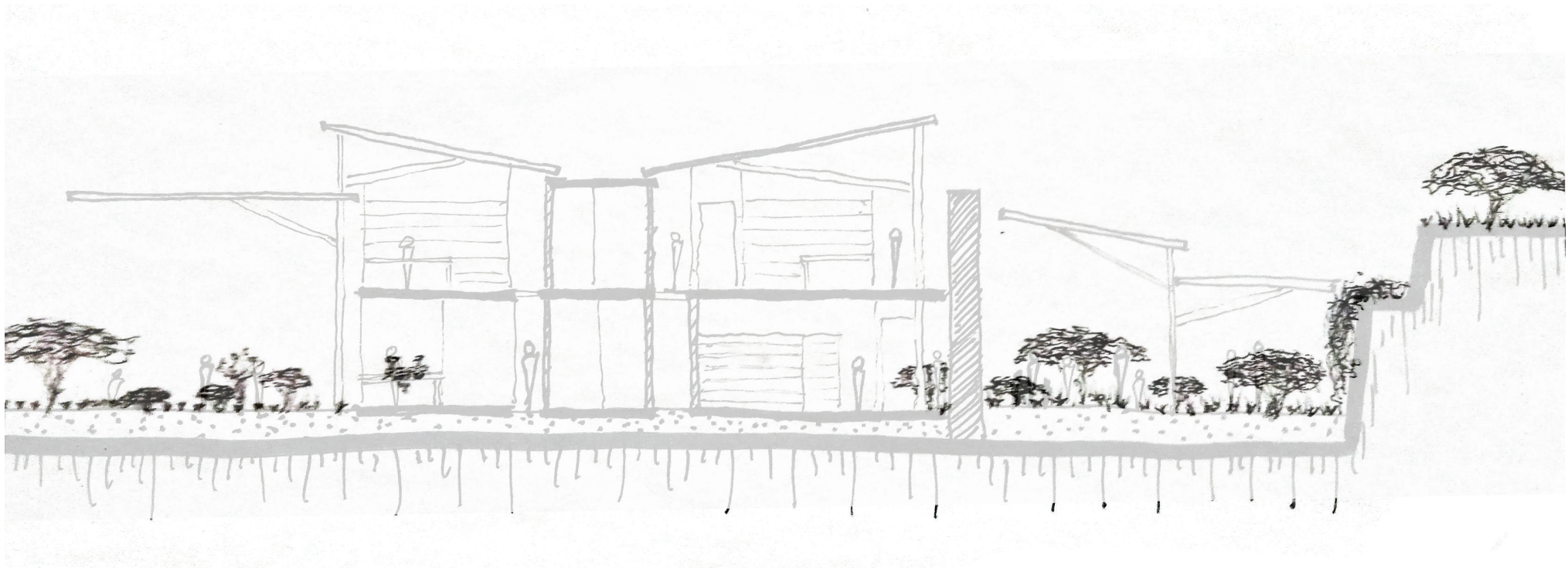


FACILITATING NATURAL GROWTH

A MUTUALISTIC APPROACH TO DESIGNING THE PUBLIC AND RESEARCH FACILITIES AT THE BOTANICAL GARDENS IN WINDHOEK



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**A Mutualistic Approach to Designing the Public and Research Facilities
at the Botanical Gardens in Windhoek**

**A Masters Design Thesis
completed during the Master of Architecture Programme
offered by the Department of Architecture, Planning and Construction
at the Namibia University of Science and Technology**

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April 2024



I, Christian Dieter Strohbach, hereby declare that the work contained in the thesis entitled: A Mutualistic Approach to Designing the Public and Research Facilities at the Botanical Gardens in Windhoek is my own original work and that I have not previously in its entirety or in part submitted to any university or higher education institution for the award of a qualification.

Signature:.....

Date:.....



I enjoy nature due to an experience of clarity and a peace of mind. It grounds us back to earth. A long exposure to nature, for me, comes with relaxation and appreciation.

We cannot truly appreciate if we do not understand. This is why awareness, education and research are such an important aspect of our experience.



The natural environment provides us with spaces of relaxation and gives us a common social space along with fostering a positive mental status (Wu, 2014). An increase in natural disasters, and their intensity (McGrath, 2021), has led to an architectural response which focuses on the artificial reproduction of previously destroyed green spaces (Spirn, 2014), to rehabilitate, revitalise or compensate for the impact the construction industry has on these environments (Snook, 2017). Combined with a rapid urbanisation pattern in the global south (Wijesinghe & Thorn, 2021) and ecosystem domestication (Wu, 2014), Windhoek is at risk of losing its green spaces (Munasinghe, 1999). An understanding of natural systems can assist with the facilitation of construction techniques (Spirn, 2014) and design principles, which in turn create mutually beneficial spaces (Workman, 2004), leading to an improvement in daily lived experiences (Wu, 2014). It is clear that humans are reliant on nature (Kim & Park, 2018), and that we also have a need to be protected and sheltered from it (Gruebner et al., 2017). This distinction has led to harsh infrastructure which divides the architectural spaces from natural spaces (Wijesinghe & Thorn, 2021), causing further dilapidation of the natural ecosystems around larger cities (McDonald et al., 2018). The theory of mutualism suggests that these two systems could have mutual benefits if observed as though it were one system to begin with (Workman, 2004). The National Botanical Research Institute in Windhoek is an appropriate site to test this idea through an explorative design process, informed through precedent studies, site investigations and a literature review. The living library of the Botanical Gardens will be extended with adaptive research facilities to study the potential growth of Namibia’s diverse flora population to ensure the protection and rehabilitation of its green spaces, while also allowing the education about and experience of the authentic natural environment by the public and researchers alike.



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3. Introducing the Thesis

(1)



3.1 Research Proposal

(2)

This section is split into 2 sub-sections. The first of which is the research proposal, which outlines the thesis and gives a broad overview of the topics covered in this document. The background and problem statement will explore the reasoning and purpose of this document. The objectives and research questions then outline the aims, which get further supported by the literature review, which goes into a bit more detail. The research design then explores the different methodologies implemented throughout the document. The second subsection then starts to dissect the different aspects mentioned in the background to the study.

The natural environment is the most important resource we have as a species. It provides us with nutrients to live off of, the air we breathe and the opportunities we require to survive and develop. The natural sphere further provides us with spaces that are relaxing while giving us a common social space and the automatic response of fostering a positive mental status (Wu, 2014). Climate change is an ongoing issue, the effects of which are becoming more and more apparent with a recent increase in natural disasters (Thomas & Lopez, 2015). These disasters have increased in intensity and impact, resulting in constant economic deficits (McGrath, 2021). The impacts of climate change can already be seen in Namibia, with an estimated accumulation of 2,305,295 people who have been affected by droughts, 919,308 affected by diseases and an approximate 5000 further people affected by floods and fires (Wijesinghe & Thorn, 2021), over the period of the last seven years. A major contributor to the effects of climate change is the construction industry which is responsible for an estimated 23% of air pollution, 40% of drinking water pollution, 25% of drinking water consumption and a 50% contribution toward the landfill waste problem (Snook, 2017). The same study by Snook (2017) then concludes that the construction industry is directly and indirectly responsible for around half the climatic change. Spirn (2014) adds to this by stating that in order to protect the earth sufficiently, natural processes need to be understood in order to develop and utilise design strategies and construction materials in an informed manner. This concept is already well known within ecological studies as mutualism, whereby two species adapt to and with each other, for their mutual benefit (Workman, 2004).

In response to growing environmental awareness in the building industry, green architecture and integrated urban planning schemes have started showing up across the world, evidence of which can be found throughout Southern Africa and Namibia in the recent trend of designing green star rated buildings. This understanding starts with the several natural cycles, such as the carbon cycle, the water cycle, nutrient transfer cycles, the various mineral cycles and various other natural processes, which are required for sustaining life on a fundamental level. This allows us to better facilitate, in the form of a building or structure, the natural systems around us, which then further improve our daily lived experiences (Wu, 2014). This study tries to do just that, to create a proposed building or structure which integrates the architectural sphere with the natural one, to design one system for the mutual benefit to man and nature.

Cities are currently developing at such a pace, and in such a way, that the ecological benefits of nature, otherwise known as ecosystem services, are often overlooked (Gruebner et al., 2017). With a rapid development and urbanisation pattern, especially in the global south, such as in Windhoek, Namibia, (Wijesinghe & Thorn, 2021) we are posed with the question, whether we are still a species surrounded and reliant on nature. Kim and Park (2018) say that yes, we do still require the support from nature, adding that it is therefore our responsibility to take care of the planet. This process of rapid urbanisation grows the necessity for infrastructure, which in turn causes the clearing of sites and the implementation of harsh infrastructure, such as concrete buildings, roads and paved surfaces (Wijesinghe & Thorn, 2021).

Current ideas around green design have been described as a form of ecosystem domestication (Wu, 2014), which has become evident through the several approaches to green design. With these approaches however, nature is often added through superficial means, with a focus on their aesthetic qualities rather than the actual processes of formation behind the natural features (Snook, 2017). The approach to clearing existing ecosystems only to superficially re-green buildings has a far larger effect on the microclimate of a given region than we had initially anticipated (McDonald et al., 2018). This process leads to the dilapidation of natural spaces, which in turn decreases our mental well-being and therefore impacts society as a whole (Gruebner et al., 2017). This problem is specifically visible in construction projects on urban greenfield sites which host existing natural ecologies.

The current research facilities at the National Botanical Research Institute located in Windhoek Namibia is one of these sites. The vast open field is located close to the central business district of Windhoek and its main function is being a living library of vegetation species indigenous to Namibia. This means that any further extension executed on this site should be done with the utmost care to the surrounding environment and its larger context in order to prevent the now predictable most likely outcome and influence of such a project.

Removing a massive portion of the local ecosystem would have a major impact on our local climate, as the current site acts as a breathing zone within our city. The entire botanical gardens further supports the distribution of nutrients, dispersion of pollen and collection of water, so that other surrounding green spaces can thrive. Not extending the facilities on the other hand causes several spatial issues, as sister organisations of the NBRI, such as SASSCAL and BotSoc, do not currently have sufficient facilities. This further discourages the collaboration between these different entities and their relevant projects with the public and local as well as international scholars. To better solve both these issues, an equilibrium needs to be achieved, which is where mutualism makes the strongest argument, by combining the need for practical spaces, and the need to protect and preserve the natural environment and its ecosystem services of the botanical gardens.



- This document and the full study aim to:
- Critically analyse the shortcomings of current approaches of integrating natural systems within commonly used green and sustainable design techniques in order to appropriately respond to a local climate.
 - What are the contemporary discussions, parameters, and precedents around naturally responsive design that need to be taken into consideration?
 - Which of the local natural cycles require further investigation and which need special attention, especially when designing a localised and comprehensive intervention?
 - Propose a design approach, which focuses on touching the earth in a mutualistic way, by creating a locally adaptive architectural response, within the city of Windhoek, Namibia.
 - Which of the aforementioned parameters and guidelines need to be adopted to design a mutually beneficent architectural and natural site?
 - Inspire, remind, and educate the general public about the importance of natural cycles, and spending time surrounded by nature itself.
 - How can a building draw attention to itself and the programme within, while being respectful to the natural processes?
 - How can the building highlight the importance of natural systems, without the need to study and read up on these aspects?



Architecture is often described as the re-definition of and translation of space, a description which includes the reshaping of natural spaces (Kirshenblatt-Gimblett, 2004). It is therefore the responsibility of architects to ensure the proper and appropriate architectural and urban response to the constantly growing urban areas (Wijesinghe & Thorn, 2021). Spirn (2014) and Wu (2014) agree that cities are part of nature, and believing otherwise is ignorant. A point that is further proven through the emergence of diseases and a higher level intensity of climate based disasters, brought upon by clearing of forests in order to provide space for cities and their surrounding agricultural support systems (Thomas & Lopez, 2015). The idea that nature and people should coexist, is also not a new one, as we have been and always will be extremely dependent on the well-being of our natural surroundings.

Colding and Barthel (2019) reviewed the current viewpoints and discussions around socio-ecological systems from the last 20 years and concluded that a lack of definition in what this topic is truly meant to achieve, led to a variety of interpretations around the idea of natural integration in architecture. While some architects make use of roof gardens and green walls in order to claim a reduced carbon footprint of the building, others utilise expensive and hard to maintain mechanical systems to achieve carbon neutrality. What is evident is that green and sustainable architectural design responses all lack complexity when it comes to natural integration in architecture (Workman, 2004). This means that buildings often tend to respond to only a certain aspect or element of natural spaces, rather than responding to the larger problems at hand, including the variety of potential natural processes present on site. The buildings commonly respond extremely successfully to their individual contexts, yet fail to respond to the immediate surroundings. These buildings frequently still make use of materials which require a high carbon production based manufacturing and transportation process, such as concrete and bricks. Buildings, which make use of local and carbon neutral materials, in turn often exclude the utilisation of natural processes by artificially adding and implementing natural elements which were generally never part of the site to begin with, and affect the local microclimate in ways beyond our control (McDonald et al., 2018).

While symbiotic design approaches address this topic by taking two separate systems and merging them, mutualism proposes a way that allows the mutual benefit of two species within one system (Workman, 2004). Mutualism is a term borrowed from the field of ecology, which describes the efficient co-existence of two species (Workman, 2004). By re-defining this simple approach to the problem stated above, one can design from the perspective of nature and architecture being part of one mutual system to begin with, rather than re-merging two completely separate systems (Workman, 2004). This entails that the same care and focus of architects give to the construction processes, materiality and the lifespan of the building, should also be applied to the natural environment and its relevant processes.

In order to sufficiently answer the questions that have arisen from the objectives, the qualitative study will undergo three explorative and four investigative strategies. The investigative strategies includes a literature review, an assessment of the local ecological context as well as a theoretical framework and a precedent studies, while the explorative strategies include an observational exploration, a set of defined design guidelines and an explorative design process, comprised of explorative model building, sketching and drafting of plans and sections. The first is a detailed literature review to identify key theoretical approaches to the subject in relation to the problem statement set out above.

An assessment of the ecological context of Windhoek will provide an understanding of the specific ecosystem conditions in the region and constitute a design guideline for the selection of climatically appropriate measures in the design.

A comparative assessment of architectural precedents that deals with the integration of natural processes will be evaluated against the criteria of appropriateness and effectiveness of design solutions in their respective natural contexts.

Observational investigations and a comparative analysis of greenfield sites within the Windhoek urban context will allow for the selection of a site for the proposed design. The chosen site will then be investigated through several mapping methods and site observations, to identify the key design informants of the site that will form the design parameters for an intervention.

The design guidelines, parameters, theoretical framework and precedent studies, will provide a measure against which various design hypotheses can be tested through an explorative design lens and process. The design process will be done through model building, sketching and drafting of plans and sections.

The largest limitation to the study is finding the balance between the need for an intervention and the preservation of natural spaces. The balance between natural processes and human spatial needs, along with the severity of an architectural intervention will therefore cause the largest number of issues throughout the designing stage. It is further important to note that the surrounding context, along with municipal policies and visual appropriateness will be taken into consideration when designing the final building. Further, the precedent investigations and analysis will remain an inspiratory process, meant to inform and inspire, and not to copy or critique the works of other architects. Ethical considerations will be taken towards the inclusion of severely endangered species, by designing private and enclosed greenhouses, away from the view of the public. Similar considerations will be taken towards the conservation of species, and the prevention of overgrowing, to better preserve the natural spaces.



This project will become a case study for the integration of architecture and nature on a greenfield site. By adopting a multi-dimensional design approach, this study will contribute toward design research on mutualism in architecture and further the discussion on the importance of sustaining natural ecosystems in urban contexts. It does so by approaching the design process from multiple angles, as opposed to the one typically used. These are the impact of any design choice on the construction process and the equivalent impact of this on the natural environment, while also looking at the epistemology of the various spatial requirements as well as understanding the anthropology of potential visitors, staff and global researchers. This adds to the global discussion around ecological awareness during the design process by including the natural aspect just as much as the anthropological one.

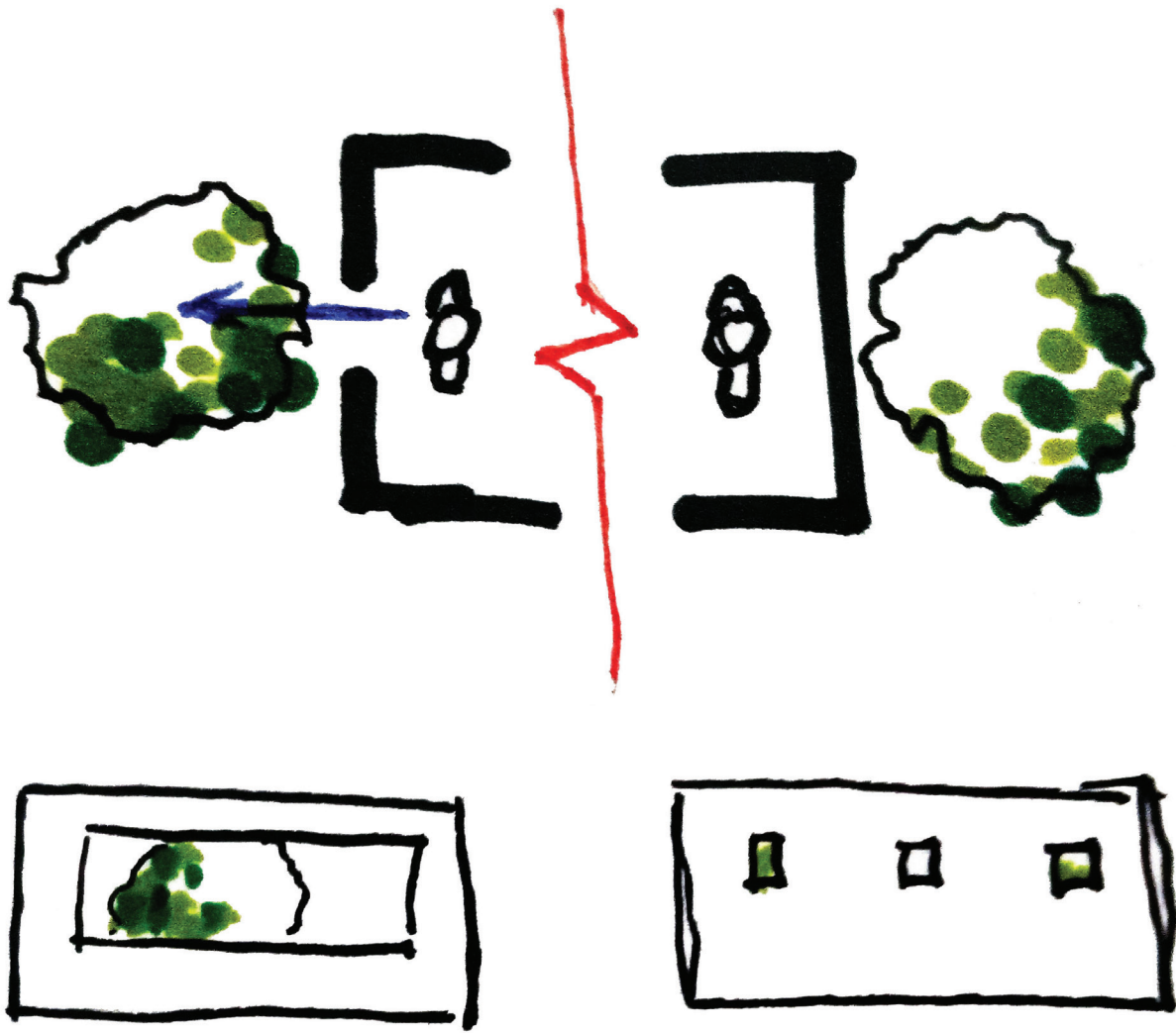


This section looks at the importance of natural green spaces within the urban context, including the benefits associated with the environment. It will continue by looking at climate change and its impact on natural as well as urban spaces, and the impact that the construction industry has on climate change. Lastly, this section will look at future projections of rural-urban migration in Windhoek, followed by the subsequent impacts thereof. This is done to better understand and appreciate the true importance of the ecosystem and to project the potential future impact a rapid increase in housing and building density can have on these significant spaces.



Figure 1: The chart showcases a large array of ecosystem services, as split into their four categories. (Reese, 2022)

Ecosystem services are described as the benefits obtained from natural spaces (Daily, 2012). These services can be split into two categories; tangible and intangible, which can further be split into provisioning, regulating, cultural and supporting services, respectively. The tangible benefits range from the provision of water and food to the regulation of climate, floods, and diseases among others (Daily, 2012). The intangible benefits include recreational, cultural and spiritual significance as well as providing support for the soil formation and nutrient cycling (Wu, 2014). While tangible benefits such as the provision of food, water, purified air and habitation are more commonly known, the intangible services are often overlooked or are currently being researched (Wu, 2014). Some of these include known benefits, such as the pollination of plants and nutrient cycling, to lesser known supporting services such as the biological information network created by intricate and connected root systems (Bolund & Hunhammar, 1999). Heal (2000) goes on to add that the domestication of these green-spaces, by adding monetary value, cannot reliably replace the true value of these spaces, along with their ecosystem services, as many of these are near impossible to value in the first place. The attempt to monetary valuation, combined with a lack of understanding has led to massive negative impacts on the ecosystem by the human species, which in turn has cost us access and purity of some of the ecosystem services (Heal, 2000). The increase in a person's well being is one of these benefits, which will be discussed in the following pages.



Figures 2 & 3: A comparison between a direct visual link between a viewer and nature and the absence or lack of visual connection. This immediately evokes different feelings and connections to the natural sphere.

There are generally two separate types of health benefits associated with a connection to natural spaces; physical health benefits and mental health benefits. Wu (2014) cites a study by Ulrich done in 1984, which showed significant improvement in physical health by patients who spent more time with a direct view on the outdoors. This study is further supported by several similar studies, whereby patients recovered faster when they spent time in exterior courtyards than those rehabilitating with professional equipment (Gruebner et al., 2017). This can mainly be attributed to the increase in mental health of people surrounded by a larger number of vegetation (Wu, 2014). The same studies concluded that urban areas are often the reason for an increase in anxiety, depression, schizophrenia and stress (Gruebner et al., 2017), which can be decreased significantly by being surrounded by vegetation or having a simple view onto natural green spaces (Wu, 2014). This positive mindset, combined with a healthy activity in the fresh air, leads to a faster recovery, especially for patients with physical ailments (Gruebner et al., 2017). Wu (2014) then concludes that engagement within the natural sphere leads to less stress and a decrease in aggression and violence, and an overall decrease in crime, especially in spaces which are well managed.

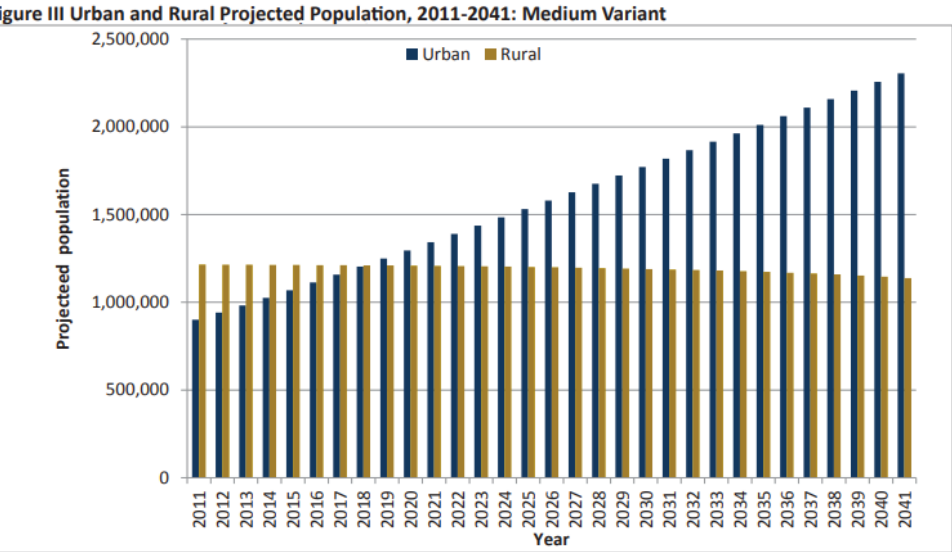
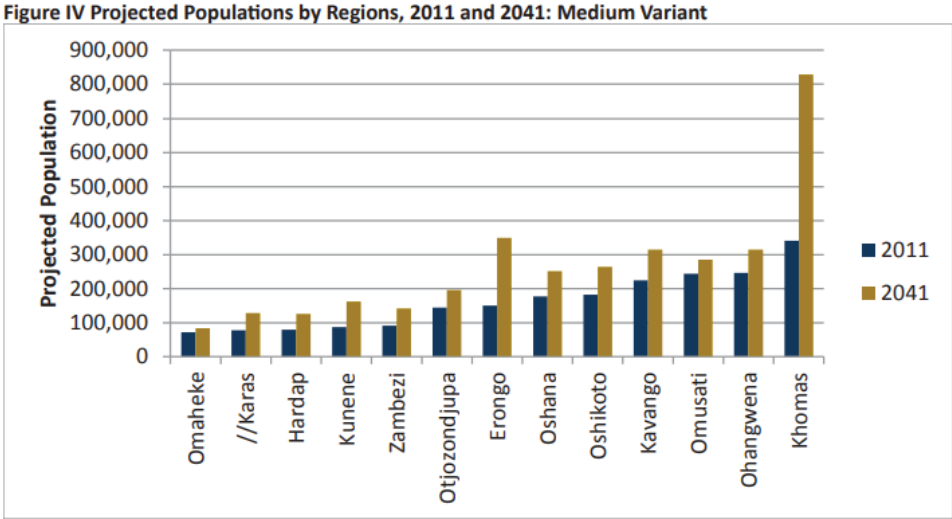
The world has recently seen a spike in climate related disasters, brought upon by an improvement of weather and climate reporting (McGrath, 2021), and an overall increase in global temperatures (Masson-Delmotte et al., 2019). A further increase in global temperatures could have catastrophic consequences on the environment (Masson-Delmotte et al., 2019) and an even greater effect on our economy (McGrath, 2021). According to a study done by McGrath (2021) the number of natural disasters has multiplied by 5 over the last 50 years, causing recovery costs, which have multiplied by 7 (McGrath, 2021).

The main reason for this discrepancy is the increase in intensity of these natural disasters (Thomas & Lopez, 2015), which have a larger impact in urban areas due to a high population density. Thomas and Lopez (2015) go on to say that this increase in intensity needs to be met with an increase in climate resilient planning and designing, in order to ensure economic growth along with the survival of this planet.

A massive part of why this is so important to architects, is that the architectural profession is indirectly responsible for around half the effects of climatic change (Snook, 2017). The construction industry significantly contributes to climate change. Here are some of the direct impacts of the construction industry for which architects are often the spearheaders for:

- 23% of air pollution
- 40% of drinking water pollution
- 50% of landfill wastes
- 40% of global energy usage
- (Snook, 2017)

The impacts of climate change can already be seen in Namibia, with an estimated accumulation of 2,305,295 people who have been affected by droughts and an approximate 5000 further people affected by floods and fires, over the period of the last seven years (Wijesinghe & Thorn, 2021). It is the direct influence that architecture has over the industry which poses it with a simple question; Is it better to continue as is and accept the consequences or to redesign and rebuild the entire urban sphere with carbon neutral/ negative strategies?



Figures 4 & 5: The graphs show a projection in population growth per region and a projected growth in urban population throughout Namibia respectively. These clearly show a trend towards a major increase in population in Windhoek within the next 20 years. (Namibia Statistics Agency, 2014)

3.5 Rural Urban Migration

Cities are currently developing at such a pace, and in such a way, that the ecological benefits of nature, otherwise known as ecosystem services, are often overlooked (Gruebner et al., 2017). With a rapid development and urbanisation pattern, especially in the global south (Wijesinghe & Thorn, 2021) we are posed with the question, whether we are still a species surrounded and reliant on nature. Kim and Park (2018) say that yes, we do still require the support from nature, adding that it is therefore our responsibility to take care of the planet. With this process of rapid urbanisation, the need for infrastructure increases, which in turn causes the clearing of sites and the implementation of harsh infrastructure, such as concrete buildings, roads and paved surfaces (Wijesinghe & Thorn, 2021). The reference to harsh infrastructure is that which has high heat retention and high embodied energy, a topic covered in section 5 within the materiality investigation of this document. Windhoek, being the capital of Namibia is one of these cities, which is estimated to grow immensely over the next few decades. The Namibia Statistics Agency released a report in 2014 that used the 2011 national census to project a large increase in urbanisation, a majority of which will impact the Khomas region as seen in the graphs in figures 4 & 5. According to the 2001 census, the Khomas region is already made up of 230 791 residents, only 43.3% of which were born in the region (Ottolenghi & Watson, 2011). This indicates that a large spike in residents over the coming years is likely due to a large spike in rural urban migration, which creates the need for the development of infrastructure, which results in the clearing and scrapping of greenfield sites, further destroying the urban ecosystem.

3.6 Conclusion

The natural environment is the most important resource we have, providing us with the ingredients needed to sustain life, while also giving us reason to maintain that very life. The massive increase in climatic disasters however poses a threat to urban areas, which desperately need to be reshaped to include the natural green spaces in order to prevent a further disruption. With the massive increase in population over the next few years, Windhoek will need to expand at a rapid pace, which needs to be planned and executed carefully. The following section will explore the potential risk and problems which Windhoek can face if not developed mindfully. As discussed by Gruebner et al. (2017), a city made of concrete, large paved surfaces and “dead” facades can and will increase the mental health crisis.

The rapid urbanisation discussed previously has already led to a variety of “symptoms” of natural degradation as well as devaluation of property. This section will go through some of the observable issues within Windhoek caused by rapid construction, site clearing as well as showing the impact of improper greenspace planning and the mis-understanding of ecosystem services and its impact on structures and other infrastructure. The typical site operations before, during and after construction will then be explored and described, in relation to the natural sphere; i.e. the clearing of sites and improper domestication of natural green spaces, amongst others.

Sustainable design approaches will then be explored as possible solutions, along with their shortcomings and strengths. To reinforce this, the section will include a number of existing sustainable projects as a form of precedent analysis in regard to their overall sustainability. Criteria for this will be drawn from assessing their suitability to the existing context compared directly to their implementation in a Namibian/ Windhoek context.

As mentioned previously, some of the problems with improper usage of the natural resource and the uninformed implementation of infrastructure can already be seen. The following pages will focus on some examples of natural degradation and forgotten/ abandoned spaces (both natural and architectural). From these it becomes obvious that there is a mutual impact, from which one can deduce that if done correctly, a mutual benefit can arise.

Figures 6-9:
These images were taken in the CBD of Windhoek, behind the train tracks near Wernhill Mall. Away from public eyes, water channels were constructed to carry spring water and water run-off away from the infrastructure of the CBD to the natural underground reservoirs. This was done to redirect the natural streams in order to construct the needed infrastructure without problems. Today these channels typically stand filled with highly polluted water, due to blockages in the channels, combined with an improper usage of these waters for washing of clothing, along with the biohazard pollution in the form of human faeces and other excrements. This not only possesses a major health risk, but also provides a contaminated water source for local animal species. As mentioned above, this then further flows into natural reservoirs, which are utilised as one of the primary drinking water sources for the residents of Windhoek.



Figure 6: Pollution of the channels



Figure 8: Plastic flowing along channel



Figure 7: Clothing washing basin



Figure 9: Invasive plants growing in polluted channels



Figure 10: Photo of a recently cleared site

Figure 10:
This photo was taken south of Otjomuise, Windhoek at a local scraping site, where fill material is extracted. These sites are used to scrape topsoil, which is then further used to construct large overpasses, bridges and highways. This scraping process leads to soil erosion, destruction of natural systems and the disabling of natural rehabilitation. This leaves these sites to lose their major facility for the cycling of nutrients, and without enough depth to regrow a proper root system for most plant species. This causes the local flora to either grow rather weak and small, or not grow at all, which then in turn impacts the larger environment due to the density loss. The continuous scraping of sites, along with the lack of rehabilitation projects, combined with an unregulated site preparation process, continuously creates the dilapidation of several sites, both within and outside the city.



Figure 11 : A site cleared over 30 years ago

Figure 11:
The image was taken just a few metres from the previous photo. This site was scraped over 30 years ago, and has been unable to fully regrow. Grasses, smaller bushes and trees have started growing, yet nothing is older than a few years. Similarly, the vegetation density of this site can directly be compared to the hill in the background of the previous image, proving the scarcity of flora in this location, and the point raised by the previous image.



Figure 12:
This photo shows the remains of a demolished building which was torn down years ago, near the Delta Primary School in the Windhoek CBD. The site has not been cleared of rubble, nor has it been developed further. It has now become a dumping site for rubbish and a space for the growth of invasive species, such as cacti. The ongoing pollution brings with it a plethora of opportunities for the festering of diseases, and the habitation of pests and rodents. This process not only affects the environment, but also the health and safety of locals. Consideration for endangered and protected species need to be taken, especially due to the difficult growth pattern of these species.



Figure 13: A site unable to naturally regrow

Figure 13:
This was taken on an empty lot across from the Susanne Grau old age home close to the CBD in Windhoek. The site was cleared years ago to develop, but left once the construction was not carried on. This site has never recovered as a natural space despite decades of inactivity due to a combination of the initial clearing, the scraping of the topsoil and the undeveloped/ non-existent greenspaces surrounding the site. This combined with harsh winds, and high reflective sunlight caused by surrounding buildings, lead to the ongoing issue of lack of supporting services. The topsoil is not only not deep enough, but lacks sufficient genetic and mineral/ nutritional material in order to continue a healthy natural growth of plant species, without severe intervention.



Figure 14: Local aloe species destroyed

Figure 14:
The image of a protected plant species was taken at an ongoing construction site near the Botanical Gardens in Windhoek. While the foundations were being dug, heavy machinery destroyed several large Windhoek aloes that were in its way. The aloe is not only an important symbol to Windhoek and a protected species, but also a well known staple of the biodiversity of flora found in Namibia.



Figure 15: Improper drainage destroying a local road

Figure 15:
The image was taken behind the library of the Namibian University of Science and Technology, and shows the destruction of infrastructure by constant run-off. This causes a regular need for maintenance of the road, which gets used on a daily basis by students and local residents. While a sewage drain is installed nearby, the water is required to cross the road, thereby washing away the tar and its sublayers on a regular basis. This creates a constant backlog of repairs, leaving behind a consistently broken road, and a larger financial deficit on the municipality of City of Windhoek.



Figure 16: A retaining wall destroyed by drainage, causing further destruction to the drainage channels below

Figure 16:
A similar issue can be seen at a local school, where an old retaining wall has been constructed and left to wash away. As seen in the image above, the concrete has already been washed away and broken through in some areas, causing it to further crack, and the earth underneath to wash out. This will further create a sinkhole, speeding up the destruction of the retaining wall and the retained hill. A lack of maintenance will continue this process. The washed away soil will continue to be redirected into the drainage channels, set in place to redirect the run-off water away from the surrounding buildings. This will continue to block these channels, and in turn creating a further financial deficit on the school due to regular maintenance, repair and cleaning of the drainage system.



Figure 17: A strip foundation being dug

Figure 17:
Another indication of the clearing of a site to dig a trench for a future foundation, can be seen in the image taken above. The proposed site across from the NBRI is intended for future residential development, and a few strips of land have recently been cleared to dig these trenches. A larger border was cleared to allow heavy machinery to manoeuvre across the site, which has now left a divided greenfield subject to natural degradation.



Figure 18: A photo showing the invasive species thriving amongst the rubble

Figure 18:
This photo shows a demolished site which has been overgrown by invasive species. The demolished building site seen in the background has removed the possibility for the growth of indigenous trees due to a combination of the blockage of sunlight, the disruption of natural nutrient networks and the pollution left behind in the form of building rubble. This lack of new indigenous growth has left the opportunity for alien species, such as the cacti seen above, to overcrowd the site. This growth takes away resources and space from local species, while giving back extremely little or no locally useful nutrients back into the cycle. This leaves local plant species to forcibly adapt, or not grow at all, both of which lead to the altering of the genetic make-up of a specific green site, which in turn has an effect on the environment and its biological systems and rhythms.

The approach to clearing existing ecosystems only to superficially re-green buildings has a far larger effect on the macroclimate of a given region than we had initially anticipated (McDonald et al., 2018). This leads to the dilapidation of natural spaces, which in turn decreases our mental well-being and therefore impacts society as a whole (Gruebner et al., 2017). This problem is specifically visible in construction projects on urban green-field sites which host existing natural ecologies. These sites are designated green spaces within cities which provide the ecosystem services mentioned above. Construction on these often entail a full redesign, replanting or completely eradication of existing ecosystems. The following diagrams relay a typical timeline of a typical construction site as observed here in Windhoek.



Figure 19: A diagram of a site before construction



Figure 20: Example of tree removal

The first thing done at a potential construction site is the clearing of trees, as seen in the photo below. This is done to allow the heavy machinery to enter a site, level it out and move around freely. Clearing the entire site allows for the setting up of temporary structures and allowing for external storage of materials as observed as the standard site layout. While this does improve the overall efficiency of construction, it destroys the embedded biological information of that site, along with disrupting the existing networks created by the roots of the vegetation.

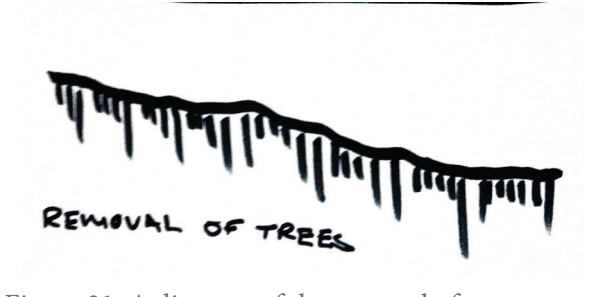


Figure 21: A diagram of the removal of trees



Figure 22: Example of site scraping

The second thing typically done at a given site is the levelling out of the site. This is done by either filling it up with soil, which was scrapped somewhere else, or by scraping the site itself. A combination of the two can also often happen. This disrupts the natural nutrient cycling along with other processes, needed to maintain the vegetation, and by extension the local ecosystem.



Figure 23: A diagram of the leveling of site



Figure 24: Example of construction

Once flattened, the site is excavated, to create foundations, and eventually the building gets constructed. This process can be rather messy, with construction material often contaminating and poisoning the site itself. Construction vehicles leave large imprints on the surrounding spaces of a structure, destroying the soil in the process, and once completed, these sites are often left untreated.

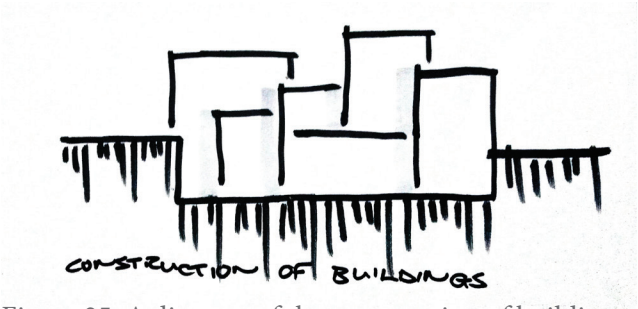


Figure 25: A diagram of the construction of buildings



Figure 26: Example of replanting

For mostly aesthetic reasons, vegetation then gets artificially planted in flower beds, planters and open courtyards. A specifically demarcated site gets re-filled with topsoil, into which a plant is situated. These plants are disconnected from the site by not being adapted to the immediate local soil, with no guarantee of receiving the right nutrients. If maintained, these introduced plants will alter the genetic makeup and nutrient composition of the surrounding soil, further impacting the immediate surroundings and the larger context by extension.

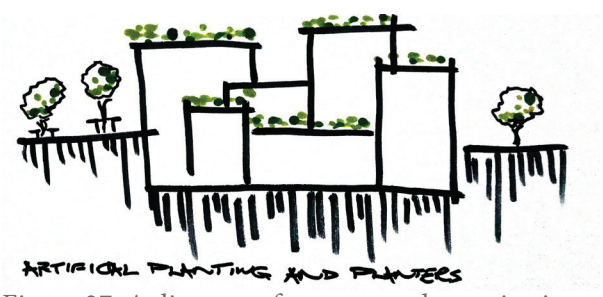


Figure 27: A diagram of ecosystem domestication



Figure 28: Example of plant degradation

If maintained, the vegetation will naturally reproduce and allow the rest of the site to adapt accordingly. This can be beneficial to the site, if endemic species are introduced, and allowed to spread. Commonly however, invasive species are planted, or species which are better suited to a different biome. These often need higher maintenance and attention. This then often leads to the unsuccessful greening of a particular site.

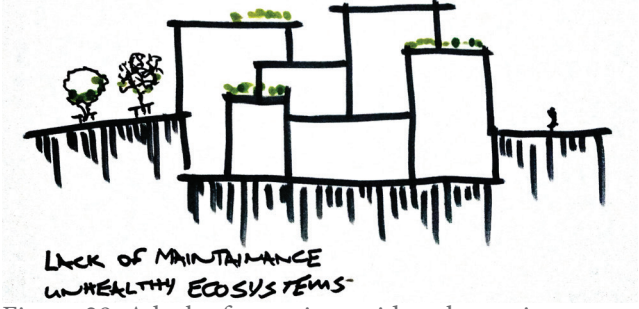


Figure 29: A lack of attention paid to the environment

4.3 Construction Process

Introduction

This subsection will look at 4 of the most prominent and common approaches to sustainable design utilised throughout the globe. While there are more, these have been selected as prominent due to their relatively broad natures. When designing a sustainable building, one of these 4 will typically be made reference to by the respective designer. The approaches will be briefly defined, followed by a rundown of their positive intentions and their negative result or improper application. This is not done to critique any of these approaches, as they do have their individual merits and appropriateness, but rather to explain why these might not be fully sustainable here in Namibia given the expected urban growth Windhoek will experience by 2041 (Namibia Statistics Agency, 2014). With this growth, as mentioned previously in subsection 3.5, there will be a need to develop infrastructure at a rapid pace, for which an appropriate approach will need to be taken, as to not fall into the trap of ecosystem domestication, which in turn disrupts the larger environment (Wu, 2014), or a predominant focus on the aesthetic values of natural features, rather than fitting the structure(s) into the nature (Snook, 2017).

Green Design

Green building design is a focused approach, which created several guidelines to a detailed sustainable design across the world. Each guideline sets out a base set of criteria which a design needs to fulfil in order to be certified. Different levels of certification can also be achieved. South Africa and Namibia have adopted and adapted the Australian system, the Green Star rating system (GBCA, 2023), which has a strong focus on the quality of life, ecosystem biodiversity and (GBCSA, 2017) providing a strong economic return value on an investment into their system (Andrew, 2020). The approach unfortunately requires mechanical intervention to achieve even the basic level of certification. This leads to an extreme financial implication for anyone pursuing certification. This has further led to a limited usage of the approach within Namibia.

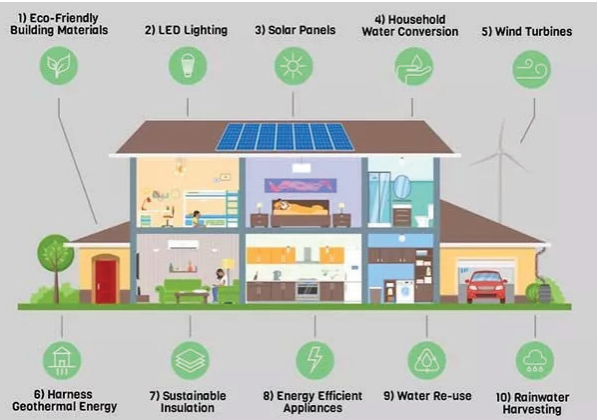


Figure 30: (CADPro, 2023)

Passive Design

Passive design is often referred to as climate responsive design, whereby the building is adapted to the surrounding environmental and climatic conditions (Hyde, 2013). Using form and other design principles, a designer could achieve a comfortable house, with minimal to no mechanical intervention, for the improved living conditions within any given space (Zaki et al., 2008). Scientific principles such as Bernoulli’s principle, stack ventilation and thermodynamic properties of materials, amongst several others, are implemented to achieve this form (Hyde, 2013). Additionally, the site specific conditions further determine the specific shape, form and responses of a given project (Zaki et al., 2008; Hyde, 2013). Unfortunately however, the approach is often misused, by focussing primarily on ventilation and lighting, with no interest in the immediate surroundings. Outside of that, this approach is extremely adaptive to its given environment and site, and is therefore an extremely ideal option for anyone looking to design a sustainable building.

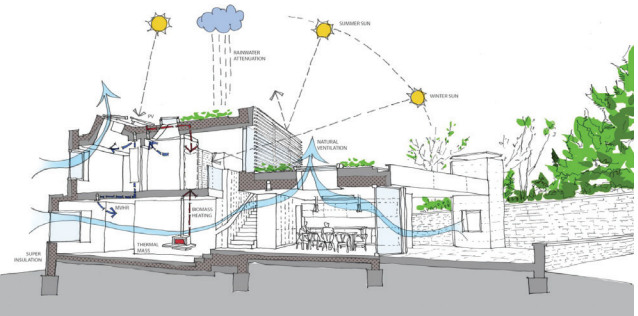


Figure 31: (CaSA Architects, 2023)

Carbon Offsetting

Carbon offsetting is the idea that one can reduce the embodied carbon within any building by cutting or replacing carbon emissions throughout the project (Pilkington, 2022). The idea is that by using natural materials and less materials one can reduce the carbon emissions (Pilkington, 2022). A large part of this is the investing into afforestation projects (Kilgore, 2021). These projects aim to re-grow the already depleting forests, and companies looking to construct can invest in such projects to plant sufficient trees elsewhere to compensate for the carbon emissions from the project (Kilgore, 2021). Barker (2022) points out that in order to compensate for the already existing increase in temperature, one would need to reforest an area 5 times the size of India, nevermind compensating for future growth. Planting that many trees can of course have different effects on the natural environment, which could lead to even stronger natural disasters.

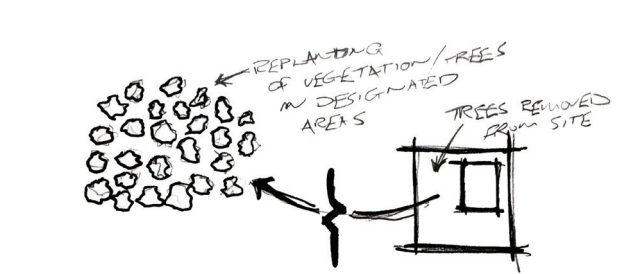


Figure 32: Sketch of Carbon Offsetting Principles

Biomimetic Design

Biomimicry is a concept that transcends architecture (Verma, 2023). Engineers have been solving life’s issue for years by simulating structures and systems found within nature (Verma, 2023). The most common example can be found in self-stabilising cameras, which are directly translated from the neck of a chicken, which is able to hold its head completely still (du Plessis et al., 2019). Taking this to architecture, biomimicry uses a scientific process and research to find a detail within nature, to then try and replicate this within the structure of a building (du Plessis et al., 2019). This concept has unfortunately been misused as well, as often a structure will visually resemble something from nature rather than learning something from it (Kellert, 2018). It further puts little focus on the surrounding environment. The approach of learning from a fully sustaining termite hill for example can be an extremely great approach to sustainable design, yet it requires extreme knowledge and vast amounts of research to truly understand the system of this natural phenomena.



Figure 33: (Arya, 2023)

Conclusion

It is clear that when used correctly, each one of these approaches and systems can become extremely successful at creating a sustainable outcome. Unfortunately though, each one of these either requires a sacrifice of some sort. Passive design has a strong focus on only natural lighting, ventilation as well as water and energy saving costs. Green design requires a great deal in financial backing, to be fully effective, and economically rewarding. Carbon offsetting is mere compensation, with no real measure to ensure the success of the off-site projects. And lastly, biomimicry requires a deep understanding of something extremely specific, with less detail and effort put into other aspects. It is however important to recognise once again, that while they each do have their flaws, they are all great solutions to specific issues from which we can still learn and take inspiration from. The following subsection will look at some precedents which make use of these approaches from which inspiration can be taken.

4.5 Precedents

This subsection will look at some existing precedents which make use of interesting design techniques and different sustainable design approaches. The idea is to learn off of these to implement and combine into the project a few strategies and concepts. Each precedent will be assessed by their primary sustainability approach, and its respective effectiveness. This will be done by looking at the resulting robustness of both the infrastructure and the natural environment of each of the projects. The precedent analysis will then be followed up by a respective lessons learnt paragraph, which will detail the significance to this document and the relevance to the project.

4.5.1 FPT University



Figure 34: A render of the internal courtyard, showing the extreme natural coverage (Oh, 2015)

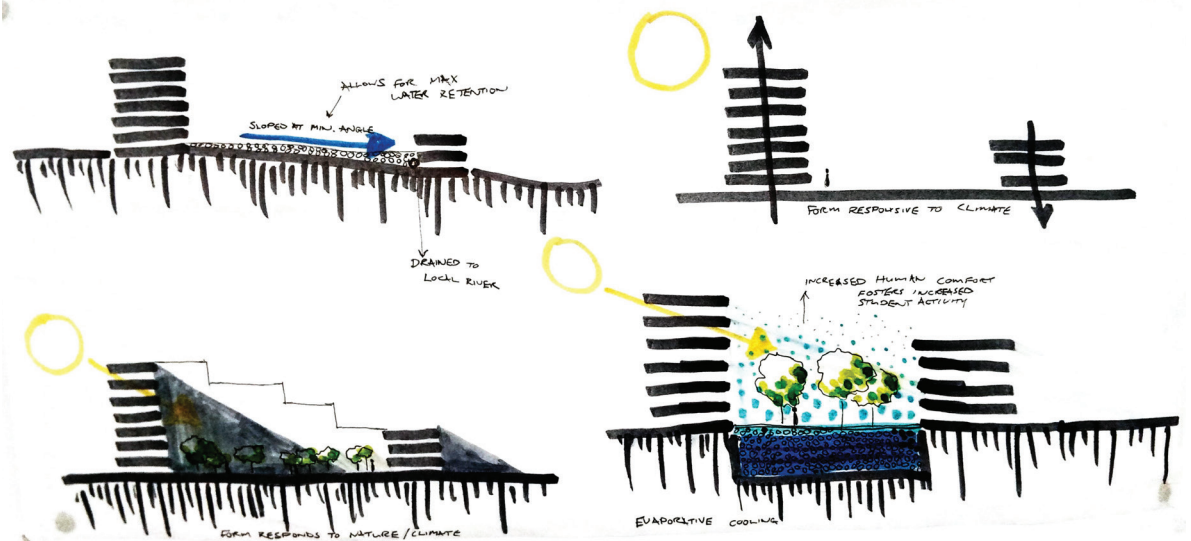


Figure 35: Diagrams exploring the use of form, slopes, trees and the water retention system to cool the space, without the need to intervene with mechanical systems for maximum ecosystem services

Project Title: FPT University Ho Chi Minh City
Architect: Vo Trong Nghia Architects
Location: Ho Chi Minh City, Vietnam
Project Year: 2015
Primary Sustainability Approach: Carbon Offsetting
Appropriateness: Context specific appropriate
Short Description: This is a new university campus in Vietnam, with the intention to increase the green cover within the city, outside of providing an additional tertiary educational campus (Stevens, 2016). The city itself has a green coverage of less than 1%, which has led to a severe strain on their ecosystem services (Oh, 2015). This is why it was so important to ensure a flora species overpopulation within the construction site.

Robustness:
Infrastructure - Will require severe maintenance and continuous waterproofing
Natural Sphere - Yes

Lessons Learnt: The university uses a combination of form, vegetation and water storing system to cool down the entire internal spaces and courtyard. It is the combination of ideas that makes this work as a concept. Further, the architect utilises an underground water retention system, which allows water to slowly keep moving, while also being available for the vegetation year round. This system provides us with the opportunity to keep the little rainwater we get, for a longer period of time, without evaporation, or the festering of diseases or mosquito nesting pools. This allows us to utilise less water to keep the vegetation hydrated throughout the year.

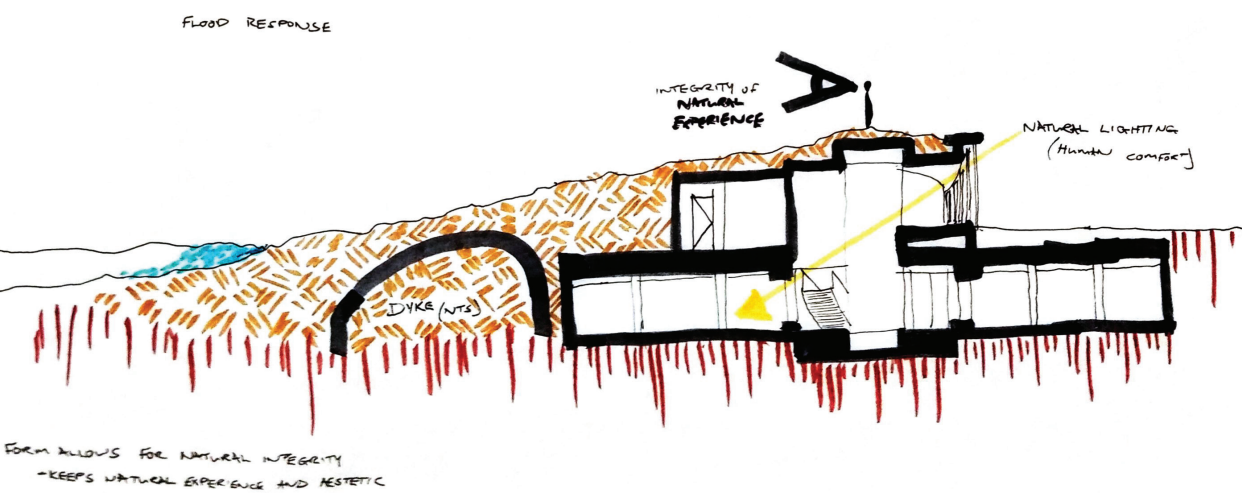


Figure 36: Diagram of a sectional representation of the project, to show the natural slope and the dike in relation to the underground parking, while maintaining a positive natural experience.

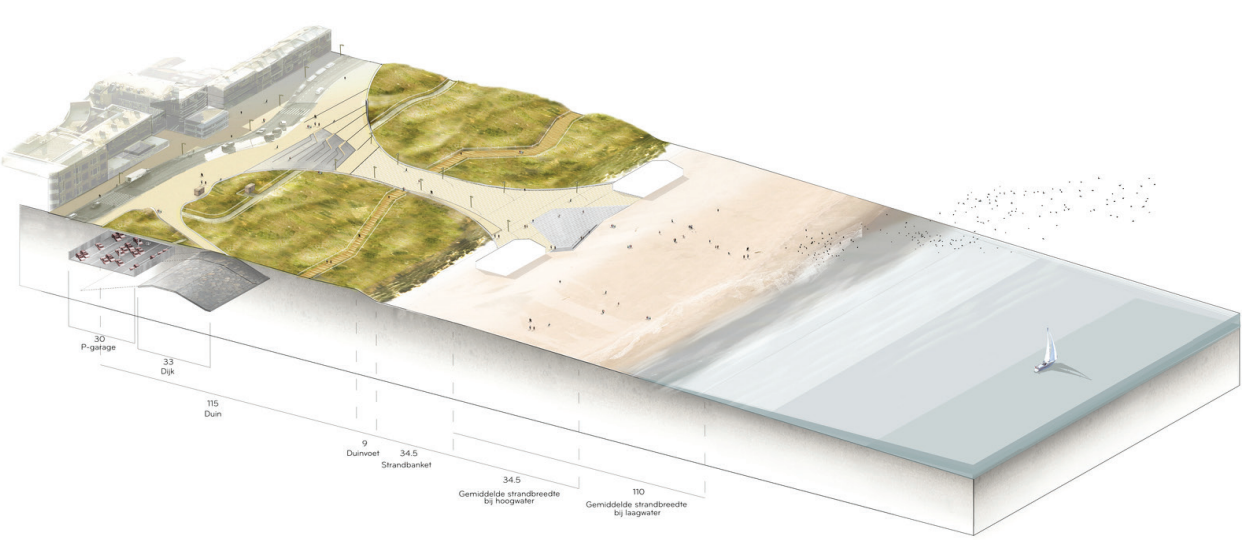


Figure 37: A larger 3D section showing the full picture of the extremely gradual slope. (Arch Daily, 2016)

4.5.2 Katwijk Underground Parking

Project Title: Underground Parking Garage Katwijk
Architect: Royal Haskoning DHV
Location: Katwijk Aan Zee, The Netherlands
Project Year: 2015
Primary Sustainability Approach: Green Design
Appropriateness: Context specific appropriate
Short Description: The underground parking solves a handful of spatial issues, such as the introduction to a formalised public beach front, and the addition of around 500 new parking spots (Architonic, 2023). More importantly though, the project introduced a dike to aid in the prevention of potential flooding in the future, by raising the entire landscape above the natural sea level, right at the coast (Arch Daily, 2016).

Robustness:
Infrastructure - Yes
Natural Sphere - Yes

Lessons Learnt: The project makes use of an endangered site to solve both a spatial issue, and a natural one. By tucking in the parking garage underneath the beach, and allowing for sufficient topsoil above it, it allows the natural vegetation to continue thriving, and giving the coastline a proper public beach. Access water gets dammed off toward the ocean side, while also allowing rain water to naturally escape back into the hillside, and then the ocean. This proves that a facility can have unseen advantages, by introducing a natural hill to fight a potential natural issue, therefore combatting mutual issues, and strengthening the ecosystem services.

Project Title: Coromandel Estate Manor House
Architect: Marco Zanuso
Location: Lydenburg, South Africa
Project Year: 1975
Primary Sustainability Approach: Passive Design
Appropriateness: Context specific appropriate
Short Description: This project is the main residential house to an estate in South Africa. It makes use of local materials to blend into the surrounding landscape, often described as a long rock outcrop (Hidden Architecture, 2016). The architect used different flooring material to differentiate between indoor and outdoor spaces. Interiors received a raised rock floor, or a timber flooring system, while exterior spaces received natural stone, pebbles or was kept as a natural sand (Architizer, 2014).

Robustness:
Infrastructure - Meant to be overgrown
Natural Sphere - Yes

Lessons Learnt:
The building uses primarily natural materials, and keeps as many floor surfaces untouched as possible. This gives the surrounding plant species the opportunity to overgrow the now abandoned structure. Combined with the stone walls, this creates a consistently cool structure, and counteracts the surrounding heat island. This project proves that natural materials can create comfortable spaces, while simultaneously giving plant species space to grow. The long narrow form of the building further creates long shaded walkways, while also not interrupting the natural cycles from one side of the building to the other.

4.5.3 Coromandel Estate Manor House

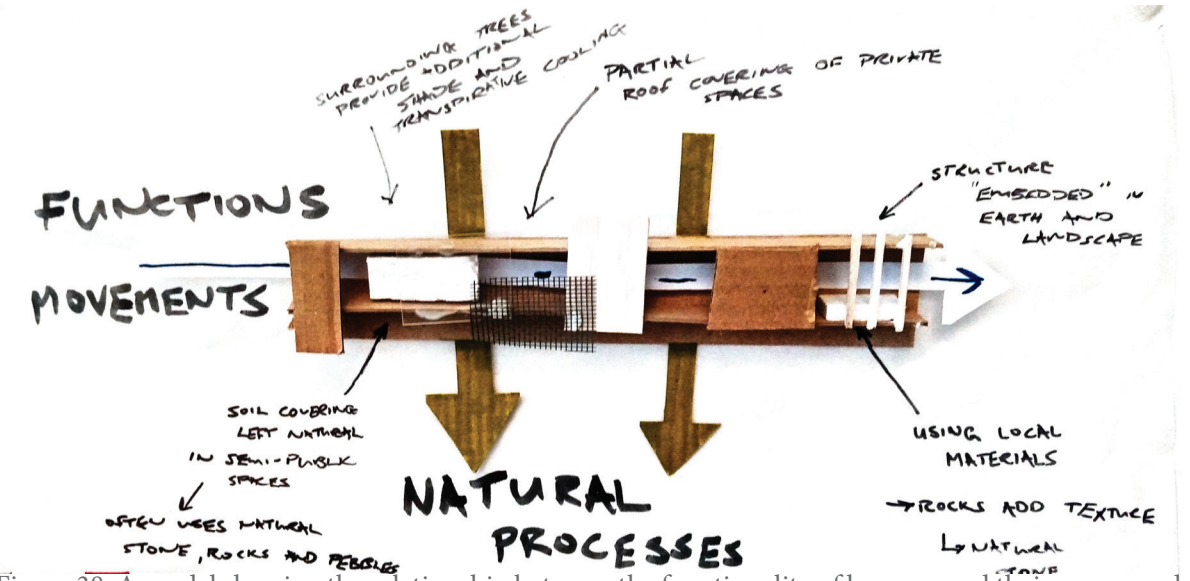


Figure 38: A model showing the relationship between the functionality of humans and their spaces and the natural

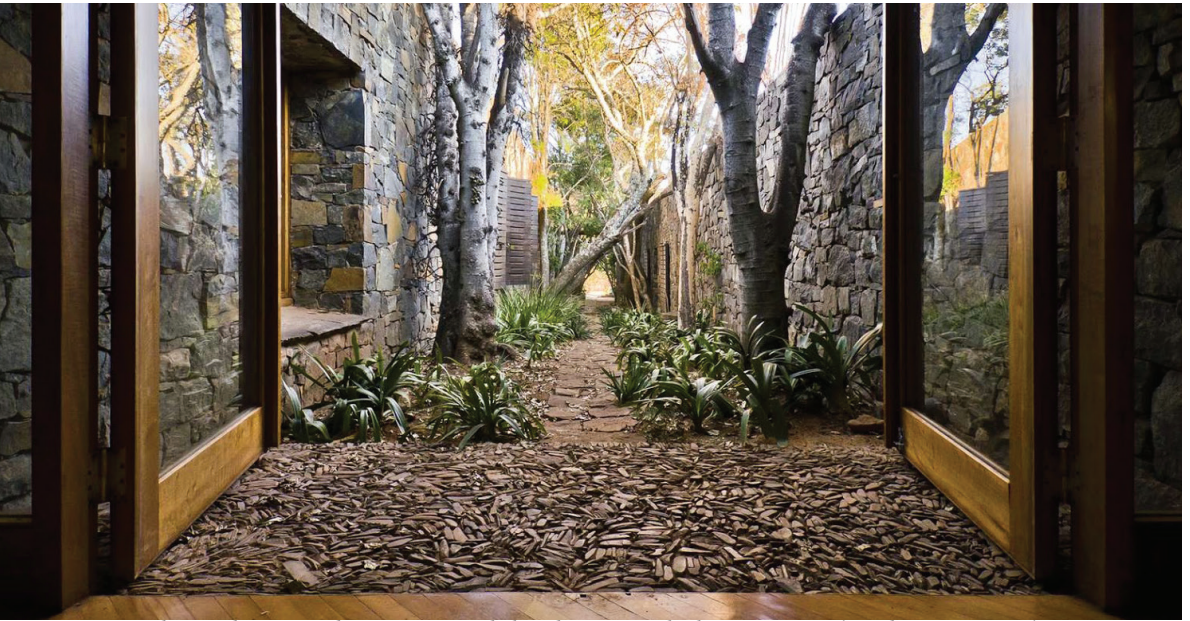


Figure 39: A photo showing the overgrowth by the natural plant species (Architizer, 2014).

It is clear that the environment has an impact on infrastructure and that infrastructure has an impact on the natural environment. As humans, we have failed to take care of our surroundings, and furthermore, we have often implemented structures and processes that hurt not only the climate, but the biodiversity and the natural networks.

A large part of this we have already tried to solve, through several sustainable design approaches, which if used correctly can have a massive impact. Unfortunately, however, these often require extreme financial input, which causes economic strain, or a detailed understanding of scientific principles, which can require further education beyond that of an architect or engineer. These can also lead to an intervention or project which focuses on one aspect of sustainability or natural integration, even if at a high detail, rather than encompassing a larger ecosystem.

Examples of this can be found within the precedents, which were analysed in this section. The FPT University has an intricate water retention system, which is combined with natural transpiration cooling techniques. This allows for an efficient drainage and storing process of run-off water, yet no emphasis was set on the direct surroundings of the campus or the continuous maintenance needed to keep it functional. The underground parking has massive ecosystem services in the form of a continued natural beachfront as well as adding a dike to protect from future potential flooding. Due to the planting system involved however, the formation of natural root networks and by extension a natural growth and expansion will not be fully possible without consistent human intervention and maintenance. The coromandel house uses natural surfaces, materials and elements to create interior outdoor spaces, which further strengthens the ecosystem services. This project does not have an impact on the immediate natural surroundings though, and lacks natural lighting within the fully interior spaces, removing certain comfort levels within the building.





In order to address the issues of natural growth and insufficient ecosystem domestication, combined with an increase in population, an efficient system and approach to sustainable design needs to be implemented. This system needs to take both the human comfort and other spatial requirements as well as the natural requirements, along with the larger ecosystem into account. Mutualism does just that. The term is borrowed from the field ecology, whereby two species, which often oppose each other (i.e. predator and prey), work together for mutual benefit (Workman, 2004). A huntsman spider and frog for example in Australia, have combined forces, whereby the spider protects the frog from other predators, and the frog returns the favour by catching smaller insects for the spider to feast upon (Workman, 2004). This system has allowed the two species to coexist despite being separated in the food chain. Similar relations can be seen throughout the natural sphere across various natural relationships. Two species which inhabit the same space/ habitat and which are not natural enemies or competition, will often evolve toward a mutual benefit. This proves that two systems can work in unison despite it going against their nature and typical patterns of life. Similarly, the pattern within the relationship between nature and construction, is one of destruction, disruption and domestication, as discussed throughout this document.

When looking at nature and infrastructure it is obvious that there are mutual impacts of destruction, as discussed in the previous section. This means that there has to be mutual benefits as well. This section will look at the possible positive impacts different structures, systems and typologies can have on the ecosystem, and what benefits the introduction of a healthy local ecosystem can have on a given space. This will be done by looking at several architectural elements and their impact on nature, following an investigation of natural aspects in the larger ecosystem and the impact they have on spatial comfort, resolution and considerations. Lastly, due to the water shortage currently found in Windhoek, a filtration system will be explored as a mutually beneficial system.



The natural sphere is made up of several elements, processes and systems, which are all interlinked and mutually influential. This subsection will explore a handful of these systems and elements, their necessity and importance along with their impact on or from spatial interventions. The subsection will highlight lesser known aspects of the ecosystem, rather than reiterating the water cycle, impacts of slopes or orientation and form changes due to sunlight. Drainage will still form a big part of the intervention, as will natural lighting, thermal comfort and wheelchair accessibility. Attention needs to be put on the network of root systems, healthy soil and all its components, as well as the additional benefits of trees, as these aspects can often be overlooked or ignored.

The nutrient cycle is the combination of several of the individual mineral cycles which make the ecosystem work as a permanent loop. Each of the systems is influenced by the next, and vice versa. While there are hundreds of cycles, the main ones can be seen in figure 40, which details the different aspects of any given nutrient network. These nutrients are transferred across entire ecosystems through several different methods, ranging from animal transfer, to root nutrient sharing systems and the decomposition of organic matter. All of these can play a vital role in an environment, which is why the uninterrupted connection of natural elements within an intervention are so important. The root system can compensate for lacking minerals by transferring them from an area of abundance to an area with a lack of a given mineral, which can therefore ensure the healthy growth of the ecosystem. The following subheadings will go into further detail of the organic and the carbon cycle, while also looking at soil and its components.

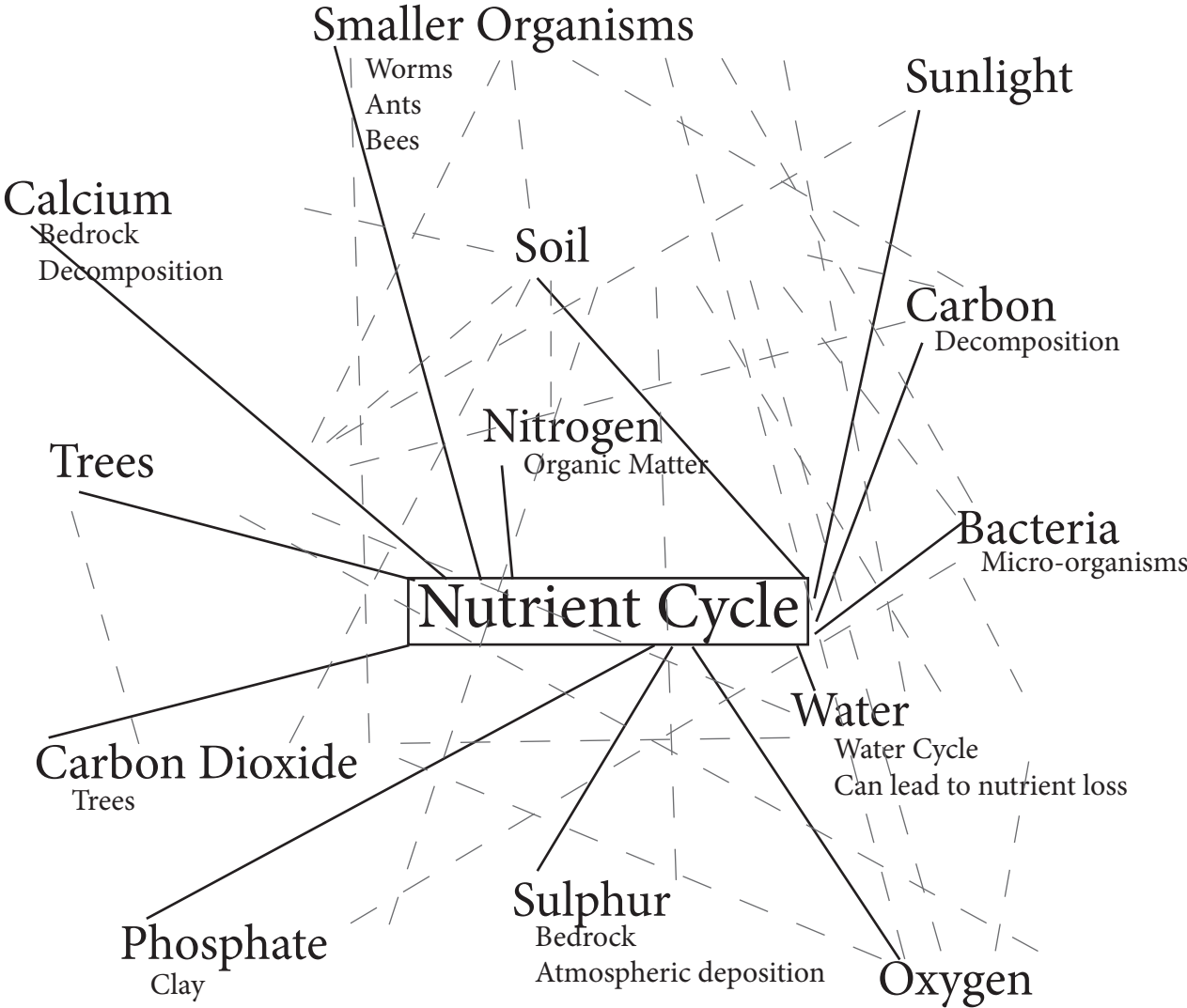


Figure 40: A mind map of the intricate details and connections within the nutrient cycle and its major components

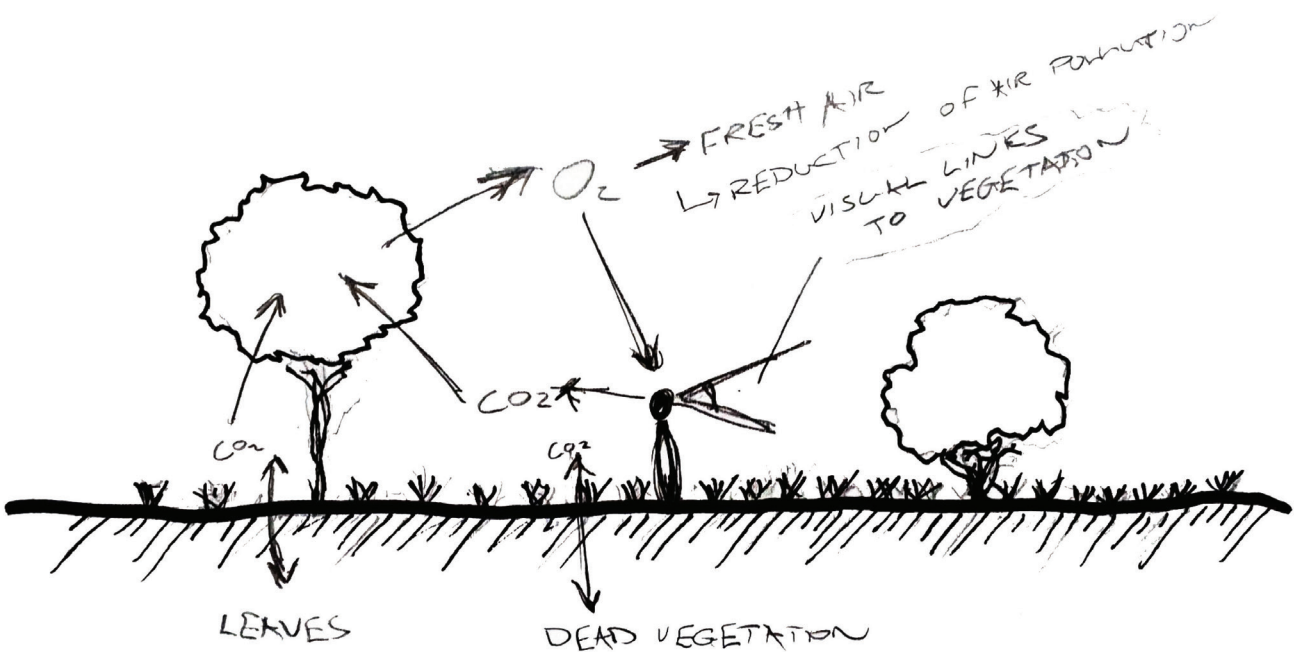


Figure 41: A diagram of the interchange of minerals and other byproducts within nature

The organic cycle refers to anything living within the ecosystem based on carbon. This includes both fauna and flora of a given site. Trees, bushes, flowers and grass make up part of the environment which most people associate with nature, along with wildlife and birds. Organisms such as worms, bacteria, insects and microorganisms make up the lesser known part, despite often being the most important parts. These are the supporting ecosystem services, referred to in the previous sections. Organisms that break up other organic matter into its individual minerals in order to return it back to the earth, for the next species of plants to use. Similarly, bees and other insects carry genetic information in various forms, such as pollen, seeds and dead plant cells, from one area to the next. Plants themselves are also a part of this, as oxygen is not their only byproduct, nor is carbon dioxide their only mineral intake. To have a healthy organic cycle, a variety of plant species are needed, as each gives off a different byproduct, which the next can consume, and vice versa. This need for biodiversity is also a massive reason why many domesticated ecosystems fail, or need sufficient care, potting soil and fertiliser; they did not have the necessary minerals required to sustain themselves, and with them the ecosystem.

The carbon cycle forms part of the organic cycle, which in turn is part of the nutrient cycle. Carbon itself however, is a vital ingredient to live on earth, as the vast majority of species are carbon based. Carbon dioxide is one of the nutrients of plants for example, which require it during photosynthesis. A tree however can only take in a specific amount of carbon dioxide at a time, meaning that a specific balance of gases in the atmosphere is required to successfully sustain the ecosystem. Construction sites on the other hand, produce a lot of carbon dioxide as well as carbon monoxide, which tip the balance to one side, meaning that natural processes can no longer catch up, which is why carbon offsetting is such a preferred sustainable design approach. Building materials also add to this issue by often having a low ability to take in carbon, but rather releasing it into the atmosphere over a larger period of time. This means that the more infrastructure with high embodied carbon materials, the higher the carbon output will be, the more strain it puts on the environment, and lastly, the more impact it has on the climate.

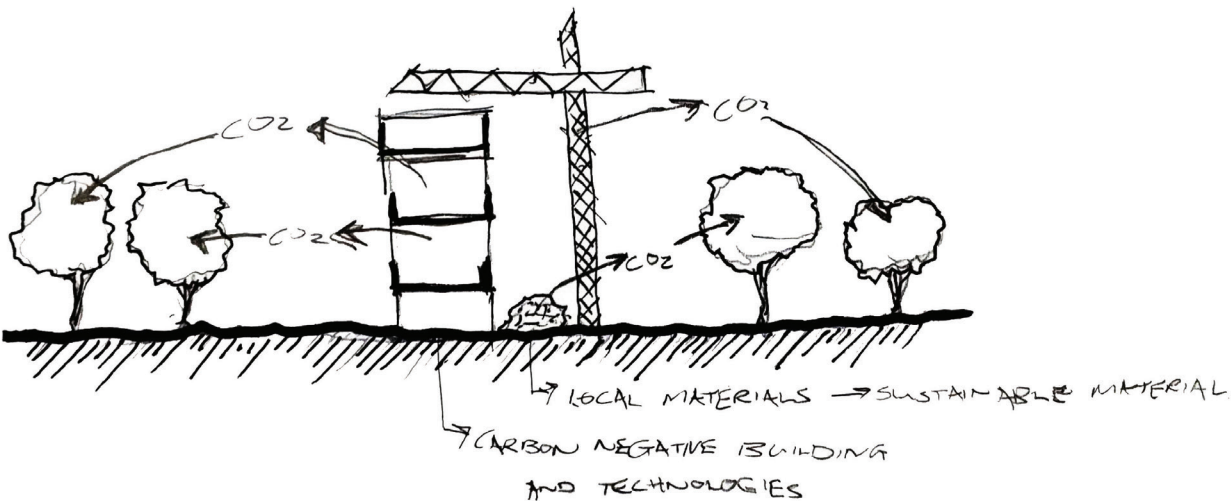


Figure 42: A diagram of the interchange of carbon dioxide on an ideal construction site, without overworking the trees around it (carbon-negative strategies).

SOIL LAYERS

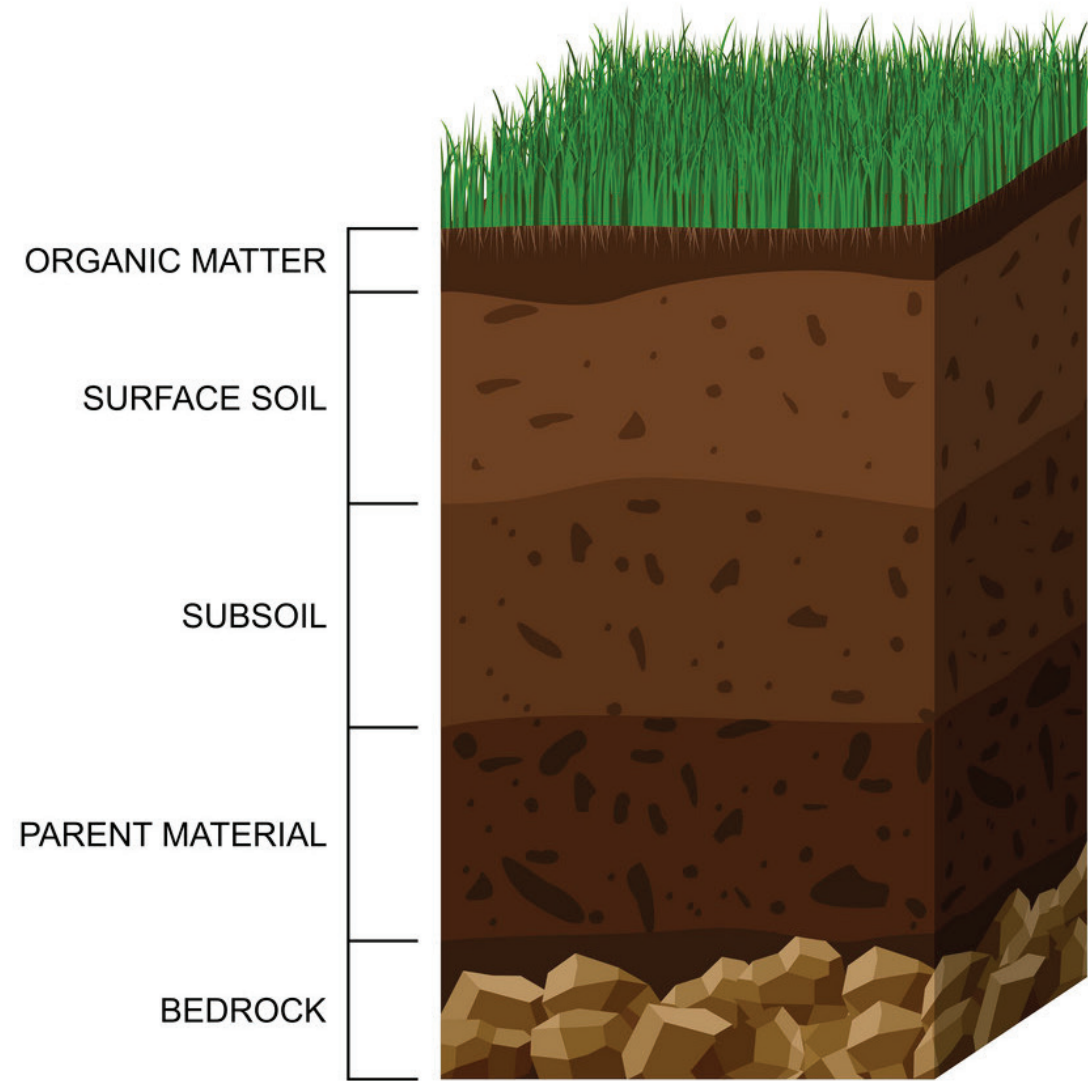


Figure 43: A 3D model representation of the typical makeup of soil, showing the different layers. (Photoplotnikov, 2023)

The soil is made up of several different layers which are important for the healthy growth of plants. Earth is commonly known as the topsoil, or potting soil, and is made up of the organic material layer and the surface soil layer as seen in figure 43. These contain the majority of the minerals needed to sustain life for a plant. The subsoil and parent material layers are below these and give the tree a strong foundation, to hold onto with its root system. In Windhoek, these 4 layers can be between 1 m and 30 cm thick depending on the landscape. On hilltops and mountain ridges, this layer will be the thinnest, as it has often been washed away due to soil erosion, leaving less material and soil for the growth of plant species. This material gets washed down the mountains and hills and ends up in rivers and valleys, where this material is then deposited. With the scraping of sites, there is often no soil left, for a healthy regrowth, and even if soil is left over, the nutrient rich topsoil layers have been removed or disrupted.

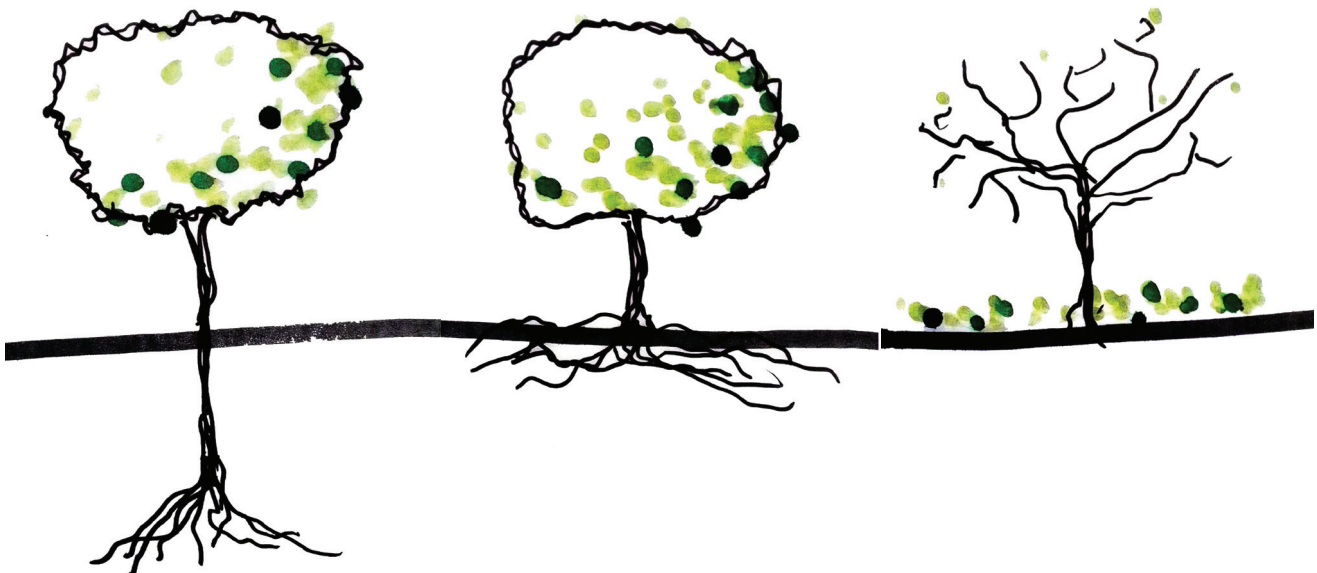


Figure 44: Diagrams of the tap root system and the fibrous root system, followed by a diagram of the seasonal shedding of leaves by deciduous trees

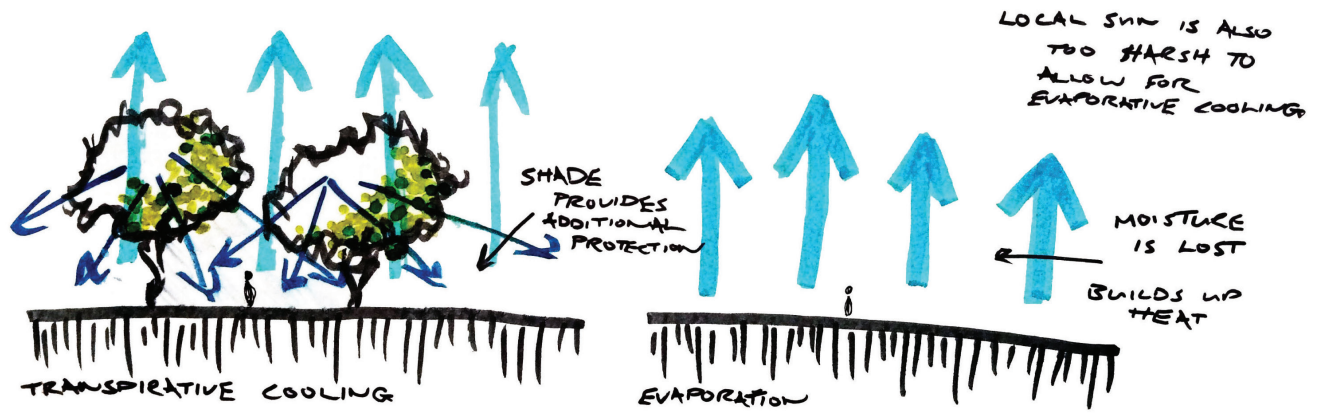


Figure 45: A diagram transpiration cooling system compared to that of evaporation, and the difference trees can make

The tree has several visual qualities about itself, which bring a handful of ecosystem services with them. Transpiration cooling is one of these benefits, whereby moisture in the tree is able to trap heat, and cool down the space. Combined with the act of transpiration from the tree and the shadows created by it, a tree can have massive cooling effects on a space. The tree itself however, also gives off certain minerals, which other species can utilise. Trees generally also have two main root systems, both of which are the same size as the crown. The difference is that one spreads out within the topsoil layer and is able to survive off of the moisture content within this layer, while the other digs deep, to find a sufficient water source, from where it pulls its nutrients. This difference can have an impact on the foundation, piping and walls of a structure, which is why choosing the right species becomes important for the protection of the infrastructure. Lastly, the tree can have a textural quality, both within its bark and its leaves. The leaves can shed during winter, where these fall onto the floor and become an auditory texture, while in summer they create patterns within their shadows, and an auditory rustling effect.

To argue for the classification of nature as a client and against domestication, one needs to pay it the same level of attention and understanding. A large part of this is understanding the way species grow, along with several other aspects explored above. Individual indigenous species grow at different rates, to different heights, using different support systems, root systems and populate a given area in various different ways. The following ten plant species are just a few of the species proposed to be planted within the intervention. Each one shows different growth rates, sizes and patterns. They have been chosen for their colour, typical habitat, and services towards the end users (i.e. shade, smell, colour, cooling effect). Understanding the growth of these species (amongst others), will give an indication toward their healthy facilitation. This includes the knowledge of soil depth, width between species, direct access to sunlight along with soil make-up and soil grain.

COMMIPHORA AFRICANA

Common Name: African Myrrh

Plant Type: Tree
Soil Type: Sandy and Rocky
Flowers: Small and red
Shade: Full sun
Propagation: Seeds
Root System: Creeping Root
Size: 3-5m
Growth: Self Supporting
Growth Rate: Slow

(Curtis & Mannheimer, 2005)



Figure 46: Photo of the African Myrrh tree (Musch, n.d.)

COMBRETUM IMBERBE

Common Name: Leadwood

Plant Type: Tree
Soil Type: Sandy and Rocky
Flowers: Yellow Green Samaras
Shade: Full sun
Propagation: Seeds
Root System: Deep Tap Root
Size: 6-10m
Growth: Self Supporting
Growth Rate: Slow

(Curtis & Mannheimer, 2005)



Figure 47: Photo of the Leadwood tree (Jürgens, n.d.)

CRATEROSTIGMA PLANTAGINEUM

Common Name: Blue Gem

Plant Type: Perennial Herb
Soil Type: Riverine
Flowers: Blue/ Purple
Shade: Indirect Light
Propagation: Seeds
Size: 10-20 cm
Growth: Self Supporting
Growth Rate: Fast

(Curtis & Mannheimer, 2005)



Figure 48: Photo of the Blue Gem flower (JMK, 2022)

VACHELLIA KARROO

Common Name: Sweet Thorn Acacia

Plant Type: Tree
Soil Type: Riverine
Flowers: Yellow
Shade: Full sun
Propagation: Seeds
Root System: Tap Root
Size: 2-20m
Growth: Self Supporting
Growth Rate: Fast

(Curtis & Mannheimer, 2005)



Figure 49: Photo of the Sweet Thorn Acacia tree (JMK, 2023)

GLORIOSA SUPERBA

Common Name: Flame Lily

Plant Type: Perennial Climber
Soil Type: Terrestrial
Flowers: Red
Shade: Indirect Light
Propagation: Seeds
Size: Up to 3 m
Growth: Self Supporting
Growth Rate: Fast

(Curtis & Mannheimer, 2005)



Figure 50: Photo of the Flame Lily bush (Kojian, n.d.)

EUPHORBIA KAOKOENSIS

Common Name: Kaoko Spurge

Plant Type: Succulent Shrub
Soil Type: Rocky Slopes
Flowers: Inflorescences
Shade: Light Shade - Full Sun
Propagation: Seeds
Root System: Fibrous Root
Size: up to 50cm
Growth: Self Supporting

(Curtis & Mannheimer, 2005)

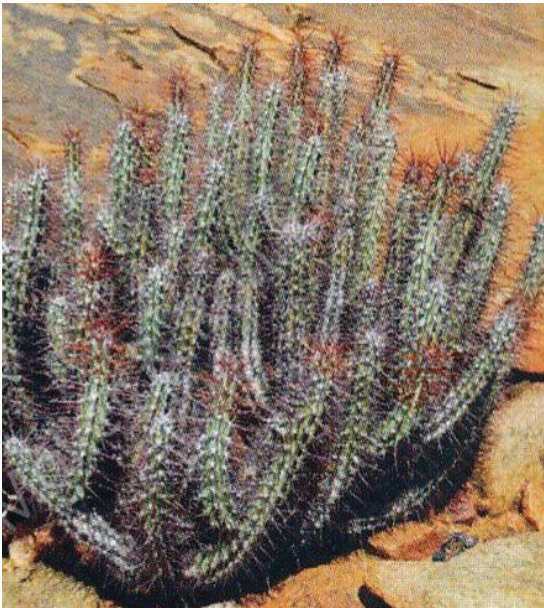


Figure 51: Photo of the Spurge shrub (Leach, n.d.)

ANSELLIA AFRICANA

Common Name: Leopard Orchid

Plant Type: Orchid Flower
Soil Type: Sandy Riverine, High Organic Content
Flowers: Yellow with Brown Spots
Shade: Full sun
Root System: Fibrous Creeping Root
Size: Up to 80cm
Growth: Dependant on Trees

(von Flintel, 2003)



Figure 52: Photo of the Leopard Orchid (von Flintel, 2003)

BOSCIA ALBITRUNCA

Common Name: Shepherd’s Tree

Plant Type: Tree
Soil Type: Sandy Riverbeds and Rocky Outcrops
Flowers: Green-Yellow
Shade: Full sun
Propagation: Seeds
Root System: Deep Tap Root
Size: 3-10m
Growth: Dependent Seedlings, Self Supporting
Growth Rate: Extremely Slow

(Curtis & Mannheimer, 2005)



Figure 53: Photo of the Shephard’s tree (Dreyer, 2006)

PACHYPODIUM LEALII

Common Name: Bottle Tree

Plant Type: Succulent Tree
Soil Type: Rocky Hilltops
Flowers: White
Shade: Full sun
Propagation: Seeds
Root System: Tuberous Tap Root
Size: 1-8m
Growth: Self Supporting
Growth Rate: Medium

(Curtis & Mannheimer, 2005)



Figure 54: Photo of the Bottle tree (Plant Net, n.d.)

SCADOXUS MULTIFLORUS

Common Name: Blood Lily

Plant Type: Bulb
Soil Type: Sandy and Drained
Flowers: +- 100 red flowers
Shade: Indirect Sunlight
Propagation: Seeds
Root System: Large Fibrous Root
Size: up to 60cm
Growth: Self Supporting

(SANBI, 2023)



Figure 55: Photo of the Blood Lily Flower (Notten, 2001)

A majority of the species mentioned, require a mixture of deeper looser soil and or rocky outcrops. Given a sufficient nutrient supply, most of these species will sustain by themselves. The prolonged access to water will be necessary as well to ensure the successful growth. Continuous soil will further aid the transfer of nutrients from one side of the site to the next. These soil conditions will lead to the healthy diffusion and distribution of nutrients and water to better facilitate the plentiful growth of these species. A constant breeze, access to fresh air and direct sunlight will further ensure the growth of the tree species. Most of the flower species mentioned require some form of indirect sunlight, and will therefore make for great groundcover and can perform well within the building, and darker spaces. To discourage ecosystem domestication, it is important not only to get a strong variety of species, but a cohesive cycle of nutrients, along with a variety of growth patterns and speeds.

The architectural sphere has to do with different architectural elements, their connections, and their respective influence on nature and its processes. This will give an indication of which elements to avoid, and which connections to use along with giving an idea of what to look out for when using these in the design. The subsection will primarily look at foundations, slabs, walls, columns and materials in their relationship to the soil, as this is the primary contact between nature and infrastructure. Different materials can release different harmful chemicals, while others have better adaptability and higher water retention properties. All of this will be explored within the following pages.



Figure 56: A model of a strip foundation

Strip foundations work by creating strips deep in the ground, to reach a suitable hold. These strips are dug out, therefore removing the topsoil, and filled in with material, which is typically concrete. The depth of the foundation combined with the smaller surface area not only disrupts the natural systems, but further puts a lot of strain on the site.



Figure 57: A model of raft foundation

Raft foundations are based on the slab being the primary foundation, lying on top of solid/compacted earth, to hold the structure in place. This type of foundation deals with less depth in the foundation, meaning that outside of the topsoil layers, no further digging is required. The foundation also spreads the weight of the structure over a larger area, therefore putting less strain on the site.



Figure 58: A model of pad foundations

Pad foundations are foundations which are very small in size. This can create large amounts of strain on the site. Using multiple pad foundations combined however can have a great impact, as the weight is now once again distributed relatively evenly amongst the site. The depth of these can have a lasting effect though as once again the topsoil needs to be disrupted. Larger structures, further, cannot be sufficiently supported by pad foundations, unless dug deeper, and increased in size, therefore increasing the impacts on the soil. These foundations can however be put on top or close to the surface of the soil to reduce the impacts and make for great options for individual columns. With the footing being close to the ground, the soil can continue sharing nutrients underneath the foundation.

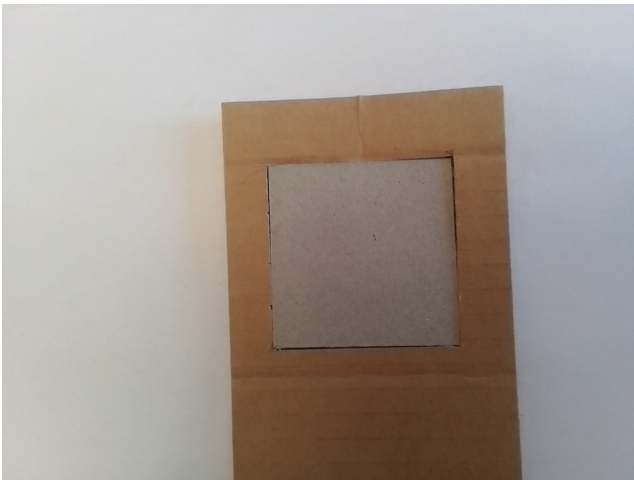


Figure 59: A model of flush slabs

This type of slab sits either right on top of the soil, or is flush within it. This allows for minimum disruption of the topsoil. The large surface area of this can however lead to large sections of the topsoil (directly underneath the slab) to lose access to sunlight, which can have a negative impact on the organic matter and microorganisms within it.



Figure 60: A model of raised slabs

Raising of a slab can be done in two ways. One would be to create a mound upon which the slab sits, or raise it on stilts. Creating a mound requires access soil to be brought to the site and raising the slab onto stilts requires a bunch of pad foundations. The raised slab further restricts the accessibility of the building. While the stilts would allow for the soil to thrive, it requires additional support, for larger structures or heavier materials.

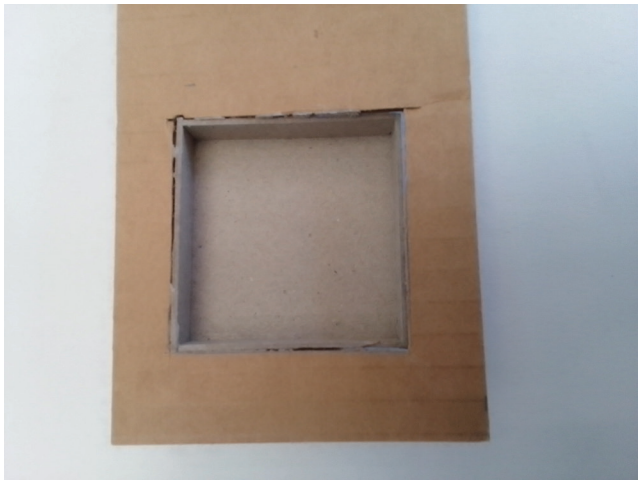


Figure 61: A model of sunken slabs

Another option would be to sink the slab into the ground. This would eliminate the need for a foundation on certain sites, but does have a larger impact on the site as it needs to be dug out. Either you lower it by an entire story, which then completely disrupts the natural processes, or you lower it by just a metre, or less, which can have massive implications for the rainy seasons, due to flooding.



Figure 62: A model of smaller slabs

A way to solve the issue of a large foundation in terms of its area, is to lower the footprint of the slab. While this can have positive impacts on the soil, this would either require additional height of a structure, or the cramping of spaces into a confined footprint, which can lead to a lower comfort.



Figure 63: A model of combined slabs

To retain the same footprint as the larger slabs, one could make use of a combination of slabs with different materials, each with their own impact and a separate functionality. This would be ideal for the retaining of a specific footprint and lowering the strain exerted on the topsoil, but would still not allow natural process underneath the slabs, due to their large spans, nor give access to any form of natural light for the smaller organisms.

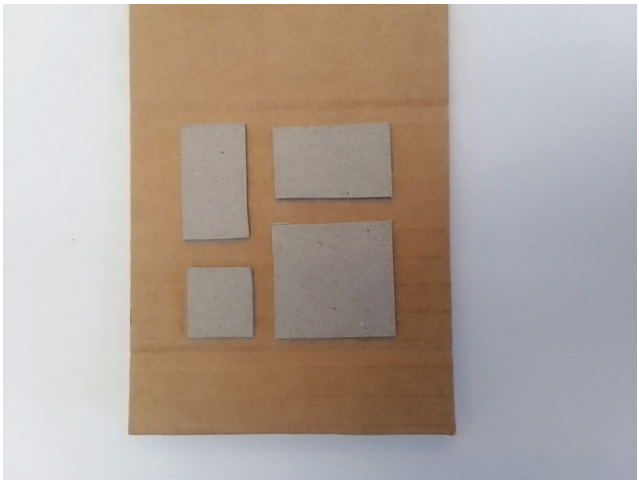


Figure 64: A model of separated slabs

To counter this, one could leave the walkable portions of a building as buffer space between several smaller slabs. This would allow for an increase in usable footprint, while lowering the strain on the site, and the area covered by each individual slab. This gives process shorter distances to cover underneath the slab, enough direct and indirect lighting and opens the opportunity for bringing nature into the building.



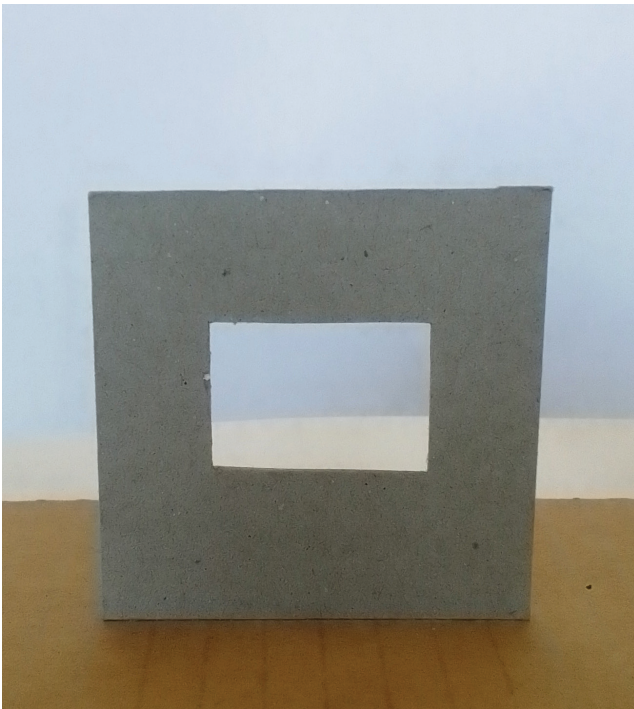


Figure 65: A model of a standard wall with window

While walls have barely any impact on the soil, outside of weight, its compression and needed structural support, including the previously discussed foundations. Finding a material that is light weight is therefore relatively important. Other strategies can also be used, such as the inserting of a window, as seen in figure 65, which lowers the surface area and therefore also the weight on the ground underneath it. This decreases the amount of compression, allowing for a better diffusion of nutrients, due to the increased porosity.



Figure 66: A model of a wall of stepped blocks

The other impact that walls have in relation to the natural sphere is the thermal comfort of the spaces surrounding it. The introduction of windows or perforations, decreases the amount of energy and heat stored within the wall. Even stacked/ stepped blocks, as interpreted in the model in figure 66, have the impact on thermal comfort mentioned above. A way to solve this, is to use this as a secondary skin, with a buffer zone between. This however, doubles the weight of the wall, increasing the aforementioned issue.



Figure 67: A model of a gabion wall

To better solve the issue of the weight to compression ratio, along with the issue around embodied energy, and thermal comfort, it is important to look at materiality of a wall. Using a gabion wall, as modelled in figure 67, for example, can accommodate the natural processes better, while also allowing for a cool breeze, and not allowing any direct sunlight. Due to the larger gaps and because of the porous nature of the wall, the soil underneath it creates permeable spaces for water and minerals to wash through what would otherwise be larger barriers.



5.3.3 Wall Investigation

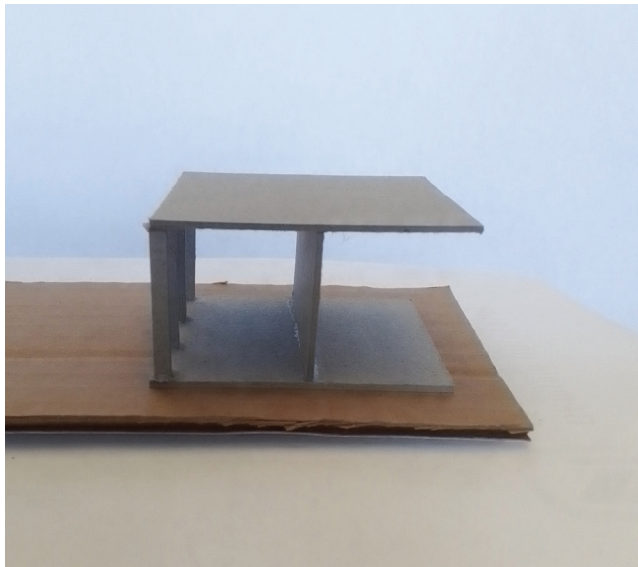


Figure 68: A model of columns and the wall sharing a slab

Similar to walls, columns add additional weight to the foundations, increasing the compression underneath. One way of dealing with this is to allow the wall and column to share the same slab. This increases the surface area of the slab, and the size of the foundations, further increasing the total weight of the structure. This creates the same issues as mentioned in the foundation, slab and wall investigations above.



5.3.4 Column Investigation

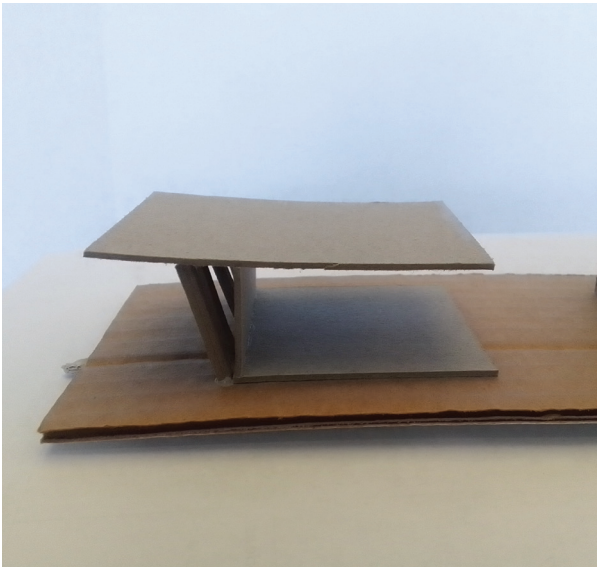


Figure 69: A model of columns sharing their foundations with a wall

The other way to deal with this, would be to tie the columns into the wall, either at the slab level, as depicted in figure 69, or at a higher level. This requires a stronger foundation, once again increasing the weight, but comes at a reduced surface area of the slab, and is therefore less compressive. The problem comes from the dead space created inside the triangle, with less usable space. Shifting the connection upward can counter this, but creates a limit of how far out an overhang can reach, the higher the connection is placed.

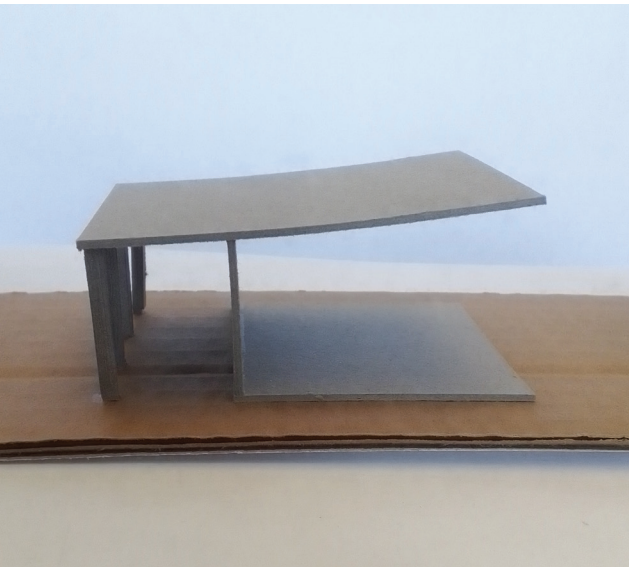


Figure 70: A model of columns separated with their own pad foundations

One way to tackle this issue, is to split the columns from the walls, and give them their own pad foundations. The size of the slab is reduced, weight is reduced on the foundation, and the walls are no longer required to carry the full weight of the roof, columns and itself, therefore decreasing the size of the foundation. The smaller pad foundations do create a higher point of compression, but due to its smaller size and the vast gaps between foundations is a compromise between the facilitation of the natural systems and the functionality of the architectural structures.

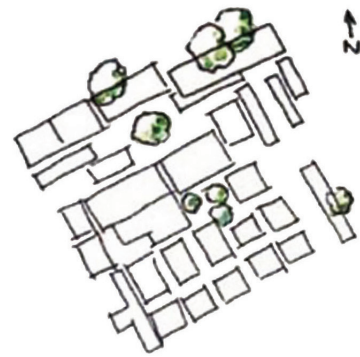


Figure 71: A sketch of the site plan of Waldorf School

Figure 74: A sketch of the site plan of the NBRI

Figure 77: A sketch of the site plan of the NUST Hotel School

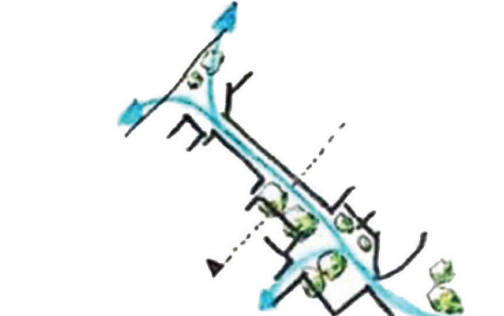
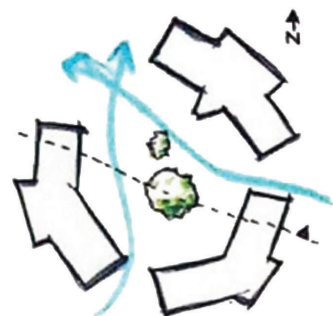


Figure 72: A sketch of the directional winds of Waldorf Primary School courtyard

Figure 75: A sketch of the directional winds of the NBRI courtyard

Figure 78: A sketch of the directional winds of the NUST Hotel School courtyard

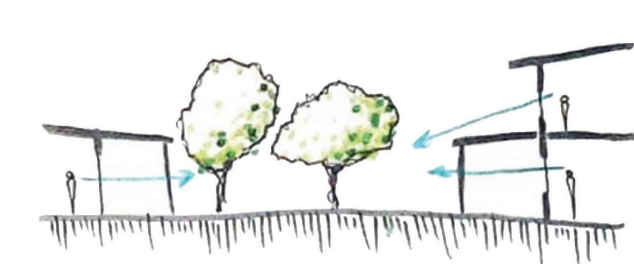
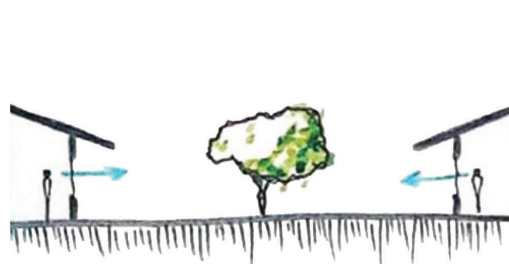


Figure 73: A sketch section through the Waldorf School courtyard

Figure 76: A sketch section through the NBRI courtyard

Figure 79: A sketch section through the NUST Hotel School courtyard

5.3.5 Courtyard Investigation

(49)

Choice in material can have an impact on the diffusion of minerals from one side of the site to the other, an impact on thermal comfort, and an impact on embodied energy, as mentioned above, and in previous sections. The following section starts by looking at a few different responses and types of ground cover, and compares their heat retention and their water absorption capabilities. The section will end with the choice in material, explain the choice, restrictions, properties and the installation of these materials. It is important to keep in mind the transport, extrusion and manufacture of the material as these have the various impacts on the climate described in subsection 3.4. Further, the first part of this section will look at the heat island effect created by large areas of ground cover. It is important to use materials that work exterior, allowing for the movement of nutrients throughout the site, while also being wheelchair friendly. Simply keeping the gravel will therefore not suffice.

5.3.6 Material Investigation

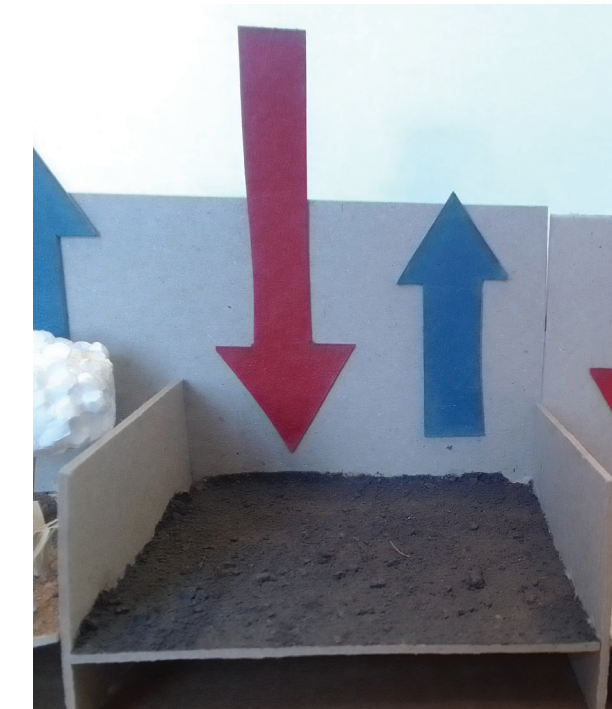


Figure 80: A model comparing the heat gain and evaporation rates of composite tar

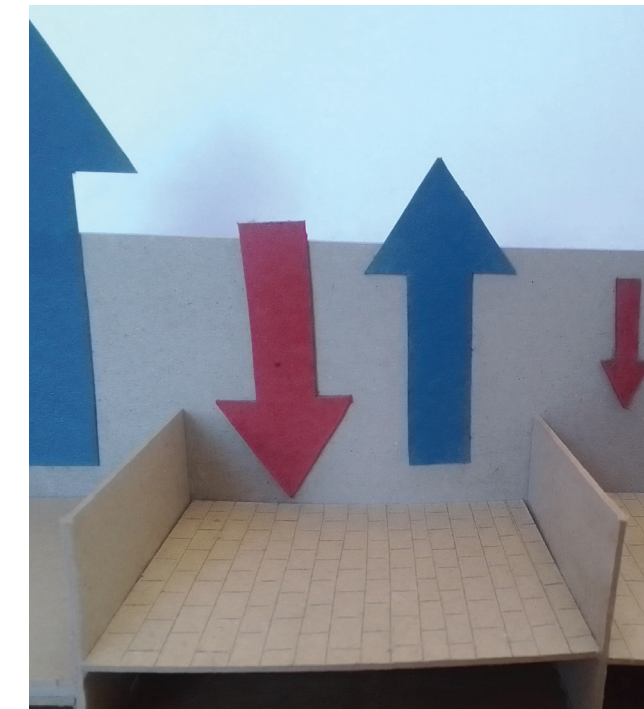


Figure 81: A model comparing the heat gain and evaporation rates of paving

The first ground cover one can look toward is the idea of composite tar. This tar makes use of less sand, which therefore creates gaps within the mixture, allowing water to permeate rather than running off. This allows water to seep into the ground, slowly infiltrating the ground and in turn cooling down the entire surface. Unfortunately the tar still produces toxic fumes during manufacturing and pouring, along with the toxins given off during its lifespan. Even painting the tar white, to reduce heat intake will not solve that problem.

Another common ground coverage, which does not retain as much heat as concrete or tar is the use of pavers. They are often used for their simple installation, lightweight and aesthetic capabilities. Unfortunately however, they only make use of the tiniest gaps, and still affect the growth of species, as most of these rely on seeds as a form of propagation. Further, water still runs off, and heat retention is still a major issue, given the concrete nature of the pavers.

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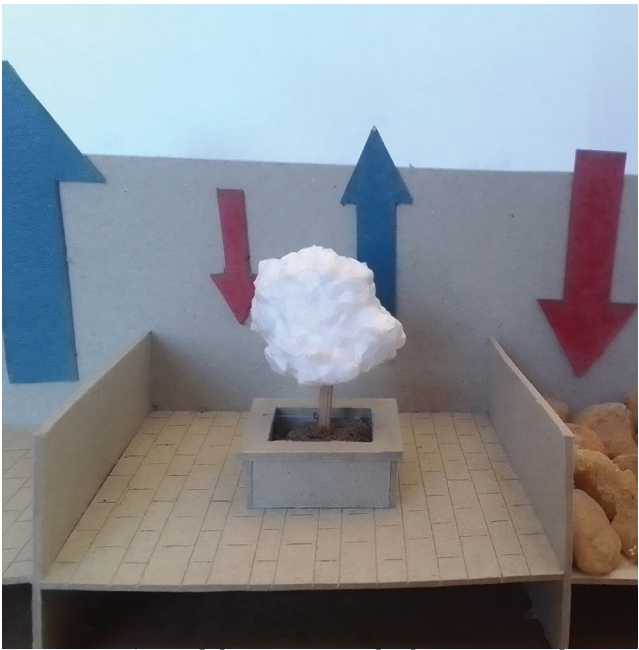


Figure 82: A model comparing the heat gain and evaporation rates of planters

The addition of planters to pavers does however, make a large difference. Not only is there an increase in moisture due to the transpiration based cooling effect, but an increase in moisture stored within the soil of the planter. The shade of the leaves reduces the heat retention even more, while the additional soil and root system take in more water than with just pavers. The propagation of species however still remains an issue, which is why a surface treatment is needed, which allows for a hardened surface, is still permeable and allows for the natural growth and distribution of a given species.



Figure 83: A model comparing the heat gain and evaporation rates of an integrated system used at the FPT University

This is where the precedent of the FPT University was such a great help. They used a metal grid structure as a surface treatment, which allowed for comfortable human usage, while a sloped substructure created a water capturing and diversion system. The gaps and perforations within the metal structure allow for the free growth of the vegetation around it, and allow nearly none of the water to run-off. The permitted growth of trees and other plant species will further add to the effect mentioned previously.

From the previous sections it is extremely clear that a porous and penetrable material is required to properly facilitate natural growth. It also needs to be strong enough for general usage, without requiring toxic manufacturing processes, or leaving behind major carbon based emissions. Similarly, the walls would require a material which is capable of breathing, allowing minerals to pass through, while still supporting themselves. The next page will address the 3 major materials used throughout the site.

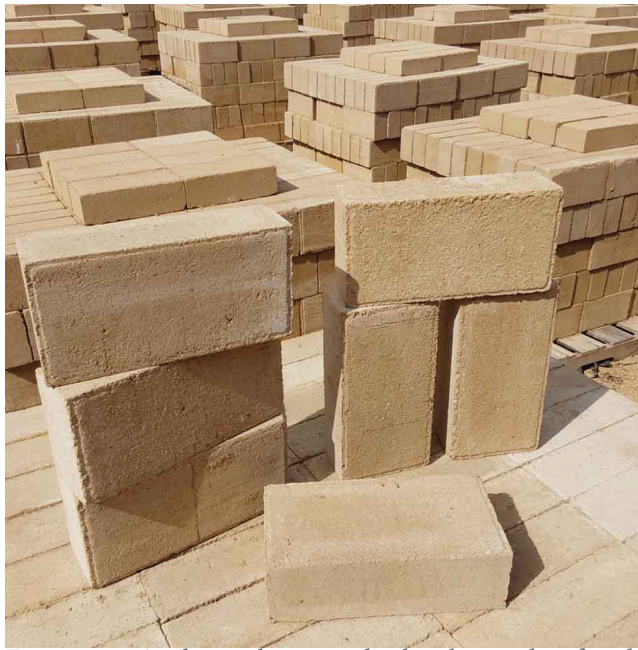


Figure 84: A photo showing the bricks made of soil, used to build as though they are concrete bricks (EarthBlock, 2022)

To deal with slabs, as well as the underground water run-off, and distribution, the first material is that of compressed earth. Soil is used in combination with some water, and a small amount of cement to harden the surfaces, and prevent dust from entering into the spaces. The typical ratio of cement to sand in concrete is around 1:6, by doubling this, one can already achieve massive climatic benefits. At 1:18 respectively, the slabs are hardened, but not made entirely out of concrete. This allows the material to tip the scale towards taking in carbon rather than releasing it throughout its lifespan.



Figure 85: A photo showing the aesthetic qualities of a rammed earth wall (Rammed Earth Constructions, 2023)

Using a similar ratio, earth blocks can be created, which can be used instead of bricks. Due to the lower ratio, these are lightweight, but still hard enough to endure the forces from above. This material can be made on site, which would reduce the transportation costs even more. The earth blocks are easy to install, and have incredible insulating properties, along with being waterproof and low on embodied carbon. Throughout its lifespan it will further take in more carbon, while supporting the surrounding natural growth by not releasing any toxins into the surrounding soil.

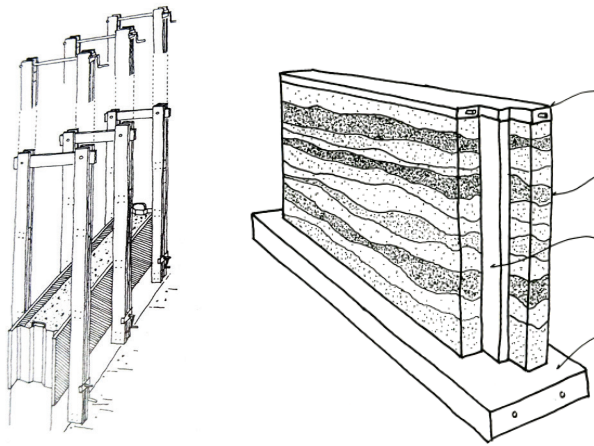


Figure 86: Diagrams depicting the construction of rammed earth walls (Minke, 2012)

The third material used is rammed earth. The idea of using rammed earth comes from the lack of topsoil often found at a site. Section 6 will deal with the site, its introduction and selection. It is however important that the rammed earth wall(s) not only introduce an aesthetic feature, but further support the natural growth. Rain water washes down the wall, and seeps into the surrounding soils, taking the minerals present in the various soils with it. This will provide a strong kickstart to the site, to allow it to become self-sustainable over time. Rammed earth also allows for thermal insulation, along with being root system friendly. Roots are able to grow into the wall, without destroying it, and can even grow through it, and further stabilise the wall itself. All of these reasons make rammed earth a fantastic choice in material.

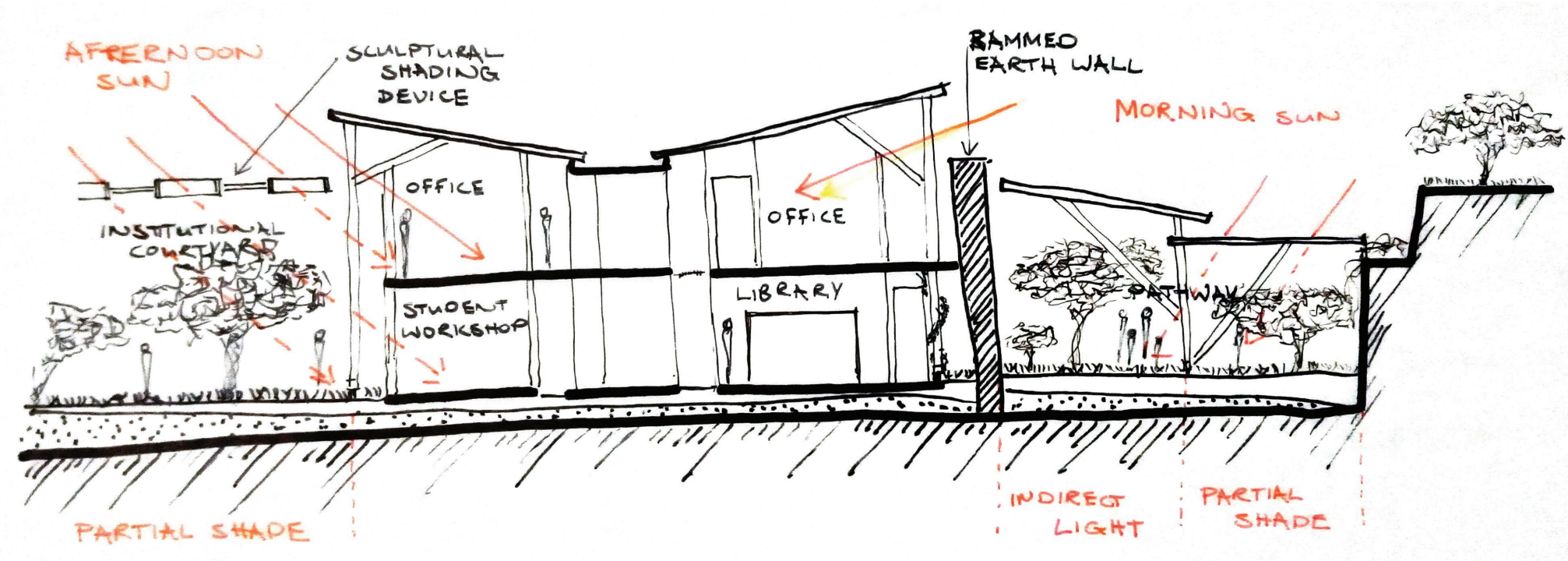


Figure 87: Diagrammatic sketch showing the effects of the morning and afternoon sun respectively

This subsection deals with the combination of architectural systems and natural ones. The previous subsections discussed various ideas around spatial experiences, natural growth stimulants and the effects of various changes to these systems. The first diagram explores the effects of sunlight, both in the morning and in the afternoon of the proposed building. In the morning, the pathway leading to the botanical gardens receives a bunch of light, along with the one wing of offices. This also provides strong indirect light to the library, and its exposed study niches. The afternoon sun on the other hand provides indirect light to the institutional courtyard and the student workshops, while the pathway gets shielded by the building and the rammed earth wall from the harsh direct sunlight, creating a cooler passageway. This means that each space used for vegetation has access to sunlight, but is also protected from overheating.



5.4 System Integration

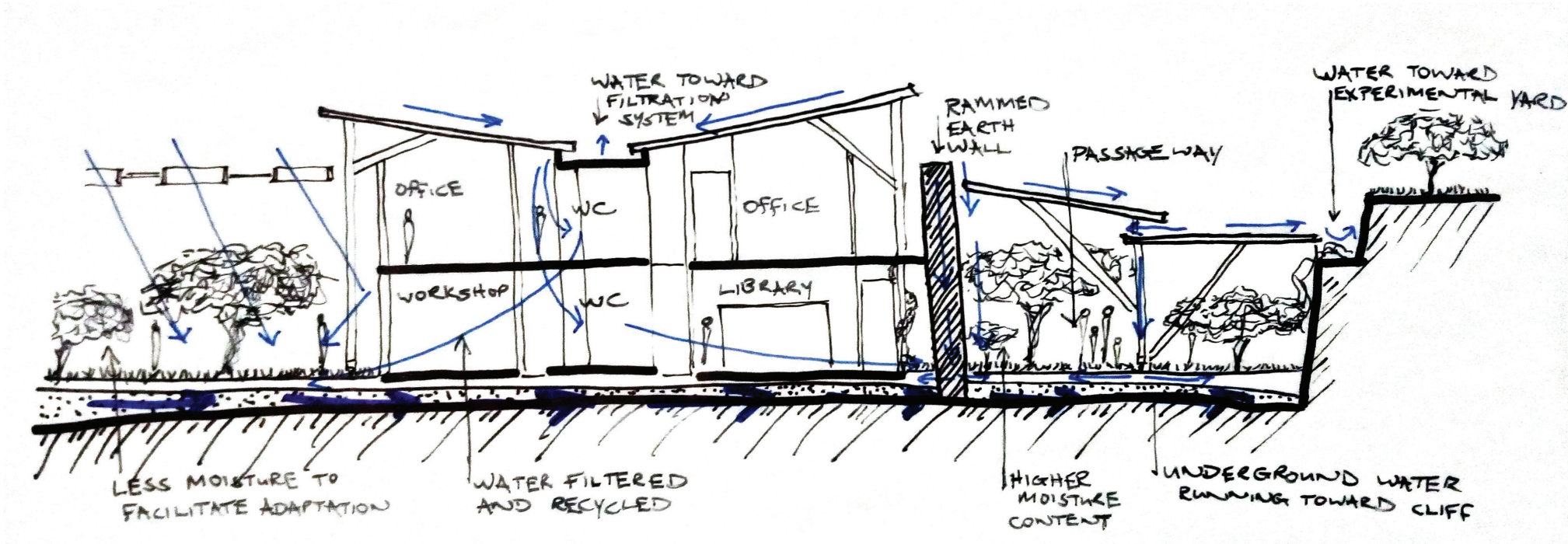


Figure 88: Diagrammatic sketch showing the water collection, redirections and collection points, along with groundwater seeping into the ground

The second diagram deals with the distribution of water. The building itself collects water, sends it to a filtration system through the bathrooms, and further to the institutional courtyard. The roof above the passageway is split in half. The one side collects water and redistributes it into the soil via the columns, while the other end collects and sends it to the experimental courtyard. The rammed earth wall is exposed, and can therefore wash the minerals downward, while the slope underneath the ground keeps the water moving. This not only aids the sharing of minerals, but further prevents standing water, and therefore prevents diseases, mould and mud from developing and forming respectively. The slow movement of the water underground though helps keep the water longer in the soil than usual, further supporting the natural growth.



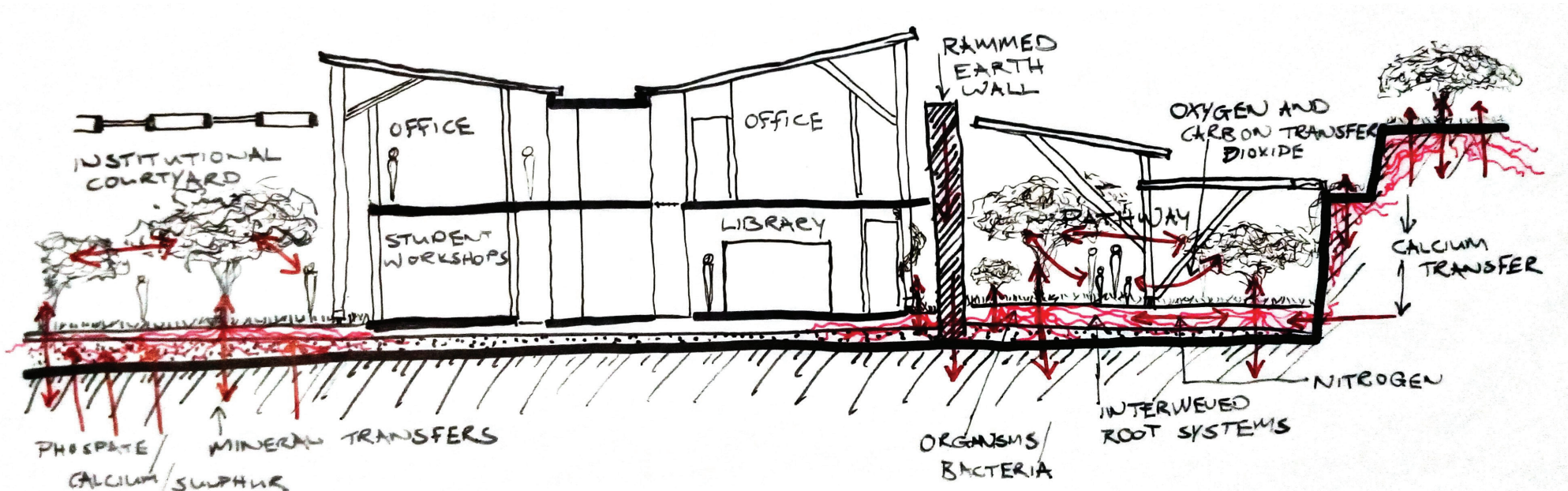


Figure 89: Diagrammatic sketch showing the various mineral transfers within the site

This third diagram depicts the various mineral transfers occurring on site. The most important one is the transfer of carbon dioxide and oxygen, from people and plants respectively for the benefits of the other. A vast majority of the other transfers occur underneath the earth surface. Calcium, phosphates and sulphates are supplied by the rocks and bedrock present on site, with the cliff being a strong supplier. Nitrates, carbon and other minerals are transferred and shared via the interweaved root systems, which most commonly spread out, rather than dig deep. The infill soil situated on top of the sloped compressed earth houses most of these processes, and gives room for the biological components, such as the decomposition of carbon based materials, along with living organisms ranging from worms to bacteria. These are allowed to prosper due to the presence of moisture and minerals supplied from the rammed earth wall. All of these combined allow the natural growth to flourish, and form a micro-sized and healthy ecosystem within the site.

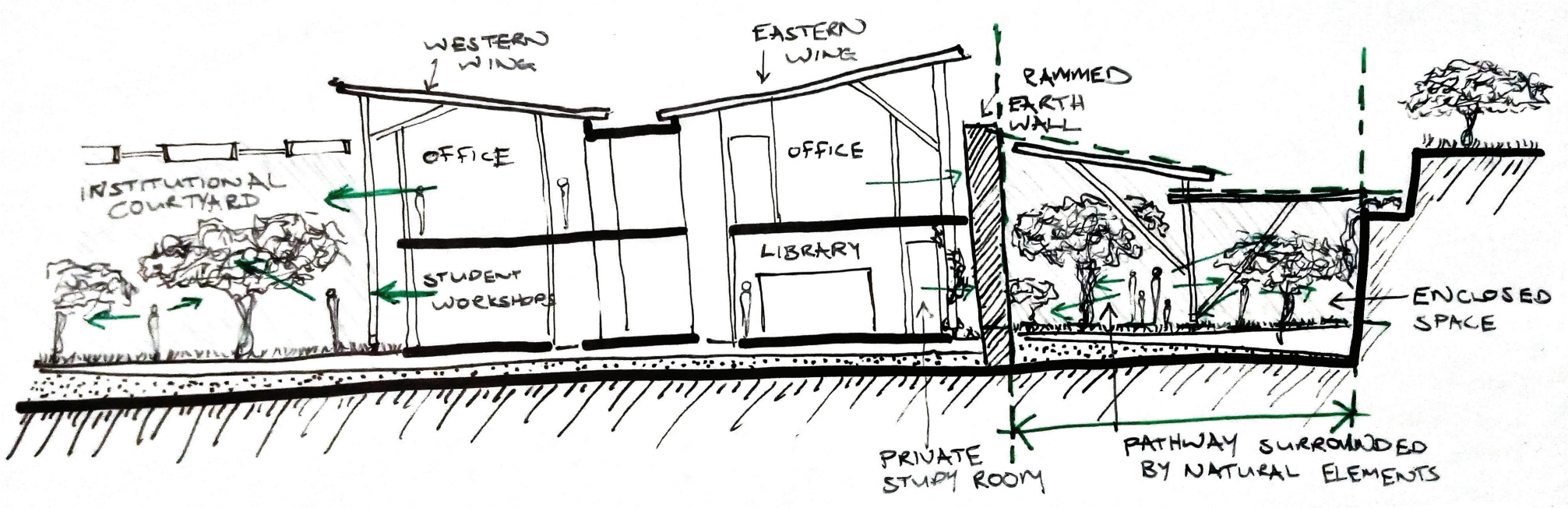


Figure 90: Diagrammatic sketch showing the various visual and physical links between users and the natural sphere

The last diagram depicts the experience aspect of the natural sphere. This leans closer to the ecosystem domestication aspect discussed previously, but remains one of the most important ecosystem services. The benefit of spending time in nature, and having visual access to nature is not only important, but was strengthened by the systems working together to achieve a functional architectural space within a healthy natural sphere. The western wing of the building has visual links to the institutional courtyard, while the pathway toward the gardens, lies along several display areas, planters and is sandwiched between a rock cliff and a rammed earth wall. This multiplies the idea of sitting within the soil, further drawing attention to the importance to it. The eastern wing is next to the rammed earth wall, and the first floor offices have adjacent balconies overlooking the plants below. The library opens up toward the rammed earth wall, and has a two metre gap, in which smaller courtyards are situated. These courtyards are defined by the private study rooms, and the exterior seating, allowing readers and students to have links to the vegetation present.

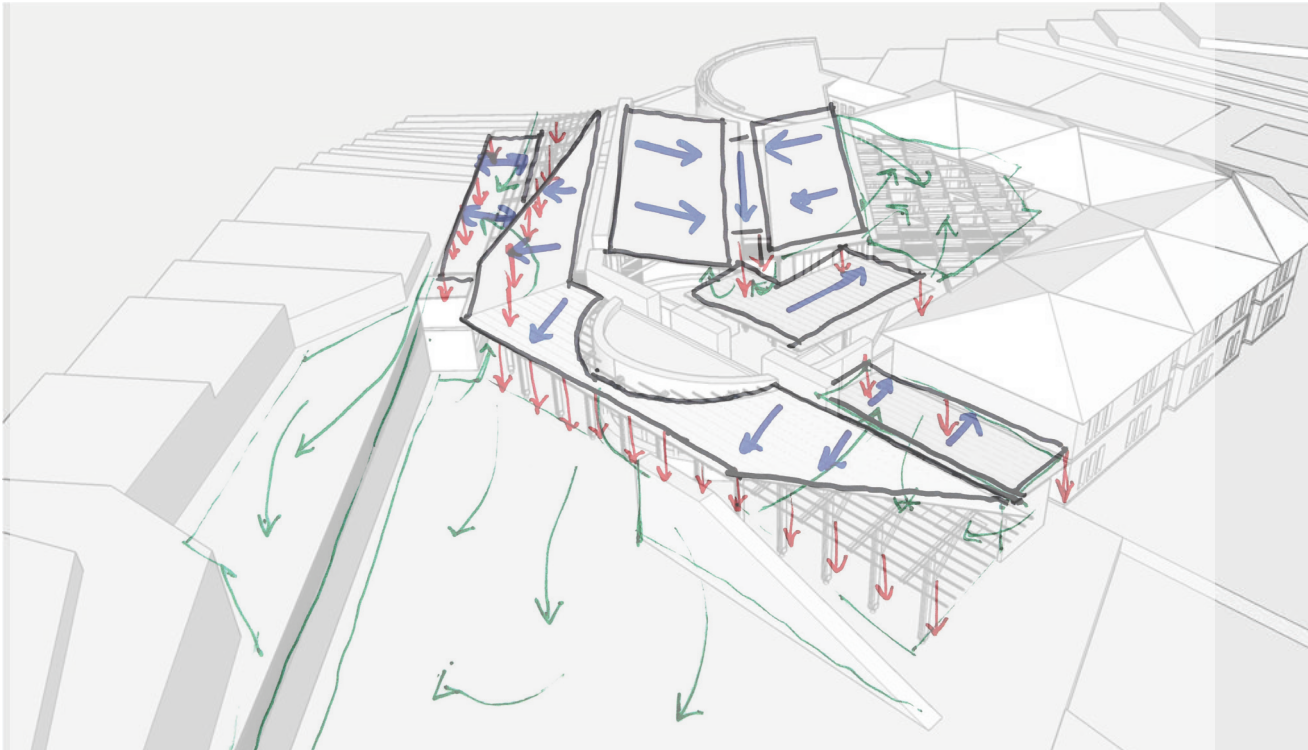


Figure 91: An illustration of the rain water drainage (blue) leading down into the ground (red) and being redistributed into the surrounding greenspaces (green), within the proposed intervention.

As mentioned above, the rainwater is caught and filtered to be used by the toilets, and further filtered and processed to be used within the institutional courtyard. During the dry seasons, the greywater is still being recycled by these filters. Simple filters remove the toxic chemicals, toxins and material, excreted by human bodies, and release the leftovers into a water pump, which brings the water and the minerals to the institutional courtyard, between the old and the new buildings. This courtyard will then always have a strong and good water source, allowing for the healthy growth of species, along with testing, experimenting and adapting others. The filtered out materials can then be further processed as fertilisers and used elsewhere on the site. This not only saves costs on artificial fertilisers, but reduces the water consumption, and therefore lower the overall negative impact on the environment. These mechanical systems are a compromise for the benefit of both, bringing back the idea that mutualism proposes in the first place.



Figure 92: A map of the NBRI and the entire Botanical Gardens (Google Earth, 2022)

The National Botanical Research Institute is based in Windhoek near the CBD, and is commonly referred to as the botanical gardens. The following section will explore the site itself, their function and purpose, a site analysis along with a post occupancy evaluation. This will give us a strong basis from which to design from.

The subsection on functions will help us understand who they are, and what they are involved in, and what they need in terms of spatial resolution, which will further be supported by the discussions held with staff. Photos and site analysis will give us a better understanding of the existing services, spaces, and a better feel for the *genius loci*.

A large reason for choosing the NBRI is their direct involvement and care with and for nature. The botanical gardens create the perfect canvas for proving the mutualistic approach to designing. As we will discover, the sites chosen within the gardens allow for both the rehabilitation of a specific natural site, which has been destroyed, as well as the preservation of the natural qualities present at the secondary site.

The NBRI is the leading research institute in Namibia when it comes to all things plants related. The specific departments and fields of research depend entirely on the staff. The institute will always have three major functions. The first of which is housing the Botanical Gardens of Namibia, which is open, during office hours, to the public and tourists to join for a visit. The secondary function is that of academics, which currently includes the researchers in the fields of forestry, endangered species, succulents, invasive species, and genealogy among others. The academic portion also includes the outreach to schools, followed by guided tours, collaboration with local students and global scholars. The third portion of the NBRI is the storing and safekeeping of the Namibian biodiversity in the form of a gene bank, a seed storage, a herbarium and the botanical gardens themselves, which further acts as a living library of the species.

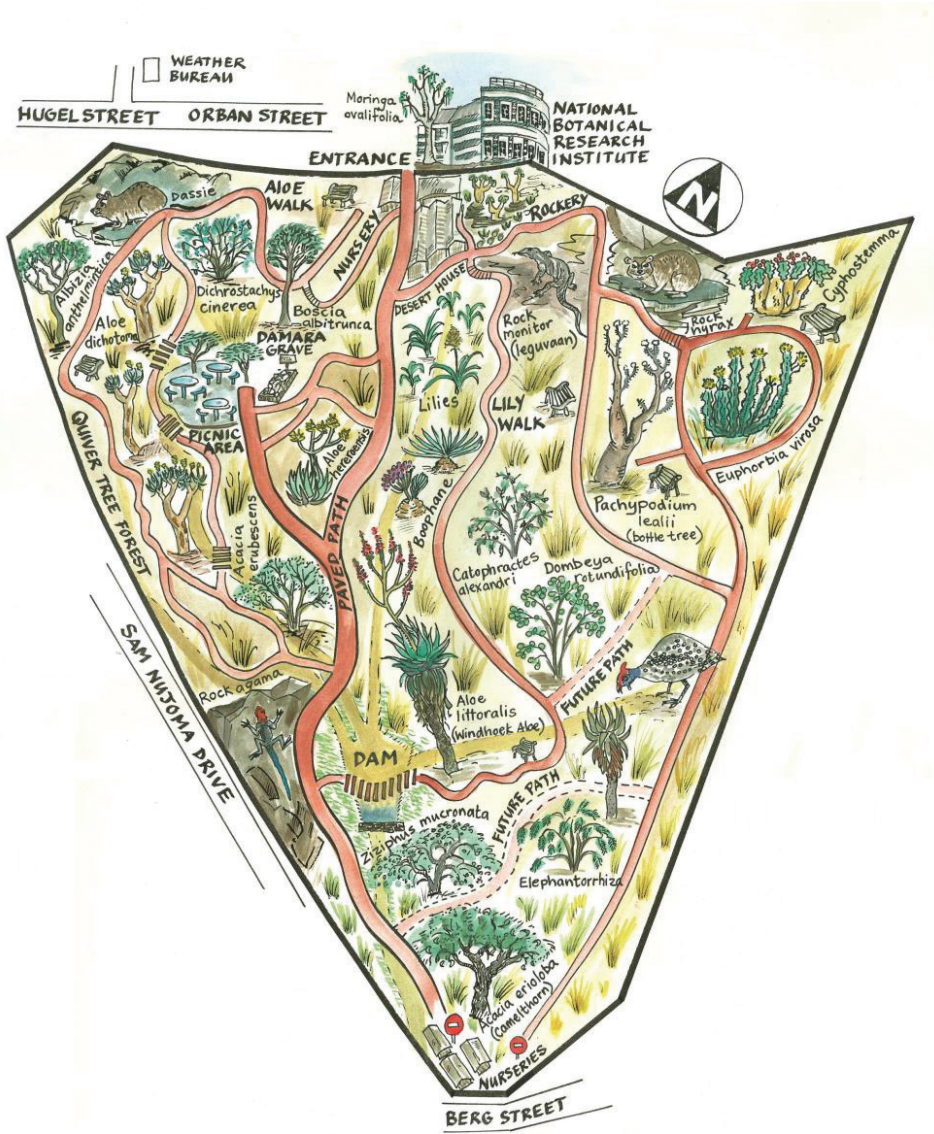


Figure 93: A sketch map of the NBRI and the entire Botanical Gardens handed out to tourists visiting the institute (NBRI, 2023)

6.2 NBRI Functions



Figure 94: A poster of one the invasive species, as part of a campaign started by the NBRI to rid the environment of alien vegetation

6.3 Discussions with the Staff

To better understand the needs of the NBRI and its staff, as well as learning more about their day to day processes, three informal discussions were held. The first of which was with Sonja Loots, who is an expert on endangered and invasive species, currently leading the fight against invasive cacti populations. During the discussion it was revealed that a large responsibility of the NBRI is to intervene at national border crossings to confiscate endangered species from people trying to smuggle them across the border. A further research facility, with a focus on adaptability is needed to ensure that these species do not become extinct. Currently, due to the lack of such facilities, these confiscated species are disposed of despite their status as an endangered plant. A further issue that arose was the lack of storage of the gene bank due to having to share their offices with other departments.

The secondary discussion was held with Quanita Daniels, who is the department head of the Botanical Gardens. She revealed the serious lack of wheelchair accessibility to the gardens, the urgent need for public restrooms and a further need for public facilities, such as the introduction of a kiosk or restaurant to the site. This will also keep an influx of people in the garden, while also keeping them in there for longer periods of time. At the moment, the Botanical Society (BotSoc) is the most active within the gardens. They organise guided tours every month, a night walk almost every second Saturday, and night runs under fairy lights on a regular basis. They further used to organise botanical fun days, which provide an open market type affair. Outside of that, the gardens get used mainly by joggers in the morning looking for a safe space to exercise in, as well as tourists looking for a quiet day or a picnic at the Botanical Gardens.

The third and final discussion was held with several staff members from various departments. The discussion revealed the need for seed multiplication spaces, where species can be multiplied once they have been acclimated to the Windhoek atmosphere, and then planted into the gardens. Outside of re-affirming the needs mentioned in the first two discussions, only two other spatial requirements came to light. The first of which is the fact that local students do not have a space to work, research and experiment on their thesis' and research papers. A collaboration space is desperately needed, for students as well as global scholars and researchers. The second requirement is the direct link to the natural sphere, as the current offices have smaller windows, and the fact that the majority of the researchers in question spend most of their time in the field, and not behind an office desk.



Figure 95: The institutional nurseries near the unused back entrance



Figure 97: The courtyard explored in a previous section



Figure 99: The interior of the desert house



Figure 101: A dam wall at the bottom of the valley to keep water in as long as possible



Figure 103: One of the water holes provided for bird watching purposes



Figure 105: One of the bridges built by a local youth group over 30 years ago



Figure 96: The gene bank and its offices



Figure 98: The picnic area within the Botanical Gardens



Figure 100: The intended main entrance of the Botanical Gardens



Figure 102: The entire garden is extremely well signed, including directional markers, maps, plant descriptions and signs dedicated to the employee responsible for that section



Figure 104: One of the two weather stations within the garden



Figure 106: A connection detail of one of the bridges



Figure 107: One of the many views from a park bench along the main route



Figure 109: A view over the western side of the gardens



Figure 111: Another view toward the west of the gardens, from the opposite hill of the garden



Figure 113: The Windhoek CBD as seen from the viewpoint on the northwestern edge of the site



Figure 115: The recently excavated site, known as the hole as seen from the northernmost edge



Figure 117: A photo showing just how steep the cuts are into the site



Figure 108: A view in a more private area of the gardens



Figure 110: A resting area toward the lower end of the site



Figure 112: The view beyond the eastern edge of the garden



Figure 114: The boys hostel of WHS as seen from the same viewpoint as in figure 113



Figure 116: The hole as seen from the herbarium



Figure 118: The hole as seen from inside the cafeteria



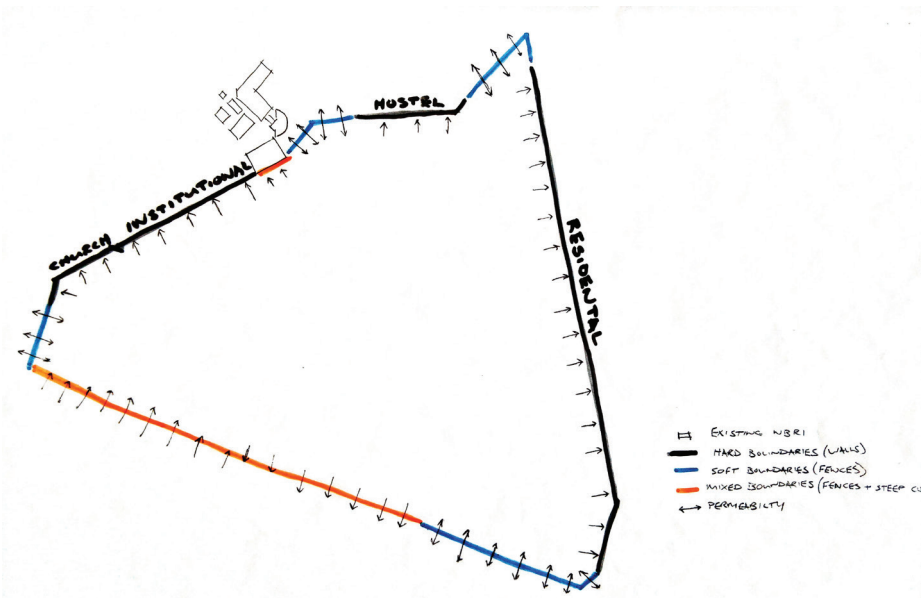


Figure 119: The botanical garden and its relationships with surrounding spaces

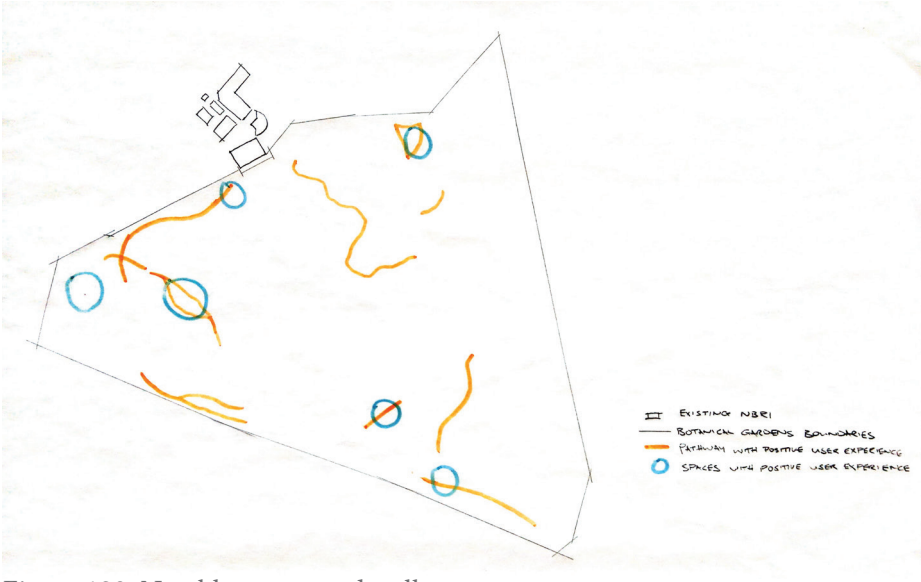


Figure 120: Notable spaces and walkways

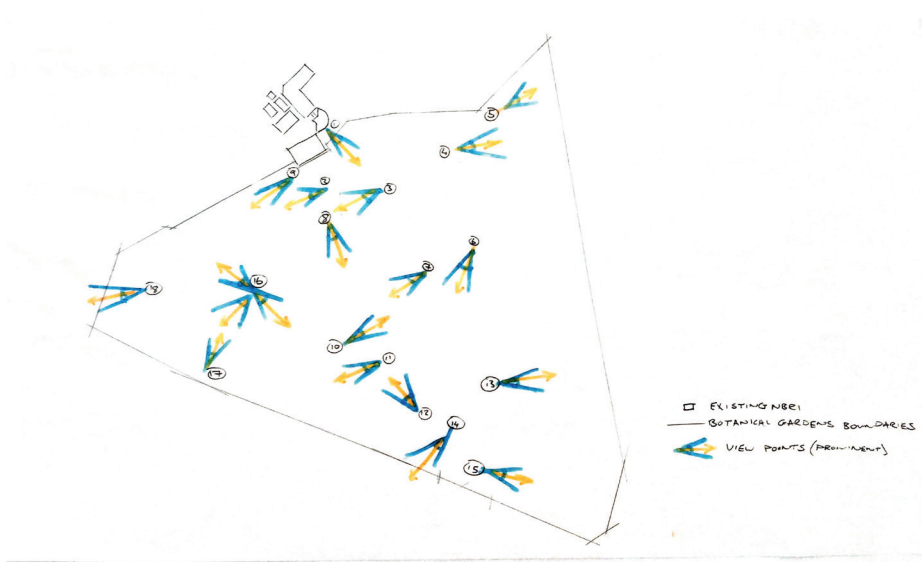


Figure 121: Existing viewpoints



Figure 122: Existing benches, trash cans and water points

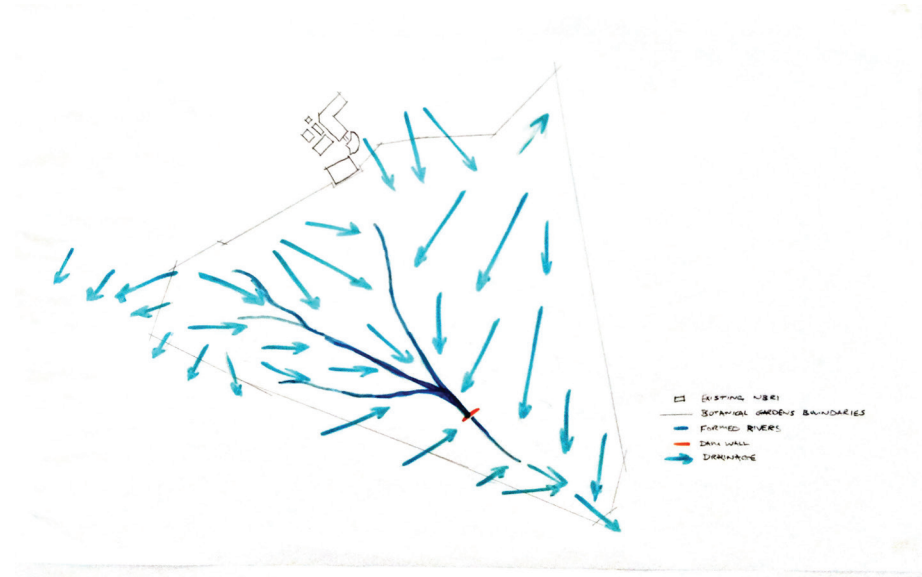


Figure 123: The natural slopes and subsequent drainage of the site

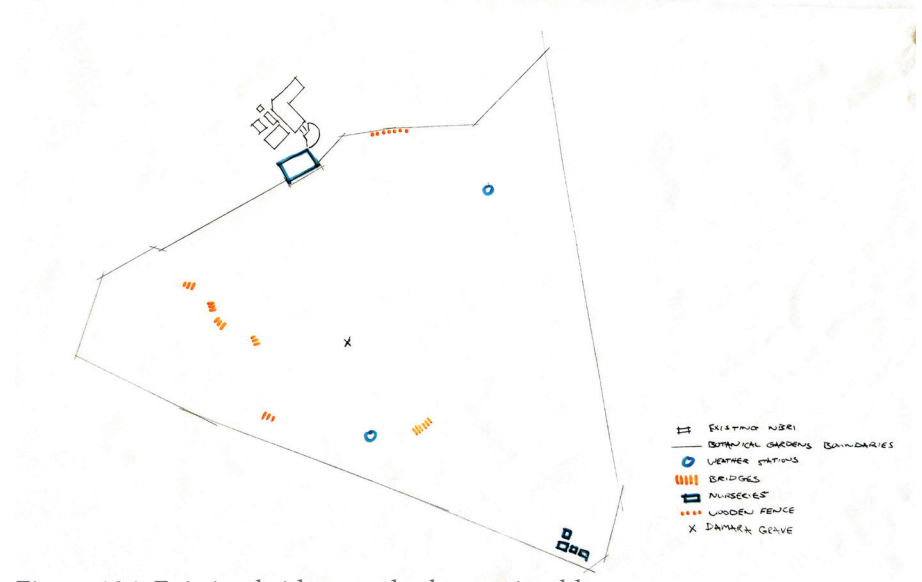


Figure 124: Existing bridges, and other noticeable spots

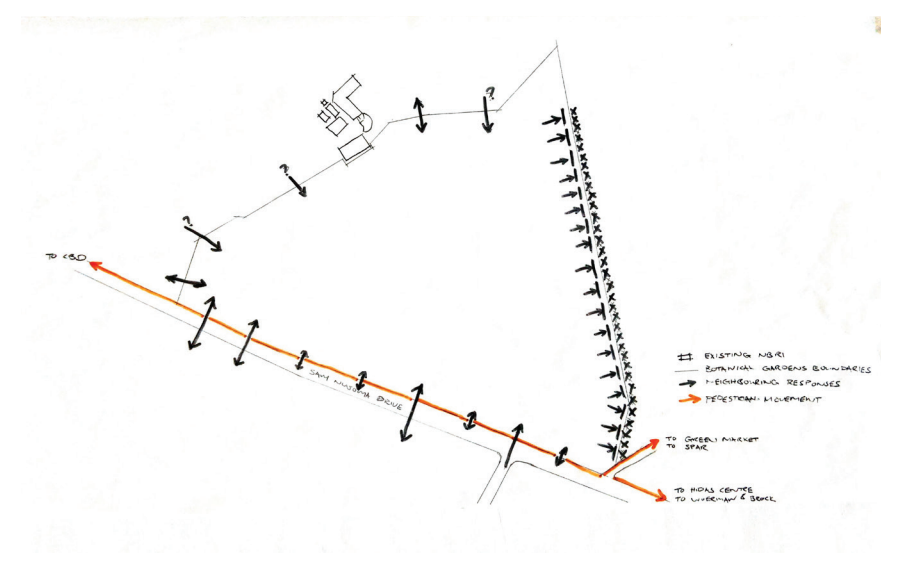


Figure 125: The existing fencing and the subsequent boundaries created



Figure 126: Existing pathways

6.5 Site Analysis

Site 1 is the site directly next to the existing NBRI, which has been recently excavated to start another project. Due to complications the site has been left untouched since the cutting process. The site is now just left empty, allowed to collect rainwater, which ends up standing around for weeks on end. This site gives us the opportunity to intervene and potentially re-vitalise the disrupted site completely. The proposed project was the following:
Project Title: Offices for the National Botanical Research Institute
Architect: Nina Maritz Architect
Location: Windhoek, Namibia
Project Year: On hold
Reason: Uncertainty of ownership, combined with a lack of funding
Appropriateness: Context specific appropriate
Short Description: The new extension to the offices of the NBRI was meant to include new offices, student facilities, a specimen warehouse and an upgraded gene vault (Maritz, 2018). Further, the building offers offices to the SASSCAL project, which currently operates from several offices spread throughout Windhoek. The building is planned to use passive design principles to obtain sustainability.



Figure 127: Cross Section (Maritz, 2018)



Figure 128: Contour Map of site 1 (Google Earth)



Figure 129: View toward the CBD from site 2

Site 2 is the viewpoint on top of the northwestern most hill. The views over the entire garden, as well as views over the CBD allow for a great public intervention. The site itself is mostly flat, easily accessible from the main building, and gives the opportunity to create spaces for seed multiplication due to its access to sunlight.

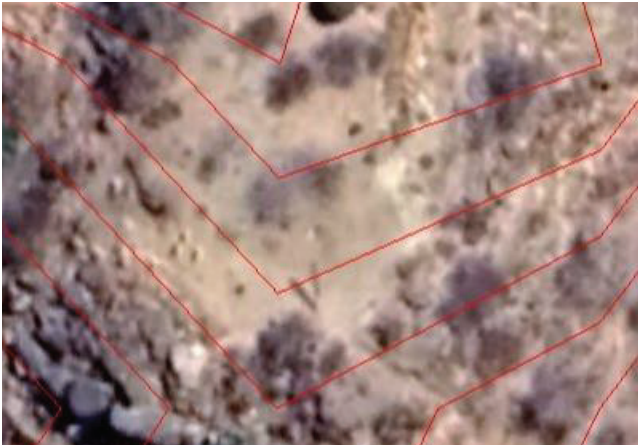


Figure 130: Contour map of site 2 (Google Earth)

6.6 Site Selection

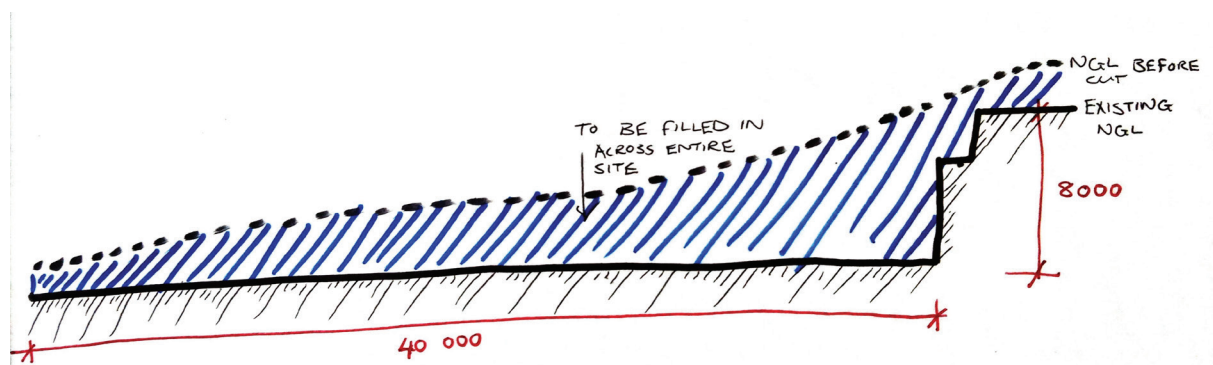


Figure 131: A sketch diagram showing the amount of soil needed to refill the entire site, which will be displaced elsewhere

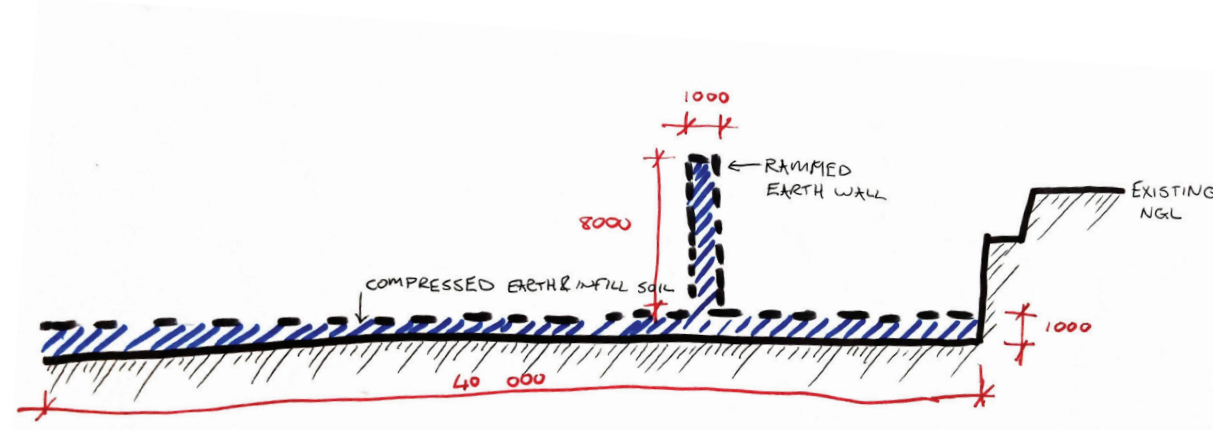


Figure 132: A sketch diagram showing the amount of soil used instead, in comparison to figure 131

Due to their direct involvement within the ecosystem, and their care for nature, the NBRI makes for the best client. The institute itself lends several design opportunities, and spatial requirements near the Windhoek CBD. Site 1, located directly next to the existing offices, will act as the primary site of intervention. Several other sites will also be identified to propose future intervention, while site 2 will serve as a conceptual language for these smaller pavilions and interventions. The problem with site 1 though, is the complete lack of any topsoil whatsoever, and the fact that the site has already been excavated. In the ideal world of designing something that is integrated into the ecosystem, the solution would be to fill up the entire site, and start from scratch. Reality however is, that the site, like many others has been excavated, will remain in that condition for the foreseeable future. As discussed in section 5, the site will be filled with up to 1 m worth of compressed soil and earth, for the support of natural growth. The intervention will further include a 1 m thick rammed earth wall for its mutual benefits as discussed previously. All of this soil will be sourced from around Windhoek, as the soil from the site has already been removed, and utilised elsewhere. To minimise the damage to the environment of the scraping sites, as seen in figure 10, it is better to remove less soil and confining the site to the dugout space, than to attempt to re-fill the entire site. For this reason, the following section will use the predefined hole as a design constraint. This is further supported by the issues raised around carbon-offsetting in a previous section.

6.7 Conclusion



7. Developing Design

(71)

This subsection will focus on using the knowledge gained from the previous sections, combined with the need for spatial resolution to create a new proposal for the research and public facilities at the NBRI.



(72)



Figure 133: Touchstone showing the rippling effect

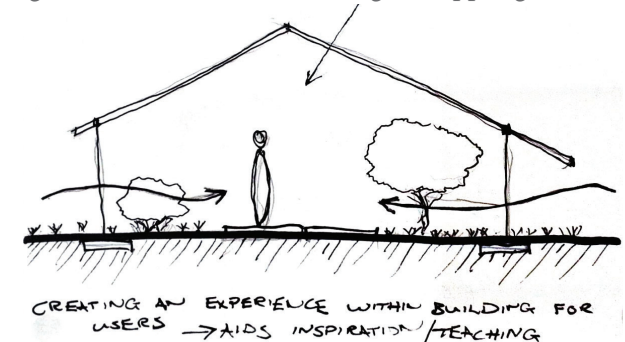


Figure 134: Diagram representing natural education

The site is one that requires intervention over a larger area to pull people throughout the entire site. Smaller intervention could therefore be implemented connected via a common thread, and an overarching theme, working toward a similar goal. The project itself then has the ability to educate and inspire, not just the staff and visitors, but also the designers of future infrastructure.

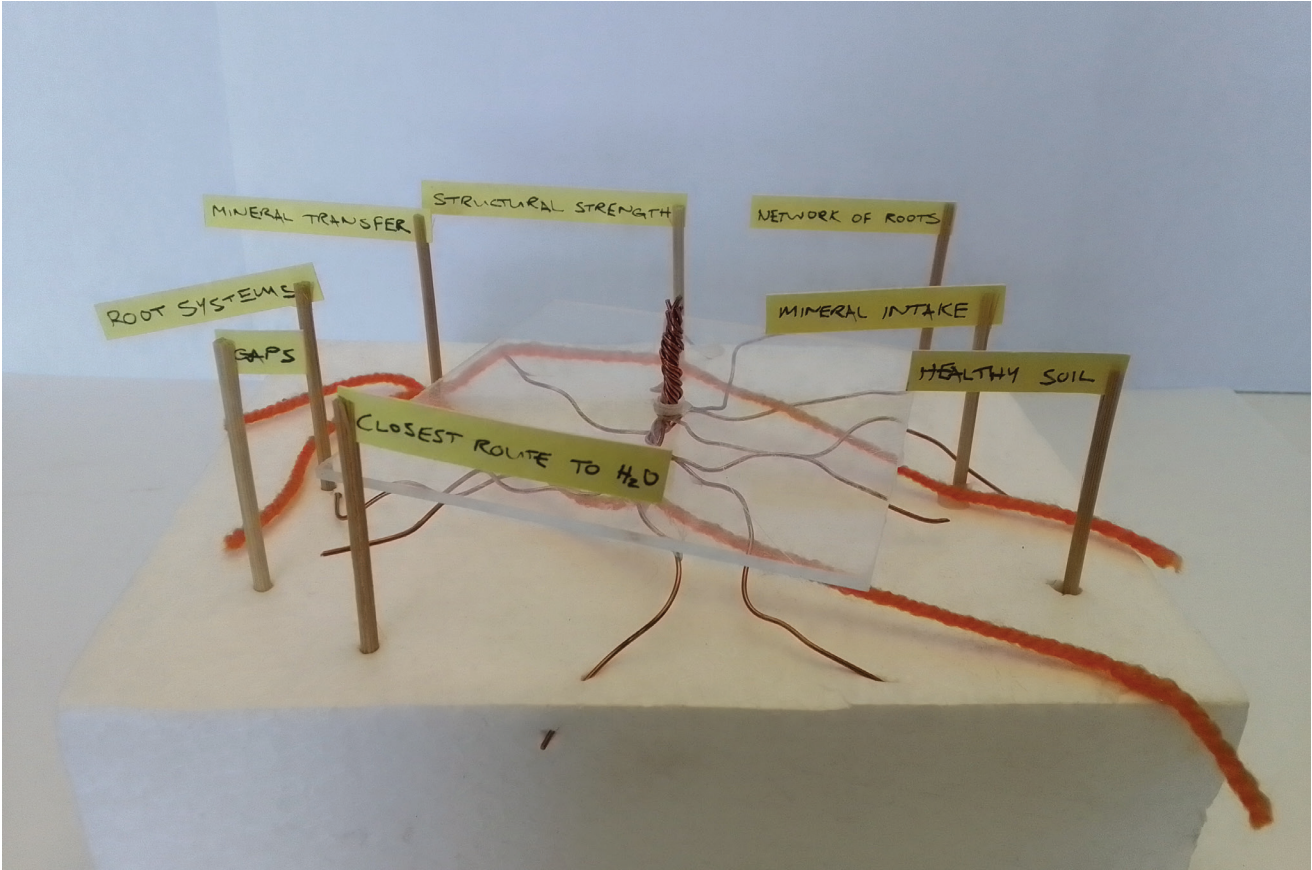


Figure 135: A model of the roots of a tree and the systems, and networks created from that

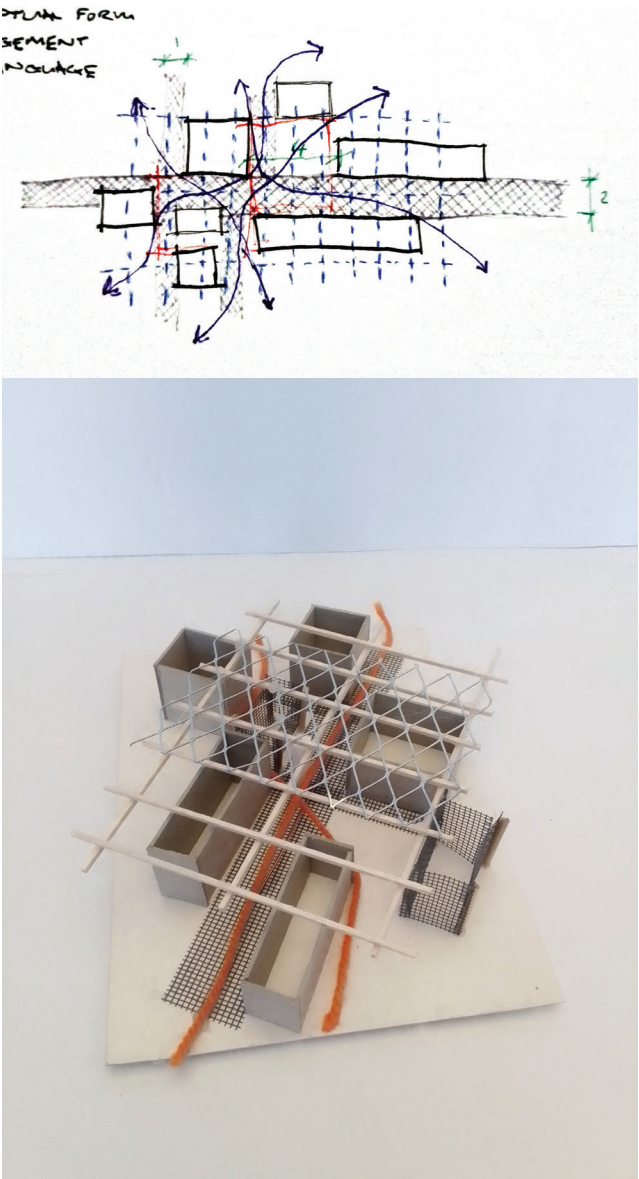


Figure 136: Model and plan of initial response to knowledge gained combined with touchstone

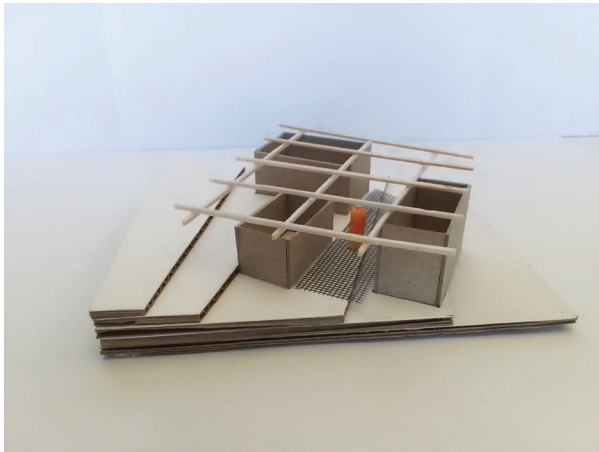
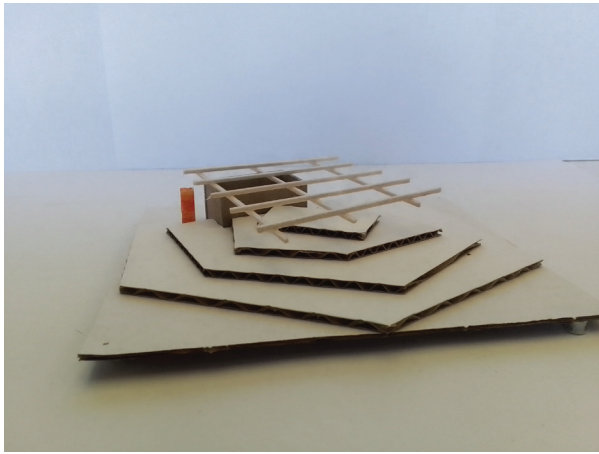


Figure 137: Conceptual models of different potential interventions and how they deal with site, using the same linguistic principles

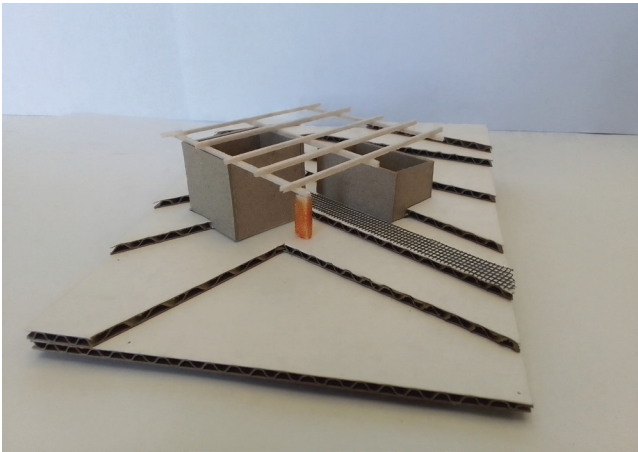
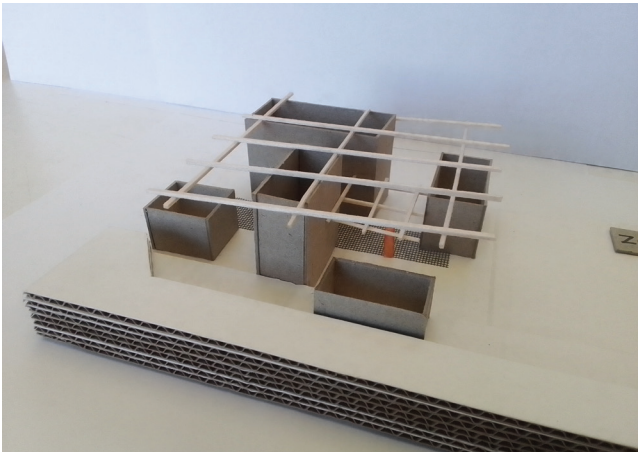


Figure 138: The NBRI has already set up specific areas for specific biomes from Namibia, which they have already started to implement. The sketch map above, details their current plans for the library of living plants

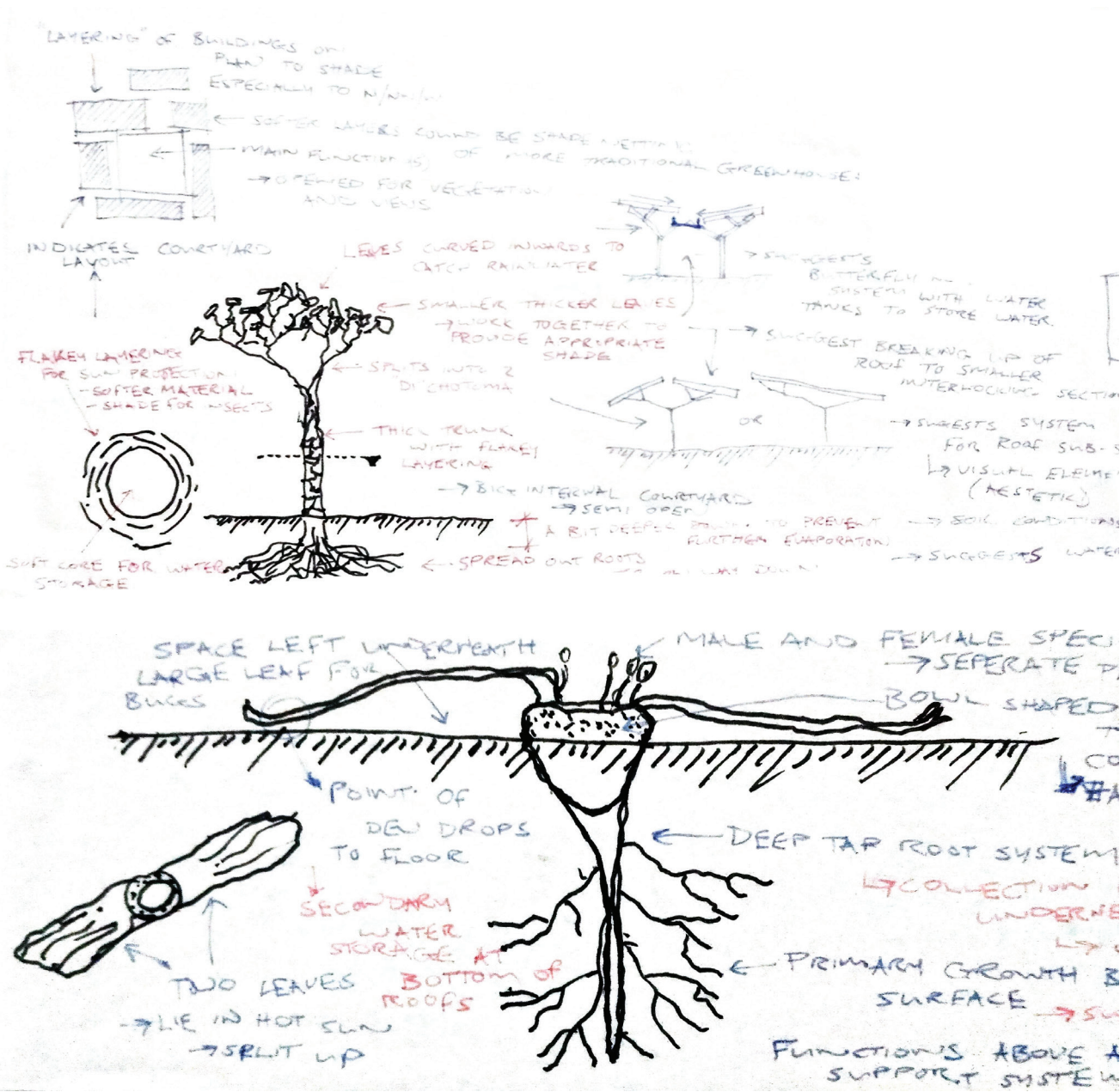


Figure 139-140: To the left are the design strategies of the quiver tree for site 2 and the welwitschia for site 1, based on the southern karoo and the kaokoveld biomes respectively. The use of welwitschia for the research centre emphasises the focus on endangered species. Figure 140 above is a photo taken in the Botanical Gardens of their quiver tree forest.

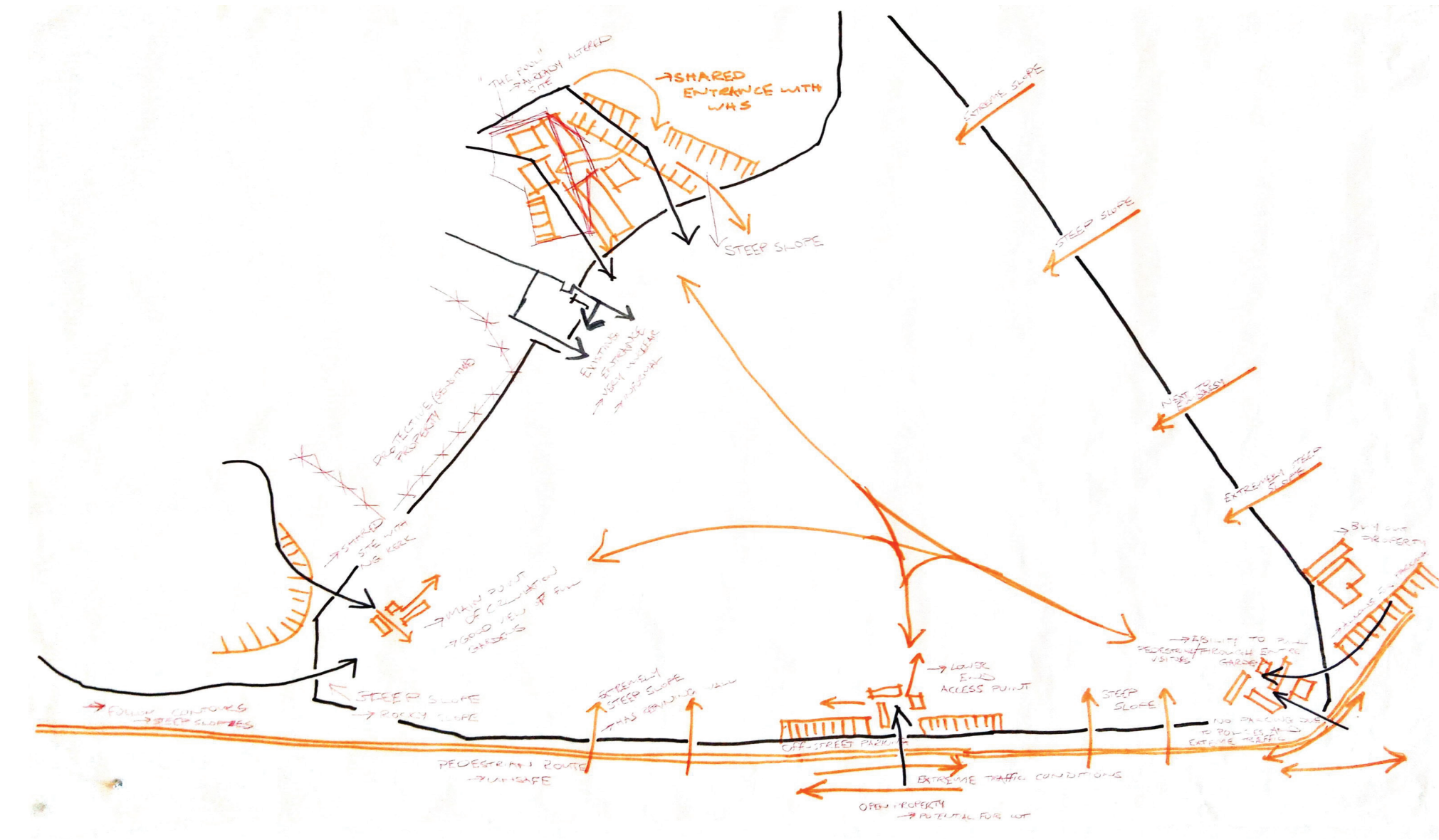


Figure 141: The initial placement and design concerns of a master plan

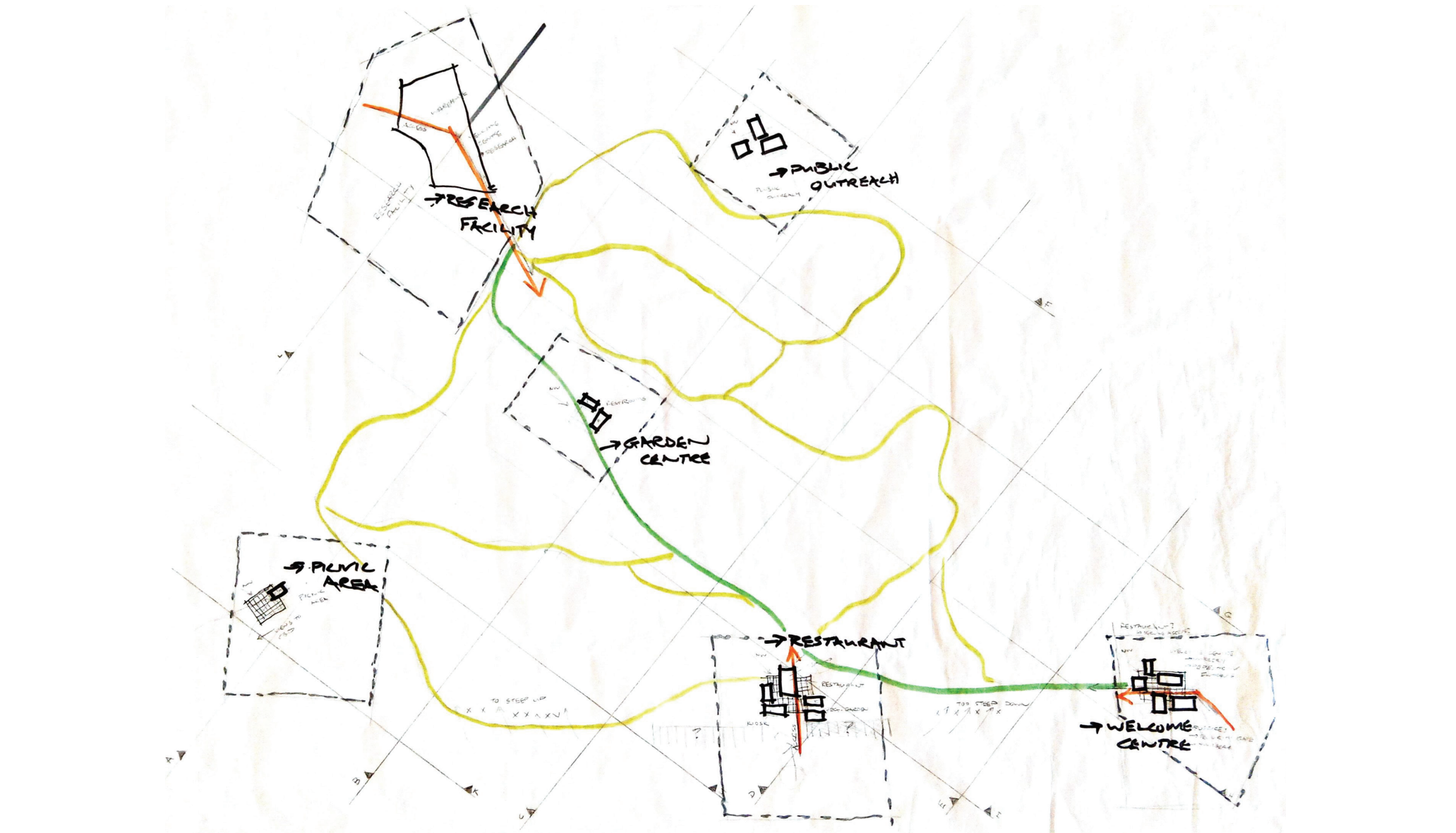


Figure 142: The final placement of the different interventions based on space, pull factor, and potential future growth. The garden centre, restaurant and welcome centre are planned as potential sites of phases 3 to 5, based on funding. The addition of the pavillion, will already be able to generate some form of funding, for the expansion

BUILDING 1 → RESEARCH CENTRE

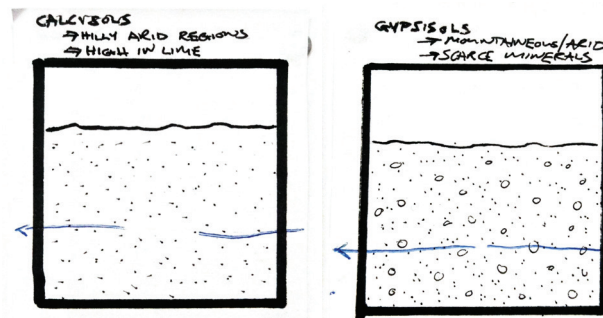
- STAR GAZING
- ROOFTOP OF HERBARIUM
- NEEDS WATERPROOFING
- SEATING
- ENDANGERED SPECIES
- AWARENESS
- DISPLAY CASES (ENCLOSED NURSERIES)
- PATHWAY
- WAREHOUSE (ADAPTATION)
- GREENHOUSES
- STORAGE
- NURSERIES
- NURSERIES (MULTIPLICATION)
- OFFICES @ 20
- LABS FOR BOTH
- DRYING OVEN
- DUCTS
- STUDY AREA (STUDENTS)
- COLLABORATIVE SPACES
- RECEPTION
- WAITING AREA
- PARKING
- EXISTING
- NEW BUILDING @ 20
- PUBLIC
- 10 SPOTS
- 2 BUS STOPS
- UCLs
- PUBLIC
- 5 FEMALE
- 5 MALE
- 2 DISABLED
- DUCTS
- STAFF
- 3 FEMALE
- 3 MALE
- 2 DISABLED
- DUCTS

Figure 143: A list of spaces in need of accommodation

KAOKOVELD

- SOIL CONDITIONS
- GYPSISOLS
- CALCISOLS
- PLANTS
- COMMIPHORA GIESSEII
- DAMARA CORK WOOD
- INARA
- WHIP-STICK ACACIA
- SLENDER-LEVED SHEPHERDS TREE
- BOTTLE-TREE
- KAKO TREE - EUPHORBIA
- VELWITZIA
- CLIMATE
- HOT AND DRY
- UNRELIABLE RAINFALLS
- MOUNTAINOUS

Figure 144: A simple breakdown of the kaokoveld biome



Figures 145 & 146: Diagrammatic explanations of the consistency and water levels of the predominant soils found in the kaokoveld



Figure 147: A bubble diagram arranging the various spaces along a major route into the gardens



Figure 148: The direct translation of the spaces from the bubble diagram to the functional building



Figure 149: The resolution of these spaces, their simplification, and the roof structures

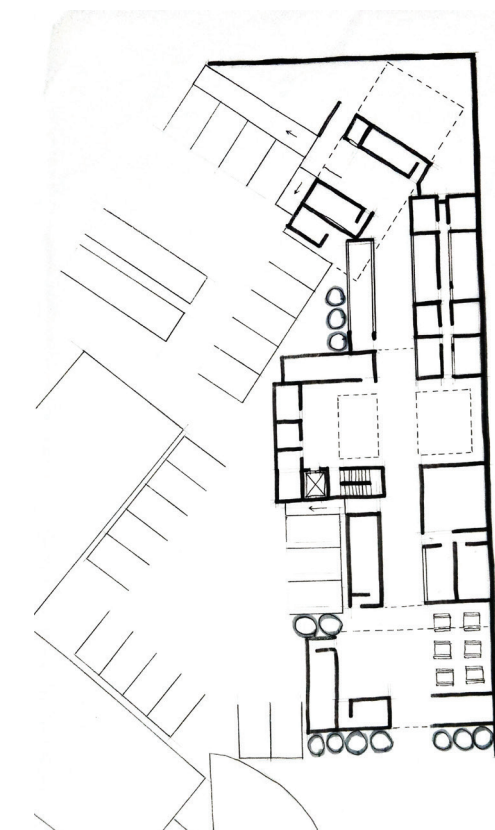


Figure 150: A final diagrammatic plan of the first iteration of the main building

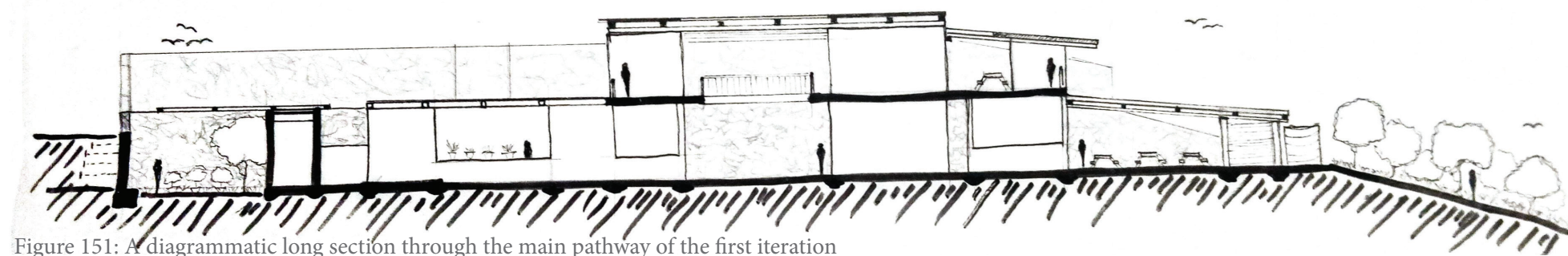


Figure 151: A diagrammatic long section through the main pathway of the first iteration

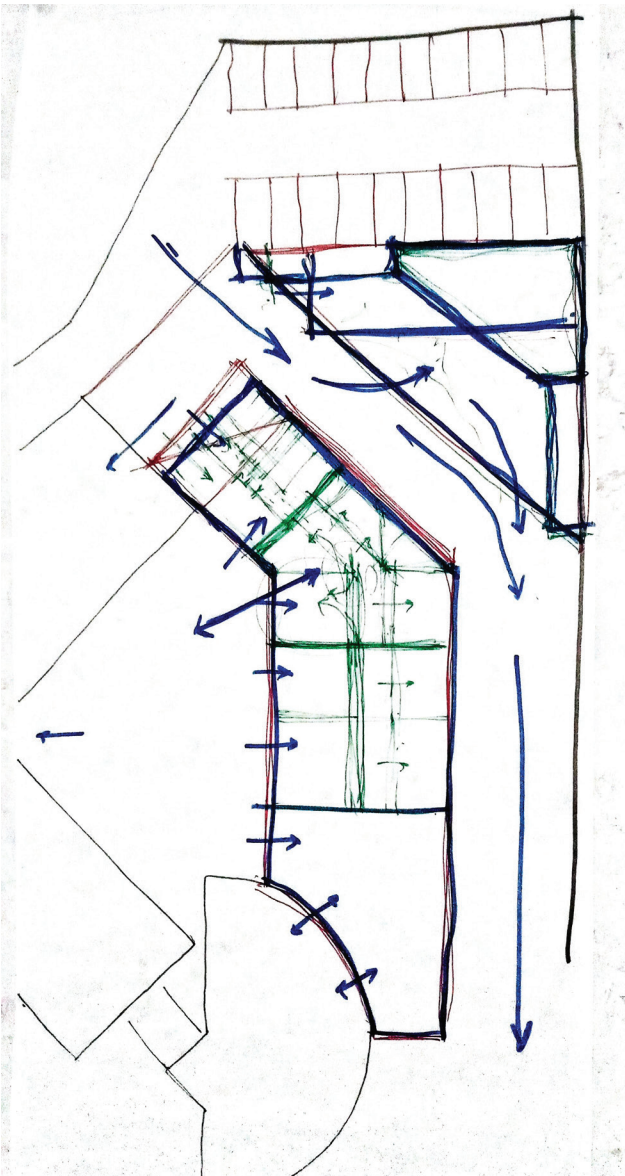


Figure 152: An initial sketch of the form of the second iteration of the building, created to establish a connection between the old and the new

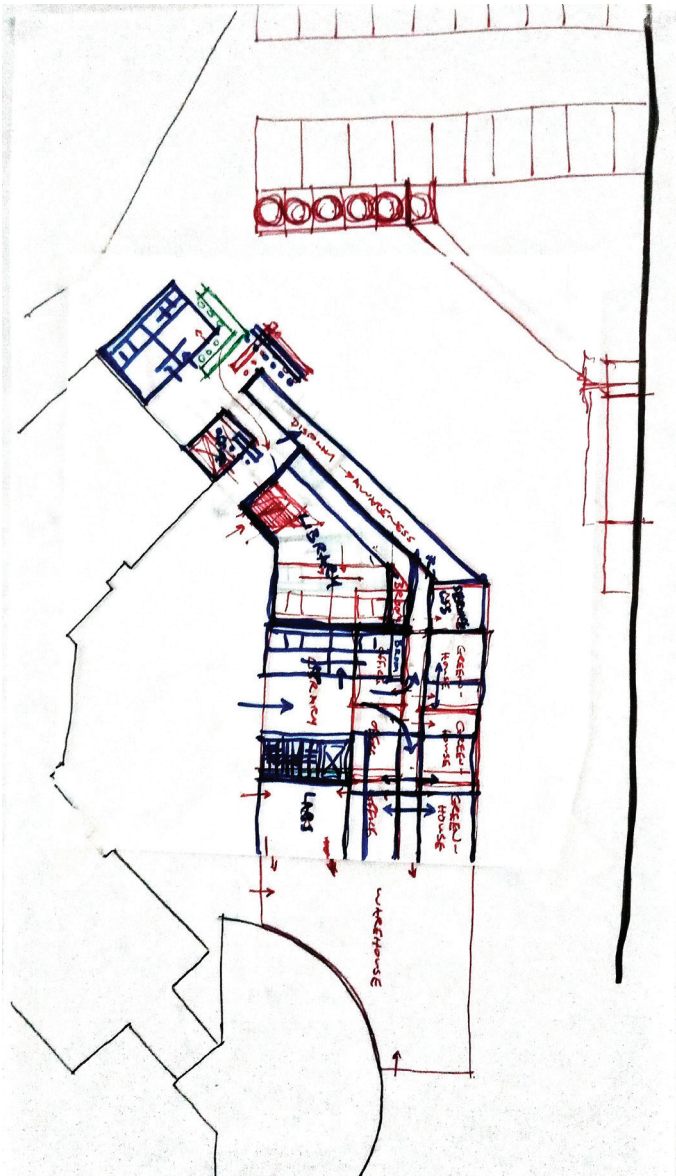


Figure 153: The resolution of the spaces within the form

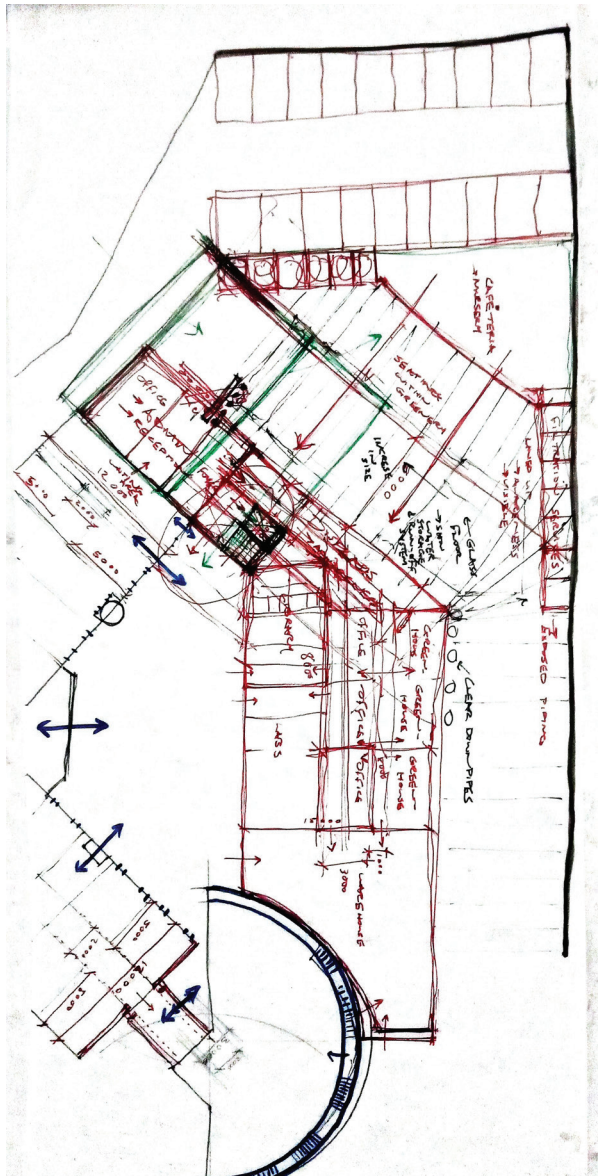


Figure 154: A sketch plan reconfiguring those spaces to allow for more inbetween green spaces

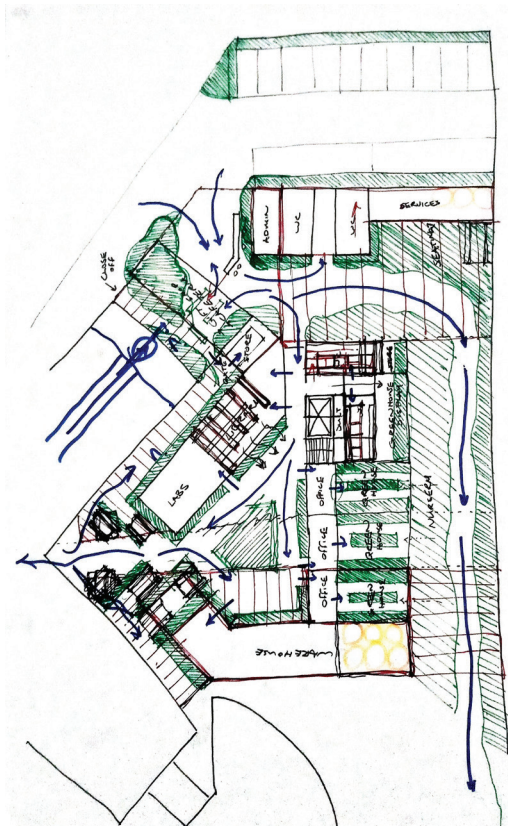


Figure 155: A diagram introducing the planters and various green spaces throughout the site, to better accommodate the theme of the thesis

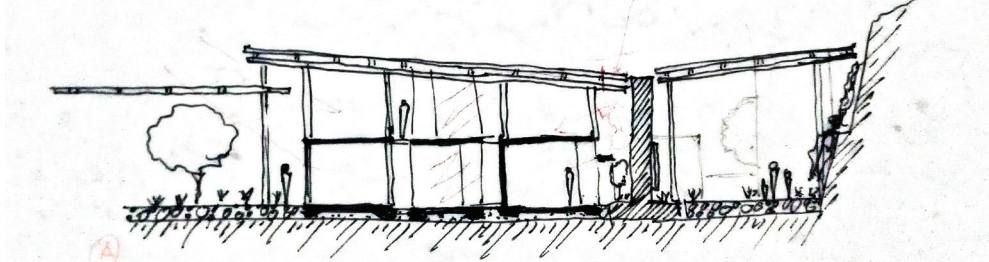


Figure 158: An initial cross section of the spaces, with a specific look at experiences

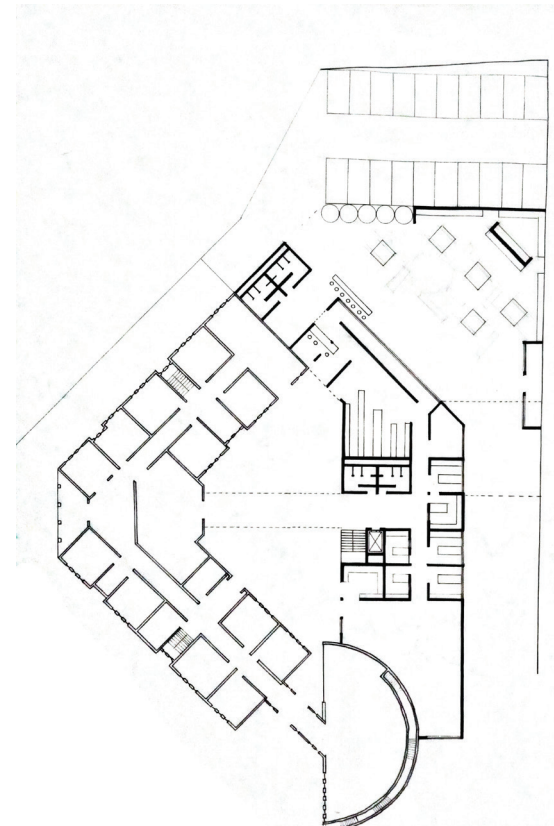


Figure 156: A plan drawn for the purposes of simplifying the entire intervention, and the origin of a central architectural element, defining the spaces around it

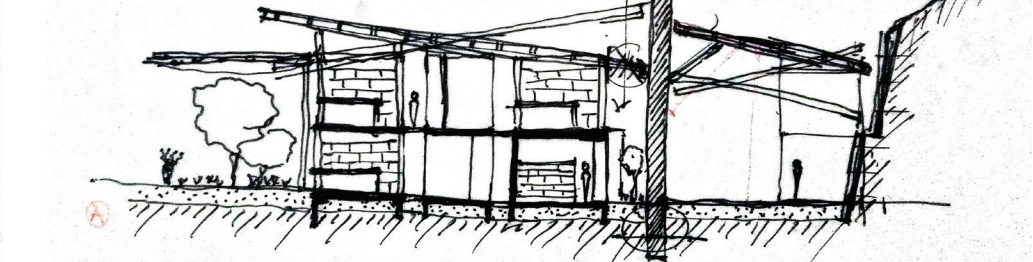


Figure 159: A further sketch section exploring the possibilities of the roof structures

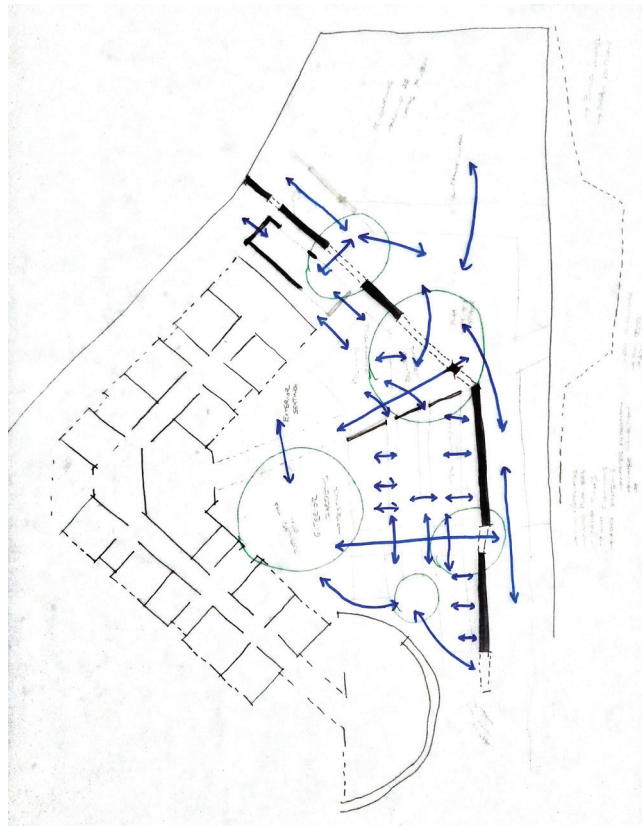


Figure 157: An exploration of movement, connections and links in and around this one central elements, which becomes the rammed earth wall

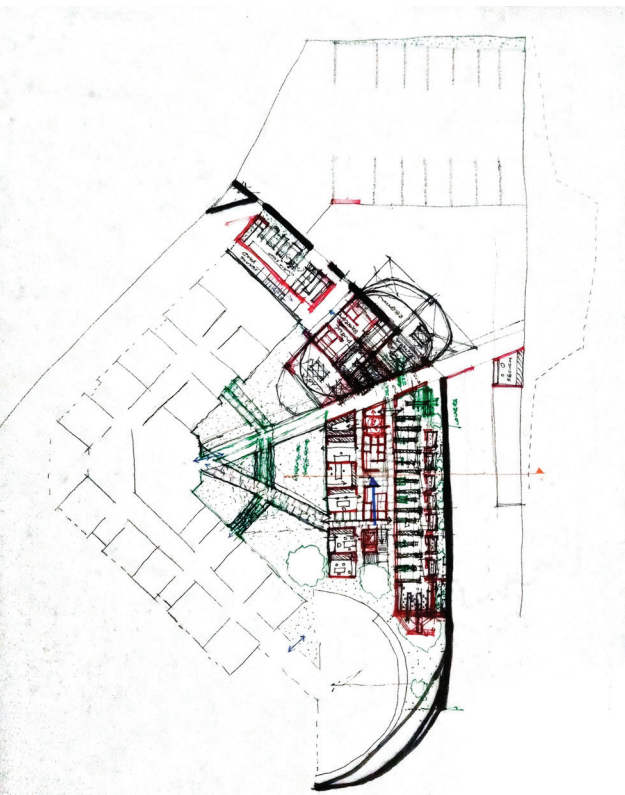


Figure 160: The final explorative plan, before going into the detailed resolution, where most of the spaces are defined

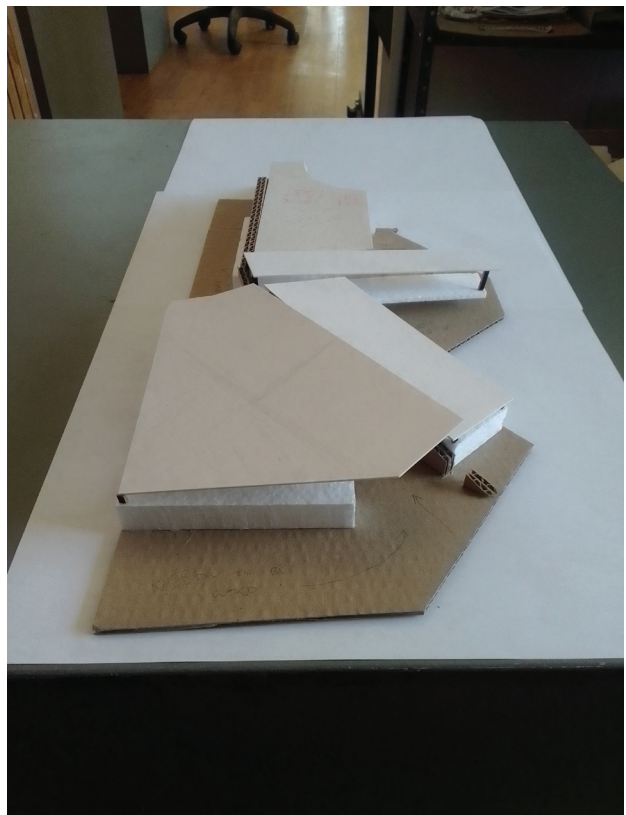


Figure 161: A first working model of the building, exploring form and roof

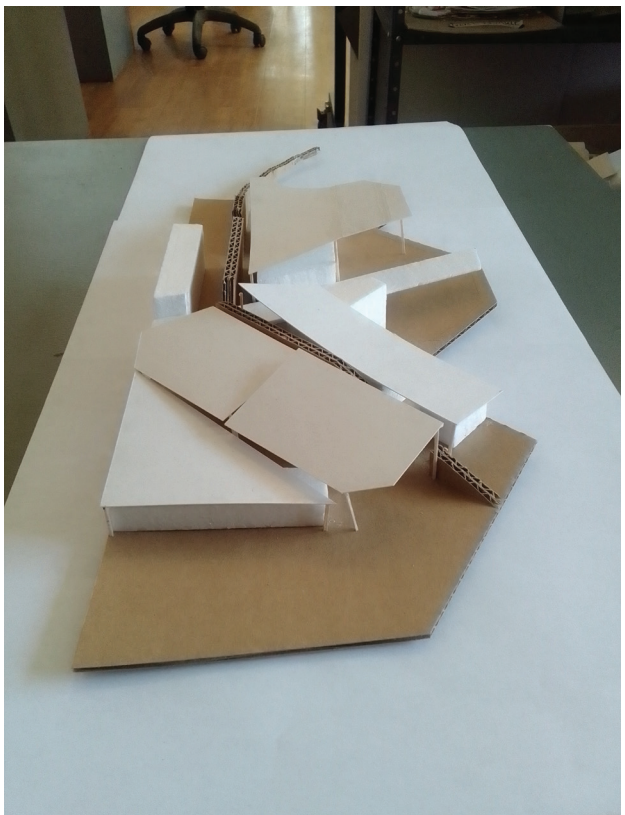


Figure 162: Another working model breaking up these roofs into smaller structures

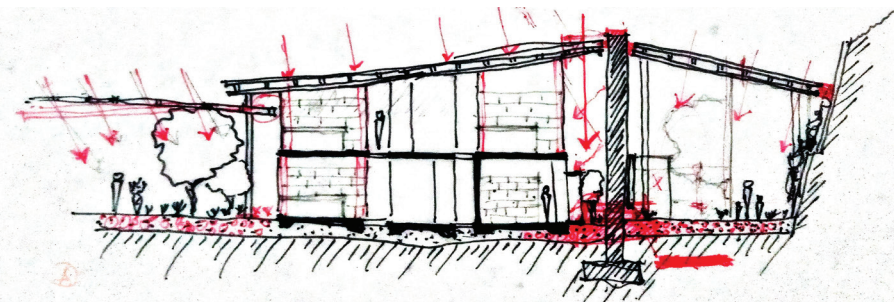
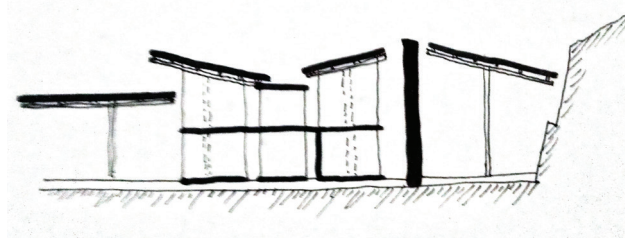
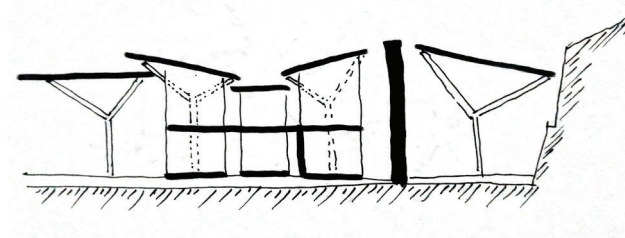
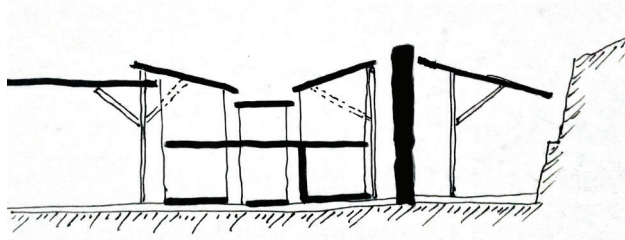
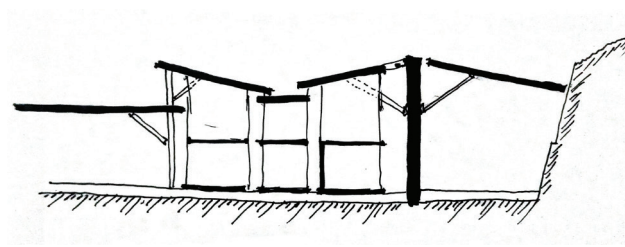
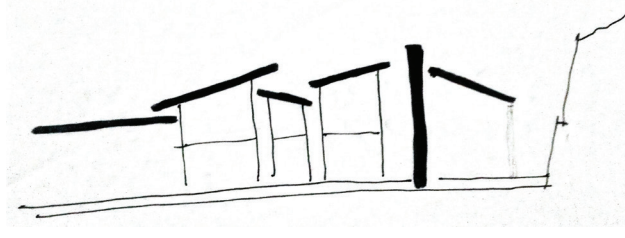
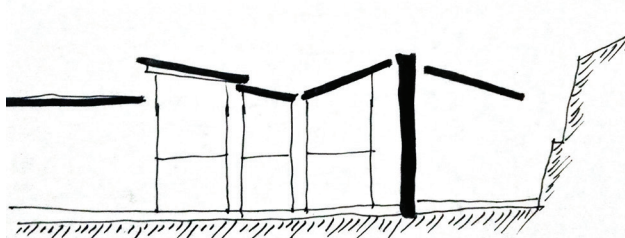
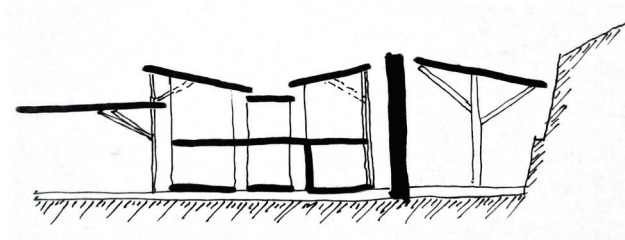
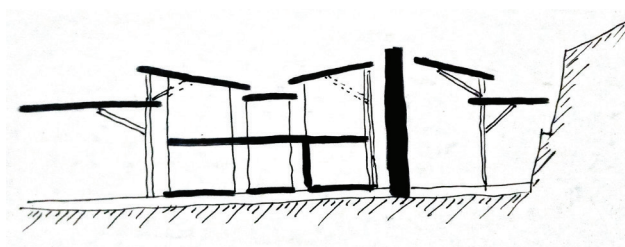
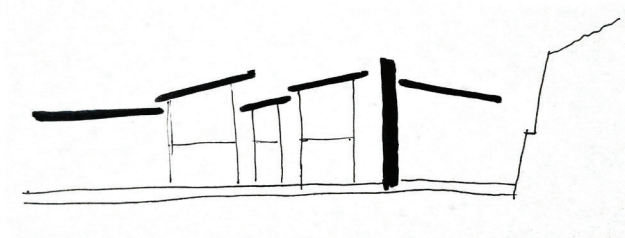
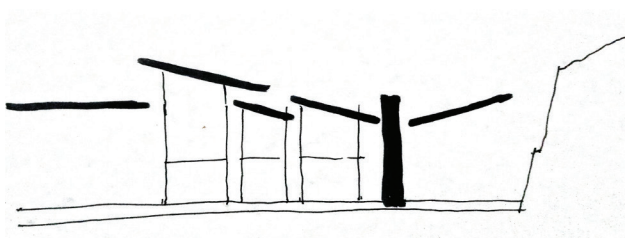
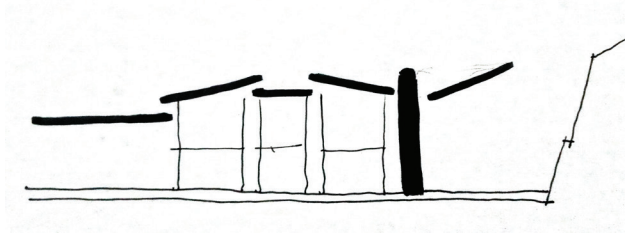
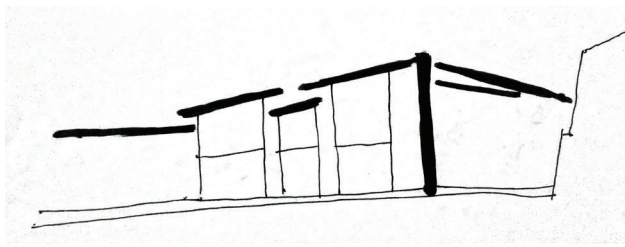
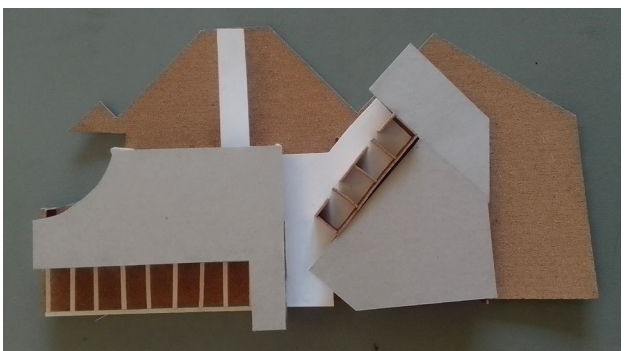
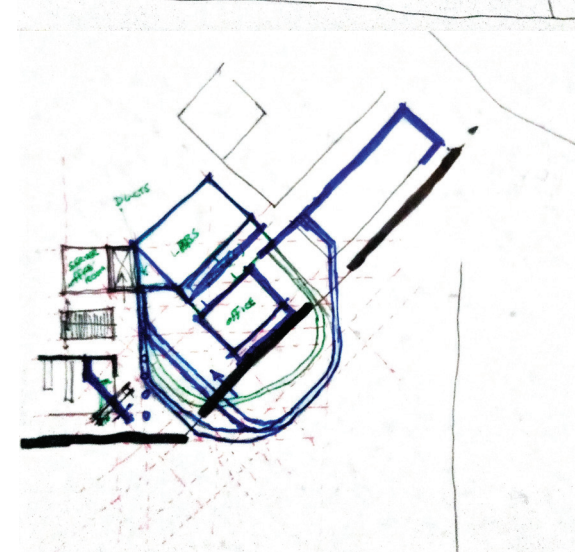
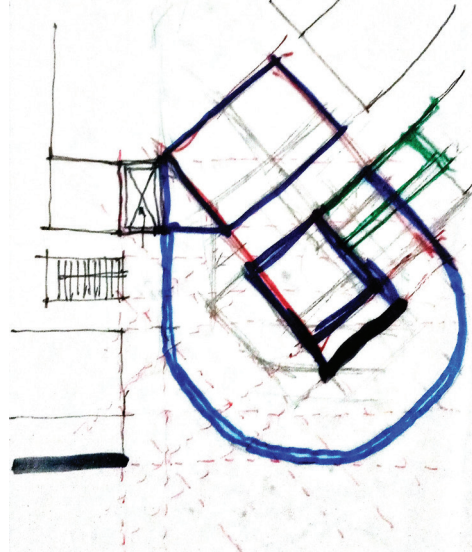
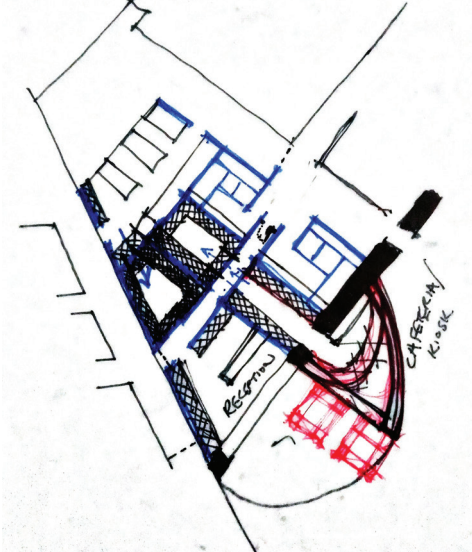
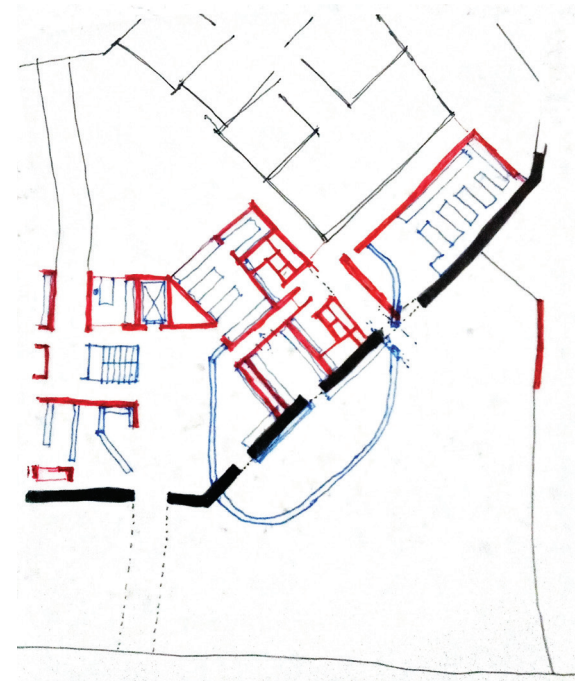
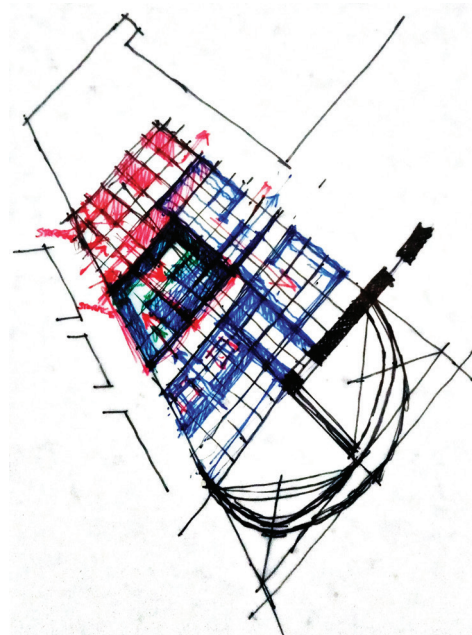
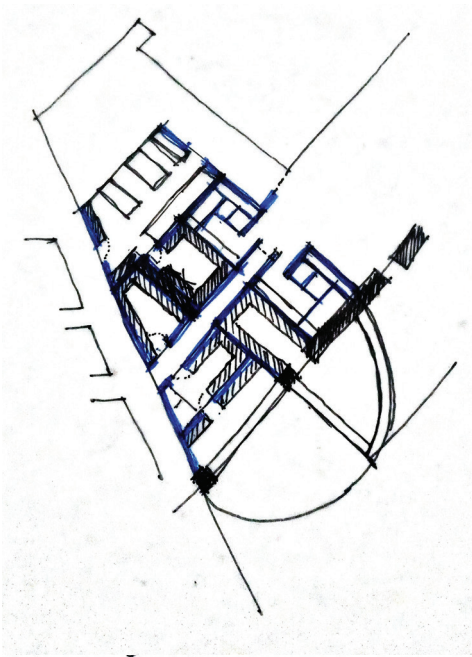


Figure 163: A sketch section looking at the integration of the mutualistic approaches discussed in section 5

Figure 164: A working model, with a focus on the interior spaces, and different roof coverings



Figures 165-176: A sectional exploration of form and roof structures, along with its support



Figures 177-182: An exploration into the form and functionality of the reception. This is the point at which the 2 different angles meet, creating a variety of issues and problems. This eventually led to the use of a circular structure, which further complimented the existing herbarium

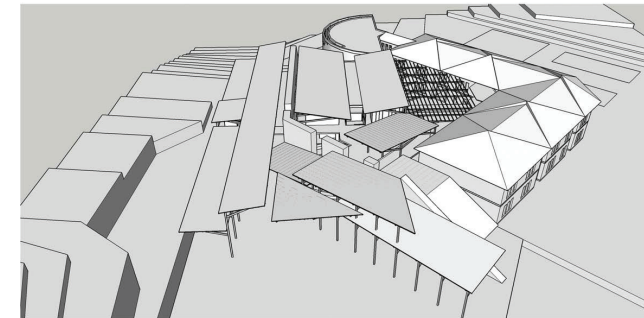


Figure 183: A 3D render of the roof explorations from above

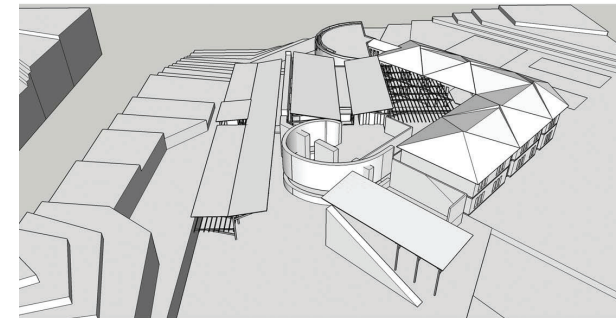


Figure 185: The same view from above, with a simplified roof structure

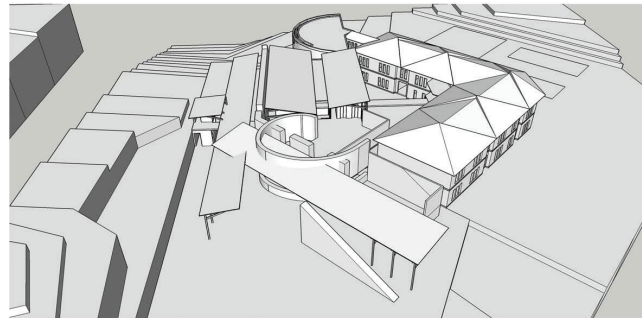


Figure 187: A further simplification of of the roof structures as seen from above

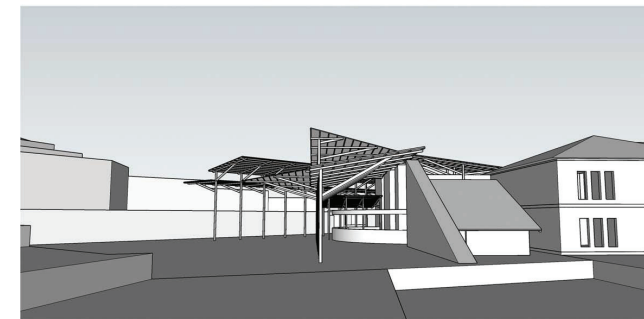


Figure 184: The same roof exploration, as seen from the entrance

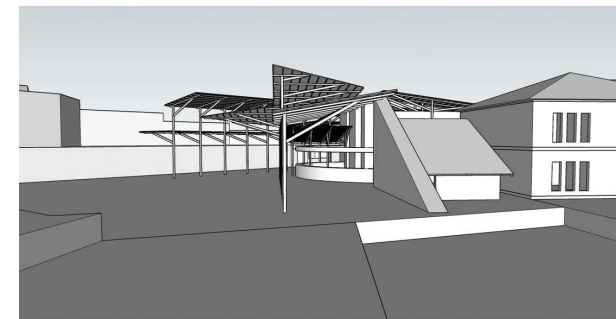


Figure 186: The same roof exploration, as seen from the entrance, which still lacks flare

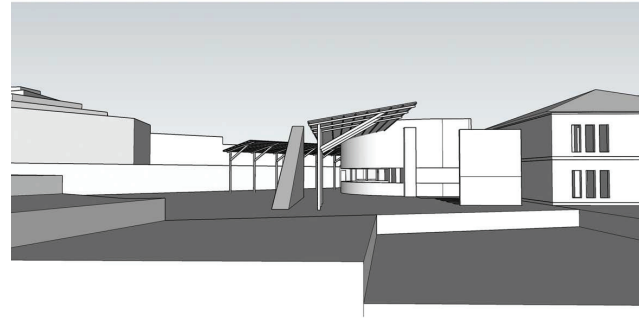


Figure 188: The front view now opening the nursery toward the entrance, creating a better foyer and arrival space

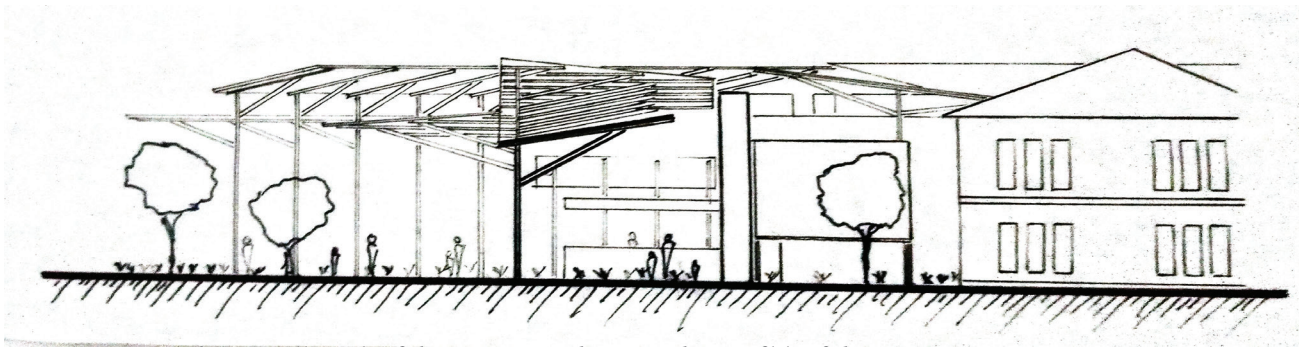


Figure 189: An elevation (NTS) of the entrance, showing the roof(s) of the structure

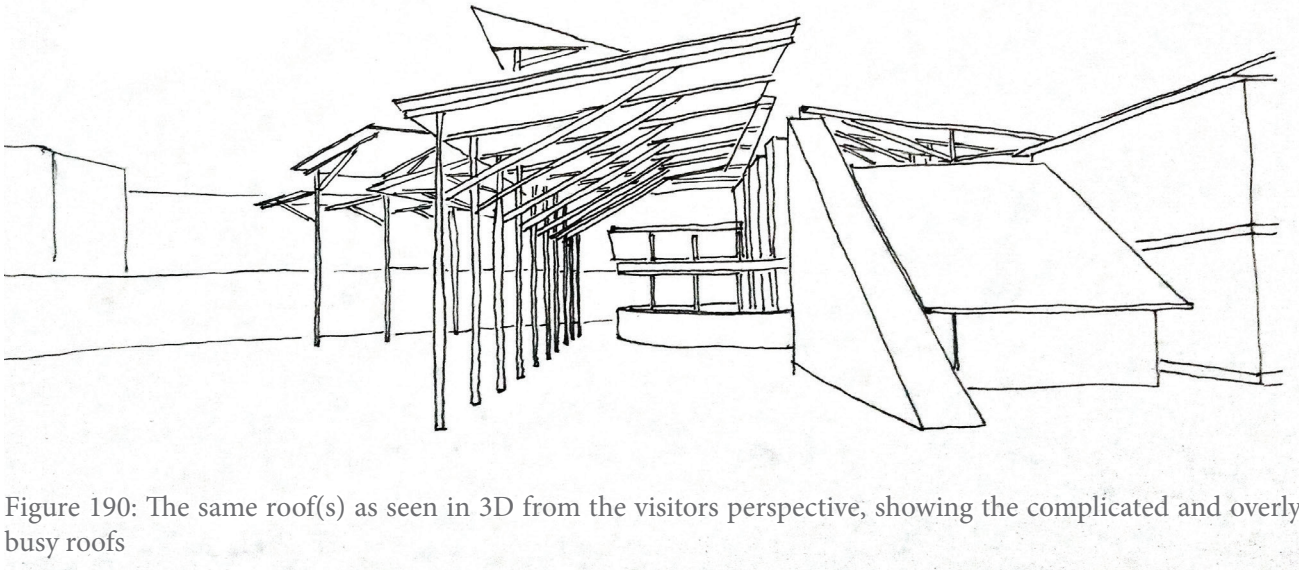


Figure 190: The same roof(s) as seen in 3D from the visitors perspective, showing the complicated and overly busy roofs

Figure 191: A final working model, with a primary focus on the entrance

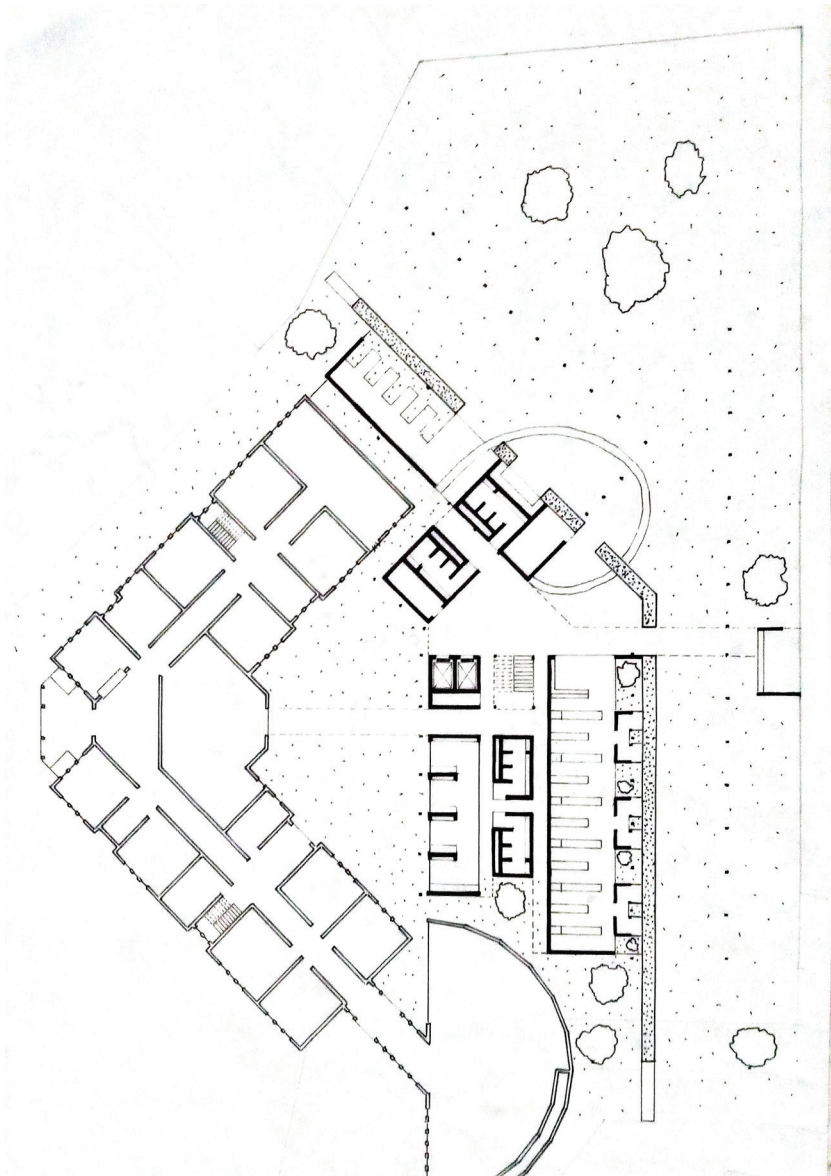


Figure 192: The ground floor plan (NTS), showing that the entrance is not yet clearly defined, and therefore further divides the 2 sides of the rammed earth wall

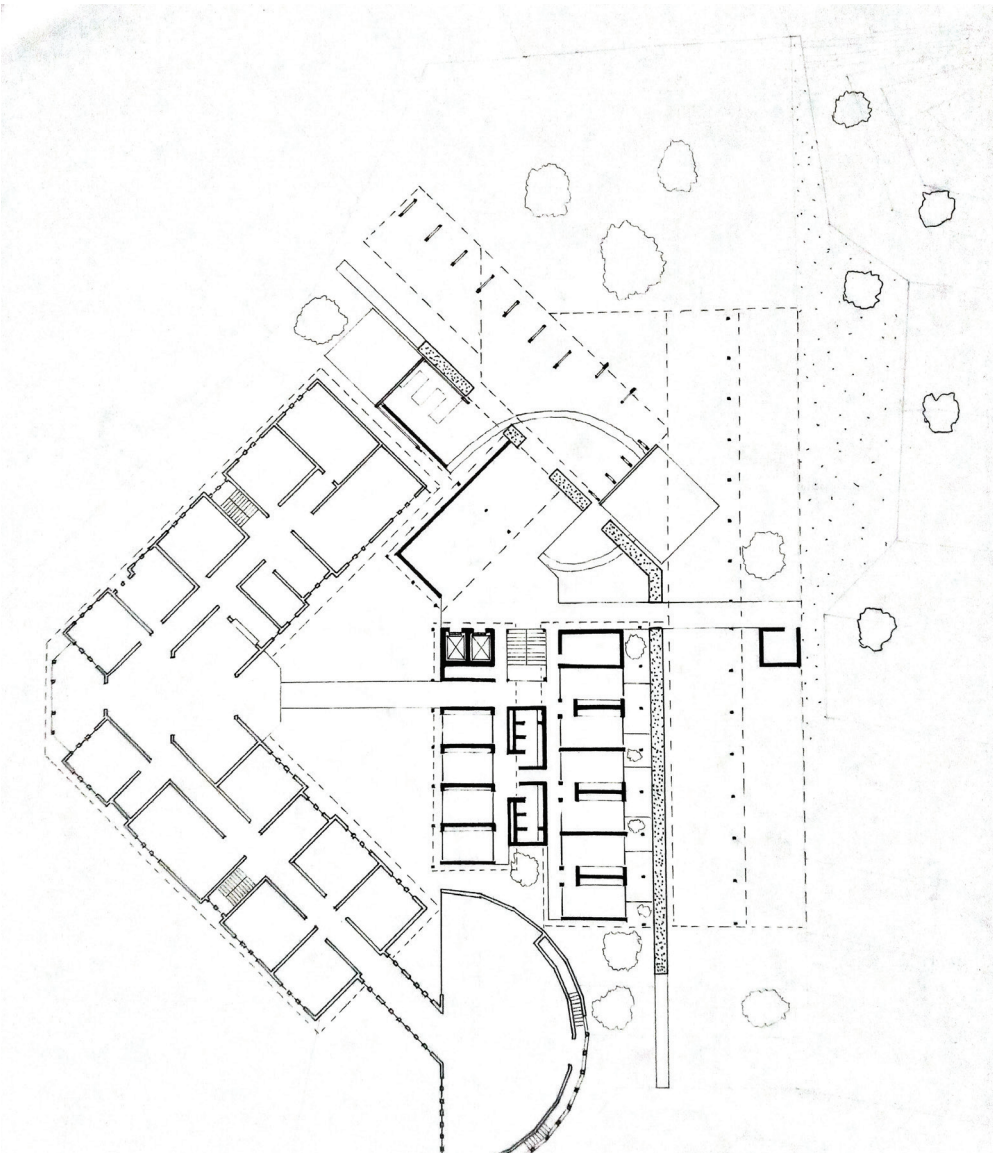


Figure 193: The first floor plan (NTS) showing the same issue. The other side of the wall however, now opens up to allow space for parking, and the occasional open market

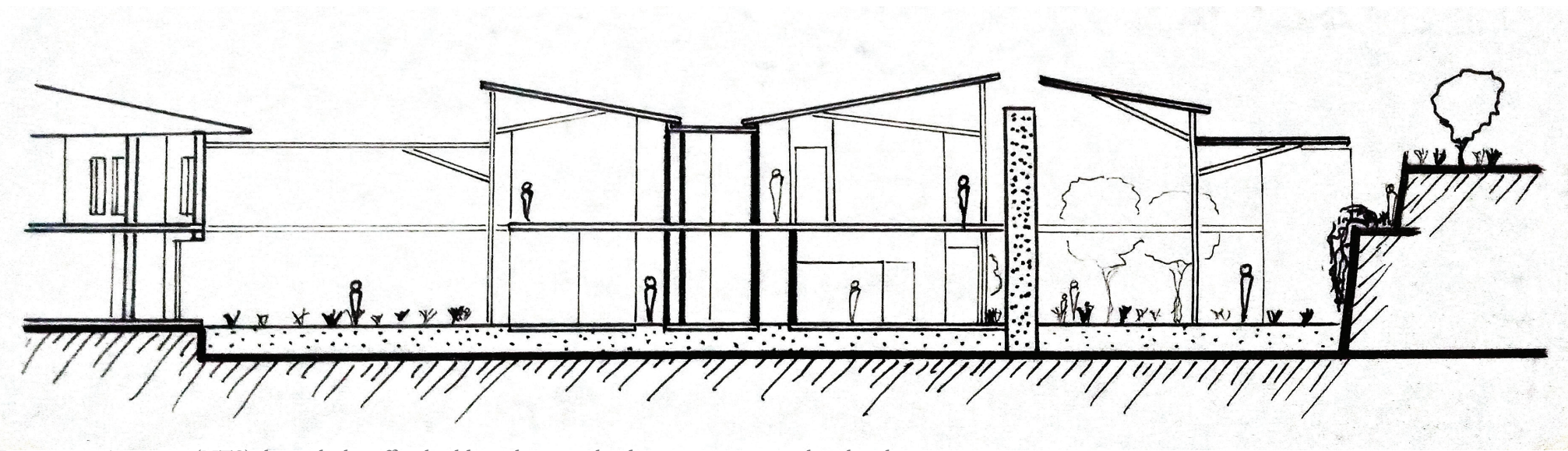


Figure 194: A section (NTS) through the office building showing the disproportionate ceiling heights

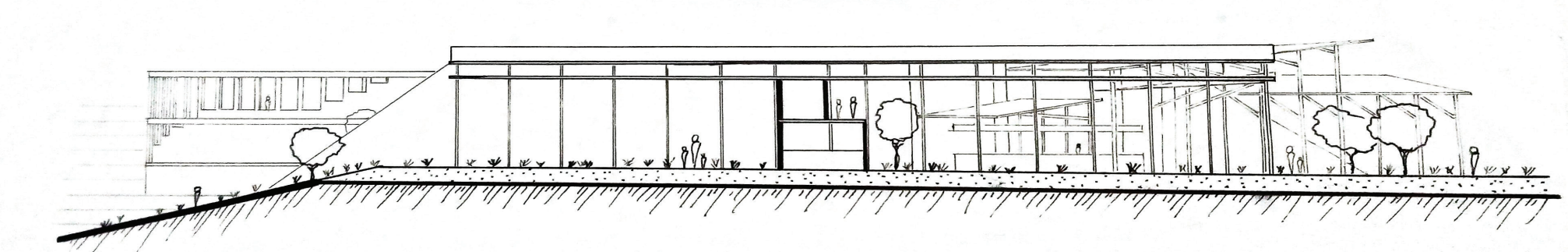


Figure 195: The eastern elevation (NTS) showing the response toward the passageway along the rammed earth wall, showing the lack of natural integration and human activity

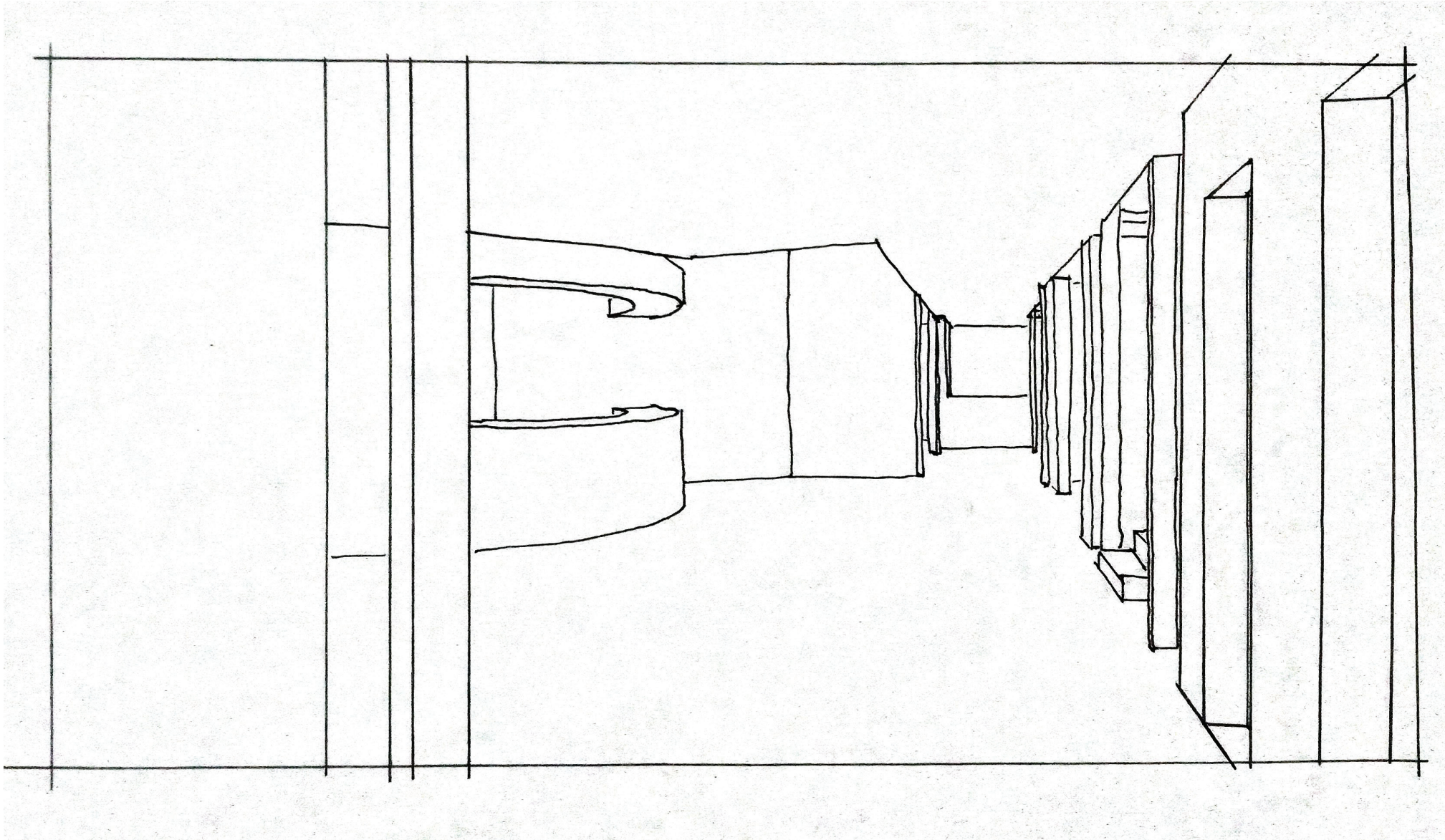
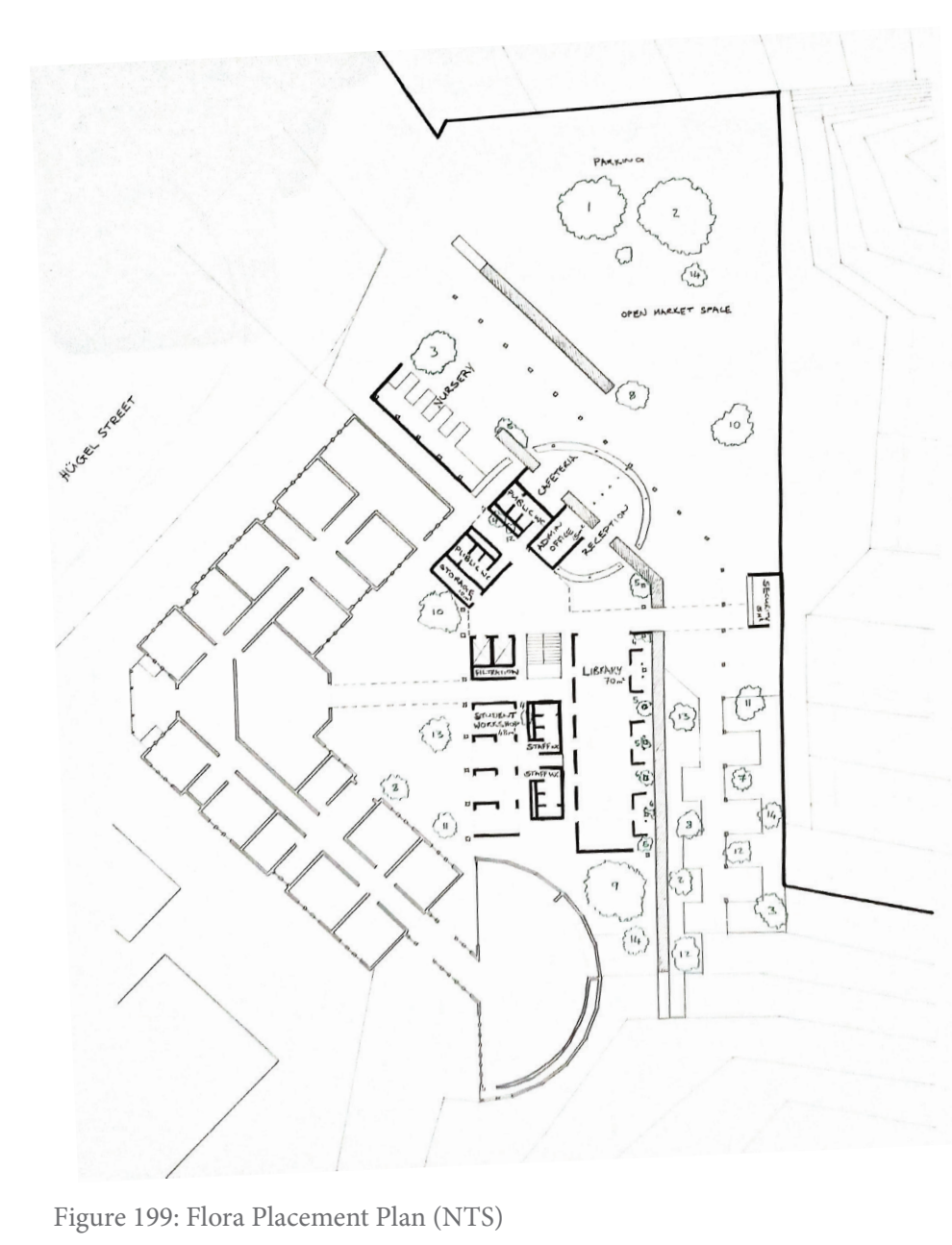
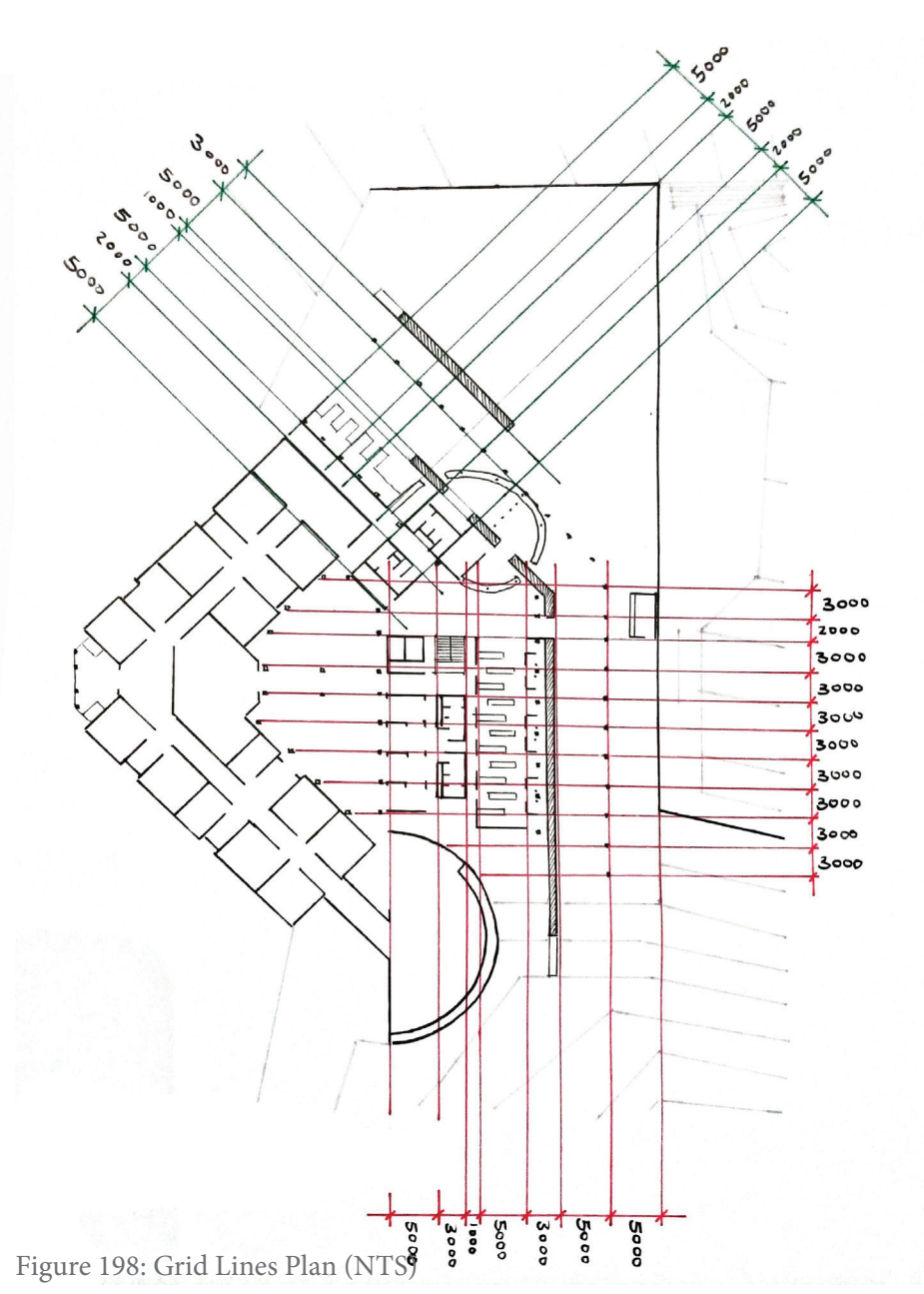
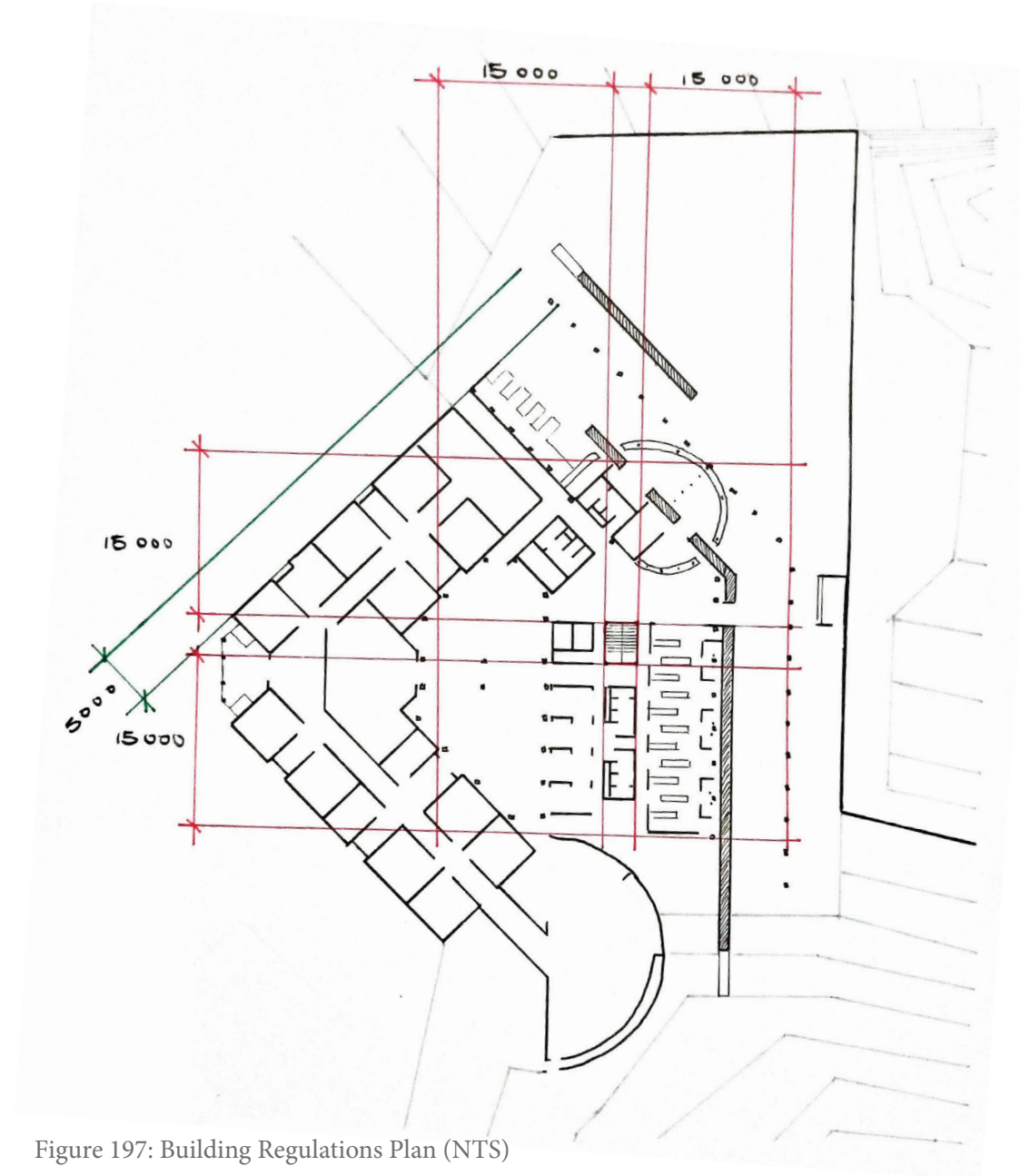


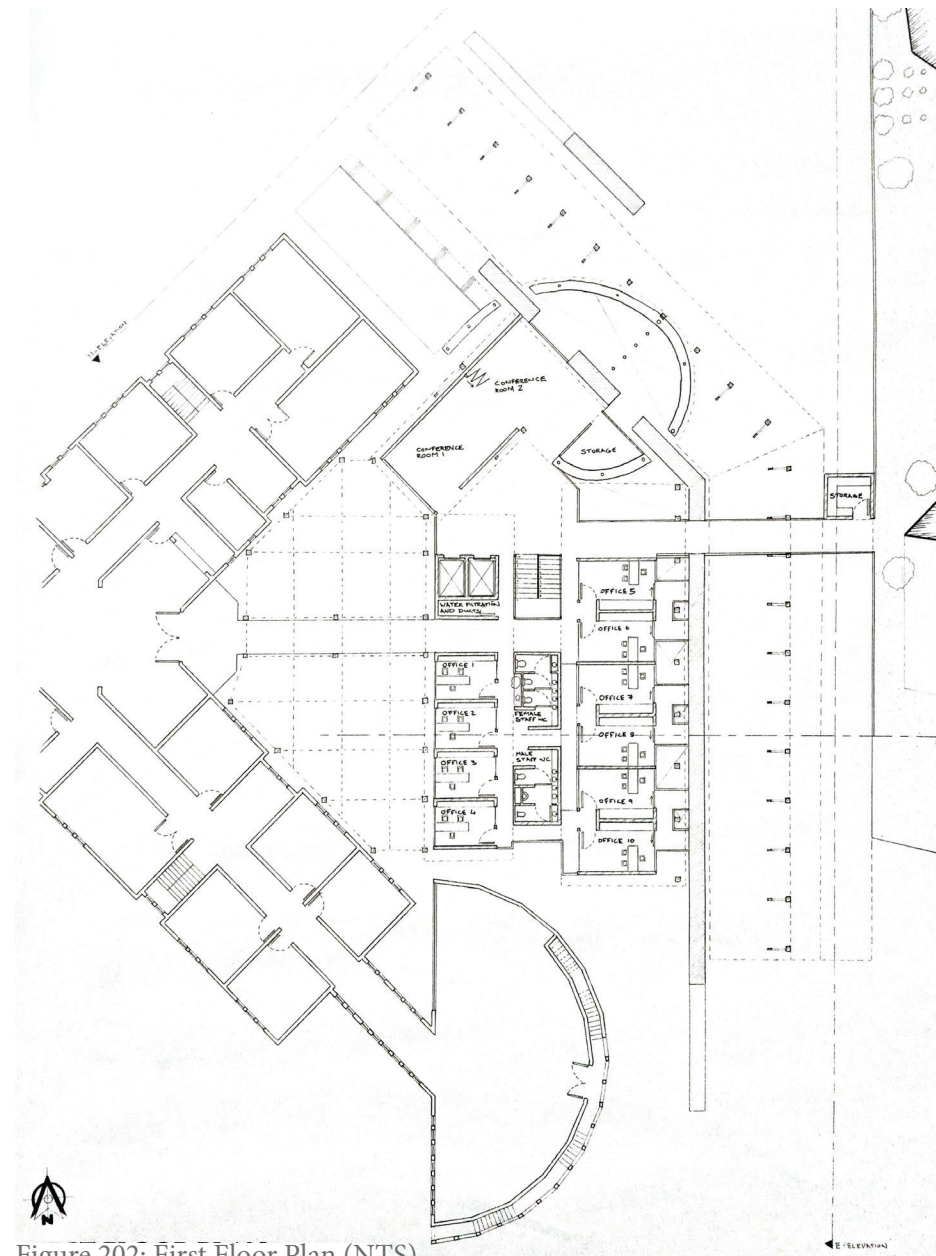
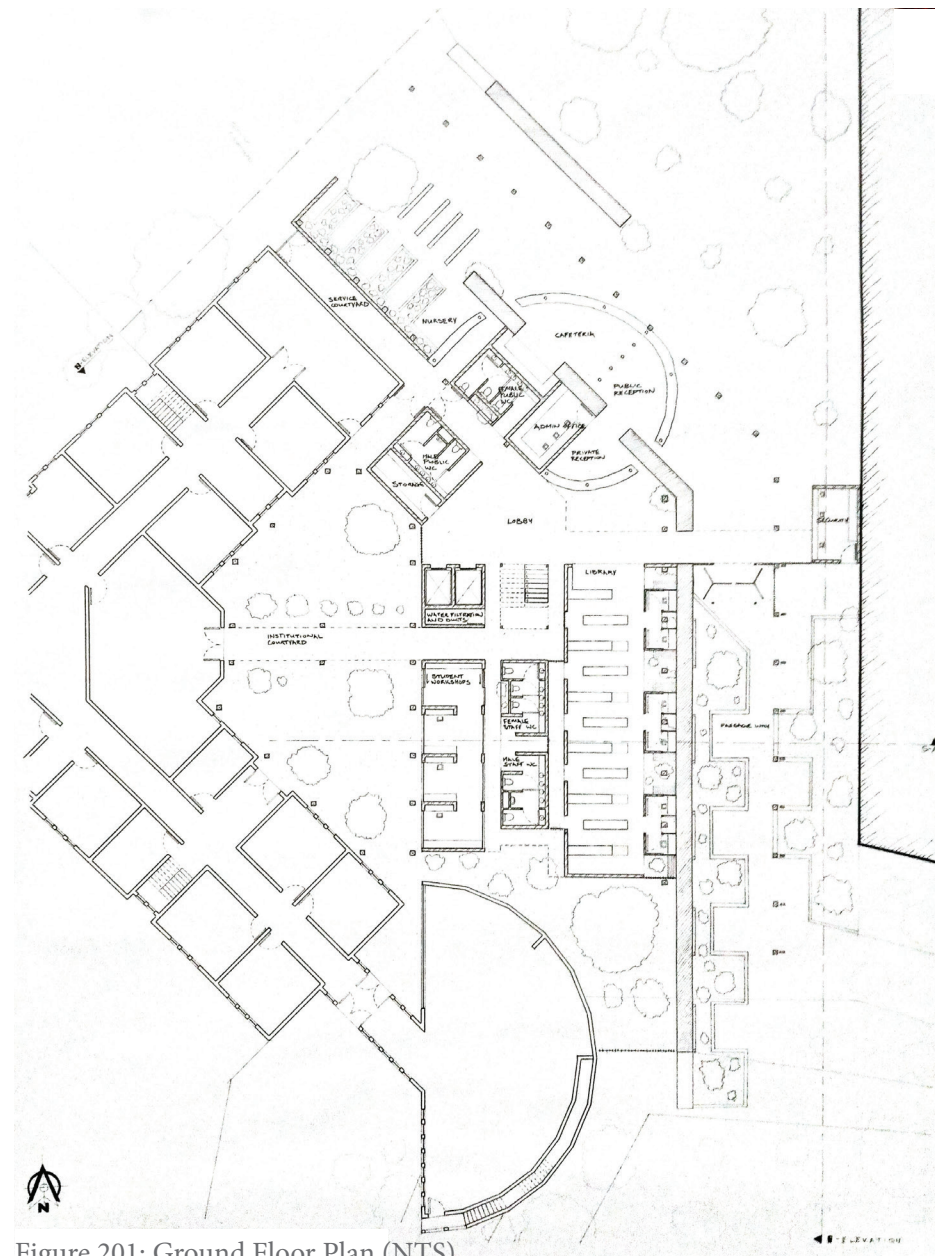
Figure 196: A 3D sketch of the interior private reception and foyer area, as seen from the elevators





- 1 COMMIPHORA AFRICANA
- 2 COMBRETUM IMBERBE
- 3 VACHELLIA KARROO
- 4 CRATEROSTIGMA PLANTAGINEUM
- 5 GLORIOSA SUPERBA
- 6 ANSELLIA AFRICANA
- 7 ASYSTASHA GANGETICA
- 8 EUPHORBIA KAKOENSIS
- 9 ACACIA ERIOLOBA
- 10 BOSCHIA ALBITRUNGA
- 11 COMMIPHORA CRENATO-SERRATA
- 12 SEADOXUS MULTIFLORUS
- 13 PACHYPODIUM LEALII
- 14 SENEGALIA ROBYNSIANA

7.4 Research Centre Final Representation



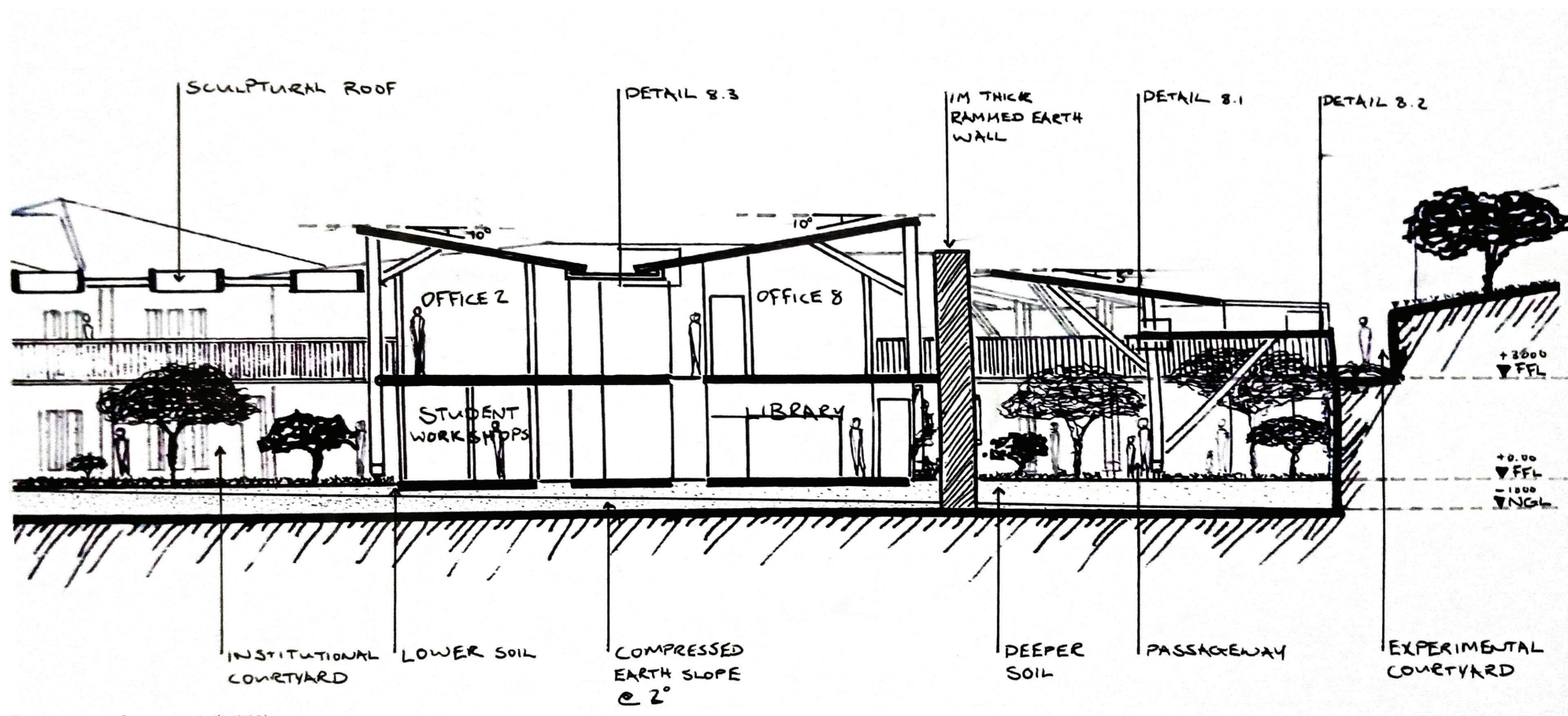


Figure 203: Section A (NTS)

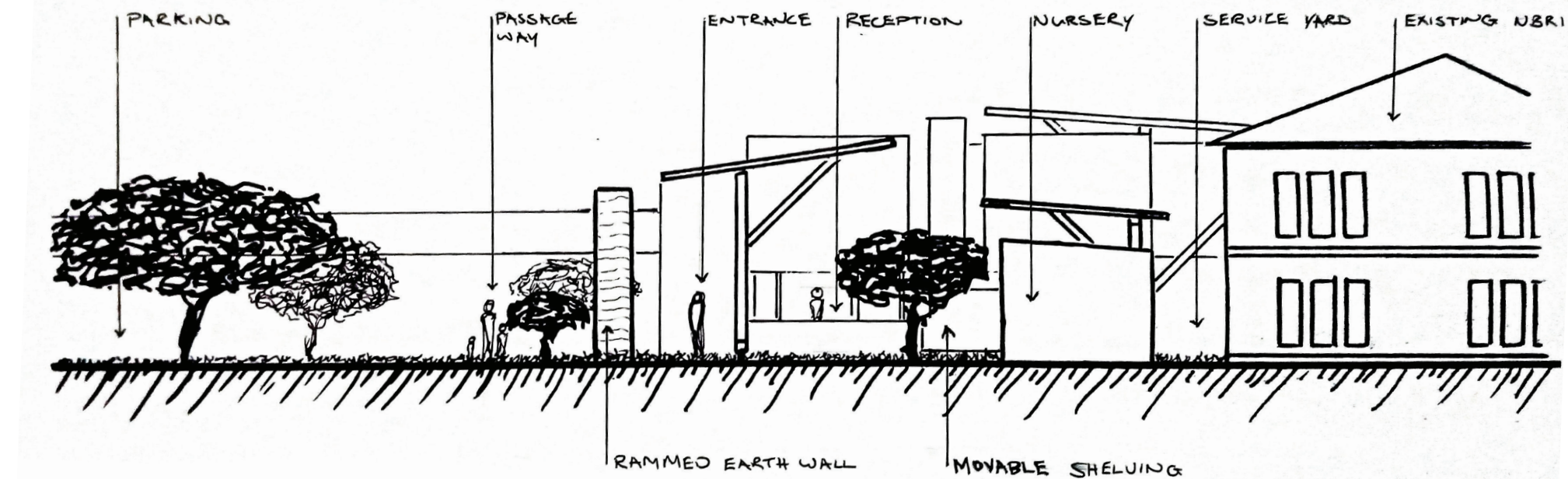


Figure 204: North Elevation (NTS)

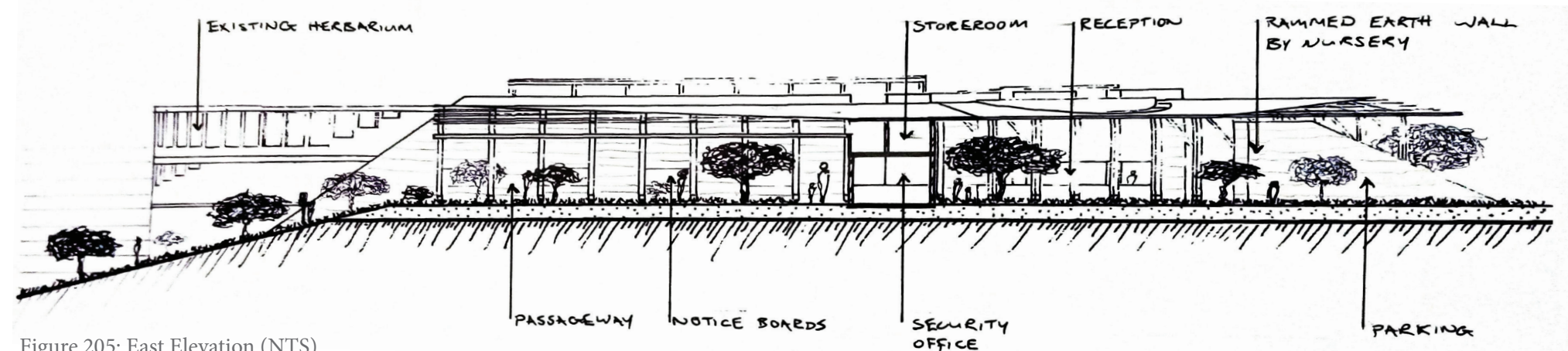


Figure 205: East Elevation (NTS)

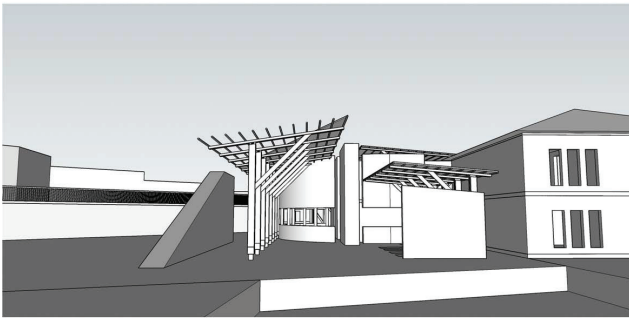


Figure 206: 3D image toward the entrance

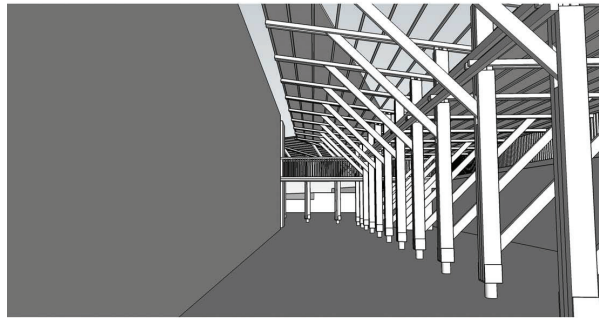


Figure 208: 3D image of the pathway coming from the garden

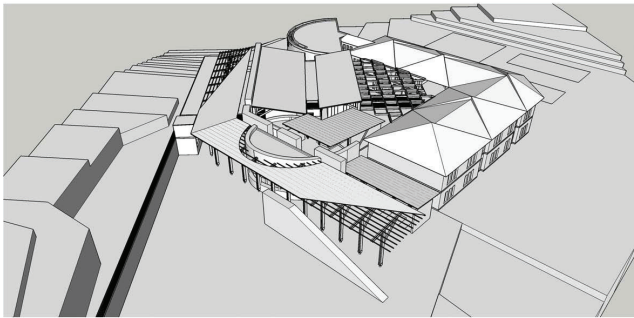


Figure 210: 3D aerial image

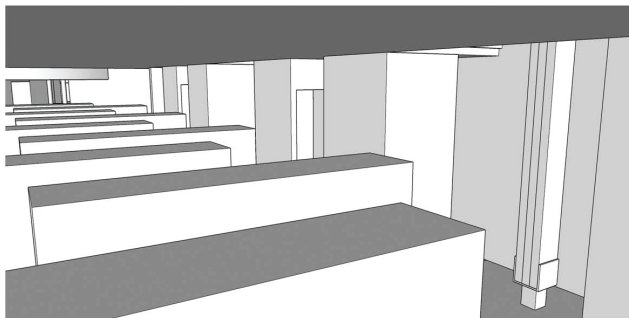


Figure 207: 3D image of the library interior

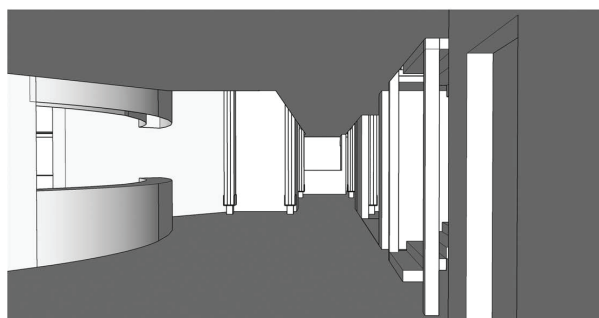


Figure 209: 3D image of the private lobby and reception

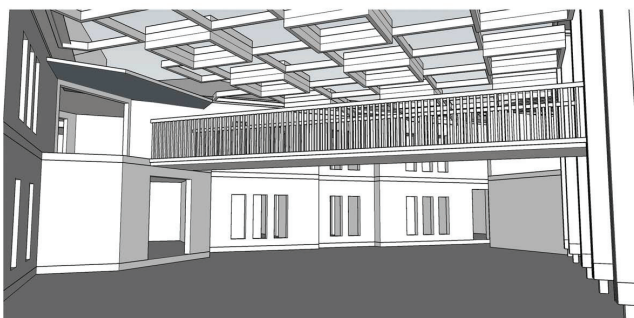


Figure 211: 3D image from within the institutional courtyard



Figure 212: Model of the ground floor plan



Figure 213: Model of the passage way

SOUTH KAROO

→ SOIL CONDITIONS

→ LEPTOSOLS

→ ARENOSOLS

→ PLANTS

→ SWEET THORN ACCACIA

→ BLUE BUSH

→ DEW FLOWERS

→ QUIVER TREES

→ CLIMATE

→ HARSH

→ COMMON DROUGHTS

→ ARID TO SEMI-ARID

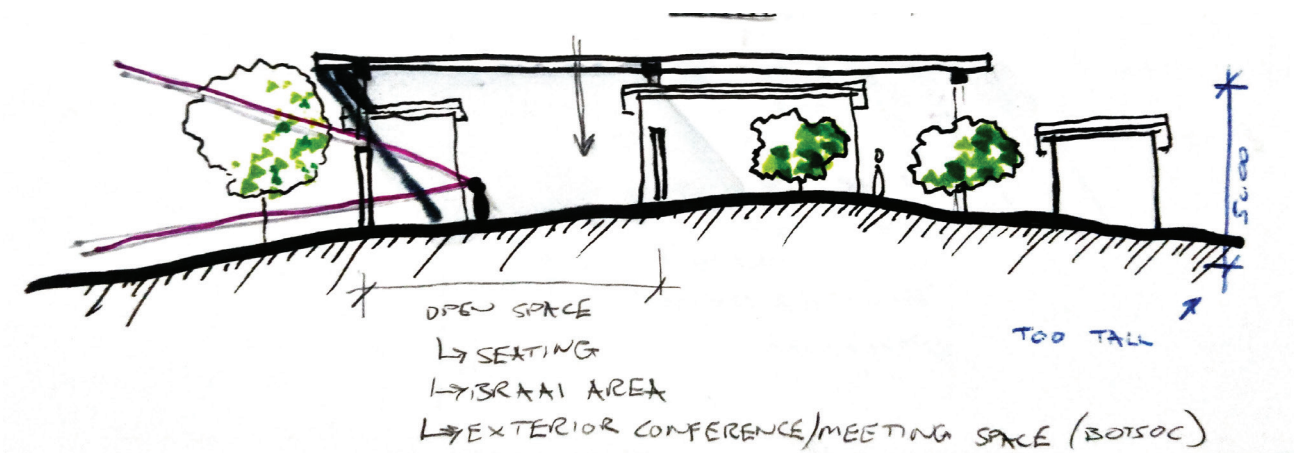


Figure 217: A sketch section showing the initial idea of form

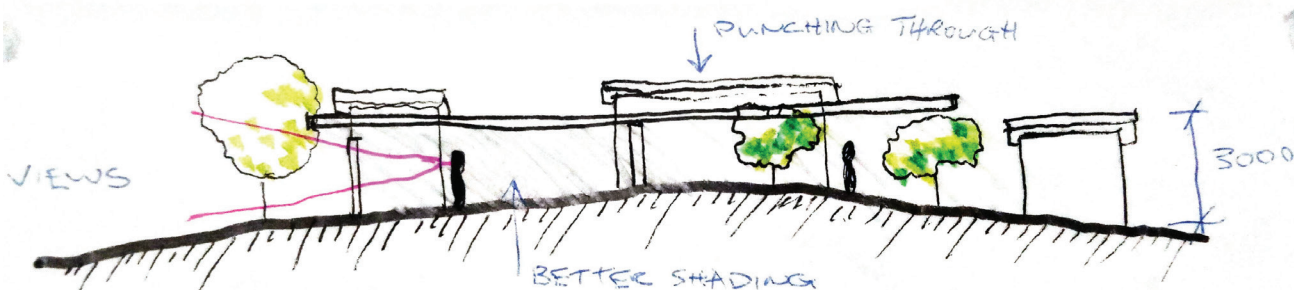


Figure 218: A sketch section with the roof lowered for better shading and ergonomic atmosphere

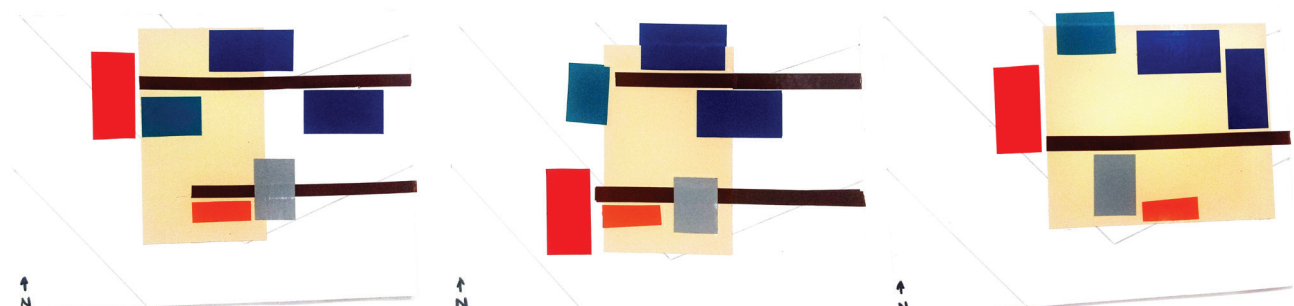


Figure 219-221: 3 iterations of bubble diagrams, trying to use the arrangement and layering learned from the quiver tree

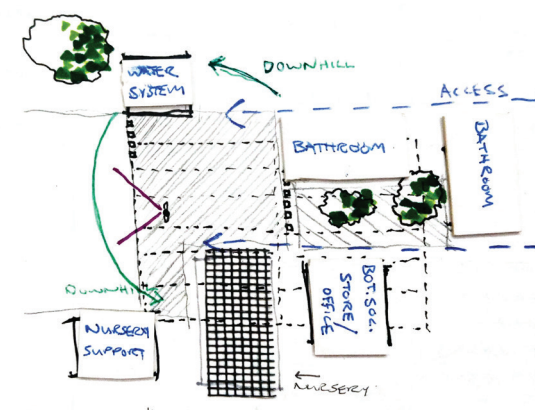


Figure 219: A first plan allocating the functions of the space, according to the bubble diagram

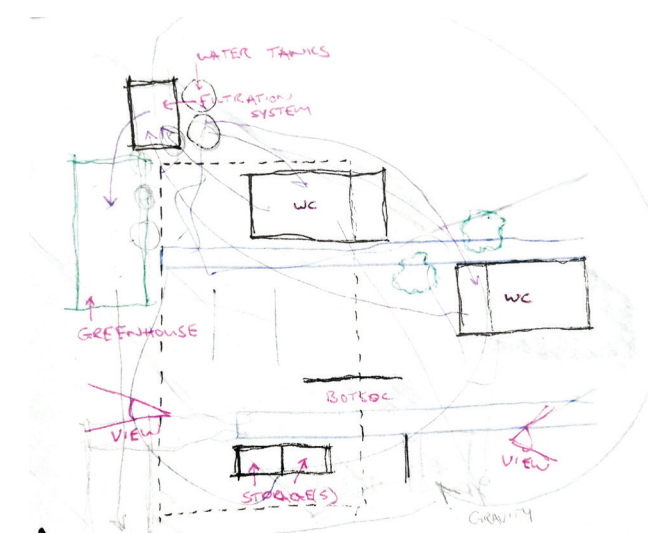


Figure 220: The first plan of the pavilion looking at the water cycling possibilities on site

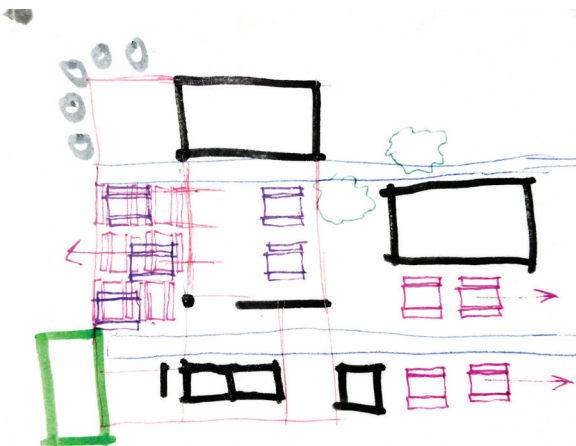


Figure 221: The first iteration of the pavilion, with the first seating arrangements

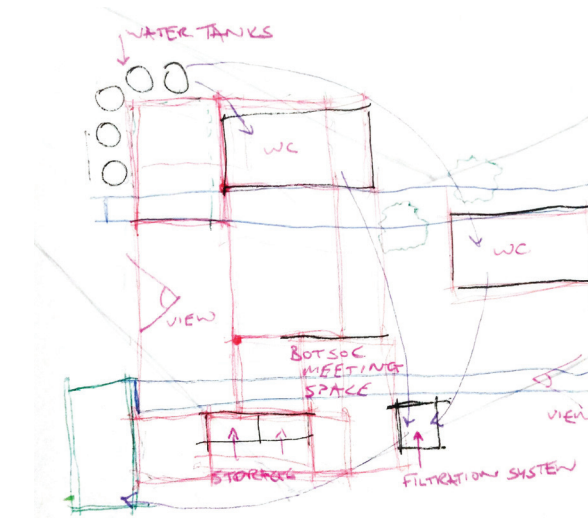


Figure 222: Overlaying a roof plan onto the plan in figure 221 in relation to the water cycling throughout this first iteration of the pavilion

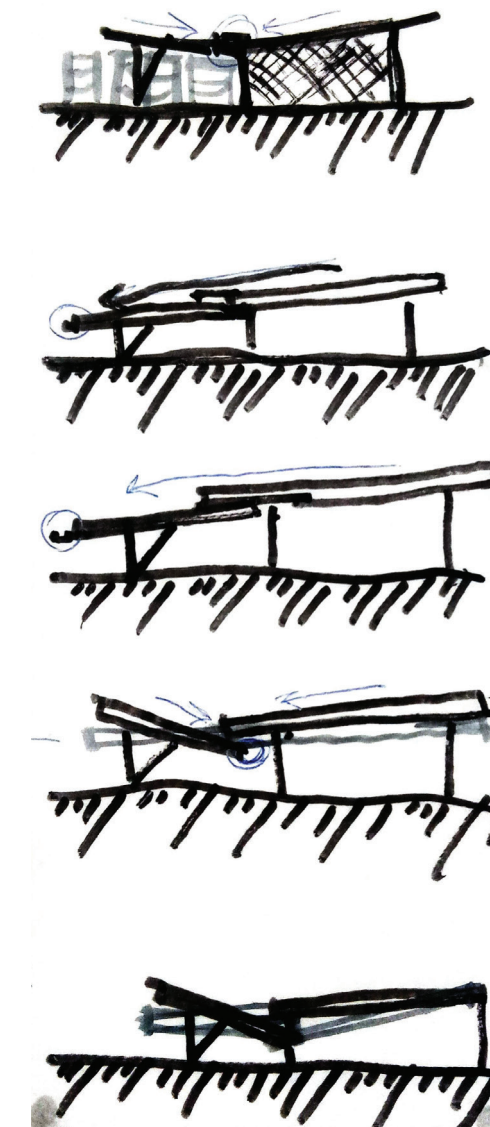


Figure 223: A sectional exploration of roof pitches and their equivalent drainage

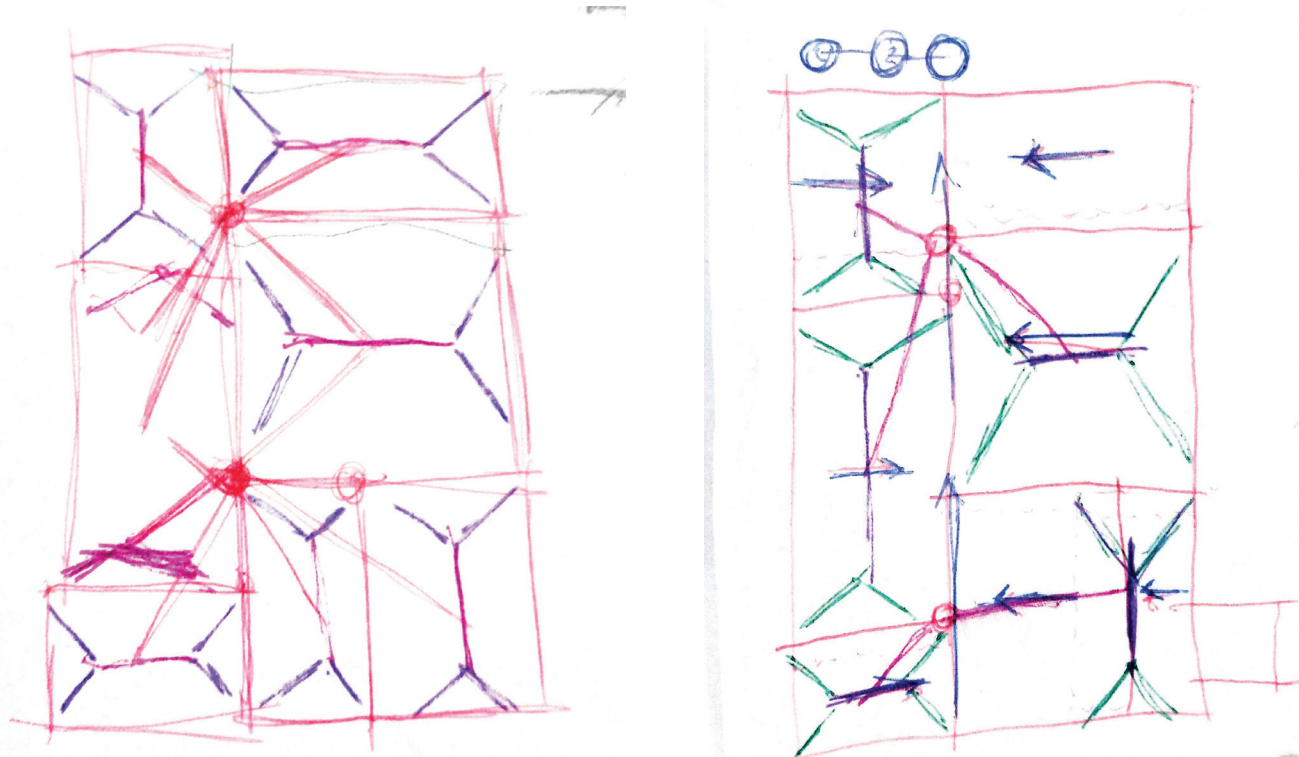


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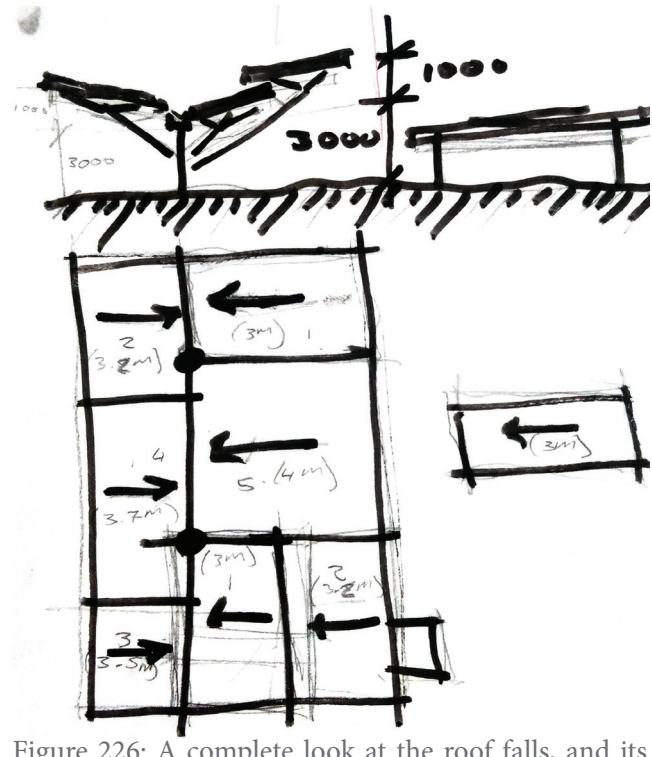


Figure 226: A complete look at the roof falls, and its respective section

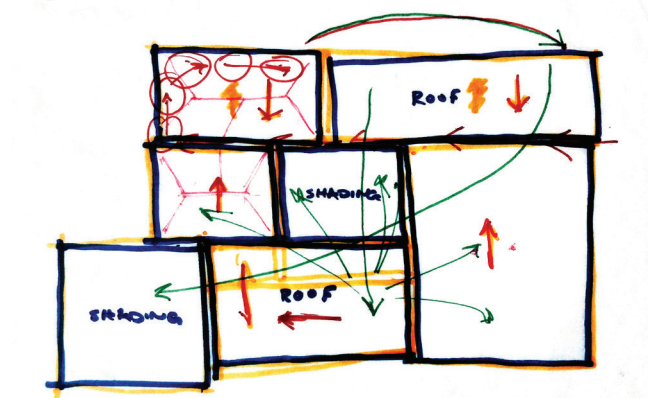


Figure 228: A roof plan to study the drainage pattern and falls of the various roofs

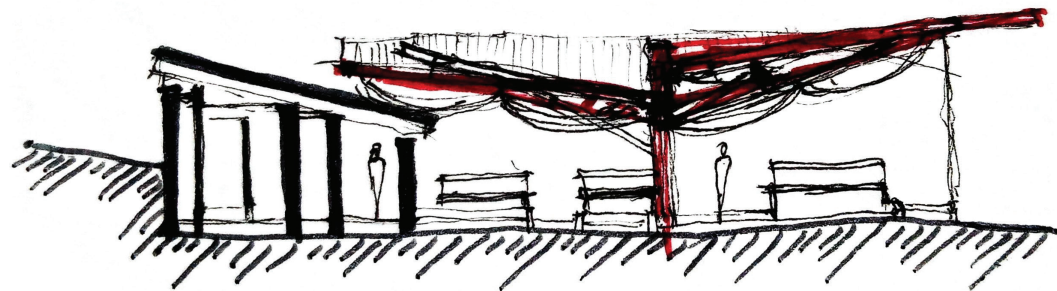


Figure 227: A section, applying the previous roof systems, levelling and arrangement onto site

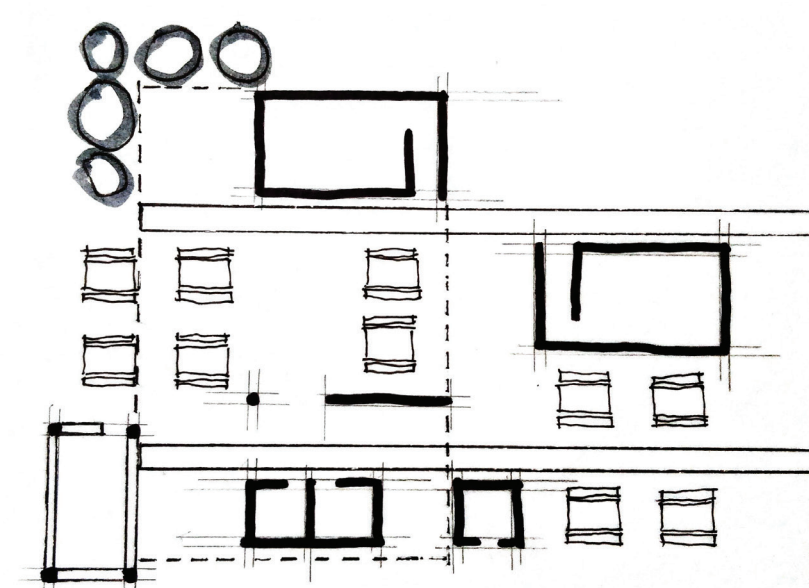


Figure 229: A plan (NTS) looking at the final arrangement of the first iteration



Figure 230: A plan attempting to open up the space, with larger open areas and more seating

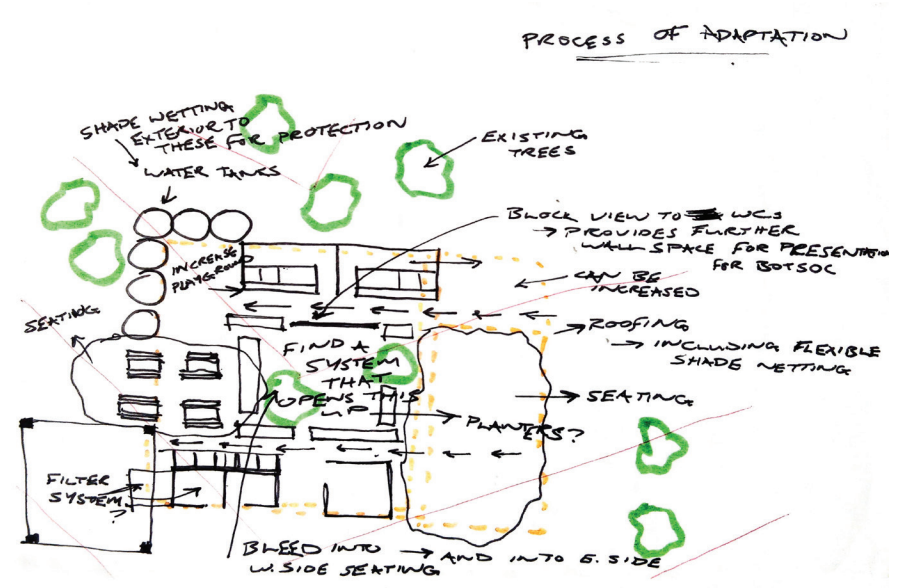


Figure 231: The design reached a point, where the natural integration needs to come in, while also simplifying the construction

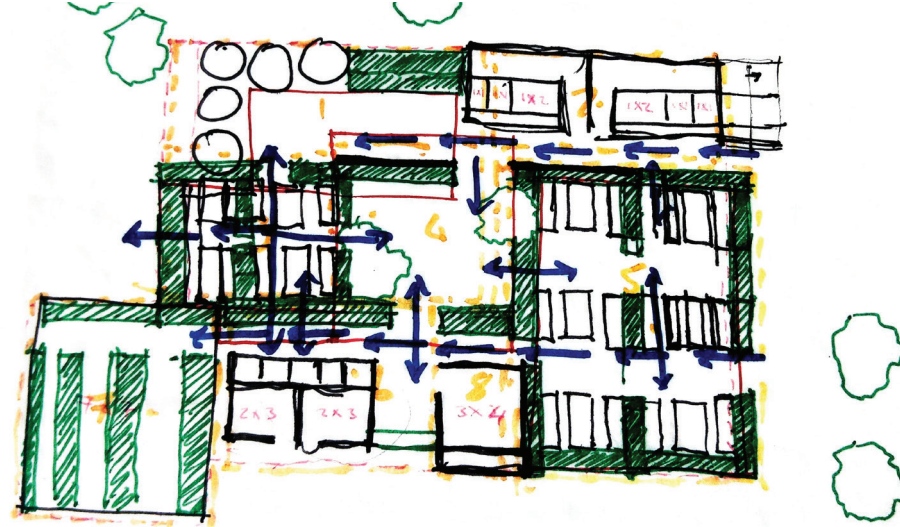


Figure 232: The initial attempt at adding formal planters to help rearrange the spaces, essentially creating a picnic area inside a greenhouse

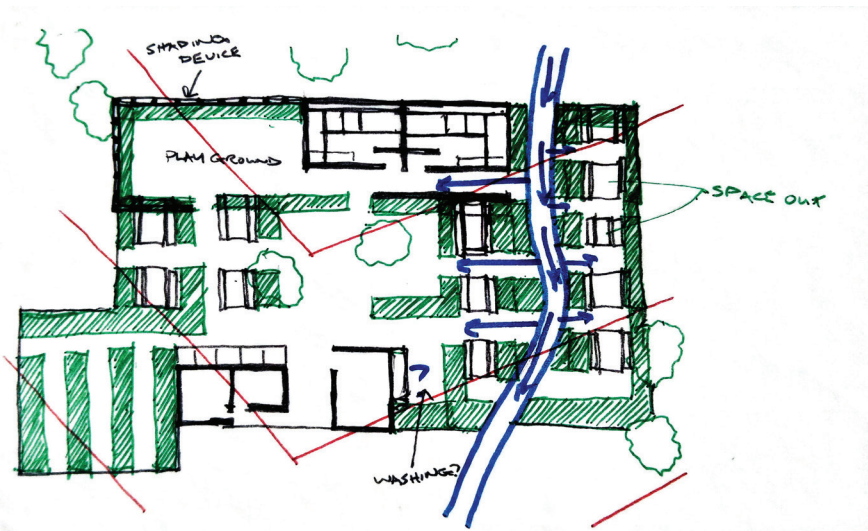


Figure 233: Reintroducing the pathway to go through the pavilion rather

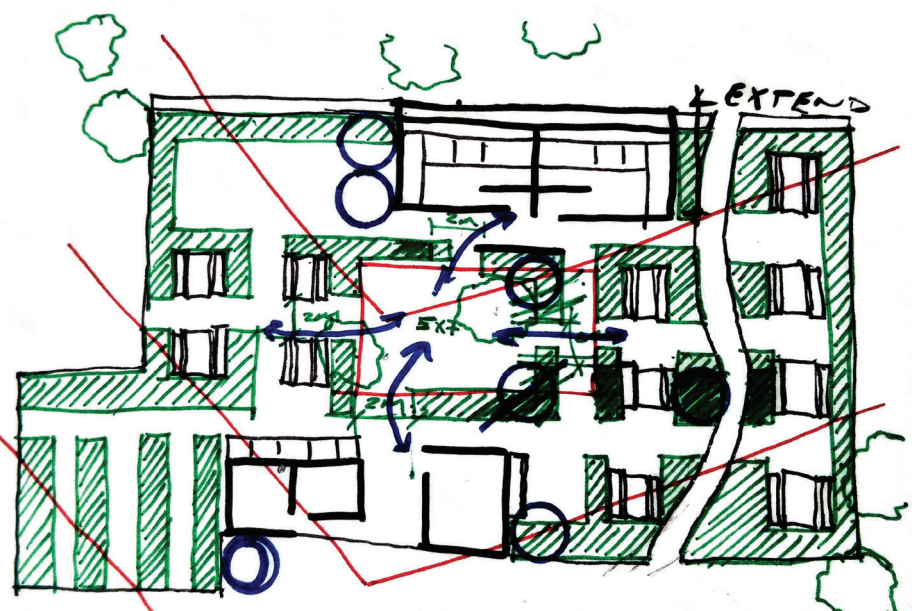


Figure 235: Attempting to understand the central meeting space, and its relationship to the surrounding spaces

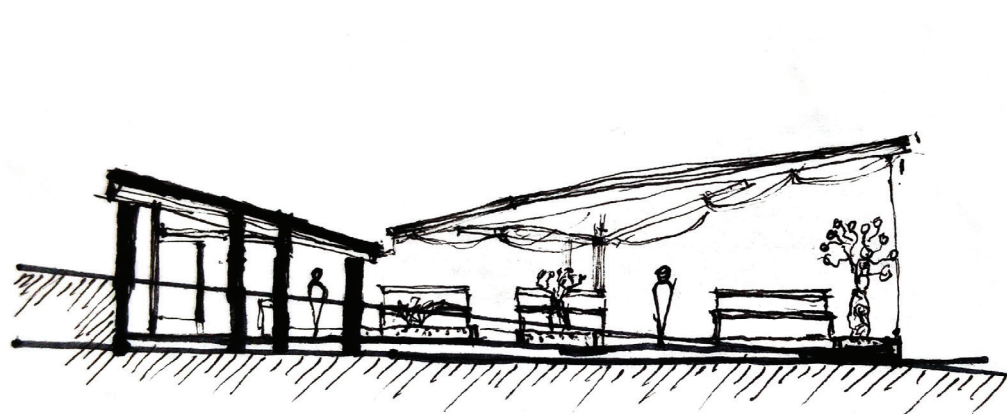


Figure 234: A final sectional exploration of the spaces and their relationship to the roof

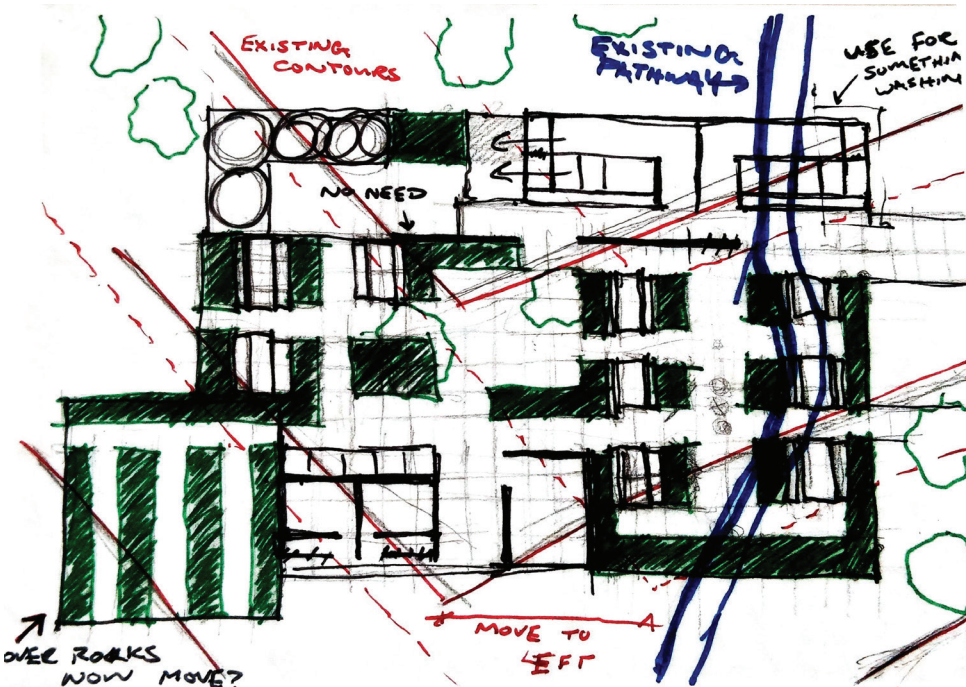


Figure 236: An accurate plan looking at the effects of the slope and pathway onto the pavilion



Figure 237: A plan showing the pavilion shifted away from the pathway and sitting on a single platform

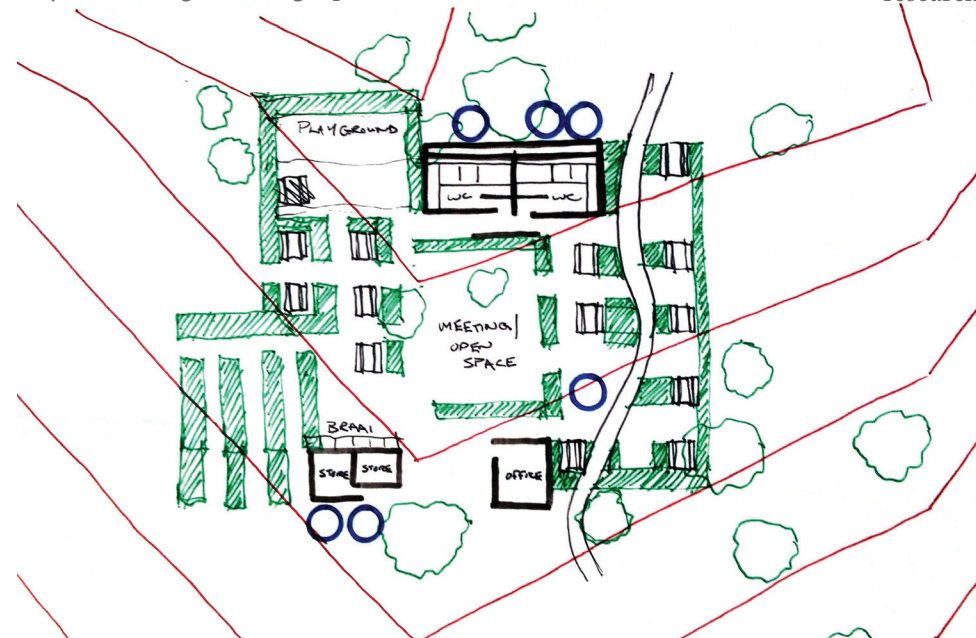


Figure 239: A plan stretching the various functions onto their own platforms, creating more open space in between the buildings

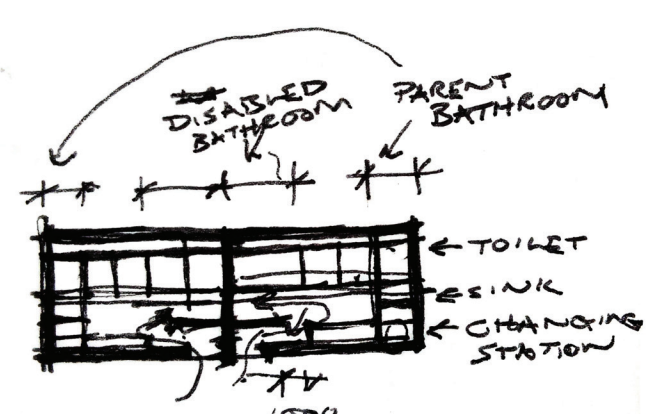


Figure 238: A sketch of the bathroom configuration, including wheelchair accessible bathrooms and parent changing tables in both wings. A similar design as the ones used in the research facility

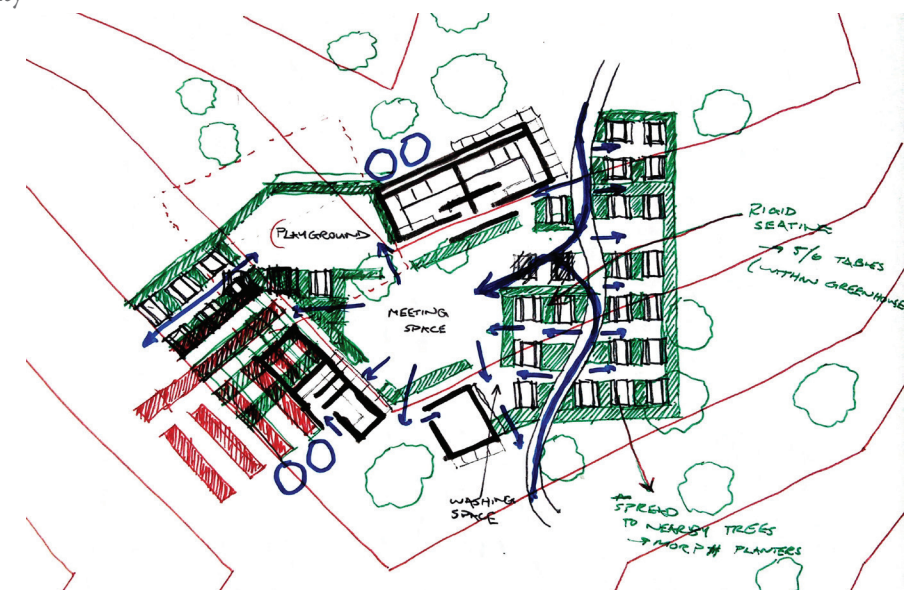


Figure 240: Taking all the functions, and running them along the contours, while also spreading out the seating to have larger picnic spots, and smaller seclusive ones for an array of users

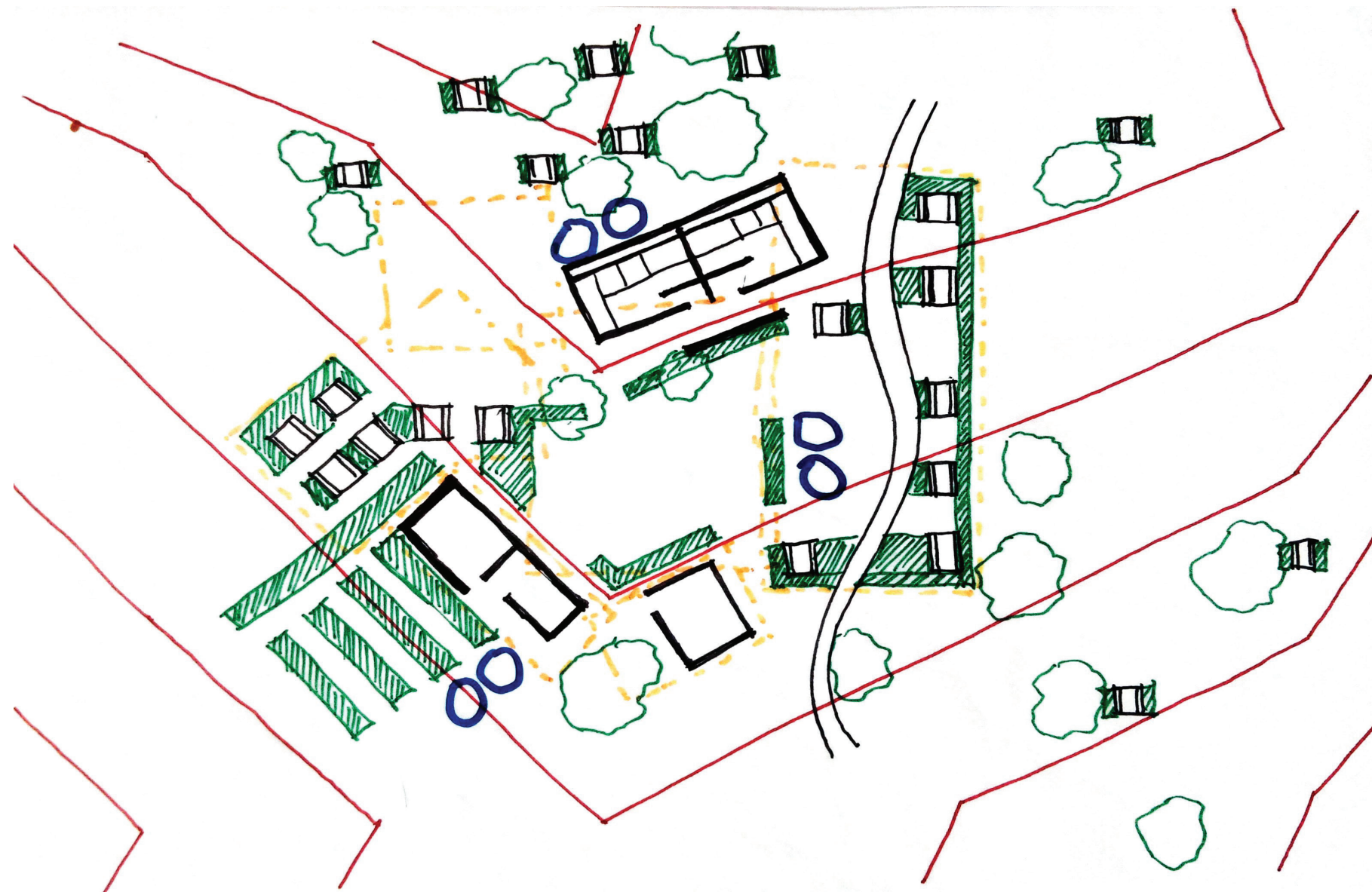


Figure 241: A final sketch plan (NTS) showing the full layout of the pavillion

The following spaces where allocated within the Research Facility, and proposed Pavillion:

Research Facility

Public Facilities

New Entrance
Nursery
Reception
Public Cafeteria
Public Pathway
Educational Displays
6 Public Bathrooms
Open Space for Parking and Markets

Semi-public Facilities

Library
6 Private Study Niches
Student Workshop
Private Reception
2 Conference Rooms and Storage
2 Elevators

Staff Facilities

10 Offices
Administrative Office and Storage
Security Office
Institutional Courtyard
Experimental Courtyard and Storage
Water Filtration System
12 Staff Toilets

Pavillion

Public Facilities

6 Public Toilets
Playground
Open Meeting Space
Braai
Washing Area
Private Picnic Tables
Larger Picnic Areas
Office for BOTSOC

Research Facilities

2 Storage Rooms
Greenhouse and Planters

7.6 Accommodation List

This section deals with the details which require a bit more attention, than just the simple and standard resolutions. Detail 8.1 deals with the central columns in the passageway, which catch water, and redirect this water to the soil they stand on. Detail 8.2 looks at the composition, make up and waterproofing of the various groundcovers. In this case specifically it uses the ideas formed by designing the planters, which is later applied to the experimental courtyard. Details 8.3 solves the issue found at the butterfly roof, which is not supported for the last four metres in the southern end of the building.

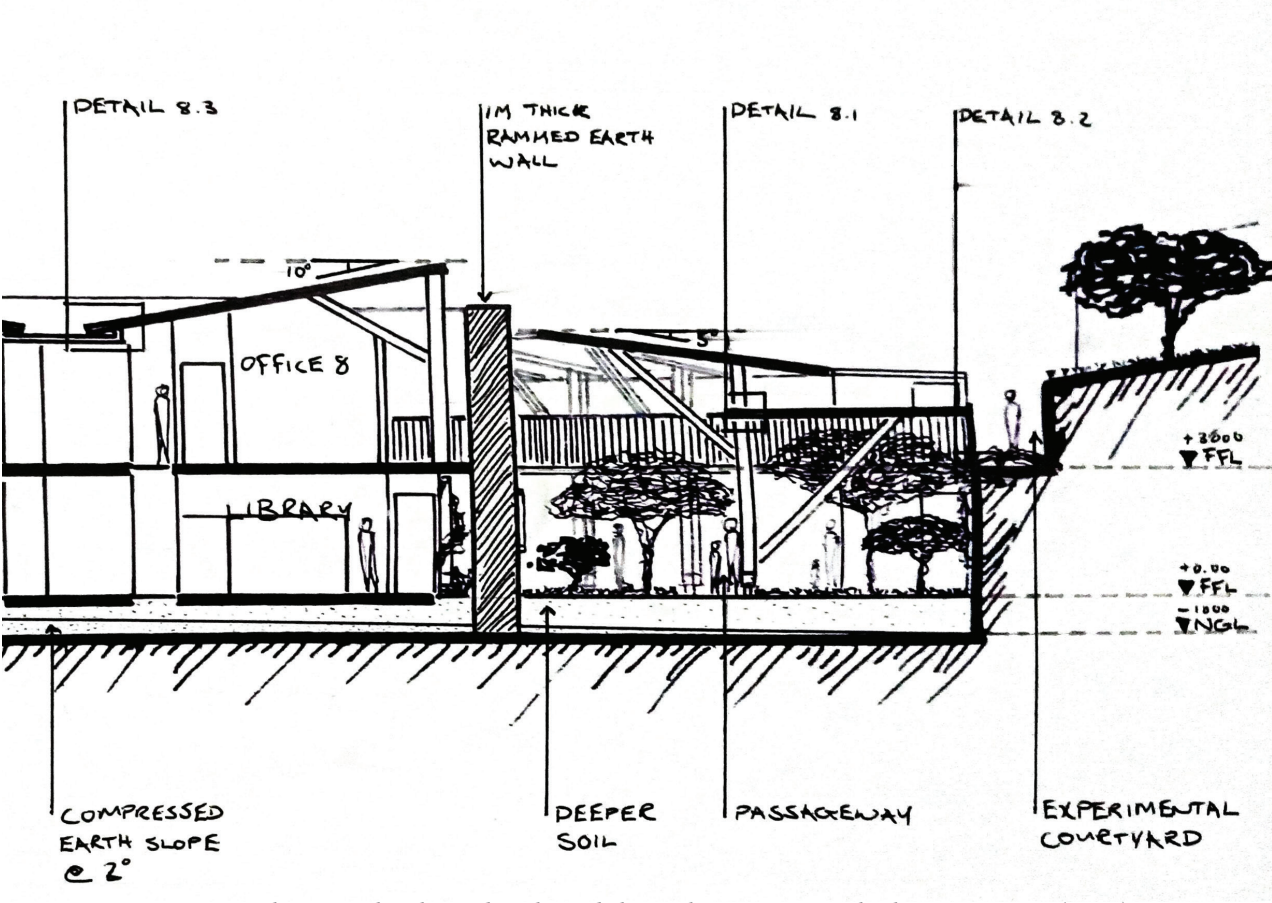


Figure 242: Section A showing the three details and their placements on the larger section (NTS)

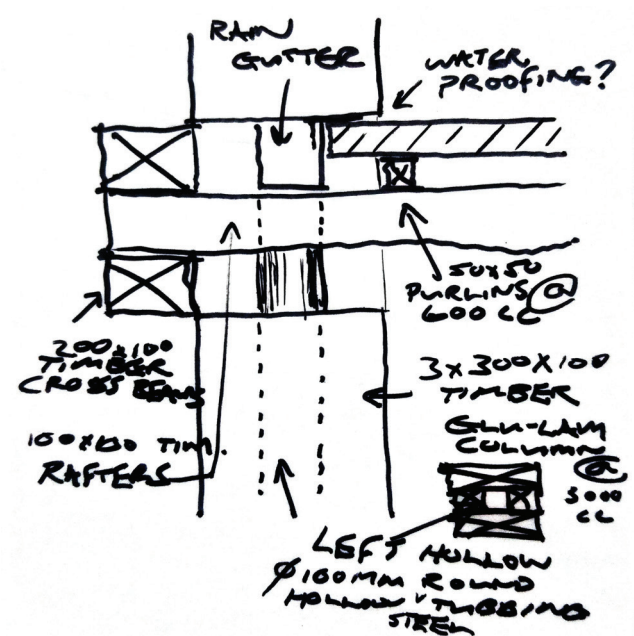


Figure 243: The initial sketch of a solution to the problem

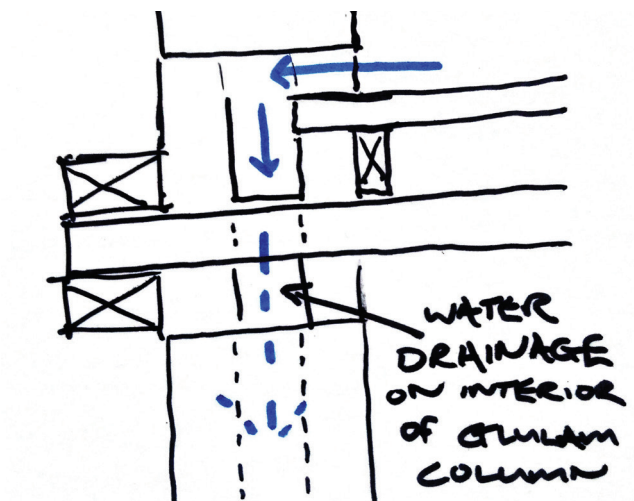


Figure 244: A sketch showing the understanding of how water moves when it comes to this detail

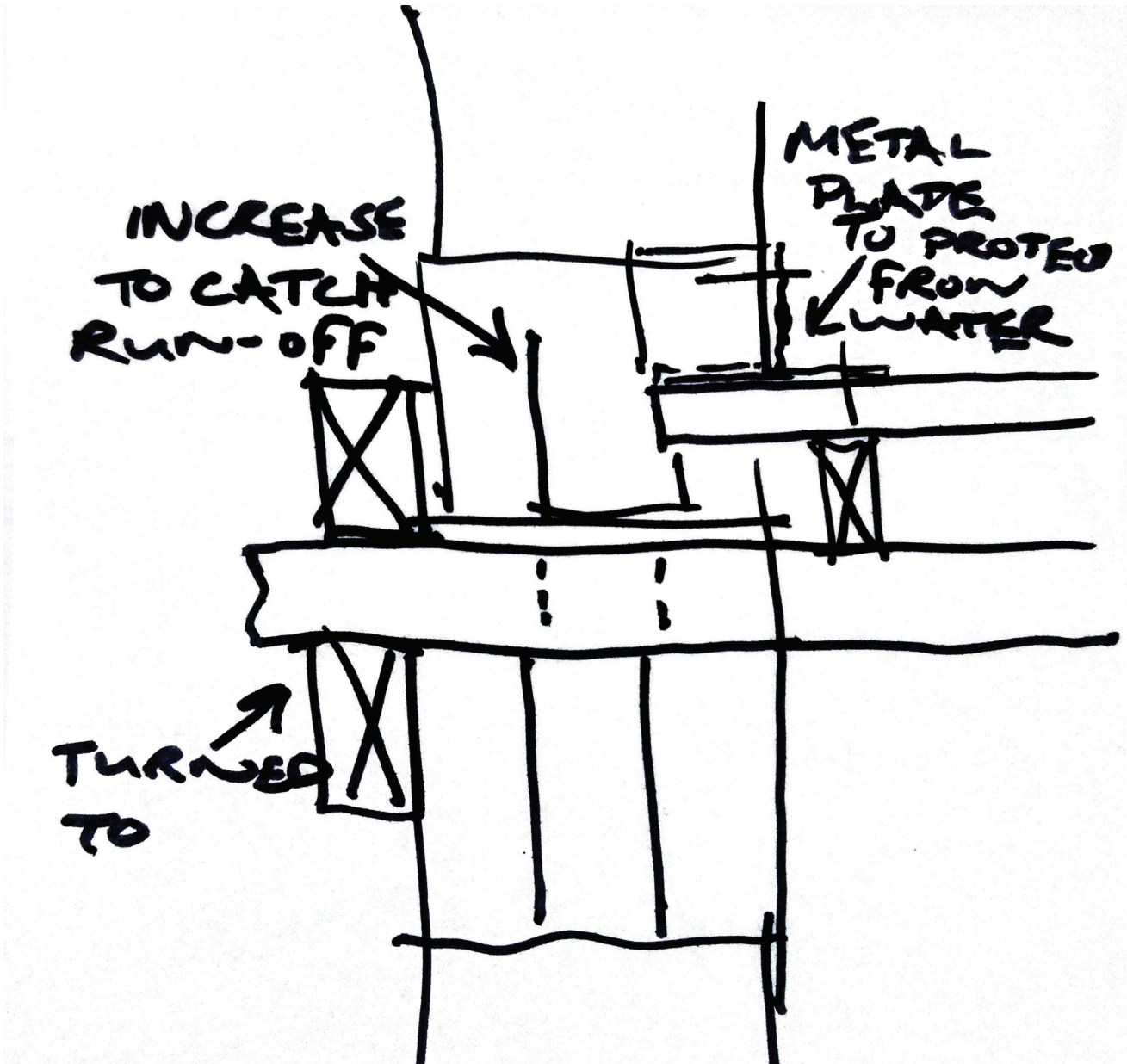


Figure 245: A final sketch of the detail considering the movement of the water

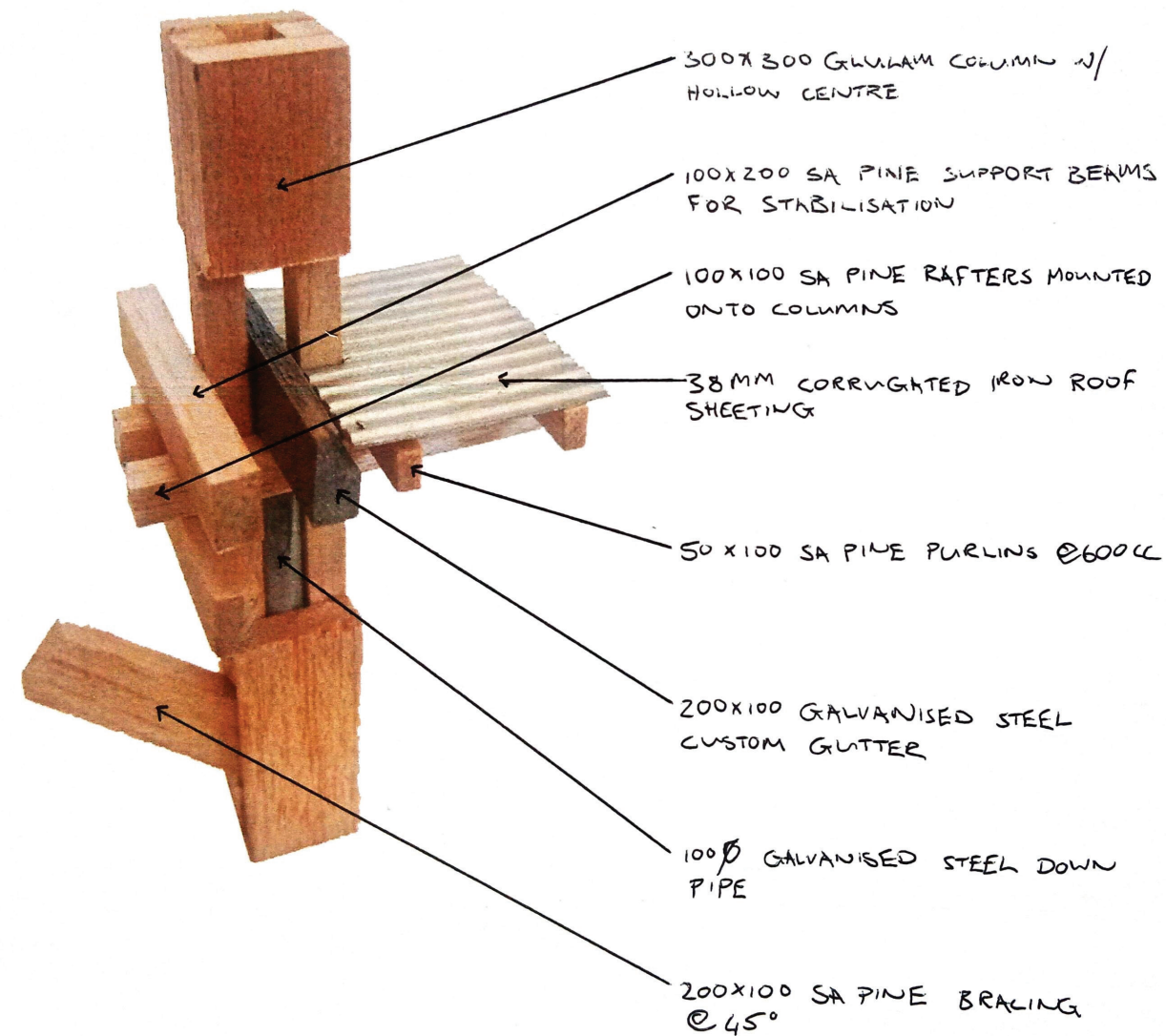


Figure 246: A photo showing the column detail built as a 1:20 model

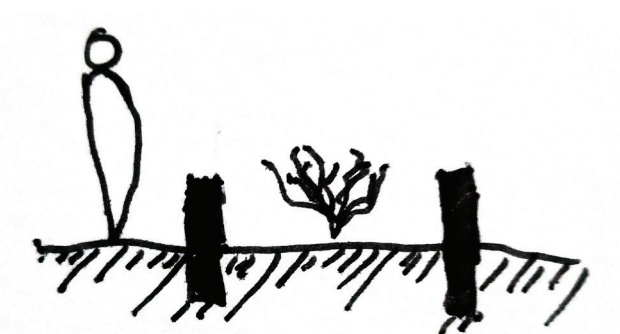


Figure 247: A sketch showing the basic planter detail

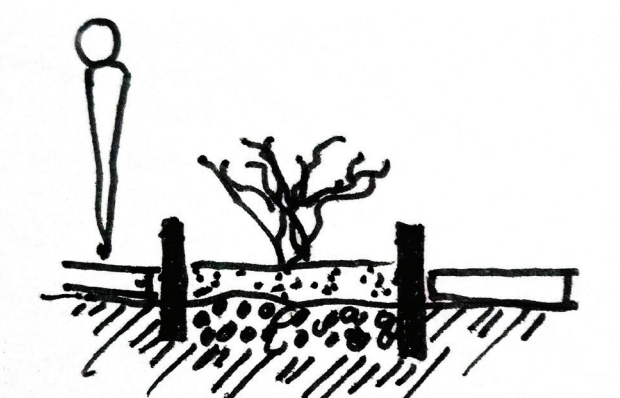


Figure 248: A sketch showing the introduction of the system used at the FPT University



Figure 249: A sketch showing one type of raised planters, which limit the size of the roots

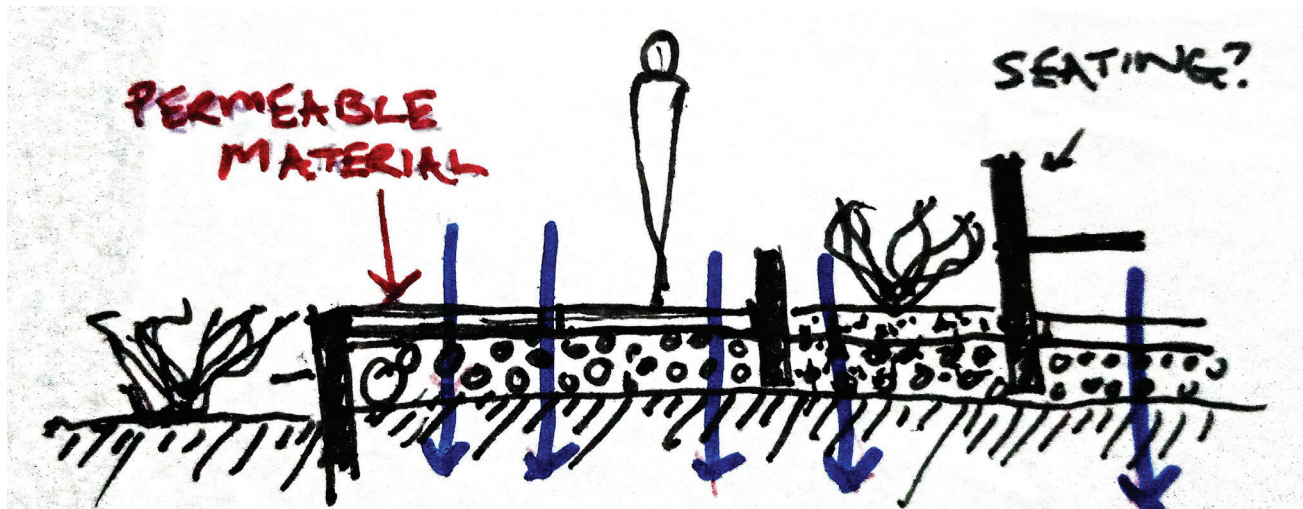


Figure 250: A sketch applying the planter system to site, in combination with the walkways and other used surfaces

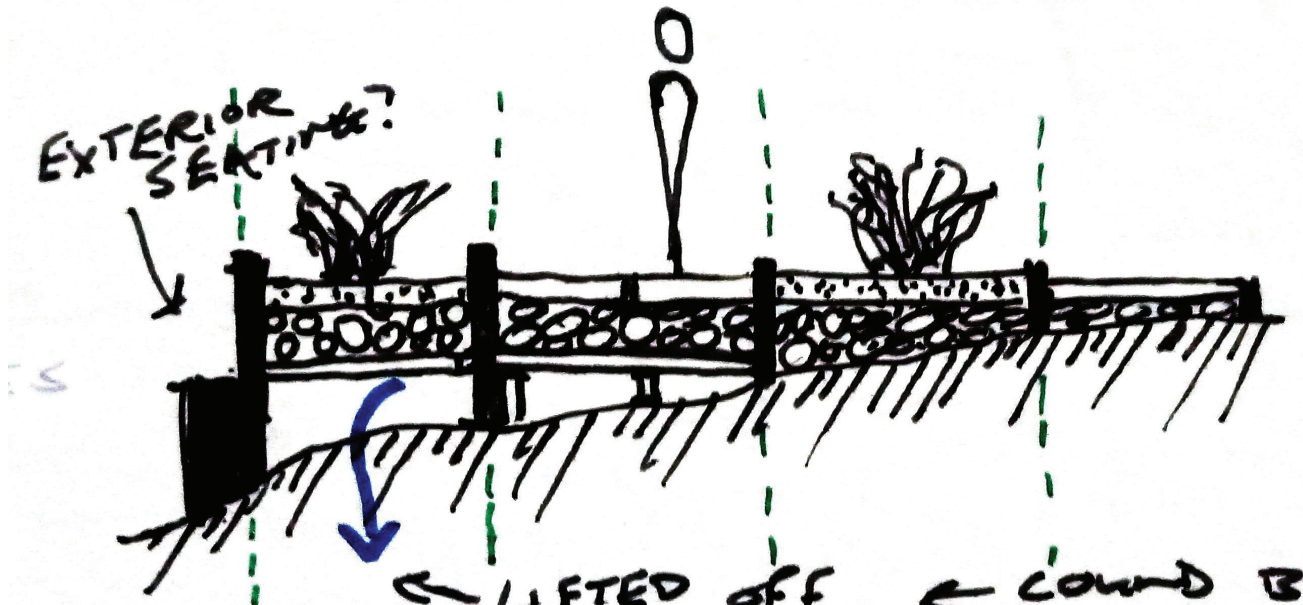


Figure 251: A sketch showing this same system applied to a sloped site

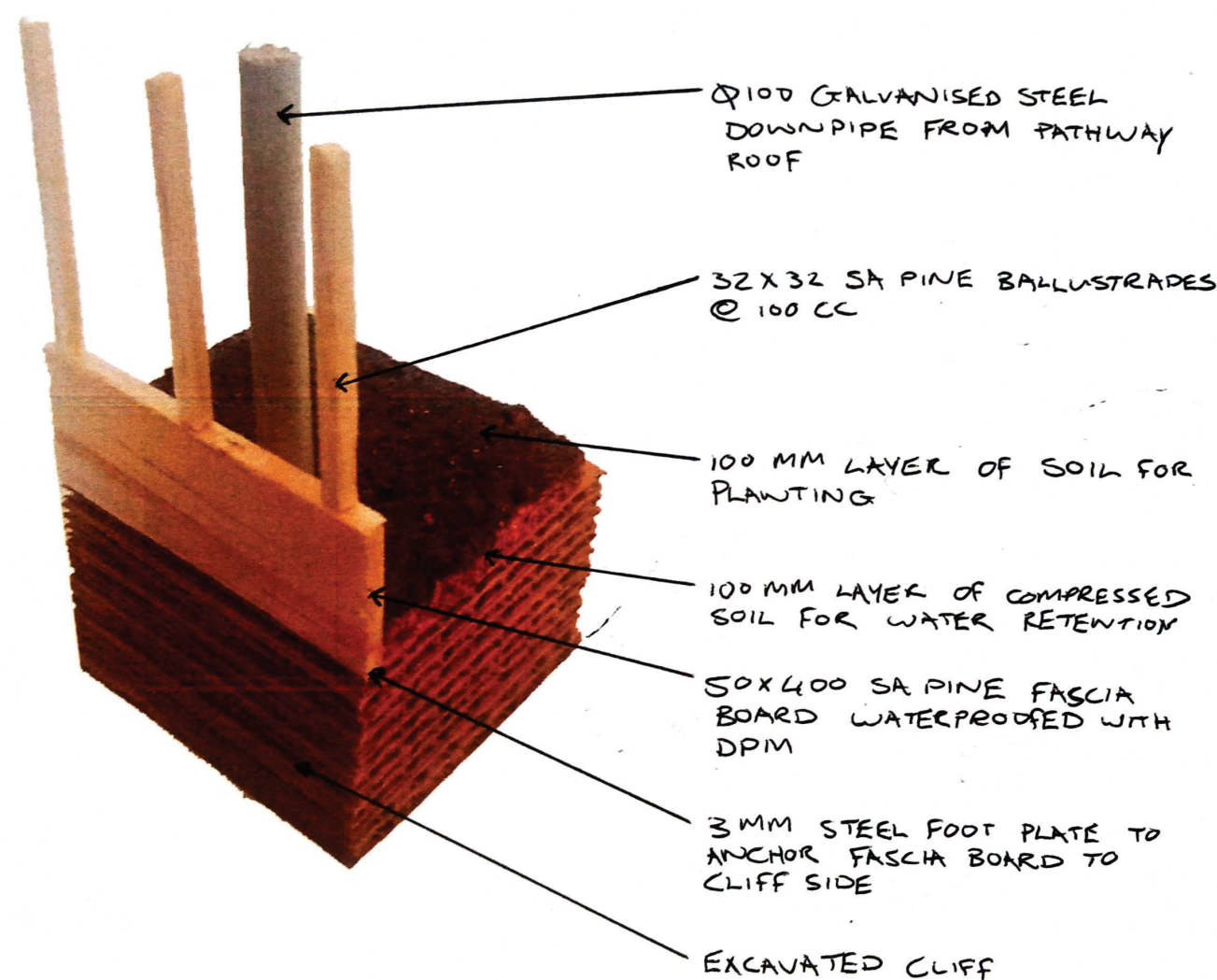


Figure 252: A photo showing the ground cover detail built as a 1:20 model

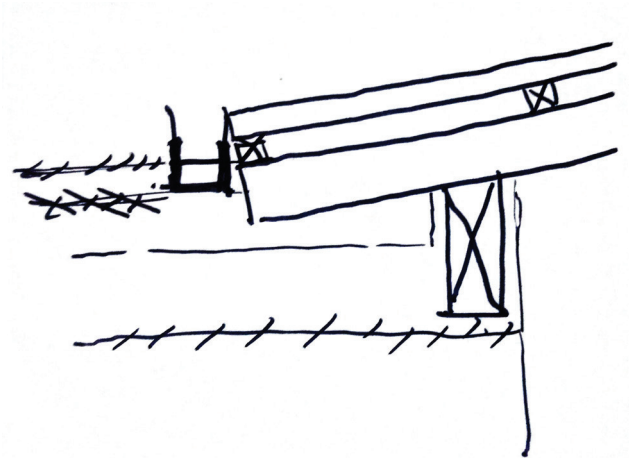


Figure 253: Attempting to understand the detail, and its problem

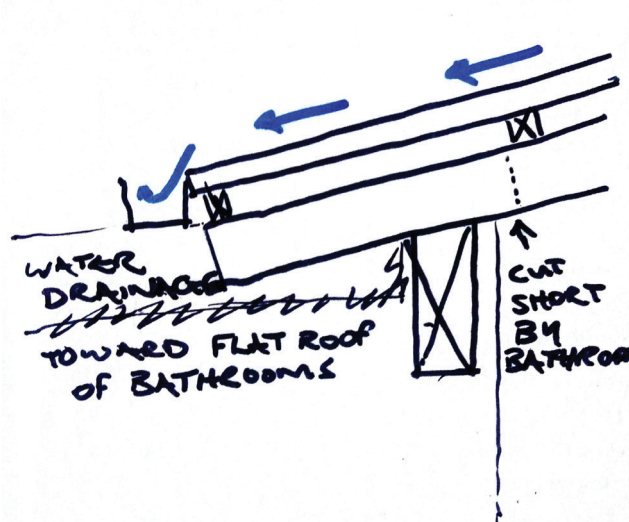


Figure 254: A sketch showing the water movement, and addressing some of the issues

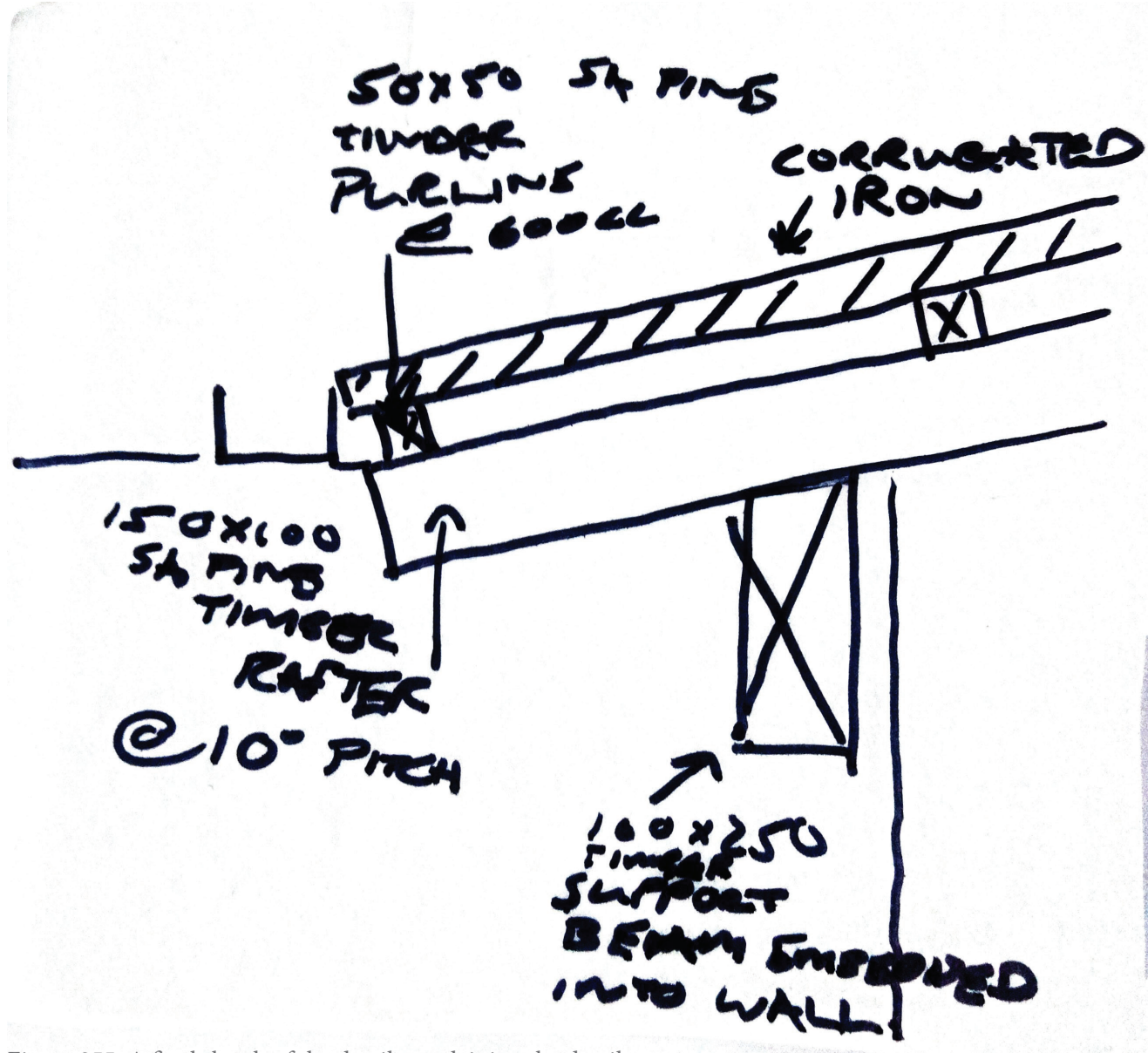


Figure 255: A final sketch of the details, explaining the detail

8.3 Resolving the butterfly roof

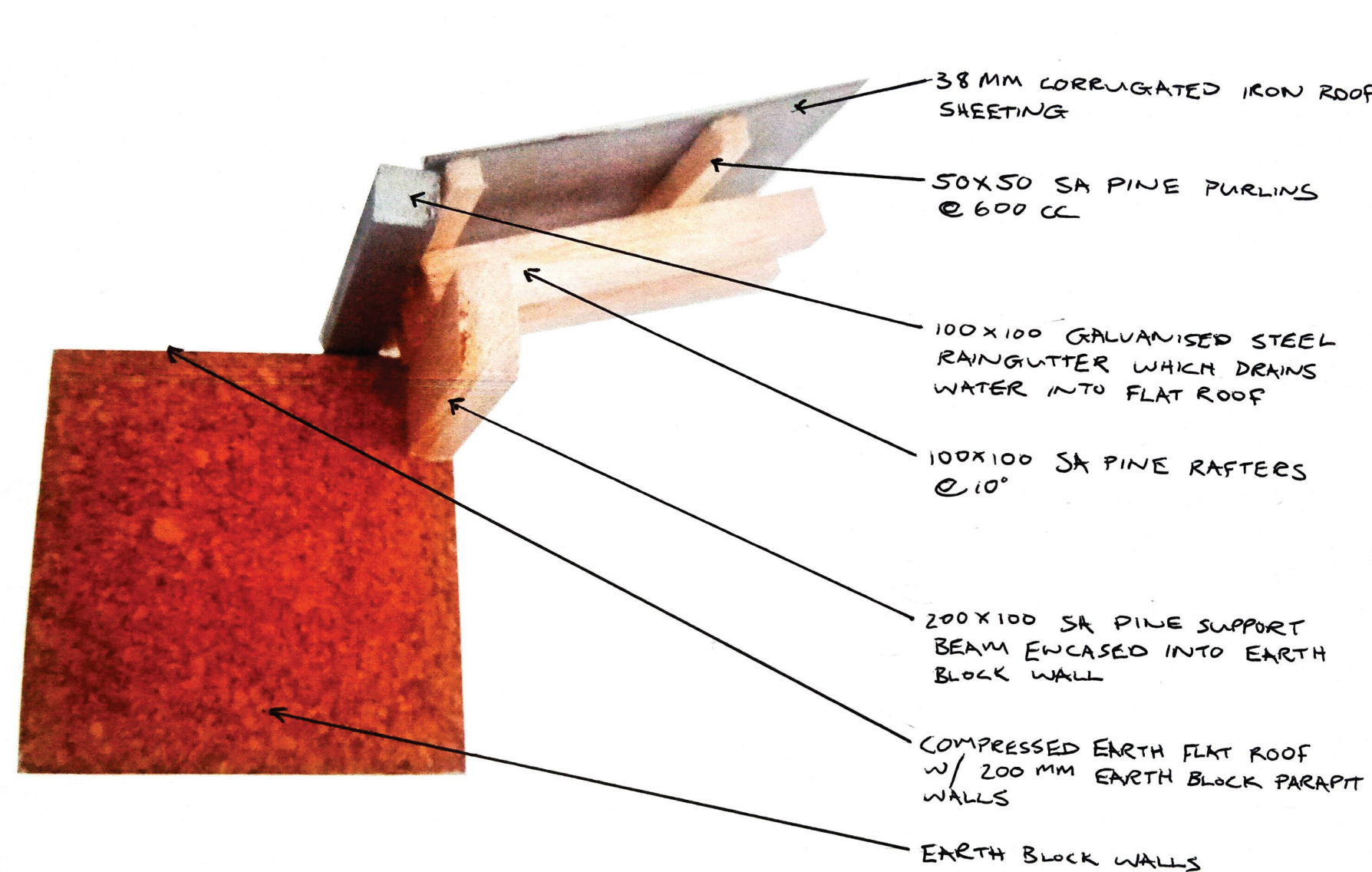


Figure 256: A photo showing the butterfly roof detail built as a 1:20 model



Nature is one of the most important elements on earth, and yet our relationship with it becomes more and more divided. Between the development happening all around cities and the active ecosystem domestication by professionals, there are several issues, often leading to even further issues. These have been known for decades, if not centuries, and attempts to solve these have been made. In the architectural sphere, the use of sustainable design approaches has increased drastically, and have become extremely favoured design approaches by a vast majority of people. It is however, important to re-evaluate the effectiveness of these design approaches, especially if various aspects of sustainability are ignored or even overlooked. It is as though we are taking out the gears of a clock, removing a few, and putting the gears clock back together. It might work temporarily, it might work just a tiniest bit slower or it might only work in theory. We cannot, given the time, expect these clocks to function properly and as intended. Similarly, we cannot expect the ecosystem and nature to function, when destruction is happening within soils and within the larger atmosphere.

It is therefore rather straightforward that a comprehensive understanding of the entire ecosystem needs to be kept in mind. By taking the idea of nature as a client, the theory of mutualism proposes just that. The same way we give spaces to ourselves, which are spacious, comfortable, functional and feasible, we too need to give these spaces to the natural environment. The open space next to the National Botanical Research Institute in Windhoek, Namibia offers a great canvas for the testing of the theory. Not only is it one of many unfinished/ non-developed/ abandoned projects and spaces, but further lends the opportunity to focus specifically on the issue of the importance of soil, and the appropriate facilitation of the various natural elements.

Designing such a facility therefore opened the possibilities of extreme natural integration to due the clients key interests. Using a site which was already worked on, or dug out, will always create issues, as the refilling would offset the issues of not having appropriate topsoil elsewhere. Further issues to explore would be the mutualistic approach to designing for a different client, with different programs, or the adaptive reuse of an already existing structure. It is clear however, that certain compromises will always have to be made. Much like the spider not eating the frog, however, some compromises are worth it though, as they are way more beneficial in the long run, than they are detrimental.



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