DOWN TO EARTH

A Design Thesis Submitted to the Department of Architecture
North Dakota State University

By
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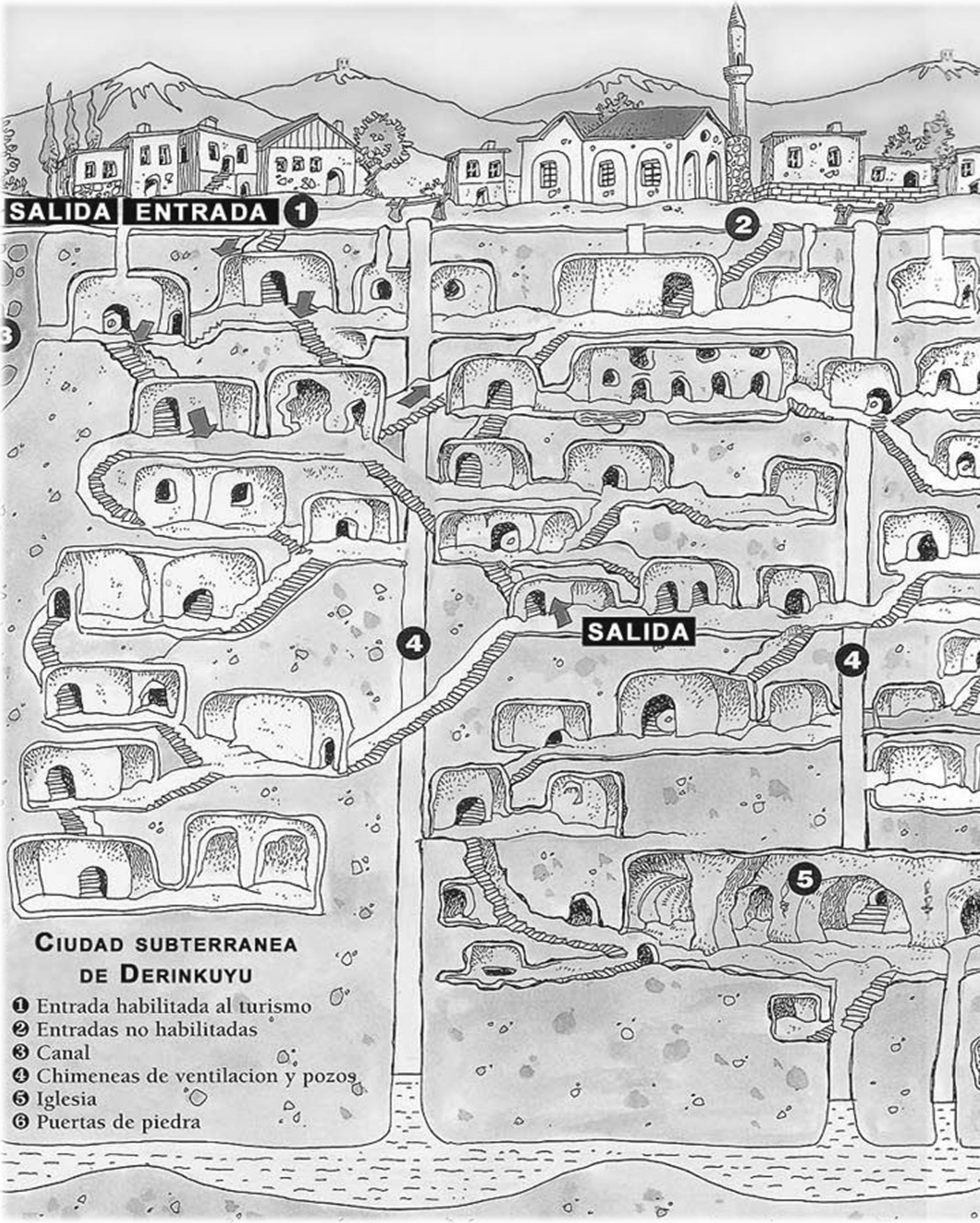
In Partial Fulfillment of the Requirements
for the Degree of
Master of Architecture

May, 2021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ENTRADA
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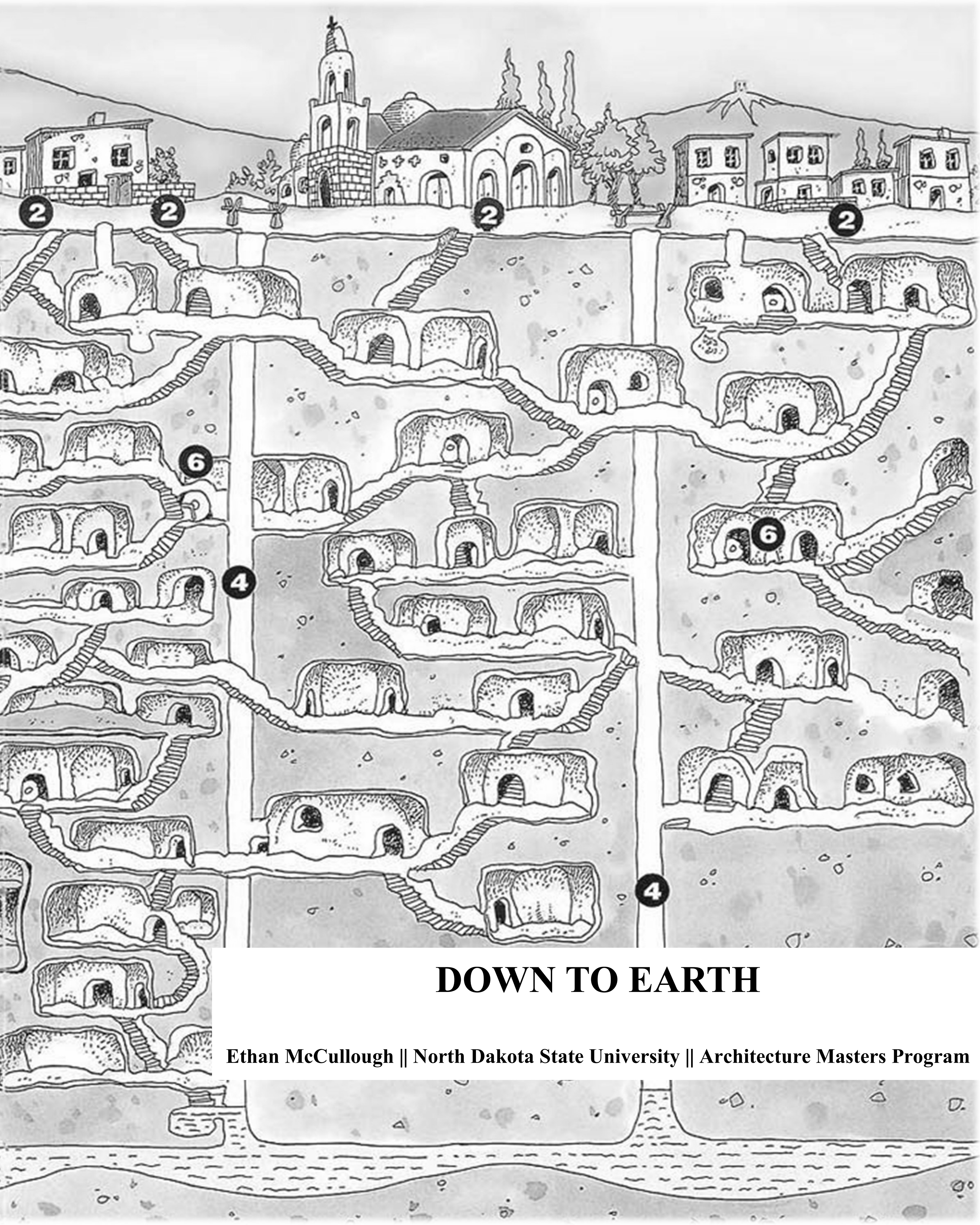
CIUDAD SUBTERRANEA
DE DERINKUYU
❶ Entrada habilitada al turismo
❷ Entradas no habilitadas
❸ Canal
❹ Chimeneas de ventilacion y pozos
❺ Iglesia
❻ Puertas de piedra



DOWN TO EARTH

Ethan McCullough || North Dakota State University || Architecture Masters Program

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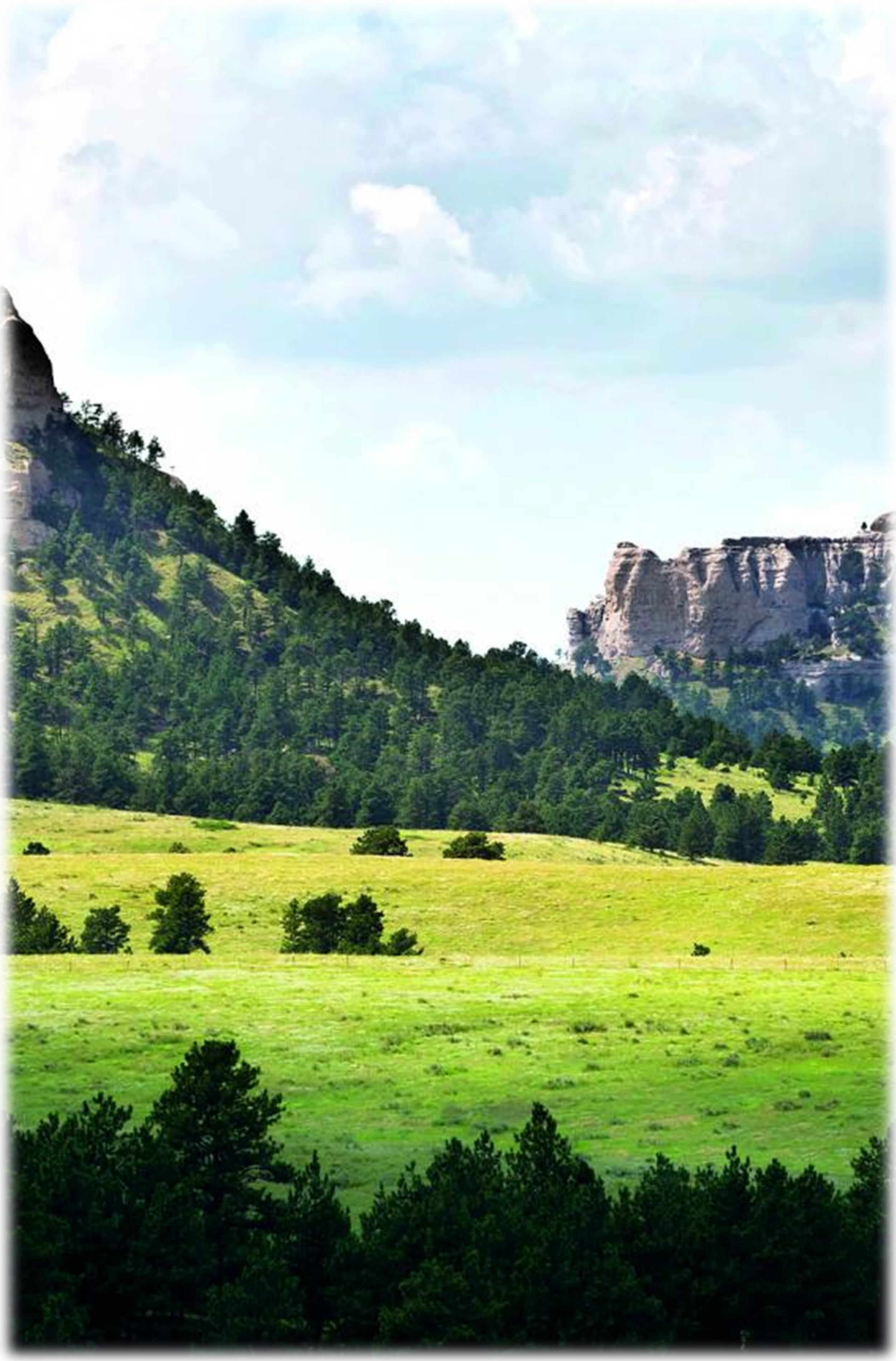


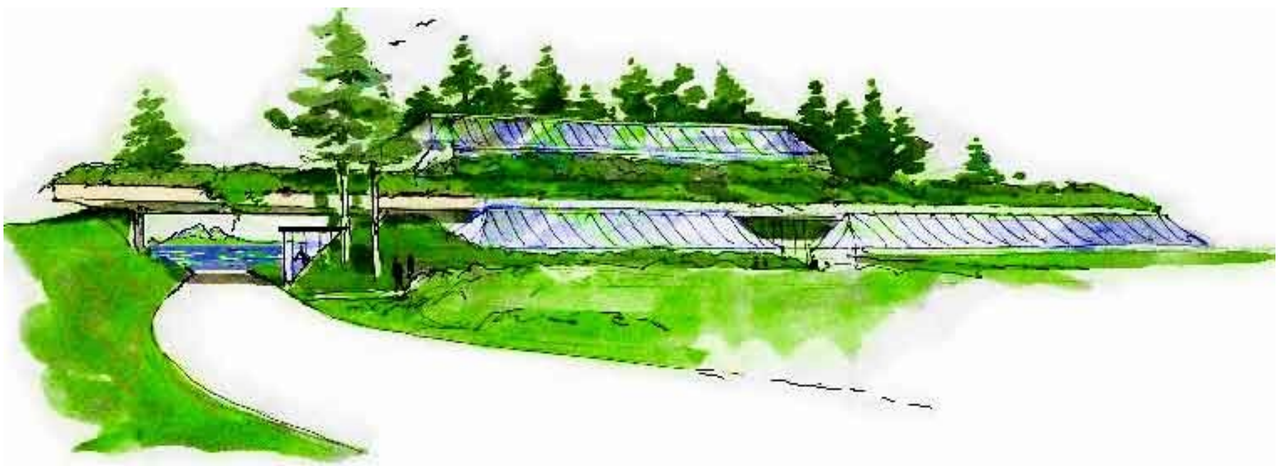
Thesis Abstract

My thesis project dives into the question, "Can subterranean architecture create a more sustainable design?" The idea is to submerge the architecture into the landscape for the purpose of creating designs that can be more sustainable than the typical green design. The best way to answer this question with the chosen site is to design a multi-family housing multi-use facility. An apartment complex with additional purposes could support the community to achieve a healthier relationship between landscape and urban spaces. The research methods that will be used to answer this question will consist of an emphasis on case studies to find common trends, historical research to find cultural and past psychological impacts on humans, and a mix of qualitative/quantitative research. The results of the research will initiate the design concept for the project that will be located in Omaha, Nebraska.

Thesis Narrative

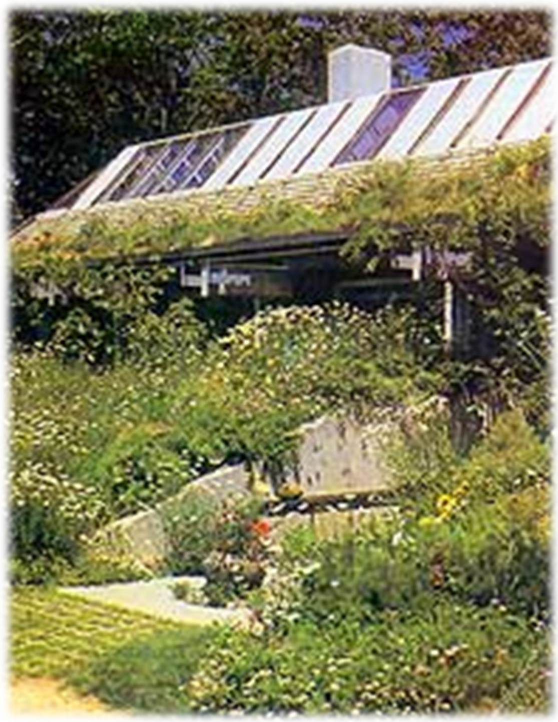
Humans have lived underground as one of their first shelters. It is in our instincts to find a shelter that can protect us from the outside elements. We now live in built structures that are hurting this planet. With the initiatives we have done to minimize the carbon footprint, buildings still cause the greatest impact on this earth. Simply adding more green roofs isn't good enough and most designs only focus on the minimum requirements to reach a certain threshold for initiatives like LEED. It is known that green roofs and green walls help create a healthier planet, but how can we push the limits of it? We need to think outside the box to achieve a true equilibrium between the built and natural environment, because otherwise, no matter what we do, the "solution" will be only a temporary fix.

The expanded question that is being asked is, "Could subterranean architecture create a more sustainable design that can be more effective at achieving the comfort levels of our modern needs?" The question is relevant to architecture, because it is our responsibility to design for the comfort levels of the users and to allow the users a comfortable future. The users, however, won't be comfortable in the future if their own buildings are harming the surrounding environment. This will just cause more problems until we can find a solution that doesn't create a different problem.



Another premise that will be addressed is the benefits of the subterranean design. The father of subterranean design says, "But now another type of building is emerging: one that actually heals the scars of its own construction. It conserves rainwater—and fuel—and it provides a habitat for creatures other than the human one. Maybe it will catch on, maybe it won't. We'll see." (Wells, 2002) His earth-shelter designs will be reviewed and analyzed into the benefits and potential issues that can arise.

To address the question, a plethora of knowledge on various earth and water compositions needs to be known. The water table varies greatly and changes month to month, therefore subterranean architecture could look different depending on location. The differing types of soil and their pros and cons of subterranean architecture will be addressed on which ones are best to use. How well the type of soil can absorb water is another important premise to address. Native plants to the region will be dependent on this question as well, because plants are natural producers of non-greenhouse gas.



This image is a drawing from Malcom Wells, the father of modern earth-sheltered architecture, that encapsulates another premise. Even though the occupancy may change as buildings live longer, the nature will be able to remain undisturbed during this time.

The idea that needs to be learned is a way to design that takes advantage of the properties of the ground that we haven't used to the proper extent yet. There are current designs out there that have designed subterranean architecture, and they will be analyzed through case studies, then compiled into various design strategies to answer the question. The design of a subterranean multi-use building in Omaha, Nebraska will be used to provide support that subterranean design can achieve more than a typical design.

The Project Typology

The closest typology that can be used to examine this question lies in the reason why this question is being asked. The reason the question should be asked is because we aren't doing enough design work to solve the climate change fast enough. We need to think outside the box to design, not only for the current generation but also for the future generations. A mixed-use apartment complex gives the ability to showcase how subterranean architecture can impact different typologies and what results come from subterranean architecture throughout multiple typologies. The goal will be to create a living environment that has optimum comfort levels to lower the need for transportation and increase walkability.

Typological Research

The typological research will be done to learn how not only buildings can live underground, but how people can live underground comfortably. The projects selected revolve around the residential typology, because it is the main typology that will be designed for the thesis. The principles that the case studies use will inform the design to ensure all parties of the multipurpose residential building to feel like they aren't actually underground and just in another building. The principles should also help form evidence and solutions into the thesis question. Research elements are needed to establish the focus of the typological research. These elements that will be focused upon is how subterranean architecture is achieved through sustainability, materials, spatial organization, and topography.

#1. Ktima House

Location: Antiparos, Greece

Architects: Camilo Rebelo Aquiteto, and Susana Martins

Area: 950 m²

Project Year: 2014

#2. Villa Vals

Location: Vals, Switzerland

Architects: SeARCH & CMA; Design: Bjarne MastenBroek & Christian Muller

Area: 160 m²

Project Year: 2009

#3. Dutch Mountain House

Location: Huizen, The Netherlands

Architects: Denieuwegeneratie

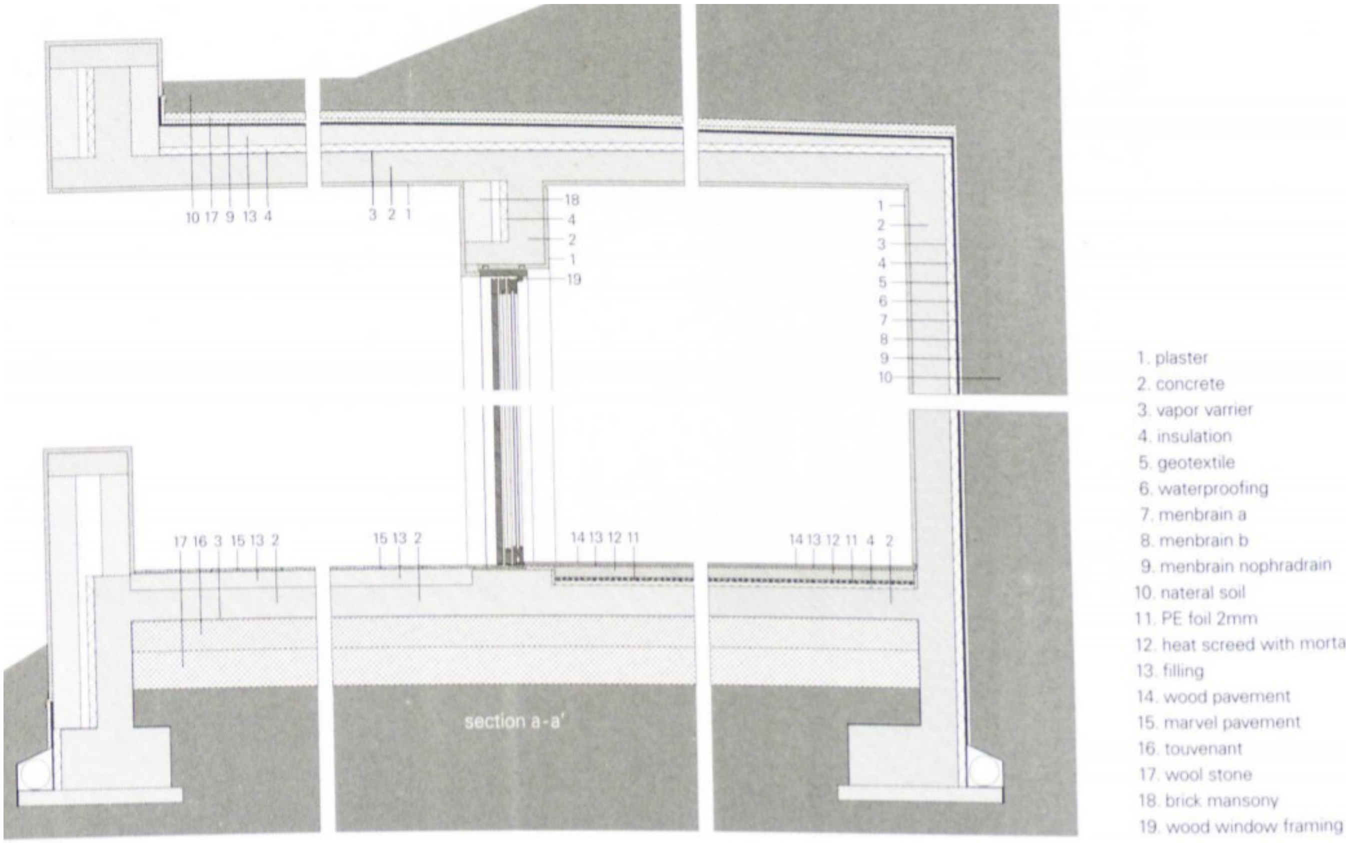
Area: 230 m²

Project Year: 2011

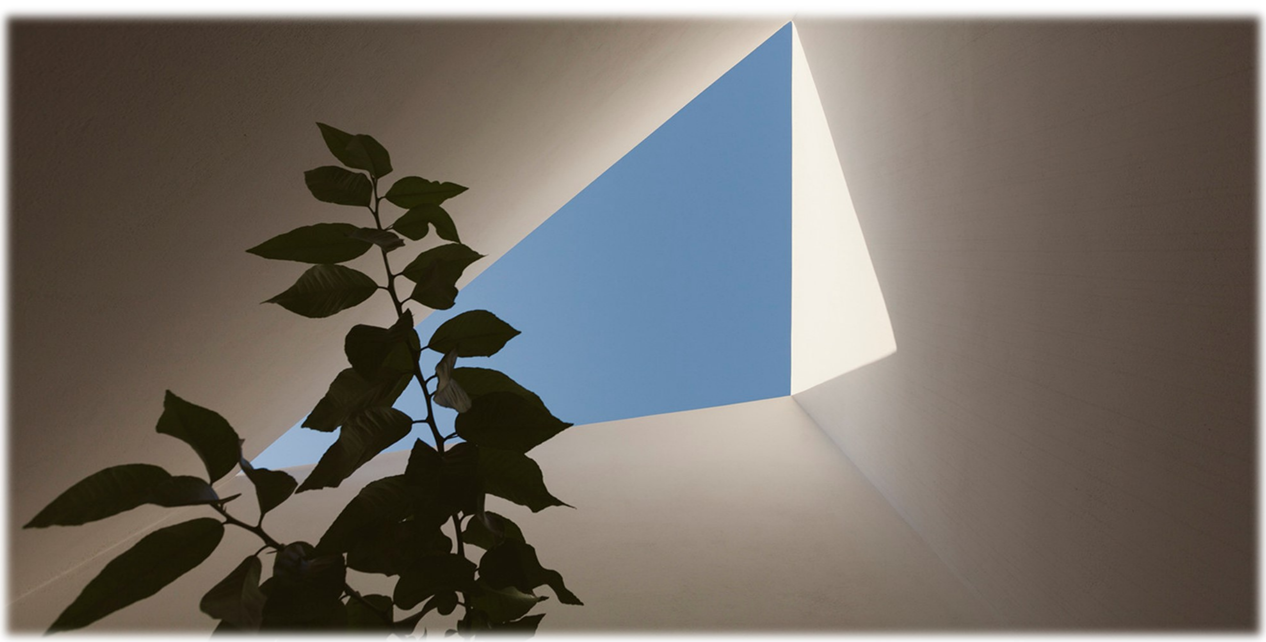
#1. Ktima House

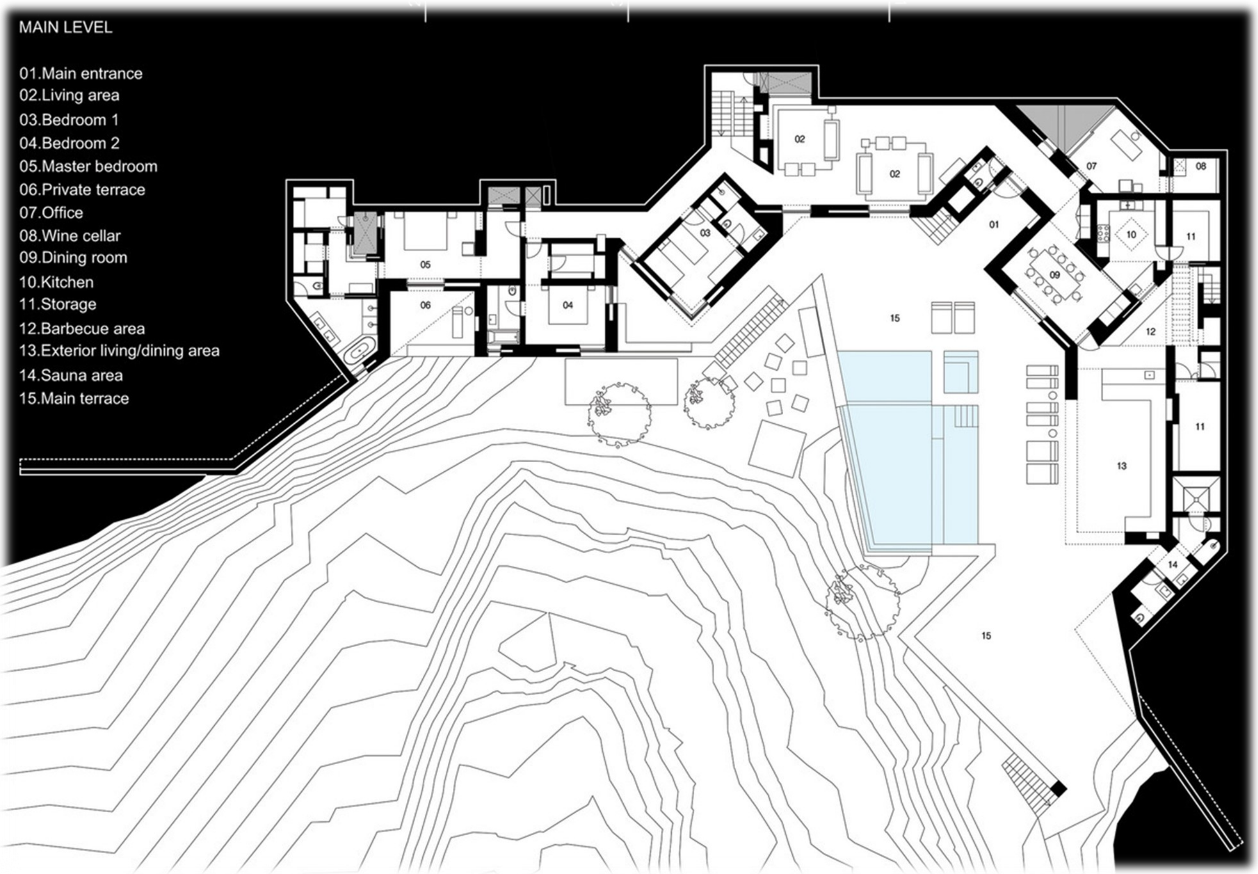
Camilo Rebelo and Susana Martins

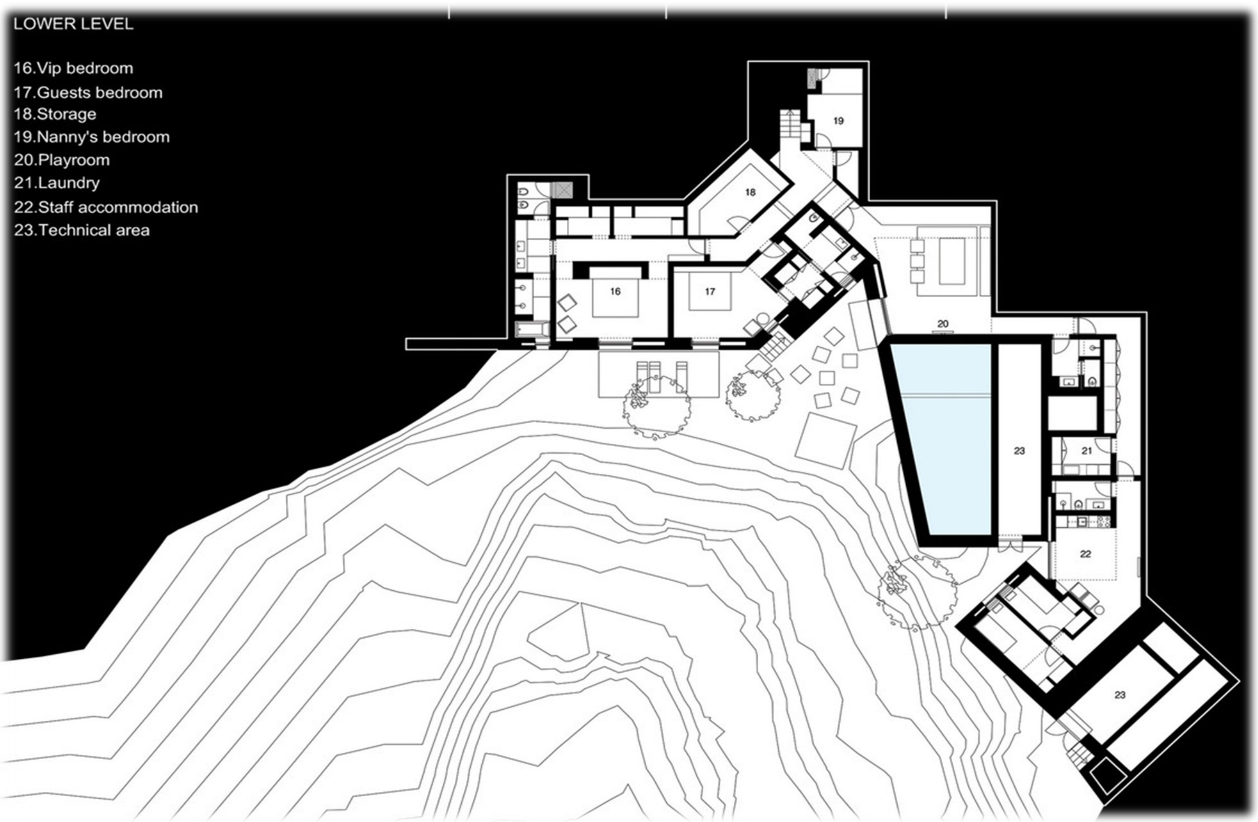
Ktima, means land that is fertile in the Greek language, when looking at the house, sums up what is the house's identity. The Greek civilization, back when they were an empire and even after, was a place of both order and chaos. This house was designed around this concept. Designed by Camilo Rebelo Arquiteto and Susana Martins, the house utilized the topography on site to conceal this house. The house can be perceived very differently based on where one stands. From above the house, all you can make out is the landscape surrounding the house along with a minimal white abstract line to accommodate the topography. The Greek regulations restricted the design process to not exceed any volume that is ten meters long, therefore the architects came up with the idea to divide the house in two levels to acclimate this regulation, in favor of the topography and program, separating the main part of the house and the lower level, that consisted of the guest house, service, and staff areas.



This design formed a sustainable viewpoint that allowed for green roofs to be formed in a natural way that was connected directly to the site landscape. This also created an increased efficiency of the interior spaces to decrease the range of temperatures throughout the year, thus it was not needed to install a powerful cooling system that would have been needed, if not for the subterranean design. An issued that was raised in the design process was the need for an increase in ventilation as the further underground spaces needed desperately. To accomplish this, the design allocated space in the further back parts of the house for patios that allowed light and fresh air into both sides of the building. The building's structure consists of three layers of brick to be able to hold up the amount of earth and the top level.





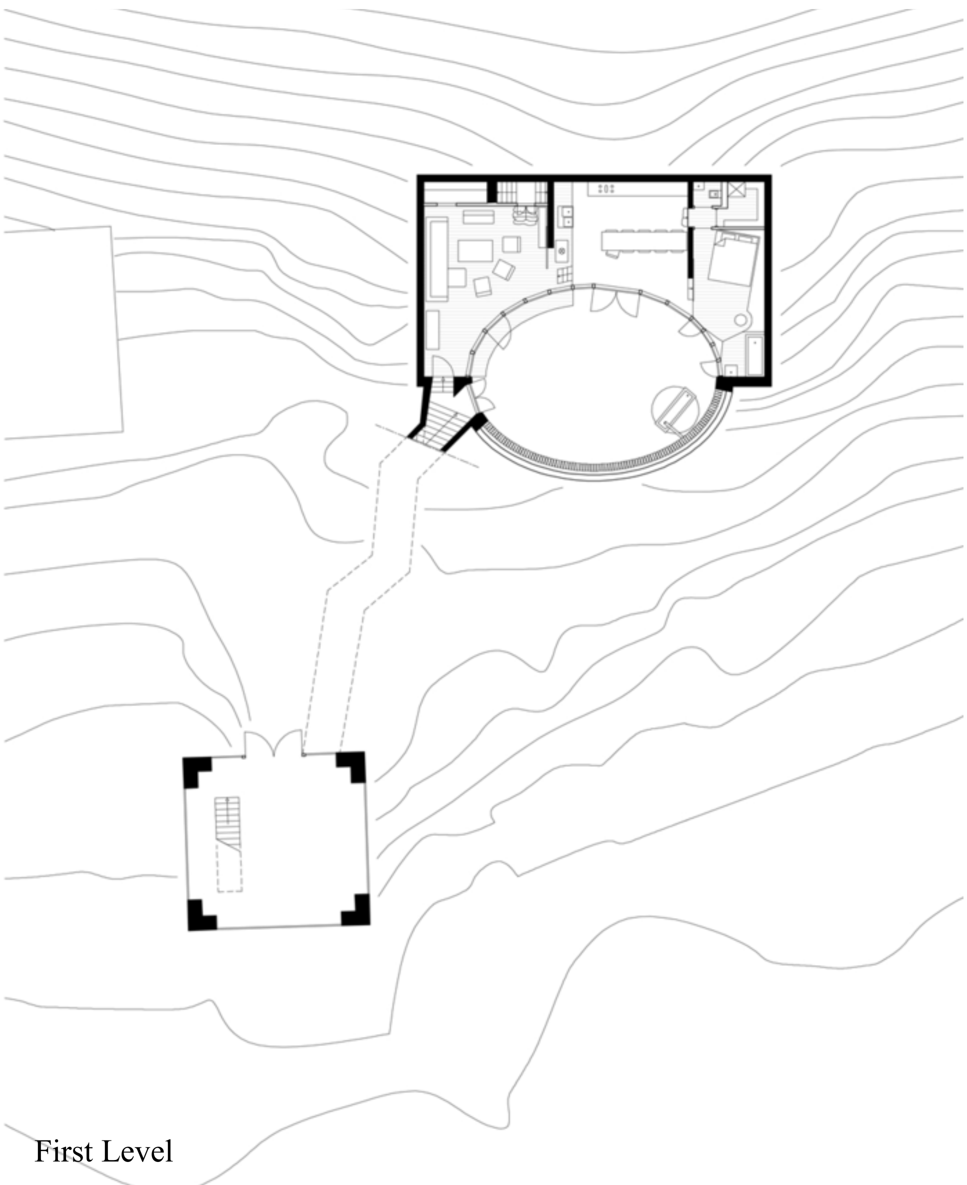


The circulation of the space shows how it attempts to remain parallel to the topographic lines in response to the natural form of the hillside. The walls are shown as extremely thick, which is to provide the proper amount of support, but could also provide enough insulation, with the addition of the earth around it, to keep the users comfortable throughout all the local seasons.

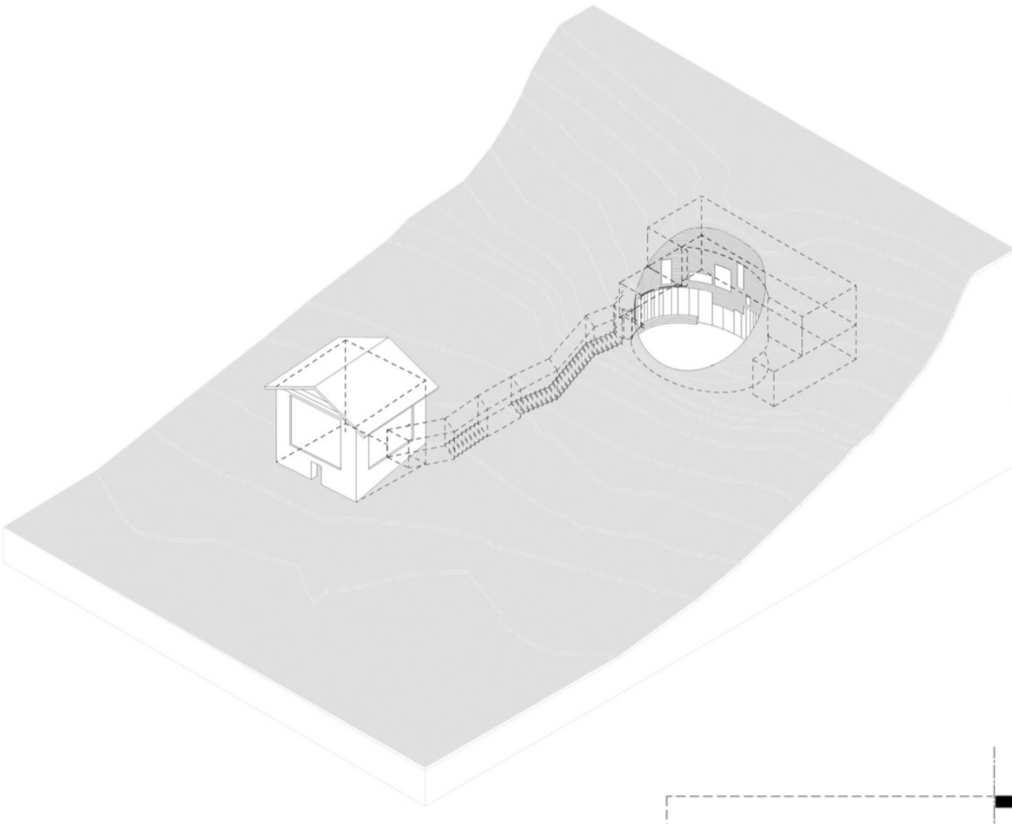
The building provides ways to successfully integrate a house into the landscape. One being the light tunnels in the back of the building that also allows air to enter and exit from to keep a natural flow. The geometry that was used seemed to have been designed to allow the sun to enter only at certain times of the day within certain spaces within the building. The materials used provide insight into what kinds of materials should be used in buildings such as this one.

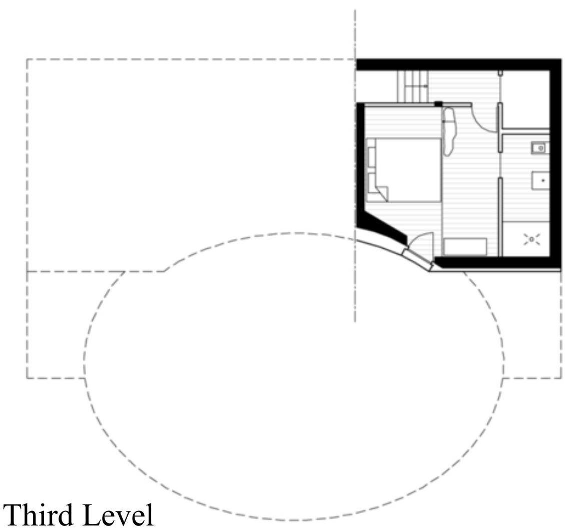
#2. Villa Vals

Villa Vals is located close to the famous Therme 7123, but that's not the only reason why Villa Vals is famous. The site of Villa Vals was originally a worn-out barn that the owner refused to sell. The new owner, the designer of Villa Vals, Bjarne MastenBroek and Christian Muller, managed to purchase the parcel of land from the farmer, because he planned on keeping the barn as that was a requirement to sell. The barn was remodeled and became the main entrance into the newly designed house. An underground tunnel was added as well as a subterranean building that connected to the barn, so this too, like the other case study is a subterranean typology. This building differs from other buildings because of its massing. The patio area that dwells within the mountain side is an oval area that creates a common space to allow natural light and ventilation into the inner parts of the building that go deeper into the mountain. The subterranean part of the building doesn't go deep enough in the mountain to create a natural light issue, unlike the previous case. The structure of the building heavily involves concrete to sustain the necessary loads and water tightness needed to have a safe design for the dwellers.



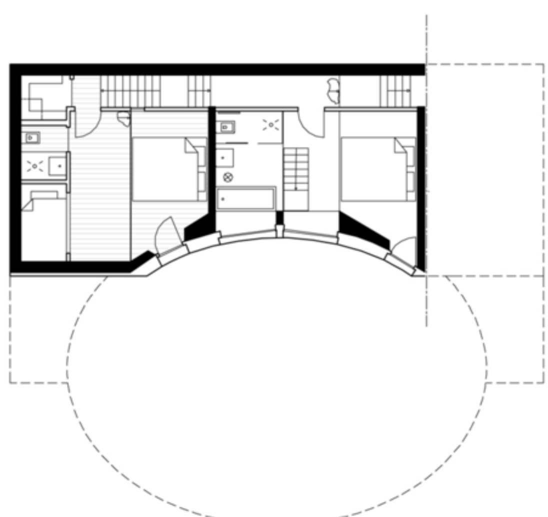
First Level



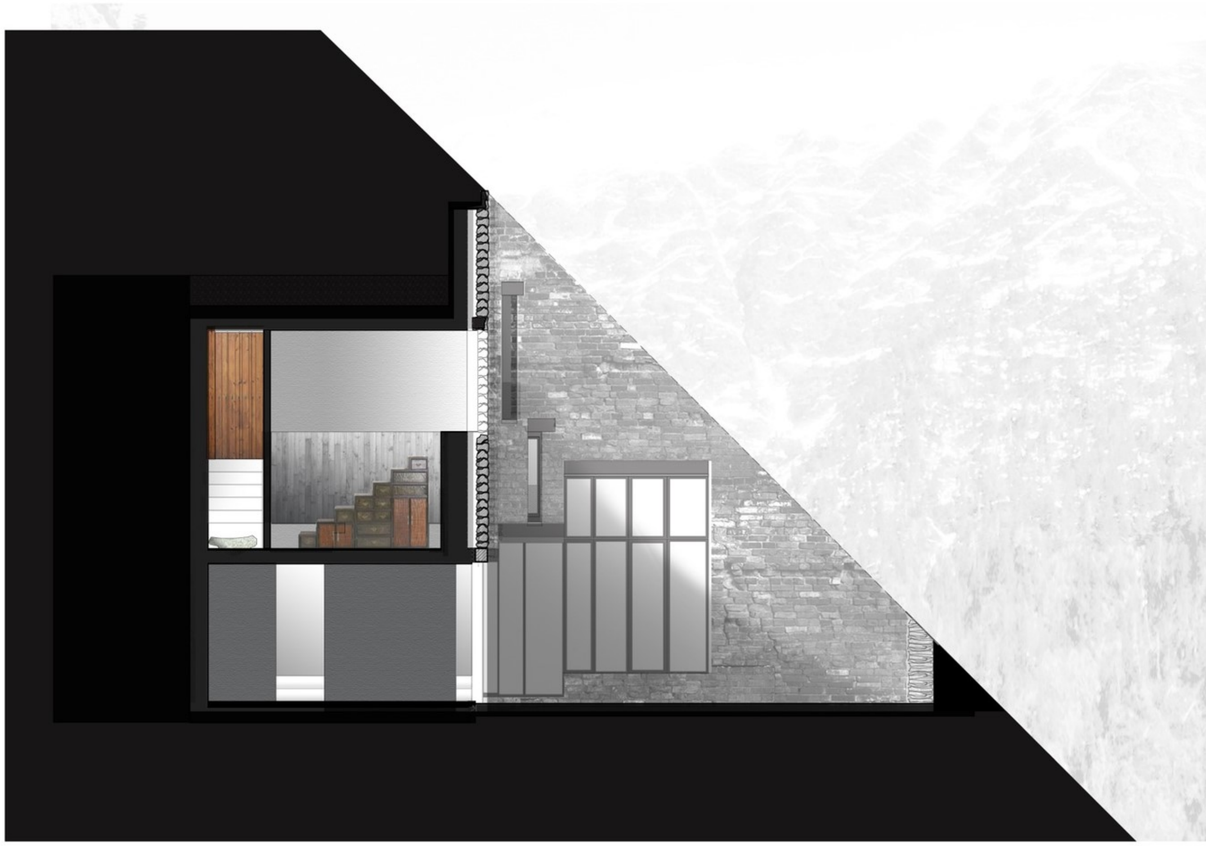


Third Level

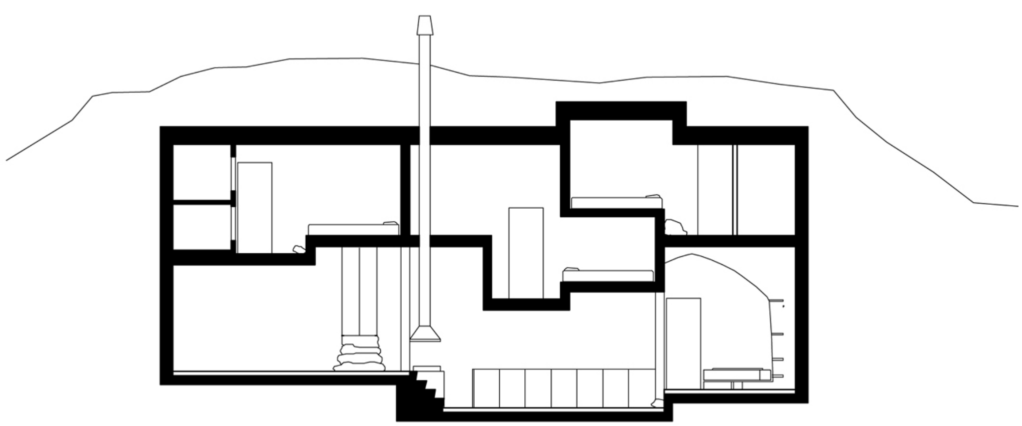
The two buildings act independently from each other through the design. This design seems like an additive and subtractive design. The barn could represent the mass of the design, while the oval area subtracts the earth to create a void to counter the barn out. This creates a balance towards the landscape and structure of the design. With how simple the design is, it creates a complex special organization that combines circulatory and linear spatial organization. The furthest back of the building provides a linear placement of a corridor of stairs that connect the necessary levels together. These spaces still share the major organization of the circulatory as the rooms revolve around the oval space.



Second Level



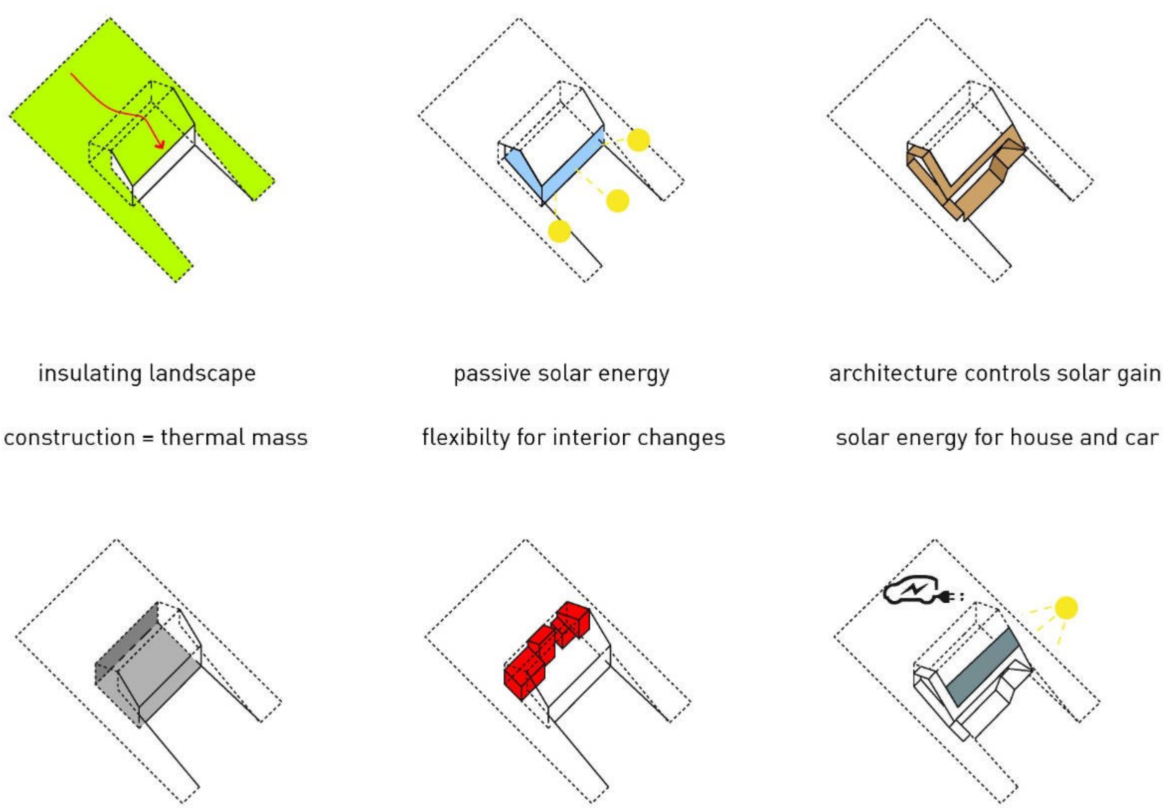
With this case study, the spatial organization was apparent to be informative in the design process on the flat site that has been chosen. The additive and subtractive ideas could unlock the potential the flat site will need to be able to create a subterranean space similar to this case study. The contributions of this case provides not just ideas to use, but a better understanding to what needs to be addressed in subterranean projects similar to this. The thesis design will involve a larger scale but will still be able to utilize similar design solutions, such as a specific subtraction of earth to provide ample light to enter into each inner space.

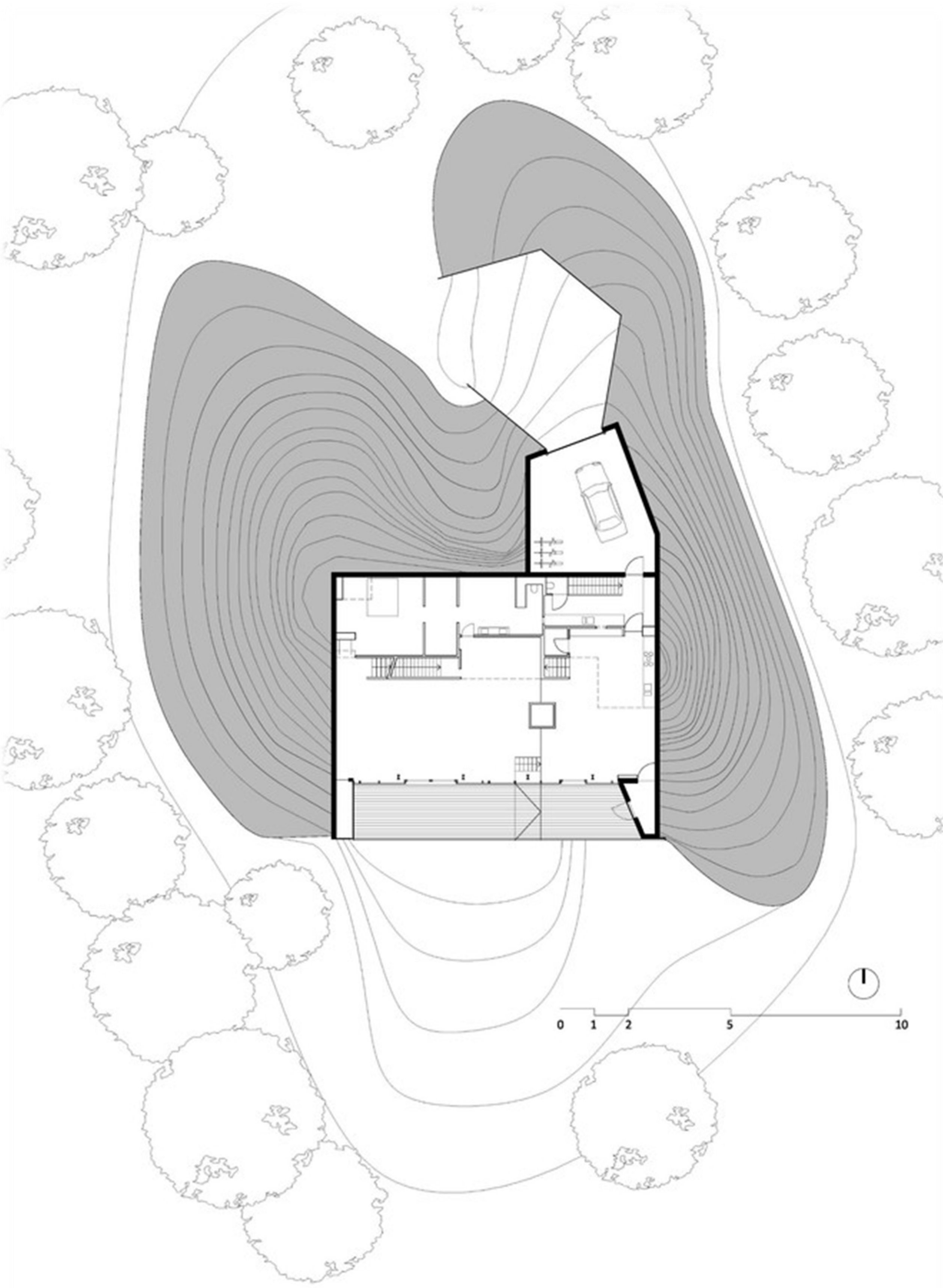


#3. Dutch Mountain House

The Dutch Mountain House is different from the other cases, as this one begins in an open field that is primarily flat, much like the thesis site. This case was chosen for this reason. The house is encased in an artificial hill, protecting the house from the elements. The ecological footprint of the house was greatly reduced, which was the client's intentions. The hill hides the building on the entrance side, to form a sense of privacy, while the other side is opened up to allow for exterior programs to occur on site. The earth is used as thermal insulation to keep the house at a comfortable temperature without the need for active systems as much, saving money and energy.

Timber is used on the south side to give a sense of natural traits for a transition of nature to the structure. A system of canopies is used to control the amount of sun that is allowed to enter the living spaces, depending upon the season. The design solution to sunlight being used seems to work when applied to this house, which would be ideal in the thesis design, because Omaha receives plenty of sunlight that should be dispelled in the summer. The structure includes wood from the local field of which it stands on, allowing for an even lower ecological footprint that should be adopted in every building. The spatial structure is designed using steel to cross the entire width of the large open space, allowing for flexibility for the program of the house, giving future inhabitants the option to evolve the space.

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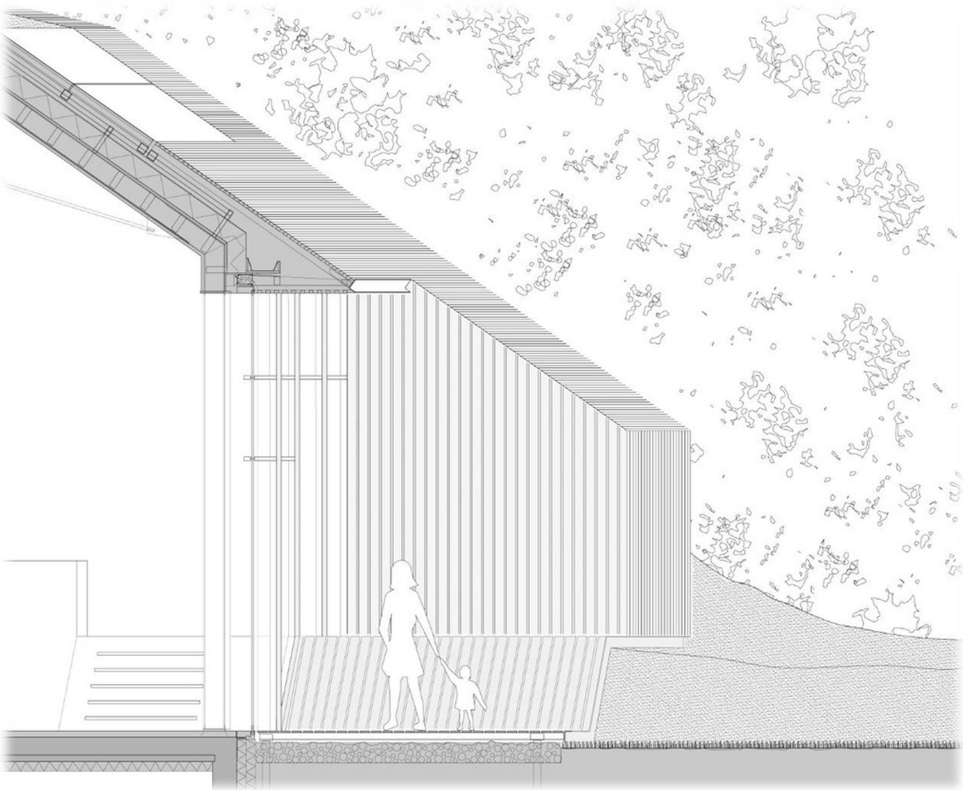
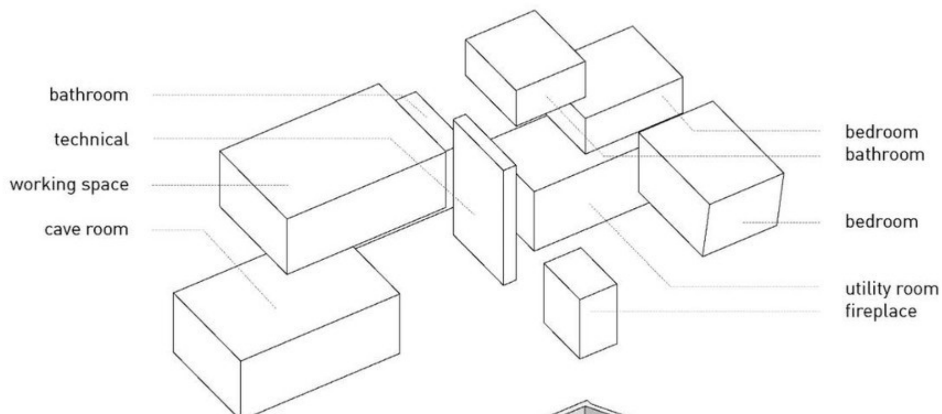
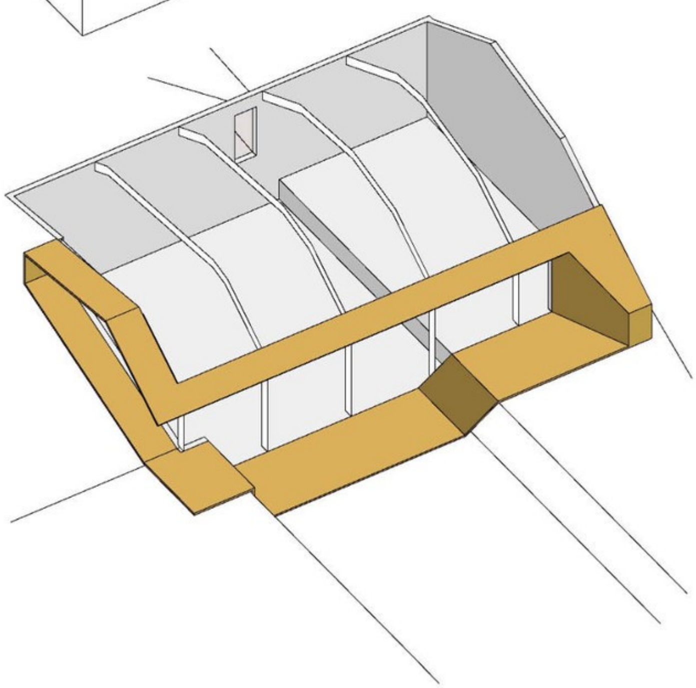
Much like the first case, the house provides two viewpoints of the house, giving a different sense of experience. You can be within the house where the light will enter through small cracks from the top of the man-made hill, reminding the user that they are underground, or you can be in an enlarged space with glass facades that allow endless sunlight to enter where you don't feel like you are underground.



My thoughts on these case studies is that it provides me solutions and insights that I will need to go forward with the thesis design. This case was an experiment that utilized sustainable strategies through architecture as well as the technical installations, such as photovoltaics, LED lighting, CO2 monitored ventilation and others that form excess energy used for electric cars. This and the other case studies gave me principles and ideas when it comes to the functional, spatial, and topographic relationships that can help reduce technical issues when it comes to sustainability and comfort.


bathroom
technical
working space
cave room
bedroom
bathroom
bedroom
utility room
fireplace



Major Project Elements

The major project elements consist of the convenient solutions to the living day-to-day needs that provide shelter, water, electricity, food, and more. These elements will be designed to minimize carbon emission over time. The list below shows the elements that will be incorporated into the project.

Apartment complex: This will be used for shelter and amenities to live in a comfortable setting. This complex will provide all the necessary modern amenities for the residents.

Food Services: This is a collection of publicly accessible food, ranging from restaurants to a mini-grocery store to give residents walkable access to food.

General Spaces: These areas will provide permeable parking above ground and subterranean parking, circulation for both the public and residents, yet still offer privacy and gathering spaces for the residents that live in the complex.

User/Client Description

Residents: These are the main users of the site who will live in the apartment complex. The site will primarily be catered to them as they will be the largest population of the users/clients.

Apartment Employees: These employees will be maintaining the apartment complex and making sure everything goes smoothly and that each apartment unit is used to maximize profits, given the design intentions.

Customers: These users are those that access the food services on site or simply want to relax in the gathering spaces.

Food Service Employees: These employees are those that sell food products to the people who wish to purchase food.

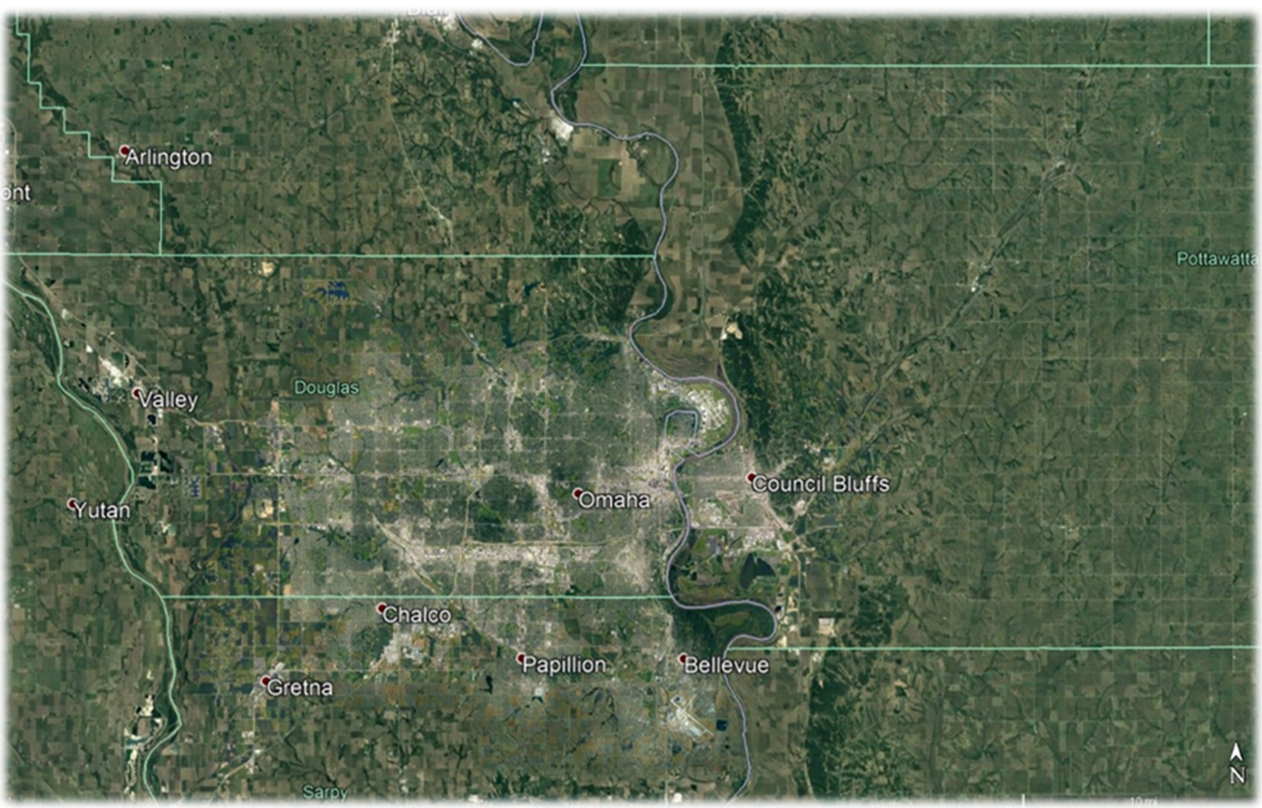
Groundskeeping/Maintenance: These people are those that keep the entire site clean, such as mowing, trimming, cutting dead branches, ensuring the drainage and runoff systems are working properly and more.

Site Information

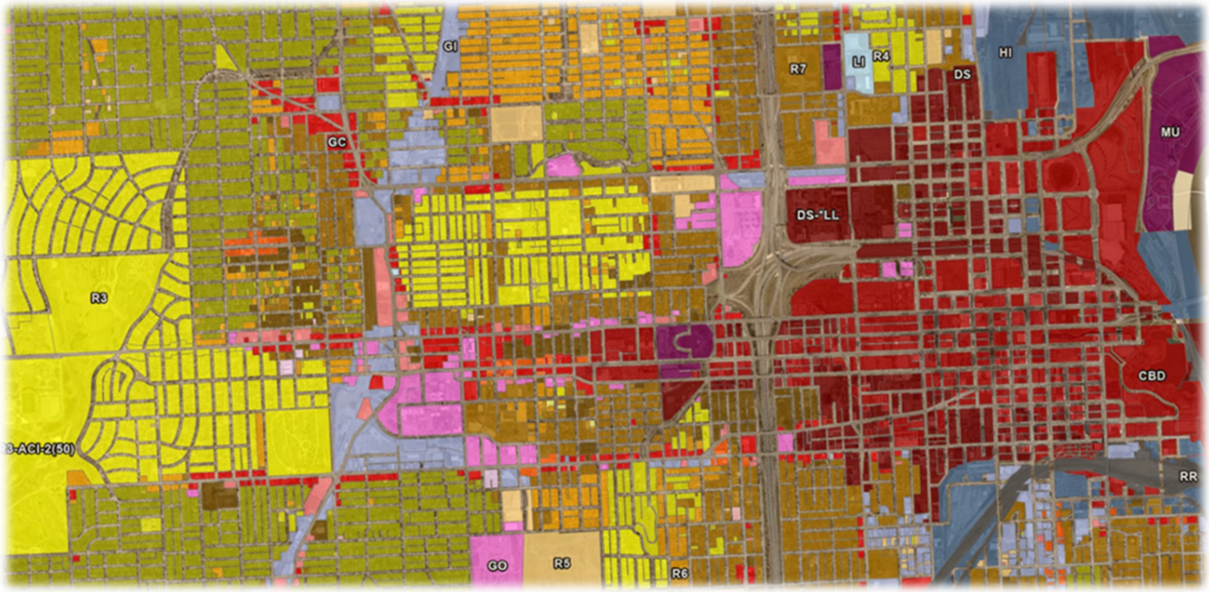
The site location is in Omaha, Nebraska, Block #79. Having lived in Omaha over the summer, the place has a lower cost of rent compared to the nation's median. This block is within the downtown of Omaha, which is close to many job opportunities, so the need to use cars is low. I personally only used my car to get groceries and just walked to work. This is why a grocery store is in the design to further limit the need to drive places. There is an Omaha Metro System that offers public transportation near the site, in case it is needed. Omaha has a growing economy and the population of the city is rising, thus more apartments could assist in alleviating future housing issues.

A large flood occurred a year ago in the city. It hit most of the southern end of the city, near the Offutt Airbase. Since then, they have been creating preventative measures so that won't happen again. Even with this scare, the chosen site is well outside the flood zone.

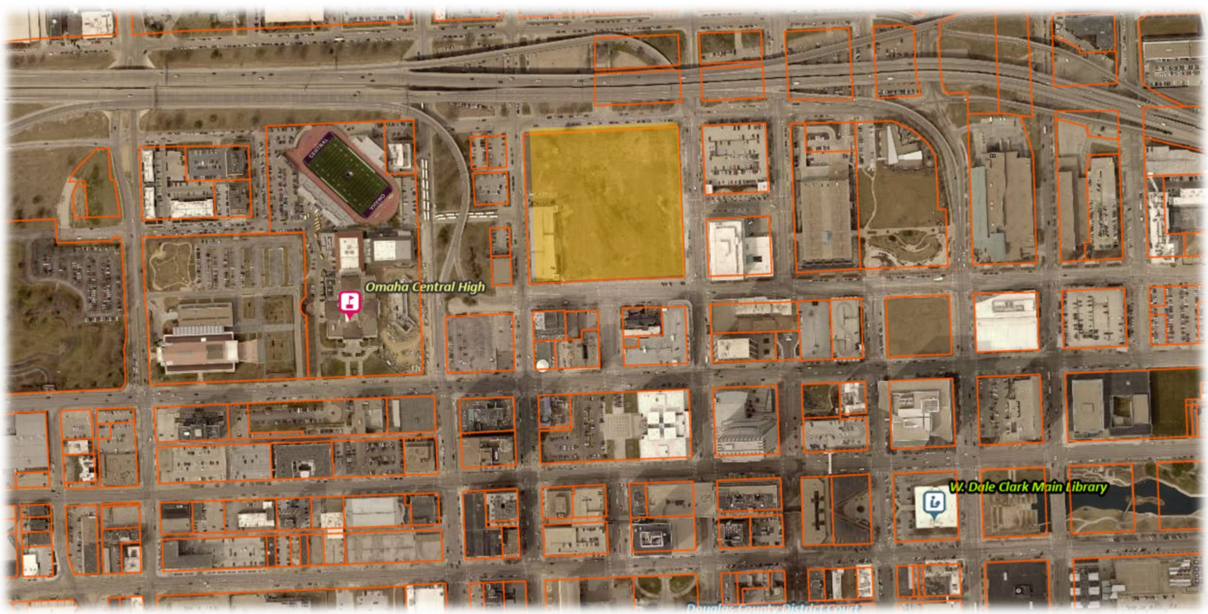
The site is at a slight slope, allowing the subterranean design to prove that it can be beneficial in any topographic setting, which is the reason of it's selection. There is a parking ramp on the southwest corner of the site.



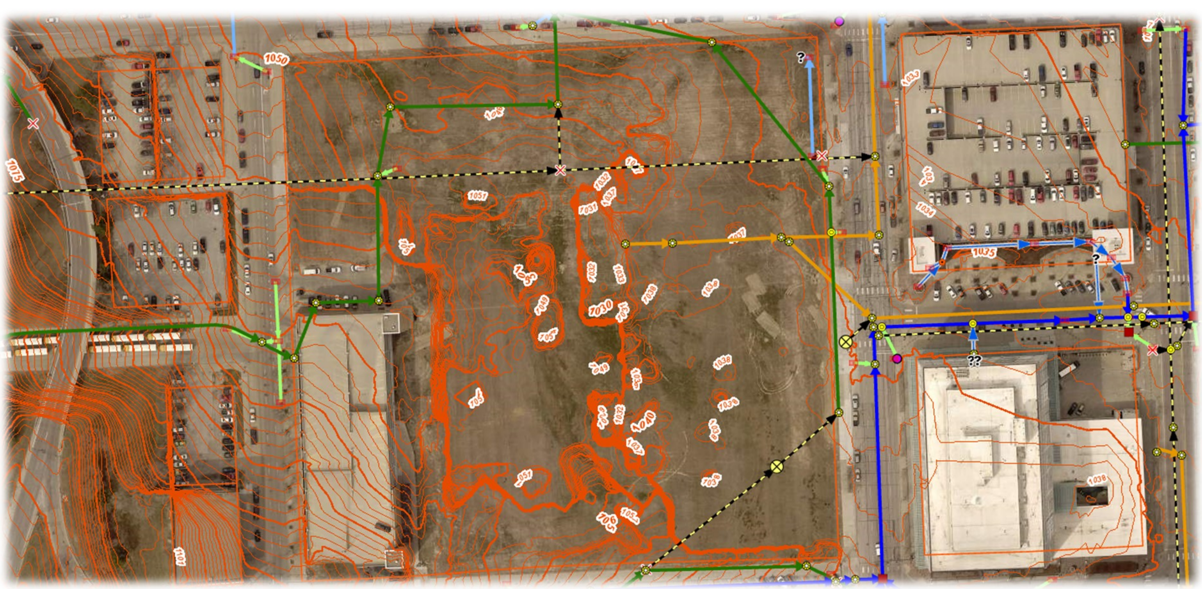
Regional Map



City Zoning & Context



Selected Site



The Project Emphasis

The project emphasis will be to focus on the impact that living underground has on the individual and how that relates to the sustainability of the design. The affordability is less of a priority simply because this idea is still not a standard, and therefore will be expensive to integrate into society, but with the emphasize of the positives, the hope will be to inform others that there are better ways to build that minimizes future cost of environmental problems. To point out this emphasis, there will be both the discussion of pros and cons, and where and how subterranean architecture makes sense to be implemented.

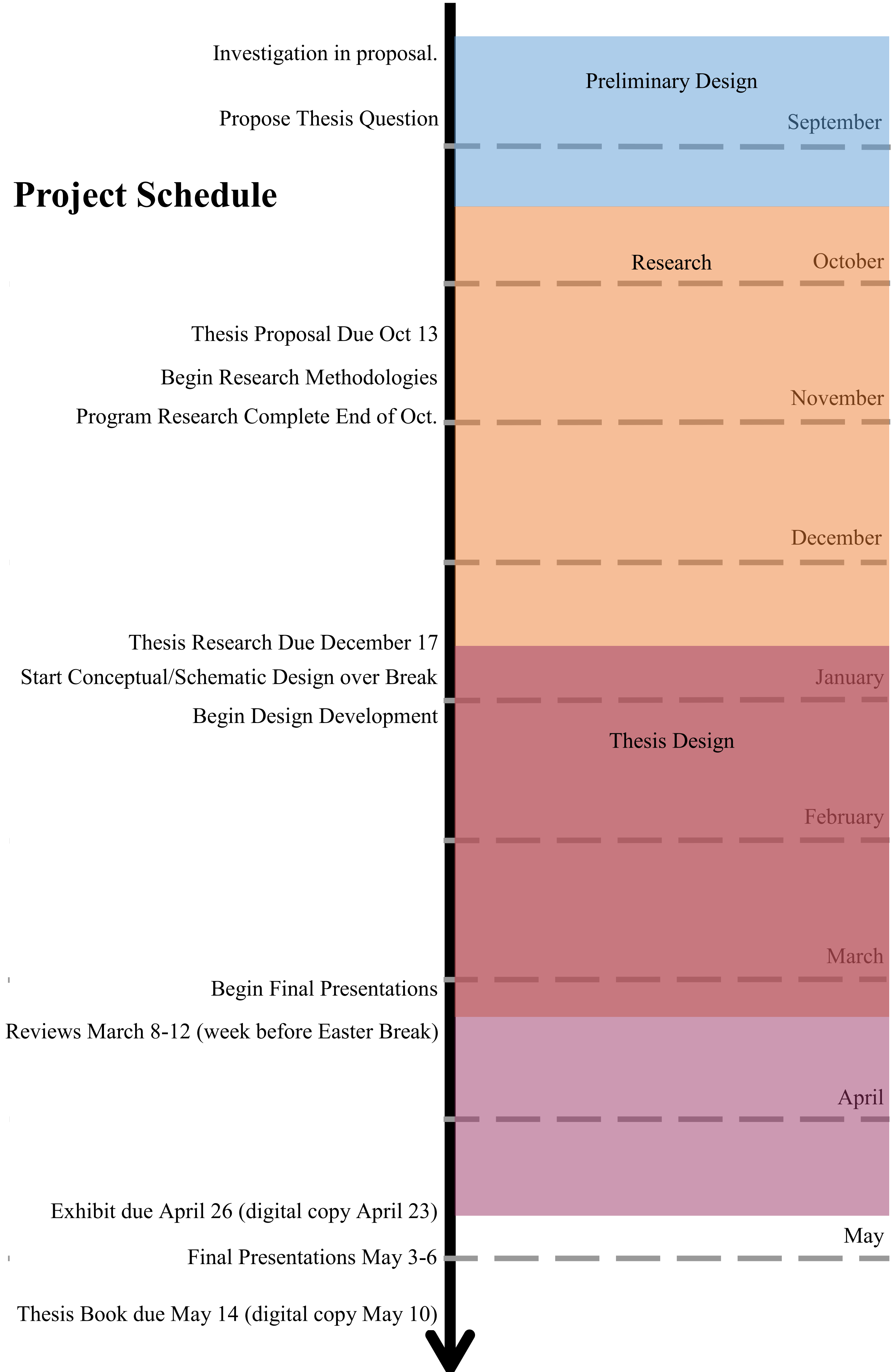
Project Goals

Personal: The main idea of this project began for me years ago, knowing I'd have to do a thesis during my fifth year. I have a personal goal to truly answer this question in favor of spreading the subterranean architecture trend through this thesis. The idea for it began when I would see fictional places in movies. The very idea of living underground piqued my interest and as I began to learn more in class, I developed a hunch that subterranean architecture is not only going to be a part of the future trends but will also help save the future, extending our planet's life.

Academic: I want this thesis to test my research and compiling of the research skills into a paper that provides the analysis needed to answer the question. This is to be a catalyst to continue my education into this subject and to extend it into other topics of architecture that are related in nature. I hope to learn quite a bit on this topic.

Professional: After this thesis, with the knowledge and evidence I will learn, I would like to be able to specialize in subterranean design. I would potentially form my own firm that will focus on underground dwellings and other types of buildings given the need of the client.

Project Schedule



Plan for Proceeding

The Theoretical Premise

Research will be conducted to answer the thesis question, "Can subterranean architecture create a more sustainable design?" More case studies will need to be established, both old and new to find the common denominator of subterranean design that can help answer this question.

Project Typology

Since the typology is multipurpose but primarily residential, case studies of each separate program will need to be involved to establish a subterranean ideology that can be incorporated throughout the whole design seamlessly.

Historical Context

The historical context will be the start of the historical research that will involve the local area of the site itself, in addition to the global historical context of subterranean architecture. This will show how we branched away from living in caves to self-built, above-ground structures.

Site Analysis

The site will provide a large sum of data that'll inform the design and any issues on the site. These issues could then create research paths in order to solve it, such as runoff or poor soil on site. This can then help to understand the site, which will be important for the design and research.

Programmatic Requirements

The program requirements will be researched based on the typology of each building that is planned to be designed on the site. The case studies and qualitative research will be able to extract this information to provide sufficient program requirements.

Design Methodology

<u>Historical Research</u>
Discover past case studies on subterranean spaces.
Learn the principles of why we stemmed away from these spaces.
Learn the human history of the underground.

<u>Case Studies and Combined Strategies</u>
Discover present day and future case studies on subterranean spaces.
Provide links to design solutions and sustainability.
Learn something from each case study that can be applied to the thesis design

<u>Qualitative/Quantitative Mixed Research</u>
Attempt to quantify the thermal insulation capacity of earth, though an experiment.
Discover any downsides to subterranean spaces, through either interviews or archival search.
Provide additional analysis through journal articles, research papers, and books.

Documentation of the Design Process

The documentation scheme for this thesis will be based on phases. Documentation will be compiled at the end of the recognized phase of the process. It will be preserved throughout various mediums, depending upon the phase, but will ensure backups are in order. The thesis project, once documented fully and completed, will be publicly available through the North Dakota State University Department of Architecture Repository. Depending upon the societal recommendations of presenting the conclusion of this thesis, the presentations will most likely be presented through the final boards, and an oral/graphic presentation.

Thesis Research

Introduction:

The priority of the research portion of this thesis was to learn how underground living could be a solution to designing in a sustainable manner. Another priority was to learn the benefits and consequences of living underground and what can be done to mitigate the disadvantages. Literature reviews were conducted to inform the design and add information that helped with the thesis question. Historical Research was conducted, which helped focus on what the benefits and disadvantages were in past cultures that utilized these spaces. The negative side effects of living underground was answered as to why humans stemmed away from living underground. However, with new technologies today, this could change how we see subterranean spaces. One benefit that earth is said to have is its great insulating capabilities. An experiment was conducted to see how effective soil can be at insulating. The test helped inform the thesis to just how effective soil can be as an insulator with just 4 inches. Mixed research was conducted by searching for known technologies that can mitigate any issues that might arise in subterranean spaces, as well as technology that has made these spaces more sustainable than originally thought. This research also went further to answering the question "Can subterranean architecture create a more sustainable design?" It managed to extrapolate the success subterranean spaces have on sustainability through various small case studies.

Primary Research Elements:

Literature Reviews

Historical Research

Experimental Research

Mixed Research

Case Studies

Literature Reviews

Summary

There are three literature reviews throughout this thesis. Two of them surround the thesis question's main premise. The third one does as well, however, it ties further into the history of the subterranean world. Therefore, there will be two official literature reviews as the other is reserved for the historical research section of this thesis book. The two that will be explored and reviewed will consist of the Russian text of "'Earthlings' Housing as A Component of Ecological Architecture" and "Visceral Sensation in the Space of Death". Both articles endorse the thesis premise based on the understanding and collection of research and greater thoughts from professionals within their own field. Each literature review discusses a different angle to how earth and underground spaces can be perceived and utilized.

The "'Earthlings' Housing as A Component of Ecological Architecture" does very well in encapsulating the efforts of this thesis. The person who wrote and collected research that birthed this article was by Svetlana Smirnova, an associate professor at the Volga State University of Technology. The whole text was written in Russian, so the translated version might have lost a few key points. Regardless, the article shows how earth-sheltered homes have been lost in practice and then evolved into the current times because of tough environmental issues.

The main reason the article was written was to remind designers that many of the materials we no longer use as often are still viable options. These old techniques and materials have stood the test of time but has been forgotten. Designers have been aware of the rising climate issues and have been designing to limit these issues from worsening. However, many still aren't producing the designs needed to combat it efficiently. The ability to design architecture in a way that will not just prevent the environmental issues but heal the environment. The solution the article discusses has been used by many cultures for many generations that is no secret to the designer. It is well known and well documented, but the need for this solution is paramount to our environment. The solution is the environment.

Architecture has been one of the leading causes of the failure to prevent the environmental issue from progressing. It isn't just architecture, but the construction industry as well. It is very easy to take to the quick and cheap route to stimulate the economy. However, this is the mindset that trapped us into this corner in the first place. The article establishes the solution, or at least, part of the solution as the combined efforts of using the material for building over the others. This building material has been used longer than any other material out there and some countries haven't stopped using this material. These cultures had a need that was met and continues to meet their needs of livelihood, so there is no need for change. Many of the larger countries and cultures always need to try to find a better and cheaper option, without first thinking of the long-term consequences.

There are many ways and different techniques that can be used on this building material. The different techniques are discussed in the review and show the benefits and pioneers of said technique. There are a handful of architects and countries that are already utilizing this building material to benefit their own environment. These countries and architects should be used as a model of success between a bond of man-made structures and nature.

The second review is from the "Visceral Sensation in the Space of Death". This article addresses different types of architecture that can impact an occupant within a certain space. Each space has certain abilities to place an imprint upon the occupant. Whether it is good or bad, there is typically an opposite to that space. These opposites can create a sense of balance between the occupant should the user feel certain senses. The space of death refers to the shadow of the society of which we get too wrapped up into. This space can be difficult to understand, with much mystery and uncertainty surrounding this space.

The article discusses how this space of death can also be the space of the living. A counter to the average way of life. This space is of death, but also of life. Once the space is experienced, the occupant will think and sense differently from what they would do normally. Although this article is shorter than the other, it establishes the essence of the power of this space that is coined this space of death in the article. The inversion of every idea and object can counter the effects of their counterpart. This article discusses this inversion and how the combination of this and sensations can be tools for each other to retain balance.

With uncertainty comes fear. It might sway the balance one thinks they have. However, this architecture of uncertainty takes the control away from themselves, loosening the anticipation and overloaded sense to reform to the basics. The article showcases this through an example of how the space of death can imprint on our visceral sensations.

Literature Reviews

“Earthlings” Housing as A Component of Ecological Architecture

This review will cover the article “‘Earthlings’ Housing as A Component of Ecological Architecture”. The article is originally in the Russian language. However, it was converted into English using the google docs translation feature. Svetlana Smirnova is an associate professor at the Volga State University of Technology, who is the author of this article. Since it was translated, some of the meanings might be misinterpreted. Some of the parts weren’t reviewed due to the translator not translating everything.

The article discusses earthen architecture as a component of ecological architecture. It delves into the history of earthen dwellings. Ecological architecture is the focus of this article as it tries to convey that earthen materials should be considered the primer of most buildings. Recessed houses are discussed as one of the first forms that most cultures initially lived in. Although it doesn’t discuss subterranean architecture, it follows the same principles as it shows the solution to the problem as earth being the main primer within the design.

The article suggests that even though architects have been advocating sustainability more so currently than in the past, we still refuse to look at the main issue of the problem. This article, too, suggests that the unexpected answer is right underneath our feet. It defines sustainable buildings as a building that is in an ecological balance with both the humans and the environment. This is like the thesis premise of using earth to support the design as it has numerous benefits to the human dwelling.

Much like the thesis, this article strives to express the importance of the ground underneath possesses. We are forgetting that we have hindered the natural environment to the point that it could collapse in the next few decades, resulting with our demise as well as the natural environment’s demise. The history we share with the earth is substantial and now we need to look down at our mistakes and address it head on. To do so, the article suggests we use the oldest material in the world.

The oldest material on this earth is the earth and its derivatives like clay, sand and soil. The effect of using environmentally friendly, in the article it uses the term bio positive, materials and recycled materials, which possess a positive trait on human health when we utilize these. It says that there are three requirements to the primer material for the building. The three requirements of the material are that it doesn’t pollute the environment during manufacture, requires minimal energy consumption during the manufacturing process, and has the capability to be recyclable, much like how living nature is.

These requirements show that not many materials should be used in the construction of buildings if we are to form a bio-positive relationship with the natural environment. One of the examples in the article shows a reconstructed dugout in Glenwood, Iowa, not too far from the site. It is unknown if it is currently being used, however, the fact that it is still standing shows that the earth is still stronger than all the materials we have been using lately. The fact that earth doesn't work well with skyscrapers or putting large amounts of money into our wallets has distorted our views, even with the scholars of sustainability. The requirements are fulfilled when it comes to materials that are seen to be recyclable. They also are materials that can be replicated directly from nature. These materials that follow the three main requirements for potential uses are: wood, bamboo, straw, peat, stones, soil, wool, felt, leather, cork, silk, cotton, natural adhesives, natural rubber, and most other nature forming materials. The most important one discussed in this article is soil, or earth. Earth used in the building material has various benefits that most of the other materials do not share.

The article shows the comparison of the energy content of materials from typical building materials. In short, soil has a lower energy intensity compared to bricks, steel, and aluminum. The brick possesses the average energy intensity, which is around 2-7 GJ/t. Steel has the energy intensity of 30-60 GJ/t, which is considered a high level. However, aluminum has an extremely high energy intensity at around 200-250 GJ/t. That amount is obscene, which is bad because many buildings use aluminum for many uses. The great thing about soil is the fact that it has a very low energy intensity compared to the other materials. The soil's energy needed for production is less than 0.5 GJ/t. The soil as a building material provides many benefits compared to other materials. It has a low cost, high availability, little to no need for transportation, and thermal insulation properties. It also doesn't disrupt the state of the environment, can maintain a desired microclimate within the building, can be formed in many shapes, and can be reused at will.

Although it doesn't discuss the added benefits in colder climates to have the building at least partially underground, it does still show the low energy cost and maintenance of soil are considerably lower than other materials. One thing that is not mentioned is the effect soil has on the deeper it becomes. The age of this material is intriguing as most of other materials discussed are younger than soil itself. This is counterproductive to our societal development when a previous material we used is still better than our highly innovative solutions we came up with as we played with chemistry. The problem is that we didn't realize the impact these new materials would end up costing us in the long run, we cared only about getting a quick buck. This ideology caused articles like this to be researched and presented in an educational setting to inspire the world of design to look back at previous materials that we know works, instead of inventing a new material that could just lead to more issues. The best part of using earth is the benefit that even if there ends up being negative consequences to it, the natural environment benefitted from it regardless and we could always try again as it is recyclable.

Since earth is the oldest-used building material, there is plenty of evidence to support the benefits and durability through history. Many counts of cultures have used earthly dwellings and has managed to exist for more than 9000 years. It began as dugouts and slowly turned into earthen and adobe construction that was raised above the ground. This is evident across the world. Adobe has been used for many centuries and it needs to be looked back on. Adobe is just one example in the earthen architecture world to have been used by almost every culture. Dugouts were one of the first types of dwellings. The dugouts used the soil as a roof to protect from the weather, while the walls helped reduce the climate's impact on the inner space of the dugout. A small opening would be created at the start for a door, then would be further dug into to create a void within the ground. This allowed small units of families to dwell in safety from the outer elements. From there, some cultures grew and began to compact the earth and other natural materials to create a harder material that possessed even more benefits of protection from the elements.

Adobe was used to construct one of the first above-ground buildings that we are aware of. This is important to note, as some of these structures, even the dugouts are still standing to this day. But as some grew, they began to get out of the ground and build similar buildings of which they already lived in. However, these were placed into a formwork or soil blocks to allow the structure to stand upright on its own. Today, there are some places that still primarily use these techniques in response to their extreme climate. One such place is the city of Matmata in Tunisia. They use semi-underground dwellings as dugouts that are deep into the ground. Another one is the traditional dwelling of the Chinese subethos Hakka, which is built of clay bricks. These structures are called tulou, or earth fortress. It is also called the house-village, which is a result of a shortage of land and has a need to be more effective in protection from the enemy. These buildings are also still around, showing the durability of buildings made from bricks of mud.

One of the best examples of the soil as a building material is from the Republic of Yemen. There is a city that has clay skyscrapers that can get up to 30 meters high. That could be up to around 7 stories tall if 4 meters would be from floor to floor. These are apparently the oldest on the planet, dating back to the 9th century in some cases. Even today they still perform functions without any maintenance or repair. Other examples include adobe use. The Great Wall of China and the Moroccan city of Ait Benhaddou are the most famous and among the oldest as well. The Moroccan earthen city is even considered a UNESCO World Heritage Site.

In Russia, Paul I ordered the Priory Palace in Gatchina be constructed. Paul I was an enthusiast of earthen buildings, so N.A. Lvov designed the palace, which managed to get built within only two months in the late 1700s. Today, it is still standing on the shores of the Black Lake. Apparently, the designer selected a composition of soil mass that ended up possessing the same strength as reinforced concrete. This shows that the impact of the different types of soil and other natural materials that go into making compositions for building material can vary greatly. This specific composition by volume consists of gravel with a size of 3-7mm at 4%, sand at 58%, fine earth at 20%, and clay at 18%. When this building gained traction within the community, it began widespread implementation into the practice of building materials based on using the land.

The Society of Fire-Resistant Construction of Russia helped spread the use of the fire-resistant structure as it solved the problem of wanting the replacement of the wooden buildings, which was the most common at the time. It allowed for structures to be fire resistant with affordable means at a lower price. Russia is a perfect example at the time, because of its more extreme climates than other countries. They nationally promoted the earthworks, at least until prefabricated reinforced steel was implemented in the middle of the 20th century.

Russia possesses one of the coldest climates in the world. Even in the warmest parts of the country where most of the population live, the regions can get very cold and dry. With the success of the earthworks, in the 1800s, it showed that the advantages of earth compositions as a building material can indeed work in colder climates. This largely relied on the composition N.A. Lvov selected. The proper selection seems to be necessary based on the local region's climate and weather factors. With a different selection, the building could have been deemed not as effective as the original selection. The selections would need to also be considered limited based on the region as not every region possess the same amounts of sand or gravel, for example. Based on the composition, it seems that the highest percentage was sand at 58%, which implies that since the composition matched the strength of reinforced concrete, the higher the sand within the composition, the stronger it'll get. However, too high amount of sand could result in the material being too loose, as there would be not a large enough binding agent to keep it all together, such as the clay or fine earth that it used.

Not only Russia but many other cold countries have used the earth as a technique in building houses. Take the Icelandic dwelling as an example. The walls were made of peat with stone supporting it, while the roof consisted of turf providing thermal insulation in harsh sub-arctic climates. This was great, but they must also bury the building partly underground to reduce heat loss. However, with reinforced concrete becoming the next best thing and its rapid development, earth technologies were forgotten in many parts of the world. The construction is now considered the past, but since the 1970s energy crisis, architects are reconsidering their views. Even then, they aren't designing buildings in ways to embrace the benefits that earth can have on solving this crisis.

The 1972 designers from around the whole gathered in hopes to bring back and develop the experience of a building from soil. The following years from the international conference provided earth construction technologies. These technologies consist of zembit, saman, and a few others that were lost in translation. Zembit walls that are formed from soil. It gets packed into a formwork or made from soil blocks, then it is erected into a wall. These soil blocks that are used for construction provide more stability as the blocks are laid down over each other adding individual strength into a group like strength. Shrinkage occurs as the wall finishes drying, but since they are in blocks stacked on each other, the likelihood of cracking decreases. Each soil block can also be checked for quality purposes very easily. The saman is a different form of technique. It is a composite material that consists of earth, clay, sand, straw, and water, which are then laid by hand during construction in a monolithic formation. This technique has in the past been used for flood control and bunkers, but is now being used for home construction.

An American architect called, Nader Khalili, uses the saman composite material as a technique for designing buildings. He even wrote a book on how someone else could build their own house with similar materials. He has developed a system that NASA was interested in for a super-self-system for construction of potential lunar colonies. Houses could last for decades and longer if they used the dirt-dome technique by adding a few more ingredients to it.

To conclude, the article expresses similar concerns to the thesis premise by trying to solve the crisis through earthen buildings. The article focused on the benefits of earth being used as a building material over other materials due to its natural behaviors. Then it gave multiple examples that this idea has been used before, we just simply gave up on it as new materials became a cheaper option but resulted in the crisis, we are currently in. With the pull back to these older techniques the natural environment and humans could create a bio-positive relationship that could be the most sustainable long-term option to living in harmony.

Literature Reviews

Visceral Sensation in the Space of Death

This review will cover the article "Visceral Sensation in the Space of Death". The article discusses the constant exposure to large amounts of sensory experiences, almost always within the urban reality. This causes the individual to be overstimulated. Over stimulation can convey a reduction in sensation and self-awareness as the individual begins to enter a state of mental dullness. The same amount of sensory experiences in comparison to urban life over rural life shows that when one over the other experiences the same thing, the rural person will acknowledge and have a state of mental sharpness and an increase in sensations compared to their counterpart.

This article hopes to liberate the urban dweller and to allow a recovery of self-awareness and sensations. The city is considered a dense void, and the solution to liberate the urban dweller is to experience the opposite space that the architecture of inversion explains to be the complete void space on the equal scale of the city, the underworld. This could in turn allow reflection and reverse the causes the urban density has on our senses. It goes on to investigate the phenomenology of dark space and the lose of subjectivity. Darkness is considered not the absence of light, but it can surround and go through the individual as an experience. This could be achieved by confronting the simple and direct experience through architecture.

The article seems to reinforce the increasing need for people to experience the opposite of urban living through underground principles. These principles could heal and refocus the mind and body of the occupant from a day of being in a city to potential being in an underground like space. They must find something of equal scale or potency that can be used to counter and liberate the urban dweller's increasing mental dullness. In this case, it is the underground tunnels throughout the city. The tunnels go up and down and stretch out as far as the city does. Now these spaces that can be used to counter shouldn't necessarily need to be the same size, just the equal scale of impact on the individual. It works because the urban spaces are too dense and not loose for long-term living. The opposites of the above-ground urban spaces to the underground spaces could play a role into why the article seems to think the experience of the underground is needed at all.

The article discusses the architecture of inversion. Polarity between two binary oppositions allow different conditions to form a symbiotic relationship. This relationship is yin and yang, for short, which complements each other regardless of their differences. Architecture creates both form and space, or solid and void, which creates spaces that can allow the occupants breathe, think, and feel. When earth is excavated, a void space is formed, while the earth is placed on the top of the ground level, creating a solid space. The void space resembles a burial process of the dead. However, the void space also allows the living to enter. The space is a metaphor for life. It is a container of the living's shadow. Without the shadow, the life would seize to exist as nothing can be projected from the living. Without the life, there would be no shadow, no acknowledgement of any existence or footprint would be possible. This metaphor shows opposites are designed by nature. Everything possesses an inversion of itself.

The idea of the architecture of inversion seems to create a symbiotic relationship in a way. The inversion shows extreme opposites that still complement each other. Subterranean spaces become void of the earth, while the earth is the solid. The opposite is true for above ground spaces. The erect buildings are the solids, while the air around it is the void. According to the article, void space seems to be able to control and limit the senses. This control keeps the occupants from becoming overloaded with the lifestyle of urban living. The urban dweller suffers from the lack of self-awareness and sensory acknowledgement, because they are being exposed to large doses of sensory experiences consistently. Void space the underground has could become a standard way to balance urban sensory overloading if there were spaces these people could go to, without needing to enter the sewers or underground cemeteries.

The space can find lost items that disappeared for ages; hence, it is both a place for lost items and to find items. The items could be considered both tangible and intangible, as memories and connections could be found from the excavator's past. The architecture of inversion uses this polarity of space, which can be an interesting condition to experience. The space that is in between the polarity of void and solid is a threshold, which act as a bridge from the above to the below, dense to vacuum, and light to dark. These thresholds extend from a ladder, staircase, or tunnel which are used by the occupants. The thresholds act as a connection to the underworld and the urban reality. All these thresholds possess different levels of connections but prepare the occupants for the underworld.

Without a threshold, nothing can be achieved as that is the nature of a threshold. Once one passes the threshold, then something can be done. The passing of the threshold in the article's case shows the acknowledgement of a bridge between two differing worlds. These different worlds can help give meaning to each space that is within each one. The meanings can vary depending upon the discussion, but in this article, the discussion revolves around the visceral sensations while in the space of death. The space of death sounds bad but gives life as it cuts off the visitor's connection to the urban reality. When this is happening, the visitor looks inward of themselves. This gives them an enlightenment that they have been sensing too much without any limitations that nature uses to impose upon them. This gives the individual an alternative to perceiving the world, the way it should be perceived.

The article mentions the architecture of uncertainty. The uncertainty stems from the shadows, darkness, spatial forgotten margins, and the questionable scale, which cause fear and phobia. These fears begin to exaggerate and amplify by design to connect to our senses that can then be turned into a traumatic event. This could be solved through proper design within these spaces. The symptoms of hysteria, anxiety, and disorder are increased from the uncertainty of spaces. There is an area near the Chicago River that exposes its existence to its own shadow. Occupants could enter these spaces but possess no preconception of the inner spaces, causing uncertainty and ambiguous feelings.

There are many examples of cities having their own shadow. New York possesses endless tunnels that are interlaced throughout the city, covering the same amount as the streets of the city. It almost reflects the city into an underground version. These spaces, however, are unkempt and particularly abandoned. A few urban explorers, soul seekers, or darkness admirers still utilize these spaces to experience these spaces in their own ways. Regardless of the city, these spaces are largely mysterious and only a few venture to experience it for themselves. The article uses Chicago as its example. When they enter the space, uncertainty surrounds them as there is no conceivable way to tell the shape, size, or depth of how far these spaces go. It could be a dead-end. With multiple entrances, it trances the visitor to enter with caution as it will test their soul.

The further in the occupant goes, the greater the spatial uncertainty. The visitor's uncertainty causes the nervous system to reach disorientation, which begins to shed off worldly thoughts. Now it seems that this space has made the visitor more focused on the here and now. The uncertainty forced the visitor to reach into the consciousness and its own bodily existence, giving a boost in sensations on the present rather than the future. This boost of sensations is due to the space possessing the lack of sensations. Since the urban dweller is always overstimulated, these spaces of little senses amplify the power of the senses, not the senses themselves. This has the impact to liberate the urban dweller from their unlimited sensory living into a limited visceral sensory experience that will leave them to ponder and rebalance their center. The rebalance revitalizes their state of mental dullness into a sharper focused version that can take in senses on a more limited sense. The limiting of senses using the underground can teach the individual the power of forming one's own threshold on these senses. However, not all thresholds are equal.

These thresholds dislodge the visitor from its urban reality from the use of the architecture of sensation. Spatial awareness might seem to dissipate within the underworld, but then allows the spatial experience of the space to reach a climax, managing to focus on its inner thoughts. These void spaces must include three extreme contrasts, which are of scale, texture, and light. The scale sets the tone of the senses by showcasing the depth and sheer scope of these spaces. The amount of light, or lack thereof, can help shows the immersion that these spaces possess that urban spaces rarely show. Each space of these three factors offer a different degree of isolation that can provide an amplified visual, acoustic, tactile, and olfactory sensory experiences that one would not fully utilize. The article attempts to involve the urban architecture in a way where it isn't dwarfed by the spatial limitation from above. The same scale as a city could be involved in the architecture of sensations that the underworld possesses. It could provide these visceral experiences that could change one's outlook on life, once they return to reality.

To conclude, the article shows that urban dwellers have been overloading their senses. They have become to lack the sensory depth needed to understand it. The contrast between the above and below, the solid and the void, is designed to question what direct experience is in architectural discourse. The strive to not be dwarfed by the scale of a city and lack the reflection needed to counter the excess of urban density in one's life. The article covered architecture of inversion, uncertainty, and sensation surrounding the urban landscape and the underworld that established a similar premise to the thesis.

Historical Research

The underground is unknown. The underground beneath conceals itself. The underground provides us a feeling more so than a place. It has been depicted as dark, and gloomy, hellish in some cases. Hell was stemmed from the root word “kel-“, which means “conceal.” Through Greek mythology and many other mythologies, the underground represents hell and the unknown. However, the underground holds much wisdom and untapped potential. There are layers upon layers of human history frozen in time that the underground holds. Humans share a relationship with the underground, giving us a subconscious pull to find out more. *The Underground: A Human History of the Worlds* provides a quote: “Most people move through the world in two dimensions. They have no idea what’s beneath them. When you see what’s underground, you understand how the city works. But it’s more than that. You see your place within history, how you fit in the world.” (Hunt, 2020)

One thing to note is in history, people have referenced underground human dwellers. The Greek historian Herodotus described a race of people who lived underground. Strabo and Pliny the Elder, too, referenced similar stories of humans that preferred to live underground. All the way up to the eighteenth-century, even Linnaeus, the botanist who established the taxonomic classification of the natural world referenced that there were two types of humans, day men and night men. One living on the surface and the other living underground that possessed more nocturnal behaviors. As these were primarily stories and had a lack of eyewitness testimonies, the references are simply interested stories that we can use into how humans think back then to even today. Regardless of the lack of reality, these ideas of a night human gradually faded, but proved that we always sought to have a hidden counterpart to ourselves be revealed. It is as if we are, or were, in the search to find our opposite, our own shadow within the earth.

Throughout other cultures, there is an uncanny similarity of their emergence myths, how humans began. Almost all these cultures possess emergence myth of humans being born and emerged from the earth. These similarities provide an unintentional trend in human history that we first thought and believed we began not in the ocean but underground. The underground possesses many minerals that these cultures have used and loved. The most popular throughout various cultures are the red ochre, which has been mined for various ceremonies, rituals, and certain traditions. The sacred red ochre has a deep connection to the human history of our past connections to the underground. The cultures also share a common goal of possessing spirituality using the darkness within the earth. The underground can be considered the spiritual dimension of reality. Cultures have shared that they could become closer to past spirits and divine communication. Today we call this the dark zone that makes our brain see things that aren’t necessarily there if we are encased in complete darkness. Within a few hours of pitch darkness, humans begin to temporarily hallucinate. Depending upon the trip, it can create an enlightenment in almost everyone that attempts this.

We did find evidence that animals can survive solely underground in the late 1600s. We started finding new species that purely dwelled underground not needing the necessities many sub-surface animals require. This is important to know as if animals can adapt to this harsh environment without advanced technology, humans can with advanced technology. The only question will be how to best adapt to these environments and how long it would end up taking. Animals have been observed to burrow into the ground as it is one of the most vital modes of existence. Even with mankind's vast improvements in technology, we still consider the earth to be the most vital backup in case of a nuclear fallout scenario, or something similar. Cities have dug down into the earth to protect from foreign invaders for a very long time. There are many reasons for this.

Darkness is encasing and can be absolute on a person's senses. The full immersion of darkness has chances for the person to experience negative psychological effects. These effects can create aberrations in the mental state that will stress the person occupying a pure dark space that is formed from a subterranean space. These issues are partly considered nightmares people might have from being in a dark space. When a person enters the underground, there is a sense that the natural light from the sky, the sun, and the surface layer that provide color and livelihood are going to disappear forever once entombed into a subterranean space.

Light is essential to prevent nightmares of being completely cut off from the light while in subterranean space. Large amounts of darkness impact comfort levels far more than large amounts of light, so countering that needs to be kept in mind when it comes to subterranean spaces. Another nightmare that is an issue while underground, is that we feel restricted as humans in these spaces. It can limit ourselves compared to the abilities we have top side, without compensation. Our limbs themselves can feel restricted in these spaces, resulting with an increase in stress and decrease in dopamine. As parts of our body feel limited and restricted, we could begin to feel limited and restricted in other parts of our lives as well. The obvious nightmare is the thought of the element that provides us of life, which isn't in large supply underground compared to above ground. Oxygen is essential to live that when we enter these spaces, we feel unsettled subconsciously. As we enter these spaces, our lungs work harder to ensure the necessary oxygen gets rushed throughout your body. With all these effects, the person still might go in these spaces for other factors.

The curiosity of the unknown is a strong component in the absence of knowledge that can be given from these earth concealed spaces. Leonardo da Vinci once said, “two contrary emotions arose in me, fear and desire – fear of the threatening, dark cavern, desire to see whether there were any marvelous things in it.” (Hunt, 2020) This can explain why even though there are many problems with underground spaces, there should always be a pull to explore and understand the unknown in different ways. In this case, it was to find marvelous things that could provide an enlightenment in the individual and potentially everyone. Even though we typically avoid the underground because of these effects, it has always been our very first biological refuge in dire times. Humans have lived underground and within caves before because of the accessibility and low maintenance.

The underground has interested people in hopes to find unfathomable riches. These riches look different from person to person. The humankind looks to find and learn from their past. By doing so, exploring underground parts of major cities and digging in curious places can lead to these riches. One thing that has been found are fossils and historical artifacts that have been around for ages. These riches provide a connection not just between the human history, but also provides a greater understanding that the earth preserves our footprints that we and the past environment have had on this earth. This urges us to find more and become more familiar with the subterranean side of our planet. Past civilizations have been discovered not by looking upwards, but downwards and into the earth. The earth hides our connections, so we are then allowed to forget until we need to remind ourselves of where we are in the timeline of our history and future. As intriguing underground spaces can be along with it’s negative side effects, one thing that is beneficial in these spaces is the insulation of sound.

The large amounts of noise we hear today is the opposite to what we use to witness as humans. We didn’t have many noises that we currently do today. No traffic noises, cars buzzing, trains honking, intercoms speaking, and many other components weren’t around back when we transitioned from surrounding ourselves from natural environments to man-made environments. This change could very well have modified the inner responses we have on our surroundings as negative. However, when someone confides within a space underground, they no longer can witness the amount of noise that is being produced from everyday life. The earth can be a tool to repair how we perceive the environment around us. Stamping out unwanted sound can improve the human health, as these noises can produce an increase in anxiety.

The ground is unfortunately unkind to humans by hindering their allowance of oxygen within a space. However, there is still oxygen that could enter through various means. Historically, when people entered underground spaces that haven't been used for many years, the air is found to be stale and dank. The moldy flowing air that is being inhaled doesn't bode well for humans. In some cases, it is just moldy, as the spaces are setup to allow plenty of oxygen to flow in and out of the space. Spaces that have been used by workers or were old places of interest would have easy access to the air up top through either natural venting or incorporated venting. The importance of this issue stems to the human need to breathe when underground and can be solved if we look to past solutions to this problem.

To conclude, the history of subterranean spaces must be acknowledged. The reason we don't tend to stay underground, even though we share a history from almost every culture, is the same reason society needs to keep on improving. Until we get stuck from the current environmental issues, we might need to revisit what our own history has told us about subterranean spaces. Although our needs have changed from our ancestors today, we might have the capability to live under the conditions we currently see fit, while simulating our past cultures to live underground again.

Experimental Research

Reasoning

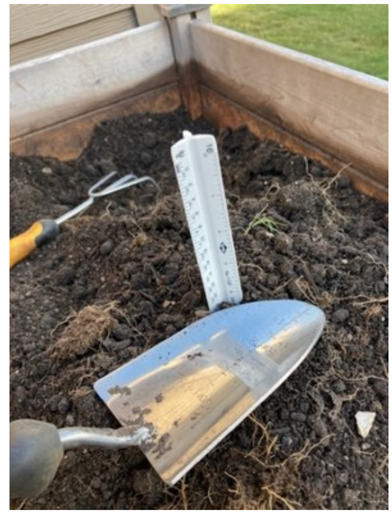
The goal was to find out how effective earth has on retaining and dispelling heat. The question I had that pushed this experiment forward was, “How well does earth provide natural protection from the climate with only 4 inches of soil? I learned prior to the research that the typical green roof ranged from less than 1 inch to 1 ft or more. That range showed me that it was primarily for the benefit of water retention and the placement of plants that influenced the thickness of the green roofs earth than it did for thermal insulation.

Based on the case studies researched, I was curious of how little earth was needed to consider a building “underground.” Technically, as long as there is earth surrounding the majority of the walls and the rooftop, it is considered a subterranean building. Through limitations of resources and the hope to provide helpful analysis of climate differences of underground to air, the experiment was set to collect data on the temperature 4 inches deep. This experiment is to purely give quantitative data on how effective 4 inches of earth can be as this collection of data will show how thick the green roof layer should be in the design phase of the project.

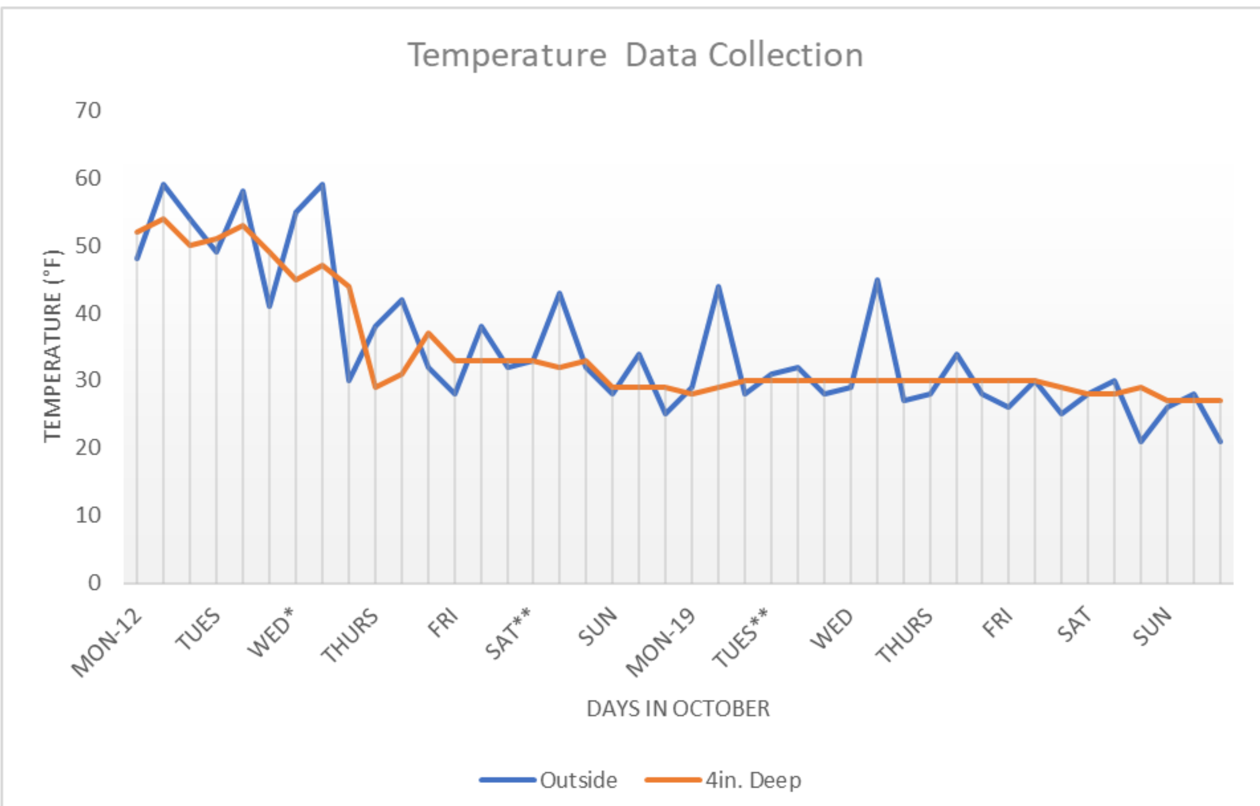
Setup

The tools used consisted of a planter that held dirt, a temperature gauge, and a ruler. The temperature gauge that was used had two sensors. One was submerged in 4 inches of dirt on top of it as well as beneath it. This was essential as the planter used was raised up and the change in temperature could have impacted the collection of data. The dirt used was the kind that people purchase for plants to grow in. The type of soil and depth of the soil was considered upon the design of this experiment.

The depth at 4 inches was selected because of the limit of soil used and to propose the quantitative side of the earth where it can be used in the design to answer how little the depth of the earth could be. These sensors I established as a representation of a potential building design, one being above ground, while the other is underground. Both possessed a Ziploc bag to ensure the sensor isn’t impacted by the sensor being wet. The bag represented the skin of the buildings as the sensors were to help record the space within the bags. The observations of the differences between these buildings will provide enlightenment on how little the depth of the design can go and still have the earth insulation benefits.



The first step in the setup was to measure, using the ruler, the earth 4 inches from the bottom of the planter to where the sensor was placed. The sensor was placed on the 8-inch mark from the ruler and earth covered it up to the 4-inch mark on the ruler. This method ensured that the earth encompassed the sensor by 4 inches in all directions.



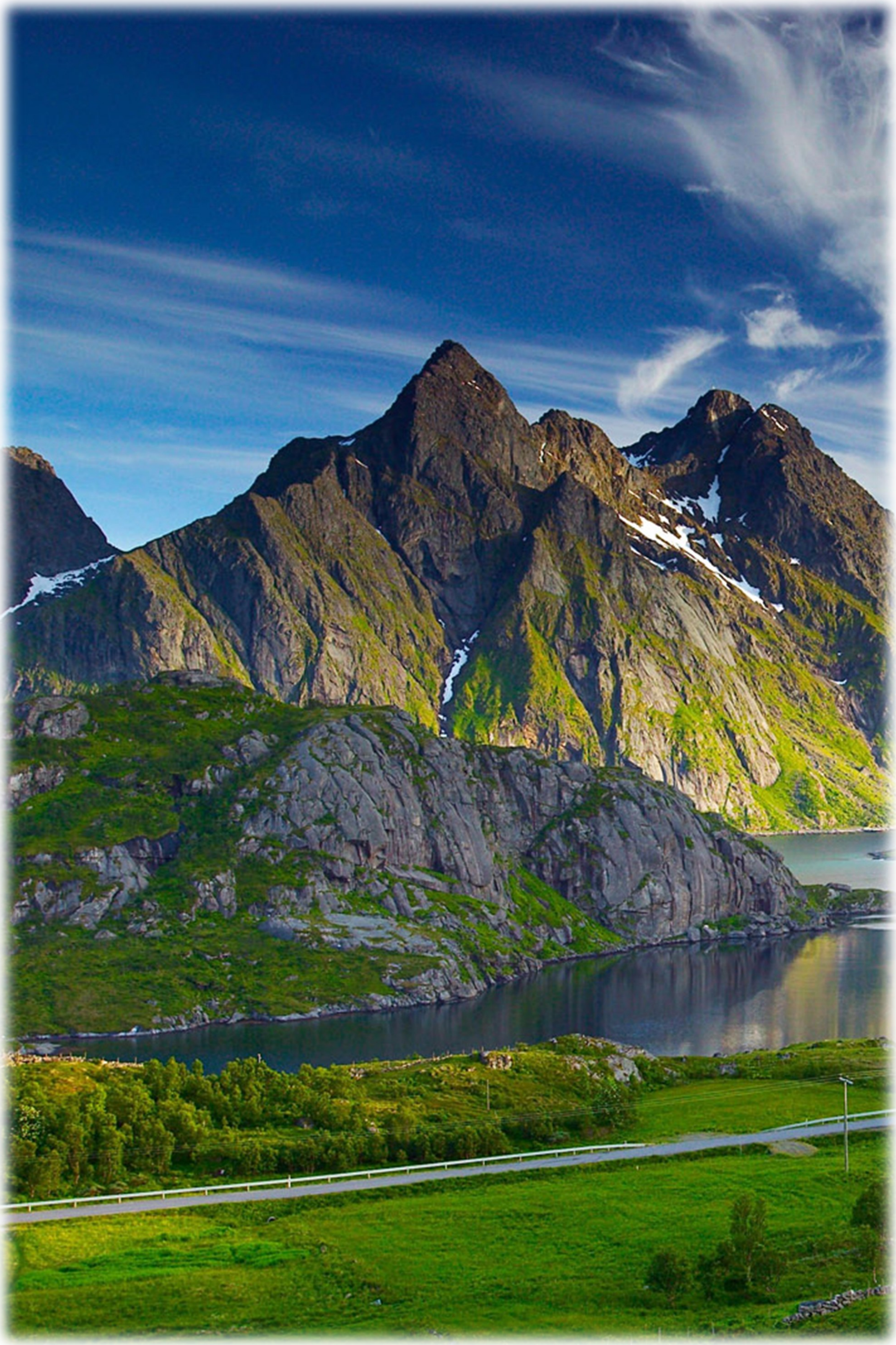
The graph above provides the collection of data from the experiment. Three data points are provided per day per sensor, which are based on the times of the day, 9am, 12pm, and 9pm. The single asterisk signifies the days it rained. The double asterisk signifies the days it snowed. The graph shows two weeks' worth of data from October the 12th to 25th.

Reactions

The start of the experiment began on October the 12th and was scheduled to last indefinitely until enough data was collected to begin analyzing and learning from. The temperatures were recorded on a sketchbook every morning, noon, and nighttime. The times that were most consistent was at 9am, 12pm, and 9pm every day. The data was collected using °F and rounded to the nearest whole number. The initial days went by and the observation that the earth was warmer at night was apparent. However, I assumed it to be that the earth will always be warmer than the air. I was incorrect. I also observed a day where it rained that seriously altered the assumptions I initially had. The rain soaked the earth, making the space within the earth significantly colder than the outside air for at least 24 hours. At this point I realized the change in temperature, not the temperature itself was what I should be truly looking at. I began to focus on the temperature changes throughout the days, not the temperatures themselves.

Throughout the two weeks I realized a trend that the earth's temperature was mostly delayed and slowed the change in temperature compared to the air. The earth's temperature was steadier than the air's temperature. The wind only affected the air temperature, showing that the earth clearly protects from most weather types, excluding rain. When it rained, the earth temperature dropped with a 12-hour delay versus the air reacting immediately. However, the air wasn't greatly affected by the temperature of the rain. It greatly impacted the earth temperature, which was minimal, but still important to note when it comes to designing for rain protection. There were a few days where the temperature drastically changed for both sensors, but even then, the earth's temperature was more stable and consistent than the other sensor. To conclude, the data shows that the earth provides protection from the natural elements and gives a greater stability of the changing of temperatures in underground spaces even at 4 inches deep.

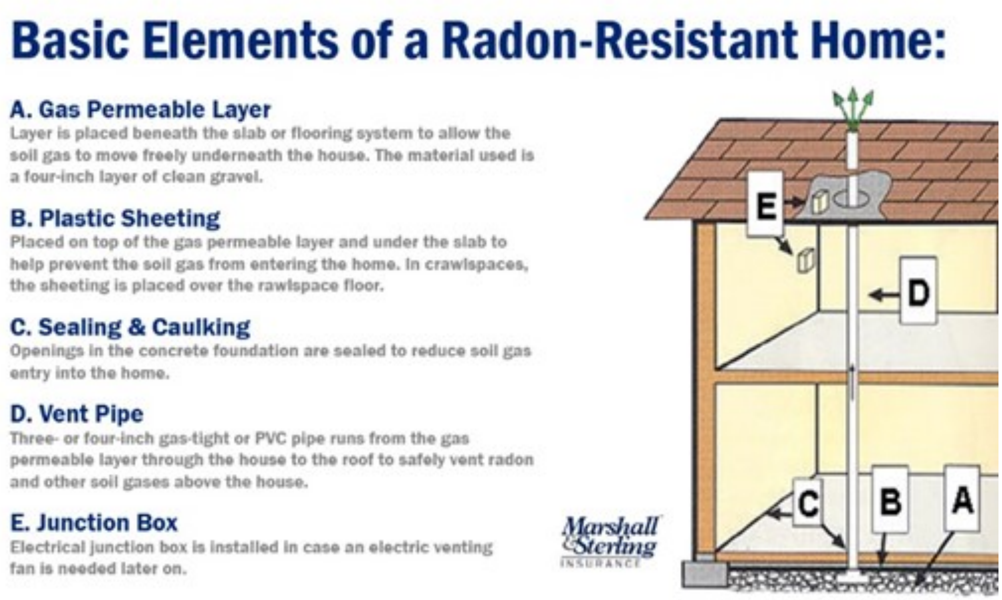
Update: After more research, a trend was found of the earth becoming more stable in temperature the further down you go. The consistency of the temperature can be a sustainable trait, especially when it comes to locations that have extreme weather swings. This could be taken advantage of by enveloping a design within the earth, at the very least 4 inches deep on all sides of the building to take full advantage of this trait. The ability to maintain a certain temperature could potentially be used as a heating and cooling system that can go hand in hand with the protection of the earth. This experiment shows the impact earth can have on architectural designs that could be a future trend to implement in response to lowering the cost and usage of energy daily.



Mixed Research

The Dangers and Solutions of Radon

Radon is a radioactive element that is one of the most important factors in subterranean spaces. It is colorless and tasteless, while being toxic to humans. This element's radioactive decay is used to treat cancer, used to detect leaks, and in radiography. It primarily harms an individual if that individual comes into large contact with it. Radon is the decay product of radium, while both are part of the uranium decaying process. All three of these elements can be found in almost all rock, soil, and water on earth. The type of soil and its chemistry is what depends on the amount of radon being present in the soil. There are factors that alter the amount of radon that escapes the soil and enters a building. These factors are weather, soil porosity, soil moisture, and the tightness of the building. This radioactive gas enters the building through the ground to the air above, so it goes through any holes and cracks from the foundation and once it enters the house might end up preventing the gas from escaping, slowly building up the gas within the space.



This graphic shows a few other elements that can be included in the designing process for a building to be as radon resistant as possible. Materials are important to consider as some materials can help the radon enter the space easier, so protective layers will be important to think of including materials when it comes to the skin of the building.

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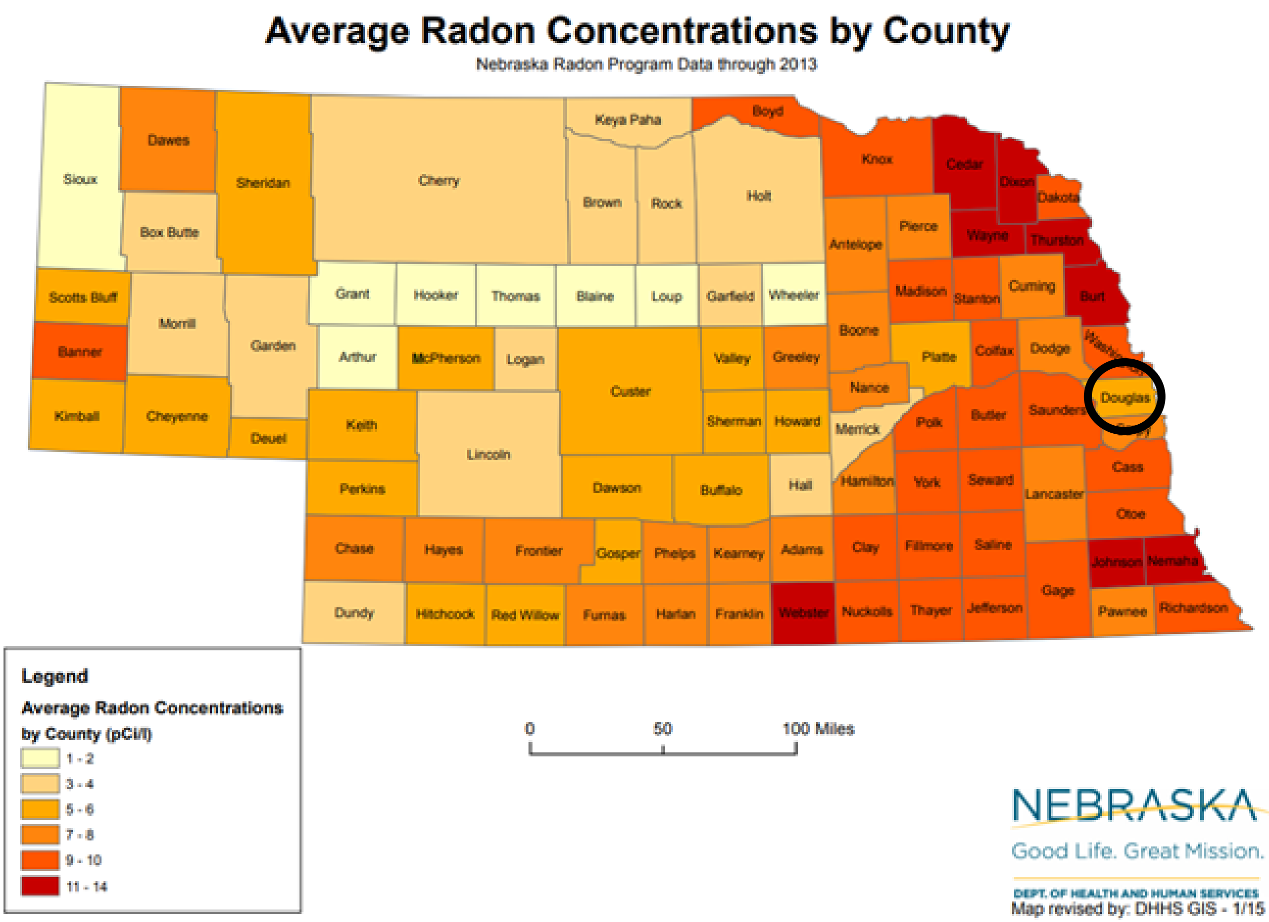
All buildings can possess a radon issue, regardless if it is new or old, well-sealed or drafty, basement or no basement. A benchmark of the amount of radon for outdoors would be 0.4 pCi/L, picocuries per liter, while the average indoor radon level is about 1.3 pCi/L. If it goes over 4 pCi/L the EPA recommends the building be fixed to lower the amount. Radon can enter through water as well, but an easy solution to water can be to provide a point-of-entry treatment that removes radon from the water before it enters the building. According to the EPA, the best way to mitigate radon is having a vent pipe system and fan, also called the soil suction radon system, which vents the radon beneath the building to the outside in the most efficient way possible. Basement and slab-on-grade buildings have four types of soil suction to mitigate radon, which are active or passive sub-slab suction, drain tiles, sump-hole suction, and block-wall suction. The best way in the long run is to design the building to resist as much radon as possible, as it is comparably inexpensive to add it in after the construction is complete. A heat-recovery ventilator, HRV, is a great way to increase ventilation while helping reduce the radon levels in a building. The HRV is most effective at reducing radon in a basement like setting.

RADON REDUCTION OF VARIOUS MITIGATION TECHNIQUES

Technique	Typical Radon Reduction	Comments
Subslab Suction (Subslab depressurization)	50 to 99 percent	Works best if air can move easily in material under slab.
Passive Subslab Suction	30 to 70 percent	May be more effective in cold climates; not as effective as active subslab suction.
draintile Suction	50 to 99 percent	Can work with either partial or complete drain tile loops.
Block-wall Suction	50 to 99 percent	Only in homes with hollow block-walls; requires sealing of major openings.
Sump-Hole Suction	50 to 99 percent	Works best if air moves easily to sump from under the slab.
Submembrane depresserization in a Crawlspace	50 to 99 percent	Less heat loss than natural ventilation in cold winter climates.
natural ventilation in a Crawlspace	0 to 50 percent	Costs variable.
Sealing of Radon Entry Routes	See Comments	Normally only used with other techniques; proper materials and installation required.
House (Basement) Pressurization	50 to 99 percent	Works best with tight basement isolated from outdoors and upper floors.
natural ventilation	Variable/Temporary	Significant heated or cooled air loss; operating costs depend on utility rates and amount of ventilation.
Heat Recovery ventilation (HRv)	Variable/ See comments	Limited use; effectiveness limited by radon concentration or the amount of ventilation air available for dilution by the HRV. Best Applied in limited-space areas like basements.
Private well water Systems: Aeration	95 to 99 percent	Generally more efficient than GAC; requires annual cleaning to maintain effectiveness and to prevent contamination; requires venting radon to outdoors.
Private well water Systems: Granular Activated Carbon, or GAC	85 to 95 percent	Less efficient for higher levels than aeration; use for moderate levels, around 5,000 pCi/L or less in water: radioactive radon by-products can build on carbon; may need radiation shield around tank and care in disposal.

Note: Mitigation costs vary due to technique, materials, and the extent of the problem. Typically the cost of radon mitigations are comparable to other common home repairs.



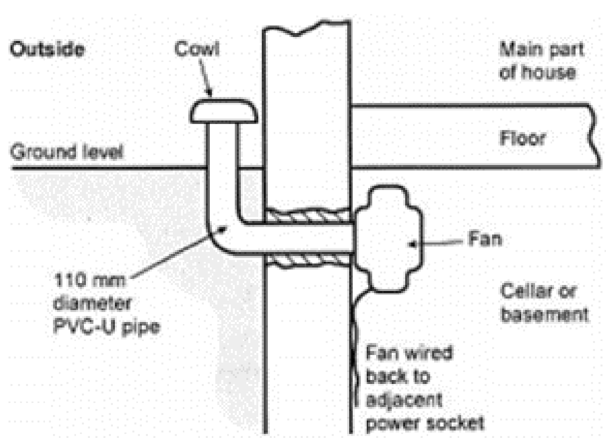
The knowledge of radon’s impact on the human body is substantial. With these systems as potential countermeasures, the design will incorporate these systems to ensure the safety of the users. These systems might be considered only required for subterranean designs, but is an issue within every design as earth connects to every building to some degree. Subterranean designs do need more counter measures than the average design for radon protection, but with a proper design it shouldn’t make the space any less sustainable than what other buildings can achieve, it is simply an extra design challenge that must be faced.

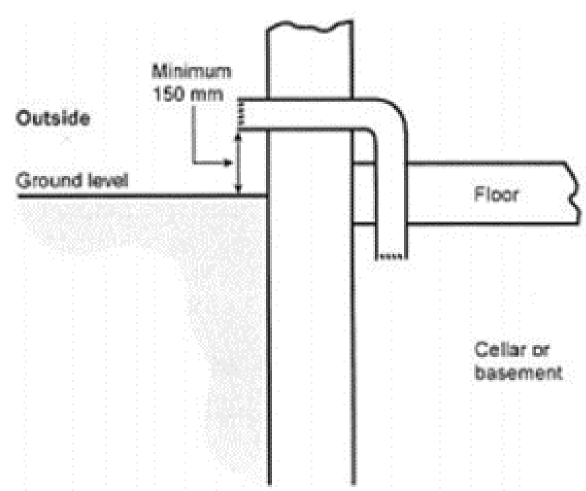

COOLER
WARM
WARM

Air Quality/Heating Solutions

There are two ways to ventilate underground spaces: natural or mechanical ventilation. The most sustainable way would be to maximize the use of natural ventilation, but depending on the depth of the space, that might not even be possible nor feasible. Ideally the design will be focused to allow for easy access to natural ventilation, but certain spaces will still be required to possess mechanical ventilation. The natural ventilation would be primarily for the residential rooms utilizing the windows to allow for air to enter and exit.

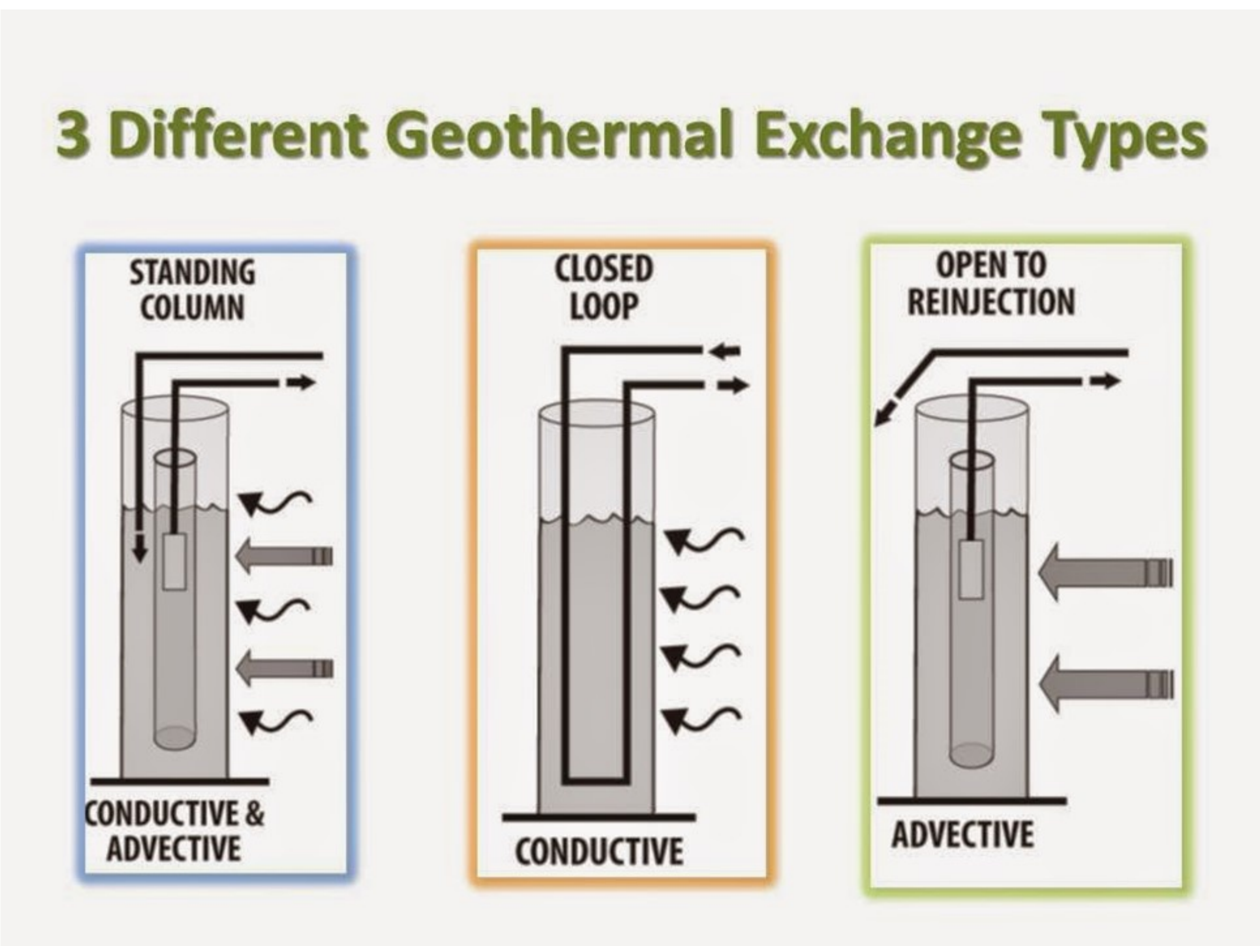
For common areas that might be further underground won't have access to windows, thus an HVAC system will be the primary usage to mechanically ventilate these spaces. Residential spaces will possess mechanical ventilation but will also be designed to allow for natural ventilation should the user see fit. Since high-rises can't utilize natural ventilation throughout the whole building, the high-rise typical HVAC system could be utilized throughout the design project to ensure plenty of ventilation is acquired throughout the spaces. The figures below show a small-scale version of how natural and mechanical system could be applied for the subterranean residential units.



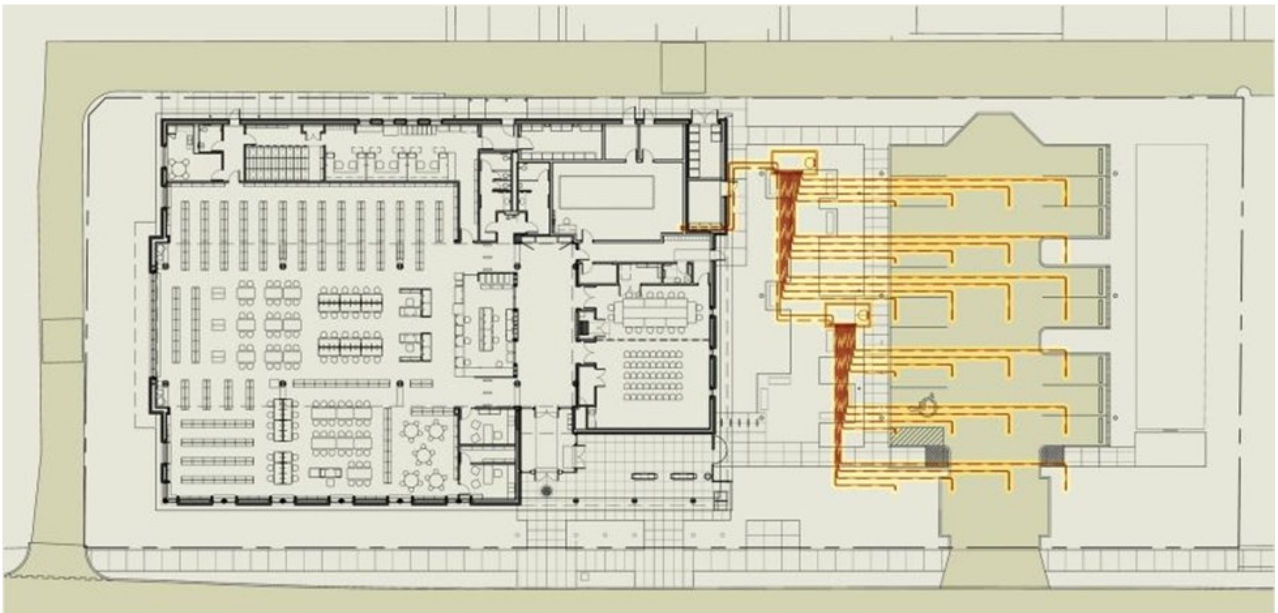


“The temperature of the Earth down 20 or 30 feet is a relatively constant number year-round, somewhere between 50 and 60 degrees” says the COO of the Geothermal Exchange Organization, John Kelly. This organization has been lobbying for a wider adoption of ground-source heat pumps (GHPs). GHPs can replace typical boilers and air-conditioning systems by utilizing the relative consistency of the upper portion of the earth’s crust to heat or cool a building. For example, say the air temperature is 90 degrees and underground is 55 degrees in the summer, while the air temperature is 25 degrees and underground is still 55 degrees. This system would use the heat from underground in the winter to heat the building. While in the summer, it’ll use the cooler temperature underground to cool the building. These GHPs are significantly cheaper to operate than the typical heating and cooling systems. These will be incorporated into the design as it is the best option in heating and cooling the design.

There are three different types of GHPs: closed loop, open loop, and standing column wells. The closed-loop system circulates water through pipes underground, then transfers the heat from the earth to the building. The open-looped system used groundwater from wells to move it into a heat exchanger then returning it to the wells to go into the aquifer. The standing column wells are an open-loop system that drills wells into the bedrock. Groundwater gets pumped from the well, through a heat exchanger, the top of the well, and then filters downward, exchanging heat with the surrounding bedrock.



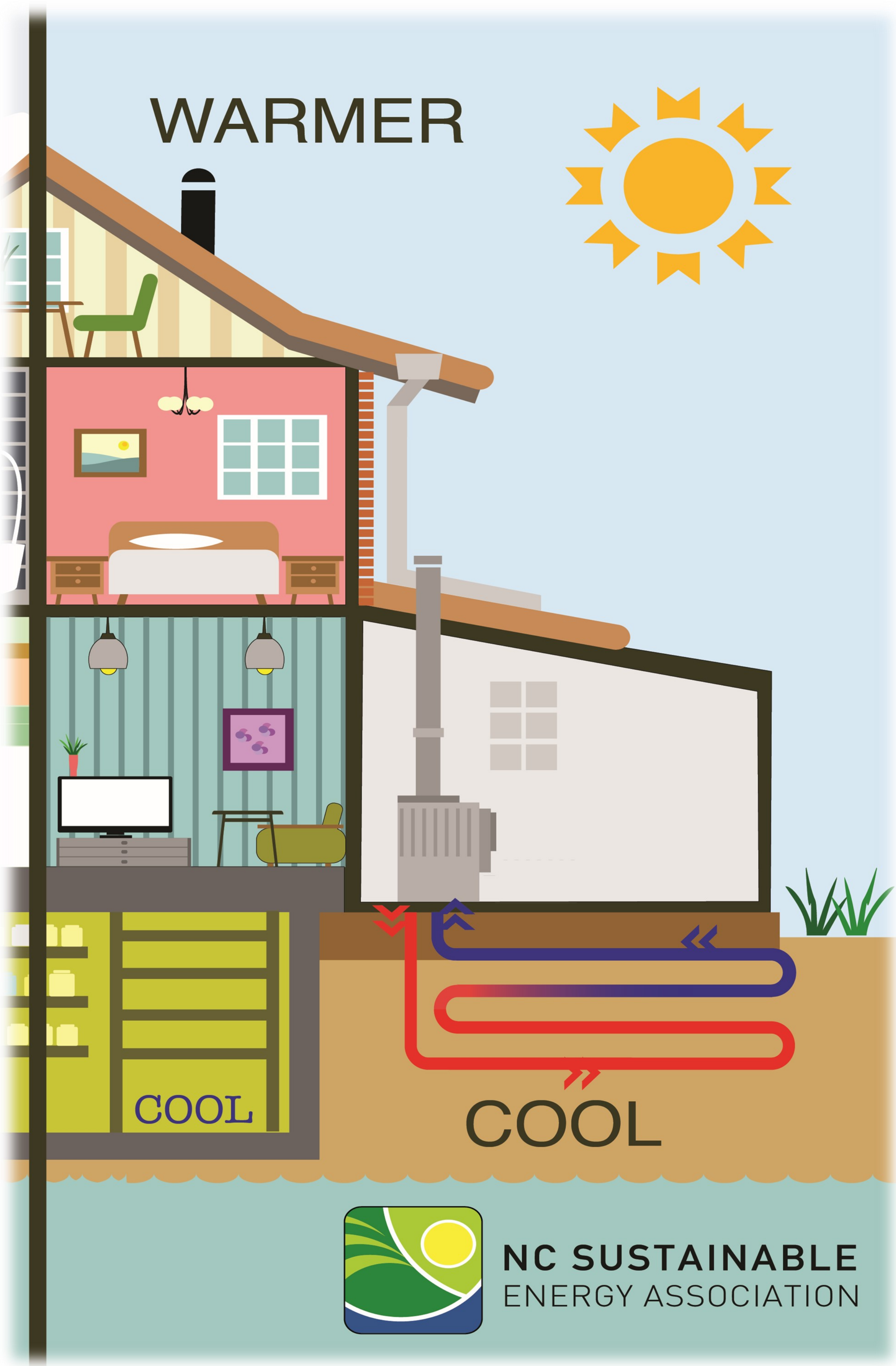
Ideally the closed-loop system would work best for the given site, given the bedrock and geology. However, because of the varying degrees of these systems, these heat pumps could work anywhere in the world. According to the EPA, GHPs "are 48 percent more efficient than the best gas furnace and 75 percent more efficient than the best oil furnace. They require 25 to 50 percent less energy than other HVAC systems and bring down operation and maintenance costs by as much as 40 percent." The upfront installation cost of these systems deters most people from choosing this option. However, the annual savings on energy bills offset the up-front cost, making this a far more sustainable option. The Lohan Anderson's Richard M. Daley Branch Library drilled 24 closed-loop wells to a depth of 395 feet beneath its library, which contributed significantly to become LEED certified.



Type	System Cost	Operating Cost per year	Repair Cost	Zoning	Longevity	Efficiency Rank
Geothermal Heat Pump	$18,250	$375-$600	$$-$$$$	Yes: $-$$	20-25 yrs	#1
Mini Split Heat Pump	$8,400	$515-$1,065	$$-$$$	Yes: $$$-$$$$	17-22 yrs	#2
Standard Heat Pump	$7,100	$750-$1,200	$-$$$	Yes: $-$$	15-20 yrs	#3
Split AC & Furnace	$6,700	$900-$1,440	$-$$$	Yes: $-$$	15-20 yrs	#4
Boiler & AC	$9,750	$1,150-$1,500	$-$$$	Yes: $$-$$$	20-30 yrs	#5
Electric Furnace & AC	$6,100	$1,225-$1,750	$-$$$	Yes: $-$$	15-25 yrs	#6

Notes:

- System Cost includes the cost of a system for an average 2,000 square foot home in a moderate climate.
- Operating Costs is an average if the unit is the main source of heating and/or air conditioning. The efficiency of the unit significantly affects operating cost.


WARMER
COOL
COOL
NC SUSTAINABLE
ENERGY ASSOCIATION

Most Sustainable Option: Reuse

There are many abandoned tunnels, subways, mines, and quarries out in the world. A few of them learned that if their space was filled with functionality, these spaces could be revitalized. Mines and quarries have lately been redesigned to be used for the general public. The Wieliczka Salt Mine in Poland is an example of this. Macy Miller got a tour of this mine and provided pictures for the research. They also host events such as weddings. The place is a historic monument that has managed to retain the technology that was used back in the day to mine salt. The pictures below shows a large open space that can hold a large amount of people. They show the extend the ceiling's span can achieve while in a subterranean setting. It also shows that many caves, quarries, and mines that are now discontinued can be renovated into spaces that the public can utilize in many ways. The natural darkness of subterranean spaces can be countered by incorporating large lights.

Theoretically, reusing underground structures is the most sustainable option for subterranean design as it doesn't require the large up-front cost most new subterranean spaces require. This way current underground structures can always be renovated into the functionality it needs at any given point in the future. Since excavated spaces could be considered a sustainable option, creating a new subterranean structure ensures that the new space could last forever with constant changing in the programs the space could provide. New designs would then need to be implemented in an effort to future proof the structures. This could grow our profession if we had architects specialized in underground renovations as a way to limit new construction in favor of a more eco-friendly planet. We tend to take, such as salt in this case, and not give back to the earth. In this case, we can't give back directly, but we can utilize the space we created and turn it into a usable space, respecting the earth in the process.

Retaining Walls

Basement walls have been known to bow and buckle from the pressure of water expanding. One of the biggest reasons is runoff issues. Large uses of non-permeable materials are used for roads and pathways that push water to lower elevations, which in some cases is near foundations or retaining walls. To ensure that retaining walls both inside and outside can hold out the dirt and water with limited issues, the best thing would be to select the right type of retaining wall materials and to eliminate all uses of non-permeable materials for pathways and other uses. Although concrete isn't particularly environmentally friendly, it is one of the best materials to use to keep outer elements out of the subterranean spaces when it comes to the retaining wall material. Bricks and stones are a great material to use as well, depending on local resources when it comes to carbon footprint, but might be limited into being used for retaining walls.

One of the important factors in underground spaces is to prevent flooding from occurring. One way to help with this is properly grading the site to ensure rainfall runs away from the building as much as possible as that tends to lead to floods occurring in basements. Another way is to incorporate soil and earth above the building where most of the rainfall ends up. The soil absorbs much of the water reducing the need to move runoff away from the building. The grade could potentially lead to a rain garden and swale hybrid, which could be located close to the edge of the site as an added way of solving potential runoff issues. Thicker retaining walls will be needed the further down it goes and same goes for the floors, which will need to be thicker than the typical thickness of 2 to 3 inches.

The hydrostatic pressure outside of the retaining wall might change so a drain tile or something with the same traits will be required to prevent water seepage. It would be ideal to add waterproofing membranes along the foundation walls for cracks to be less of an issue in the wall. Sump pumps, perforated drain pipes near the cove joint (floor and wall meet), and drain tiles with washed gravel at the base of the wall allows the hydrostatic pressure to be relieved providing a pathway for the water to escape so the pressure is eliminated as well as the seeping water problem.

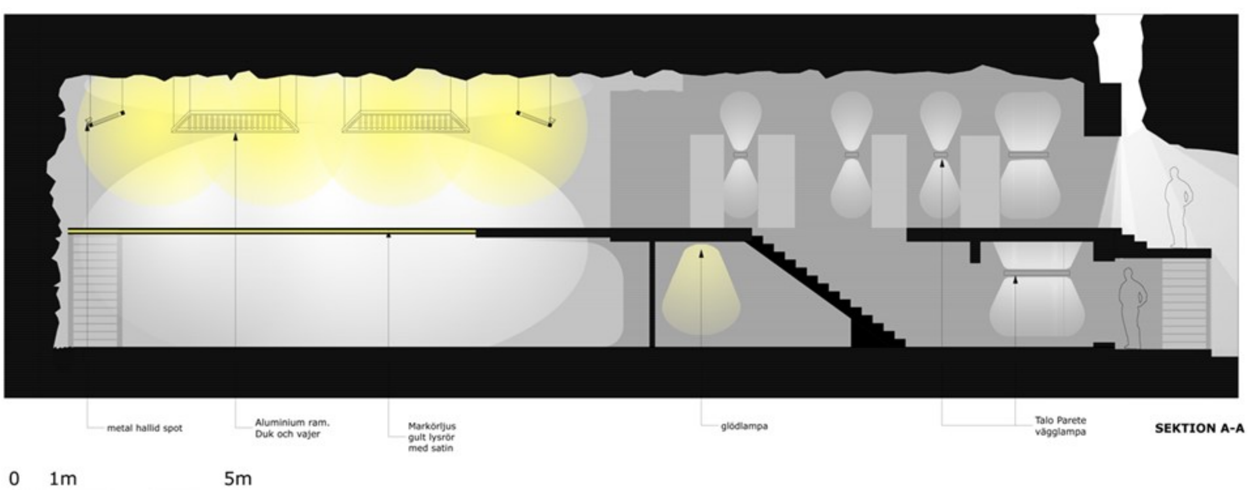
Sump pumps will be required in most spaces as well, to prevent water from entering the spaces and can disperse the water when needed, while backups should be in place as well for worst-case scenarios. If rain spouts are utilized for certain parts of the design phase, they will need to be extended enough away from the building to decrease chances of water build up near retaining walls. When it comes to landscaping, heavier mulch could become useful in absorbing water. Other materials that can hold large amounts of water will be considered to make sure the site fully takes runoff into account as that can cause huge issues if not anticipated and create flooding problems within the underground spaces themselves, which is the greatest con of subterranean spaces. This will need to be addressed fully and explained properly on how the site is mitigating flooding from occurring within the interior spaces through the design process.

For this reason, not every location is suitable for subterranean design. Some places possess soil that doesn't allow water to flow into the substrate easily, creating flooding issues. The water table is a big factor in this as well. When a water table is high enough where the volume of the lowest level is entirely under the table, it could still be a viable option, but everything is riding on the fact of just how waterproof the envelope of the building is. One mistake and the entire place could leak to the point of internal flooding, so great engineering and designing are important to making these deeper spaces possible. Even with this extra challenge, it would only impact the initial cost of construction and would still provide long-term sustainability benefits for years to come.

Case Study Research

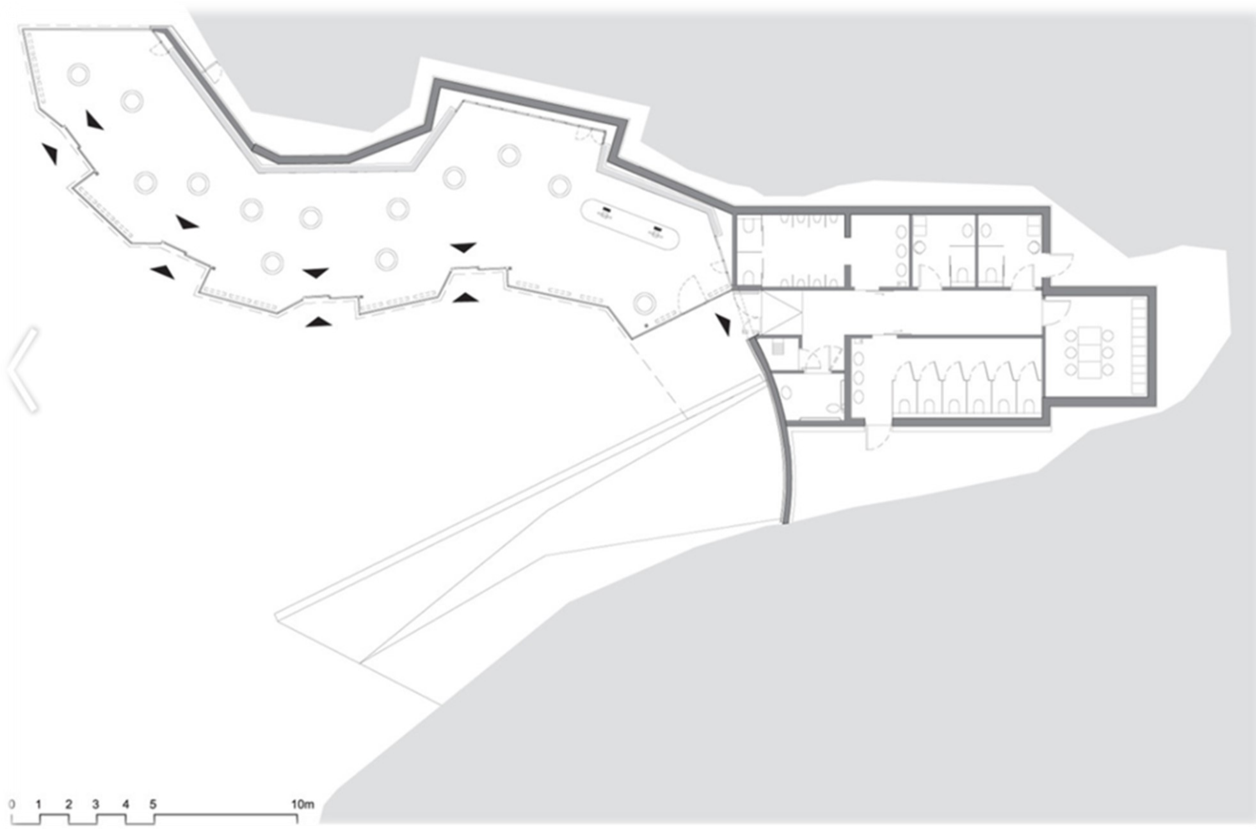
Office Buildings in Stockholm, Sweden

Space allocation of the case studies researched show the need to rely on the site around it. In this example, the site consisted of a usual situation where it was an unused anti-atomic shelter in Stockholm, Sweden. 30 meters beneath the surface the construction needed to be partially blown up to obtain the angles needed to allow a building to be constructed underground. Even though parts of the stone needed to be blown up to fit the building, the design was inspired by the original space that the shelter possessed. The biggest issue for this one was the lighting as there was little natural light options. Lighting was setup to replicate the natural depiction of the sun in certain spaces. A few spaces had a light tunnel that allowed for natural diffused light to enter.



Exhibition/Retail Pavilion in Postojna, Slovenia

An underground cave in Postojna, Slovenia is being used for the general public. They renovated it back in 2011. The dimensions that the natural form of the cave possessed limited the designs spatial allocation but ensured that the environmental impact wouldn't cause any issues and promote environmental performances in favor of low operating costs. The building is formed to respond to the natural environment, using each crevice to its advantage, respecting the space to not impede upon nature. The exhibit possesses a transparent wall which serves as an extension for the concert hall, incorporating the parts of the cave, making it apart of the exhibit.



Conservation Hall in Nashville Tennessee

The Exhibition Center in Nashville, Tennessee needed an expansion for the increase in events hosted on the grounds. A conservation hall was created underground to preserve the historic residence's land. A recessed courtyard can be found in the ground allowing for natural light and green space into the event venue, even though the spaces are around 25 feet beneath the lawn. The design involves over 15,000 square feet for the facility that has dining, event spaces, green space, restrooms, and a few other auxiliary spaces. Local recycled materials were mostly used in the project as there was a limited palette of materials permitted, thus making the used materials have a high yield of recycled materials. Polished concrete floors were used to reduce the maintenance cost for the future of the building. This project implemented certain materials into the construction to reduce the negative environmental impact and increase the environmental performance of the building. The site is flat and still managed to create an appealing space without the need of the berm technique from being used.

Antinori Winery in Bargino, Italy

Antinori Winery is in Bargino, Italy, where it takes its history and connection to the land as an architectural image to conceal itself and blend into the land as a way to tell its story. The building merges with the landscape to become even closer to the land as if the building itself is trying to preserve itself and age gracefully, much like the wine it creates. The roof is used as farming land to develop the ingredients for the wine. Directly below the roof, is where the wine is stored to mature in barrels. This way the wine is guaranteed the ideal thermo-hygrometric conditions for proper aging of the products. The rest of the building provides similar principles with many spaces following the slope of the site. The advantage of this design promotes the use of every square foot possible of farmland, while still having a building in the site that won't intrude on the farmland.

Sancaklar Mosque in Turkey

This new mosque in Turkey is designed in contrast to natural and man-made. Reinforced concrete slabs makes up the man-made roof that goes against the site but uses natural stone stairs when it is using the natural slope of the hill. The underground possesses the power of enlightenment that our forefathers achieved from. Religion is one of many types of these enlightenments as spaces that are created to lack senses, allows the individual to search within oneself or within the world and explore what it has to offer spiritually. This mosque successfully utilized the interior, designing it like a simple cave where you can be one step closer to God on the spiritual plane. The limit of light encourages the user to seek not with eyes, but with your mind and soul, an inner presence that connects to the mosque. Small controlled daylight is allowed in but is limited for the given space.

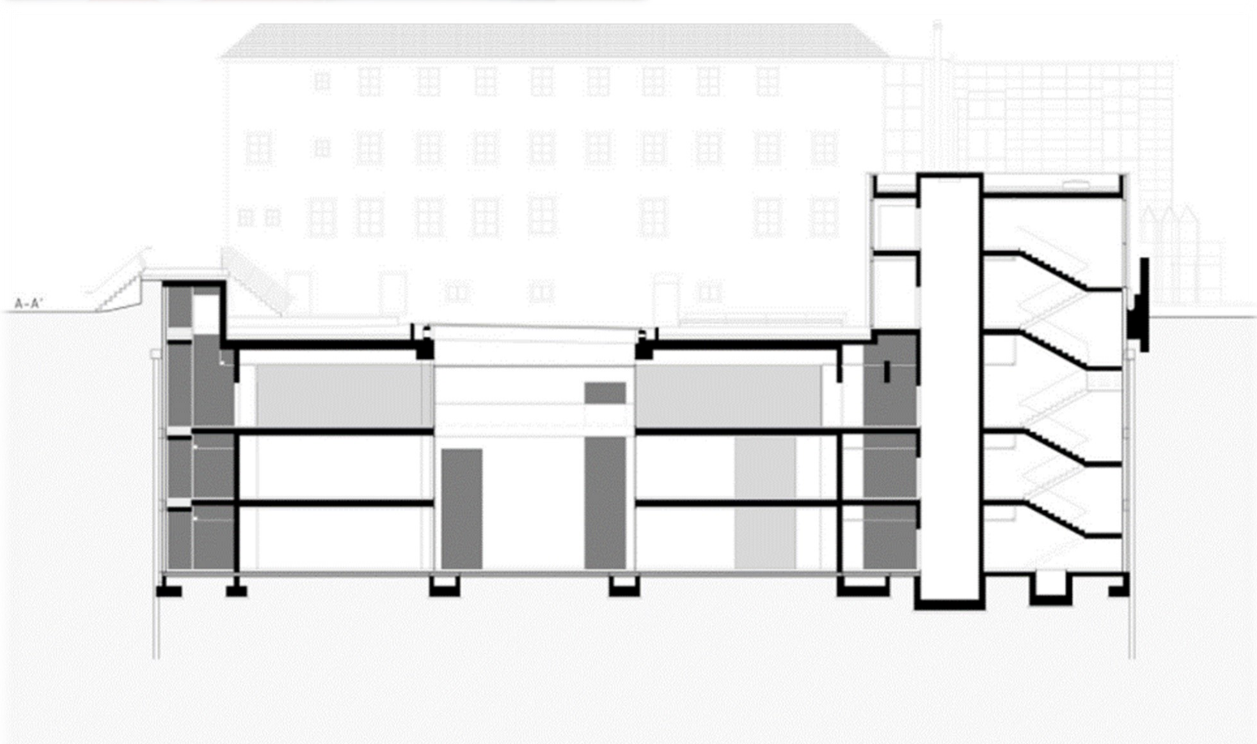
Gruto do Escoural Caves in Portugal

The Gruta do Escoural needed new a new structure within this cave, as it was becoming unusable. With the new design, they added structure that contrasted with the limestone rock of the cave. The structure used dark black and opaque materials for the circulation of the cave that creates a distinct pathway and difference from the man-made structure and nature. Lights were added to oppose the natural darkness of the cave. However, the lights were designed to contrast with the man-made structure as well out of respect for the cave.

Hannah Arendt Underground School in Bolzano, Italy

The Hannah Arendt Underground School in Bolzano, Italy is a perfect example of how underground spaces can be achieved in a sustainable manner. This building goes four levels deep, which is around 17 meters underground. The lighting was the biggest issue for this design but managed to succeed in this category. The lighting design consisted of glazed surfaces, large skylights in rooms, and glass walls for many rooms. This way every room had some form of natural light entering the inner spaces. The atrium utilized skylights as well as solar chimneys to allow the natural light to enter the area, which entered the adjacent spaces as well. Artificial lighting was still used, but they had sensors that changes the amount of light that emitted based on the time of day, maintaining the circadian rhythm clock of the occupants throughout the day.

The humidity of the area was solved by inserting several layers of insulation, sheathing, and plaster spray that also provided protection against radon gases from entering. These walls seem like exposed concrete walls can contain the forces of the earth four stories deep. The ventilation is maintained through recycling the air, which is being controlled by a mechanical system through ceiling diffusers or grilles that are built into certain cabinetries.

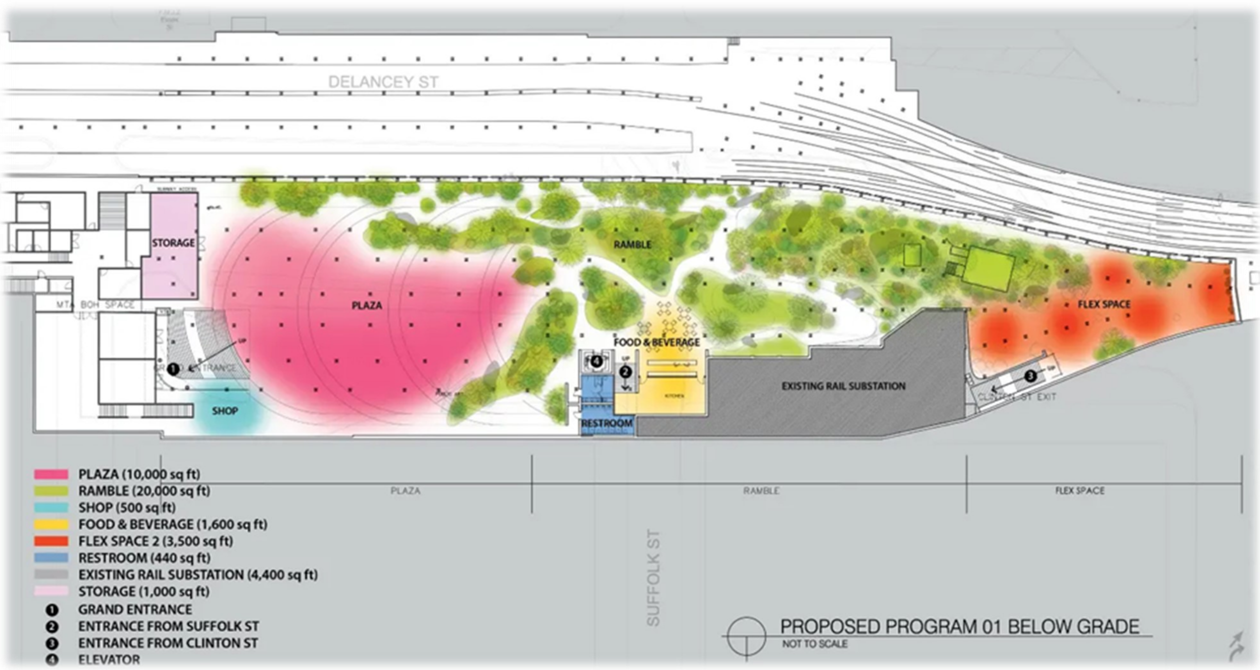


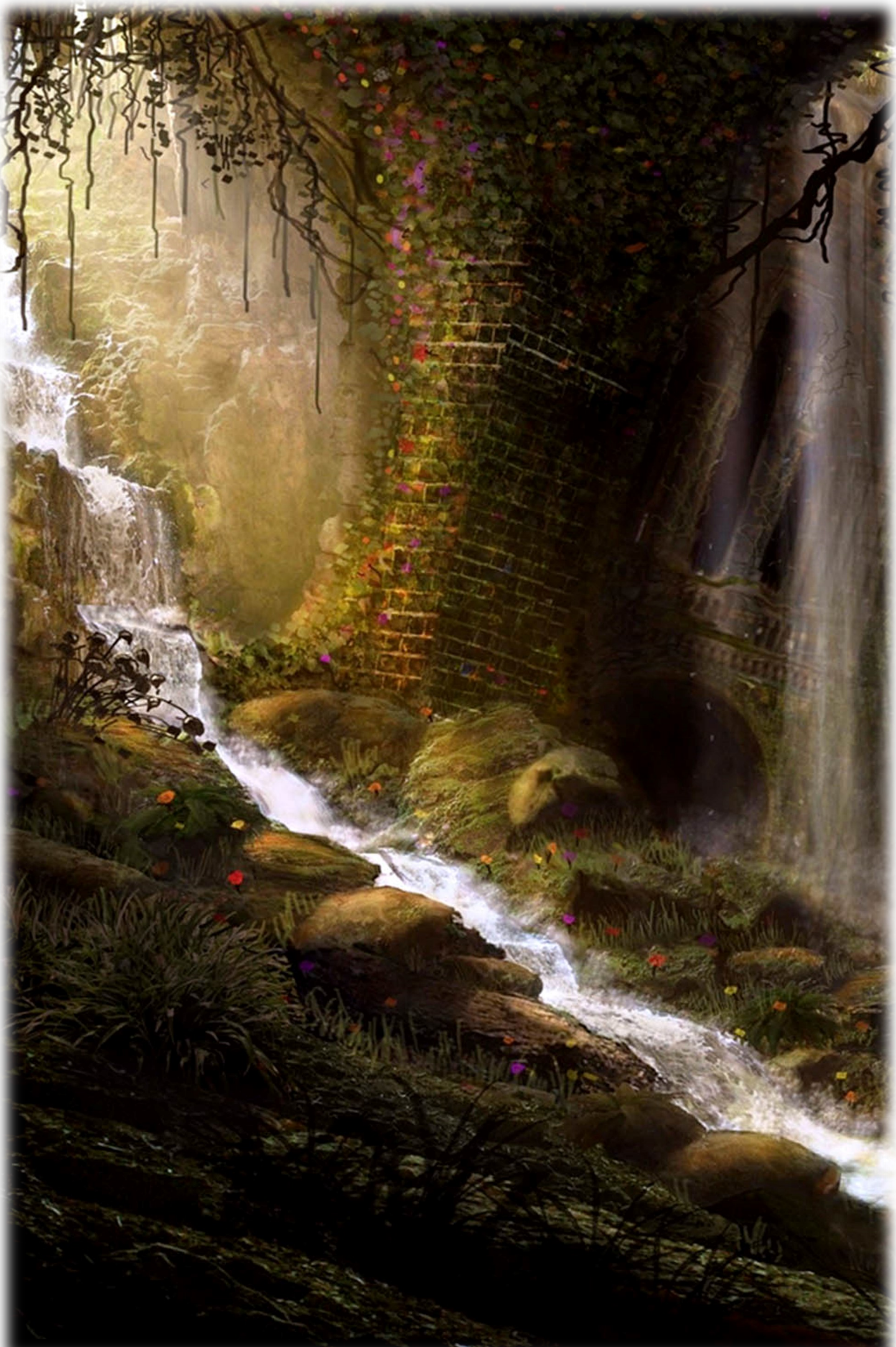
Stadel Museum in Frankfurt, Germany

The Stadel Museum in Frankfurt, Germany was expanded in 2007. The expansion went underground to save the museum's garden from being replaced. This subterranean structure goes down about 8 meters into the earth. From the outside, hundreds of roof lights allow for natural lighting to enter and light the museum's garden up at night. These lights were specially designed so they can be walked on. These lights even offer integrated shading elements to mitigate excess sunlight. The structure is below the water table, so it is anchored by deep piles to prevent the structure from potentially floating on the water table. Another key feature of this design is that it has geothermal piles, which go deep into the earth allowing the space to be heated from the temperature of the earth in the summer and cool in the winter. This expansion is sustainable in all respects, especially with it being underground.

Lowline Park in New York City

New York City greenlit a project called Lowline. This project is set to create the first underground park. It will fix up an abandoned space, which used to be the Williamsburg Bridge trolley terminal. This space is about the size of a football stadium in square feet. The plan is the design a space that contrasts the concrete jungle from above. It will use remote skylight technology, which uses fiber-optic helio tubes to filter sunlight into the subterranean space. This hopes to give the densely populated neighborhoods with more green space. The park is said to have a garden that will be utilized year-round and have a ventilation system designed to keep the space with fresh air. This project is estimated to cost around $80 million to build and complete. The project was incepted by the combining efforts of new, innovative technology that allows this space to potentially exist and subterranean architecture. These abandoned spaces are now being considered by the city as potential new spaces for the citizens. The reality of cities being underground is already being established and only has just begun.





Project Justification

The personal reason why this project was initiated was because it has been fascinating to see architectural buildings that are integrated into the site itself. For about four years the interest only grew as more was learned on how a building can be implemented within the underground and take advantage of the ground's properties. The more that was learned, the more the realization that these types of buildings should be more popular with the sustainable movement than is currently. The importance of me leading this project with my academic development stems from the fact that I knew I needed to develop a thesis and knew early on that it was to be revolved around subterranean architecture.

With the increase need of sustainable features in buildings more so than ever, a focus on these types of buildings was put on the sustainable advantages of these spaces over other spaces. It could lead to a healthier relationship of man-made structures and the environment. The need of this project being done at this stage in my professional development could inspire others and myself to create designs and firms that incorporate subterranean principles into their designs to spread its use and the sustainable advantages. This could give me confidence into forming a firm dedicated to creating these structures that can help both the client with reduced long-term operating costs both from economical and sustainable sorts.

This project will add knowledge on the pros and cons of subterranean spaces and to what extend it is worth it. It has provided insight into how vital certain features are when these specific spaces lack certain features. Even with the cons of these spaces, there are a vast number of ways to counter these cons and further amplify the pros. The project will inspire me to follow a path towards specializing in underground spaces that can create sustainable opportunities. The skills learned would be more so the knowledge gained on how subterranean spaces work. Designer skills would be added with this knowledge, when it comes to the varying factors on how best to design spaces that provide limited ability of light and ventilation.

The profession has designed buildings that today lead in the energy consumption of non-renewable fuels that are poisoning the air and making it harder on the environment. It is vital that this project, at least, reminds the profession to design for the future of this earth. This project is supposed to remind and inform the profession that we need to take more outside-the-box methods, even with high up-front costs, to incorporate to regrow our bond with nature.

The project is an important academic exercise to learn how best to achieve true sustainable designs. Even the typical sustainable design long term will need to be redone as they weren't designed to last as long. The importance of this exercise shows the need to design buildings to last much longer than we are currently designing them for, allowing these designs to not only recoup their initial profits, but then can be reused repeatedly for years to come.

It is very clear, even without exact numbers, that this project has extremely large up-front costs. However, it can be justified because it is an investment for the future of our society and culture to manage a sustainable relationship with the environment around us by not just taking but giving as well. The project idea isn't economically justified if the plan is for the space to be utilized for short-term projects. However, the large up-front cost can be recouped and them some with the lower operating cost of the spaces compared to typical spaces. Many case studies have proven that this model is economically justified if handled properly throughout the subterranean space's lifetime, which could be two to three times longer than a typical building.

The project is a large investment of time, resources, and money. The funds that would go into the project would be converted into lower operating costs that can in the long term be a positive net profit. The large sum of money needed to fund this project would be paid back over a longer time but will produce immediate benefits in operating costs and environment saving costs.

The funds would come from grants and government subsidies initially as many of these practices aren't typical and have large up-front costs that many aren't willing to invest in, but it will have greater long-term benefits than other buildings. For example, solar panels were tremendously expensive until the government provided solar power subsidies and tax incentives to increase individual benefits, which in the long-term benefits society more so than that individual. Today, solar power has become much more affordable and efficient because the initial government assistance spurred innovation to create more jobs and more competition in these fields of manufacturing, thus lowering the cost of availability and affordability. This is happening to geothermal heat pumps as well, so it could at some point be done with subterranean designs at least to a certain degree of support.

The post-occupancy of the project will impact the project to establish a way of life underground can be no different than living above ground, while maintaining the environmental benefits. This impact justifies the project as at some point we will need to inevitably use every space possible as population increases and reduce energy consumption. The digging up the dirt and soil to construct a building underground will have a short-term negative consequence that temporarily removes most of the nature from the site. However, this is the case for most buildings, even above ground buildings, and the main difference is that the underground buildings will return the soil and nature to it's rightful place all while still having that space to be occupied by humans. This way humans and nature can live together in harmony, healing their relationship.

The technology will be focused on conserving as much energy as possible while producing its own energy in a renewable way. Heating and cooling are the buildings biggest use of energy and these spaces will greatly reduce that usage of energy. In a social context, the project will provide the social trends of reducing carbon emissions and the pathway to a healthier planet for both humans and the environment as a way to accomplish their goals. It could increase the need for the profession to continue to be a leader in preserving this planet. A cultural shift of living underground could allow for more nature around us benefitting all people within urban areas, which need it more than other areas.

The site that was chosen to pursue the location of this project stems from various reasons. The site has been visited prior to choosing the site for the project, which helps bring a more realistic viewpoint on the surrounding context of the site and the site itself. The site is large enough to be a blank canvas that will be used to design without size restrictions, especially since the project could require large amounts of space while undergoing the construction. The city it is in is justifiable as the city has a growing urban revitalization and growing economy that will need enough spaces to live in the city in a short distance. There are other similar parcels that are just waiting to be used, making this location perfect to start the roots of this project in hopes that the growing economy can produce more projects like it to inspire diversification of typologies, while maintaining low energy consumption.

The profession has already created a foundation into the sustainability trend of creating and updating buildings to produce more energy, while using less energy. This project and principles have already begun to be used in projects, but at a limited capacity. The project could advance the profession by being a tool for redesigning existing and new buildings to come. There is a limited amount of time this project's role will be optional. There are many ways architects are managing to preserve and sustain the environment through proper designs of buildings but will that be enough even when other industries are doing the exact opposite of what architects are trying to achieve?

Down the road, it could be estimated that the project could end up being imperative for our society as other industries and people within our own industries don't try to limit the use of non-renewable energies. The project can very well be solved by others in the profession, and in some ways they already have. The problem is the lack of awareness that subterranean spaces are a more viable option than one thinks of. The reasoning of the lack of awareness is that it hides behind the high up-front cost of implementing. I think this project and thesis can not necessarily solve it but can raise awareness that these principles are already in use and showing great benefit, that we should be doing more of it than ever before, because of the time we live in.

Cultural Context

A small movement that has been growing is earth-sheltered homes as there are more benefits to living underground in relation to the current developments within our society. Many architects have been designing projects that do just that, one of which is Malcom Wells, the father of modern earth-sheltered architecture. He and many other have expressed the advantage of earth-sheltered buildings provided the needs of the client as well as the needs of the environment. A carbon footprint has been coined for a culturally trend of trying to limit and increase efficiency of energy consumption of buildings as heating and cooling a building is one of the highest trends of carbon footprint being emitting from.

Our society has made many performance criteria to continue the cultural developments for the world. One example is LEED, where using geothermal heat pumps over a typical and cheap alternative if preferred create intangible benefits for the greater good of our society and thus modifying our way of life. A goal for this thesis project is to provide a space for people that have all their essential needs within a small vicinity while the building itself provides the needs of shelter and amenities to create comfort without requiring a majority of non-renewable energies.


Upp
Ej upp

Social Context

The effect of living around and within the environment itself can be characterized as a growth of our bond between man-made structures and nature. The physical context of this project is best explained by the relationship buildings and nature have currently to what the project is trying to achieve. The building and nature relationship on average are considered parasitism, which means that an organism (a building) is harming their symbiotic partner (the environment) while reaping all the benefits. Parasites live if their symbiotic partner does but it is not a sustainable relationship when the partner has its own limits.

The project wants to create and express is a endosymbiosis relationship. This form of relationship is that one of the species (buildings) lives inside the tissue (ground) of the other, while both benefits from each other. The benefit the earth has is more so that is doesn't suffer from the interaction versus placing on top of the surface could entail less space the ground could be using to counter runoff or limit the capacity to provide green space. The benefit the building receives is the social context of society being able to live and thrive within the space using the traits from the earth to its own benefits.

Historical Context

Subterranean spaces have been around longer than any other space in existence. These spaces housed the first of our kind as well as many other species. We then evolved as we grew in strength to become surface dwellers. Underground spaces have been interpreted by our ancestral as various spaces. Spaces that are sacred where people would go to be enlightened. People would go to survive. People would go to die. There were and still are many uses for these spaces. Whole cities were built underground or carved out of stone on the land where we deem to be the start of human civilization that we know of today.

The historical context extends from the day before yesterday to the beginning of this earth. However, to define a smaller scope, it would begin when human civilization began. The underground cities were one of the first of this type of project to be used. It was said the people at the time lived down there and would even have merchants who would trade within the ground. It was not typical when we became civilized to live underground and in caves as it seemed to be a form of barbarianism. It was shunned in order to acknowledge progress that we wouldn't need to go back to living under soil. However, with wars and pillaging the last line of defense for many would be to hide underground, such as the Cold War. Switzerland had one of the most amounts of underground bunkers scattered across the country in fear of nuclear warfare. Now these bunkers were converted into livable spaces for a quick get away from the bustling lives we now possess compared to our ancestors.

As we have progressed as a species, we have gotten to the point that the only predator to humans is ourselves. Human's own downfall will be themselves. We extracted millions of years-old animals and managed to convert it into energy that we now heavily rely on to live. These advancements didn't account for the side effects to occur. When they started being noticed we began to preserve our own human history as the underground's history is tied to ours.

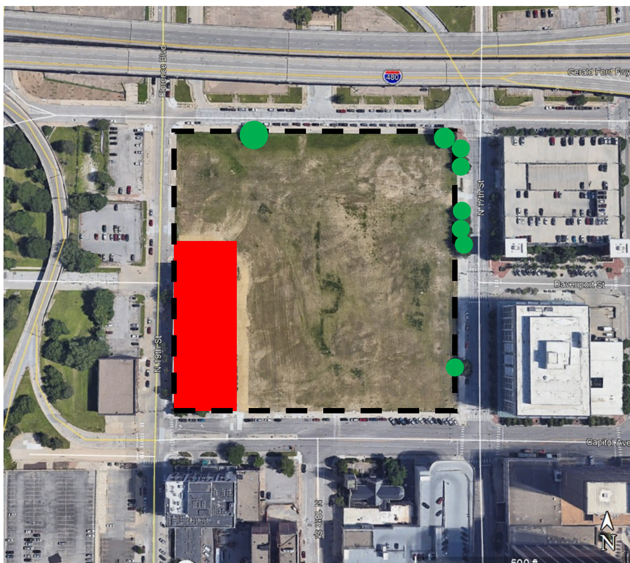
The history of these hidden underground spaces is directly tied into human history, where without underground properties, such as the collection of oil, our current problems would never have occurred, but it seems to also be a solution to that problem. Designs are becoming more common in implementing buildings into the landscape and not just on top of the landscape.

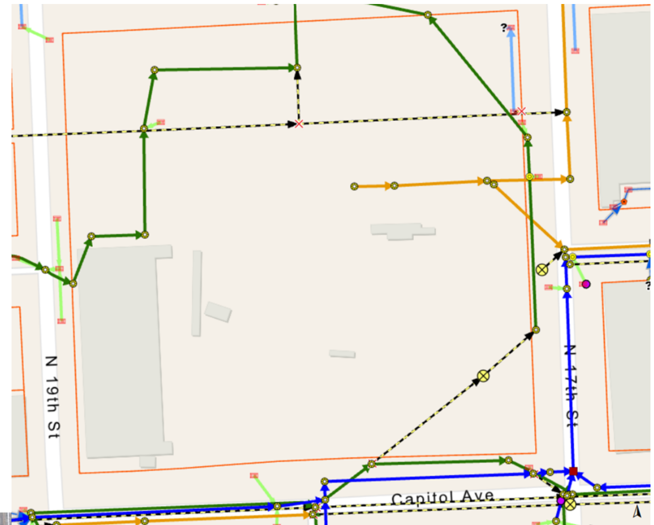
Site Analysis

Views/Maps:

Base map:

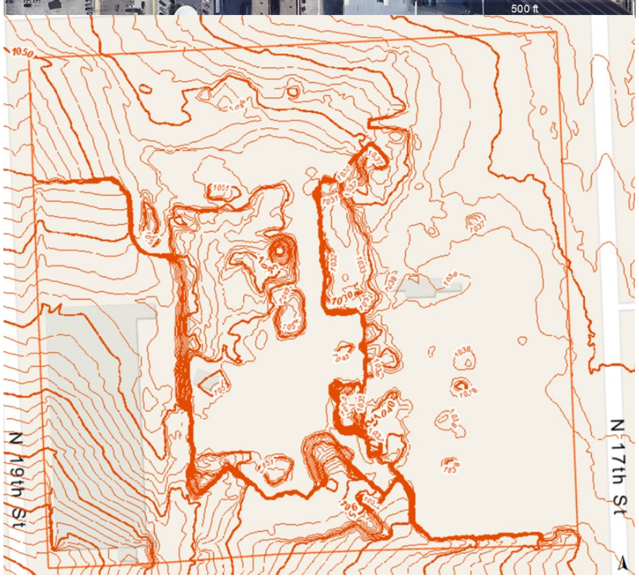
The site itself is very barren. The only presence of large trees or vegetation cover is located where the green circles are on the base map. The location of the existing boundaries are represented by a dashed line. The location of the existing buildings/parking on site is located in red.





Utilities:

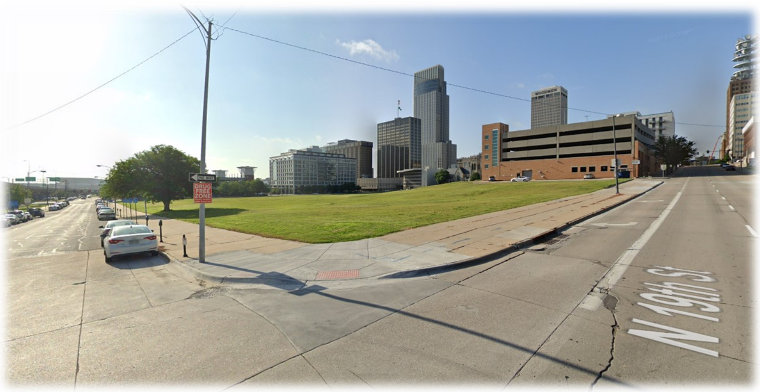
The green arrows are sewer lines that are a combined sewer line. The yellow nodes are combined manholes. The dashed lines are abandoned combined sanitary sewer lines. Light blue is storm combined sewer lines. The squared pink are storm combined inlet/catch basin. The red Xs are storm combined dead end or stub out structure types. Light Green is the Storm Combined Inlet Lead. The blue lines are storm sewers. The orange lines are combined sanitary collectors. The red boxes are storm junction boxes.



Topographic Map:

Each line represents a 1-ft slope difference. The slope on the site is minimal, giving a flat appearance when on the site itself. The given topographic survey shows the influence of the previous building's footprint prior to demolition. For most of the site the slope seems to be between 1% and 4% of a slope allowing for the site to use many activities. For those areas that have a low slope, the design will need to incorporate an increase in slope to help with site draining.

Site Vistas/Reconnaissance



Northwest Corner

Northeast Corner

Southeast Corner

Southwest corner

Built Features:

The site recently has been modified, so the ex-government facility is no longer on site. There is currently only one structure on the site, which is a parking ramp. There are a few trees on the north-east corner. The features around the city are governmental buildings, office spaces, parking spaces, and a highway system north of the site.

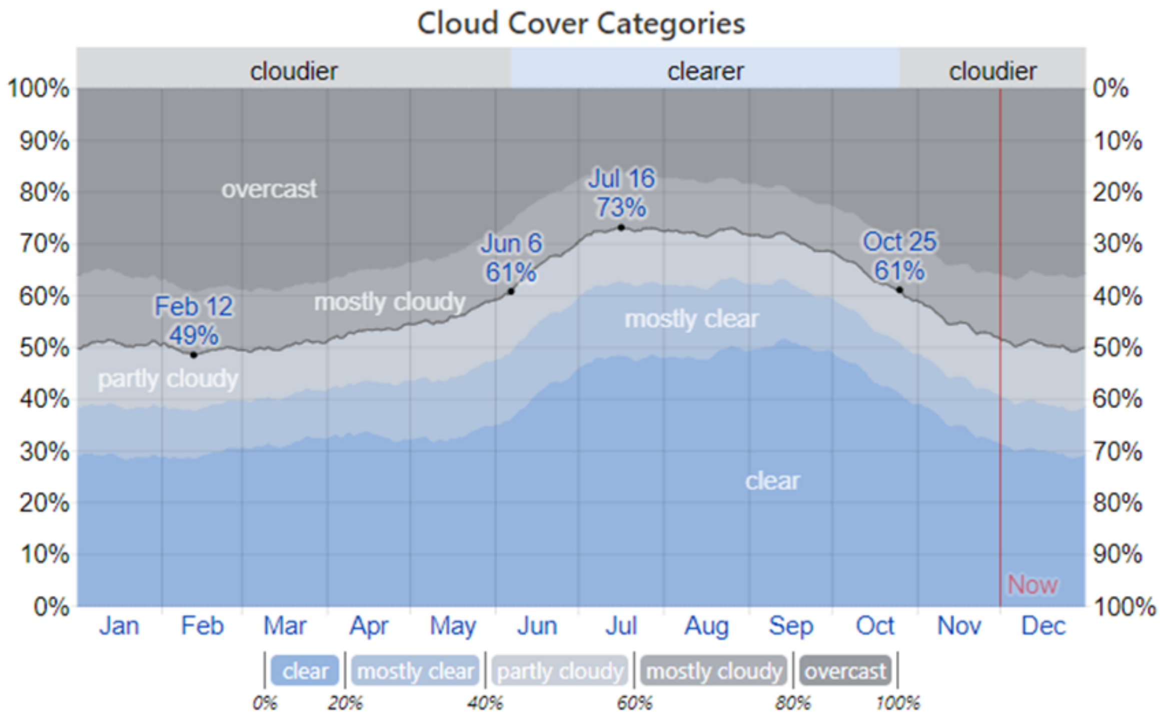
Human Characteristics:

Having been to the site, I noticed a few people crossing the site to get from point A to point B, cutting through as a shortcut. The human characteristics of the site seem to be welcoming and hope to convey that in the design.

Distress:

The distress of the site primarily is the amount of parking surrounding the site. Even then parking seems to be limited under normal work-day conditions. Apart from that, there is little distress on site.

Light Quality



The percentage of time spent in each cloud cover band, categorized by the percentage of the sky covered by clouds.

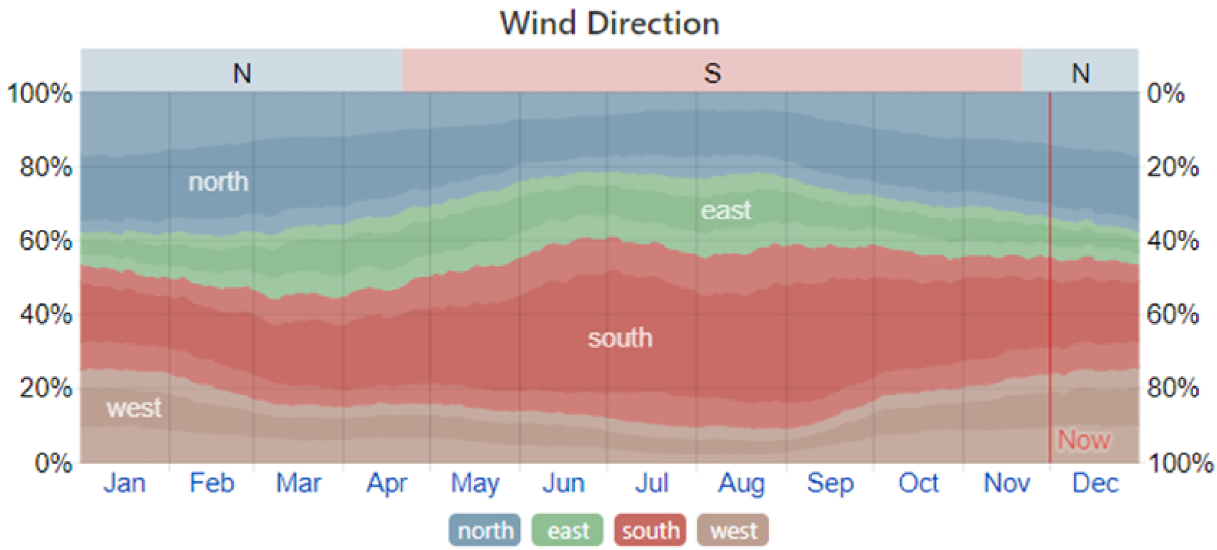
Light Quality:

Based on the amount of clouds throughout the year, the light quality seems to be more intense during the summer than the winter time. The temperature of the area impacts the light quality when there is a combination of overcast and clear skies throughout the day. When I was there, almost every day was either fully sunny or fully cloudy. Therefore, both the color and temperature of the light are consistent depending on the day.

Site Character:

There are more than one bus stops within the area that could be used as an alternative to transportation. The site holds the character of the capitol district, of which it is in. It has apartments close by, a high school, a university, a college football stadium, soccer stadium, museums, restaurants, corporate offices, banks, a church, hotels, and many other buildings. Based on the residential market at the time I lived here, the apartments only had a few spots open and was at 97% capacity for each one within the area. Therefore, this reinforces the multi-family housing typology to be used for this site.

Wind



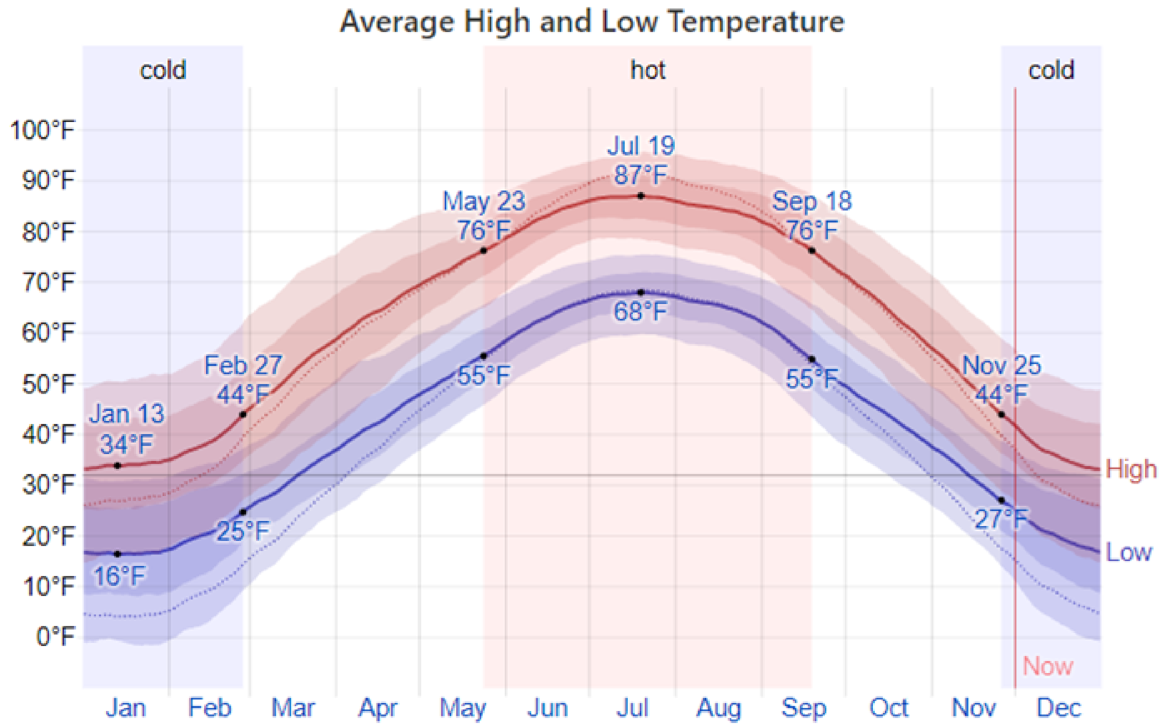
The percentage of hours in which the mean wind direction is from each of the four cardinal wind directions, excluding hours in which the mean wind speed is less than 1.0 mph. The lightly tinted areas at the boundaries are the percentage of hours spent in the implied intermediate directions (northeast, southeast, southwest, and northwest).

Soil/Water Table

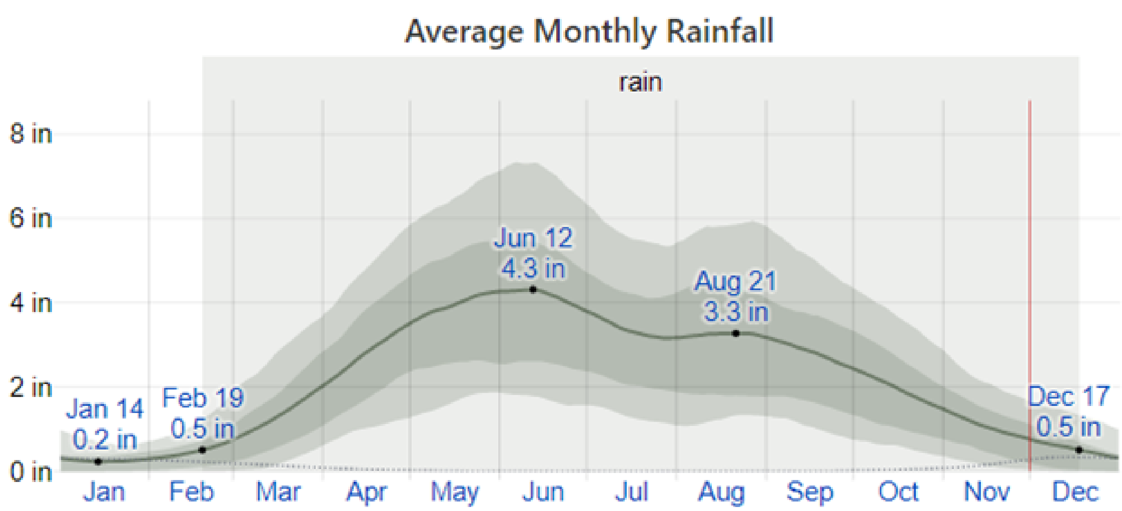
The soil in the area will define the impact the soil will have to retain water and using it during construction. The parent material of the soil is disturbed fine-salty loess. Till and loess is the most common in the area. The bedrock of the site is made up by limestone, shale, shaly siltstone, and shaly claystone. The bedrock is generally 100 ft below the flood plain. The make up, by the layers of the site, is from 0-12 inches being silty clay loam. From 12 inches to 80 inches is primarily silt loam.

The water table of the site is said to be at least 10 feet deep or more. The frequency of current flooding and ponding occurring on the site is currently at zero. That doesn't mean it won't happen, so it should still be accounted for in the design.

Climate Data



The daily average high (red line) and low (blue line) temperature, with 25th to 75th and 10th to 90th percentile bands. The thin dotted lines are the corresponding average perceived temperatures.

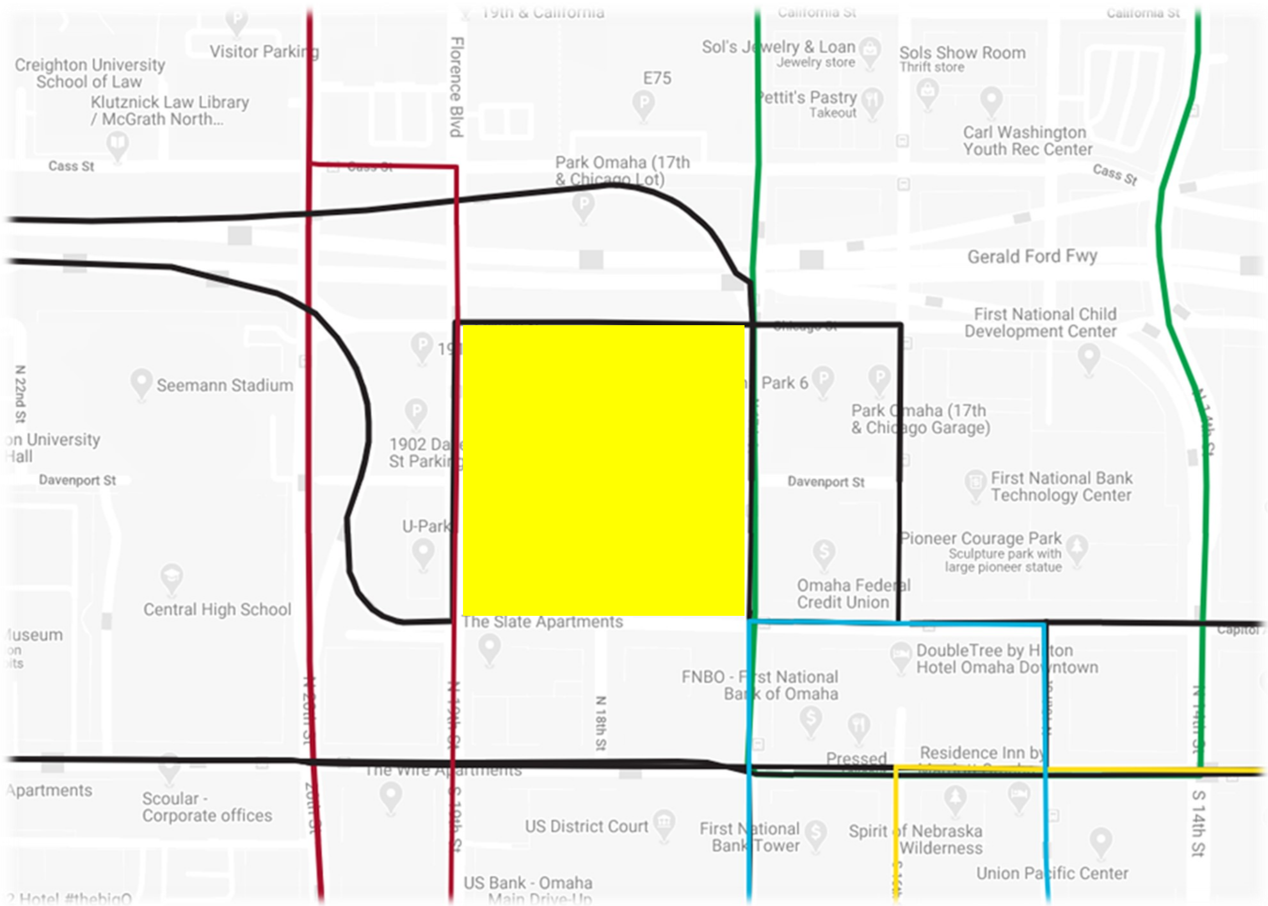


The average rainfall (solid line) accumulated over the course of a sliding 31-day period centered on the day in question, with 25th to 75th and 10th to 90th percentile bands. The thin dotted line is the corresponding average liquid-equivalent snowfall.

The mean annual temps are 39°F to 61° F, while the mean annual precipitation is 24°F to 36°F. The sun path goes from east to west and the angle of the path depending upon the time of the year. The noise of the area can be quite loud, as an active highway is directly north of the site. There are a few locals who rev up their engines at night, which creates noise.

Vehicular Traffic

The traffic in the area in as busy as a typical metro area, people going to and from work at the same time. People would drive to work as they lived further away. The traffic wasn't terrible although the parking did have some issues, but that goes with every city. The map below shows the current bus routes near the site.



Pedestrian Traffic

I personally walked to work, and the pedestrian traffic was fairly easy, even with all the construction going on at the time within the city. Many other people, I observed, always walked to work or took the bus every day. The area is pedestrian friendly with small parks throughout the city. The city is very beautiful and is developing rapidly, as it is revitalizing many streets in the area.


WOODMEN
FirstComp

Performance Criteria

The spaces and layout of the design will be measured on how spaces interact with the users and other spaces. The square footage of each space will require a certain amount depending upon the space that is designed. Floor plans will be essential in determining the flow of the spaces and where they should be. The spatial design will be complete upon a clear and concise setup that allows the users easy use within each space.

The main aspect of the performance of the design will analyze the daylight factor that enters into these spaces. The analysis that is involved in the measuring of the daylight factor will primarily be the Insight add-on feature for Revit. The daylight factor will alter the design where it needs to ensure a realistic expectation for a subterranean design. The analysis will conclude the attempt and performance criteria in terms of natural light entering the building. It will meet criteria when the analysis summary shows the daylight factors being as present as they can be within a subterranean design and maximizes these factors through various analysis.

The building will need to reflect positive environmental performance based on how the landscape is incorporated into the design. A way to measure this will be to ensure vegetation restores balance to the ecosystem by countering the urban context of the site. The amount of environmentally friendly design principles will judge the completion of the criteria by simply counting the amount on a site plan.

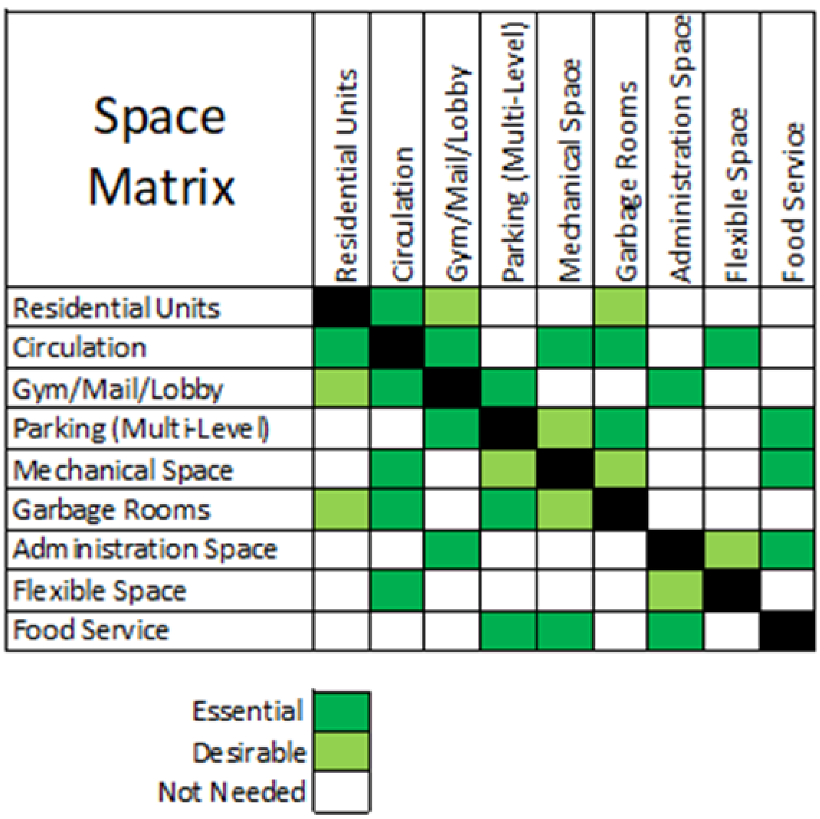
The psychological impact of these spaces will be measured to ensure the users don't feel like they are underground. The source of the performance measure will come from the design's implementation of living requirements to ensure a positive psychological impact on the users. All the senses will be used as tools to implement a design users can be comfortable in. Each space will need natural light, to reduce noise, and other factors that keep at least one sense as a focus.

The environmental impact of these spaces will measure the loss or gain of natural elements within the site. These elements will be determined based on how much each will positively and negatively impact the environment around the site.

Code compliance will be a required to fulfill the criteria. The spaces will need to comply with local fire codes and follow ADA guidelines. The ADA codes, local building codes, and zoning requirements will be used to achieve this criterion. Once the spaces involve the required types of spaces and size of spaces appropriately will complete the criteria.

Space Allocation Table

Space	Square Feet (SF)	Percent (%)
Residential Units	150000	54.5
Circulation	25000	9.1
Gym/Mail/Lobby	5000	1.8
Parking (Multi-Level)	40000	14.5
Mechanical Space	30000	10.9
Garbage Rooms	3000	1.1
Administration Space	2000	0.7
Flexible Space	5000	1.8
Food Service	15000	5.5
Total	275000	100



Thesis Design

Introduction:

The design work is the follow up to the research of the thesis. The design is the solution and applied effort into establishing a conclusion to the thesis proposal. The following pages offer design documentation into how it was designed and how well it performed.

Primary Design Elements:

Design Process

Solution Documentation

Performance Analysis: Site/Context

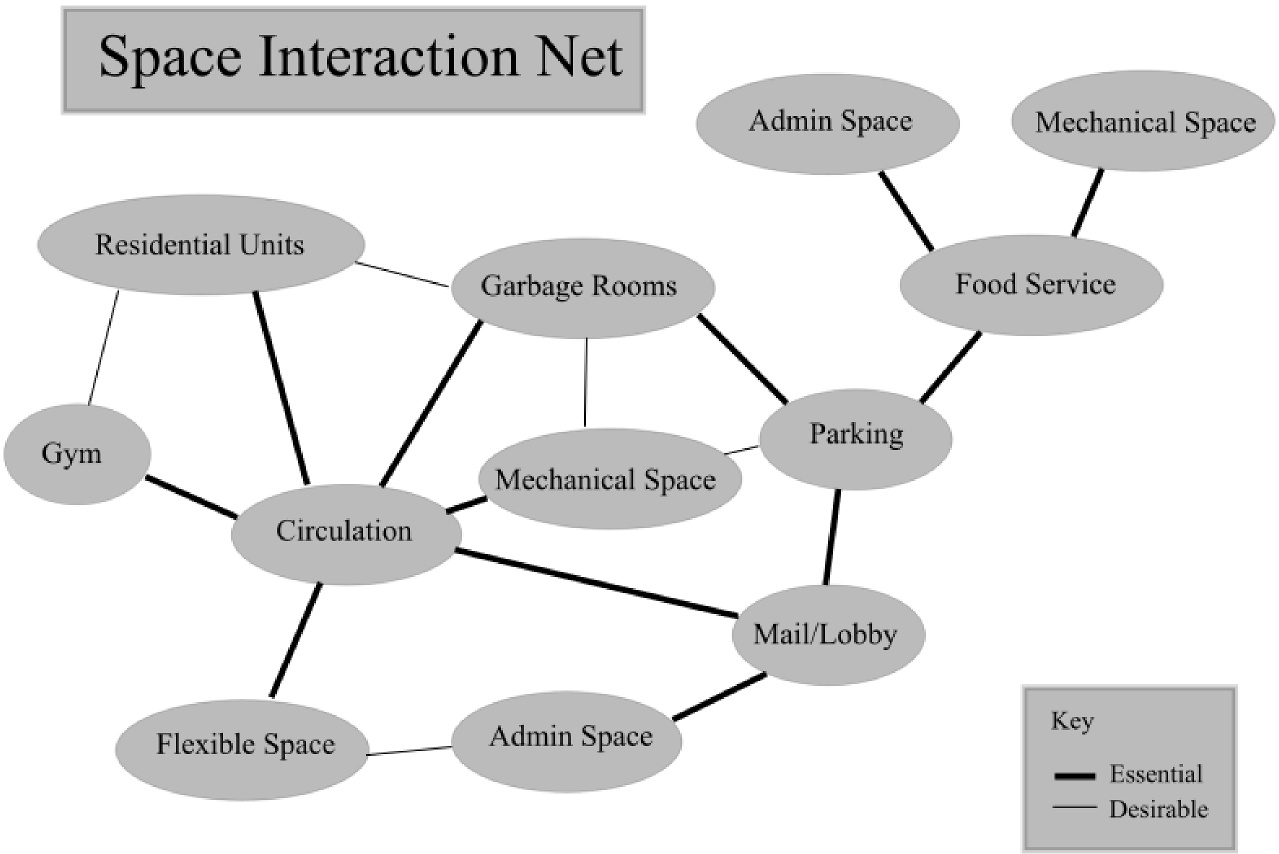
Performance Analysis: Typology/Research

Performance Analysis: Project Goals/Emphasis

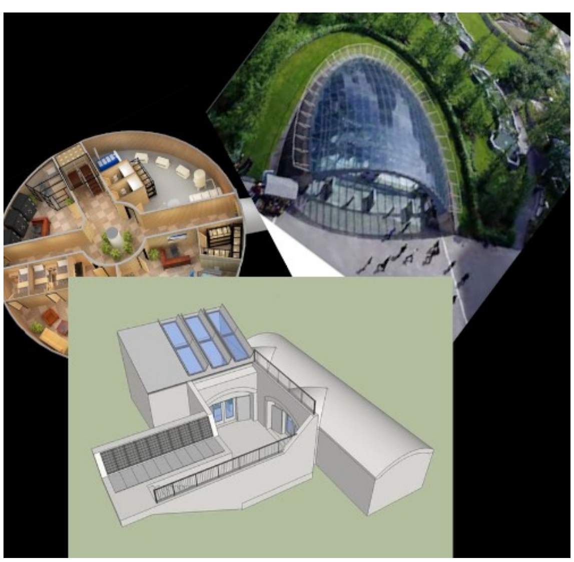
Applied Research Methods

Design Process

The beginning of the design process started with the space interaction net and user circulation. This helped create parameters for the design.



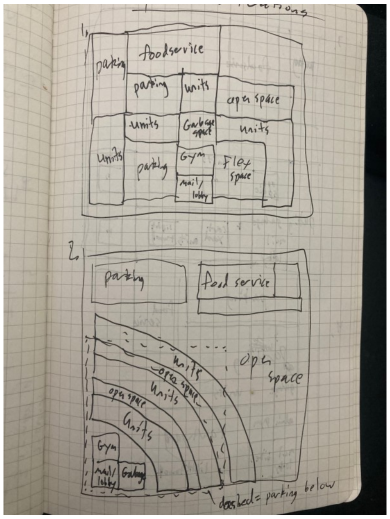
Once the spaces were finalized, I put a focus on imagery of subterranean design elements that would help inspire and influence the design and program.

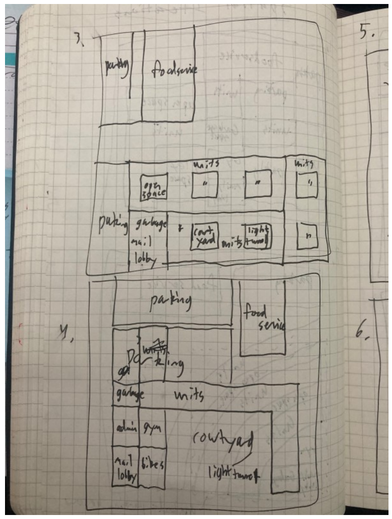


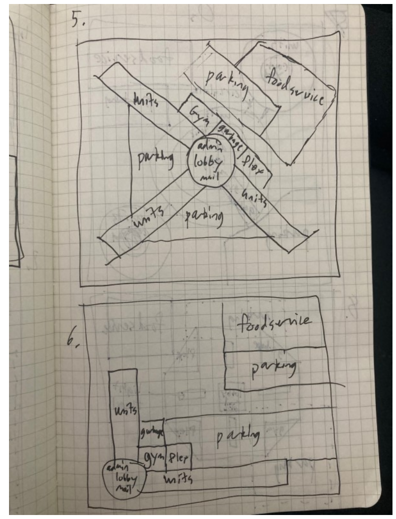

Pool bar
70ft long pool
Jacuzzi
Sauna
Changing rooms
Security
Massage room
Hair salon
Games room
Thermal bore holes
Orangery
WITANHURST HOUSE
Terraced gardens

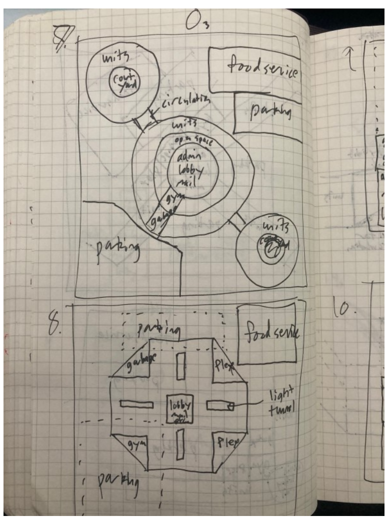

STORYBOX
House location
Kensington Palace
Kensington Gardens
10 Kensington Palace Gardens
Study area
Family bedroom
Gallery
Family bedroom
Master bedroom
Gallery
Principal guest room
Family room
Gallery
Dining room
Wine cellar
Central hall
Wall
Road
Garden Minimum depth of 1 metre
Terrace
Proposed development
Car museum
Viewing gallery
Pool
Viewing gallery
Sports hall

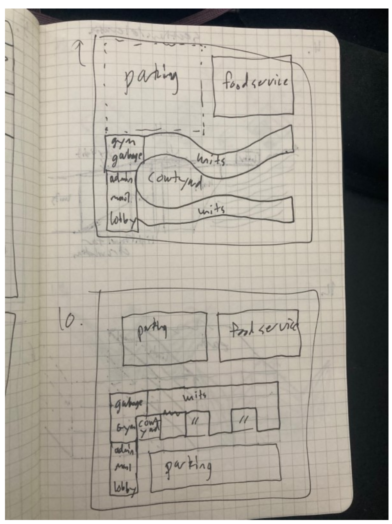
Following the inspiration and imagery, I focused on the site plan and how the flow of the site is established. I started with many sketches on what might work and not work. These sketches were preliminary for the spatial aspect of the site.

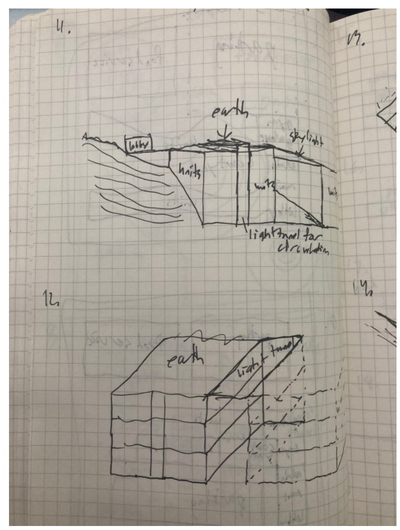


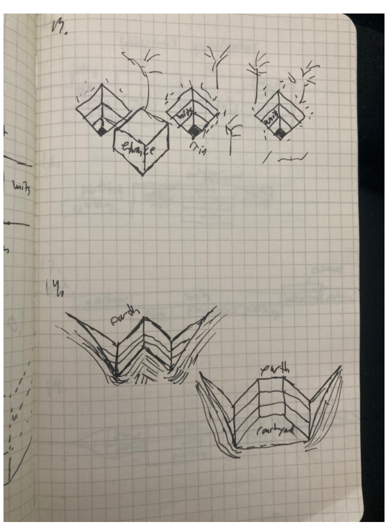


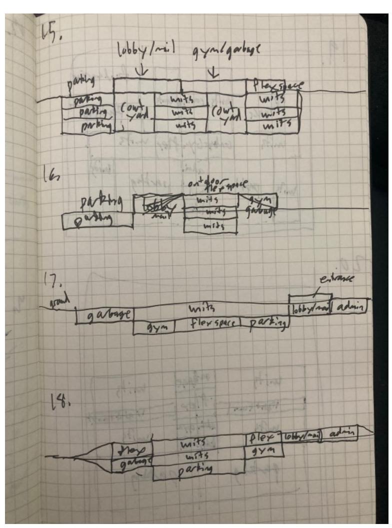


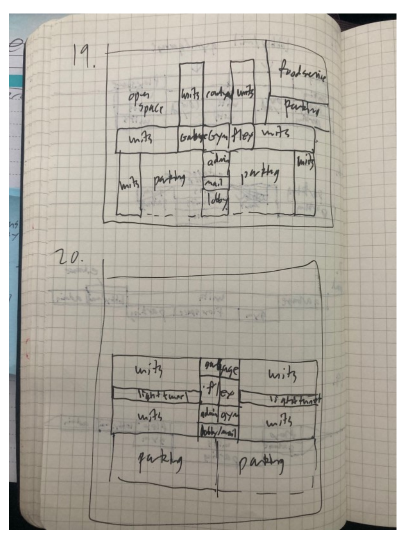




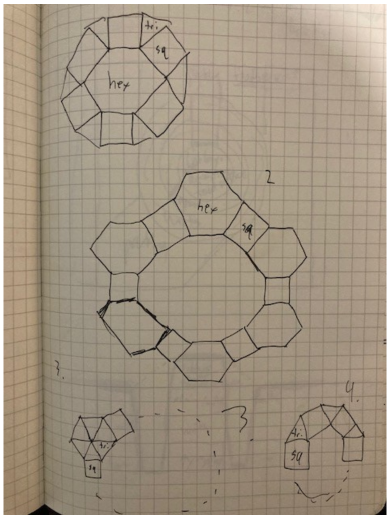


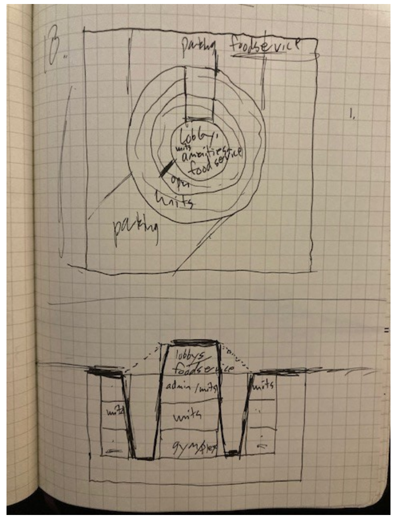


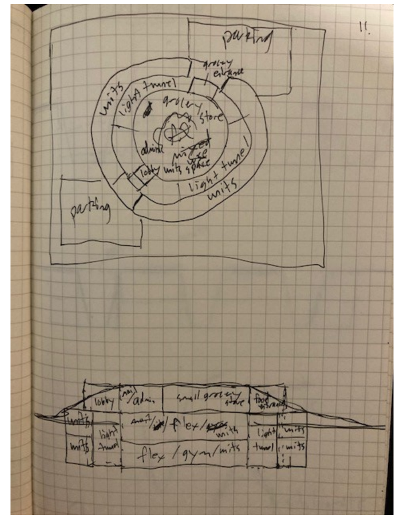


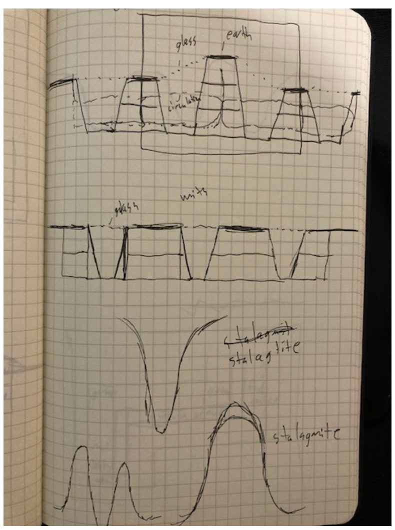


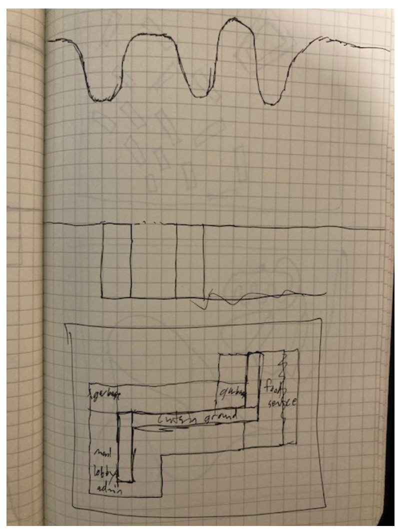
I continued creating different forms and spaces to see how the site played with these designs. The more iterations I tried the more designs I eliminated as it didn't work with the site nor subterranean design.

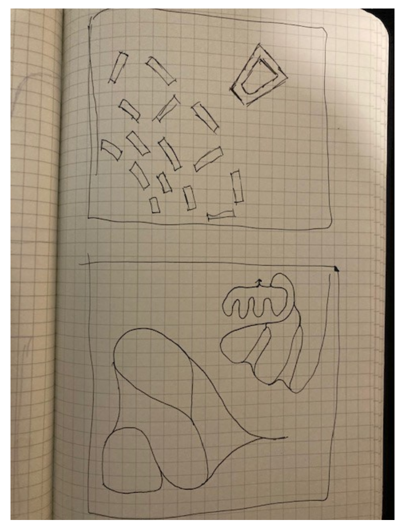






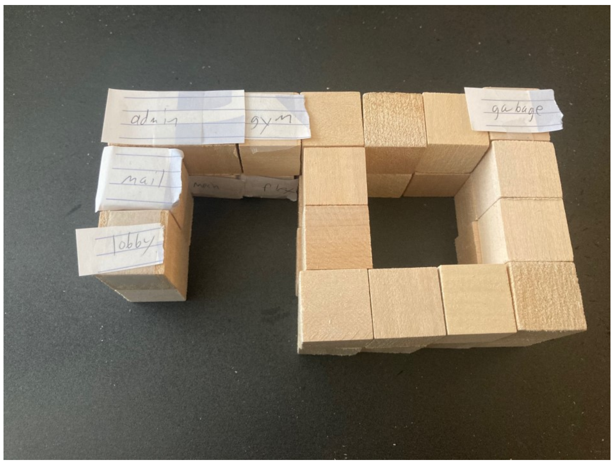


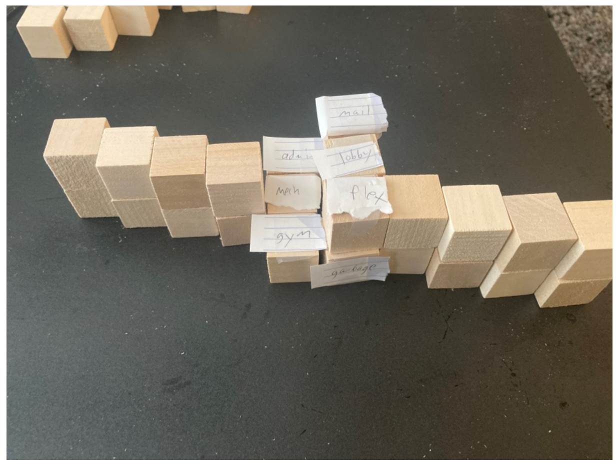


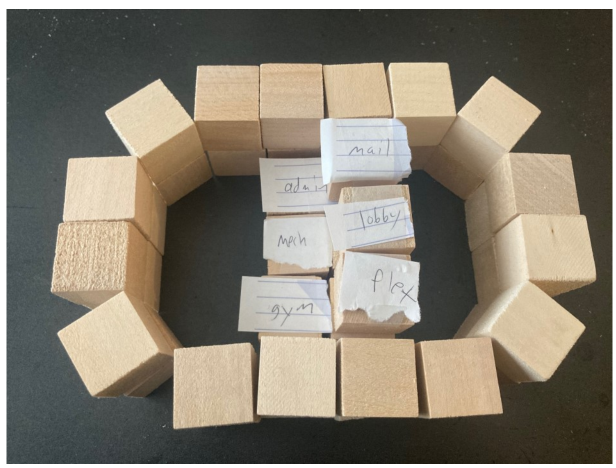


At different views, it was easier to organize the spaces and see how these spaces worked underground and the amount of light that would enter. These iterations helped focus on common trends that worked for subterranean design.

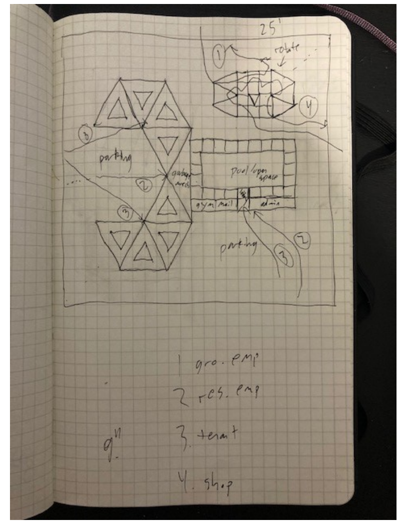
I finished the preliminary spatial iterations and needed to focus on the 3D aspect of the designs to better understand subterranean design as it is very different from above ground design. It was harder to design and visualize these spaces without the 3D version, so I made a few physical iterations using small wooden blocks that added a sense of scale to further the design process.

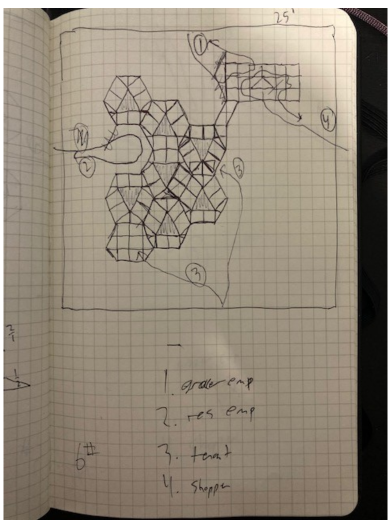


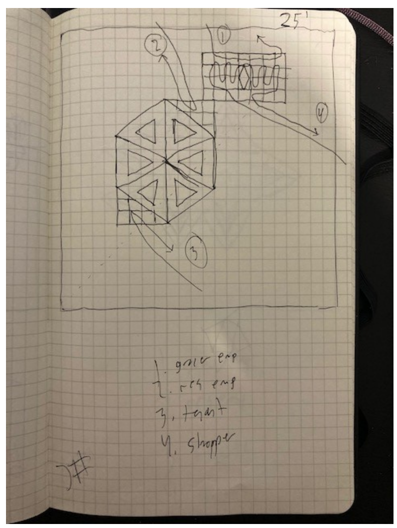


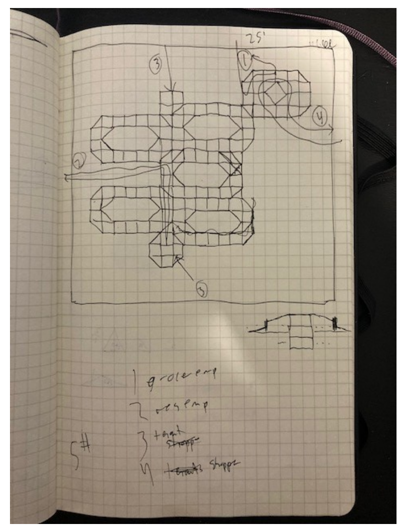


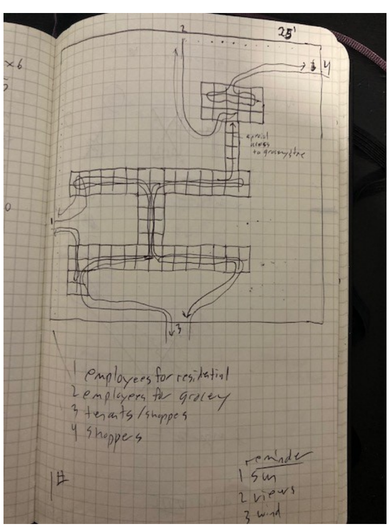
The final spatial iterations took more information into accounted, including the four different types of users. These four different paths were applied to new iterations. These newer iterations focused on the flow and circulation of the spaces. Very quickly in these iterations, a common trend emerged where all of the circulation and spaces began to revolve around the courtyard light tunnel areas to allow light into these spaces. These iterations also were created using various space grid patterns to form a scale and patterns that repeat themselves to create other shapes. Triangular spaces were introduced as a way to form repetition and represent the triple bottom line that correlates with the direction of this thesis. The triple bottom line representing each corner of the triangle: planet, profit, and people. The top right image is the iteration that became the base for the rest of the design. The biggest change from this iteration is the rotation of the grocery store to allow more space for a loading space for food.

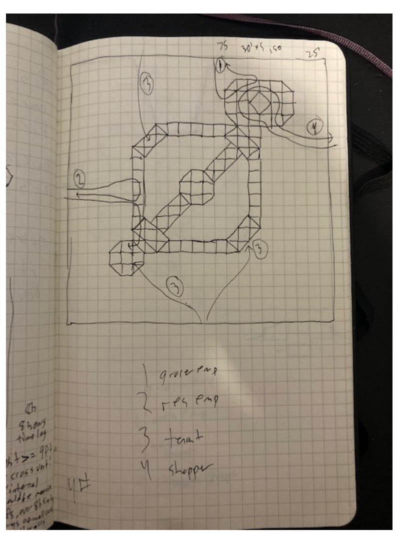


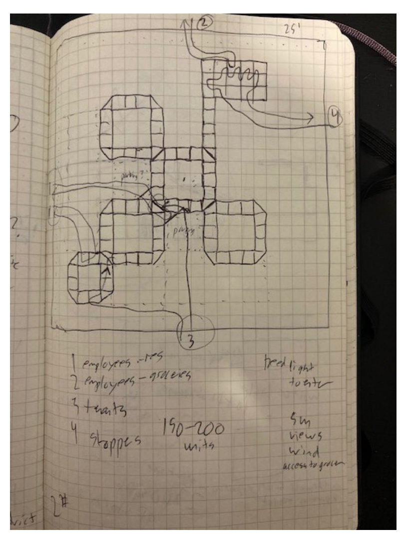




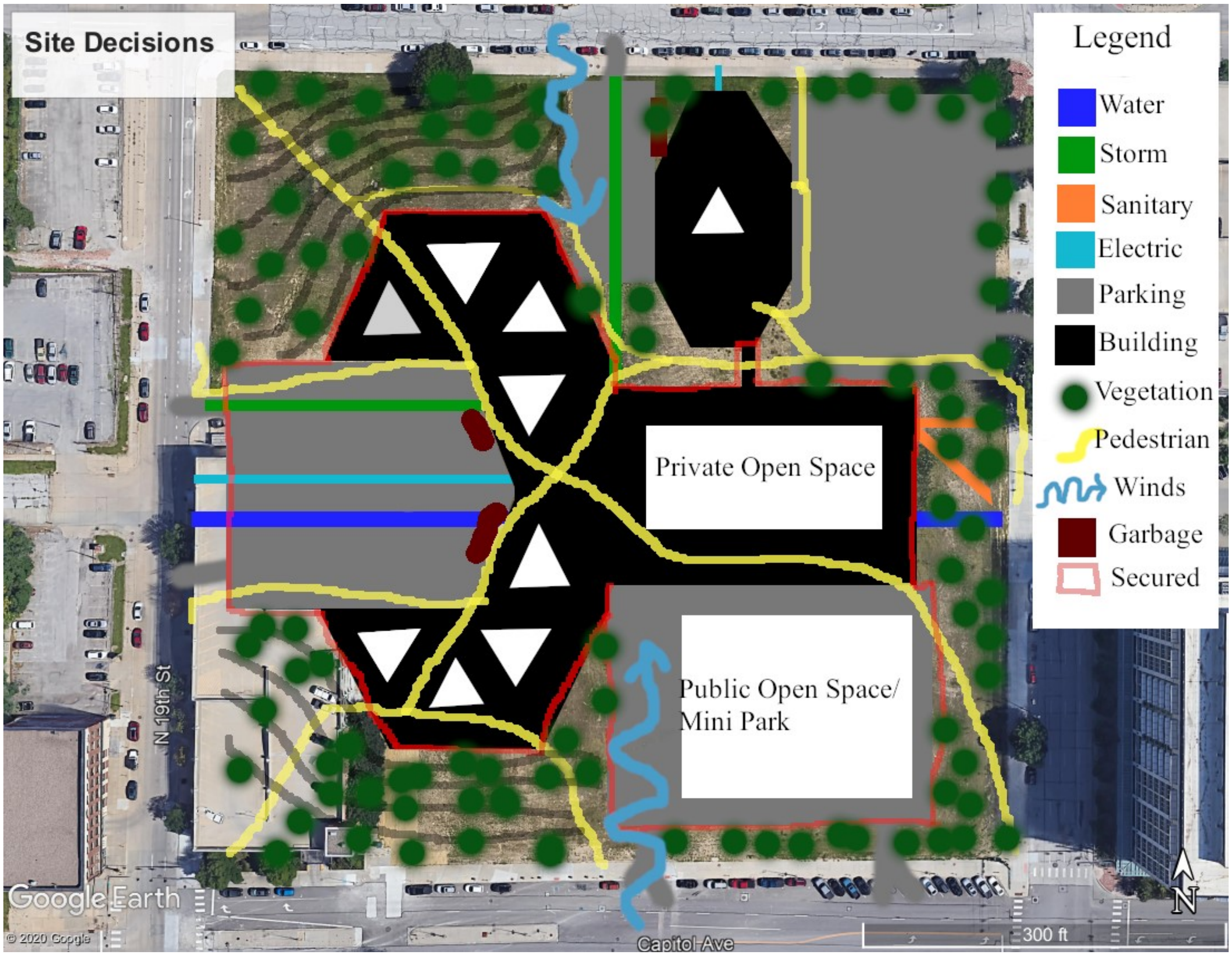








The next part of the design process was to have a template for the site plan and direction. Most site information was collected using GIS and other sites to create these site decisions. The advantage of having space below grade allows pathways and communal spaces to be provided to the public and create more natural space in an urban setting.



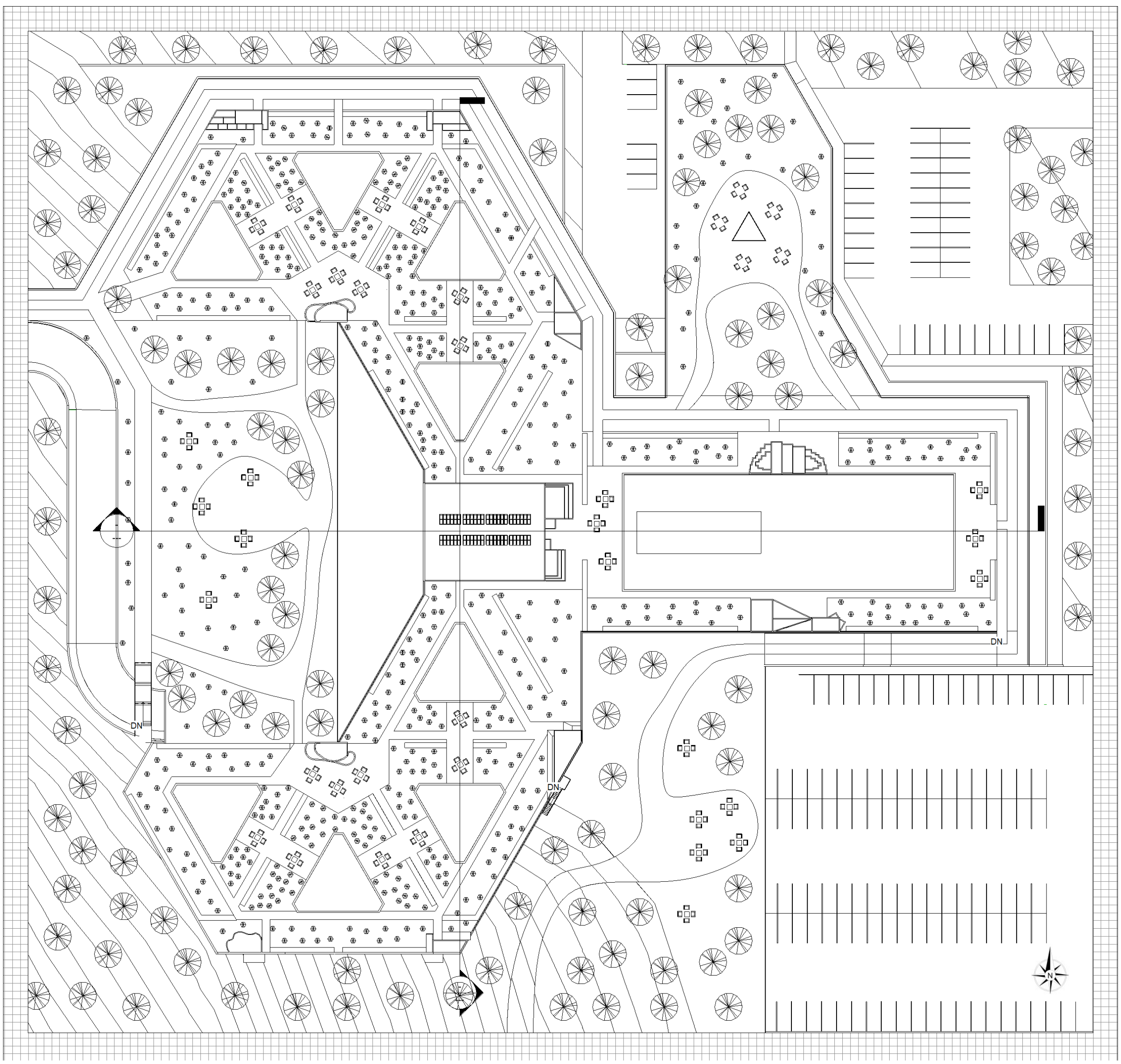
The white spaces are the courtyards of the building, which are the focal points to allow light and natural ventilation to enter the building. Some of these decisions were modified to allow more parking and natural public open spaces, such as the security now being focused on the entry points and not the perimeter of the rooftop access. The rooftop access is now open to the public. A green space was created above the west parking lot to limit unnatural runoff and promote green space on site.

The mid term presentation provided some insight on how far the design has come and what could be improved or changed. The insights were to rethink whether the rooftop should be private or open to the public as it is a large part of the site. This is where I decided to switch the rooftop from private space to public space with the exception of the central area that has solar panels and ventilation units.

A few notes from the mid term was to replace symbolic nature entering these courtyards into a more literal one, using green walls. With that insight, I wanted to also incorporate the four elements into these spaces in some way, fire being the sunlight, air being the sky, earth being local stone for the flooring, and water. The water would be a water fountain in the middle of these spaces to create a more natural ecosystem. This ecosystem would incorporate vegetation along the walls, plants in certain areas of the space, a water fountain for both visual and acoustical elements. The railings were recommended to be replaced with planters with vegetation along it to further allow nature back into the site. Other than a few tweaks, the final design was close to finished.

Design Solution Documentation/Digital Presentation

The final design solution is the result from the thesis proposal, research, and design process. Below is the official final site plan. All requirements and implementations from the research was applied all within the site.



Not to Scale — Site Plan

This design addresses and applies the theoretical premise. It utilizes systems in the design to reduce energy consumption and impact on the environment. It takes the site and forms it to work with the structure using retaining walls and green roofs. This design takes some earth volume from the site, and utilizes the properties of the earth to its advantage, but also gives the earth back, keeping it on the site to grow native plants.

This reduces the need for energy to water plants and lower heating and cooling loads. The building goes three stories deep. The reason it was not deeper was primarily due to the efficacy of light entering the lower areas and water table depths. For the color and material palette, I went with concrete for the exterior of the building because I wanted to contrast the built and natural environment to show off the symbiotic relationship that exists on site.

The inner courtyards emphasize bringing as much nature into the area. I like to think of bringing in the four basic elements of nature, fire is the sun, water is the water feature, rock is the locally sourced stone flooring, and air is the sky itself. The water feature helps bring our senses into focus, creating a therapeutic amount of flowing water to mitigate underground sensory deprivation.

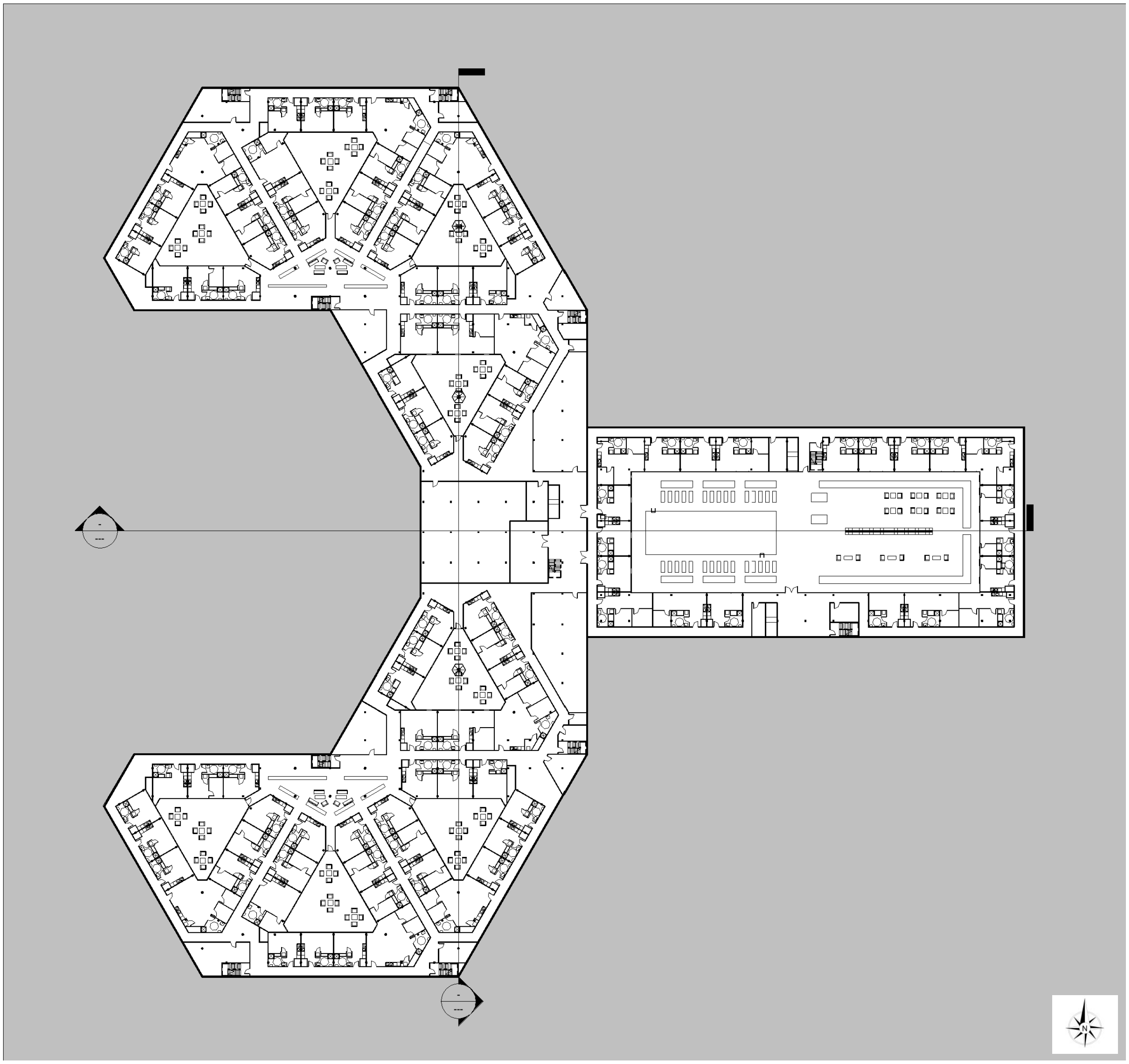
In the residential units, the window is raised up along with the ceiling to maximize the daylight factor impact for these units. This was modified when I was analyzing the daylight factors throughout the building. This was one of the design changes the analysis influenced.

Exterior Courtyard Perspective

Interior Unit Perspective

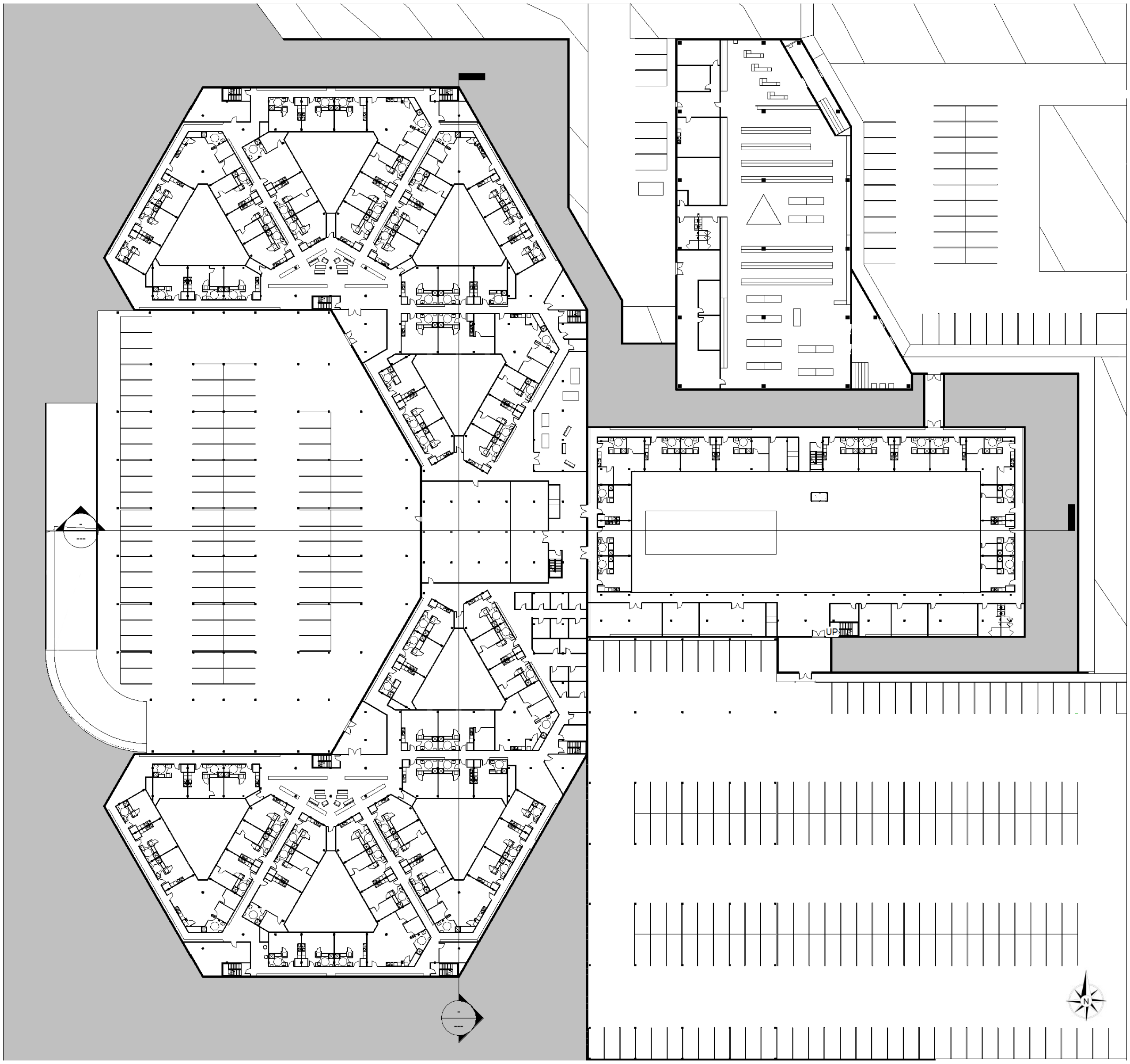
Winter Rooftop Perspective

Exterior Pool Perspective



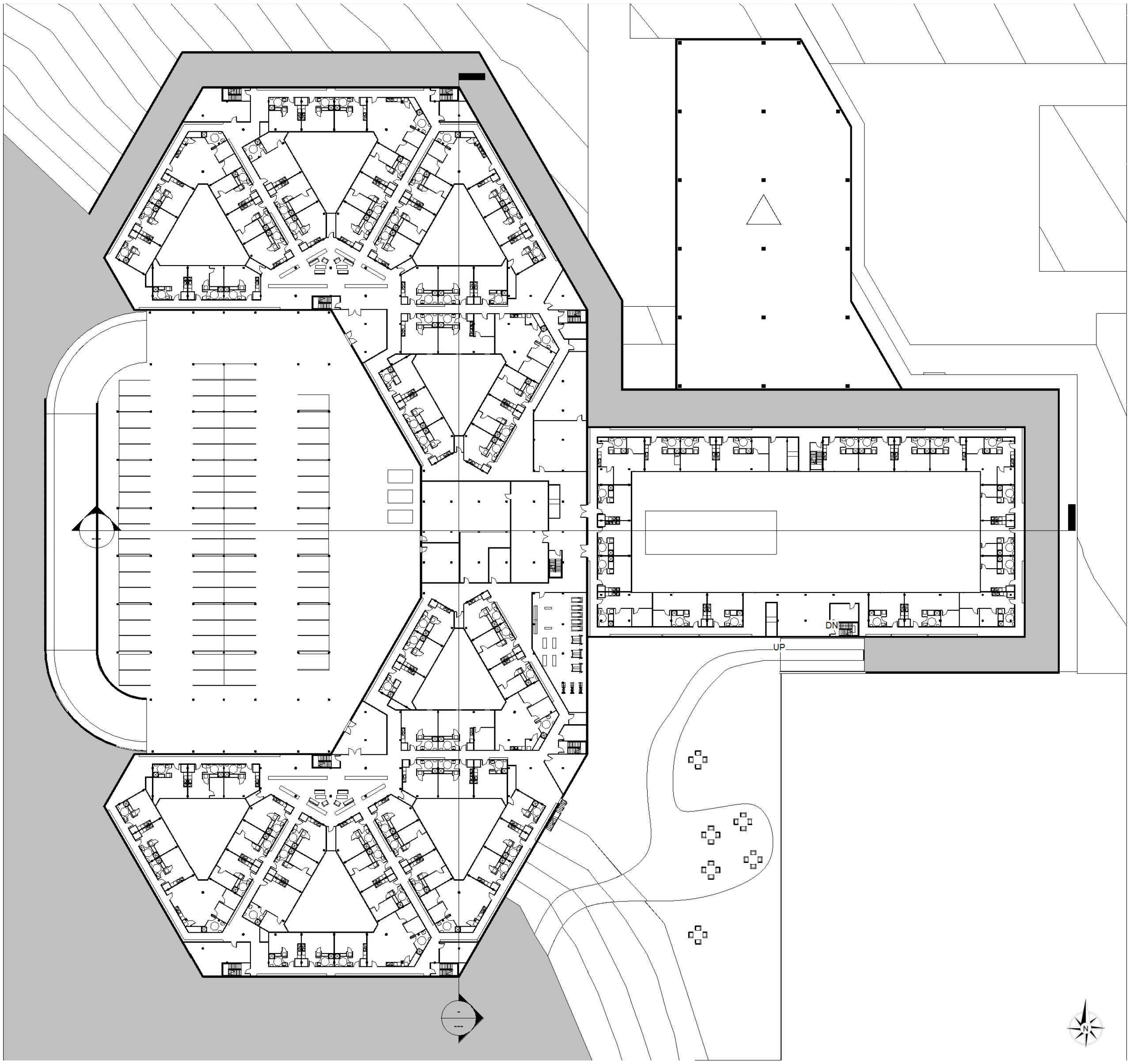
Not To Scale—First Floor Plan

The first-floor plan of the building possesses access to the courtyards. The central area is primarily maintenance rooms, a garbage room, and a storage room for chairs and tables. The vertical circulation is highlighted in red to emphasize how far away they are at any given point from each other.



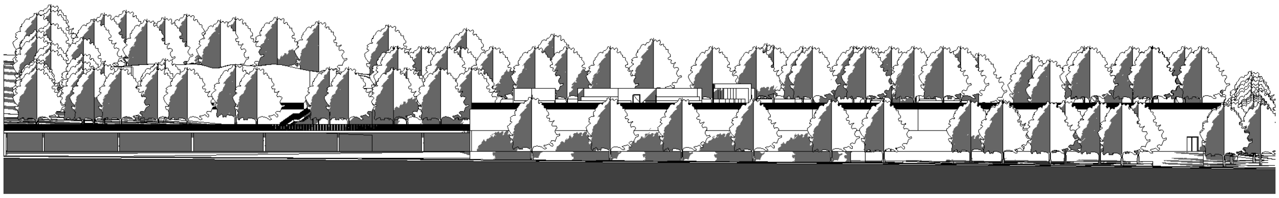
Not To Scale—Second Floor Plan

The second floor is where the main entrances are. There are four in total that connects to the parking lots and grocery store area. Near the main entrance on the southeast side is where the administration, public bathrooms, mail room, and bike room are located. The bike rooms I noticed when I lived in the area was present in almost all the apartments along with a secure mail room. I wanted to follow that trend in the area and because the bike room would also promote using a bike instead of a vehicle. Other amenities on this floor include a game room and rental storage units that tenants can pay monthly to use. Again, these features were incorporated to have tenants not need many reasons to drive places unless it is necessary.



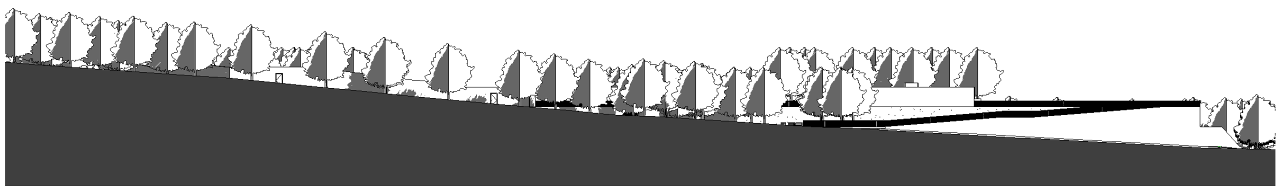
Not To Scale—Third Floor Plan

The third-floor plan possesses the handyman workshop that was recommended to be included in the program. The idea was to have a designated handyman that would be more available to the tenants should issues arise for various reasons. This floor also includes the gym, that can be used by any of the tenants. Should they feel the need to workout, they won't need to purchase a gym membership and drive to the gym.

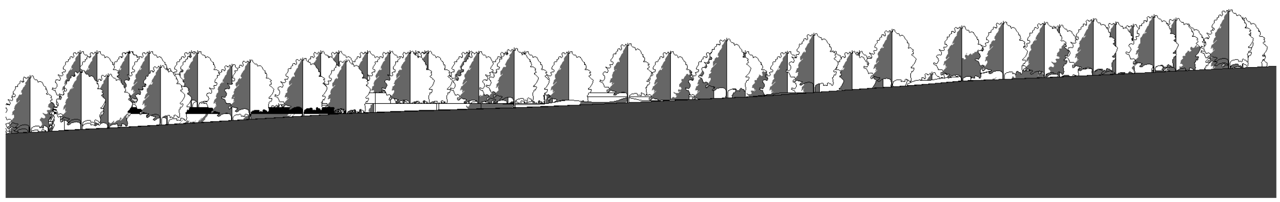


Not To Scale—East Elevation

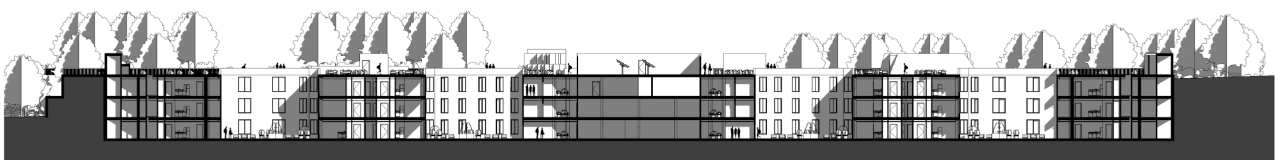
Not To Scale—North Elevation



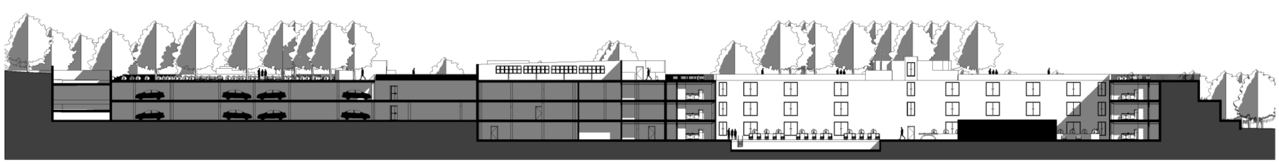
Not To Scale—South Elevation



Not To Scale—West Elevation

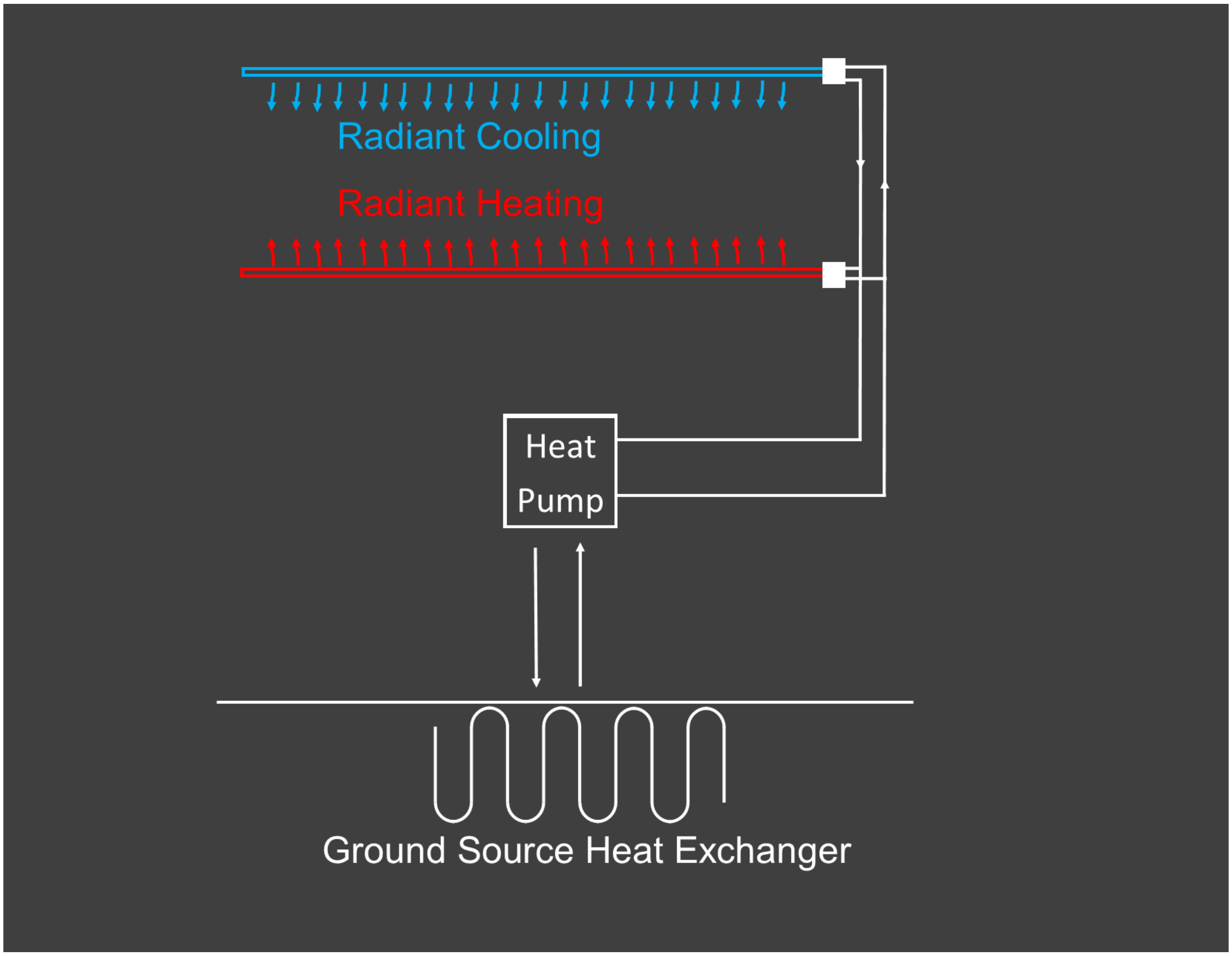


Not To Scale—Latitudinal Section

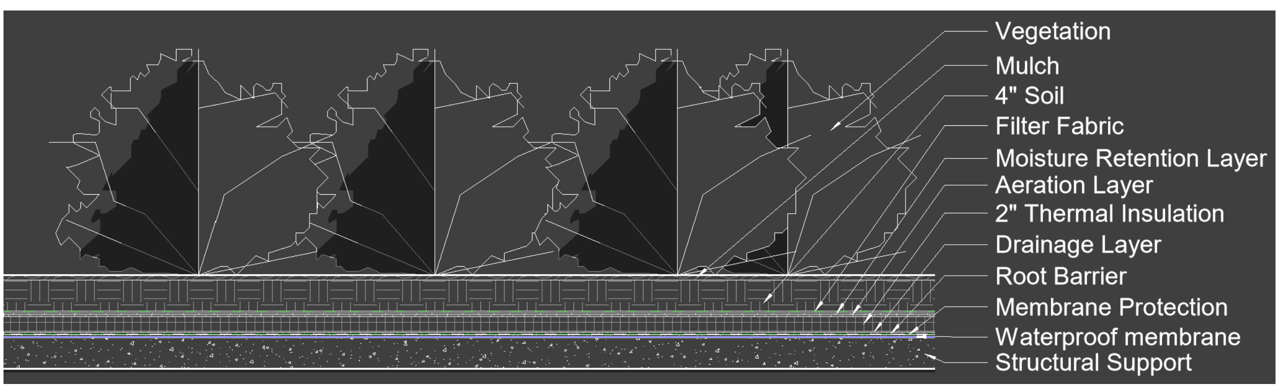


Not To Scale—Longitudinal Section

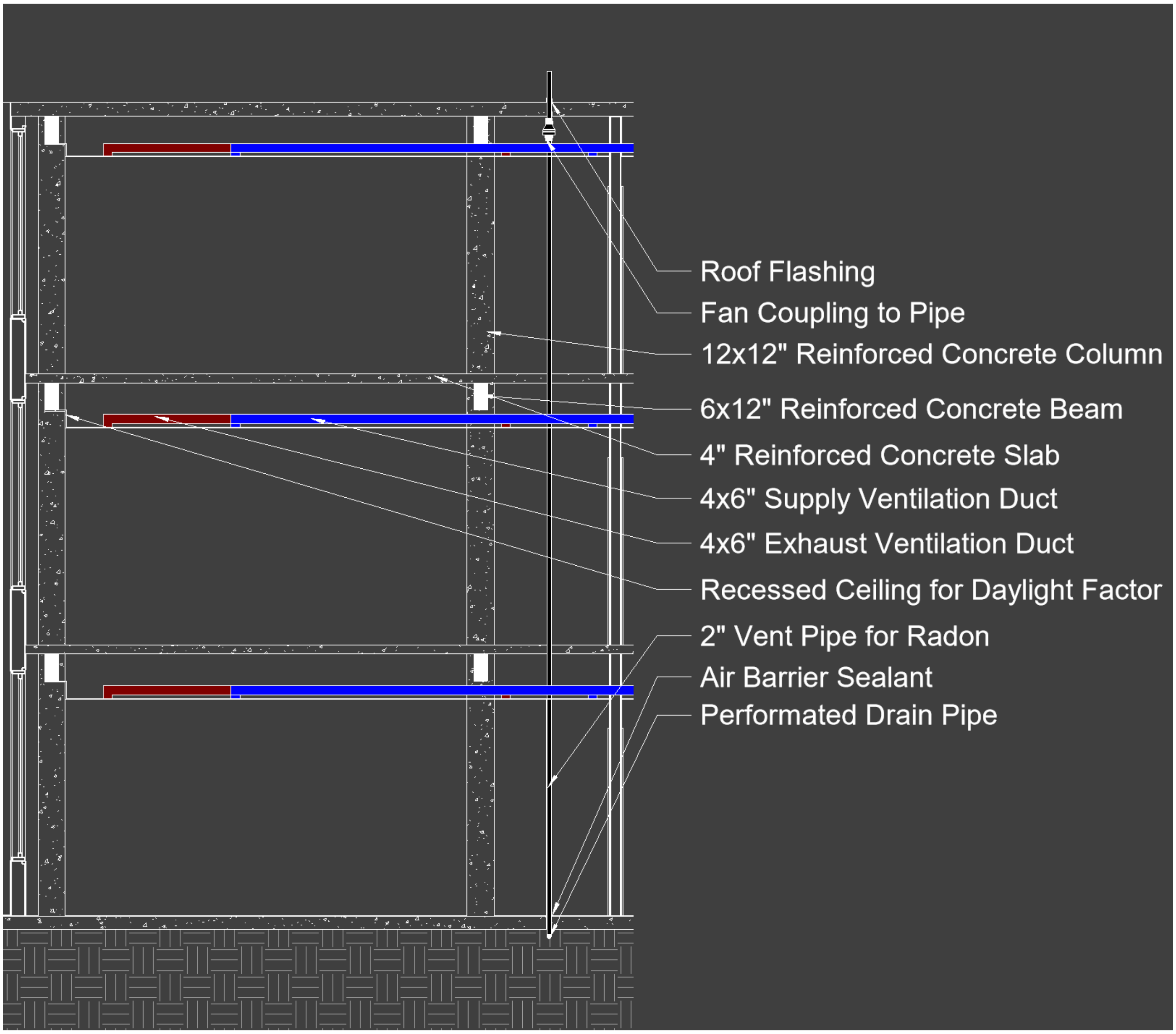
The elevations and section cuts show primarily the grade the site possesses and how the building is place on site. It also shows the amount of nature that was brought back into the site compared to the original infill.



This is a simplified diagram for the type of heating and cooling system I have for my design. It uses the ground-source heat exchanger underneath the parking lots. The liquid in the closed horizontal moves using a heat pump that transfers the collected temperature of the earth and then send it throughout the building using pipes to then heat up the floor or cool down the ceiling materials.

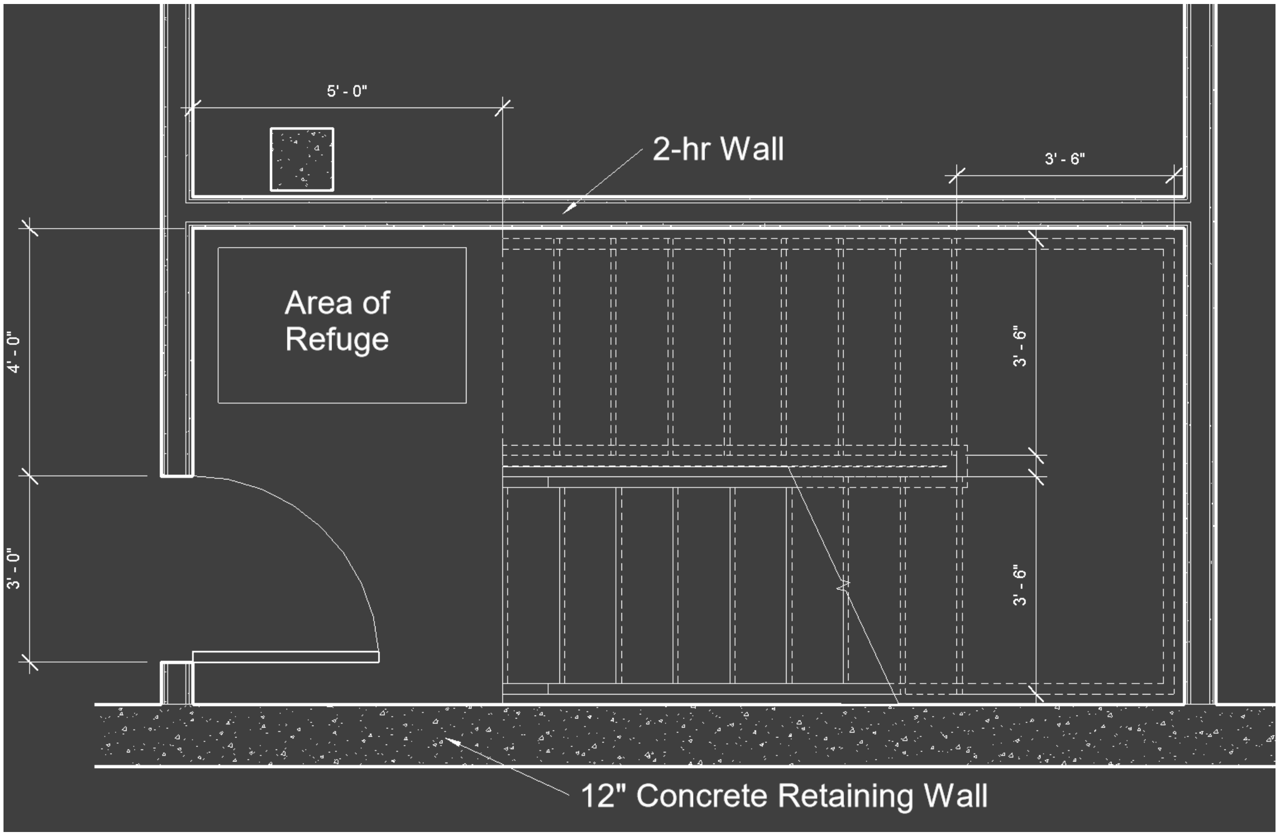


Not to Scale—Green Roof Detail



Not to Scale—Ventilation/Structure/Radon Detail

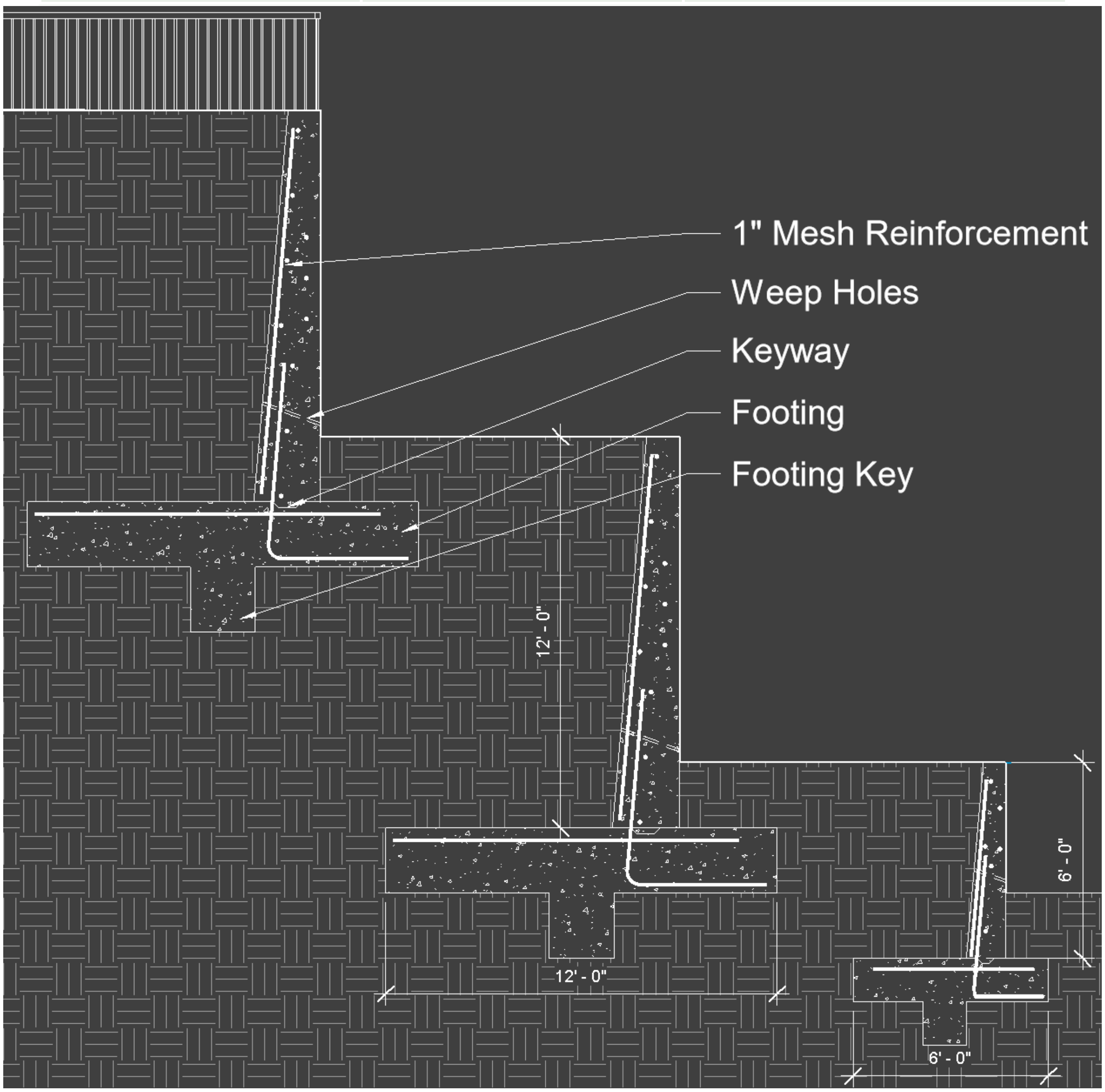
The ventilation system is a dedicated outdoor air system (DOAS), which is a highly efficient heat recovery ventilator (HRV). The radon system is self contained and expels from the ground into dedicated pipes and releases from the rooftops. The HRV system helps mitigate radon gas as well. The structural system uses reinforced concrete columns, beams, and slabs to maintain structural integrity. These columns range from 16-20 ft between other columns.



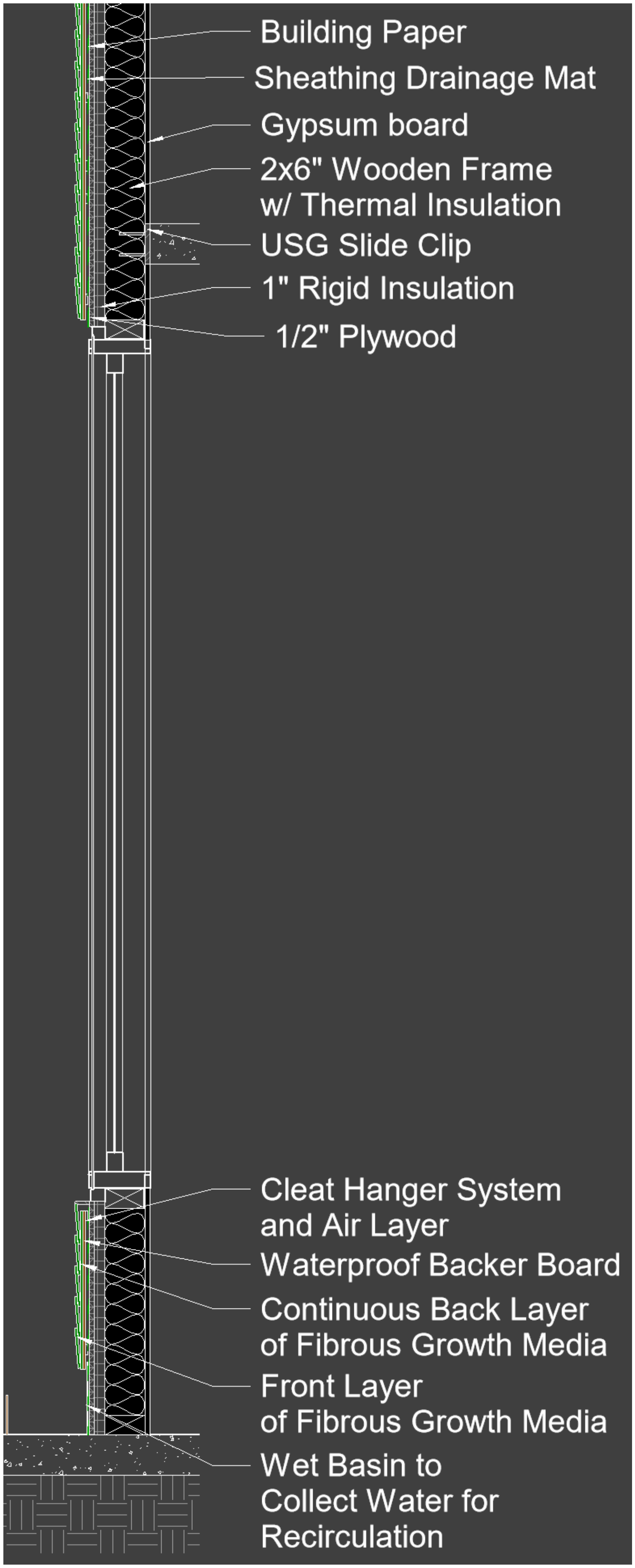
Not to Scale—Fire Escape Detail

Typology	Required	On Site
Apartment	325 parking spots	339 parking spots
Grocery	37 parking spots	40 parking spots + 6 for employees

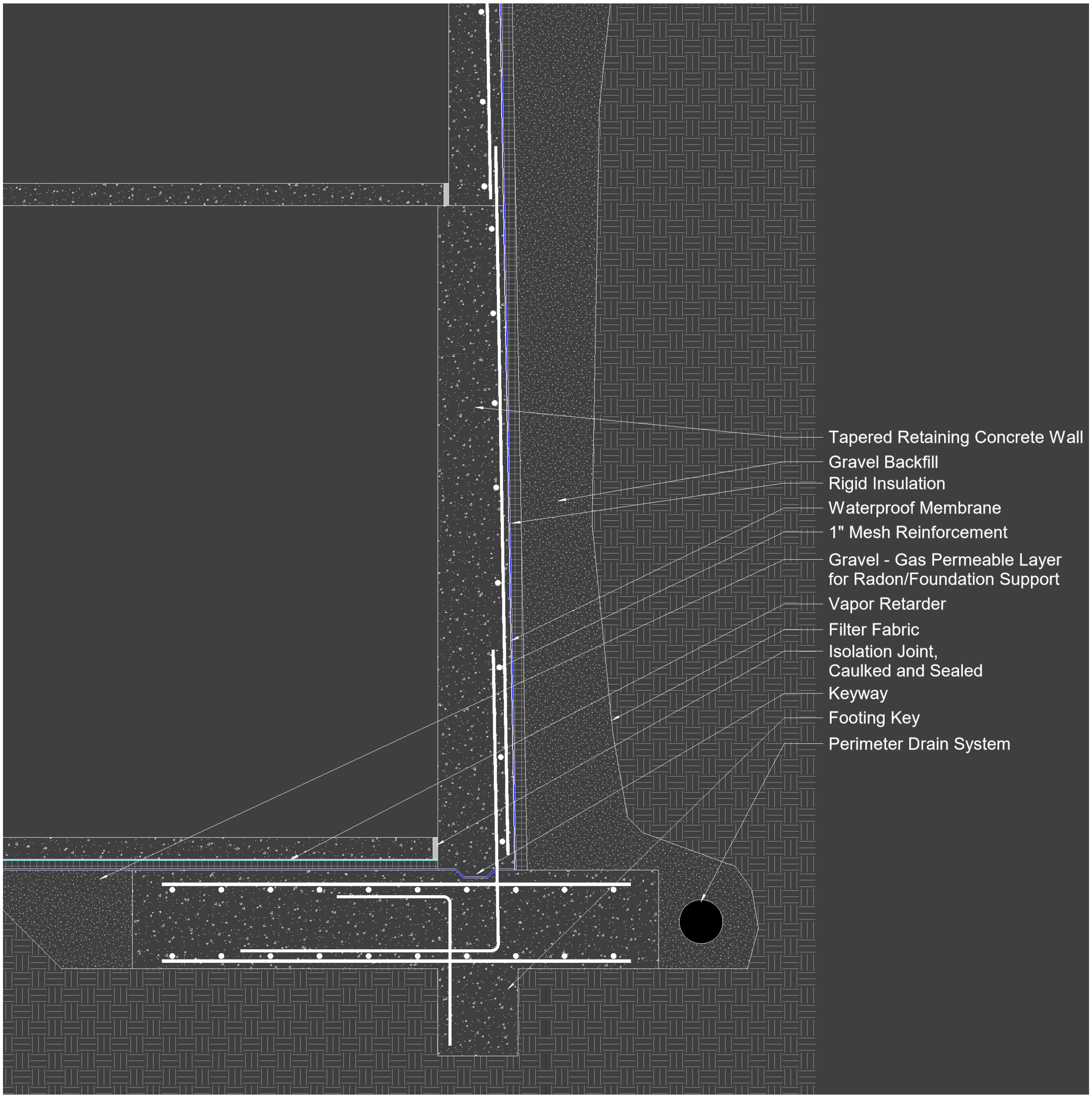
Typology	Required	On Site
Apartment	1 per unit	1 per unit + 6 for employees
Grocery	1 per sex	3 per sex for both custom-er and em-ployee



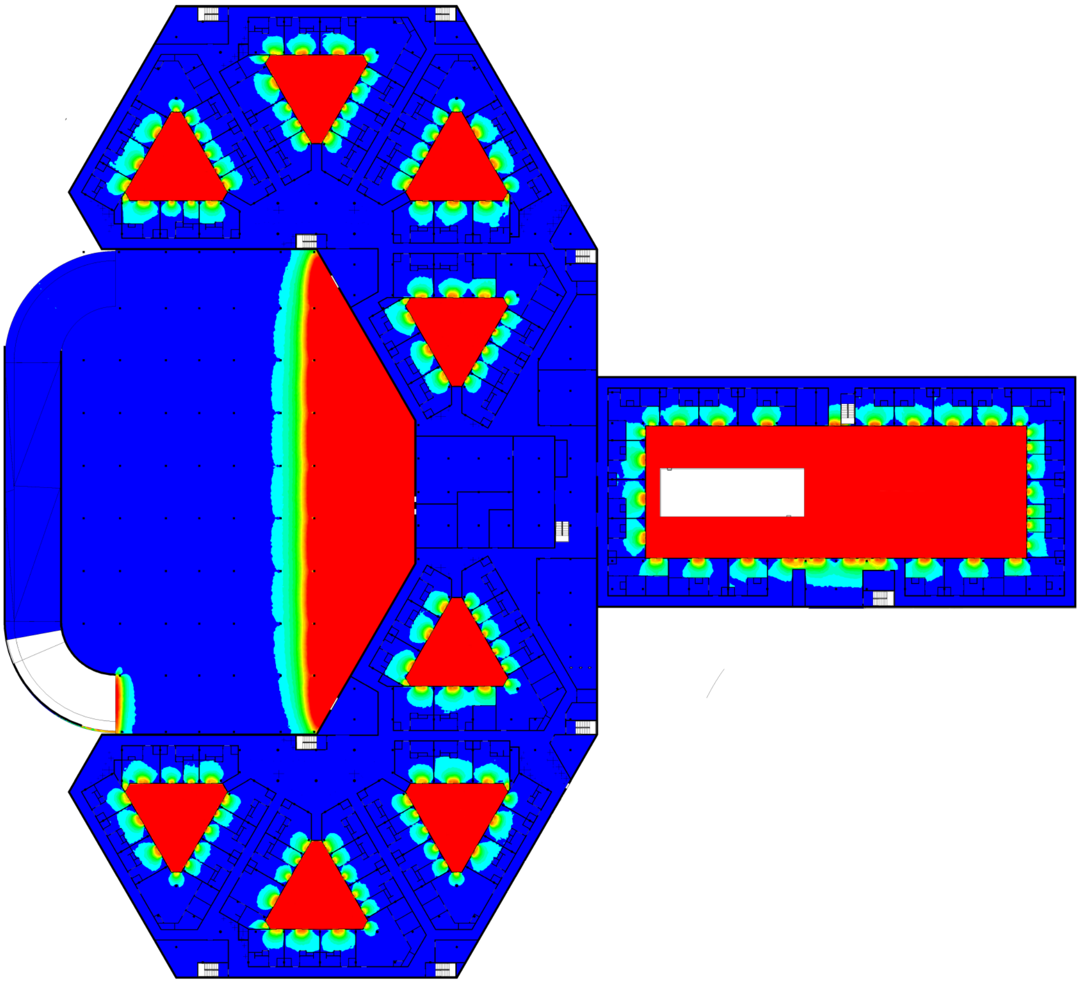
Not to Scale—Retaining Wall Detail



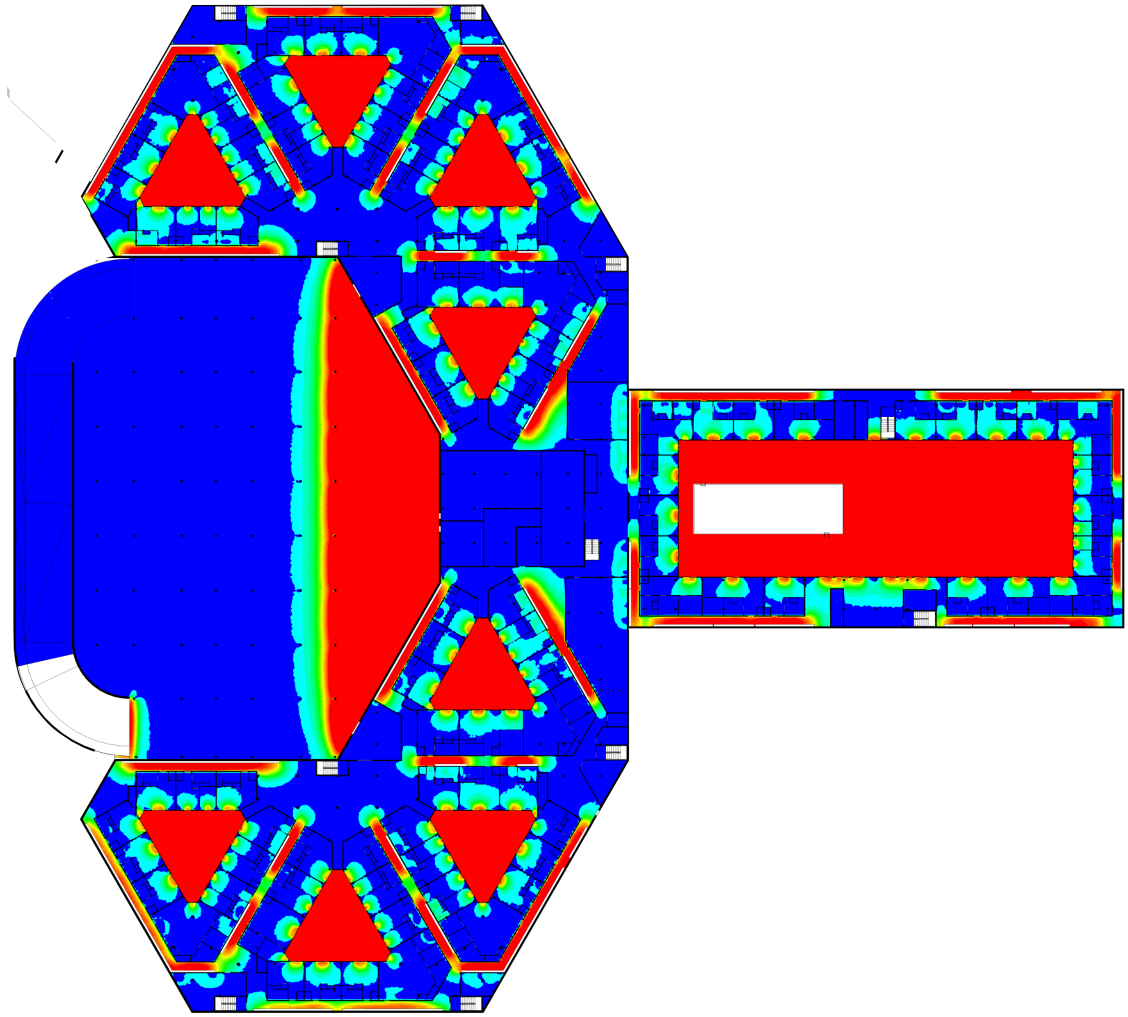
Not to Scale—Green Wall Detail



Not to Scale—Wall to Foundation Detail



To perform an analysis that represents how effective the design is for lighting a daylight factor analysis was conducted. In the original analysis not shown resulted with the windows needing to be raised and part of the ceilings close to the windows to be raised as well. The Daylight Factor Attempt 2 resulted with the progression of the design by deciding to incorporate skylights into the hallways to allow light to enter on the floors.



The finalized analysis Attempt 3 shows how the addition of the 3-foot wide skylights impacted the final design on the third floor which emulates similar trends on the lower floors. To note the lower floors are similar as the hallways provide 1-foot wide skylights to penetrate to the first floor. This shows that even subterranean design can allow light into spaces should it be needed dependent upon the depth of the design.

Performance Analysis: Site/Context

Based on the site and context of the site information and analysis, the final design was analyzed on how well it performed. The site itself was originally infill with the intent of the design to replenish the infill with native plants and buildings that fit within the context. In response to the site analysis, a grocery store was established to create a point of interest in the area as the rest of the context lacks a dedicated grocery store.

With the flooding and ponding not being present at any point in the site's history, the selected site was performed to be a suitable selection for the design. The design itself, based on an analysis of the performance of it in relation to flooding and the impact of water on the site could have, the site was a perfect sponge for this sort of project. The performance analysis of the final site plan confirms that there was an appropriate response to the site analysis, thus concluding the performance analysis of the site and context.

Performance Analysis: Typology/Research

The typological research primarily used case studies. These case studies all had a subterranean design associated with them. However, these case studies didn't all possess the same project typology with the goal of the project. The lack of exact typology with a subterranean design was either never attempted or publicized from the author's knowledge. This meant that the case studies that needed to be selected wasn't to do with the typology as much as it was with the type of design, being a subterranean design. All of the case studies involved subterranean design with the majority being the next closest to multi-residential building, single-family homes. This means that the performance of the typology was successful using case studies as a research method for the selected typology into subterranean design.

The research of the thesis was to find information regarding the history of subterranean spaces, and positives and negatives of subterranean design. The research that was conducted was a mix that informed the design in many parts of the design itself. The research on radon informed the radon details and response for the design. The ventilation and lighting were identified as an important factor that if not taken into account the performance analysis would be a failure. The analysis of the final design shows that the research in these factors influenced and formed a response in the design using courtyard systems. Many other parts of research that was conducted was utilized and the design had a response to each collection of research. The only exception was the research on the matter of reuse in subterranean spaces. This was excluded as a design response, as it wasn't applicable within the selected site.

Performance Analysis: Project Goals/Emphasis

The goal of the project was to answer the question "Can subterranean architecture create a more sustainable design?" This question became more clear as to how to answer this question following the completion of the design. The theory that was formed to answer this question was to take the design solution and pretend that it was an above-ground structure to compare the underground and aboveground differences. The biggest change of these two designs would be that one doesn't possess any earth surrounding the walls, using no earth insulation than its counterpart. That insulation would greatly impact the performance of the building in the extreme climates, making the heating and cooling loads more sporadic with the lack of it. In response to this theory, that this design was used as the benchmark to compare the above-ground version of the design. This exercise shows a clear answer due to heating and cooling load being the largest part of the fight for sustainability in the modern sense. The answer is established to be, "Yes." The alternative would result with less insulation making that design less sustainable compared to the subterranean version, suing the earth as an additional blanket from the local climate.

Even though the goal was the answer the question, the emphasis of the project was simply to form a design that allowed for a symbiotic relationship between the built environment and the natural environment. This emphasis was established more so than the question was to ensure the design could not just answer the question, but focus also on the benefit of that subterranean architecture. It is among the top solutions to the long-term problem of the lack of a healthy relationship between the building and nature. When there is no healthy relationship, there is no respect coming from either side. This design provides that respect and establishes a welcoming hand to each of the parties involved. This analyzes the performance of the emphasis to be a success in response to the final design as it showed the ability for both the built environment and natural environment to live in harmony.

Applied Research Methods

The applied research methods used in this thesis was collected into three categories. The three categories were historic research, mixed research, and experimental research. The historic research focused on the premise into why we haven't used the subterranean idea extensively anymore. It also established an old bond humans once had with the underground that could be reestablished with a proper design solution. The mixed research was a mix of case studies and research on various issues or parts of subterranean design. The various issues that were researched needed to be brought to the surface to properly design for a subterranean structure and counter any issues from occurring. The case studies showed real designs that have already been established in response to subterranean design. The case studies were the greatest information gathered to properly establish a further connection of the positive impacts it has on the relationship between the built and natural environment. The experimental research provided a creation of data from 4 inches of soil. The current data collection proved the theory that even 4 inches of soil provides benefits to a space surrounded by 4 inches of soil. This was required to understand the importance of even a little amount of earth being used on the building itself as earth is the best form of nature to achieve a symbiotic relationship. All of these applied research methods were critiqued and were established to be successful in their applications to the response of the design.

Thesis Appendix

Proposal Case Studies

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Previous Studio Experience

2nd Year || Fall: 2017 || Booker, Darryl
Projects
Tea House || Moorhead, MN
Boat House || Minneapolis, MN

2nd Year || Spring: 2018 || Greub, Charlotte
Cripple Creek Single Family || Cripple Creek, CO
Multi Family || Fargo, ND

3rd Year || Fall: 2018 || Ramsay, Ronald
Chapel Expansion || Agincourt, Iowa
Shaker Recital Hall || Mt. Lebanon, NY

3rd Year || Spring: 2019 || Alenjery, Niloufar
Storytelling Architecture || Rocky Mountain National Park
Native American Museum || Moorhead, ND

4th Year || Fall: 2019 || Barnhouse, Mark
Highrise Capstone Project || Florida, Miami

4th Year || Spring: 2020 || Barnhouse, Mark
Marvin Competition || Fargo, ND
Urban Design Film Project || Miami, Florida

5th Year || Fall: 2020 || Mahalingam, Ganapathy
Innovation Challenge || Fargo, ND