

RB |



iN-FLOW.

An inside look into Kumbh-mela's extreme form of temporary urbanism

MSc Architecture, Urbanism & Building Sciences



MMXX |

IN-FLOW

IN-FLOW

An inside look into Kumbh-mela's extreme form of temporary urbanism

Arav Kumar

Graduation Thesis Project | 2019-20

Architectural Engineering | Robotic Building

Mentors

Henriette H. Bier

Ferry Adema

Arwin Hidding





IN-FLOW

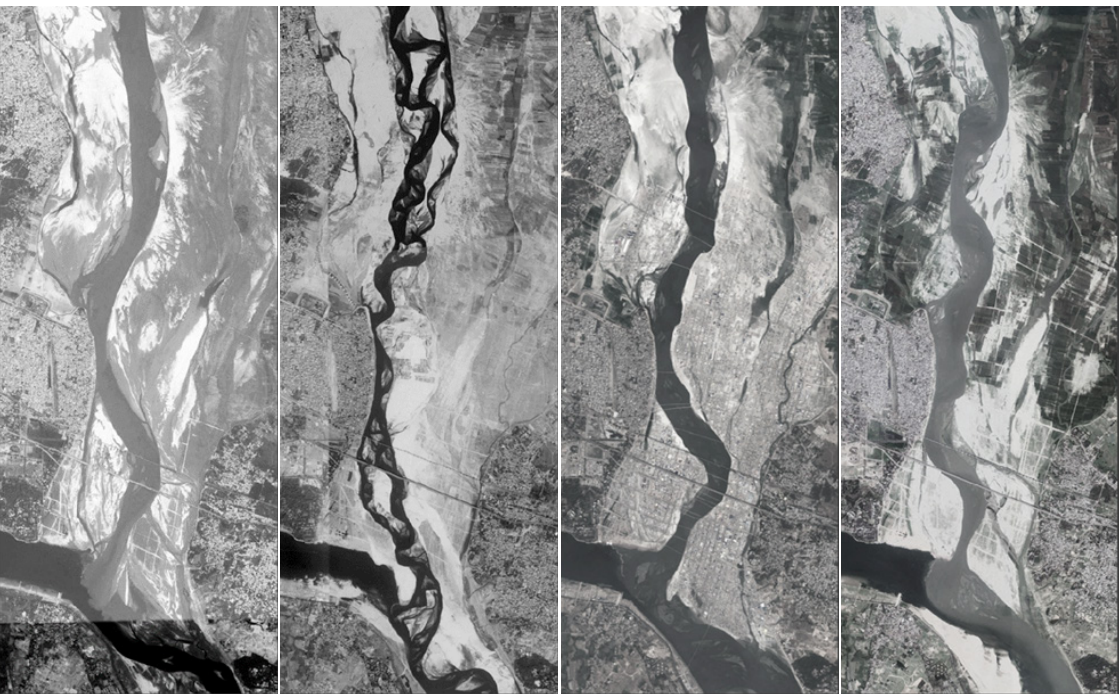
An inside look into Kumbh-mela's extreme form of temporary urbanism

"Pilgrims came by millions! Some arrived on overcrowded trains carrying five times normal capacity. Some came by bus, some by car, some by ox drawn carts and some rode on horses, camels and even elephants. The rich and famous chartered private planes and helicopters; the less affluent came on foot, carrying their bedrolls and camping equipment in heavy bundles on their heads. Wave after wave, the pilgrims formed a veritable river of humanity that flowed onto the banks of the Ganges at Allahabad to celebrate the greatest spiritual festival ever held - the KUMBH MELA."

*-Jack Hebner and David Osborn
Kumbh Mela: The World's Largest Act of Faith*

IN-FLOW deals with a context driven research into the unique ephemeral nature of a temporary pop up city in India. The site is situated in the northern city of Allahabad[now Prayagraj] at the confluence of two river, Ganga and Yamuna respectively. The site facilitates the gathering for religious festival called "The Kumbh Mela". It is the largest public gathering in the world, drawing 150 plus million pilgrims over the course of three months. The site functions on a set of temporal cycles where the site is under water during rainy season, the city materialises during the dry period once the water subsides and after the festival is dismantled the farmers use the same plots for farming. The Thesis deals with a system where the site goes through various differential states and hence leads to flow of architecture and material structure from one state to another. This reversibility could serve as a rich case study to examine the working behind a temporary pop up city.

[In-Flow]- Background Research



[Phase-I]
[July-river]

[Phase-II]
[October-planning]

[Phase-III]
[January-metropolis]

[Phase-IV]
[April-agropolis]

The site lies between two rivers and joins two parts of the city when assembled stretching across 32 sq kms of total site area. The local earth is made up of sand[80%], clay[15%] and silt[5%]. As a design concept it was decided to take this material mix as the primary building material system.

ALLAHABAD

INDIA

25°28'22.9224"N | 81°52'42.0852"E

IN-FLOW

Introduction

The thesis is initiated with a context driven research into the unique ephemeral nature of the temporary pop up city in India. The site is situated in the northern city of Allahbad at the confluence of two river, Ganga and Yamuna respectively. The site facilitates the gathering for religious festival called “The Kumbh Mela”. It is the largest public gathering in the world, drawing 150 plus million pilgrims over the course of three months. The site functions on a set of temporal cycles. The site is under water during the rainy/monsoon season. When the water subsides after the monsoon, the site materializes in the form of the reclaimed river bed. Construction commences on site by December with a complex layer of road/sanitation/services and other infrastructure. The festival is dismantled after three months leaving behind the gridded city remains etched into the banks of the Ganga. Farmers use these residual lines to cultivate wheat and rice. Herds of cows and goats graze while water buffalo plunge into the river.

The ephemeral metropolis is transformed into an agropolis. The Thesis deals with a system where the site goes through various differential states and hence leads to flow of architecture and material structure from one state to another. This reversibility could serve as a rich case study to examine the working behind a temporary pop up city. Understanding the spatial, social, and logistical elements of the Kumbh Mela can lead to understanding and deployment of these systems in a variety of places and situations, in particular camps for refugees of war and natural disasters. The thesis is carried out at the Robotic Studio, with emphasis into the various robotic tools available to form a design intervention which adheres to the social and material culture of the site. The specific research question raised here is: Can Innovative tools (Robotic fabrication) further the craft of local construction principals around the site and can we create a system where in the material lifespan is equal to the site functional lifespan.



An aerial view of the metropolis

IN-FLOW

Mahakumbh

The Kumbh Mela, in India, which results in the biggest ephemeral mega city in the world is an extreme case in this condition and forces us to reflect deeply about the way we think of cities more broadly. For, this example raises a nuanced set of questions about how ‘reversibility’ could be better imagined in the production of future cities. In matter of weeks, the biggest public gathering in the world, the Kumbh-Mela deploys its own roads, pontoon bridges, cotton tents serving as residences and venues for spiritual meetings, and a spectrum of social infrastructure all replicating the functions of an actual city. This pop-up mega city, which arises for a Hindu religious festival at the confluence of the Ganges and Yamuna rivers, held every 12 years, serves 5 to 7 million people who gather for 55 days and an additional flux of 10 to 20 million people who come for 24-hour cycles on the five main bathing dates. Once the festival is over the whole city is disassembled as quick as it was deployed reversing the constructive operation, disaggregating

the city to its basic components and recycling a majority of the material used. One of the most valuable lessons offered by the Kumbh Mela, is in the implementation of tactics that allow the deployment of a whole city as a holding strategy for temporary urban processes, which does not aspire to be permanent. This alignment between the temporary nature of the problem (in this case to house 5 to 7 million people for 55 days) and that of the solution, is something, we could -and should- incorporate as a basic protocol for the cities we reshape and create in the future. The deployment of the city can be then divided in four main stages that affect the nature of its governance. The four phases are first an initial phase of planning, which is held outside the physical space of the Kumbh, and that involves government authorities that range from the local to the national level. This is followed by Implementation that happens both in the peripheries of the site while the river is still high and on site when the river Ganges and Yamuna recede.

Thirdly the process of Management which correspond to the period in which the city is in operation in which besides the challenge of handling the crowds of people the administration has to deal with a river that might fluctuate or shift in its trajectory by thirty feet per day. And finally the deconstruction stage which starts after the last bathing day and is the process that reprograms the space into agricultural fields for a few weeks before the Ganges floods again in the monsoon to reclaim the site of the city. Reversibility is the main attribute that supports the physical deployment of the city. The implementation strategy which is generic, and employs low-tech constructive technics allow to shape the most amazing buildings and morphologies leaving open the possibility of reversing such operations once the festival is finished. Thus allowing the materials to be reincorporated into regional economies and local industries. What is most remarkable about the Kumbh is not that it is constructed in such a short period of time but also that it has the ability to get disassembled as quickly. Multiple highly heterogeneous structures are organized around combinatory system that relies on minimal building strategies.

The construction techniques used also allow greater degrees of flexibility. The generic condition of basic element like sticks connected by rope or simple nails in both orthogonal and diagonal relationships offer infinite possibilities of recombination. The strength is in the capacity of achieving specific and determinate forms with a couple of indeterminate solutions applicable in different contexts and that are re-adjustable at any moment. On account of this 'a kit of parts' approach, the material used for erecting tents, gathering spaces and even monuments that are several meters high can be afterwards reused in other constructions. Each of the few building techniques implemented at the Kumbh are based in the repetition and recombination of a basic module with simple inter-connections. This is usually a stick (approximately 6 to 8 feet long) that by aggregation generates diverse enclosures in a wide range of forms from small tents into complex building paraphernalia that give expression to diverse social institutions such as theaters, monuments, temples, hospitals etc. All of them are constructed out of the same elements, bamboo sticks, corrugated metal, fabric & plastic.

Material components are small and light enough to be easily transported and distributed to every corner of the settlement in a rapid and efficient manner facilitating both, construction and reconstruction as well as formation and re-absorption into the various ecologies and geographies of the region. Everything is constructed, and afterwards de-constructed with equal ease.

This reversible condition becomes counterpoint to our contemporary building culture. The one aspect that has been notoriously absent from the contemporary debate is the after-life of the things we build once they are not useful anymore. The Kumbh Mela, uses materials whose life span extends that of the functional lifespan of the city and hence this part needs to be seen as to how we can use a local material system whose life span can be equal to the functional lifespan of the programme. Looking at these dimensions of the Kumbh and thinking about how we can learn from this occurrence, one could suggest that it is time for urbanism and design more generally to find new ways for effectively factoring in reversibility as a critical component of its institutional and technological repertoire.

“Pilgrims came by millions! Some arrived on overcrowded trains carrying five times normal capacity. Some came by bus, some by car, some by ox drawn carts and some rode on horses, camels and even elephants. The rich and famous chartered private planes and helicopters; the less affluent came on foot, carrying their bedrolls and camping equipment in heavy bundles on their heads. Wave after wave, the pilgrims formed a veritable river of humanity that flowed onto the banks of the Ganges at Allahabad to celebrate the greatest spiritual festival ever held - the KUMBH MELA.”

*Jack Hebner and David Osborn
Kumbh Mela: The World's Largest Act of
Faith*



[In-Flow]- Background Research | Reversibility

MAHAKUMBH

Theology & History

Like many pilgrimage events in India, the Kumbh Mela is anchored in Hindu mythology. It is widely believed that at four sacred sites—Haridwar, Allahabad, Ujjain, and Nashik — amrit or the nectar of immortality, fell from a pot (Kumbh) carried by the goddess Mohini as she whisked it away heavenwards, out of the grasp of the covetous demons who had tried to claim it. Her fight, and the following pursuit, is said to have lasted twelve divine days, which is the equivalent of twelve human years; therefore, the Mela is celebrated every twelve years, staggered at each of the four sites in this cycle. The Mela is one of the four fairs traditionally recognized as Kumbh Melas. An annual fair, known as Magh Mela, has been held at Prayag Triveni sangam since ancient times. Every 12 years, the Magh Mela turns into a Kumbh Mela, and six years after a Kumbh Mela, it is an Ardh Kumbh (“Half Kumbh”) Mela. The Kumbh has been celebrated continuously since the Gupta period [4th to 6th centuries CE].

The first description of the event was recorded sometime between 629 and 645 by the Chinese Buddhist monk Hsuan Tsang, who had travelled to India in search of Buddhist sacred texts. Since the mid-nineteenth century, the festival has exploded in size and scope. It has been celebrated for its mass appeal, but some have questioned whether it exacerbates tensions between classes and competition between religious orders, and whether it is even possible to maintain crowd control, recalling the deadly stampede in “1954 in which hundreds lost their lives. The Maha Kumbh Mela, held in 2001 & 2013 in Allahabad, attracted between 60 and 70 million & 150 million people respectively over the course of the weeks, and has been noted as the largest public gathering and collective act of faith anywhere on the planet. On the most auspicious bathing days, the crowd was large enough to be visible from a space satellite.



Kumbh Mela by the English painter J. M. W. Turner. Steel engraving, 1850s.

SITE-ANALYSIS

Morphological Study

Allahabad is situated in the fork of the confluence between the Ganga and Yamuna. The river front and bathing access is central to the Mela structure in these cities. The transport infrastructure of roads, trains, and highways is critical to the smooth functioning of the Mela, and these great pilgrimage fairs provide the occasion for a concerted effort to improve the transportation infrastructure. The urban layout of the city also includes the space for the large temporary encampments that are essential for the Mela. The city, therefore, interacts with an unpopulated terrain nearby, used alternately for agriculture and as a site for the temporary city during the Mela. This is fertile and useful land, able to sustain the density and dynamism of the temporary city as well as the long stretches of relatively quiet agriculture landscapes in between. In the Kumbh Mela site a grid structure is visible throughout the seasons. During the festival it determines basic paths of movement and zones in the temporary city; at other times, it structures the

farmland so that various crops may grow at different times of the year. The grid fulfils a dual role on the site, a simple and sustainable method of organizing land use on a fairly expansive site.

The site is the holiest of the four Kumbh Mela sites, because it is believed that a third invisible river, the mythical Saraswati, also joins the two sacred rivers here. The confluence of three rivers, or triveni, holds a special place in the Hindu imagination. Allahabad thus draws the largest gatherings of all the Melas, and with each passing festival, reinforces its image as the center of Hindu spirituality. The area of Allahabad used for the Kumbh is highlighted here in white. It is adjacent to the main city, occupying the ground where the rivers converge.



Site demarcation - The 2019 kumbh mela was allotted 32sqkm's of land.



[In-Flow]- Site Analysis



01 | *Site conditions during rainy season. The site is almost covered with water.*



[In-Flow]- Site Analysis



02 | *After the water recedes post rain, Construction starts on site.*



[In-Flow]- Site Analysis



03 | *The temporal city pops up around January.*



[In-Flow]- Site Analysis



04 | After the city is dismantled the farmers use the residual grid lines of the city to cultivate wheat and rice.



[In-Flow]- Site Analysis



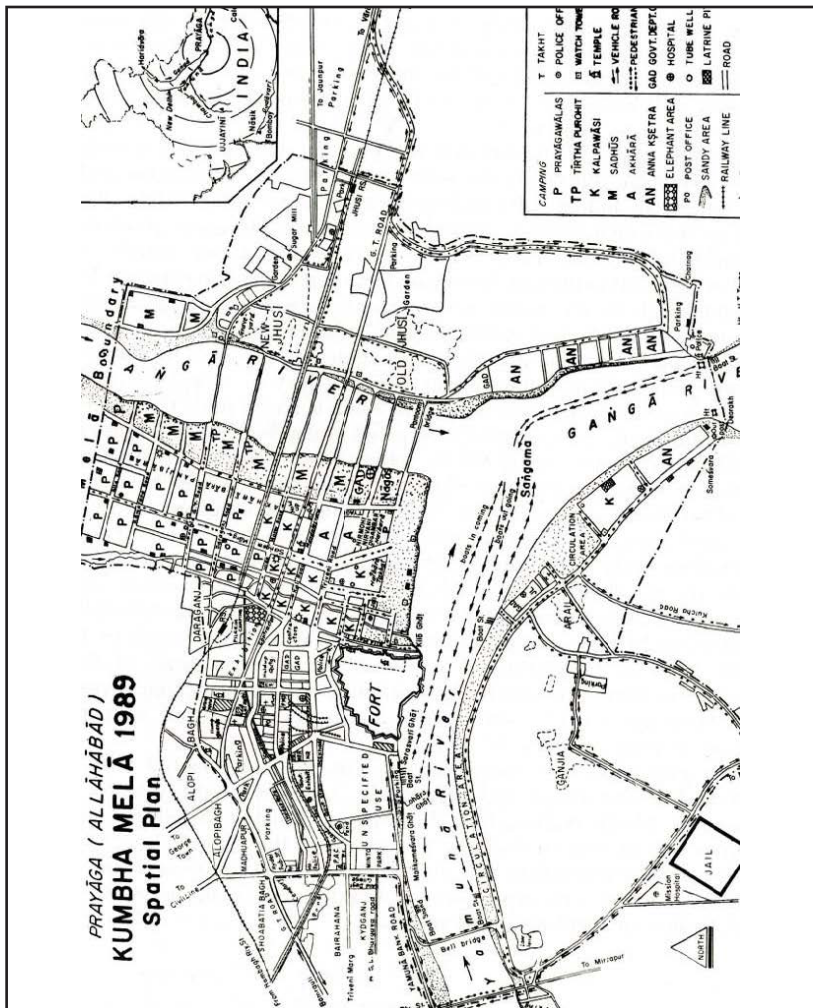
This process occurs every year: transitioning from a pastoral landscape to a densely populated tent city to islands of wheat and rice paddies to a monsoonal deluge of silt.

SITE-ANALYSIS

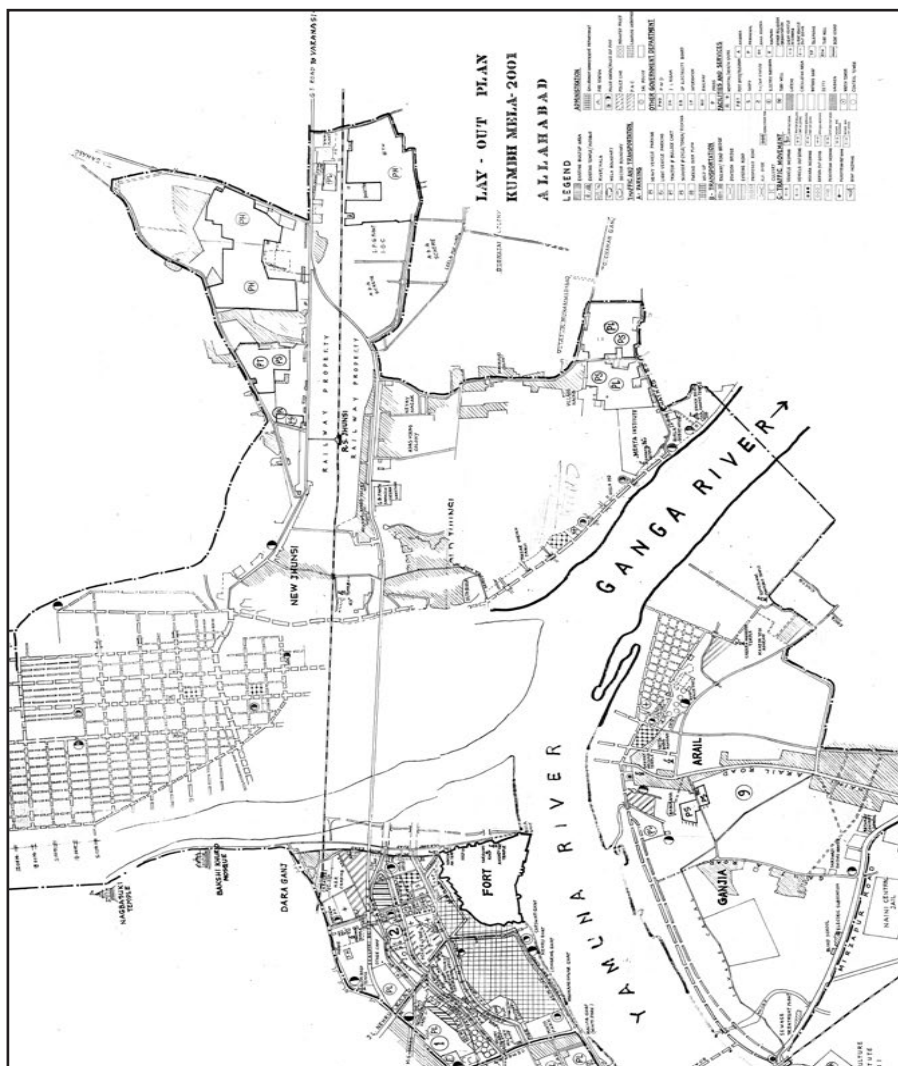
Planning

The form of urbanism that emerges after the construction and occupancy of the Kumbh Mela, provides: ephemerality, cacophony, multiplicity and simultaneity. The Kumbh Mela offers a flexible model for spatial construction that is temporal, cyclic, in constant advancement, and ready to spring into motion as the environment changes, making way for the needs of pilgrims seeking to connect with a dynamic geography. As we have seen, the Kumbh's design anticipates elasticity, building robustness through the capacity to articulate competing indices of population, velocity, and concentrations. It does so without even having to erase or restrict the spatial manifestations of the religious practice around which it is constructed. The city is designed to frame the human experience, thus, its religious component is always at the core of its form. This forms central to the design principles along with important urban issues like accessibility, infrastructure, public and private functions etc. which poses certain important questions.

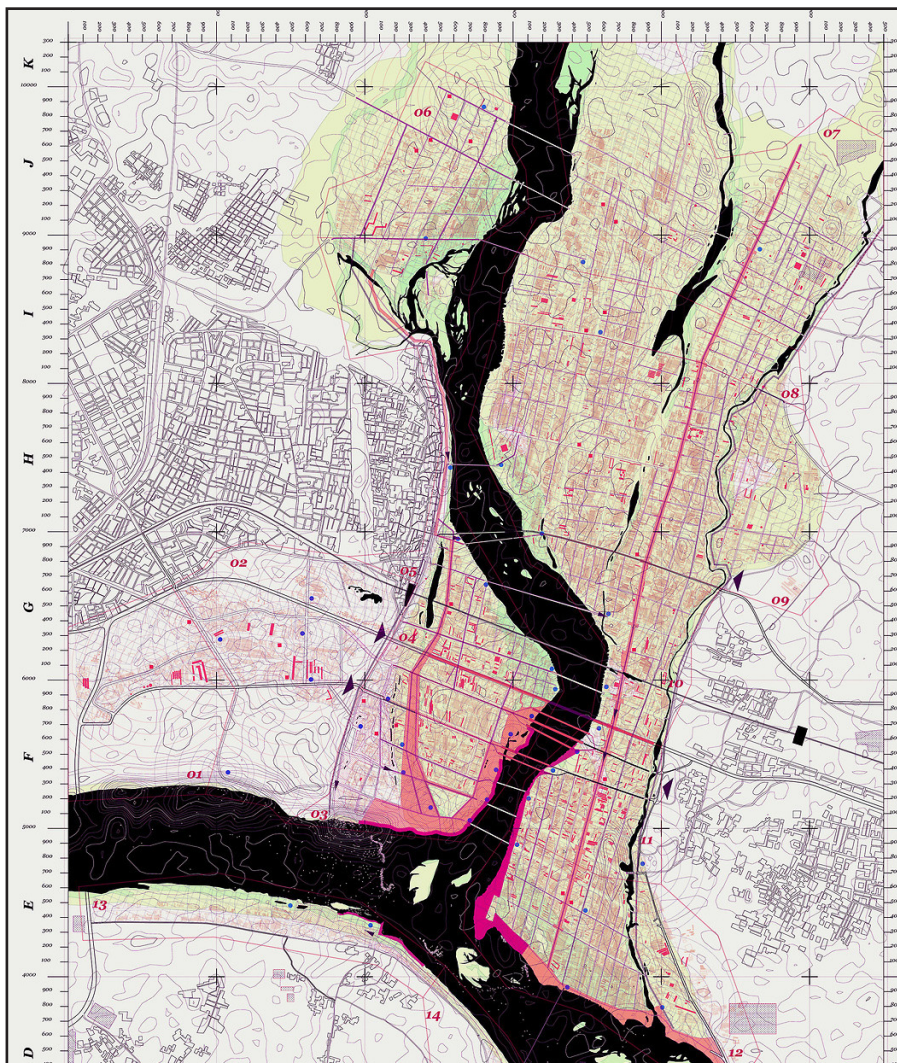
How can we visually and spatially document temporary urbanism? What is the relationship between the physical structure of the temporary city and the temporal events that occur there? How is land allocated? How does temporal or temporary urbanism challenge large and permanent, but often brittle, urban form? How can the spatial systems that emerge from this study inform natural and political emergency situations (i.e., refugee camps)? What are the physical boundaries of the festival, and do they change from festival to festival? How is the city zoned between public and 'private' (residential) spaces? How are the collective systems—tent construction, electricity, water, sewage management, internet, cell phone towers, public rest-rooms, food distribution, medical care, and crowd control, to name a few—spatially constructed and deconstructed? What are the timetables and route maps of public transport in the surrounding city, and to what extent do they change for the festival? What is the land use data



Understanding spatial structure of the temporal city- Kumbh Mela | 1989



Understanding spatial structure of the temporal city- Kumbh Mela | 2001



Understanding spatial structure of the temporal city- Kumbh Mela | 2013



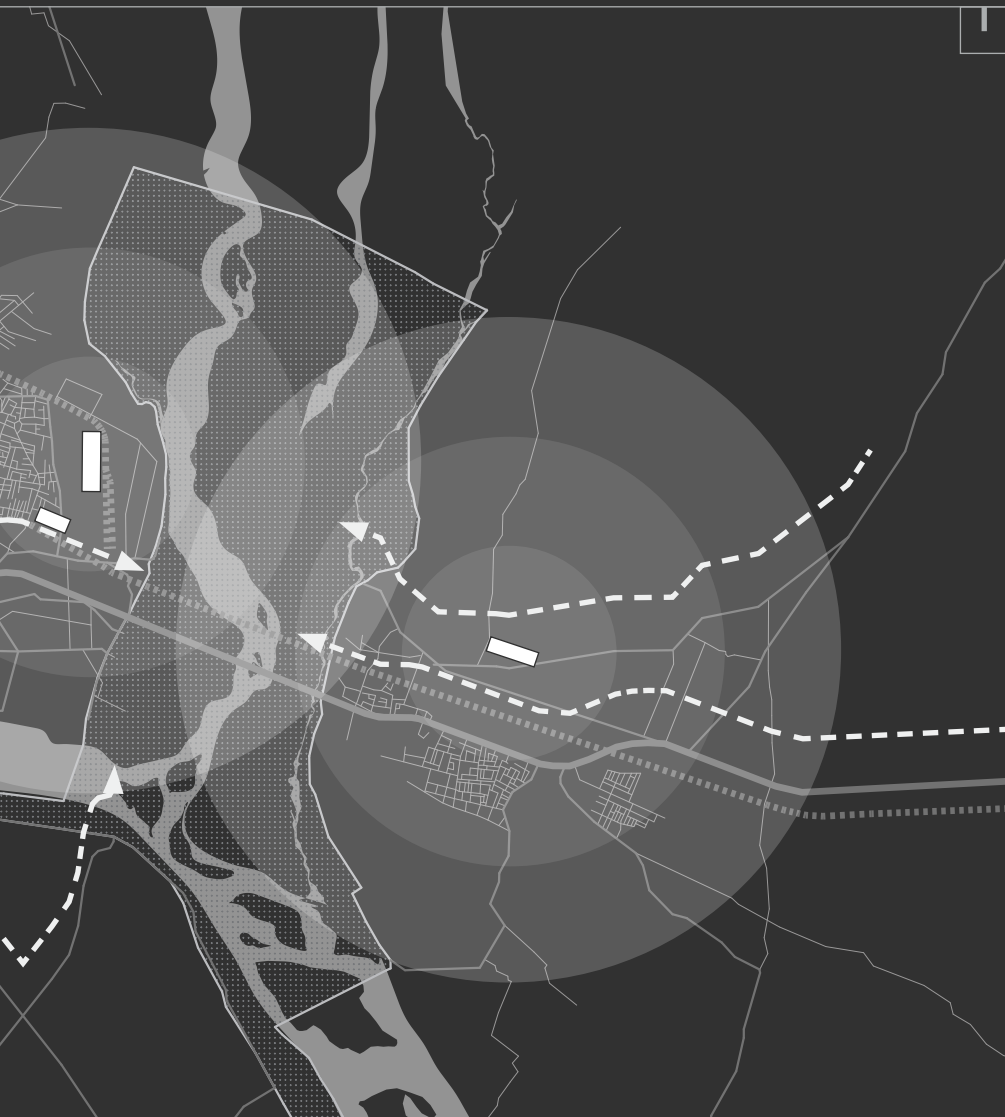
[In-Flow]- Site Analysis



Understanding spatial structure of the temporal city- Kumbh Mela | 2019



[In-Flow]- Site Analysis - Accessibility



People arrive into the site mostly via public infrastructure like rail and bus services. The stations walking radius demarcate the proximity to the site.



[In-Flow]- Site Analysis - Fragmentation



*The site is fragmented into different sectors as seen above in the planning of
Kumbh Mela 2019.*

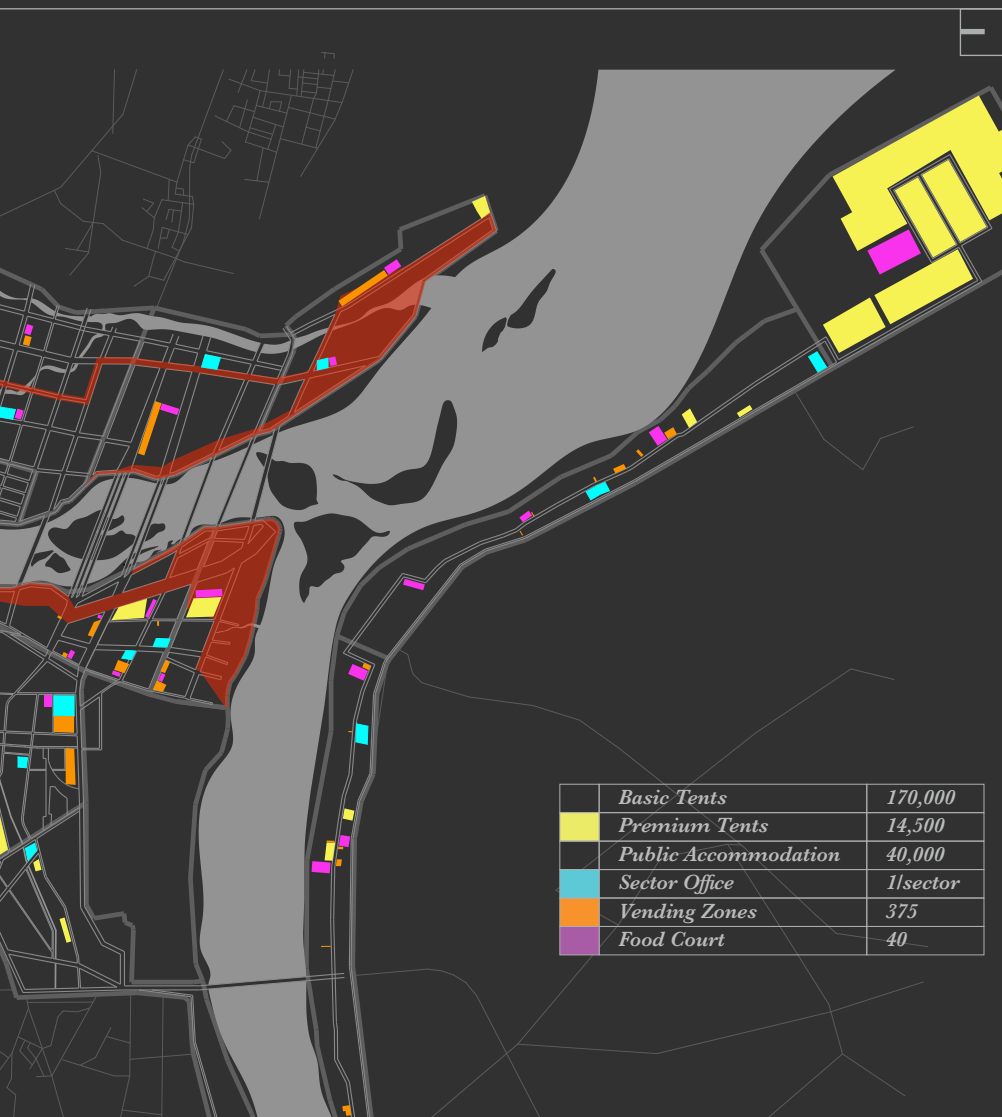


[In-Flow]- Site Analysis - Infrastructure



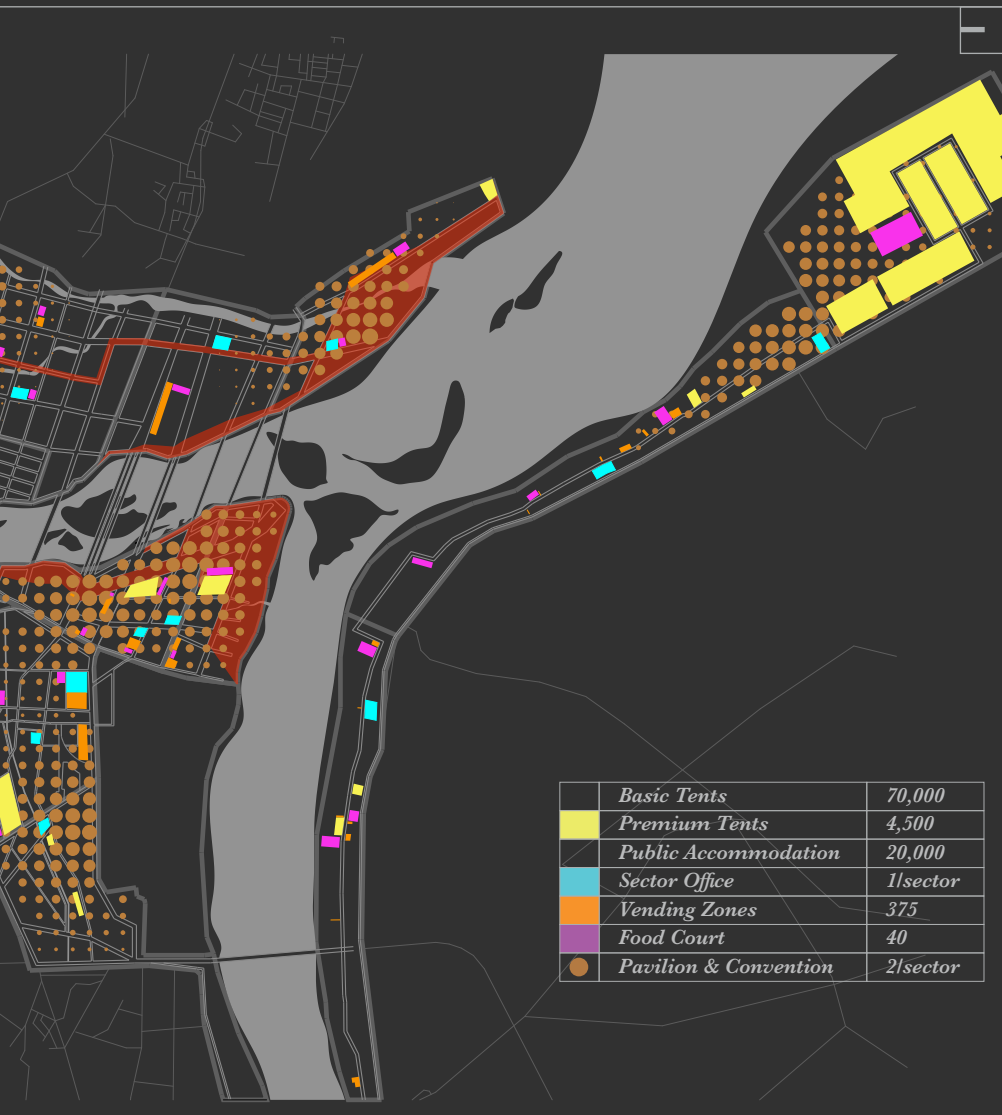
The site has main procession roads bisecting the site carrying large amount of devotees from each sector to the river edge which is the holy epicenter of the site. These primary roads vary from 25-40m while secondary and primary roads are 10-15m and 4-8m respectively.





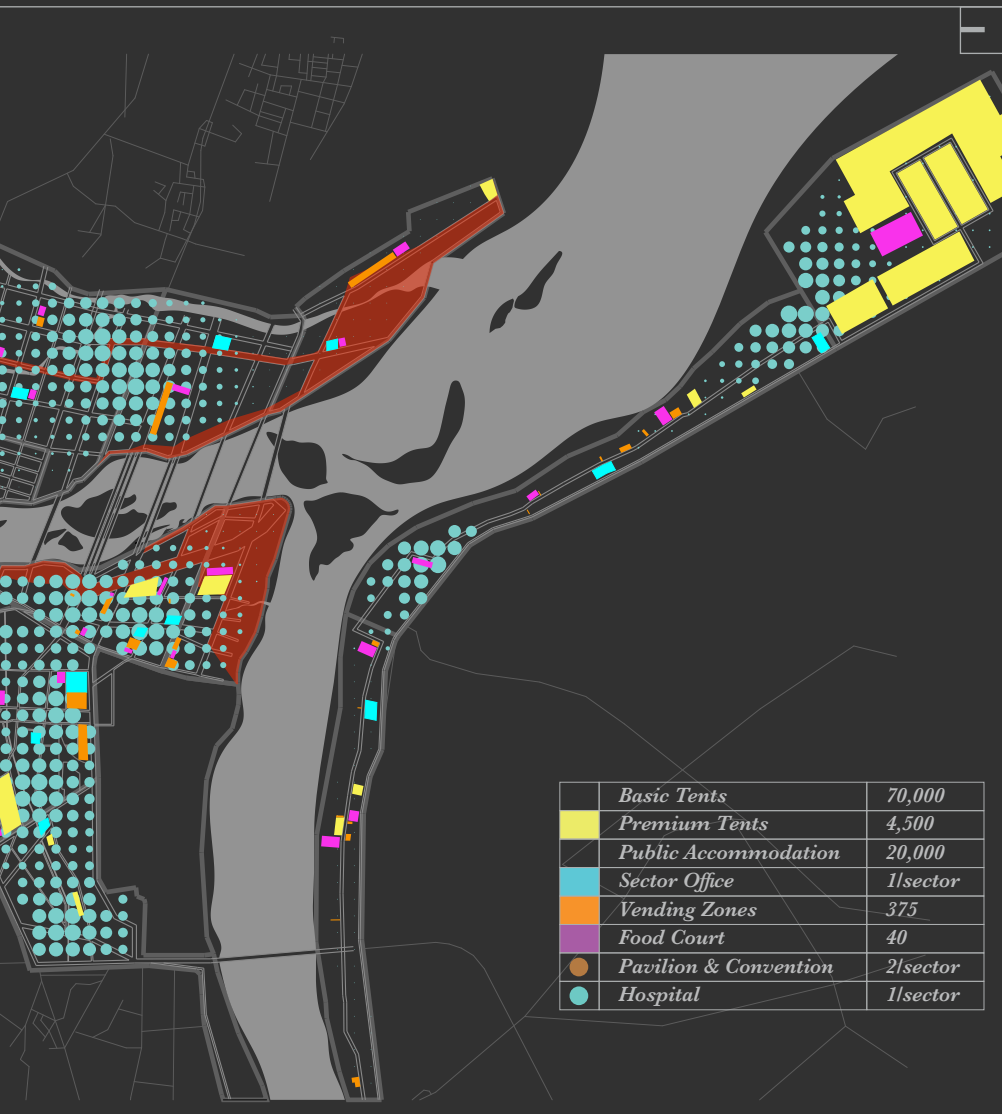
[In-Flow]- Site Analysis - Public and private Functions





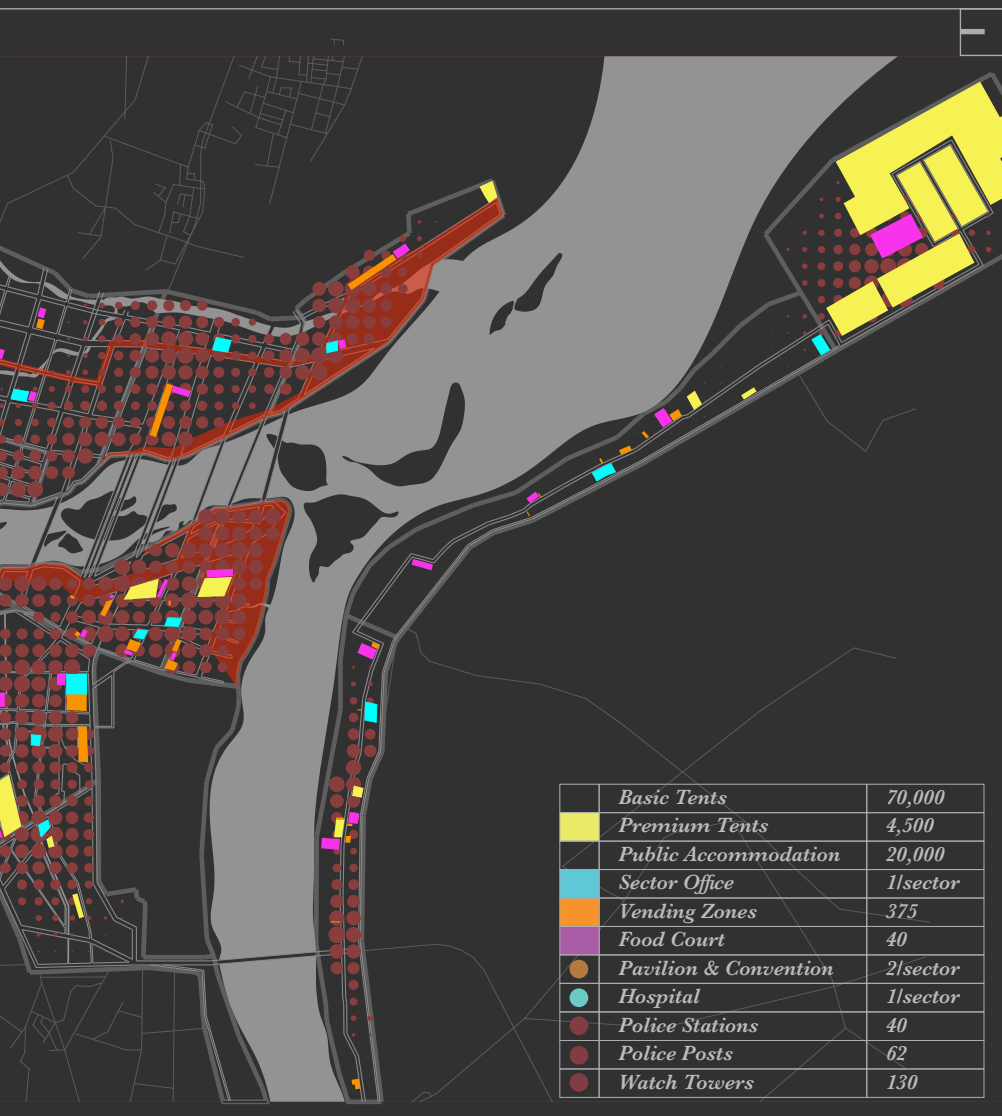
[In-Flow]- Site Analysis - Public and private Functions





[In-Flow]- Site Analysis - Public and private Functions





[In-Flow]- Site Analysis - Public and private Functions

[Infrastructure]

Roads Developed	141 Km
Pontoon Bridges	22
Parking Lots	94
Bathing Strip	8 Km
Water Pipeline	57 Km

[Hospital]

Hospital I	1 - 100 beds
Hospital II	10 - 30 beds

[Security]

Watch Towers	135
Police Stations	40
Police Posts	62
Holding Areas	85

[Commercial]

Shops	375
Food Court	40 stalls
Pavilion I	10,000 pax
Convention Halls	4
Pavilion II	2,000

[Sanitation]

Toilets	150,000
Waste	40 compactors 120 tippers

[Dwellings]

Basic Tents	700,000
Premium Tents	4,200
Public Accommodation	20,000

Site Area-Kumbh Mela,2019
3,200 Hectare| 20 Sectors
Expected Footfall: 120-140M

Final areas and requirements



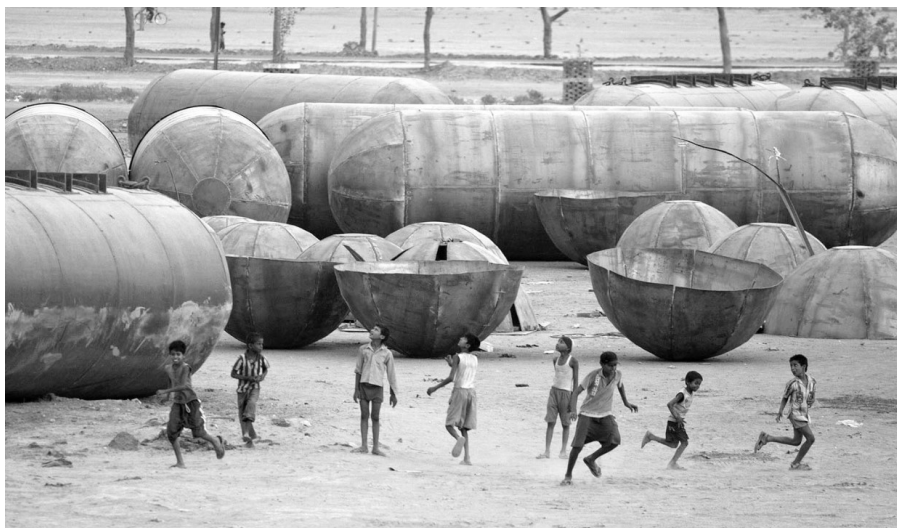
The following images shows a pictorial journey through the functional and infrastructure requirements.



[In-Flow]- Site Analysis - Construction Process



The site is cut and filled to mold the city grid.



[In-Flow]- Site Analysis - Construction Process



The bridges are constructed off-site, transported to site and then manually put into position in the water.



[In-Flow]- Site Analysis - Construction Process



Once in position, steel girders are laid on top to anchor each pontoon together.



[In-Flow]- Site Analysis - Construction Process



Wooden planks are then laid and fastened to the girders.



[In-Flow]- Site Analysis - Construction Process



Around 200km of steel plate roads are laid over the entire site.



[In-Flow]- Site Analysis - site functions



*Pictorial view of Public and private functions strewn across various sectors
around the site*



Dwelling Tents



Public Structures



Public Toilets



Public Toilets



Drinking water



Washing areas for clothes and utensils



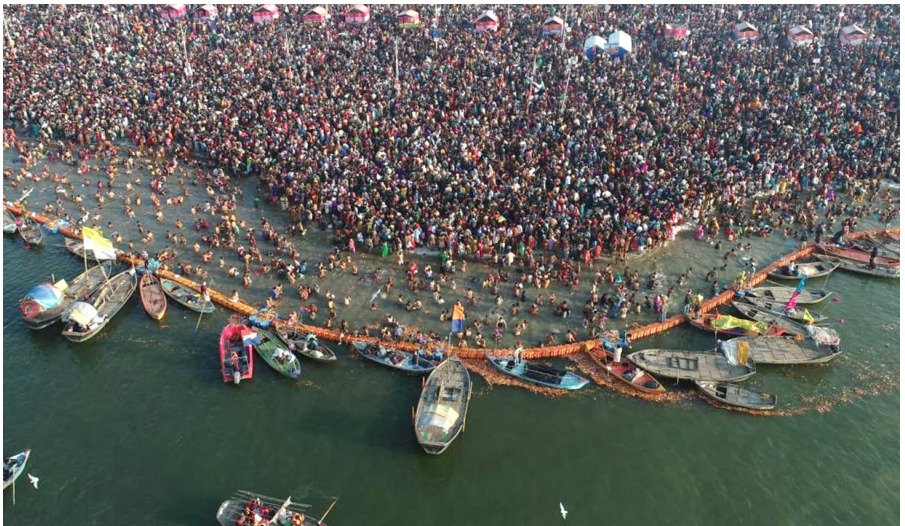
[In-Flow]- Site Analysis - Ethnographic Study



The following images depict the everyday life at the Kumbh. Before designing its important to understand how people are living inside this megapolis in order to pin point the shortcomings of the system.



The most important part of the site is the river which is considered holy in the Hindu religion. Massive crowd throng the river edge to take a dip in it



At an average one million permanent people are living in this megapolis. On its busiest days it caters to about 30 million people and in its entirety the mela hosts upwards of 150 million people.



*With huge number of people accessing the site there is a need
for proper crowd movement analysis*



First observation seems that the grid planning is hindering the movement of masses, often creating sudden angular shifts leading to stampedes.



Each sector is divided into multiple blocks which has communities. The communities have dwelling areas, temple and sanitation services.



sanitation

The sanitation area is highlighted in yellow.



The first observation on the dwelling area is that a lot of activities like cooking, socializing & cleaning spill over outside on the tertiary road.



The dwellings are also closely packed together having almost no buffer in between.



The washing areas are sometimes quite close to the dwelling areas and create sanitation problems.



The view above shows the difference in the living area between normal standard tents and luxury tents.



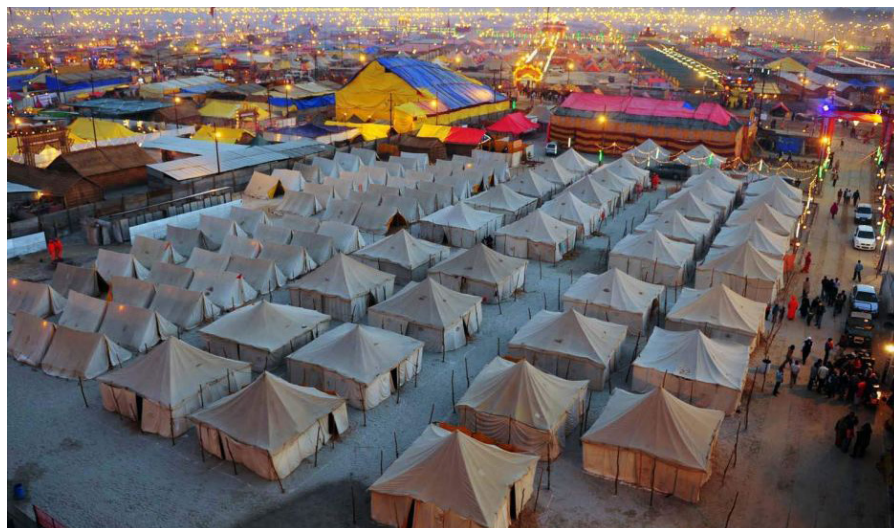
[In-Flow]- Site Analysis - Ethnographic Study



Some more examples of disparity between different types of tents



The above two images depict standard and makeshift tents in the top and bottom picture respectively. The adjacent images depict the public accommodation which can be booked.



Some more examples of disparity between different types of tents



The tents have no buffer between them and this is a hindrance in disaster cases like fire or stampede.



The primary material used in the tents are flammable plastics and fabrics.



[In-Flow]- Site Analysis - Ethnographic Study



The site lacks proper urban spaces like meeting areas or cleaning and cooking areas



[In-Flow]- Site Analysis - Ethnographic Study



Daily chores like cooking and washing don't have a proper designated area.





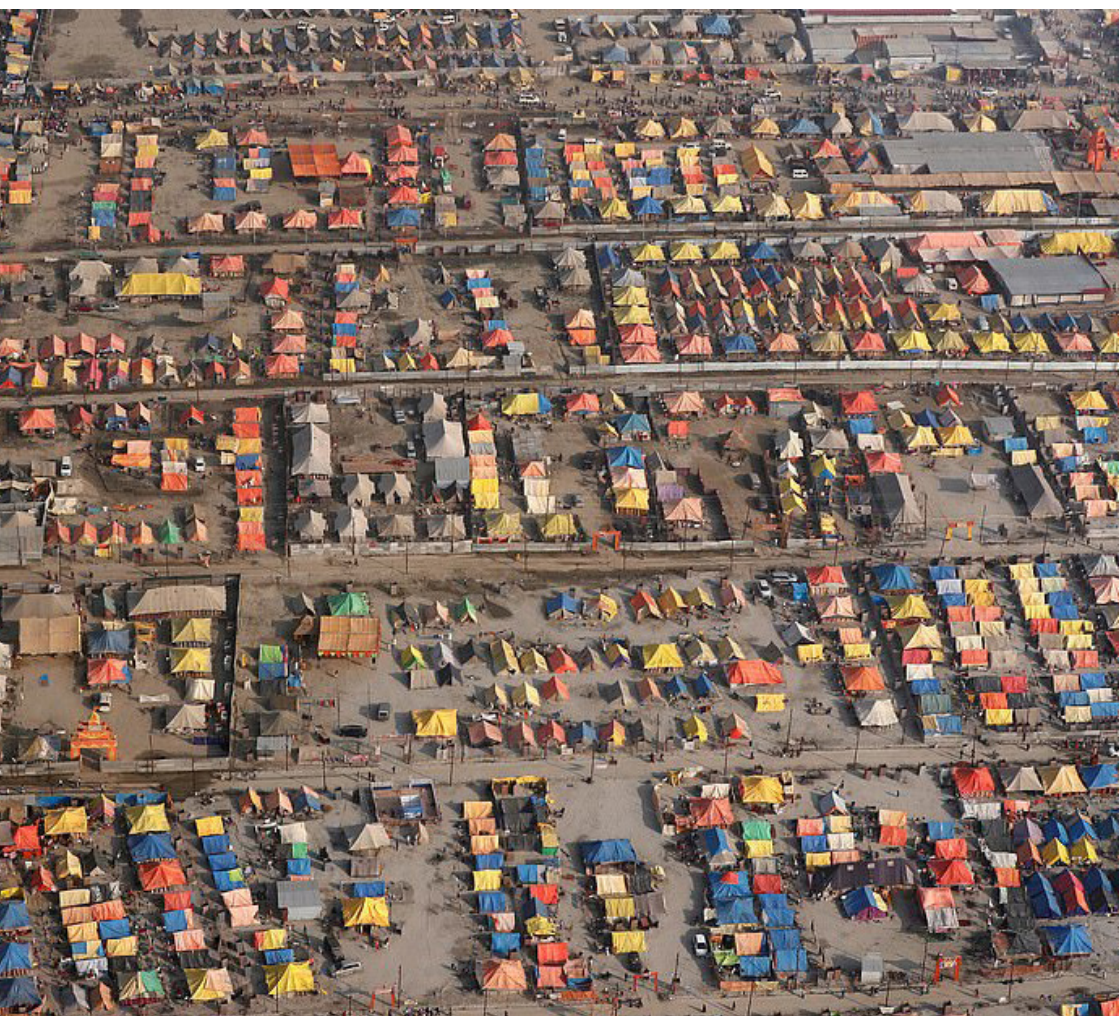
IN-FLOW

Case - Study

Temporary architecture as a typology is a concept that must be used for specific purposes and for a particular type of program. Projects that successfully function as temporary structures must be easily constructed and deconstructed in order to make the argument for an impermanent intervention on the site. The idea of temporary architecture has been in practice since the beginning of man's most basic dwelling. It can be used to accommodate an alternative lifestyle, free from the restriction of remaining on a single site for a long period of time. The practical applications of a temporary architecture include programs that go through cyclical uses or require the implementation of activity in multiple locations. Contemporary applications of programs like this are becoming more and more common in urban settings. Temporary architecture is implemented on large scales at reoccurring gatherings of people. Research on these sites could be helpful to understand the mechanism behind a temporary megapolis.

Examples of temporary urban environments are seen all over the world, in a range of contexts. The successes and shortcomings of these designs are based on functionality & the social structure during an event and after the gathering has concluded.

For case study purpose it was decided to look into the planning and material use of some variable temporary cities like festivals, religious sites & refugee cities. The results were beneficial to understand the minimum requirements for designing the city. Detailed case study was also done to understand the social structure of people visiting the kumbh and relations within persons of concern, including clan, tribes and extended family arrangements, as well as their traditional settlement layouts and shelter preferences. This consideration will yield a greater degree of satisfaction, and sense of ownership.



Understanding the material and social culture of similar temporal cities.



Burning Man Festival



Refugee camps in Syria & Somalia



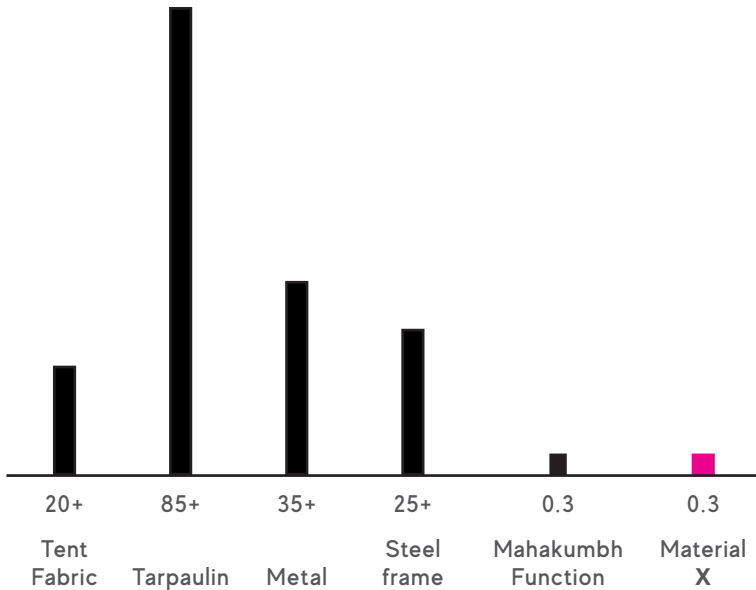
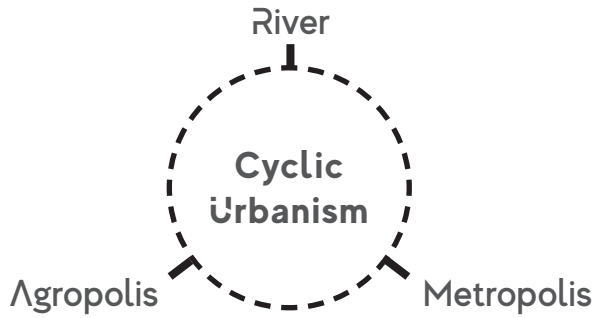
The one common factor amongst all these examples were the tent types and materials used in the structures irrespective of location, social structure and geographical location.



The above example is that of Sahrawi refugee camps where a positive intent is shown to use local materials which is good for the local climate and adheres to the social culture of the context.



The Kumbh also has similar spaces and materials whereas the utilization by people are completely different.



The material used in Kumbh has high embodied energy and has a lifespan which far extends the lifespan of the Religious function itself. As a concept it was decided to use a local material whose lifespan equals the functional lifespan of the site.



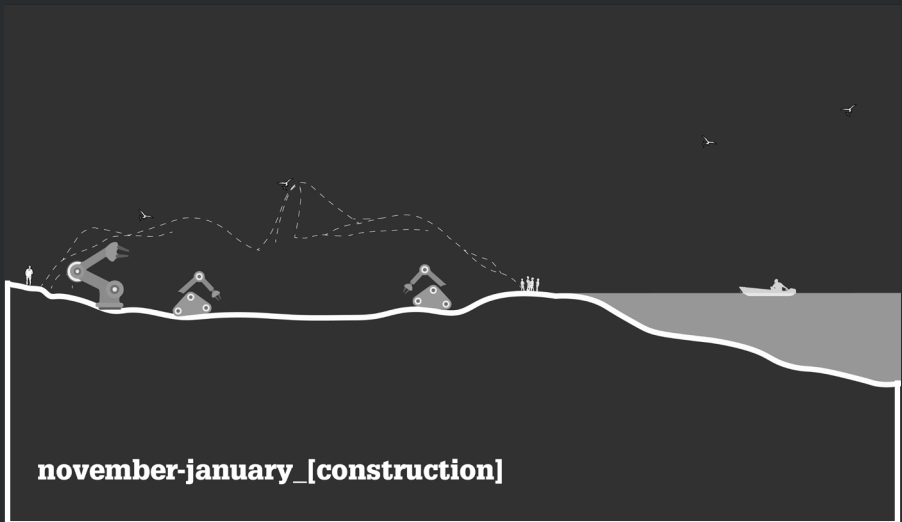
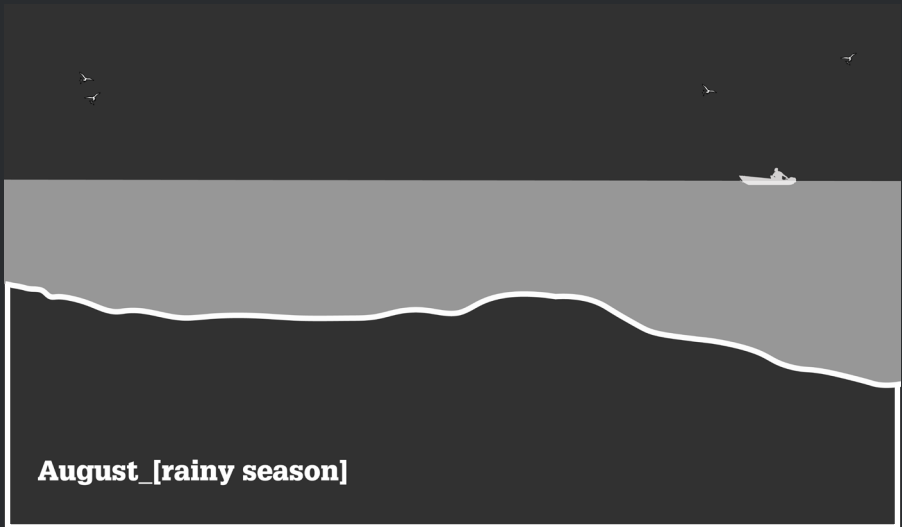
Observing the site it immediately becomes clear as to take the local material available to build structures. In this case the site is made up of sand, clay and silt. India has a long history of constructing dwellings out of sand and clay in its interior villages.



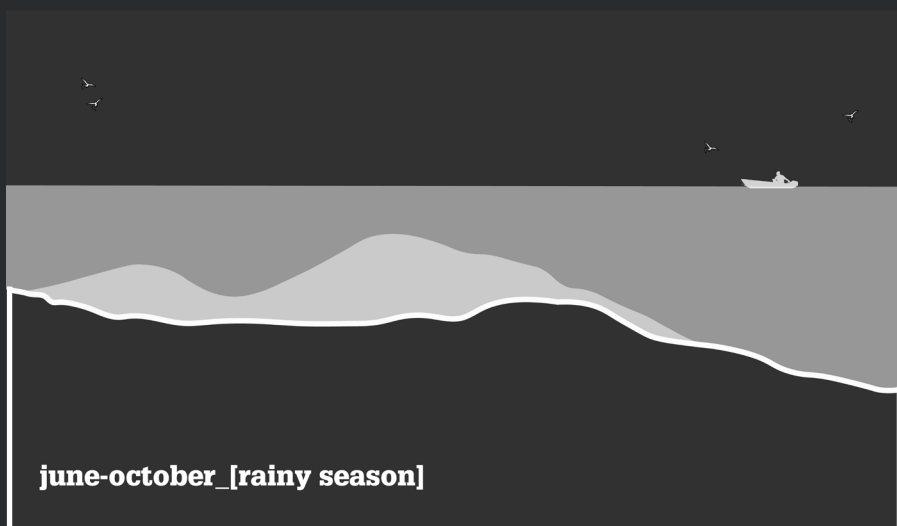
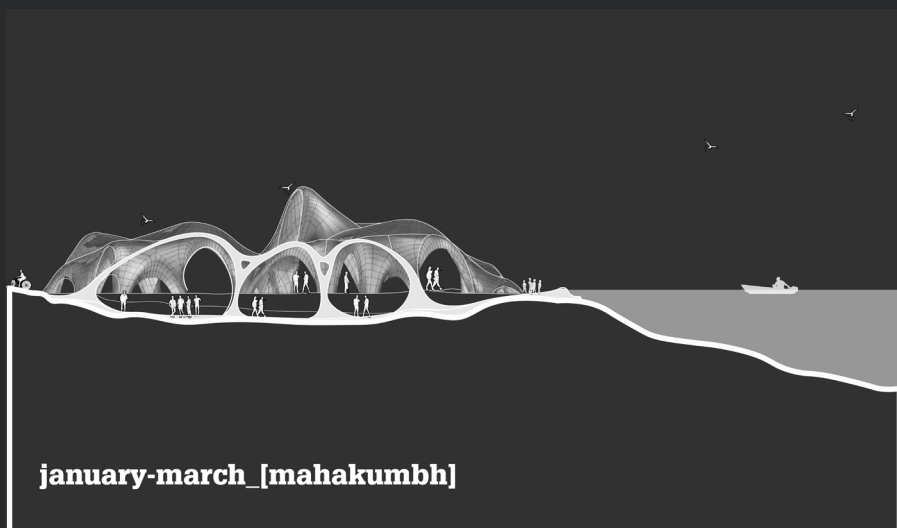
While constructing the Kumbh, the government deposits a huge amount of sand mounds around the site while constructing roads and flattening irregular contours. These sand mounds and other areas around the site could be used to extract the raw materials for the structures.







The conceptual idea states the material lifespan to be equal to the functional lifespan of Kumbh. The process would start with the construction of the sand structures once water recedes. After the completion of the festival the structure is left as it is and when water level rises it will eventually dissolve in it.



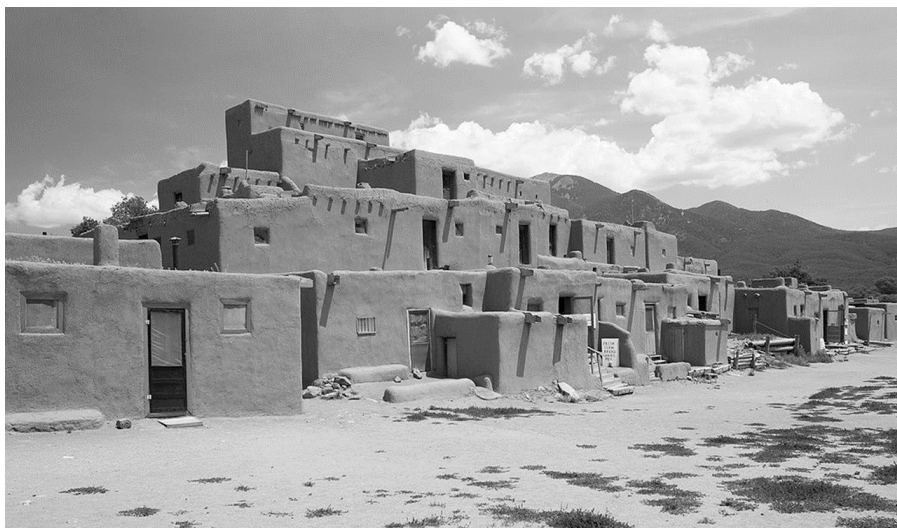
To understand the material application and properties case studies are done of contemporary as well as traditional sand structures in the following chapters.



Ninety percent of the people who visit kumbh come from interior villages of India who live in earth structures. One such village cluster was evaluated.

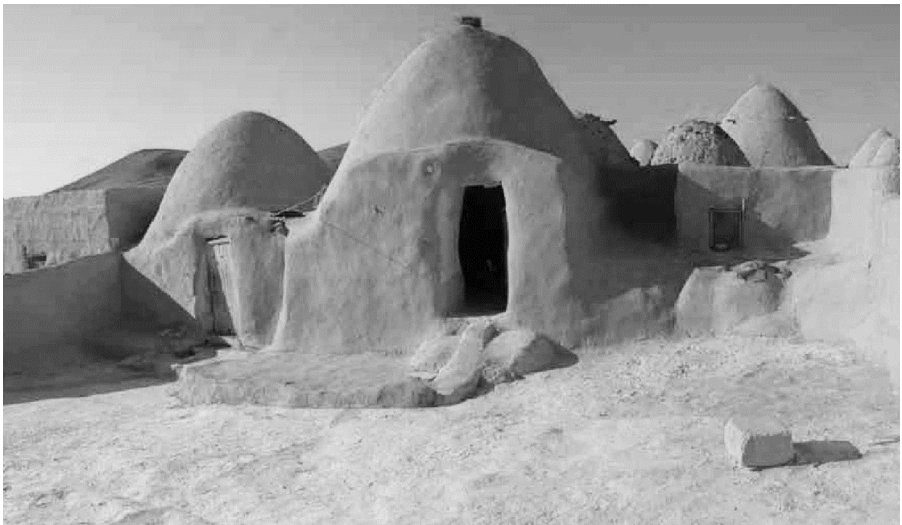


Technique: Low-Tech
Material: Sandstone, Clay and sand
Binder: Mortar
Coating: Cow-Dung / Lime

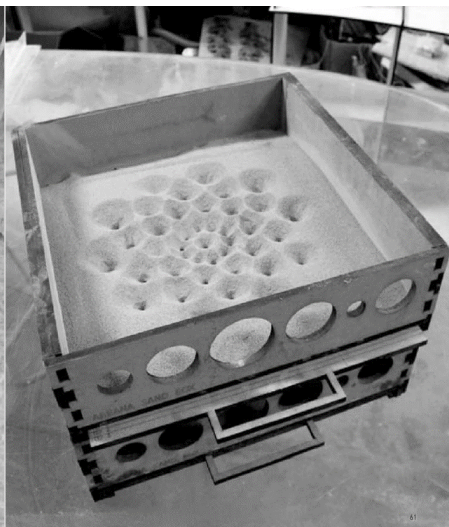
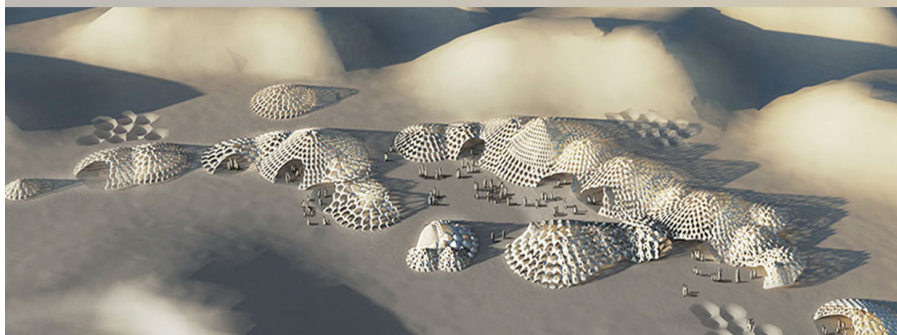
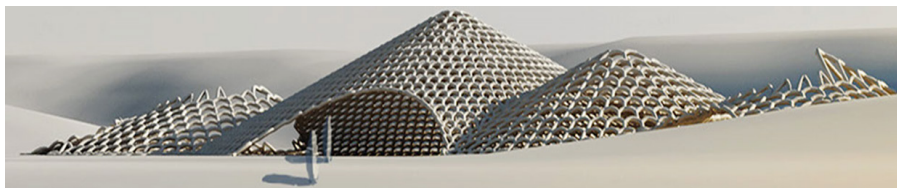


Bottom image: Adobe house at Pueblo, New-Mexico

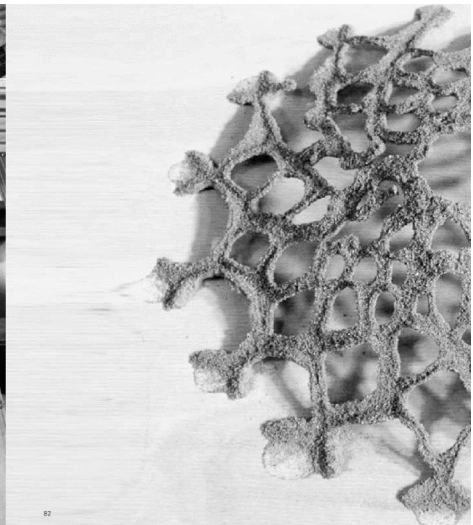
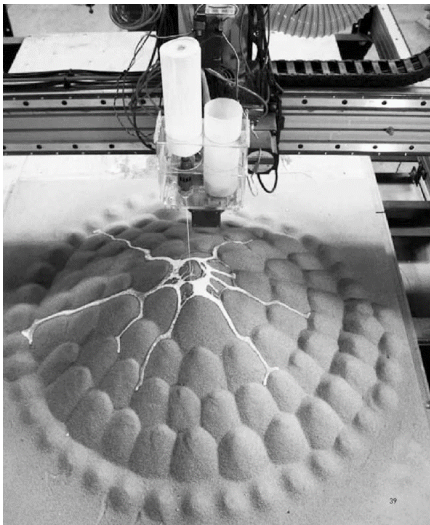
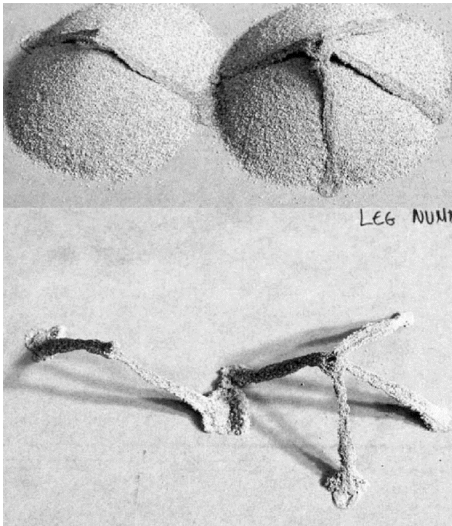
Facing page top image: Shibam, Yemen



Technique: Low-Tech
Material: Sand, Clay and Stone
Binder: Mud-Mortar & Water
Coating: Mud



*Academic Project: Iaac, Barcelona
Areana*

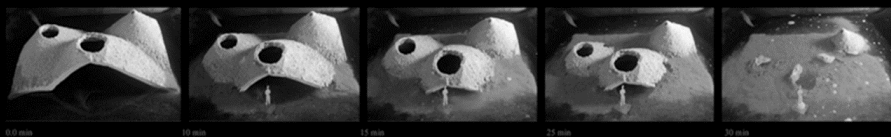
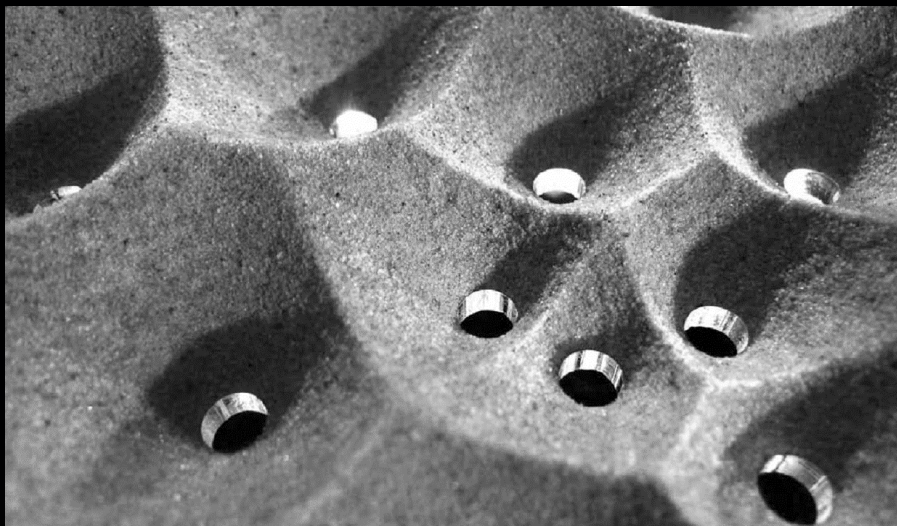


Technique: Hi-Tech | CNC - collection & redistribution

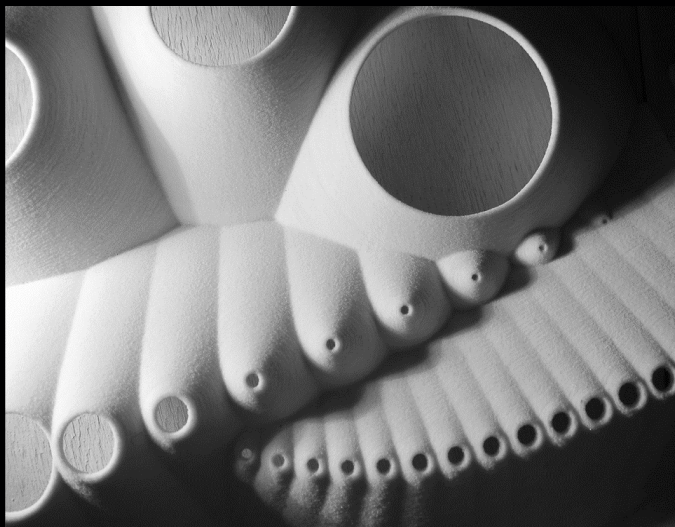
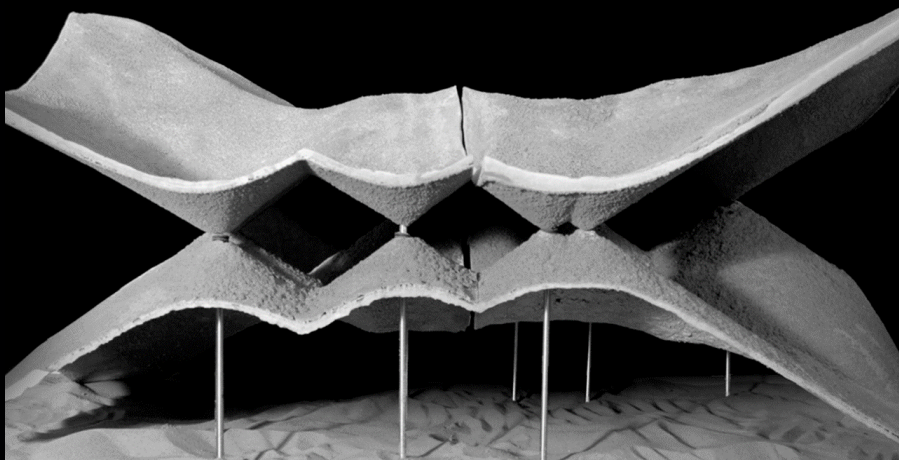
Material: Sand

Binder: Water & Glue

Computation: Cellular Automata Rules



Academic Project: AA-DRL, London
Sandworks



Technique: Low-Tech | Distributing sand under gravity

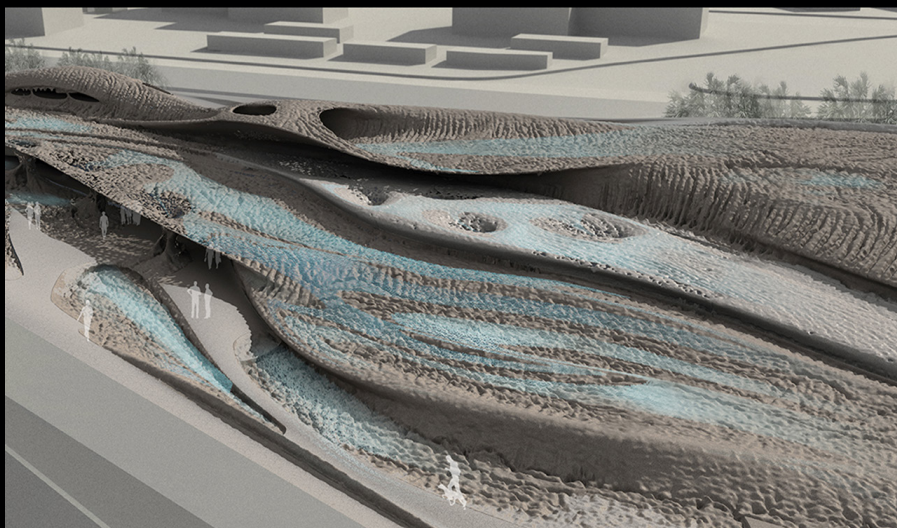
Material: Sand

Binder: Crystallization of Sodium salt

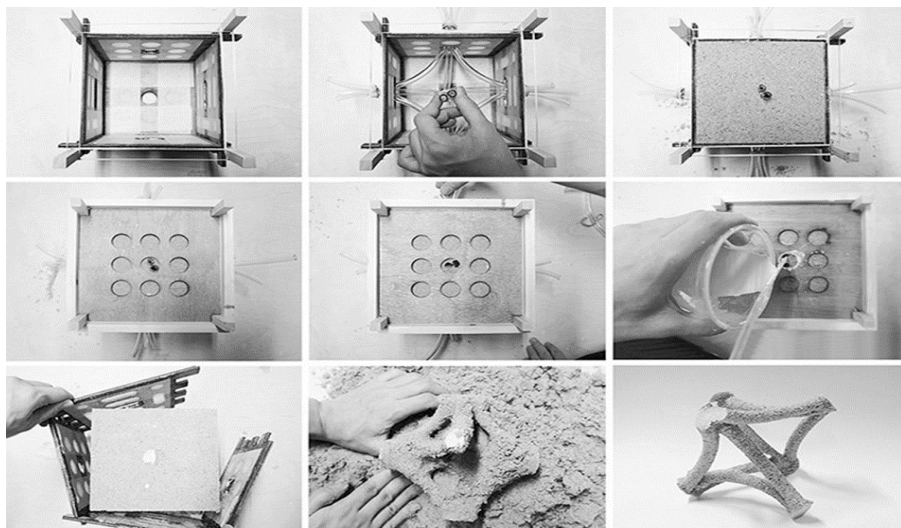
Computation: Algorithmic Rules



Academic Project: AA-DRL, London
Erosion



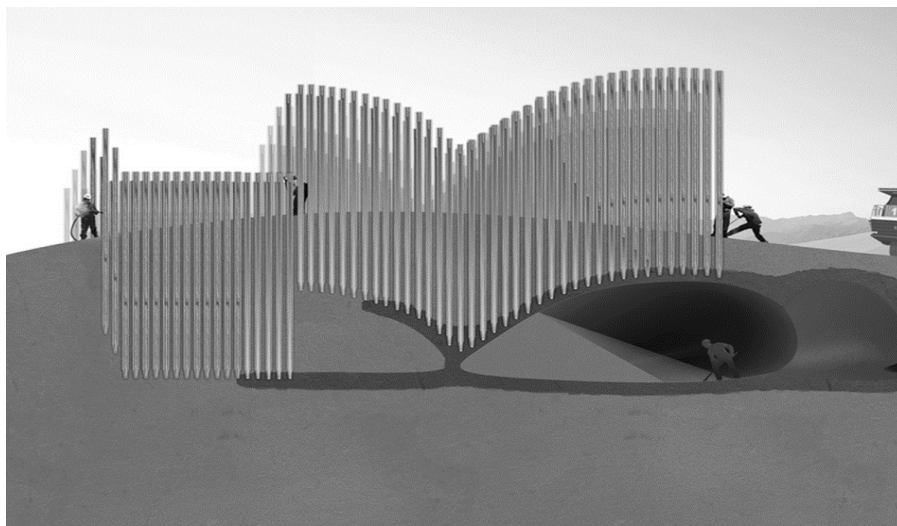
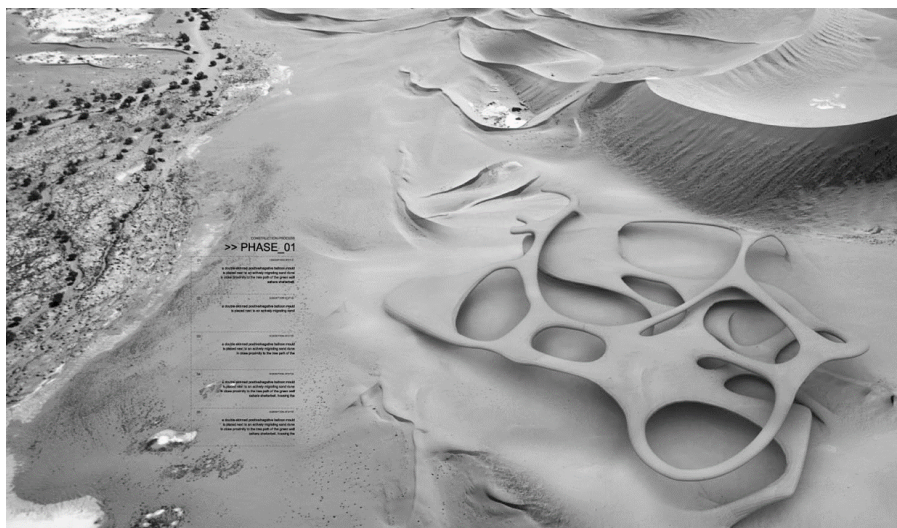
Technique: Low-Tech | Distributing sand under gravity
Material: Sand/Plaster/Clay
Binder: Water



Academic Project: Bartlett, London
Sandprint

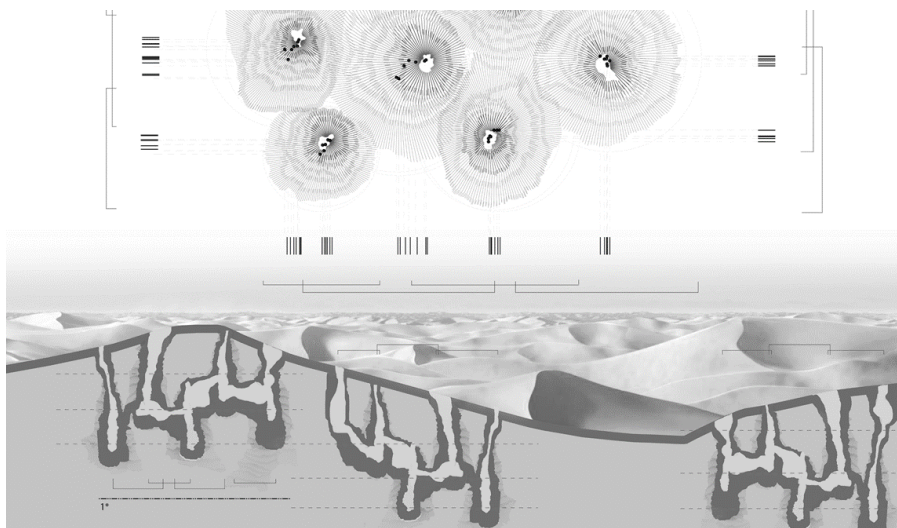


Technique: Low-Tech | Mold-Making
Material: Mold-Sand, Casting-Plaster, Tools-Rubber tube
Binder: Water & Glue
Computation: L-System_Generation



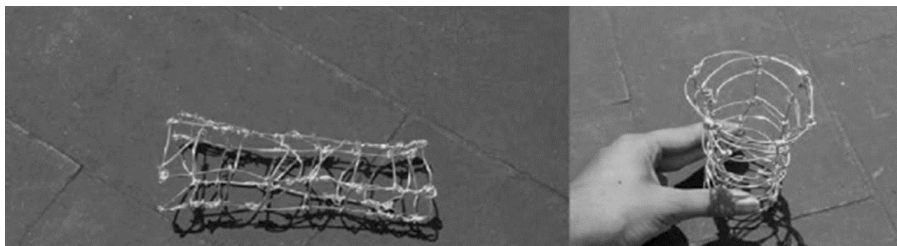
*Academic Project: AA-DRL,
London
Dunes*

*Technique: Low-Tech | Microbial Reaction
Material: Sand
Binder: Bacillus pasteurii & Urea*



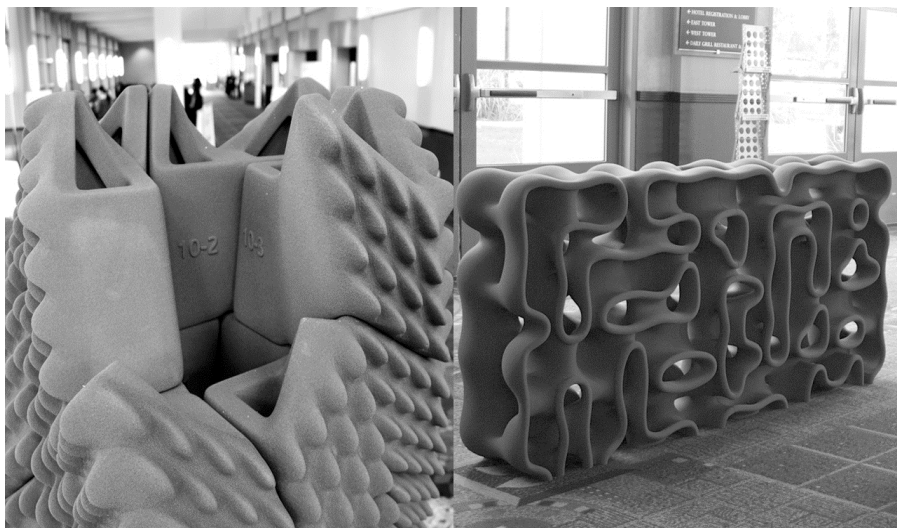
*Academic Project: Iaac,
Barcelona
In:Sand*

*Technique: Hi-Tech | Additive
Material: Sand
Binder: Corn Starch/Oil/Wax &*



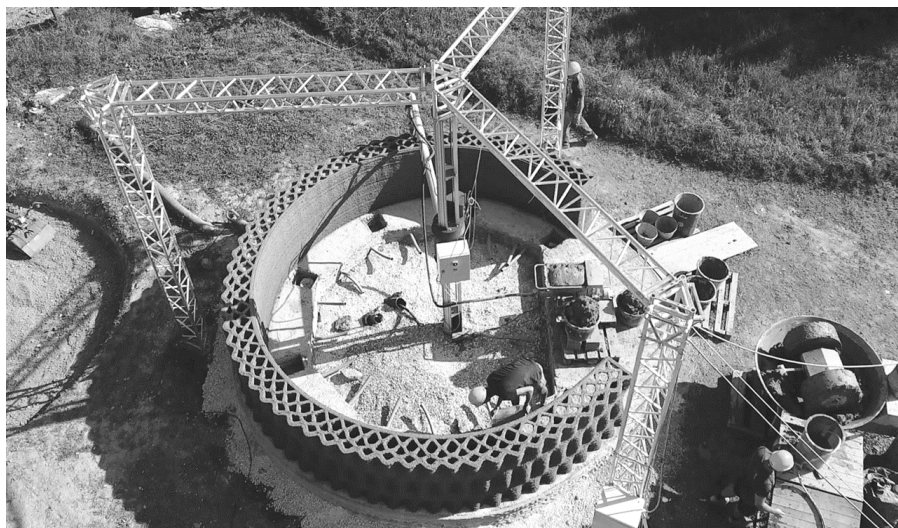
*Academic Project: Iaac,
Barcelona
Stone-Spray*

*Technique: Hi-Tech | Additive
Material: Sand/Cement
Binder: PolyPavement/Water*



*Top Image: Lewis Grand Hotel
Technique: HI-Tech/Additive
Material: Sand/Volcanic Ash*

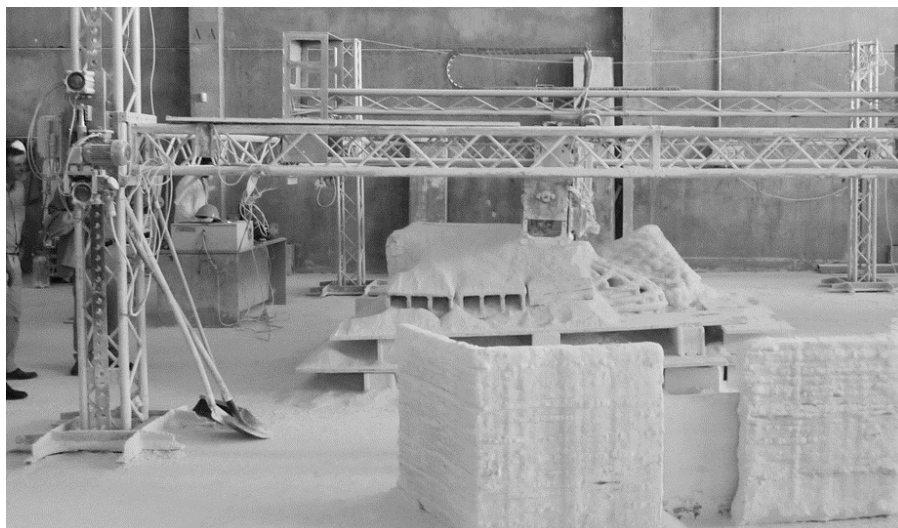
*Bottom Image: Emerging Objects
Technique: Casting
Material: Sand*



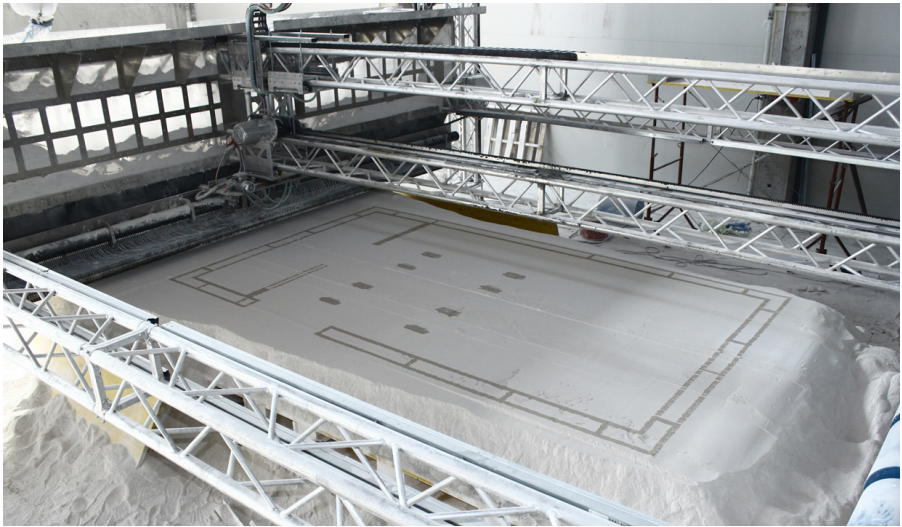
GAIA Wasp



Technique: HI-Tech/Crane Wasp
Material: Clay, Silt, Sand, Straw & Husk
Binder: lime
Coating: shaving claylaminallinseed oil



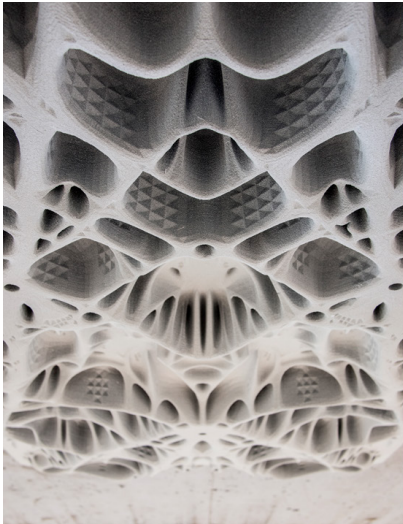
D-Play



Technique: HI-Tech/ Binder Jetting Technology
Material: Sand/Magnesia based cement
Binder: Saline Water Solution



D-Play



Above Image : D-Play
Bottom Image: Smart Slab. Eth-Zurich
Particle bed 3d printer used for production



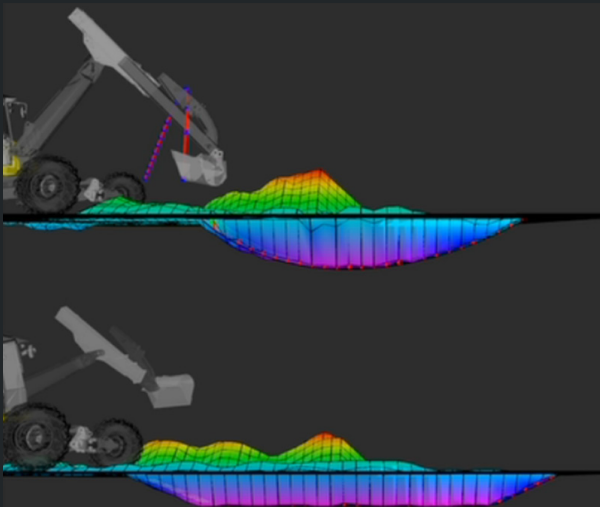
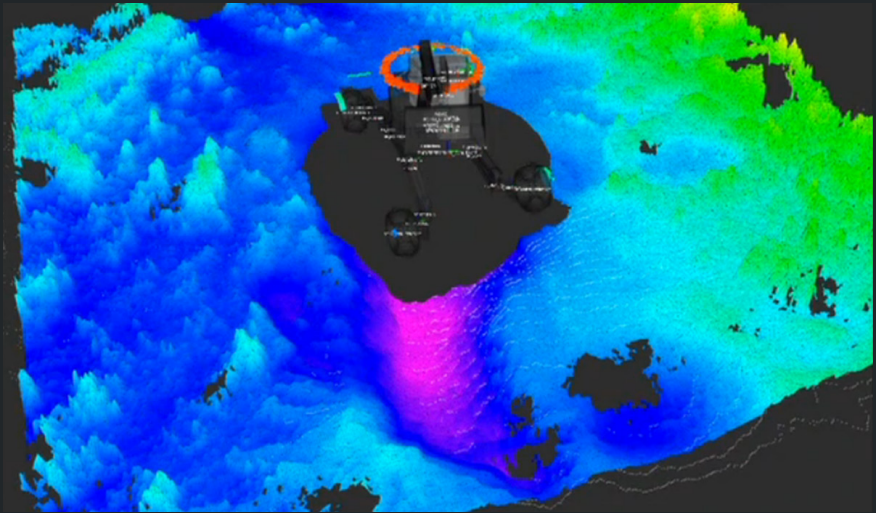
Digital Grotesque, Michael Hansmeyer



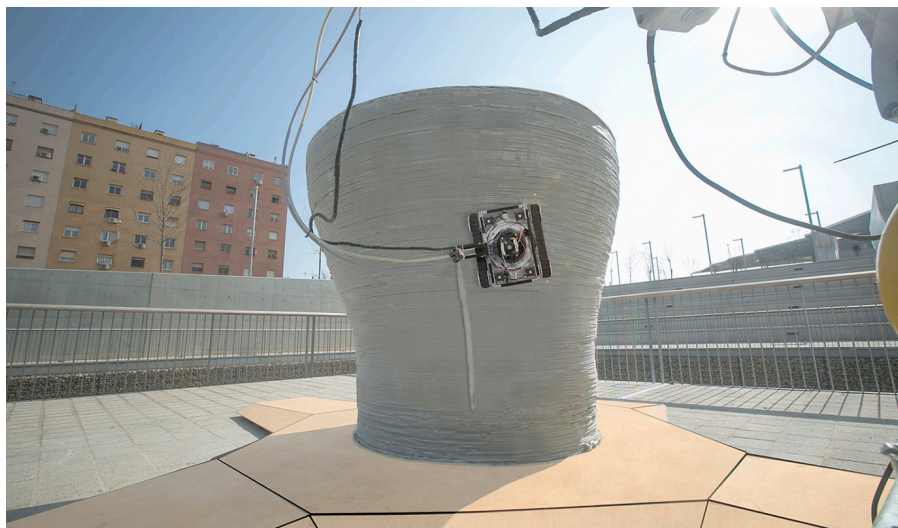
Technique: HI-Tech/ Binder Jetting Technology
Material: Sand



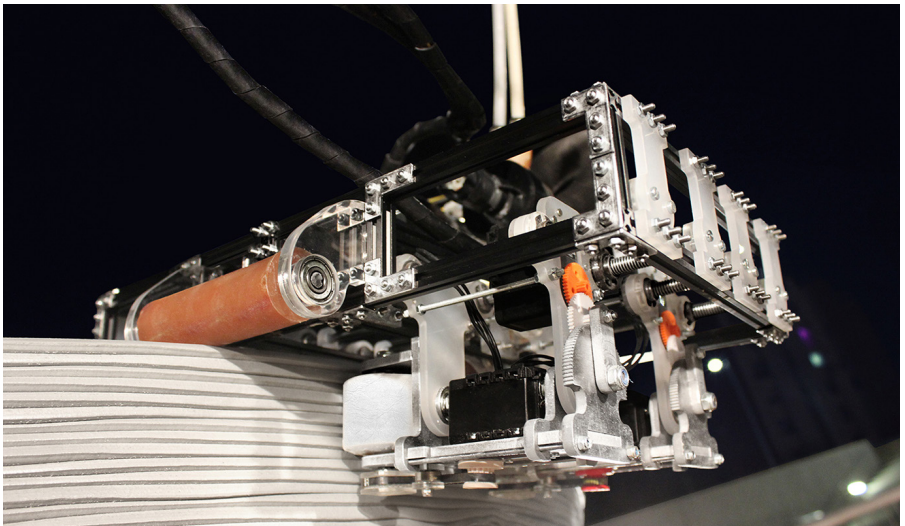
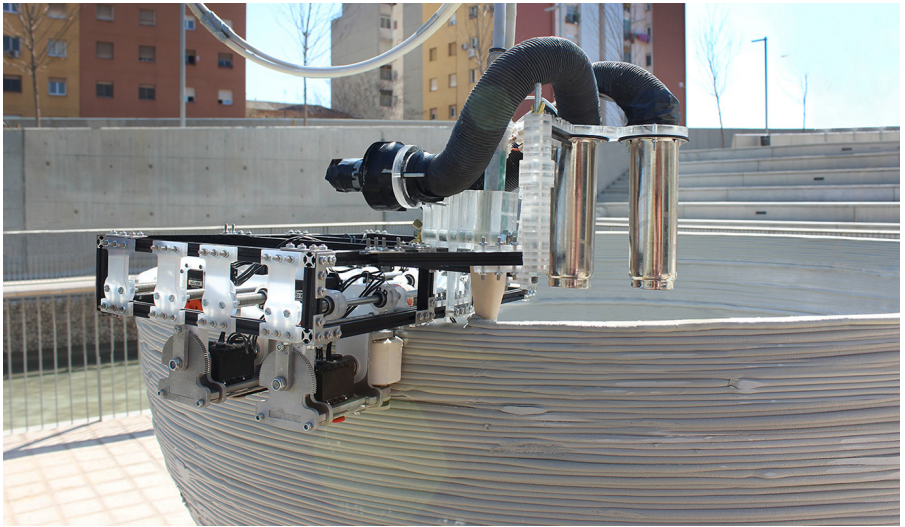
Heap, ETH-Zurich



Technique: Autonomous robotic crane for deposition and molding site.



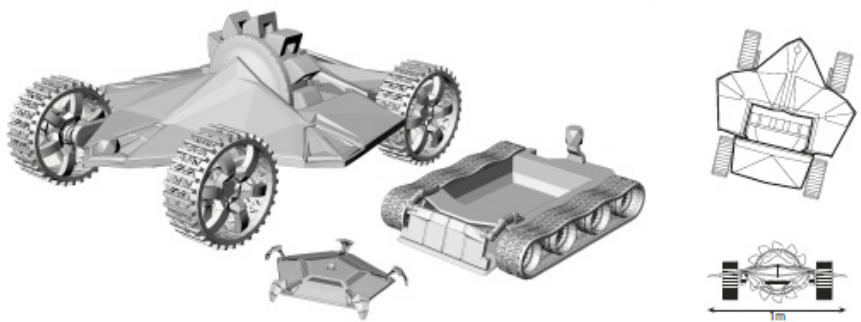
Mini-Builders, Iaac-Barcelona



Technique: Swarm Robotics



Mars Habitat, Fosters & Partners



Technique: Swarm Robotics



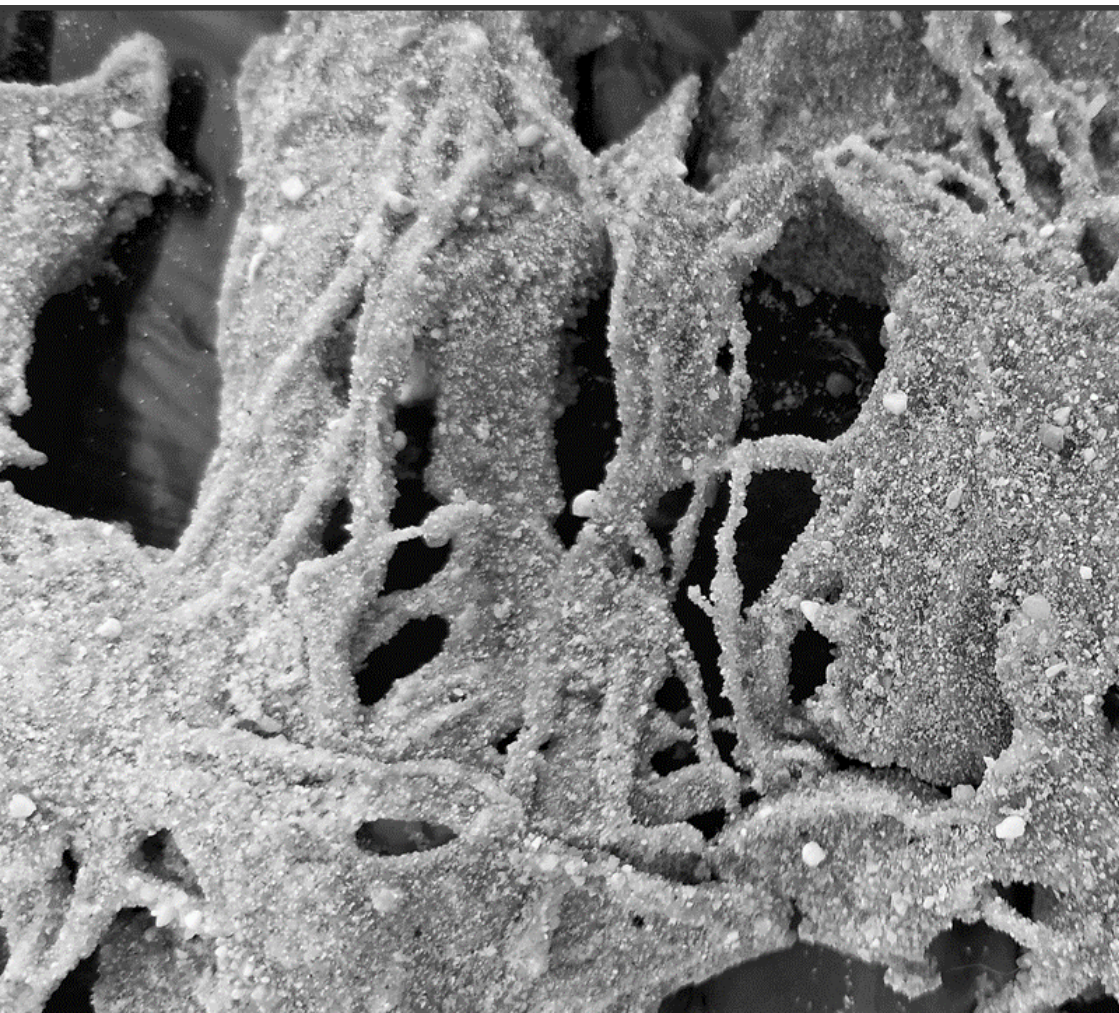


IN-FLOW

Design Progression [P2]

The thesis is initiated with a context driven research into the unique ephemeral nature of the site due to its positioning at the confluence of two rivers which renders it usable for a few months during the year due to variable water depths throughout the year. In the previous sections we saw that contextual research like figure ground mapping of previous iterations was done to understand how the festival fits together with the existing urban fabric. At the architectural level, historical research led to different findings on the development of shelter, its use and functional distribution throughout the festival's history. Material culture theories by Tim Ingold and I. Hodder made me sensitize to the way material was used at the site. Realizing that "material culture is inseparable from culture and human society", I started gathering literature data on local temporary shelter typology to form a material catalogue to work with. The data collected via historical literature precedent and interviews with users gave an

informed view on the type of space and material needed by the users which opposed the conventional mass-produced system of plastic and fabric tent settlement system found across the globe irrespective of location, environmental and social conditions. The research and data led to an informed decision to use old vernacular earth (clay and sand) material by replacing the old construction technique with new tools like robotic fabrication. This forms the main research of my thesis investigated via practice-based research methodologies like experiments and robotic workshops. In the following chapter we will see the design progression during p2 where we will tackle macro problems of the site starting with urban design. The design being carried out at the Robotic Studio will emphasize the various robotic tools available to form a design intervention which adheres to the social and material culture of the site.



Material Investigations carried out during p2- Stage



Satellite imagery of the 2019 site profile

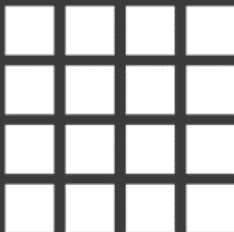


The first attempt was to disregard the rigid planning of the site as it doesn't match with its context which has organic/relaxed grid due to variable contours as we approach the river. The rigid planning leads to chaos at the site since a large amount of sand is cut and filled to make this grid.





In the above images one can see the hindrance these sand piles create in the movement between spaces. Hence it was thought to take the contours of the site into account when planning urban spaces and connections.



[xs]Family

Size : 1.0 | 5pax | 225 sqm

[s]Community

Size : 16 x Family | 80pax | 3600sqm

[m]Block

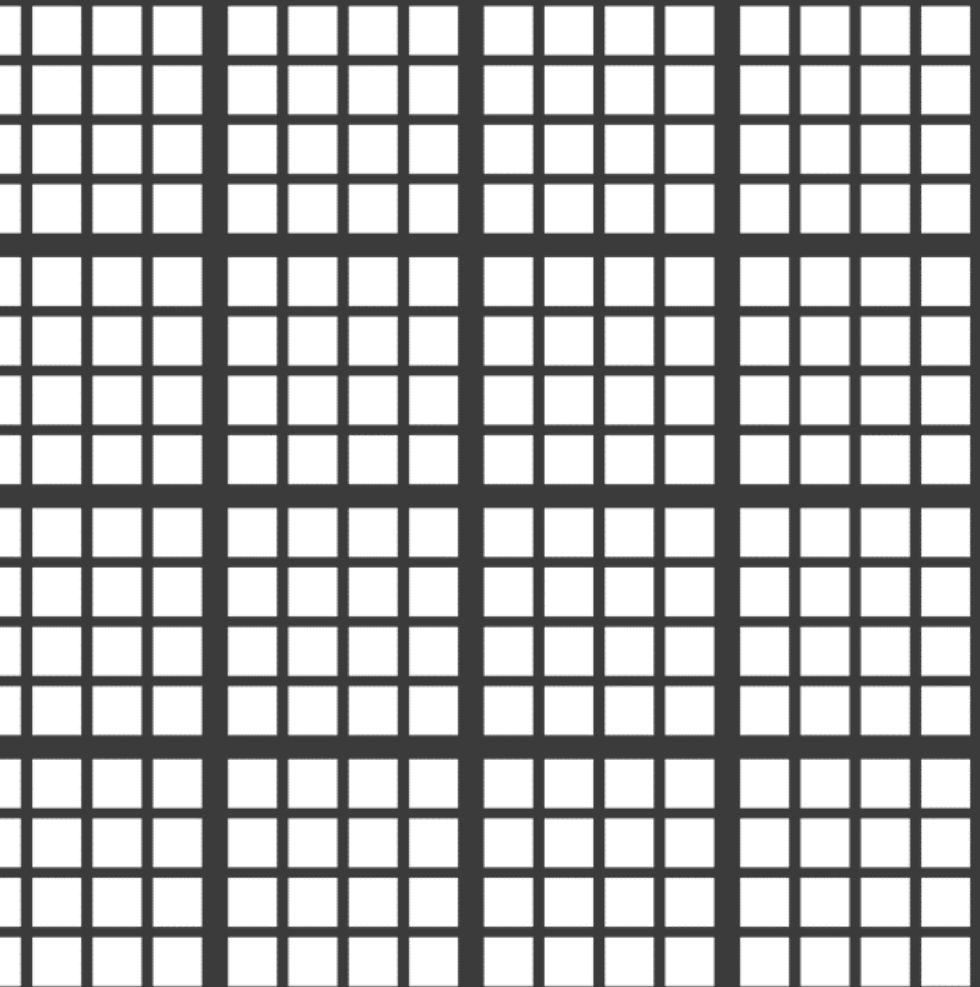
Size : 16 x Community | 1,250pax | 56,250sqm

[l]Sector

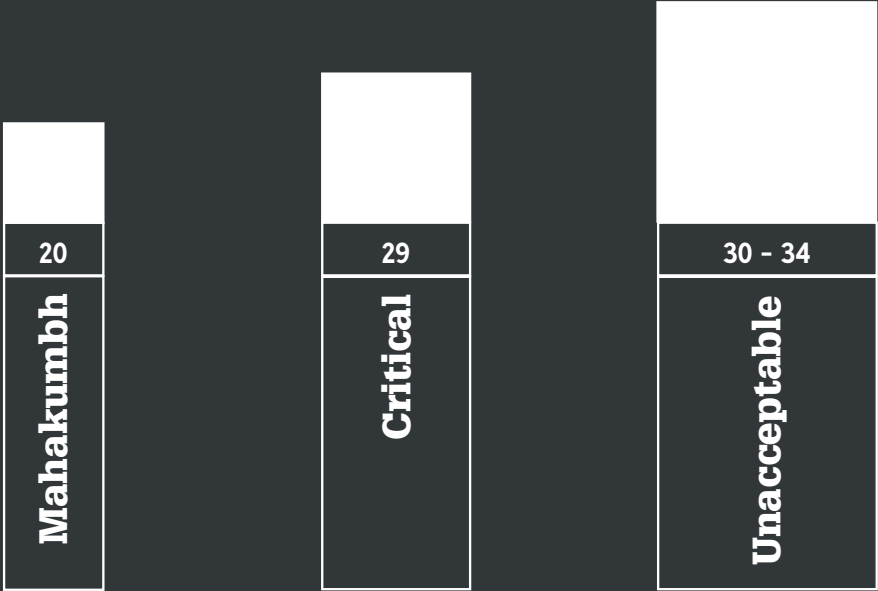
Size : 4 x Block | 5,000pax | 225,000sqm

[xl]Settlement

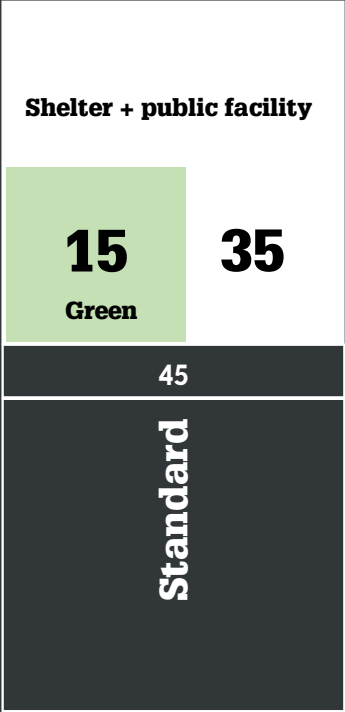
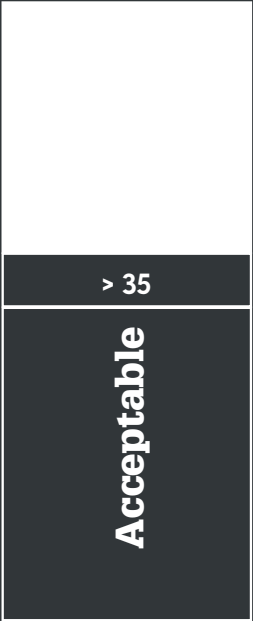
Size : 4 x Sector | 20,000pax | 900,000sqm



The site is fragmented into various fractions based on requirement for each family and its ancillary functions. The main site is divided into 4 sectors which is further divided into 4 block with 16 communities in each block.



The following figures shows that mahakumbh provides less than acceptable area per person. For design requirements 45sqm per person is being taken in accordance with UN-Refugee agency emergency standard.



Average camp area - 45 sqm/person

Minimum covered area - 4.5 sqm

Minimum ceiling height - 2m



Two settlements are taken for further designing accounting for almost a combined area of roughly 2 million sqm.



The site is first fragmented with the main access routes connecting the sites to each other and its immediate context, because this needs to be clear and the shortest and straight length possible as this route caters to large amounts of people.



Contour data is extracted from Google earth.



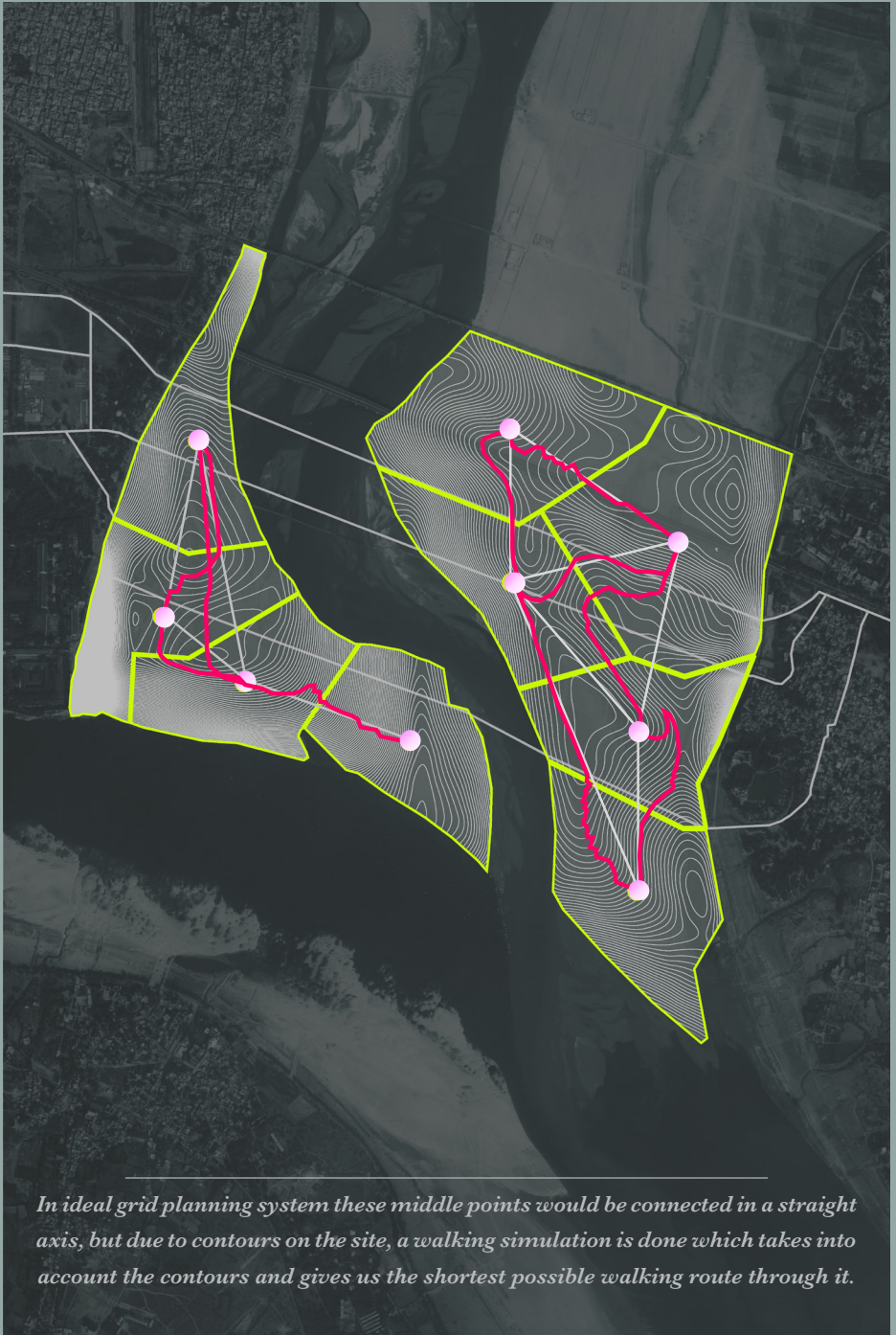
A drip simulation helps in extracting the valley and mountain curves and helps in understanding the natural flow of different land parcels. These would later help in identifying parcel boundaries.



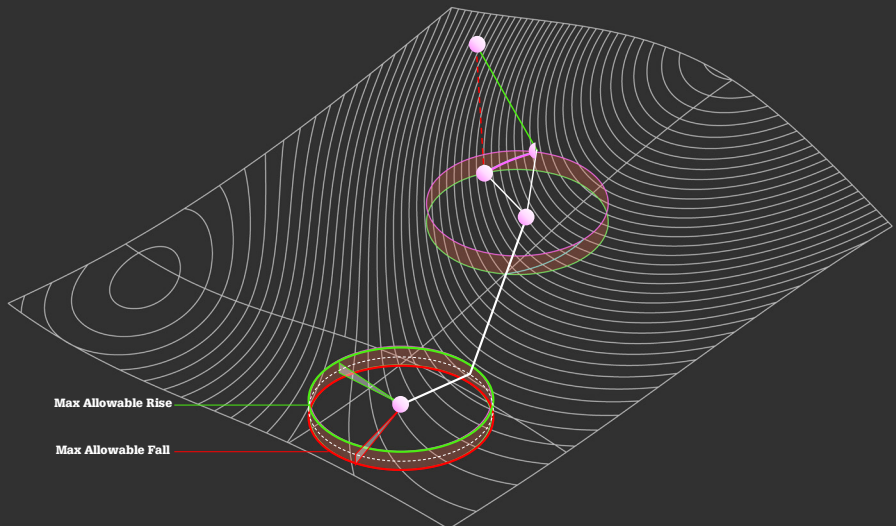
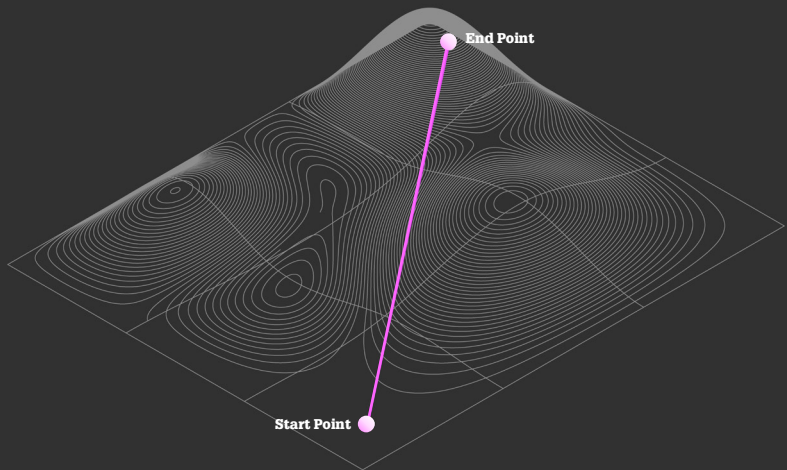
We use the primary mountain and valley curves as our sector boundary which yields 4 to 5 sectors per settlement.



Every sector has a pavilion at middle point since the Hindu planning system states that the middle point will have the most important functions as it is considered holy. These middle points are interconnected and will carry major traffic since they cater to public functions.



In ideal grid planning system these middle points would be connected in a straight axis, but due to contours on the site, a walking simulation is done which takes into account the contours and gives us the shortest possible walking route through it.



The simulation checks for the max allowable rise and fall around the subjects perimeter. The max allowable deviation is kept at 1:20 . It checks for all points which concurs with the allowable deviation and selects the point closest to the end destination point and this process repeats until the subject reaches its end point.









Sector-B









Sector-F

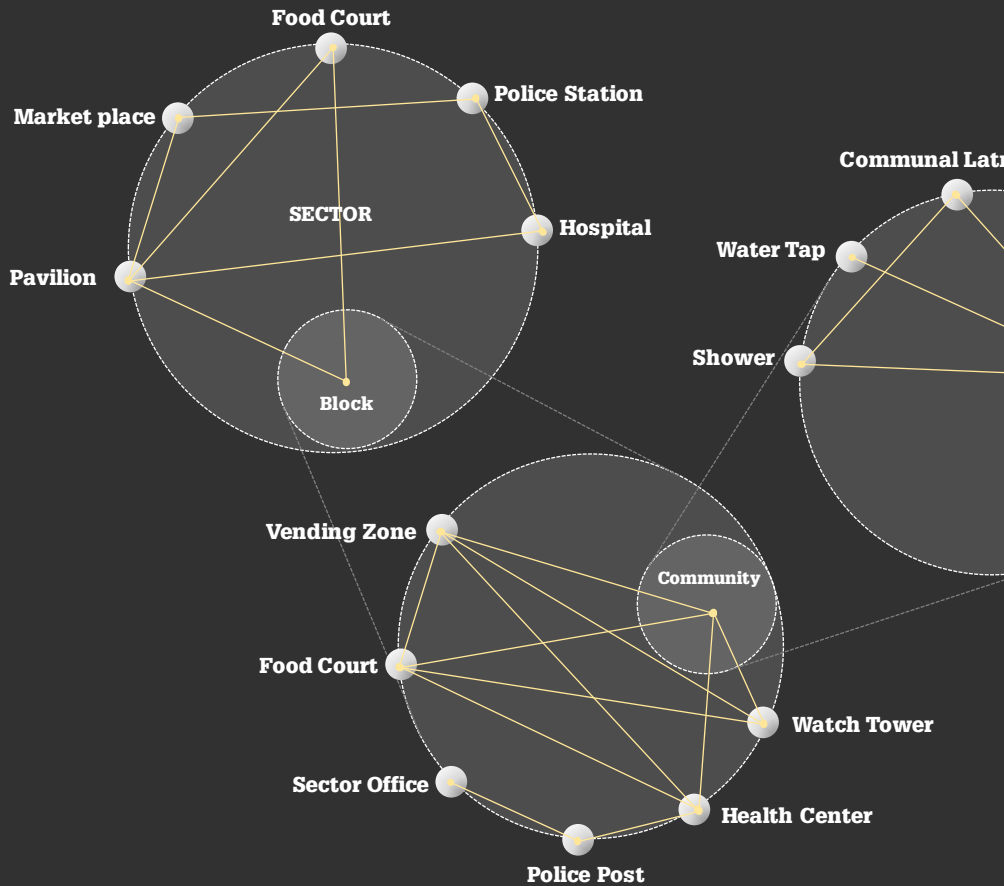




Sector-H

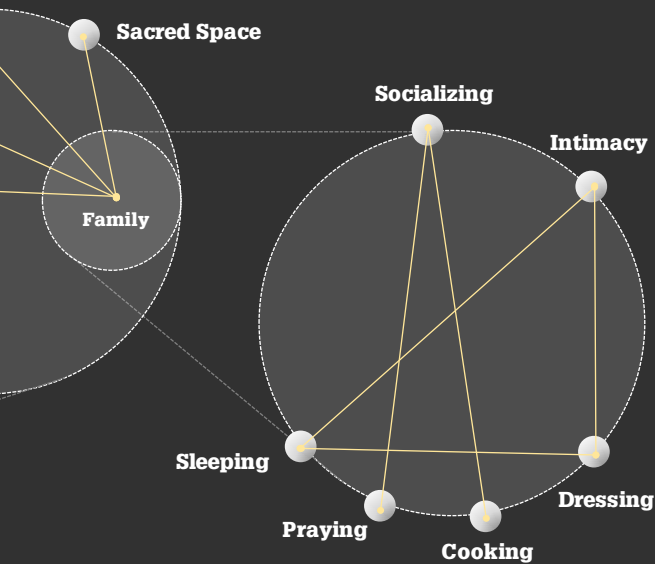






The diagram shows the functional distribution in each parcel types and the urban rules to be followed for urban plan detailing.

latrines



Urban Rules

Sacred Space - Mid Point

Dwelling >>> Sacred Space

Water Tap >>> Sacred Space

Water Tap >>> Shower

Latrines > Shower

Latrines > Water Tap

Latrines () Dwellings | 6m>X>50m

Urban Rules

Pavilion >>> Food Court

Pavilion >>> Market Place

Food Court >>> Market Place

Pavilion> Police Station

Pavilion> Office

Police Station >>> Office

Police Station >>> Hospital

mad

news

fellowship

works

- status

- location

- typology

art

books

office

jobs

contact

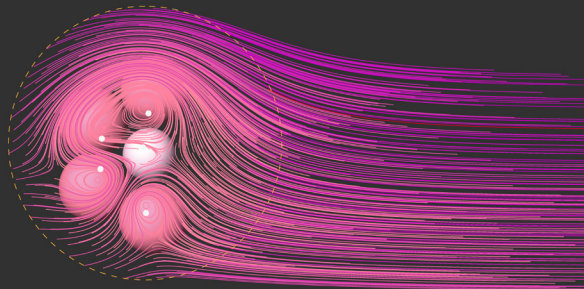
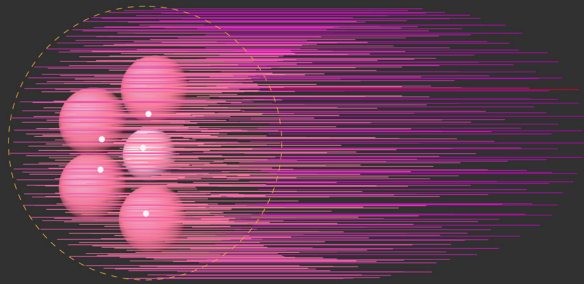
中文



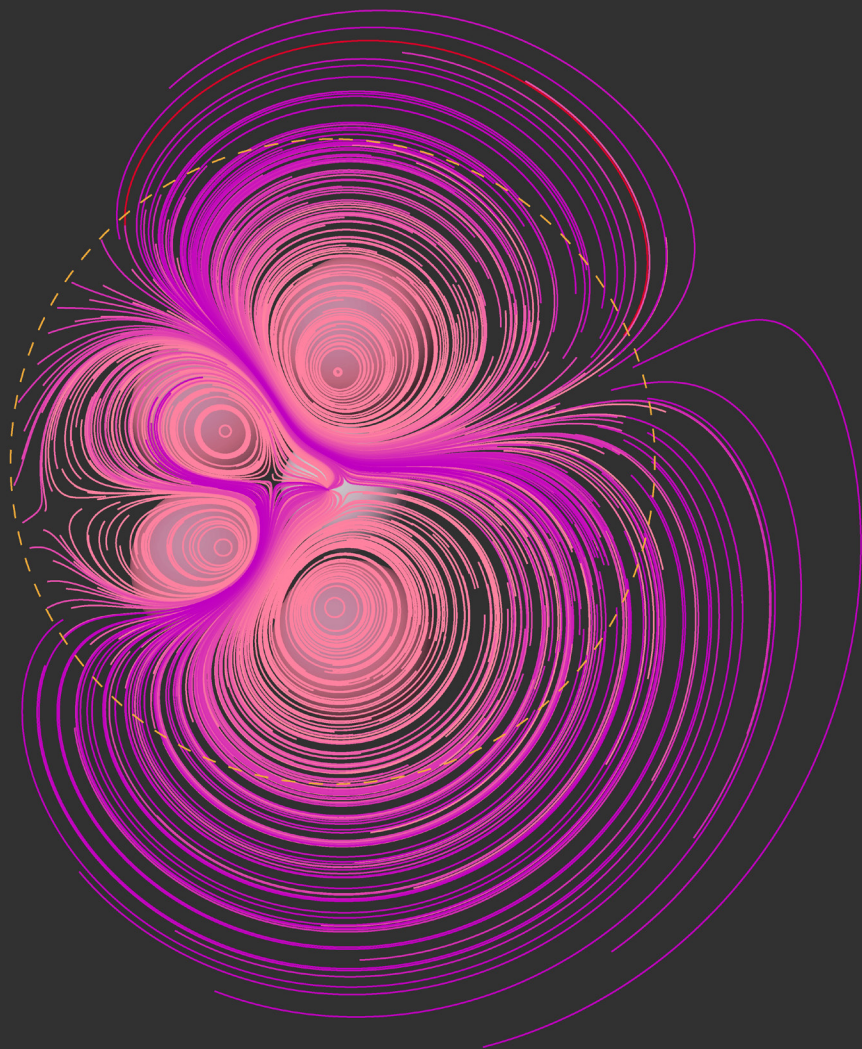
Reference Image- Mad Architects



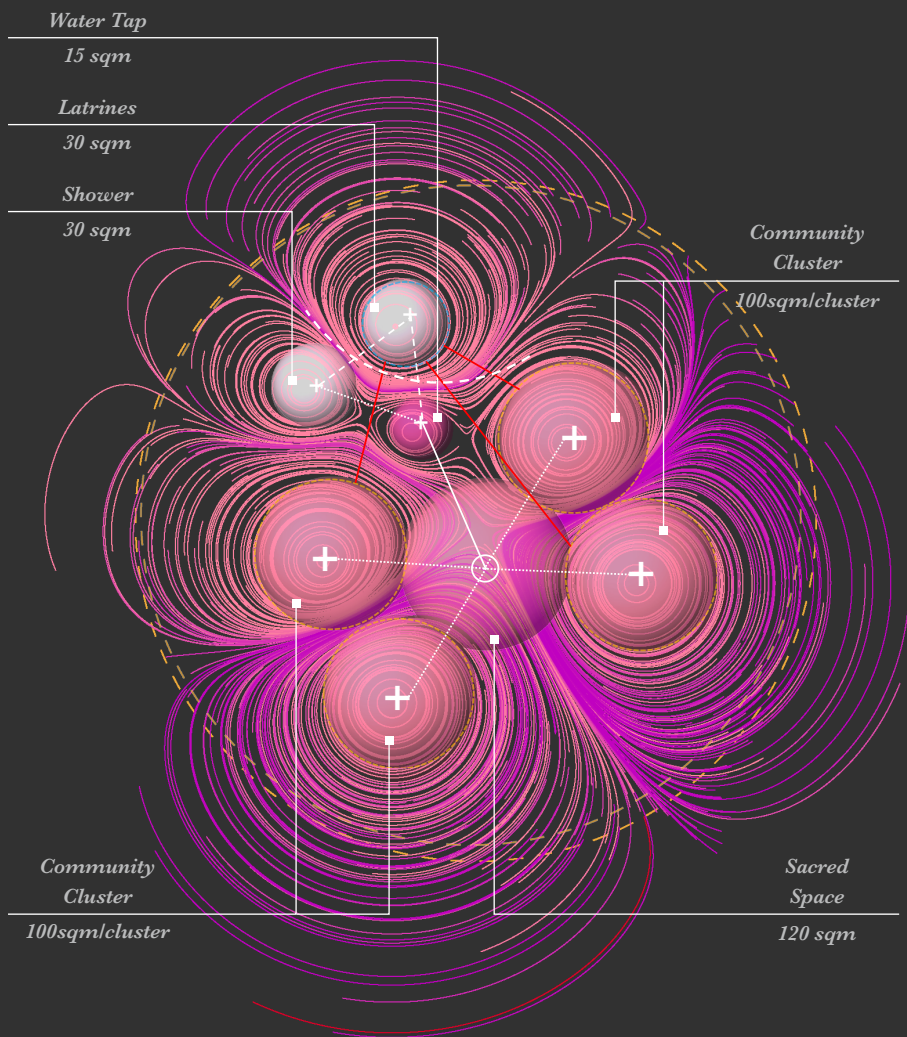
Keeping in line with the design concept of using contours, a design decision was taken to take inspiration from interconnected catenary mounds as it suits the sand material used and also creates a dual accessibility around the site along the surface and the roof of the structure.



Functional volume are clustered together based on urban aggregation rules which then disrupts the contour in order to integrate the catenary structures.



Vector fields determine how the field is disrupted. Point field determines the extent of the volume, rotational field determines the type of interaction between two functions and line field is for the open social spaces and circulation



Community Cluster
Average Cluster Area - 750 sqm

Urban Rules

Sacred Space - Mid Point

Dwelling >>> Sacred Space

Water Tap >>> Sacred Space

Water Tap >>> Shower

Latrines > Shower

Latrines > Water Tap

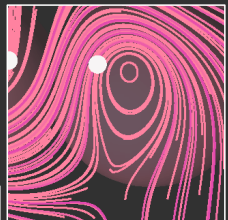
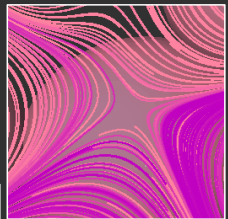
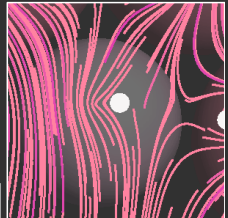
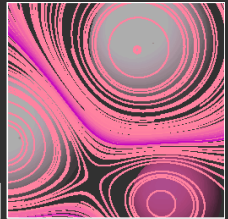
Latrines () Dwellings | 6m>X>50m

Buffer

Social

Public

Private



The community cluster has 16 families divided in 4 clusters around a sacred space.

Market Place

350 sqm

Food Court

400 sqm

Pavilion

1500 sqm

Office

120 sqm

Hospital

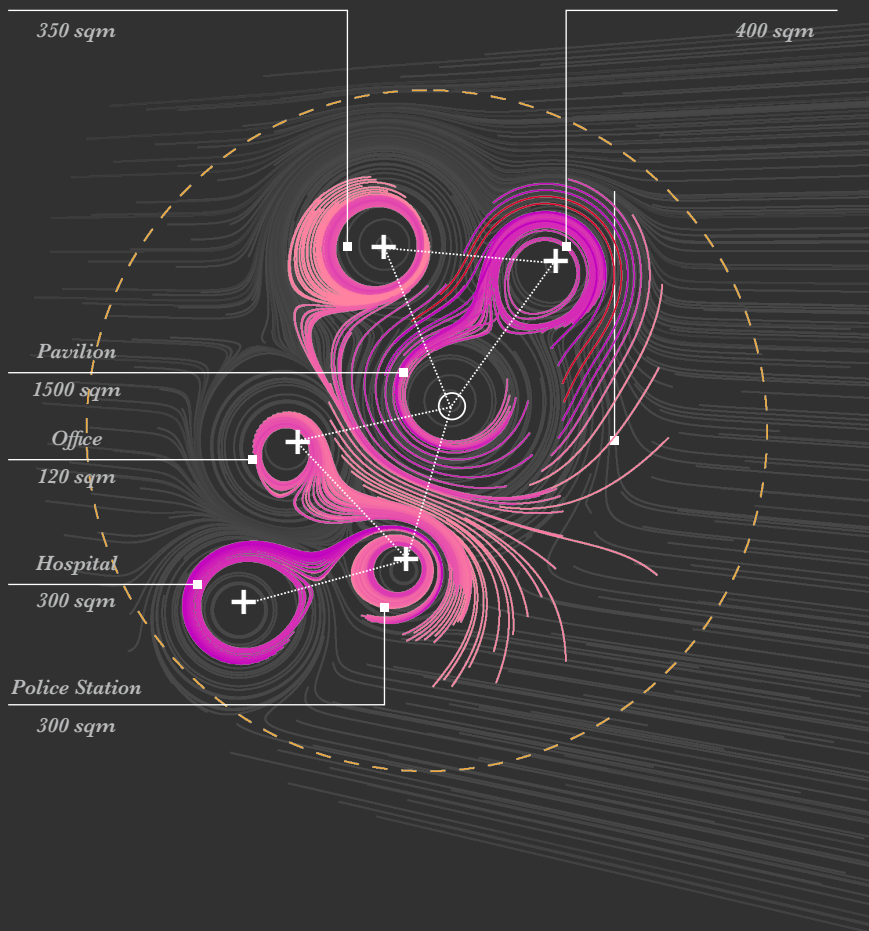
300 sqm

Police Station

300 sqm

Public Cluster

Average Cluster Area - 3500 sqm



Urban Rules

Pavilion >>> Food Court

Pavilion >>> Market Place

Food Court >>> Market Place

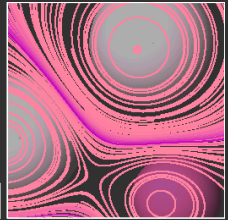
Pavilion> Police Station

Pavilion> Office

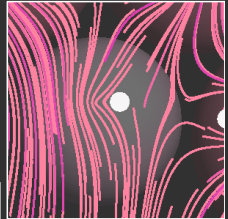
Police Station >>> Office

Police Station >>> Hospital

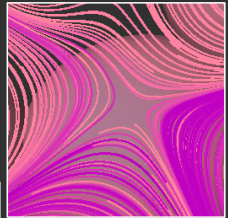
Buffer



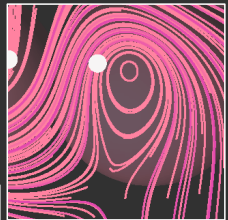
Social



Public



Private



The public cluster has the pavilion at its heart connected directly to the market place and food court and indirectly connected to other public functions like hospitals and sector office.

TYPE	FUNCTION/ACTIVITY			PAX	NUMBER	AREA	ATTRIBUTES
FAMILY	SLEEPING						Site Area @ 45sqm per person
	PRAYING			5	1	225	Dwellign area @ 4.5sqm per person
	DRESSING						
	INTIMACY						
	SOCIALIZING			5	1	225	
COMMUNITY	16 X FAMILY			80		3600	TOTAL AREA
GREEN AREA	TOTAL GREEN AREA					1188	33% of total area
	GREEN AREA PER DWELLING					74.25	
SHELTER AREA	DWELLING HUTS			5	16	360	AREA @ 4.5 sqm per person
	COMMUNAL LATRINES				5	7.5	4 male, 1 female 1 per 20pax
	SHOWER				3	4.5	1 per 50 pax
	WATER TAP				2	2	1 per 80 pax
	SACRED SPACE				1	120	1.5 per pax
	ROADS					720	15% of area

Final Community area



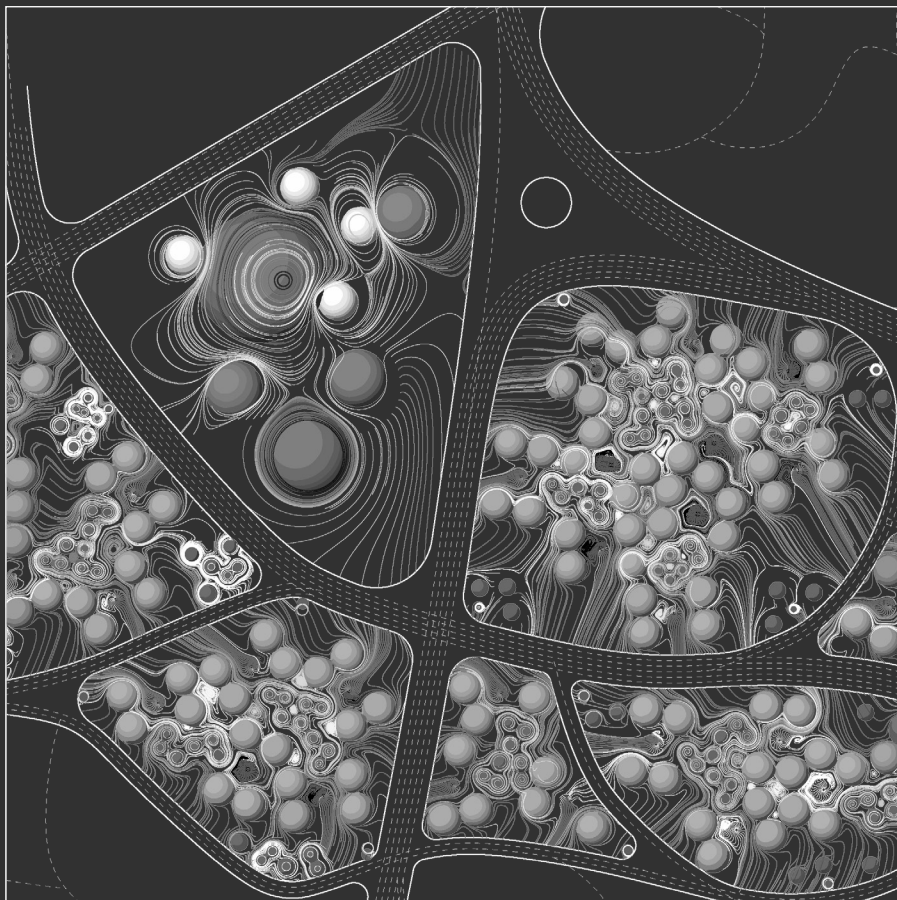
The functional catalogue will now be applied to one of the sector in the settlement.



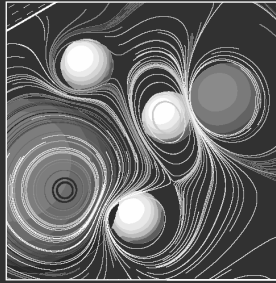
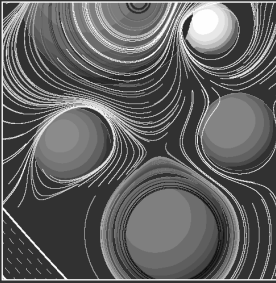
Selected Sector



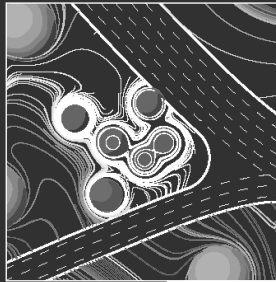
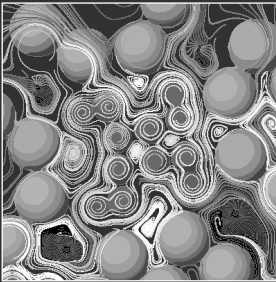
Applying primary and secondary roads extracted from urban design simulations.



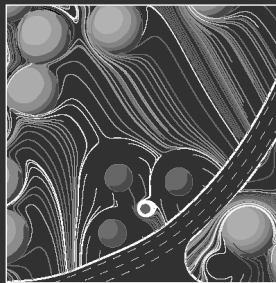
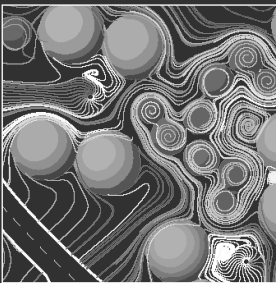
Applying functional simulation to the site



Space Interaction

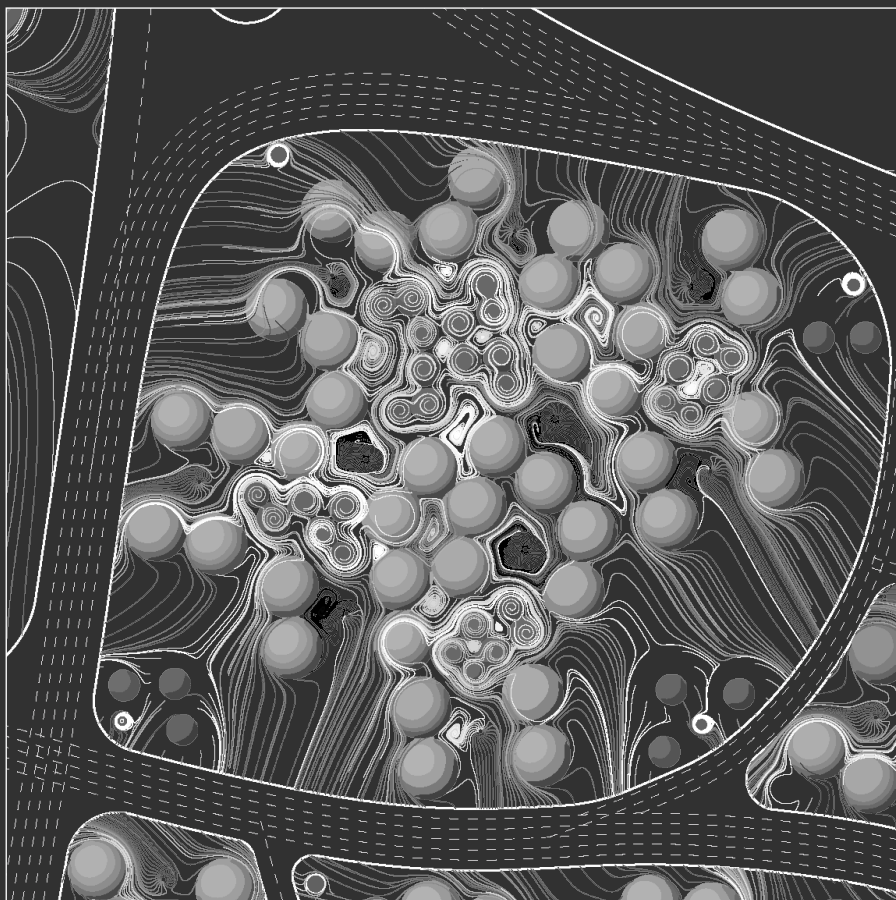


Buffer /Privacy

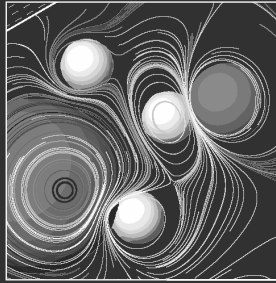
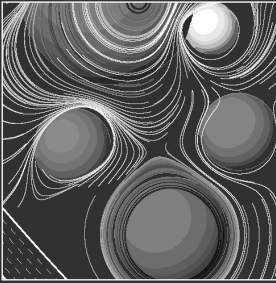


Social Spaces

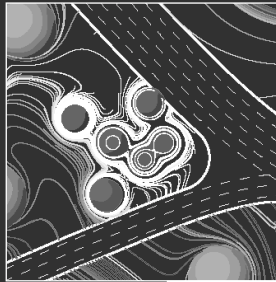
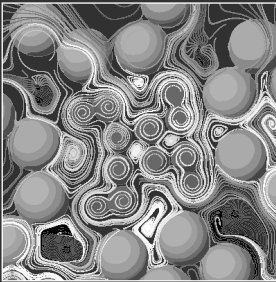
Different kind of open, private and buffer spaces depending on different kinds of functions.



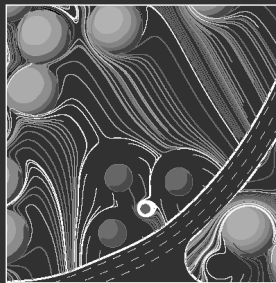
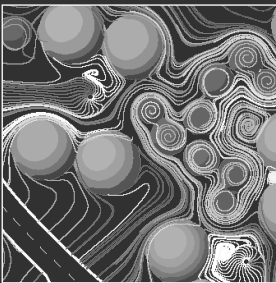
Zoomed-In community cluster



Space Interaction

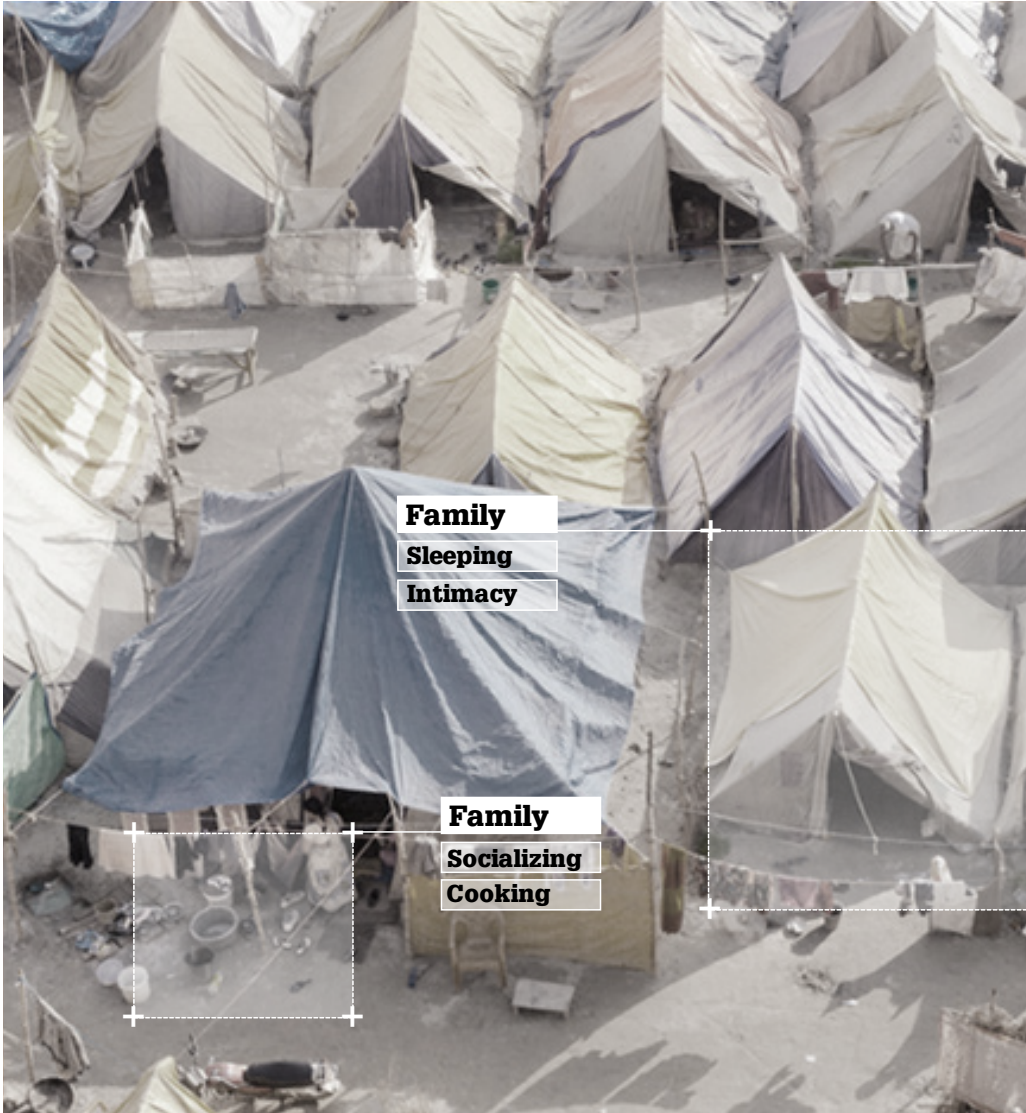


Buffer /Privacy



Social Spaces

Different kind of open, private and buffer spaces depending on different kinds of functions.



Once the basic urban structure is established and we get the basic functional volume position at the site, we make architectural catalogue's of different spaces starting with the main function of the site, i.e.- Dwelling



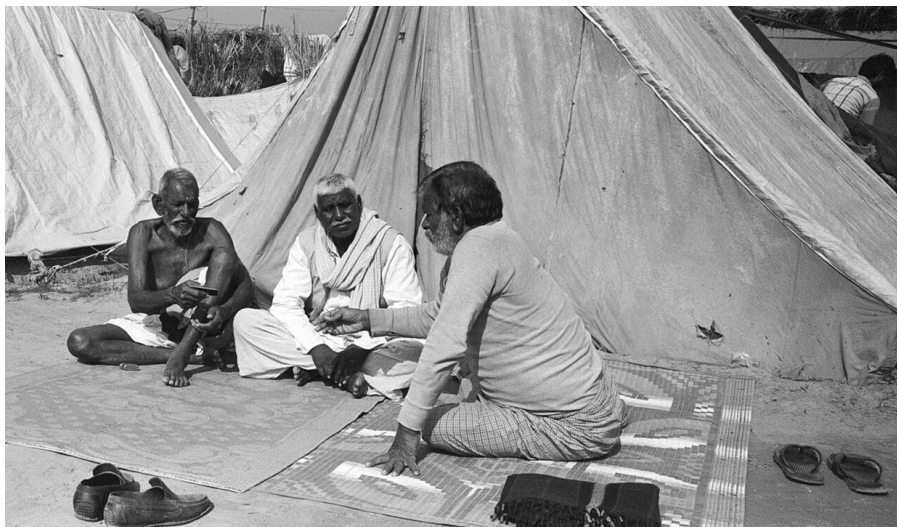
Preliminary findings showed us overspilling of functions outside on the street.



Everyday activities like cooking and washing are done outside and there is no clear demarcation for these functions which creates chaos.



There is hardly any buffer between two tents.



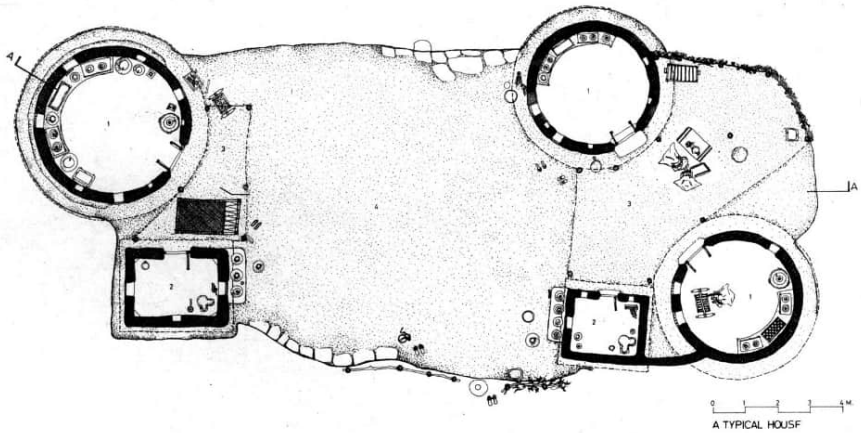
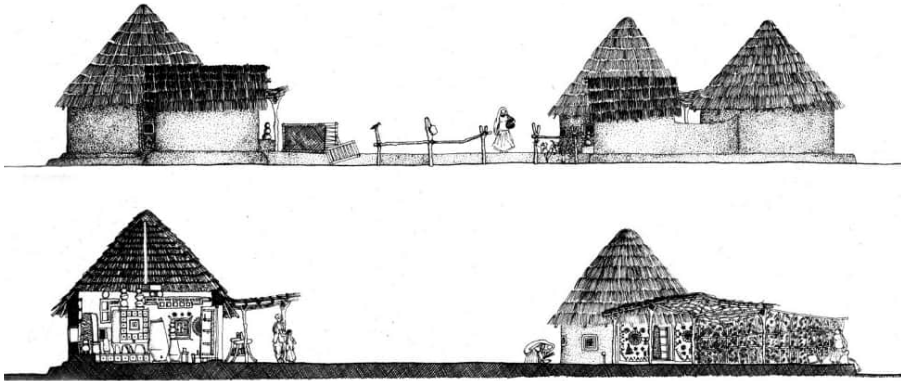
Lack of proper social spaces leads to overspillage of functions



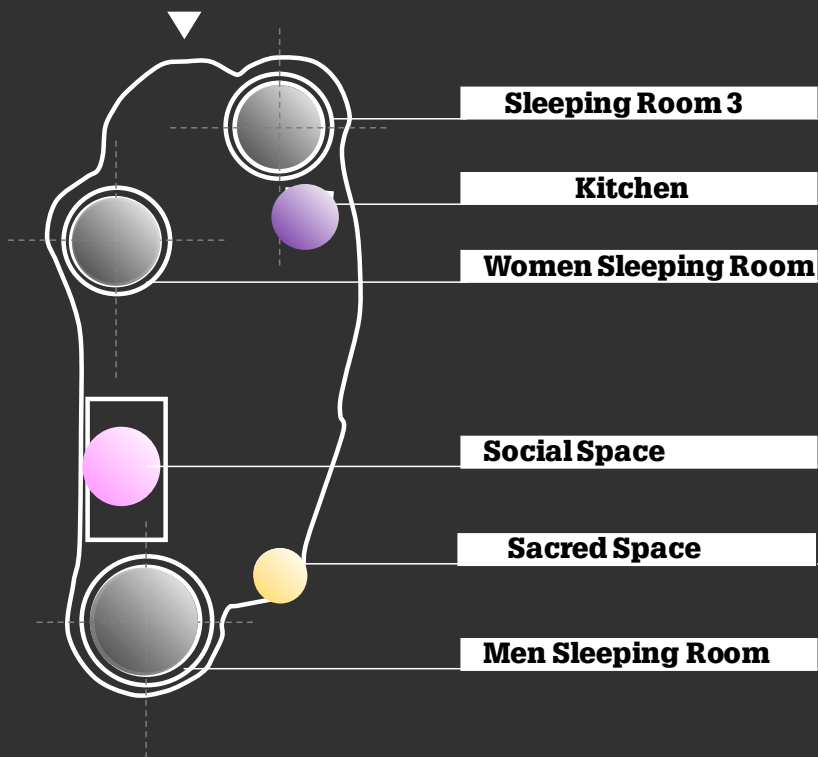
Coking and washing activities



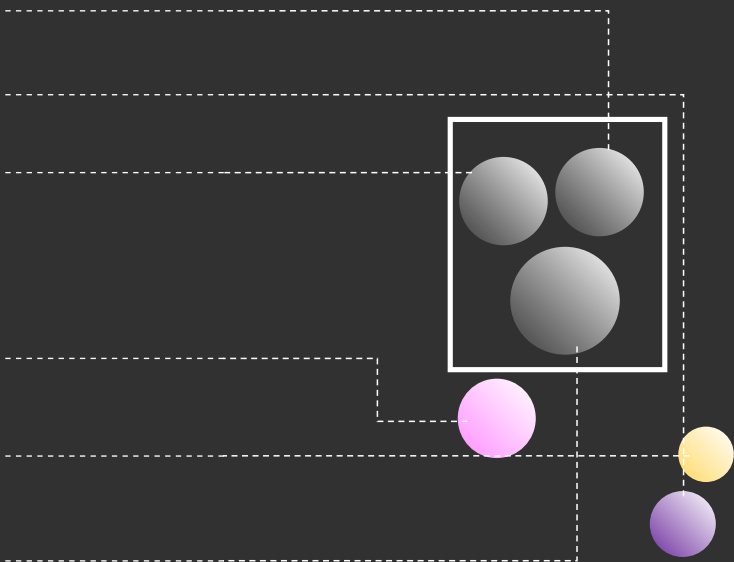
The traditional vernacular settlements made of earth materials is taken as reference for optimal living conditions required at site.



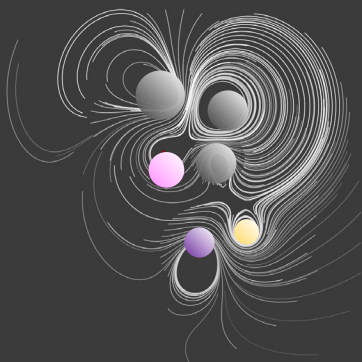
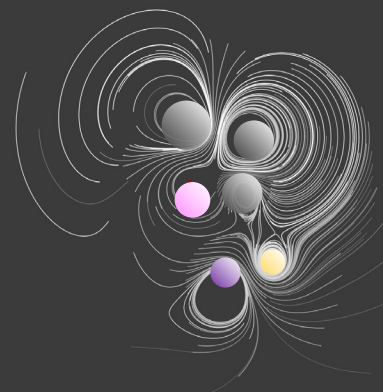
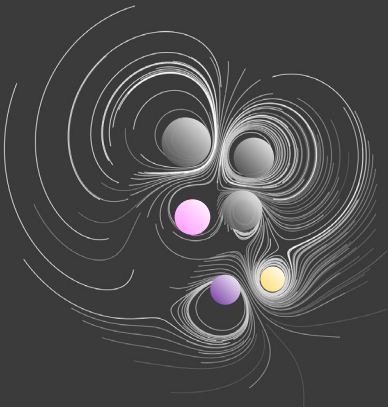
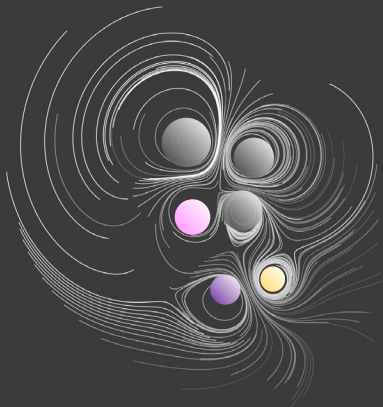
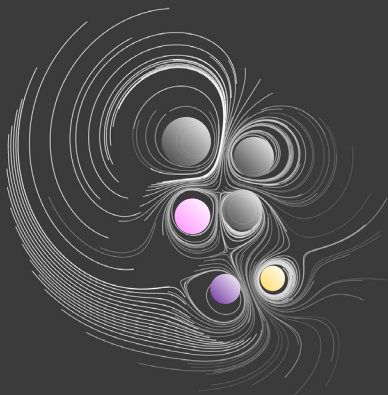
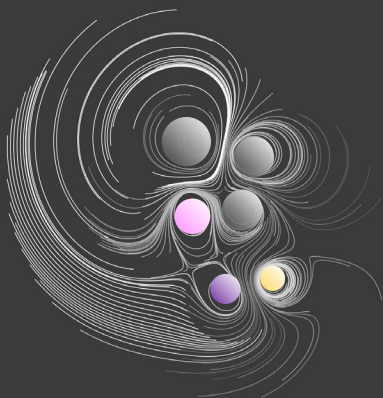
Detailed designs show proper demarcation for everyday activities like cooking and washing and also socializing.

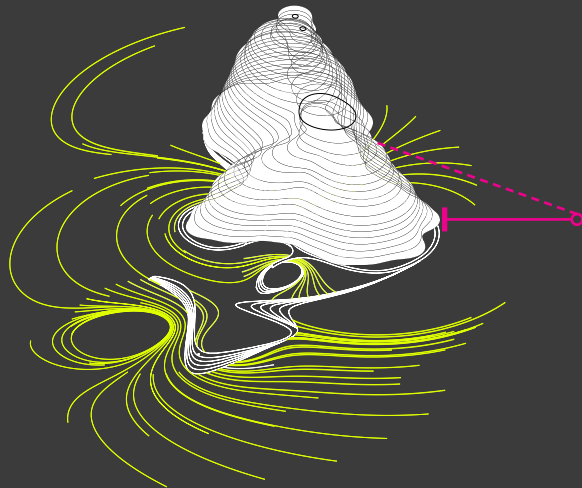
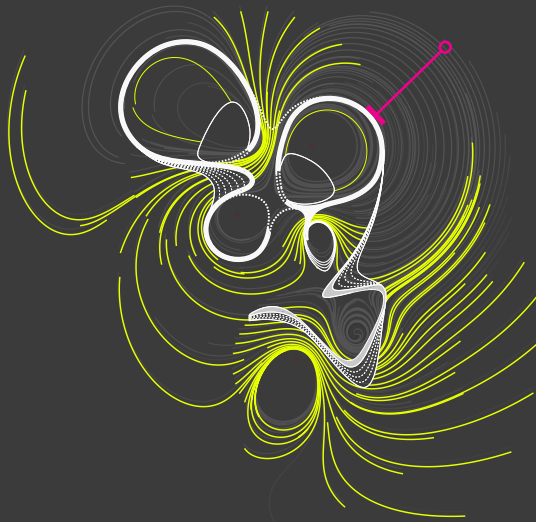


The traditional village house is taken as an example since 90 percent of the people who visit Kumbh come from villages.

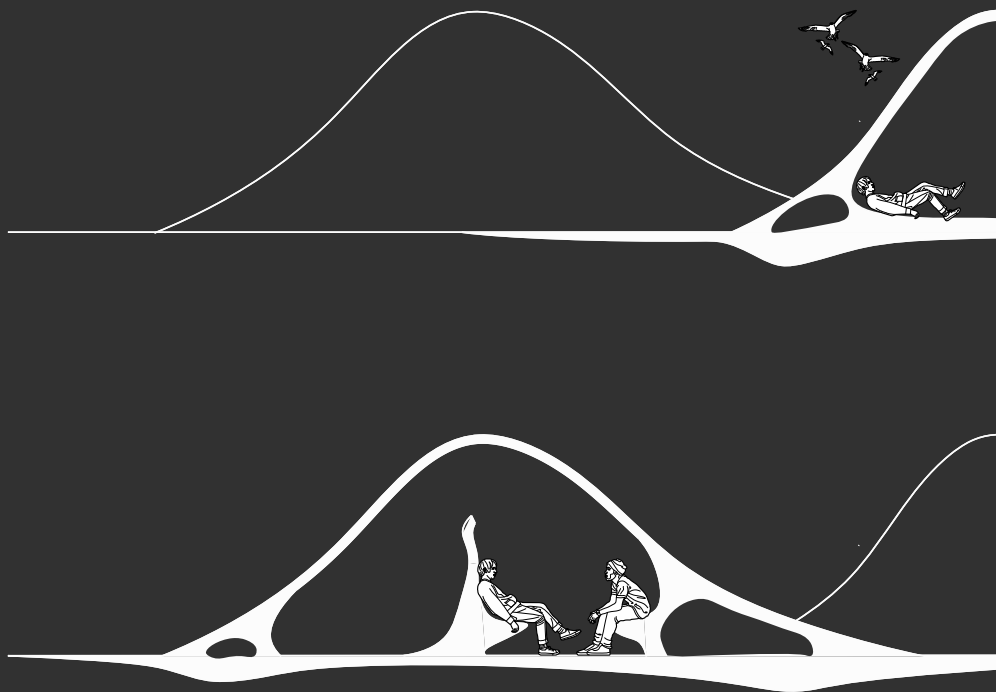


Research showed that area allocated per human is less than required amount as seen above where all the functions overspill outside.

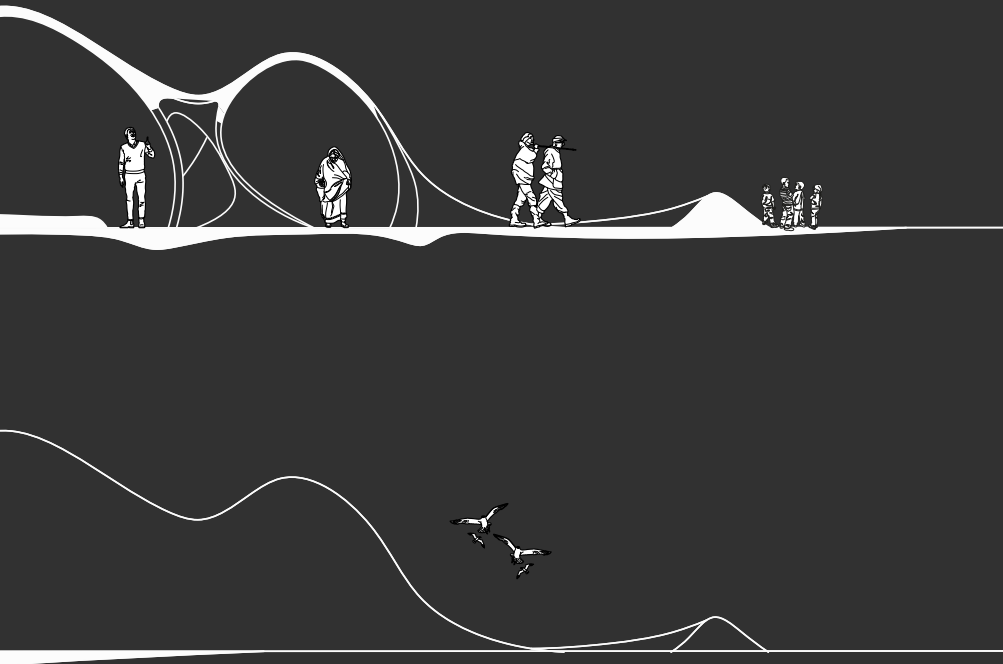




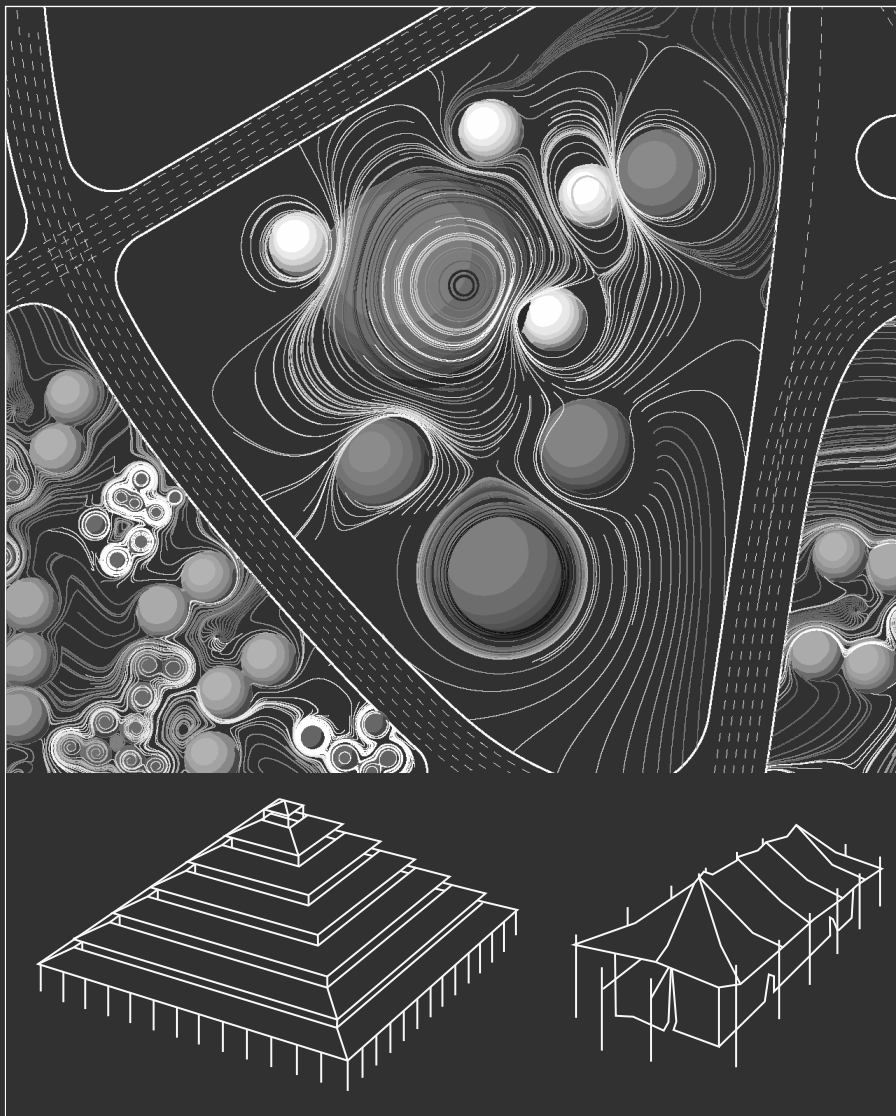
Taking all the functions together, Different aggregation rules were applied which uses the same contour disruption simulation. The results gives us the basic extent and height of the volume as well as buffer space needed for ramp system which would lead to interconnected catenary system.



[In-Flow]- P2



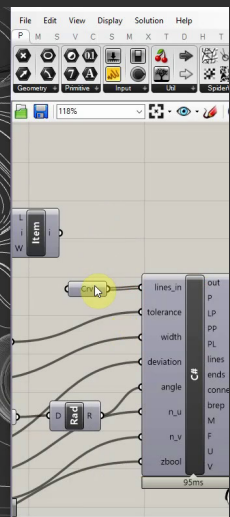
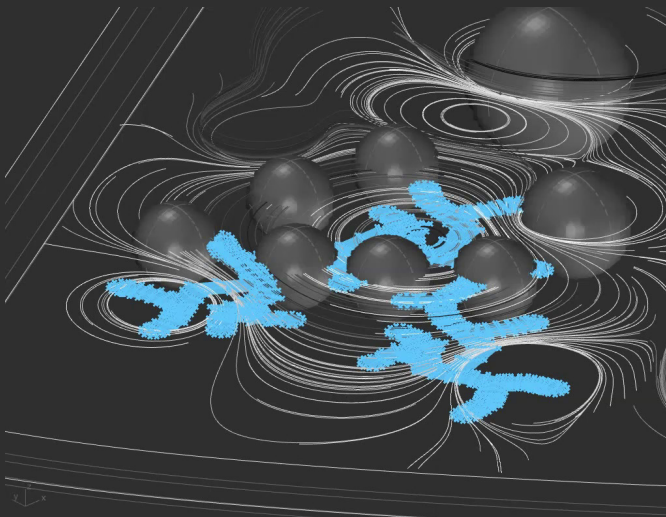
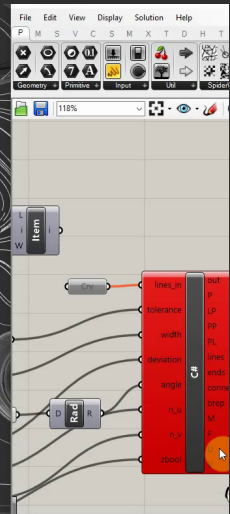
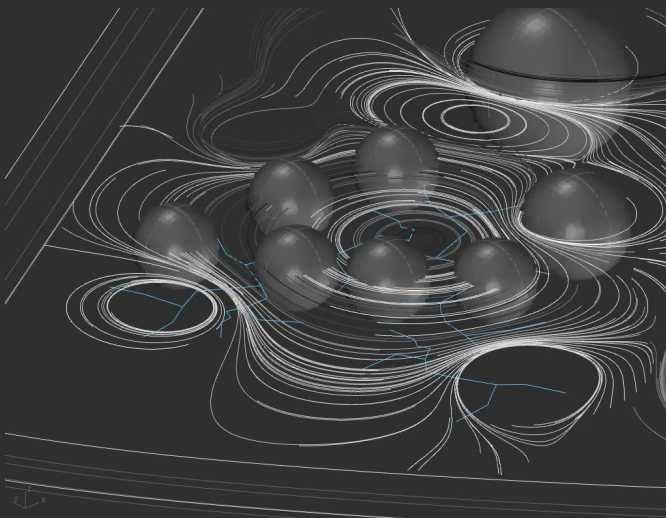
Schematic sections showing integration of furnitures in the main structural system.



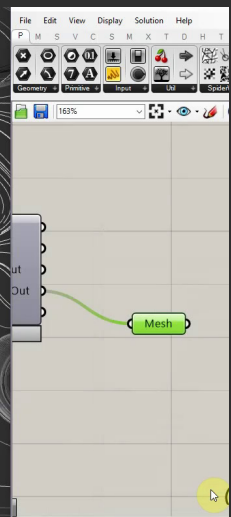
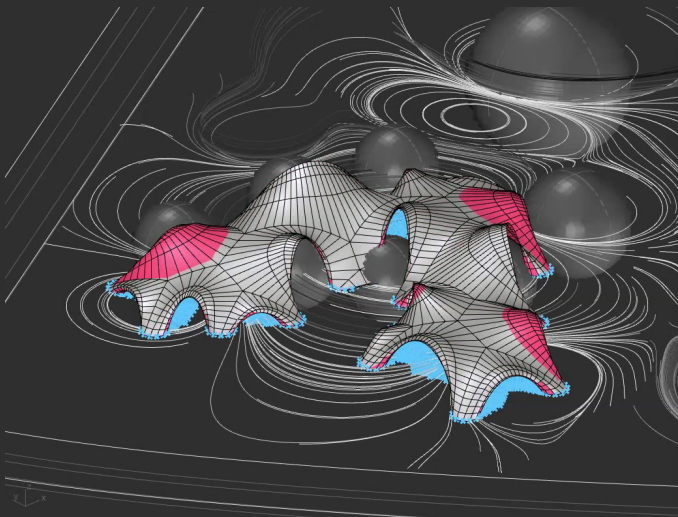
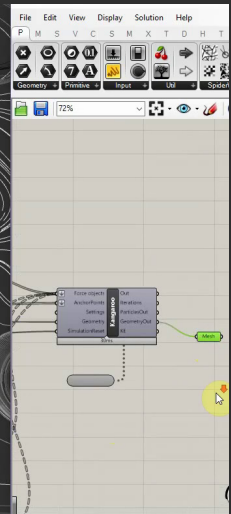
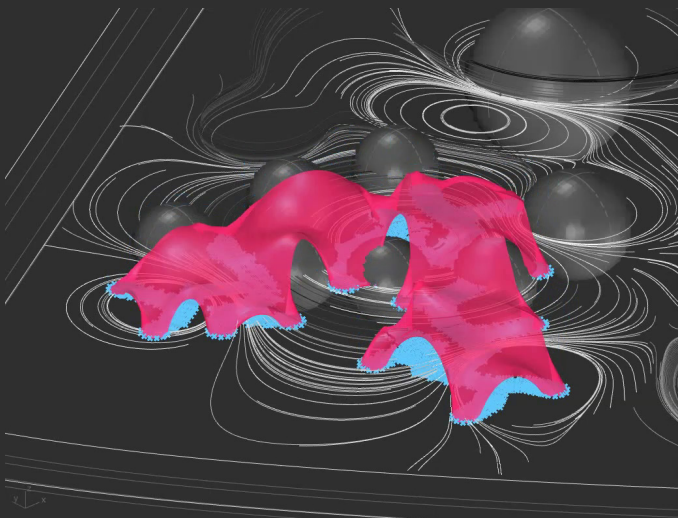
The next architectural function to be detailed is the public function buildings.

Facing page- Pavilion

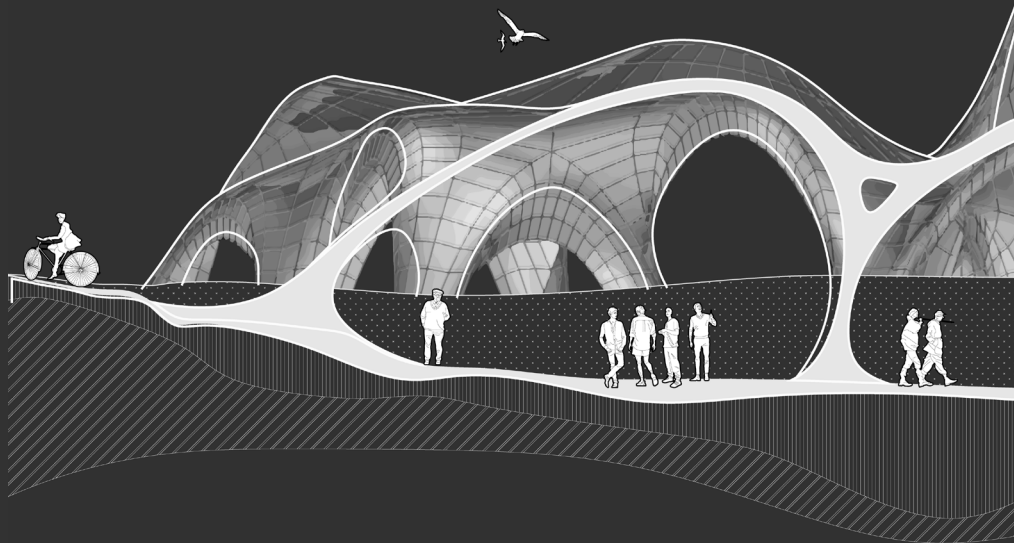




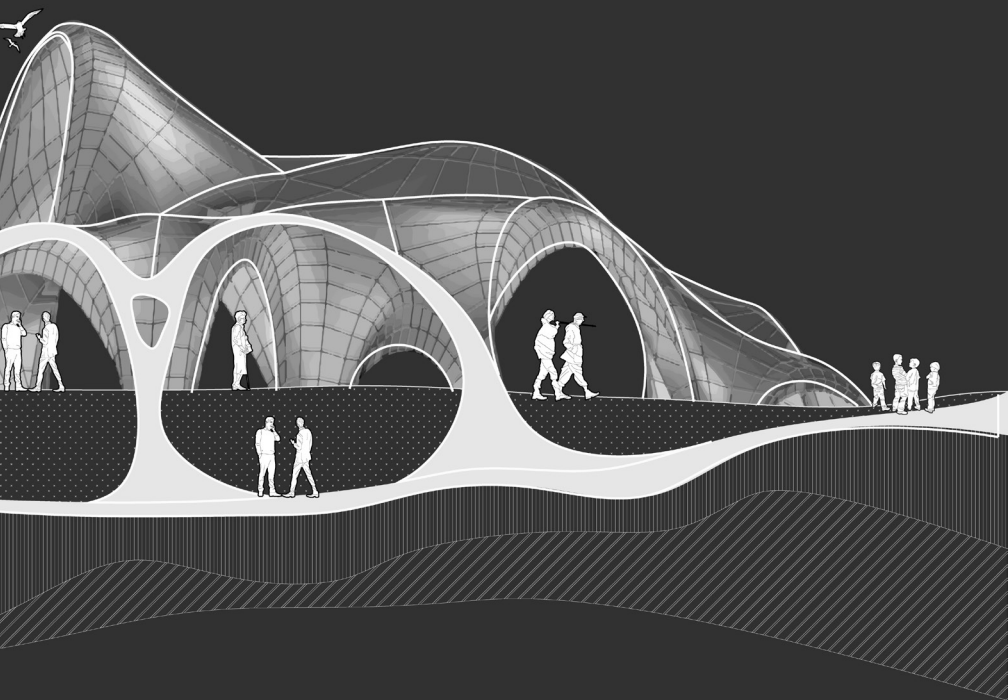
The above image shows the basic distribution of public functions. The tertiary network around the site is taken as spine for the catenary system and distributed amongst the spaces.



The simulation can control the slope, height and opening sizes of the model. These basic information are inputs from previous contour disruption simulations.



[In-Flow]- P2



Schematic section of public building showing interconnected catenary system.

IN-FLOW

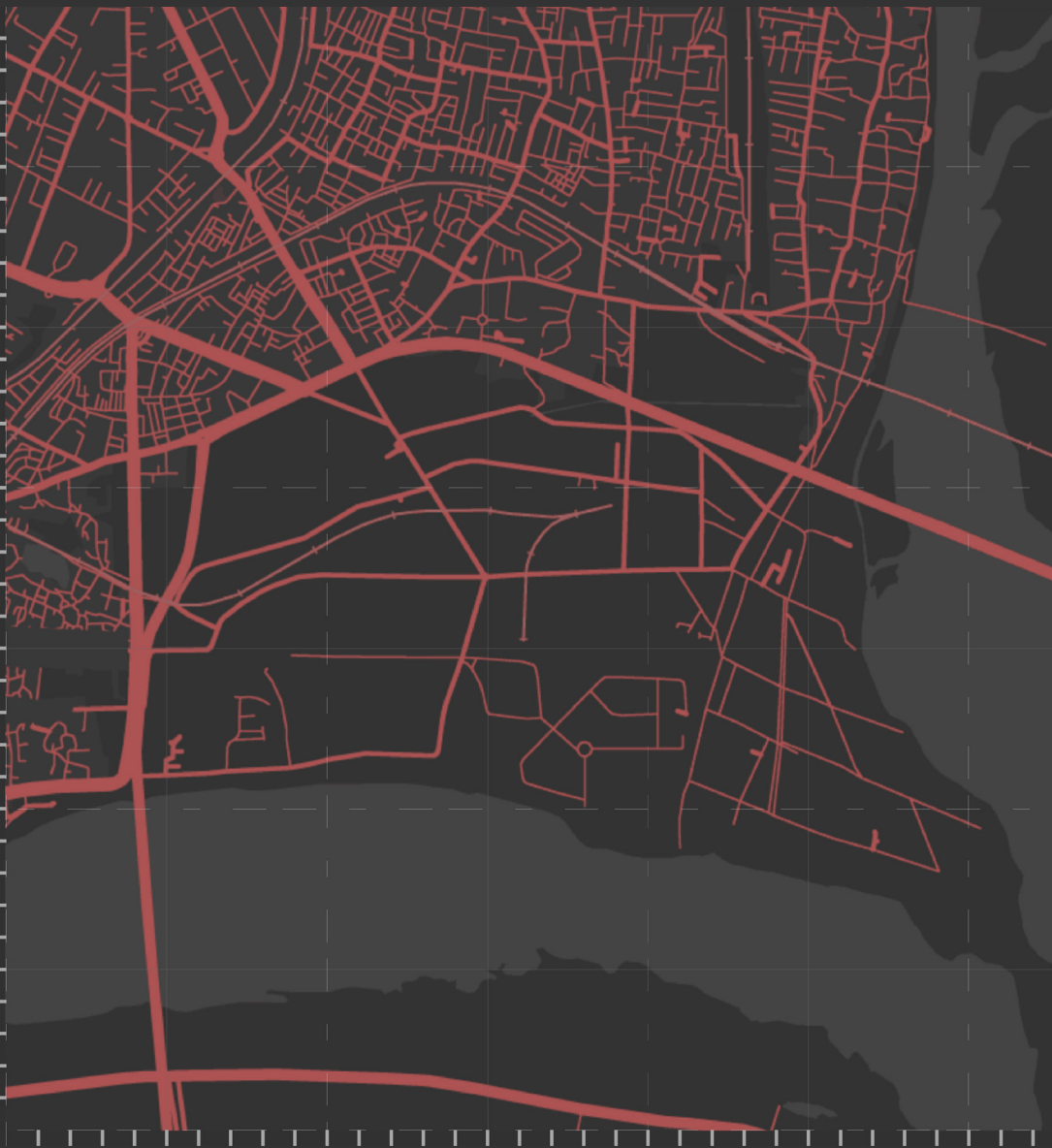
Design Progression [P3-P5]



The chapter shows the continuation of design progression from P2.



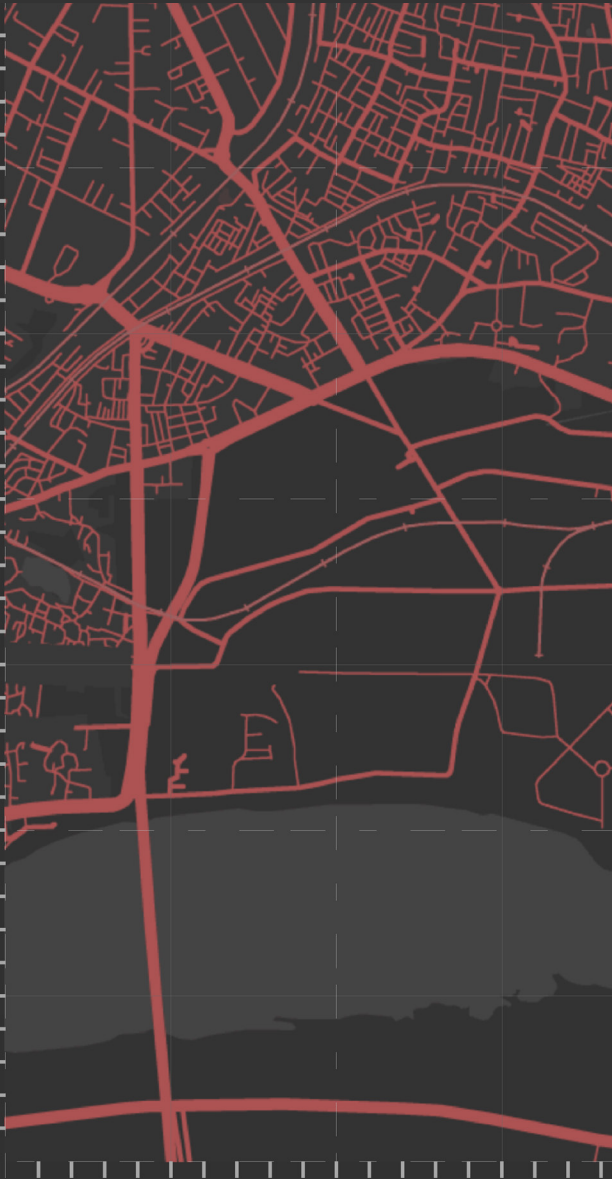
Urban Design Physical Model



[In-Flow]- P3-5 Design Progression



Site Mapping, Kumbh Mela, Allahabad



[In-Flow]- P3-5 Design Progression



Overlaying kumbh 2019 satellite imagery



[In-Flow]- P3-5 Design Progression



Extracting primary and secondary road networks.



The overlapped grid shows the discrepancy in the flow of the urban design as we come near the river bank. The design is done thinking about the area requirements and articulating it into rigid grids and doesn't take into account the contours of the site.



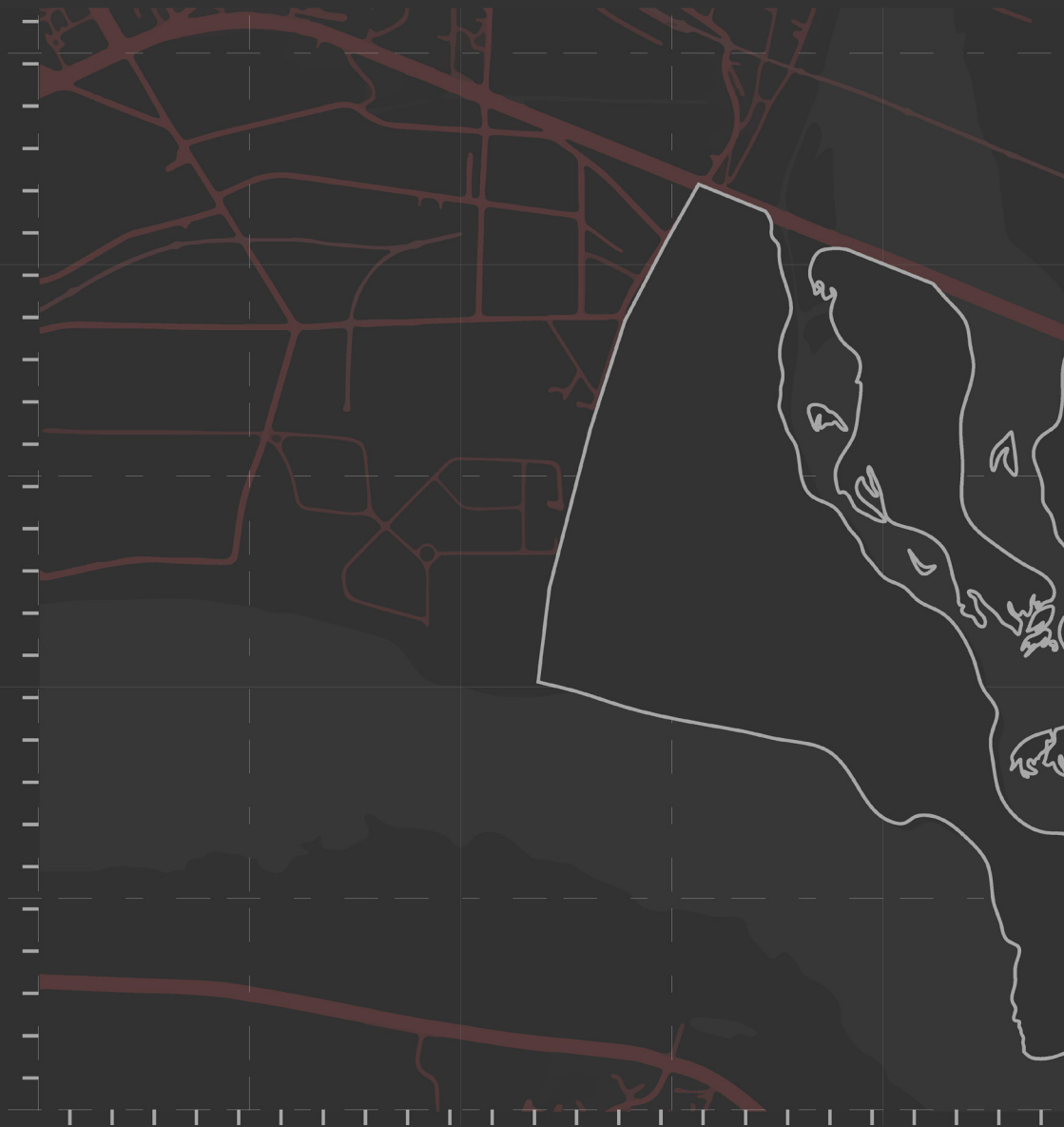
The rigid planning leads to chaos at the site since a large amount of sand is cut and filled to make this grid.



[In-Flow]- P3-5 Design Progression



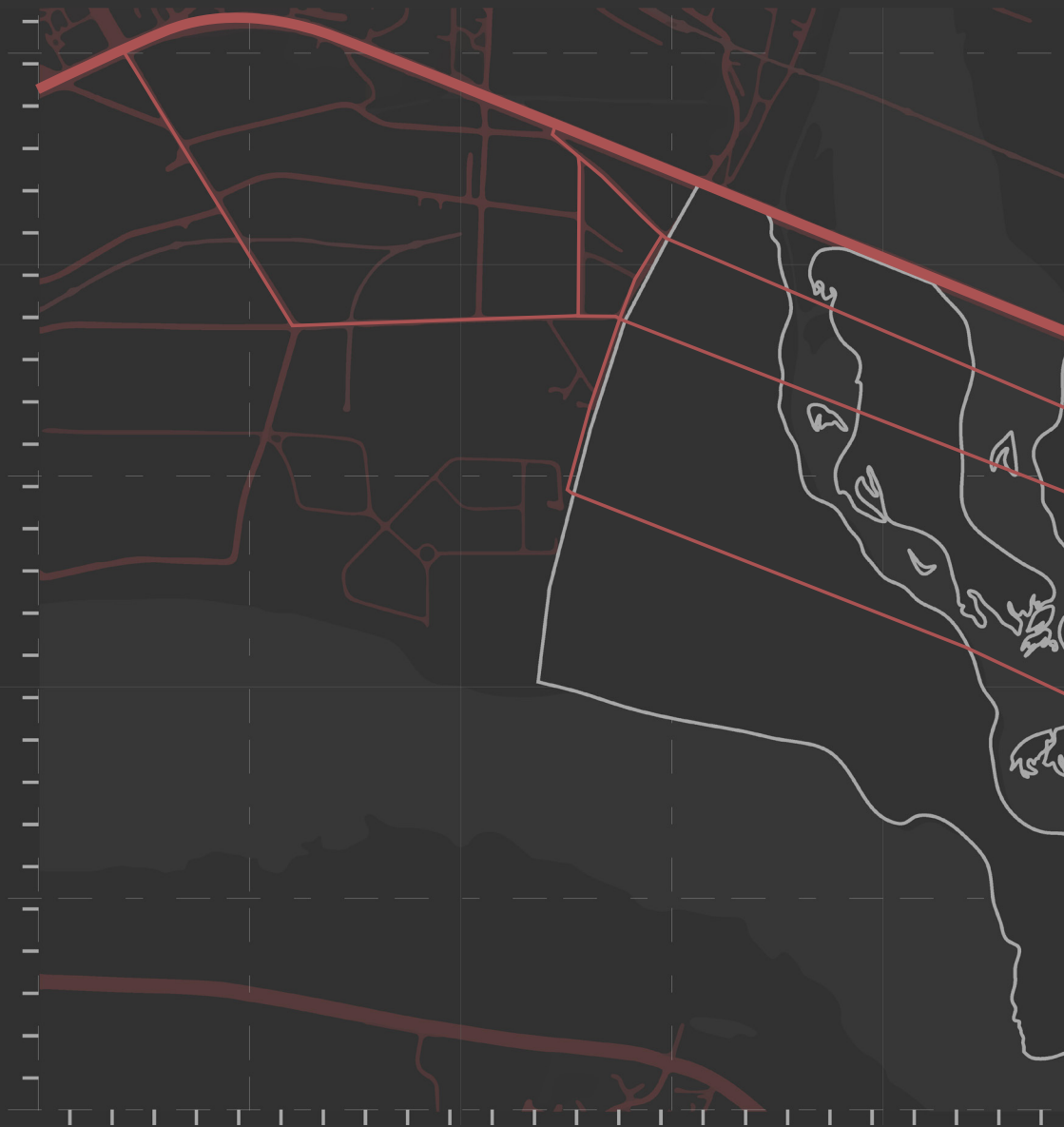
In the above images one can see the hindrance these sand piles create in the movement between spaces. A huge amount of traffic navigates the site every day and hence its important to take into account the contours and make the primary connections which respect the natural contours of the site..



[In-Flow]- P3-5 Design Progression



Two settlements are taken for further designing accounting for a combined area of almost 2 million sqm.



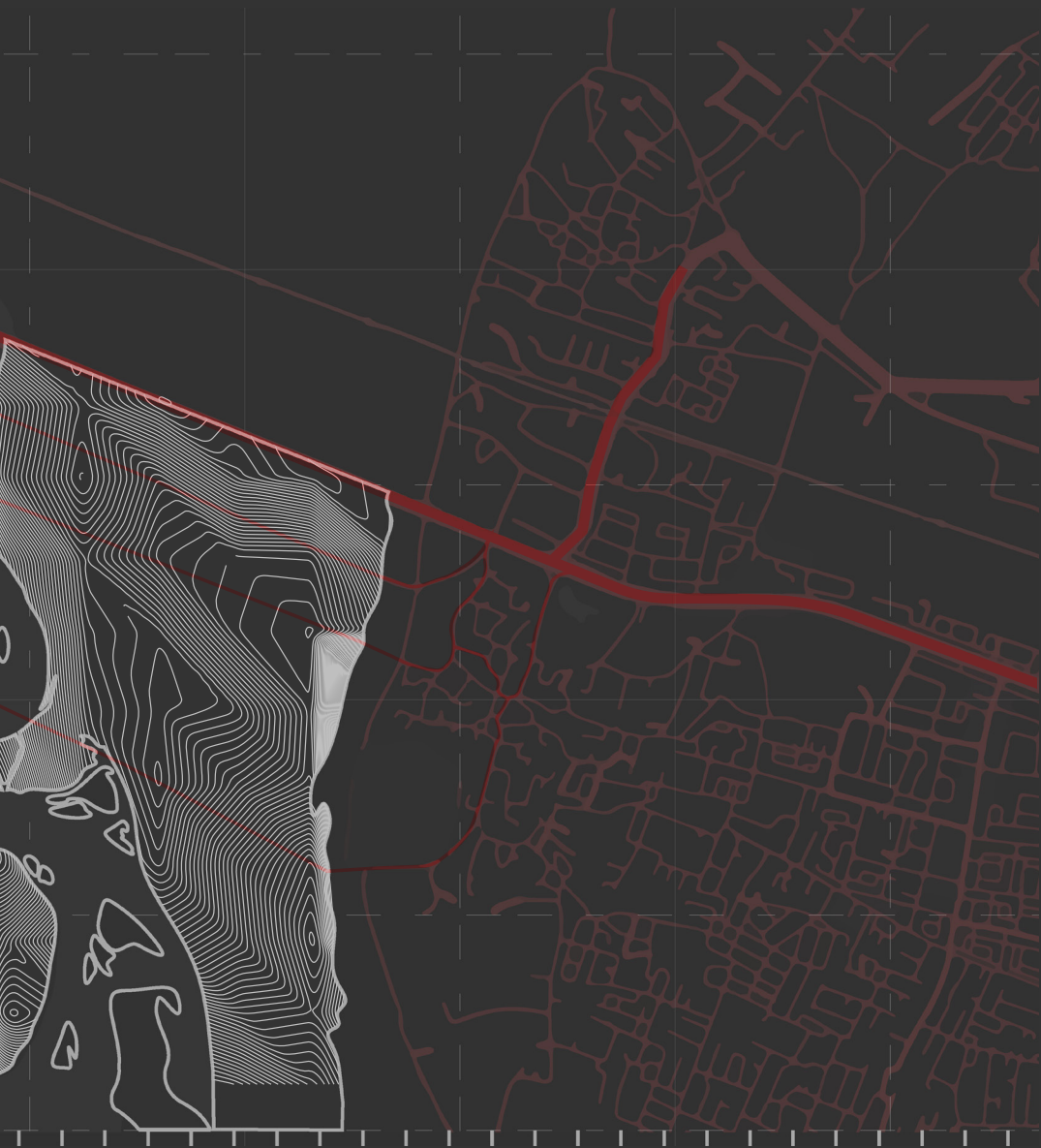
[In-Flow]- P3-5 Design Progression



The site is first fragmented with the main access routes connecting the sites to each other and its immediate context, because this needs to be clear and the shortest and straight length possible as this route caters to large amounts of people.



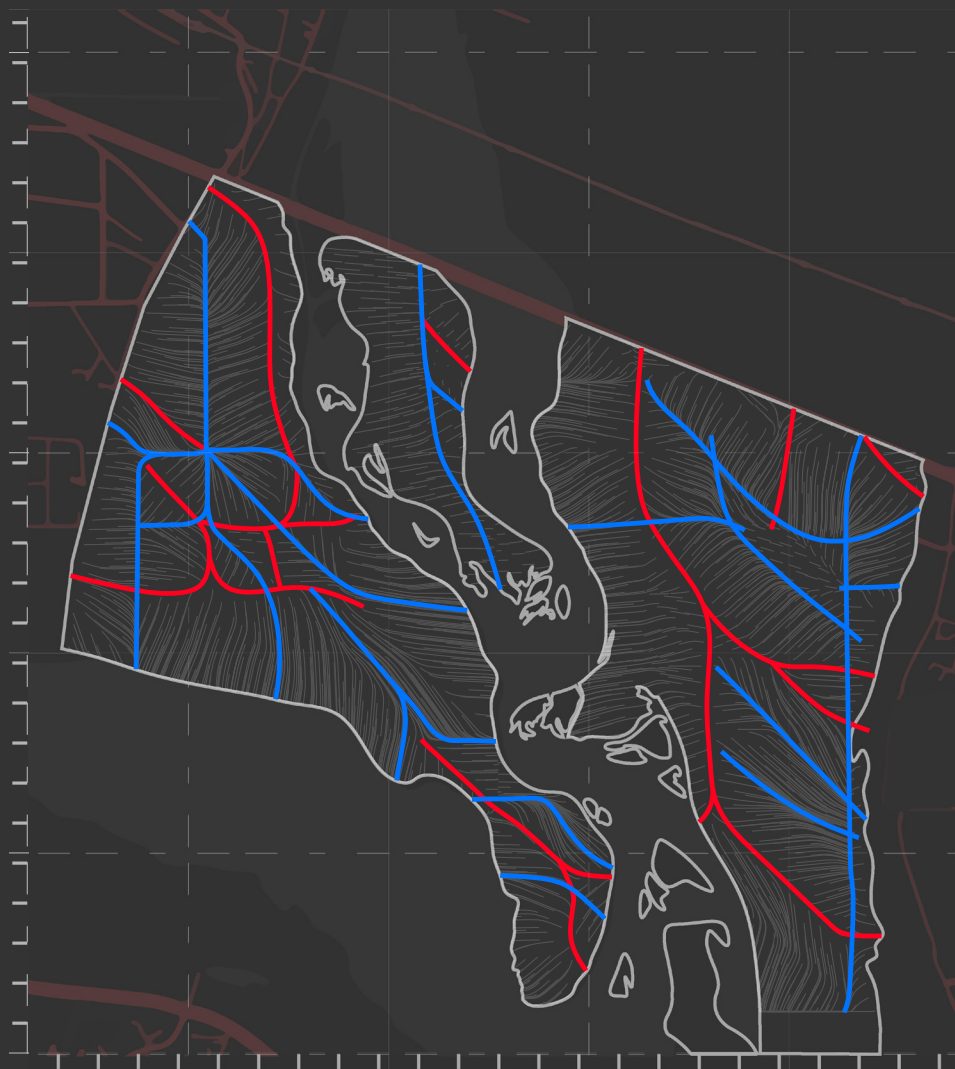
[In-Flow]- P3-5 Design Progression



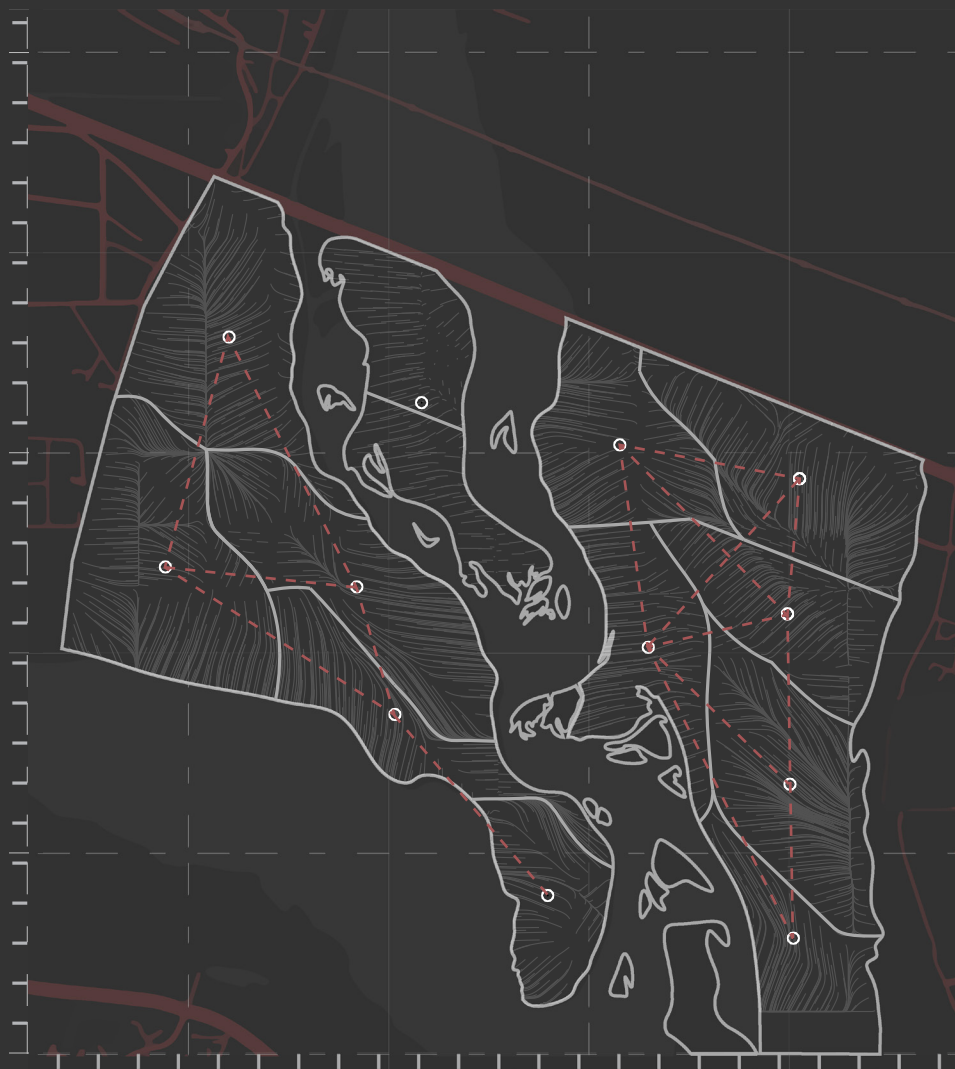
Contour data is extracted from Google earth.



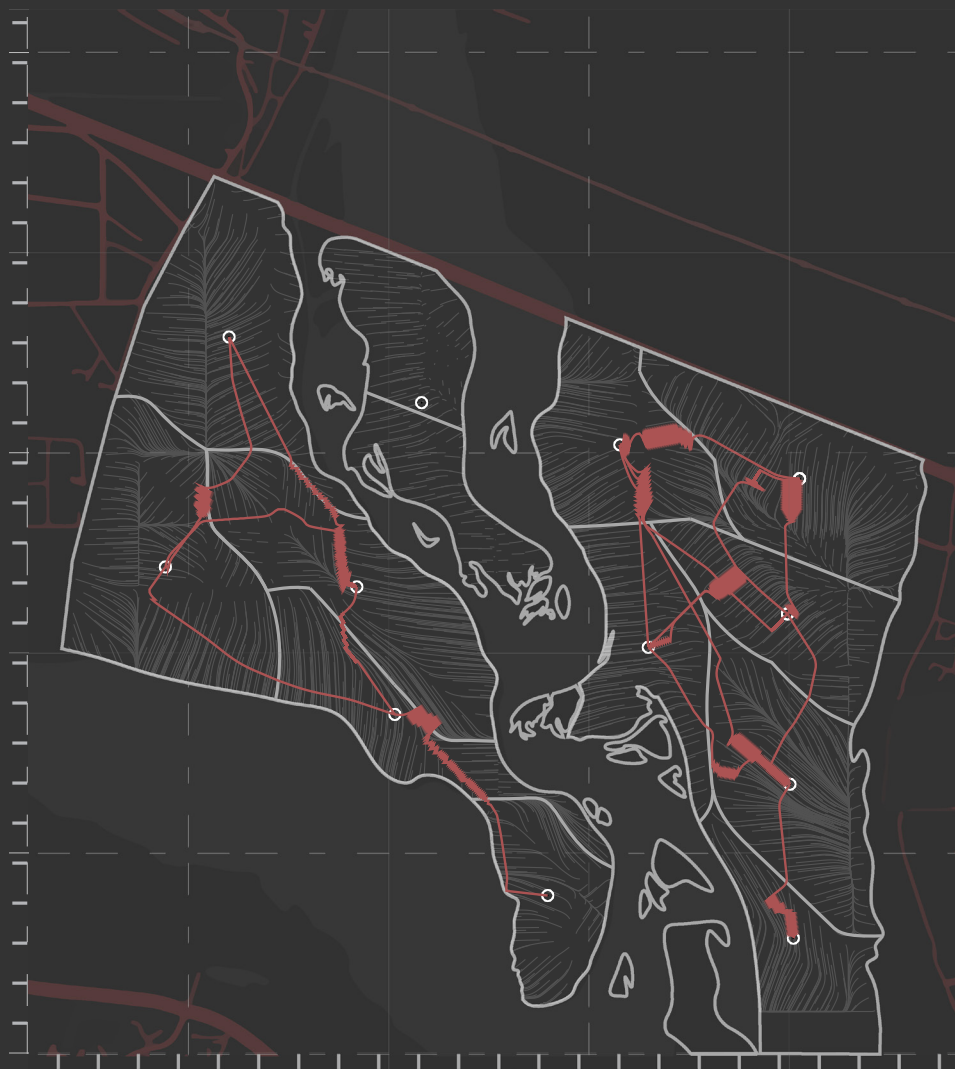
A drip simulation helps in extracting the valley and mountain curves and helps in understanding the natural flow of different land parcels. These would later help in identifying parcel boundaries.



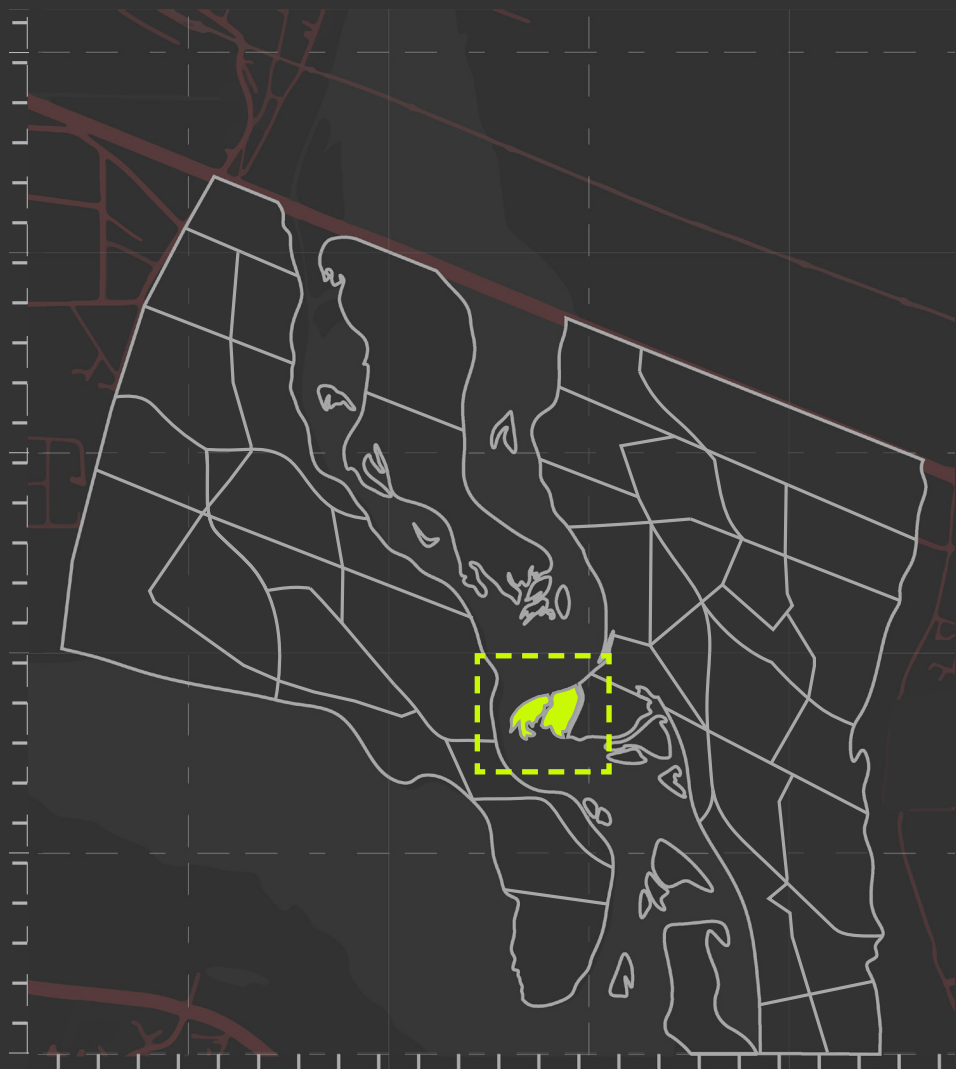
We use the primary mountain and valley curves as our sector boundary which yields 4 to 5 sectors per settlement.



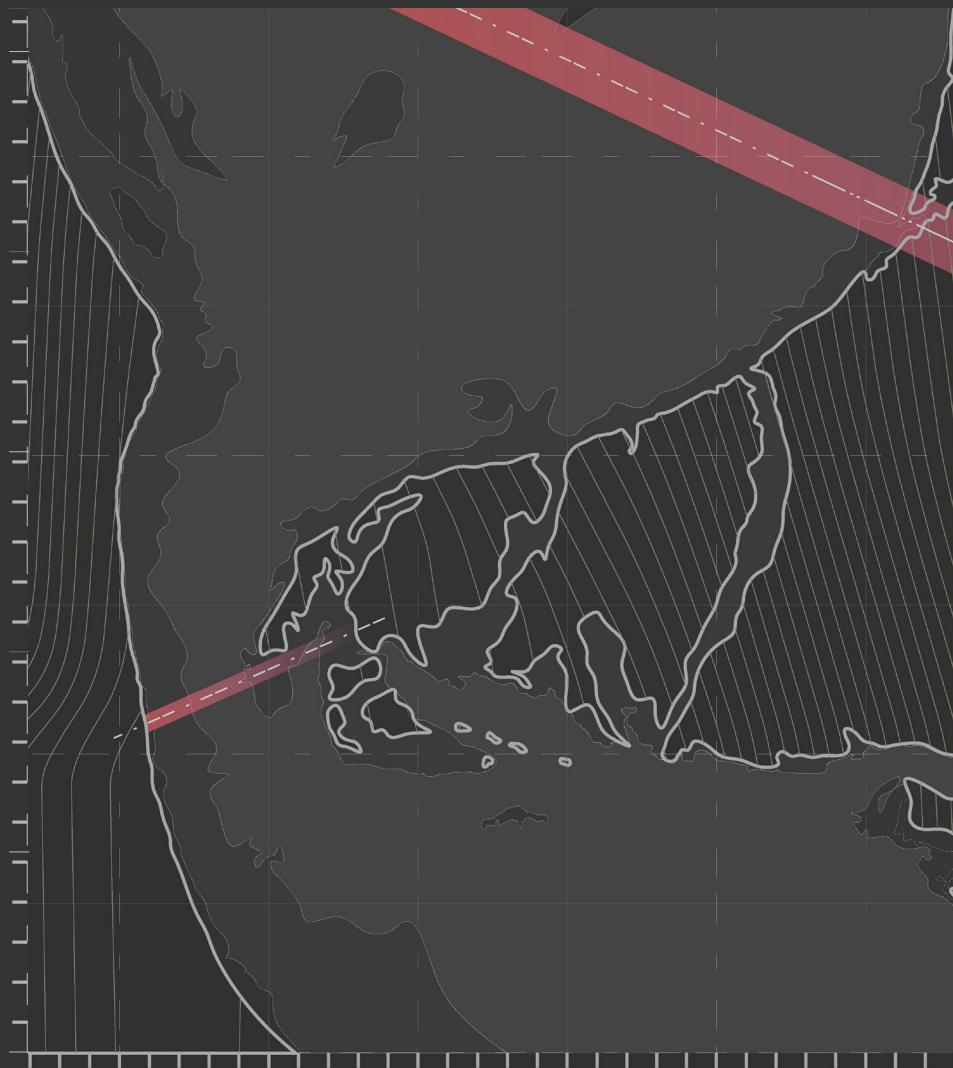
Every sector has a pavilion at middle point since the Hindu planning system states that the middle point will have the most important functions as it is considered holy. These middle points are interconnected and will carry major traffic since they cater to public functions.



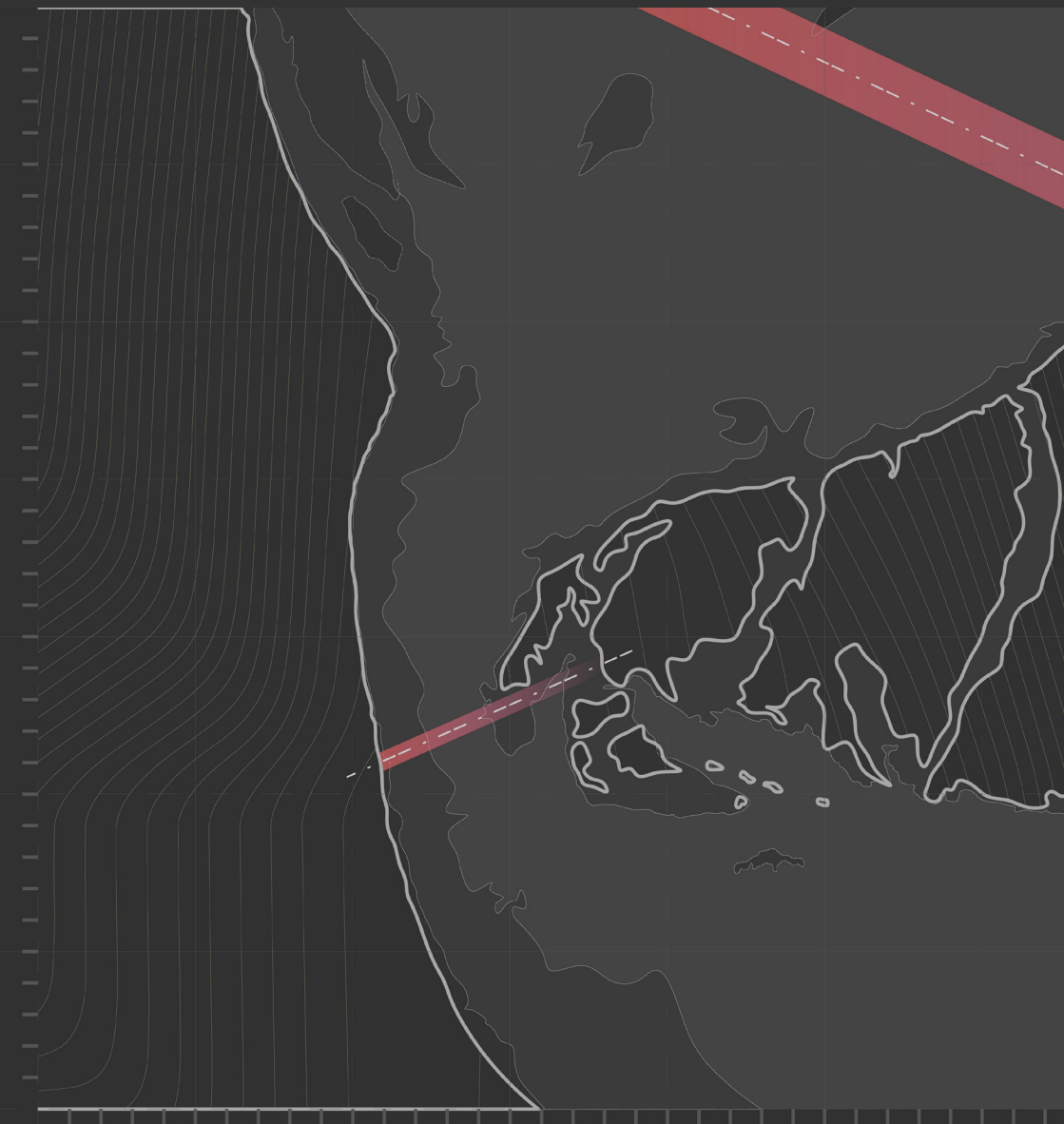
In ideal grid planning system these middle points would be connected in a straight axis, but due to contours on the site, a walking simulation is done which takes into account the contours and gives us the shortest possible walking route through it.



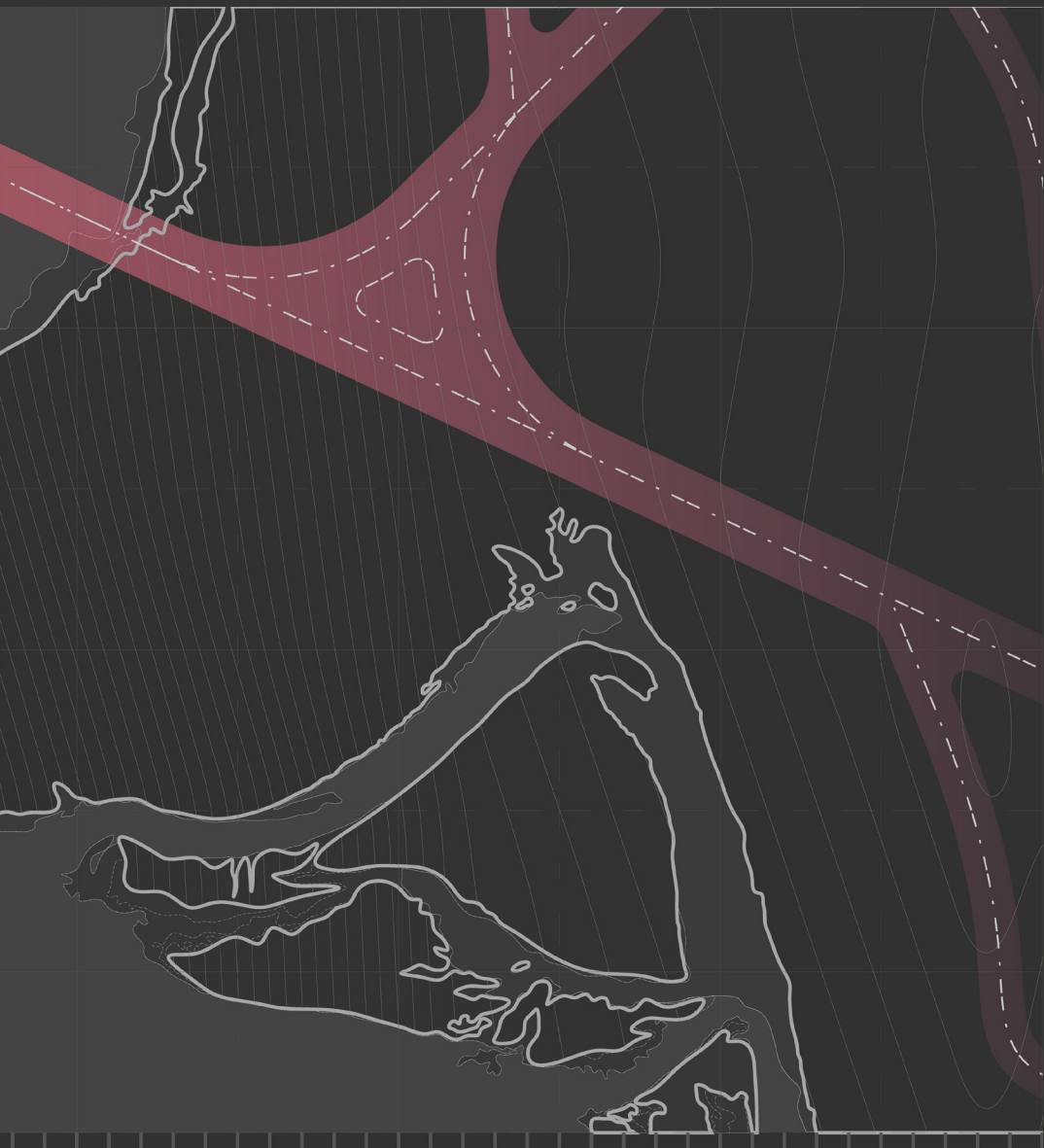
Combining all the data from the two simulation and the site fragmentation based on access we get out final site fragmentation into blocks. One final block is selected for further detailing.



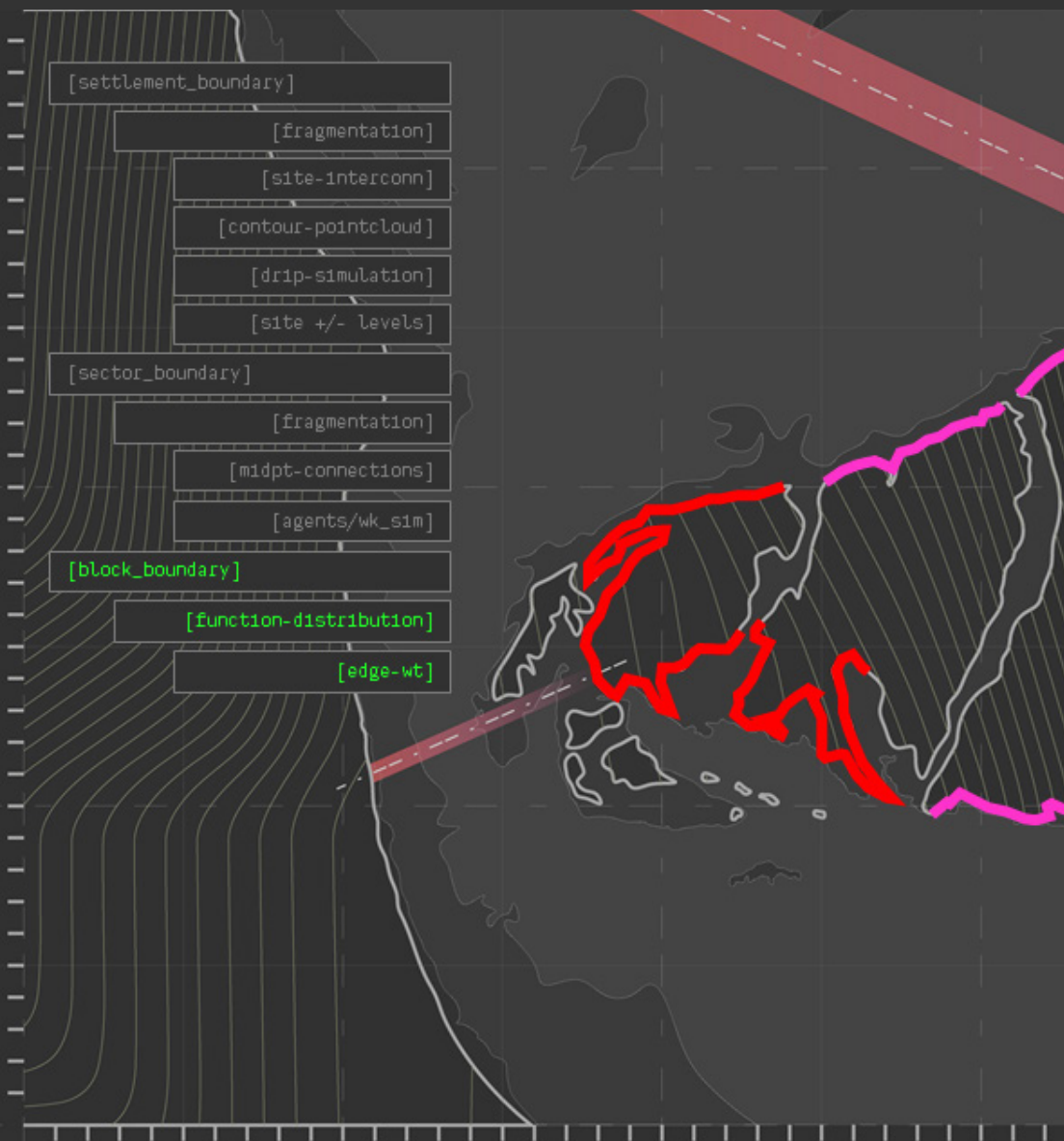
Selected block for detailing.

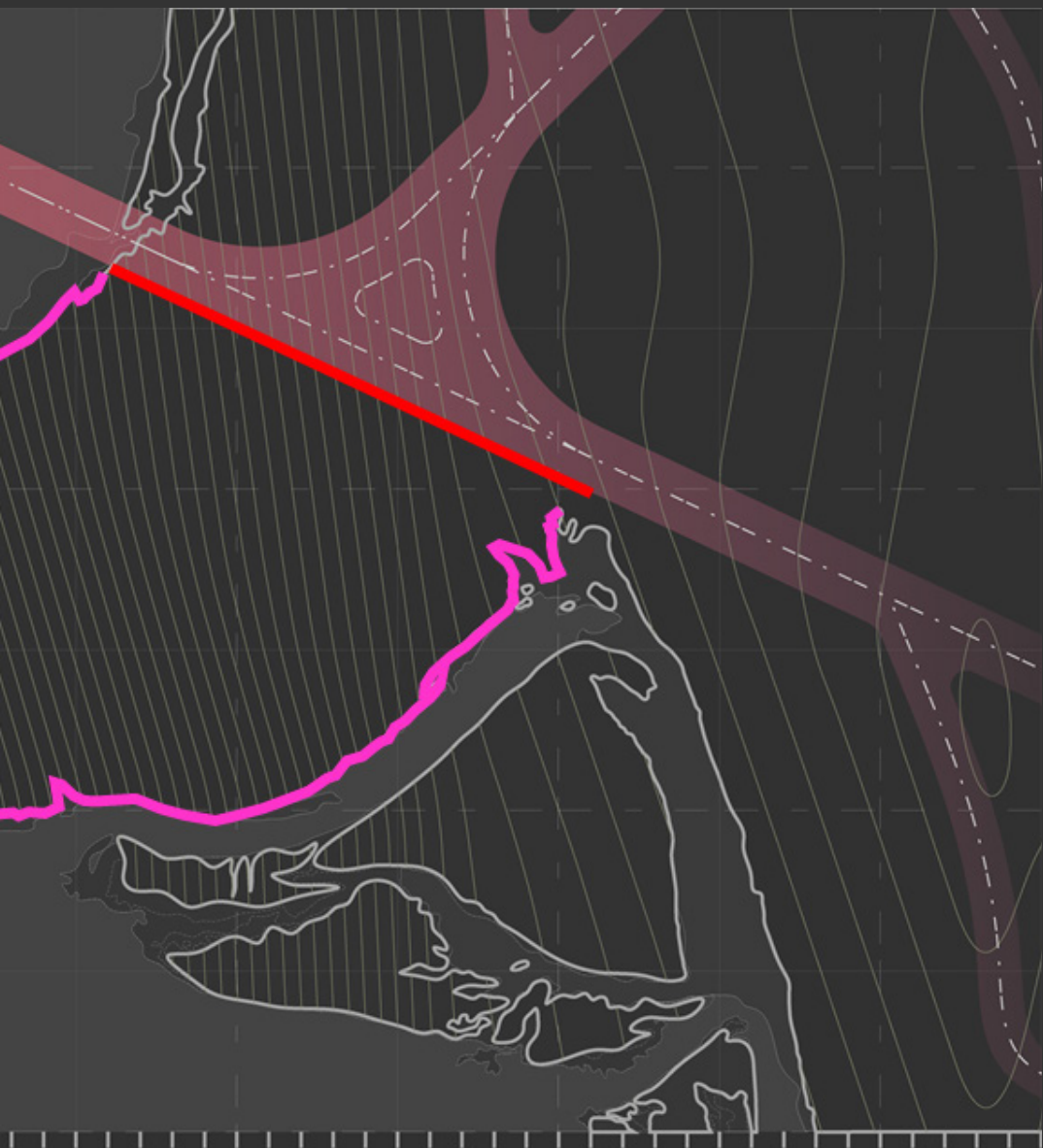


[In-Flow]- P3-5 Design Progression

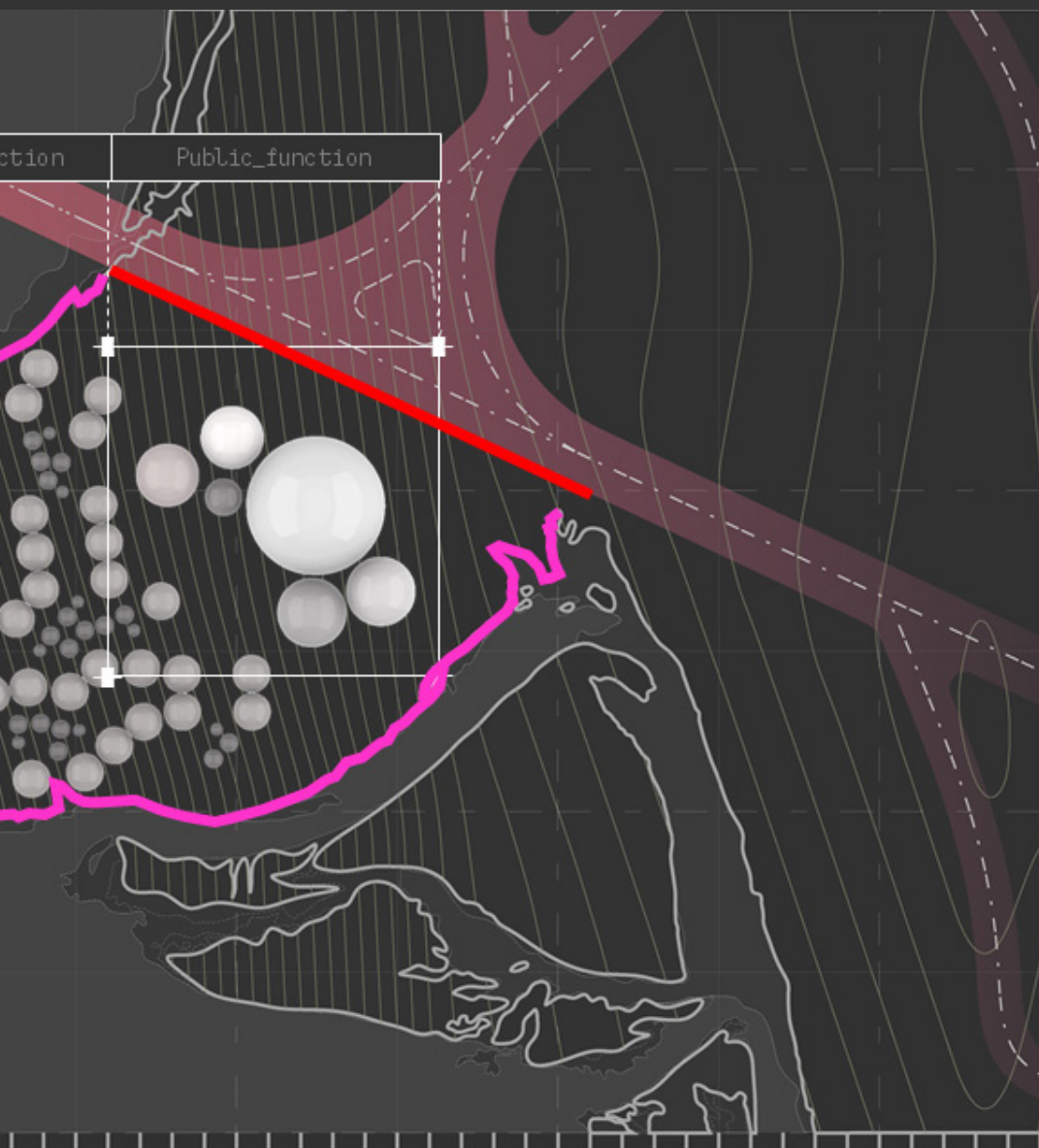


Design catalogues done during p2 stage are now embedded into this block with added edge conditions parameters.

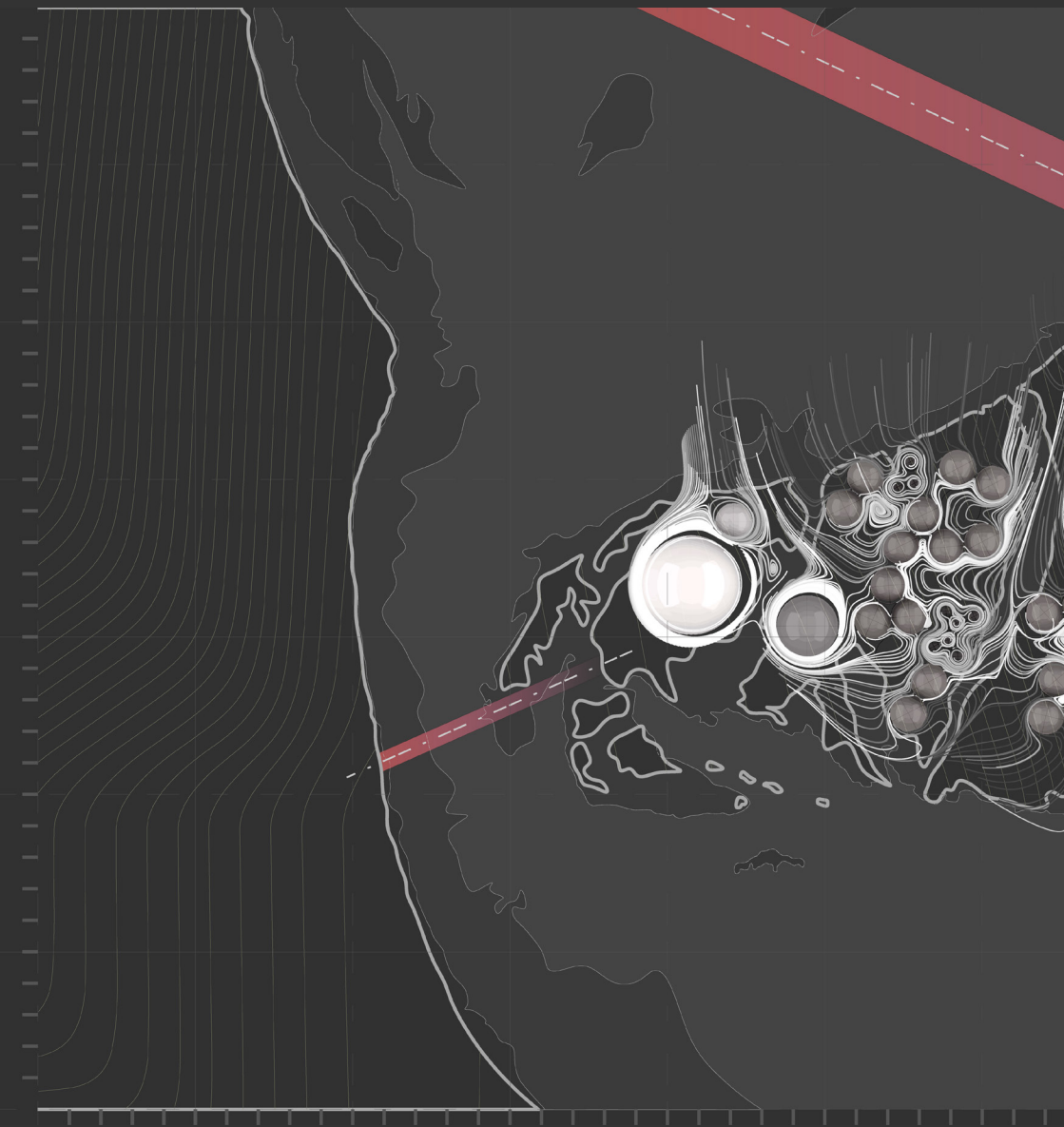




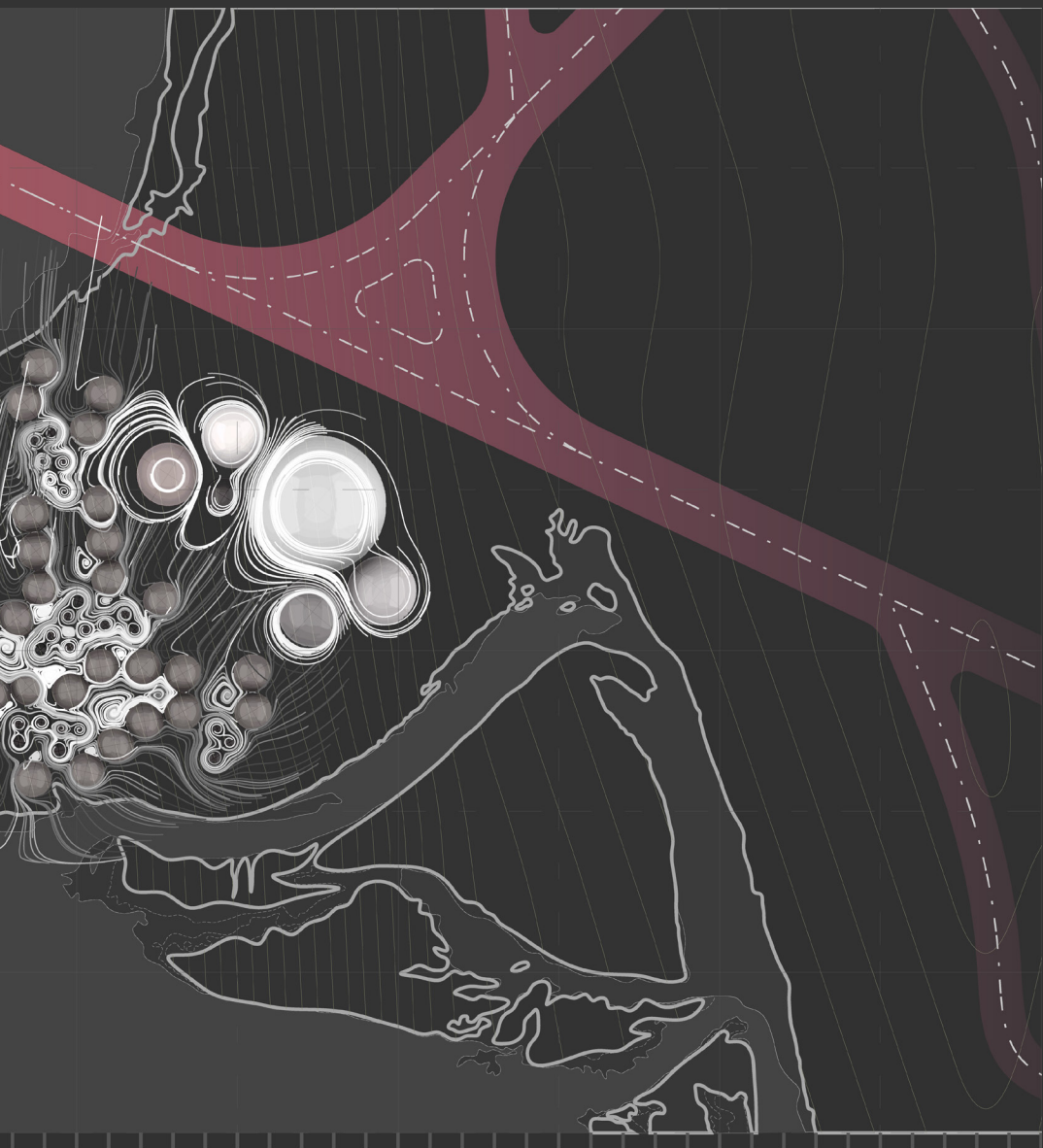
Different edge conditions will dictate the positioning of public services, private services and sanitation infrastructure.



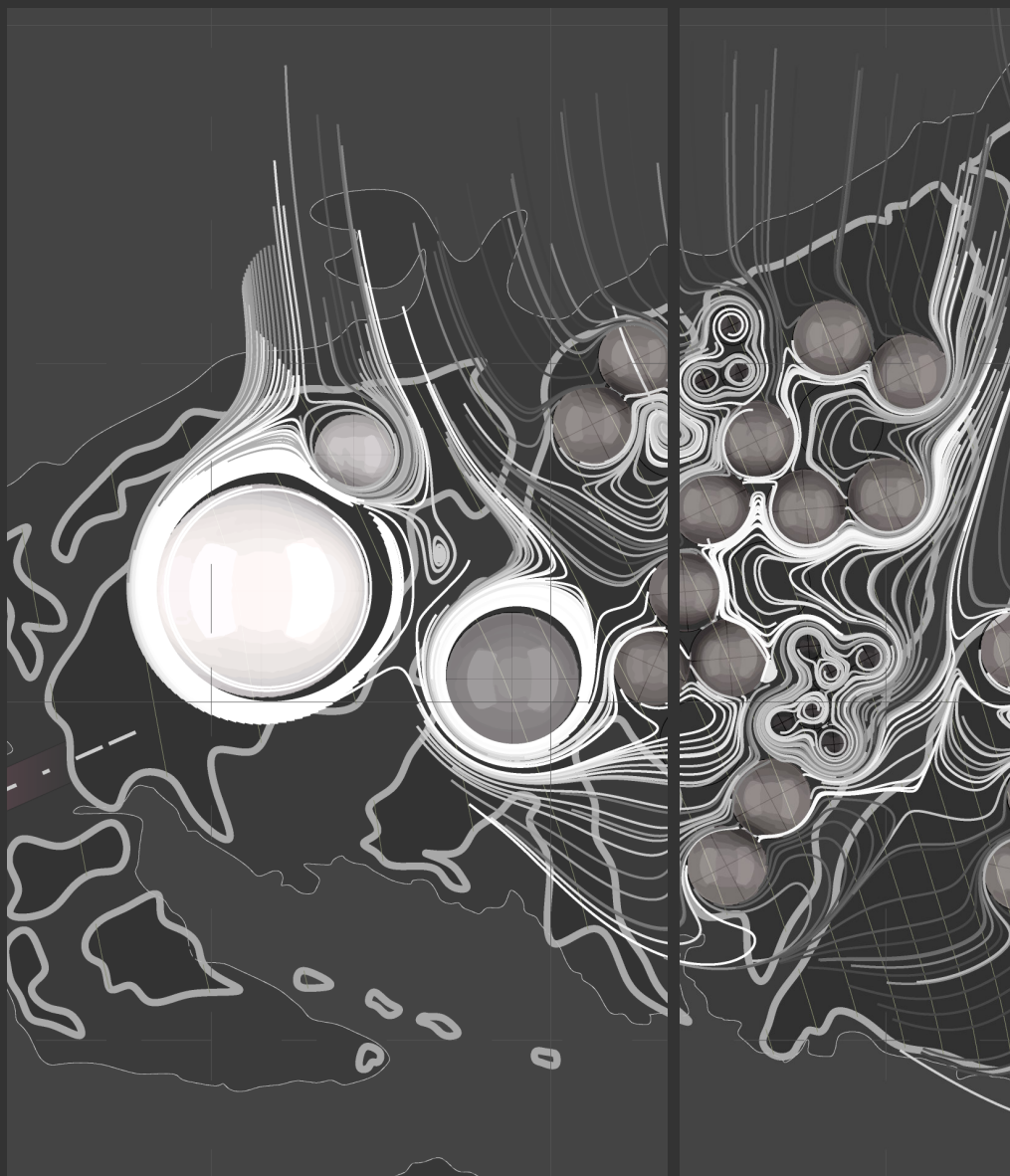
Public facilities are pushed to the periphery, the main access road and the river bank while the dwelling clusters are in the interior part.



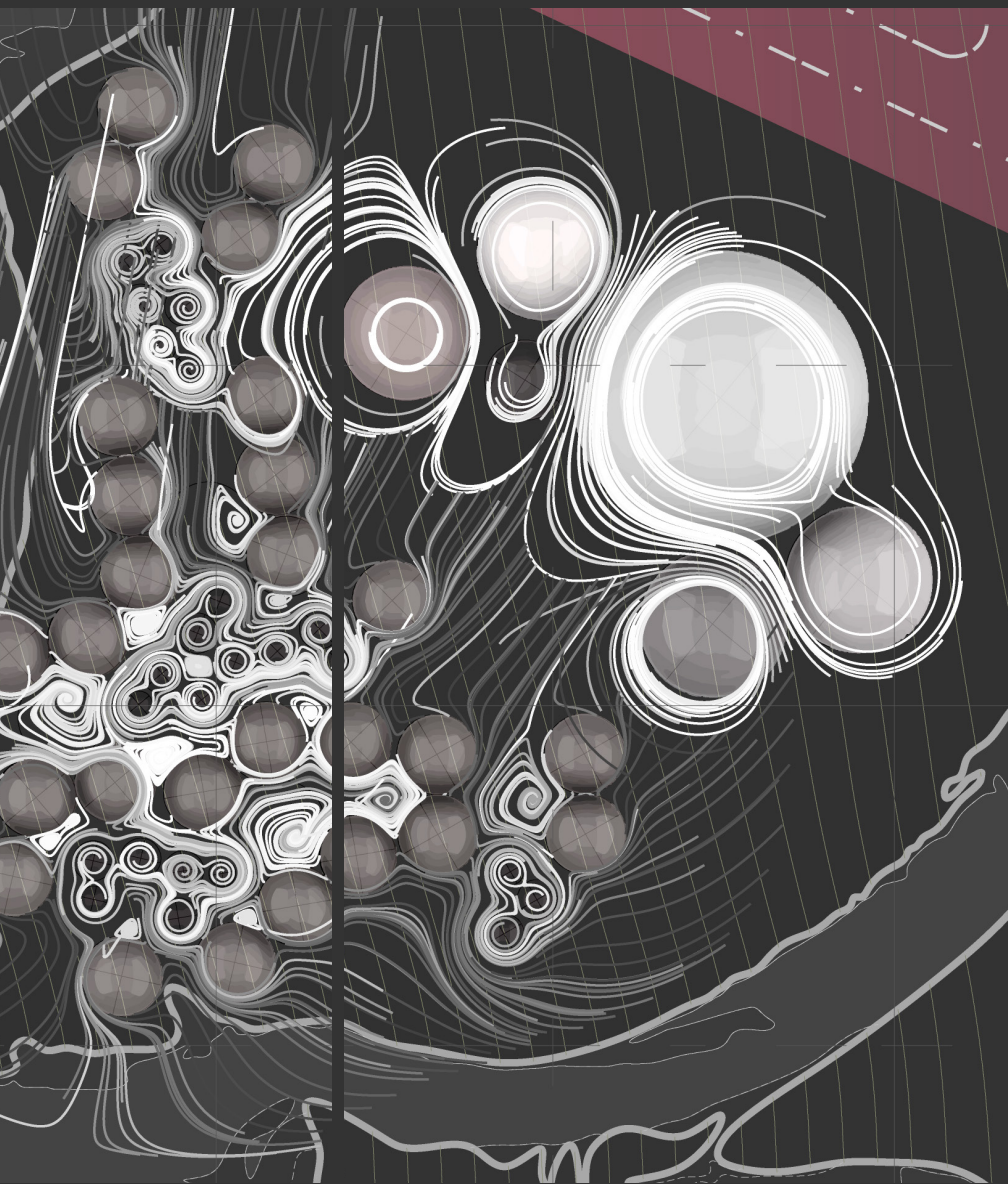
[In-Flow]- P3-5 Design Progression



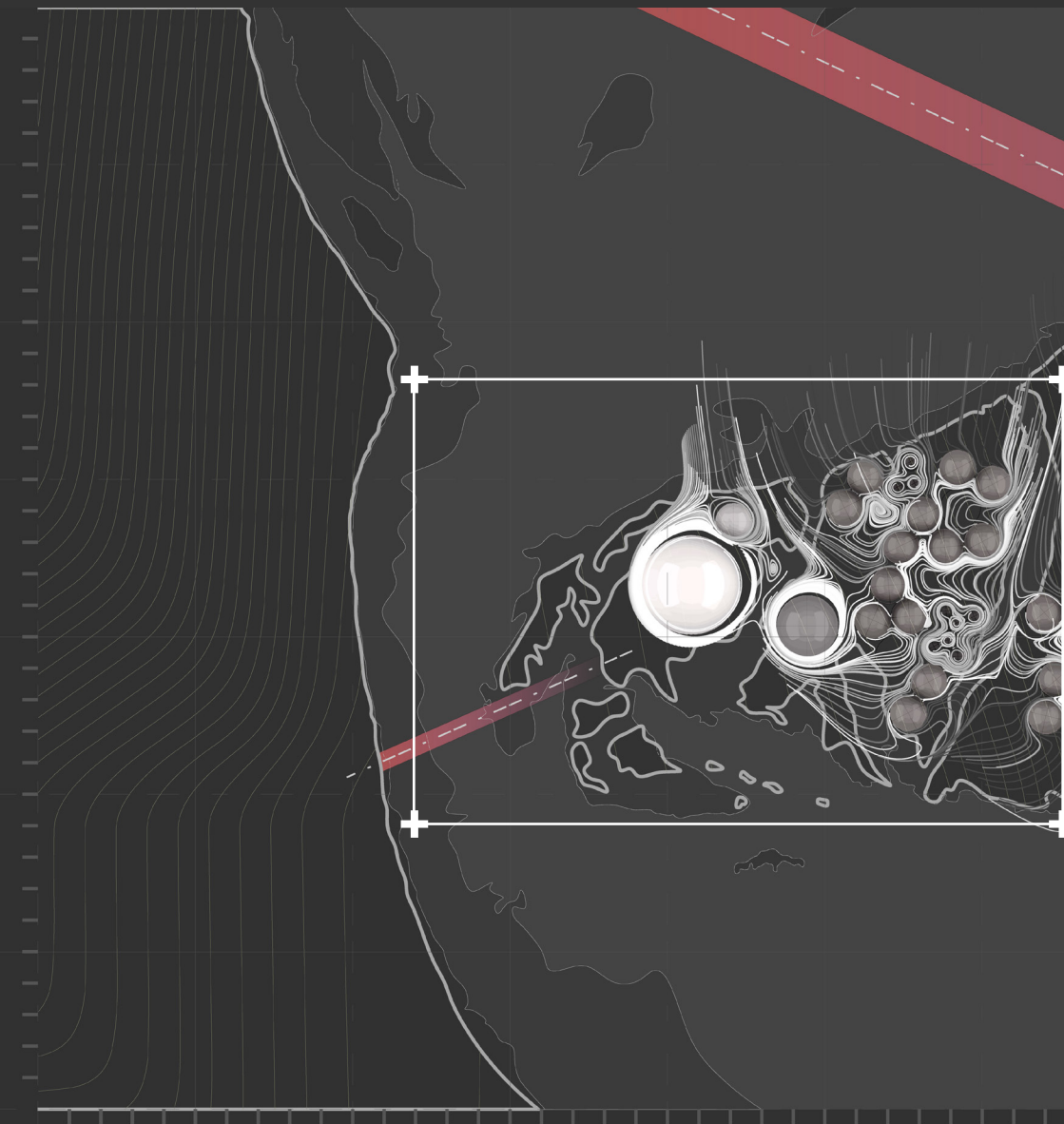
Applying functional simulation to the site yields different kinds of open, buffer and private spaces.



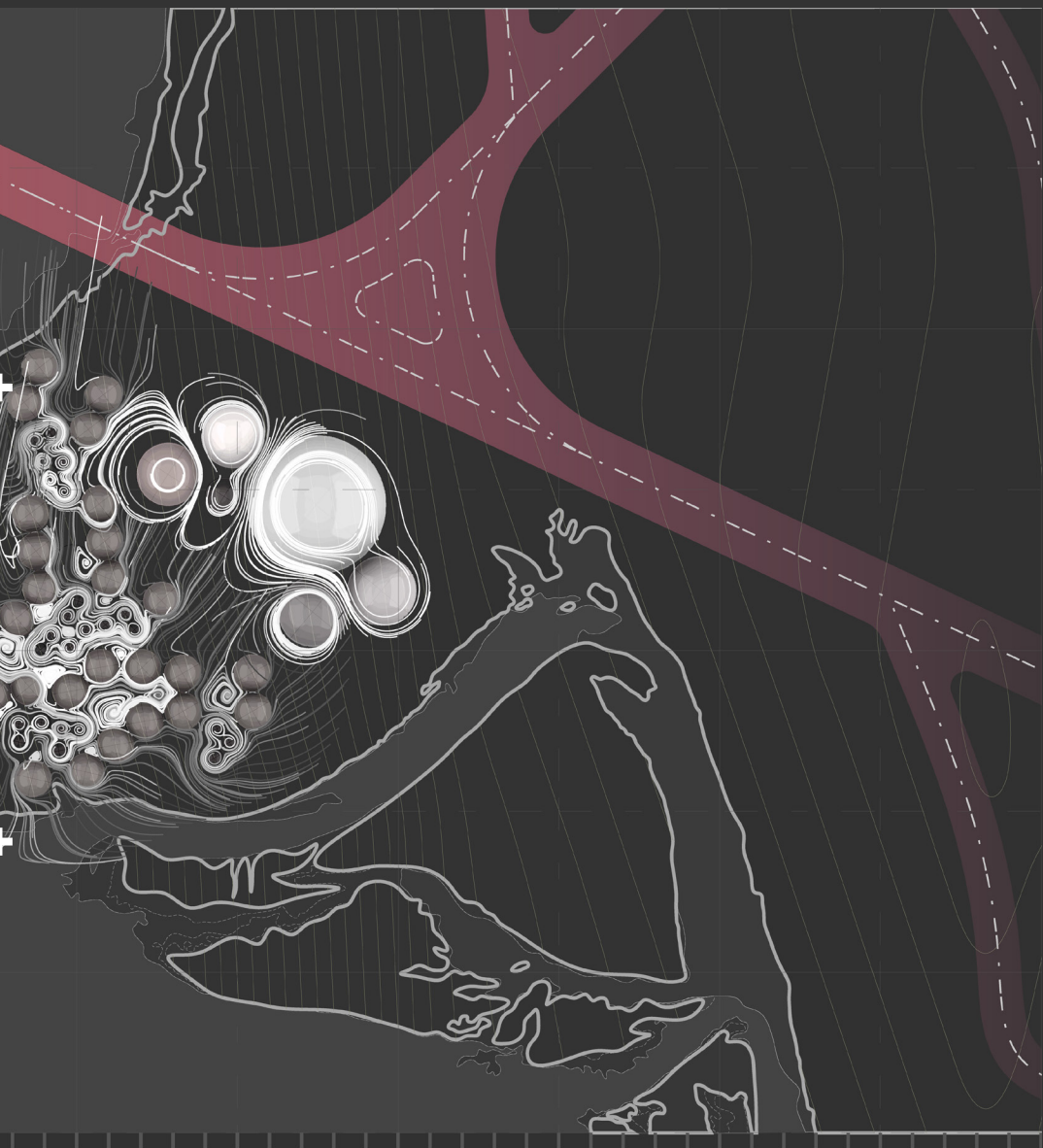
[In-Flow]- P3-5 Design Progression



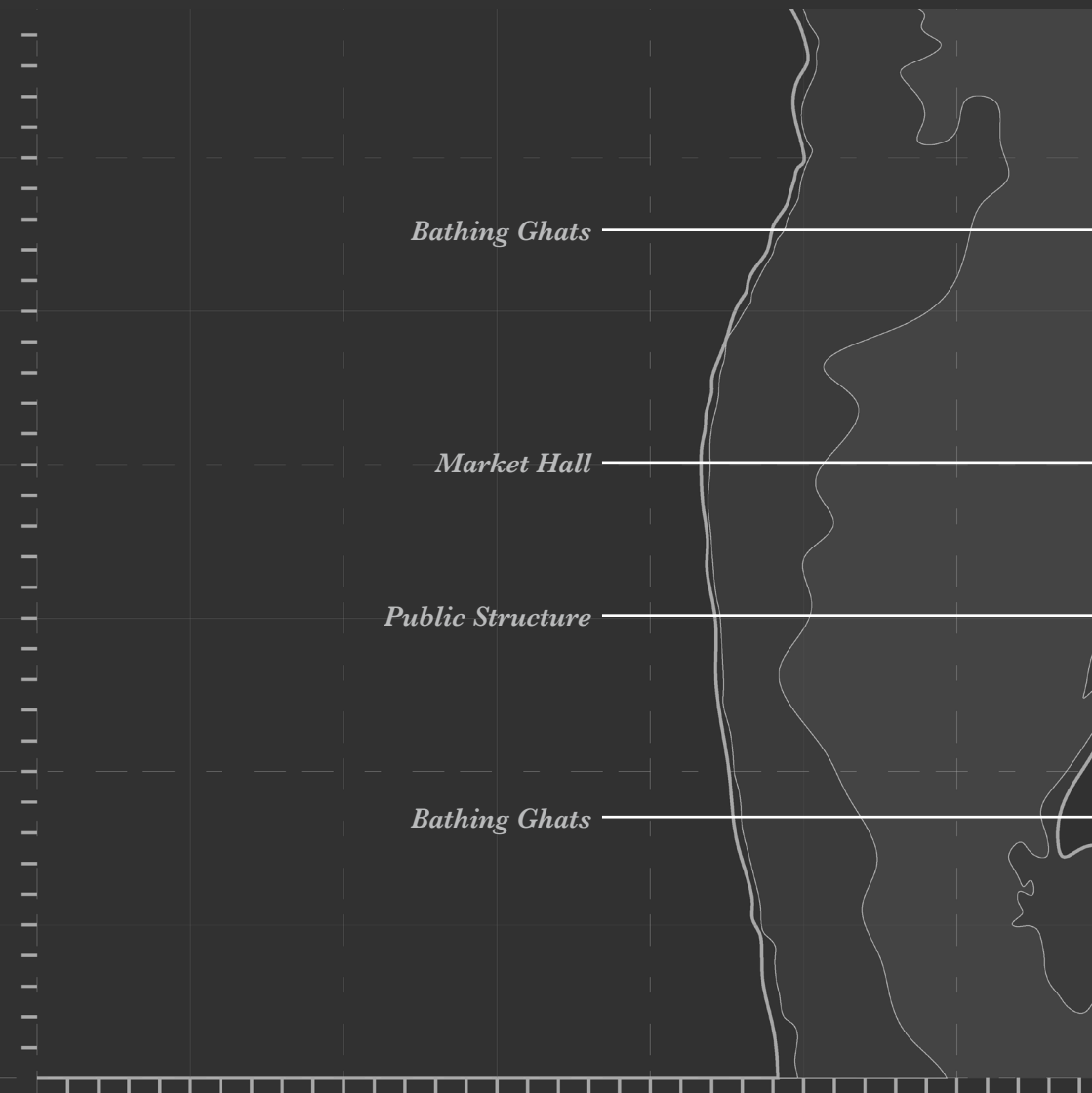
Zoomed-In view of the simulation.



[In-Flow]- P3-5 Design Progression



Once the urban structure is established, a smaller part of the site is selected for further detailing.

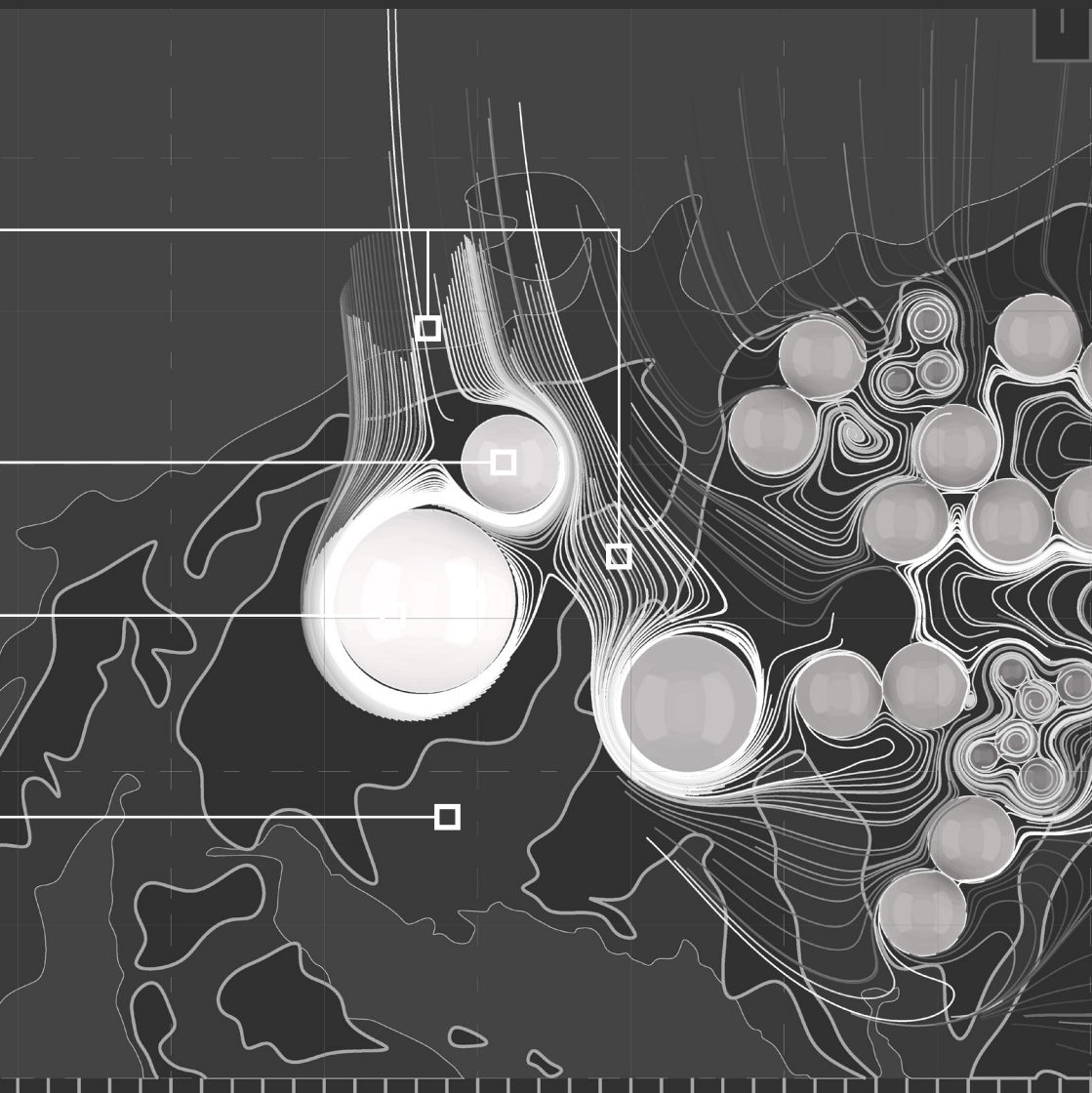


Bathing Ghats

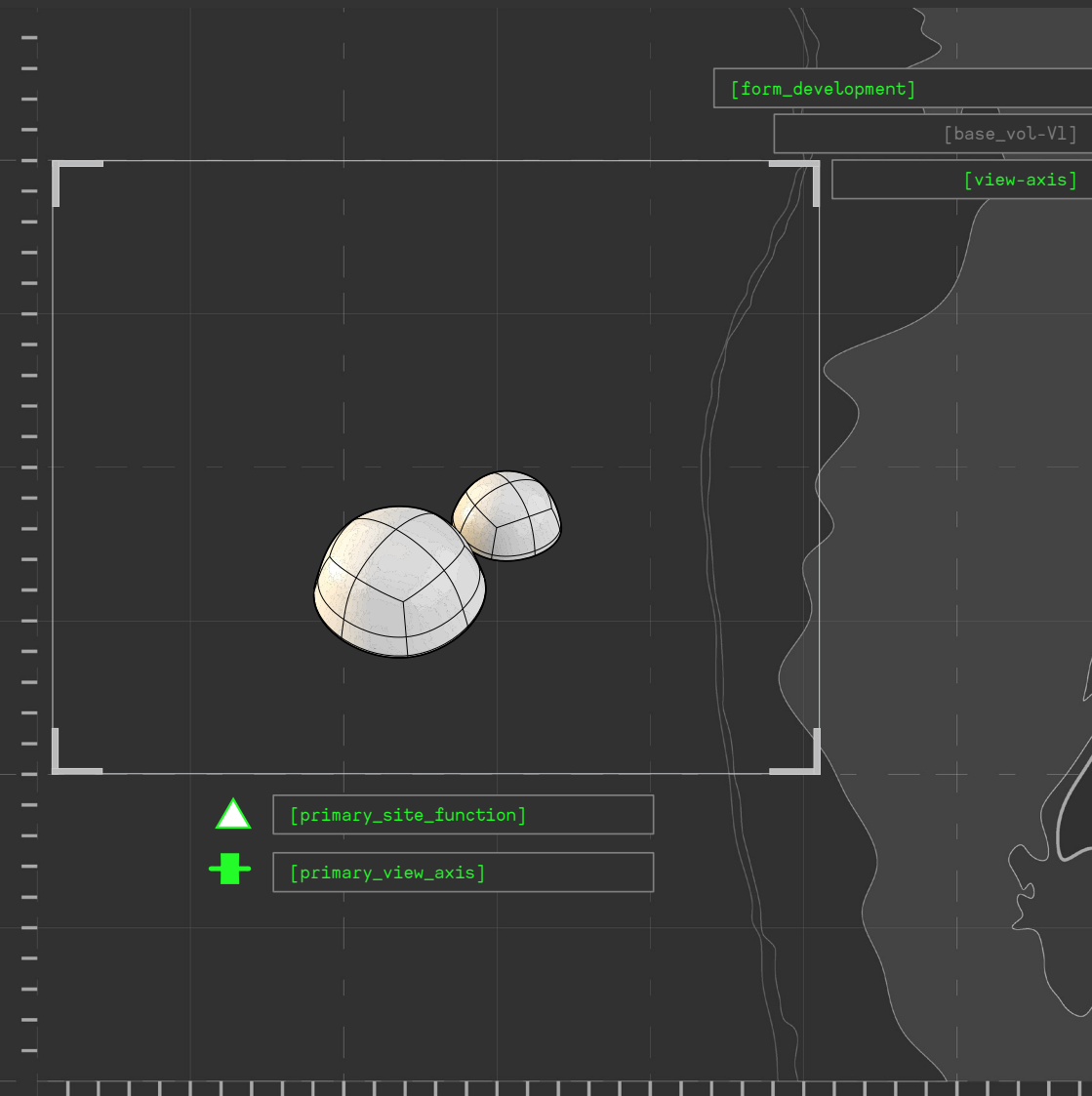
Market Hall

Public Structure

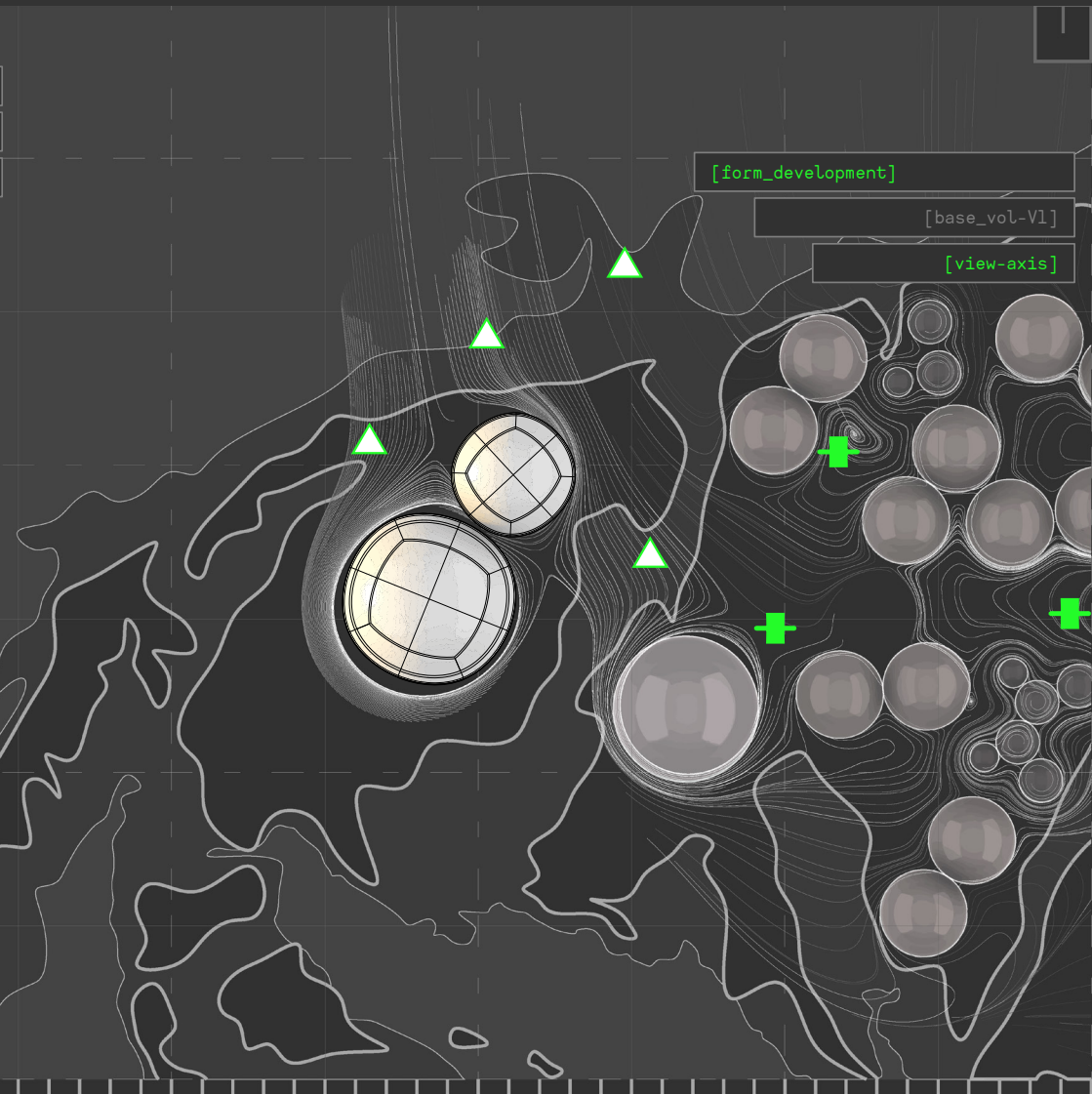
Bathing Ghats



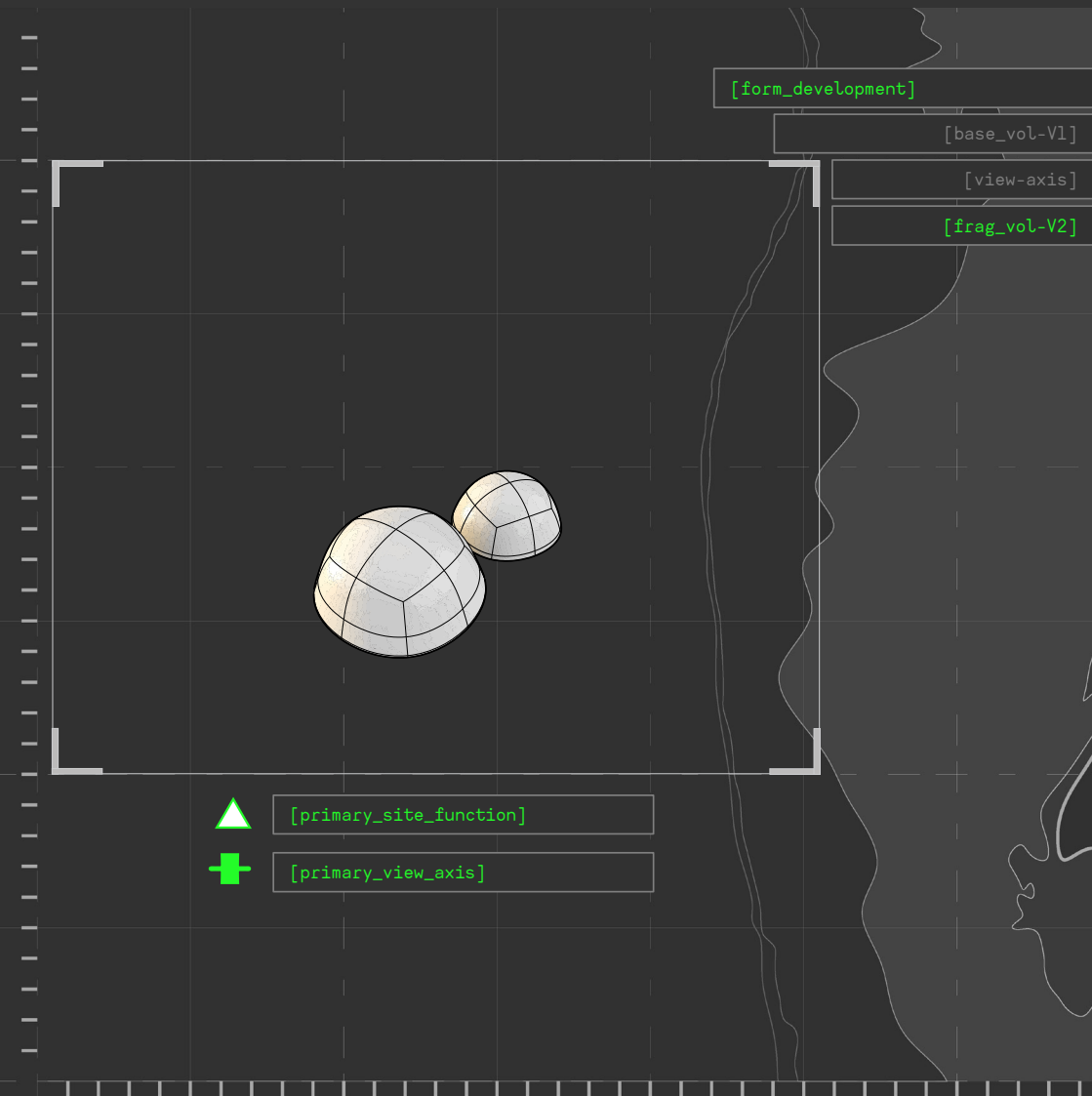
*For final meso scale detail, public function building is taken up for further detailing.
The public structure comprises of prayer hall, prayer cells,
market hall and bathing ghats.*



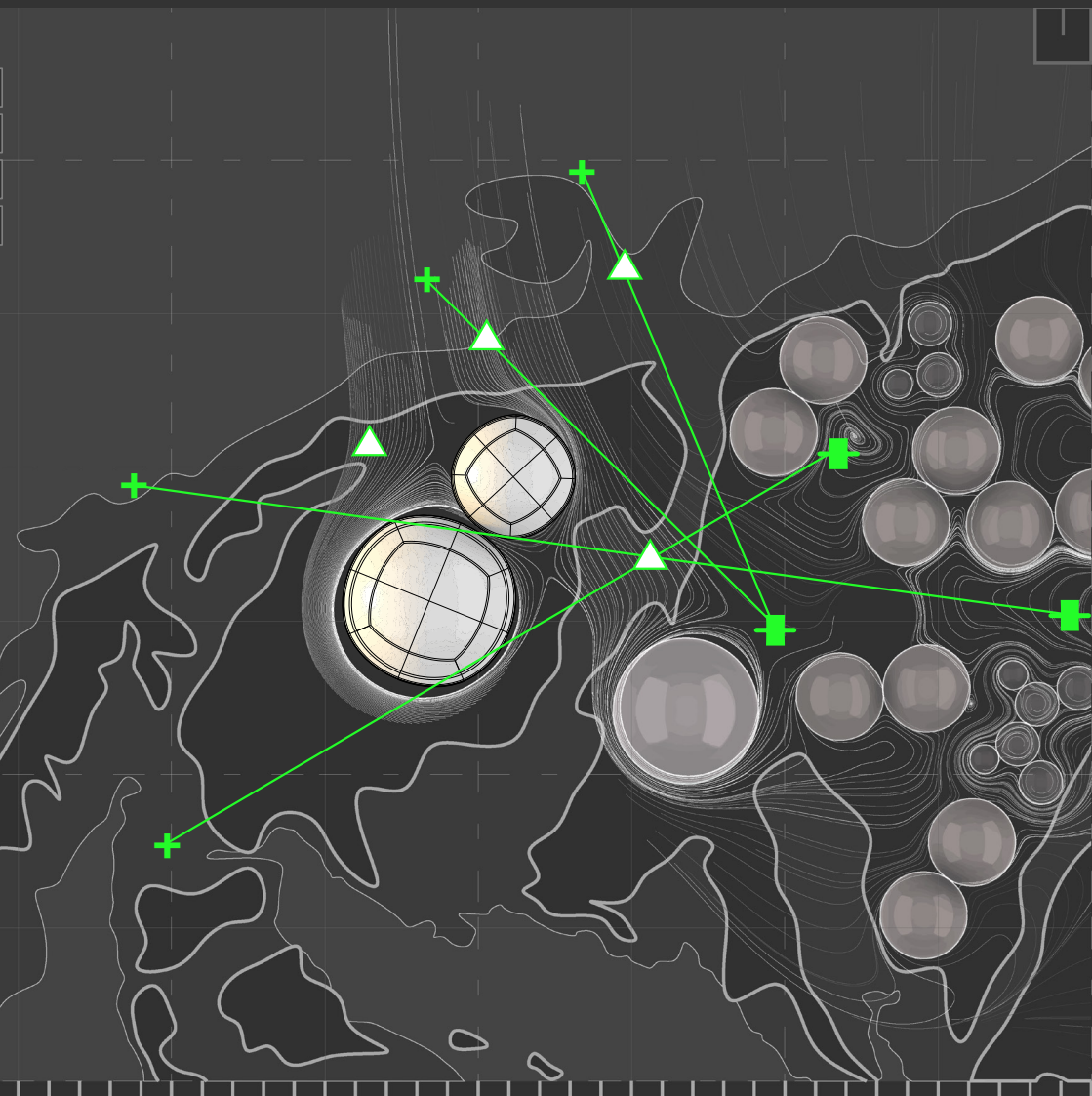
[In-Flow]- P3-5 Design Progression



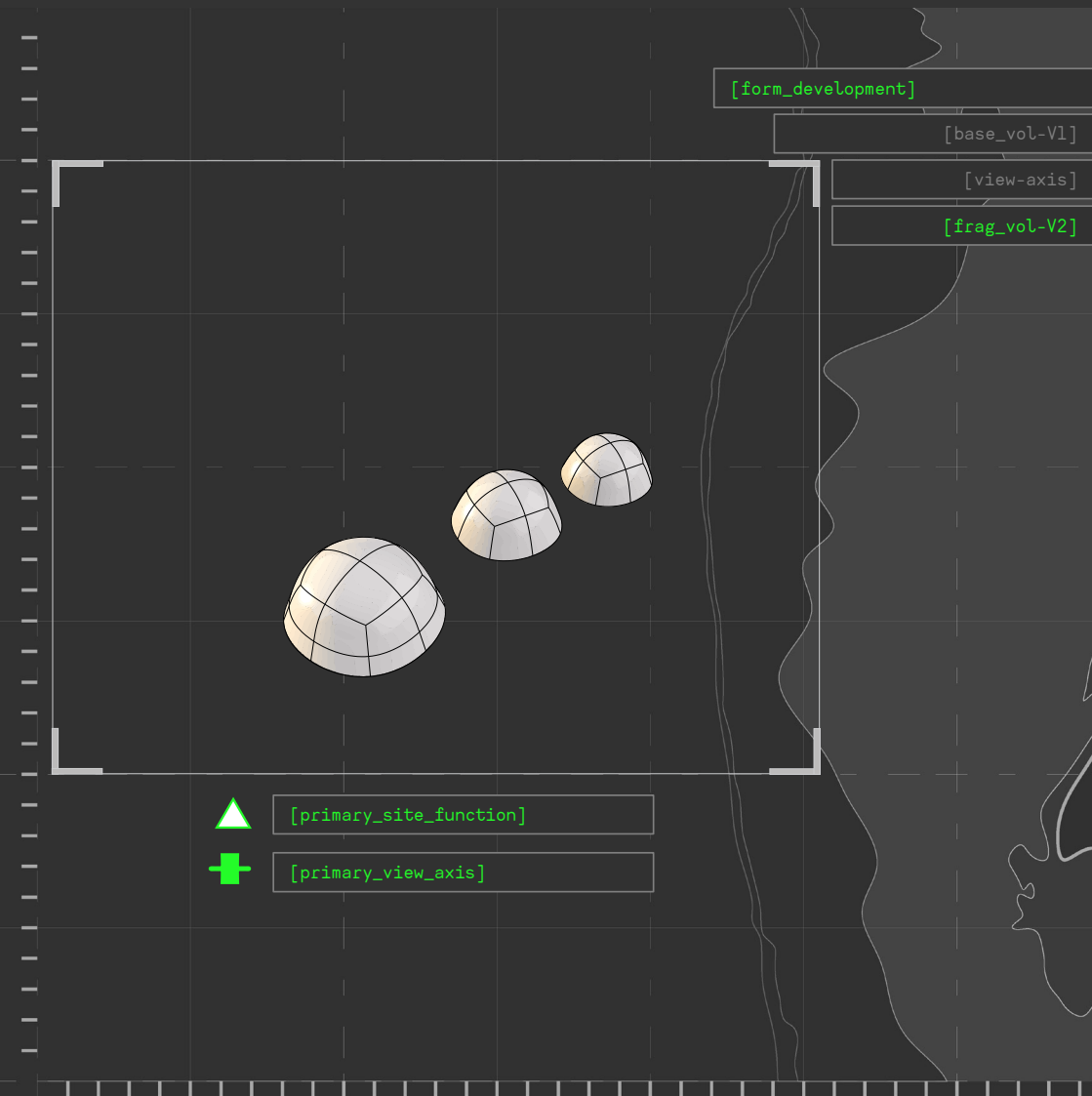
The primary functional volume is analyzed for view axis based on primary site function i.e.- bathing ghats. Majority of devotees will visit the bathing ghats which is also depicted in the urban design simulations where we see the curves flowing towards the primary site positions.



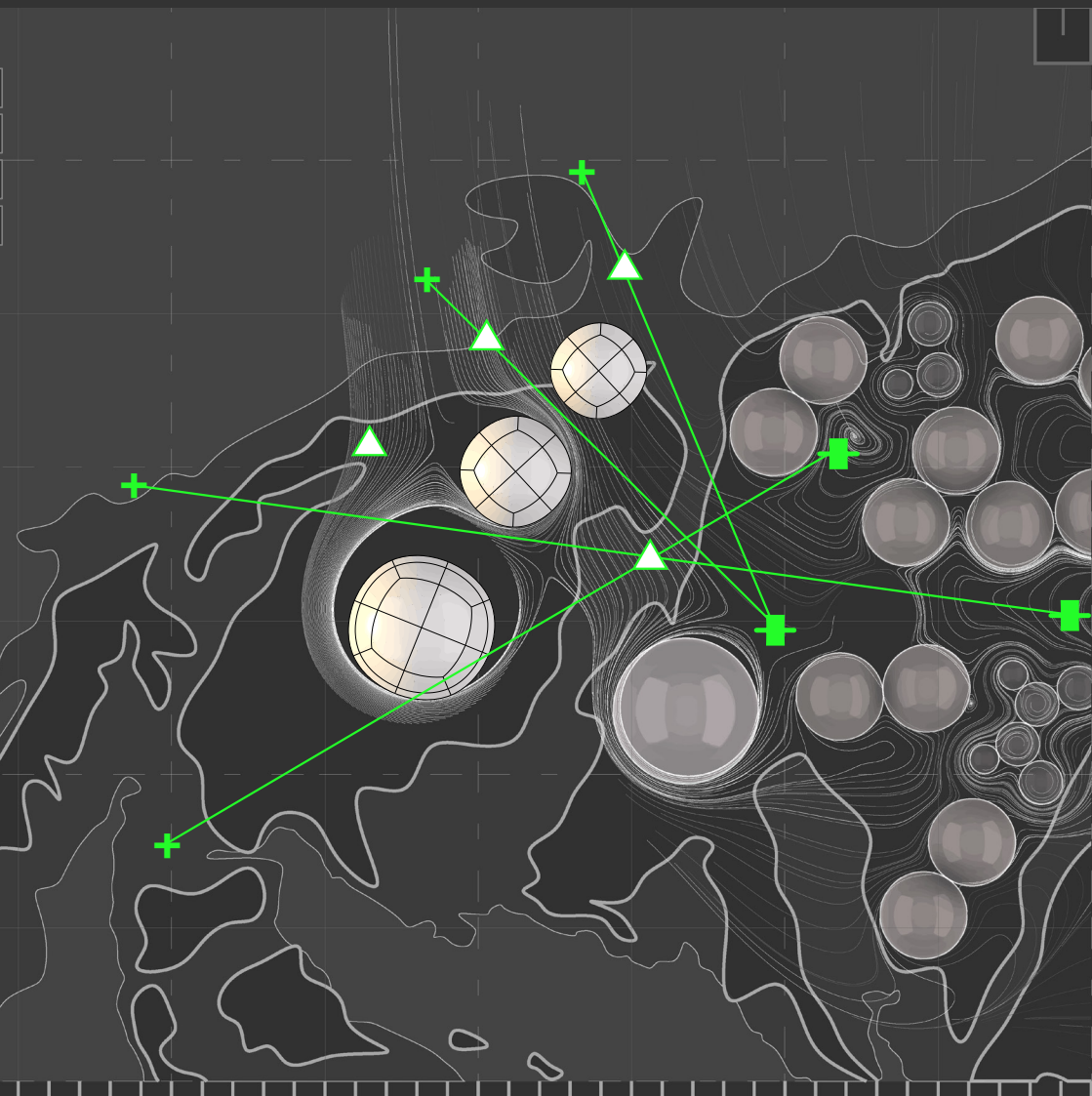
[In-Flow]- P3-5 Design Progression



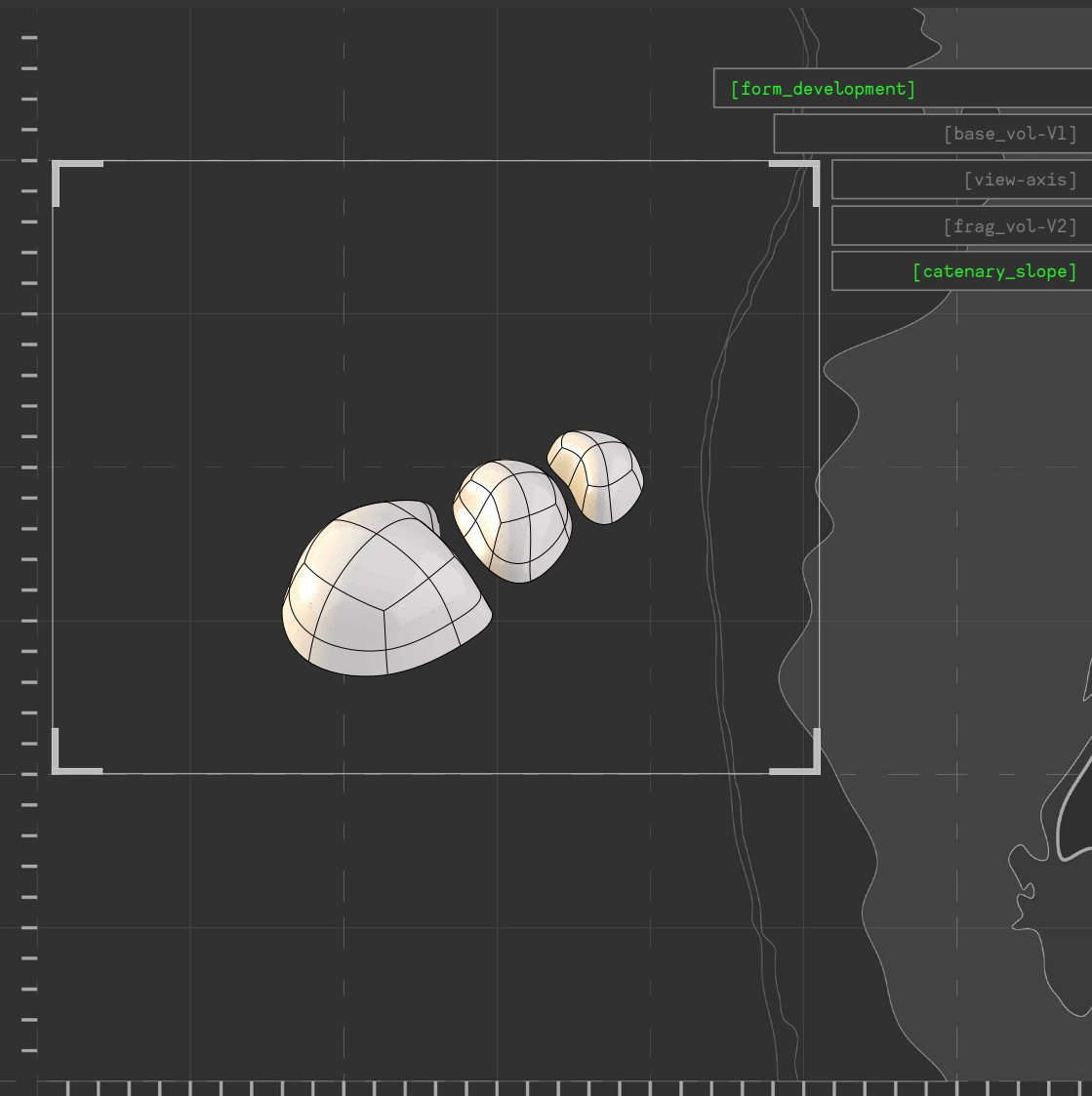
When the devotees arrive at the site, the first thing they would want is to visit the bathing ghats. The diagram shows site lines which is being blocked by the volume block.



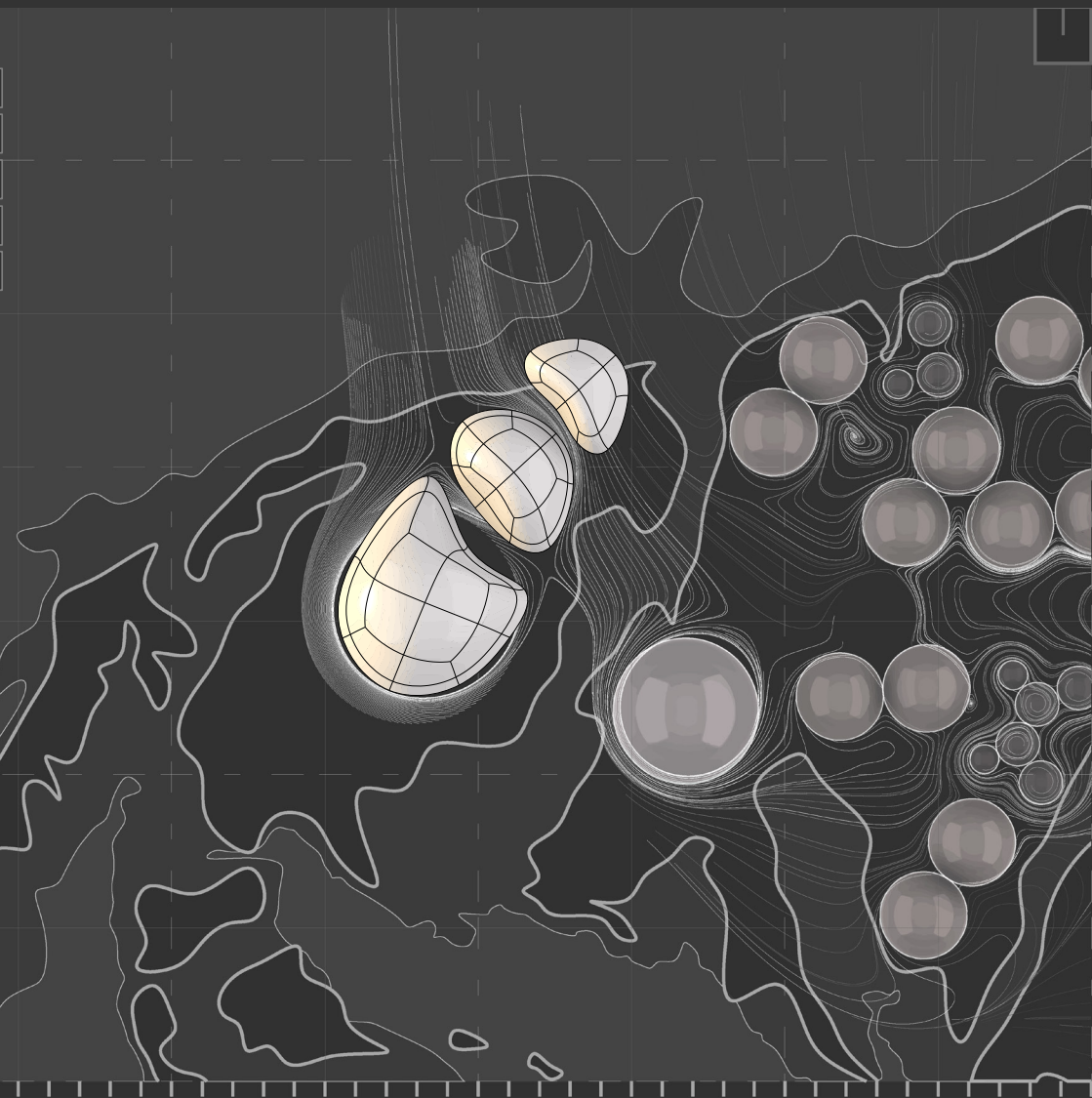
[In-Flow]- P3-5 Design Progression



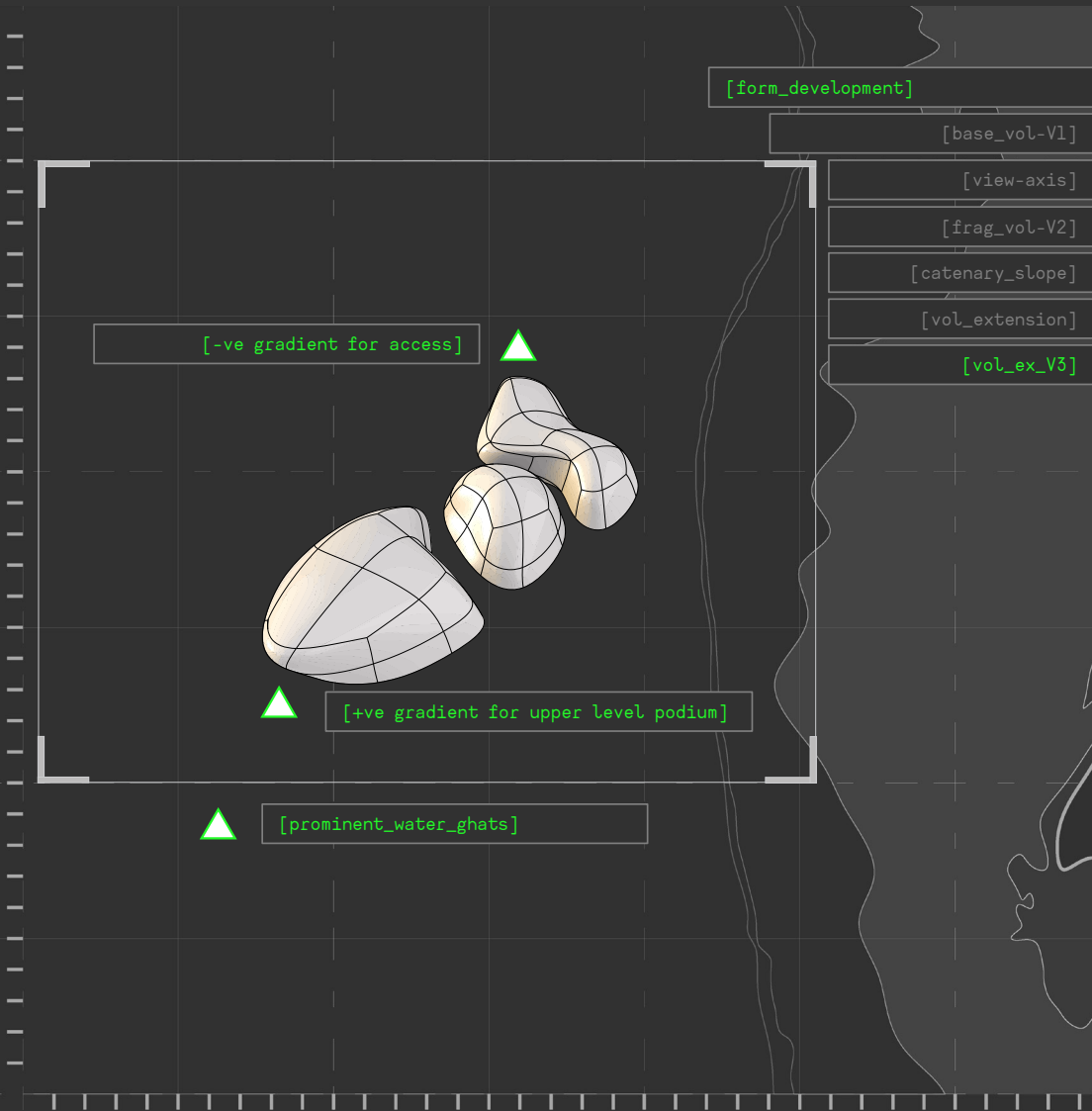
The volume is bifurcated into three parts so that the devotees have a clear frame of their final destination.



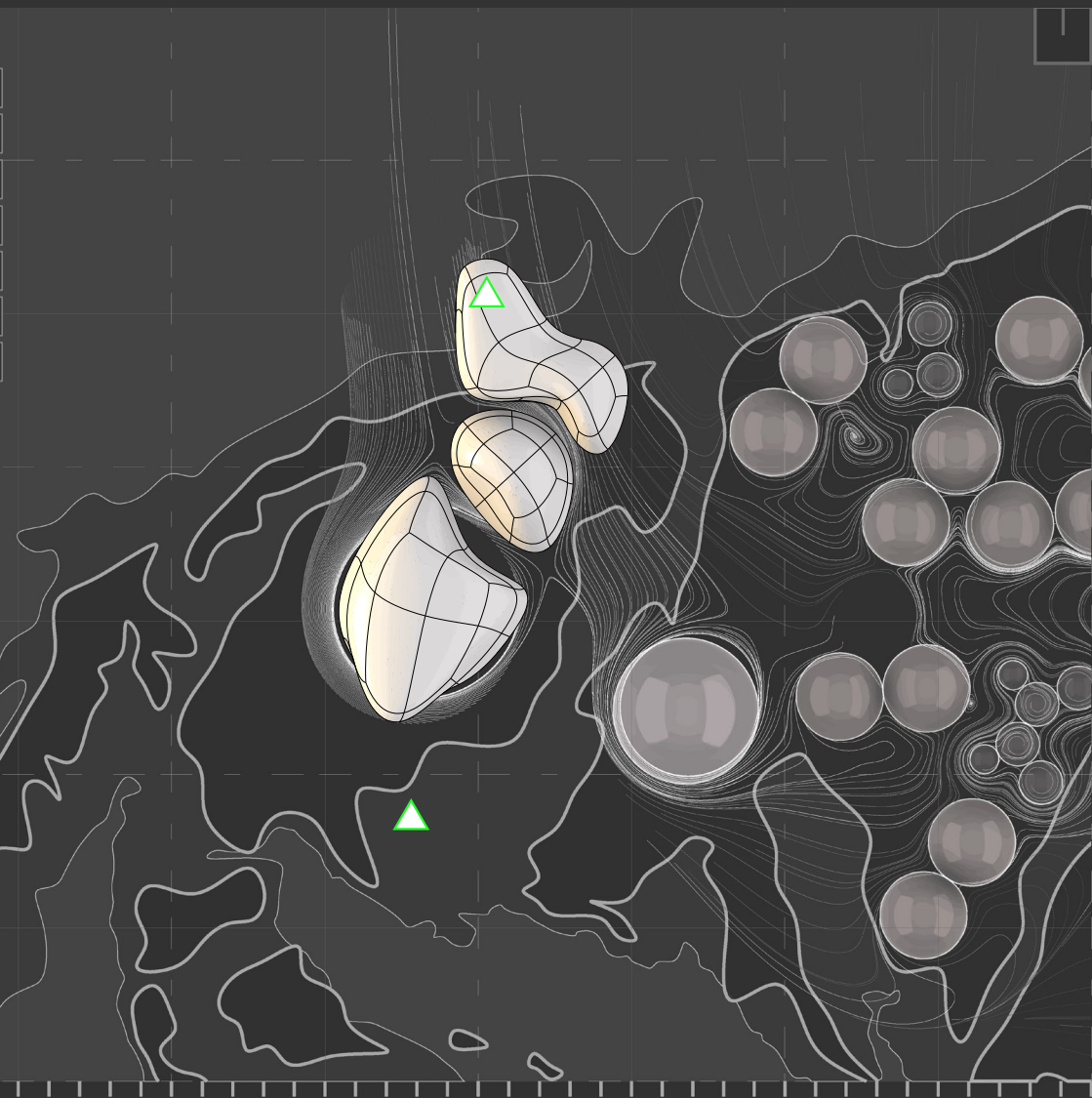
[In-Flow]- P3-5 Design Progression



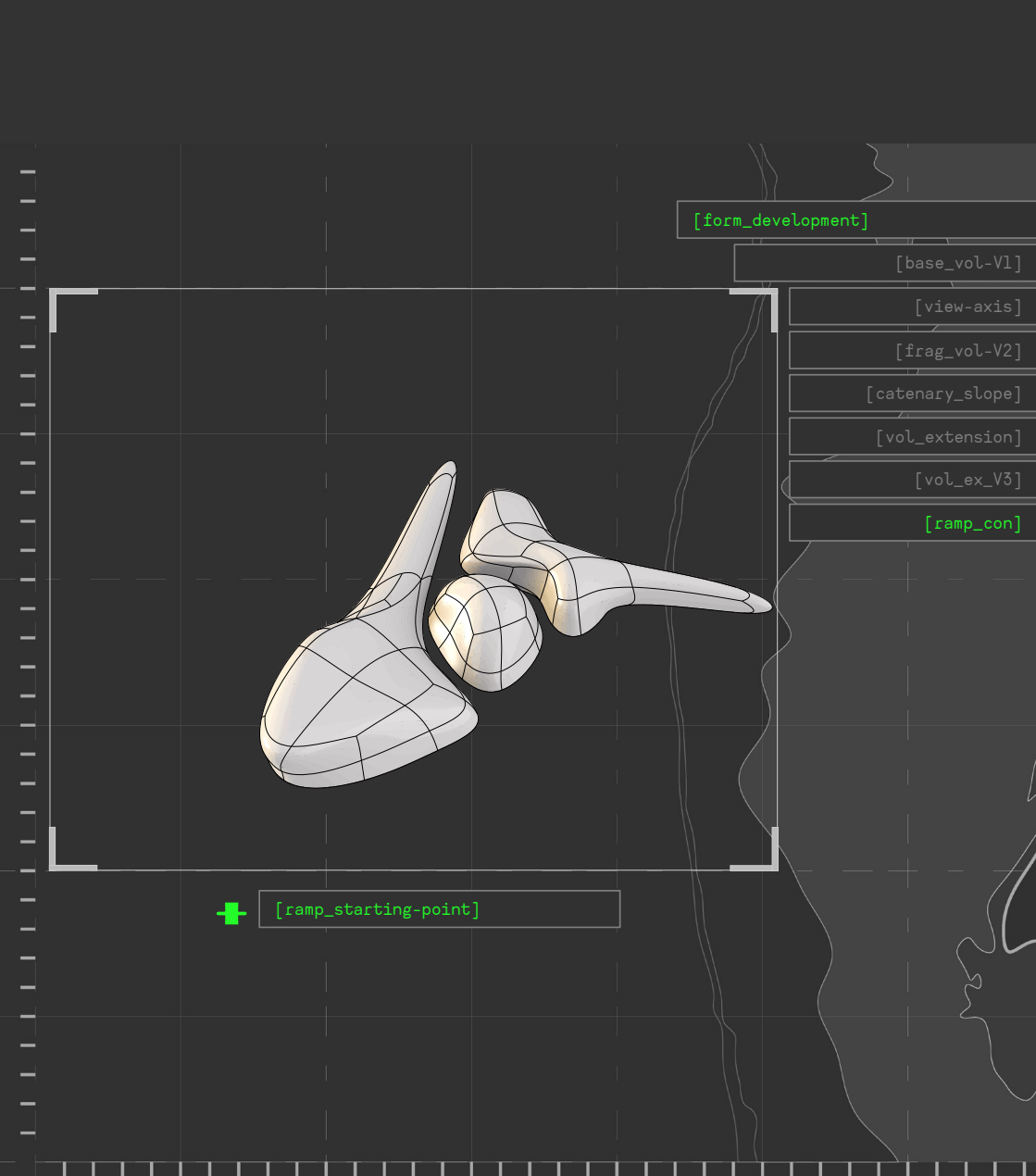
Volume extends towards the flow curves from urban design simulation. The simulation prescribes data for basic height and slope for each building.



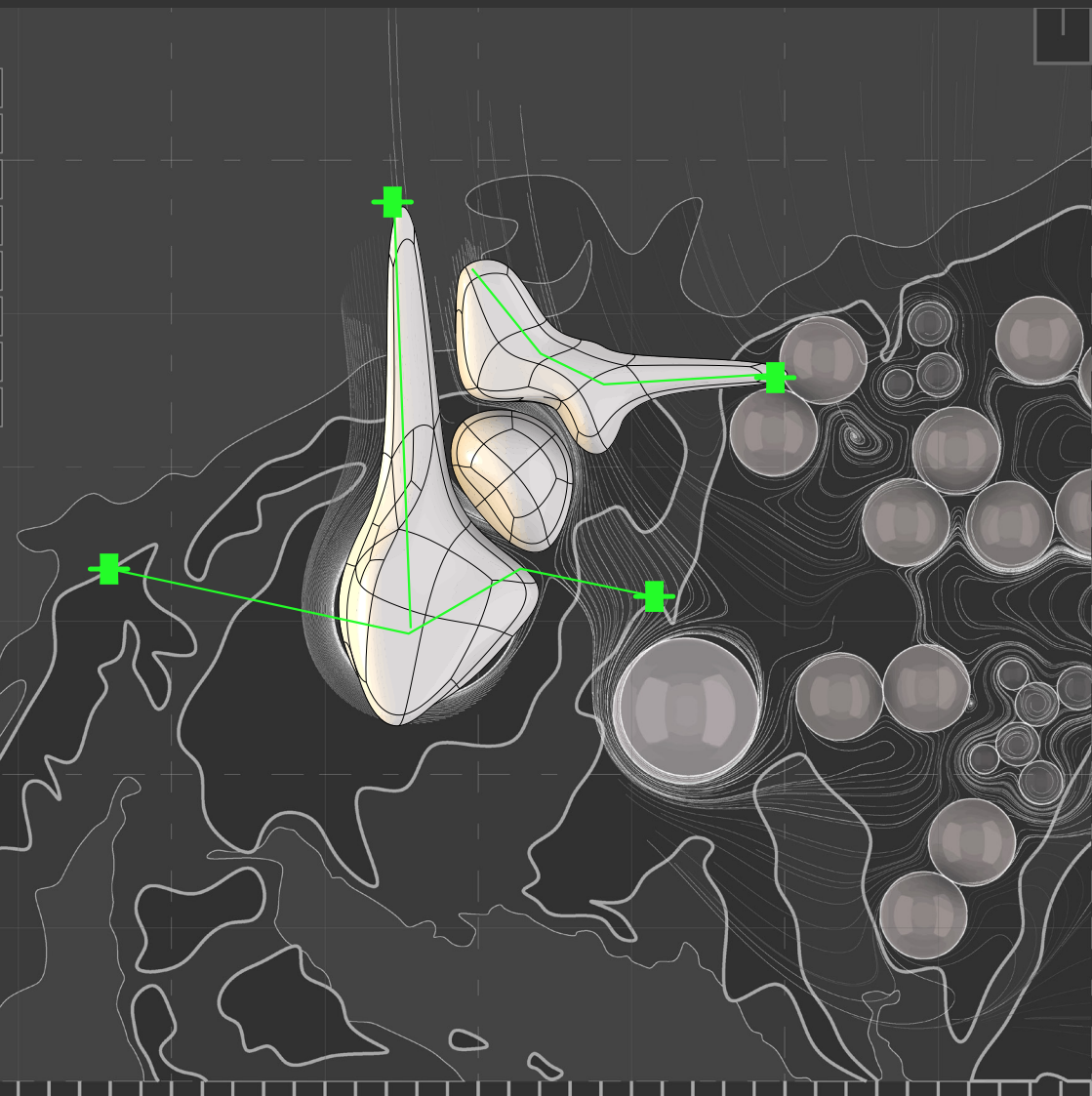
[In-Flow]- P3-5 Design Progression



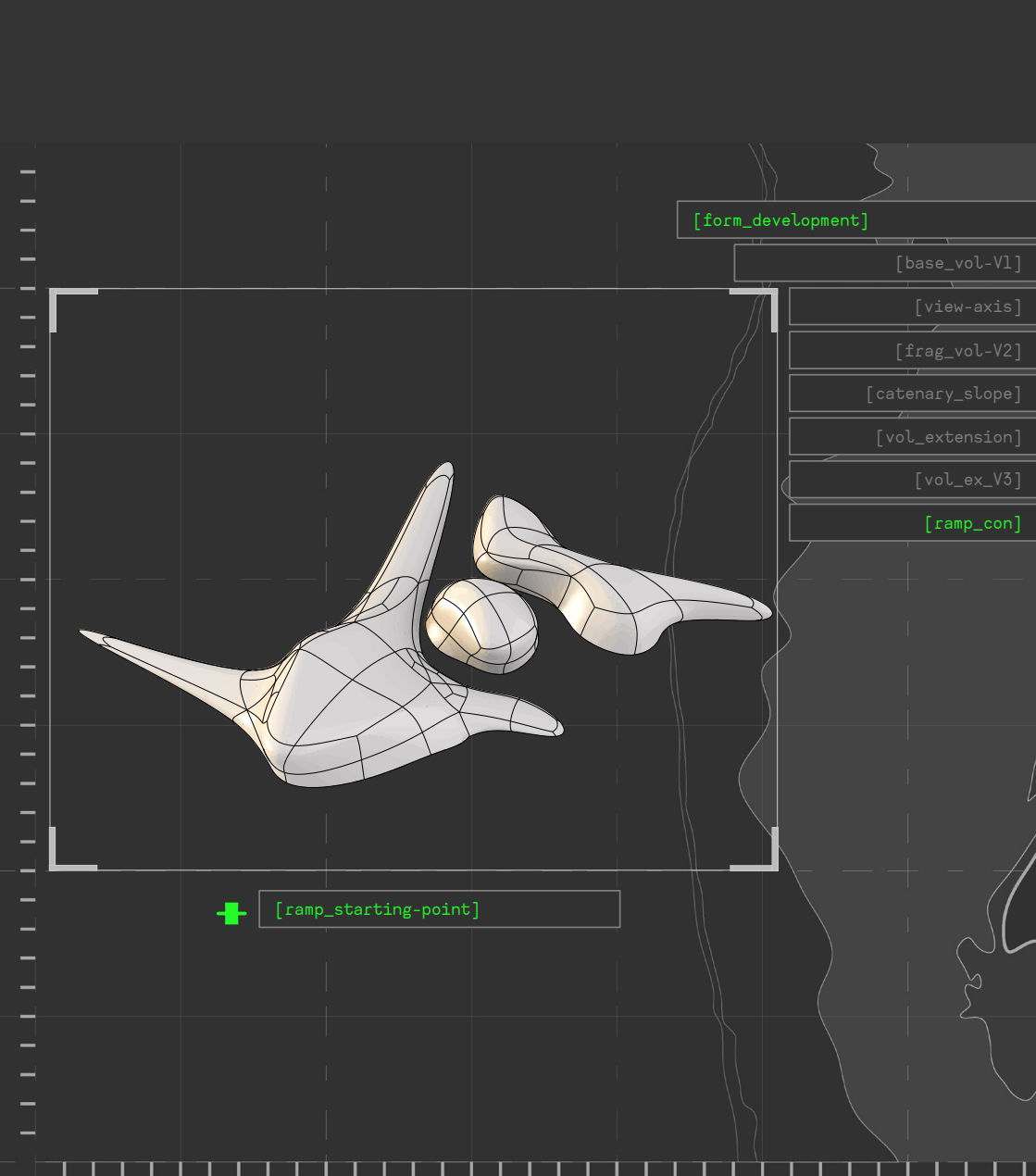
Since the ghats are an important aspect of the site, the building responds to these two areas. The front part of the volume slopes up to overlook over the front ghat while the back part slopes down like a ramp to integrate with the ghats.

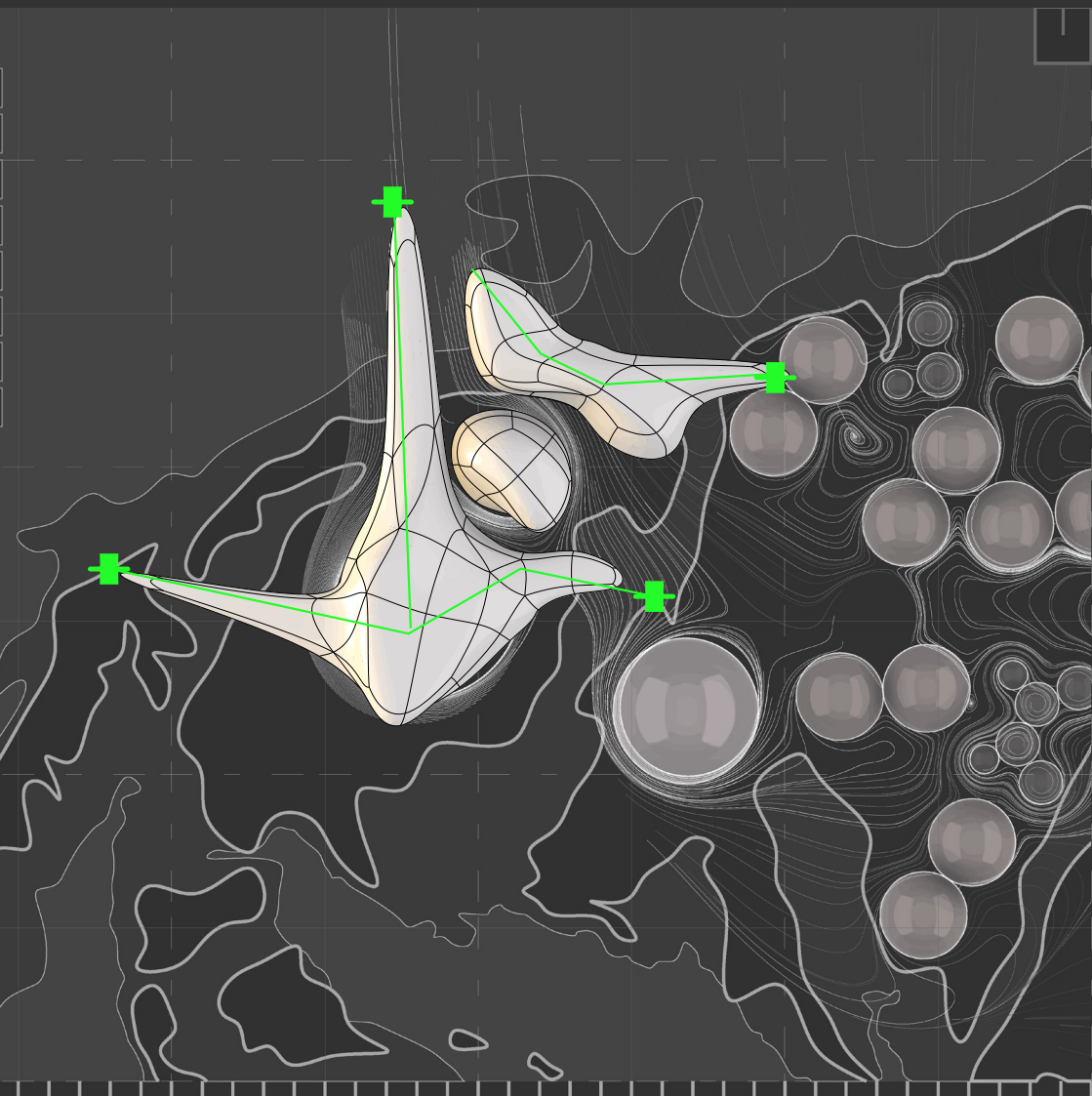


[In-Flow]- P3-5 Design Progression

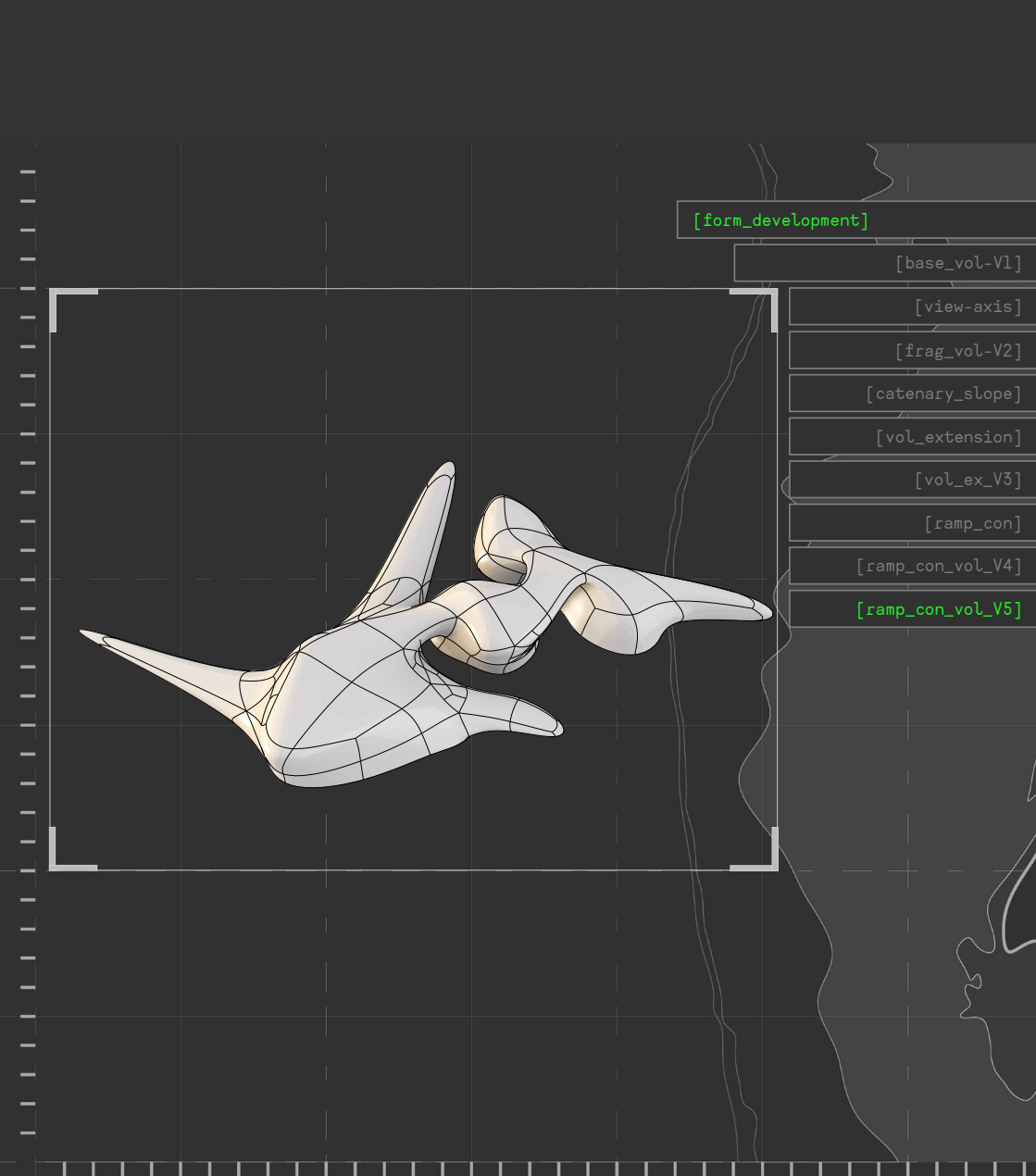


Keeping in line with the design idea to have interconnected catenary mounds all over the site, the building is connected to its context with ramps.

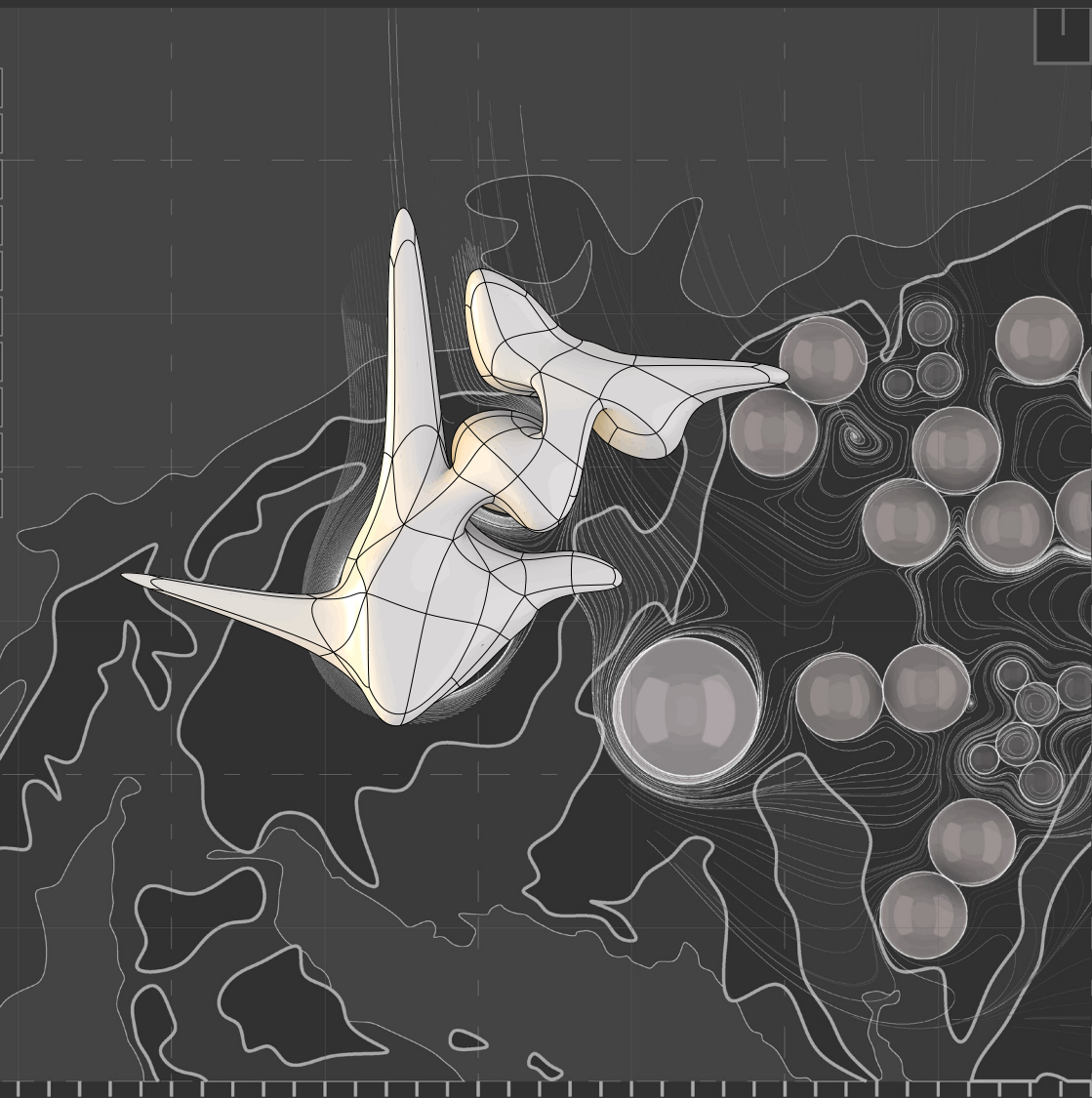




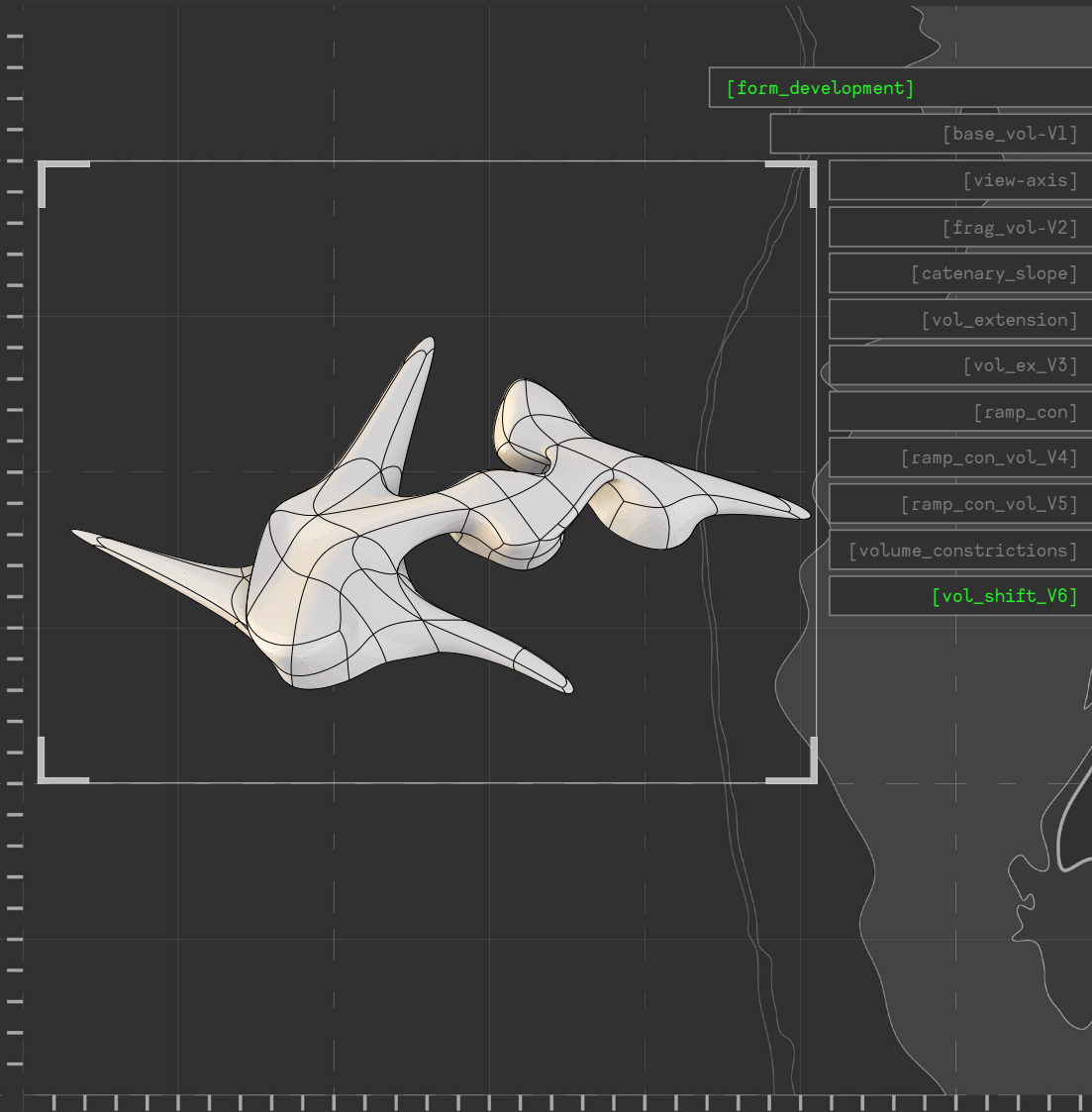
The complete ramp model.



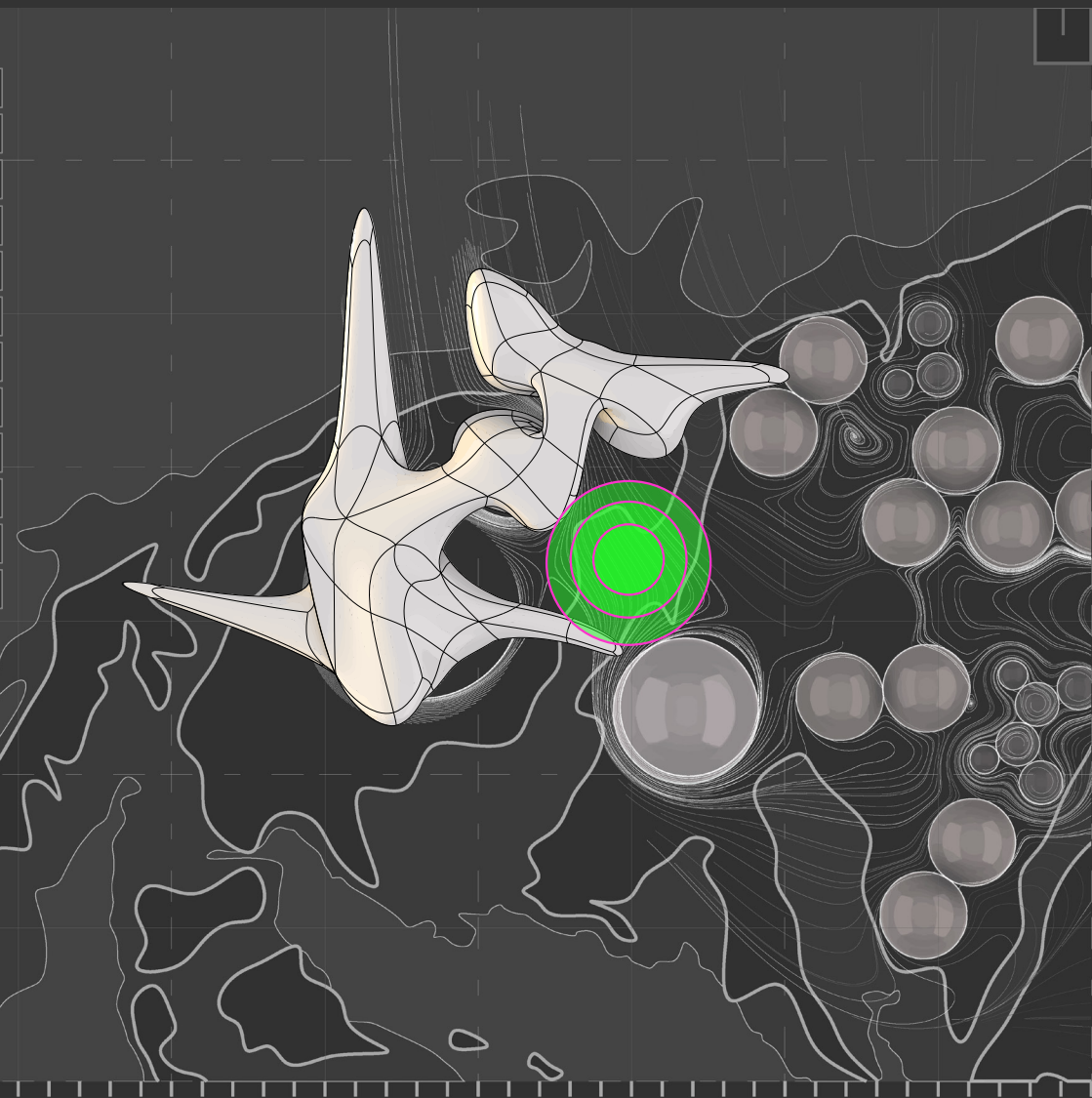
[In-Flow]- P3-5 Design Progression



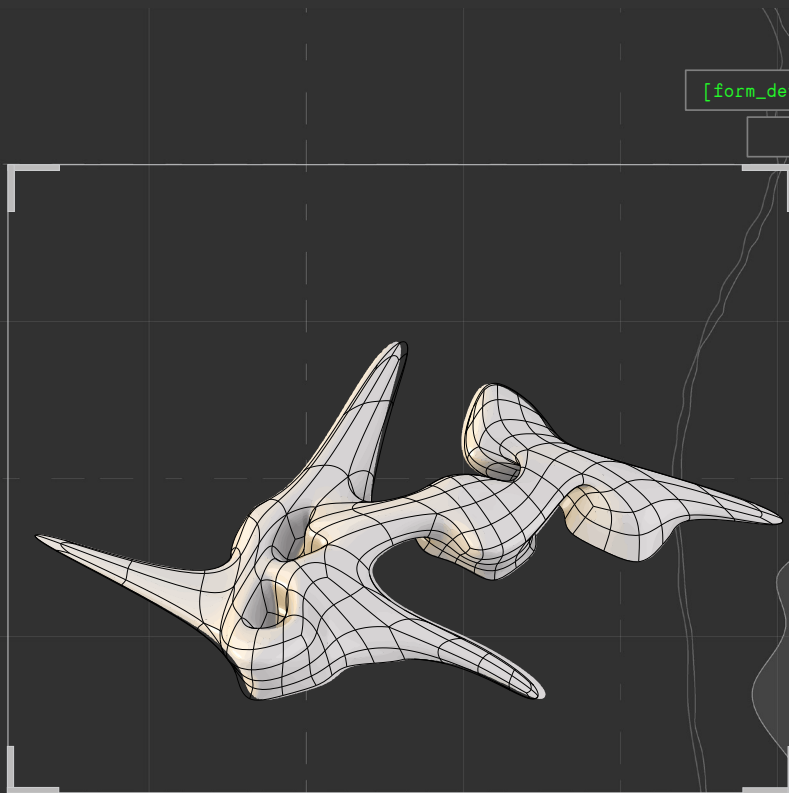
The bifurcated model is stitched together to create a continuous ramp system.



[In-Flow]- P3-5 Design Progression



The volume is shifted to accommodate the outdoor spill area.



[form_development]

[base_vol-V1]

[view-axis]

[frag_vol-V2]

[catenary_slope]

[vol_extension]

[vol_ex_V3]

[ramp_con]

[ramp_con_vol_V4]

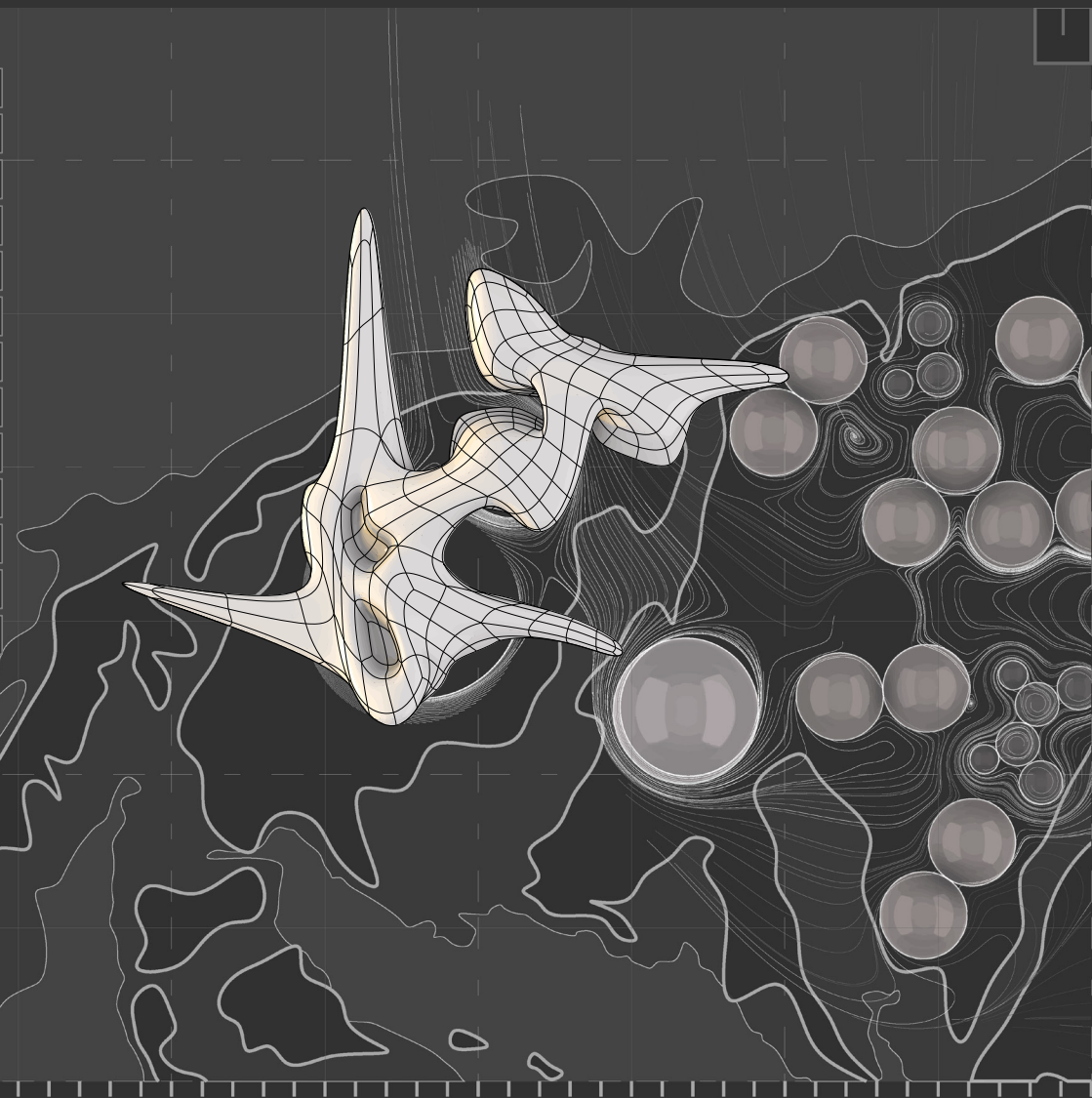
[ramp_con_vol_V5]

[volume_constrictions]

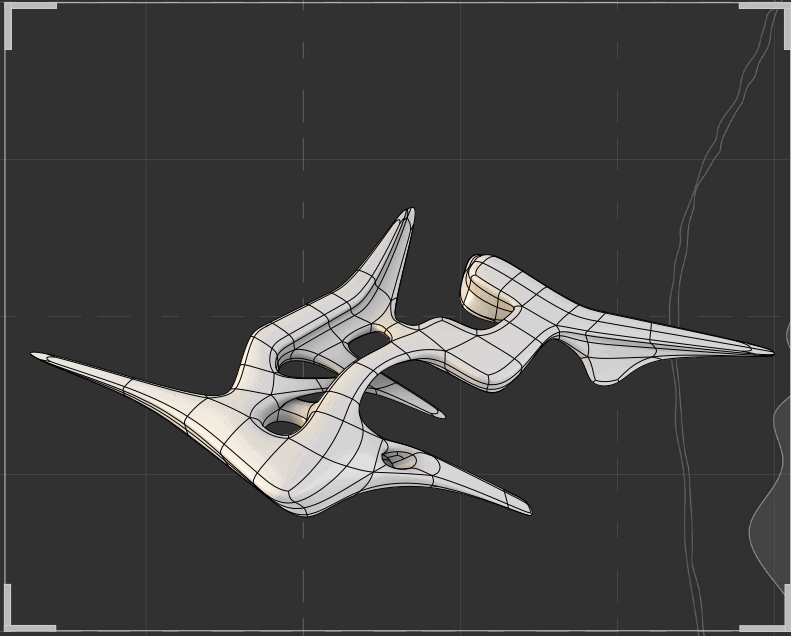
[vol_shift_V6]

[vol_courtyards_V7]

[In-Flow]- P3-5 Design Progression



*Introducing courtyards into the building in accordance with
Indian planning principles.*



[form_development]

[base_vol-V1]

[view-axis]

[frag_vol-V2]

[catenary_slope]

[vol_extension]

[vol_ex_V3]

[ramp_con]

[ramp_con_vol_V4]

[ramp_con_vol_V5]

[volume_constrictions]

[vol_shift_V6]

[vol_courtyards_V7]

[vol_strip excess_V8]

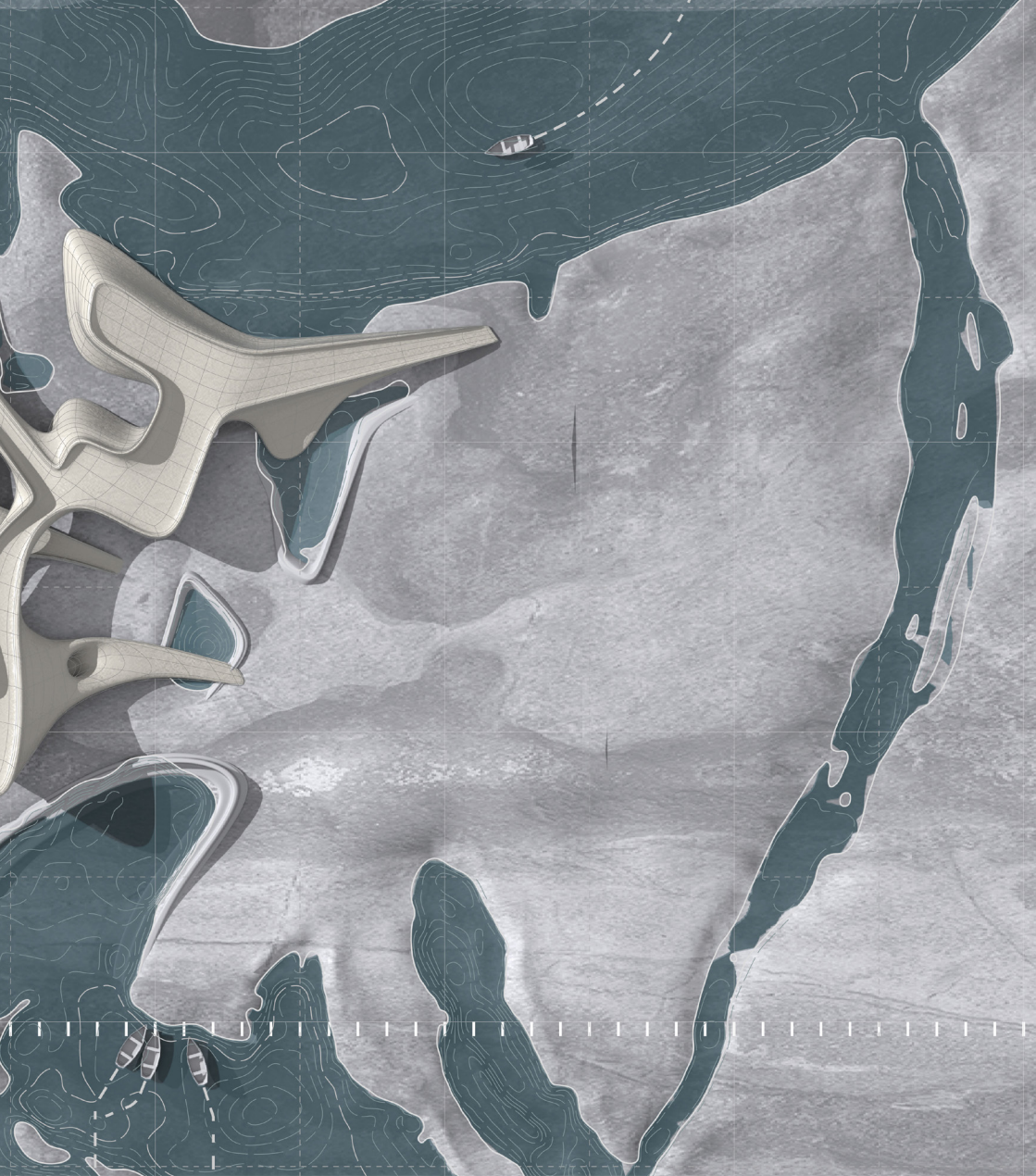
[In-Flow]- P3-5 Design Progression



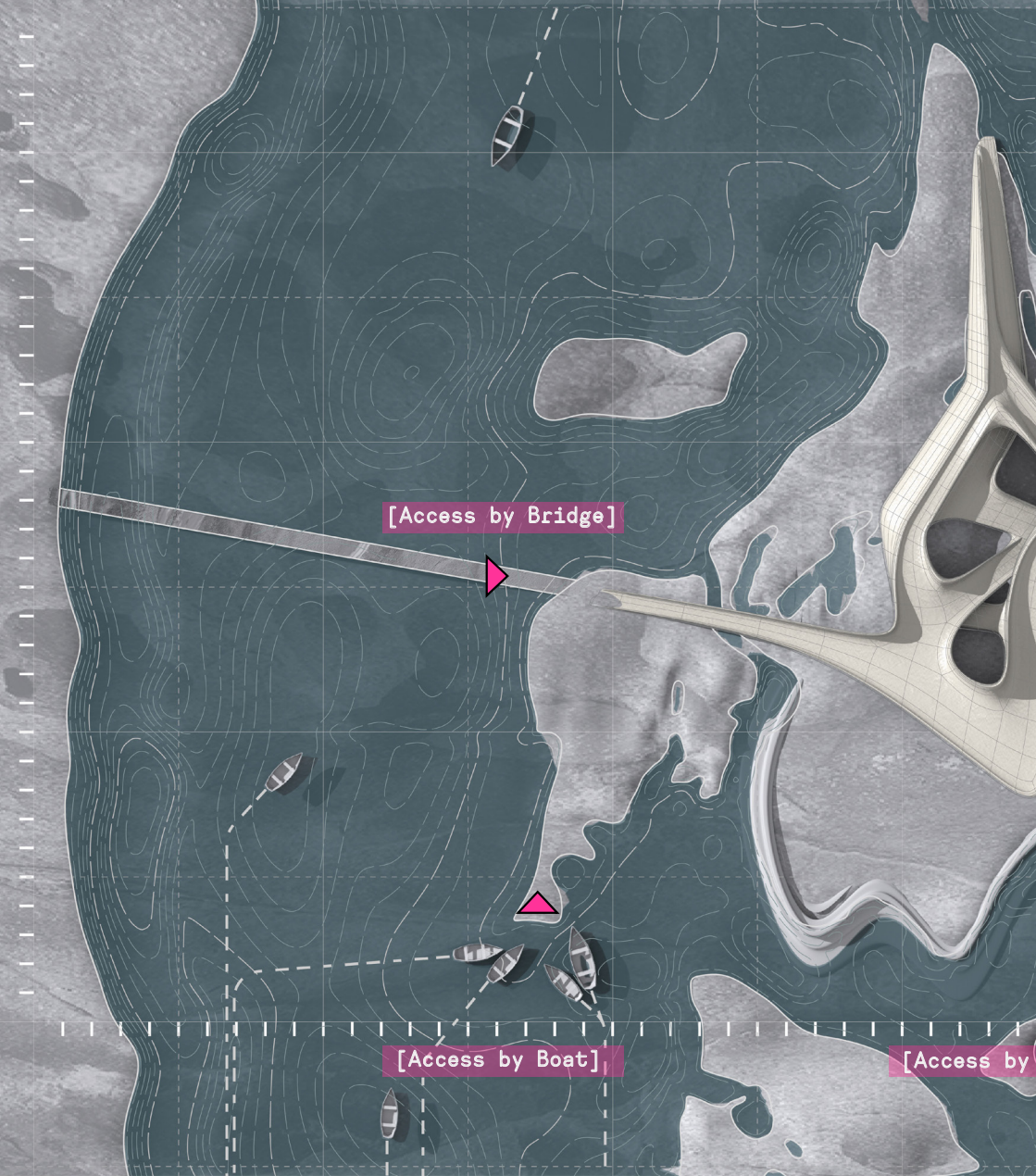
The excess volume is stripped according to anthropometric needs of the ramp system and volume needs based on human occupancy which gives us the above final shape of the building.



[In-Flow]- P3-5 Design Progression



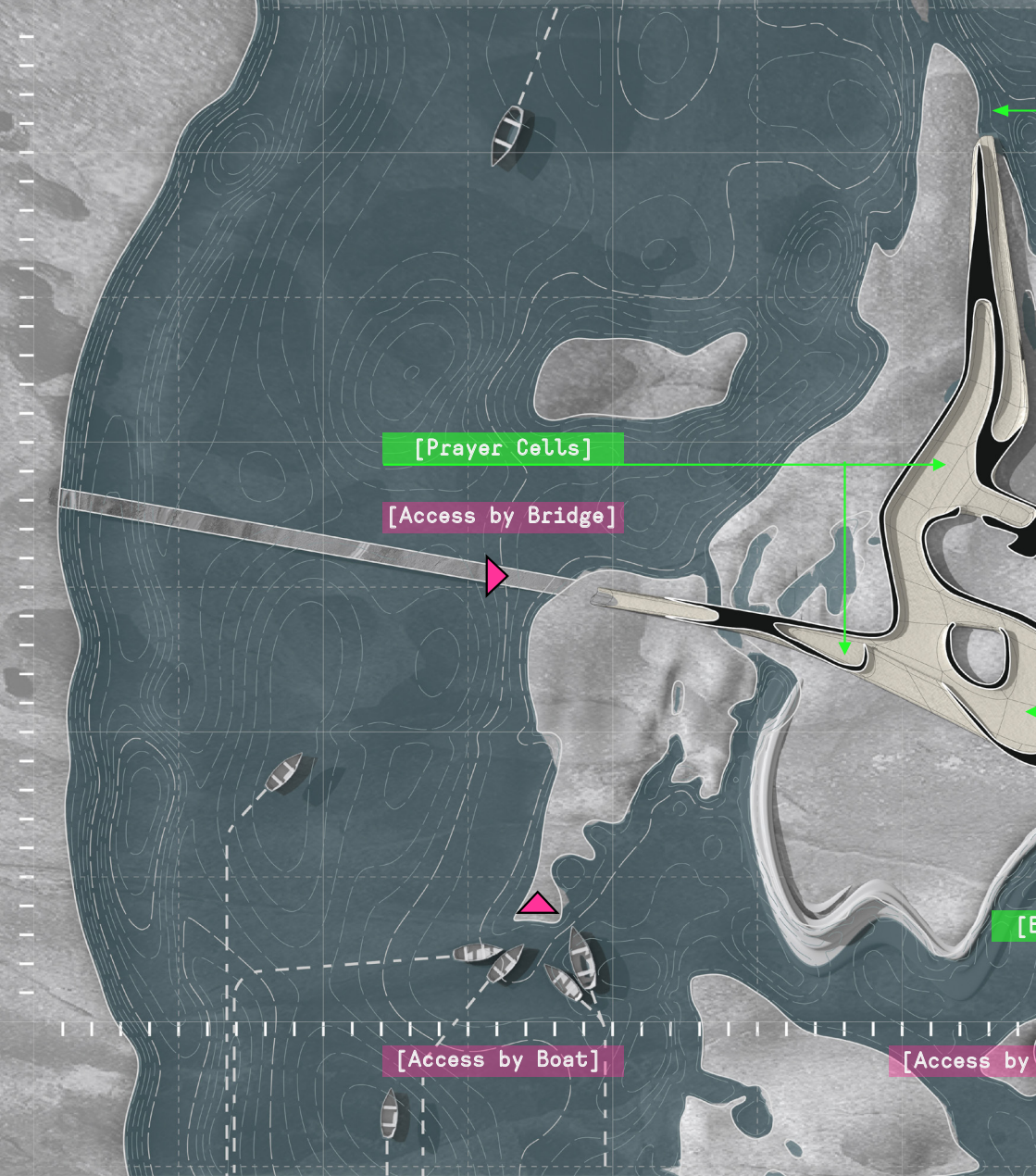
Final Site Plan



[In-Flow]- P3-5 Design Progression



Final Site Plan



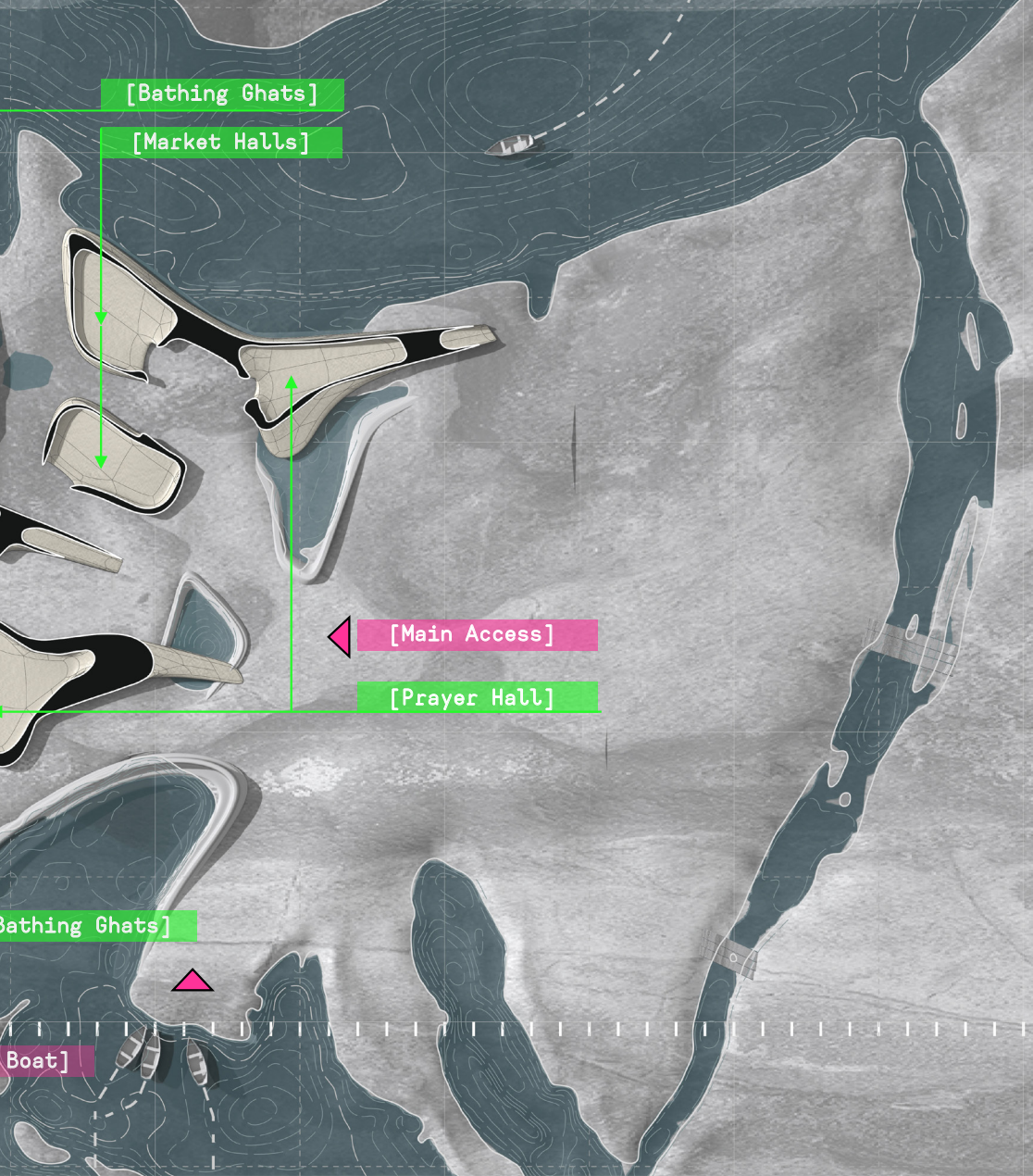
[Prayer Cells]

[Access by Bridge]

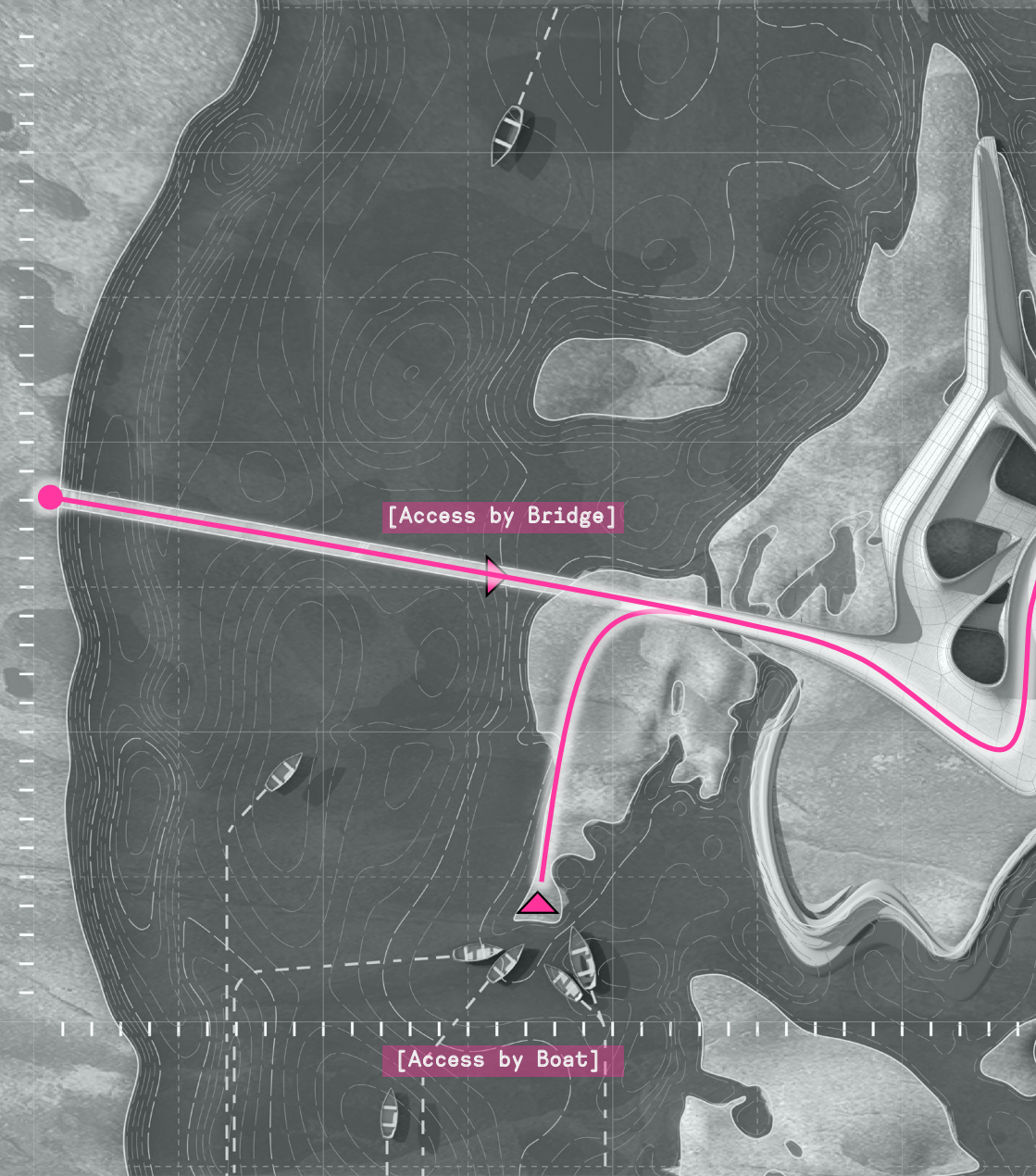
[Access by Boat]

[Access by]

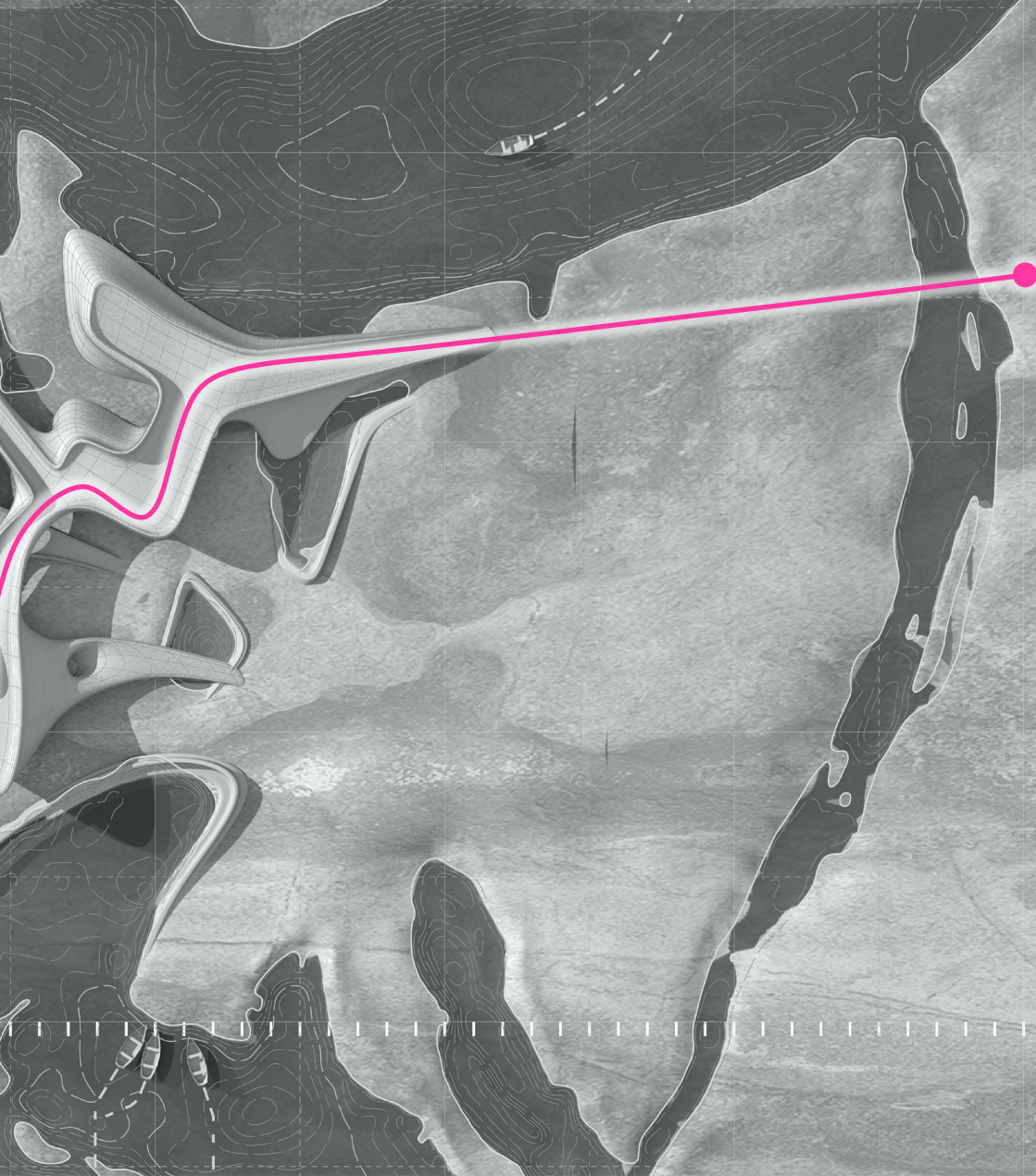
[In-Flow]- P3-5 Design Progression



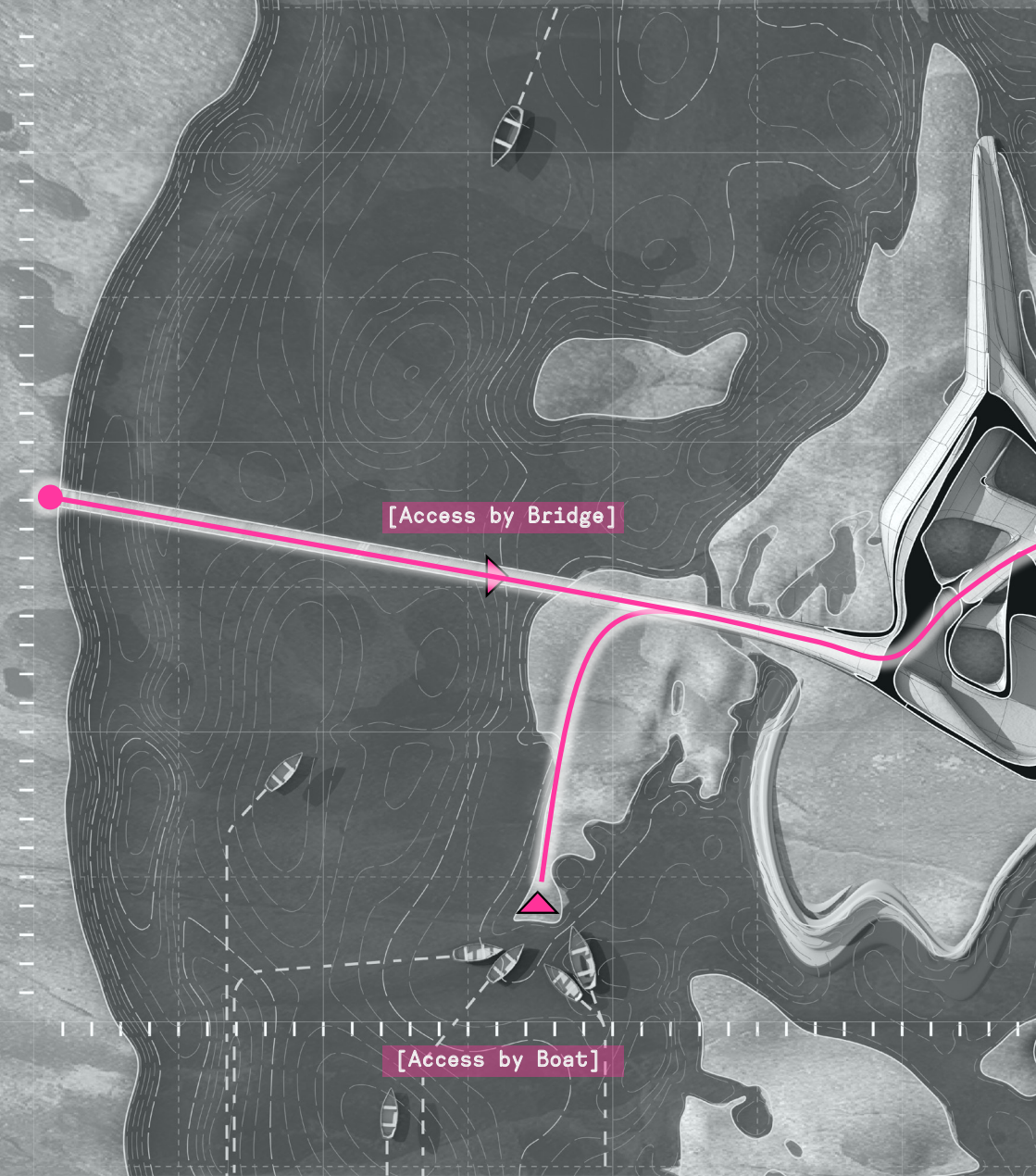
Plan at level +2m - ground level showing functional spaces.



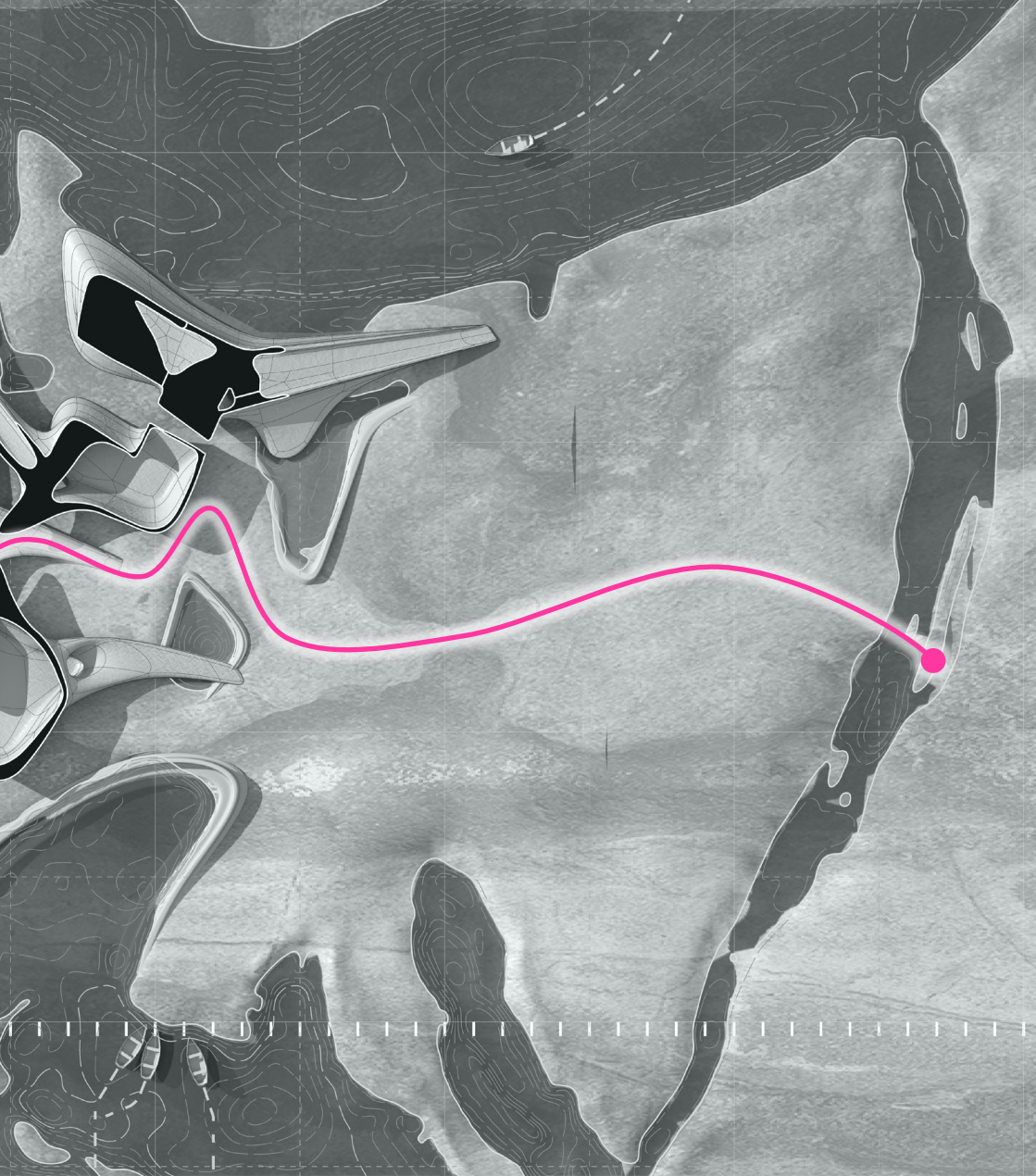
[In-Flow]- P3-5 Design Progression



The building creates a ramp system which makes it easy for people to transverse through the site. In a normal situation where people need to walk around a building in this case people can just walk over it hence creating the shortest route possible to quickly take people from pt A to pt B.



[In-Flow]- P3-5 Design Progression



The building has multiple ramps carrying people to different points in the site.



[In-Flow]- P3-5 Design Progression

Bathing Ghats]

Bathing Ghats]

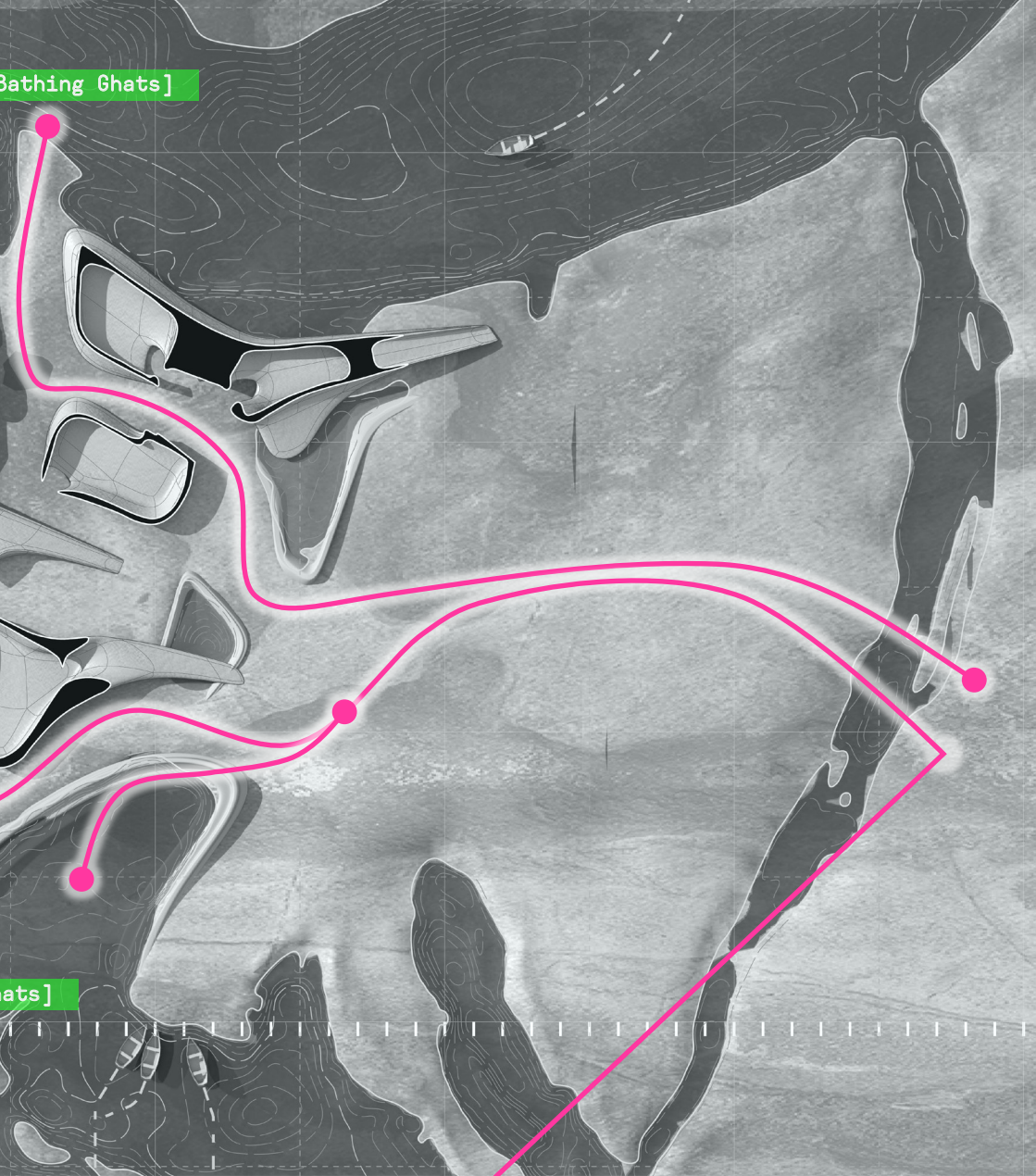
*Accessibility diagram - Access for people arriving by boat and from
nearby site to bathing ghats.*



[Bathing Ch

[In-Flow]- P3-5 Design Progression

Bathing Ghats]

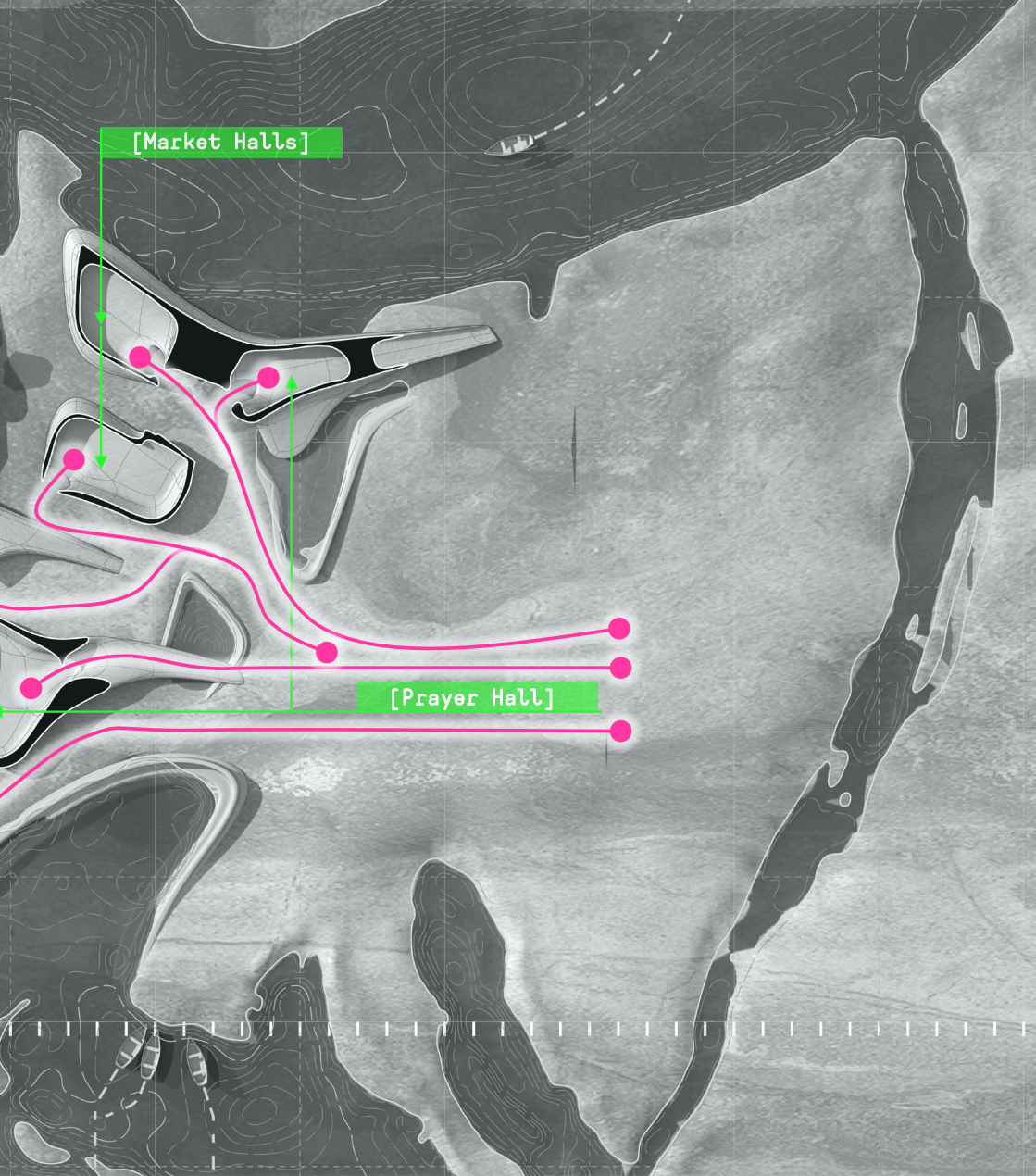


Bathing Ghats]

Accessibility diagram - Access for people arriving from immediate context to bathing ghats.



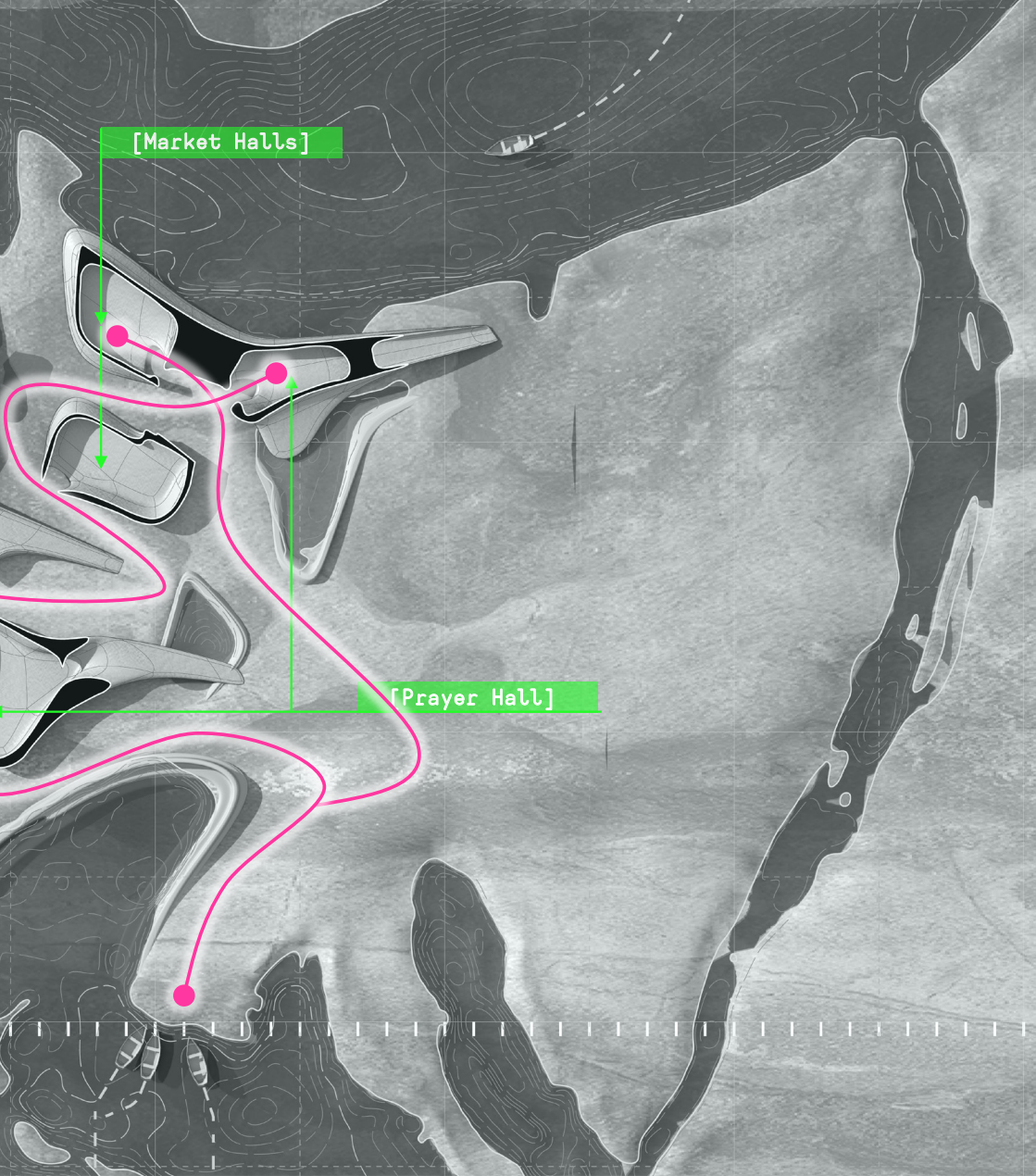
[In-Flow]- P3-5 Design Progression



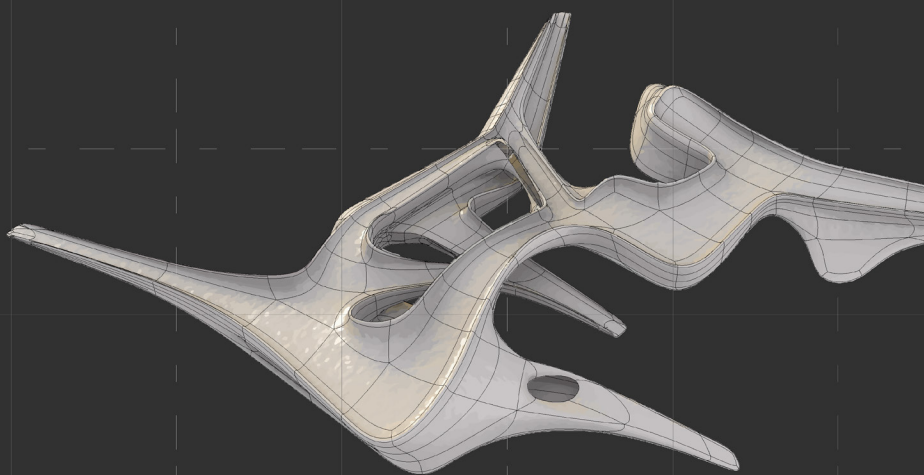
Accessibility diagram - Access for people arriving from immediate context to functional spaces.



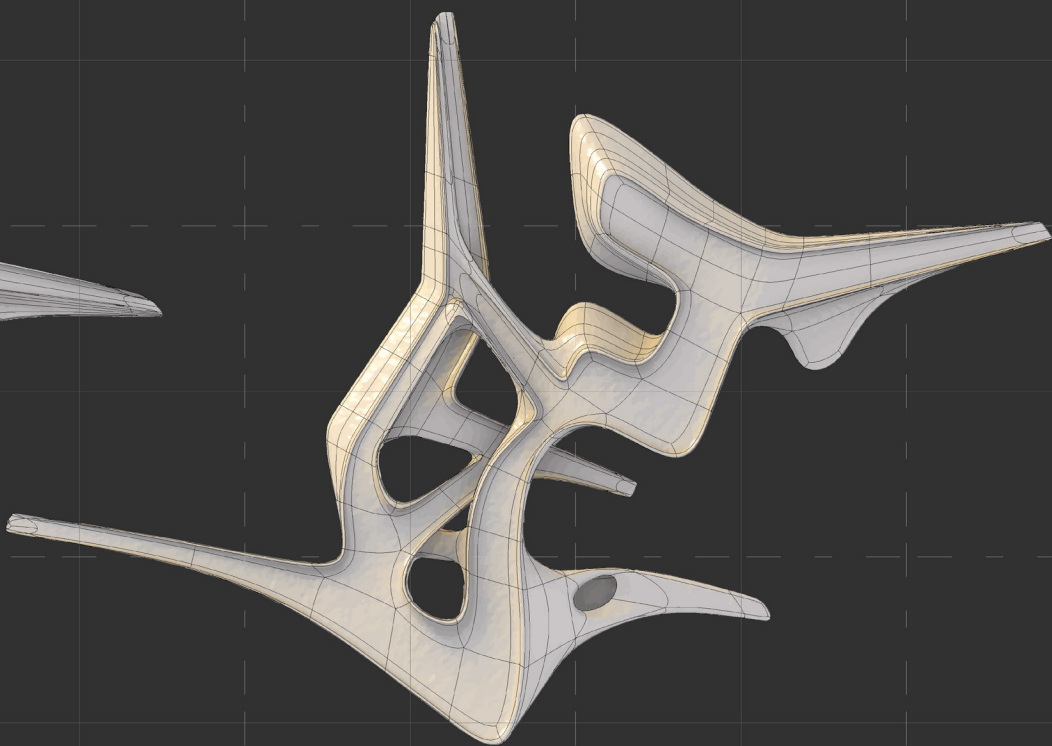
[In-Flow]- P3-5 Design Progression



Accessibility diagram - Access for people arriving by boat and from nearby site to functional spaces.

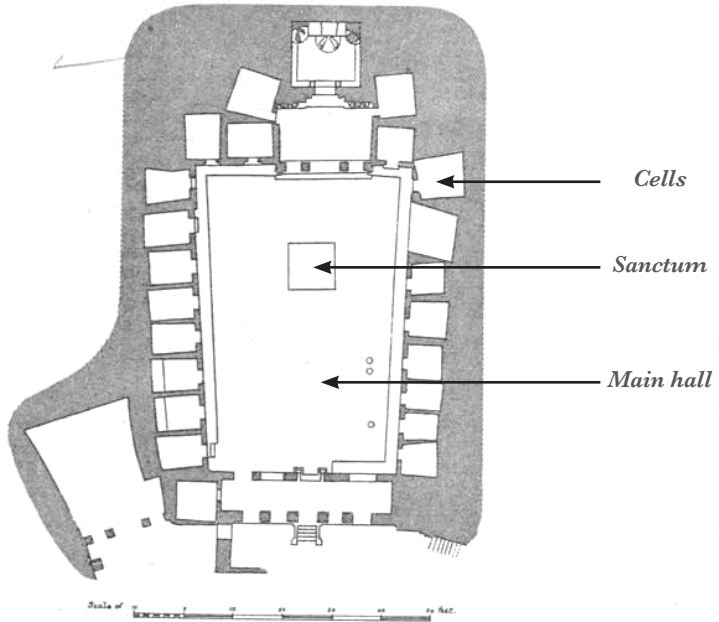


[In-Flow]- P3-5 Design Progression

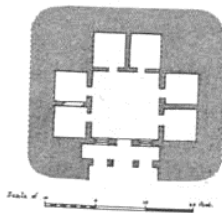


Final design volume

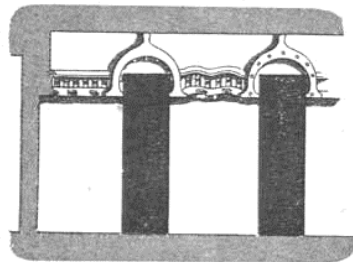
NASIK.
I. PLAN OF CAVE XV.



2. PLAN OF CAVE XIV.

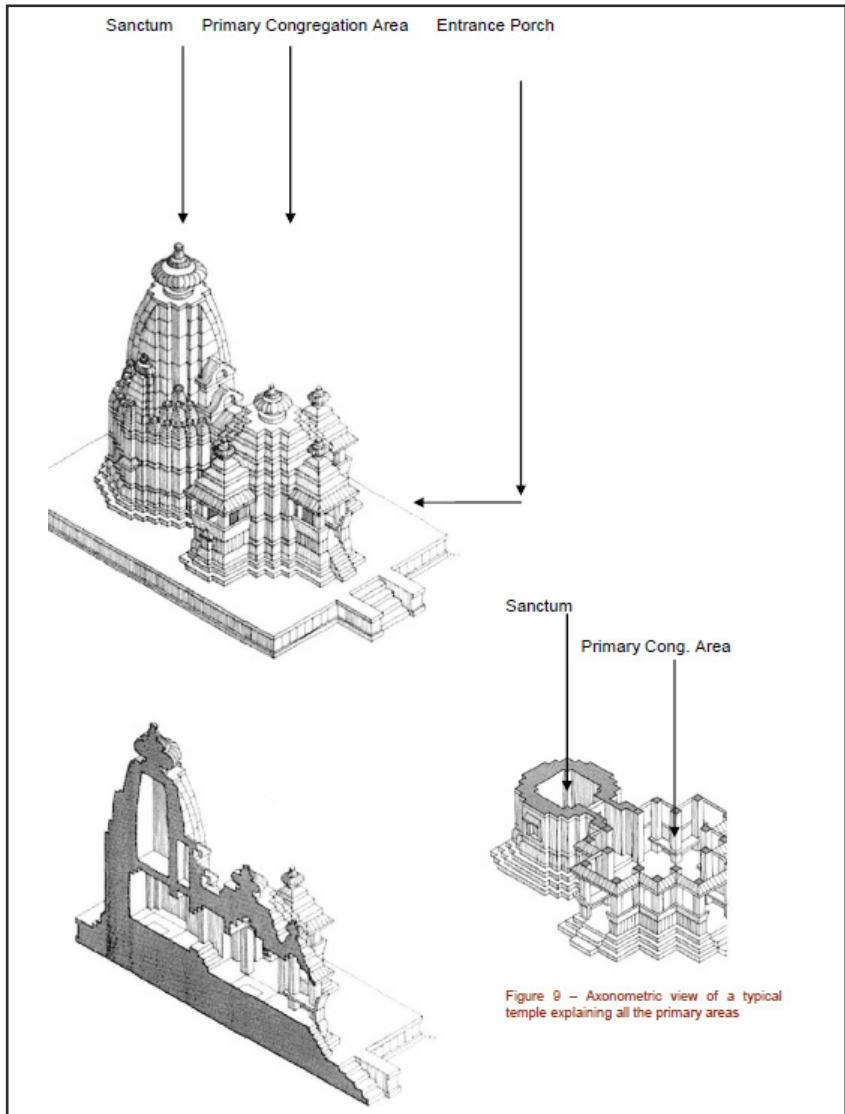


3. WALL ELEVATION IN CAVE XIV.

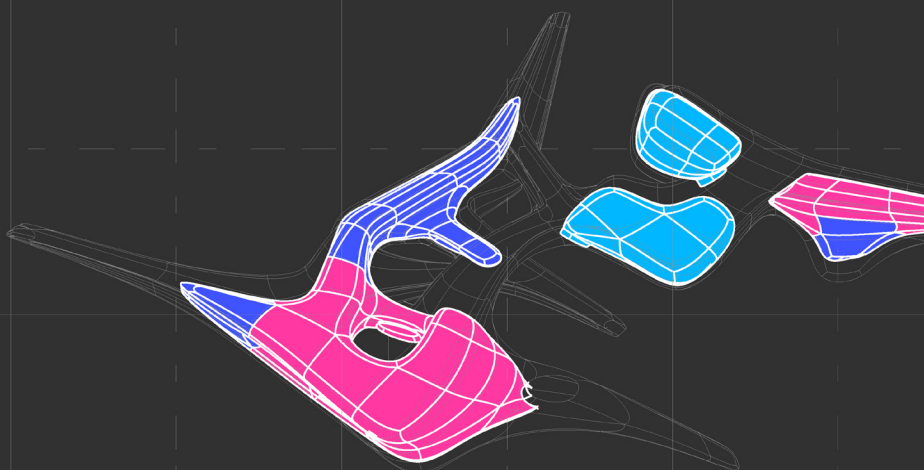


J. Burgen.

W. GRIGGS, PHOTO LITH. LONDON, E. R.



The design takes inspiration from traditional temple planning systems in particular the design of the sanctum and prayer cells connected to main hall.



[geometry_space utilization]

[public-structure]

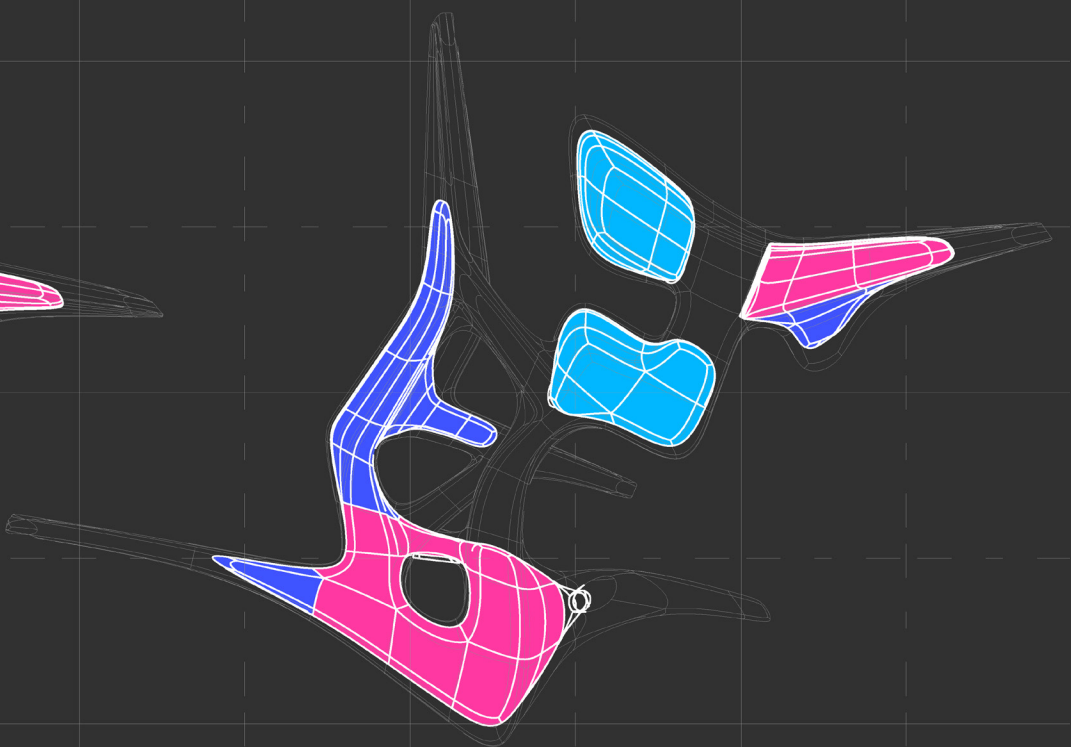
[prayer-hall]

[prayer-cells]

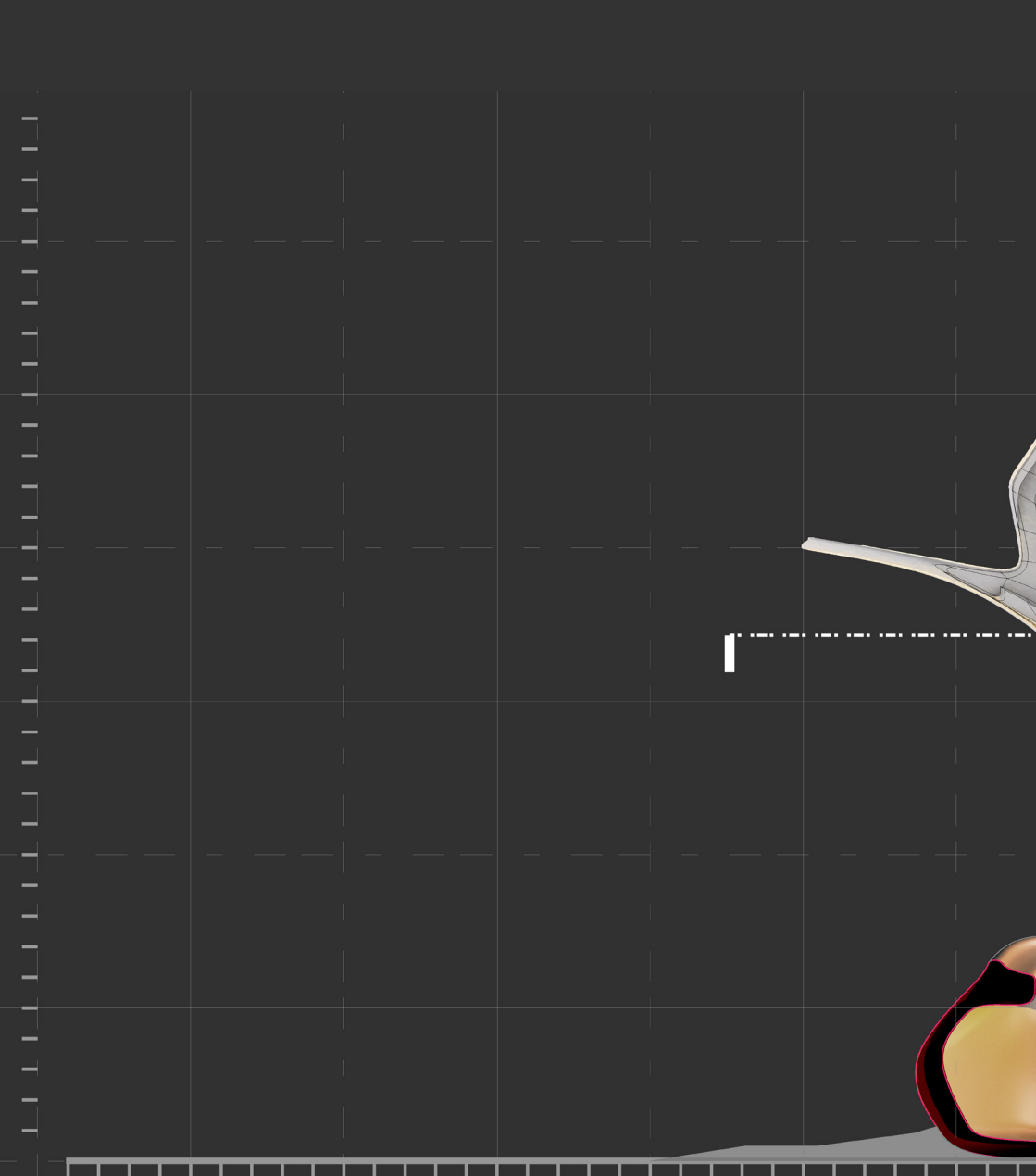
[courtyard]

[market-hall]

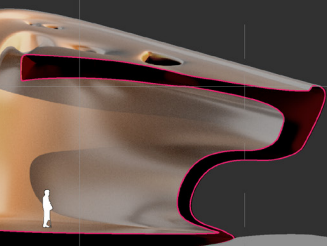
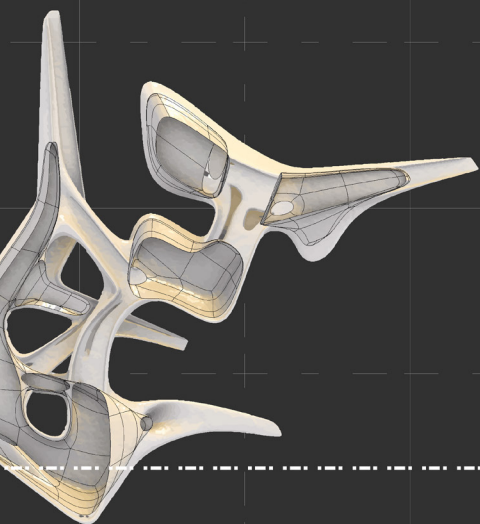
[In-Flow]- P3-5 Design Progression



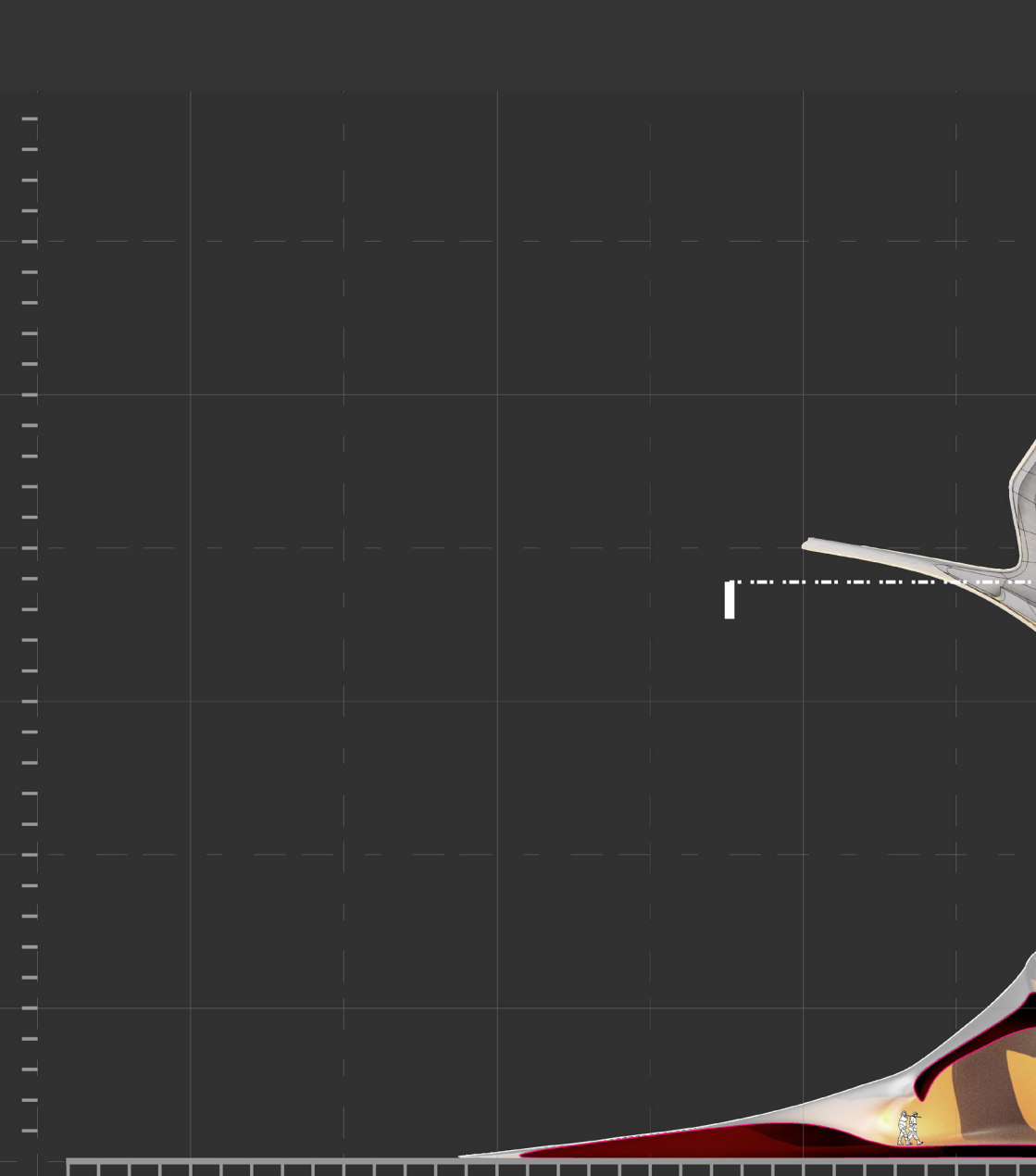
The main halls are connected to the cells with the sanctum in the middle.



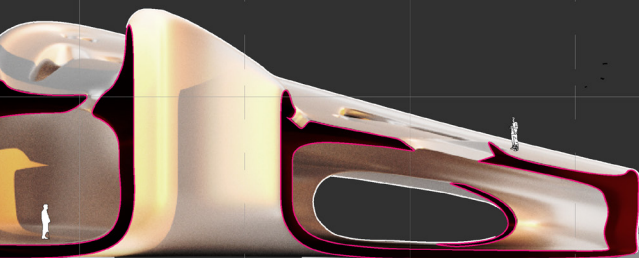
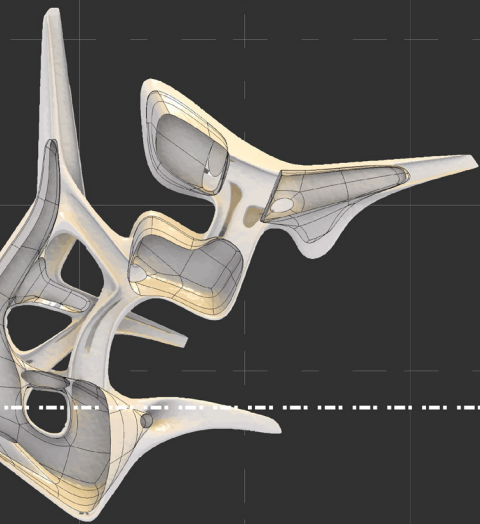
[In-Flow]- P3-5 Design Progression



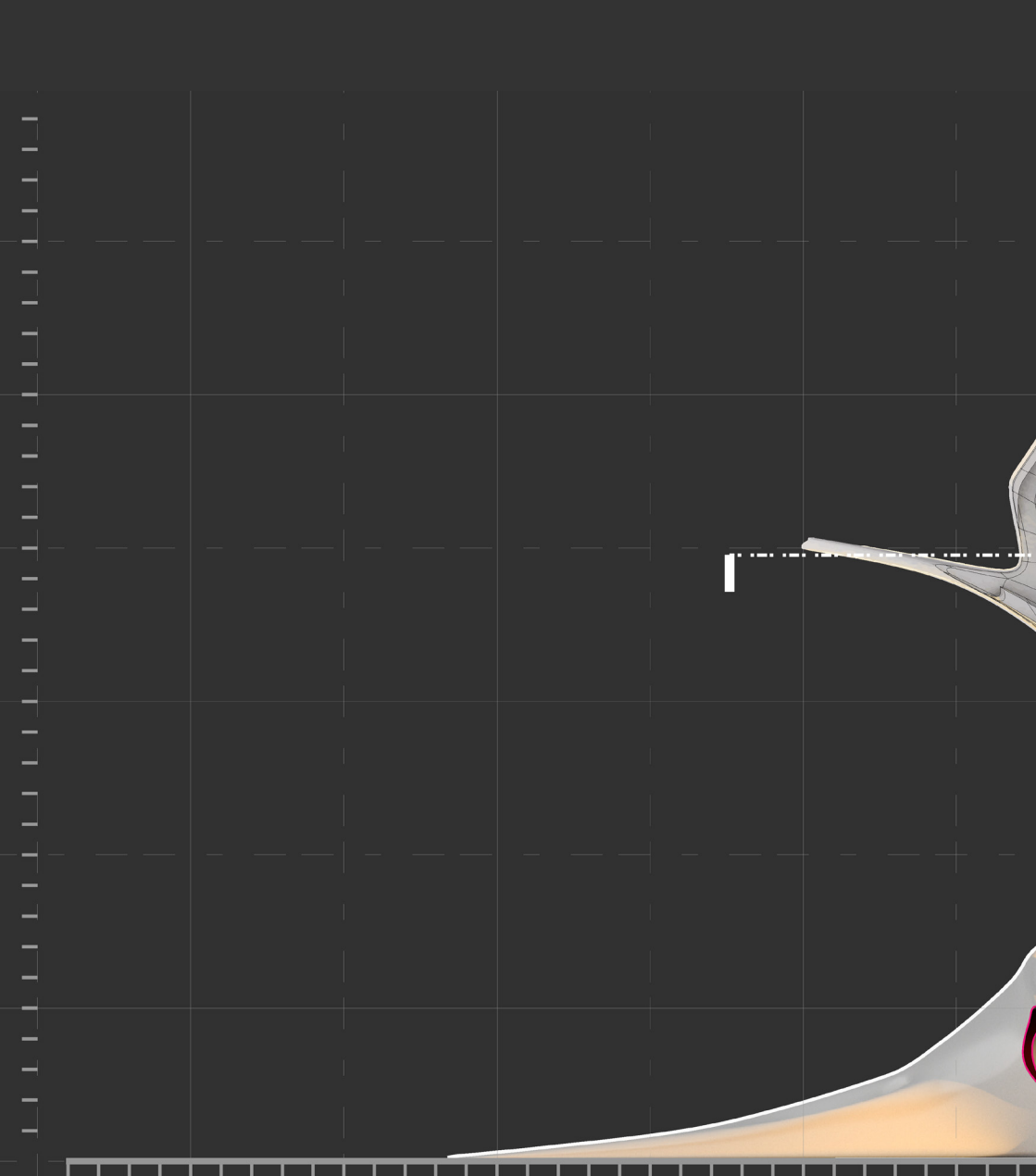
Section through main hall.



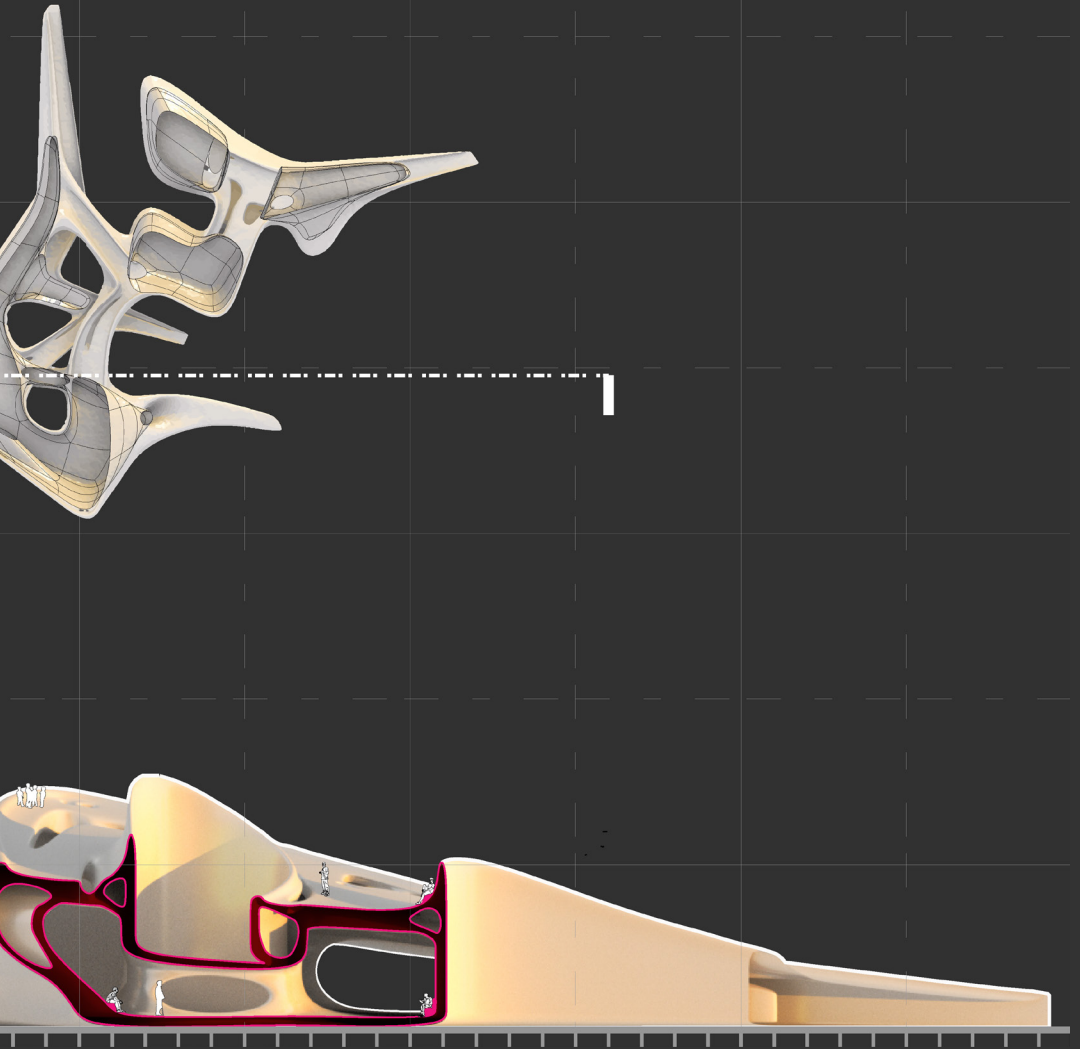
[In-Flow]- P3-5 Design Progression



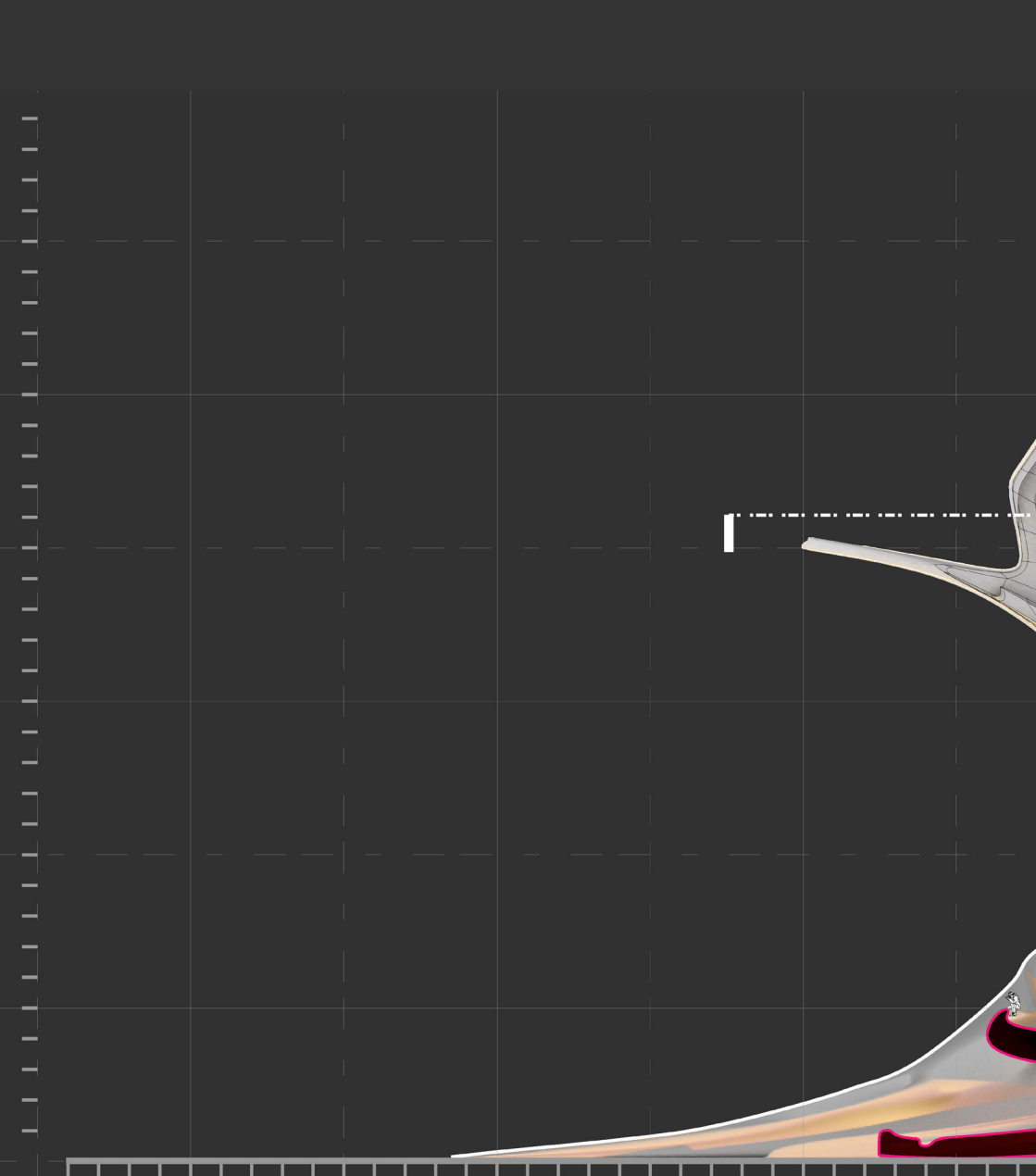
Section through sanctum.



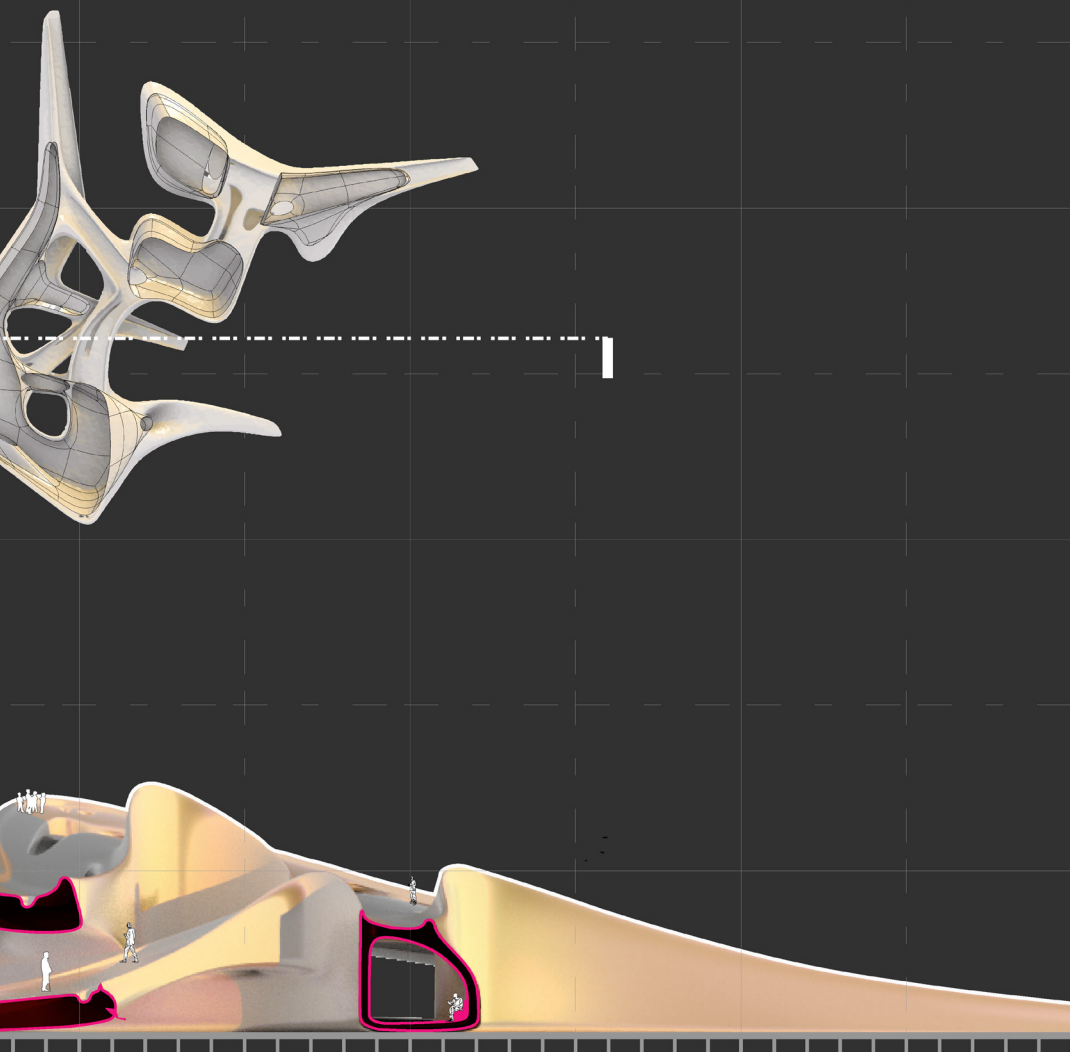
[In-Flow]- P3-5 Design Progression



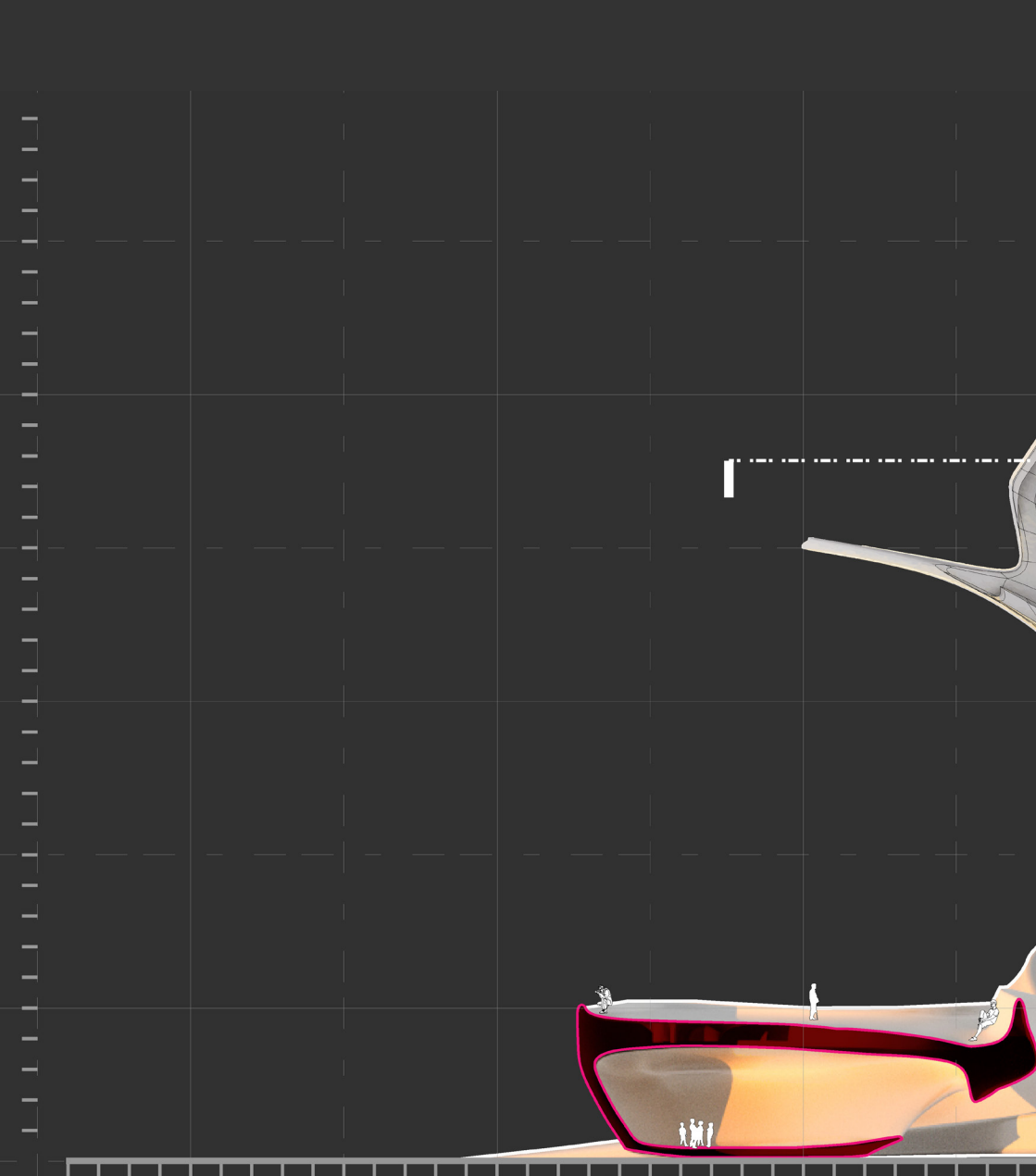
Section through connecting cave between sanctum & hall



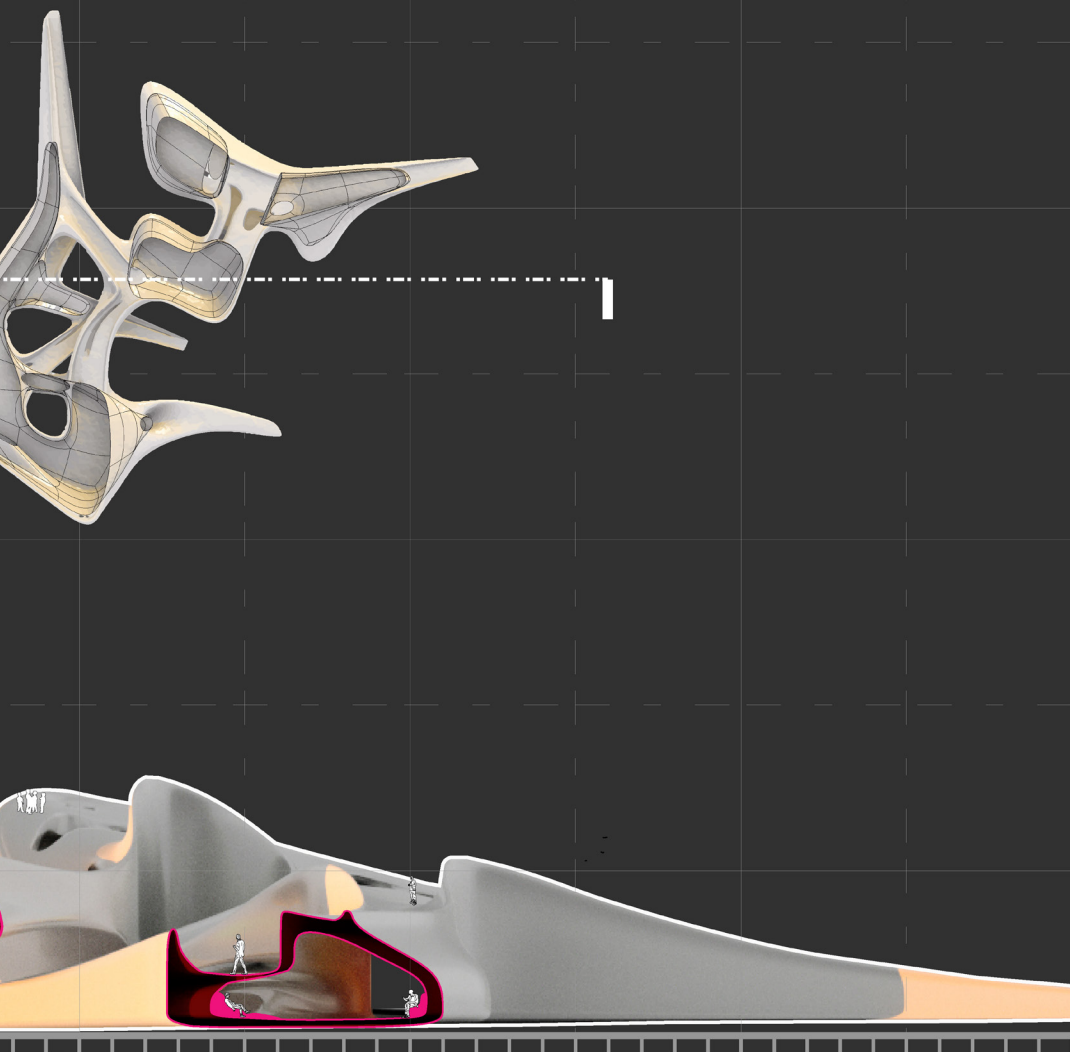
[In-Flow]- P3-5 Design Progression



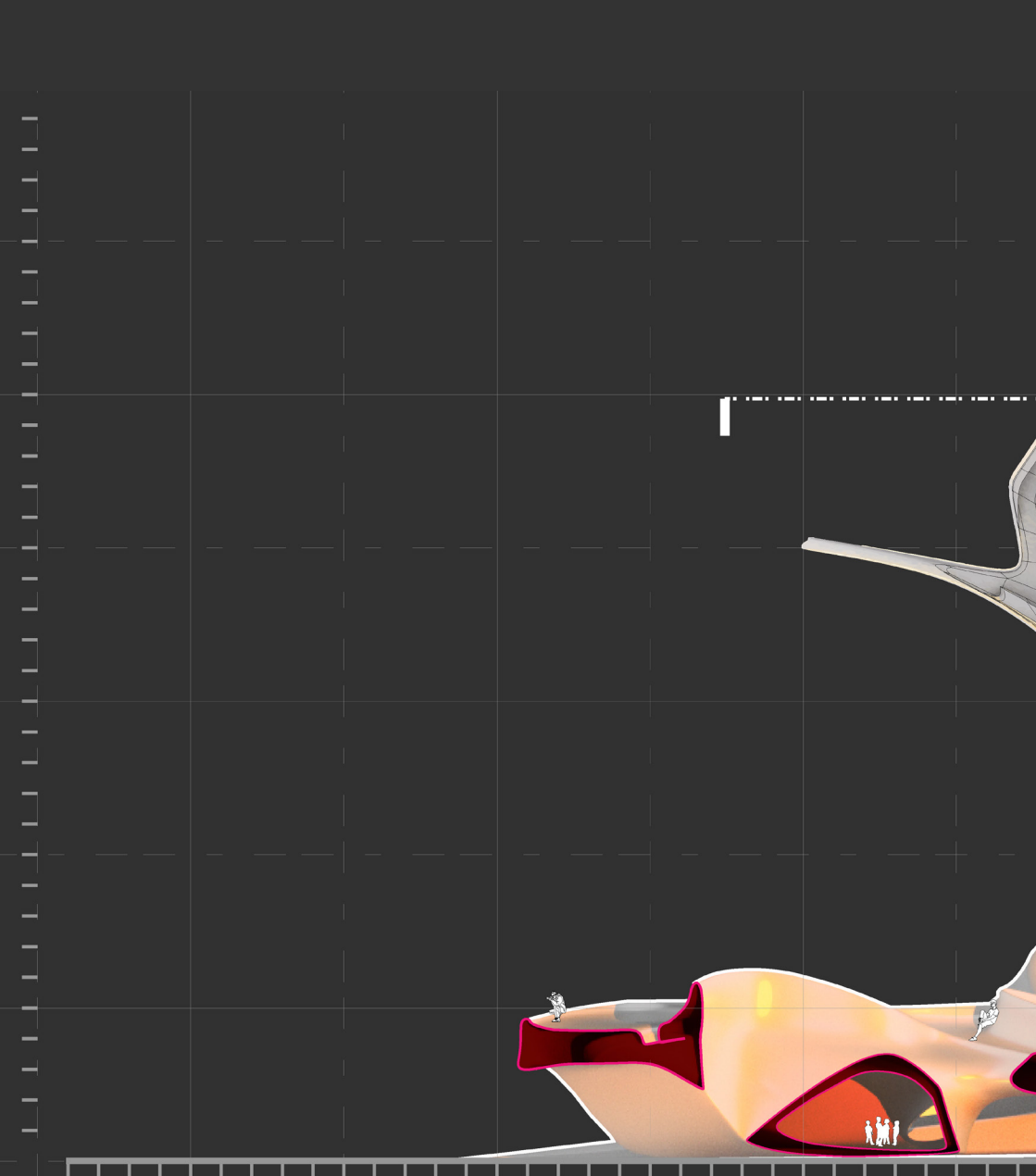
Section through cells & bridges



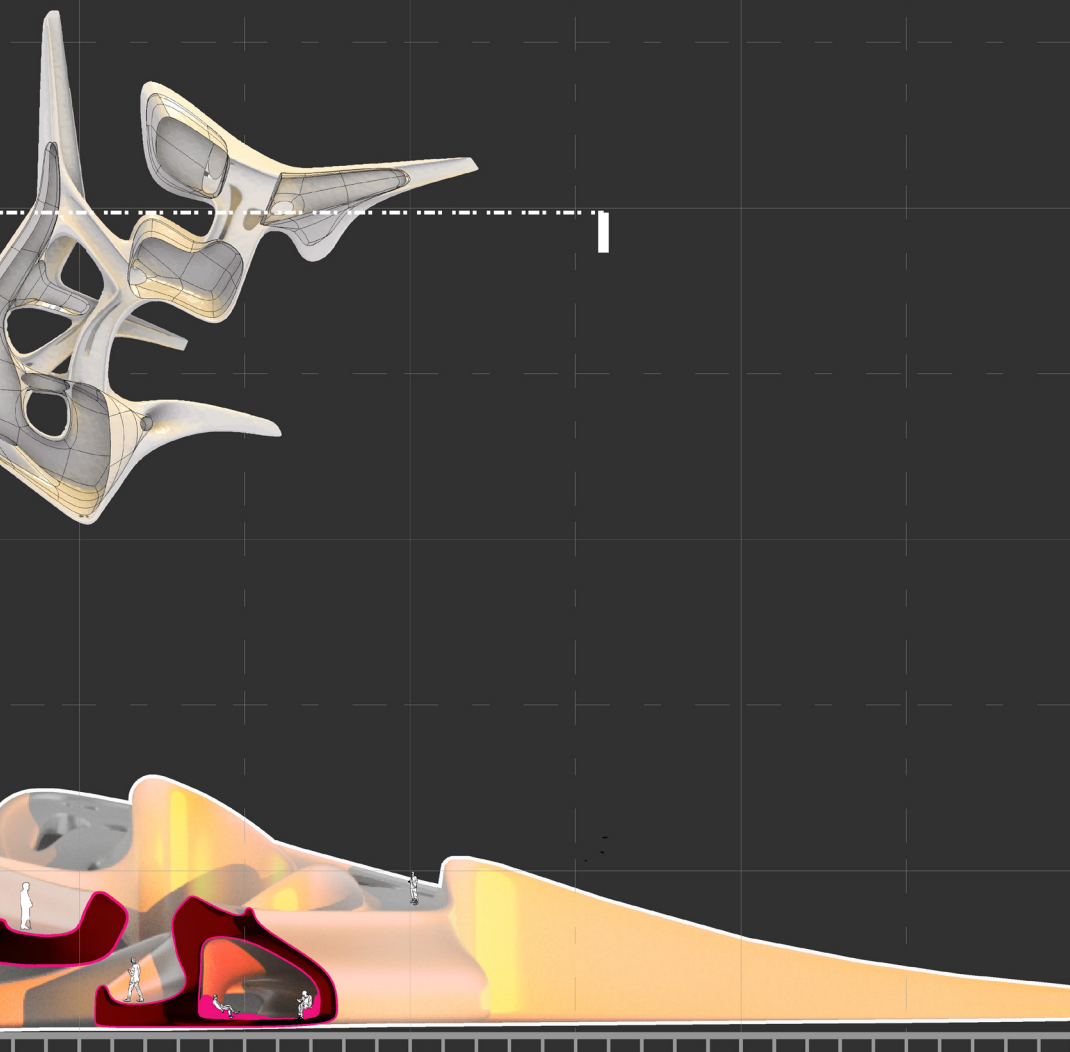
[In-Flow]- P3-5 Design Progression



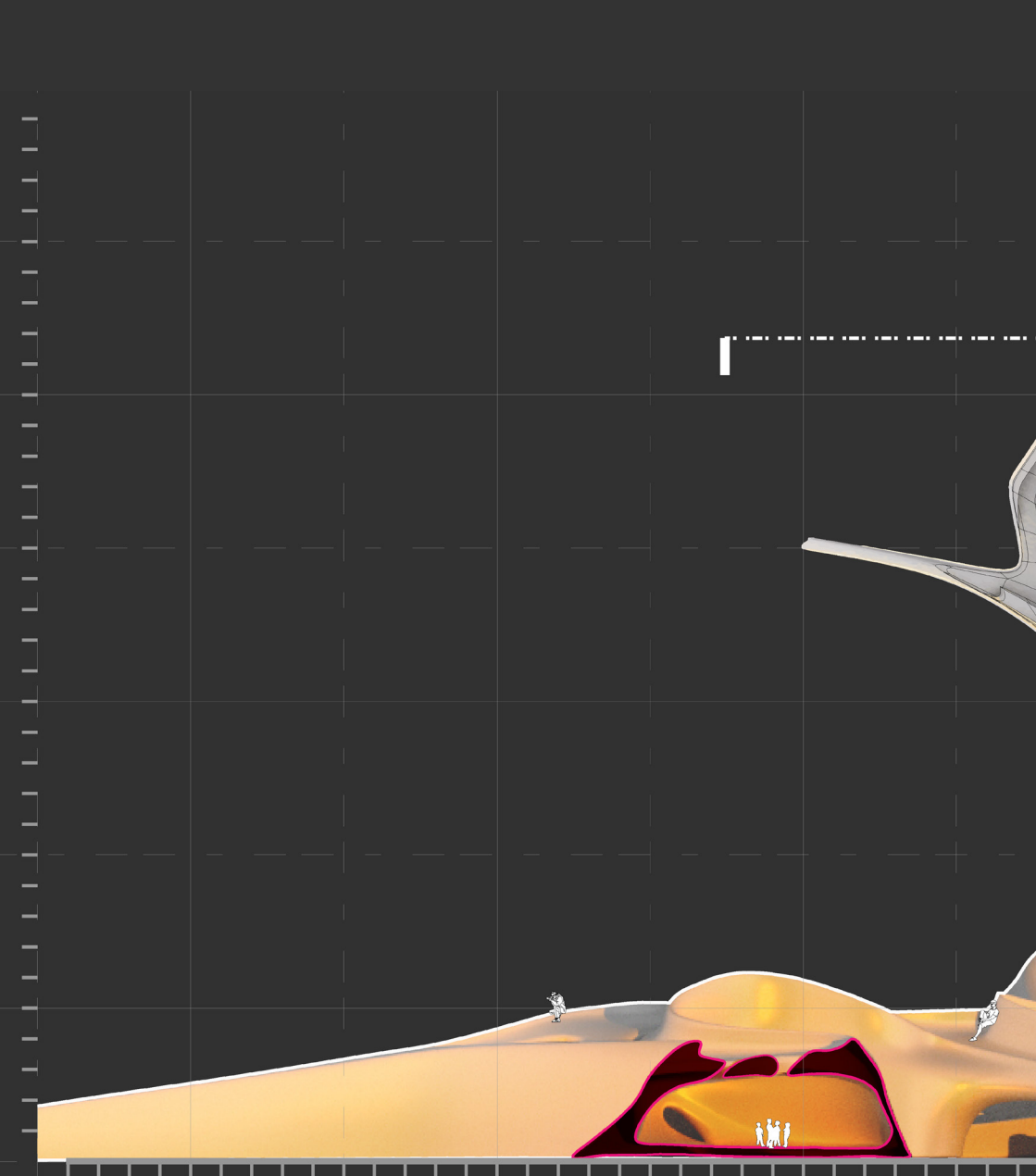
Section through market hall & cells



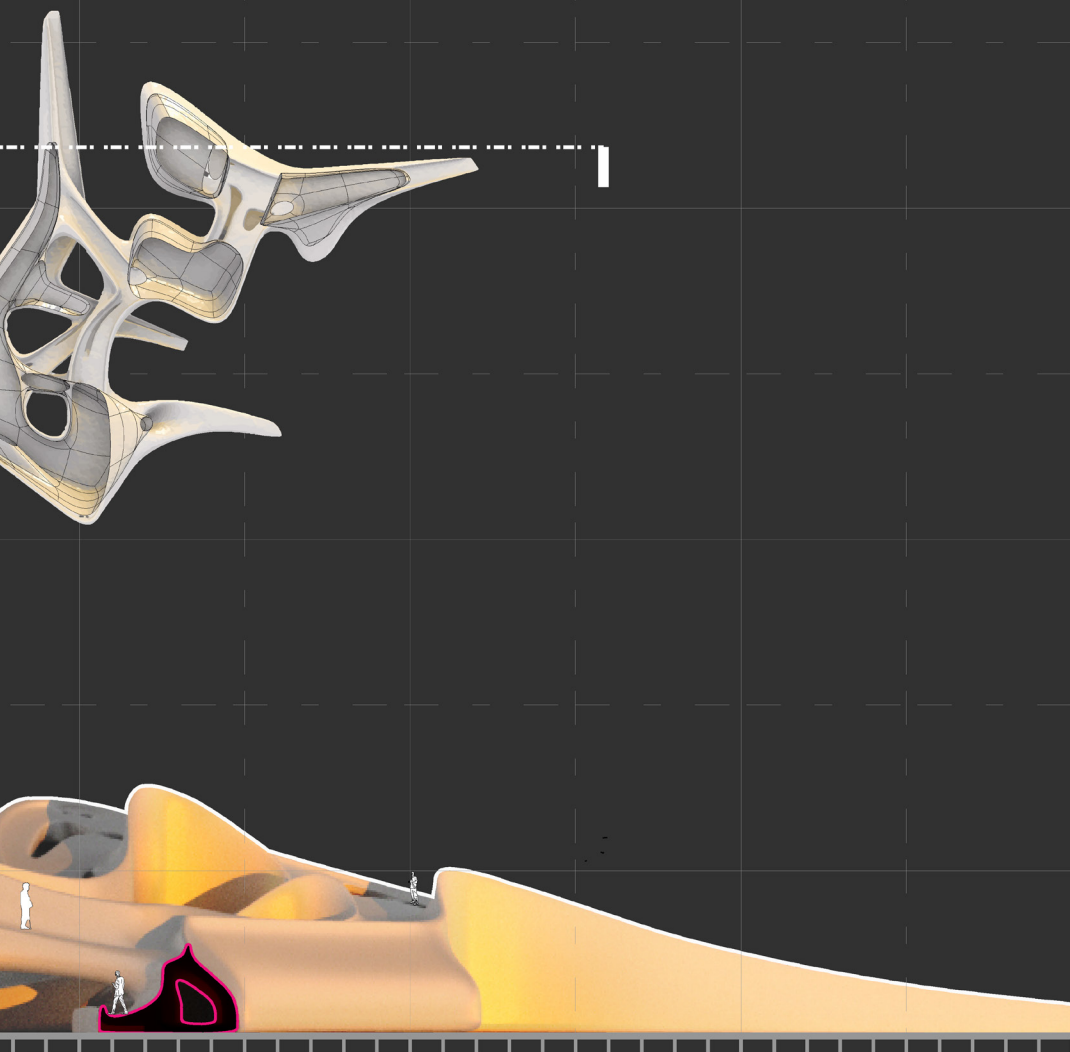
[In-Flow]- P3-5 Design Progression



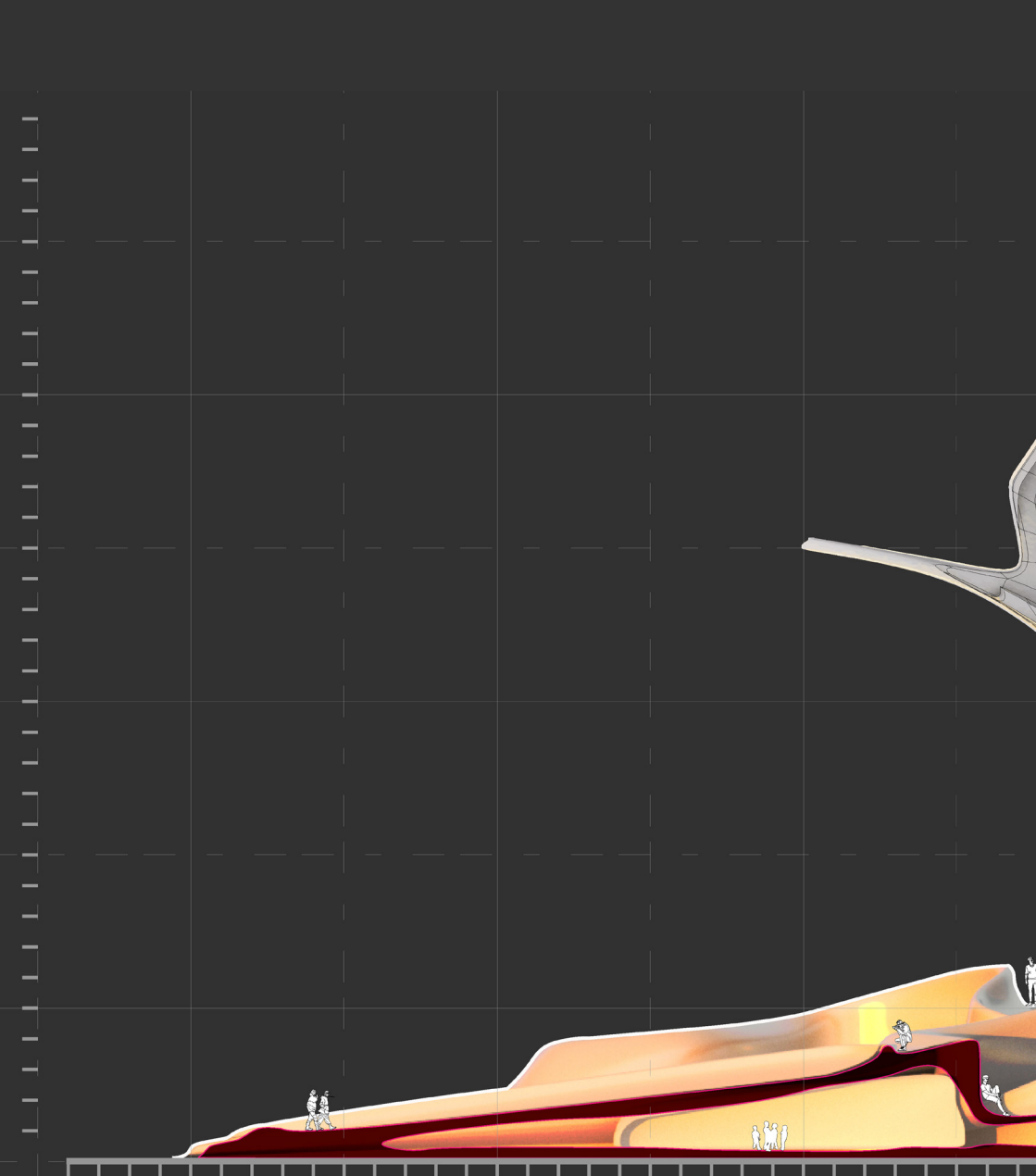
Section through meeting hall & cells



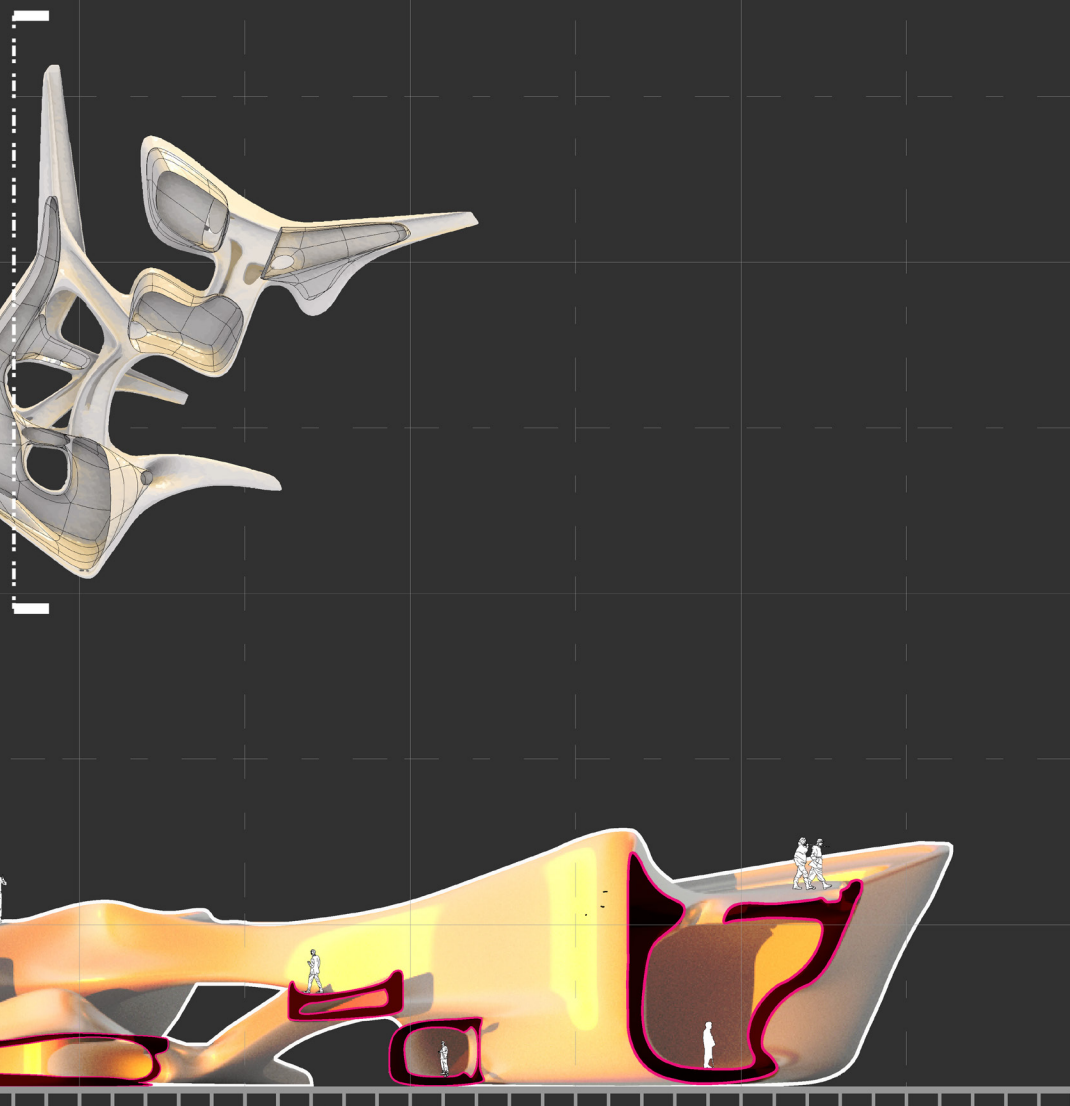
[In-Flow]- P3-5 Design Progression



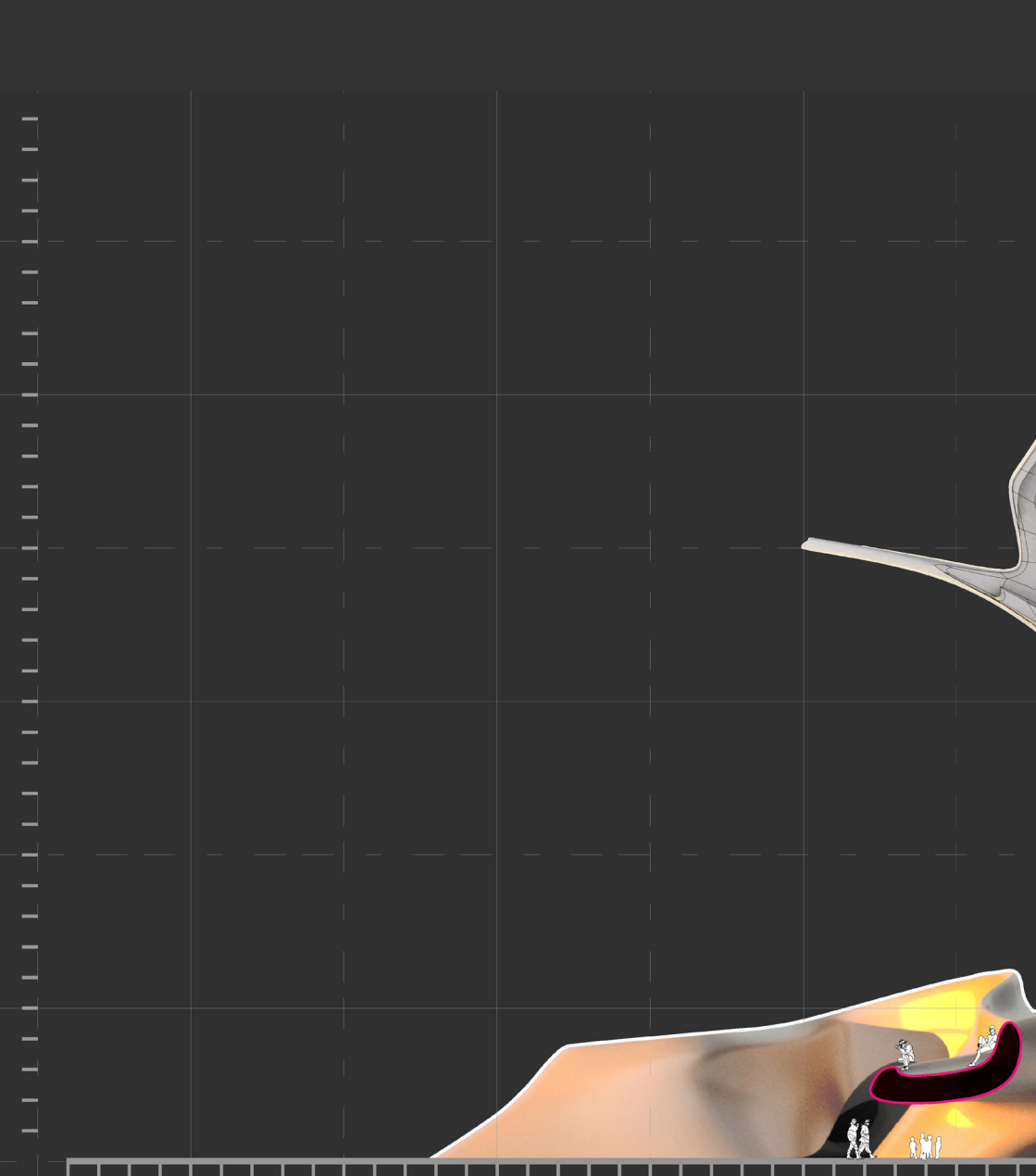
Section through meeting hall



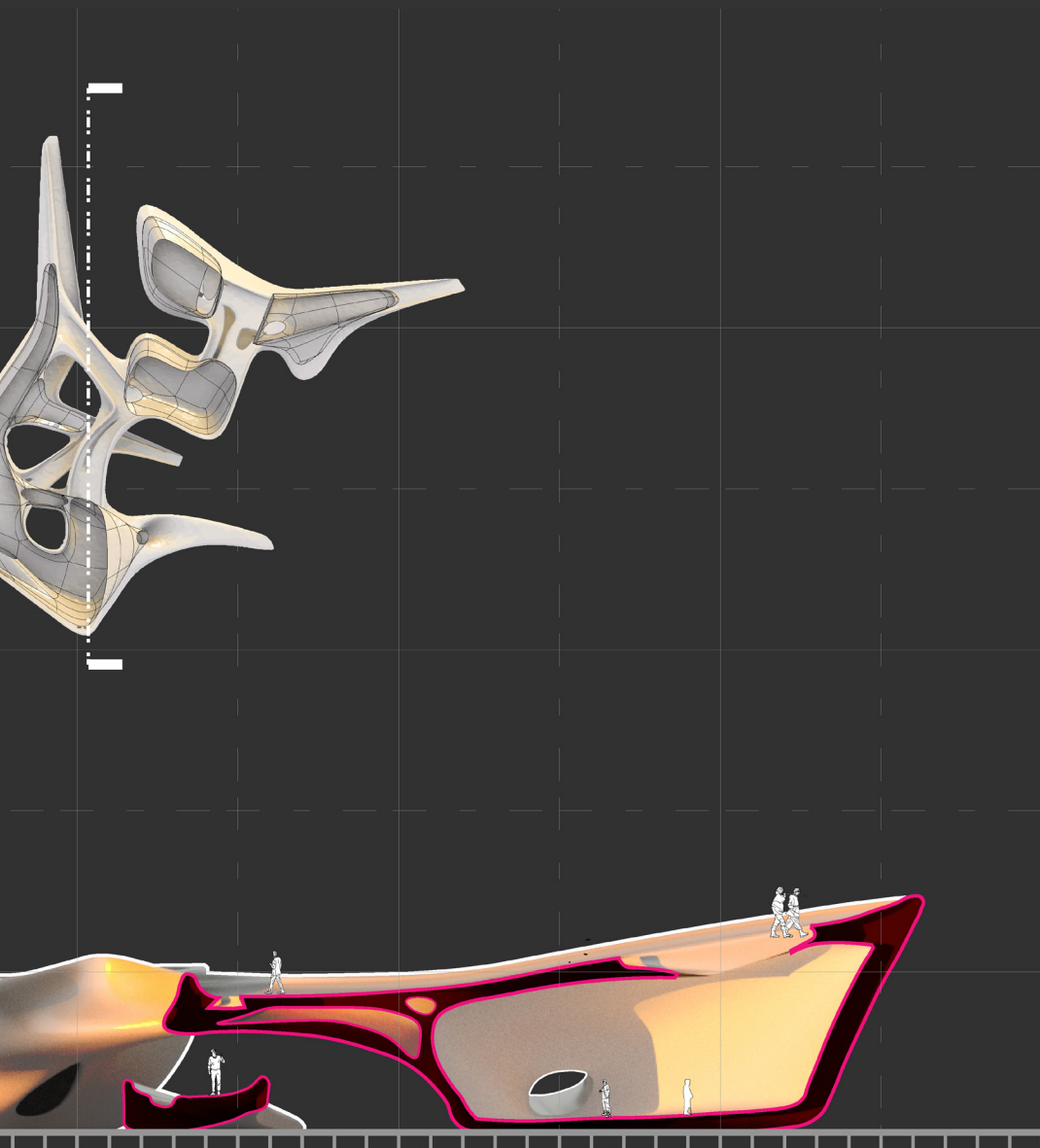
[In-Flow]- P3-5 Design Progression



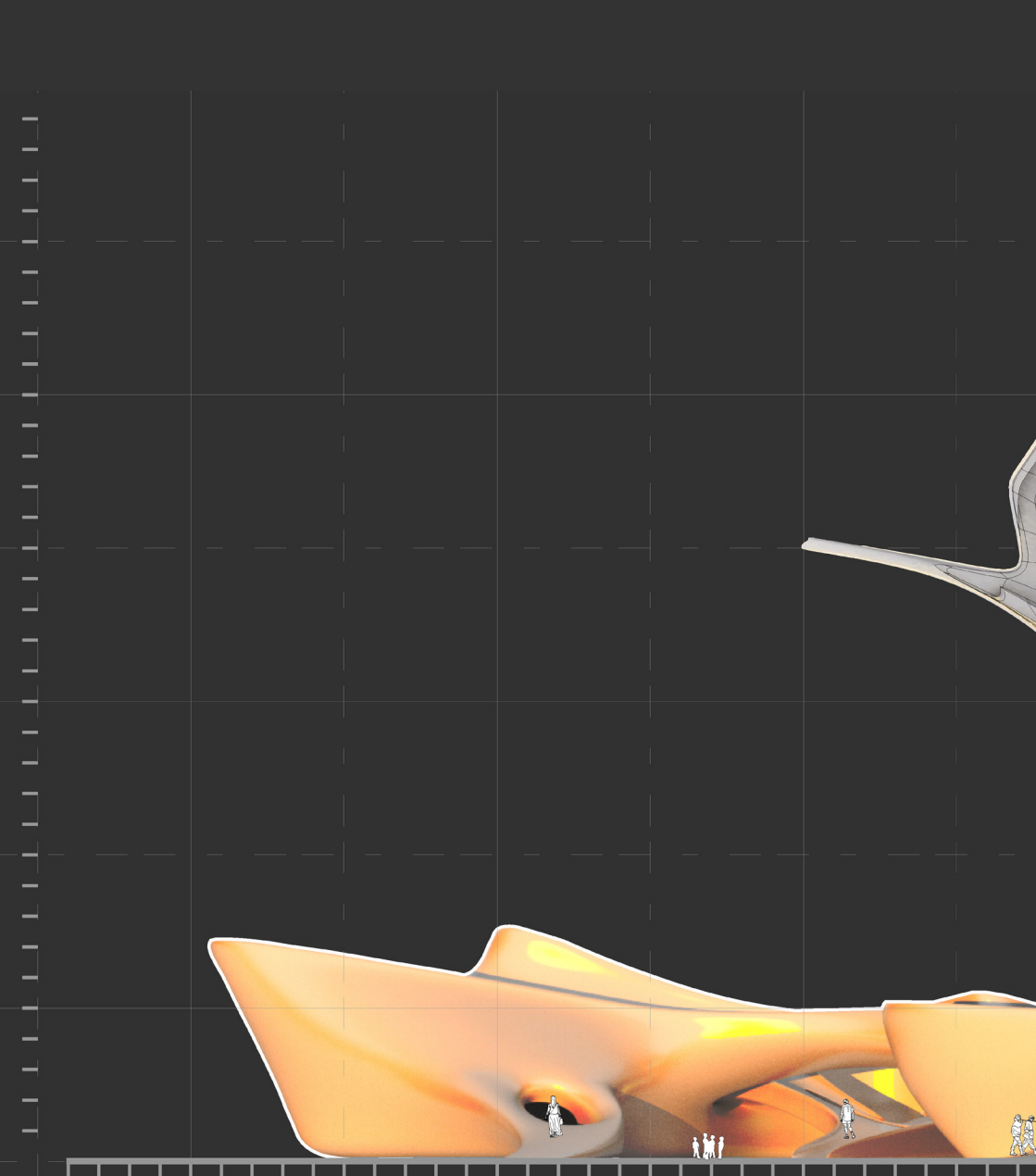
Section through cells, sanctum & halls



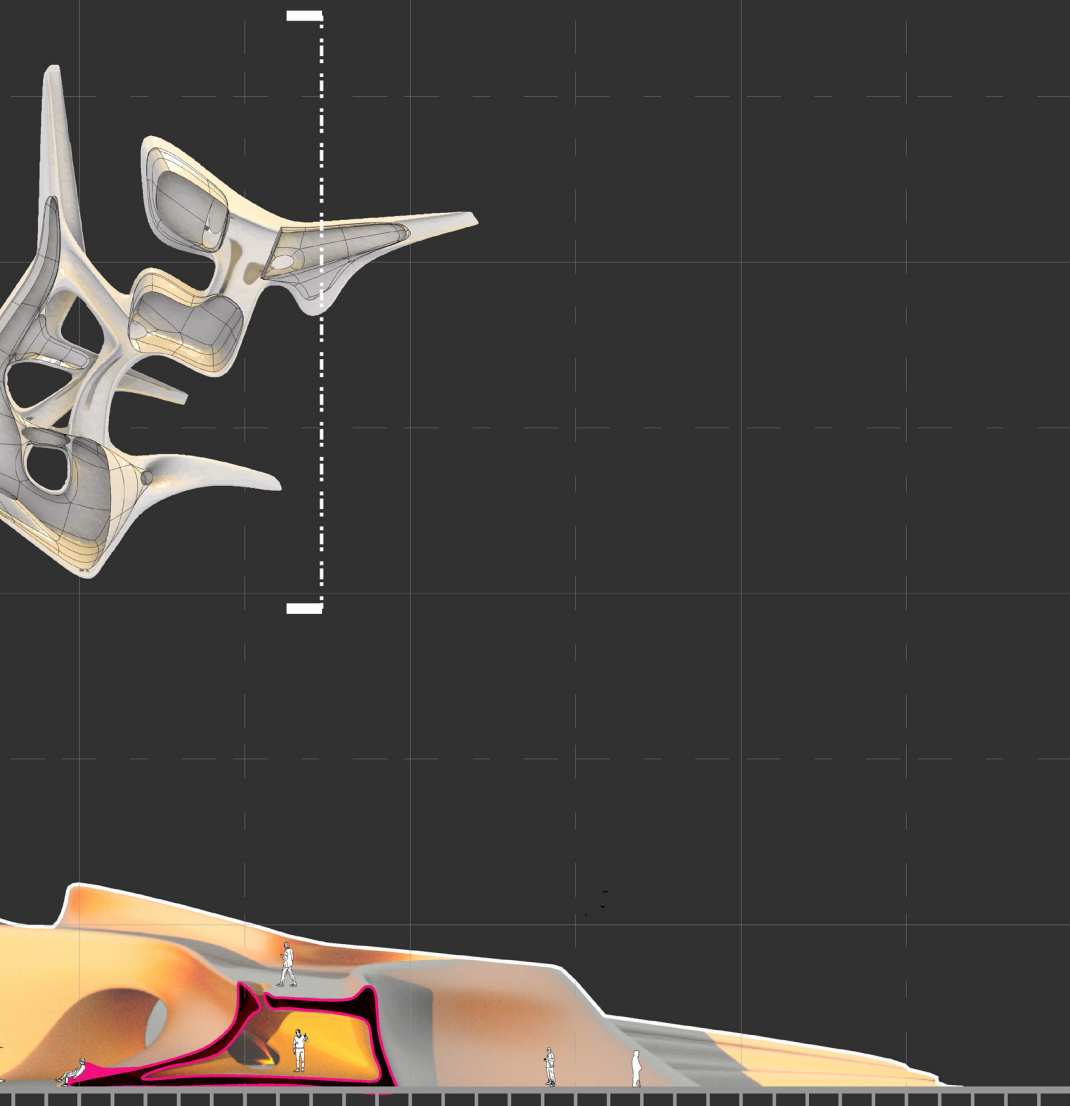
[In-Flow]- P3-5 Design Progression



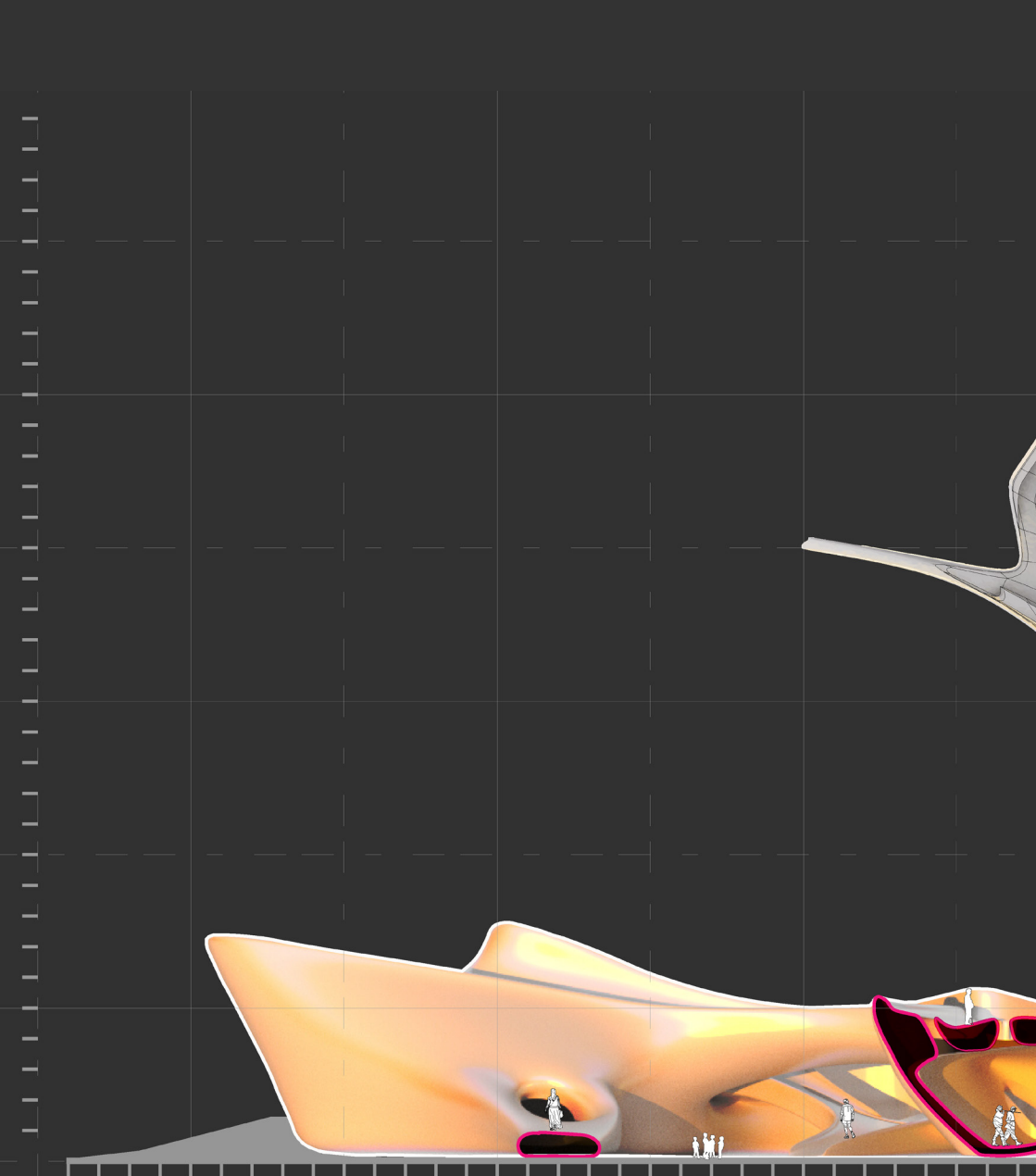
Section through bridges & prayer hall



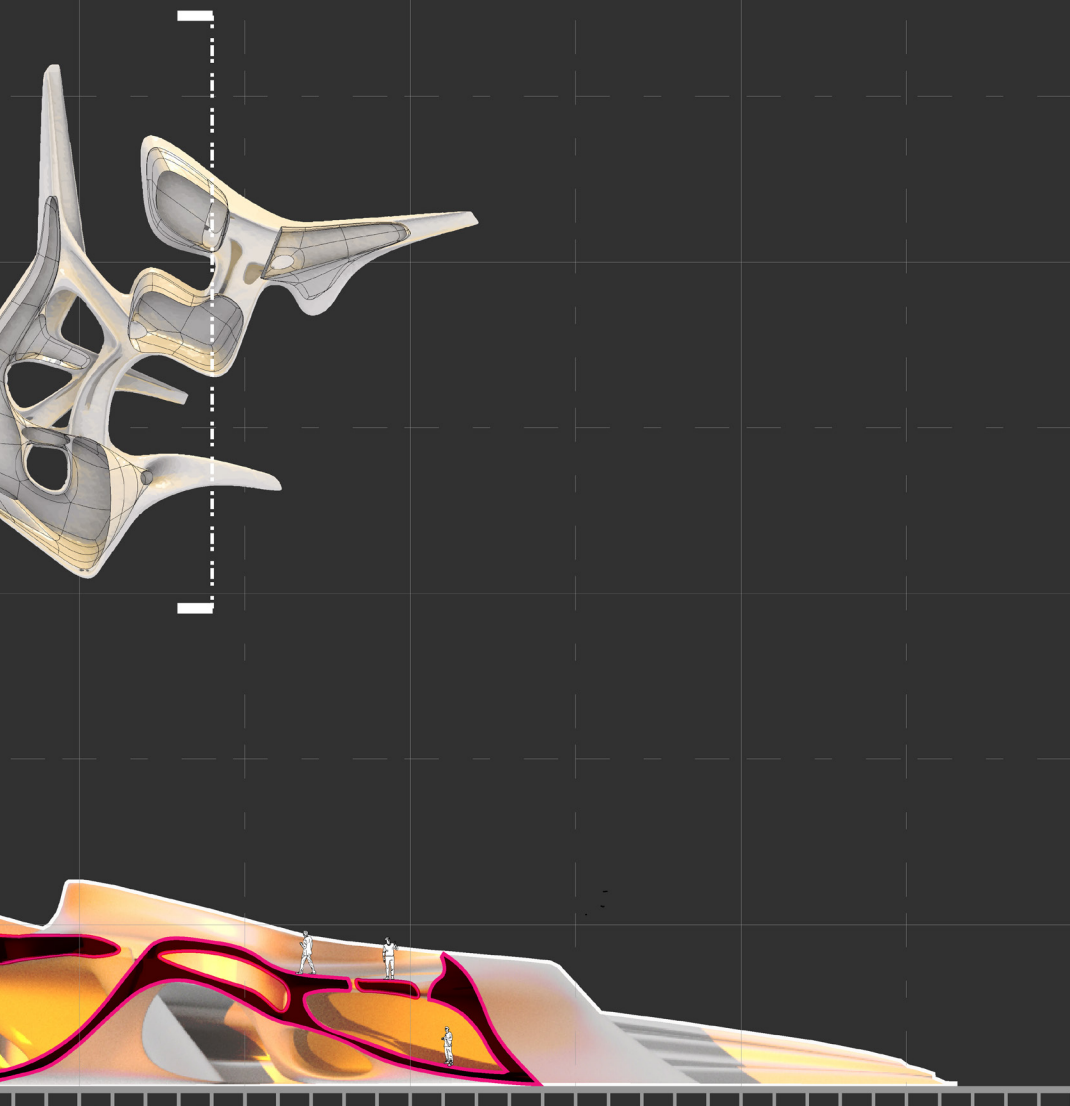
[In-Flow]- P3-5 Design Progression



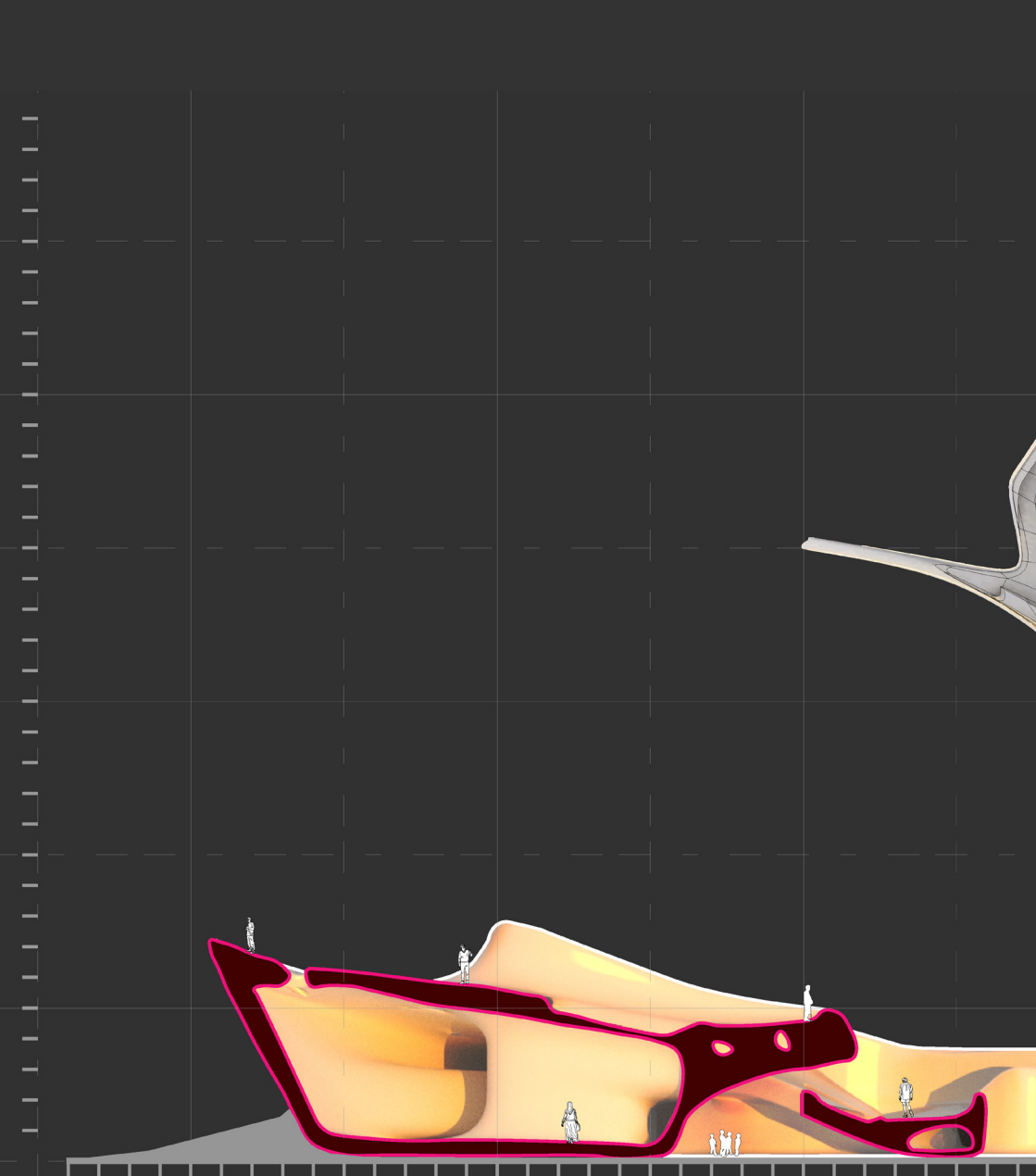
Section through meeting hall



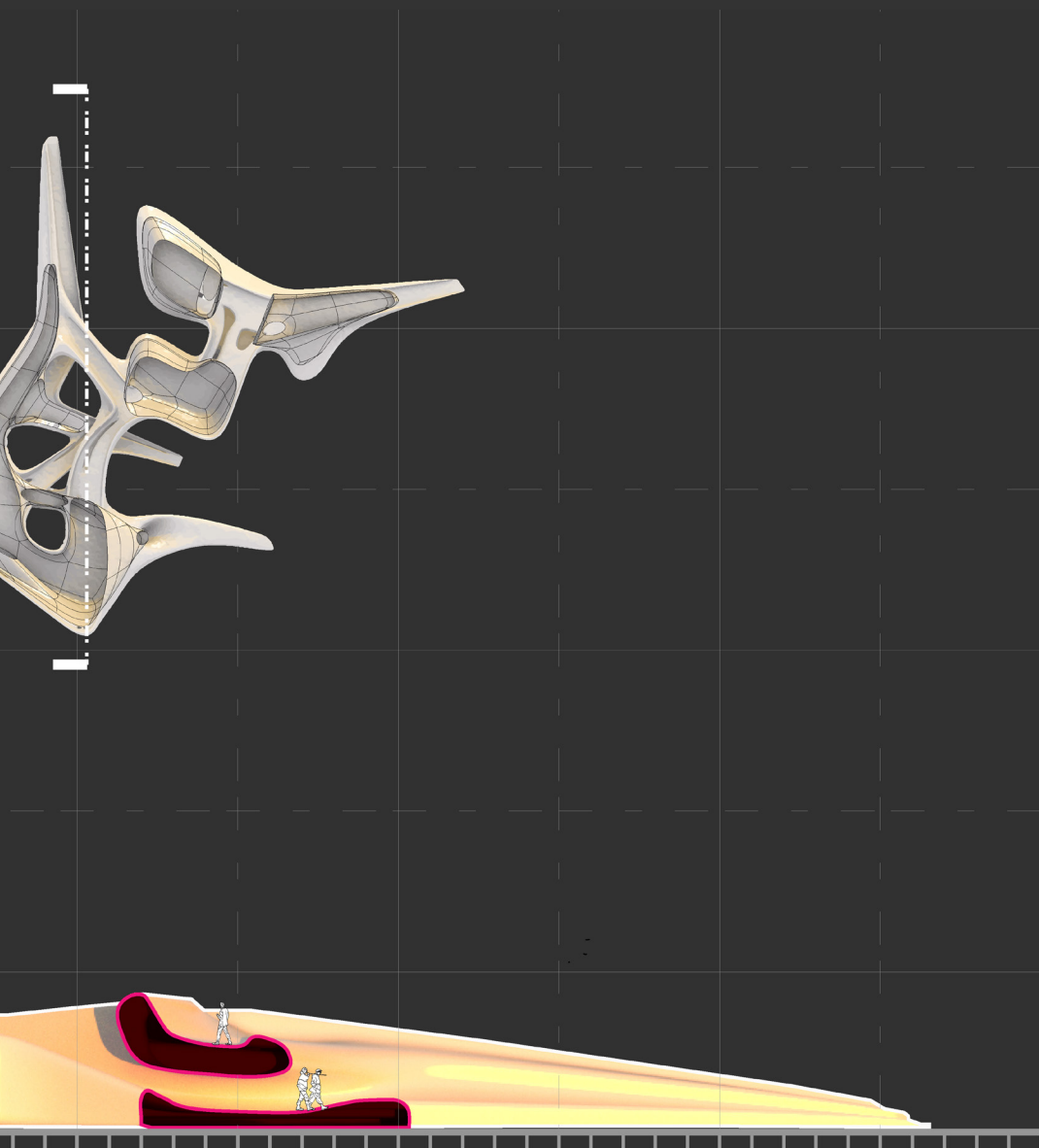
[In-Flow]- P3-5 Design Progression



Section through market place & meeting hall



[In-Flow]- P3-5 Design Progression



Section through prayer hall & bridges



[View from approaching boats]

[In-Flow]- P3-5 Design Progression

[View from nearby mainland]



[Main access view]



The elevations are molded according to experiential view as framed from different access points.



[In-Flow]- P3-5 Design Progression



The frontal elevation faces the access from boats. This elevation is kept minimal and mimics the geometry of a traditional temple. The elevation is kept minimal so that it stands out clearly as one approaches from boat.



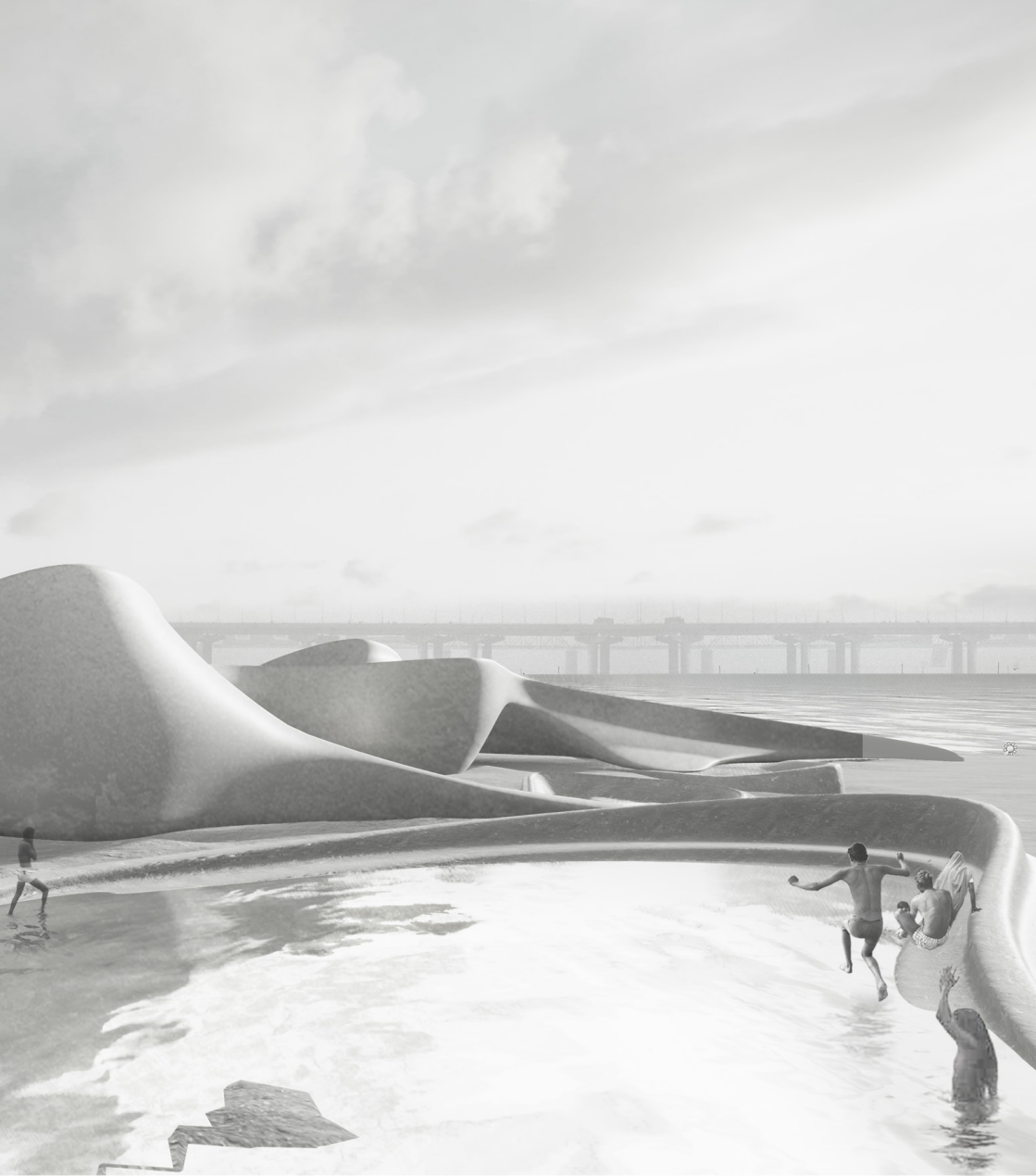
[In-Flow]- P3-5 Design Progression



Front elevation



[In-Flow]- P3-5 Design Progression



Front elevation and the bathing ghats



[In-Flow]- P3-5 Design Progression



The back elevation faces the nearby landmass. Since one can observe the building closely from here the geometry is more expressive this side with a series of interconnected ramps system joining various catenary spaces.



[In-Flow]- P3-5 Design Progression



The side elevation frames the view for the approaching people on foot. The grand arches acts as a welcoming gateway towards the bathing ghats.



[In-Flow]- P3-5 Design Progression



View from far away landmass.



[In-Flow]- P3-5 Design Progression



The tower towards the left shows the level of water that it will attain during monsoon time.



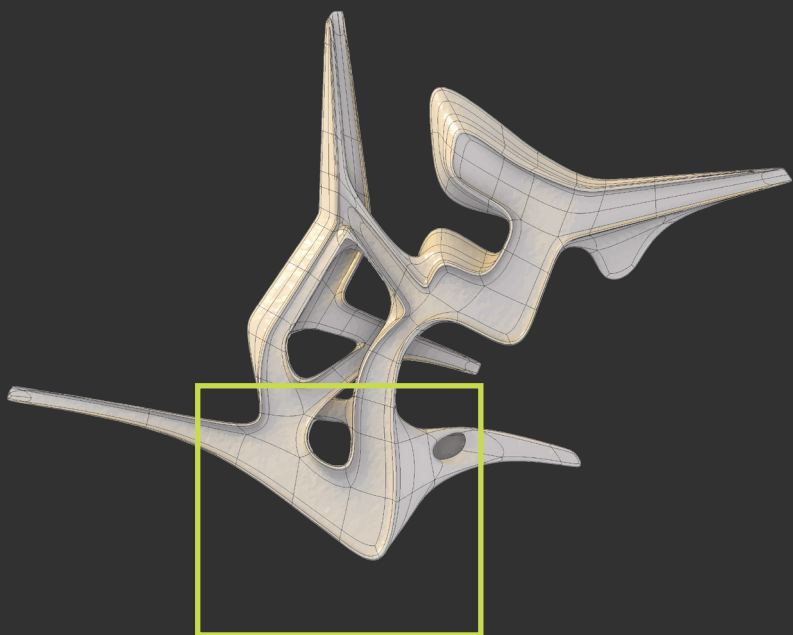
[In-Flow]- P3-5 Design Progression



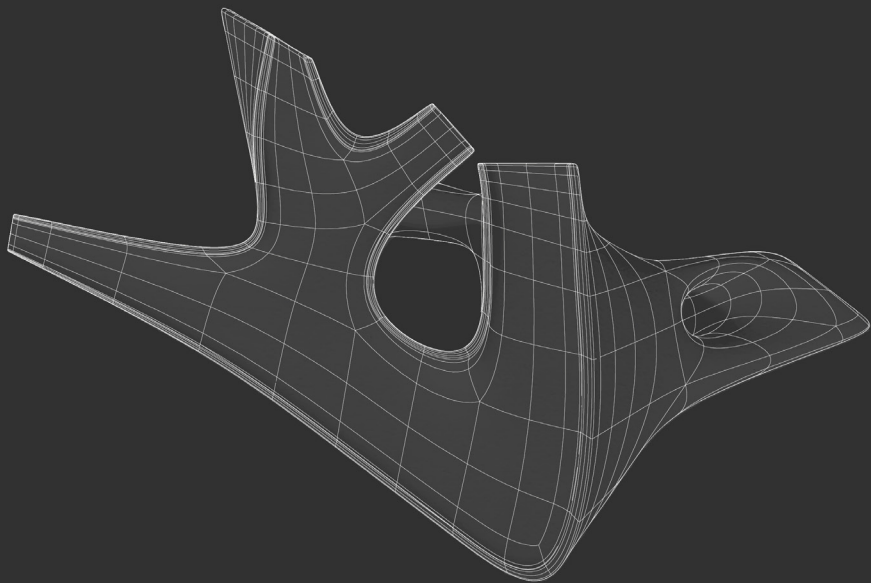
Final view



Fragment - Meso Detailing



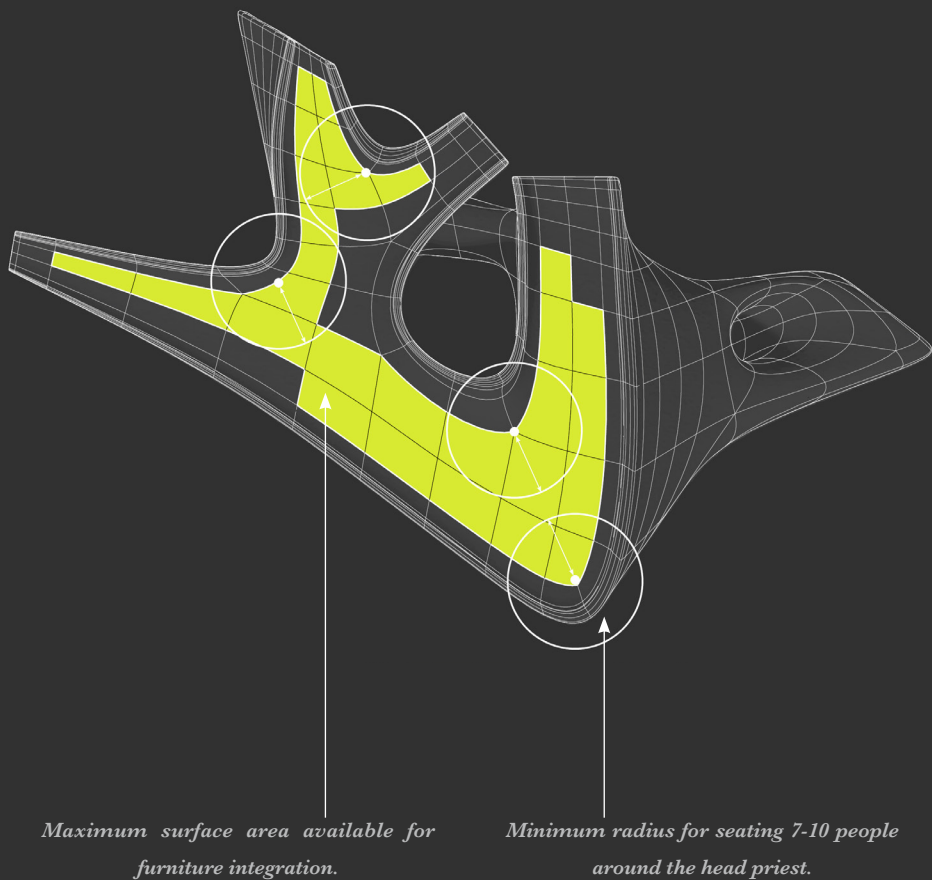
Meso Fragment selection



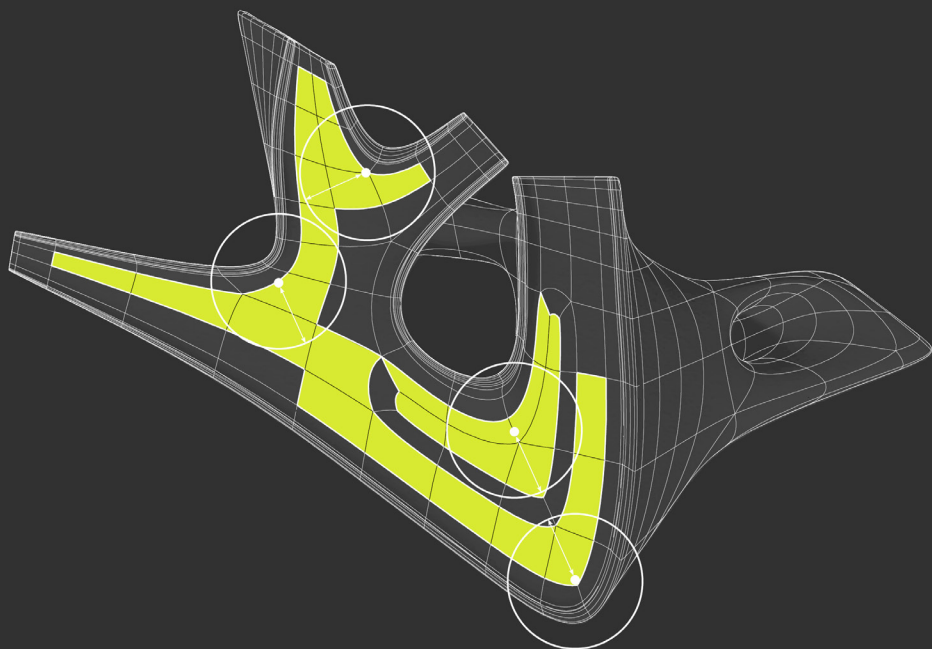
Final meso geometry



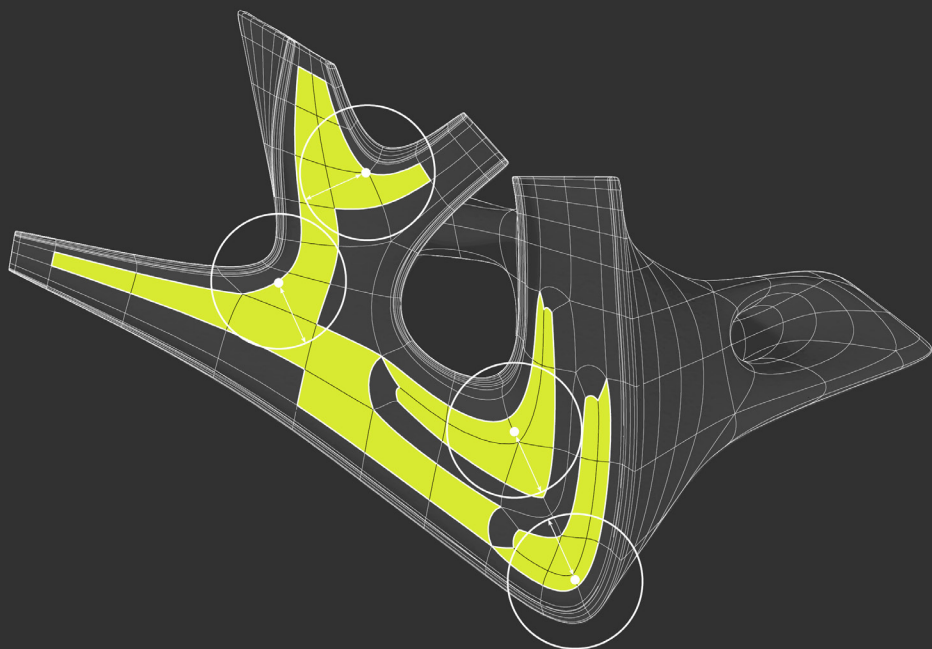
The above images shows the seating positions showing a cluster of people seating around the head priest [yogiguru].



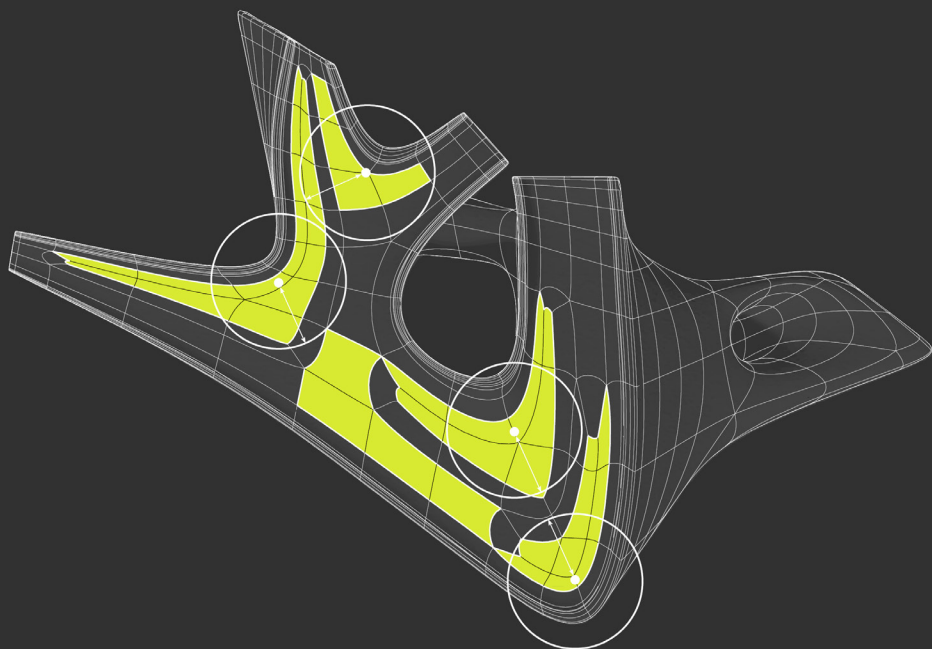
The seating reference is taken into account and minimum anthropometric requirements are worked out to place them on the geometry.



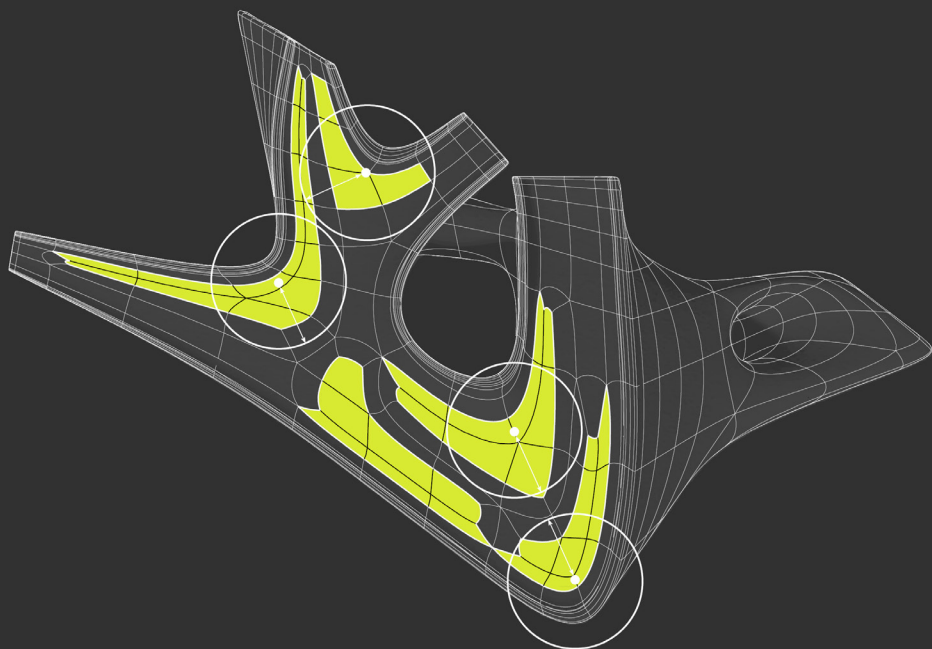
*Surface are deleted where it is not needed to include circulation
around the seating areas.*



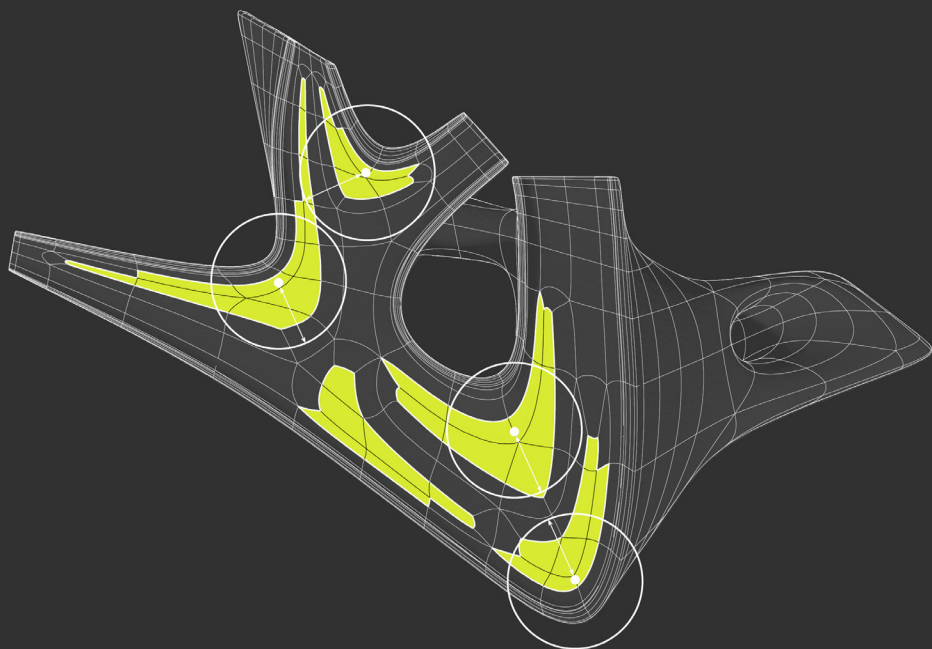
Circulation update#2



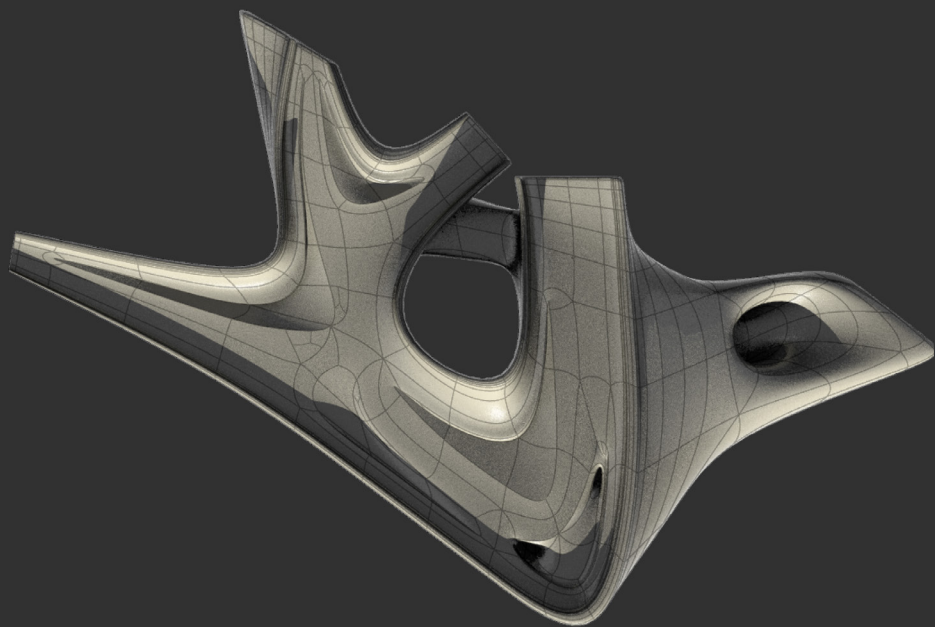
Circulation update#3



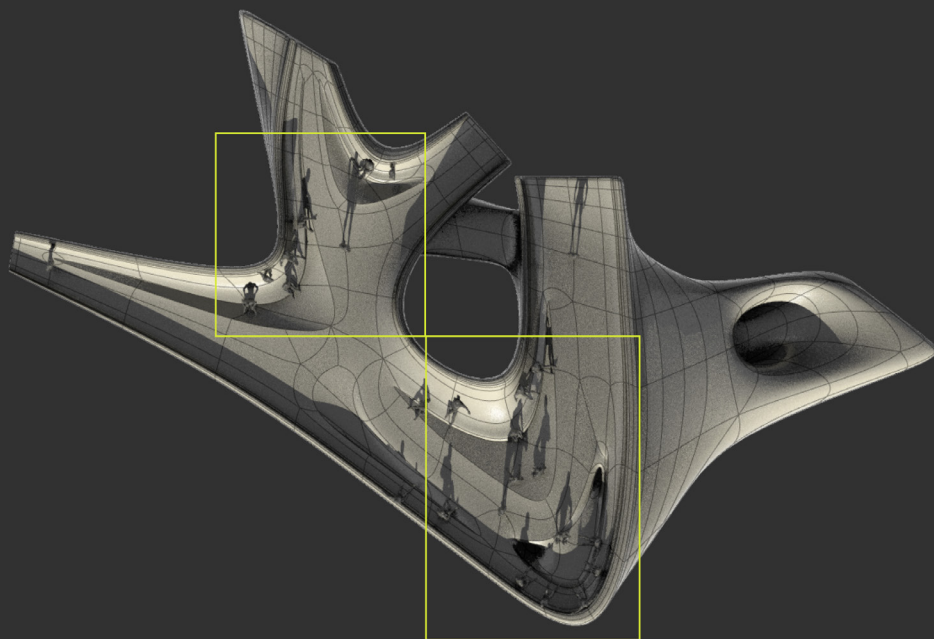
Circulation update#4



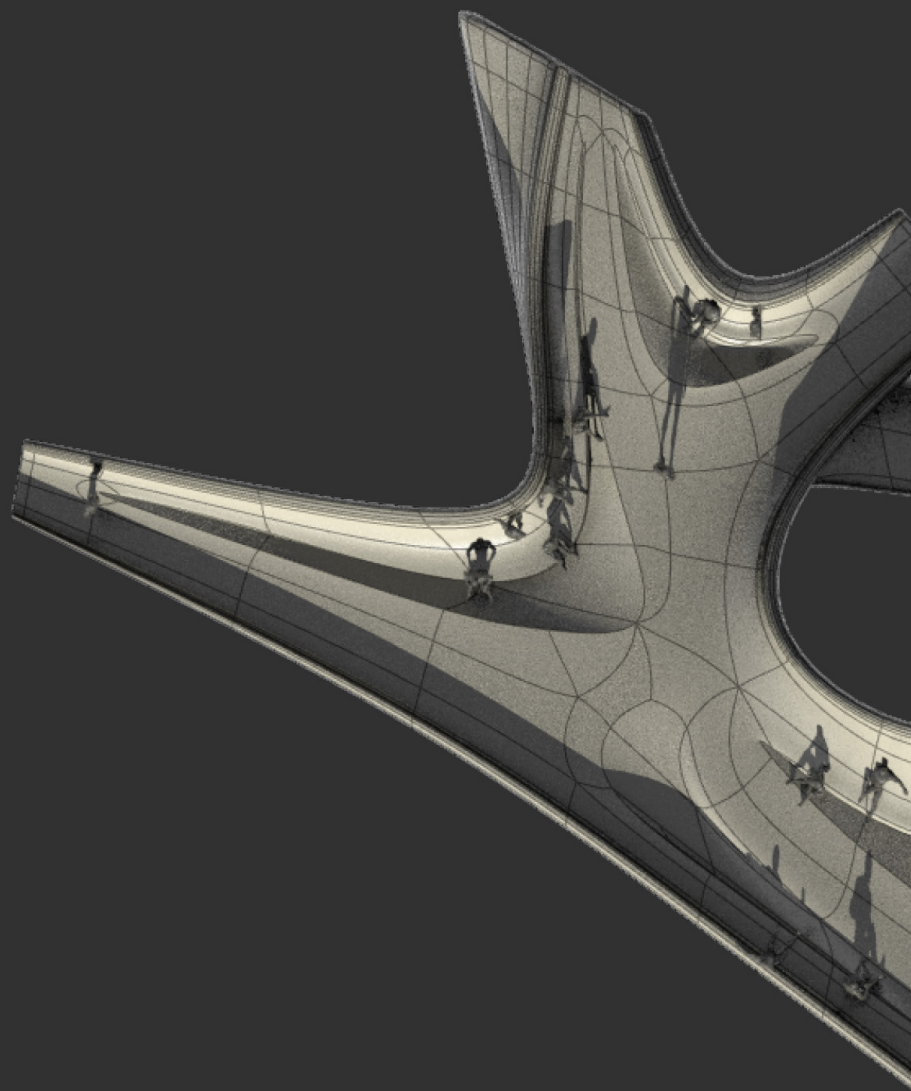
Circulation update#5

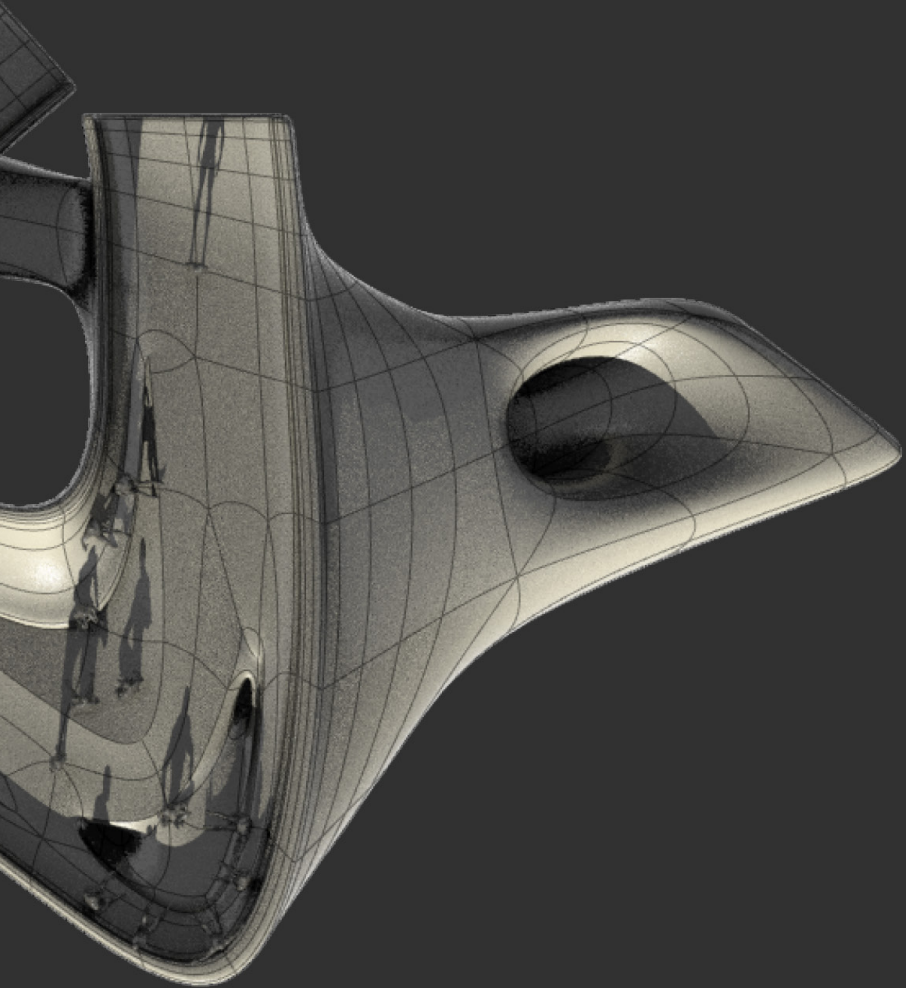


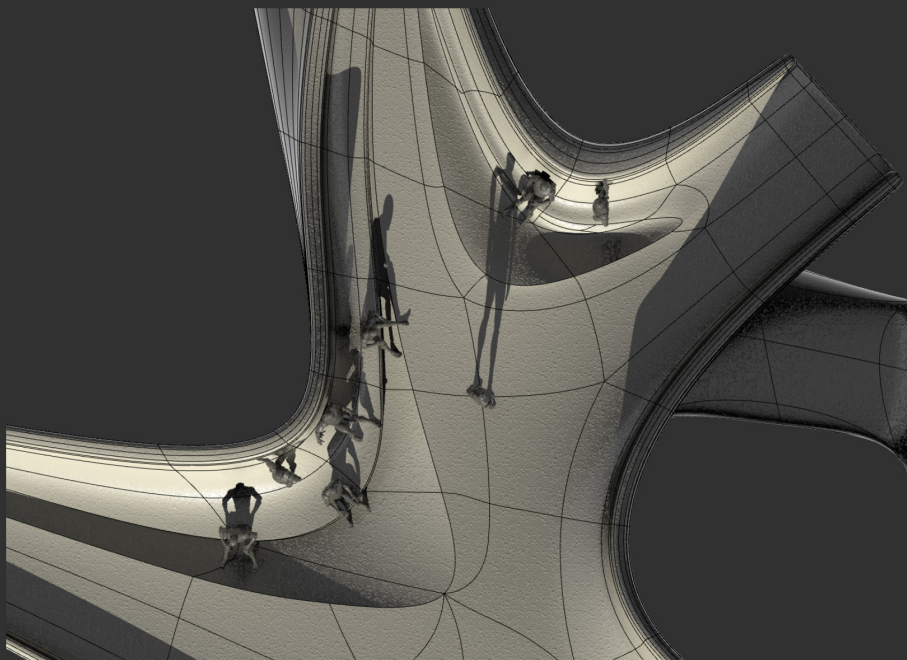
Final embedded furniture



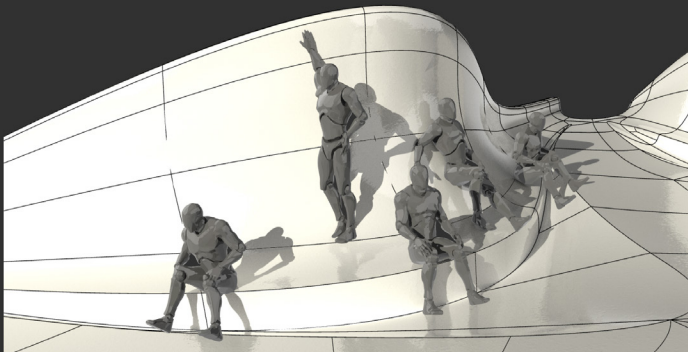
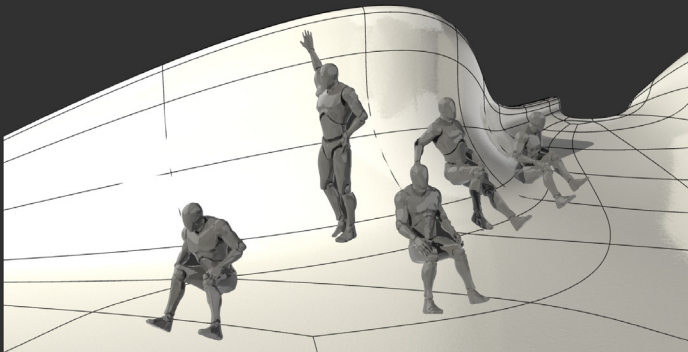
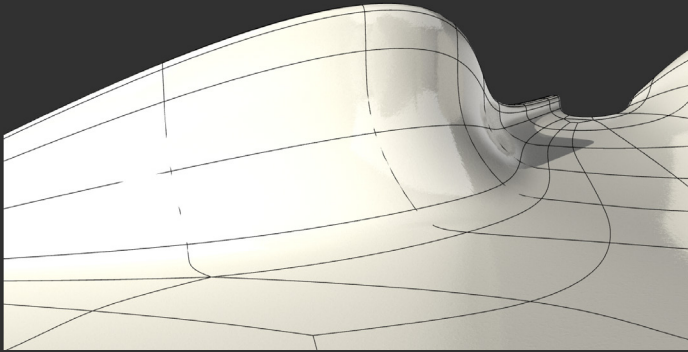
Seating positions



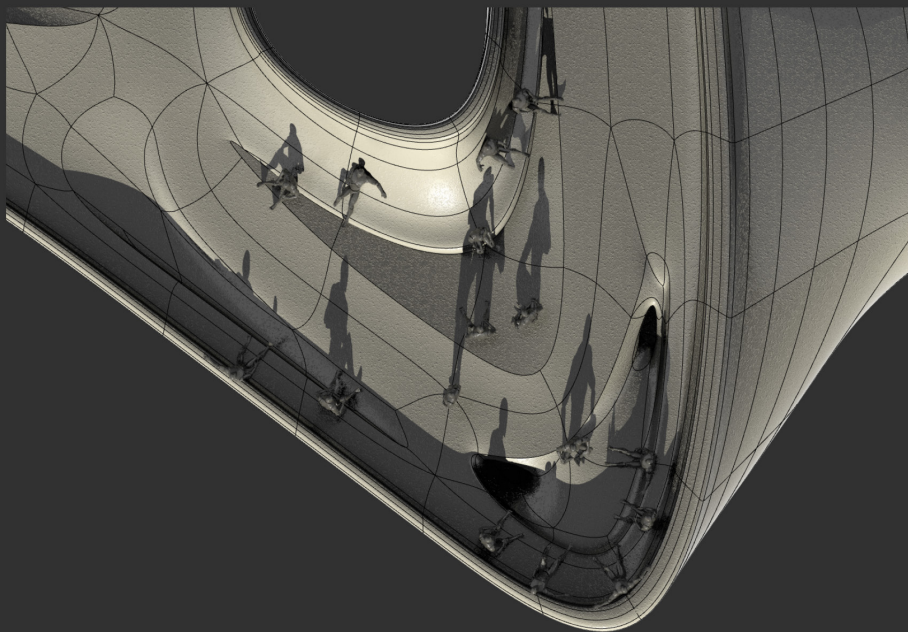




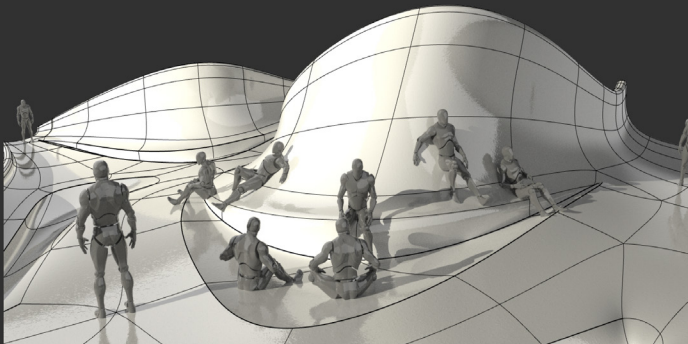
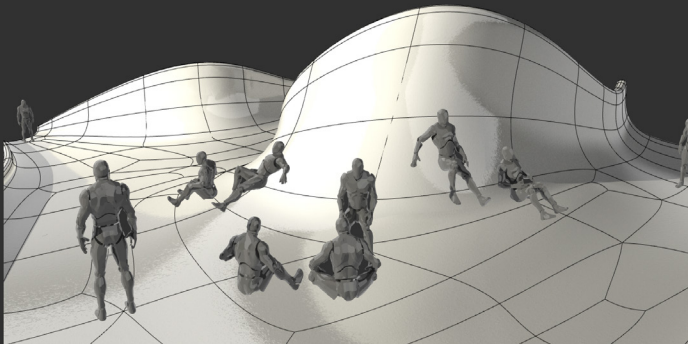
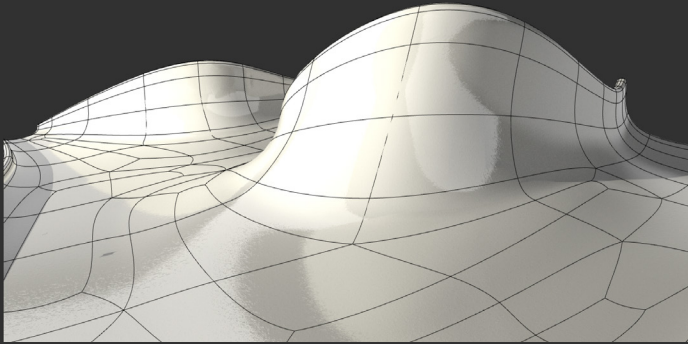
Zoom-In seating area -1



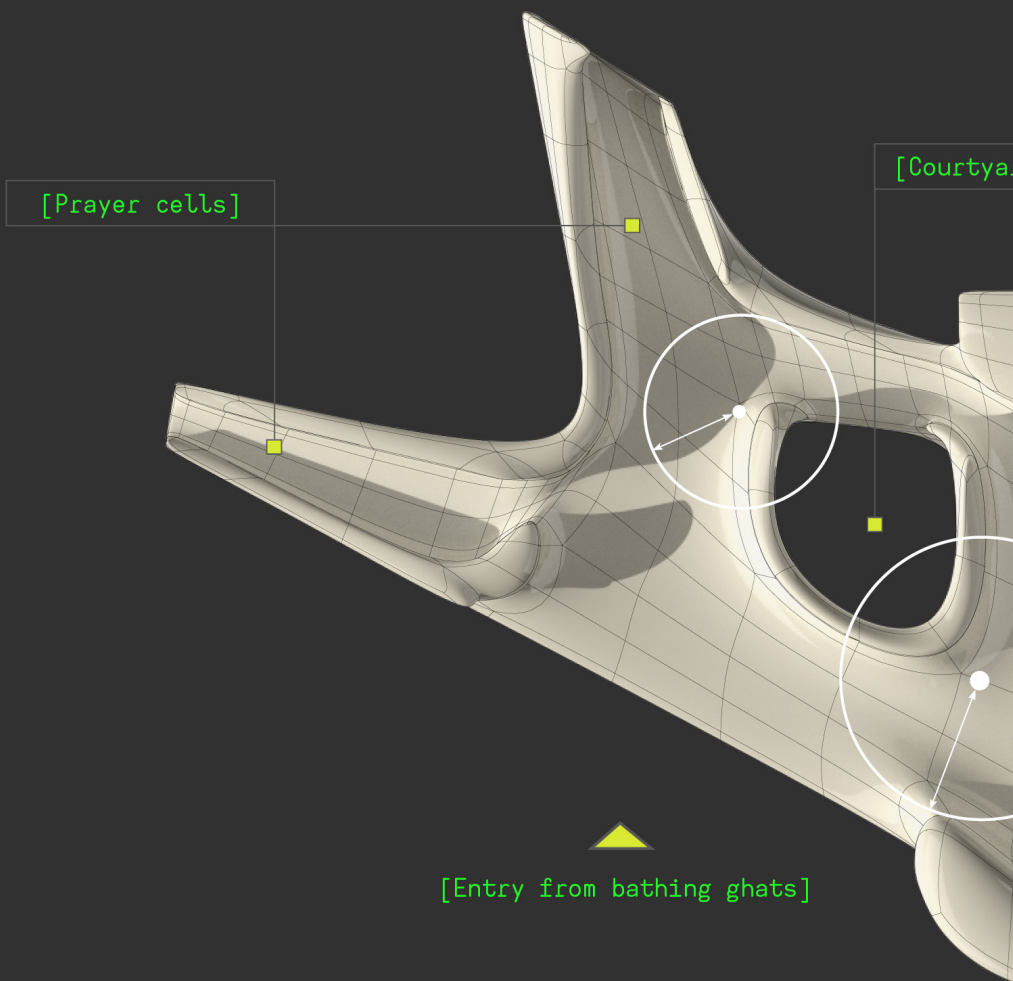
Progression from base mesh to mesh with integrated furniture based on human position curves.



Zoom-In seating area -2

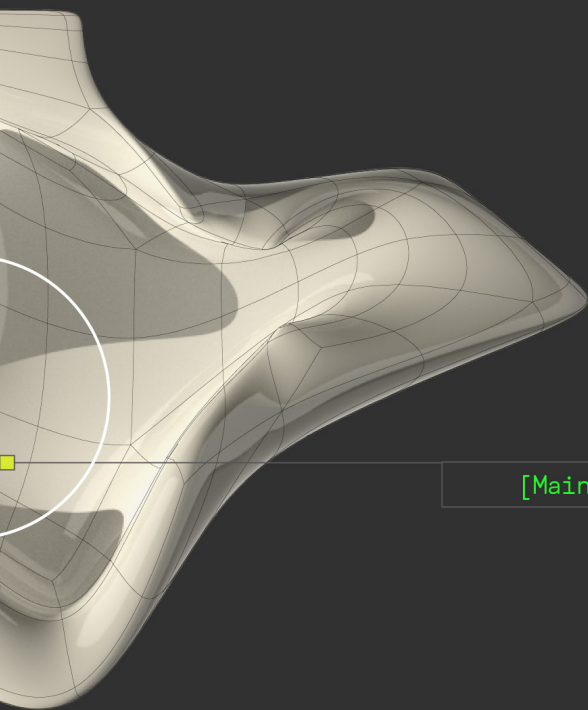


Progression from base mesh to mesh with integrated furniture based on human position curves.



Lower ground plan

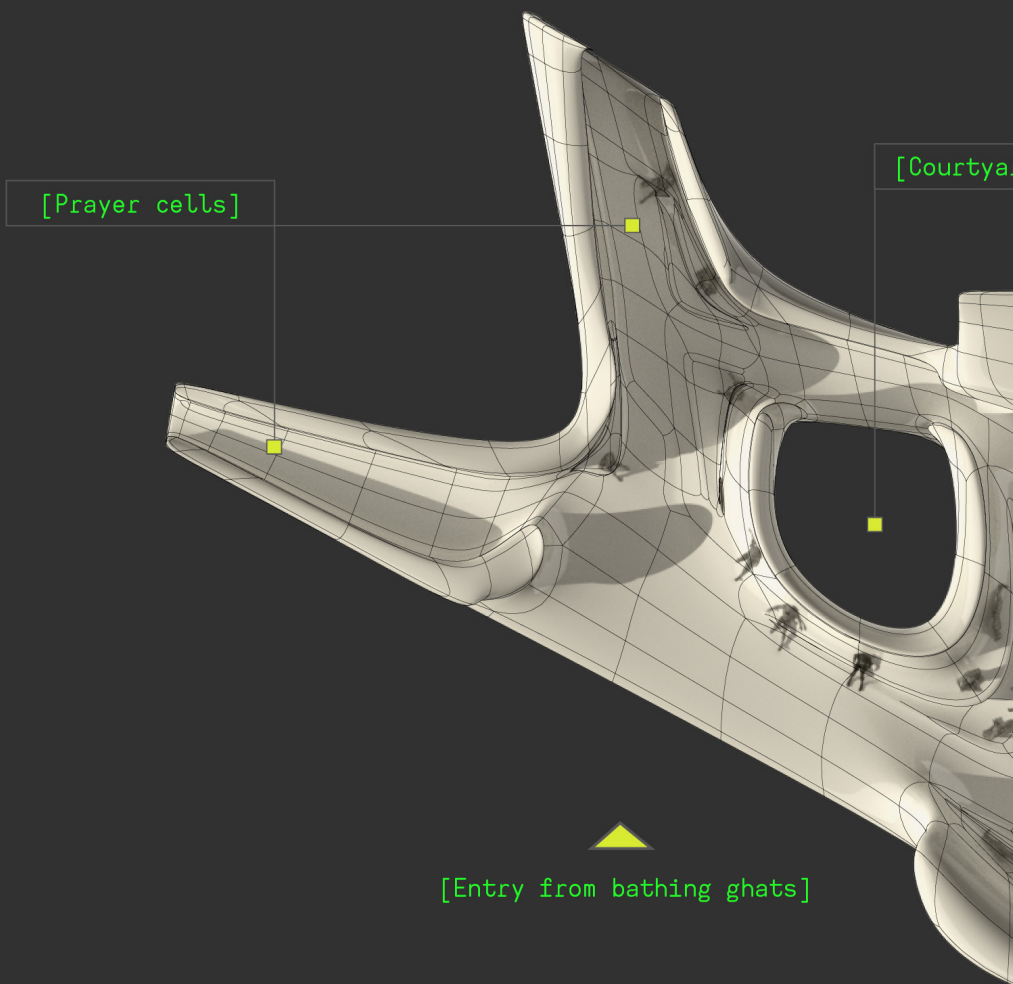
[rd/Sanctum]



[Entry from mainland]

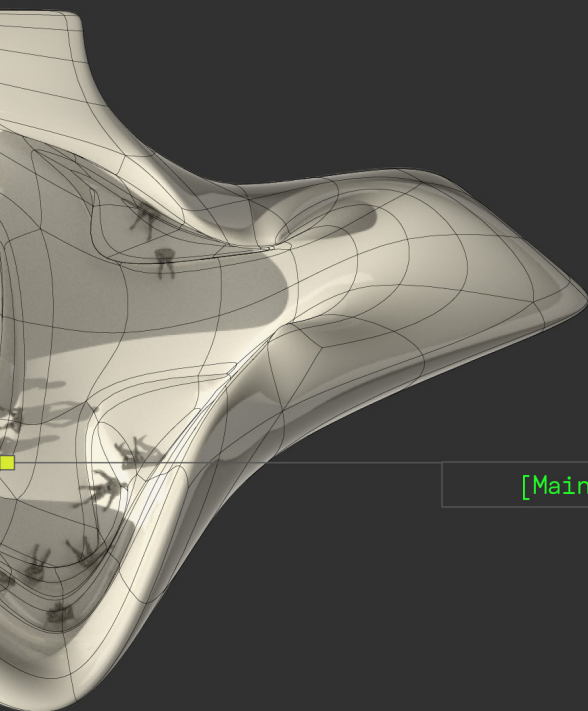
[Main Hall]

The same process is done in the interior space identifying potential spaces for furniture.



[In-Flow]- P3-5 Design Progression

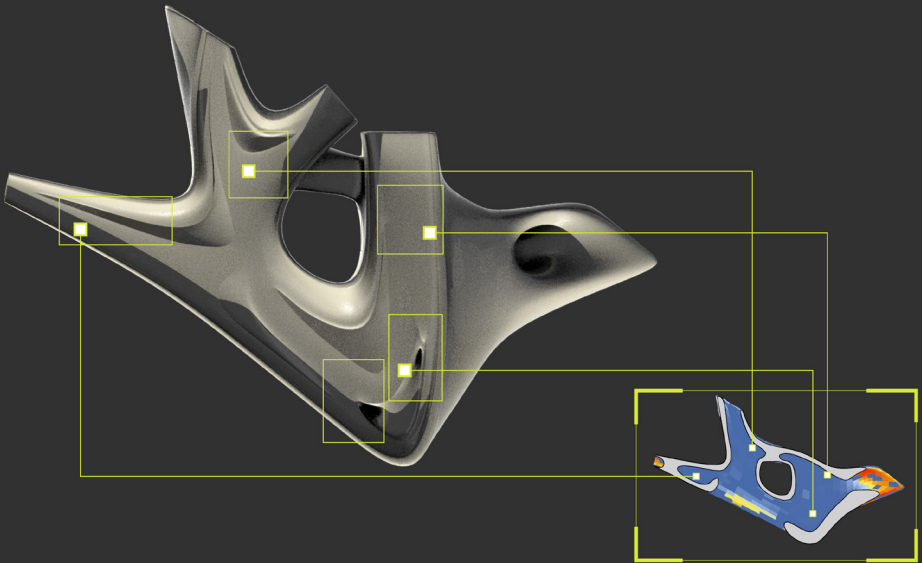
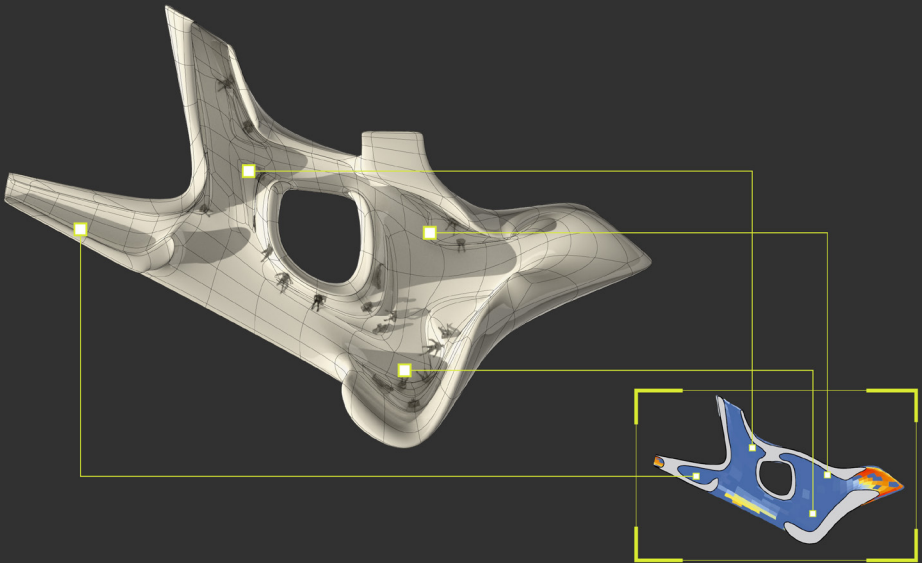
[rd/Sanctum]



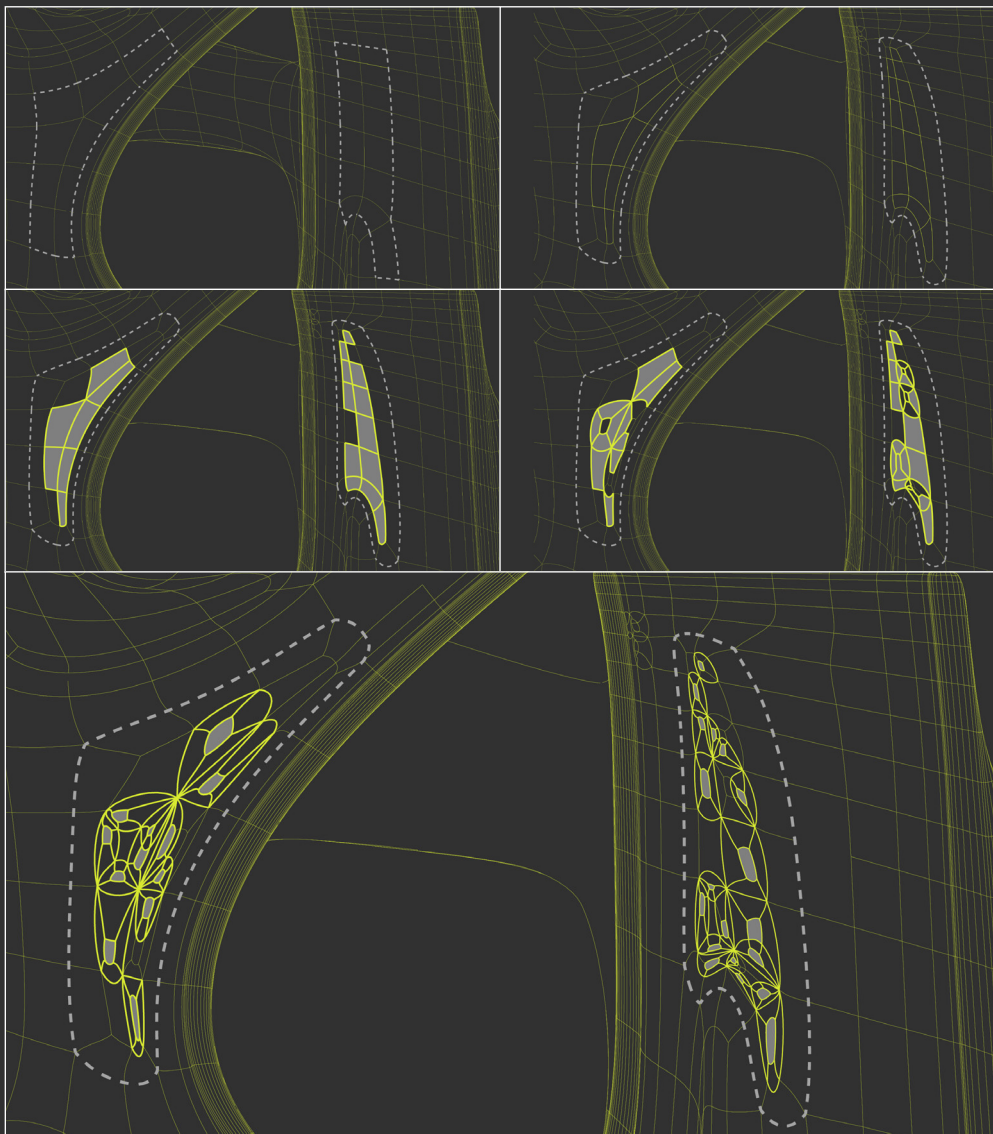
[Entry from mainland]

[Main Hall]

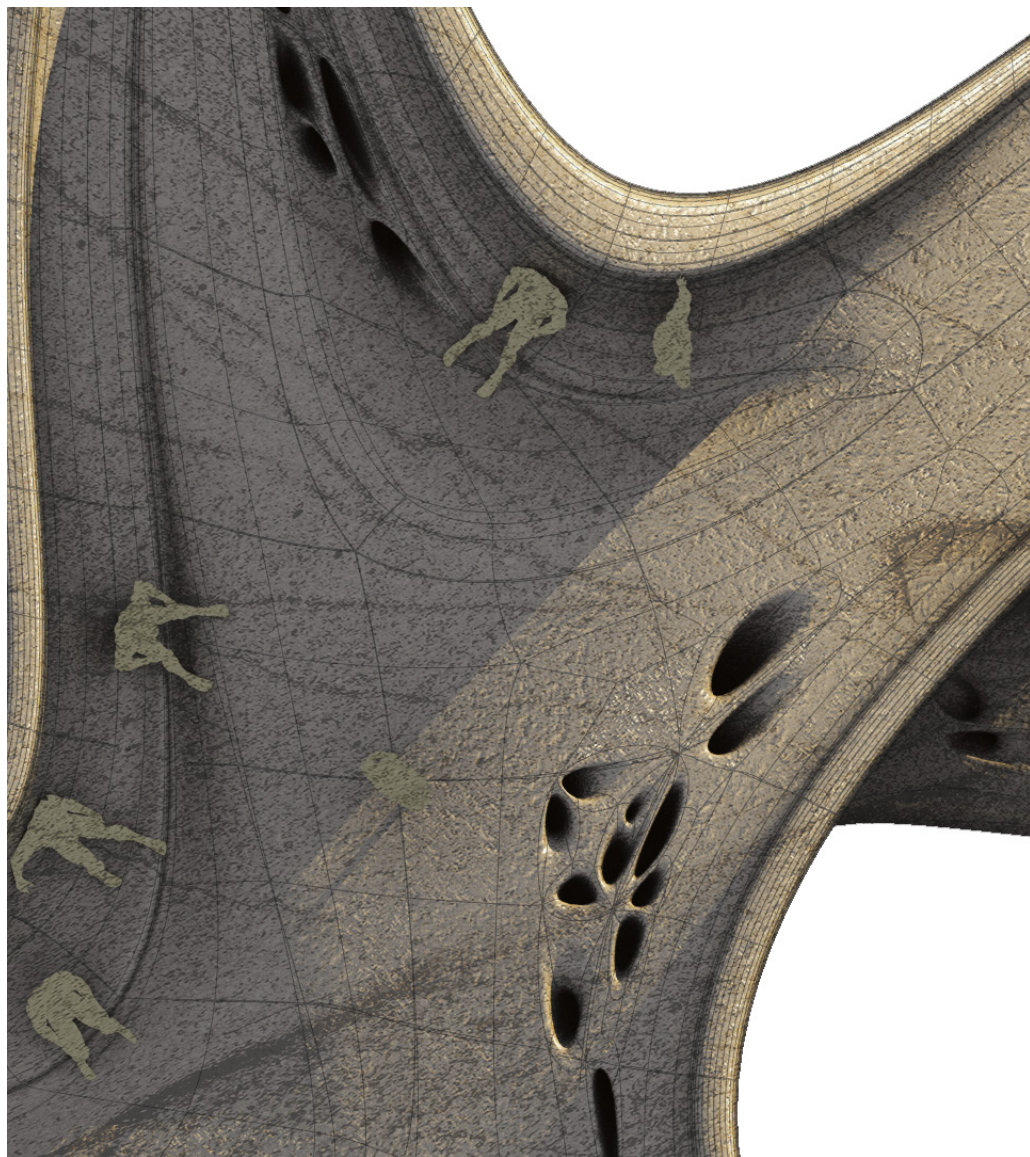
Lower level seating plan



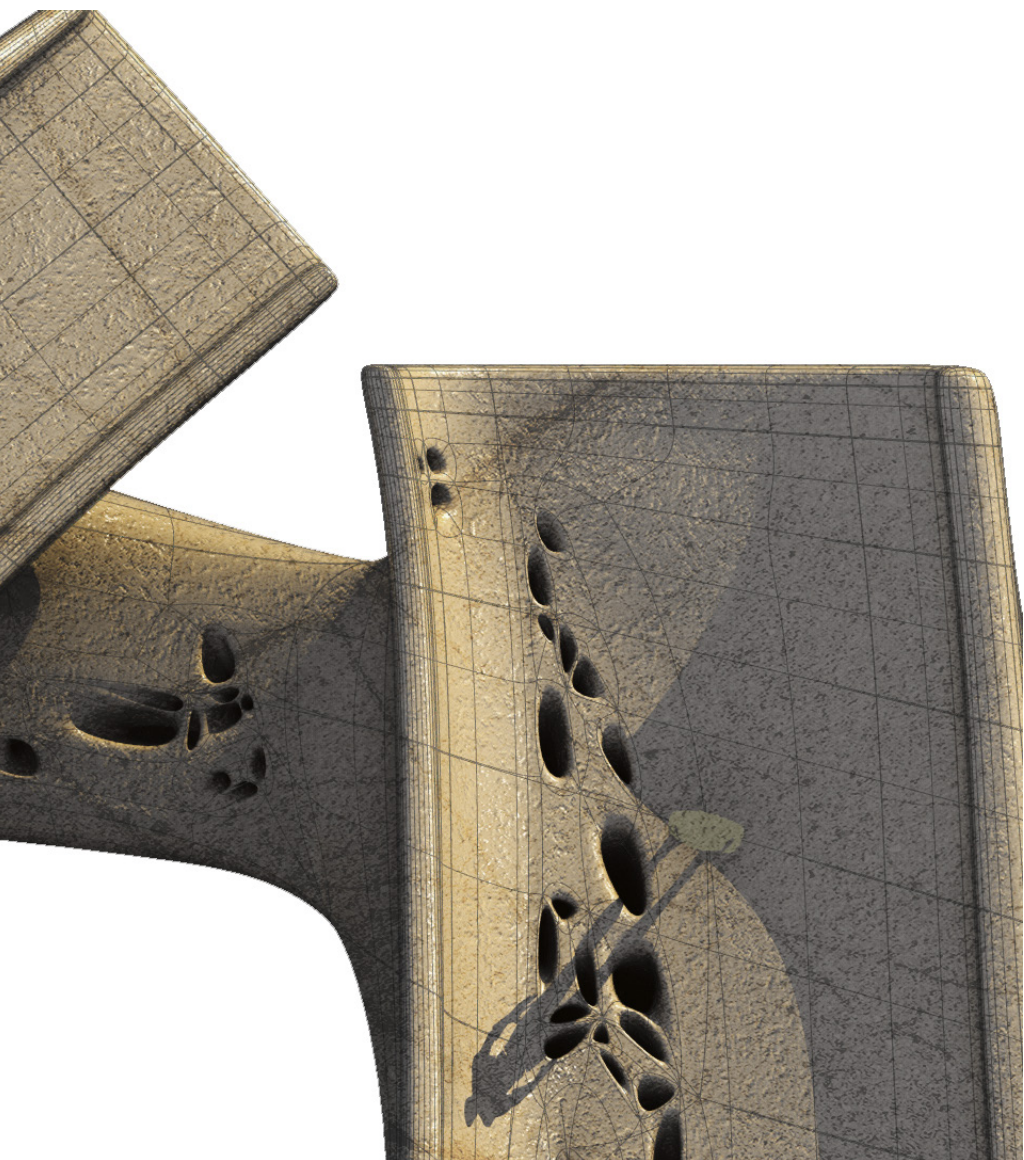
The next step of detailing is to integrate perforations. The strategy here was to introduce diffused lighting into the interior spaces similar to Indian temples. For this it was decided to have perforations on the roof.



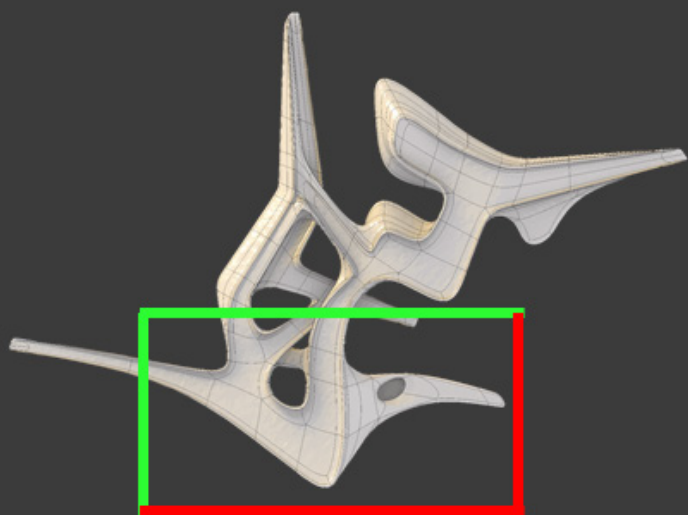
The base mesh was subdivided using catmull-clark subdivision algorithm to introduce perforation based on required lighting needs.



[In-Flow]- P3-5 Design Progression

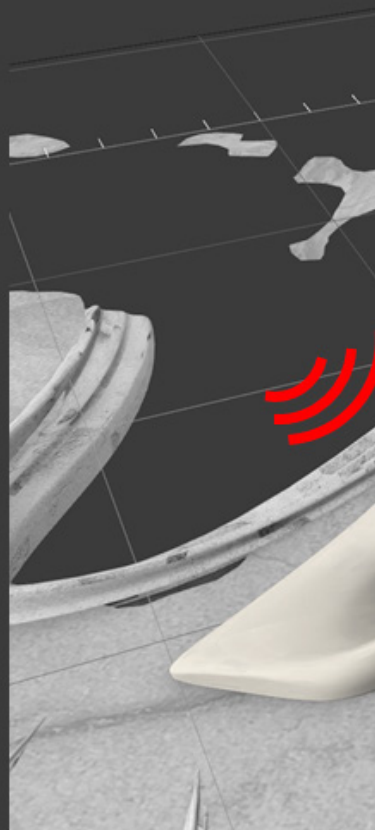


Perforations

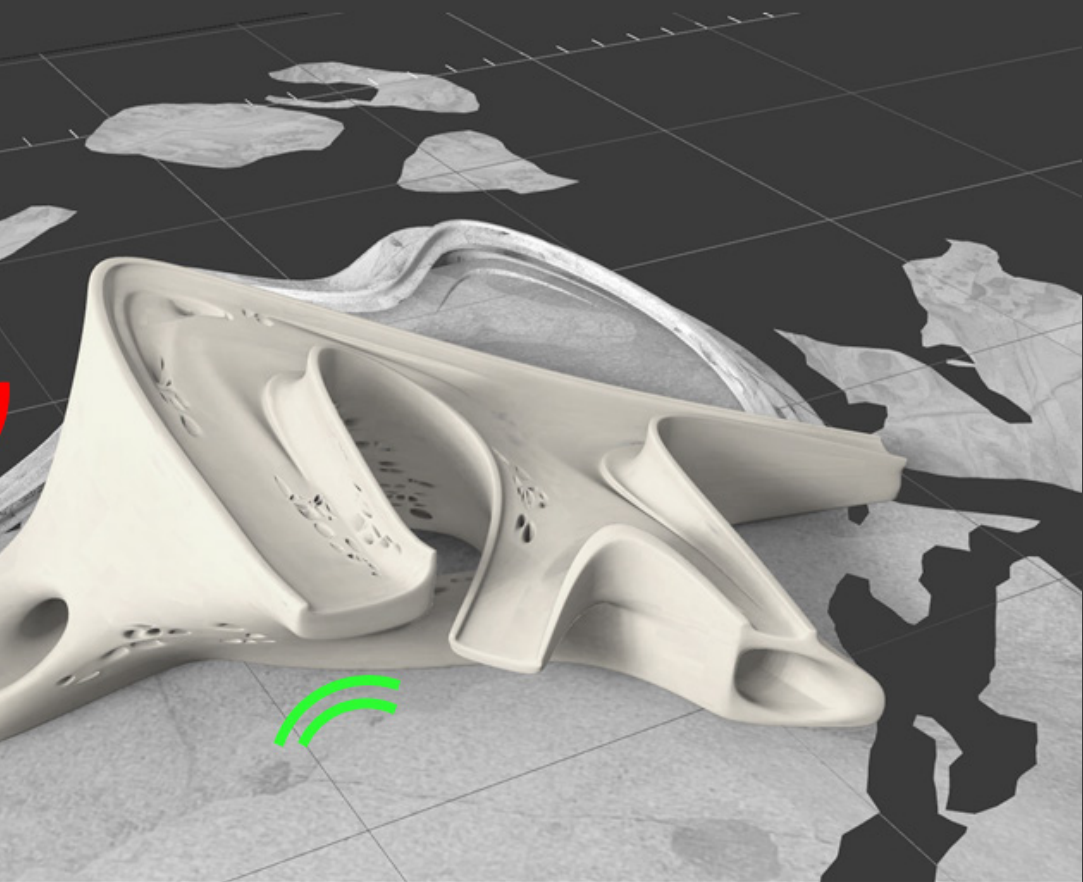


— [Noise Location]

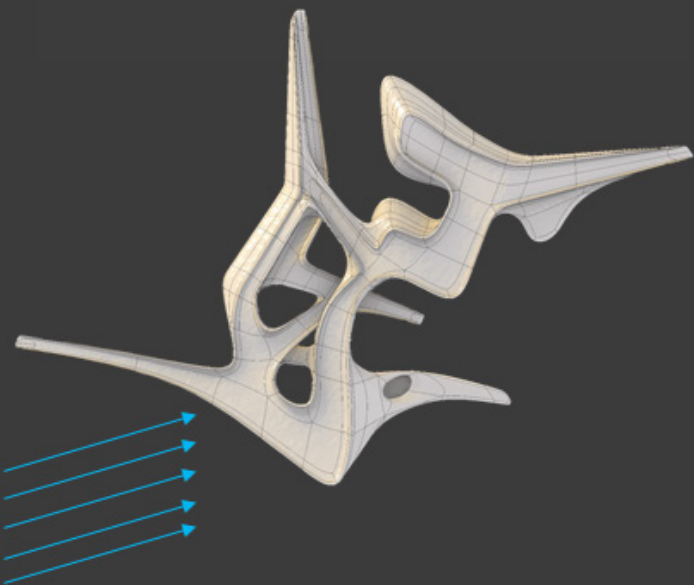
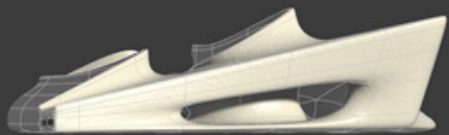
— [Quiet Location]



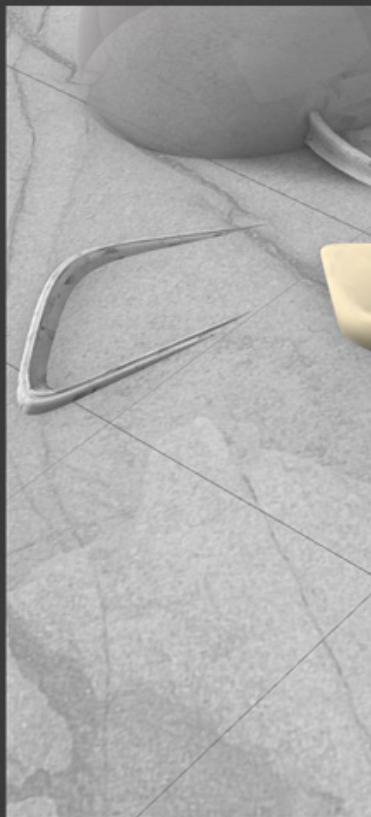
[In-Flow]- P3-5 Design Progression



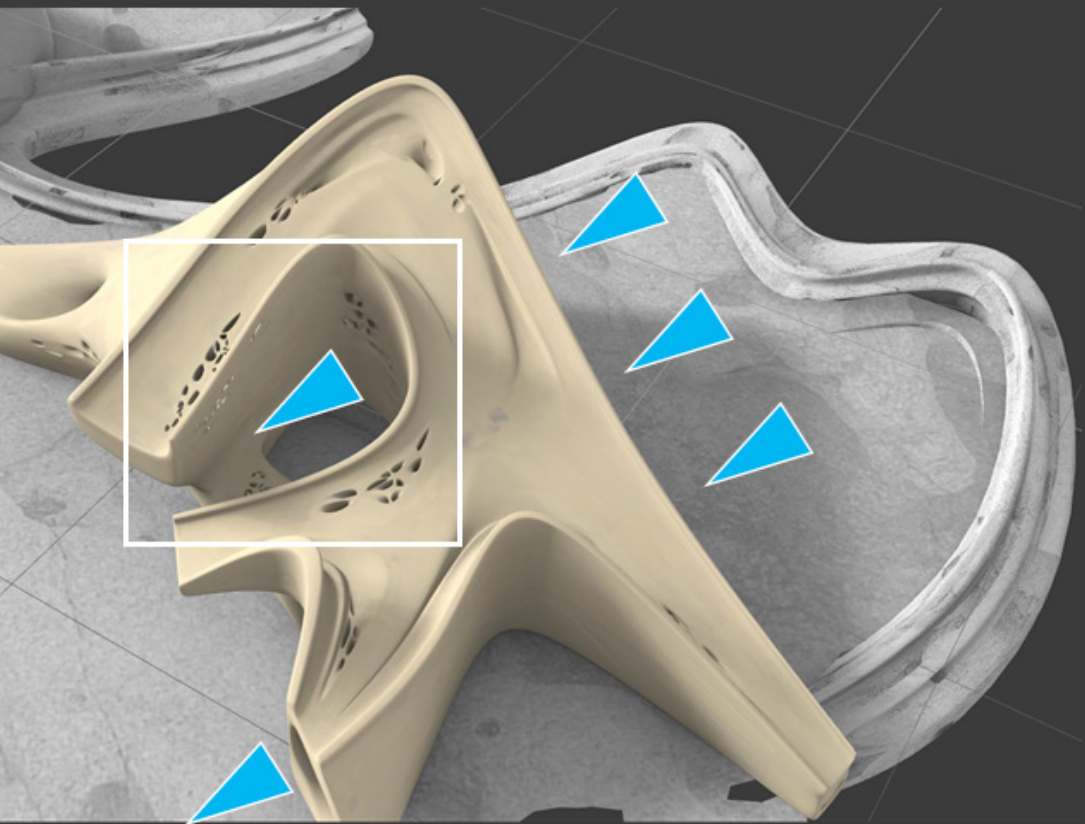
Perforations are only at planes which don't have issues with privacy or noise.



[Wind_Direction-Jan to Mar (43%)]

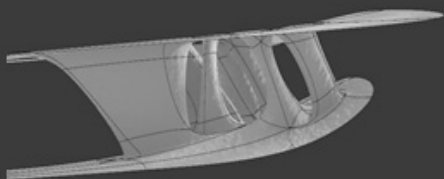


[In-Flow]- P3-5 Design Progression



Ventillation & light for inner parts

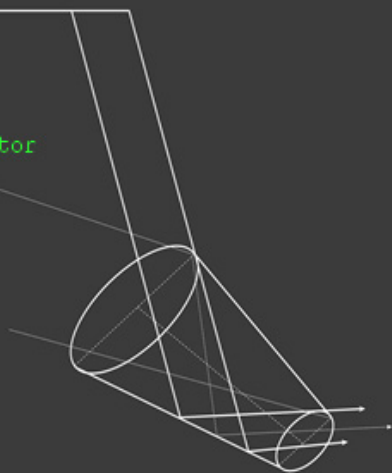
The big main opening funnels the predominant wind from south west through the building.



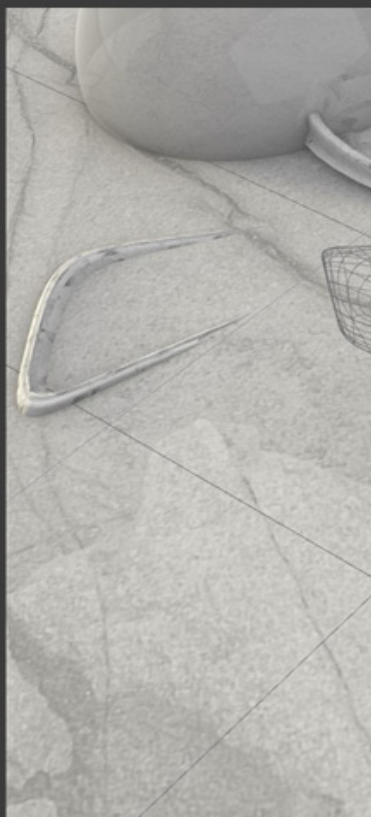
Afternoon sun vector

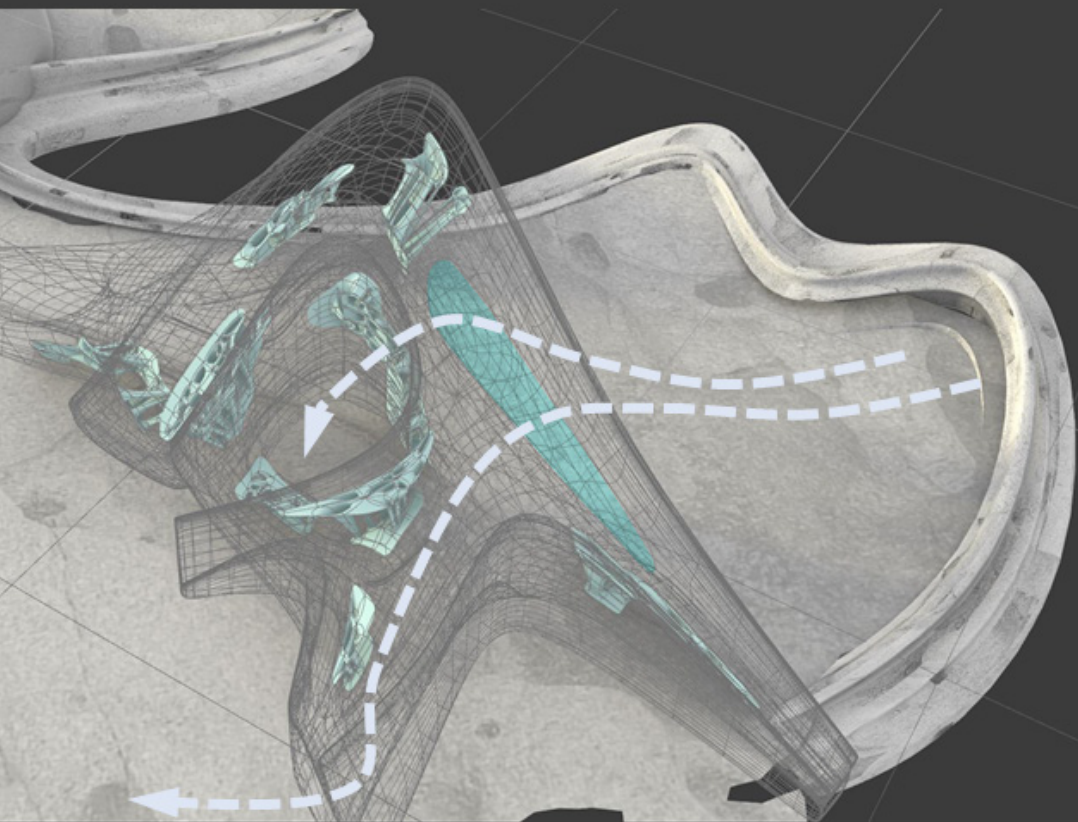


Evening sun vector

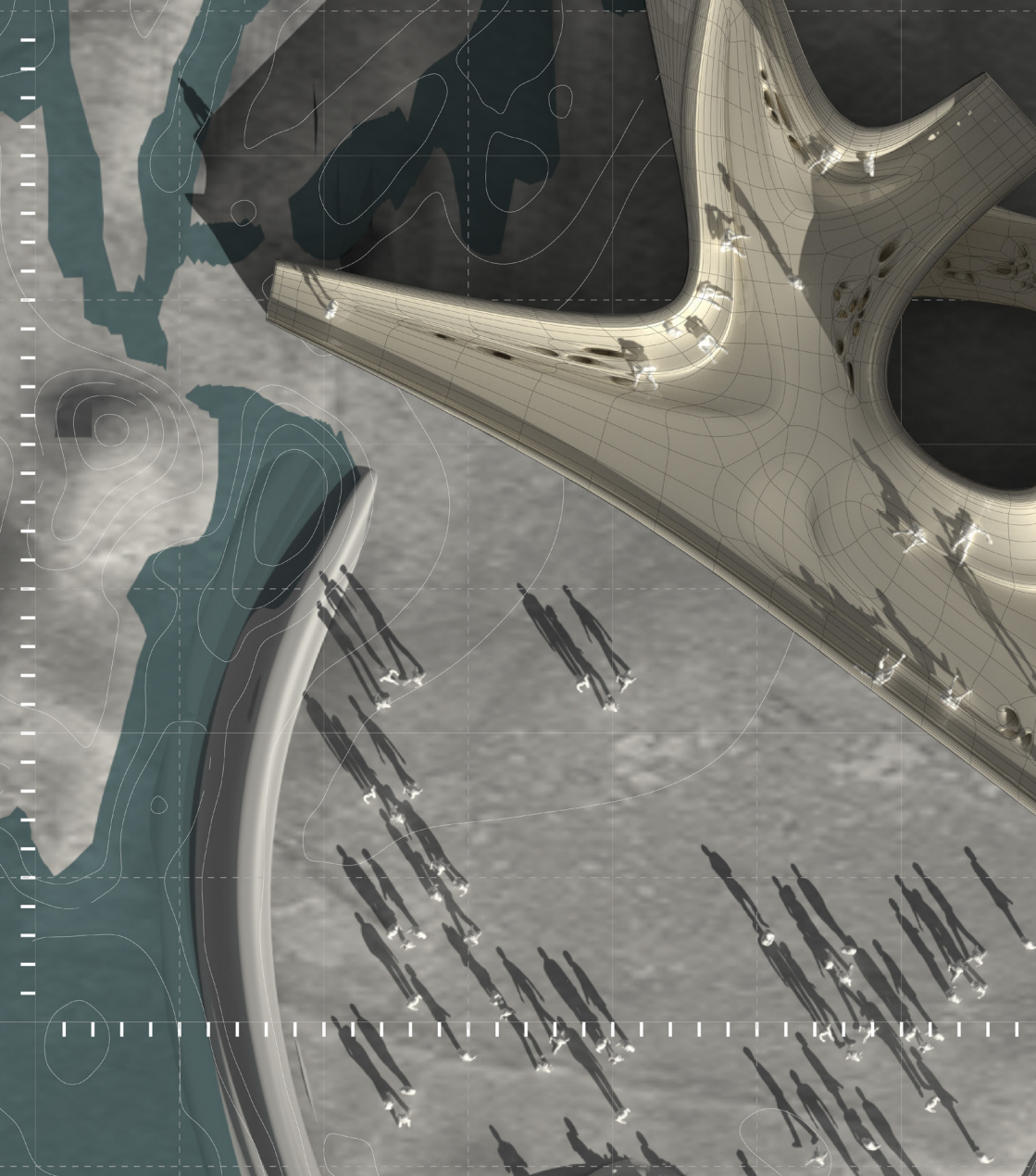


[Perforations at different angles to
Accommodate diffused lighting]

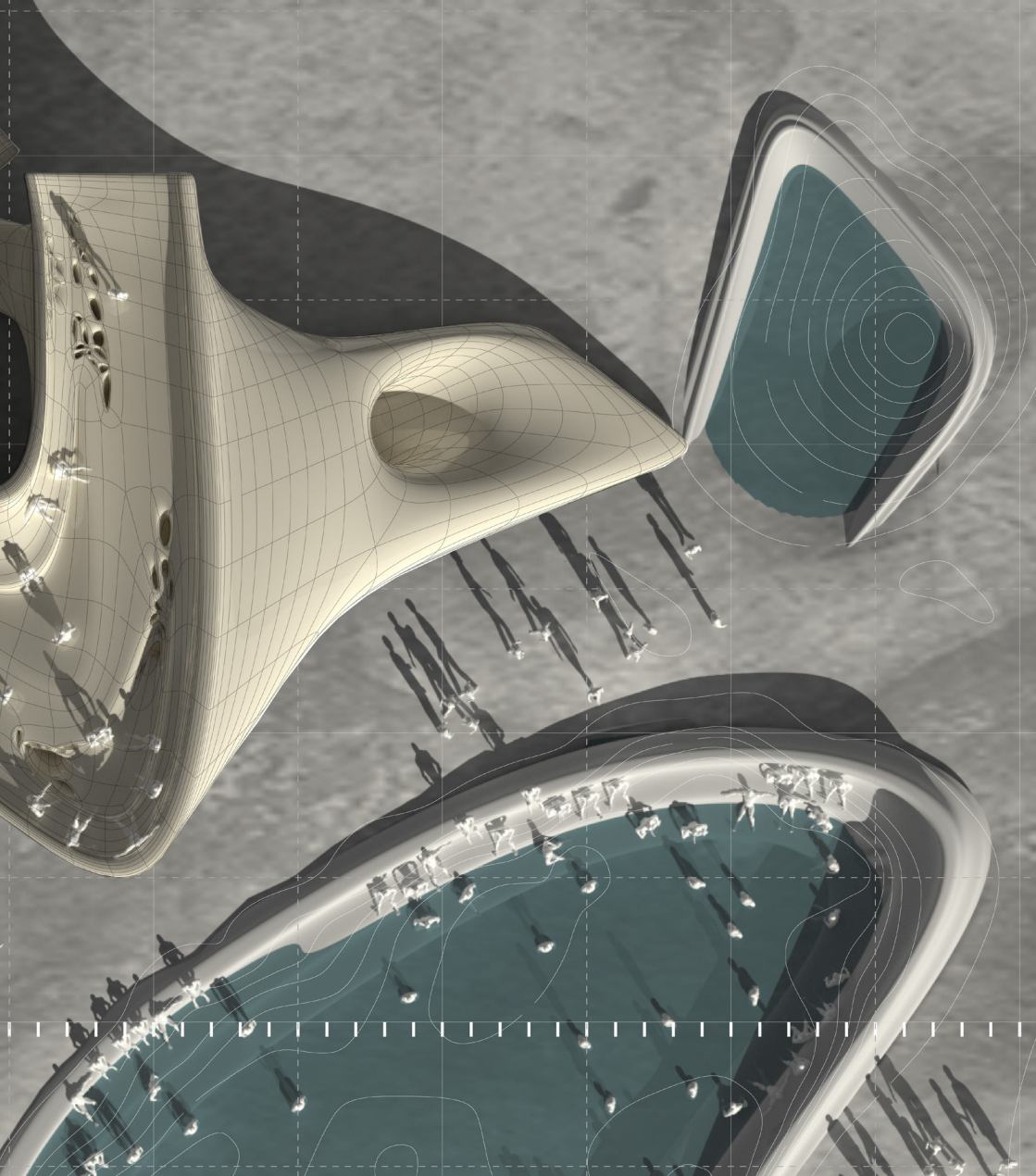




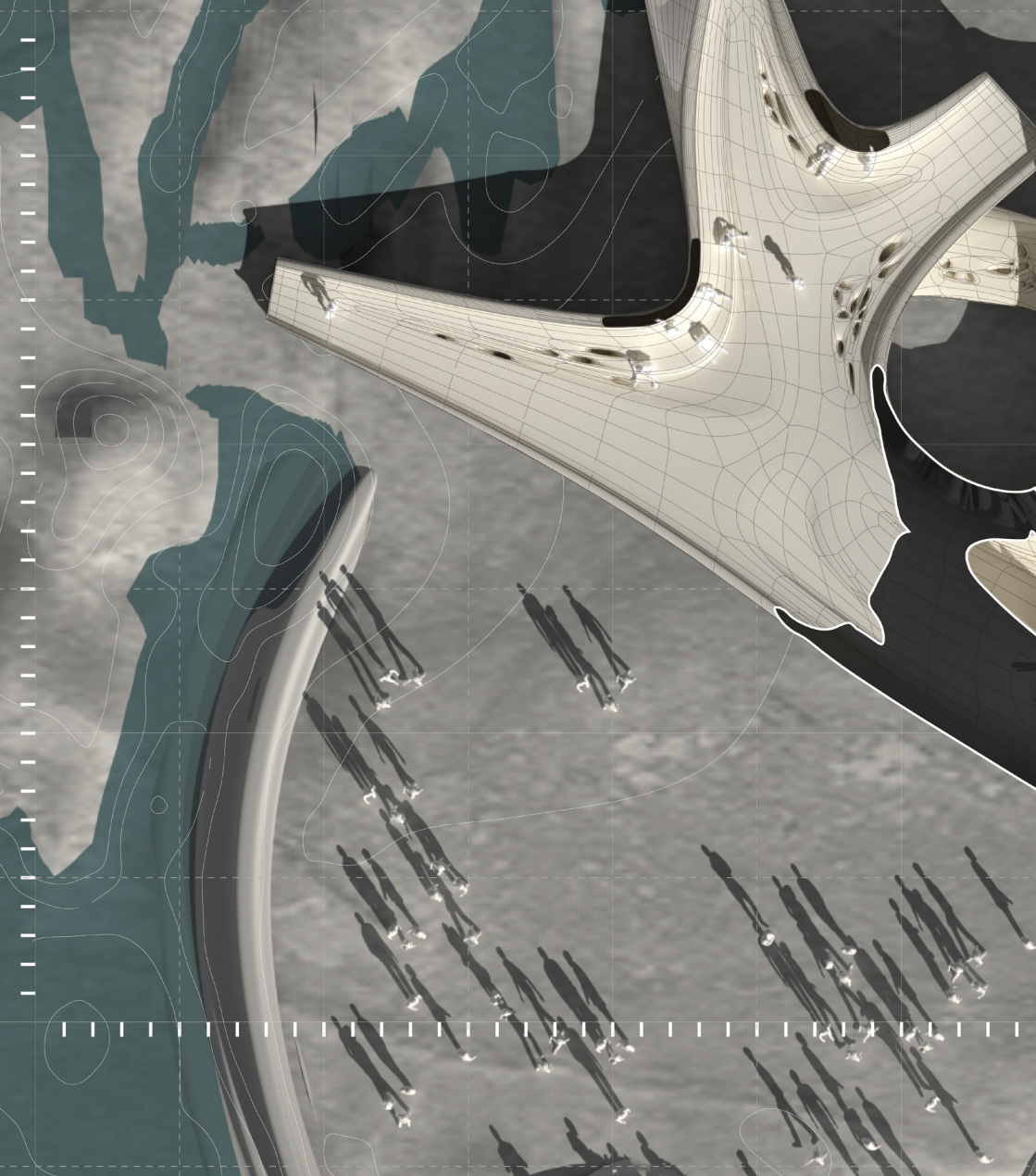
Light wells and angular in accordance to required azimuth angles for diffused lighting.



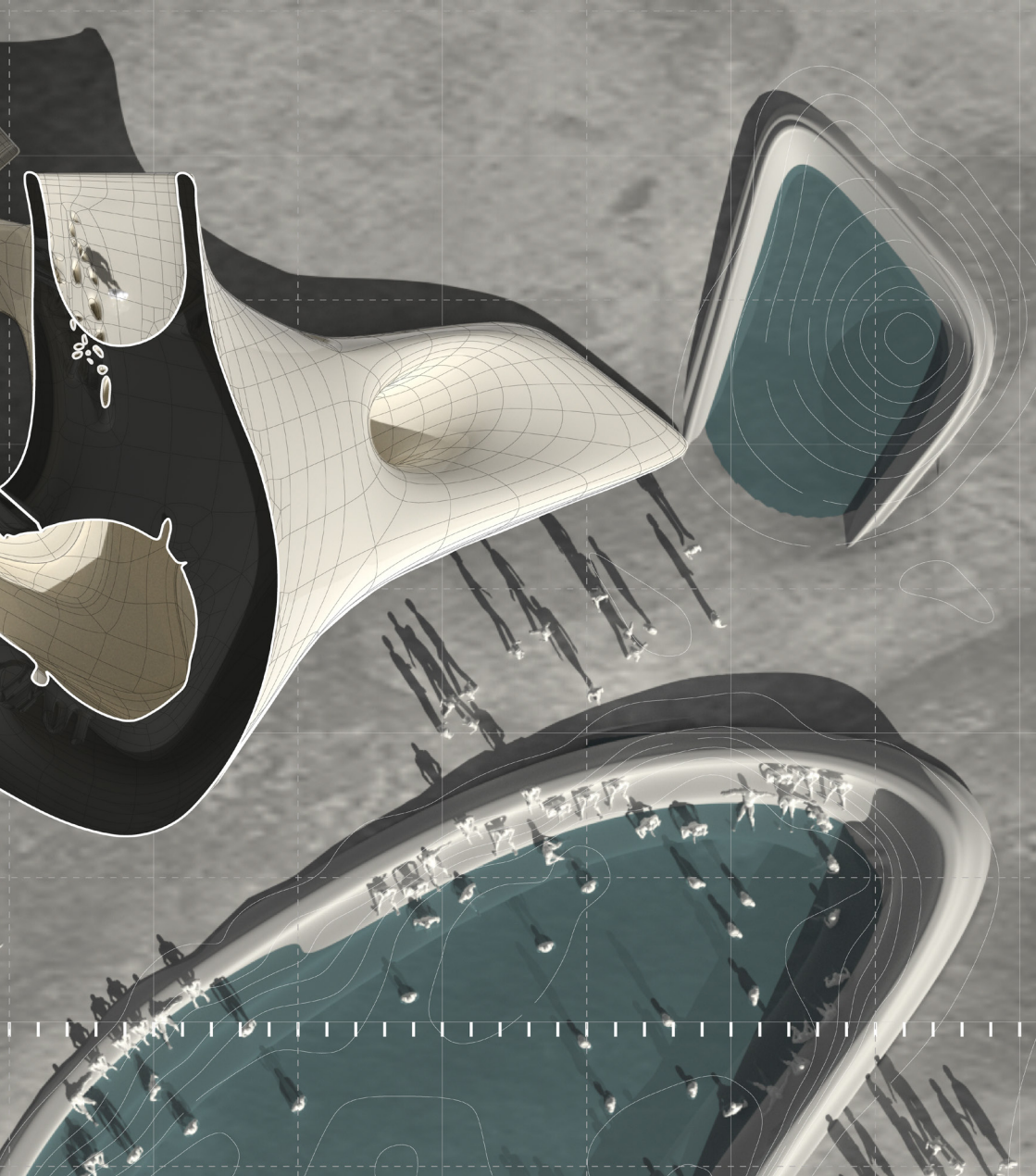
[In-Flow]- P3-5 Design Progression



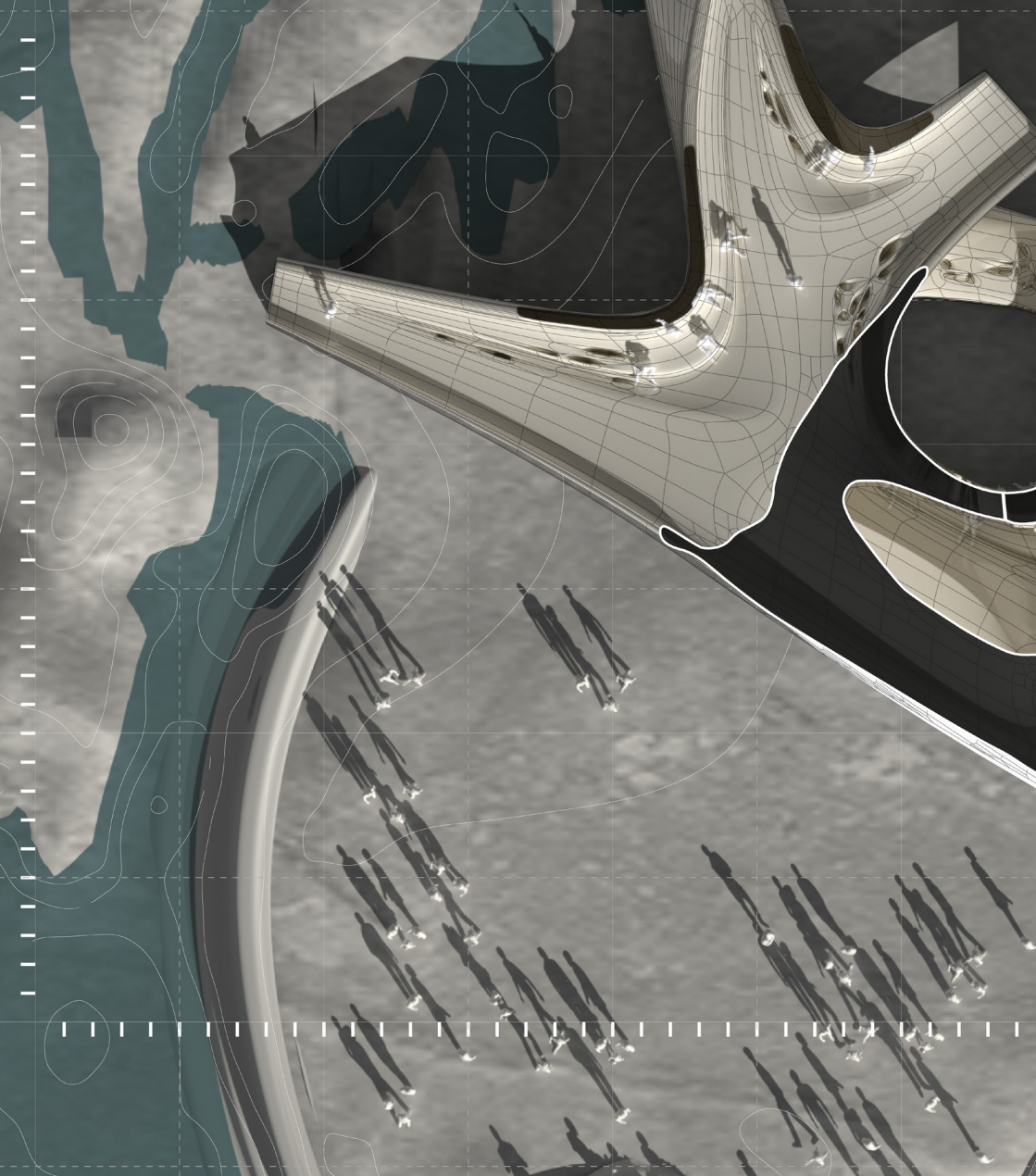
Final Plans



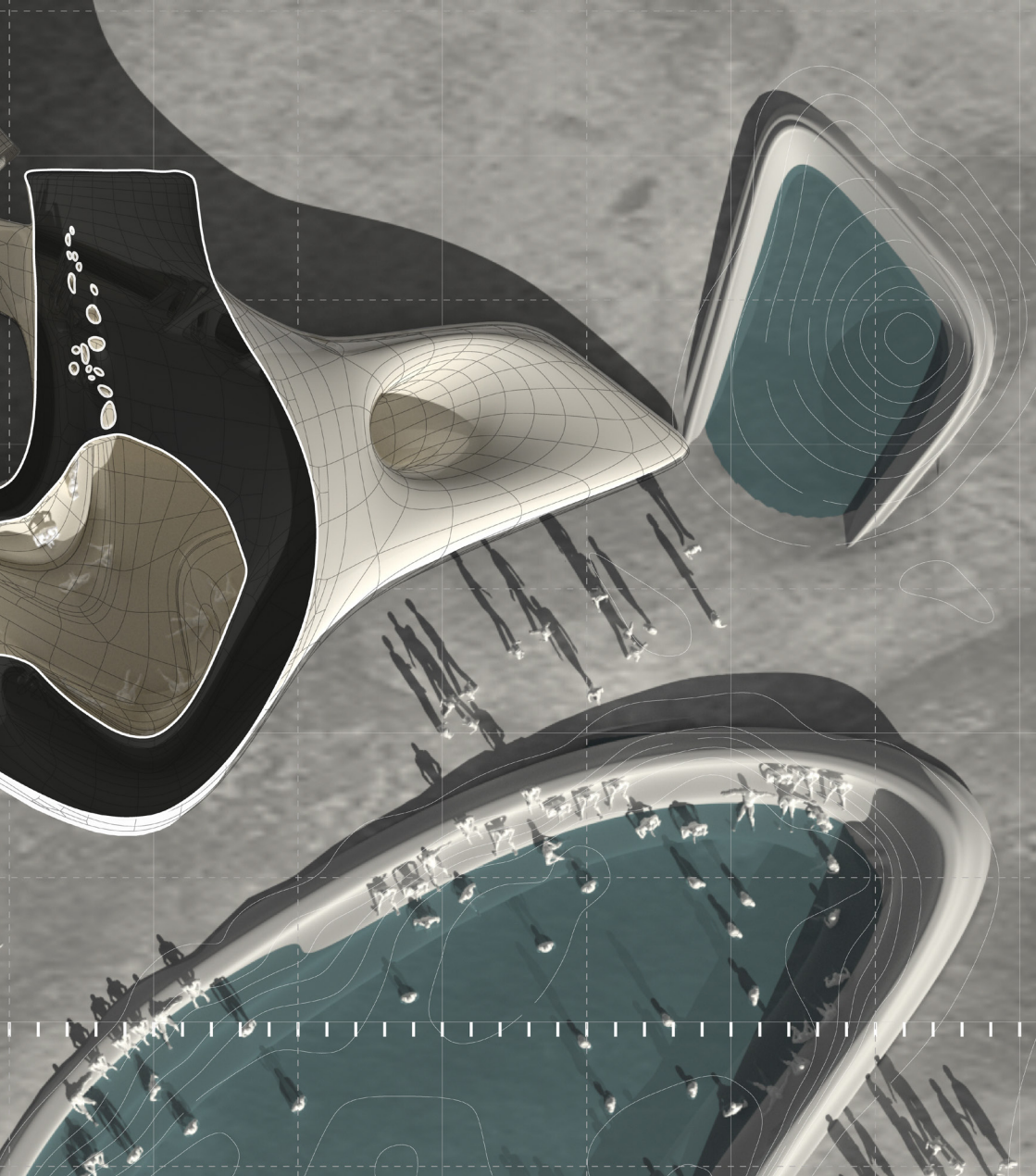
[In-Flow]- P3-5 Design Progression



Plan at lvl+8m



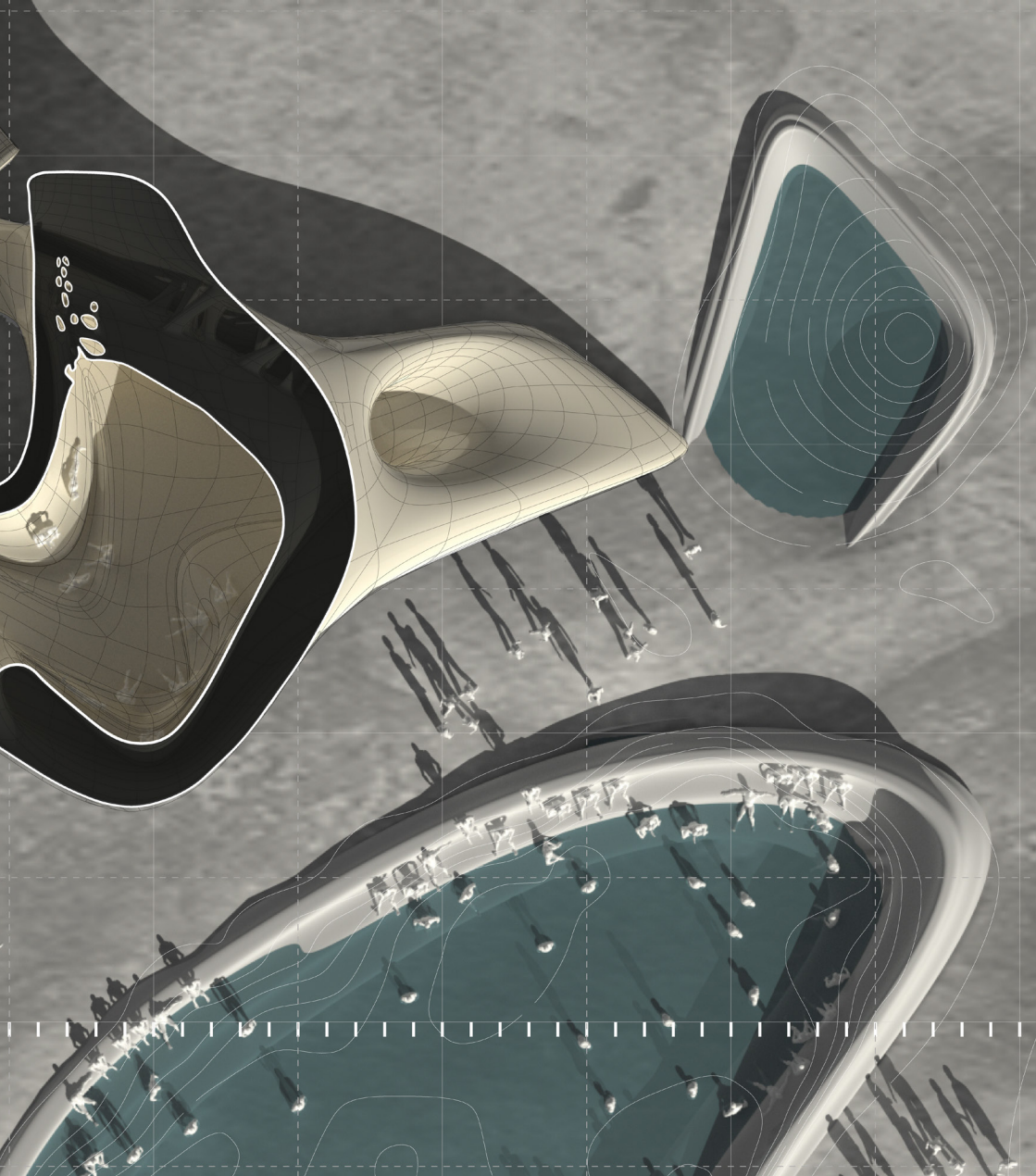
[In-Flow]- P3-5 Design Progression



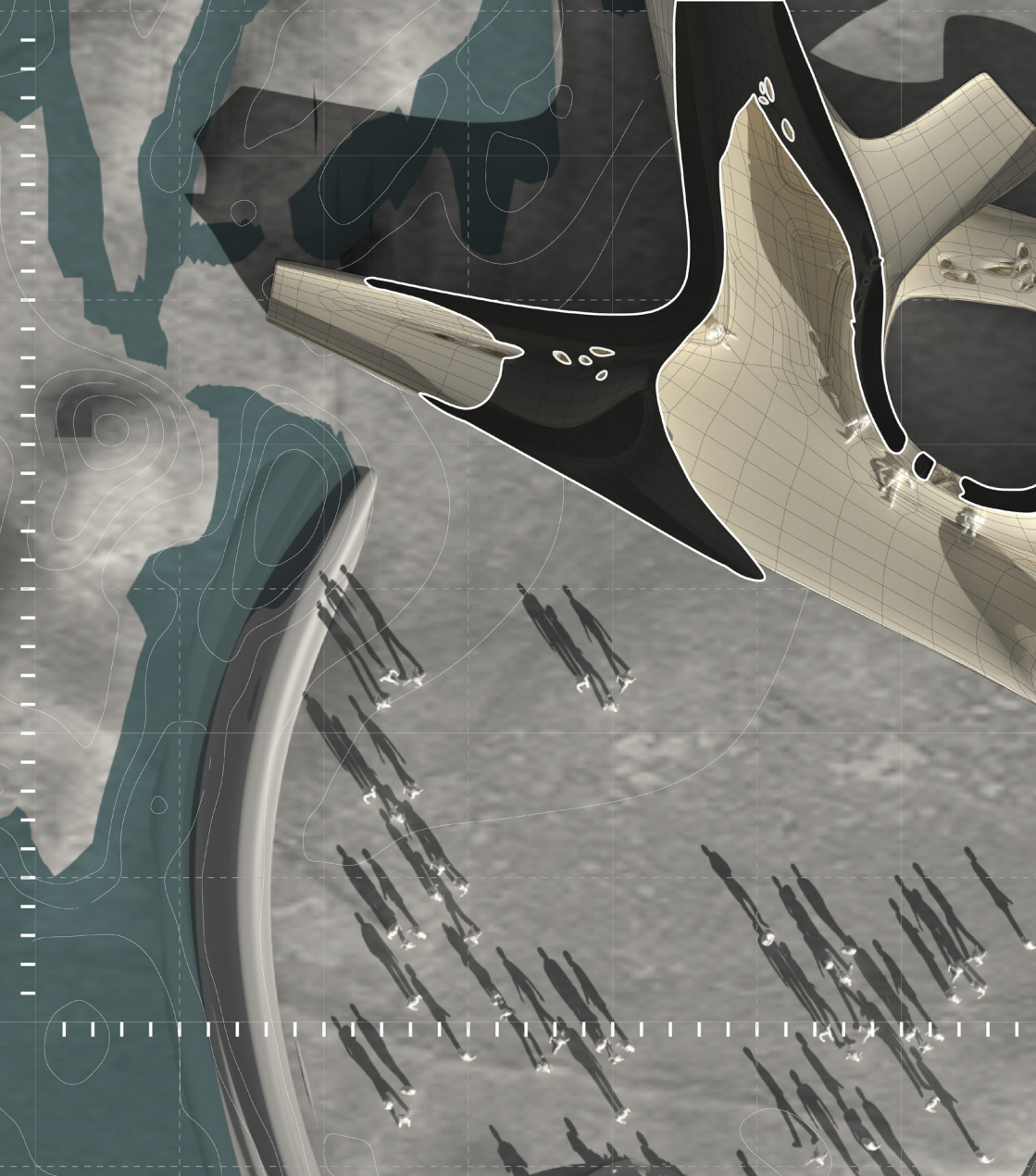
Plan at lvl+6m



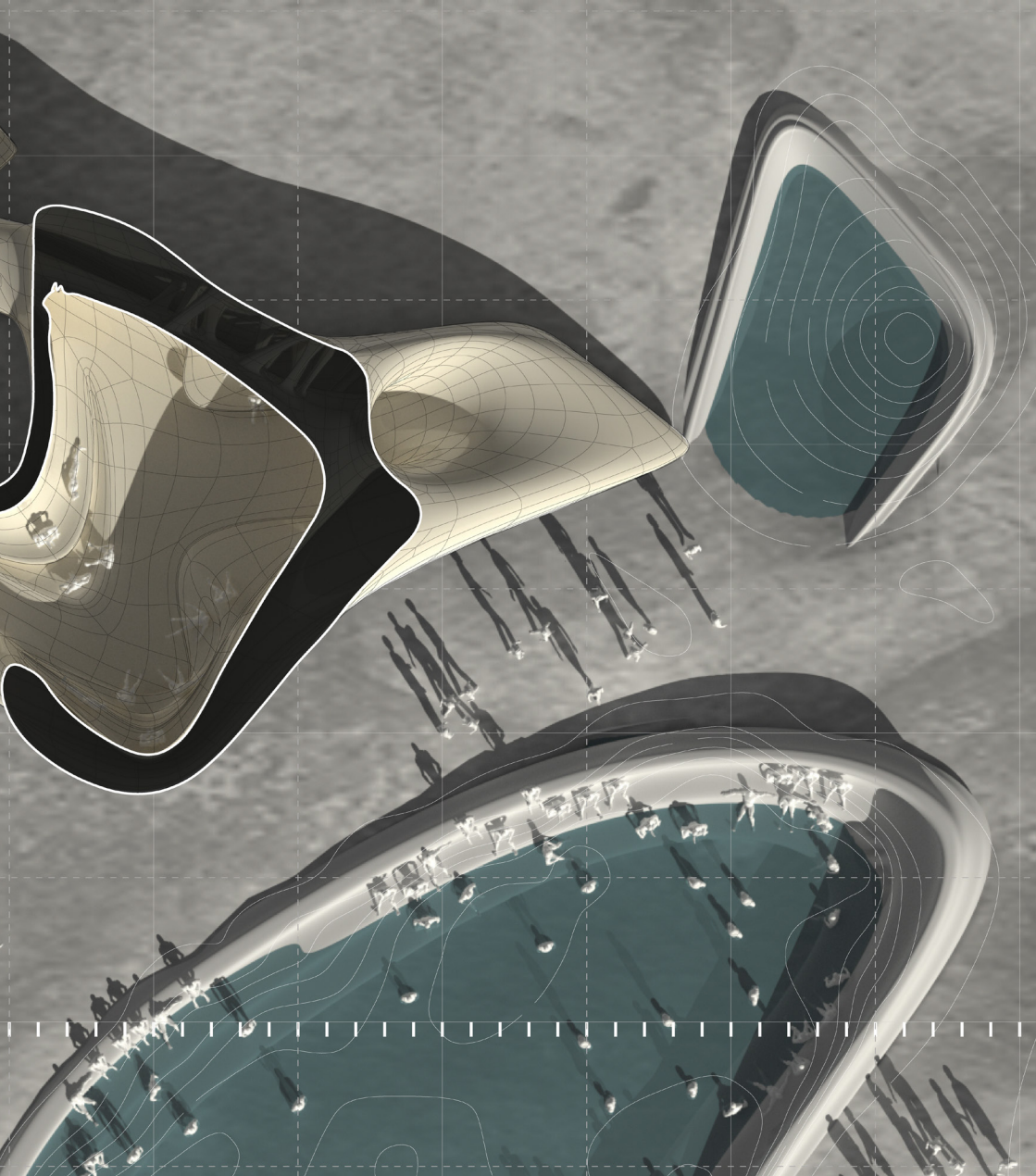
[In-Flow]- P3-5 Design Progression



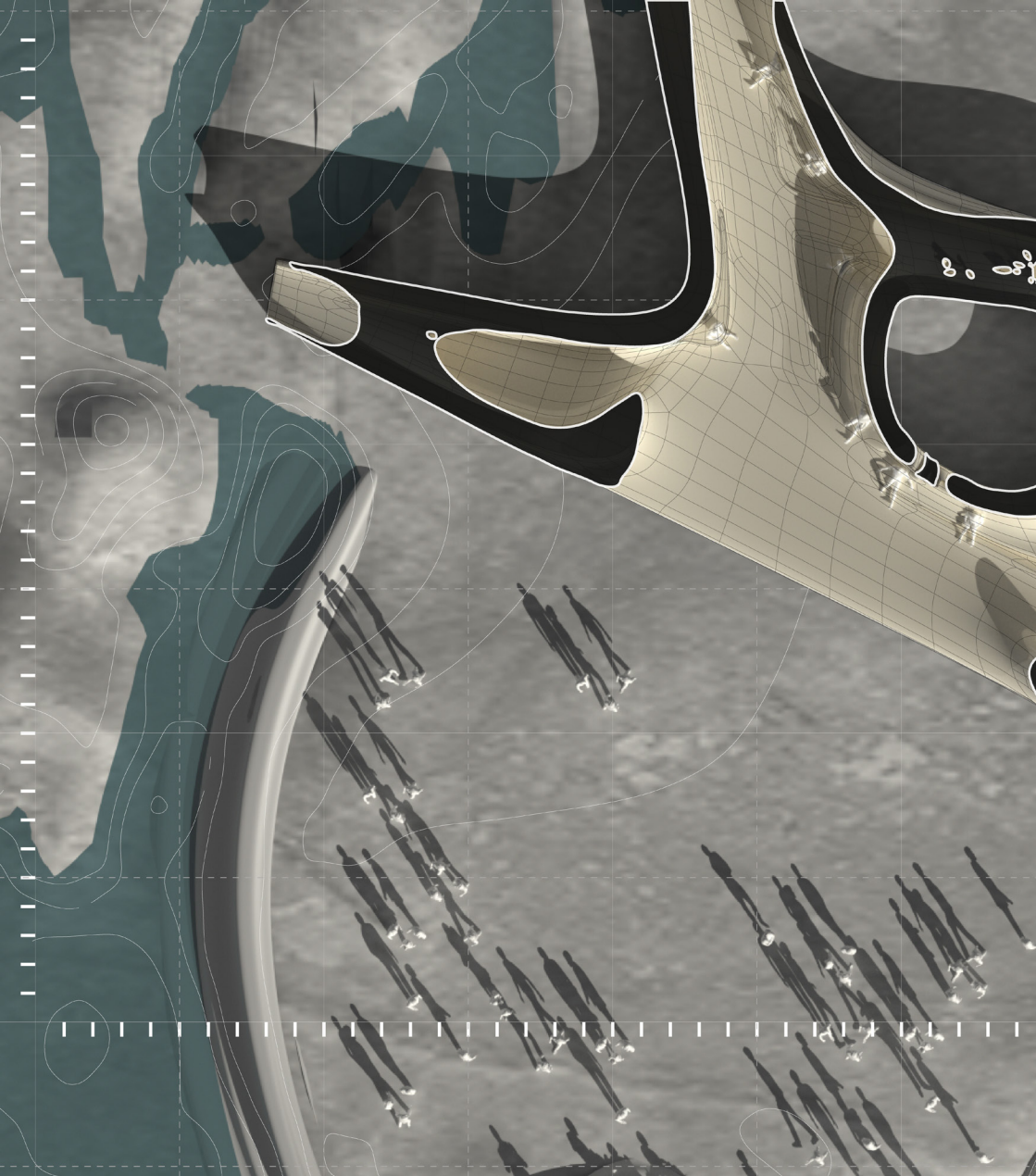
Plan at lvl+4m



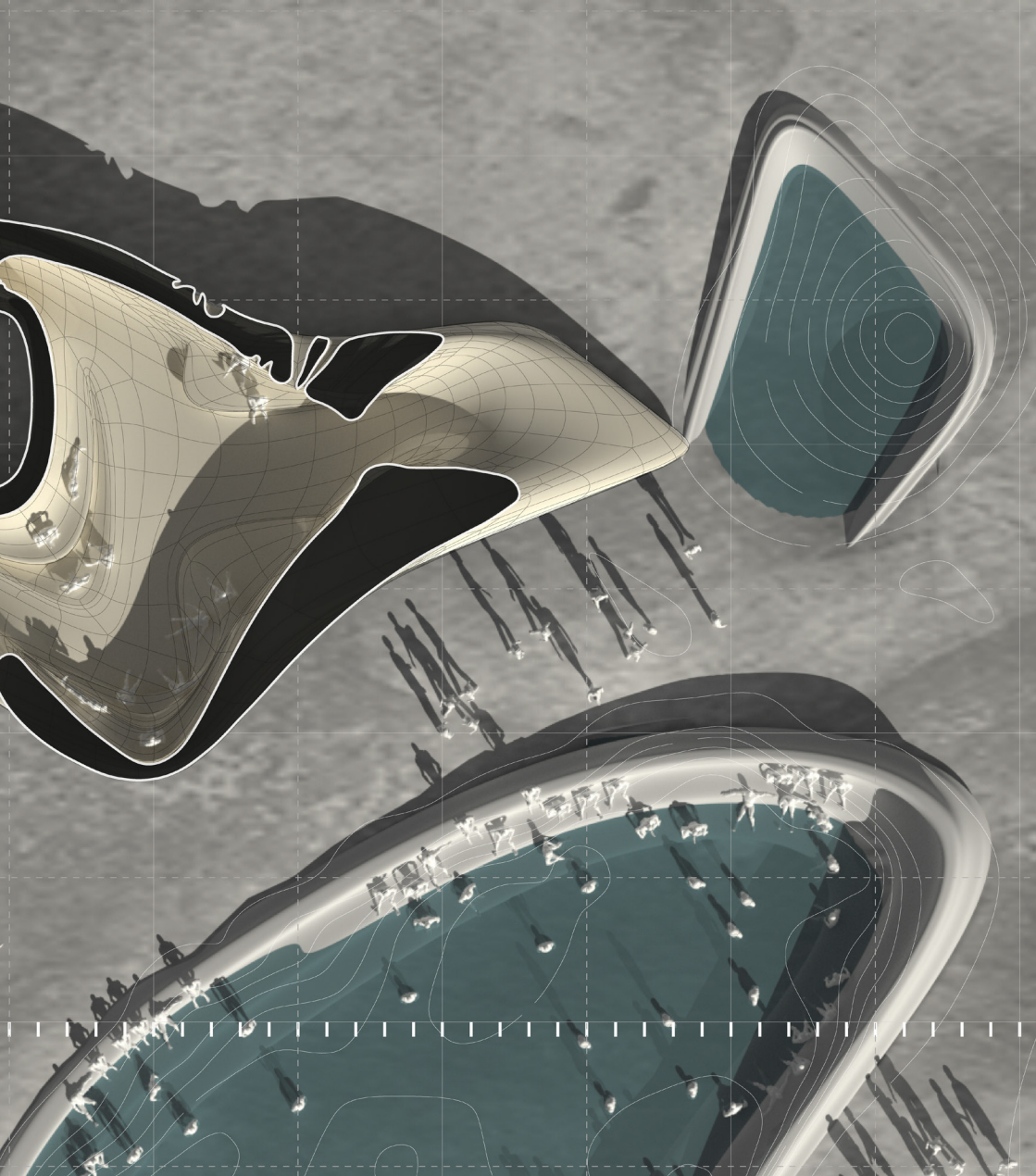
[In-Flow]- P3-5 Design Progression



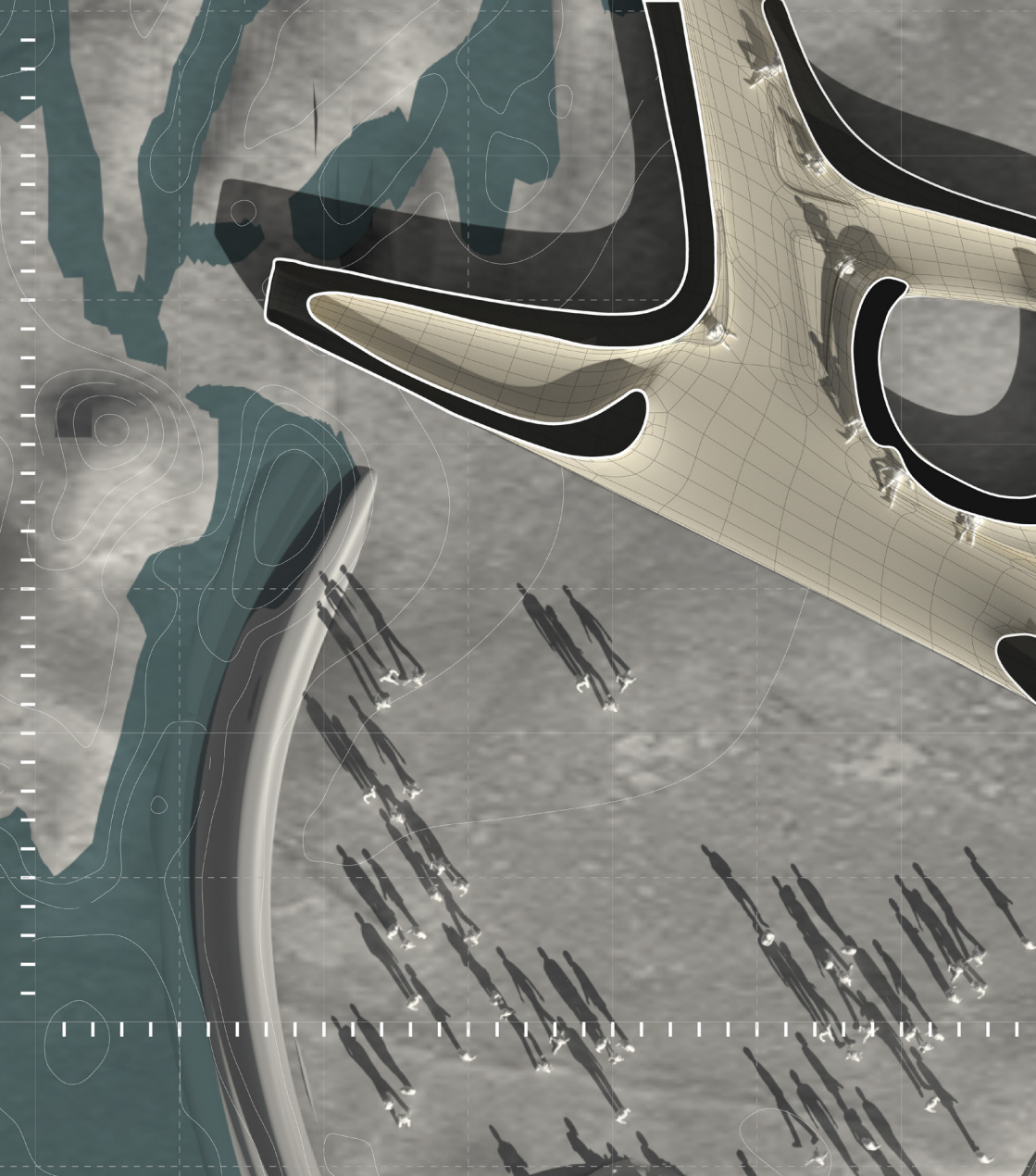
Plan at lvl+3m



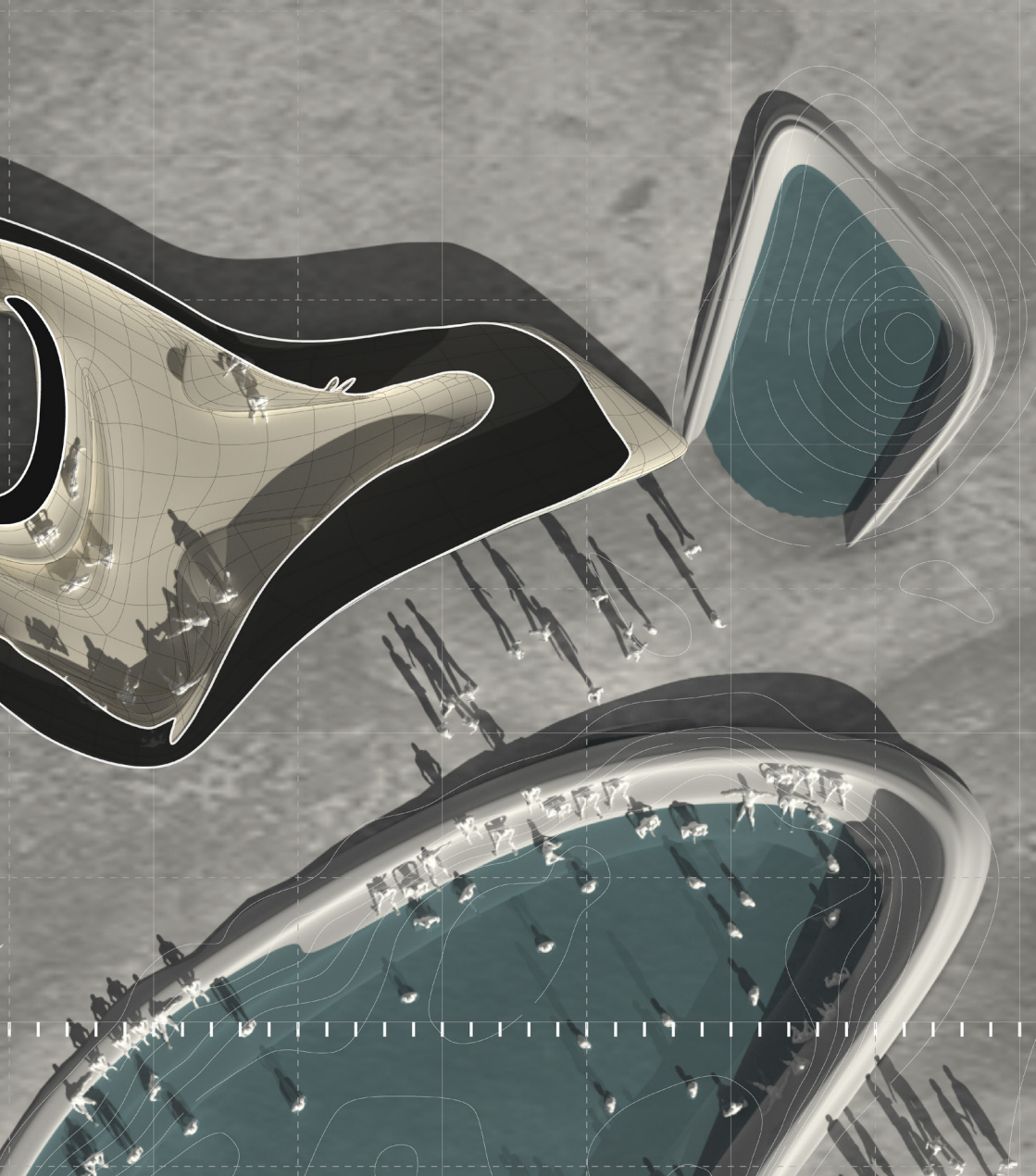
[In-Flow]- P3-5 Design Progression



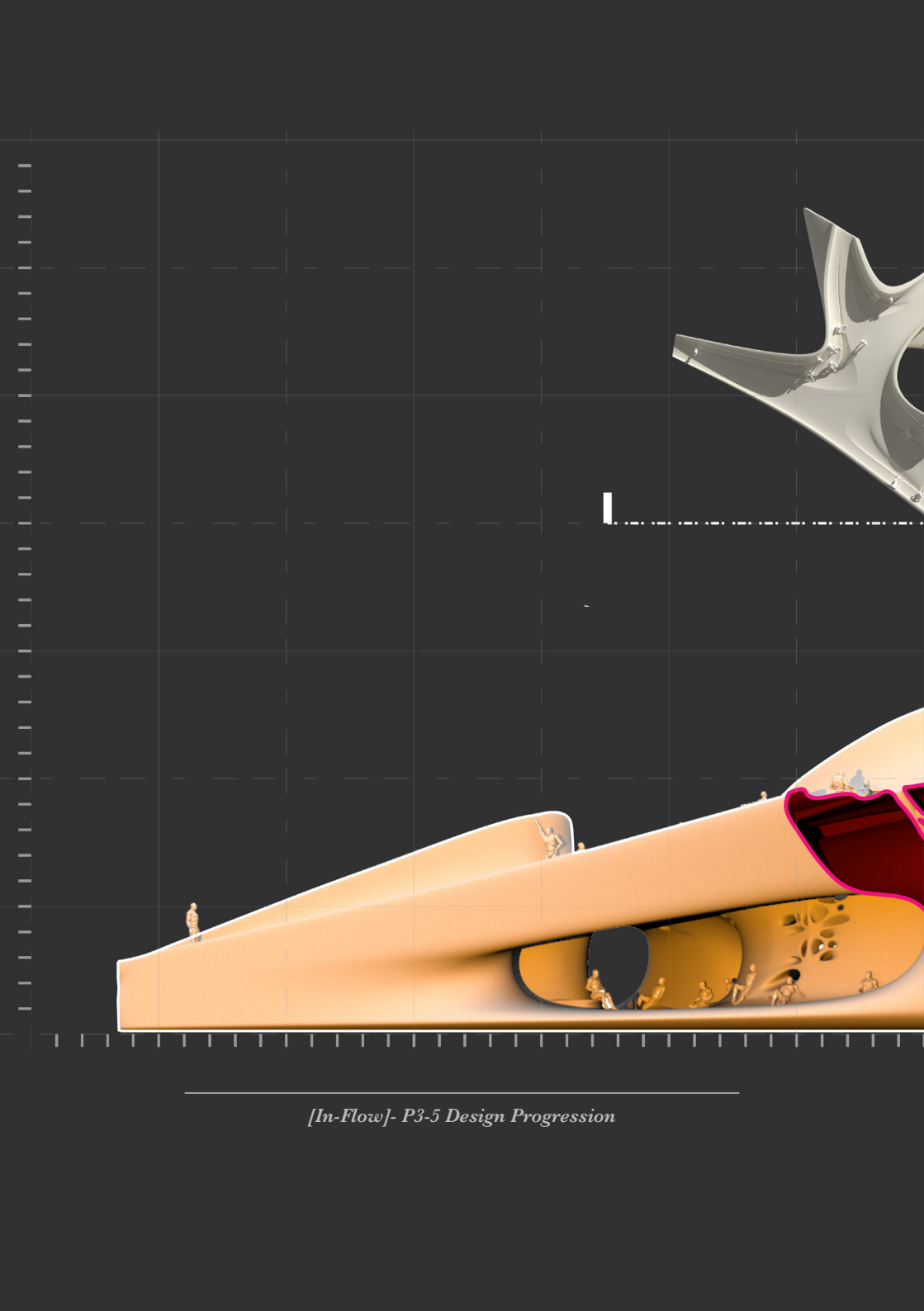
Plan at lvl+2m



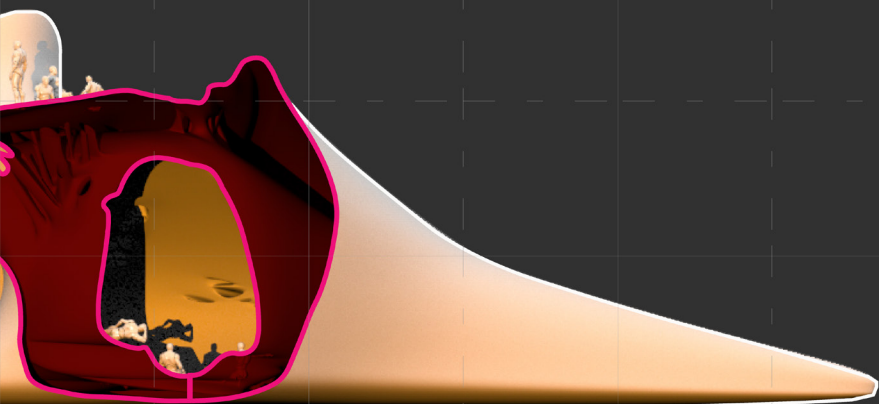
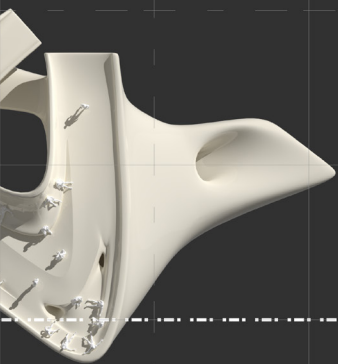
[In-Flow]- P3-5 Design Progression



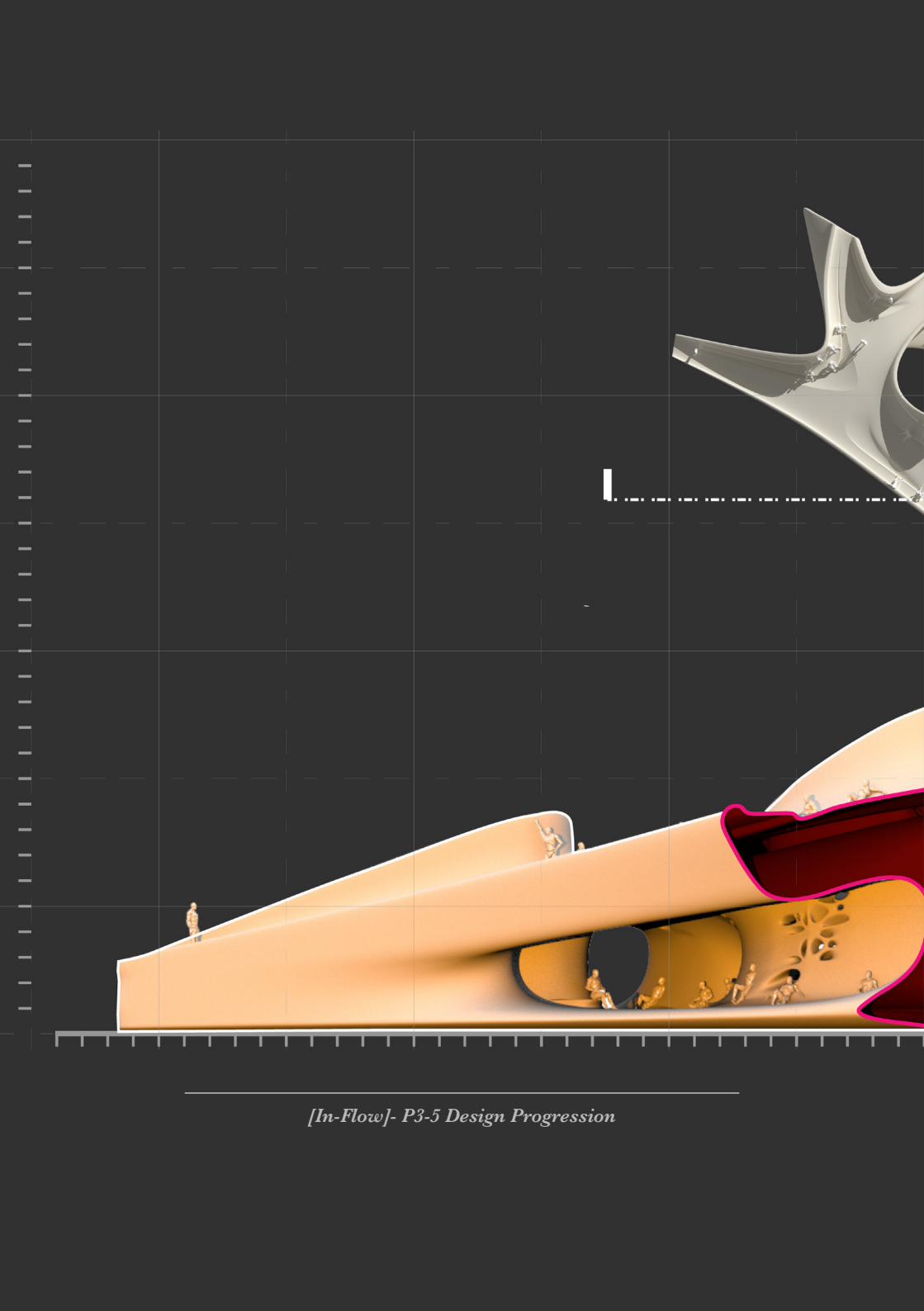
Plan at 1:1m



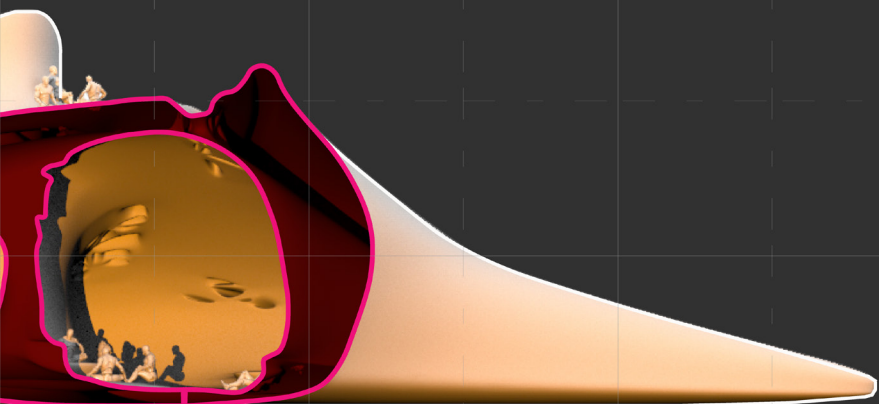
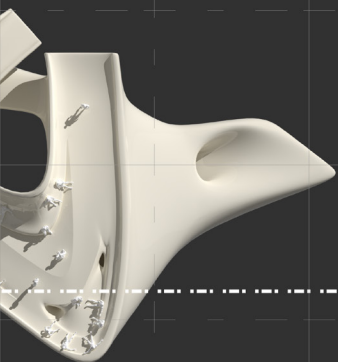
[In-Flow]- P3-5 Design Progression



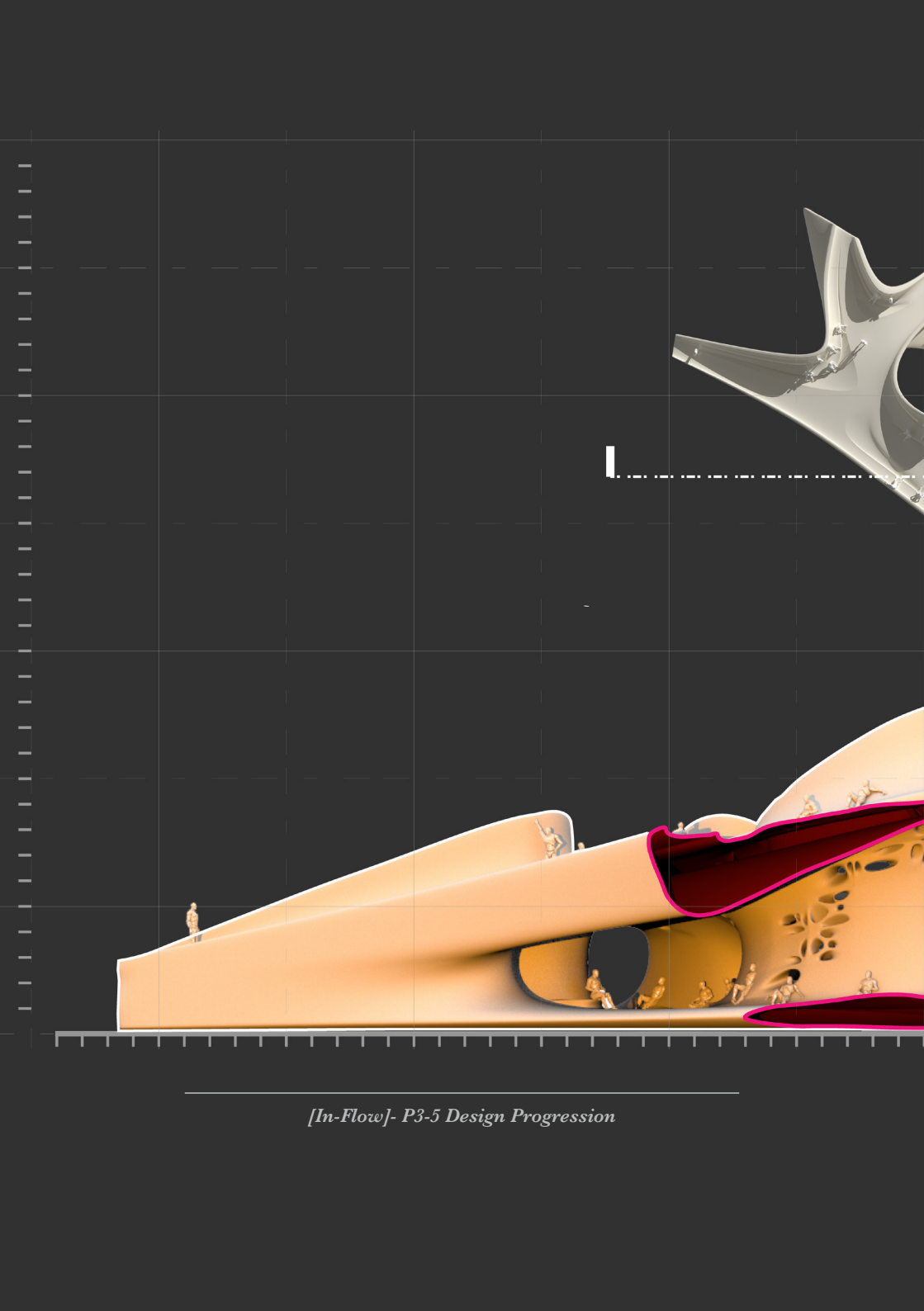
Sections



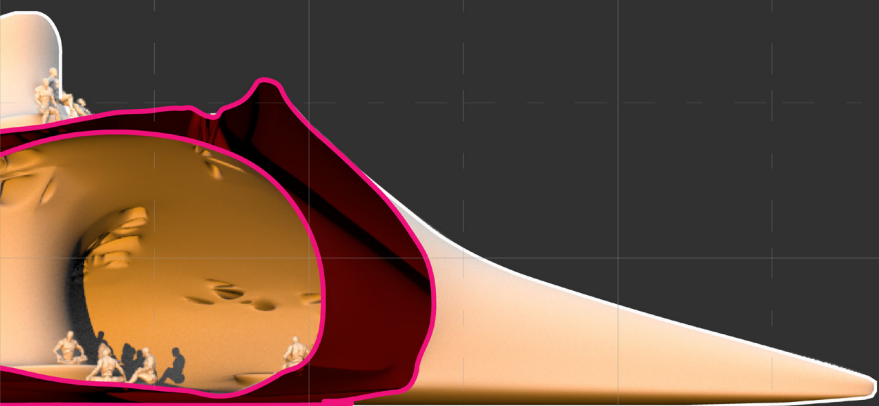
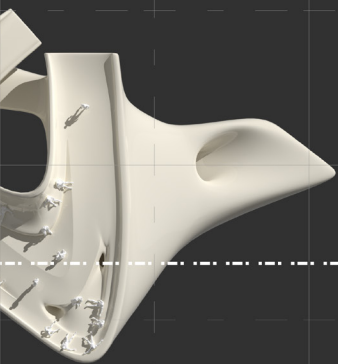
[In-Flow]- P3-5 Design Progression



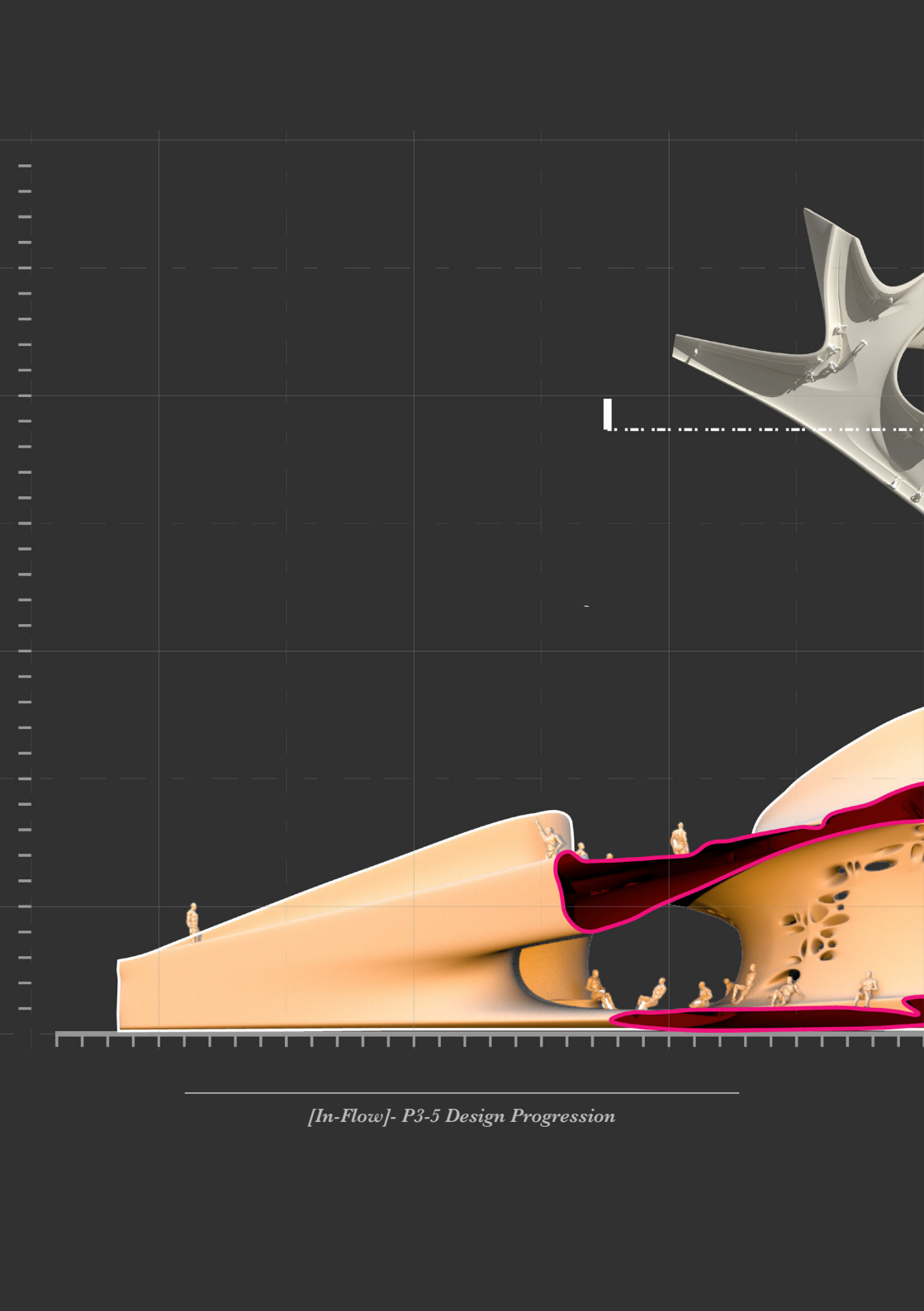
Sections



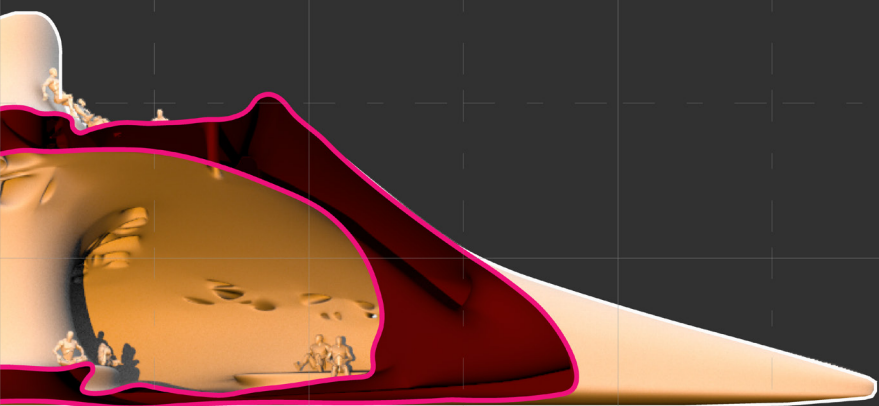
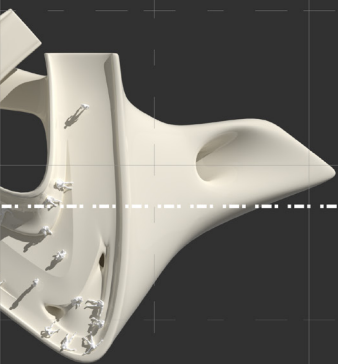
[In-Flow]- P3-5 Design Progression



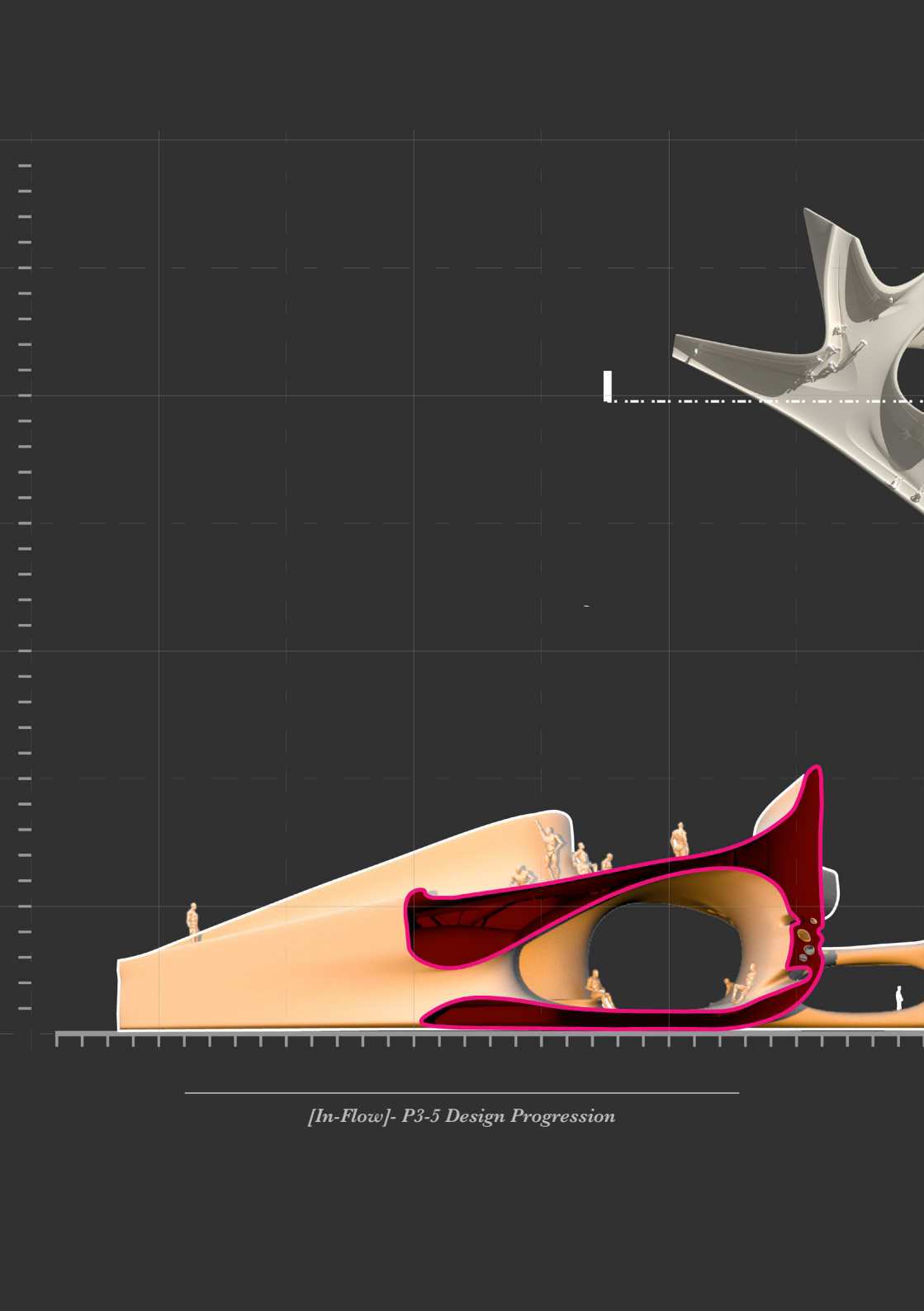
Sections



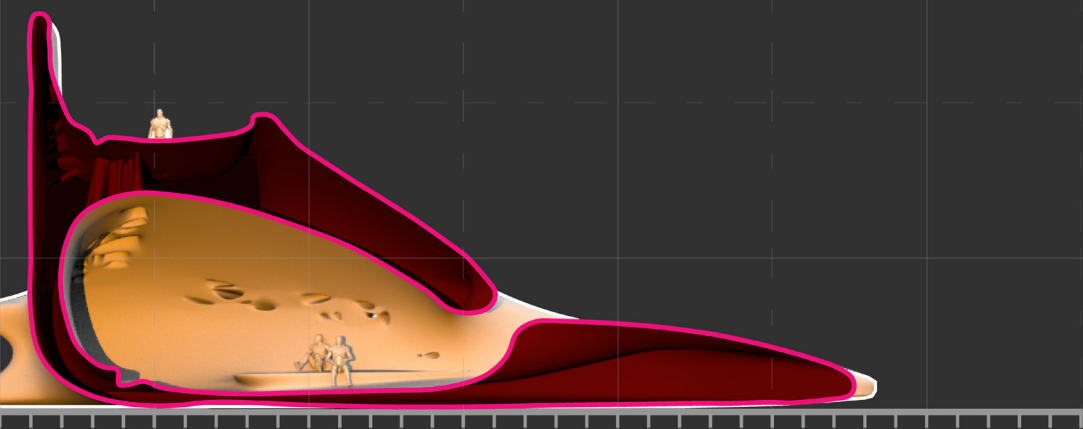
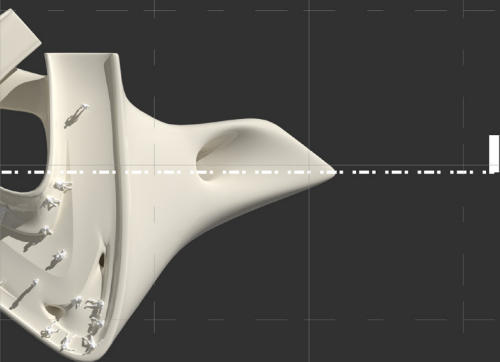
[In-Flow]- P3-5 Design Progression



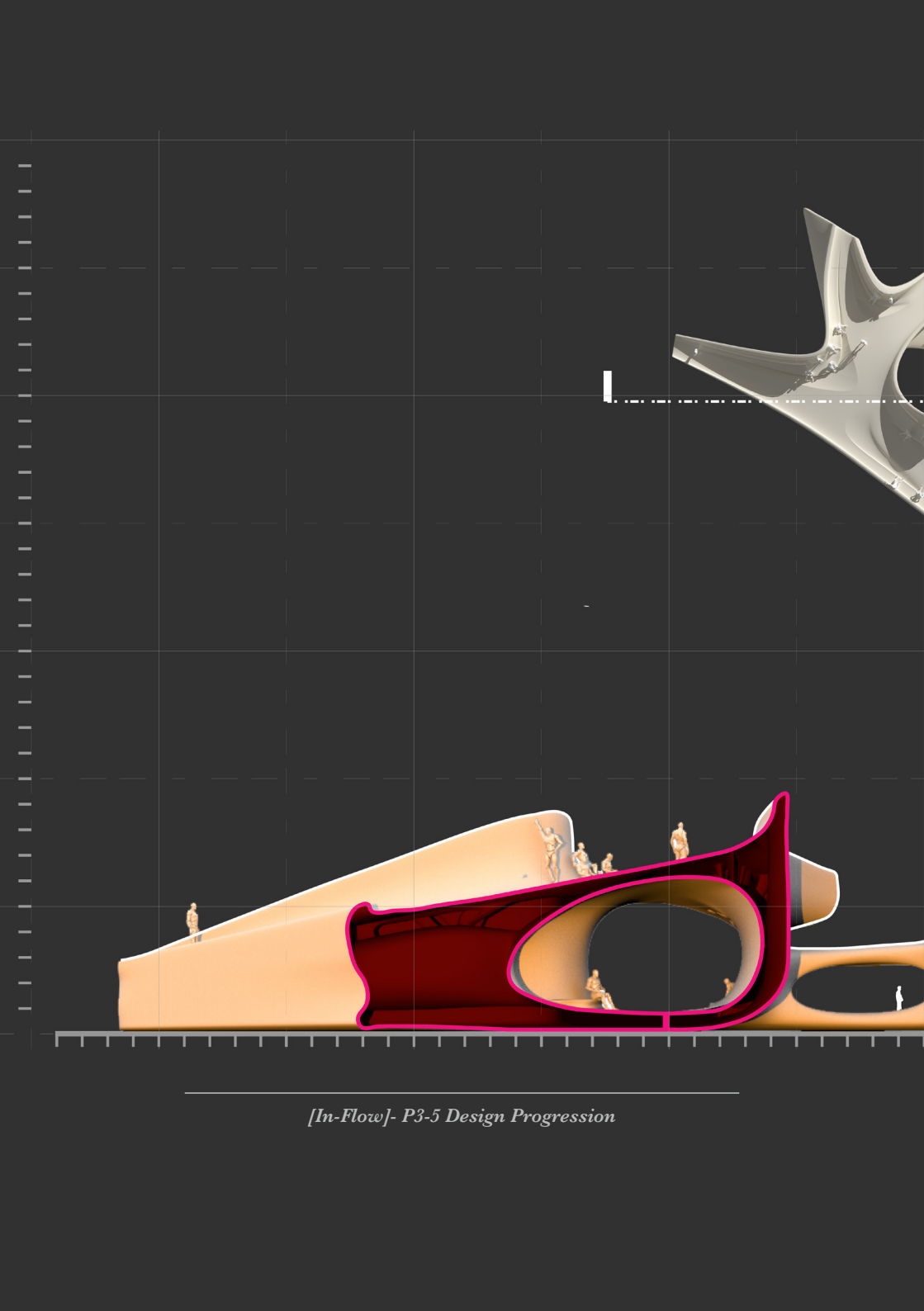
Sections



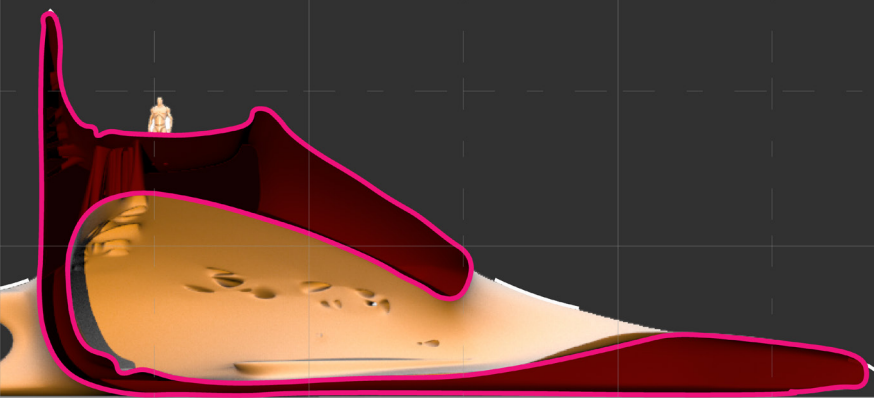
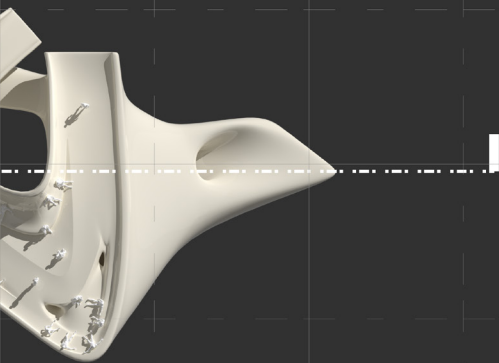
[In-Flow]- P3-5 Design Progression



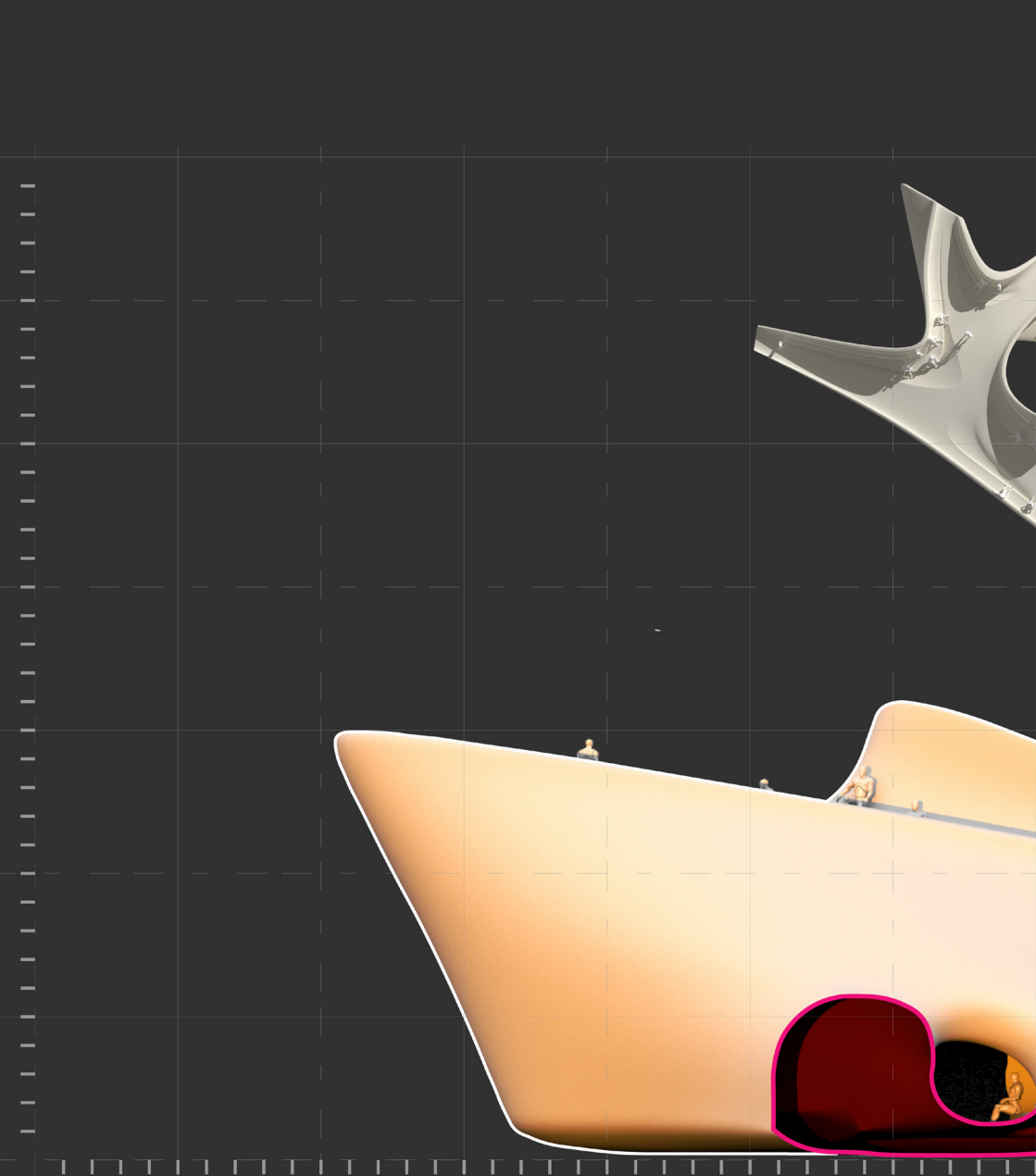
Sections



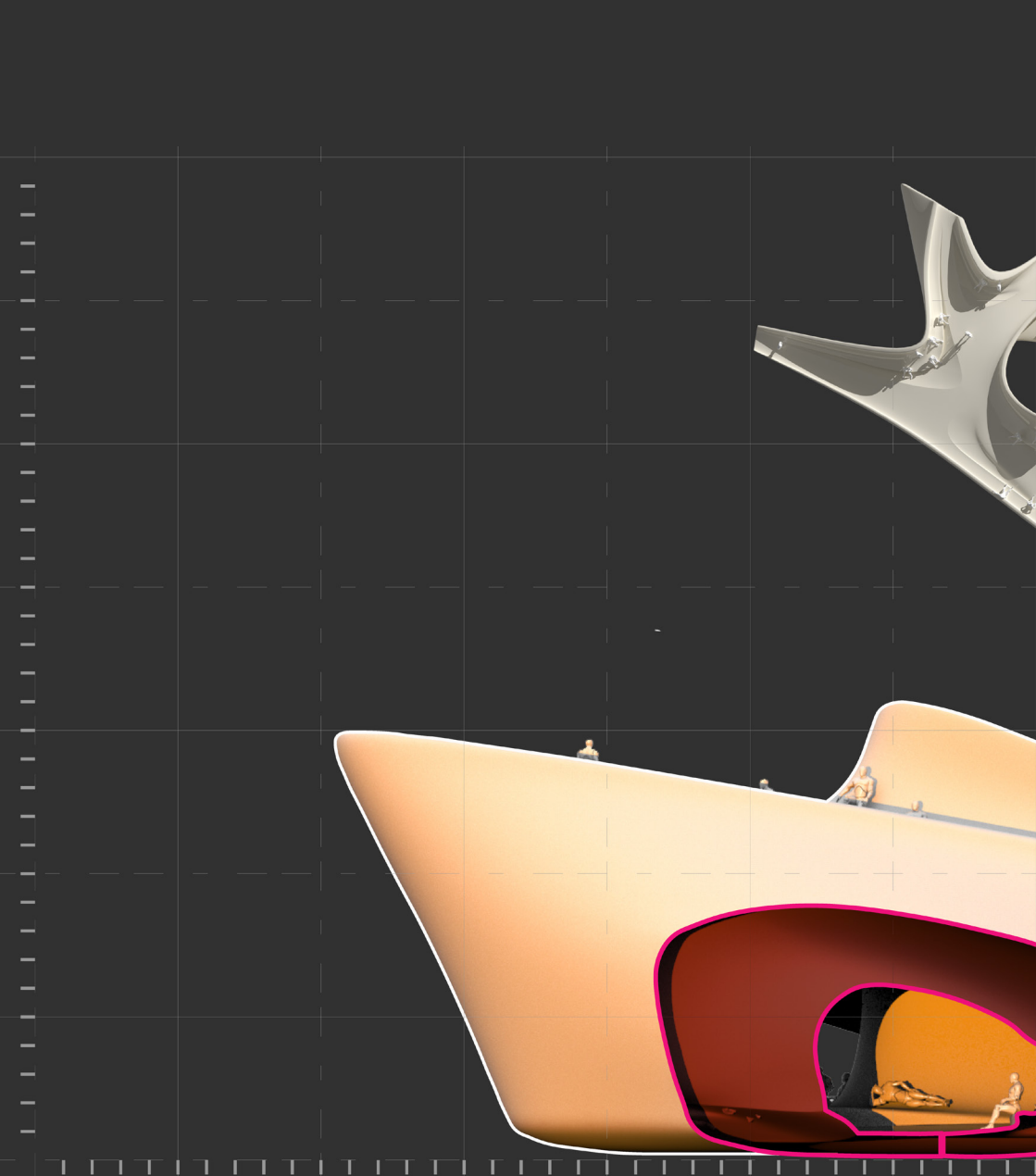
[In-Flow]- P3-5 Design Progression



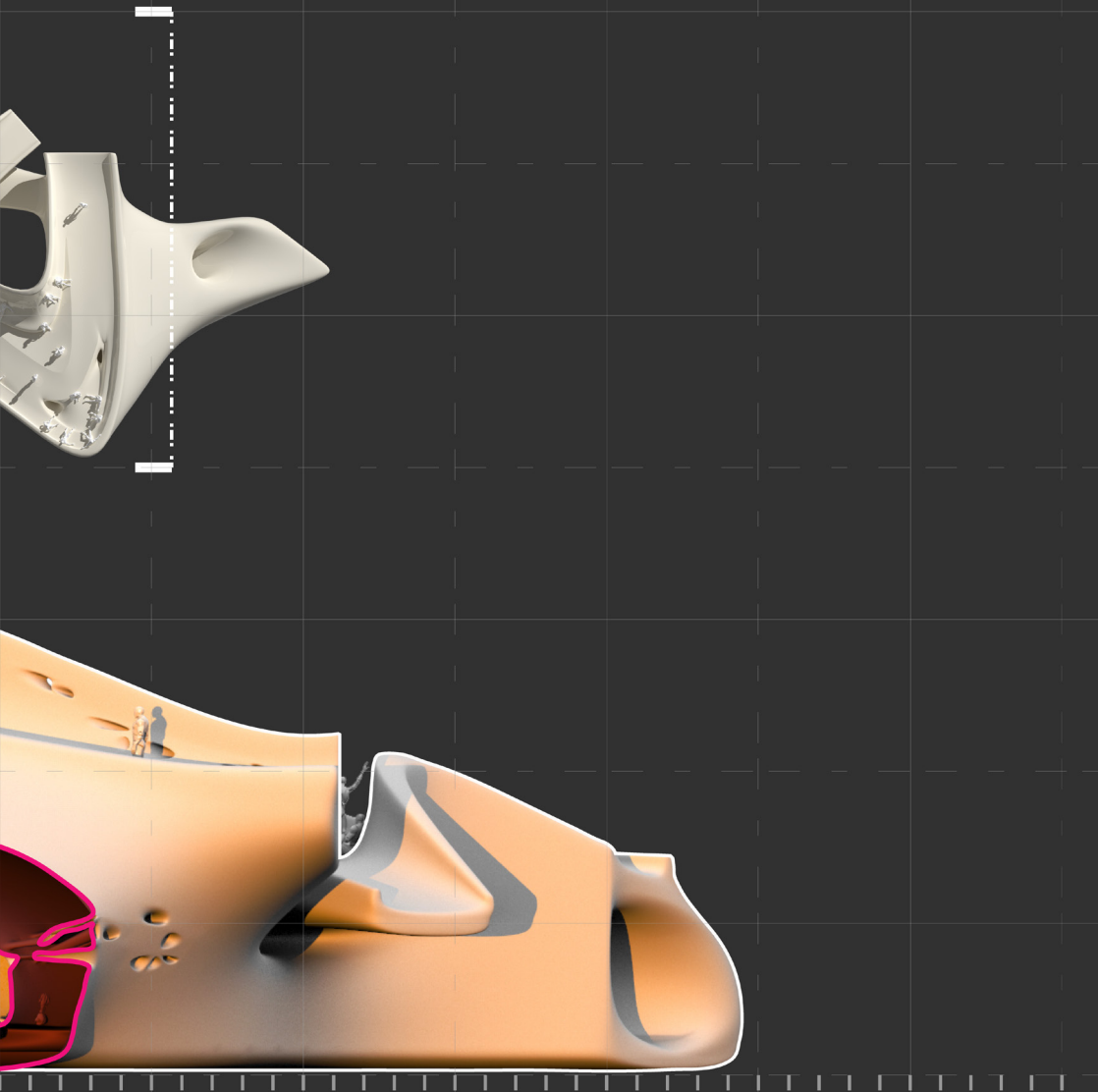
Sections



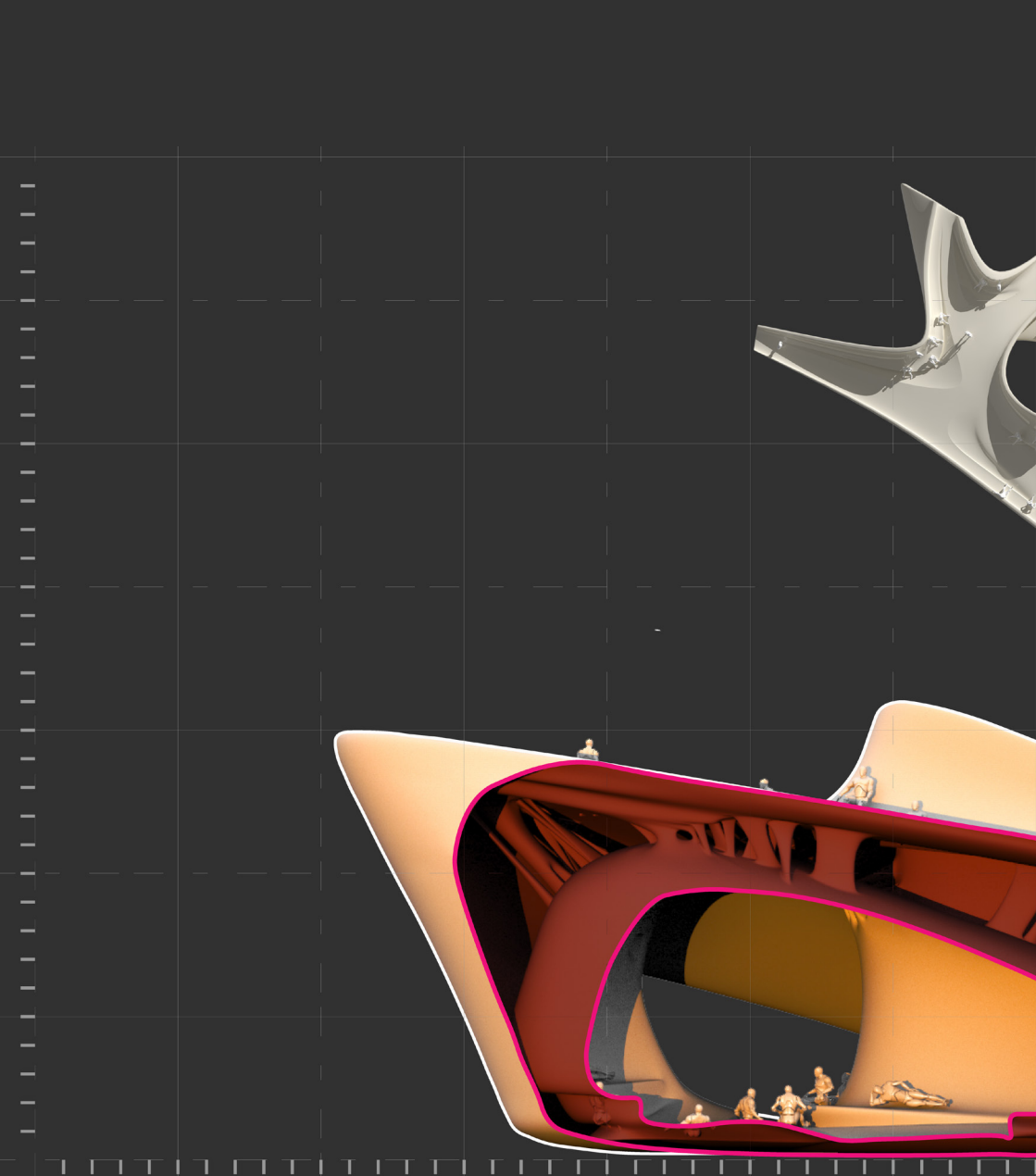
[In-Flow]- P3-5 Design Progression



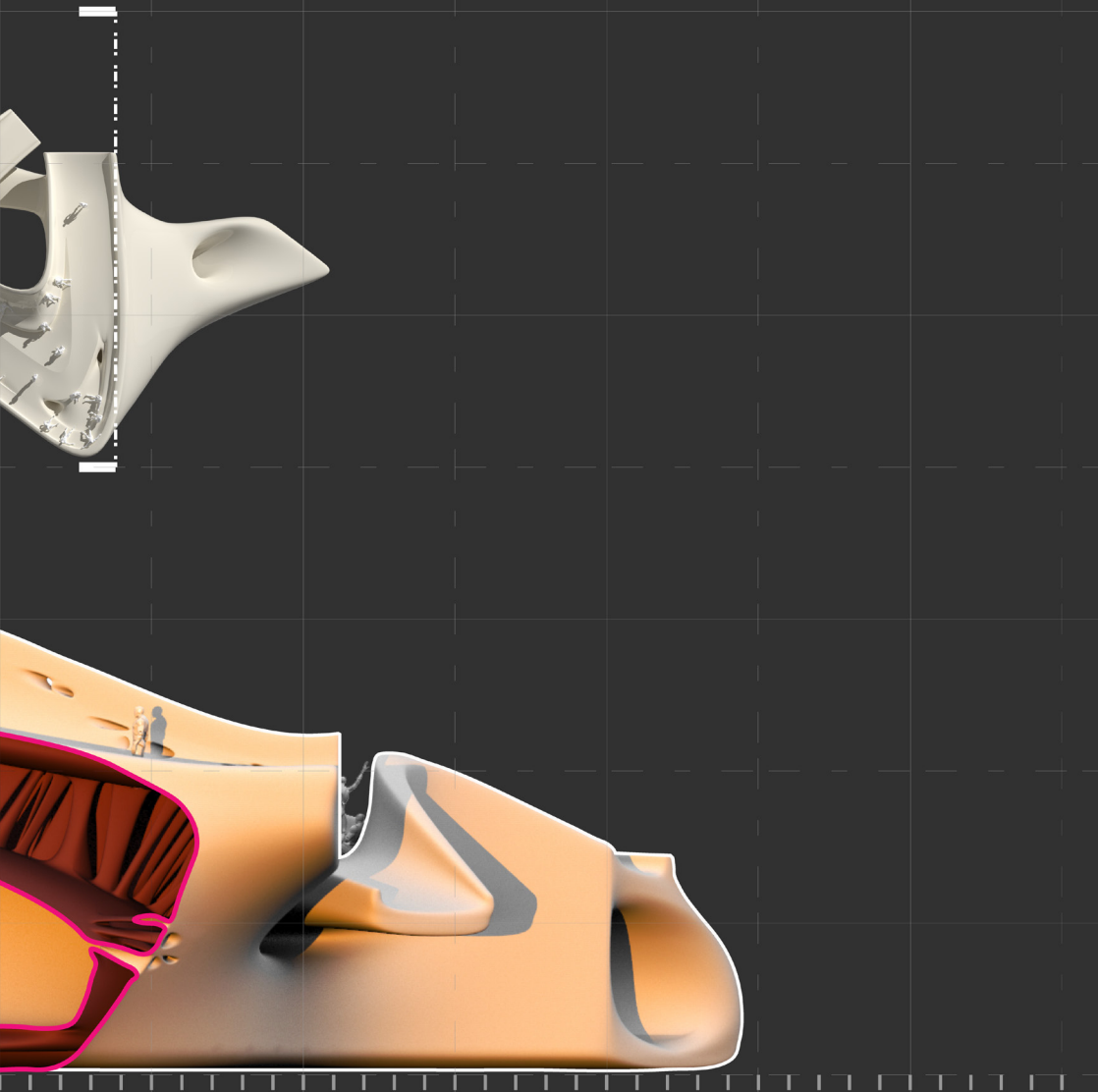
[In-Flow]- P3-5 Design Progression



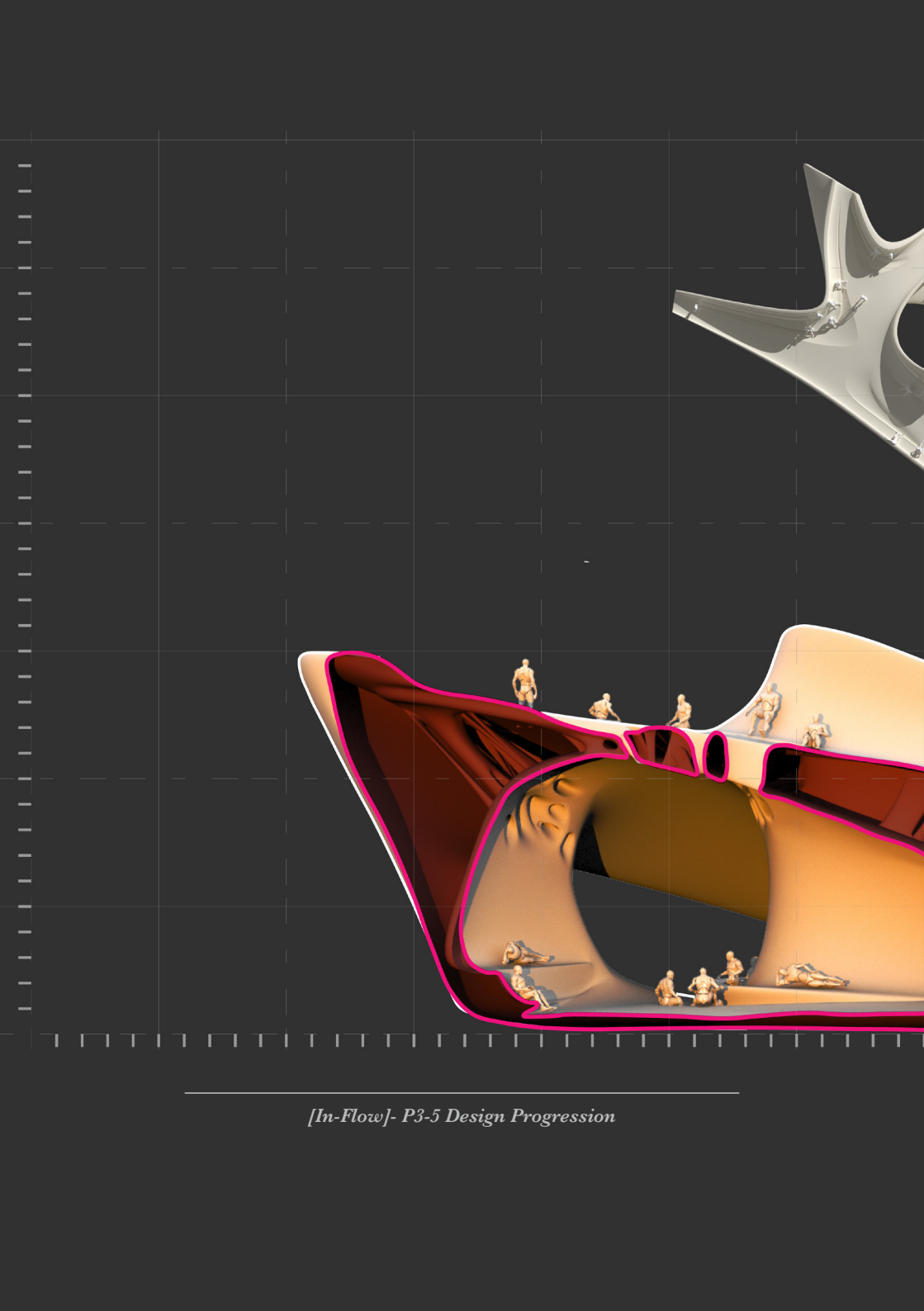
Sections



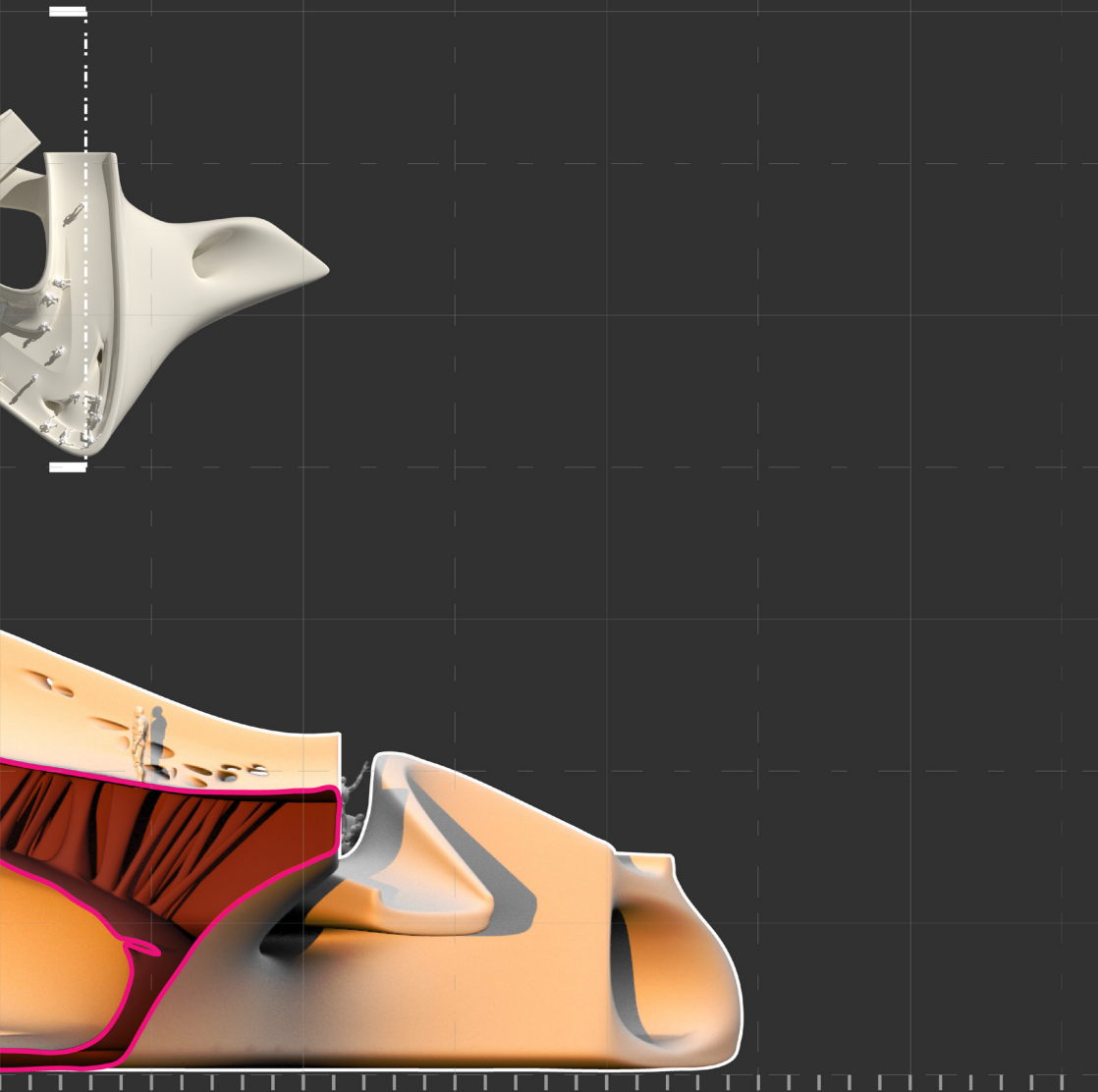
[In-Flow]- P3-5 Design Progression



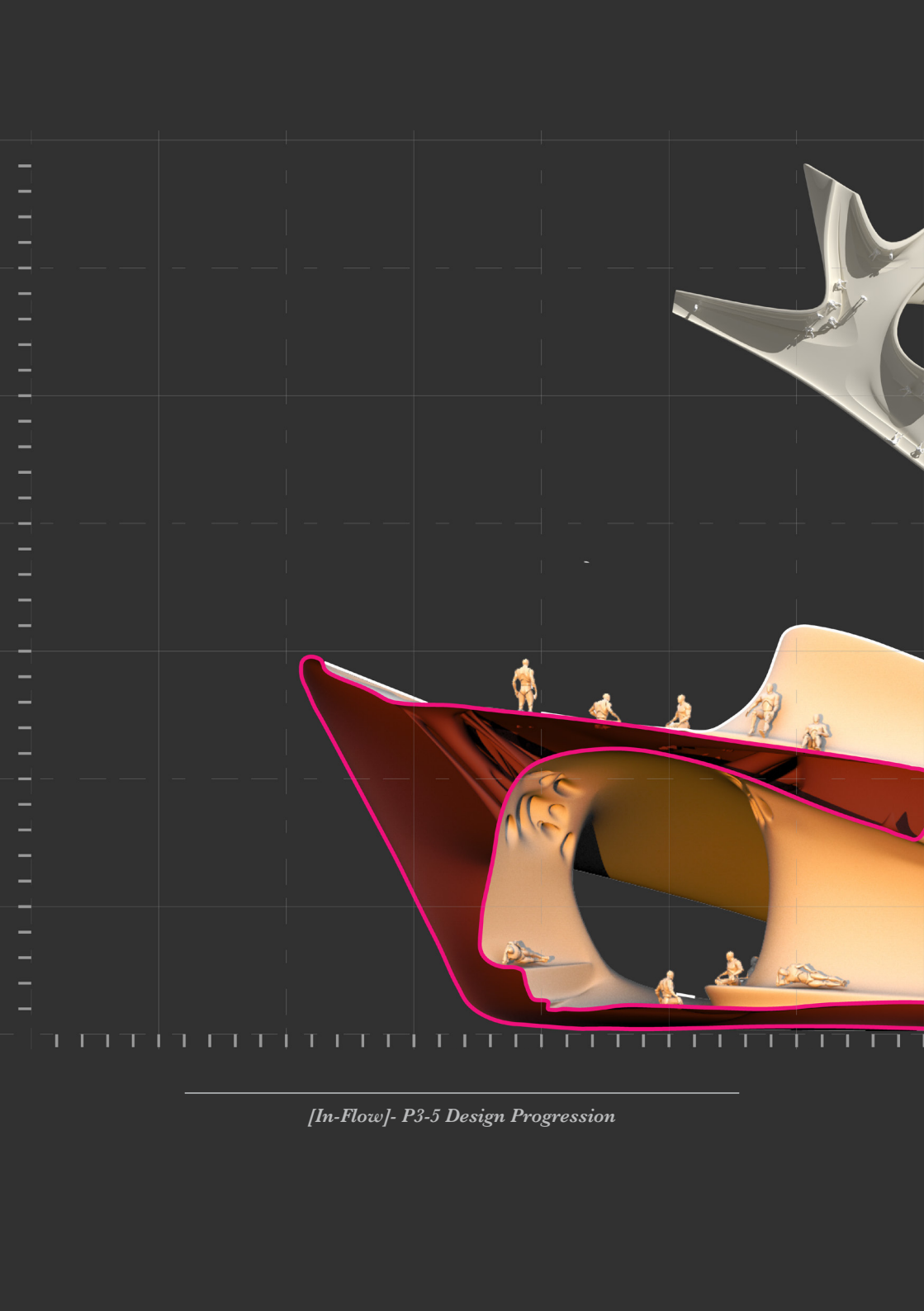
Sections



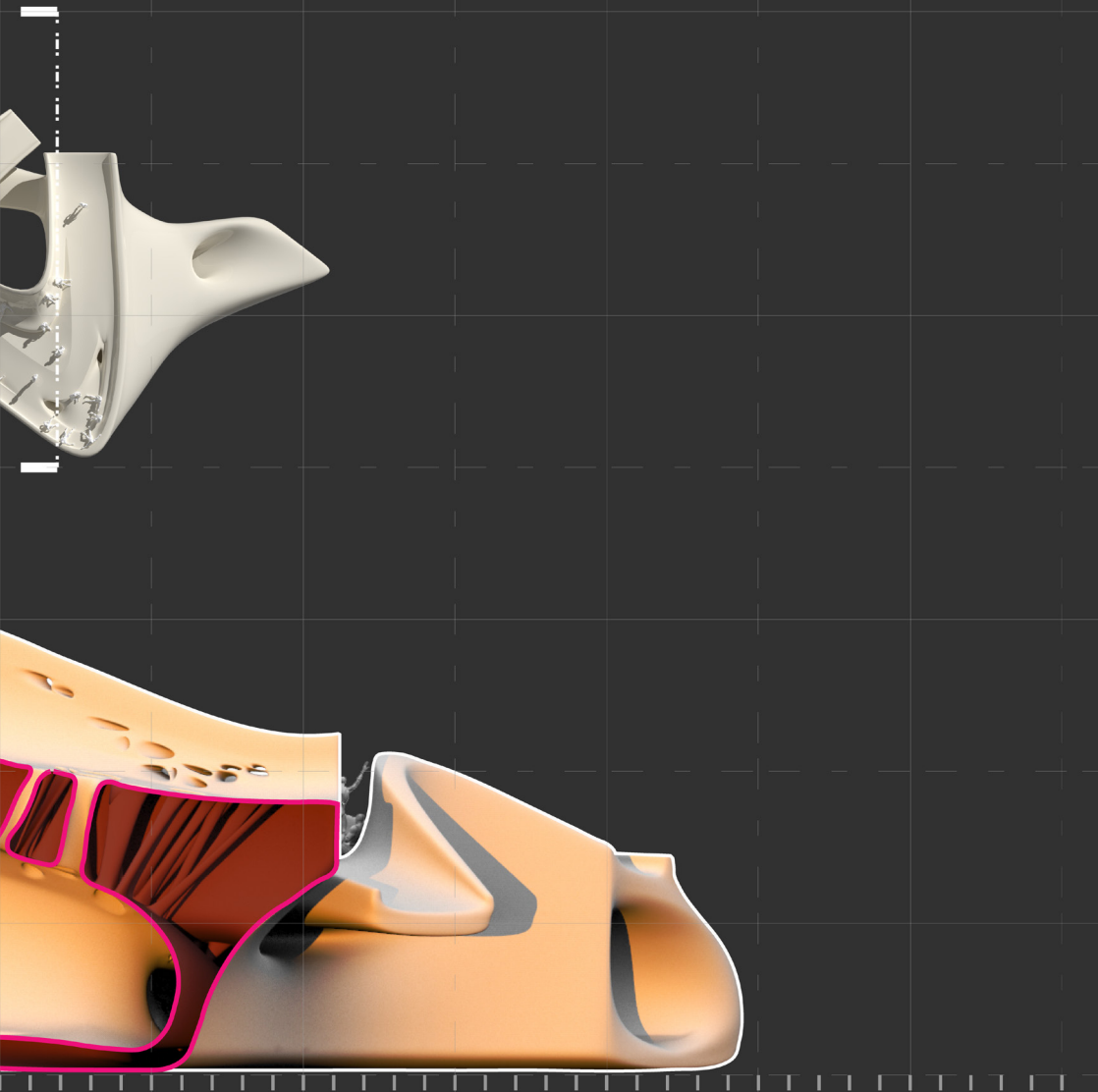
[In-Flow]- P3-5 Design Progression



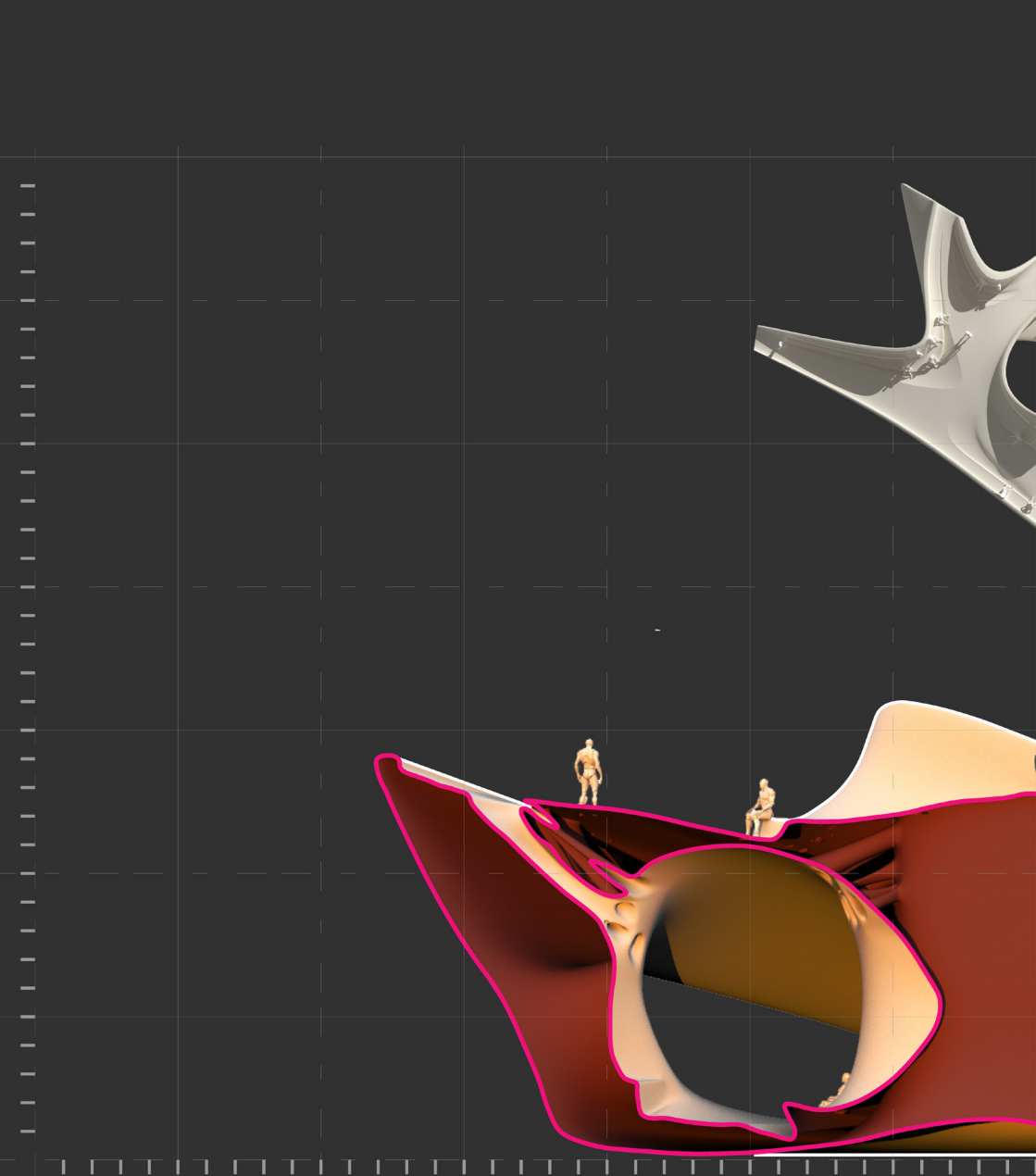
Sections



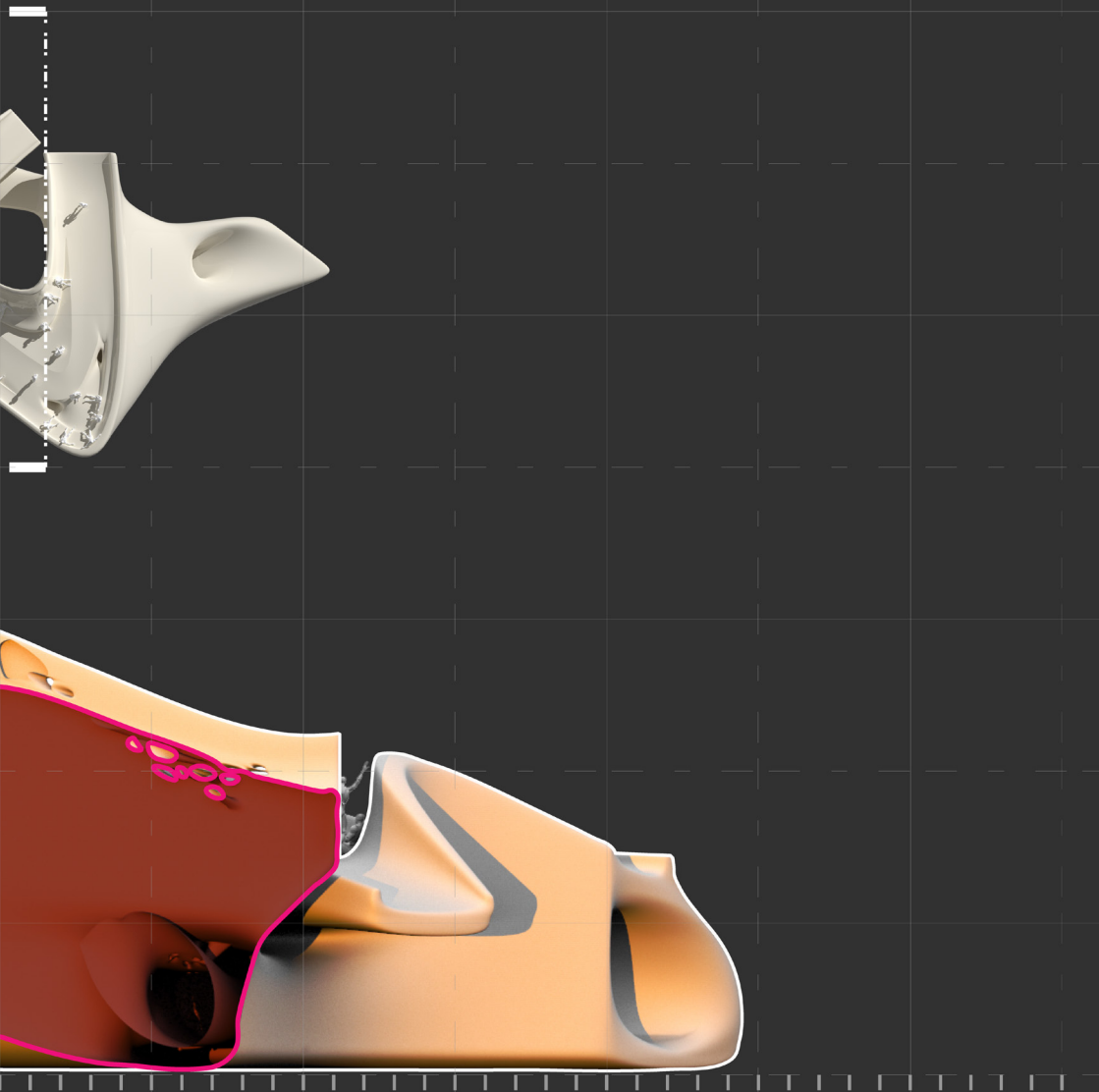
[In-Flow]- P3-5 Design Progression



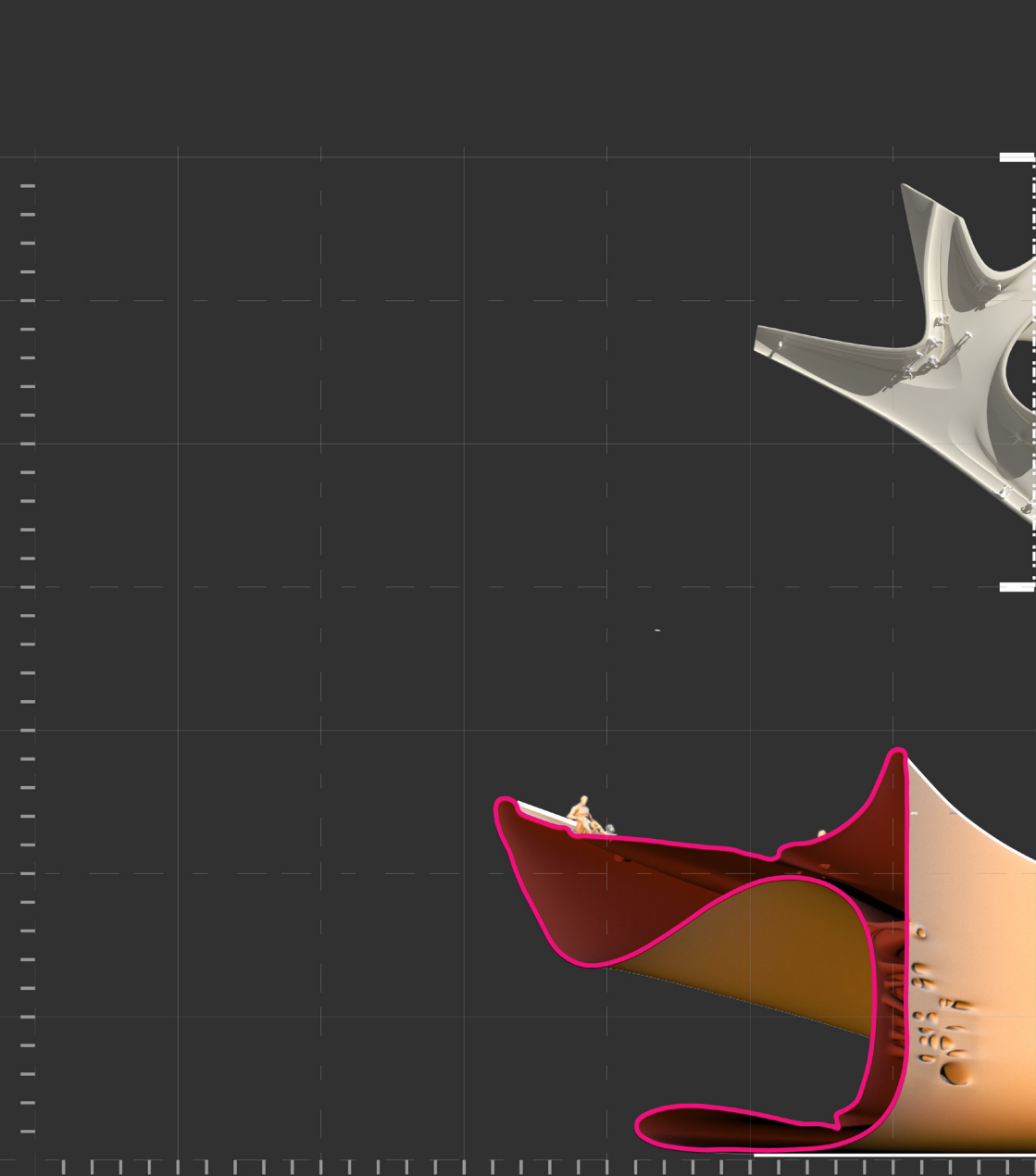
Sections



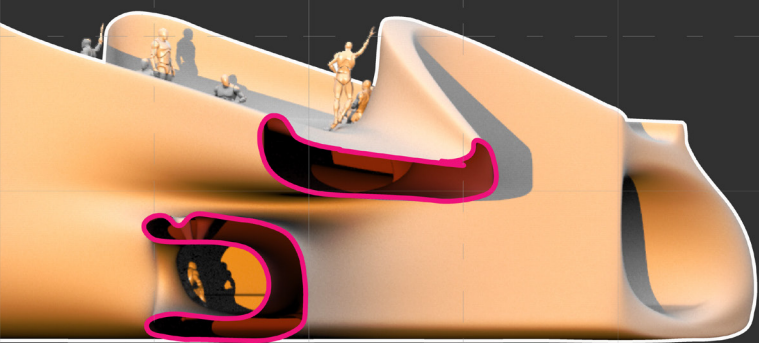
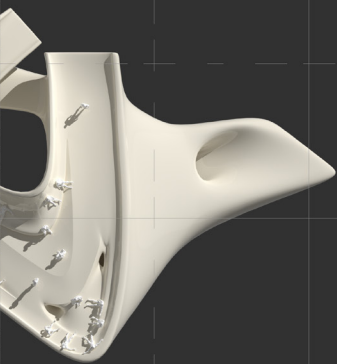
[In-Flow]- P3-5 Design Progression



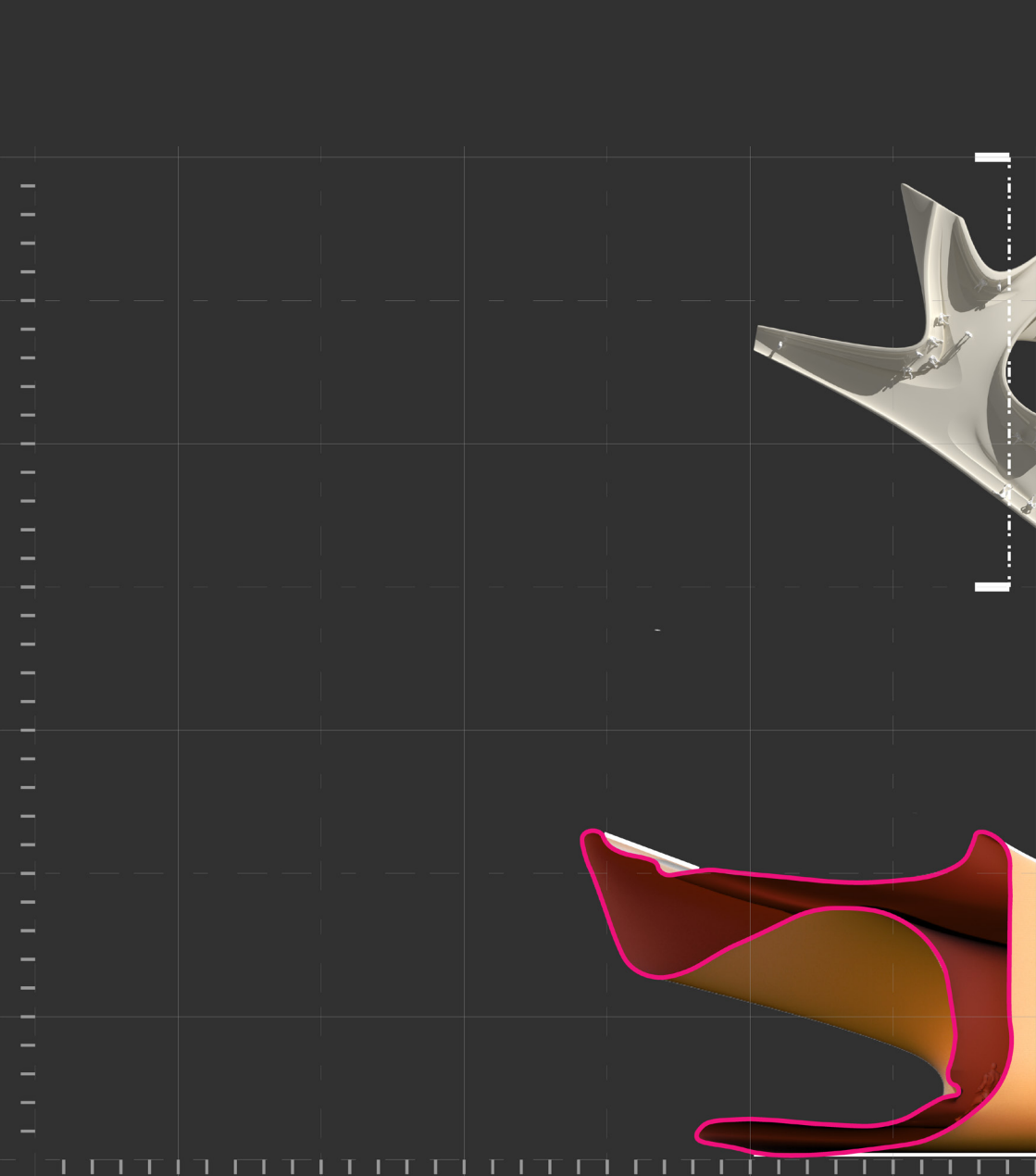
Sections



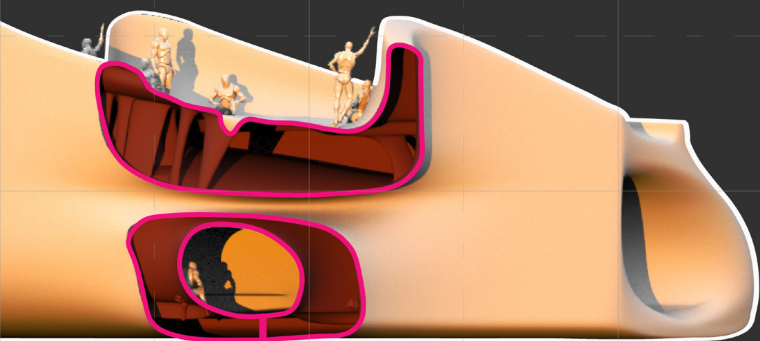
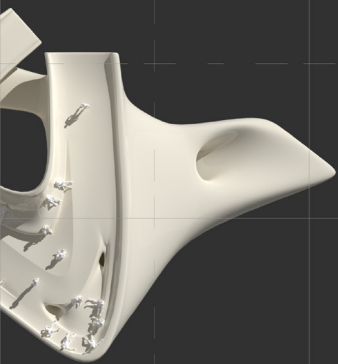
[In-Flow]- P3-5 Design Progression



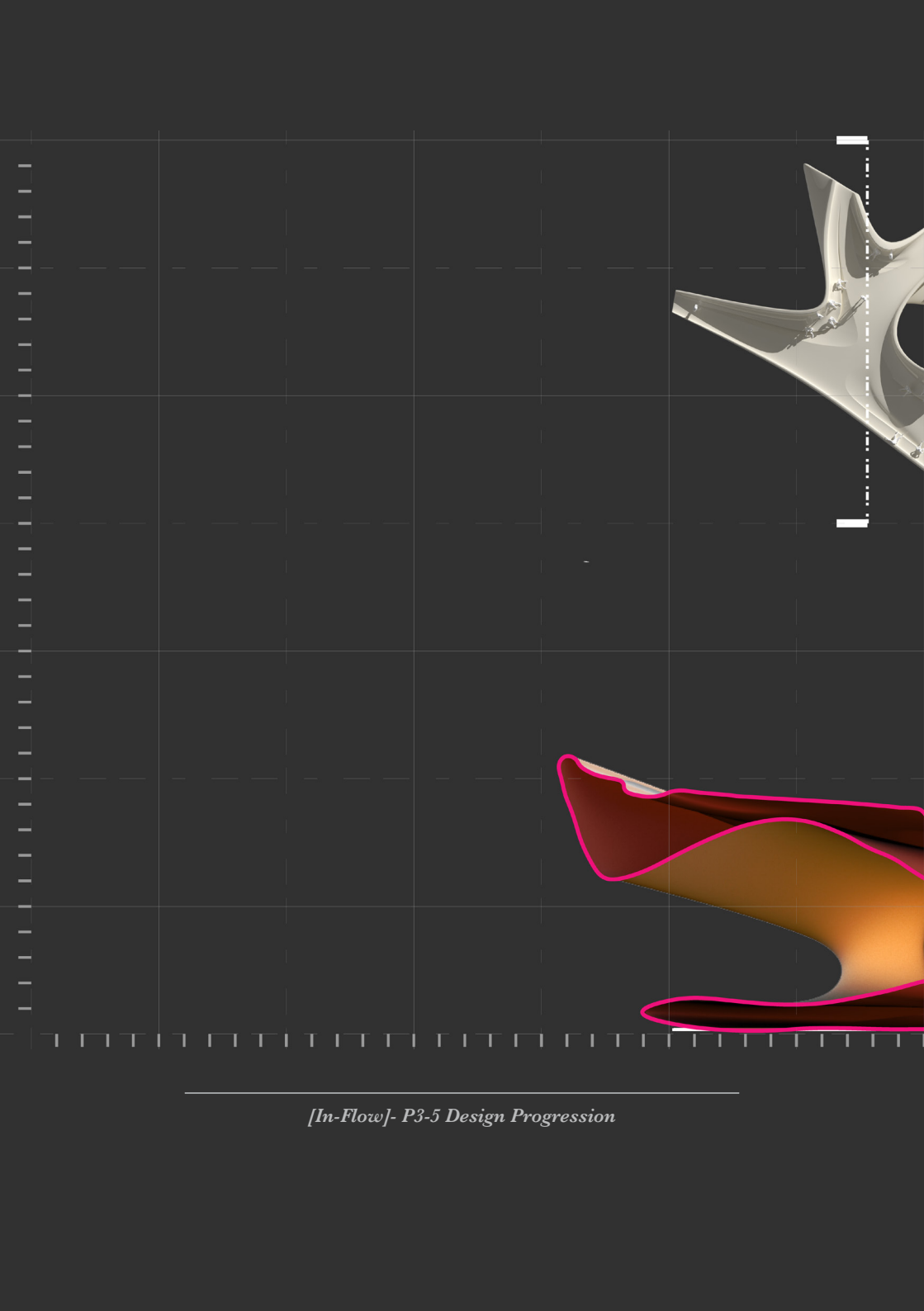
Sections



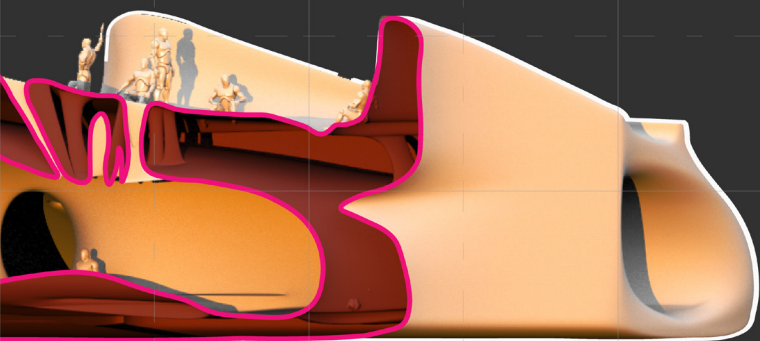
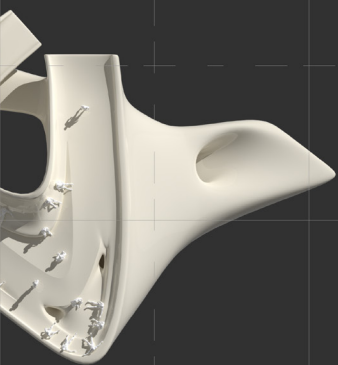
[In-Flow]- P3-5 Design Progression



Sections



[In-Flow]- P3-5 Design Progression



Sections



Micro Detailing



[In-Flow]- P3-5 Design Progression



For micro detailing the main attempt is to introduce variable pattern on the geometry surface. One of the reference is the natural rough variable stone type variations like one in the above image.



[In-Flow]- P3-5 Design Progression



The other pattern reference is the ornate kind of repetitive pattern.



[In-Flow]- P3-5 Design Progression



Banyan tree has a strong tie with Indian temples and often you see them intertwined with the temple over time sometimes totally taking it over.



[In-Flow]- P3-5 Design Progression



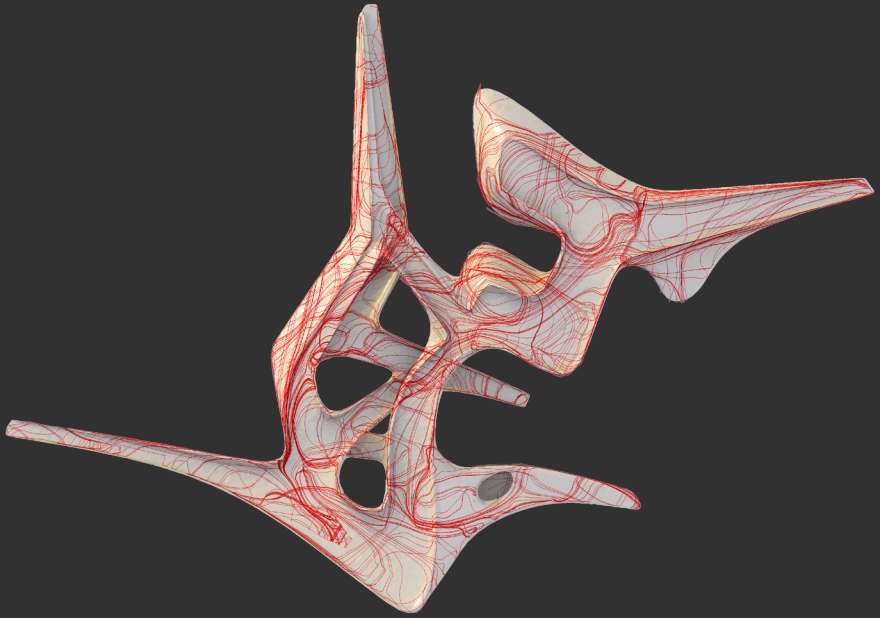
The yogis are often found meditating under a banyan tree. Inducing the banyan tree like pattern was thought of as one type of pattern.



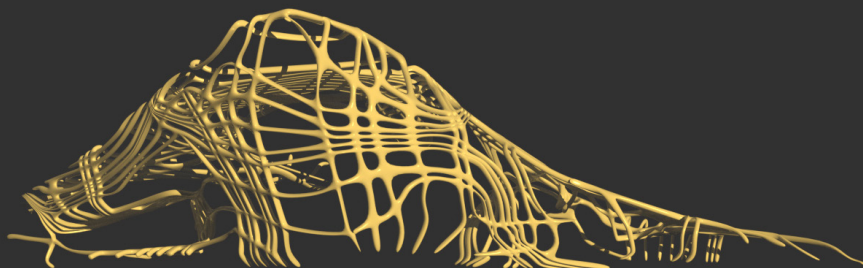
[In-Flow]- P3-5 Design Progression



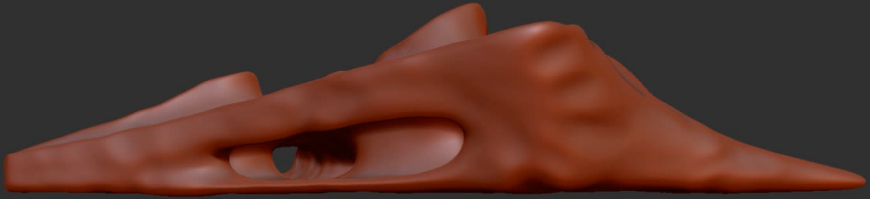
Another place where yogis are often found are caves which exhibit a powerful natural fractal pattern as seen on the elevation and roof here.



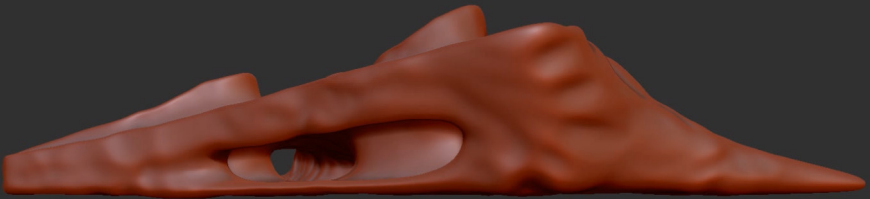
To induce the banyan roots type pattern, the principle stress lines were taken as base reference to add more materials there to make the building structurally sound and at the same time to project the pattern.



Principle stress lines - fragment part

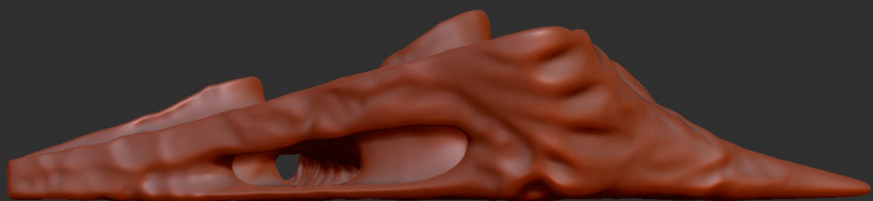


iteration_01

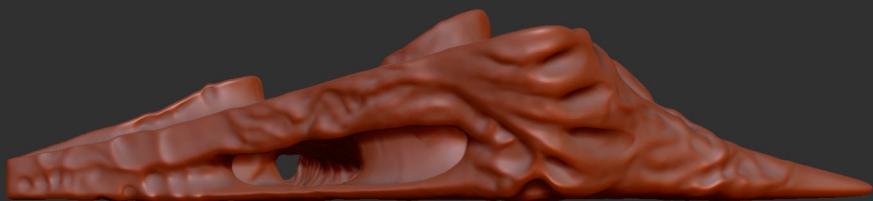


iteration_02

[In-Flow]- P3-5 Design Progression

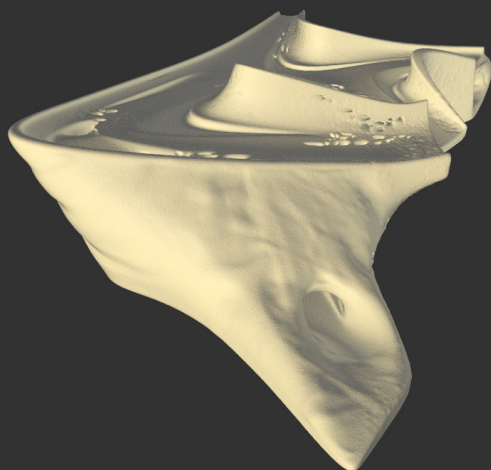
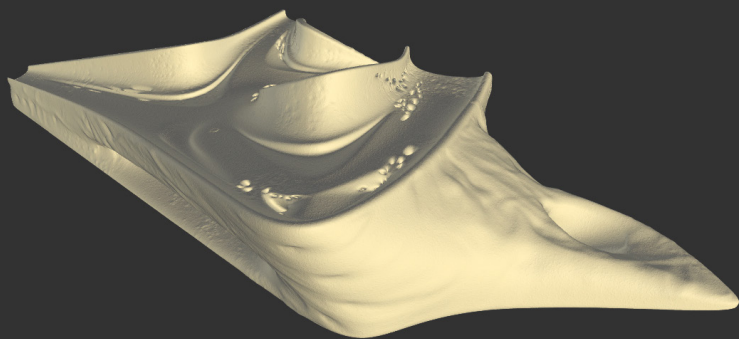


iteration_03

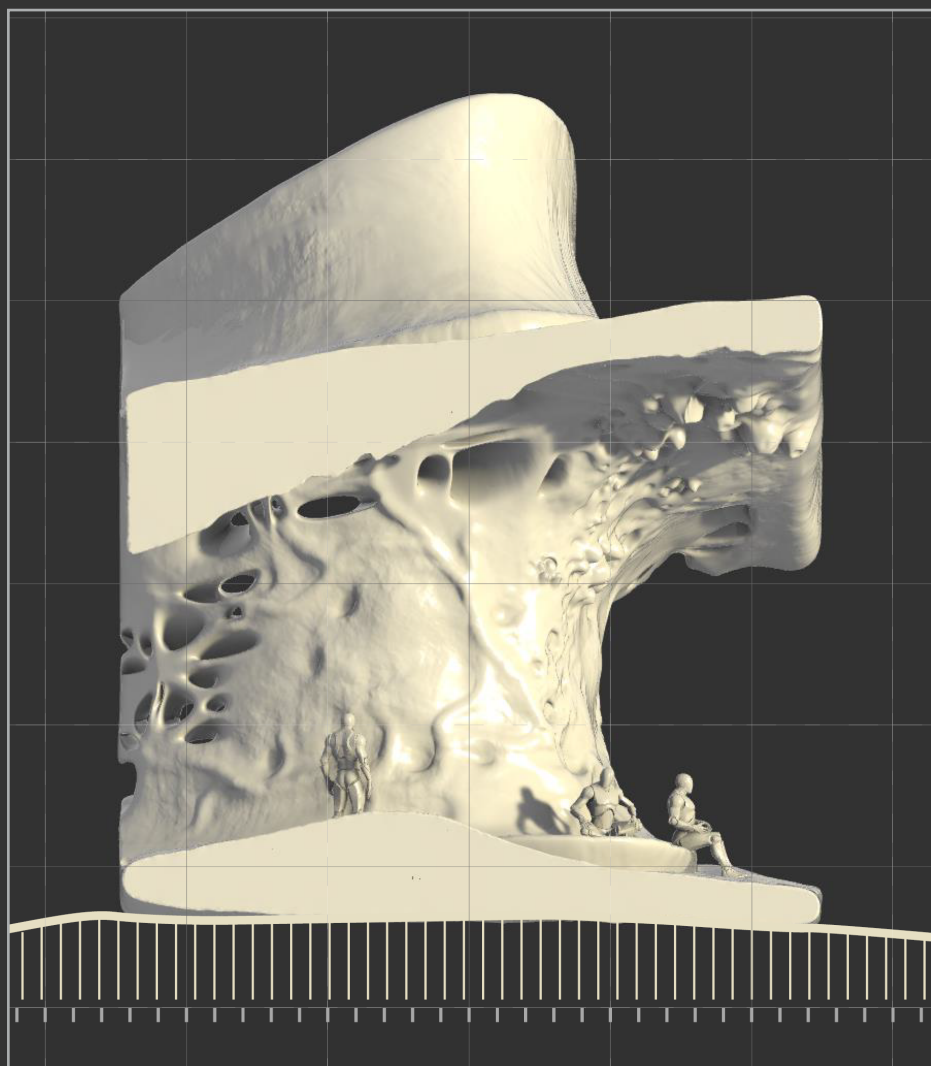


iteration_04

Variation of material removal from part were it is not needed.



[In-Flow]- P3-5 Design Progression



Variation of material removal from part were it is not needed.



[In-Flow]- P3-5 Design Progression



To induce more detailed pattern the Indian temple pattern is research upon to understand the origins behind the complex geometry.



[In-Flow]- P3-5 Design Progression



One contemporary reference to induce such details can be seen in the work of Michael Hansmeyer. The above image is that of his work - Digital Grotto.



Lower ground plan



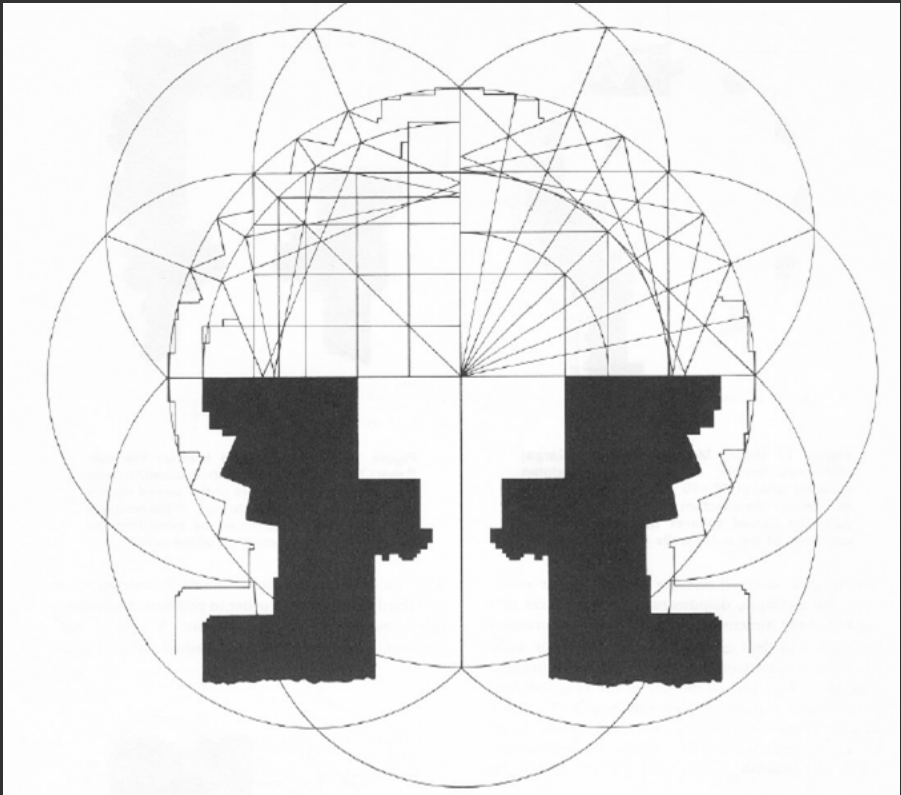
Pattern detail



[In-Flow]- P3-5 Design Progression



The wall is composed of bricks stacked on top of each other.



The Indian temple planing system follows a simple iterative process where the geometry starts with a line, forming an angle, evolving a triangle, then a square & distinctly a circle and so on ultimately deriving complex shapes.

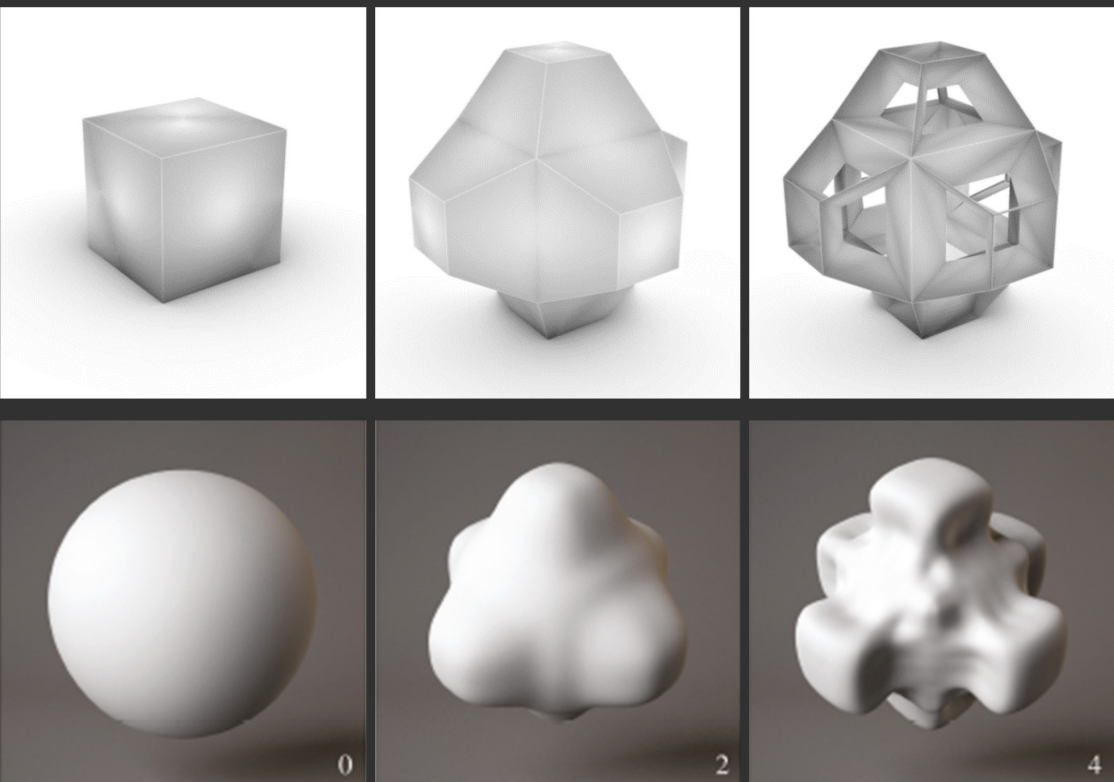


TEMPLE FORM GENERATION

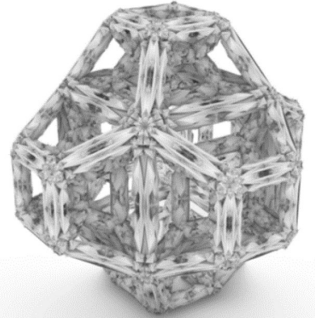
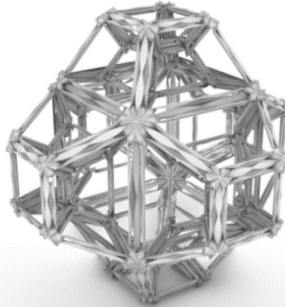
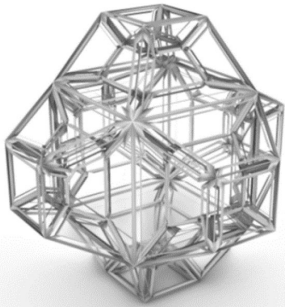
All these progression and iteration have some specific behavioural attributes of action.

[Projection, Staggering, Splitting,
Progressive Multiplication & Expanding Repetition]

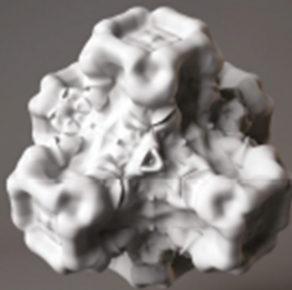
In the above image again we see progression and iteration having certain simple rules. In the above case the shape rules are projection, staggering, splitting, progressive multiplication, expanding repetition.



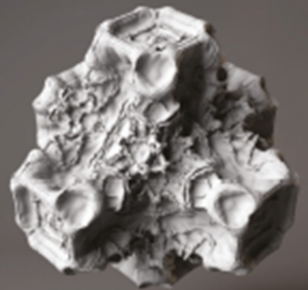
Michael Hansmeyer's Subdivision algorithm has similar approach to the temple geometry generation.



6

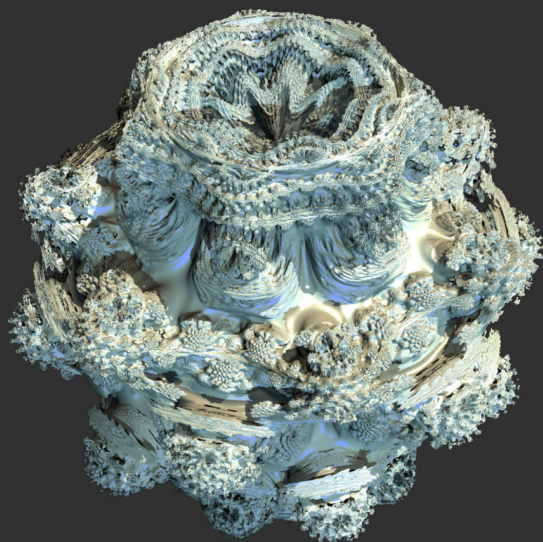


8



10

The algorithm divides a square area into four small areas, which are divided again until the corners for the naked eye to be recognized as a concave or convex shape, whereas, in fact, be quite small polygons.



MANDELBULB FORMULA

The Mandelbulb is a three-dimensional fractal, constructed by Daniel White and Paul Nylander using spherical coordinates in 2009

[iteration] [10]

[n] [2.4]

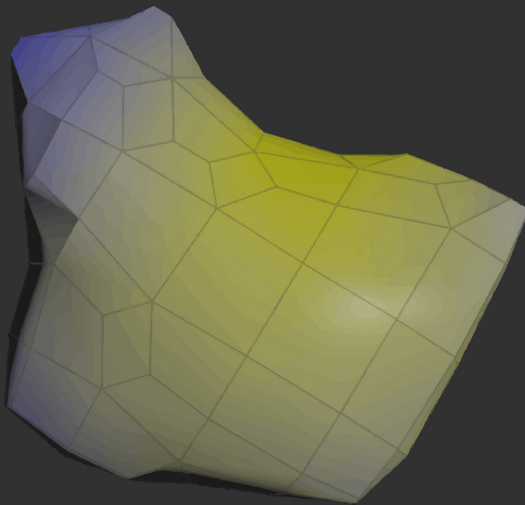
[resolution] [1]

[formula] [x]

[parameter]

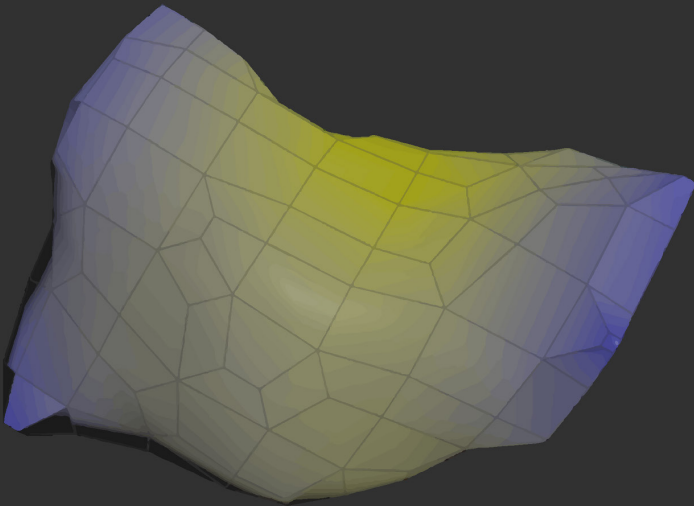
[“Apply scale+add”; if it is 1, the values of the Scale, Z add, Y add, and X add parameters are applied to the point when computing successive iterations. This results in the shape being repeated at different sizes and locations.]

[next apply transformational parameters like folding, projecting, vary scale etc.]



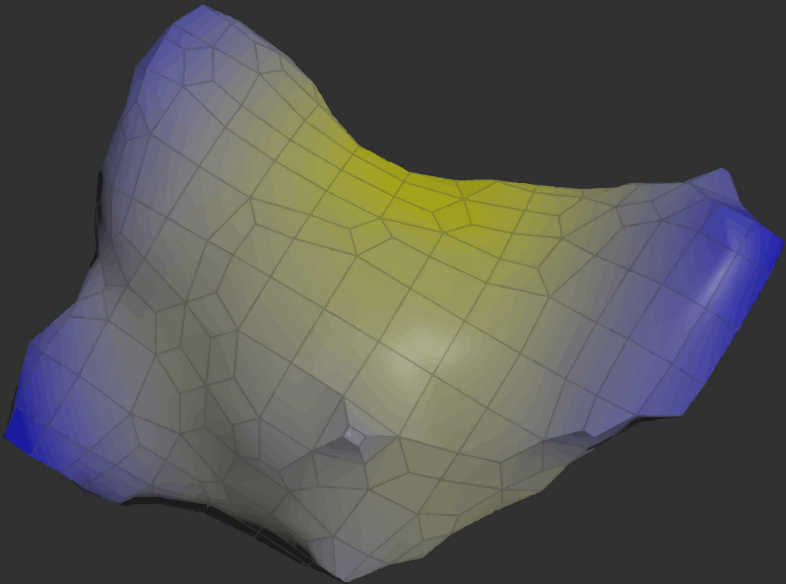
To work on a pattern, the mandelbulb geometry was taken as a base geometry. The base formula was tweaked to mimic the shape rules of the Indian geometry pattern. The pattern was induced on a small fraction of the main building.

[iteration]	[10]
[n]	[2.4]
[resolution]	[12]
[formula]	[x]



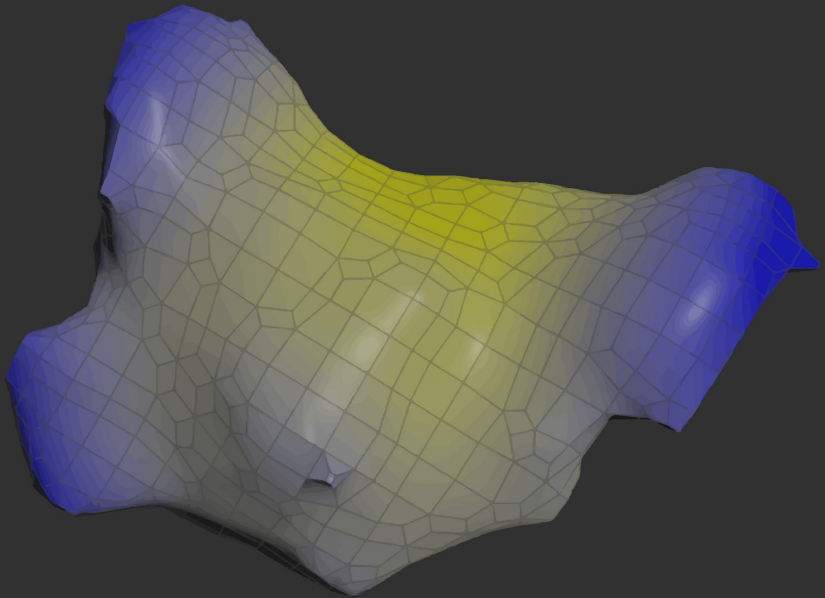
Michael Hansmeyer's Subdivision algorithm

[iteration]	[10]
[n]	[2.4]
[resolution]	[18]
[formula]	[x]



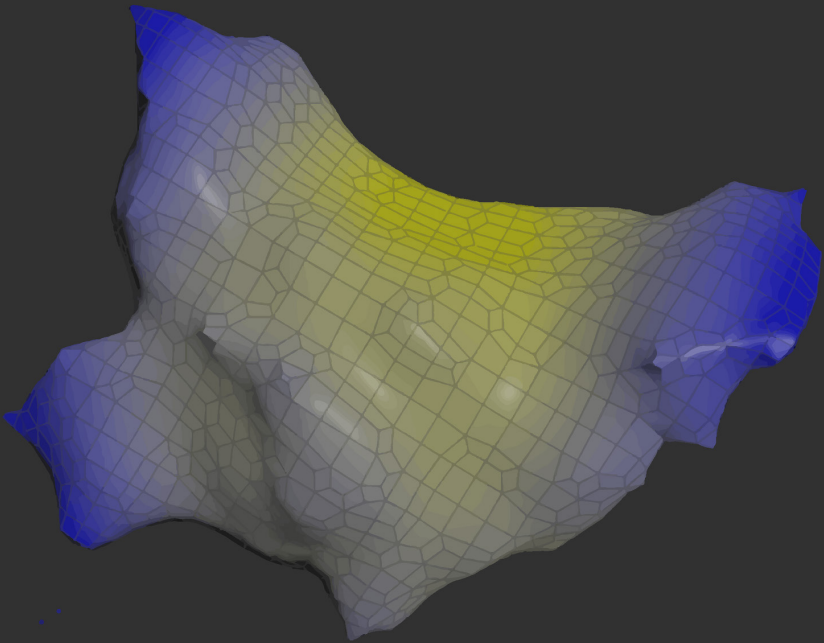
As the pattern iteration goes up it adds more complexity to the geometry.

[iteration]	[10]
[n]	[2.4]
[resolution]	[26]
[formula]	[x]



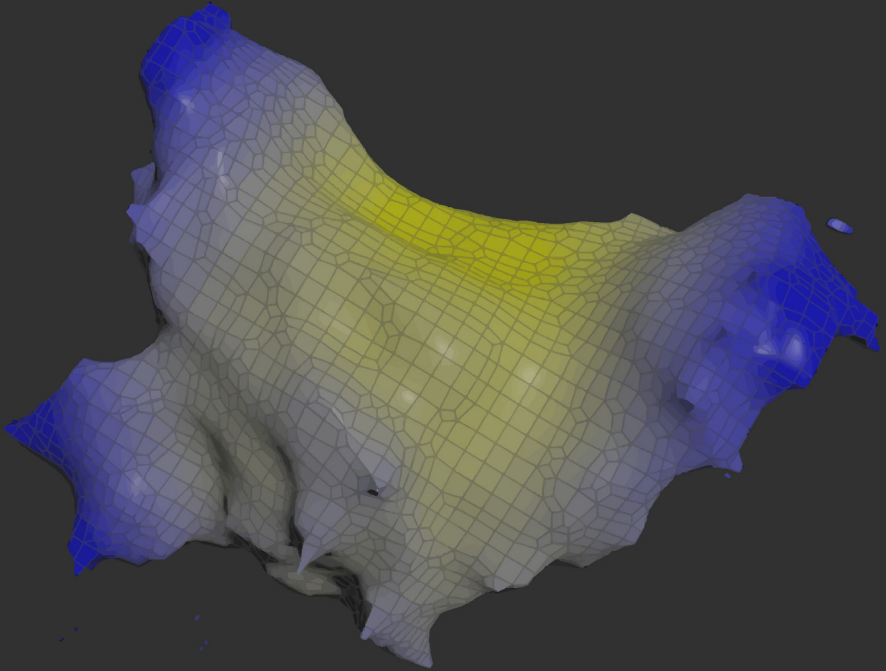
Michael Hansmeyer's Subdivision algorithm

[iteration]	[10]
[n]	[2.4]
[resolution]	[35]
[formula]	[x]



Pattern iterations

[iteration]	[10]
[n]	[2.4]
[resolution]	[50]
[formula]	[x]



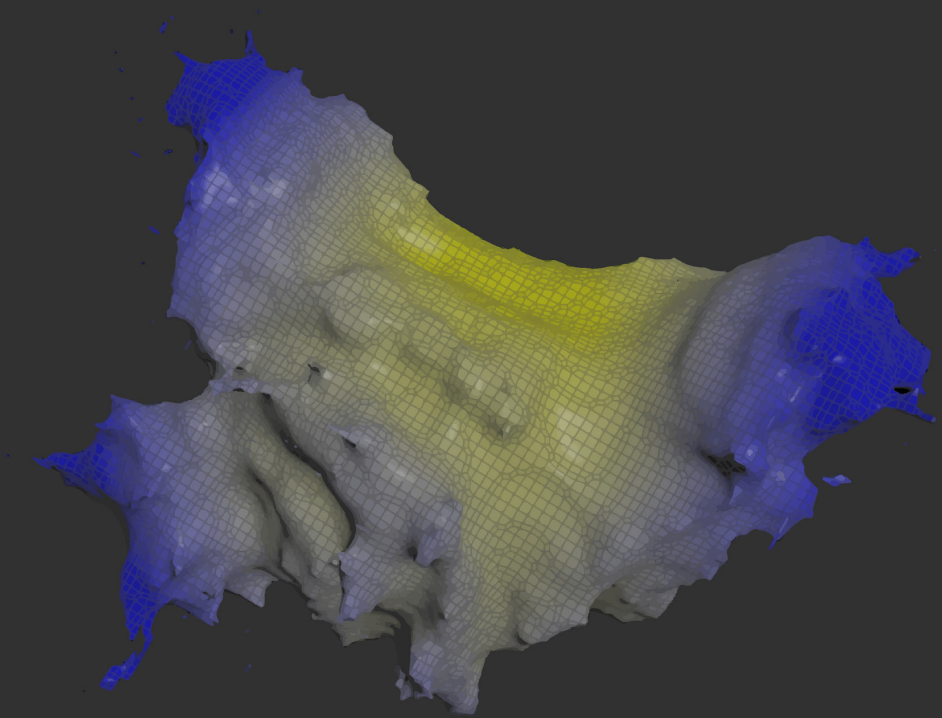
Michael Hansmeyer's Subdivision algorithm

[iteration] [10]

[n] [2.4]

[resolution] [100]

[formula] [x]



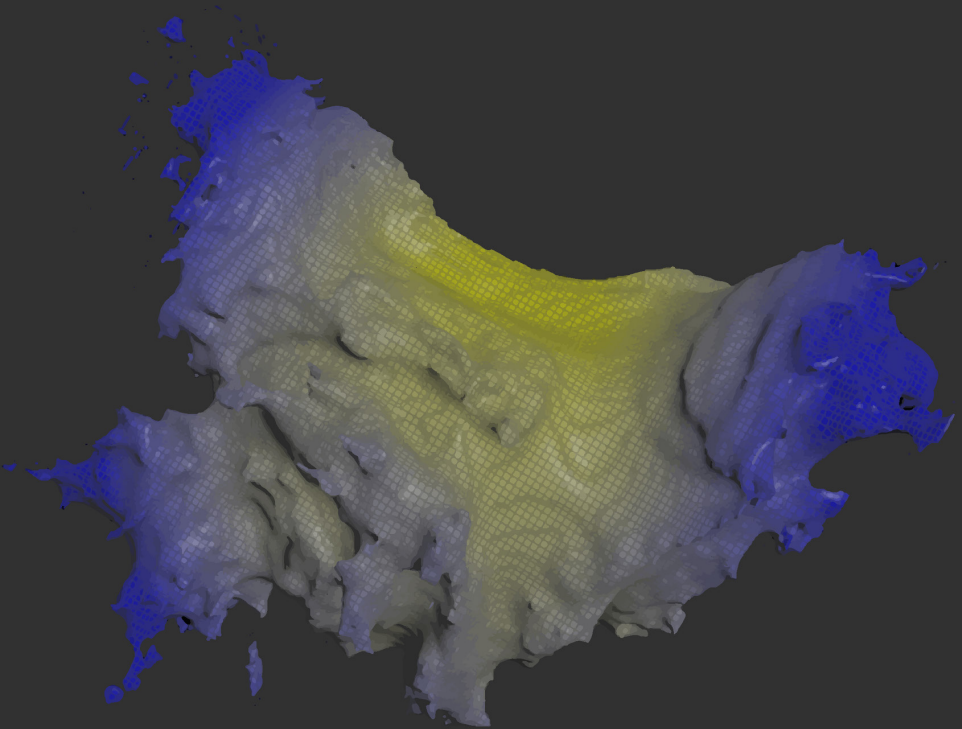
Pattern iterations

[iteration] [10]

[n] [2.4]

[resolution] [150]

[formula] [x]



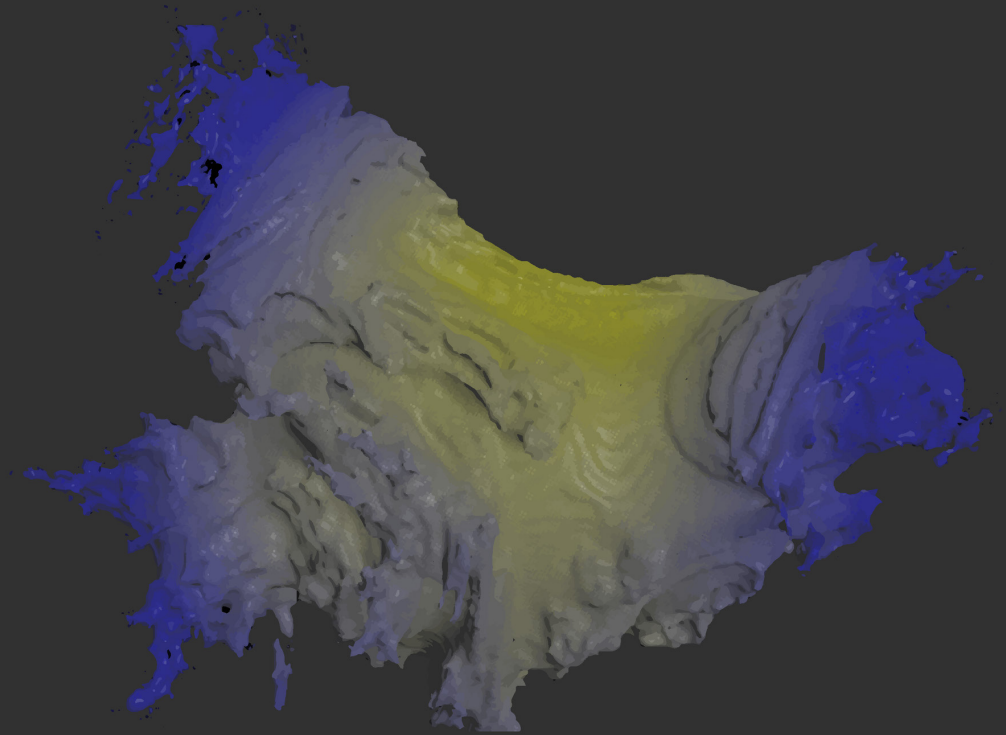
Michael Hansmeyer's Subdivision algorithm

[iteration] [10]

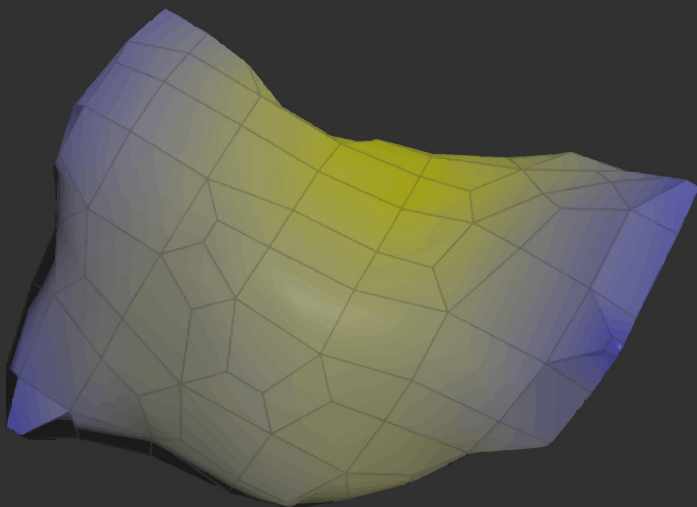
[n] [2.4]

[resolution] [300]

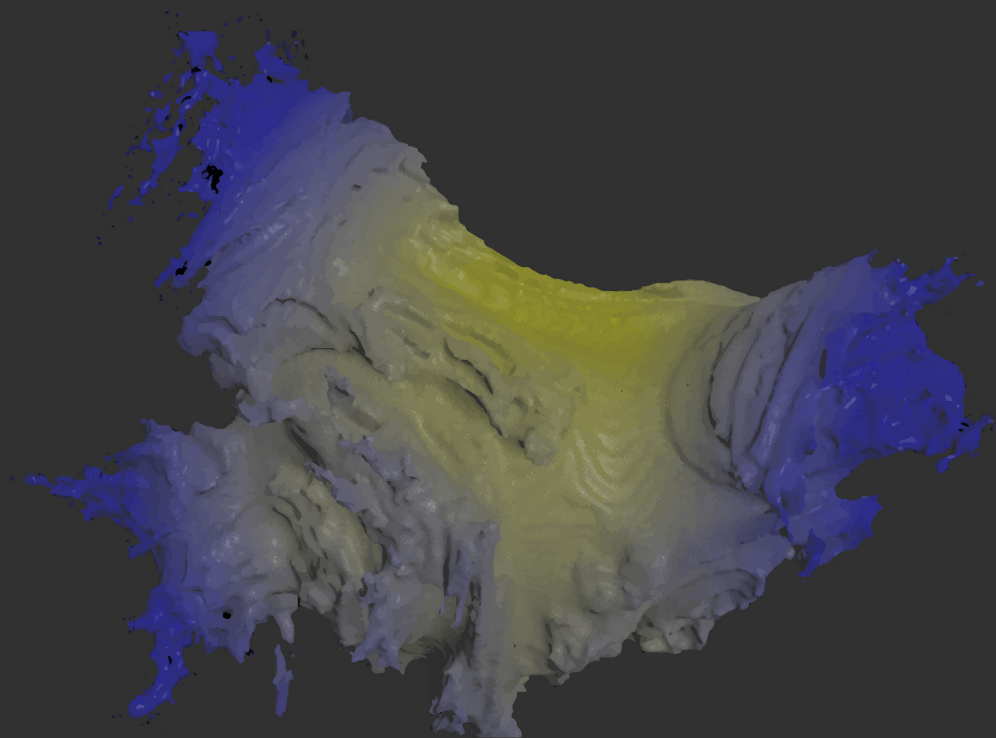
[formula] [x]



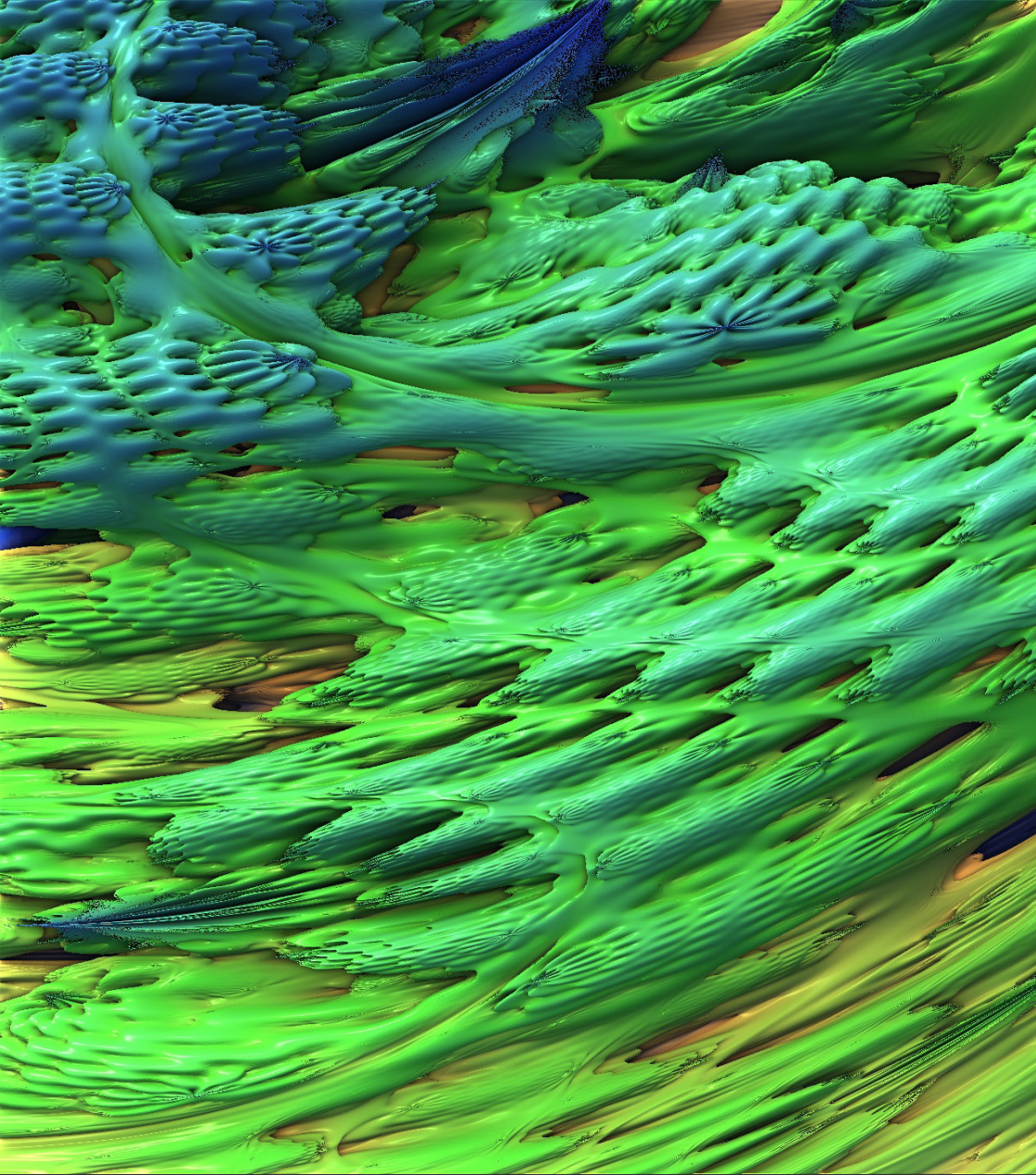
Pattern iterations



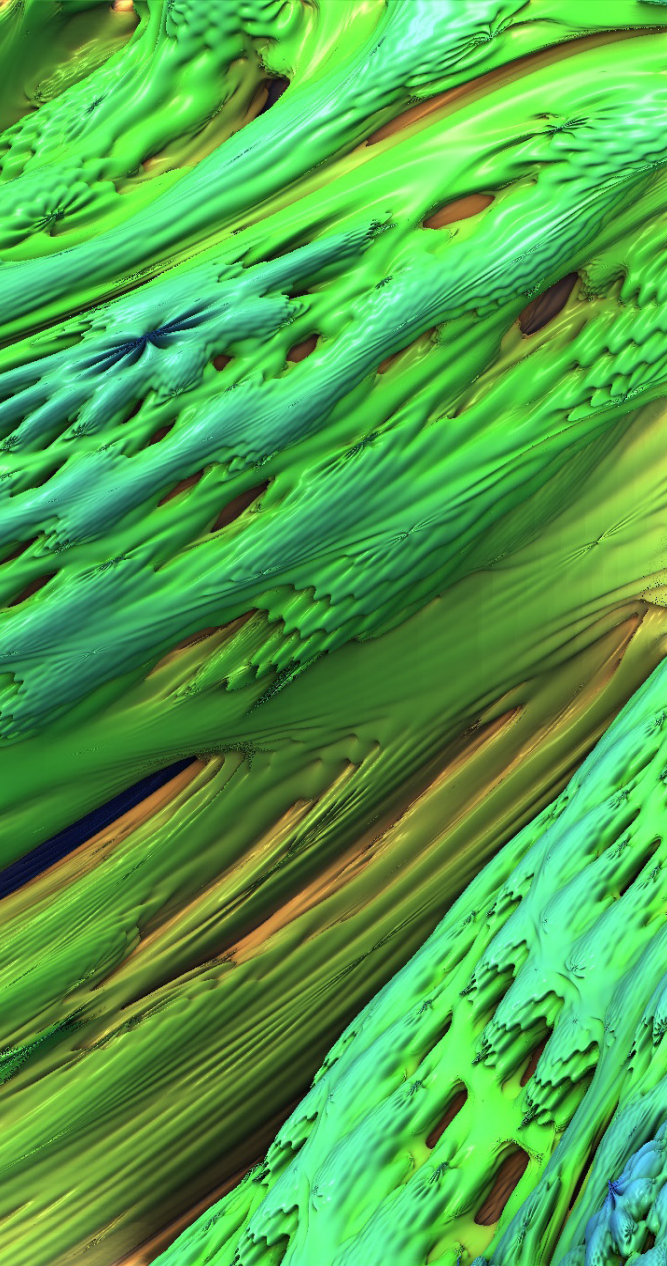
Michael Hansmeyer's Subdivision algorithm



Final difference between base geometry to detailed geometry



[In-Flow]- P3-5 Design Progression



Formula1 • Fo.2 • Fo.3 • Fo.4 • Fo.5 • Fo.6
3D 3D 3Da 4D 4Da Ads Ads Ads dIFS dIFS dIFS

_RotatedFolding i hidden JIT

Fold rotation X 0
Fold rotation Y -10.875
Fold rotation Z 0
Fold of x 1.4

Alternate Interpolate DEcombine Reset
Formula1 • Fo.2 • Fo.3 • Fo.4 • Fo.5 • Fo.6
3D 3D 3Da 4D 4Da Ads Ads Ads dIFS dIFS dIFS

_Rotate i hidden JIT

Rotation1 X 11.625
Rotation1 Y 45.75
Rotation1 Z 0

Alternate Interpolate DEcombine Reset
Formula1 • Fo.2 • Fo.3 • Fo.4 • Fo.5 • Fo.6
3D 3D 3Da 4D 4Da Ads Ads Ads dIFS dIFS dIFS

_Scaling i hidden JIT

Scale 1.2

Alternate Interpolate DEcombine Reset
Formula1 • Fo.2 • Fo.3 • Fo.4 • Fo.5 • Fo.6
3D 3D 3Da 4D 4Da Ads Ads Ads dIFS dIFS dIFS

_addC i hidden JIT

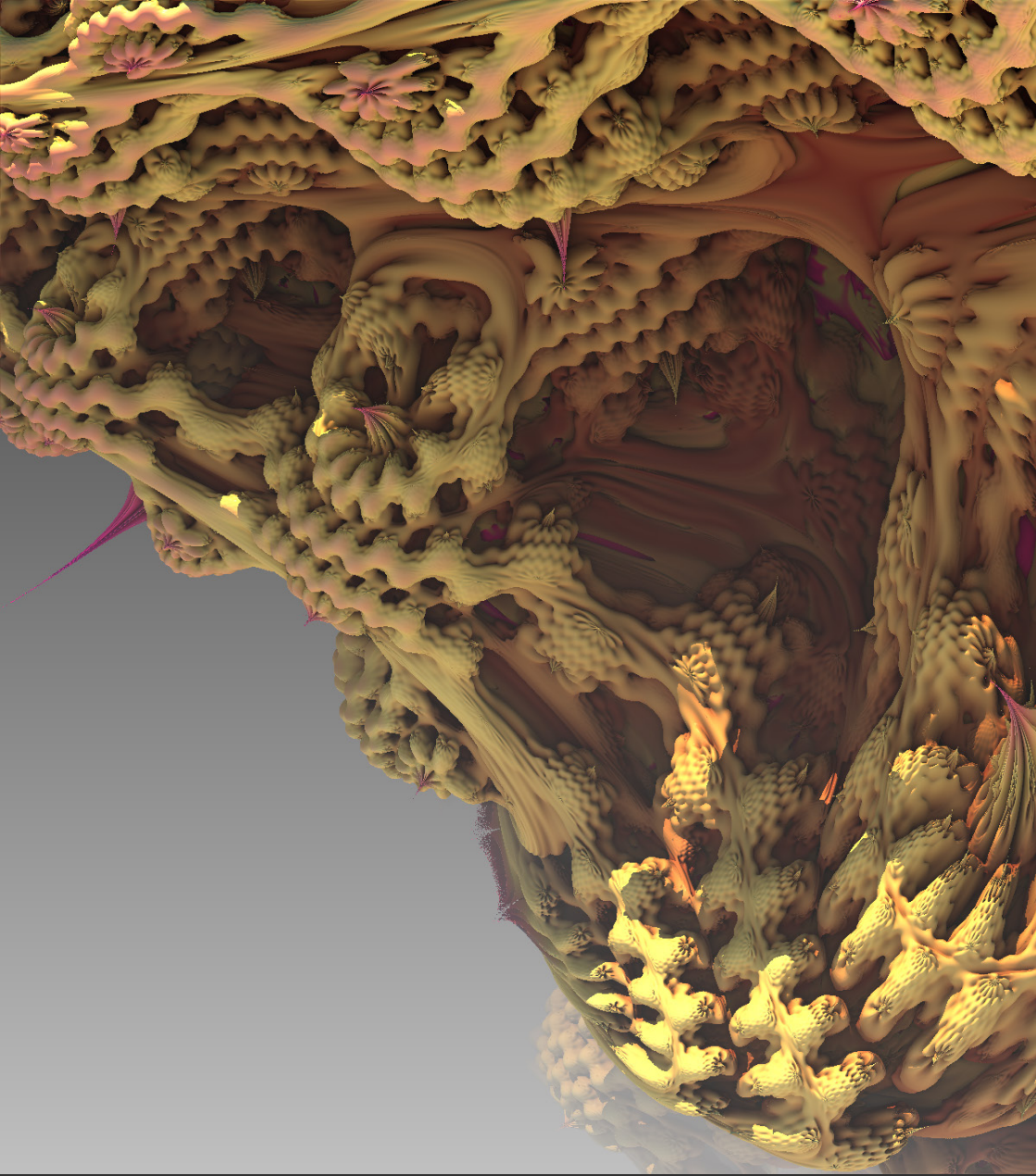
Cx multiplier 1
Cy multiplier 1
Cz multiplier 1

Alternate Interpolate DEcombine Reset
Formula1 • Fo.2 • Fo.3 • Fo.4 • Fo.5 • Fo.6
3D 3D 3Da 4D 4Da Ads Ads Ads dIFS dIFS dIFS

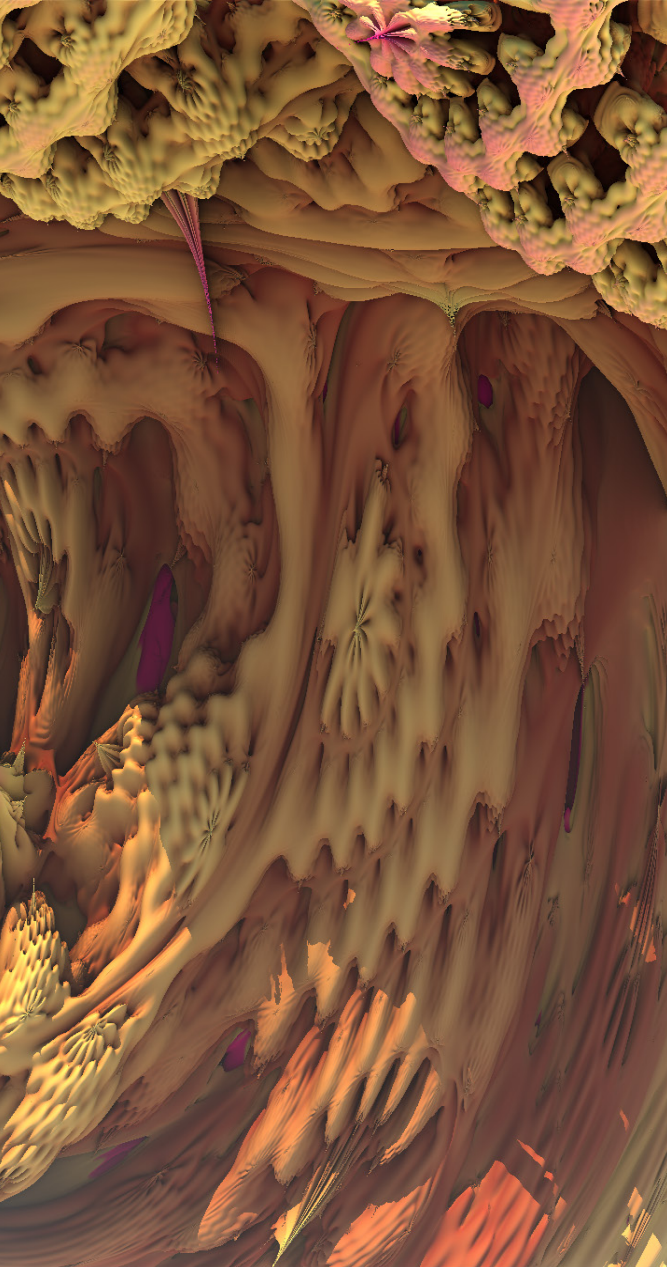
_RotatedAbs i hidden JIT

Fold rotation X 0
Fold rotation Y 0
Fold rotation Z 0
AddX 0
SubX 0

The mandelbulb formula was worked on extensively to extract more patterns.



[In-Flow]- P3-5 Design Progression



Formula1 • Fo.2 • Fo.3 • Fo.4 • Fo.5 • Fo.6

3D 3D 3Da 4D 4Da Ads Ads Ads dIFS dIFS dIFS

_RotatedFolding i hidden JIT

Fold rotation X 0

Fold rotation Y -10.875

Fold rotation Z 0

Fold of x 1.4

Alternate Interpolate DEcombine Reset

Formula1 • Fo.2 • Fo.3 • Fo.4 • Fo.5 • Fo.6

3D 3D 3Da 4D 4Da Ads Ads Ads dIFS dIFS dIFS

_Rotate i hidden JIT

Rotation1 X 11.625

Rotation1 Y 45.75

Rotation1 Z 0

Alternate Interpolate DEcombine Reset

Formula1 • Fo.2 • Fo.3 • Fo.4 • Fo.5 • Fo.6

3D 3D 3Da 4D 4Da Ads Ads Ads dIFS dIFS dIFS

_Scaling i hidden JIT

Scale 1.2

Alternate Interpolate DEcombine Reset

Formula1 • Fo.2 • Fo.3 • Fo.4 • Fo.5 • Fo.6

3D 3D 3Da 4D 4Da Ads Ads Ads dIFS dIFS dIFS

_addC i hidden JIT

Cx multiplier 1

Cy multiplier 1

Cz multiplier 1

Alternate Interpolate DEcombine Reset

Formula1 • Fo.2 • Fo.3 • Fo.4 • Fo.5 • Fo.6

3D 3D 3Da 4D 4Da Ads Ads Ads dIFS dIFS dIFS

_RotatedAbs i hidden JIT

Fold rotation X 0

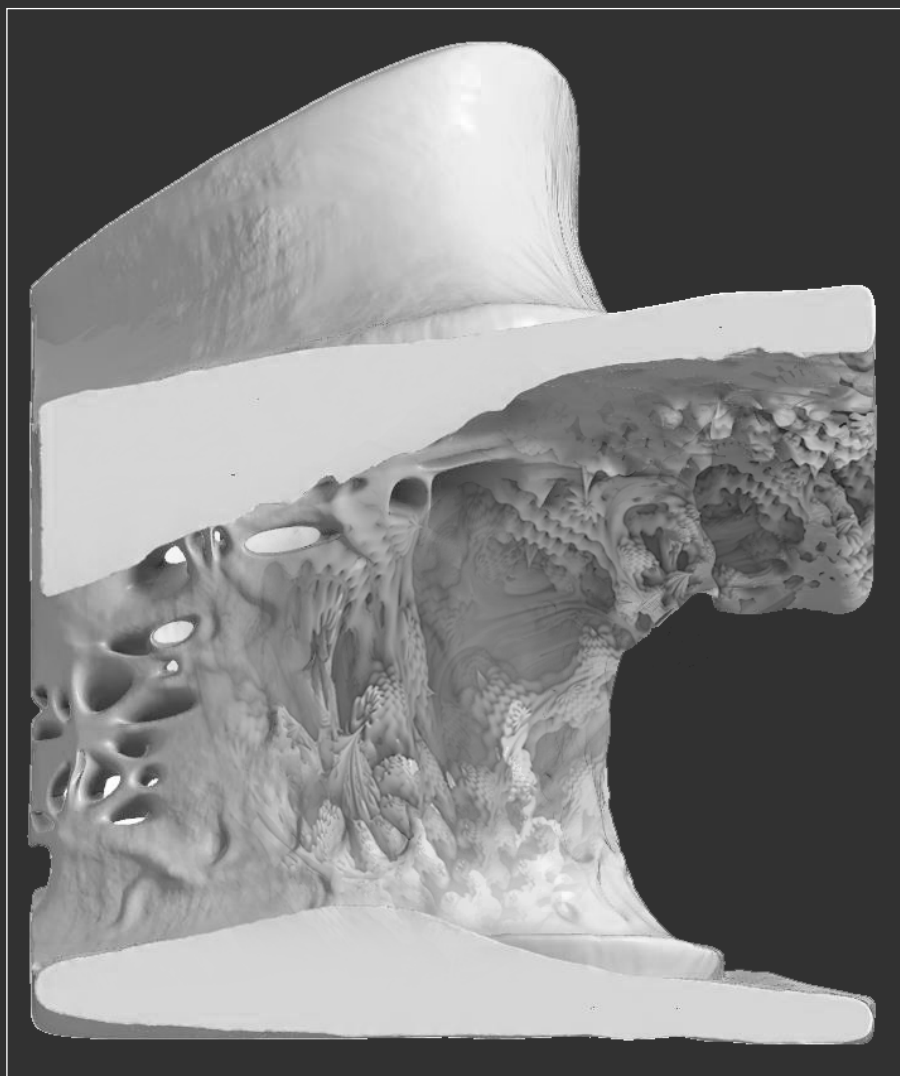
Fold rotation Y 0

Fold rotation Z 0

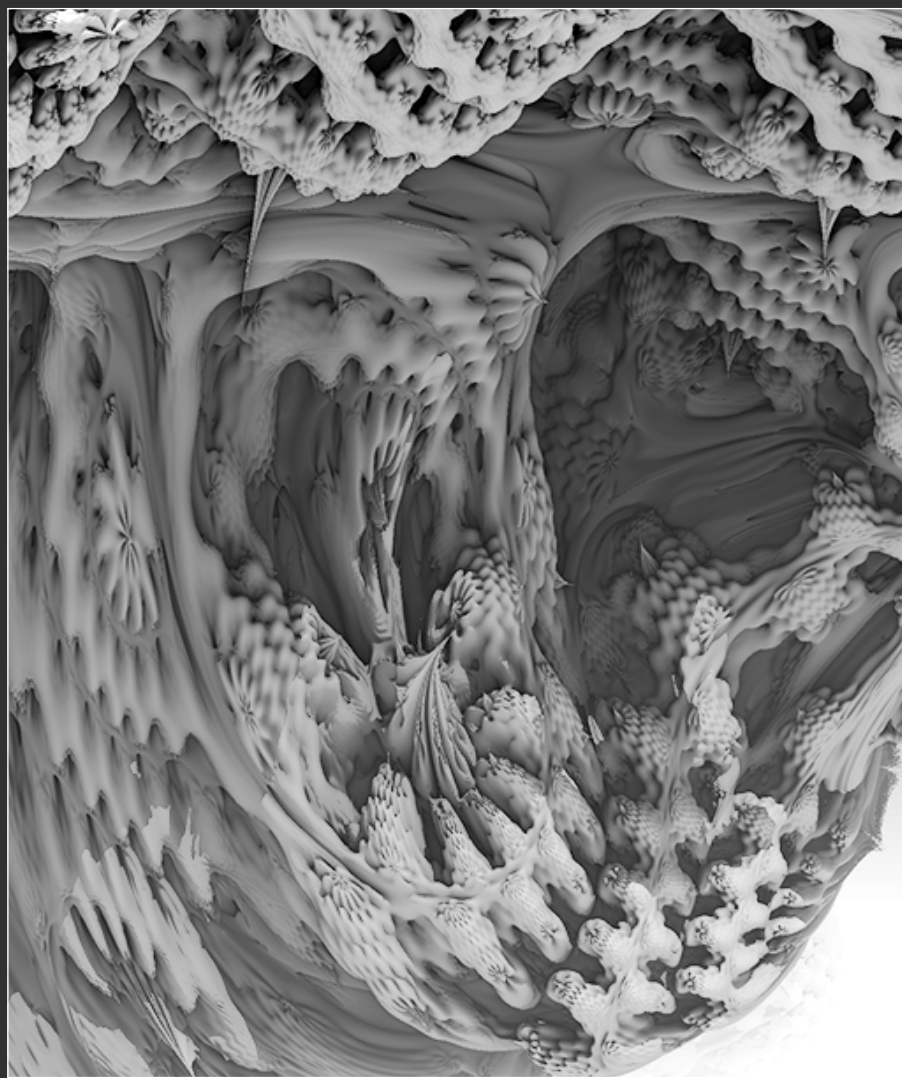
AddX 0

SubX 0

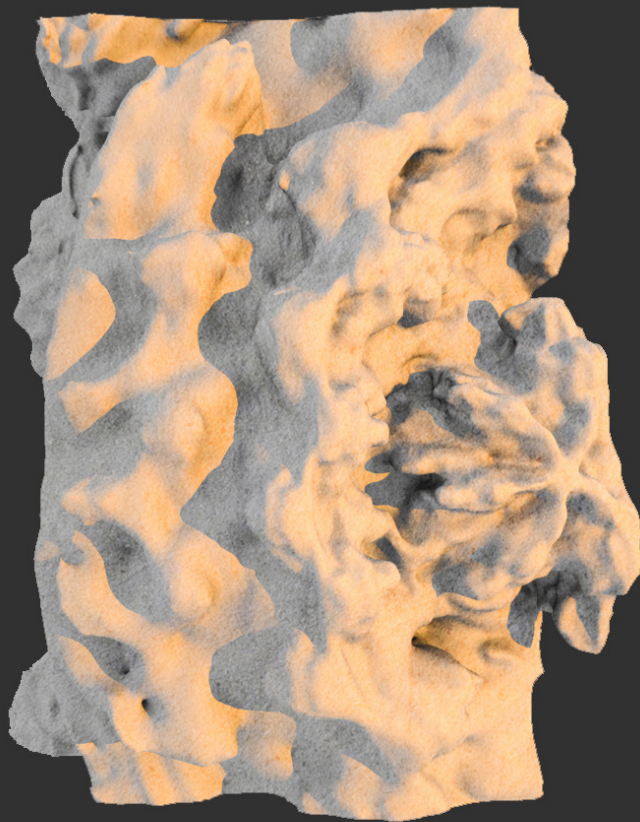
The mandelbulb formula was worked on extensively to extract more patterns.



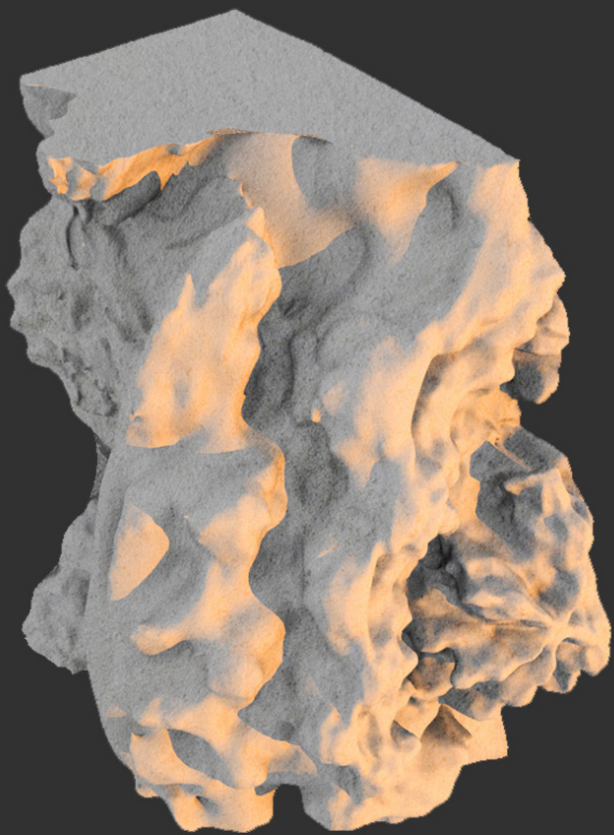
Interior view with the pattern embedded on walls and ceilings.



Selected pattern



[In-Flow]- P3-5 Design Progression



Final 1:1 detail of a bulb in the pattern



Building Technology

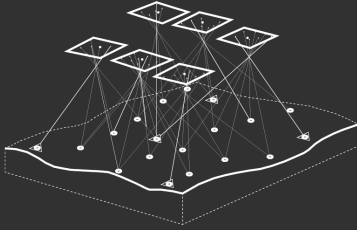
MACRO-[D2RP]

Urban intervention - Drone Photogrammetry Mapping

UAV platforms are nowadays a valuable source of data for inspection, surveillance, mapping and 3D modeling issues. New applications in the short- and close-range domain are introduced, being the UAVs a low-cost alternatives to the classical manned aerial photogrammetry. Rotary or fixed wing UAVs, capable of performing the photogrammetric data acquisition with amateur or SLR digital cameras, can fly in manual, semi-automated and autonomous modes. With a typical photogrammetric pipeline, 3D results like DSM/DTM, contour lines, textured 3D models, vector data, etc. can be produced, in a reasonable automated way. Automation is nowadays necessary and feasible at the image orientation, DSM generation and orthophoto production stages, while accurate feature extraction is still an interactive procedure. Once a set of images has been oriented, the following steps in the 3D reconstruction and modeling process are surface measurement and feature extraction.

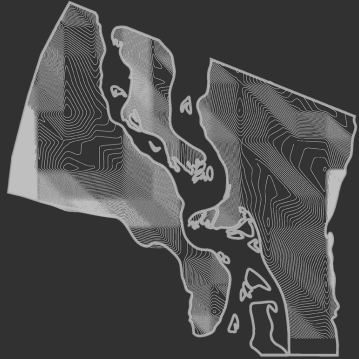
Starting from the known exterior orientation and camera calibration parameters, a scene can be digitally reconstructed by means of automated dense image matching techniques or interactive methods for man made features and vector information extraction. Interactive approaches deliver sparse point clouds which need structuring and editing in order to create accurate 3D data. Automated methods produce a dense point cloud describing the surface of the surveyed scene (DSM), which has to be interpolated, maybe simplified and finally textured for photo-realistic visualization. A powerful image matching algorithm should be able to extract dense 3D point clouds with a sufficient resolution to describe the object's surface and its discontinuities. This data is then used to create detailed designs for landscape and urban planning via CAD software which is then fed to another robotic pipeline for further robotic manipulation of the landscape/site terrain.

[A]



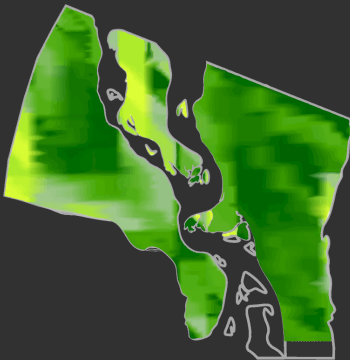
[Drone 3D aerial photogrammetry]

[B]



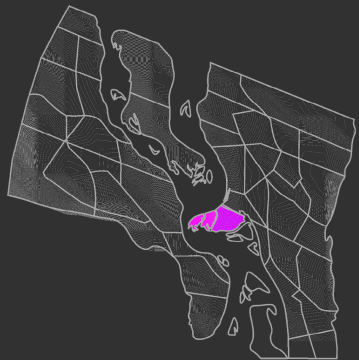
[Digital Terrain Model]

[C]



[Digital Terrain Model]

[D]



[Upload Design Mesh- Cloud Points]

[a]- Drone maps the terrain which extracts vector information in form of point cloud data which is converted to contour model [b] and height maps [c]. The final urban strategy uses this data and creates a digital link for further robotic fabrication steps.

MACRO-[D2RP]

Urban intervention - Robotic Landscape

The technological advances in robotic construction equipment for large scale earth moving is revolutionizing how we think and act on terrain. With the development of HEAP, a full scale autonomous walking excavator by the Robotic Systems Lab of Professor Marco Hutter within the NCCR Digital Fabrication ETH Zurich, we can now shape large-scale natural granular material like sand, soil and gravel with unprecedented geometrical complexity according to a precise digital blueprint. The robotic platform enables feedback loops between the physical reality, the existing terrain and the proposed computational design, creating new potential for dynamic landscapes that can change over time. The ability to search, recognize and manipulate locally found materials allows us to rethink the design of the built environment to be economically and environmentally regenerative. This changes how landscapes or large-scale green infrastructures are formed and maintained

HEAP (hydraulic excavator for an autonomous purpose) is a customized Menzi Muck M545 developed for autonomous use cases. The machine has novel force-controllable hydraulic cylinders in the chassis that allow it to adapt to any terrain. The primary autonomous use case is robotic landscaping/autonomous excavation.

Until today, on-site robotic construction processes in landscape architecture have been limited to predefined and controlled environments like road building or mining pits. We are presently developing an autonomous walking excavator that paves the way for new and advanced on-site design strategies. The shift towards robotic construction in terrain modelling and landscape architecture demands an adaptive design approach, where the resulting topology is inherently linked to landscape performance and the local conditions of a site.

-Ilmar Hurkkens,

Christophe Girot & Marco Hutter

[A]



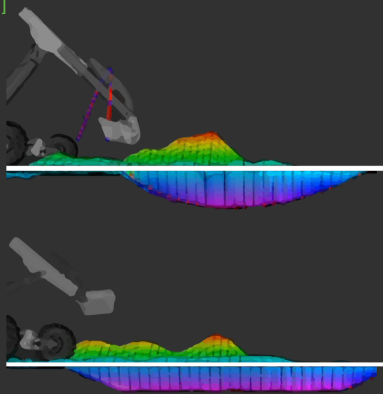
[Autonomous robots digging in sand]

[B]



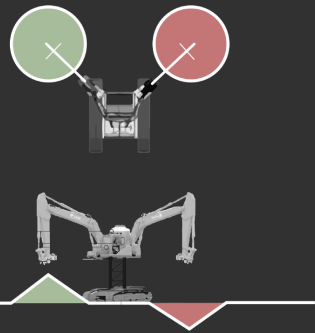
[HEAP-ETH Zurich, Prototype Autonomous Digger]

[C]



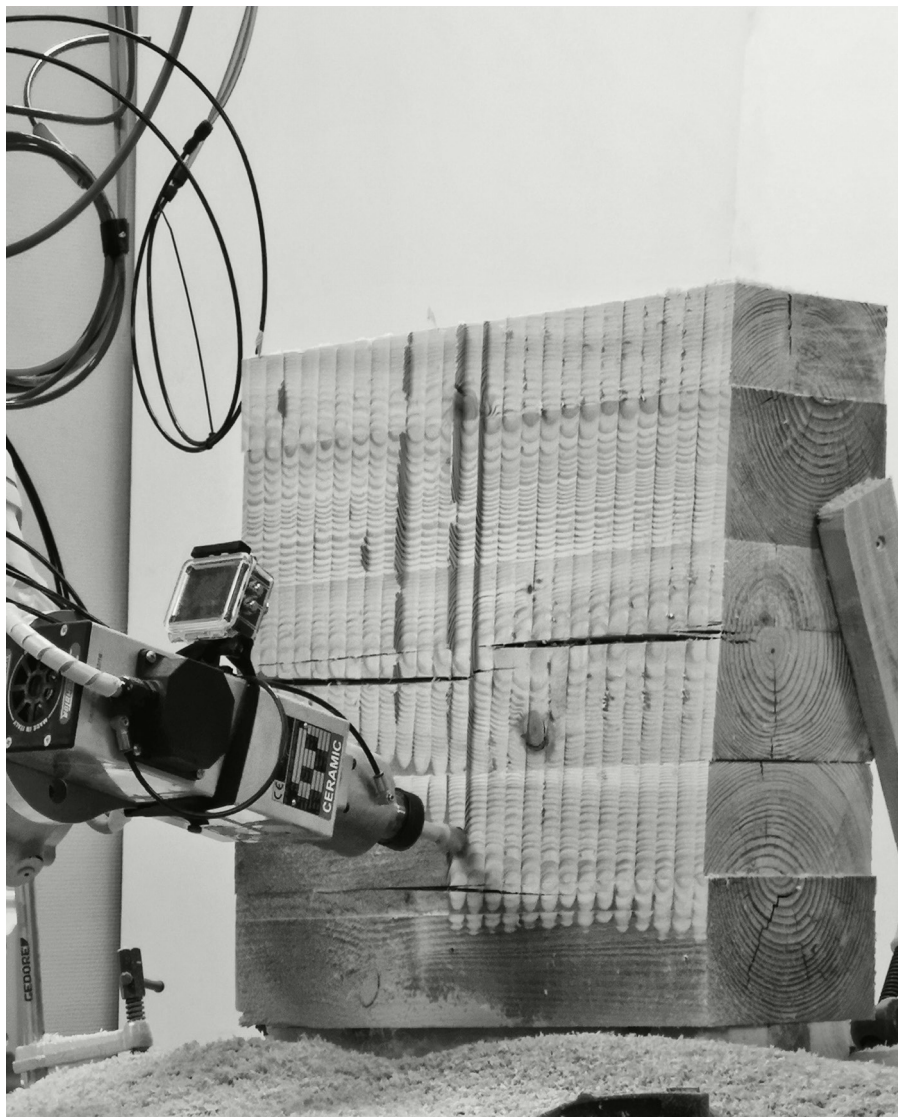
[Global & Local navigation]

[D]

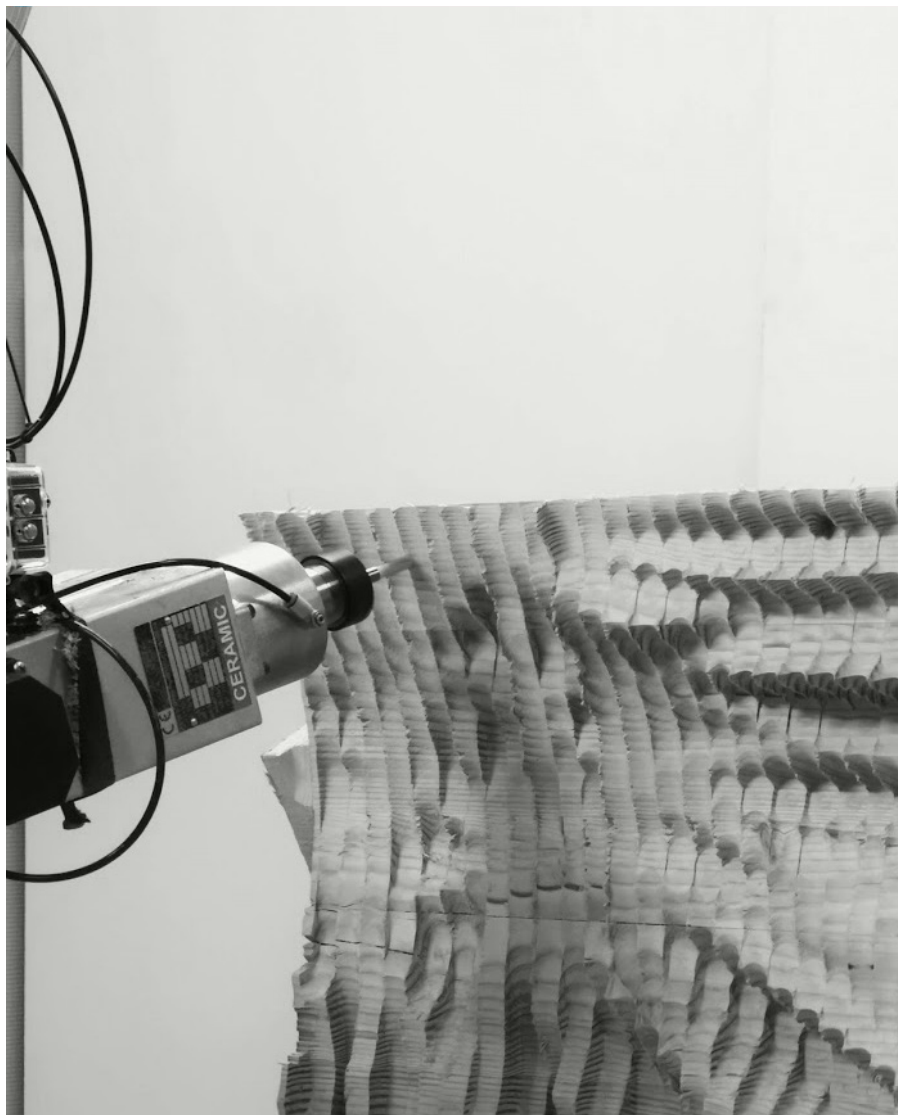


[Autonomous Robot digging according to cloud points]

Heap will be used in the project to replace conventional means of making roads and urban spaces on site. The robots will take the design inputs as data to mold roads and spaces via a process of digging, deposition and vacuum of materials.



To replicate the robotic movement on a surface experiments were done on wood to carve out different patterns resulting in voronoi contours.



*The code had to be changed to accommodate the limits of the robots movement
due to the size of the head.*



The fabrication constrains of HEAP, limit the topological freedom to the maximum freedom of movement given by the robotic excavator. In this case the excavator has a maximum excavation depth of 5.14 m and a maximum jib range of 8.21 m. These parameters needs to be kept in mind while performing deposition and extraction of materials



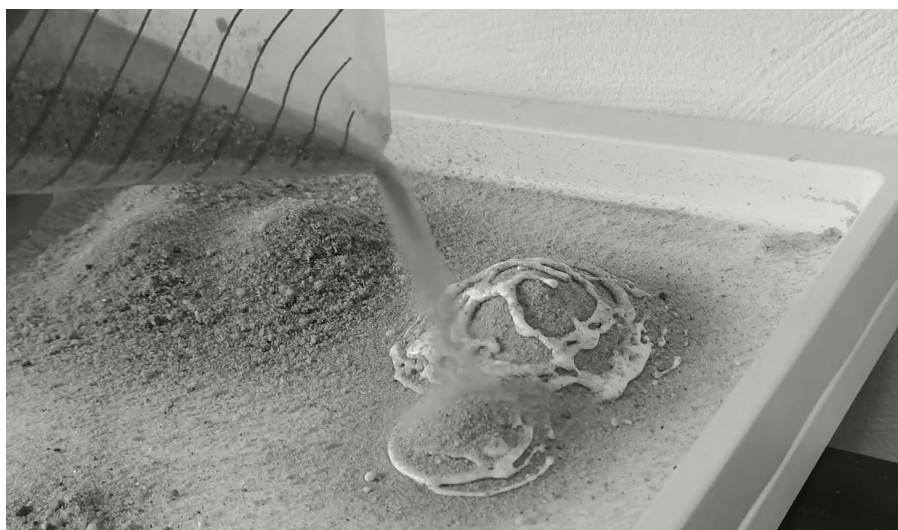
The same results were experienced with these experiments where the g code had to be changed based on different robot types. Hence its important to deduce which robots to work with at the start of the project as it effects the design pipeline.

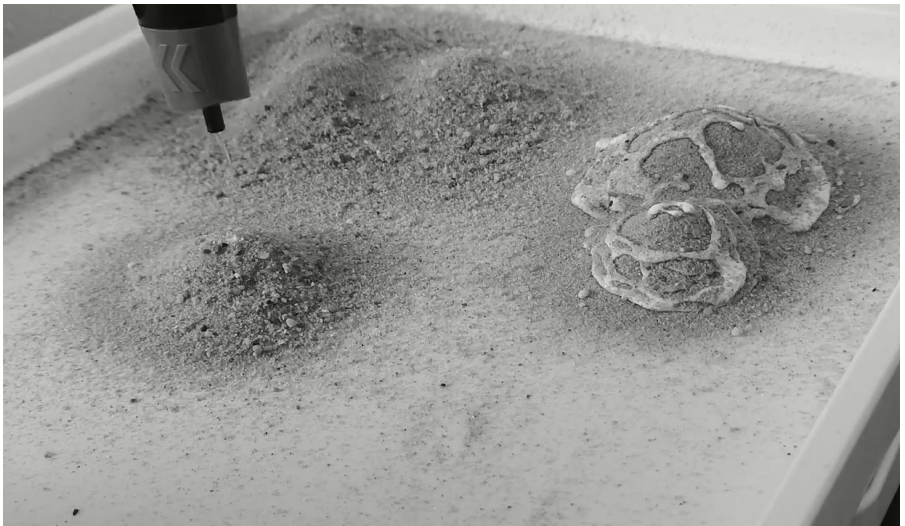
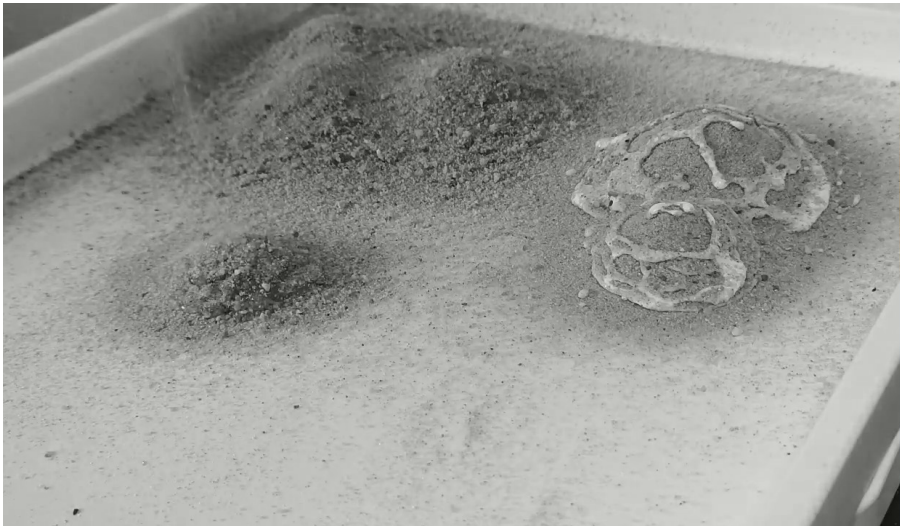


These experiments try to identify the material properties when it is deposited from a height. The binder reaction with the material is also recorded to see the effect on final patterns.

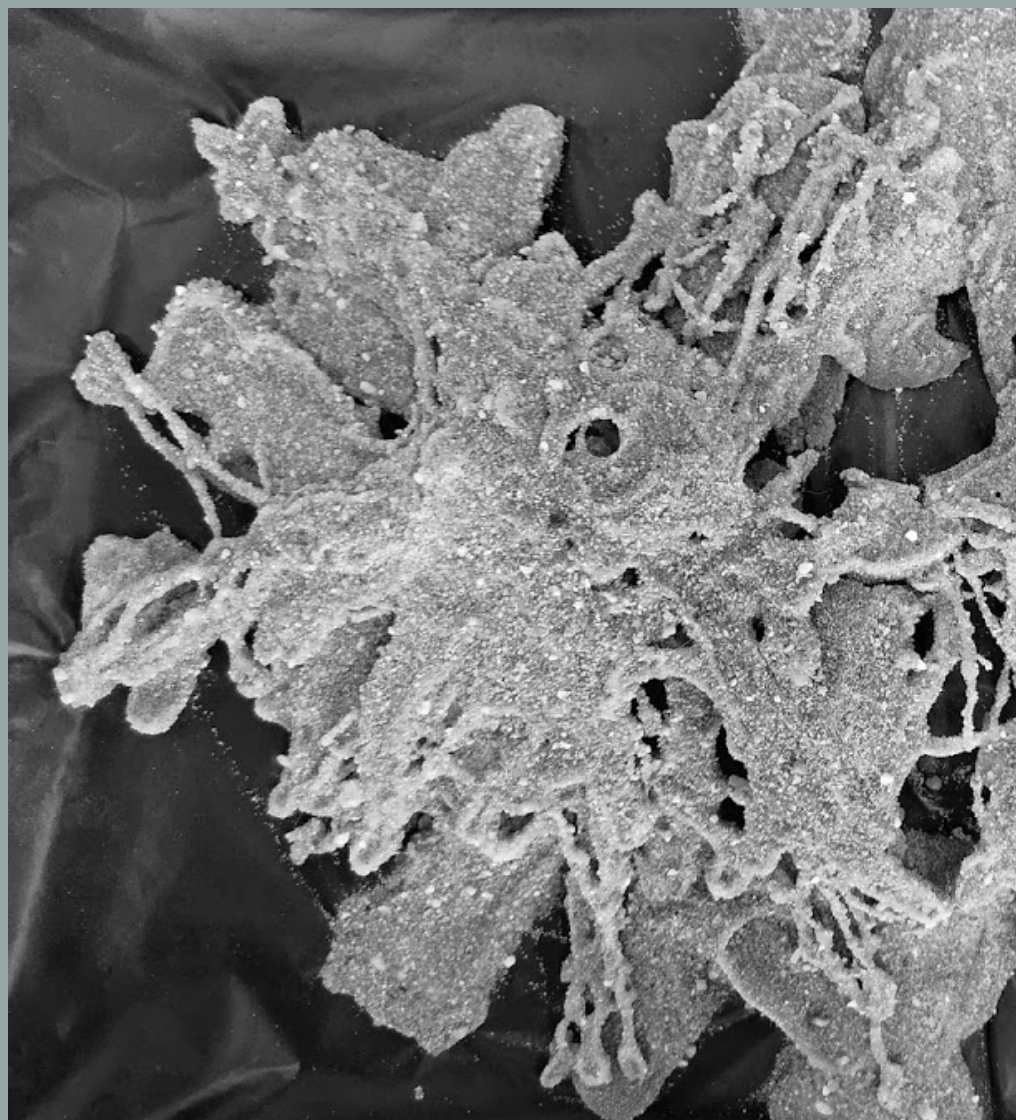


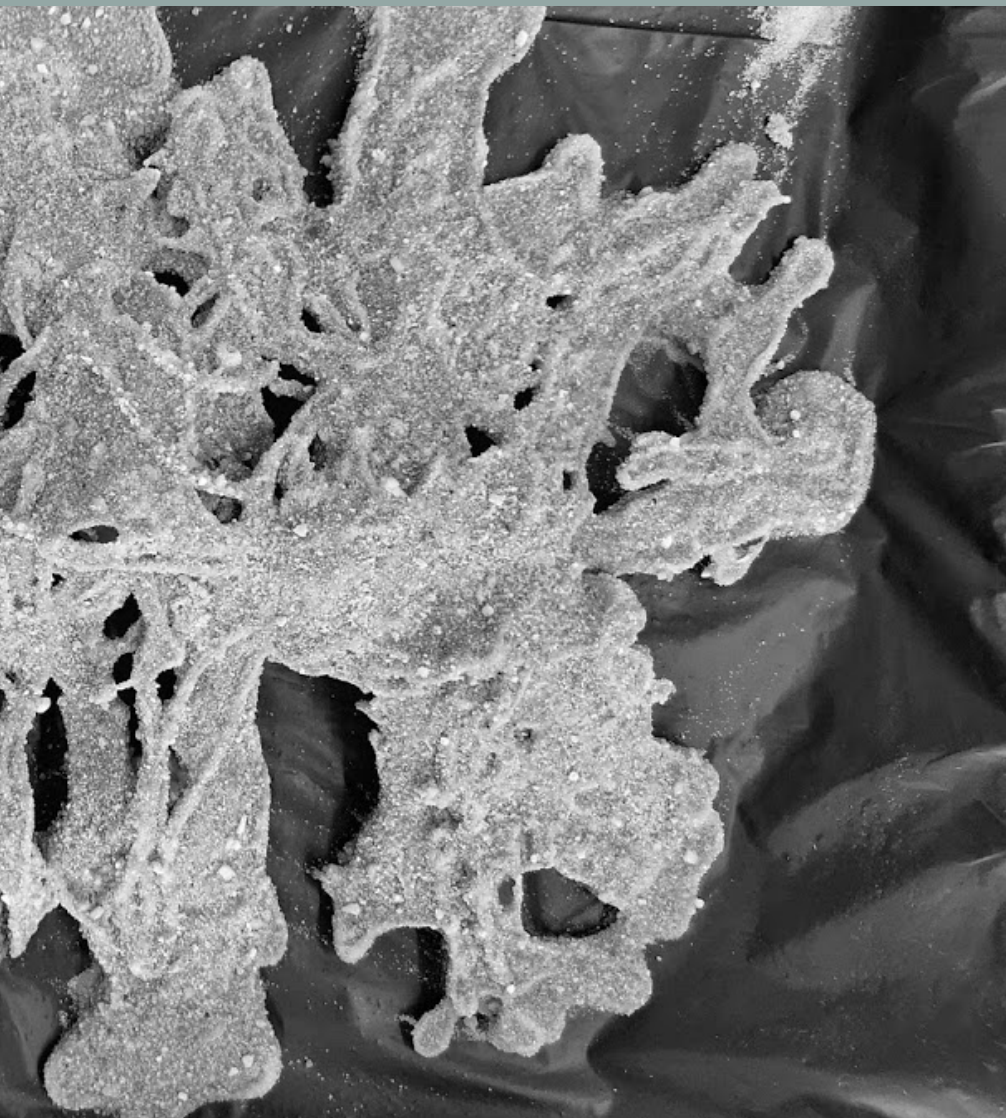
Material- Sand/ Clay/Silt
Binder- Wood Glue





Material- Sand/ Clay/Silt
Binder- Wood Glue



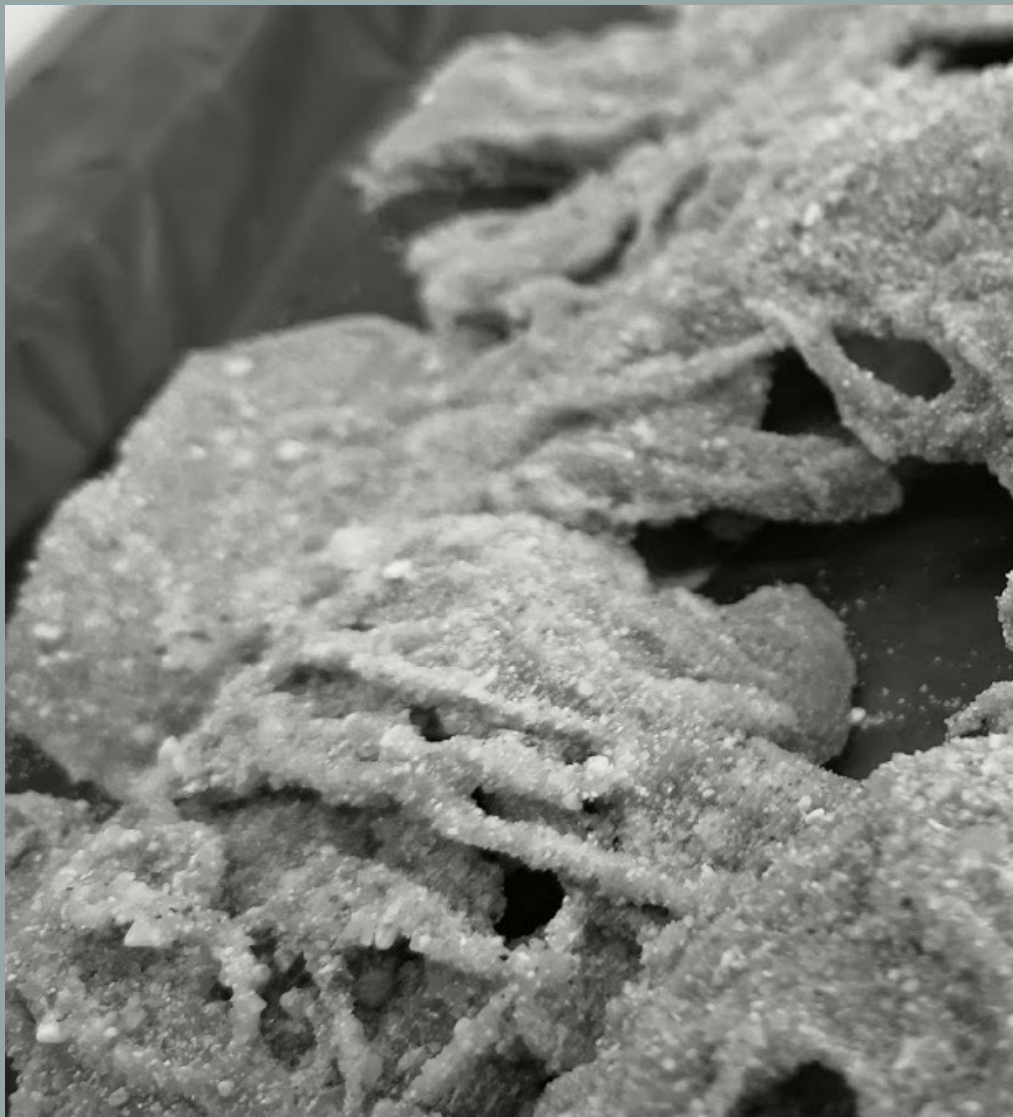


The final result was a series of catenary mounds where the web is at an angle of 35 degrees which is the natural angle sand attains when deposited under gravity.





Possible openings for the structure



These were early material explorations based on the idea that kuka robot will be used to deposit material.



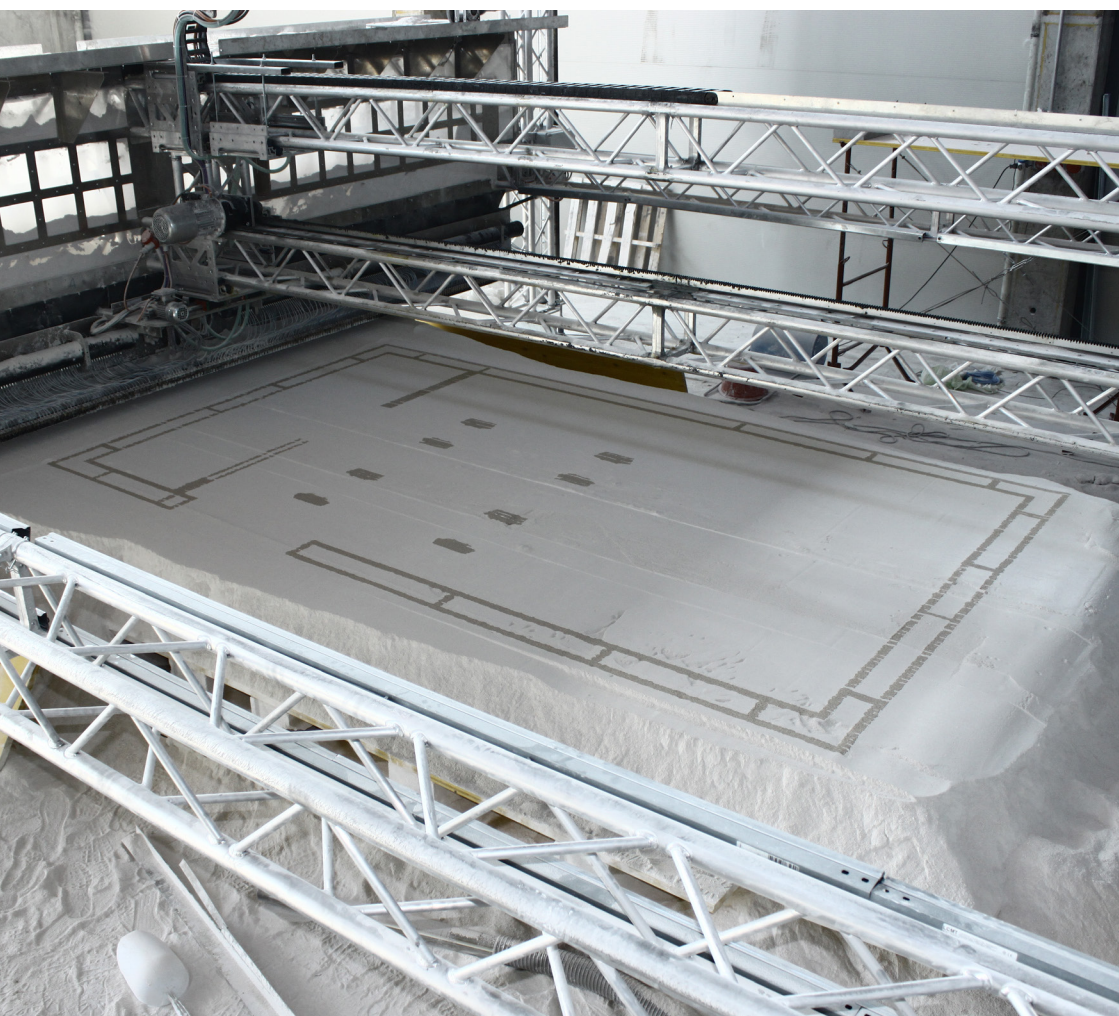
As the design got more detailed we understood that we need to change this approach since kuka couldn't deliver the micro details we wanted to achieve. Hence the following research explains the change in the approach in meso to micro scale.

MESO & MICRO-[D2RP]

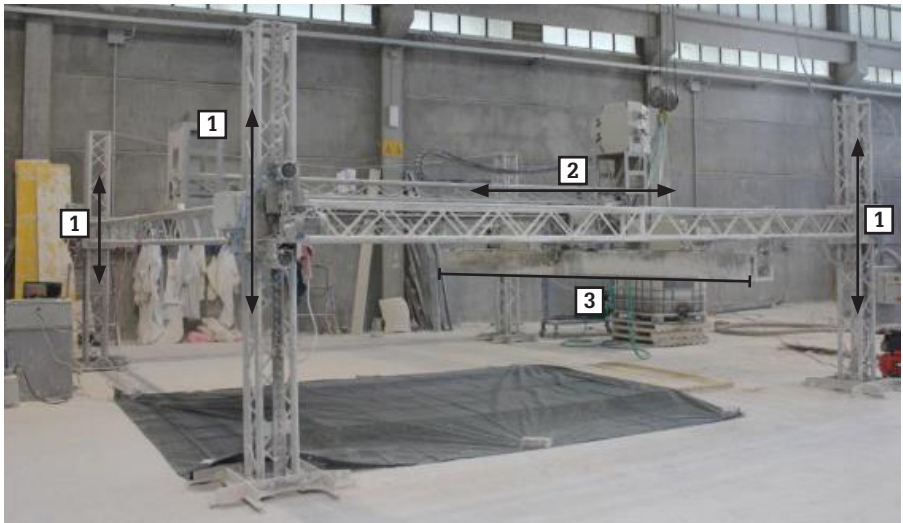
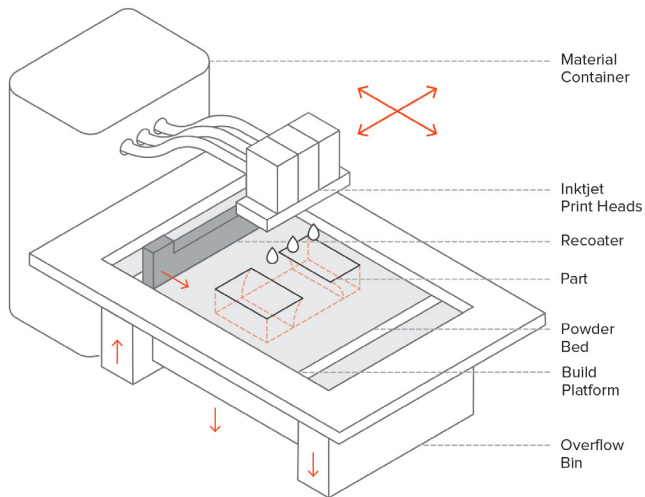
Particle Bed 3D-Printing

The printer uses a binder jetting technology, and is currently D-Shape is the single available company providing printers of this type. Using a large gantry structure to move, the printer creates an alternative type of concrete by selectively applying a liquid binder on top of layers of powder material consisting of a cement-sand blend. Where the binder is applied, the powder material solidifies, while the remaining unbound material remains as a support for the solidified parts. The printer allows to print 3D models directly from file into concrete-like shapes with a high degree of form freedom. These shapes are not only extremely difficult or even impossible to obtain with any other traditional construction technology, but are very often a great challenge also for other types of 3D Printing technologies. On the other hand, directly printing buildings with this technology is very slow due to the need for removal of large quantities of support material.

The technology is therefore well suited for the production of unique pieces and parts, whereas it is deemed less suitable for direct fabrication of conventional buildings. The D-Shape 3D printer is probably best suited for off-site prefabrication of various highly complex construction elements. The D-Shape printing process is effectively an up-scaled binder jetting process, where a binder is selectively deposited on each layer of powder material. The powder material in this case is consisting of sand and magnesia-based cement, which are mixed together into a dry powder, before being fed to the 3d printer and spread into layers. The jetted (or sprayed) binder material is a saline water solution, which is deposited on each layer of dry powder material, similar to ink on paper in a traditional desktop ink-jet printer. When deposited, the binding material travels through the powder layer, reaching the layer below. The process is repeated for each layer, until reaching the end of the structure.



The D-Shape printing technology [a printed layer]



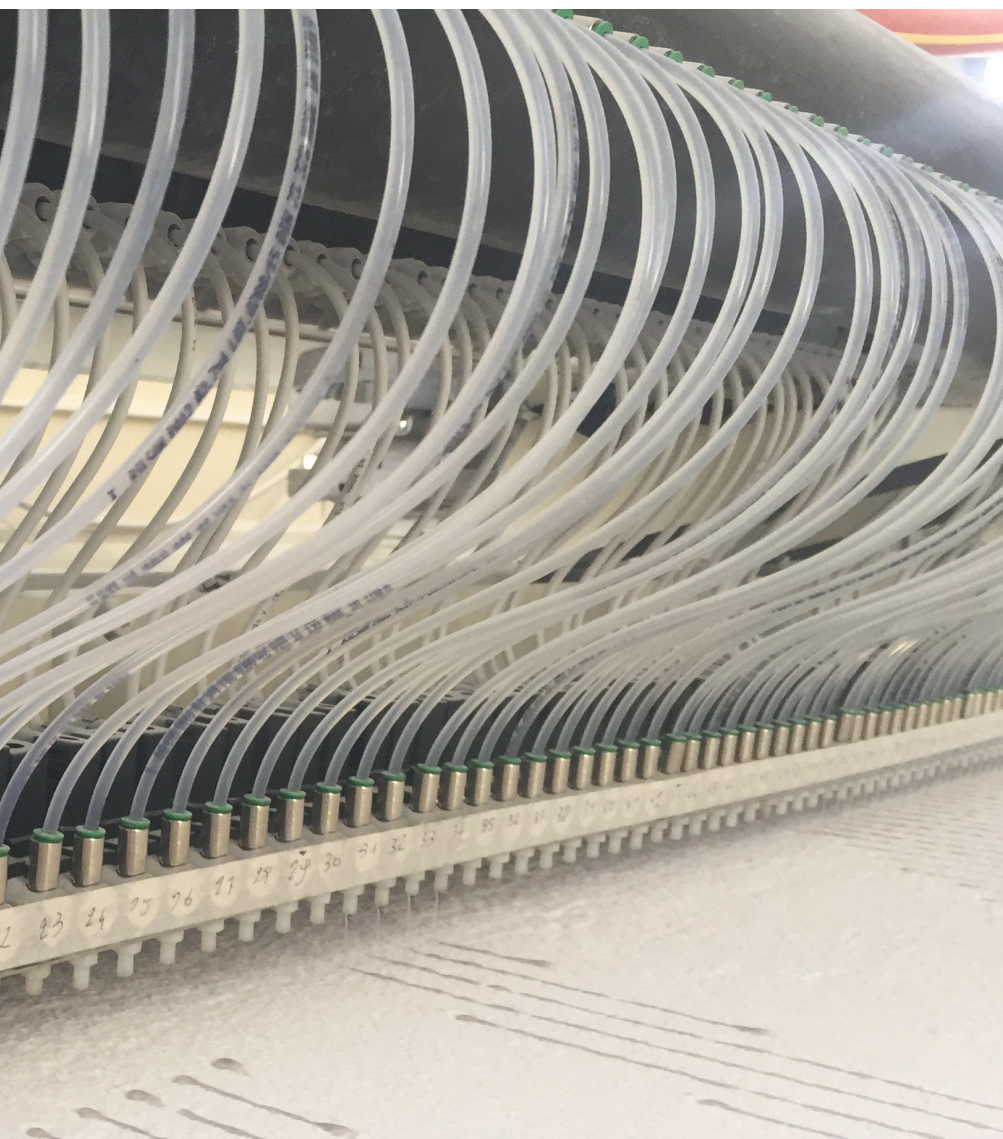
Movements of the machine in all the possible directions: -
vertical movement along the 4 columns (1)
horizontal movement along the middle beam (2)
offset motion of the nozzle array (3)



The D-Shape printer in outdoor conditions



Process of alternating layers of granular material and ‘writing’ on them with a binder that turns the granular material into a shape.



D-Shape deposits any mix of granular material in a range of diameter starting from 0,1 to 4 mm , and any liquid Binder having a viscosity between water and a cementitious slurry. The nozzles of the D-Shape's printer head deposit droplets of binder' whose volume is about 100 times bigger than existing inkjet printer heads.



[D-SH

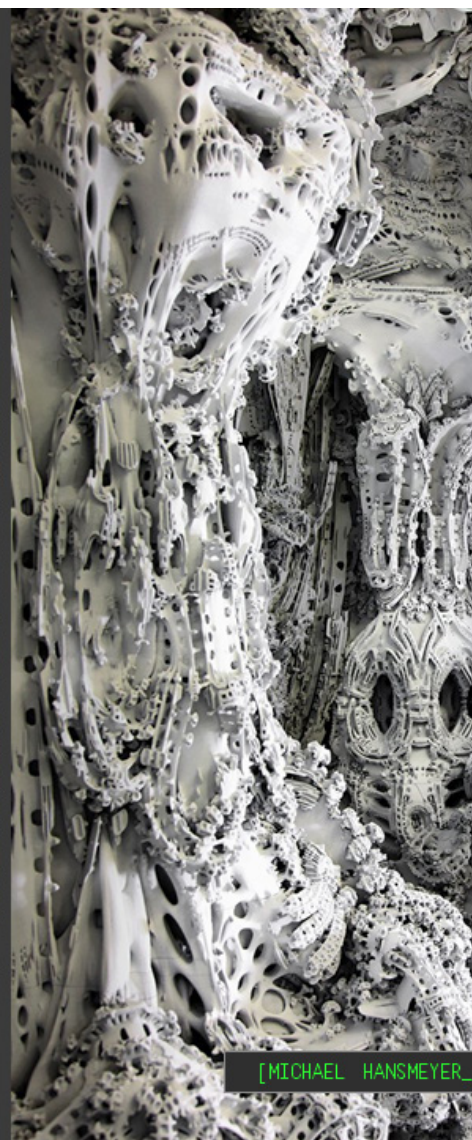


D-Shape projects using powder bed 3d printer





*D-Shape projects using powder bed 3d printer.
The first pedestrian bridge printed in 3D in the world in the urban park of Castilla-La Mancha in Alcobendas, Madrid.*



[MICHAEL HANSMEYER]



Michael Hansmeyer's Digital Grotesque detailed wall element using the powder bed production technology.

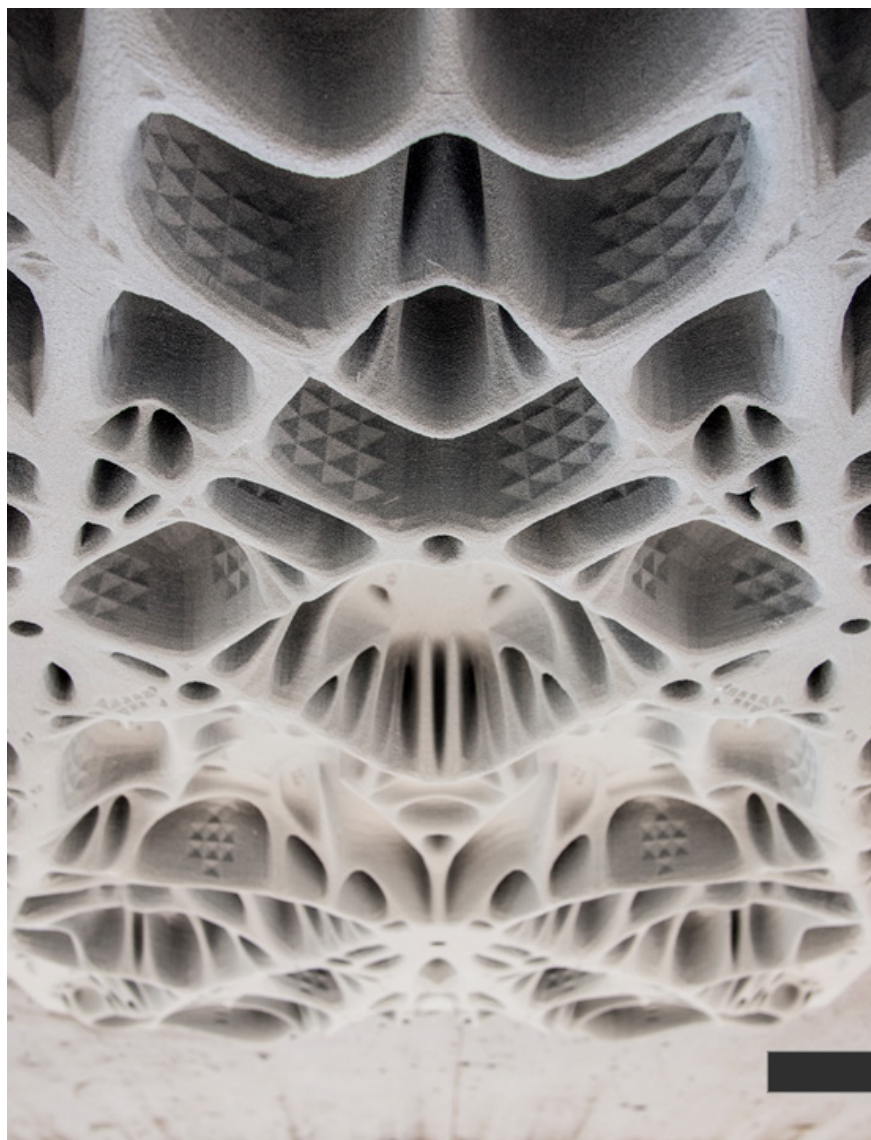


at a resolu



tion of a tenth of a millimeter

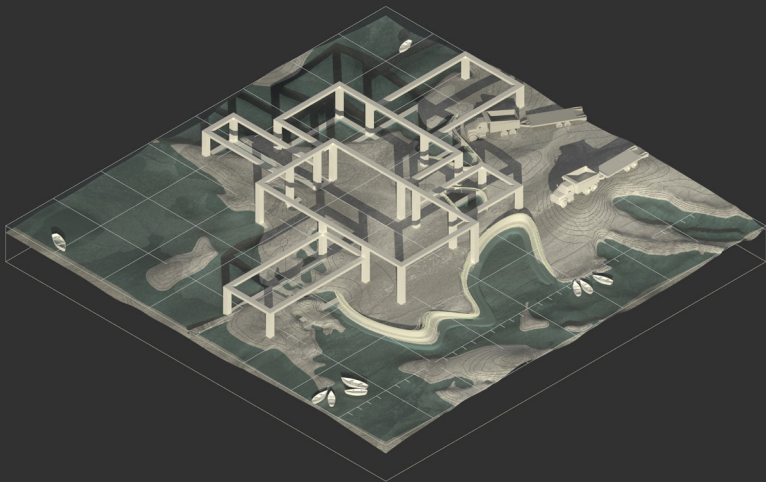
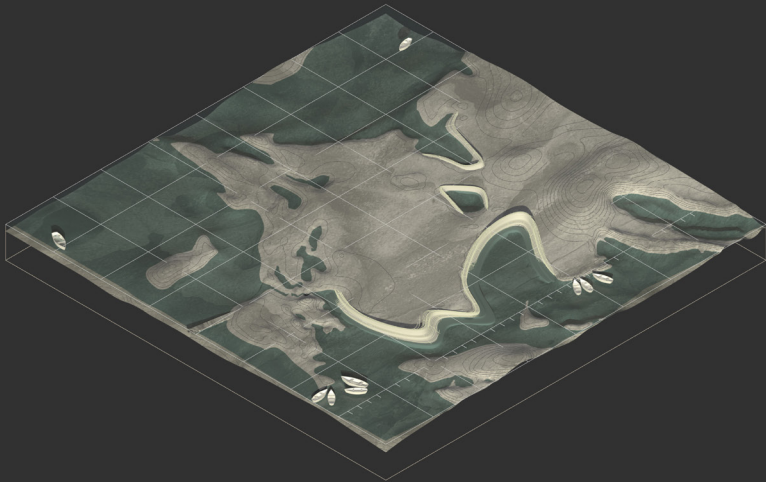
Michael Hansmeyer's Digital Grotesque detailed wall element using the powder bed production technology - the process yield high level of detailing upto 600 dpi.



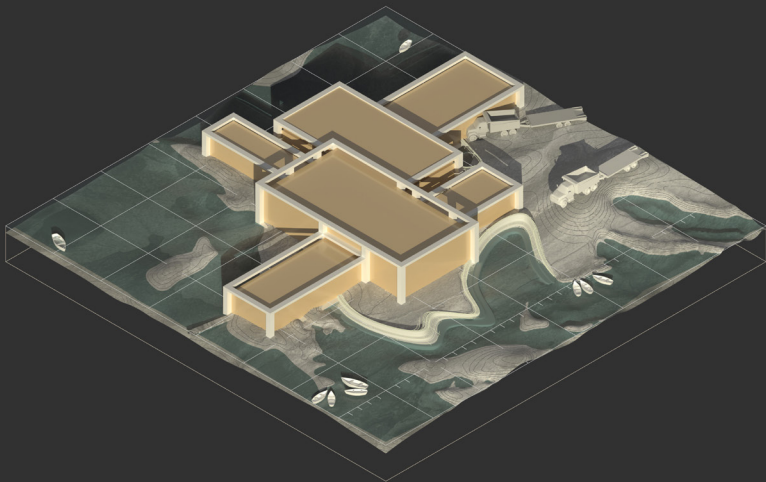
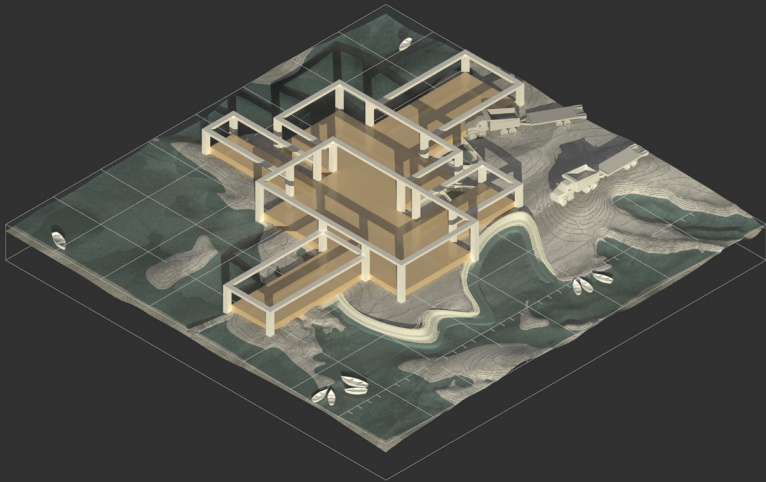
[SMART SLAB_



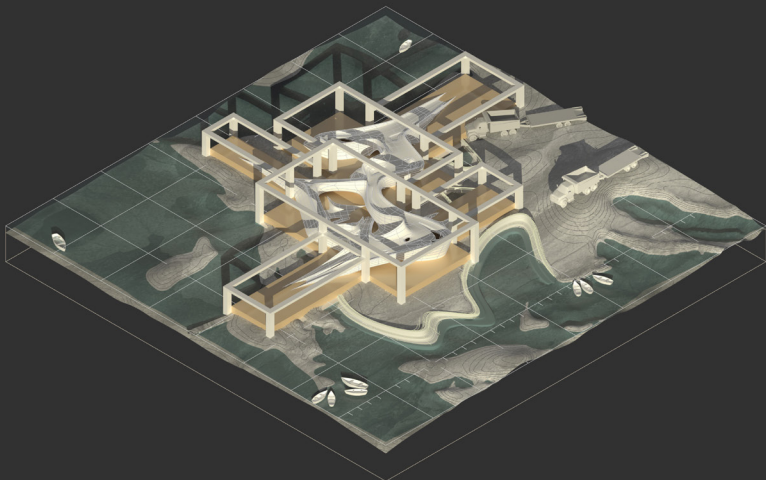
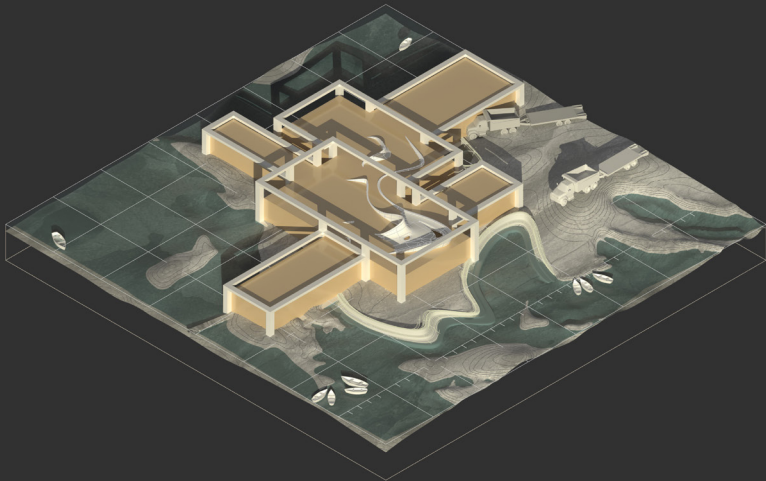
Smart slab project at ETH-Zurich using the powder bed production technology



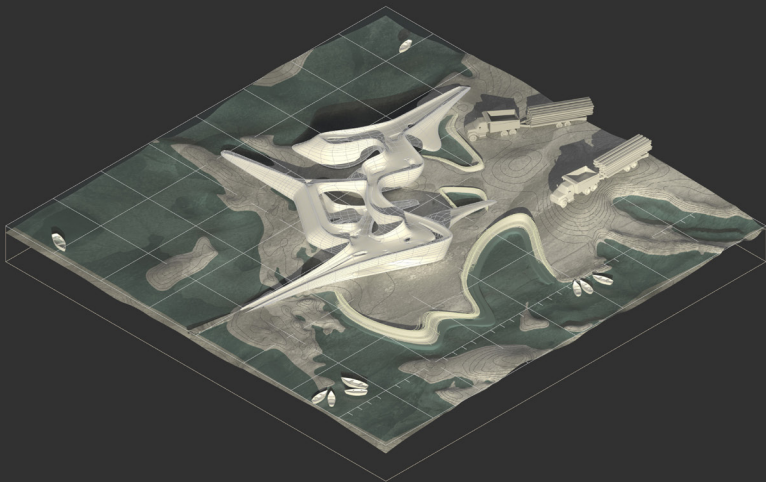
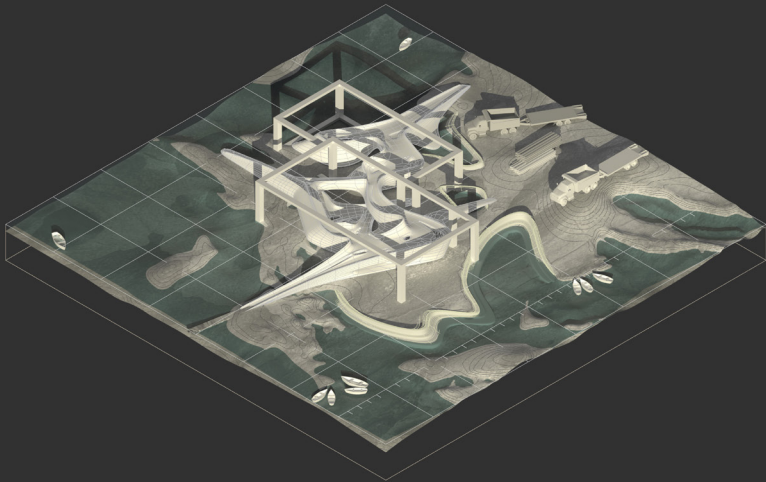
The process starts with setting the bed structure on site brought by trucks.



Once the structure is setup printing commences.



Once printing is done the unbided sand is vacuumed off.



The gantry structures are dismantled and used in the other site along with the left over sand. This process is currently available by D-Shape. However its quite time consuming and hence it is proposed to use swarm printing as seen in the following research.

MESO & MICRO-[D2RP]

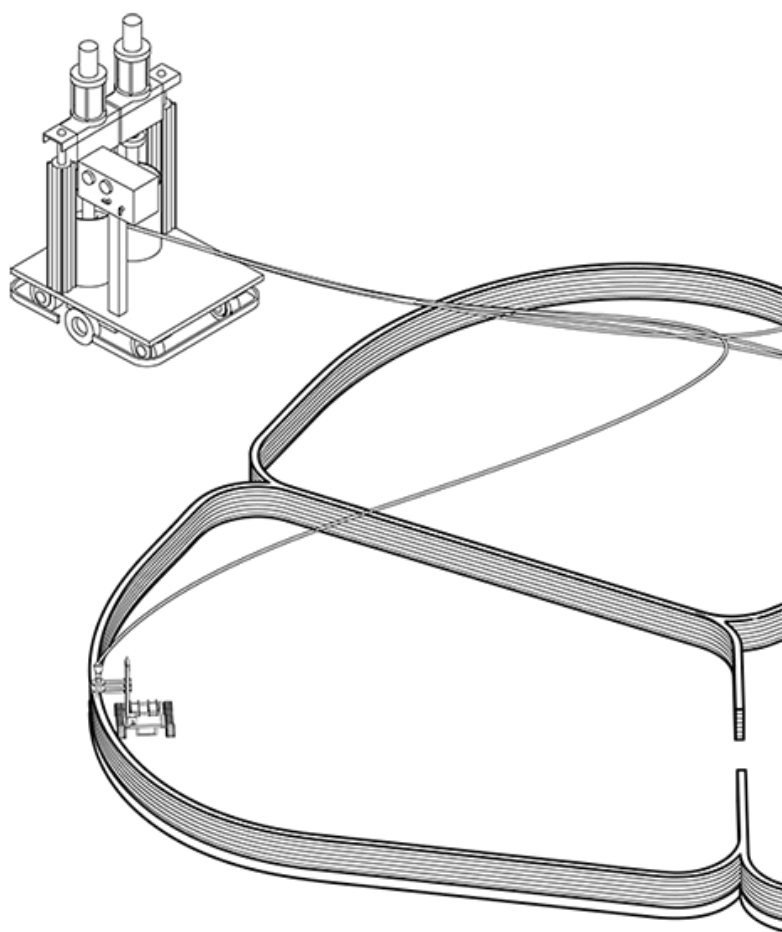
Swarm Printing - minibuilders [iaac]

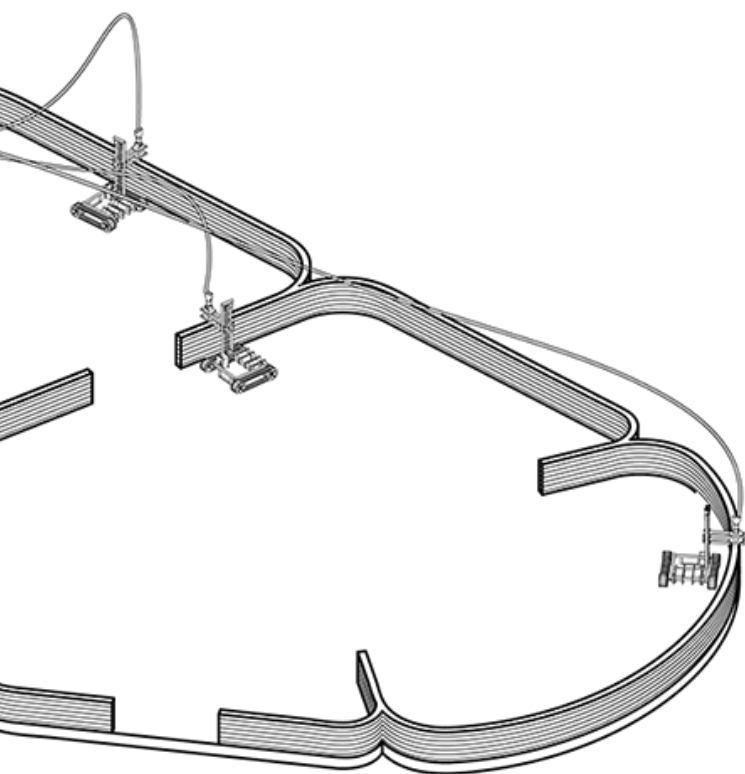
Minibuilders is essentially a layered material extrusion process, where a fused material is pushed through a nozzle and deposited in layer. This technology is very typical and well established both in 3D Printing in general (known as Fused Deposition Modeling or FDM), as well as in its construction-scale variants. But what sets Minibuilders miles away from all other process is a very innovative and completely different approach to actually printing the structure. While other technologies use gantries or robotic arms that move a nozzle around the printable surface, Minibuilders uses a swarm of small robots that work together, and even climb on top of the structure while printing it. The first part of the printing is done by a Foundation robot, that lays the first 50 centimeters of printed structure, starting from a flat surface. The printer moves on flat surface and deposits the material through a nozzle located on the side of it.

The second part of the printing is done by a Grip robot, that is fixed on top of these first 50 centimetres of hardened print. The robot grips on the previously printed layers and moves them while printing on top of them at the same time. With each new layer, the printer moves on top of the layers it has already printed, making the printed structure increase in height. The robot can print each layer slightly offset from the previous one, allowing to create gradual inclinations and overhanging structures or ceilings. Finally, once the printed structure is finished, a Vacuum robot is attached on of the already printed surface and prints additional thickness layers on top of it. This allows to thicken the printed structure or create additional shapes on its surface. All the three types of robots are attached to a larger master unit, which controls them and provides the material. Once the last part or layer has been printed, the process is finished. The printed object is then left to harden completely.

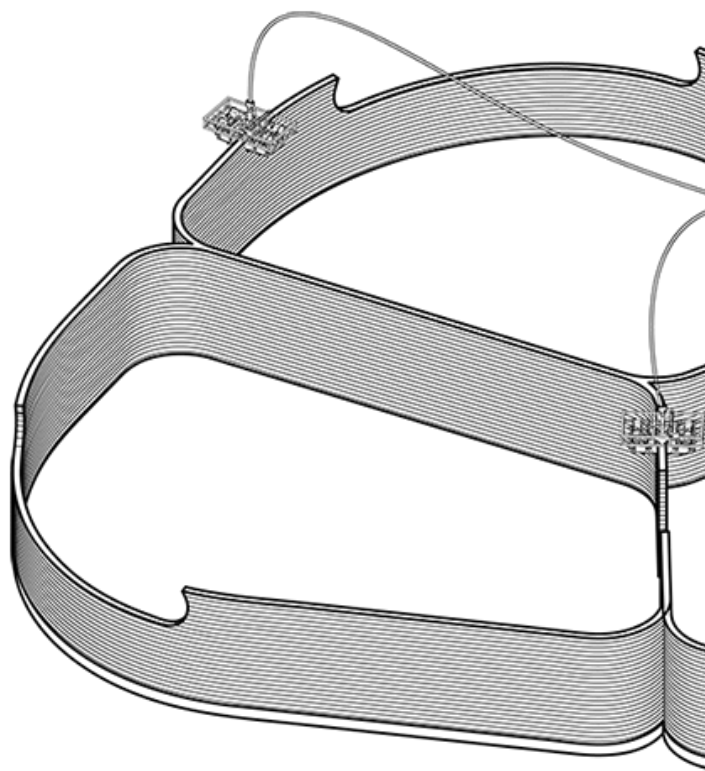


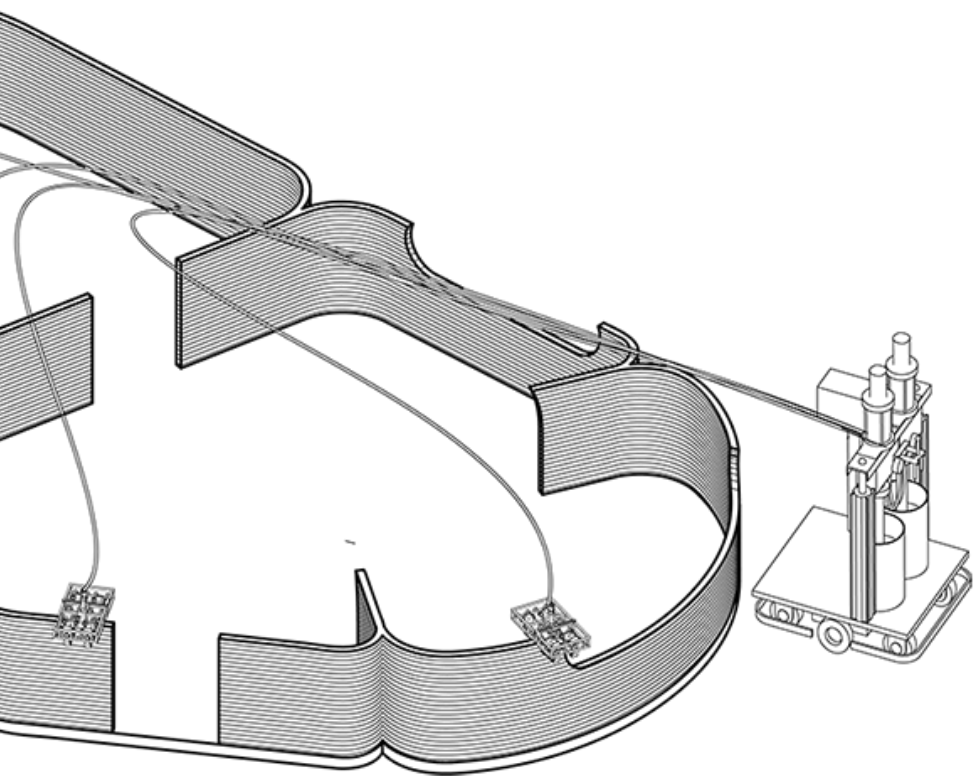
The largest print up to date (2 x 1.5 meters approximately)



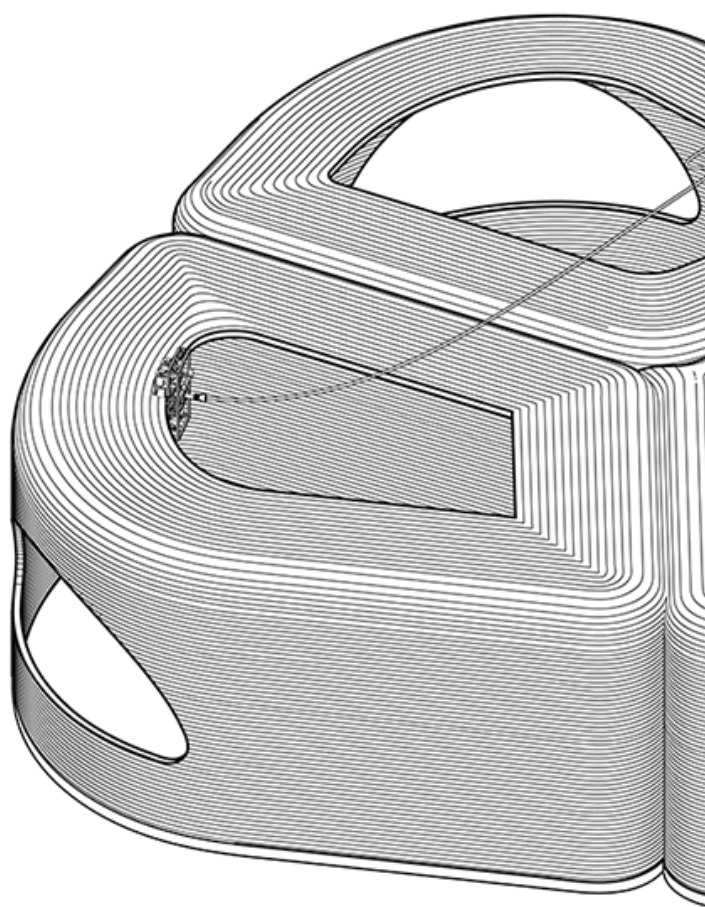


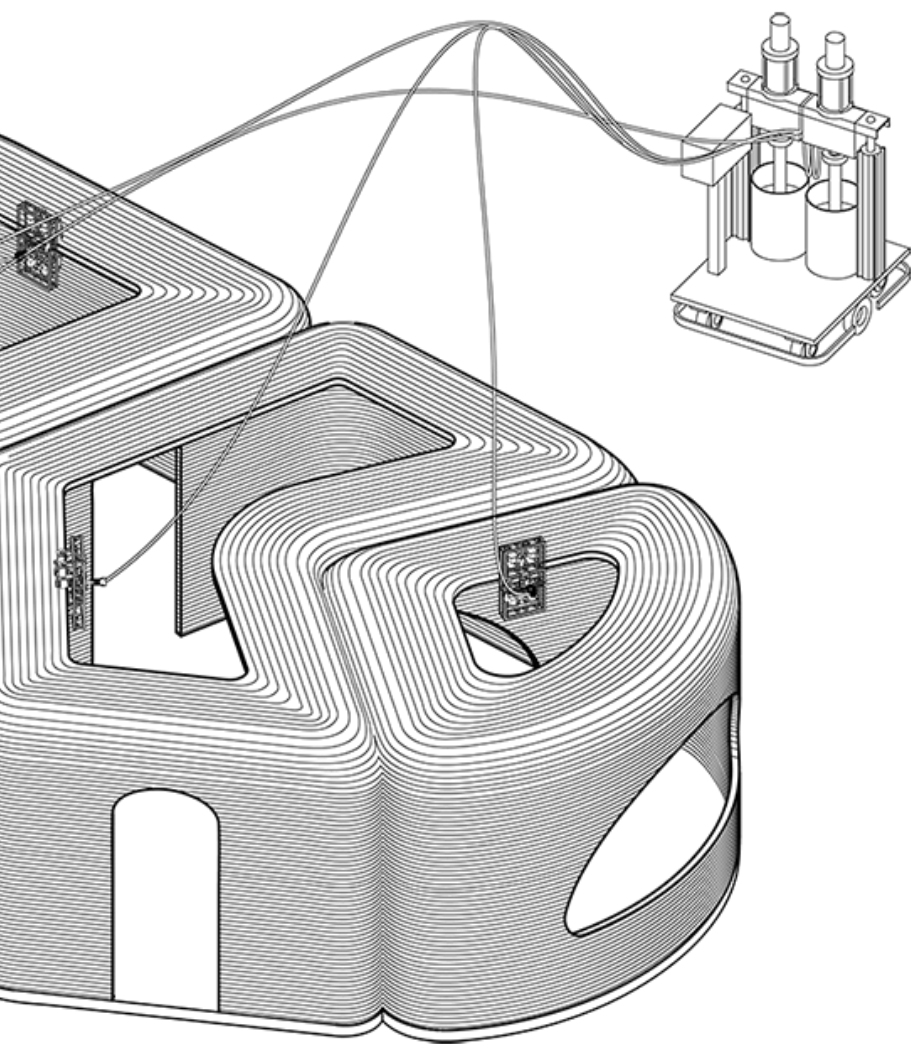
1st phase - first 50 centimeters with Foundation robots



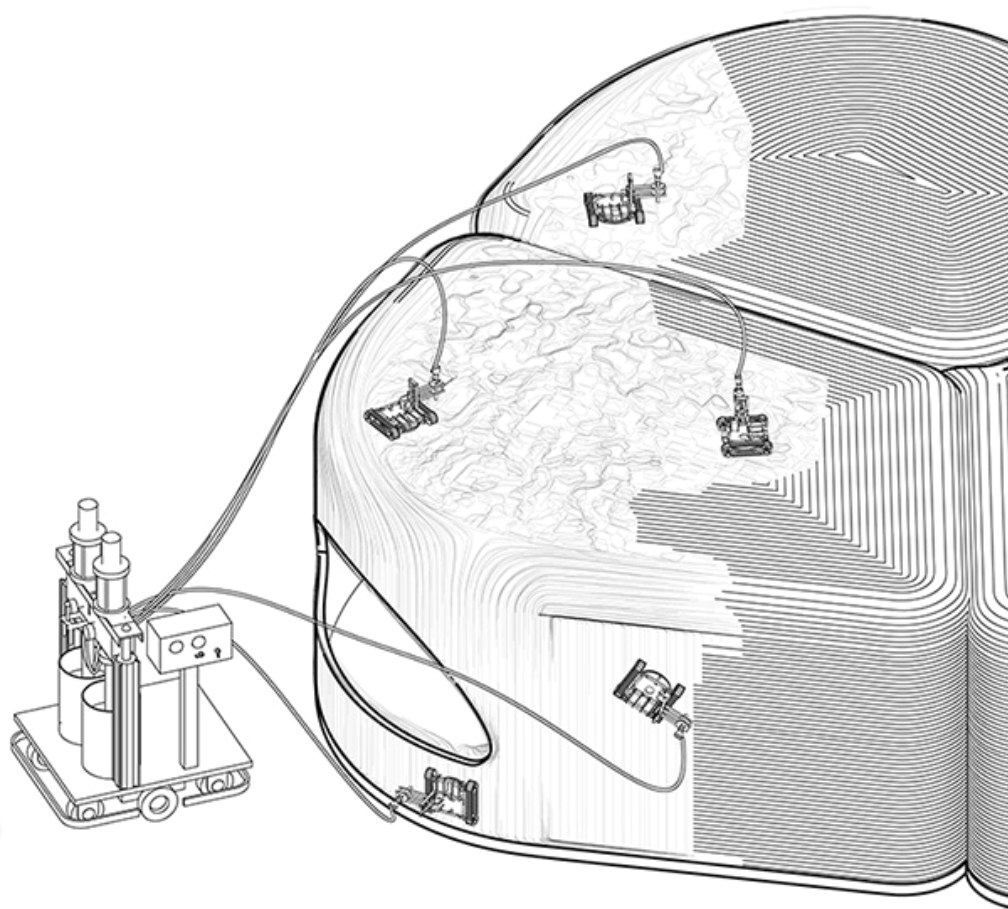


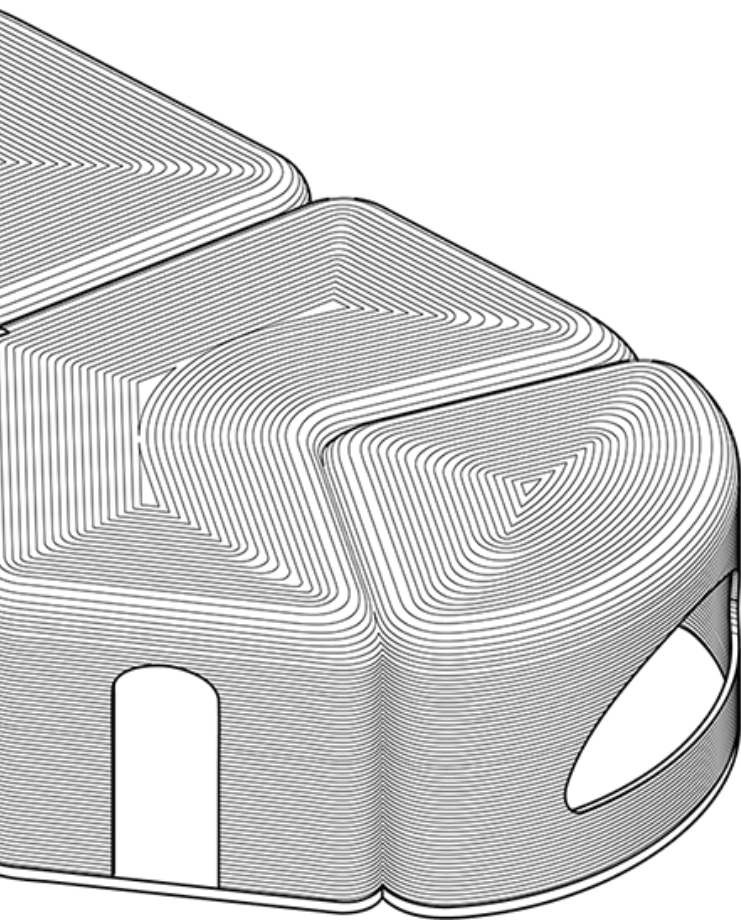
2nd phase - Walls and Ceilings printed with Grip robots



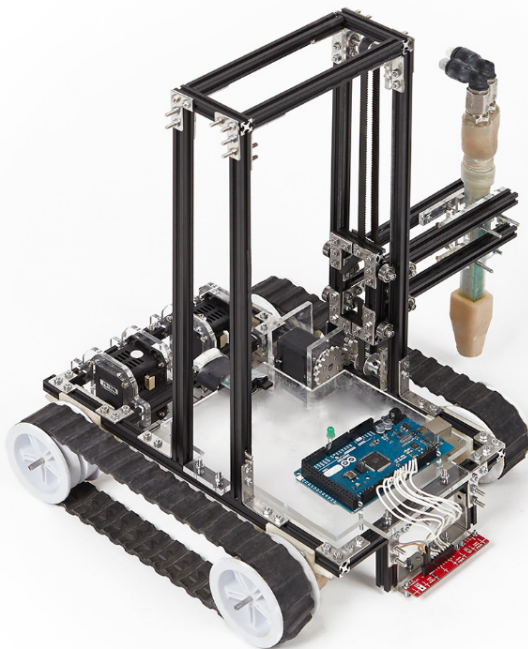


2nd phase - Walls and Ceilings printed with Grip robots

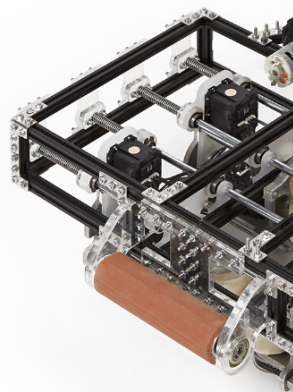




3rd phase - Additional thickness layers with Vacuum robots



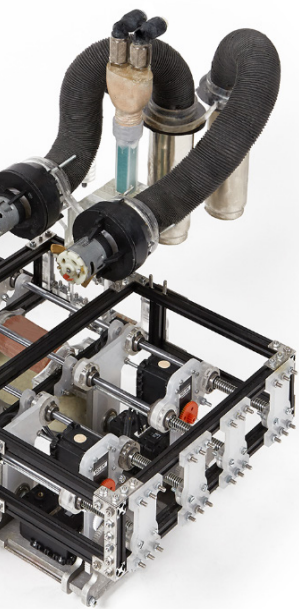
Robot-A



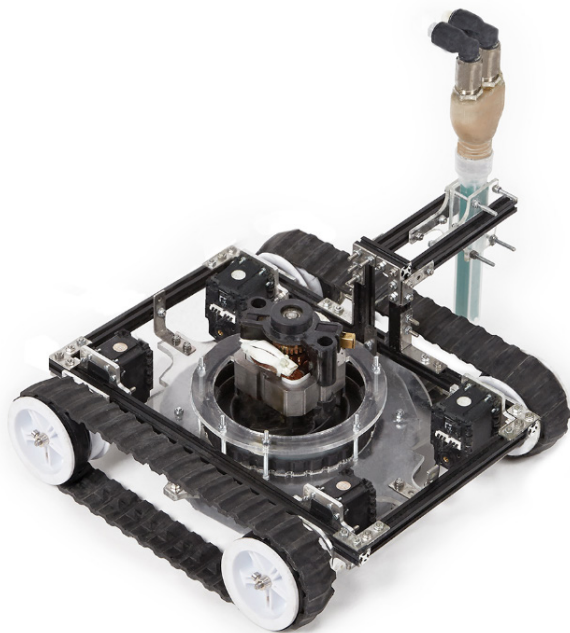
Robot-B

A- The Foundation robot with nozzle (1), rubber tracks (2), vertical frame (3) and on-board Arduino controller (4)

B-The Grip robot with frame (1), gripping wheels (2), top rollers (3) nozzle (4) and hot air blowers (5)



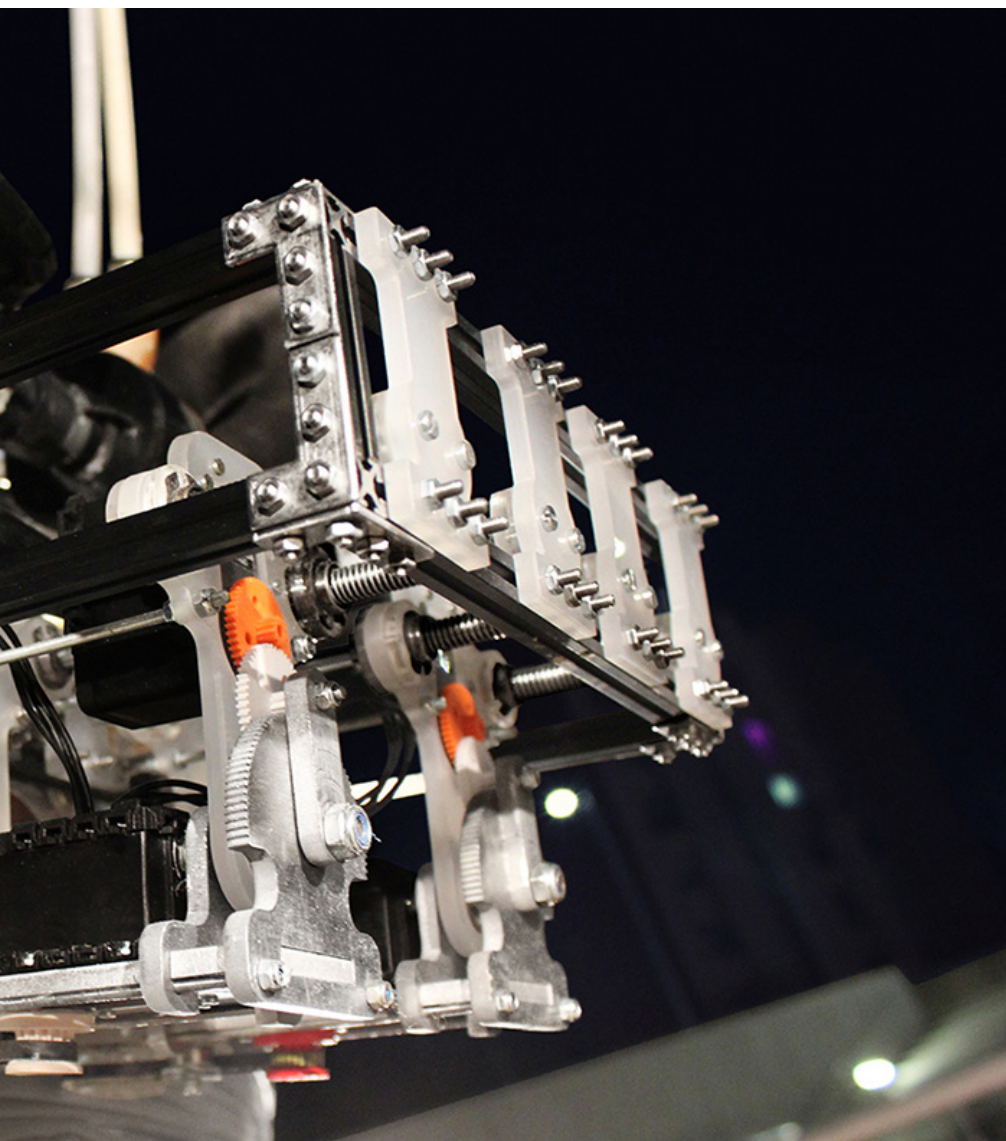
Robot-B



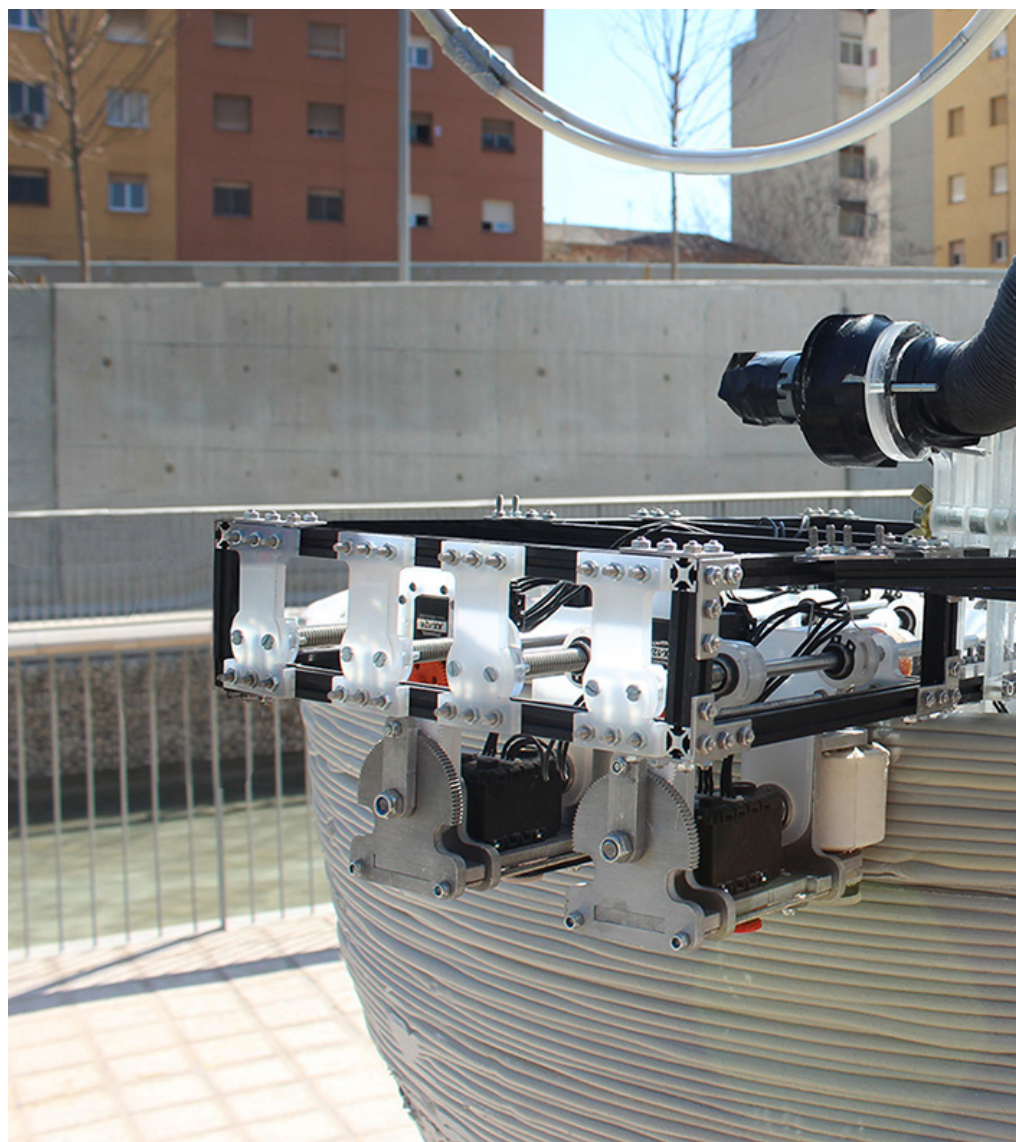
Robot-C

C-The Vacuum robot with rubber tracks (1), nozzle (2), and vacuum generator (3)





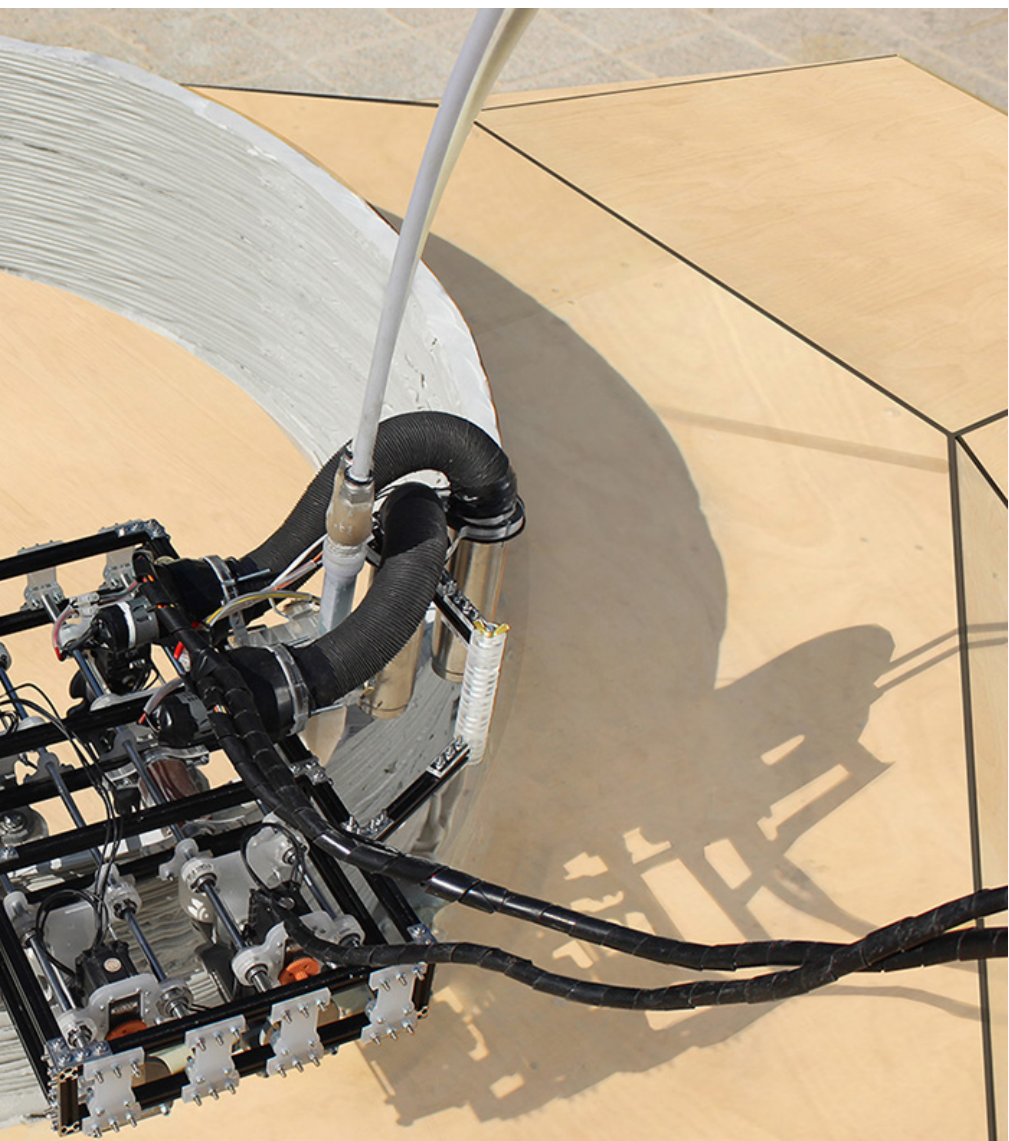
One of the grip robots in action





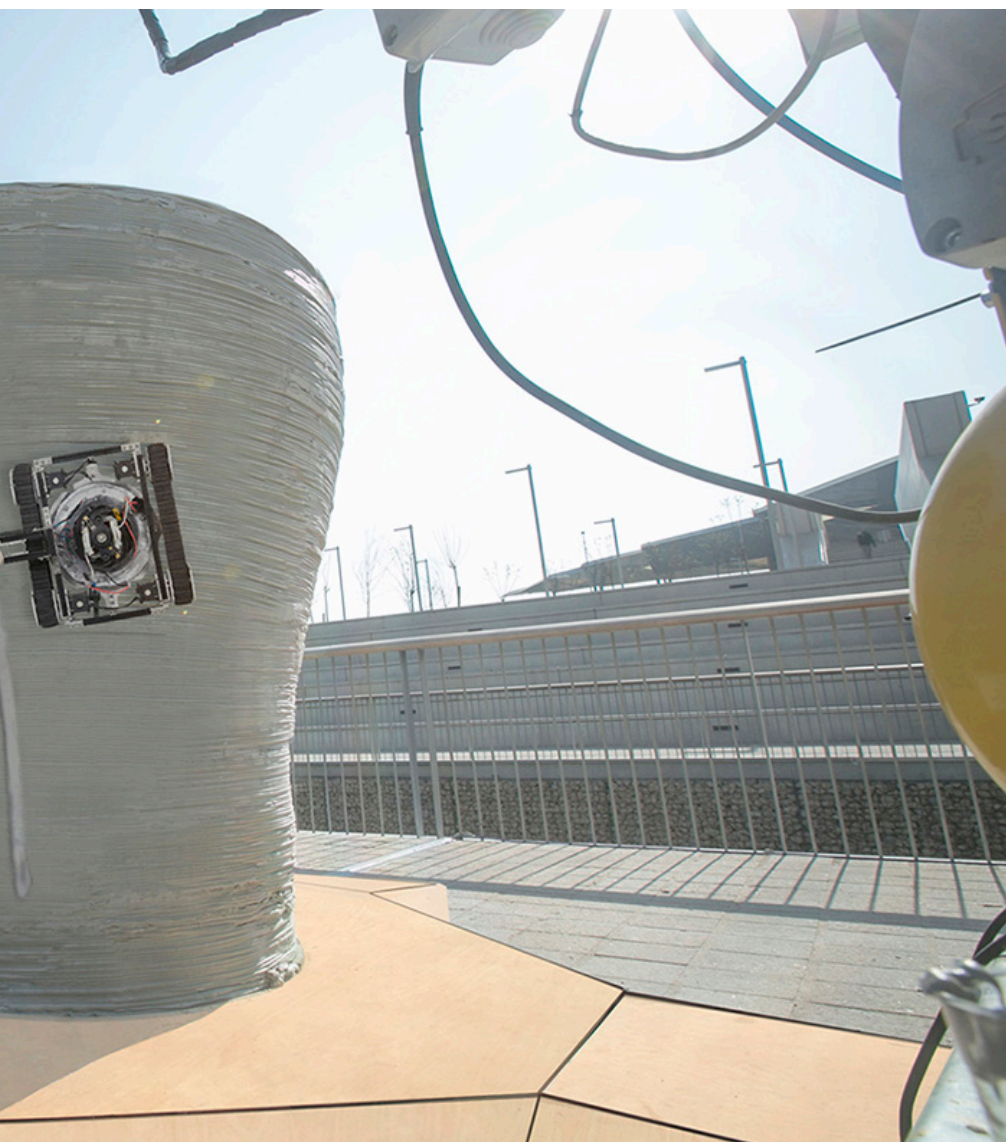
One of the grip robots in action



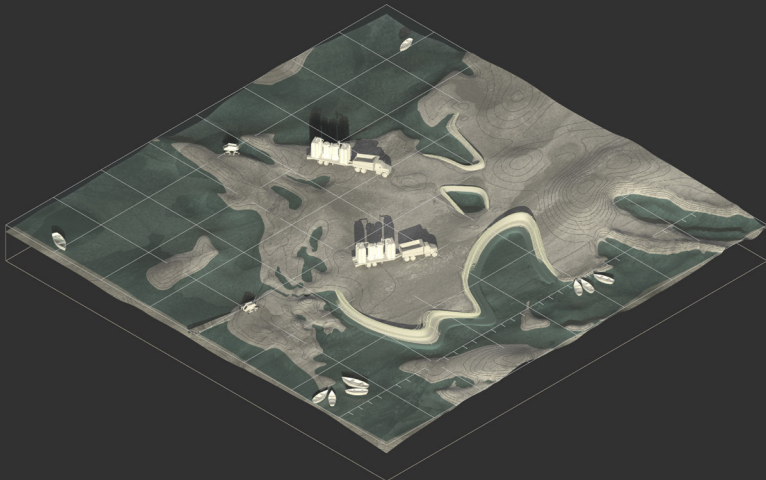
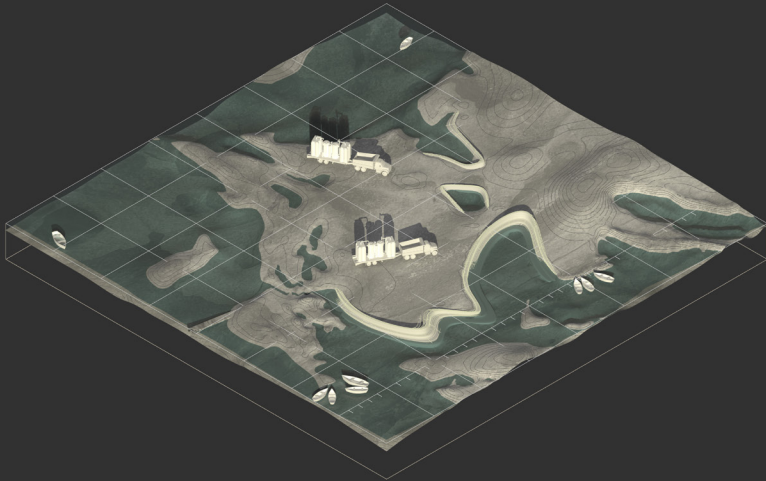


One of the grip robots in action

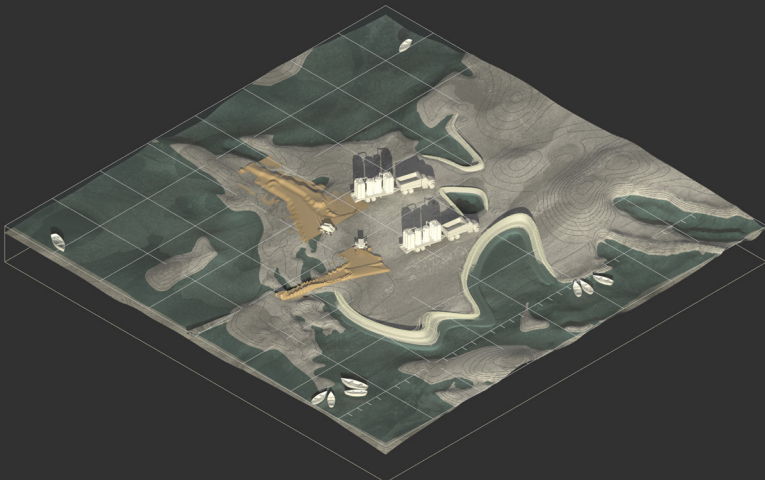
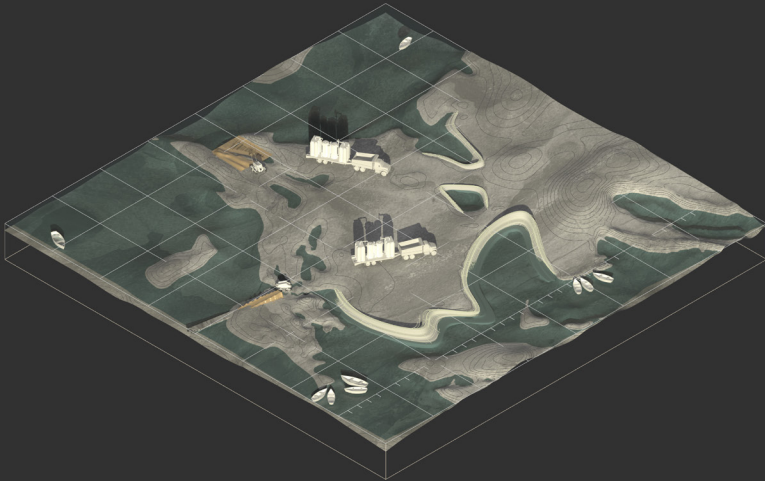




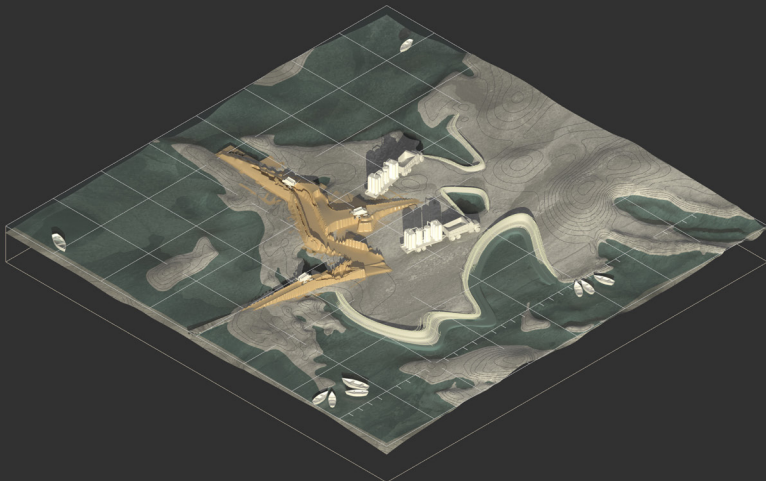
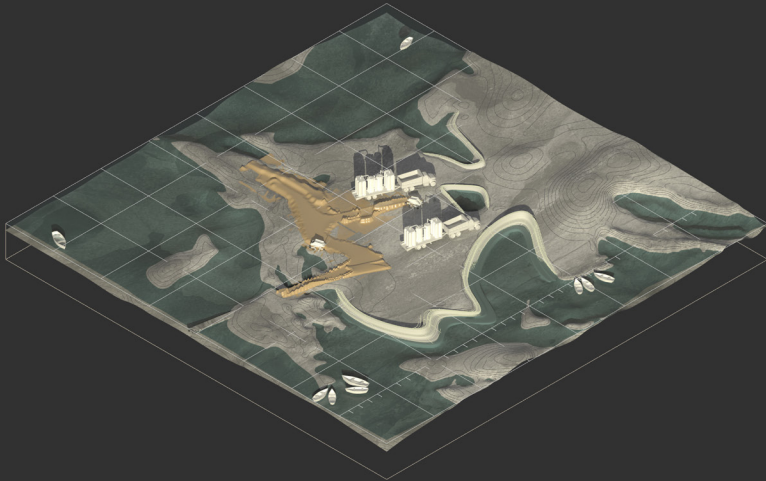
The Vacuum robot attached onto the vertical face of a printed object



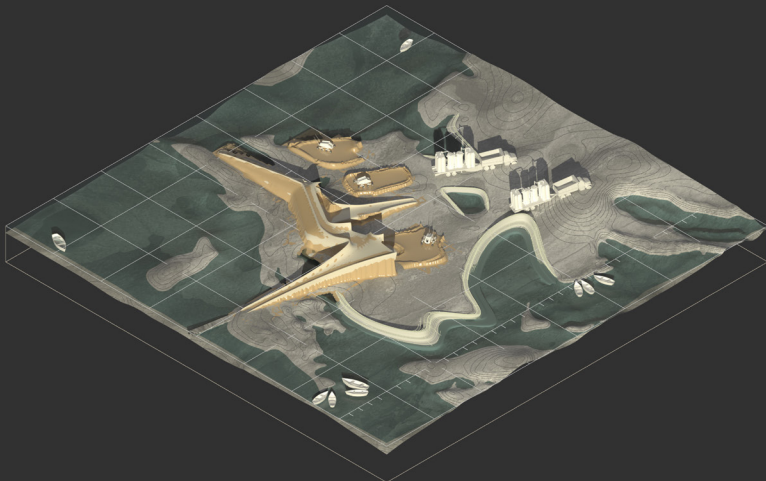
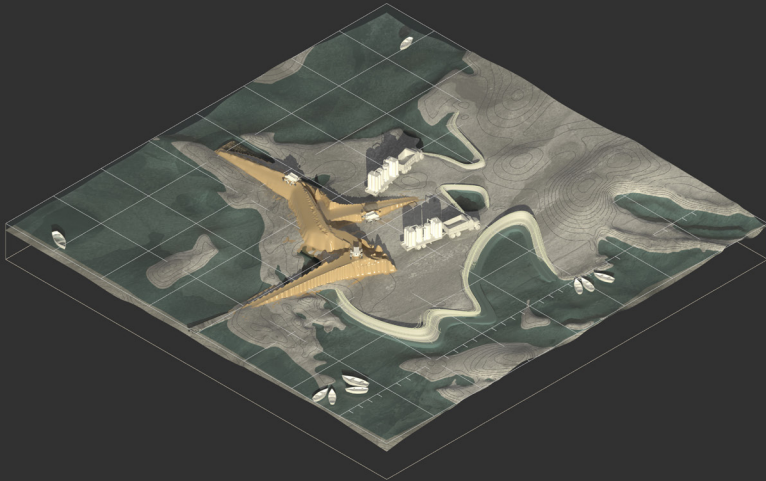
The Robots are connected to the truck which has the material and the binder



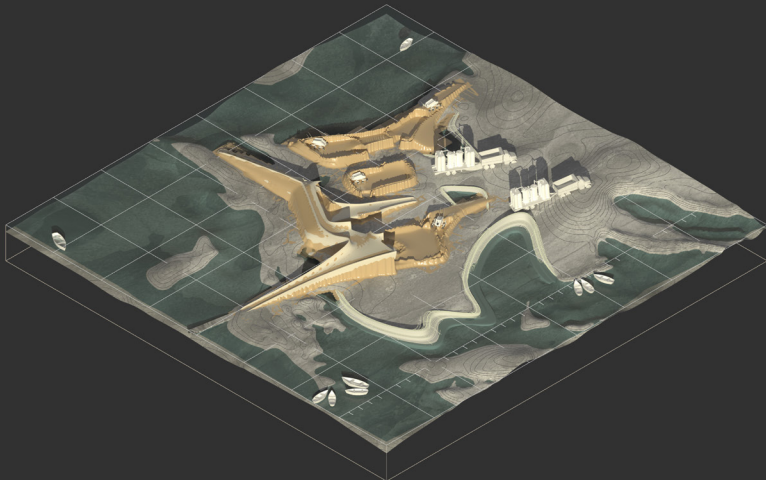
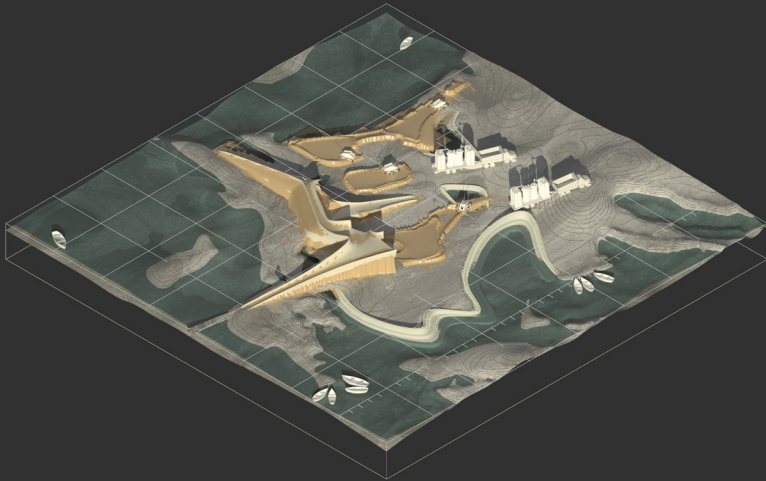
The robots starts depositing sand, binder and support sand structures layer by layer .



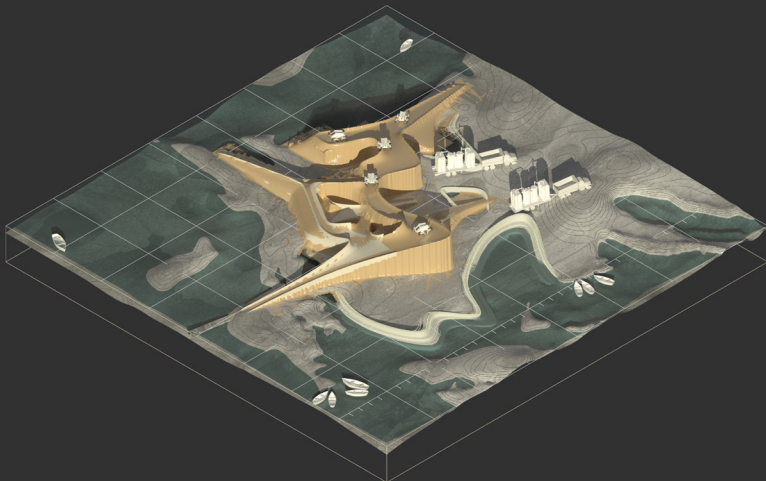
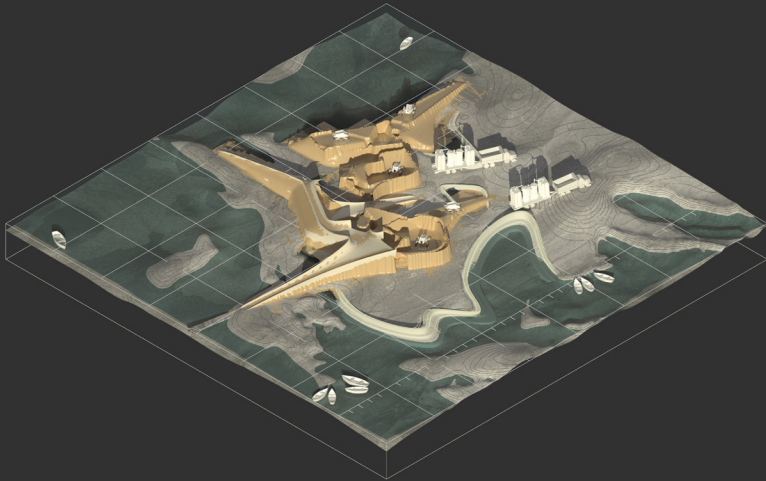
The support structure has a binder which can be washed off with running water



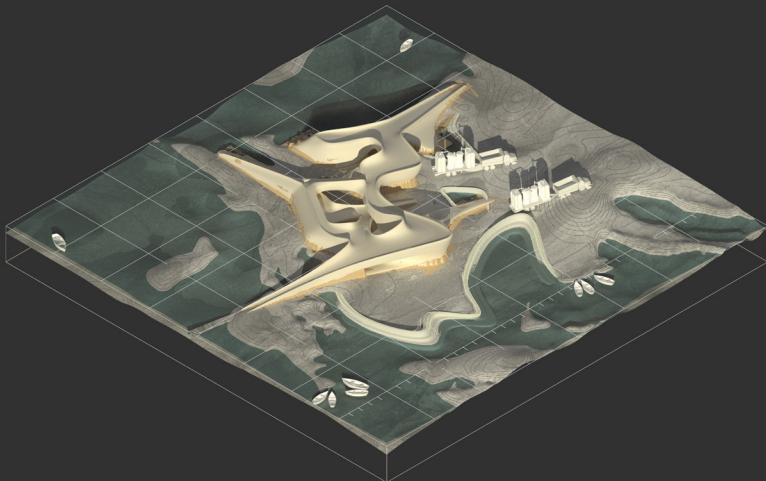
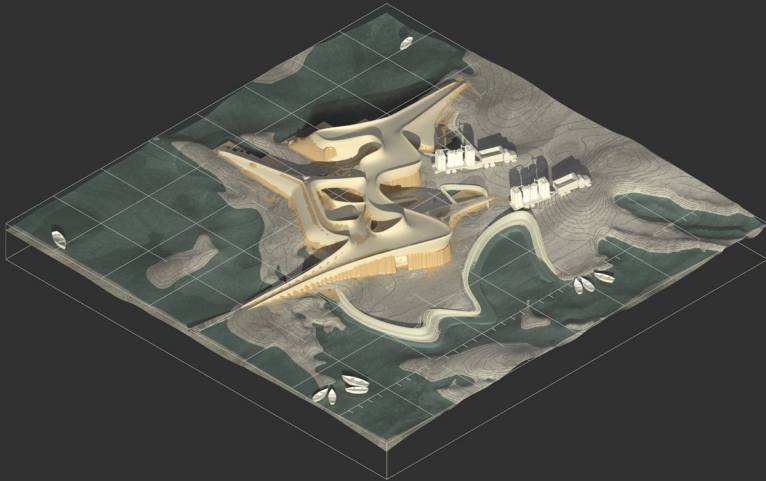
The g code is optimized to first build the geometry which acts as an embankment and structural support for the following catenary arches.



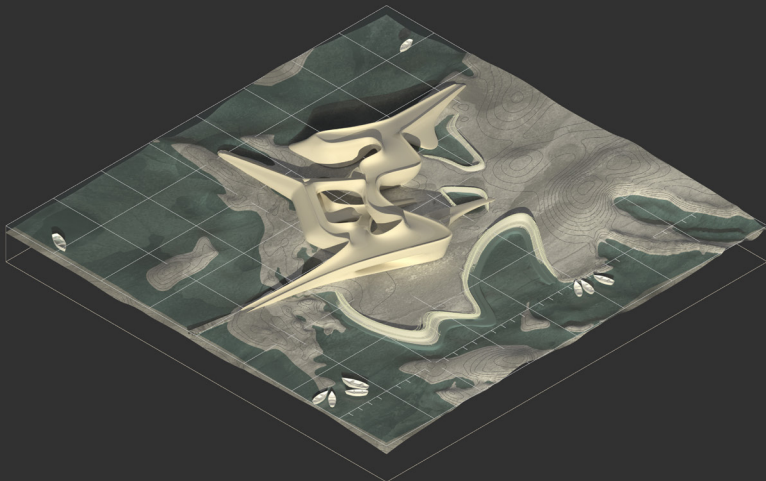
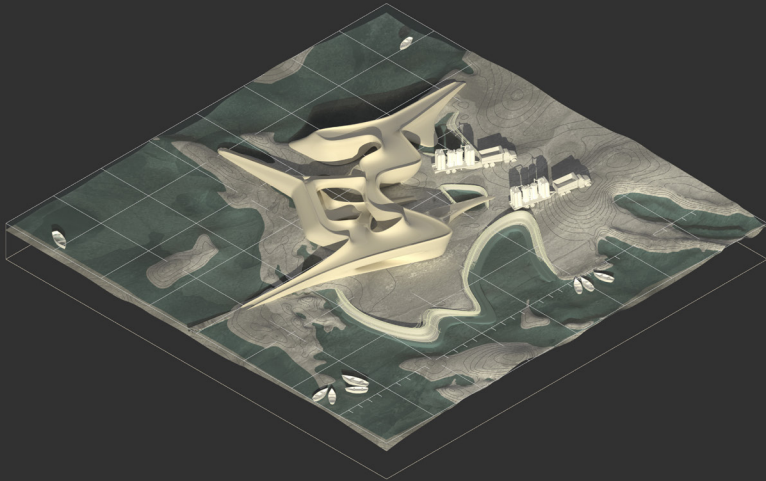
*Once a part is finished the gripping robots work on smoothening the top surface
of any unwanted extruding parts.*



Once the base of the arches are done, supports structures are created and the gripping robots are hoisted on them to create the final arches.



The support structures are vacuumed off or washed away.



The final prototype.





The material used in these systems are bio-bricks made essential of sand/clay and binded by bacteria and urea. The key issue here was to tweak the binder in a way so as to make it soluble in water under certain conditions for the structure to disintegrate when water level rises on site.



[Peter Trimbl

The thesis proposes a microbially induced casting procedure, which presents the bacterium “bacillus pasteurii” as a method of cementing natural granular materials using minerals as a binding agent for the creation of sand structures

Calcium + Urea Solution

Sand + Bacteria[*Bacillus Pasteurii*]

'Bio-SandStone

e-Sand Stool]

In the right circumstances, the bacterium's enzymatic urease catalyst hydrolyses urea, which—when the process occurs in a calcium-rich environment—generates calcite (the most stable polymorph of calcium carbonate), which binds the individual grains of sand together.

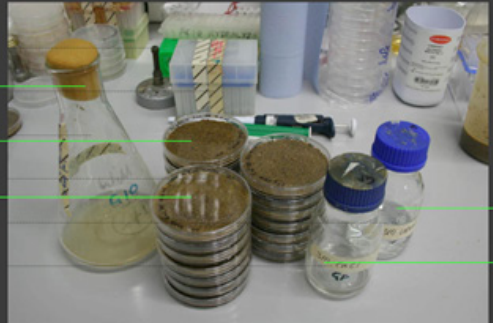
[Magnus Larsson - Soil interaction Laboratory, University of California]

[BINDER INGREDIENTS]

Bascillus Pasteurii

Sand

Clay



Urea so

Calcium



Bascillus Pasteurii & urea + Water = Ammonium + Carbonate
 $\text{CO}[\text{NH}_2]_2 + 2\text{H}_2\text{O} = 2\text{NH}_4 + \text{CO}_3$

Ammonium & Carbonate + Calcium Chloride = Calcium Carbonate Crystals

Calcium Carbonate Crystals[CaCO_3] Reacts with flowing water to dis

The process requires the bacteria to be injected into sand which is filled in water tight tanks. This is left overnight for bacteria to establish themselves between the sand particles. Next add urea and water solution which binds this whole material.

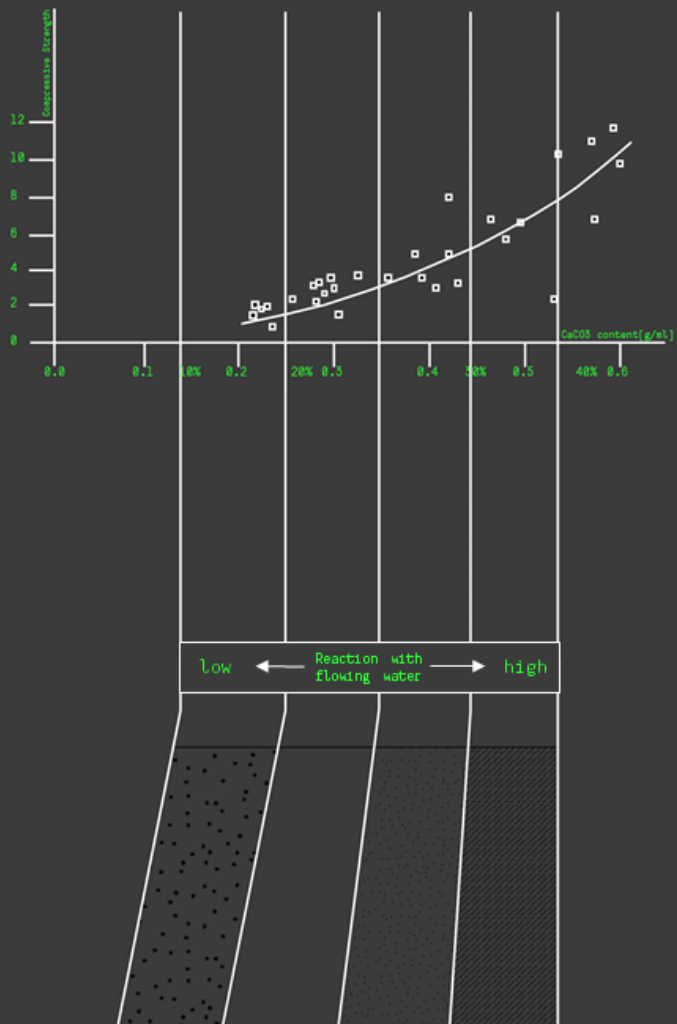
nia]

lution

Chloride

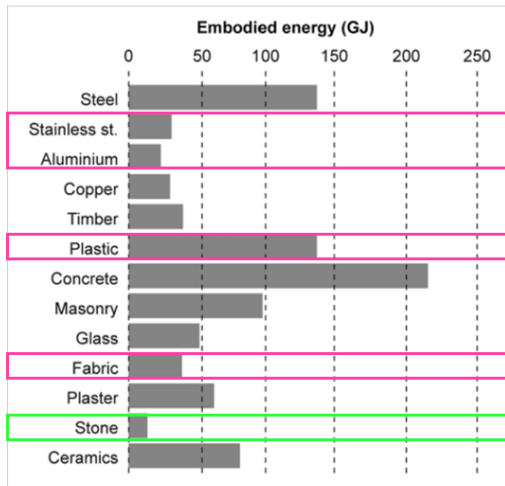
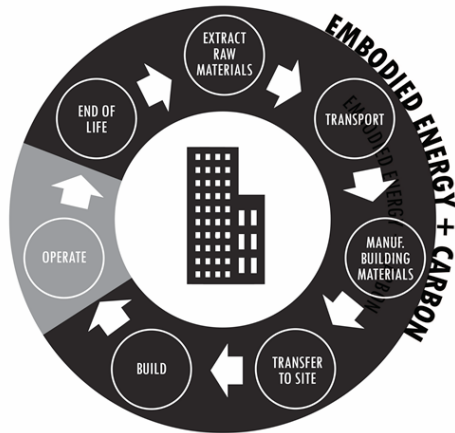
ls[CaCO₃]

integrate

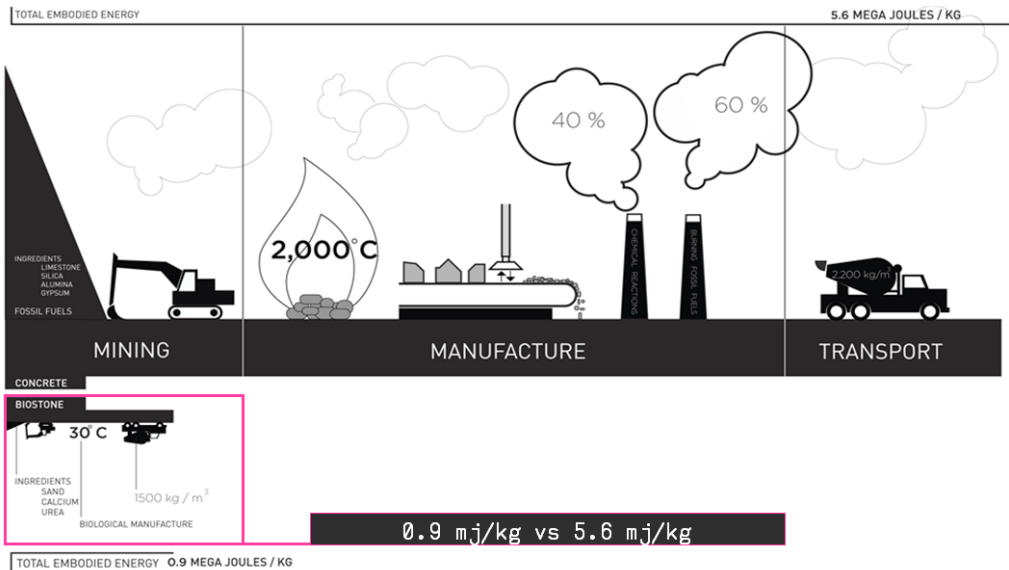


When we add calcium chloride to this solution it forms pockets of crystals in this sand structure which reacts with flowing water to disintegrate and hence the structure gets weakened. Greater the amount of crystals, quicker it gets to disintegrate the structure.

LIFE CYCLE OF A BUILDING



The materials currently used at the site is highlighted in pink. The total embodied energy being used is quite high for this big a scale of site. Currently materials use “heat beat and treat” methods of production, carving things down from the top with 96 % waste and only 4 % product.



Compression Strength | psi[pounds per square inch]

We can see in the chart that stone uses less embodied energy. Research shows that bio-sandstone accounts for only one fifth of the total energy utilized in manufacturing and transportation of conventional stone/concrete, while still being structurally sound.



Reflection

REFLECTION

In-Flow

The thesis is initiated with a context driven research into the unique ephemeral nature of the temporary pop up city in India. The site is situated in the northern city of Allahbad at the confluence of two river, Ganga and Yamuna respectively. The site facilitates the gathering for religious festival called “The Kumbh Mela”. It is the largest public gathering in the world, drawing 150 plus million pilgrims over the course of three months. The site functions on a set of temporal cycles. The site is under water during the rainy/monsoon season. When the water subsides after the monsoon, the site materializes in the form of the reclaimed river bed. Construction commences on site by December with a complex layer of road/sanitation/services and other infrastructure. The festival is dismantled after three months leaving behind the gridded city remains etched into the banks of the Ganga. . Farmers use these residual lines from the once sprawling metropolis to cultivate wheat and rice. Herds of cows and goats graze while water buffalo plunge into the river. The ephemeral metropolis is transformed into an agropolis.

The Thesis deals with a system where the site goes through various differential states and hence leads to flow of architecture and material structure from one state to another. This reversibility could serve as a rich case study to examine the working behind a temporary pop up city. Understanding the spatial, social, and logistical elements of the Kumbh Mela can lead to understanding and deployment of these systems in a variety of places and situations, in particular camps for refugees of war and natural disasters.

The thesis is carried out at the Robotic Studio, with emphasis into the various robotic tools available to form a design intervention which adheres to the social and material culture of the site. The specific research question raised here is: Can Innovative tools (Robotic fabrication) further the craft of local construction principals around the site?

Reflection

Research and design, historically they have been considered as two discreet linear process. Renaissance architect Leon Battista Alberti made a clear distinction between the designer and the builder hence abstracting architecture away from the construction. Contrary to this model anthropologist Tim Ingold argues that masonry techniques during medieval times was an iterative process. A research which grew with the building in the form of theory design and construction experiments. The thesis amalgamates both these aspects advocated by Ingold involving the synthesis of research, design and making (techniques and tools). The thesis is initiated with a context driven research into the unique ephemeral nature of the site due to its positioning at the confluence of two rivers which renders it usable for a few months during the year due to variable water depths throughout the year. Contextual research like figure ground mapping of previous iterations was done to understand how the festival fits together with the existing urban fabric. At the architectural level, historical research led to different findings on the development of shelter, its use and functional distribution throughout the festival's history.

Material culture theories by Tim Ingold and I. Hodder made me sensitize to the way material was used at the site. Realizing that "material culture is inseparable from culture and human society", I started gathering literature data on local temporary shelter. typology to form a material catalogue to work with. The data collected via historical literature precedent and interviews with users gave an informed view on the type of space and material needed by the users which opposed the conventional mass-produced system of plastic and fabric tent settlement system found across the globe irrespective of location, environmental and social conditions. The research and data led to an informed decision to use old vernacular earth (clay and sand) material by replacing the old construction technique with new tools like robotic fabrication. This system acknowledges the various theories of material culture like material cycle were in the material is procured from the site i.e.-clay and sand, and moulded according to the needs of the site environmental and social needs. Once the site function is no longer in use the material mix disintegrates in the water which covers the site during rainy season.

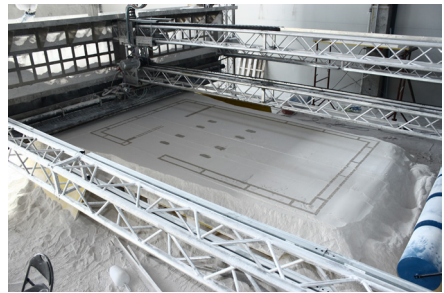
The Thesis stresses on using research via practice based system in order to come up with a design scheme. The architectural engineering track gives me this opportunity as great stress is put on coming up with a detailed scheme which is an amalgamation of research, design and building technology. Robotic Building pushes this idea of research based practice with computation tools and an active lab to test our ideas.

In order to change the archaic design systems currently being employed at the site, it was important to integrate a computational pipeline throughout the design and construction system which gives the designer greater role in achieving parity at all levels of design [macro to micro]. A procedural framework is applied at the master-plan level for fragmentation of the site into smaller units based on local contours data and public movement simulations. This meso data is combined with material investigation to propose a design to robotic production process using local materials for printing the building.

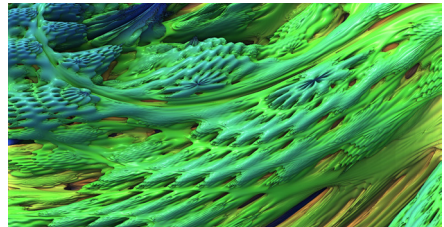
Robotic pipeline [macro -meso -micro]



macro: Robotically molded landscape.
ref: Robotic Landscape, ETH,Zurich



meso: Sand 3d printing particle bed system
ref: Enrico dini, D-Shape



micro: using subdivisional techniques to extract detailing from sand models.

All-though the thesis is context driven and takes the example of an Indian city, the design pipeline includes the contextual parameters and material and social culture to come up with a design system that can be used in different conditions. It strives to demonstrate how these systems can be used for low impact and economical urban design systems. The design systems caters for a large population and hence can be case study for other disaster camps or even large scale festivals. My role as a designer here is to make this procedural system available which can be used as a template to produce different design systems using the same core system replacing the contextual parameters. Using local materials instead of using plastic tents [as can be seen in any temporary system like a refugee, disaster or festival camps] arose from ethical issues as seen at the site in India. The plastic tents are not insulated enough for the cold conditions neither do they give privacy for the inhabitants. Using earth as construction material was a way to include reversibility in the design system which i feel is very important in the professional

framework these days. The sand buildings provides better insulation and stability compared to the plastics tents. This constriction system goes back a long way in India and the middle east. Incorporating this whole system in a procedural framework ensures proper transferability of the thesis for different purposes. Also its important for Architects to not only know how to manage the energy generated and consumed by a building during its working life, but also about that used to create it. Architecture accounts for one third of global carbon emissions, energy consumption and waste. Buildings are increasingly understood to impact broader ecologies. Yet embodied energy – the various forms of energy required to extract raw matter, to produce and transport building materials and to assemble a given building – remains largely underexplored. For this purpose the thesis demonstrates a strategy where the material is formed on site and also disintegrates on site using local materials effectively negating transportation from the energy cycle.



©arav kumar 2020

