A KŌRERO WITH COMPUTATION

TYLER HARLEN

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Expanding upon traditional Māori materials in architecture's digital age

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PREFACE

While completing an architecture project that promoted the development of indigenous craft in Tanzania, it became apparent to me that mass industrialisation and globalisation has suppressed the potential of indigenous design practices globally.

In Tanzania, I noticed that the appeal of Western approaches to construction and economies of scale has led to the prioritisation of mass-produced materials and techniques over locally produced and culturally specific methods. An example of this is in rural areas where cement blocks were widely used instead of the vernacular earthen construction.

Subsequently, this has led to the thought; what if modern technologies were not viewed in opposition to indigenous practices but could instead be used to lead a revival through the use of digital design and fabrication?

Fig. 01.01 CEMENT BLOCKS (TANZANIA 2016)
AUTHORS OWN PHOTOGRAPH

IV

ACKNOWLEDGEMENTS

This thesis was nurtured and supported by many people towards whom I would like to extend my sincerest gratitude.

To my supervisor, Derek Kawiti, for believing in my research and me: this thesis would not have been possible without your support.

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Thank you, Jesse Ewart and Jason Tan for your critical discourse as well as social conversations.

Finally, the VUW architecture cohort of 2018-2019, it was a pleasure working with and sharing a studio with everyone.

Fig. 01.02 INTERLOCKING BRICKS (TANZANIA 2016)
AUTHORS OWN PHOTOGRAPH

ABSTRACT

THIS RESEARCH EXPLORES THE RELATIONSHIP BETWEEN DIGITAL FABRICATION AND INDIGENOUS MĀORI MATERIALS. THE AVAILABILITY OF NEW TECHNOLOGIES SUCH AS ADDITIVE MANUFACTURING POSES A UNIQUE OPPORTUNITY TO BUILD UPON UNDERSTANDINGS OF TRADITIONAL MĀORI MATERIALS WHILE CONTRIBUTING TO MĀORI CULTURAL IDENTITY AND ASSETS.

WORKING IN CONJUNCTION WITH THE IWI NGĀTI TUKOREHE, AND THEIR AFFILIATED HAPŪ ON THE SITE OF ŌHAU, THIS RESEARCH EXPLORES LOCAL MĀTAURANGA MĀORI (MĀORI KNOWLEDGE)

IN RELATION TO DIGITAL ARCHITECTURE FABRICATION TECHNIQUES. THE PROJECT LOOKS AT THE USE OF LARGE-SCALE HIGH-PRESSURE INJECTION GROUTING AS A METHOD FOR THE CREATION OF FREE-FORM SUBTERRANEAN STRUCTURES. FREEFORM INJECTION GROUTING COULD BE USED TO MITIGATE COASTAL SHORELINE EROSION FOR KUKU BEACH AND PROVIDE SHALLOW GROUND ANCHOR FOUNDATION SYSTEMS, EXCAVATABLE POST-DISASTER HOUSING AND PAVILION STRUCTURES. THE GROUND MATERIAL ACTS AS A PRESSURISED ‘SCAFFOLD’ AND FORMWORK FOR THE CREATION OF THE SUBTERRANEAN STRUCTURES THAT

CAN THEN BE EXPOSED THROUGH THE EXCAVATION OF COVERING SOILS.

FREE-FORM INJECTION GROUTING REQUIRES SPECIALIST GEOTECHNICAL KNOWLEDGE OF GROUND PRESSURE AND SOIL COMPOSITION. COMPUTATIONAL PROCESSES IN REALFLOW ARE USED TO PROVIDE NEAR ACCURATE SIMULATIONS OF THE SUBTERRANEAN FORM-MAKING PROCESS, PROVIDING AN UNDERSTANDING OF GROUND PRESSURE/COMPACTION, COMPOSITE SOILS/PARTICLE SIZE AND INJECTION PRESSURE. THE INJECTION GROUTING TECHNIQUE WAS TESTED AT VARIOUS SCALES AND FOCUSSED ON

THE USE OF INDIGENOUS MATERIALS, INCLUDING COMPOSITES OF LOCAL SAND AND PUMICE FOR THE GROUT AGGREGATE. FLAX FIBRES WERE ALSO USED AS INTERNAL REINFORCING FOR THE FREE-FORM STRUCTURE. IT WAS ESSENTIAL TO THE RESEARCH THAT LOCAL MATERIALS WERE USED AS A MEANS TO CONNECT TO LOCAL UNDERSTANDINGS AND CUSTOMS AROUND INDIGENOUS MĀORI DESIGN PRACTICES RELATING TO PLACE AND THE PEOPLE OF NGĀTI TUKOREHE.

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INTRODUCTION

HOW CAN WE USE DIGITAL DESIGN AND FABRICATION TO BUILD UPON AND EXTEND TRADITIONAL MĀORI MATERIALS, IN A WAY THAT COULD STRENGTHEN CULTURAL IDENTITY AND GROW IWI RESOURCES?

Fig. 01.03 AERIAL MAP (OHAU 2017)
CAIRNS, LAWRIE. 2017. AERIAL PHOTOGRAPH
BETWEEN ŌHAU AND WAIKAWA RIVERS, HOROWHENUA.

01

INTRODUCTION

"A Kōrero with Computation" connects Ngāti Tukorehe to their material landscape through the use of digital design and fabrication. Through the design process, 3D printing and digital simulation software provide additional understanding of local knowledge (mātauranga and tikanga Māori) and materials that may not have had previous applications in additive manufacturing. This dialogue between indigenous knowledge and digital software offers up a new area of research and could contribute to the growth of Tukorehe's cultural identity and assets. In a broader context, this research could assist in the development of all iwi in Aotearoa.

The question is, therefore, how can we use digital design and fabrication to build upon and extend traditional Māori materials, in a way that could strengthen cultural identity and grow iwi resources?

Fig. 01.04 ARTISTS STUDIO (KUKU 2018)
AUTHORS OWN PHOTOGRAPH

01.01

PHYSICAL CONTEXT

Physical Context:

Ngāti Tukorehe's rohe (tribal domain) on the Kāpiti coast is comprised of a network of sand dunes. Their rohe extends along the western coast from the Tararua Ranges across to the coastline between the Ōhau and Waikawa Rivers. It is within this context that the research sought to explore two processes of freeform injection grouting termed 'soft forming' and 'hard forming' by the wider research group. Both methods are defined by the specific pressures they entail; 'soft' pertained to loose aerated soils, and 'hard' was used to describe undisturbed compacted ground.

Fabrication:

It was clear that soft forming had more flexibility in terms of its mobility and application. The scope of the thesis research and capability also meant that strategically the different pressure environments would be a determining factor in their application to the three uses alluded to earlier. Soft forming could be applied to research into freeform structures to control shoreline erosion, as well as to create pavilion structures. Conversely, hard forming could be used to create non-standard ground anchor foundation systems in unstable terrain.

Simulation:

Digital simulation in RealFlow was used initially as part of the desk study analysis at the front end. As a frontend tool, simulation allows the designer to influence the parameters of the material and environmental forces in advance of the actual physical modelling work. In this particular case, RealFlow simulation software enabled the author to experiment and speculate while communicating key principles of the design to Ngāti Tukorehe. This process allowed the formal aspects of the project to develop as a result of changes in the environment, thereby enabling the author to shape the design indirectly. The use of digital tools as a generative frontend design driver also enabled a better understanding of how iwi inputs could contribute to the design. Together, these two 'feedback' mechanisms have the potential to create more resilient and sustainable architecture through designs shaped by the local environment and iwi. Developed out of the relationship between designer and Tukorehe, this project forms a nexus between digital design tools and Ngāti Tukorehe's whenua.

Fig. 01.05 COWS AND OLIVE GROVE (KUKU 2018)
AUTHORS OWN PHOTOGRAPH

01.02

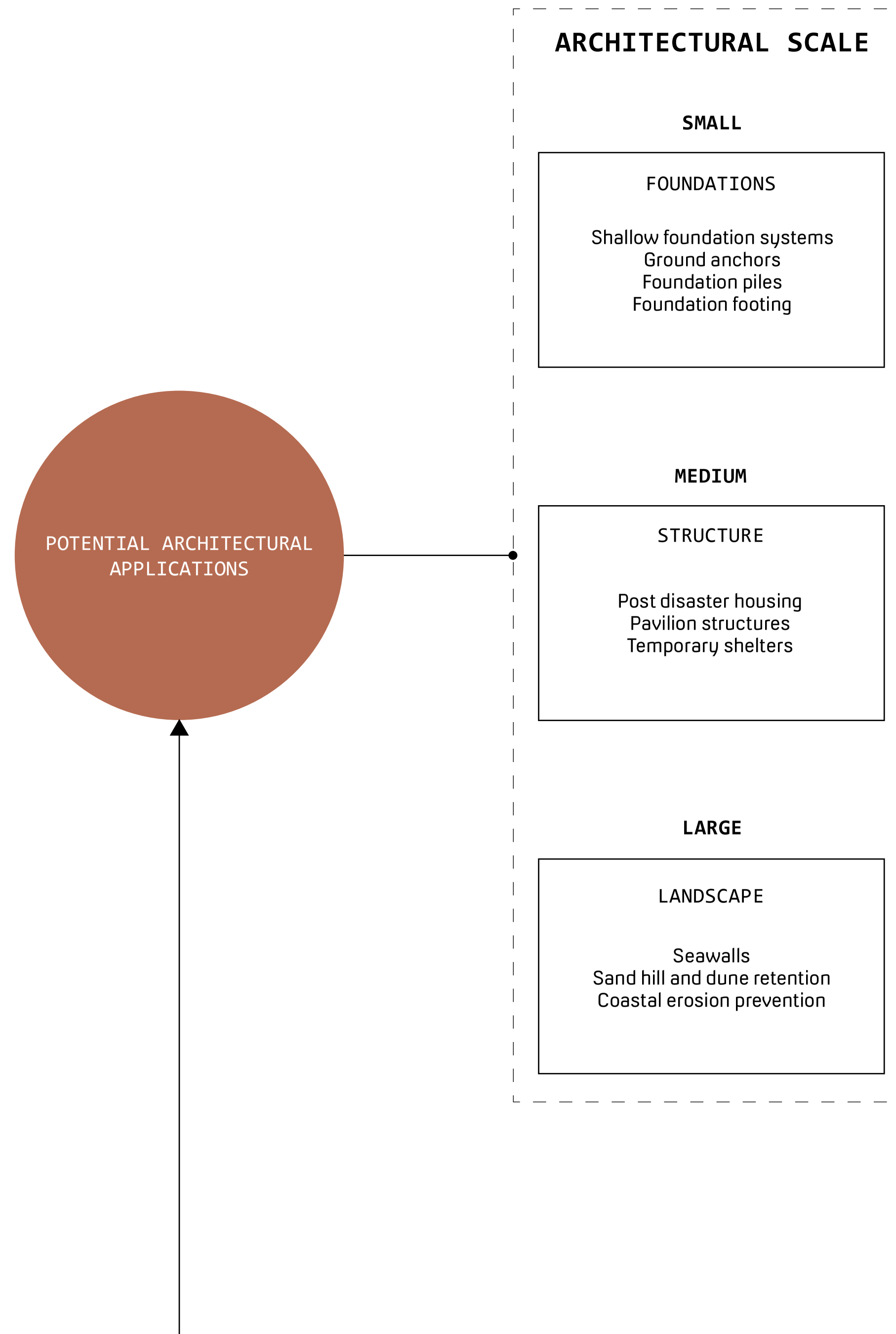
METHODOLOGY

Tool Based Approach:

The research methodology relies on a 'tool-based approach' (fig.01.07), where the research focus is on the design of a set of tools for research, rather than the creation of a final product or architectural object. The intention is that the developed set of tools can be applied across a range of architectural typologies and scales, rather than designing for a fixed typology and scale.

Integral to this research methodology is collaboration and the sharing of research space, in this case with our iwi partner Ngāti Tukorehe (fig.01.09). Through on-site engagement with Tukorehe's iwi members, ongoing feedback and knowledge were openly exchanged to inform the ongoing diversity of the iterative design process and the design outcomes. As mentioned previously, the use of digital tools as an essential part of the process enabled a broad exploration of the dialogue between digital fabrication and indigenous Māori materials.

Fig. 01.06 WORKSHOP (KUKU 2018)
AUTHORS OWN PHOTOGRAPH


POTENTIAL ARCHITECTURAL APPLICATIONS
ARCHITECTURAL SCALE
SMALL
FOUNDATIONS
Shallow foundation systems
Ground anchors
Foundation piles
Foundation footing
MEDIUM
STRUCTURE
Post disaster housing
Pavilion structures
Temporary shelters
LARGE
LANDSCAPE
Seawalls
Sand hill and dune retention
Coastal erosion prevention

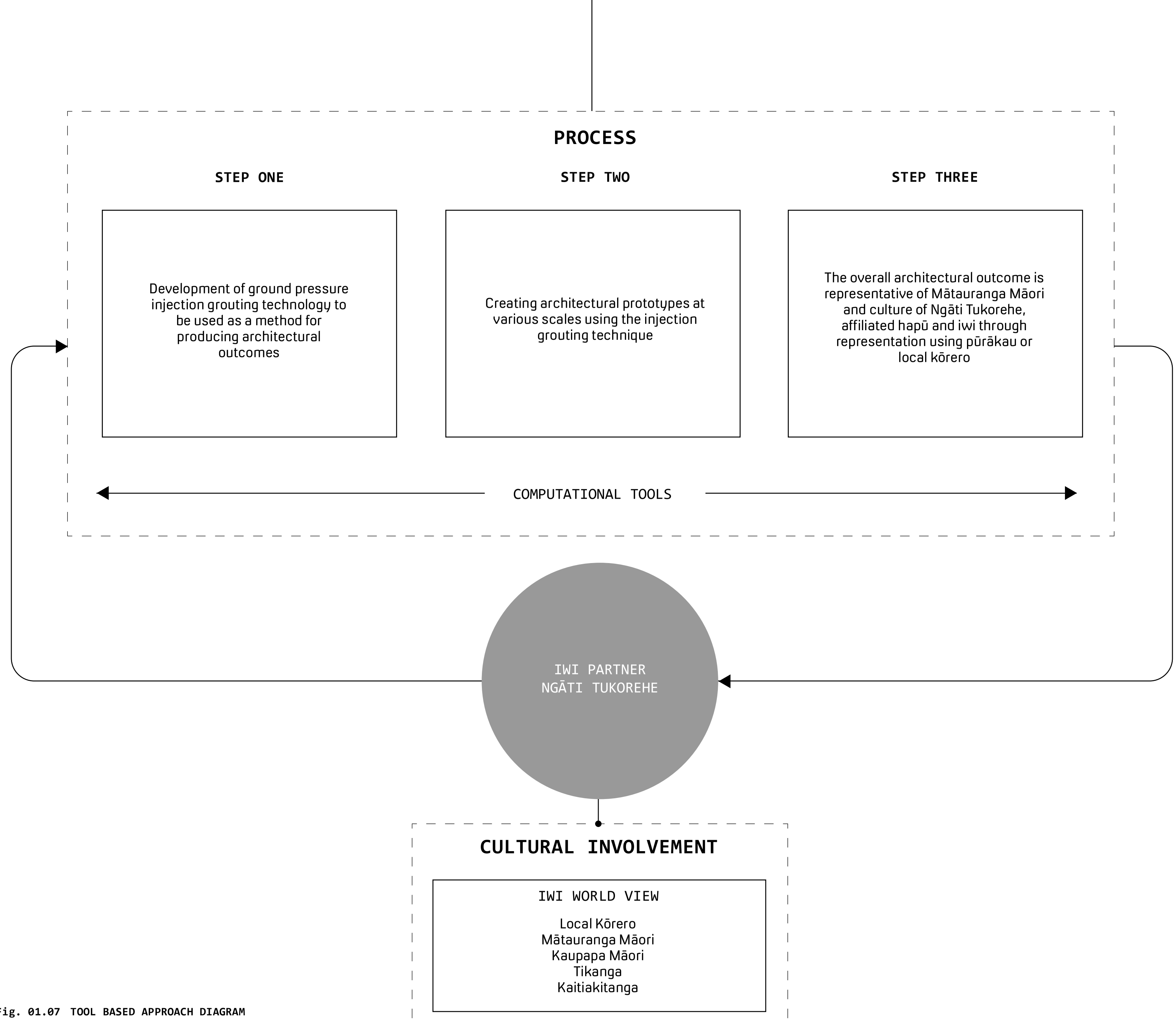


Fig. 01.07 TOOL BASED APPROACH DIAGRAM


KEEP CLEAR

01.03
PROJECT SCOPE

The scope of the project involved small-scale proof of concept testing of ways to resolve scaffolding, reinforcing and formwork issues. Proof of concept testing was achieved through analogue physical modelling. A custom injection grouting system was created for larger scale tests. The research involved injecting and extruding a fixed volume of granular materials to test the viability of the high-pressure injection grouting technique to create freeform structures.

For the tests, different granular materials were used. These were tested against a range of binding materials such as PVA glue, plaster of Paris and cement. Other parameters were factored in, such as soil compaction, injection/extrusion pressure and injection/extrusion volume. Alongside digital modelling, these tests also contributed to an understanding of geotechnical ground conditions and soils.

Computational processes in Grasshopper and RealFlow gave principles of control to the form-making process, as well as simulating ground pressure, soil composition, injection size, and injection pressure.

The final stage of the research was large-scale testing. This phase involved the creation of an injection grouting system that produced controlled structures through high-pressure injection and extrusion. This process was based on previous small-scale testing and computation processes as well as design input from kōrero with iwi members.

Cultural Aims:

Overall, the objective of this research was to leverage digital fabrication techniques and mātauranga Māori to facilitate the retention and development of culturally embodied architecture. The research could also be used to develop large-scale primary structures, for example in post-disaster housing or to control shoreline erosion. This process could have a considerable impact on computational thinking and empowerment of Māori iwi in Aotearoa and indigenous communities globally.

Fig. 01.08 KEEP CLEAR (KUKU 2018)
AUTHORS OWN PHOTOGRAPH

NGĀTI TUKOREHE

TRADITIONAL CRAFT
KNOWLEDGE

TEAM // WHĀNAU

Huhana Smith
Derrylea Hardy
Aroha Spinks
Moira Poutama
Jane Richardson
Martin Manning
Murray Patterson

IWI PARTNER
NGĀTI TUKOREHE

NGĀTI TUKOREHE SCOPE

Long term livelihood
Education
Indigenous outreach
Alternative economy
Commercial revenues
Traditional materials

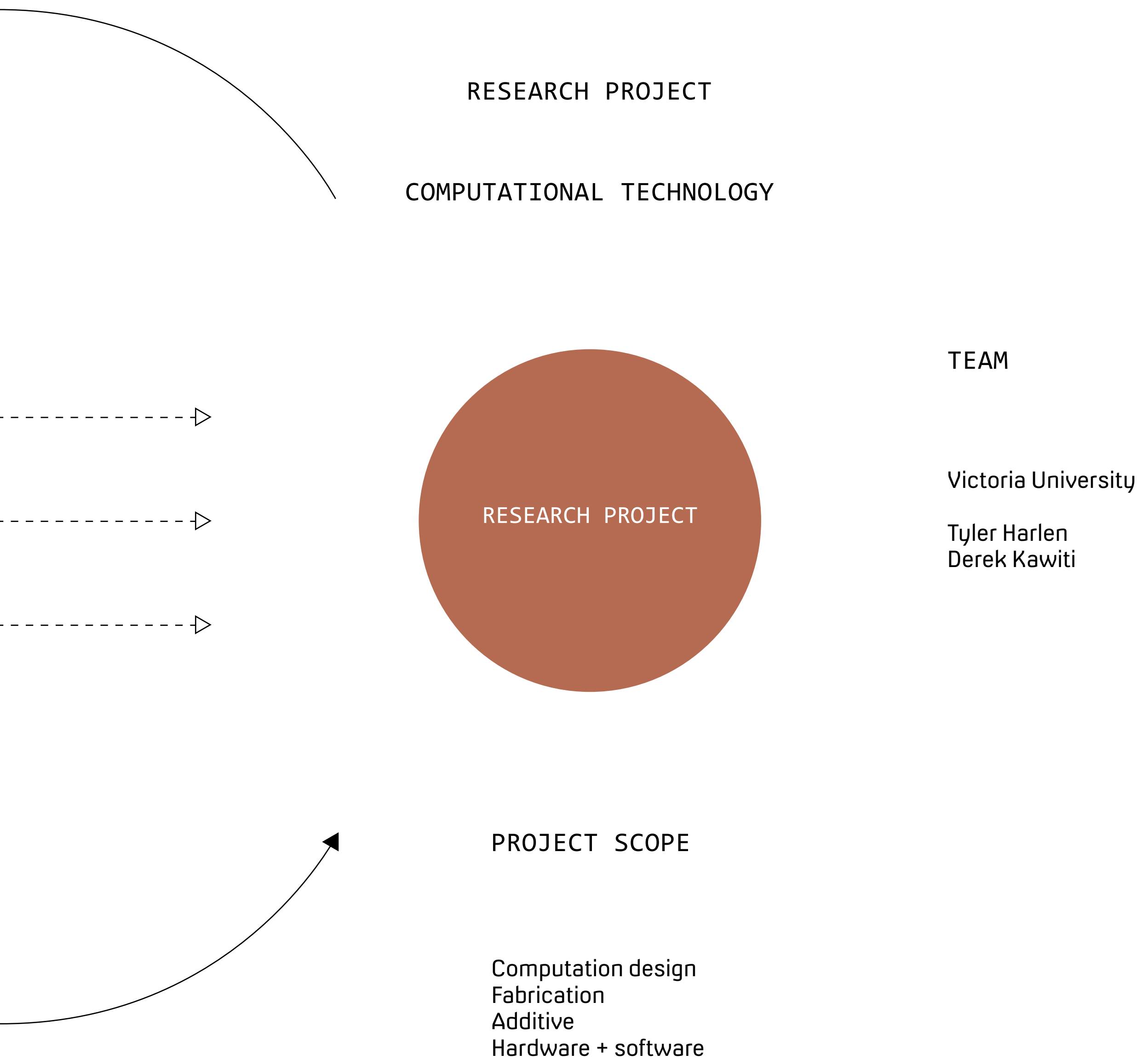


Fig. 01.09 DOMAIN BASED RESEARCH DIAGRAM

SCALE		
	SITE	NGATI TUKOREHE ON-SITE RESEARCH HIKOI
	THEORY	DIGITAL FABRICATION GREG LYNN ETH ZURICH BARTLETT RC6 JON MCTAGGART
S	ANALOGUE MODELLING	SOFT FORMING RELATIONSHIP TO THE LAND FREE-FROM INJECTION GROUTING
M	DIGITAL MODELLING 3D PRINTING	DIGITAL DESIGN ANIMATION AND GENERATIVE DESIGN 3D PRINTING
	PROTOTYPE	ADDITIVE MANUFACTURING TOOL FABRICATION ON-SITE SET UP
	ANALOGUE MODELLING	HARD FORMING MATERIAL AGENCY RELATIONSHIP TO THE LAND ADDITIVE MANUFACTURING TOOL
		SOFT FORMING COLUMNS RELATIONSHIP TO THE LAND ADDITIVE MANUFACTURING TOOL
		MATERIAL TESTING SOURCING LOCAL MATERIALS MATERIAL TESTING
	DIGITAL MODELLING	DIGITAL DESIGN 2 REALFLOW MATERIAL AGENCY
L		PAVILION DESIGN REALFLOW MATERIAL AGENCY

01.04

THESIS STRUCTURE

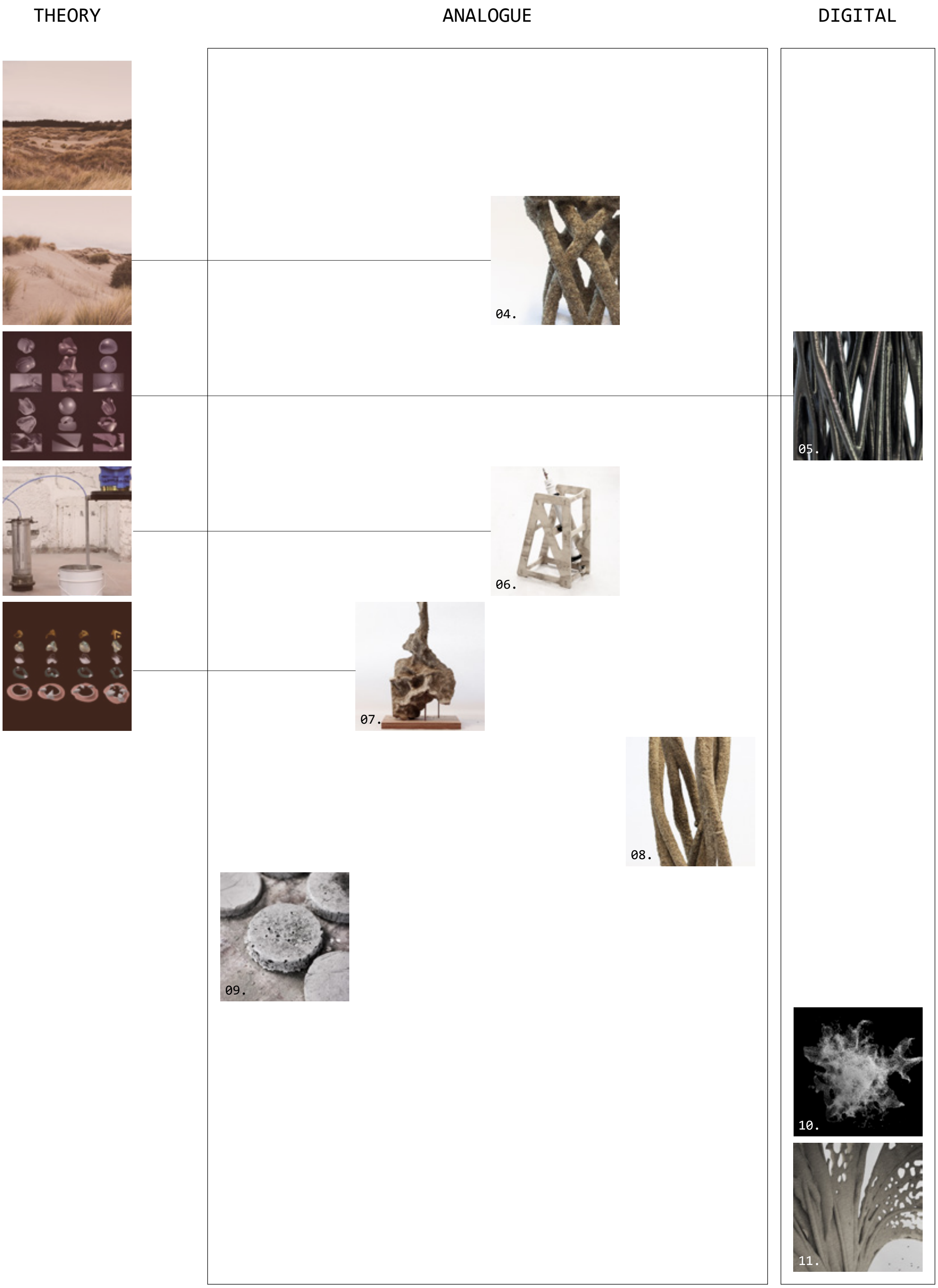
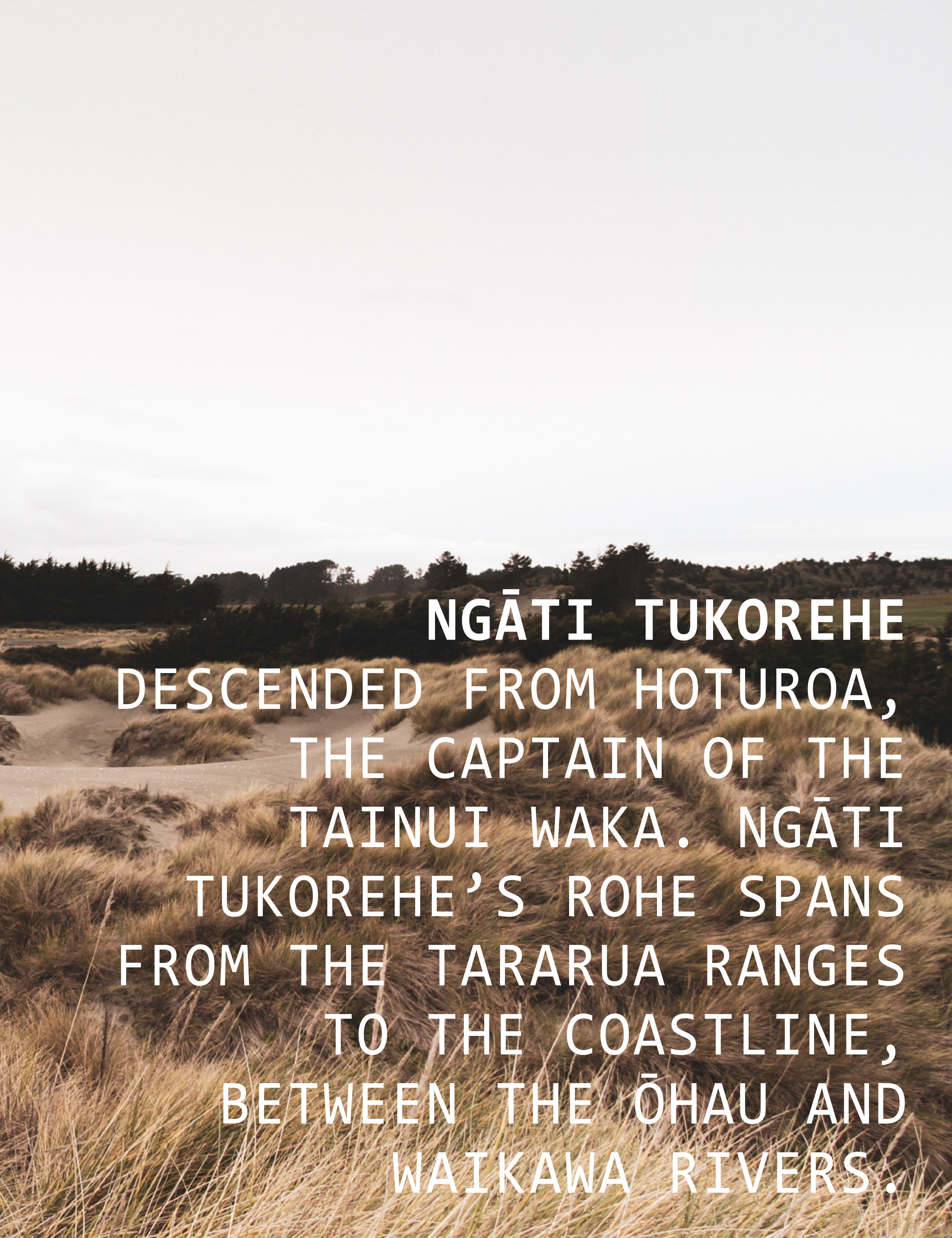


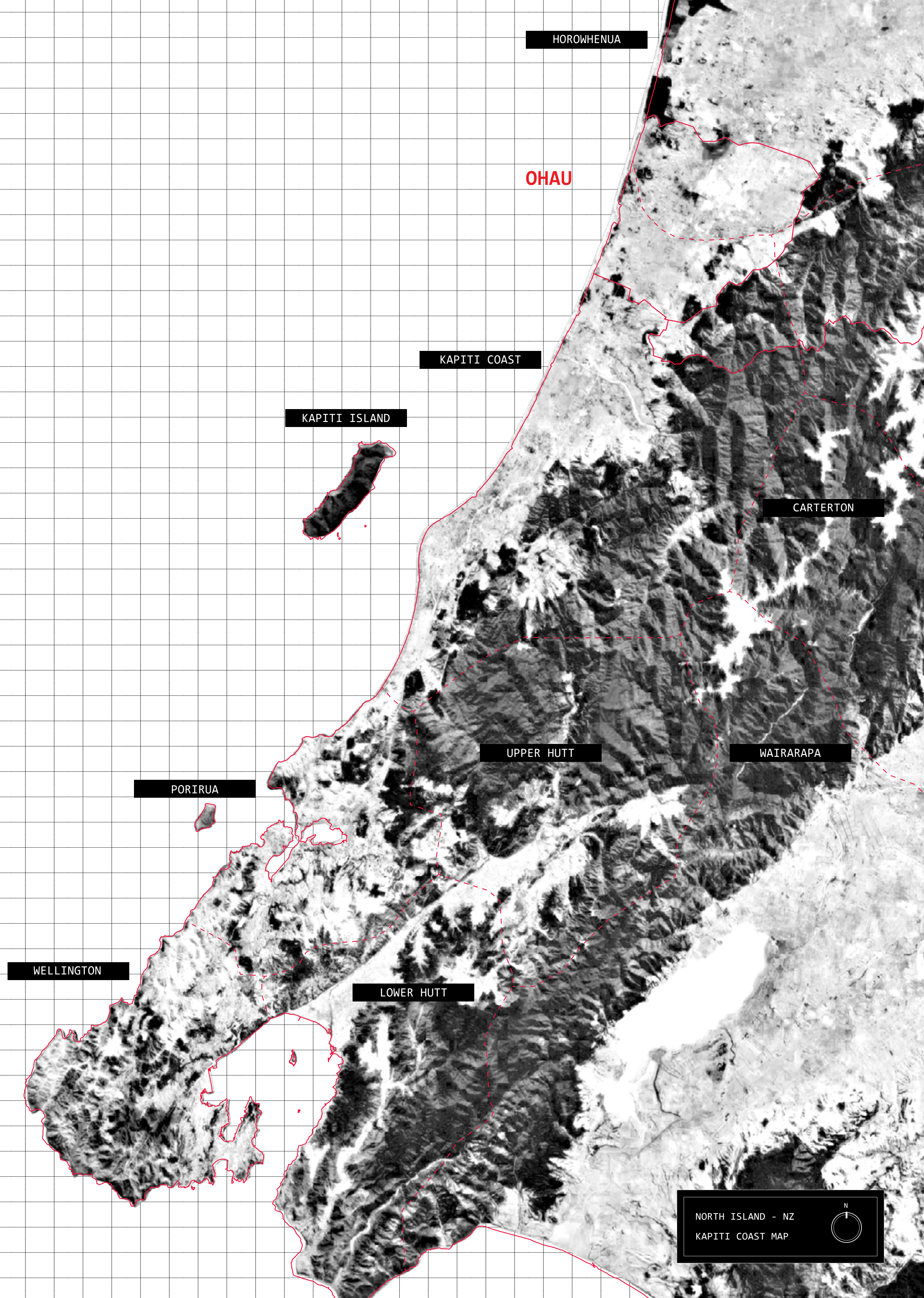
Fig. 01.10 THESIS STRUCTURE

Fig. 02.01 DUNE SYSTEM (OHAU RIVER MOUTH 2018)
AUTHORS OWN PHOTOGRAPH



NGĀTI TUKOREHE

DESCENDED FROM HOTUROA, THE CAPTAIN OF THE TAINUI WAKA. NGĀTI TUKOREHE'S ROHE SPANS FROM THE TARARUA RANGES TO THE COASTLINE, BETWEEN THE ŌHAU AND WAIKAWA RIVERS.


HOROWHENUA
OHAU
KAPITI COAST
KAPITI ISLAND
CARTERTON
UPPER HUTT
WAIRARAPA
PORIRUA
WELLINGTON
LOWER HUTT
NORTH ISLAND - NZ
KAPITI COAST MAP
N

02

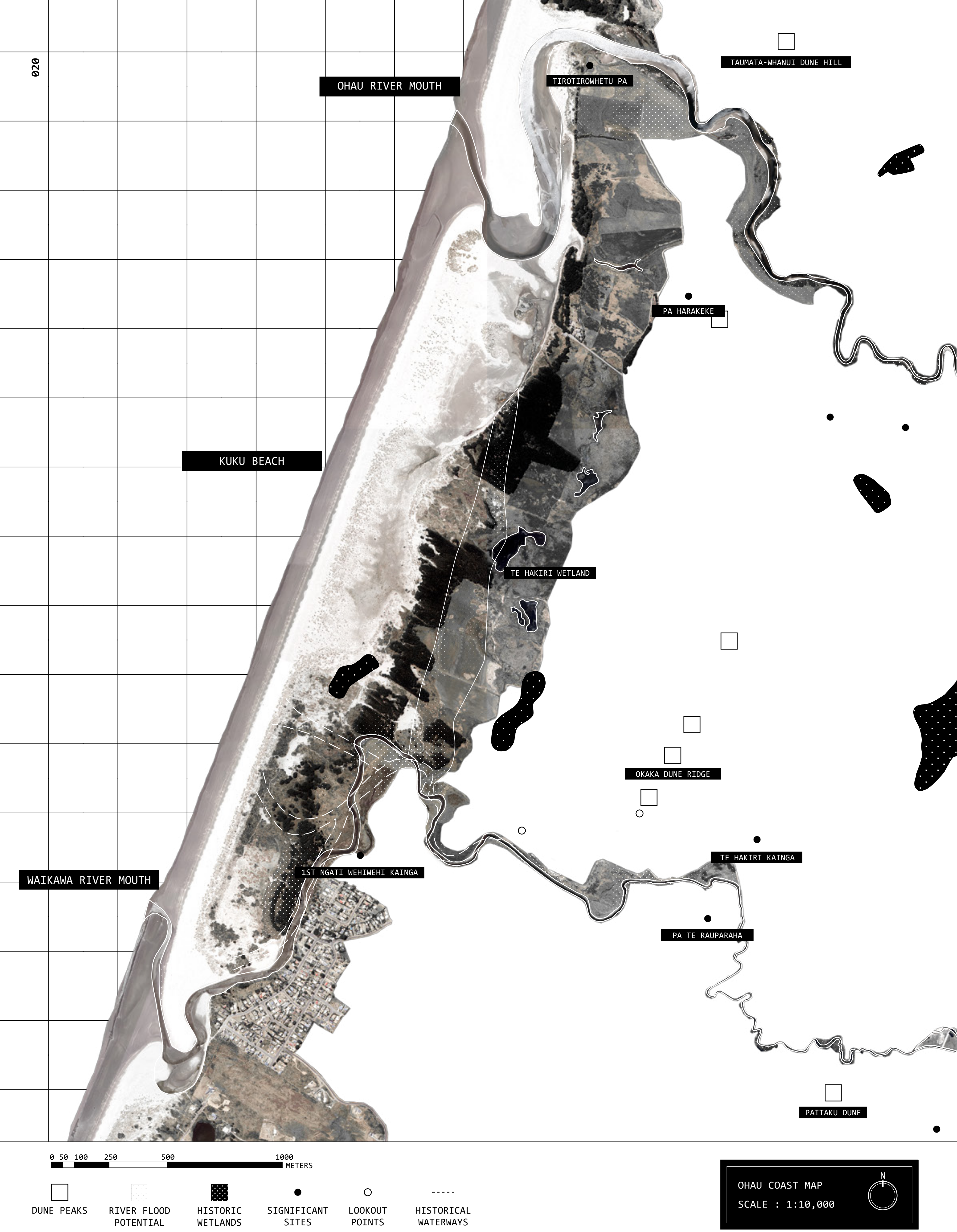
NGĀTI TUKOREHE ENGAGEMENT

Ngāti Tukorehe is an iwi descended from Hoturoa, the captain of the Tainui Waka[1]. Tukorehe's rohe is situated within the Horowhenua region 7km south of Levin, which spans from the Tararua Ranges to the coastline, between the Ōhau and Waikawa Rivers (fig.02.02). Tukorehe is rich in tribal history and diverse patterns of settlement (fig.02.03), with much of their tribal land holdings still in continuous ownership.

Ngāti Tukorehe has an active interest in innovative and collaborative research that has a significant impact on the livelihoods and future wellbeing of Tukorehe iwi. They are committed to the preservation and enhancement of their cultural, spiritual and physical domains.

Fig. 02.02 OHAU LOCATION MAP

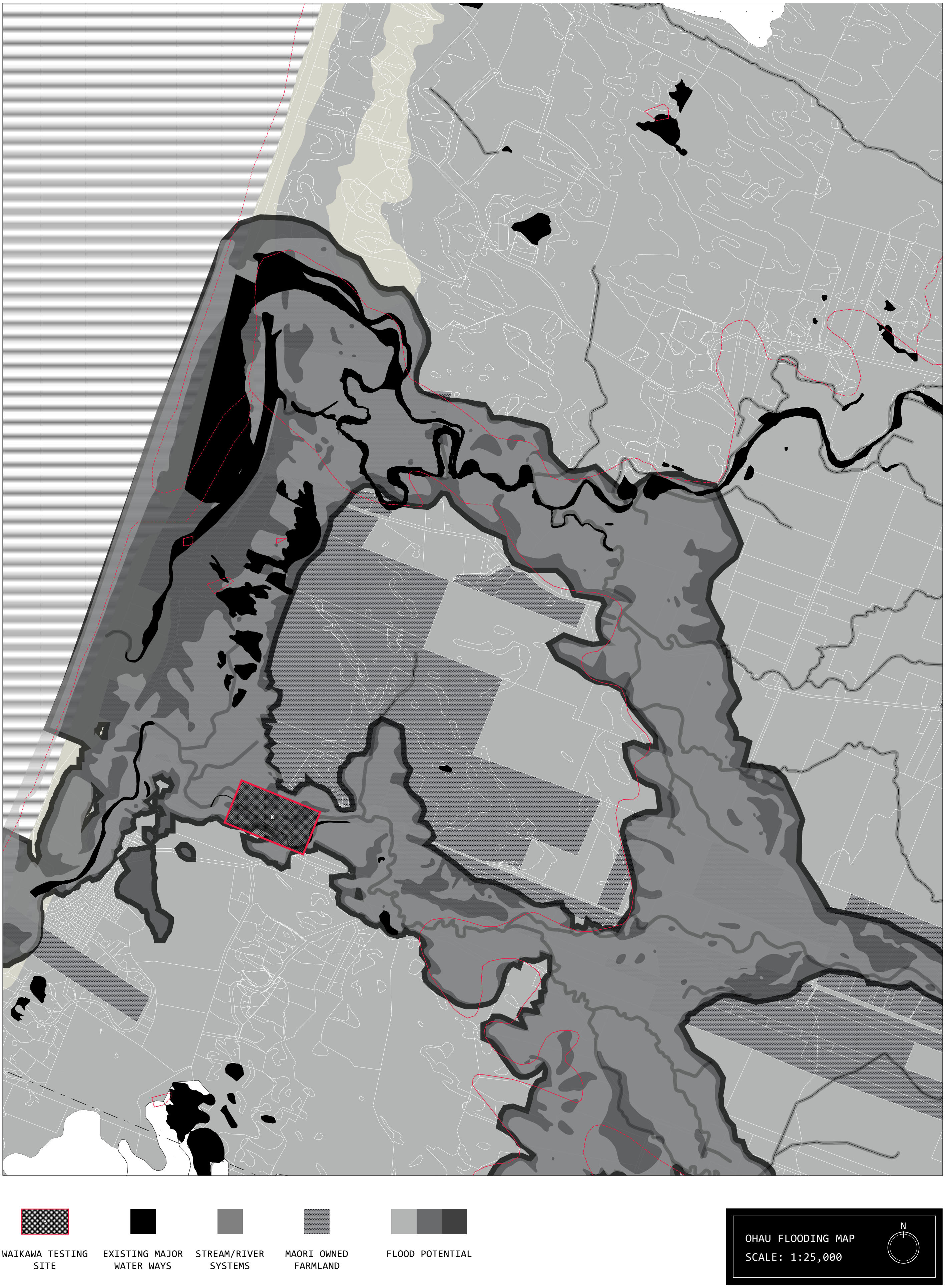
1. PAPA, RĀHUI, "HISTORICAL BACKGROUND", *NGĀTI KOROKI KAHUKURA*, ACCESSED JUNE 5, 2018, HTTPS://WWW.KOROKIKAHUKURA.CO.NZ/WHAKAPAPA.HTML


OHAU RIVER MOUTH
TIROTIROWHETU PA
TAUMATA-WHANUI DUNE HILL
PA HARAKEKE
KUKU BEACH
TE HAKIRI WETLAND
OKAKA DUNE RIDGE
TE HAKIRI KAINGA
1ST NGATI WEHIWEHI KAINGA
WAIKAWA RIVER MOUTH
PA TE RAUPARAHA
PAITAKU DUNE
0 50 100 250 500 1000
METERS
DUNE PEAKS
RIVER FLOOD POTENTIAL
HISTORIC WETLANDS
SIGNIFICANT SITES
LOOKOUT POINTS
HISTORICAL WATERWAYS
OHAU COAST MAP
SCALE : 1:10,000
N

To facilitate the exchange of knowledge, Ngāti Tukorehe conducted a pōwhiri to welcome us as researchers onto their whenua, via their marae, named Tukorehe. The marae is placed near the foothills of the Tararua mountains Otararere and Poroporo, with the wharenui and wharekai Ngāparetaihinu facing the sea (fig.02.17). Regular site visits were conducted, during which there would be a gathering for wānanga (discussion) and hīkoi (walking). Hīkoi involved a meeting then a walking discussion within Tukorehe's rohe to talk about the whenua and tikanga – the customs that revolve around the land.

Through this hīkoi, it was apparent that like many coastal iwi, Ngāti Tukorehe faces the challenge of forced lifestyle changes due to the effects of climate change and depletion of natural resources, particularly īnanga (the most common type of whitebait) and tuna (eel).

Fig. 02.03 OHAU SIGNIFICANT LOCATIONS MAP


WAIKAWA TESTING SITE
EXISTING MAJOR WATER WAYS
STREAM/RIVER SYSTEMS
MAORI OWNED FARMLAND
FLOOD POTENTIAL
OHAU FLOODING MAP
SCALE: 1:25,000
N

Shareholders of Ngāti Tukorehe coastal farm, Tahamata are mainly dependent on dairy farming as their primary source of economy and livelihood. Coastal farming will be severely affected by climate change through sea level rise, coastal erosion, and groundwater inundation and increased flooding of the two main rivers, Ōhau and Waikawa (fig.02.04). A higher groundwater table has already led to the inundation of these farms. In 2017, the Horowhenua district experienced its wettest year on record. Following this extreme weather event and others, Tukorehe representatives are investigating alternative economies for farming, as well as returning to traditional resources such as harakeke, pumice, clay, and enhancing habitats for īnanga and tuna fishing.

Te Hatete Trust, led by Moira Poutama, selected an area of farmland adjacent to the Waikawa River in order to connect this hapū back to their natural, material landscape. They are exploring new seasonal housing, increasing freshwater fisheries and investigating the viability of a harakeke fibre industry again.

Fig. 02.04 FARMLAND, WAIKAWA

Fig. 02.05 **MARRAM GRASS** (OHAU RIVER MOUTH 2018)
AUTHORS OWN PHOTOGRAPH

Fig. 02.06 **DUNE SYSTEM** (OHAU RIVER MOUTH 2018)
AUTHORS OWN PHOTOGRAPH

Fig. 02.07 CLAY FLATS (KUKU BEACH 2018)
AUTHORS OWN PHOTOGRAPH

Fig. 02.08 SAND DUNE EROSION (KUKU BEACH 2018)
AUTHORS OWN PHOTOGRAPH

Fig. 02.09 **COASTAL EROSION** (KUKU BEACH 2018)
AUTHORS OWN PHOTOGRAPH

Fig. 02.10 DRIFTWOOD EROSION CONTROL **(KUKU BEACH 2018)**
AUTHORS OWN PHOTOGRAPH

Fig. 02.11 WETLAND POND (TE HĀKARI WETLAND 2018)
AUTHORS OWN PHOTOGRAPH

Fig. 02.12 TE HĀKARI WETLAND (TE HĀKARI WETLAND 2018)
AUTHORS OWN PHOTOGRAPH

Fig. 02.13 MAORI OWNED FARMLAND (WAIKAWA 2018)
AUTHORS OWN PHOTOGRAPH

Fig. 02.14 **WAIKAWA RIVER** (WAIKAWA 2018)
AUTHORS OWN PHOTOGRAPH

Fig. 02.15 **MAORI OWNED FARMLAND** (WAIKAWA 2018)
AUTHORS OWN PHOTOGRAPH

Fig. 02.16 **MAORI OWNED FARMLAND** (WAIKAWA 2018)
AUTHORS OWN PHOTOGRAPH

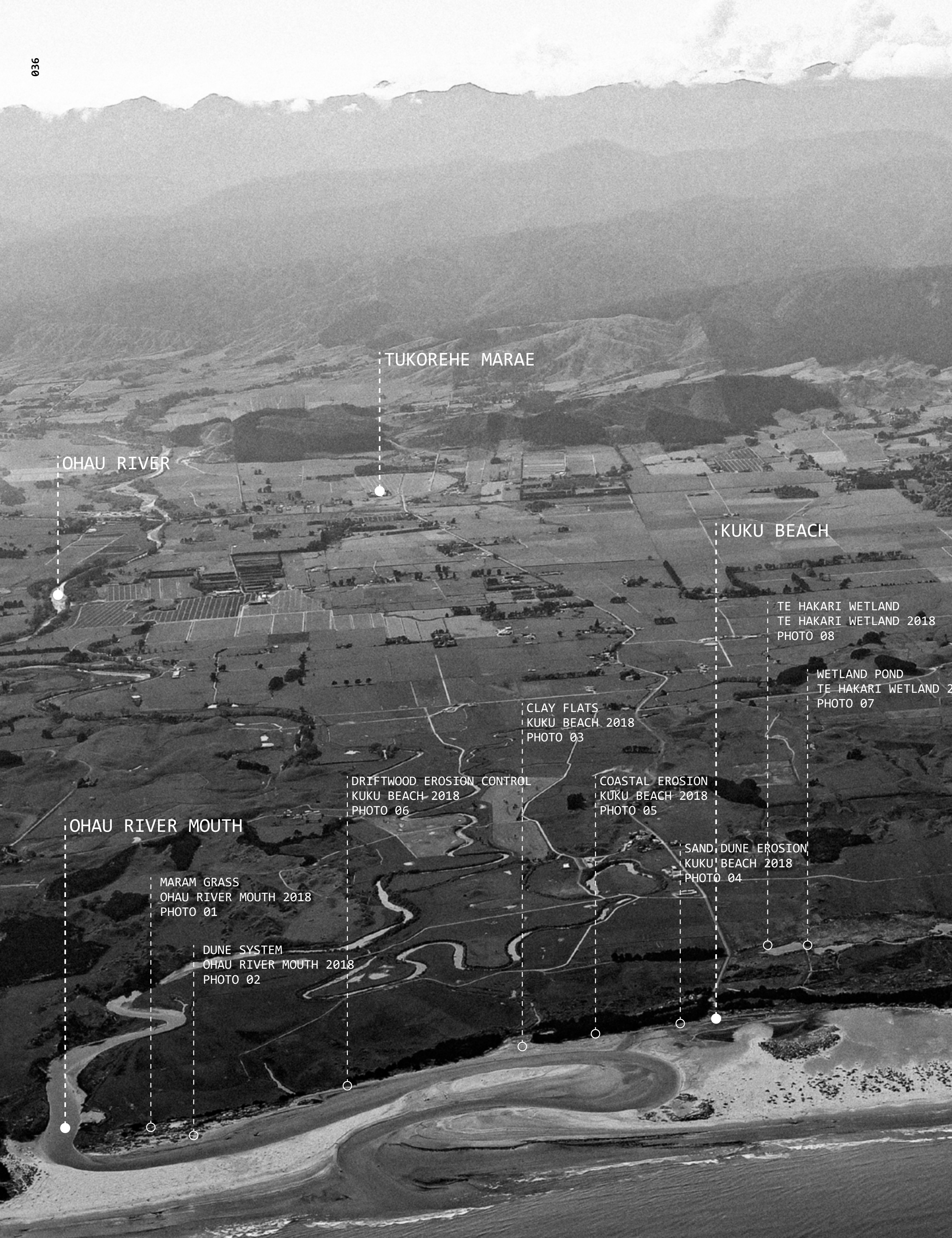

TUKOREHE MARAE
OHAU RIVER
KUKU BEACH
TE HAKARI WETLAND
TE HAKARI WETLAND 2018
PHOTO 08
WETLAND POND
TE HAKARI WETLAND 2
PHOTO 07
CLAY FLATS
KUKU BEACH 2018
PHOTO 03
DRIFTWOOD EROSION CONTROL
KUKU BEACH 2018
PHOTO 06
COASTAL EROSION
KUKU BEACH 2018
PHOTO 05
OHAU RIVER MOUTH
SAND DUNE EROSION
KUKU BEACH 2018
PHOTO 04
MARAM GRASS
OHAU RIVER MOUTH 2018
PHOTO 01
DUNE SYSTEM
OHAU RIVER MOUTH 2018
PHOTO 02

Fig. 01.11 PHOTO LOCATION MAP (OHAU 2017)
CAIRNS, LAWRIE. 2017. AERIAL PHOTOGRAPH
BETWEEN ŌHAU AND WAIKAWA RIVERS, HOROWHENUA.

IMAGE REDACTED

Fig. 03.01 “TEA AND COFFEE TOWERS.” (LYNN, GREG 2003)

03
DIGITAL DESIGN + FABRICATION

Literature Review

Themes

Greg Lynn - Animate form

Animation

Material agency

Motion

Parametrics

The Bartlett - SanDprint

Computation

Sand casting

Digital fabrication

ETH Zurich - Free Formwork

3D printing

Cement casting

Digital fabrication

Jon McTaggart - Artefact

Robotic 3D printing

Traditional craft

IMAGE REDACTED

Fig. 03.02 “EMBRYOLOGICAL HOUSE.” (LYNN, GREG 1998)

IMAGE REDACTED

Fig. 03.03 “EMBRYOLOGICAL HOUSE.” (LYNN, GREG 1998)

GREG LYNN

ANIMATE FORM

Themes

Animation

Material agency

Motion

Parametrics

Animate form proposes a shift in thinking; from architecture being about the design of inert objects through traditional static modelling to thinking about architecture as dynamic and introducing computational design tools and animation software[2].

Greg Lynn described the idea of a material having agency rather than being viewed as static and inert; "Forms can be shaped by the collaboration between an envelope and the active context in which it is situated."[3] Architectural forms can be informed and influenced by the forces and fields they are created within, rather than being pieced together or sculpted by the designer through direct manipulation of the material[4]. A designer would, therefore, refrain from imposing form on a material, instead, letting the material find its form through forces and changes in its environment. The designer may adjust the parameters of environmental forces as well as the parameters of the material being manipulated. These dynamic forces can be described computationally using animation software that introduces motion, time and parameters into the design process[5]. This software can be used creatively as a tool for architectural design.

2. LYNN, GREG, *ANIMATE FORM: GREG LYNN*, (NEW YORK: PRINCETON ARCHITECTURAL PRESS, 1997) 9
3. IBID., 10
4. IBID., 36
5. IBID., 20

IMAGE REDACTED

Fig. 03.04 “FREE FORMWORK.” (JIPA, ANDREI 2016)

IMAGE REDACTED

Fig. 03.05 “FREE FORMWORK.” (JIPA, ANDREI 2016)

ETH ZURICH

FREE FORMWORK

Themes

3D printing

Cement casting

Digital fabrication

Introduction:

Completed at ETH Zurich by Digital Building Technologies researchers in 2017, Free formwork investigated 3D printed plastic formwork for concrete architectural components[6]. The project focused on fabricating freeform geometries out of the most abundant building material: concrete[7]. Custom 3D printed formwork enables concrete to be cast into highly optimised architectural structures as well as different freeform geometries.

Design and fabrication:

Two different 3D printing techniques were explored in the creation of free formwork: fused deposition modelling and binder jetting[8].

Thin plastic moulds were printed in two parts, which can be disassembled later. Concrete is poured into the models then left to set. After the concrete is set, the mould is pulled off, leaving the freeform concrete geometry. Surface texture can be added to the 3D printed mould to leave patterning on the concrete form.

Evaluation:

Free formwork has limitations in terms of how to create scaffolding and support for the formwork. The internal concrete reinforcing also needs to be resolved in order to produce large-scale architectural structures.

6. JIPA, ANDREI, "FREE FORMWORK." *DIGITAL BUILDING TECHNOLOGIES*, ACCESSED APRIL 8, 2018, HTTP://DBT.ARCH.ETHZ.CH/RESEARCH-STREAM/FREE-FORMWORK/.

7. IBID.

8. IBID.

IMAGE REDACTED

Fig. 03.06 “SANDPRINT RC6” (CAO, XIYANGZI 2014)

IMAGE REDACTED

Fig. 03.07 “SANDPRINT RC6” (CAO, XIYANGZI 2014)

THE BARTLETT
SANDPRINT RC6

Themes

Computation
Sand casting
Digital fabrication

Introduction:

Completed at the Bartlett School of Architecture in 2014, SanDprint explored the structural potentials of sand casting for architectural forms[9]. The project used a mix of analogue and digital modelling to inform the geometries created.

Design and fabrication:

PVC pipes are flexed and bent into various curved geometries within a defined volume. The pipes are covered with a sand mixture to form a mould around the pipes. The pipes are then removed from the sand mould, leaving cavities within the sand where the pipes were removed. A plaster mix is poured into the cavities and left to set. Once set, the sand surrounding the plaster is removed and the plaster form is revealed.

Evaluation:

SanDprint used a sand casting process to create curved freeform geometries. The computational processes enabled complex shapes to be produced by plotting geometries from within a defined volume and bending flexible pipes to match the geometry. This process allowed for the creation of complex prototype geometries quickly and easily through analogue means.

Sand casting has limitations on the size and geometry of casting within a fixed volume due to the casting material being poured through a cavity. This pouring and casting process could be translated into a freeform 3D process using injection and pressure similar to a clay extruder. This process could enable larger single extrusions and 1:1 scale architectural prototypes.

9. CAO, XIYANGZI, “BARTLETT SCHOOL RC6.” *DESIGNBOOM*, LAST MODIFIED OCTOBER 10, 2014, HTTPS://WWW.DESIGNBOOM,COM/DESIGN/BARTLETT-SCHOOL-OF-ARCHITECTURE-SANDPRINT-RC6-B-PRO-MARCH-GRADUATE-STUDIO-10-10-2014/

IMAGE REDACTED

Fig. 03.08 “ARTEFACTS.” (MCTAGGART, JON 2015)

IMAGE REDACTED

Fig. 03.09 “ARTEFACTS.” (MCTAGGART, JON 2015)

JON MCTAGGART

ARTEFACT

Themes

Robotic 3D printing

Traditional craft

Introduction:

Completed by Israel-based designer Jon McTaggart in 2015, Artefact explored the relationship between traditional craft and digital design and fabrication[10]. Artefact used computational processes in Rhino and Grasshopper to create abstract geometries, which were translated to 3D printed models using soil and resin[11]. A bowl was used as a testing ground for these geometries.

Design and fabrication:

The form of the bowl was parametrically generated in Rhino and Grasshopper. A script was created in Grasshopper that translated the geometry into a 3D printing tool path. That toolpath was sent to a robotic arm that moved along the toolpath to 3D print the geometry.

In order to 3D print the geometry, a bucket filled with sand was placed in a defined position for the robot to print within. A pressurised canister attached to the end of the robotic arm pumped resin into the sand while the robot moved along the predefined toolpath. The resin was left to dry in the sand before the covering soils were removed and the bowl excavated.

Evaluation:

The process involved a custom designed tool attached to a robotic arm in order to manipulate the resin material. The tool allowed different parameters to be changed by the designer, creating different design outcomes. The form of the bowls was dictated by the robotic toolpath but also through the natural composition of the sand.

10. MCTAGGART, JON, "ARTEFACTS." JONMCT, LAST MODIFIED 2015, HTTP://JONMTC.COM/#PROJECTS.
11. IBID., 10


Precision Air

04
SOFT FORMING

Sub-chapter
page numbers

Fig. 04.01 WORKSHOP SET UP
AUTHORS OWN PHOTOGRAPH

04

SOFT FORMING

QR CODE. SOFT FORMING VIDEO

Introduction:

Soft forming was the first design enquiry of this research which investigated how to create freeform 3D printed structures. It explored ways to resolve to the scaffold and reinforce and create formwork through analogue physical modelling. The intention was to maintain Ngāti Tukorehe's tikanga of a strong connection and relationship to the whenua.

Ngāti Tukorehe's tikanga was achieved using the whenua from the Tukorehe domain as a type of scaffolding and formwork to support and shape a freeform subterranean structure. Using soil as a scaffolding structure left the potential to excavate the covering soils, revealing the freeform design.

Aim:

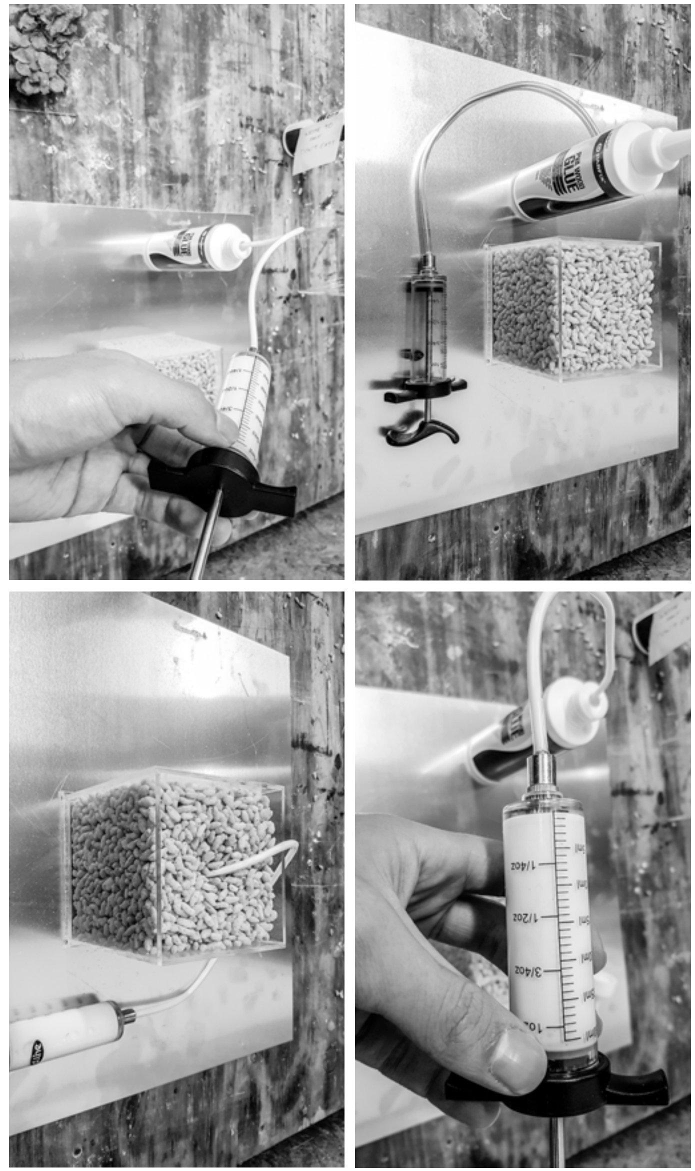
How can we gain control of the injection and extrusion of a substance into a granular or particulate material to create freeform and freestanding structures? How can we emphasise the sculptural and aesthetic qualities of Tukorehe's whenua in the design process, in addition to the structural elements?

Method:

Four iterative series of investigations were conducted, whereby a binder was injected and extruded into a granular material. In each series of investigation, the parameters of the injection or extrusion binder were changed, as well as the granular or particulate material. The volume of binder being injected and the number of injection points also changed in each series of investigations. The overall scale and volume of material were increased for the final series of iterations.

Fig. 04.02 WOVEN STRUCTURE

Fig. 04.03 **INJECTION PROCESS** (RICE BUBBLES + CORNFLAKES)



04.01

CONGLOMERATION

Aim:

The first series of design experiments aimed to investigate what effect particle size and density has on the way granular material conglomerates and binds together around a point of injection.

Method:

A series of preliminary investigations were conducted using PVA (polyvinyl alcohol) glue as the binder. PVA glue was injected with a syringe into either cornflakes or rice bubbles (Fig.04.03). The cornflakes or rice bubbles were held within a 10cm3 box (Fig.04.04). The parameters being changed through iteration were particle size, using either rice bubbles (4mm) or corn flakes (6mm), and the location of injection in a 3D volume.

Findings:

Findings from the first series of design experiments showed that a larger particle size allowed a larger volume of particles to conglomerate together (Fig.04.05). Having a large conglomeration of particles was due to the PVA glue encountering a path of low resistance between particles. Injecting in the centre of the volume allowed the PVA glue to propagate further down, due to the weight of particles above providing greater resistance.

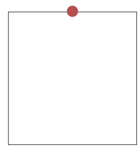
These findings led to the next series of experiments to verify if these results could be produced at a different scale.

INJECTION PROCESS

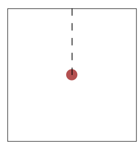
Fig. 04.04 **EXCAVATION MATRIX** (RICE BUBBLES + CORNFLAKES)

INJECTION PARAMETERS | **INJECTION LOCATIONS** | **FINAL OUTCOME**

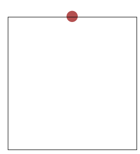
SUBSTRATE:	RICE BUBBLES
SUBSTRATE VOLUME:	10CM³
INJECTION MATERIAL:	PVA GLUE
INJECTION TYPE	SYRINGE
INJECTION LOCATION:	SURFACE
INJECTION VOLUME:	20ML



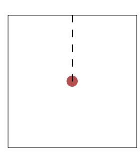
SUBSTRATE:	RICE BUBBLES
SUBSTRATE VOLUME:	10CM³
INJECTION MATERIAL:	PVA GLUE
INJECTION TYPE	SYRINGE
INJECTION LOCATION:	CENTRAL
INJECTION VOLUME:	20ML



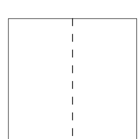
SUBSTRATE:	CORNFLAKES
SUBSTRATE VOLUME:	10CM³
INJECTION MATERIAL:	PVA GLUE
INJECTION TYPE	SYRINGE
INJECTION LOCATION:	SURFACE
INJECTION VOLUME:	20ML

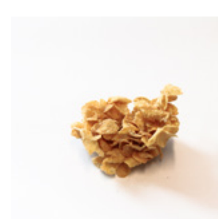


SUBSTRATE:	CORNFLAKES
SUBSTRATE VOLUME:	10CM³
INJECTION MATERIAL:	PVA GLUE
INJECTION TYPE	SYRINGE
INJECTION LOCATION:	CENTRAL
INJECTION VOLUME:	20ML



SUBSTRATE:	CORNFLAKES
SUBSTRATE VOLUME:	10CM³
INJECTION MATERIAL:	PVA GLUE
INJECTION TYPE	SYRINGE
INJECTION LOCATION:	BOTTOM
INJECTION VOLUME:	20ML



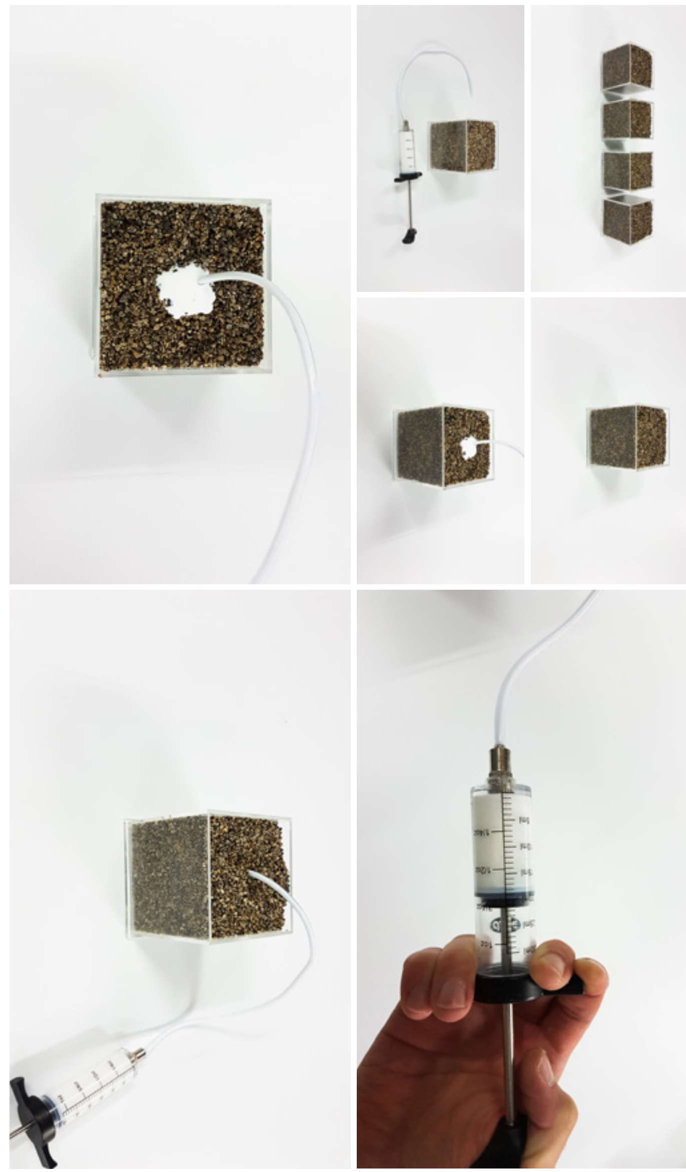


KEY
Point injection ●
Extrusion movement ○
Extrusion depth - - - -

(SECTION)

Fig. 04.05 INJECTION RESULTS (RICE BUBBLES + CORNFLAKES)

Fig. 04.06 INJECTION PROCESS (PROPAGATION SAND)



04.02

INJECTION + EXTRUSION

Aim:

To see if the results produced with cornflakes and rice bubbles could be scaled to a sandy substrate.

Method:

For the second series of design experiments, cornflakes and rice bubbles were replaced with propagation sand with a particle size of 2mm (Fig.04.06). The other parameters – injection location and the volume of PVA glue being injected – were kept the same as in the first series. For the last two tests in the series, an extrusion method was used instead of injection.

Findings:

Findings from the second series of design experiments showed that the results using cornflakes or rice bubbles were able to be scaled when using propagation sand. Similar results were produced when comparing the number of particles conglomerated together and the form of conglomeration with the injection location (Fig.04.08). The final two tests yielded more controlled freeform structures using extrusion instead of injection (Fig.04.08). The method of extrusion used for the final two tests was developed further in the next stage of research.

INJECTION PROCESS

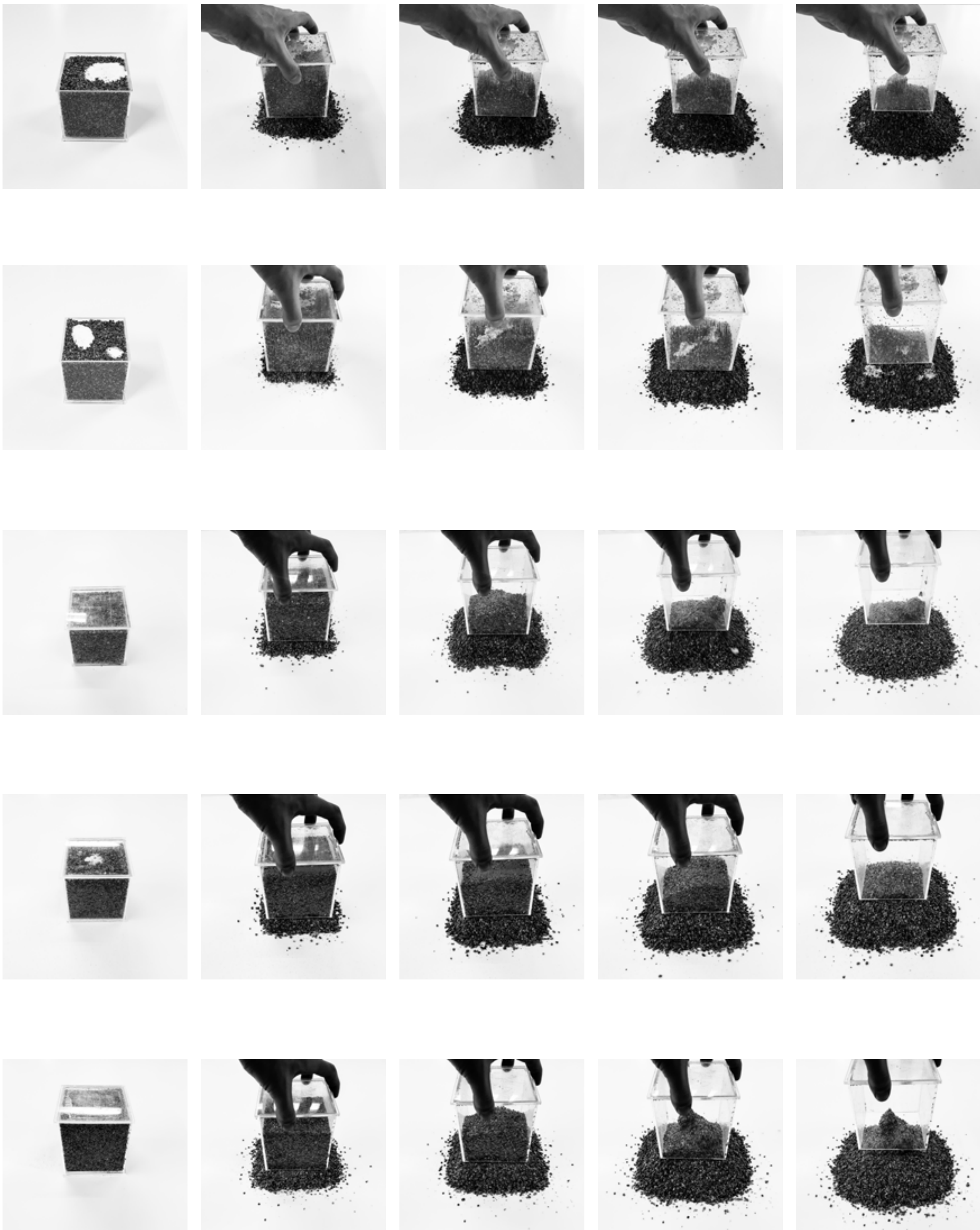
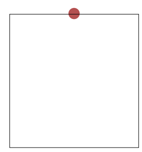


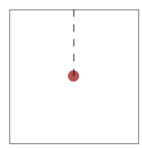
Fig. 04.07 EXCAVATION MATRIX (PROPAGATION SAND)

INJECTION PARAMETERS | **INJECTION LOCATIONS** | **FINAL OUTCOME**

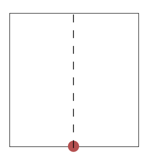
SUBSTRATE: PROPAGATION SAND
SUBSTRATE VOLUME: 10CM³
INJECTION MATERIAL: PVA GLUE
INJECTION TYPE SYRINGE
INJECTION LOCATION: SURFACE
INJECTION VOLUME: 20ML



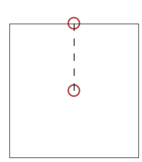
SUBSTRATE: PROPAGATION SAND
SUBSTRATE VOLUME: 10CM³
INJECTION MATERIAL: PVA GLUE
INJECTION TYPE SYRINGE
INJECTION LOCATION: CENTRAL
INJECTION VOLUME: 20ML



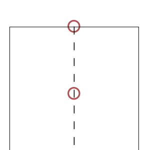
SUBSTRATE: PROPAGATION SAND
SUBSTRATE VOLUME: 10CM³
INJECTION MATERIAL: PVA GLUE
INJECTION TYPE SYRINGE
INJECTION LOCATION: BOTTOM
INJECTION VOLUME: 20ML

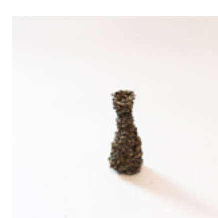


SUBSTRATE: PROPAGATION SAND
SUBSTRATE VOLUME: 10CM³
INJECTION MATERIAL: PVA GLUE
INJECTION TYPE SYRINGE
INJECTION LOCATION: FREEFORM
INJECTION VOLUME: 30ML



SUBSTRATE: PROPAGATION SAND
SUBSTRATE VOLUME: 10CM³
INJECTION MATERIAL: PVA GLUE
INJECTION TYPE SYRINGE
INJECTION LOCATION: FREEFORM
INJECTION VOLUME: 30ML





KEY
Point injection ●
Extrusion movement ○
Extrusion depth - - - -

(SECTION)

Fig. 04.08 INJECTION RESULTS (PROPAGATION SAND)

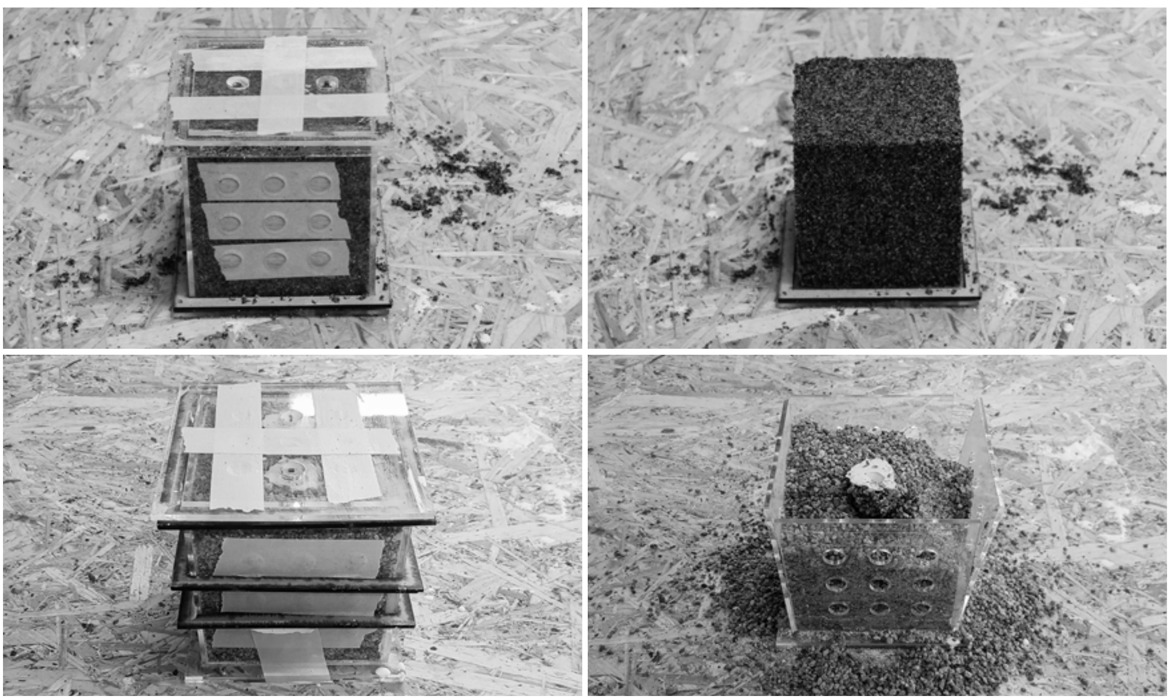


Fig. 04.09 INJECTION PROCESS (PROPAGATION SAND + FINE SAND)

04.03

FREE-FORM EXTRUSION

Aim:

The third series of design experiments aimed to develop the previous method of extrusion by using a hard setting plaster of Paris as the binder material instead of PVA glue.

Method:

The parameters of the granular material were also changed to test the viability of sand as scaffolding and formwork by comparing the difference in form and materiality between propagation sand (2-3mm) and fine sand (0.01mm) (Fig.04.09).

Findings:

Findings showed that the fine sand allowed for more controlled freeform geometries, while the larger particle size of the propagation sand had the potential to create more rhyzomic structures (Fig.04.11). The use of plaster of Paris enabled faster setting times and stronger bonding of the granular material. These factors, in turn, developed the complexities of the freeform geometries. The next series of design experiments used plaster of Paris at a larger scale to develop upon the complexity produced in this series of tests.

INJECTION PROCESS

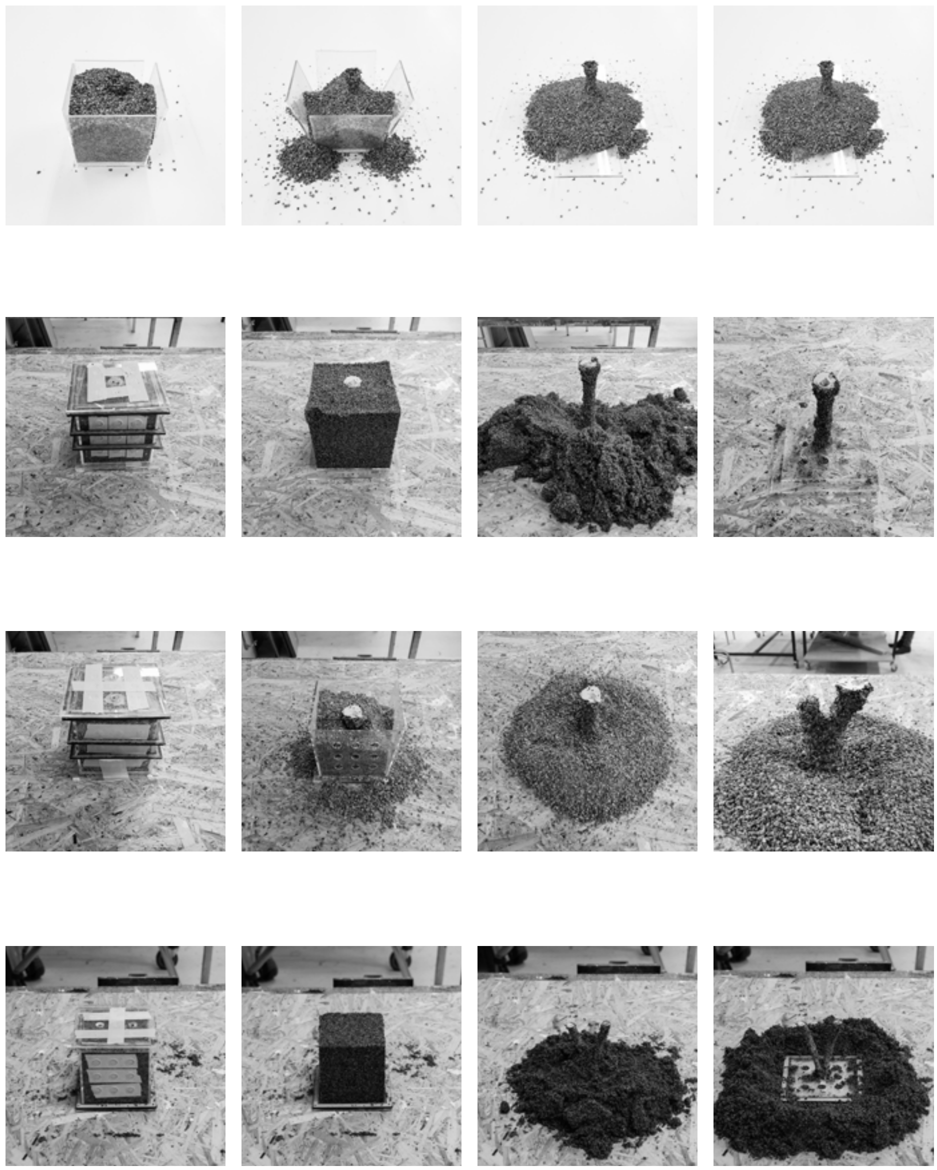
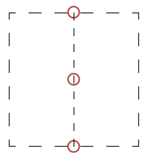
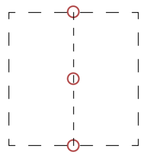
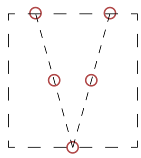
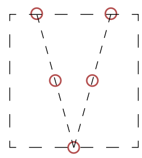


Fig. 04.10 EXCAVATION MATRIX (PROPAGATION SAND + FINE SAND)

INJECTION PARAMETERS		INJECTION LOCATIONS	FINAL OUTCOME
SUBSTRATE:	PROPAGATION SAND		
SUBSTRATE VOLUME:	10CM^3		
INJECTION MATERIAL:	PLASTER OF PARIS		
INJECTION TYPE	SYRINGE		
INJECTION LOCATION:	FREEFORM VERTICAL		
INJECTION VOLUME:	30ML		
SUBSTRATE:	FINE SAND		
SUBSTRATE VOLUME:	10CM^3		
INJECTION MATERIAL:	PLASTER OF PARIS		
INJECTION TYPE	SYRINGE		
INJECTION LOCATION:	FREEFORM VERTICAL		
INJECTION VOLUME:	30ML		
SUBSTRATE:	PROPAGATION SAND		
SUBSTRATE VOLUME:	10CM^3		
INJECTION MATERIAL:	PLASTER OF PARIS		
INJECTION TYPE	SYRINGE		
INJECTION LOCATION:	FREEFORM ‘V’		
INJECTION VOLUME:	30ML		
SUBSTRATE:	FINE SAND		
SUBSTRATE VOLUME:	10CM^3		
INJECTION MATERIAL:	PLASTER OF PARIS		
INJECTION TYPE	SYRINGE		
INJECTION LOCATION:	FREEFORM ‘V’		
INJECTION VOLUME:	30ML		

KEY
Point injection
Extrusion movement
Extrusion depth

(SECTION)

Fig. 04.11 INJECTION RESULTS (PROPAGATION SAND + FINE SAND)

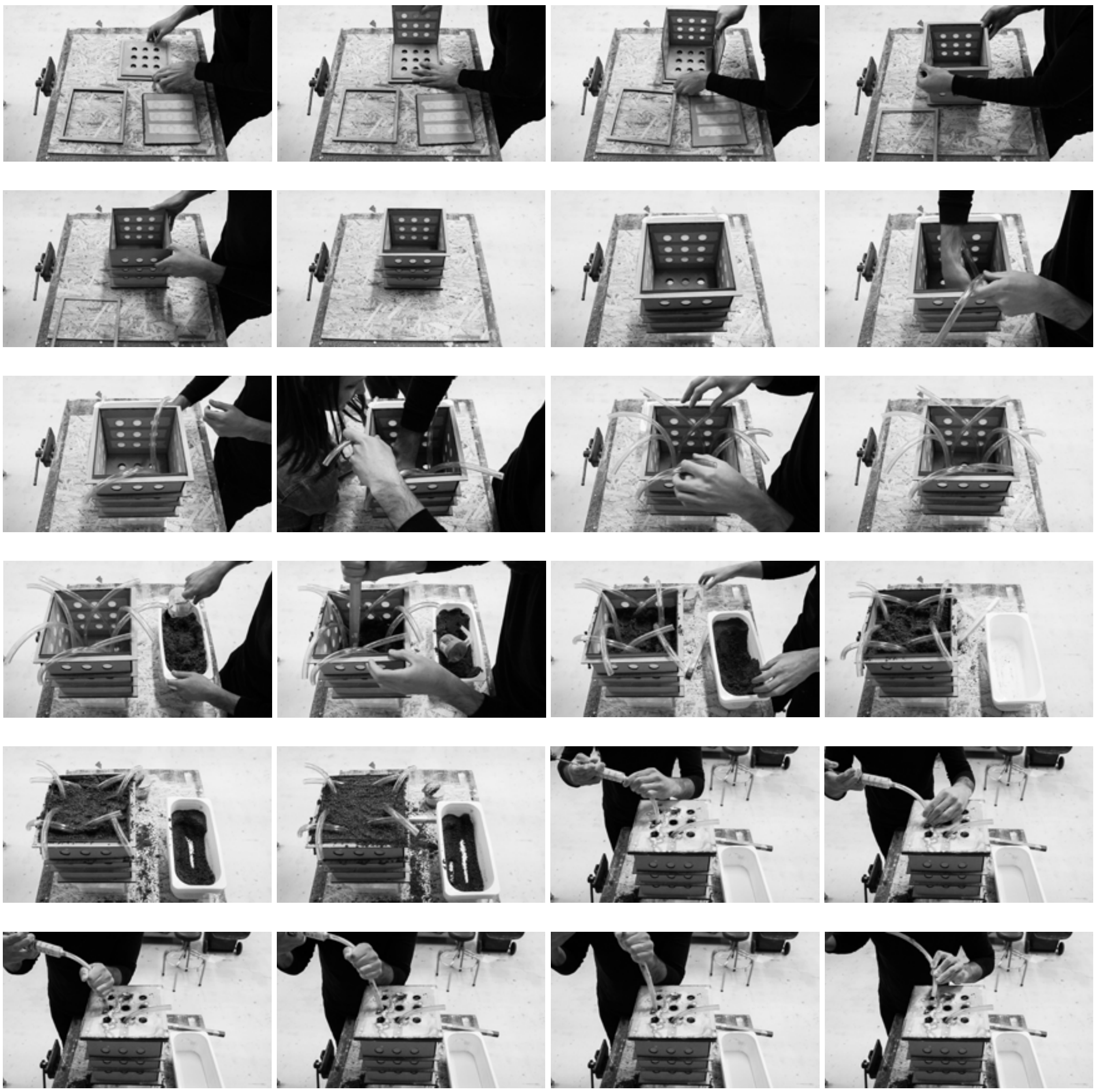


Fig. 04.12 INJECTION MATRIX (FINE SAND)

04.04

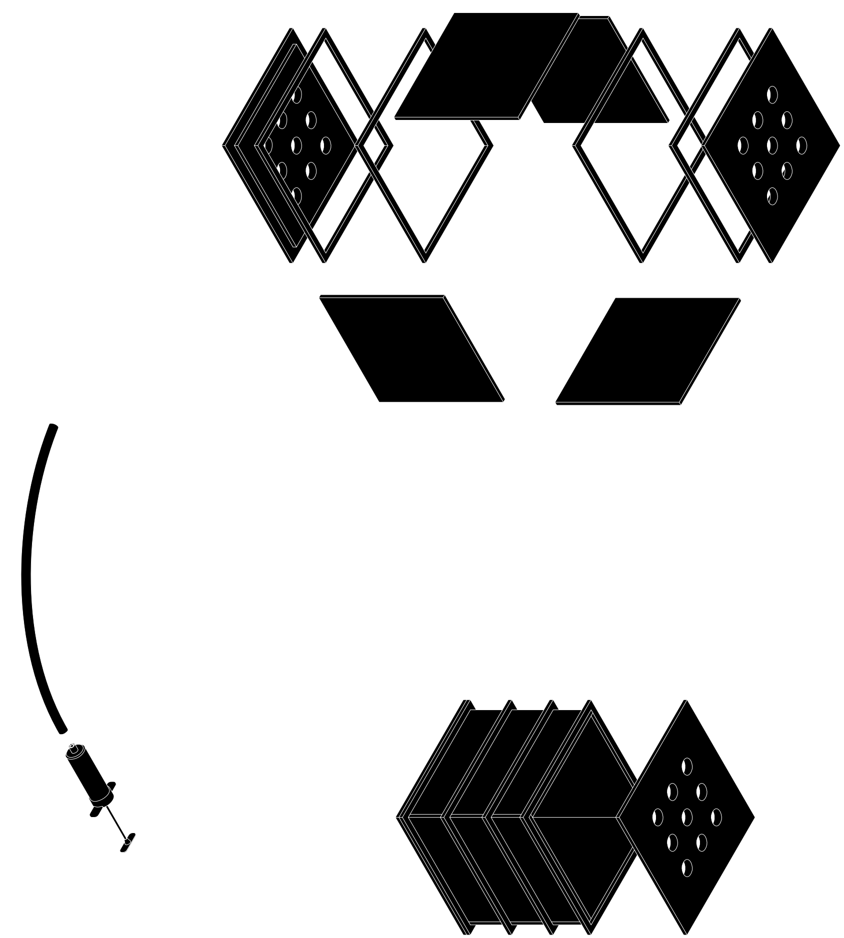
SOFT FORMING

QR CODE. SOFT FORMING VIDEO

Aim:

The final series of design experiments investigated analogue form finding as well as interrogating the extrusion process and workflow. Soft forming is the name given to this extrusion technique. This soft forming series looked at how to emulate Māori ideas of weaving and curved structures to inform the form finding process. Māori structures can be some of the most refined and sophisticated but also some of the most beautiful and sculptural. Emulating woven and curved forms allowed for exploration into the types of complexities and designed outcomes that could emerge using the soft forming technique.

Fig. 04.13 BOX JIG (ASSEMBLY DIAGRAM)



Method:

The parameters being controlled through this series of iterations were the number of injection locations in plan view, the toolpath of injection in a 3D volume and the volume of the substance being injected.

The soft forming process involved setting up a 25cm3 box jig to contain the sandy substrate used as the scaffolding and formwork for the freeform structure (Fig.04.13). Flexible pipes were then laid within the box to simulate the toolpath and the nozzle of the extruder. Using a syringe, plaster of Paris was extruded through the pipes as the pipes were withdrawn from the box along the fixed toolpath. Here, the covering soils (which previously acted as the scaffolding and formwork) could also be excavated to reveal the freeform structure (Fig.04.12).

INJECTION PROCESS

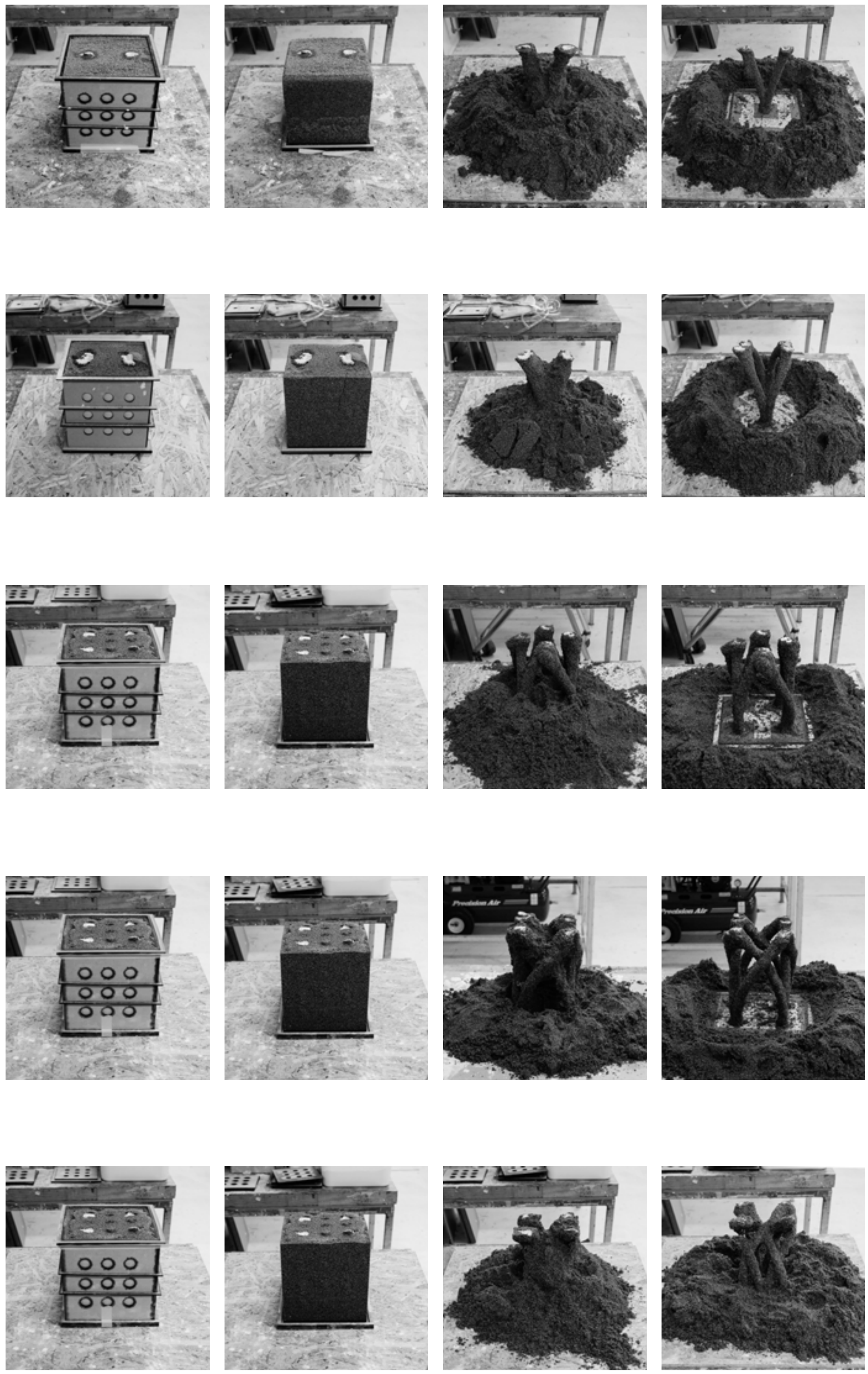
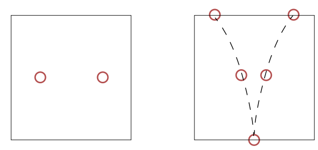
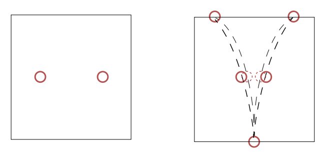
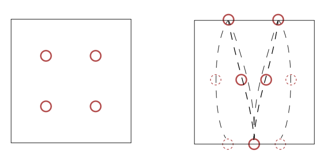
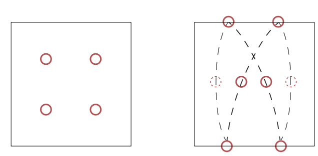
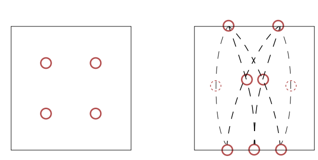
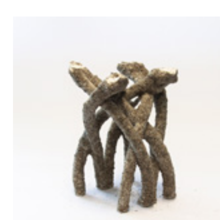


Fig. 04.14 EXCAVATION MATRIX (FINE SAND)

INJECTION PARAMETERS		INJECTION LOCATIONS	FINAL OUTCOME
SUBSTRATE:	FINE SAND		
SUBSTRATE VOLUME:	$25CM^3$		
INJECTION MATERIAL:	PLASTER OF PARIS		
INJECTION TYPE	SYRINGE		
INJECTION LOCATION:	FREEFORM ‘V’		
INJECTION VOLUME:	90ML		
SUBSTRATE:	FINE SAND		
SUBSTRATE VOLUME:	$25CM^3$		
INJECTION MATERIAL:	PLASTER OF PARIS		
INJECTION TYPE	SYRINGE		
INJECTION LOCATION:	FREEFORM X2 VAULT		
INJECTION VOLUME:	90ML		
SUBSTRATE:	FINE SAND		
SUBSTRATE VOLUME:	$25CM^3$		
INJECTION MATERIAL:	PLASTER OF PARIS		
INJECTION TYPE	SYRINGE		
INJECTION LOCATION:	FREEFORM X4 VAULT		
INJECTION VOLUME:	90ML		
SUBSTRATE:	FINE SAND		
SUBSTRATE VOLUME:	$25CM^3$		
INJECTION MATERIAL:	PLASTER OF PARIS		
INJECTION TYPE	SYRINGE		
INJECTION LOCATION:	FREEFORM WOVEN		
INJECTION VOLUME:	90ML		
SUBSTRATE:	FINE SAND		
SUBSTRATE VOLUME:	$25CM^3$		
INJECTION MATERIAL:	PLASTER OF PARIS		
INJECTION TYPE	SYRINGE		
INJECTION LOCATION:	FREEFORM WOVEN		
INJECTION VOLUME:	90ML		

(PLAN) (SECTION)

KEY
Point injection ●
Extrusion movement ○
Extrusion depth - - - -

Fig. 04.15 INJECTION RESULTS (FINE SAND)

Fig. 04.16 DOUBLED VAULT (PLASTER + FINE SAND)

Fig. 04.17 FOUR VAULTS (PLASTER + FINE SAND)

Fig. 04.18 DOUBLE WEAVE (PLASTER + FINE SAND)

Fig. 04.19 COMPLEX WEAVE (PLASTER + FINE SAND)

Fig. 04.20 DOUBLE WEAVE DETAIL (PLASTER + FINE SAND)

Fig. 04.21 COMPLEX WEAVE DETAIL 1 (PLASTER + FINE SAND)

Fig. 04.22 TAXONOMY OF FORMS

RICE BUBBLES 10CM³ PVA GLUE 20ML INJECTION: TOP 01	RICE BUBBLES 10CM³ PVA GLUE 20ML INJECTION: TOP 02	RICE BUBBLES 10CM³ PVA GLUE 20ML INJECTION: CENTRE 03	RICE BUBBLES 10CM³ PVA GLUE 20ML INJECTION: BOTTOM 04	CORN FLAKES 10CM³ PVA GLUE 20ML INJECTION: TOP 05
CORN FLAKES 10CM³ PVA GLUE 20ML INJECTION: TOP 06	CORN FLAKES 10CM³ PVA GLUE 20ML INJECTION: CENTRE 07	CORN FLAKES 10CM³ PVA GLUE 20ML INJECTION: BOTTOM 08	PROPAGATION SAND 10CM³ PVA GLUE 20ML INJECTION: TOP 09	PROPAGATION SAND 10CM³ PVA GLUE 20ML INJECTION: TOP 10
PROPAGATION SAND 10CM³ PVA GLUE 20ML INJECTION: CENTRE 11	PROPAGATION SAND 10CM³ PVA GLUE 20ML INJECTION: BOTTOM 12	PROPAGATION SAND 10CM³ PVA GLUE 40ML INJECTION: TOP X3 13	PROPAGATION SAND 10CM³ PVA GLUE 30ML FREEFORM 14	PROPAGATION SAND 10CM³ PVA GLUE 30ML FREEFORM 15
PROPAGATION SAND 10CM³ PLASTER OF PARIS 30ML INJECTION: TOP 16	PROPAGATION SAND 10CM³ PLASTER OF PARIS 30ML FREEFORM 17	PROPAGATION SAND 10CM³ PLASTER OF PARIS 30ML FREEFORM ‘V’ 18	FINE SAND 10CM³ PLASTER OF PARIS 30ML FREEFORM 19	FINE SAND 10CM³ PLASTER OF PARIS 30ML FREEFORM ‘V’ 20
FINE SAND 25CM³ PLASTER OF PARIS 90ML FREEFORM ‘V’ 11	FINE SAND 25CM³ PLASTER OF PARIS 90ML FREEFORM VAULT X2 12	FINE SAND 25CM³ PLASTER OF PARIS 90ML FREEFORM VAULT X4 13	FINE SAND 25CM³ PLASTER OF PARIS 90ML FREEFORM WEAVE 14	FINE SAND 25CM³ PLASTER OF PARIS 90ML FREEFORM COMPLEX WEAVE 15

Fig. 04.23 MATERIAL COMPOSITION

Fig. 04.24 MULTIPLE EXTRUSION TEST

Fig. 04.25 REINFORCING PROCESS (HESSIAN REINFORCING)

04.05

REINFORCING

Reinforcing Methods:

This stage explored two different methods of extrusion. The first design used multiple extrusion pipes bunched together instead of a single pipe (Fig.04.24). Bunching pipes together allowed for a stronger overall form. Multiple extrusion pipes also provided the added aesthetic quality of overlapping tendrils. The second design used a hessian sleeve around a flexible PVC pipe (Fig.04.25). The PVC pipe was removed as the plaster was being extruded, leaving the hessian sleeve in the ground as reinforcing.

Fig. 04.27 **COMPLEX WEAVE DETAIL 2** (PLASTER + FINE SAND)

Fig. 04.26 **SOFT-FORMING MODELS** (PLASTER + FINE SAND)

04.06
CONCLUSION

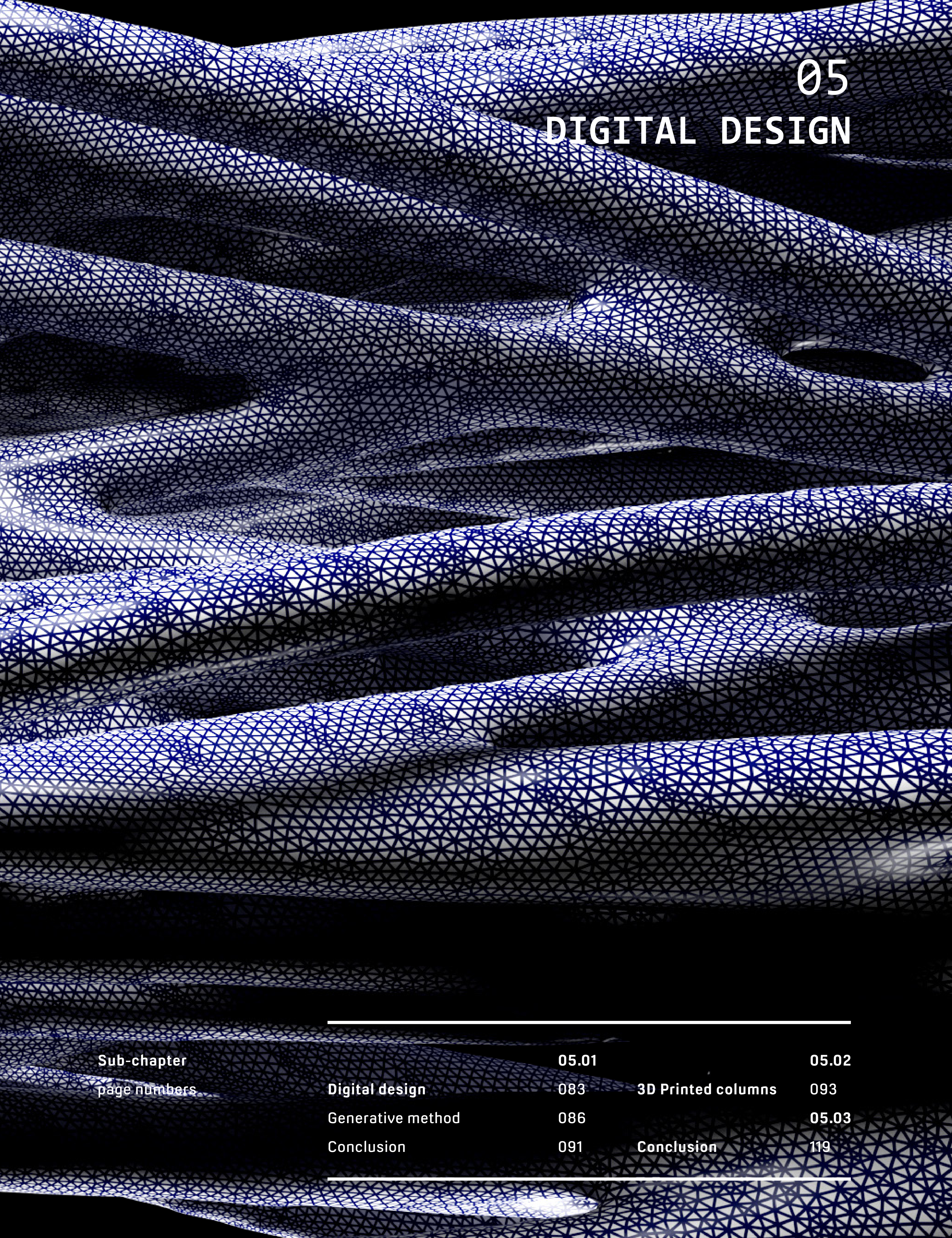
Findings:

In conclusion, soft forming is a viable technique to create freeform 3D printed structures using soil as scaffolding and formwork at a small scale. This process needs to be scaled up to test the viability in creating architectural forms. The geometries created through soft forming can emulate woven and curved structures. Soft forming is important for Ngāti Tukorehe in their domain due to their whenua being comprised of a series of sand dunes unique to Tukorehe. Soft forming also emphasises the sculptural and aesthetic qualities of the form, as well as the beauty in the materiality of the whenua, once the covering soils have been excavated.

However, the unstable and shifting nature of the sand dunes adds a unique agency to the whenua that Ngāti Tukorehe want to explore. Soft forming is designer-led due to the nature of using flexible pipes as the 3D printing toolpath. Because of the controlled toolpath, the agency is removed from the material, and the whenua and the authorship remains with the architect/designer. Tukorehe are interested in exploring the potential use of soft forming on their whenua to stabilise eroding sand dunes and coastlines. Soft forming has the potential to stabilise erosion by anchoring sand together. Other possibilities for soft forming are to create seasonal and temporary pavilion structures, as well as post-disaster shelters, for the United Nations.

Overall, this design enquiry was useful at this stage to focus on the aesthetic and formal qualities of the design. The next stage of research describes this attempt at shifting the authorship.

Fig. 05.01 DIGITAL COLUMN 02 RENDER
AUTHORS OWN PHOTOGRAPH



05
DIGITAL DESIGN

05.01

DIGITAL DESIGN

Introduction:

Using Rhino and Grasshopper, computational processes digitally simulated processes similar to the soft forming technique. Simulation of soft forming gained control of the form making process, as well as producing various sculptural design outcomes. Computational software also gave more agency to the material and form of the design through the creation of a generative Grasshopper algorithm. This algorithm allowed for simulation of the 3D printing toolpath and size of the 3D printing extrusion. The algorithm also simulated intelligent behaviours within a computer model. These intelligent behaviours are based on multi-agent systems and lend themselves to simulating the flocking of birds or the swarming of ants. The multi-agent behaviour was important as it enabled more agency of form through design.

Complexities and interesting formal characteristics of the design thus emerged based on a simple set of parameters. This emergence gave rise to an increased agency of the form. Small changes to any of the parameters have the potential to produce an entirely new set of formal characteristics.

Research Aim:

How can we simulate digitally as well as expand upon the design limitations of the analogue soft forming process? In addition, how can we do so in a way that provides more agency to the material, form and process of the design?

Fig. 05.02 DIGITAL COLUMN 02 (WIRE FRAME)

GENERATIVE METHOD

Method:

A generative algorithm was created within Grasshopper using the plugin Anemone. Anemone simulates intelligent behaviours such as swarming and flocking within a computer model through a looping function.

The form was generated in the Grasshopper algorithm through interaction with nearby agents or points (Fig.05.03), which were defined in the Grasshopper model. In plan view, the points were defined to be injection or extrusion sites for the creation of a freeform structure (Fig.05.04). These points had behaviours and agency to generate a formal outcome. The initial state or behaviours of the points were based on the parameters input by the designer. For the first digital design enquiry, these parameters were defined as: movement speed (step size), the range at which the points will converge on each other (attraction range), the range at which the points will diverge from each other (repulsion range), the amount the points will move parallel to each other (alignment factor).

As the points moved based on their initial state, they left behind trails, which tracked the point's movement in three-dimensional space. These trails were intended to act as the toolpath for creating the freeform column-like structures with soft forming.

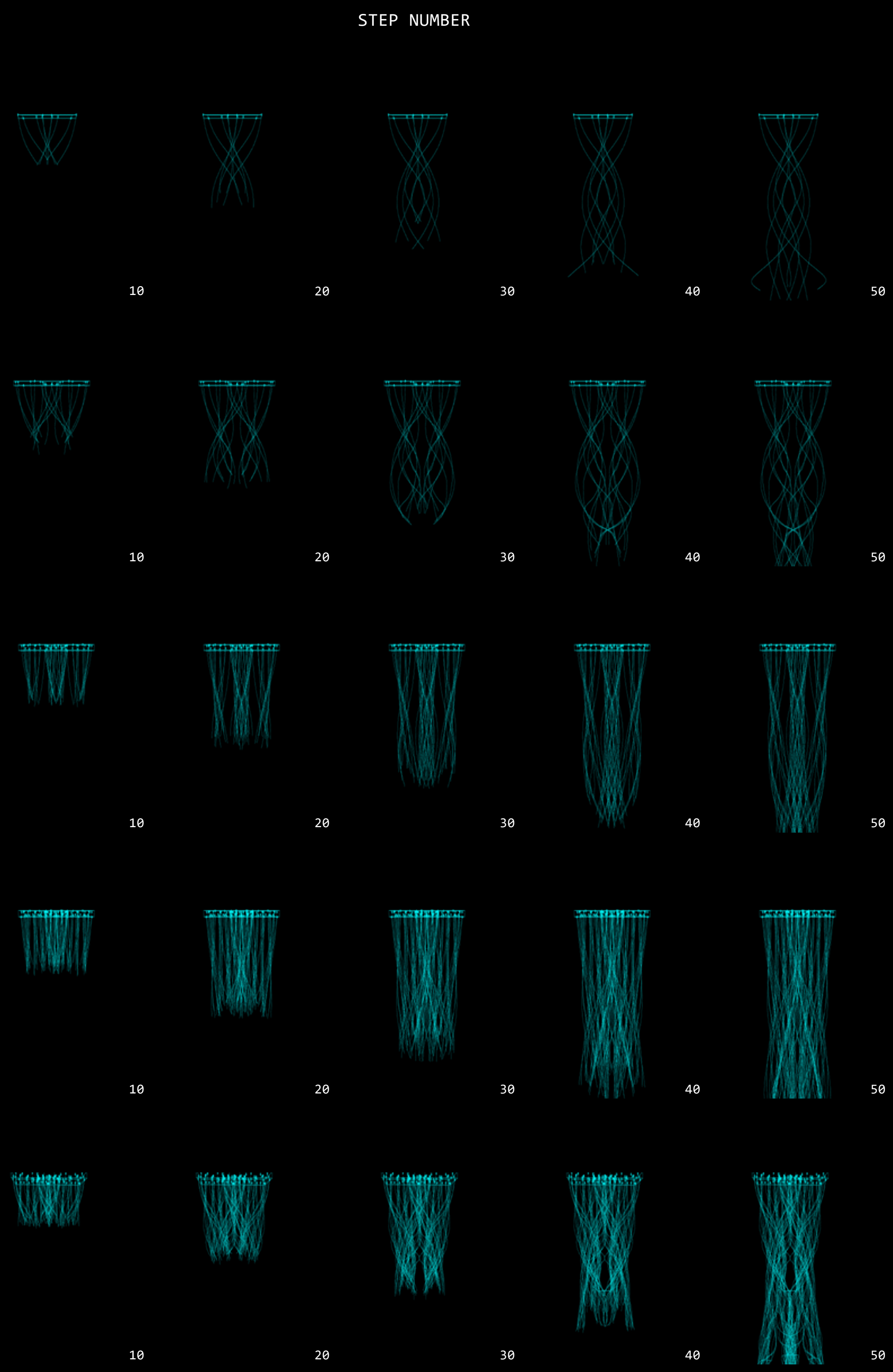
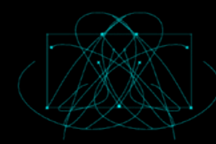


Fig. 05.03 AGENT TRAILS MATRIX (ANIMATION STEPS)

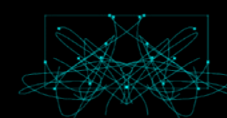
GRASSHOPPER PARAMETERS | POINT LOCATIONS

VOLUME: 2.0M X 0.6M X 0.3M
POINTS: 10
POINTS DISTRIBUTION: RANDOM SYMMETRY
STEP SIZE: 40MM
ATTRACTION RANGE: 150MM - 50MM
REPULSION RANGE: 0MM - 50MM
ALIGNMENT FACTOR: 3.0



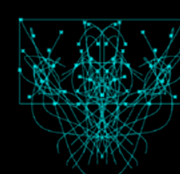
01

VOLUME: 2.0M X 0.6M X 0.3M
POINTS: 20
POINTS DISTRIBUTION: RANDOM SYMMETRY
STEP SIZE: 40MM
ATTRACTION RANGE: 150MM - 50MM
REPULSION RANGE: 0MM - 50MM
ALIGNMENT FACTOR: 3.0



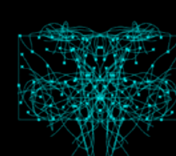
02

VOLUME: 2.0M X 0.6M X 0.3M
POINTS: 50
POINTS DISTRIBUTION: RANDOM SYMMETRY
STEP SIZE: 40MM
ATTRACTION RANGE: 100MM - 10MM
REPULSION RANGE: 0MM - 10MM
ALIGNMENT FACTOR: 5.0



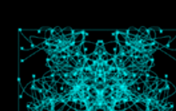
03

VOLUME: 2.0M X 0.6M X 0.3M
POINTS: 80
POINTS DISTRIBUTION: RANDOM SYMMETRY
STEP SIZE: 40MM
ATTRACTION RANGE: 100MM - 10MM
REPULSION RANGE: 0MM - 10MM
ALIGNMENT FACTOR: 5.0



04

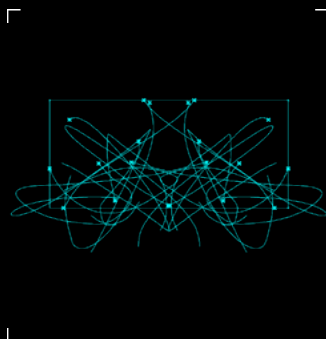
VOLUME: 2.0M X 0.6M X 0.3M
POINTS: 100
POINTS DISTRIBUTION: RANDOM SYMMETRY
STEP SIZE: 40MM
ATTRACTION RANGE: 50MM - 05MM
REPULSION RANGE: 0MM - 05MM
ALIGNMENT FACTOR: 3.0



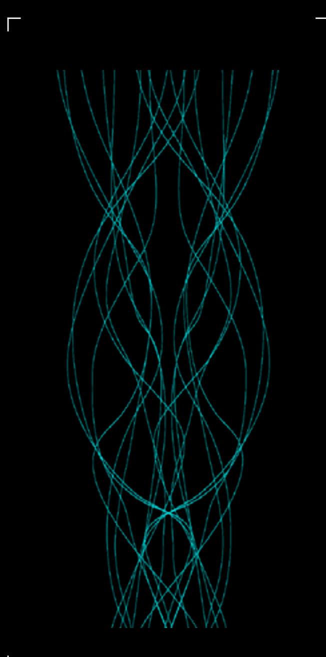
05

Fig. 05.04 INJECTION SITES (PLAN VIEW)

02

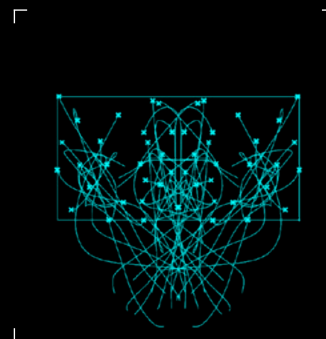


PLAN

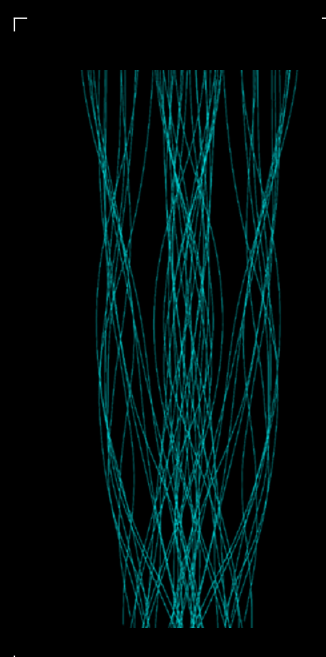


ELEVATION

03

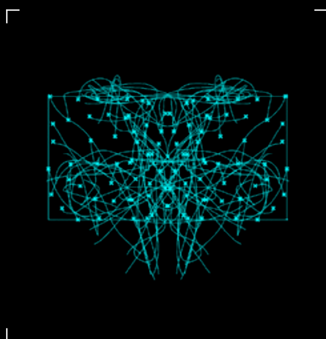


PLAN

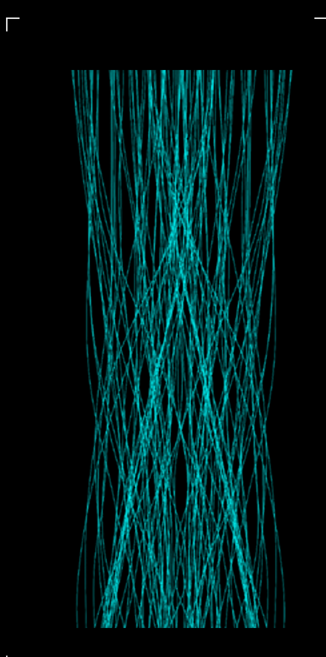


ELEVATION

04

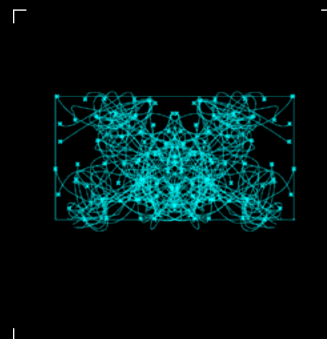


PLAN

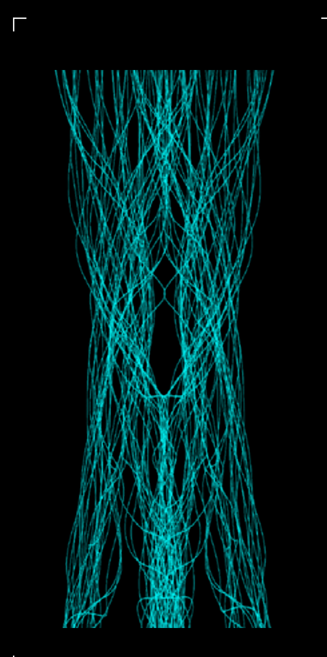


ELEVATION

05

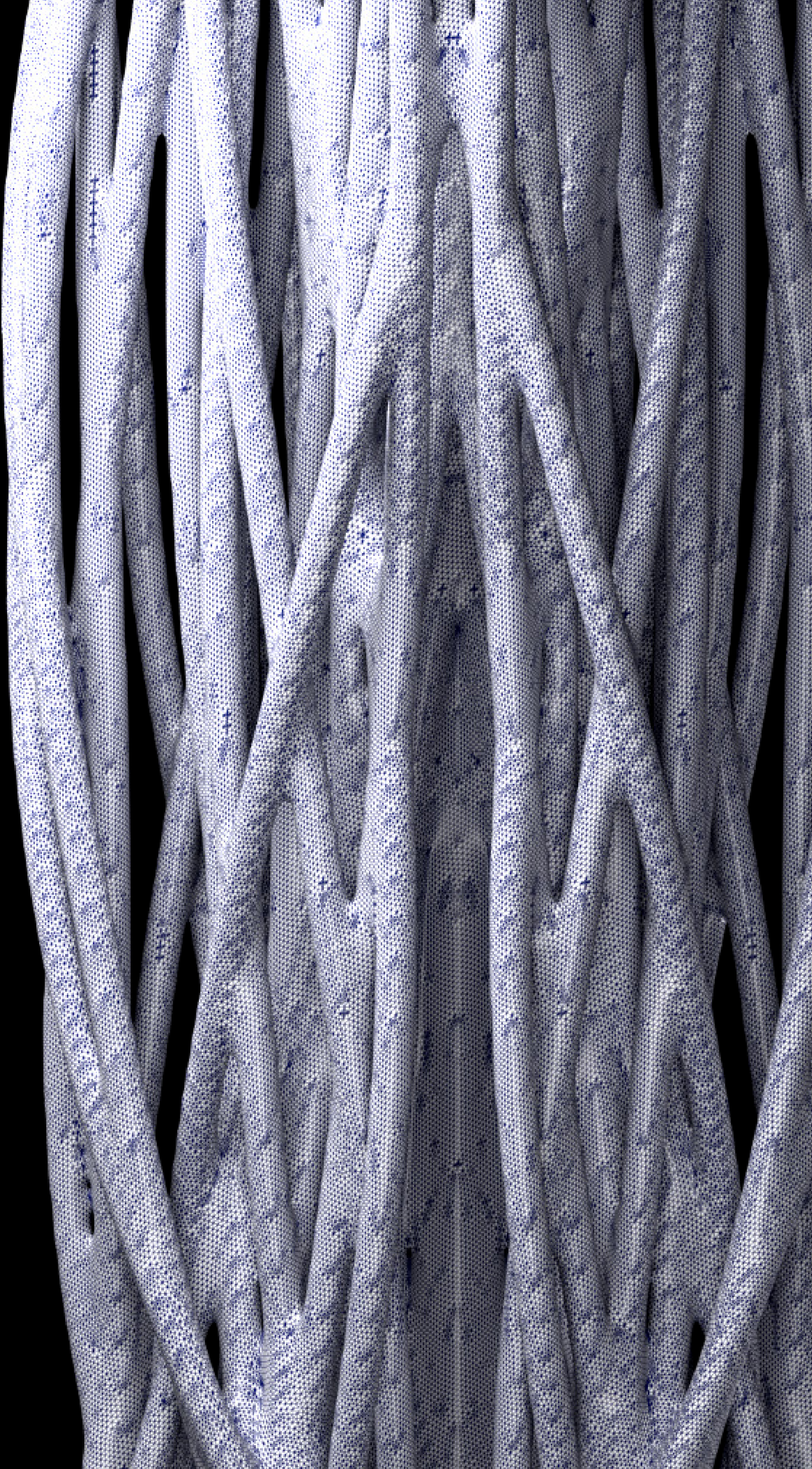


PLAN



ELEVATION

Fig. 05.05 AGENT TRAILS RESULTS



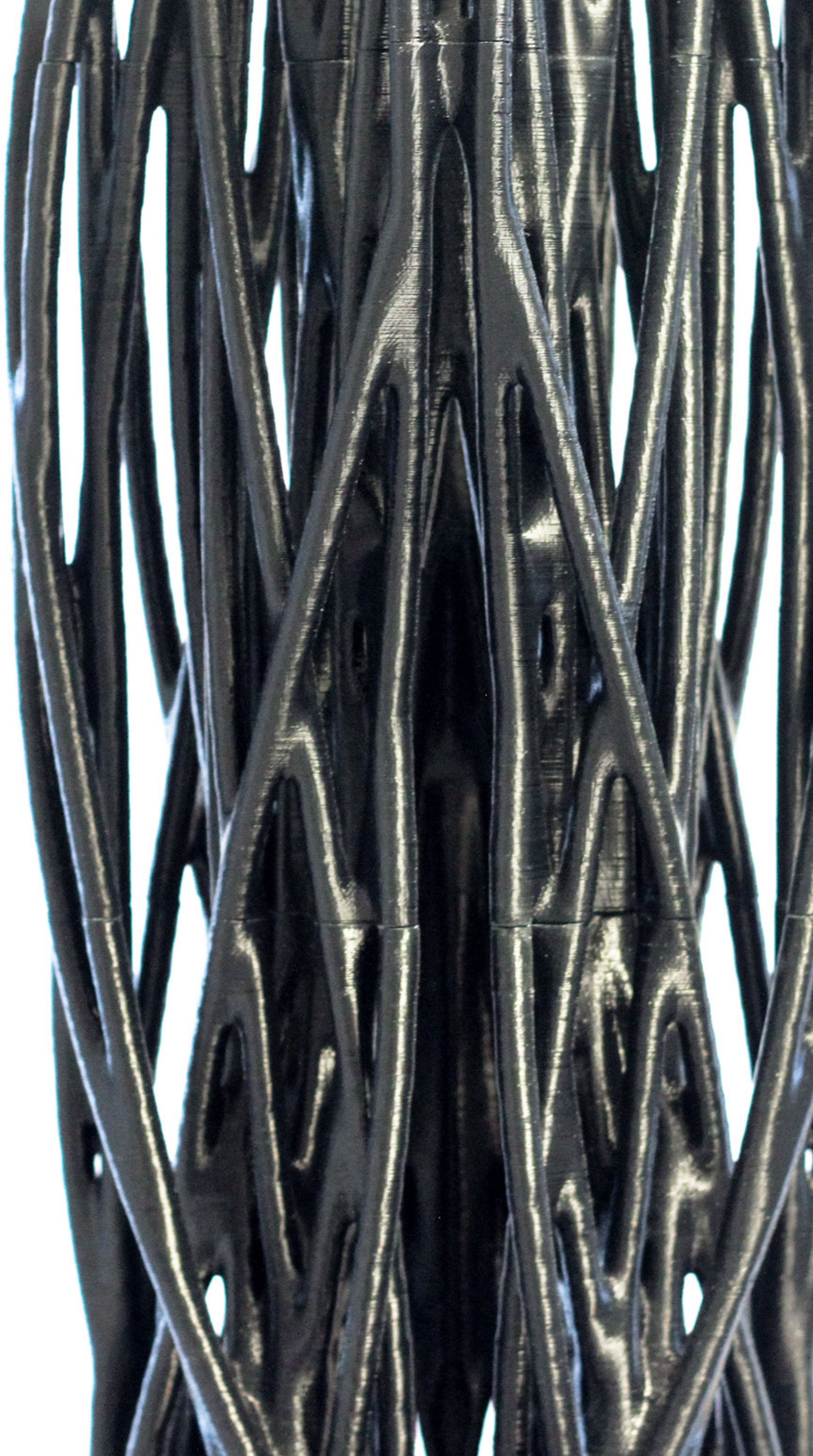
CONCLUSION

Findings:

In conclusion, the computational process of multi-agent systems in Grasshopper allows for the digital simulation of the soft forming process. The emergent properties of the multi-agent system enabled expansion of the design's formal qualities beyond what had been established in the analogue process. The use of a generative algorithm also gave agency to form, due to the ability of multi-agent systems to simulate the flocking behaviour of birds or the swarming behaviour of ants.

The advantage of the Grasshopper workflow was that it allowed the designer to set agent parameters or behaviours based on the designer's structural expertise or geotechnical knowledge. The role of the designer is thus as the curator, to select the best-designed outcome out of many new forms. Grasshopper also enabled a File-to-factory workflow where computationally produced designs were fabricated without the need for a third party. Protection of intellectual property (IP) is significant for Ngāti Tukorehe. The next stage investigated how the design of an additive manufacturing tool could protect Tukorehe's IP. Overall, the use of multi-agent systems in Grasshopper was beneficial at this stage as it opened up a range of potential uses for the technique through the digital model.

Fig. 05.06 DIGITAL COLUMN 02 (WIRE FRAME)



05.02

3D PRINTED COLUMNS

Introduction:

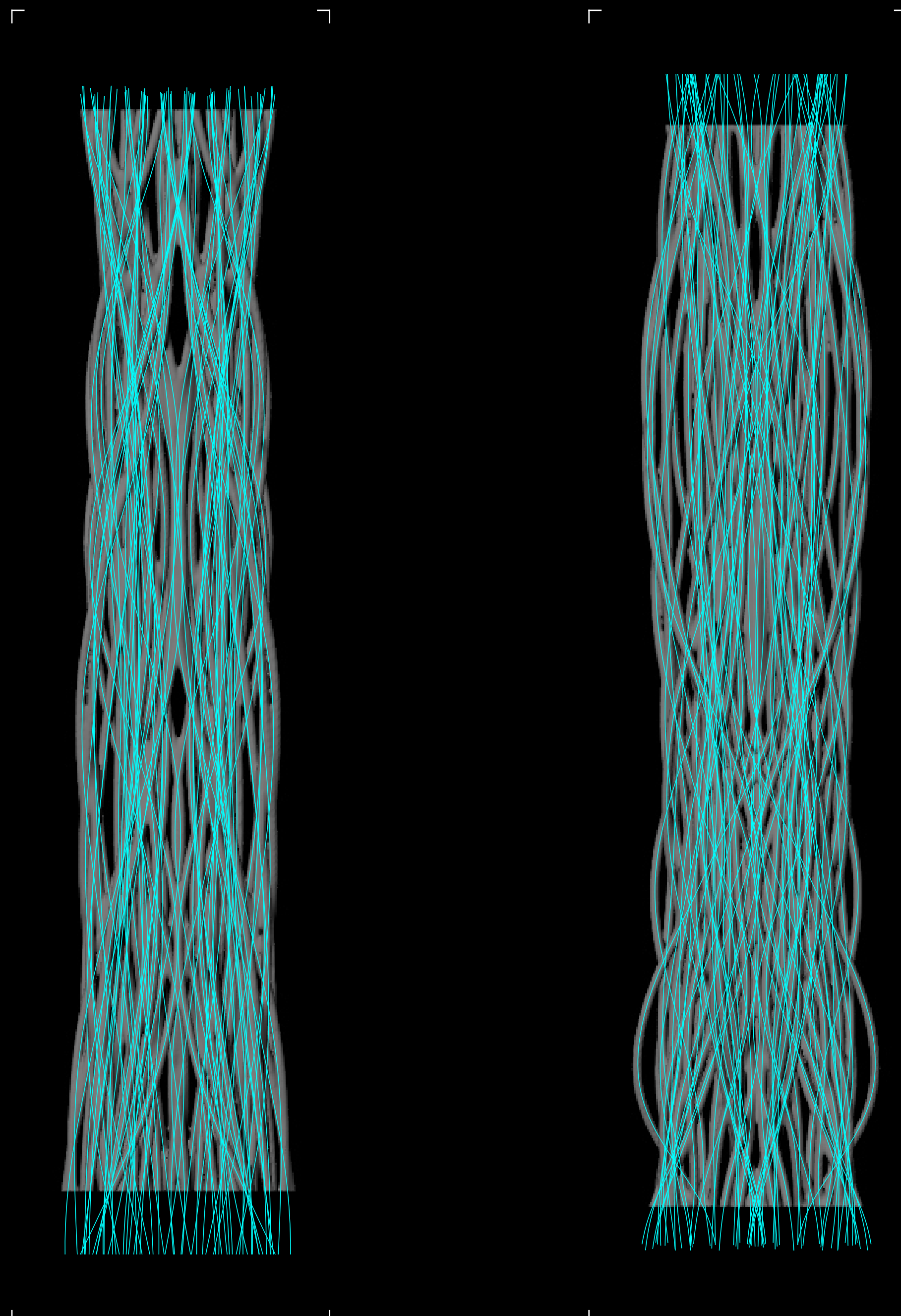
The 3D printed columns explore the translation of an abstract computational process into a 3D digital geometry then into a physical 3D printed form. The purpose of this is to emphasise the sculptural and formal properties that could be produced with a multi-agent algorithm. An architectural element of a column is used as a testing ground for these design ideas.

Aim:

How can we translate a multi-agent algorithm into a large-scale physical model? What types of geometries could be produced digitally and what typology of structure would the physical model lend itself to producing?

Fig. 05.07 COLUMN 02 (3D PRINT)

01 02



ELEVATION ELEVATION

Fig. 05.08 AGENT TRAILS + RESULTING MESH

Method:

Using Chromodoris, a plugin for Grasshopper, an algorithm was created to build an isomorphic surface (iso-surface) around the agent trails, forming a 3D digital geometry (Fig.05.08). Each agent trail had to be divided into points and voxelised to build an isomorphic surface. The geometry could then be manipulated and changed depending on a set of parameters. The number of divisions or points created increased the resolution of the geometry. Voxel size altered the width of the geometry formed around the agent trails. Voxel range changed the distance at which the nearby geometries interacted and joined to one another. The 3D geometry was translated into a mesh that could then be relaxed or smoothed to achieve the desired quality.

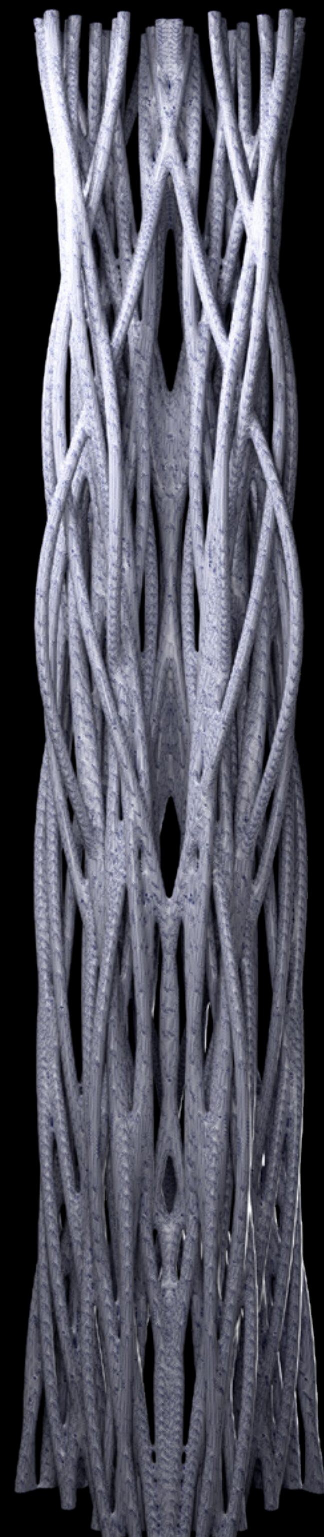


Fig. 05.09 DIGITAL COLUMN 01 (ELEVATION)

Fig. 05.11 DIGITAL COLUMN 01 (PERSPECTIVE 02)

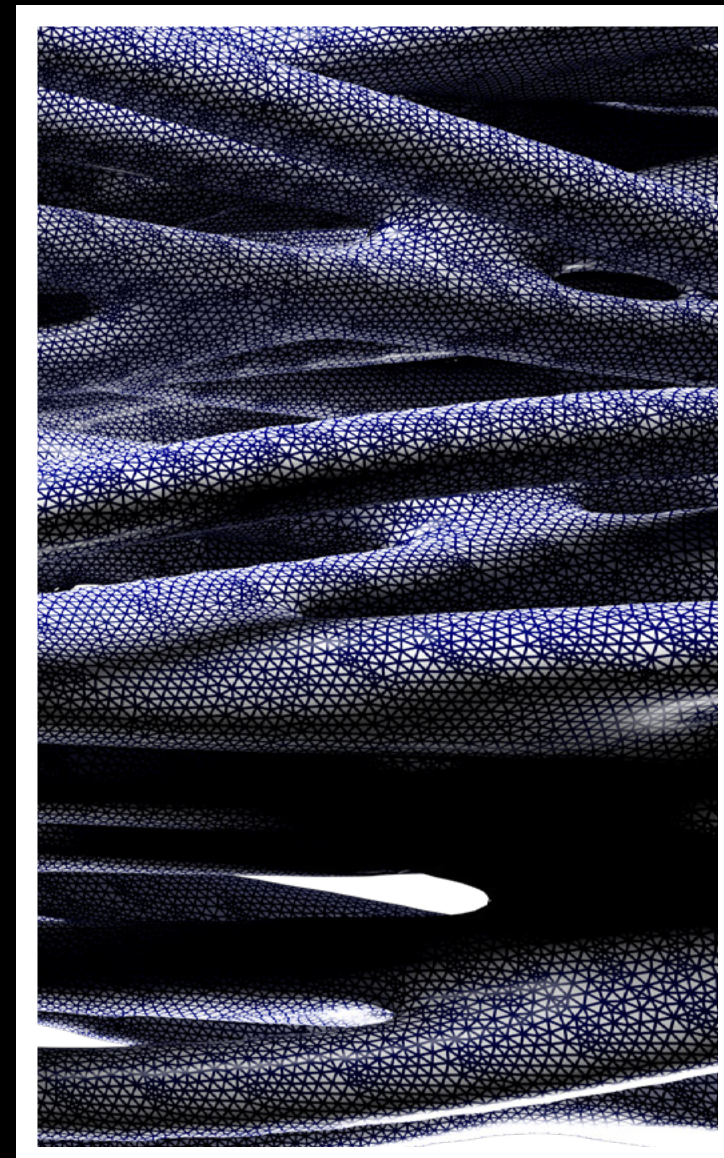


Fig. 05.10 DIGITAL COLUMN 01 (PERSPECTIVE 01)

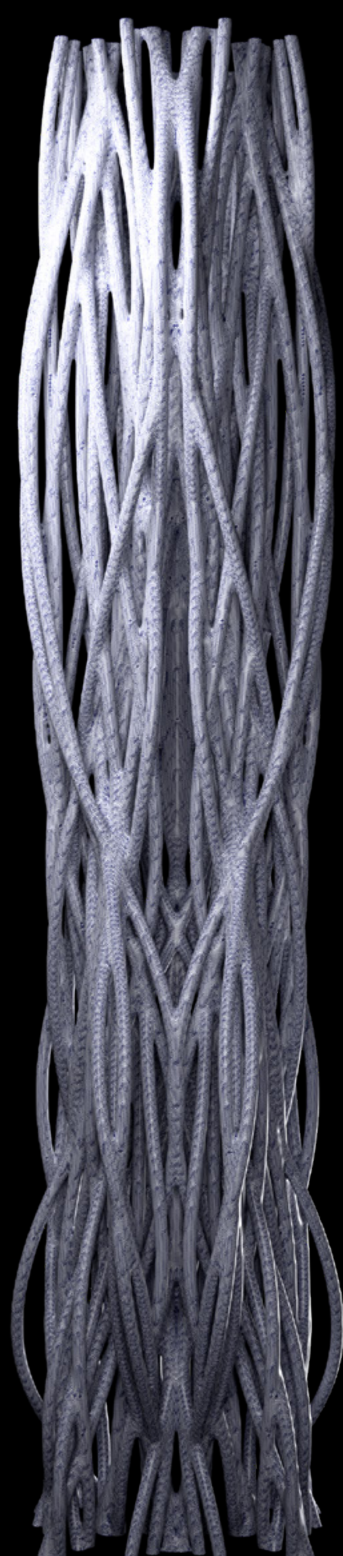
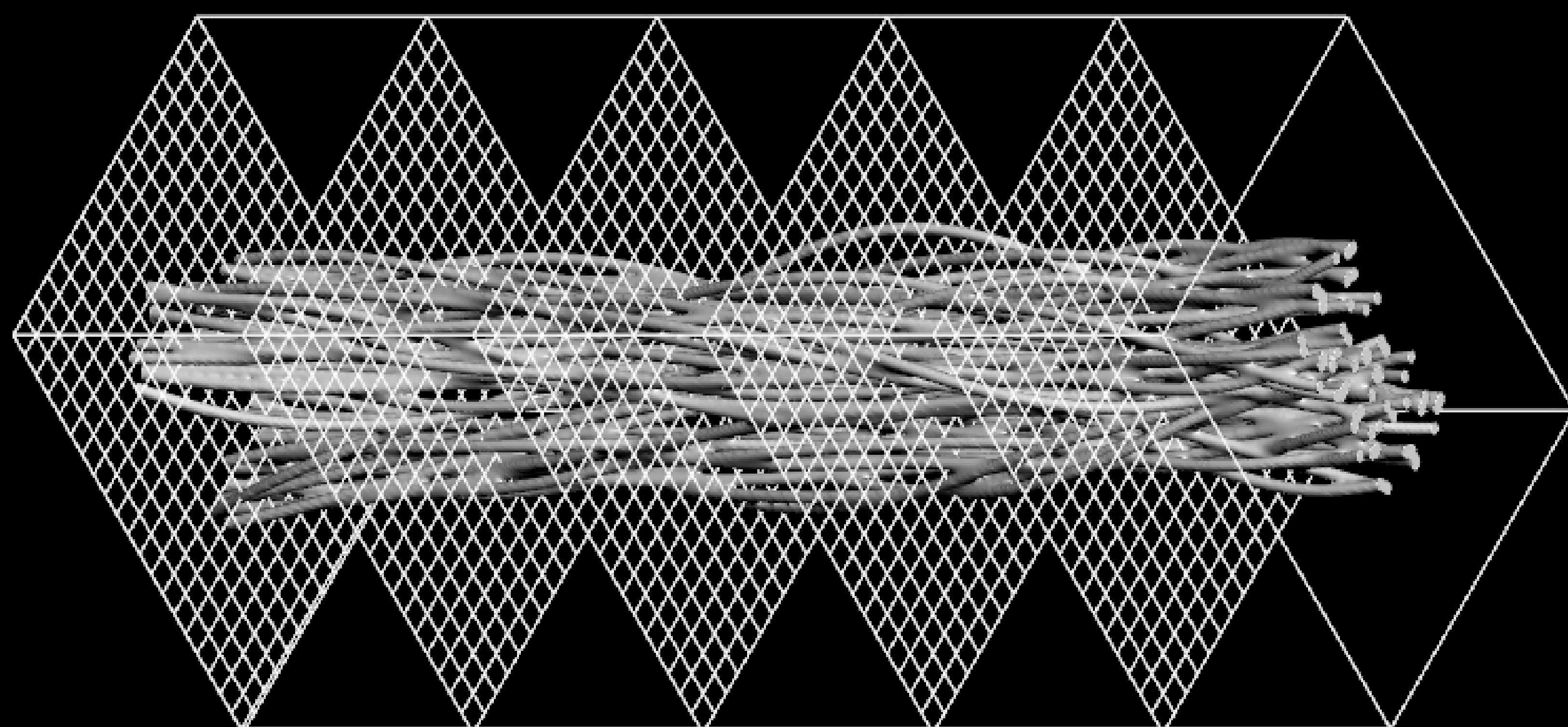


Fig. 05.12 DIGITAL COLUMN 02 (ELEVATION)

Fig. 05.14 DIGITAL COLUMN 02 (PERSPECTIVE 02)

Fig. 05.13 DIGITAL COLUMN 02 (PERSPECTIVE 01)

Fig. 05.15 SLICING 3D MODEL FOR 3D PRINTING



FDM 3D printing translated the digital model of the iso-surface into physical geometry using an UPBOX + 3D printer. To 3D print, the digital model had to be scaled, sliced and nested. After scaling, the digital model was sliced into five segments (Fig.05.15), to fit within the print volume of 205mm x 255mm x 205mm.

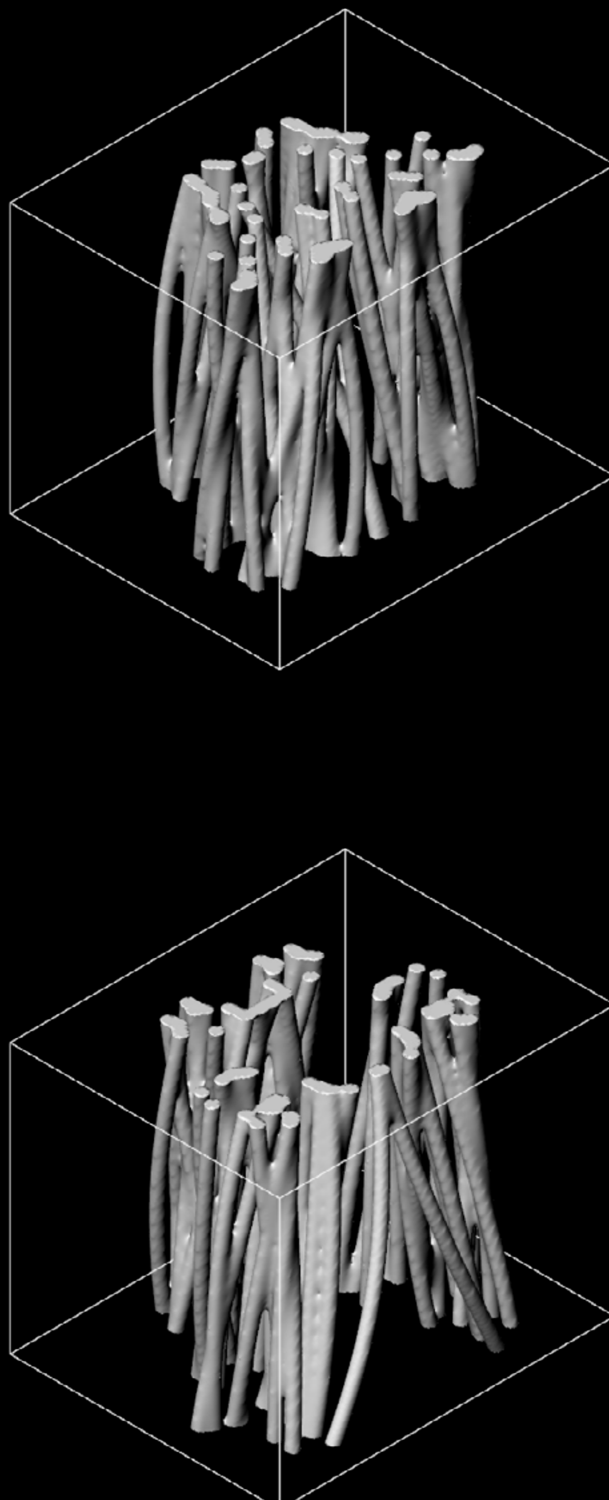


Fig. 05.16 NESTING 3D MODEL FOR 3D PRINTING

These five segments were joined back together later. Nesting involved orienting the sliced segments to the 3D printing bed so that each segment fit within the 3D printing volume (Fig.05.16). Once nested, the geometry could be exported for 3D printing. Two different column options were printed, with similar formal qualities to each other but with different emergent geometries. A surface materiality of sand was spray glued onto the second column option.

Fig. 05.17 3D PRINTED COLUMN 01 (FRONT ELEVATION)

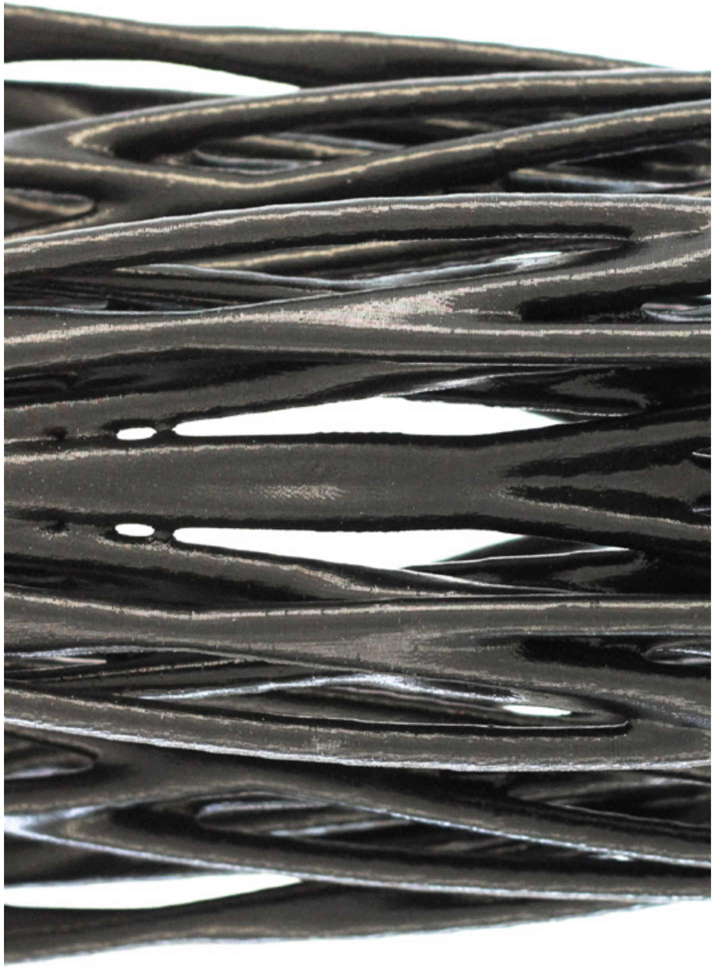


Fig. 05.19 3D PRINTED COLUMN 01 (SECTION 02)

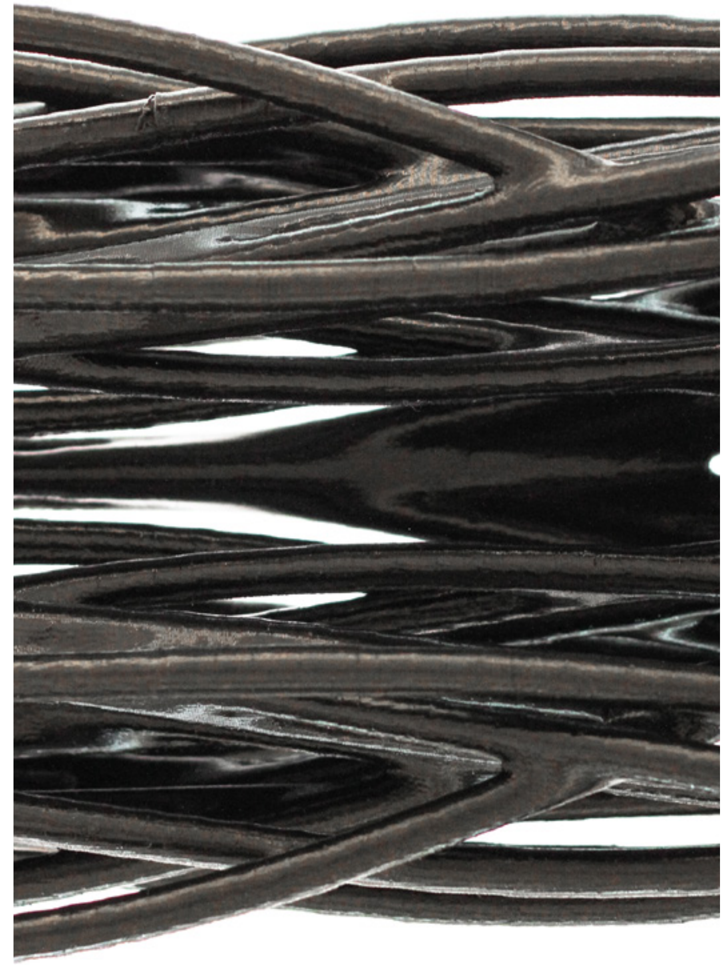


Fig. 05.18 3D PRINTED COLUMN 01 (SECTION 01)

Fig. 05.20 3D PRINTED COLUMN 02 (FRONT ELEVATION)

Fig. 05.22 3D PRINTED COLUMN 02 (SECTION 02)

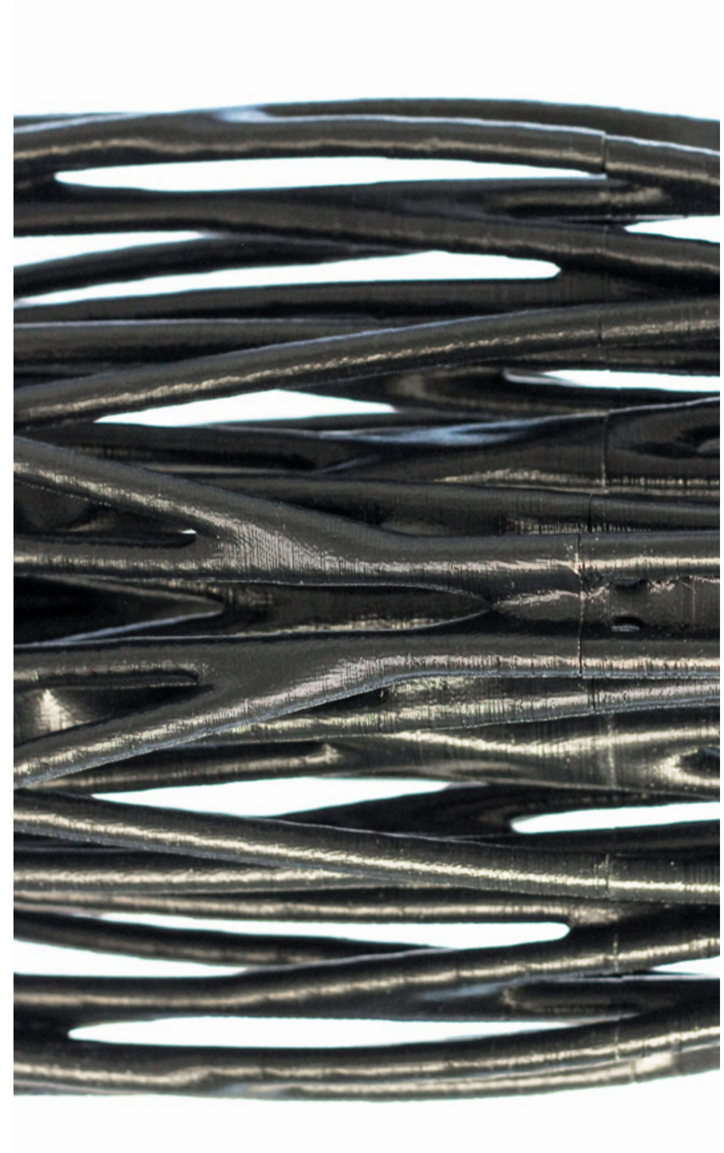


Fig. 05.21 3D PRINTED COLUMN 02 (SECTION 01)

Fig. 05.23 SAND COATING COLUMN 02 (FRONT ELEVATION)

Fig. 05.25 SAND COATING COLUMN 02 (SECTION 02)

Fig. 05.24 SAND COATING COLUMN 02 (SECTION 01)

Fig. 05.26 3D PRINTED COLUMN 02 (DETAIL)

Fig. 05.27 SAND COATING COLUMN 02 (DETAIL)

05.03

CONCLUSION

Findings:

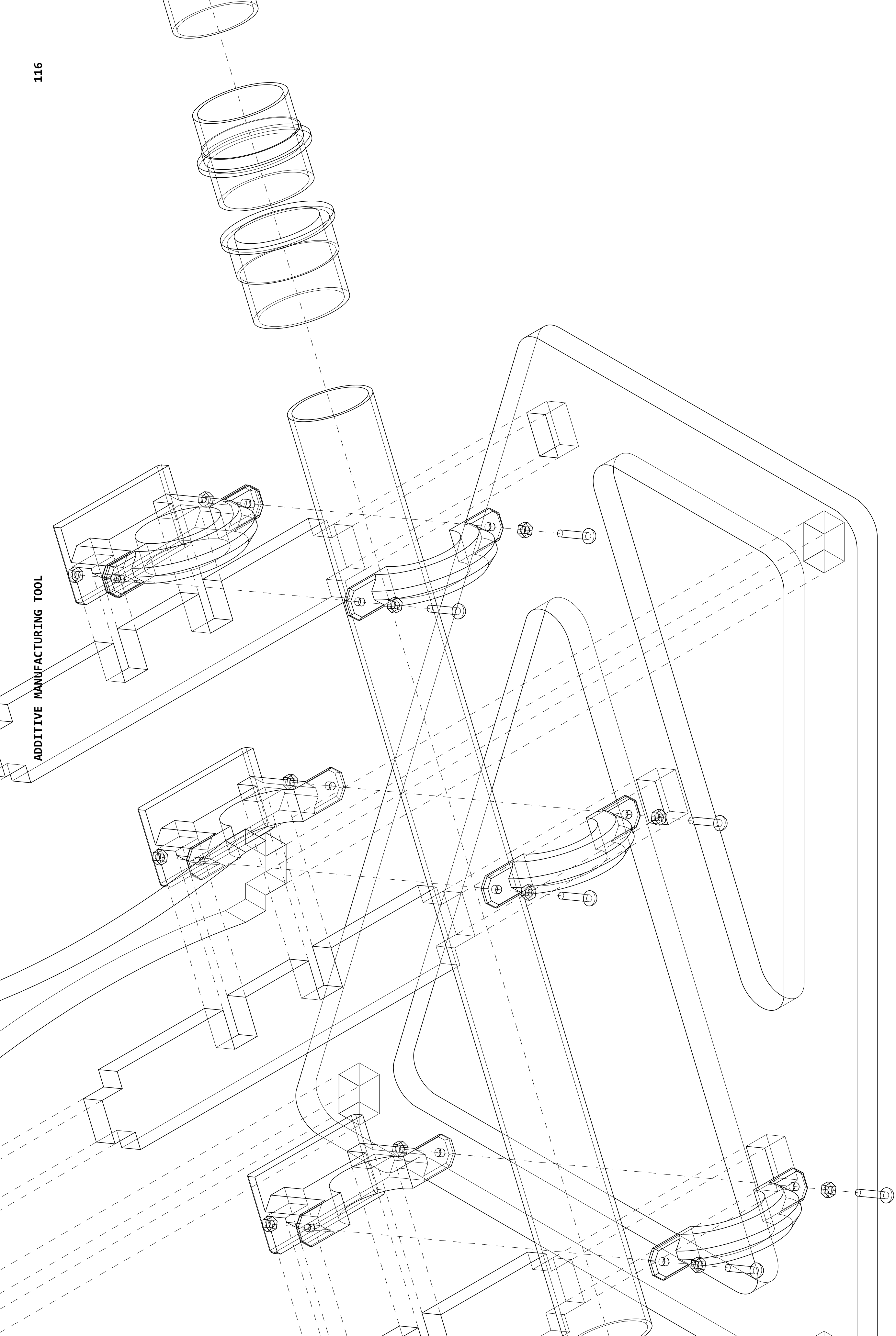
Coating the 3D printed column in sand (Fig.05.23) maintained the idea of emphasising sculptural and aesthetic qualities of the form and materiality from the soft forming investigations. Ngāti Tukorehe likened the form of the columns to tree roots. The idea of creating roots of a tree or plant that burrow underground resonated with Tukorehe, like the way pīngao (a beach grass) grows on Tukorehe's coastal dune network. Tukorehe liked the idea of being able to preserve their coastlines and sand dunes through an architectural root system that could encourage the growth of other plant species. Like the pingao roots, the column clumps sand together, preventing sand from being swept away by the wind, rain and the ocean. These structures could be optimised in Grasshopper to be more effective than biological roots at erosion prevention.

The combination of computational processes within Rhino and Grasshopper and additive manufacturing has the potential to merge the design process with manufacturing and fabrication. The File-to-factory system allows for the direct transfer of a 3D digital file to a 3D printer without the intervention of third parties for either the design or the fabrication stages. This workflow allows for the protection of any IP belonging to Ngāti Tukorehe and is vital for iwi with interest in the protection of IP.

Fig. 05.28 SAND COATING COLUMN 02 (DETAIL 02)

Fig. 06.01 ADDITIVE MANUFACTURING TOOL
AUTHORS OWN PHOTOGRAPH

06
ADDITIVE MANUFACTURING TOOL



06.01

ADDITIVE MANUFACTURING TOOL

QR CODE. EXTRUDER ASSEMBLY VIDEO

Introduction:

This stage explores the design and construction of an additive manufacturing tool. The design was based on existing injection grouting systems used in the construction industry. Injection grouting is used in the construction industry for levelling or strengthening of building foundations and structural walls. By contrast, this additive manufacturing tool is used to create highly controlled free-form structures. The first iteration of the tool is a 1:2 scale prototype.

Aim:

How can the design of an additive manufacturing tool based on a high-pressure injection system aid the production of controlled freeform structures?

Fig. 06.02 ADDITIVE MANUFACTURING TOOL (EXPLODED)

Fig. 06.03 ASSEMBLY STAGES

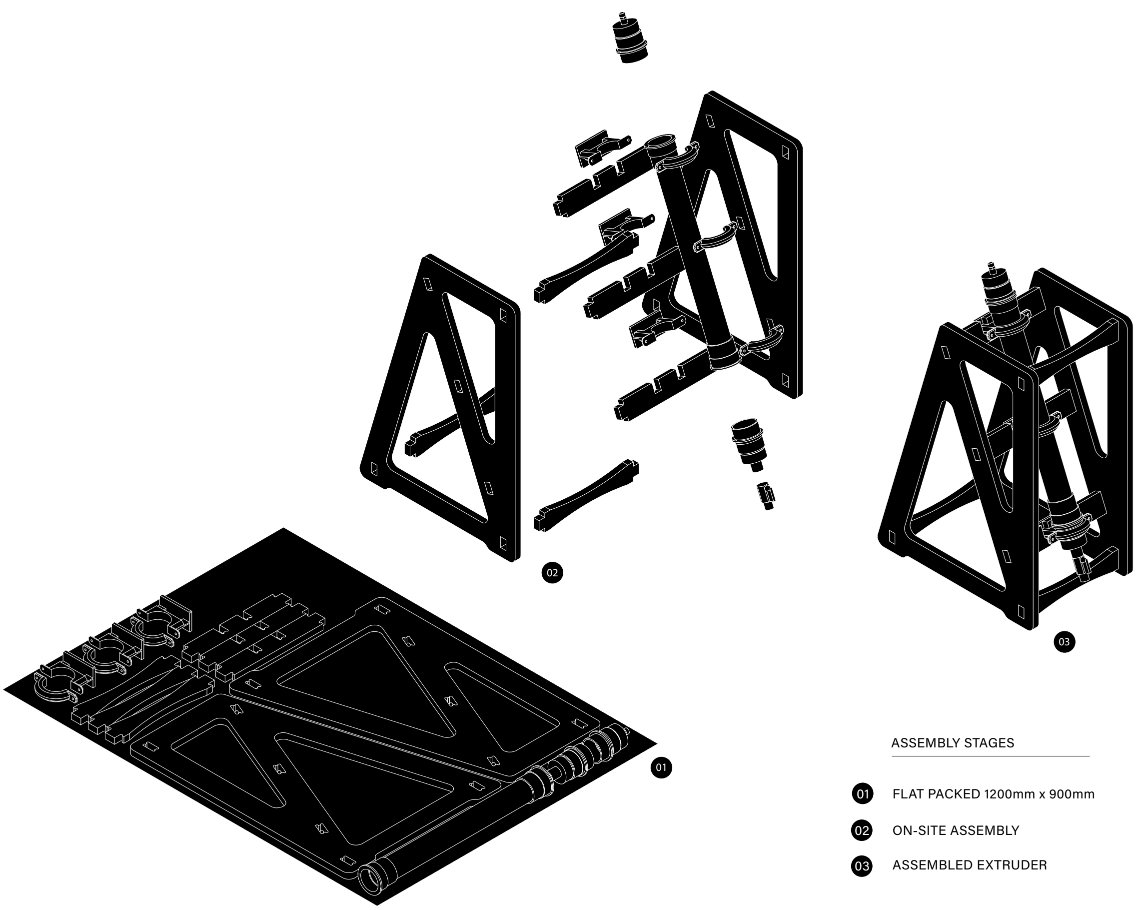


Fig. 06.04 ASSEMBLY DIAGRAM

06.02

FABRICATION

Extruder Design:

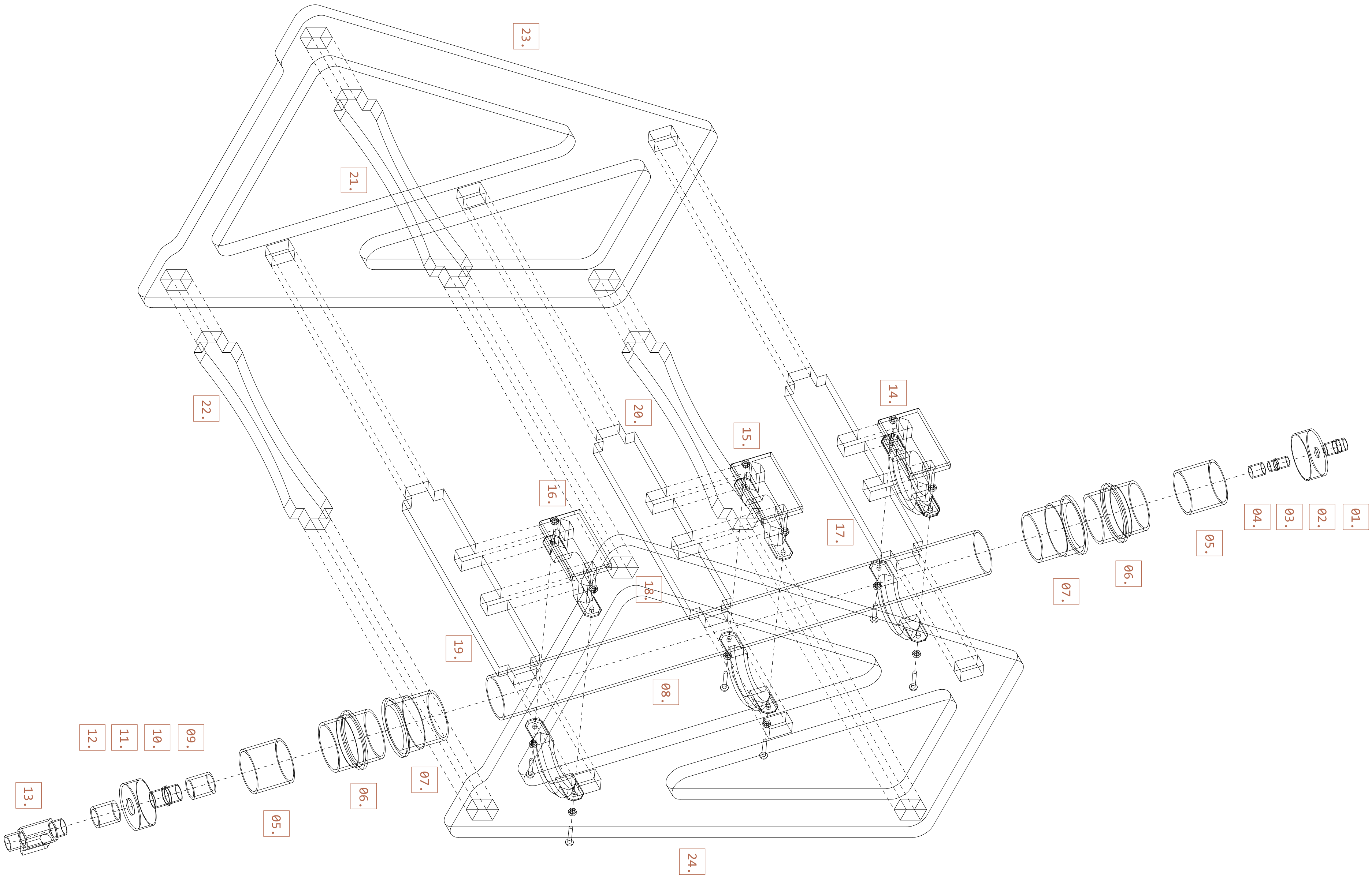
The additive manufacturing tool stands at approximately 1m tall (Fig.06.07). The physical design can be broken down into three categories: the extruder assembly, the CNC routed frame and the 3D printed brackets.

The extruder assembly is made up of an interchangeable length of uPVC pipe. This uPVC pipe acts as a vessel to contain the injection material. At either end of the pipe, a female pipe thread was fitted, allowing for interchangeable attachments at both ends. At the bottom end of the pipe, the standard fittings are a uPVC pipe fitted with a 15mm diameter tap and fitting for a length of hose to attach. At the top end, are a ¼ inch air hose fitting for a compressed air line to attach. The top end of the pipe can be removed to pour in the injection material. During the tests, compressed air was fed through the top end, forming a pressure cell. The injection material was then forced out the bottom end of the uPVC pipe as the tap was released.

The CNC routed frame was routed out of 18mm plywood and was made to be assembled, disassembled and flat packed into a 1m2 area (Fig.06.03). The frame provides a stable support structure for the extruder, which was mounted onto it with the aid of 3Dprinted brackets. These brackets clip onto the CNC routed plywood. New brackets could be printed to accommodate for a uPVC pipe extruder of larger diameter.

Overall, the first iteration of the tool was a prototype created at 1:2 scale (Fig.06.05).

Fig. 06.05 ADDITIVE MANUFACTURING TOOL (COMPONENTS DIAGRAM)



EXTRUDER ASSEMBLY

01. 1/4inch BSP F/F Brass Airhose Fitting
02. 50mm F uPVC Pipe cap
03. 1/4inch BSP M/M Brass Airhose Fitting
04. 1/4inch BSP F Brass Airhose Fitting
05. 50mm uPVC Pipe - 50mm
06. 50mm uPVC Pipe Adaptor Male
07. 50mm uPVC Pipe Adaptor Female
08. 50mm uPVC Pipe - 650mm
09. 15mm Brass Thread Socket F
10. 15mm Brass Thread Socket M/M
11. 50mm F uPVC Pipe cap
12. 15mm Brass Thread Socket F
13. 15mm Ball Valve Water Tap M/F

3D PRINTED BRACKETS

14. Bracket Assembly 1
1x 3D Printed Bracket, 1x 3D Printed Clip, 2x Bolts, 4x Nuts

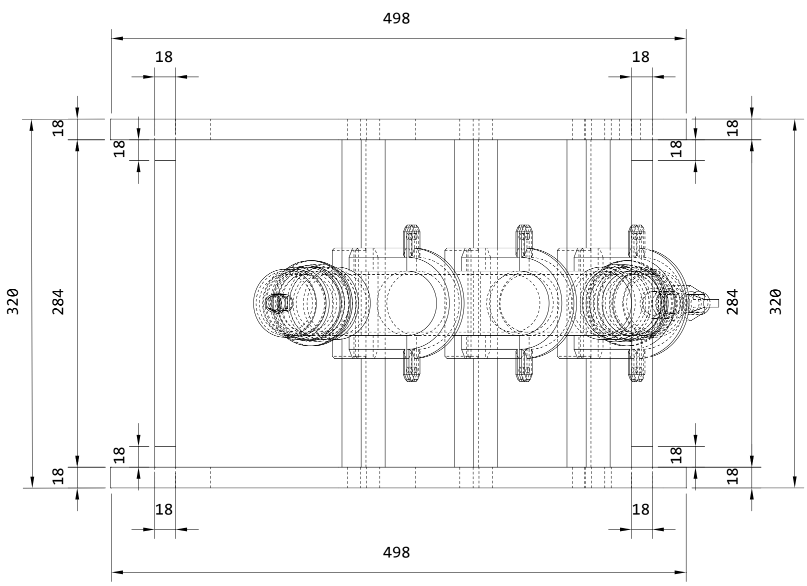
15. Bracket Assembly 2
1x 3D Printed Bracket, 1x 3D Printed Clip, 2x Bolts, 4x Nuts

16. Bracket Assembly 3
1x 3D Printed Bracket, 1x 3D Printed Clip, 2x Bolts, 4x Nuts

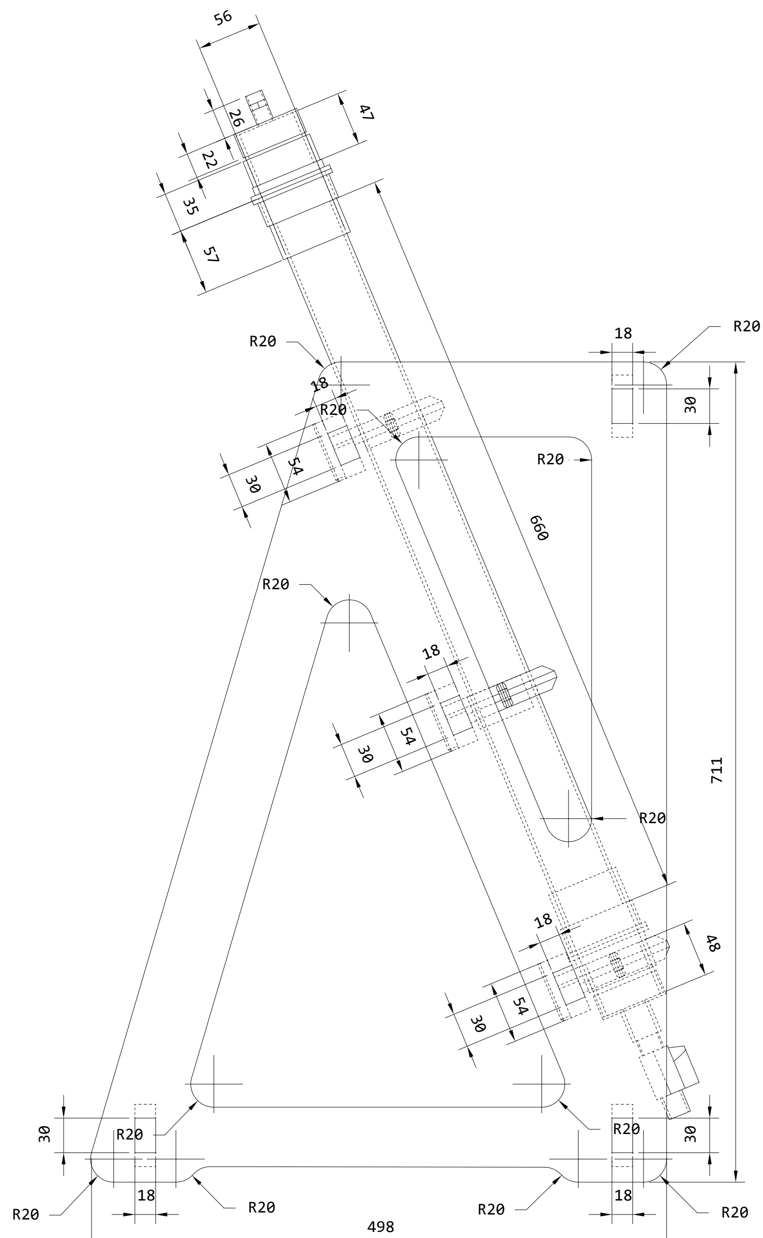
CNC ROUTED FRAME

17. 18mm Plywood Extruder Support 1
18. 18mm Plywood Extruder Support 2
19. 18mm Plywood Extruder Support 3
20. 18mm Plywood Frame Support 1
21. 18mm Plywood Frame Support 2
22. 18mm Plywood Frame Support 3
23. 18mm Plywood Extruder Frame Side 1
24. 18mm Plywood Extruder Frame Side 2

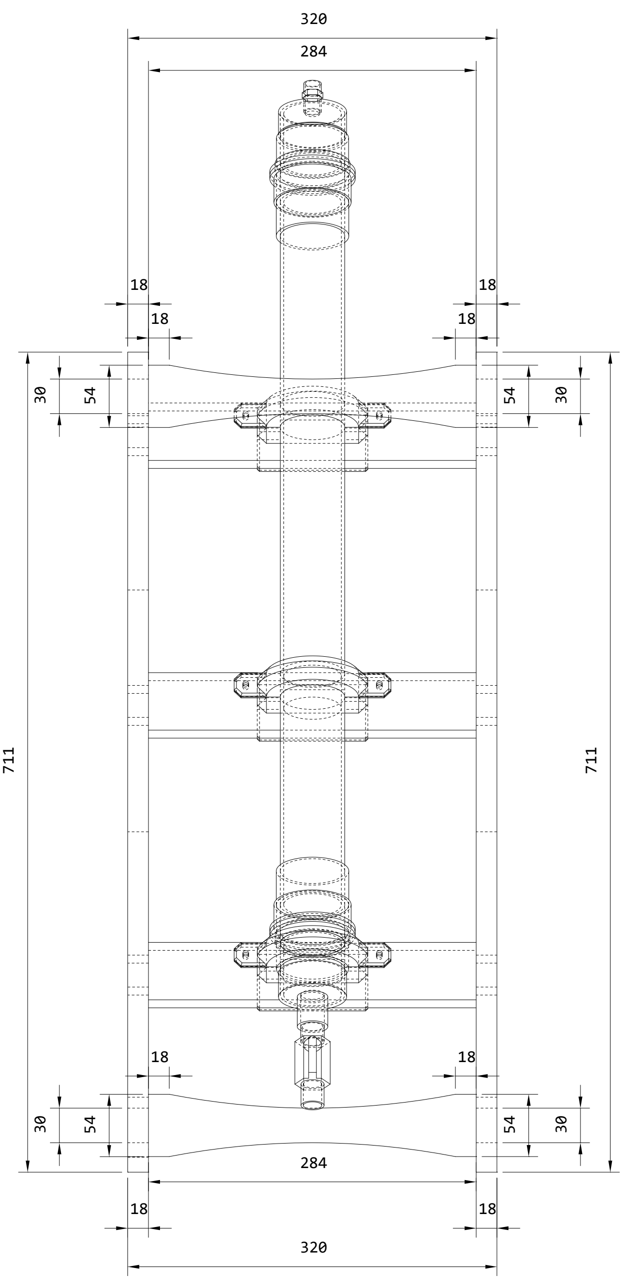
Fig. 06.06 ADDITIVE MANUFACTURING TOOL (PARTS LIST)



PLAN



FRONT ELEVATION



RIGHT ELEVATION

Fig. 06.07 ADDITIVE MANUFACTURING TOOL (DIMENSIONED)

Fig. 06.08 ADDITIVE MANUFACTURING TOOL (ASSEMBLED)

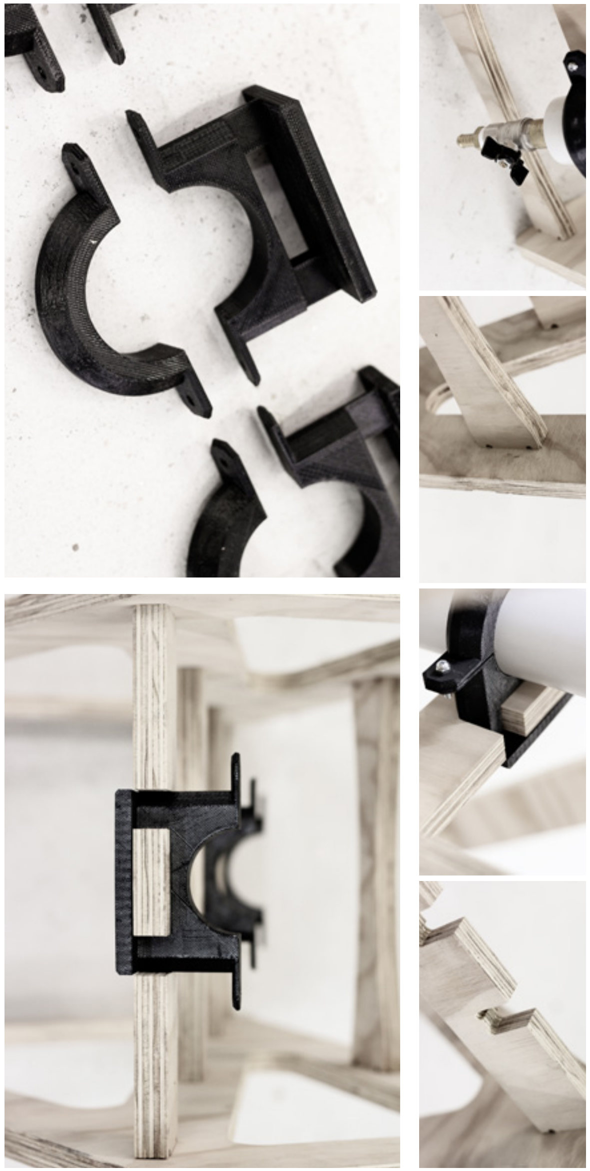


Fig. 06.10 ADDITIVE MANUFACTURING TOOL (DETAILS)

Fig. 06.09 ADDITIVE MANUFACTURING TOOL (ELEVATIONS)

06.03

ON-SITE SET UP

Introduction:

This stage explored a potential on-site set-up of the additive manufacturing tool and how it could be deployed in order to create scale prototypes, using the soft forming and hard forming process. The case study site, a section of farmland adjacent to the Waikawa River, was used to explore the potential on-site use of the tool (Fig.06.12). This section of farmland is 'off-the-grid' and roughly 2km from the nearest main road. This stage aimed to test the viability of on-site work and prototyping using the additive manufacturing tool.

Equipment:

The necessary equipment required for scale prototyping to occur was packed into the back of a four-wheel drive vehicle and taken out to the site. This equipment consisted of the additive manufacturing tool, a 50L compressor and a 6000W petrol generator to power the compressor (Fig.06.14).

Set-up:

The on-site set-up of the equipment would involve first setting out a site working area covered by a tent, where equipment and materials such as cement bags could be left or stored. Another tent would be pitched over the area where prototyping and testing would be conducted, using the compressor, generator and additive manufacturing tool. This area would be covered for the prototyping stage of the process so that a controlled environment could be maintained for testing (Fig.06.12).

Fig. 06.11 SITE CONTEXT (WAIKAWA, 2018)
AUTHORS OWN PHOTOGRAPH

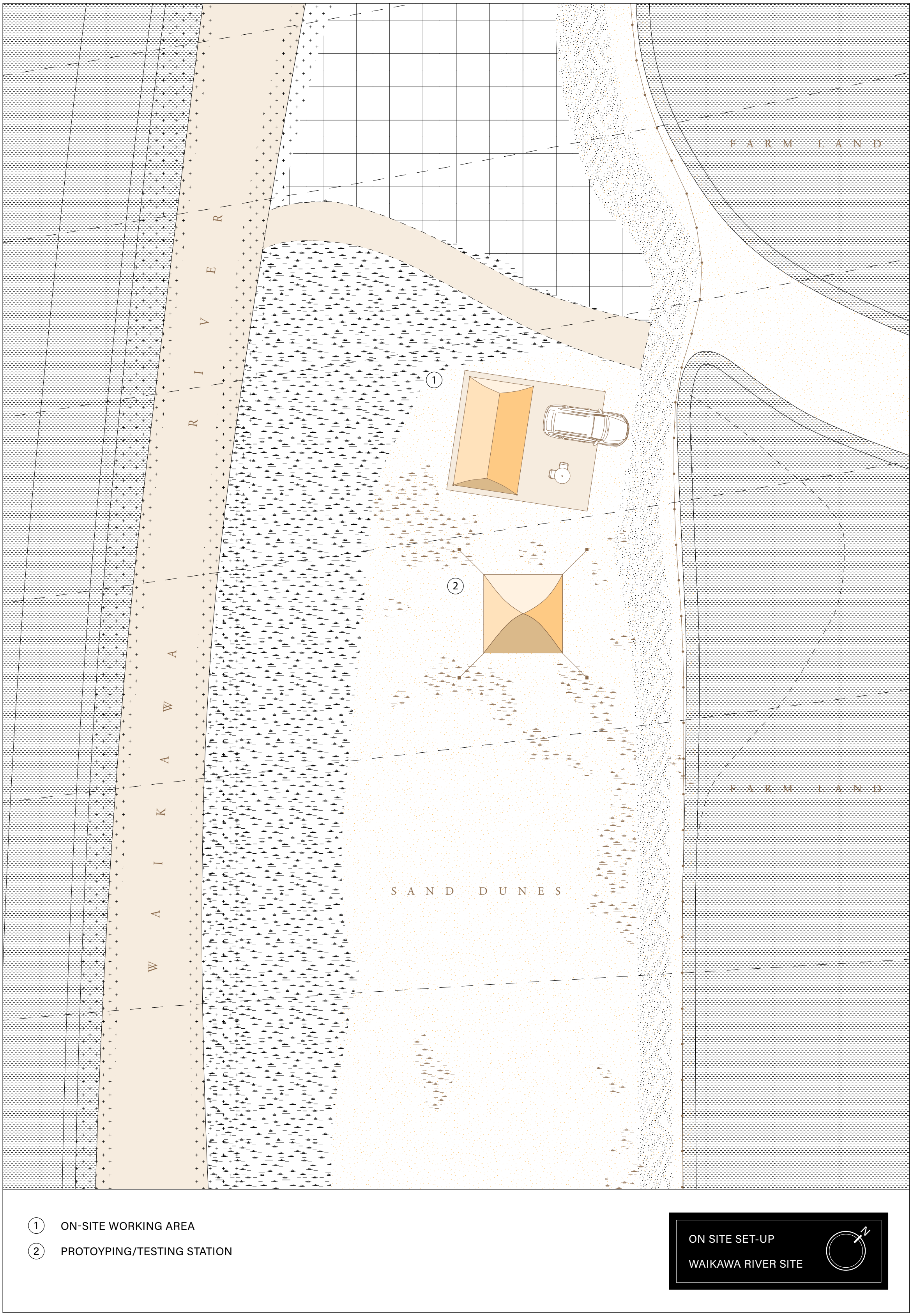
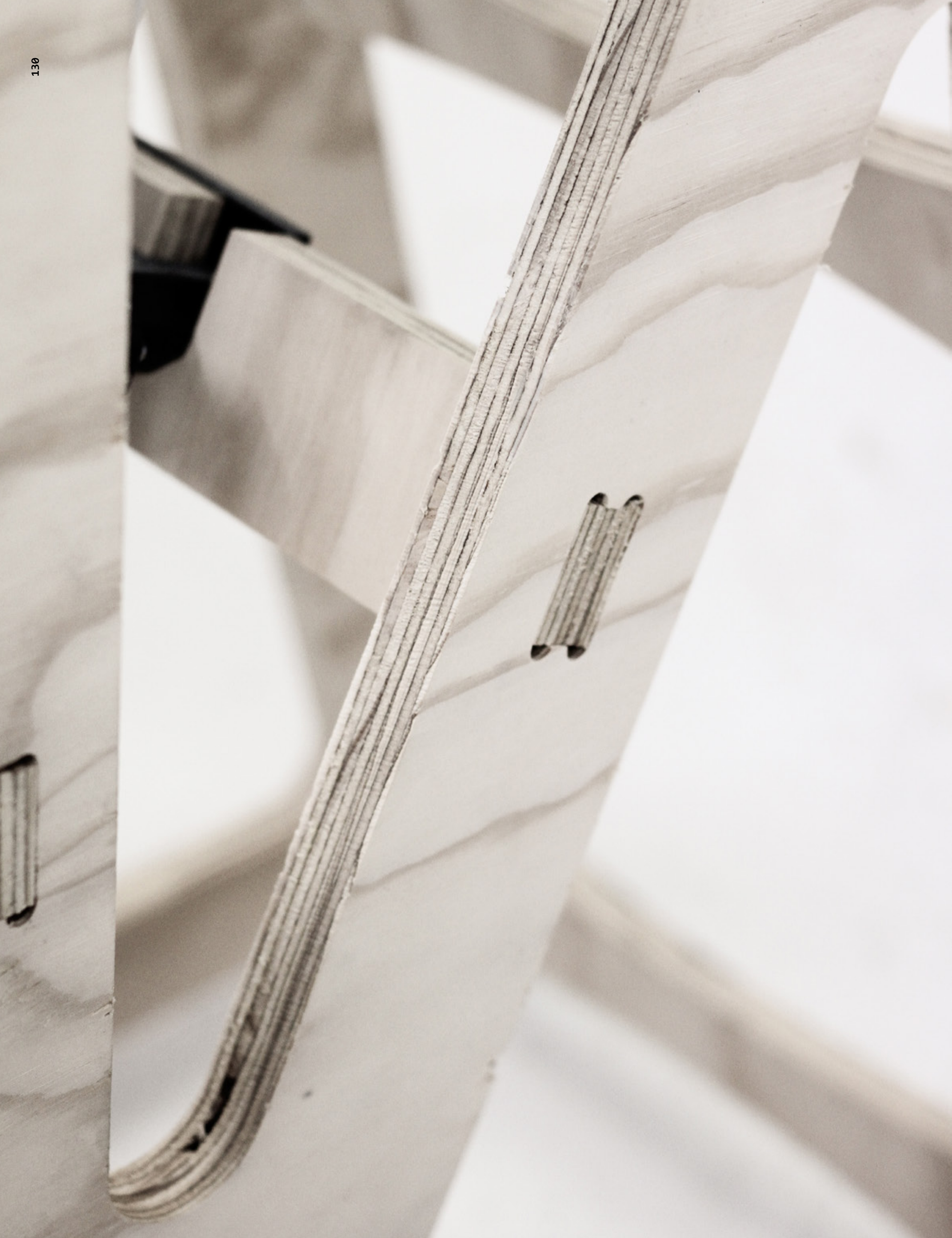


Fig. 06.12 ON SITE SET UP MAP

Fig. 06.14 EXTRUDER SET UP WITH GENERATOR AND COMPRESSOR (WAIKAWA, 2018)
AUTHORS OWN PHOTOGRAPH

Fig. 06.13 SITE SET UP (WAIKAWA, 2018)
AUTHORS OWN PHOTOGRAPH



06.04

CONCLUSION

Findings:

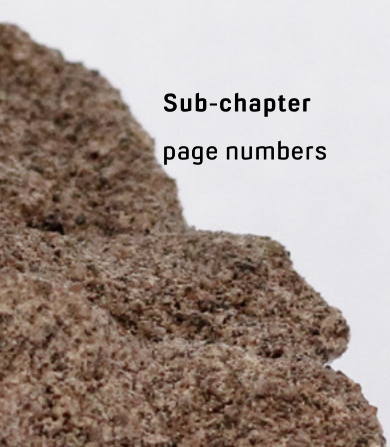
The creation of an additive manufacturing tool closed the loop of a File-to-factory system. The design and manufacturing processes were kept within Ngāti Tukorehe, allowing for the protection of any IP belonging to the Iwi. This process is also essential for other iwi.

The extruder replaced the smaller scale syringe and the FDM printer used to create the 3D printed columns. The increased volume of the uPVC pipe compared to the syringe allows large-scale forms to be produced that were previously restricted by the small-scale soft forming process. A compressed air connection allowed for a controlled extrusion rate through regulated air pressures ranging from 0psi to 120psi. The factors of increased volume and regulated airflow also enabled the continued exploration of a hard forming process. The next stage investigated the use of the additive manufacturing tool to create complex freeform structures.

Fig. 06.15 SITE CONTEXT (WAIKAWA, 2018)

Fig. 07.01 ARTEFACT FIVE (DETAIL, TOP)
AUTHORS OWN PHOTOGRAPH

07 HARD FORMING



07.01

HARD FORMING

QR CODE. HARD FORMING VIDEO

Introduction:

'Hard forming' was the next design enquiry. It investigated the potential to directly inject a binding material into the ground without the need for PVC pipes, instead relying on the ground composition and pressure of injection to inform the structure. Hard forming requires a technical understanding of ground pressure and composition. Following injection, the sand surrounding the structure was excavated like an artefact to reveal the geometry created by the injection process. The intention was to give the forms more agency, creating a co-authorship between the whenua, the material and the designer. Maintaining a relationship with the landscape and acknowledging the agency of the landscape in this way is in keeping with Ngāti Tukorehe's tikanga.

Aim:

How can we gain control over the injection of a binding substance into the sand in order to create freeform geometries, without using PVC pipes and instead relying on the ground composition and pressure of injection to inform the structure? What geometries can we create from this process and what architectural structures does this technique lend itself to producing?

Fig. 07.02 ARTEFACT FIVE (DETAIL, BOTTOM)

Fig. 07.03 INJECTION MATRIX (PLASTER + FINE SAND)

INJECTION

Method:

The hard forming process involved using the additive manufacturing tool to inject a binding material (plaster of Paris) into a fixed volume of sand. The sand surrounding the plaster geometry was then excavated to reveal the geometry created through injection (Fig.07.03). A series of investigations were conducted through injection of a binder into a granular material. The parameters being controlled through this series of iterations were the pressure of injection measured in PSI and the compaction of the sand used as the ground material.

Fig. 07.04 HARD FORMING SET UP

Method:

The process involved stacking two 253 cm box jigs on top of each other. A sand substrate was contained within this volume and was used as the scaffolding and formwork that would inform the injected geometries. One end of a flexible PVC pipe was buried just beneath the surface of the sand, and the other end was attached to the nozzle of the additive manufacturing tool.

Plaster of Paris was used as the binding material to form the injected geometries. The plaster of Paris mix was tipped through a funnel into the uPVC pipe that formed the extruder of the additive manufacturing tool. The end cap of the uPVC pipe was screwed on, and a compressed air line fitted. The extruder containing the plaster was pressurised, and the plaster was released from the extruder into the volume of sand by opening the tap at the opposite end of the extruder.

The box jig containing the sand was collapsed, and the soil surrounding the structure removed to reveal the results of the injection.

Fig. 07.05 ARTEFACT ONE (PLASTER + FINE SAND)

07.02
ARTEFACTS

Artefact One

Plaster of paris into fine sand

Parameters:

Sand volume: 50^3 cm

Sand compaction: No compaction

Injection pressure: 20 PSI

Injection volume: 2000 mL

Fig. 07.06 ARTEFACT TWO (PLASTER + FINE SAND)

Artefact Two

Plaster of paris into fine sand

Parameters:

Sand volume: 50^3 cm

Sand compaction: No compaction

Injection pressure: 35 PSI

Injection volume: 2000 mL

Fig. 07.07 ARTEFACT THREE (PLASTER + FINE SAND)

Artefact Three

Plaster of paris into fine sand

Parameters:

Sand volume: 50^3 cm

Sand compaction: No compaction

Injection pressure: 50 PSI

Injection volume: 2000 mL

Fig. 07.08 ARTEFACT FOUR (PLASTER + FINE SAND)

Artefact Four

Plaster of paris into fine sand

Parameters:

Sand volume: 50^3 cm

Sand compaction: Small compaction

Injection pressure: 50 PSI

Injection volume: 2000 mL

Fig. 07.09 ARTEFACT FIVE (PLASTER + FINE SAND)

Artefact Five

Plaster of paris into fine sand

Parameters:

Sand volume: 50^3 cm

Sand compaction: Medium compaction

Injection pressure: 50 PSI

Injection volume: 2000 mL

Fig. 07.10 ARTEFACT SIX (PLASTER + FINE SAND)

Artefact Six

Plaster of paris into fine sand

Parameters:

Sand volume: 50^3 cm

Sand compaction: Large compaction

Injection pressure: 50 PSI

Injection volume: 2000 mL

Fig. 07.12 ARTEFACT FOUR (DETAIL)

Fig. 07.11 ARTEFACT THREE (DETAIL)

Fig. 07.14 ARTEFACT SIX (DETAIL)

Fig. 07.13 ARTEFACT FIVE (DETAIL)

Fig. 07.15 ARTEFACT THREE (FORM CLOSE UP)

Fig. 07.16 **ARTEFACT FIVE** (FORM CLOSE UP)

07.03
CONCLUSION

Findings:

At a small scale, hard forming is a viable technique to create freeform structures without the need for PVC pipes, instead relying on the ground composition and pressure of injection to inform the structure. Due to the natural composition and compaction of the sand informing the created geometries, hard forming gives agency back to the material. To gain control of the form making process, the designer could dictate the pressure of injection, where the injection occurs and how much material is used. The nature and shape of forms produced are determined by the material being injected and the composition of the sand. This process enables the landscape to shape the structure, instead of the designer imposing a form on the material.

The type of structures created through hard forming can emulate custom or non-standard foundation footings and anchor piles. Ngāti Tukorehe is interested in exploring the potential for hard forming to create non-standard foundations for temporary or seasonal structures on difficult sandy terrain.

Overall, this design enquiry was useful in testing what types of architectural structures could be produced with the additive manufacturing tool. Further testing would need to be conducted using a cement based material and at 1:1 scale on-site with Ngāti Tukorehe. The next stage explored further testing of the additive manufacturing tool using soft forming.

Fig. 07.17 ARTEFACT FIVE (SIDE ELEVATION)

Fig. 08.01 WORKSHOP SET UP 02
AUTHORS OWN PHOTOGRAPH

08
SOFT FORMED COLUMNS

Sub-chapter
page numbers

08.01

SOFT FORMED COLUMNS

QR CODE. COLUMN EXCAVATION VIDEO

Introduction:

This design enquiry investigated soft forming at a larger scale through the fabrication of three 1:4 scale columns using the additive manufacturing tool. Each column produced had different formal qualities, with two being made of plaster of Paris extrusions and one from concrete. This design investigation looked at the viability of soft forming for larger architectural elements. It looked at the forms that long extrusions could create, as well as simple reinforcing for larger structures. The intention was to expand on the previously established soft forming technique.

Research Aim:

How can we expand on the previously established soft forming technique in order to test the viability of soft forming for larger architectural elements such as columns?

Fig. 08.02 SOFT FORMED COLUMN (EXTRUSION DETAIL)

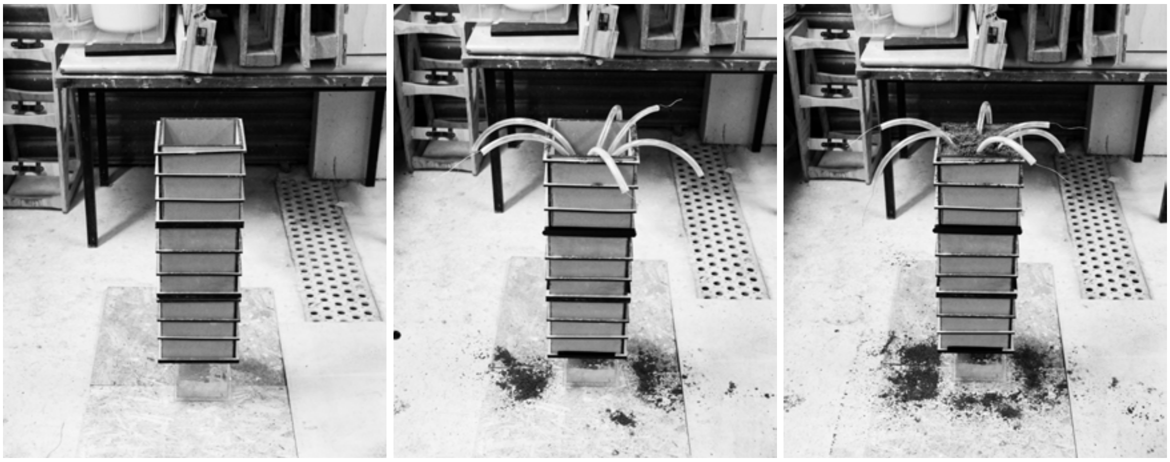


Fig. 08.03 FILLING BOXES WITH SAND

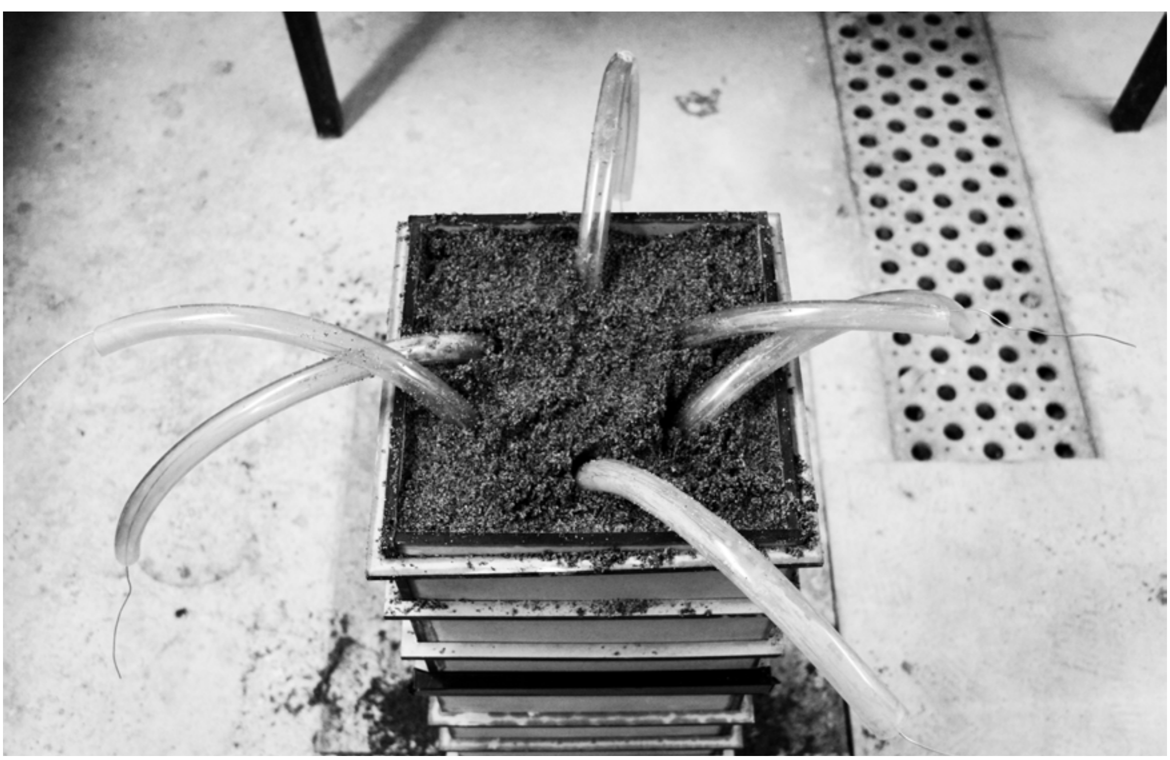


Fig. 08.04 FILLED BOX WITH FLEXIBLE PIPES

COLUMN FABRICATION

Method:

The process involved using three stacked 253 cm box jigs (Fig.08.03). Flexible pipes were then laid within the box in a pre-determined path. These paths determined the geometry of each column. A single length of steel wire was placed within each flexible tube to reinforce the structure. The stacked boxes were filled to the top with fine sand to cover over the flexible pipes. The ends of the pipes containing the reinforcing wire were left to hang out of the top of the boxes (Fig.08.04). These would later be connected to the additive manufacturing tool.

Fig. 08.05 SOFT FORMING PROCESS (KEY COMPONENTS)

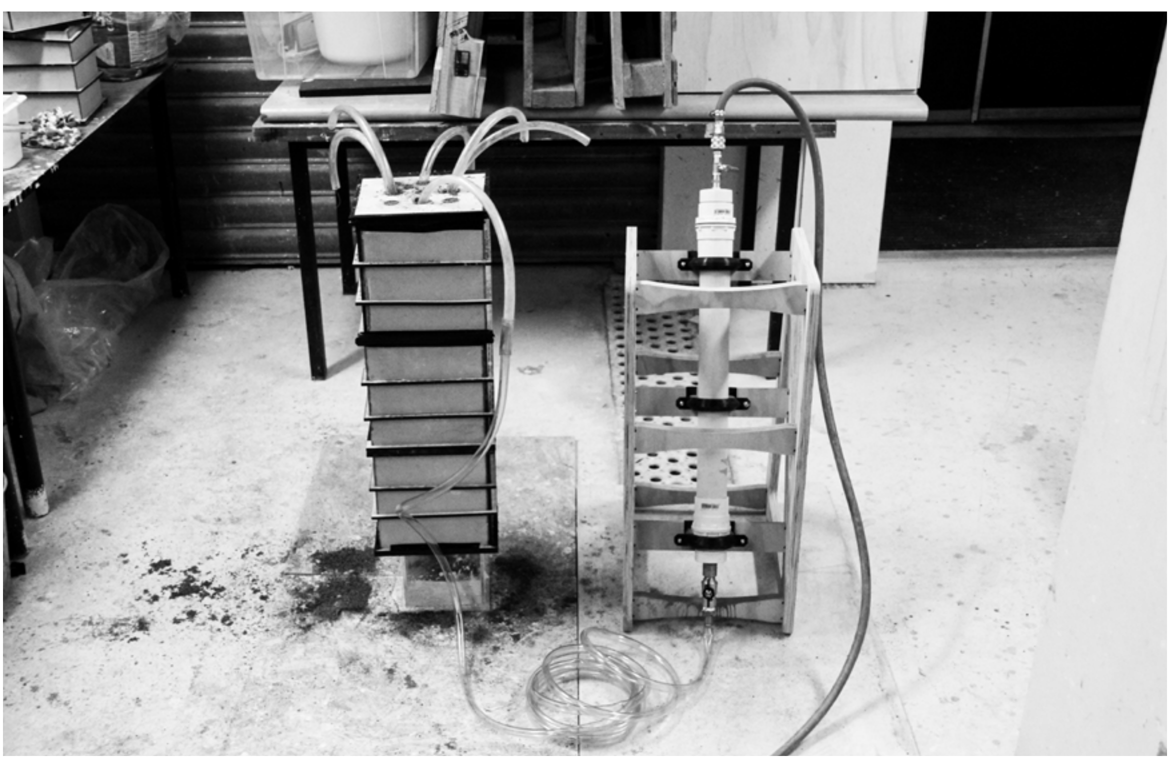


Fig. 08.06 SOFT FORMED COLUMNS (EXTRUSION SET UP)

Method:

The flexible pipes were connected to the additive manufacturing tool via a pipe attached to the nozzle of the extruder (Fig.08.05). The flexible pipes functioned as an extension of the extruder, similar to the nozzle on a 3D printer. With the tap in the closed position, the binding material was tipped through a funnel into the uPVC pipe that formed the pressure cell of the extruder. For the first two tests, a plaster of Paris mix was used as the binding material. The plaster of Paris was substituted for a cement-based binder in the final test. The end cap of the uPVC pipe was screwed on, and a compressed air line was fitted. The pressure cell containing the plaster was pressurised to 20psi. Plaster of Paris was extruded as the pipes were withdrawn out of the box along the fixed toolpath.

Fig. 08.07 EXCAVATION MATRIX (SOFT FORMED COLUMN)

QR CODE. COLUMN EXCAVATION VIDEO

The Plaster of Paris was left to set before the box jig is taken apart. The covering soils, which previously acted as the scaffolding and formwork, were then excavated to reveal the freeform structure underneath (Fig.08.07).

Fig. 08.08 COLUMN 01 (FRONT ELEVATION)

Fig. 08.09 COLUMN 01 (PERSPECTIVE)

Fig. 08.10 COLUMN 01 (DETAIL 01)

Fig. 08.11 COLUMN 01 (DETAIL 02)

Fig. 08.12 COLUMN 02 (FRONT ELEVATION)

Fig. 08.13 COLUMN 02 (PERSPECTIVE)

Fig. 08.14 COLUMN 02 (DETAIL 01)

Fig. 08.15 COLUMN 02 (DETAIL 02)

Fig. 08.16 CONCRETE COLUMN CURING

Fig. 08.17 CONCRETE COLUMN EXCAVATED

08.02

CONCRETE COLUMN

Using the additive manufacturing tool and the same soft forming technique, the material was changed from plaster of Paris to concrete to test the relative form-making potential of both materials. The same method as the previous designs were used. A complex form was produced within a fixed volume, using flexible PVC pipes. For the concrete column, steel wire ties held the flexible pipes in place. Steel reinforcing was placed within each flexible pipe before being covered over with sand. The ends of the flexible pipe connected to the additive manufacturing tool and the same pressure as the plaster tests (20psi) were used for comparison. The concrete was left to set before excavating the column from the sand volume.

Fig. 08.18 CONCRETE COLUMN (DETAIL, MIDDLE SECTION)

Fig. 08.19 CONCRETE COLUMN (DETAIL, TOP SECTION)

08.03
CONCLUSION

Findings:

In conclusion, soft forming is a viable technique to create column-like architectural structures at 1:4 scale. Using plaster of Paris, the small-scale soft forming results using a syringe were directly translatable to large-scale extrusions using the additive manufacturing tool. The woven and curved forms from the small-scale soft forming were able to be reproduced using longer extrusion lengths at 1:4 scale. However, the extrusion of the concrete column was inconsistent due to using an established pressure for plaster. The viscosity of concrete is different from plaster; further testing needs to be conducted to match the pressure of the extruder to the viscosity of the concrete. These tests should be conducted before moving onto 1:1 scale prototyping on-site with Ngāti Tukorehe.

Soft forming could have potential uses to create pavilion structures or in the prevention of coastal erosion. Further tests need to be undertaken using concrete in order to increase the scale of the forms. The soft forming process could be developed in order to achieve results that produce a level of resolution comparable to that of the 3D printed columns.

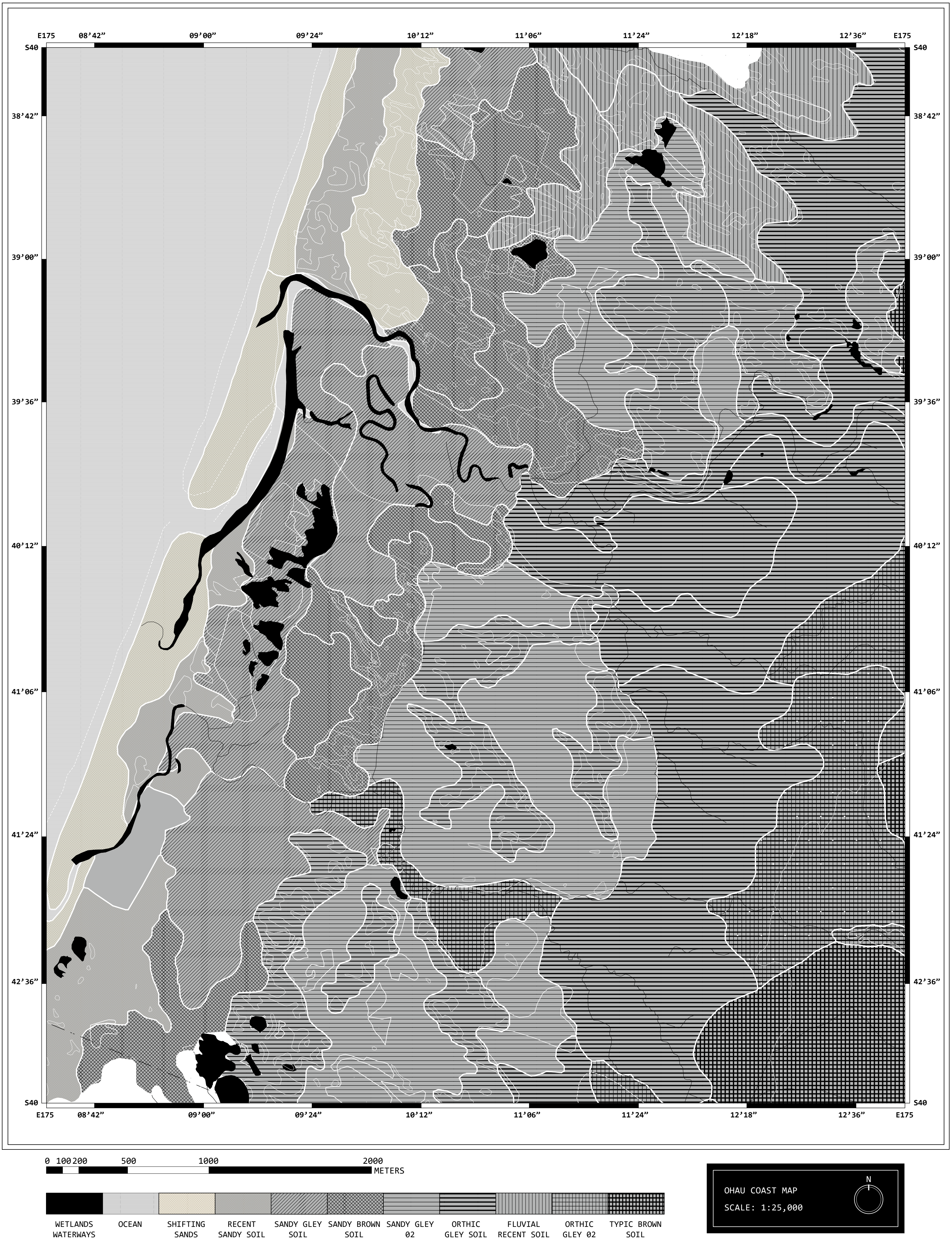
Overall, this design enquiry still emphasised the sculptural and aesthetic qualities of the form and material. The next stage investigated natural materials that could be used with the soft forming technique.

Fig. 08.20 COLUMN 01 (DETAIL 03)

Fig. 09.01 DUNE SYSTEM (OHAU RIVER MOUTH)
AUTHORS OWN PHOTOGRAPH

MATERIAL DOMAINS

HOW CAN THE USE OF THESE LOCAL MATERIALS HELP RECONNECT NGĀTI TUKOREHE BACK TO THEIR MATERIAL LANDSCAPE, WHILE ALSO PRESERVING POTENTIAL ASSETS OF NGĀTI TUKOREHE?


E175
08'42"
09'00"
09'24"
10'12"
11'06"
11'24"
12'18"
12'36"
S40
38'42"
39'00"
39'36"
40'12"
41'06"
41'24"
42'36"
0 100 200 500 1000 2000
METERS
WETLANDS WATERWAYS
OCEAN
SHIFTING SANDS
RECENT SANDY SOIL
SANDY GLEY SOIL
SANDY BROWN SOIL
SANDY GLEY 02
ORTHIC GLEY SOIL
FLUVIAL RECENT SOIL
ORTHIC GLEY 02
TYPIC BROWN SOIL
OHAU COAST MAP
SCALE: 1:25,000
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09

MATERIAL DOMAINS

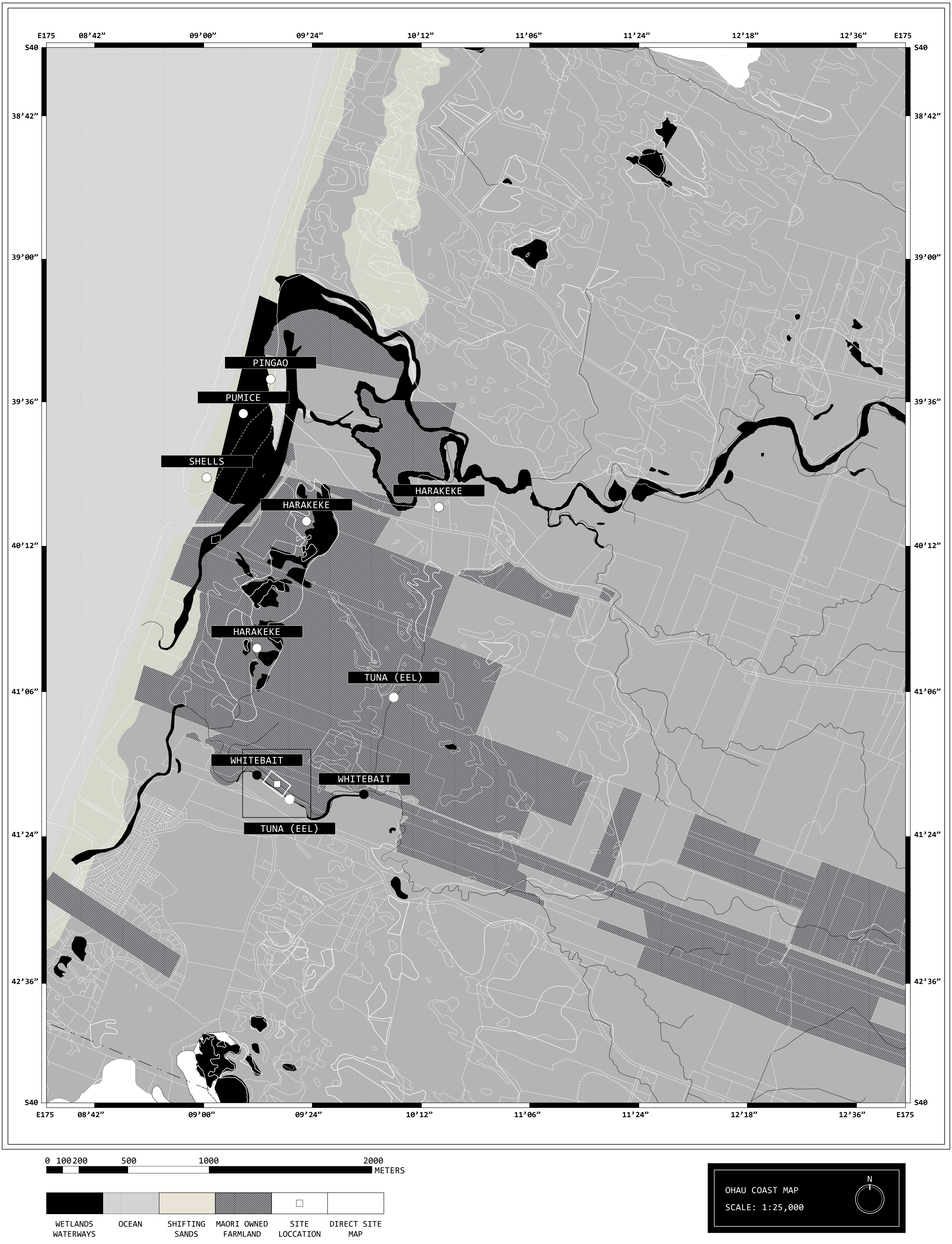
Introduction:

This stage investigated how the introduction of natural materials found in Ngāti Tukorehe's rohe builds upon the formal and material potentials of previous design enquiries. It also explores how the use of local materials could help reconnect Tukorehe with their material landscape. To begin testing, a matrix of different material compositions was created from raw materials, excavated or found in Tukorehe's rohe, to processed cementitious substances (Fig.09.06). The materials used from Tukorehe's rohe were sand, clay, pumice and harakeke. Colouration was introduced for aesthetic quality and to add meaning to the process (Fig.09.08).

Aim:

How can the introduction of natural materials found in Ngāti Tukorehe's rohe offer new design potentials? In addition, how can the use of these local materials help reconnect Ngāti Tukorehe back to their material landscape, while also preserving potential assets of Ngāti Tukorehe?

Fig. 09.02 OHAU REGION SOIL MAP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08'42"
09'00"
09'24"
10'12"
11'06"
11'24"
12'18"
12'36"
S40
38'42"
39'00"
39'36"
40'12"
41'06"
41'24"
42'36"
PINGAO
PUMICE
SHELLS
HARAKEKE
HARAKEKE
HARAKEKE
TUNA (EEL)
WHITEBAIT
WHITEBAIT
TUNA (EEL)
0 100 200 500 1000 2000
METERS
WETLANDS WATERWAYS
OCEAN
SHIFTING SANDS
MAORI OWNED FARMLAND
SITE LOCCATION
DIRECT SITE MAP
OHAU COAST MAP
SCALE: 1:25,000
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Method:

During the site visits with Ngāti Tukorehe, the hīkoi involved visiting areas that had historically significant resources and natural materials to Tukorehe.

A material palette was gathered from the natural materials found in Tukorehe's rohe (Fig.09.06). The materials were selected based on their abundance and potential as an asset for Tukorehe. Sand, clay, pumice and harakeke were selected from Tukorehe's rohe (Fig.09.03).

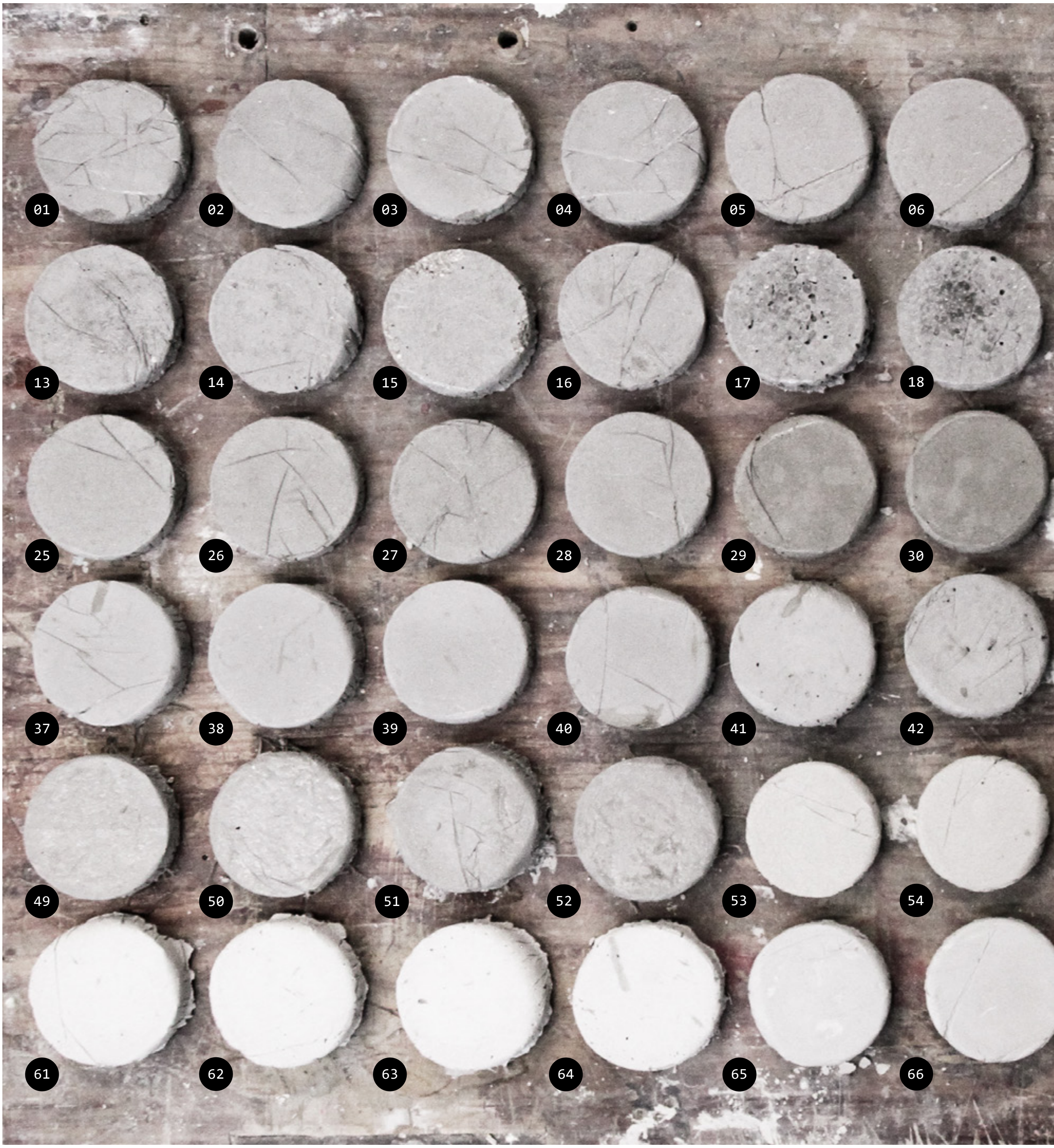
Different material compositions were created from the selected material pallet. The matrix of material compositions consisted of substances ranging from raw materials, excavated or found in Tukorehe's rohe, to processed cementitious substances. Various ratios of cement were added to sand, clay and pumice, creating a gradient of materials ranging from cement and sand to clay and sand.

Colouration was introduced here for aesthetic quality (Fig.09.08). This also added another layer of meaning to the process by using colours important to Tukorehe.

Fig. 09.03 OHAU REGION INDIGENOUS MATERIALS MAP

Fig. 09.04 CLAY BANKS (OHAU)
AUTHORS OWN PHOTOGRAPH

Fig. 09.05 MIXING EQUIPMENT
AUTHORS OWN PHOTOGRAPH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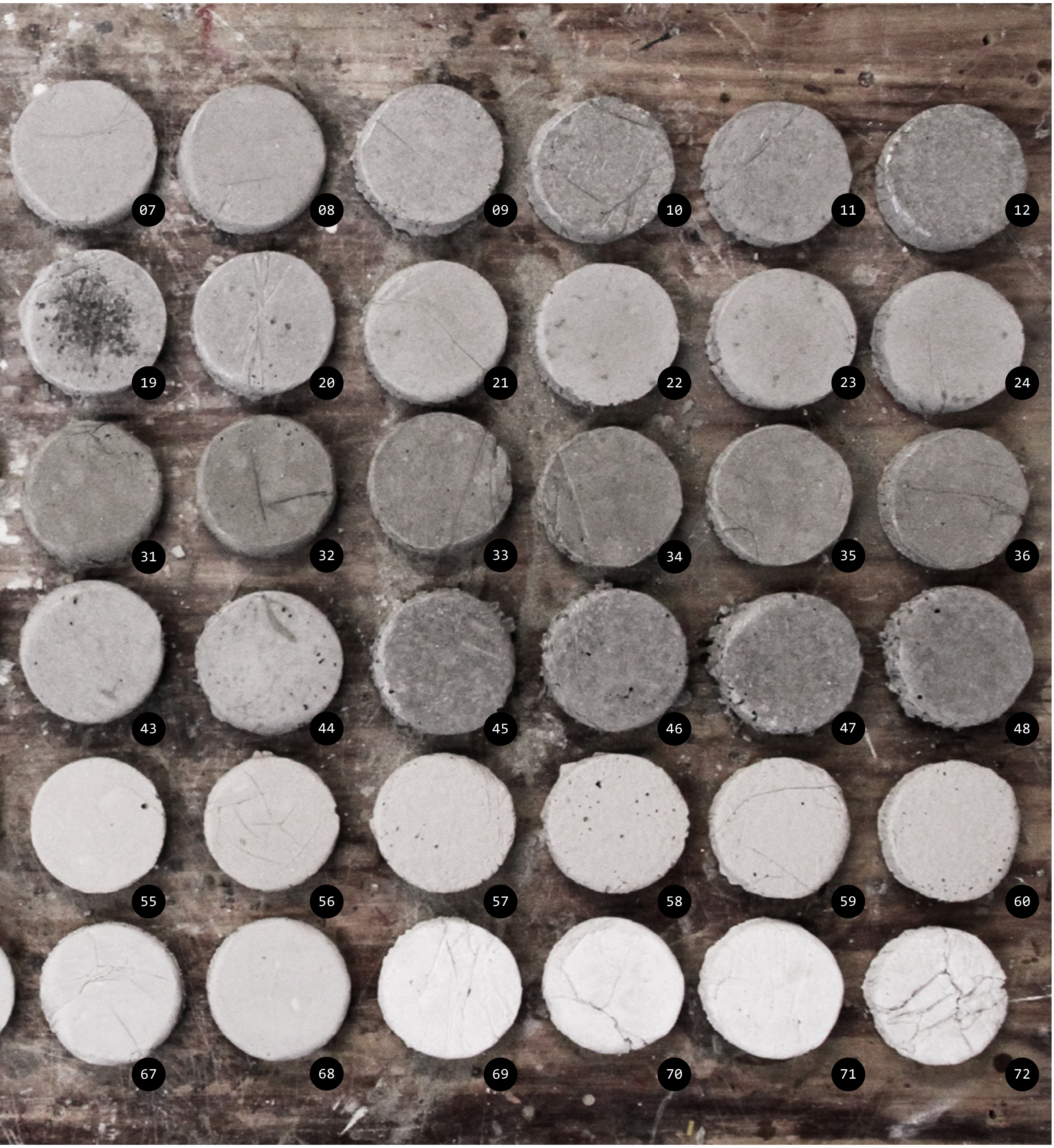


Fig. 09.06 A MATRIX OF MATERIAL COMPOSITIONS

01	02	03	04	05	06
1: Cement 3: Sand	1: Cement 3: Sand	1: Cement 3: Sand	1: Cement 3: Sand	1: Cement 3: Pumice (Fine)	1: Cement 3: Pumice (Fine)

13	14	15	16	17	18
1: Cement 1: Sand 3: Pumice (Fine)	1: Cement 1: Sand 3: Pumice (Fine)	1: Cement 1: Sand 3: Pumice (Fine)	1: Cement 1: Sand 3: Pumice (Fine)	1: Cement 1: Sand 3: Pumice (Coarse)	1: Cement 1: Sand 3: Pumice (Coarse)

25	26	27	28	29	30
1: Cement 1: Sand 2: Wood Fibres	1: Cement 1: Sand 2: Wood Fibres	1: Cement 1: Sand 2: Wood Fibres	1: Cement 1: Sand 2: Wood Fibres	1: Cement 2: Sand 1: Wood Fibres	1: Cement 2: Sand 1: Wood Fibres

37	38	39	40	41	42
1: Cement 1: Harakeke Fibres 3: Pumice (Fine)	1: Cement 1: Harakeke Fibres 3: Pumice (Fine)	1: Cement 1: Harakeke Fibres 3: Pumice (Fine)	1: Cement 1: Harakeke Fibres 3: Pumice (Fine)	1: Cement 1: Harakeke Fibres 3: Sand 3: Pumice (Coarse)	1: Cement 1: Harakeke Fibres 3: Sand 3: Pumice (Coarse)

49	50	51	52	53	54
1: Cement 1: Harakeke Fibres 1: Sand 3: Pumice (Coarse)	1: Cement 1: Harakeke Fibres 1: Sand 3: Pumice (Coarse)	1: Cement 1: Harakeke Fibres 1: Sand 3: Pumice (Coarse)	1: Cement 1: Harakeke Fibres 1: Sand 3: Pumice (Coarse)	1: Cement 1: Harakeke Fibres 1: Clay 3: Sand	1: Cement 1: Harakeke Fibres 1: Clay 3: Sand

61	62	63	64	65	66
1: Cement 1: Clay 1: Sand	1: Cement 1: Clay 1: Sand	1: Cement 1: Clay 1: Sand	1: Cement 1: Clay 1: Sand	1: Cement 1: Clay 3: Sand	1: Cement 1: Clay 3: Sand

Fig. 09.07 A MATRIX OF MATERIAL RATIOS

07	08	09	10	11	12
1: Cement 3: Pumice (Fine)	1: Cement 3: Pumice (Fine)	1: Cement 3: Sand 3: Pumice (Coarse)	1: Cement 3: Sand 3: Pumice (Coarse)	1: Cement 3: Sand 3: Pumice (Coarse)	1: Cement 3: Sand 3: Pumice (Coarse)
19	20	21	22	23	24
1: Cement 1: Sand 3: Pumice (Coarse)	1: Cement 1: Sand 3: Pumice (Coarse)	1: Cement 3: Wood Fibres	1: Cement 3: Wood Fibres	1: Cement 3: Wood Fibres	1: Cement 3: Wood Fibres
31	32	33	34	35	36
1: Cement 2: Sand 1: Wood Fibres	1: Cement 2: Sand 1: Wood Fibres	1: Cement 1: Harakeke Fibres 3: Sand	1: Cement 1: Harakeke Fibres 3: Sand	1: Cement 1: Harakeke Fibres 3: Sand	1: Cement 1: Harakeke Fibres 3: Sand
43	44	45	46	47	48
1: Cement 1: Harakeke Fibres 3: Sand 3: Pumice (Coarse)	1: Cement 1: Harakeke Fibres 3: Sand 3: Pumice (Coarse)	1: Cement 1: Harakeke Fibres 1: Sand 3: Pumice (Fine)	1: Cement 1: Harakeke Fibres 1: Sand 3: Pumice (Fine)	1: Cement 1: Harakeke Fibres 1: Sand 3: Pumice (Fine)	1: Cement 1: Harakeke Fibres 1: Sand 3: Pumice (Fine)
55	56	57	58	59	60
1: Cement 1: Harakeke Fibres 1: Clay 3: Sand	1: Cement 1: Harakeke Fibres 1: Clay 3: Sand	1: Cement 1: Clay 1: Sand 3: Pumice (Coarse)	1: Cement 1: Clay 1: Sand 3: Pumice (Coarse)	1: Cement 1: Clay 1: Sand 3: Pumice (Coarse)	1: Cement 1: Clay 1: Sand 3: Pumice (Coarse)
67	68	69	70	71	72
1: Cement 1: Clay 3: Sand	1: Cement 1: Clay 3: Sand	1: Hydrated Lime 3: Sand	1: Hydrated Lime 3: Sand	1: Hydrated Lime 3: Sand	1: Hydrated Lime 3: Sand

Fig. 09.08 RED COLOURATION (RED OXIDE, SAND AND CEMENT)

09.03

COLOURATION

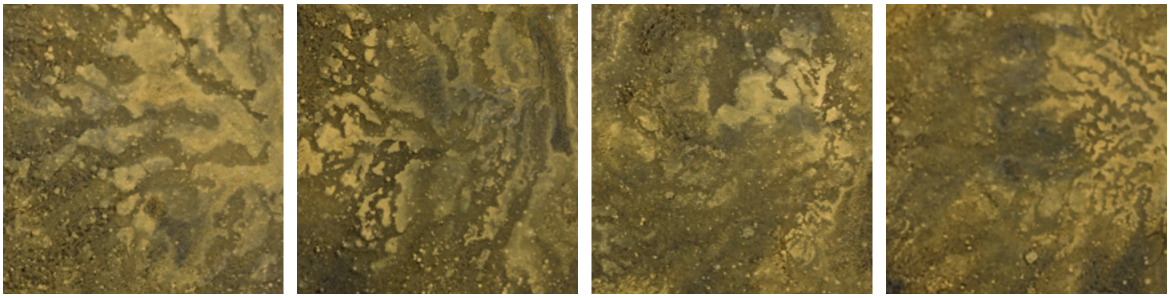


Fig. 09.09 YELLOW COLOURATION (YELLOW OXIDE, SAND AND CEMENT)

09.04

CONCLUSION

Findings:

The creation of a range of material compositions including both natural and human-made substances could enable the incorporation of the freeform structures' obsolescence and degradation into their design. Material obsolescence has potential at a larger scale as a climate adaptive solution. When injecting a substance into the ground to mitigate coastal erosion, that structure could be designed to last 20 or 50 years. After that time, the structure will have naturally eroded back into the landscape. Erosion of the structure would allow Ngāti Tukorehe to implement another, more appropriate strategy in the future.

The potential to inject minerals along with the extrusions into the soil could be explored. These minerals would replenish the landscape and encourage the growth of plants not typically grown in sandy conditions due to accelerated erosion of riverbanks and low nutrients in the sand, such as manuka and harakeke.

The next stage investigated verifying the potential to inject fluids into the ground within a digital model.

Fig. 09.10 A STACK OF MATERIAL TESTS

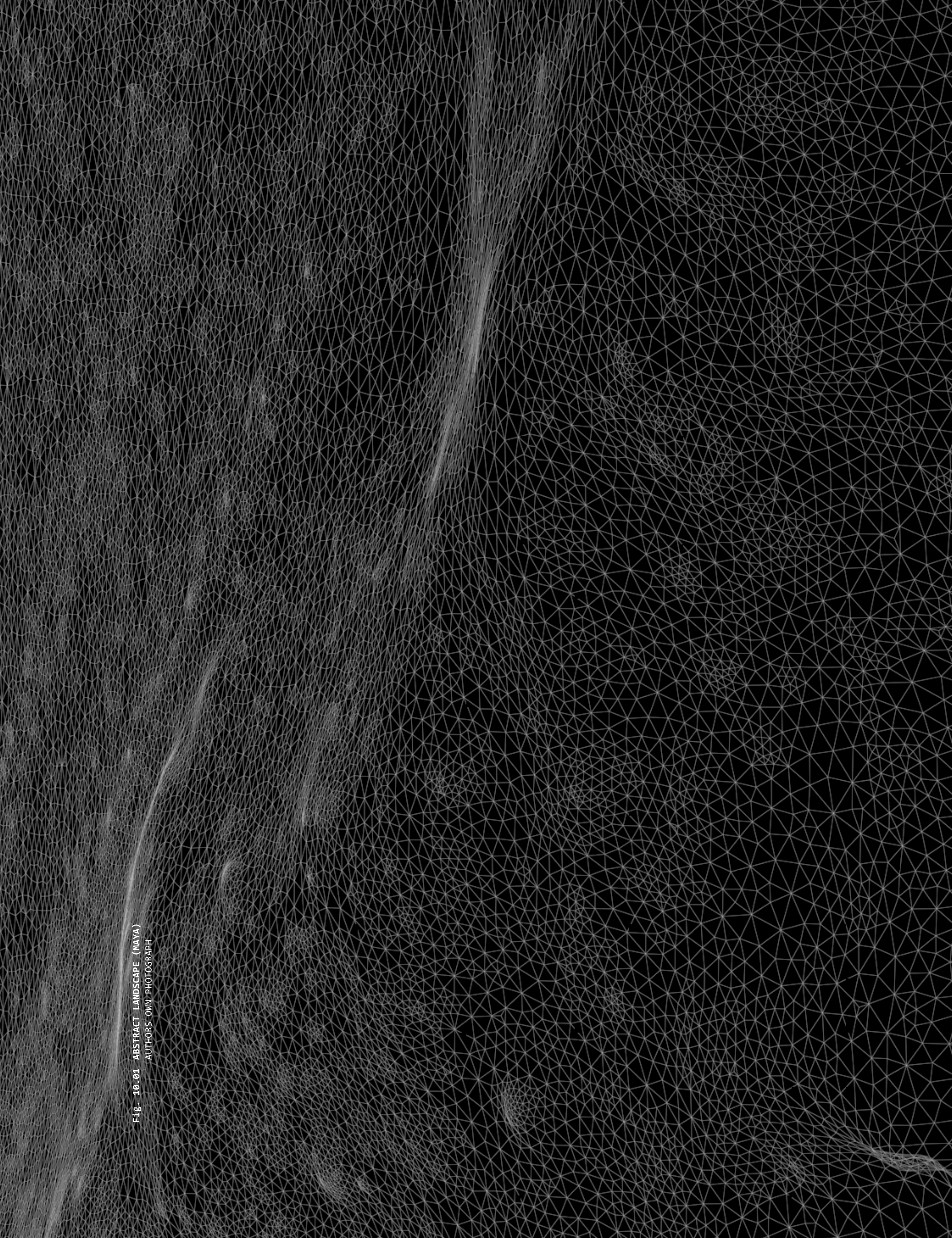
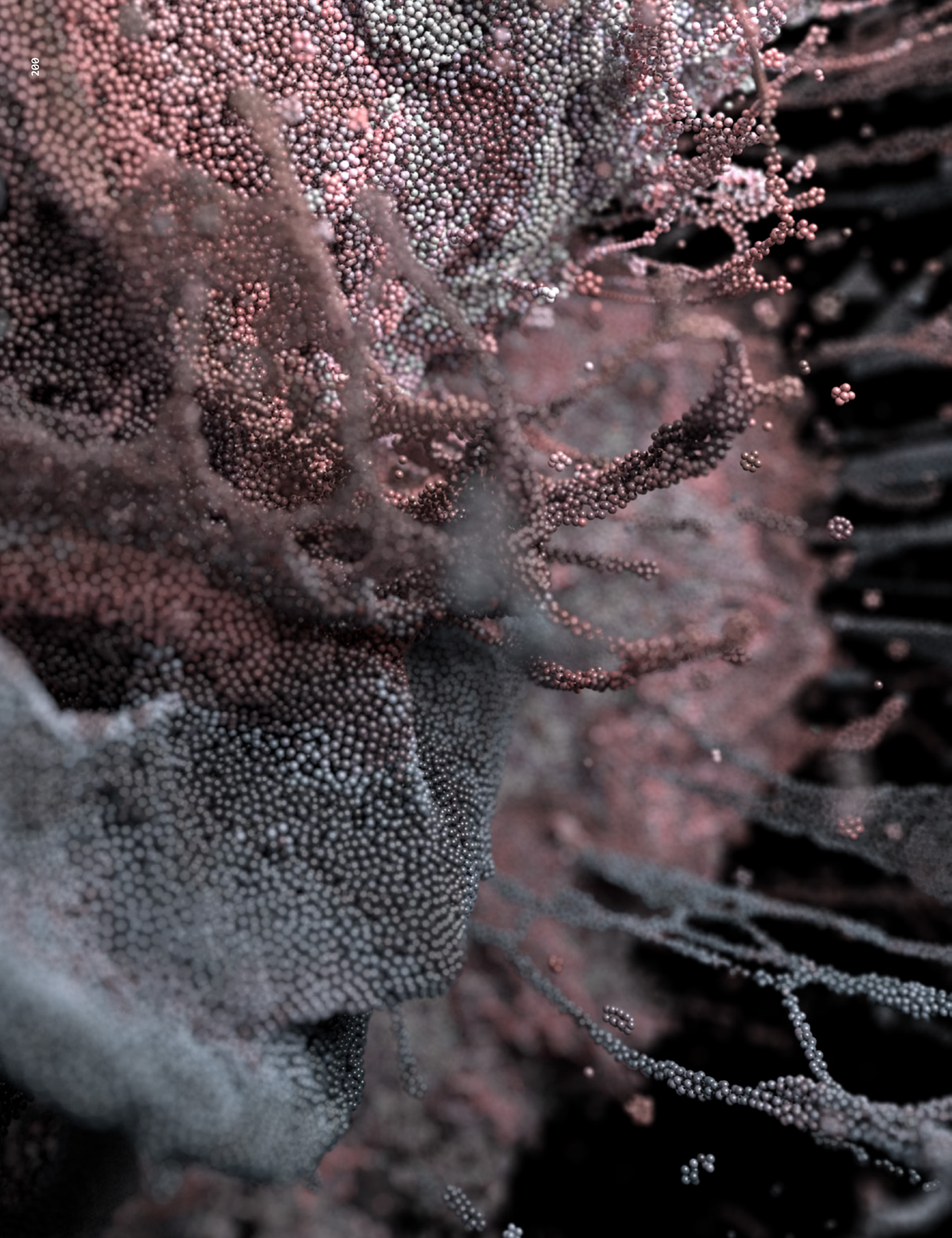


Fig. 10.01 ABSTRACT LANDSCAPE (MAYA)
AUTHORS OWN PHOTOGRAPH

10
REALFLOW SIMULATIONS



10

REALFLOW SIMULATIONS

Introduction:

The hard forming process was simulated using a fluid dynamics software, RealFlow. This software allowed the designer to influence the parameters of the material and environmental forces. The same agency held by the material in the analogue hard forming process could be simulated digitally. Digital simulation enabled the designer to shape the form indirectly through changes in the environment. The indirect manipulation of form maintained the previously established co-authorship between the whenua, the material and the designer, through digital tools.

This aspect of the project intended to see how different soil compositions affect the flow of fluid. Instead of imposing a form on the material, the environment should be left to define the shape of the form.

RealFlow can be viewed as both a tool for simulation and a tool for design. RealFlow has the potential to not only simulate the hard forming process but also to be used in creative ways to build upon the previously established hard forming technique and see new design possibilities that could arise from the process.

Aim:

How can we simulate the hard forming process digitally in order to gain an understanding of how environmental forces influence and manipulate the form of a material? How can we work with these forces to expand on the design potential for hard forming?

Fig. 10.02 ABSTRACT PARTICLE SIMULATION (REALFLOW)

10.01

HARD FORMING SIMULATION 01

Method:

First, an empty rectangular volume was set up in RealFlow. The volume was then populated with arrays of spherical objects that were designed as a representation of sand particles.

Three different configurations of spheres were used to test the effects of different soil configurations. These tests included: a linear array of 20mm spheres, randomised 20mm spheres and randomised spheres varying in size from 5mm to 40mm.

A circular particle emitter was set up above the configuration of spheres in RealFlow. The emitter was set up to emit a constant flow of particles above the volume of spheres. The emitted particles were used to simulate the flow of a viscous liquid such as plaster or cement (Fig.10.03). To gain control of the material and environmental forces, the designer could change the behaviours of the injection material and the environmental forces to produce different outcomes. These outcomes approximated more closely what was seen in the hard forming analogue models. Parameters that could be altered were particle resolution (amount of particles) fluid pressure, compression, viscosity and surface tension. The single point of particle emission (injection) and the volume of spheres (particles) were designed to simulate what happens in the hard forming tests. Based on this set of parameters, different forms were produced, the nature and shape of which were mostly determined through the material being injected and composition of the sand. The same injection size and pressure were used throughout all testing.

A series of 5 different tests were run over 120 frames in RealFlow (Fig.10.03). The series looked at how a particle field influences the behaviour and forms of a material over time. The parameters of the fluid and particle field were adjusted in different iterations.

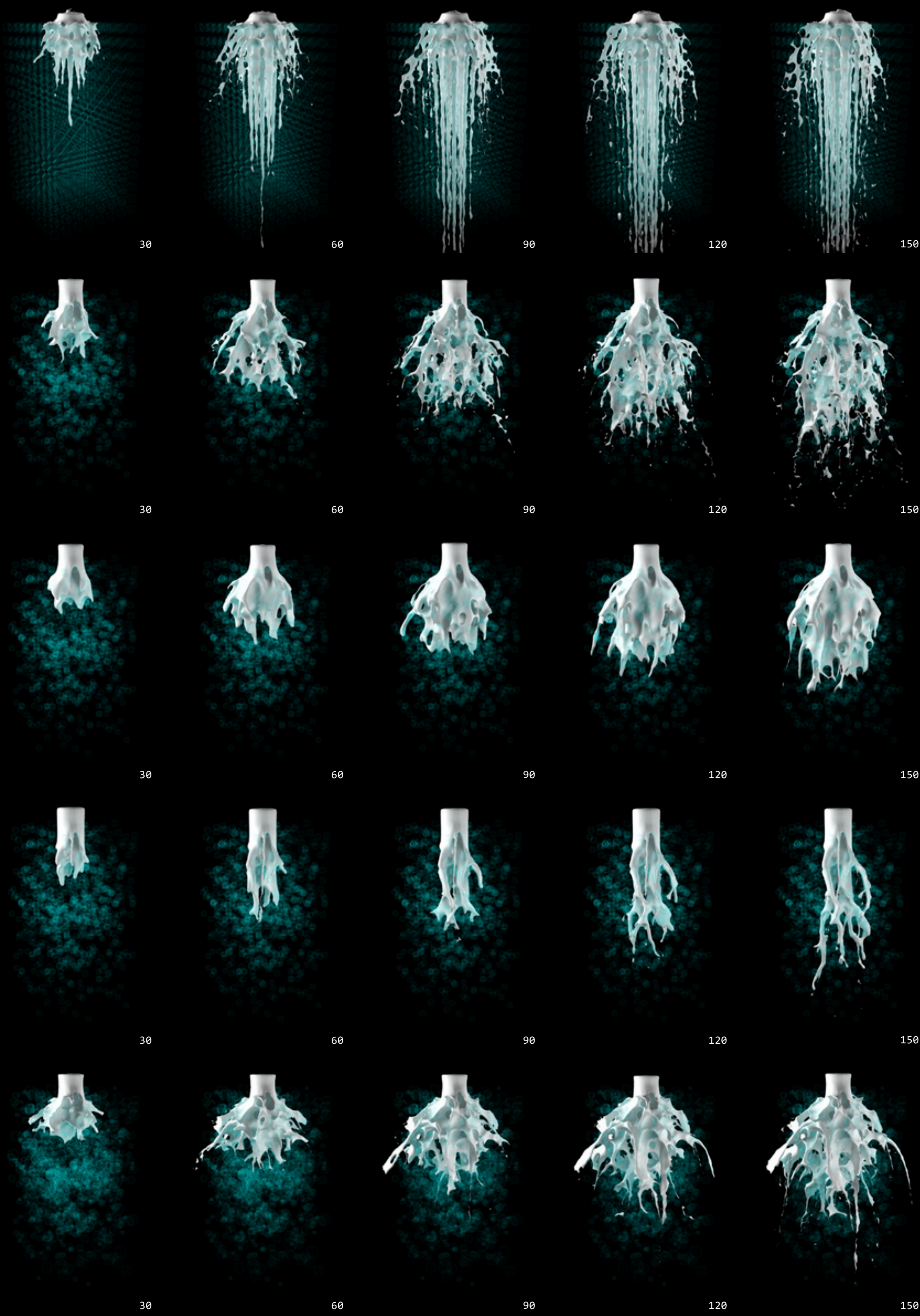


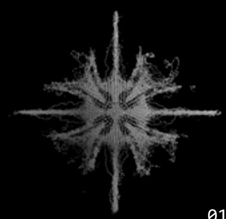
Fig. 10.03 ANIMATION MATRIX 01 (REALFLOW MESH)

(PERSPECTIVE)

REALFLOW PARAMETERS

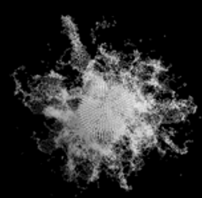
FLUID DISTRIBUTION

GEOMETRY:	LINEAR SPHERE
RADIUS:	20MM
PARTICLE RESOLUTION:	10.0
FLUID PRESSURE:	1.0
COMPRESSION:	1.0
VISCOSITY:	3.0
SURFACE TENSION:	0.0



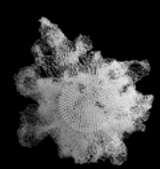
01

GEOMETRY:	RANDOM SPHERE
RADIUS:	20MM
PARTICLE RESOLUTION:	10.0
FLUID PRESSURE:	1.0
COMPRESSION:	1.0
VISCOSITY:	3.0
SURFACE TENSION:	0.0



02

GEOMETRY:	RANDOM SPHERE
RADIUS:	20MM
PARTICLE RESOLUTION:	10.0
FLUID PRESSURE:	1.0
COMPRESSION:	0.0
VISCOSITY:	20.0
SURFACE TENSION:	10.0



03

GEOMETRY:	RANDOM SPHERE
RADIUS:	20MM
PARTICLE RESOLUTION:	10.0
FLUID PRESSURE:	1.0
COMPRESSION:	10.0
VISCOSITY:	20.0
SURFACE TENSION:	10.0

04

GEOMETRY:	RANDOM SPHERE
RADIUS:	05MM - 40MM
PARTICLE RESOLUTION:	10.0
FLUID PRESSURE:	1.0
COMPRESSION:	1.0
VISCOSITY:	3.0
SURFACE TENSION:	0.0

05

(PLAN)

Fig. 10.04 INJECTION RESULTS 01 (REALFLOW PARTICLES)

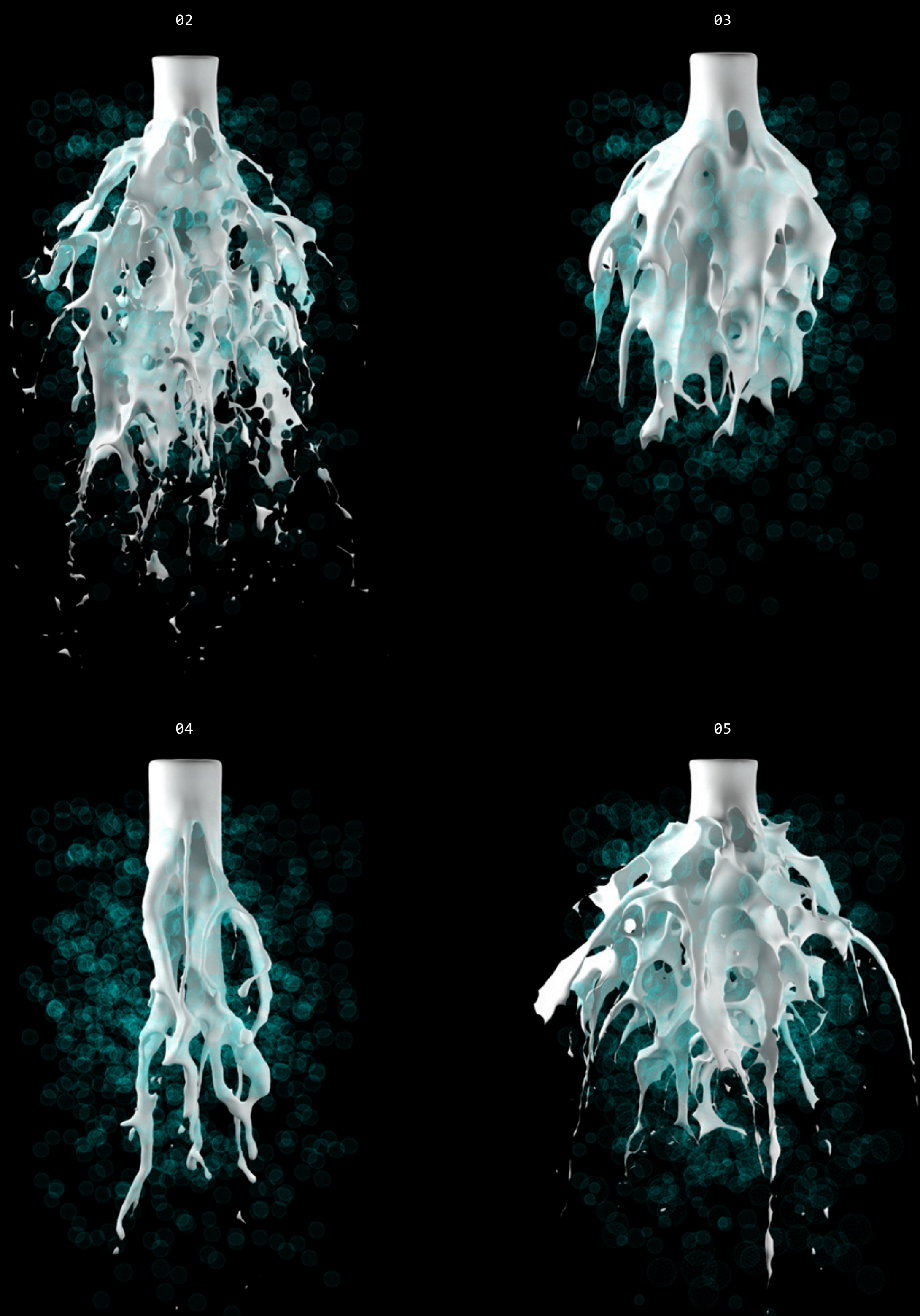
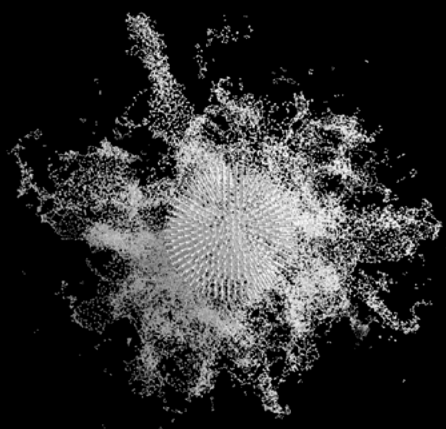


Fig. 10.05 INJECTED FORMS 01 (REALFLOW MESH)

(PERSPECTIVE)

FLUID DISTRIBUTION

02



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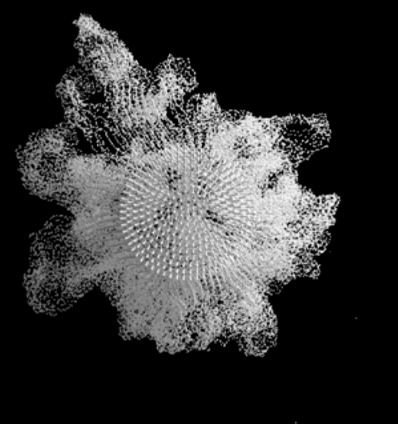

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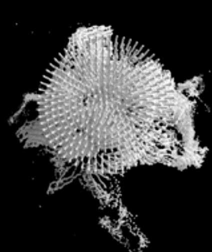
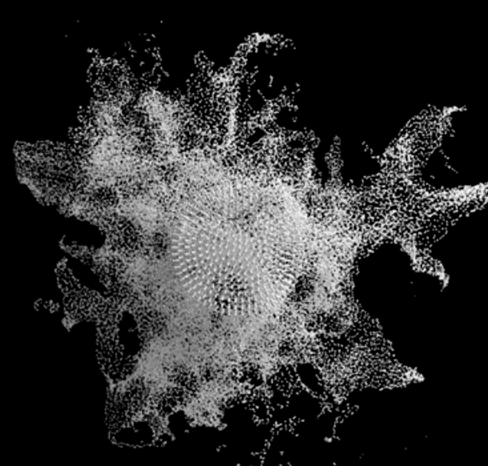


05



(PLAN)

Fig. 10.06 FLUID DISTRIBUTIONS 01 (REALFLOW PARTICLES)

CONCLUSION

Findings:

Based on these tests, the highly viscous fluid more closely resembled the particle behaviour of cement or plaster (Fig.10.05). This stage was useful for understanding how fluid interacted with a field of particles without accurately modelling ground conditions.

The next stage explored how to accurately simulate possible ground conditions on-site and compare differences between simulations.

10.02

HARD FORMING SIMULATION 02

Introduction:

The second series was conducted in four different iterations. The intention was to simulate an array of possible ground conditions found on-site next to the Waikawa River. In addition, the tests simulated how these different environments shaped the form of an injected fluid. The intention was to verify the analogue results digitally and use environmental forces to expand on the design potential to create foundation structures or other subterranean forms.

Aim:

The intention was to test how an injected fluid reacted to each stratum of soil and how the injected fluid behaved when passing from one stratum to another.

Method:

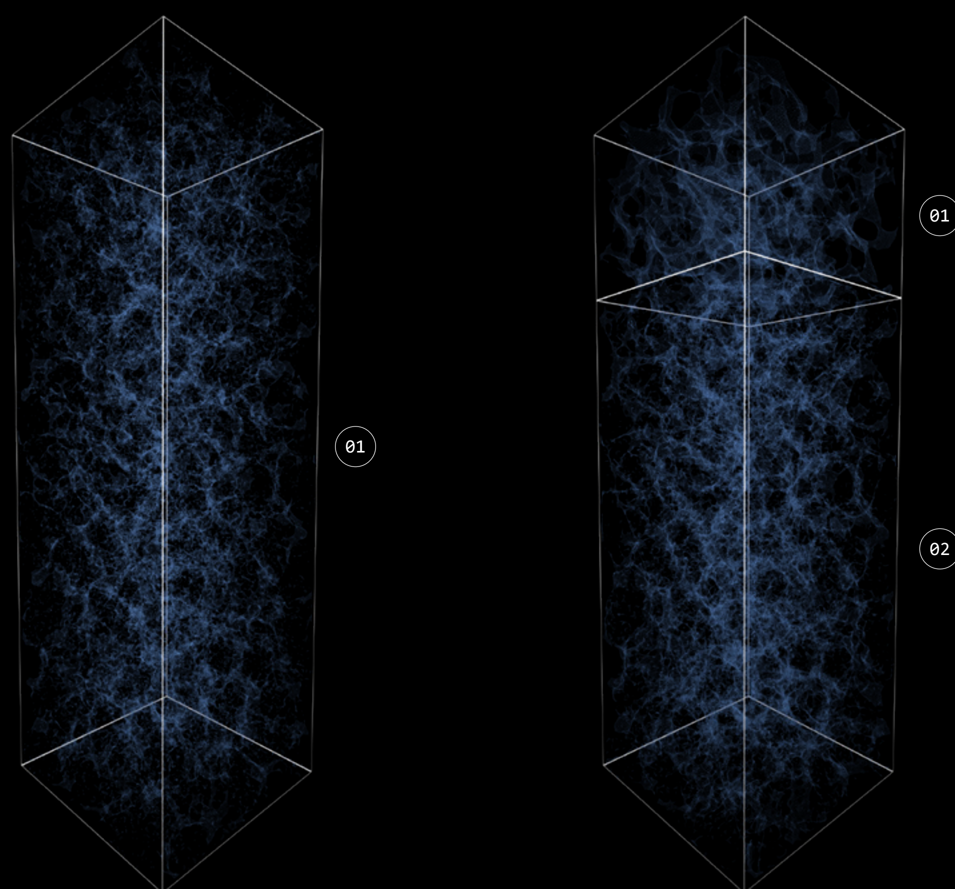
The process began with the creation of four different 12m x 3m x 3m volumes, which simulated a section of possible soil composition next to the Waikawa river (Fig.10.08). Volume 1 consisted of 12m of fine sand. Volume 2 contained 3m of organic oil and 9m of fine sand. Volume 3 contained 3m of silty sand and 9m of fine sand; Volume 4, 5m of silty sand, 5m of fine sand and 2m of clay-sand.

The soils were simulated by assigning different particle properties to each stratum of soil. A mesh was created based on the properties of those soils. This approximated ground conditions based on the porosity and permeability of the mesh.

A large square particle emitter was established above the volumes of soil. The emitter was programmed to emit particles at a constant rate through the volume of soil over 120 frames (Fig.10.09). The particles emitted were based on the previous tests which simulated a viscous material.

Fig. 10.07 INJECTION RESULT CLOSE UP (REALFLOW MESH)

01 02

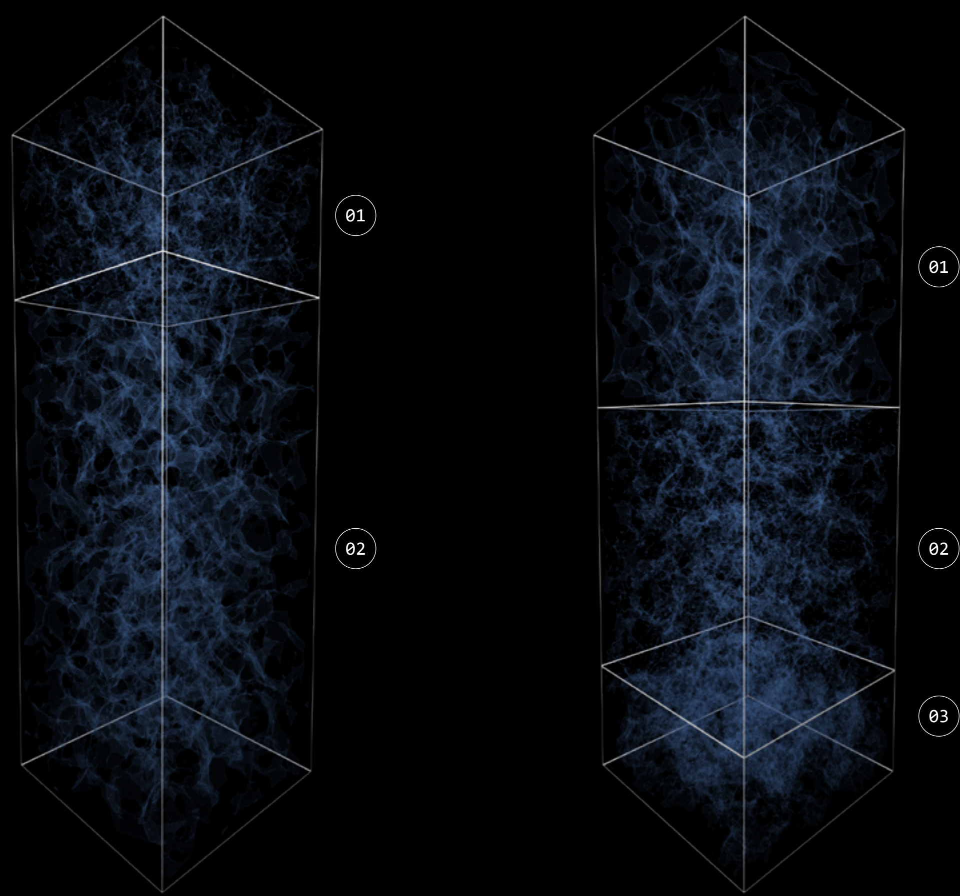


01:
SOIL TYPE: FINE SAND
PERMEABILITY: 5.0CM/HR
DEPTH: 12M

01:
SOIL TYPE: ORGANIC SOIL
PERMEABILITY: 5.0CM/HR
DEPTH: 3M

02:
SOIL TYPE: FINE SAND
PERMEABILITY: 5.0CM/HR
DEPTH: 9M

03 04



03

01:
SOIL TYPE: FINE SAND
PERMEABILITY: 5.0CM/HR
DEPTH: 3M

02:
SOIL TYPE: SILITY SAND
PERMEABILITY: 3.0M/S
DEPTH: 9M

04

01:
SOIL TYPE: SILITY SAND
PERMEABILITY: 3.0M/S
DEPTH: 9M

02:
SOIL TYPE: FINE SAND
PERMEABILITY: 5.0CM/HR
DEPTH: 3M

03:
SOIL TYPE: CLAYEY CLAY
PERMEABILITY: 0.5CM/S
DEPTH: 2M

Fig. 10.08 SOIL COMPOSITIONS (REALFLOW MESH)

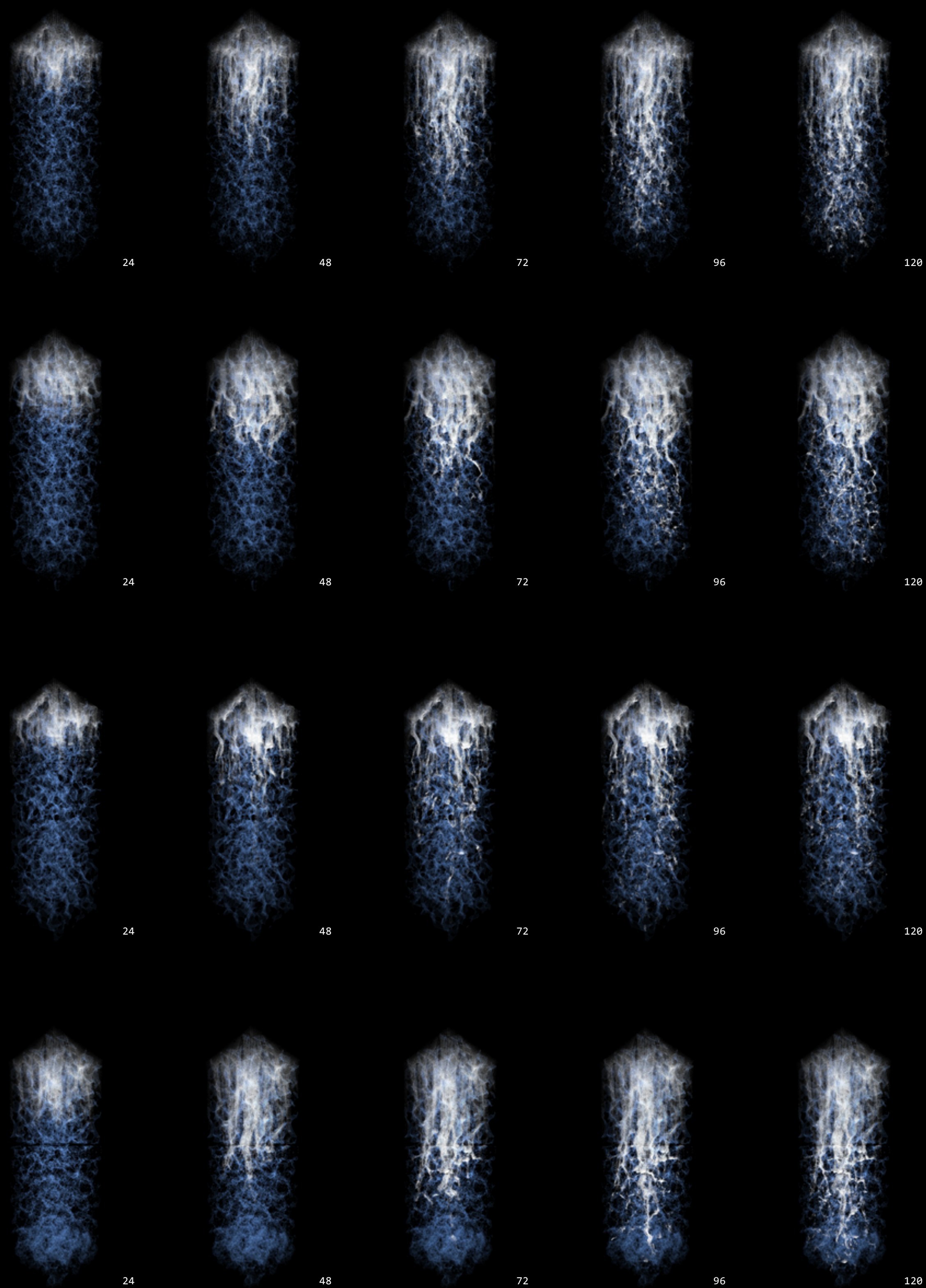


Fig. 10.09 **ANIMATION MATRIX 02** (REALFLOW PARTICLES)

(PERSPECTIVE)

REALFLOW PARAMETERS

FINAL OUTCOME

SOIL COMPOSITION:	01
DEPTH:	12M
PARTICLE RESOLUTION:	10.0
FLUID PRESSURE:	1.0
COMPRESSION:	0.0
VISCOSITY:	20.0
SURFACE TENSION:	10.0

01

SOIL COMPOSITION:	02
DEPTH:	12M
PARTICLE RESOLUTION:	10.0
FLUID PRESSURE:	1.0
COMPRESSION:	0.0
VISCOSITY:	20.0
SURFACE TENSION:	10.0

02

SOIL COMPOSITION:	03
DEPTH:	12M
PARTICLE RESOLUTION:	10.0
FLUID PRESSURE:	1.0
COMPRESSION:	0.0
VISCOSITY:	20.0
SURFACE TENSION:	10.0

03

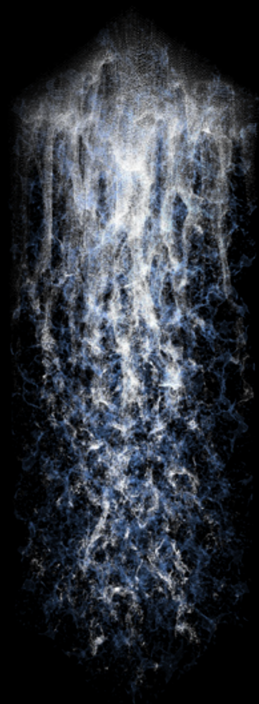
SOIL COMPOSITION:	04
DEPTH:	12M
PARTICLE RESOLUTION:	10.0
FLUID PRESSURE:	1.0
COMPRESSION:	0.0
VISCOSITY:	20.0
SURFACE TENSION:	10.0

04

(PLAN)

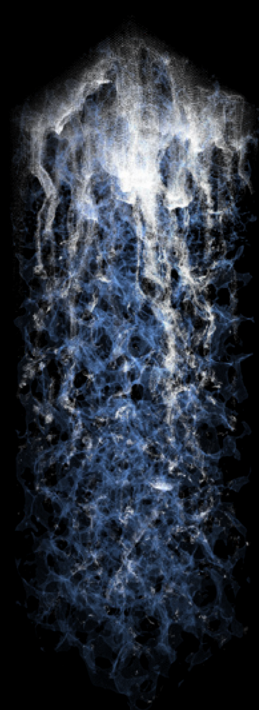
Fig. 10.10 INJECTION RESULTS 02 (REALFLOW PARTICLES)

01



02

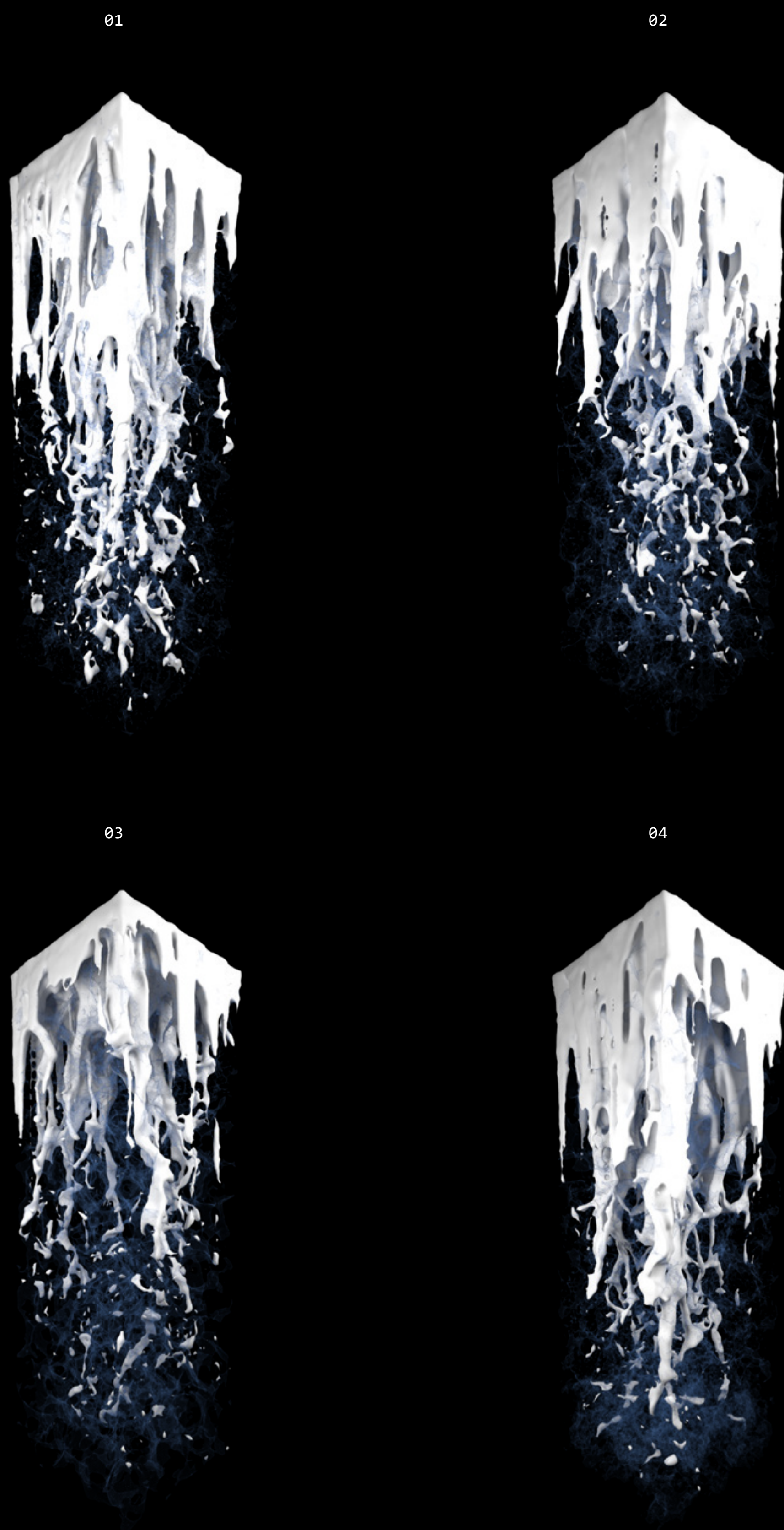
03



04

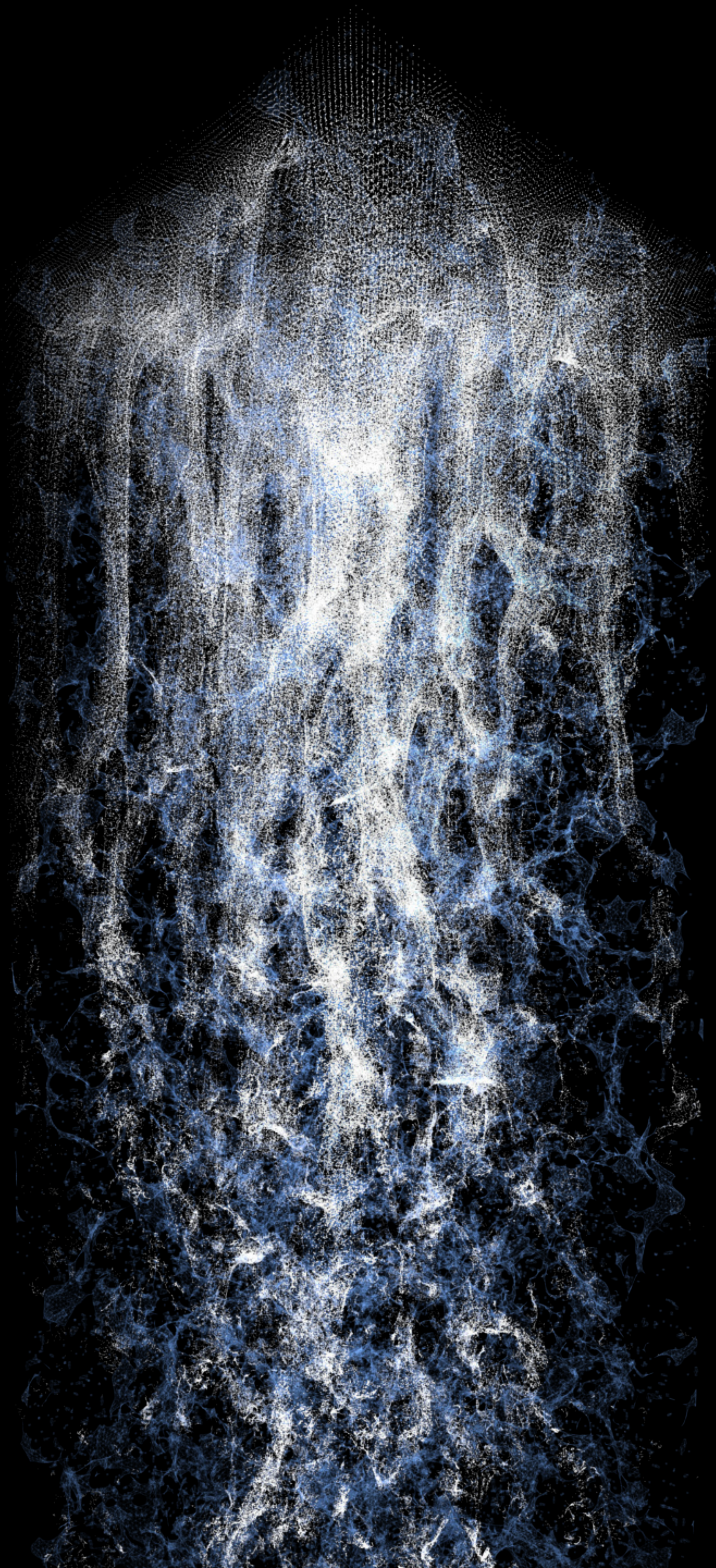
(PERSPECTIVE)

Fig. 10.11 INJECTED FORMS 02 (REALFLOW PARTICLES)



(PERSPECTIVE)

Fig. 10.12 **INJECTED FORMS 02** (REALFLOW MESH)



CONCLUSION

Findings:

The simulation revealed how the established soil conditions shape the form of the fluid passing through. This test was useful for understanding how different soil types could affect the hard forming process. However, the simulations were not an accurate representation of the hard forming process. The inaccuracy is because the fluid was emitted from a rectangle with the same surface area to the top face of the volume into which the fluid is injected, instead of being emitted from a single point of injection. However, these findings are essential for testing the ability to inject minerals into the soil to see how fluids percolate through different soil types.

Fig. 10.13 INJECTION RESULT CLOSE UP (REALFLOW PARTICLES)

PAVILION DESIGN

THE PROJECT BUILDS NGĀTI TUKOREHE’S CAPACITY TO ADAPT PROACTIVELY AND PRODUCTIVELY TO CHANGES WITHIN THEIR ROHE.

Fig. 11.01 MAORI OWNED FARMLAND (WAIKAWA 2018)
AUTHORS OWN PHOTOGRAPH

11

PAVILION PROCESS

Fig. 11.02 A DRONE 3D SCANNING THE SITE TERRAIN

Introduction:

This stage shows the potential on-site application of the techniques researched, and how they could be used to connect Ngāti Tukorehe with their material domain. The pavilion design process explored how different digital design tools such as 3D scanning, animation in Maya and particle simulations in RealFlow could build upon the knowledge previously established in this research, to design and fabricate a pavilion for Ngāti Tukorehe.

The programme of the pavilion is a whitebaiting shelter. The shelter would function as a monitoring station for whitebait and tuna, significant resources for Tukorehe. In light of the nationwide endangerment of these species, Tukorehe was concerned about the dwindling numbers of these fish in the Waikawa, the river near which the site is located. The site also benefits from its proximity to sites relevant to Tukorehe's material landscape; in the north was a pā harakeke and the Okaka ridge and to the west, historical dunes and Te Hakere wetland.

Fig. 11.03 DRONE SCANNING SET UP (DJI PHANTOM 3)

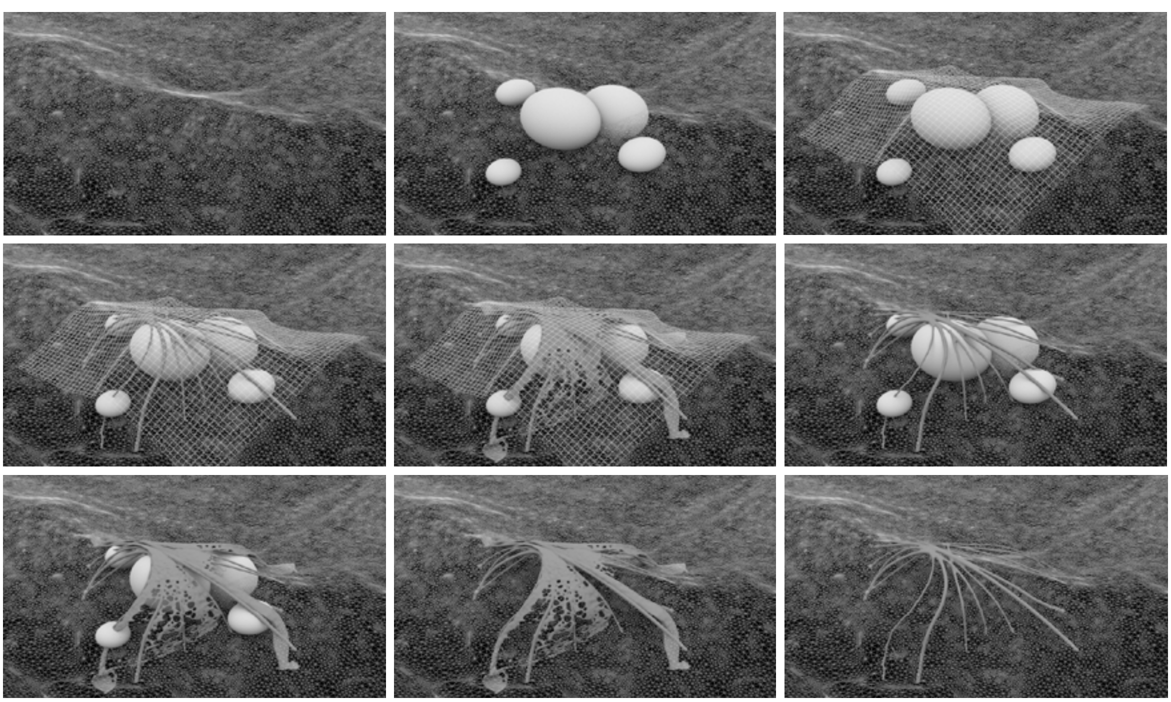


Fig. 11.04 3D SCANNING AND REALFLOW PROCESS

11.01

3D SCANNING

Method:

The pavilion was designed in RealFlow, using software to simulate both soft and hard forming processes. The site terrain and topography was 3D-scanned using a drone (Fig.11.03). This data was then translated to a 3D mesh using Autodesk Recap360 and imported into RealFlow (Fig.11.05). In Maya, programmatic areas were created, using spheres as 3D boundary volumes (Fig.11.06). These three areas represent the central circulation of the pavilion, a fishing spot and waka launch and main access. Using nCloth physics solvers in Maya to approximate the shaping of a natural landform, a digital sand dune was draped over the programmatic areas and superimposed on the 3D-scanned digital terrain (Fig.11.07). This digital landform created in nCloth was then used as a boundary for simulation in RealFlow (Fig.11.08).

Fig. 11.06 PLACEMENT OF PROGRAMMATIC AREAS ON TOP OF THE 3D SCANNED TERRAIN (STAGE 02)

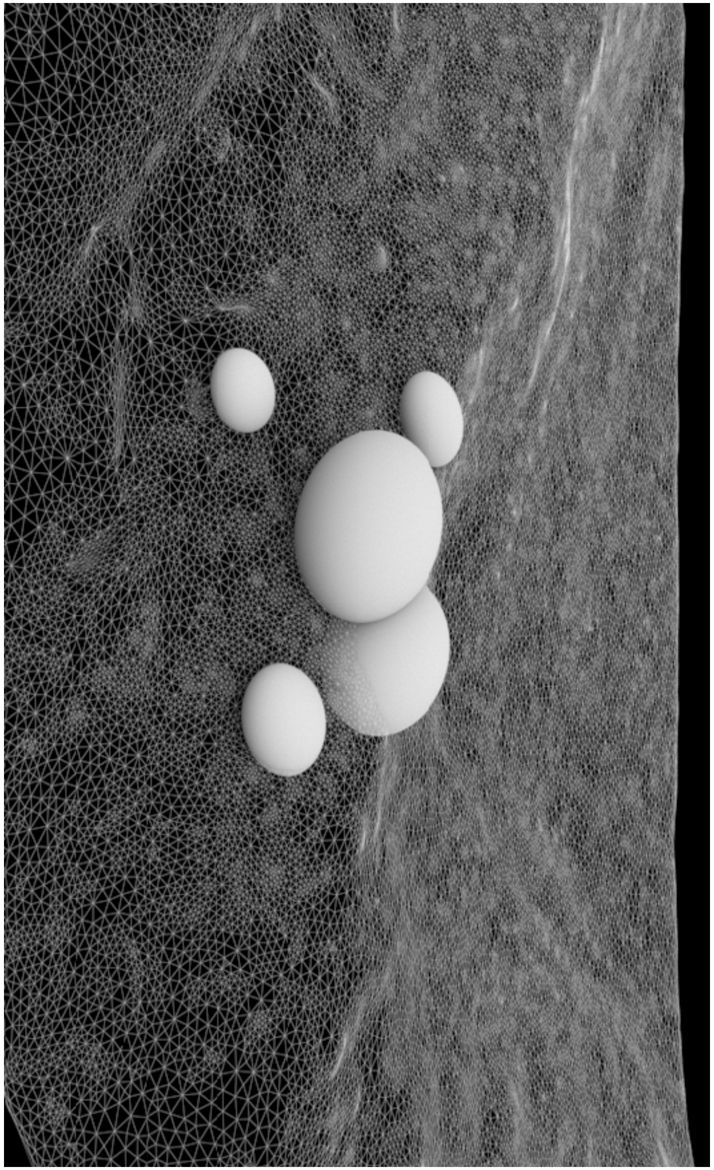


Fig. 11.05 3D SCANNED LANDSCAPE (STAGE 01)

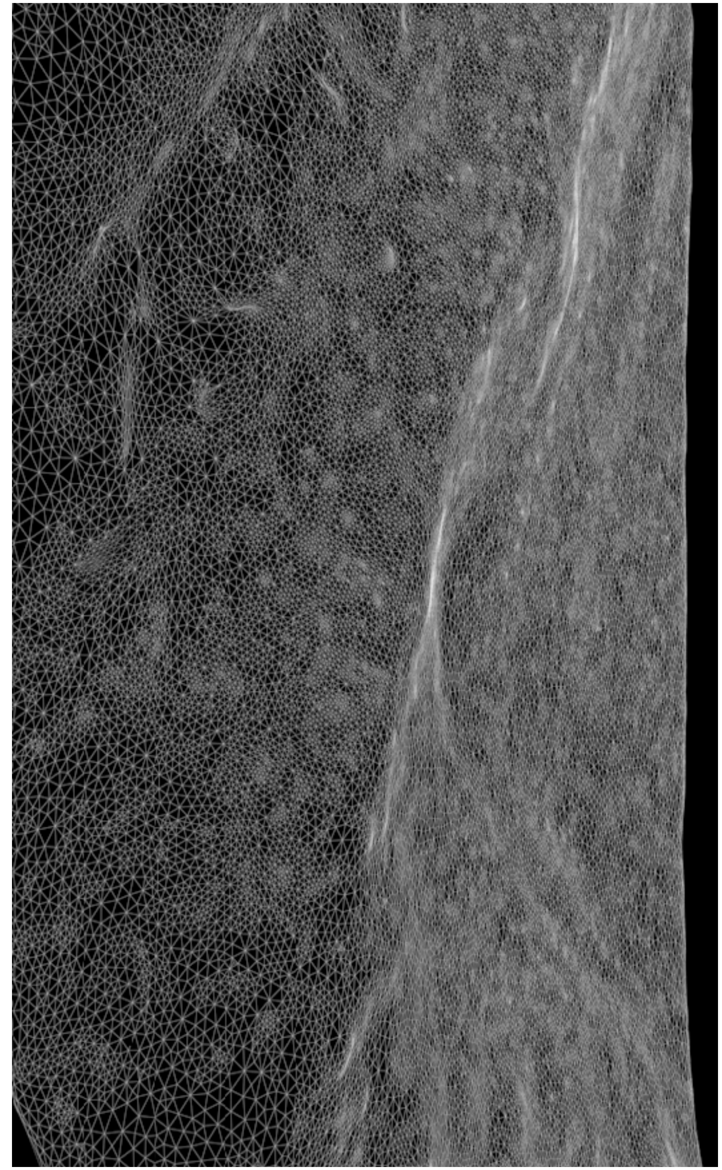


Fig. 11.08 SIMULATION OF DIGITAL SOFT FORMING (STAGE 04)

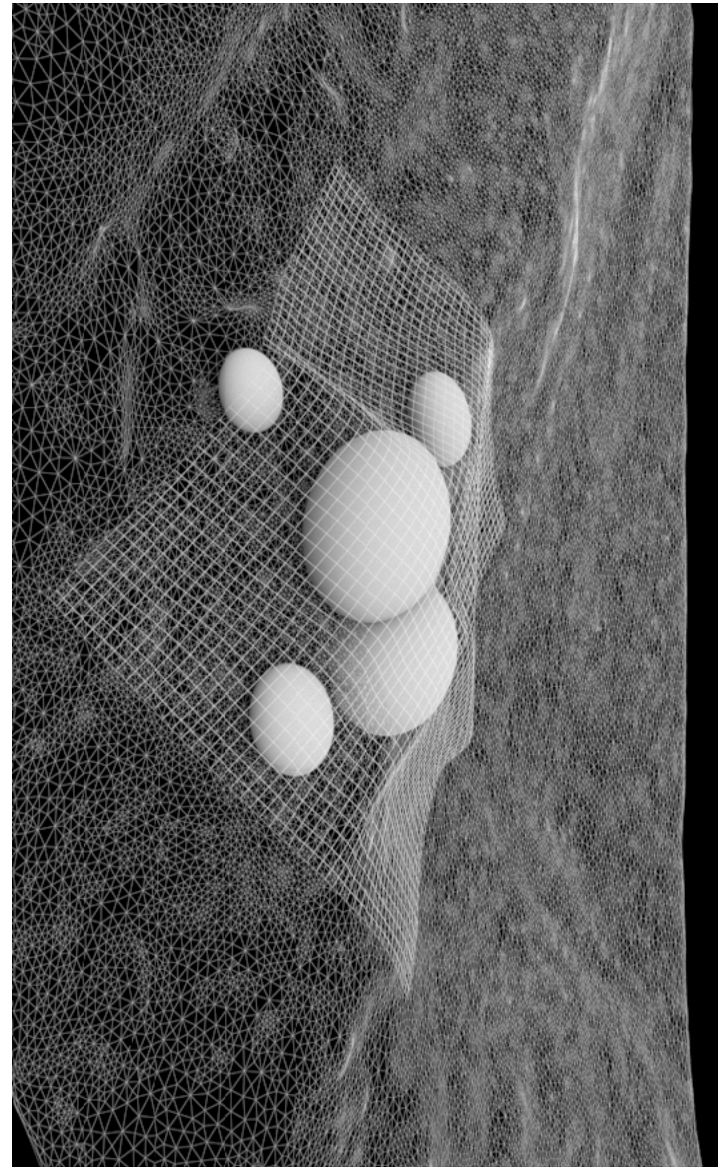
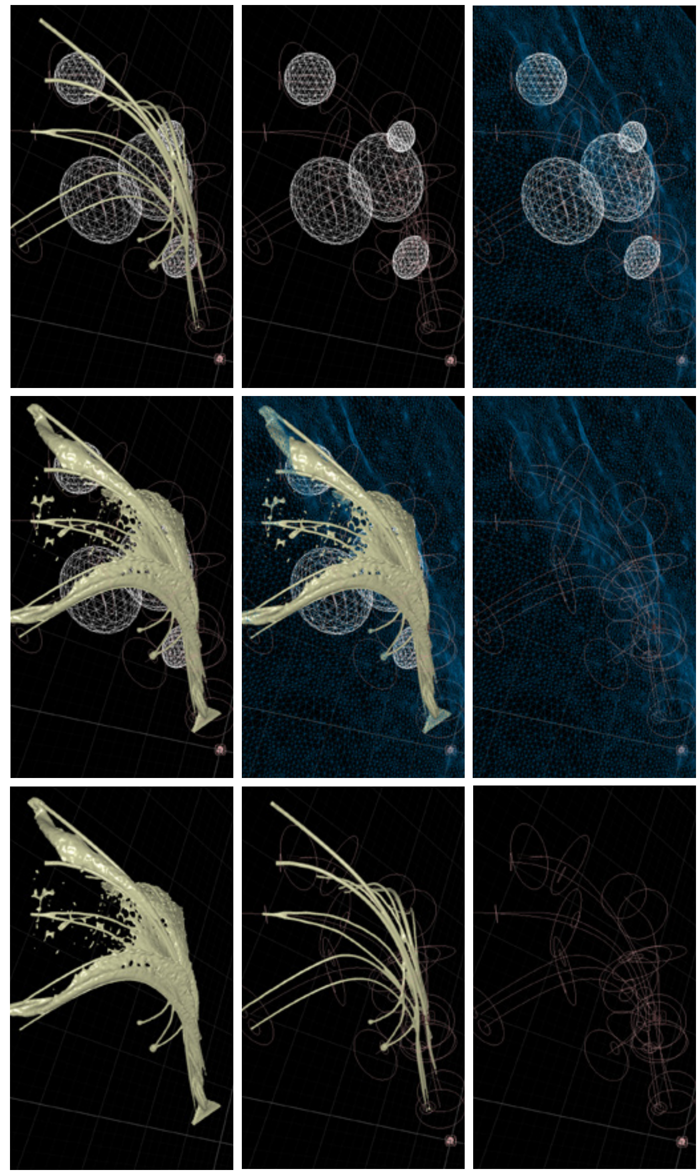


Fig. 11.07 NCLOTH LANDFORM SUPERIMPOSED
ON THE 3D SCANNED TERRAIN (STAGE 03)

Fig. 11.09 DESIGN STAGES IN REALFLOW



11.02

REALFLOW

Method:

In RealFlow, particle emitters were established to emit a fluid along a fixed toolpath, simulating the injection and extrusion of material similar to the soft forming process (Fig.11.10). Particles were emitted over and around the established programmatic areas, thereby informing the interior spaces of the pavilion (Fig.11.11). Forces and fields were also established in RealFlow to manipulate the flow of particles, shaping the exterior form (Fig.11.13).

Fig. 11.11 PLACEMENT OF PROGRAMMATIC AREAS ON TOP OF THE 3D SCANNED TERRAIN (STAGE 02)

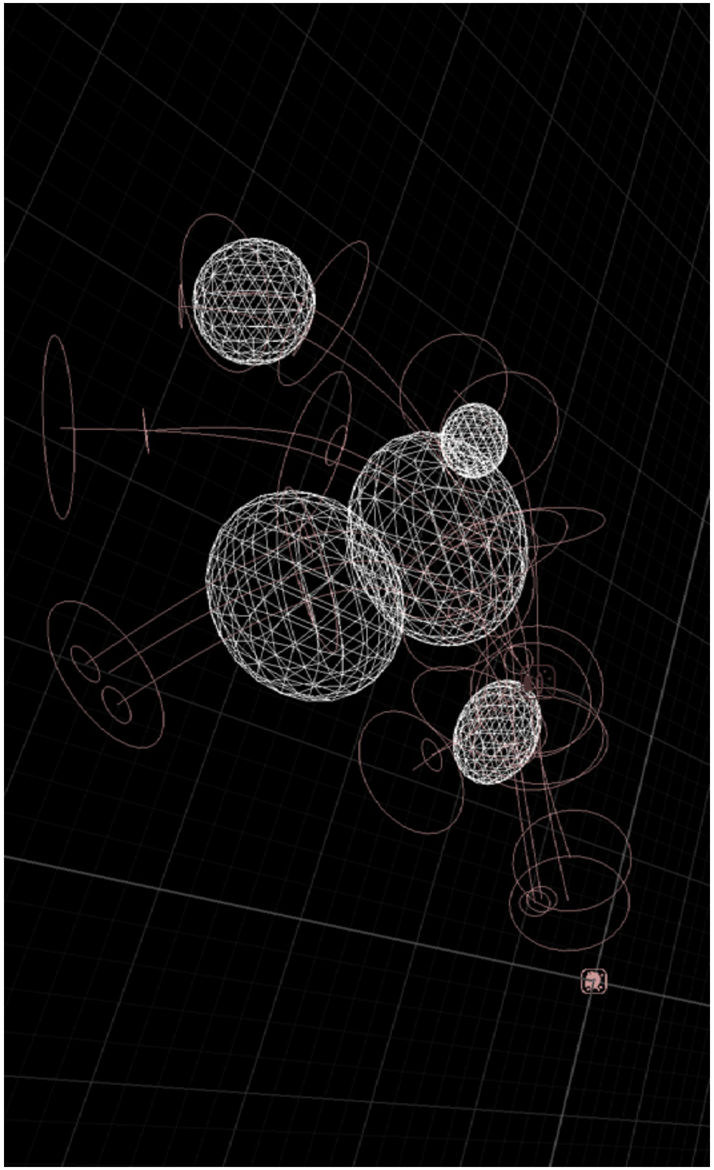
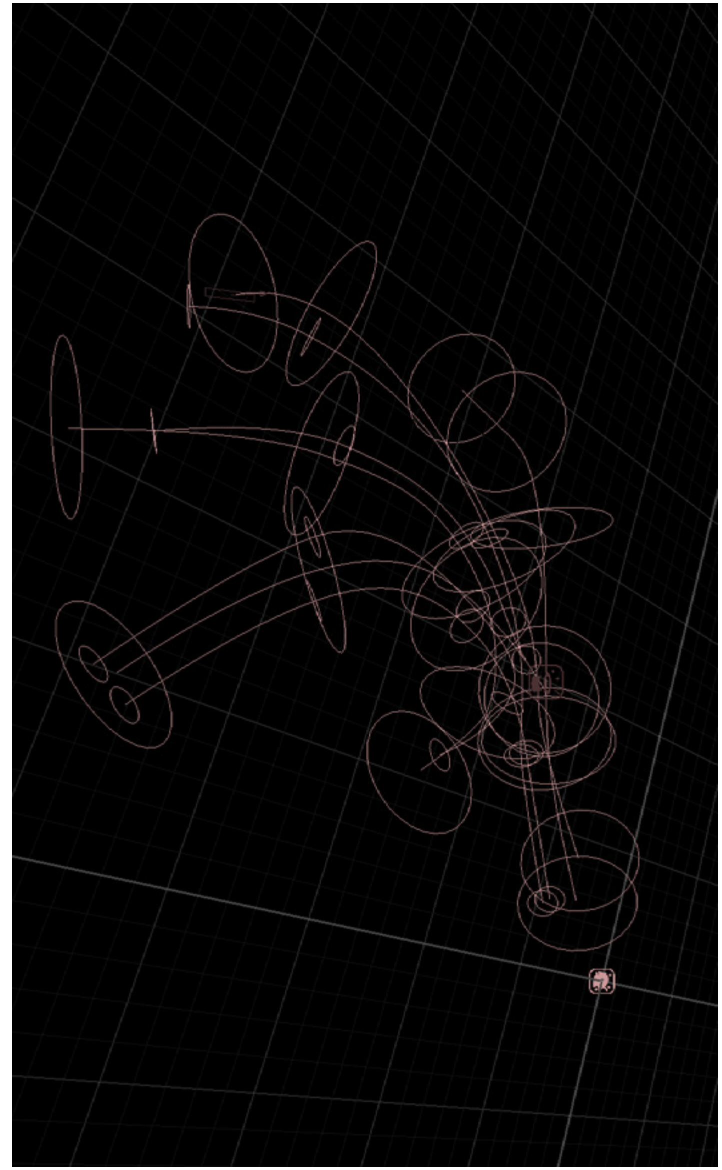


Fig. 11.10 3D SCANNED LANDSCAPE (STAGE 01)



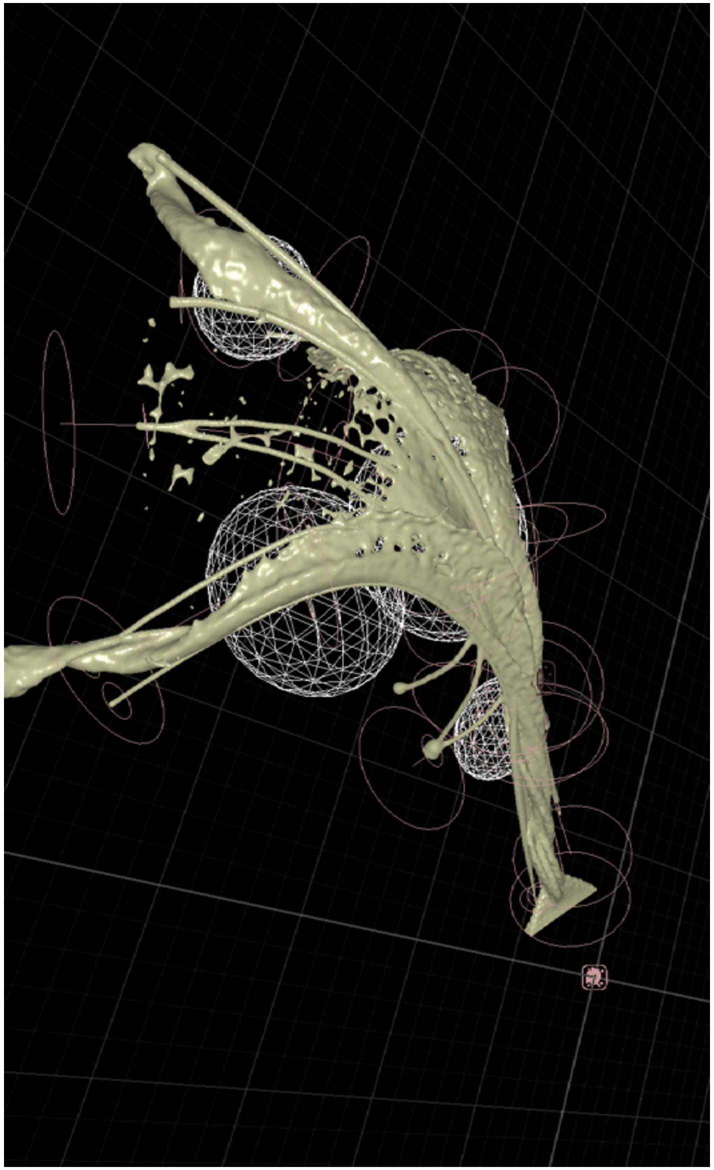


Fig. 11.13 SIMULATION OF DIGITAL SOFT FORMING (STAGE 04)

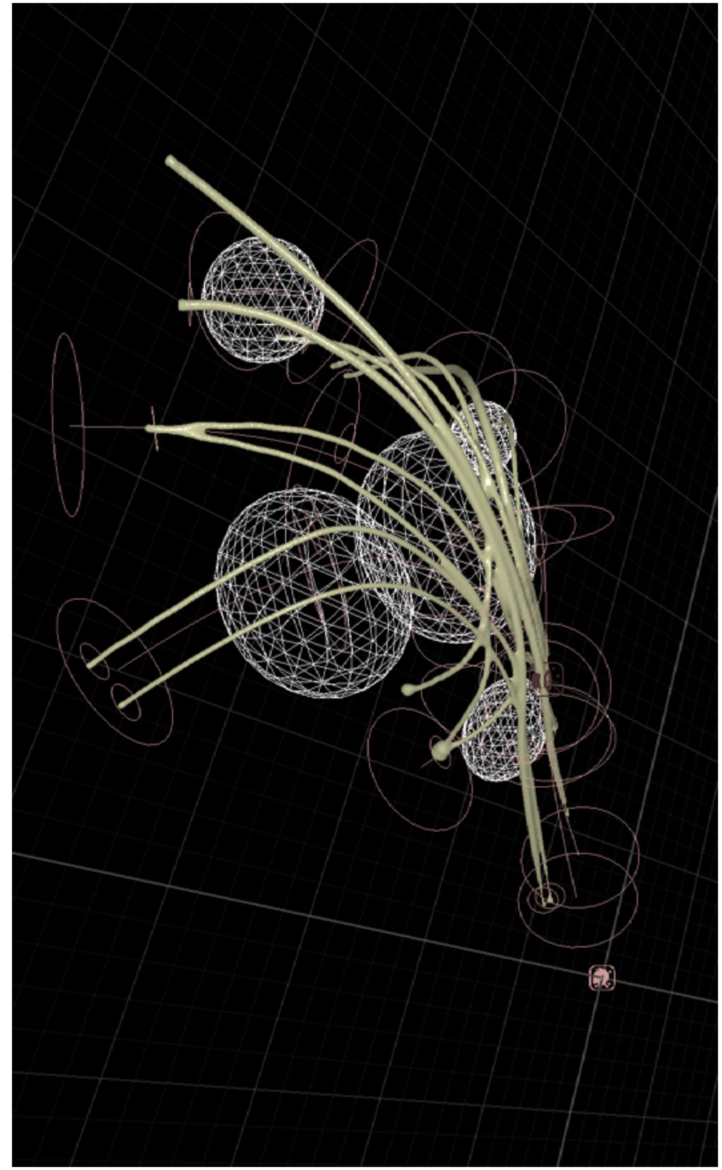
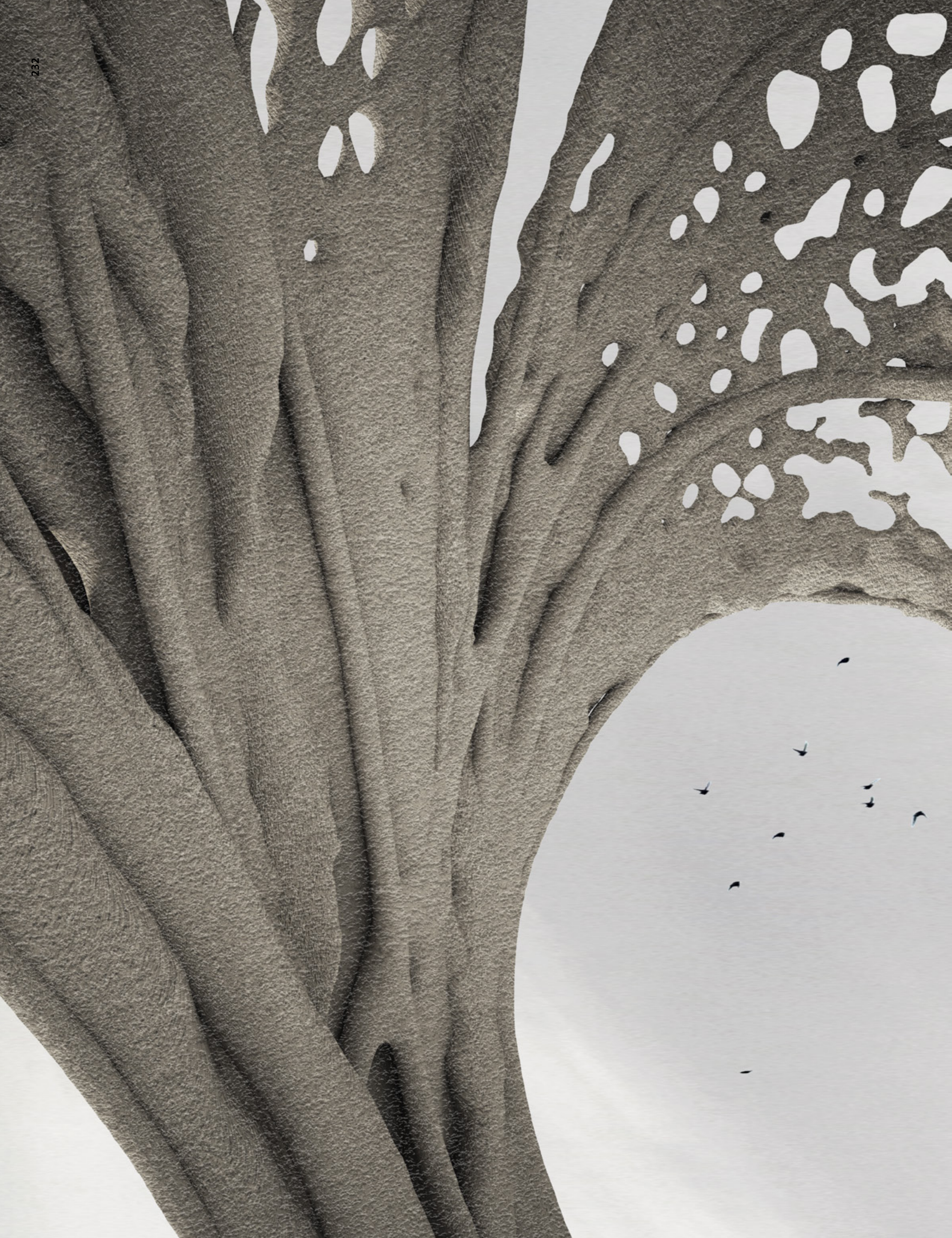


Fig. 11.12 AN APPROXIMATION OF A LANDFORM SUPERIMPOSED ON THE 3D SCANNED TERRAIN (STAGE 03)



11.03
PAVILION

Fabrication:

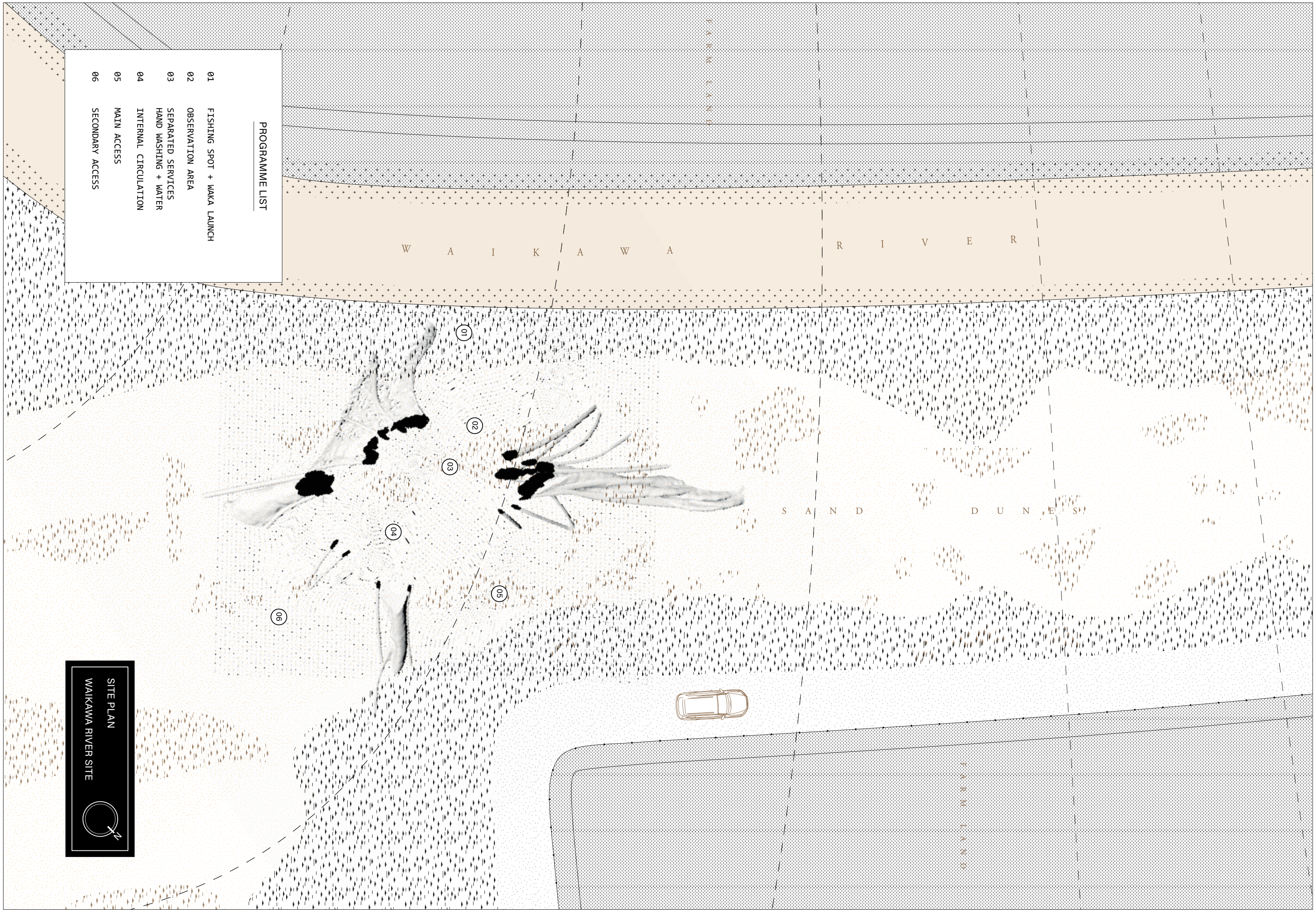
The digitally superimposed dune was used to calculate the volume and shape of sand needed to either pile on the existing dune or to be constructed offsite for prefabrication.

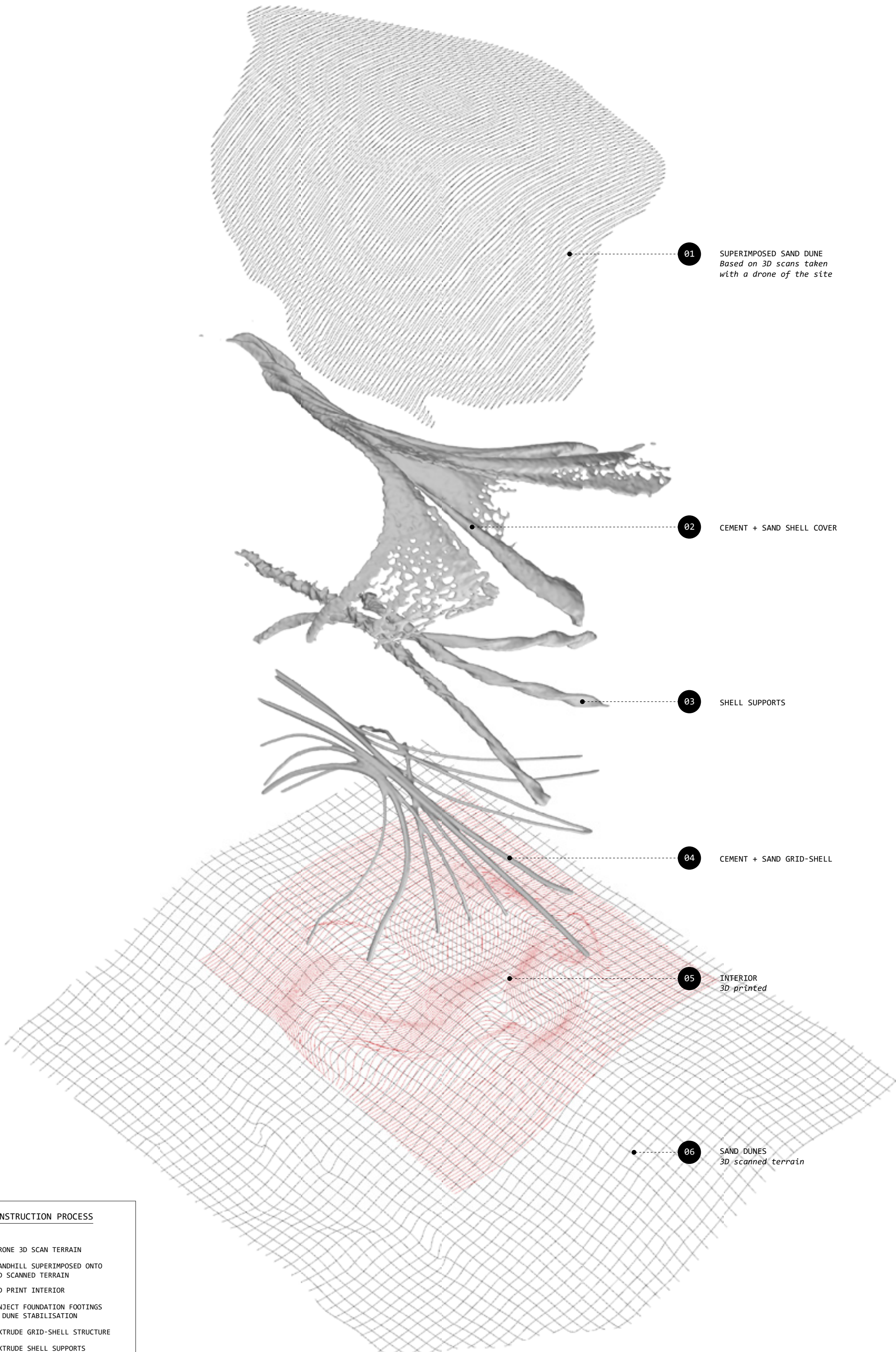
Hard forming was conducted on-site to create an anchor pile foundation to prevent uplifting. The soft forming extrusions attached to the top of the anchor piles forming the lattice or grid-shell pavilion structure. Using soft forming, three larger reinforcing structures were constructed over the grid-shell to support the covering shell. Soft forming was also used above the grid-shell to create a thin, lightweight sand and cement shell structure to shelter the dunes (Fig.11.17).

Fig. 11.14 PAVILION UNDERBELLY 01

Fig. 11.15 PAVILION BECOMING AND EXTENSION OF THE DUNESCAPE
AUTHORS OWN PHOTOGRAPH

Fig. 11.16 PAVILION SITE AND PROGRAMME PLAN





CONSTRUCTION PROCESS

01	DRONE 3D SCAN TERRAIN
02	SANDHILL SUPERIMPOSED ONTO 3D SCANNED TERRAIN
03	3D PRINT INTERIOR
04	INJECT FOUNDATION FOOTINGS + DUNE STABILISATION
05	EXTRUDE GRID-SHELL STRUCTURE
06	EXTRUDE SHELL SUPPORTS
07	LAY COVERING OVER SAND
08	EXCAVATE

Fig. 11.17 CONSTRUCTION PROCESS DIAGRAM (EXPLODED AXO)

Fig. 11.18 THE PAVILION FUNCTIONING AS A FISHING SPOT
AUTHORS OWN PHOTOGRAPH

Fig. 11.19 PAVILION UNDERBELLY 02

11.04

DESIGN CONCLUSION

Extension of the landscape:

Ngāti Tukorehe wanted an impermanent structure that would not interrupt the landscape and allow natural processes to continue as much as possible. This design was intended to be an extension of the dunescape, by not interfering with natural ecologies or waterways and using a majority of materials local to the site. Furthermore, the materials used contribute to the design's obsolescence through natural degradation over time. Tukorehe also required a mobile design that could be fabricated off-site and moved onto the site via helicopter if accessibility were difficult. The use of digital modelling to simulate the landscape combined with the soft forming technique allows for prefabrication in this way, due to the flexibility of both methods.

Locally available resources:

The project builds Ngāti Tukorehe's capacity to adapt proactively and productively to changes within their rohe by returning to and protecting traditional resources such as harakeke, īnanga and tuna. The methods explored also enable construction on sandy coastal ground vulnerable to erosion. Previously, sand dunes have mostly been used as a resource for farmland rather than a resource to construct housing and other structures. Being able to build on sandy ground is therefore important for Tukorehe as they attempt to diversify their economies beyond farming.

Fig. 11.20 PAVILION UNDERBELLY 03

Protection against erosion:

The pavilion design also provides an alternative method to traditional erosion prevention strategies, allowing for multiple uses of the riverbank and coastal sandy areas. The design encourages resilience in coastal Māori communities by identifying culturally informed erosion adaptation strategies. This process could contribute to the resolution of climate-induced problems faced by Aotearoa's Pacific neighbours, resulting from forced lifestyle change due to sea level rise, erosion and extreme weather events.

Overall, the design reflects and incorporates traditional materials and knowledge, without interfering with natural processes or aesthetics. The design aesthetics reflect Ngāti Tukorehe's tikanga of integration with the landscape.

Fig. 12.01 OLD FARMHOUSE
AUTHORS OWN PHOTOGRAPH

12
CONCLUSION


SLOW
70

12.01

CRITICAL REFLECTION

Cultural integration - A Critique and Summary:

Working with Ngāti Tukorehe has been instrumental in the development of an architectural process that contrasts with 'traditional' client and architect models of consultation. Instead, the process attempted to work collaboratively on site with iwi. The collaborative design process leveraged the power of digital design tools with subsequent fabrication, allowing constant feedback to the design from all parties and participants.

As a workflow model, the process attempted to better align with the current and future needs of Tukorehe, especially around iwi environmental aims. A significant part of the process was how ongoing kōrero with iwi representatives provided a feedback system that aided the development of the tool and its application.

While the research gave rise to a good working relationship between researcher and Ngāti Tukorehe, if not for the limitations of time and the logistics of getting to the site, the research might have delved deeper into the cultural design drivers for the project. Therefore, having a stronger relationship with Ngāti Tukorehe would allow for a stronger designer and iwi integration. Before future research with iwi, universities should develop a relationship with the iwi and forewarn each party involved of the research model so that researchers on the project are viewed as co-collaborators rather than experts.

Improved cultural integration would also help to develop a stronger connection to Ngāti Tukorehe's tikanga and mātauranga. Similarly, more kōrero with Tukorehe would improve understanding of the range of possible materials and different ways of using them.

The design of a process when working with iwi is more valuable to the community than the design of a final product. The process is more flexible and can be developed further by testing over a range of applications. Working with an indigenous community is a valuable pursuit for design thinking and the future development of architectural identity in Aotearoa.

Fig. 12.02 RAILWAY BY DUSK
AUTHORS OWN PHOTOGRAPH

Digital Tools: A critical perspective:

The digital modelling in the various software such as Grasshopper and RealFlow was independently well developed, as was the physical testing process of materials from Ngāti Tukorehe's rohe used alongside it. However, the connection between digital tools and indigenous materials might have been stronger. The research primarily focussed on the design process, overall design outputs and material studies as the architectural scope permitted. Since research into both digital tools and indigenous materials is relatively uncharted, further research could expand upon the work of this project. Further research could also engage with the materials science and performance side of the research. Engagement with this side of the research would allow for broader interaction between an understanding of the materials and the digital design.

Additionally, more testing using RealFlow needs to be conducted. Although progress was made with the physical modelling side of soft forming and hard forming, further testing would assist the optimisation and performative understanding of the structures, conceptual translation of the tools and the use of RealFlow as a powerful frontend tool for the generative shaping of the forms' aesthetic qualities.

Fig. 12.03 3D PRINTED COLUMNS (FINAL REVIEW)
AUTHORS OWN PHOTOGRAPH

Fig. 12.04 CORNFLAKES AND RICE BUBBLES (FINAL REVIEW)
AUTHORS OWN PHOTOGRAPH

Fabrication:

As alluded to earlier, advances in digital design and fabrication technology allow for the development of new forms of collaboration and production. These forms include indigenous design, cultural processes and local materials that could contribute to innovation in the building industry. The process generated by this research is an example of a technology and method that could further this growth, and which could be explored in further research. For example, both soft and hard forming methods could be developed to create freeform structures informed by the novel pattern-based symbolism found in Ngāti Tukorehe traditions and their carved and woven histories.

Although the project outputs showed a wide area of materials research and analysis, the shift into 1:1 scale architectural prototypes would have allowed a more in-depth understanding of the material limits to the soft and hard forming techniques. Further research into these techniques should, therefore, include on-site testing at 1:1 scale, using the soft forming and hard forming techniques. The logistics of fabrication would change as a result, and on-site testing would involve the design of a new extruder for the increased volume and pressures of 1:1 scale injection. To maintain accuracy during testing, the integration of Arduino would regulate injection pressure or extrusion rate of the material. Digital control, in this case through Arduino, is crucial because it allows for automation of the fabrication process to create highly precise forms based on the toolpaths produced in the digital model. Robotic control could also dictate the toolpath of the extrusions, which could expand on the design's formal articulation.

Soft Forming over Hard Forming Injection techniques:

Soft forming could be developed in many ways to extend its possible uses. Soft forming is more flexible than comparable techniques due to the control of material composition offered and the mobility in and around the soft form material provided by the additive manufacturing tool. The viability of natural reinforcing systems such as porous pipes made from hemp or hessian could also be explored. These alternative pipes could replace PVC pipes and could then be left in the ground as a sacrificial reinforcing. Using a natural alternative to steel reinforcing could incorporate material obsolescence into the process.

Further soft forming testing could also be explored using multiple, bunched extrusion pipes instead of a single pipe. Bunched pipes would possess enhanced strength and aesthetic qualities over a single extrusion. The materials that were developed should also have additional testing undertaken, such as strength testing, weathering rate, and exploration of extruding and injecting different materials.

The soft forming process could also be developed to achieve a higher resolution of extrusion. These extrusions could be highly optimised for strength or to mitigate coastal erosion. Achieving a higher resolution of extrusion could create high filigree structures similar to the 3D printed columns or intricate biological root systems.

Degrees of Cultural Collaboration:

Overall, the research might have been improved by reducing the research scope to focus on one fabrication driver of the project; in the case of this research, soft forming. Due to its flexibility and ease of use as a method, focusing on soft forming may have allowed more scope for design input from Ngāti Tukorehe. Another aspect of the research that could have been explored further is the use of materiality as a form-finding method in the early stage design for the project. Both these research paths might have led to more diverse meaningful designs, through design iteration and better involvement from either iwi or the primary source of materials – Ngāti Tukorehe whenua.

Fig. 12.05 SUSPENDED 3D PRINT (FINAL REVIEW)
AUTHORS OWN PHOTOGRAPH

Fig. 12.06 ŌTAKI EXHIBITION 01
AUTHORS OWN PHOTOGRAPH

12.02

OTAKI EXHIBITION

Fig. 12.07 ŌTAKI EXHIBITION 02
AUTHORS OWN PHOTOGRAPH

12.03

FINAL REVIEW

Fig. 12.08 **FINAL REVIEW PRESENTATION** (VUW SCHOOL OF ARCHITECTURE 2018)

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SOURCE OF FIGURES

FIG. 01.03 AERIAL MAP (OHAU 2017)
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FIG. 01.11 PHOTO LOCATION MAP (OHAU 2017)
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