
The Sponge House
living with rain

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Abstract

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Over the past few decades, rain has brought blessings to human lives, but it also gives threats sometimes. Rain, or "water," has had a significant impact on the development of the city and human culture. At the same time, unpredictable weather, such as storms and floods, has affected human lives due to recent dramatic climate change. This thesis focuses on the issues that come from D.C.'s characteristic climate and current situation, examines the current state of drainage systems and house typologies, and explores new designs to address upcoming climate change. The study begins to figure out the current management and solutions in the city and find out several ideas for any design approach that pursues sustainability.

The project targets an actual vacant lot at Eckington in the Northeast of Washington, D.C. The first phase of design consists of a survey of tree species and characteristics, followed by a building layout that allows for more preservation. The second phase examines the details of the design that will retain more rain. The house is envisioned as the first step in a prototype solution for D.C.'s unpredictable and rainy climate.

The concept is for the rowhouse to become as a sponge that retains rain. The proposed concept envisions rainwater retention in the building and throughout the site, featuring a landscape based on the site's characteristics with many trees, water retention through rooftop and wall greenery, and two types of rain gutters for discharge.

Overall, the thesis identifies the potential benefits, possibilities, and realization of implementing a comprehensive sustainable strategy. It explores how problems can be addressed through site-specific planning and detailed design for the local climate and examines the impact on the environment and human beings. The Sponge House becomes an example of setting principles and methods for sustainable houses in D.C.

General Audience Abstract

The Sponge House

living with rain

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The thesis suggests a new type of rowhouse in Washington, D.C., focusing on accepting the local climate and current management and conditions organized by the government.

The rowhouse is proposed to become a sponge that retains rainwater and helps slow runoff. Environmentally friendly strategies are suggested and designed in the building, inside and outside, and throughout the landscape, featuring tree savings based on the site's characteristics.

" The Sponge House" seeks to understand Washington, D.C.'s climate and how housing can be adapted. The project will explore how the city's current environmental problems can be addressed through the planning and detailed design of a rowhouse tailored to the local climate. This thesis will be a prototype for sustainable housing in D.C.

Acknowledgments

First, I would like to thank my thesis committee chair, Professor Andy Linn, for his invaluable patience and feedback in developing my ideas during the process.

I could not have undertaken this journey without Professor Paul Kelsch, who generously provided knowledge and wisdom of landscape and surrounding nature.

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I am also grateful to my family, especially my parents, who always encouraged me to take on this challenge and supported me from far away in Japan.

Lastly, I would be remiss in not mentioning the rest of WAAC for giving me an excellent opportunity to learn and study architecture and experience a lot during the semesters.

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01 Introduction

figure 1. Wahington D.C. and rain

D.C. and its watershed

Washington D.C. is a part of Chesapeake Bay, one of the the most enormous watershed in the United States(figure 2).

This watershed contains some major States in eastcoast, such as New York, Pennsylvania, Maryland, Virginia, and D.C. The left map highlights the watershed area and developed areas within it, and the area is regarded as such.

Moreover, it is obvious that some parts of the D.C. area cannot absorb water due to the impervious surface (figure 3). The development strongly affects ground conditions and causes frequent rain runoff, which influences humans' lives and nature.

How has the rainfall changed?

Annual rainfall is not so huge when it comes to think national average. When it comes to summer, June and July, monthly rainfall is more than 4 inches because of the storm water. In this situation some part of ground cannot absorb the rain due to its impervious materials and its characteristics(figure 4). However, over the 100 years, there have been more than 10 times of storms, and the city has experienced severe damage, such as tidal surges and floods. The storms must have affected human beings' lives, depriving their living space at the moment.

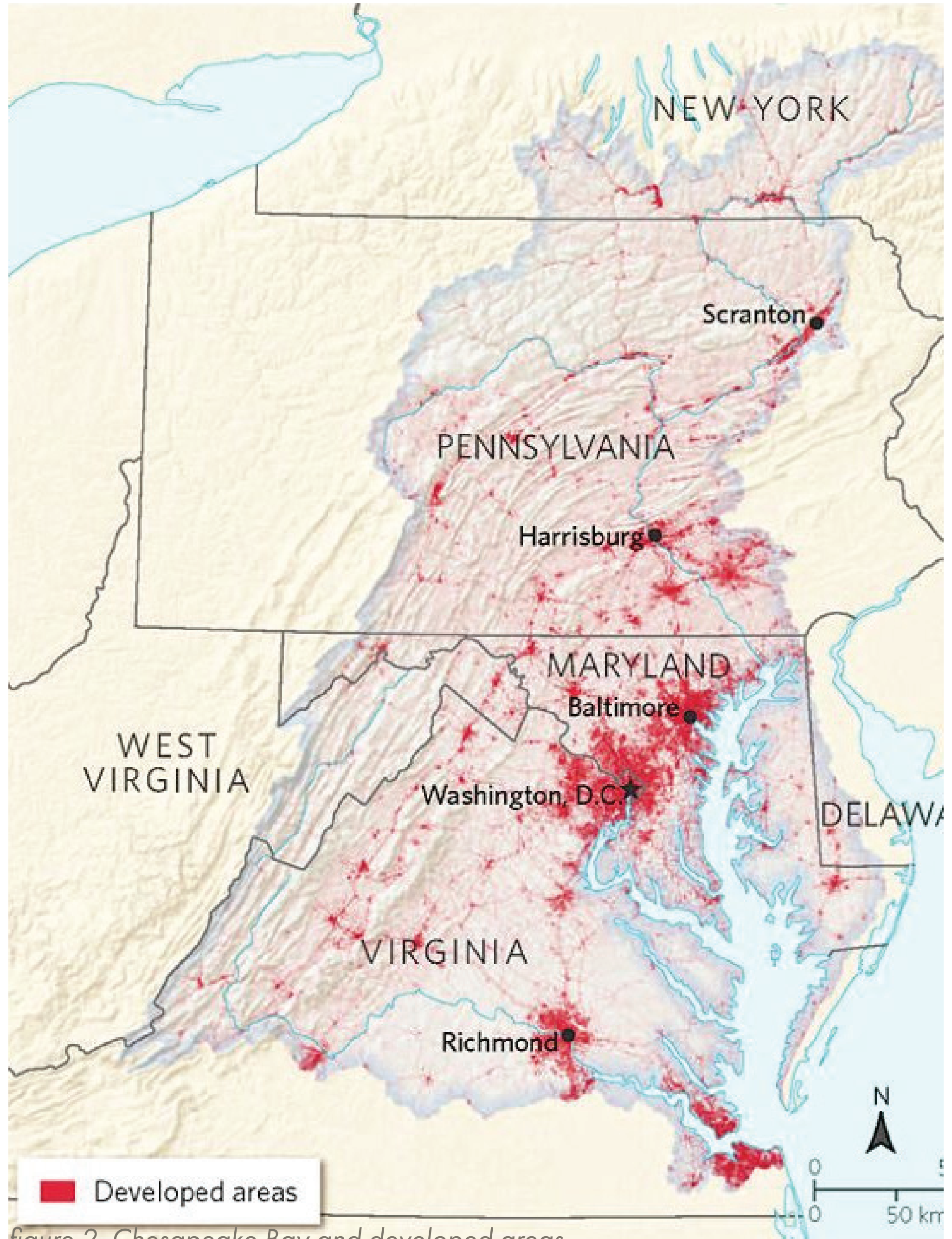


figure 2. Chesapeake Bay and developed areas

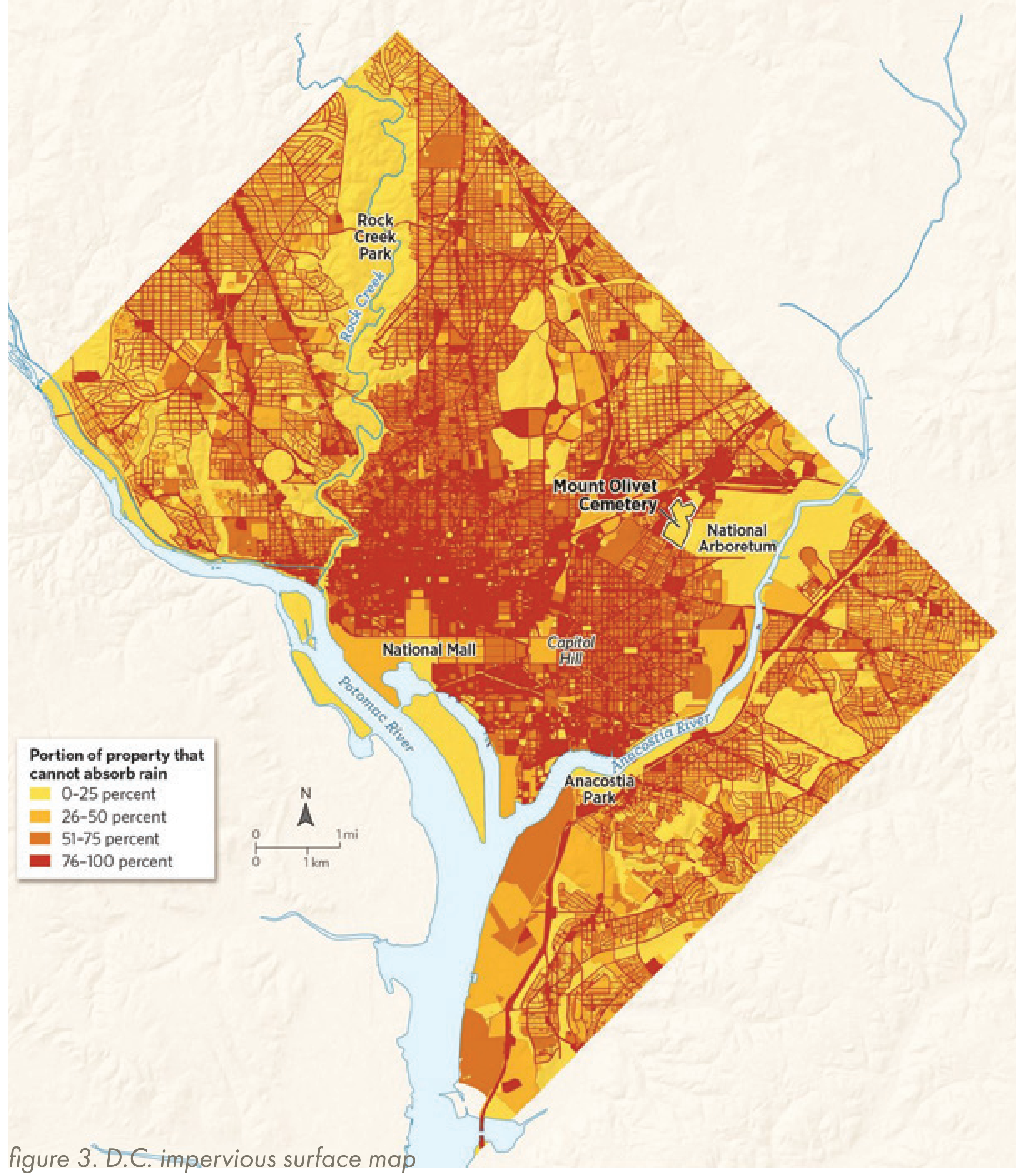


figure 3. D.C. impervious surface map

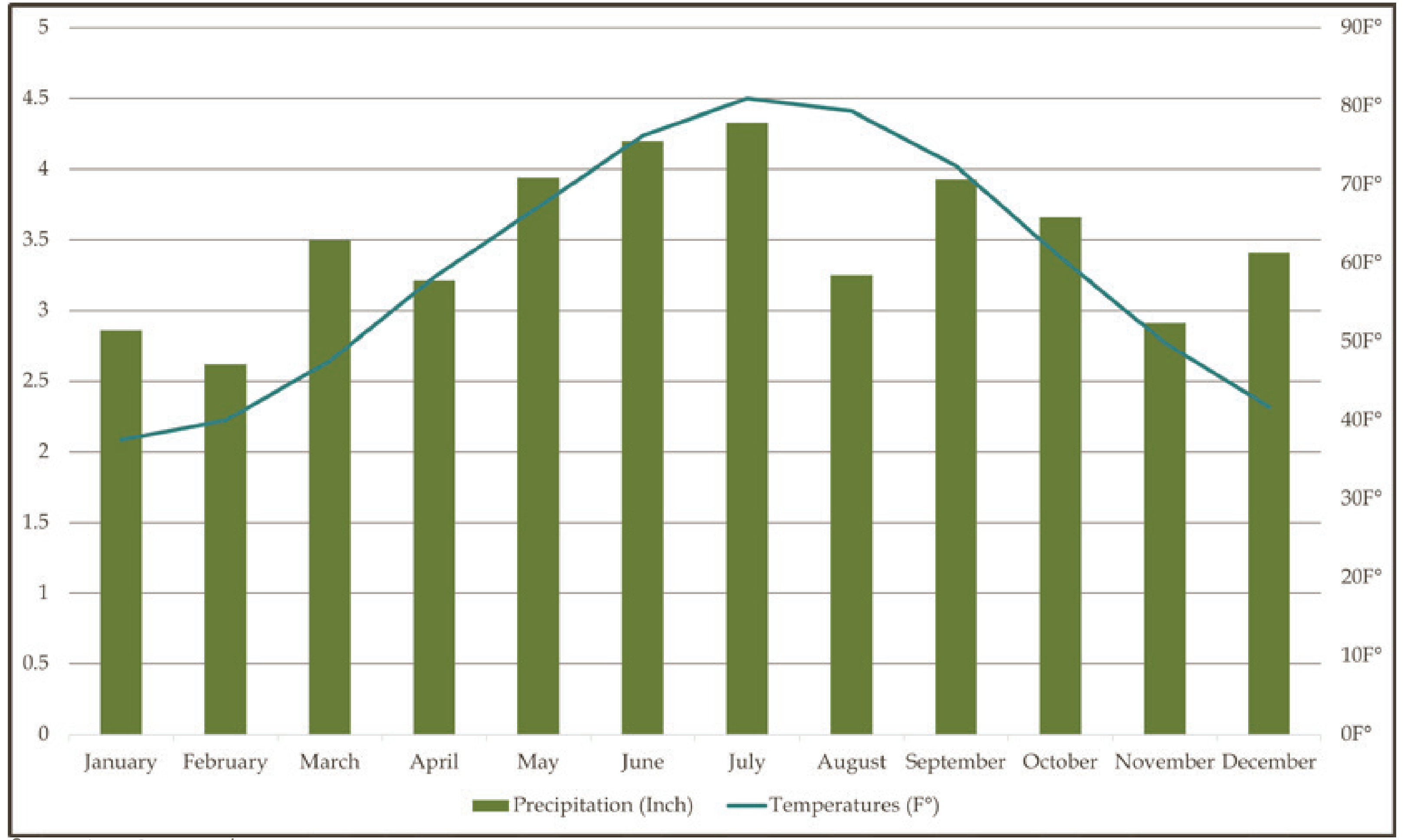


figure 4. D.C. annual precipitation

How is the water used ?

D.C. has two types of sewer systems, combined and separate. Most of the area in D.C. has a combined sewer system that transports sanitary sewage and stormwater in the same pipe. This type of sewer system was developed before the 19th century and expanded a significant part of the city over the decades. On the other hand, two independent piping systems, sanitary sewage and stormwater, consist of separate sewer systems. When it is heavy rain, combined sewers have a problem that sewage and rainwater are together and contaminate the river. Sewage comes from ordinary human lives, such as taking a bath or using washers, so this event must happen.

Usage of water

Washing teeth
10 minute showers x 2 gallons a minute
20 gallonsight

Bath
A full tub is about 36 gallons

Toilet
3 gallons per flush x 6-8 flushes per day
= 18-24 gallons

Washer
A washing machine utilizes
15 gallons a load

Cooking
Depending on efficiency of dishwasher
4 to 10 gallons

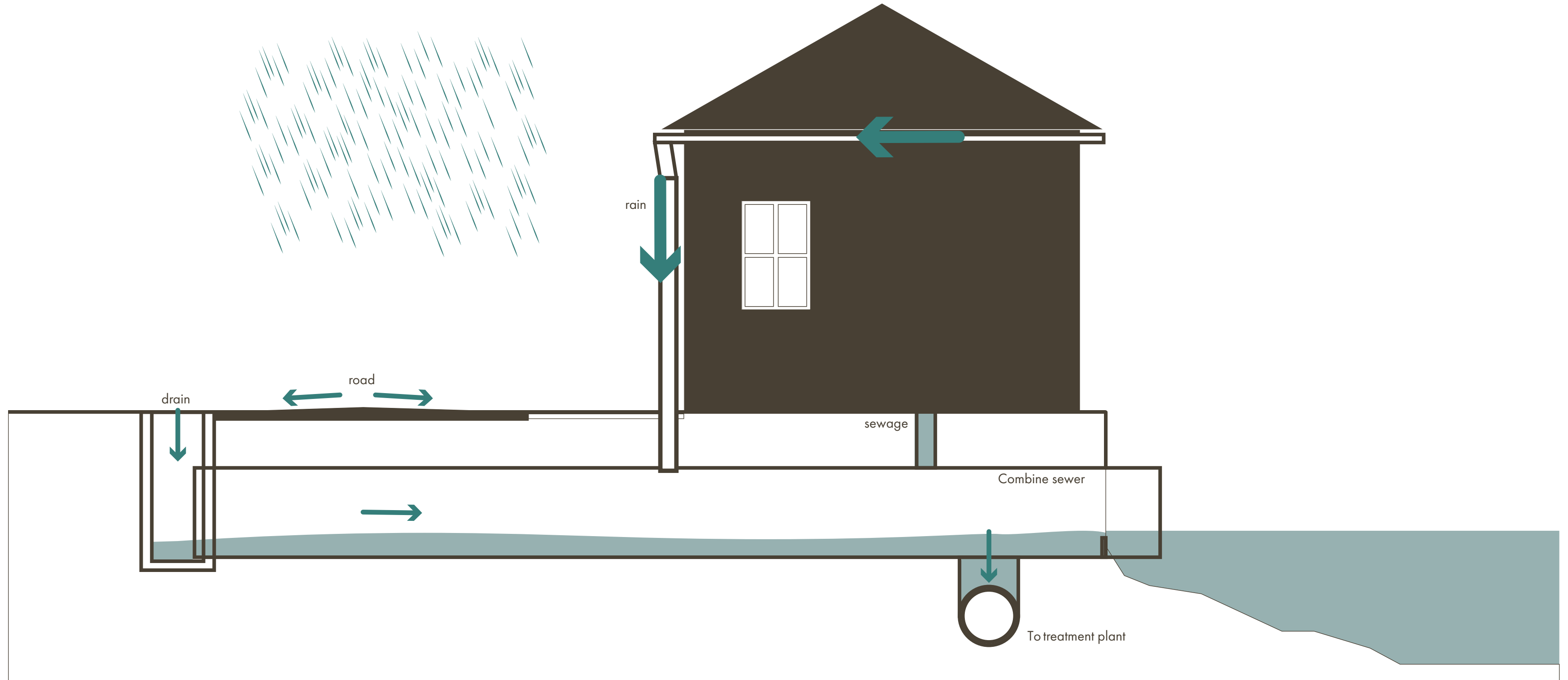


figure 5. Diagram of combine sewer system

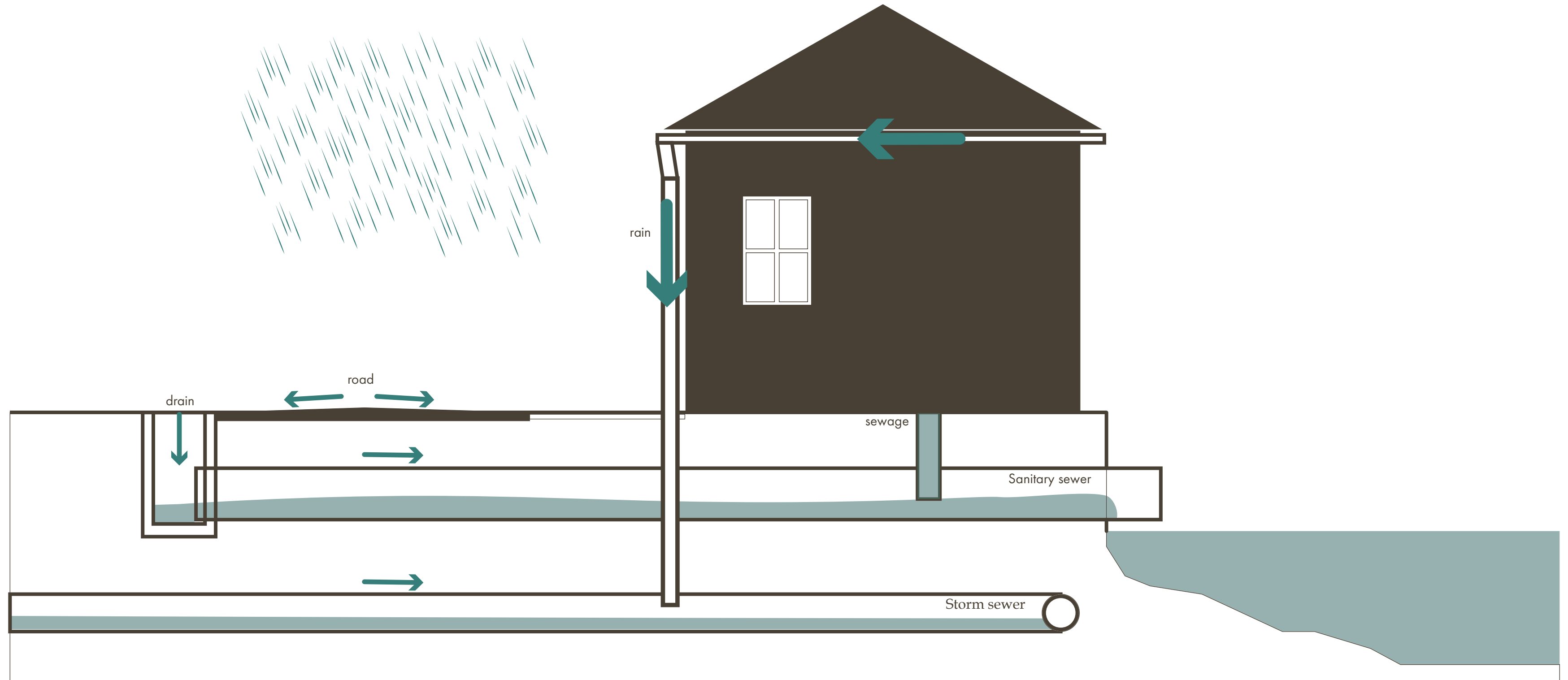


figure 6. Diagram of separate sewer system

Current solution to deal with stormwater.

The GAR, Green Area Ratio, is an essential zoning regulation incorporating environmentally friendly design strategies into architecture and site design to encourage architects and developers to work on sustainable buildings and surroundings. The idea originated in cities such as Berlin, Malmo, and Seattle, and was officially published in D.C. in 2013[1]. The D.C. government requires this when they are engaged during the site development and construction process.

There are five main categories to which the GAR score can be applied: soil depth, bioretention facilities, vegetation, buildings, and pavement. Each solution has its GAR ratio, between 0 and 1.0, defined by the characteristics of landscape and site design methods and the total area. The multiplier sets a high GAR score per square foot to reflect the benefits of climate change adaptation and mitigation related to current environmental issues, such as urban heat islands and floods caused by stormwater.

The GAR score is decided to apply to areas other than residential zones or residential flat zones. This means the score is not applicable to houses, including rowhouses. However, these indicators are quite helpful in examining the thesis.

1 GREEN AREA RATIO GUIDEBOOK. (2017), 8. https://doee.dc.gov/sites/default/files/dc/sites/ddoe/service_content/attachments/GAR-Guidebook_FINAL_November2017_0.pdf.

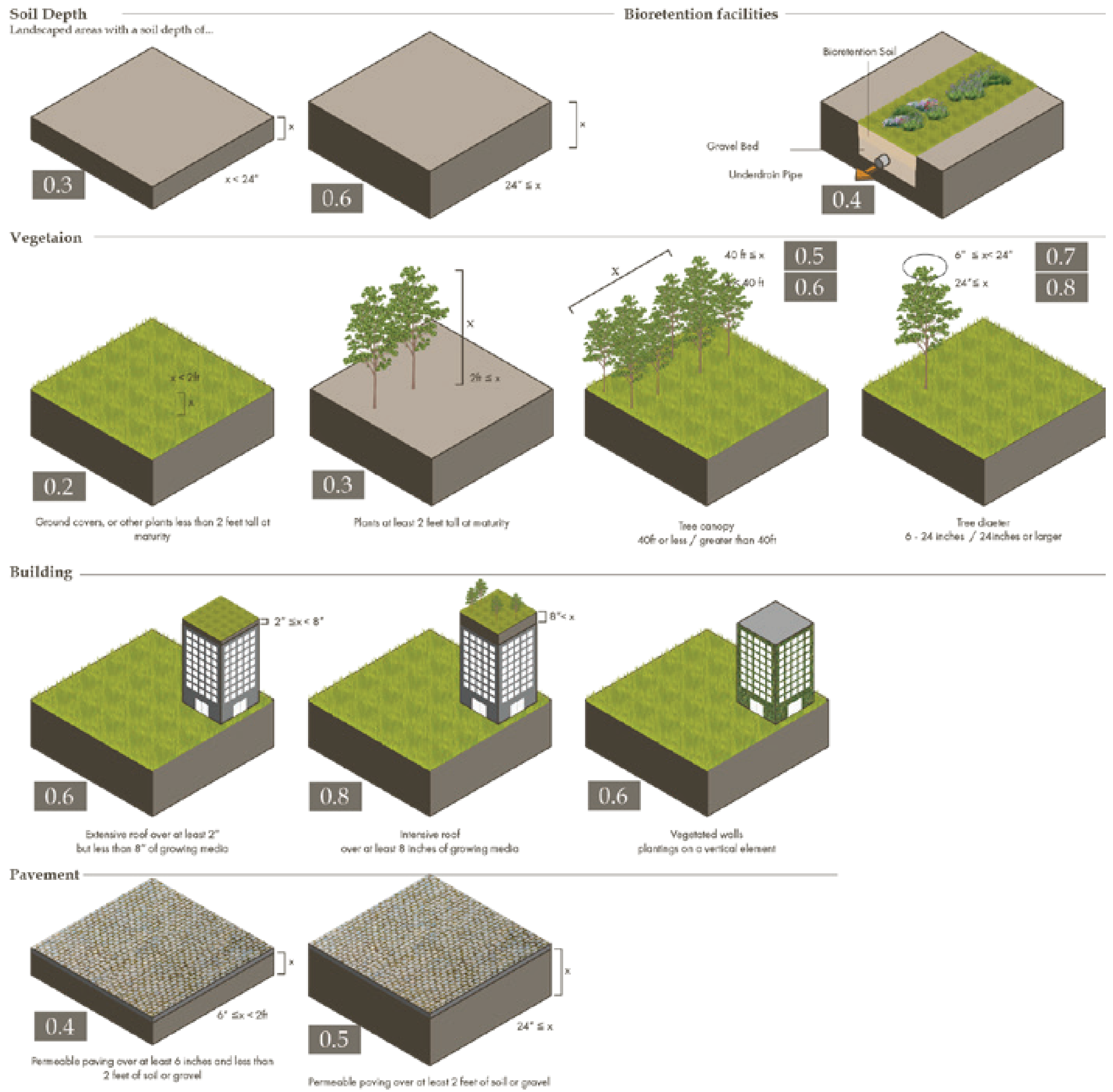


figure 7. Diagram of GAR multiplier

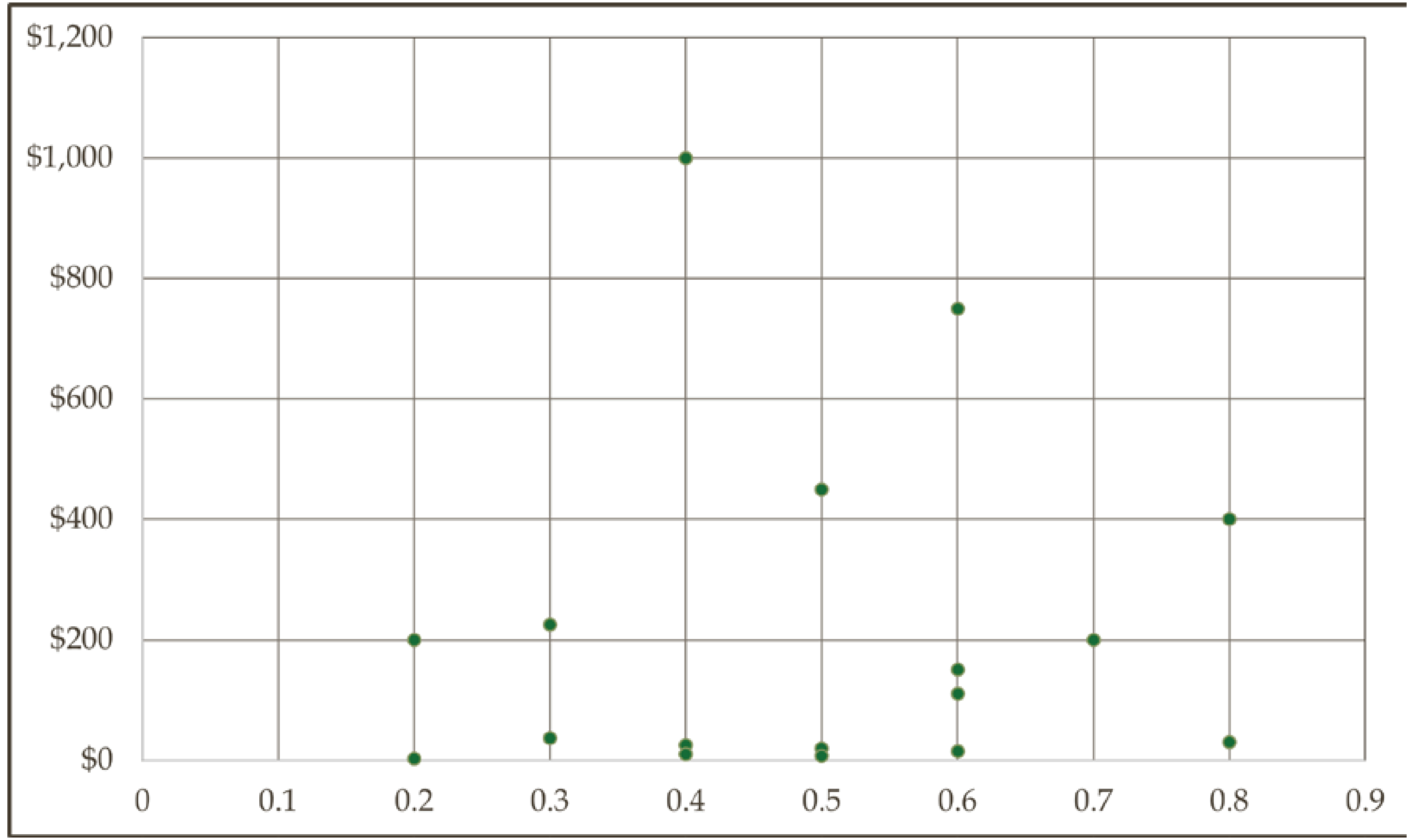


figure 8. GAR multiplier and Cost for installing

Cost for installing

The graph indicates how much we need to install each idea/solution per square foot of the developing site. The more cost is, the higher the effect can be gained. Moreover, some solutions, such as green walls and roofs, have productive methods, such as rain retention, at reasonable prices.

River Smarthome

The government highlights four suggestions for the River Smarthome to retain as much rain as possible and prevent an unexpected runoff situation. The diagram on the right shows each idea.

01. Rain Barrels
Rain barrels attach to a downspout and collect rainwater as it runs off residents' rooftops. The barrel stores water during a rainstorm so that it can be used when it is not raining to water lawns and landscaped areas.

02. Shade Tree Planting
Vegetated trees help control stormwater runoff by catching large amounts of water during rainstorms and keeping them out of local rivers and streams.

03. Rain Gardens
Directing the downspout to the rain garden allows stormwater to flow away from the foundation part of the home. It holds it in the garden until it can naturally absorb into the ground.

04. Permeable Pavers
Compared to impervious surfaces such as concrete and asphalt, permeable pavers prevent rain runoff. This type of pavement can drain well and gradually seep underground.

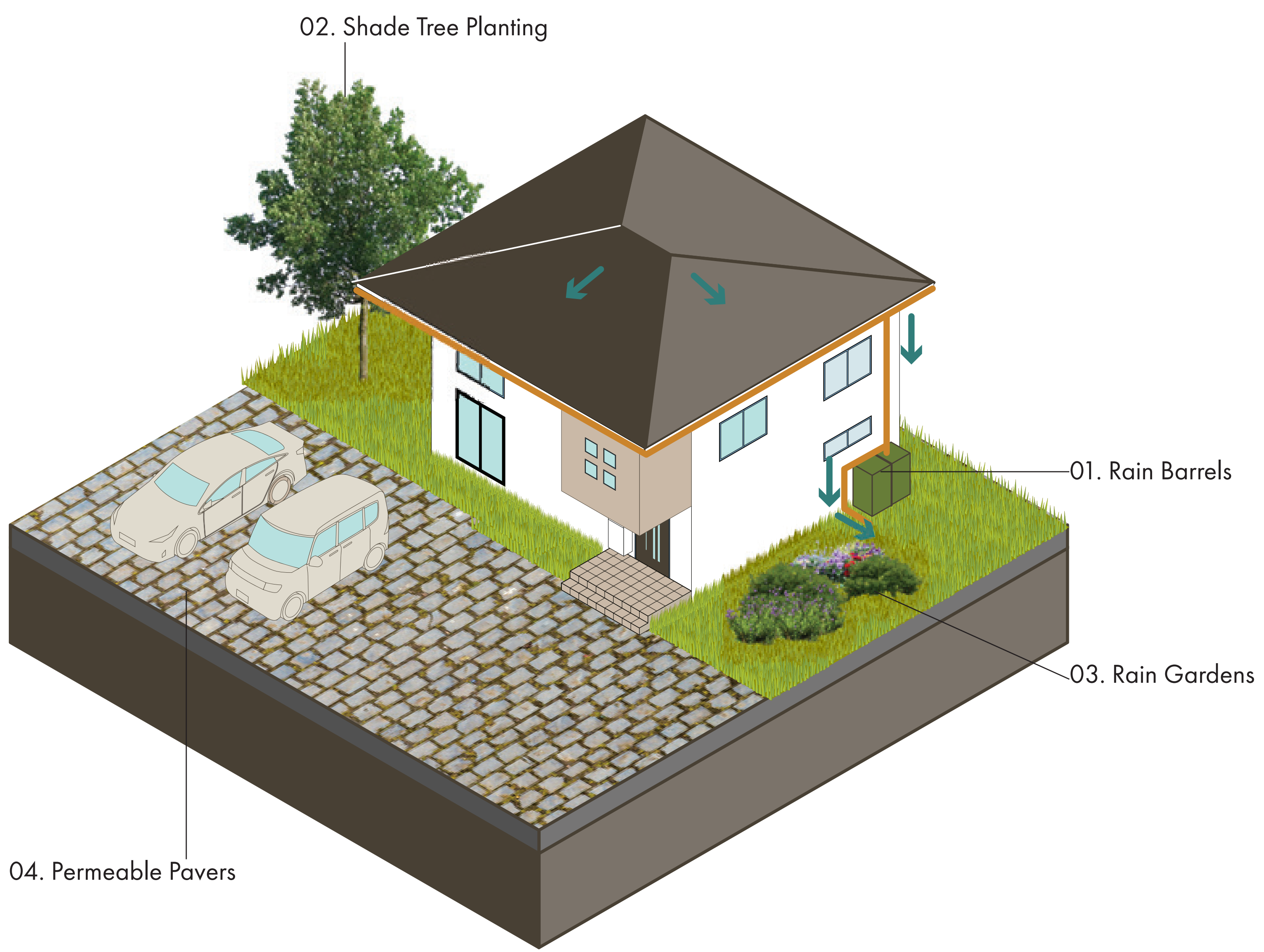


figure 9. River Smarthome

House Typology in D.C.

According to the house typology map, humans have been trying to avoid rain over the past few decades. As for D.C., the neighborhood has three major types of single-family houses: rowhouses, semi-detached, and detached. The map illustrates the location of each type of house. Rowhouses are mainly located in central D.C., whereas detached houses can be seen in the northwest area. A semi-detached house is scattered everywhere in the city but crowded in northeast D.C.

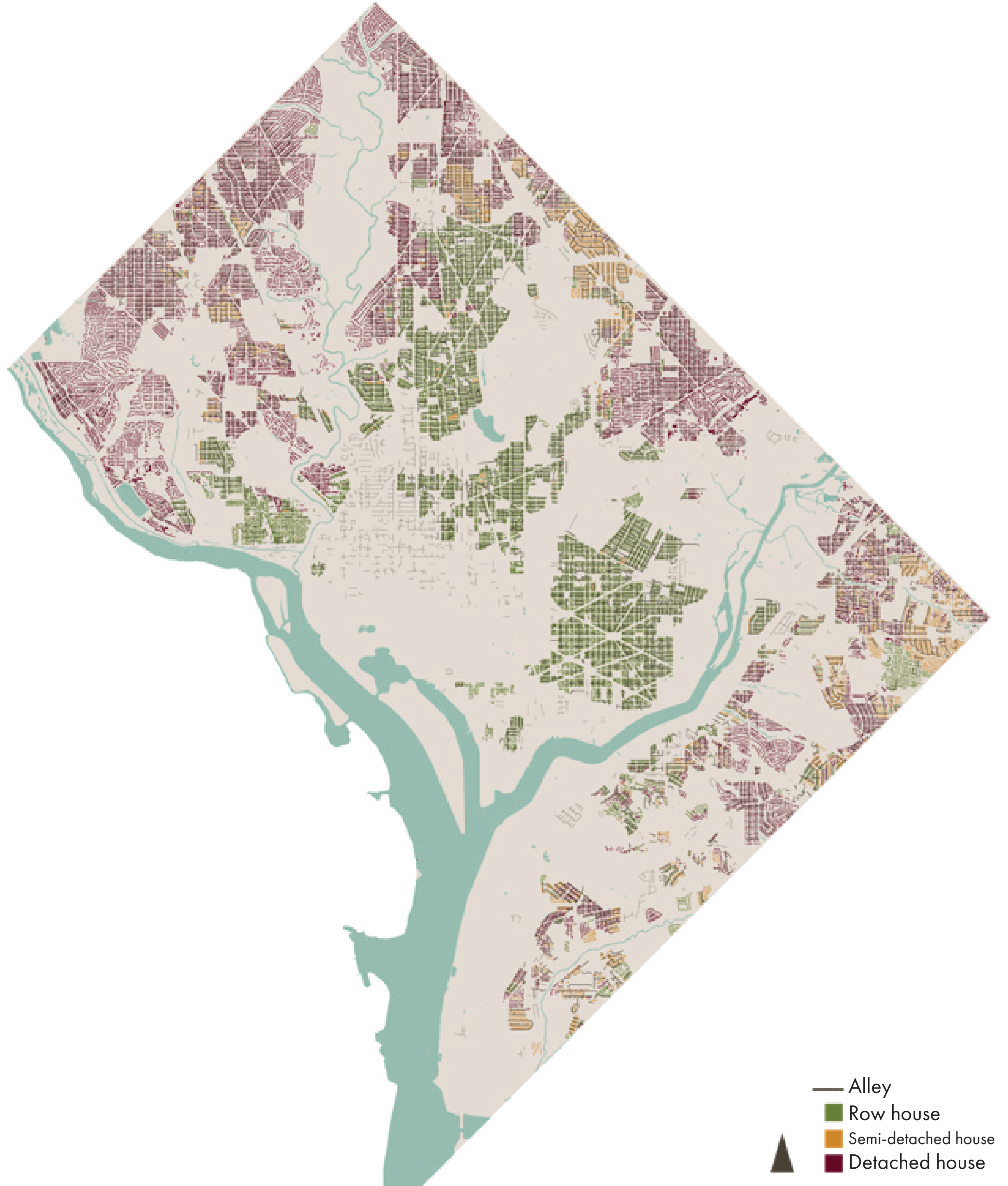
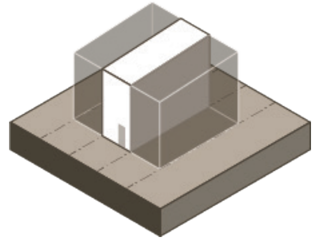


figure 10. House typology map

A. House Type

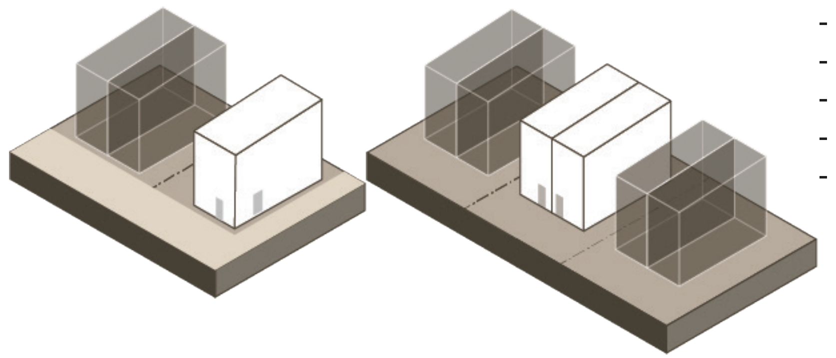
Several caracteristics can be seen in each type of house, some of them are similar. All types are located in residential zone or residential flat zone.

Rowhouse



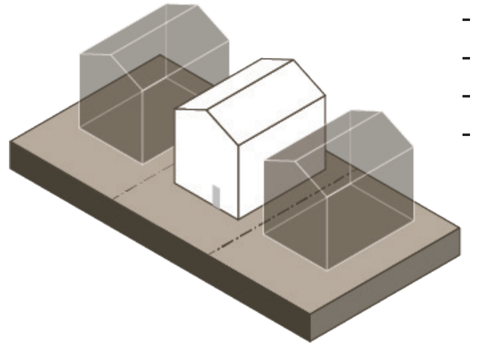
- Zoning = RF
- Middle area and Southeast
- Minimum rear setback of 20"
- Each unit has party walls to attach another unit
- Setback from the road and porch area to enter units

Semi-detached



- Zoning = R, RF
- North and Southeast
- Minimum rear setback of 20"
- Minimum side setback of 5" to 8"
- Two types of entrance

Detached



- Zoning = R
- North and Southeast
- Minimum rear setback of 20"
- Minimum side setback of 5" to 8"

figure 11. Diagrams of house type

B. Roof Shapes

The two types od roof shapesin D.C. are flat and sloped. The design of a roof shape is based on a number of considerations such as the building's height, useage, wall materials and structural issues.

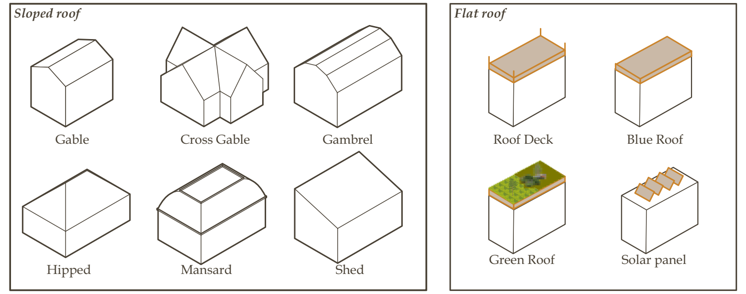
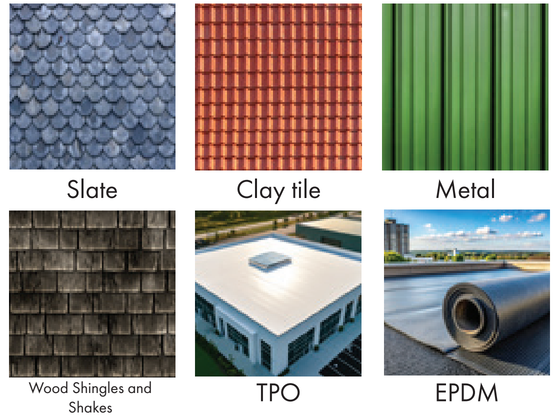


figure 12. Sloped roof / flat roof and gutter diagrams

C. Roof Materials

Metal, slate, clay tile, asphalt shingles, wood shingles, and wood shakes are the most commonly discovered sloping roof materials. TPO and EPDM are widely used for flat roofs.

The map also shows the usage of roof materials. Most parts of the rowhouse use a metal roof (ME), whereas slate (SL) and composition shingle (CS) are widely used for semi-detached and detached houses.



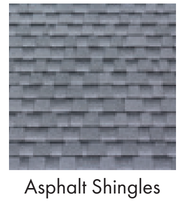
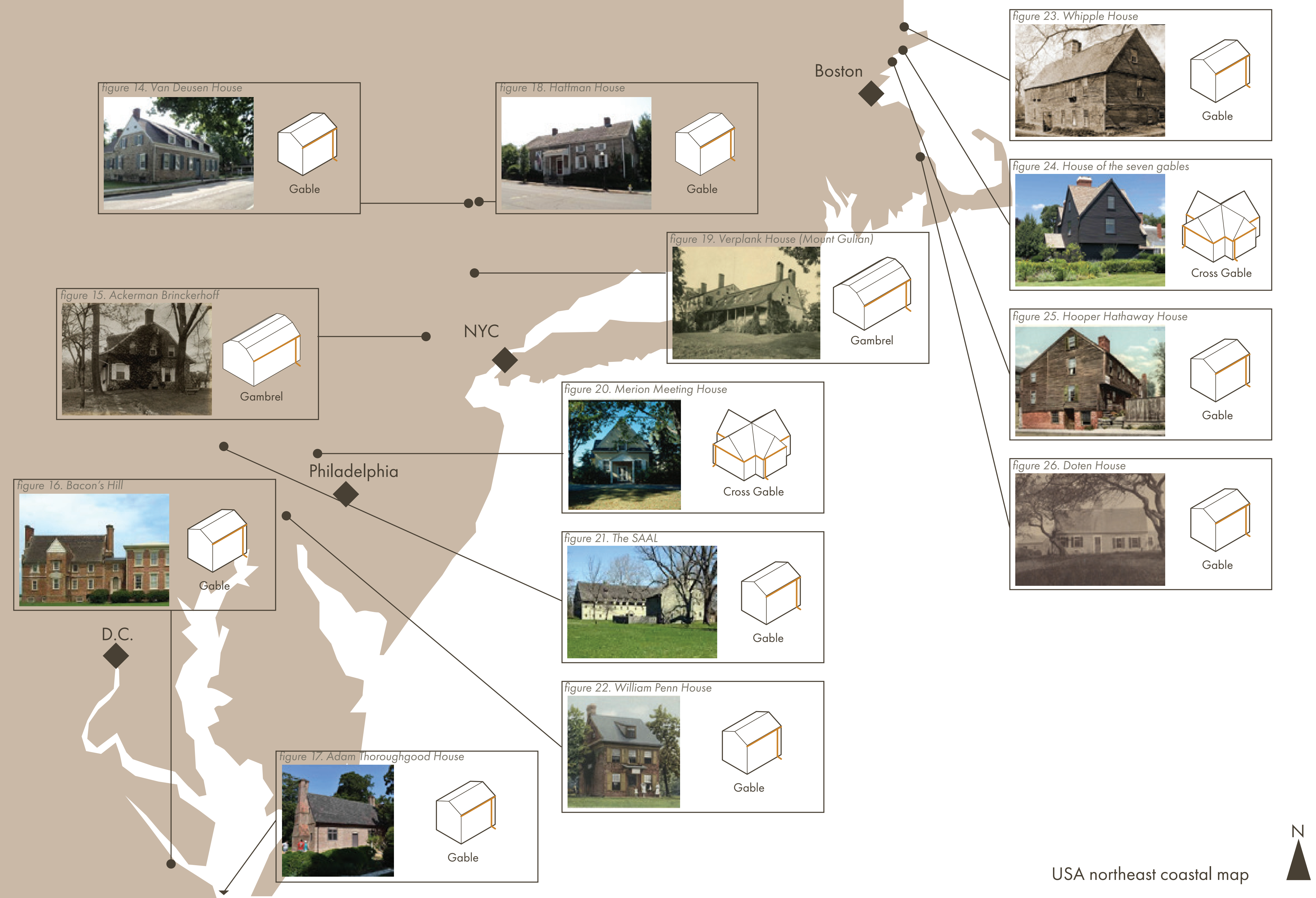


figure 13. Roof materials



USA northeast coastal map

Northeast colonial house typologyy

Based on the traditional colonial houses in the United States, a typical relationship is found between the shape of the roof and the gutter/downspout. Almost all colonial houses had sloped roofs, often angled, and gutters were always attached to the slope to catch the rain and snow.

Typically, for gable and gambrel-style roofs, there are gutters for only two sides, and the other two sides, which do not have eaves, allow the rain to get inside in some cases. In contrast, cross-gable roofs have four sides so that people can avoid rain.

02. Precedent Study

This section separates two studies. The first study looks at some precedents to learn how architects deal with rain by designing roofs, walls, and foundations. The second study is about understanding the differences between the typical gutter and a hidden gutter by illustrating its detail as drawings.

Nira House (Leek House)
Architect ; Terunobu Fujimori

Nira House, or which means Leek House in English, is an artist's house in Tokyo, built in 1997. Approximately 800 potted leeks are planted on the wooden gable roof, giving residents a sense of ecology. No irrigation systems are installed, and residents need to replace new pods every year.

figure 27. Nira House (Leek House)

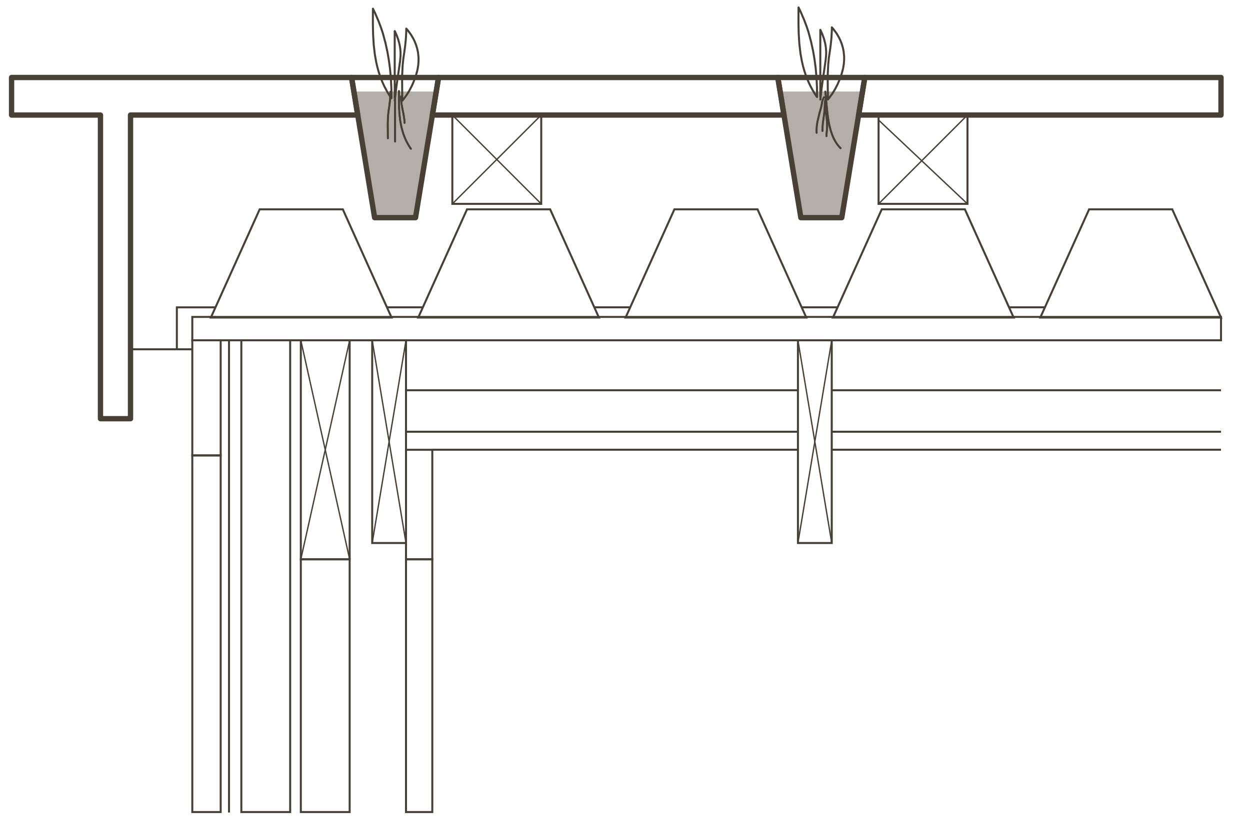


figure 28. Roof detail drawing of Nira House (Leek House)

House for Trees
Architects; VTN

The residence is in Tan Binh District, one of the most densely populated regions in Ho Chi Minh City.

The site has five buildings designed as "pots" to vegetate several trees on the roofs. The wall has a thick soil layer and supports the green roof. The architecture can also retain storm-water for a long time, reducing the risk of flooding in the city.

figure 29. House for Trees

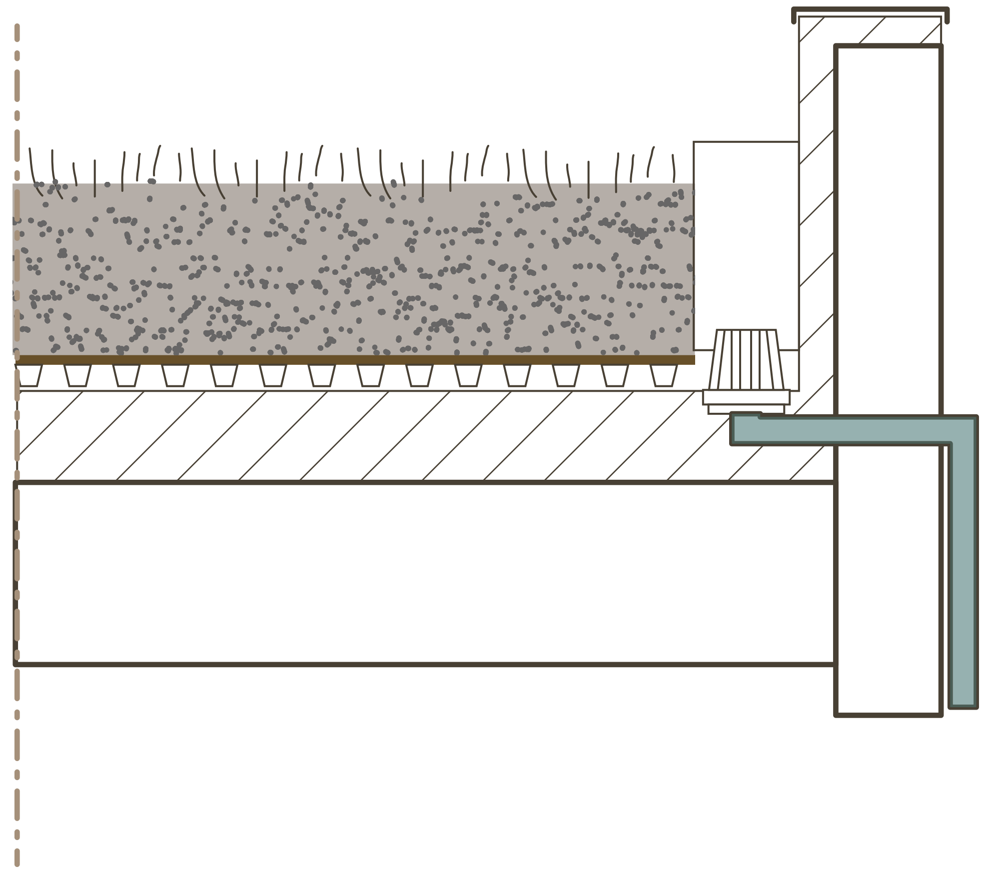


figure 30. Roof detail drawing of House for Trees

Blue Roof

Blue roofs are non-vegetated roof storage systems that can store rainwater. This is installed over a sealed roof membrane to capture rainwater before it reaches the gutter. It is practical to retain the rainwater temporarily and slowly release it into the gutter or remove it by evaporation. This is used for buildings with flat roofs.

figure 31. Blue roof

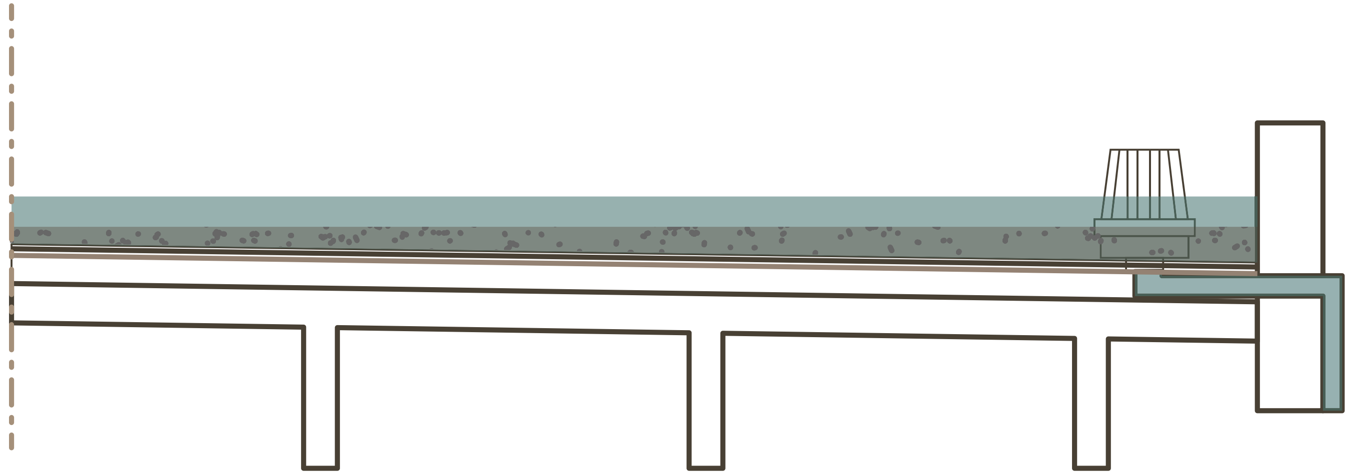


figure 32. Roof detail drawing of Blue roof

Stacking Green Architects; VTN

This apartment in Vietnam has several features that improve energy efficiency, such as a wide wall opening to install the "pod. " These pods are 20 inches to 40 inches in height so that various types of vegetation can be planted. The gap between the pod allows the wind to come through the whole house and keep the room cool.

The green wall protects strong sunlight from the outside, and residents can live without air conditioning, even in tropical climates.

figure 33. Stacking Green

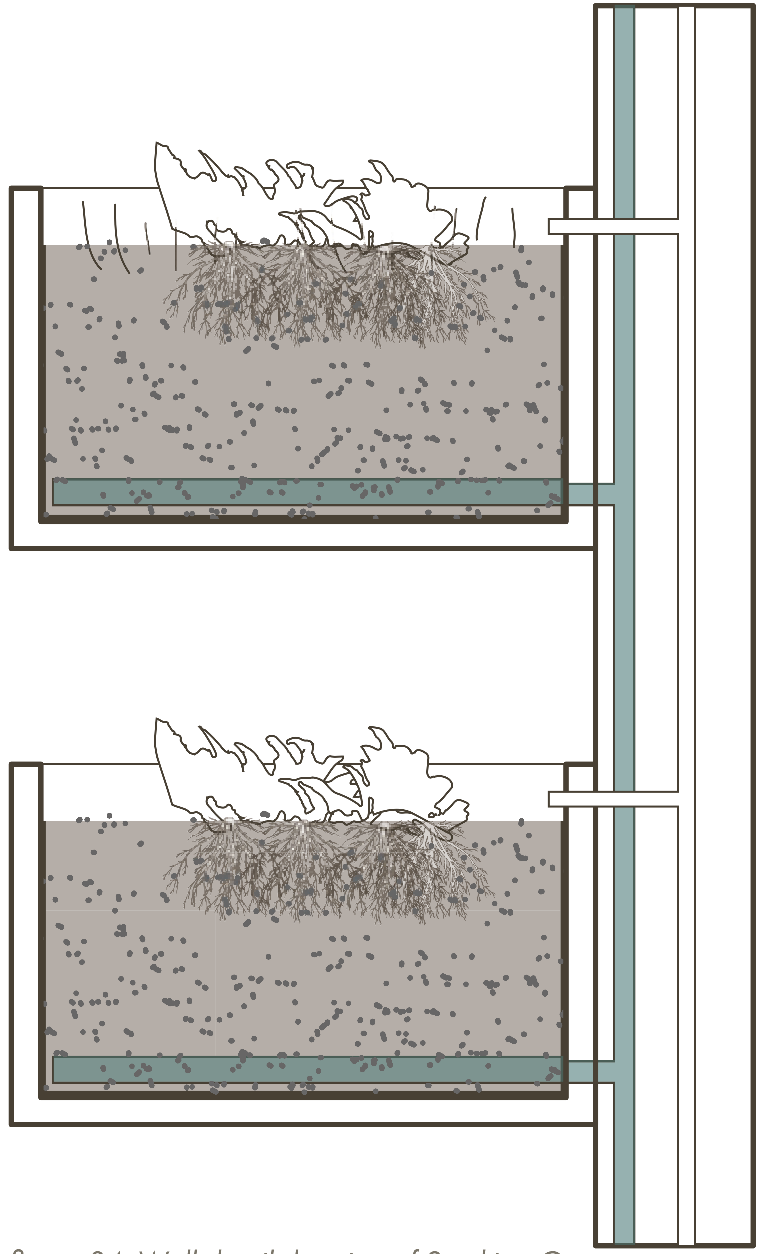


figure 34. Wall detail drawing of Stacking Green

Tanpopo House (Dandelion House)
Architect; Terunobu Fujimori

Another Terunobu Fujimori project can be explained with the challenge of green walls and roofs.

Over 1,000 dandelion seeds were gathered by hand and planted on the roof and wall. Their bloom is brief, lasting around a month a year. Flowers and Grass grow between Volcanic slates.

figure 35. Tanpopo House (Dandelion House)

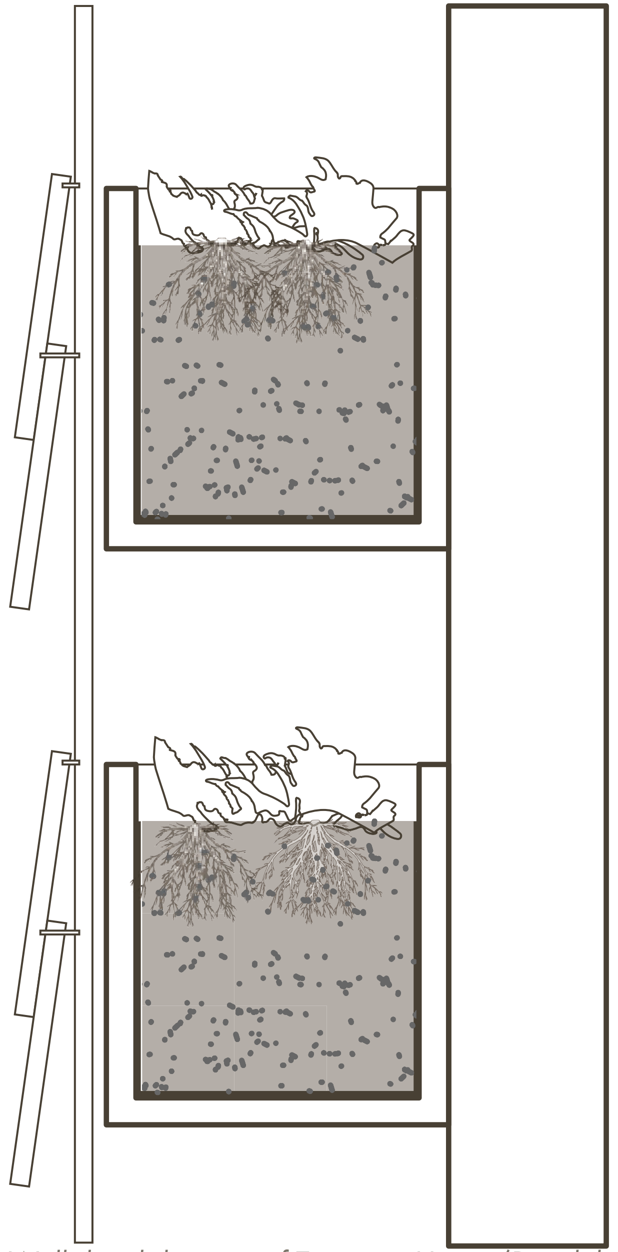


figure 36. Wall detail drawing of Tanpopo House (Dandelion House)

Rain Screen

A rain screen is the exterior cladding that is installed away from the waterproof barrier of the building facade. It creates a gap between the cladding and the wall to provide ventilation , helping to protect the walls from rain and sunlight.

figure 37. Rain screen

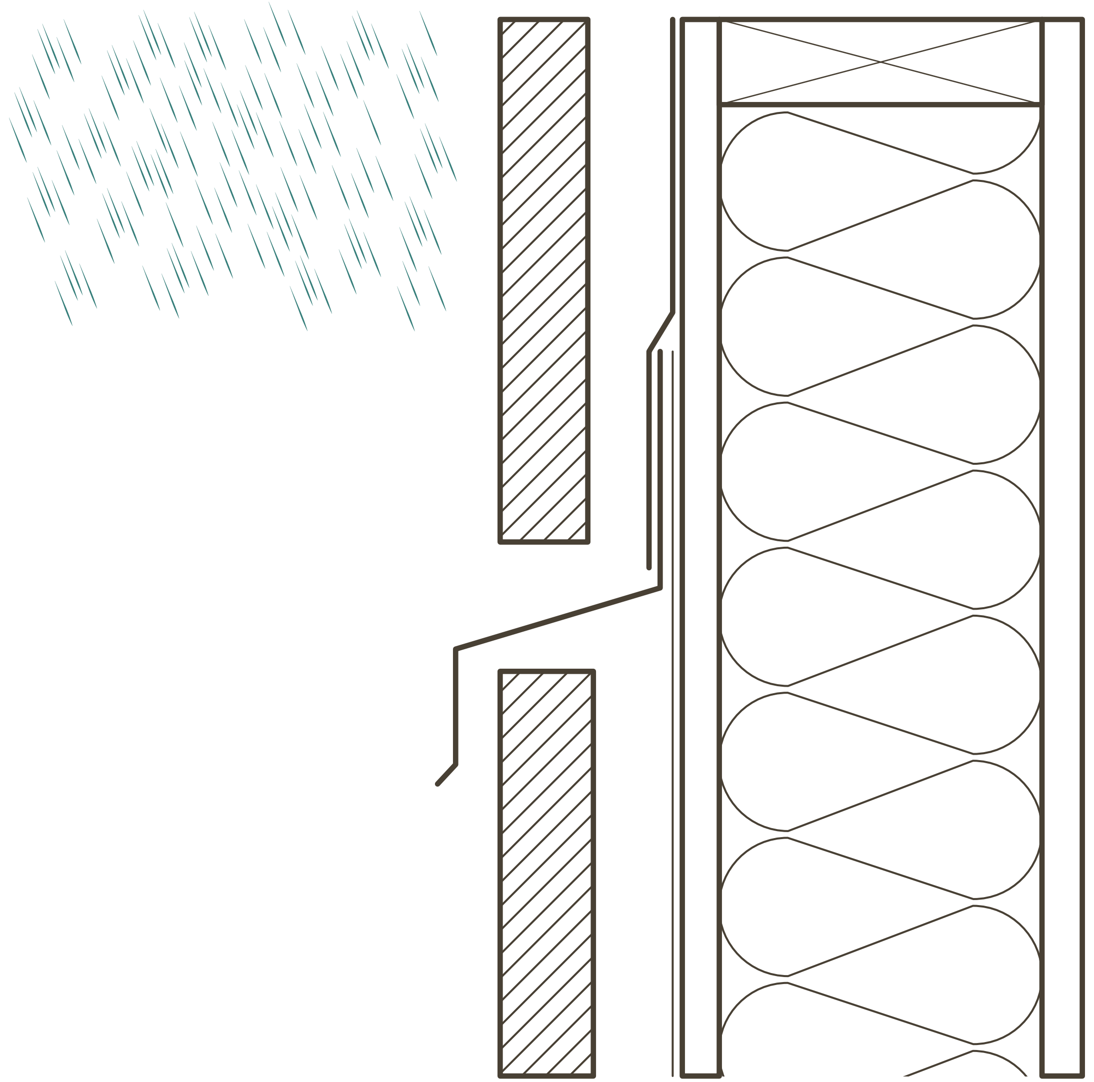


figure 38. Wall detail drawing of Rain screen

French drain system

A French drain is a trench filled with gravel or rock that directs surface water or groundwater away from a living area. Drains typically consist of perforated pipe surrounded by gravel or other drainage material.

figure 39. French drain system

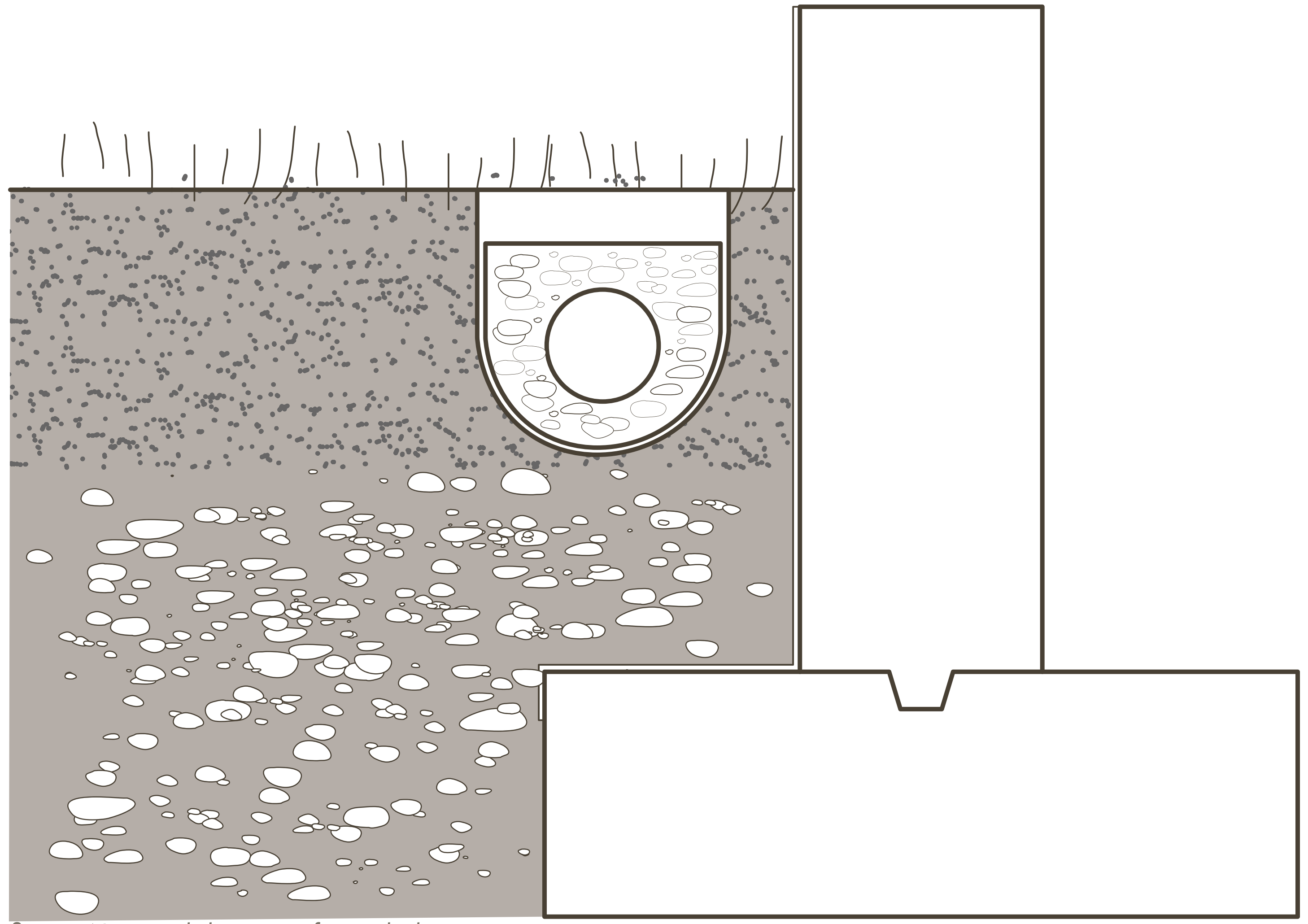


figure 40. Detail drawing of French drain system

Footing Drain System

A footing drain is installed along the outside of the footings of foundation walls to directly infiltrate water and moisture away from the foundation and safely enter the ground.

figure 41. Footing drain System

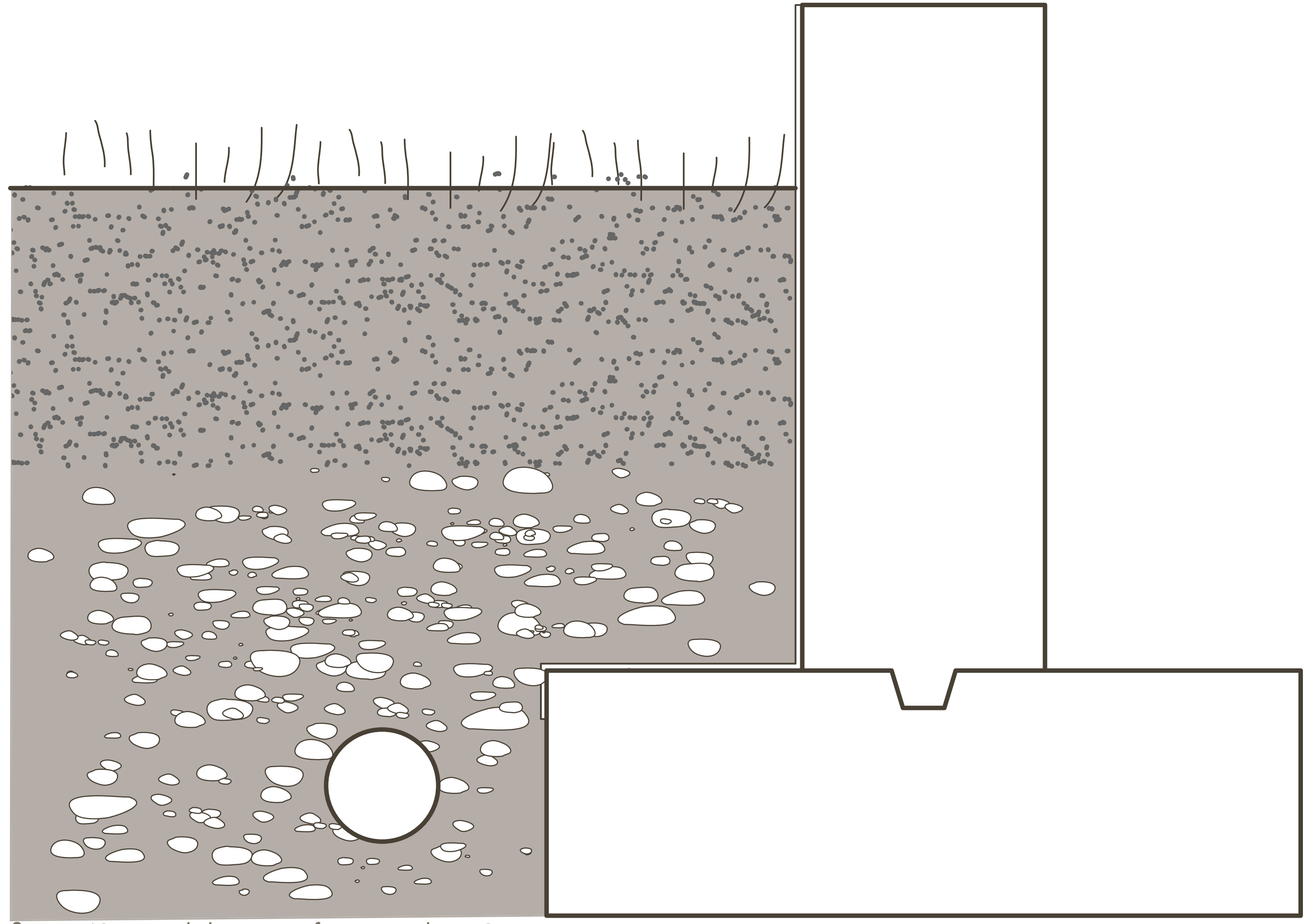


figure 42. Detail drawing of Footing drain System

Precedent study 2.Gutter System1

Typical gutter system

The usual gutter and downspout are easy to attach to the walls and roofs. Aluminum, Plastic, PVC, Vinyl, and Polypropylene are widely used as materials.


figure 43. Gutter


figure 44. Gutter and downspout

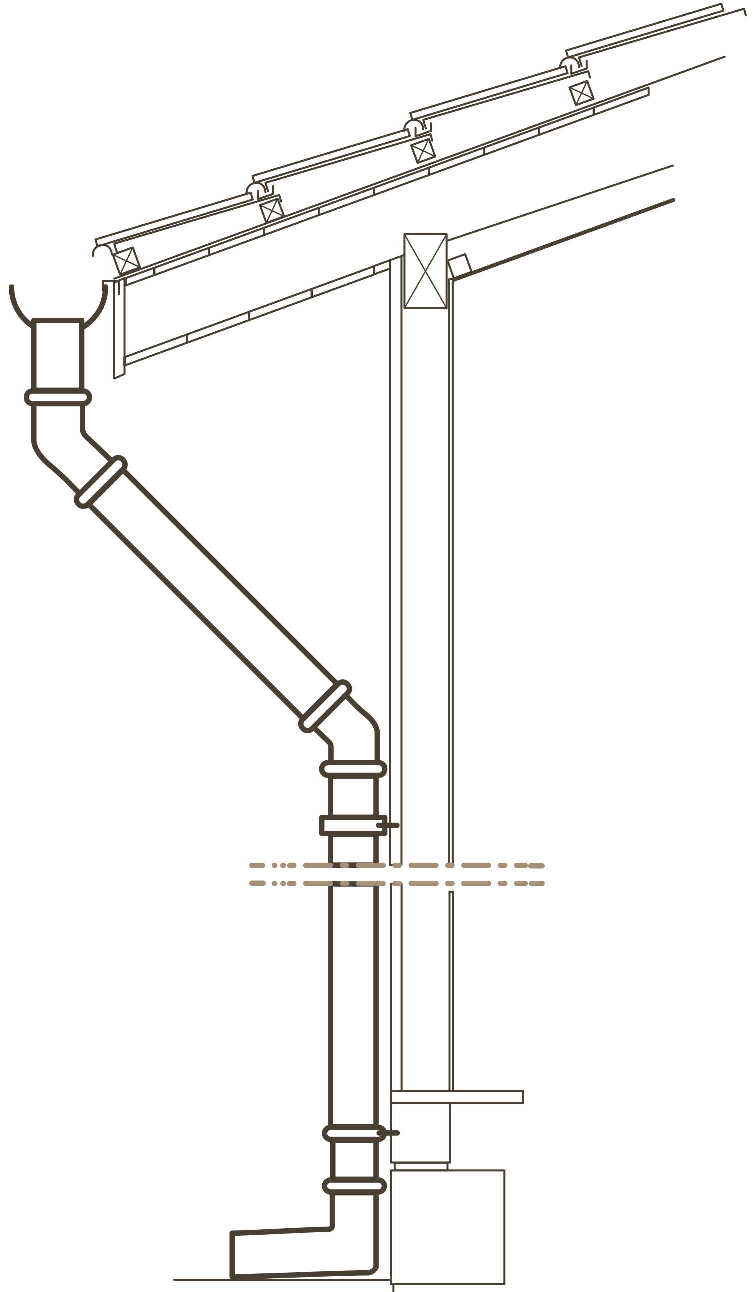


figure 45. Drawing of typical gutter and downspout

Katsura Rikyu Gepparo Bamboo Dawnspout


figure 46. Gutter and downspout


figure 47. Downspout

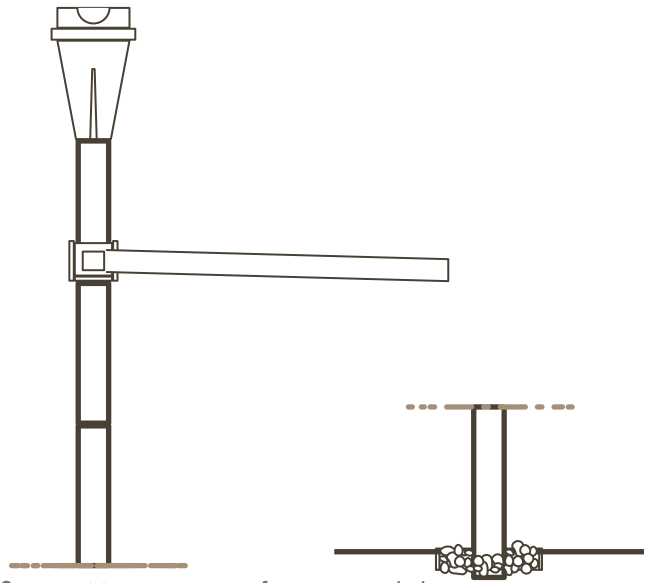


figure 48. Drawing of gutter and downspout

Japanese shrine Rain Chain


figure 49. Rain chain

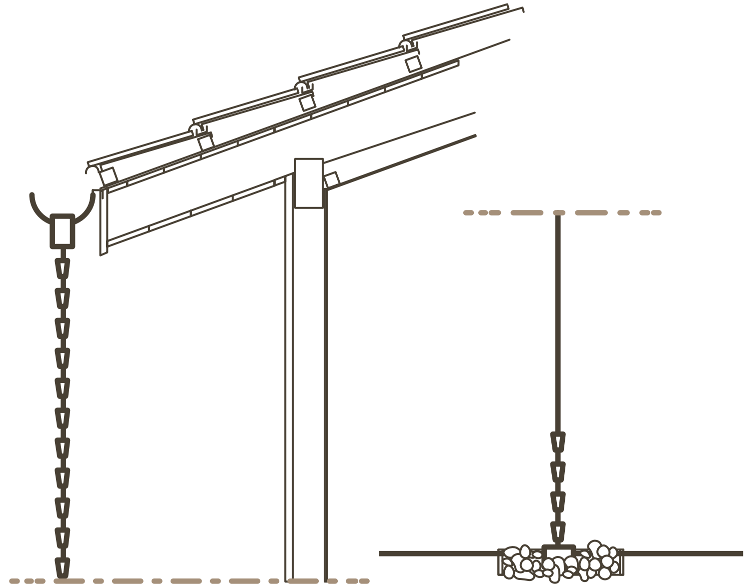


figure 50. Drawing of rain chain

Precedent study 2.Gutter System 2

Hidden gutter system

A hidden gutter system is a gutter system that's built into the roof or wall of a building, making it less visible. This system allows architects to expand their design style.

figure 51. Hidden gutter

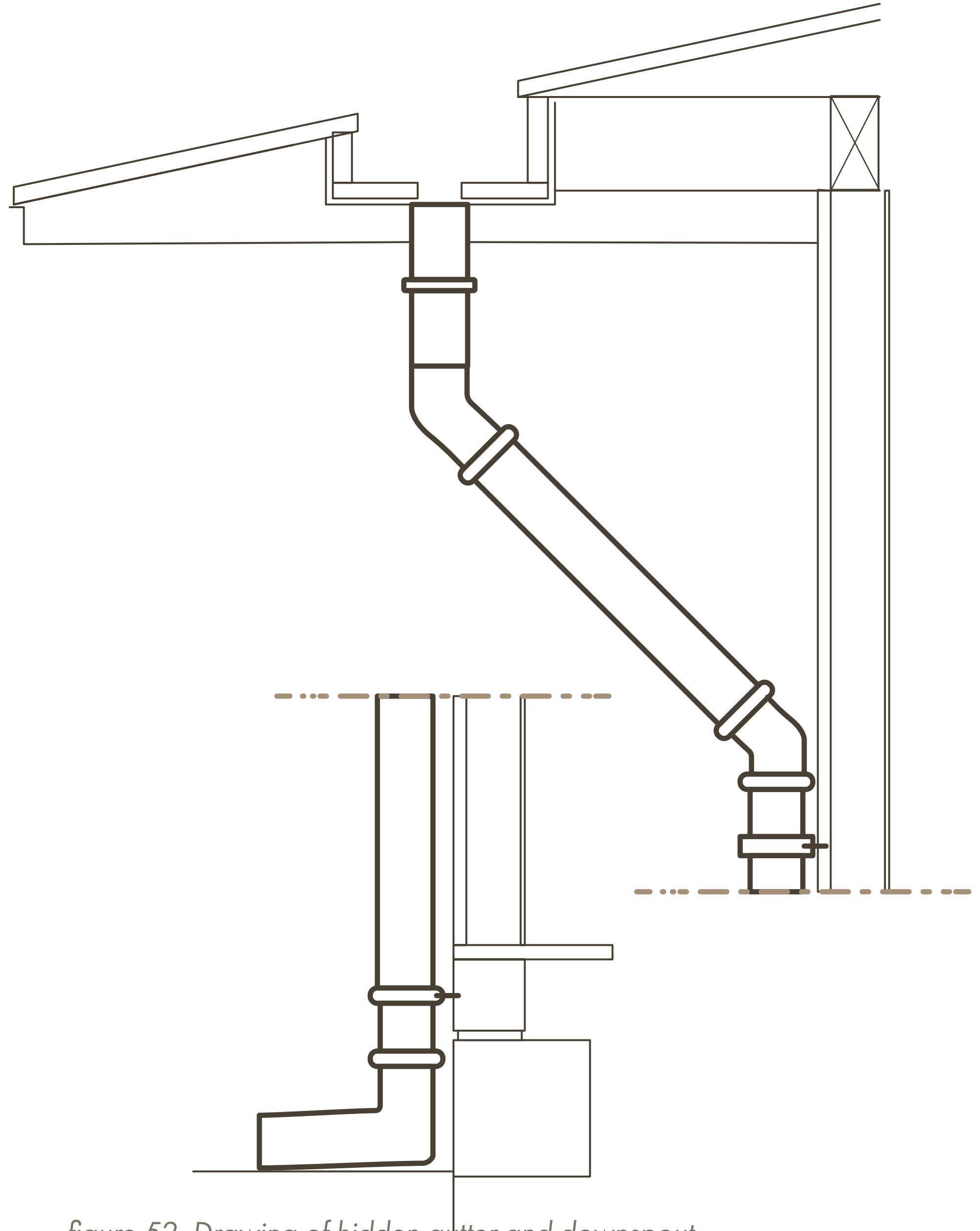


figure 52. Drawing of hidden gutter and downspout

Makino Museum of Plants / Hiroshi Naito
Hidden Gutter + Suspended Downspout

figure 53. Gutter and downspout

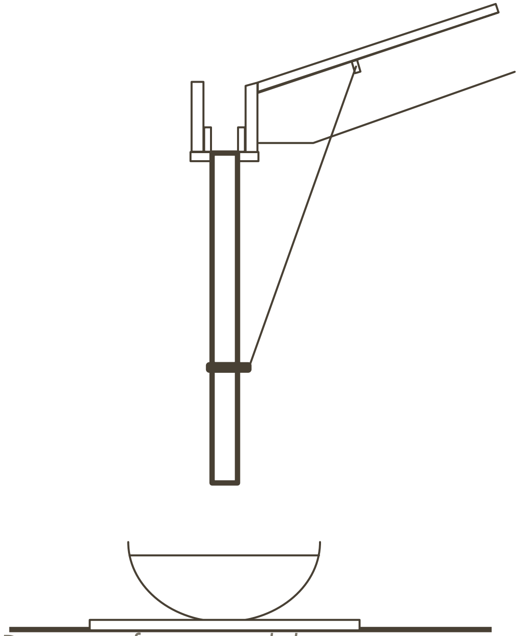


figure 54. Drawing of gutter and downspout

Magney House / Glen Murcutt
Inner Gutter + Downspout

figure 55. Gutter and downspout

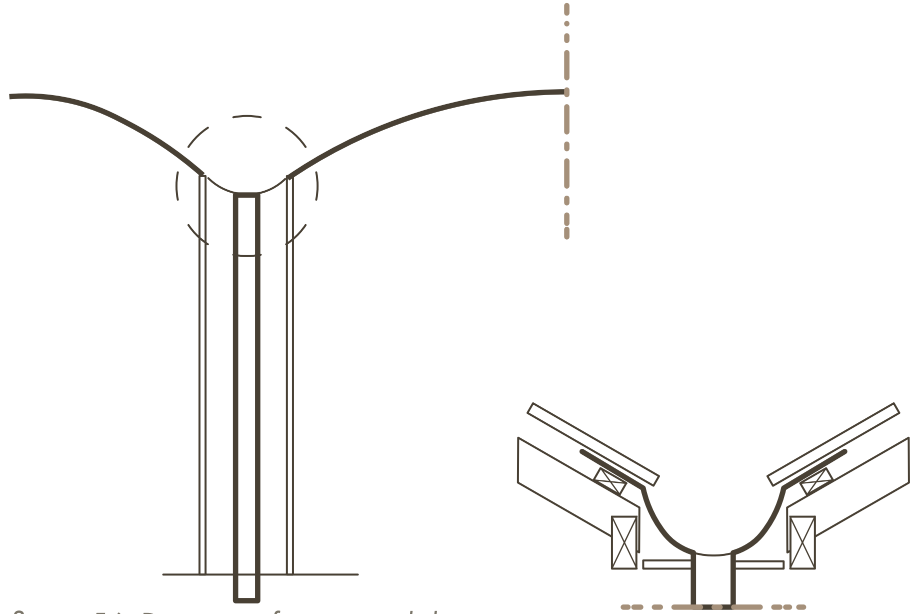


figure 56. Drawing of gutter and downspout

03. Site Analysis

Three sites were initially selected based on several research studies and some site analyses based on the sewer map. This project focuses on how this house impacts reducing rain runoff to the alley, and feasibility is the key to propose. The popular property website is utilized to find the vacant vacant lot in the D.C. alley.

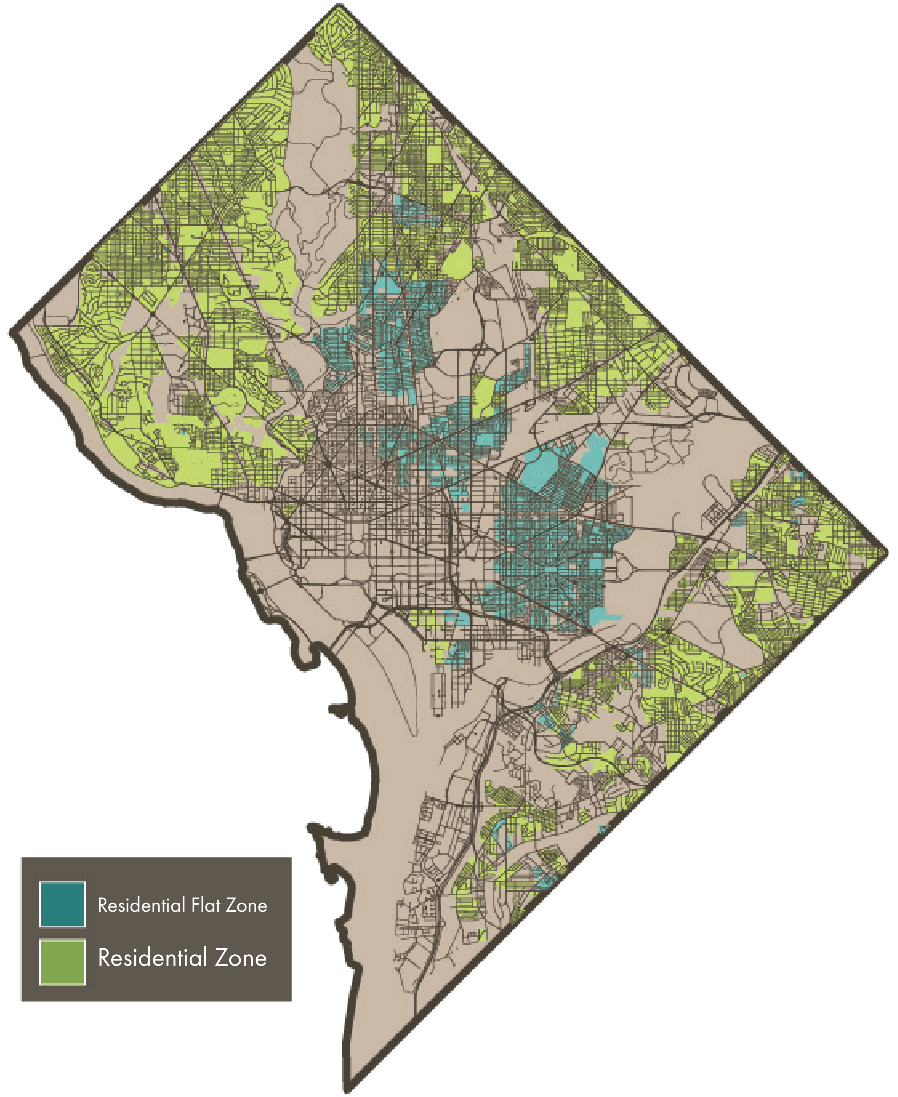


figure 57. D.C. zoning map

01. Zoning Map

The map shows the area including regidential flat zone and residential zone, where proposed rowhouse would be intervened.

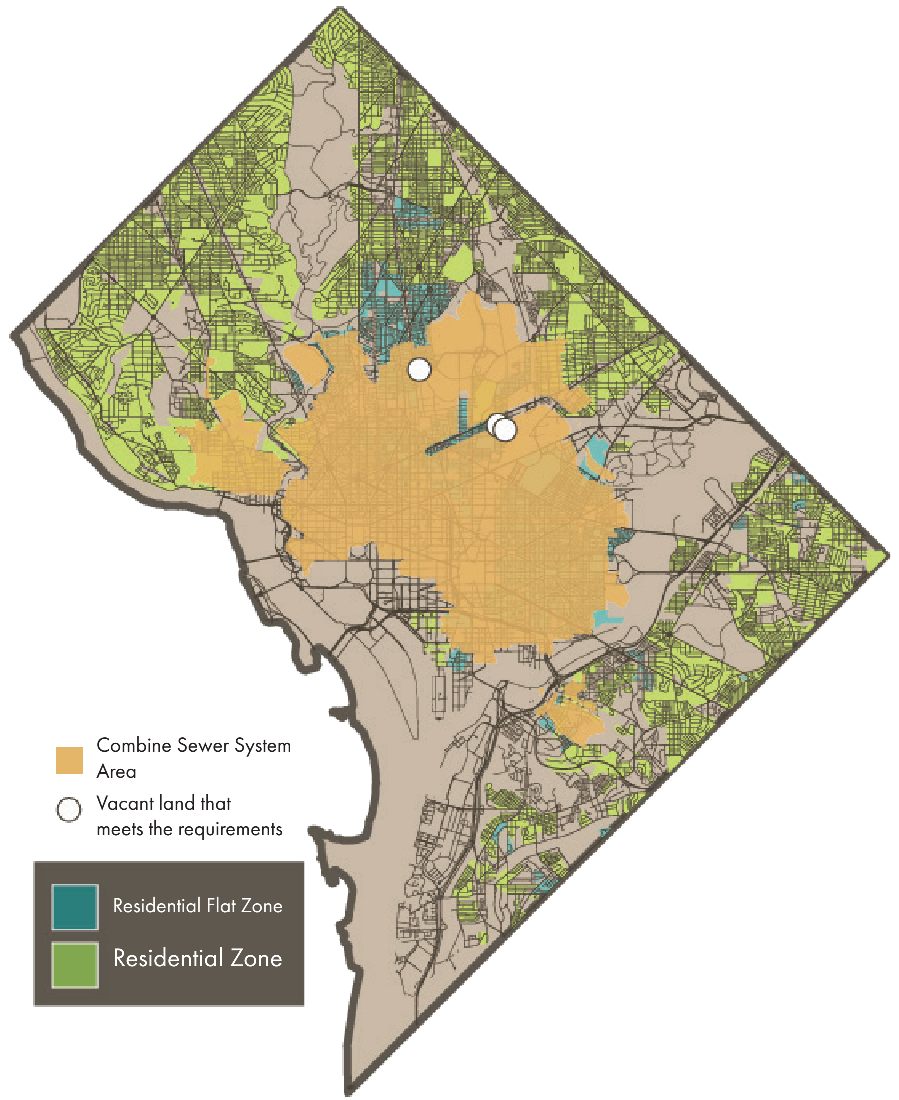


figure 58. Combine Sewer System Area

02. Combine Sewer System Area

Three alley lots in the combined sewer zone were selected to examine sustainable methods. The white circle shows current vacant lots located in alley lots.

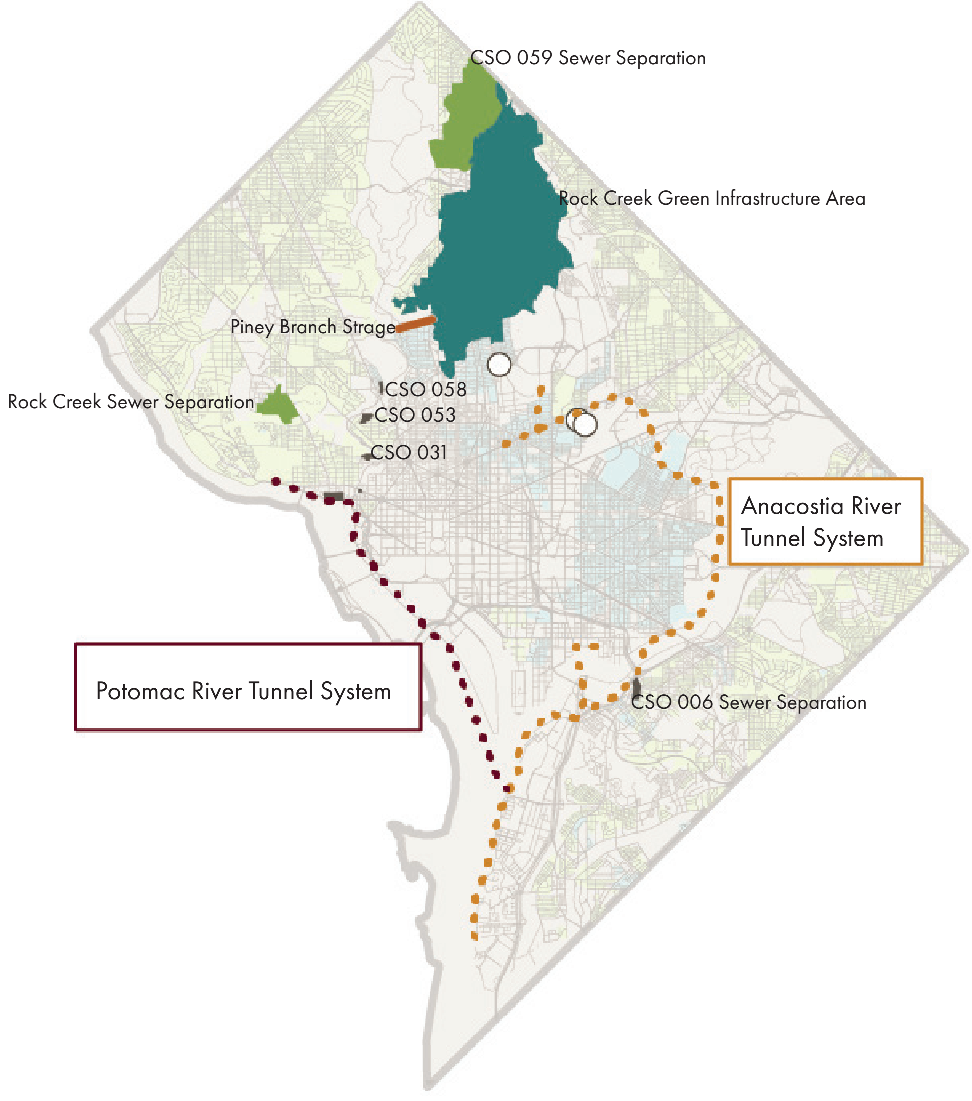


figure 59. Separate Sewer System Area

03. Separate Sewer System Area

There are two main separate sewer system, Anacostia River Tunnel System and Potomac River Tunnel System.

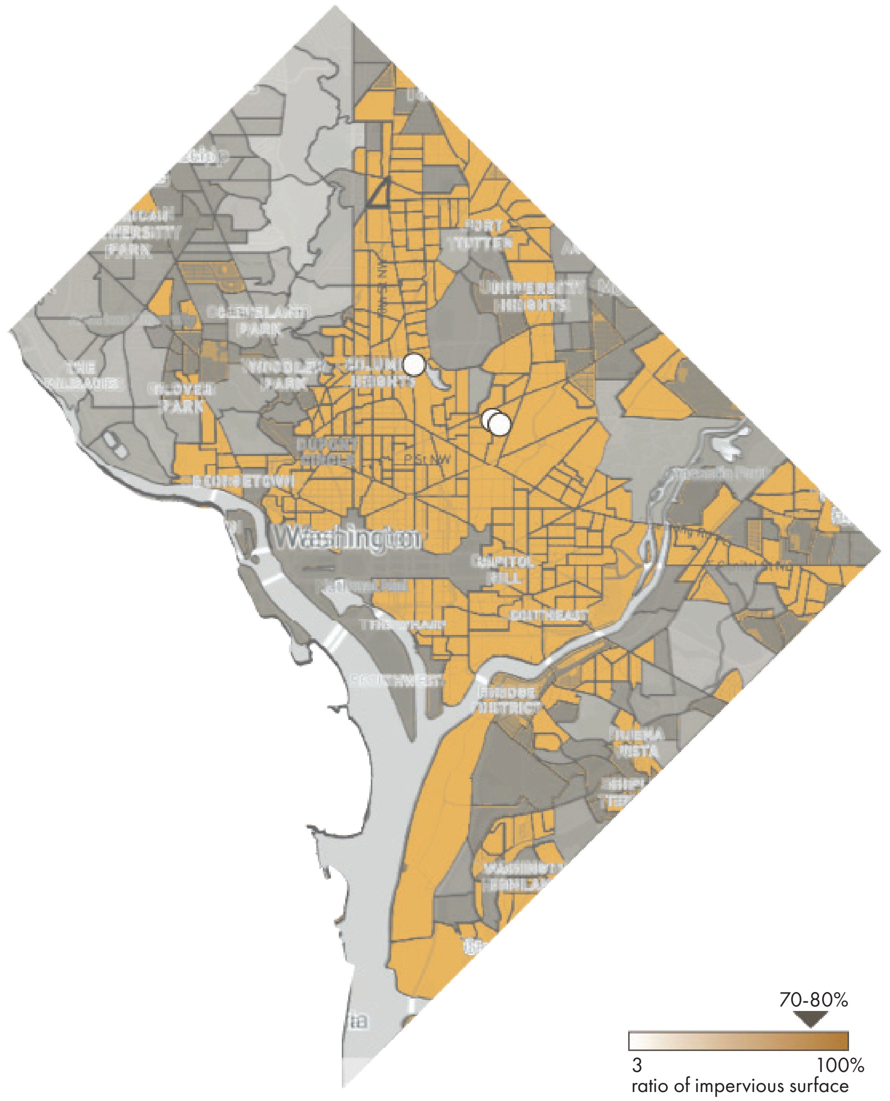


figure 60. Impervious Surface

04. Impervious Surface

The orange areas highlights the higher percentage of the usage of impervious surface.

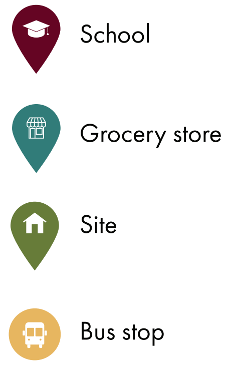


figure 61. Site selection map

Site Selection

Site selection was processed by examining each neighborhood condition, such as walkability, to examine how the site adapts to city life. Then, the site's area size was compared; site one is huge and has enough space to find many solutions and approaches to discovering the sponge house.

figure 62. Photo of site 1 and the alley

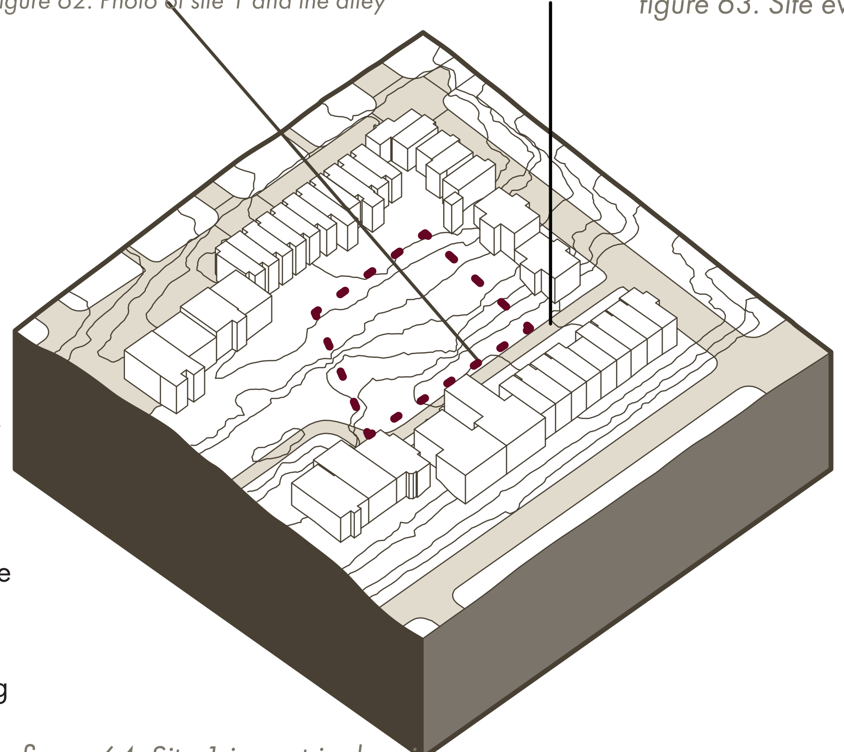


figure 64. Site 1 isometric drawing

Criteria	Zoning	Sewer System	Impervious Surface (%)	Neighborhood condition (the figures refer to minutes from the site.[2])					Acceptable family number	Characteristic			
	Residential area is required	Combine or Separate		Transportation	Avg. minutes	Eating (mins)	Stores (mins)	Transit (mins)	known by property boundary	Location	Area		
Site1	RF-1	Combine	70-80%	good	9.3	6.8	18.7	9.1	7 to 9 families	**ALLEY LOT**	1,5246 sqft	Better to focus on several house designs	Much opportunity to think about rain runoff (**NO catch-drain**)
Site2	RF-1	Combine	70-80%	good	11	6.6	20.6	9.2	1 or 2	face to the street	3,693 sqft	Better to focus on **a single** house design	Good condition for rain runoff
Site3	RF-1	Combine	70-80%	so so	7.2	5.9	9.5	5.8	1	middle of the row house	871 sqft	Better to focus on **a single** house design	Good condition for rain runoff

figure 63. Site evaluation criteria

2. Stevens, H. (2024, December 7). How walkable is your neighborhood? Use our interactive map to find out. Washington Post; The Washington Post. https://www.washingtonpost.com/climate-environment/interactive/2024/walkable-neighborhoods-suburban-sprawl-pollution/?itid=hp-top-table-main_p001_f007

figure 66. Photo of site 2-2

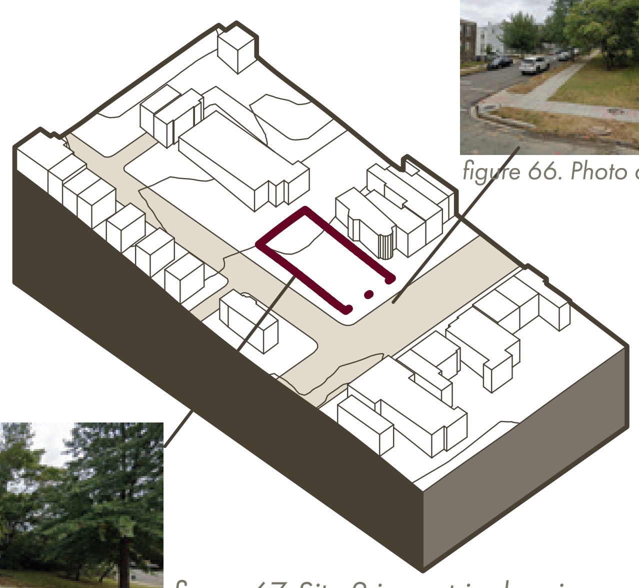


figure 67. Site 2 isometric drawing

figure 65. Photo of site 2-1

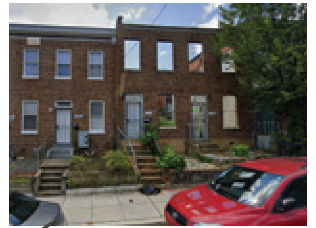


figure 69. Photo of site 3-2

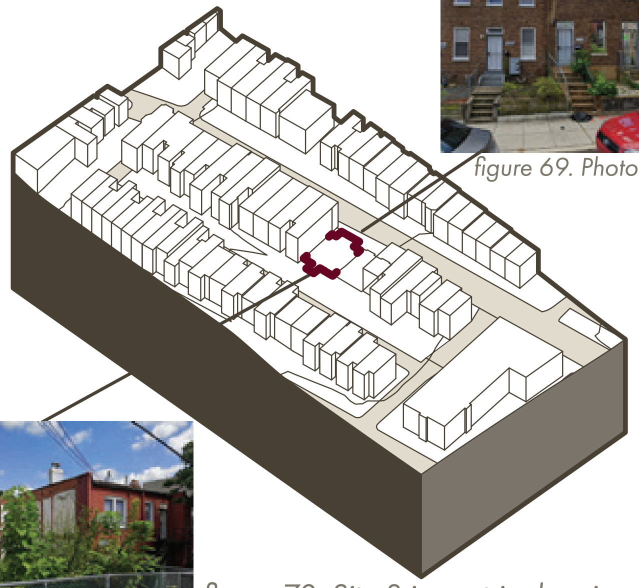


figure 70. Site 3 isometric drawing

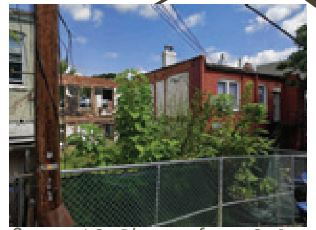


figure 68. Photo of site 3-1

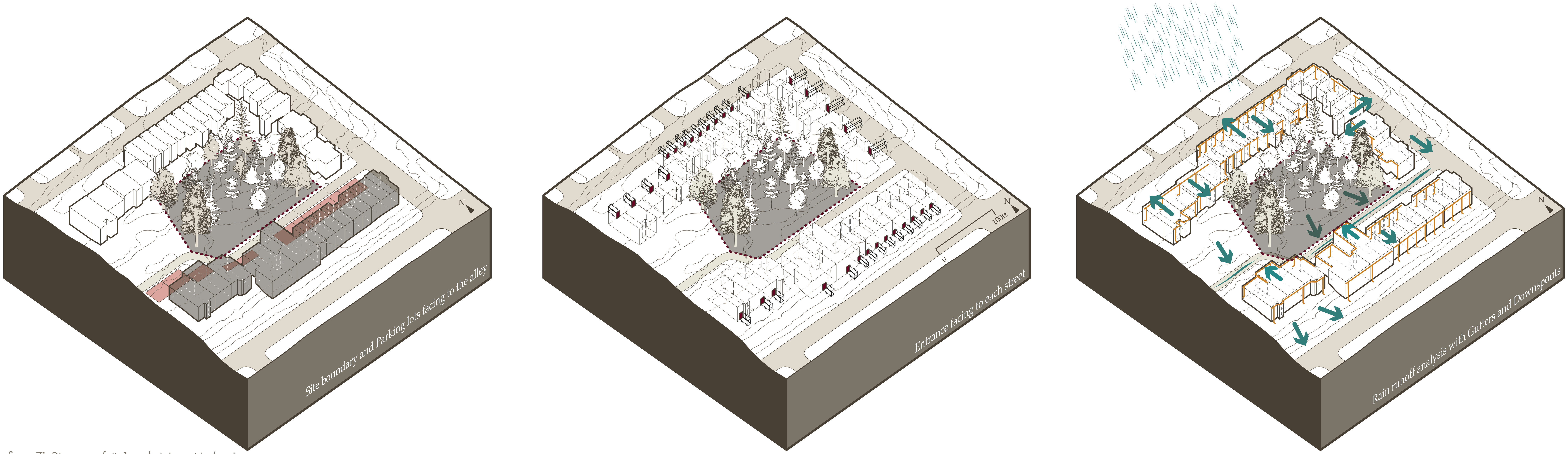


figure 71. Diagrams of site1;analysis isometric drawings

Tree Analysis

Various trees grow naturally in the site and sopport the foundation with its roots. The map shows the location of each tree and its name. There are more than 25 trees and 21 species.

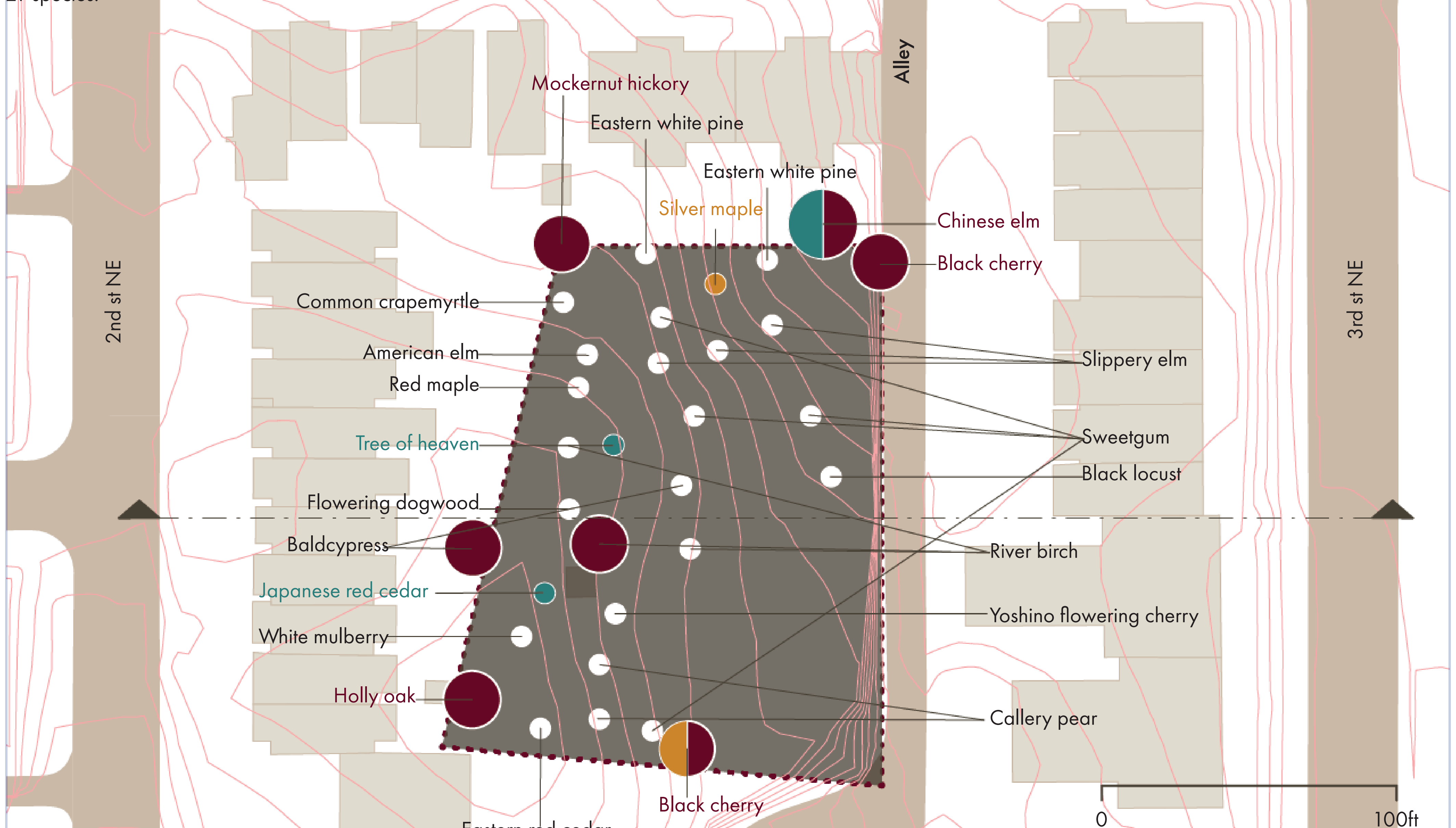


figure 72. Tree location map

Trees List

Some species are called special trees or heritage trees and require permission to be removed (red color). This is because special tree has a circumference between 44 to 99.9 inches and heritage tree 100 inches or more. In contrast, silver maple and black cherry are intolerant to construction disturbance, so some actions should be taken (orange color). Invasive trees that came from overseas, such as Japanese red cedar and Tree of Heaven, are considered to be removed from this site (blue color).

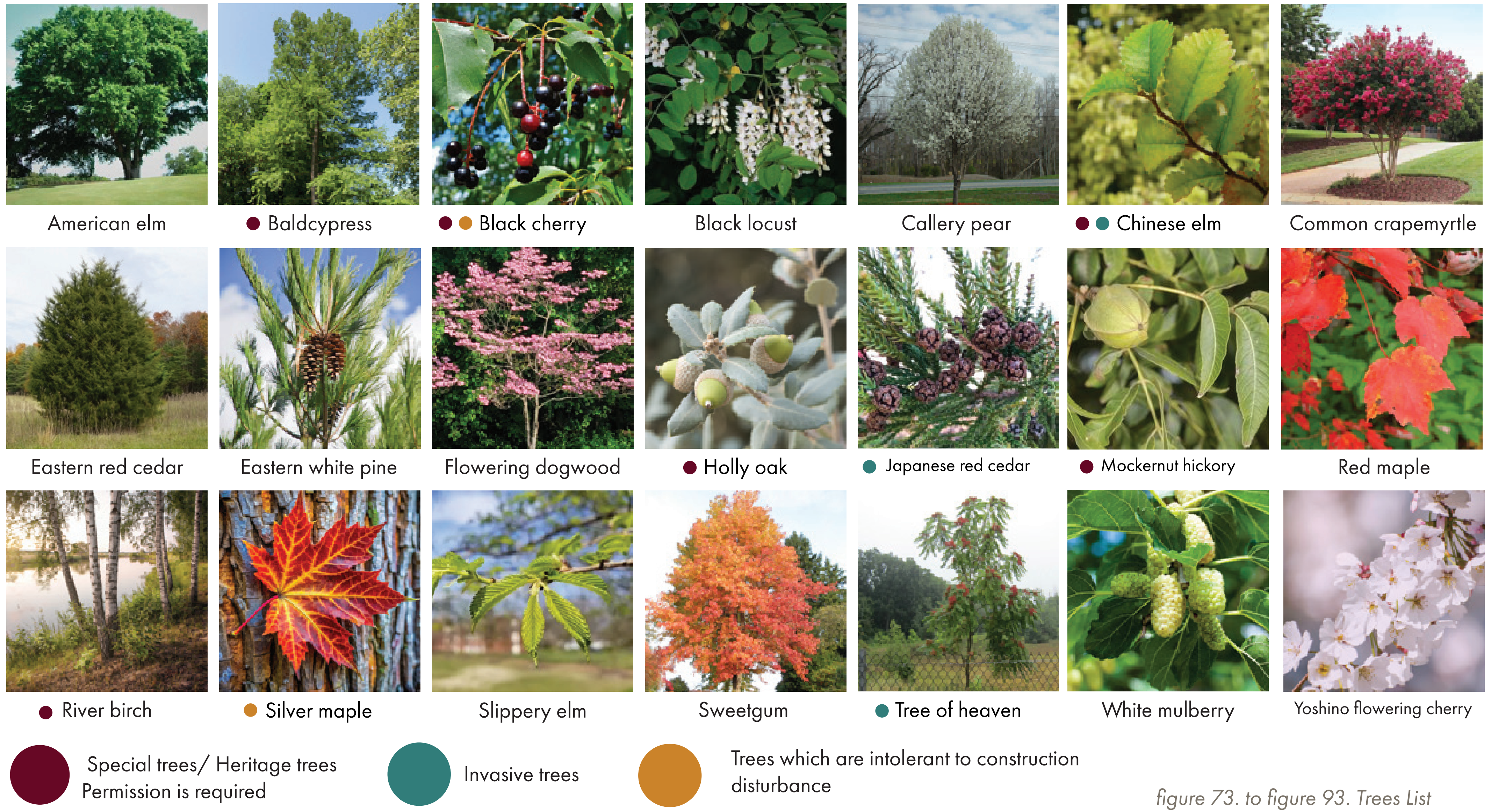


figure 73. to figure 93. Trees List

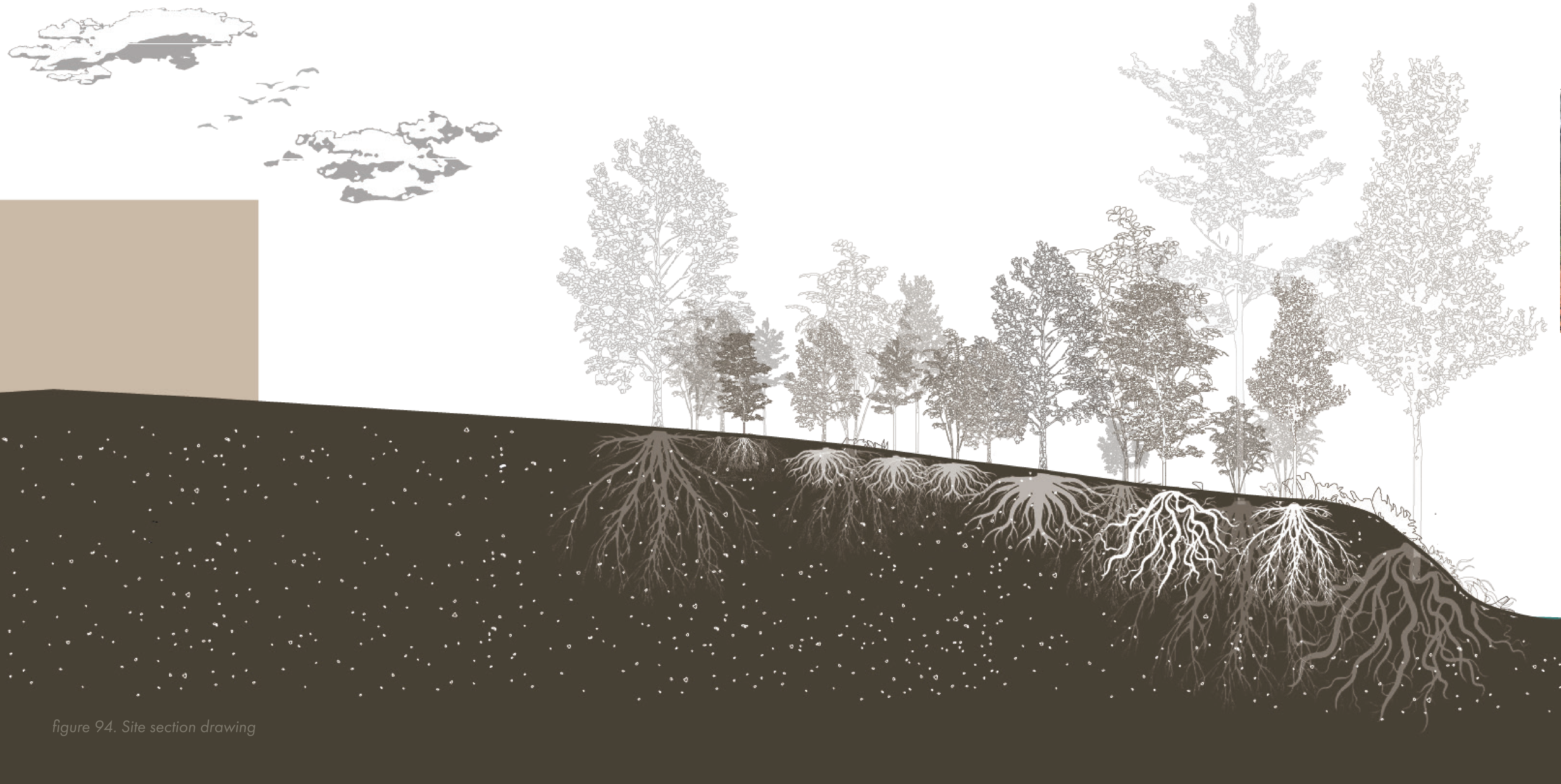


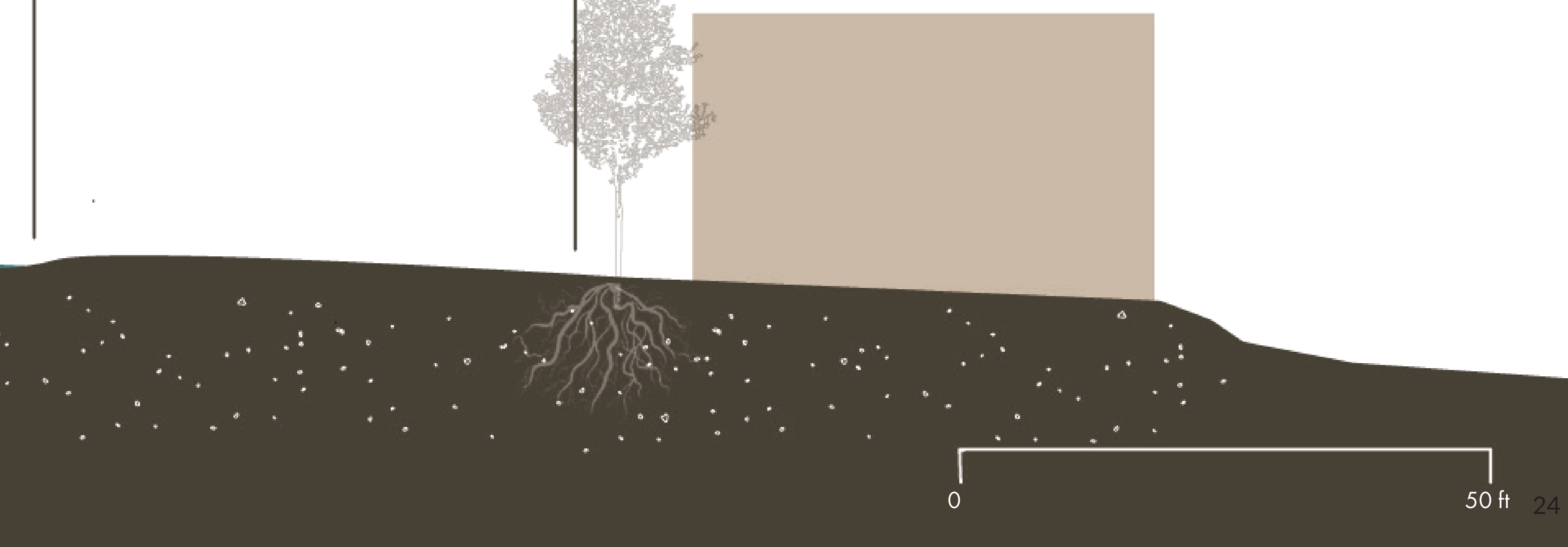
figure 94. Site section drawing

figure 95. Alley

Bad road condition when it is raining due to the impervious surface

figure 96. Parking lot

Parking lots are faced to the alley.



04. Design

Understanding these trees and their roots is the first step of the design process. Heritage trees should be retained as part of this project's sponge, whereas some other trees are removed or vegetated on the roof or other spaces of this site.

Initially, it is important to know CRZ and SRZ, as well as the critical root zone and structural root zone, to avoid root pruning. CRZ, a critical root zone, is the soil area immediately adjacent to a tree's trunk where roots essential for tree health are located. SRZ, a structural root zone, is the area around the base of a tree that is required for the tree's stability in the ground.

The CRZ is determined by measuring the main stem 4.5 feet above ground level, then providing 1.5 feet of protection (radius of the circle) for every 1-inch in tree diameter measured. The SRZ is determined by measuring the main stem 4.5 feet above ground level, then providing .5 feet of protection (radius of the circle) for every 1 inch in tree diameter measured.

Using this method, the circles for every heritage tree were drawn. Then, the building zone was set to avoid these areas. Each unit is based on the current property boundary. After making the mass, the floor level was changed depending on the top line. Each unit has 2 to 4-foot differences at both ends, so apparently, 2 or 4 feet of rising occurred. For the final step, a 20-foot setback from the alley was confirmed to ensure the parking lot.

figure98. *Drawings of zoning (isometric)*

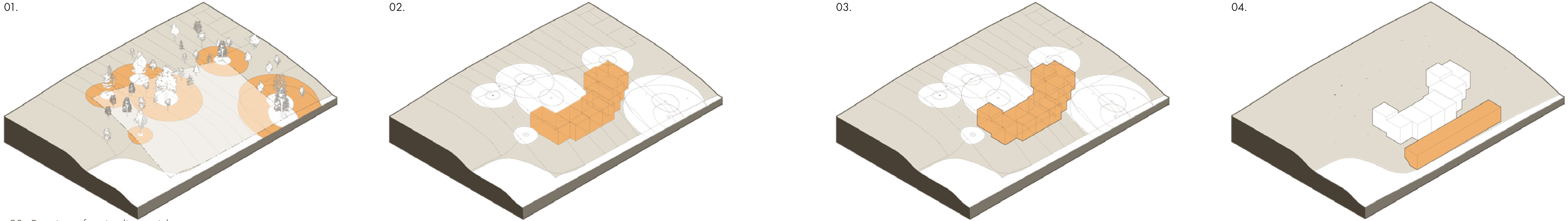


figure98. *Drawings of zoning (isometric)*

figure99. Site plan and floor plan; ground level

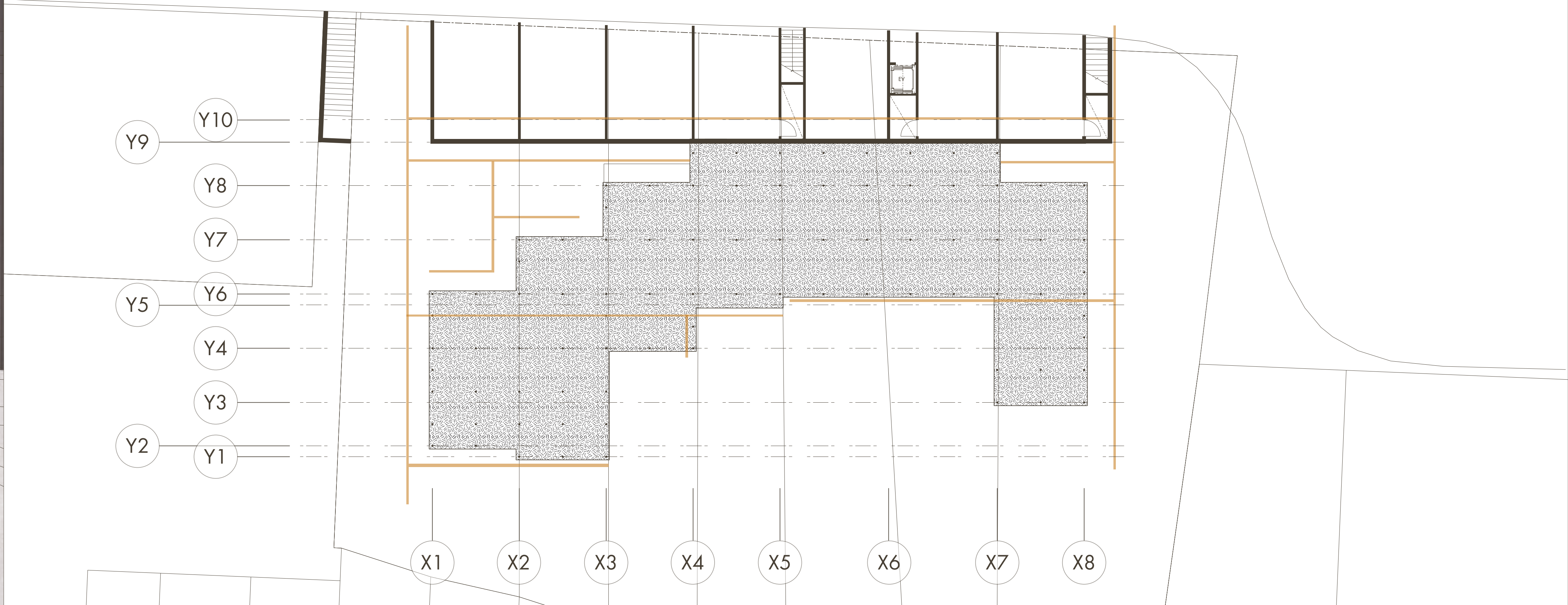


figure100. Floor plan; basement

As the plan shows, four unit types are proposed (figure 99). Each floor plan has at least one visible line from front to backyard, which means residents can feel the outside from everywhere in the room. Alternatively, they could feel the rain as its sound and landscape. The east side is the main entrance for residents and visitors, whereas the west is private areas such as community spaces and playgrounds for children. The front and the back are connected by a wood deck surrounding the houses and connected to the private porch in the backyard.

French Drain System

N

Floor plan; second level

Each unit is designed to allow residents to access the outside through the balcony and stairs connecting to green roof so that they can see and feel the rain without any inconvenience.

Roof plan

For the green roof, some small trees are planted to create semi-private space; residents can isolate themselves from other residents but feel it. Hidden gutters are installed on the boundary of each unit, connecting to the downspout on both the east and west sides of the building.

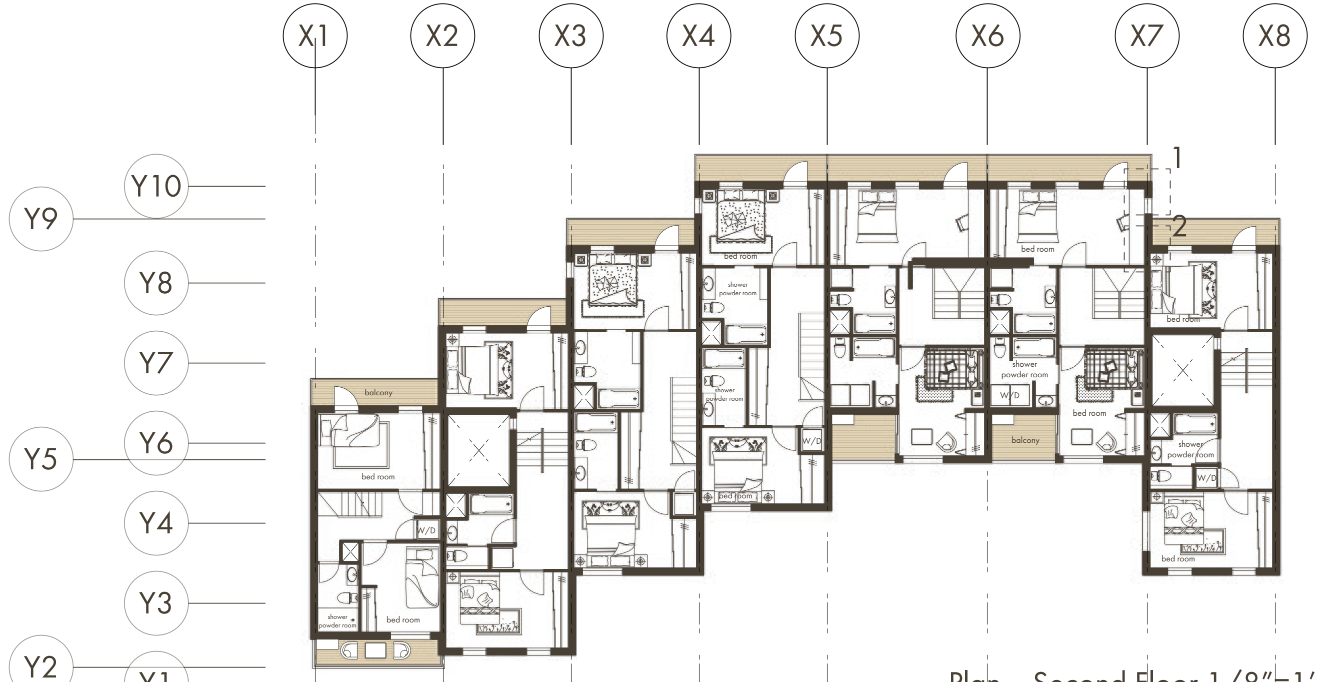


figure101. Floor plan; second level

figure102. Floor plan; roof plan

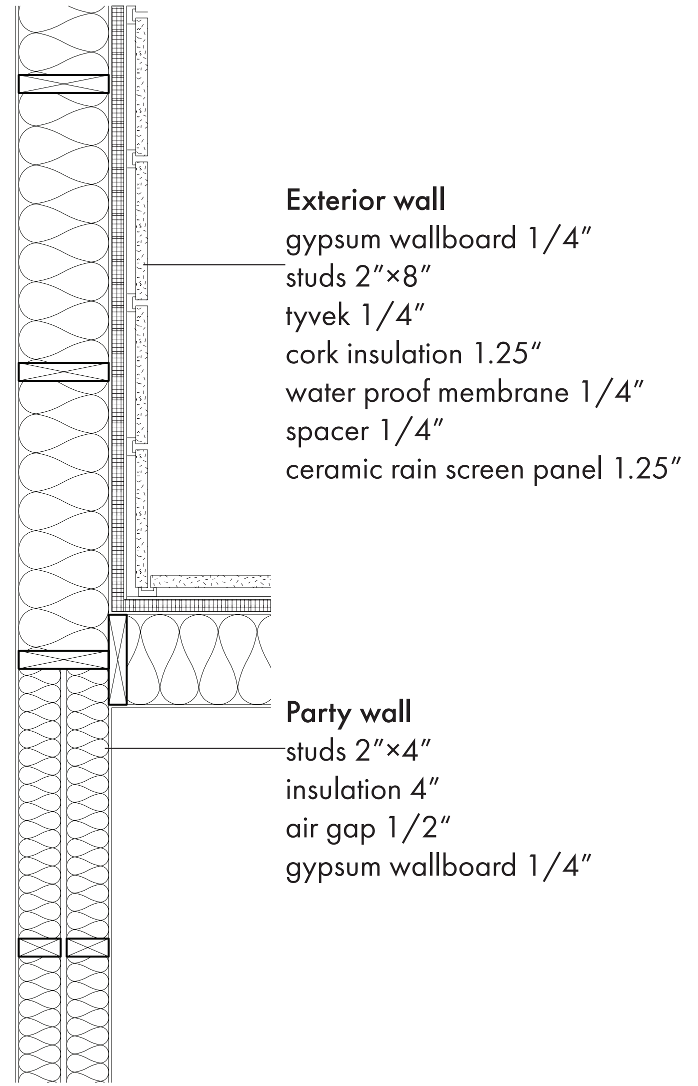


figure103. Plan Detail 1, 9/10"=1'

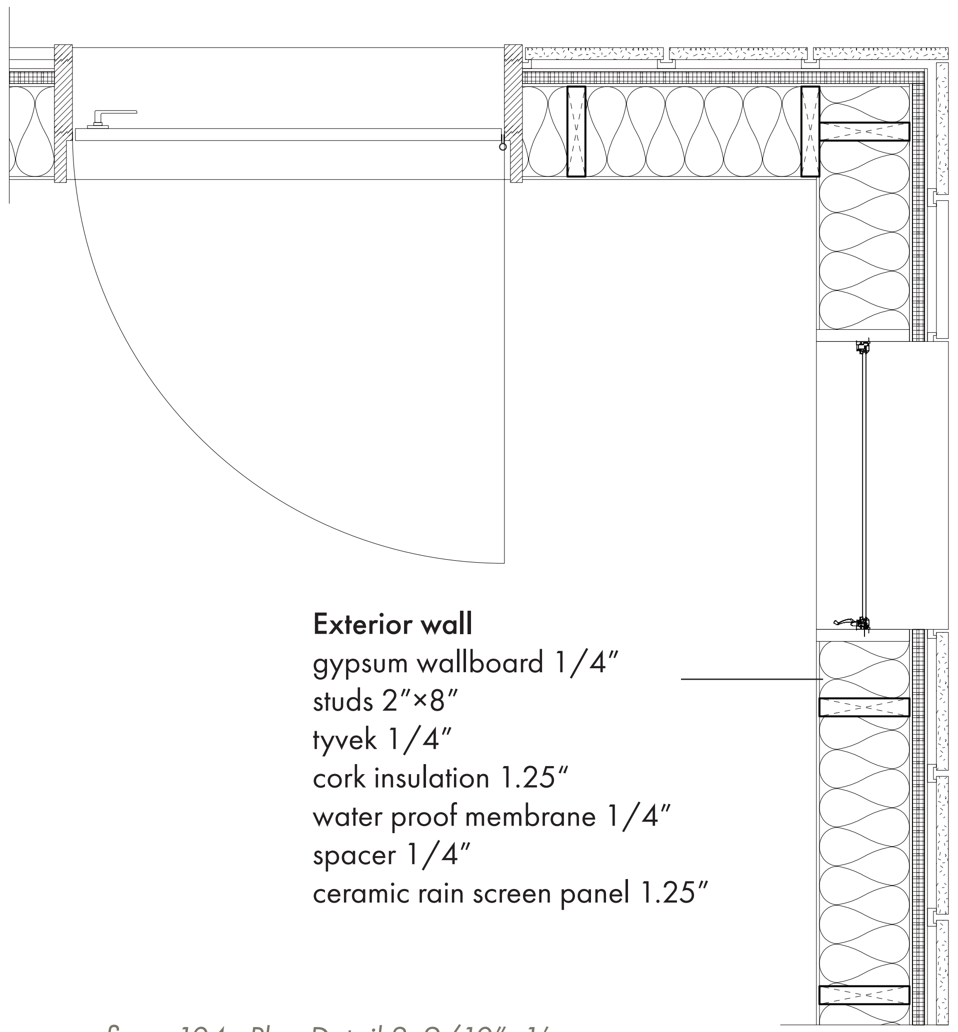


figure104. Plan Detail 2, 9/10"=1'

Elevation from east

The main part of the Sponge House is a two-foot-deep green roof, which can retain almost all precipitation in typical rain and some storm rain events.

Another type of downspout is installed, with a rain chain/wire as the facade to support the growth of vines in the summer. Because there are no trees there, this can prevent strong sunlight from the east (figure 105 and figure 106).

Aside from accepting rain storage, it is also important to consider preventing rain from getting inside. Ceramic panels are chosen to be installed as rain screens. This helps rain flow to the underground without getting inside the house.

Underground is a crawl space covered with gravel so that people can put a water tank to store the rainwater(figure 107 and figure 109).

As for the garage, pervious surfaces called grasscrete is used for ground and pavement next to the building so that rain does not runoff to the alley. These rain flows to the french drain pipes and gradually flow to underground of the site (figure 108 and figure 110).

figure105. East side elevation drawings with renderings,1/8"=1'

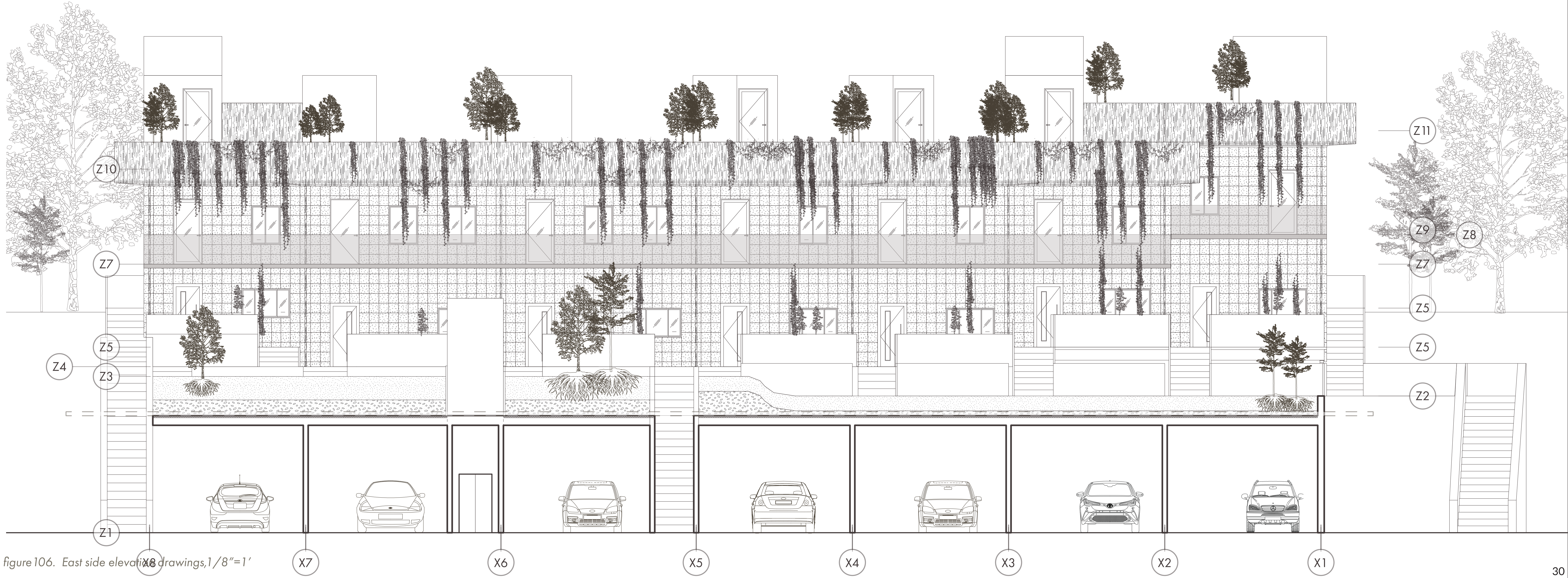


figure 106. East side elevation drawings, 1/8"=1'

figure107. Section drawings with renderings : type B,1/8"=1'

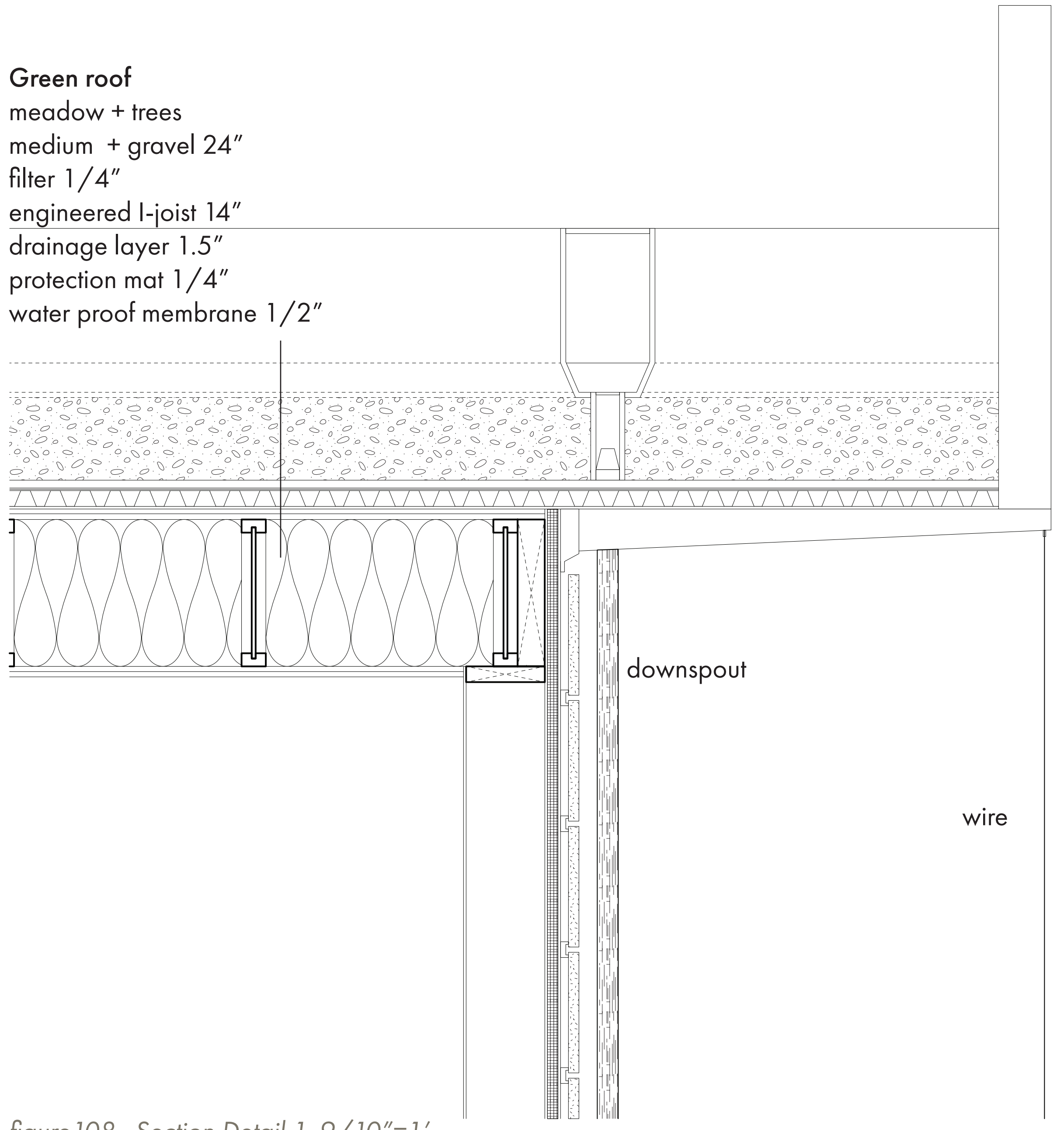


figure108. Section Detail 1, 9/10"=1'

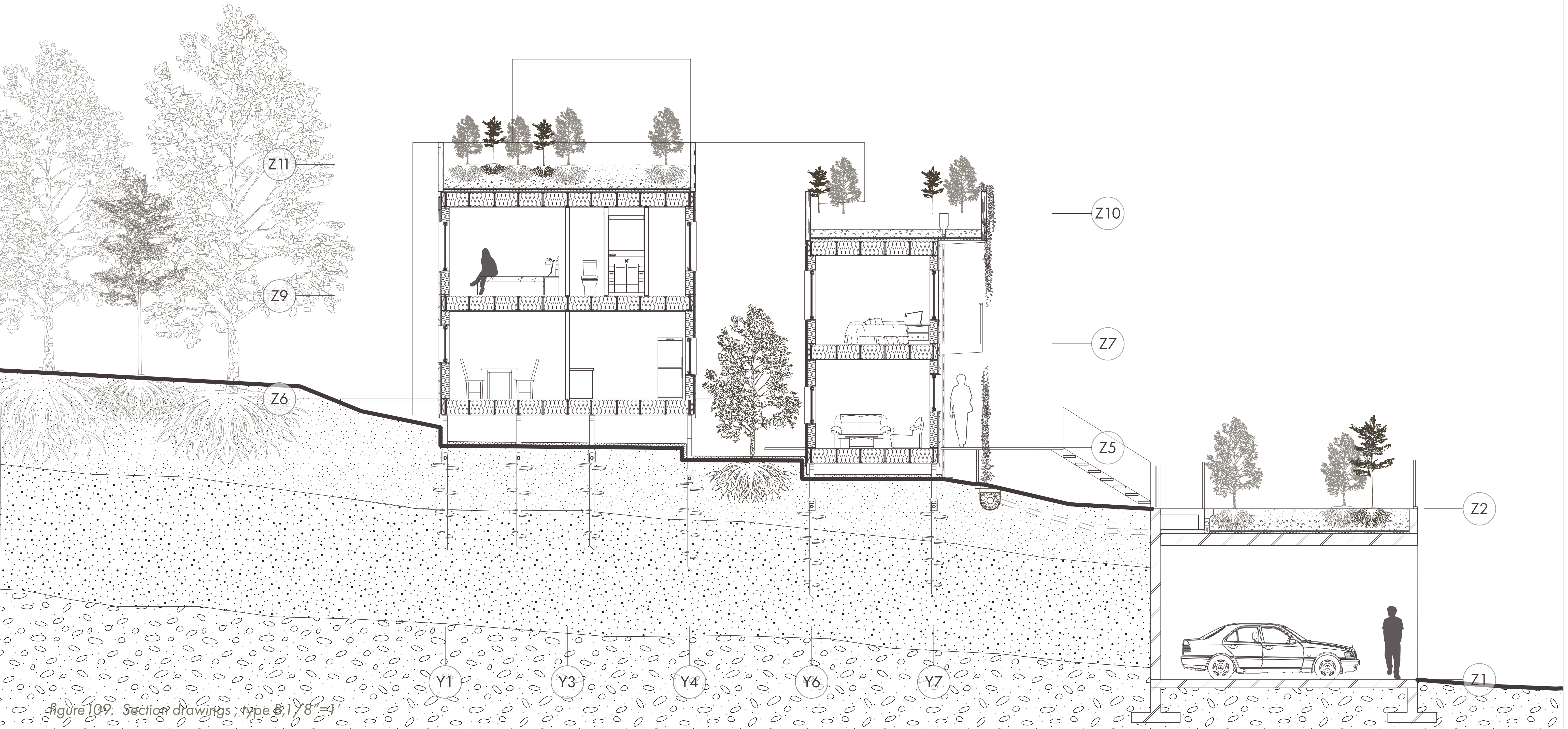


figure109. Section drawings ; type B,1/8″=1′

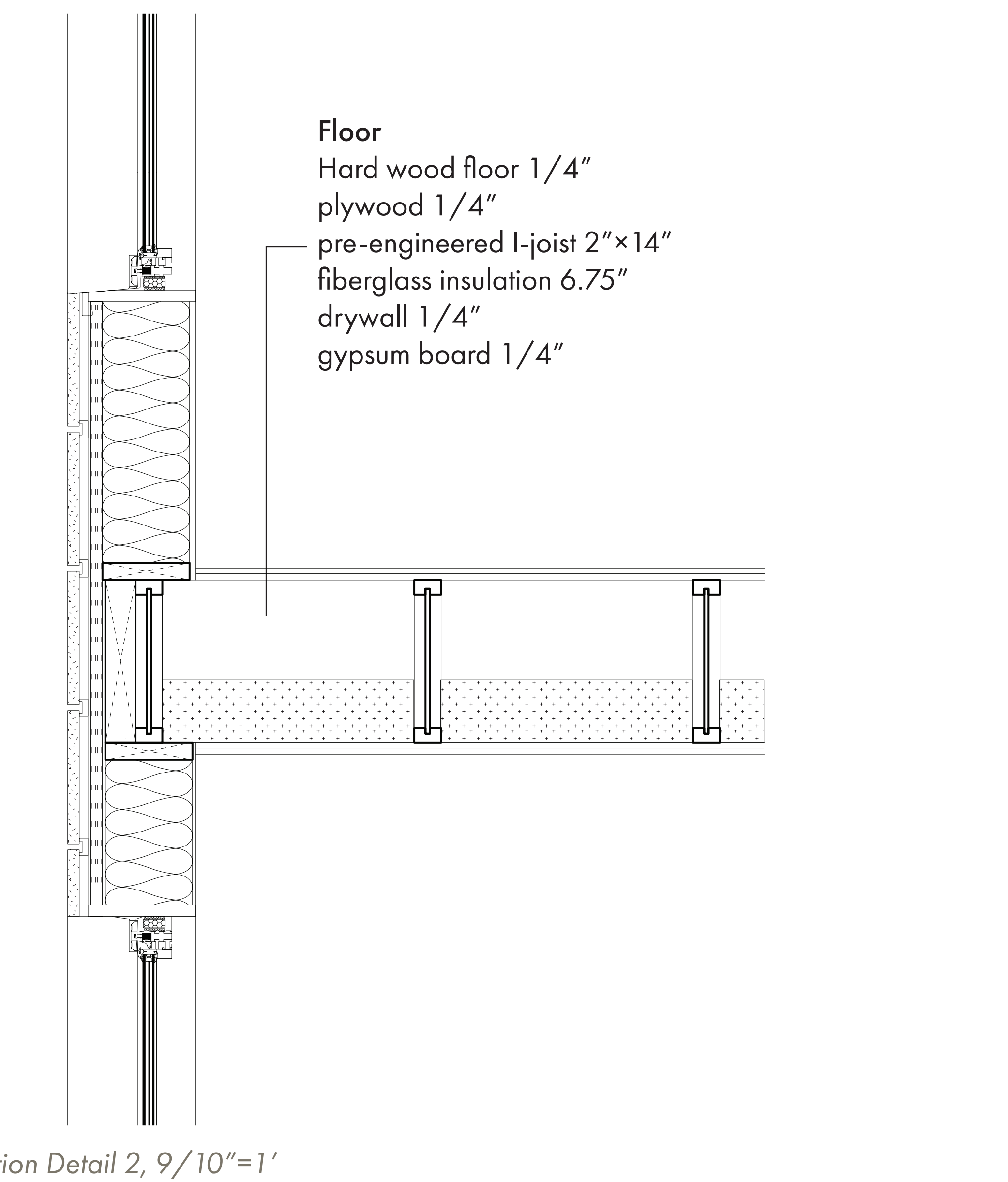


figure110. Section Detail 2, 9/10″=1′

Rain flow system
Building and Site

The green roof on the building and the garage become the main part of the sponge to retain rainwater. An about 1-foot-deep green roof can retain nearly 100 percent of precipitation for light rain, approximately 80 percent for moderate rain, and about one-third for heavy rain. The retained water can stay for several hours to a day and then penetrate underground or into the sewer. This slow-flowing system is helpful in reducing the rain runoff to the alley and preventing the road from being flooded and impassable flood.

In addition, the green roofs as well as the preserved trees will provide environmental benefit in reducing the heat island effect as compared to conventional development of the lot. If the building principals expand all over the D.C. area it helps the flows to existing combine sewer system and results to reduce the contamination of Potomac river, the main reiver in D.C.

01 Green Roof
4150 sqft 2 feet depth green roof
Meadow and small trees such as river birch can retain 50 to 70% of rain water

02 Downspout
gather the water from roof and flow to the ground

03 Wire for vines
Vines can grow up following the wire so that they protect the aperture from the sunlight in summer.

04 Rain screen
Prevent rainwater from getting inside the houses.
Support flows down to the crawl space.

05 French drain system
Collecting rainwater

06 Green roof on garage
1800sqft 2 feet / 4 feet depth green roof
Intensive green roof /grass and trees.

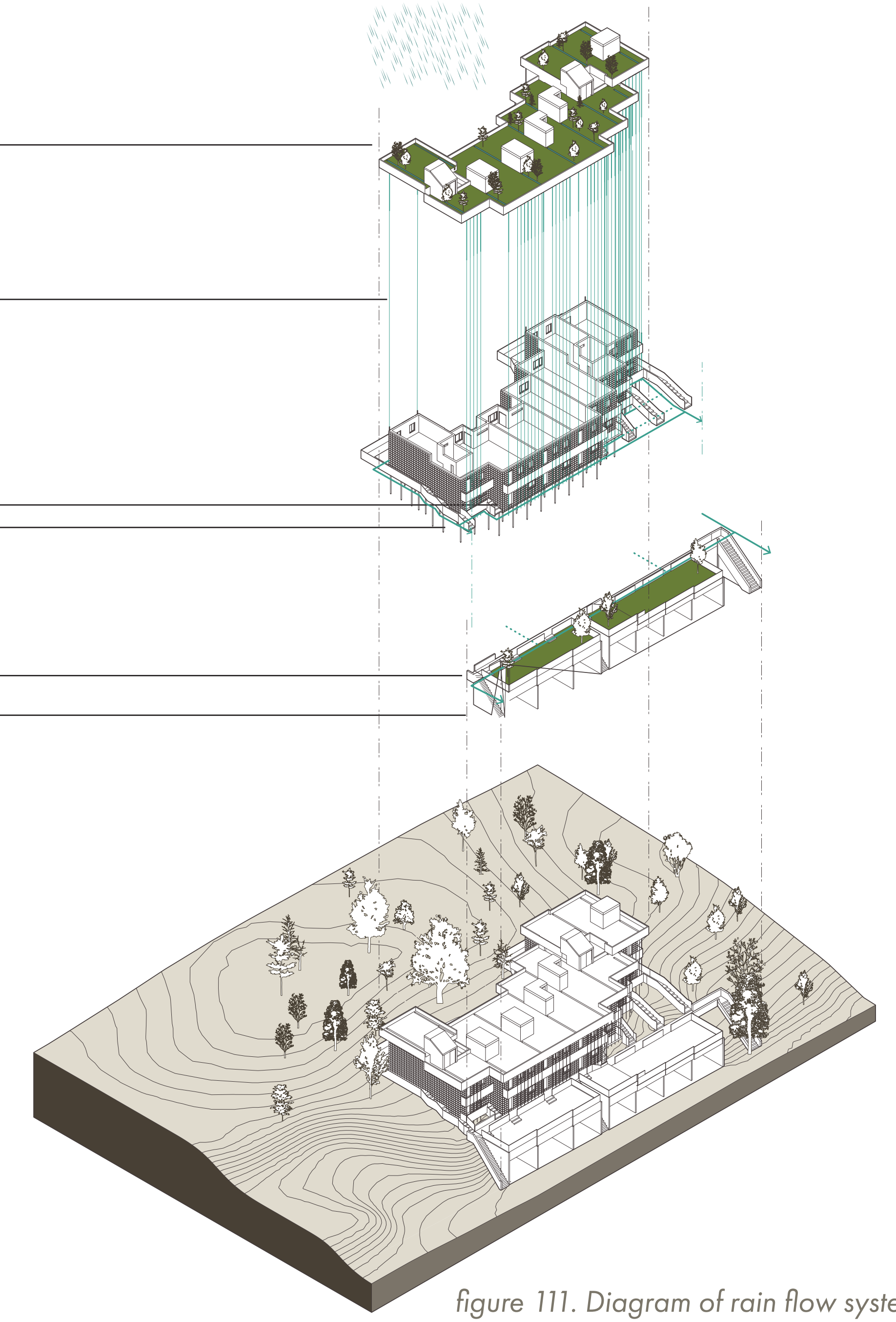


figure 111. Diagram of rain flow system

figure 112. Perspective in collidor

figure 113. Perspective from southeast

Exploring the Sponge House aims to gain flexibility and resilience to the D.C. climate over the next few decades. Storm issues, especially in the summer, are severe and threaten human beings. Unlike regular rain, this is difficult to predict and completely saves space due to the current architectural ordinary characteristic: preventing the water from getting inside the house.

During the thesis, various design approaches were quite helpful in discovering the idea of a sponge. Choosing the existing vacant lot aims to look for feasible solutions and a design strategy that is acceptable to real architects and developers.

In conclusion, this thesis highlights a new approach to adapting to the current and future climate for decades. By understanding the current situation in the city and its architectural details, an advancing methodology is suggested to be intertwined with nature and rain. Rain should bless human beings and flourish the lives and the city for a long time.

figure 114. Physical model 1

figure 115. Physical model 2

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