of the deforestation of Nepal, wood is becoming more and more expensive (Toffin, 1991). Nevertheless, most Newari houses use this material in large amounts. Wood comes in two main types: hardwood and softwood.

The most common type of hardwood is Sal or *Shorea robusta*, which grows in the southern part of Nepal, the Terai (Bodach et al., 2014). This type of wood is the biggest cost in constructing a building, the Sal wood costs around 5000-7000 rupees/m² (Puri R. Personal interview. 2016, September 26). Since the sections are taken from the centre of a tree trunk, they are of considerable higher quality and therefore more expensive.

The most common type of softwood on the other hand is pine, growing in the surroundings of the Kathmandu Valley. The important loadbearing elements must be realised out of hardwood, since this type of wood is of much better quality. Nevertheless, for many components the less expensive softwood can serve as well, reducing the overall cost drastically. However, the softwood needs treatment against beetles and rot, whereas the hardwood can last without treatment (Toffin, 1991).

Since wood is only available in certain sizes, proper connections should be made in order to make the various parts of a bigger whole work together. In many places of the building structure, a connection between masonry and wood, or even different materials, is made. However, special attention should be paid to their interconnection. The joints between two materials should be realised flexibly (with a certain tolerance), in order to allow a certain degree of displacement. If these joints would have a high stiffness, these interconnections would be the first elements where failure occurs, resulting in severe damage.

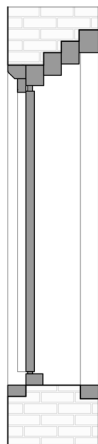
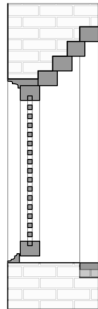
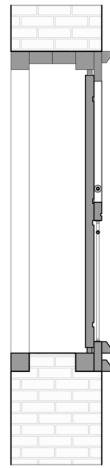
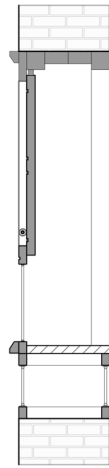


Scale 1/50
Proper support for opening in spine wall.



Scale 1/50
Surrounding bricks adapted to double framed window.

Spans for openings in the walls are realised out of wood. The hardwood window frames in the Newari architecture are doubled, with a frame on the in- and outside of the wall, in order to tie the building together and realising an opening properly. The masonry of the walls is generally built around these double framed windows. Therefore, the size and form of the masonry are adapted to the frames (Toffin, 1991). Usually, the window opens up towards the interior, maximizing the incidence of light and minimizing the view from people passing by. This is realised by the design of a frame that enlarges step-like.



Scale 1/50
Detailing of the various Newari windows.
Adapted from: Ranjitkar, 2006



Horizontal band of the VDC building in Khokana.

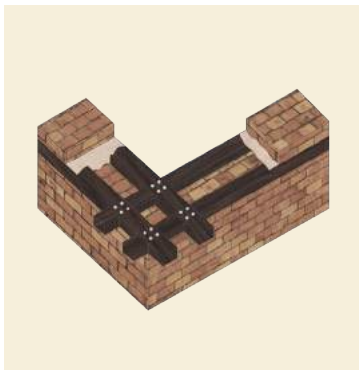
© UMEDP

On the scale of the whole building, houses should be reinforced with horizontal bands (or bond beams) (Government of Nepal, 1994). However, frequently these bond beams are left out or are poorly executed.

These bands are to be located at the plinth level, right underneath the roof and at the level of every floor. They should be realised out of hardwood and special attention should be given to the technical realisation of the bands. They should be continuous, therefore precise connections are to be made. The bond beams should be properly tied to the wall by adding multiple layers of bricks and optionally adding extra anchors (Michiels, 2014). The implementation of these horizontal bands is crucial for the seismic performance of a building, since they make sure walls are tied together at all times and therefore are working together, creating a box-effect.



horizontal band



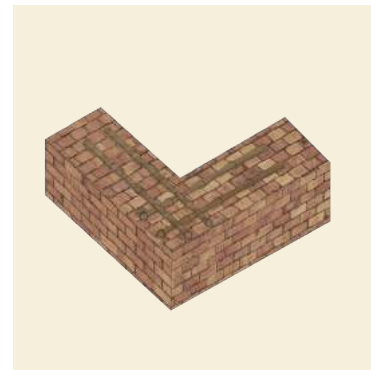
connections - wood

Adapted from: Government of Nepal, 1994



connections - wood

Adapted from: Government of Nepal, 1994



connections - bamboo

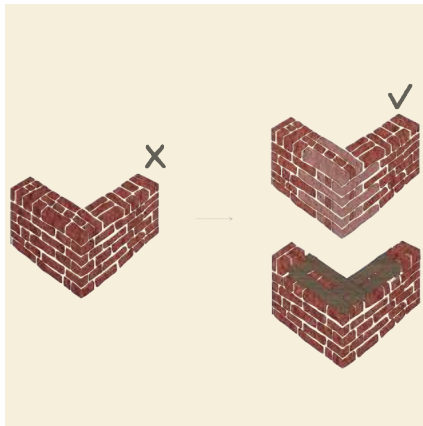
Adapted from: Government of Nepal, 1994



Cracks near the corner of a building in Bungamati, 2016

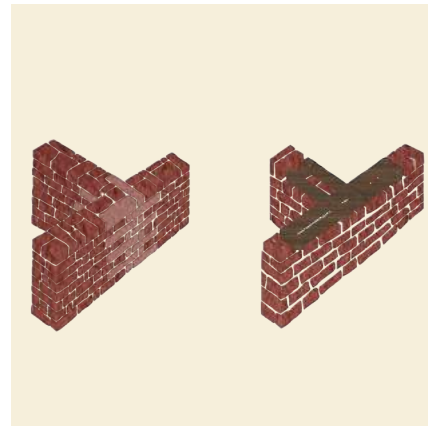
When an earthquake happens, the cracking is usually located in the corners of the building. Therefore, corner keys could optionally be integrated (Government of Nepal, 2015). These connections reinforce the building by making sure that the (nearly) perpendicular walls will work together, and the corners keep being tied together when forces are exerted on them. The corner keys can be realised out of stone or hardwood (Michiels, 2014). This kind of reinforcement can be implemented at T-junctions as well.

Another point of attention is that all kinds of moisture infiltrate the wall. Water damages the mud, which is present in both the bricks and mortar, but it also affects the wooden elements connected to the walls. Therefore, the amount of water inside the walls should be minimized. The overhang of the roof should thus be large enough to protect the facade from rain. In addition, facades should not be plastered since they prevent the moisture inside the wall from evaporating (Ranjitkar, 2006). It is also recommended to incorporate a damp proof layer inside the wall and floor, at the plinth level, to block rising damp from the ground (Government of Nepal, 1994). Constructing a drainage system on the street alongside the house also prevents an abundance of water to soak in the walls and foundations.



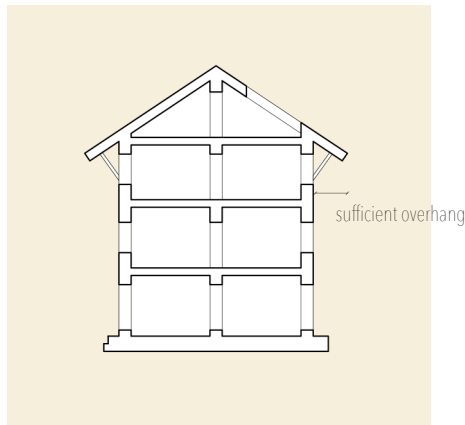
corner keys

Adapted from: Government of Nepal, 2015

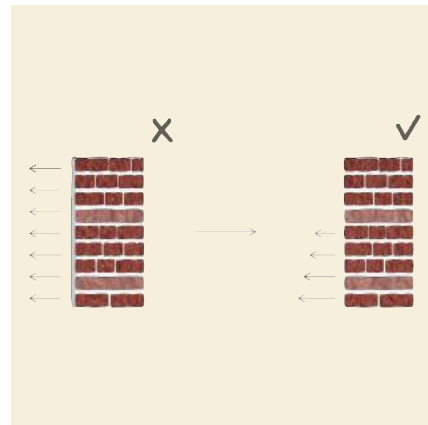


T-junctions

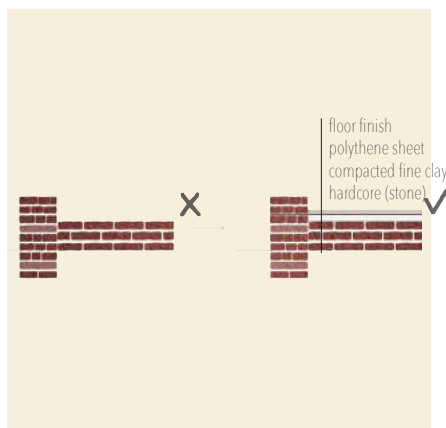
Adapted from: Government of Nepal, 2015



overhang of the houses

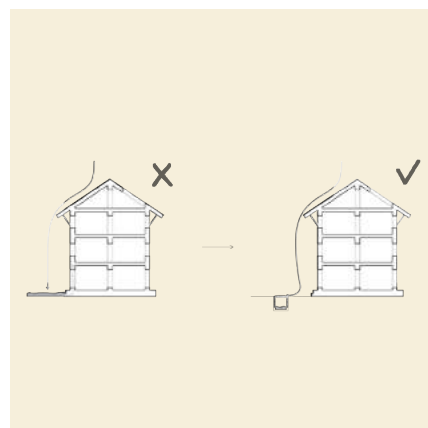


no plastered facades



damp proof layer

Adapted from: Government of Nepal, 1994



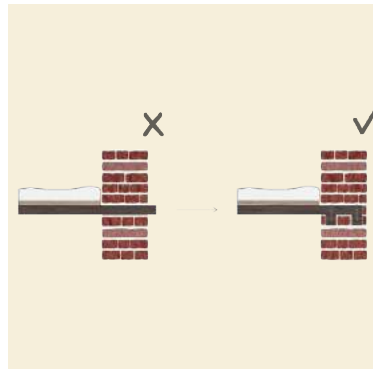
street drainage system

Floors

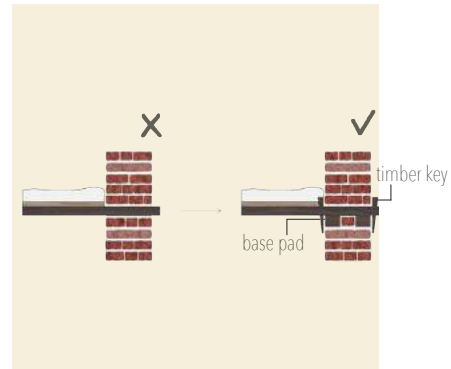
The span between the various load bearing walls is realised out of constructive wooden beams (or joists), covered with timber planks as bridging material, and a layer of mud. Since the wooden joints are the structural basis of the floor, the maximum distance between two loadbearing walls is defined by the longest possible beam of wood. In general, the length of wooden beams, made out of Sal wood, is limited to three or four metres.

The various joists should be interlocked with the walls. Interlocking both elements makes sure the building will work as a whole, resulting in better seismic behaviour. This interlocking is generally done by using timber keys on both the in- and outside of the wall (Government of Nepal, 1994). However, when the bond beams are properly implemented, the beams could be interlocked with them, forming one big wooden frame that strengthens the whole building.

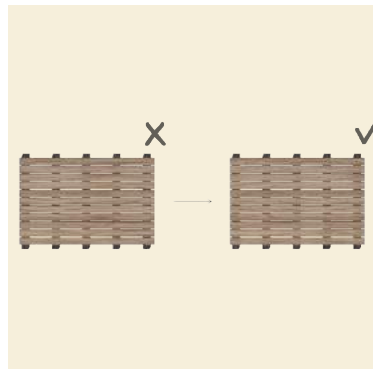
In addition, the floor can be strengthened by nailing the timber planks to the constructive wooden beams. A double layer of planks can be applied under an angle of 45° in order to increase the stiffness of the floor by creating a diaphragm (Ranjitkar, 2006). When fixating the planks to the beam, it is important to use appropriate nails that reach until the centre of the constructive beams. Furthermore, the upper mud layer can be reduced to a minimum in order to decrease the overall weight of the building. The forces exerted on the building by the earthquake are influenced by two parameters, since force equals mass x acceleration. Therefore, minimizing the mass means reducing the forces. However, according to Mr. Puri, expert in conservation of the Newari architecture, it should be thick enough to maintain its contribution to the thermal inertia of the floor, resulting in kind of a floor heating (Puri R. Personal interview. 2016, September 26).



interlocking constructive beams with horizontal band

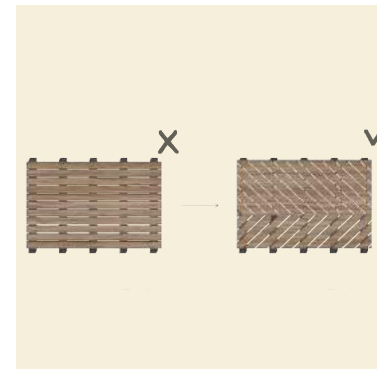


interlocking constructive beams with wall

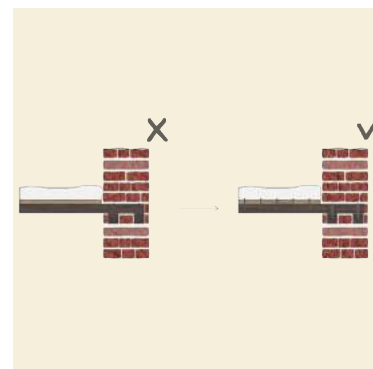


nailing down floor planks

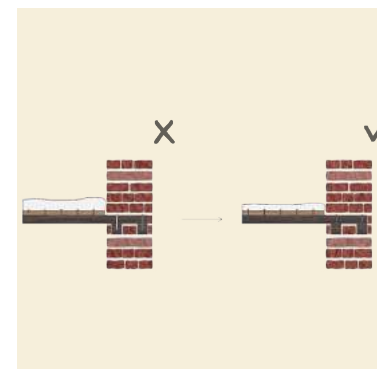
Adapted from: Government of Nepal, 1994



double layers of planks



using appropriate nails



reducing thickness of mud layer



Roof structure covered with CGI sheets in the Salan guthi building in Khokana, 2016



Roof structure covered with CGI sheets in a private house in Khokana, 2016

Roof

On top of a Newari building we have a sloping roof structure, which is also realised out of hardwood. The roof structure is composed of multiple layers of constructive beams, covered with timber planks, a thick layer of mud and ceramic tiles on top. Similar to the constructive beams of the floor, it is of fundamental importance to interlock the roof structure properly to the underlying masonry structure in order to prevent the roof from falling down when an earthquake occurs (Ranjitkar, 2006). In addition, it has shown that at the level of the roof, the horizontal bands should be assisted with gable bands in order to integrate the roof (Government of Nepal, 1994).

The mud layer in the roof contributes to the general insulation of the building but also increases its weight significantly (Ranjitkar, 2006). Therefore, it could be an interesting choice to replace both the tiles and the layer of mud by CGI sheets (Government of Nepal, 1994).

However, these roof tiles are not expensive, since clay is widely available in the Kathmandu Valley. The tiles cost 3 roepies per piece, while the newer ones, which are of better quality cost around 7 roepies per piece (Puri R. personal interview. 2016, September 26).

The hardwood inside the roof could be replaced with bamboo, a valuable alternative for wood, which is more locally available and therefore less expensive. However, the life span of bamboo is much less than that of Sal wood and should be replaced more often. Therefore only parts which are relatively easy to replace, like the roof structure, can be realised in bamboo. Hereby the remark should be made that bamboo needs to be treated with borax salts against termites and rot.



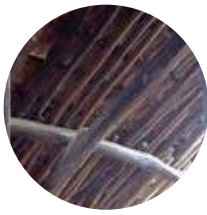
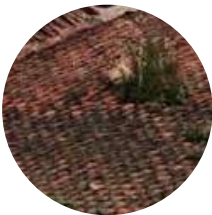
gable band



interlocking roof structure

Adapted from: Toffin, 1991

Overview of building guidelines



roof structure:
constructive hardwood beams (interlocked with wall)
layer of timber planks
layer of mud
finishing layer of clay tiles



floor structure:
constructive hardwood beams (interlocked with horizontal bands)
double layer of timber planks
layer of mud (min. thickness)

corner keys

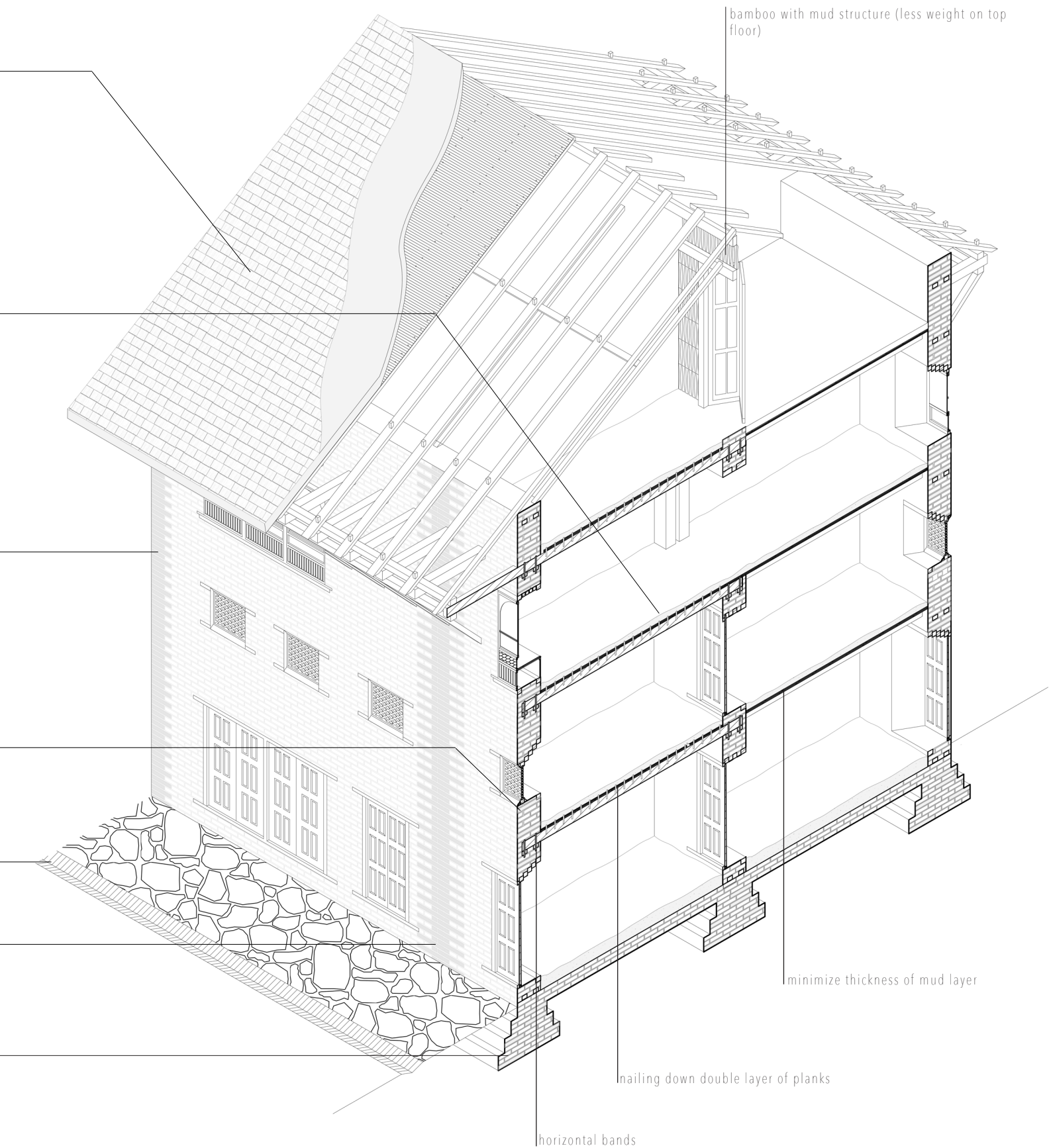
through-stones



drainage system on street

strengthened T-junctions

proper foundations



The intelligence of maintenance

The maintenance of traditional buildings, as well as the traditional water system, is strongly linked to religious activities. Following professor Tiwari of the Tribhuvan University, expert in cultural heritage, various festivals are combined with specific cleaning activities in order to keep a certain regularity in the preservation (Tiwari S.R. Personal interview. 2016, October 10). Various cleaning moments are shown, however only the most important are described in detail.

The first important festival is called *Sithinakha* (Gurung, 2000). This festival takes place in May, right before the monsoon. Before this *jatra*, people take all the weed of their roof and thoroughly clean all the water facilities. Even the buildings that are under construction are being cleaned.

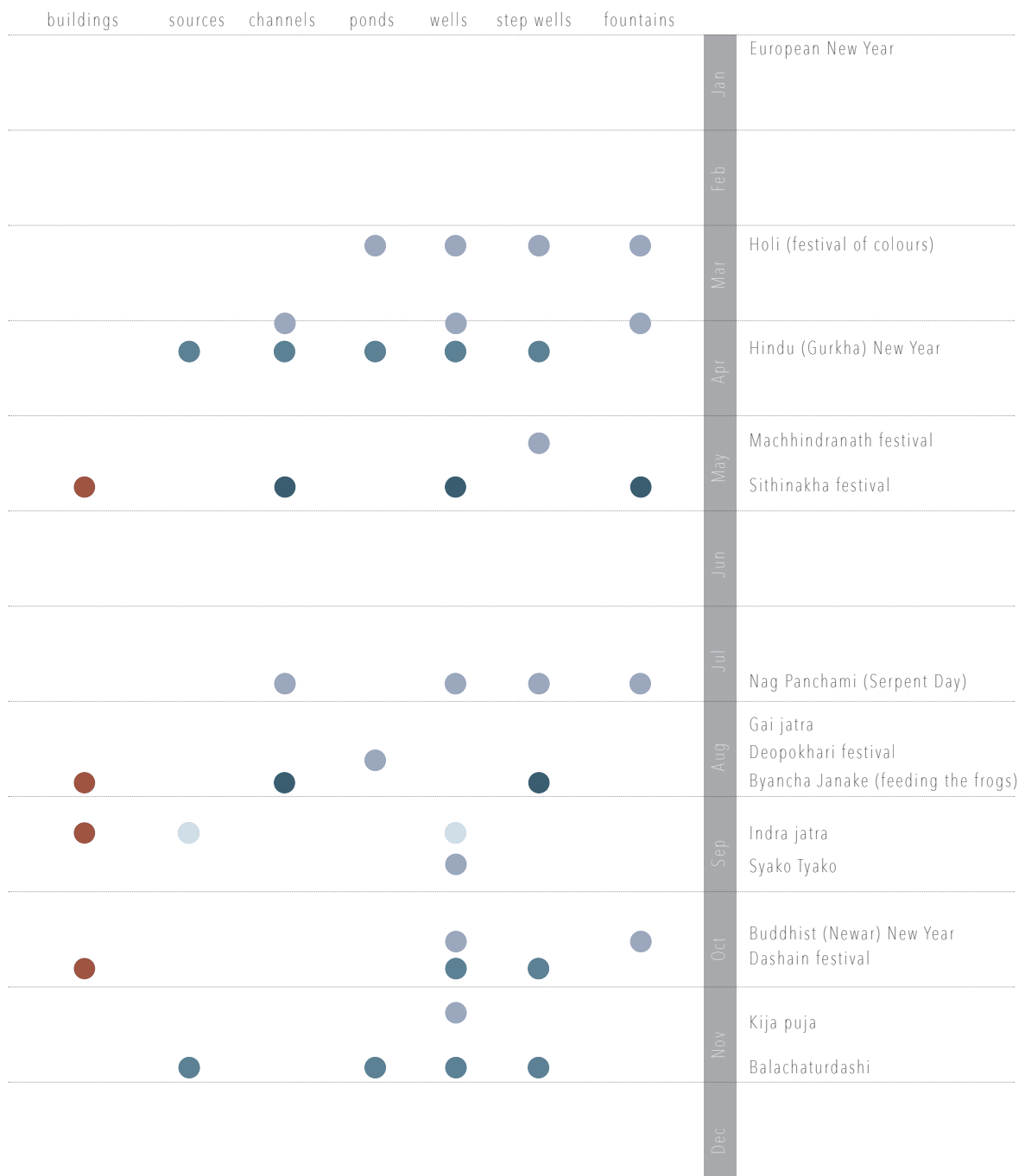
In the beginning of August, *Nag Panchami* or “Serpent Day” takes place (Gurung, 2000). Serpents are the symbols of water, so it makes sense to hold this festival during the monsoon. During this festival, inhabitants polish the symbols of serpents wherever present: on doors, statues, or water resources. This is not the only time cleaning is linked to serpents: when someone gets ill, Newari legends say this is a curse from a serpent, adding that, to lift the curse, the water resources need to be cleaned.

The third moment of maintenance also takes place in August, namely during a festival dedicated to the frogs, called *Byancha Janake*. This is a festival about the defeat of demons, so the cleaning is also linked to this theme. The inhabitants believe their house is occupied by an evil spirit that needs to be chased. The inhabitants open all the windows and doors to ventilate the house, and burn a bundle of hay filled with thorny weeds and cow dung (Tuladhar A. Personal interview. 2016, September 1). The burning hay is then taken through every room, while dust from bricks or mortar from each room is added to the bundle. The people believe the ghost or spirit will be attracted by the burning bale, so they take it outside to a special area for ghosts, called *chhwase*. Each neighbourhood has its own *chhwase* as they form the intangible boundaries of the neighbourhoods.

Finally, before *Dashain* (in October) and *Tihar* (in November) the people clean and repaint their entire house. These festivals celebrate the end of the monsoon and the beginning of the harvest, so the entire family comes together and needs to be received in a beautiful house.

Guthi houses and public rest houses such as *patis* are cleaned before the *Indra Jatra* in September.

- building maintenance
- water maintenance
 - general maintenance moments
 - by city
 - by neighbourhood
 - by family



Maintenance/festival calendar. Source: Amay Marin et al., 2015

2.

Modern building culture

Appropriations

During the fieldwork, it became clear that the contemporary houses vary greatly in size and organisation. In some cases, the Newari traditions are still visible: the kitchen is often on the upper floor and the ground floor is used as storage and workshop room. However, many other variations exist. There are houses where the kitchen is on the ground floor, and even houses in which some rooms are rented to another family, creating a way of living similar to apartments.

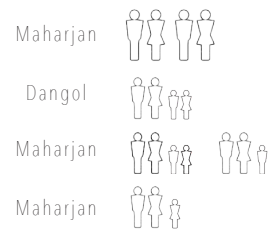
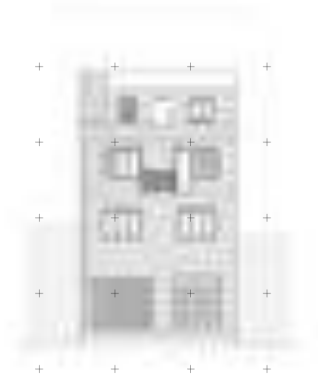
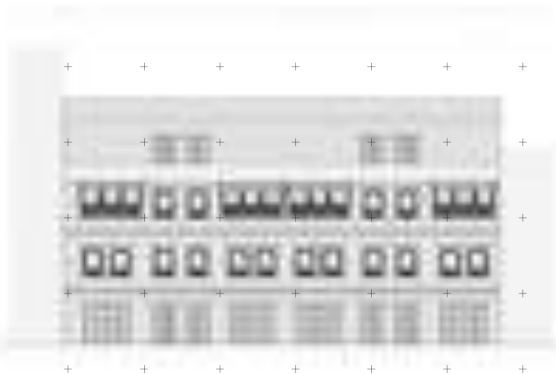
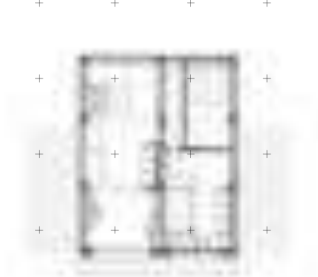
In terms of loadbearing structure, the distinction can be made between reinforced concrete, brick and “Namaste” houses.

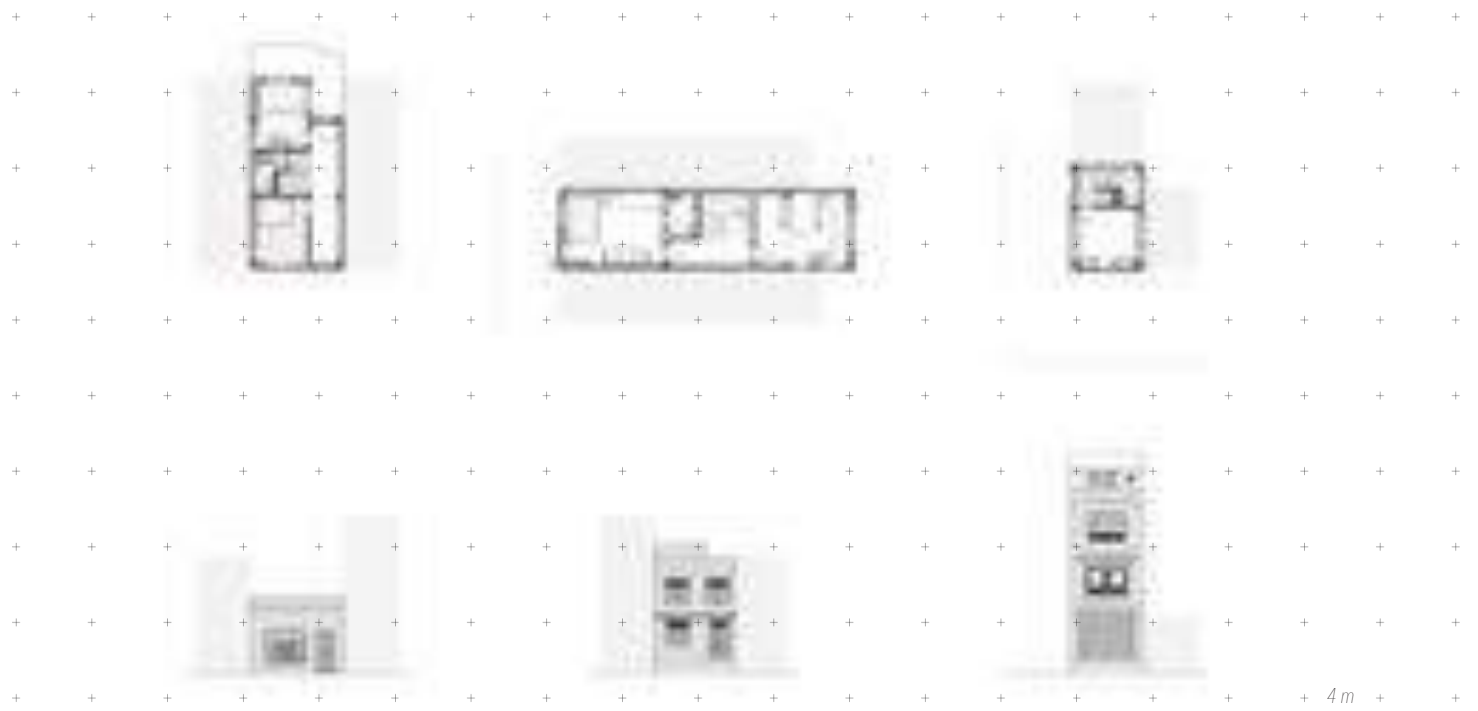
The question whether the contemporary buildings are more earthquake resilient than the traditional Newari houses is an ongoing discussion. However, as explained in the previous paragraphs, the original Newari architecture has a very resilient detailing and has withstood earthquakes for centuries. In Khokana and Bungamati, in general the RCC houses remained more intact than the traditional ones, although many are also damaged. It should be noted, however, that the risks for injuries or even death of a collapsing concrete building are far greater than those of a brick building.





View on the main street 'Tha Lachhi' of Khokana





Vajracharya



Tuladhar



Tuladhar



Different RCC - masonry before frame typologies measured in Bungamati & Khokana



3

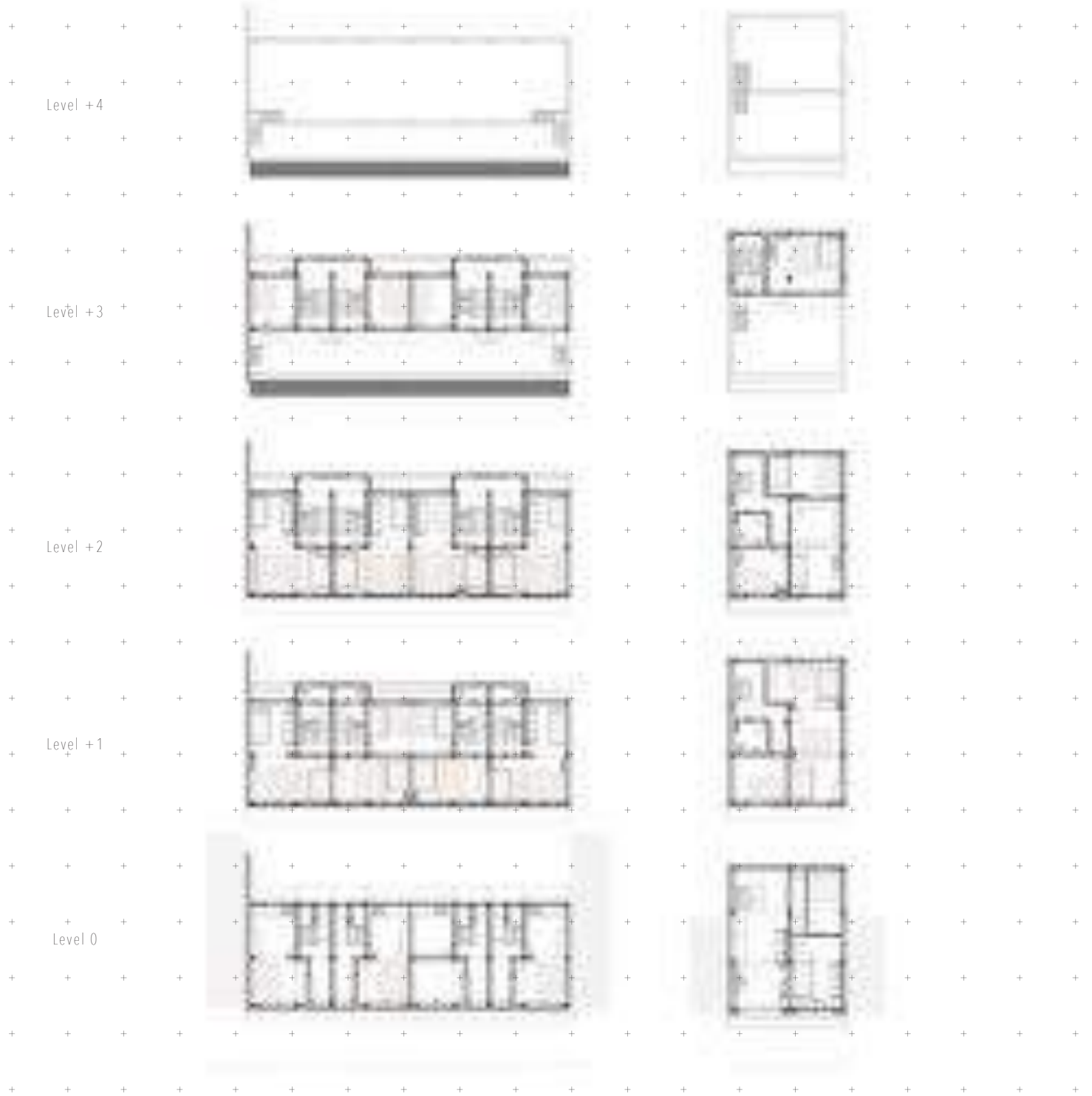


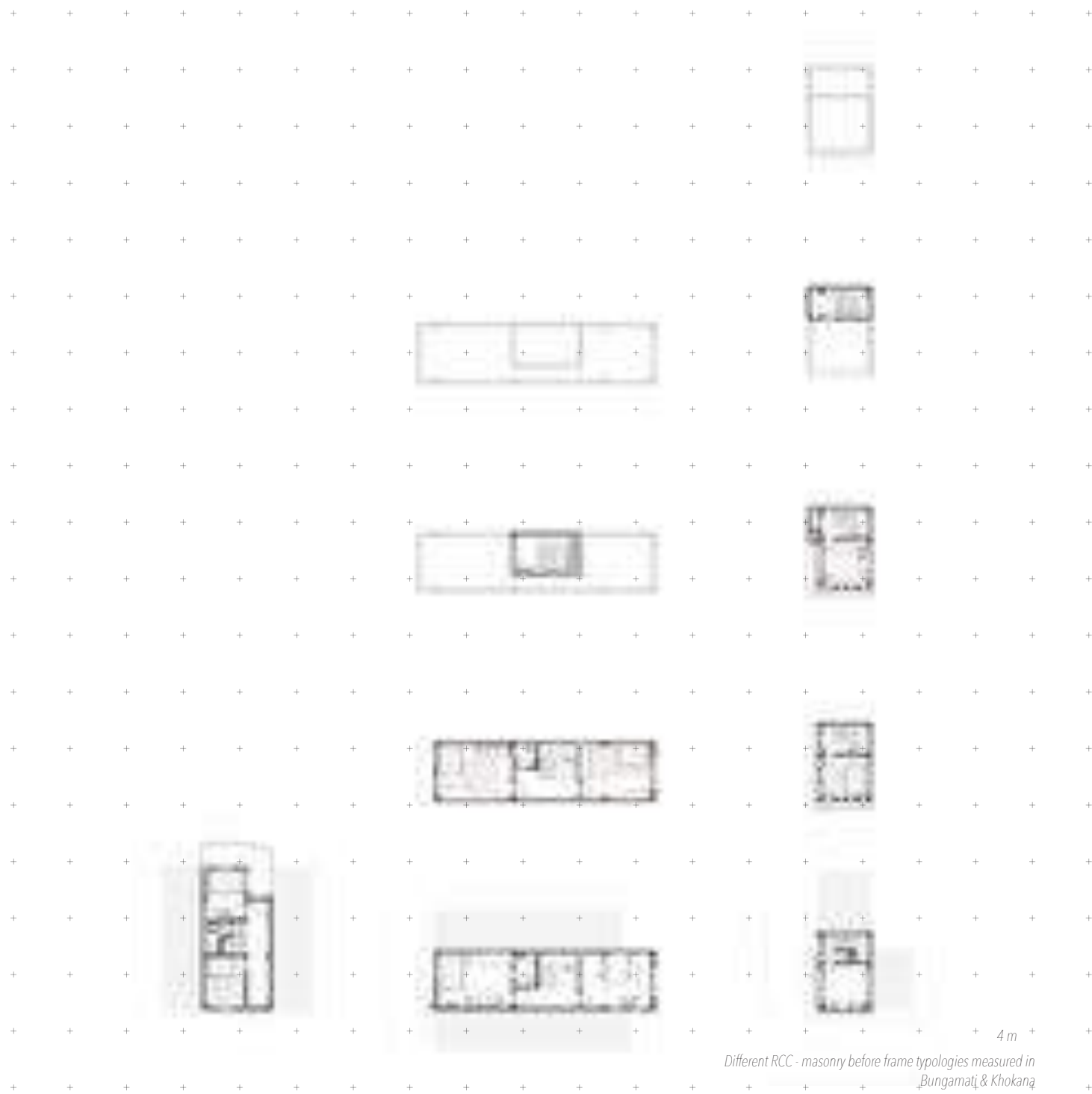
4



5

people living in the house







Facade of the house in Bungamati, 2016



Ground floor used as a bedroom in Bungamati, 2016



Modern kitchen on the ground floor in Bungamati, 2016

The RCC buildings are often the tallest houses in a settlement. They have more and higher storeys than their traditional neighbours. Additionally, most RCC houses have a brick infilling and only use concrete for the loadbearing parts. Since RCC allows for lighter structures, these houses have far thinner walls than the traditional Newari dwellings. The combination of these two factors offers more living space on the inside (Ranjitkar, 2006). On the other hand, building thinner walls also reduces their thermal mass, and thus the thermal insulation is no longer automatically regulated. The use of concrete roofs or corrugated iron sheets and the lack of mud decrease the insulation even further. Hence, while the modern houses are generally larger and more spacious than the traditional ones, they are also hotter in summer and colder in winter.

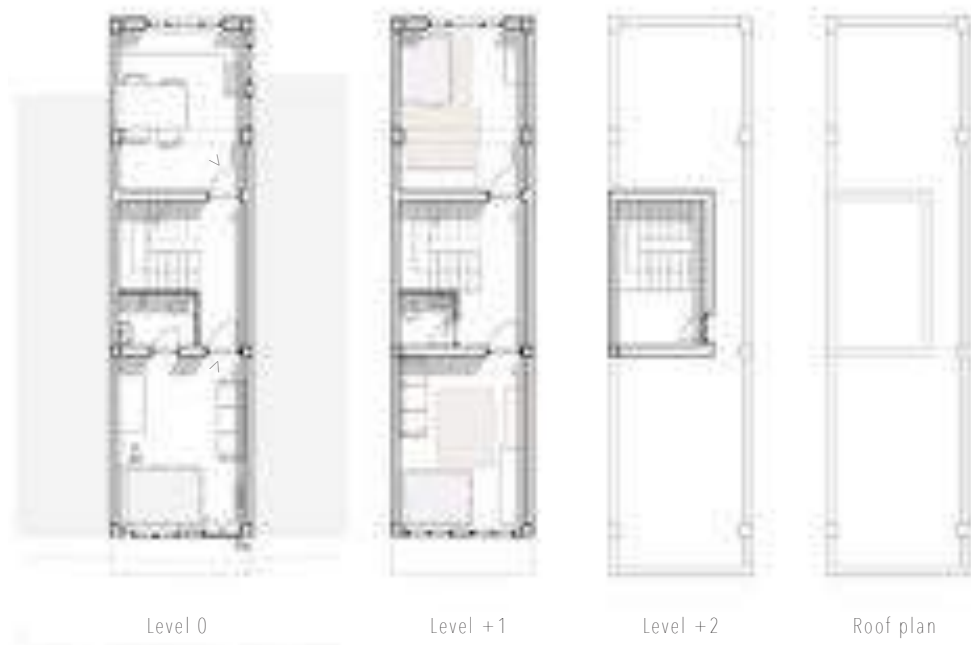
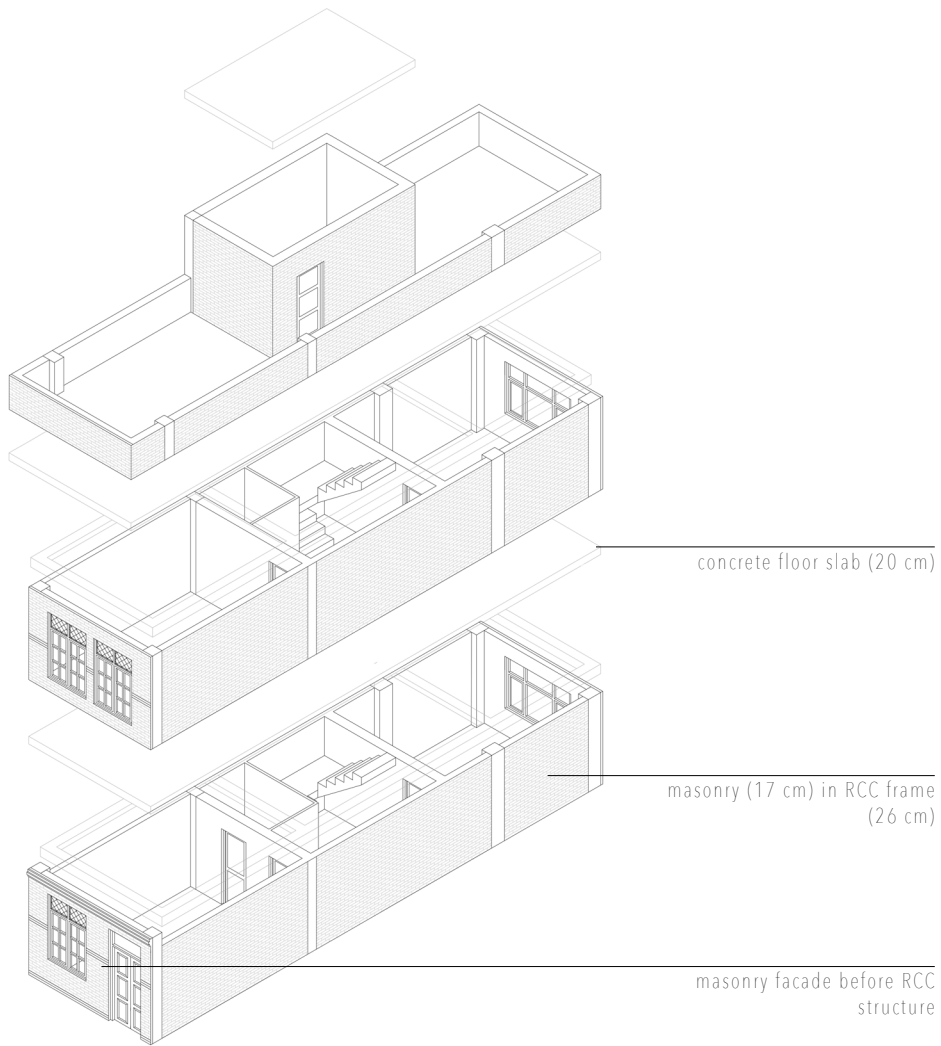
Since the roof is flat and hardly has any overhang, the water is not automatically directed away from the facade. This problem is solved by adding a drainpipe. Often these houses have a private tank on top of their roof collecting the rainwater. As mentioned earlier, the use of drainpipes and flat roofs has decreased the recharge of groundwater drastically.

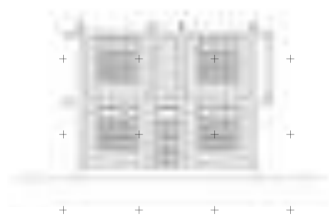
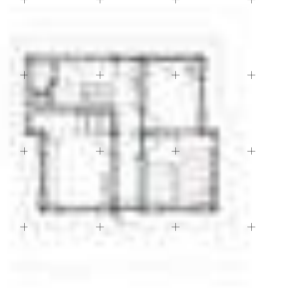
The visual aspects of RCC houses can vary. Some have a plastered facade, in which case it is painted in bright colours. Others simply leave the masonry infilling visible. Nowadays, a new trend is emerging to build RCC houses with a traditional Newari facade. From the outside, the building then looks like a Newari house, although the bricks are more regular in size and colour. On the inside, however, the house may totally differ from the traditional houses. There might even be a living room or kitchen on the ground floor, and in general the house is bigger than an authentic Newari dwelling. More and more people seem to be choosing a house of this type. While they are still very rare in Bungamati and Khokana, there are already several RCC houses with a traditional facade in Bhaktapur. Such houses offer modern comfort while maintaining the traditional street view, but the traditional organisation of space is lost on the inside. Houses of this type have a facade that is completely independent from its construction: first the structure is built, and then the facade is constructed in front of it with a few connections.

1/200

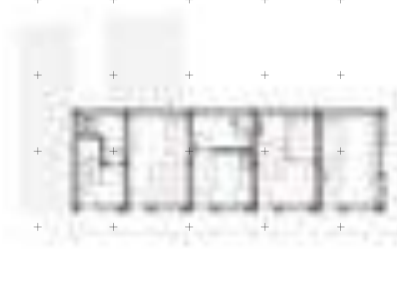
Axonomy of a RCC building with Newari masonry facade (before RCC structure) in Bungamati





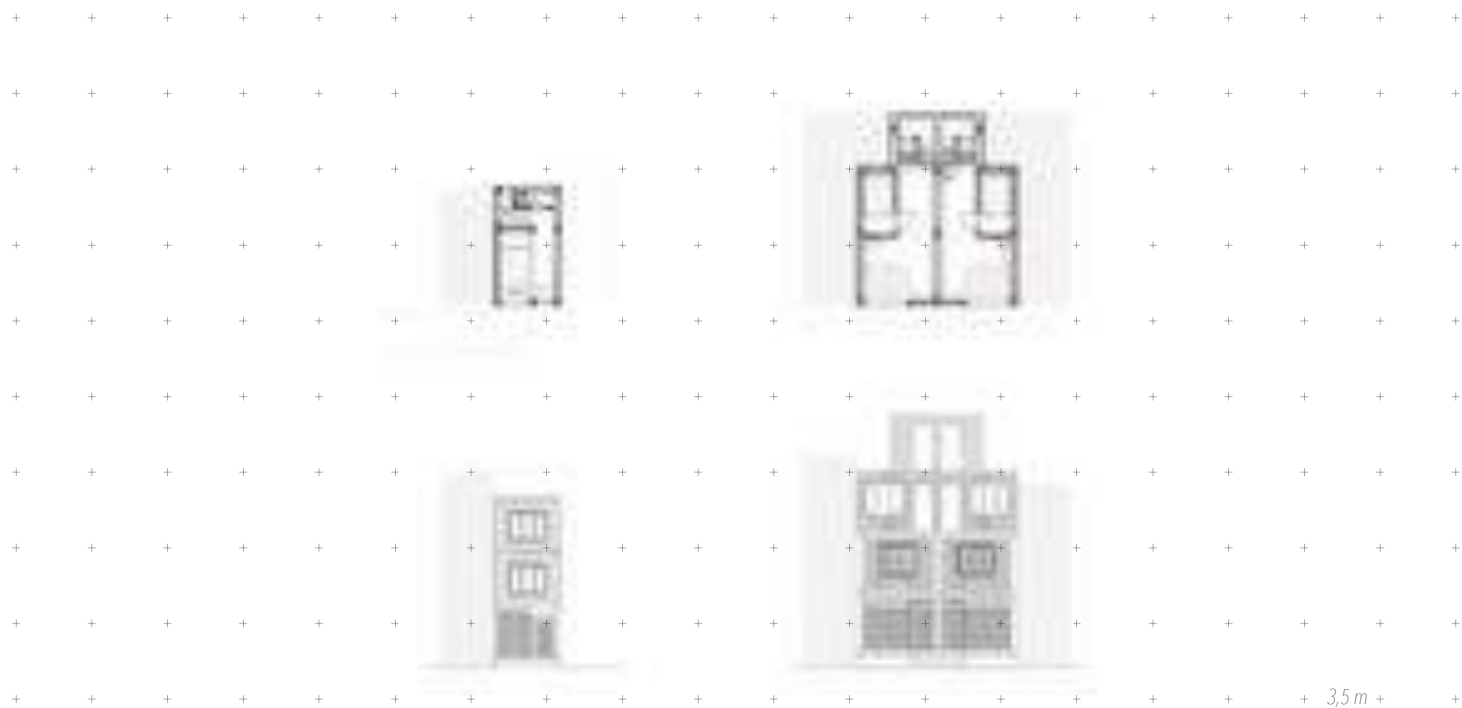


Dangol



Maharjan





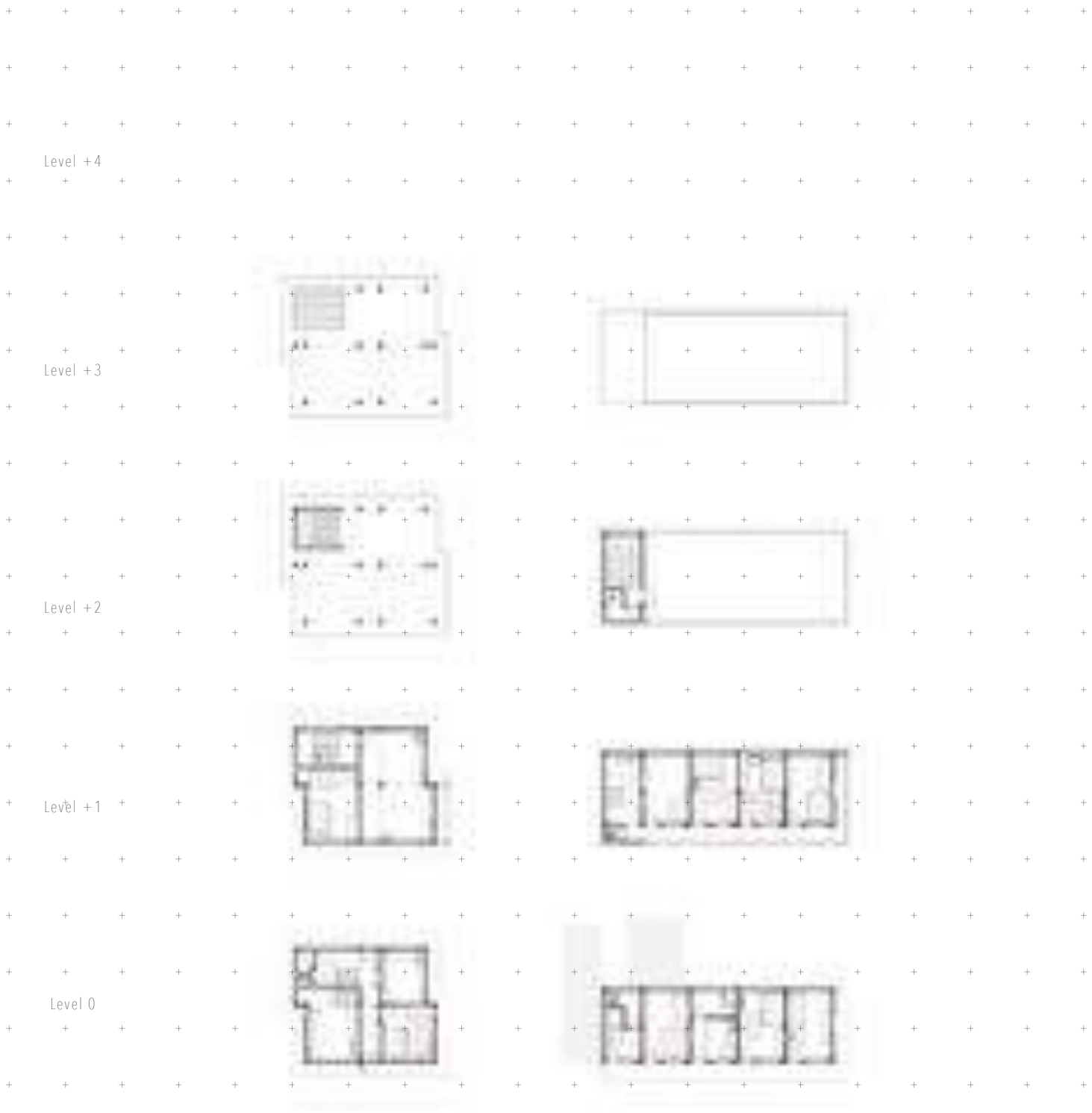
Different RCC - masonry in frame typologies measured in Bungamati & Khokana

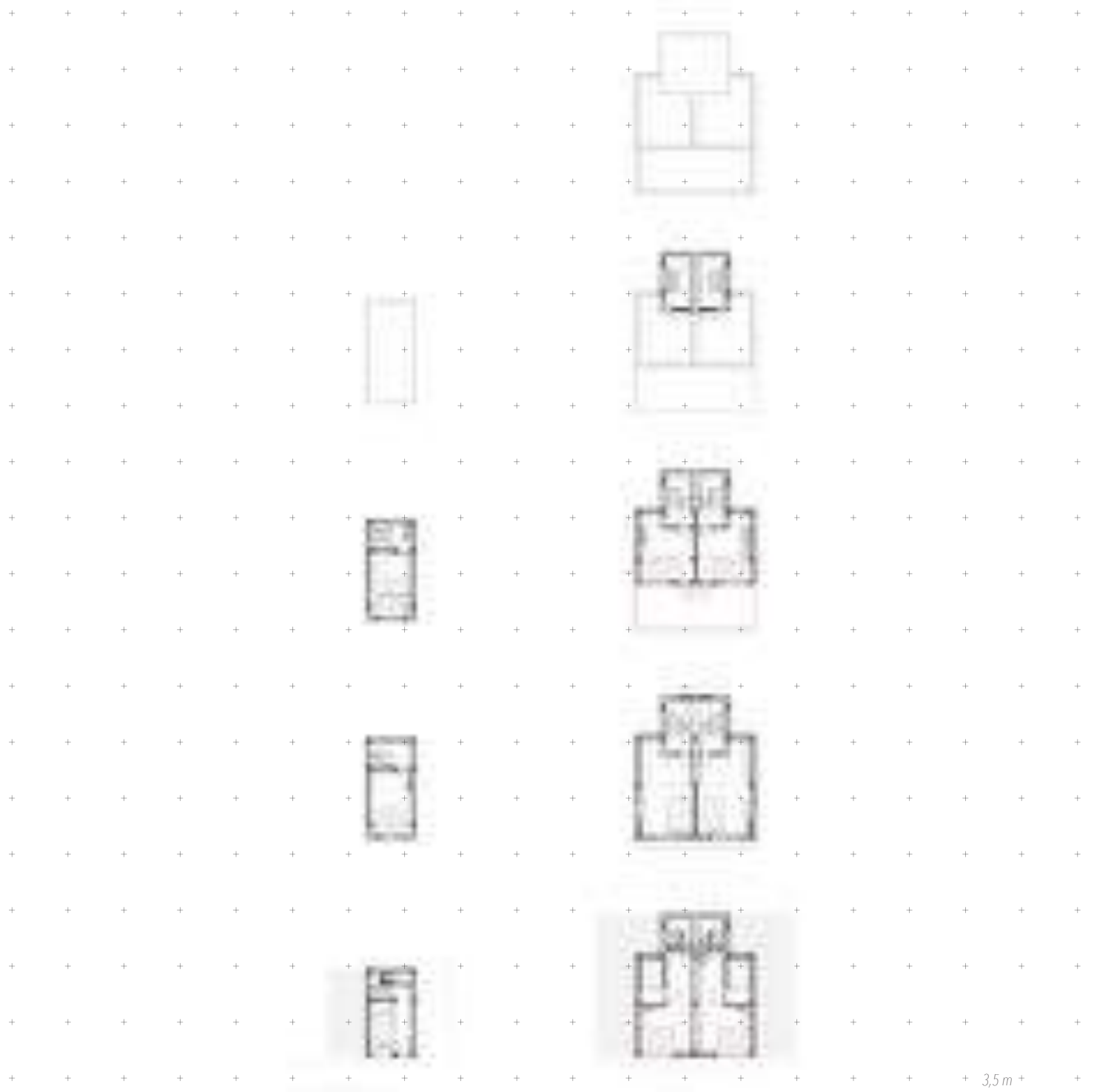
Shahi



Kasai







Different RCC - masonry in frame typologies measured in Bungamati & Khokana





Facade



Kitchen on the ground floor



Bedroom/living room on the ground floor



Storage room on the first floor



Roof plan



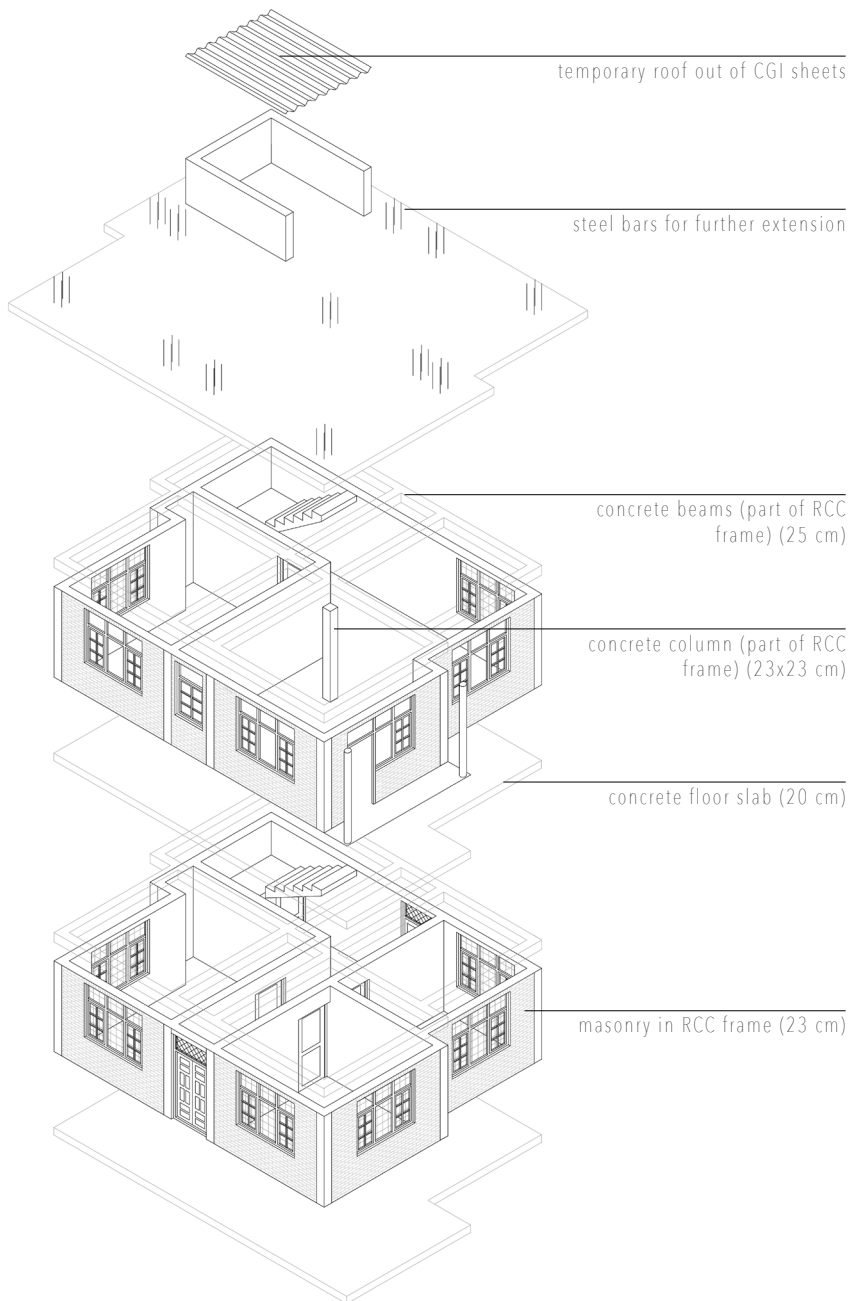
Level +2



Level +1



Level 0



1/200

Axonometry of RCC building with
masonry in frame in Khokana





Maharjan



Dargol



Dargol

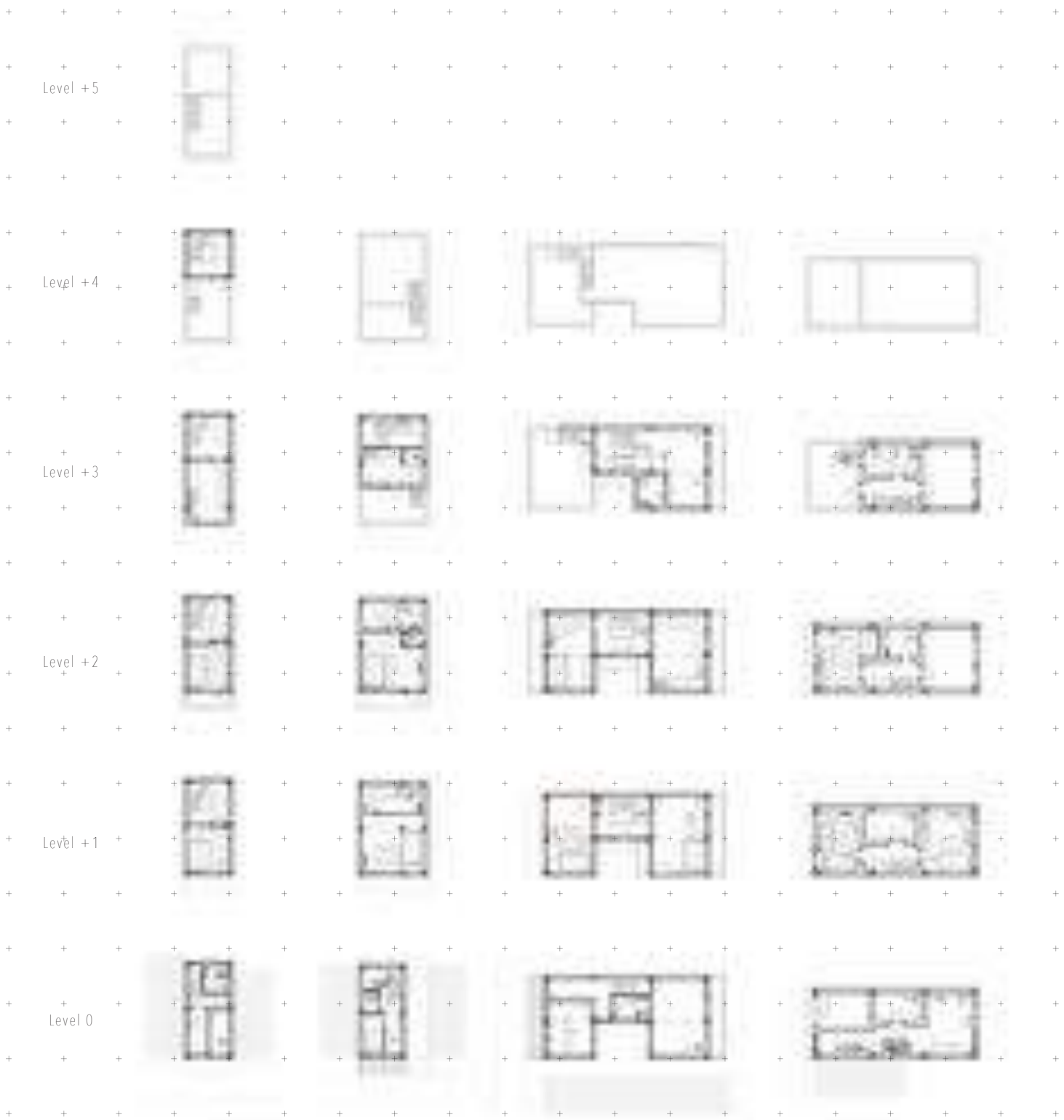


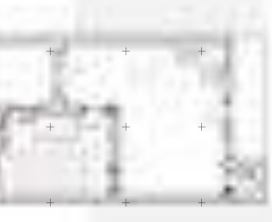
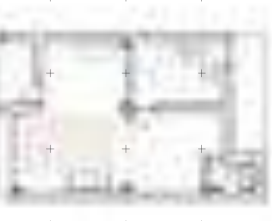
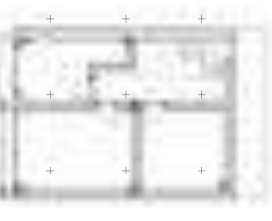
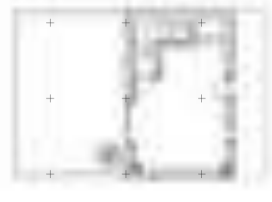
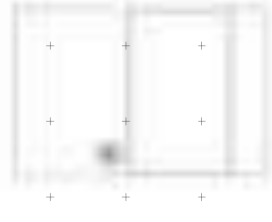
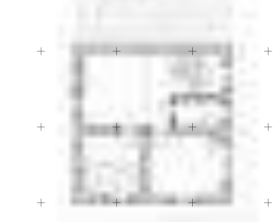
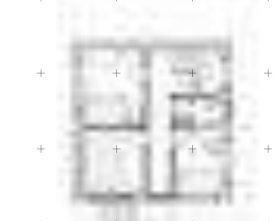
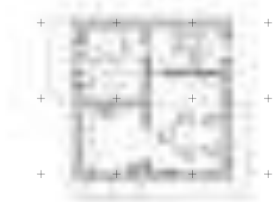
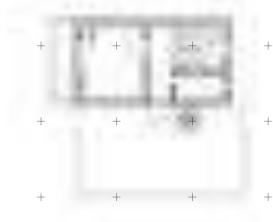
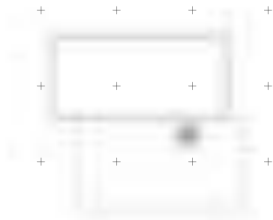
Tuladhar



RCC | Namaste







3,5 m
Different RCC - Plastered/Namaste
typologies measured in Bungamati
& Khokana



Facade



Kitchen on the second floor



Dining room exceptionally furnished with table and chairs on the second floor



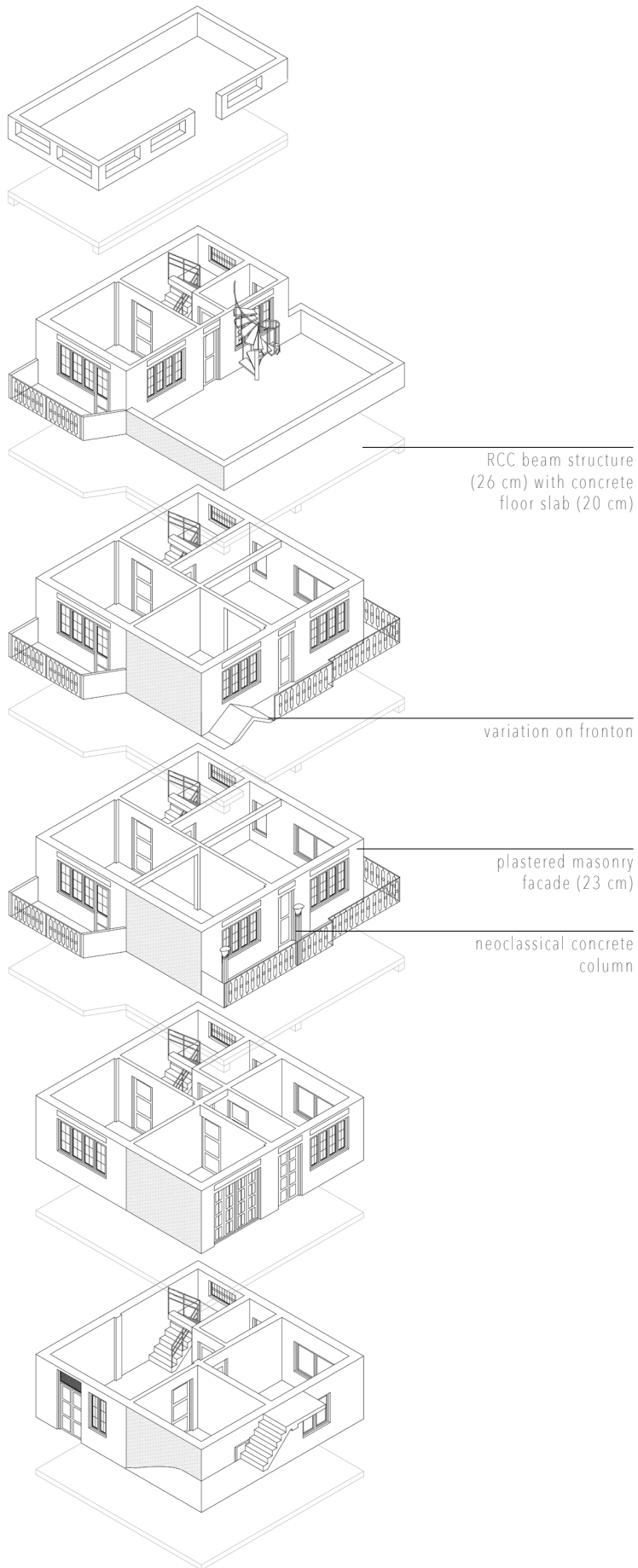
Living room on the first floor

This type of house has an RCC structure, but a very typical facade: it is plastered and painted in bright colours, and it has a few neoclassical elements such as vividly decorated columns and a fronton. It has many religious decorations such as paintings of Buddha. Often these houses are very spacious on the inside, with large rooms and several storeys. The interior is also plastered and painted in different colours. Usually a larger family lives in a house like this, or several family members share one house. While a Namaste house is very large and offers modern comfort such as a fully equipped bathroom, its internal organisation still reflects parts of the Newari tradition. Kitchens are on the higher floors and there is often a worshipping room on one of the upper storeys.

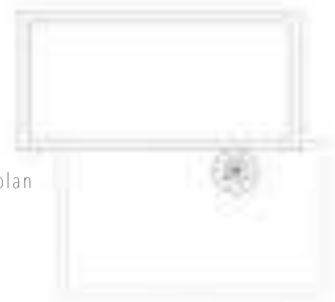
1/200

Axonomy of a Namaste house in Bungamati





Roof plan



Level +3



Level +2



Level +1

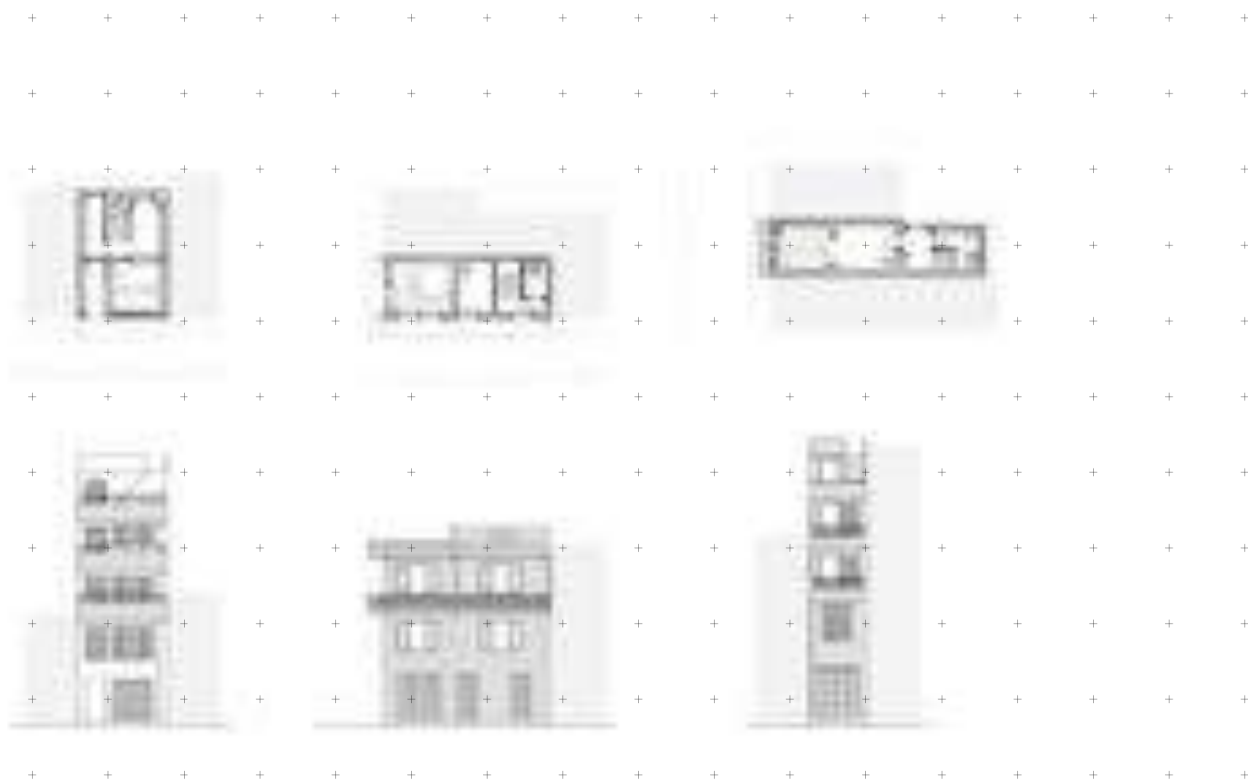


Level 0



Level -1





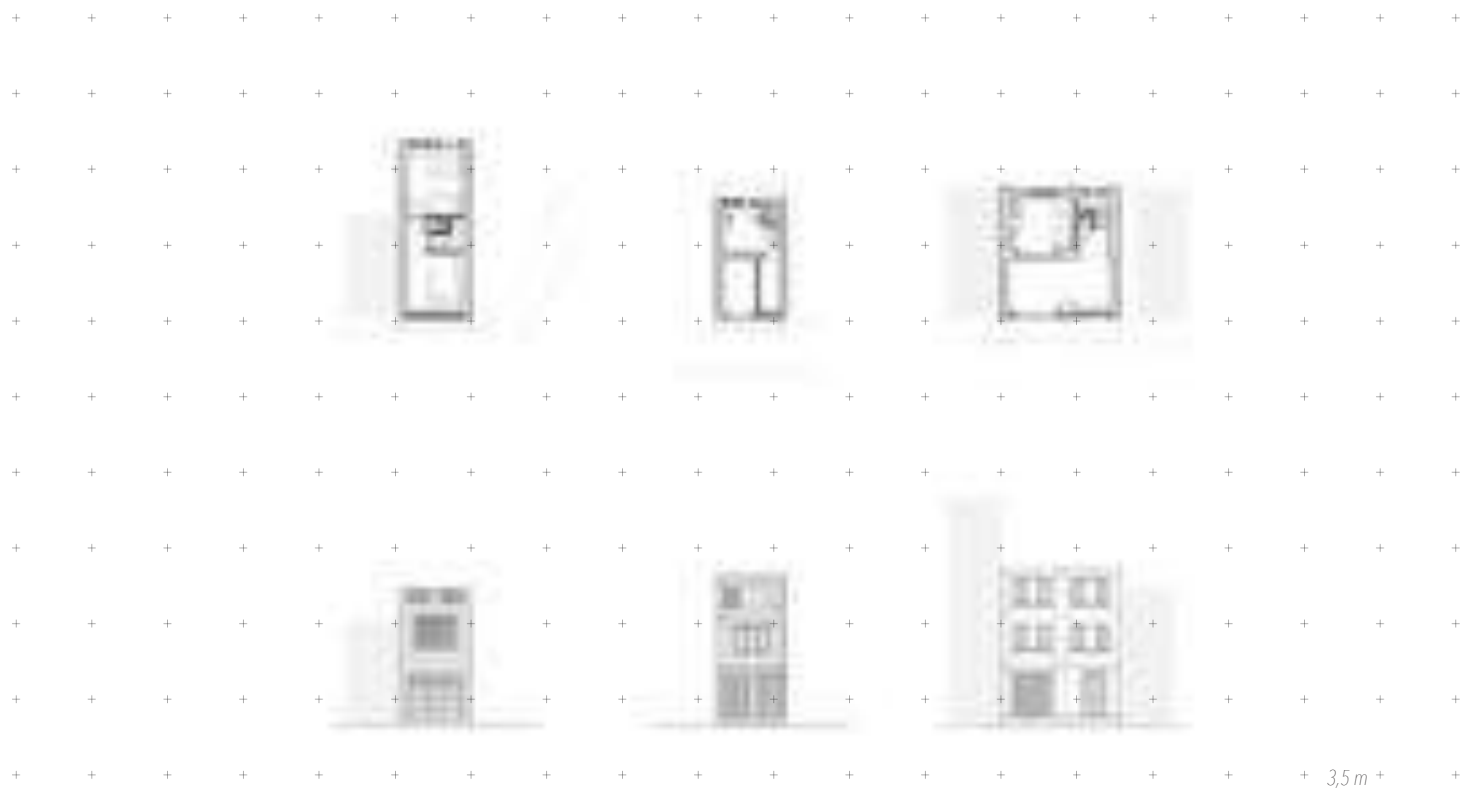
1



2



3



Shrestha



Vajracharya



Buddhist



*Different loadbearing
masonry typologies
measured in Bungamati &
Khokana*



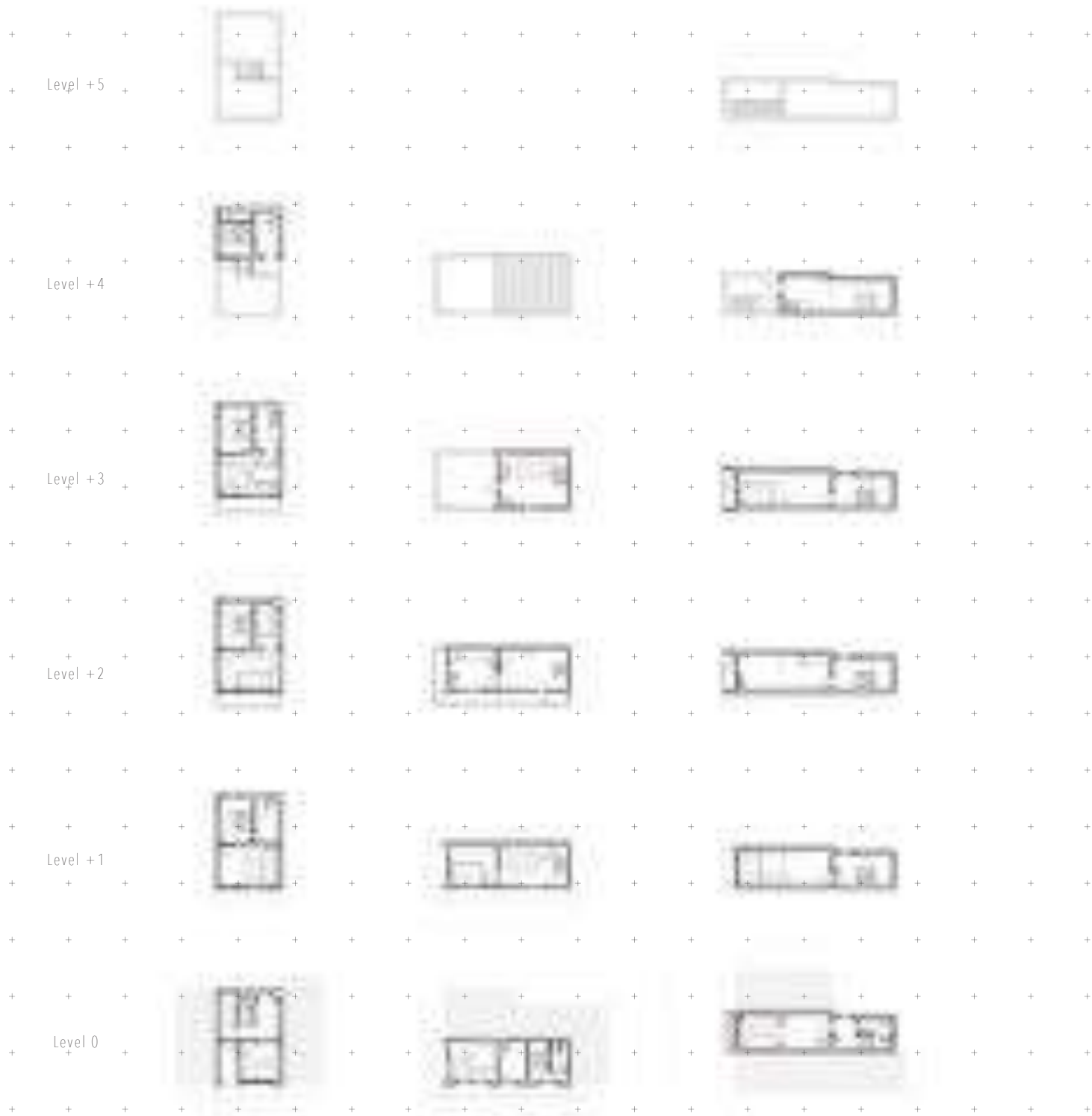
4

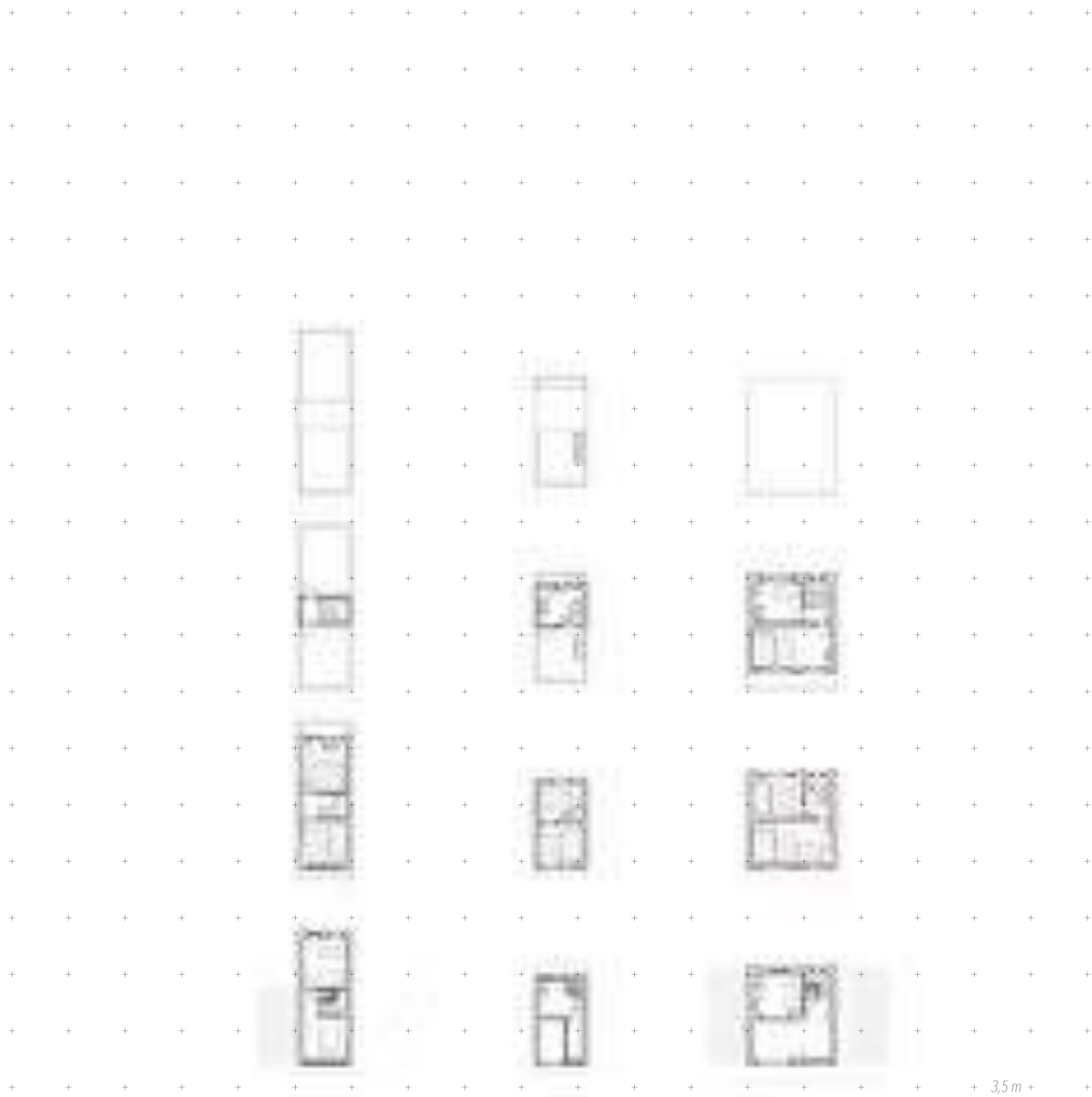


5



6





3,5 m

*Different loadbearing
masonry typologies
measured in Bungamati
& Khokana*





Windows on the first floor



Entrance of the house



Child playing on the roof terrace on the second floor



View from the kitchen on the second floor



Facade

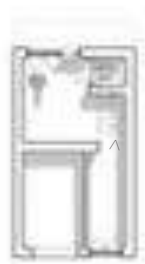
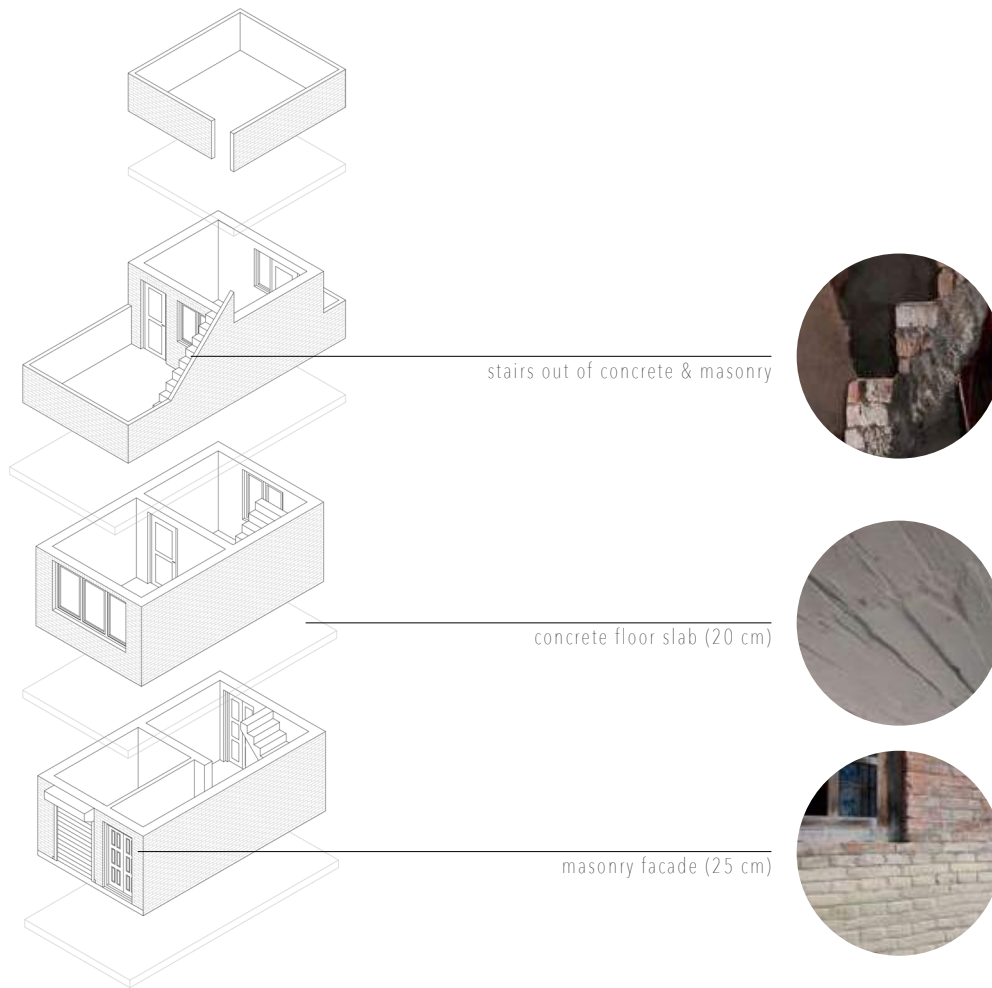
This type is usually smaller than an RCC house. During earthquakes, masonry walls are not stable enough if the building has more than two storeys (Government of Nepal, 1994). Nevertheless, many loadbearing masonry houses have three storeys. Exceptions exist in the form of four-storeyed houses, but these are rare. Loadbearing masonry houses often have concrete floor slabs. Both inside and outside, the materials are often left bare, although some houses also use plaster and brightly coloured paint.

Since this type of house is smaller than the average RCC and even Newari house, it also requires a different way of living. Rooms often have multiple purposes, bedrooms are shared between many family members, and in general there is no separate worshipping room. The kitchen is still usually on the top floor, and combined with the masonry structure, this indicates that the internal organisation of these houses often tends more towards the Newari house than to RCC variations.

1/200

Axometry of a loadbearing masonry house in Bungamati





Level 0



Level +1



Level +2



Roof plan

3.

Earthquake response



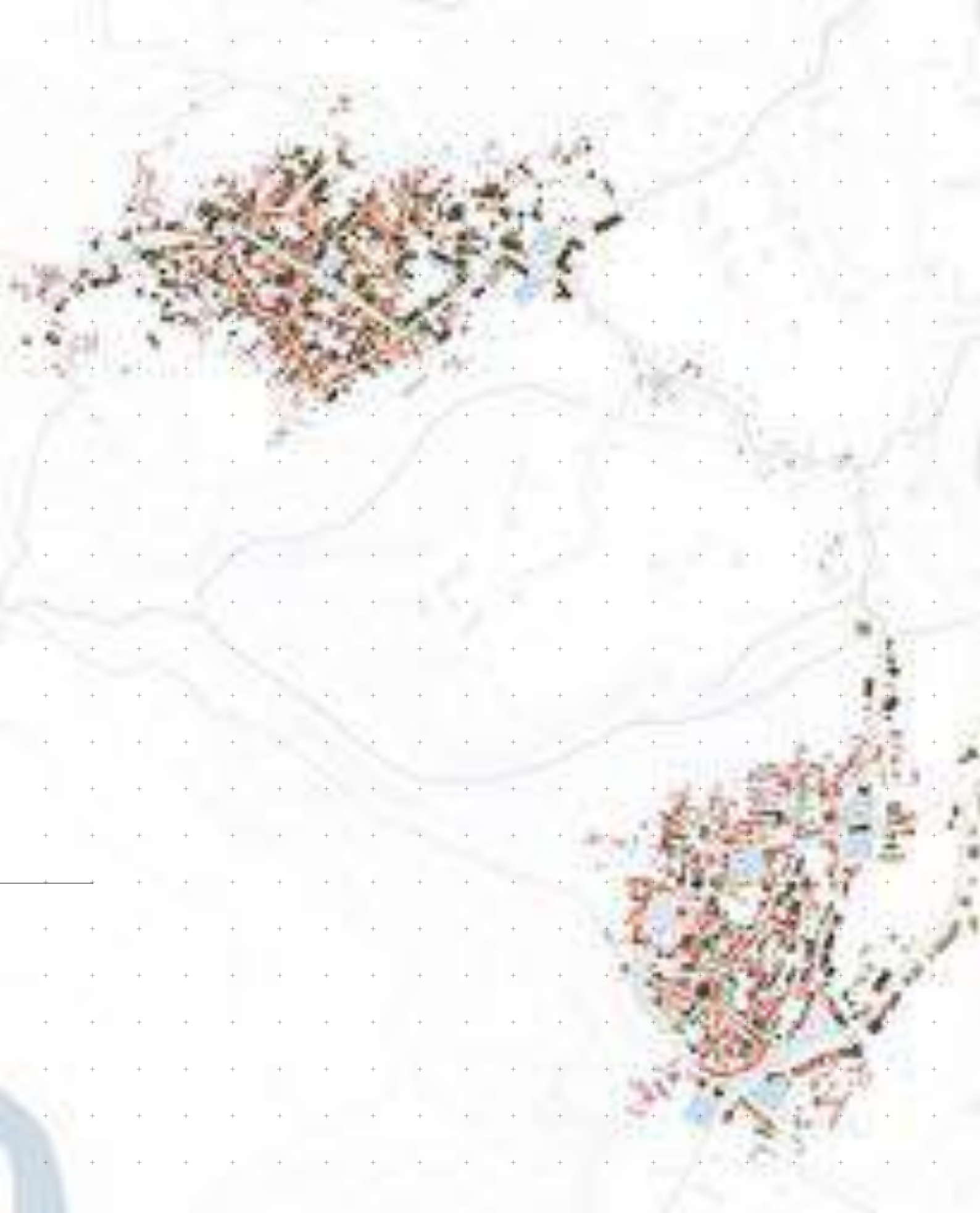
Shelters at the edge of Khokana, 2016

The unorganized urban growth caused a denser tissue and thereby the loss of important evacuation space in an earthquake-prone area. Because of this denser tissue, several parts of the villages are inaccessible by car and, more alarming, inaccessible for emergency services. Furthermore, the built structures have never been subjected to any form of quality control (Jigyasu, 2002). The consequence of so many damaged and collapsed houses after the earthquake of April 2015, was that many people were left without a house and thus temporary shelters arose everywhere. While they were originally intended as temporary structures, they are still there two years after the earthquake. The shelters were built on open spaces, partially inside the settlements, but mostly at the edges. This implies that a lot of agricultural land is currently occupied for living instead of farming. The shelters were built during dry season, neglecting the fact that they would face the risk of flooding during the monsoon.

⊙ + 50 m +

Location of shelters around the damage grade map Bungamati & Khokana

- No visible damage
- Minor cracks
- Major cracks
- Storeys removed for safety
- Partially collapsed
- Completely collapsed





Typologies

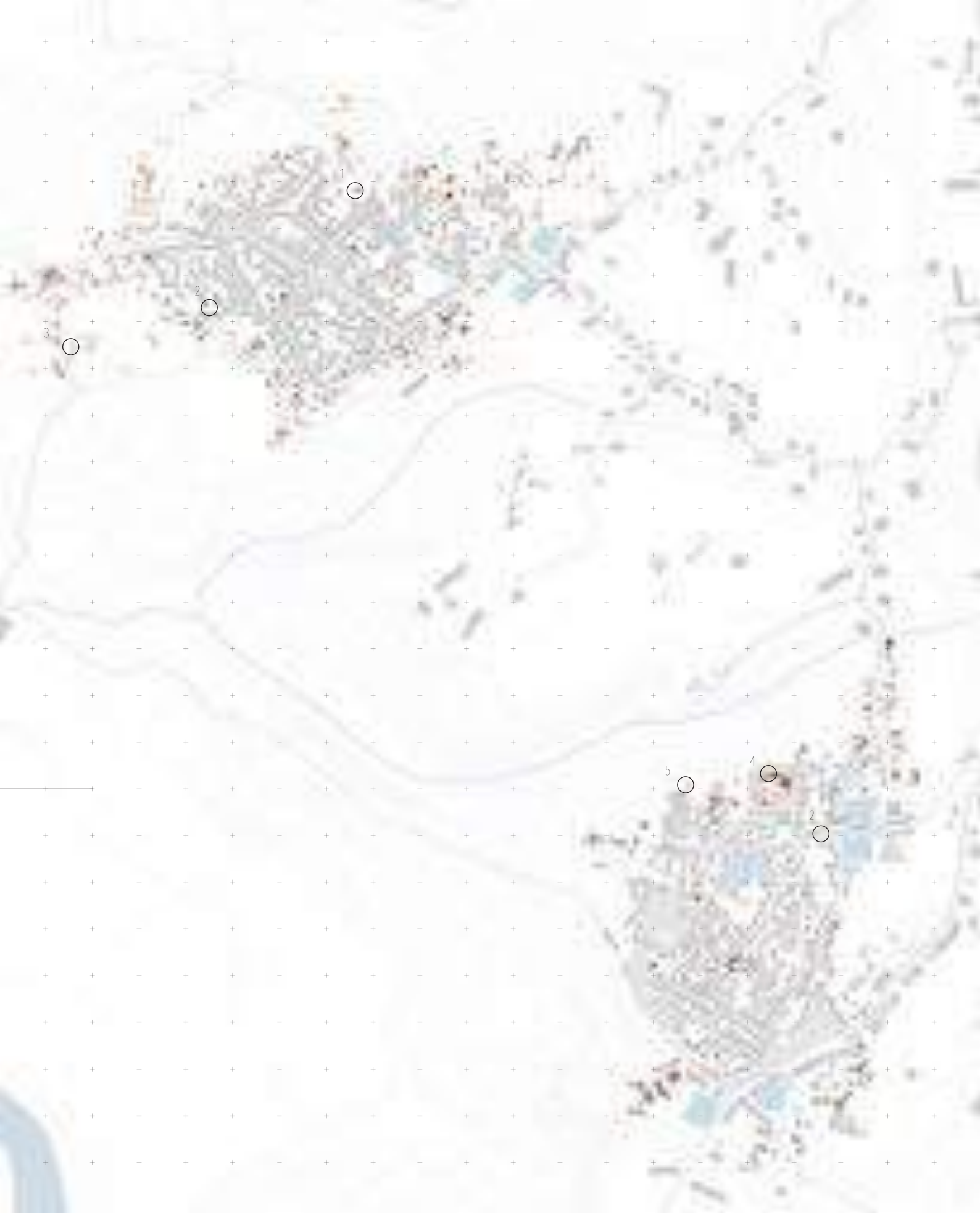
Similar to the houses, there are different typologies of temporary shelters, varying in size and construction. Nevertheless, most shelters consist of only one room. A concrete slab serves as both foundation and floor.

From various interviews, it became clear that many inhabitants face problems while living in a temporary shelter. People at the boundaries of the settlements mostly complained about wild animals, while inside the settlements the issues mostly consisted in heat and noise from the rain. A common problem was, understandably, the lack of space. Most families suddenly needed to cook, sleep and live all together in one room.

⊙ + 50 m +

Different types of shelters located around Bungamati & Khokana

- Bamboo frame w/ CGI sheets
- Bamboo frame w/ wooden plates
- Bamboo wall w/ mortar
- Bamboo wall
- Steel barrel vault
- Steel frame w/ CGI sheets
- Brick shelter
- Wooden frame
- Danish shelter
- Tent
- Indication of discussed shelters



Bamboo structure with CGI sheets

This temporary shelter has a loadbearing structure of bamboo, with corrugated iron sheets as walls and roof.

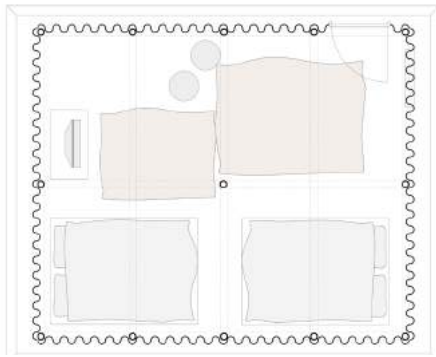




"My name is Dipu Dangol and I am a 22-year-old student. I share a temporary shelter with my mother. I have three sisters who are all married and live nearby in Bungamati, Khokana and Bhaisepati. I study biotechnology and I am trying to get a scholarship to continue my studies in the U.S."

"Our house is quite damaged and it is not safe to live in anymore, but we still use it for cooking. Our temporary shelter is located near our house and we have electricity inside. I like to see science fiction movies and I am a big fan of Johnny Depp!"

"We really want to rebuild our house, but to pay for the house we need to sell some of the rice fields that we own. We also get some money from the rent we get from the weaving company that uses the building behind our house."



*Scale 1/100
Plan of Dipu's shelter.*



Shelter cluster in the ricefields in Khokana, 2016



Outside of Dipu's shelter in Khokana, 2016

Steel barrel vault

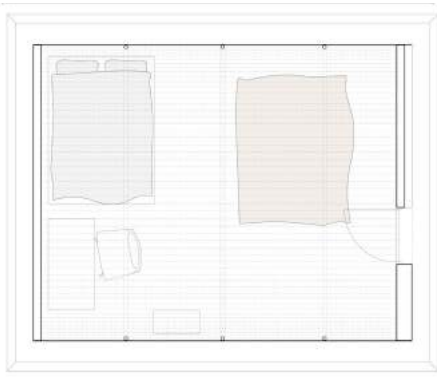
This type of temporary shelter is the smallest one there is, but it is the easiest one to build. It has a roof of bended corrugated iron sheets.





"I am Gyan Lal Maharjan and my family owns two traditional houses. I am a farmer and I own 8 Ropanis of rice field. The harvest is used for our own consumption. The shelter is not situated on my own land, but we do not have pay rent because the owner does not use his land much."

The shelter is funded by my brother, who is a driver. The solar panels were donated by the school of my grandchildren. Now I am preparing new mud for the maintenance of the shelter."



Scale 1/100
Plan of Gyan's shelter



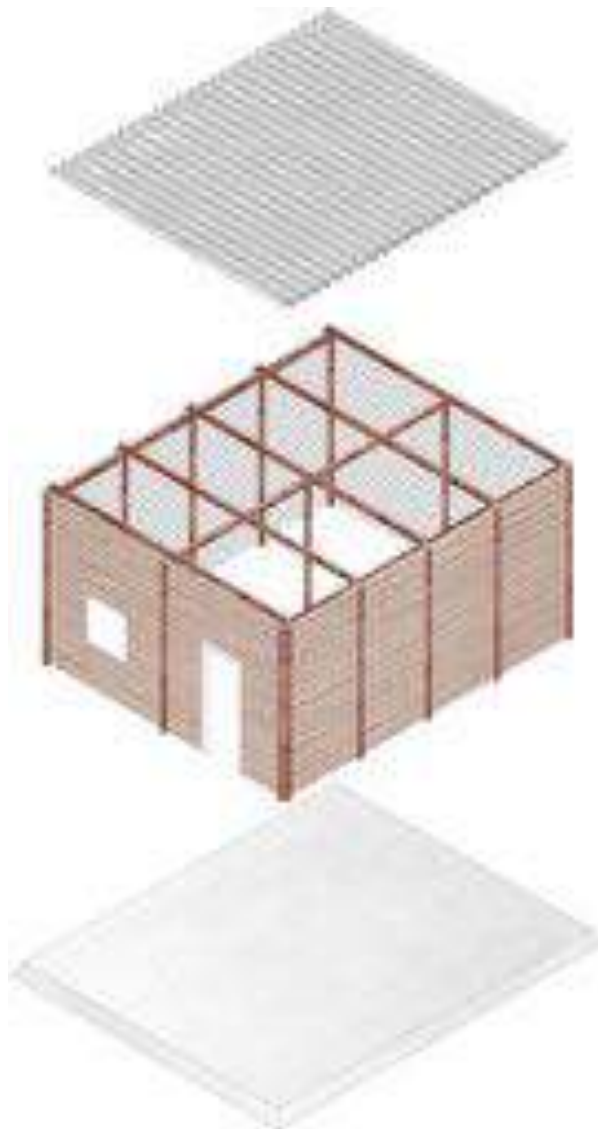
Inside the vaulted shelter in Bungamati, 2016

"Our family of six people is divided over two shelters. This is the only land we have, so we built the shelters where our house used to be. It was a Newari house, with three storeys. Luckily our shelters were funded by an unknown man, because our only income comes from my father, who is a taxi driver. The other shelter lies on rented land and now the family members that live there only come here to eat, even though we used to live all together. That is because we had a lot more room in our house than we have now. On top of that, in our shelter we have a lot of noise from the rain and it is very hot in summer. That is also why I prefer the Newari architecture over concrete houses, it is more comfortable."



Bamboo walled shelter

Similar in structure to the first typology, yet with bamboo walls instead of corrugated iron sheets, therefore looking differently.

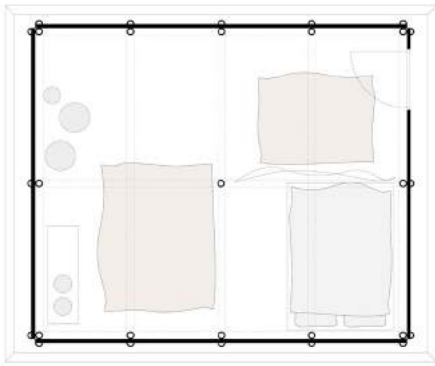


Scale 1/100
Axonometry.



"The temporary shelter is rented and built on the land of our neighbours. Our land is located a lot further, so this was just easier. We live with eleven people in this shelter. Because the shelter is located on the rice fields, there are a lot of snakes. In addition, the toilet is quite far away and taking a bath is almost impossible.

In our house, we only use the ground floor as a storage space and we use the water pipeline for water supply. We are not planning on rebuilding a new house due to financial reasons, but if we have the money, we would choose a RCC building with a traditional facade."



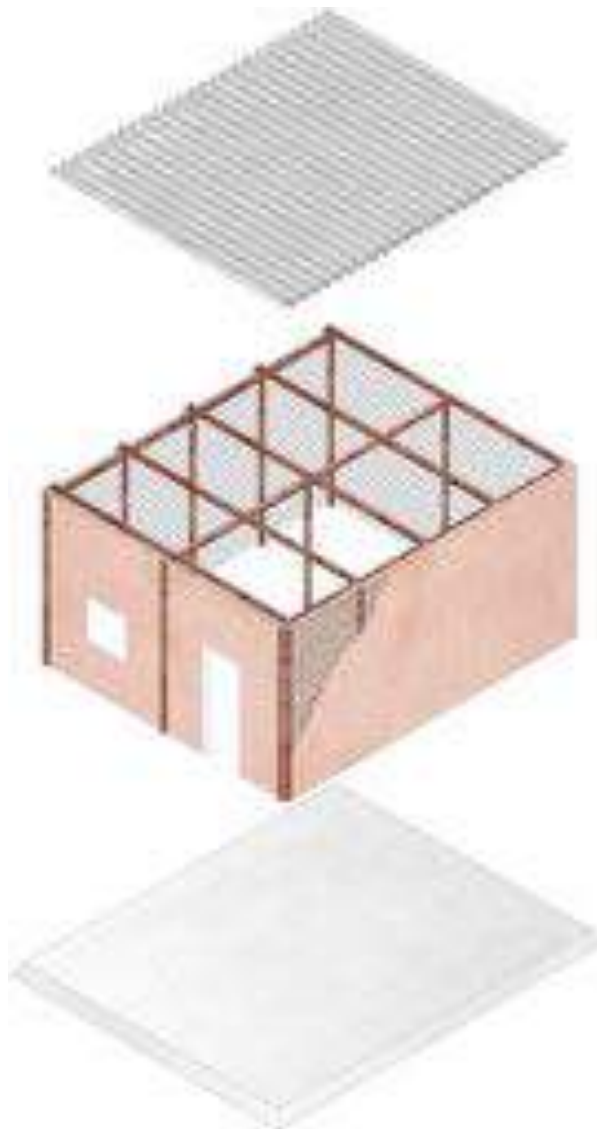
Scale 1/100
Inside the shelter.



Entrance shelter cluster in Khokana, 2016

Bamboo walled shelter with mortar

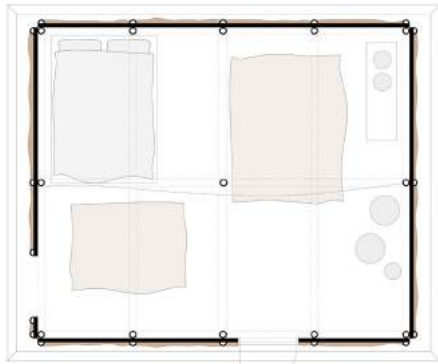
This shelter has the same structure as the previous one, but has an extra insulation layer of red mud against its walls. This type of shelter is most commonly built by the association Enfance Nepal.



Scale 1/100
Axonometry.



"We live with eight people in this shelter that is now divided in two. Our shelter is placed right before our house, that had way more room. We do not pay rent for the shelter because it is located on public land. We built one part ourselves and the other part was funded. Our relatives also built their shelter on the square. The climate of the shelter is very extreme. In summer it is very hot during the day, but at night it gets very cold. We also have a lot of trouble with the mosquitos. All the shelters have the same kind of problems, so I do not think another type of shelter would be better. The house was a traditional Newari house with three storeys. Behind our house is a piece of farmland on which we cannot build, because it is the only land we own. We use it to grow fruit and crops, which is the main source of our income. Before, we used to have a balcony where we could dry our crops. Now we dry them on the roof of the shelter. We can still use the ground floor of our house as kitchen and living space, and in the back there is a place to storage our livestock. When we are going to rebuild our house, we want a traditional facade but a concrete structure, because we think it will be stronger."



Scale 1/100
Inside the shelter



Shelters at the edge of Khokana in the ricefields, 2016



Exterior of the shelter in Bungamati, 2016

Danish People's Aid shelter

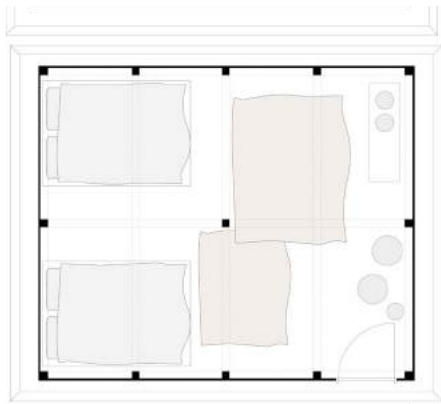
Provided by the Danish People's Aid, these shelters have a timber loadbearing structure and recognizable green walls. This typology is especially prominent in Bungamati, where none in Khokana.



Scale 1/100
Axonometry.



"We live with three people in this shelter and our house was located right across from it. We used to live with eleven people in the house, and for a few months all of us lived together in the shelter, then most of our family members moved to another shelter close by. We used to live in a traditional Newari house with 3,5 storeys. Because we only live with 3 people in the shelter, we have as much room as we had in our house. Because the kitchen is still located in the house, we still share it with the entire family. This shelter is only used for working and sleeping. The land here is rented, but the shelters to which the other family members moved are built on our own land. The shelter is funded by the Danish People's Aid. We used to rent another place in Bungamati for woodcarving, but after the earthquake we also do the woodcarving in this shelter. We are very afraid of wild animals because we live so close to the forest. We are also scared of thieves because this place is so isolated, but at least we are satisfied with the type of shelter. When we are going to rebuild our house, I want a concrete building because we do not have enough money for a Newari house, and I think concrete buildings are stronger. I really want the windows to be carved like a Newari house though, so it would be a combination of modern and traditional."



Scale 1/100
Inside the shelter



Logo presented on the Danish shelters



Danish shelter at the edge of Bungamati, 2016

Future aspirations

The temporary shelters seem to become a long-term solution. This is mainly because in order to start building, people need the funds provided by the government. To receive the money, they need to have their design approved by the municipality (Bastola S. Personal interview. 2016, October 10). However, the new by-laws for traditional settlements are still not finalised and keep on being postponed, and as long as these by-laws are not finished, no plan can be officially approved. Hence, nobody from Khokana or Bungamati has received his grant yet.

Khokana has an additional problem to this: most inhabitants of the settlement do not have an official land owner's certificate (Bastola S. Personal interview. 2016, October 10). This creates extra difficulties, slowing down the reconstruction process drastically. Firstly, the government only gives the grants to inhabitants of the houses that have officially been declared as damaged or collapsed by the survey of the National Society for Earthquake Technology (NSET). However, if the inhabitants do not officially "own" the house, they cannot receive the money because they cannot prove they own a damaged house. Secondly, they cannot draw an official floor plan because legally they cannot make adjustments to houses they do not own.

While the reconstruction process is going slowly, there also is no plan for what to do with the shelters afterwards. Either they will continue to take up valuable space, or their materials will become part of the existing waste management problem.

This waste management problem arose along with the rapid urban growth when the amount of solid waste reached new highs (Dangi et al., 2011). Since the 1980s there was more attention for solid waste management (Pokhrel & Viraraghavan, 2005) and since then, different institutions have been held accountable for developing the sanitation. The Solid Waste Management and Resource Mobilization Centre (SWMRMC) were the first to get the responsibility over the management of solid waste in the Kathmandu Valley. They received financial support from the German Technical Cooperation Agency (GTZ), but that ended in 1993. When the Local-Self-Governance Act was established in 1999, the task was given to the different municipalities, authorizing them to take action at a local level (Water Aid, 2008).

In Bungamati and Khokana, both part of the Karyabinayak municipality, solid waste is collected twice a week and brought to the Okharpunwa Landfill (Pokhrel & Viraraghavan, 2005). However, no further recycling is done there. Since the waste collection is insufficient and poorly organised, many villagers tend to dump their waste in the forest, along the streets and even on the river banks since they do not know where to leave it. In both Bungamati and Khokana there are several dumping spots with large amounts of waste. This trend of dumping waste suggests the non-reusable shelter materials will face a similar fate.







VI.

Conclusion

Both Bungamati and Khokana are situated in an earthquake vulnerable area, insurmountably leading to earthquakes which occur with a cyclic frequency. Therefore, the Newari building culture is strongly based on a seismic culture, present in both the urban and architectural scale. However, due to a lack of knowledge and the advent of modernity, the building culture is transforming.

The Newari architecture has evolved over centuries on a trial and error basis in order to build structures which are earthquake resilient. However, since the ancient building knowledge is only tacit, and in addition with the increasing use of modern materials such as steel and concrete, the traditional building techniques are fading to some extent. Regardless, the Newari building culture has exceptional qualities, which should be preserved. An increased awareness can be perceived since the Government of Nepal is working on National Building Codes, integrating distinct chapters about the traditional core areas of Newari settlements. The building codes for the cores prescribe rules that make sure the traditional architecture will be conserved.

In addition, there is a clear evolution within the urban tissue. The traditional core of the Newari settlements has a unique and well thought out urban fabric. In general, the core areas are shaped by auspicious forms, and a maze of courtyards and kitchen gardens connect the inner tissue of the building blocks. However, this ancient network is also exposed to contemporary conditions, both reshaping and contributing to it. The expansion happens in a more random way than the traditional organisation. A link between the vernacular and the contemporary is missing, leading to a discontinuity in the urban tissue.

Both of the Twin Villages are rural and therefore agriculture based. A complex system provided water both for irrigation and personal use in the past. However, while this system is partially outdated, it is additionally compromised since the development of the municipal water supply. Because the inhabitants started to prioritize the modern water supply, the entire traditional system started to deteriorate. However, the earthquake of 25 April 2015 and its aftershocks heavily damaged the waterpipes of the modern system, causing the inhabitants to suddenly rely on their traditional water sources.

The water from the vernacular water system is currently heavily polluted, because it relies on contaminated groundwater. The lack of a proper wastewater system, combined with an insufficient waste management system, has caused both waste and wastewater to simply flow into the rivers and ponds. The edges of the settlements are used as landfill areas, where the inhabitants discard their organic and non-organic waste. The harmful chemicals from the non-organic waste soak into the ground and therefore pollute not only nature but also the groundwater.

The reconstruction process after the earthquake of 2015 offers an opportunity to revive the Newari traditions, and simultaneously to revise them, in order to meet the contemporary needs of Bungamati and Khokana.

Strategies

It is our aim to propose a reconstruction strategy, while respecting and reviving the Newari building culture. The goal is to (re)design strategic parts of the village and by doing this, prioritizing its durability and adaptability towards further exponential urban growth.

First of all, a cooperative model of waste management is proposed. The design of this model focuses on sorting and recycling waste in order to decrease the areas currently occupied as landfill sites. Furthermore, due to the beginning of the reconstruction process, some temporary shelters are left deserted. In this regard, the question arises on what to do with these uninhabited structures. People do not tend to clean them up, and leaving them abandoned will waste a lot of fertile land. Therefore, the waste management model will be supplemented by a collection of the various building materials used for the temporary shelters.

The next aim is to restore and re-articulate the traditional water supply system. By rethinking the vernacular system and complementing it, it will provide an integrated use of traditional and modern where the municipal supply is insufficient, while at the same time it will be a useful backup during earthquakes. A proper wastewater system is proposed, combined with additional features to maximize rainwater collection. Recycled wastewater, rainwater and purified groundwater will, together with the municipal supply, meet the needs for water usage of the inhabitants. All of this will be translated into the use of public space.

The last focus will be on the seismic building culture. Therefore, strategic locations centred around traditional waterbodies are chosen where architecture will be the key factor for the revitalisation of the various public places. By further detailing the architectural scale, this design will equip the inhabitants with proper information to build contemporary vernacular Newari buildings which are more sustainable, while retaining the historical and cultural values of the Newari architecture.

I.

Strategy for the Twin Villages

A strategy providing a solution in terms of waste and debris management. A collective structure, focusing on collecting, sorting and recycling, is implemented along the armature that connects both Newari settlements.



Recycle bank

As described in the analysis, the waste management of both settlements is not fully developed. There is some sort of waste collection, however people tend to gather their solid waste and subsequently bring it to one of the landfills at the edges of the settlements (Pokhrel & Viraraghavan, 2005). Some people even sort their waste but dump it at the river banks afterwards, to make a statement towards the government (Dangol B. Personal interview. 2016, October 9). Since all kinds of waste are being dumped amidst nature, pollution of both the soil and the groundwater is an insurmountable result (Pokhrel & Viraraghavan, 2005). In addition, people are slowly starting to rebuild their houses and therefore leaving their temporary shelters. Once they move out of the shelters, they are no longer of use and people are leaving them scattered all over the edges of the settlements, occupying what could be fertile land.

Therefore, it is our aim to provide a waste and material bank, called the recycle bank. This construction is a waste management system combined with an assembly and recycle point for the materials of the abandoned temporary shelters.

The functioning of the proposed recycle bank is based on the system of waste banks, which are already implemented in Thailand and a few other countries (Singhirunnusorn et al., 2012). The idea is that the waste as well as the materials from the (no longer useful) shelters are sorted and then brought to the recycle bank. When bringing materials or waste to the recycle bank, you make a 'deposit'. In return you get a certain credit according to the value of the materials that you brought in. The value of the different possible deposits is documented in advance by specialists.

This system will stimulate the inhabitants to sort their waste and no longer dump it in nature or on the streets. It might even motivate a few people in cleaning up the contested areas, reducing the areas currently used as landfills and decreasing pollution (Brown & Milke, 2016). In addition, this recycle bank will create numerous jobs, improving the economy of both settlements. Furthermore, the reconstruction process might be slightly accelerated, since there is a recycling system for building materials as well: this will turn the debris into a valuable resource in the recovery and rebuilding process (Brown et al., 2011) and generate cheaper building materials. In addition, people get a credit, which they can invest in reconstructing their houses.



Landfill at the west edge of Bungamati, 2016



Landfill at the west edge of Khokana, 2016



Landfill at the north edge of Khokana, 2016



*fertilizer for the fields, composted by
Biocomp Nepal located in Khokana*



recycling in India



ORGANIC WASTE

plastic

metal

paper

NON-ORGANIC WASTE



The waste and various materials can be brought to the recycle bank any time. In addition, the truck of the recycle bank will perform a solid waste collection twice a week, giving the inhabitants the opportunity to deliver their waste in return for a deposit.

However, the solid waste should be sorted in advance to further process it. Studies show that 21% of the solid waste inside the Kathmandu Valley is recyclable (non-organic waste), while an even larger proportion of 62% is compostable (organic waste) (Pokhrel & Viraraghan, 2005). Therefore, the organic and non-organic waste should be distinguished. Inside the recycle bank, the non-organic waste will be further separated in three categories: plastic, metal and wood. The sorted non-organic waste will be transported every month to a larger non-organic waste bank in the city. In order to recycle the materials in specialized recycle factories, large amounts of non-organic waste will be exchanged with India, since none of these factories are settled in Nepal (Larsson et al., 2010). However, the organic waste will be further processed locally, at the Biocomp Nepal factory located at the west edge of Khokana. By composting it, valuable fertilizer for the agricultural fields is created.

In means of the building materials, masonry, wood, concrete and metal (including CGI sheets) are separated. Intact bricks, good quality wood, bamboo and CGI sheets can be further sold inside the recycle bank at a discount price, to stimulate the inhabitants to use recycled materials. The damaged bricks will be exchanged with the brick kiln of Bungamati, on the condition that no cement was added during the construction or baking process. In addition, the bad quality wood will also be transferred to the brick kiln in order to generate heat for the baking process.

Lastly, concrete will be exchanged with a cement factory, located in Kathmandu, to re-use it for making high quality concrete.

DEBRIS & SHELTER MATERIALS

MASONRY

intact



selling at discount price/reused by owner
Source: Sidiq, 2016

damaged



Bungamati brick kiln
© Kristine, 2017

WOOD

bad quality



*selling at discount price for construction houses/
reused by owner*

good quality



bamboo



*selling at discount price for construction houses/
reused by owner*

CONCRETE



recycling in cement factory, Kathmandu.
© Saliy, 2016

METAL

metal



recycling in India

CGI sheets



selling at discount price for constructing lighter roof



Current situation with rice fields and a number of abandoned temporary shelters, 2016



Site located on the connection road between Bungamati & Khokana, 2016

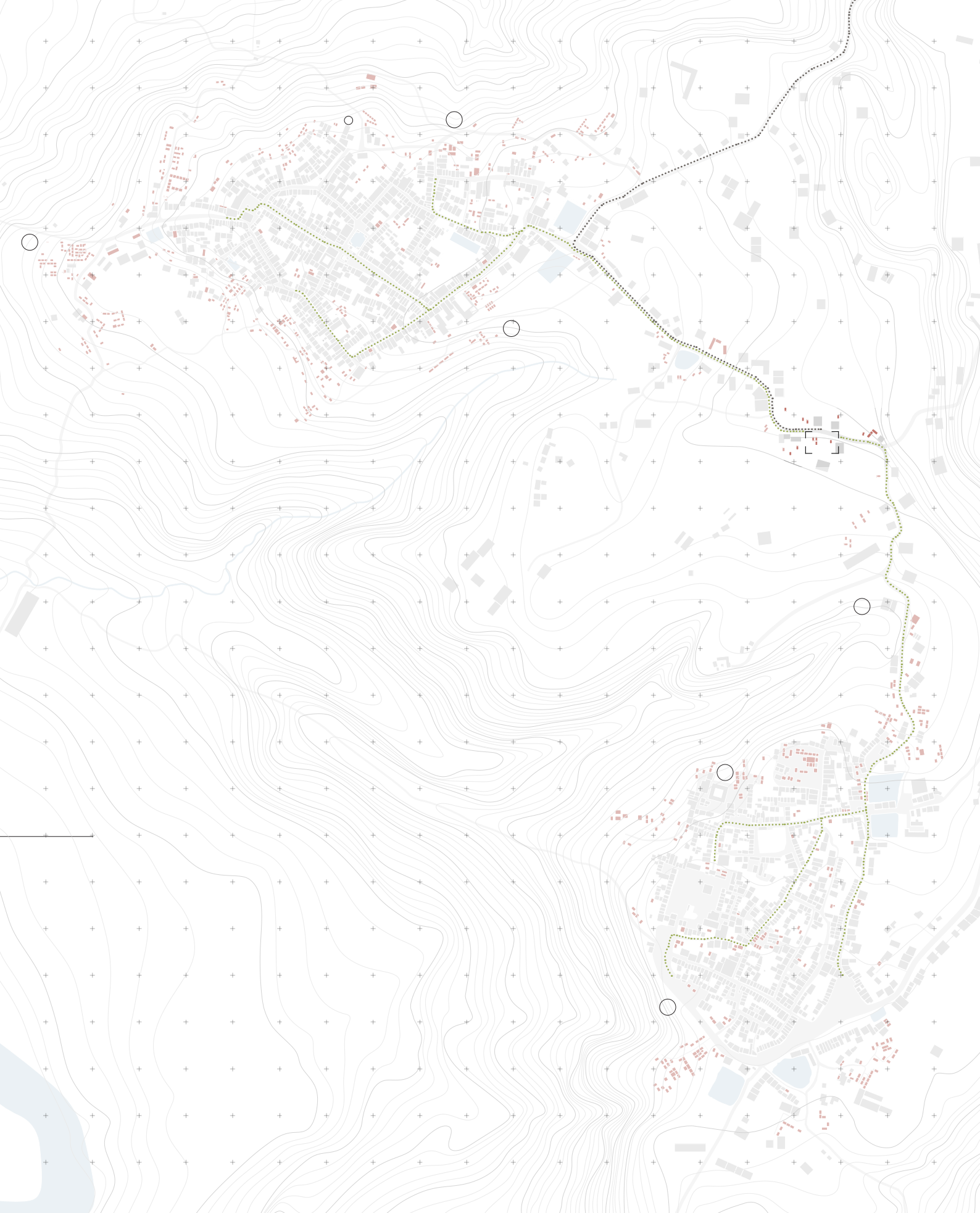
In order to optimize the functioning and advantages of this recycle bank, a collective system is proposed for Bungamati and Khokana, based on a cooperative model. Therefore, the recycle bank will be implemented on the armature which connects Bungamati and Khokana in order to minimize the distance for the inhabitants of both settlements. Currently, the dumping spots are already located at the edges of the settlements, so by implementing the recycle bank in between the villages, the inhabitants do not have to walk that much further.

This location also ensures that the truck that collects the waste and debris, to transport it to Kathmandu for further processing, can easily reach the recycle bank.

⌚ + 50 m +

Recycle bank situated on the armature between Bungamati & Khokana and its accessibility

- Temporary shelters
- Buildings
- ⋯ People going to the recycle bank
- ⋯ Truck from Kathmandu going to recycle bank
- Location of the dump spots





Scale 1/150
Section recycle bank

The building of the recycling bank is entirely constructed out of recycled materials originating from temporary shelters. Various containers, made from brick, are positioned underneath a collective protecting roof structure. The roof structure is realised out of bamboo columns and beams, covered with corrugated iron sheets, resembling the structure of most temporary shelters. Since the majority of the shelters is constructed out of these materials, they can be recovered from the shelters which are no longer in use.

The different containers vary in dimensions according to the category of waste that they will collect. The average inhabitant of a municipality with less than 20 000 inhabitants inside Nepal produces 0,25 kg of solid waste per person per day of non-organic waste (UNEP, 2001). If this kind of waste is collected by a truck once a month, there will be approximately 75 000 kg of solid waste. This needs a container of almost 55 m². In addition, almost two-thirds of the solid waste is organic (UNEP, 2001), resulting in a container of 35 m² for the organic waste and one of 20 m² for the non-organic waste. Since the waste will be collected more frequently (approximately once a month) by the Biocomp Khokana and a truck from Kathmandu respectively, these containers are located at the streets.

The dimensions of the containers used for the building materials are reasoned according to the amount of materials and their average dimensions. Therefore, the containers for both wood and CGI sheets are larger since these elements tend to have bigger dimension and are more difficult to transport. For the same reason, these containers are also located closer to the street. The container for the masonry has larger dimensions as well, since this represents a respectively large share of the building materials inside the Newari settlements. The container for rests of concrete is relatively small since almost no shelter uses this material.



Entrance to the recycle bank

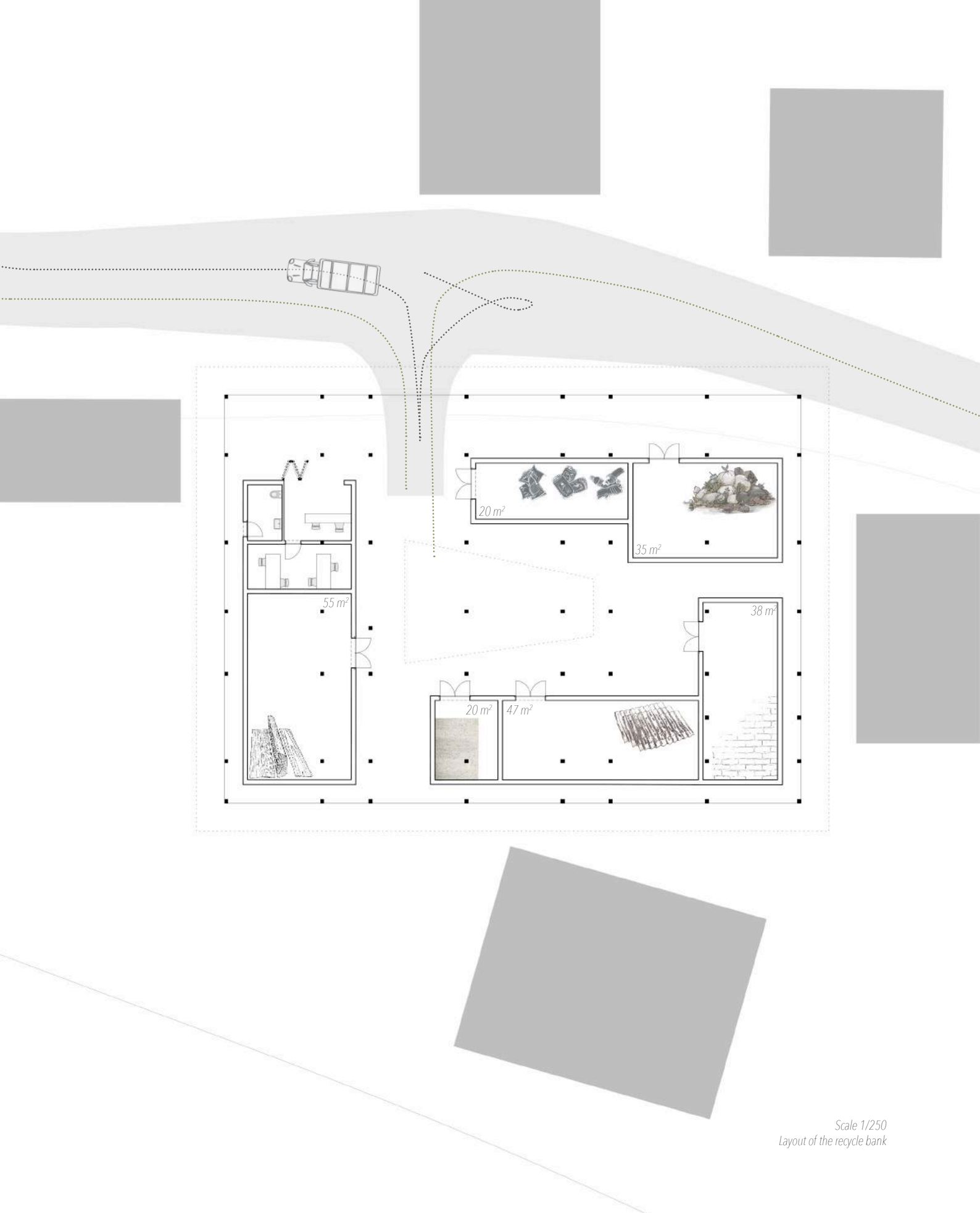
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Since the structure of the recycle bank is spacious and easily adjustable, debris from the damaged buildings caused by the earthquake can also be collected at this point.

Research has shown that disaster waste management is an important factor in coping with a (natural) disaster (Brown et al., 2011; Fetter & Rakes, 2011; Baycan, 2004). Poor management has a negative impact on the recovery and environmental health. Therefore, providing a material collection point after an earthquake is an important factor in the disaster management (Brown et al., 2011). In addition, planning this management of disaster waste will make the strategy more effective. If a collection point is marked in advance, the information can be spread among the inhabitants, increasing the preparedness in the sense that inhabitants and aids know where bring the debris. In addition, larger open spaces can be kept clear, contributing to the safety during aftershocks.

Currently, the *guthi* system and their rituals play an important role in coping with disasters (Bhandari et al., 2011). Bhandari even suggest that following the authorities of the *guthi* system might increase the efficiency of disaster management (Bhandari et al., 2011). The *guthis* engage in cleaning up debris and *guthi* buildings are even used as storage spaces after a natural hazard. However, the available storage space is limited. This post-disaster extension of the recycle bank will provide an appropriate support to complement the existing *guthi* system in means of disaster management.



II.

Bungamati: rethinking water cycles

Yanne Gillekens & Katrien Valcke

Building further on the “Action plan for Bungamati”, this design proposal focuses on water management in Bungamati. Water shortage and water contamination are an ongoing problem in the settlement. At the same time, water has always played an important role in the social and cultural life of the Newars. This design aims to restore these values by combining and completing traditional and modern water management.







1.

Introduction



Ancient stone spout. © Gutschow, 2011

Bungamati was built on a hill between two rivers, the Bagmati river and the Nakhu river, in order to maximize the surrounding agricultural fields and at the same time be safe from flooding. However, providing water on top of a hill is more difficult than in a valley or at the base of a slope, where most water sources are located. The climate complicates the situation even more: 80 to 90% of the rain falls during the rainy season, which lasts only four months (from June until September) (Becker-Ritterspach, 1995).

Therefore, systems had to be developed to keep the water supply on a constant level. In each village, ponds or pukhus were dug. In Bungamati there are six ponds, varying in size, and with a total surface of circa 5 300 m². There are two tables of groundwater: a shallow and a deep aquifer (Pandey et al., 2010). Since the ponds constantly feed the shallow aquifer, water can directly be extracted from it by using the wells (*kuvu*) and stone spouts (*hiti*). Consequently, the shallow aquifer can be seen as an enormous water reservoir, allowing the villagers to have clean water throughout the year, even during the dry season. This system has been functioning for hundreds of years. Additionally a large part of the social life took place around the ponds and spouts.

1/2500

- Irrigation canal or creek
- Plastic water tank
- Concrete water tank
- Traditional well
- Stone spout
- Non-active traditional waterbody
- Gutter for rainwater
- Sewerage network
- Connection with Rajkulo





Dried spout and deteriorated pond in Bungamati, 2016

For centuries, the ponds were supplied by a canal: the *Rajkulo* or royal canal (Becker-Ritterspach, 1995). The state of the royal canal was very bad, but the NGO “Environment and Heritage Conservation Nepal” (EHCN) is currently restoring it with funds of the Indian government (Bisht, 2011; Aryal, 2005). The restored *Rajkulo* will provide water for 40 000 inhabitants of Patan and irrigate 450 hectares of land (Aryal, 2005). However, it is unclear how much of this water will eventually reach Bungamati.

Due to the urban growth, the recharge area of the groundwater decreased very fast, which has resulted in a lower groundwater table and the malfunctioning of wells and stone spouts. Additionally, the growing population caused increasing pollution of the groundwater. Bungamati has a sewer system, but the unclean water is discharged at the borders of the town and flows to the nearest river.

In Bungamati, the modern tap water was introduced around 30 years ago (Webb & Bajracharya, 2016). The water originates from two reservoirs, the Sivapuri reservoir and the Parphing reservoir (Gurung, 2000).





Cleaning up of Dyo Pukhu, Bungamati. © Tuladhar, 2017

A consequence of the introduction of the modern water supply system is that the majority of the households are no longer depending on the traditional water system, which caused the vernacular waterbodies to be rather neglected (Gurung, 2000). Over decades, the maintenance of the water bodies has fallen into oblivion. Nevertheless, there seems to be renewed attention for the vernacular water management: one of the ponds, *Dyo Pukhu*, is currently being revitalised under the guidance of UN-Habitat.

Our design focuses on three aspects: wastewater treatment, rainwater collection and revitalising public space. All three are connected to each other.



wastewater treatment

rainwater collection





revitalising public space

2.

Wastewater treatment

One of the main problems in the overall water management is the contamination of water: groundwater for household use, and irrigation water for agricultural purposes, get heavily polluted due to the lack of a proper wastewater system. The entire sewage system needs to be examined and possible repaired or replaced, since many pipelines got broken during the 2015 earthquake. Some parts of the settlements even lack a connection to the sewer pipelines.

Additionally, there needs to be a thorough investigation of how contaminated water can be treated. Nowadays, the wastewater simply flows into the rice fields and further down to the river. However, correctly treated wastewater can be used to irrigate the rice fields. In Studio Kathmandu volume 2, Valentina Amaya calculated that one hectare of agricultural land needs approximately 2 350 mm of irrigation (Amaya Marin et al., 2015). These needs are easily met during monsoon, but become more problematic in dry season.

Although the amount of treated wastewater cannot cover the total water demand for irrigation, it can offer a solution in terms of a constant basic supply throughout the year. Another option, referring to the calculations of Valentina Amaya, is fully irrigating a limited amount of 100 hectares land all year long. In these calculations, 40 litres per person per day of wastewater was taken into account.

A sewerage system is thus crucial for the preservation of the traditional water system. Equally important is the treatment of wastewater, so it can be reused. To treat the wastewater from black water to irrigation water, two stages are implemented in Bungamati: biogas tanks are installed at the end of the sewer pipes for the primary treatment of the water, and three large reed beds are implemented for the secondary treatment. After that, the purified water can flow to the fields through irrigation canals.

Splash and WaterAid Nepal both have funded projects regarding water sanitation and providing drinking water in the valley before. They could be interested to become stakeholders for this project.

1/2500

Masterplan for wastewater treatment in Bungamati

- Sewerage network
- Biogas tank
- Reedbed
- Irrigation canal or creek
- Rice field
- Cornfield





Earthquake Resistant Ductile Pipes. © KUBOTA, 2017

Sewerage system

The existing sewerage network is incomplete. It consists of three separate networks that all have their own ending point at the edge of town. Currently the ending points are simply dumping spots where the wastewater flows down the hills, through the rice fields and ultimately into the river.

The network needs to be updated and completed to provide the entire settlement with a sewer.

Because the pipelines need to be resistant to several earthquakes, Earthquake Resistant Ductile Iron Pipes (ERDIP) can be considered (Oda et al., 2015;; Haddaway, 2015). The Japanese Kubota Corporation provides pipes that can withstand earthquakes with a magnitude of up to 9.0. This would of course be a big financial investment, but it is a crucial consideration, since without earthquake resistant sewerage systems, the groundwater could be contaminated each time there is an earthquake, increasing the chances of epidemics.

1/5000

Current sewerage system

- Network 1
- - - Network 2
- · · Network 3



1/5000

Proposed, completed sewerage system

- Network 1
- - - Network 2
- · · Network 3
- New sewer



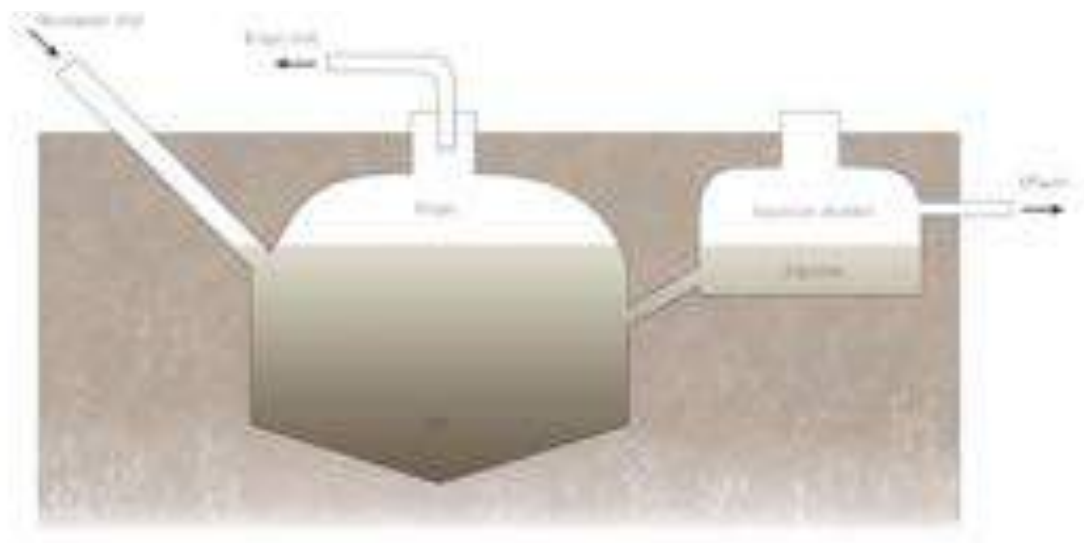


Part of the sewerage network in Bungamati, 2016

Biogas

When wastewater is left to rest in an airtight tank, an anaerobic environment is created (Eawag & Spuhler, 2014). This breaks down the pollutants in black or grey water. During the fermentation process, a combination of methane, carbon dioxide and rest gases is formed, called biogas. For this process a temperature between 20-35° C is needed. The pressure of the gas pushes silt into the expansion chamber, where the digestate remains. This can be used as a fertilizer. The gas itself is pushed to the top of the tank by its own pressure, where it can be collected in tanks or distributed by pipelines. The effluent is sent further to the reed beds for secondary treatment.

The energy of biogas is 6 kWh/m³ (Sasse, 1988). An average human person can provide for 0,02 m³ biogas per day (Eawag & Spuhler, 2014). Bovine animals, however, can produce 0,4 m³ gas per kg dung. In this design strategy the assumption is made that only human waste is added to the tanks in Bungamati, but there probably will be a certain surplus if the dung of their livestock is added.



*Biogas tank. Adapted from:
Biddlestone & Cooper, 2009*

Since one person produces $0,02 \text{ m}^3$ biogas per day, and the energy of biogas is 6 kWh/m^3 (Eawag & Spuhler, 2014), an average person can produce $0,12 \text{ kWh}$ of energy per day in biogas, or $43,8 \text{ kWh}$ per year. Given that Bungamati has a little under 6 000 inhabitants (Bista, 2014), together they could produce $43\,800 \text{ m}^3$ biogas or $262\,800 \text{ kWh}$ of energy per year. As opposed to most renewable energy sources, biogas is rather easily storable (Rutz et al., 2015).

There are three logical ways of using biogas in the case of Bungamati: lighting of houses with gas lamps, cooking on a gas cooker, and combined heat and power (Rutz et al., 2015). We will discuss all three possibilities, their range and their possible disadvantages.



Biogas lamp. © Maruli, 2012

Lighting

The caloric efficiency of a biogas lamp is 3% (Eawag & Spuhler, 2014), which means that compared to the produced biogas, only a small fraction will actually be used. Given that one lamp needs 0,1 m³/h of biogas (Eawag & Spuhler, 2014), and assuming one family will use an average of four lamps at once for four hours per day, one household will need 876 m³ biogas per year for their lamps on average. This means at these rates, 50 households can use biogas lamps throughout the year in Bungamati.

It is clear that biogas lamps have a low efficiency. It should also be noted that biogas lamps can get very hot and can therefore form a fire hazard if they are placed directly underneath the roof (Sasse, 1988). The biogas needs to be mixed with oxygen for the lamp to work.



Electricity wires on the road between Khokana and Bungamati, 2016

Combined heat & power (CHP)

To provide electricity and heat, the biogas needs to be dried and cleaned first (Rutz et al., 2015). Normally, a CHP unit can produce about 35% electricity and 65% heat. This means a biogas tank has an energy efficiency of up to 90% when it comes to CHP. However, in winter a small percentage of the heat is needed to fuel the biogas plant, in order to maintain the required temperature for the fermentation process (Sasse, 1988). The remaining heat still accounts for up to 80% of the produced heat, which means still 52% of the original energy can be used as heat for central heating. If the efficiency for electricity is 35%, then the inhabitants of Bungamati can together produce 91 980 kWh of electricity per year. An average Nepalese household uses 331 kWh of electricity per year (Enerdata & World Energy Council, 2016), which means there would be electricity for 278 households. However, an average Indian household already uses over 1 000 kWh per year, so it is safe to assume the consumption in Nepal will rise quickly. We will therefore calculate with a consumption of 900 kWh per year per household. This means the electricity produced by the biogas tank will be able to provide electricity for at least 102 families.

With a heating efficiency of 52%, 136 656 kWh per year can be yielded for heating. Given the mild climate of the Kathmandu Valley, it can be assumed that heating is only necessary during the colder winter months. This means that there are rather low needs for heating, compared to Northern European countries. Assuming an average need of 120 kWh/m² per year for one household (European Environment Agency, 2013) and 90 m² of area in a house that needs to be heated (public spaces, restrooms, storage rooms,... are excluded), an average family in Bungamati would need 10 800 kWh of energy per year for heating. Around 12 families can therefore use the energy of the biogas tank for central heating. Since this is rather few, it would be more interesting to use the heat for *guthi* buildings or other public buildings.

CHP units have high initial costs, and installing district heating takes great effort (Rutz et al., 2015). The cost also increases with the length of the pipelines between the tank and the eventual household, so the distance between the tank and the household should not exceed 4 km.



Gas cooker in Bungamati, 2016

Cooking

The last option for biogas usage in Bungamati is a simple gas cooker. The efficiency of biogas in this case is 55%, so it is still lower than CHP but a lot higher than the efficiency of lamps (Eawag & Spuhler, 2014). An average household in Bungamati will need 1,35 m³ biogas per day for cooking (Eawag & Spuhler, 2014), or 492,75 m³ per year. The conclusion is that around 89 households can cook on biogas.

Design considerations and conclusion

A fixed-dome biogas tank should always be under pressure, so it must never be empty (Sasse, 1988). If not, cracks can appear in the brick dome because of the lack of pressure from the inside, which can cause great gas losses. The inlet and outlet pipe must not be in the gas zone. The only way to reach the gas is through the sealed opening at the top of the tank. A fixed-dome has a longer lifespan than the so-called floating dome variant and has low installation costs (Eawag & Spuhler, 2014). Since it is an underground construction, it does not require a lot of space. For one person, a tank of 1 m³ or 1 000 l is sufficient. Logically, for Bungamati, a tank of 6 000 m³ would be sufficient. Since reed beds will be planted on three locations, this volume can be spread over these three locations, so 2 000 m³ each.

The pressure of the gas decreases with the length of the pipes (Khoiyangbam et al., 2011). If the distance between the gas tank and the consumer is over 2 km, an additional pump is needed to transport the gas. Since there are three locations on which the biogas tanks will be installed, the distance will never exceed these 2 km. Given the high costs of CHP units and the low efficiency of biogas lamps, the easiest application of biogas in Bungamati would be cooking on gas cookers, although the other applications also remain an option. For cooking, people can easily go to the tank and fill up a personal tank so no additional pipelines are needed. Given the explosion danger of biogas, no large amounts of the gas should be stored inside a house.

🕒 1/2500

Location of the biogas tanks:
current wastewater dumping spots

🚰 Sewerage network
🔴 Biogas tank





Reed beds. © Cress Water Solutions

Reed beds

Reed beds or constructed wetlands can be used to treat wastewater in a natural way (Biddlestone & Cooper, 2009). There are two main types of reed beds: horizontal and vertical reed beds. For secondary water treatment, a vertical reed bed is needed.

1/2500

Overview of the three reedbeds, biogas tanks and their connection to the new sewerage network.

- Sewerage network
- Biogas tank
- Reedbed
- Irrigation canal or creek
- Rice field
- Cornfield





Common reed - *Phragmites*
© Thinglink, 2015

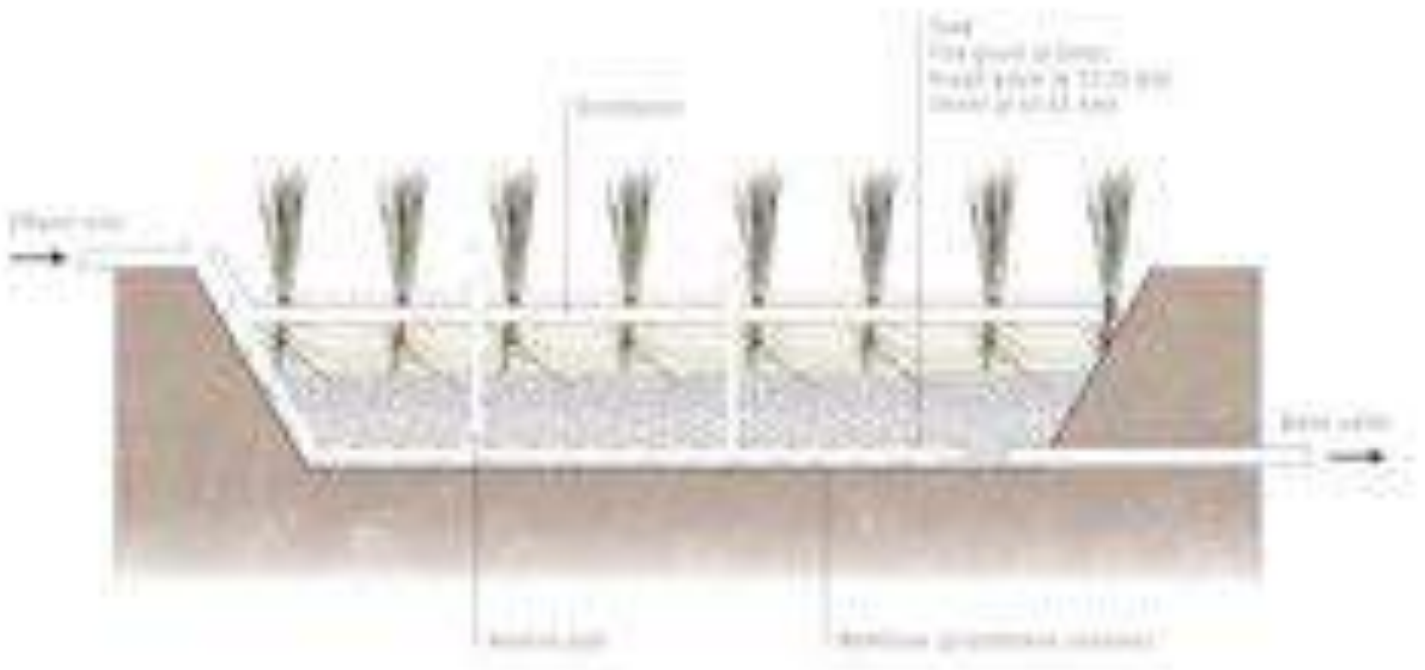


Greater reedmace - *Typha latifolia*
© Jeffrey Kontur, 2008

In general, all reed beds work according to the same system. Emergent water plants are planted in a matrix of sand and gravel (Biddlestone & Cooper, 2009). The largest particles, like small stones and rough gravel, are at the bottom, whereas the finest particles are on top. Sand forms the top layer. The vegetation of the reed bed is specially selected. Common reed (*Phragmites Australis*) and great reedmace (*Typha Latifolia*) are very suitable. The most important feature of these plants is that they have a root structure called “rhizomes”. The rhizomes consist of thick, hollow stems from which the roots then hang down. The plants extract oxygen from above the water surface and this oxygen is brought down through the rhizome structure. This allows for large colonies of aerobic micro-organisms to live underneath and in between the roots. The anaerobic micro-organisms then cluster at a different location, further away from the roots. This creates underground zones of alternating aerobic and anaerobic microbial populations.

The wastewater is spread across the surface and slowly dribbles to the bottom (Biddlestone & Cooper, 2009). Apart from initiating the aerobic microbial population, the rhizosphere also ensures hydraulic conductivity. While the water dribbles through the matrix, it encounters the two opposite types of microbial populations. These will modify the polluting components of the wastewater: carbonaceous, nitrogenous and phosphate contaminants will be converted.

In a vertical reed bed, it is important that the water is conveyed in phases in order to give the water the needed time to percolate through the matrix. To ensure this, a regulating device is needed. A siphon is a good choice for this, because it requires no power.



Reed bed. Adapted from: CAT

While the water drains, extra oxygen is drawn into the reed bed. This can be combined with perforated pipes to conduct even more oxygen into the matrix. The large amount of oxygen and thus aerobic micro-organisms is what makes a vertical reed bed so suitable for secondary wastewater treatment, more particularly, ammonia removal (nitrification) and removal of biochemical oxygen demand pollutants.

The inlet and outlet pipes should have a diameter of 100 mm and be made out of PVC (Lismore City Council). In the inlet pipes, holes of 5 to 10 mm can be drilled to allow the effluent to easily spread across the reed bed. The inlet pipe lies just underneath the surface to protect it against animals or vermin and to avoid the escape of unpleasant smells.



1/1500

The processes of breaking down the pollutants takes time. In order to be sufficiently cleaned, the water thus needs a residency of five to seven days (Lismore City Council, 2005). Therefore, the geometry and sizing of a reed bed is essential for it to function properly. For a reed bed with a depth of 75 cm, 3 m² per person is needed. In this design the reed bed is deeper than 75 cm. Moreover, the larger the amount of people the reed bed is for, the smaller the required area is, even as small as 1 m² per person. It is therefore a safe assumption to calculate with 2 m² per person (Centre for Alternative Technology, 2016). Bungamati had a population of a little under 6 000 people in 2011 (Bista, 2014). Therefore, a reed bed of approximately 12 000 m² in total is required. The reed beds are divided over three different spots, namely the locations where the wastewater is currently being dumped. The conclusion is that an area of 4 000 m² per spot is needed. However, since Bungamati is expected to grow with more or less 2 500 people (Bruneel et al., 2016) it is better to already install a reed bed that allows for expansion. A total area of 17 000 m² of reed beds would be needed to incorporate the urban growth. Each of the three zones therefore needs a reed bed of 5 667 m². Since the reed beds are located at the edges of the town, this does not create a problem. For the first stage of the project, only the current need of 4 000 m² per reed bed will be provided. In later stages, the remaining 1 667 m² can be added.





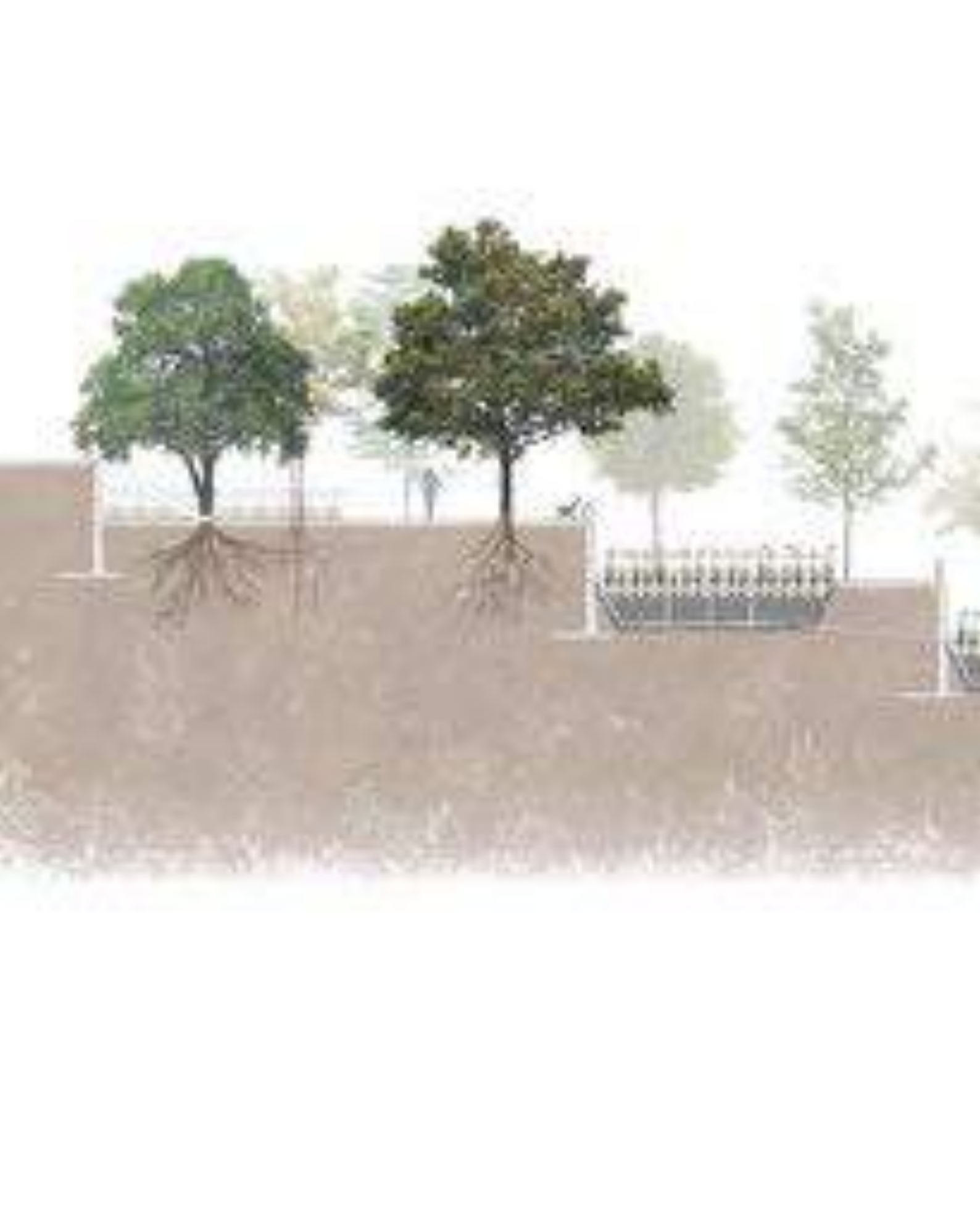
1/1500

The slopes at the edges of Bungamati are perfect for the reed beds. In vertical reed beds, a difference in height of at least 1,5 m between the inlet and outlet is required to avoid the need for pumps or other mechanical devices (Lismore City Council, 2005; Centre for Alternative Technology, 2016). In this case, the slopes are steeper than necessary, but that can easily be solved by simply placing the reed beds in a series of terraced beds. This also immediately solves the problem of the size of the reed beds. For reed beds in series, the highest reed bed always has a higher risk of clogging than the others. Therefore in this case it is even more important that the reed beds follow the primary treatment of the biogas tank. The retention time of the water will be divided between the different beds of the series.



Based on the retention time and the overall geometry, the reed beds will be subdivided in 50 smaller beds of 80 m² each (Schierup et al., 1990). The two most northern reed beds touch one another but work separately.

The design of the reed beds follows the natural topography of the landscape. The existing trees are left on their original location as much as possible, in order to provide shade against evaporation and to prevent landslides. In addition, combined with the paths and stairs, this creates a pleasant landscape.





Constructed wetlands creating a public space

3.

Maximizing water collection

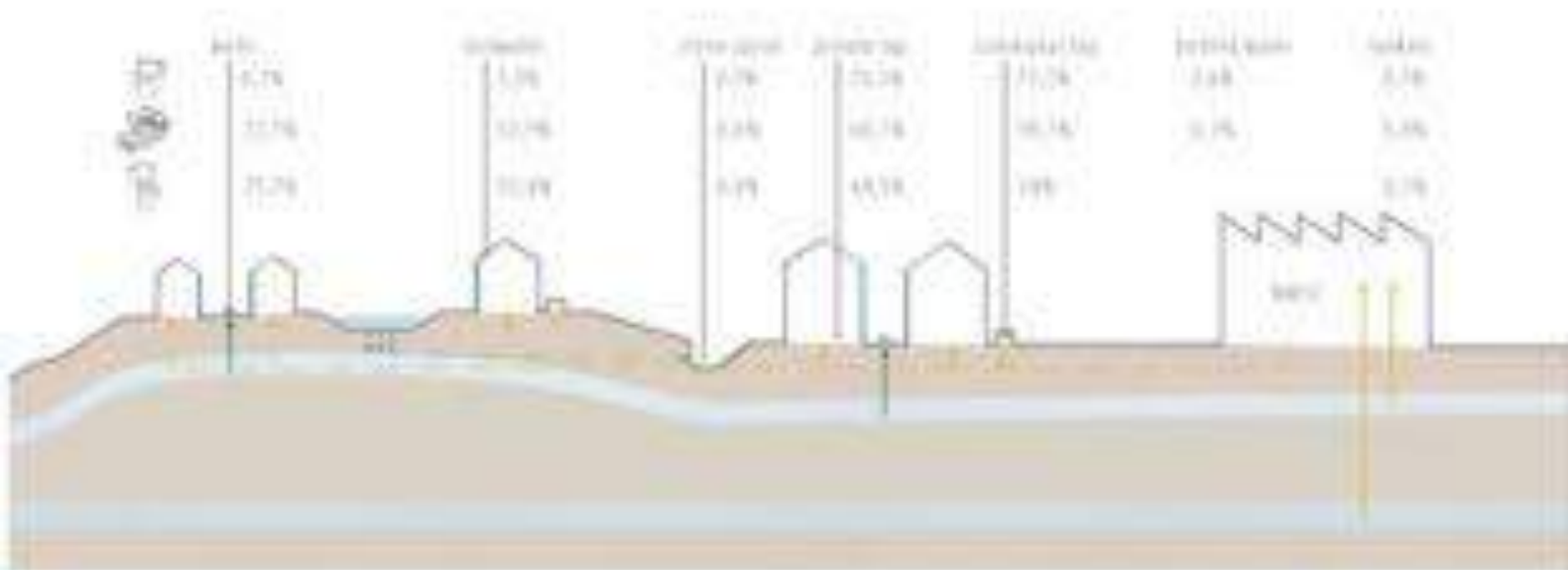


Plastic water tank on top of non-functional well, and concrete water tank next to pond in Bungamati, 2016

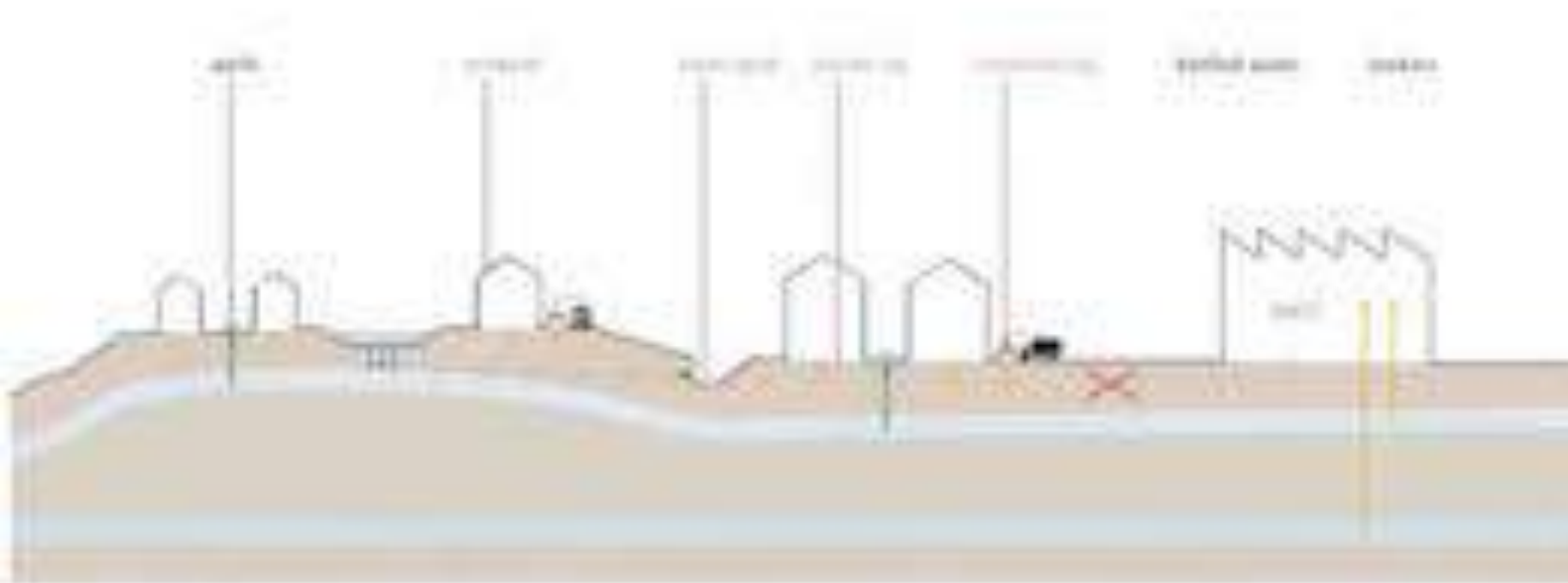
Water supply

Approximately 70% of the households in Bungamati have a private connection to the modern water supply (Webb & Bajracharya, 2016; Bista, 2014). The majority of these households use this water as drinking water, but also for secondary purposes such as washing, cleaning and flushing the toilet (Webb & Bajracharya, 2016). For the less fortunate inhabitants, there are ten big concrete water reservoirs spread over the village. This water is mainly used as drinking water, but a third of the population uses it for secondary purposes too. For these secondary purposes, the use of rainwater and water from the wells is a popular alternative for respectively about 50% and 70% of the population.

Due to the earthquake of 2015, the majority of the houses in Bungamati are severely damaged or destroyed. Furthermore, the water pipelines of the municipal water supply were broken, causing a severe water shortage one month before the beginning of the monsoon. Fresh drinking water had to be delivered in bottles and by tankers, while water for other purposes, such as cleaning, was provided by the traditional, albeit deteriorated, water system. Even though the water supply has been repaired by now, the availability of sufficient water remains a problem. There is only water available a few hours a day, according to the schedule of Kathmandu Upatyaka Khanepani Limited (KUKL) (Kharel, 2014). During this time most families tap as much water as possible and store it in big plastic containers. However, the quality of the water remains questionable. On top of that, the containers used to store the water add extra weight to the top floor of the house, which increases the effect of an earthquake.



Percentage of villagers using a certain water source before the earthquake.
Adapted from: Webb & bajracharya, 2016



When the municipal water supply was no longer available after the earthquake, other water sources gained



In order to improve this situation, several calculations were made to examine whether the traditional water system can be upgraded, or if alternatives are possible. Since the water of the NWSC is now by a large part of the inhabitants also being used for secondary functions, restoring and rethinking the traditional water system could help relieve the pressure on the municipal supply. At the same time, a functioning traditional system will provide a useful back-up during emergencies.

The Kathmandu Valley Preservation Trust has helped in restoring a traditional *biti* and several squares. They might be interested in becoming funders for this project. As mentioned, Splash and WaterAid Nepal both already have funded actions in the Kathmandu Valley related to water sanitation and drinking water. They could be possible stakeholders for this part of the project as well.

⌚ 1/2500

Existing condition of waterbodies in Bungamati

-  Irrigation canal or creek
-  Plastic water tank
-  Concrete water tank
-  Traditional well
-  Stone spout
-  Non-active traditional waterbody
-  Gutter for rainwater

Groundwater recharge

Bungamati consists of 1 304 households, 5 966 residents and has an area of 4,03 km² (Bista, 2014; Shrestha, 2001). When calculating the amount of water that possibly infiltrates and contributes to the groundwater level in Bungamati, the area that lies lower than the town centre, and so below the *pukhus*, *kuvas* and *bitis*, cannot be taken into account, as it does not contribute to the collection of rainwater. Therefore, another area needs to be determined. The zone above the centre, even when it is geographically not a part of Bungamati, does contribute. This constitutes a total contributing area of roughly 400 000 m². Of this surface approximately 39 000 m² is roof area, 25 000 m² is paved area and 5 300 m² are ponds.

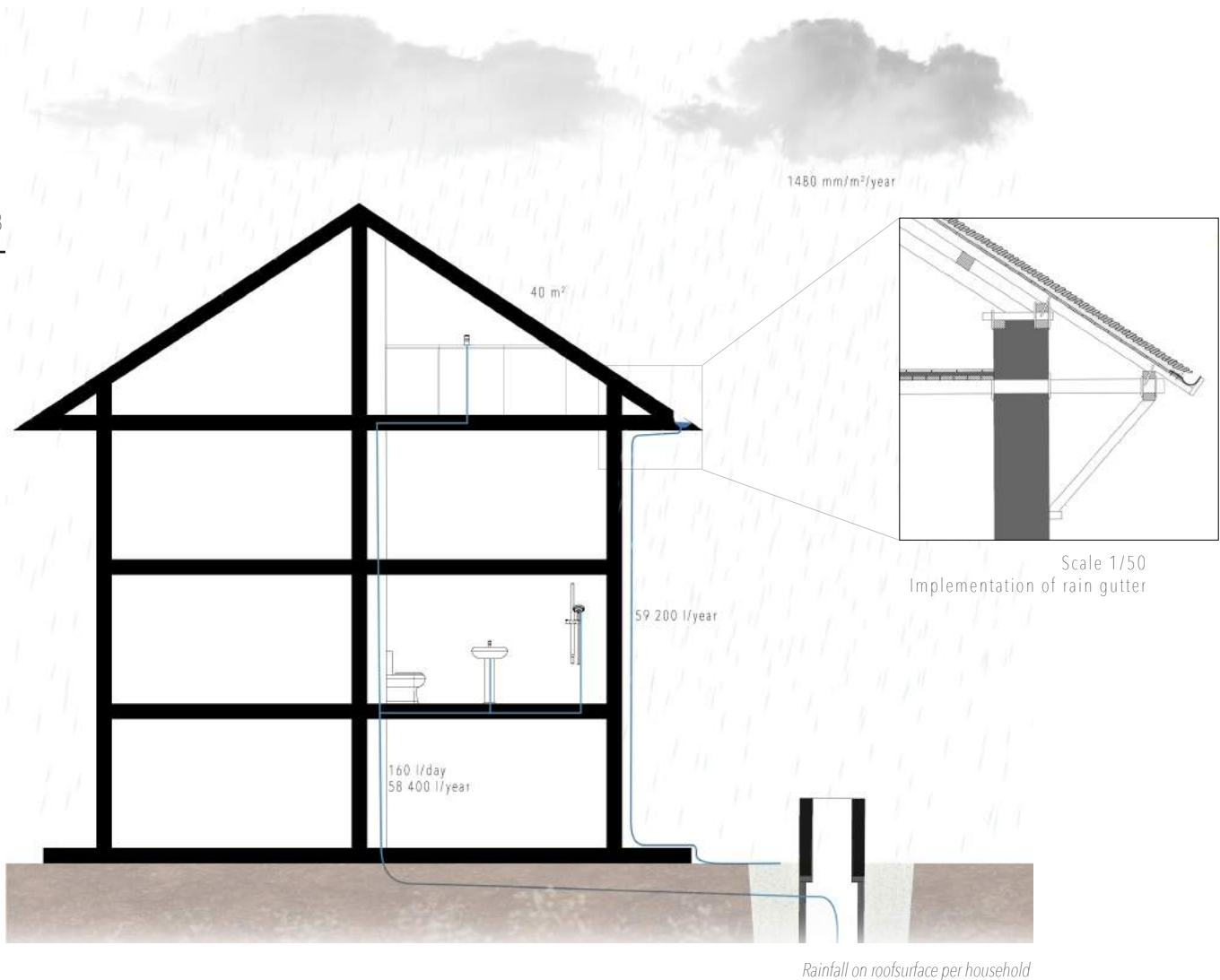
The next factor to consider is the amount of rain per year. In Nepal the yearly average rainfall amounts to a volume between 1 400 and 1 740 mm/m² (Thapa et al., 2008; Shukla et al., 2012). During the wet season, which lasts roughly 4 months (June – September), an average of 280 mm/m² of rain falls in the Kathmandu valley, while in the dry season this is significantly less. The following graph presents the amount of rain each month.



Source: Amaya Marin et al., 2015

Using an average yearly rainfall of 1 500 mm/m², and assuming all water infiltrates in the ground, 600 000 m³ water could be added to the groundwater. The actual amount will be lower, since water evaporates and/or flows to lower areas.

A study in preparation of the Melamchi project showed that the average water consumption in Nepal amounts to 73 litres per capita per day (Joshi et al., 2003). Assuming that approximately 50% of this volume is needed for drinkable water, about 35 litres per day are needed for all other functions. In order to relieve the pressure on the modern supply, rainwater could be used for these other purposes.



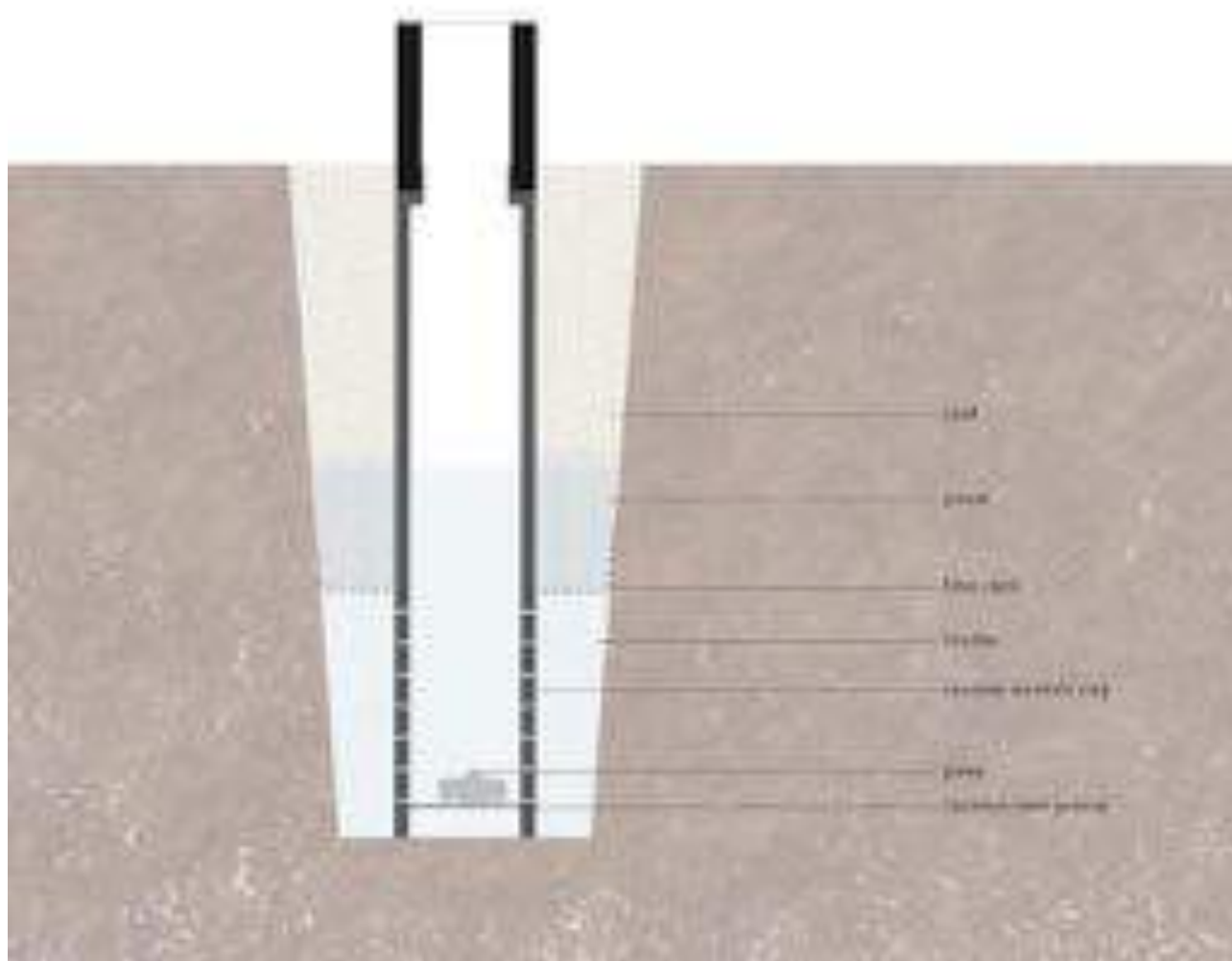
Microscale rainwater harvesting

Currently, the rainfall on the roofs is not yet systematically collected. Some houses do have plastic tanks to harvest rainwater. This water is used in the home garden as well as for cleaning and washing. However, because of the long dry season, these tanks are only useful during a small part of the year. Therefore we examined whether the investment in a direct collection system of water is feasible.

To give a well-founded answer, some data is needed. In Bungamati, the roof of an average house has an area of 40 m^2 . Further, the average household in Bungamati consists of 4,58 persons (Bista, 2014). When assuming that an average person uses 35 litres of water each day, each household would have a daily water consumption of 160 litres. Processing all these data into a table, there would be a water surplus four months (June to September). Calculated over a whole year, this consumption level would result in a small water excess.

The only remaining problem is how to store the water. The answer came by looking into the functioning of the traditional water supply. The characteristics of the soil in the Kathmandu Valley, a deep and shallow aquifer separated by a 200 m thick clay layer, make it a natural water reservoir (Pandey et al., 2010).

The rainwater from the roofs is guided through rain pipes to recharge areas nearby, ideally on the courtyard. These recharge areas consist of different types of gravel and sand, so rainwater can infiltrate easily into the ground, where pollutants stay behind. A well in the recharge area provides direct access to the groundwater and a collective water pump supplies the surrounding houses. This water pump is supported by a stainless steel grating that can be adjusted in depth, avoiding soil to penetrate into the pump. The electricity for a collective pump can be provided by solar panels on the roofs to pump up the water from the shared well.



Schematic section of shared well

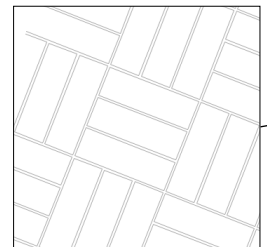
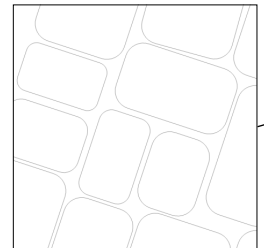


Different types of gutters in Bungamati, 2016

Streets directing the water

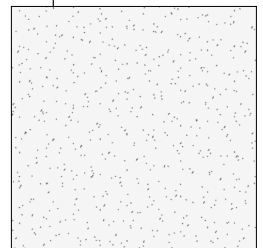
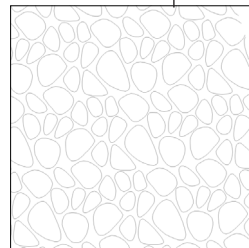
Since it might take some time before all houses have a connection to the shared well, a functioning traditional system is still needed for the other inhabitants. Restoring the vernacular water system will at the same time help reviving the public spaces around the traditional waterbodies.

Most of the streets are paved with bricks, local natural stone or concrete. In most cases the streets do not have a gutter and the rainwater ends up in a half open sewer, guiding the water to the edges of town together with the wastewater. Sporadically there is a gutter at the side of the road, but these gutters almost always lead the water ultimately to the sewerage system as well.



1/2000

Pavement patterns in
Bungamati





*Each street should have both a closed sewer
(to prevent rainwater from getting in) and an open gutter*

Leading the rainwater to the sewerage is an enormous missed opportunity. Providing all the paved streets with a proper rain gutter, leading the water to recharge areas or ponds, would help increase the groundwater level. Nowadays only the ponds (and the non-paved areas) recharge the groundwater. The rainfall collected directly into the ponds is approximately 7 844 000 litres per year. By guiding the water from the streets to the *pukhus*, this yearly average can be multiplied almost six times. Because of large evaporation rates, not all of this water will penetrate into the ground. Nevertheless, the gains by providing gutters in the streets are substantial.

⌚ 1/5000

Current rain gutters

- Existing gutter
- Location where rain flows into the sewer



⌚ 1/5000

Proposed completion of gutters to direct rainwater towards ponds

- Existing gutter
- - - New gutter





Current state of the ponds

Furthermore, the rainwater flowing to the ponds will first be guided through a sedimentation pit and/or sand filter. The purpose of this filter is to clear the fixed particles in the water in order to prevent the clogging of the ponds and facilitating maintenance. The ponds will also be redesigned with attention for the natural ecosystem. Nowadays most of the ponds are surrounded by walls, obstructing the flow of rainwater. Additionally there are no banks or water plants supporting the natural ecosystem of the ponds.



*Proposed solution*

The walls will be removed and banks with a height-to-width ratio of 1:3 will be implemented, together with several emergent water plants. This will allow oxygen to flow through the water, thus naturally regulating the ecosystem and purifying the water.

Conclusion

Implementing small-scale rainwater harvesting spots can provide for up to 50% of the average household needs, or 35 litres per day per household. On top of that, restoring the vernacular system and recharging the groundwater level will revitalise an important Newari tradition. It will also be a solution for those who will not immediately have a connection with a shared well. Thus, combined with the municipal supply and the proposed wastewater treatment, the household and irrigation needs of Bungamati could be fulfilled. This also implies that, in time, the private watertanks to store water from the municipal supply will become smaller. Once the Melamchi project is complete, they might even disappear completely.



4.

Public space shaped by water



Starter projects around waterbodies

In the past, the ponds were connected to each other with earthen conduits. However, these connections got lost over time. They will now be restored, though in a slightly different way: there will be two cycles of three ponds each, instead of one larger cycle. By working with smaller cycles, the pipelines are shorter and therefore easier to implement. This also reduces the risk during earthquakes: shorter pipes have a lower risk of breaking at a given point. On top of that, when one pipe breaks, the entire system will not fail: there is always still the other cycle.

The restored traditional water system and the renewed connections provide an opportunity to shape the public spaces in relation to the water. Water has always played an important role in the cultural and social life of the Newars, so it is only appropriate that it is rehabilitated as having more value than merely water supply. By redesigning the ponds ecologically while at the same time creating a pleasant public space, this cultural and social aspect can also be restored. When the stone spouts and wells will work properly again, they in turn will create a more lively atmosphere.

- 
- No visible damage
 - Minor cracks
 - Major cracks
 - Storeys removed for safety reasons
 - Partially collapsed
 - Completely collapsed

The two cycles are surrounded by heavily damaged and collapsed houses, making them ideal as starter projects. UN-Habitat is currently working on a design around *Dyo Pukbu*. The last part of our design will therefore focus on the other cycle.



The restored ponds will function as starter projects: by becoming lively public spaces, more reconstruction projects will easily follow. Due to recharged and cleaner groundwater, the spouts and wells will start working again, and the areas around them will then in turn become more vibrant places. That way, the waterbodies all around the settlements will catalyse further reconstruction.





Bladderwort - Utricularia Vulgaris



Hair grass - Eleocharis Acicularis



Curly pondweed - Potamogeton Crispus



Cyperus Corymbosus



Cyperus Exaltatus



Cyperus Pangorei



Hydrocharis Dubia



Common reed - Phragmites



White Lotus - Nymphaea Lotus



Monochoria



Sparganium Emersum



Greater reedmace - Typha Latifolia

*Overview of emergent aquatic plants that can be planted alongside the banks of the ponds
Image credits in bibliography*



Ziziphus budhensis
The seeds of the fruits are used to make malas (Buddhist prayer beads)



Peepal tree - *Ficus religiosa*
Considered sacred in Hinduism and Buddhism



Butea Monosperma
The flower is used to worship Lord Shiva



Axlewood - *Anogeissus Latifolia*



Litsea Cubeba
The wood can be used for woodcarving



Magnolia campbellii



Hydroclaris Dubia



Nepalese bell - *Capsicum Annuum Longum*
Chili peppers grow on this plant



Rhododendron Arboreum
This shrub grows the national flower of Nepal



Night blooming Jasmine - *Nyctanthes Arbor Tristis*



Sorbus Insignis



Taxus Sumatrana

*Overview of trees and shrubs that can be planted at the bus park and other public spaces
Image credits in bibliography*

Design for the bus park

306

The bus park is chosen as a first location for such a starter project. It is the location where everyone from outside of the settlement first arrives or finally leaves. It is a vibrant public space with direct connections to Kathmandu, Patan, Bhaisepati and Chhampi. For many small businesses, this is a strategic location to open a shop or a restaurant. Two entire rows of houses surrounding the square were destroyed during the earthquake of 2015, so there is need for substantial reconstruction. The three ponds forming the first cycle mark the edge of the bus park, which means the water can really be integrated in the public space.





The first two ponds (*Naa Pukhu* and *Po Pukhu*) work as communicating vessels, since they lie on the same height. The natural topography of the bus park makes the water flow southeast, contrary to the overall flow of the settlement. Therefore, the connection between *Po Pukhu* and *Kha Pukhu* takes the form of an open river, so the rain is immediately added to the cycle of the ponds. An open connection is also less easy to break and, if needed, faster to restore after an earthquake. When the first two ponds flood, the connection with *Kha Pukhu* immediately prevents flooding of the bus park as the water flows downwards. When *Kha Pukhu* also floods, the water is guided to the irrigation canals of the rice fields, so no problems will occur either.

Since Bungamati has a well-known volleyball team (Lucky Star Club), a volleyball field on the square where everyone arrives will promote this aspect of the settlement. A long *peti* of bamboo in front of the southern reconstruction site creates a promenade next to the various shops and is used as a terrace for the restaurant and café. The waiting area for the buses remains on the square. The buses only leave once they are full, so often people need to wait for a while before their bus departs. This creates a unique atmosphere of people who will get a drink or do some shopping while they wait for their bus to fill. To stimulate this vibrant atmosphere, the bus stop remains on the square.



View on the bus park of Bungamati,
2016





Bricks with variable joints are used to pave the public space. Larger joints are used for the greener areas, allowing more grass and moss to grow in between the bricks. At the same time, this lets water infiltrate into the ground.
© Michèle & Miquel Landscape Architecture, 2015



The green zone between the bus stop and the houses will have a soil of gravel. This allows for groundwater recharge and plants can easily grow.
© A. C. Hesse, 2017



The street will continue the brick pavement, albeit with much smaller joints. This will create a sense of uniformity, while the difference between vehicles, pedestrian area and green area is still clear. This pattern is already used in Bungamati.

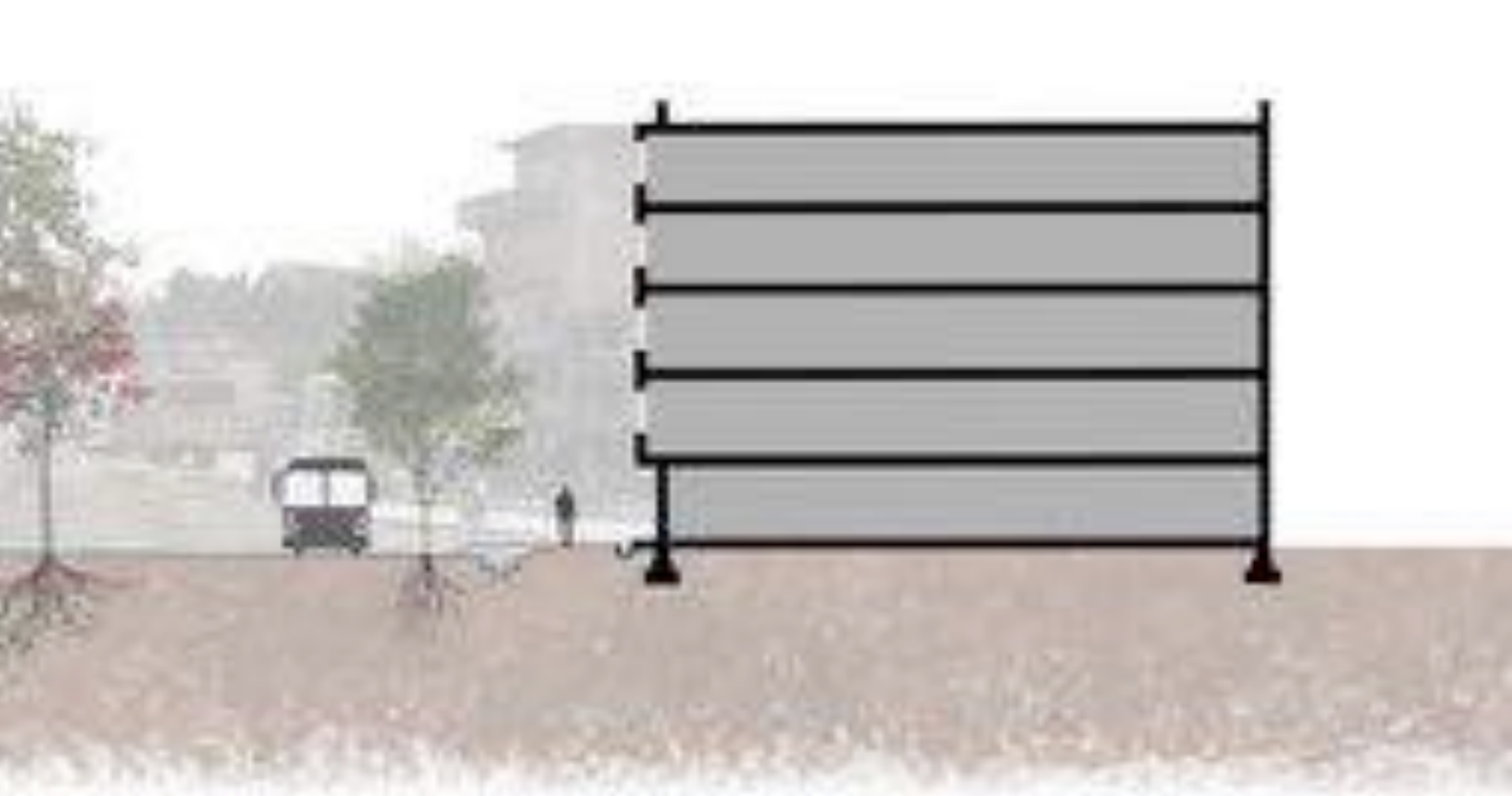


The large *peti* that also functions as a terrace in front of the houses, is made of bamboo. This creates a wooden look, while bamboo grows excessively in Nepal. The material needs to be maintained and replaced about every ten years. It is also important that air can flow around every part of the bamboo branches.
© Alfred Molon, 2010









The Nepalese Ministry of Urban Development has currently provided funds to reconstruct the bus park, so they could logically become the first funders. Given the fact that UN-Habitat is currently investing in parts of the other cycle, they might be interested in funding the restoration of the cycle around the bus park as well. The Nepal Rotary Club has also funded several projects in Bungamati before and could become a stakeholder of this project too.

Lokajit, Bungamati Foundation Nepal and the Relief Committee of Bungamati are all local NGOs. They all have supported small-scale projects in Bungamati before, such as relief support, housing and guesthouses. They would be very suitable funders for the individual housing projects. In addition, Oxfam has a program about housing to “build back better” and they help families to kick-start their career. They might be interested in helping several of the families with their small businesses.





View on the bus park before and after reconstruction



View on the bus park after reconstruction







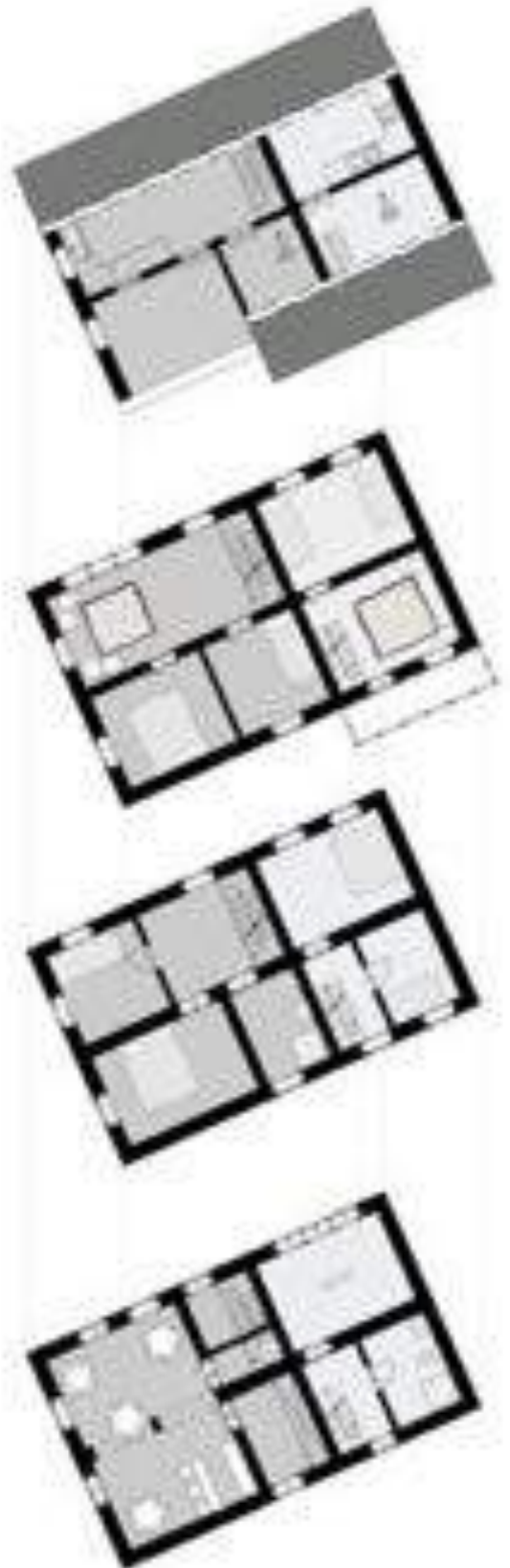


A small guesthouse will be built as a starter project behind the southern site of heavily damaged houses. The majority of these houses is currently still in use. Therefore, the guesthouse will first serve as a rotation unit, a temporary home for the people who cannot live in their homes during the reconstruction works of the further phases. Additionally, the shops on the ground floor of the houses will have to close during this period, leading to income loss. Therefore the long *peti* will be built in the same phase, providing an ideal location and base for little temporary shelter shops.





In the following phases the reconstruction of the southern row of houses takes place. The first part of the reconstruction houses a shop and a small café that is currently located in a temporary structure. All houses will have an as open as possible ground floor in which all the economic functions will take place. This creates a market-like experience alongside the street.





Later, two larger phases will give place to various shops and a restaurant. A first step is already made towards later expansion.







In the next phase, a more recent typology is introduced in the form of apartments. In this way a higher urban density is reached, using the traditional building techniques.











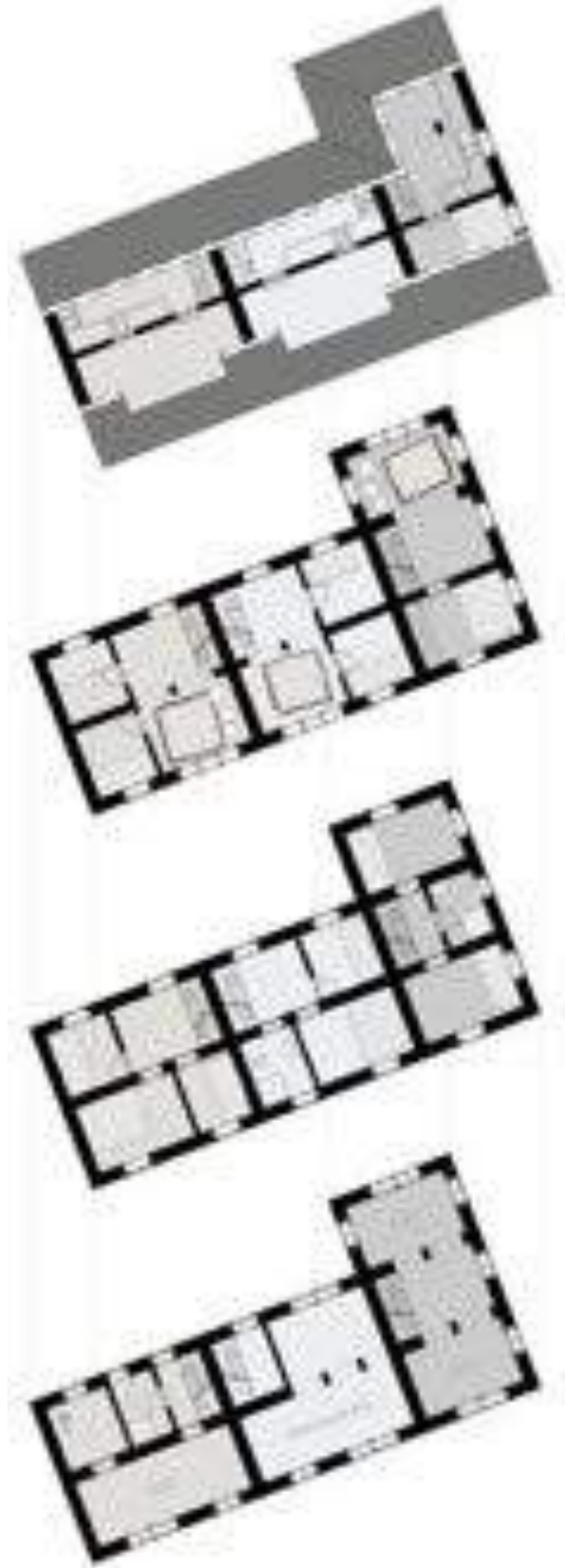


The northern site is divided in three shorter building units, creating a passage that connects the bus park with the centre. A restaurant and café are located on the most vibrant corner of the site. As these are located directly next to the bus park, they will easily become a popular meeting point.





Various shops are located in the second building unit, making use of the economically advantageous location next to the bus park.





In the last phase, the current motor shop gets more working space. A small atelier completes the building block, enclosing the courtyard. This atelier can be used as additional storage space for the motor workshop, but it can be used for other purposes too.



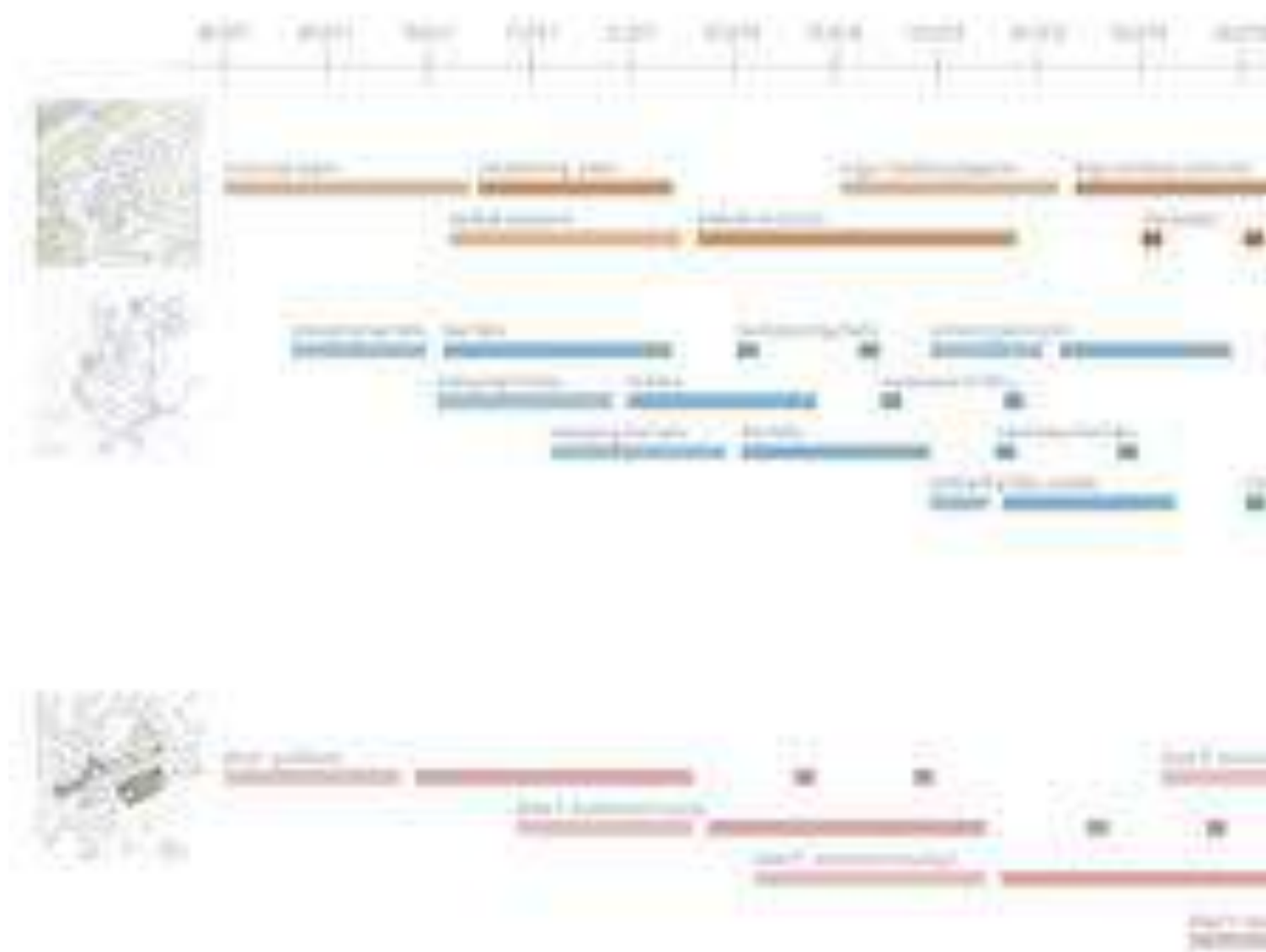








Phasing



III.

Khokana: extending the streetscape

Evelien Roelands & Sophie Van Hulle

A design proposal focused on the reconstruction, densification and expansion of the village while respecting the existing tissue. A re-interpretation of the Newari building culture is provided, both in means of architecture and urban planning by combining water, vegetation, public life, economy and housing in various projects. Based on the set of visual building guidelines, the architectural scale is further detailed in order to concretise the projects for the inhabitants.



1.

The street as connecting factor

Auspicious symbol
Swastika



Khokana is a typical Newari settlement based on a Buddhist auspicious symbol, the swastika. Today, this symbol is still clearly tangible in the street network of the village.

Religious symbols
Main square



In this auspicious symbol the center, called the main square of Khokana, is of great importance. It consists of various cultural identities with the Rudrayanee temple in the middle. It forms the core area of the village and is extended in both directions by the main street of the village, Tha Lachhi.

Original urban tissue
First degree growth



The first generation of people that inhabited the village, started to build their houses around this main square and the swastika symbol.

Expansion
Second degree growth



As the settlement grew over the following decades, new public spaces based on religious were created. The urban growth happened in a dense way following a straight street network.



Expansion Organical growth

Today, the growth of the settlement happens in a less structured way than it did before. Organic and informal growth are characteristics of these later stages of expansion of the settlement. Due to this urban growth, Khokana expanded in a rather unstructured way, following the pathways that farmers used to follow while going to their fields. The structured and unstructured phases are clearly distinctive, by means of grade of density; while the historical core of the village is dense, the later organic expansion is more open and looks like the trending sprawl that is happening all around the Kathmandu Valley.



Khokana in 1973, clearly showing the swastika.
© Gutschow, 2011

Since the further expansion of the city is an insurmountable process, a secondary road of expansion, going from the busstop to the centre of the village, is chosen as the focus of the design proposal. This route is situated alongside the main structure and touches the swastika figure at certain points. The goal of the analysis is to examine how this route differs from the swastika and how it behaves in relation to the whole settlement. In this regard, both traditional and modern buildings are taken into account since they both affect the formation of the village. This results in a proper basis for the various design proposals located at different sites, going from the core area to the edges of the settlement. In providing this design proposal, further expansion can happen in a less randomly way, providing a resourceful and well-planned expansion which respects the historical frame of the village.

This secondary route will be used as the connector figure for the different locations of the design proposal.

⊙ + 50 m +

Evolution of Khokana



A large amount of houses were badly damaged and almost no reconstruction has started yet. Inhabitants of the various damaged houses are, 2 years after the earthquake, still waiting for the grant which is promised by the government. In addition, the inhabitants of Khokana are facing the problem that none of them own an official land owner certificate (Bastola S. Personal interview. 2016, October 10). In order to receive the grant, this legal work should be completed, leading to a enormous delay of the reconstruction process.

This route is chosen because a lot of the adjacent houses were badly damaged. However, apart from the main route, it is the most used route of the town. In addition, this route is composed of a variety of both housing typologies and economic functions. A clear pattern can be seen in the presence of the various typologies; where the secondary road touches the swastika, clearly more traditional buildings are facing the street.

The route connects various important public spaces linked with waterbodies which each have a unique relation. The reviving of both the public spaces and waterbodies will form the basis for the design proposal by extending the streetscape in several configurations. The main goal of the design proposal is to connect these elements, while taking into account sustainable reconstruction of the settlement and a diversity of greenery. Furthermore, the economic value is of considerable importance in the design proposal. New functions will be proposed in order to boost the local economy.

Interventions

Functions

- Shop
- Meatshop
- Crafts Atelier
- Sewing Atelier
- Weaving
- Metal Atelier
- Oil Mills

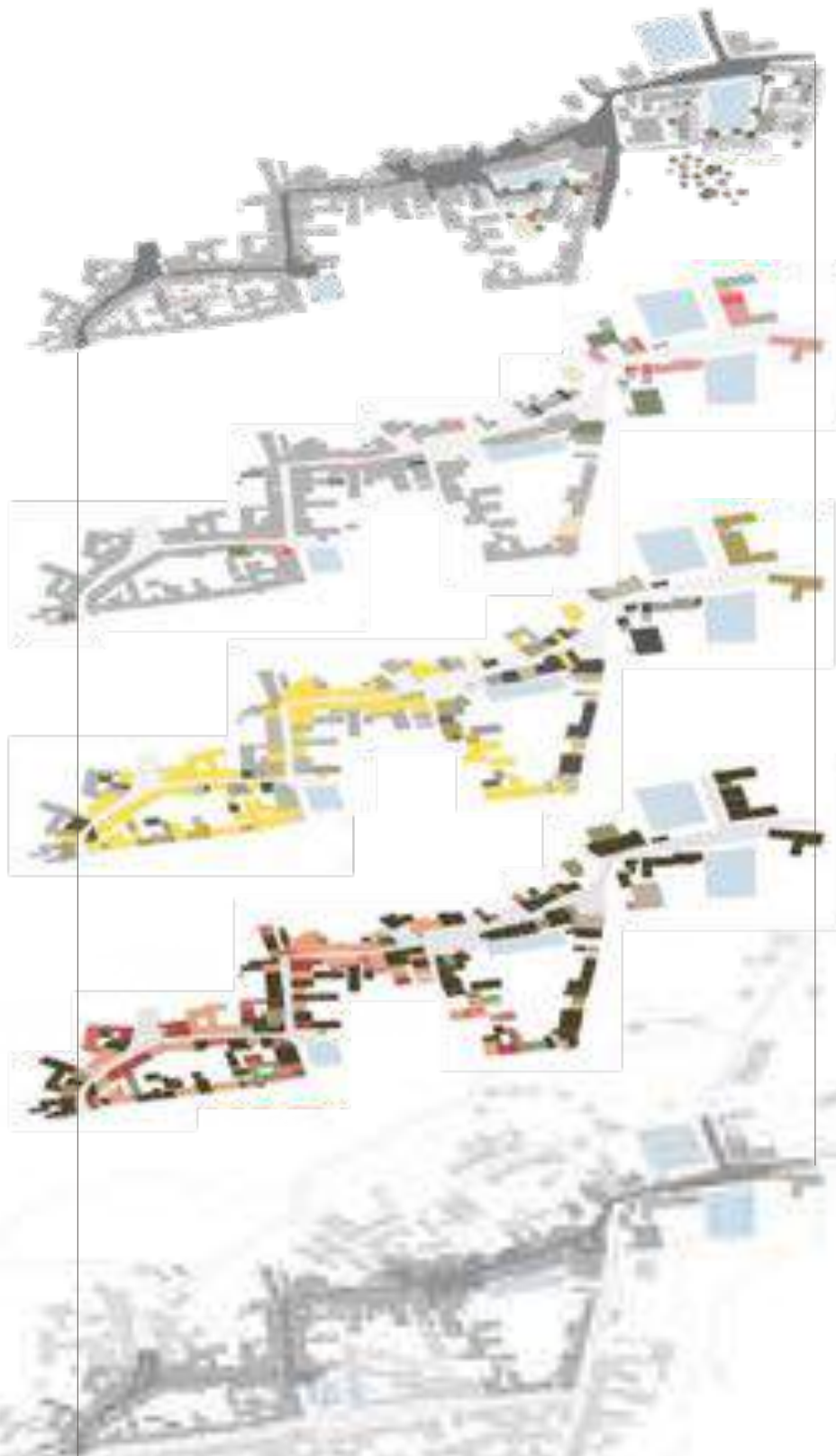
Typologies

- Traditional Newari
- Traditional Newari w/ extension
- RCC w/ masonry in frame
- RCC w/ masonry before frame
- RCC w/ plastered facade
- Namaste
- Modern w/ loadbearing masonry

Grade of damage

- No visible damage
- Minor cracks
- Major cracks
- Storeys removed for safety
- Partially collapsed
- Completely collapsed

Street network



Use and appropriation of the street





Scale 1/1000

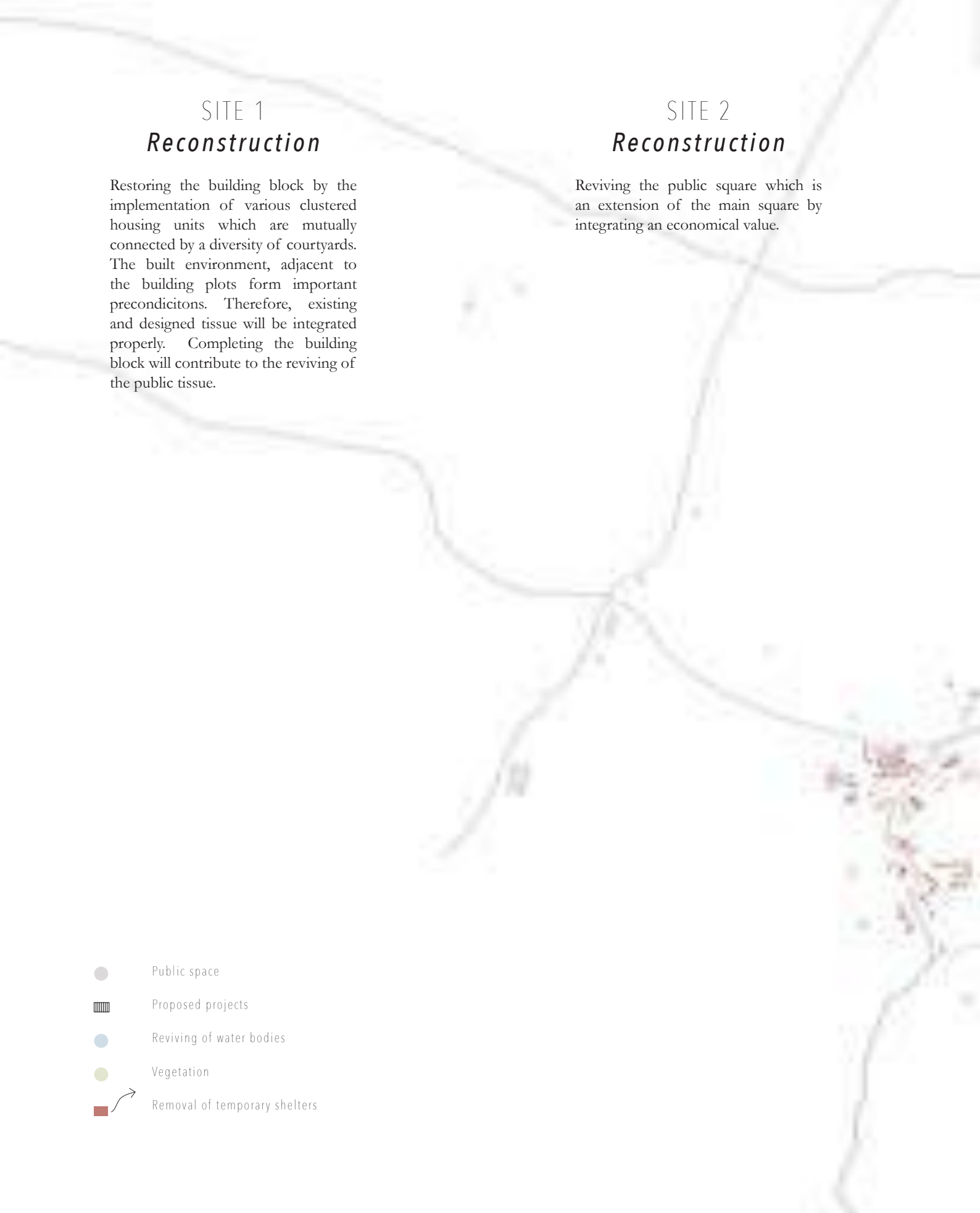


SITE 1 *Reconstruction*

Restoring the building block by the implementation of various clustered housing units which are mutually connected by a diversity of courtyards. The built environment, adjacent to the building plots form important preconditions. Therefore, existing and designed tissue will be integrated properly. Completing the building block will contribute to the reviving of the public tissue.

SITE 2 *Reconstruction*

Reviving the public square which is an extension of the main square by integrating an economical value.

- 
- Public space
 - ▤ Proposed projects
 - Reviving of water bodies
 - Vegetation
 - Removal of temporary shelters

SITE 3 *Densification*

Extending the public space in order to include the existing waterbody. Based on the principle of enclosure and shadow, new buildings will be added to revive the street network. A green collective garden will be realised in addition with a carpenter's atelier, representing an important economical contribution.

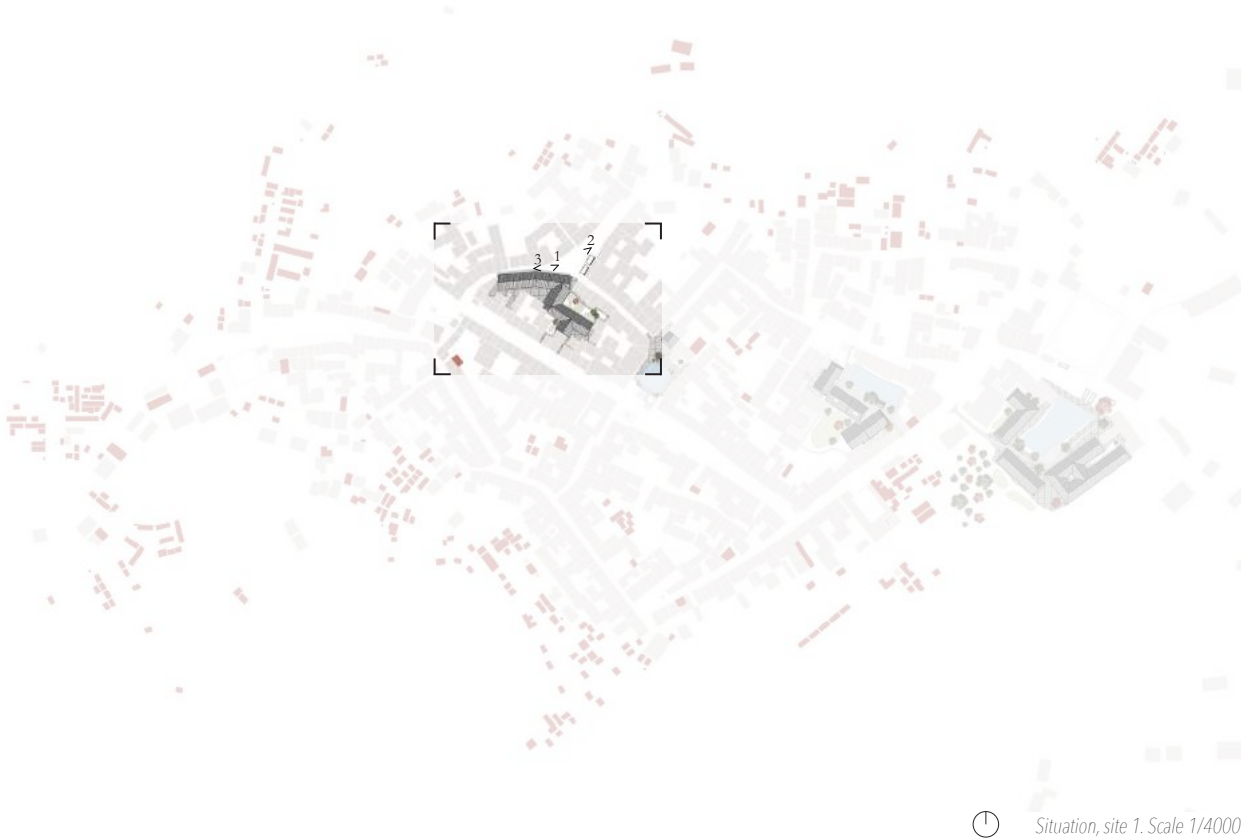
SITE 4 *Expansion*

Site located at the edge of the settlement and therefore taking into account urban growth. The design proposal aims to connect the existing urban tissue with an extension of the village. Including the waterbody in the public square by building around the pond.



2.

Site 1 | Reconstruction & housing



Situation, site 1. Scale 1/4000

Site 1 | Reconstruction

The reconstruction site is located at the historical core of the settlement. The core is composed of four whole building blocks and then started to expand gradually. After the earthquake of 2015, one of the four building blocks was heavily damaged. Almost one-third of the buildings have completely collapsed. Therefore, a lot of people originally living there were forced to move to temporary shelters at the edges of the village.

The public space located adjacent to the damaged edge of the building block is mainly used by farmers who pass by while going to the fields and women who get water from the well to wash their clothes. The two *patis* on this public space are damaged and in addition, one of them is currently filled with building materials, preventing people from using it as a resting space.

Since the collapsed edge of this building block is next to a carpenter's home, this site forms the perfect spot to start the reconstruction process.

Khokana is inscribed in the UNESCO tentative list to become World Heritage. However a lot of traditional Newari houses have collapsed, compromising the traditional streetscape. Since this design is situated within the historical core of Khokana, UNESCO might be an appropriate funder for the construction process.



Destroyed facades

The moment the earthquake struck, this whole row of houses was destroyed leaving behind a gap in the streetscape.



Extended public space

This scene has a great impact on the view and atmosphere of this public space. Now people are living elsewhere which means less activity around the space.



Lost elements

The movement of the square is compromised because of the collapsed buildings surrounding it.



existing condition

The existing situation with an abundance of ruins inside the building block.



phase 1

Building of the first housing units to reduce the amount of temporary shelters at the edges. In addition, the kitchen garden inside the building block is designed.



phase 2

Building of next housing units, segregating the kitchen garden and completing the adjacent public space.



phase 3

Building of final housing units, completing the edges of the building block. Reviving of the public space because of the reconstruction of the *patis* and surrounding buildings.



Phasing of site 1. Scale 1/1000

■ Damaged houses
■ Shelters



existing condition



phase 1



phase 2



phase 3



Restoring the feeling of inclosure

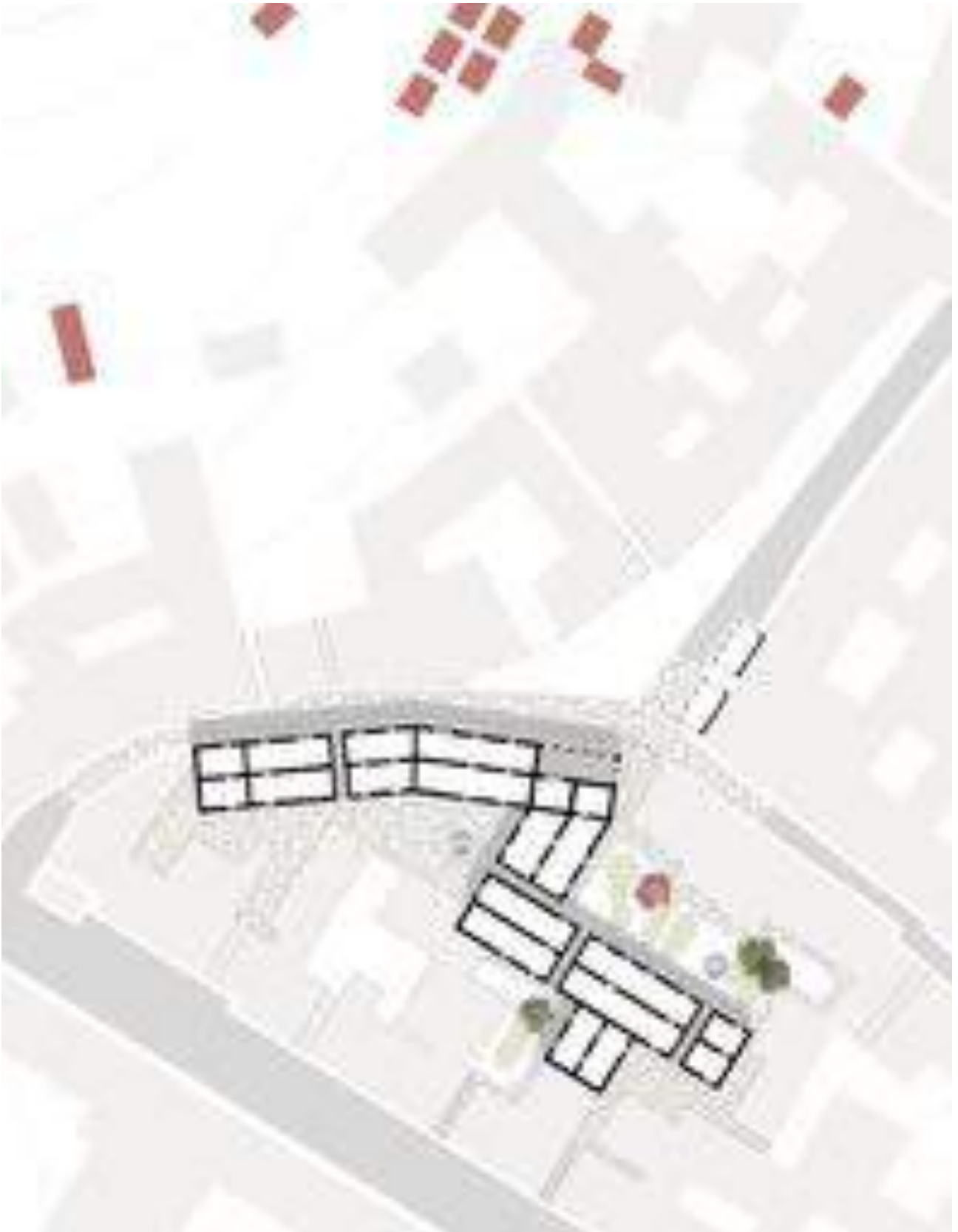


Facades on the side of the street. Scale 1/250

This design is focused on housing, since a lot of people lost their homes within this area. However, the houses on the side of the street have the possibility of settling a small shop or work space on their ground floor.

The designed intervention respects the original structure inside the building block, but creates a better thought out whole. By implementing a simple form, the open space inside the building block gets subdivided, creating various inner courtyards which offer added value to the surrounding houses. A true network of courtyards is realised by providing several passages between them, reassuring the fact that there is always an escape route during future earthquakes. The paved courtyards can be used for washing, drying crops, ... While the larger open space inside the building block is used as a kitchen garden for the surrounding households. Crops can be grown, in order to provide fresh vegetables for the related neighbours.

In order to supply enough water for the variety of activities on the courtyards, two additional wells are provided to collect the majority of the rain water and to prevent floods during the rain season.



Masterplan site 1. Scale 1/500

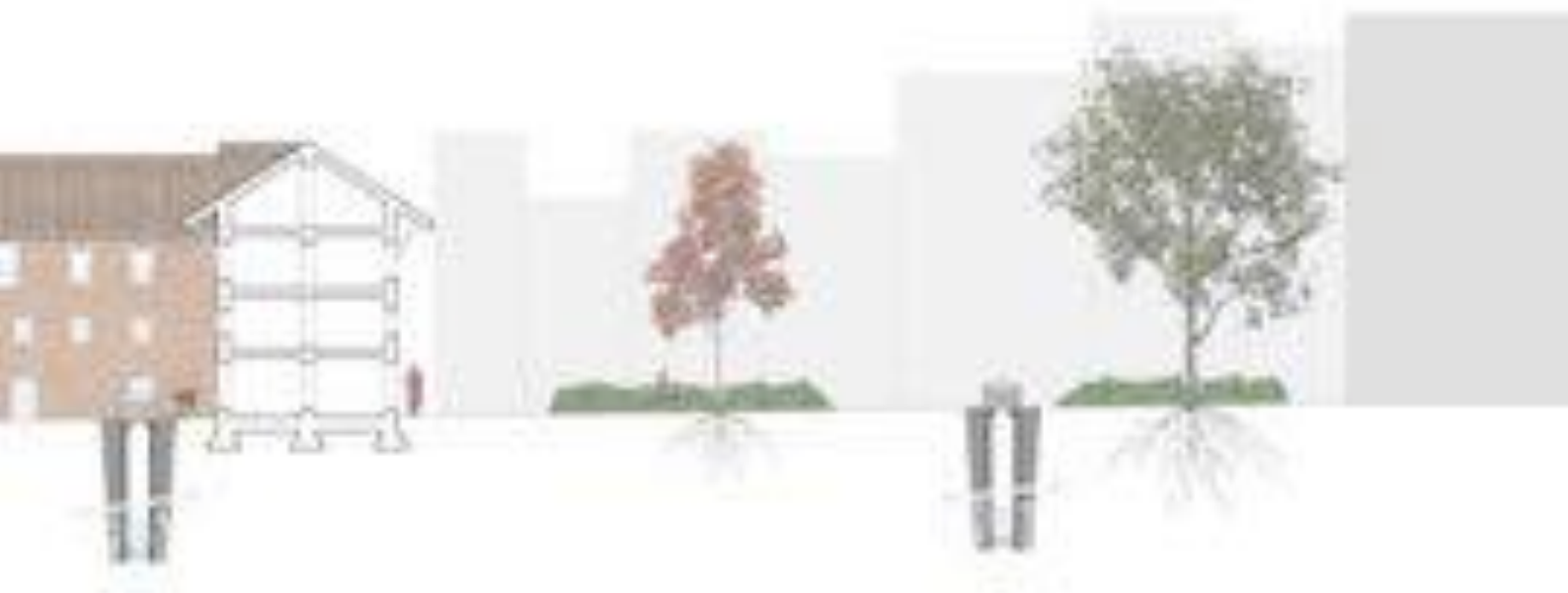


Shelters



The design also addresses to the adjacent public space. By rebuilding the surrounding houses, the public space will be more vibrant, since the sense of enclosure will be restored by the facades of the building block. In addition, a lot of attention is paid to the realisation of dynamic *patis*. Since the houses are North oriented, a lot of shadow will be added to the public space, increasing the daily activities on it.

By relocating the modern water tank, the traditional well will regain space and attention. Lastly, the two existing *patis* will be reconstructed, to provide more resting space for the numerous farmers who pass by when returning from their fields.



Sections of site 1. Scale 1/250



Phase 1, site 1. Scale 1/1000

■ Shelters

Housing units

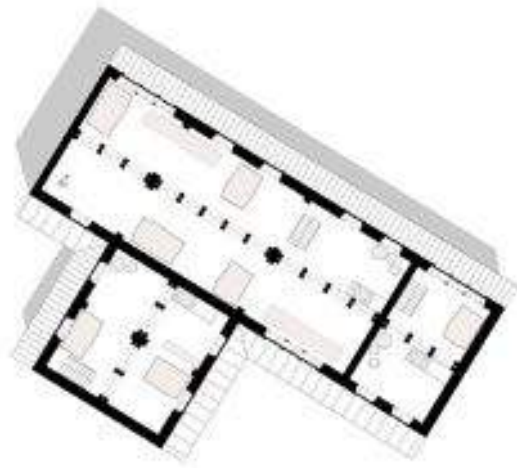
In means of having enough space for the building process, the first phase of the construction will be the houses in the middle of the building block. These houses belong to three households from within one wealthier family which have enough resources to start the rebuilding of their houses.

A big house, adjoined by two smaller ones is inserted within the boundaries of the surrounding existing buildings. The newly constructed houses are realised at a distance of 20 cm from the existing buildings, to prevent the different houses from damaging each other during an earthquake.

In addition, these houses are constructed with a blunt facade in order to be able to fixate the horizontal tie beams integrated in the houses of phase 2. By doing this, both buildings will be strengthened and better seismic characteristics are realised.

The principles of the Newari architecture and its building codes form the basis of the architectural design. However, they are slightly re-interpreted to answer to the contemporary needs of the inhabitants. Bigger buildings are realised, securing the possibility of properly subdividing the building later on. In addition, a bathroom is provided on the ground floor, increasing the comfort of the inhabitants.

In means of water management, an individual water tank is provided on the top floor, collecting the rain water from the roof. The collected water is used for the kitchen and bathroom. The black water from the toilet is brought to an individual septic tank, creating grey water which can flow to the collective drainage system for further processing.



Level +3



Level +2



Level +1



Level 0

Appropriation over time

The Newar men follow the tradition of living with their parents throughout their entire life. When the resident sons get married, the house gets subdivided over the various brothers. Currently these vertical divisions are frequently visible in the facade since dividing walls are placed in front of windows, compromising the incident of natural light.

In the design proposal, the future subdivision of the house is anticipated. The impetus of the division walls are realised, indicating where the houses can be divided. Possible appropriations are illustrated according to the desired subdivision.



Upper housing plot separated in 2



Upper housing plot separated in 3



Lower housing plot separated in 2







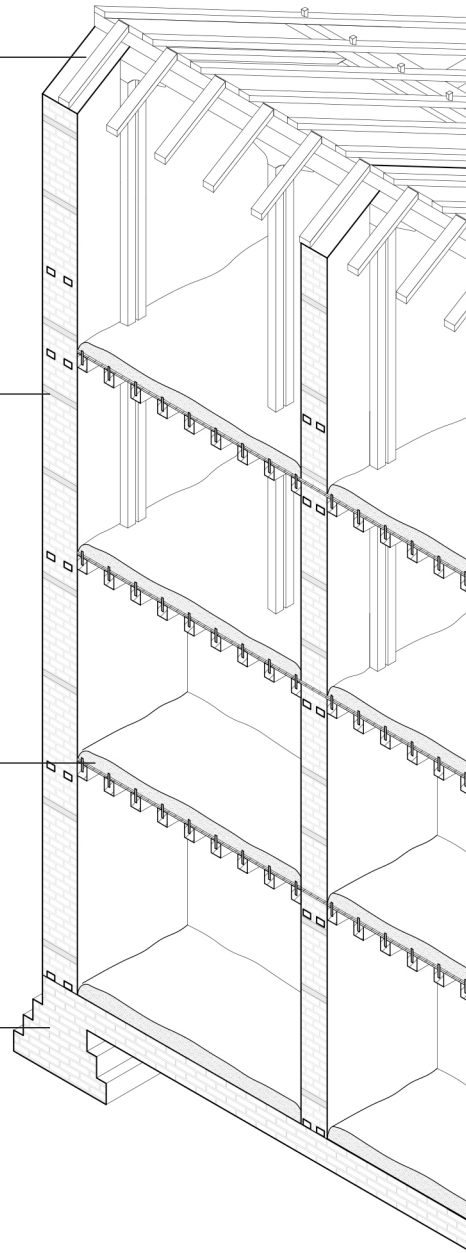
constructive roof structure

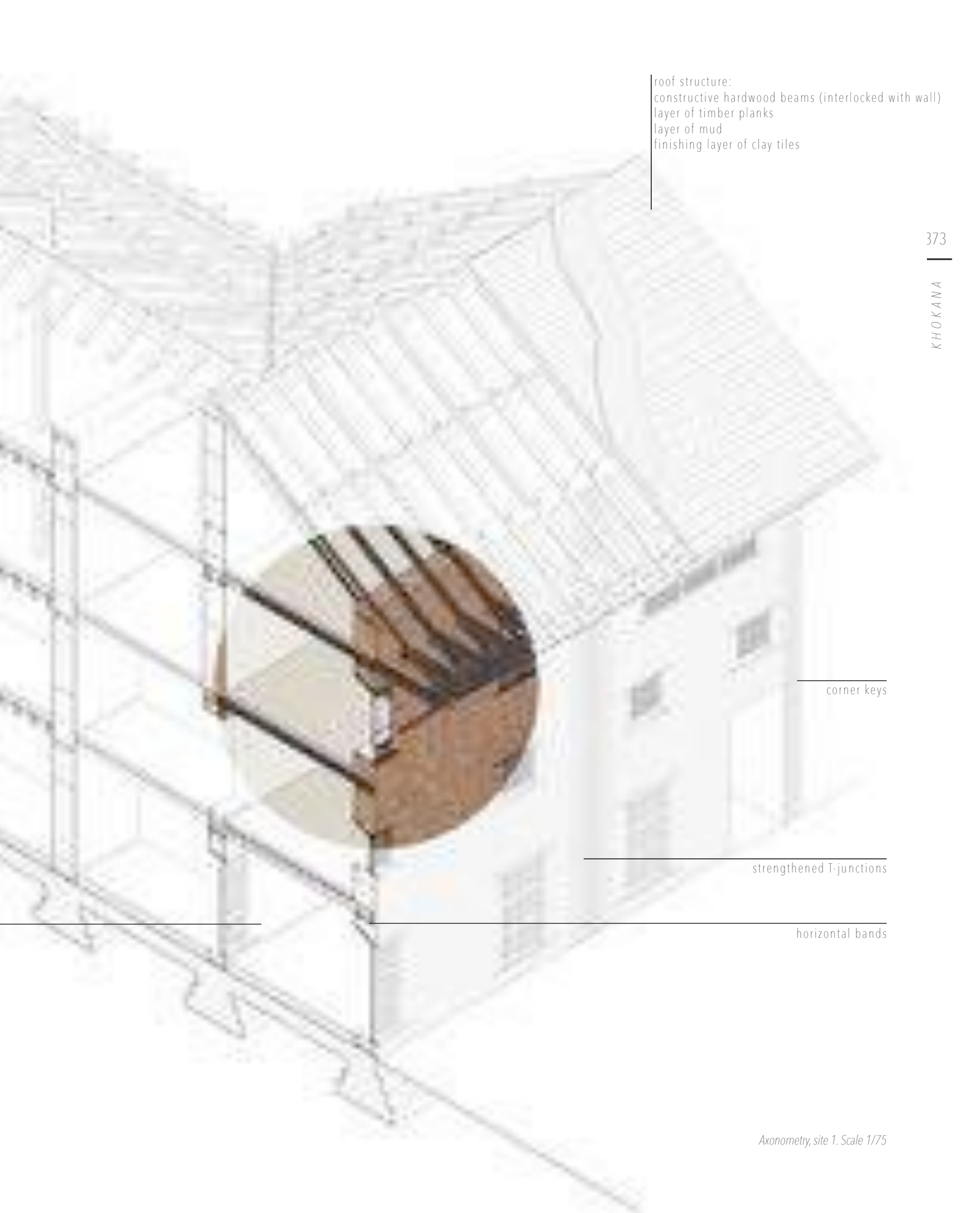
through-stones

floor construction:
constructive hardwood beams
double layer of timber planks (nailed down to the beams)
finishing layer of mud (min. thickness)

proper foundations

spine wall





roof structure:
constructive hardwood beams (interlocked with wall)
layer of timber planks
layer of mud
finishing layer of clay tiles

corner keys

strengthened T-junctions

horizontal bands

Phasing

1 month



phase 1 - housing

The first housing units, a big house adjoined by two smaller ones, are realised. These houses belong to a bigger family, currently in the possession of the required resources to build new houses. The individual kitchen gardens are constructed once the houses are finished.



phase 3

The resulting housing units, adjacent to the streets are realised. Their structural horizontal beams are, in their turn, fixated inside the guard facade of the building of phase 2 in order to provide structures with better seismic behaviour.

rebuilding patis

Once the primary housing demand is handled, the public spaces can be revived.

maintenance

Maintenance of the various buildings is an important factor in the durability and the preservation of the architecture. Approximately every two months, the houses and public structures should be managed.

preparation

When the rain season is over, the first step is to clear the inside of the building block which forms the site of the reconstruction design. The remains of the deteriorated buildings (including possible remaining foundations) are cleaned up and taken to the recycle bank. The plot is made ready-to-build.



phase 2

The next figure of housing units is constructed. Its structural horizontal beams are fixated inside the blunt facade of the building of phase 1 in order to provide structures with better seismic behaviour.



reserve

Two months of extra time are included in order to anticipate on possible delays.

restoring adjacent street network

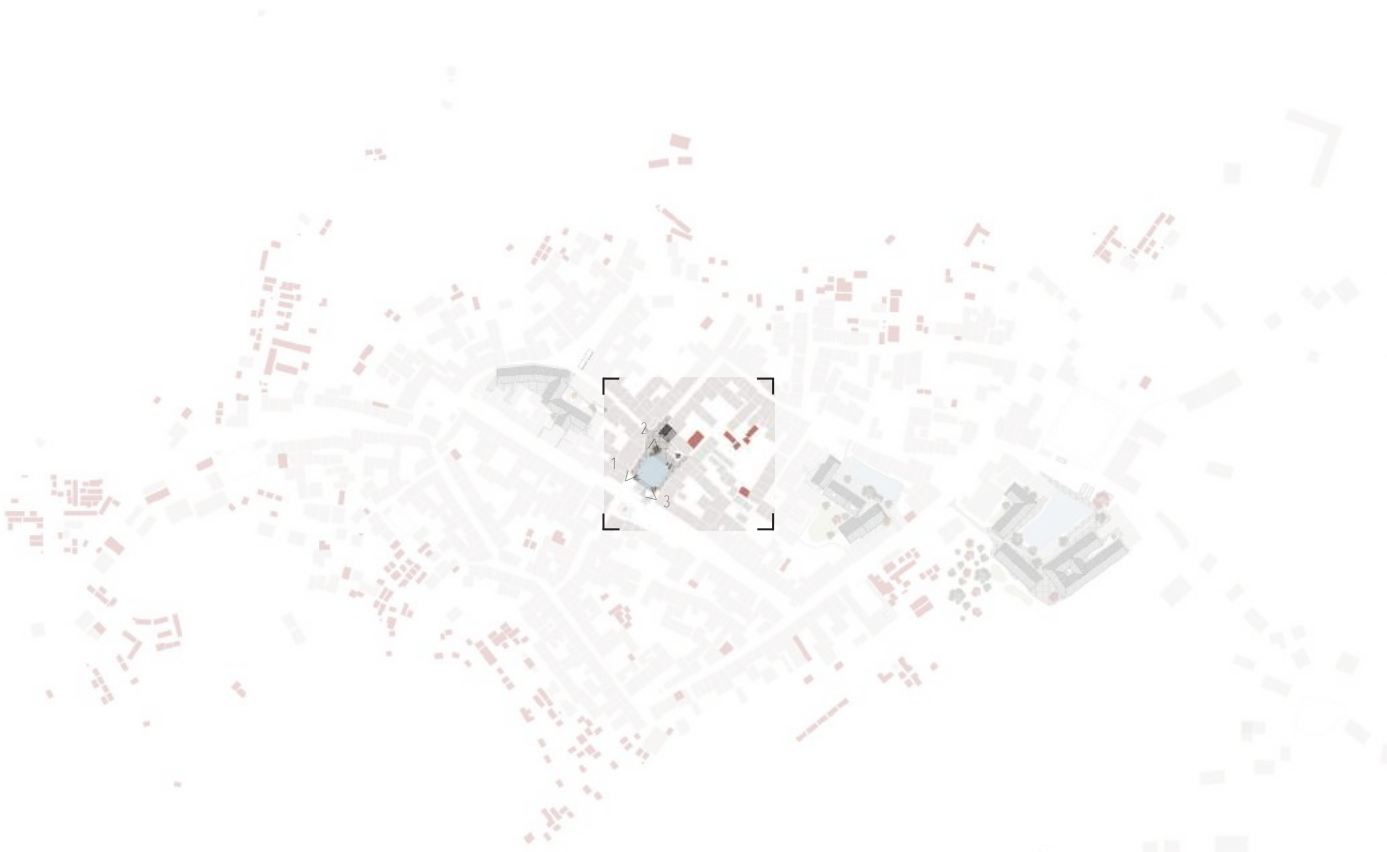
Restoring the street network is the final step in the reconstruction process, in order to prevent the newly paved streets from being damaged due to the construction of houses.



Vibrant kitchen garden inside of the building block

3.

Site 2 | Reconstruction & restaurant



Situation, site 2. Scale 1/4000

Site 2 | Reconstruction

This reconstruction site is located at the very centre of the traditional settlement of Khokana and represents the node of both the swastika figure and the secondary route. This extended square is commonly crowded with people due to the presence of various shops adjacent to the square. However, something is missing.

At the edges of the settlement, various eateries are located. However, within the settlement there is only one, which, in addition, is frequently closed. Therefore, an informal restaurant is proposed to fill in this damaged spot, supplementing the variety of functions located at this square.

Within Khokana, a women cooperative called SABAH is running a small restaurant, a sewing atelier and a weaving atelier. This cooperative also has establishments in Patan. Since the women cooperative is successful within the various branches and is quite large, this cooperative can fund an extra establishment within the core area of Khokana, expanding their business.



Extension of main square



De Pukhu

The central pond of Khokana contributes intensively to the cultural tradition and ambiance of this settlement. Although the pond is not well maintained, it is still used by playing teenagers.



Water spout

Next to the pond, a water spout is located. However, this water spout is no longer working due to the damaged traditional water system.



existing condition

The existing situation centred around the polluted main pond.



phase 1

First, the pond will be cleaned in order to restore the traditional water system. When these cleaning actions are finished the restaurant (including a housing unit) is built and the adjacent street network is reconstructed.

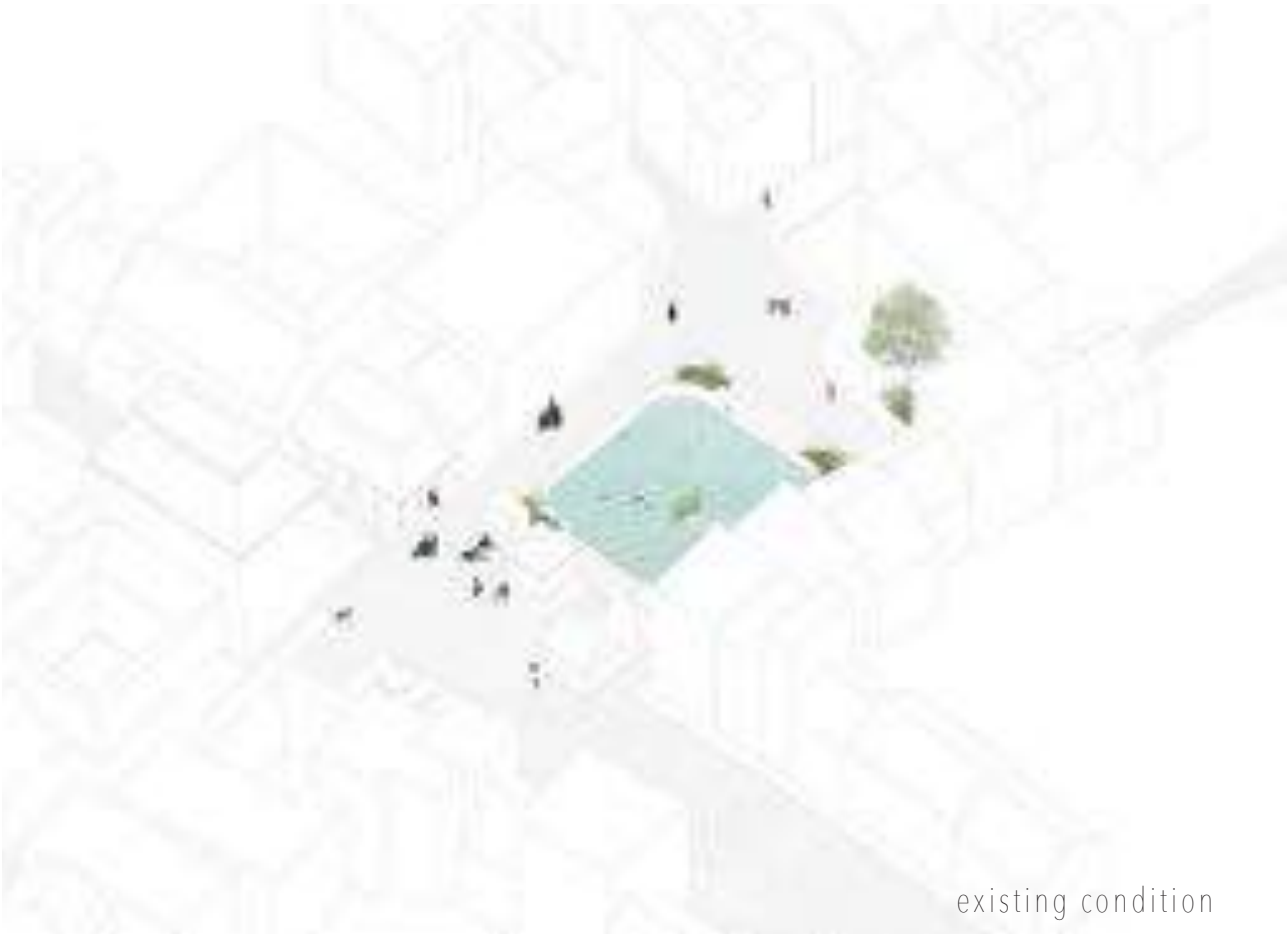




Masterplan of site 2. Scale 1/500



Shelters



existing condition





phase 1



Section of site 2. Scale 1/250



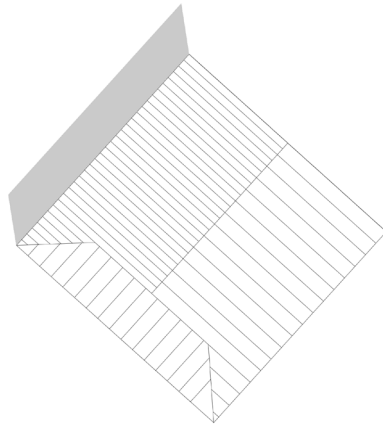
⌚ Site 2. Scale 1/1000
 ■ Shelters

Restaurant

This building spot will be filled with a single building which encloses both a housing unit and a social restaurant. The restaurant is located at the ground floor and in order to create a continuity between interior and exterior, the facade of the ground floor is kept as open as possible without compromising the earthquake resilience of the building.

In order to open up the entire ground floor for economical purposes, the stairs serving the housing unit is located at the exterior. A balcony on both facades enlarges the area of the housing unit, compensating its loss of the ground floor. This new typology is adapted to the surrounding context and is a variation on the existing Newari typologies.

Like in the previous design proposal, the perimeter of the new building is kept at a distance of 20 cm from the surrounding buildings in order to prevent mutual damage due to the forces exerted on the buildings during an earthquake.



Roof plan



Level +2



Level +1



Level 0



Floor plans restaurant. Scale 1/200





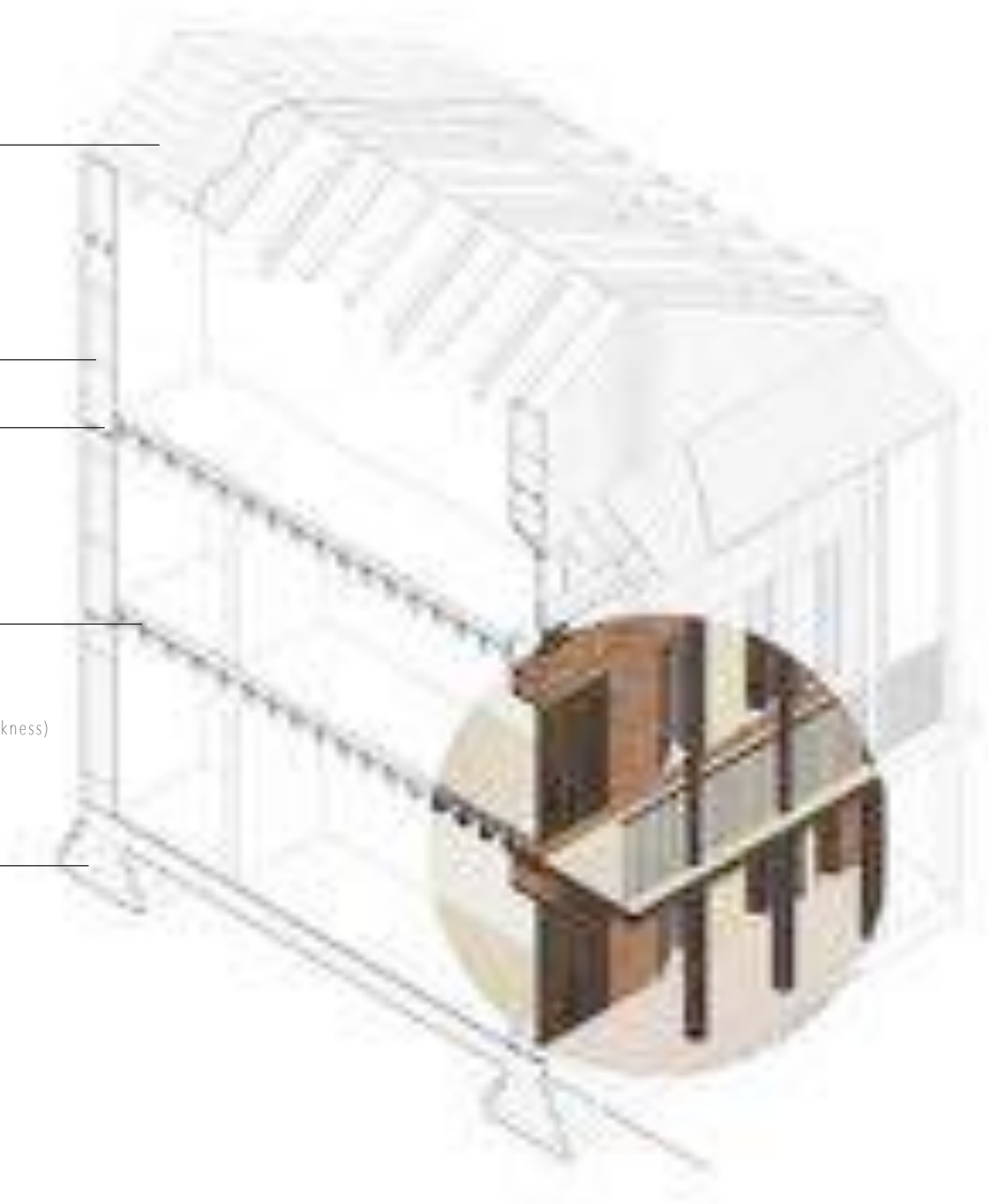
roof structure:
constructive hardwood beams
(interlocked with wall)
layer of timber planks
layer of mud
finishing layer of clay tiles

through-stones

horizontal bands

floor construction:
constructive hardwood beams
double layer of timber planks
(nailed down to the beams)
finishing layer of mud (min. thickness)

proper foundations



Phasing

390

1 month

cleaning pond

The main pond of the village plays an important role in this reconstruction design. The water is currently badly contaminated and in order to restore the traditional water system (chapter: “Bungamati: Rethinking water cycles”) the pond should be thoroughly cleaned. Since the pond is filled with enormous amounts of mud, an excavator should be used. Since this requires a lot of space, these actions should be conducted first.

construction restaurant

When the cleaning and preparation actions are finished, the construction of the restaurant can start.

greenery

During the reconstruction of the street network, additional greenery is provided on this main square in order to generate more shadow and therefore increasing its use.



preparation

When the rain season is over, the first step is to make the building plot ready-to-build. This can happen simultaneously with the cleaning of the pond.

restoring adjacent street network

Restoring the street network is the final step in the reconstruction process, in order to prevent the newly paved streets from being damaged due to the construction of houses.

maintenance

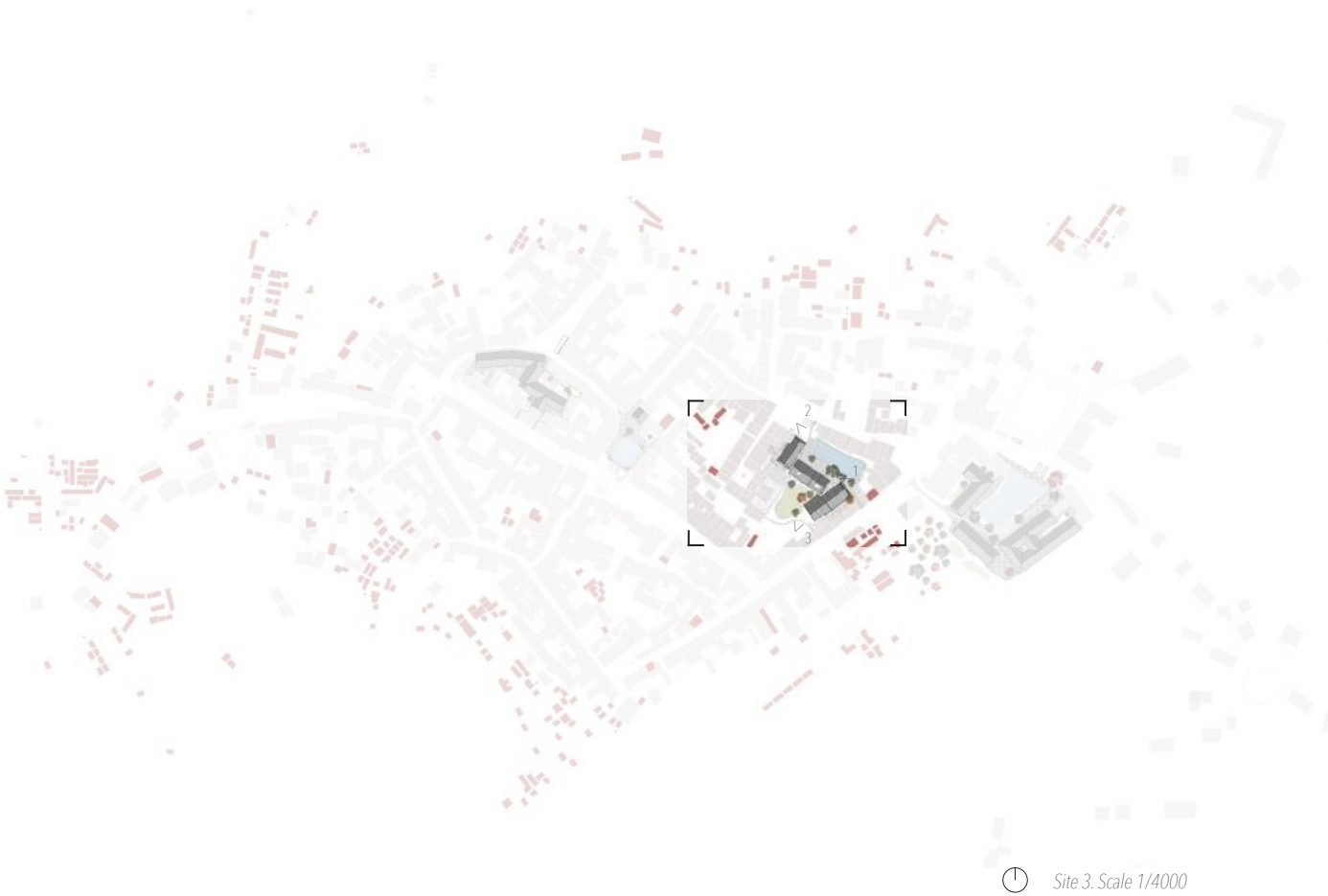
Maintenance of the various buildings is an important factor in the durability and the preservation of the architecture. Approximately every two months, the houses and public structures should be managed.



*Revitalising the main square by cleaning the pond
and creating a social restaurant*

4.

Site 3 | Densification & carpenter's
atelier



Site 3. Scale 1/4000

Site 3 | Densification

Although Khokana is a very dense and crowded village, it still contains some micro organisms or hidden oases of greenery within its urban tissue. In addition, there is a significant waterbody located at this site. However, this pond is currently unrecognisable and even most of the villagers do not know it is there. The pond is separated from the adjacent street network by a row of modern houses, built as a result of the expansion of the village. Since this micro organism contributes to the settlement as a whole and plays a fundamental role in the groundwater recharge, the goal of the design proposal is to preserve this green spot. The water body is integrated into the street network by extending the public space.

In addition, within this building block a lot of economic activities are present, making this location an interesting building spot.

Next to the building block, two earthquake related committees are located; the Khokana Reconstruction and Rehabilitation Committee and the Khokana earthquake Victim Committee. Since they both are strongly invested in post-disaster related programs, they could be interesting investors for this design proposal. In addition they could relocate towards this location contributing to the comprehensiveness of a multi-functional building block.



Entrance to the green oasis



View from the street network

This public space will be extended in order to integrate the pond in the street network.



A green oasis within the city borders

When entering through the narrow entrance alley, you reach an unexpected green oasis. Even though the village is filled with houses connected by paved courtyards, there are some hidden green oases present within the Newari urban tissue.



existing condition

The existing situation with the micro organism of greenery. The facades of the surrounding buildings will guide the evolution of the design.



phase 1
carpenter's atelier

Building of a carpenter's atelier so that the carpenter can relocate to a bigger work space in order to provide wooden elements for the further reconstruction of the settlement.



phase 2

Building of housing units, so shelters on the site can disappear. This unit will complement the collective garden resulting from the green oasis and bound the public space centred around the pond.



phase 3

Building of final housing units, creating a large *peti* and passage towards the inside of the building block. In addition the public space centred around the pond is revived by restoring the adjacent street network and the construction of a *pati*.



Phasing of site 3. Scale 1/1000

Shelters

This design focuses on integrating the invisible pond with the surrounding street network. In this regard, the existing public space is extended and an extra connection between this public space and the street at the south-east side is realised. This connection is designed as a vibrant public space which becomes more than a pure connector. A *pati* is built next to the pond, creating a resting place that stimulates passers-by to stop for a minute.

In the Newari urban tissue, shadow plays an important role for various reasons. Public spaces tend to be dimensioned on shadow, since it is more pleasant to reside in a cool place within this warm climate (during the summer). In order to both bound the new public space and optimize its use, a building with numerous housing units is positioned at the south edge of the public space. In addition, the greenery next to the pond provides shadow, minimizing the evaporation of the water inside the pond. Behind these housing units a collective garden is designed with elements from the green oasis. The adjacent houses are equipped with a terrace on their top floor, enhancing the relation between the private households and semi-public garden.

An additional economical function is provided within the master plan for this building site. There are currently two carpenter's located inside Khokana, who both have only limited working space. Therefore, a carpenter's atelier is provided adjacent to the collective garden, allowing the local carpenters to relocate to a bigger location.



existing condition



phase 1
carpenter's atelier



phase 2



phase 3





*By adding the carpenter's atelier the space
becomes more lively*





Sections site 3. Scale 1/250



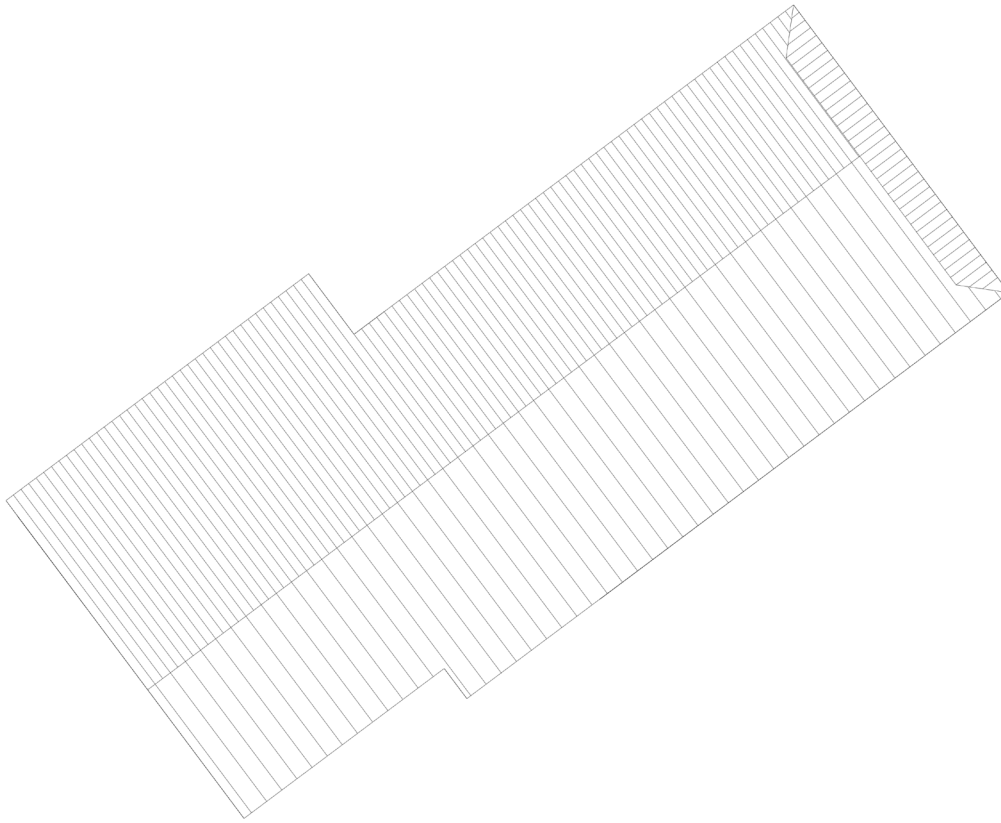
⌚ phase 1, site 3 . Scale 1/1000
 ■ Shelters

Carpenter's atelier

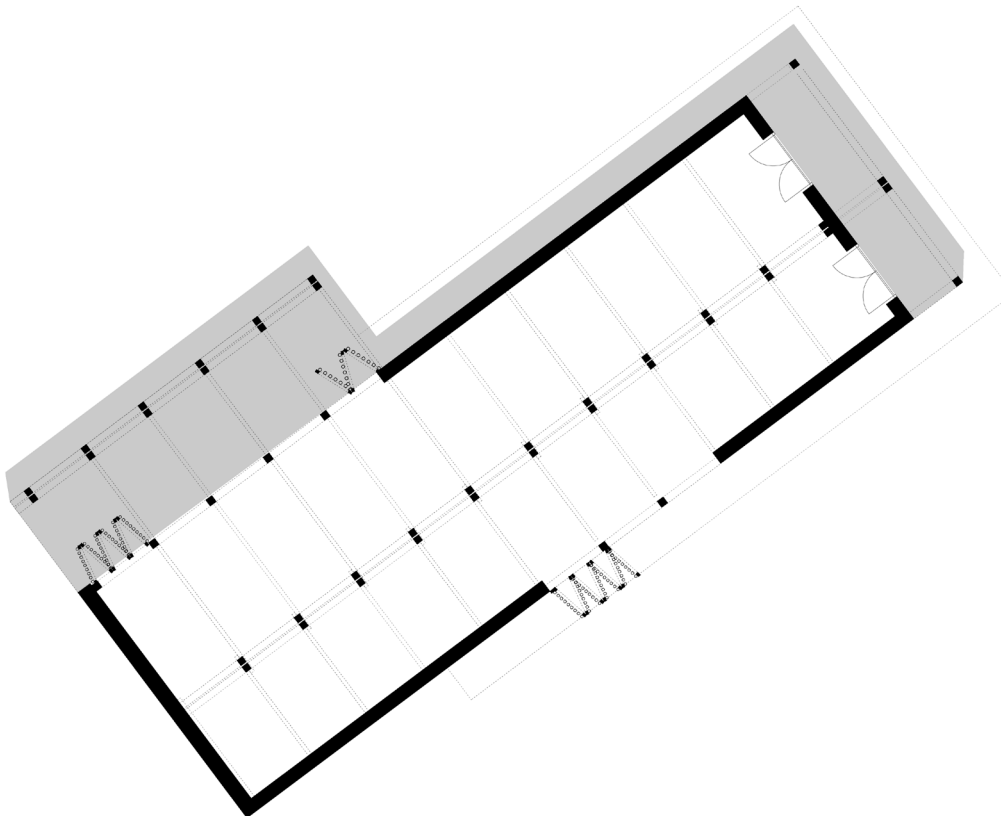
The first phase of this design is the building of a carpenter's atelier. By realising this large atelier, the carpenter can relocate and improve his business. In addition, the atelier can be used as a learning school for the inhabitants of Khokana. Since the people mainly build their own houses, it will be of great value if more people could be educate. Local building techniques could be transmitted properly from generation to generation, resulting in an optimisation of the Newari building culture, which is primarily famous for its outstanding carpentry. In addition, this economical value will stimulate the micro-economy within the settlement of Khokana.

The architectural refinement of this building is slightly different from a conventional Newari house. First of all, the strucure is primarily realised of a wooden column and beam structure, counting only one storey which is supplemented with a semi-storey underneath the sloped roof. By minimizing the load on top of the loadbearing structure, the facades can be designed in a more open way, allowing to create an intense relation between the interior of the atelier and the adjacent collective garden. Therefore, the masonry facades are alternated with slidable bamboo panels. These panels are semi transparant, allowing more light to get in but allowing the possibility of shielding. Furthermore, the roof is designed in an assymetrical way to create an covered outdoor area which could be used to work outside.

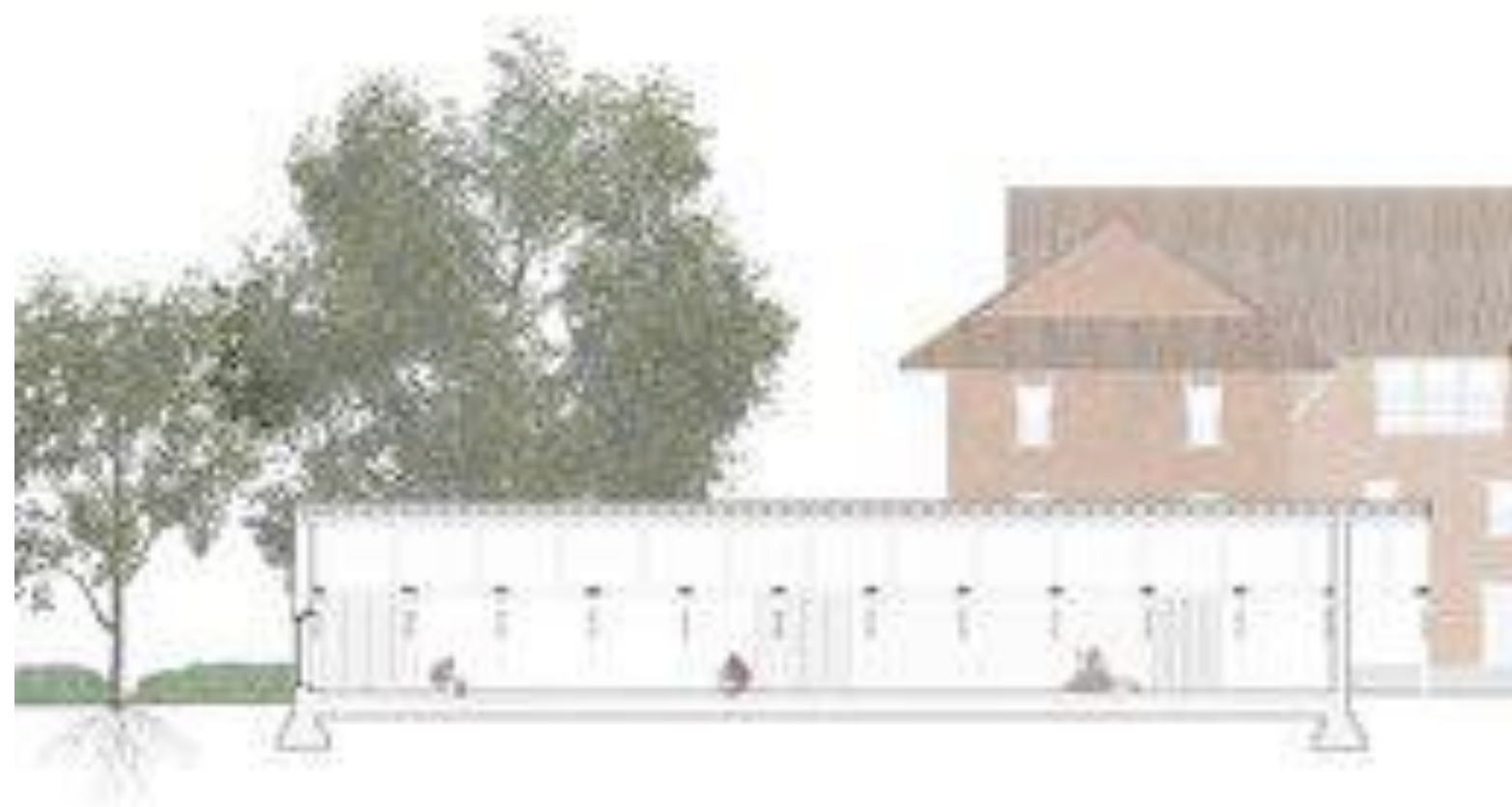
On top of the wooden structure, timber planks can form a floor, creating a storage space underneath the roof which could be reached by a ladder.

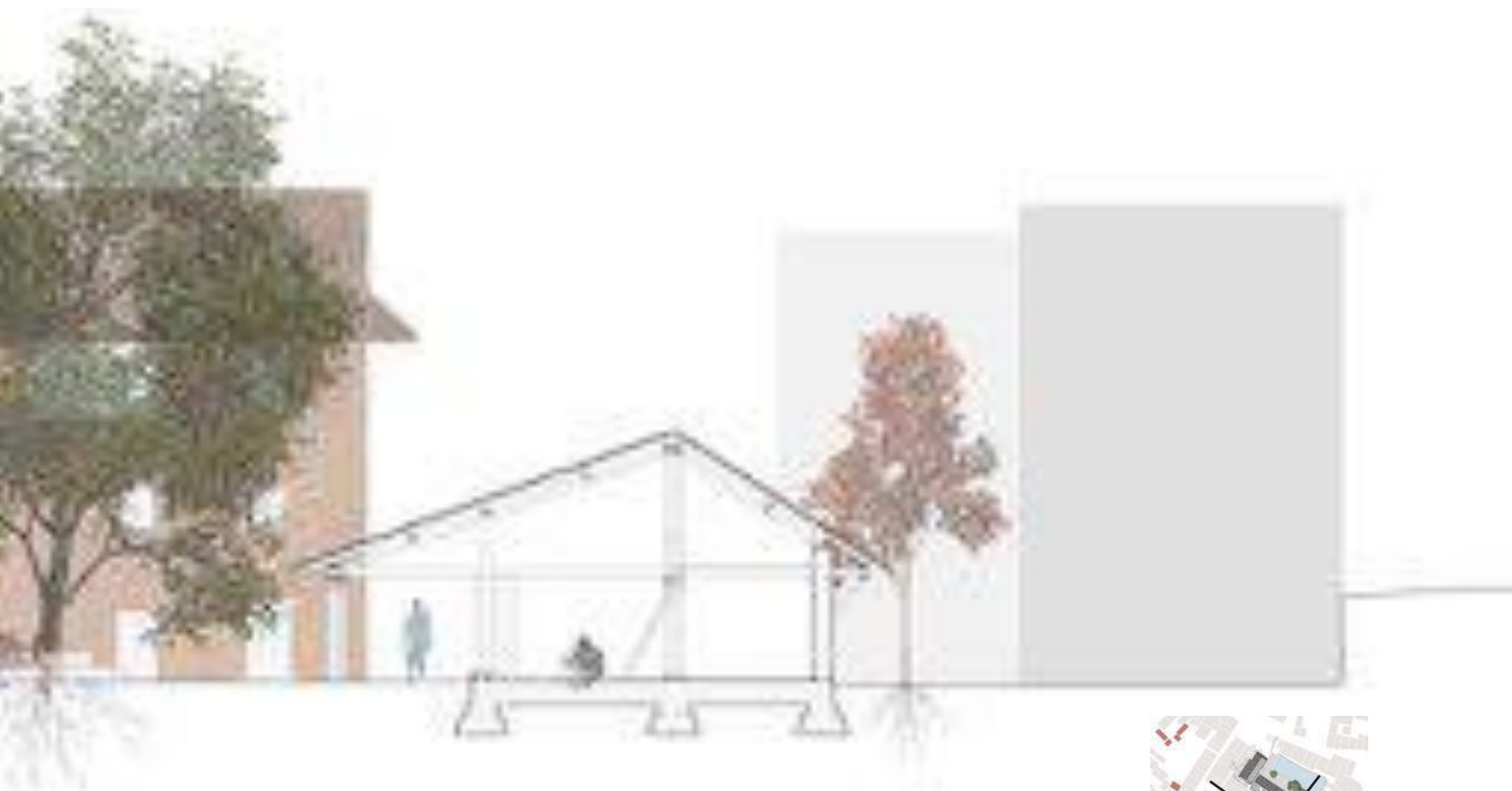
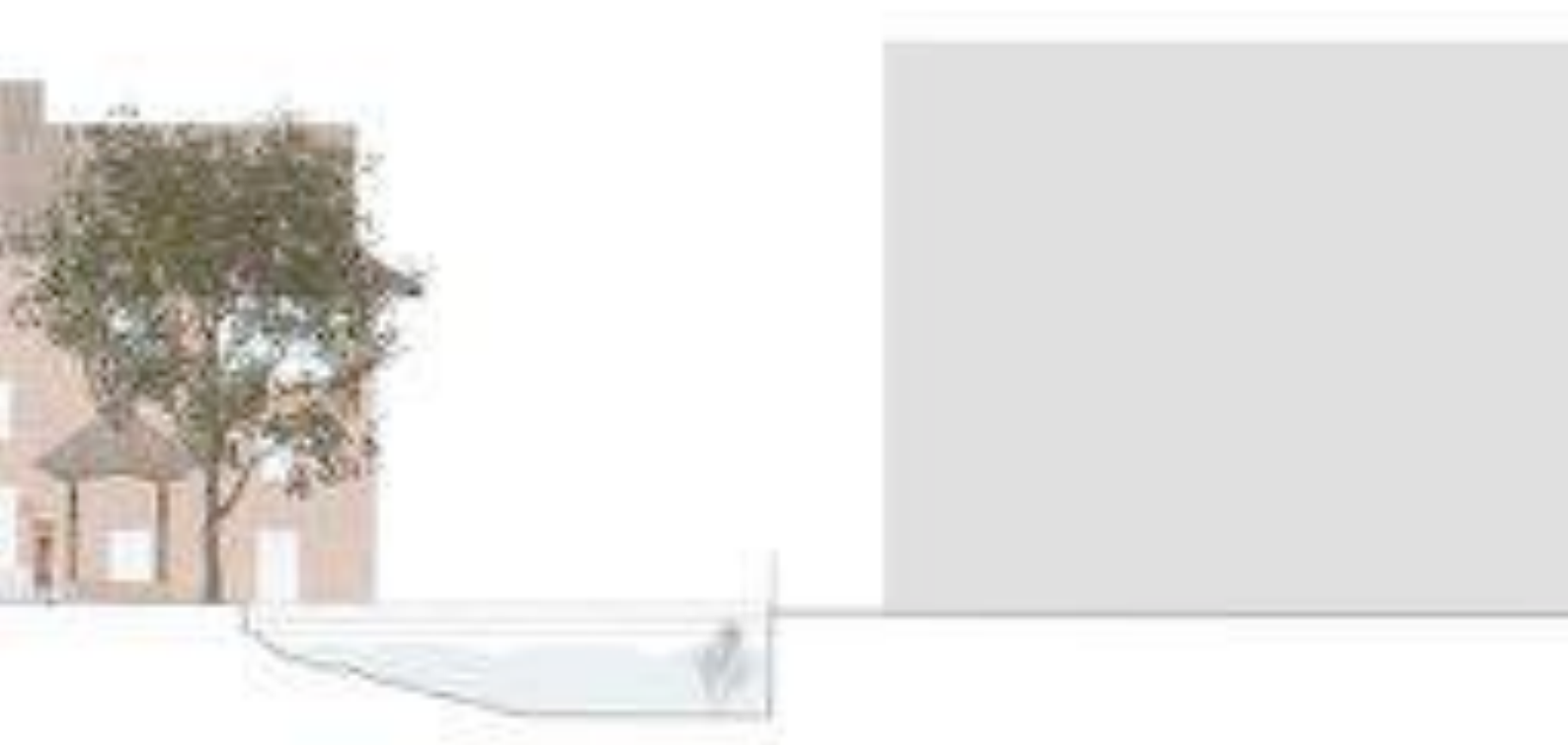


Roof plan



Level 0



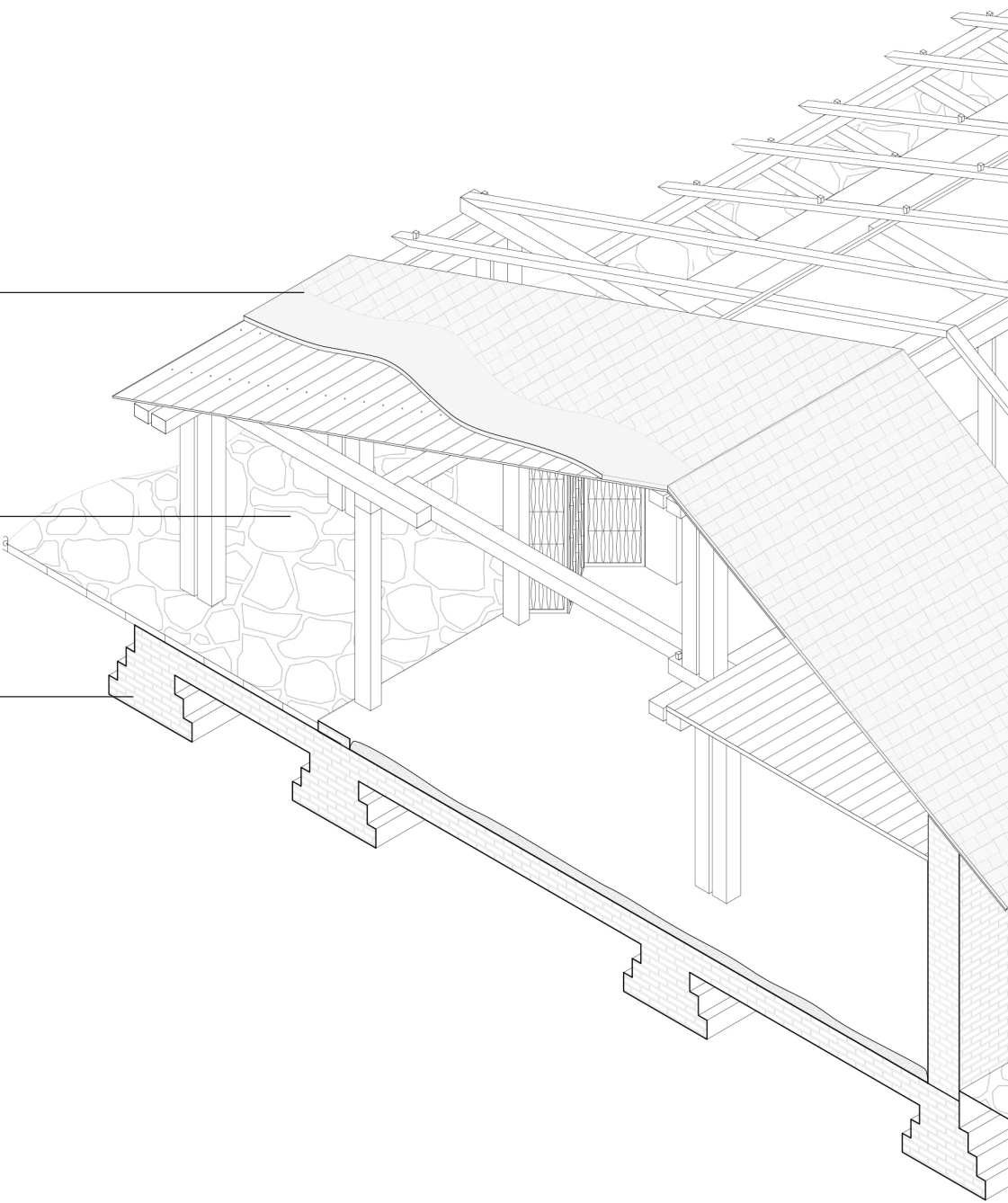


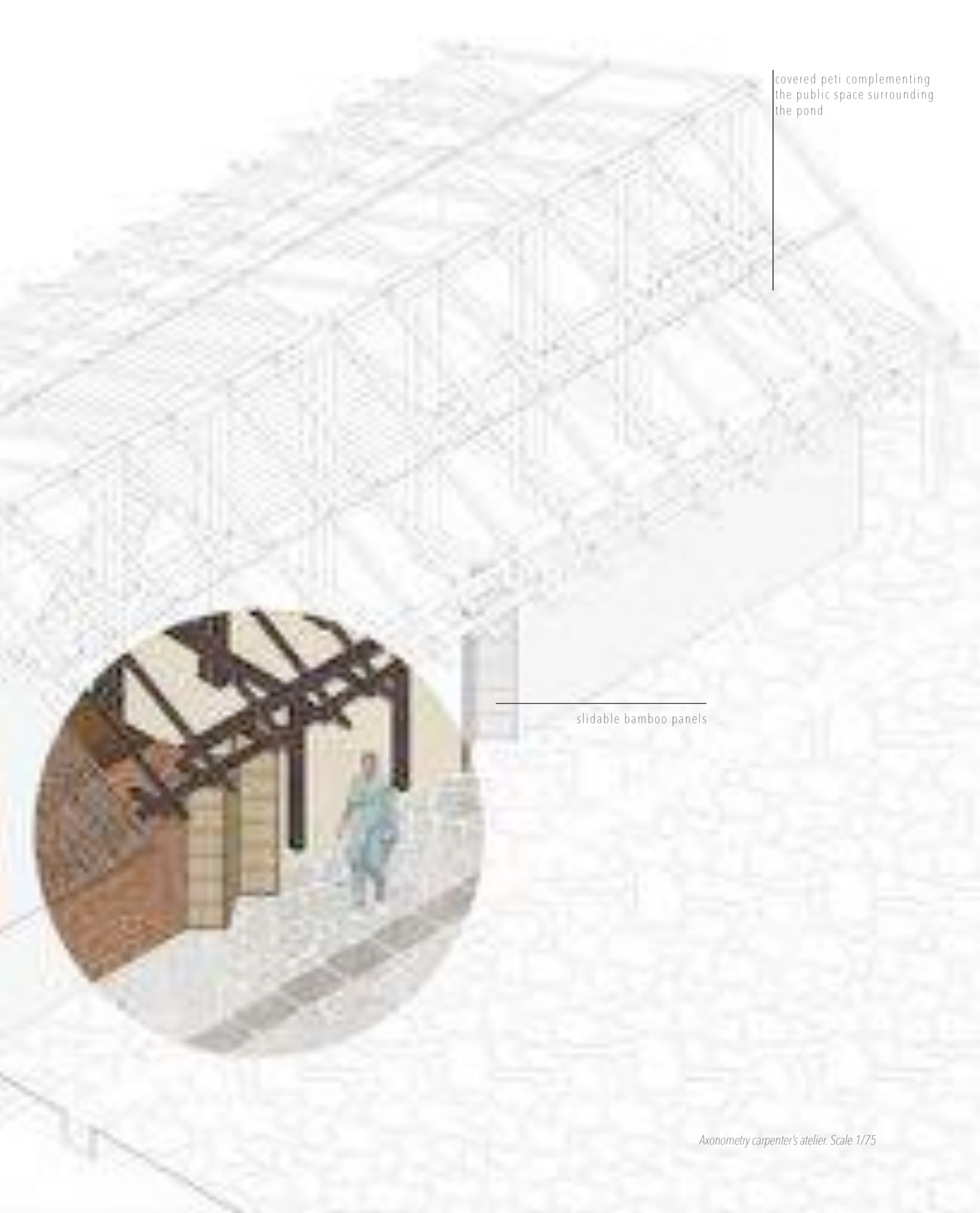
Detailed sections carpenter's atelier Scale 1/150

roof structure:
constructive hardwood beams
(interlocked with wall)
layer of timber planks
layer of mud
finishing layer of clay tiles

covered outdoor area

proper foundations





covered peti complementing
the public space surrounding
the pond

slidable bamboo panels

Phasing

1 month

cleaning pond

The pond at this building site is currently completely neglected. The pond is filled with mud and almost no water is present. In order to restore the traditional water system (chapter: “Bungamati: Rethinking water cycles”) the pond should be thoroughly cleaned. Since the pond is filled with enormous amounts of mud, an excavator should be used. Since this requires a lot of space, this actions should be conducted first.



phase 2

The next step is the building of the adjacent housing units with the help of the local carpenters.



reserve

Two months of extra time are included in order to anticipate on possible delay.

preparation

When the rain season is over, the first step is to clear the inside of the building block which forms the site of this densification design. The bushes and weeds should be removed, however the trees are preserved at all times. In addition, the plot is made ready-to-build.

phase 1 - carpenter's atelier

The first step in the building process of this design is the construction of the carpenter's atelier. Once this atelier is finished, the carpenter can relocate in order to provide wooden elements for the further reconstruction process of both this site and the entire settlement.



phase 3

The resulting housing units are constructed.



building *pati*

Once the primary housing demand is handled, the public spaces can be revived.

maintenance

Maintenance of the various building is an important factor in the durability and the preservation of the architecture. Approximately every two months, the houses and public structures should be managed.



View from the outside covered space

5.

Site 4 | Expansion & guesthouse



Situation, site 1. Scale 1/4000

Site 4 | Expansion

When people build a house at the edges or outside the settlement, no considerations are made about further expansion and building processes in the surrounding environment, leading to dispersed isolated buildings. However, the expansion of the settlement should happen in better relation to the urban tissue of the traditional village. The village needs to foresee further expansion in a less fragmented way.

For this design view, the building site located adjacent to the buspark of Khokana is chosen. This buspark is the main entrance of Khokana, indicated by the welcoming ponds, and is therefore a very busy and crowded location. In the surroundings of the building site, an abundance of economic functions are present, answering the needs of the villagers and travelers who enter Khokana at this place.

Despite the fact that all travellers cross this point when visiting Khokana, no accomodation possibilities are provided. Therefore, the implementation of a guesthouse at this building site would be efficient, upgrading the economy of the village.

The SABAH cooperative would be an suitable funder for this project too. Investing in the establishment of an extra branche, namely a guesthouse, would be an interesting move in order to expand their business.



Kamal Pukhu, one of the welcoming ponds



*View from buspark to the Kamal Pukhu
Now a forgotten pond because of its isolated location.*



Panoramic view over the design proposal



existing condition

The existing pond is surrounded with consecutive ricefield and a forest. The pond is slightly hidden due to its inefficient location.



phase 1

Finishing the existing building block by providing housing units, which decrease the amount of shelters in the surrounding areas.



phase 2
guesthouse

A guesthouse is implemented. This project is prioritised in order to invite voluntary workers to assist the reconstruction process of Khokana. Building of additional housing units, separating the forest from the pond and further decreasing the number of temporary shelters. In addition the pathway connection both adjacent streets is realised.



phase 3

Building of second order housing units oriented towards the street at the west side.



Phasing of site 4. Scale 1/1500

Shelters

This design shows an expansion of the traditional settlement, while respecting the preconditions and context. The various elements present at the building site are integrated in the design proposal, strengthening their value and fully appreciating them. By anticipating on how to plan a larger scale master plan, the effect of urban sprawl which is affecting the whole of the Kathmandu, is reduced.

One of the welcoming pond forms the centre of the design proposal, generating various typologies representing living adjacent to the pond. The pond is revived by creating a vibrant public space around it and is further integrated by extending the public space over the pond with a wooden platform. The public space around the pond is optimized by erecting various buildings at its edges, creating a pleasant atmosphere based on the principle of shadow. To complement this public space, various larger building blocks are realised, positioned according to each other while shaping different kinds of connecting and escape routes.

The housing units at the south are fitted with a gallery facing the pond. In this way, the typology of appartments can be implemented, increasing the density of the building plot.

The building at the west side is the second order of the west street, seperated from the first order by a collective kitchen garden. The 'back' side of these houses gives an additional view over the pond, increasing the qualities of these housing units. In order to strengthen the relation between this building and the public space around the pond, these housing units have a balcony on the second floor.

Since this site is located at the edges of the settlement, a lot of fertile land remains free in the surrounding environment. In order to increase the amount of available building materials for further construction processes, bamboo will be planted at this site. After a period of 3 years (Government of Nepal, 1994) they will be fully grown in order to use them as building materials (once they have been treated properly).



existing condition



phase 1
guest house



phase 2



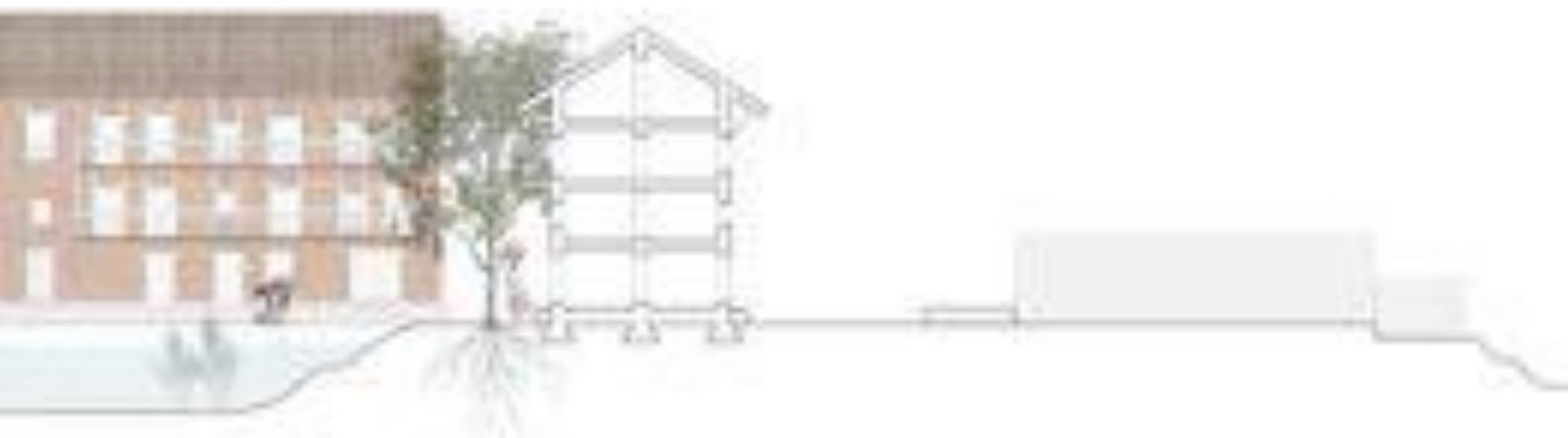
phase 3





Path towards the guesthouse





Sections, site 4. Scale 1/250



Phase 2, site 4. Scale 1/1500

Guesthouse



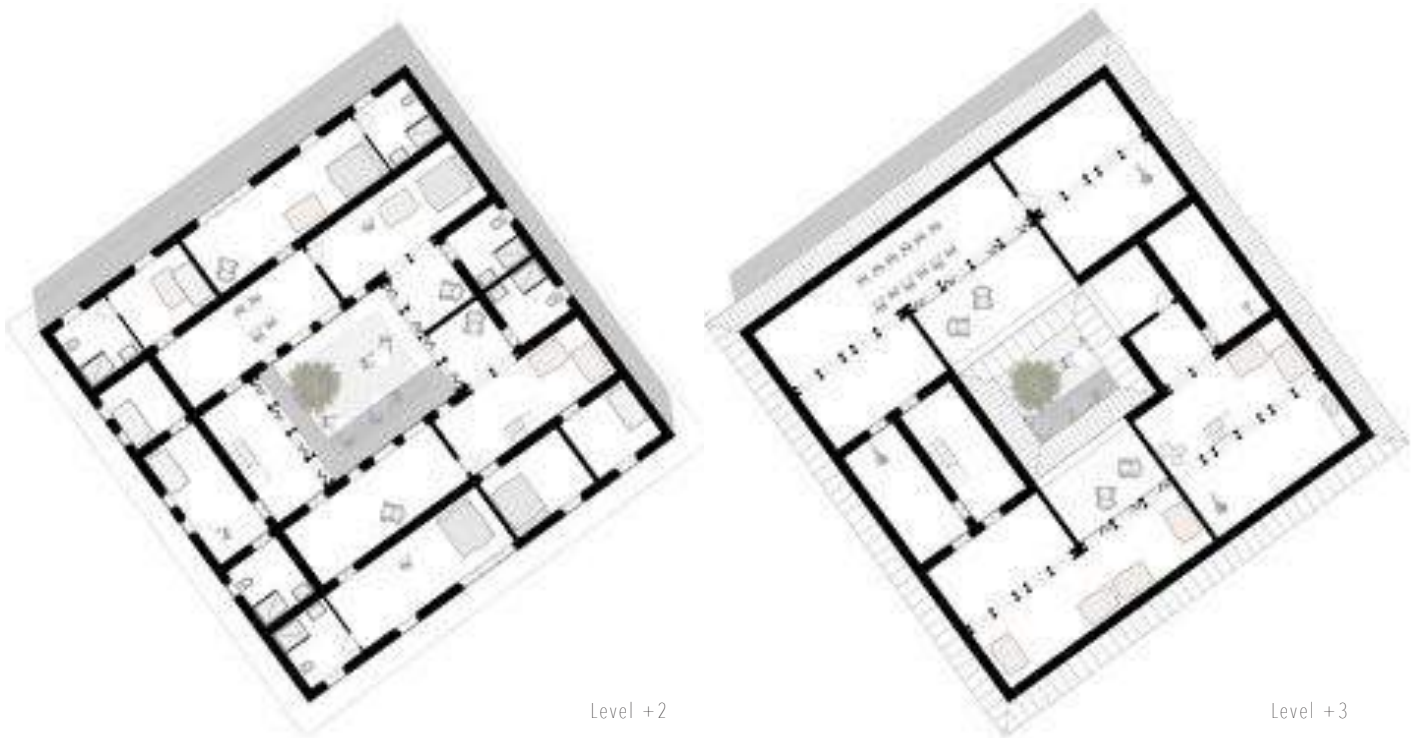
Level 0



Level +1

The most important architectural project within this masterplan, is the construction of a guesthouse. As stated before, within the urban tissue of Khokana there are no accommodation possibilities. However, travellers do visit Khokana. In addition, a lot of post-disaster research groups are conducting fieldwork in Khokana because of its unique value. These groups, of which we were one, generally stay for a longer period of time. The aim of these researches is to analyse the various elements of Khokana and provide some sort of solution in order to help the settlement. If these numerous groups, in addition with travellers, would be able to stay inside of the village, the overall economy would certainly benefit from it. Therefore, a proposal is made to build a relatively large guesthouse. The guesthouse includes a variety of different rooms, going from single rooms to triple rooms.

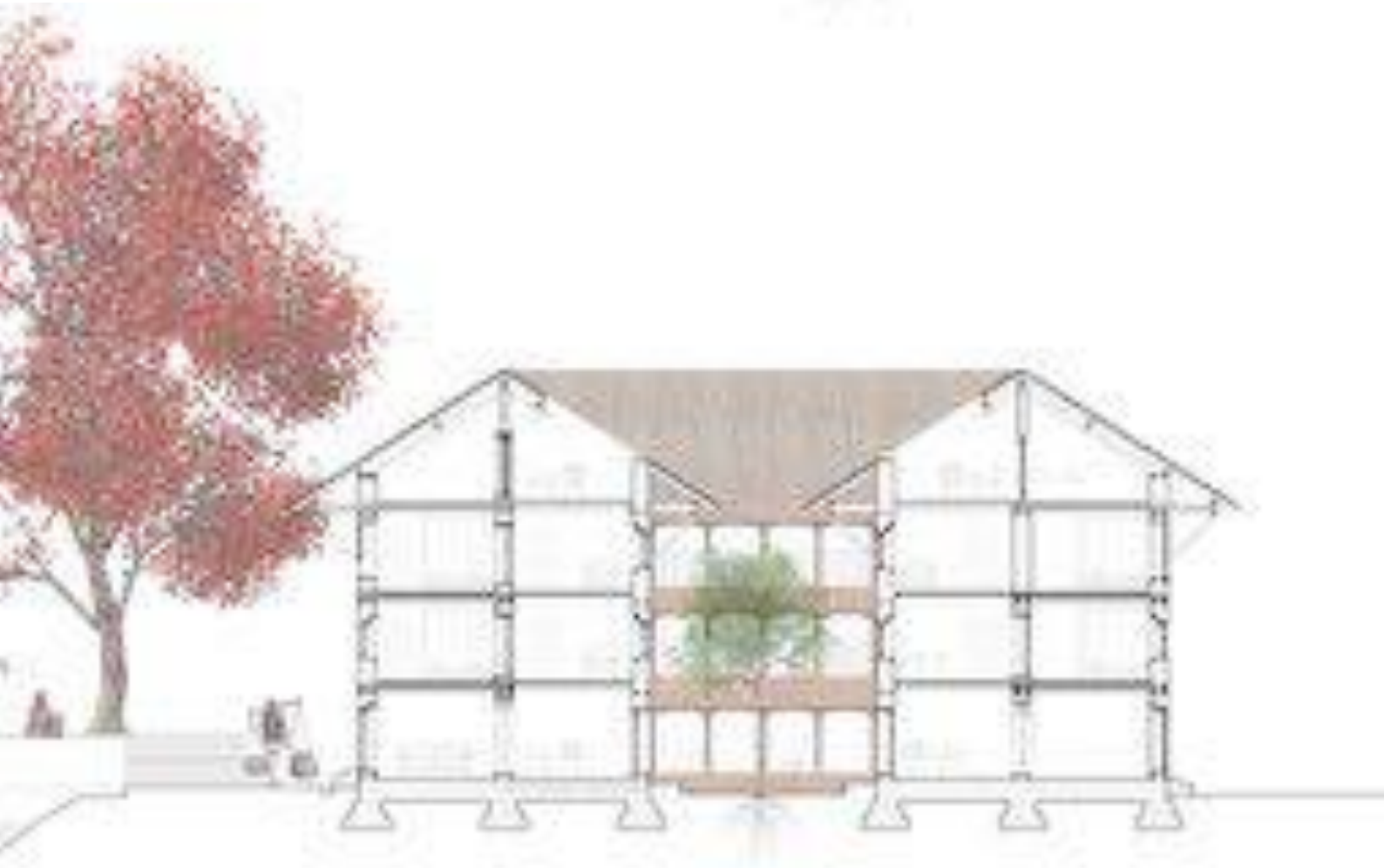
This guesthouse is shaped as a more introvert building, focussing on its private inner courtyard. On the ground floor, a working or informal conference room is provided, taking into consideration these various research groups. If these groups would stay within the same building, the separately obtained information could be exchanged, leading to an improvement of the post-disaster management.



Level +2

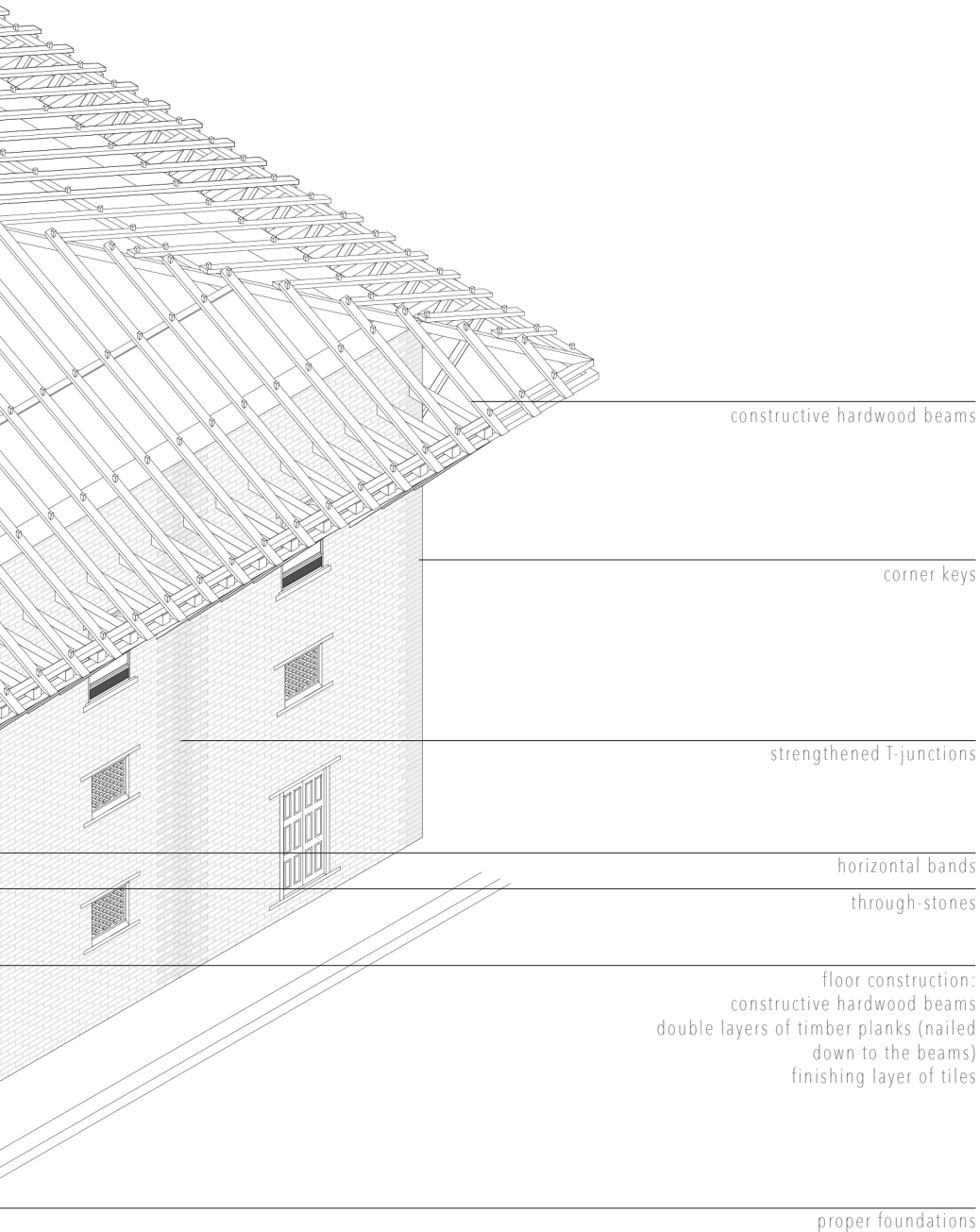
Level +3







inner courtyard



Timeline

1 month

cleaning pond

The ponds located at the buspark play an important role in this reconstruction design. The water is currently badly contaminated and in order to restore the traditional water system (chapter: “Bungamati: Rethinking water cycles”) the pond should be thoroughly cleaned. Since the pond is filled with enormous amounts of mud, an excavator should be used. Since this requires a lot of space, these actions should be conducted first.



phase 2 - guesthouse

The next step is the building of a guesthouse, which will collect various outsiders which can contribute to the further (re)construction of the Newari settlement. In addition, housing units are provided.



reserve

Two months of extra time are included in order to anticipate on possible delay.

preparation

When the rain season is over, the first step is to make the plot ready-to-build.

phase 1

The next step in the building process is finishing the building block at the buspark in order to complement the more spread out buildings located at the edges of the village



phase 3

The resulting housing units are constructed.

maintenance

Maintenance of the various buildings is an important factor in the durability and the preservation of the architecture. Approximately every two months, the houses and public structures should be managed.



Interior view of the guesthouse

General timeline of the design proposal



PRE-PHASE

funding strategies
community meetings
workshop building guidelines
general preparations

PROJECT PHASE

nov. 2017 - start of dry season

jan. 2018

july 2018



site 1 - reconstruction



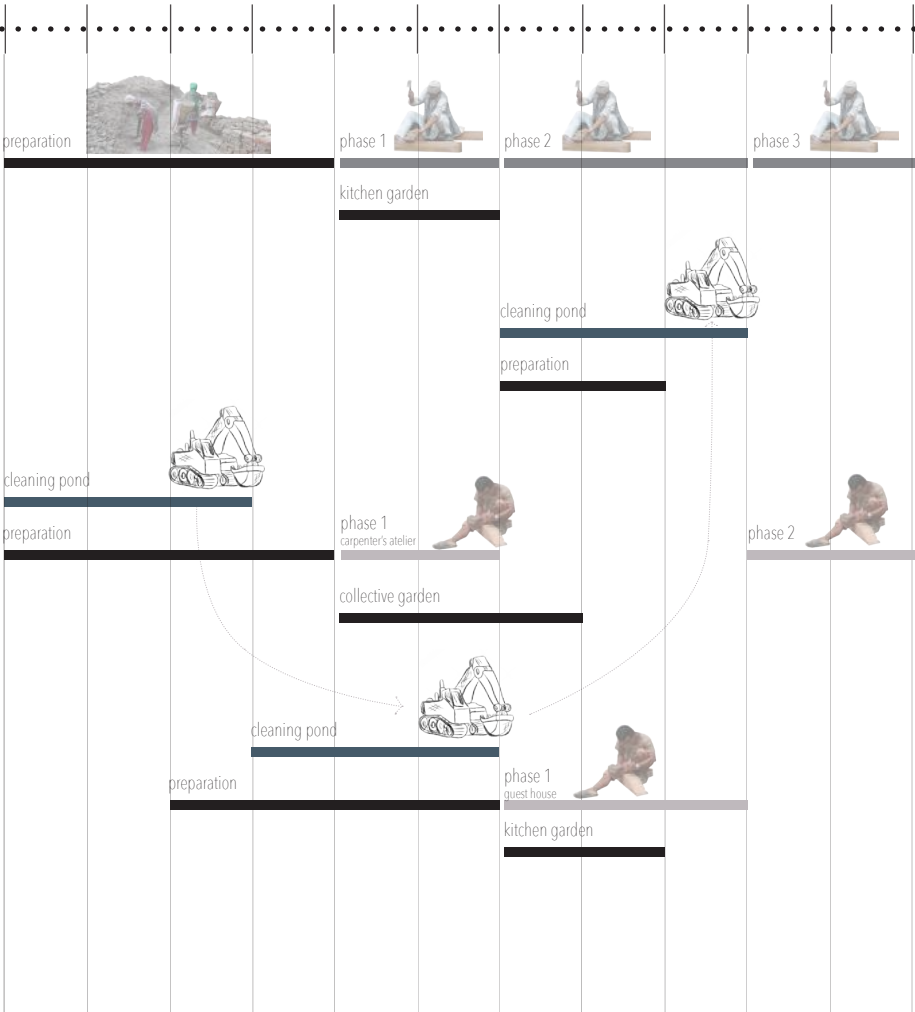
site 2 - reconstruction

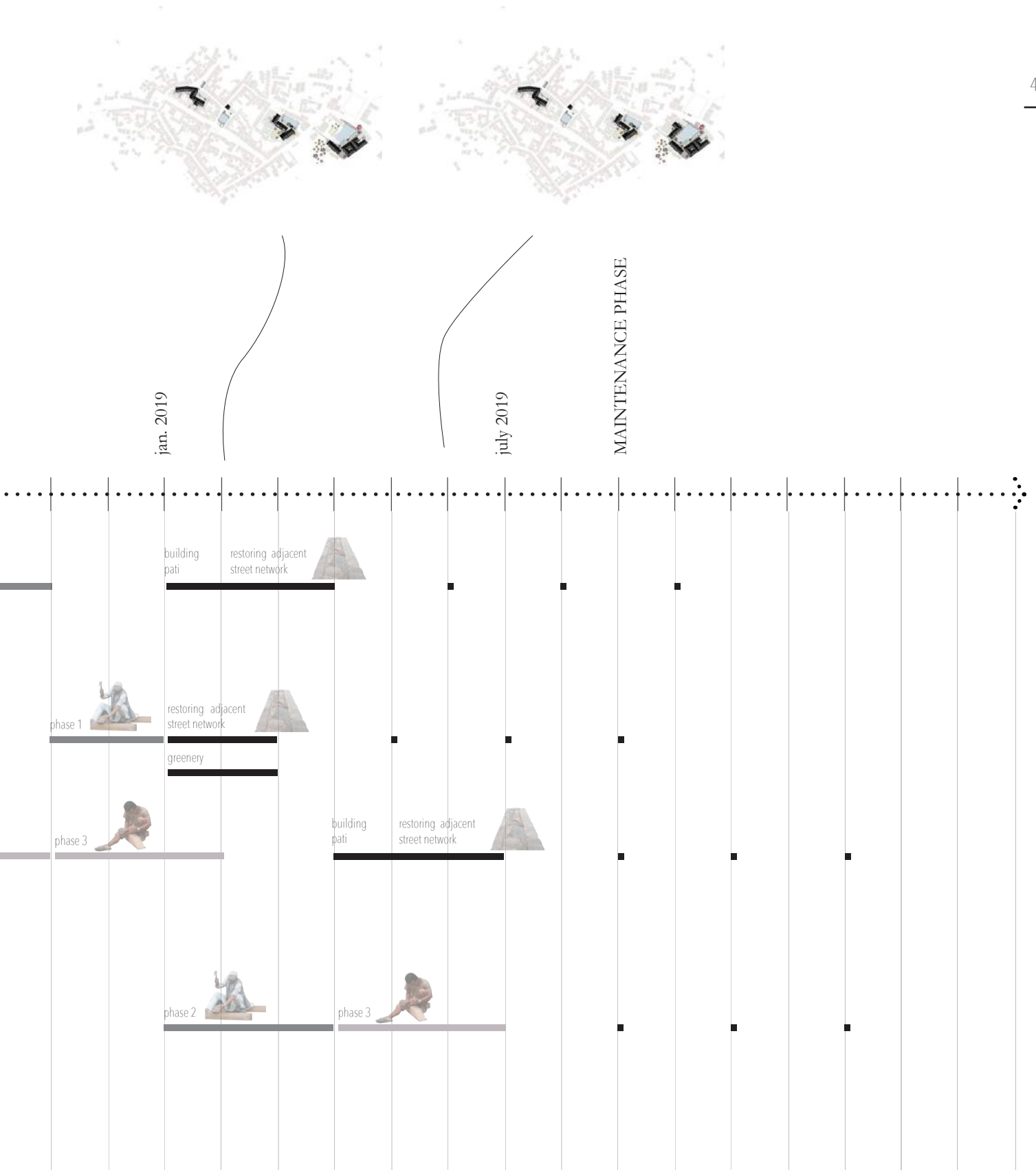


site 3 - densification



site 4 - expansion





Newari vocabulary

<i>Babil</i>	Closed courtyard.
<i>Baigab</i>	The attic of a Newari house, containing the kitchen and storage space.
<i>Byancha Janake</i>	A festival dedicated to worshipping the frogs.
<i>Caste</i>	Hindu hierarchic principle based on someone's ancestry.
<i>Chaitya</i>	A Buddhist shrine, sometimes containing a relic or important manuscript.
<i>Chedi</i>	The ground floor of a Newari house, mostly used as a storage room or workshop.
<i>Chhwase</i>	An area where ghosts reside, forming the intangible boundary of a neighbourhood.
<i>Cvata</i>	Living room, situated on the second floor of a traditional Newari house.
<i>Dabari</i>	Square platform used to perform religious dances.
<i>Dashain</i>	One of the biggest festivals in Nepal, celebrating the ending of monsoon and the beginning of the harvest. It lasts for two weeks in October.
<i>Deity</i>	A god or goddess.
<i>Ghanta karna</i>	A festival that takes place in August. During this festival evil spirits are chased away by performing certain rituals.
<i>Guthi</i>	An inter-caste group of people forming a community.
<i>Hiti</i>	A stone spout, one of the traditional waterbodies.
<i>Indra jatra</i>	A festival celebrated in September prior to which guthi houses and public rest houses are cleaned.
<i>Jatra</i>	Nepali word for festival.
<i>Kumari</i>	A living goddess, representing the destroyer of the male demons.
<i>Kuva</i>	A dug well.

<i>Machbindranath</i>	The Newari god of rain.
<i>Mandala</i>	A circular pattern, often used in a spiritual context.
<i>Mata</i>	Bedroom, located on the first floor of a Newari house.
<i>Nag Panchami</i>	Typical festival celebrating the serpents.
<i>Nani</i>	Open courtyard.
<i>Pati</i>	A public rest house for travellers and passers-by.
<i>Peti</i>	An elevated transition zone between private houses and public spaces.
<i>Pepal tree</i>	A holy tree, providing shadow.
<i>Pukhu</i>	A pond, one of the traditional waterbodies.
<i>Rajkulo</i>	Royal canal that leads water from the rivers to the cities.
<i>Ropani</i>	Nepalese unit of area that equals 508 m ² .
<i>Rudrayanee</i>	Goddess worshipped in the main temple of Khokana.
<i>Sikali</i>	Typical festival celebrated in Khokana, short for Siddhikali.
<i>Sitbinakha</i>	An important day for maintenance of Newari architecture.
<i>Stupa</i>	Buddhist monument, characterised by a domed structure.
<i>Tihar</i>	The festival of light, celebrated in November.
<i>Tole</i>	A neighbourhood.
<i>Vaastu-vidya</i>	Hindu principle clarifying the link between the earth and the universe, “the science of dwelling”.

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445

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