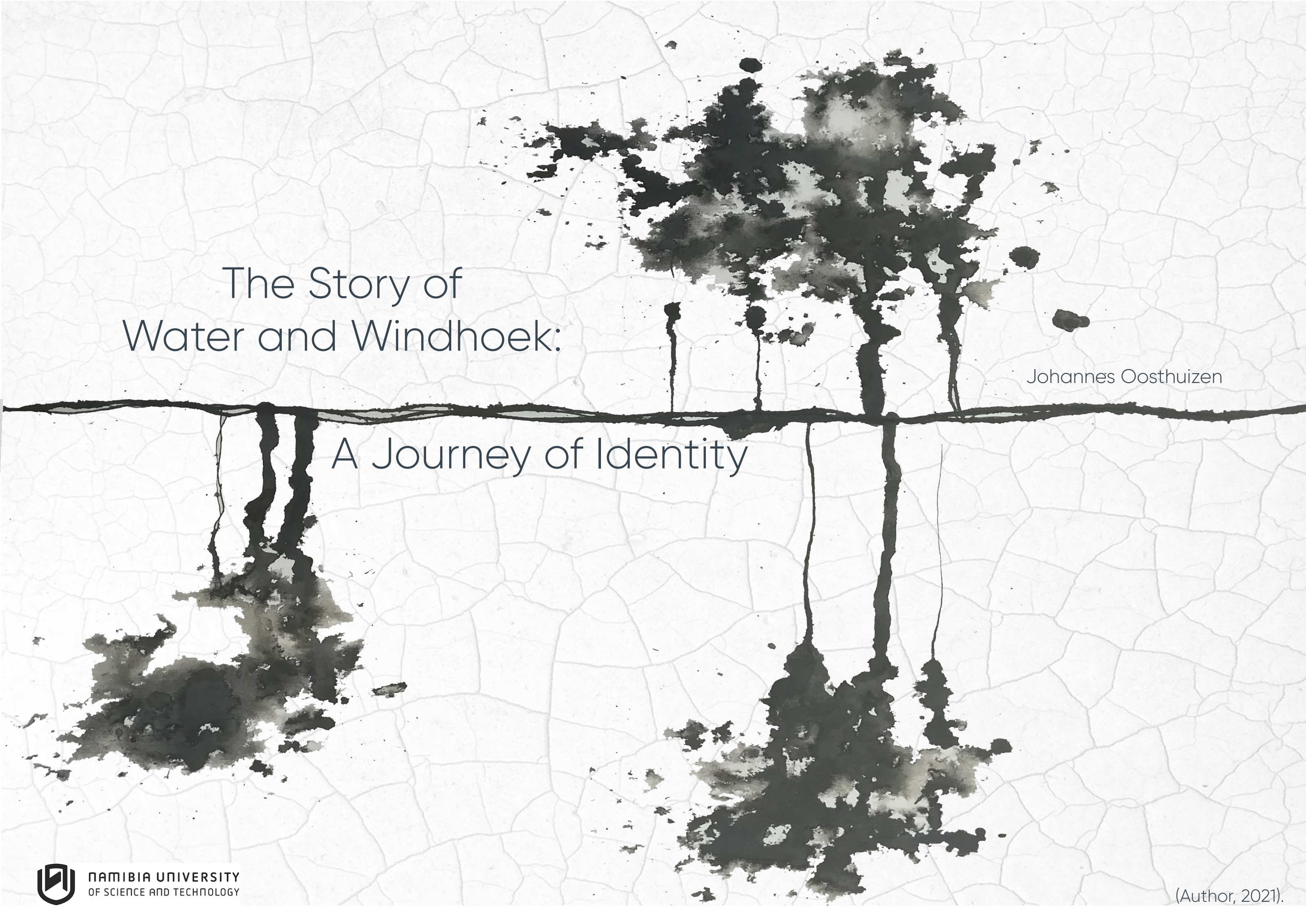




The Story of Water and Windhoek:

Johannes Oosthuizen

A Journey of Identity

The Story of Water and Windhoek: A Journey of Identity

Student: Johannes Augustinus Oosthuizen 214037614

Mini-thesis presented in partial fulfillment of the requirements for the degree of Master of Architecture at the Namibia University of Science and Technology.

Supervisors:

Dr. Madelein Stoffberg; Prof. Jacobus Wasserfall; Dr. Phillip Lühl

June 2022

DECLARATION

I, Johannes Augustinus Oosthuizen hereby declare that the work contained in this mini-thesis, entitled "The Story of Water and Windhoek: A Journey of Identity" is my own original work and that I have not previously in its entirety or in part submitted it at any university or other higher education institution for the award of a degree.

Signature:  Oosthuizen

Date: 13 May 2022

ACKNOWLEDGMENTS

Firstly I would like to honor my Lord and Savior Jesus Christ for giving me the mental capacity and will required to complete this journey. I want to thank my loving wife for her support and patience without which I would not have been able to get as far as I did. My parents played an important role in my interest in architecture and motivated me through the hardest of times. I would also like to give acknowledgment to my In-laws as they too went to great lengths to support me through this time. I also need to credit my close friend Morne Louw for his support. Lastly I would like to praise my Professors; Dr. Madelein Stofberg, Prof. Jacobus Wasserfall and Dr. Phillip Lühl for the wealth of knowledge they have imparted on me as well as their patience and desire to see me succeed.

"When the well is dry, we will know the worth of water."

(Franklin, 1998)

ABSTRACT



Water in Windhoek is scarce and without managing consumption, life will not be feasible for future generations. This thesis will attempt to provide a precedent in water sustainability through the implementation of an architectural intervention into Windhoek's water system. With the aid of the motion picture "Rango", the city's challenges regarding water will be investigated through both a narrative approach as well as a case-study of Windhoek's existing water infrastructure. This could lead to a more sustainable infrastructure design in Windhoek, where the city's inhabitants are aware of their impact on the water system. This research aims to improve awareness of sustainable water use as well as providing a precedent of the integration of a structure with the Pahl fault-line. The building will facilitate water testing and collection as well as archiving important information pertaining to water in Windhoek. The building will provide spaces for experiencing and discussing the above mentioned elements in order to promote learning and awareness. Water shortages in arid cities south of the Sahara are exacerbated by rapid urbanisation and the impact of global climate change. Sustainable, water-focused architecture, will become a future lifeline.

Figure 1: Rango in the beginning (Verbinski, 2011: Rango.).

CONTENT

Chapter 1 4 - 10	Chapter 2 13 - 54	Chapter 3 56 - 74	Chapter 4 76 - 104	Chapter 5 106 - 108	Chapter 6 110 - 112	Chapter 7 114 - 117
Background 5 Problem statement 5 Objectives 6 Significance 6 Methodology: Research Design 7 Literature review 8-10	Windhoek's water system 14 Existing approaches 15 Rango: The story 16 Comic 17-18 Narrative 19 Characters 20 Structure 21 Themes 22 Initial Situation 23-24 Complications: Equality 25-26 Sustainability 27-28 Ecology 29-30 Reaction 31-32 Resolution 33 Final Situation 34 Precedents: Mexico City 35-37 Levanto Water Purification 38-39 The Dwellings 40-41 Site 43-48 Site and Rango 49-50 Clien and brief 51 Programme 52 Intervention 53 Accommodation 54	Touchstone 57-60 Concept Development: -Site 61-68 -Building 69-74	Plans: Locality 77-78 Site 79 Roof 80 Ground floor 81-82 Basement 83-84 Elevations: North and South 85 East and West 86 Sections and details: A 87-88 B 89-90 F and G 91 Walkway section 92 Walkway 93 River Bridge 94 Perspectives 96-104	Conclusion 108	References 111-112	List of figures 115-117

PREFACE



Figure 2: Rango dried-up faucet scene (Verbinski, 2011: Rango.).

You open the faucet in your home and nothing comes. You open another one, but still nothing. You ring up City of Windhoek and they confirm your suspicions. After multiple near misses in previous dry seasons and many warnings about impending drought, the proverbial dam has finally broken. Windhoek is at day 0 with no relief in the foreseeable future. How long will the Jojo tank in the back yard last?

CHAPTER 1

Research

Background	5
Problem statement	5
Objectives	6
Significance	6
Methodology	7
Literature review	8-10

RESEARCH

Background and problem

Background

Namibia is the most arid country south of the Sahara with an average annual rainfall of 360 mm and an annual evaporation rate of 2,170 mm. (Murray, R., Louw, D., van der Merwe, B. & Peters, I. 2018). Historically, settlements were established in the vicinity of water. Similarly Windhoek, the capital of Namibia, was settled due to its surface springs originating from an underground aquifer, the remnant of a prehistoric lake. During the large scale extractions from the aquifer in the 1950s, these springs dried up and water had to be pumped over great distances to meet the growing demand. The ever decreasing annual rainfall and high evaporation coupled with the city's expansion put the water supply at risk and will not be able to support life for much longer (Murray et al., 2018).

Problem

Due to the arid nature and historic patterns of droughts, Windhoek is headed toward severe water shortages as soon as 2025 (Bigen Kuuma & SCE Consulting Engineers, 2020). This is further exacerbated by unsustainable water consumption and pollution of the aquifer/ underground water table by residents due to a lack of knowledge on supply and demand. Urgent intervention is needed to resolve demand chains through sustainable practices.

RESEARCH

Objectives and significance

Objective

Investigation of methods that could promote the sustainable provision of Windhoek's very limited water supply.

The Story of Water and Windhoek aims to achieve the following:

- Exposing the current infrastructural system's impact on the sustainability of Windhoek's water resources.
- Addressing different perceptions caused by inequality in relation to Windhoek's water system.
- Using architecture as a tool for water sustainability to aid in Windhoek's water supply longevity.

Significance

Water in Windhoek is scarce and without managing consumption, future droughts will endanger the economy, create more inequality as well as damage the local ecology. This research aims to provide guidelines for sustainable, future urban expansion of Windhoek where everyone has access to potable water. These findings could be valuable for other Sub Saharan countries and the global south due to rapid urbanisation and the impact of global climate change on more arid regions. The inhabitants of the city as well as the municipality of Windhoek could benefit from improved water security alleviating fears of impending droughts. This research aims to create a basis for future architectural interventions in other urban contexts with similar challenges regarding water and arid climates.

RESEARCH METHODOLOGY

Research Design and Literature Review Summary

Research design

The methodology for the chosen research direction is a case study on the city of Windhoek. This includes mapping of existing water infrastructure and a narrative approach. The narrative is compiled making use of the animated motion picture "Rango" due to the many similarities with Windhoek's water situation (Verbinski, G., 2011). Exploring "Rango" has provided creative insight into possible methods of providing clarity for the layman of the relevance of the research. Patterns identified within Windhoek's water supply and demand will guide the investigation of research questions from multiple opinions and backgrounds. Research will also be conducted on precedents to identify possible solutions applied elsewhere, but Windhoek being as unique as it is will be considered the main case study.

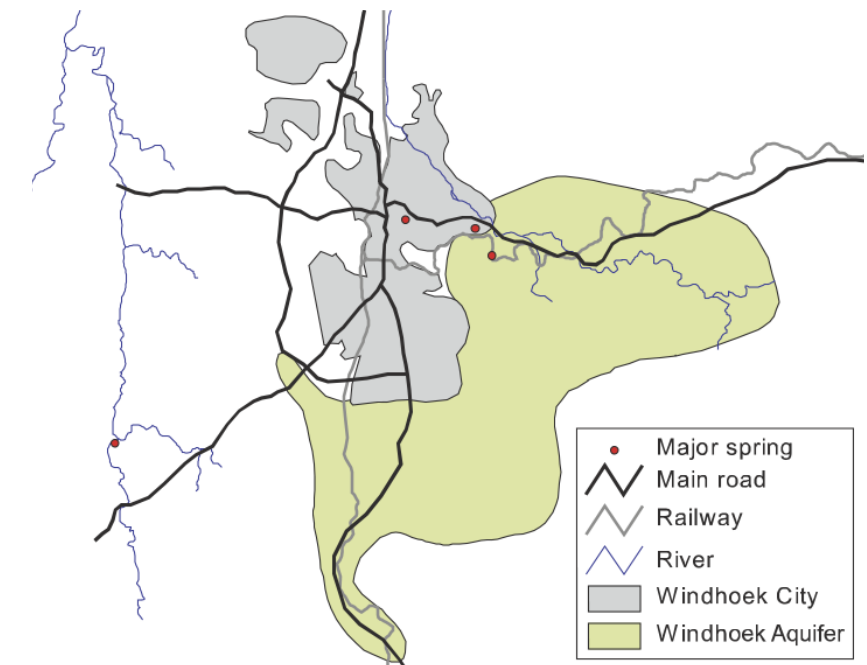


Figure 3: Windhoek's aquifer map (Christelis et al., 2001: pg. 78.).

LITERATURE REVIEW

Water Supply

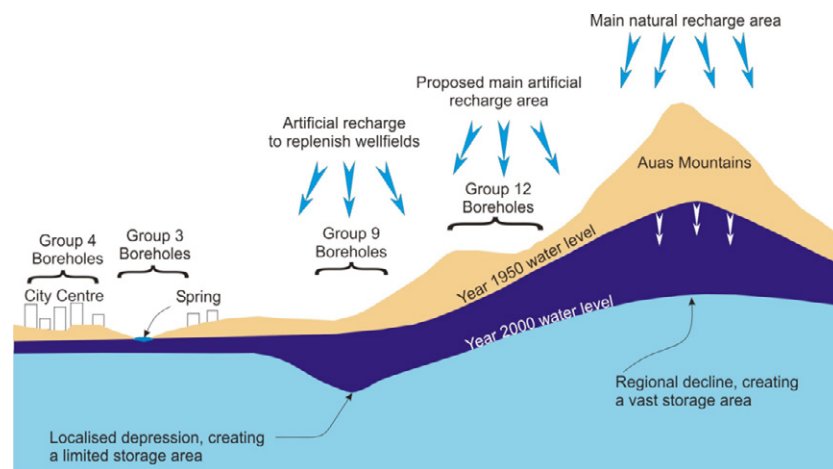


Figure 4: Windhoek's aquifer section (IWA, n.d: online)

The biggest supply concerns of water in Namibia are water loss due to leaks on the national water carrier channels that connects open water sources to cities and the pollution of these sources as well as aquifers (Van Rensburg, 2006). According to Van Rensburg the higher water table resulting from the managed aquifer recharge schemes makes the aquifers even more vulnerable to pollution. Many concerns are due to poor maintenance and a lack of capital. This leads to another concern, the issue of supply promotion instead of demand management. Namibian cities have a finite water supply that is decreasing due to global climate change, thus an effort must be to conserve what we have instead of the unsustainable production of new infrastructure for financial gain (Mapani, 2005).

LITERATURE REVIEW

Water Demand

Magnusson (2005) stated that with the developing world becoming more urbanised, waste and water management in the inevitable unregulated areas is a complex issue that needs to be addressed. She also mentions that global south cities have two systems, regulated and unregulated and that the diversity between them must be approached through policy (Magnusson, 2005). According to Pennington et al. (2005) a major challenge concerning the demand management of water in Namibia relates to the perceptions of the major cities residents regarding the supply. Technology and investment in infrastructure will have little impact if the unsustainable water use of inhabitants is not addressed (Pennington et al., 2005). Many poorer inhabitants of the country do not understand the water systems in the cities and the need for sustainable use. This is due partly to a lack of education of their context and a distrust in those who hold places of power that stems from the apartheid era when the upper class received water of superior quality (Pennington et al., 2005). These factors all lead to pollution of water sources in these communities as well as unsustainable water use. According to Uhlen Dahl et al. (2010) the lack of contextual awareness is not restricted to poorer areas of Windhoek, but can be seen all over the city. He states that the areas with the highest water usage are the higher income areas, luxury resorts and hotels. Uhlen Dahl et al. also states that there is a great gap in equality with regard to water infrastructure in the poorer areas that are the reason for lower water usage. Prepaid systems help reduce water usage but runs the risk of safety during fires and at great inconvenience in daily life (Uhlen Dahl et al., 2010). According to Van Rensburg (2006) Water demand management was a successful part of sustainability in Windhoek but after downsizing the department it no longer has a notable impact. He also states that the municipality plans to invest capital in this area in future to improve effectiveness (Van Rensburg, 2006). Managing the demand is a more sustainable strategy when considering the scarcity of water in Namibia. This can be achieved through educational programs that involves the community (Pennington et al., 2005).

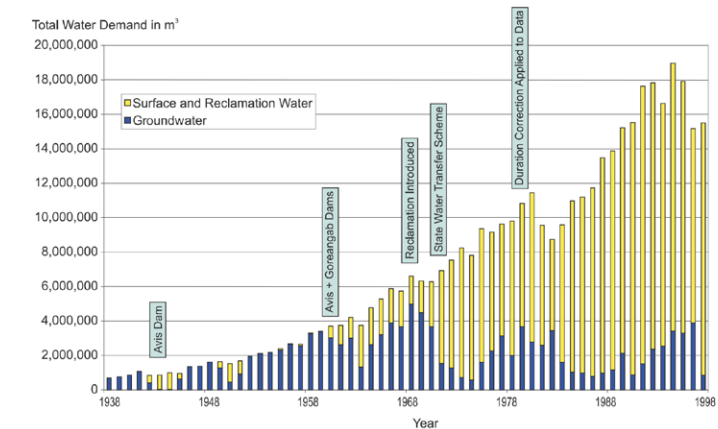


Figure 5: Windhoek's water demand graph (Christelis et al, 2001: pg. 79).

The literature review highlighted two main themes, the supply and demand of water. Supply is managed by both Windhoek's municipality and Namwater, a public enterprise contracted by the Namibian government (Murray et al., 2018). Strengths include new infrastructure that mitigate the effects of drought such as the managed aquifer recharge (MAR) scheme and wastewater reclamation plants. Limitations include major flaws such as leaks in the main water carrier and unsustainable expansion of infrastructure to meet demand. Risks of pollution of the aquifer in the MAR scheme were also discovered (Mapani, 2005). Water demand investigation exposed challenges caused by unsustainable water consumption as well as pollution to these sources. These concerns include over-use of the limited water supply, pollution from both industries and residents as well as shortcomings in the current water demand management system. Many of these challenges point to a lack of awareness and education of the inhabitants of Windhoek on the system and scarcity of water. Issues surrounding different perceptions influencing water and pollution patterns were discovered (Pennington et al., 2005).

CHAPTER 2

Context

Windhoek's water system	14
Existing approaches	15
Rango:	
-The story	16
-Comic	17-18
-Narrative	19
-Characters	20
-Structure	21
-Themes	22
-Initial Situation	23-24
-Complications	25-30
-Reaction	31-32
-Resolution	33
-Final Situation	34
Precedents	35-42
Site	43-48
Site and Rango	49-50
Client and brief	51
Programme	52
Intervention	53
Accommodation	54

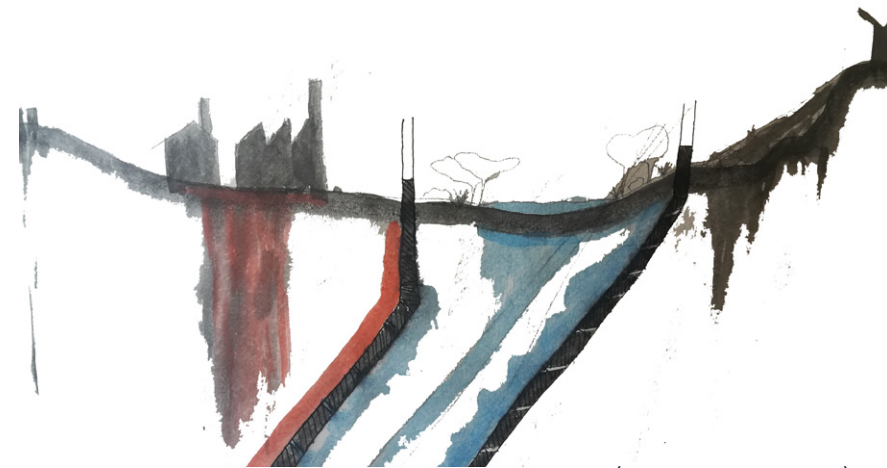
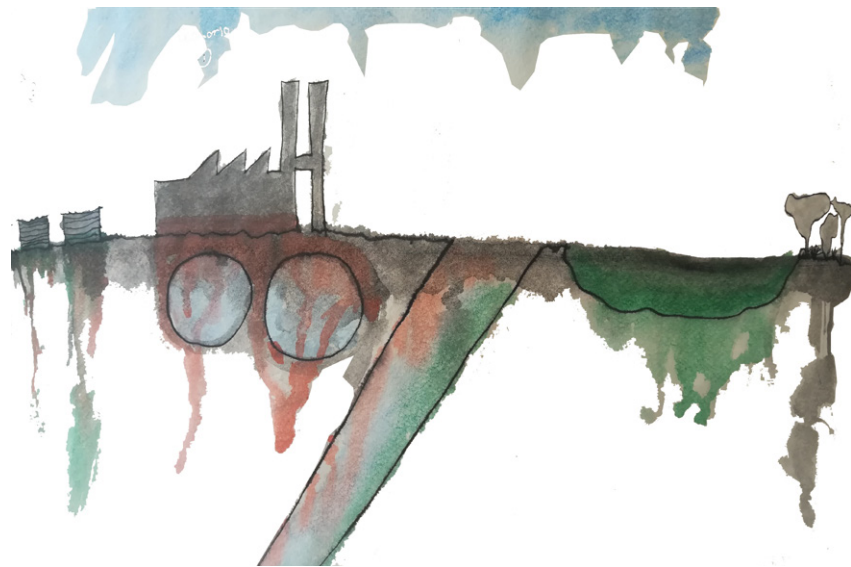
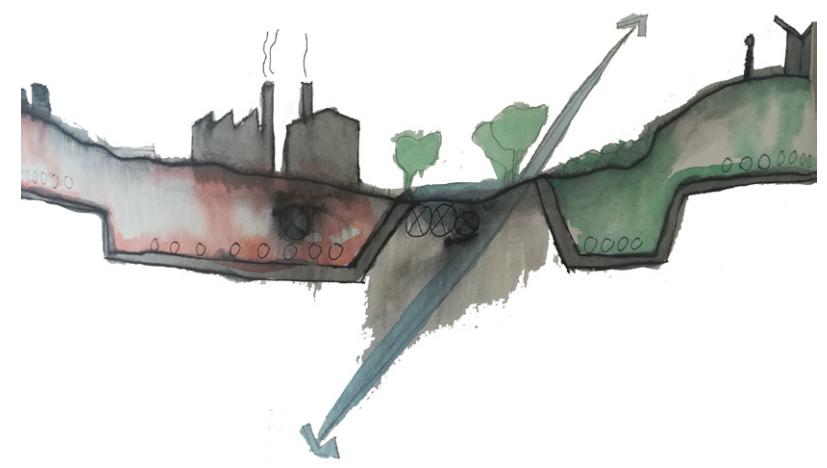


Figure 6: Site exploration in section (author, 2022.).



CONTEXT

Windhoek's Water System

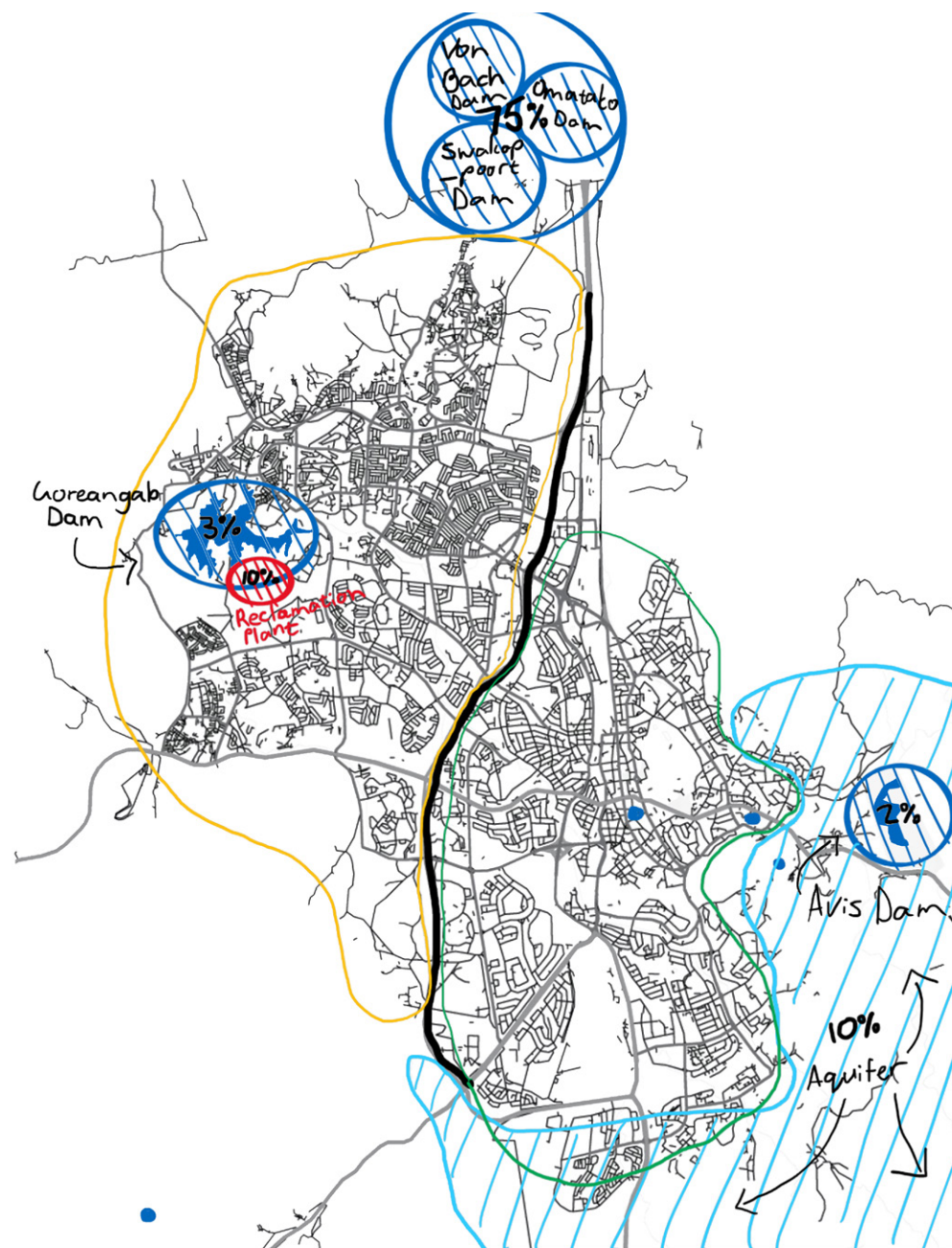


Figure 7: Windhoek's water sources by (author, 2022.).

Windhoek's municipality is responsible for the water infrastructure in Windhoek such as servicing property, the boreholes, reclamation plants and the aquifer. Namwater is in control of the three main dams that supply the city's bulk water (75%), which is mixed with reclaimed water before being sold to residents (Christelis et al., 2011). Windhoek's biggest water conservation methods are the Goreangab waste water reclamation plant as well as the MAR scheme, both run by the municipality (20%). Industrial waste water in the northern parts of the city is treated by the Ujams waste water treatment plant outside Windhoek to prevent contamination of the residential systems (van Rensburg, 2006). According to Murray et al., (2018) the MAR scheme was started due to the extreme evaporation rate in Namibia and aims to pump water from the three main dams into the aquifer for storage and use in critical water shortages. He also stated that the MAR scheme aimed to replenish the aquifer's levels that have been severely exploited since the large scale extractions in the 1950s, which has been successful (Murray, 2018). Tredoux et al., (2009) state that the rock formation under Windhoek left by the prehistoric lake is well suited to hold water without it permeating through the bottom. He does mention a concern about the porosity of the upper layers being susceptible to pollution, this is due to the fault lines that run across the city. The main concerns of this scheme, according to Mapani (2005), include possible pollution of the aquifer if strict measures are not adhered to when injecting and extracting water from the aquifer. The city also reclaims waste water from residential sewage as well as industrial waste with two separate plants. The residential plant has been in place for decades and is part of the reason Windhoek can still sustain life (Christelis et al., 2011).

EXISTING APPROACHES

CoW's Managed Aquifer Recharge Scheme pumps water from the three main dams into the aquifer in good rainy seasons to minimize evaporation. This water is then extracted through boreholes during a drought. CoW's Water Demand Management scheme greatly reduced water use in the city by promoting sustainable practices with posters and fliers distributed throughout the city. Unfortunately the number of people working in this department have been greatly reduced and thus are not as effective currently. The Old and New Goreangab Waste Water Reclamation Plant is one-of-a-kind in regard to the high percentages of potable water it produces from raw sewage. The Ujams Waste Water Reclamation Plant treats all the waste water from the Northern Industrial area of Windhoek using state-of-the-art technology to remove industrial waste. These industries include a brewery, poultry and beef abattoirs, tannery and a maize and wheat refinery. Water tariffs become exponentially more expensive to act as fines for higher water use. Some residents of medium and high income areas are aware of the water situation in the city and have adapted to more sustainable practices. These include recycling shower and laundry water for garden use; collecting the cold shower water in buckets for laundry and dishes; filling swimming pools with rain water collected from roofs; planting gardens consisting of endemic plants and trees (Uhlendahl et al, 2010, & Pennington, 2005).

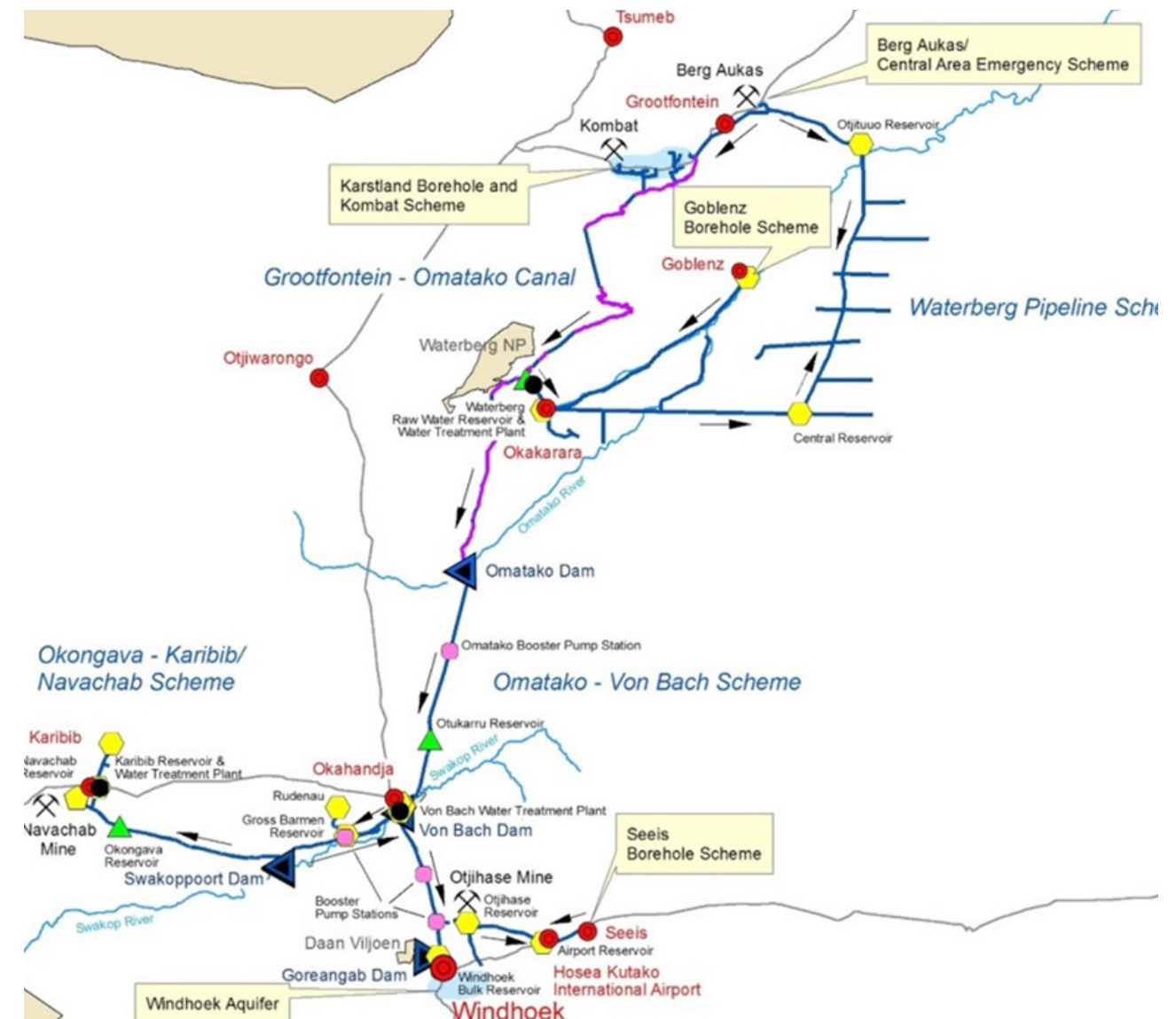


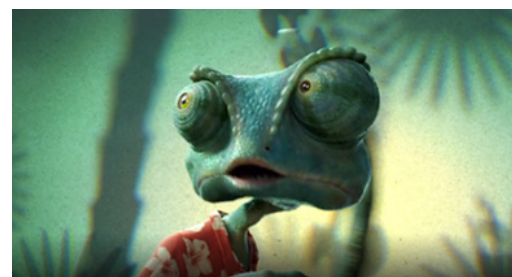
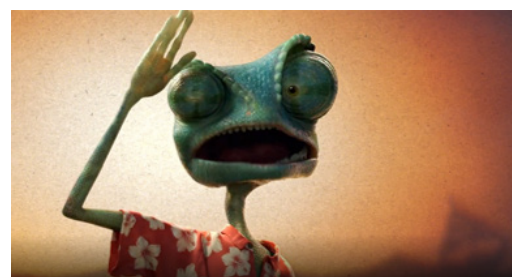
Figure 8: Namibia water supply scheme (LCE, 2016: online.).

THE STORY

A Journey of Identity



In this section the animated motion picture "Rango" will be used as a tool to unpack Windhoek's complex water system and situation. "Rango" was chosen because of the many similarities to the challenges and possible solutions discovered in Windhoek.



Initial Situation
Complications
Reactions
Resolution
Final Situation

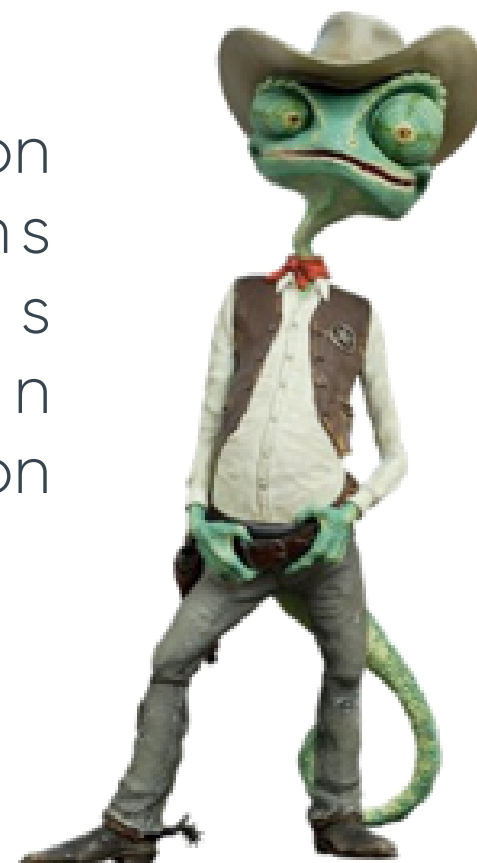


Figure 9: Rango identity development (Verbinski, 2011: Rango.).

COMIC

Scenarios

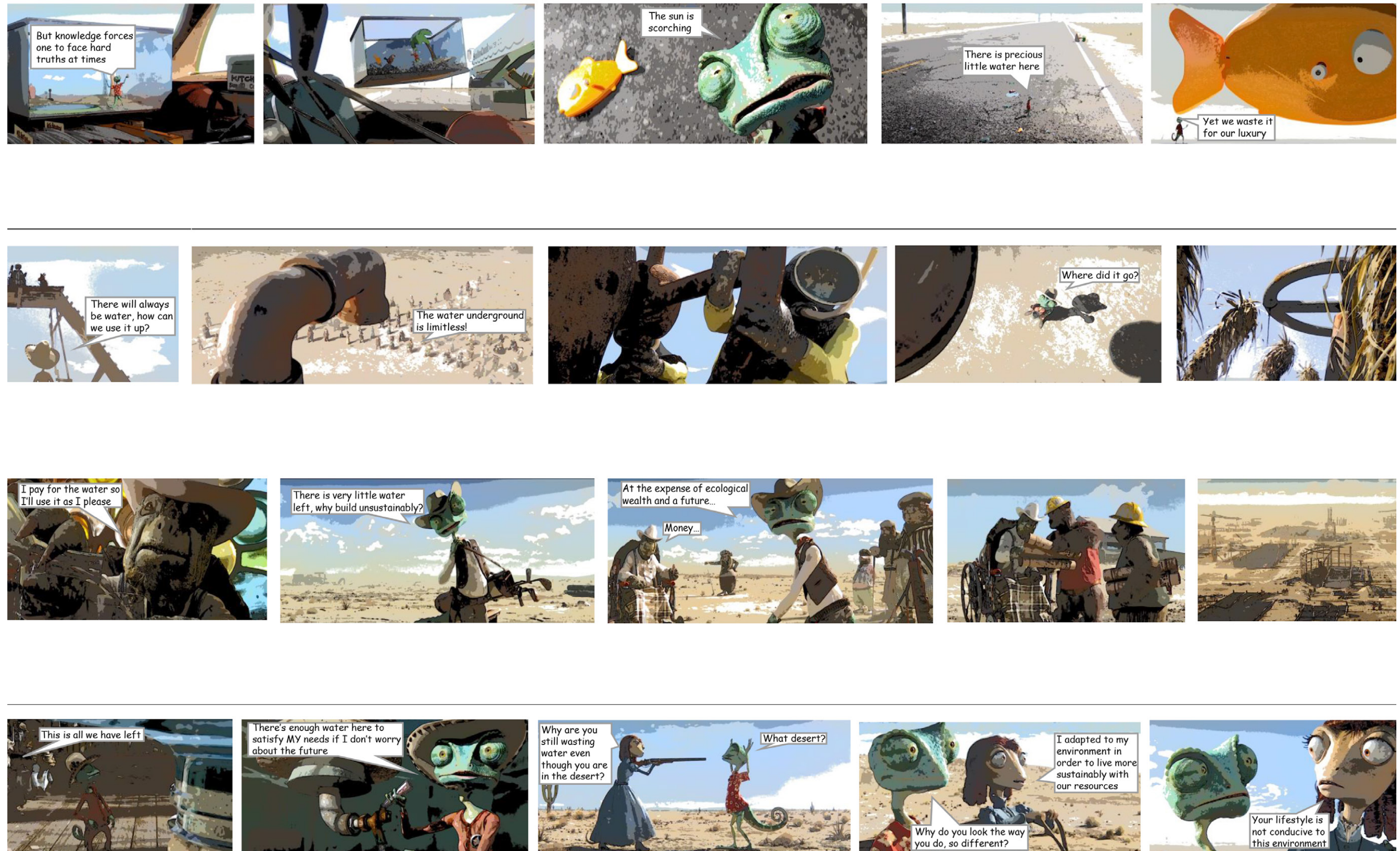


Figure 10: Scenario exploration using Rango (author, 2022: Rango.).

COMIC

Moments of realisation

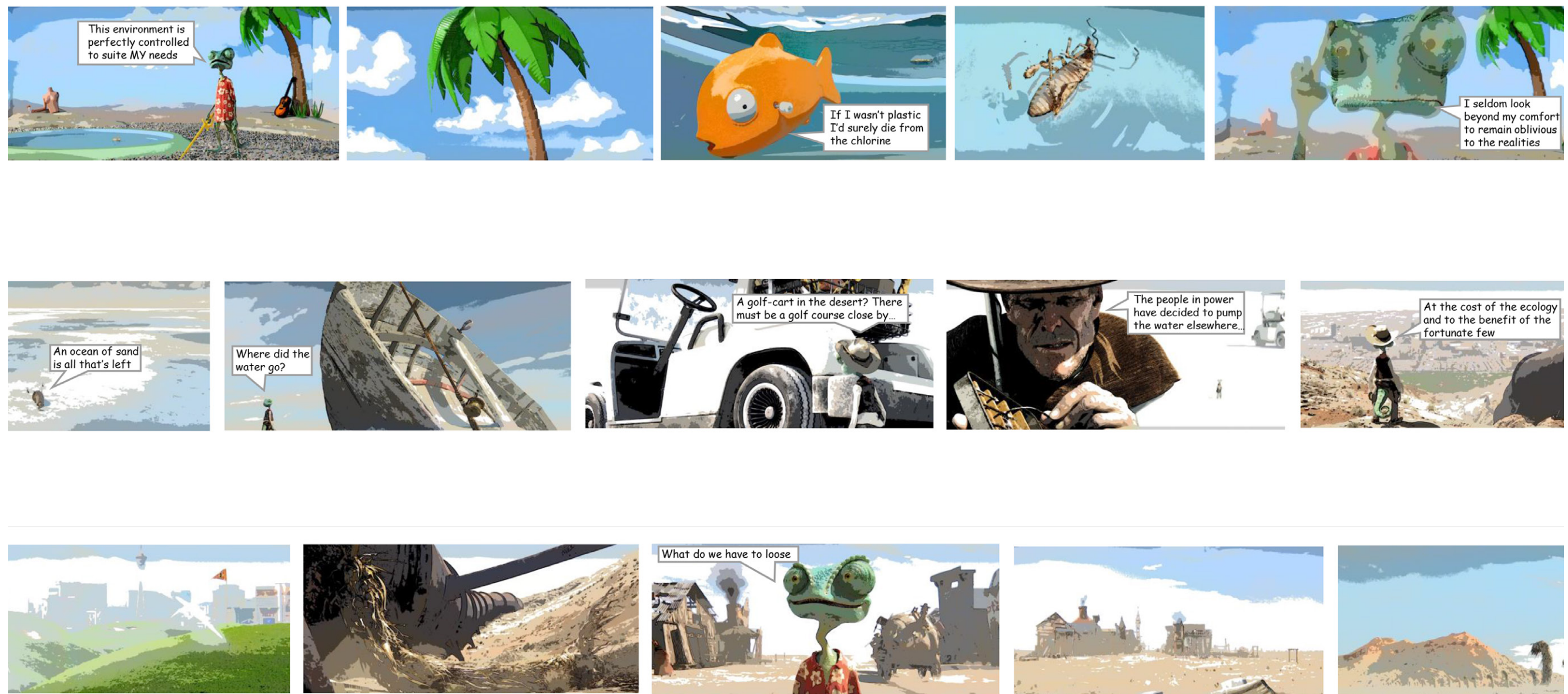


Figure 11: Depicting moments of realisation using Rango (author, 2022: Rango.).

RANGO NARRATIVE

Through the narrative method of site investigation very different insights and concerns were discovered specific to their areas or profession. These include:

The Story

The protagonist is on a literal journey when he is thrown from the comfort of his enclosure into reality which in this case is a desert. He is forced to question his identity in this new environment where he must adapt to survive. Together with other inhabitants of the desert he sets out on another journey to find water that turns out to be diverted away from the town to create a large development. In the end this journey to find water leads to self discovery and purpose.

Plot(Problem Statement)

Villains use and pollute the precious water supply to such an extent that the city is on the brink of another water crisis, at the same time, the victims are already experiencing challenges due to undependable water supply which they are also polluting. The victims do not fully understand their role in the story and also fight for answers. The Heroes try to save the city with unorthodox methods, but without the cooperation of all characters. This is eventually futile.

Characters (Actors)

City of Windhoek Municipality; NamWater; Informal residents; High income Residents; Industry and Factory owners; Environmentalists; Water Engineers.

Scenes (Area of Interest)

Informal settlement (Water Point); Ludwigsdorf and Country Club (private pools and lush gardens); Northern Industry (pollution & Ujams waste water treatment plant); Avis Dam (nature); Goreangab Dam (pollution and new Goreangab waste water treatment plant); The Windhoek water system.

Setting (Context)

Windhoek: Capital to the most arid African country south of the Sahara where the city is already divided. Will differences in water culture divide Windhoek even more?

Themes

Equality; Ecology; Sustainability

CHARACTERS



Rango

Rango represents the protagonist/hero but also unsustainable water use and disregard for the resource, but as he learns of the error in his ways attempts to adapt to a more conducive lifestyle. In many ways Rango IS Windhoek.



Beans

Beans represents the Activist/Environmentalist and sustainability with regard to water use and strives to educate others regarding the value of the resource.



The Common Folk

The Common Folk represents those who are affected the most by water challenges due to poverty and a lack of awareness.



The Outlaws

The Outlaws represents factories and industries that pollute the water system to save costs.



Tortoise John

Tortoise John represents the policy making authority that has been corrupted/negligent and only focuses on personal financial gain from the misuse of water resources. (CoW, NamWater).

Figure 12: Rango characters (Verbinski, 2011: Rango.).

STRUCTURE

Informal Residents

They perceive the cost of water to be too high and want water to be free. The distance to communal water points is great and they say that water tastes different than in formal areas. The lack of maintenance of water infrastructure in these areas concern the residents as well as the tampering and leaks. There are fire concerns connected to the prepaid water system in these areas as a fire cannot be extinguished if the water point is too far. They also want indoor plumbing and not water points due to the socio-economic appearance. These residents are under the impression that water is abundant due to the water usage culture they see in high income areas.

High income Residents

Some of these residents see water as property being paid for and thus can use it how they please, but others save water and recycle because they are aware of the current situation. Most of these residents have water purification systems in their homes and consider the water quality lacking. Many of them keep pools closed to limit evaporation and some use rain water to supplement demand.

Environmentalists

These people have concerns about new development happening on top of aquifer, pollution in Northern Industrial area and general aquifer pollution. They support demand management over infrastructure generation and promote sustainable water use practices by residents.

Water Engineers

They have concerns pertaining to leaks on the eastern water channel (carrier), the northern industrial area's waste disposal and capital costs of maintaining the aging infrastructure. These people are also concerned by Goreangab dam's polluting contaminating Swakoppoort dam as well as the rivers in Windhoek. Their main concern is that NamWater and CoW have different goals/objectives that creates unsustainable conflict and the uncontrolled pollution and expansion of informal settlements surrounding Windhoek.

THEMES

The three main themes identified through the “Rango” narrative exploration are **sustainability**, **equality** and **ecology**. In the next section these themes are unpacked in relation to Windhoek’s current water situation in order to demonstrate the similarities. The solutions to the challenges faced in “Rango” are integrated into the final architectural reaction to the local challenges.



Figure 13: Rango equality scene (Verbinski, 2011: Rango.).

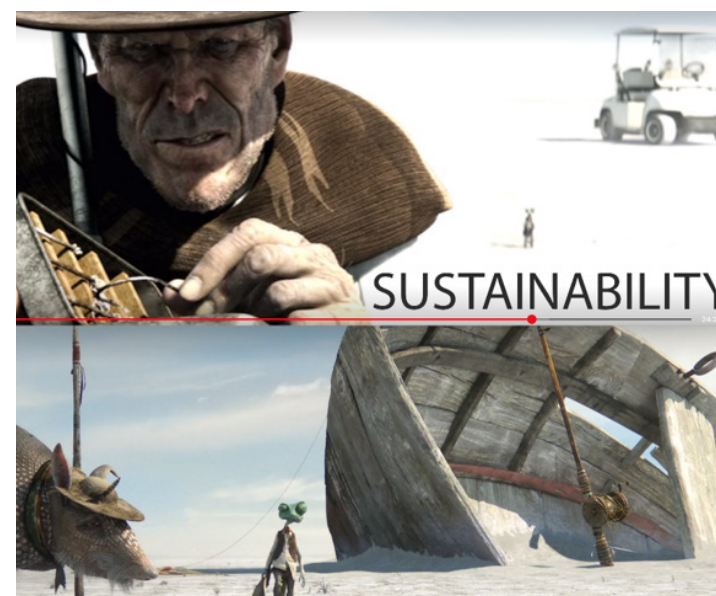


Figure 14: Rango sustainability scene (Verbinski, 2011: Rango.).



Figure 15: Rango ecology scene (Verbinski, 2011: Rango.).

INITIAL SITUATION

The Initial Situation in "Rango" entails the protagonist's forceful eviction from his comfortable, artificial surroundings into harsh reality. The contrast between the two scenarios that relate to Windhoek is that of the blissful perception of water security when in reality the city is on the brink of drought.



Figure 16: Rango desert scene (Verbinski, 2011: Rango.).

An image from early in the movie where Rango questions his identity while looking beyond his comfort. This is the moment before he is thrown from the vehicle into the desert reality.

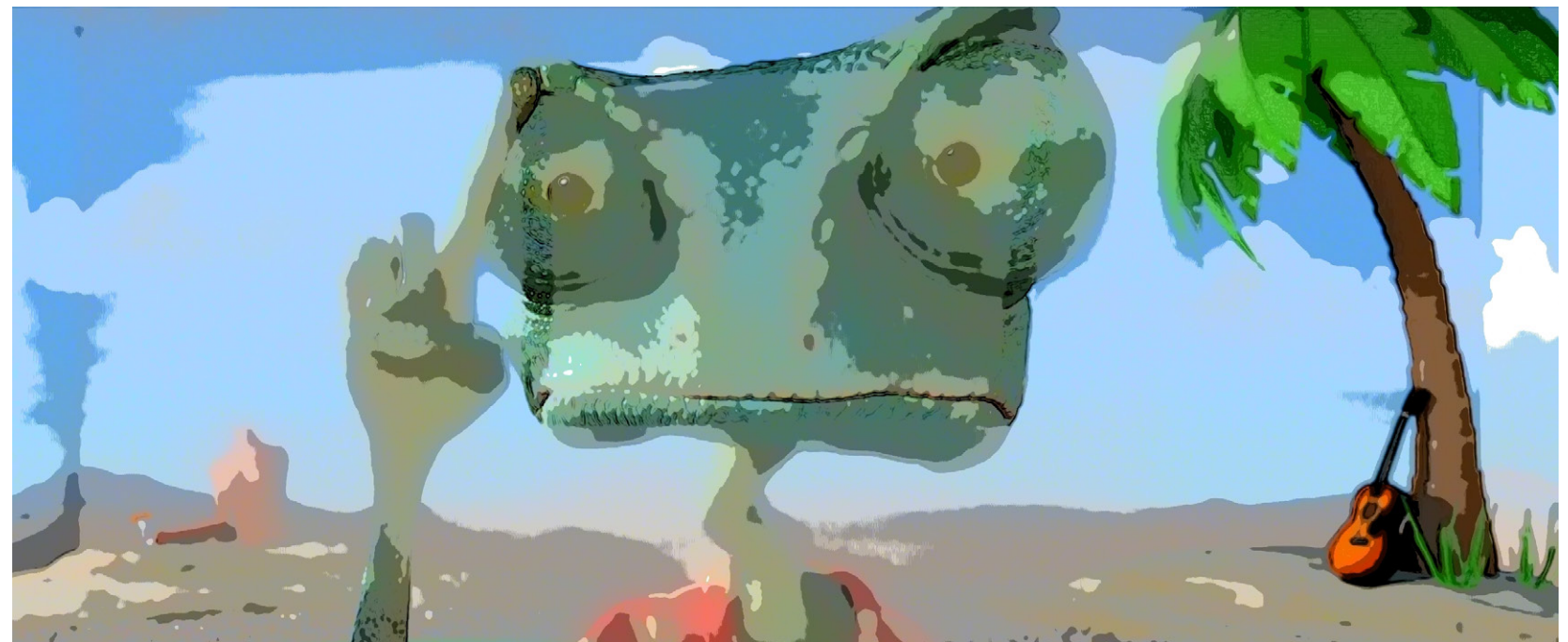


Figure 17: Rango enclosure scene (Verbinski, 2011: Rango.).

INITIAL SITUATION

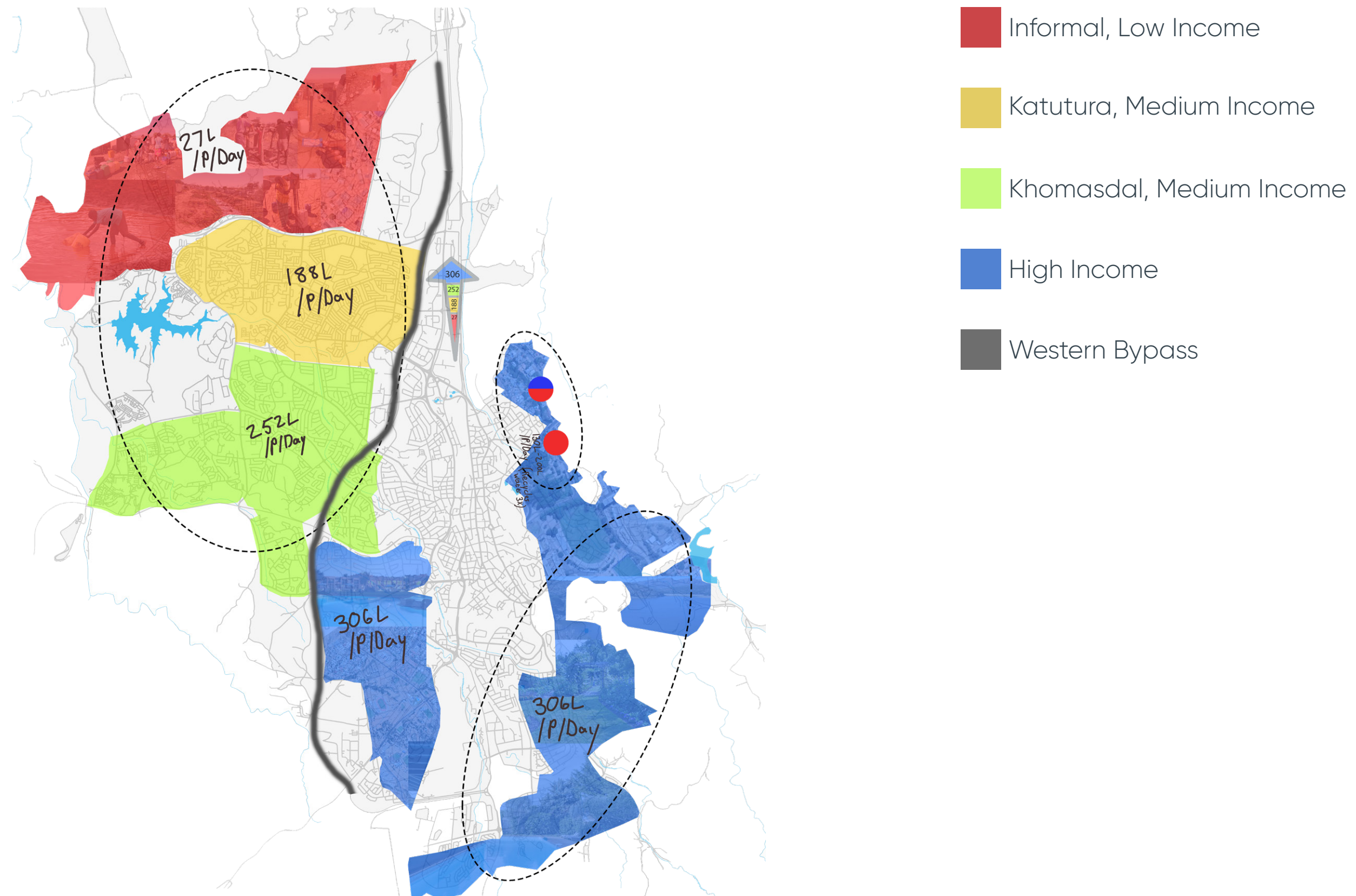


Figure 18: Windhoek water consumption by income (author, 2022.).

COMPLICATIONS

Equality

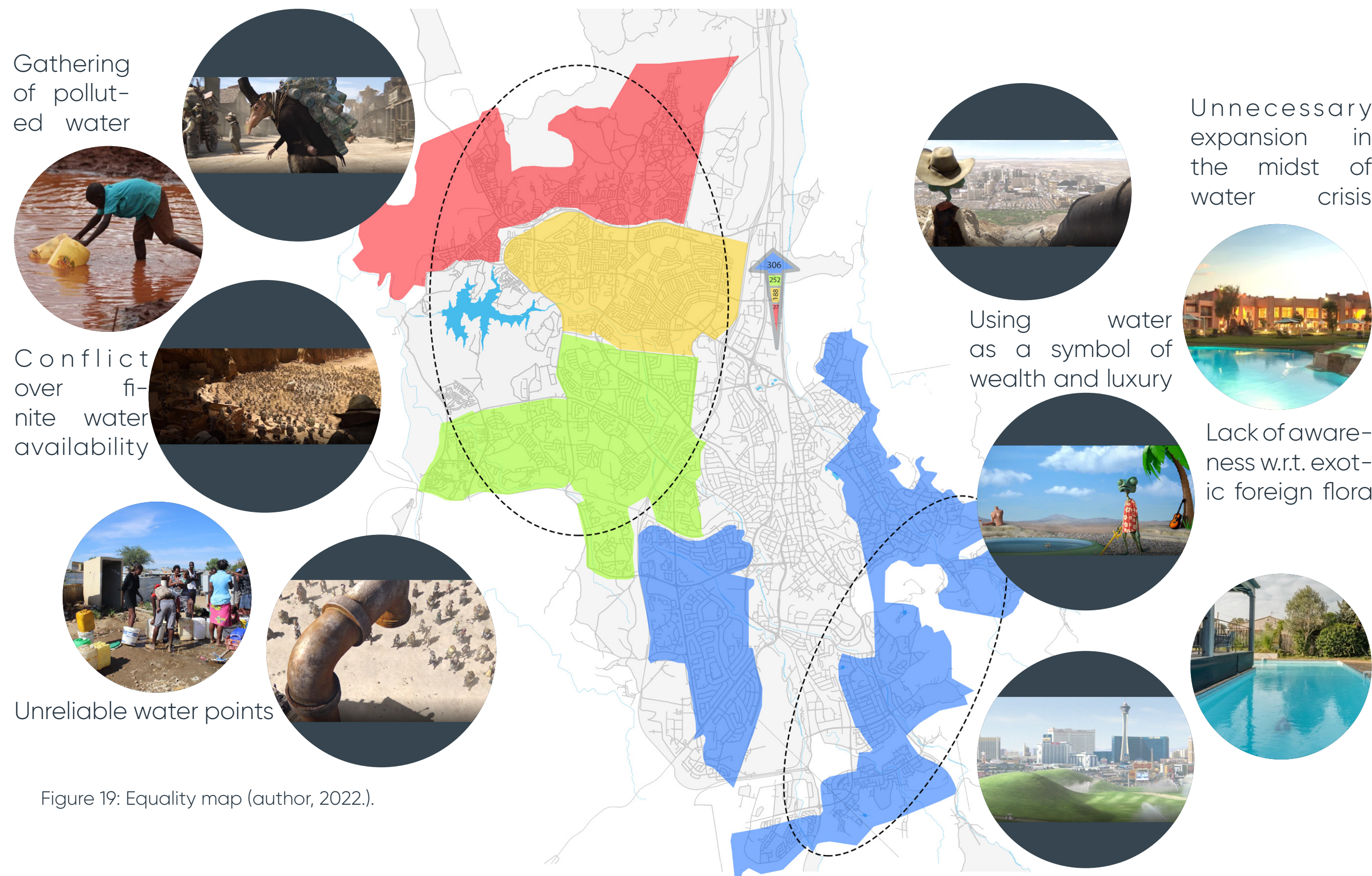
A city divided by income and the Western Bypass is also segregated by water availability and perception. On the eastern side water is regarded as a given and is used for leisure. On the western side water supply is scarce and undependable for people that struggle to survive.



Figure 13: Rango equality scene (Verbinski, 2011: Rango.).

COMPLICATIONS

Equality



COMPLICATIONS

Sustainability

Unprecedented population increase in urban centers in developing countries is putting increasing strain on natural resources, Windhoek is no different. The city is on the brink of serious water shortages due to the ever-increasing demand caused by the influx of people looking for a better future. This trend is unsustainable and the City of Windhoek Municipality is looking at energy intensive desalination as the only solution. The focus is thus shifted from demand management to supply increase due to the financial incentive of selling more water, water that we don't have.



Figure 14: Rango sustainability scene (Verbinski, 2011: Rango.).

COMPLICATIONS

Sustainability



COMPLICATIONS

Ecology

Overuse of the finite water supply and pollution thereof from factories and the unserviced informal settlement, will lead to future droughts as well as irreparable damage to ecology. Sensitive aquifer ecology is at great risk from groundwater pollution which puts Windhoek's emergency water reserve in peril. Surface pollution puts wildlife as well as people at risk of illness and death, all of which could have a long term impact on the ecosystem.



Figure 15: Rango ecology scene (Verbinski, 2011: Rango.).

COMPLICATIONS

Ecology

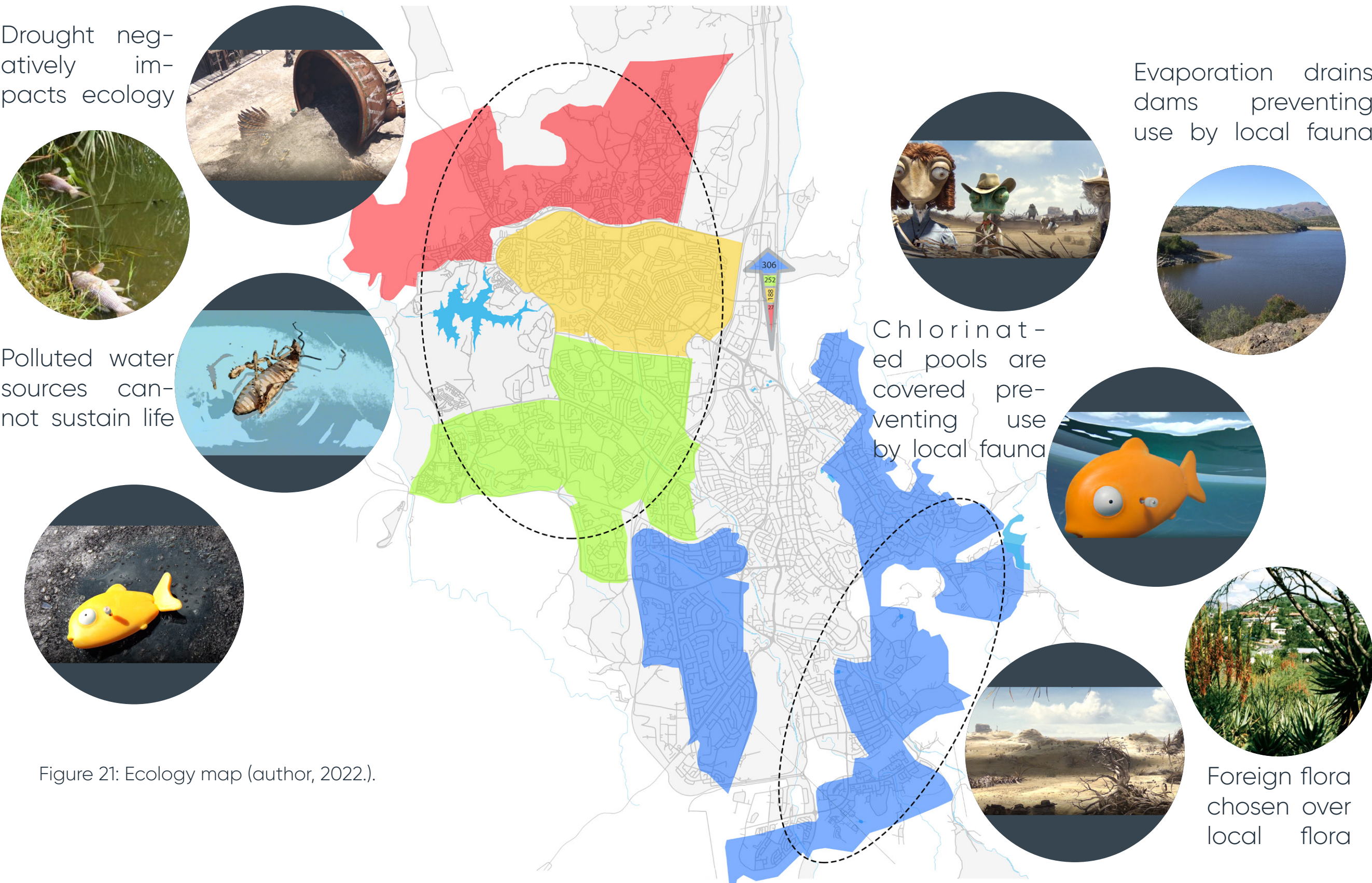


Figure 21: Ecology map (author, 2022.).

REACTION

The reaction phase in "Rango" entails the protagonist rallying the Common Folk and Beans to fight against injustice and inequality surrounding the water crisis.



Figure 22: Rango pipe reconnection scene (Verbinski, 2011: Rango.).



Figure 23: Rango spigot opening scene (Verbinski, 2011: Rango.).

REACTION



Figure 24: Ujams (LCE, 2016:online.).

In Windhoek's situation the reaction is aquifer recharge, demand management through education, transparency from stakeholders and sustainable water practices.



Figure 25: Water queue (The Guardian, 2018: online.).

RESOLUTION

The resolution to the complications in the movie was achieved through the whole community's unification against Tortoise John (NamWater & City of Windhoek) and Rattle Snake Jake (Polluting factories). This was only possible due to the character transformation undergone by the protagonist (Rango). His discovery of identity leads to a shared vision among the inhabitants of the town that resulted in actions that saved them. The final situation of the movie is a once dried-up town returning to the flood plains it once was.

An image from the moment Rango realises his role in the story and rallies the community to take action against the outlaws. This image is seen through the eyes of someone looking through glass at Rango in his new environment that he has finally adapted to.



Figure 26: Rango spring scene (Verbinski, 2011: Rango.).



Figure 27: Rango dry lake scene (Verbinski, 2011: Rango.).

FINAL SOLUTION



Figure 28: Rango spring scene (Verbinski, 2011: Rango.).

In "Rango" the final solution scenario is that of excess water returning from the underground system, which in this case is a pipeline that was previously diverted. When considering Windhoek's context this could be the aquifer being replenished to its former glory where it would re-establish springs along the fault line.



Figure 29: Rango abundant water scene (Verbinski, 2011: Rango.).

PRECEDENTS

Mexico City

Levanto Water Purification Plant

The Dwellings

PRECEDENTS

Mexico City

SEQUENCE OF THE LAKE-CITY RELATIONSHIP

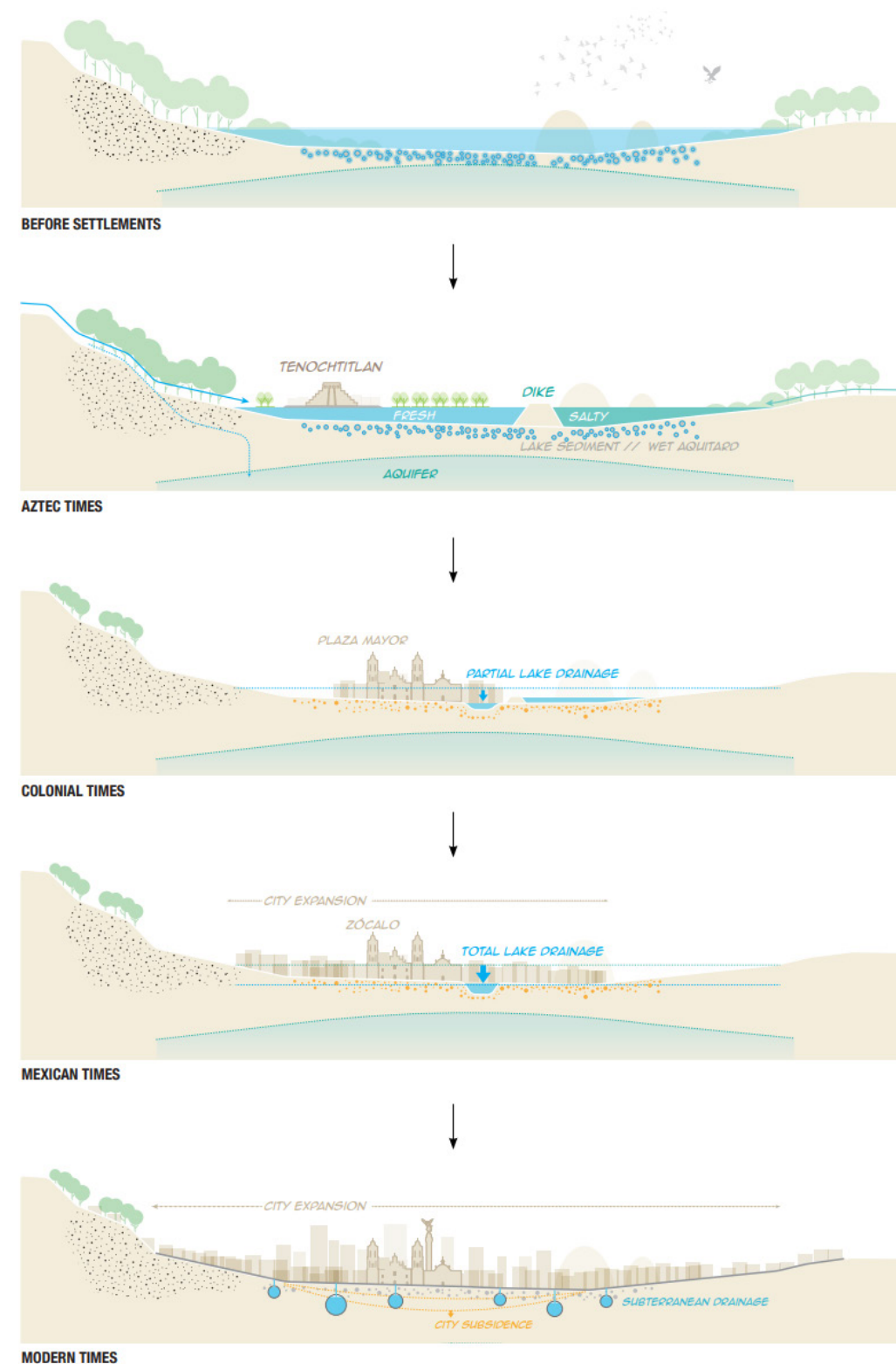
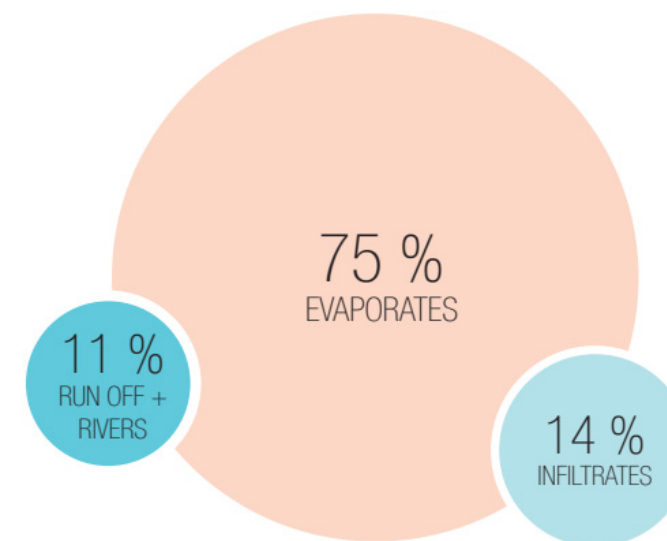


Figure 30: Historical transformation (Boer & Marín, 2015: online).

Mexico City has many similarities to Windhoek especially in regard to water shortages and origin. Like Windhoek, Mexico City was settled due to the lake and aquifer on which the city was eventually built. After years of over-extraction of the water source, the city started to face shortages and global climate change exacerbated this even further. Given Mexico City's high evaporation rates no surface water sources are a viable solution, even with excessively high annual rainfall. This has led low income residents to implement their own rainwater harvesting methods (Boer & Marín, 2015).



(Figure 31: Water loss, Boer & Marín, 2015).

PRECEDENTS

Mexico City

What was learned

Even with high rainfall, poor demand management and inappropriate infrastructure can still lead to water shortages. In Mexico's scenario education to improve general awareness and public forums could support the current water system and possibly lead to sustainable solutions.

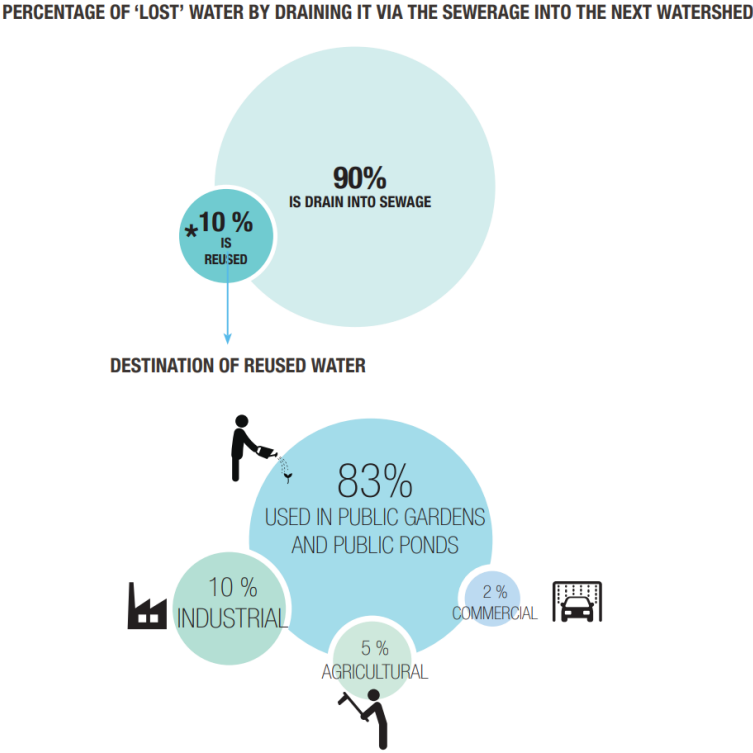
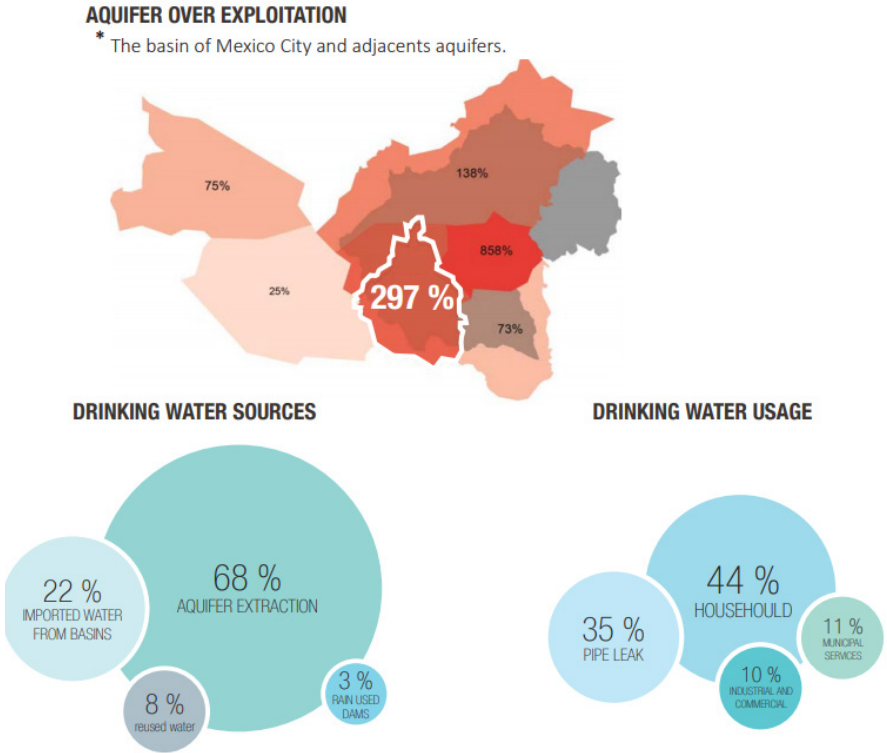
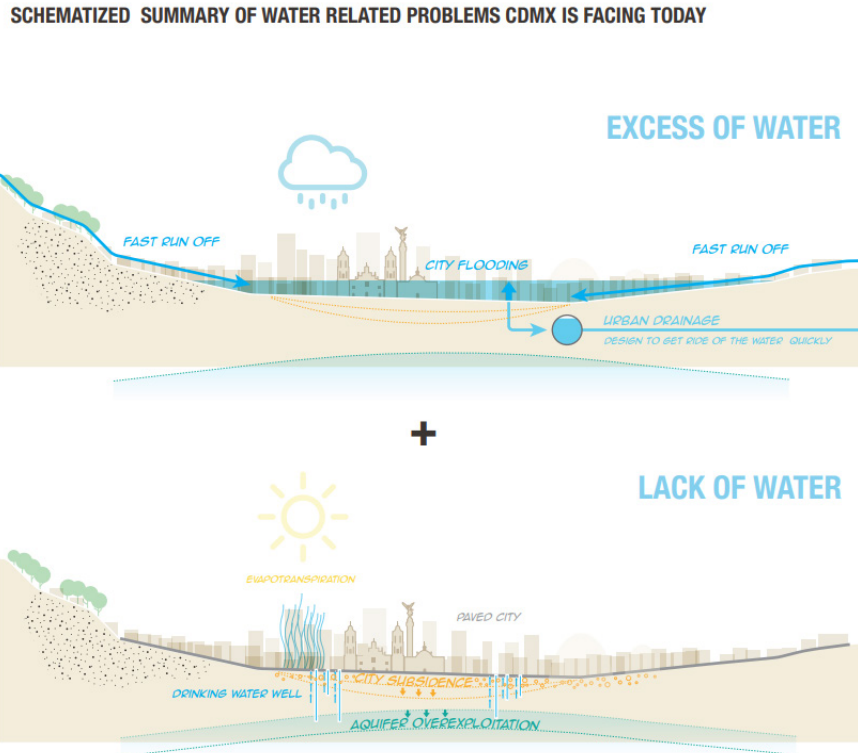


Figure 32: Two scenarios (Boer & Marín, 2015: online.). Figure 33: Water distribution (Boer & Marín, 2015: online.). Figure 34: Water waste (Boer & Marín, 2015: online.).

PRECEDENTS

Mexico City

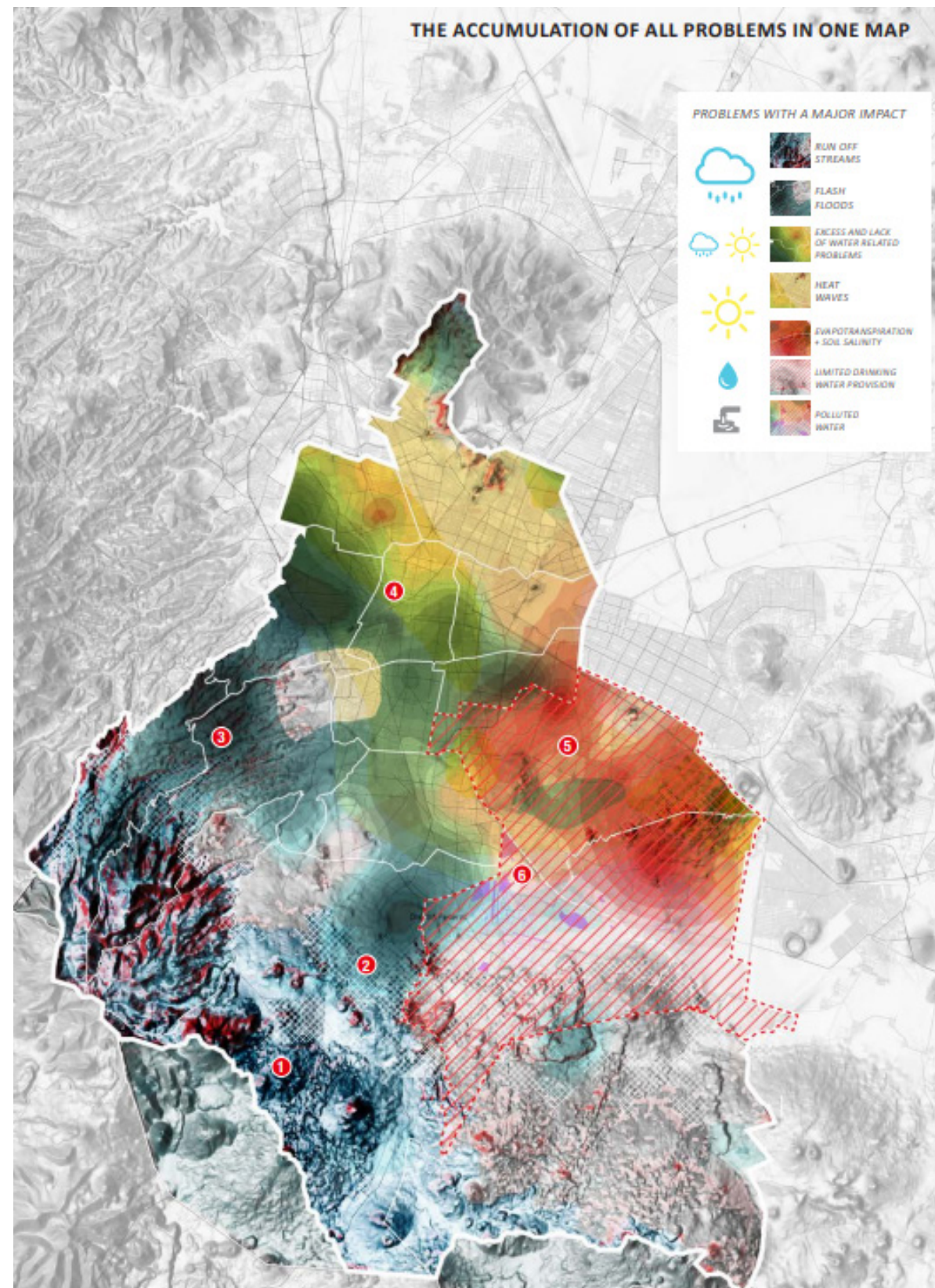


Figure 35: Problems (Boer & Marín, 2015: online.).

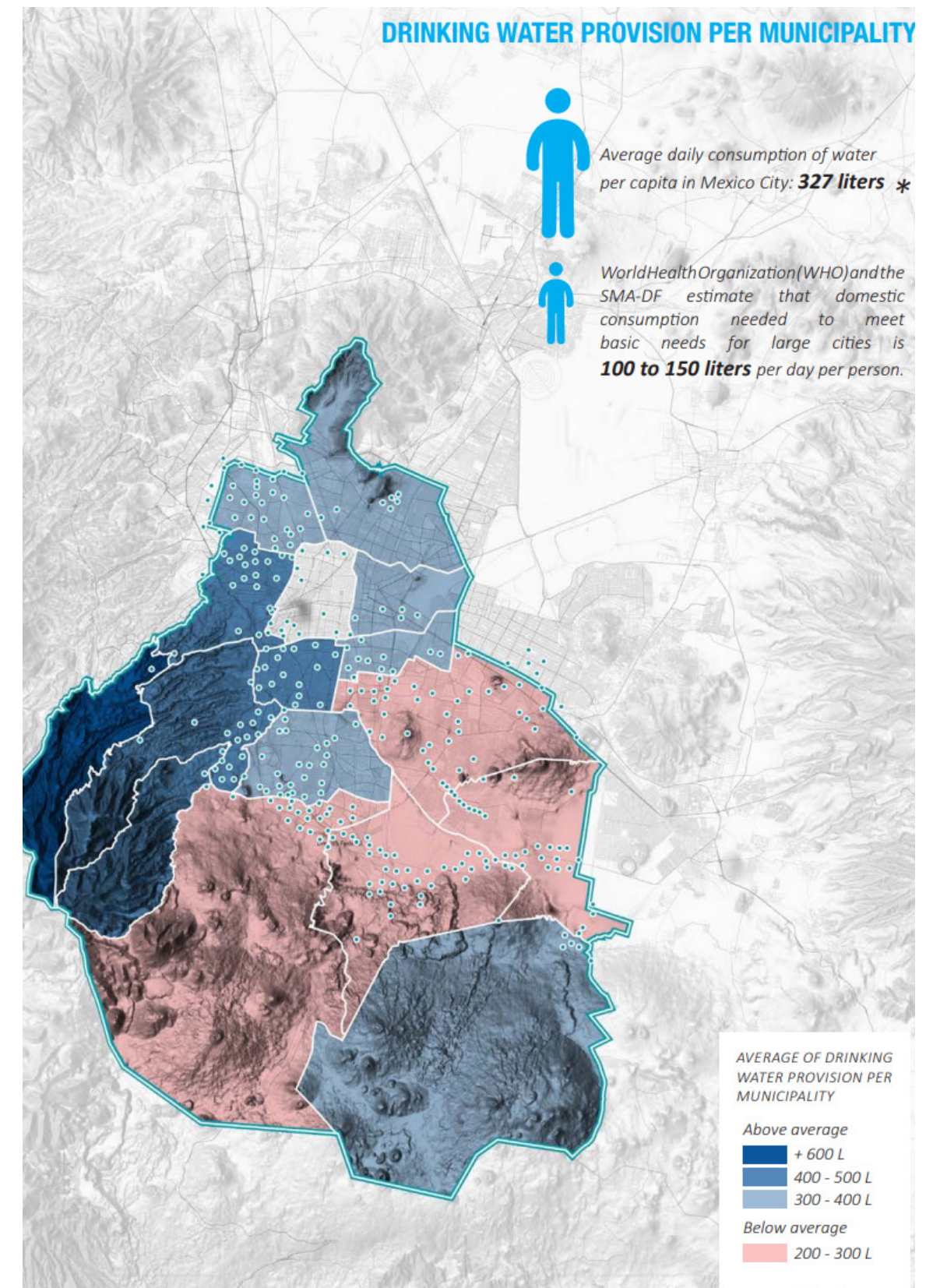


Figure 36: Water provision (Boer & Marín, 2015: online.).

PRECEDENTS

Levanto water purification plant: Italy

Levanto Water Purification Plant is a publicly accessible building which aims to educate local residents of the importance of water management. The structure is integrated into the landscape and boasts a well-used set of public spaces (Archdaily, 2016).

What was learned

This precedent shows that technical aspects can be separated from public and administration functions, but still function as a cohesive unit. The building showcases it's function by cutting into the landscape from which it extracts water.

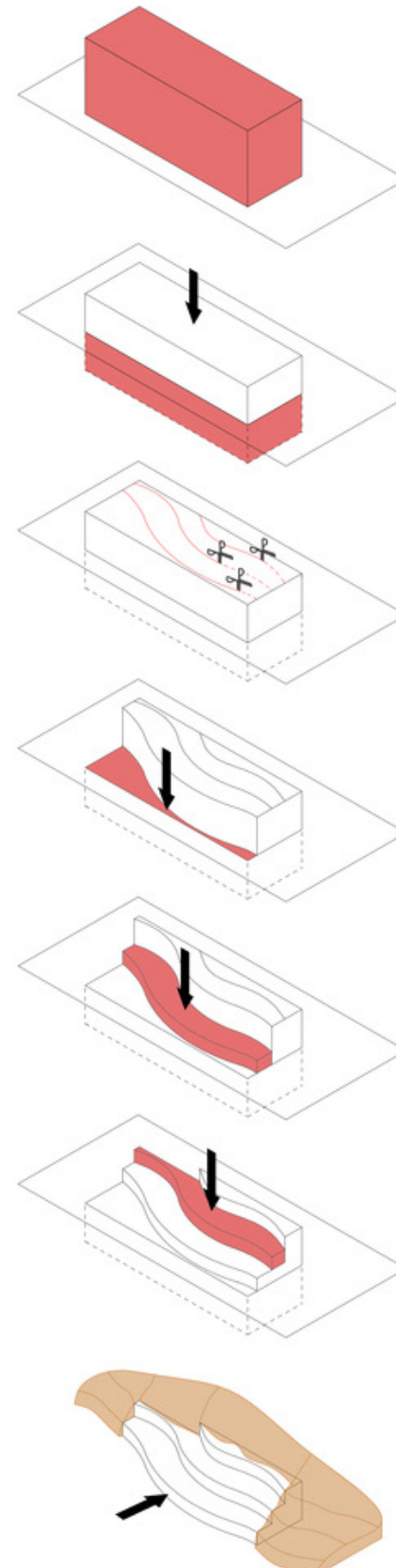


Figure 37: Morphology (Archdaily, 2016: online.).



Figure 38: Site (Archdaily, 2016: online.).



Figure 39: Ground floor plan (Archdaily, 2016: online.).

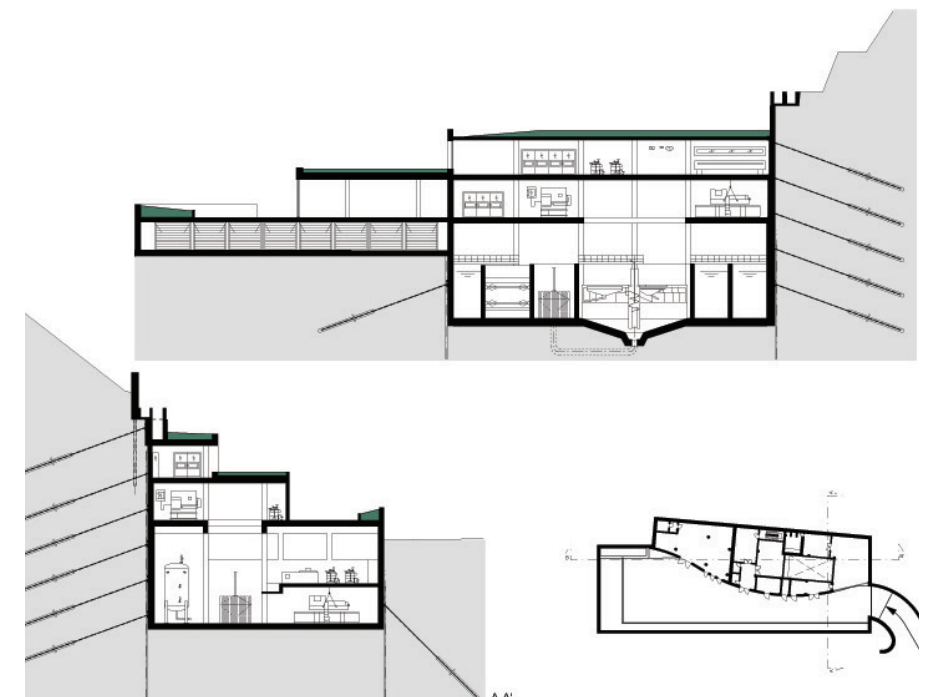


Figure 40: Sections (Archdaily, 2016: online.).

PRECEDENTS

Levanto Water Purification Plant



Figure 41: Photo from water (Archdaily, 2016: online.).



Figure 42: Photo of background (Archdaily, 2016: online.).



Figure 43: Photo from public space (Archdaily, 2016: online.).



Figure 44: Photo of treatment area (Archdaily, 2016: online.).

PRECEDENTS

The Dwellings: Israel

The Dwellings is a thesis project by Tulane Grad Yara Hantash which explores an architectural solution to the Israeli-Palestinian conflict by making use of the subterranean. The proposed intervention in short, is an underground refuge including all the amenities required to sustain life without the need to surface. The concept was derived from existing tunnels that cross the border of the two countries (Archinect, 2020).

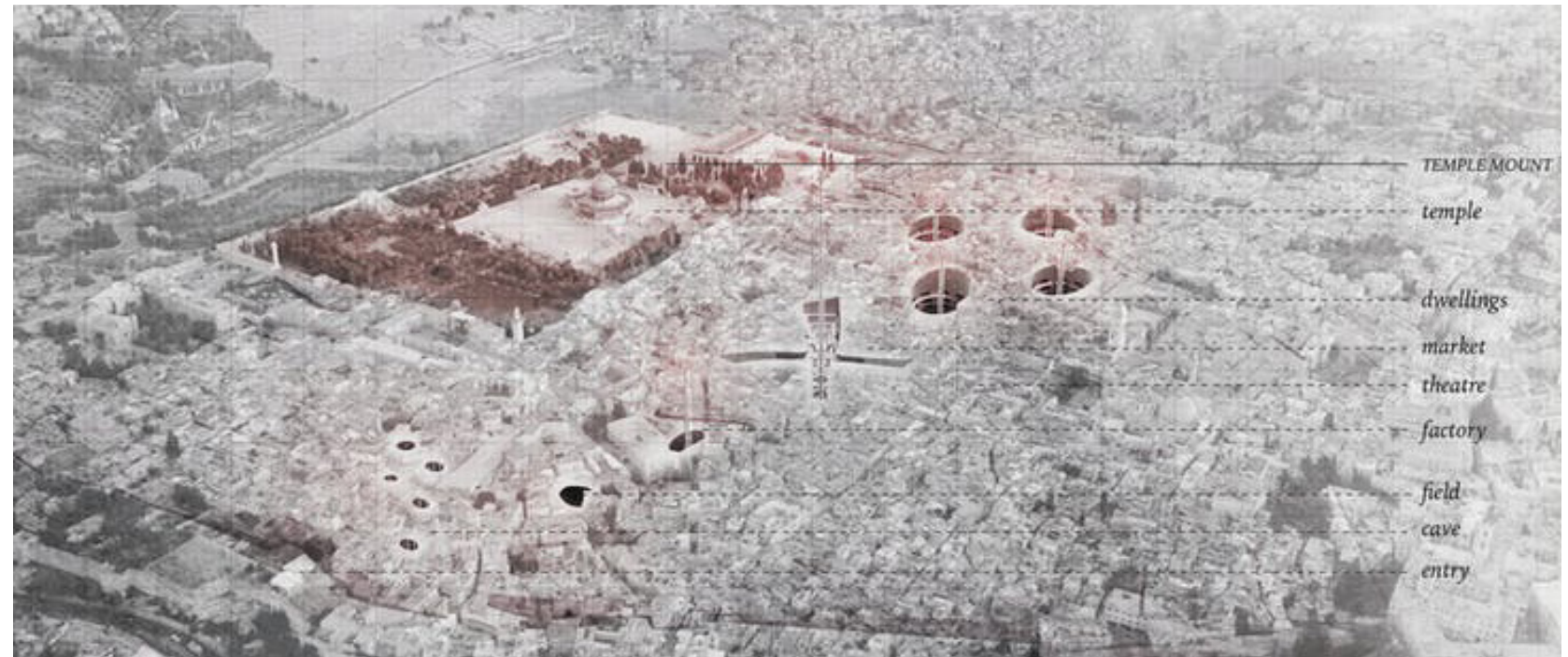


Figure 46: On the surface (Archinect, 2020: online.).



Figure 45: Existing tunnels (Archinect, 2020: online.).

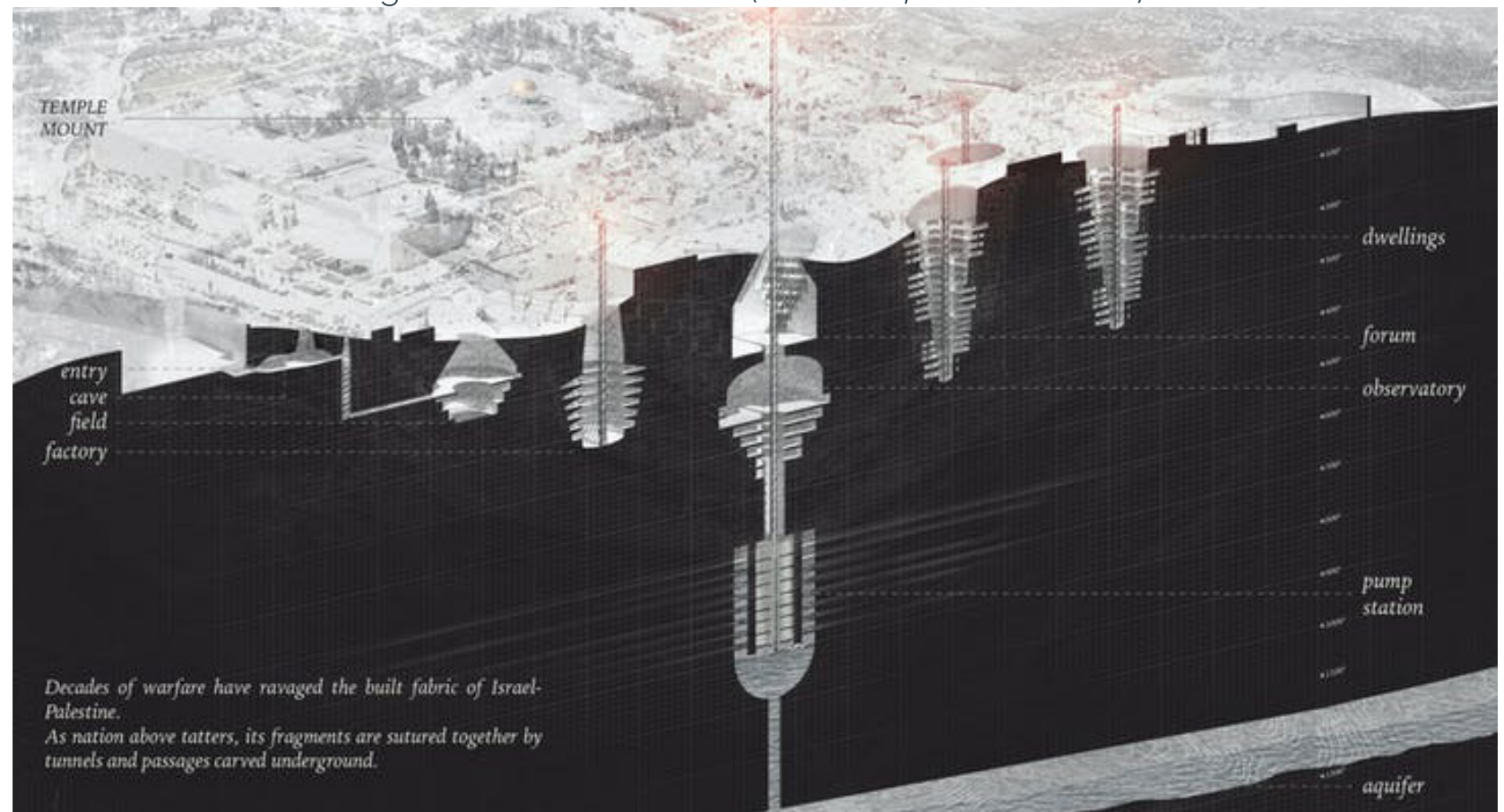


Figure 47: Beneath the surface (Archinect, 2020: online.).

PRECEDENTS

The Dwellings

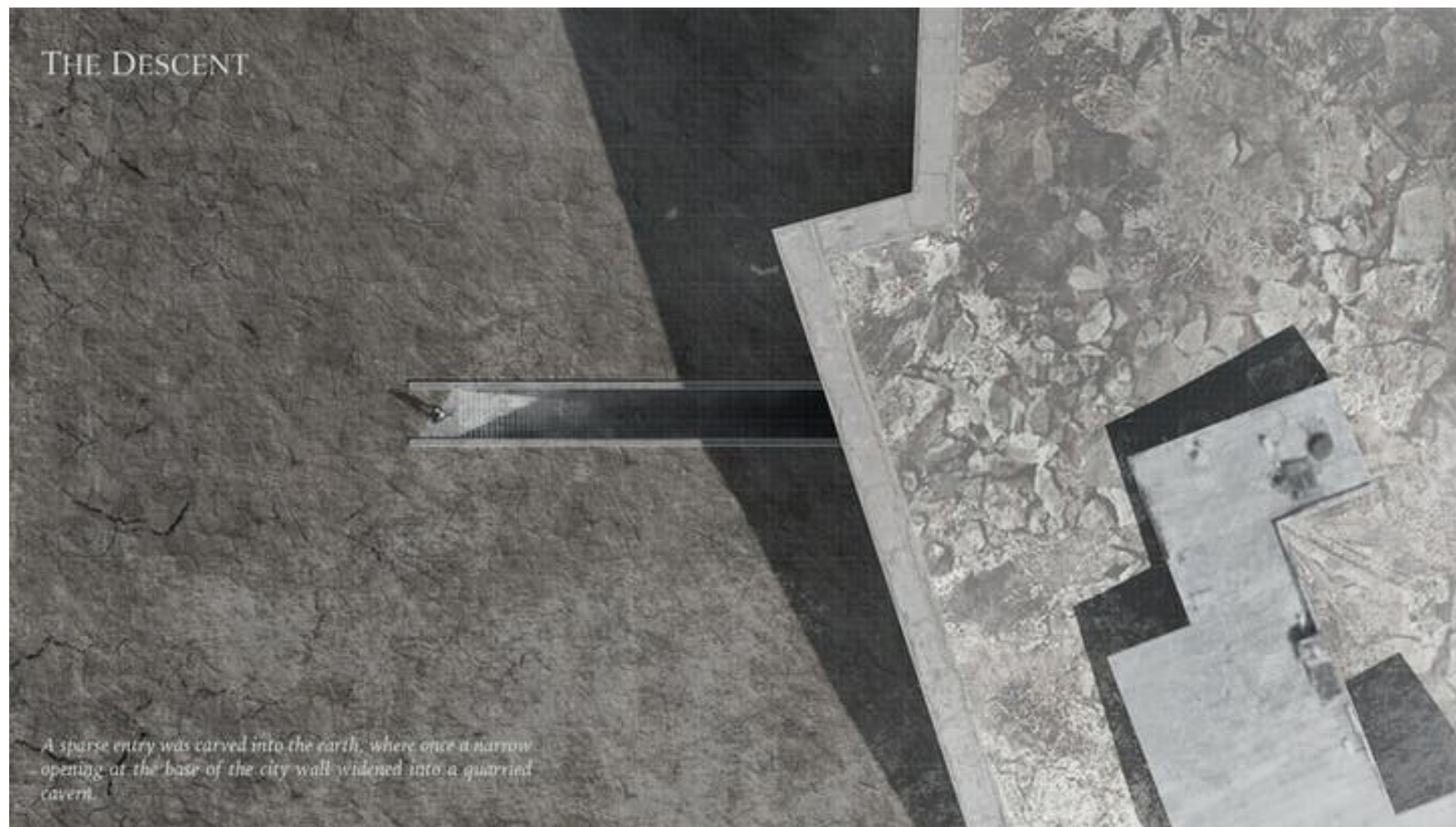


Figure 48: Entrance (Architect, 2020: online.).

What was learned

This project showcases how new opportunities can be exposed and contextual challenges overcome by building subterranean. This project deals with inequality by creating a space of refuge from a civil war as well as the elements.



Figure 49: Outside space (Architect, 2020: online.).

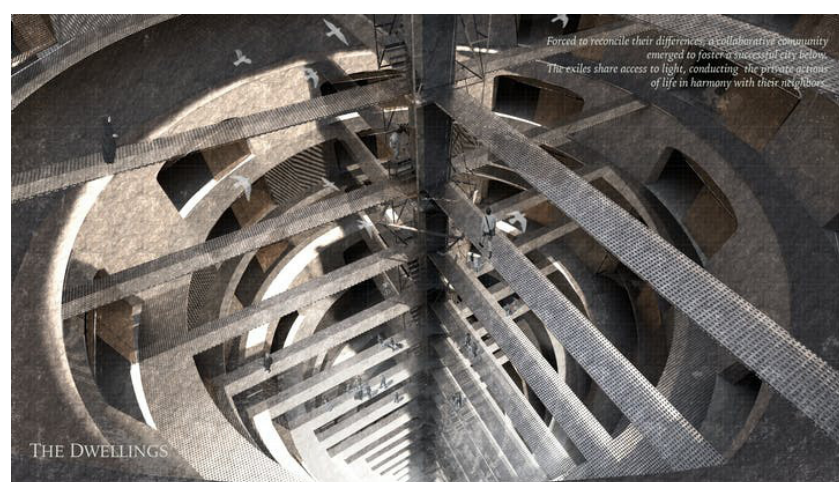


Figure 50: Circulation (Architect, 2020: online.).

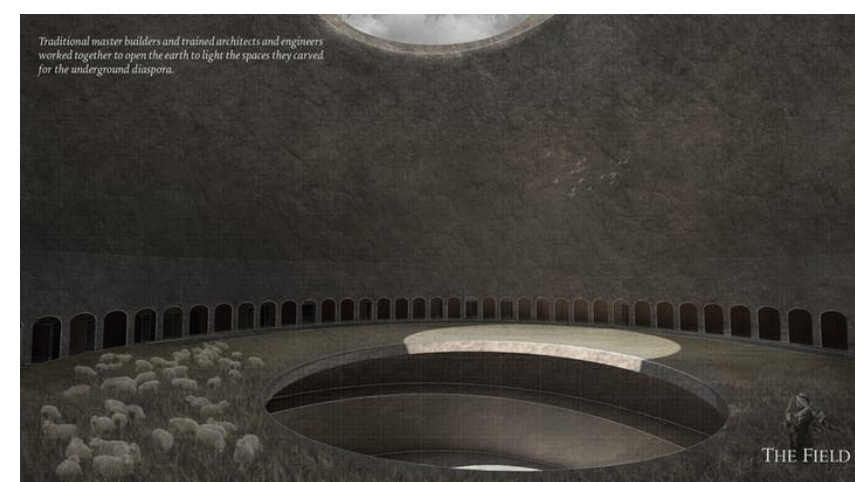


Figure 51: Farm skylight (Architect, 2020: online.).



Figure 52: Entertainment (Architect, 2020: online.).

SITE

Windhoek's Water Influencers

The chosen site for intervention is situated on the Pahl Fault on which Windhoek was originally settled. More specifically the area being targeted is one most at risk of pollution seepage into the aquifer. Storm water from the CBD is channeled to this area from the south. Industrial waste is produced in close proximity on the western side and multiple dump sites can be found to the east of the site. One of Windhoek's main distribution reservoirs is situated West of the chosen site.

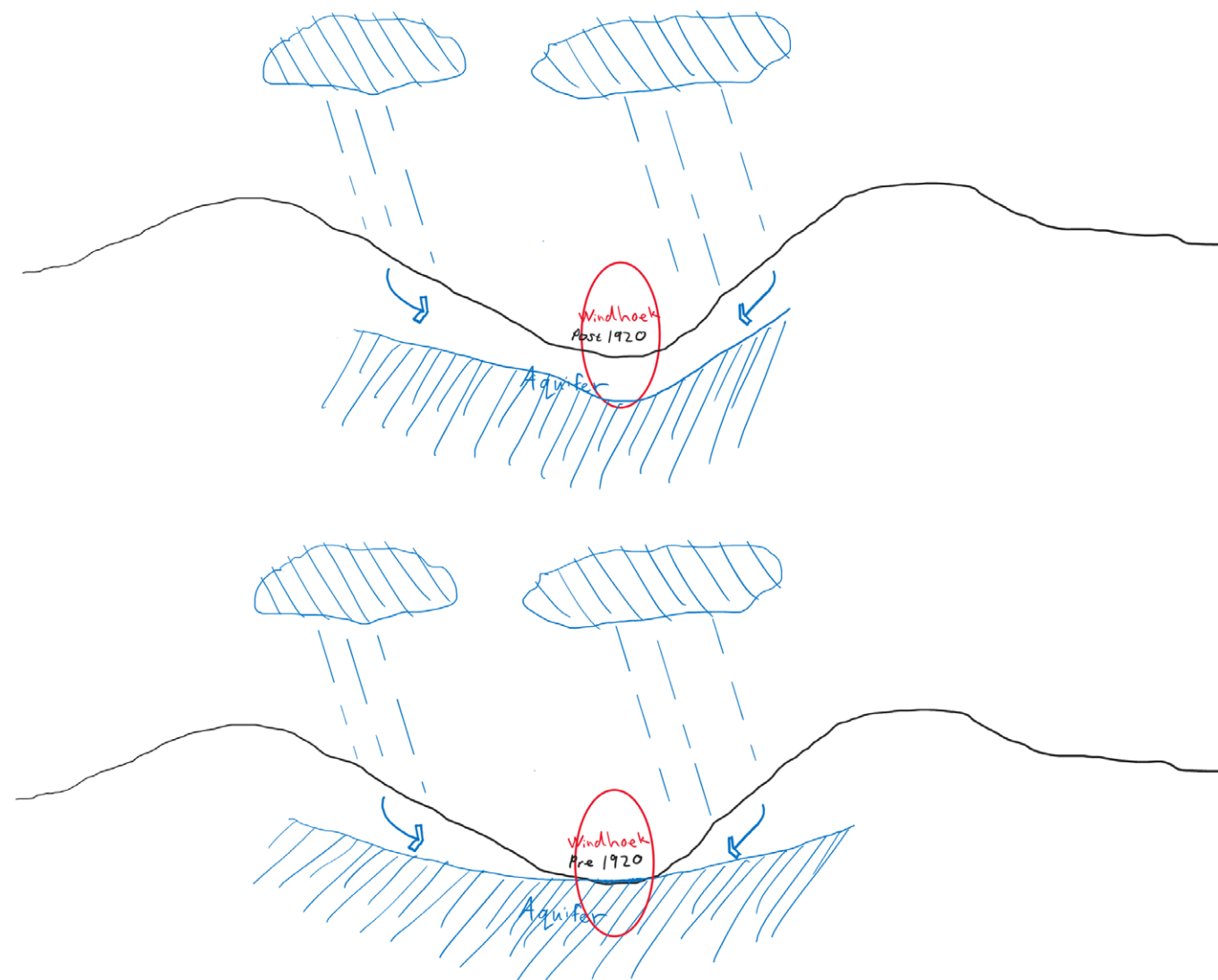


Figure 53: Historical aquifer level (author, 2022).

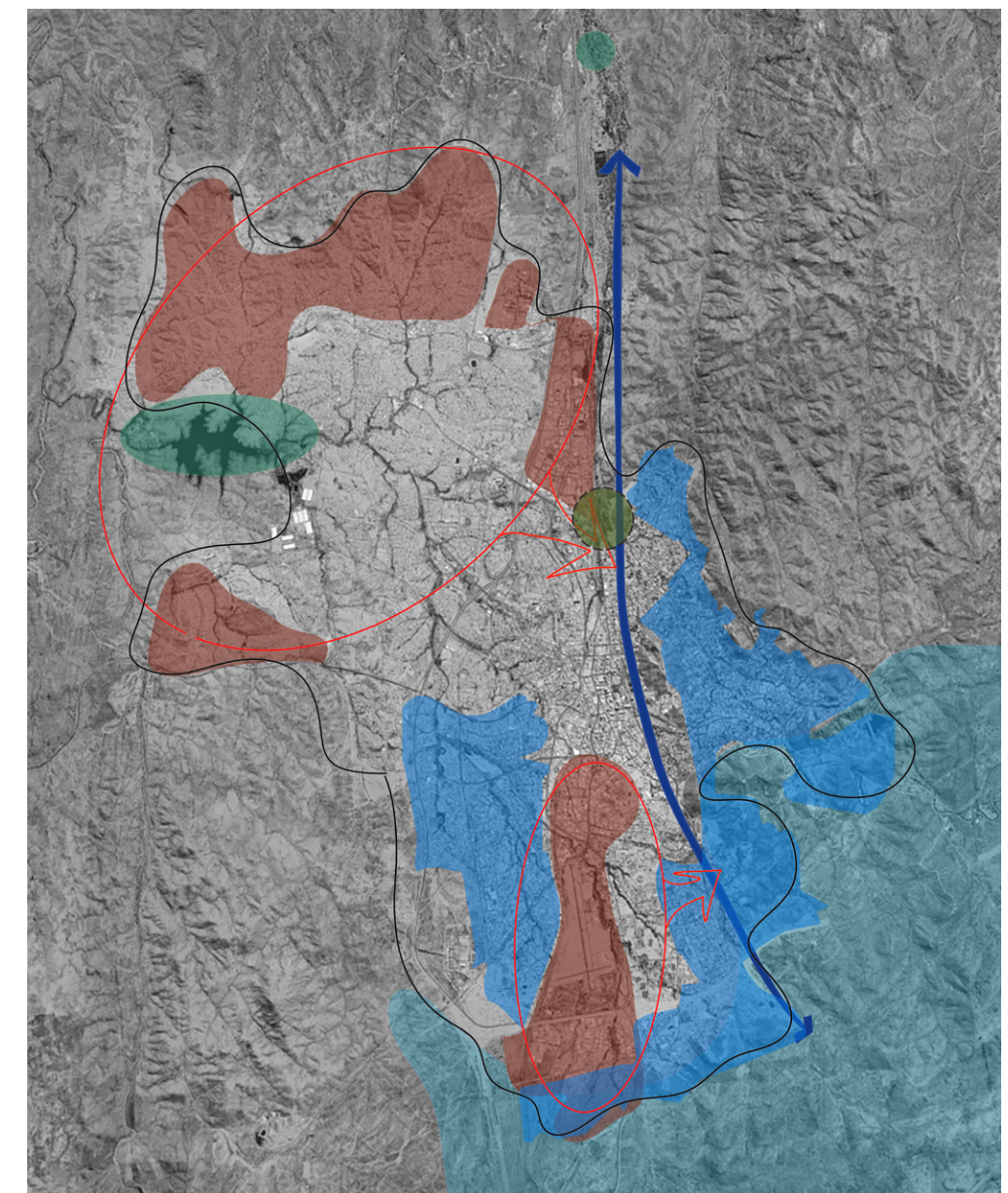


Figure 54: Aquifer influences (author, 2022).

SITE

Conceptional exploration

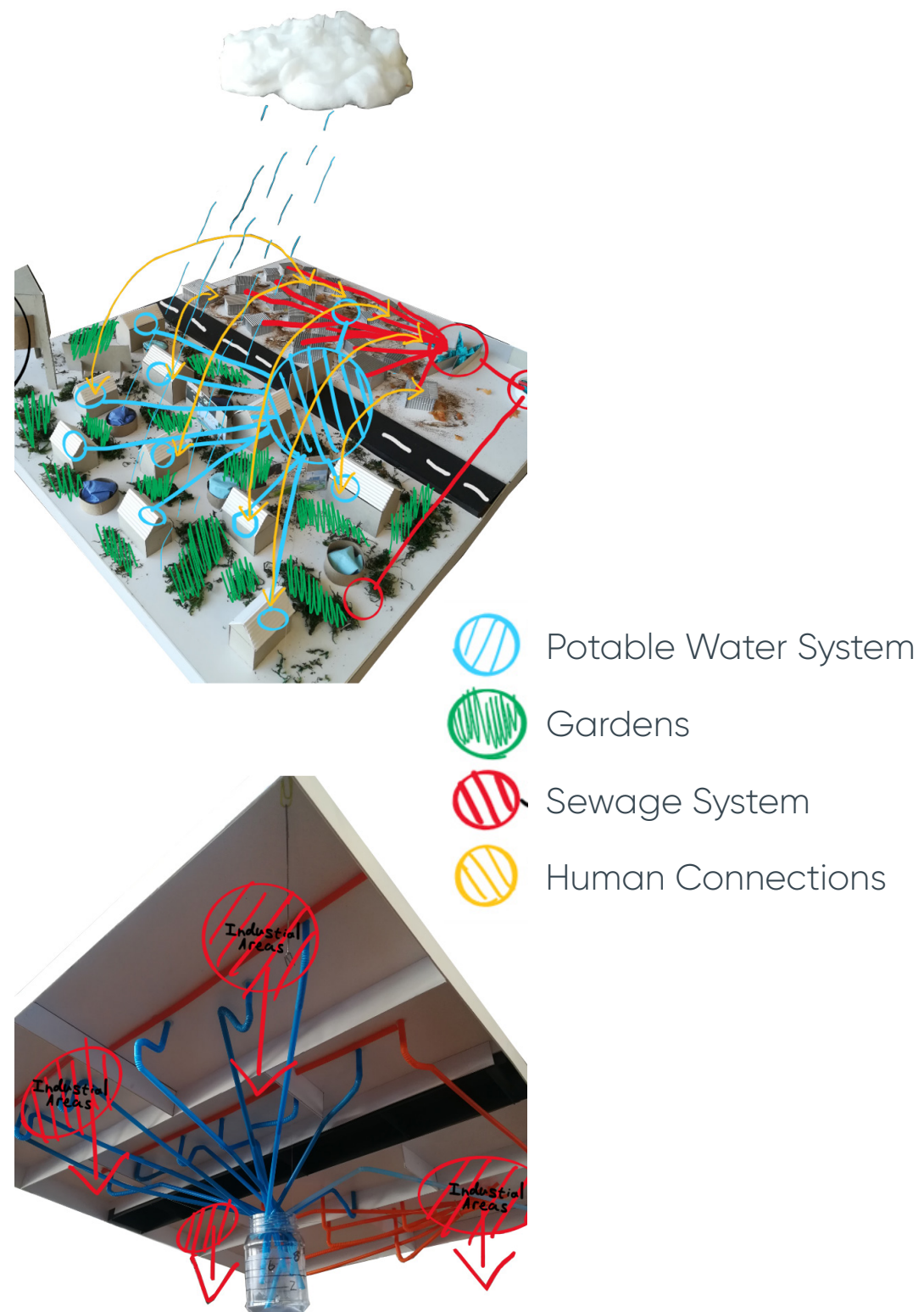


Figure 55: Visible and invisible connections (author, 2022).

In the early stages of exploration, a model was used to showcase the way Windhoek's different socio-economic groups are disconnected on the surface, but linked through water under the surface.

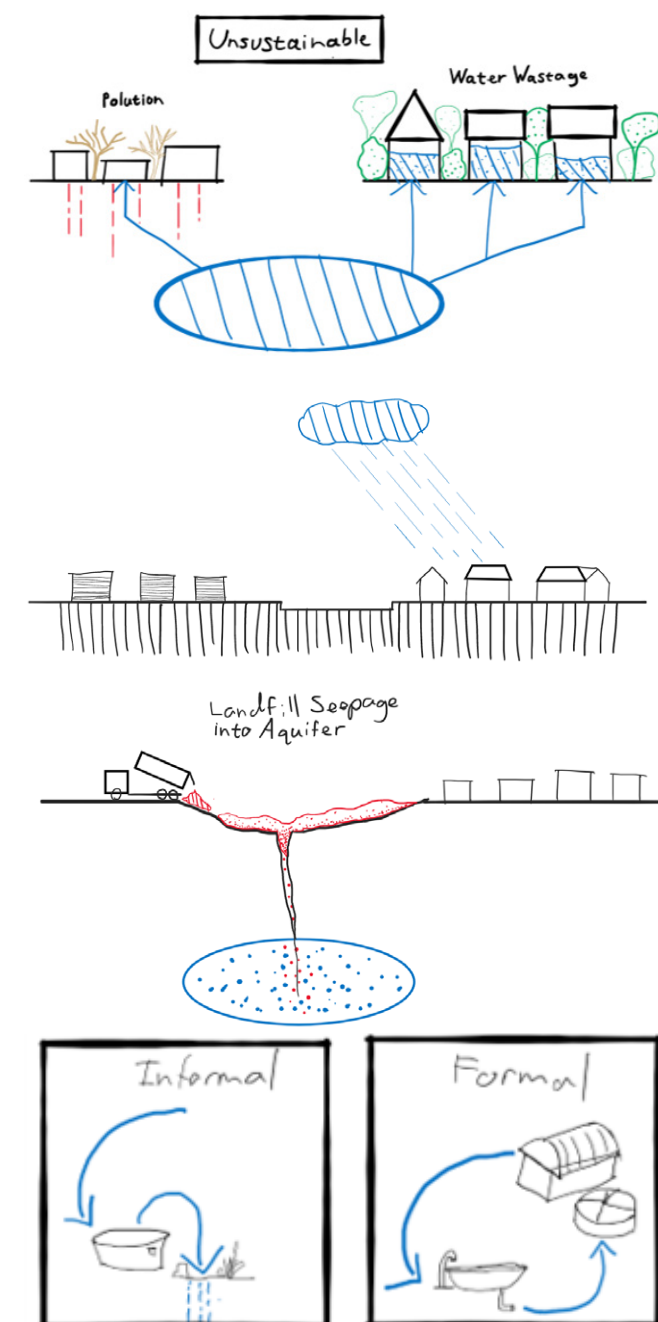


Figure 56: Formal vs. informal water cycles (author, 2022).

SITE

Conceptional exploration

The dark blue arrows show the main water supply of the Northern industry being pumped from the major dams into Windhoek's biggest distribution reservoir and then into a smaller reservoir. Orange lines show the two residential areas East and West of the site as well as arrows showing estimated tectonic movement. The yellow line represents the Pahl fault line and red the Northern industry with the red arrow showing flow of piped industrial waste water to the Ujams reclamation plant. The green arrows show natural sloping of the topography towards the river, that is represented as light blue lines, and the fault line.

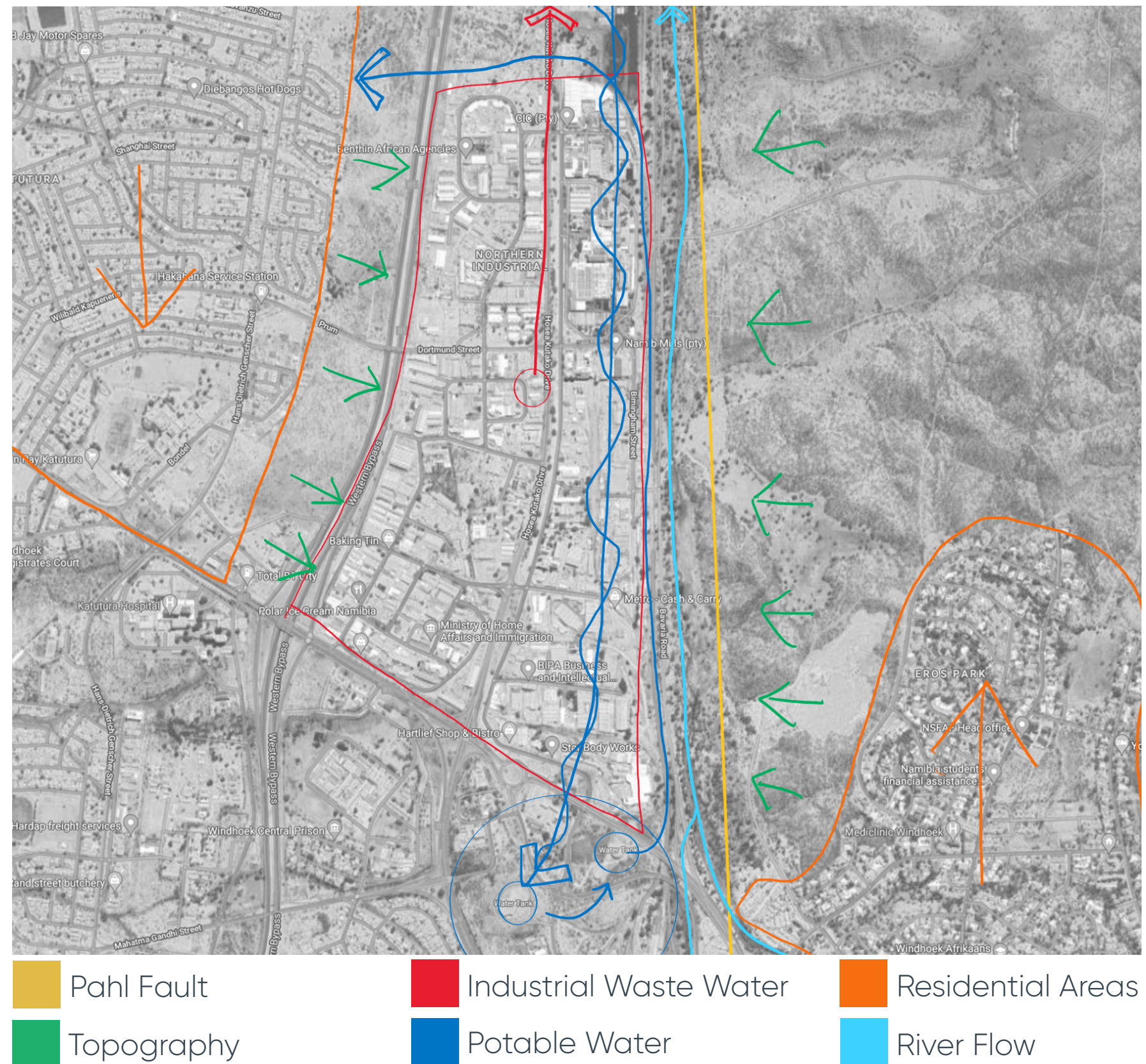


Figure 57: Economic division by water and fault line (author, 2022).

SITE

Conceptual exploration



Figure 58: Natural and man-made water movement (author, 2022).

Overlaying different map layers onto the contour model of the site, provided insight into how the topography influences the movement of water. Rain water does not only flow down the mountain valleys to the river, but underground water in the fault line also flows from south to north.

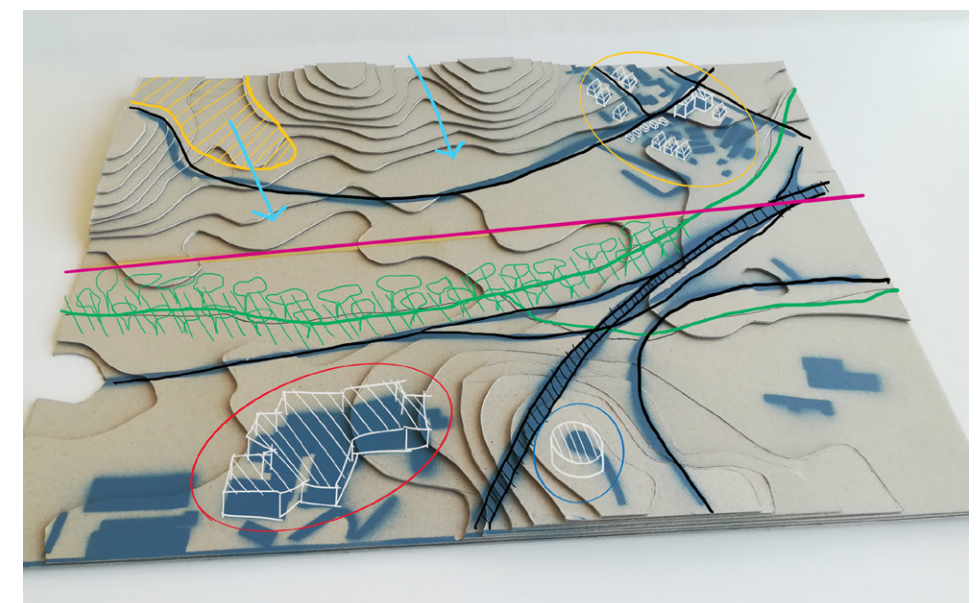


Figure 59: Site system exploration on model (author, 2022).

SITE

Conceptional exploration



Figure 60: Points of interest surrounding site (author, 2022).

SITE

Conceptional exploration

The following map shows all the unseen water and sewer lines that run around and through the site. These are shown in connection with proposed movement to the site.

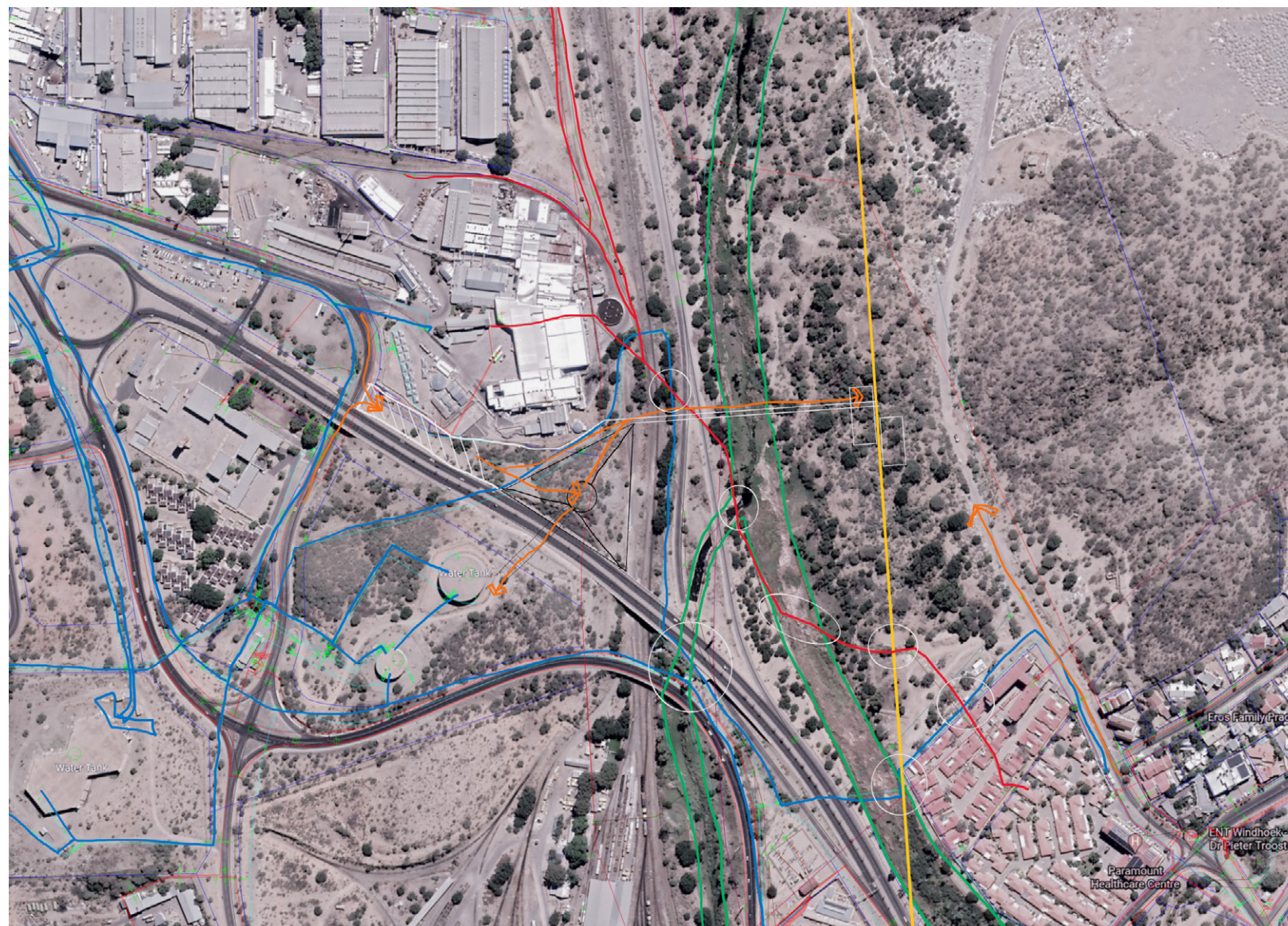


Figure 61: Site exploration diagram (author, 2022).

SITE AND RANGO

Conceptional exploration

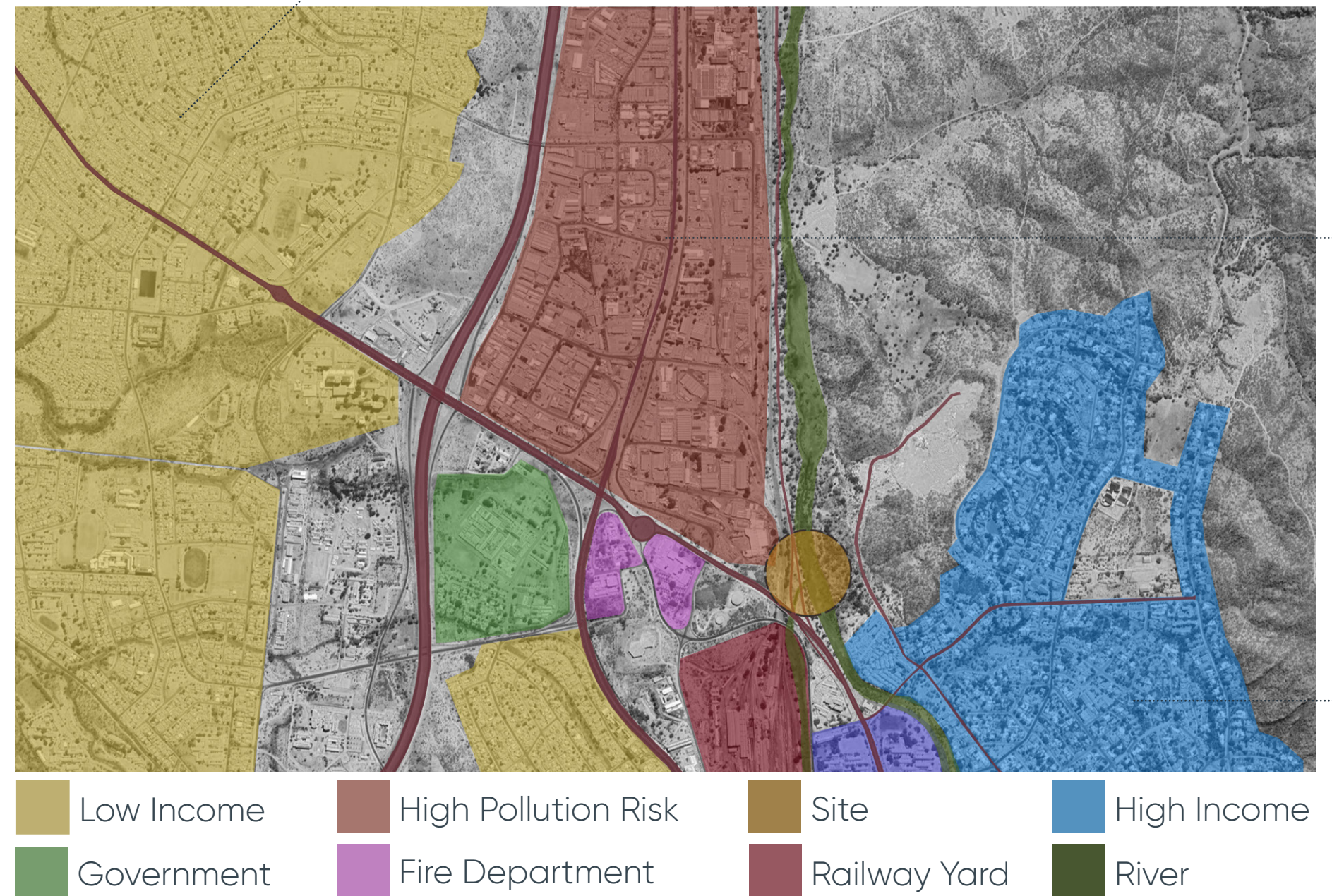


Figure 62: Site function and Rango (author, 2022).

SITE AND RANGO

Conceptual exploration

The Common Folk



Tortoise John



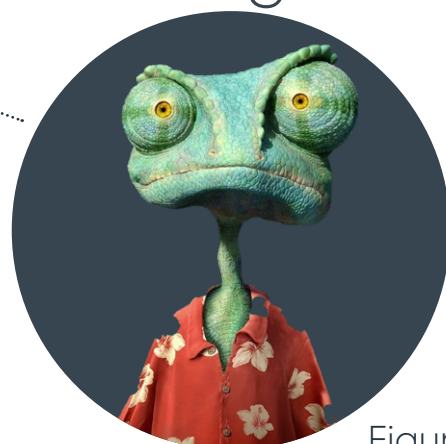
The Outlaws



Beans



Rango



Relating the site to "Rango" requires the actors introduced previously to be linked with specific areas influencing the area. These include the low income area to the West, the Northern industrial area to the North and the high income area to the East.

Figure 16: Rango characters (Verbinski, 2011: Rango.)

CLIENT AND BRIEF

Client, brief and general approaches

Client

City of Windhoek Municipality, Namwater and Windhoek residents

Brief

Aquifer recharge, water testing and filtration will be functions handled by the laboratory as well as education pertaining to these functions. The whole structure's roof will act as a water catchment element. The building will also function as a pavilion with emergency water access. An embodiment of "The Story of Water and Windhoek" through architecture to expose what remains unseen. The structure must capture the essence of the Pahl Fault-line while exposing the water infrastructure that lies beneath.



Figure 63: Logo (Namwater, n.d: online.).

General approaches include

- Sustainability through education which can be achieved through architectural intervention. For example the water system used in Windhoek is unknown to most of the population and exposing the system through architecture will expose some aspects of the underlying water infrastructure.
- Creating architecture that is better suited to the arid context through Resilience models. Moving away from the current architectural practices that are not adapted to the low rainfall and high heat will also improve passive cooling and the ability of buildings to collect water.
- Architecture that incorporates the existing water infrastructure will be the most attainable due to it being tested in the local context.
- Monitoring of refuse dumping and enforcing regulations on industrial activity over aquifers to preserve this water source and prevent incidents such as the Ramatex scandal where toxic chemicals were improperly disposed of and eventually leaked into the soil. These chemicals could possibly percolate through the soil, into Windhoek's ground water system.



Figure 64: Logo (City of Windhoek, n.d: online.).

Programme:

- Public: Visitors centre Pavilion, parking, ablution block, water access points, reception, exhibition, auditorium, restaurant.
- Semi private: Technical facility Filtration, injection, pumping, testing laboratory, archive.
- Private: Administration and restaurant Archive, offices (administration), ablution block, kitchen, seating space (restaurant).

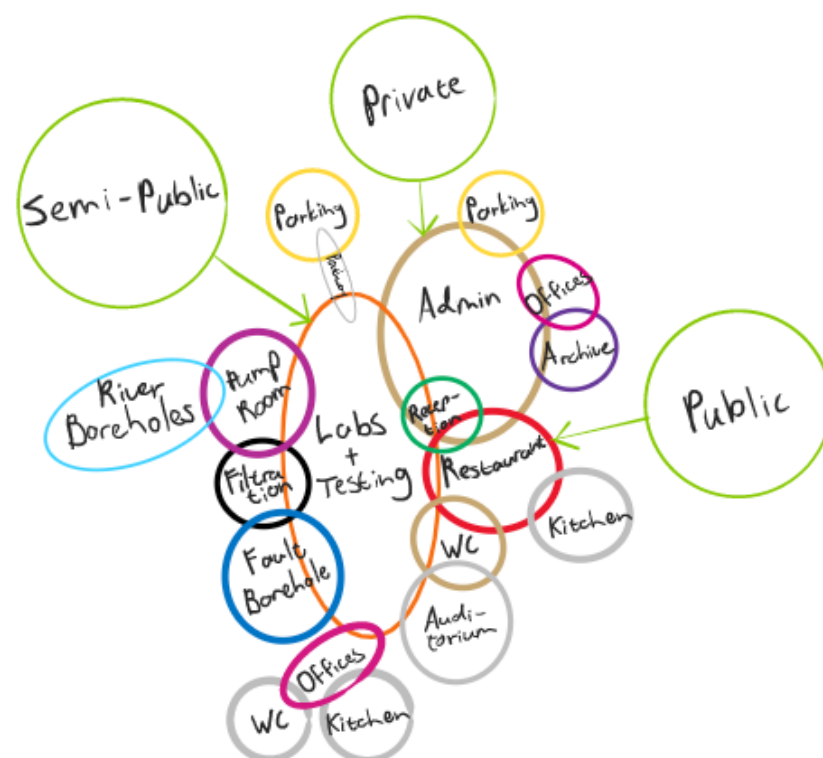


Figure 65: Programme development (author, 2022).

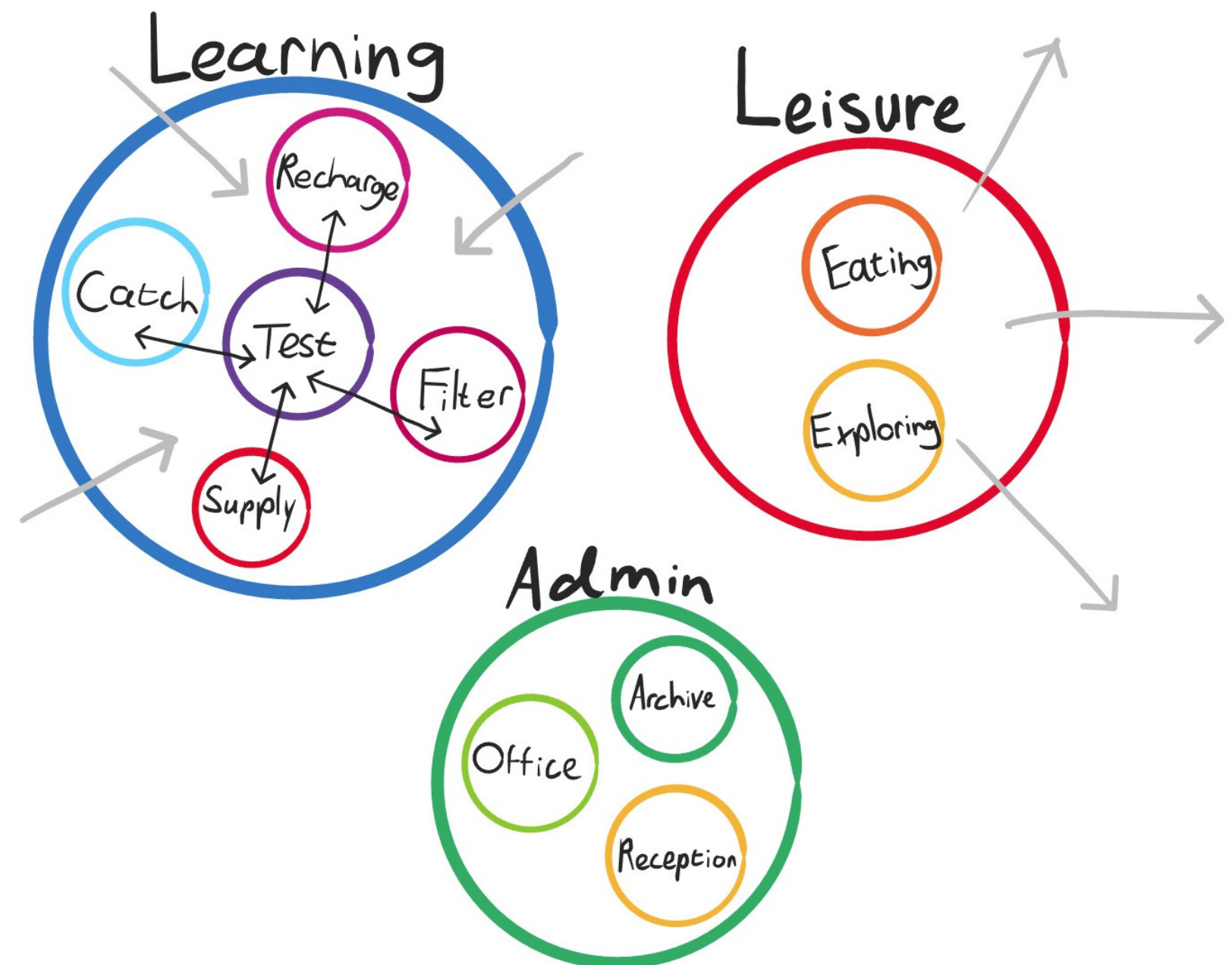


Figure 66: Programme (author, 2022).

INTERVENTION

The intervention strives to promote awareness on Windhoek's current water infrastructure through the educational aspect of the building. These include exposing the Pahl fault through architecture as well as water testing laboratories that will focus on biological and chemical aspects to showcase the water's potability. The auditorium will provide a space for lectures on the current water situation and a possible space for Windhoek's residents to discuss concerns and solutions to future water challenges. The auditorium also acts as a leisure space for experiencing the building. The intervention aims to promote awareness on sustainability by showcasing various methods of water collection, filtration as well as testing of the water that enters the building. These methods include rainwater collection, river water collection and the injection of water into the aquifer through the Pahl fault. Wind and solar energy is used to further showcase sustainable means by which to extract and move water. Further learning is promoted by the archive in the administration aspect of the building where the public as well as professionals will have access to all information regarding water in Windhoek. The restaurant aims to attract the public to the building to expand on the awareness aspect of the intervention.

ACCOMMODATION

Schedule

Water Testing

- Pump rooms
- Filtration area
- Biological lab and office
- Chemical lab and office
- Utility room (chemical & general storage; darkroom)
- Break Room (kitchen; ablution block; shower)

Public

- Auditorium
- Restaurant
- Ablutions

Administration

- Reception foyer and office
- Offices
- Archive
- Boardroom
- Kitchen
- Ablution block

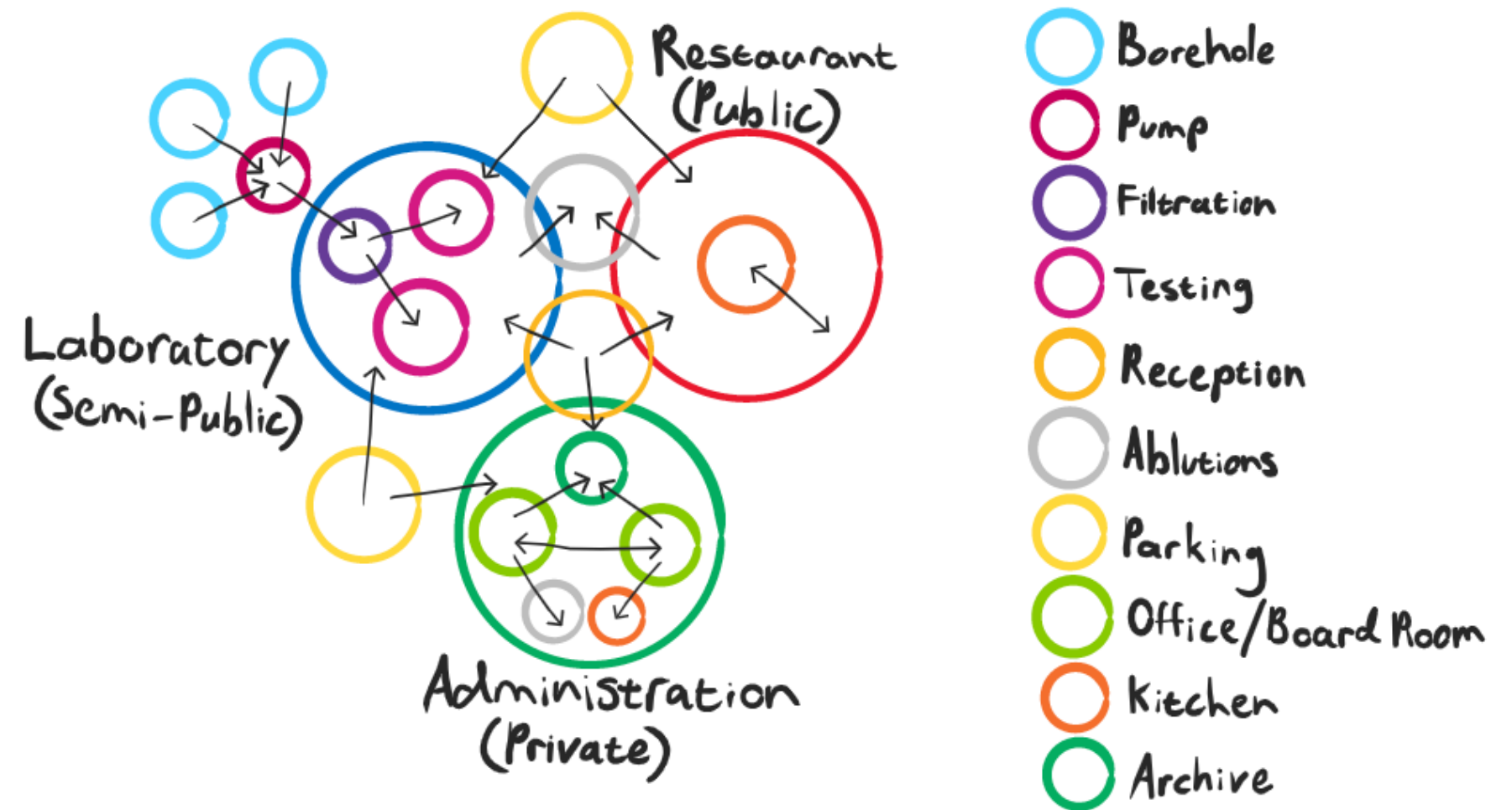
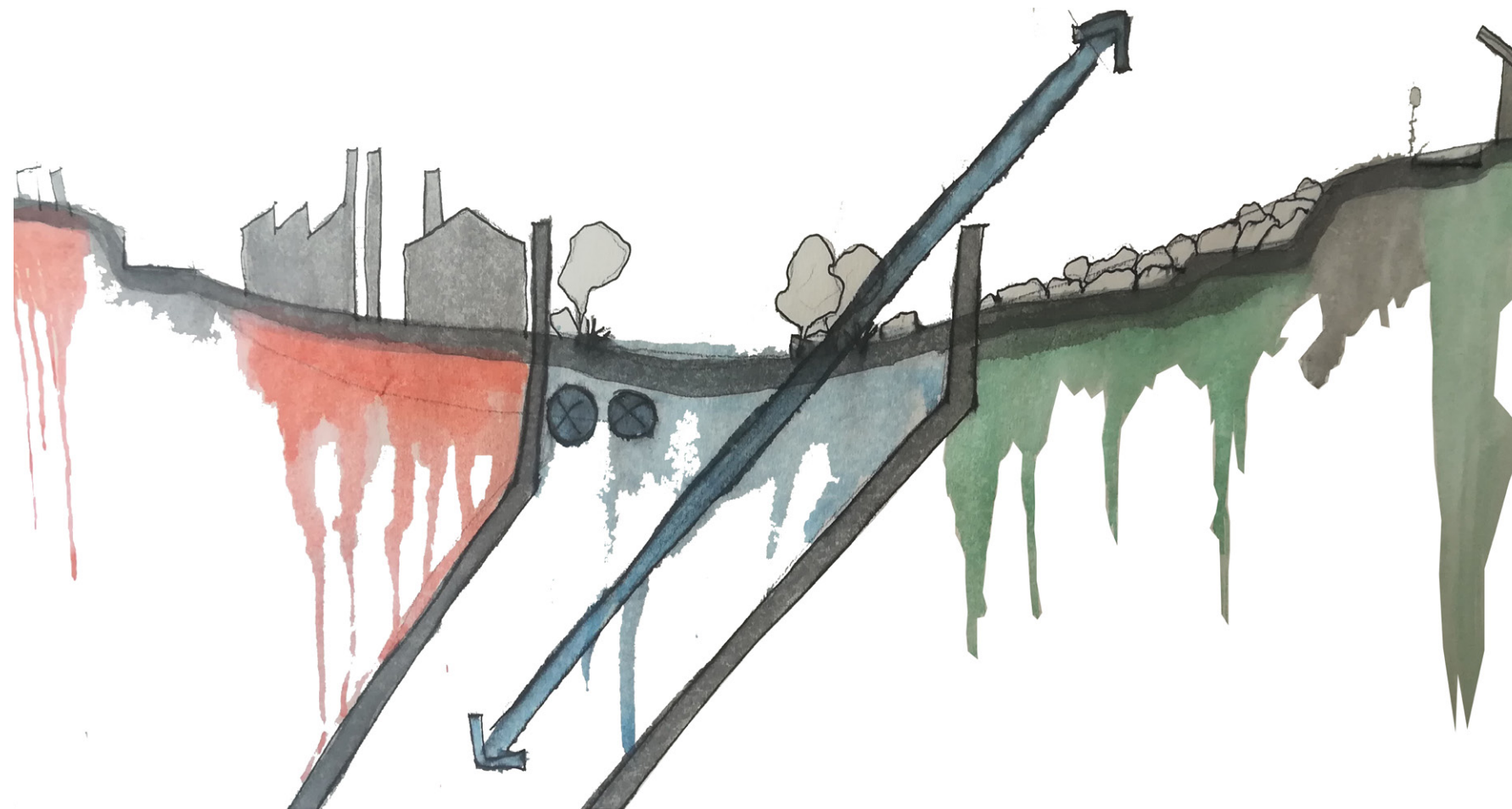


Figure 67: Accommodation (author, 2022).

CHAPTER 3

Concept development



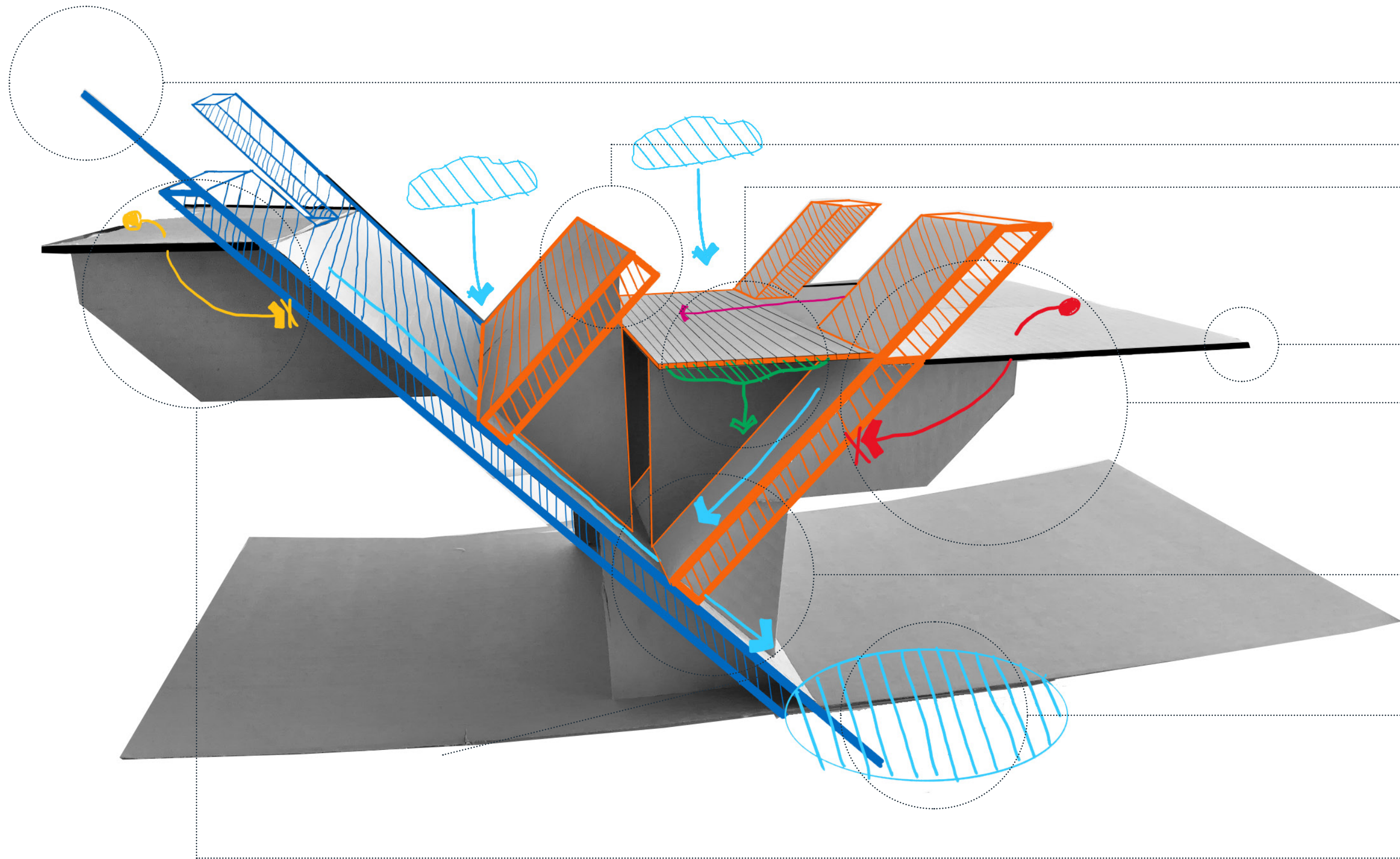
Site exploration in section

Touchstone	57-60
Concept Development:	
Site	61-68
Building	69-74

All drawings in this chapter are by the author and are not to scale unless stated otherwise.

TOUCHSTONE

Exploration



Pahl fault

Intervention

River pollution

Natural ground level

Industrial pollution

Filtration point

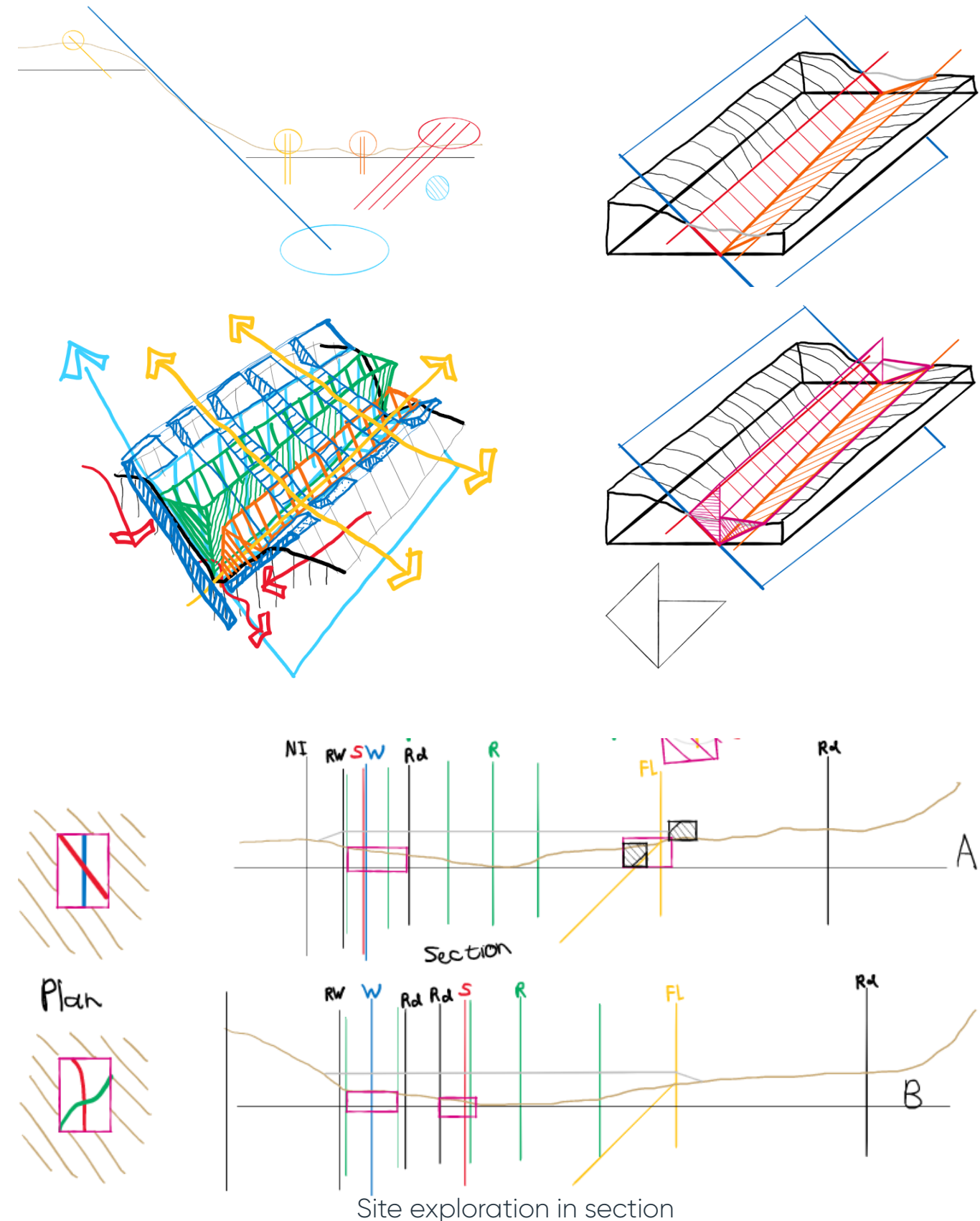
Aquifer

Landfill pollution

TOUCHSTONE

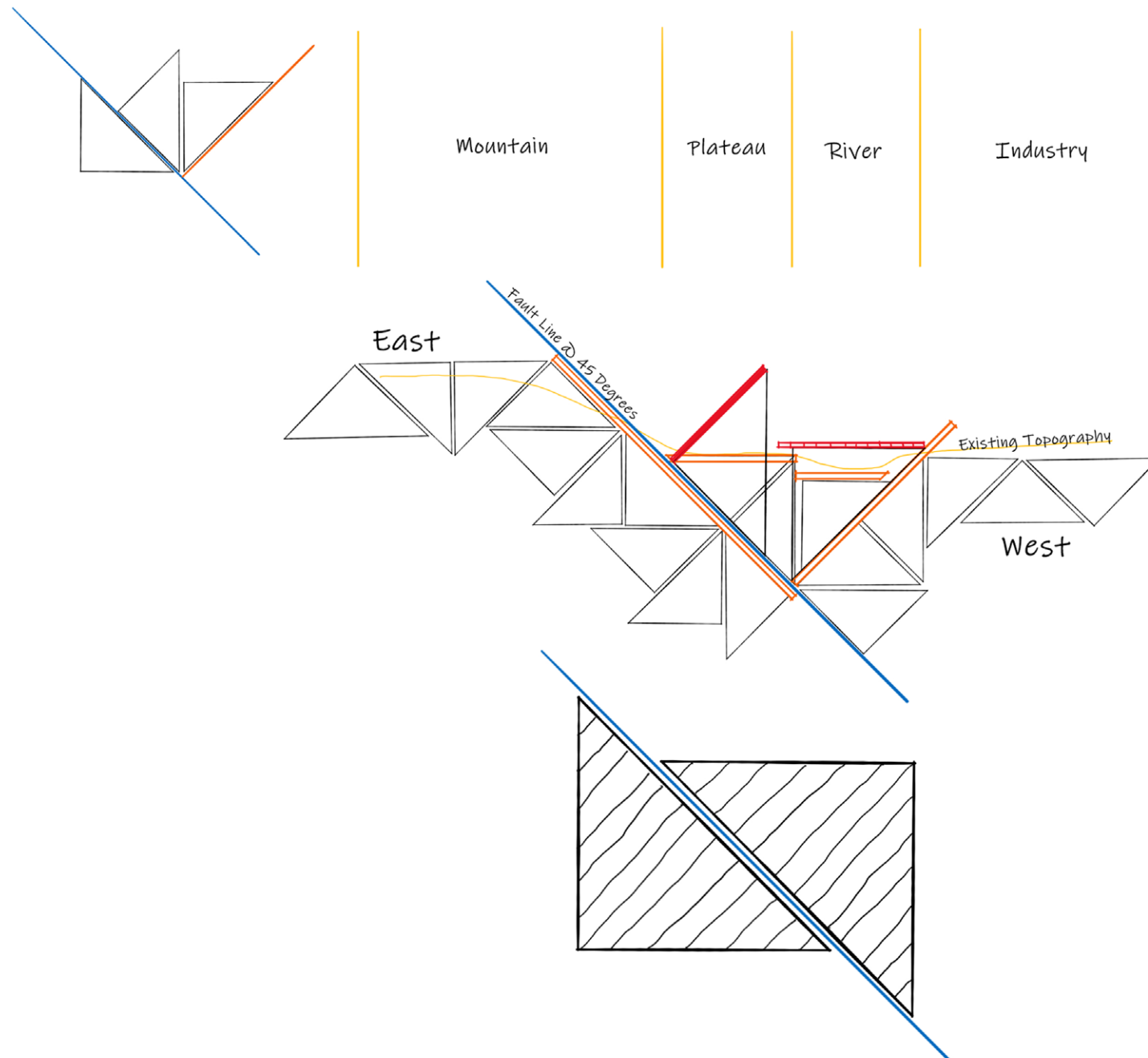
Exploration

The Touchstone concept for the intervention started with an exploration of the angle of the fault and although it is not necessarily 45 degrees, it provided a basis to start from. The next aspect explored was the different levels created by the fault in the larger scale (river to the west and mountains on the east). Lastly the different linking elements that bridge the fault was considered, including natural water flow, piped water, sewage pipes and possible pollution entering the fault from both sides.



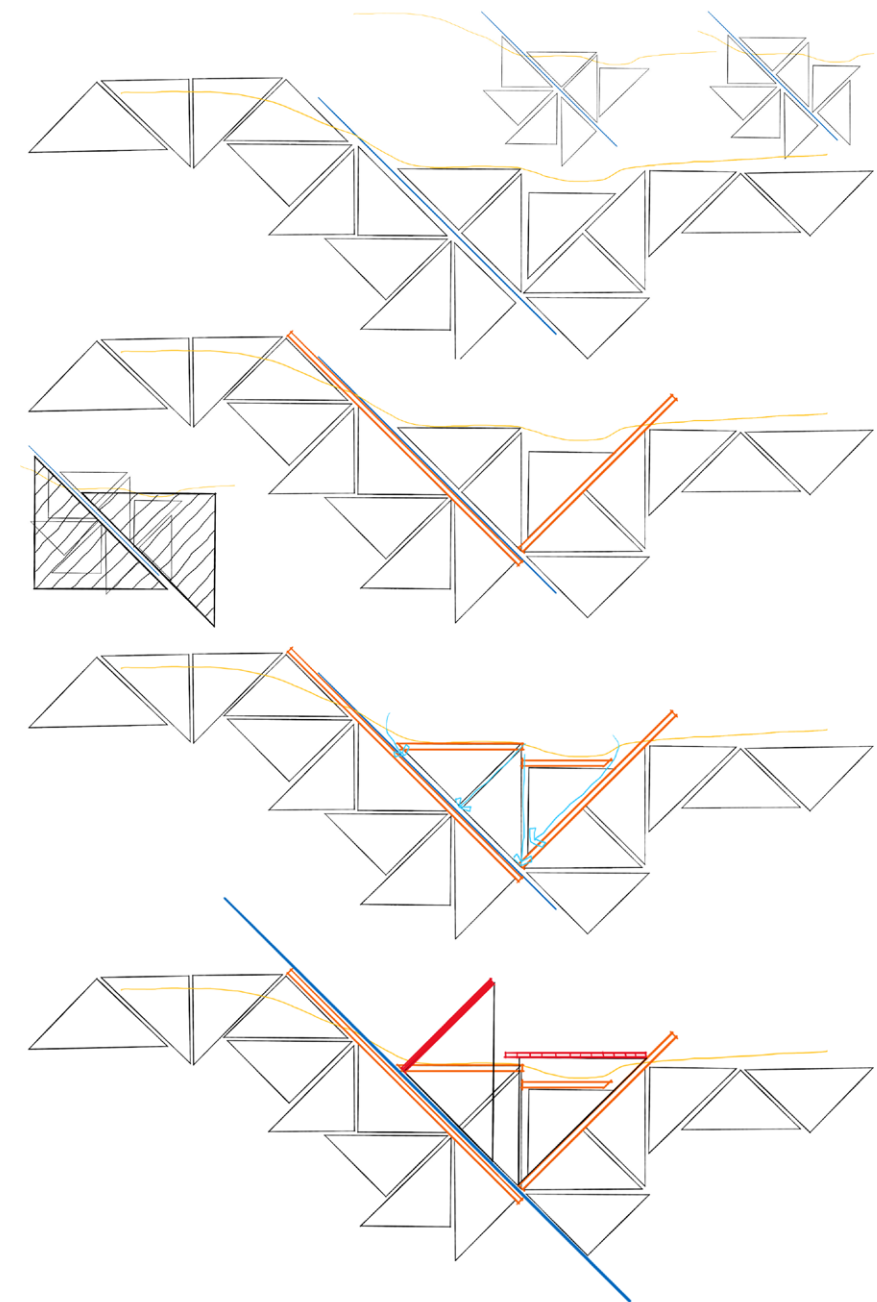
TOUCHSTONE

Exploration



Touchstone exploration in section

Exploration of the Touchstone in section with the fault angle being the main focus



Touchstone exploration in section

DEVELOPMENT

Site Systems

In order to understand the site an exploration was done on existing natural and man-made elements on site. These include the river, fault line, vegetation, reservoirs and the roads that interact with the site. After the first investigation the barriers were identified to expose movement consisting of both water and pedestrians moving through the site.

- Pahl Fault
- River and Weirs
- Interventions
- Solid Elements
- Pedestrian Movement



Existing linear elements



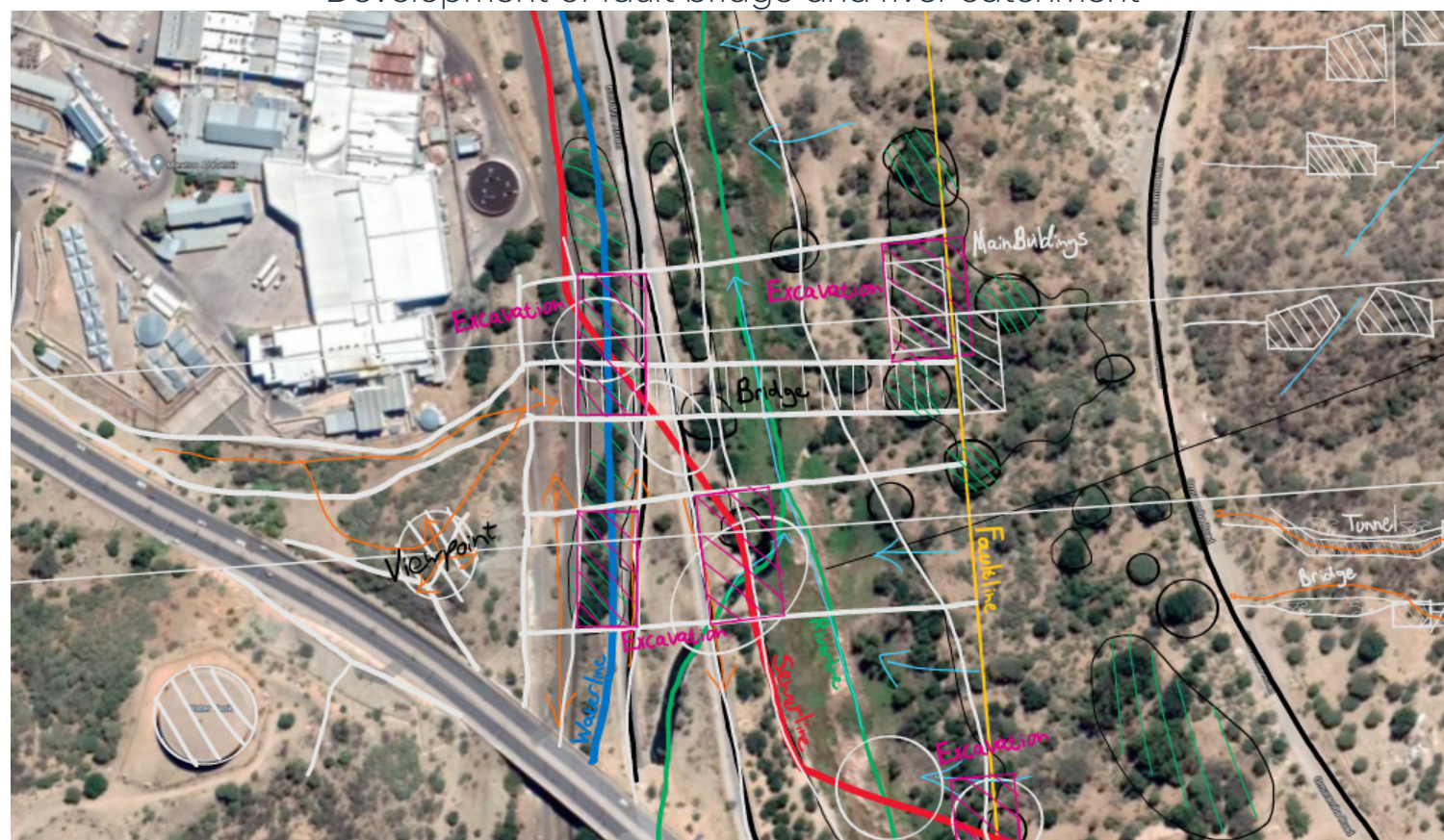
Movement of water and pedestrians

DEVELOPMENT

Site Systems



Development of fault bridge and river catchment



Development of intersections

To create a coherent map of the context of the specific site connections, intersection and relationships between existing systems and proposed interventions were considered. While keeping the most important element in mind, the Pahl fault line.

- Pahl Fault
- River and Weirs
- Interventions
- Pedestrian Movement
- Excavations

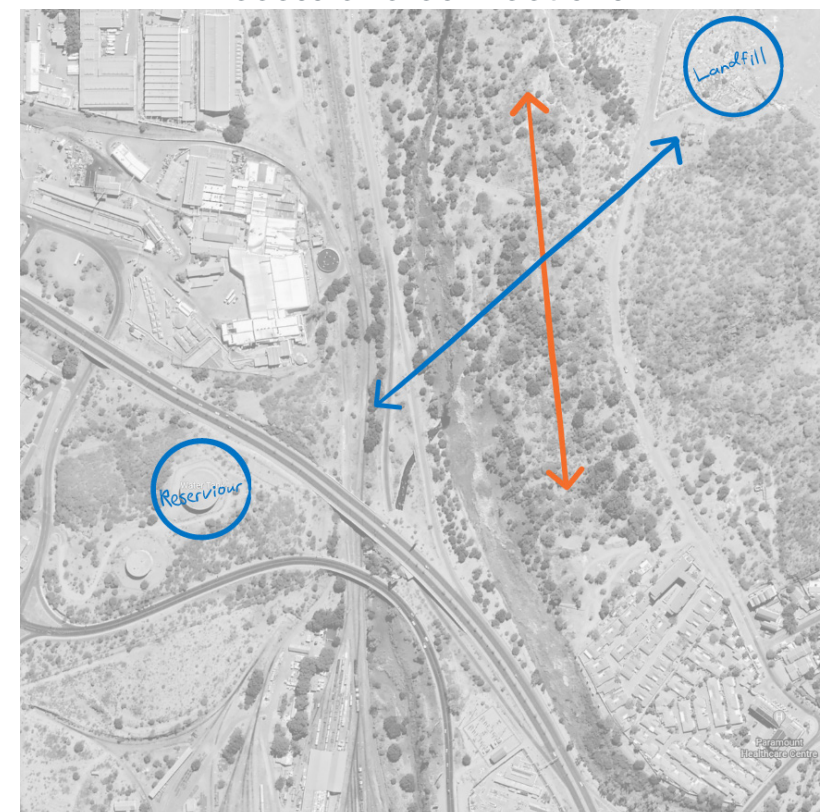
DEVELOPMENT

Site systems

The main elements of the site investigation were condensed and documented to set clear guidelines to follow in the later sections.



Access and connections



Two main axis



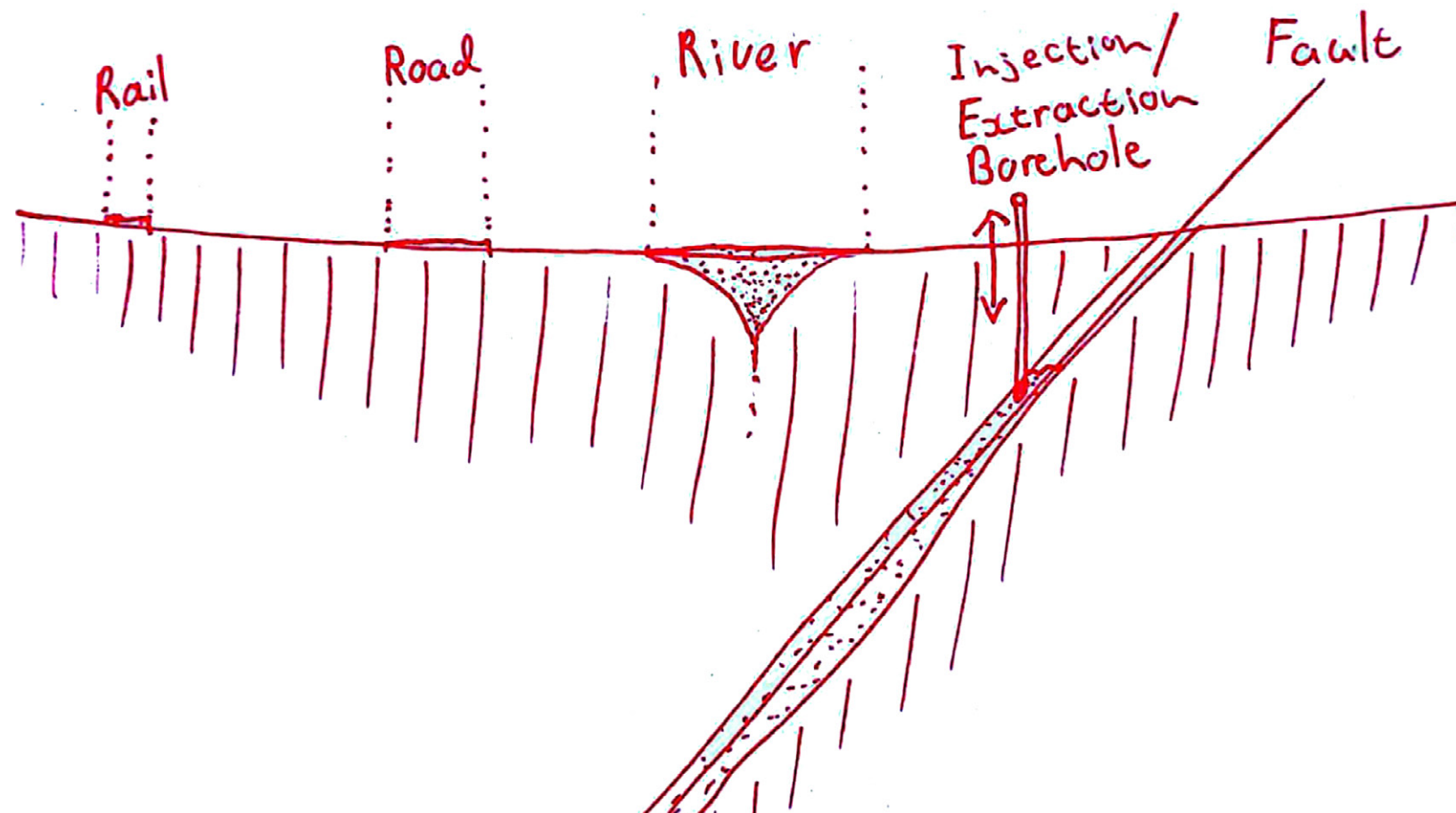
Water flow



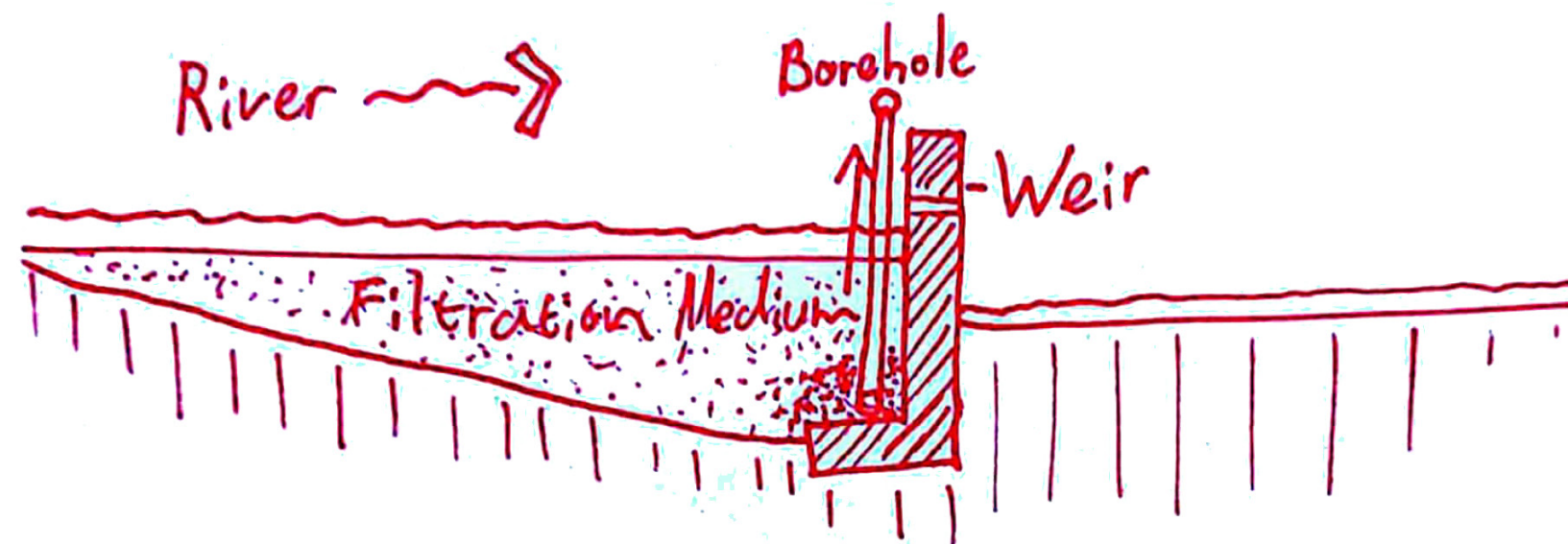
All site systems

DEVELOPMENT

Site systems



Section through the linear elements of the site which will be bridged for access from the west. The Pahl fault is also shown as well as the injection and extraction bore hole that will be located in the laboratory. The river in relation to the fault should be noted as pollution flowing in the river can seep into the fault.



This section through one of the three river-damming element shows how water flow will be slowed to allow for percolation filtration to occur. This water will then be pumped out to the laboratory for testing as well as creating another source of potable water.

DEVELOPMENT

Site Systems

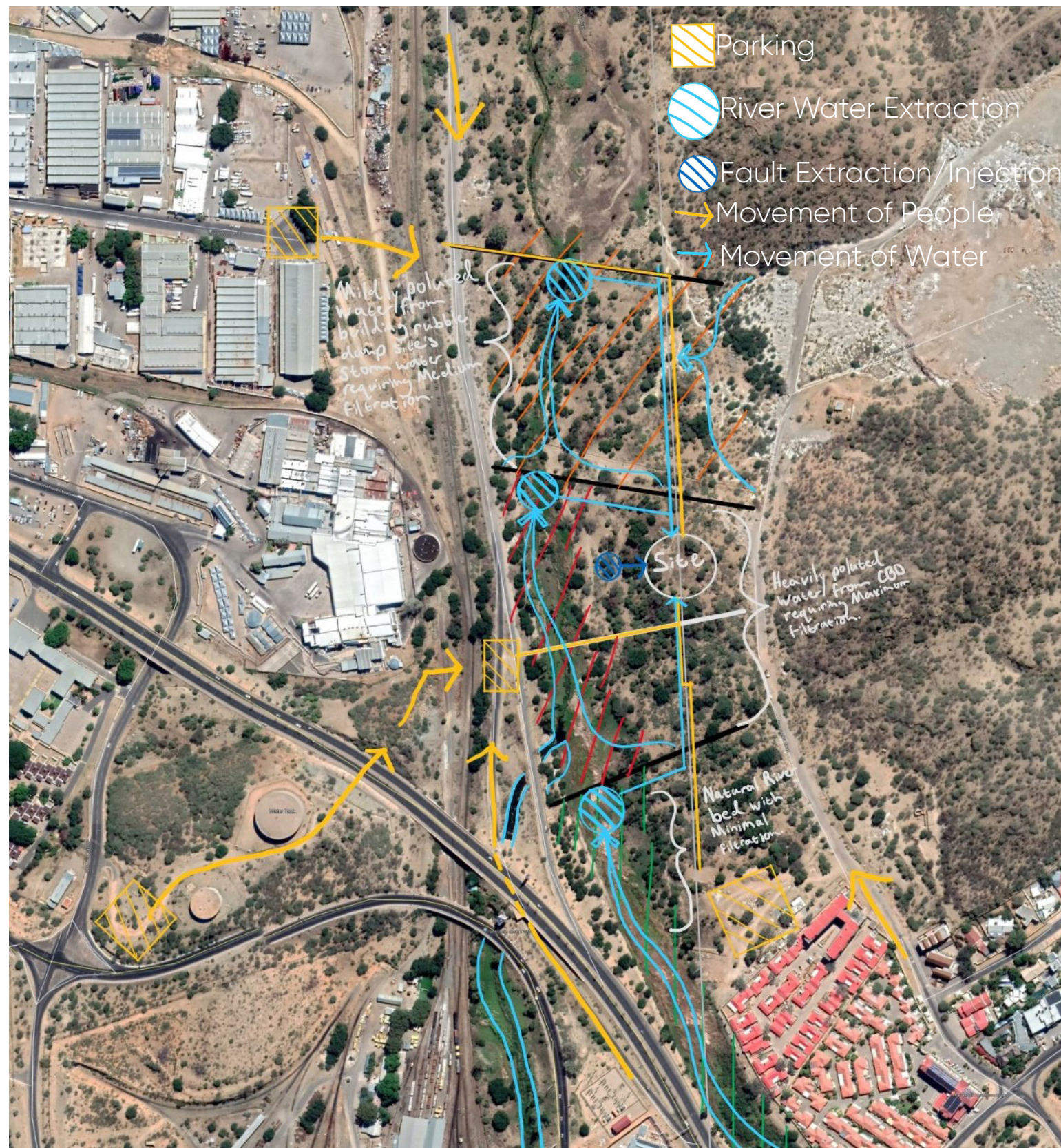
- River
- Existing Roads
- Existing Buildings
- New Walkways
- Existing Vegetation



Site exploration

DEVELOPMENT

Site Systems



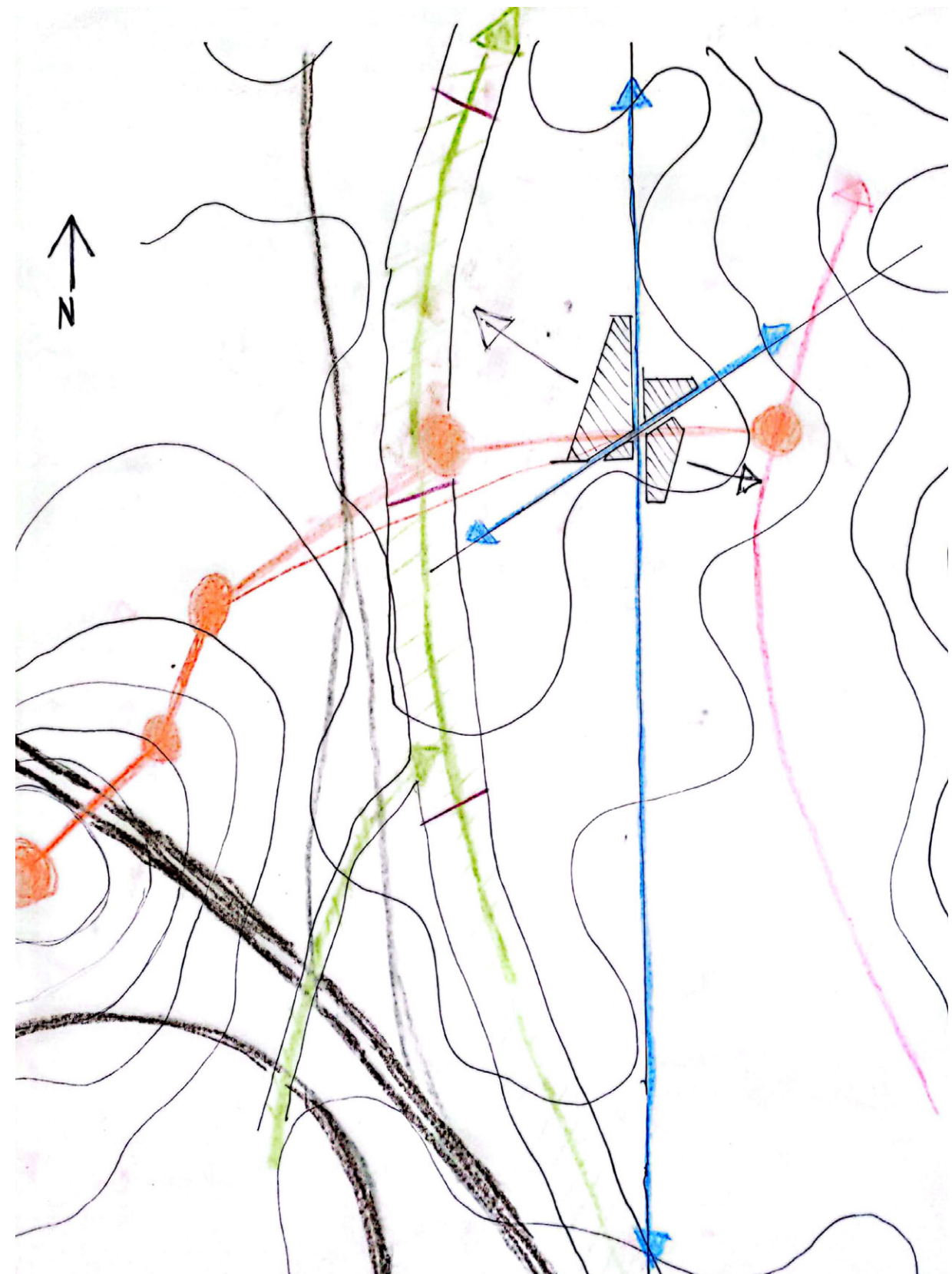
This map shows the basic framework into which the intervention will be integrated. Explored elements include the pathways along the fault line and from the reservoir, water catchment points in the river as well as the walls that interact with natural water flow in the river and surrounding run-off.

Water and pedestrian movement

DEVELOPMENT

Orientation; Form and Pathway

With the previous site exploration the building form can now be integrated into the context. The east and west facades face the river and the mountain range while being strongly influenced by the fault line as well as the reservoir axis.



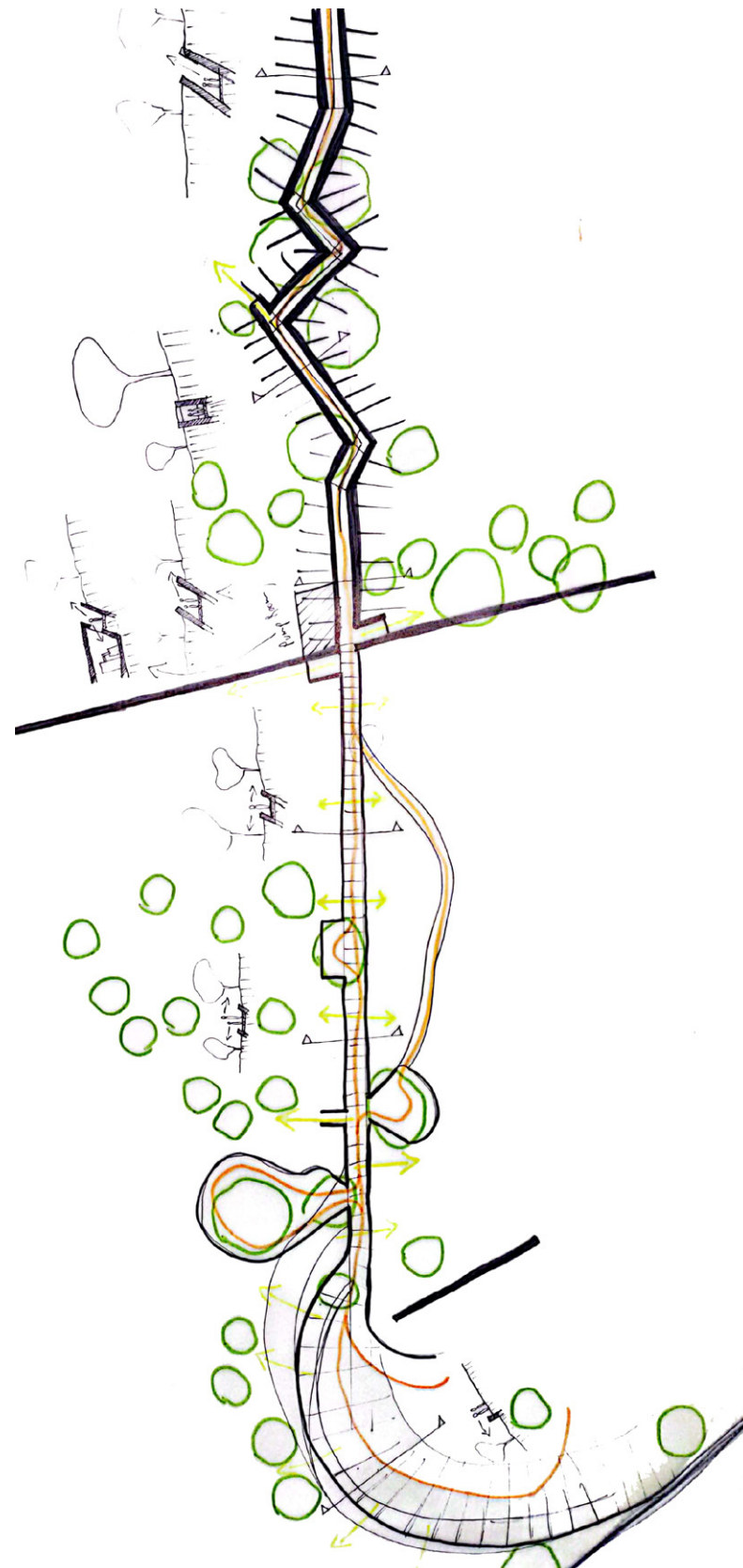
Building form in relation to context

DEVELOPMENT

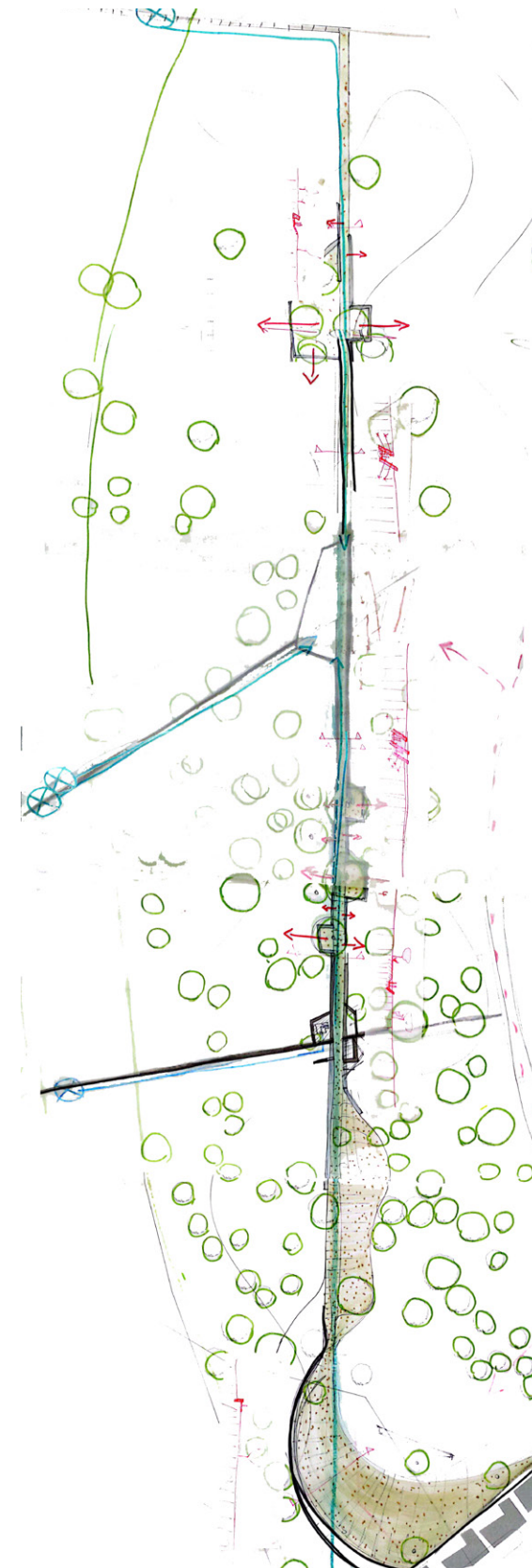
Site and pathway



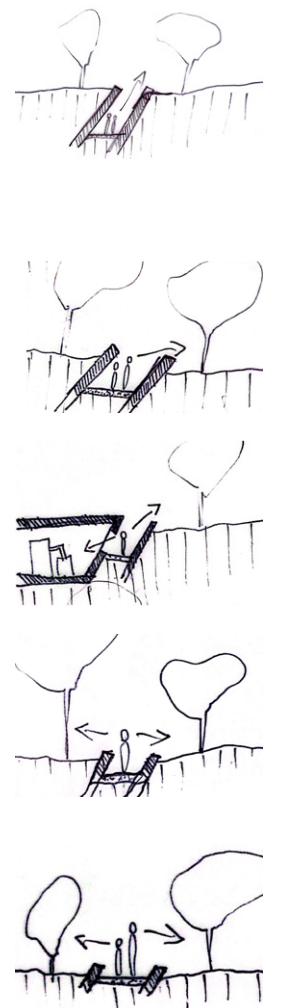
Pathway exploration



Pathway exploration

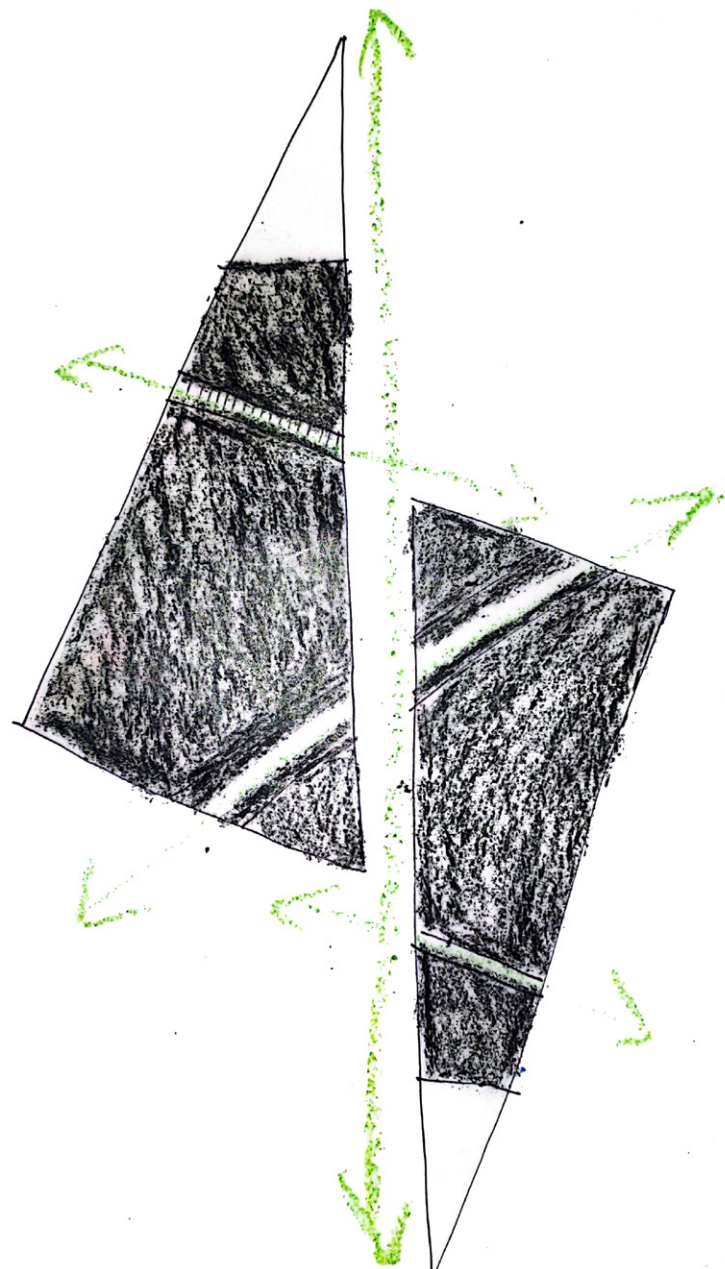
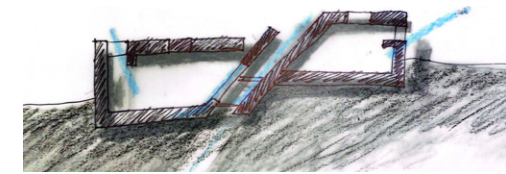
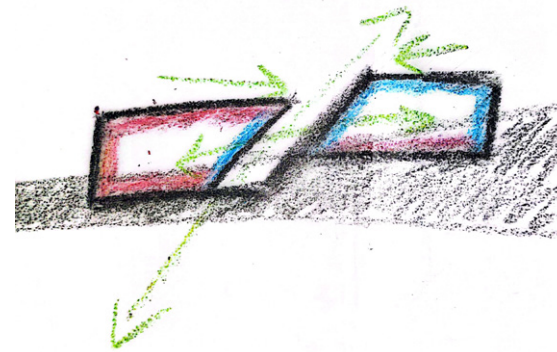
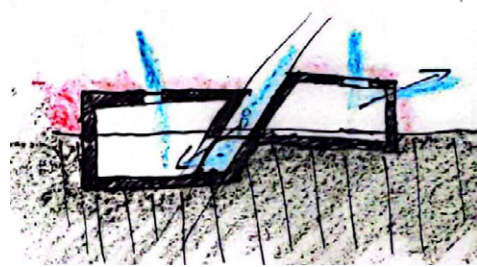


Pathway exploration

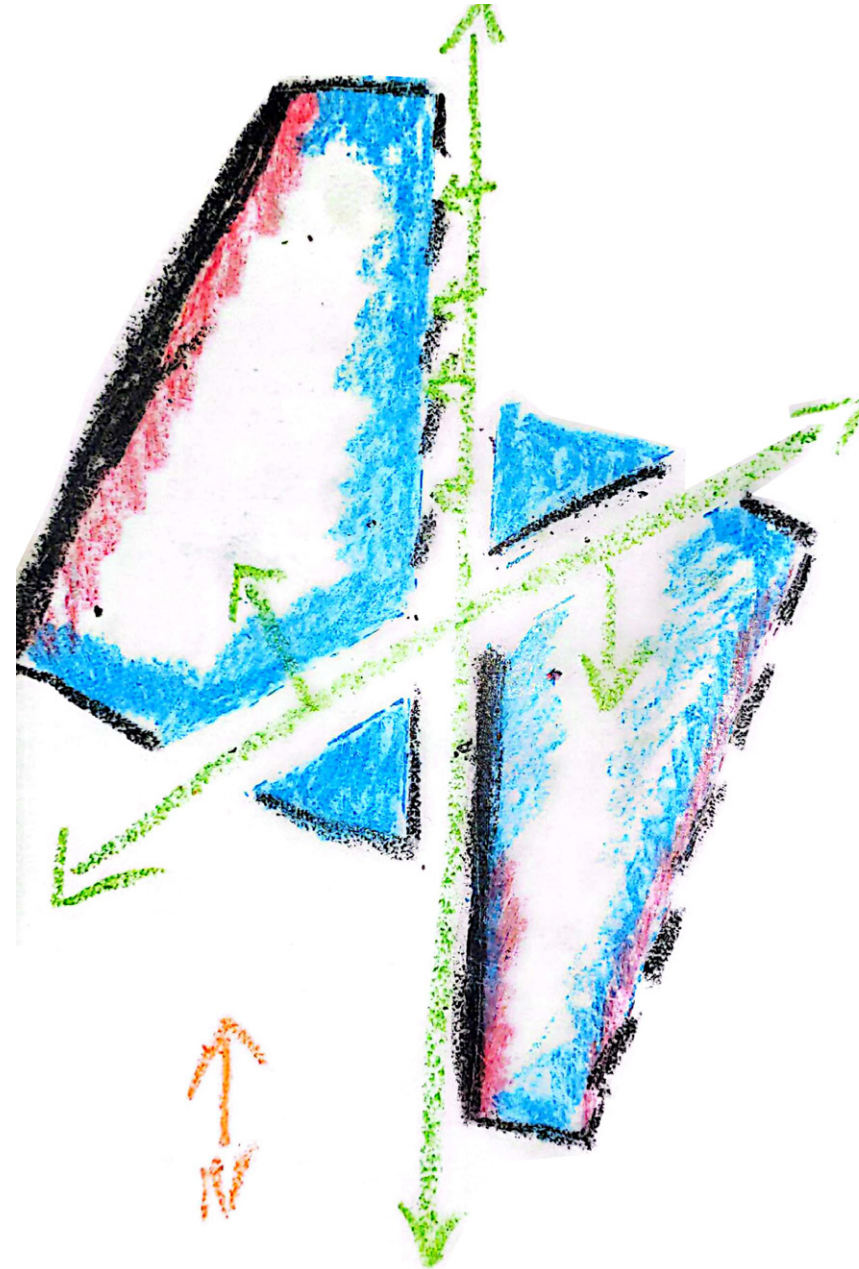


DEVELOPMENT

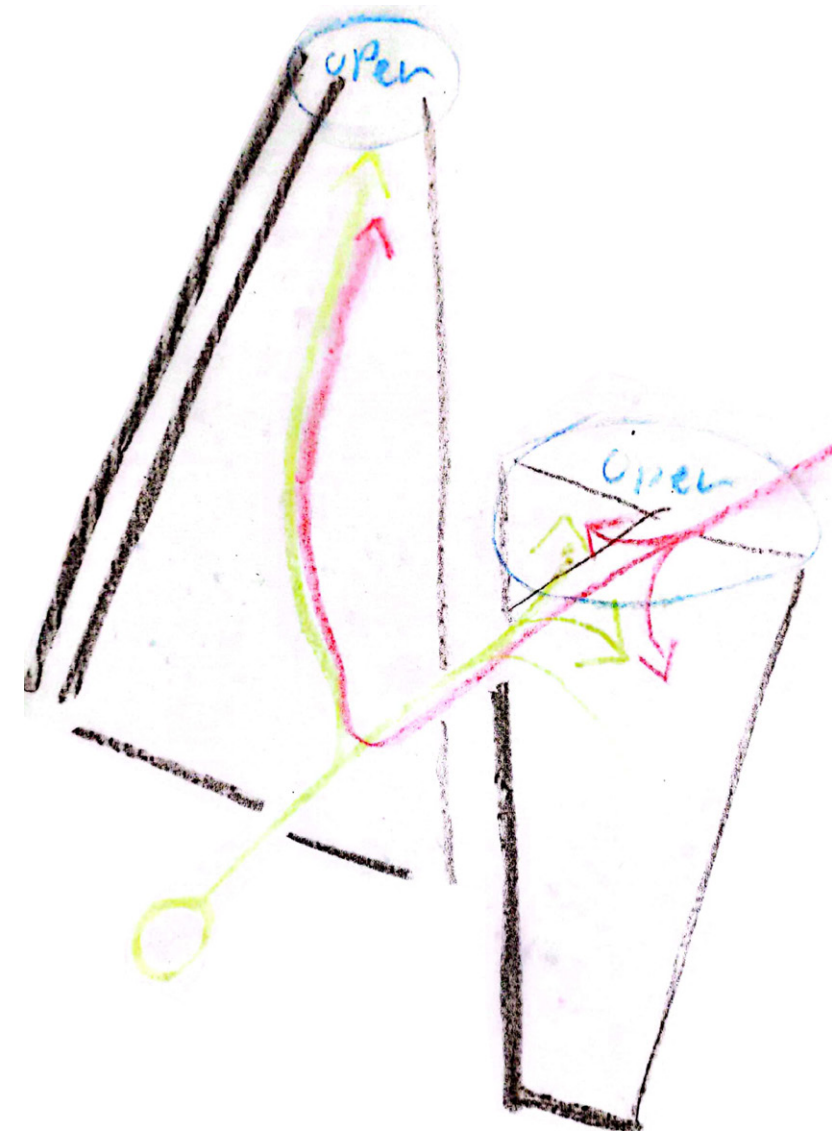
Solid/void; open/closed and circulation



Solid; void and circulation



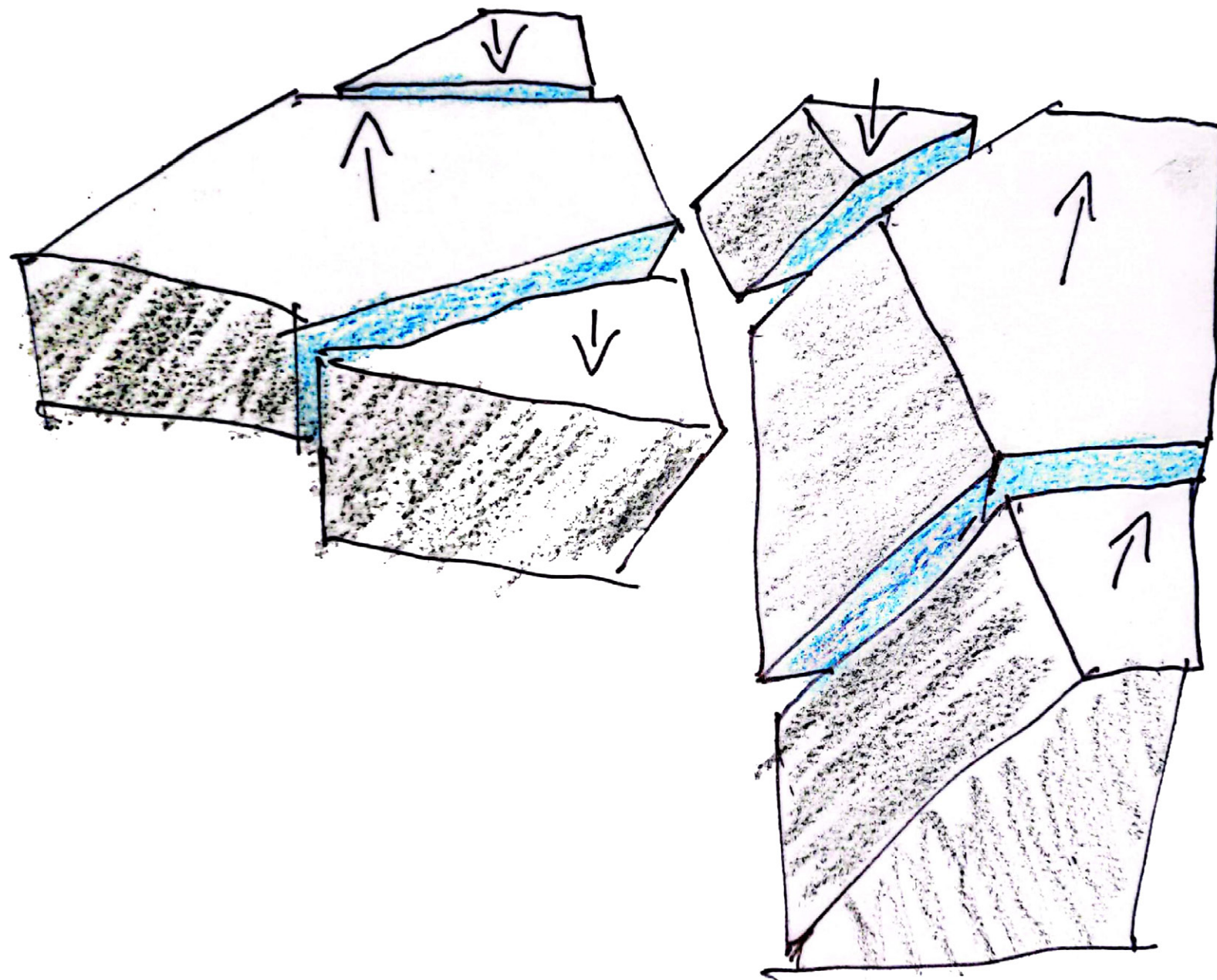
Temperature and circulation



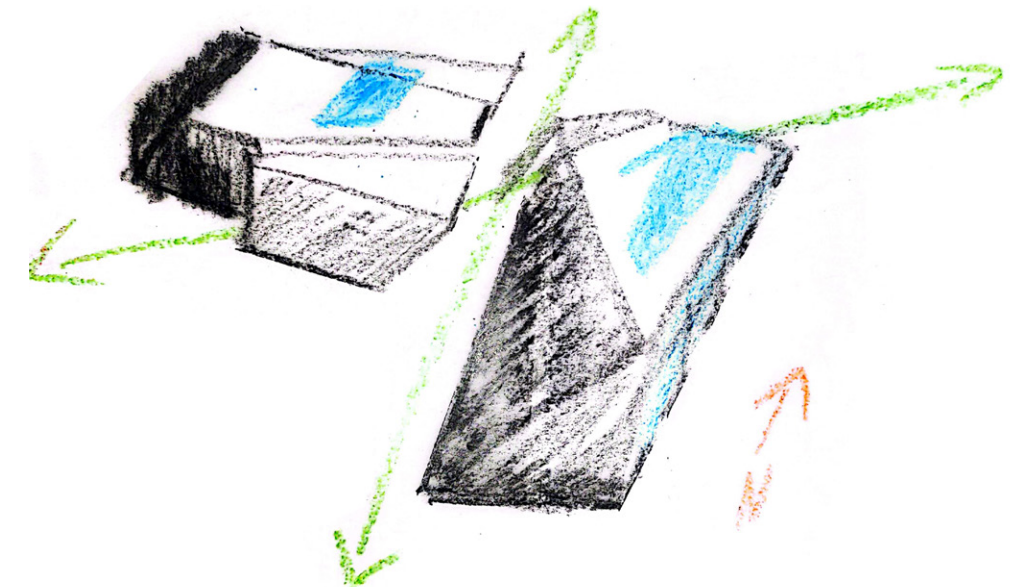
Solid; void and circulation

DEVELOPMENT

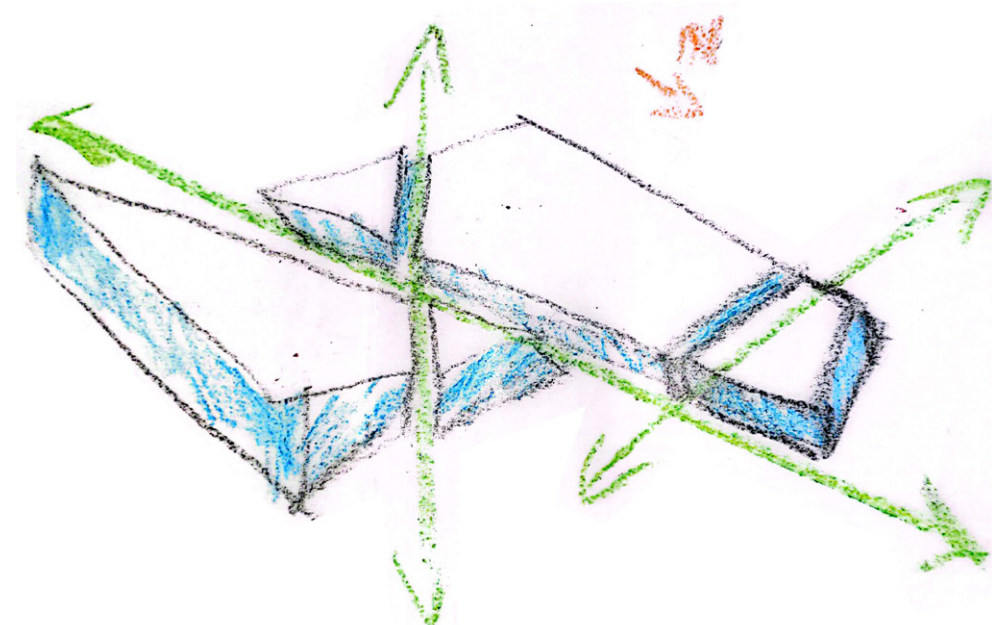
Solid/void; mass and circulation



Form; solid and void



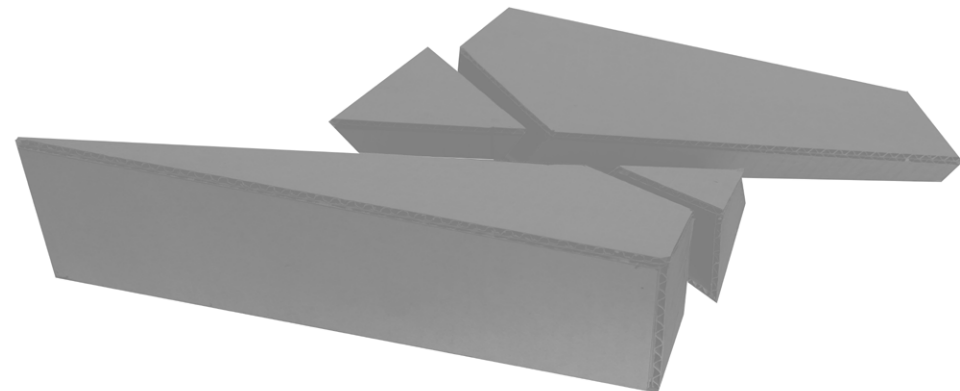
Form and circulation



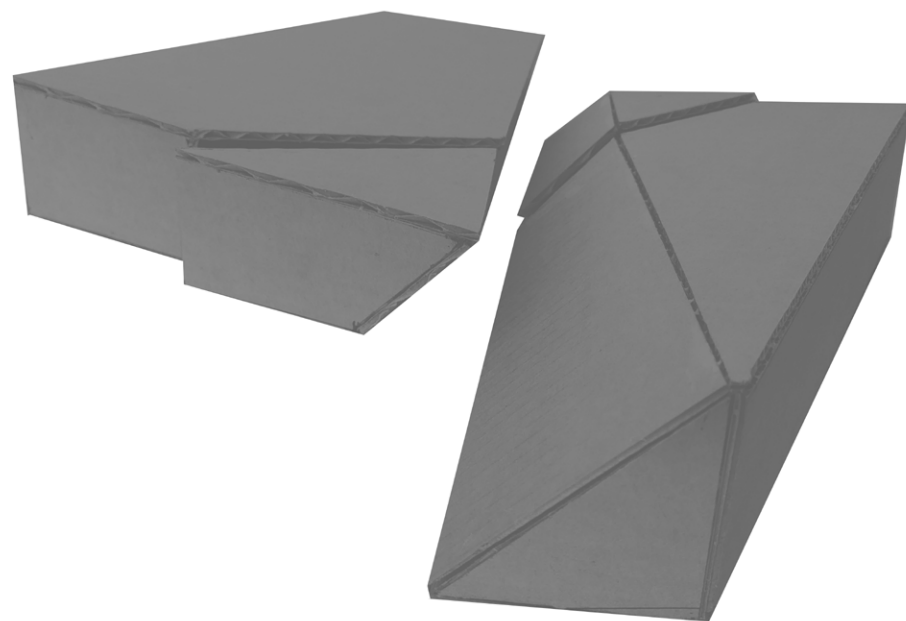
Form and circulation

DEVELOPMENT

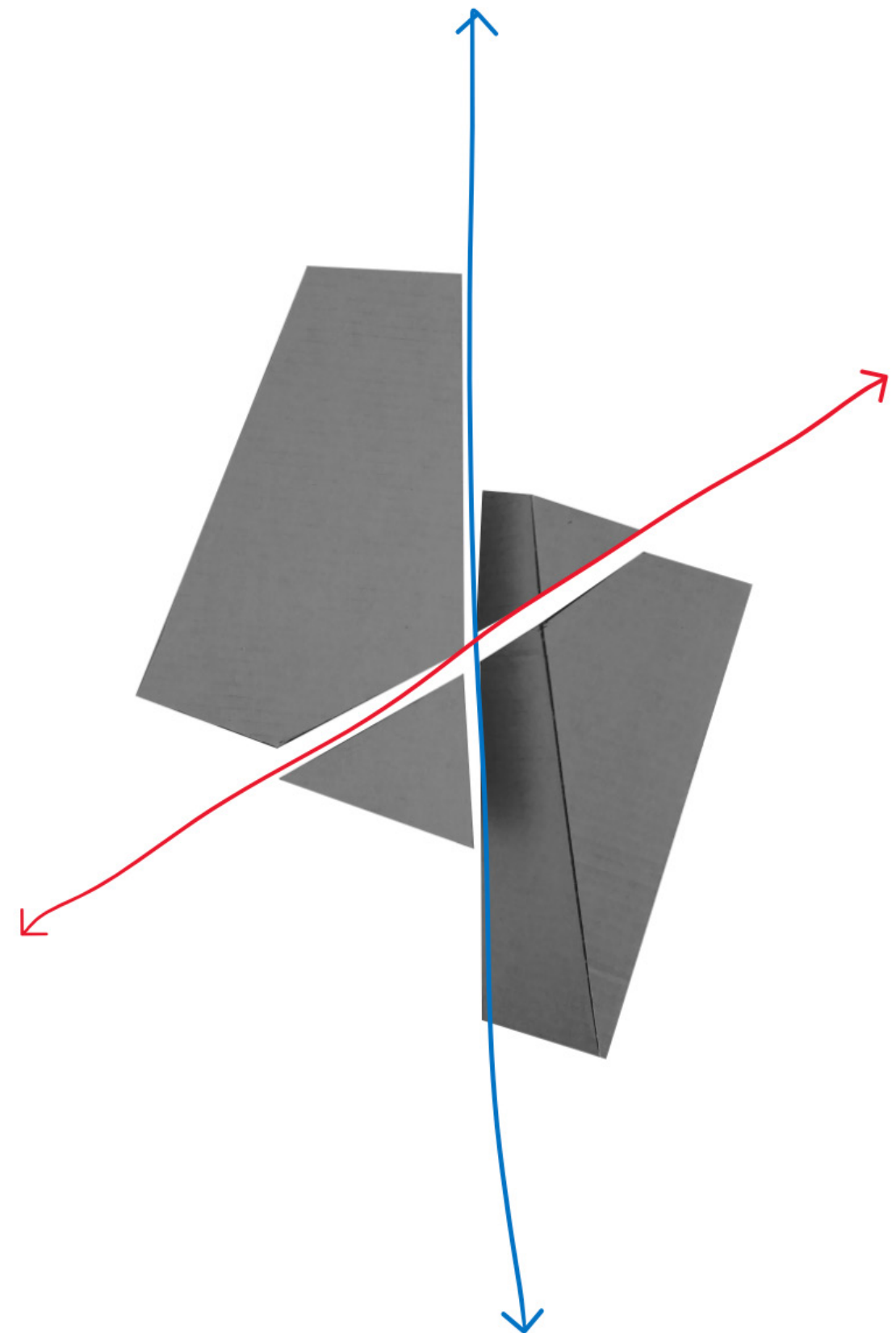
Form exploration



Solid and void model



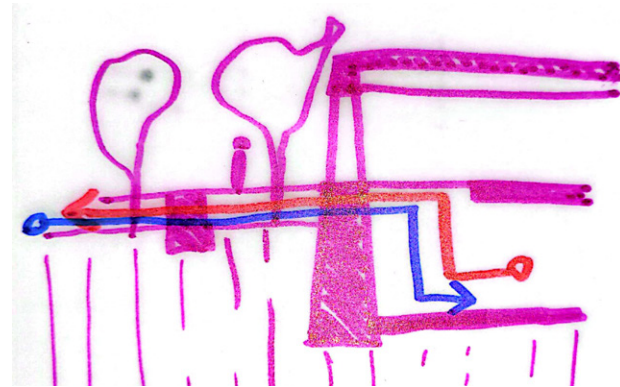
Solid and void model



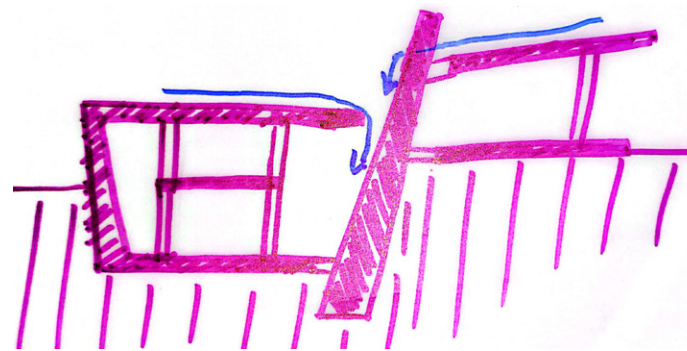
Solid and void model with axis

DEVELOPMENT

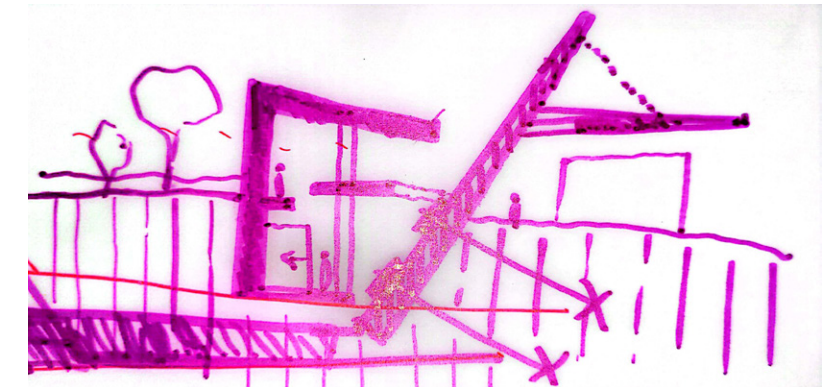
Form and function exploration



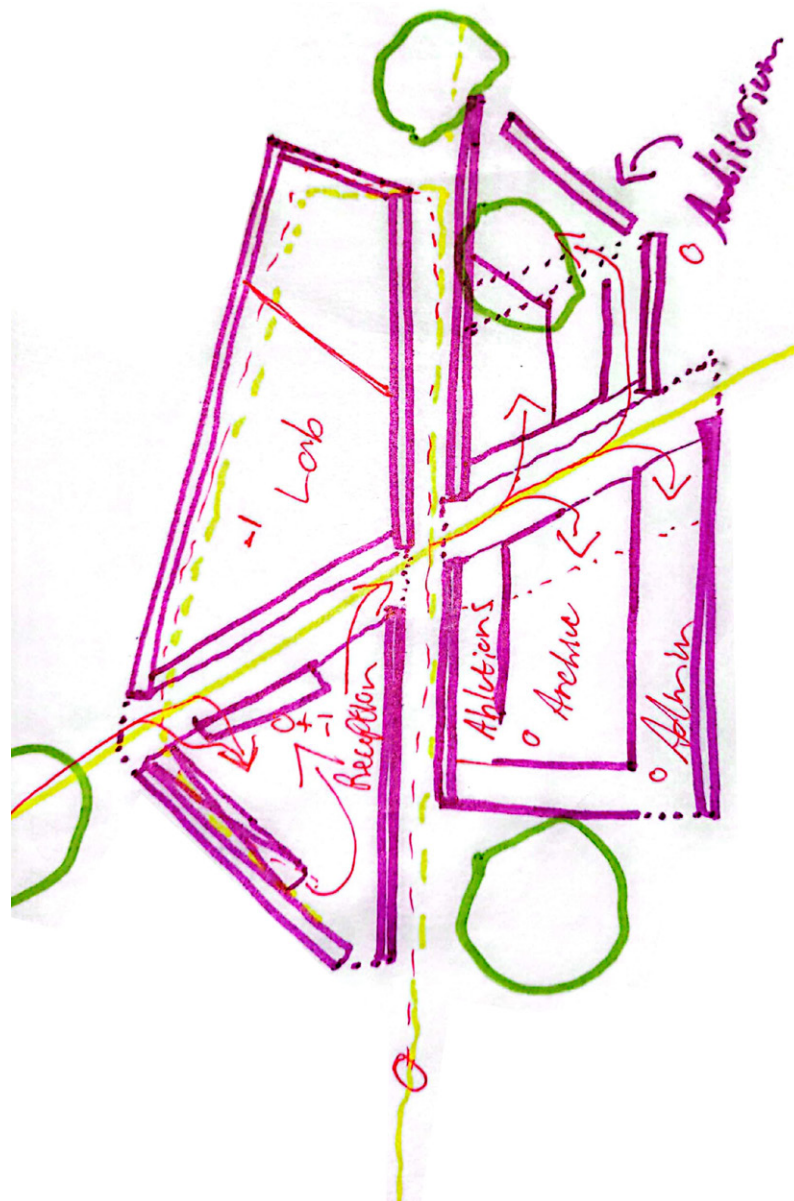
Water circulation in and out of the lab



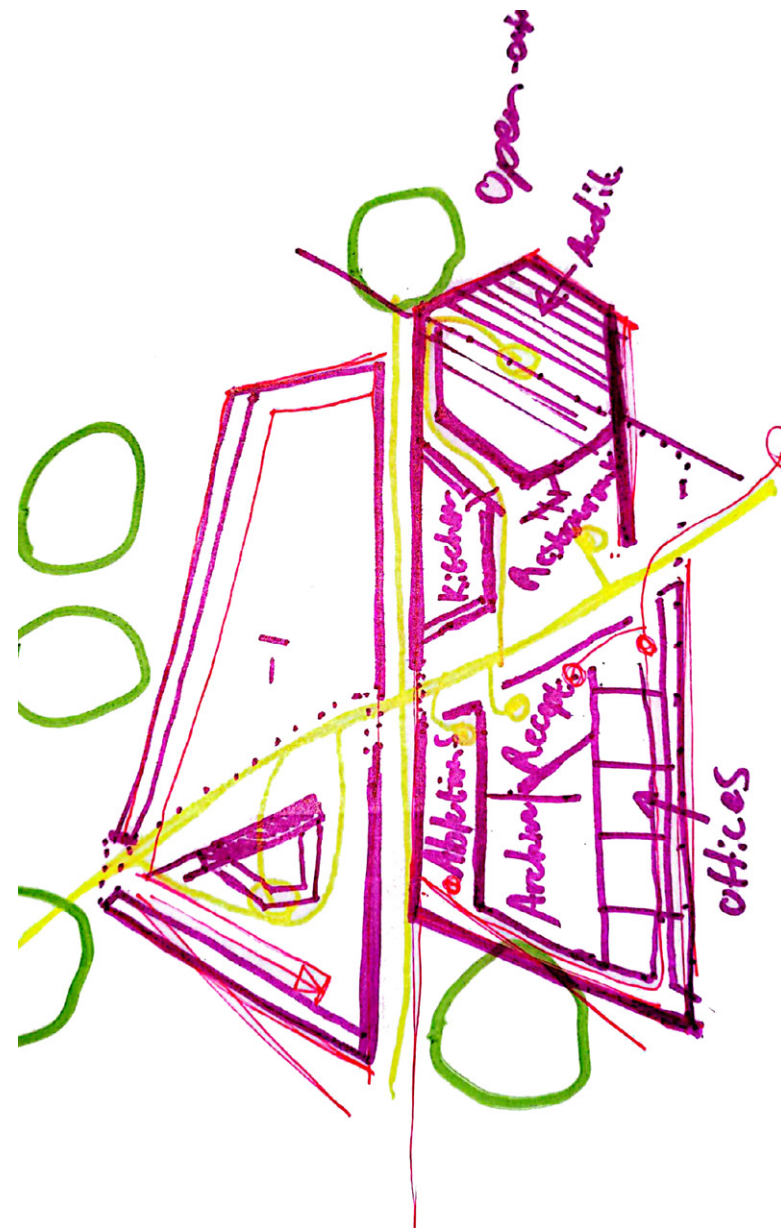
Rain water catchment



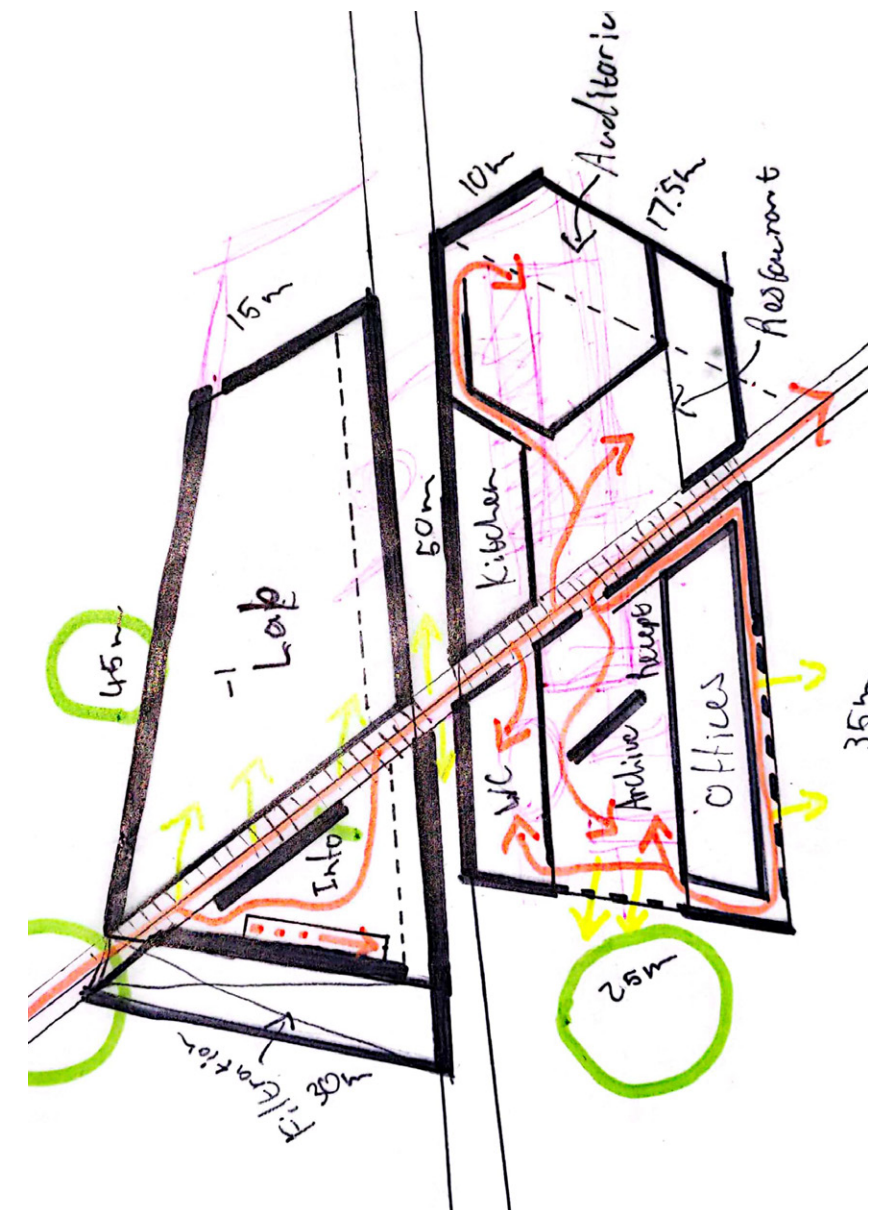
Structural elements of the building



Solid; void and circulation



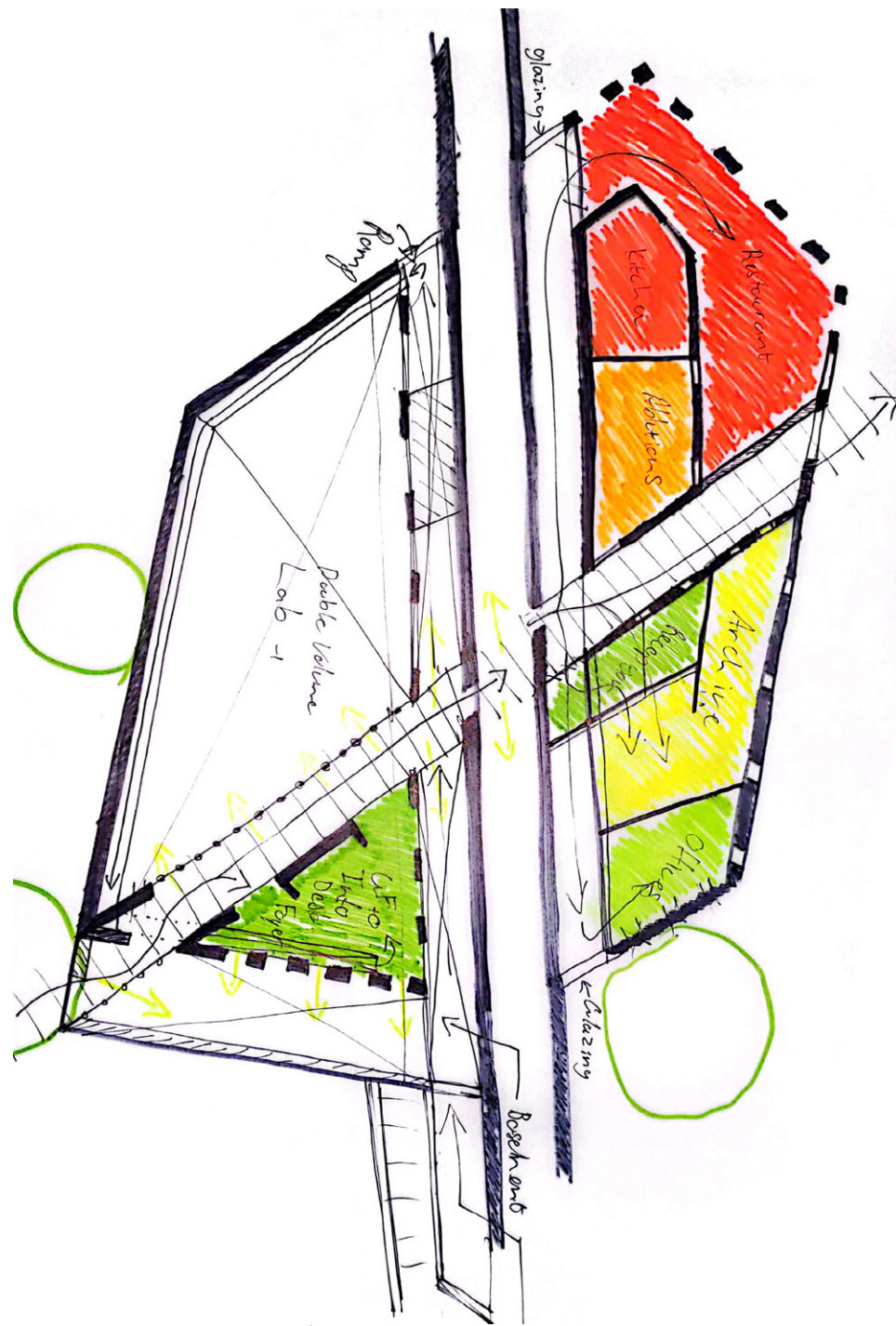
Function and circulation



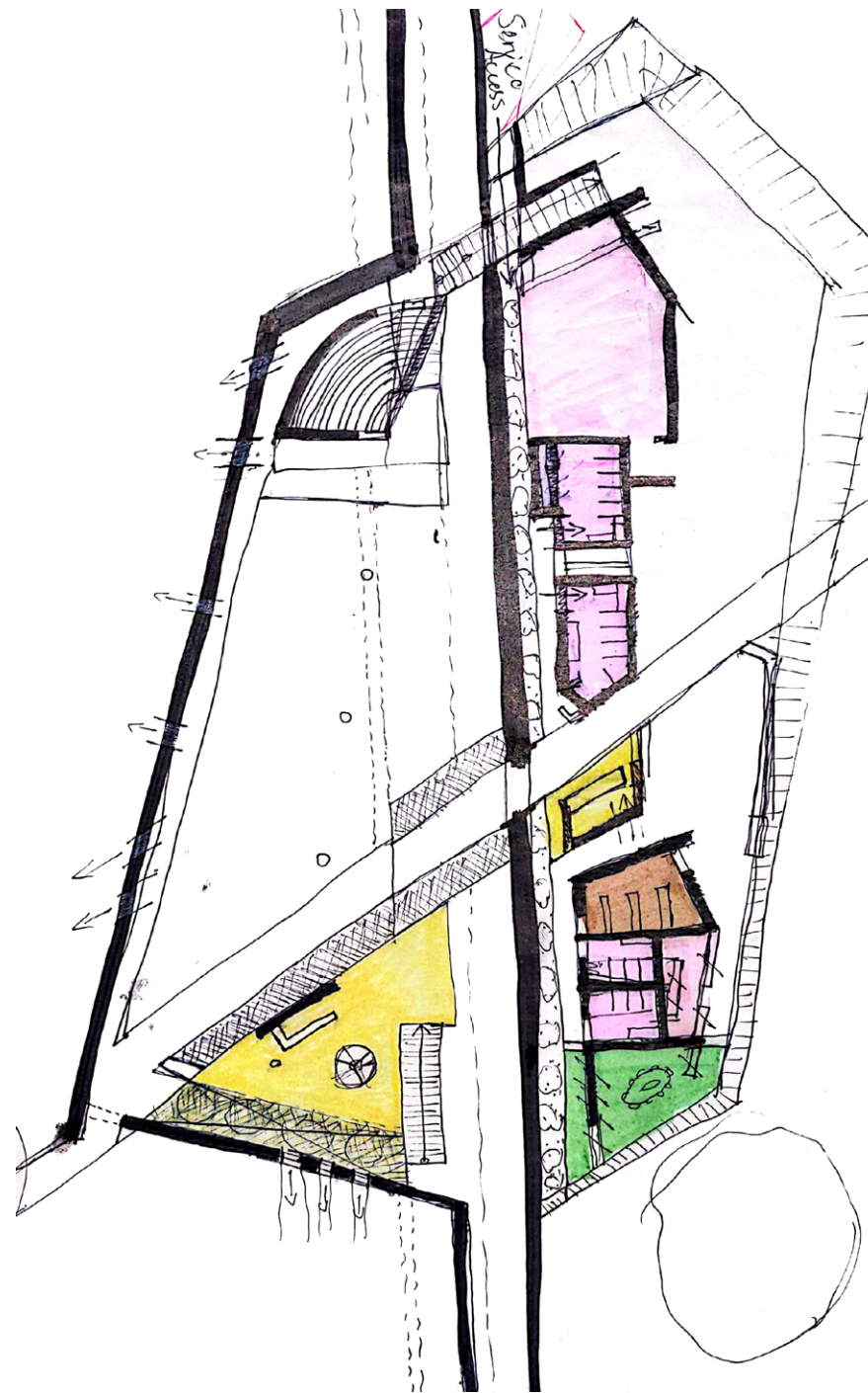
Function and circulation

DEVELOPMENT

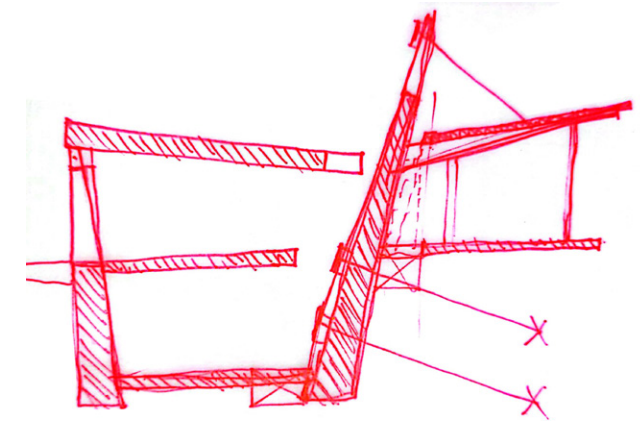
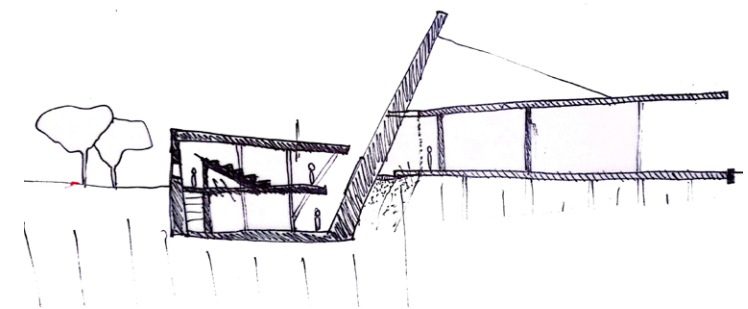
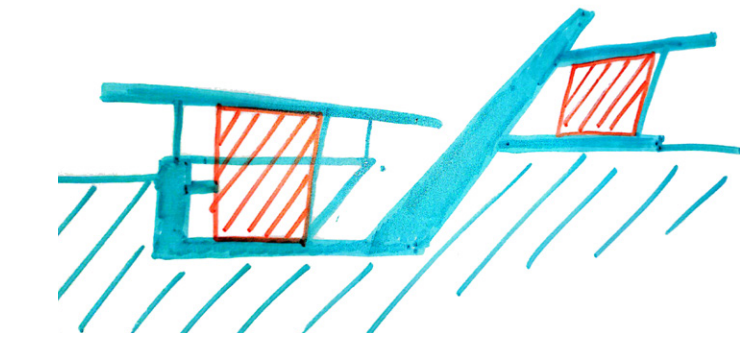
Form and Function exploration



Solid; void and function



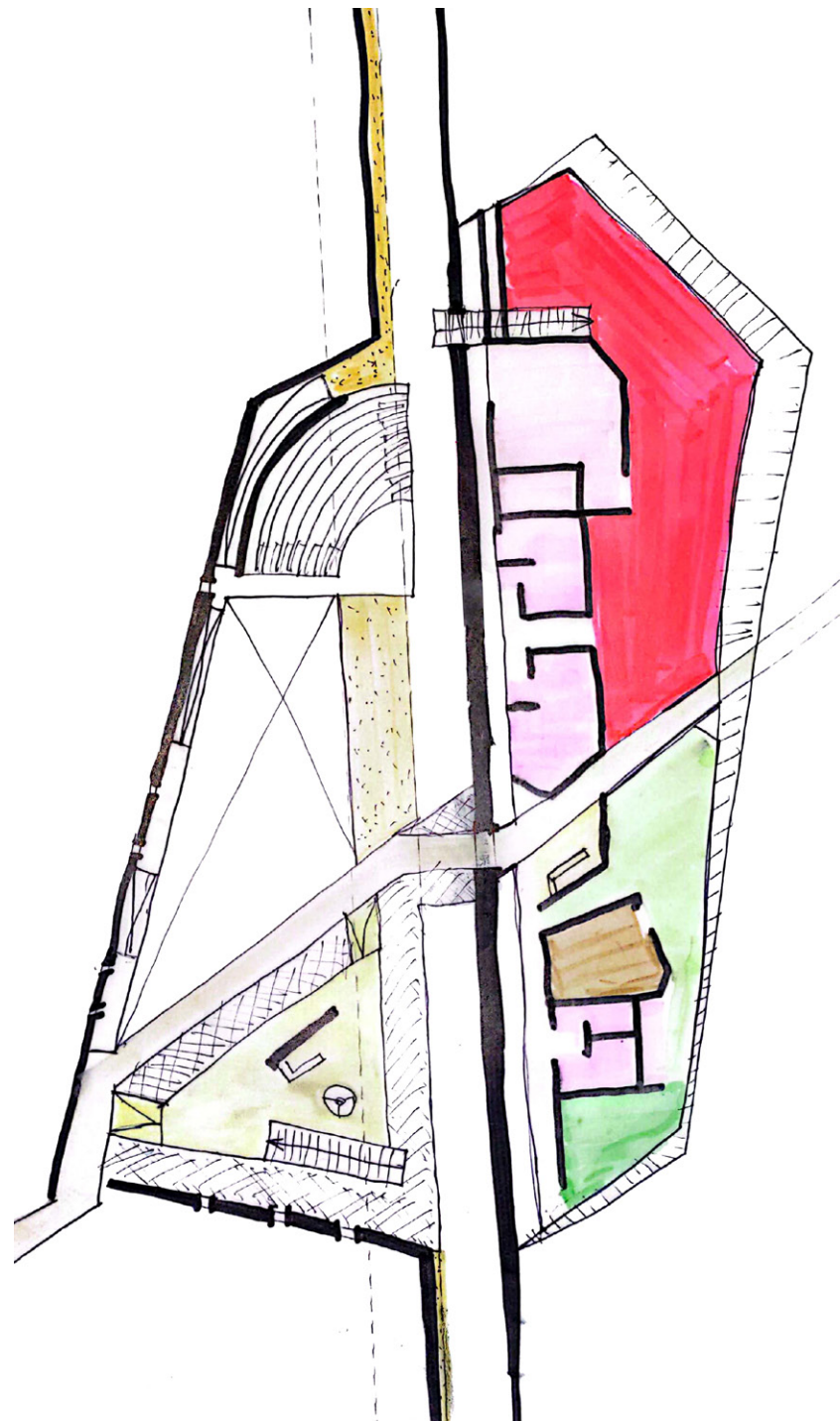
Solid; void and function



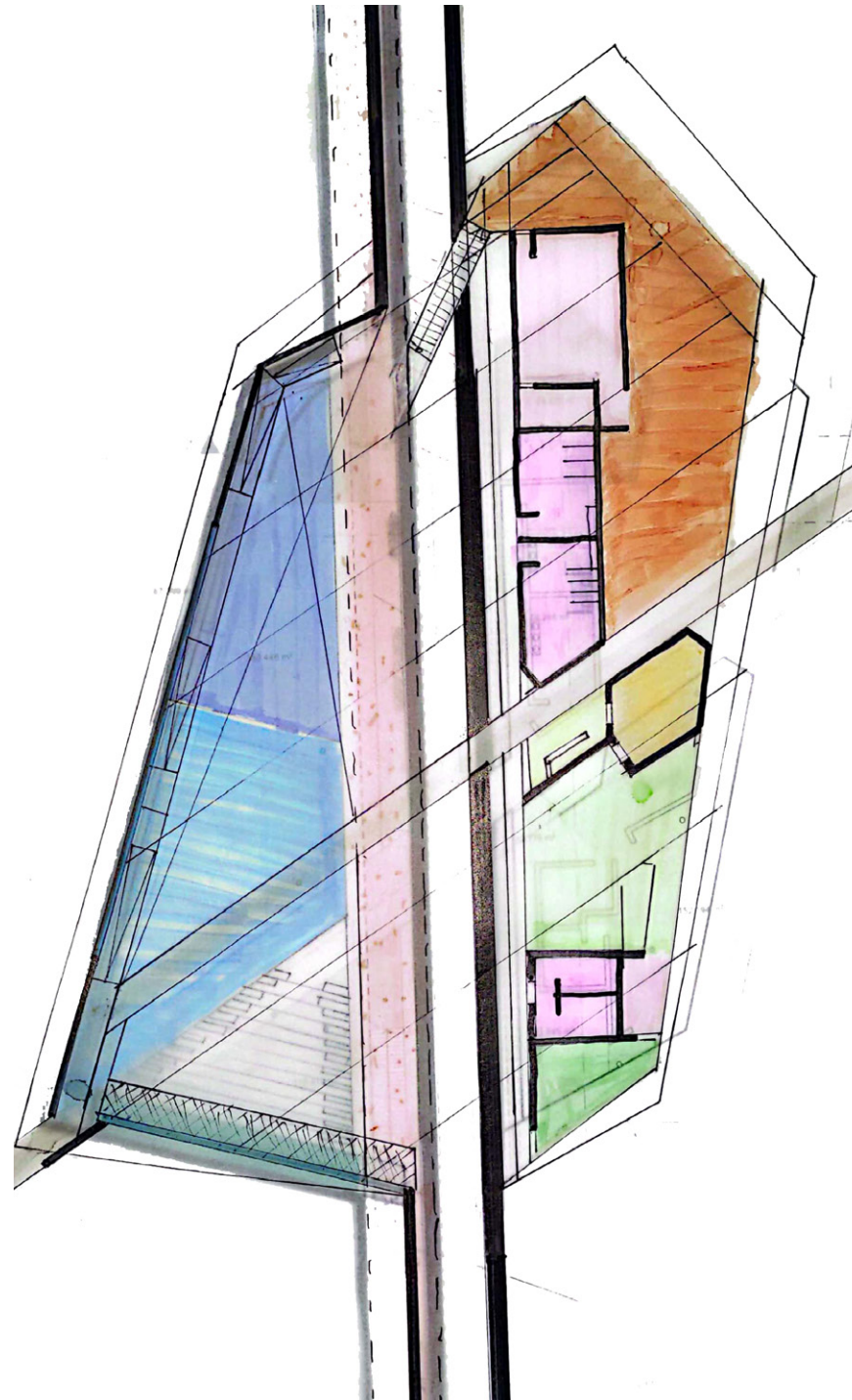
Fault wall and function sections

DEVELOPMENT

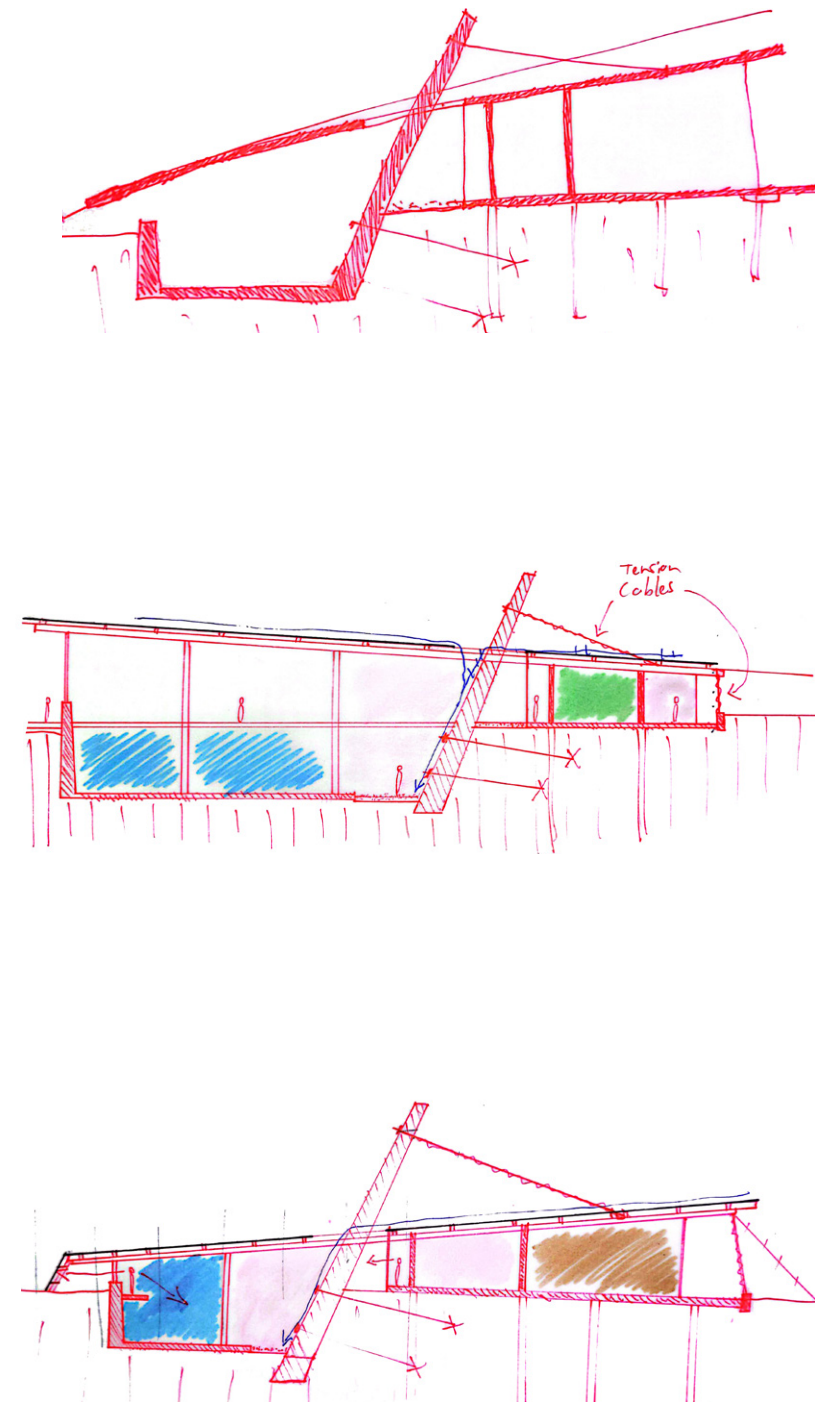
Form and Function exploration



Solid; void and function



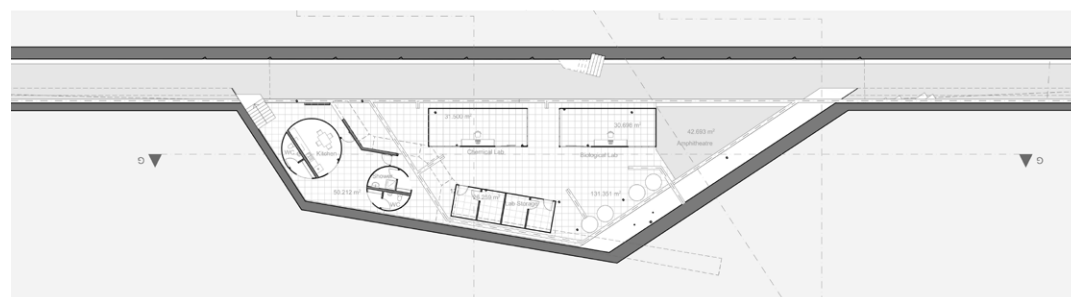
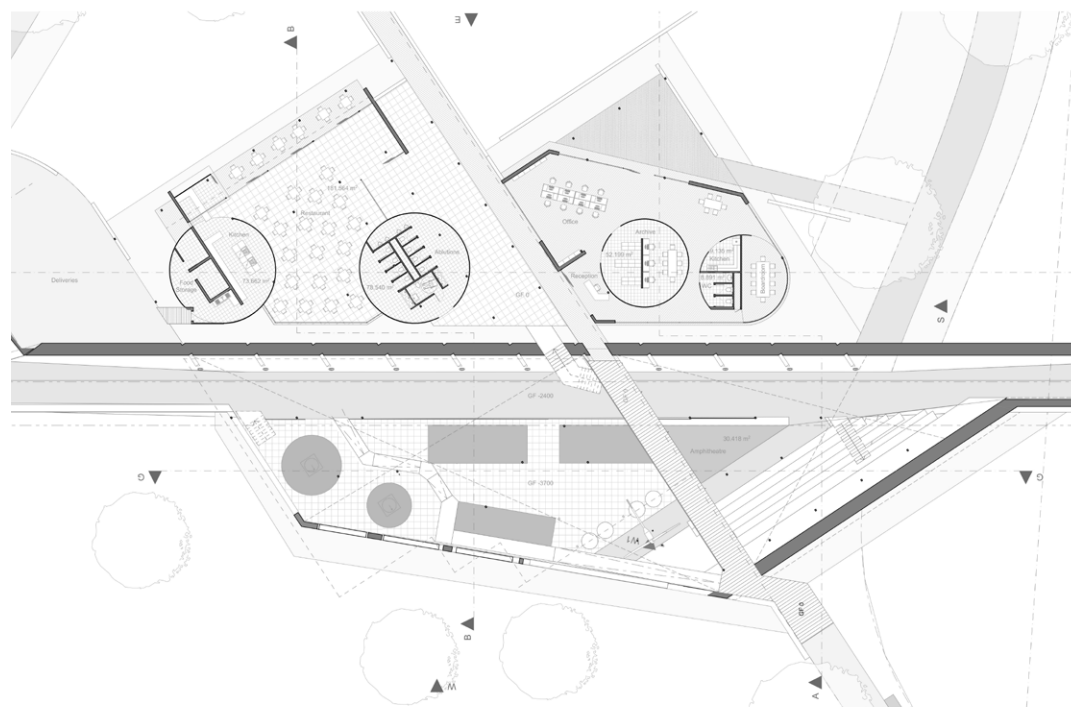
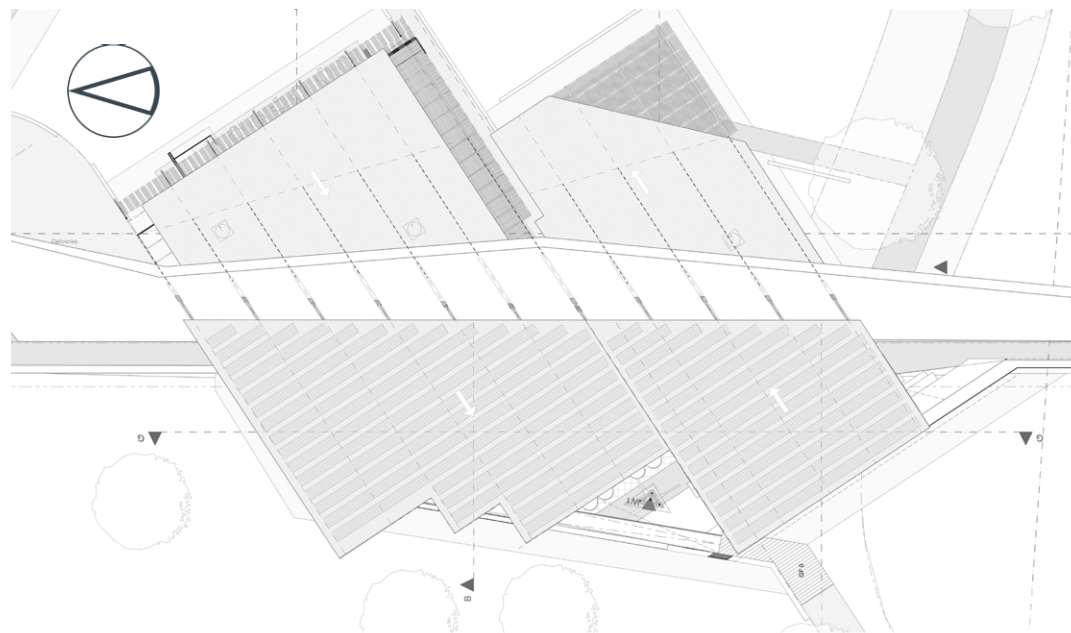
Solid; void and function



Fault wall and function sections

Chapter 4

Final Documentation



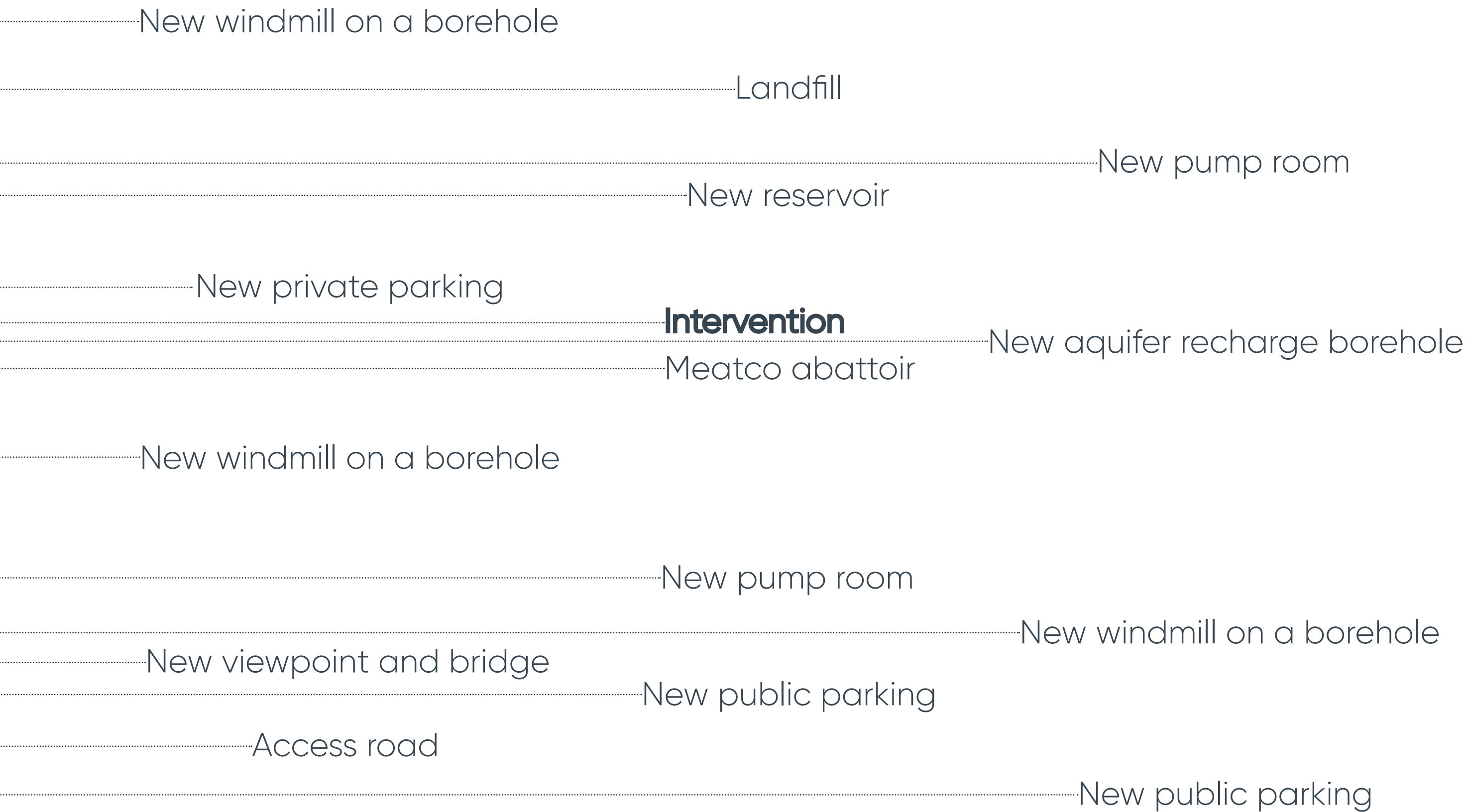
Plans:	
Locality	77-78
Site	79
Roof	80
Ground floor	81-82
Basement	83-84
Elevations:	
North and South	85
East and West	86
Sections and details:	
A	87-88
B	89-90
F and G	91
Walkway section	92
Walkway	93
River bridge	94
Perspectives:	96-104

All drawings in this chapter are by the author and are not to scale unless stated otherwise.

DOCUMENTATION

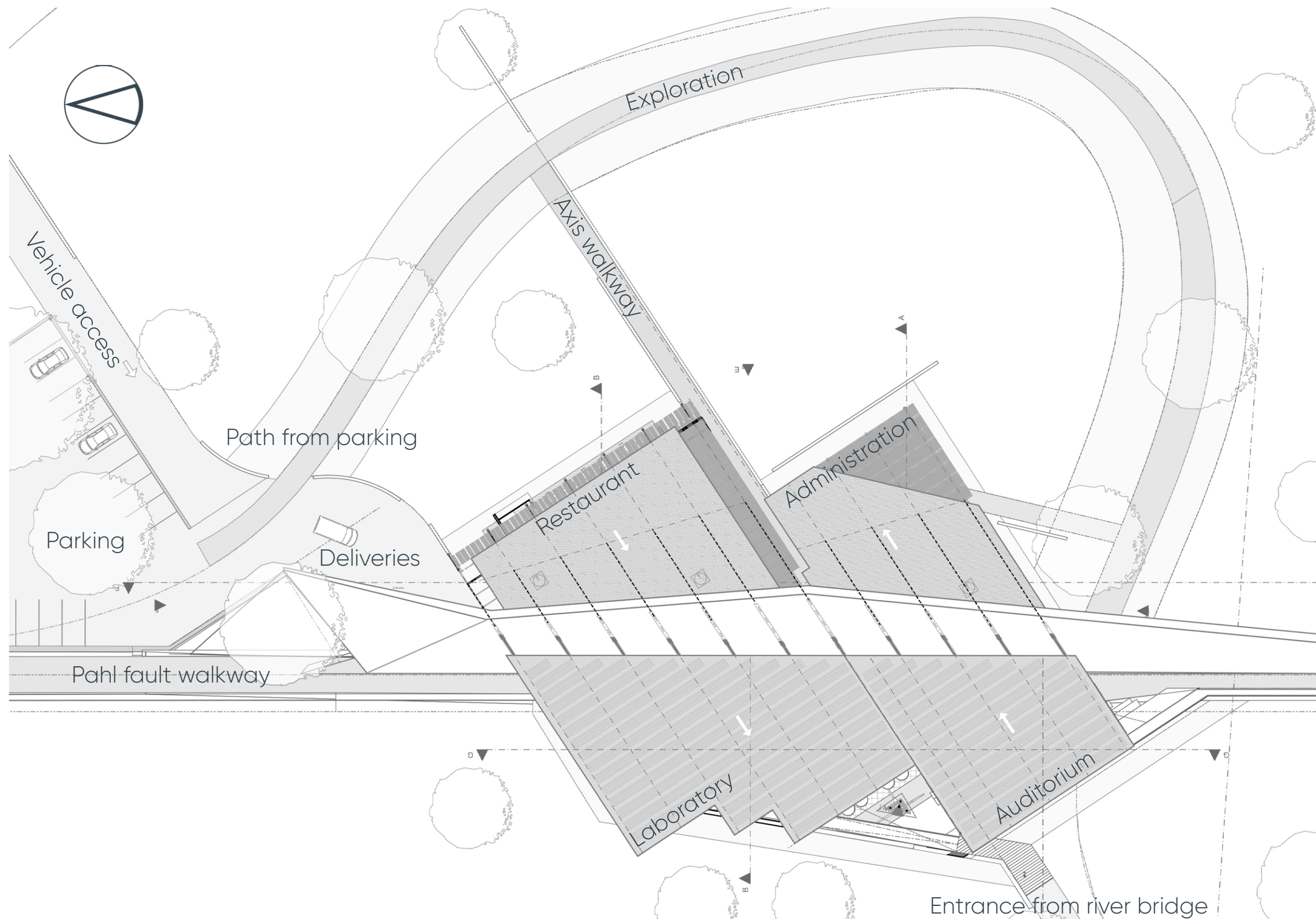
Locality plan





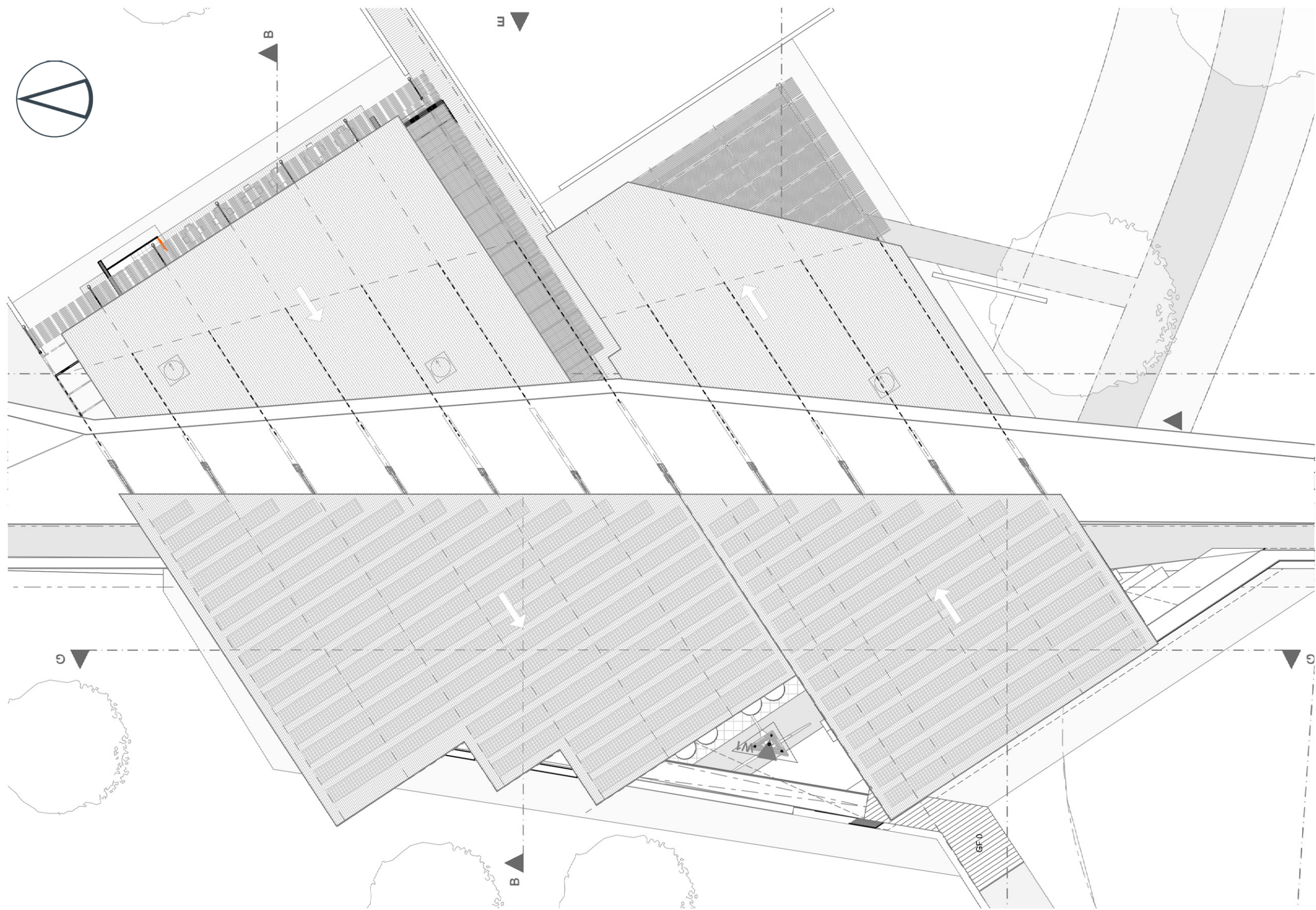
DOCUMENTATION

Site plan



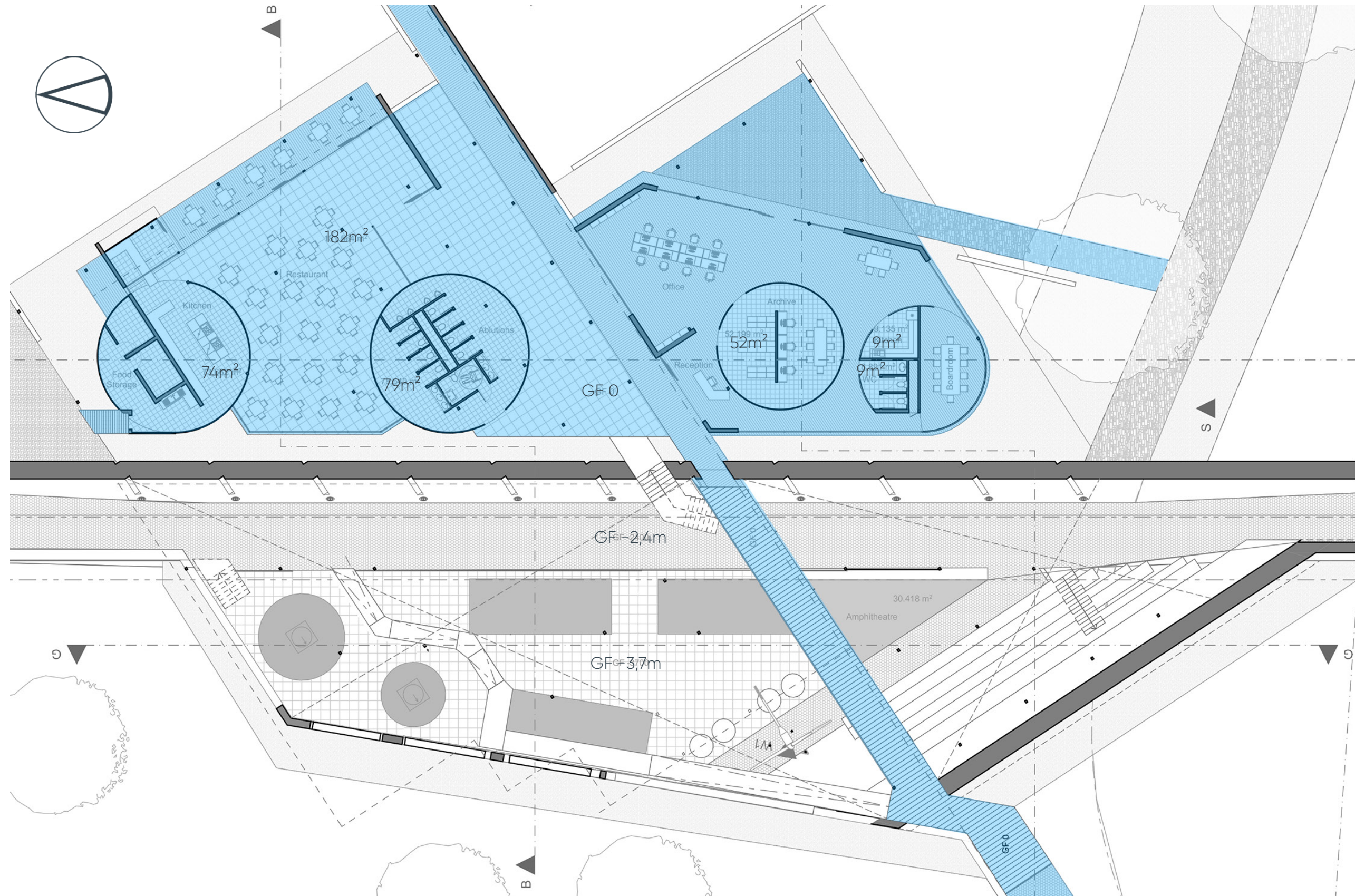
DOCUMENTATION

Roof plan



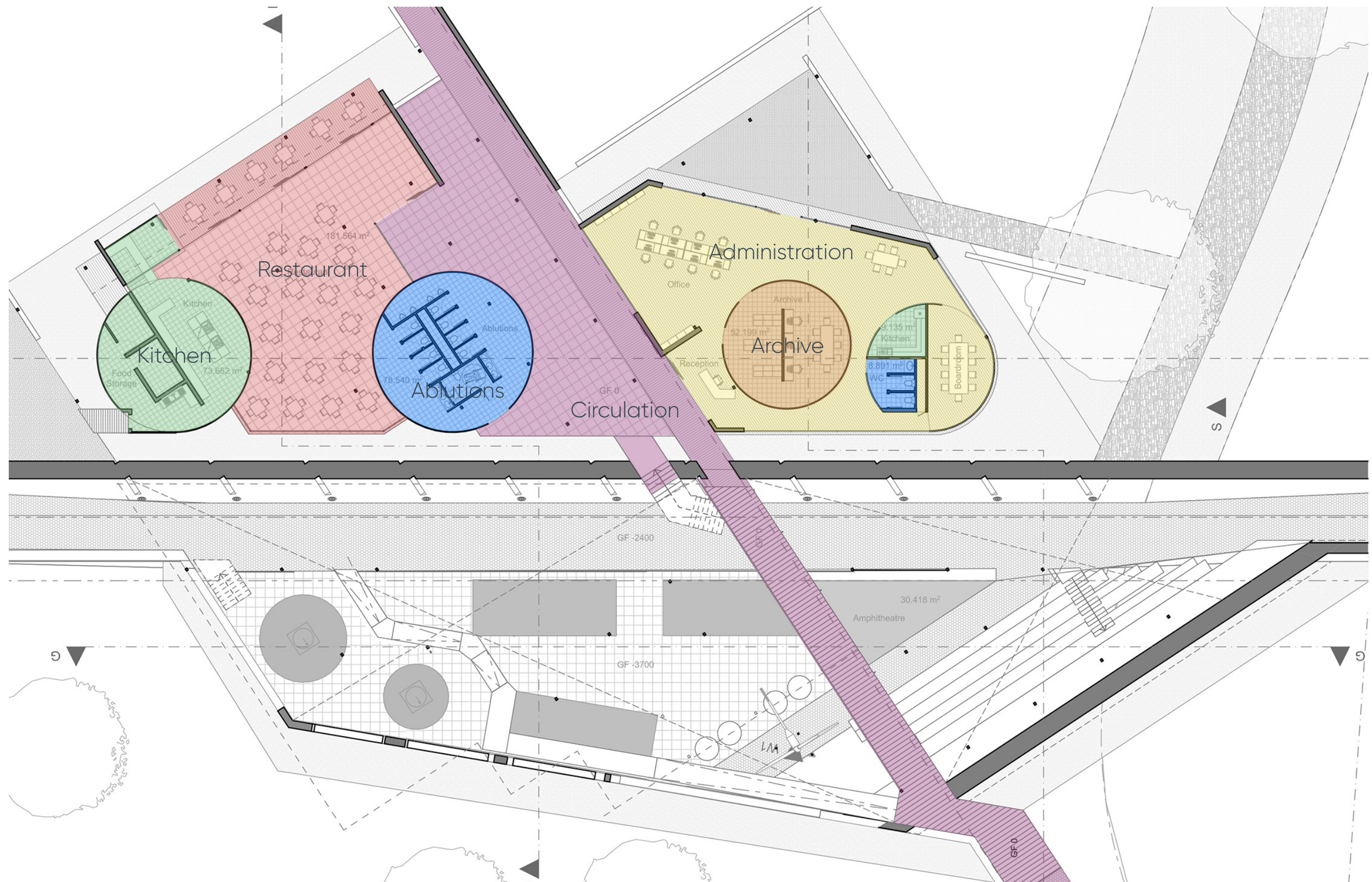
DOCUMENTATION

Ground Floor plan



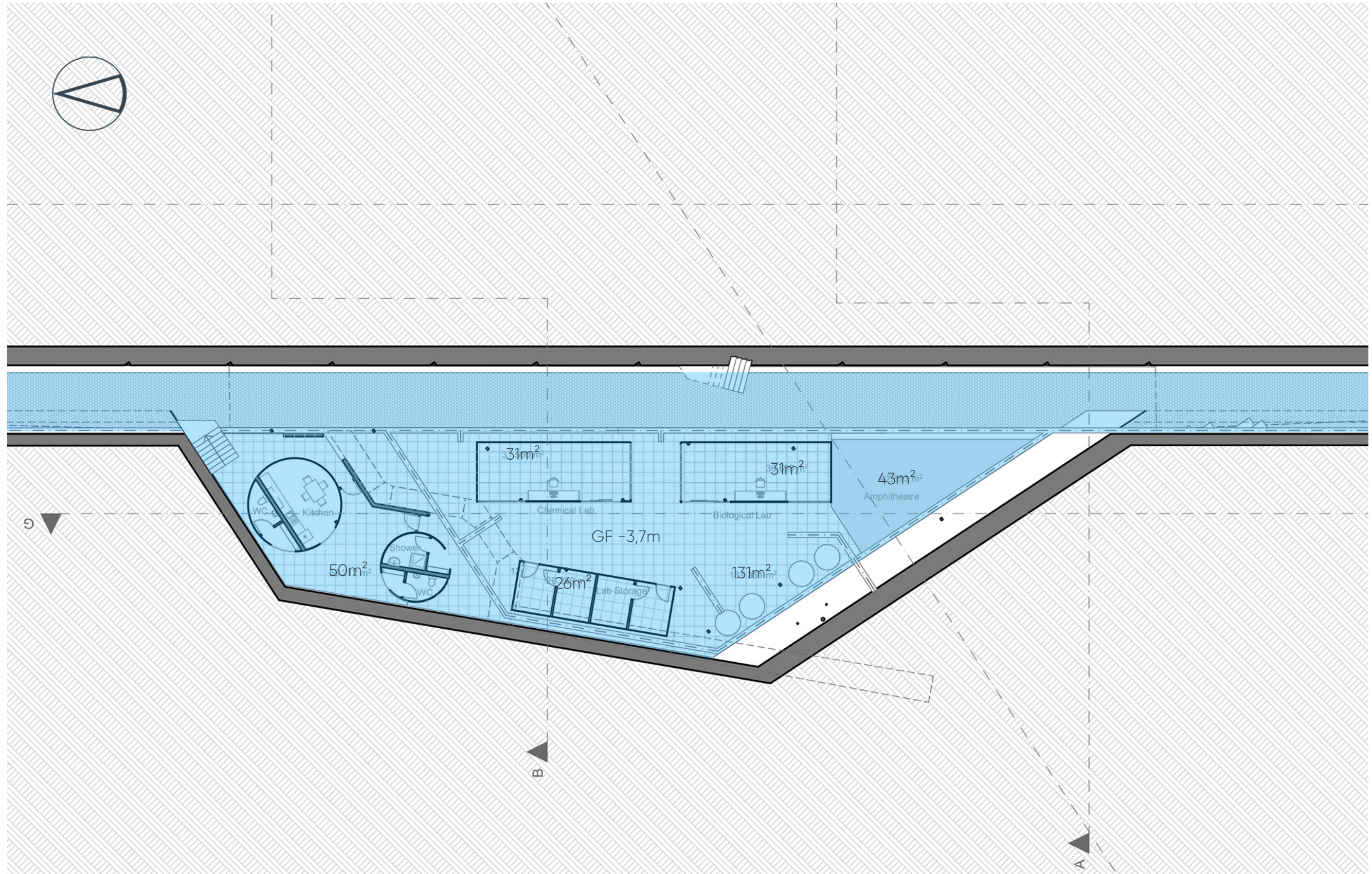
DOCUMENTATION

Ground floor functions



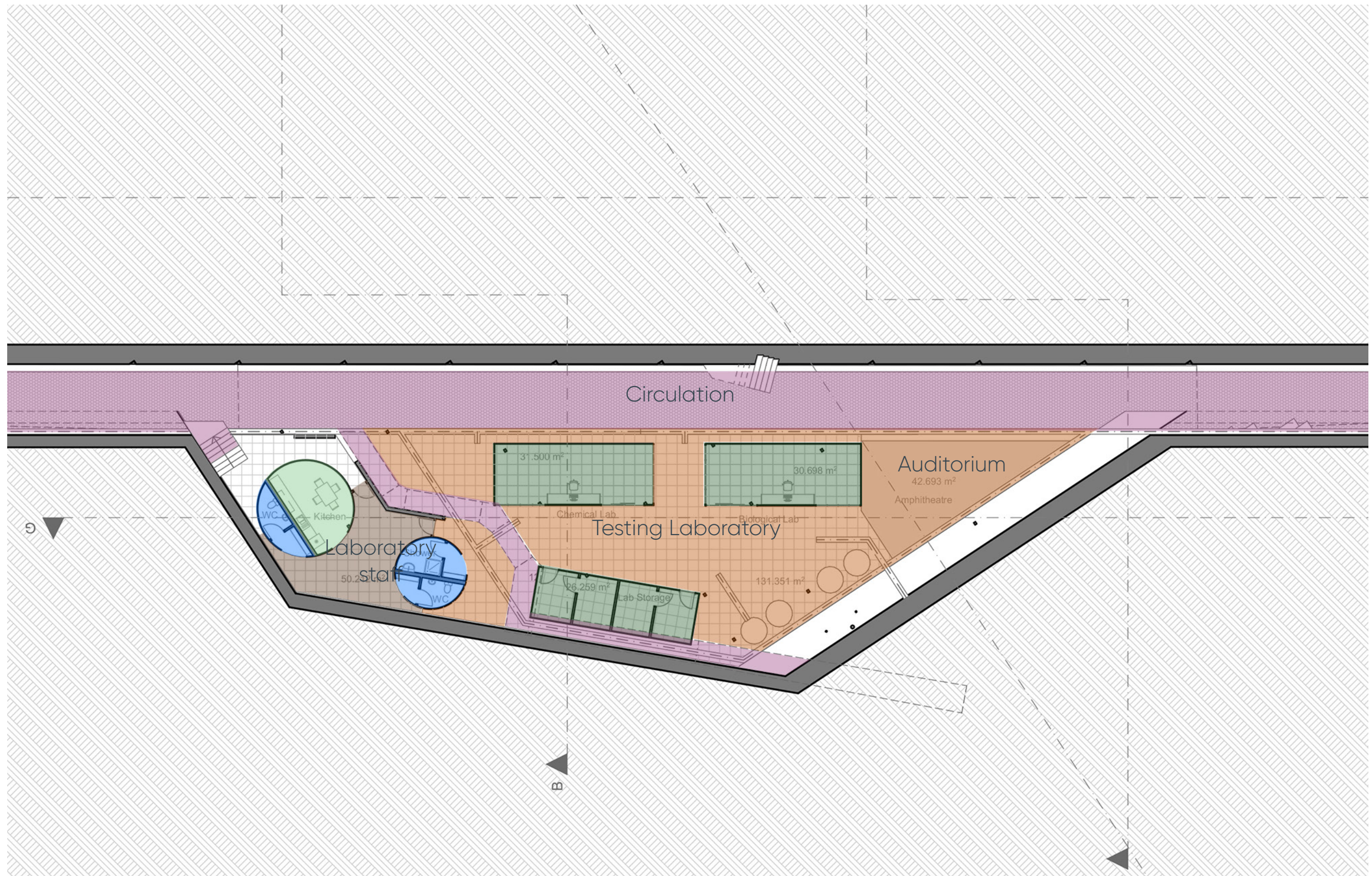
DOCUMENTATION

Basement floor plan



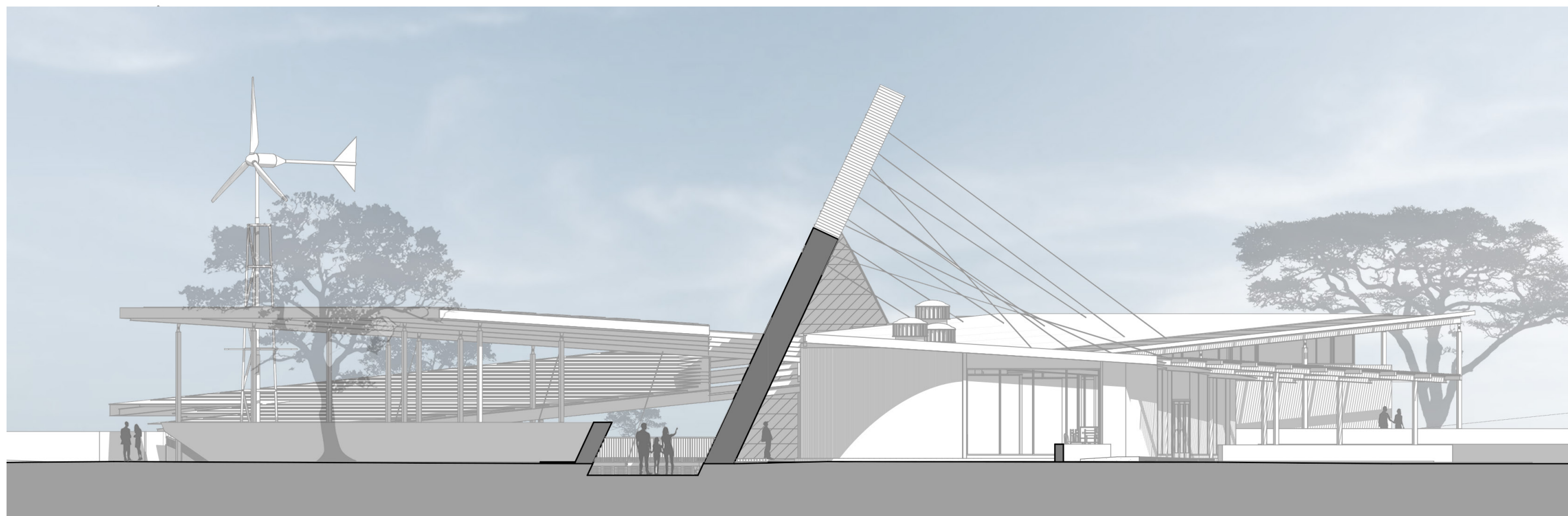
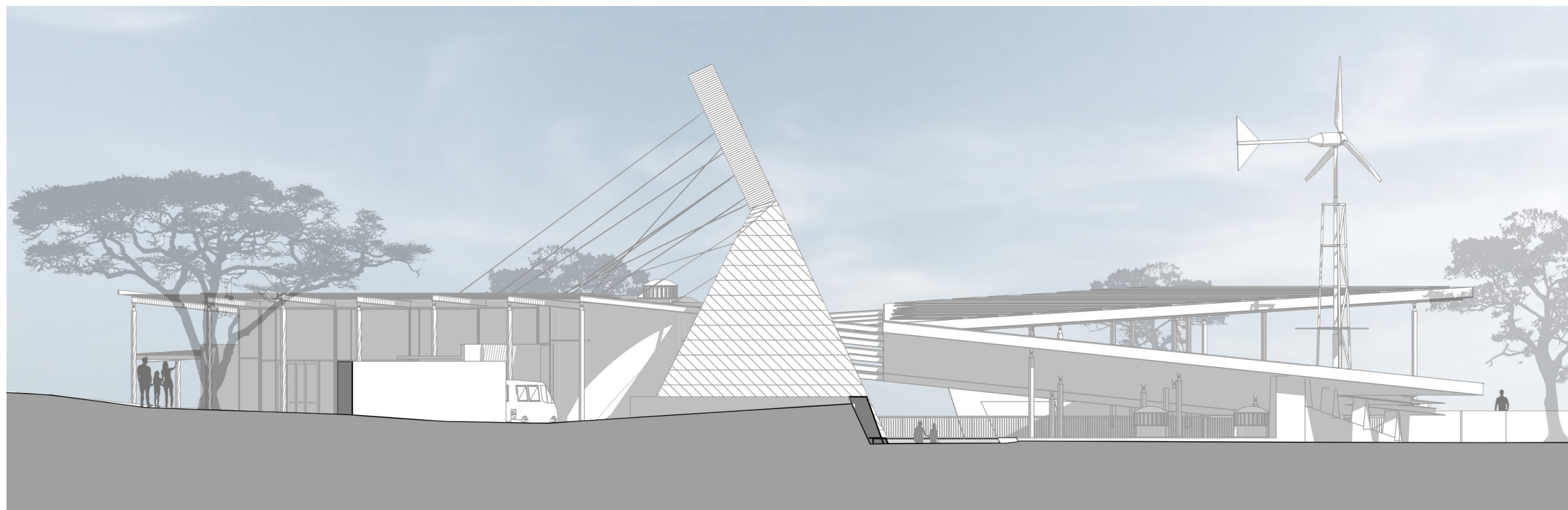
DOCUMENTATION

Basement floor functions



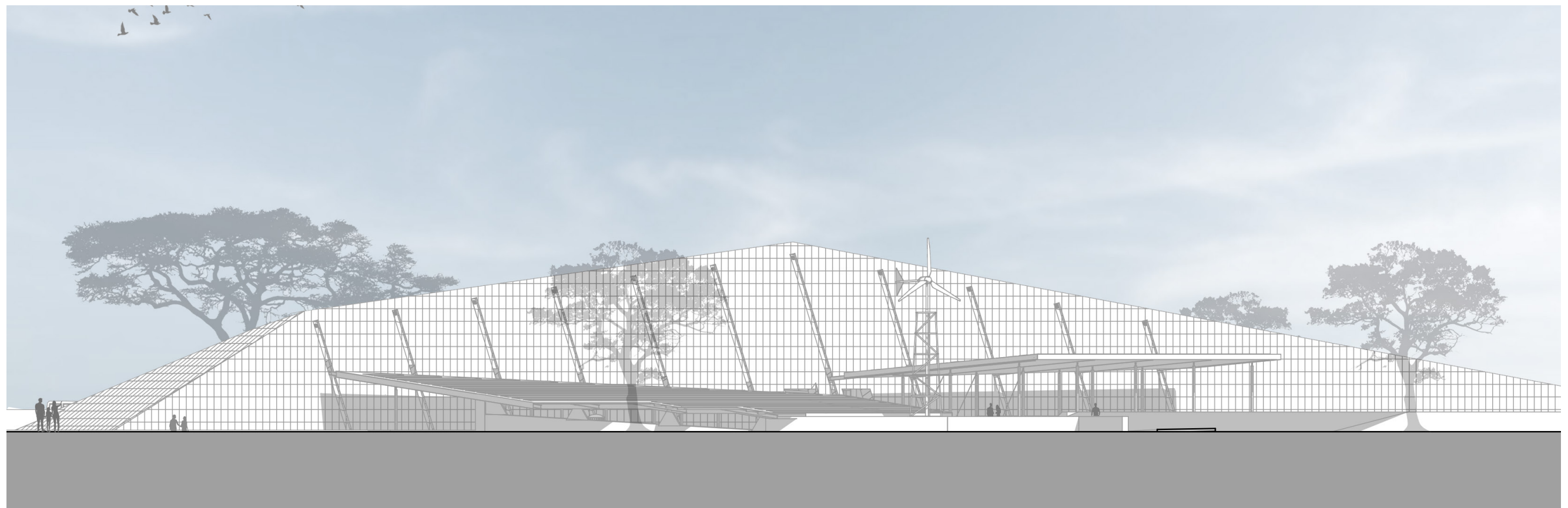
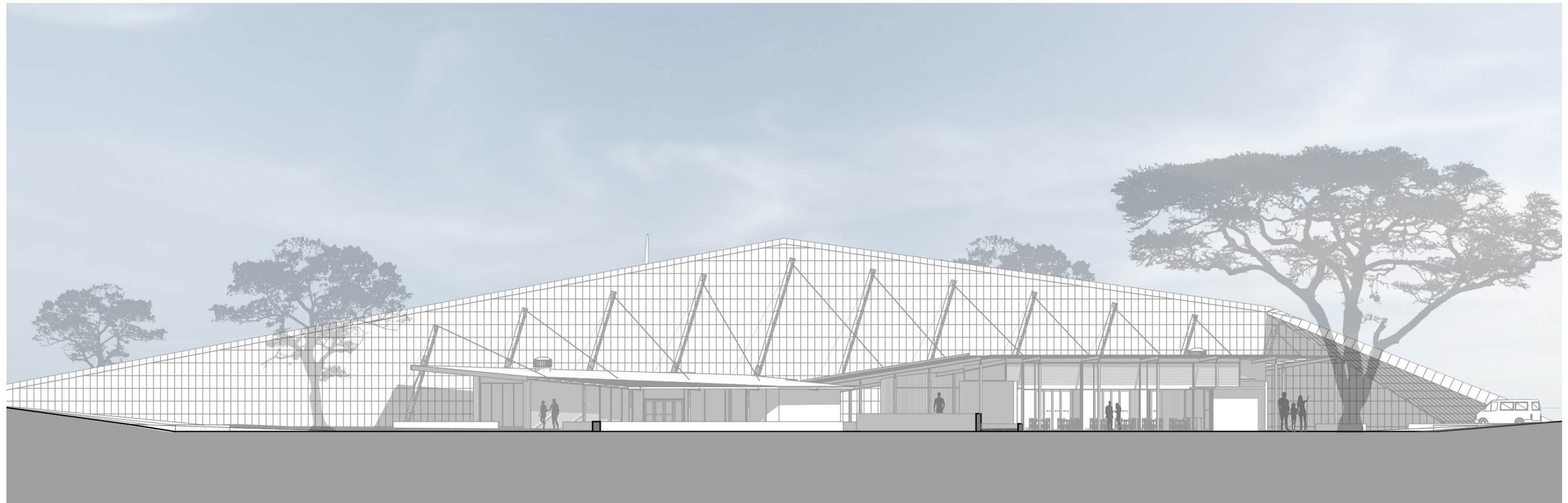
DOCUMENTATION

North and south elevations



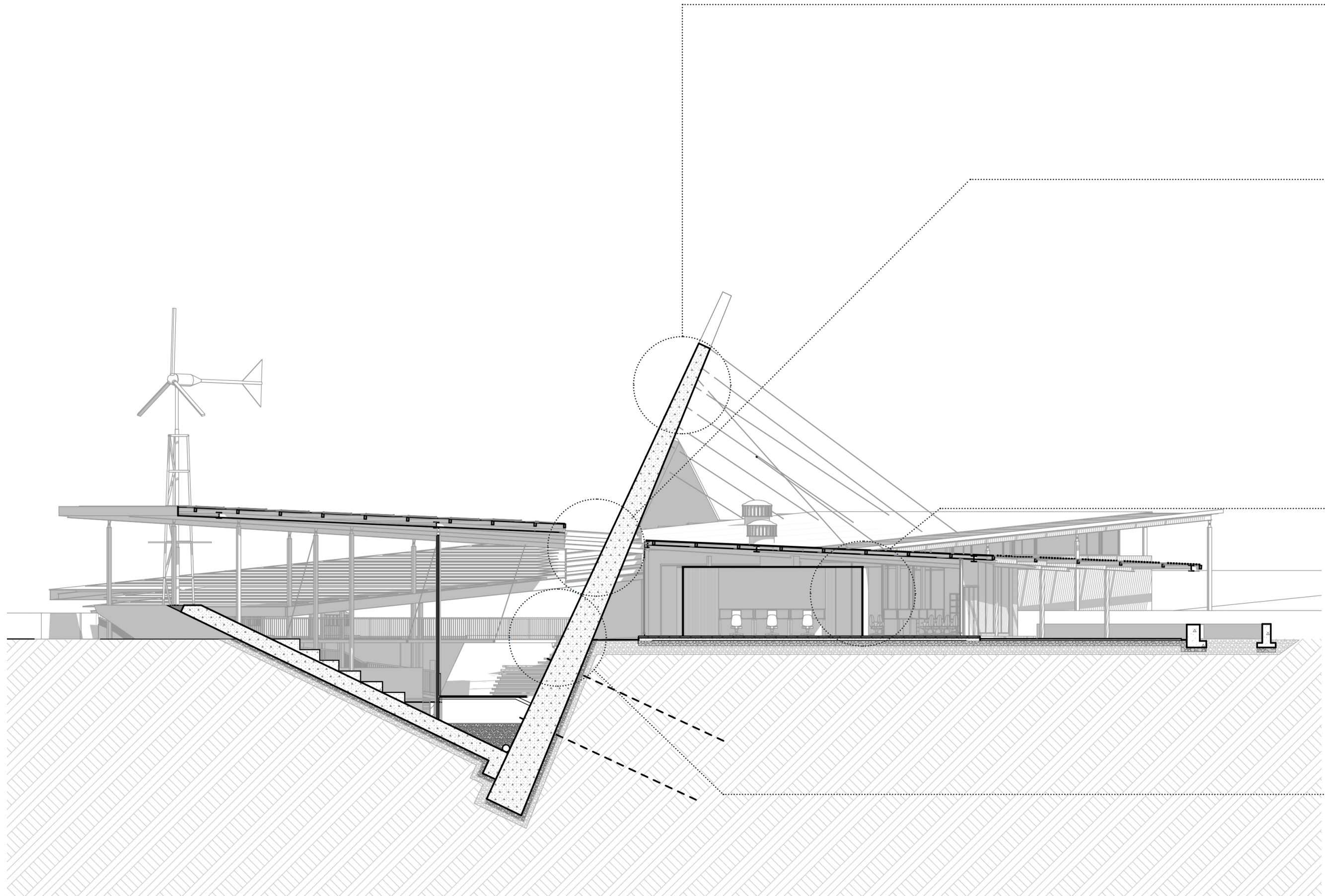
DOCUMENTATION

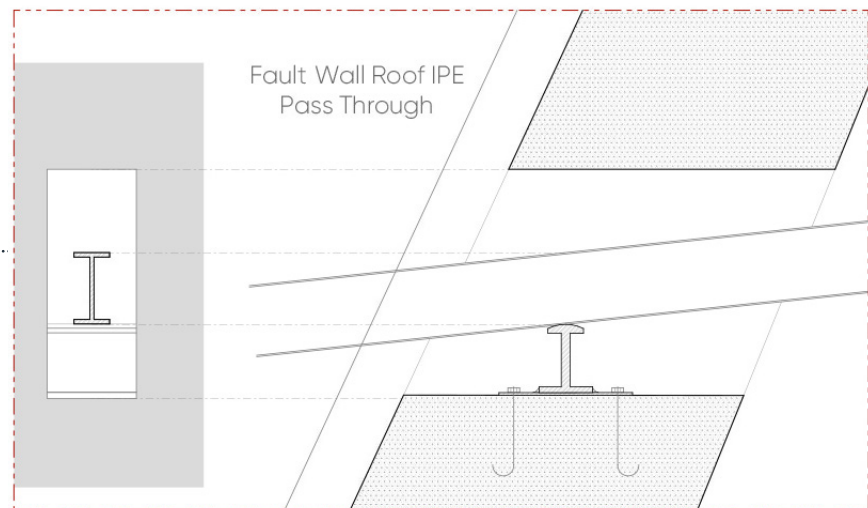
East and west elevations



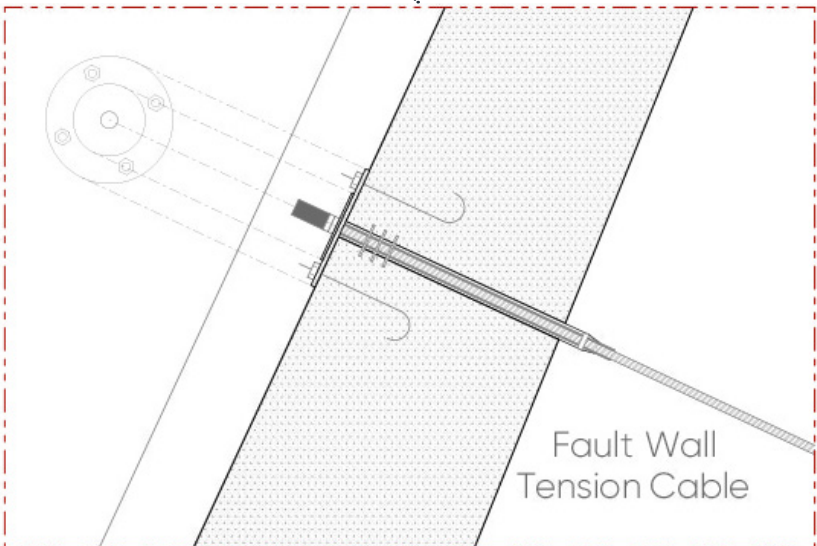
DOCUMENTATION

Section A

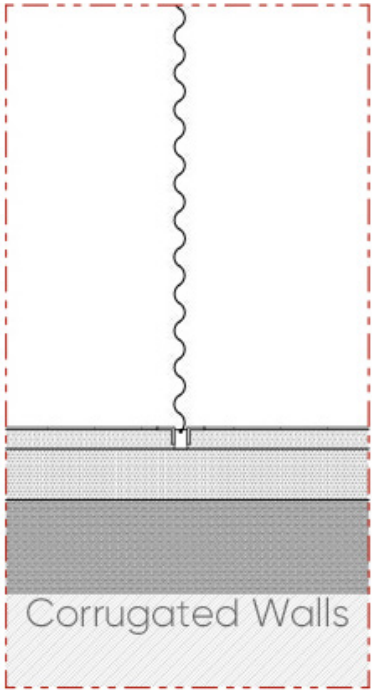
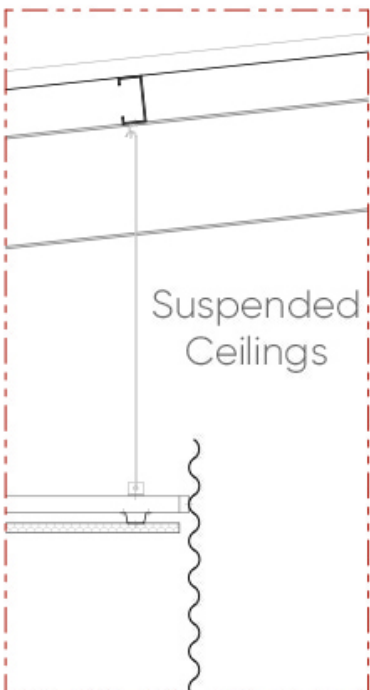




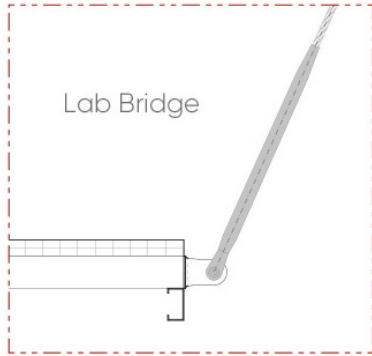
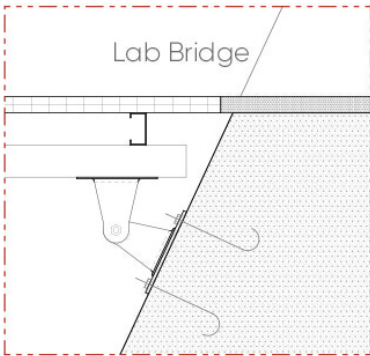
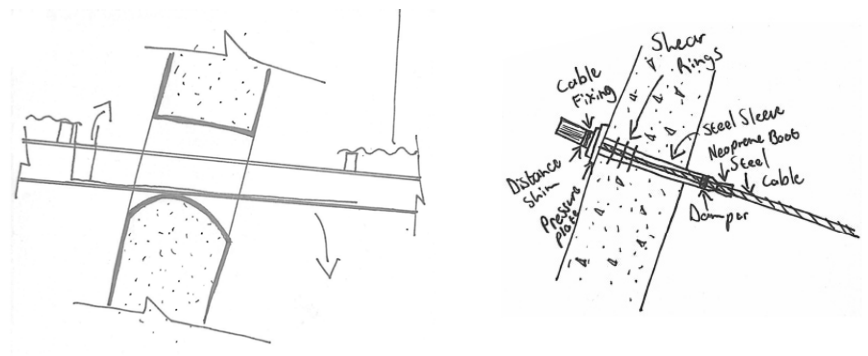
Steel IPE roof beam crossing concrete fault retaining wall, pivoting on recycled steel railway track to create a flexible connection. Railway beam welded to mild steel plate bolted into concrete.



High-tensile steel cables, connected to a tension adjuster, attached to a steel plate bolted into the retaining wall. The opposite end of these tension cables supports the Eastern roof structures by bolting to a mild steel bracket, welded to a steel IPE. Perforation in the roof sheeting to accommodate the bracket must be sealed with waterproofing membrane.



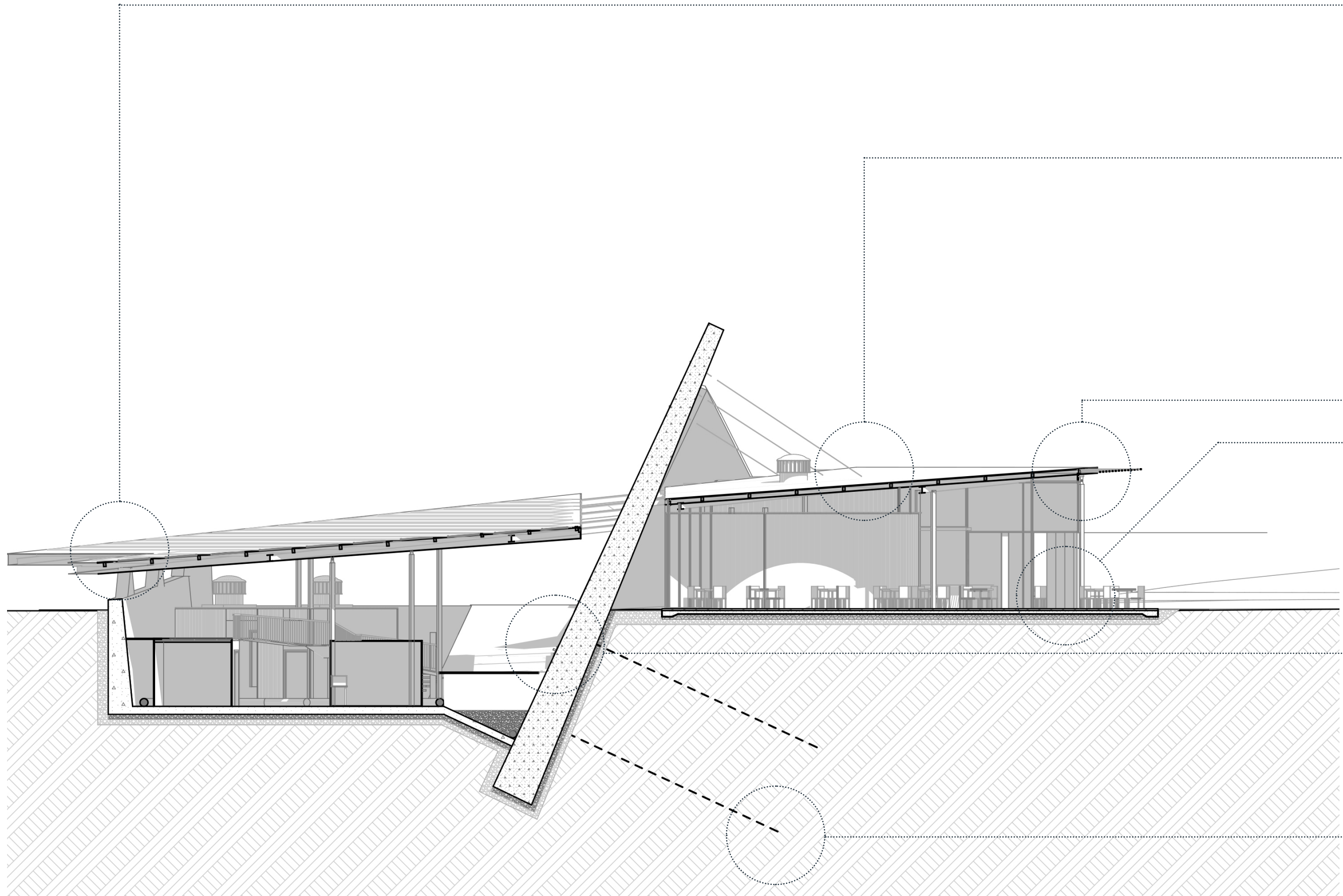
Circular corrugated sheeting as used in local rural dam construction used as partitioning element due to self-supporting properties and noise performance. Foot of partition is integrated into the floor slab with a bracket and the top is connected to the suspended ceilings.



Rectagrid platform fixed to mild steel lipped channel structure, welded to mild steel bracket bolted into concrete retaining wall as well as being fixed to roof IPE through a mild steel bracket attached to a steel tension cable.

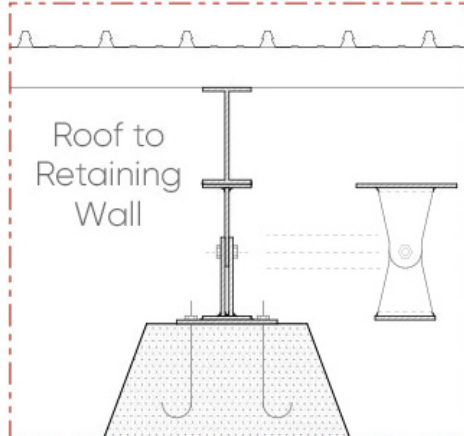
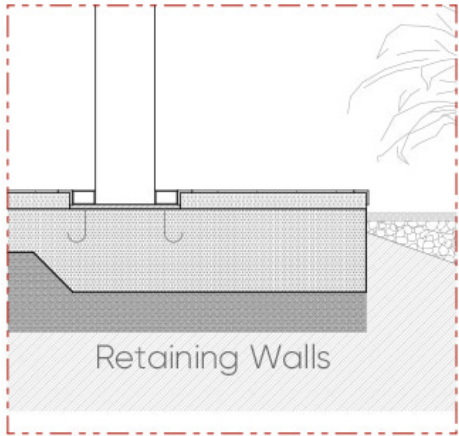
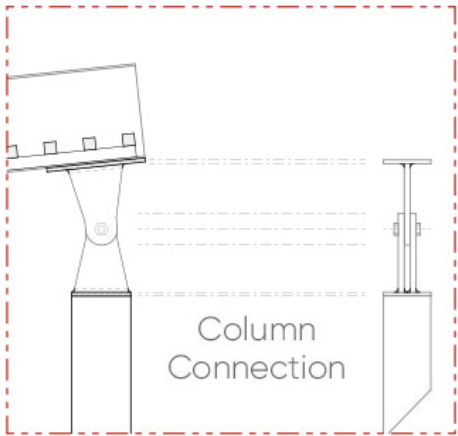
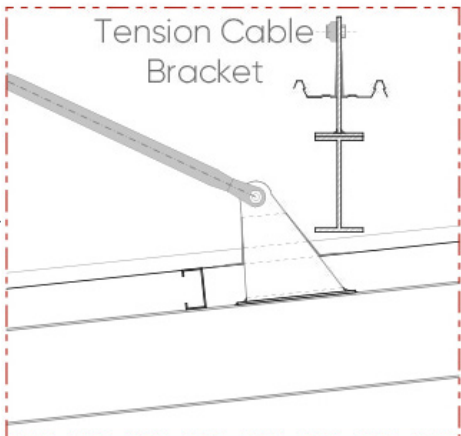
DOCUMENTATION

Section B

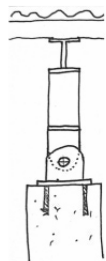


DOCUMENTATION

Details

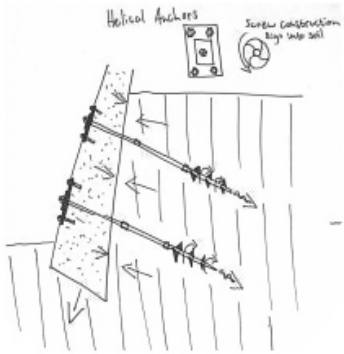
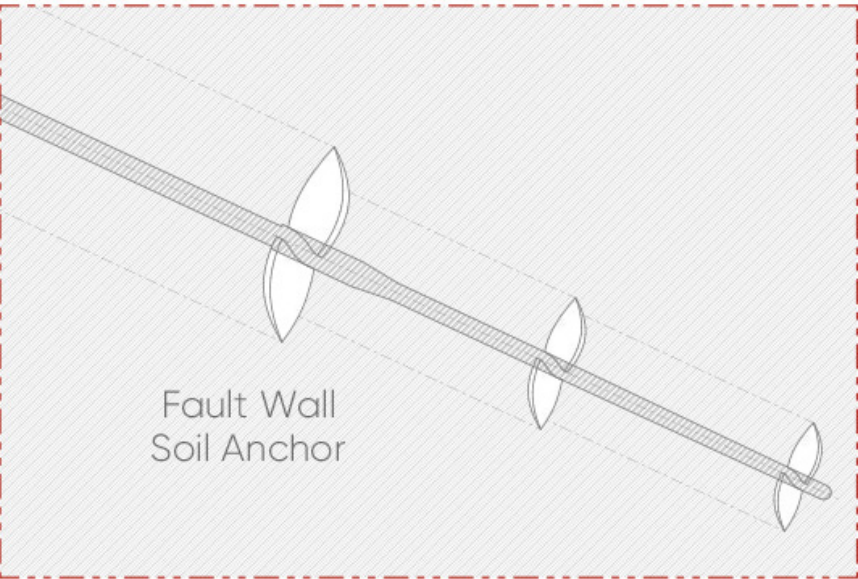
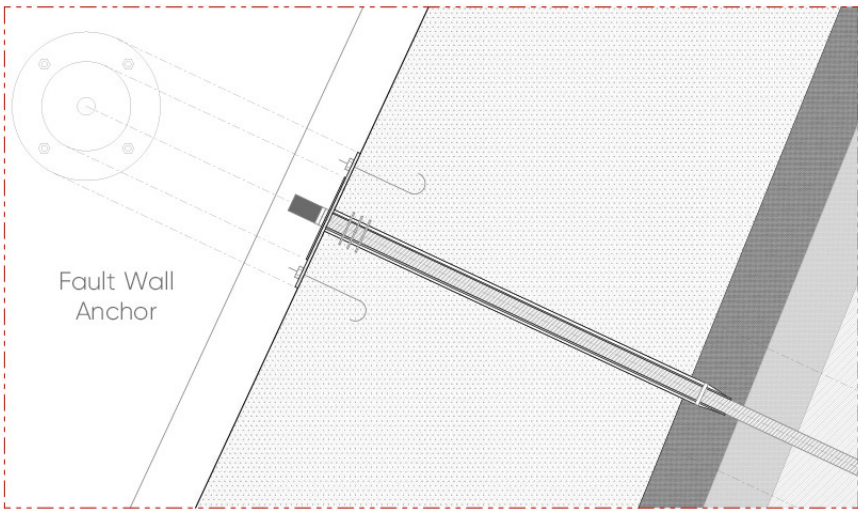


Pinned mild steel connection brackets bolted into concrete and welded to a mild steel beam.



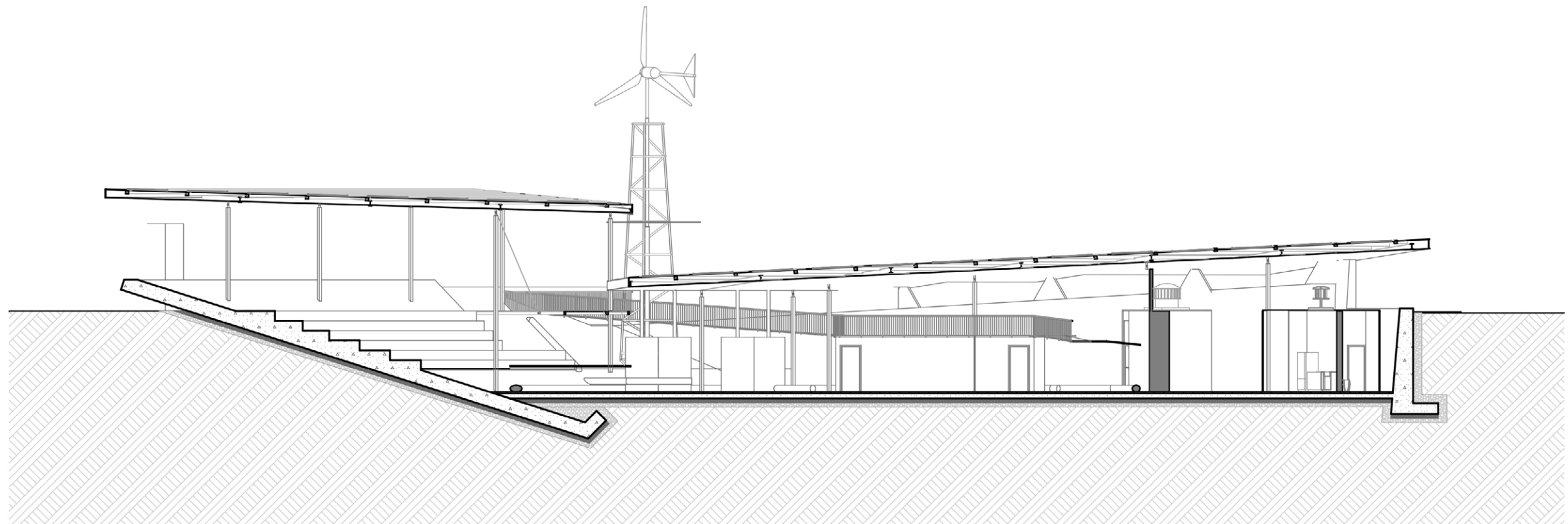
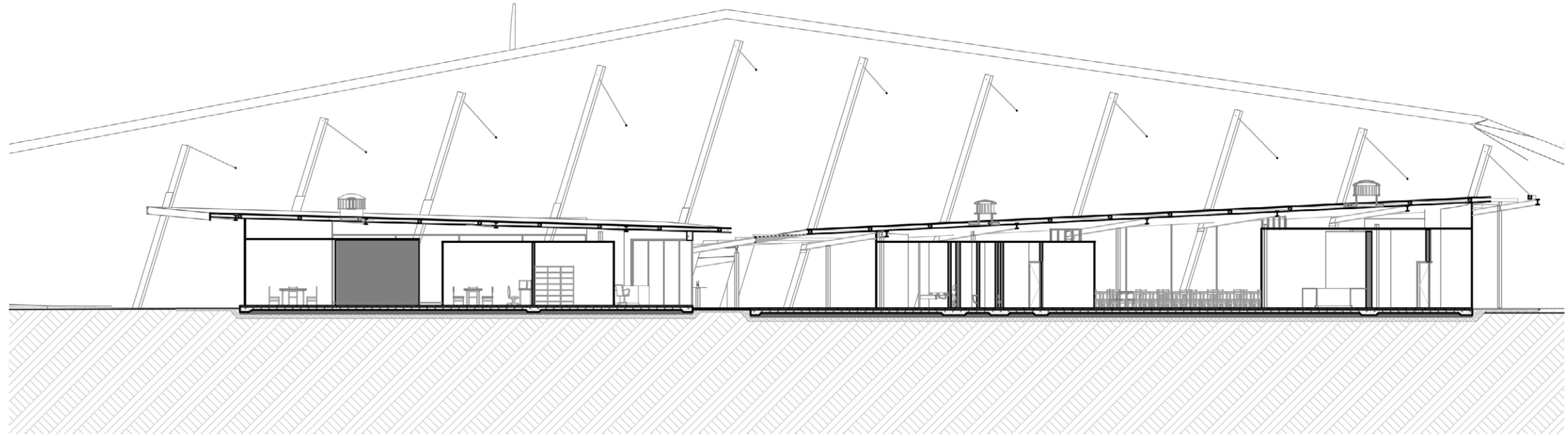
Helical retaining wall anchors screwed into the earth, attached to high-tensile steel rods, connected to a tension adjuster, attached to a steel plate bolted into the retaining wall.

Mild steel column welded to a mild steel plate bolted into the concrete floor slab.



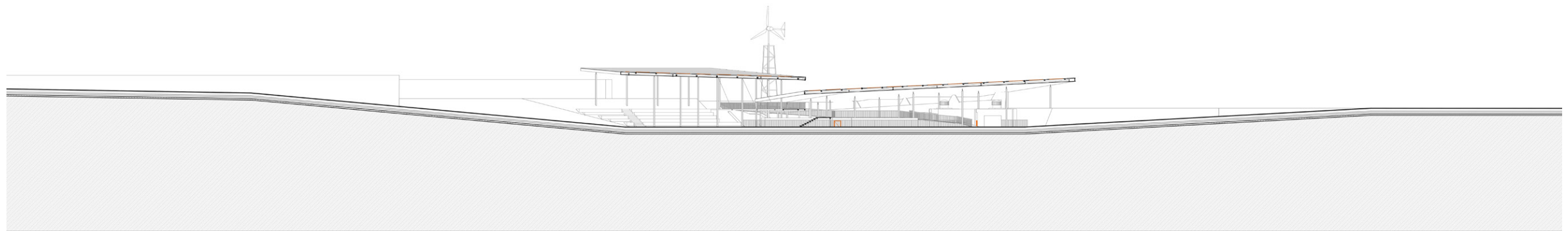
DOCUMENTATION

Section F and G



DOCUMENTATION

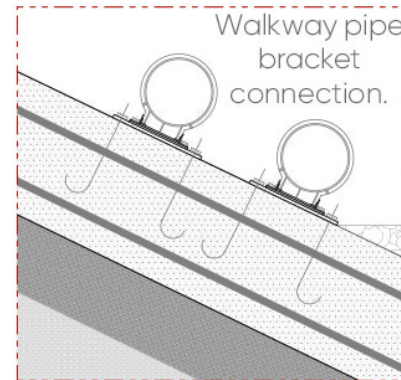
Walkway section



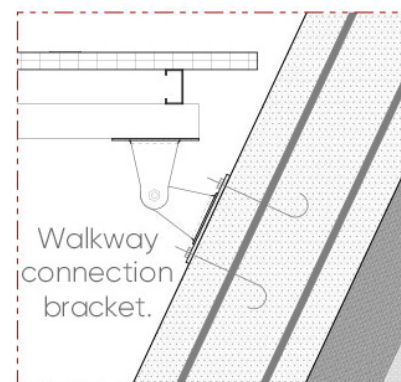
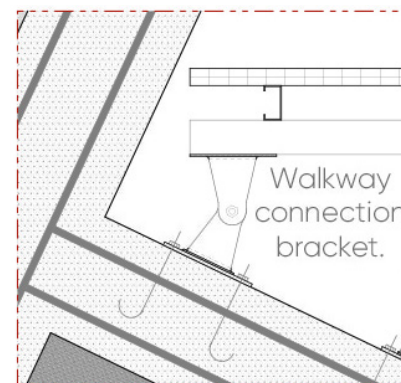
DOCUMENTATION

Walkway

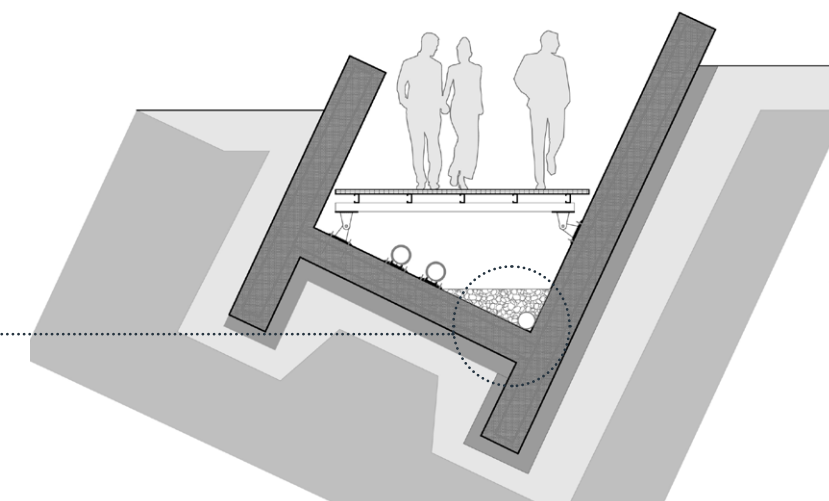
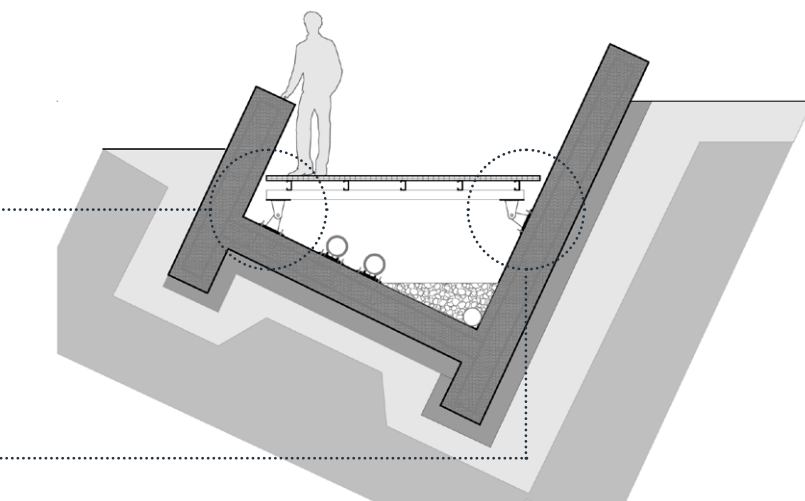
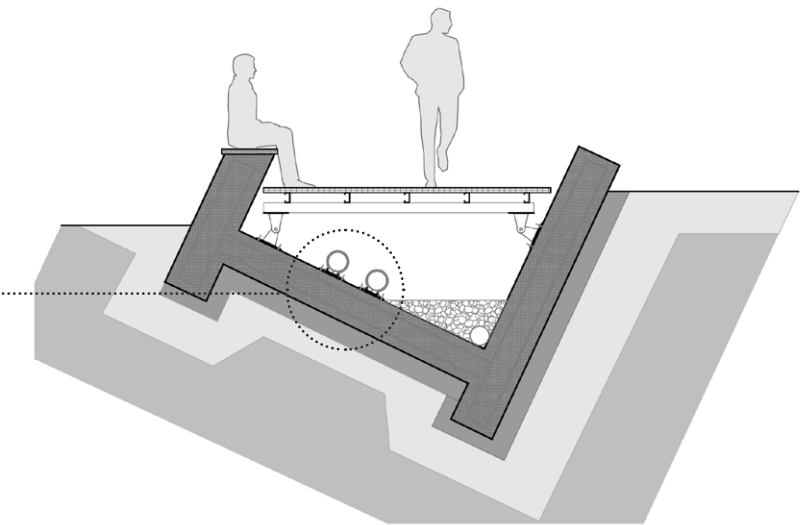
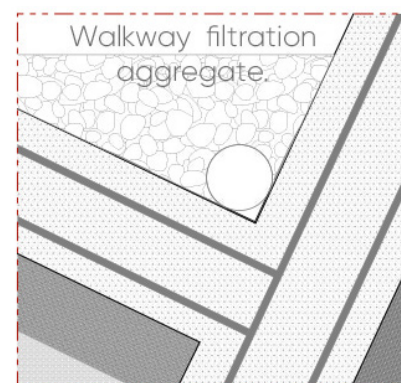
Mild steel pipe bracket welded to mild steel plate, bolted into concrete structure.



Rectagrid platform fixed to mild steel lipped channel structure, welded to mild steel bracket pinned to another bracket welded to a mild steel plate, bolted to concrete structure.

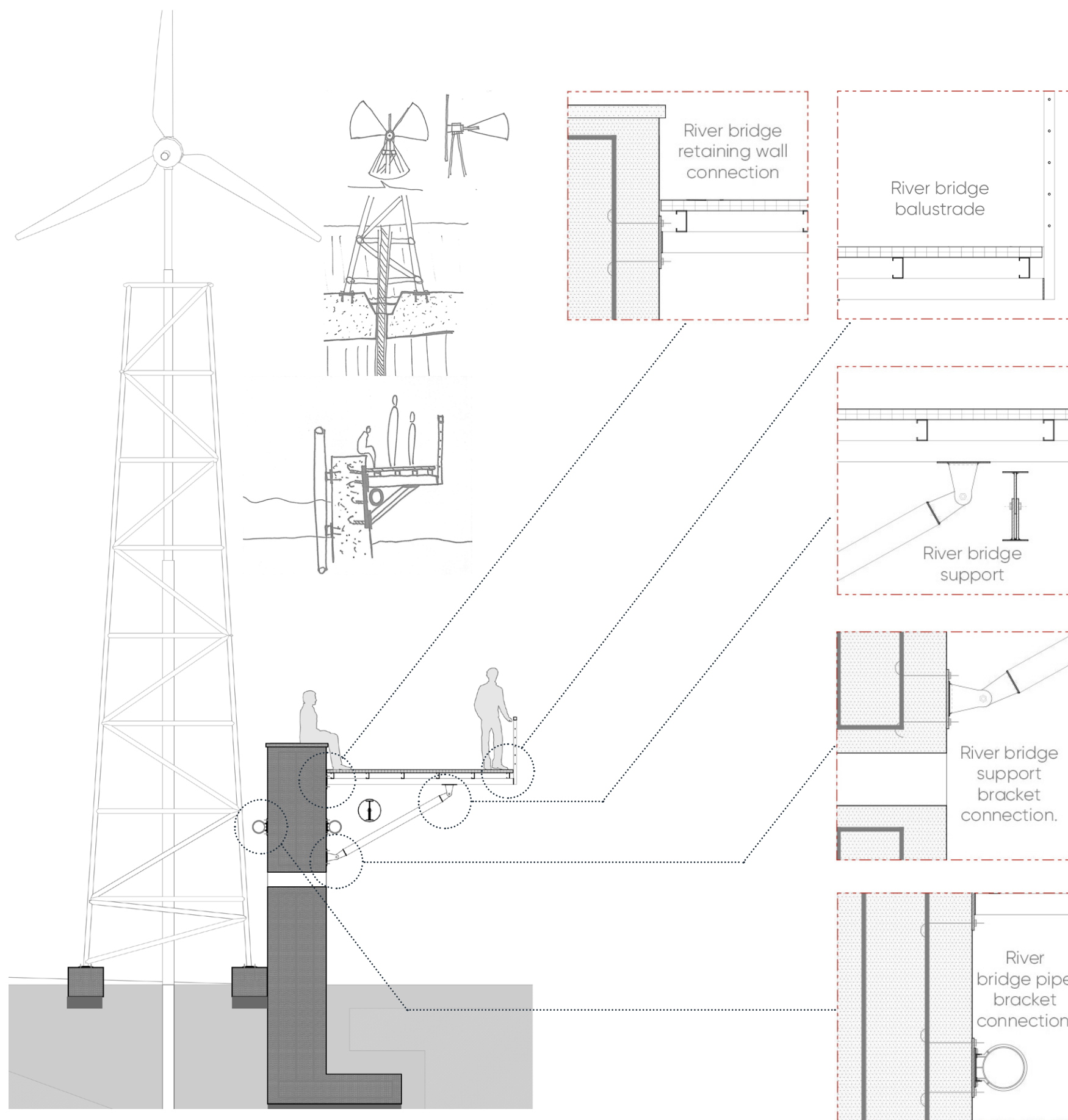


Lower part of the concrete channel to be waterproofed with galvanised sheet metal and waterproofing, covered with filtration medium to filter rainwater.



DOCUMENTATION

River bridge



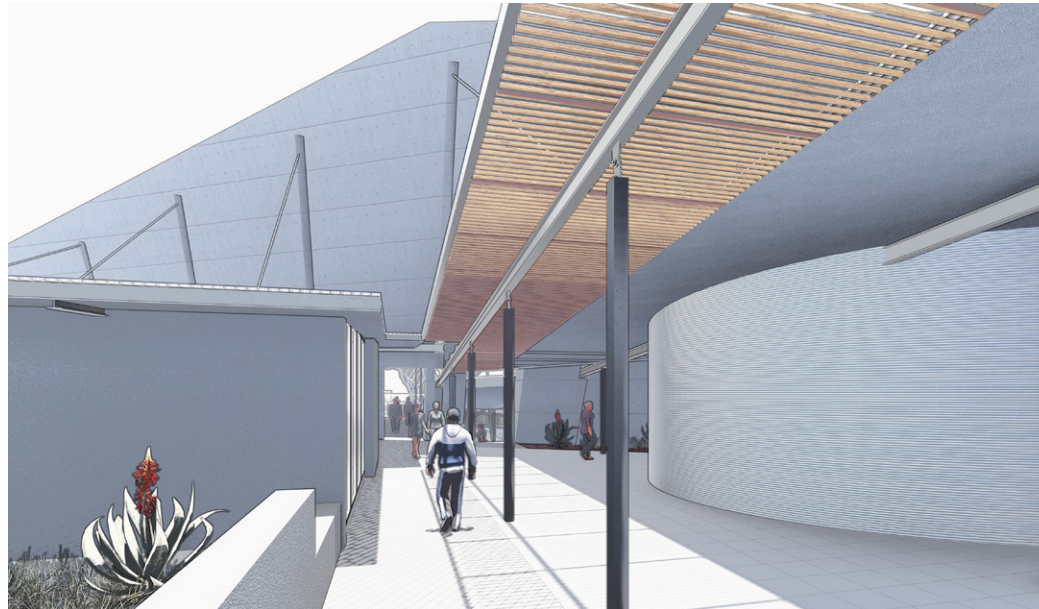
Mild steel square tubing balustrade welded to a mild steel plate welded to mild steel lipped channel structure.

Rectagrid platform fixed to mild steel lipped channel structure, welded to mild steel plate bolted into concrete retaining wall as well as being fixed to retaining wall with mild steel plate welded to mild steel bracket pinned to another bracket welded to a mild steel plate.

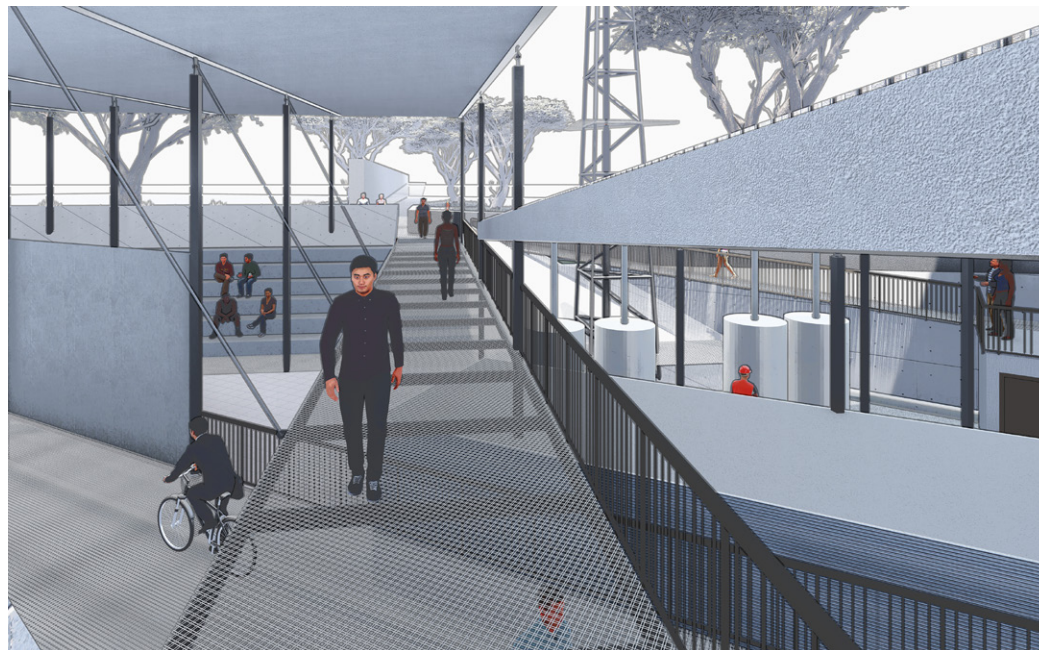
Steel water pipe bracket welded to mild steel plate, bolted into concrete retaining wall.

DOCUMENTATION

Perspectives



.....Eastern entrance

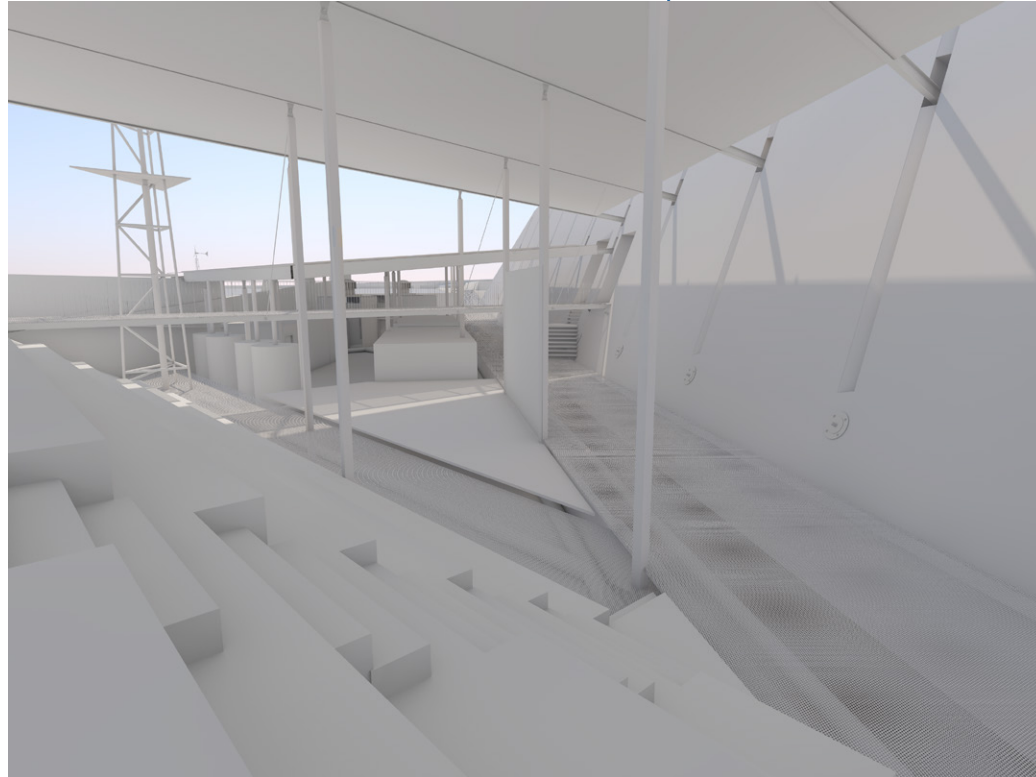


.....View to the west

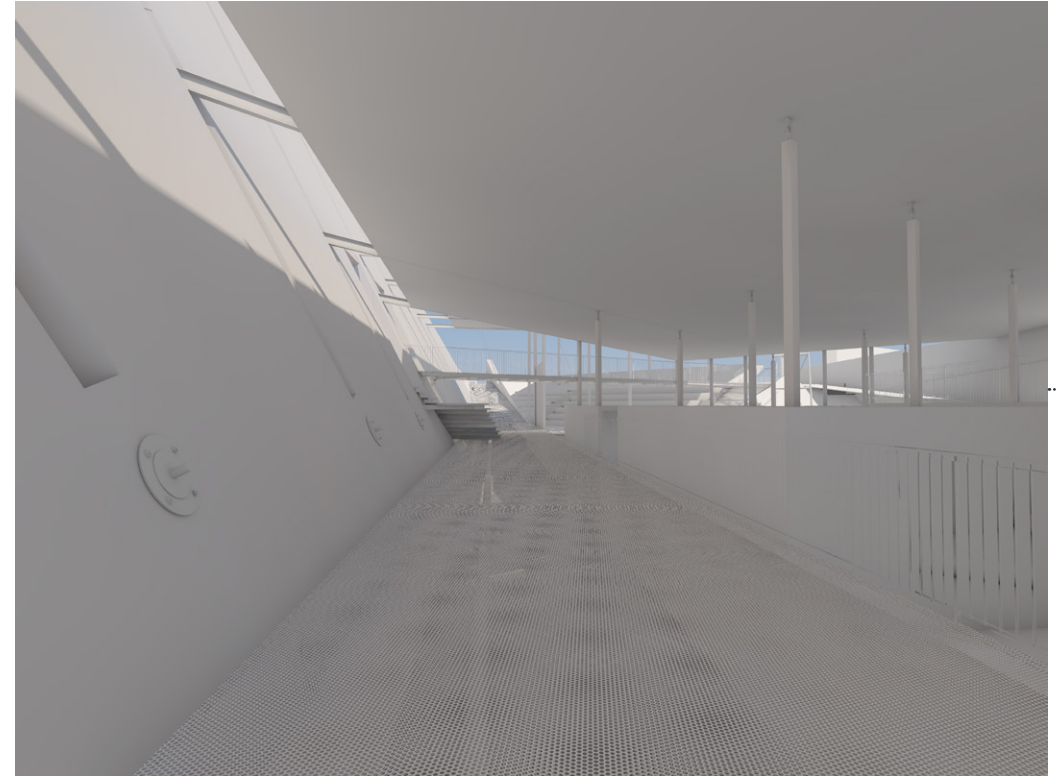
DOCUMENTATION

Perspectives

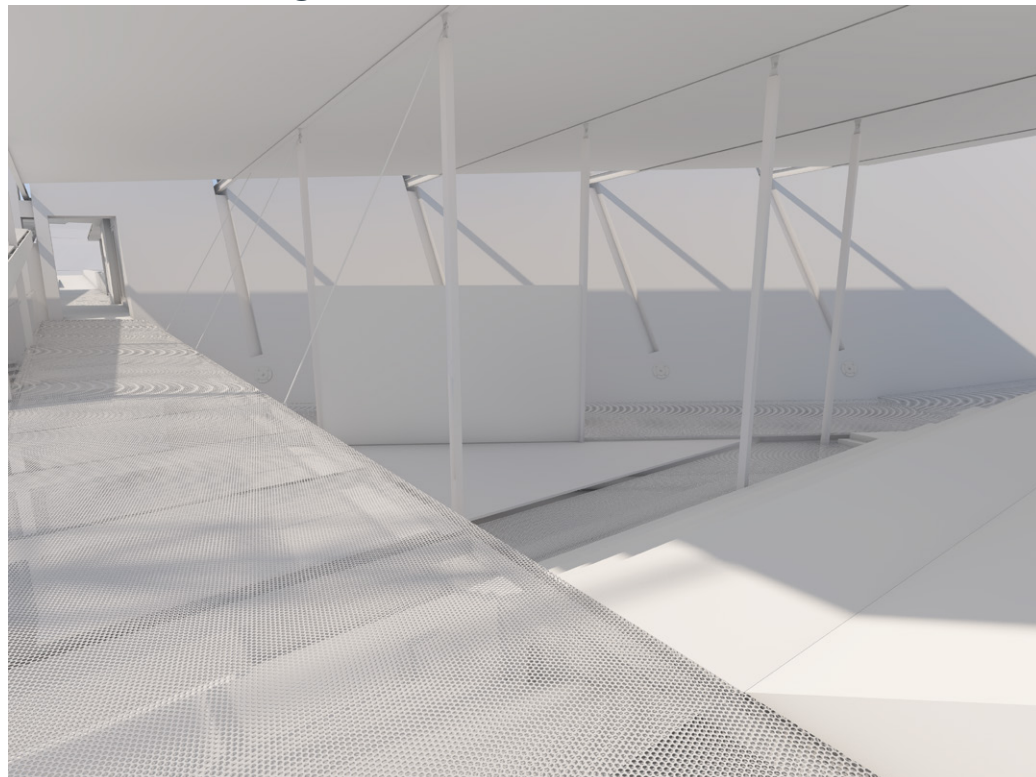
View from top of auditorium



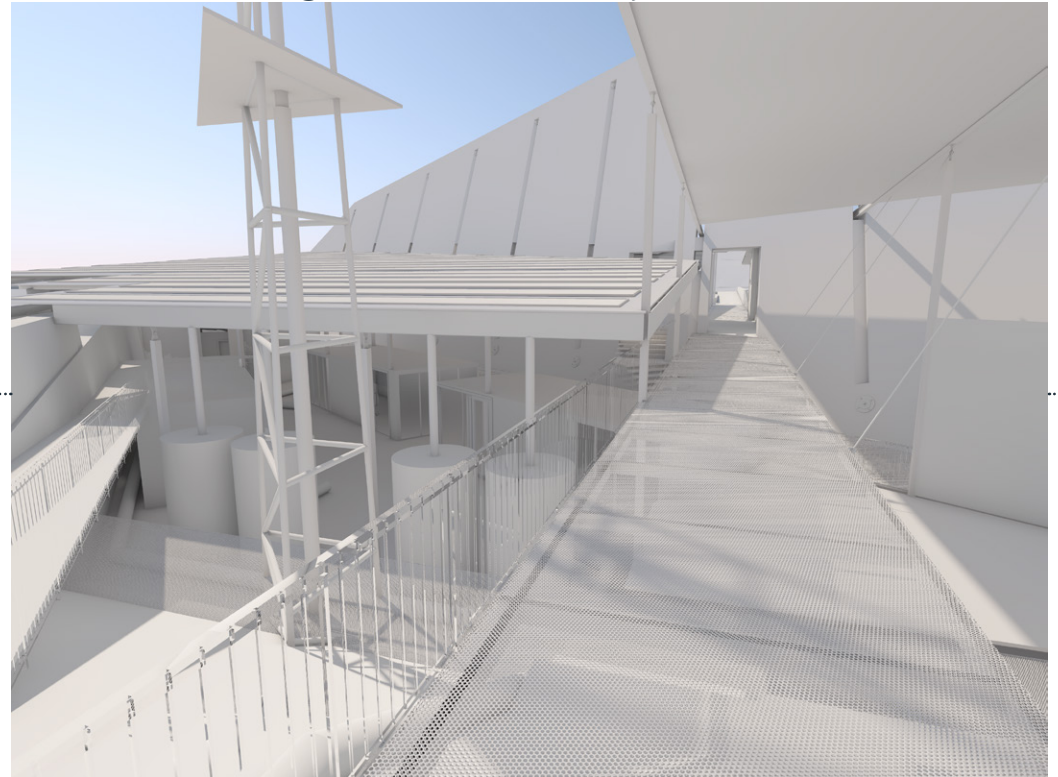
View of laboratory adjacent walkway



View from bridge into auditorium

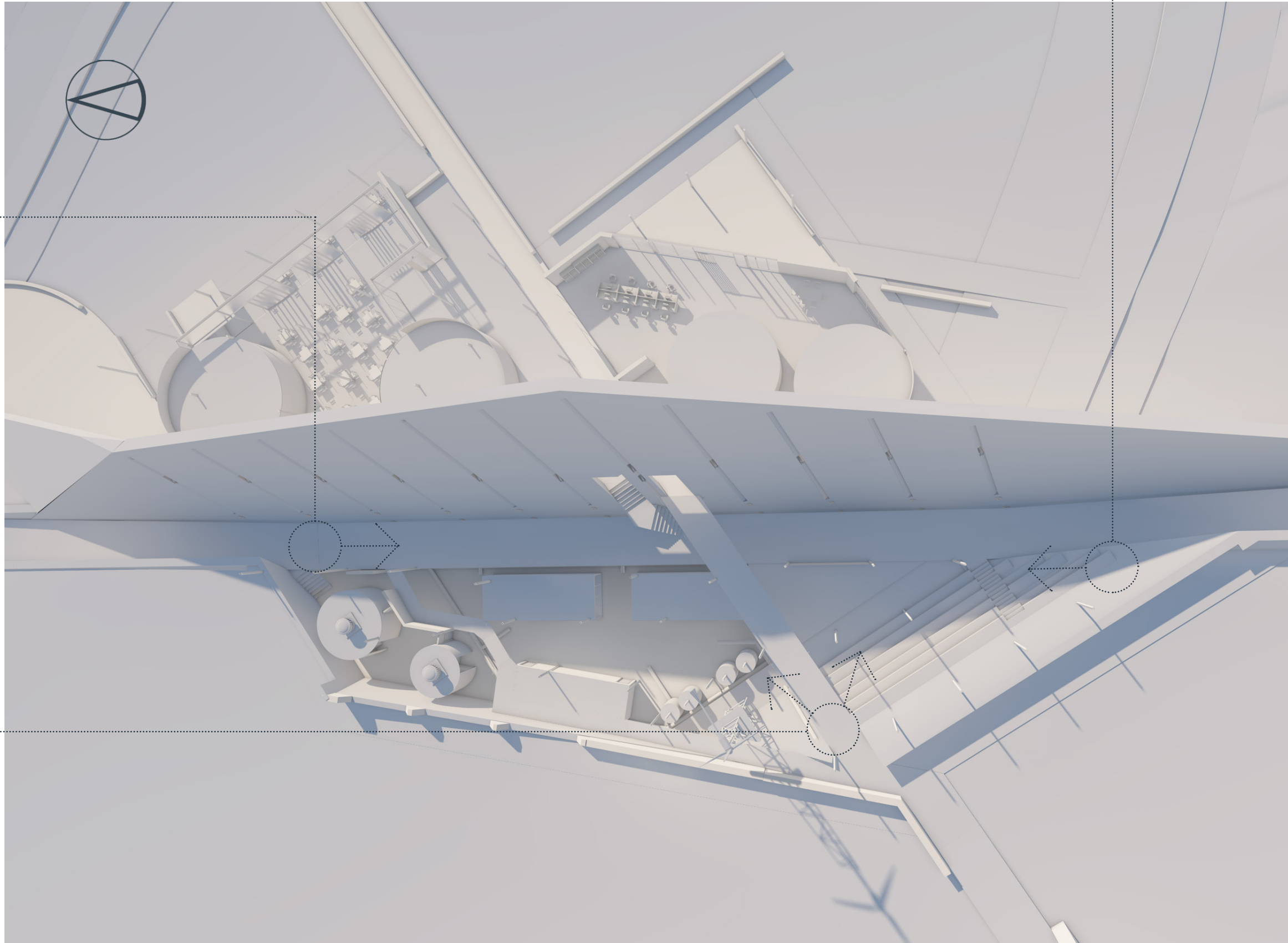


View from bridge into laboratory



DOCUMENTATION

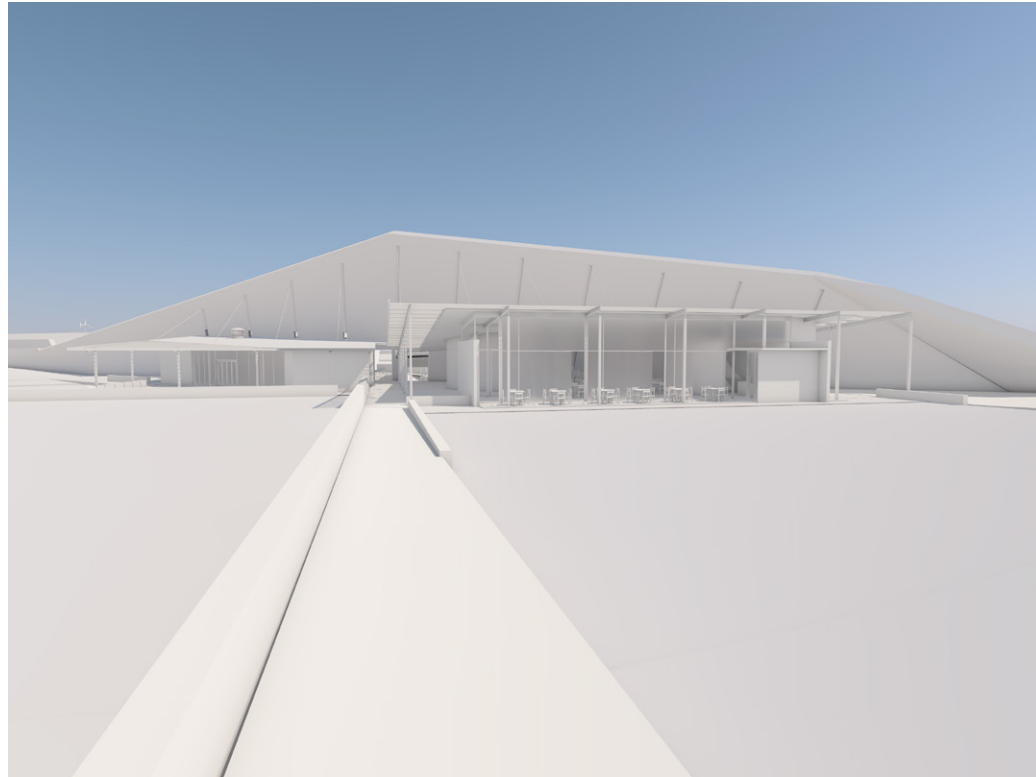
Perspectives



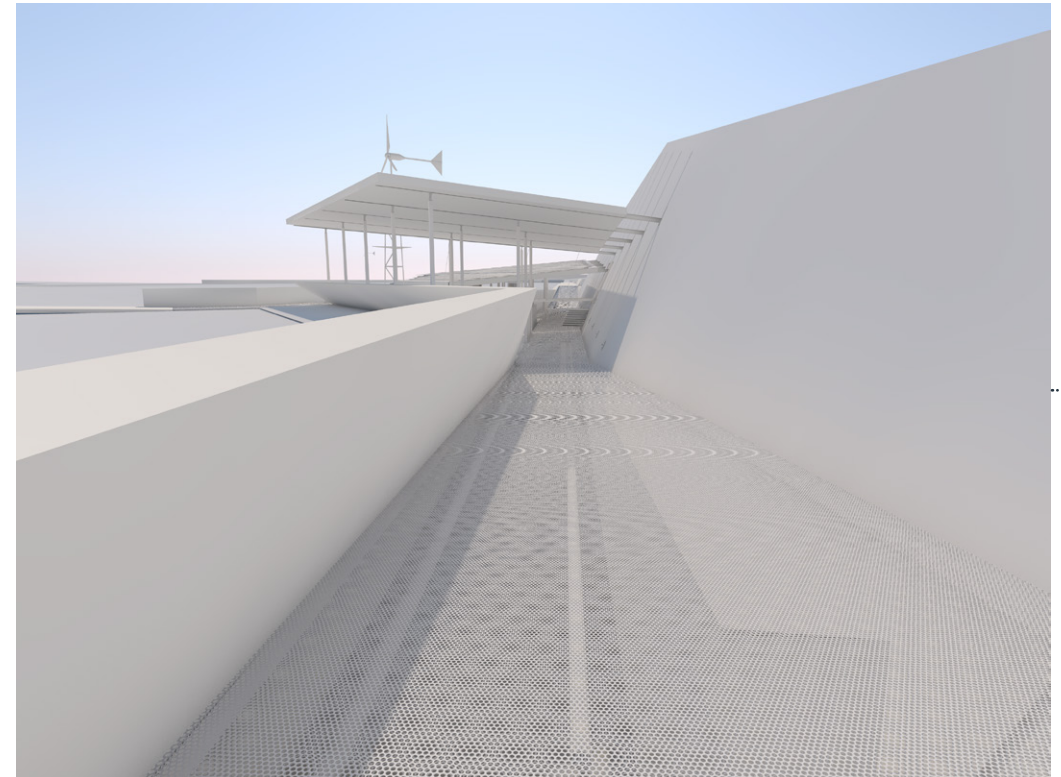
DOCUMENTATION

Perspectives

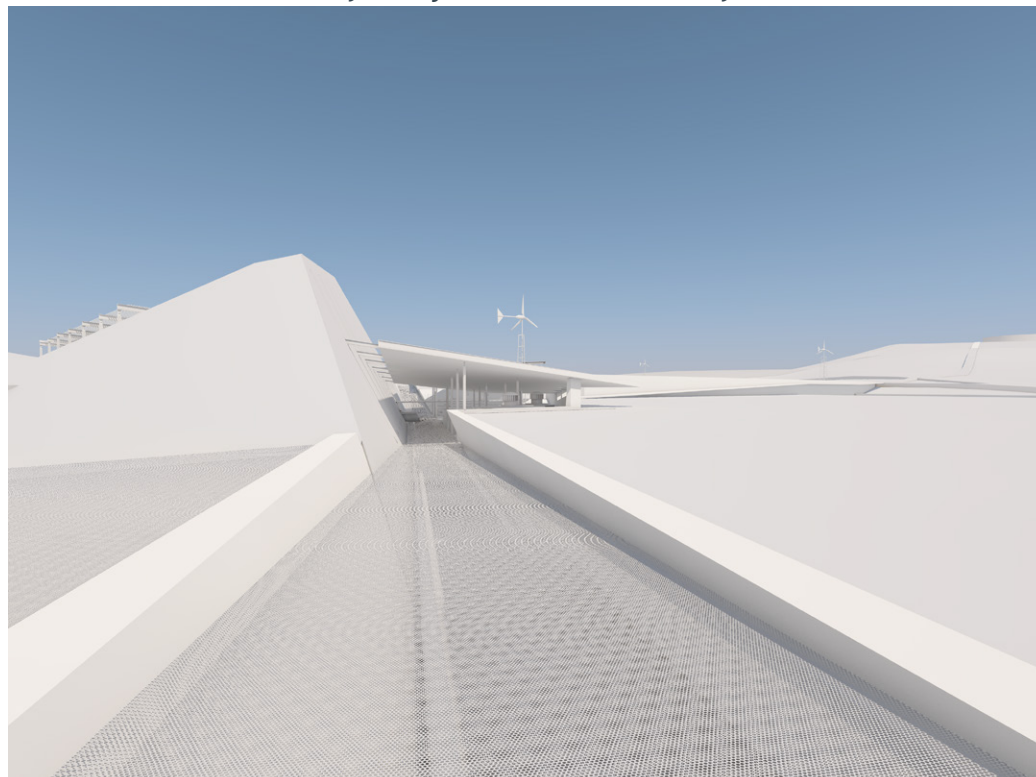
View of restaurant and administration from the east



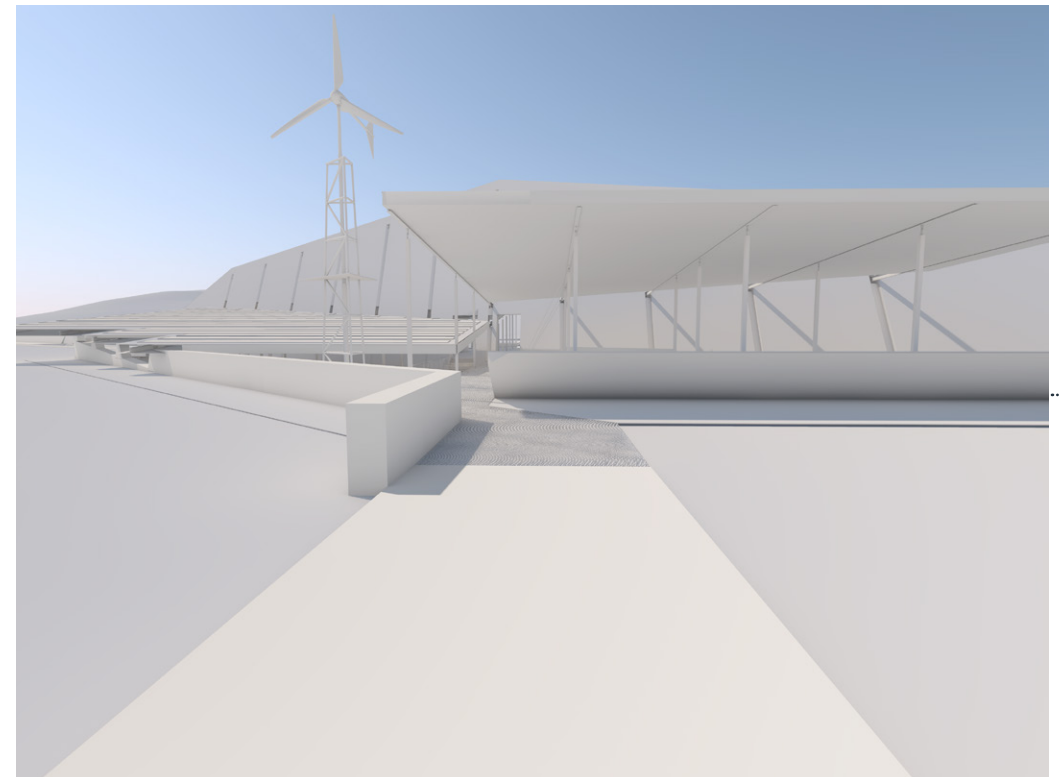
View of auditorium adjacent walkway from the south



View of laboratory adjacent walkway from the north

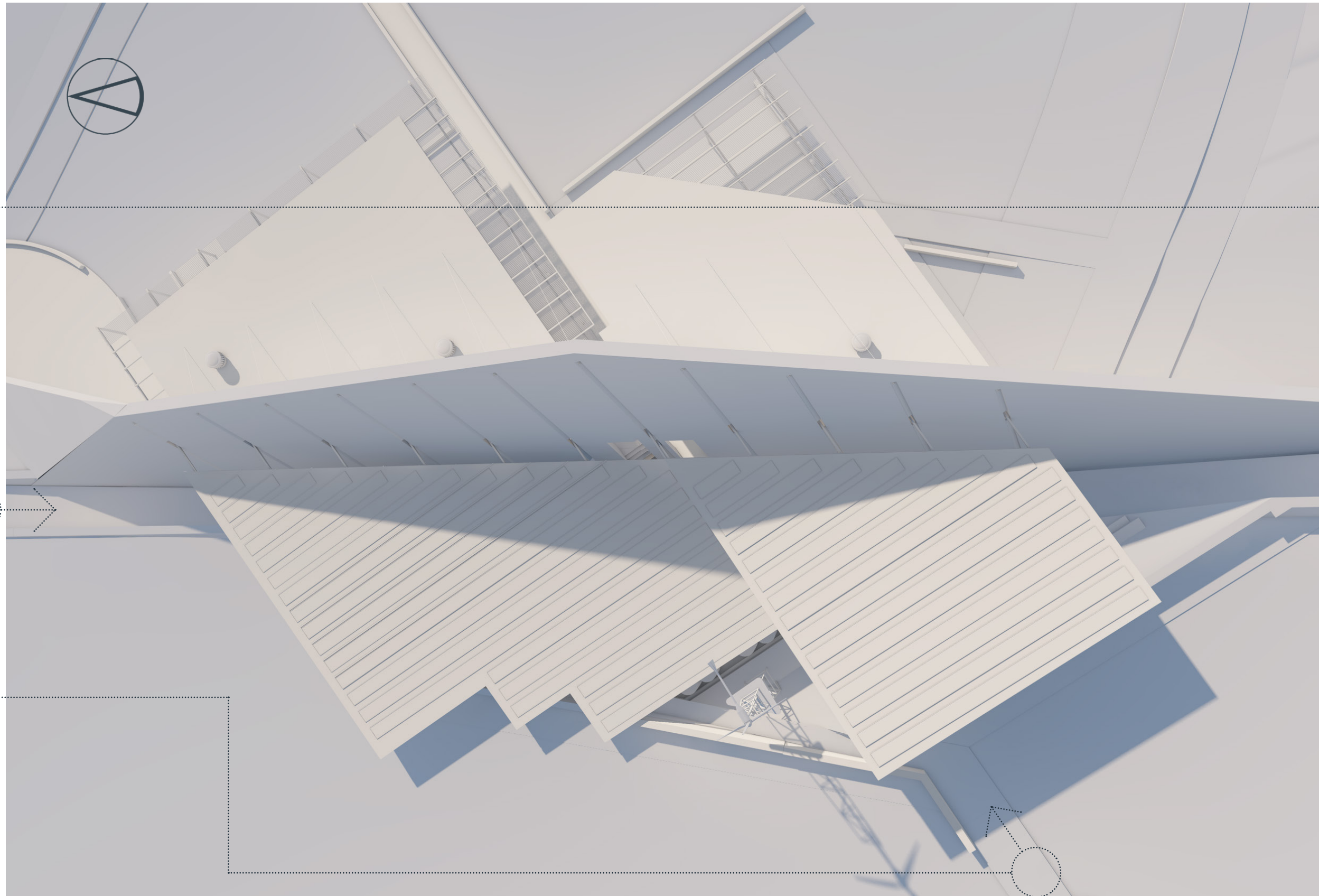


View of upper auditorium entrance from the west



DOCUMENTATION

Perspectives



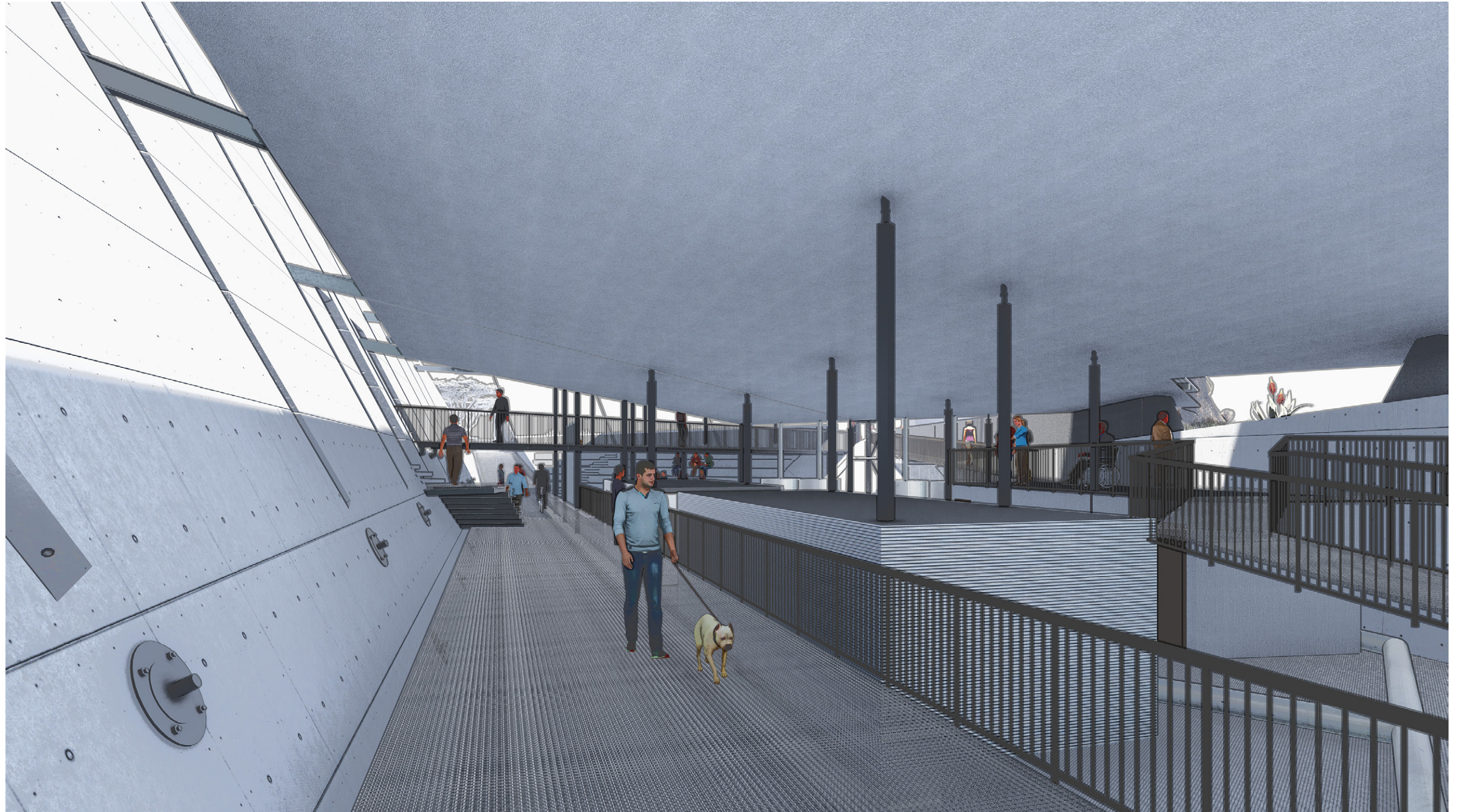
DOCUMENTATION

Perspectives

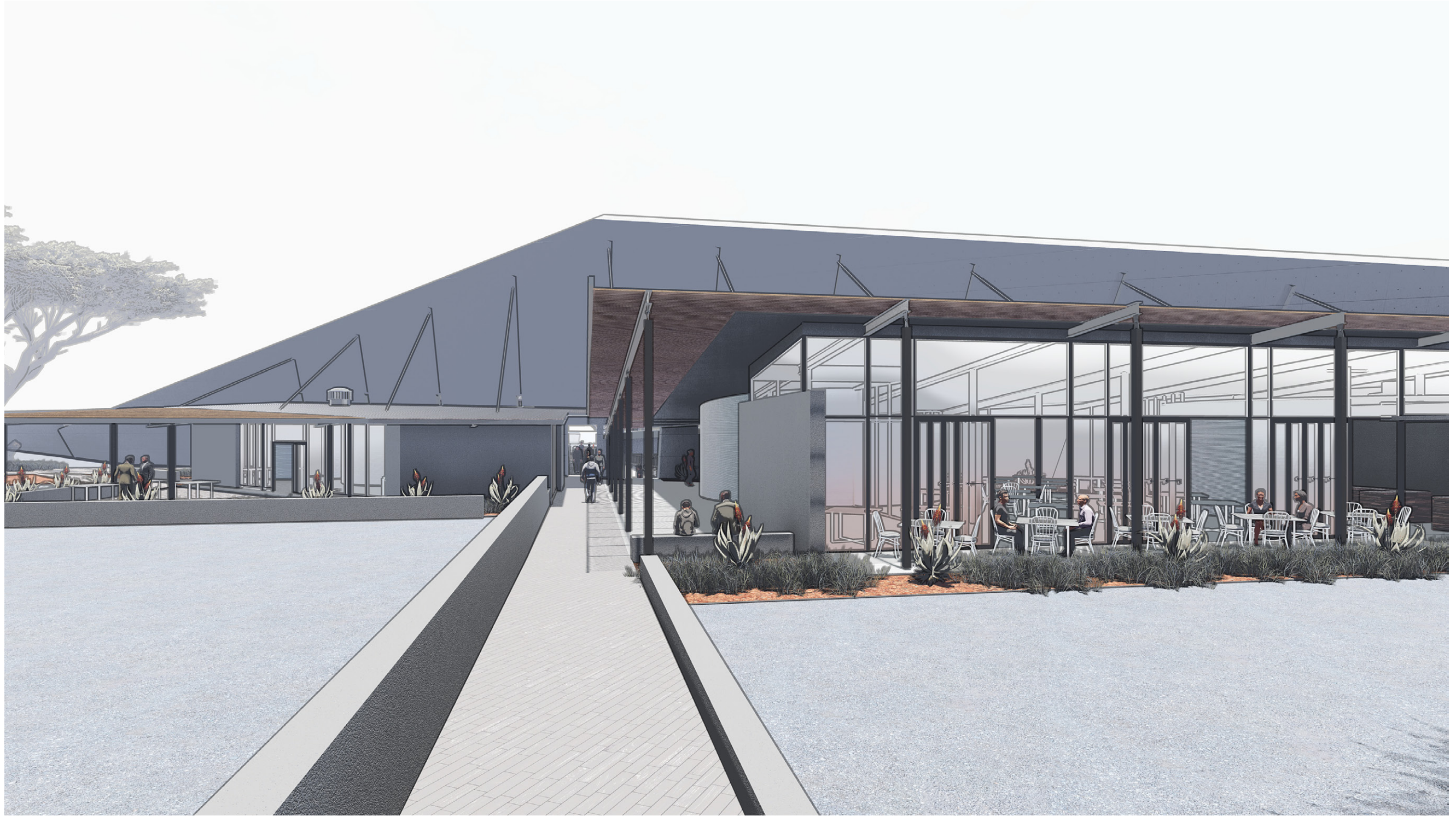


DOCUMENTATION

Perspectives







CHAPTER 5

Conclusion

Conclusion 108

CONCLUSION

This intervention aims to provide an architectural example for sustainable, infrastructural expansion on the Pahl fault-line in order to promote awareness. Awareness being an important factor with regards to managing water demand in Windhoek. The intervention creates spaces where Windhoek's water system can be explored and celebrated to aid in dispersing doubts surrounding the quality of water in lower income areas. This aims at targeting the resulting impact on equality, derived from different perceptions pertaining to water purity. The story of water in Windhoek must not only be known by it's inhabitants, but celebrated inclusively.

CHAPTER 6

References

References

111–112

REFERENCES

APA 7

Archdaily. (2016). Levanto Water Purification Plant. Retrieved from <https://www.archdaily.com/801251/levanto-water-purification-plant-mmaa>

Archinect. (2020). Tulane Grad Yara Hantash: The Dwellings. Retrieved from <https://archinect.com/features/article/150202648/tulane-grad-yara-hantash-uses-subterranean-architecture-to-invert-architecture-s-role-in-the-israeli-palestinian-conflict>

Christelis, G., Struckmeier, W., Bäumle, R. & Bethune, S. (2001). Groundwater in Namibia: An explanation to the hydro-geological map. Windhoek, Namibia: Dept. of Water Affairs, Division Geo-hydrology.

City of Windhoek. (n.d.) Retrieved April 15, 2022, from: <http://www.windhoekcc.org.na/>

Franklin, B. (1998). Benjamin Franklin Wit and Wisdom, p.53, Peter Pauper Press, Inc.

Boer, F., & Marín, S. E. (2015). Towards a water sensitive Mexico City : Public space as a rain management strategy. Retrieved September 20, 2021 from: <https://research.gsd.harvard.edu/mci/towards-a-water-sensitive-mexico-city-public-space-as-a-rain-management-strategy/>

International Water Association. (n.d.) IWA: The Upper Swakop River Basin. Retrieved April 15, 2022, from: <https://iwa-network.org/the-upper-swakop-river-basin-2/>

Kuuma, B. & SCE Consulting Engineers. (2020). Swakop Upper-Omatako Basin Integrated Water Resource Management Plan: Final Report (Republic of Namibia, Ministry of Agriculture, Water and Land Reform). Windhoek: Ministry of Agriculture, Water and Land Reform.

LCE Consulting Engineers. (2016). Project: Ujams Waste Water Treatment Plant. Retrieved from: <https://lce.com.na/portfolio/ujams-waste-water-treatment-plant/>

- Magnusson, T. S. (2005). Urban Water Security 2013 Local Conditions and Regional Context: A case study of attitudes and water use behaviour in Windhoek, Namibia.
- Mapani, B. (2005). Groundwater and urbanisation, risks and mitigation: The case for the city of Windhoek, Namibia. *Physics and Chemistry of The Earth* 30. 706–711.10.1016/j.pce.2005.08.011.
- Murray, R., Louw, D., Merwe, B. & Peters, I. (2018). Windhoek, Namibia: from conceptualising to operating and expanding a MAR scheme in a fractured quartzite aquifer for the city's water security. *Sustainable Water Resources Management*.
- Namwater. (n.d.) Retrieved April 15, 2022, from: <https://www.namwater.com.na/>
- Pennington, C. A., Ruoff, G., Rivers, J. M., & Cartwright, M. L. (2005). Addressing Water Misconceptions in Katutura. Retrieved from <https://digitalcommons.wpi.edu/iqp-all/806>
- The Guardian. (2018). How Cape Town was saved from running out of water. Retrieved from: <https://www.theguardian.com/world/2018/may/04/back-from-the-brink-how-cape-town-cracked-its-water-crisis>
- Tredoux, G., Van, D. M. B., & Peters, I. (January 01, 2009). Artificial recharge of the Windhoek aquifer, Namibia: water quality considerations. *Boletín Geológico Y Minero*, 120, 2, 269–278.
- Uhlendahl, T. C., Ziegelmayer, D., Wienecke, A., Mawisa, M. L. & Pisani, P. (2010). Water consumption at household level in Windhoek, Namibia: : survey about water consumption at household level in different areas of Windhoek depending on income level and water access in 2010.
- Van Rensburg, F. (2006). Urban water security in the city of Windhoek (Master's thesis, University of Stellenbosch, 2006). Stellenbosch: University of Stellenbosch.
- Verbinski, G. (Director). (2011). *Rango*. [Film]. Hollywood, California: Paramount Home Entertainment.

CHAPTER 7

List of figures

List of figures 115–117

LIST OF FIGURES

Figure 1:	Rango in the beginning	pg. x
Figure 2:	Rango dried-up faucet scene	pg. 2
Figure 3:	Windhoek's aquifer map	pg. 7
Figure 4:	Windhoek's aquifer section	pg. 8
Figure 5:	Windhoek's water demand graph	pg. 9
Figure 6:	Site exploration in section	pg. 13
Figure 7:	Windhoek's water sources	pg. 14
Figure 8:	Namibia water supply scheme	pg. 15
Figure 9:	Rango identity development	pg. 16
Figure 10:	Scenario exploration using Rango	pg. 17
Figure 11:	Depicting moments of realisation using Rango	pg. 18
Figure 12:	Rango characters	pg. 20; 50
Figure 13:	Rango equality scene	pg. 22; 25
Figure 14:	Rango sustainability scene	pg. 22; 27
Figure 15:	Rango ecology scene	pg. 22; 29
Figure 16:	Rango desert scene	pg. 23
Figure 17:	Rango enclosure scene	pg. 23
Figure 18:	Windhoek water consumption by income	pg. 24
Figure 19:	Equality map	pg. 26
Figure 20:	Sustainability map	pg. 28
Figure 21:	Ecology map	pg. 30
Figure 22:	Rango pipe reconnection scene	pg. 31
Figure 23:	Rango spigot opening scene	pg. 31
Figure 24:	Unjams WWTP	pg. 32
Figure 25:	Water queue	pg. 32
Figure 26:	Rango spring scene 1	pg. 33
Figure 27:	Rango dry lake scene	pg. 33
Figure 28:	Rango spring scene 2	pg. 34

LIST OF FIGURES

Figure 29:	Rango abundant water scene	pg. 34
Figure 30:	Mexico city: historical transformation	pg. 36
Figure 31:	Mexico city: water loss	pg. 36
Figure 32:	Mexico city: two scenarios	pg. 37
Figure 33:	Mexico city: water distribution	pg. 37
Figure 34:	Mexico city: water waste	pg. 37
Figure 35:	Mexico city: problems	pg. 38
Figure 36:	Mexico city: water provision	pg. 38
Figure 37:	Levanto: morphology	pg. 39
Figure 38:	Levanto: site	pg. 39
Figure 39:	Levanto: Ground floor plan	pg. 39
Figure 40:	Levanto: sections	pg. 39
Figure 41:	Levanto: photo from water	pg. 40
Figure 42:	Levanto: photo of background	pg. 40
Figure 43:	Levanto: photo from public space	pg. 40
Figure 44:	Levanto: photo of treatment area	pg. 40
Figure 45:	The Dwellings: existing tunnels	pg. 41
Figure 46:	The Dwellings: on the surface	pg. 41
Figure 47:	The Dwellings: beneath the surface	pg. 41
Figure 48:	The Dwellings: entrance	pg. 42
Figure 49:	The Dwellings: outside space	pg. 42
Figure 50:	The Dwellings: circulation	pg. 42
Figure 51:	The Dwellings: farm skylight	pg. 42
Figure 52:	The Dwellings: entertainment	pg. 42
Figure 53:	Historical aquifer level	pg. 42
Figure 54:	Aquifer influences	pg. 43
Figure 55:	Visible and invisible	pg. 44
Figure 56:	Formal vs. informal water cycle	pg. 44

LIST OF FIGURES

Figure 57:	Economic division by water and fault line	pg. 45
Figure 58:	Natural and man-made movement	pg. 46
Figure 59:	Site system exploration on model	pg. 46
Figure 60:	Points of interest surrounding site	pg. 47
Figure 61:	Site exploration diagram	pg. 48
Figure 62:	Site function and Rango	pg. 49
Figure 63:	Logo Namwater	pg. 51
Figure 64:	Logo City of Windhoek	pg. 51
Figure 65:	Programme development	pg. 52
Figure 66:	Programme	pg. 52
Figure 67:	Accommodation	pg. 54

END