MATERIAL PROCESS AS A DESIGN TOOL: INVESTIGATING THE MAKING OF CERAMICS IN NOVA SCOTIA

by

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ABSTRACT

Materials are a significant aspect of architectural design, the construction components are selected for their availability, location, cultural meaning, physical characteristics and properties. The construction components are defined by their processes of fabrication and making. This thesis investigates processes of making utilizing local materials. It focuses on the relationship between raw material, fabrication, building application and spatial experiences.

The proposed site is the former brickyard located outside Bridgetown, Nova Scotia, Canada. Material excavation, fabrication, and construction will all take place on-site. Through material studies, site strategies, and phased program development, it is hoped that an architectural language has been generated that successfully represents the potentials of developing underutilized locally sources material.

ACKNOWLEDGEMENTS

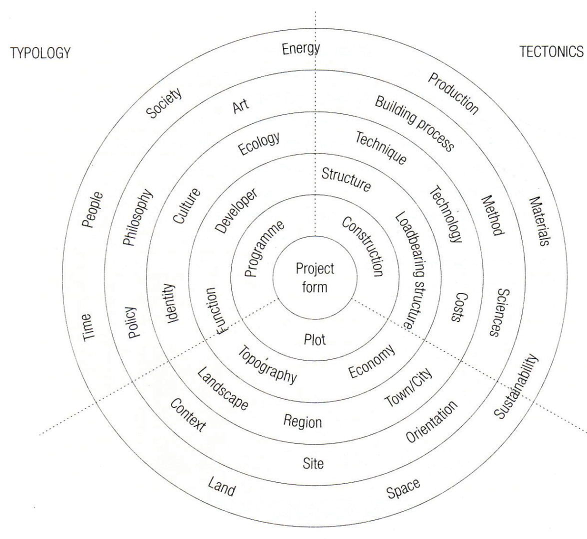
I would like to thank my supervisor, Roger Mullin, and my advisor, Richard Kroeker, for their patience, support, and receptiveness to my design process. I would also like to thank Rory Macdonald and Doug Bamford at N.S.C.A.D. University's Ceramic Department for sharing their knowledge, expertise and interest and ceramics and material processes. I would also like to express my gratitute to the members of Shaw Brick for generously providing site fabrication information and their material insight. I would like to give special thanks to my peers Maribeth McCarvill, Olivia Ferguson-Losier, Thanasis Ikonomou, and Justin Rankin for their moral support and encouragement throughout the development of this thesis project. Finally, a great thank you to my family and friends for their love and support throughout my studies in architecture.

CHAPTER 1: INTRODUCTION

> It seems anchored in an ancient, elemental knowledge about man's use of materials, and at the same time to expose the very essence of the materials which is beyond all culturally conveyed meaning. I try to use materials like this in my work. I believe that they can assume a poetic quality in the context of an architectural object, although only if the architects is able to generate a meaningful situation for them, since materials themselves are not poetic.[1]

Materials in Architecture

An architectural language is revealed through the implementation of a design approach. As Elsener's diagram illustrates, construction, site, and program are all integral aspects that are negotiated through the design process of built form. One could argue that physical materials play a significant role in all of these aspects. In terms of construction, material characteristics effect what and how we build. In terms of site, raw building materials can be taken from, and placed within the landscape. In terms of program, materials can be experienced aesthetically within spaces.



Christoph Elsener, Project form diagram from Andrea Deplazes, *Constructing Architecture: Materials Processes Structures: A Handbook* (2005) Illustrates the relation of tectonics and building form.

1 Peter Zumthor, *Thinking Architecture* (Basel: Birkhauser, 2002), 10.

Material selection becomes critical for any architectural project. For the purposes of my thesis investigation, local materials will be explored and used as the vehicle for my design process. The way in which I hope to study materials is through a comprehensive material process investigation. This includes exploring factors like material characteristics, fabrication processes, and construction applications.

Local Materials

By using local materials, a designer invites the relationship between the design project and its context to be established. The built form connects visually to the surrounding landscape, and also connects culturally through well-established building techniques and local economy. These characteristics add up to a well-grounded project, making it more sustainable and relevant over time.

Material Process

Material process is a series of operations that transform materials from one state to another, improving their effectiveness. Aspects like strength, durability, porosity, fire-resistance and aesthetic characteristics, are all ways a construction material can be improved. Material processing is also informed by context. Resource availability, climate, technology, economics, and methods of building can all influence the ways in which we choose and make building materials. These improvements allow for the innovative construction components to be developed, resulting in architectural projects that respond to their time and place.

Methodology

Architectural concepts are made tangible through material investigation and interpretation. The thesis explores the significance of physical material within the design process. Ceramic investigations will study this material through construction methods, site, and program. How can ceramic processes and site context generate architectural language?

Material and Construction

One could argue that ceramics in Nova Scotia are a readily available but underutilized building material. Ceramics building components, apart from brick, are virtually unexplored in Nova Scotia. For example, the use of mortar as a bonding agent for exterior brick wall systems is inefficient due to the frequent annual freeze-thaw cycles in Nova Scotia. It is my hope that the potential for ceramics can be explored, and more effective building components can be developed.

Material and Site

A building site can inform many aspects of a design project. Architectural form can be heavily influenced by landscape surfaces, settlement patterns, historical context and geological layers. Because Nova Scotia has an abundance clay deposits, there has been a large number brick production companies in the area. The selected site for my project is on a former brickyard, situated on a deposit of high quality clay in Bridgetown, N.S. It is my hope that the thesis project will effectively relate ceramic building component development to the material and its place of origin.

Material and Program

The thesis proposes a research facility investigating the making of ceramic building components in Nova Scotia. Using a building as a framework, the program consists of several activities including, excavation, investigation, fabrication, customization, production, and construction of ceramic building components. Geometric variations, methods of installation and potential uses for ceramics would inform the development of each component. Since material investigations involve an iterative working process, the architecture will interpret programmatic changes over time. The initial building will accommodate researchers and initial investigations, and as the activities on-site become more extensive, the scale of the building project increases.

Design Approach: Process of Making

> My experience of making my own design ideas convinced me that understanding materials, and gaining practical experience of using them was essential to developing ideas and finding ways of making them happen.[2]

Making allows you to think with your hands. Exploring without preconceived ideas, to see differently. Richard Sennett in “The Craftsman” expresses the importance of exploring through making. Process is defined here as a series of events that happen over time to achieve a particular end. The process of making is a series of actions of putting components together or taking them apart aiming for a particular intent. It applies to design, fabrication, construction and building use over time. The process that transforms raw material in the landscape into construction components is called a material fabrication process.

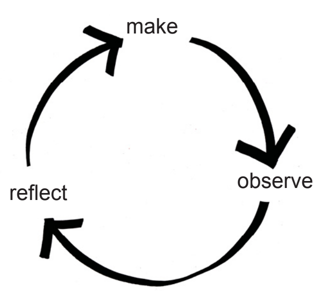


Diagram showing the creative design process cycle

2 Thomas Heatherwick, *Thomas Heatherwick: Making* (New York: The Monacelli Press, 2012), 10.

The design intends to find an architectural language that gives a sense of place in addition to expressing its own identity. The focus of the thesis is on local materials utilizing potential alterations within its fabrication process to generate architecture.

The proposed approach, builds on Sennett's idea on encouraged thinking while making. The starting point is making things with clay, and furthering ones understanding of material characteristics. This was followed by approaches using a variety of media that allowed for opportunities to compare and observe the material's main aspects. For example, starting with clay as a modeling material, followed by paper models, or changing from model making to drawing, will mobilize different languages. The voices of new formal languages are rooted deeply in the observations from previous explorations.

CHAPTER 2: BUILDING WITH CERAMICS

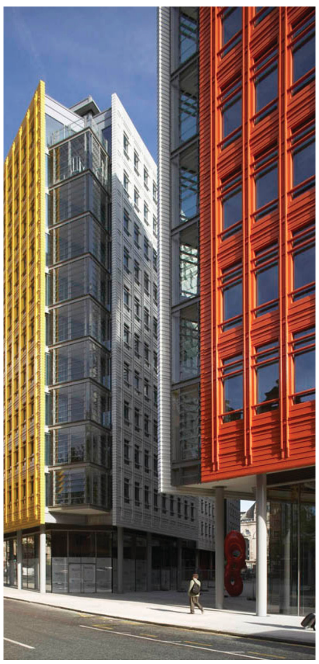
Origin of Clay

Wind, glaciers, pressure, and especially water cause weathering on the earth. The weathering of rocks forms clay deposits. Clay composition is directly related to the composition of parent rocks. There are 2 kinds of clay, primary and secondary. The primary clays are the ones that stay with their parent rocks. Secondary clays are a results of glaciers carrying particles from parent rocks to current deposit location. In Nova Scotia, the majority of clay deposits are secondary. In the process of transportation a variety of oxides and organic materials are added to the clay. Every clay deposit has its own transportation path, which means its own composition. The specificity of each deposit route explains the significant amount of variables within same types of clay.

Characteristics

The most important clay characteristics for production are particle size, plasticity, moisture absorption ability, firing temperature and color. Most of the clay deposits in Nova Scotia result in the making of earthenware, low-firing clay, much of which contains iron oxide and fires red. The color varies depending on the temperature at which it was fired. The physical nature of clay is also really important when drying. Daniel Rhodes describes the clay particles as “plate shape”. The orientation of the particles gives the material its grain structure, which determines the direction of the shrinkage. The geometry of the particles has a large surface area and is conducive to attract water molecules. Higher water content will increase the shrinkage ratio. The higher the shrinkage, the higher the tension is between particles. This tension can make cracks or warp the pieces of clay creating a weak component. For example, if the clay only has fine particles, they will absorb a considerable amount of water, which could make the brick warp. For that reason, the brick manufacturers usually add a considerable amount of shale or sand to their mix. The shale absorbs less water and gives the mix more stability in the clay body. Water is a critical aspect in the fabrication process of ceramics.

Building Applications



Facade photograph of Central Saint Giles, London; from ArchDaily

Facade component photograph of Central Saint Giles, London; from ArchDaily

Clay is an abundant organic material. Ceramics are a non-toxic, recyclable building materials. They also have a wide range of construction applications. The structural capabilities of ceramics are very good in compression but very poor in tension. Ceramic components often work more effectively in combination with other materials.

Nova Scotia has a very high number of freeze thaw cycles per year. Water is the first factor of premature deterioration of buildings. Water causes rotting and molding, deformation of material, efflorescence, stresses, movement and breakage. When exposed to water, ceramic components need to be non porous. Making a non-porous ceramic component with Nova Scotia clay is not a prohibitive. In a standard brick and mortar connection, the mortar is more porous than the brick itself. This does become an issue when the mortar absorbs water, and the water freezes, expands, and creates tension in the ceramic making cracks and allowing water penetration. What are the implications of water with ceramic components in architecture? How does it deal with several freeze thaw cycles? The study focuses on 3 ceramics applications. In response to the Nova Scotia climate, these are the exterior cladding and the landscape surfaces. The Central Saint Giles by Renzo Piano demonstrate an alternative to a ceramic mortar connection where the custom curtain wall panels are held in place by steel structure. Another relevant example is the Villa Nurbs by Enric Ruiz Geli. It uses plasticity and a glazed clay to its advantage. It also uses slump molds to make complex geometries. The applied glaze finish gives every piece its own identity.

Photograph showing the connections of ceramic pieces in the Villa Nurbs; from Enric Ruiz Geli

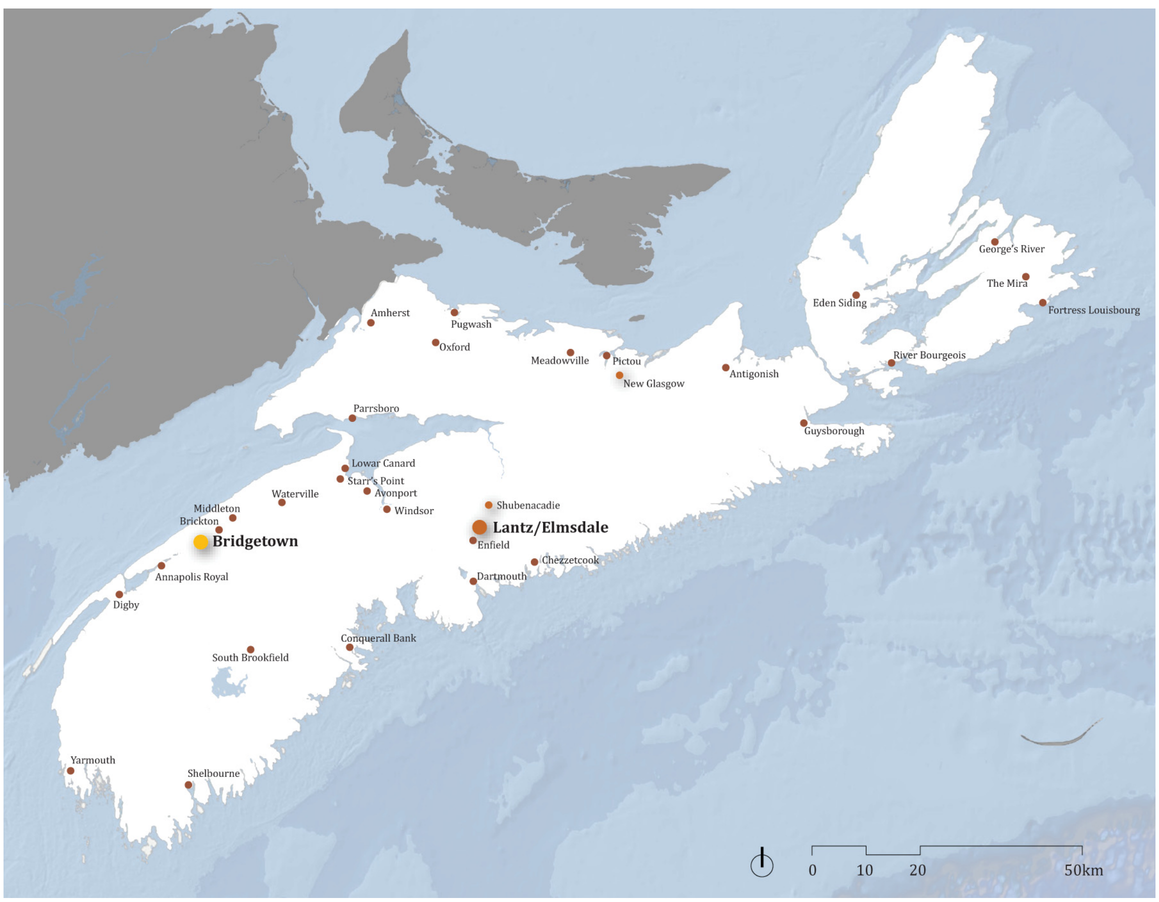
Photograph showing the glaze variation on Villa Nurbs; from Enric Ruiz Geli

Photograph showing Villa Nurbs; from Enric Ruiz Geli

CHAPTER 3: CERAMICS IN NOVA SCOTIA

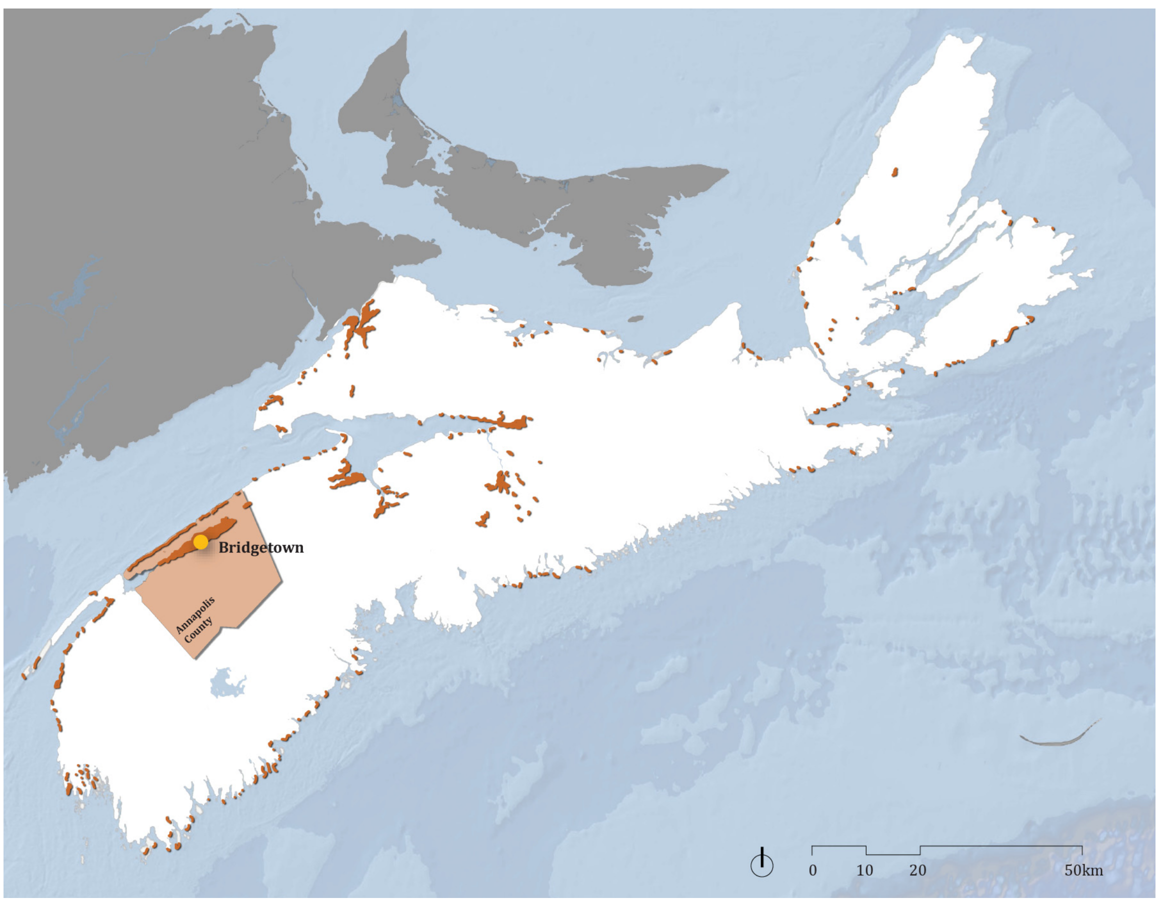
Clay is a local material in Nova Scotia. It is a significant element of the province's beautiful landscape, and a great number of clay deposits can be found in the province.

In the 1900, several brickyards were producing bricks. Throughout the years, the respective brickyards centralized into the Shaw Brick enterprise. It is the only remaining brickyard in Nova Scotia. They currently fire all their bricks in Lantz, NS. Shaw Brick have three excavation areas. Each excavation pit provides a different clay color; the red color is located at the brickyard in Lantz, the brown color is excavated in Shubenacadie and the buff color in New Glasgow.

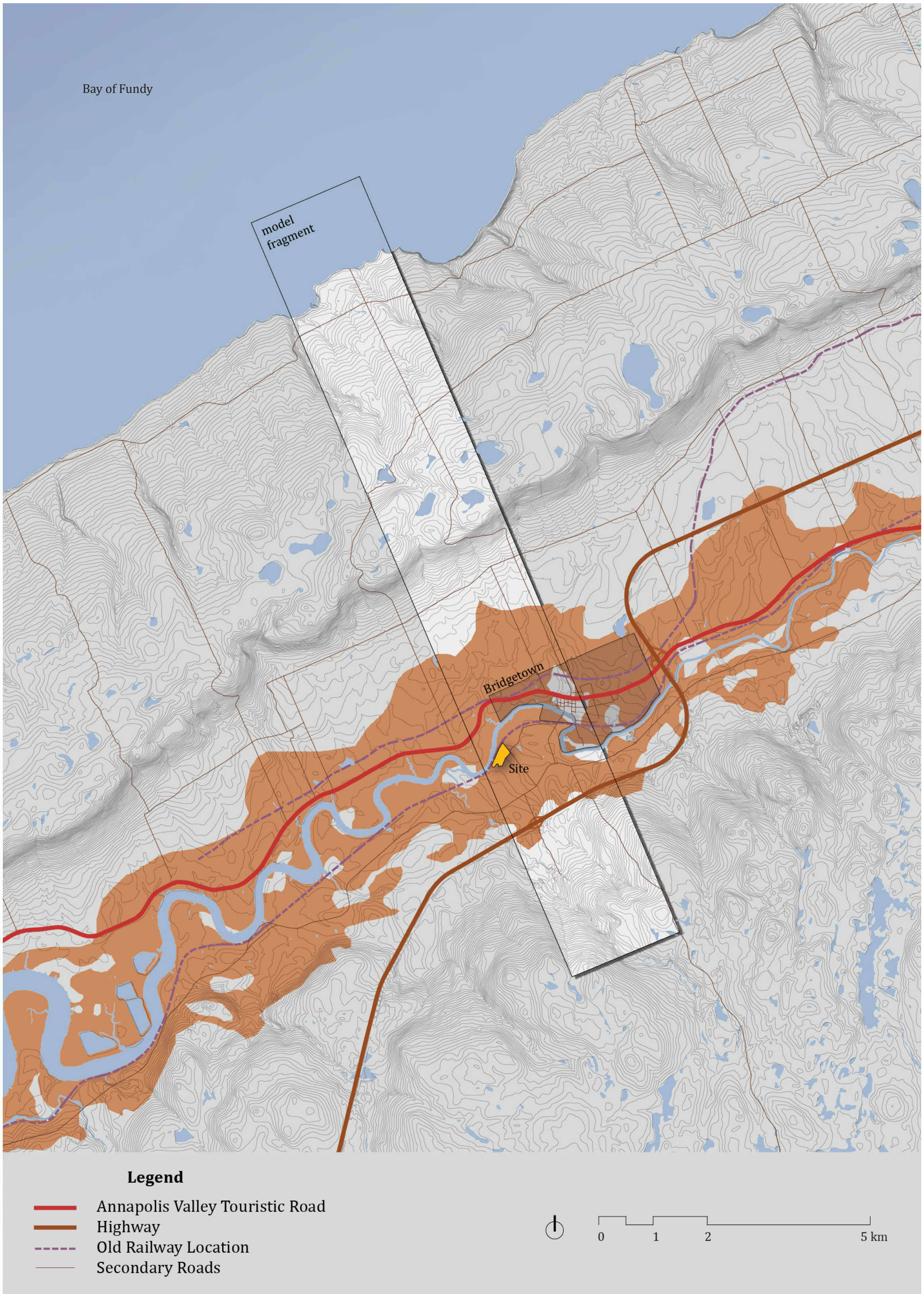


Historical and current brickyards in Nova Scotia; data from H. Millard Wright, *Building Nova Scotia Brick by Brick*

Due to the seemingly endless possibilities of clay as a material, the selection of a site became a significant aspect for establishing design constraints for the project. The proposed site is near Bridgetown, Nova Scotia. Specifically, I'm interested in building on an important clay deposit in Annapolis Valley where there was once an operating brickyard. Today the only remaining trace from the site's industrial past is the clay excavation area. Over time, the area became a pond. The pond is located beside the old railway. Which has been disassembled and developed into a biking and walking trail. The trail offers a twenty minute walk through nature connecting the site to the town center.



Clay deposit in Nova Scotia; data from Nova Scotia Department of Natural Resources, Map of Surficial Geology of the Province of Nova Scotia

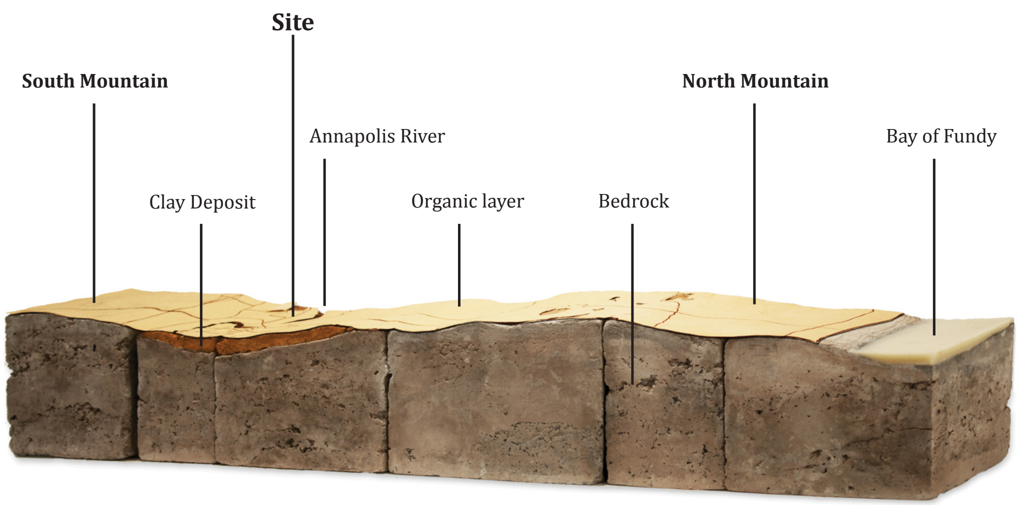


Clay deposits in Annapolis Valley; data from Nova Scotia Department of Natural Resources

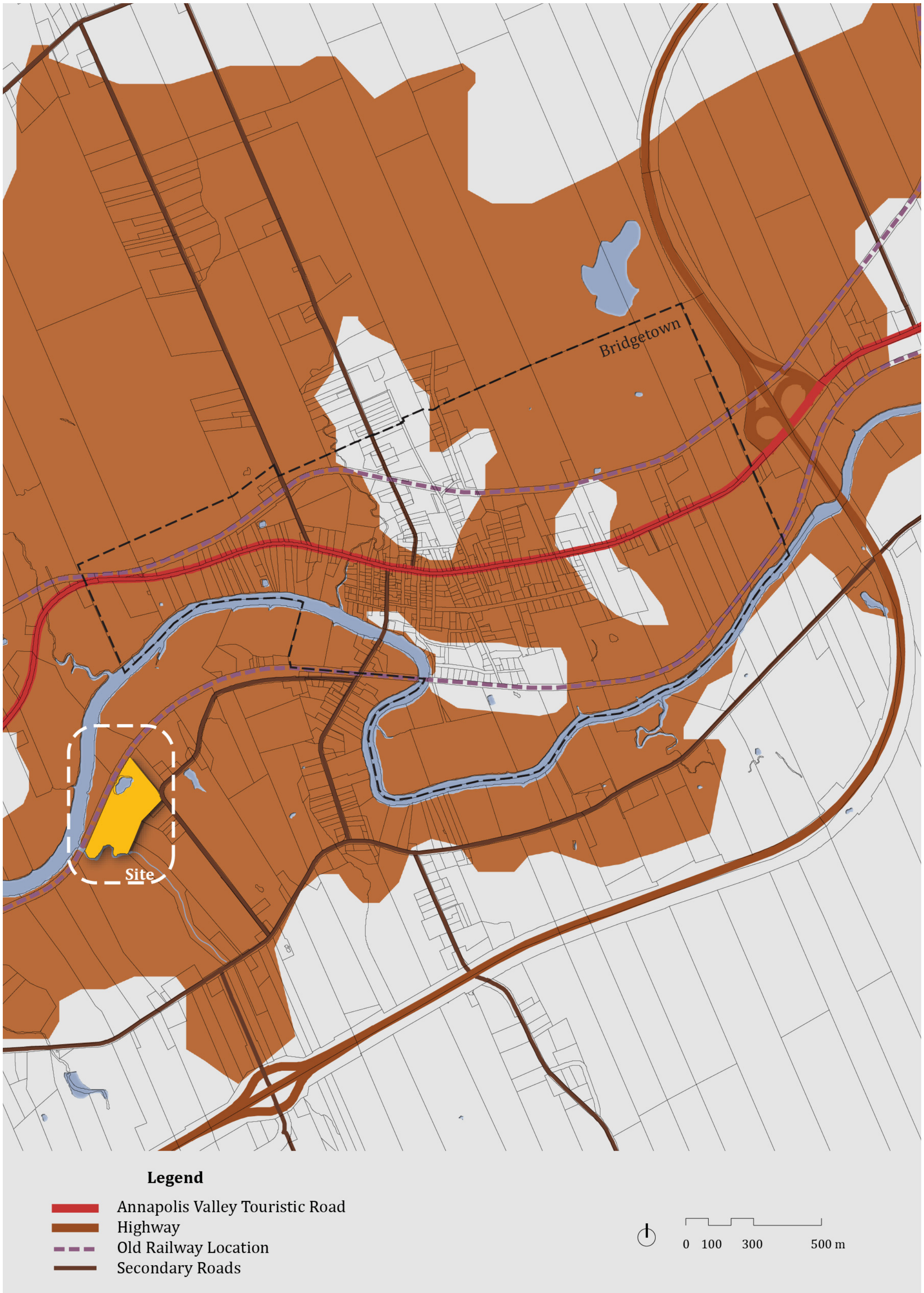
The site selection was based on three criteria. Firstly, it is located on a clay deposit, where quality raw materials could be excavated, processed, and assembled on site. Secondly, since the location was formally a brickyard, it has a significant connection to processes of making. Lastly, it is in a rural setting, where a relationship between building and landscape could be elaborated to become a significant part of design process.

Site Layers

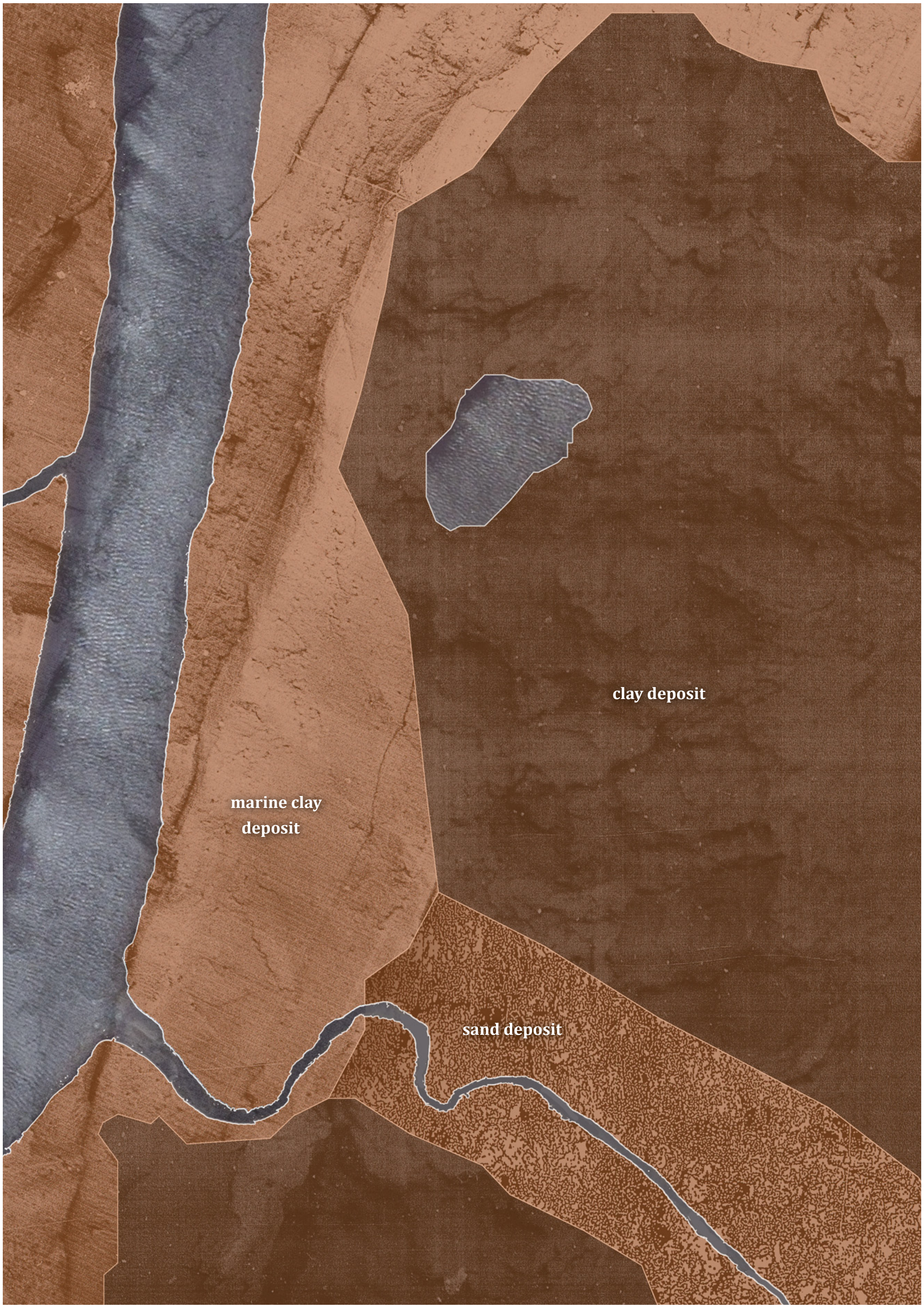
Weathering influences the geology of the site. On this site, the weathering is predominately caused by the Annapolis River. Over many thousands of years, the river has sculpted the terrain, creating two mountains, the North and South mountains. The terrain is an accumulation of many geological layers; first comes the bedrock layer, then the deposit layer, followed by the surface, organic layer. These layers inform the settlement patterns, such as roads, paths, property access, boundaries and industrial sites. In this region, the main roads are placed along the Annapolis River. The majority of the properties lie perpendicular to the river in long narrow parcels which maximize the river access.



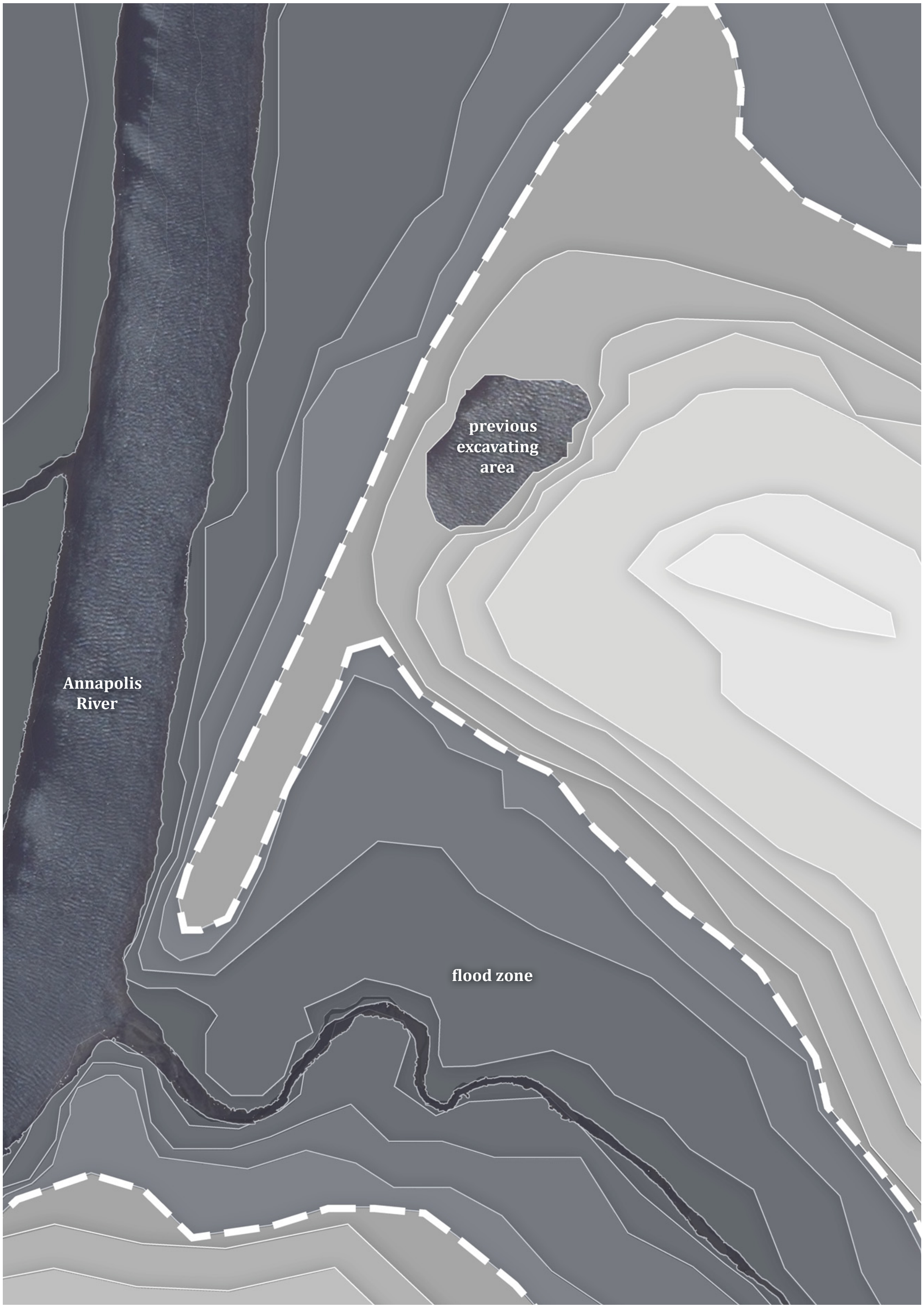
Interpretive model of Annapolis Valley showing the relation between the geological layers and the ground surface.



Clay deposits in Bridgetown, NS; data from Nova Scotia Department of Natural Resources



Map of clay and sand deposits on site 1:4000



Map of terrain and flood zone on site. 1:4000

Map of site boundaries and access on site 1:4000

CHAPTER 4: MAKING CERAMICS

Firing clay makes ceramics. Firing is one of the main reasons that ceramics absorb significantly less water than clay. Therefore, it is possible to expose ceramics to water without deformation and loss of strength. Water is the main element that determines the plasticity of the clay. The ceramic process is a cycle composed of several phases related to the different material states; raw, wet, leather hard, dry and fired.

Fabrication Process

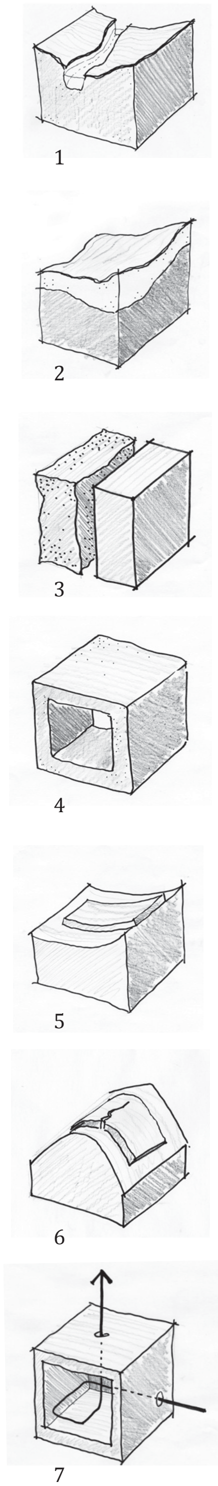
The water content of clay is decreasing during the fabrication process; therefore the plasticity decreases. The clay stages are defined by plasticity. Plasticity, geometry and weight of the pieces determines the tools and equipment required during the fabrication process. The phases of the ceramic process are the geological formation of clay, the extraction of raw clay, mixing clay body, compressing, shaping, drying, firing, and use.

The fabrication processes for ceramic building components are highly adaptive. Variations in clay body composition, extrusion, and firing yield significantly diverse results. Material strength, porosity, plasticity, texture, and color are all attributes that correlate to these variables, emphasizing the direct relationship between building component and the fabrication process.

Models photographs and drawings - In search of an architectural language. Using formal exploration (in clay) to interpret the different stages of water content. Starting by raw, wet, leather hard, dry and fired. Interpreting the clay exercises utilizing papers models and drawings.

Photographs of ceramic process, illustrating the relationship between clay stages and the sequence of action and tools

Photographs showing several material explorations made in relation to a sequence of actions within the process.



An illustrated series of observations from the material explorations

Explorations and Observations

A series of explorations were made based on moments appearing in the ceramic process. Here are some observations;

1. Raw clay in nature is constantly shifting state; from dry to wet. Its plasticity cycle ranges from easy to shape, to dry, to hard.

2. In order to excavate clay the organic layer has to be removed.

3. While mixing, organic materials can be added to the clay. Allowing for a more porous fired product. The opposite can be achieved by adding sand or shale, obtaining more vitrified state leading to less water absorption during use.

4. During compression, the overall geometry is determined. In order to dry more evenly and use less energy firing, the component should be a thin tile like surface or a hollow volume.

5. When almost dry, a second manipulation such as a slump mold can be use to alter the shape or carved to add texture.

6. Depending the temperature differences within the component while drying, the shrinkage can create tension and cracks.

7. Understanding the kiln air flow is very important. Uneven heat distribution can crack the component.

Illustration of manual small scale process

This thesis aims to address the potential of clay as a building material in Nova Scotia. The project addresses the lack of ceramic innovation in Nova Scotia by providing artists and researchers facilities to explore the process of making ceramics.

Three Phases: Accommodation, Innovation and Production

The process of making ceramics can be done at any scale, from a small-scale operations utilizing manual labor, to modern operations using large, sophisticated equipment. The program will evolve and grow over time. The intent is to use the built forms as research frameworks ranging from a small-scale intervention to a larger scale building. Since this project is intended to expand over time, it can be subdivided into three program phases.

The first, ‘accommodation’ deals with housing the initial production and living spaces for researchers and artists. This phase is critical for the initial development of material ideas by allowing ceramic enthusiasts to share their knowledge of ceramics.

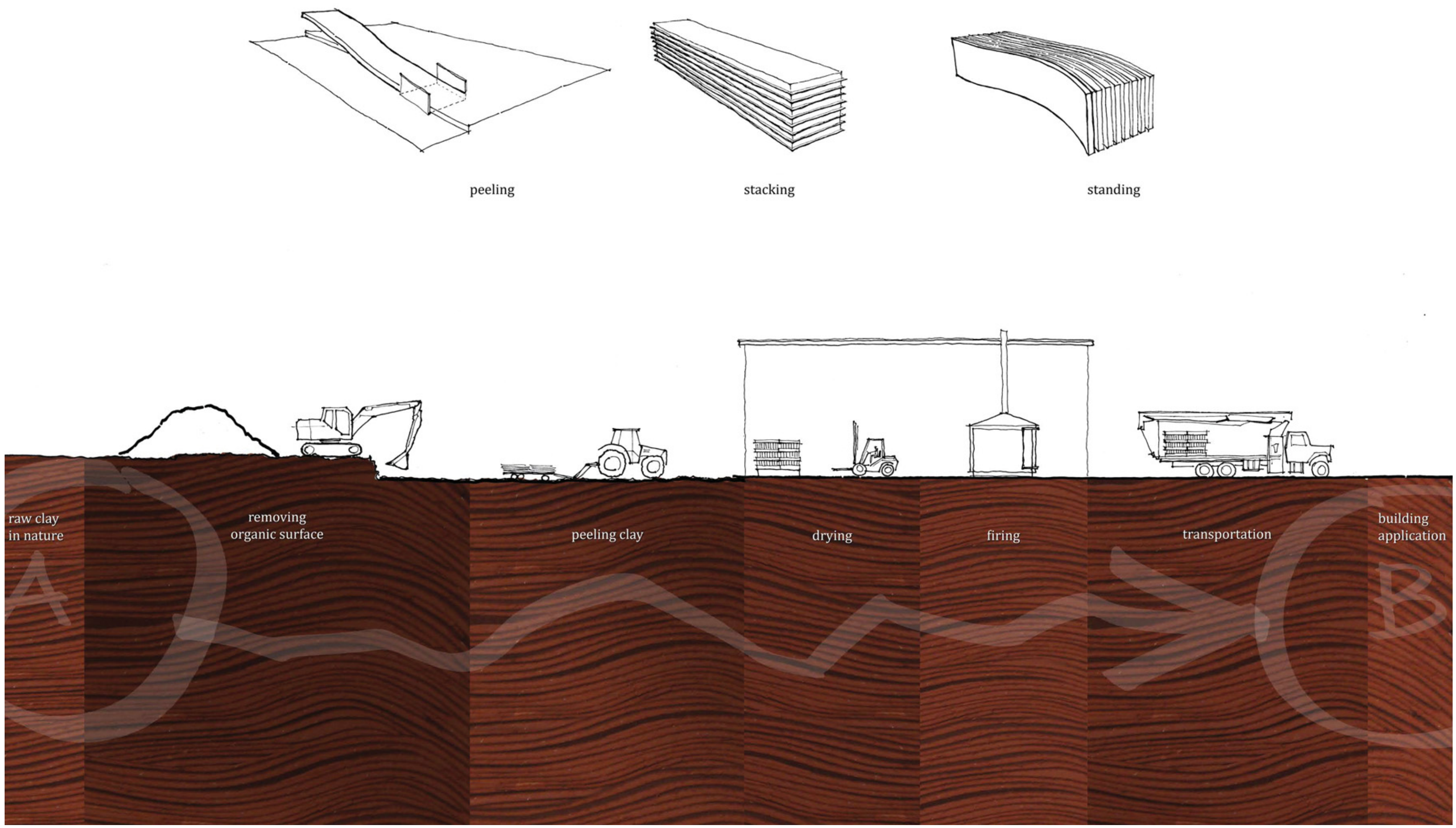
The second, ‘innovation’ deals with providing studio and work spaces for an expanded production and research team. More sophisticated techniques can be explored through the use of a kiln, material testing labs, studios and offices. Variations in material processes can take place within these spaces.

The third, ‘production’ would involve the construction of a large-scale warehouse, where more sophisticated machinery and technology could be introduced for mass-customized ceramic products.

Proposed Excavation Process: Peeling Clay

In theory, the clay on site can be used as is. Using an excavating machine to gather the clay decompresses it from its naturally, usable state. To return, the clay to a compressed state, it must undergo a process of remixing and extruding. Is it possible to extract the clay without decompressing it?

To accomplish this, the proposed excavation process involves a peeling machine. It keeps the natural compression of the clay deposit. The excavation process starts with removing the thin organic layer with an excavator, followed by a machine hauled by a tractor that cuts thin layers of clay out of the ground. The thin layers of clay are cut into specific lengths that correspond to desired tile dimensions. The clay tiles are stacked on top of each. In order to maintain their individuality, a canvas is added in between the pieces. The canvas prevents the clay tiles from bonding together. The tiles are then transported to a sheltered area for drying. When sheltered, the tiles are arranged on a kiln cart. The tiles are rotated from horizontal to vertical and given a curve to stand on their own. Putting the tiles on their short edge exposes more of its surface area to air. It allows for a more uniform and effective drying process. When dry, the cart is wheeled into the kiln. After fired, the ceramic pieces can be stored and distributed for use in building applications.



Illustrated sequence of the proposed mass costumization process

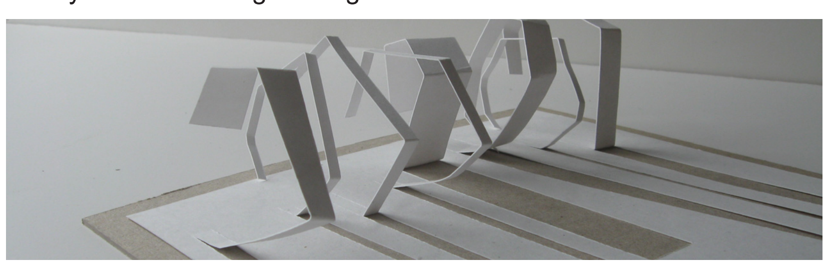
CHAPTER 5: DESIGN RESPONSE

Formal Vocabulary

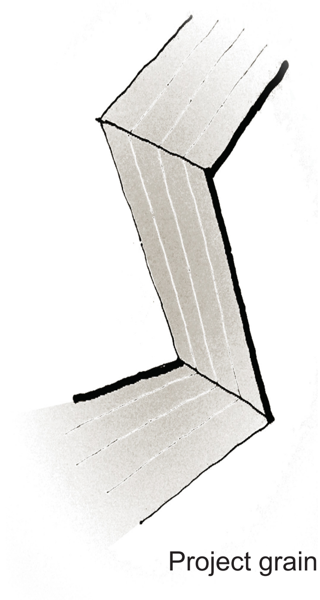
One of the initial criteria for the site selection was a significant relationship between the built project and its immediate rural context. Based on site observations, material process studies, and model making, the most design language expresses a formal quality of peeled surfaces. Appropriating the linear directionality of the agricultural plots in the surrounding landscape, the building morphology can work within this language. The excavation process would be completed in accordance with the existing stratified sediment deposits. Layers of clay would be removed to reveal what is underneath. The formal language of 'peeling' is appropriate for relating site, building, and program, as it connects both formally and physically with the surrounding landscape.

Photograph taken in Annapolis Valley showing tractor traces

Clay model showing carving



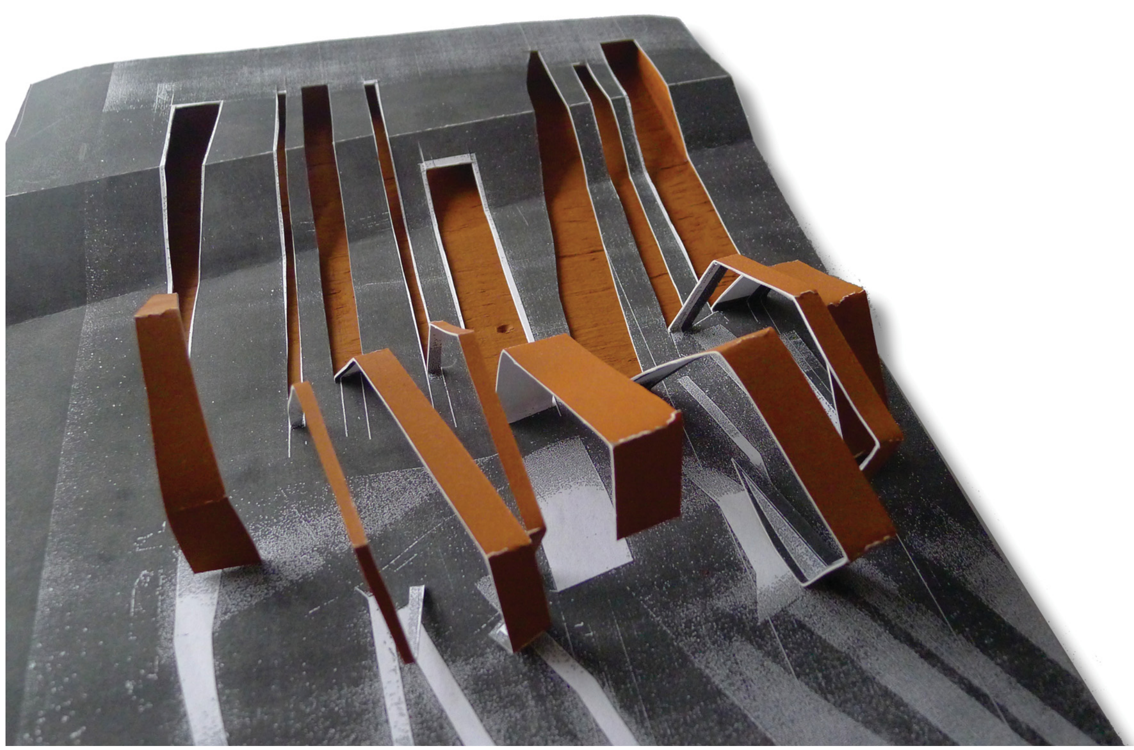
Paper model representing peeling



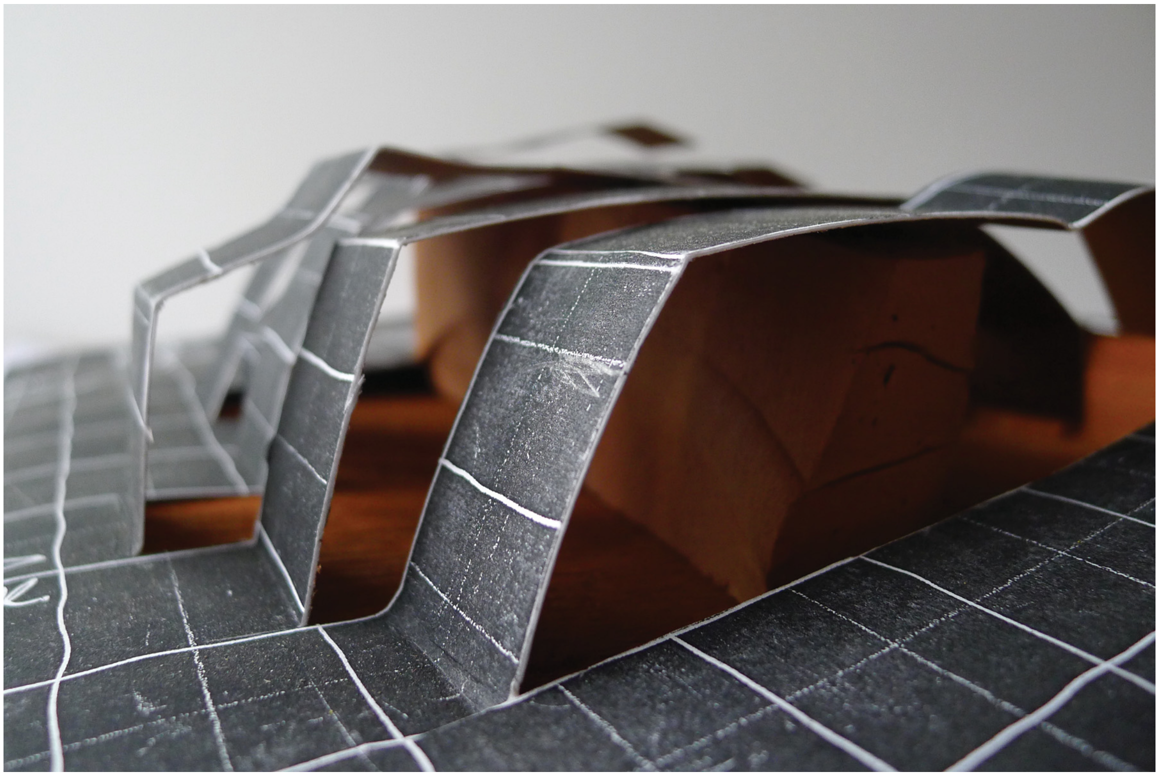
Project grain

Peeling Models

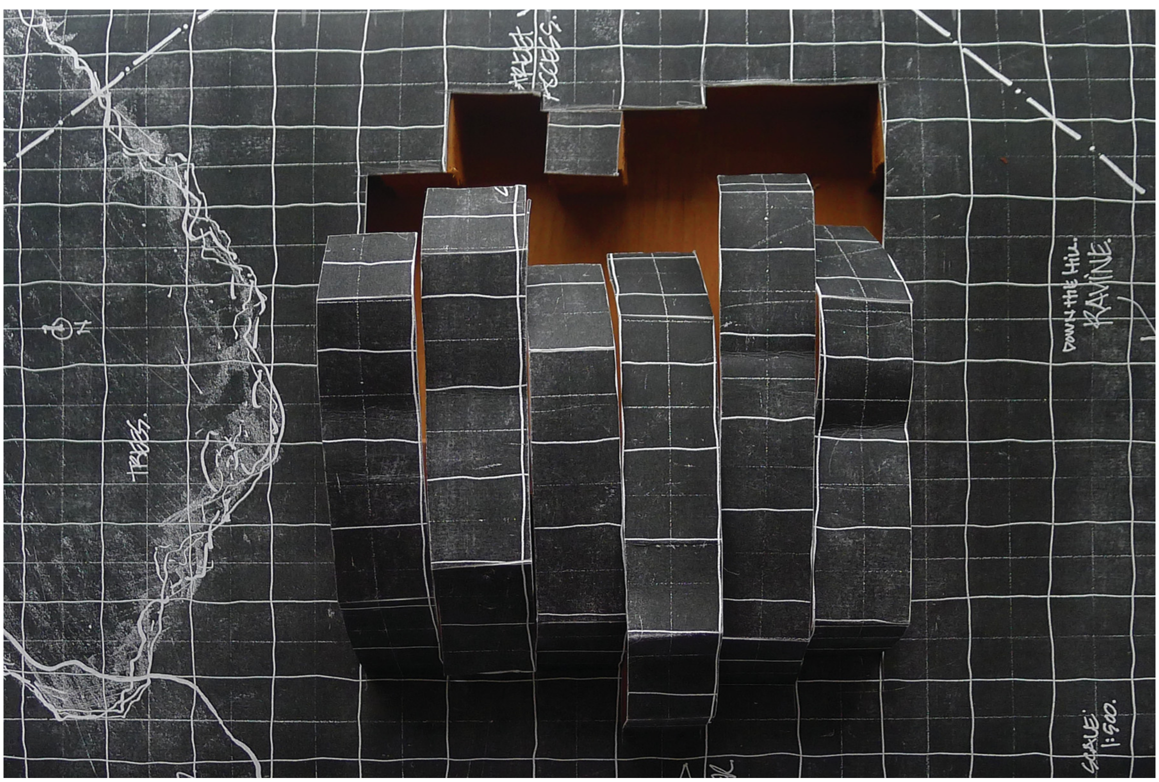
The use of model making led to how to best inhabit a site in constant excavation. By manipulating and adding to previous models an architectural language emerged. In the new models, the paper represents the ground surface and the volumes illustrate the clay mass. The folded paper corresponds to peeling surfaces giving shelter and direction to the architecture. Based on this logic, the project grain consists of relatively narrow bands going from south to north.



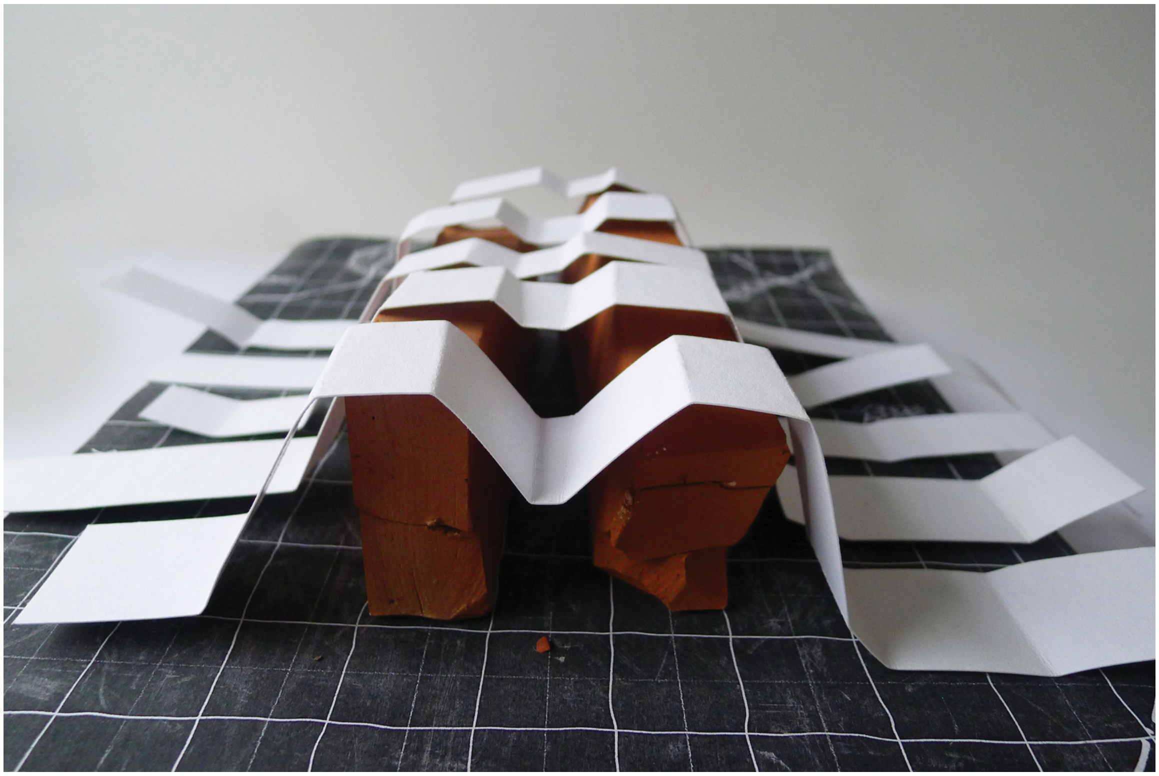
Model peeling the ground



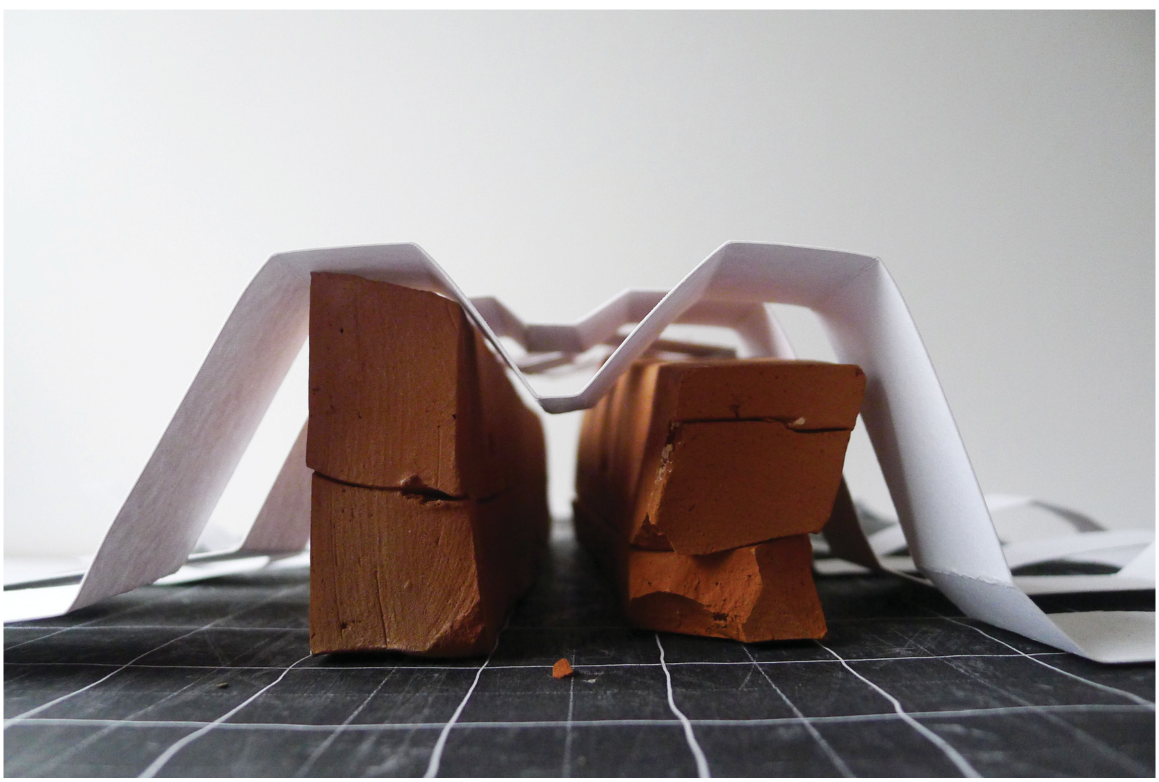
Model photo showing inhabiting under the peel



Top view model photograph



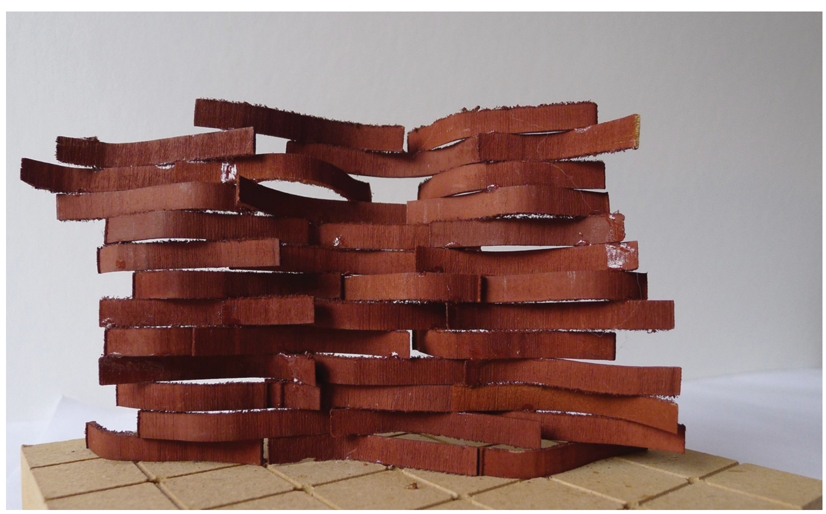
Peeling model showing potential gaps allowing for natural light



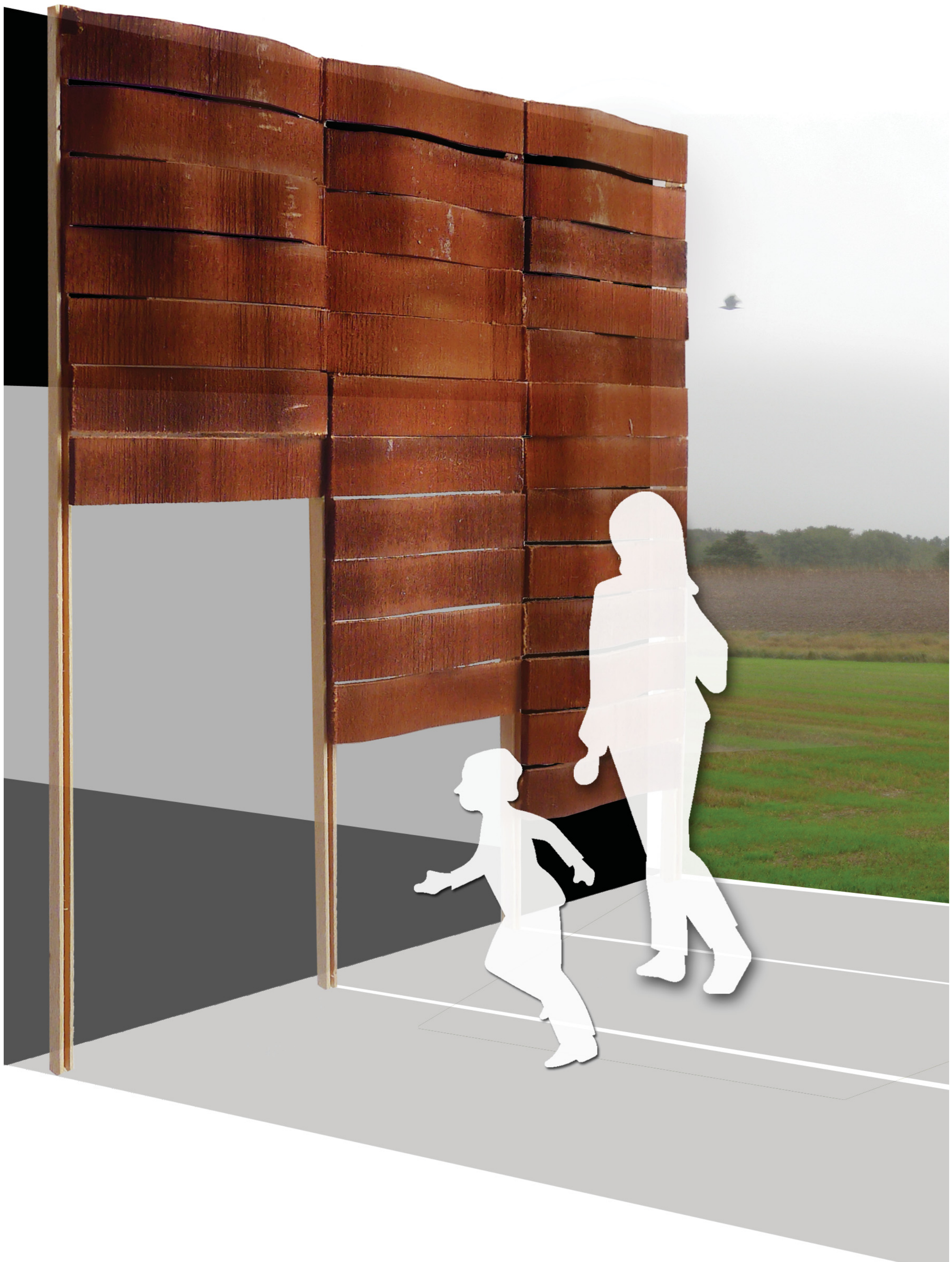
Side view model photograph

Ceramic Components

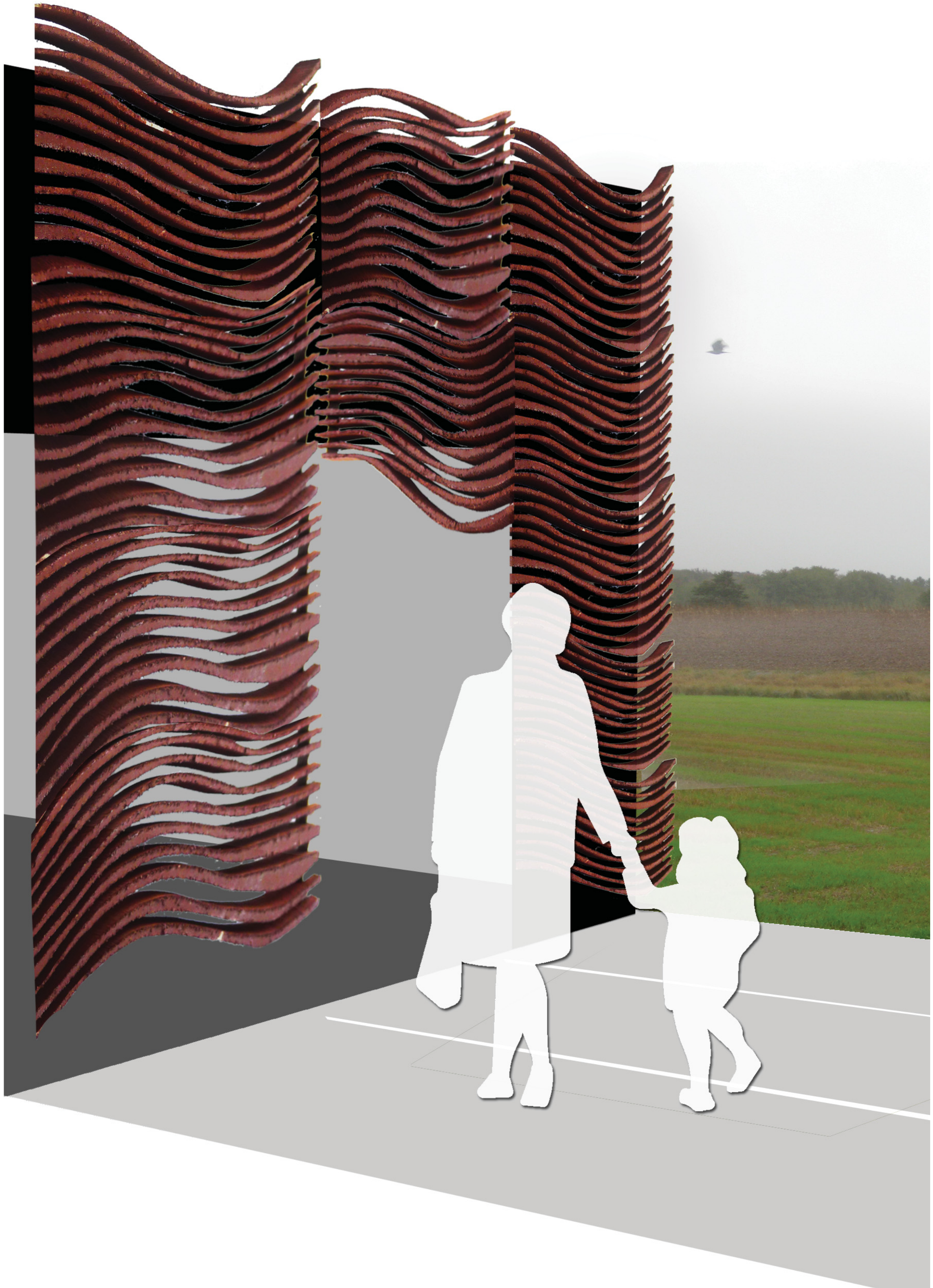
One of the design intentions is to express a continuous peeling band from the ground to the roof. The use of the same material throughout allows that reading. Within the peeling band the ceramic components have three applications; permeable ground surface, wall cladding and roof tile. The component's geometry is a result of its process. The size takes into account its weight and standard construction modules. The component should be able to be lifted by one worker. Its dimensions are 4 feet by 8 inches by three quarters of an inch thick. The components can be placed horizontally or vertically. Both orientations can act as a screen depending on the distance they are installed from each other.



Model exploring potential component surface configuration.



Photomontage of the facade condition with ceramics component placed vertically



Photomontage of the facade conditions with ceramics components placed horizontally

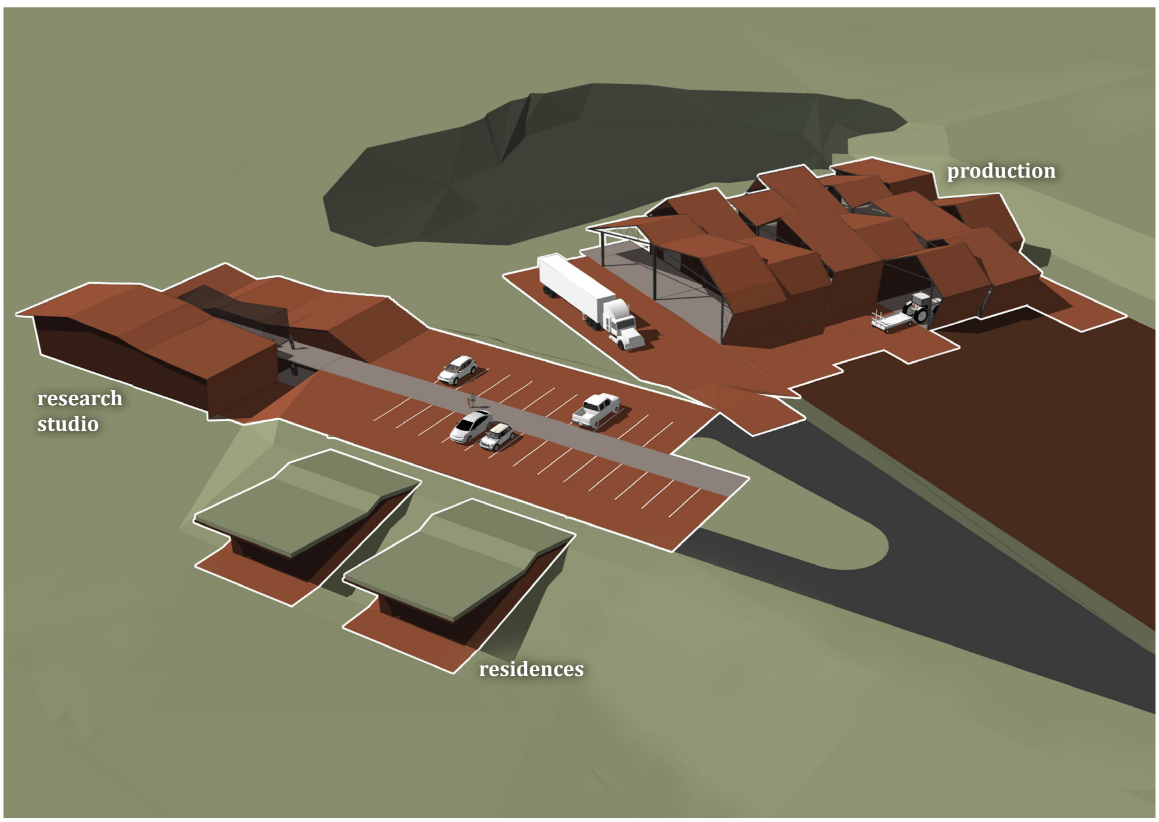
Siting

The neighbouring buildings located on the east side of the property are small houses. Acknowledging the scale of the surroundings, the project intends to not be visually imposing. The design interventions are concentrated in the northern area of the site, where clay is easily accessible and the topography is higher and away from the flood zone. The lower part of the site which is in the flood zone stays untouched. The site enables an on going excavation process in parallel to three construction phases responding to evolving programmatic needs.

The residences, built in the first phase, require privacy and comfort. Addressing those needs, the residences are placed further from the road, on the edge of the flood zone and sunken into the hill. The fenestration offers great southern light and views of the agriculture fields from the living area. Deeper in the plan and the hill the more private spaces are located.

The research studios, built in the second phase, require flexibility and variety in spaces that allows for discovery and sharing. The building responds to four main site conditions; the east side gives public access from the parking area, the west side faces the Annapolis River, the north side allows daylight without glare and a visual connection to the pond and the south side allows direct sunlight and views of the agriculture field. The building is composed of 2 volumes spaced from each other to create a gap in between. The south volume contains 2 levels, the kiln room and testing lab on the ground, and the offices on the second level. The north volume contains the studios and includes a kitchen, washrooms and a storage area.

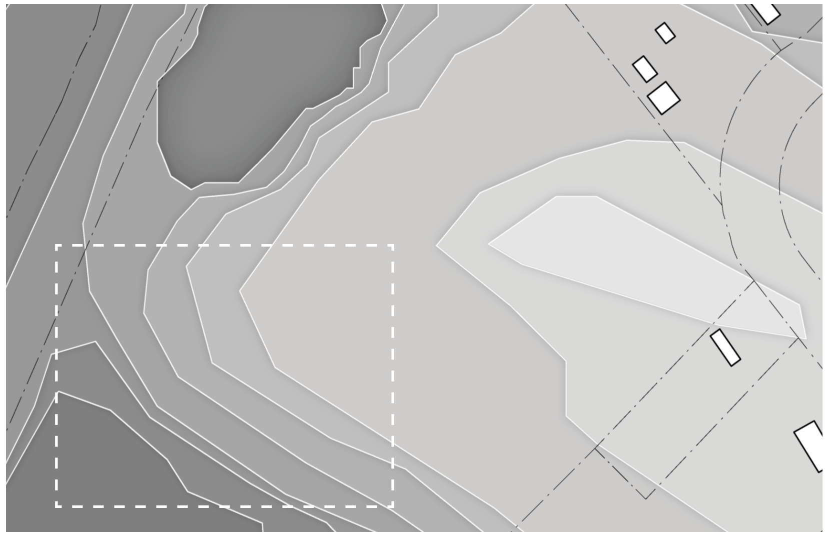
The production warehouse, built in third phase, needs large spaces that allow for movements and production flexibility. The warehouse is located close to the studio delimiting an exterior space for storage and transportation. It also facilitates access to the studio by the workers. Placed on the edge of the tree line, the warehouse provides 2 main interior spaces, a shaping area and drying and firing area.



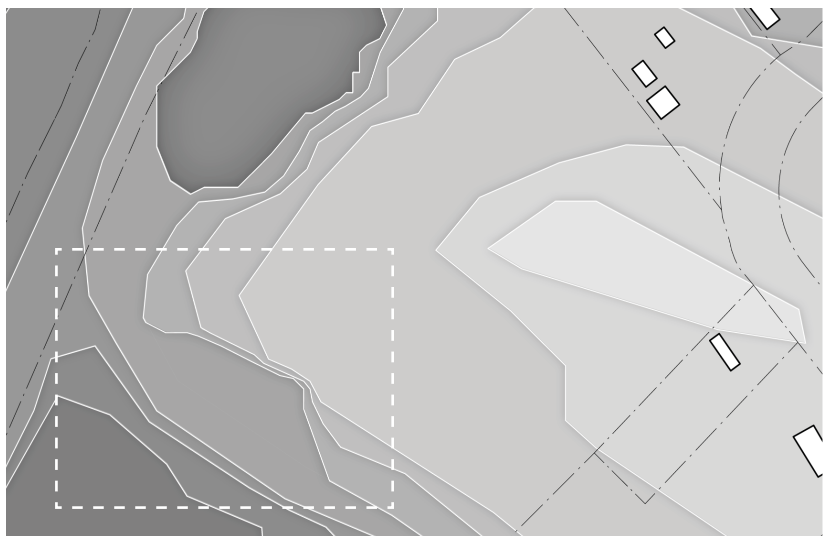
Program distribution

Site plan 1:4000

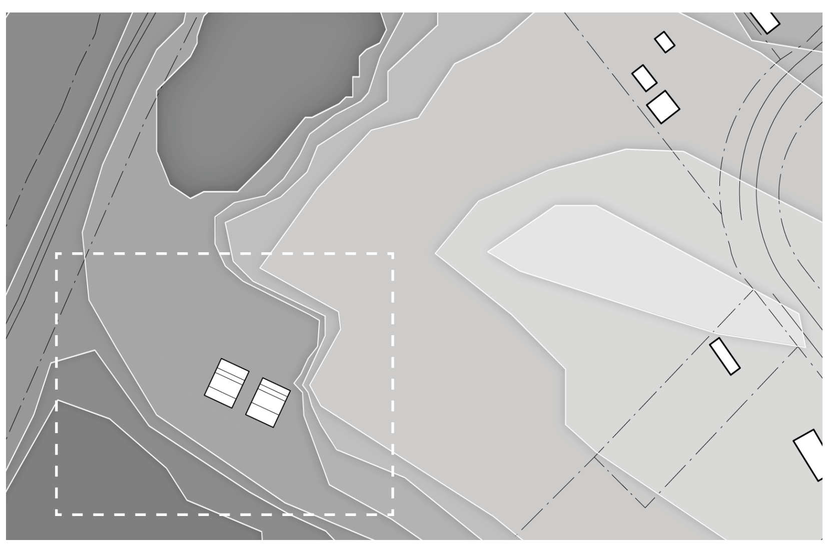
Site existing topography (1m contours)



Excavating the side of the hill for the residences

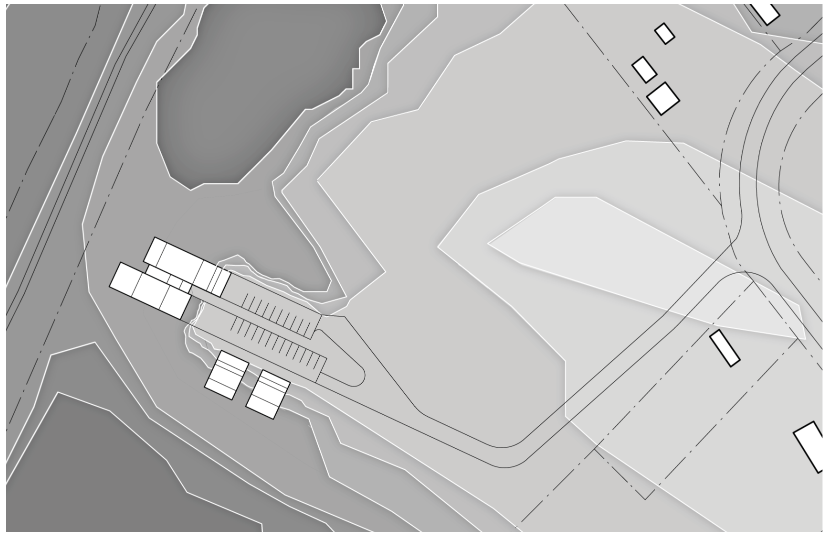


Built residences and excavating for the research studio

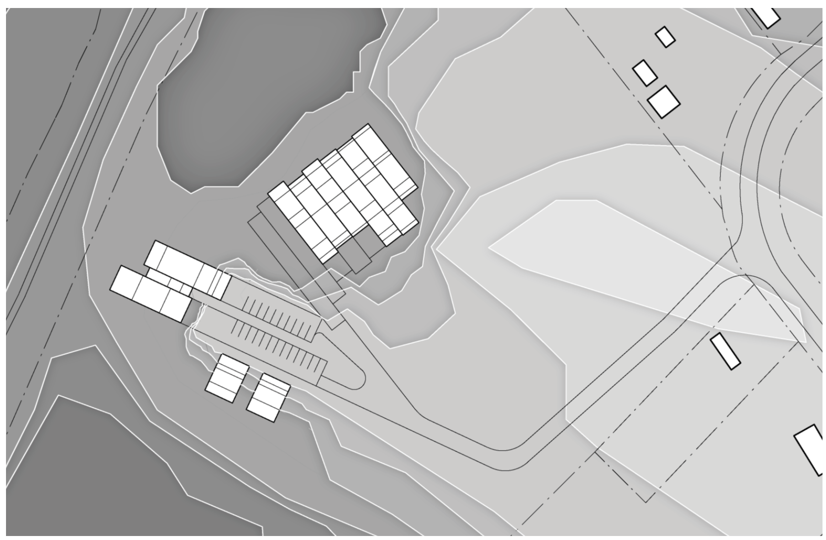


Site terrain evolution

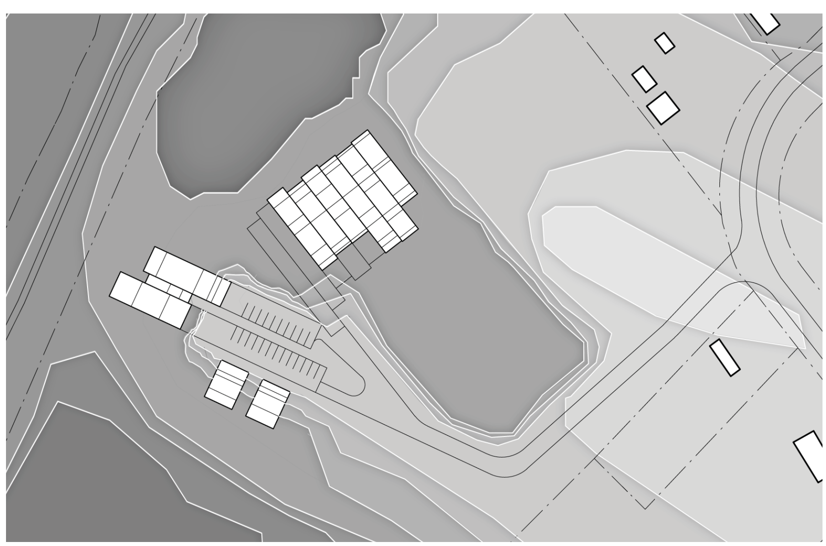
Built research studios and infill parking with organic materials



Excavating and building production warehouse

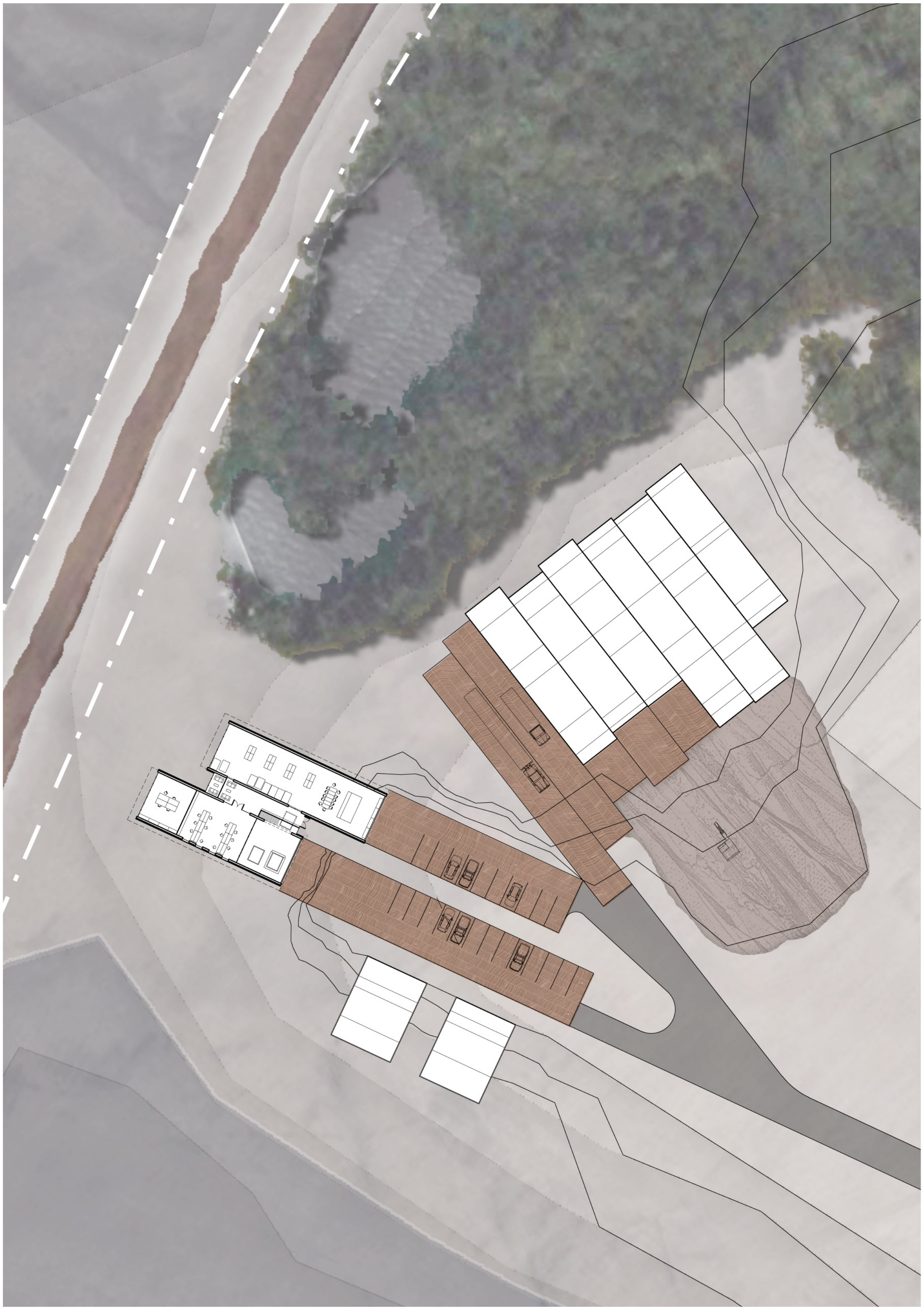


Ongoing clay excavation for production



Site terrain evolution

Site plan ground level

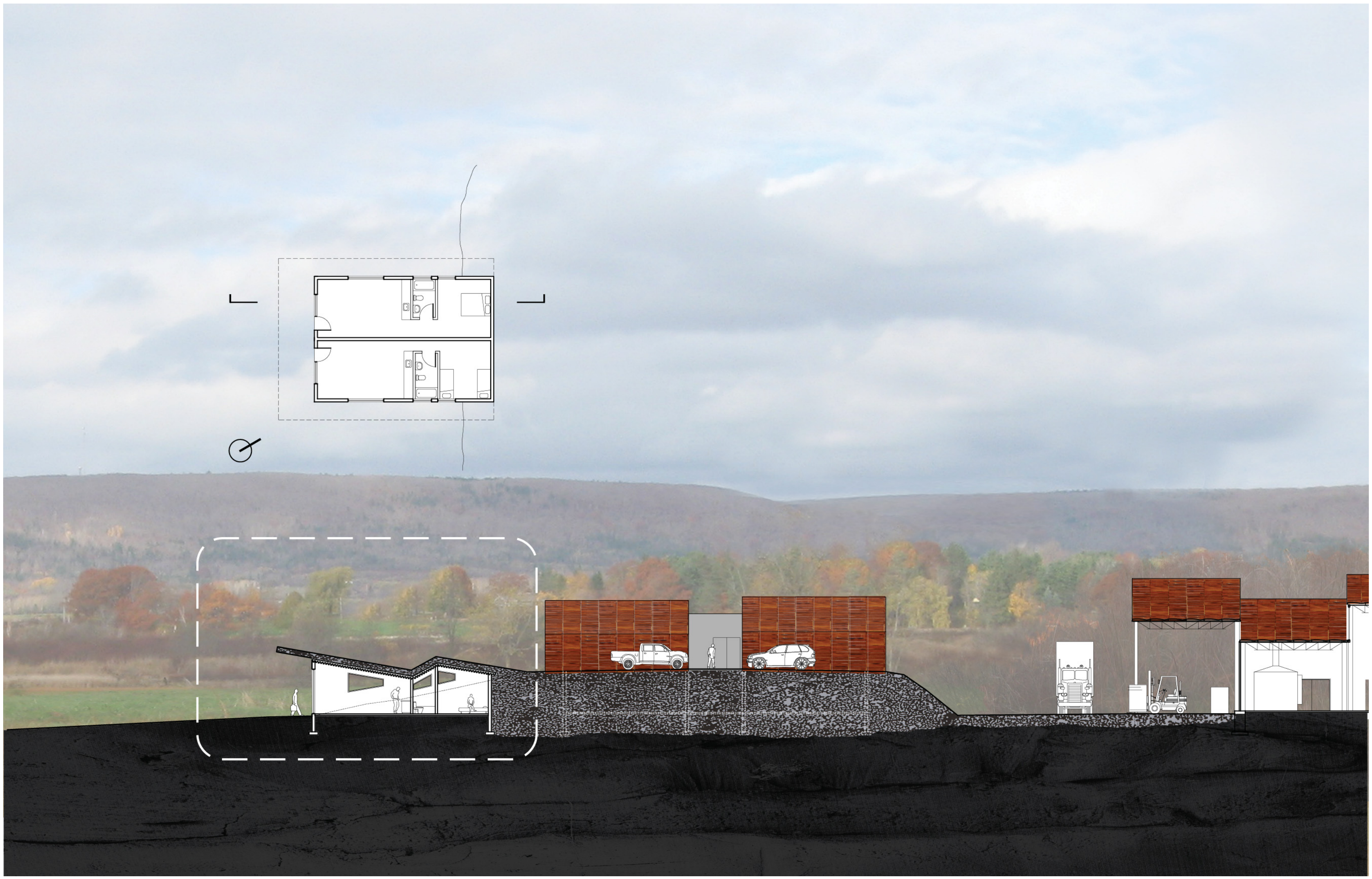


Site plan level 1

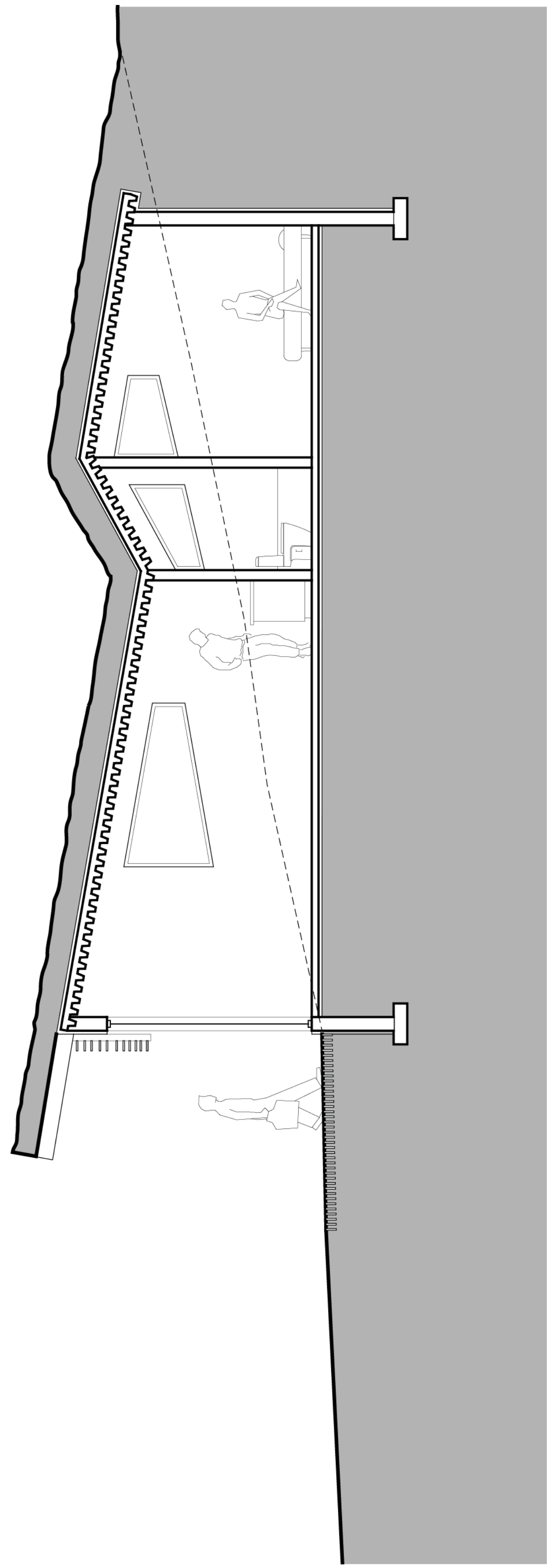
Spatial Experiences

The approach to the building initiates the spatial experience of the project. Three main user groups inhabit the site at different times. First, the external researchers and artists, second, the public from the community and third, the production workers. Each of these groups have a different sequence of tasks and events throughout the project. Therefore they have a different spatial experience. The researchers and artists live on site. They walk from the residences overlooking the fields to the research studios. They access them under the steel bridge on the ground floor. Inside the studio, a view of the pond is unfolding. The public driving to the site, first sees the excavation area from the road. Located between the rows of parking are some material prototypes being tested for their response to weather. The public access the studios from a bridge linking the parking to the building, revealing the ground level difference. Upon entering the building the heart of the ceramic process is revealed to them, a double height space opens down to the kiln room. The workers experience the daylight from the opening in the roof. For views and natural ventilation, openings at eye level are placed toward the pond.

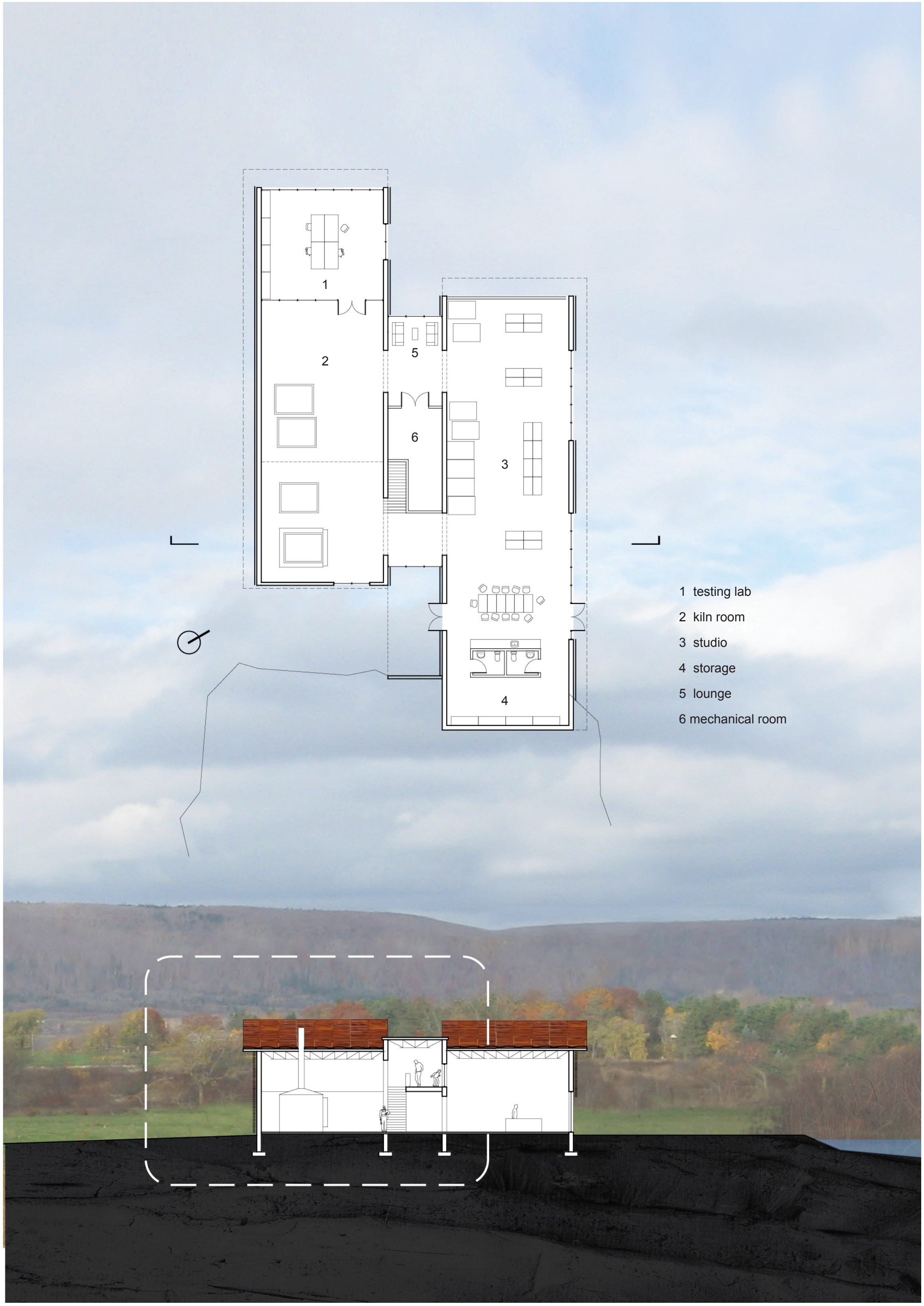
The interior materials are informed by structure. Even though the overall language of the buildings is consistent, the structural systems are different because of the variation in scale. The structure of the residences consists of rammed concrete walls and structural steel decking. The studio has a steel structure roof and rammed concrete structural walls. The warehouse is a steel structure which allows for disassembly and removal after excavation deposits are depleted.



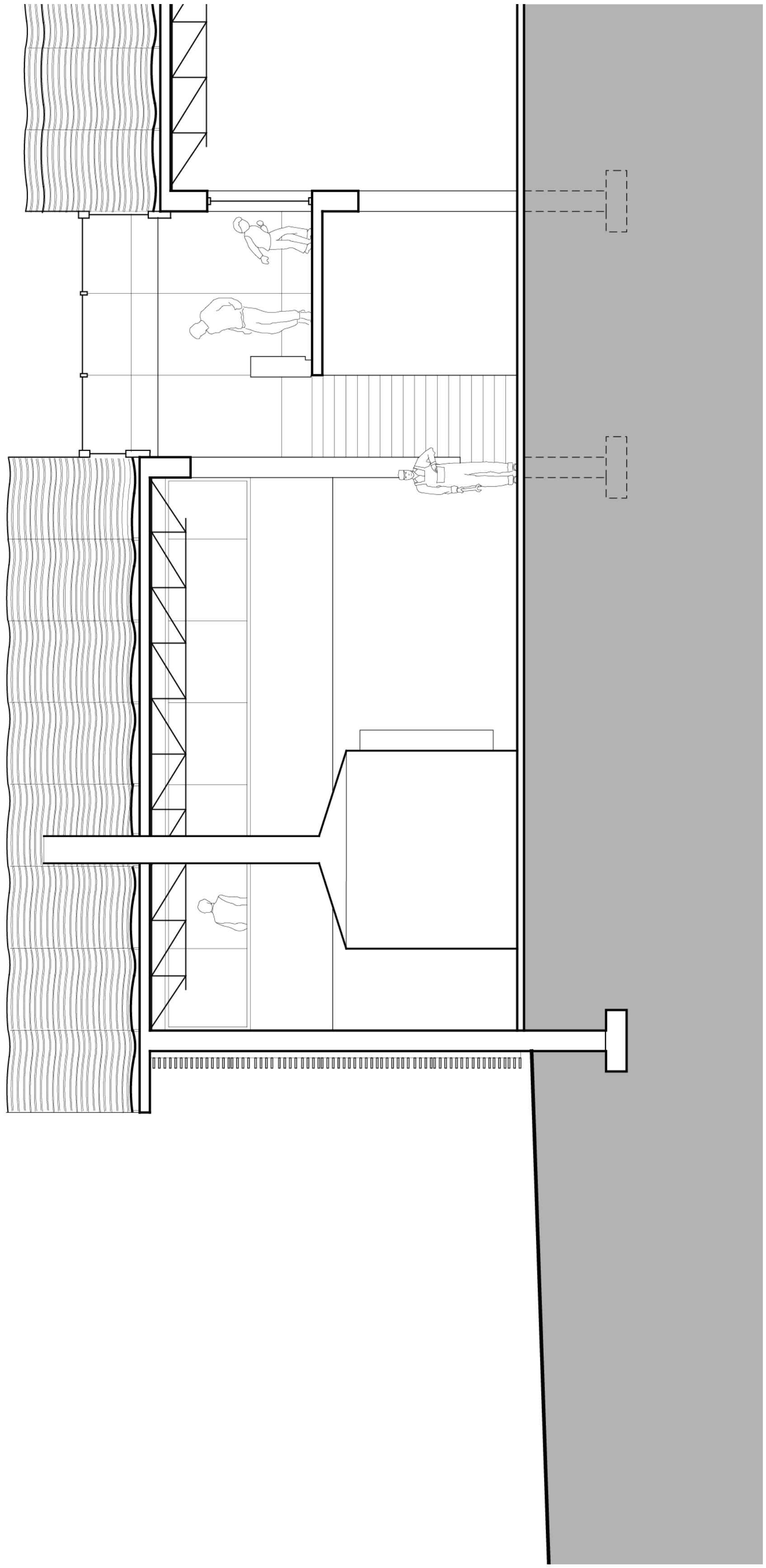
Plan and long section of the residences



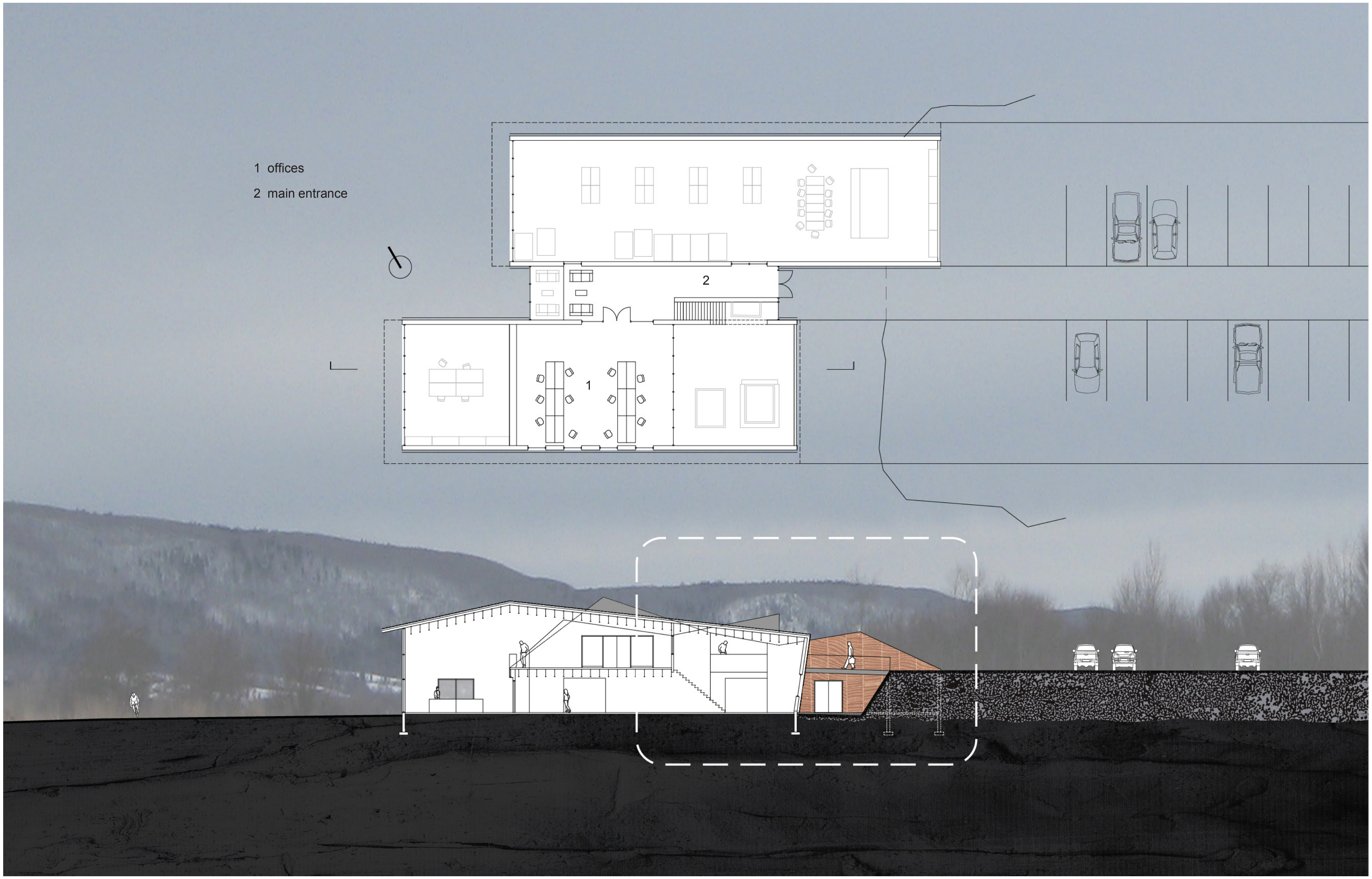
Zoom in residence section 1:100



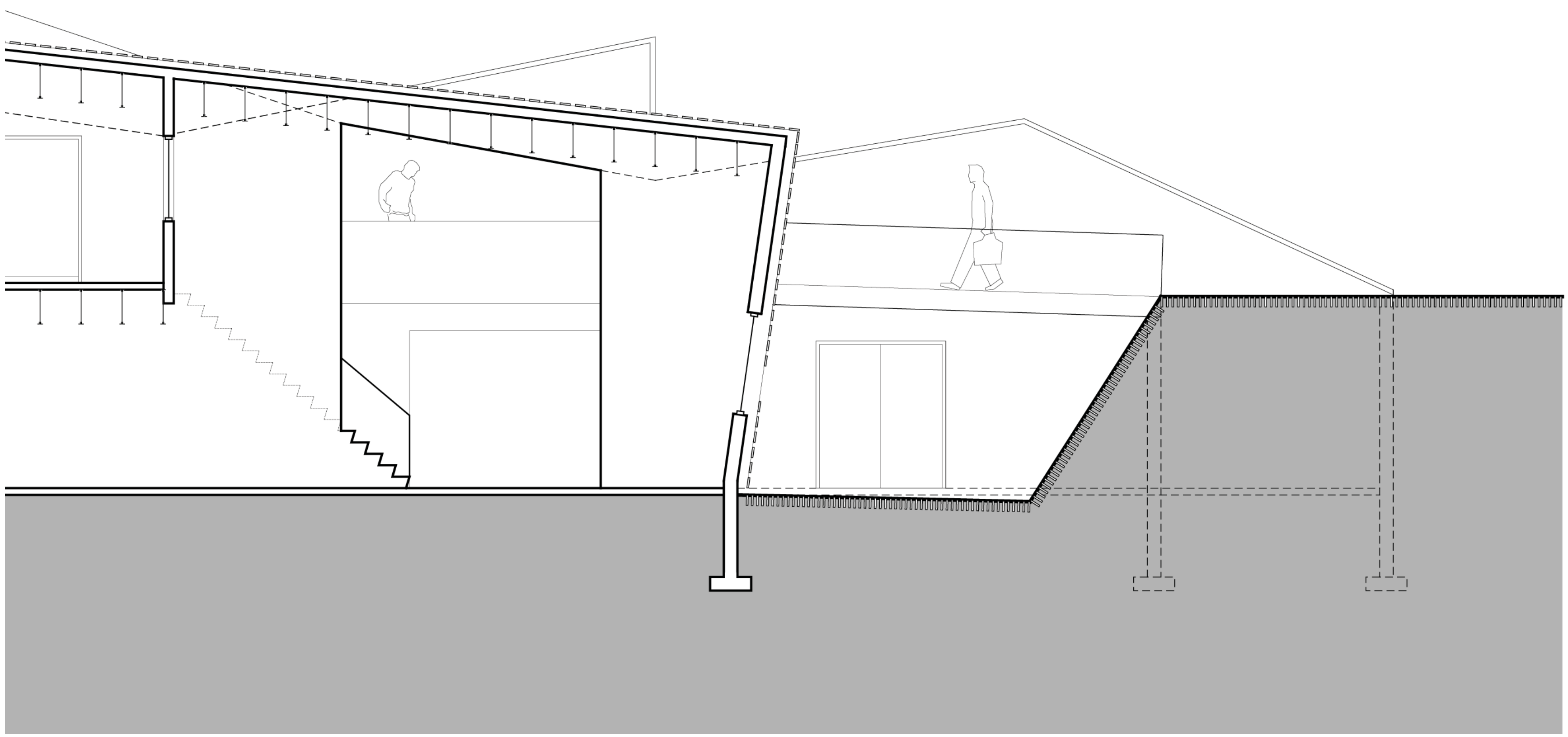
Research studio ground plan and short section



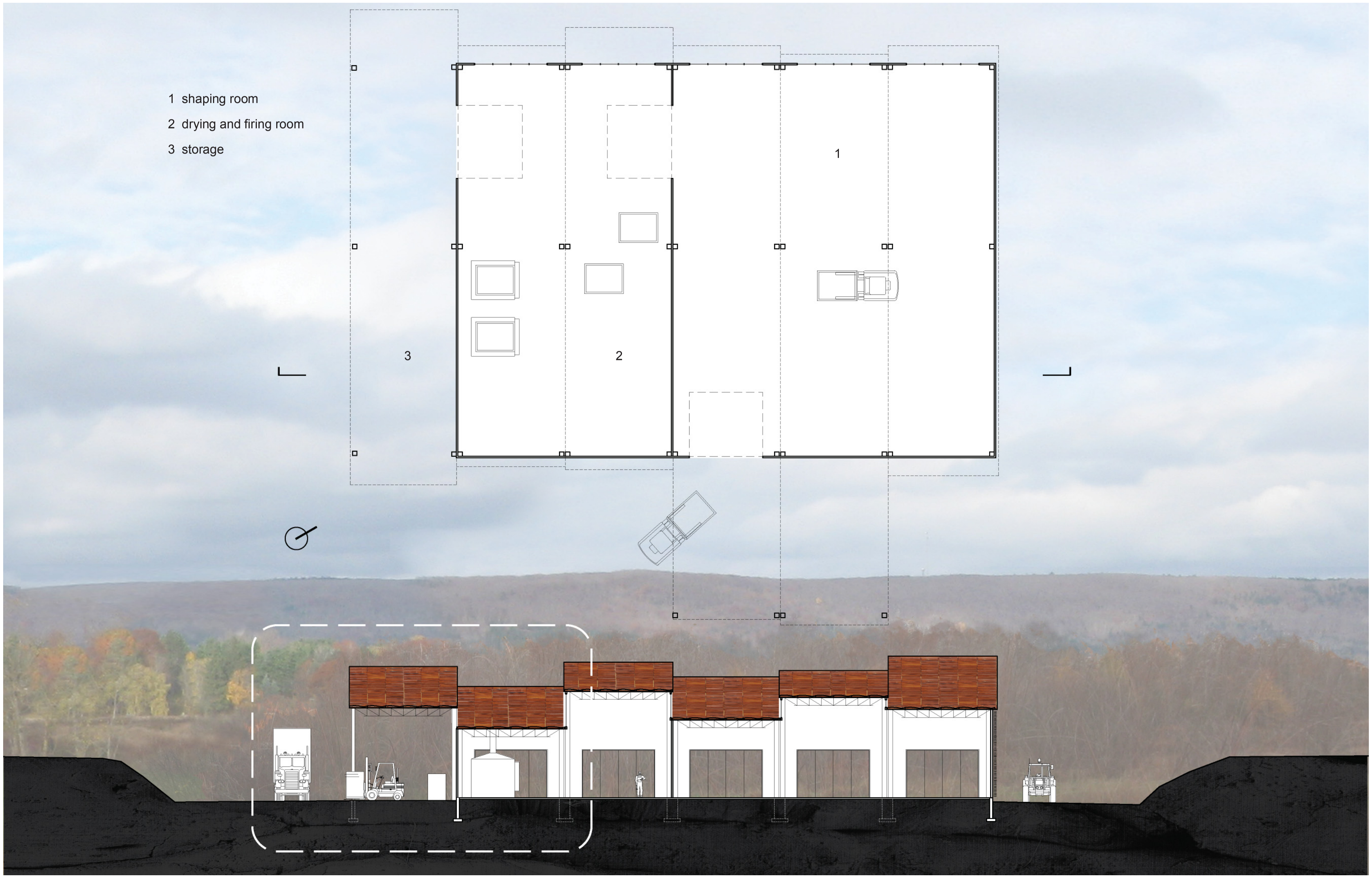
Fragment of the research studio section 1:100



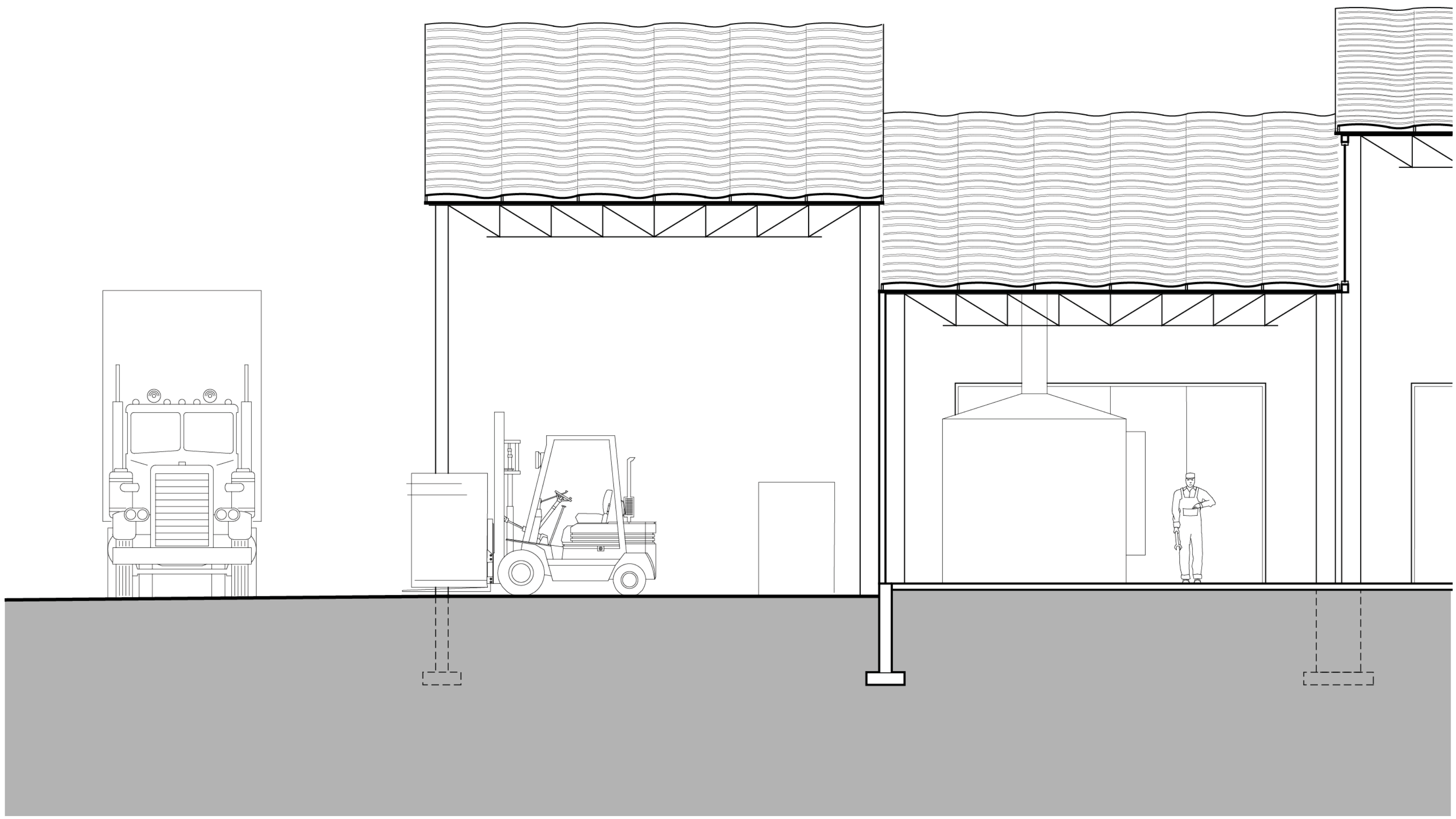
Research Studio First Level Plan and Long Section



Fragment of the research studios section 1:100

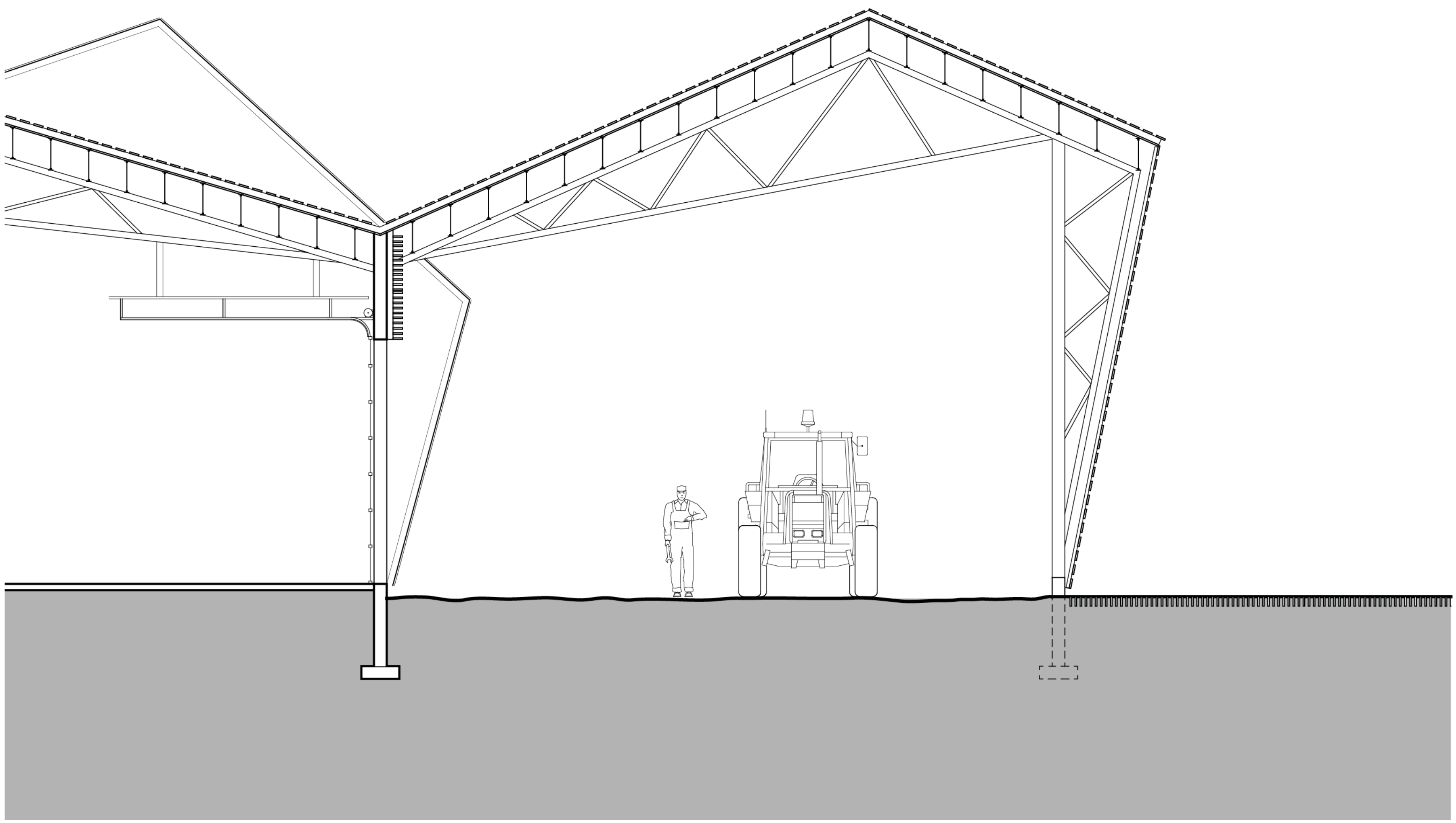


Plan and long section of the production warehouse



Fragment of the production warehouse section 1:100

Plan and short section of the production warehouse



Fragment of the production warehouse section 1:100

CHAPTER 6: CONCLUSION

The study of building with ceramics revealed the purpose and potential of ceramic components in architecture. The study demonstrates potential for a continuous ceramic component from ground to roof, as well as the use of mortar-free connections to steel substructure instead of mortar bonding.

The study of Nova Scotia's ceramics showed the relevance of geological layers within site study in architecture. The geological layers of the site informed the landscape and settlement patterns, and therefore also informed site activities. This study communicates the connection between landscape and the architecture, using the peeling gesture, massing and project grain.

This study explored the process of making ceramics in relation to the development of site strategies and components in architectural assemblies. It helped to develop a new excavation process, clay peeling. The project provided three building scales, responding to an evolving program that welcomes ongoing research and innovation.

I believe the design project demonstrates how material plays a key role in linking site, program and construction, allowing for a meaningful project. As mentioned by Zumthor, architects make "meaningful situations" for materials. This design approach attempts to implement this sentiment.

BIBLIOGRAPHY

ArchDaily. Central St Giles Court / Renzo Piano & Fletcher Priest Architects. accessed January 28, 2013. http://www.archdaily.com/104147.

Bing. Aerial Image of Bridgetown. 2012. http://www.bing.com/maps.

Brand, Stewart. *How Buildings Learn: What Happens After They're Built*. New York, NY: Viking, 1994.

Coward, Elizabeth Ruggles. *Bridgetown, Nova Scotia; Its History to 1900*. Kentville, NS: Kentville Pub. Co,1955.

Deplazes, Andrea. *Constructing Architecture: Materials, Processes, Structures: A Handbook*. Basel: Birkhäuser, 2005.

Frampton, Kenneth, and John Cava. *Studies in Tectonic Culture: The Poetics of Construction in Nineteenth and Twentieth Century Architecture*. Cambridge, Mass: MIT Press, 1995.

Geli, Enric Ruiz. Photograph of Villa Nurbs, Castelló d'Empúries, 2009. www.ruiz-geli.com.

Gouthro, Suzan. *Properties and Uses of Nova Scotia Clays and Shales*. Halifax: Department of Mines and Energy, 1989.

Heatherwick, Thomas. *Thomas Heatherwick: Making*. New York: The Monacelli Press, 2012.

McDonough, William, and Michael Braungart. *Cradle to Cradle: Remaking the Way we Make Things*. New York: North Point Press, 2002.

Minke, Gernot. *Building with Earth Design and Technology of a Sustainable Architecture*. Basel: Birkhauser, 2006.

Mori, Toshiko. *Immaterial/ Ultramaterial: Architecture, Design, and Materials*. Cambridge, Mass: Harvard Design School in Association with George Braziller, 2002.

Nova Scotia Department of Natural Resources. "Map of Surficial Geology of the Province of Nova Scotia" [map]. 1:500,000. Halifax: Nova Scotia Department of Natural Resources, 1992.

Nova Scotia Department of Natural Resources. "OFM 1998-002" [map]. 1:50,000. Halifax: Nova Scotia Department of Natural Resources, 1998.

Nova Scotia Government, "Annapolis County" [GIS Data]. 1:10000. NSTDB [ArcView]. 2012. Halifax: Province of Nova Scotia, 2012.

Pye, David. *The Nature and Art of Workmanship*. London: Cambridge University Press, 1968.

Rhodes, Daniel. *Clay and Glazes for the Potter, Revised*. Radnor: Chilton Book Company, 1973.

Sennett, Richard. *The Craftsman*. New Haven: Yale University Press, 2008.

Wilson, Hewitt. *Ceramics Clay Technology*. New York: McGraw-Hill Book Company, 1927.

Wright, H. Millard. *Building Nova Scotia Brick by Brick*. Halifax: Etc. Press, 2004.

Zumthor, Peter. *Thinking Architecture*. Basel: Birkhauser, 2002.