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Pulchowk Lalitpur

Thesis Report

B.Arch. V/II

Geothermal Spring Center

- At Chame, Manang

Submitted By:
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Submitted in partial fulfillment of the requirement for the degree of Bachelor of Architecture in the Department of Architecture.

Department of Architecture
Pulchowk, Lalitpur, Nepal

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Declaration

I hereby declare that the thesis entitled “Geothermal Spring Center” submitted to Department of Architecture in partial fulfilment of the requirements for the degree of Bachelor in Architecture, is a record of original work done under the guidance of Thesis Supervisor- Prof. Dr. Sushil B Bajracharya. This thesis contains only the work complete by me except for the consulted material which has been duly referenced and acknowledged.

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Aanchal Sunuwar

074/BAE/201

April, 2023

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My sincere gratitude to my thesis committee for giving me chance to challenge my research from various perspectives with their insightful comments, critique, workshops and words of encouragement.

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Abstract

Architecture is all about creative spaces and functions with optimum use of resources around the site without exploiting the source. In today's world of "Energy Crisis" where nonrenewable source of energy is running out and will not be replenished for millions of years, the eco-friendly architecture utilizing renewable source of energy is the ideal way that we all should strive for. Geothermal energy is one of the renewable sources of energy that is the heat within the earth and geothermal spring is a natural hot spring that is heated by the geothermal gradient beneath the earth that ultimately rises to the surface through fissures and fractures of the rocks. Humans have always used geothermal spring as long as we can trace back the history because of its health benefits (thermalism, balneology and hydrotherapy) which has been proved by present day medical science. As the time has changed, people not only use hot water for health purpose but also for relaxation and as a means of creating bonding experience with other people. This has boosted local as well as international tourism in the place with natural hot water spring. Hence, soaking in hot water has become a public activity and the place where there are human activities; it demands architectural functions as per the activities. This report revolves around studying and designing various functions, anthropometry and comfortable spatial services for such activity with creative touch. I believe that there is a need of research and work to be done in the field of geothermal spring architecturally because it is often neglected in case of Nepal despite being of much importance in global architecture. Geothermal Spring Facility has never been on "Architectural Limelight" of Nepal but it is high time that we give our attention to such project.

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Chapter 1. Introduction

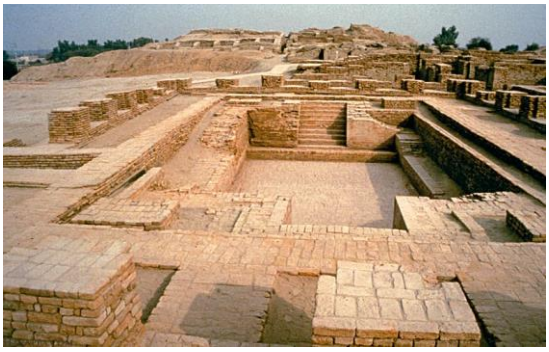
1.1 Background

Public bathhouse originated when people didn't have access to private bathing facility but in today's context, public bathhouse is received as a way of recreation, relaxation and vacation spot. Public bathhouses are used not only for bathing purpose but also for socialization. Nowadays bathhouse provides saunas, massages, other relaxation therapies as well as accommodation service. There is provision of both cold water as well as hot water service in bathhouse. Energy efficient bathhouse is located in area with geothermal spring.

Geothermal spring (hot spring) is a renewable natural source of hot water that gets heated by the geothermal gradient beneath the earth and ultimately rises up to the earth's surface through the fissures or fractures of the rocks. Hot springs are mostly originated in the area of volcanoes (e. g. in Japan) and in the area of young tectonic belts (e. g. in Nepal). The idea of this research revolves around finding out complete spatial and design requirements of a "Public/private thermal bath" at a site with natural source of thermal spring. Such buildings have special requirements for ventilation, building services, air circulation, hygiene function, facility maintenance, anthropometry and architectural zoning. The vision for this research is to design a climate responsive and well-planned thermal facility by utilizing the renewable resource of energy i.e., Geothermal Energy. There is a need of research and work to be done in the field of geothermal spring architecturally because it is often overshadowed in present scenario despite being of much importance in global architecture.

1.2 Rational

Public bath has always been significant to human civilization since ancient times of which public bath built in the Indus Valley around 2500 BC in the lost city of Mohenjo-daro being one of the earliest known baths in whole world. Artistically well-developed Roman civilization also gave great importance to bath complexes (known as "Thermae" and "balneae") that existed in great number thought the city. They were some of the most common and most important public buildings in the empire as some of the first buildings built after the empire would conquer a new area. There is a square-shaped structure with steps all around to ascend to the water level in front of Maya devi temple in Lumbini. This structure is called Puskarini where Gautam Buddha's mother Mayadevi used to bathe. Lord Buddha's first bathing was also done in this pond. Hot spring in Japan has been existing for thousands of years and is still very relevant today. "Onsen" is a hot spring, or a resort that has developed around a hot spring. These socio-cultural and functional public baths inspire us for further research and its application so that the culture of public bath can go on.



(Kenoyer, n.d.)

Figure 1 Public bath of lost city of Mohenjo-daro

Figure 2 Roman Baths in ancient Rome

Source: ScopEmpire

Photo Source: Juan Jimenez / EyeEm / Getty Images

Figure 3 Puskarini, pond where Maya devi used to bath

Maya Devi Temple and Pond as pictured in Lumbini on Tuesday, October 23, 2018. Photo: Sandeep Sen

Figure 4 Japanese Onsen (hot spring) culture

Photo source: Dreamstime

1.3 Research Questions

What is the importance of public bath in society in past and present? How can we enhance the functionality, comfort and spatial experience of people visiting geothermal spring through architecture for optimum visitor satisfaction? What kind of functions and spaces we might need to establish a geothermal spring center?

1.4 Scope of Research

The research puts an impact to physical, social and economic development of the area to be designed and it will be helpful document for designing hot springs in the area of natural source of geothermal spring. Sustainability of the building can be ensured if we can utilize geothermal energy of the area. We can further explore the role of an Architect for utilizing renewable energy and its future possibilities in architecture. Economy of local area will be flourished as it can uplift the economy with more employment opportunities and side business around the hot spring area.

The chemicals and minerals composition found in geothermal springs are proved to be beneficial for health as it helps to cure arthritis, joint pain, gastric disorder, skin diseases such as scabies, soft-tissue rheumatism etc. Geothermal springs are often located near volcanic area as well as near mountainous region and riverside which makes it an attraction point for tourists. Hence, through proper management and planning of hot springs, tourism of local area can be boosted. As these springs are located in extraordinary geographical landscape, it automatically draws attention for environmental concerns as well. While designing a built environment around such area, we must be careful to not disturb the natural setup and the system of the source of hot spring. We must never go overboard with exploitation of the resources.

Chapter 2. Methodology

Research methodology is the path going through which, a researcher needs to conduct their research. It shows the path through which problem or objectives of research is formulated and result of the data obtained from during the study period. This study used primary and secondary sources with both qualitative and quantitative methodologies in order to achieve the main research objectives. The analysis and findings from the quantitative data are supported by the qualitative data. Since the researcher used both qualitative and quantitative data types in the data analysis, the outcome is triangulated. The methodology includes following in order:

2.1 Topic selection

The topic based on geothermal spring sparked my interest after I noticed the architectural problem of systematic spatial flow and management of the hot spring center during my visit to Singa tatopani, Myagdi. After further study, I found that this is a neglected problem that is prevalent in all geothermal springs of Nepal. Hence, the topic was selected.

2.2 Proposal

A proposal of designing a geothermal spring center was presented to our thesis committee.

2.3 Literature review

Since the start of thesis project, the literature review about thermal springs of Nepal and other countries along with the design requirements of bath-house from a credible source was conducted throughout the period.

2.4 Case study

Data collection for case studies and site

During the case study visit and site visit for the inventories and inspection, primary and secondary datas were collected.

2.4.1 Primary data

- Field visit to Pokhara, Myagdi and Sindhupalchowk for casestudy.
- 3-day field visit to Chame, Manang on september 10th to september 12th, 2022 A.D

2.4.2 Secondary data

Government publications, websites, books and journal articles

2.5 Site selection and analysis

Site selection was done after an analysis study of the problems and needs of the place.

2.6 Program formulation

First of all, the functions and spaces required for the project was listed with reference to the case studies. The site-specific needs for the functions were listed as well. Then the program was formed after comparisons of data available from the case studies and standard design data from literature review.

2.7 Design Concept

A concept was designed for the project in order to solve the problem of the project. Initial phase of design involved hand drawn sketches, bubble diagrams, flow charts, activity mapping etc.

2.8 Design Development

Design was further developed and reflected through maps, plans, elevations, sections, 3D exterior and interior drawings with the help of softwares like AutoCAD, SketchUp, Lumion and photoshop.

2.9 Final Drawings

The final drawings included architectural drawings, working drawings, electrical drawings, sanitary drawings which were prepared in fixed scale.

2.10 Modelmaking

For the better visualization of the design, block models as well as detail model was prepared in different scales.

2.11 Final Output

The final drawings and renders were arranged in sheets as per the topics. The thesis report and annex were finalized after the approval of thesis supervisor.

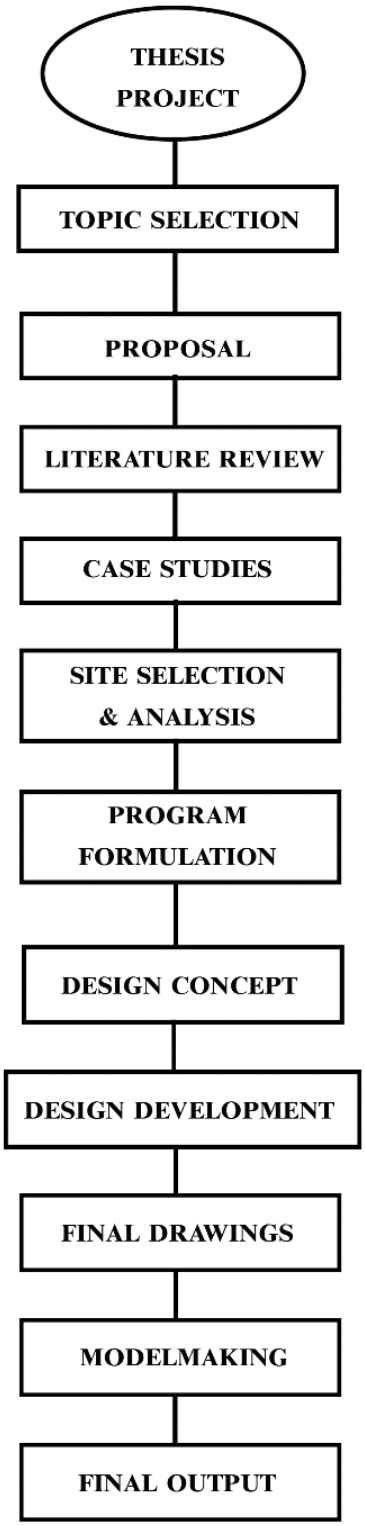


Figure 5 Flow chart of methodology

Chapter 3. Literature Review

3.1 Spring and its formation

Spring water is a water resource formed when the sides of excavated materials such as hills and valley bottoms intersect with groundwater flowing below the groundwater level, under which the groundwater is saturated with water. When it reaches a horizontal fissure or layer of insoluble rock, such as sandstone or shale, it begins to cut laterally, forming an underground stream. As it progresses, the water hollows out more rocks, eventually freeing up space where the spring stream can be considered a cave. This process is said to take tens of thousands to hundreds of thousands of years.

Thermal Spring

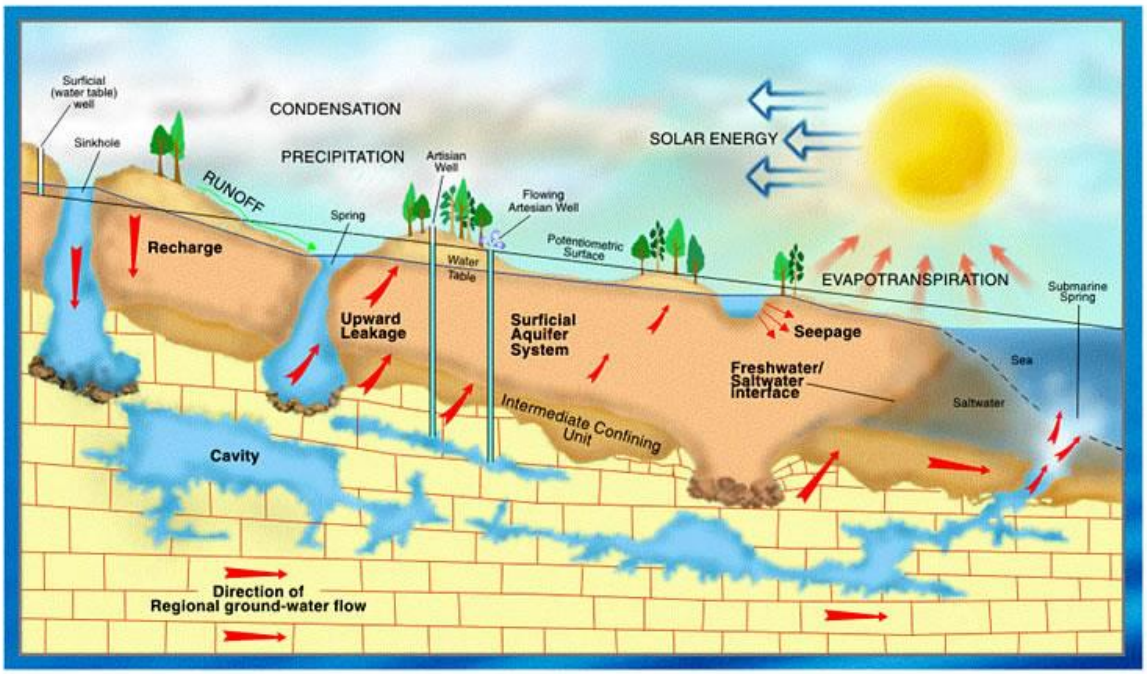


Figure 6 Thermal spring source. Source: Brittanica

Hot springs are ordinary springs, except that the water is warm and there are hot springs in some places. Many hot springs occur in areas of recent volcanic activity and are supplied by water heated by contact with hot springs far below the surface. Rocks get warmer with depth, even in places where there is no recent volcanic activity. In such areas, water slowly moves to considerable depths and warms as it descends rocks deep within the Earth. Then, when you reach a large crevasse that provides a less resistant path, it can rise faster than it descends. Water that does not have time to cool before it leaves forms a hot spring.

3.2 Formation of Thermal Springs

Geothermal energy is defined as heat from the earth. A clean and recyclable resource. Geothermal systems require heat, effusivity, and water. Heat from the Earth's core continuously flows outwards. The heat of magma can reach the surface as lava, but it usually

stays under the crust and heats nearby rocks and water. Sometimes it can reach 700 degrees Fahrenheit. When water is heated by geothermal energy, hot water or steam can be trapped in the permeable porous rock beneath the impermeable rock layer, forming a geothermal reservoir. This hot geothermal water can appear on the surface as hot springs or geysers, most of which remain deep underground and are trapped in cracks and porous rocks. This collection of natural hot water is called the geothermal reservoir. Geothermal hot springs (hot springs) are renewable natural hot springs that are heated by an underground geothermal gradient and eventually rise to the surface from rock crevices and crevices. Hot springs usually occur in volcanic areas (eg) G. Japan) and areas of the young tectonic zone (eg Nepal)

3.3 Types of Springs

- Seepage or filtration spring. The term seep refers to springs with small flow rates in which the source water has filtered through permeable earth.
- Fracture springs, discharge from faults, joints, or fissures in the earth, in which springs have followed a natural course of voids or weaknesses in the bedrock.
- Tubular springs, in which the water flows from underground caverns.
    - Spring discharge, or resurgence, is determined by the spring's recharge basin.
    - Factors that affect the recharge include the size of the area in which groundwater is captured, the amount of precipitation, the size of capture points, and the size of the spring outlet.
    - Water may leak into the underground system from many sources including permeable earth, sinkholes, and losing streams. In some cases entire creeks seemingly disappear as the water sinks into the ground via the stream bed.
    - Human activity may also affect a spring's discharge--withdrawal of groundwater reduces the water pressure in an aquifer, decreasing the volume of flow.

3.4 Water content

Minerals dissolve in water moves through the underground rock. This can add flavor and carbon dioxide bubbles to the water, depending on the geological nature of the water flow. A spring that contains a significant amount of minerals is sometimes referred to as a "mineral spa”. Spring containing a lot of dissolved sodium salts, mainly sodium carbonate, is called "soda spring". Many hot spring towns revolve around mineral springs and are known as health resorts. The water from the fountain is usually clear. However, some springs may be colored by minerals that are dissolved in water. Iron and tannins often give the spring an

orange color. A stream that carries a spring outflow to a nearby primary stream is called a spring branch or run. Groundwater tends to maintain the average temperature of the aquifer for a relatively long time. Therefore, the flow from the source will be cooler than on a summer day, but will not remain frozen in the winter. The cold water of the fountain and its branches can harbor species that are otherwise unsuitable for the climate of warm regions, such as certain advertisements.

3.5 Hot Springs: General Uses

There are levels at which Hot Springs water can utilized depending

upon the end user/users and its purpose-

- Primary level- local use/household
- Secondary level- private spas
- Tertiary level- energy generation

Various uses of Hot Spring Water are classified as follows-

Table 3:1 Fluid temperature and their economical uses table

Fluid Temperature	Category	Electrical Conversion Yield	Economical Uses
<100 DC	Low enthalpy	<2%	Space heating, domestic hot water, agricultural and food industries
100-200°C	Medium enthalpy	2·10 %	Chemical Industry, fresh water by distillation, evaporation in sugar refining, drying farm products, canning of food
>200 °C	High enthalpy	10-20 %	Drying of timber, heavy water via hydrogen sulphide process, refrigeration by ammonia absorption, electricity production (binary cycle)

Uses of hotspring water

1. **Daily water usage**-People supply water by ladling with a dipper, turning on a faucet or drawing from a well to wash clothes &dishes, clean up and/or for Yutanpo (a hot-water bottle).
2. **Public baths**- It is not only for tourists but also for citizens to get relaxed and communicate with each other.
3. **Gardening** - Cyclamen and Orchid flowers are cultivated in a house heated by thermal steam; many of them are shipped to the metropolitan area.
4. **Cooking food Jigokugma** ; It is the way of cooking by making use of thermal steam. Fresh food, such as eggs, vegetables and rice are steamed instantly in the hot vapour retaining nutrients; they slightly smell ofhot spring
5. **Heating**-It looks like an electric heater, but is a hot spring heater which makes the room as warm as spring without polluting the air. Also, the floor heated by thermal steam is nice & warm to make you feel comfortable.
6. **Geothermal energy** - large amount of electrical energy is derived
   by the steam generated from hot springs.
7. **Fish breeding**-The fry of carps are raised in thermal water under a strict temperature control. The hot water is used to raise fish and alligator.
8. **Spas-mineral-rich baths** offer a slew of natural health benefits.
9. **Therapeutic treatments**-The therapeutic use of water, or balneotherapy, could be just what the doctor ordered when it comes to relieving pain, stress, skin woes and more.
10. **Vegetation for animals** - Animals from cold countries feed on the lush green vegetation growndue to the hotspring water.

3.6 Impacts of Thermal Springs

3.6.1 Social Impact

Society comprises of people living together harmoniously despite differences in culture, religion, economic class, gender, political interests, philosophies etc. Just like mortar binds the building blocks in a building, peaceful communication is what binds people with differences in a society. Hot spring is such a space which relaxes people and create a comfortable ambience for communication. This is not just a theory but an actual practice which has been existing since ancient time. Community bathing always inspire communication. Hot spring is enjoyed by sitting still in a pool for a long time. This is a great opportunity to communicate and strengthen the bond with someone we are there with and

also it offers the opportunity to meet new people and make connections which can be beneficial in future.

3.6.2 Spiritual Impact

Hot spring is located in a nature preserved location. Soaking in a hot water and staying still for a long time helps a person to detox their mind, body and soul. The ambience inspires the person to contemplate their life decisions so far and desire how they want to move forward. In today's world of advanced globalization and technology, we have forgotten to isolate ourselves inside our own thoughts. We have forgotten to look within us for what we want rather than look outside. We search happiness and validation from another person which can never be achieved as that person in itself is a complex being with their own problems and thoughts. We have forgotten the simple way of life. Hot spring at least creates an ambience for people to connect with themselves.

3.6.3 Mental Health Impact

Hydrotherapy is worldwide known for a way of mitigating mental health problems like depression, anxiety, ADHD, stress etc. Studies have shown that hydrotherapy increases the release of endorphins in the body. It helps people to relieve feelings of stress and anxiety. Nowadays, we can see every person suffer from stress and anxiety in one form or another to certain extent. High competition, low success rate, daily rat race, overuse of technology such as social medias, nonstop gaming for hours, isolation of living alone or not connecting with friends and family etc. are the common traits of large number of people these days. Hot spring offers an escape from all these and buy some time for rejuvenation. A whole new experience can change people's mind in drastic way.

3.6.4 Architectural Impact

Hot spring is a space which plays with two elements i.e., nature (water) and human spaces. From architectural perspective we can be creative playing with these two elements. As the project is site specific, every project of hot spring comes with new challenges and new stories of the place. The climate, culture, stories, myths, beliefs, people, way of life, building materials, topography of the land etc. can all be different. Hence, it is like creating an art in new canvas every time. It demands the attention of multiple fields such as hydrology, water engineering, geology, architecture etc.

3.6.5 Development Impact

Hot springs are generally located in difficult terrain in rural area with difficulties in infrastructures. Hot spring is an attractive vacation destination for tourists who seek

momentary escape from daily routine. If hot springs are well managed enough for touristic visits, then it opens a gate for bigger opportunity for example- hotel and lodge services, street vendors, shops, restaurants, local cultural shows, road constructions etc. creating job opportunities in mass. Like a butterfly effect, it impacts development of rural area.

3.6.6 Environmental Impact

As far as destruction and loss of natural resources, there are several examples worldwide. It either happens by natural cause such as flood, earthquake, soil erosion, landslide or due to human carelessness such as dumping toxic materials into the water source, deforestation, decreasing soil quality and its bearing capacity with pollution and deforestation. Hot spring is a renewable source of energy but if not conserved and protected, the source can be lost or buried with land mass. Awareness on importance of hot spring can motivate local people to be an environmentalist and use the resources in a responsive manner. This alone can create big impact as it inspires afforestation, embankment construction, no pollution, no mixing toxic substances and drainage in the river source.

3.7 Scenario of Nepal

3.8 Hot Springs Origin in Himalaya

The 2400 km long Himalayan range, including the Mt. Everest, the highest mountain of the world, is formed by the continent - continent collision between the Indian and southern edge of the Eurasian (Asian) plates. Even after the evolution of the Himalayan range, the Indian continent maintained its subduction activity below the Eurasian continent and today, the Indian plate is still moving northward bulldozing through the Asian plate resulting the convergence, deformation and uplift processes with an average convergence rate of 5 cm/year. (Molnar, 1975)

3.9 Hot Spring Locations in Nepal

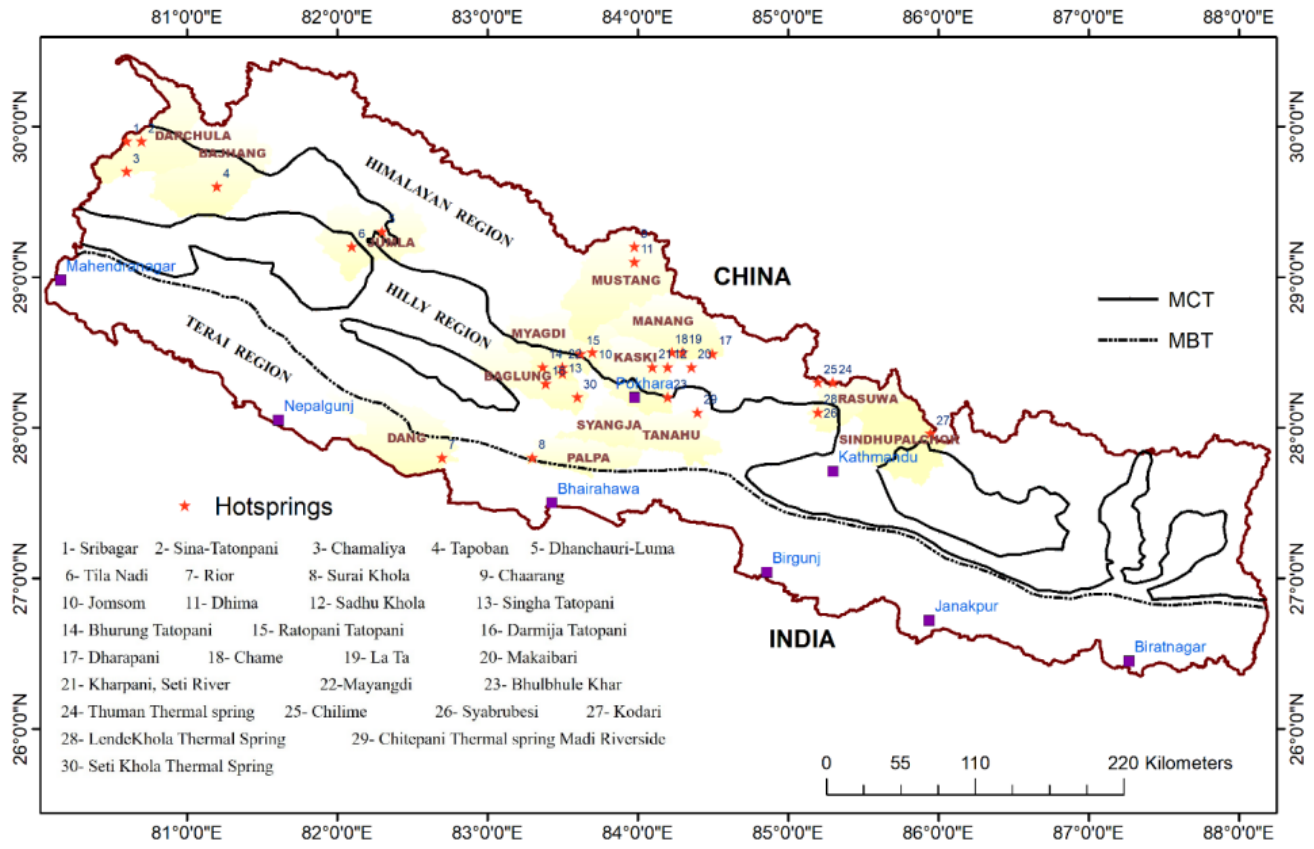
About 32 geothermal springs have been identified in Nepal among which 23 of them have been officially recognized by the Nepal Government.

Geological circumstances suggest that there could be many hot springs in Nepal. However, due to poor accessibility to the potential locations they are yet to be investigated in detail. They may be located at the difficult terrains or there may not be any settlements around to provide information on it. Some of the well-known hot springs are located around the accessible area connected by the motor-able roads or trekking routes: Syabrubesi (Rasuwa); Kharpani (Seti River); Jhinu (Modi Khola); Marsyangdi River (just below the headquarter of Manang district); Tatopani village (bank of the Kaligandaki River Valley); Khalanga Bazaar (bank of Tila Nadi Mayana near Bauli Gad and Jeoli Gad); Tapoban (Bajhang); Valley of the Ritha God River (Darchula); bank of Burhi Gandaki River (Manaslu Base Camp route), Bhurung (Myagdi) along Annapurna circuit; Singha Tatopani along Myagdi Khola; Kodari, Tatopani Bazzar (near Nepal - China boarder, Sindhupalchowk district).It can be said that in the Nepal Himalaya the meteoric water or surface water seeps beneath the ground through the discontinuities existed in the rocks exposed in the region. The water then reaches at greater depth around the MCT or the RT and gets heated due to high temperature in the crust and rises up to the surface along these fractures/thrust faults in the form of hot spring. The same phenomenon can be attributed to the springs in the Siwalik Hills situated to the south of the MBT. (Santa Man Rai, 2020)

Table 3:2 Chemical composition of hot spring localities in Nepal (in mg/l)

S.N	Location	pH	Na	K	Mg	Ca	Cl	SO_4	HCO_3	SiO_2	B	TDS
1	Bhurung Tatopani	7	370	95	27	108	583	207	370	71	14.1	1650
2	Jomsom	8	60	5.6	54	113	96	249	302	14.3	2.4	850
3	Tila Nadi	7.3	56	0	1.2	6	45	130	0	60	0	253
4	Dhanchauri Luma	7	49	1.3	0.2	6.1	82	104	217	56	0	803
5	Mayangdi	8	460	49	17	2	351	68	430	43	0.3	1340
6	Rior	9	310	4	3	4	14	70	7.9	37.5	6	788
7	Surai Khola	9	123	3.9	28	18	3.2	70	370	38.5	0.1	510
8	Sribagar	7	100	11	5.5	NA	34.2	18.5	NA	35	0	516
9	Chamaliya	7	NA	NA	NA	NA	39.6	10.7	NA	10	NA	1320
10	Tapoban Bajhang	5	NA	22	10	NA	50.1	25.9	NA	16	0	444
11	Sadhu Khola	7	300	12	0.6	10	268	197	78	60	0	954
12	Chilime	7	7.35	8.1	20.8	25.8	10	6	180	47.1	0	166
13	Singha Tatopani	7.2	64	1.5	1.8	6.8	51	140	10	68	0	353
14	Syabrubesi 1	8	73	44	84	38	66	94	848	59.7	NA	620
15	Syabrubesi 2	7.5	7.2	12.5	90.5	75.9	12	121.4	760	35.3	NA	1300
16	Kodari	7.3	147	29.7	20.5	53.5	31.5	85.6	412.5	44.3	1.36	NA

(Ranjit, Geochemical studies in some thermal springs of Nepal. The United Nation University. , 1994)



(Ranjit, Geothermal Energy Update of Nepal., 2005)

S.No.	Locality	Longitude (E)	Latitude (N)	Flow rate (lit./s)	Water temperature at surface (^{0}C)
1	Sribagar, Darchula	80.60^0	29.90^0	0.90	73
2	Sina-Tatonpani, Darchula	80.70^0	29.90^0	0.80	30
3	Chamaliya, Darchula	80.60^0	29.70^0	0.30	30
4	Tapoban, Bajhang	81.20^0	29.60^0	0.3	31
5	Dhanchauri-Luma, Jumla	82.30^0	29.30^0	0.8	24
6	Tila Nadi, Jumla	82.70^0	27.90^0	3	42
7	Rior, Dang	82.70^0	27.80^0	1.5	33
8	Surai Khola, Kapilvastu	83.70^0	27.80^0	1.7	37
9	Chaarang, Mustang	83.98^0	29.20^0	0.2	33
10	Jomsom, Mustang	83.70^0	28.50^0	0.07	72
11	Dhima, Mustang	83.98^0	29.10^0	1.5	NA
12	Chookumau, Mustang	83.70^0	29.80^0	0.2-0.5	21
13	Sadhu Khola, Mustang	84.20^0	28.40^0	1.39	69
14	Singha Tatopani, Myagdi	83.30^0	28.20^0	6	54
15	Bhurung Tatopani, Myagdi	83.70^0	28.40^0	1.8	72
16	Ratopani Tatopani, Myagdi	83.80^0	28.90^0	1.5	54
17	Darmija Tatopani, Myagdi	84.08^0	29.25^0	1.0	40
18	Gurja, Myagdi	NA	NA	NA	NA
19	Tareja, Myagdi	NA	NA	NA	NA
20	Dharapani, Manang	84.35^0	28.50^0	0.16	33
21	Chame, Manang	84.23 ^{0}	28.50^0	1.0	55
22	La Ta, Manang	84.30^0	28.50^0	NA	NA
23	Makaibari, Manang	84.36 ^{0}	28.40^0	NA	NA
24	Kharpani, Seti River	84.10^0	28.40^0	0.4	48
25	Mayangdi	83.50^0	28.20^0	2	40
26	Bhulbhule Khar, Tanahu	84.20^0	28.20^0	1.05	34
27	Thuman thermal spring	85.30^0	28.30^0	0.83	48
28	Chilime, Rasuwa	85.20^0	28.10^0	0.4	34
29	Syabrubesi, Rusuwa	85.20^0	28.10^0	0.3	34
30	Kodari, Sindhupalchok	83.90 ^{0}	27.90^0	5.5	42
31	MachaKhola, Gorkha	NA	NA	NA	NA
32	Hotiyana, Sankhuwasabha	NA	NA	NA	NA
33	Lendekhola thermal spring	85.20^0	28.10^0	NA	NA
34	Chitepani thermal spring, Madi Riverside	84.40^0	28.10^0	NA	NA
35	Seti Khola thermal spring	83.60^0	28.20^0	0.2	44

(Ranjit, Geochemical studies in some thermal springs of Nepal. The United Nation University. , 1994)

Table 3:3 Chemical composition of some hot spring localities in Nepal (in mg/l)

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5	Mayangdi	8	460	49	17	2	351	68	430	43	0.3	1340
6	Rior	9	310	4	3	4	14	70	7.9	37.5	6	788
7	Surai Khola	9	123	3.9	28	18	3.2	70	370	38.5	0.1	510
8	Sribagar	7	100	11	5.5	NA	34.2	18.5	NA	35	0	516
9	Chamaliya	7	NA	NA	NA	NA	39.6	10.7	NA	10	NA	1320
10	Tapoban Bajhang	5	NA	22	10	NA	50.1	25.9	NA	16	0	444
11	Sadhu Khola	7	300	12	0.6	10	268	197	78	60	0	954
12	Chilime	7	7.35	8.1	20.8	25.8	10	6	180	47.1	0	166
13	Singha Tatopani	7.2	64	1.5	1.8	6.8	51	140	10	68	0	353
14	Syabrubesi 1	8	73	44	84	38	66	94	848	59.7	NA	620
15	Syabrubesi 2	7.5	7.2	12.5	90.5	75.9	12	121.4	760	35.3	NA	1300
16	Kodari	7.3	147	29.7	20.5	53.5	31.5	85.6	412.5	44.3	1.36	NA

(Ranjit, Geothermal Energy Update of Nepal., 2005)

3.10 Tourism in Nepal

TABLE 4.1: TOURIST ARRIVALS BY PURPOSE OF VISIT, 1993-2020 (CONTD.)

Year	Holiday Pleasure	Trekking & Mountaineering	Business	Pilgrimage	Official	Conv./ Conf.	Others	Not Specified	Total
2006	145,802	66,931	21,066	59,298	18,063	0	72,766	-	383,926
	(27.7)	(12.7)	(4.0)	(11.3)	(3.4)	(0.0)	(13.8)		100.0
2007	217,815	101,320	24,487	52,594	21,670	8,019	78,644	22,156	526,705
	(41.4)	(19.2)	(4.6)	(10.0)	(4.1)	(1.5)	(14.9)	(4.2)	100.0
2008	148,180	104,822	23,039	45,091	43,044	6,938	99,634	29,529	500,277
	(29.6)	(21.0)	(4.6)	(9.0)	(8.6)	(1.4)	(19.9)	(5.9)	100.
2009	140,992	132,929	22,758	51,542	24,518	9,985	87,134	40,098	509,956
	(27.6)	(26.1)	(4.5)	(10.1)	(4.8)	(2.0)	(17.1)	(7.9)	100.0
2010	263,938	70,218	21,377	101,335	26,374	9,627	52,347	57,651	602,867
	(43.8)	(11.6)	(3.5)	(16.8)	(4.4)	(1.6)	(8.7)	(9.6)	100.0
2011	425,721	86,260	17,859	63,783	24,054	10,836	37,311	70,391	736,215
	(57.8)	(11.7)	(2.4)	(8.7)	(3.3)	(1.5)	(5.1)	(9.6)	100.0
2012	379,627	105,015	24,785	109,854	30,460	13,646	48,540	91,165	803,092
	(47.3)	(13.1)	(3.1)	(13.7)	(3.8)	(1.7)	(6.0)	(11.4)	100.
2013	437,891	97,309	30,309	40,678	39,881	15,952	62,214	73,381	797,616
	(54.9)	(12.2)	(3.8)	(5.1)	(5.0)	(2.0)	(7.8)	(9.2)	100.0
2014	395,849	97,185	24,494	98,765	32,395	13,432	53,728	74,271	790,118
	(50.1)	(12.3)	(3.1)	(12.5)	(4.1)	(1.7)	(6.8)	(9.4)	100.0
2015	3,86,065	9,162	20,876	14,996	21,479	9,038	77354		538,970
	(71.63)	(1.70)	(3.87)	(2.78)	(3.99)	(1.68)	14.35))		100.0
2016	489,451	66,490	24,322	82,830	21,310	12,801	55,797		753,002
	(65.0)	(8.83)	(3.23	(11.0)	(2.83)	(1.7)	(7.41)		100
2017	658,153	75,217	na	141,033	na	na	65,815		940,218
	(70.0)	(8.0)		(15.0)			(7.0)		100
2018	703,843	187,692	na	169,180	na	na	112,357		1,173,072
	(60.0)	(16.0)		(14.4)			(9.6)		100
2019	778173	197786	na	171937	na	na	49301		1,197,191
	(65.0)	(16.52)		(14.36)			(4.12)		100
2020	139202	28530		35893			26460		230,085
	(60.5)	(12.4)		(15.6)			(11.5)		100

Note: estimated figure.

(Ministry of Culture, 2021)

3.11 World Scenario: Thermae of Roman Baths

3.11.1 Hypocaust

The hypocaust is a building's central heating system that creates and circulates hot air under the floor of a room, and can also heat walls with a series of tubes through which hot air passes. This air can also heat the upper floors. The word is derived from the ancient Greek word hypo, meaning "below" and caust means "burnt" (as in the case of corrosive). The

Hypocaust was used to heat ancient Roman baths and other public buildings. It was also used in private houses. It was a must-see for the wealthier merchant-class villas of the entire Roman Empire.

The hypocaust ceiling was lifted above the floor by a layer of tiles, then a layer of concrete, and a pillar called a pyrae pile that supported the floor tiles in the upper room. Hot air and smoke from the furnace circulate in this closed area and then up through the mud or brick vents in the walls of the upper room to the exit of the roof, thereby the floor and walls of the upper room. To heat. The vents in these bricks were called calidacts.

The room intended to be the warmest was located closest to the lower furnace, and its heat output was adjusted by adjusting the amount of wood supplied to the fire. Running the hypocaust was costly and labor intensive and required constant attention to fire and large amounts of fuel, so it was usually found only in large villas and public baths.

Vitruvian describes their construction and operation in his work Dearchitecture, circa 15 BC. includes details on how to save fuel by building a men's hot room (caldarium) next to women's next to tepidarium to operate public baths efficiently. He also describes a device for regulating heat with a bronze fan on the vaulted ceiling.

3.11.2 Building Layout

3.11.3 Palaestra

A public area in ancient Greece and Rome dedicated to the teaching and practice of wrestling and other sports. This palaestra was the exercise ground for the young men, or perhaps served as a promenade for visitors to the baths.

3.11.4 Apodyterium

A room for undressing in which all visitors must have met before entering the baths proper. Here, the bathers removed their clothing, which was taken in charge by slaves known as

capsarii. A spacious chamber, with stone seats along three sides of the wall. Holes are still visible on the walls, and probably mark the places where the pegs for the bathers' clothes were set. The chamber was lighted by a glass window, and had six doors.

3.11.5 Tepidarium

Warm Room

It was the warm bathroom of the Roman baths heated by a hypocaust or underfloor heating system. The speciality of a tepidarium is the pleasant feeling of constant radiant heat which directly affects the human body from the walls and floor. The tepidarium is generally the most highly ornamented room in baths.

3.11.6 Caldarium

Hot Room

This was a very hot and steamy room heated by a hypocaust, an underfloor heating system using tunnels with hot air, heated by a furnace tended by slaves. This was the hottest room in the regular sequence of bathing rooms. Temperature could not be higher than 50–55 °C (122–131 °F).

3.11.7 Laconicum

Dry hot room (like modern sauna)

It was a chamber still hotter than the caldarium, and used simply as a sweating-room, having no bath. It was said to have been introduced at Rome by Agrippa. It is a hot, dry area for inducing sweating. It was provided at one end of the caldarium, but as a rule it was a separate room raised to a higher temperature and had no bath in it. In addition to the hypocaust under the floor, the wall was lined with ceramic flue pipes

3.11.8 Sudatorium

Moist Steam Bath

3.11.9 Frigidarium

Cold Room

It is a large cold pool at the Roman baths. After the caldarium and the tepidarium, which used hot water to open the pores of the skin, the frigidarium would be reached. The cold water would close the pores opened by the hot water. There would be a small pool of cold water or sometimes a large swimming pool

3.12 Modern Bathhouse Requirements

3.13 General

The dressing, shower, and restroom facilities that must be available next to all swimming pools are referred to as "bathhouses." When sufficient facilities are easily accessible, as established by the regulatory body, partial or complete omission of the poolside shower and restroom facilities may be permitted.

3.14 Technical Design Criteria

3.14.1 Bathhouse Route

The bathhouse location should be such that guests must pass through the bathhouse to enter the pool. The bathhouse should be arranged so that guests leaving the changing room can pass through the toilet and the shower on their way to the pool.

3.14.2 Bathhouse Design

The bath floor is made of smooth material with a non-slip surface, is moisture-tight, easy to clean, and slopes at least 2 cm / m (1/4 inch / foot) with respect to the drainage channel. is needed. Carpets in the shower and toilet areas are not allowed. The transition between the wall and the floor must be curved. The walls and dividers should be made of smooth, impermeable material with no cracks or open joints. Partitions between changing rooms must end at least 25 cm (10 inches) above the floor or be placed on a continuous masonry or concrete pad at least 4 inches (10 inches) high. there is. The rocker should be installed on a solid masonry or concrete base that is at least 4 inches (10 inches) high, or on legs where the bottom of the rocker is at least 25 cm (10 inches) away from the ground. The locker should be built to allow proper ventilation.

Fixture Requirements

Unless otherwise specified in Section 12.1, bathhouses facilities shall be provided based on maximum guest load in accordance with of the following facility plan.

	FIXTURES REQUIRED MALE				FIXTURES REQUIRED FEMALE		
PATRON LOAD	TOILETS	URINALS	LAVATORIES	SHOWERS	TOILETS	LAVATORIES	SHOWERS
0-50	1	1	1	1	1	1	1
51-100	1	1	1	1	2	1	1
101-150	1	2	1	2	3	1	2
151-200	1	2	1	2	3	1	2
201-250	2	2	2	3	4	2	3
251-300	2	3	2	4	5	2	4
301-400	2	3	2	5	5	2	5
401-500	3	3	2	6	6	2	6
501-1000	3	4	2	7	7	2	7
1001-1500	4	5	2	10	9	2	10
1501-2000	5	6	2	15	11	2	15
2001 +	6	7	3	20	13	3	20

(Neufert, 1936)

3.14.3 Showers and Lavatories

Shower must be watered with temperatures above 90 degrees Fahrenheit (32 degrees Fahrenheit to 115 degrees Fahrenheit or less). At a speed of at least 1.5 gallons (5.7 L) per Fahrenheit (46) Minutes per shower head. The toilet needs to be watered with temperatures above 90 degrees Fahrenheit (32) and below 115 degrees Fahrenheit (46 degrees). All plumbing shall conform to state and local building codes Liquid or powdered soap dispensers shall be provided. Glass soap dispensers are not acceptable. Bar soap should not be provided at either showers or lavatories.

Suits and Towels

Where towels and/or swimming suits are furnished, facilities shall be provided for storage of clean and collection of used items.

Hose Bibs

A hose bib should be prepared and placed so that the entire area of the bathhouse can be washed away with a 15m hose. All hose bibs must be fitted with an approved suction device to provide overall protection for the pool's water distribution system and related facilities. Pool Cleaning System

A system should be installed to remove dirt and other foreign matter from the bottom of the pool. When using the vacuum system as an integral part of the circulation system, the fitting should be installed on the pool wall at least 8 inches (20 cm) below the waterline, where the

bottom of the pool can be made. Reached with a suction hose less than 15 m (50 ft). Nothing in this section prohibits the use of the surface skimmer for vacuuming purposes.

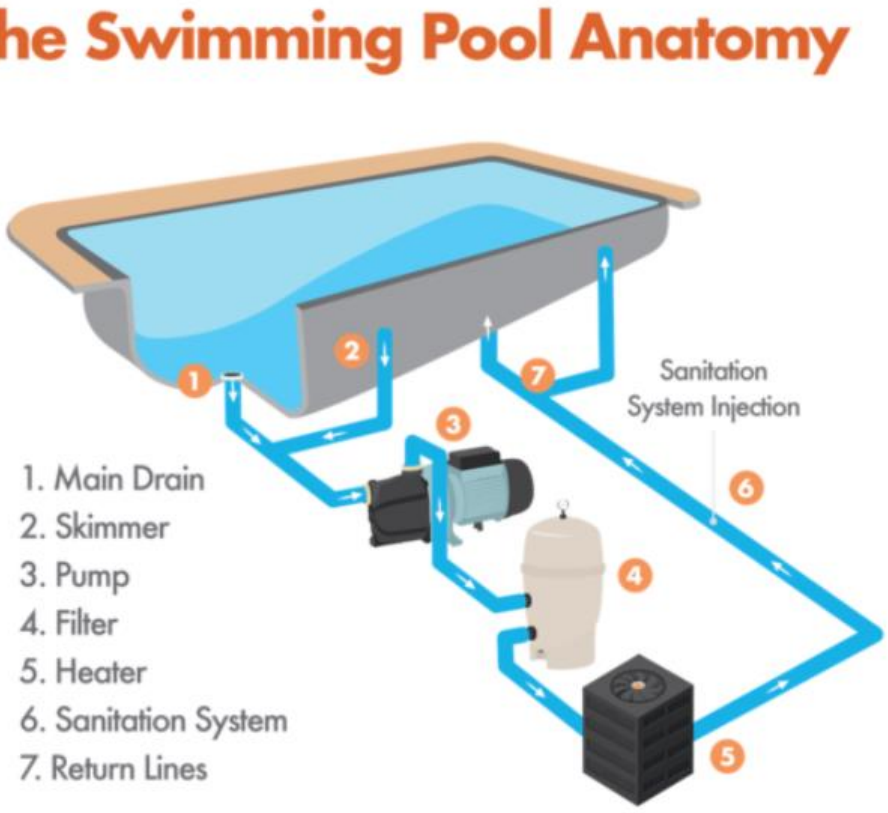
Manual

We will need to provide the instruction manual for the pool. The information contained in the manual includes instructions for proper installation, operation, cleaning, protection against the cold, and maintenance of all pool equipment. A parts list containing the drawing and the corresponding code, images; charts; instruction manuals.

3.14.4 Rinse Shower Area

After the use of hot water pool, people need to take shower so that the smell of minerals in the hot water doesn't stay in the body and also to prevent itching sensation for some people who might be allergic to the mineral rich water.

3.14.5 Hot water pool design requirements



(Palumbo, 2014)

Figure 7 Pool requirements

Color, Pattern, Finish:

The color, pattern or finish of the pool interior shall not conceal the presence of objects or surfaces within the pool.

Water Depths

-minimum water depth of 21/2 feet (762 mm)

-maximum water depth of 4 feet (1219 mm)

Swim spa pools maximum water depth- 5 feet

(1524 mm).

Steps and Handrails

No. of sets of steps: one for each 75 feet (22 860 mm).

Step sets for spa-type pools with 200 sq ft. (19 m2) or less of pool water surface area shall comply with the following:

Step treads minimum width :10 inches (254 mm)

Tread length:12 inches (305 mm).

Step riser heights: 12 inches (305 mm)

3.14.6 Physical Separation

The spa pool must be physically separated from the other pools and there should be no water mixed between the spa pool and the other pools.

3.14.7 Patron Load

The visitor load should not exceed 1 person per 3 feet (0.9 m) of seat or bench measured from the front edge.

3.14.8 Maximum Depth

The maximum depth is 4 feet (1.2 m) as measured from the waterline. The maximum depth of a seat or bench is 2 feet (0.6 m) measured from the waterline.

3.14.9 Stairs, ladders and recessed treads

Stairs, ladders, or recessed treads shall be provided when spa depths are greater than 2 feet (0.6 m). A spa shall be equipped with at least one means of egress with handrails for each 50 feet (15 m) of p deck, which may include the coping, shall be provided on two sides or 50 percent or more of the spa. When the spa is adjacent to another pool, the spa shall be located at the shallow end, with a minimum distance of 5 feet (1.5 m) between the pools.

3.14.10Deck Width

We need a continuous, unobstructed deck with a width of 1.5 m (5 feet) or more on each side, or percent or more of the hot tubs that may contain the perimeter. If the spa is adjacent to another pool, the spa should be at the shallow end with a minimum spacing of 1.5 m (5 ft). between the pool.

3.14.11Pool Drainage

We should provide a means to drain the pool completely and allow frequent drainage and cleaning of the pool.

3.14.12Entrapment Protection

The outlet should be designed so that the pump system prevents user confinement. Acceptable means are the use of multiple valveless outlets, anti-vortex drains, and 12 "x 12" (30cm x 30 cm) Square grid or one of equal areas.

3.14.13Surface Skimmer

Surface skimmer is provided every 100 surface square feet (9.3 m), or most of it.

3.14.14Recirculation system inlet

We provide minimum 2 inlet.

3.14.15Air Induction System

If an air intake system is installed, it is necessary to prevent the backup of water, which can pose a risk of electric shock. Air intake must not allow the entry of poisonous gases or other pollutants.

3.14.16Recirculation rate

The recirculation rate should provide a flow rate of (110L) of 30 gallons per minute or a turnover rate of 30 minutes per skimmer, whichever is higher.

3.14.17Agitation system

The agitation system should be separated from the water treatment circulation system. The agitation system should be connected to a 10-minute timer that is out of reach of anyone in the spa.

3.14.18Caution Signs

We need to post a warning sign next to the entrance

3.15 Lighting, Electrical, Ventilation and Acoustical Requirement

3.15.1 Lighting

All pools intended for nighttime use or without proper natural light should be equipped with artificial lighting so that all parts of the pool, including the bottom of the pool are easily visible without glare. A lamp must be installed for a uniform light distribution.

Water Surface

Lighting from above the surface should be at least 30 footcandles (320 lux) if underwater lighting is provided. Without underwater lighting, a minimum illumination of 50 foot-candles (540 lux) on the water surface shall be provided.

Under Water

We should provide at least 60 lamp lumens per square foot (930 cm~) of pool surface for outdoor swimming pools and 100 lamp lumens per square foot (930 square cm2) of pool surface for indoor swimming pools when underwater lighting is provided.

3.15.2 Ventilation

Room ventilation

Bathhouse, equipment rooms, storage areas, and pool enclosures should be heated and ventilated at the request of the appropriate regulatory agency. Dehumidifier, air conditioner, heat exchanger system must be under requirement codes. A fuel-burning heating unit shall be provided with air for combustion and vented to the outdoors as required by the regulatory agency

3.15.3 Acoustical Control

For the indoor pool, acoustic control is provided. Surface materials and fixtures used for acoustic control must be made of washable, non-absorbent, water-resistant material.

3.16 Water Supply and Waste Water Disposal

3.16.1 Water Supply

The water supplied to public swimming pools and all related plumbing fixtures (including drinking fountains, toilets and showers) must meet all quality standards set by the relevant regulatory authorities.

3.16.2 Cross Connection Control

All parts of the water distribution system that supplies public pools and related facilities must be protected from backflow and back suction. Water that flows directly into the pool or into the recirculation system must pass through the air gap or through the appropriate approved check valve at the request of the appropriate regulatory body.

3.16.3 Sanitary Wastes

Approved methods for the disposal of sanitary wastewater must be carried out in public pools. If possible, we should use the municipal sewerage system. If you need to use a personalized treatment system, you will need to obtain system approval from the relevant regulatory body.

3.16.4 Pool Waste Water

Wastewater from public pools must be drained by the method approved by the relevant regulatory agency.

3.16.5 Back Flow Prevention

Public pools should protect the circulation system and pool deck drainage pipe from backflow of wastewater in a manner approved by the appropriate regulatory agency.

3.16.6 Heat Exchangers

The heating or cooling system connected to the pool circulation system in any way must contain only non-toxic heat transfer media or use a jacketed heat exchanger with vent cavities.

3.16.7 Recirculation System

Each pool should be equipped with a circulation system that pumps, purifies, chemically balances and disinfects the water in the pool. The recirculation system must include pumps, plumbing, filters, chemical supply equipment, and associated control and monitoring equipment.

Recirculation Rate

The spa pool circulation system should circulate an amount of water equal to the capacity of the pool within 30 minutes, except that a minimum speed of 35 gallons per minute is required.

3.16.8 Pipe Sizing

Swimming pool recirculation system piping shall be designed so that the water velocity shall not exceed 10 feet (3.0 m) per second on the discharge side of the recirculation pump, and 6 feet (1.8 m) per second in suction piping.

3.16.9 Skimmers

It is limited to 2,000 or less square feet (186 m or less) of surface area, and should be limited to widths of 30 feet (9.1 m) or less.

Number of skimmers

At least one surface skimmer is provided for each 500 square feet (46 m) of surface. Additional skimmers may be required to achieve effective skimming. At least two skimmers should be provided.

3.16.10Main Drain System (Outlet)

Design and Location

The main drain is designed to protect against suction entrapment.

Multiple Drain

Two or more main drains must be installed. Drain pipes must be at least 91 cm (3 ft) apart and must be connected in parallel. Also, the drain pipes cannot be shut off individually and must be shut off with a valve.

Single Drain

The total area of a single main drain is at least 144 square inches (930 cm).

Spacing

The drain placement shall be greater than 20 feet (6.1 m) on centers, and an outlet shall be provided not more than 15 feet (4.6 m) from each side wall.

3.16.11Inlet

The recirculation system requires proper inlets at design, number, and location to ensure effective distribution of treated water and maintenance of uniform disinfectant residue throughout the pool. All other types of intake systems not listed below must be approved by the regulator.

Number

Wall inlets must be spaced not over 20 feet (6.1 m) apart, with one inlet within 5 feet (1.5 m) of each corner of the pool and one in each recessed step area.

Location

Wall inlets must be located at least 12 inches (30 cm) below the design water surface, or not less than 6 inches (15 cm) if designed to provide downward flow. Bottom inlets must be uniformly spaced, with a separating distance of no greater than 20 feet (1.5 m), and with rows of inlets within 15 feet (4.6 m) of each side wall. In any pool over 60 feet (18 m) in width, bottom inlets should be provided.

3.16.12Components of Water supply system

Water source, Water purification and treatment facility, Transmission and distribution system, Storage System, Pumping Stations, Accessories

(Snare, 2012)

3.16.13Water Fixture Requirements

Table 4 Sanitary Fixture Requirements for Hotel

St No	Fitments	For Residental Public and Staff	For Public Rooms		For Non-Residential Staff	
			For male	For Females	For Male Staff	For Female Staff
1		2	3	4	5	6 7
I)	Water-closets	1 per 8 persons omitting occupants of the room with attached water-closets; minimum of 2 if both sexes are lodged	1 per 100 persons up to 400 persons For over 400, add at the rate of 1 per 250 persons or part thereof	2 per 100 persons up to 200 persons For over 200, add at the rate of 1 per 100 persons or part thereof	1 for 1-15 persons 2 for 16-35 persons 3 for 36-65 persons 4 for 66-100 persons	1 for 1-12 persons 2 for 13-25 persons 3 for 26-40 persons 4 for 41-57 persons 5 for 58-77 persons 6 for 78-100 persons
ii)	Ablution taps	1 in each water-closet	1in each water-closet	1in each water-closet	1 in each water-closet	1 in each water-closet
iii)	Urinals	-	1 per 50 persons or part thereof	-	Nil, up to 6 persons 1 for 7-20 persons 2 for 2-45 persons 3 for 46-70 persons 4 for 71-100 persons	
iv)	Wash basin	1 per 10 persons omitting the wash basins installed in the room suite	1 per water-closet and urinal provided	1 per water-closet provided	1 for 1-15 persons 2 for 16-35 persons 3 for 36-65 persons 4 for 66-100 persons	1 for 1-12 persons 2 for 13-25 persons 3 for 26-40 persons 4 for 41-57 persons 5 for 58-77 persons 6 for 78-100 persons
v)	Baths	1 per 10 persons omitting occupants of the room with bath in suite	-	-	-	-
vi)	Slop sinks	1 per 30 bedrooms; 1 per floor, Min	-	-	-	-

(Nepal National Building Code 208, 2003)

Table 5 Sanitary Fixture Requirements for Restaurants

TABLE B9 – RESTAURANTS
(Including Buildings more than 4 storey)

St No	Fitments	For Male Public	For Female Public	For Male Staff	For Female Staff
1	2	3	4	5	6
I)	Water-closet	1 for 50 seats up to 200 seats For over 200 seats, add at the rate of 1 per 100 seats or part thereof	1 for 50 seats up to 200 seats For over 200 seats, add at the rate of 1 per 100 seats or part thereof	1 for 1-15 persons 2 for 16-35 persons 3 for 36-65 persons 4 for 66-100 persons	1 for 1-12 persons 2 for 13-25 persons 3 for 26-40 persons 4 for 41-57 persons 5 for 58-77 persons 6 for 78-100 persons
ii)	Ablution taps	1 in each water-closet	1in each water-closet	1in each water-closet	1 in each water-closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water-closets and urinals			
iii)	Urinals	1 per 50 persons or part thereof		Nil, up to 6 persons 1 for 7-20 persons 2 for 21-45 persons 3 for 46-70 persons 4 for 71-100 persons	
iv)	Wash basin		1 for every water-closet provided		
v)	Kitchen sinks and dish washers	1 in each kitchen			
vi	Slop and service sinks	1 in each Restaurant			

(Nepal National Building Code 208, 2003)

3.17 Design suited for Nepal

-Sloped path way and design at contour

- Use of Ramps
- Utilization of scenic view Semi open structure
- Provision of proper shower as well as private bath tubs.

-Natural wild hot springs give sense of connection to the nature and thrilling adventure

- Use of central space for access to multiple room.
- Dual entrance helps in circulation and crowd management.
- Separation wall that does not reach ceiling
- Service of basic rooms
- Ambience of local culture.
- Landscaping with outdoor hot pools and hot shower.

3.18 Grey Water Treatment Plant (Natural Method)

The conventional method of grey water treatment is energy intensive, requires high operation and maintenance cost and skilled manpower. Apart from that, odor and aesthetic issues are to be pointed out as well. So, there is a clean and green solution developed by IIT Bombay which overcome these points promising a negligible amount of power and minimal operation and maintenance cost.

Integrated Wetland Technology (IWT), is an innovative natural treatment system for treatment of sewage naturally. This technology was developed in IIT Bombay. IWT is an engineered wetland system which uses wetland vegetation, support media, and their associated microbial assemblages to assist in treating wastewater. It comprises of primary, secondary and tertiary treatment systems.

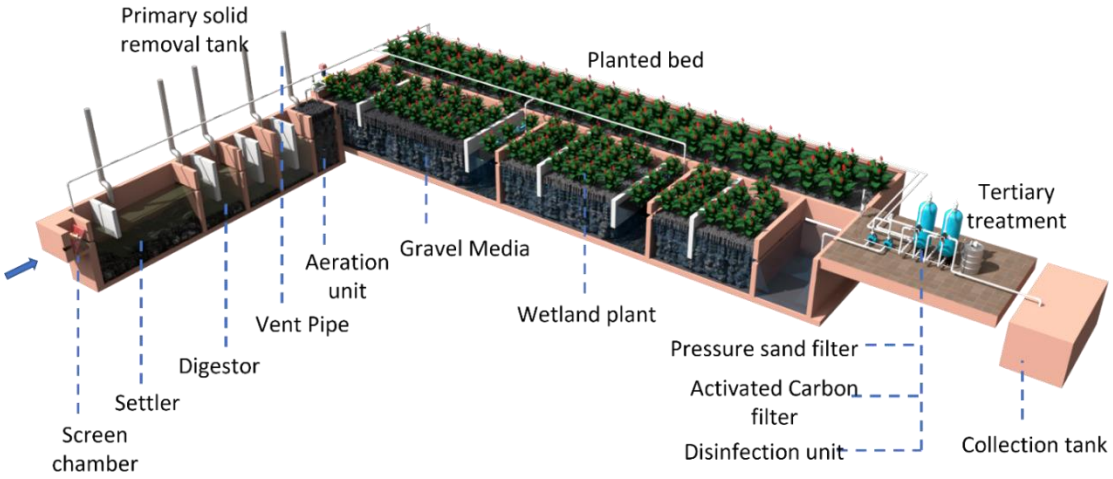
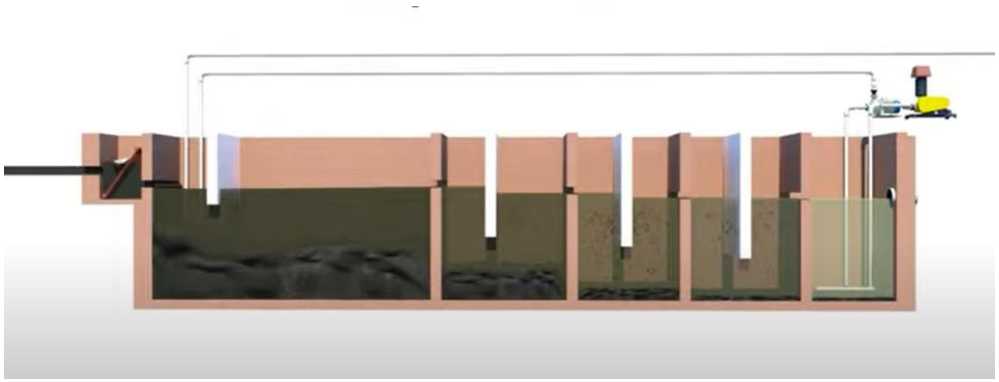


Figure 8 Integrated Wetland Technology

(IIT, 2020)

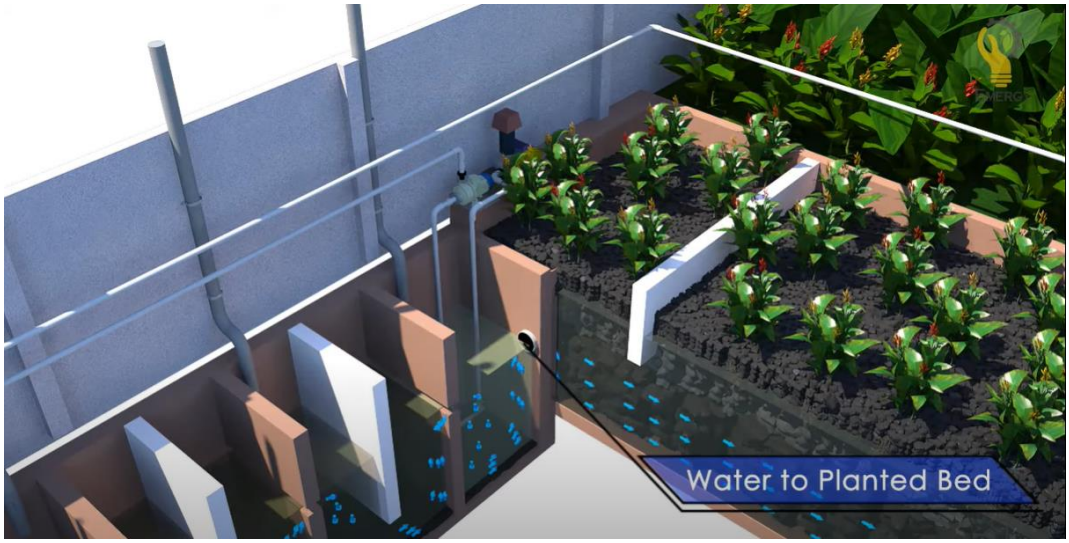
1. **Primary solid removal tank (PSRT):** It reduces suspended solids (70-80%).
   It reduces biochemical oxygen demand (BOD) (45-55%)
   Sewage flow through each unit via gravity minimizing power consumption and hence increase the efficiency.

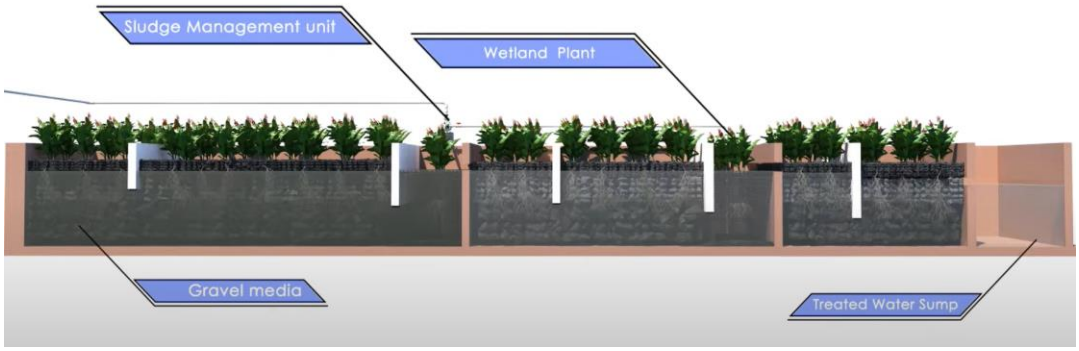


2. **Planted bed:** It reduces BOD (80-90%)

PSRT is followed by planted bed which is secondary treatment unit. It consists of porous gravel media, treated water sump, wetland plant and sludge management unit. Natural filtration and sedimentation take place here. Planted bed is a complex ecosystem that collectively acts upon pollutants present in the partially treated sewage. Porous gravel media of different size supports the root structure of wetland plants. Gravel also provides large surface area for micro flora and acts as an absorption media. Wetland plants provide oxygen to aerobic bacteria and their extensive roots provide surface area for their growth. Wetland plant reduce nutrients by utilizing them for their growth.

In planted bed, flow is subsurface i.e., sewage flow beneath the subsurface of gravel media due to which top layer of planted bed is completely dry and prevent breeding of mosquitoes and flies. Commonly used wetland plants are Colocasia esculenta, Canna Indica, Cyperus alternifolius etc. In planted bed, sewage flow is driven by gravity reducing power requirement to operate the plant.

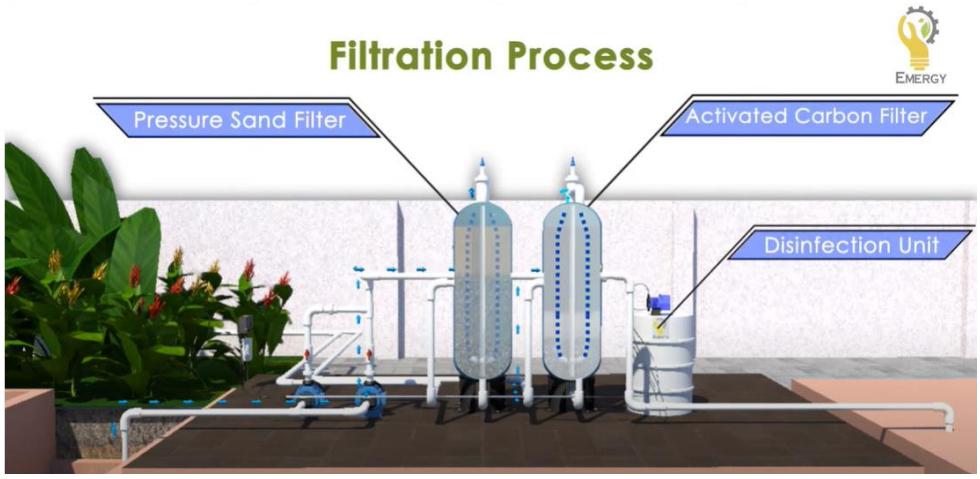




(IIT, 2020)

3. **Tertiary treatment**: Remove remaining suspended solids and microbial contamination.

Treated sewage from planted bed is subjected to tertiary treatment which include pressure sand filter, activated carbon filter and is followed by disinfection unit. Disinfection can be achieved by Ozone treatment or UV treatment or hypochlorite dosing. Tertiary treatment unit removes remaining suspended solids and reduces microbial contamination. Final treated water is collected in separate water collection tank. (IIT, 2020)



(IIT, 2020)

One of the unique features of this plant is two stage sludge management. Its innovative design ensures cleaning of gravel media without removing it from bed. It also prevents choking of media and hence overflow of bed and more importantly pumps operate twice a month for three to four hours. The system makes use of integrated approach of anaerobic, anoxic and aerobic processes in planted bed to remove suspended solids, organic matter and nutrients. Final treated water meets CPCB discharge standards for irrigation inland surface water.

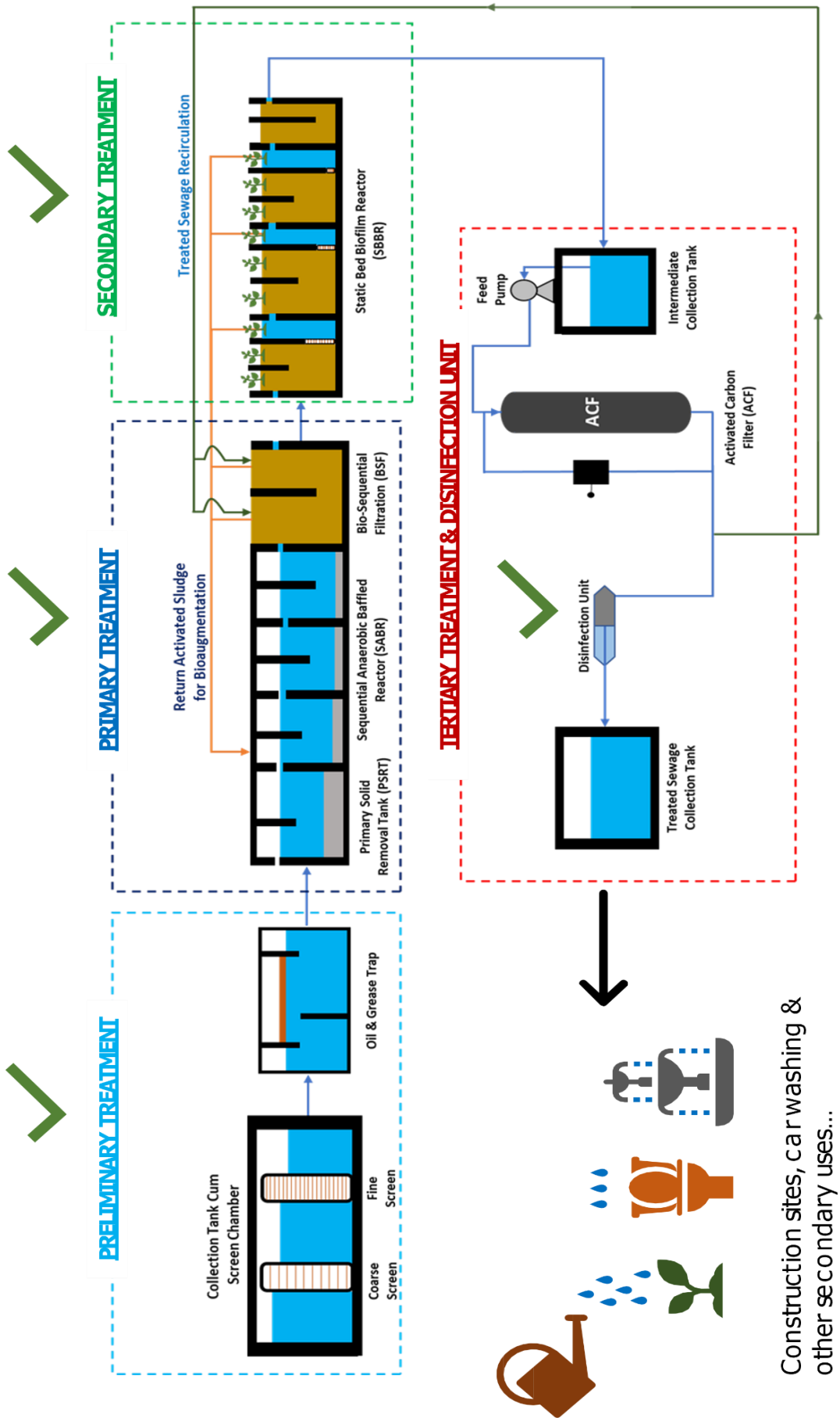


Figure 9 IWT flow

(IIT, 2020)

The final treated water from the system meets discharge standards set by CPCB.

Advantages of Integrated Wetland Technology

- Minimal Operation & Maintenance
- Technologically Feasible
- Minimal energy requirement
- Cost effective
- Aesthetically pleasing
- No odor
- No mosquito breeding
- Sustainable

(IIT, 2020)

Chapter 4. Nepal Building Codes

4.1 NBC 206: 2015 Architectural Design Requirements

Table 6 Maximum Floor Area Allowances per Occupant

	Building Type	Max. area per occupant [Sq.m] - A	Minimum Occupants per 100sq.m [example]
A.	Residence		
A1	General	11.5	9
A2	Residential with limited commercial use	9	12
A3	Residential Apartments	18	6
A4	Dormitory& Hotels	4.5	23
B.	Assembly		
	Fixed seating	As per no of fixed seats	
	Without fixed seat	1.4 net	72
C.	Educational	1.8 net	56
D.	Hospitals& Clinics	14	8
E.	Commercial		
	Main floors & Basement	2.75	37
	Areas on other floors	5.5	19
F.	Office& Industries	9	12
G.	Storage/ warehouse	28	4

The occupant load of the building or area within the building can be calculated using the relation below.

$$\text{Occupant Load of the building or area} = \frac{\text{Net or gross area}}{\text{Area per occupant}}$$

(Nepal National Building Code 206, 2015)

4.2 NBC 202: 2015 Guidelines on Load Bearing Masonry

4.2.1 Building Size Limitation

Table 7 Building Size Limitations

	Floor	Min. Wall Thickness (mm)	Max. Height (m)	Max. short-span of Floor (m)
Two storied construction				
Load-Bearing Brick Masonry in Cement Mortar	Attic	230	3.2	3.5
	First	230	3.2	3.5
	Ground	350*	3.2	3.5
Load-Bearing Stone Masonry in Cement Mortar	Attic	350	3.0	3.2
	First	350	3.0	3.2
	Ground	350	3.0	3.2
One storied construction				
Load-Bearing Brick Masonry in Cement Mortar	Ground	230	3.2	3.5
Load-Bearing Stone Masonry in Cement Mortar	Ground	350	3.0	3.2

Note: In two storied constructions, the walls in the first storey shall be exactly above the walls in the ground storey and the thickness of wall in the first storey shall not be greater than that in the ground storey.

4.2.2 Footing

The building must be well connected to the foundation and the earth. While selecting a proper site or evaluating the suitability of a given site, clause 4 shall be followed.

The footing should be provided at a depth below the zone of deep freezing in cold regions and below the level of shrinkage cracks in clayey soils but not less than 800 mm for one storey building and not less than 900mm for two storey building.

Table 8 Base Width of Footing

Masonry Type	No of Storey	Minimum base width (mm) of wall footing for soil type:		
		Soft	Medium	Hard
Brick	Two	900	650	550
	One	650	550	450
Stone	Two	*	800	600
	One	800	600	600

Horizontal Reinforcements in Wall

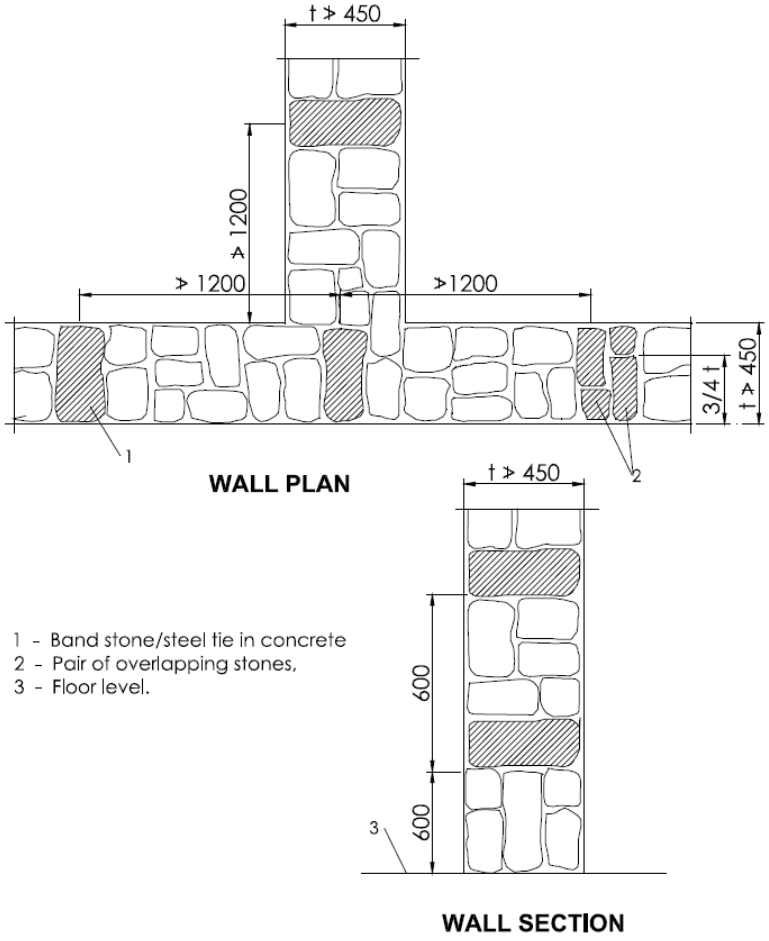


Figure 10 Through Stones or Bond Elements

(Nepal National Building Code 202, 2015)

4.2.3 Horizontal Bands or Ring Beams

The most important horizontal reinforcing is by means of reinforced concrete bands provided continuously through all load-bearing longitudinal and transverse walls at plinth, lintel and roof eave levels, and also at the top of gables according to the requirements stated below.

Plinth Band

This should be provided in all masonry buildings. It may also serve as a damp-proof course. Plinth bands are more important in soft or uneven soils.

Sill Band

A continuous sill band shall be provided through all walls below openings (especially, just below windows). It should be provided in all storeys in all buildings.

Lintel Band

A continuous lintel band shall be provided through all walls just above openings. Thus the top-level of all the openings (doors and windows) shall be at the same line as far as practicable. Lintel bands must be provided in all storeys in all buildings. Additional reinforcement may be required to be provided over openings to distribute loads to the walls on the sides of the openings.

Dowel Band (Stitches)

This band shall be provided where dowel-bars are required.

Roof Band / Floor Beam

Roof band shall be provided at the eave-level of trussed roofs and also just below the joists on all such floors which consist of joists and covering elements (flexible floors), so as to integrate them properly at their ends and fix them into the walls. Floor beam shall be constructed monolithically with RCC slab over all bearing walls when RCC slab is provided.

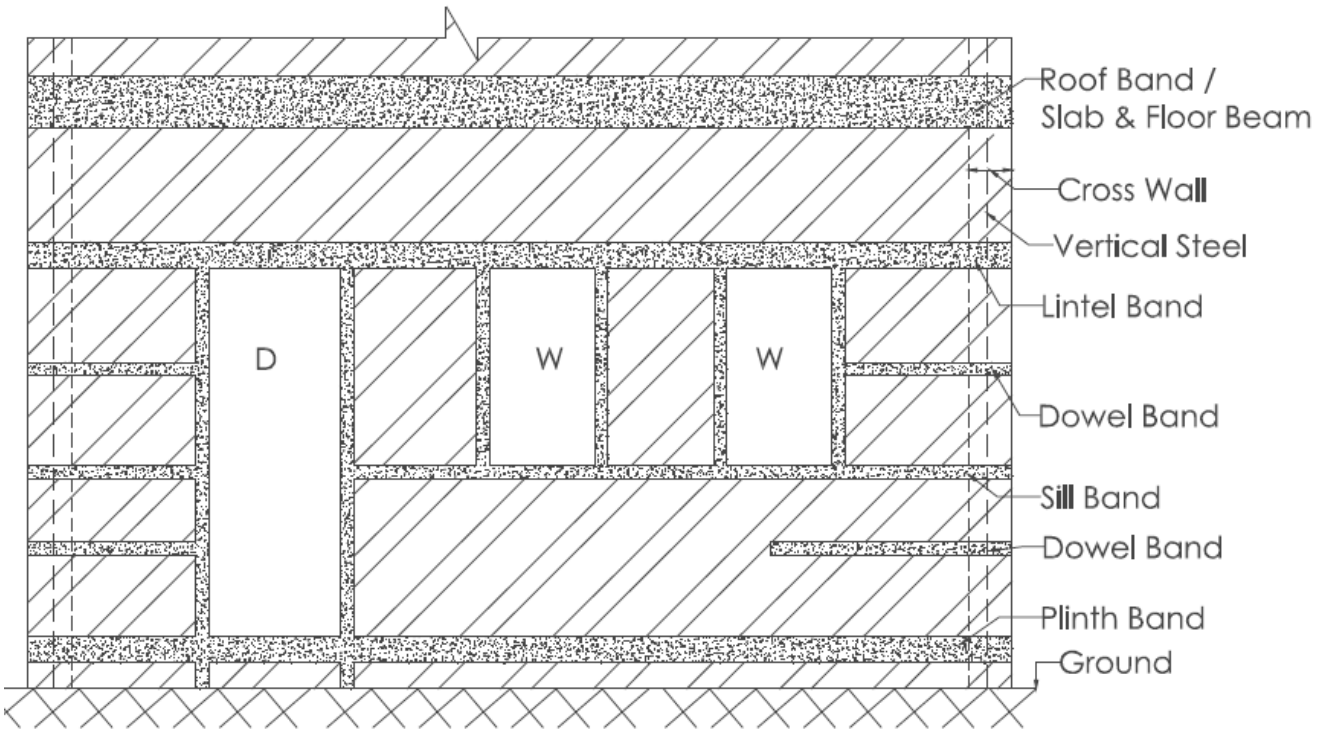


Figure 11 Different Bands in Building

(Nepal National Building Code 202, 2015)

4.3 NBC 203: 2015 Guideline for Earthquake Resistant Building Construction: Low Strength Masonry

4.3.1 Foundation: Strip Footing

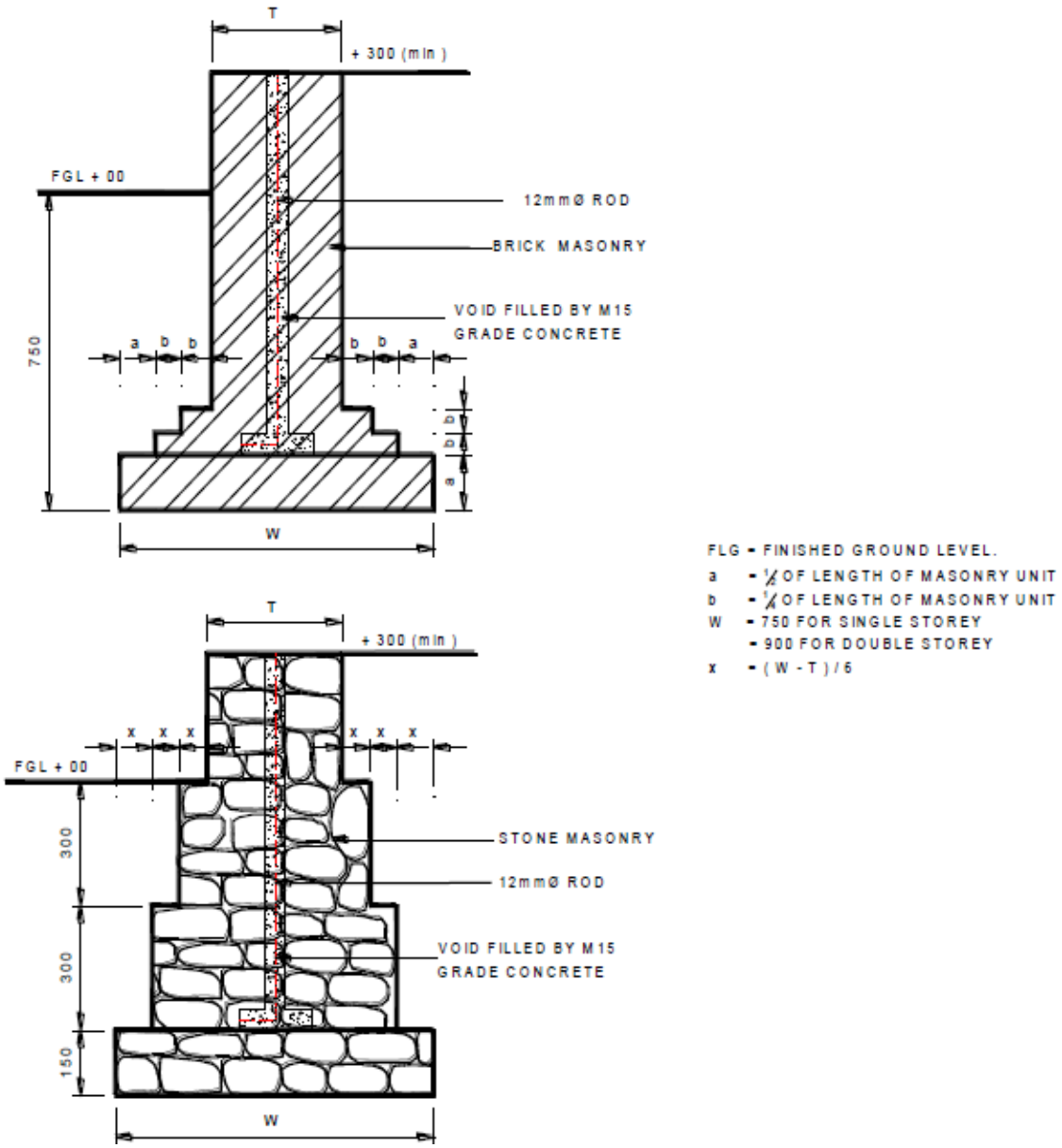


Figure 12 Details of Strip Footing Masonry Foundation (where cement and concrete available)

(Nepal National Building Code 203, 2015)

Table 9 Size of Strip Footing for Different Soil Types

TYPE OF CONS-TRUCTION	SOIL TYPE	NO OF STOREY	
		One	Two
BRICK	Hard	550	650
	Medium	650	750
	Soft	750	900
STONE	Hard	750	750
	Medium	750	800
	Soft	800	*

Masonry Bond

Random rubble masonry construction should be constructed in lifts of not more than 600 mm.

THROUGH-STONES of a length equal to the full wall thickness should be used in every 600 mm lift at not more than 1.2 m apart horizontally. If full-length stones are not available, pairs of stones, each about three-quarters of the wall thickness long, shall be used in place of one full-length stone so as to provide an overlap between them. Alternatively, wooden bars at least 38 mm x 38 mm in cross-section, or equivalents, may be used instead of through-stones. The wood shall be well-preserved through seasoning and chemical treatment so as to be durable against both weathering action and insect attack. Long stones shall also be used at corners and junctions of walls to break the vertical joint pattern and to provide bonding between adjacent walls.

Mortars and Concrete

Where steel reinforcing bars are provided, the bars shall be embedded in a cement-sand mortar not leaner than 1:4, or in a cement concrete mix of (1:2:4) (Grade M15).

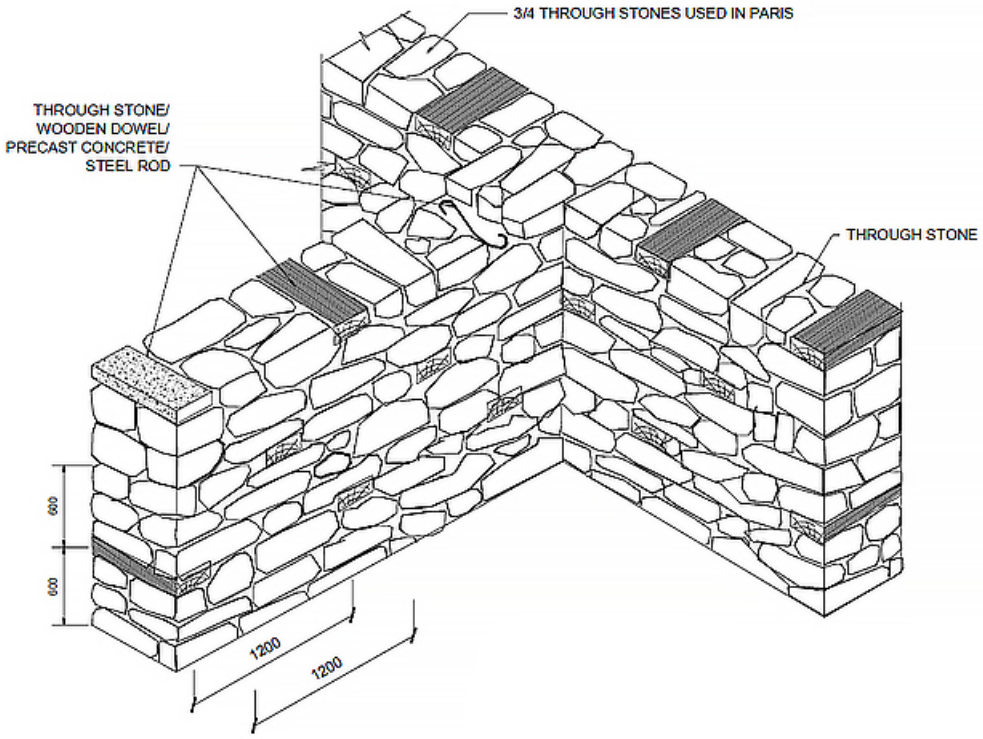


Figure 13 Random Rubble Masonry with 'Through' stones or other Bonding elements

(Nepal National Building Code 203, 2015)

4.3.2 Minimum Wall Thickness

Table 10 Minimum Wall Thickness (mm) for Different Storey Heights

MASONRY TYPE	NO OF STOREY		
	One	Two	Two Plus Attic
Stone	350-450	450	450
Brick	230	350	350
Stone /Cement Solid Block	300	300	300
Stabilized Soil Block	300	300	300

4.3.3 Height of Walls

Table 11 Maximum Thickness to Height Ratio of Walls

MASONRY TYPE	RATIO
Stone	1:8
Brick	1:12
Stone/Cement Solid Block	1:12
Stabilized Soil Block	1:12

4.3.4 Unsupported Wall Length

The maximum length of unsupported wall shall not exceed 12 times its thickness.

4.3.5 Wall Plates (Horizontal Band)

Wall plates or horizontal bands shall extent all around the walls. They shall be placed on the wall so that the joists rest on them.

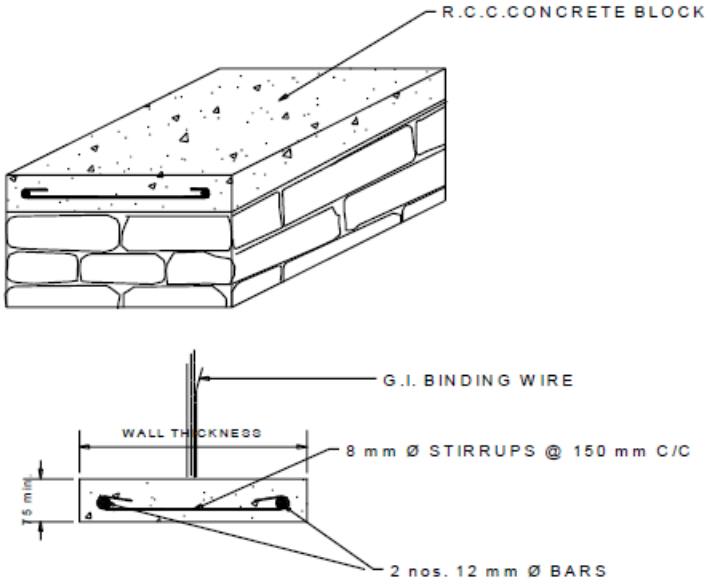


Figure 14 Details of Fixing Wall Plates (where concrete and steel are available)

4.3.6 Beams and Bearings

Beams shall never rest directly on a wall. A base pad for the beam shall be provided. This pad should be either of timber or a large flat stone covering the whole width of the wall. The minimum thickness of such a pad shall be 75 mm.

The beam shall be long enough to extend beyond both the supporting walls. Timber keys shall be provided on both the external and internal walls.

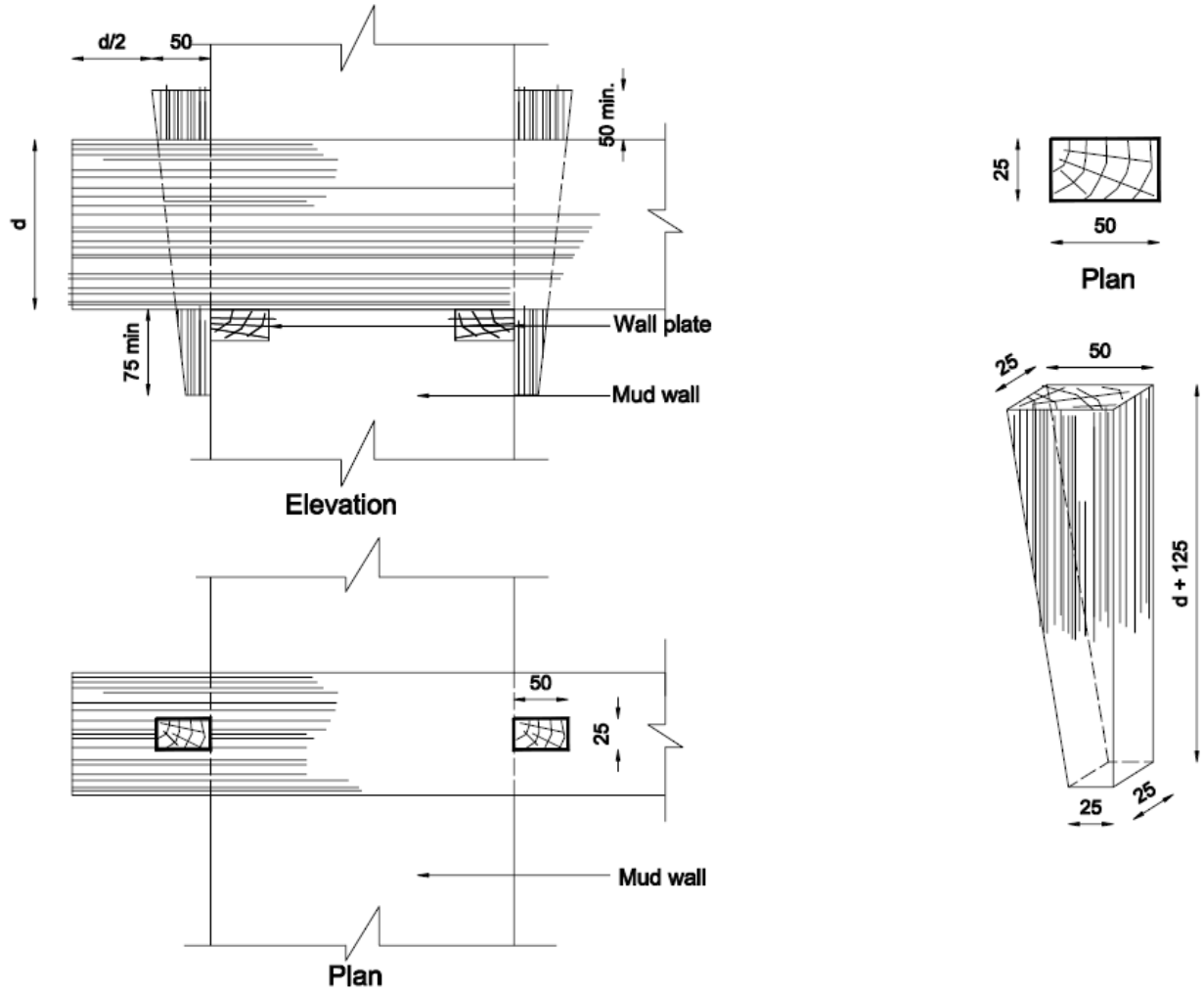


Figure 15 Details of fixing keys on beam

Table 12 Size of Beams (mm) for Various Spans

SPECIES	Size (DxB) of Beam for SPAN of				
	2 m	2 to 2.5 m	2.5 to 3 m	3 to 3.5 m	3.5 to 4m
Hardwood	190x100	220x100	240x120	270x140	300x150
Softwood	230x120	270x140	310x150	340x160	370x170

4.3.7 Joists and Rafters

The joists/rafters shall be long enough to extend beyond supporting members such as walls and/or beams. The extended joists/rafters should have timber keys on both external and internal sides of both the supporting elements.

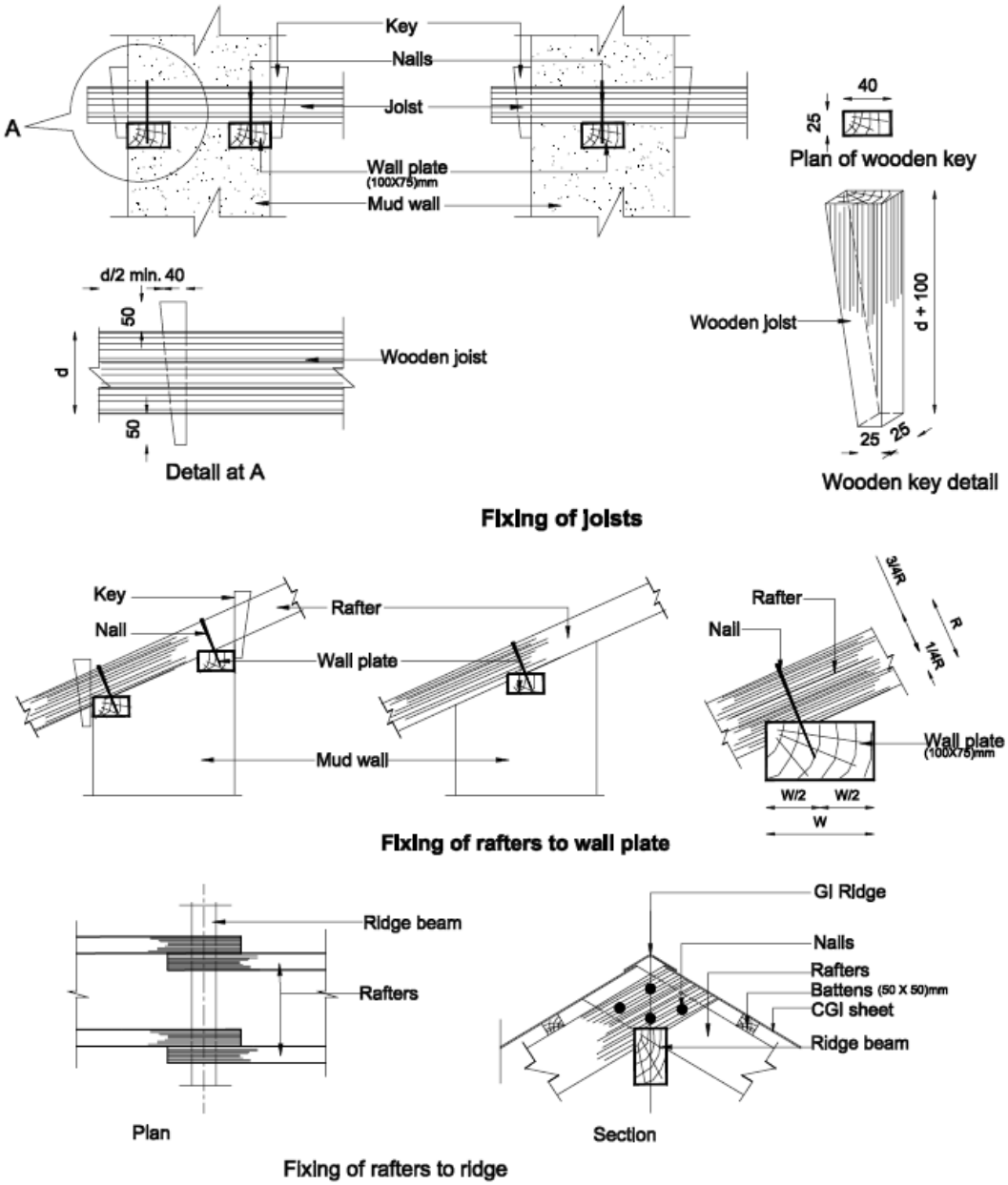


Figure 16 Details of Fixing Joists and Rafters.

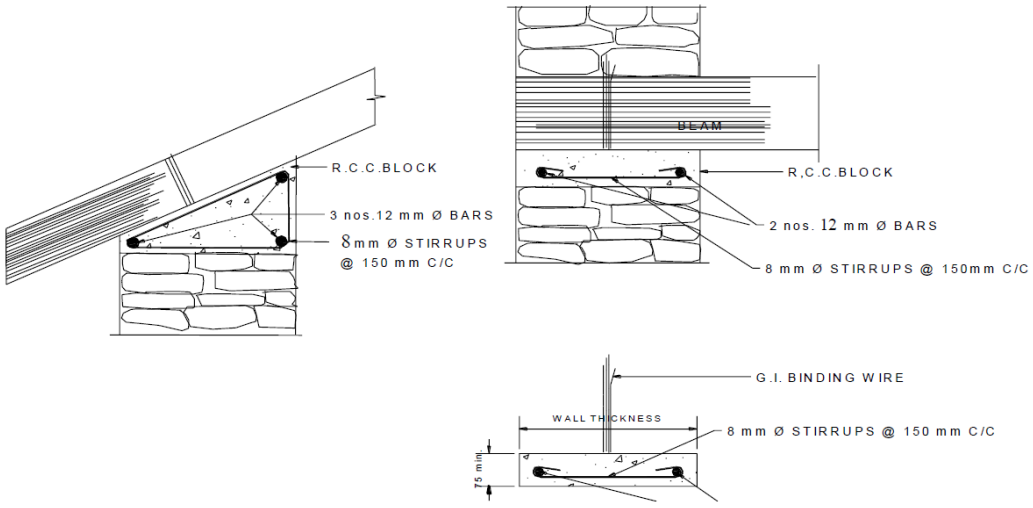


Figure 17 Details of Fixing Joists and Rafters (In areas where steel and cement are available)

Table 13 Minimum Depth of Joists and Rafters

SPECIES	Dimension (DxB) FOR SPAN UPTO					
	1 m	1.5 m	2 m	2.5 m	3 m	3.5m
Hardwood	100*65	100*65	100*65	120*65	130*75	140*80
Softwood	140*75	140*75	140*75	170*90	180*90	200*100
Spacing (c/c)	≤0.5m	≤0.5m	≤0.5m	≤0.5m	≤0.5m	≤0.5m

4.3.8 Floor Finishing

Using better bridging materials allows joists to be spaced wider apart which will not only reduce the construction cost, but also makes the building lighter. If chopped (split) wood or planks are used as bridging materials, they shall be nailed to each joist supporting them. If bamboo, reed, or any other material is used, it also shall be tied to the joists. It is preferable to use better bridging materials between the joists to achieve a stiffer flooring. Timber planks and half-cut bamboos are examples of these. The mud layers used for the floor base and finish shall not be more than 75 mm thick in total.

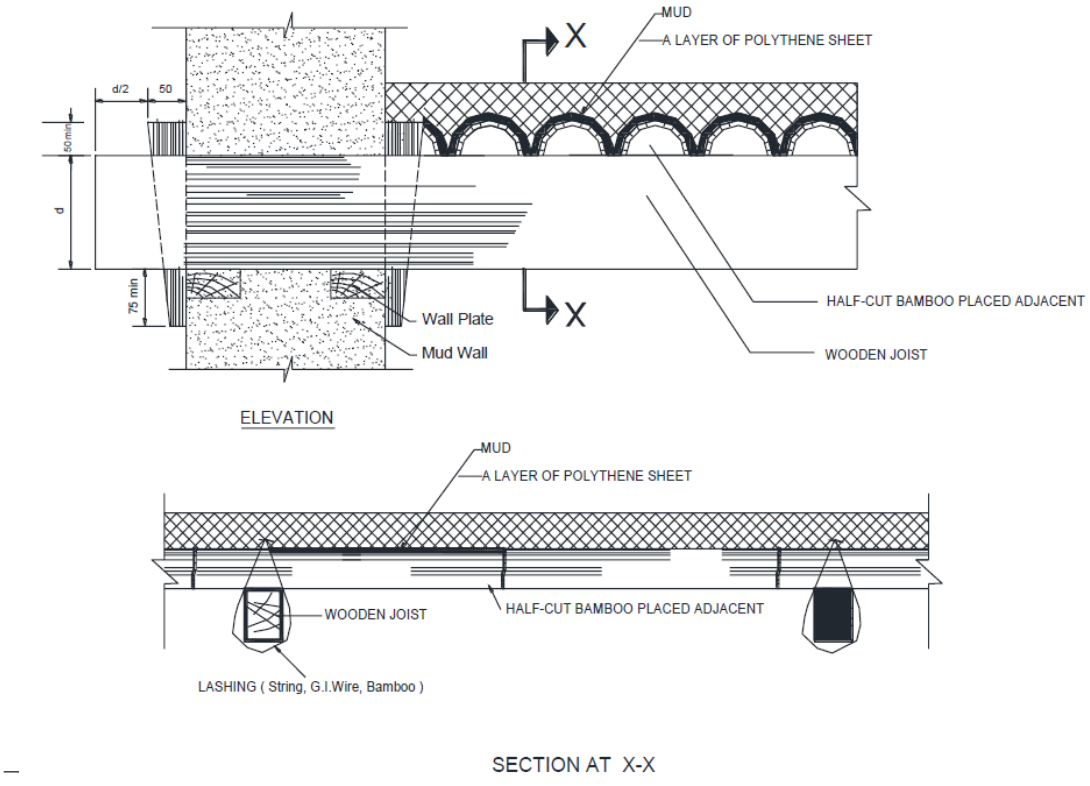


Figure 18 Details of Fixing Bridging Material to Joists and Rafters

4.3.9 Roof Covering

Building Material: Stone Slabs

Only thinner slabs shall be used for roofing. A minimum overlap of 75 mm shall be provided on all sides. They should be properly tied to the purlins and rafters. Thin slates shall be preferable to thicker ones. Slates shall be of uniform size. They shall be nailed to purlins and laid with a minimum overlapping of 75 mm to prevent leaking.

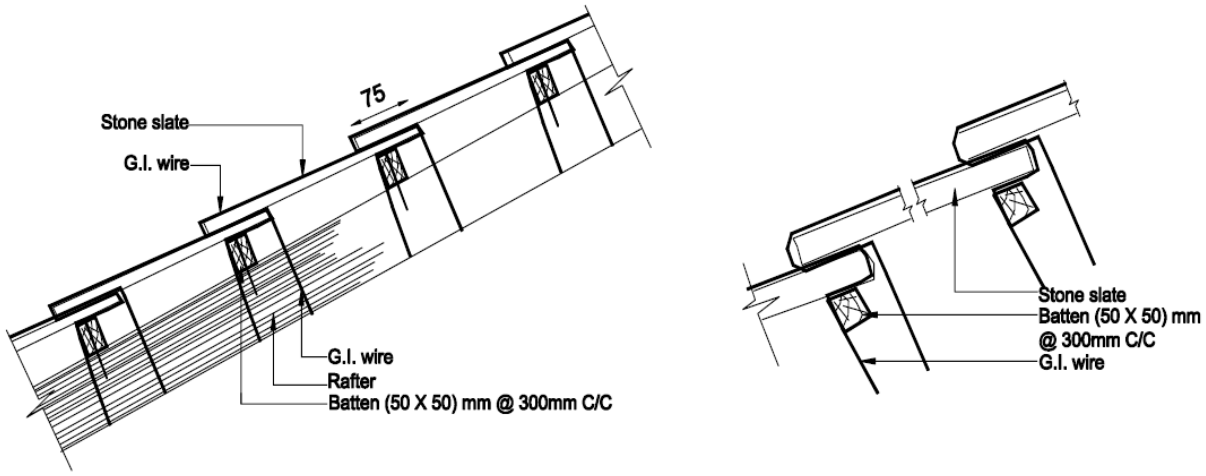


Figure 19 Details for Anchoring Stone Slabs

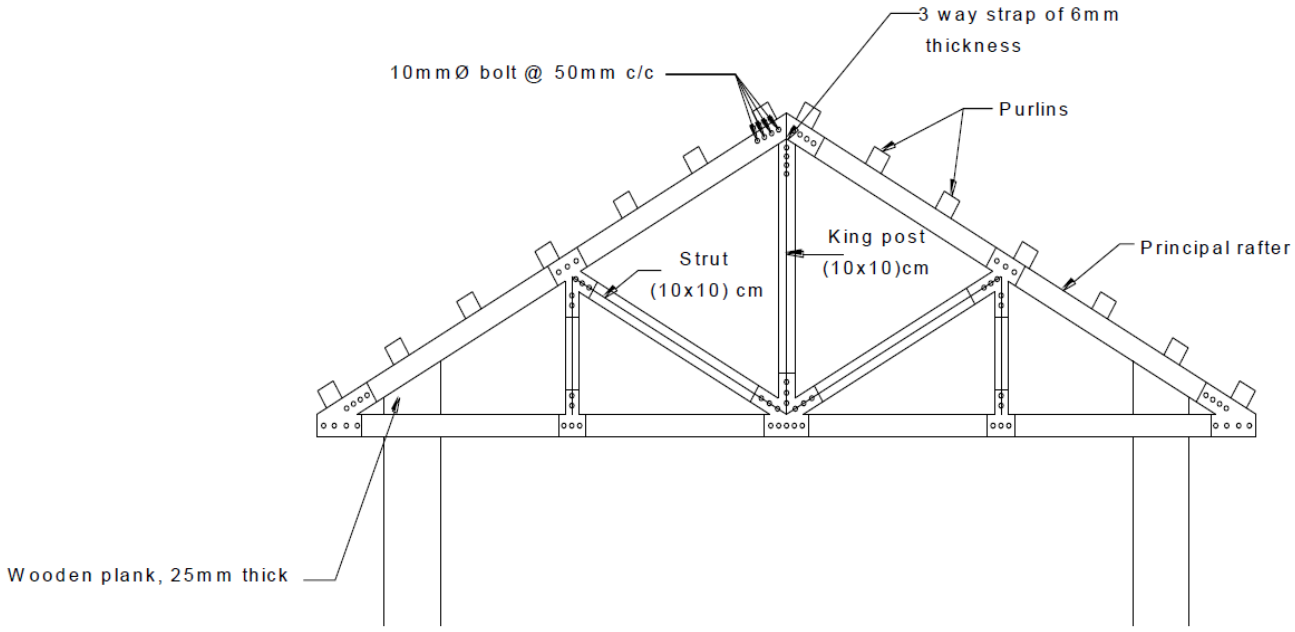


Figure 20 Details of Wooden Roof Truss

(Nepal National Building Code 203, 2015)

4.4 Seismic Resistance Components

4.4.1 Vertical Reinforcement

No masonry wall shall be constructed without vertical reinforcement. The materials used for vertical reinforcement shall depend upon the availability of suitable materials in the locality. Steel bar, which is the best, is not available in most of the rural Nepal. Bamboo is another potential material for vertical reinforcement. The size of vertical bamboo reinforcement shall be more than 80mm in diameter having thickness of at least 10mm.Timber can also be used. In order to enhance the bonding between vertical bamboo post and wall, lime, as a better bonder than mud, shall be applied at every corner and junction of wall. Long dressed stones (say 450mm) shall be laid at every corner and junction of wall where stone masonry is provided.

Vertical reinforcements shall be located at all corners and junctions of a wall. It shall start from the foundation and continued to the roof band.

Bamboo

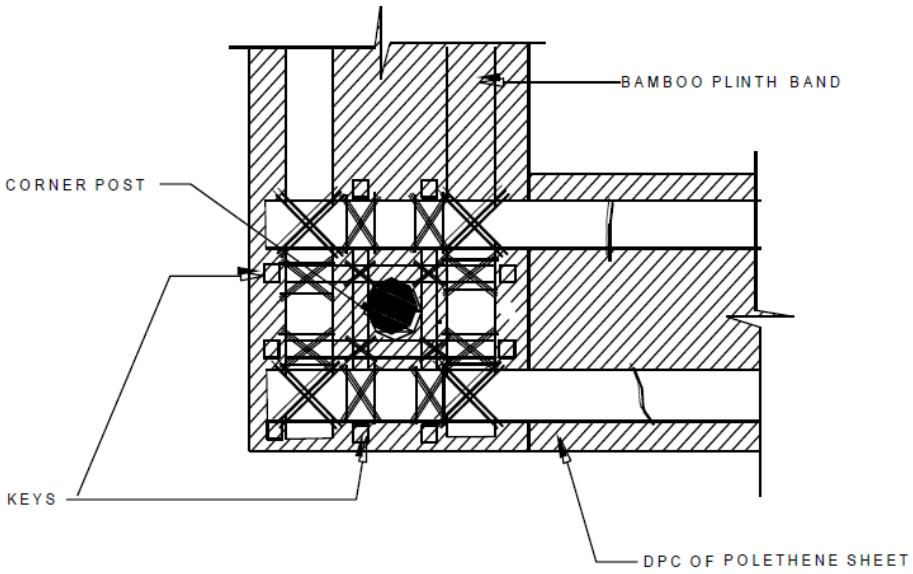


Figure 21 Bamboo as Vertical Reinforcement

Timber

It is difficult to find a single timber long enough to span between the foundation and the roof. Dovetail joints shall be used to connect the different timbers to form a single unit.

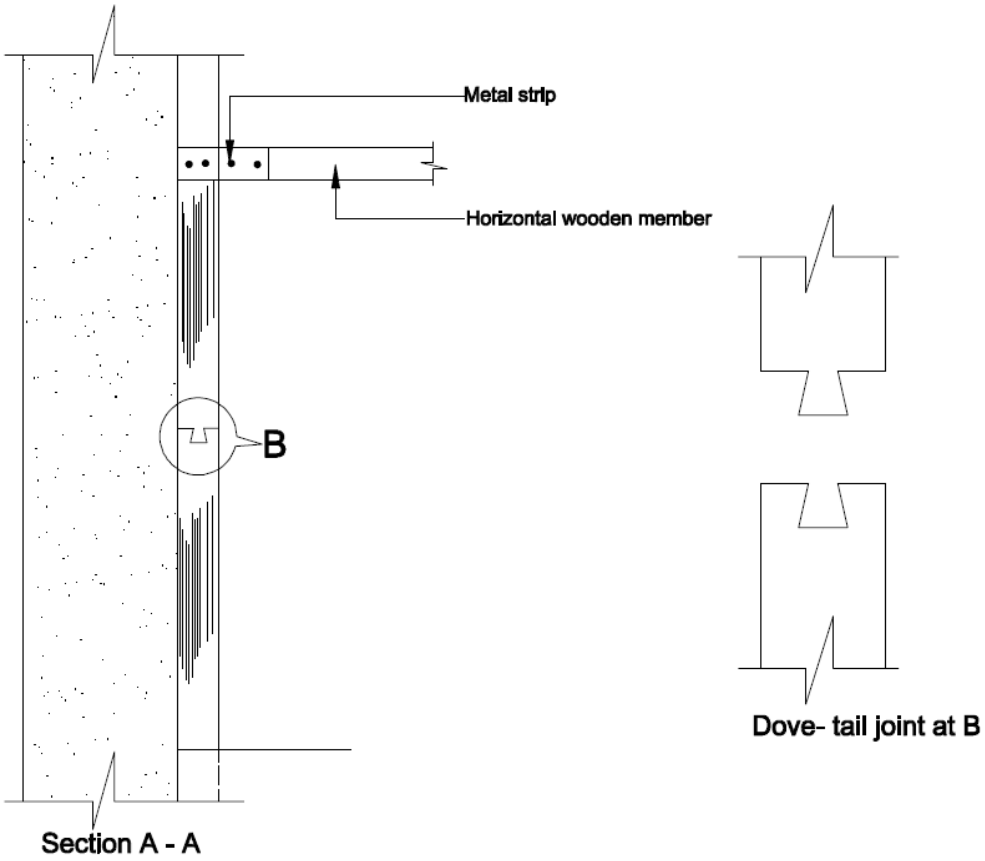


Figure 22 Timber as Vertical Reinforcement

4.4.2 Horizontal Band

Bamboo Band

An assemblage of two parallel bamboo length connected by struts shall be made wide enough to cover the entire thickness of the wall to create a horizontal band.

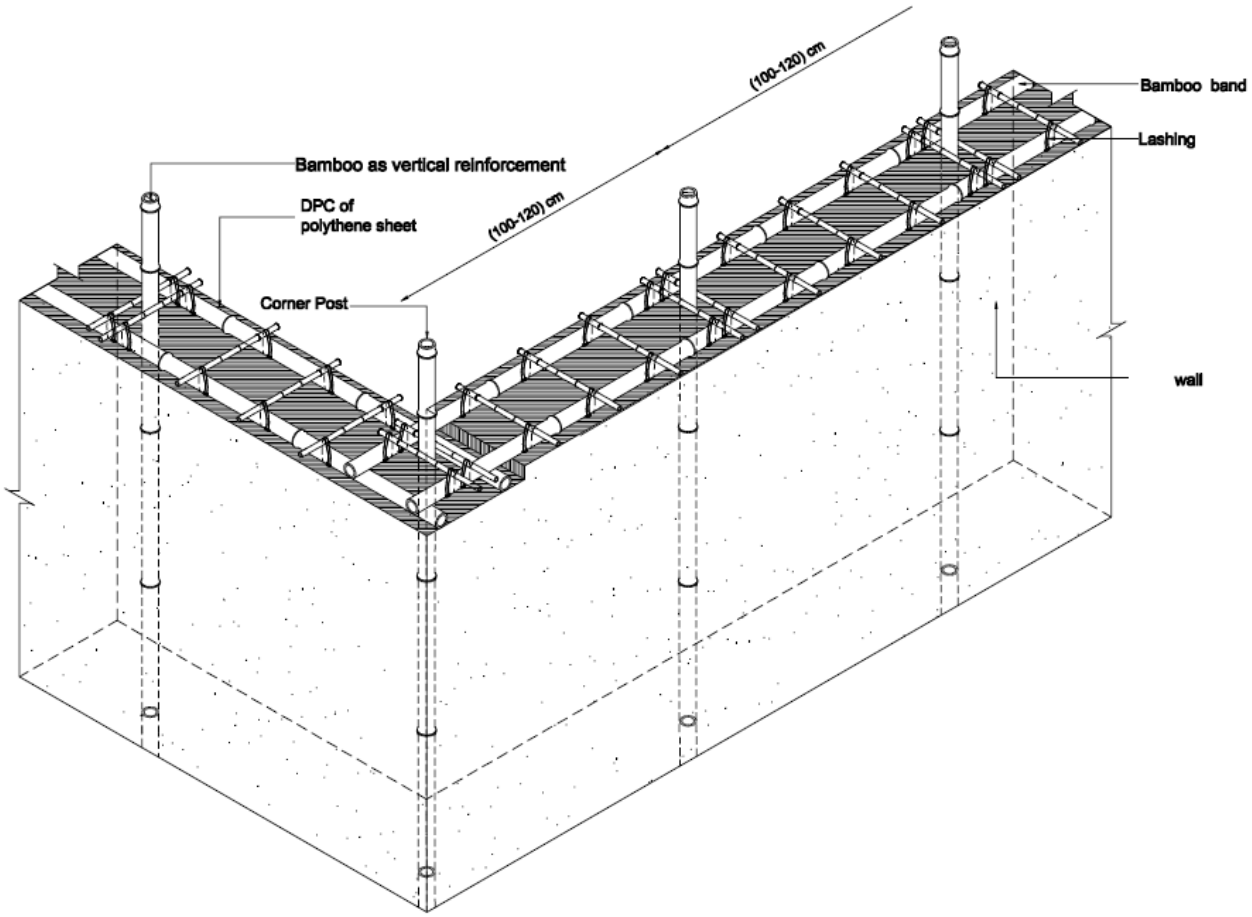


Figure 23 Bamboo for Horizontal Reinforcement

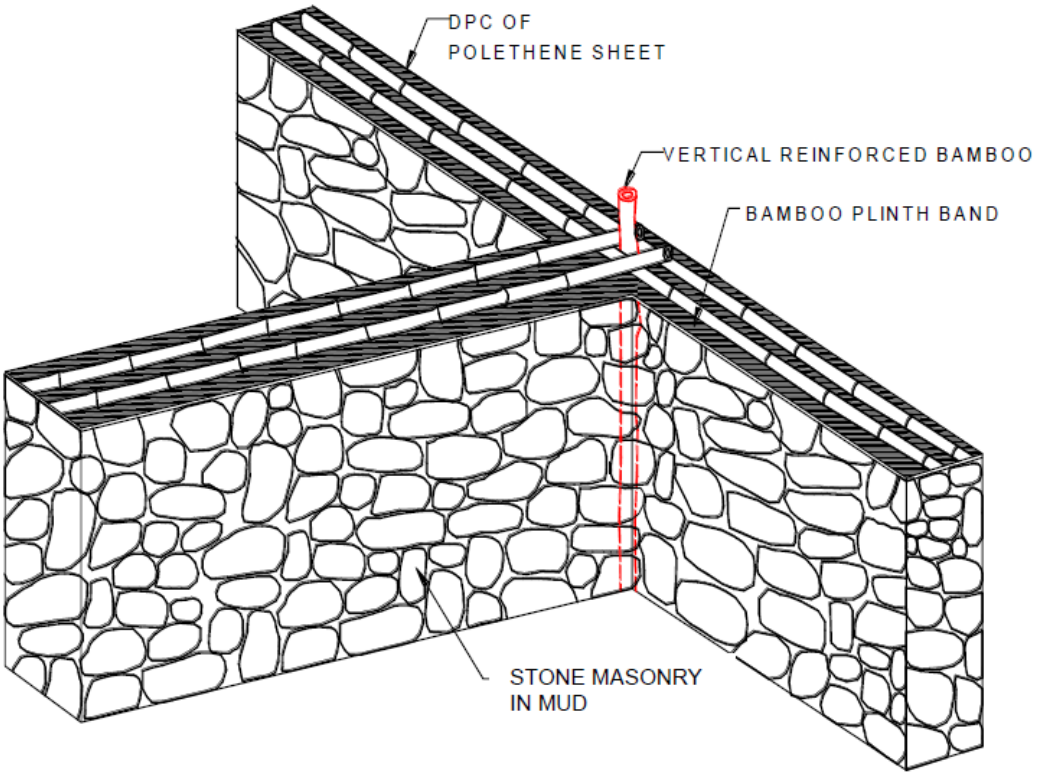


Figure 24 Bamboo as Horizontal Band

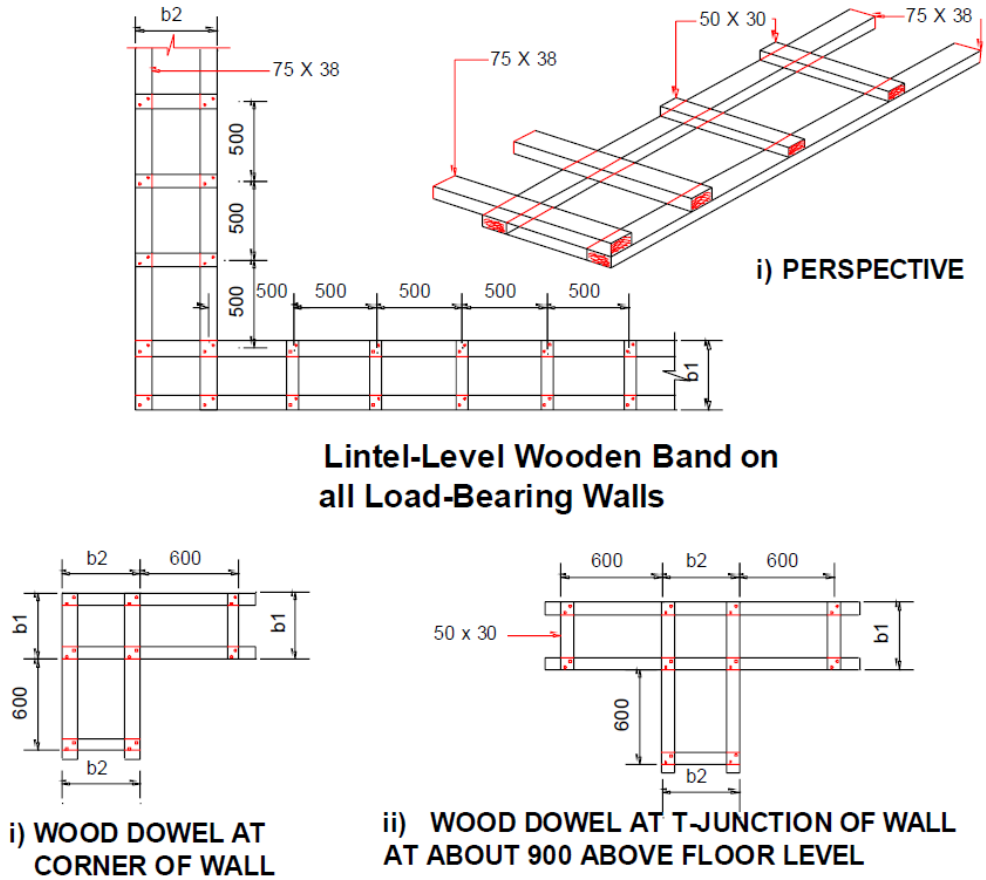


Figure 25 Details of Timber Reinforcing at Corners and T-Junction

4.4.3 Damp Proof Course

Damp rising from the ground up into the superstructure not only damages the masonry units, but also accelerates the decaying of timber and bamboo elements. Damp rising through the floor makes it unhygienic. The rise of damp to the upper portion of the wall can be checked by inserting a damp-proof layer on the wall at the plinth level.

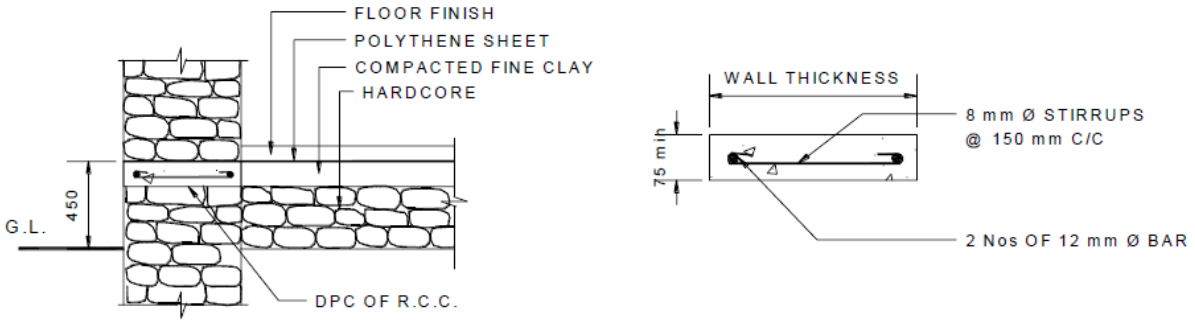
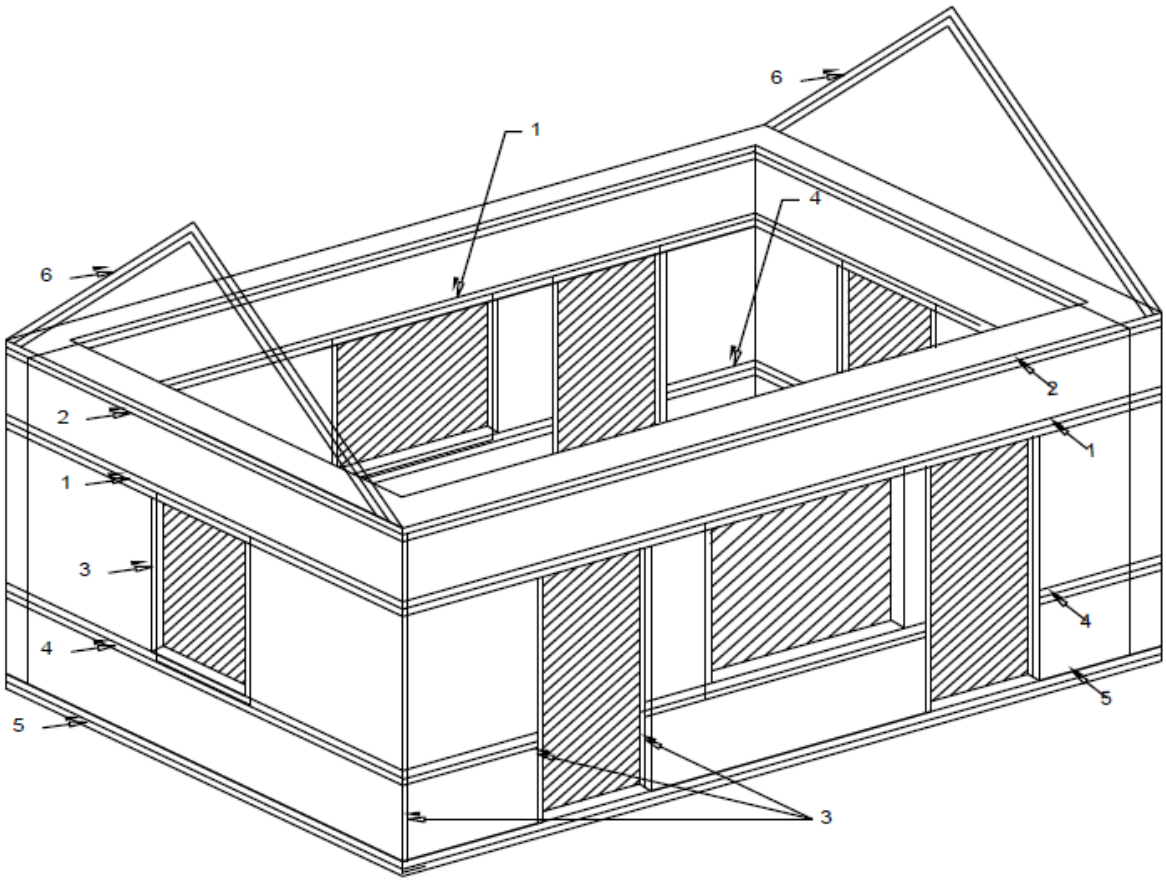


Figure 26 Damp Proof Course on Plinth level (where steel and concrete are available)

(Nepal National Building Code 203, 2015)

4.4.4 3D View of Seismic Resistance Components



1 - Lintel Band
2 - Roof Band (only for pitched roofs and under roofs and floor)
3 - Vertical steel.
4 - Sill Band.
5 - Plinth Band.
6 - Gable Band.

Figure 27 Seismic Resistance Components

(Nepal National Building Code 203, 2015)

Chapter 5. Case Studies

5.1 International Context

5.1.1 Roman Baths at Isthmia, Greece

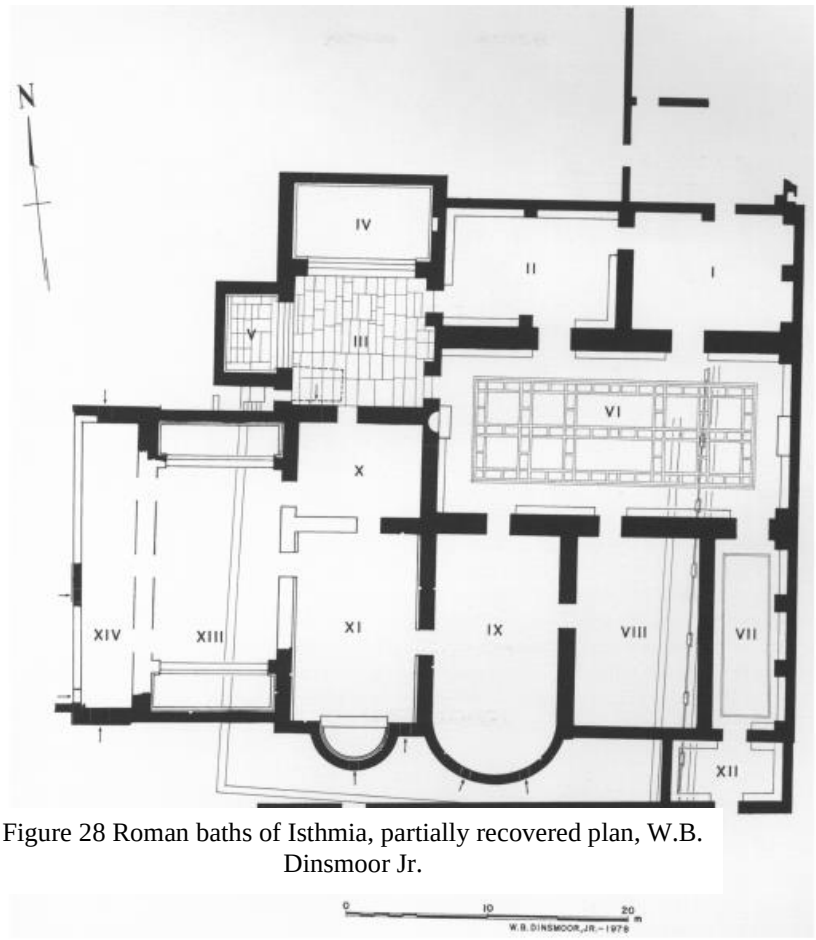


Figure 28 Roman baths of Isthmia, partially recovered plan, W.B. Dinsmoor Jr.

At northwest corner of Sanctuary of Poseidon at Isthmia, there are Roman baths establishments of medium to large size. Dating to middle decades of 2nd century A.D., the baths were among the last major addition to sanctuary under Roman rule. The architectural design of the bath follows an arrangement known as "hall type". It is characterized by a large rectangular main hall communicating with the heated rooms, the frigidarium (a cold room in an ancient Roman bath) and some of the lounges and changing rooms.

The bath block (roughly 51mX39m) is composed of tightly organized group of rectangular halls parallel or right angled to each other.

The halls along south and southwestern are heated (IX, X, XI, XIII)

Frigidarium occupies northwest corner (III, IV, V)

Main hall (VI) is placed centrally, accessible from cold and hot areas

Primary entrance (XII, VII) to the complex is from southeast

Secondary entrance is from northeast into room I by the way of an independent vestibule, the latter only partially explored.

Interiors of the bath complex

- The baths were sumptuously decorated.
- Floors show mosaic or marble slab pavement.
- Walls were revetted in polychromatic marbles or stucco molded into geometric patterns and painted.
- Some evidence of wall painting (mainly non figural, floral or garden scenes) exists but this appears to late renovations.
- In some rooms, large areas of wall retain low relief stucco decoration imitating ashler work.
- The main hall was distinguished by a monochromatic mosaic depicting Nereids and Tritons, as well as other marine scenes. (Yegül, 2015)

Figure 29 Overall view (looking North) of Roman baths of Isthmia

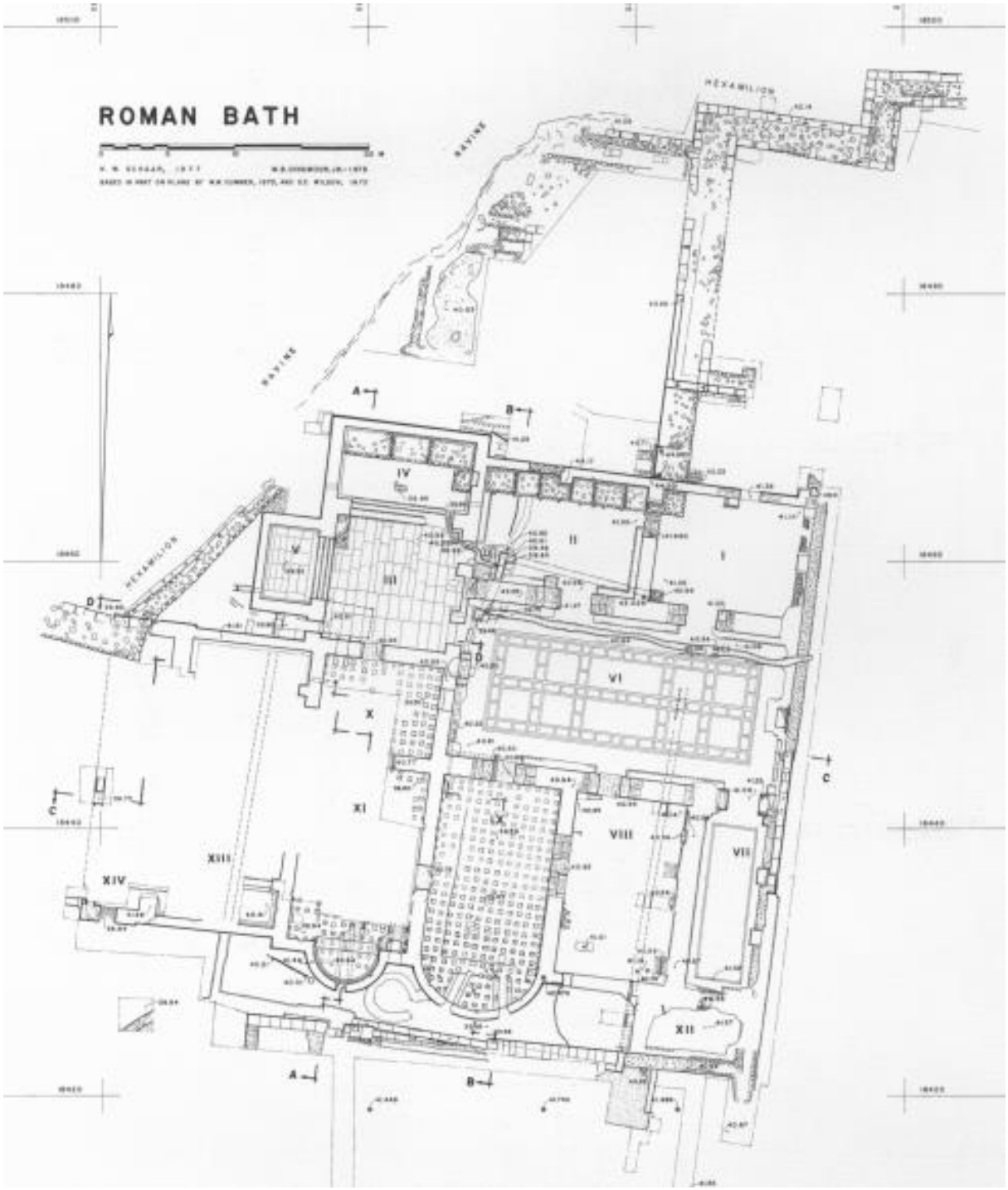


Figure 30 Master plan of Roman bath of Isthmia

(Yegül, 2015)

Inference from Roman bath of Isthmia

- Use of Palaestra for access to multiple room.
- Interior decoration based on the myth and history of the site through artistic use of materials
- Dual entrance helps in circulation and crowd management

5.1.2 The Lares Hotspring, Peru

Introduction

400 thermal sources in Peru due to **volcanic activity**

One of the hottest and best hot springs located in Lares village in **Peru**!

Hot spring source: An extinct volcano named Quimsachata

Figure 31 Outdoor landscaping of the Lares Hotspring, Peru

Photo Credit: Packing up the Pieces Travel Blog

-**Altitude**: Almost 10,600 feet with scenic views tucked in the beautiful Andes Mountains next to a beautiful river

-**Minerals present in water**: calcium, magnesium, sodium, potassium, sulphates, iron, manganese, and copper, among others. All of these minerals cause the water to have a yellowish tinge.

-**Color of water**: Brown almost yellow water may appear dirty, but it is packed full of rich minerals.

-**Users**: Hikers during Lares trek that runs 3 days and local villagers as community bathhouse.

-Few nice observation viewpoints that look down over the pools.

-Large green space to enjoy a picnic lunch or set-up a tent with designated camping zones & bonfire pits.

-Possible to rent simple rooms, as they are open 24 hours

Types of Pools

-The **first type** has 4 pools with a temperature of **105º C**, which is supplied from the main waterhole combined with cold groundwater with surface temperature of **64° C**. Pool dimension:5 m long, 3.50 m wide, 1.50 m deep.

-The **second type** pool temperature:**35°C** with size of 6 m long, 4m wide, 1.5 m deep.

-The **third type** pool has a temperature of **38 °C**, its size is 15 m long and 8 m wide and 1.5 m deep. (Megan, n.d.)

Figure 32 Lares hot springs perfectly nestled in the picturesque Lares valley

Figure 33 Space to pitch a tent -

Figure 36 Brown almost yellow water as it is packed full of rich minerals with healing benefits

Figure 34 Small thermal pool

Inferences

- Service of basic rooms for the users who wants to stay.
- Creating the ambience of local culture.
- Landscaping with outdoor hot pools and hot shower.
- Outdoor garden with picnic spot, camping zone & bonfire pits.

Figure 35 Shower walls bleached due to minerals present in the water

Photo Credit: Packing up the Pieces Travel Blog

5.1.3 Koganeyu Sento, Tokyo, Japan

Architects: Schemata Architects

Area: 1114 m², Year: 2020

Communal gathering place where people feel a sense of connection to their communities

Japanese public bathhouses have long been a preferred setting for social gatherings where people experience a feeling of community.

Material: concrete and other materials that harmonize with the exposed structural frames.

(Abdel, 2020)

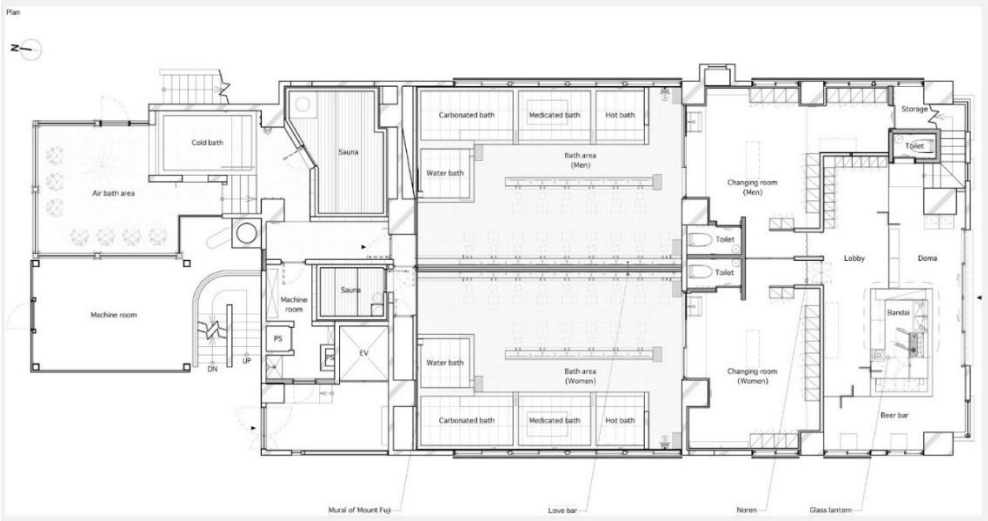


Figure 37 Floor plan of Koganeyu Sento

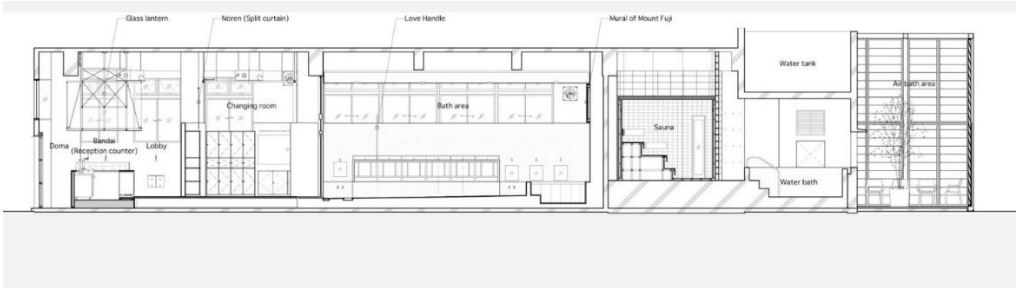


Figure 38 Section drawing of Koganeyu Sento

Figure 40 Bathhouse

Figure 39 Separating wall between men's and women's bath areas, which does not reach the ceiling and leaves an opening between the top of the wall and the ceiling.

Figure 42 Reception

Figure 41 Locker and changing room

Figure 43 Beer Bar

Figure 44 Room temperature and humidity measurement

Figure 46 Carbonated Bathtub

Figure 45 Hot tub for relaxation

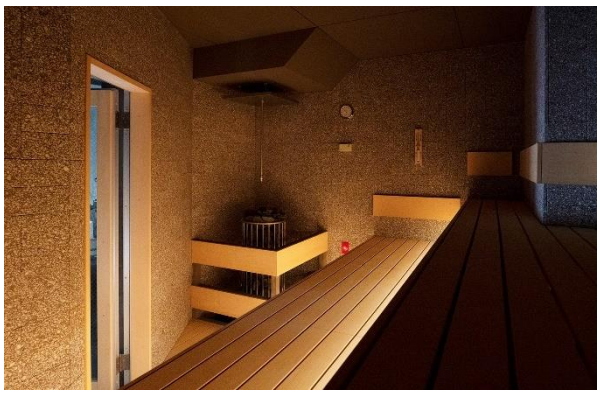


Figure 48 Sauna

Figure 47 Cold tub

Photo Source: archdaily.com

Inference from Koganeyu Sento

- Shower and bath tub in close proximity for convenience of users
- Male and female bath area separated by wall that does not touch the ceiling for better HVAC resource management.
- Flow of space from hot bath to sauna to cold bath.

5.2 National Context

5.2.1 Singa hotspring (सिङ्गा तातोपानि कुण्ड), Myagdi

Location: Beni, Myagdi

Bank of Myagdi river west from Beni Bazar

Altitude: 2,743 m at sea level

Water Temperature: 45° c. to 48° c. and is 54° c. to 57° c, at the foundation.

Chemicals: black salt and phosphorus which itself is a natural antibiotic.

Big Pool Capacity: 300 people at a time

Small Pool Capacity: 12 per small pool

Fee per person: Rs 300

Visitors per year: Above 60,000

No. of visitor inflow

Figure 49 View of Singa tatopani from across the myagdi river. Photo credit: Poke Production

Peak season: Asojh, Kartik, Falgun, Chaitra

Average user inflow: 1020 per month

Off season: Shrawan, Bhadra, Mangshir, Poush

Average user inflow: 247 per month

Users of Singa Hot Spring, Myagdi

-Local people of Myagdi

-People suffering from diseases like gastric, rheumatism, uric acid, back ache, skin disease, swelling, goiter and arthritis.

-Tourists visiting Mustang

-Trekkers on Annapurna Circuit Trek

Female visitor twice as male visitor

Figure 50 Case study site visit

Spring pool

Spring pool has a of dimension 11.0 m X 5.8 m X 0.62 m and can hold up to 100 people at a time. Bathing in the pond takes place 18 hours a day with alternating shift of three hours for male and female.

Figure 56 Truss roof design for humidity control

Figure 53 Large pool used by male and female at different timing

Figure 54 Small private pools for small group and families who want to take the service exclusively

Figure 55 Scenic view of myagdi river from small pool

Figure 52 Outdoor wild pool for locals to use without any ticketing

Figure 51 Hot spring source point in Myagdi river

Figure 59 Office of Singa Tatopani

Figure 58 Ticket Counter

Figure 60 Shower Area

Figure 57 Toilet

Figure 62 Changing area with curtains

Figure 61 Common Changing Area

Figure 63 Cool Down Area

Figure 64 Water Tank (2000L tank-2, 1000L tank-3)

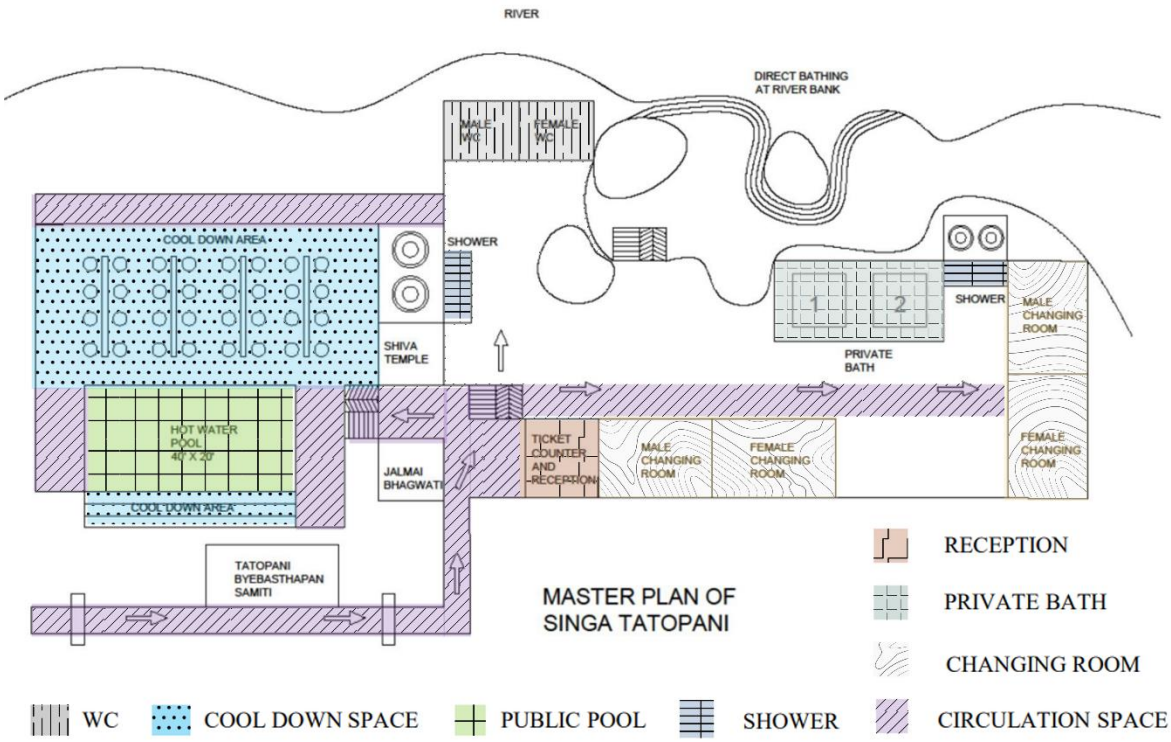


Figure 65 Master plan of Singa Tatopani, Myagdi

Uses

Bathing, Holy water, curing diseases, washing clothes, drinking water.

Structural Elements

-Rccbuildings

-Trussroof

- Semi open structure for ventilation in pool

- Shear Wall against flooding

Drawbacks

-No proper changing room

-No proper lockers

-Shower height not following anthropometry.

Impact on society

-Local tourism and local business

-Street Vendors for hot water supplies

-Hotels & homestays

-Responsible locals for preservation of natural source of hot water

Inference

- Use of Ramps for physically challenged people.
- Utilization of scenic view of river during bath.
- Semi open structure for balancing humidity.
- Provision of both common as well as private pools.

5.2.2 Kharapani Hotspring, Kaski

River Source: Bhurjung Khola (Seti River)

Type: Wild Hot Spring

Location: Kharapani Village, Sardikhola VDC, Kaski

Water Temperature: 48°C

Accessibility: Half hour ride from Pokhara

Bathing Area

- A area of a river with the source barricaded to control the speed of the river flow.
- The users can take bath without getting swept away by river.

No locker room, No changing room

Nature based adventure tourism

Natural Disaster: On 05 May 2012, a landslide near Machhapuchre Mountain in the Kaski district triggered a massive flash flood in the Seti River

Flood height- 30ft

Casualty: 17 people killed, 50 people missing, many of whom were having picnics along the river.

Cause of flashflood:

-Continuous rain over 3 days

-heavy buildup of snow, ice and mud from an avalanche of Machhapuchre mountain

-Flow of Seti River temporarily blocked by avalanche

-Water broke through the block causing flash flood.

Impact of Lost Hotspring

Loss of Natural resource of geothermal spring

The place once vibrant for riverside restaurants, small business and picnic spot now abandoned.

Lost opportunity of village for development through tourism.

Present Situation

Small remains of Hot spring

Limited area of hotspring as most of the source has been destroyed.

Not used by tourists for bathing like before but used by local people at present.

Inference

-Natural wild hotsprings give sense of connection to the nature and thrilling adventure

-Source of thermal springs needs to be protected.

5.2.3 Kodari Hotspring, Sindhupalchowk

Location: Sindhupalchok, Province 3, Nepal.

Address: Araniko Highway, Kodari village, Bhotekoshi Rural Municipality

River Source: Bhotekoshi

Hot spring of religious value

- Devotees take bath
- Chaitra Mela
- Sankheswor Mahadev

Reasons to visit

Kodari Border

Sino-Nepal Friendship Bridge

Miteri Pul

Site Details

Rural Area: Buildings affected by earthquake

North: Tatopani Custom Office (Bhansar) & Nepal-China Border

South: Riverside Hotels

East: China across Bhotekoshi river

West: Unpitched Araniko highway and a monastery across

Visitor Flow-

1000 to 1200 per day for temple (before earthquake 2015)

80 to 100 per day for bath (after earthquake)

Ticket price - Rs 20 for shower

-Rs 100 for bath tub

Peak Months- Kartik and Chaitra special Mela

Deity of the hotspring: Shankheswor Mahadev

-Tap water very hot 44°C

-No temperature regulator

-Changing room (Privacy through curtain)

Figure 66 Bird's Eye View of Kodari Tatopani

Figure 67 Bhotekoshi river separating Nepal and China

Figure 68 Site of Kodari Tatopani at the border of Nepal. Source: Google map

-Semi open bathing area to control humidity
-Tap water very hot
-No temperature regulator
-Locker (Just outside the bathing room)
-Changing room (Privacy through curtain)
-Semi open bathing area to control humidity

Figure 69 Shower Area

Figure 71 Locker area

Figure 72 Group Bath tub

Figure 73 Single Bath tub

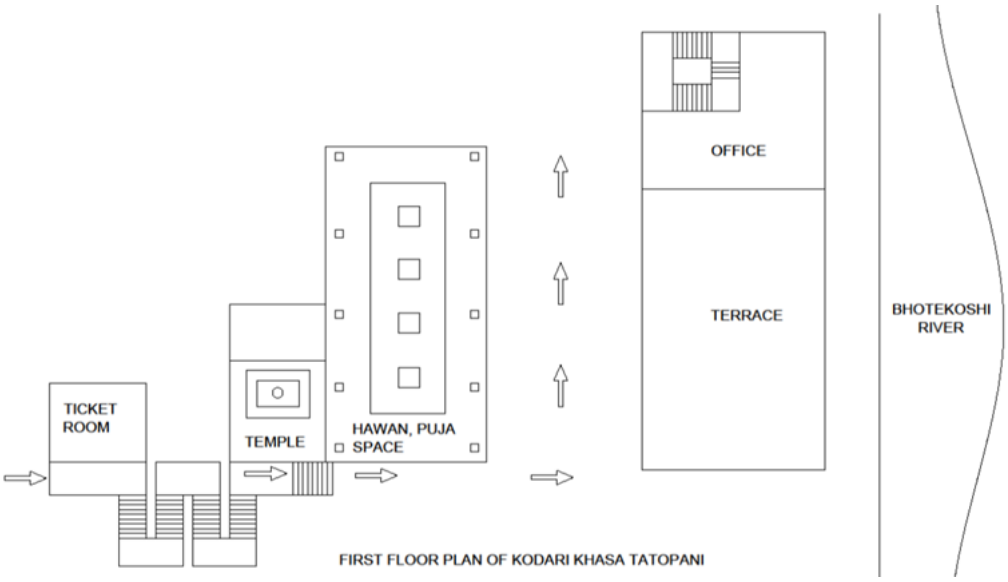


Figure 70 First floor plan of Kodari Tatopani

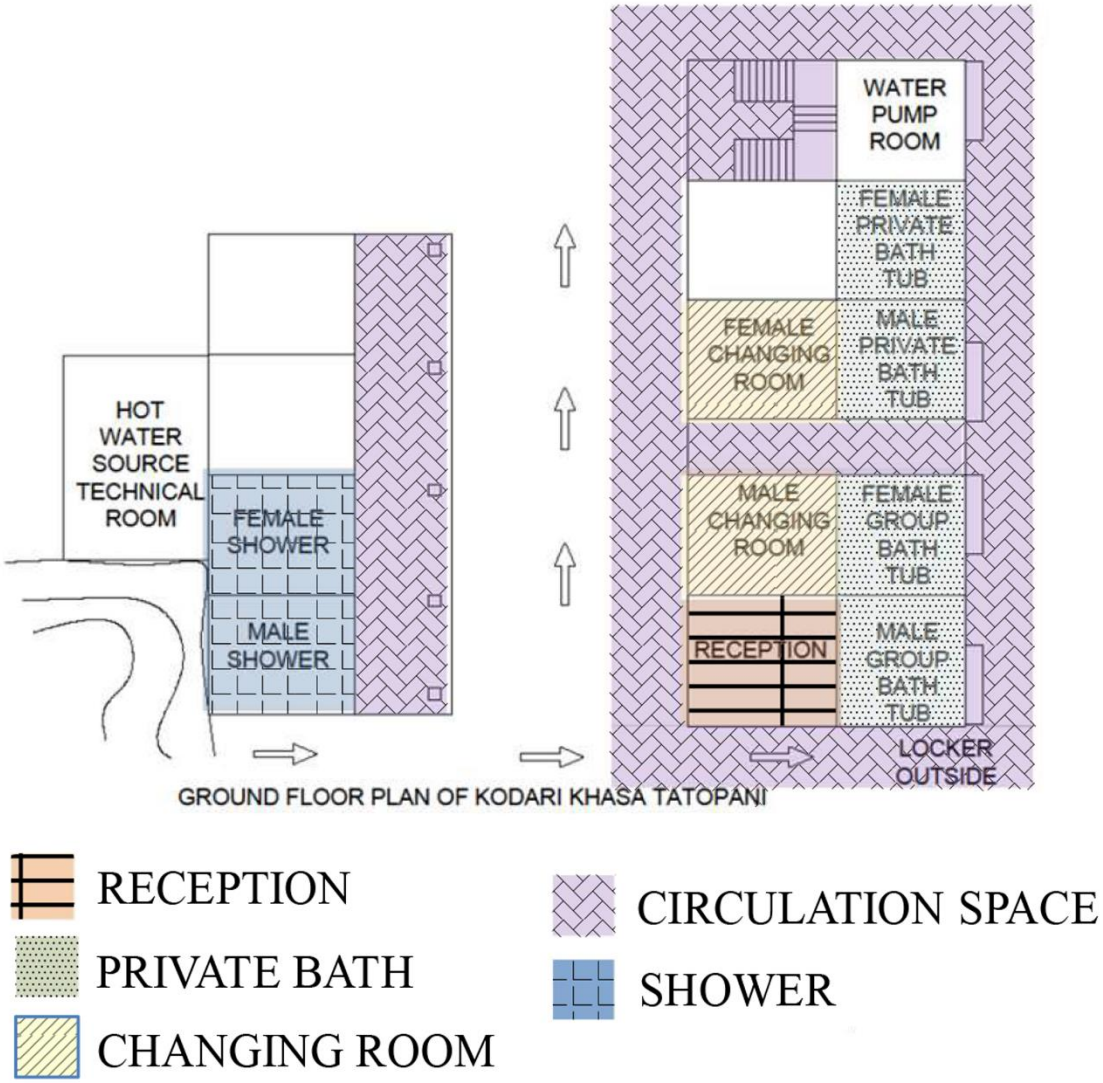


Figure 74 Ground Floor Plan of Kodari Tatopani

Inference

-Provision of proper shower as well as private bath tubs

-Enclosed bathroom without proper ventilation will be problematic for breathing.

Table 14 Comparision table of case studies

Case Study	Roman Bath	Koganeyu Sento	Lares Hotspring	Singa Tatopani	Kodari Tatopani	Kharapani Tatopani	Remarks
Country	Greece	Japan	Peru	Nepal	Nepal	Nepal	-
Site	Village	City	Village	Village	Village	Village	Village
Thermal Source	Hypocaust	Machine	Quimsachata (extinct volcano)	Myagdi River	Bhotekoshi River	Seti River	River in context of Nepal
Surface water temp	45° c	44° c	37° c, 38° c, 44° c, 48° c	45° c - 48° c	44° c	48° c	45° c
Natural Hotspring	✗	✗	✓	✓	✓	✓	✓
Site Area	5478.37 sq.m	410.54 sq.m	7874.34 sq. m	2800.39 sq. m	3372.16 sq.m	-	
Bathspace	Indoor	Indoor	Outdoor	Semiopen	Indoor	Outdoor	All
Bathing Facilities	4 Hot pools 2 Cold pools	6 Hot tubs 2 Sauna 1 Cold pool	4 small hot pools 1 large hot pool 2 cold pools	1 large pool, 2 small pools	No large pool, Private pools, Hot shower	Wild hot spring, no artificial pool	All types
Capacity	-	44	100	300	90	30	-
Big pool Dimension	12.2m X 6m	-	15m X 8m	11m X 5.8m	-	12m X 6m	Average 110sq. m
Small Pool Dimension	-	2.8m X 2.8m	5m X 3.5m 6m X 4m	3.2m X 3.2m	1.7mX1.7m 1.7mX0.7m	-	Average 12 sq. m
Pool Depth	1.6 m	1 m	1.5 m	1.2 m	0.6 m	1.6 m	1.22 m
Shower Area	-	5m X 1.8m	5m X 2m	3m X 1.5m	4m X 2m	-	Average 9 sq. m
Changing & Locker Room	4m X 3m	5m X 3.6m	3.6m X 3.6m	4.2m X 3.2m	3.6m X 3m	-	Average 12 sq. m
Rooms	✗	✗	✓	✗	✗	✗	✓
Structure Type	Roman architecture	Enclosed RCC	Outdoor pools	Semi open truss	Enclosed RCC	Outdoor	-

5.3 Overall Inference

- Use of Ramps for physically challenged people.
- Utilization of scenic view of river during bath.
- Semi open structure for balancing humidity.
- Provision of proper shower as well as private bath tubs.
- Enclosed bathroom without proper ventilation will be problematic for breathing.
- Natural wild hot springs give sense of connection to the nature and thrilling adventure.
- Source of thermal springs needs to be protected.
- Use of central space for access to multiple room.
- Interior decoration should be based on the myth and history of the site through artistic use of materials.
- Dual entrance helps in circulation and crowd management.
- Separation wall that does not reach ceiling for better humidity control.
- Provision of sauna before cold bath.
- Use of mural showing traditional bathhouse art for interiors.
- Service of basic rooms for the users who wants to stay.
- Creating the ambience of local culture.
- Landscaping with outdoor hot pools and hot shower.
- Outdoor garden with picnic spot, camping zone & bonfire pits.

Chapter 6. Site Study

6.1 Site Background

Manang is situated in the broad valley of the Marshyangdi River to the north of the Annapurna Mountain range. The river flows to the east. Our site is located in Chame which is the headquarter of Manang District in the Gandaki Zone of northern Nepal. Chame is a resting point along the journey to one of the top favored tourist destinations in Nepal for example- Tilicho lake, Mustang, Annapurna Circuit Trek. The elevation of Chame is 2650m.

Figure 75 Chame Rural Municipality

6.1.1 Climatic Features

Climate: **Cool Temperate** climate zone.

mild to warm summers and **cool to cold winters**

Moderate rainfall or sporadic drought

Average Minimum Temperature 2°C

Average Maximum Temperature 20 °C

Average Snowfall 2cm (Avg. 20 days)

Average Rainfall 400mm (July and August being maximum rainfall month)

Average Wind 9 kmph

Average UV Index 4

(Manang Climate Weather Averages, 2022)

Figure 76 Water freezing on cliff in December,2021. Photo Source: Samir Gurung

6.1.2 Tourist Inflow

27,068 foreign tourists visited the trekking route in 2017 which is the highest number for tourist record in 21 years since the record keeping was started. Statistics from Annapurna Area Project Conservation (AACP) show that there were more visitors in 2017 than in any years. (Gurung, 2018)

Sources at the Tourist Check Post in Besisahar, Lamjung district, said as many as 60 tourists pass through Lamjung for Annapurna Trekking Circuit on a daily basis.

Around 200 international tourists reach the trekking route on a daily basis during the peak tourism season. (Nepal Travel News, 2016)

September to November and February to April are considered to be the peak seasons for Annapurna trekking. with 5,039 international tourists recorded for last year. (Nepal Travel News, 2016)

Comparison of flow of tourist in Nepal and in Manang

The graph shows the number of tourists in Nepal and in Manang. The trends of the number of tourists in Nepal and Manang are similar.

No. of people visiting hotspring in Chame- **200 per day**

Source: ACAP office in Manang

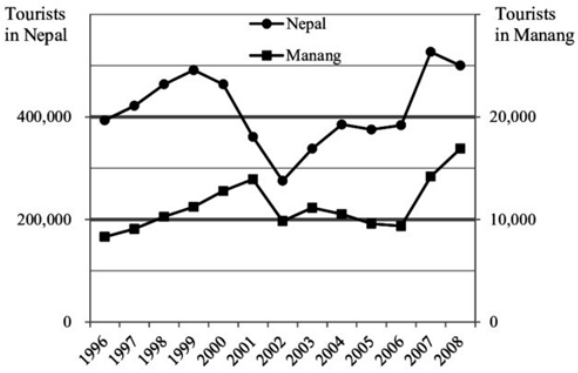


Figure 77 Comparison of tourist in Nepal and in Manang. Source: ACAP office in Manang,2008

CHART 4.1: TOURIST ARRIVALS BY PURPOSE OF VISIT, 2020

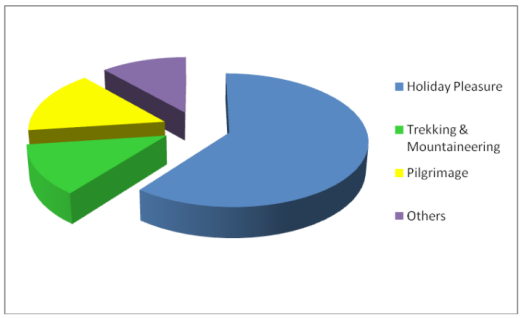
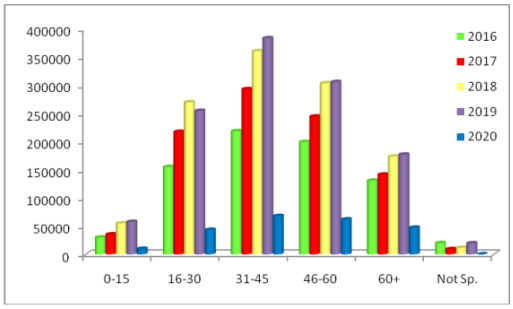
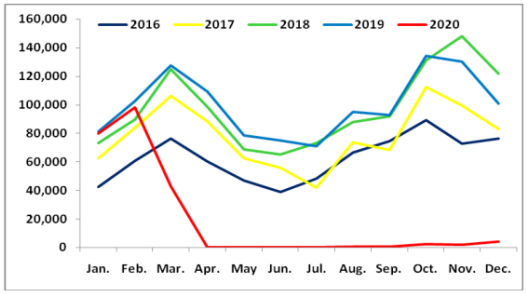


CHART 2.5: TOURIST ARRIVALS BY AGE GROUP, 2016-2020



(Ministry of Culture, 2021)

CHART 2.2: TOURIST ARRIVALS BY MONTH, 2016-2020



(Ministry of Culture, 2021)

6.1.3 Population of Chame

According to **2011 Nepal Census**, the population of Chame Rural Municipality was 1129 living in 279 individual household. (National Planning Commission, Nepal Census 2011, 2012)

According to **2021 Nepal Census**, the population of Chame Rural Municipality is 1272 living in 333 households with 391 families where there are 728 males and 544 females.

(National Planning Commission, National Census 2078, 2021)

मनाङ					
चामे गाउँपालिका	३३३	३९१	१२७२	७२८	५४४
नार्पा भूमि गाउँपालिका	१२५	१२५	३९८	१७०	२२८

द्रष्टव्य: स्थानीय तहको जनसंख्यामा संस्थागत परिवारको जनसंख्या समावेश गरिएको छैन । त्यसकारण स्थानीय तहको जोड जिल्लाको जनसंख्यासँग फरक पर्न सक्दछ ।

(National Planning Commission, National Census 2078, 2021)

तालिका १७: सबैभन्दा बढी र कम जनघनत्व भएका पाँच जिल्लाहरु

क्र.सं.	जिल्ला	जनसंख्या		जनघनत्व		क्र.सं.	जिल्ला	जनसंख्या		जनघनत्व	
		२०६८	२०७८	२०६८	२०७८			२०६८	२०७८	२०६८	२०७८
१	काठमाडौं	१७४४२४०	२०१७५३२	४४१६	५१०८	१	मनाङ	६५३८	५६४५	३	३
२	भक्तपुर	३०४६५१	४३०४०८	२५६०	३६१७	२	मुस्ताङ	१३४५२	१४५९६	४	४
३	ललितपुर	४६८१३२	५४८४०१	१२१६	१४२४	३	डोल्पा	३६७००	४२९५९	५	५
४	रुपन्देही	८८०१९६	१११८९७५	६४७	८२३	४	हुम्ला	५०८५८	५५४९६	९	१०
५	सुनसरी	७६३४८७	९३४४६१	६०७	७४३	५	मुगु	५५२८६	६६६५८	१६	१९

(National Planning Commission, National Census 2078, 2021)

6.1.4 Social Structure

The social structure of the place is a matriarchal society where women are the head of the family and manages overall cash inflow and outflow in the house along with taking care of house, hotel and the family affairs. The men of the society are more towards staying out of the house for work as most of them are drivers and some of them are out of the city for work and education.

Key Informant:

Binod Gautam (Accountant at Infrastructure Development Office, Manang at Government of Nepal)

Samir Gurung (Civil Overseer from Chame)

6.1.5 People of Chame

Gurung of Tibetan origin, Manangi, Tamang etc caste people reside in Chame, Gurung being the largest number. Due to the provision of red passport for Manangi, many immigrants from other districts especially Gorkha, have married the Manangi and settled here. In Manang, there is a tradition of groom living in the house of bride after marriage. Many Tibetans also write their surname Gurung for the same purpose.

6.1.6 Vegetation in Chame

(S Bhattarai RP, 2007)

Plant species	Used as living fence	Harvested for fencing	Used as fuelwood
Abies spectabilis	No	No	Yes
Berberis angulosa	Yes	Yes	No
Berberis aristata	Yes	Yes	No
Berberis ceratophylla	Yes	Yes	No
Berberis lycium	Yes	Yes	No
Betula utilis	No	No	Yes
Hippophae salicifolia	Yes	No	No
Juglans regia	No	No	Yes
Juniperus communis	No	Yes	Yes
Juniperus indica	No	Yes	Yes
Juniperus squamata	No	Yes	Yes
Pinus wallichiana	No	No	Yes
Rosa macrophylla,	Yes	Yes	Yes
Rosa sericea,	Yes	Yes	Yes
Salix wallichiana	Yes	Yes	Yes
Taxus wallichiana	No	No	Yes

6.1.7 Economic activities in Chame

Tourism

Tourism is the main source of earning money in this place, the peak season being Asojh, Kartik and Mangsir. Around 200 international tourists reach the trekking route on a daily basis during the peak tourism season. (Nepal Travel News, 2016)September to November and February to April are considered to be the peak seasons for Annapurna trekking. with 5,039 international tourists recorded for last year. (Nepal Travel News, 2016)

Apple Orchard

The climate and soil of Chame is suitable for apple farming. Some families own large apple orchard and make the living out of it. Most of the families in this place have apple trees in their backyard. The apples are mainly used for exporting it to cities like Chitwan, Kathmandu, Pokhara through Besisahar.

Another main purpose of harvesting apple is for producing local alcohol.

Agriculture

People in Chame have agricultural fields to produce kodo, phapar, aalu, makai, banda and saag. The crops are not produced for economical purpose as it is not produced in large scale but it is produced for their own family and the locality.

Figure 78 Local people of Chame preparing apple alcohol in the outhouse.

Figure 80 Phapar cultivation in Chame

Figure 79 Cabbage, Spinach cultivation in Chame

6.1.8 Architectural Narrative

Traditional Architecture

Traditional loadbearing houses made up of Stones, lime mortar, timber (saal), lime coating on exterior wall and sloped roofs. One or two storey building. Houses have central courtyard for multiple purpose (drying vegetables, apples, children playing area). The boundary wall of the houses were of height 1.5m which was made by stacking stones one on top of another. Most of the houses owned small outhouse inorder to prepare apple alcohol and to store firewoods as well. Some had backyards with small kitchen garden with apple trees where as some houses even owned cattles.

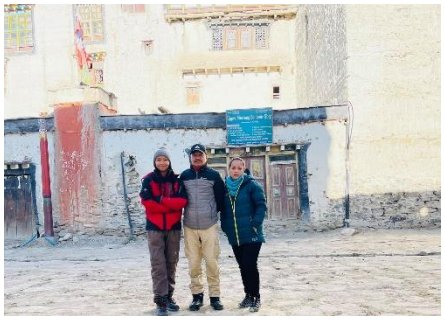


Figure 81 Houses with load bearing stone wall coated with lime

Modern alteration for trekkers

-Colourful houses to attract trekkers.Mainly blue and purple colour used with white. Yellow and red colour used in beams, railings, posts, furnitures to some extent.

-Bigger windows with modern glass panels.

-Some RCC buildings were present as well even though the transportation cost of building materials like steel, cement, glasses etc were almost twice or thrice the original price as it is transported all the way from Chitwan.

-Three storey houses were seen in order to accommodate more rooms for the trekkers to stay at night

Figure 82 Traditional houses modified for tourists. Addition of vibrant colour.

Figure 83 A local two storey house in chame with loadbearing features, traditional windows, lime plaster.

Figure 84 Kitchen with centrally positioned improved wooden stove.

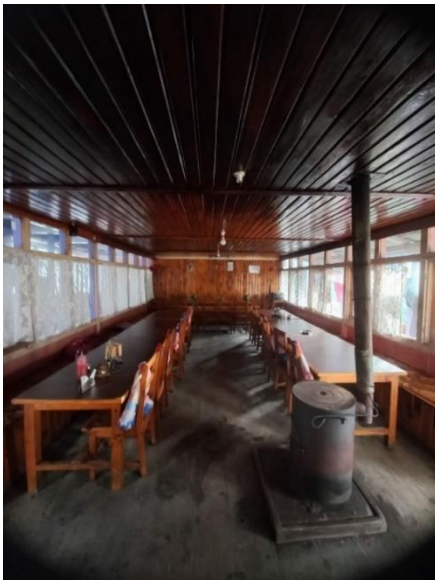


Figure 85 Dining hall with improved firewood heater.

Kitchen in Chame

1. Central chulo(traditional wooden stove made up of mud) which also act as central heating system in the room.
2. The chulo is improved stove where the smoke is passed out of the house through a pipe which leads to the water tank because of which the house recieves hot water for small house hold purpose.
3. The location is centralized for equal distribution of heat in all direction.
4. The ceiling and wall was painted black so that the ceiling and wall can absorb heat and keep the interior of the house warm.
5. In dining area, there was a heater which transmitted heat throuh radiation. Fire wood were burnt inside of the container and the smoke was allowed to flow out of the room through pipe and the heat only transmitted from upper portion of heater.

6.2 Site Location

Chame Rural Municipality, Manang (district headquarters of Manang)

Riverside site at south of Marsyangdi river and north of Besisahar- Chame sadak.

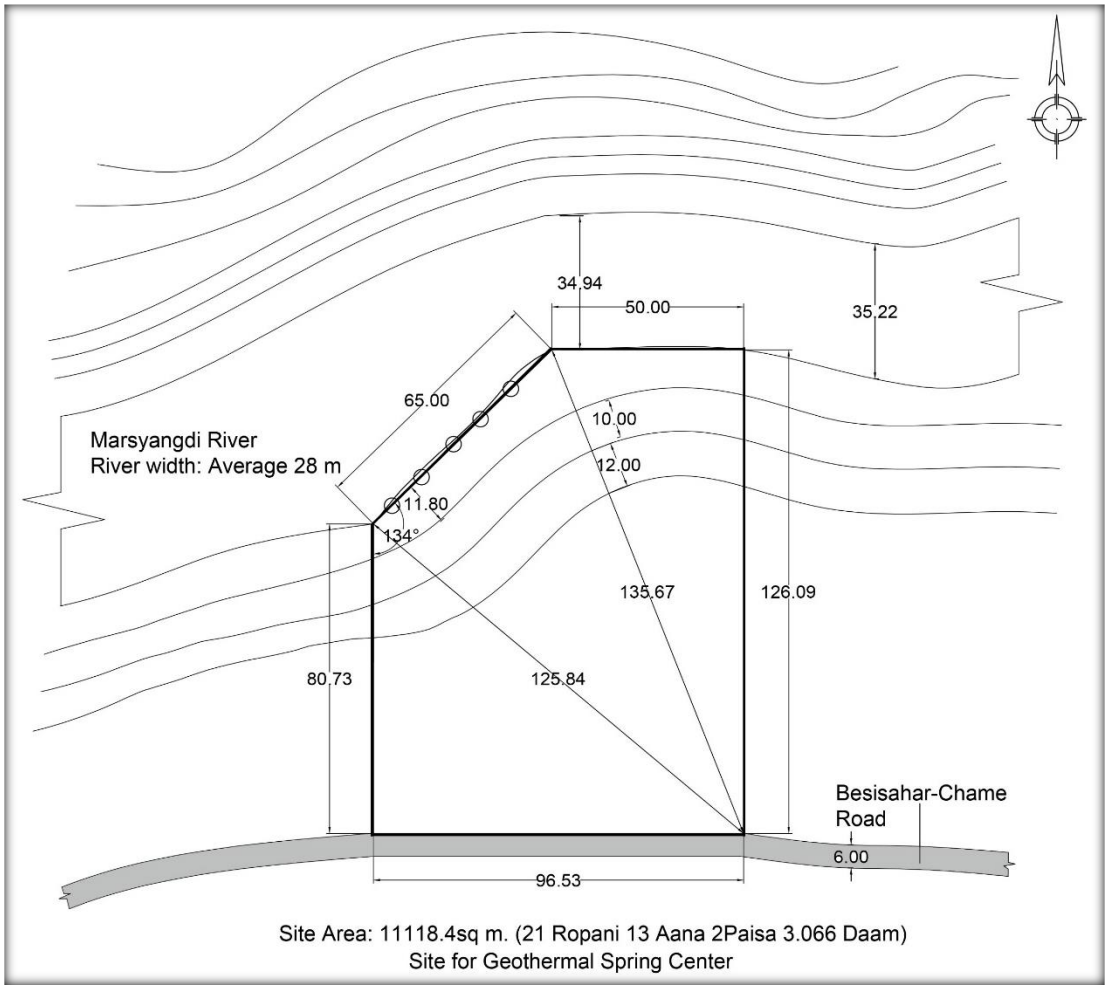


Figure 86 Site Measurement Details

6.3 Site surrounding

Site location: Chame Rural Municipality, Manang

Altitude of Chame: 2650 metre from sealevel.

Climate: **Cool Temperate** climate zone.

mild to warm summers and **cool to cold winters**

Moderate rainfall or sporadic drought

North of site: Marsyangdi River and contour on the other side

South of site: Settlement area (Residential and hotels)

East of site: Forest and hotel

West of site: Restaurant

Total site area: 11118.4 sq m. (21 Ropani 13 Anna 2Paisa 3.066 Daam)

Figure 87 A hotel in Chame during site visit.

6.4 Site Analysis

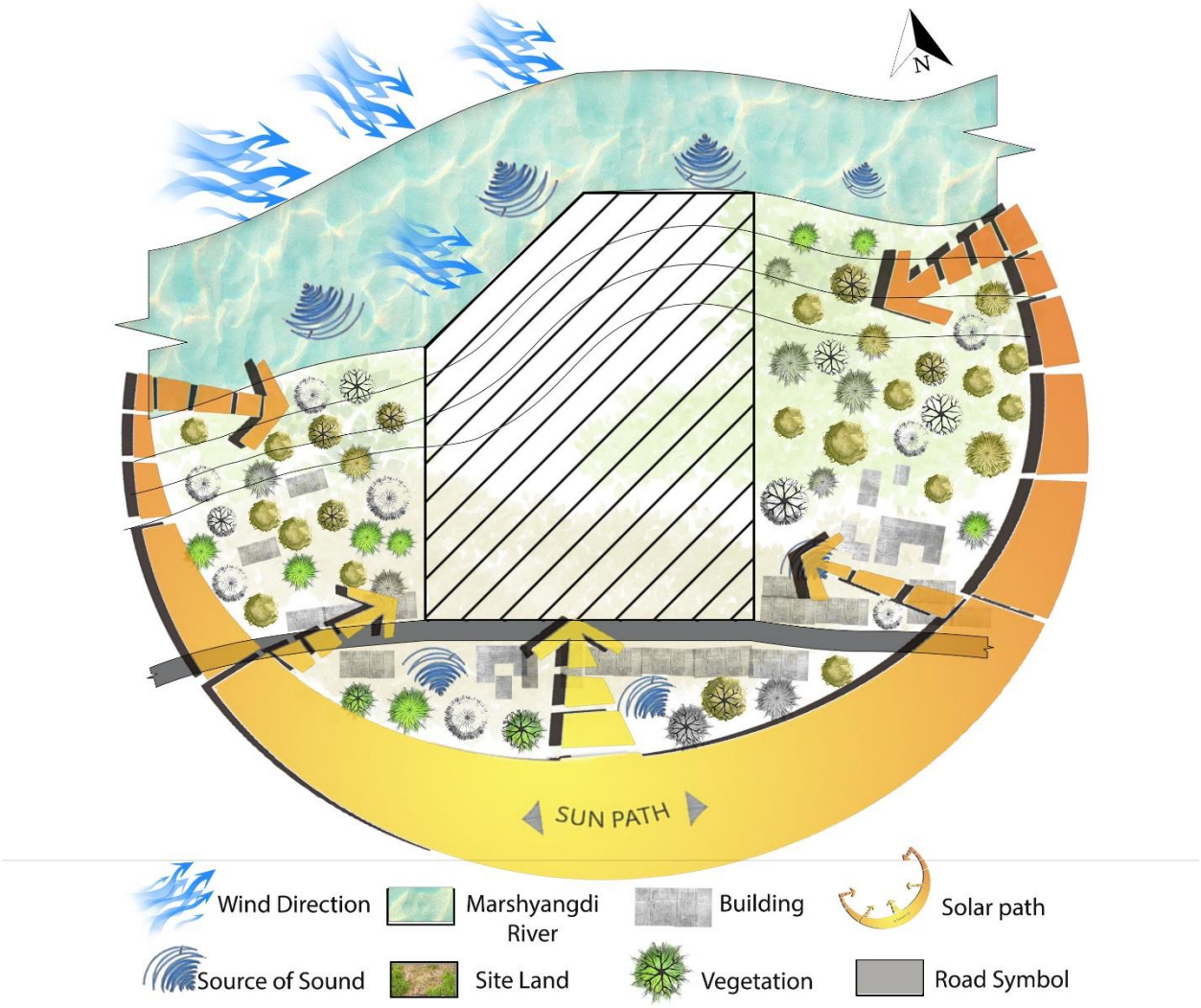


Figure 88 Site Analysis Illustration

Photos of Site

Figure 90 Site from Besisahar-Chame Road

Figure 89 Site with apple trees in some corner

Figure 91 Side of the site near Marshyangdi River

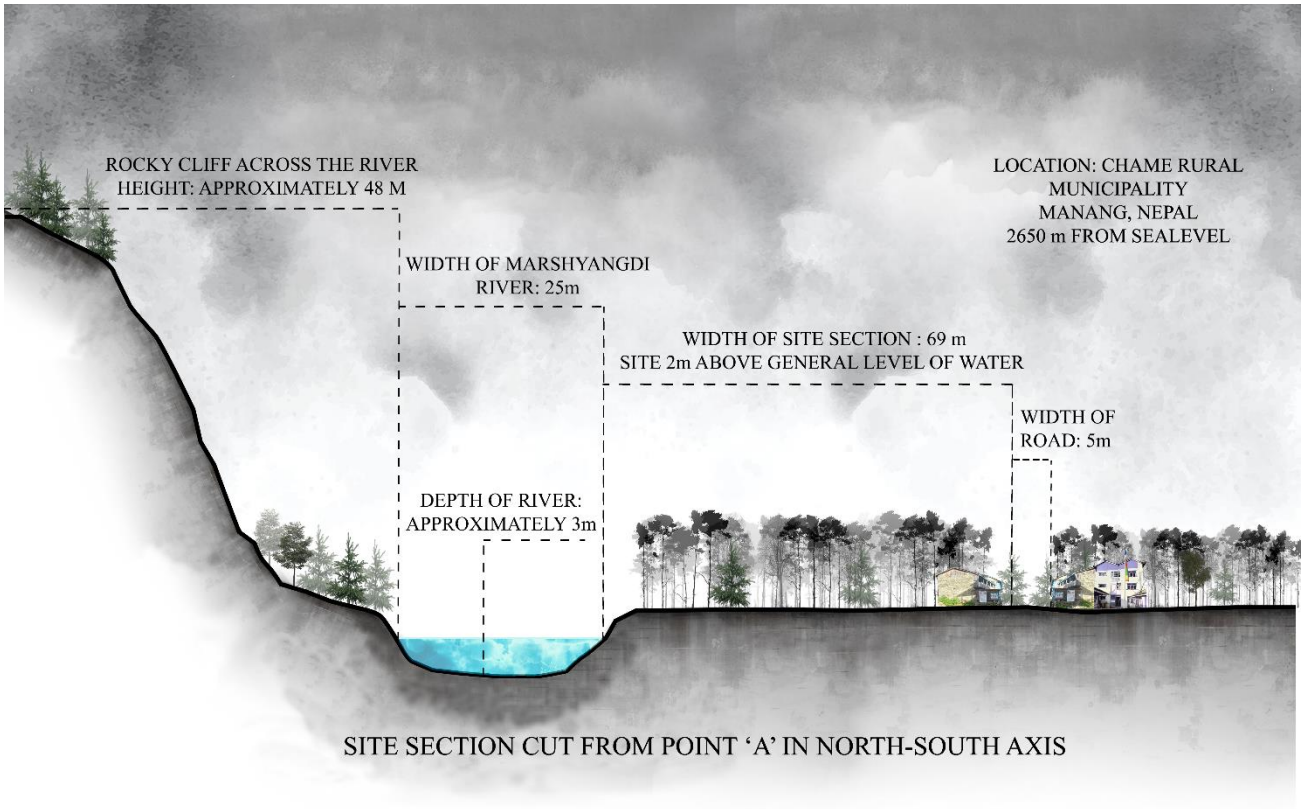


Figure 92 Site Section from Point 'A' in North-South Axis

Figure 94 Rocky Mountains of Chame

Figure 93 Embankment at the Edge of Marshyangdi River

6.5 SWOT Analysis

Strength

1. Besisahar-Chame road.
2. Tourists' inflow due to annapurna circuit trek.
3. Site is in the settlement area with services like banks, hotels, wifi, electricity etc.
4. The longer side of the site is along riverside giving more spaces for hotwater.

Weakness

1. High construction cost due to transportation problem.
2. Cold winter.
3. Gravel Road.

Opportunity

1. Riverside architecture gives scenic views and rejuvinating experience for tourists.
2. Utilization of renewable geothermal energy

Threat

1. Flood in monsoon.

6.6 Site Justification

- Chame, Manang is a resting point along the journey to one of the top favored tourist destinations in Nepal for example- **Tilicho lake, Mustang, Annapurna Circuit Trek.**
- This project gives opportunity for the local community to prosper.
- It can become **landmark for the village area**
- **More tourist engagement** which uplifts the economy with more employment opportunities and side business around the hot spring area.

6.7 Target Group

- National and International tourists passing through Chame of Manang during their trekking route.
- Local people of Chame, Manang
- Pilgrims visiting Tilicho Lake
- Pilgrims visiting Muktinath temple
- People visiting for health benefits (thermalism, balneology, and hydrotherapy)

Chapter 7. Program Formulation

The program was formulated after a sincere study of literature review, datas from all international and national case studies and data from Newfert Architect's Data. Then all those datas available were compared and analyzed. The data which was most suitable as per the site context, activity and anthropometry of target group was chosen for the final input in the table. All the required functions are listed below and the necessary parameters are listed in tabular form. After calculating total carpet area, 10 percent of it was considered for structural elements and 30 percent of it was considered for circulation space. The net total was calculated by adding all of them and finally we get the built-up area after adding all the net totals of different groups.

SN	Program	Capacity	Area (sqm.)	No.	Remarks (Sq m.)
A	-Bathing Service				
1	Indoor Hot Shower	11 per unit	16	4	64 (44at a time)
2	Indoor small hot pools	8 per unit	12	6	72
3	Lockers (for both indoor and outdoor)	38 per unit	12	4	48 (for 152 people)
4	Changing Room	8	24	4	96 (32 at a time
5	Toilet	8 per unit	20	4	80(32 at a time)
6	Health Care Room	5	30	1	30 (5 at a time)
	Total carpet area				390
	Structure10%& Circulation 30%				156
	Net Total				546
B	Restaurant				
1	Outdoor dinning	40	120	1	120
2	Indoor dinning	110	330	1	330
3	Toilet	4	12	2	24
4	Kitchen				
a	Food Preparation and s.a.	3	24	1	25
b	Storage (Dry and Cold)	-	12	1	12
c	Dishwashing Area	-	10	1	10
d	Supplies and waste coll.	-	10	1	10
	Total				531
	Structure10%& Circulation 30%				212.4
	Net Total				743.4

C	Accommodation Unit				
1	Deluxe	36	30	18	540
2	Standard	54	20	18	360
	Total		392		900
	Structure10%& Circulation 30%				360
	Net Total				1260
D	Administration				
1	Reception	35	30	1	30
2	Lobby	15	20	1	20
3	Administration Unit	2	16	1	16
4	Data Storing Unit	-	12	1	12
5	Manager's Office	1	12	1	12
6	Store Room		16	1	16
7	Toilet	1	2.5	2	5
	Total		111		111
	Structure10%& Circulation 30%				44.4
	Net Total				155.4
E	Service Area				
1	House Keeping	4	24	1	24
2	Laundry Room	4	20	1	20
3	Power House	3	20	1	20
4	Janitor's Closet	-	3.5	1	3.5
	Store Room		42	1	42
	Total		109.5		109.5
	Structure10%& Circulation 30%				26.95
	Net Total				136.45
F	Staff Area				
1	Kitchen	2	12	1	12
2	Dining Area	10	16	1	16
3	Bedroom	3	16	3	48
4	Toilet	1	2.5	2	5
5	Guard House	2	16	1	16

	Total		97		97
	Structure10%& Circulation 30%				38.8
	Net Total				135.8
	A+B+C+D+E+F=TB		2977.05		
	Total Built up area: TB		2977.05		
G	Outdoor Component				
1	Big Pool (Depth 1.5m)	36	36	3	108
2	Small Pool (Depth 1.2m)	8	12	4	48
3	Wild Hot Spring	5	12	6	60
4	Semi Open Hot Shower	8	9	4	36
5	Cool Down Space	28	30	6	180
6	Garden & Parks	-	350	1	350
7	Outdoor Unit (Toilet, Changing room, shower, locker)	1	10	8	81 (8 at a time)
8	Overhead Tank R=2.5m	15000 gal.	20	2	40
9	IWT Grey Water Treatment Plant	-	195	1	195
					1382
H	Parking Area				
a	Jeep Parking	18 Jeep	3mX 6m	18	324
b	Two-Wheeler Parking	1	1.32	64	84.48
	Total				408.48
	Circulation 40%				163.392
	Total outdoor space required				1953.872
	Total Built Up Area				2977.05
	Ground Coverage (1.5 floors)		1984.7		28%of site
	Total required Area		3938.57		7.8 Ropani
	Risk zone in site		2125.4		4.2 Ropani
	Open space due to river side		2543.7		8 Ropani
	Area of proposed site		7270.4		20Ropani

Chapter 8. Design Concept

As the project is heavily influenced with water and the project is site centric with special location of river source, the concept of this design is union with nature. The term 'Aikyam' is used for being one with nature. Through this project, we want to inspire feeling of union of humans with nature away from this busy day to day rat race that we are bound to follow. A delightful vacation experience through work of architecture and engineering with nature's gift that is hot water spring.

Source: Self sketched

8.1 Ways to inspire feeling of union with nature

8.1.1 Sensory Experience

Sensory experience of union can be felt because of unique properties of hot water spring.

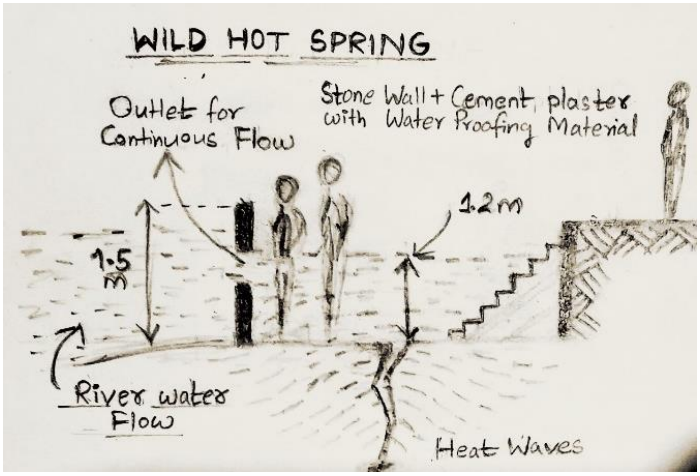
Touch: The temperature of the hot water which is generally 37° c to 48° c gives different sensation to people.

Visual: Soaking in hot spring water while looking at large rocky mountain and free flowing river is a visual treat for the visitors.

Sound: The sound of flowing river in nature gives a relaxing sensation while bathing and meditating.

Taste: The mineral contents in hot spring water makes the water taste salty. The hot spring water has been proven beneficiary for health hence can also be drank.

Smell: The natural presence of different kinds of mineral salts in the hot spring water gives a different kind of smell. This certainly gives a new experience to the way we take a bath.



Source: Self sketched

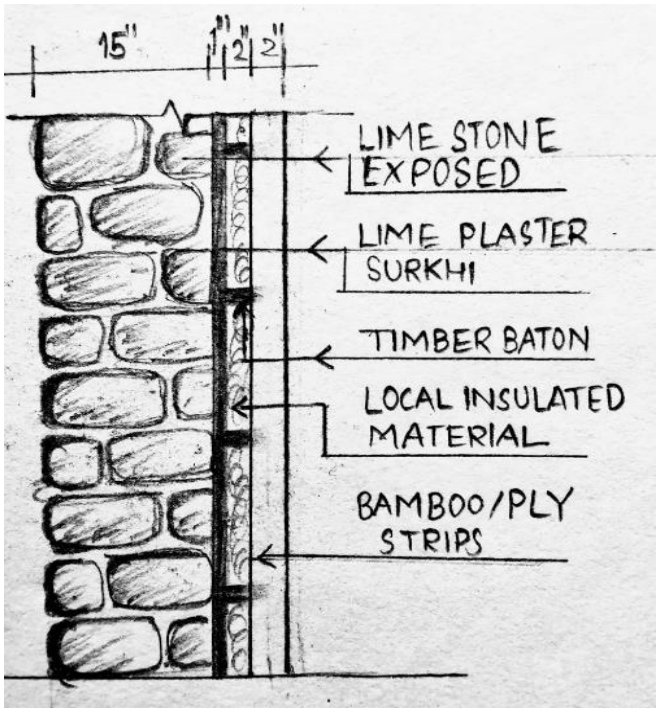
Wild Hot spring Building Material

Stone wall + Cement Plaster +Water proofing Material

Openings to be given for outflow of water along with river stream

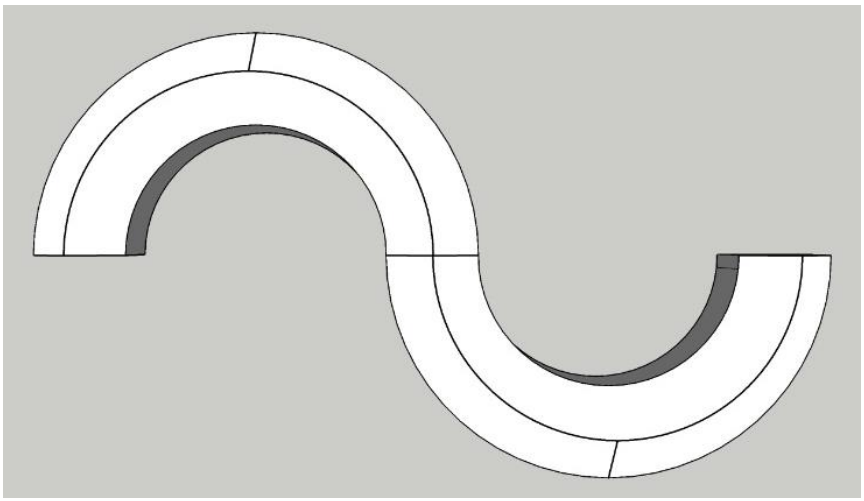
8.1.2 Building Materials and Building Construction

- Use of local building materials like lime stones of Manang, timbers, lime mortars, lime plasters, slates.
- Use of vernacular inspired design through the choice of building materials and building construction techniques. The roof will be sloped especially the use of gable roof and pyramid hip roof due to snow fall in winter.
- Use of passive solar design for energy efficient building. We are using insulated stone masonry wall, attic insulation design.

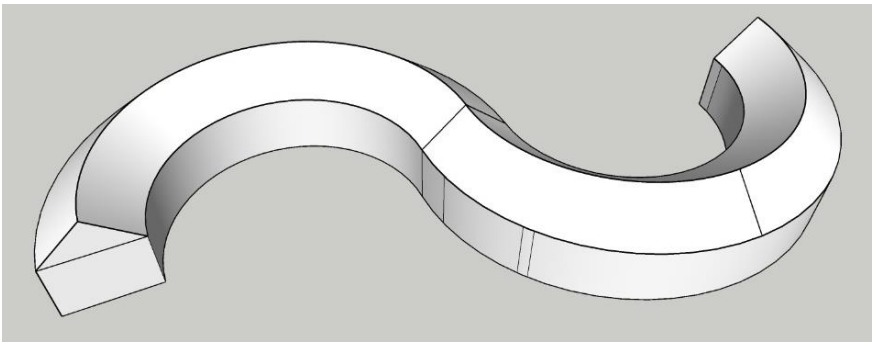


Source: Self sketched

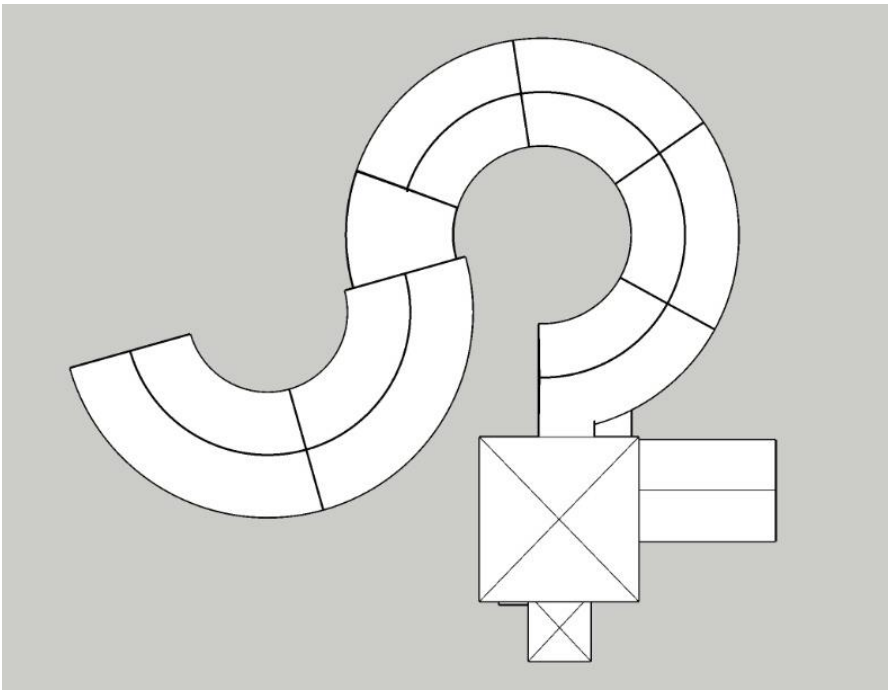
Chapter 9. Form Development



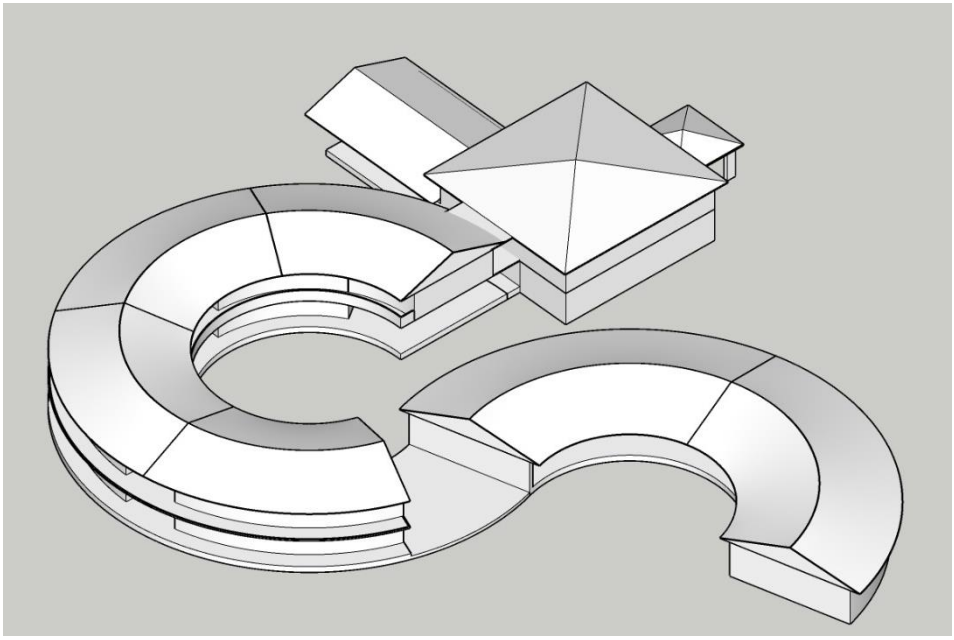
1) Initially taking the wavy line inspired from wave of river and wave of the contours.



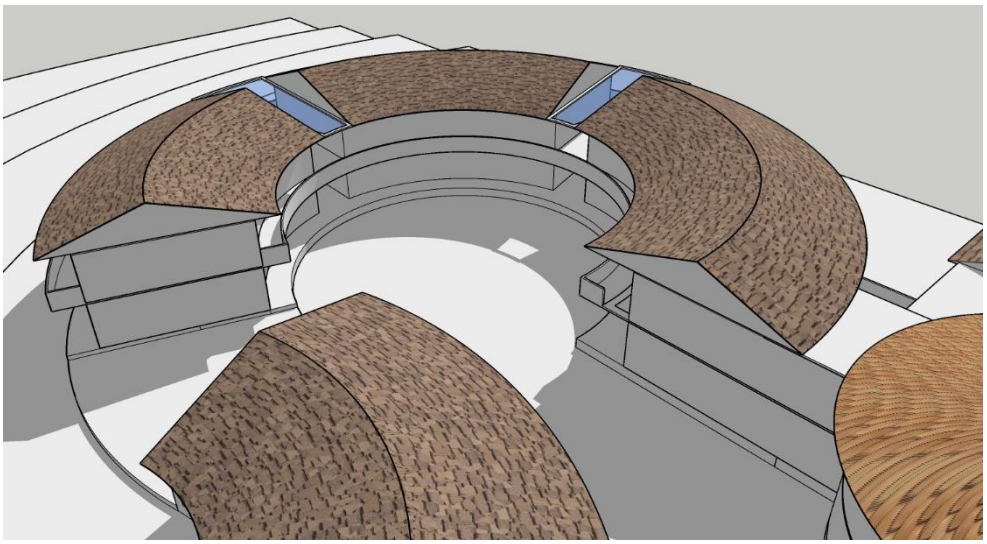
2) Roofing the shape into a sloped roof as it is necessary due to snow fall.



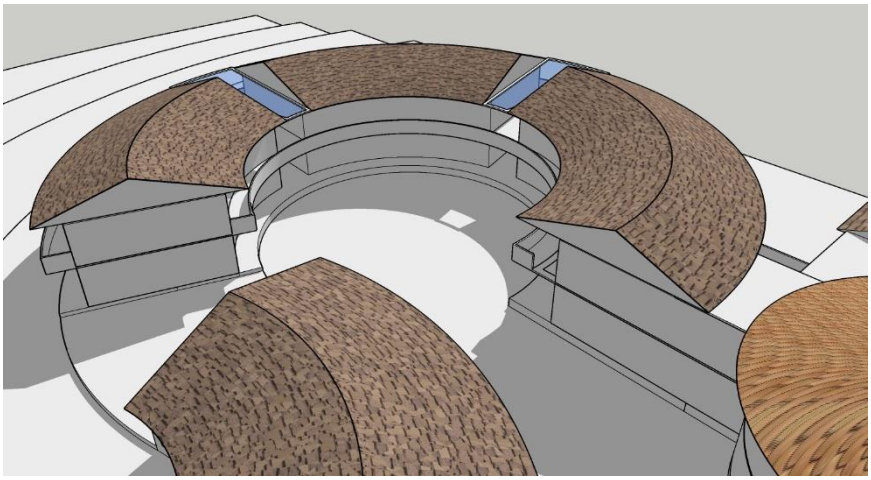
3) Adding contrasting shape to the wavy shape. Connecting & playing with the shapes



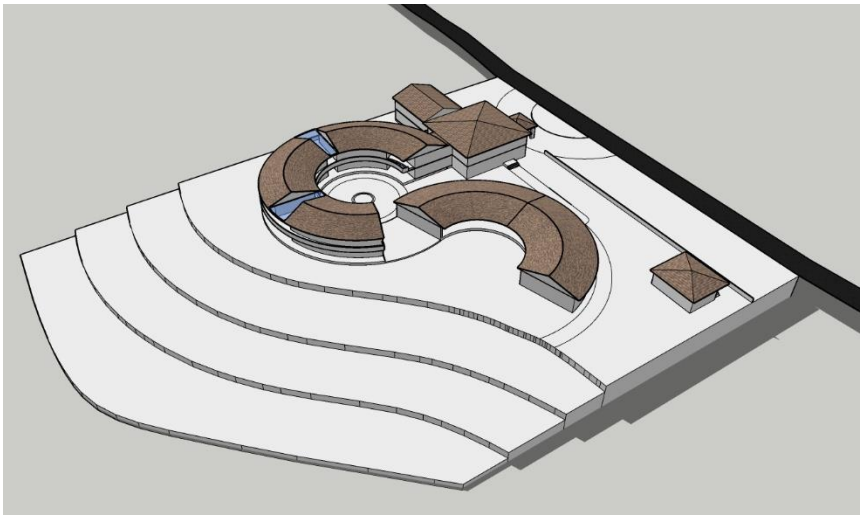
4) Roofing the 3d, subtraction in the form to break monotony.



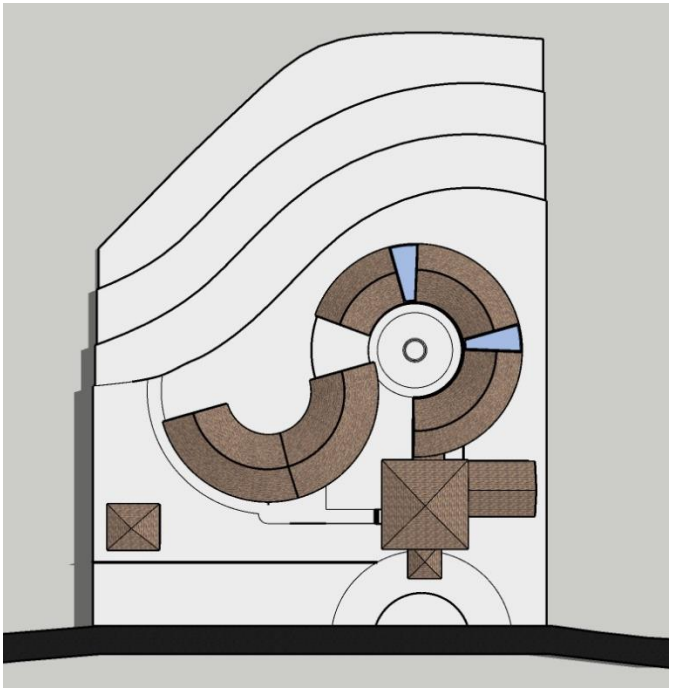
5) Further subtraction in roofing to break monotony of the roof.



Lodging facility building



Bird’s eye view



Top view of building in site

Picture Source: Self made

Chapter 10. Architectural Visualization

10.1 Zoning

Figure 95 Bird's Eye View of Project

1. The building has been designed away from river because of the mandatory river setback of 25m that we need to follow.
2. The wild hotspring has been designed at river bank at those points where springs have been identified.
3. Large hot pools which are open to sky has been placed in between the contour layer of wild hot spring and building so that the visitors can enjoy the majestic view of river and rocky mountain while swimming in the hot pool.
4. The restaurant has been placed near the roadside so that the trekkers and by passers can also take a stop and enjoy the service of restaurant without having to visit hot springs. Meanwhile, they can decide if they want to try hot spring bath as well.
5. The parking area has been placed adjacent to road as it will be easier for mobility.

10.2 Building Units Orientation

Figure 96 3D Visualization of Building

1. The hot water bath house is oriented towards river for the view of rocky mountain and river and not towards road for privacy reasons.
2. The accommodation units get both intrinsic view of gardening as well as extrinsic view of rocky mountain and river.

10.3 Outdoor Hot Pools

Figure 97 Visitors Enjoying Large Hot Water Pools

Figure 98 Water Canal System Showing Flow of Water

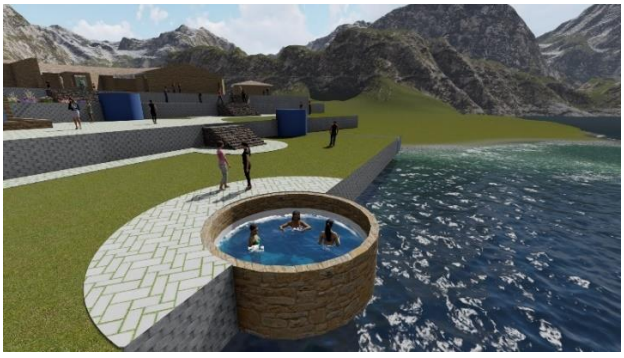


Figure 99 Visitors Enjoying Wild Hot Spring with River View and Rocky Mountain View

1. Outdoor hot pools provide larger space for the flow of people.
2. Outdoor Hot Water Pool is better as the humidity is balanced naturally.
3. A common space for both male and female. There is separate pool for male and female as well as one unisex pool so the hot spring can be enjoyed by both male and female together.
4. More space for cool down area and sun basking.
5. A vibrant environment for meeting people and for socialization.
6. Outdoor space can also be used for outdoor picnic in allocated picnic tables, playing musical instruments, relaxing in group.
7. Closer view to river and rocky mountain which gives ethereal experience.

10.4 Water Canal System and Grey Water Treatment Plant

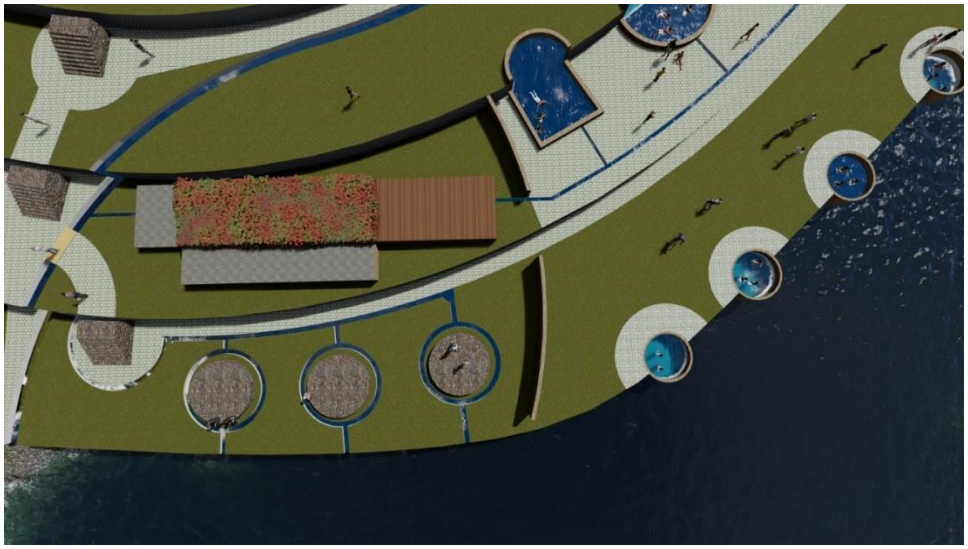


Figure 100 Water Canal System and Grey Water Treatment Plant

1. The river water has been made to flow inside the site through force of river water flow making it self-sufficient. Mechanical energy of river flow has been used instead of electrical energy to pump river water which helps to save energy and cost.
2. The downfall of water is by gravity flow method utilizing site slope which again saves energy.
3. IWT (Integrated Wetland Technology) Grey Water Treatment Plant is a natural method of treating grey water coming from hot water pools which is an innovative natural method of treatment of grey water which meets CPCB Discharge Standards.

10.5 Meditation and Yoga Area

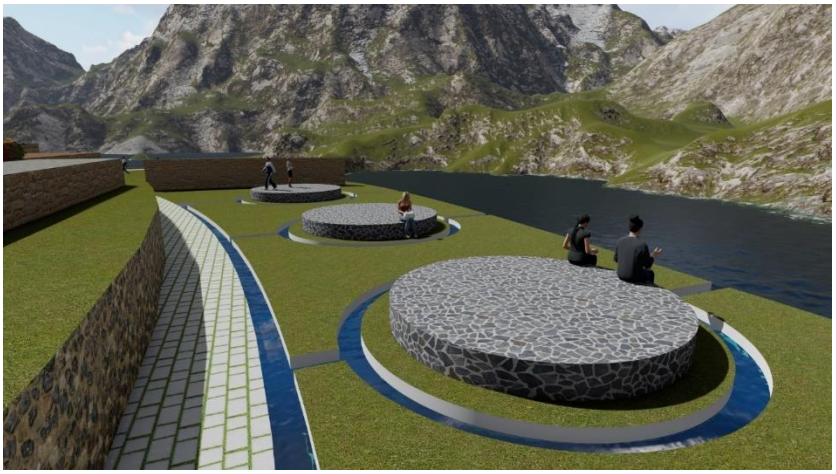


Figure 101 Meditation and Yoga Area

This space is close to river giving a beautiful view of river and rocky mountain. This place is activated by flowing water canal which enhances the experience. The view and sound of flowing river helps to create spiritual ambience.

10.6 Accommodation Facility

The visitors of hot spring often arrive for recreation and relaxation. Some might want to stay a night or two for vacation purpose or as a resting point before they continue their journey. Hence accommodation facility has been provided. Presently, the capacity for accommodation facility is of 90 people. There are two types of rooms. Type 1 is standard room and Type 2 is deluxe with luxurious experience of having a private hot tub inside their room which can be used by guests as many times as they like with full privacy.

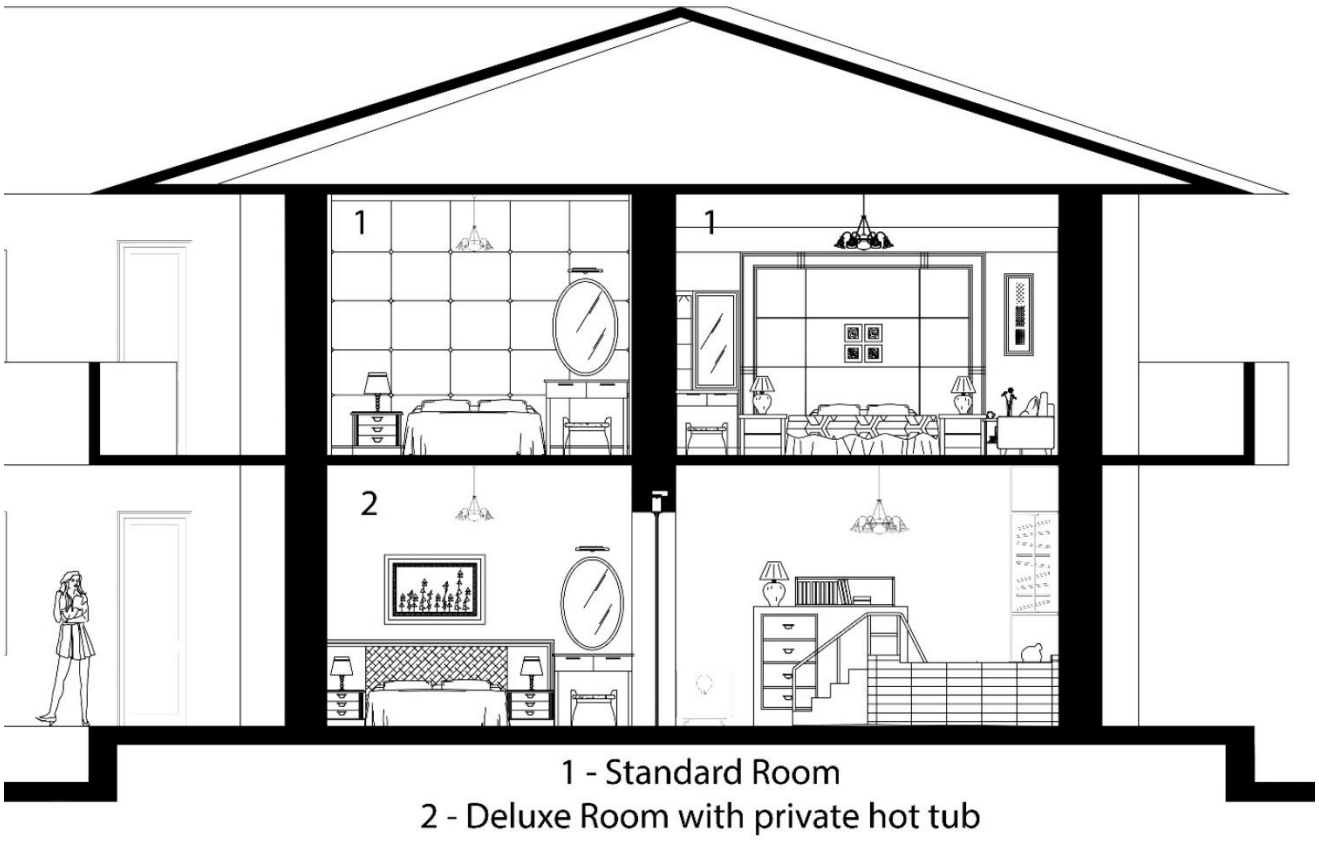


Figure 102 Different Types of Rooms

10.7 Restaurant Facility

The original essence of this place was restaurants where trekkers can stop by to have dinner lunch before they continue their journey. Hence restaurant facility has been added in this project supporting the narrative of this place as well as adhering to the requirement for the guests staying in accommodation unit. The present capacity of the restaurant is 120 at a time.

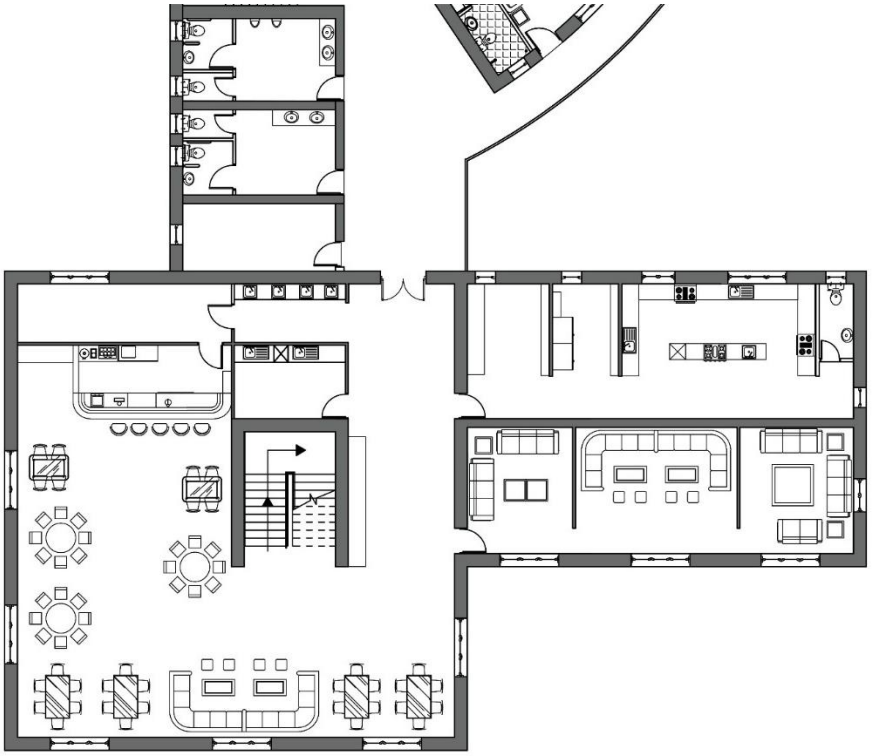


Figure 103 Restaurant Layout

10.8 Bath-House Facility

As diverse as the human nature is, some people like to experience the thrill of adventure by dipping in wild hot spring in public where as some people like to experience the hot spring in privacy with same sex people. Adhering to privacy needs, indoor bath house facility has been designed. This unit has capacity the of 48 people at a time (24 for each gender) for small hot water tub, 44 shower cubicle, changing room for 32 at a time, toilet for 32 at a time and locker for 152 people at a time (for both indoor and outdoor hot spring users). The bath house also has a resting room for those people who feel dizzy or unwell due to exposure to new environment. This room has all the first aid necessities so that the condition of sick people can be stabilized before travelling to nearest health post or hospital. The humidity balance of the bath house has been ensured through semi open architectural design. It also has a function to step outside in courtyard leading to garden for cool down breaks. The bath house faces towards the river and rocky mountain for the view.

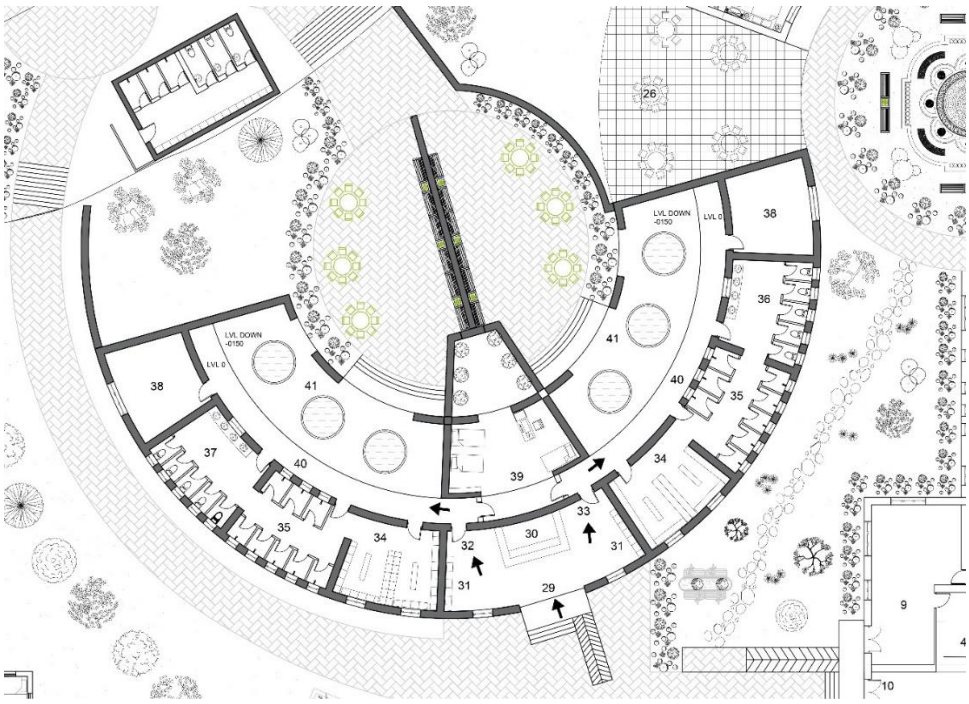


Figure 104 Bath-House Layout

10.9 Landscaping

Beautifying place with an art of gardening not only makes places poetic but also nature friendly. To make ta vacant space vibrant, landscaping has been done in various part of the site. For example- to make entrance welcoming, gardening has been done with fountains, benches, decorative placement of plants. To give view for the inward rooms of accommodation unit, courtyard has been decorated with mandala inspired gardening. The pathways have also been decorated with flowers and trees. Using plants to give sense of direction up to the point where water canal takes over to give sense of direction.

Figure 105 Riverside Facing Garden

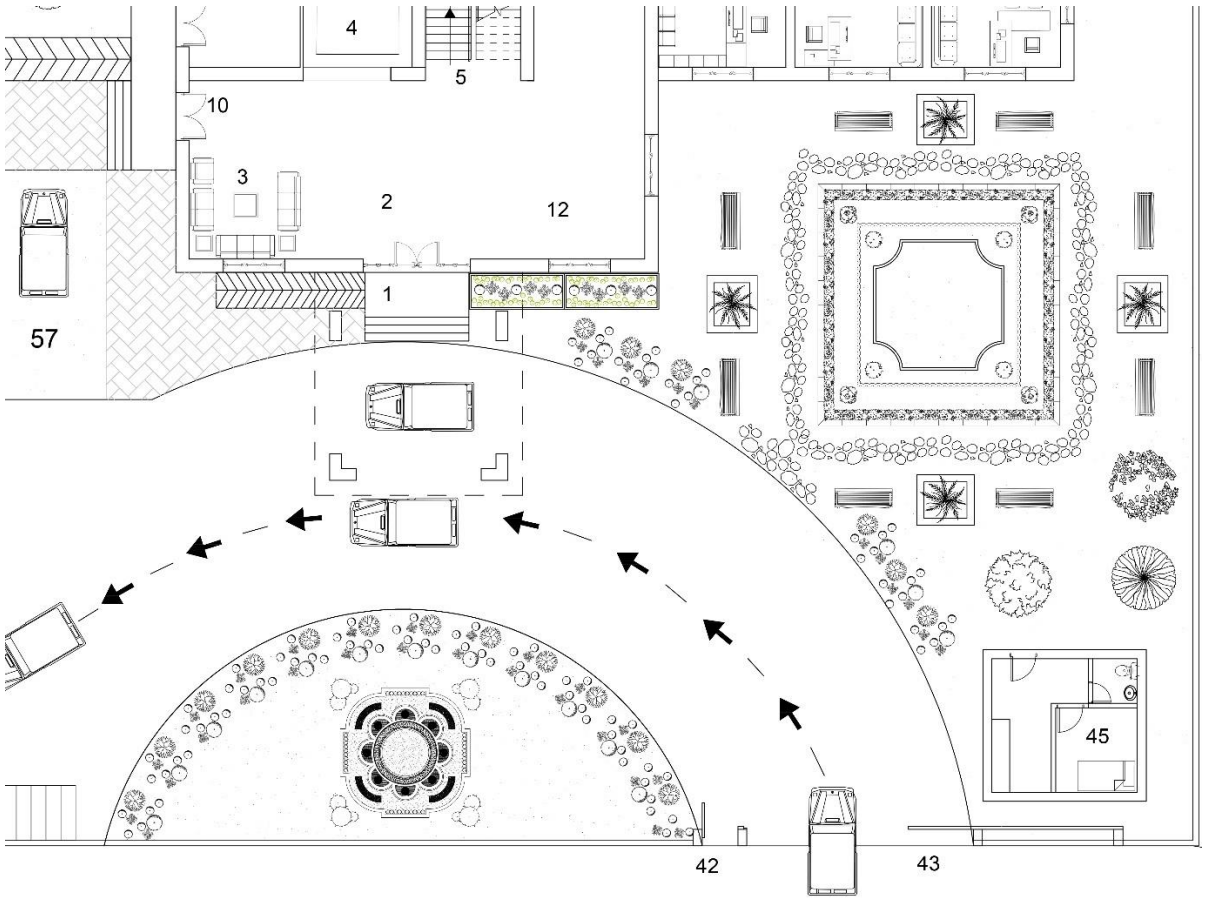


Figure 106 Welcoming Garden at Entrance

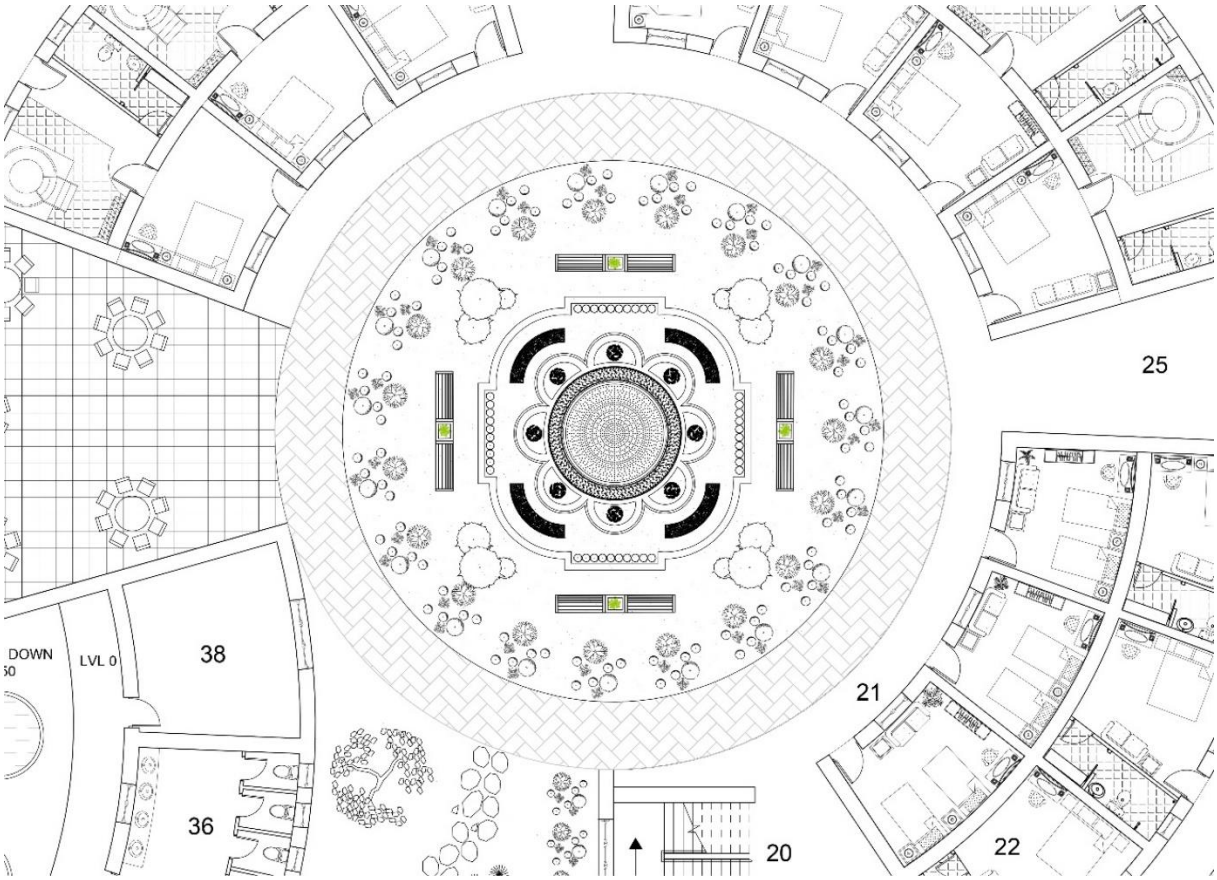


Figure 107 Courtyard Decorative Garden

10.10 Activation of Spaces by Water Canal

Figure 108 View of Rocky Mountain and River from Hot Spring Pathway

Spaces are usually activated by use of light during night time. In this design, spaces are activated even during day time with the help of water canal. The water canal run along the pathways and surrounds important spaces like gardens, wild hot spring, hot water pools, bonfire area, picnic spots, meditation and yoga spaces. The flow of water has been used for providing sense of direction.

Figure 109 Top View of Hot Spring Project

Chapter 11. Conclusions

To put the matter into a nut shell, geothermal spring (hot spring) is a renewable natural source of hot water that gets heated by the geothermal gradient beneath the earth that ultimately rises up to earth surface. As far as we can go back in history, people have used geothermal hot springs for the health benefits (heat therapy, spa therapy, hydrotherapy) proven by today's medicine. Over time, people have used hot water not only for health purposes, but also as a means of relaxation and deepening ties with others. This has boosted both local and international tourism to natural hot spring resorts. Such facilities demand certain requirements such as spatial requirements, circulation requirements and building services requirements (heating, ventilation, sanitary, waste water, electrical etc.) which can only be analyzed with architectural perspective. Such architectural requirements when addressed systematically in the complex, it not only ensures user satisfaction but also helps to prevent deterioration and exploitation of natural source of geothermal spring.

This thesis report aspires to address such architectural requirements systematically and design a hot spring center at Chame, Manang where there is a natural source of geothermal hot spring. This project creates an opportunity for local development by enhancing the tourism in this place as it is one of the most prominent stops for the Annapurna circuit trek and also for the visitors to Muktinath and Tilicho. This thesis project aspires to become an ultimate destination for both local and international tourists overcoming the narrative of being just a place to pass by while visiting another destination through engineering revitalization and architectural rejuvenation.

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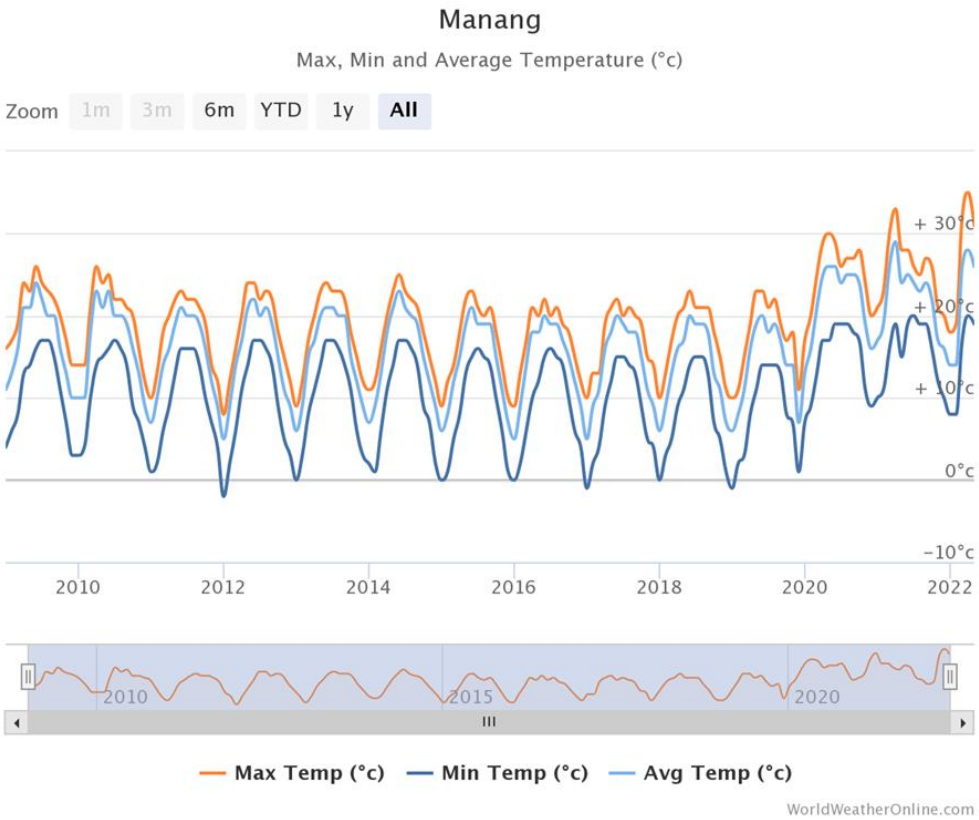
Annex 1

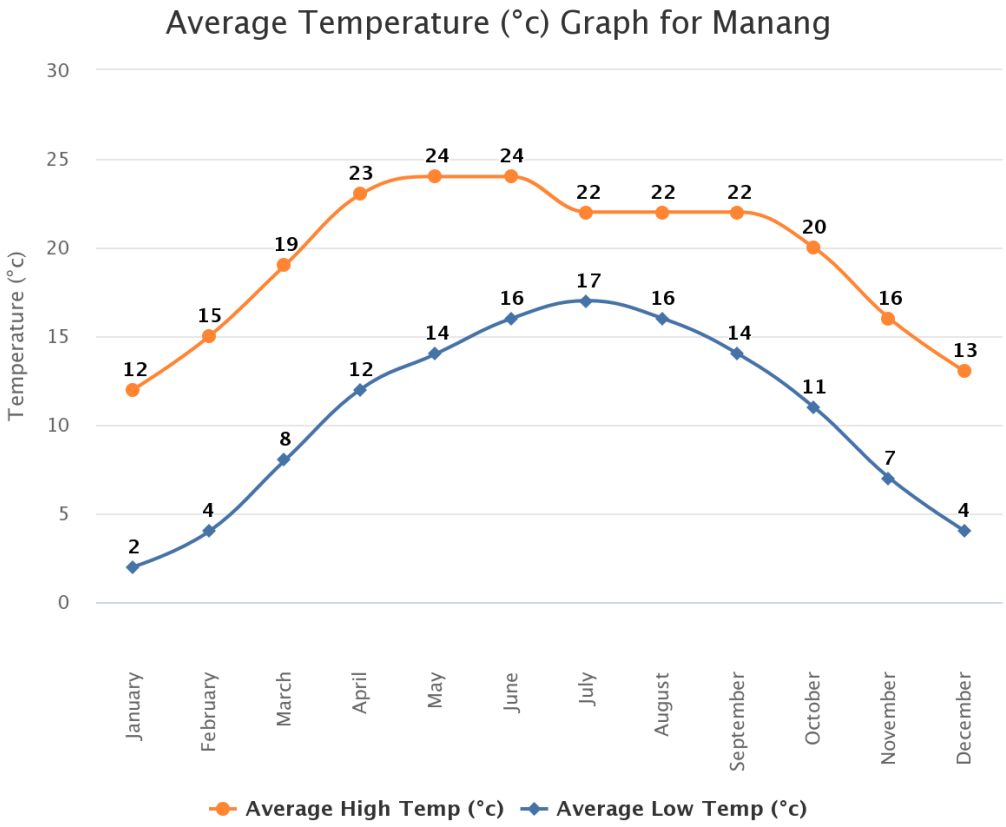
Manang, Nepal Weather Averages

Month	Day	Night	Rain Days
January	12°c	2°c	1
February	15°c	4°c	4
March	19°c	8°c	6
April	23°c	12°c	9
May	24°c	14°c	14
June	24°c	16°c	12
July	22°c	17°c	20
August	22°c	16°c	18
September	22°c	14°c	10
October	20°c	11°c	3
November	16°c	7°c	1
December	13°c	4°c	1

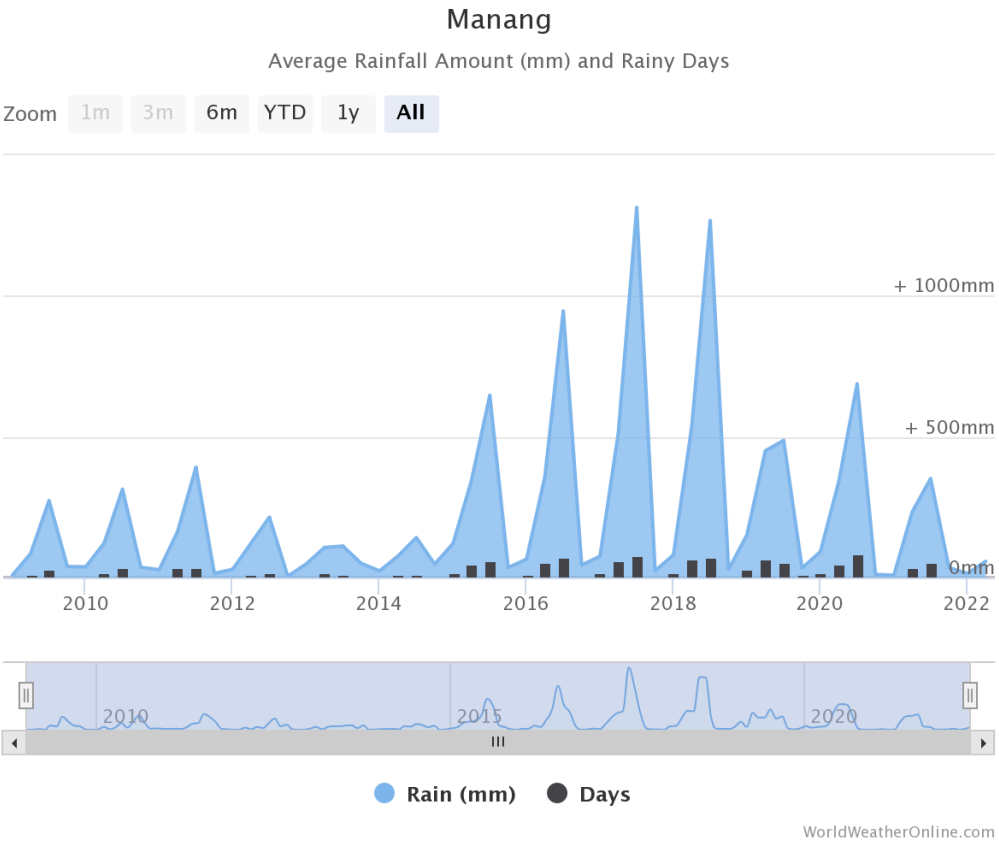
(Manang Climate Weather Averages, 2022)



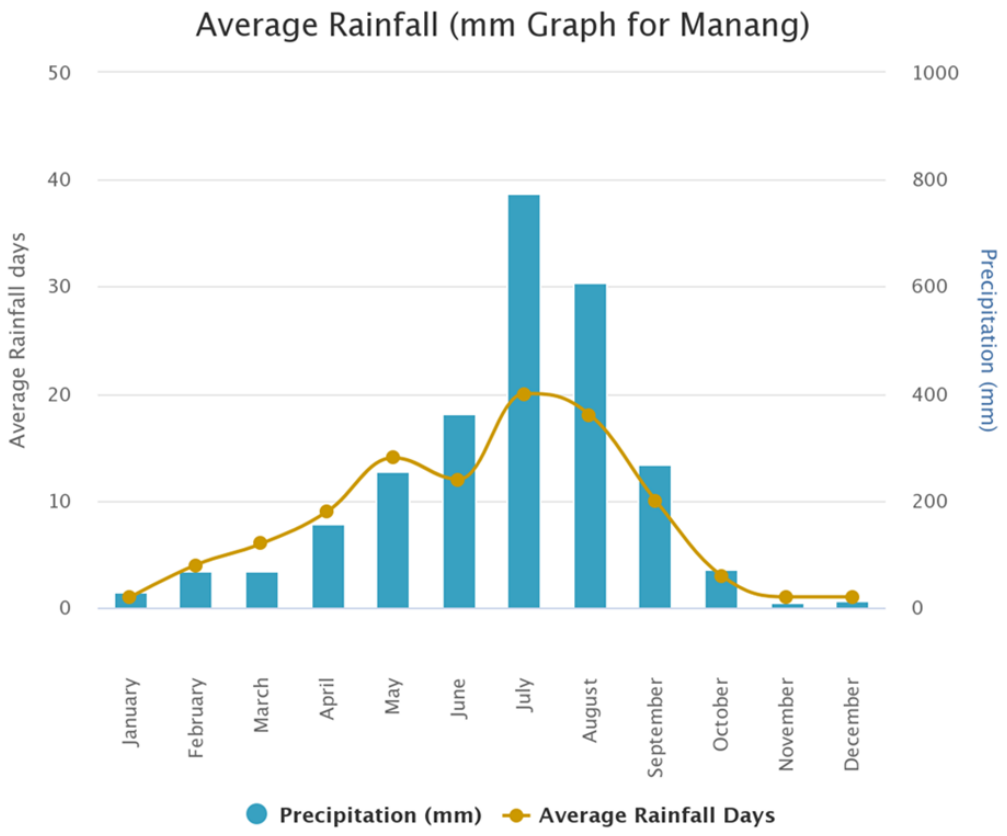
(Manang Climate Weather Averages, 2022)



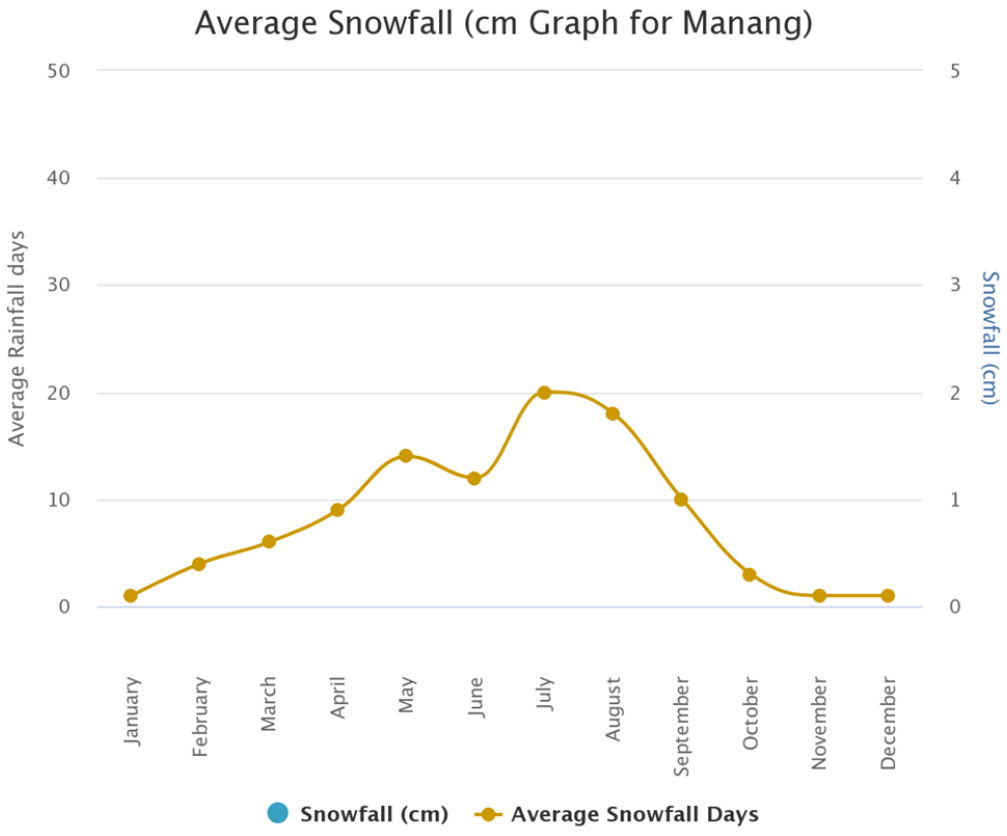
(Manang Climate Weather Averages, 2022)



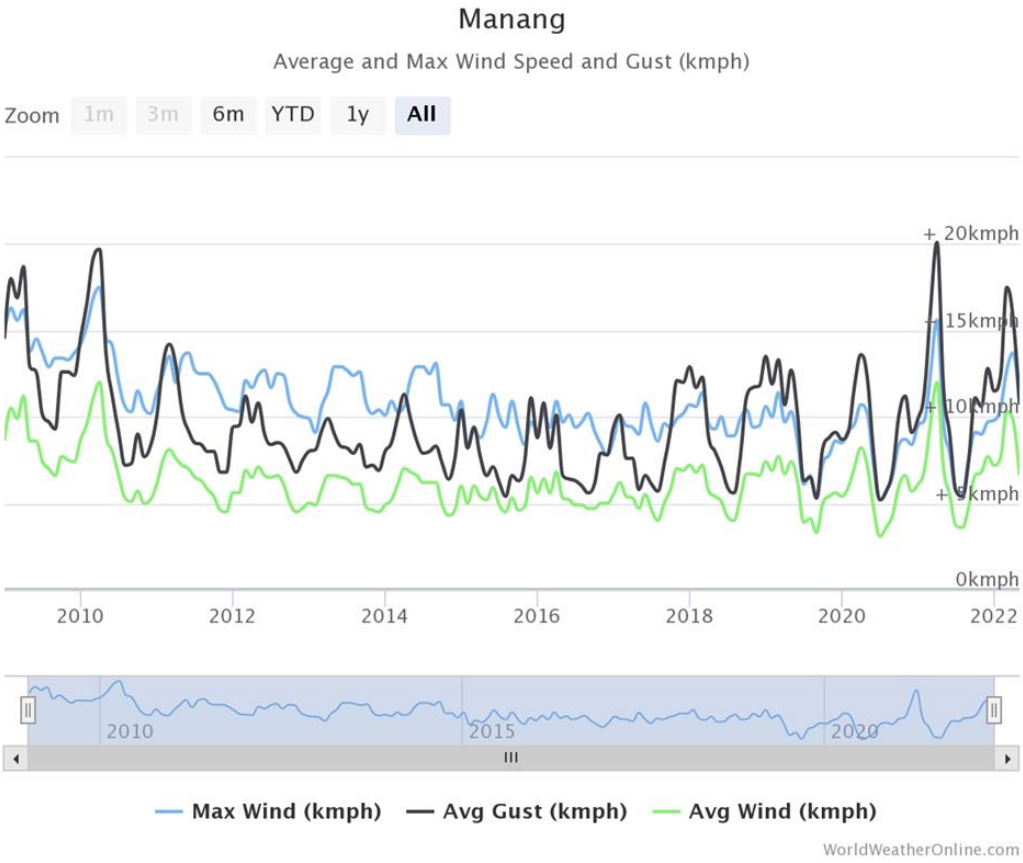
(Manang Climate Weather Averages, 2022)



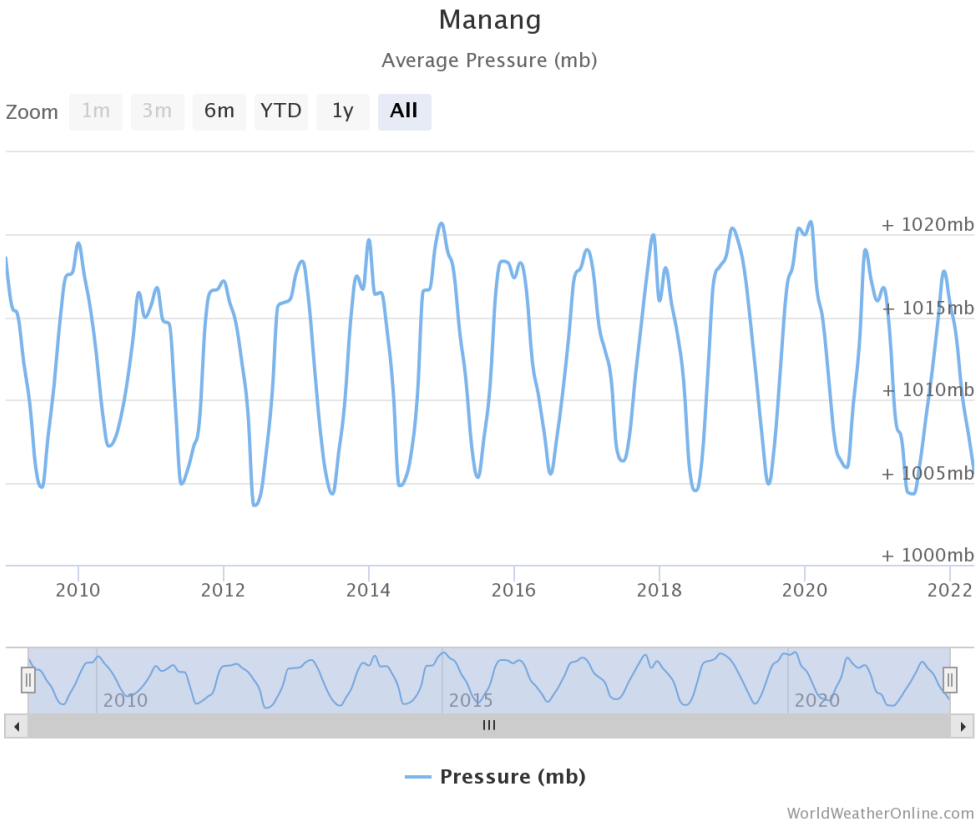
(Manang Climate Weather Averages, 2022)



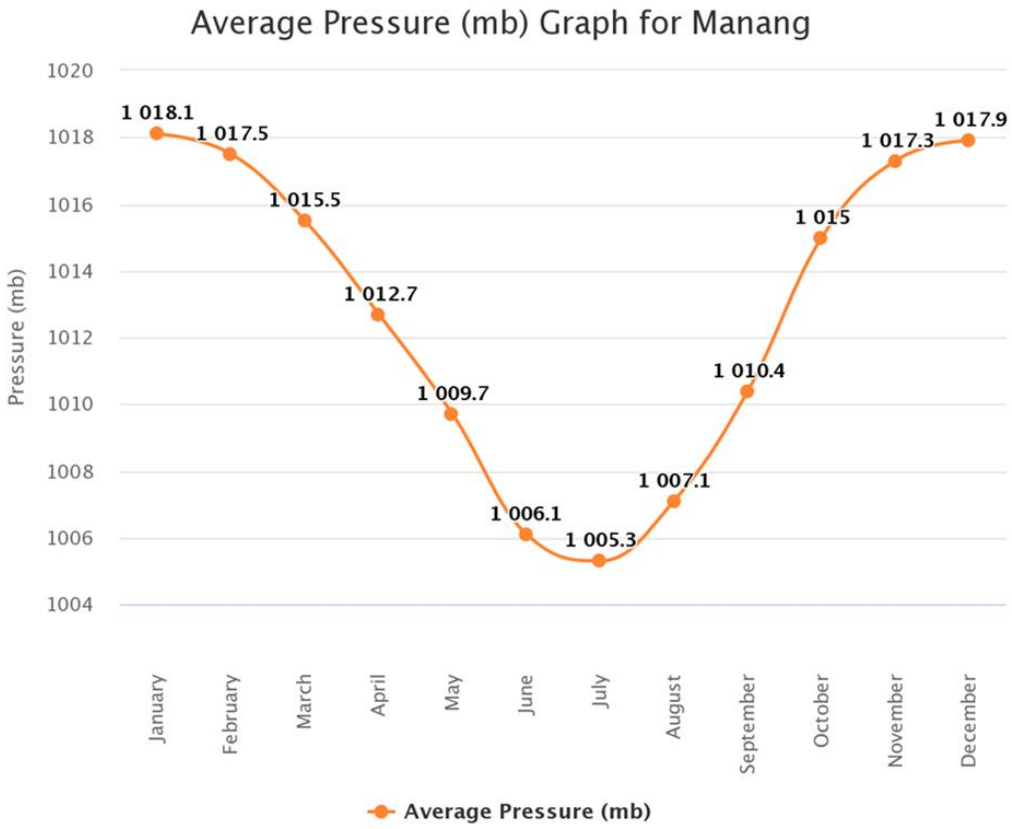
(Manang Climate Weather Averages, 2022)



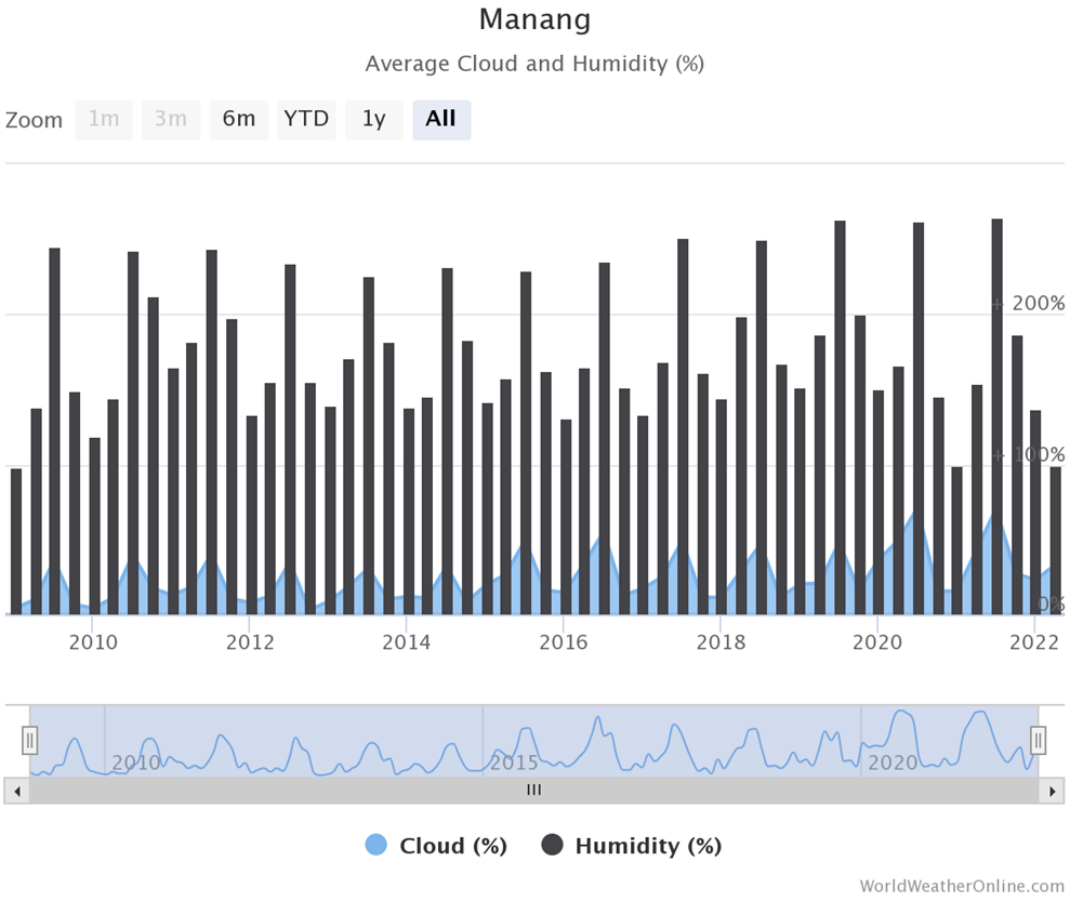
(Manang Climate Weather Averages, 2022)



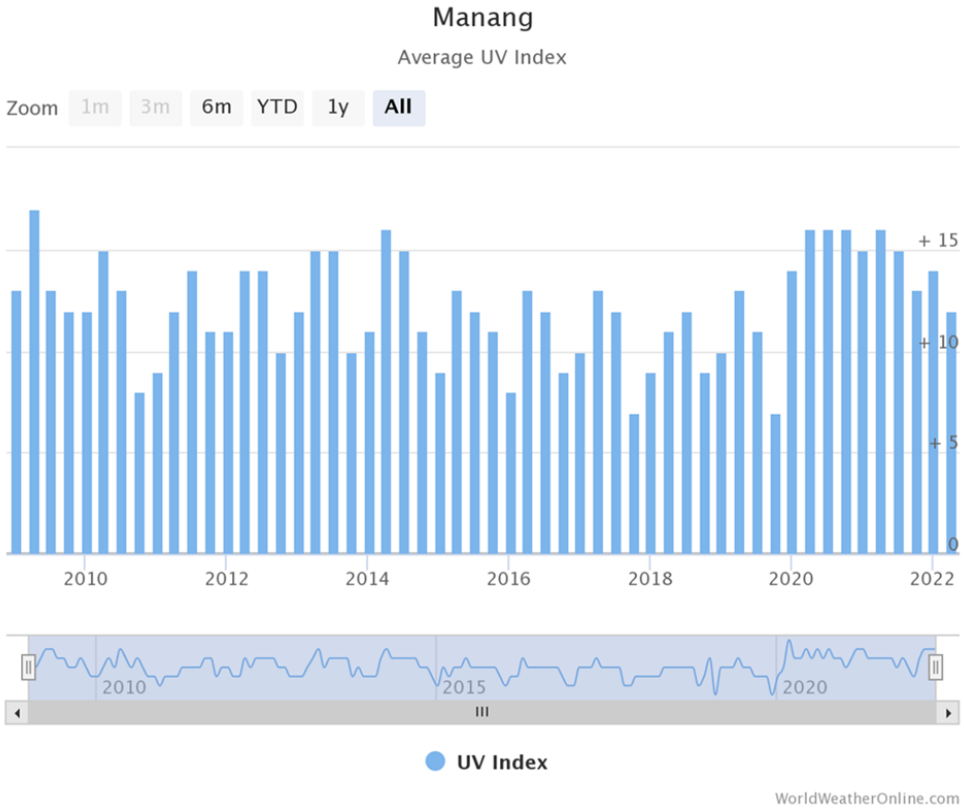
(Manang Climate Weather Averages, 2022)



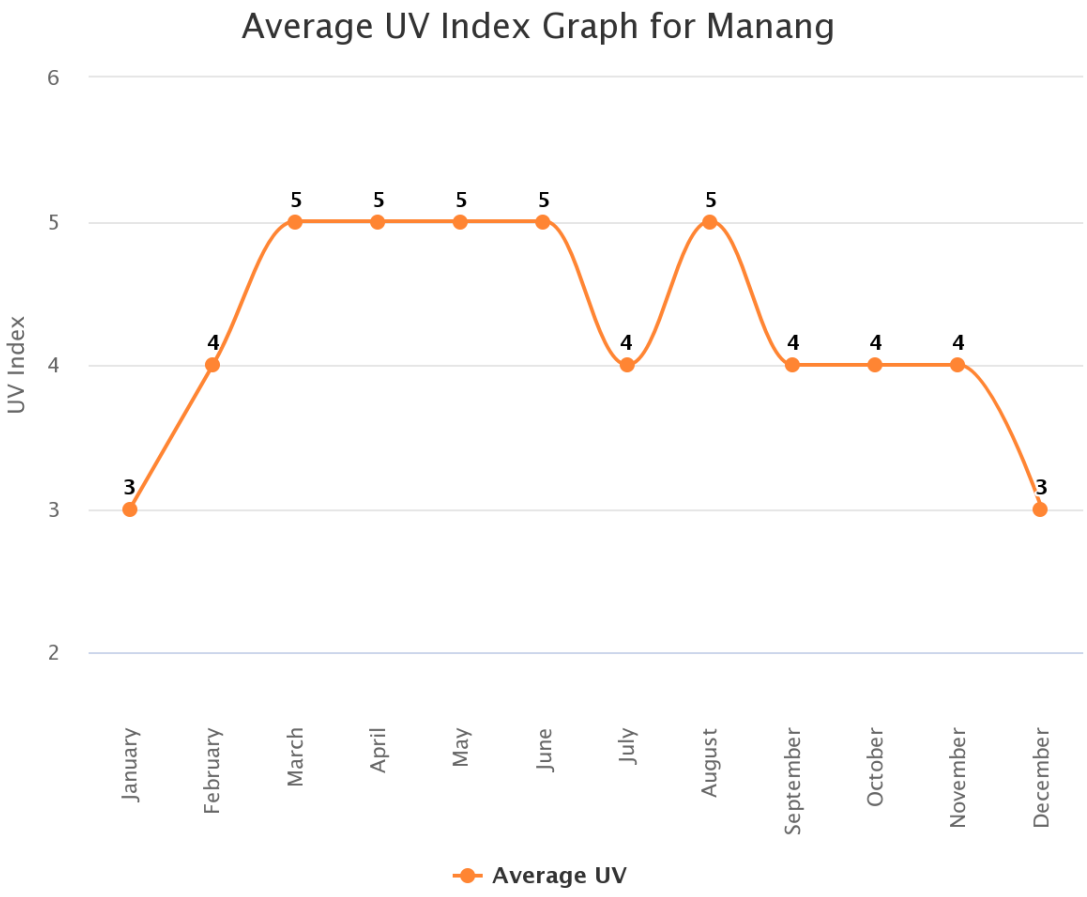
(Manang Climate Weather Averages, 2022)



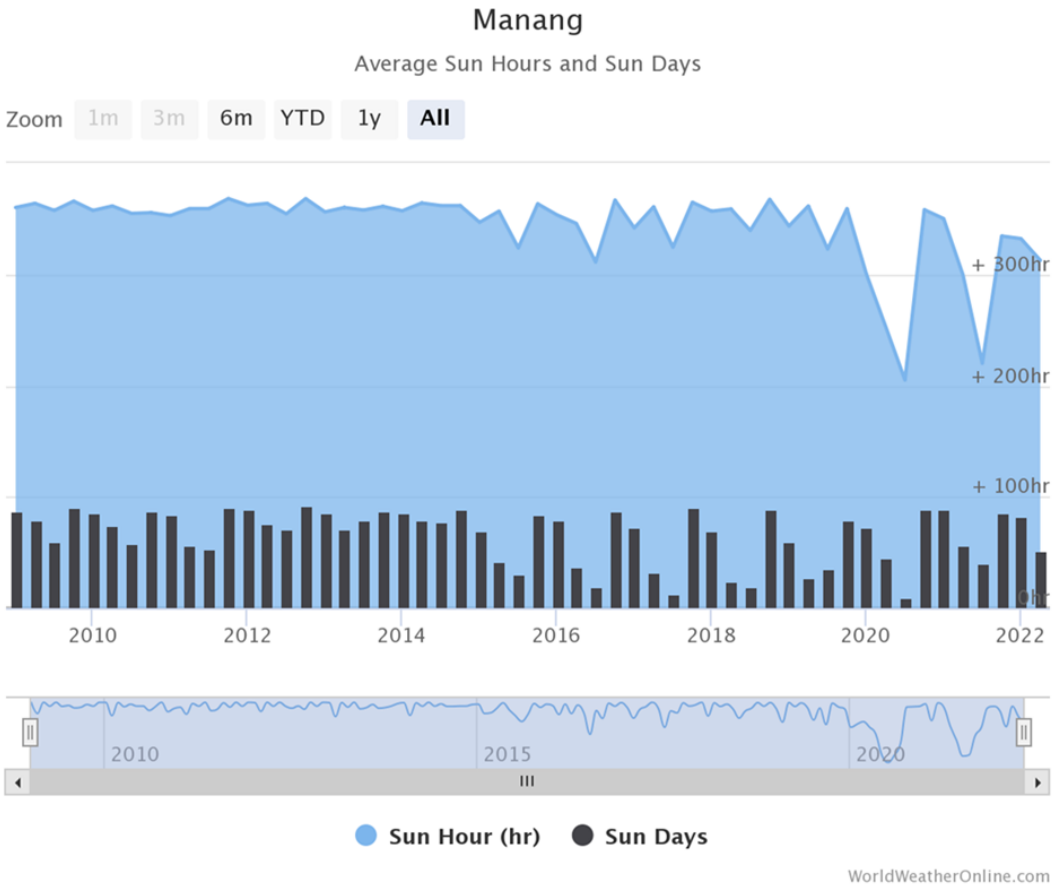
(Manang Climate Weather Averages, 2022)



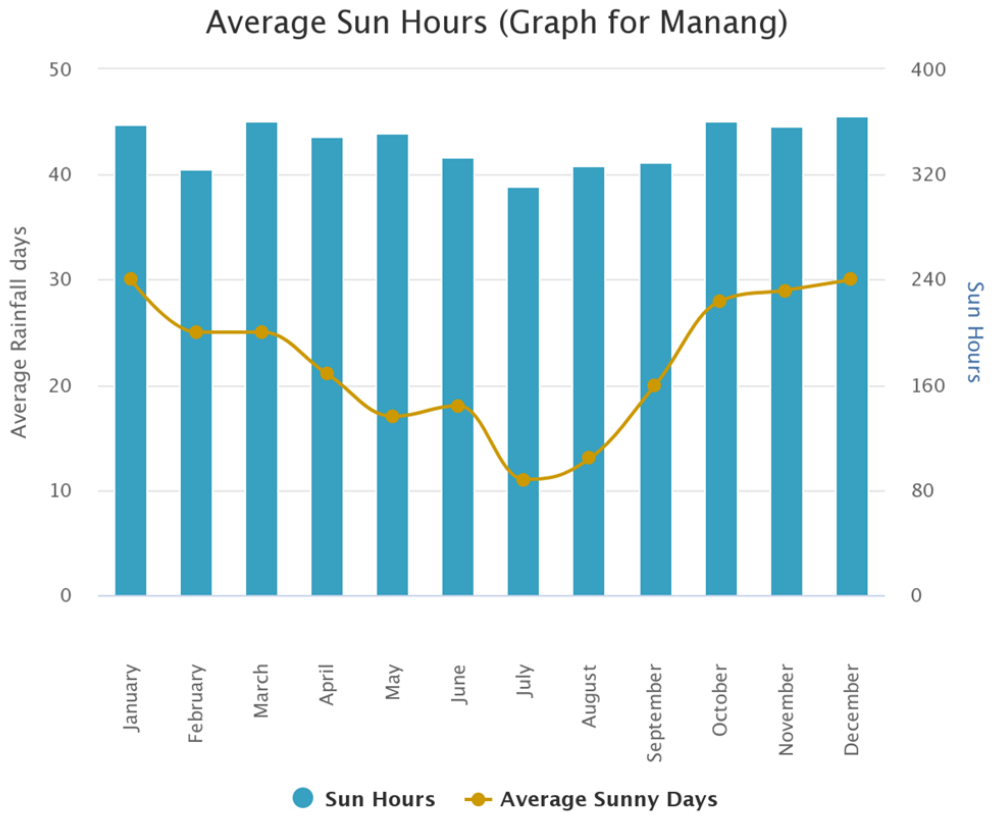
(Manang Climate Weather Averages, 2022)



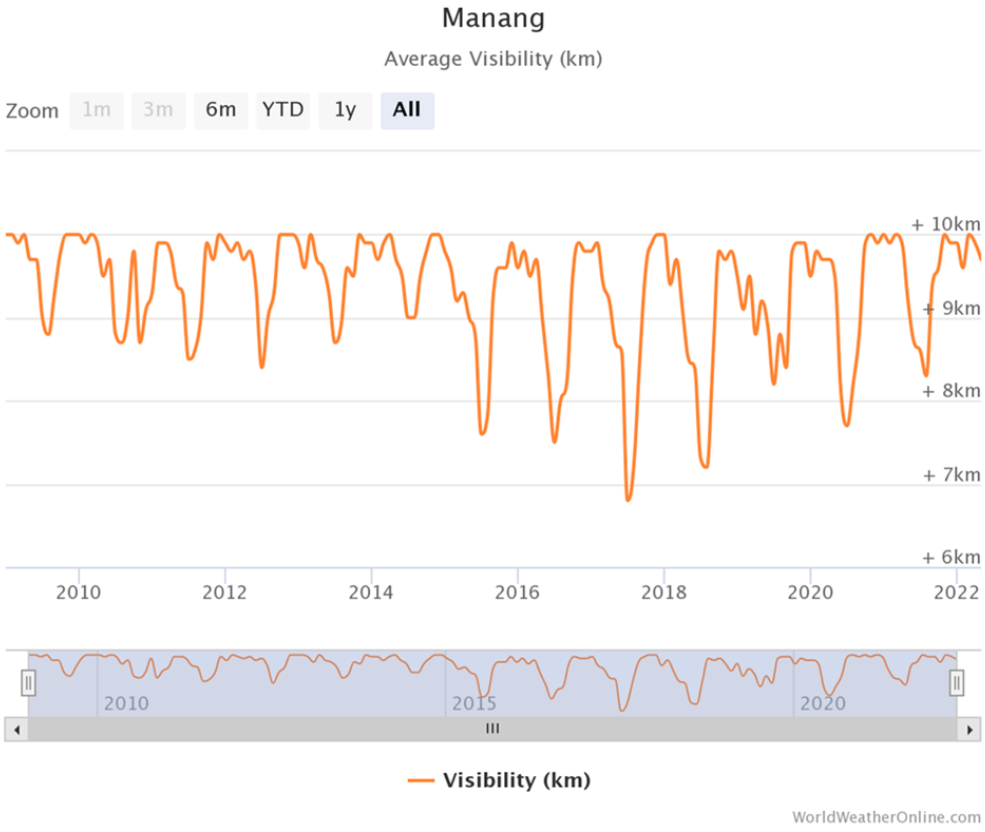
(Manang Climate Weather Averages, 2022)



(Manang Climate Weather Averages, 2022)



(Manang Climate Weather Averages, 2022)



(Manang Climate Weather Averages, 2022)

Year	Total	Age Group					
		0-15	16-30	31-45	46-60	60+	Not Sp.
2014	790,118	50441	185685	235738	183582	106666	28007
	(100.0)	(6.4)	(23.5)	(29.8)	(23.2)	(13.5)	(3.5)
2015	538970	19614	123444	157416	129614	74518	34365
	(100.0)	(3.6)	(22.9)	(29.2)	(24.0)	(13.8)	(6.4)
2016	753002	29825	154960	218479	199139	130627	19972
	(100.0)	(4.0)	(20.6)	(29.0)	(26.4)	(17.3)	(2.7)
2017	940218	35332	217143	292827	244342	141316	9258
	(100.0)	(3.8)	(23.1)	(31.1)	(26.0)	(15.0)	(1.0)
2018	1173072	54870	269648	360237	303452	173299	11566
	(100.0)	(4.7)	(23.0)	(30.7)	(25.9)	(14.8)	(1.0)
2019	1197191	57523	254399	383155	305651	176872	19591
	(100.0)	(4.8)	(21.2)	(32.0)	(25.5)	(14.8)	(1.6)
2020	230085	9768	43403	67829	61874	47211	0
	(100.0)	(4.2)	(18..9)	(29.5)	(26.9)	(20.5	0

(Ministry of Culture, 2021)

जिल्ला/स्थानीय तह	जनगणना घर संख्या	परिवार संख्या	प्रारम्भिक जनसंख्या २०७८		
			जम्मा	पुरुष	महिला
चापाकोट नगरपालिका	५७२६	६३८९	२२७८७	१०३९८	१२३८९
गल्याङ नगरपालिका	७२२६	७९७१	३११२५	१४४१३	१६७१२
हरिनास गाउँपालिका	३३१८	३५९१	१२९७९	५९५३	७०२६
कालीगण्डकी गाउँपालिका	४६६६	४९४६	१८००८	८२४२	९७६६
फेदीखोला गाउँपालिका	२९१९	३२२२	१०७८६	५०३५	५७५१
पुतलीबजार नगरपालिका	१०३९०	१२१५२	४२०७९	१९४४०	२२६३९
वालिङ नगरपालिका	११३६५	१३७०५	५०९३२	२३६५७	२७२७५
कास्की					
अन्नपूर्ण गाउँपालिका	५८११	६४०६	२२५१७	१०८६३	११६५४
माछापुच्छ्रे गाउँपालिका	५५०९	६१४४	२२०१३	१०७६२	११२५१
मादी गाउँपालिका	४०१४	४११५	१६३१८	८१३६	८१८२
पोखरा महानगरपालिका	१०१६६९	१४३१३७	५१८४५२	२५०९९९	२६७४५३
रूपा गाउँपालिका	३५६९	३६७४	१४७४१	७०९३	७६४८
मनाङ					
चामे गाउँपालिका	३३३	३९१	१२७२	७२८	५४४
नार्पा भूमि गाउँपालिका	१२५	१२५	३९८	१७०	२२८

द्रष्टव्य: स्थानीय तहको जनसंख्यामा संस्थागत परिवारको जनसंख्या समावेश गरिएको छैन । त्यसकारण स्थानीय तहको जोड जिल्लाको जनसंख्यासँग फरक पर्न सक्दछ ।

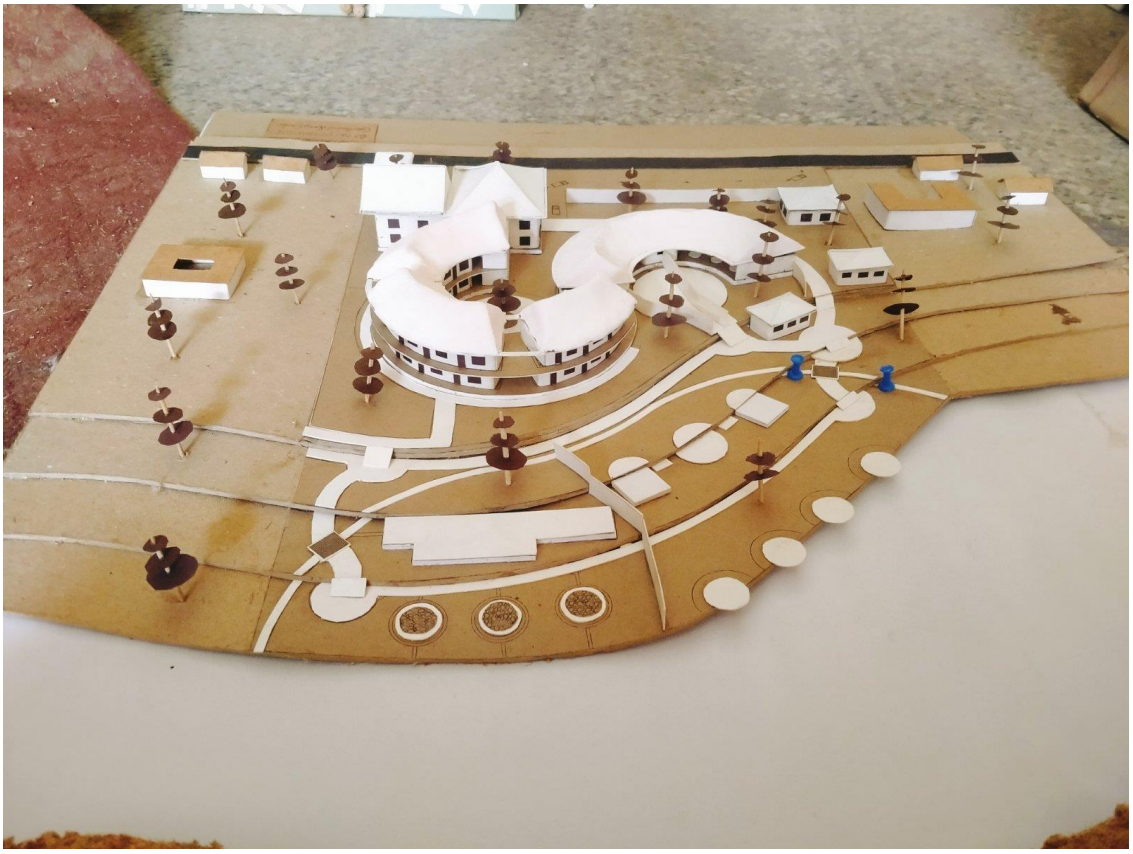
(National Planning Commission, National Census 2078, 2021)

Annex 2

Architectural Drawings

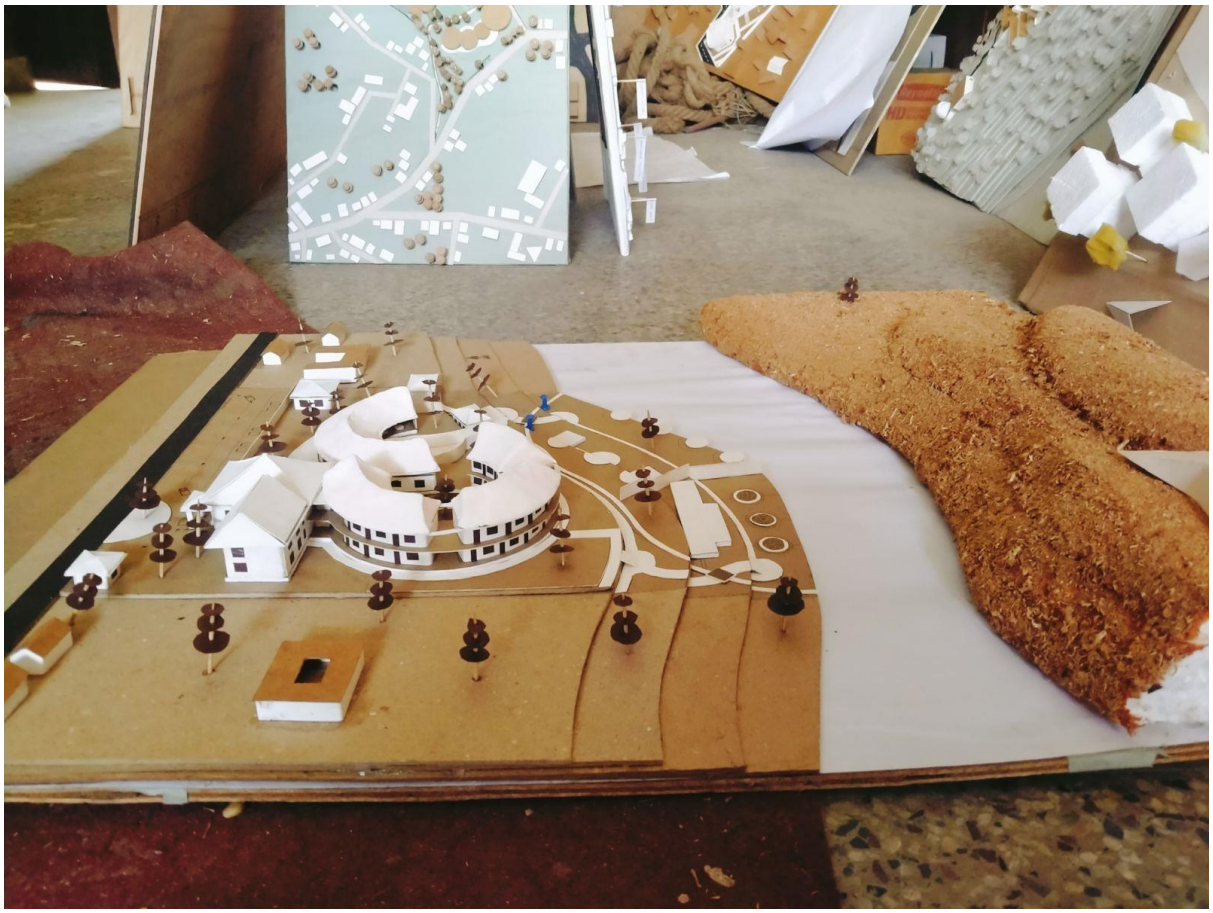
Model Photos

North Direction

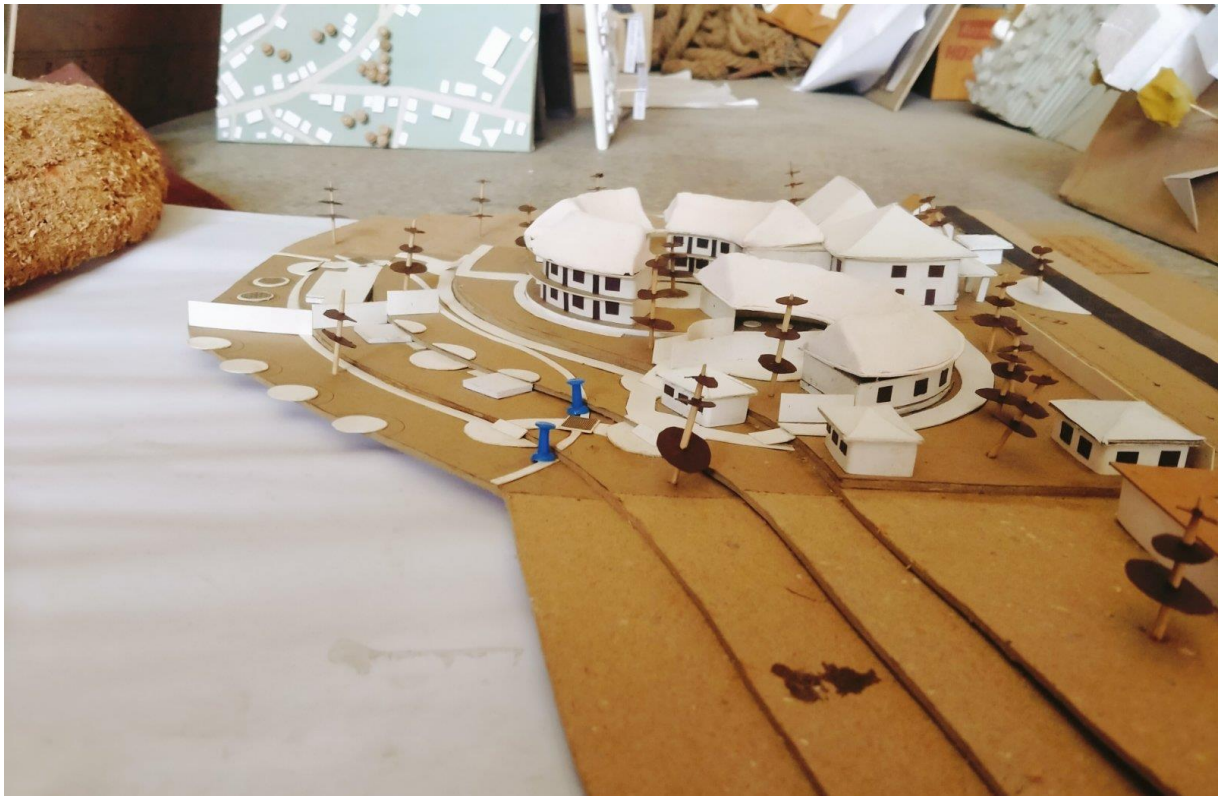


South Direction

East Direction



West Direction



3D Views