Building With Trees: Steps Forward in Forest Informed Design

by

Benjamin Goldsmith

Submitted in partial fulfilment of the requirements
for the degree of Master of Architecture

at

Dalhousie University
Halifax, Nova Scotia
June 2022

Dalhousie University is located in Mi'kmaq'i,
the ancestral and unceded territory of the Mi'kmaq.
We are all Treaty people.

To

Michael Neelin,

A life long mentor and great friend. You sparked my interest in architecture and specifically timber building. You continue to be a great role model and it has been an honor to have learned from you.

Rest in peace

Contents

Abstract v

Acknowledgements vi

Chapter 1: Introduction 1

- Forest Informed Design: The Art 1
- Precedents, Intentions in the State of the Art 1
  - Ben Law 1
  - Hooke Park 4
  - Whole Trees Structures 5
- Questioning the Method 7
- Proposing a New Method 8
  - Building Store vs Found Object 9
  - Connecting with the Material 10

Chapter 2: Furniture and Form 11

- SPF Bench 11
  - Process of Making 11
  - Distiniguishing Features 16
  - Structure and Grain Orientation 17
- Forked Tables 18
  - Process of Making 18
  - Crafting with “Waste” Pieces 24
- Willow and Oak Benches 24
  - Process of Making 24
  - The Curve 30
  - Moving Away From the Scribe Fit 30
- Material Distinction 32

Chapter 3: Detail and Assembly 33

- 1:2 Wall Section Model 33
- Puncheon, Mass Timber Floor 34
  - Critiquing the Mass Floor 34
  - Making Puncheon Floors 35

Forked Braces 37
Roof Structure and Bracing 37
Constructing The Model Frame 40
Chapter 4: Building Scale 46
Forest, Logging, and Site 46
Logging and Outdoor Recreation: A Narrow History of Site 47
Logging in Cottage Country 48
Chapter 5: Conclusion 56
Summary 56
Continued Exploration and Call to Action 57
References 59

Abstract

This thesis builds on the roundwood construction methods of Ben Law, the experiments with grown form carried out at Hooke Park, and the forestry-to-building integration by the firm Whole Trees Structures. All three feature structural frames of grown timbers evoking the forest, with the bulk of lumber remaining industrially processed. Further integration of grown timber is impeded by the volume of data involved in measuring, working, and fitting to grown forms.

Two advances are proposed in forest-informed design. The first introduces standoffs to simplify fitting – and sharpening the contrast between geometries. The second is to bypass the fitting problem by using puncheons, timbers flattened on the “working” side and flattened to lateral fit. Puncheons eliminate much sawing and waste, reduce energy inputs and improve carbon sequestration as compared to conventional mass timber.

Investigations were carried out through demonstration models, furniture making, and a building design.

Acknowledgements

Over the course of this thesis I had the opportunity to work, meet, and learn from a number of incredible people and organizations. The work presented here would not have been possible without the help of Emanuel Jannasch, Michael Putman, and Regan Southcott.

I would also like to thank:

‘The Deanery Project’ and Ron Bugelle for providing material to work with

The community at ‘Gracefield Christian Camp and Retreat Centre’

and of course countless friends and family members for their continuous support and keeping me inspired throughtout the process.

The help and love from all of you does not go unnoticed. Thank you

Chapter 1: Introduction

Forest Informed Design: The Art

Forest informed design learns from the inherent qualities of wood by utilizing a material first approach to working, building, and designing. It is in the recognition of the relationship between the forest, the tree, and the building that each influence and inform the others. Forest-informed design is a process and way of thinking that articulates and strengthens that relationship.

Precedents, Intentions in the State of the Art

Some key players in this area of work include teacher, builder, and designer Ben Law of the United Kingdom; The research at the Architecture Association's woodland campus 'Hooke Park,' also in the United Kingdom; and a multidisciplinary firm out of Wisconsin 'Whole Trees Structures.' We take these as the state of the art in the field. However, all three work off simple oppositions between grown form vs sawn lumber and a sharp divide between high- and low-tech methods of analysis and construction.

This thesis calls attention to material qualities of grown and sawn lumber beyond a simplistic opposition, explore other ways of reconciling industrial and grown geometries, and it ultimately aims to expand our relationship with wood as a material.

Ben Law

Certainly, on the low-tech end of the spectrum, the analysis of material is done simply by walking through the forest and looking for standing trees of suitable size and shape. Harvesting material, assembling frames, and raising the

building is all done on site with basic tools used in heavy timber building (chainsaws, drills, and other handheld tools). building is all done on site with basic tools used in heavy timber building (chainsaws, drill, and other handheld tools)

“A” frame bents assembled and stacked on the ground prior to raising the structure with ropes and pulleys. (Mcloud 2003)

The standing frames. Guidelines and temporary bracing are holding the structure in place. (Law 2022)

Cross bracing utilizing the sweep of the two trees (Law 2022)

The standard frame used by Ben law prioritizes largely straight members left in the round for the main structure. The bracing between bents is done with two members in an x pattern utilizing the sweep present at the base of the tree, this connection appears to mimic the look of a natural fork (Law 2022).

Hidden in the walls is the use of light wood framing set in line with the roundwood posts to create the enclosure. The exterior is then clad with a live edge slab board and the interior a plastered strawbale wall seemingly denying the presence of the stud wall within (Law 2015).

Wood siding over stud wall behind and scribe fit around grown form posts (Mcloud 2003).

Straw bale insulation on the interior eliminating any expression of the stud wall. Still from video (Law 2015).

Interior of Ben Law's "The Woodland House"(Law 2022).

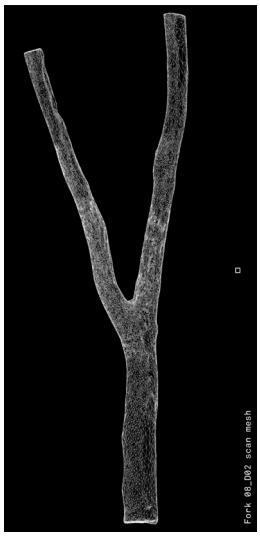
Ben Law exemplifies the accessibility to building with round wood proving its potential without the use of complex tools, working with local materials on site, and the ability to maintain healthy woodlands within the building industry. However this precedent lacks the expression of more complex grown forms and relationship between the grown form and sawn lumber.

Hooke Park

Lidar scan of a single standing ash tree (Wilson 2019).

Hooke Park is well-funded and well supported by specialists from the University of Bath, Buro Happold, and elsewhere. It represents the opposite end of the spectrum from Ben Law, relying heavily on high tech methods of working.

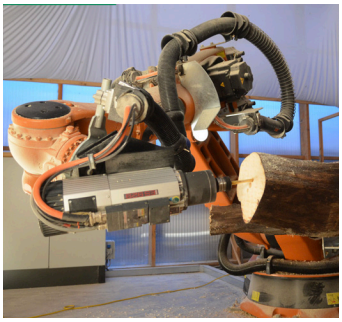
The school uses a digital inventory of the forest acquired by using a lidar scanner to document the property and then assign a code to each tree. From that model trees are selected based on their size and shape. After felling, a robotic arm cuts the joinery based on digitally modeled forms.



Catalogued scan of a single tree fork. (Hooke Park 2016).

Image taken from the Lidar scan of forest (Hooke Park 2016).

Each machine cut component can then be joined together by hand. Former warden of Hooke Park, Zachary Mollica, notes that the precision of the robotic arm is not fully manifest in green wood as the wood is still shrinking, de-stressing, and de-forming. So, despite such precise ways of working it is still common to be reworking joints by hand or using a sledge to get each timber in place (Mollica 2022).



Robotic arm acting as a multi axis CNC machine capable of cutting incredibly precise geometry (Hooke Park 2016).

Tree forks being assembled. Notice the large rubber mallet and sledge hammer on the right hand side of the image (Hooke Park 2016).

Whole Trees Structures

Whole Trees is a multi-disciplinary, vertically-integrated firm which provides digital models, specs, and wood grading based on scans of large tree members.

By creating accurate photogrammetric scans after the tree is felled, whole trees create digital models compatible with BIM software. Between this and the ability to have the company wood graders and engineers evaluate the wood members, Whole Trees makes the use of grown-form structural members much more feasible in large scale buildings.

Processing of Material

Trees selected and felled by Whole Trees are debarked in order to allow a more accurate representation of material form for structural analysis, to visually reveal the condition of wood, and to eliminate debris and gravel from further processes. The tree is then photographed or scanned in order to be digitally modeled, x-rayed for grading, and posted to market. Once the design is set, joints are cut by hand, in comparison with the hand-correction of machine cut joints as seen at Hooke Park. The hand-cut joints maybe more responsive to the dynamic material and economize on technology.

Debarking a fork (Whole Trees 2018)

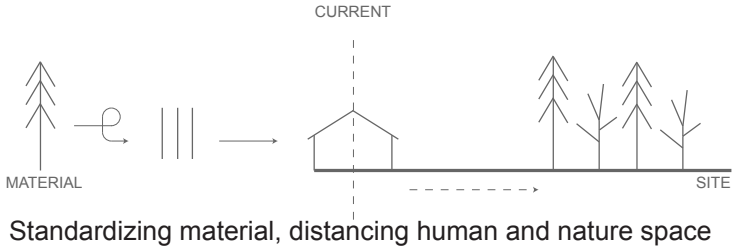
Digital model from a scan of a felled tree. (Whole Trees 2019)

Scanning a felled tree. (Whole Trees 2019)

Questioning the Method

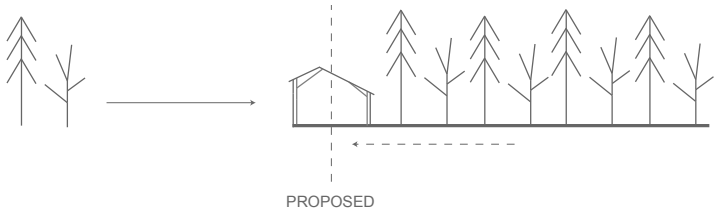
It is often said that going to a cottage or retreat space is a restorative act, a place to reconnect with nature. The term “Nature” implies an unnecessary distinction between humans and the environment on which we depend, that nature is something other than us (Morton 2019). Yet we acknowledge the need to connect with nature.

The term “renaturing” is becoming increasingly relevant within the building context and is defined as restoring to a normal condition (*Merriam-Webster* 2022). The broadening of this term I believe to be incredibly important as it is not only applicable to the connection of built forms and nature but the internal feeling a person has when entering natural spaces. Renaturing is felt at a number of scales and needs to be acknowledged as such.



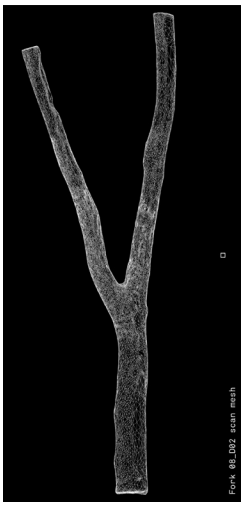
Standardizing material, distancing human and nature space as typical practice.

Our standard building practices are ignorant to that relationship, distancing humans from natural space at the scale of material, inhabitation, and site. This would be true even within many of the spaces intended for reconnecting with nature. First the large clearing of a building site and creation of a manicured landscape defining the border of the two spaces. Second the heavily industrialized processing of a once-organic material to make standardized wood building products formally foreign to their origin and in the case of a retreat space the surrounding environment.



Bridging gaps between the built and forested environments

Each board must be a unique cut attempting a scribe fit to the round posts (Mcloud 2003).



Highly detailed geometry captured within the digital model (Hooke Park 2016).

Louis Kahn speaks to the brick, famously asking what the brick wants to be (Lesser 2017, 5). We could ask the same question of a tree. Here the answer is more complex, because we can interact with material at several stages: from its most natural state, its initial form, prior to being moulded or sawn into a form we find more manageable. It's more like asking the clay what it wants to be: the answer would certainly change as proven through the art of ceramics. The formation of the brick or the squared lumber of any size is a great simplification of the inherent character or potential complexity of the material. The advantage squaring gains us is tremendous flexibility in recombining the materials into a whole – though at the cost of energy inputs (Jannasch 2004). Mapping, handling, and assembling more complex forms saves energy, but at the cost of information processing: the scanning and cutting and fitting, whether manual, mechanical, or computational. It is my belief that information and energy inputs can best be reconciled through active collaboration with material.

Proposing a New Method

> Before I fell a tree in the forest, I talk with him for a while to ask permission to fell him. I tell him why I want to do this and what I plan to make out of him. 'Meet you soon' I say -Andres Uus (Klein 2020, 57).

Uus speaks to the collaboration and respect between a material and craftsperson. When a connection is formed the material fosters improvement in the skills of the craftsperson,

and the crafter reveals the beautiful potential of the material. As exemplified in the words of Uus that relationship begins with a respect for tree, an understanding of origin and qualities. Asking permission being the consideration of if the tree is ready to be felled, contemplating the need to fell the tree, and what purpose the material may serve, deciding if this is the right tree for the job. The meeting is the collaboration between the crafter and the material getting to know each other allowing both to perform their best.

Building Store vs Found Object

The forest is the origin of wood as a material, each a unique habitat and assembly of natural elements. Analyzing the forest as a source of building material my initial metaphor was a building supply store. The trees standing both for the organizing aisles as well the products on its shelves. The forest held the building elements available. On further reflection of this analogy the abstraction became increasingly unfit. The building store implies a much higher level of standardization and predictability. It is with the quote again from Andres Uus telling the tree “meet you soon,” (Klein 2020, 57) that I realize the forest is a place of found objects. Tim Ingold’s “The Materials of Life” (2013) describes a student exercise in which each students picked an object they came across during their day and brought them back to the group. Each one with its unique qualities and stories shared in the group: telling where the object was found, inferring how it got there, and an analysis of any hints of its life left behind. Such thorough investigation convinced me that this is the appropriate method for working with the forest. The crafter must look for hints of its life, understand its life before writing the next chapter of its story. Understanding the clues found by analyzing a piece informs us whether or

how it may be used. Forest-informed design is a proposed method working with the thoughts of the “found object” and the material approaches of Louis Kahn and Andres Uus.

Connecting with the Material

The visual presence of wood in building has been found to relieve nervousness, lessen stress and have a calming effect on the mind and body (Kotradyova et al. 2019, 17). This is thought to be due to a human familiarity with the material and nature. When explaining this Kotradyova explicitly calls on the need for this understanding with architects and designers, stating:

> It is necessary to educate architects and interior designers about the benefits of using wood …Interiors designed on principles of humanization can help with reducing such negative effects. (Kotradyova et al. 2019, 18)

The study conducted is discussing wood products that would have come from a mill however if it is to be accepted that the calming characteristics come from a connection to a “natural” material it is my hypothesis that the same would be true or even enhanced using grown form wood.

Chapter 2: Furniture and Form

The furniture scale explores material assembly, processes, working with roundwood, and demonstrates the influence of grown form wood when using the found object method. Within these demonstrations the important lessons include material stand offs which not only simplify the assembly but emphasize material contrast between sawn and grown form; as well as the beginning notions of the puncheon strategy which minimizes flat surfaces to only where they are needed which reduces the influence of industrial processes on material form.

SPF Bench

Process of Making

Begining with a pine log of typical form to the species it came from, the Eastern White pine often has trunks and branches with many irregular twists or curves. The question being how to best utilize these forms. The wood is then cross cut in order to seperate the two curves present in the original member.

Single pine log

Isolating the curves from the pine log

Single curved Pine member fastened to a jig in order to prevent the log from rolling while being cut.

Making the cut. The inside of the curve is being cut using the jig above. Photographed by Regan Southcott.

In the top of the image is the wood being removed and the outer curve still mounted on the jog. This is an intial look at the concept of minimizing the amount of wood cut. Very little wood is removed to create the flat surface intented to be the seat of the bench, whereas the underside or out curve remains intact.

The bench components. On the left the two curved members fastened by machined dowels. On the right are the four legs cut to length and sanded.

Using a draw knife the spruce bark was removed and material taper exaggerated. On the left a section simply cut from the spruce pole. Moving to the right is the process of coming to the final form prior to sanding.

Top view of SPF bench

Side view of SPF bench

Front view of SPF bench

Distiniguishing Features

Spruce

Spruce legs:The knots typically wrap the tree creating a ring of branches.

Many spruces and balsam fir generally grow with a straighter trunk and consistent taper than that of white pine. The design of the bench highlights the almost straight form by using the spruce only in the legs of the bench and exaggerating the taper slightly to make the overall form more noticeable even at the short length of the legs. Other notable difference between the spruce and pine can be seen in the location of the knots/areas that once were budding branches or stems of already grown branches. Spruces and especially balsam fir generally grow branches in clusters and are symmetrical. The eastern white pine grow much larger asymmetric

branches (typically the majority growing on the opposite side to the predominant wind).

Pine

The pine seat shows the asymmetry of branches present in the species. notice the single knot on the right side.

Unlike various spruce species, pines such as the jack or eastern white pine have large noticeable bends or curves in sections of their trunks. By utilizing forms found in irregular species and specimens, forest-informed design becomes increasingly dramatic. Assembly strategies are needed that can be repeated and easily modified to a particular context. The curved beam idea works on a number of levels the first being a general structural fact: a wooden beam requires more depth towards the center of the span to resist bending forces than is needed at the ends to resist transverse shear.

Structure and Grain Orientation

The ring grain pattern shows where grain is exiting the wood, this is the end grain.

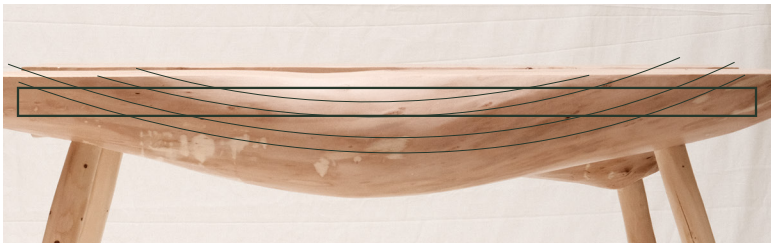
Curved members would typically be seen as a waste product within the standard methods of wood milling and therefore would be burned for fuel or cut to smaller pieces to fit into a wood-chipper. Alternatively, by acknowledging the nature of the beam only requiring its maximum depth at the center of a span, a curved member becomes the optimal form for a structural beam after the removal of a small amount of material. The off cut of which may then be used for wood chips or fuel if no other use is foreseen.

Where the ring pattern breaks and there is grain moving mostly horizontal is continuous tangential grain.

In addition to the formal elements of structure the once curved member now double tapered beam maintains the wood grain along the lower, tension face of the beam.

A determining factor in grading lumber is how much wood grain is leaving the wood. If you think of a wood stud it should be transferring any load applied vertically and the way to do that is through each straw like grain running down the stud

lengthwise but any straws turned away from that vertical orientation fail to transfer the applied load efficiently making the wood weak in those areas. In the case of the bench or a beam end grain is only exposed at the top side of the seat and either end effectively accepting the load applied to the seat and transferring it laterally to the legs.



The rectangle represents the profile of a milled board. The curved lines abstract the grain present in the bench comparing the amount of wood grain exiting the cut form in both hybrid and milled form lumber.

Forked Tables

Process of Making

Debarking in process

Debarking the fork. What I presume is Willow was still very green, as the tree was only cut the day before, making the thick bark quite difficult to remove. In the top left hand corner, evidence can be seen of my chisel getting through the bark and taking knicks from the wood which now exposed. On the right hand side a dark scar begins to show where the

bark loops back on itself. This hints at weak spots in the wood, or roots of another plant growing in the crotch. Where the fork is too narrow, moisture gets trapped in the bark between the two limbs and this causes the area to rot. This creates humus and eventually the tree or other plants grow roots there speeding up the process of decay in the limbs.

Roots are growing within the fork.

The fork was cut just over from the central plane to preserve the cluster of emergent branches. The cut reveals a new pattern of twisting grain between the opening of the fork and the crotch of the heartwood.

Splitting the fork
Cut and photographed by Regan Southcott.

Cut and photographed by Regan Southcott

After using an angle grinder to strip the bark from the cut fork

The process of planing: on the right are pencil marks I was using to gauge the amount of material being removed by the electric plane, it was insufficient. The left side is router planed.

Following the cut, the rest of the bark was removed with an angle grinder and the surface planed. In order to plane the fork leveling out the roughness of the chainsaw cut the wood was set up in a jig and cut with a router. The right side of the above image shows my initial attempts with an electric plane, but this could not remove enough material. The left-hand image shows the beginning of a router-planed surface which was much more effective.

The table tops: foreground is router planed and background is the texture left from the chainsaw cut

The Willow tables were made with the intention to be able to used together as a single large table or the two individually. The image above is a top view of the two put together.

A side view of the two tables, looking through the steel legs. The form of the legs was inspired off the outline of a tree fork and small point connections fastening the table tops to the legs were designed in respose to the complex geometry of grown form wood.

Single side table

Side view, highlighting the irregular outer curve contrasted by the straight profile of the legs

Crafting with “Waste” Pieces

A close up of wood grain in the fork. showing the difference in heart vs crown wood.

Tree forks are considered waste pieces in conventional lumbering for a number of reasons. Starting from the trimming of the tree. Cutting the branches at their base (the fork) give more predictability in where the limb will fall. Their forms do not allow for milling and depending on size can be quite difficult to get through a wood chipper.

The unique and complex wood grain present in a tree fork provides visual interest and a beautiful finish making them special pieces to work with. Where used as moment connections, as in ship’s knees, they have great structural capacity as well.

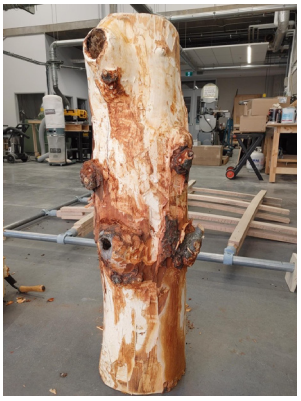
Willow and Oak Benches

Process of Making

Stripping and collecting the bark.

The benches follow the same process as the forked tables beginning with debarking. Chisels were used at a first attempt which was both very time consuming and the odd cut even after practice would go too deep. Present on all four pieces is evidence of chisels chipping away at the material. The angle grinder was significantly more effective at removal of the bark, finishing the job in a matter of minutes.

Rough chainsaw cut. photograph and cut done by Regan Southcott.



Stripping bark with draw knives and chisels.

Stripping bark with an angle grinder.

there were no forks In these pieces, to trap moisture and debris build up, but the interior of knots created a number of vulnerable spots. In order to remove the rotted peices a dull chisel was used to chip away at the flaking layers of rotten wood followed by the use of a brass wire brush to scrape away any remaining debris.

Router planing using the jig constructed with Regan Southcott

One planed seat (left) and one rough cut (right)

Layers of rotting wood within a hollowed knot

Removing the rotten wood to preserve the remaining wood in the knot

The two benches prior to finishing sat in the woodshop window to continue drying and to be on display

Front view

Rear view

Highlighting the subtle curve of the seat and the large seperation between grown and milled forms.

Side view of a single bench. A face showing the correlation between the two materials, similarities in colours and differences in prominence between wood grain.

The Curve

The mirrored curve and tangential faces of the log

Two faces of a split log

Social Implications

Although slight the curve in the bench provides a slight inward turn when the two face one another. As an opposed pair, these benches imply more engagement in conversation, defining a space of gathering within the curved forms. yet it is subtle enough to not close itself off too much from the surrounding room. They can also be placed in a gentle S form, perhaps in the middle of a picture gallery.

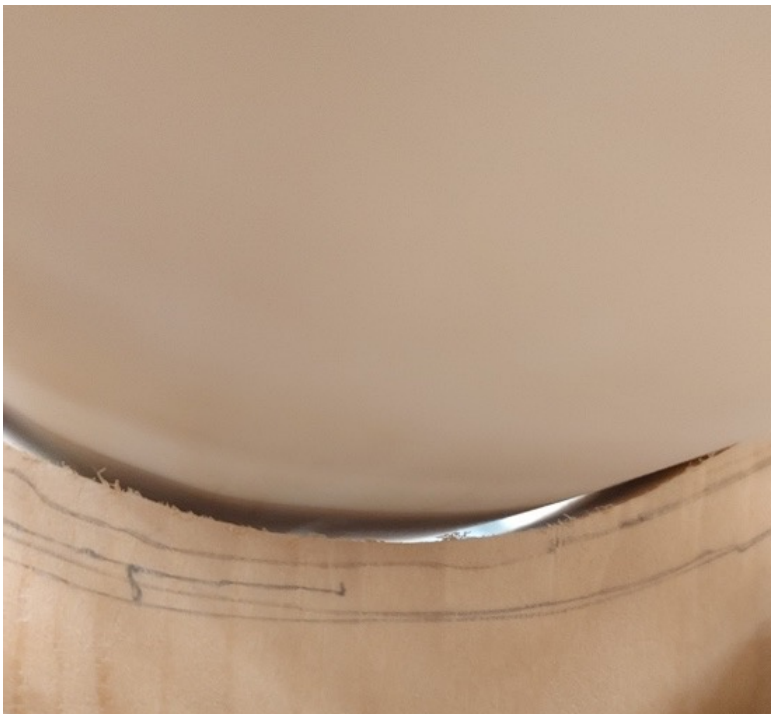
Referencing Historic Timber Frames

The split log and subtle curve pay homage to the English cruck frame. In order to have visual symmetry in the frame the two sides of the cruck were split from the same log much like the process of making the pair of benches. The curve and facing cuts are both visually appealing and reveal both symmetry and asymmetry in the organic forms.

Moving Away From the Scribe Fit

The scribe fit is laborious and requires great skill or expensive technology. The original intent in these benches was to use the scribe fit between leg-planes and seat as opportunity to study in detail the organic form of the grown timber. Where the plane of the sawn member intersected the grown form, the exact profile of the grown curve would be traced out. I managed to get a reasonable fir on one side of the sawn element but as the back of the leg-piece fell on a different curve, a thick and irregular shadow line appeared. Maybe the sawn lumber and grown form want to be considered separately - as if two alien materials.

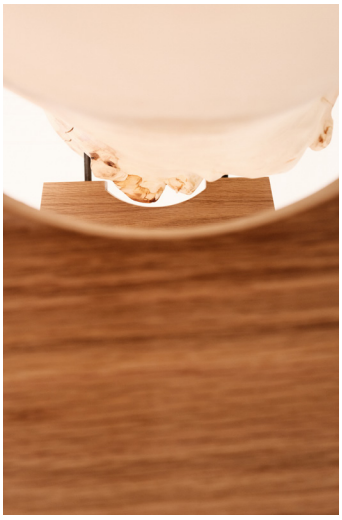
Attempting a scribe fit leg. Though imperfect after many attempts the scribe is a close fit the grown form that would rest in it.



On the inside of the above leg the scribe is much farther off. Even within the three quarters of an inch thickness the board has the curve of the grown form changes significantly. Pencil lines also depict additional attempts are marking for a new cut.

Material Distinction

The standoff between milled and grown forms streamlines the assembly process by simplifying connections and provides space to distinguish between the different formal characteristics. The regulated lines of the milled legs contrast the organic lines of the willow seat, each engaged in depicting the character of the other. These furniture pieces establish two rules. The first is to create plane surfaces only where necessary, typically on the top surface. This generates a more economical and satisfying form than the usual “rustic” live-edge furniture. The second rule applies where grown and geometric forms are juxtaposed. Keep them far enough apart to allow a simple connection and allowing each to be read independently – but keep them close enough together that the connectors remain robust and so that the contrast of character may be appreciated.



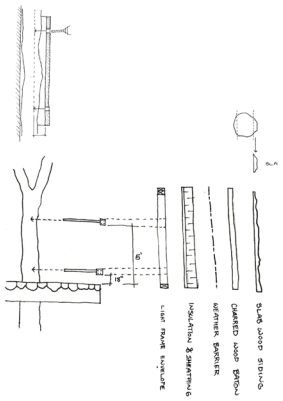
View through the reveal present due to the material stand off expressing the contrasting forms

The regulated lines and single curve of the milled wood contrasted by the organic forms, knots, and bulges of the grown form above.

Chapter 3: Detail and Assembly

1:2 Wall Section Model

At the scale of the building and its details the two groups of materials, sawn and grown, are viewed the same way as in the willow benches. The stand-off between the two creates contrast rather than interference between the regulated lines of the light frame enclosure and the organic roundwood structure. It allows visual continuity and completeness of each. This space also provides opportunity for built-ins using the stand-off as a bracket for shelves, seating, etc. Where a stand-off is not supporting another element, or where it must penetrate through envelope membranes, a round bar would be preferable to the angle.



Assembling the primary structure and envelope frames using a round bar and fastening plate

The first iteration standoff.

Connecting the steel fastener

1:2 Wall assembly

Puncheon, Mass Timber Floor

Critiquing the Mass Floor

Standard dimensional lumber, milled form wood

The benefits of conventional mass timber decks over concrete or steel are in their low embodied carbon and high carbon sequestration. As compared to conventional wood construction, advantages of CLT, NLT, or DLT decks are less clear, as they require more trees to be cut. It is possible that large amounts of wood have biophilic advantages such as the possible calming nature of the “natural” material discussed previously (Kotradovya et al. 2019, 17).

The structural strength of mass timber is in its mass. Acknowledging this the process of making mass timber is totally illogical. By milling small dimensional members mass is being removed from the material. Following that the small members are then laminated together with the goal of building strength in mass. This process begs the question of how to maintain mass in the first place.

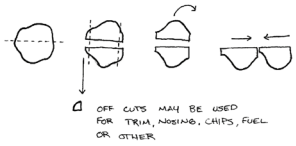
Puncheon. This is a hybrid form milled on three sides simply removing only the required material.

Puncheons are an ancient way of using timber where logs are split or sawn into two semicircular joists and trimmed to fit adjacent to one another giving a smooth upper or inner surface and a corduroy underside or back. Mass timber decks built of puncheons reveal the form of trees on the underside and reduce mechanical and chemical inputs of milling and joining. Either smaller trees can be used to achieve decks of the same strength, or the same trees can produce decks of greater strength.

To what extent the calming effect of “natural” materials extends to “natural” or roundwood forms is not known. But it appears that the tight repetition of roundwood surfaces on a ceiling can be aesthetically pleasing. In that case the

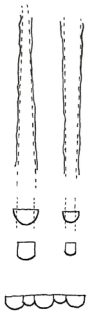
ecological benefits are both expressive and quantifiable in accounting for inputs, waste, and performance.

Making Puncheon Floors



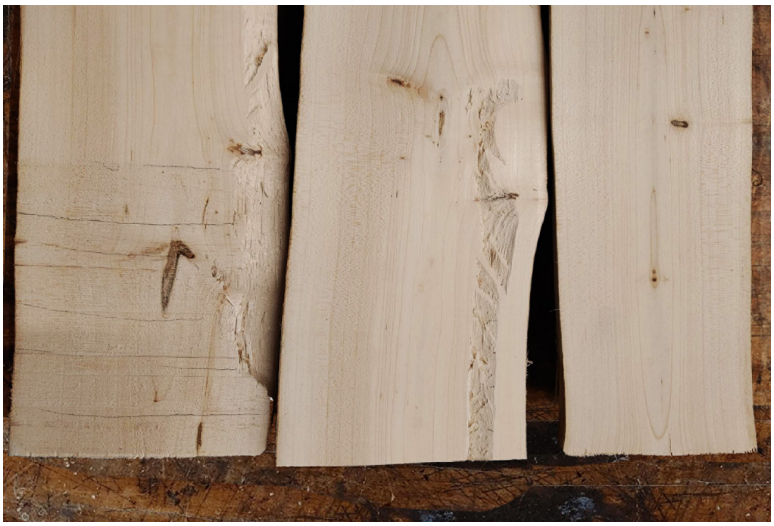
A process for cutting and assembling puncheon

Sawing a half log provides a rough but flat top surface. With this as a registration plane, flat edges can be cut on either side of the puncheon, square to the top, yet following the natural taper of the log. The flattened edge should be large enough to allow fastening with glue and dowels, biscuits, or splines, and to allow for final surfacing. But once that surface has been achieved, no more material should be removed and thus wasted. Laying out the puncheons alternating the wide and narrow end of the tapered logs should keep them generally parallel. Taper angles need not be identical as steeper and shallower angles can be balanced out by eye as the deck progresses, and the last puncheon will in any case be trimmed to the edge of the floor.



Alternating tapers

Rough but flat surface



Planing the top surfaces

End face of the assembled puncheon floor sample

Grown form side of the puncheon assembly

Planed side of the puncheon assembly

Structural Frames

Forked Braces

The branch or fork of tree may be used as a brace exploiting the inherent connection in the wood grain instead of mechanically fastening a second piece of wood.

A model of a grown brace using a forked stick.

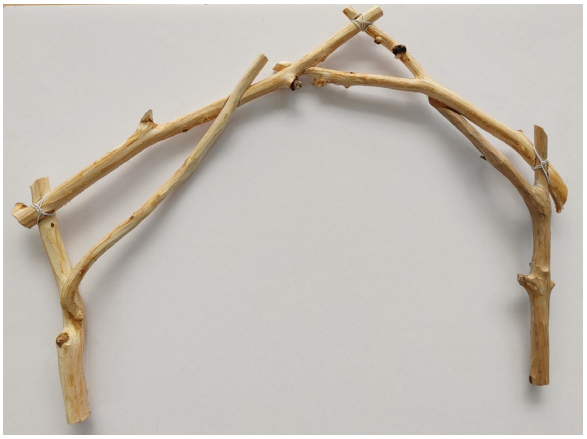
Roots growing within the crotch of a tree fork

Possible defects in the fork do need to be considered. When the fork is acute the compressed region allows for a buildup of moisture and debris making the crotch more susceptible to rot. If inspection of the standing tree appears to be okay, the removal of the bark will allow for more information when evaluating the usability of the tree fork. Bark should be removed in any case to reduce drying time and risk of wood rotting as the bark will lock in moisture.

Roof Structure and Bracing

Utilizing almost exclusively forked members within a structural bent allows most connections to be braced. Whereas forks are waste material in the industrial lumber

industry here their structural integrity is being exploited. Scaled prototype frames suggest it can be hard to acquire the number of similar forks to make compatible bents. Additionally, it was noted that the apparently simple half-lap joint is ill-suited to irregular angles and organic forms and can disastrously weaken bending members at critical points of stress. But timber joinery is a complex topic outside the scope of this thesis.



A single frame exploring forked braces

In order to reduce the number of forked members needed and alternative to a half lap the brace below takes inspiration from ship's knees. The purpose here is to stiffen the bent by introducing a crook to convert a pinned crossing point to a moment connection.

Ship's knee. Interior of the 'Reuben Tefry Blacksmith shop,' Le Village Historique Acadien. Photograph: David Goldsmith

Reinforcing a ridge connection using the concepts of a 'ship's knee'.

The crook functions much as a ship's knee except that the latter is cut from the very base of a trunk where a large root branches out. Providing material for a full heel.

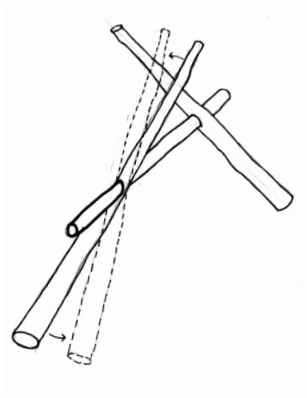
Lowing the height of the brace. A half lap is cut at each connection the only one accurate enough being the ridge.

A through tenon removes to much material weakening an already vulnerable place.

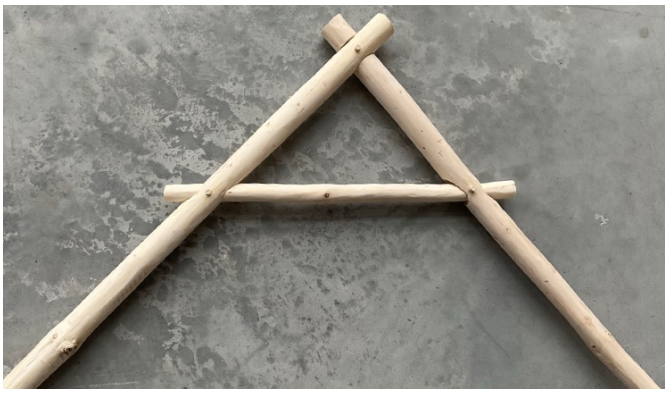
Subsequent strategies lowered the height of the brace, to both benefit the triangulation of the ridge connection and address the potential bending points in the roof assembly. The next example demonstrates how half-lap joints remove a great deal of structural material at the exact point where it is needed most. It was also difficult to cut. This frame appeared to be more rigid when casually manipulated than the previous case but would likely lead to catastrophic failure at full scale.

Pinned half lap connection

As in squared timber construction, the peak connection can safely be made with a half-lap but this joint should not be applied elsewhere without a complete understanding of the engineering design of wood joinery. The following images depict another attempt at eliminating the use of the half lap joints below the ridge however it is worth noting this too is another an assembly destined for failure.



The use of the tenon joint allows for rotation to accurately mark the location of the half lap at the ridge.

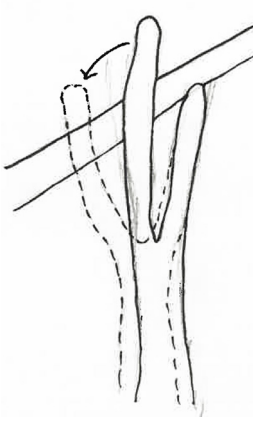


Assembled frame with through tenons and a single half lap

Constructing The Model Frame

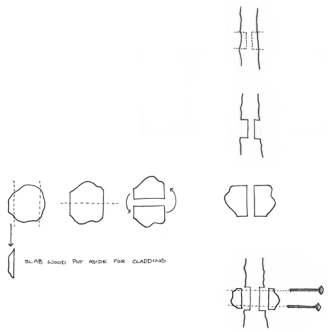
The following photos Illustrate the construction of bents at the model scale. It is well understood that success at the model scale does not necessarily mean success at 1:1. The intention of the below studies are simply suggestions in ways of working with grown and hybrid forms that have yet to be tested at a scale greater than 1:10. They by no means are to be accepted as complete details but are suggestions of a structural concept to be built upon and eventually tested.

Switching to blind tenons allows the brace to only work in compression, which resists bending and removes less material but still allows for the same method marking the ridge joint.



The same method of using both tenoned and half lap joints may be used connecting the roof and column structure.

1:10 model of roof and post connection.

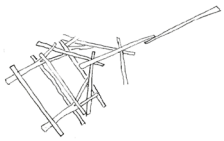


A method in cutting and fastening puncheon beams

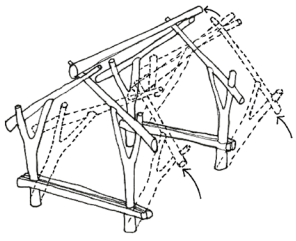
1:10 floor beam and post connection

1:10 frame model

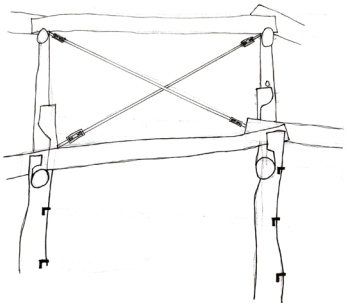
Once the bents are complete they can be raised following the procedure shown in Ben Law's Woodland house, stacking them and placing the roof beams in position (1 at the ridge and one in each of the forks formed above the column and roof beam half laps) on the ground and using a serious of ropes and pulleys attached to surrounding trees raise the bents into position by hand (Law, 2003).



Placing the bents and beams.

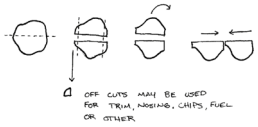


Raising the frame

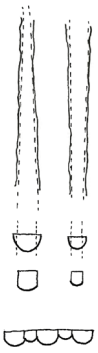


Sketch of cabled cross bracing between frames

Once the frames are in place longitudinal bracing, possibly in the form of cables, will be needed. Then the floor might be added which bridges the beams in each bent as described previously and providing a platform for further work.

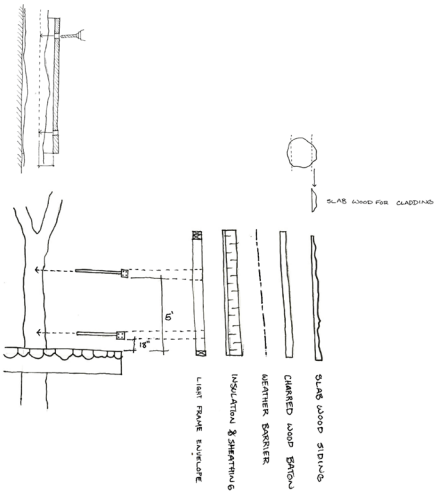


construct the floor on the existing frames.

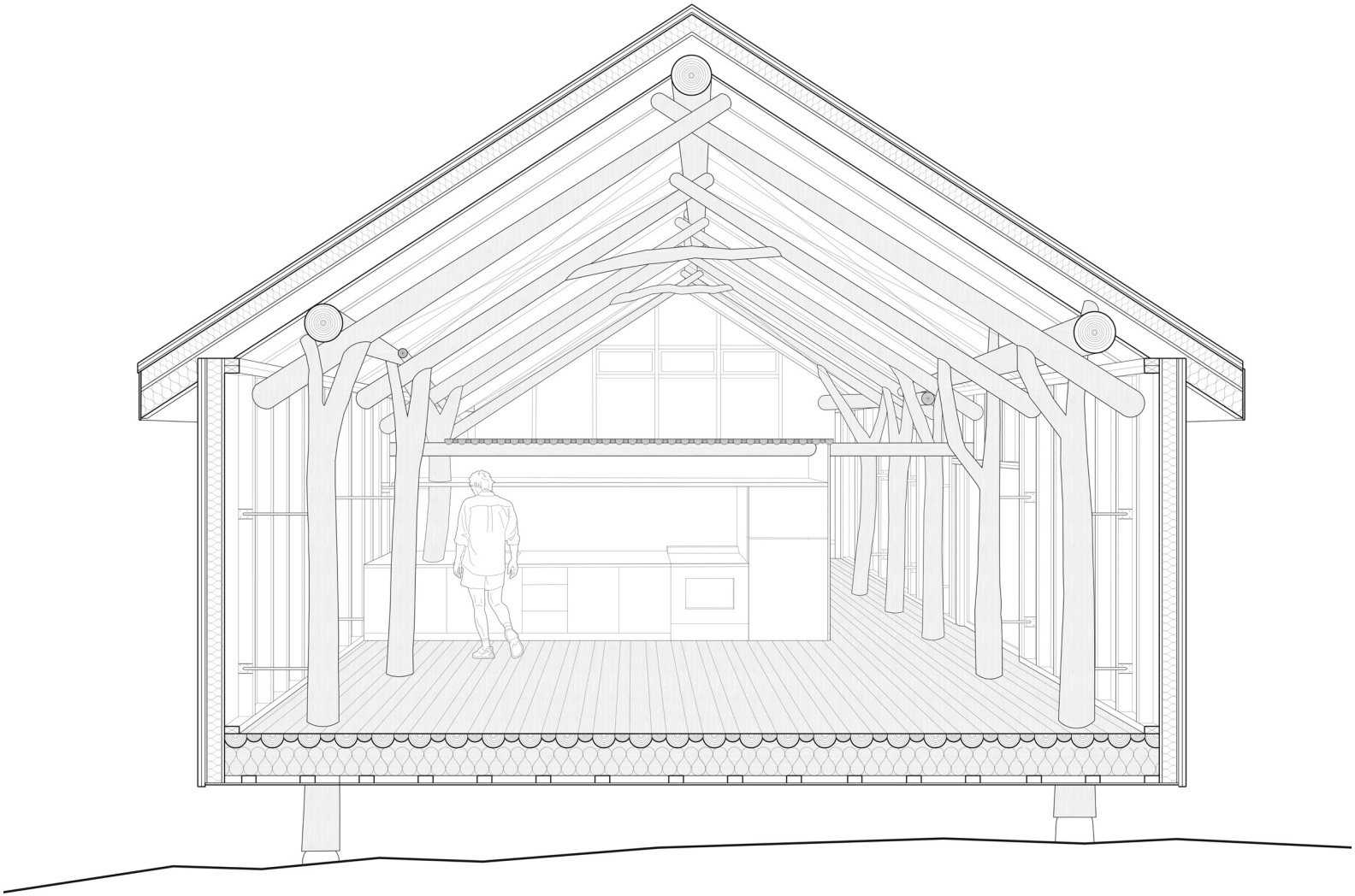


Alternating tapers

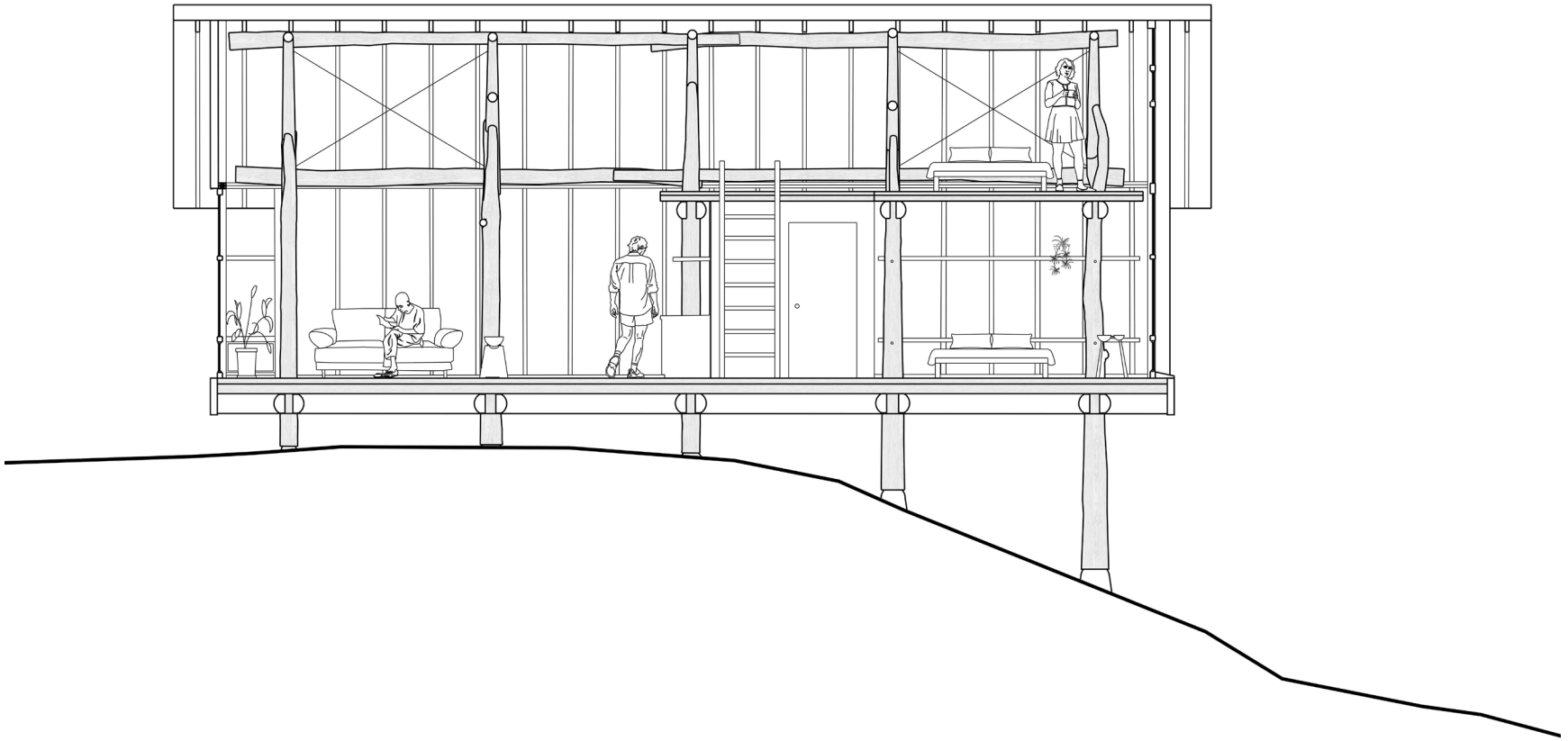
Following that, steel stand-offs are drilled into the standing columns to mount the milled wood frame/envelope. And topped with a milled wood roof as well.



Diagraming the assembly of the enclosure. The top left describes a jig to replicate the height of the holes drilled in each post.

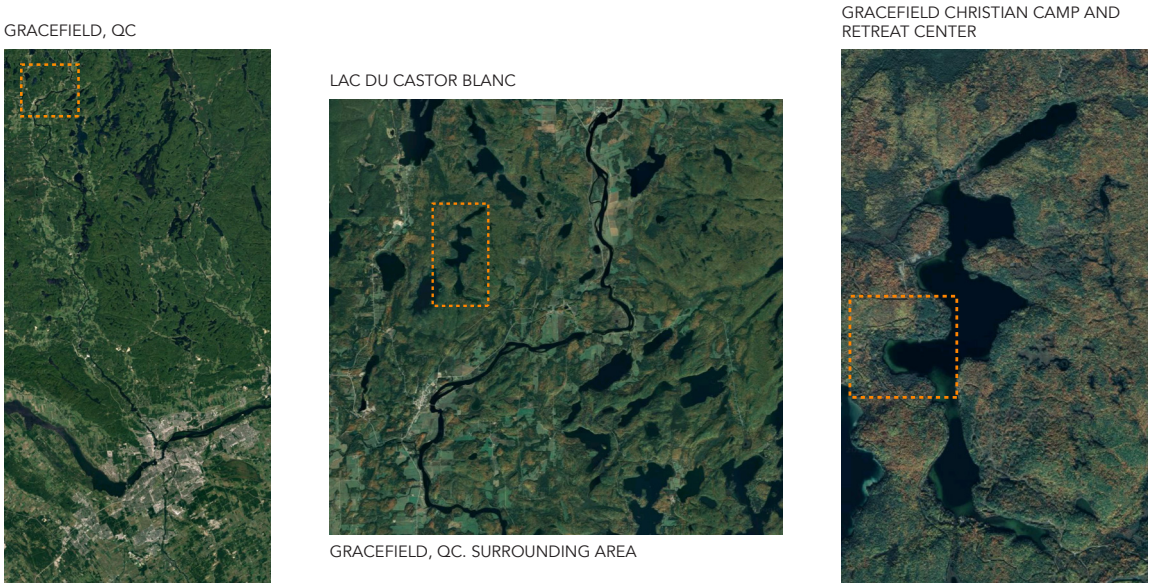


Section- perspective of the forest dwelling



Inhabited section of the forest dwelling

Chapter 4: Building Scale



Locating the site (aerial photos: Google Earth 2022)

Forest, Logging, and Site

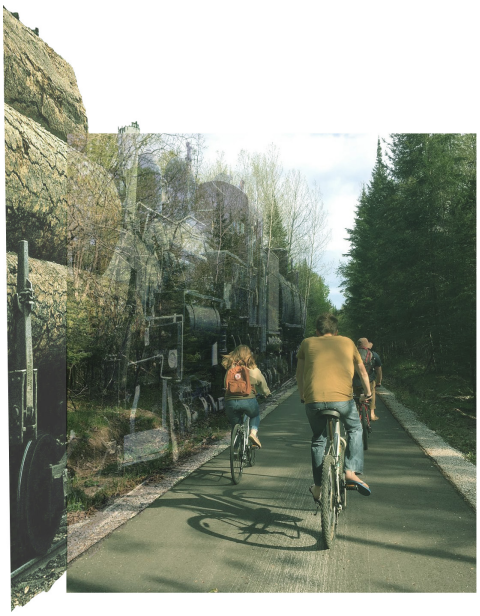
The site is at Gracefield Christian Camp and Retreat center on Lac du Castor Blanc in Gracefield, Quebec, a place I have considered home for most of my life. Integral to the program of the summer camp and camping in general is a space to connect with nature, a space for renewal. Though the nature of religion is beyond the topics discussed in this thesis the restorative feeling of connecting with natural spaces is undeniable and backed up in language of typical conversations surrounding the act of going to places such as camps, cottages, and other retreat type spaces. The site is a place to experience the natural beauty of landscape, restore a relationship to living spaces beyond the city, and renew a feeling of being a part of the “natural” world

Logging and Outdoor Recreation: A Narrow History of Site

The camp is situated in a mixed forest typical of eastern Canada, used by the logging industry at different intensities for hundreds of years and recently growing in popularity for recreational uses.

Prior to the property becoming a summer camp it was the summer home and a logging property to the Billings family. During the Billings era the estate had a train track and station for loading and transporting logs to Ottawa. The track has since been removed and has now become a part of the Trans Canada Trail (TCT) which is popular for cyclists, runners, locals, and people staying/visiting the camp. Logs were floated through Quebec via the many rivers connecting in Ottawa including the Gatineau River (which was still used to float logs into the 1990s) or taken by train to Ottawa.

Collage image of log float on the Ottawa river (Outaouais Heritage 2022) and a personal favourite place to paddle, within the white-water section of the Gatineau river, Bonnet Rouge rapids (2018).



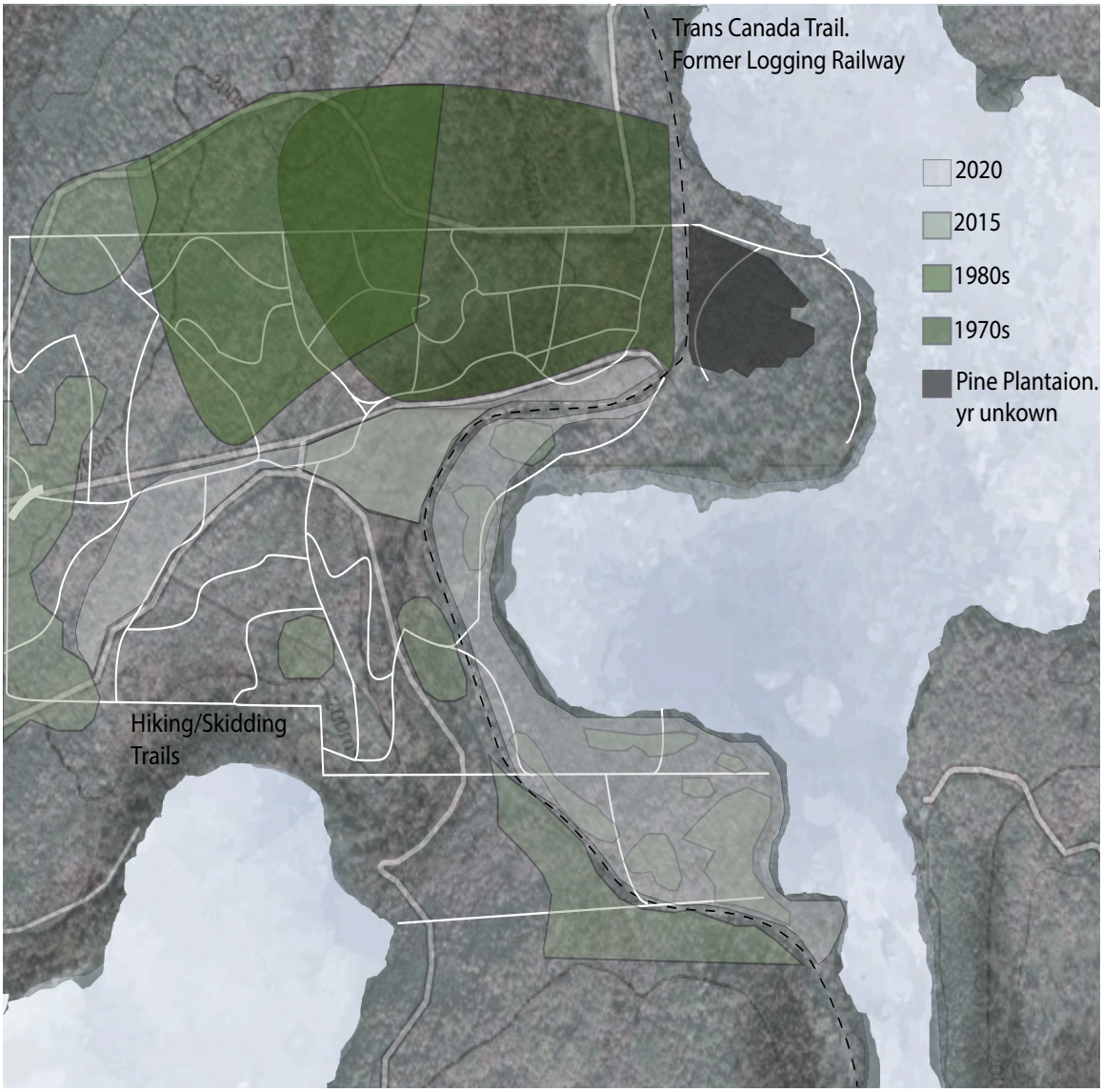
Collage of an old steam train transporting logs and Gracefield camp staff biking along the trans Canada trail (2017).

There has been a lasting relationship between outdoor recreation/connecting with outdoor environments and logging. Each of these areas continue to be logged. Responsible logging does not come at the cost of quality environments. The industry can, should, and hopefully will continue to be a part of everyday lives. Forest-informed design does not argue to eliminate the current logging practice but empower a relationship between the built and grown environments by way of wood as a material. The environment is what serves both the logging and recreational services: both need to acknowledge the need for the other. Most importantly, both need to understand the forest in such a way that both continue to serve the forest.

Logging in Cottage Country

Prior to the camp owning the property (1962) what areas were logged and to what intensity has not been well documented. However, the forest on the camp property remains diverse

in both species and age of the trees with the exception of the pine plantation which predates the existing camp with no certain year of establishment.



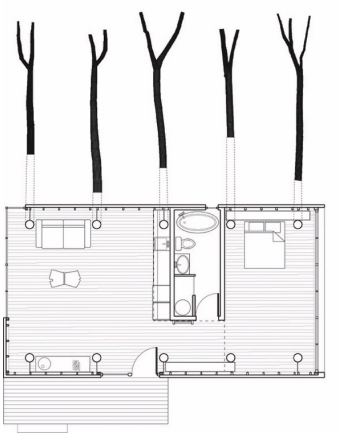
Logging and trail map of the camp property depicting the areas and years of past logging. Each year specified selective logging and thinning was conducted to the level of 5-15% thinning. (Data collected from Hamilton, 2021, Herbert, 2021, Whitehead, 2021).

This diversity in conjunction with the continued agreement of logging the property speaks to the success of the selective cutting and thinning methods used in harvesting material at the camp. The successes of these practices on site establishes feasibility for construction methods that encourage similar practice.

Taking the lessons of Uus, asking permission before felling the tree and proposing what it be made into further develops the notion of selective cutting. As discussed previously the tree forks can be more susceptible to issues of rot adding another criterion for selection. Below, 5 sample trees were selected on site, based on a) the spread within the fork b) diameter of trunk below the fork (assumed strength of post), and c) proximity to existing skid trails and building site.

Marked in orange is the building site, the other coloured dots mark the approximate location of the following forked trees proposed for the building.

Five sample trees selected from site, location marked on previous map.



Digital models of the sample trees alligned with their respective places in the building plan

Similar criteria of proximity to site and skid trails would also be used for other trees harvested. For mass timber assemblies, small diameter trees would be selected prioritizing those which would be cut when thinning the forest in order to encourage growth of maturing trees. Those cut for thinning would then be used to create puncheons for floors. This way of building is inherently silvicultural as forest thinning promotes the health of mature and maturing trees, to be cut more selectively. Ultimately this strategy focuses on the use of material form rather than commodified volumes of broad species groups. Such a management regime might increase forest diversity.

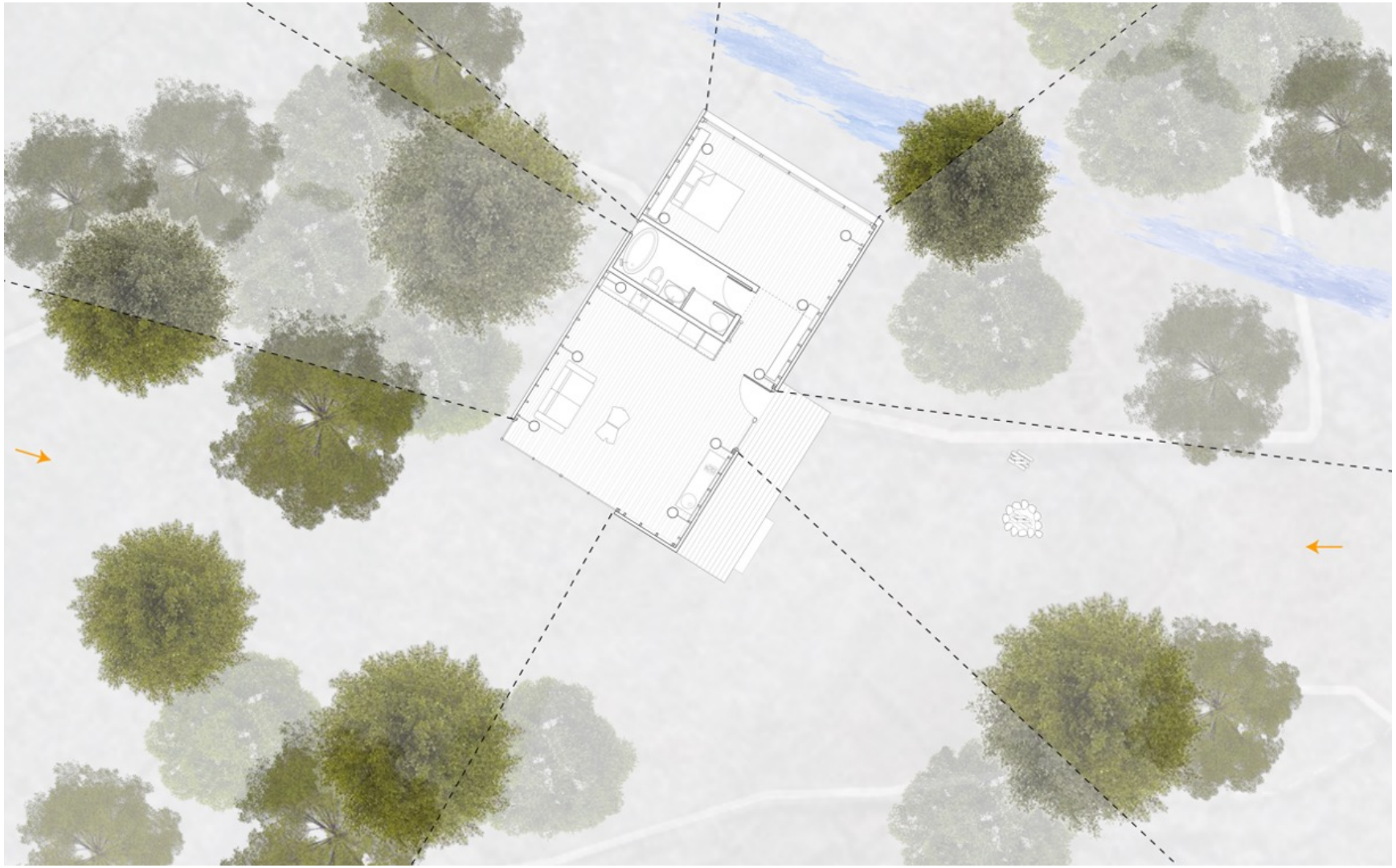
In developing this design, the material-first approach meant to work from the forest, first through physical interaction with the forest then through scaled abstractions working with actual material at various scales and lastly through drawing and photographing actual material. This process listened to the material at its origins and at every step of the thesis process. Material standoffs, simple connections, and

abstraction within the drawing allow for the final product to be determined by the grown forms.

A depiction of the design strategy learning from the material, looking to the forest for inspiration and never using drawing as the equivalent to material study.

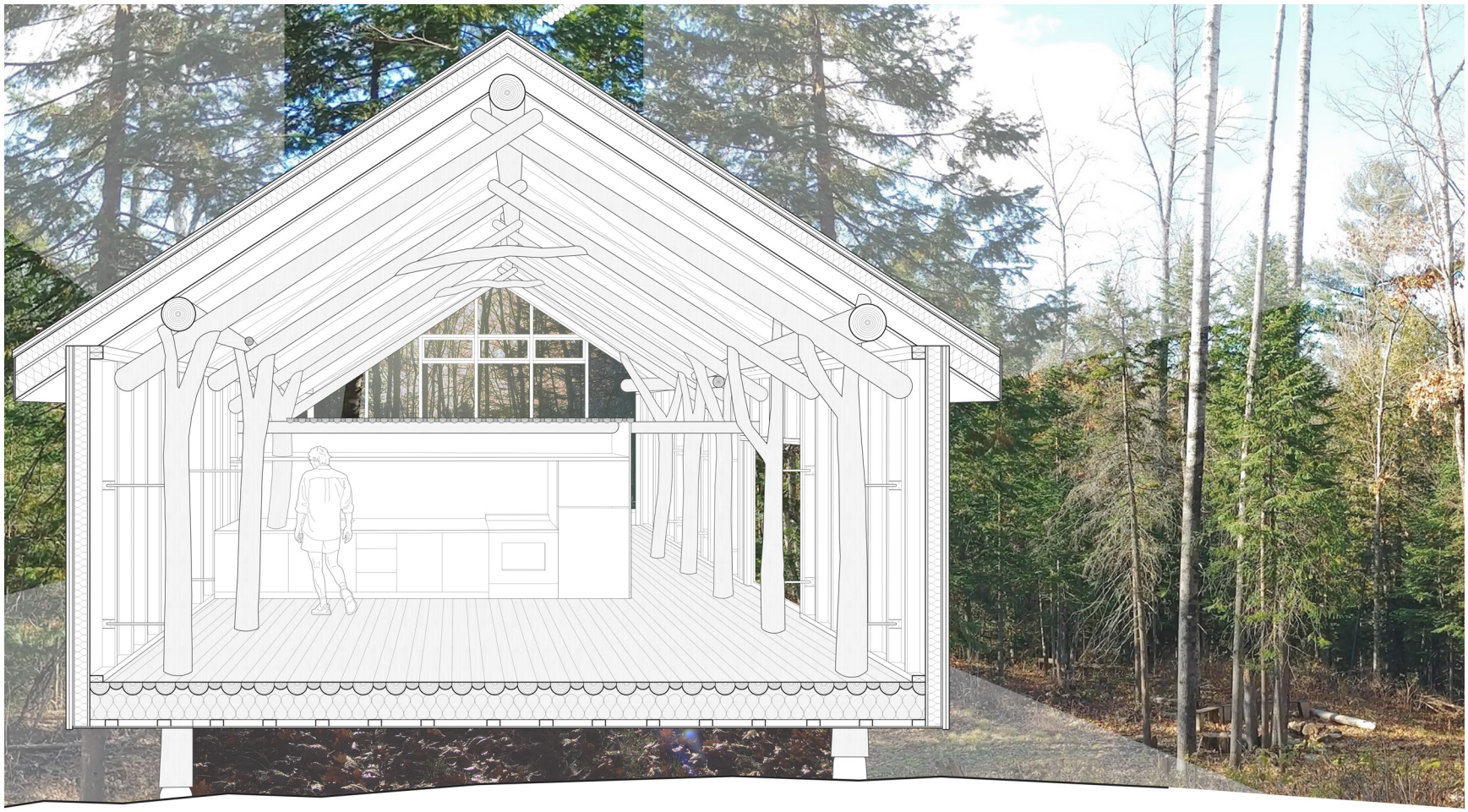
The view into the forest and a feeling of being in the trees was vital to the organization of the design. Much like walking a forest path a line of grown form posts on either side guiding your way through the woods with views out at either end of the forest dwelling.

Two additional openings at either side of the building are used to illustrate public and solitary experiences within forest and building. The living room and kitchen, the public program, of dwelling looks to the path from main camp that enters the site and opens to a clearing with an existing fire pit. The washroom and bedrooms use the existing landscape to maintain privacy. The washroom has a view of a small bunch of thick brush well hidden from view of forest paths.



Site plan and marked views. The two entrance to the immediate building site are from base camp (left) and the path from the lake look out, ‘turtlerock’ (right).

Inhabited section and views depicted with a collage of site photos



Section-perspective and views depicted with a collage of site

Chapter 5: Conclusion

Summary

Forest-informed design begins with a respect and understanding for the forest and the tree; a desire to re-establish our place as humans within nature; and a willingness for alternate ways of working with material. The forest is a place of found objects and a living system. The fundamental question is asking the tree for permission to fell it.

The felling of trees must not come at the cost of harming the surrounding environment but keeping in mind the link between logging, recreation, building, and the forest as a whole; each are connected and serve one another.

Steps forward in forest-informed design are branching from the simple opposition of grown vs milled form lumber by further exploring their relationships through material stand offs and the introduction of hybrid forms.

The stand-off between grown and milled wood provide space to view the contrasting geometries of both. This comparison highlights the qualities present in each. Grown form maintains a visual connection to its origins and most honest to its initial form. Milled lumber provides squared lines, a contrast to the organic form; a simplicity of working; and shows the issues of formal stability and comparative strength when straying from the grown form.

Hybrid members are explored in the puncheons. These minimize the amount of milling needed to produce a flat floor, arguably simplifying work, lowering the energy input

in the material; and maintaining form, mass, structure, and connection to the material origins.

Forest-informed design does not eliminate commercial logging or counter it but proposes new ways of handling material. It is a method of working that prioritizes the grown form, altering the material as little as required to take advantage of its inherent features. That potential could be in its species, mass, forks, curves, or knees. Following that, any material conducive to the industrial standardization that cannot be used elsewhere then enters the industrial process. In order of priority (the inverse order of inputs required) products might be lumber, plywood, and engineered products such as OSB or MDF glued up from waste strands, chips and dust.

Continued Exploration and Call to Action

Forest-informed design is not limited to small scale, rural builds, such as summer camps or retreat spaces. This project offers a way into much larger applications. Reframing our attitude towards wood materials provides new avenues of sustainability and the renaturing of our built environments, in urban as well as rural contexts. In order to do this additional research is required in stress testing members such as puncheons, forks, material connections, measurements in embodied energy, etc. when compared to current standard practices. Already some of these investigations are underway at the Dalhousie School of Architecture, and will be continued into the immediate future.

The poster for a 'Free Lab' proposal at Dalhousie University's School of Architecture summer 2022. The poster also includes reference to Emanuel Jannasch's course Arch 5222, which also encourages the continuation of concepts within forest informed design.

References

Benson, Tedd, and James Gruber. 1995. *Building the Timber-Frame House: The Revival of a Forgotten Craft*. New York, NY: Simon and Schuster.

Collins, June. 2022. “Gracefield Christian Camp and Retreat Centre: Sowing the Seeds of Faith for Sixty Years, 1962-2022.” The Blurb. Volume 2, 1-86.

Google Earth. 2022. Ottawa ON - Lac du Castor Blanc QC. https://earth.google.com/web/@45.78125382,-75.88208706,228.71223275a,174394.13764715d,35y,-0h,0t,0r

Hamilton, Mark. 2021. Executive director of Gracefield Christian Camp and Retreat Center. Discussion with the author.

Herbert, Alan. 2021. Former Executive director and Treasurer of Gracefield Christian Camp and Retreat Center. Discussion with the author.

Hooke Park. 2016. “Wood Chip Barn.” http://hookepark.aaschool.ac.uk/woodchip-barn/.

Hosie, R. C.1979. *Native Trees of Canada*. Don Mills, Ont.: Fitzhenry and Whiteside.

Ingold, Tim. 2013. “The Materials of Life.” In *Making: Anthropology, Archaeology, Art and Architecture*, 17–31. London: Routledge.

Jannasch, Emanuel. n.d. “Cultivating Complexity.” School of Architecture, Dalhousie University.

Jannasch, Emanuel. 2004. “Embodied Information in Structural Timber.” *In Structures and Architecture: New Concepts, Applications, and Challenges*, edited by Paulo Cruz, 2176-84. London: CRC Press.

Jones, Richard. 2018. *Cut & Dried: A Woodworker’s Guide to Timber Technology*. Fort Mitchell, KY: Lost Art Press.

Klein, Joshua A. 2020. *Another Work Is Possible*. Sedgwick, ME. Mortise & Tenon inc.

Kotradyova, Veronika, Erik Vavrinsky, Barbora Kalinakova, Dominik Petro, Katarina Jansakova, Martin Boles, and Helena Svobodova. 2019. “Wood and Its Impact on Humans and Environment Quality in Health Care Facilities.” *International Journal of Environmental Research and Public Health* 16, no. 18: 3496–3516.

Law, Ben and Kevin Mcloud. 2015. “Living in the Wild.” Episode of *Grand Design*. Television broadcast. Channel 4. Sussex, United Kingdom.

Law, Ben. 2022. “The Woodland House.” https://ben-law.co.uk/ecobuilding/the-woodland-house/.

Lesser, Wendy. 2017. *You Say to Brick, The Life of Louis Kahn*. New York, NY: Farrar,

Straus and Giroux.

McElhanney, T. A. 1935. *Canadian Woods, Their Properties and Uses*. Ottawa: Forest Service.

Mcloud, Kevin. 2003. “Grand Design ‘The Woodsman’s Cottage.’” Episode of *Grand Designs.* Television broadcast. Channel 4. Sussex, United Kingdom

Merriam-Webster Dictionary. 2022. https://www.merriam-webster.com/dictionary/renature.

Minister of Natural Resources. 2020. “Forest Composition Across Canada”. Natural Resources Canada.

Mollica, Zachary. 2022. Lecture. School of Architecture, Dalhousie University.

Morton, Timothy. 2019. *Being Ecological*. Cambridge, MA: MIT Press.

Ottawa Archives. 2013. “Billings Family History.” The Billings Family Virtual exhibit. https://documents.ottawa.ca/sites/documents/files/billings%20family%20virtual%20exhibit_en.pdf.

Outaouais Heritage WebMagazine. 2022. “Lumber Camps of the Gatineau and Pontiac.” Drawing of Timber Slide and Bridge on the Ottawa, engraving by W.H Bartlett, 1842. http://outaouais.quebecheritageweb.com/article/lumber-camps-gatineau-and-pontiac.

Verri, Selene. 2019. “Renaturing Cities: Good for Health and the Economy.” Urban GreenUP. https://www.urbangreenup.eu/news--events/news/renaturing-cities-good-for-health-and-the-economy.kl.

Whitehead, Christopher. 2021. Chair of the property commitee and member of the Gracefield Christian Camp and Retreat Center Board of Directors. Discussion with author.

Whole Trees. 2018. “About”. Video, 3:12. YouTube. https://youtu.be/piirOyIdvo0.

Whole Trees. 2019. “Technology.” Video, 1:01. YouTube. https://youtu.be/UUbQbWvsXXU.

Whole Trees. 2020. “Wholetrees Structures.” 2020. https://wholetrees.com/.

Wilson, Lucas. 2019. “An Ash Tree.” Architectural Association School of Architecture. https://www.aaschool.ac.uk/projects/an-ash-tree.