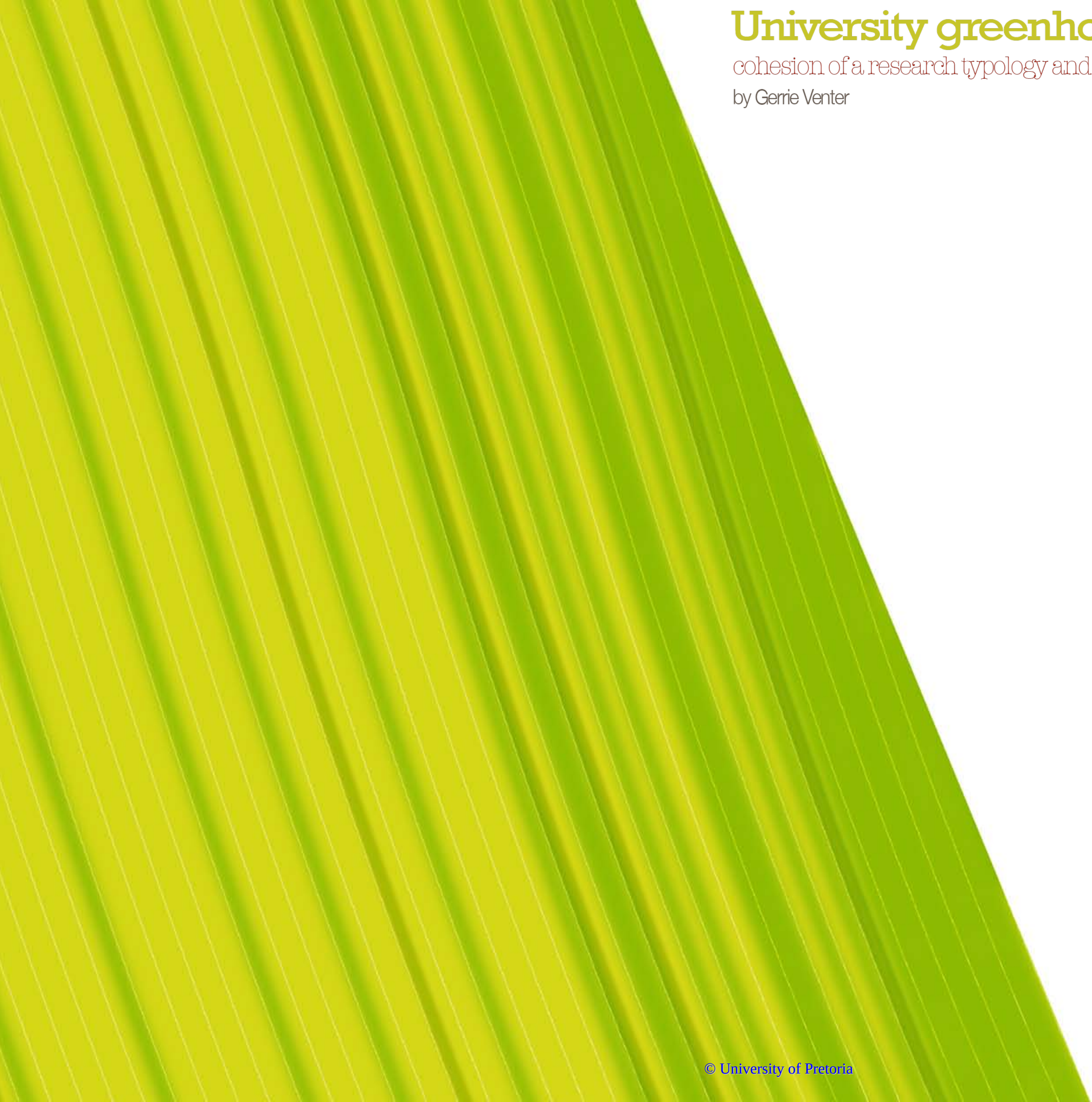
University greenhouse and Botanical park

cohesion of a research typology and the metaphysics of space

by Gerrie Venter



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Submitted in fulfillment of part of the requirements for the degree of **Master of Architecture**
in the Faculty of Engineering, Built Environment and Information Technology

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“Like the rain that’s falling,
Like the wind that’s blowing,
Like the sun upon my face
I feel the warmth in your embrace
You are everywhere.”

Thank you to my Christ and Savior. For You led me to see that creativity is one of the greatest gifts of all, to be used with humility, integrity and responsibility.

Special thanks to:
My family, Ewa Krzeciasz, Marc Jooste, Carina van Heerden, Dominique Mulder, Carlu Swart, Louise Honck, Andre and Eleanore Steenkamp, Karl Vogel, Prof. Barbara Jekot, Raymund Königk, Rudolf van Rensburg, Nico Botes and Karlien van Niekerk for all their wisdom, support and encouragement throughout the year.

The class of 2008

Image on the right: Transverse section through a piece of living Mahogany tree branch enlarged 400 times. It shows bundles of tubular cells that makes up the tree’s vascular system, responsible for carrying water and nutrients from the soil. Drawing by author

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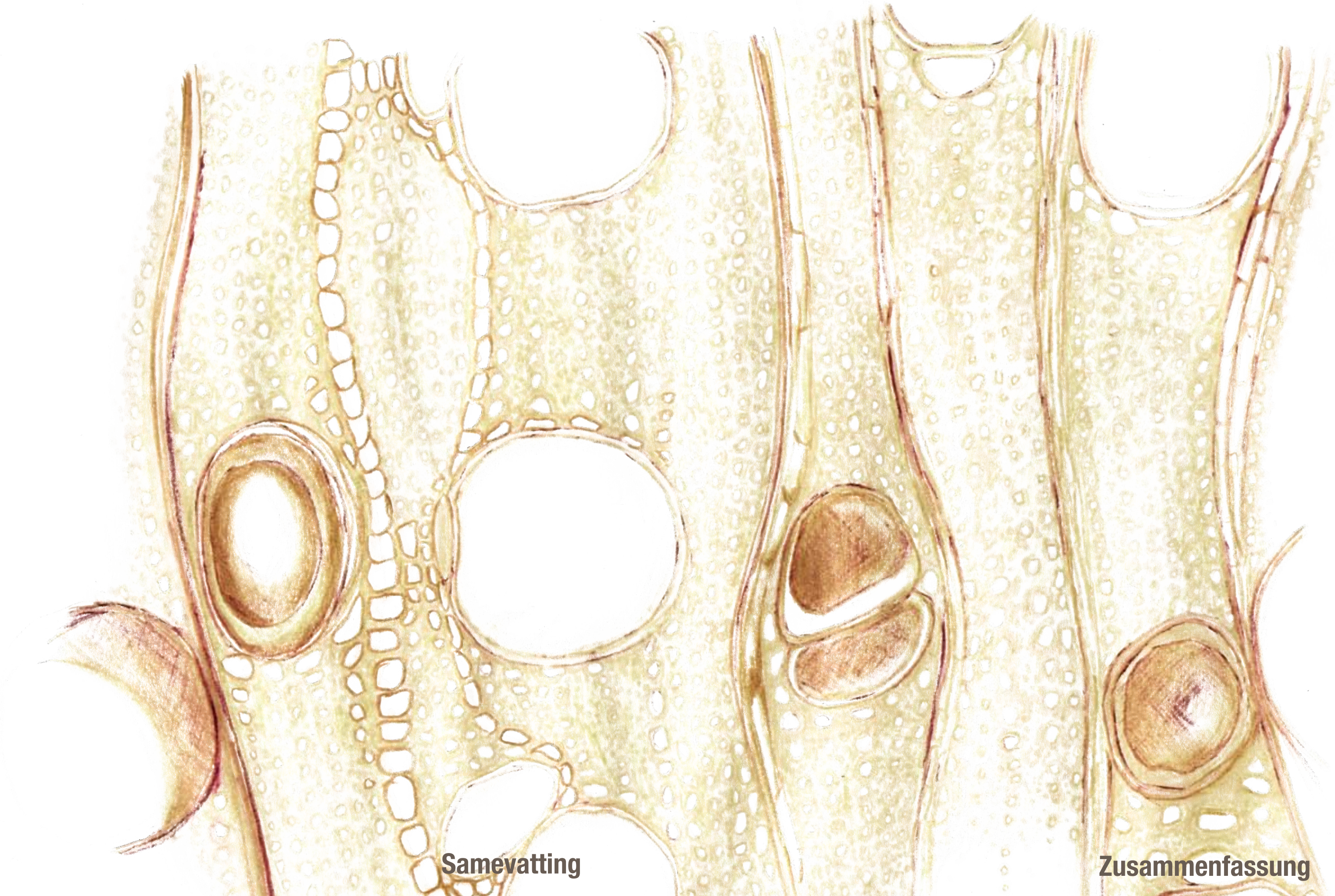

Abstract

Architecture has a dualistic social responsibility. To provide relevant buildings with appropriate function and planning that will accommodate user needs, as well as providing habitable environments and spaces that will have positive influence on peoples daily routines. This will allow users to freely dwell within their environments and create a positive community atmosphere.

It is the aim of this dissertation to investigate the social responsibility of architecture and how ordinary spaces and buildings that call for pragmatic design solutions can also enter into the realm of the metaphysical spatial experience and to find cohesion between the two.
The selected project is a glasshouse complex and plant containment research facility within the Botanical gardens at the University of Pretoria, South Africa.

Samevatting

Argitektuur beslaan oor 'n dualistiese sosiale verantwoordelikheid. Eerstens moet die relevante geboue met 'n geskikte funksie voorsien word asook die regte beplanning wat aan die verbruiker se behoeftes voldoen, en tweedens moet daar 'n bewoonbare omgewing en ruimte verskaf word wat 'n positiewe invloed op die verbruiker se daaglikse roetine sal hê. Hierdie verantwoordelikheid sal die verbruiker toelaat om hul omgewing vrylik te bewoon en 'n positiewe gemeenskapsatmosfeer te skep.

Die doel van hierdie verhandeling is om die sosiale verantwoordelikheid van argitektuur te ondersoek, asook die wyse waarop gewone ruimtes en geboue wat pragmatiese ontwerpsoplossings verlang ook die terrein van die metafisies-ruimtelike ondervinding kan betree en 'n verband tussen die twee paradigmas te vind.

Die uitgekose projek is 'n glashuiskompleks en plantinperkingsnavorsingsfasiliteit binne die botaniese tuine by die Universiteit van Pretoria, Suid Afrika.

Zusammenfassung

Die Architektur trägt gesellschaftlich dualistische Verantwortung: es ist eine Schaffung von Gebäuden, die räumliche Bedürfnisse von Benutzern erfüllen, sowie auch einer qualitätsvollen Umgebung, die tägliche Routine von einer Gemeinde positiv beeinflussen wird. Es handelt sich um eine freundliche, gemeinde Atmosphäre zu schaffen.

Dieses Projekt hat zum Ziel die Gesellschaftsverantwortung von der Architektur überprüfen. Es wird untersucht, wie vernünftige Räume, die eine Antwort für die funktionelle Bedürfnisse sind, gleichzeitig eine metaphysische Erfahrung kreieren können. Die Idee ist ein Zusammenhang zwischen diesen zwei Ansätze zu identifizieren.

Das ausgewählte Projekt ist eine gegenwärtige Gewächshäuseranlage, Forschungsanstalt und botanischer Garten auf dem Gelände der Universität Pretoria

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introduction/ brief

Real world problem and background

Currently, the University of Pretoria stands as a gated community within the Hatfield precinct. The rise in fuel prices and living costs in South Africa demands a renewed emphasis on the development of public transport within Pretoria. The Hatfield precinct has been identified as one of six development cores in terms of the Tshwane Metropolitan Spatial Development Framework (MSDF). It will also act as host to one of the three Gautrain Rapid Rail Link stations in Tshwane. Current and future developmental forecasts for the area foresee large-scale social and economical change within the area. The aim of the MSDF is to integrate certain parts of the university with Hatfield, allowing certain functions of the university to become transparent to the public and to invite participation. The botanical garden at the university is located on its Northwestern boundary, adjacent to a proposed green route extending along University Road and connecting Magnolia Dell public park with the Hatfield Central Business District (CBD).

Conservation, education, research and community service – these are the intentions and rewards of a successful botanical garden. The University of Pretoria has had the privilege to sustain its own botanical garden, or the Manie van der Schijff Botanical Garden as it was named in 1986, since 1924. Located in the western area of the campus grounds, it currently contains more than 3000 plant species in an area of more than 3,5 hectares.

The garden is run under the auspices of the Department of Botany and is mainly used as a research facility for its students.

Possible client and requirements

For the type of project proposed by this thesis, the possibility exists that a consortium of three parties could make up the client. Firstly, the University of Pretoria, as it controls all developments on campus and approves all new initiatives according to an agreed Integrated Spatial Development Framework (ISDF) for the campus. Key decision makers on the university team may consist of horticulturists involved in the Department of Plant Science, the caretaker of the botanical garden, and Technical Services. Secondly, due to the possibility that the project might extend onto municipal property, the City of Tshwane Metropolitan Municipality and the Department of Public Works will also have to be included in the decision making process. And thirdly, the Gautrain Development Board will also have to form part of the trio due to the site's close proximity to the Gautrain Rapid Rail Link.

For the purposes of this master's dissertation, a study area within and around the university premises was established by the class group of 2008. This area deals with various aspects of possible future developments, with specific areas chosen for intervention. An overall vision was determined to, over time, partially integrate the University of Pretoria with the Hatfield precinct to form a "University City". Where the botanical garden is concerned, neither the City of Tshwane nor the Gautrain Development Board has proposed for this specific site to be integrally developed within the Hatfield precinct. Therefore, the Department of Plant Science provides the only known immediate requirements for this specific terrain within the botanical garden. In a recent discussion with Mrs. Lorraine Middleton (caretaker and researcher at the botanical garden) a list of desirables and current activities was communicated:

- **Access**: Access to the garden is limited and is of such a nature that many people are not aware of it.
- **Research**: The garden serves mainly research and educational purposes for students studying botany, plant science and agriculture. It also conducts research in plants with medicinal value (Wetsren medicine and etno-botany) and houses a herbal garden used by the students of the Department of Consumer Science.
- **The glass house**: The site contains a temperature controlled glass house constructed in 1989. It is mainly used for research and the germination of different plant species. The facility was mainly developed in accordance with a Eurocentric approach and therefore the current technologies are already outdated and not suitable for the Pretoria climate. A large portion of the glass house is also shaded which reduces its capacity for certain tests to be conducted.
- Further development of **themed gardens**: The garden sprawls over a wide area along the whole western region of the campus.
- A wide variety of **protected trees** that attracts an array of birds and butterflies
- A **commemorative garden** with plaques to honor people who have had a significant influence in the development of the garden
- A **monocot garden**
- A complete collection of **Cycads**
- A s**ucculent** garden

Goal and objective:

The aim of the proposed project is to invent a platform for the integration and understanding of an already established ecosystem of organisms and plants on a historical site. The artificial human structures must be able to germinate from the earth like the plants that surround them and be in unison with their social context. Human processes in these structures, like movement, education, research, social gathering and learning, must be juxtaposed with the natural processes of the garden, but must simultaneously be able to draw from the intelligence it embeds and the metaphysical characteristics that the garden imposes.

Sub problems:

- How will this structure address the available technologies and paradigms contained in it?
- Does this facility need to address the issue of sustainability?
- How will the structure respond to its physical, economic and social context and be relevant towards it?
- How will this building respond to the historically significant buildings surrounding it, and the site on which it stands?
- How can access to the terrain be improved and what decisions concerning pedestrian and vehicular access should be made?
- Will the public become integrated with this facility and if so, to what extent?

Assumptions and delimiters:

This study accepts various proposals that were made by third parties and governmental organizations concerning the future prospects of the Hatfield precinct.

Although the study investigates various aspects such as theories on consciousness, the physiological working and composition of plants, and theories on intuition, it has to be understood that all of these are just laying the foundation of an informed design approach for an architectural dissertation.


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theoretical discourse

2.1 Credo

2.1.1 Community relevant architecture and social responsibility

Fourteen years after the liberation from South Africa's Apartheid regime, the country is still hampered by many economical and sociological problems. One of the most serious is the HIV pandemic and the effect it has on impoverished communities. South Africa has also been witness to an astonishing rate of urbanization since 1994, and this has placed enormous pressure on the economy and infrastructure of cities. Vast numbers of people are unemployed and as a result many of them are living on the breadline. Together with the abovementioned factors, the unpredictable natural climate of South Africa and the impending recession in many global markets are also placing a lot of pressure on the local economy, with rising interest rates and escalating fossil fuel costs ultimately affecting food prices directly.

In a recent study published online by Siegfried (2008:2) on the Integrated Regional Information Network (IRIN), a humanitarian news and analysis service of the United Nations (UN), it was shown how many people in South Africa are dependent on charitable associations like the Nanga Vhutshilo Positive Living drop-in center in Soweto, Johannesburg. Many of these institutions are orphanages providing meals for families (mainly children) who have lost their breadwinner as a result of HIV/AIDS.

One of the current problems that result from population growth and changing diets in developing countries such as South Africa is a drop in the food supply. This has developed as a result of erratic weather fluctuations, increased fertilizer prices due to inflation, and the percentage of agricultural land now set aside for the biofuel industry. The rising food costs are exacerbating an already difficult problem for charitable organizations, which are unable to provide enough food for people who are already dependent on them.

As a country where secondary industries are underdeveloped, South Africa has also seen its currency gain strength against larger currencies such as the United States dollar. This has reduced the prospects for exporting primary products such as maize and wheat leaving farmers with a large surplus of food supplies that can not be sold on the local market for a high enough profit to cover farming costs. Many farmers have thus opted for setting aside their farmland to pursue biofuel production that guarantees a much more stable revenue.

What role has architecture to play in all of the above-mentioned sociological issues? With the number of people living in cities at this time being higher than ever, many new initiatives and projects proposing the introduction of urban agriculture have started to emerge in developed nations. Addressing the issue of the global food crisis directly, multi-functional office and residential buildings make use of the most current greenhouse technologies and incorporate them within the building envelope. A project such as the vertical Skyfarm (Fig. 2.1) in Toronto, Canada is predicted to provide enough food for the population of the entire western side of the downtown area. Other such projects include La Tour Vivante in Rennes, France (Fig. 2.2-4). Here, the architects conceived the building as an *"…autonomous ecological machine…"* (Jodidio, 2007:94) where internal greenhouses serve as a link between different building functions such as offices, retail and residential.

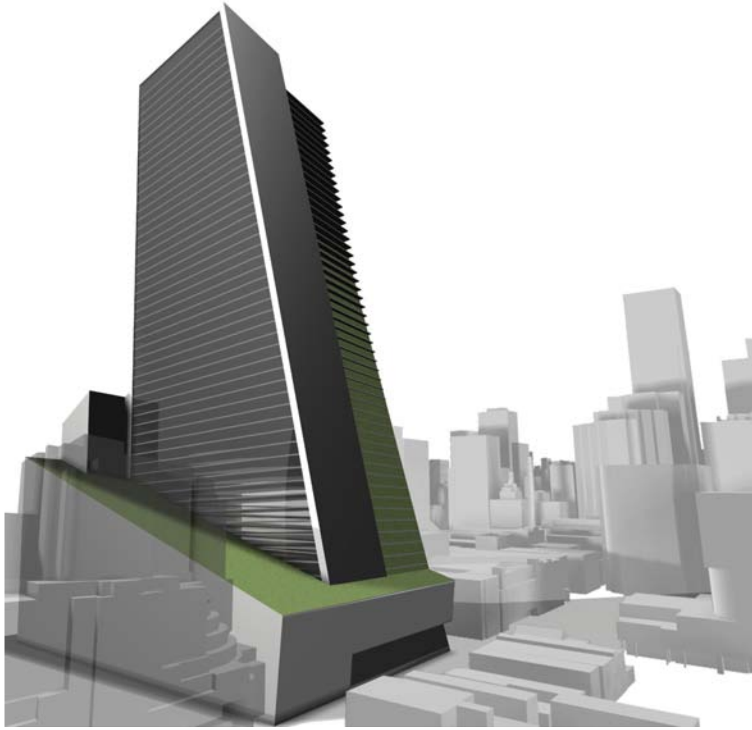


FIG 2.1 Skyfarm building, Toronto, Canada (Alter 2007:1)

FIG 2.2 La Tour Vivante, Rennes, France (Jodidio 2007:95)

FIG 2.3 La Tour Vivante, Rennes, France (Jodidio 2007:97)

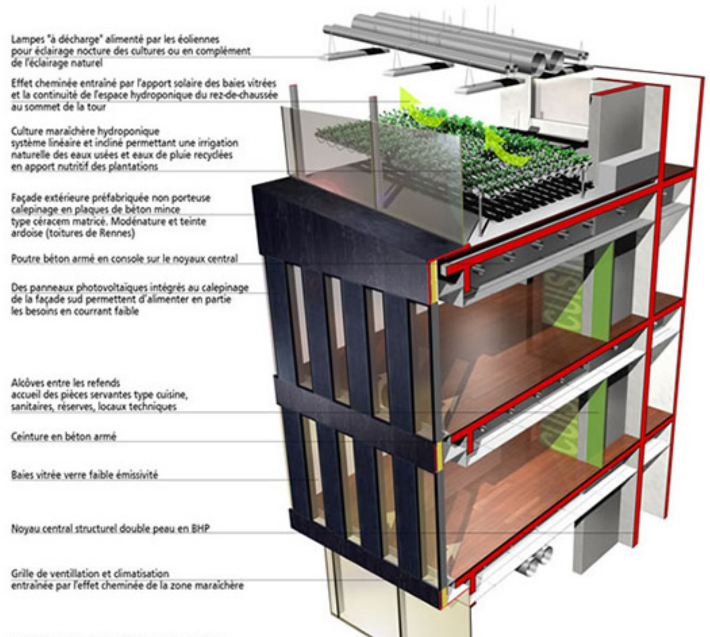


FIG 2.4 La Tour Vivante, Rennes, France (Jodidio 2007:96)

In a recent article in the Science journal, Clery and Vogel (2008:752) discuss the feasibility of such projects. The predicted outcome of vertical farms promises that they can produce more food than current traditional crop production at a fraction of the cost. Well-designed greenhouses only use up to 10% of the water and 5% of the land required by traditional farming fields. Initially the costs involved in urban greenhouses can exceed those of traditional farms, but as fuel prices are on the rise and greenhouse technology becomes more readily available, the prospects for urban greenhouses appears to be more favorable due to the possibility that transport costs can almost be eliminated.

As a further premise of economical feasibility for urban farms, the water and “soils” used in a hydroponic greenhouse system are to a large extent completely recyclable. For example, the rockwool fibres commonly used in hydroponic greenhouses are costly to recycle and undesirable to be used as landfill material. A Canadian company, SRI Petrochemical, has developed a cellulose type of rockwool material that can be re-used several times by utilising conventional recycling technology (Brodie, 2006:1).

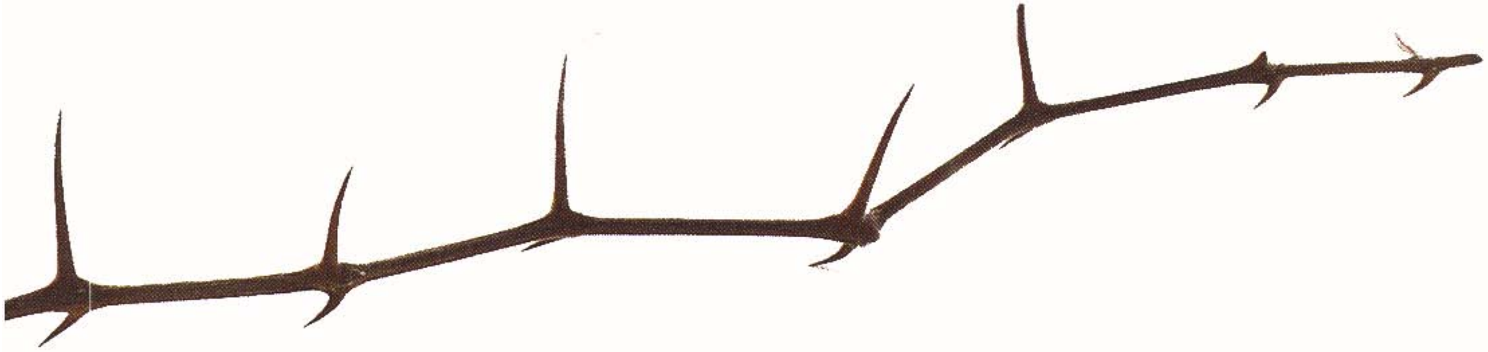


FIG 2.5 Buffalo thorn tree branch, Ziziphus mucronata, significant symbol in Nguni African legend (McCallum 2005:3)

FIG 2.6 Eames Aluminium side chair, part of the Eames Aluminium group designed by Charles and Raye Eames in 1958 (Conran & Bond, 1999: 113)

According to Clery and Vogel (2008:753), there are many favourable predictions for urban farming. But its Achilles’ heel, when it comes to promoting the paradigmatic change away from traditional farming that it can bring, lies in the fact that more research needs to be done in order to convince the authorities that it represents a step forward. Comparatively, as with years of aviation and many aircraft incidents later, each accident has provided a platform for “lessons learnt” for the future of aviation, resulting in the safe flying conditions that exist today. Clery and Vogel propose that hydroponic urban greenhouses can prove to be beneficial for the developing world, and in sub-tropical regions such as South Africa the availability of ample sunlight makes the possibilities even more promising, as the use of greenhouses can give worn-out soils a rest. The recycling of human waste as nutrient supplements for plants is also a possibility, with the appropriate technologies already available. Professor Jan Broeze, an agricultural scientist at the University of Wageningen, reinforces the above by stating that, in order for the concept of urban farming to succeed, a remarkable breakthrough in hydroponic food production technology needs to be achieved, and universities need to conduct tests with various plant specimens, genetic modification of seeds, and various growing-out techniques.

It is therefore inevitable that, in areas where the global food crisis is having an impact, universities will have to develop facilities and research centers to encompass and develop the relevant technologies as stated above. This will allow universities to be socially relevant as institutions and supplement initiatives such as urban farming in order to positively impact communities and fight global poverty.

2.1.2 Architecture and metaphysics

A research facility on a university campus runs the risk of being planned as a completely utilitarian compound only fulfilling the needs of the research functions being conducted there. If the goals of a possible University City - as discussed in Chapter 3 - are kept in mind, the fact can’t be ignored that university faculty buildings need to become architecturally more responsive towards their environments and need to entice participation by the local community.

How will this type of architecture respond and what kind of architectural fabric needs to be introduced? Joe Noero (2005:8) states that in order for architecture to move forward one has to recognize that it has to grow from the *needs* and *expressions* of the man on the street, in order to claim for itself the title of public art. The above looked at what the most urgent needs of a community in a developing country such as South Africa are, but what kind of architectural expression is being referred to? Should designers express the character of individuals in a society that are intrigued by the stories of Simon Veil and his memoirs on surviving the Holocaust, or is it the function of designers to just fuel a consumerist society’s appetite, and prickle and stimulate the senses of a majority that is already numbed by artificial food flavourings, entertainment and the media? This is what Peter Zumthor refers to when he says that:

“…everything merges into everything else, and mass communication creates an artificial world of signs” (text quoted from the writings of Peter Zumthor in Burns, Quiros & Repp, 2001:2).

Arriving at an architectural design morphology involves a constant process of finding the balance between the physi… …re and the meaning it will give to the area in which it is erected. Physically, architecture is a parametric entity built within … …xt, and relying on building technology and human ingenuity to follow to the rules of physics to shelter its users from the elements. The interior and exterior spaces a building must provide are mainly program driven, depending on building typology and user needs. Animals and plants, on the other hand, can transform their bodies in response to their needs, adapting to environmental changes and movement or locomotion (Badarnah *et al,* 2008:147). Robert Aish (Aish & Menges, 2005:53) notes that the essential abstractions that designers need to employ during the design process are geometry, composition and algorithmic thought.

Addressing how different people perceive the building envelope or experience spaces comes down to the same dichotomy of finding a balance between the rational and irrational experience of space. People are different, geometry differs and spatial parameters or characteristics differ. Designers need to create structures that are not just utilitarian, but provide an experience, a metaphysical state of awareness. People are intelligent beings, but they are also spiritual beings with arguably the majority believing in a Creator, a supernatural governing energy or God. They write poetry and paint obscure lines on canvasses to express their emotions and thoughts. Please see Table 2.1.

Buildings have a remarkable similarity to plants in the sense that they are static objects containing dynamic processes. Plants must deal with attacks and environmental constraints that surround them. Plants stay static in one position and have therefore over the millennia intuitively evolved exceptionally intelligent methods of manipulating everything around them in order to survive.

According to a legend of the Nguni African tribe, the thorns of Ziziphus mucronata, more commonly known as the Buffalo thorn tree (Fig. 2.5) that has young twigs that zigzag across the branch, teach man something about himself: that he must look ahead to the future, but must never forget where he came from (M^c^Callum, 2005:3).

This is who man is. He will always try to find ways of communicating his deeper thoughts through the objects of everyday life.

Ian McCallum (2005:56) proposes the idea that there has never been a golden age of ecological symbiosis between humans and nature, but rather that humans are evolving towards an awareness of ecological intelligence. He refers back to the idea that humans are animals and that they are earthly beings who came from the earth and will return to it again. All humans carry their history within them and they are a mindful, poetic species who are keepers of their zoo. He argues that humans have become creatures of their own undoing. They have placed themselves at the apex of creation and should come down from that peculiar pedestal. McCallum also enforces the idea that although humans are biological beings, they are also psychological entities, acknowledging the study of the conscious and unconscious that makes up human nature.

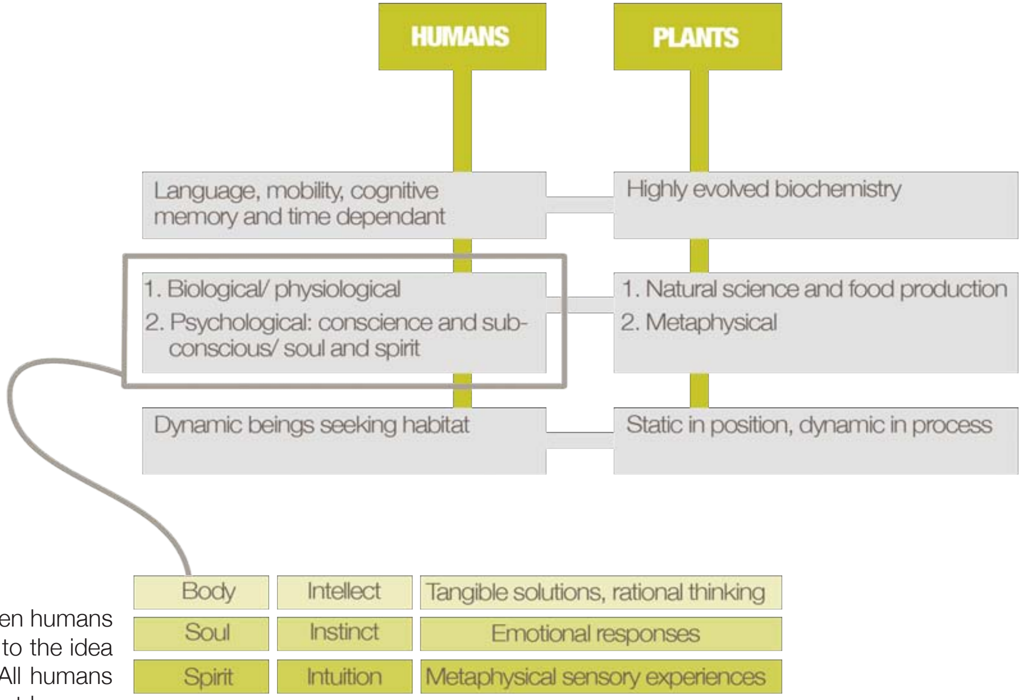
One of the concepts he expounds is that if humans are serious about rediscovering themselves in nature they need a language that speaks for science and soul, a language that narrows the gap between subject and object, a language that reminds them of where they have come from and what they have to do to be ecologically intelligent. In his opinion, poetry has always been successful at bridging this gap.

Similar to the thinking of McCallum, Michael Pollan (TED, September 2007) also acknowledges that humans have to change their relationship to the natural world and look at the world from a plant's perspective. Organisms such as humans, insects and animals have the grammar of self serving conceit in that they are sovereign subjects whereby each is getting what it wants from nature. This is a typical Cartesian mode of thinking, that one species dominates another and that by the intelligence that plants gathered over a long period of evolution they are cleverly manipulating other organisms in order to help them germinate and gain territory. According to Pollan, humans think they are suppressing grass by mowing it, but in actual fact they are helping it to succeed in out-competing trees and preventing forestation.

Everything that humans design should not be dominated by conscious thought only.

In an interview some time ago, Swiss architect Peter Zumthor (Perkins, 2002:48), who is noted for aiming to introduce metaphysical experiences within his buildings, explained that if they work well, buildings become beautiful and the spaces contained in them are beautiful to live in. The beauty of a building should contribute to the beauty of a place. He stated that nature is always beautiful. It doesn't matter what time of day or what region it is, nature is always beautiful. Architecture

TABLE 2.1 A comparison of human physiological, plant biochemical compositions and the similarities/differences of how they integrate within their environments. Collectively compiled by authors own research in McCallum, I. 2005 and Pollan, M. 2007.



nature and the beauty of the site and must enhance this beauty. Although the purpose of architecture is to be functional and to provide people with shelter, it shouldn't obviate the beauty of buildings. He compares buildings with chairs (referring to those by the revolutionary product designers of their time, Charles and Ray Eames, Fig. 2.6) or drinking glasses, which by definition and purpose are utilitarian objects. But they become objects of everyday life and the beauty of their form develops according to their nature. Zumthor mentions that good architecture must be good all the time, whether it rains or the sun shines. It must be good under all conditions, just as nature is. He goes on to say that architecture should be like nature, but when it starts to alienate itself from its functional use it isn't natural anymore. Creating architecture is an emotional response and one interacts with objects because one experiences them:

"But there is always a strong emotional part, so the way I work is of course that, at any point of the design-construction process, we try to feel it. That's why I have to produce images in my mind and in the minds of my collaborators. Any time we work on it, we have an image of how it looks. Then it's easy to react on it, because the emotions, they are fast. Emotions are immediate. This is really the instinctive part. It's sort of being intelligent about your feelings" (Perkins, 2002:48).

2.1.3 Sustainable design

In the author's opinion architecture has always been sustainable. It uses appropriate available technology, builds with products from nature, and results in places for man to dwell. Buildings serve as recreational, civic or gathering places for communities within a larger community, confined to a certain landscape. Today we realize what the global impact of cities is, but the process of urbanization that established them has been a natural occurrence for centuries. Therefore, green buildings that use energy efficiently only tackle the issue of resource efficiency and may become a trend or stylistic approach, as is already the case. They are merely symptoms of a larger problem. Architecture has become technology driven and showcases human accomplishment, restraining the forces of nature in the process. Quick building developments are merely quick fixes for immediate pressing problems, resulting in quick sociological disasters. Man's dominion over nature is currently being enforced beyond measure and results in environments that have become socially segregated, economically unstable and visually fractured.

FIG 2.7 BP headquarters in Greenpoint, Cape Town

With advances in building science, architects are confronted with three phenomena, namely: technology arrives by design, is applied by design and, in its form and use, technology itself designs (Fry, 1999:23). According to Dormer (1999:141), a building is a kit of complicated parts and "…wherever possible, methods of building are employed in" which the know-how is embedded in the system rather than individuals…" He believes that "…designers and architects could be replaced by managers whose job it is not to invent but to manage the use of existing systems". This ultimately leads to the realization that "… technology has become so predictable that it's aesthetic is predictable, even boring" (Dormer, 1997:142).

Any approach to sustainable development will not be solved by only using new sustainable technologies that have not yet stood the test of time. Sustainable building technologies should serve on an equal and parallel basis with social and economic sustainability. This will, in the author's opinion, result in integrated socially equal communities such as the Lynedoch development. Please refer to Chapter 5, Heading 5.5.

In high-density urban areas, money and power are the ultimate ruling ordinances. More specifically, large corporations and institutions rule our cities. According to Malan quoted by Louw (2006:2), Corporate Social Responsibility (CSR) refers to responsible corporations that want to make a real difference and a lasting contribution to the countries and communities within which they operate. Sustainable corporations [illegible] to social responsibilities as well as to environmental integrity.

A local example where CSR is being applied is the new BP (British Petroleum) headquarters in Greenpoint, Cape Town (Fig. 2.7). Apart from the most obvious fact that BP is one of the largest fossil fuel companies in the world, they apply CSR globally in creating sustainable and ecologically responsive buildings for their office staff. The architectural response by KrugerRoos was what Eric Noir in Darroll (2003:30) calls a *framework approach*: to establish intuitive and sustainable design principles within the surrounding urban framework, and to ensure that the building evolves as a response to these principles. Noir also states that the "environmental considerations are deeply integrated with the urban design and architecture – integral rather than add-in systems".

2.2 Deriving an architectural normative

Archetypes of nature

Stimulating human's sense has a profound impact on how we perceive the world around us. Enhancing elements within the building such as water, light, smell of natural materials and vegetation can evolve into archetypes of nature than transcends the users mind to a place of positive memory (Forests, mountains or places of similar experience). The author believes that stimulating these senses allows people to experience buildings on a level that starts adding meaning to everyday objects. Stimulating senses through archetypes of nature provides a platform that can allow people to become more aware of a different state of mind, the subconscious, which will allow the place created by the building fabric to become a place for spiritual contemplation.

contextstudy

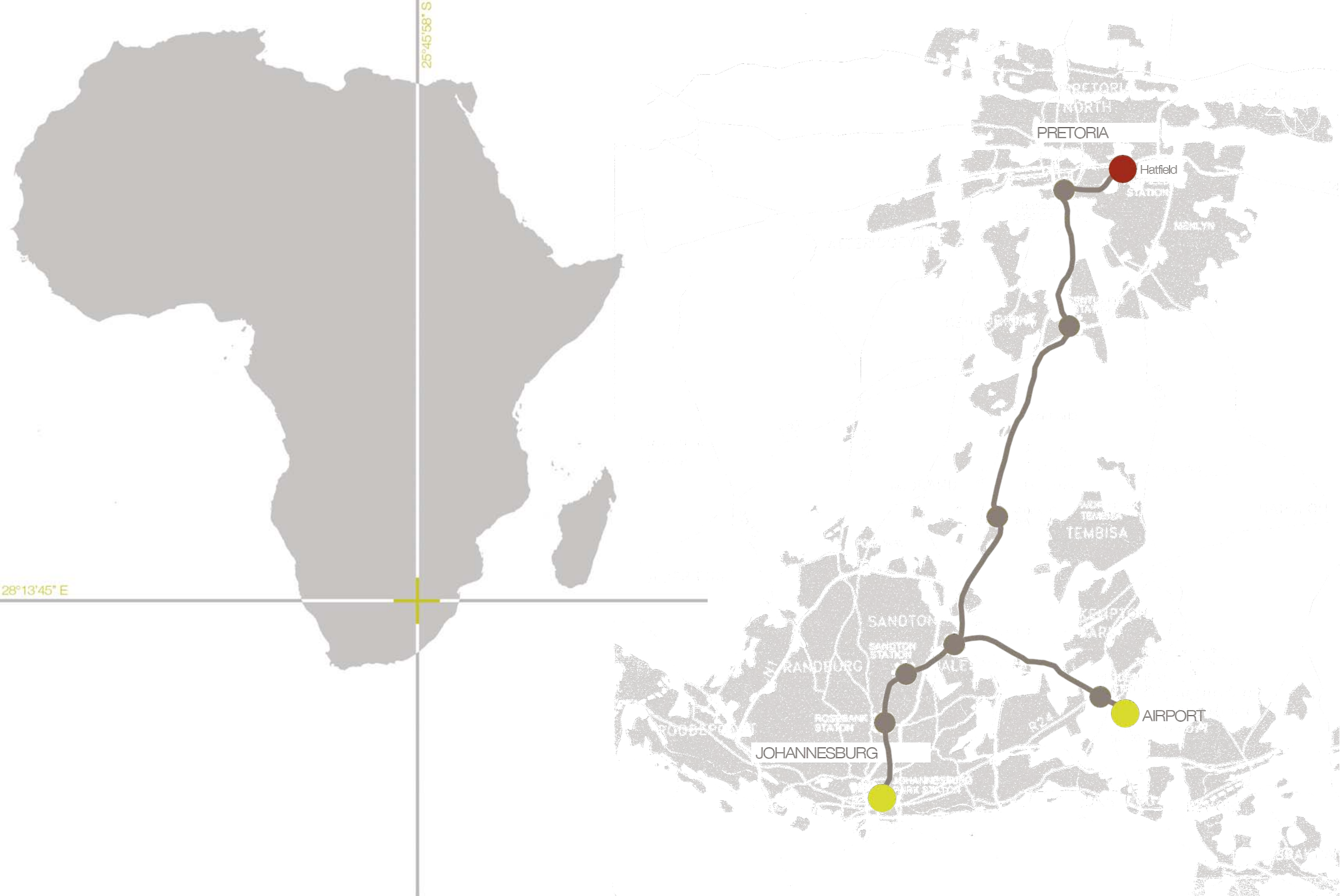


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FIG 3.1 Proposed Gautrain Rapid Rail link route

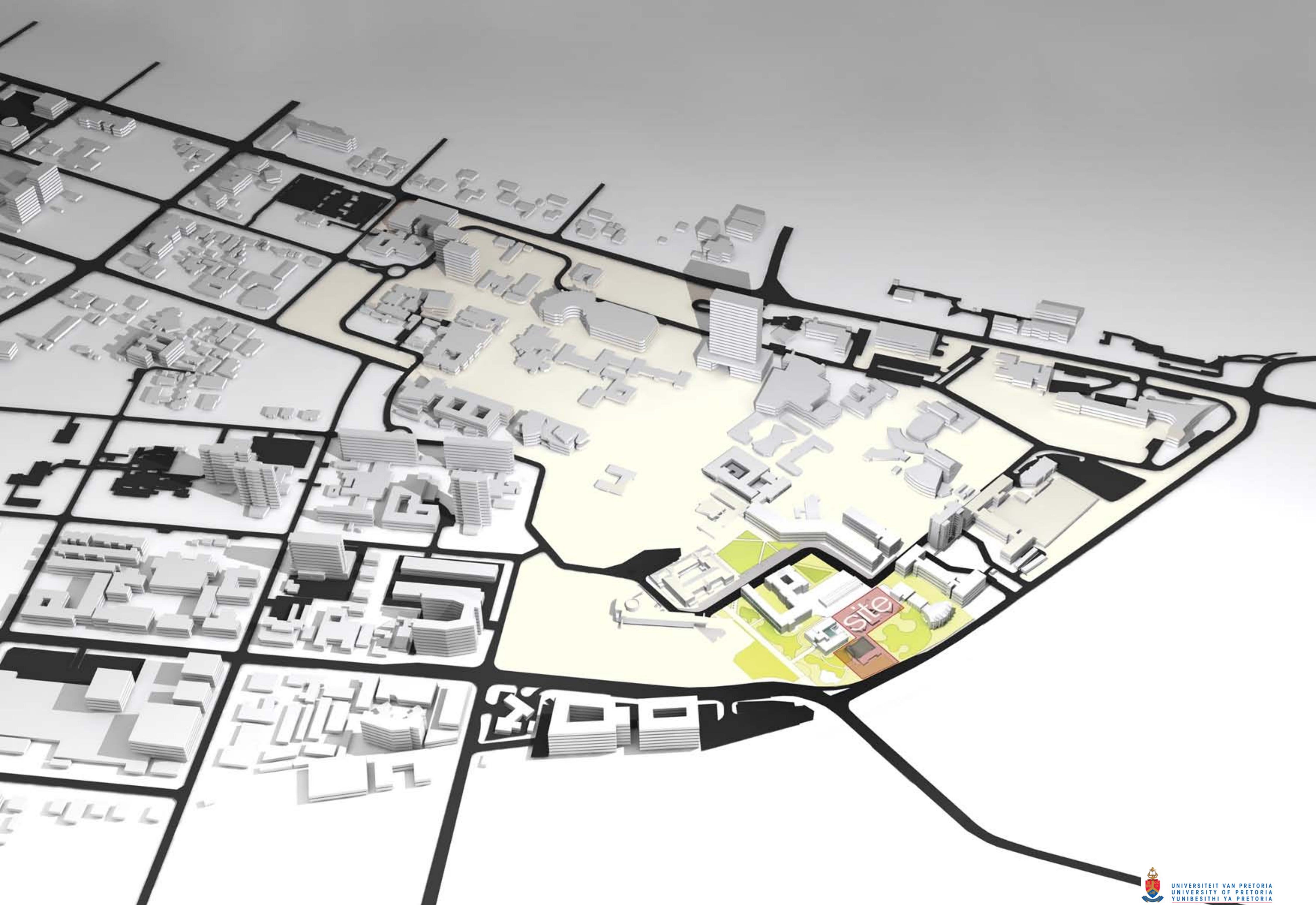

FIG 3.2 Overview of the Hatfield- and University precinct form the North

3.1 Redevelopment of the Hatfield precinct

Information on the redevelopment of the Hatfield precinct and the University of Pretoria campus has been generated from the following sources:

- The Hatfield Metropolitan Core Urban Development Framework as presented by the Metropolitan Spatial Planning, City Planning and Regional Services Department of the City of Tshwane Metropolitan Municipality, 14 August 2007.
- The Gautrain Rapid Rail Link final proposal document and impact study, March 2003.
- The vision for the University of Pretoria campus as presented by Mr. Gerrit Jordaan, 28 February 2008.
- The urban development framework for the University of Pretoria campus and surroundings, as discussed in the master's architectural studio of 2008.

In terms of the Tshwane Metropolitan Spatial Development Framework (MSDF), the Hatfield precinct has been identified as one of six metropolitan cores earmarked for densification. This is the result of market changes and an increase in the intensity of development in the area due to the proposed Gautrain Rapid Rail Link Station. Please see Fig.3.1-3.

The redevelopment of the Hatfield precinct is known as a Transit Orientated Development (TOD), which entails the creation of compact, walkable communities centered on a high-quality train system. It would eliminate the majority's dependence on private vehicle transport. The reasons for introducing such a development to a community would have the following benefits:

- Higher priority is given to pedestrian movement and access.
- The train station serves as a prominent feature of the town centre.
- A regional node is developed that contains a mixture of uses, such as civic, business, residential and retail, in close proximity to one another.
- High-quality developments are established within a ten minute walking radius of the station.
- Collector support transit systems such as light rail lines and busses are introduced.
- The system supports the easy use of bicycles, scooters and pedestrian walking as daily transport modes.

When such a development is proposed, the following challenges are presented:

- Land uses on site level intensify and become more mixed.
- Land values in the area escalate.
- Student numbers in the area are periodic – they decrease dramatically during recesses.
- The risk exists that too little allowance will be made for green spaces.

FIG 3.3 Current land use patterns

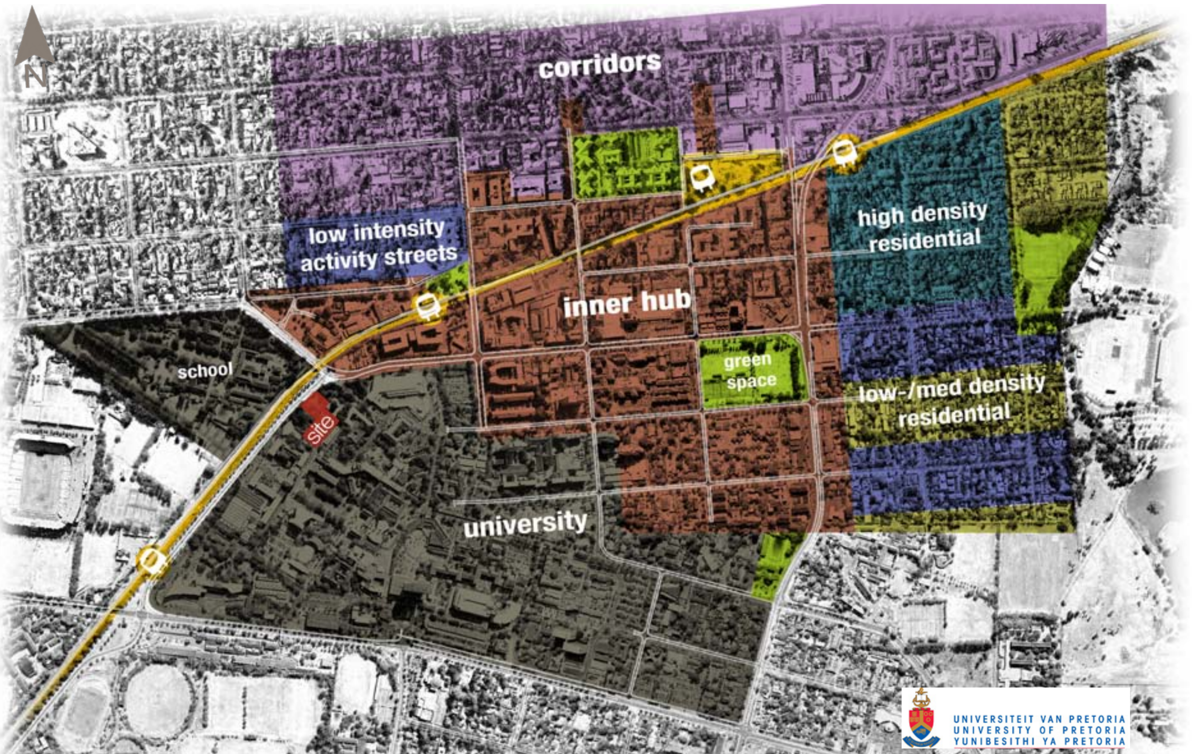

FIG 3.4 Transit Orientated Development (TOD) proposal, 2007 for the Hatfield precinct

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FIG 3.5 Alteration of the TOD proposal to allow for the university campus to integrate with the precinct over time

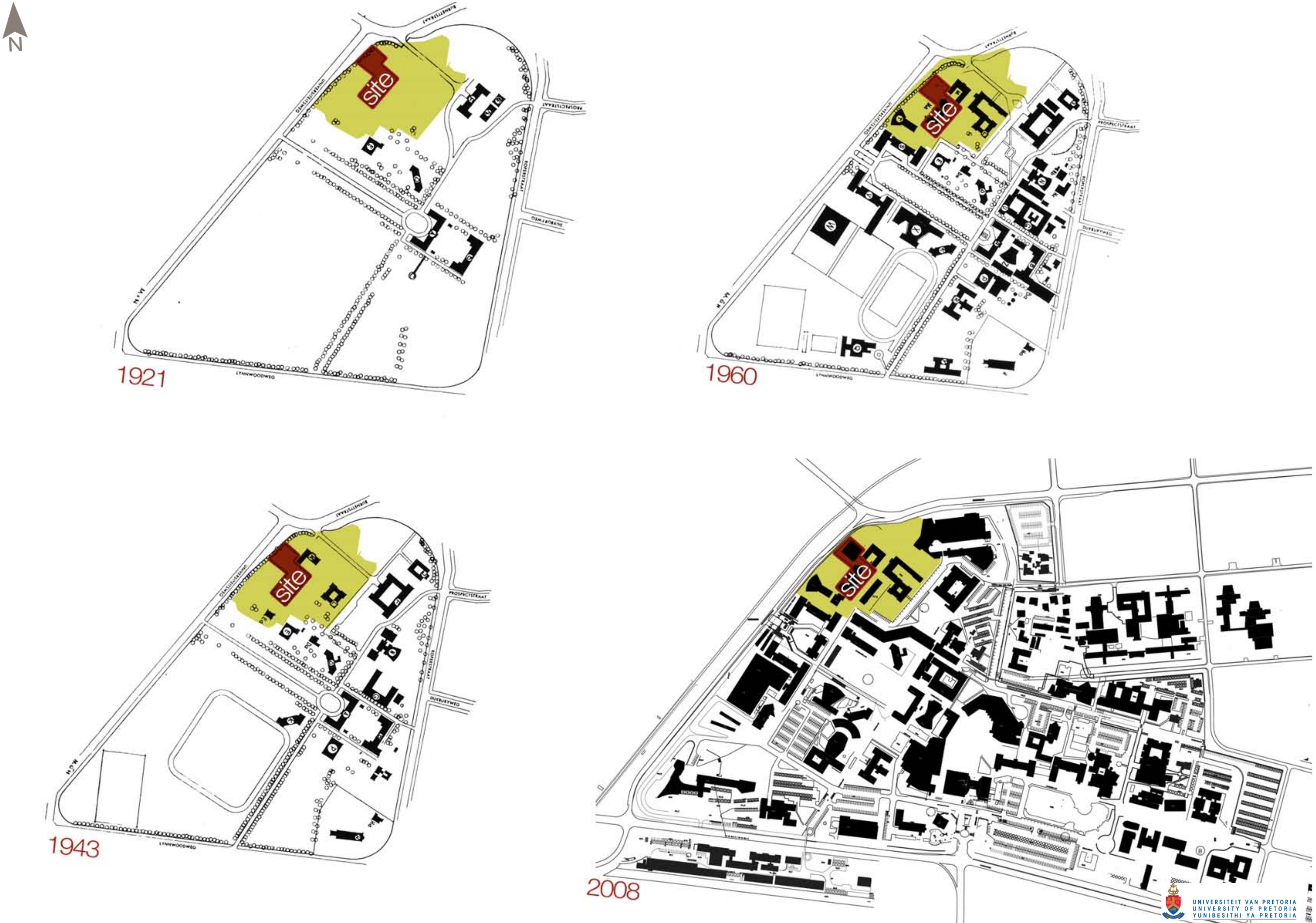


FIG 3.6 Hatfield campus growth: 1921-2008 Image by author and based on information obtained from the Universiteit van Pretoria (1996: 268-269).

3.2 Function of the University within the precinct

According to press releases on its website, the University of Pretoria has maintained its status as the top university in the country, where its research output since 1996 is concerned. The 2007-11 strategic plan states that one of its objectives is to ensure that the impact of the University of Pretoria on the local community is relevant and significant. Celebrating its centenary this year, it aims to play an integral part in the development of the nation and to encourage postgraduate research at the university to be cognisant of this objective. The university aims to be a force for social change.

On contemplation of the abovementioned, it is apparent that the processes at the University of Pretoria are always in flux and that the university recognizes its responsibility to the greater developing community. Since its beginnings, the buildings on campus have been representative of a great part of the early architectural developments that occurred in Pretoria. Influential architects that helped to shape the architectural language of the city played an integral part in developing the fabric of the campus. Currently, and with hindsight, the campus can be seen as a reflection of those times and the way in which the university's urban fabric responds to the city cannot be approached in the same way as before.

The research done by Hashimshony and Haina (2006:5-19) investigates the relevance of the university within the city, how design and planning paradigms should be oriented for future development, and if the university will still be regarded in the coming years as the primary centre of higher learning as many believe it to be today. They foresee that academic institutions will undergo major organizational and physical changes as they adapt their activities to meet present and future needs. The University of Pretoria demonstrates how a drastic alteration in political climate can force an academic institution to be more responsible to its immediate environment, in order to promote and sustain community development.

The earliest universities developed out of the needs of urban societies, and facilities were located in individual buildings no larger than a city block. Only with the creation of permanent structures were universities marked as independent institutions (Cobban, 1992:1246).

The current position of the Hatfield campus within its urban context serves as a paradox of what the university aims to be academically. Strictly controlled access and high fencing do not correspond with the strategic plan of the university to communicate its aim of having a significant local impact and to be seen as a force for social change. One can argue that, by means of academic standards,

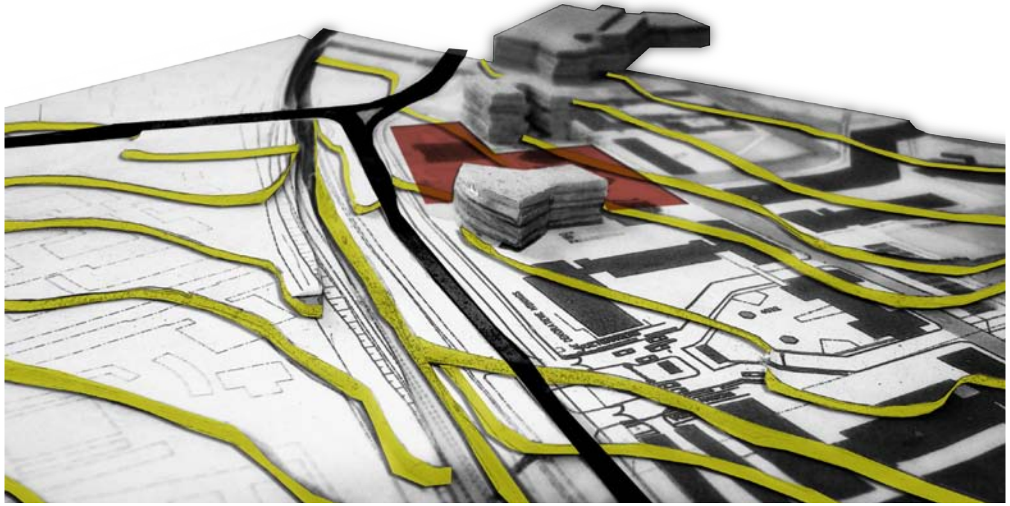


FIG 3.7 Topography of site and surroundings at 1m contour intervals

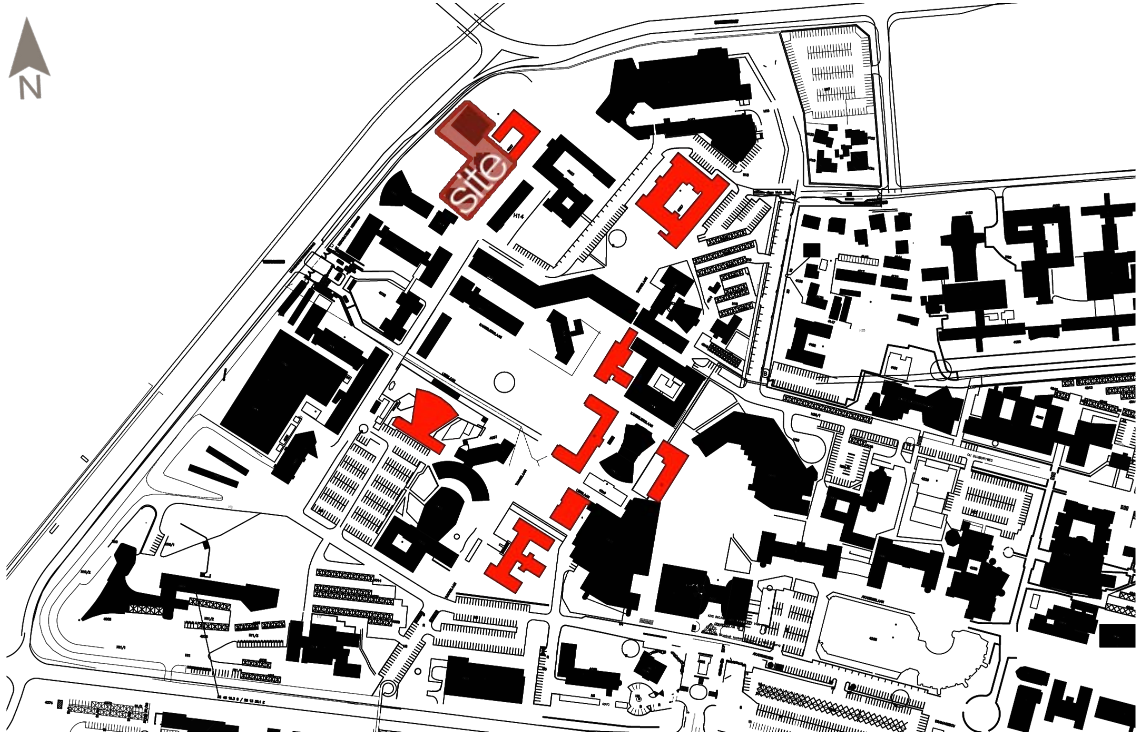


FIG 3.8 Historically significant buildings on the Hatfield campus (Older than 60 years)

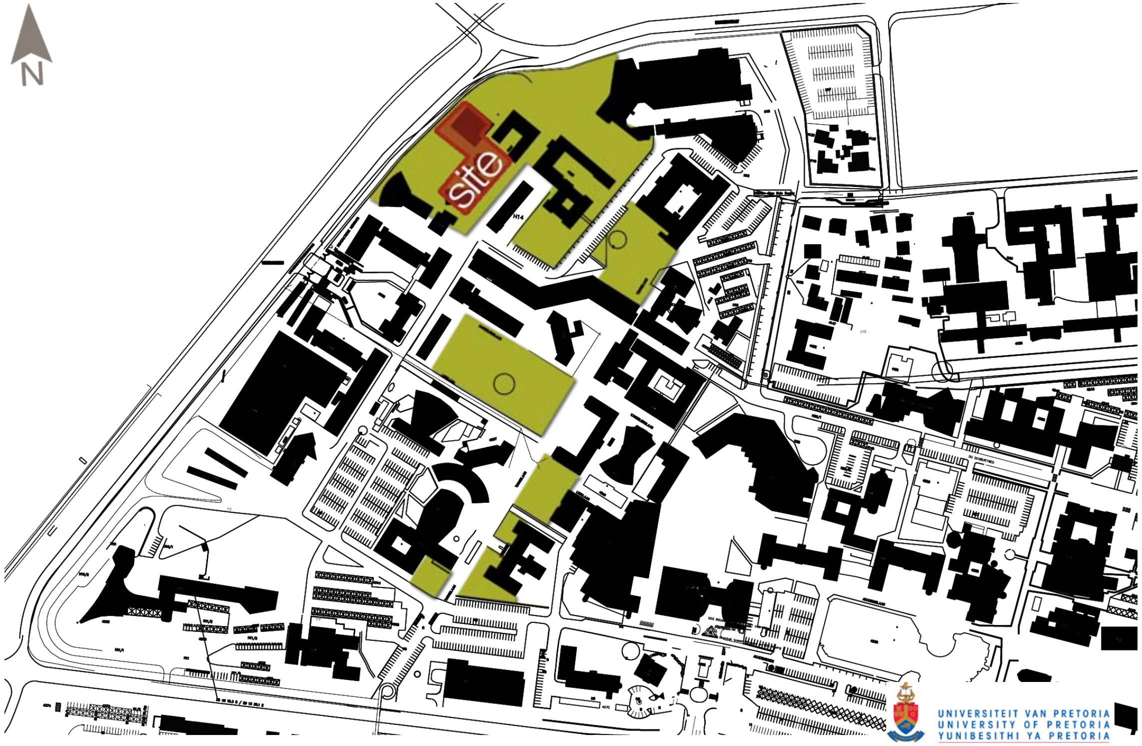


FIG 3.9 Surrounding green spaces relative to the site

existing

high energy

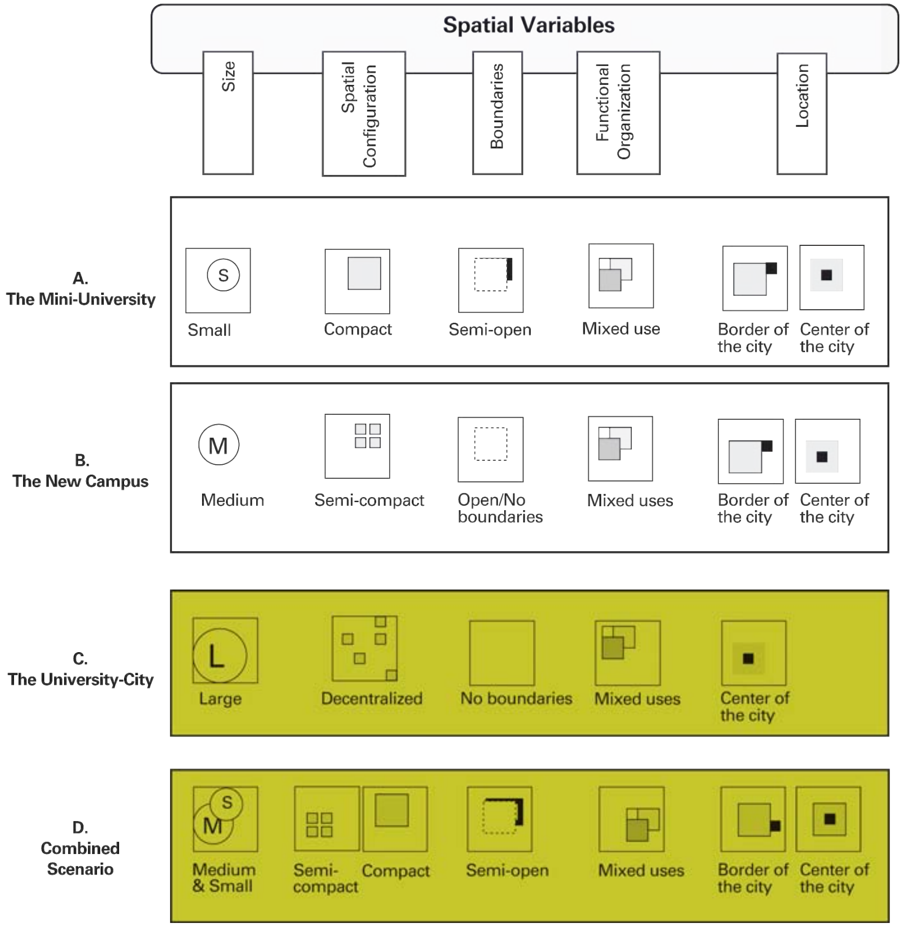
rgy

FIG 3.10 Space syntax diagram showing energy flows of cars and pedestrians on exiting campus and surroundings

FIG 3.11 FIG 3.12

FIG 3.11 Boundary screens at Musee du Quai Branly, Paris. Image with permission of Prof. B. Jekot

FIG 3.12 Metal boundary markers in water features at Musee du Quai Branly, Paris. Image with permission of Prof. B. Jekot



◄ **FIG 3.13** Four future developmental scenarios for University campuses (Hashimshony & Haina 2006:12)

community projects and relevant research strategies, the university already functions within the local community to achieve social change. But, according to Hashimshony and Haina (2006:7), the idea behind using the term “campus” is an attempt of the facility for higher education to distinguish itself from its surroundings, and to define itself as isolated and with an independent character. Therefore the university needs to express openness towards the surrounding community. Hashimshony points out that, as a result of technology and an increase in life expectancy, people have more free time to become involved in extramural activities. As knowledge is becoming freely available, people in the community are also looking for different ways in which to promote themselves. Here the University can also play an integral role and can provide relevant lectures, special short-term courses and evening activities. These can all strengthen the image of the university and allow it to respond to the needs of society more appropriately. As a result, the linkages between the university and the outside world are starting to strengthen. The conceptual and physical boundaries of the university as an institution are becoming more permeable and accessible to the greater community.

Hashimshony and Haina (2006:14) propose four models of how the university of the future may develop, and what considerations designers have to take into account. For obvious reasons only scenarios C and D (Fig.3.13) will be referred to. The University City (C) sees the university disappearing into the fabric of the city and assimilating knowledge of the urban system. Boundaries disappear completely and the university campus has a spatial configuration of being in different parts of the city.

The above-mentioned scenario has some promising outcomes and is a novel idea for future universities located within the city limits. The case is not completely relevant though for application to the Hatfield campus. The campus is too far removed from the city centre and has a long-established history of being a well respected institution. As the Hatfield precinct is experiencing a surge of intensification in users and densification in building uses, it becomes more relevant for the university to become semi-permeable and to again reconnect to portions of the city (Fig. 3.5 & 3.14). It will be a matter of coming full circle and returning to its origins by opening up to the community again. Advanced design techniques of passive surveillance and modes of access control can be applied in certain areas, as used at the Quai Branly Museum in Paris, designed by Jean Nouvel and illustrated in Fig. 3.11-12. The application of these techniques would be to entice people to become more involved in and aware of the inner workings of the university, while it still retains its character and stature as a well respected academic force.

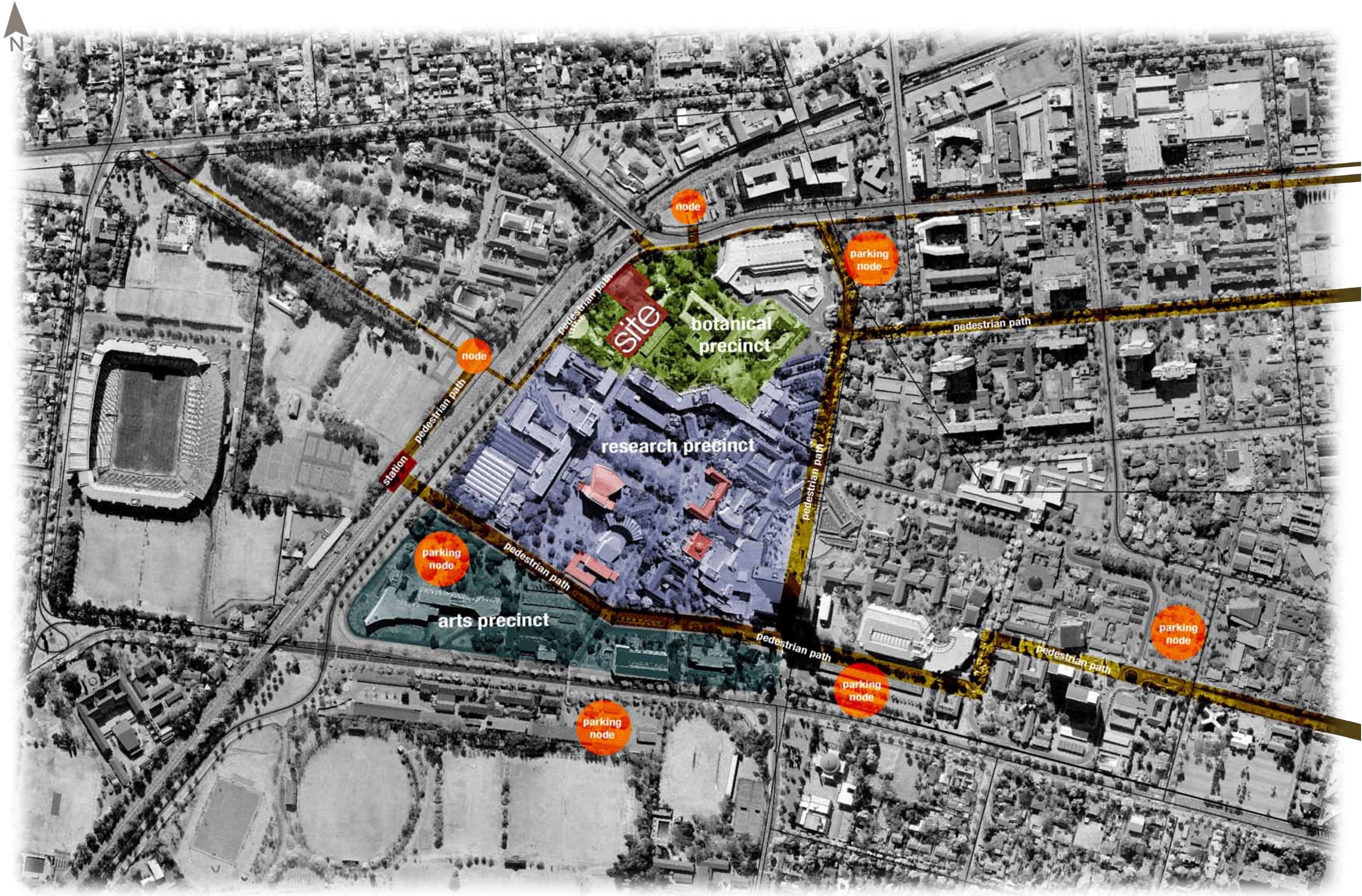


FIG 3.14 Proposed developmental strategy for the Hatfield campus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siteanalysis

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Early and middle stone age: Evidence found of tribes present in the area North of the Magaliesberg at Won-derboompoort

People of the the iron age enter from the North - mainly hunters & farmers

Ndebele and Tswana people

1832 Shaka expel Silkaats

1838 Pioneers Gert & Lucas Bronkhorst arrieve in El-nadsfontein area

1839 Gert Bronkhorst establishes his-melf on the fram Elandspoort, Noth of the Foutains valley

1855 Founding of Pretoria

1857 The land of Gert Bronkhorst is divided in 6 portions - Jan Francois Scutte owns the portion on wich will contain the University campus

1875 James Edward Mears buys the property from Schutte

1894 Building of railway to Delgoa bay that now Crosses Lynwood road

ANGLO BOER WAR

1908 Centr
Colleg
Unive

19
de

1840 **1860** **1880** **1900**

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WW I

GREAT DEPRESSION

WW II

09 Establishment of Botany
partment at UP

Eatablishment of the Pretoria
e of the Transvaal University
ge,(TUKS), later known as the
rsity of Pretoria(UP) (1930)

1912 Planting of first trees at UP along the main avenues, north, south and east boundries

1913 Architect Sir Herbert Baker leaves south africa

1920 Building of the Old Argricultural building at UP.

Only Cape-Duch style building on campus.

After it's completion an Agricultural engineering hall and a Vetenary laboratory was added respectively before 1923.

In 1923 an extra wing was added on the eastern aprt of the building and in 1929 the Dairy research institute was completed.

By 1940 the building was being occupied the department of Botany, Geography, Psycology and Home Economics.

In 1956 it was decided to build a new Agricultural building on the Experimental farm east of the first Male residences.

1931 - 1934 Planting of various plant species within the botanical garden under supervision of Prof. B. Elbrecht

1932 The discovery af the ancient civilization at Mapungubwe in the formerly Great Zimbabwe

This discovery deepened Gerhard Moerdyk's interest in ancient African culture (Fisher, S.a: 2)

1940 Plantkunde/ Botany building

1947 Vetman buidling

1949 Bateman laboratory

1953 Stoneman buidling

1966 Building of parking area south of Mathematics building

1967 Building of fishpond and expansion of Cycad garden in North west corner of the site

1970 Closing of Burnett street entrance amidst safety concerns

1989 Temperature controlled glasshouse for plantproduction

1920 1940 1960 1980

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CIL labs
Old agricultural building
Botany
Mathematics
Glasshouse
University road
Bateman
Vetman
Stoneman
parking
AE du Toit hall
Natural sciences
3
2
1
N
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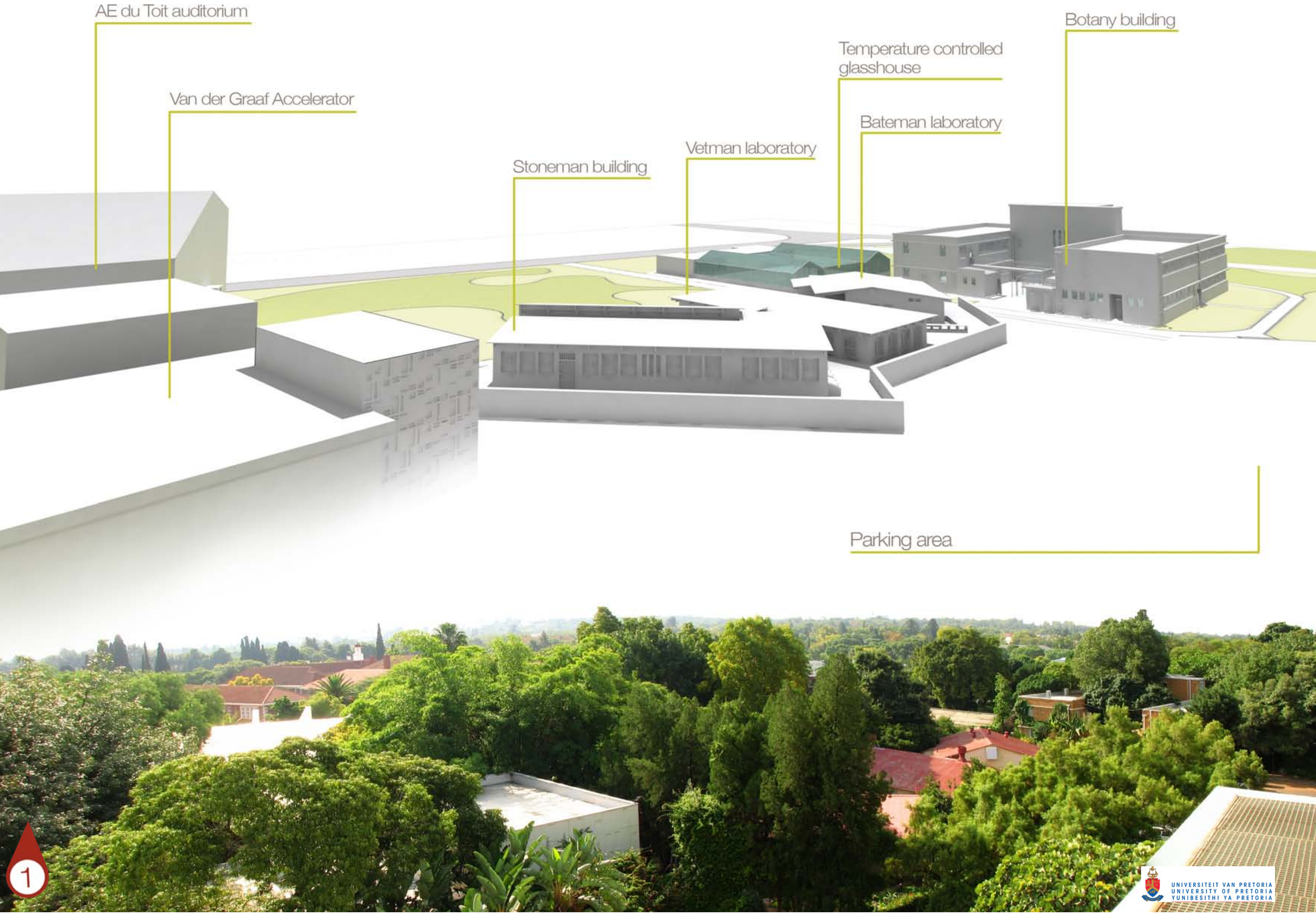


FIG 4.3 Birdseye view towards site from Southeast

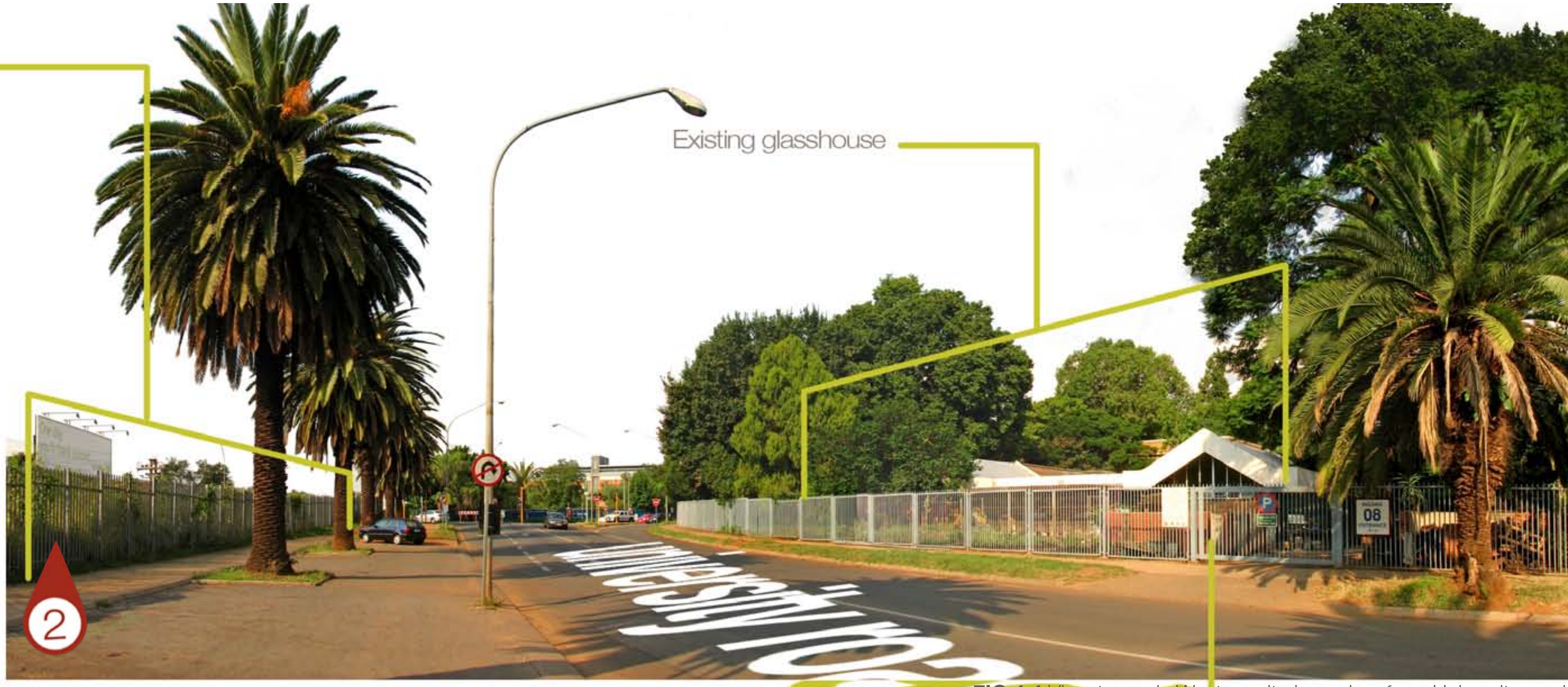
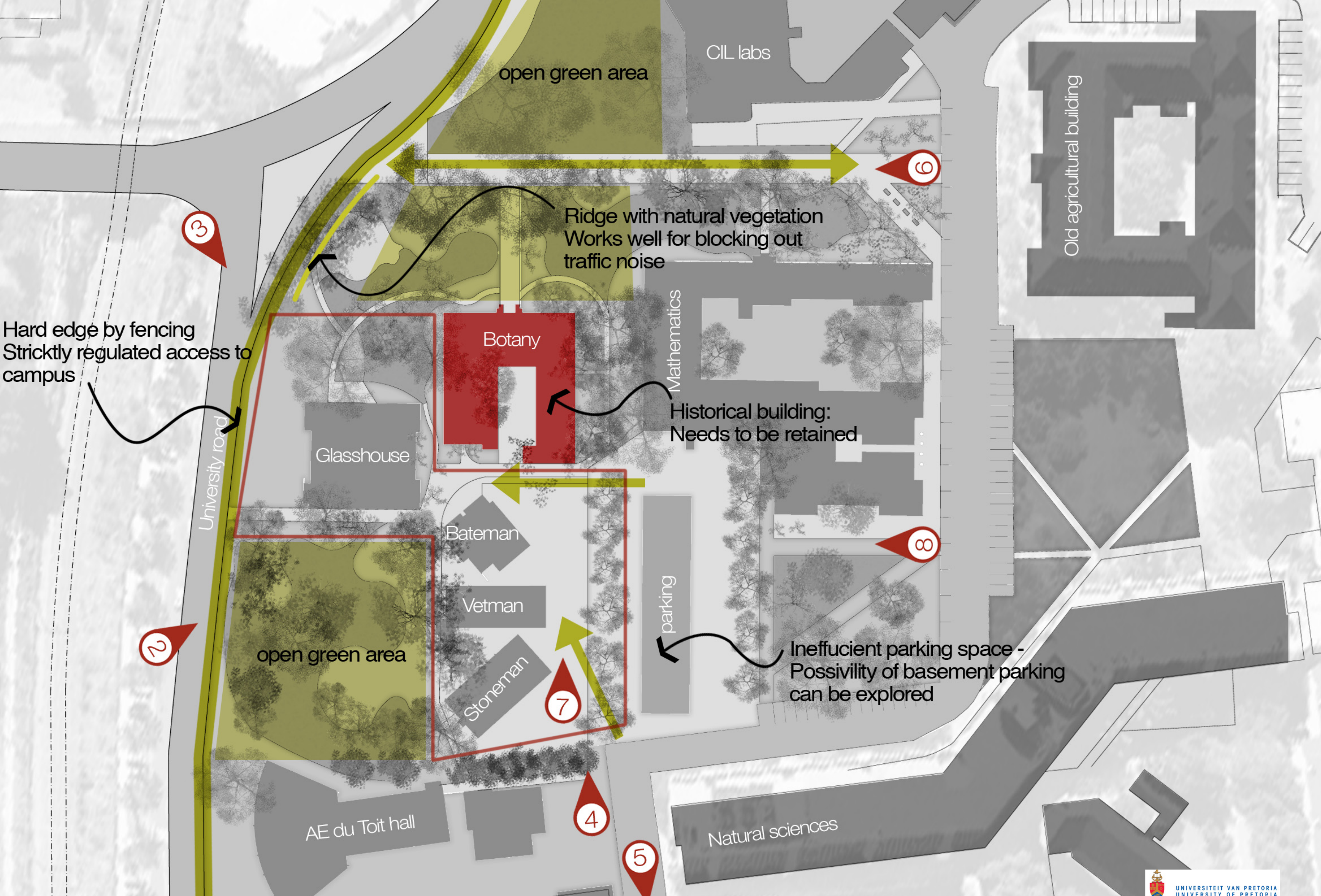


FIG 4.4 View towards Western site boundary from University road

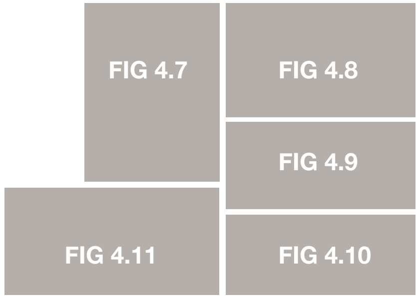
FIG 4.5 View towards South Western site boundary from Park Street

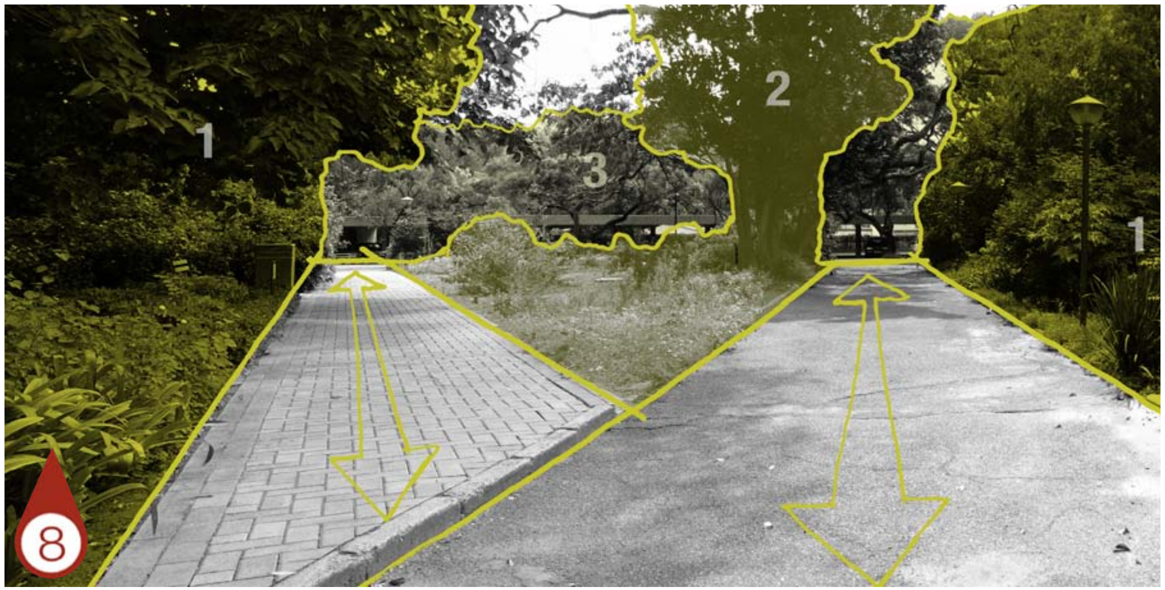


Current scenario and site constraints

◄ **FIG 4.6** Analysis of current site and site constraints

FIG 4.7-11 Access points to site with recession planes created by existing buildings or vegetation





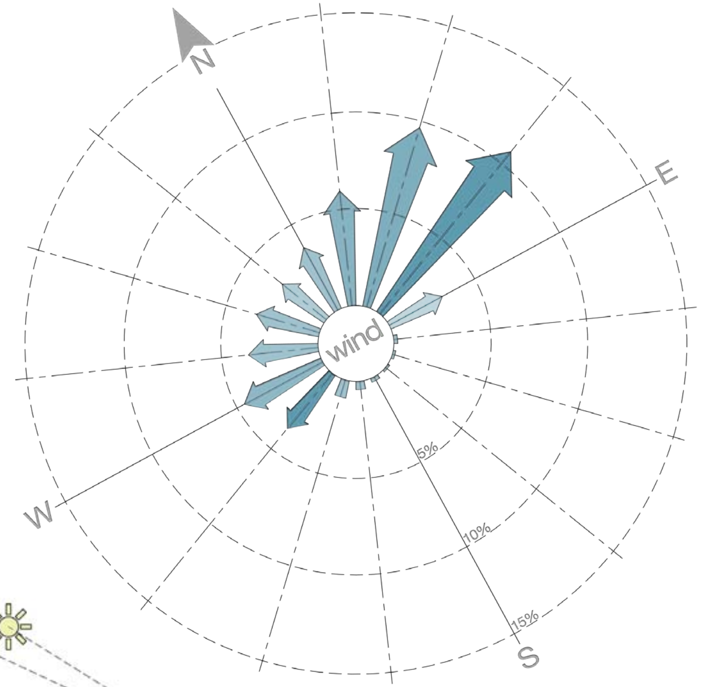
4.1 The Botanical garden [1912]:

The development of the botanical garden at the University of Pretoria is very closely related to the personal research interests of people that were involved in the Department of Botany. When the botany building was completed in 1940, it was already surrounded by many plants. Many trees that were planted in the garden from 1934 to 1944 under the leadership of Prof. J. Bredenkamp still stand today. Although the garden was dramatically reduced in size due to the addition of many new buildings to the campus, the new head of the botany department, Prof. Schweickerdt *[ditto]*, an avid collector of indigenous species, planted these plants in a nursery that occupied most of the north-western part of the site, right up to the A.E. du Toit lecture hall.

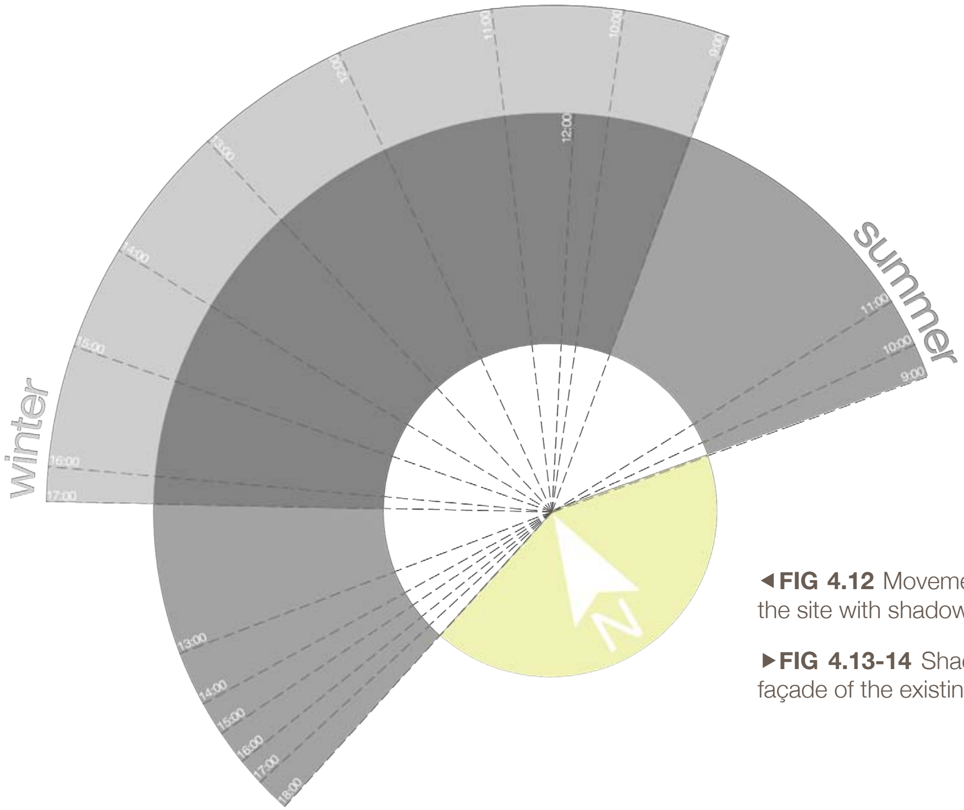
Due to a shortage of personnel, and in accordance with instructions by Prof. H.F. van der Schijff, the garden was restricted to the western region of the campus. After the Burnett Street entrance in front of the botany building was closed, the fishpond was built in 1967 and the area around it was allocated for a cycad garden. The department now owns a complete collection of indigenous cycad species.

The garden currently consists of 350 indigenous plant specimens of which 250 are wooded plants. Specimens are also planted by request for student training purposes.

According to Prof. N. Grobbelaar, the need for such a botanical garden within a research facility is of paramount importance, since the natural habitats of plants are being destroyed at an astonishing rate. South Africa hosts the largest collection of Flora in the world, but many of these have not been studied yet. With an average of two plant species becoming extinct every day in the world, it means that too many plant species are destroyed without having been studied.



▲**FIG 4.15** Prevailing wind directions of the area



◄**FIG 4.12** Movement of sunlight rays across the site with shadow castings

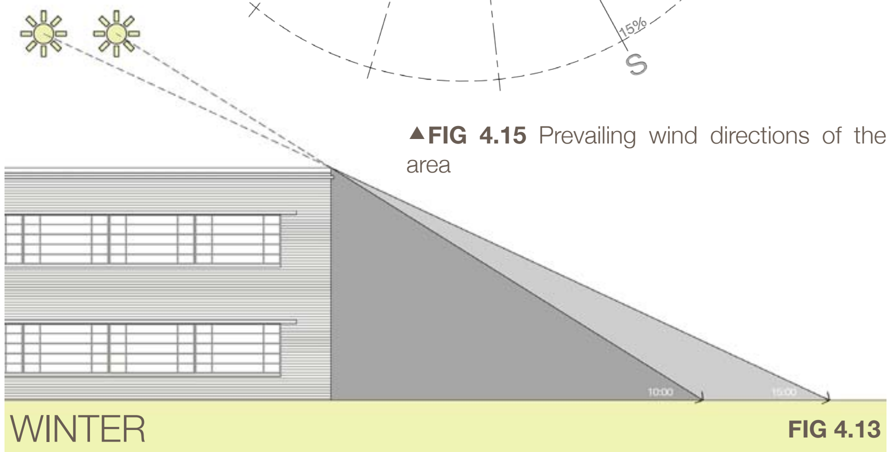


FIG 4.13

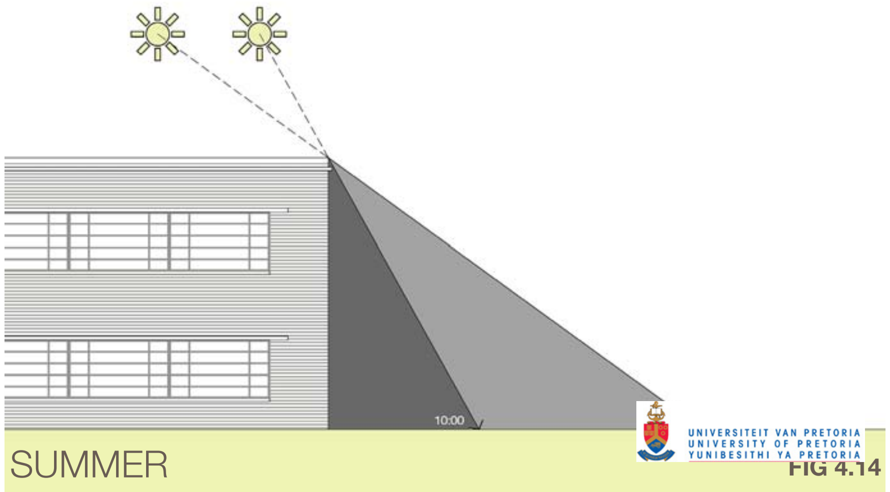
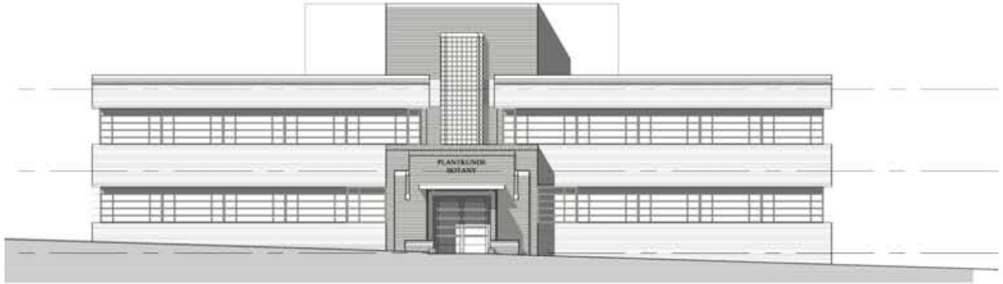


FIG 4.14

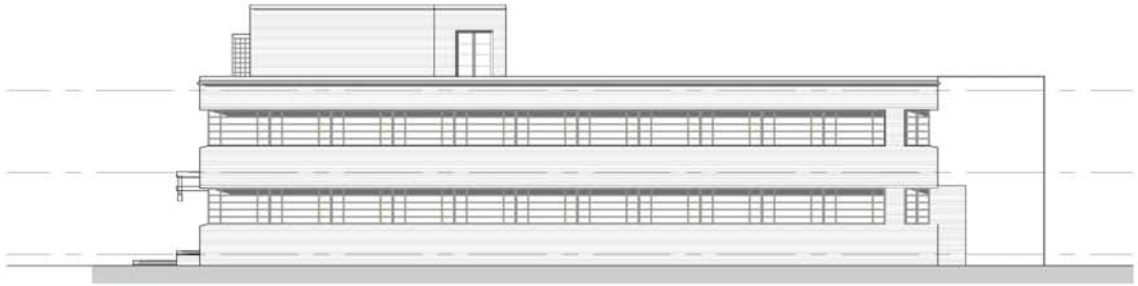
►**FIG 4.13-14** Shadows casting by southern façade of the existing Botany building

►►**FIG 4.16-21** Botany building key design features and stages of development

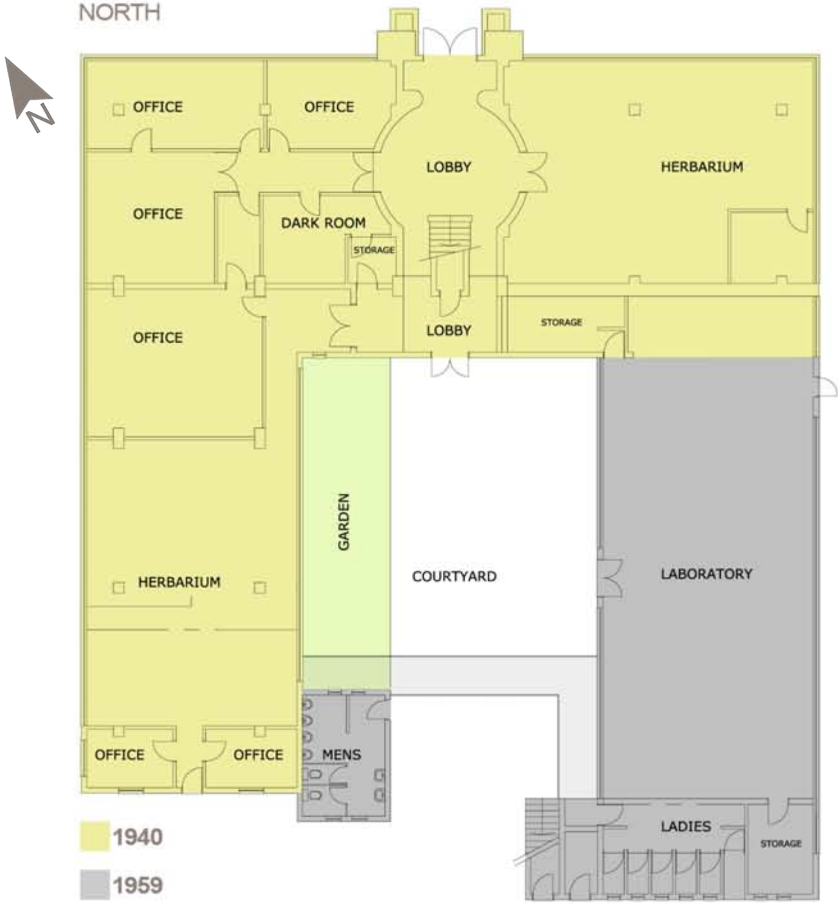
4.2 Botany building [1939]: Moerdyk and Watson



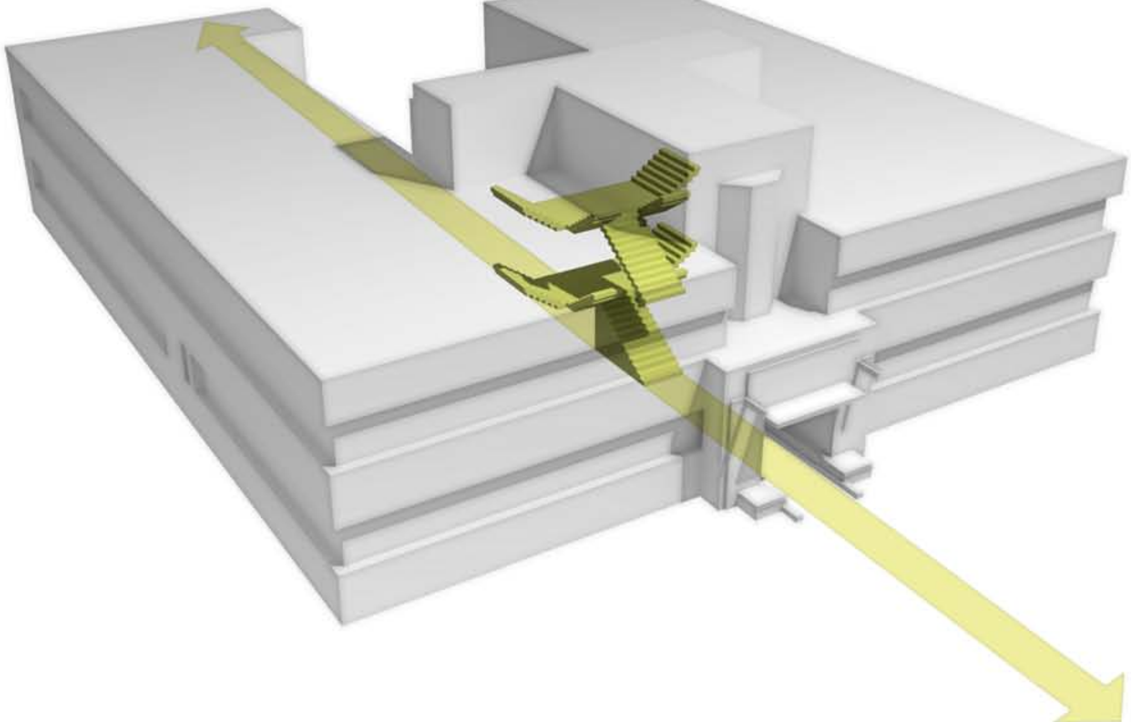
NORTH



WEST

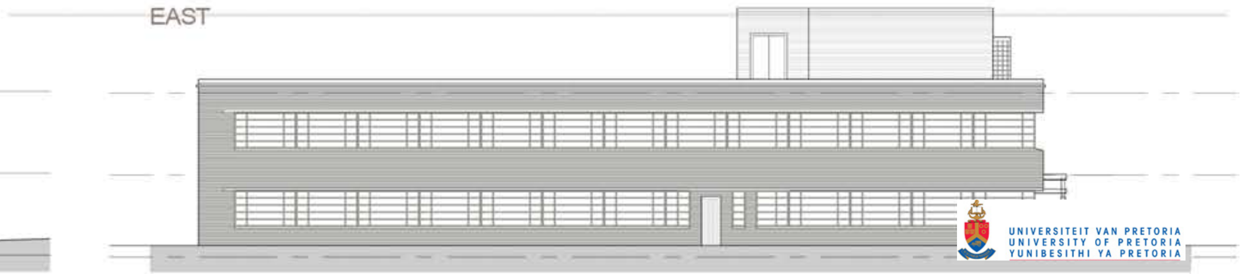


VERTICAL CIRCULATION



SOUTH

EAST



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4.2.1 History
Since the establishment of the Department of Botany in 1908, the department had to make do with the old gymnasium building in Proes Street to carry out its functions.

Despite the difficulties presented by the depression years in South Africa, Prof. Barend Engelbrecht became determined in 1932 to find a new residence for the botany department, and in 1939 a commission to design the building was handed to Moerdyk and Watson.

The cornerstone was laid on 10 April 1939 and the building was put into service later that year.

1939: Double story L-shaped wing on the western side of the site
1959: Increased student numbers forced the department to, under the proposed plan of architect J. Mazureik, built a second wing on the eastern side of the building.

4.2.2 Heritage act:
With regard to the South African government gazette heritage Act of 1999 Article 34:1:

"No person may alter or demolish any structure or part of a structure which is older than 60 years without a permit issued by the relevant provincial heritage resources authority."

4.2.3 Architectural influences
The building, which appears to be a fairly utilitarian semi-industrial building designed to expand with the capacity of the university and to enhance its research capabilities, is also a true statement of the changing architectural paradigms of its time. The building is a culmination of an array of European influences and the regionalist architecture of Pretoria.

FIG 4.24 Merensky library designed by Gerhard Moerdyk (1936)

FIG 4.22 View of Botany building from Northwest

FIG 4.23 View of Botany building from Southeast

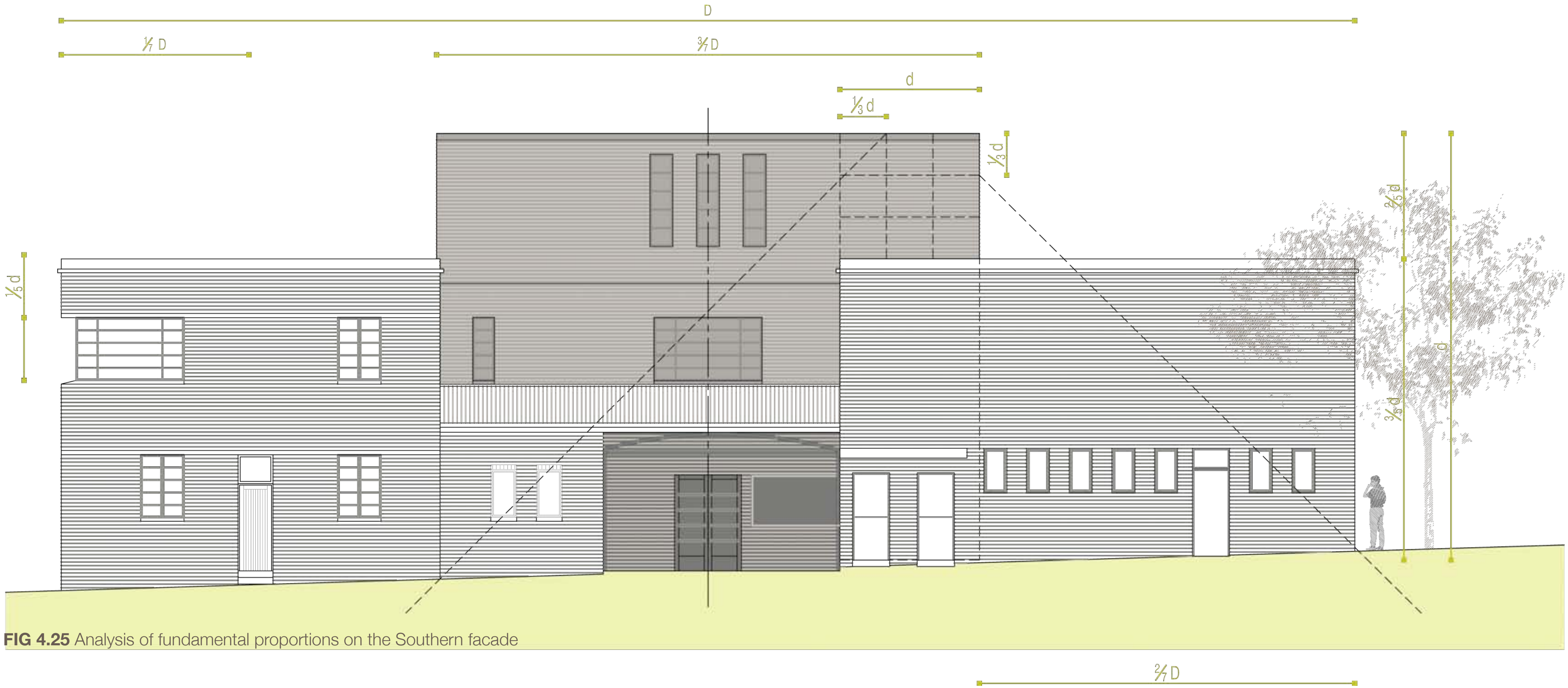

FIG 4.25 Analysis of fundamental proportions on the Southern facade

Sir Herbert Baker (1862-1946) had a remarkable influence on South African architecture during his twenty-one year stay. He renewed worldwide interest in various interpretations of classical architecture, attention to craftsmanship, detail and the traditional use of materials. After his departure in 1913, he left a long-lasting imprint of an architectural approach on the country that endured for nearly thirty years. As the first winner of the Herbert Baker Scholarship, Gordon Leith (1886-1965) became one of Herbert Baker's protégée, but remarkable buildings such as Downing Mansions (1931-2) single him out as a pioneer who took further steps towards modernism (Fisher et al, 1998:79-82).

Bearing the above-mentioned in mind, Leith collaborated from 1926 to 1932 with Gerard Moerdyk (1819-1958) and David McCubbin (1870-1948) on the Johannesburg Railway Station, which bears a slight resemblance to Baker's Pretoria Railway Station. Close to this time, in 1933, Rex Martienssen, Gordon McIntosh and Norman Hanson released a manifesto called *Zero Hour* that clearly earmarked the ambition of this so-called "Transvaal Group" to bring local architecture on a par with that of European modernist masters such as Mies van der Rohe, Le Corbusier and Walter Gropius (Herbert, 1972:19). These aspirations were attained through the strong characteristics of Pretoria regionalism, an architecture responsive to climatic constraints such as harsh sun conditions that resulted in recessed sun-shy windows, sensitivity to landscape and land features, and low-pitched iron roofs (Fisher et al, 1998:123-25). The flat roofs characteristic of the International Style proved to be problematic with regards to drainage because of the torrential Pretoria thunderstorms.

Working during these changing tides of architectural styles and interpretations, Gerard Moerdyk was a member of the Architectural Association, and also served on the Council of the University of Pretoria. After the discovery of ancient artifacts at Mapungubwe in 1932, Moerdyk developed a deeper interest in African culture. This interest is apparent in his 1936 design for the Merensky Library at the University of Pretoria. He acknowledged the Baker influence in architecture at the time, but didn't adhere to it. He had a deep desire to establish an "*Afrikaner style*". These ideologies led him to the study of Cape Dutch buildings. In 1928 Moerdyk also visited America.

FIG 4.26 Hilversum Town Hall designed by Marinus Dudok in 1931 (Baker-johnson 2003:614)

Ideas for intervention

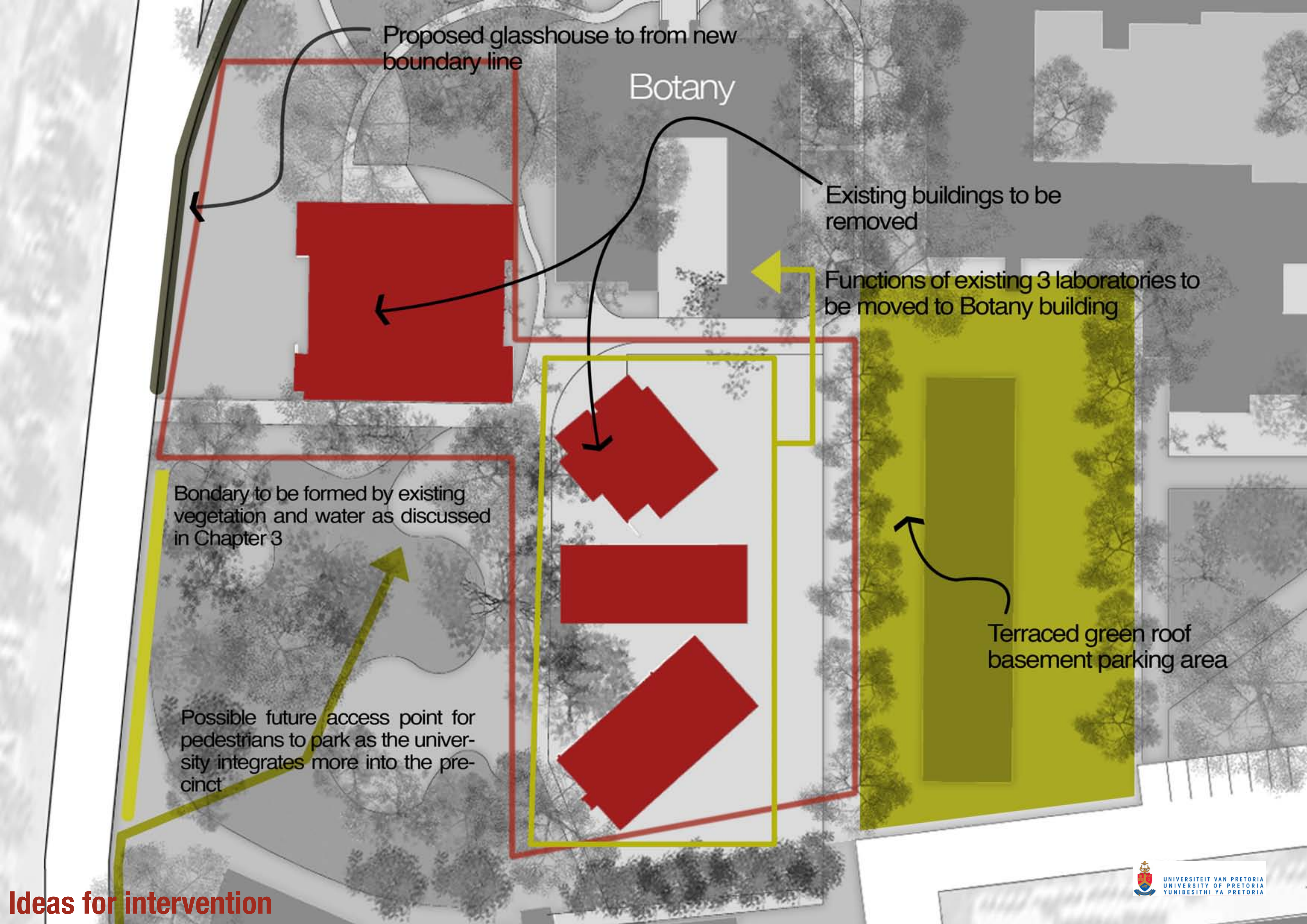

FIG 4.27-28 Existing temperature controlled glasshouse

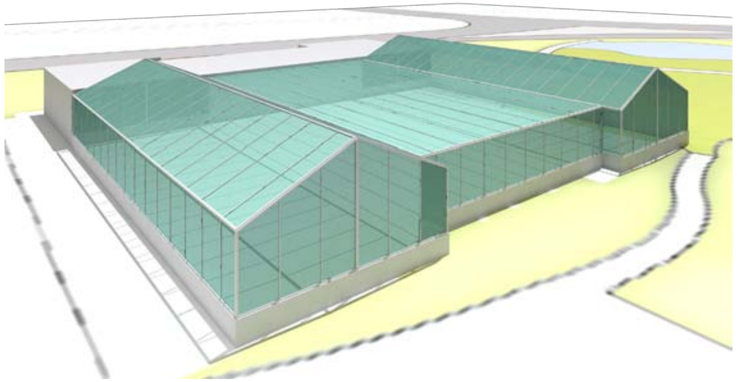

FIG 4.28

Early works by the Public Works Department, the importation of Dutch architects by Paul Kruger, and the establishment of the Kirkness brick factory on the south side of Muckleneuk Hill in 1887 contributed to the establishment of a brick aesthetic in Pretoria (Fisher et al, 1998:129).

4.2.4 Building design

Early works of the Public Works Department, the import of Dutch architects by Paul Kruger and the establishment of the Kirkness brick factory on the southern side of Muckleneuk Hill in 1887 contributed to the establishment of a brick aesthetic tradition in Pretoria (Fisher et al, 1998:129). After the Second World War Moerdyk employed many Dutch draughtsmen. His work was subsequently influenced by the work of Dutch architects such as Marinus Dudok (1884-1974) Hilversum Town Hall building in the Netherlands (Fisher S.a:4). Please see Fig. 4.26. Dudok's work on the other hand is also greatly reminiscent of the great American architect at the time, Frank Lloyd Wright (1867-1959).

In the façade of the building we can see both the influence of the modernist movement at the time in the Transvaal as well as a good example of regionalist architecture at the time. The strip windows and steel framework reminds of a typical industrial building, but the use of brick softens the façade in an attempt to blend in with its immediate surroundings of the garden. Moerdyk initially only designed the western wing of the building, but the symmetrical Northern façade design allows for easy addition of another wing on the eastern side and the possibility of incorporating a courtyard. The use of the stoep (verandah) or courtyard responds well to the hot Pretoria climate in an attempt to provide for an outside dwelling space protected from the sun's heat.

The way the building responds to the site and allowing for movement through the middle axis of the building indicates that Moerdyk has decided to disregard the thinking of Modernist ideologies of the time. The Northern façade acknowledges the previous entry axis created by the Old agricultural building.

4.3 Buildings that are to be demolished:

4.3.1 Bateman, Stoneman and Vetman buildings [1947, 1949, 1953]

The first in a series of three small unobtrusive buildings behind the Botany building, the Vetman building (the name is in reference to war veterans), was built during directorship of Prof. Margaretha Mes in 1947 and although first intended as a hostel for war veterans it was instead used as a physiological plant laboratory. The laboratory for climate studies, the Bateman building, was built in 1949 housing one of the worlds first Fitotrons. The Stoneman building that serves as a laboratory for biochemical plant research was completed in 1953.

4.3.2. Temperature controlled glasshouse [1989]

Being the first of its kind in South Africa at the time, the facility that was completed in 1989 for sophisticated research purposes consist of the following:

- Three temperature controlled rooms
- Preparation room

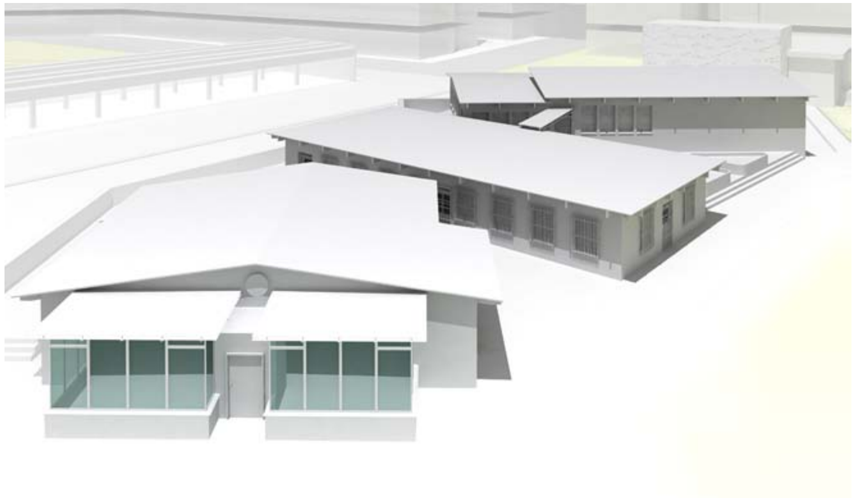

FIG 4.29 View of Bateman, Vetman and Stoneman buildings from the Northeast

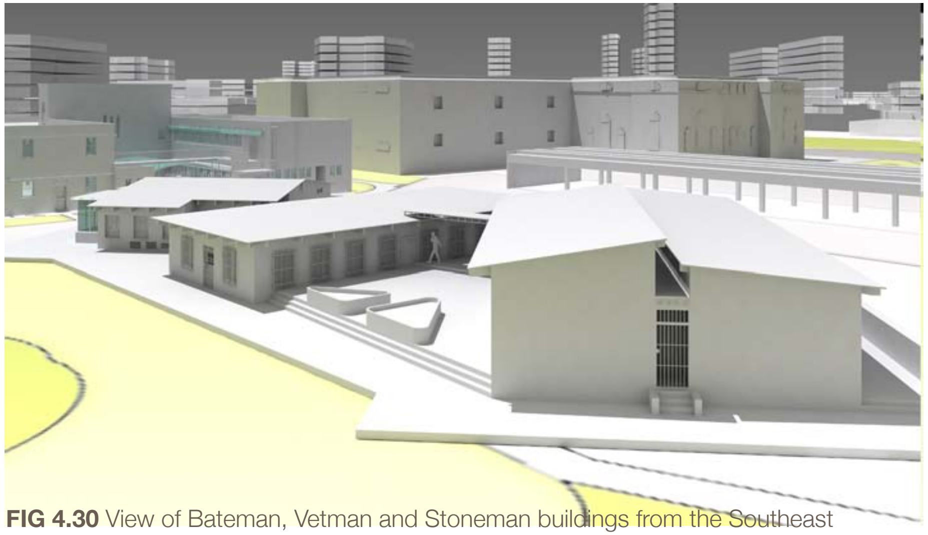

FIG 4.30 View of Bateman, Vetman and Stoneman buildings from the Southeast

FIG 4.31 Bateman building interior

- Incubation room
- Storage and machine room
- Three environmentally controlled glass houses

At the time the facility was very sophisticated and attracted a lot of attention from local and overseas researchers. The facility consists of a computer that monitors relative humidity, air-/ soil temperature and airflow. A lot of the research for constructing the facility was conducted abroad and therefore the glasshouse is mainly constructed on European standards.

Since the facility was taken into use in 1989 technology has developed in various regards on how greenhouses function. Aero-/ Hydroponic technology has advanced a remarkably the last ten years and having access to such a facility can open a wide array of research potential, especially on cultivating seedlings for low cost food production in dense urban areas.

4.4 Ideas for intervention

4.4.1 Ecumenical urban park

The Botanical garden consists of the same potential that Paley Park (Fig. 4.32-34) in New York City embodies. Paley Park is a small vest pocket just off the busy 5th avenue and 53rd street. The waterfall forms a focal point within the space and drowns out much of the city noise. People interviewed like the park because it always provide a shelter from the summer sun with the dappled light coming from the trees.

Paley Park entices people who walk past to enter the area. It seems mysterious in a sense fro the outside and once people step into it they experience a radically different atmosphere from

FIG 4.33 Entrance to Paley Park on 53rd street. New York City, New York

FIG 4.32 Plan of Paley park on 53rd street. New York City, New York

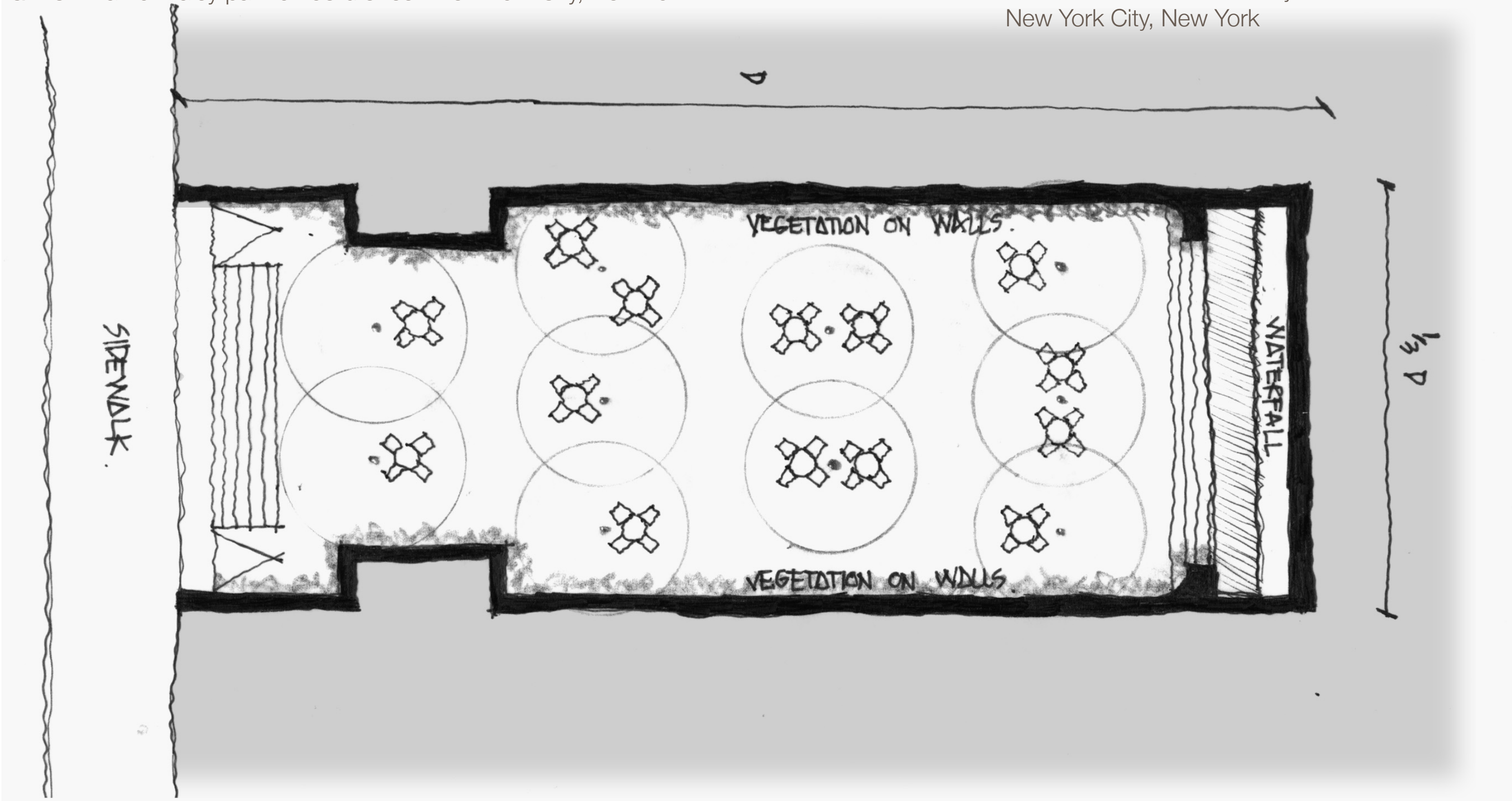

FIG 4.34 View towards street insi rd street. New York City, New York

what is on the street. The Botanical garden within the greater context of the hatfield precinct and University campus also forms a vest pocket created by existing trees and vegetation. It offers the possibility for people to escape the daily routine and fabric of the commercial area into a space that offers tranquility and rejuvenation for the spirit.

4.4.2 Adjacent parking area

The University of Pretoria is notorious among students for its lack of adequate parking on campus. Many parking spaces, as the one adjacent to the site, make ineffective use of providing enough parking bays in the area that is provided. An alternative for this specific area is to provide basement-parking bays with a 2 level-ramped entry that leads to the lower basement. This approach has the following benefits

- The ramps can provide for parking spaces as well, but make the parking garage less obtrusive from the outside.
- Vegetation can be planted on the roof terraces to serve as an extension to the garden.
- The area can be used in a capacity of five times ore than is currently provided

FIG 4.37 Parkhaus am Bollwerksturm, Heilbronn (Henley 2007:180)

FIG 4.38 Office and residential building at Wimbergergasse, Vienna. Designed by Delugan Meissl associated architects (2001)

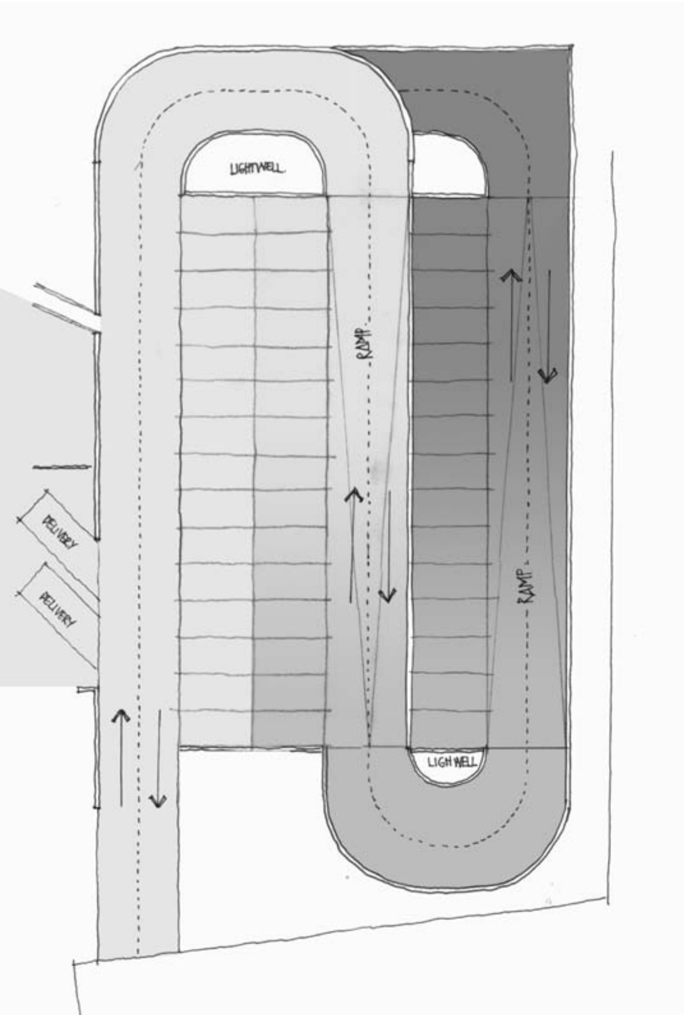

FIG 4.35 Idea for new ramp- and terraced basement parking garage

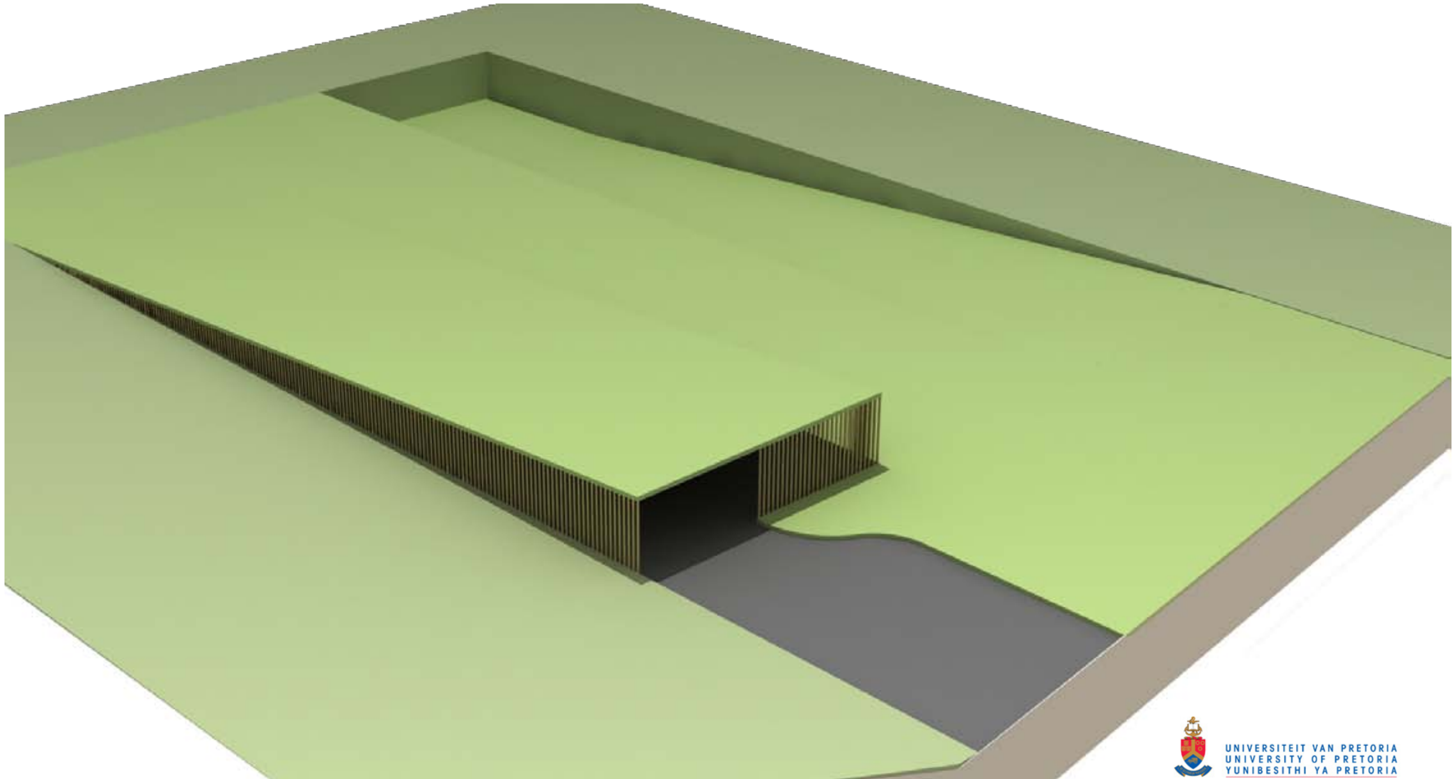

FIG 4.36 Idea for new ramp- and terraced basement parking garage


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precedent studies

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GREENHOUSES

5.1	Facility
Kirstenbosch conservatory, Cape Town, SA	
Typology	Conservatory for public interest
Reference	Visited by author

5.2	Facility
Reganwald haus greenhouse Vienna, Austria	
Typology	Fauna and flora greenhouse for public interest
Reference	Visited by author

5.3	Facility
Quarantine greenhouse Wageningen, Netherlands	
Typology	Research and contaimnet facility
Reference	Bibliographical

SEED HEALTH TESTING LABORATORIES

5.4	Facility
Seed health testing unit, Laguna, Philippines	
Typology	Research
Reference	Bibliographical

5.5	Facility
Plant quarantine regional sation. Rajendranagar, India	
Typology	Research
Reference	Bibliographical

SUSTAINABLE DEVELOPMENT

5.6	Facility
Sustainability institute, Lynedoch, Stellenbosch, SA	
Typology	Educational centre and community eco-village
Reference	Visited by author

5.1 Botanical Society Conservatory

Location: Kirstenbosch, Cape Town, South Africa
Design: Julian Elliott, MLH Architects, 1994-1996
Area:1695 m^2
Cost: ZAR 5.5 million

Situated at the Kirstenbosch Botanical Gardens in Cape Town on the warm northern face of Boschheuwel, Table Mountain, the purpose of this conservatory is to showcase the succulent species of South Africa (Fig. 5.1- 2). Although designers visited related projects in the United States and Europe, they were advised by chief horticulturist Ernst van Jaarsveld to invent a design that will be appropriate for the South African climate and conditions, as glass houses based on European principles tend to overheat during the summer months, because of the markedly different climatic conditions. According to Mr. van Jaarsveld, and due to the fact that the succulent species would be sourced from their natural habitats, the only thing they need to be protected from is the winter rainfall of the southwestern Cape.

5.1.1 Program

Conservatory:

- Main room/ Arid house - 548 m^2
- Exhibition area/ foyer
- Four corner (artificially climate controlled) units - 90 m^2 each
- Evolution garden on the Southwest
- Ablutions, kitchen and offices.

Vehicular access is provided at the back for deliveries and three other smaller greenhouses are use for preparation and preservation of species showcased in the main conservatory. An existing substation houses all electronic and mechanical operations.

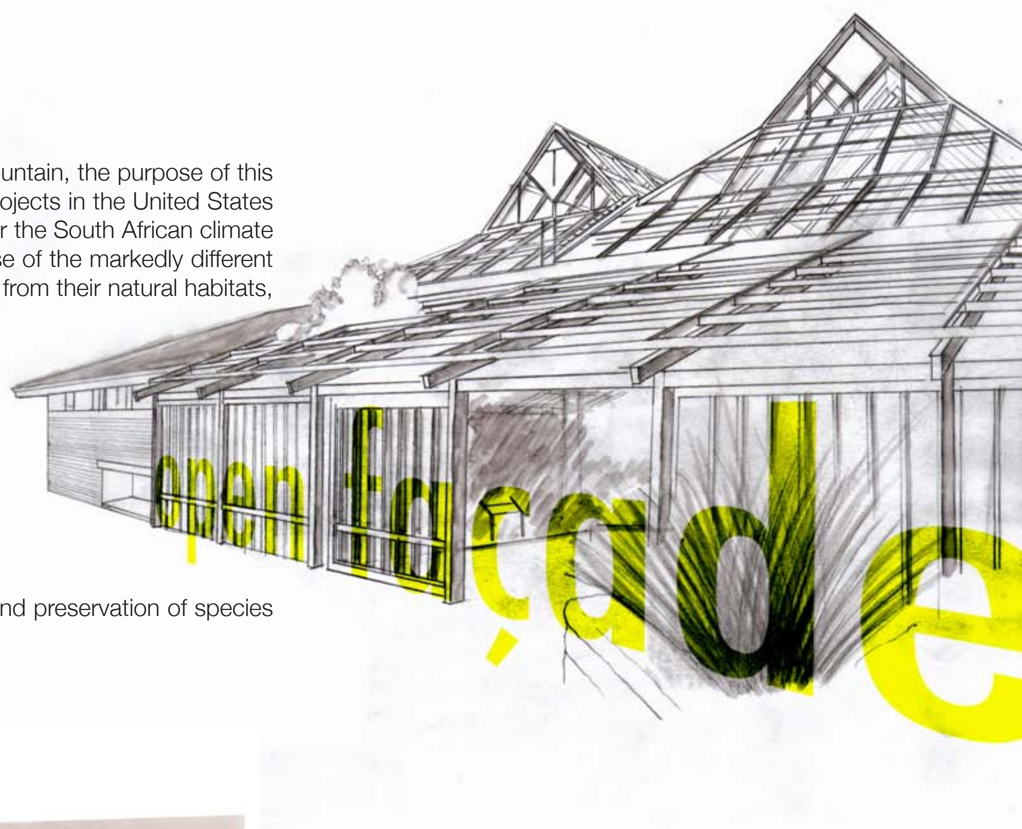


FIG 5.1 Interior view of the conservatory at Kisrstenbosch, Cape Town

FIG 5.2 View of the Western façade with openings that allows for free-/open ventilation

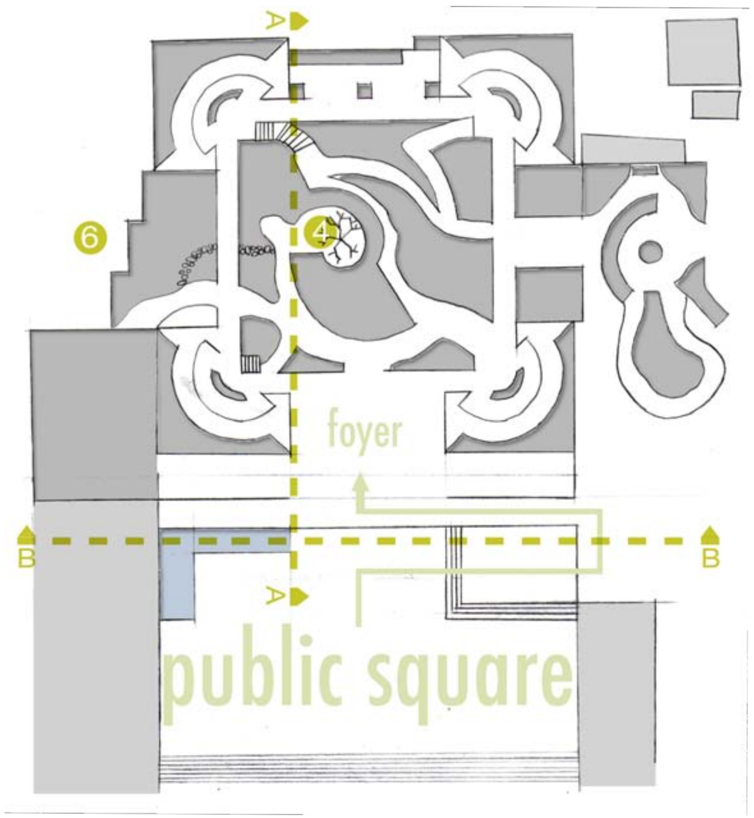


FIG 5.3 Plan of the conservatory

Visitors centre:

- Ticketing offices
- Deli
- Restaurant
- Security checkpoint
- Information desk/ points and offices
- Public squares

Ideas and constraints informing design:

- Four seasons and four variables: sun, heat, humidity and ventilation.
- Spiral floor plan with Baobab tree at centre
- Logical garden layout: North – South orientation of garden and planting representing the nine provinces of South Africa with natural rocks from each.
- Six-metre fall across entire site

5.1.2 Design:

PLEASE REFER TO FIG 5.3- 5

1. Design based on open-frame houses. Three of the four sides of the building are permanently open. Thermostatically controlled underground heating coils is installed in the arid house.
2. Thermostatically controlled, hydraulically operated, roof windows open automatically at 28˚C – automatic gauges measures wind velocity and closes them accordingly.
3. Two extractor fans are situated at both ends of the glass house and starts up when the interior temperature reaches 34˚C. The natural ventilation system works so well though that this was never necessary to use the extractor fans.
4. The spiral ramped (1:12) floor plan allows for a more inclusive building to wheelchair users
5. A cascading roof allows for maximum light in winter at midday, but reflects the sharp early morning and late afternoon rays in summer which are most likely to damage the type of plants housed within the conservatory. (Knoll 1998:8)
6. Camphor trees, blinds and tinted laminated glass shade the house from the western sun.
7. Subsoil drainage system that proves to be very affective.

FIG 5.4 Section AA

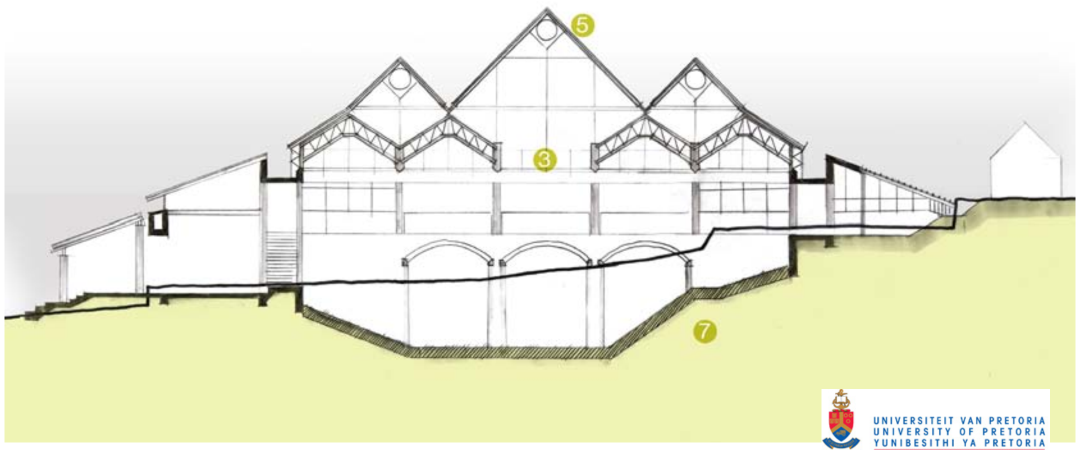


FIG 5.5 Section BB

5.2 Reganwald haus – Zoological "rainforest" glasshouse

Location: Schönbrunn Tiergarten, Vienna, Austria
Design: ARGE Architekten Neversal and Edelbacher & Hartmann, 2000-2002
Area:1000 m^2
Cost: €10.17 million (ZAR 128 million)

Just west of the CBD lays the Schönbrunn tiergarten (zoo) where the glasshouse is located just off the main entrance. Construction on the Regenwald haus (Fig. 5.6) was completed in 2002 and mimics biological and climatic conditions found in the Borneo rainforest at Kalimantan Island, Indonesia. Amongst the over 300 plant species that are found within the structure is also a carefully controlled biome that sustains life for selected fauna that is found within its real life counterpart.

The glasshouse is used as a visitors' centre and has a vast labyrinth of meandering footpaths (Fig. 5.7), elevators and hidden caves to entice visitors to get closer to the exhibitions. Upon entering the facility the visitor is directed to different areas within the compound, such as the mangrove swamp, dripstone caves, etc. The facility is built on a steep slope and as visitors progress through the interior, they later find themselves amongst the treetops, looking down on the entire rainforest area (Fig. 5.8).

An ambient temperature ranging from 25 to 27°C during wintertime, and reaching a maximum of 35°C during summer with a relative humidity of 60-90%, needs to be sustained. As a result of extensive dynamic climatic simulations, the ambient climate within the facility is maintained by using an adiabatic thermodynamic desalinated water process for heating and cooling. This eliminates the need for solar preventative measures for the glass (Fig. 5.9-10), and mechanical cooling apparatus for the rest of the compound. During summer natural ventilation panels are opened when needed. During the winter months the facility is mainly heated by making use of passive heating processes such as thermal retention through wall and floor mass, and the trapping of daytime warm air in under-floor rock chambers (similar to the system discussed in Fig. 5.21). Growth-promoting UV lamps are used for plants in dark areas.

The above information was gathered from the author's notes during a visit to the

FIG 5.10

FIG 5.8 FIG 5.9

FIG 5

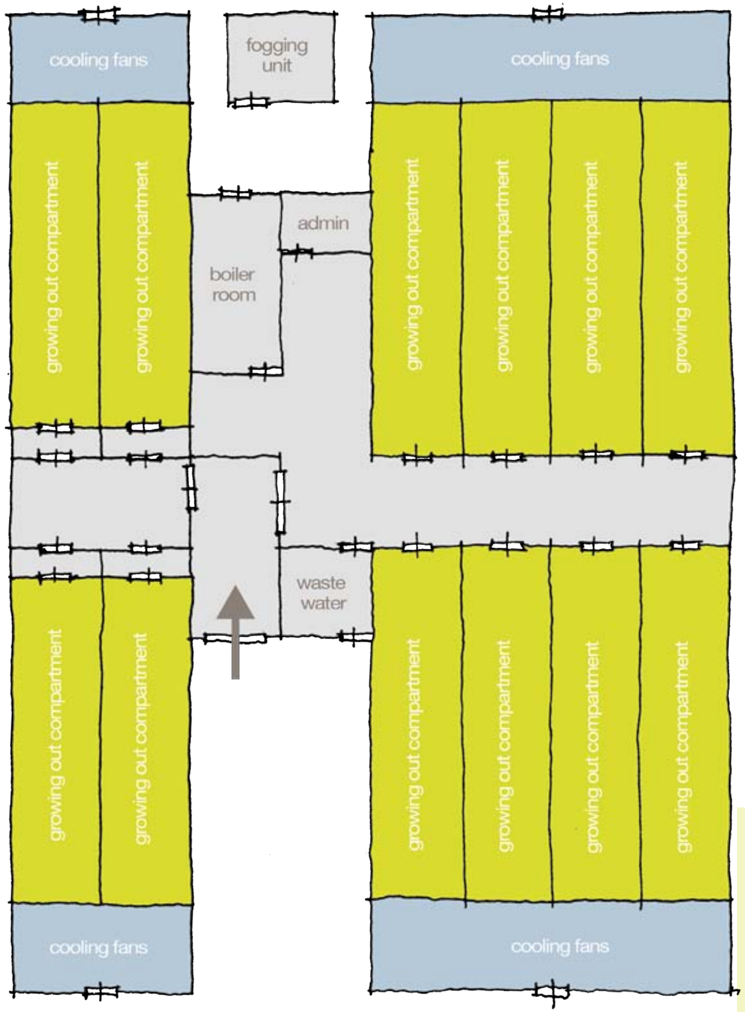
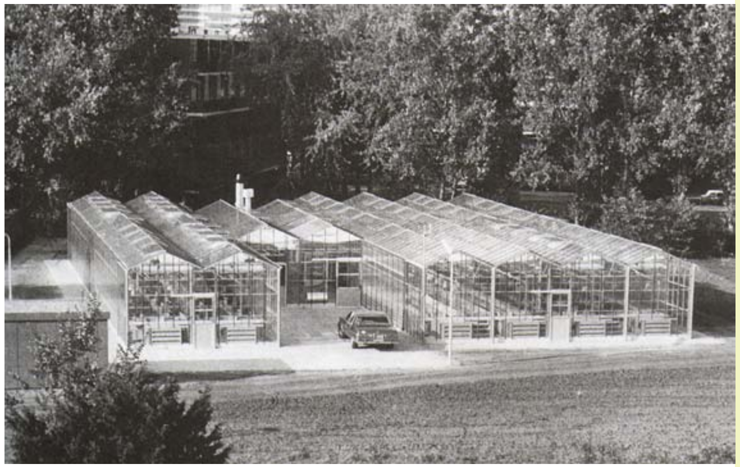


FIG 5.11 Plan of the facility

FIG 5.12 Main compound (Kahn 1999:109)



5.3 Dutch Plant Protection Service quarantine greenhouses

Location: Wageningen, Netherlands
Design: Completed in 1981
Area: 700㎡
Cost: N/A

Plant quarantine greenhouses represent a specific typology of quarantine facility that allows for specialized conditions and research. Other types of plant quarantine facilities include quarantine trial fields (open-air with isolation facilities) and quarantine stations that house phytotrons and laboratories.

Common criteria for evaluating plant quarantine facilities (as listed in Kahn, 1999: 109-11)

- Layout and accessibility of the experimental facilities
- Phytosanitary practices to avoid contamination
- Confinement of quarantine organisms
- Cleaning, disinfection or sterilization of equipment and materials
- Prevention of accidents
- Maintaining, safeguarding, clearing and destroying plant pathogenic organisms and infected materials

PLEASE REFER TO FIG 5.11 & 5.12

The main programme of the facility consists of twelve growing-out compartments, each being 40㎡. Computers remotely control the environmental conditions in each compartment. When trials are completed, each compartment can be disinfected or disinfested without disturbing trials in other compartments.

Access to the greenhouse is only granted to authorized personnel, and protective clothing must be worn after entering the greenhouse and while handling plant material. Plant material is treated as potentially infested and as such inspected twice a week for symptoms or signs of unwanted pests and diseases. Synthetic screens are used to separate plants involved in different experiments.

Outcomes on studying conservatories, glasshouses and quarantine greenhouses:

Kirstenbosch conservatory:

According to van Jaarsveld, a dispute concerning balustrade details erupted at Kirstenbosch between the project architect and the director of the botanical garden at the time. As a result, the architect lost the contract to design the public courtyard and visitors' centre that precedes the conservatory and is located just inside the main entrance.

According to the critique by Peter Dyson (1998:55) the simplicity of line, muted colors and subtle details of the visitors' centre both enhance and complement the focal point of the glass house, but the absence of greenery brings into question the relevance of the setting of the botanical garden to the architect's design approach.

The difference in the design approach of two different architects unfortunately undermines the entire project's architectural integrity. People tend to pass through the visitors' centre fairly rapidly, heading directly for the garden route to the Northeast. Few people take the trouble of taking a detour and walking through the conservatory. This can be blamed on three factors:

- **Scale:** The vastness of the two public squares preceding the conservatory with no means of proper shading from the harsh Cape summer sun, apart from a series of pergolas on the periphery.
- **Direction:** Although the symmetry of the square forms a visual axis, the path that the users have to follow along the steps does not conform to this logic.
- **Flow:** Once people have passed through the conservatorium they have to backtrack to the entrance and cannot simply pass through the glass house en route to the main Botanical garden.

The conservatory proves to be very successful and the mode of its operations undeniably represents a very sustainable approach to running such a facility in the South African climate. Sadly, the conservatorium relies greatly on the success of the visitors' centre, and unfortunately a great opportunity to illustrate how the built environment can be fully synthesized with its natural surroundings has bee [illegible] he construction industry has resulted in a loss of design intuition.

Glasshouse at Schönbrunn:

There are clear similarities between the facility at Schönbrunn and Kirstenboch:

- Conservatories-/glasshouses for public interest and education seem to have a clear organic floor plan that gives the impression of strolling through a garden
- Most of the above mentioned facilities conduct research as well, but these areas tend to be hidden from the public view. They are perceived as being Back of House facilities.
- The displays and way of communicating information at Schönbrunn is a lot more interactive allows for visitors to touch the displays. At Kirstenbosch glass screens between visitors ad displays makes the conservatory a lot less interactive.
- Free ventilation during the daytime in summer makes the glasshouse a lot more pleasant to move through. Because of the very humid conditions at Schönbrunn to sustain the rainforest climate inside causes people to stay shorter periods within the facility.

Glasshouse at: Wageningen

- Access into containment facilities is very restricted and can also be accessed by authorized personnel. Such is the case at Wageningen as well.
- Planning is pragmatic and modular. Optimum usage of floorspace with wide enough corridors for crate trolleys and wheelbarrows.

5.4 Seed Health Testing Unit, International rice research institute

Location: Los Baños, Laguna, Philippines
Design: Completed in 1987
Area: 343 m²

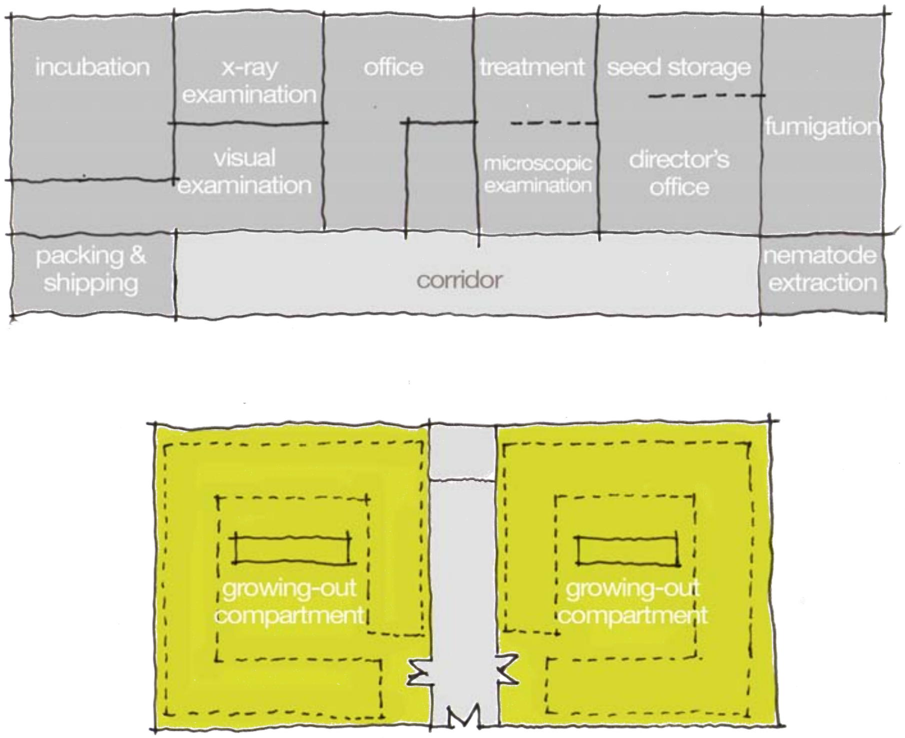


FIG 5.13 Layout plan of the main facility at Laguna (Kahn 1999:60)

5.5 Plant quarantine regional station and National plant protection-training institute

Location: Rajendranagar, Hyderabad, India
Design: Completed in 1992
Area: 255 m²

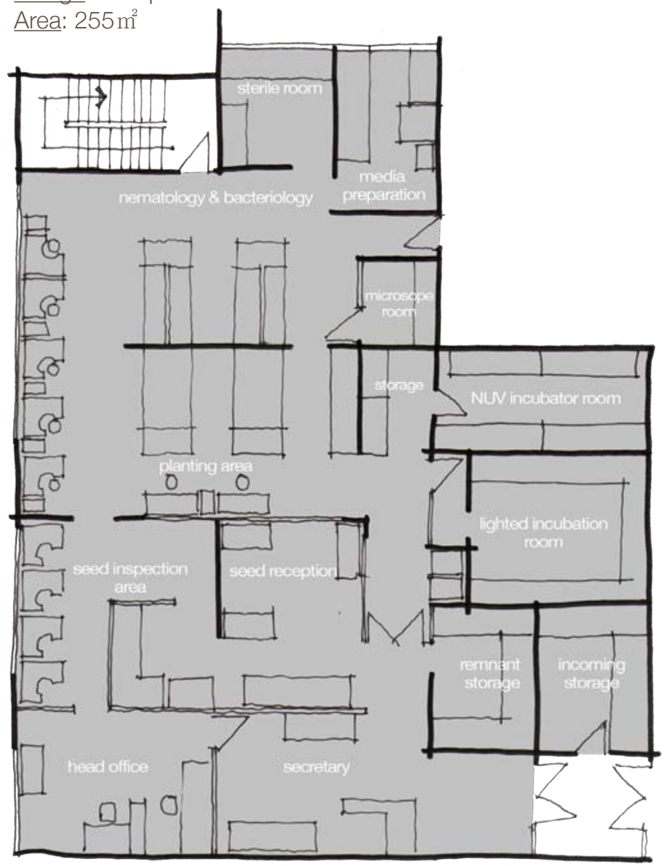


FIG 5.14 Layout plan of the main facility at Rajendranagar (Kahn 1999:39)

5.6 Sustainability institute, educational centre and community eco-village

Lynedoch eco village outside Stellenbosch, Western Cape, South Africa
Design: Prof. Mark Swilling & ARG Design
Duration: 2000 - ongoing project
Cost: Approx. ZAR 22 million (including land purchase)

This project contains a primary school, a post-graduate sustainability institute, a centre for performing arts, and businesses and offices, all within a residential community that is intended to be socially mixed. The five-hectare property is situated in the rural community west of the Spier wine estate just outside Stellenbosch. It is located near an important regional route that links Stellenbosch with the N2, and adjacent to a commuter train line linking Stellenbosch to Cape Town.

According to Darroll (2002:36), people from the Lynedoch community, many of whom work at Spier, had voiced the need for new primary school premises to replace the existing prefabricated facility. The client's intention was to create "a settlement that reflected the social and economic diversity present in this area…" (Unknown Author, Leading Architecture and Design, 2004:40).

Darroll (2002:36) explains that part of the Integrated Development Plan (IDP) acknowledges existing urban centres in the district of e.g. Stellenbosch, and seeks to contain urban sprawl around these centres by fostering medium-sized hamlet developments such as Lynedoch.

"The most significant aspect of the Lynedoch case from a sustainable design and construction point of view is that it provides a working example of an *integrated sustainable development*: *integrated* because it connects social, economic and ecological objectives and because it incorporates technologies that span the energy, water, sanitation, and building materials fields; *sustainable* because of the commitment to a long-term vision of social, economic *and* ecological sustainability; and *developmental* because of the anti-poverty and local economic development objectives" (Annecke & Swilling, 2006:2).

5.6.1 Development program:

Phase I: Acquiring of land, new buildings and readapting exiting buildings
- A primary school for 450 children
- A pre-school for 40 children
- Old Stellenbosch University dance hall: converted into a multipurpose hall
- Offices and classrooms for the Sustainability Institute
- Drie Gewels hotel and residential house: converted into 18 residences to serve as a guesthouse facility for participants in the postgraduate programme at the Sustainability institute, as well as for general use (Annecke & Swilling, 2006:3).

Phase II: Residential and hamlet (currently under construction)
- 42 dwelling units of which 14 are government subsidized
- Commercial space for offices or small manufacturers and crafters
- Village green and landscaped areas (using indigenous plants)
- Parking

Phase III: Community expansion
- The nature and extent of Phase III will be determined by community opinion and the outcome of Phase II.

FIG 5.19
FIG 5.18
FIG 5.15
FIG 5.16
FIG 5.17

5.6.2 Main building:

The site slopes steeply towards the main road. An old dance hall adjacent to the Drie Gewels hotel has been unused for years. It consisted of a double volume shed with a wraparound mezzanine level overlooking what used to be the central dance floor (Darroll, 2002:37). The following modifications were made:

- **Multipurpose hall**: The old dance floor was converted into a multi-purpose hall that serves the school, but can be leased out for performances, meetings and workshops (Unknown Author, Leading Architecture and Design, 2004:42).
- **Upper level**: Offices for the Sustainability Institute and Classrooms along the existing north and south wings.
- **Western wing**: An upper ground level entrance to the school that complements the steep gradient of the site, and classrooms that occupy the new extension.
- **Eastern wing**: Administration offices and computer laboratory.
- **Existing squash court**: Converted to hall for school sport/ other activities.

4.6.3 Ecological sustainability:

- **Wind scooping ventilation ducts:** To optimize the natural airflow through the hall by taking advantage of the direction of the prevailing winds (Darroll, 2002:37).
- **Rooflights** as **convection ventilators** – hot air extraction.
- **Extended roof overhang** and pergolas (covered with deciduous vines).
- **Rock chambers** (local river boulders): (using local river boulders): In **summer** cool night air is drawn from outside to cool the rocks. Fresh cool air is stored during the night and distributed to classrooms the following day via underfloor ducts. The same process is applied in **winter**, apart from the fact that warm air is drawn from the roof space at around 10:00 and flushed through the rock stores in order to be immediately distributed via the same underfloor ducts.
- **Adobe bricks** and concrete blocks are manufactured on site, but concrete was used for the exterior walls of the main building.
- **Potable** (municipal) and **recycled** water supply (for e.g. irrigation, flushing of toilets)
- **Open channel stormwater run-off** planted with kikuyu grass.
- **Rainwater harvesting**
- **Sewerage**: - Primary sewerage treatment through septic tanks
  - Secondary treatment via existing biolytic plant and constructed wetland
- **Energy**: - National grid (ESKOM)
  - Solar power: For water heaters and LED streetlamps
  - LP gas for cooking

FIG 5.20 Skylights and extractor fans in main hall

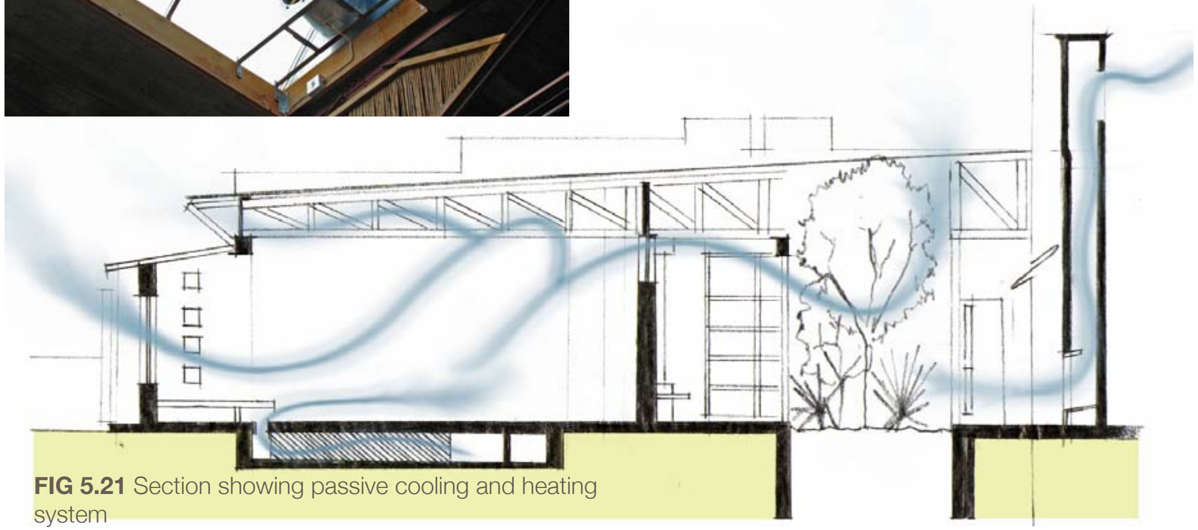


FIG 5.21 Section showing passive cooling and heating system

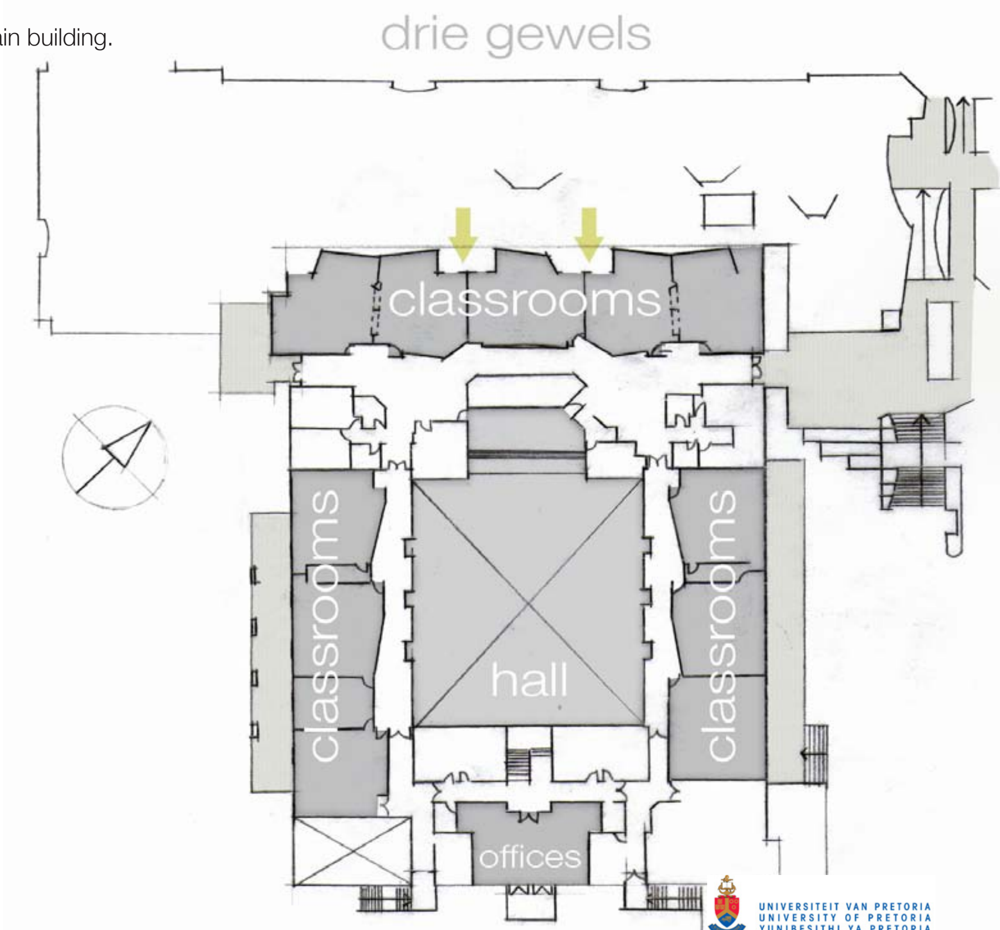


FIG 5.22 General layout plan of the institute

4.6.4 Social sustainability:

According to Annecke and Swilling (2006:11) there are three aspects of social sustainability that the Lynedoch Eco Village development addresses:

- **Governance**: All property owners, including the Lynedoch Development Company (LDC), are members of the Lynedoch Home Owners' Association (LOHA) that is responsible for all the community's service needs.
- **Maintaining a proper social mix**: People come from various walks of life, ranging from mainly black farm workers to self-employed professionals and government officials. The intent of the LDC has been to ensure a social mix through the provision of both commercially priced and subsidized plots.
- **Child centered approach**: Among many factors the most interesting is the development of an IT centre that links the primary school, the Sustainability institute and the University of Stellenbosch for the use of children, university students and community members.

6.4.5 Economical sustainability

Affluent communities can survive in enclosed local communities that do not need the poor, but the reverse is not true. Therefore, if spatial integration of low- and high-income households takes place, it becomes possible to create all sorts of markets that incorporate rather than exclude the urban poor (Annecke & Swilling, 2006:11).

Outcomes on studying Lynedoch:

- It is clear that from the research and practical applications done at Lynedoch that there is a clear sense of social responsibility within the community.
- The scheme is rural and similar thinking can be applied within urban areas, but with more sophisticated technology.

FIG 5.23 View towards classrooms down the western façade

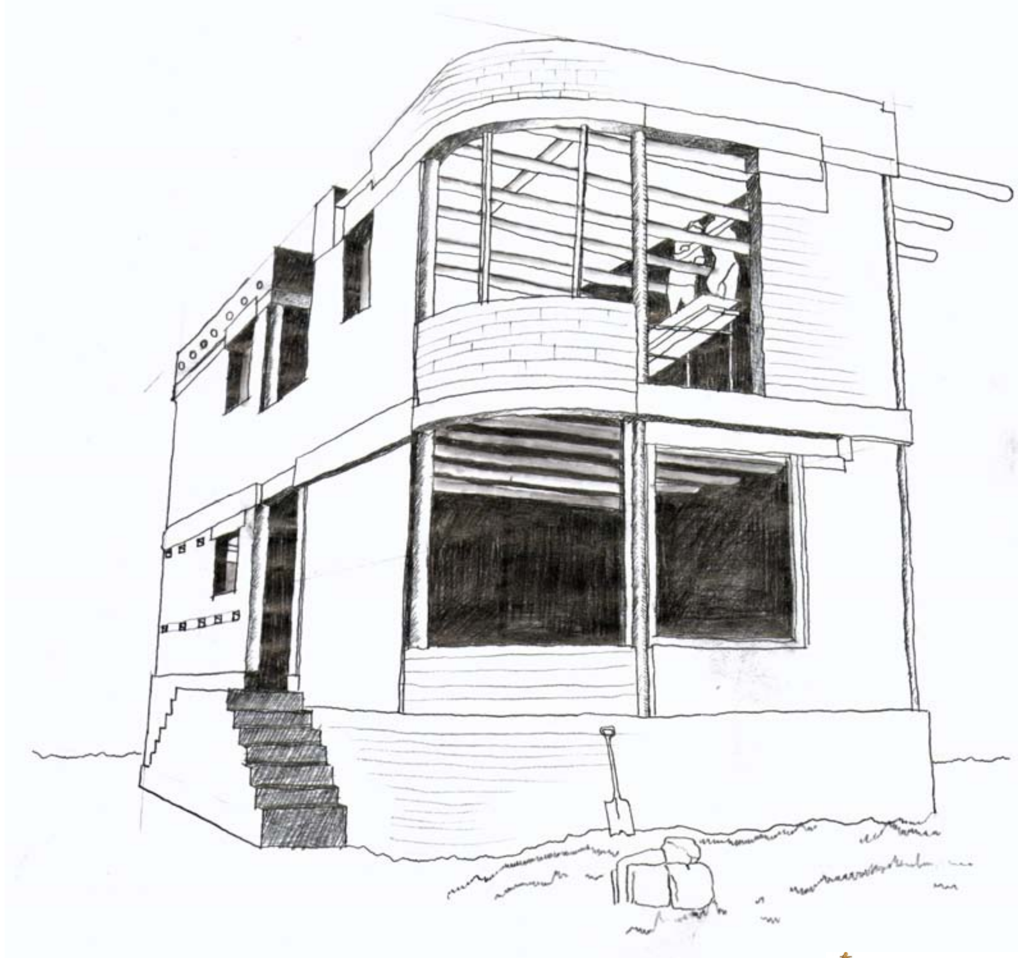


FIG 5.24 Building of low cost housing units

design development

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The garden : Kit of Parts

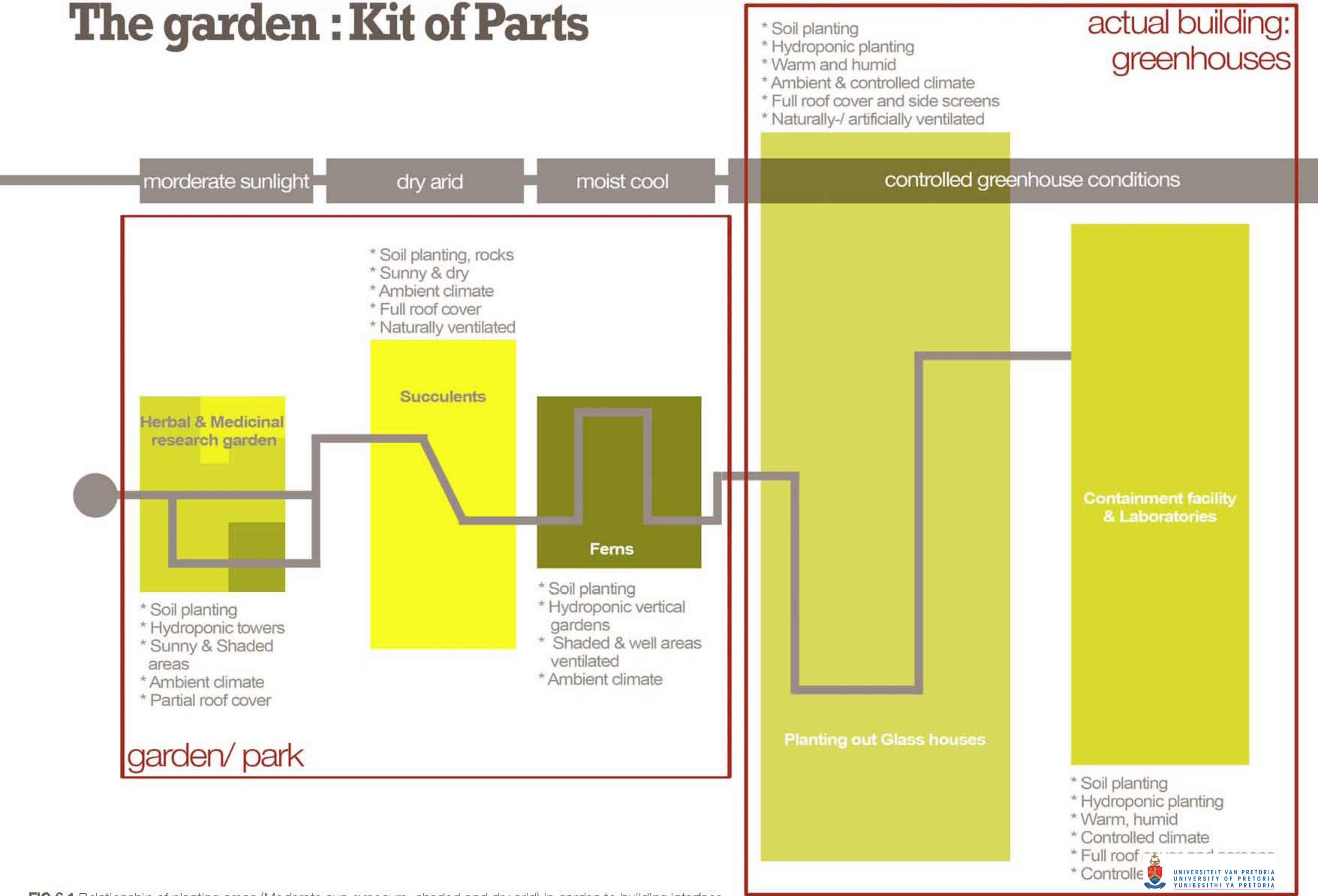


FIG 6.1 Relationship of planting areas (Moderate sun exposure, shaded and dry arid) in garden to building interface

6.1 The Garden:

6.1.1 Ferns:

The growing of ferns can facilitate the collection of medical or food production research data.

Light requirements:

- Like all plants, ferns need a light ray spectrum of blue, red and violet to fuse carbon dioxide with water in order to produce sugar.
- Ferns prefer some level of shading to carry out the process of photosynthesis.
- Too strong light for a significant part of the day can drastically alter the appearance of a fern plant.
- Too little light exposure will inhibit photosynthesis.
- Older fern plants require more light exposure as apposed to the limited light exposure that young plants need.

Atmosphere:

- Ferns require a moist atmosphere of 60-80% relative humidity during the day.
- Low humidity inhibits new growth.

Air:

- Ferns must have fresh air.
- Oxygen is needed for respiration and this is a continual 24 hour process.

Ferns in glasshouses:

- Control of relative humidity and protection against frost can be achieved.
- The roof and exposed sides of the greenhouse must be shaded (dappled shading).
- It must be well ventilated. Top ventilation is preferable in order to get rid of warm air. Down draughts must be prevented.
- Optimal air quality is obtained by vents that open in the morning and close in the early afternoon.
- Stagnant, non-circulated air encourages frost damage and the growth of moulds or bacteria.

6.1.2 Succulents:

For a detailed investigation of the growth requirements of succulent plants, please refer to the Kirstenbosch succulent conservatory discussed in Chapter 5.1.

6.2 Building : Glasshouses and Plant containment facility

These types of facilities are used to safeguard plants and to grow them under quarantine and controlled conditions:

The objective of introducing containment facilities is to manage the risks associated with exotic plants and other foreign organisms. Quarantine and associated research services implement activities to reduce these risks to acceptable or tolerable levels (Kahn and Mathur, 1999:1).

According to Kahn and Mathur (1999:82-97), exotic plant species are quarantine significant if:

- They do not occur naturally in the given country.
- They can place domestic species under severe strain.
- They are subject to a national containment, suppression or eradication programme.
- They can cause economical damage.

Design:

In South Africa the importation of plant species is not regulated by the South African National Biodiversity Institute (SANBI), but rather by the National Department of Agriculture (NDA). Regulations such as the Agricultural Pests Act 36 of 1983 are issued by the National Plant Protection Organization of South Africa (NPPOSA).

The management of risks associated with pests and foreign organisms

Low risk containment: **Open access**

Minimized climate and access control.

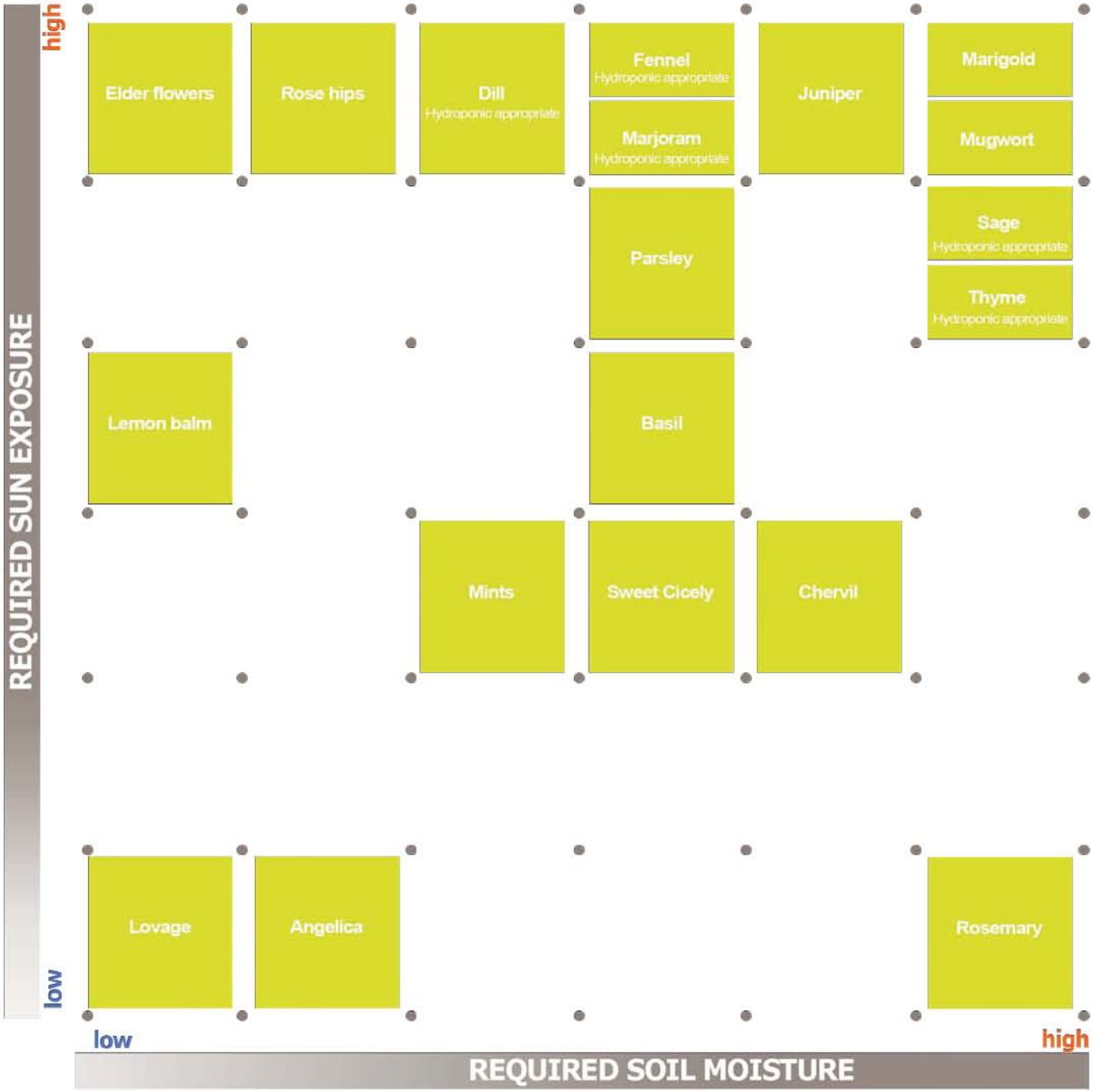


FIG 6.2 Graphical representation of sun/soil-moisture requirements for Herbs planted for medicinal research purposes. Image by author, adapted from Loewenfeld (1967:234-243)

Type	Soil moisture requirements	Sun exposure	Planting season	Culinary attributes	Medicinal attributes
Angelica	Damp rich	Shaded	Autumn	Removing tartness from food	Blood cleansing Diuretic tea
Basil	Well drained, moist, heavy and sand mix	Sunny sheltered	Autumn	Flavoring to dairy, fish and vegetable dishes	Constipation
Chervil	Well drained, light, sandy	Semi shaded	All year	Soups and sauces	Blood cleansing Muscle injuries Diuretic qualities
Dill	Well drained, moist, heavy and sand mix	Sunny	All year	Sweet flavoring for fish and vegetables	Insomnia Vomiting
Elder flowers	Damp rich	Sunny	All year	Fritters	Eye skin lotion Sciatica
Fennel	Deeply dug, rich, chalky	Sunny	Spring	Chicken, fish and egg dishes	Indigestion Cosmetic creams
Juniper	Chalky	Sunny	All year	Flavoring to game, meat, stew, poultry	Blood cleansing Indigestion Rheumatism
Lemon Balm	Damp rich	Sunny sheltered	Spring, Autumn	Flavoring for fish, lamb and vegetables	Relaxation Migraine Palpitations
Lovage	Damp rich, deeply dug	Damp	Spring, Autumn	Flavoring for all meat and vegetables	Milk production for mothers
Marigold	Any soil	Full sun	Spring, Autumn	Flavoring to breads	Skin treatment
Marjoram	Medium rich	Sunny	Spring, Autumn	Tomato and mushroom dishes Meat flavoring	Hay fever Skin treatment
...ts	Moist, rich	Semi shaded	All year	Sweets and Sauces	Mouthwash Toothpaste Headaches
...gwort	Any soil	Sunny	All year	Beer, meat, fish and duck	Chronic diarrhea
...sley	Chalky, dry, well drained	Sunny	All year	Garnish and flavoring for all appropriate dishes	Diuretic tea Rheumatism
...e hips	Clay soil	Sunny	All year	Tea and sauces	Kidney and bladder
...emary	Light sandy, dry, chalky	Sheltered	Spring	Meat, poultry, egg and vegetable dishes	Heart stimulant Indigestion Skin supplant
...e	Light sandy, dry, chalky	Sunny, dry	Spring	Meat and fish dishes, cheese making	Sore throats
...et Cicely	Medium rich, well drained, mo	Partial shade	Spring	Added to tart fruit, organic sugar, Vegetables	Perfume
...me	Chalky, dry, well drained	Dry sunny	Spring	Shell fish, mutton and pork, cheeses	Bronchitis Disinfectants Mouth washes

TABLE 6.1 Research value of most com... ...age by author, adapted from Loewenfeld (1967:234-243)

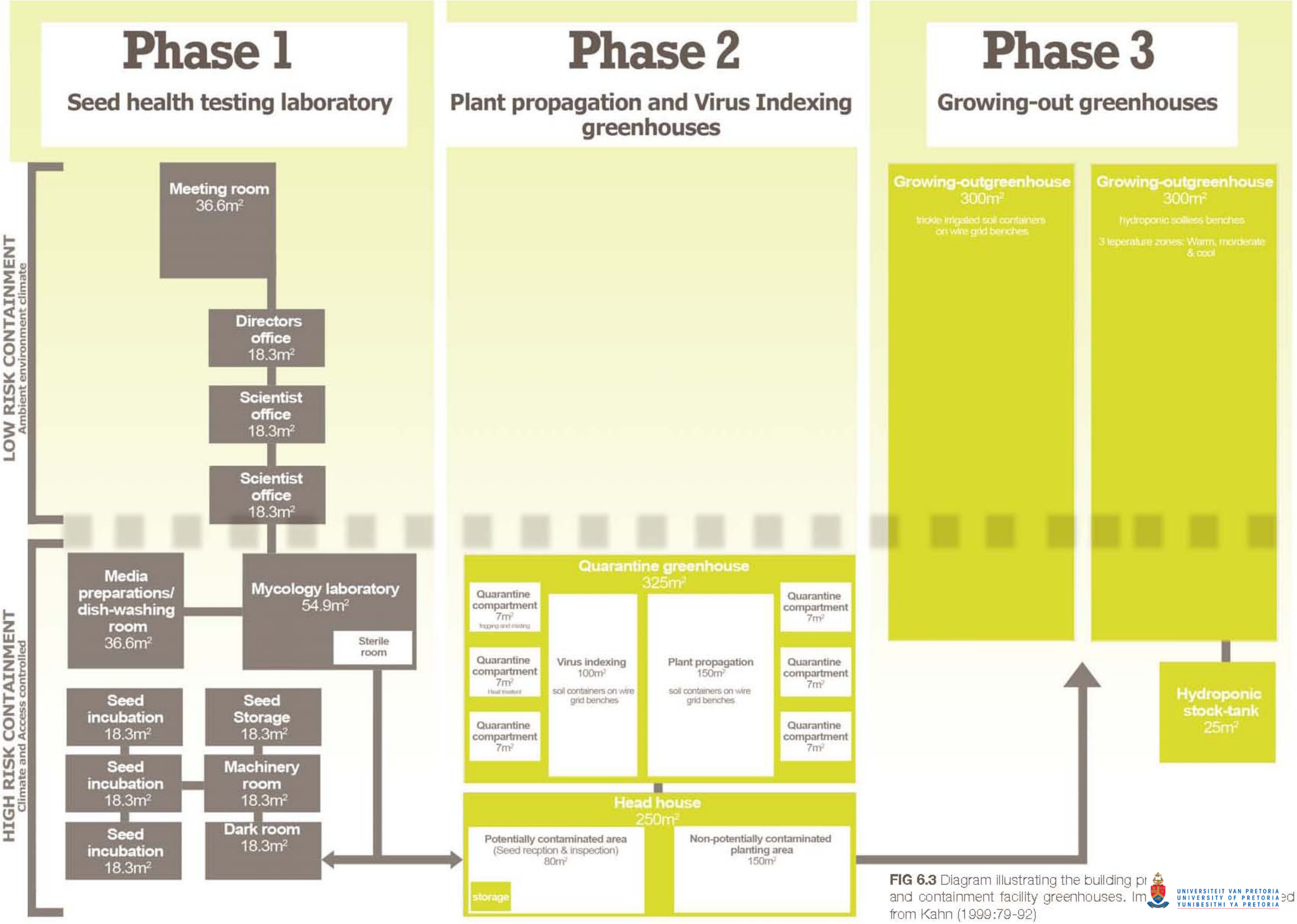


FIG 6.3 Diagram illustrating the building pr... and containment facility greenhouses. Im...ed from Kahn (1999:79-92)

Used for areas in the greenhouse complex where plant specimens have been immobilized from posing viral or bacterial threats to other plant specimens. Administrative areas and growing-out greenhouses are considered facilities for low-risk containment.

Medium-risk containment: **Single door entry**

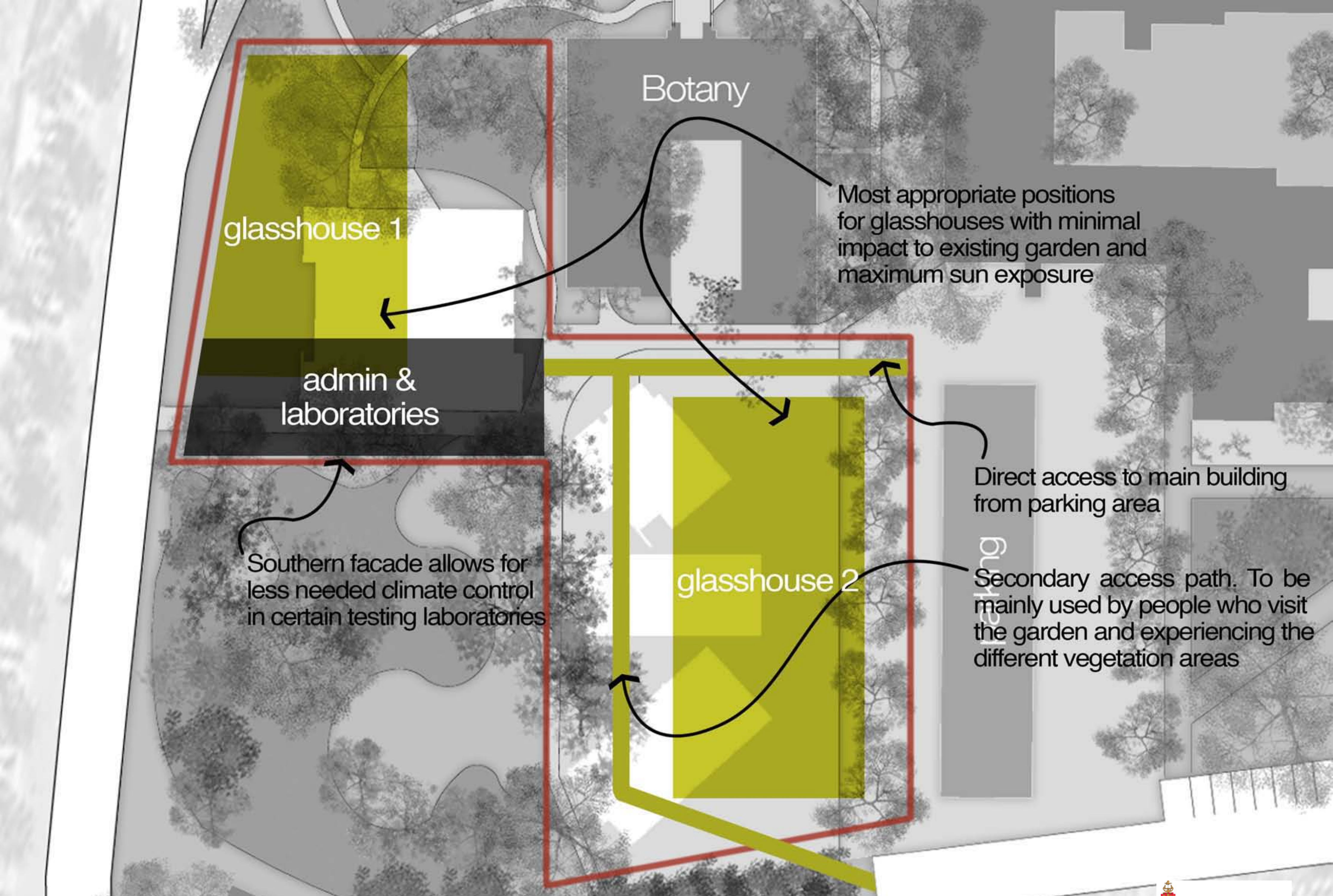
High-risk containment: **Double door entry**
Maximum climate, humidity, ventilation and access control.

A high-risk containment facility is required when a wide spectrum of species with diverse life cycles and characteristics need to be dealt with and hosted, and because the identities of the organisms needing to be hosted are unknown.

Containment greenhouses for research purposes:
A three-phase process

Function	Risk	Design considerations
PHASE 1		
Offices Meeting rooms	Low	▪ Infrequent use: Functions can be located in one area ▪ Can be constructed to connect with laboratories and other facilities
Mycology laboratory & Media preparation	Medium	▪ With supporting Media preparation and dishwashing facility that supports the laboratory. ▪ Modular furniture fittings ▪ Approx. 2.7m floor to ceiling height. ▪ Direct sunlight shouldn't fall on laboratory equipment.
Dark room Machinery room Seed incubation Seed storage (Cold room)	High	▪ Can be in the basement level in order to reduce the heat load. ▪ Carefully regulated interior temperature and humidity for each room. ▪ Façade surfaces should either be white or reflective if it is not positioned in the basement to reduce heat absorption. Alternatively tree shading. Insulation on warmer side of the structure together with a vapor barrier to ward of condensation moisture. ▪ Module must be sealed off from other modules by double doors. Each room must be protected by a double door entry. ▪ Air conditioning equipment and power generators are housed in the insulated machinery room to reduce noise and vibrations.
PHASE 2		
Head house	Medium to High	▪ Connects with a main corridor to all other greenhouses. ▪ Utility ducts and pipes can be routed through corridors. ▪ Seed reception and inspection.double doors. Each room must be protected by a double door entry. ▪ Air conditioning equipment and power generators are housed in the insulated machinery room to reduce noise and vibrations. ▪ Cold room temperatures 6-8°C
Quarantine greenhouse	Medium to High	▪ The individual greenhouses are divided up into compartments connected by a corridor leading to the main corridor. Double door entry at each compartment and a door at the connection between corridors.
Plant propagation	Medium	▪ To grow virus indicator plants. ▪ Units must be protected against the egress and ingress of insects and mites. ▪ Growing occurs in containers on wire grid benches. ▪ Double door entry ▪ Evaporative cooling and shading techniques: 30°C daytime maximum; 15°C nighttime minimum.
Plant Quarantine	High	▪ Screened against egress and ingress of insects and mites. ▪ Double door entry ▪ Floor drainage, shading and evaporative cooling. ▪ Growing occurs in containers on wire grid benches. ▪ 30°C daytime maximum; 15°C nighttime minimum. ▪ Mechanically air-conditioned. Negative pressure relative to corridor by exhausting air from each chamber through HEPA filters which discharge in the corridor. ▪ One compartment with 40°C day/night temperatures for heat treatment of virus infected plants. ▪ One compartment with independently controlled fogging and misting system. ▪ Specialized compartments can also be used for general purpose.
Virus indexing/ Seed health testing	Medium	▪ Floor drainage and double door entry. ▪ Growing occurs in containers on wire grid benches. ▪ 2 Movable internal shading areas. 30 and 50% respectively and 65% if used in tandem. This is to remove heat stress and to promote symptom expression in virus indexing. ▪ 25°C daytime maximum; 20°C nighttime minimum. ▪ Fog and shading systems should eliminate the need for mechanical refrigeration.
PHASE 3		
Planting out greenhouses	Low	▪ Specimens are planted in growing out greenhouses when seeds have been inspected and incubated for at least 7 days. Much of the risk was eliminated during this process and the main requirement for these greenhouses are to be insect proof. ▪ Glasshouse temperatures can be equal to the ambient temperature ▪ Due to the high solar radiation in South Africa, not all walls need to be screened as this also enhances natural convection. ▪ Evaporative- or fog cooling is optional. ▪ Concrete floors or similar to avoid contamination of floor for both soil-bench container growing and hydroponic waterborne fertilization.

TABLE 6.2 Detailed summary of the 3 phases of containment and risk levels within the containment facility. ...apted from Kahn (1999:79-92)



Primary building functions

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FIG 6.4

Influences

FIG 6.5 Kennet, William Morris,1883 (Sachs, 2007:83)

FIG 6.6 Japanese garden in Clingendel (Gieskes 2006:4)
Note the meandering pathways everytime creating new vistas until you reach the pavilion with its very geometric plan contrasting the natural forms and lines of the garden.

FIG 6.7 Algue, Ronan & Erwan Bouroullec (Sachs 2007:62)

FIG 6.5 FIG 6.6 FIG 6.7

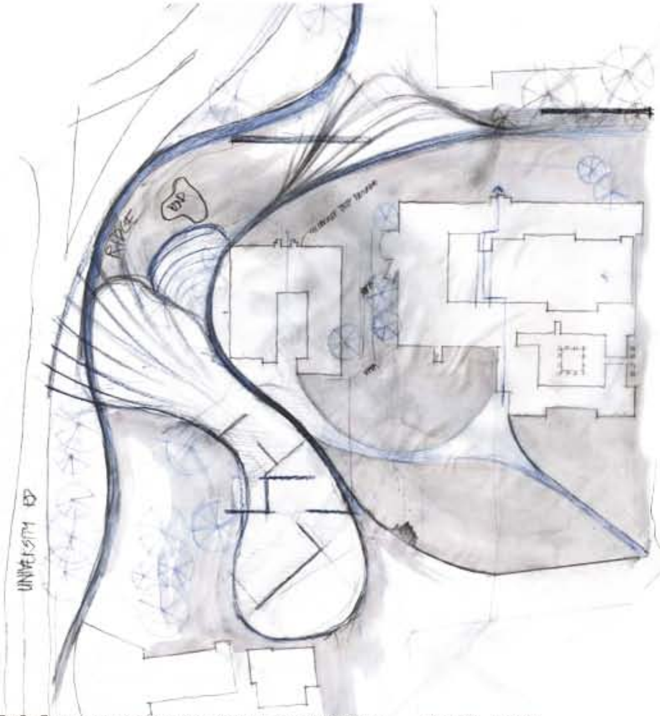

FIG 6.8 2D Building footprint exploration - March 2008

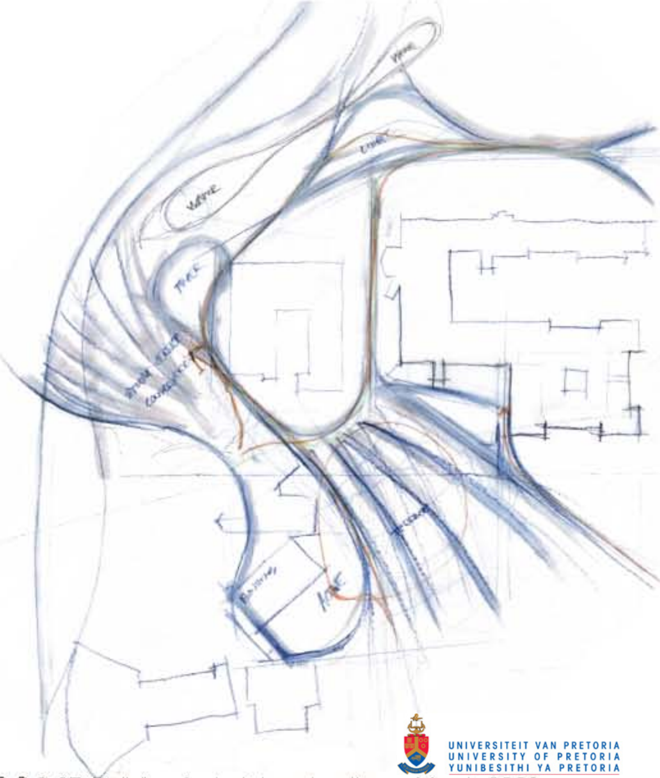

FIG 6.9 2D Building footprint exploration - March 2008

6.2.1 Footprint:

The building footprint is mainly governed by the following factors:

- Growing-out **glasshouses** for plant propagation (largest footprint) need maximum exposure to **sunlight.**
- **Laboratories** require **less sunlight** and lower levels of heat gain.
- **The botanical garden** forms part of the research area and contains many rare species of plants. Optimal sensitivity to the existing vegetation should be maintained.
- Most users **access** the site from the adjacent parking area or the southern entrance to the garden.

The design of the glasshouses and laboratory calls for a regulated and parametric approach to their layout. Most of the furniture units that will occupy these spaces are modular, with fairly rigid plan shapes that will allow for a more logical and effective use of the spaces.

FIG 6.10 3D Clay model building form language exploration. Experimentation with terracing and organic facade shapes - April 2008

FIG 6.11 3D Clay model building form language exploration. Experimentation with terracing and organic facade shapes - April 2008

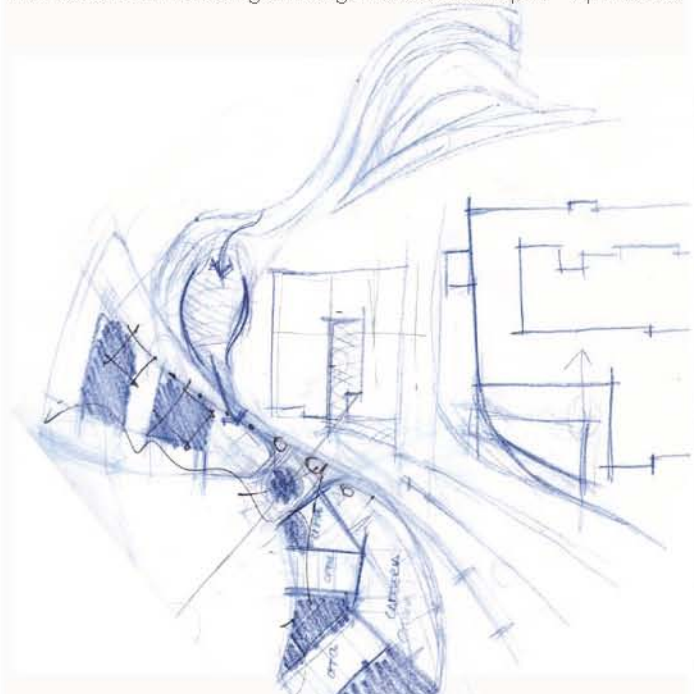

FIG 6.12 Creating "pockets" within the form

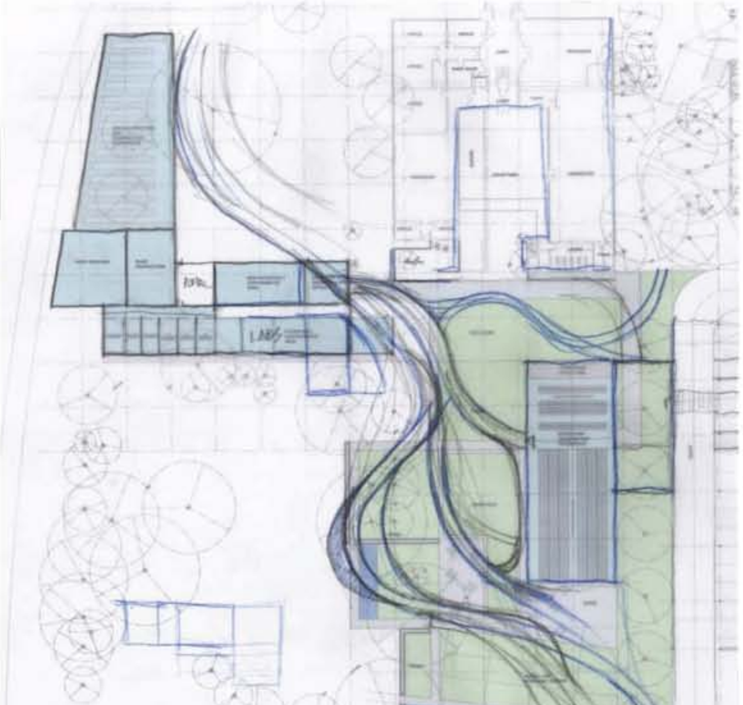

FIG 6.13 Visitor pathways are organic. It promotes changing vistas within the garden

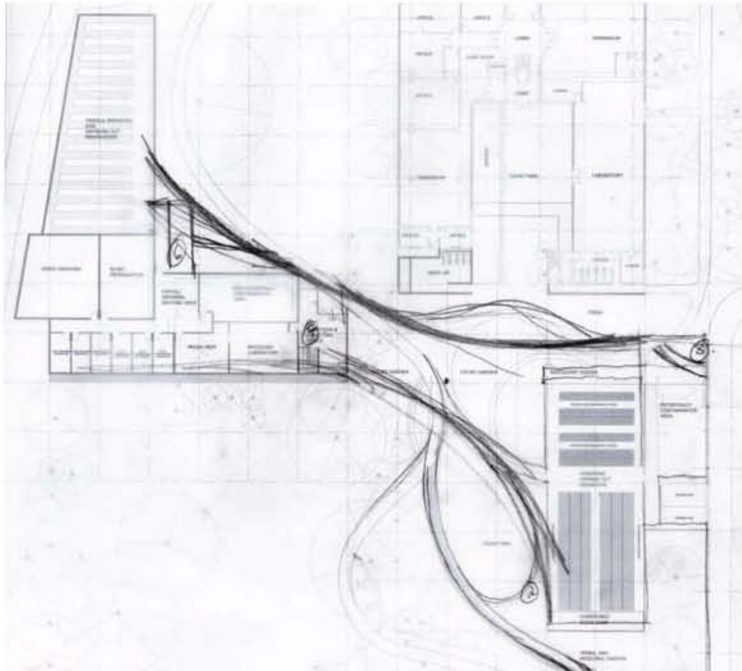

FIG 6.14 One continuing element will combi the building

6.2.2 Form language exploration:

It is my opinion that a building form language that is developed intuitively can result in a more humanly responsive architecture. Intuitive thought should always be underpinned by a strong research foundation that will support the practicalities of the design. In the case of this design, there is a strong need for the final product to create an architectural experience and expand the *genius loci* of the park as well as act independently and successfully as a high order research facility.

Basic building program and requirements were informed by site-/climatic constraint, the applicable programme required for such a facility and modular fittings for laboratories. This allowed the designer to intuitively respond with a form language that will combine the garden and the facility. This will allow regular users of the garden to move freely around and on top of the facility without intruding in on the higher order functions of the building.

FIG 6.15 Leaves displaces solar energy to from metaphysical spaces

Spatially plants form natural thresholds between humans and different levels of solar energy. Plants consume form their immediate environment what they require and displaces that energy into the fabric that compiles it. Leaves act as giant reservoirs that soak up solar energy. Leaves also form natural gutters and its shade create new ecosystems for other species emerging below it. This can result in an architectural form language that imitate this natural archetype allowing the building envelope to filter solar energy, but also for spaces to ascertain attributes that can be reminiscent of a natural environment. In this regard, the building form language becomes more an extension of the surrounding natural biome instead of dominating it completely. Building envelope becomes the glue between nature and human activity rather than the barrier.

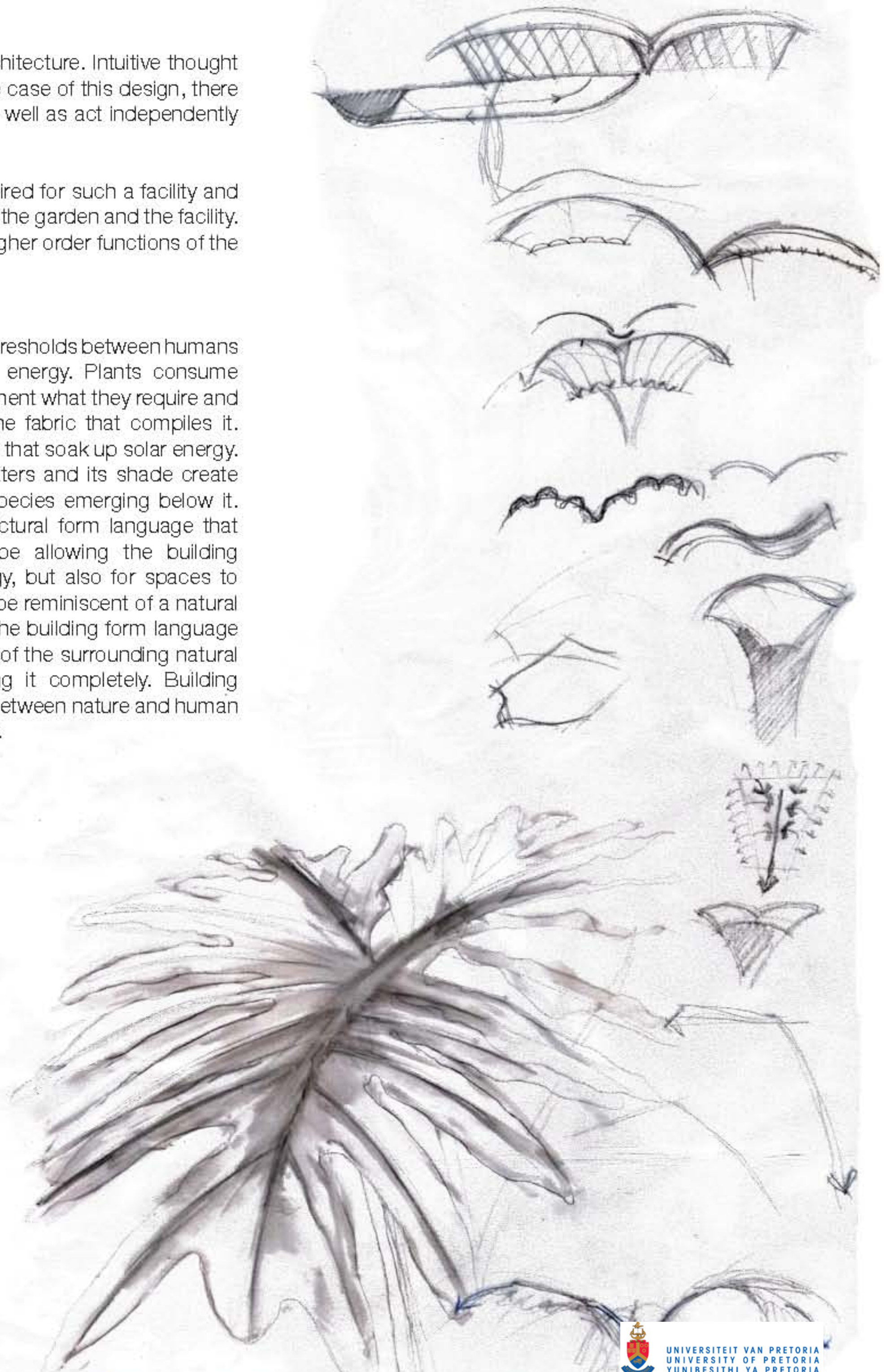

FIG 6.16 Intuitive form exploration from natural archetypes founded on natural intelligence

6.2.3 Alternative form exploration for glasshouses: Fig. 6.14-20

Alternative approaches were undertaken in using a more pragmatic approach. These had the following problems:

- Larger "stacked" greenhouses require more mechanical parts that reflects light
- Reflected light changes frequency and are less successful then for propagating plants
- The building form became too abstract and the desire for the form language to integrate with the garden was lost

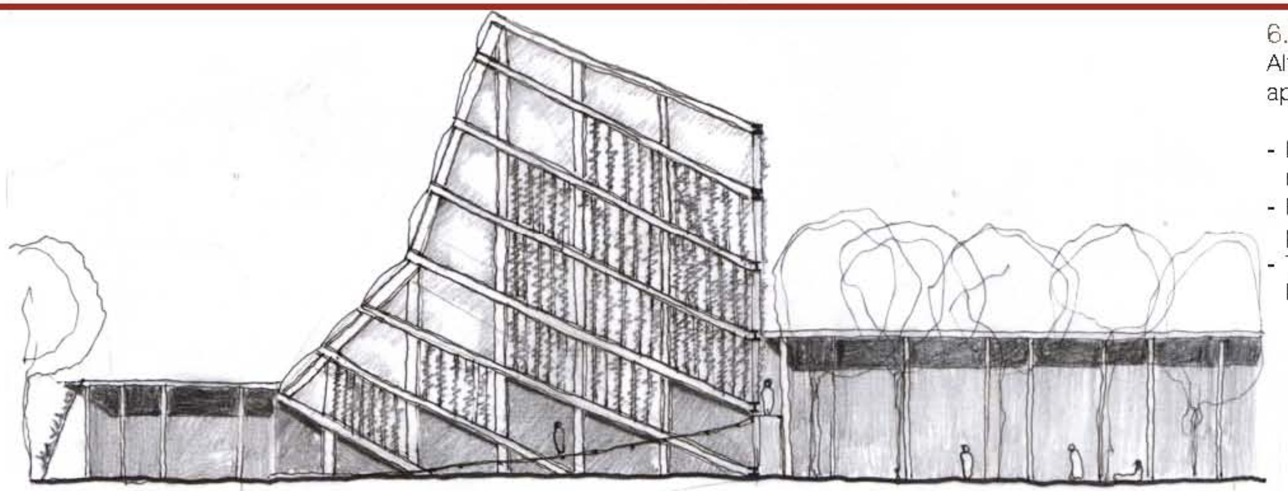

FIG 6.17 Elevation: Stacked greenhouse idea - June 2008

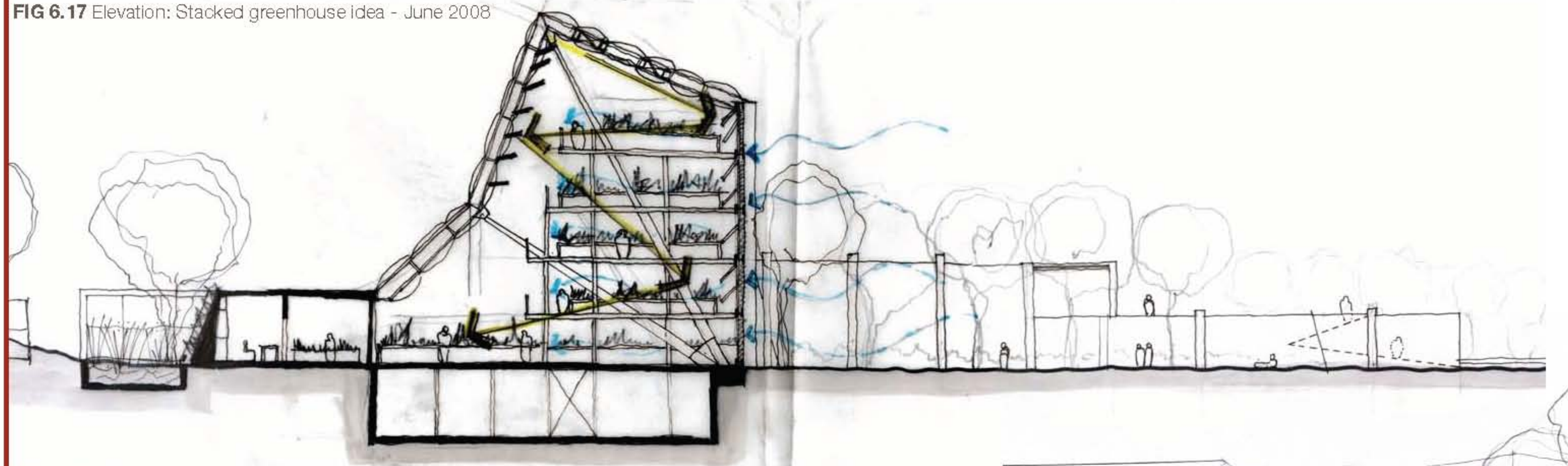

FIG 6.18 Section: Stacked greenhouse idea - June 2008

FIG 6.19 Spaceframe structure of stacked greenhouse idea - June 2008

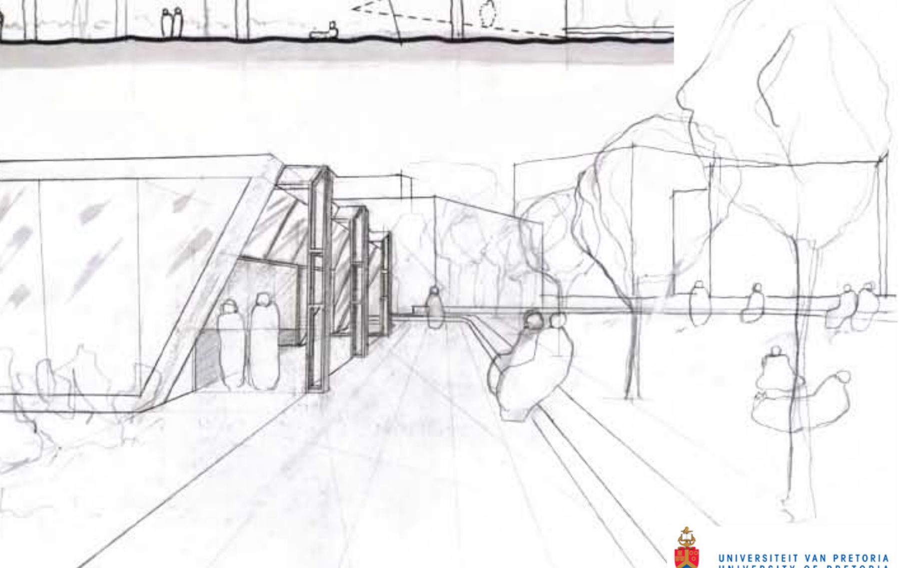

FIG 6.20 View along laboratories: Stacked greenhouse idea - June 2008

6.2.4 Roof as a unifying element:

After investigating other more pragmatic solutions for the glasshouses and garden, it was decided to revert back to the idea of using a one organic form language that will act as a unifying element over the entire site, connecting the research buildings with the garden.

The roof was considered to be complimentary to the footpaths and will allow for different controlled growing areas for plants.

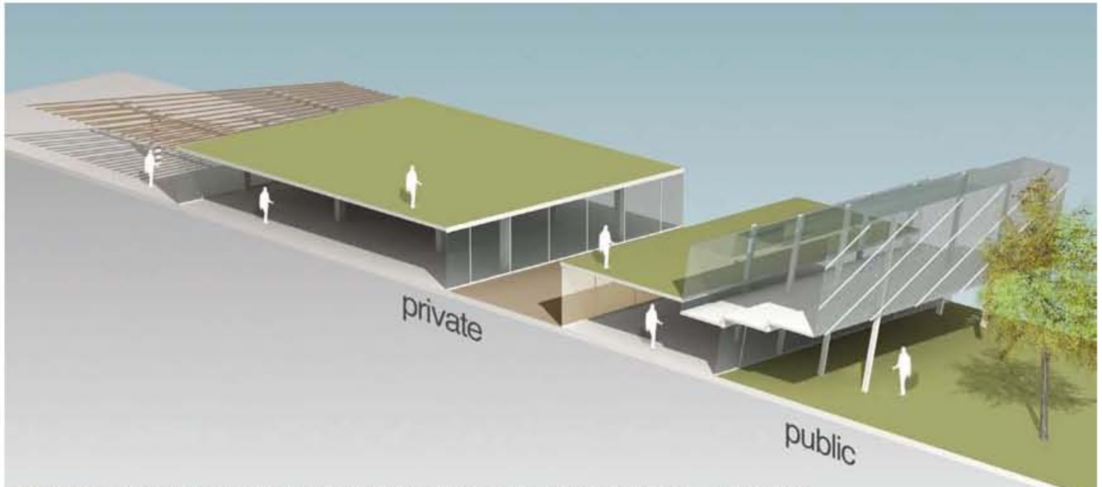

FIG 6.21 Stepping greenhouses with laboratories as thermal mass - July 2008

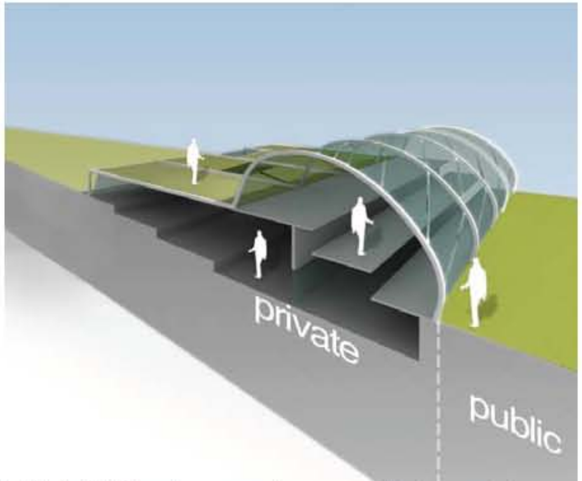

FIG 6.22 Stepping greenhouses with laboratories as thermal mass - July 2008

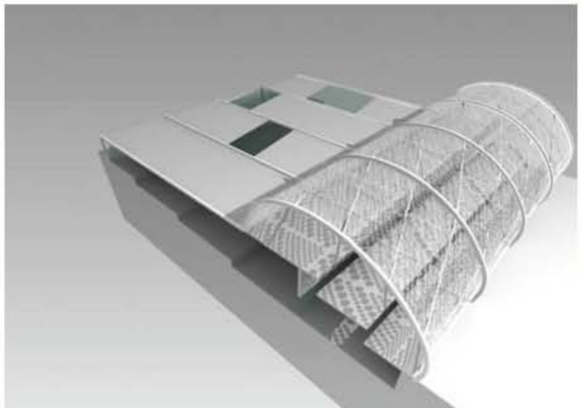

FIG 6.23 Stepping greenhouses with laboratories as thermal mass - July 2008

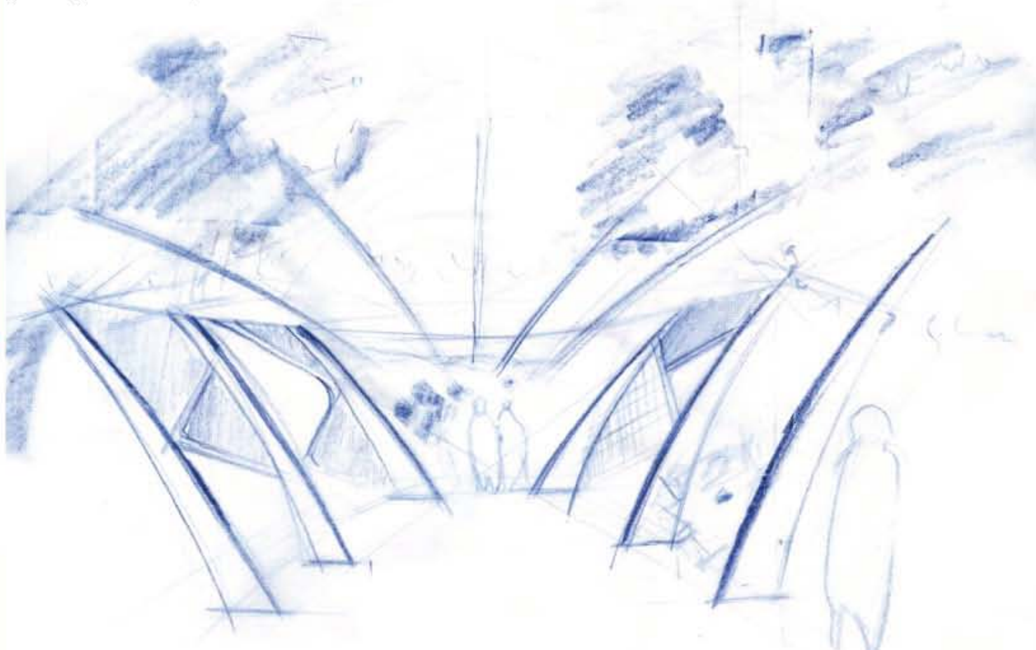

FIG 6.24 Visitors can move through the garden and between the building where the structure of the roof forms a permeable boundary - August 2008

FIG 6.25 Glasshouse facade elevation - August 2008

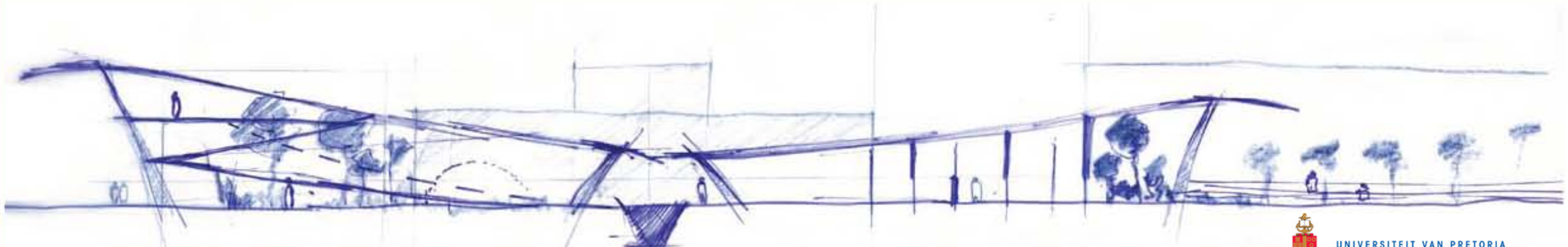

FIG 6.26 Roof structure drapes over sections of the garden and research functions. Users can move up over the building via r

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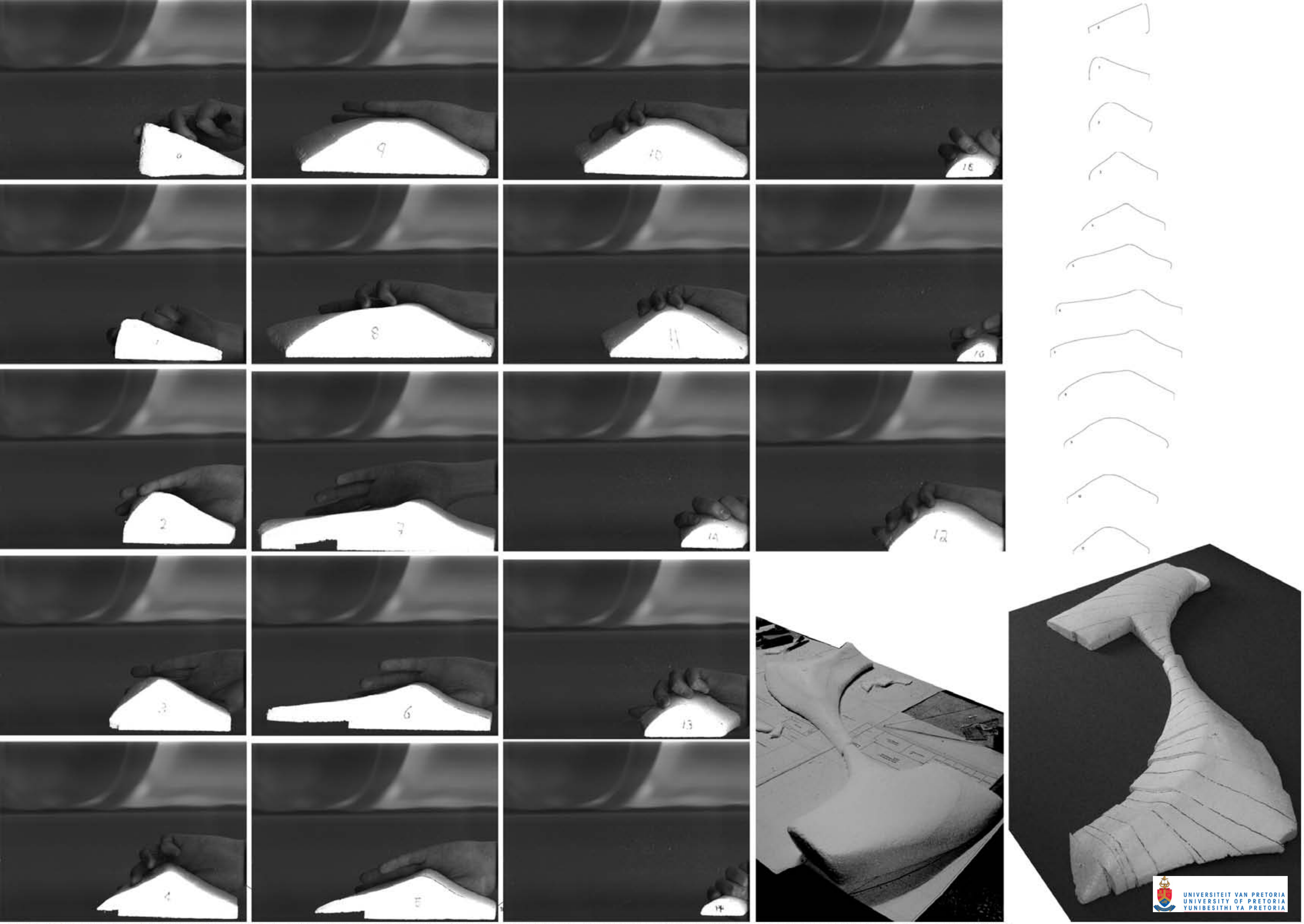


FIG 6.27-30 Roof form exploration with polystyrene models. Sections of the model was then scanned and interpolated onto appropriate 3D software - August 2008

FIG 6.28 Polystyrene model interpolation on computer - August 2008

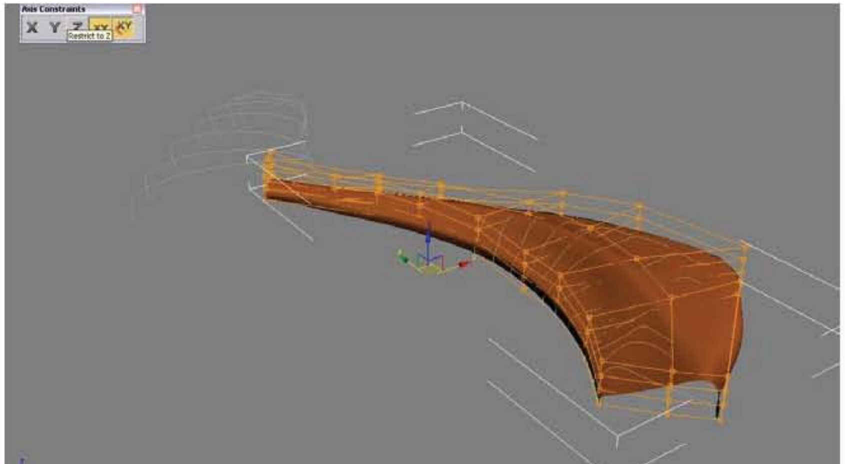


FIG 6.29 Manipulating surfaces - August 2008

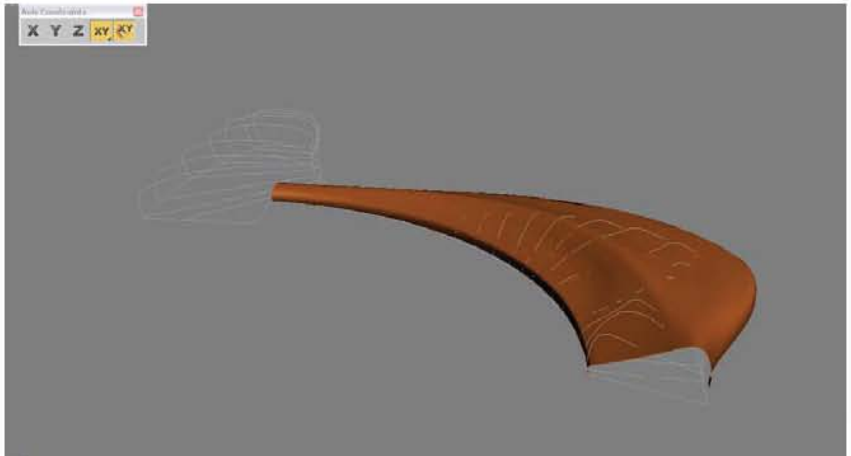


FIG 6.30 New roof form - August 2008

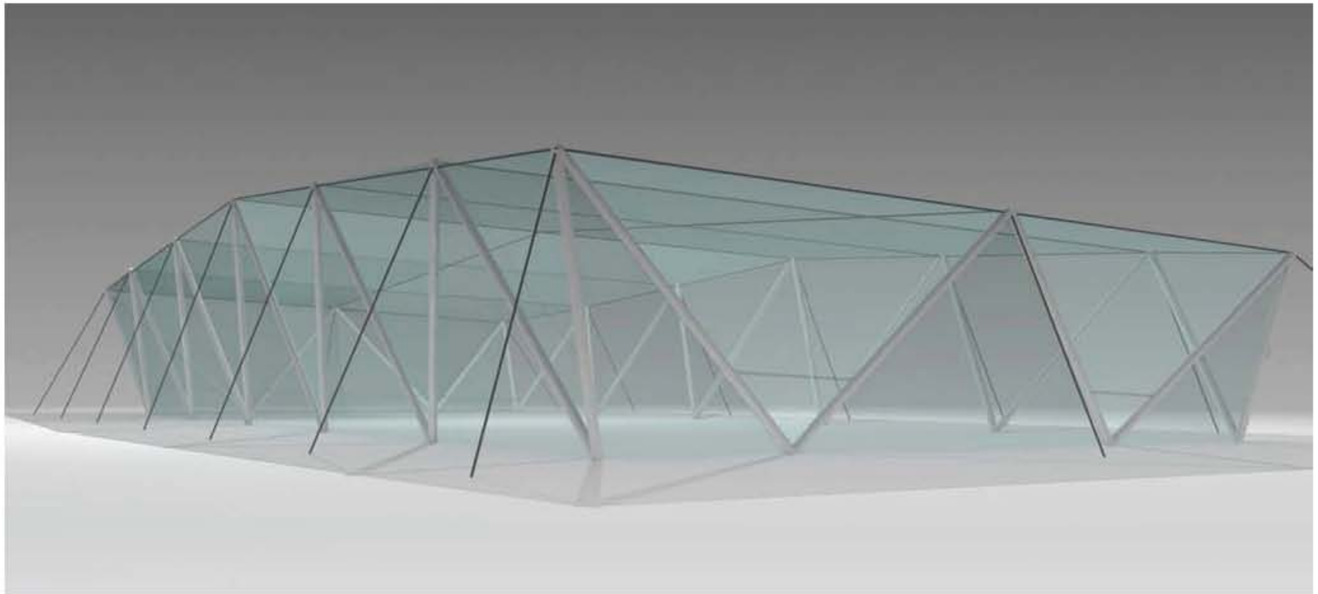


FIG 6.31 Experimenting with tensile cable structure for glasshouse assembly- August 2008

6.2.5 Tensile roof structure as a solution for creating large free areas and organic shapes

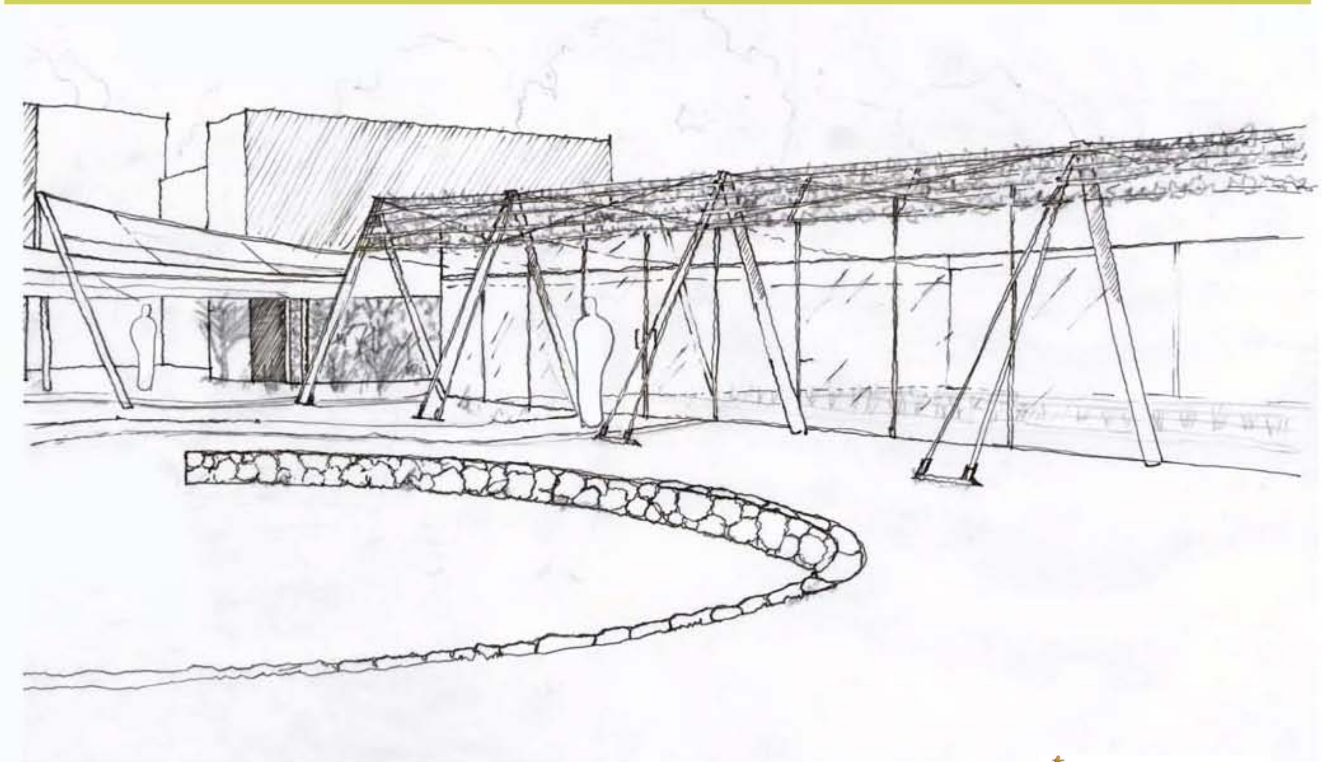


FIG 6.32 View from visitor's footpath towards glasshouse. Vegetation can be grown onto cables us ovide essential facade shading- August 2008

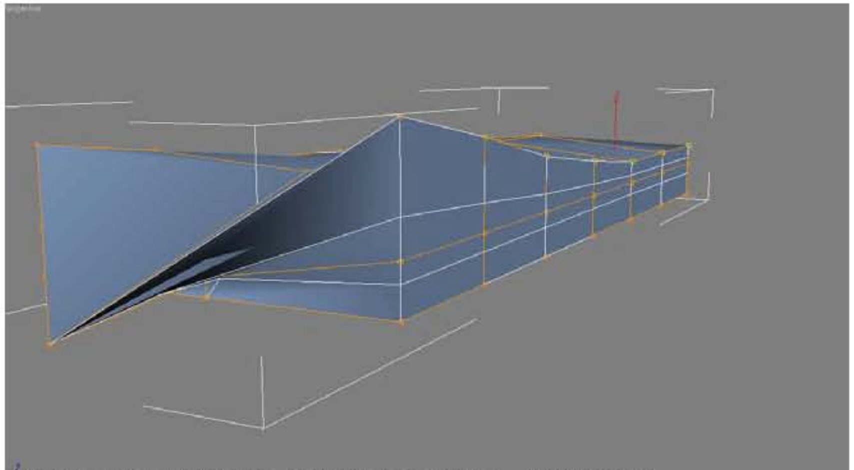


FIG 6.33 Exploring tensile structure possibilities - August 2008

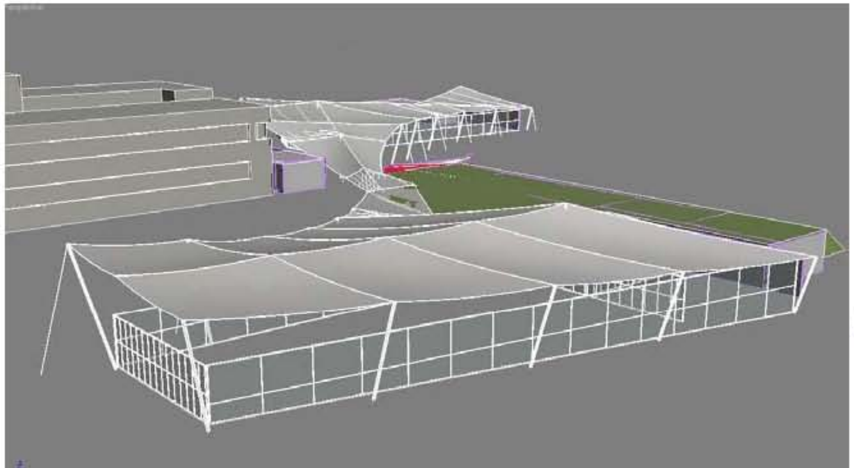


FIG 6.34 Cable roof structure connects the two galsshouses - August 2008

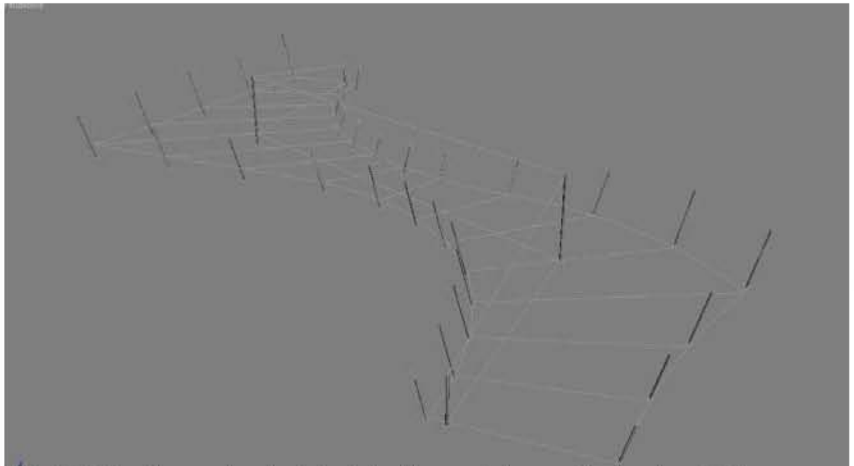


FIG 6.35 Deriving a structural logic for the roof shape - September 2008

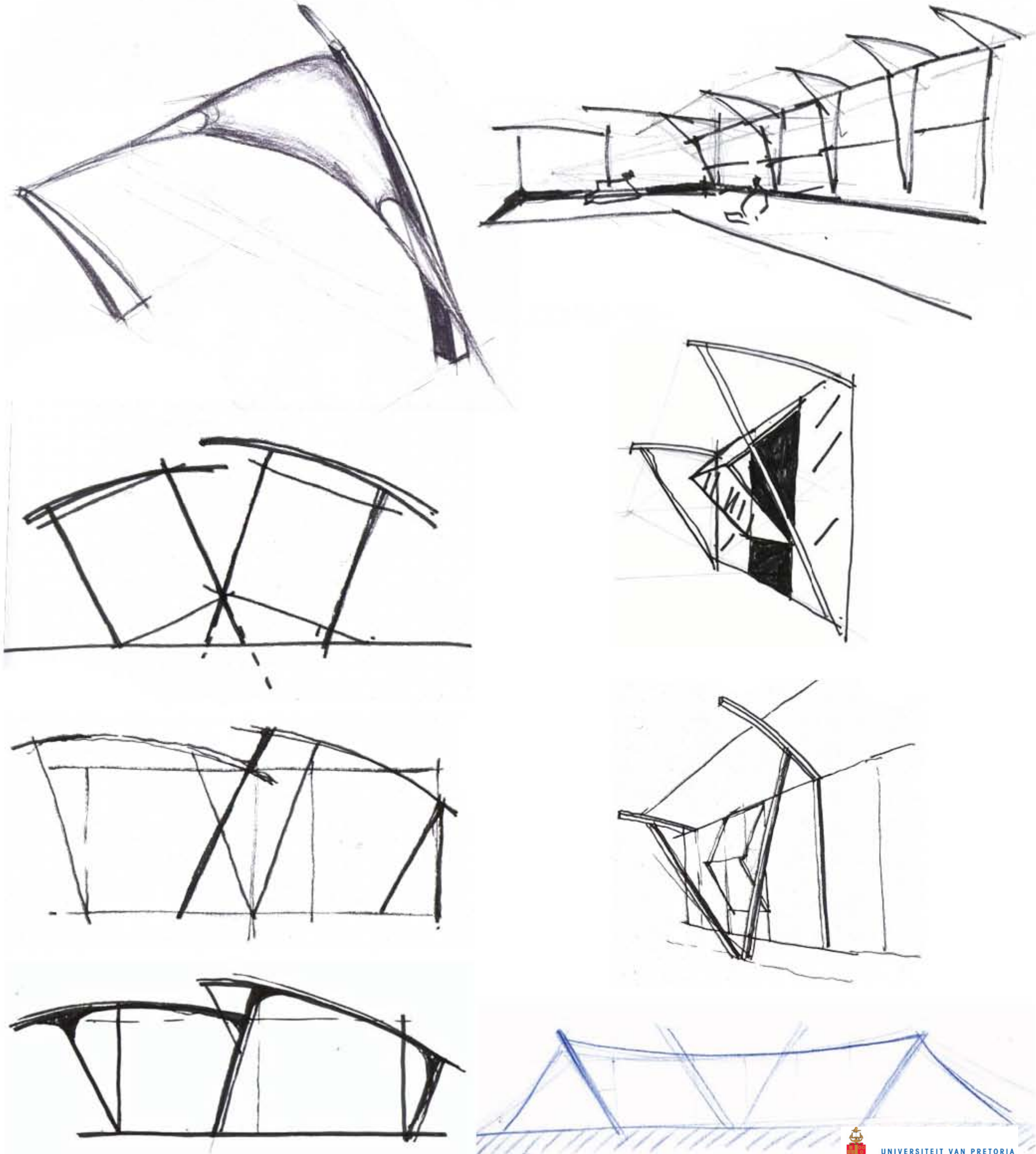
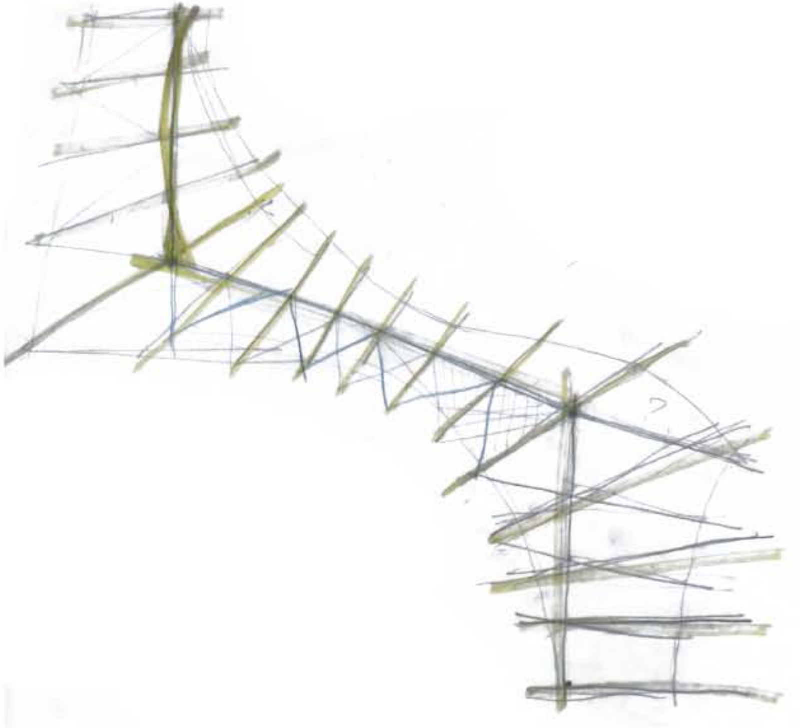


FIG 6.36 Exploring facade and section details of tensile structure. Deriving a language for structural sup vill integrate with mechanical facade elements like ventilation panels etc. September 2008



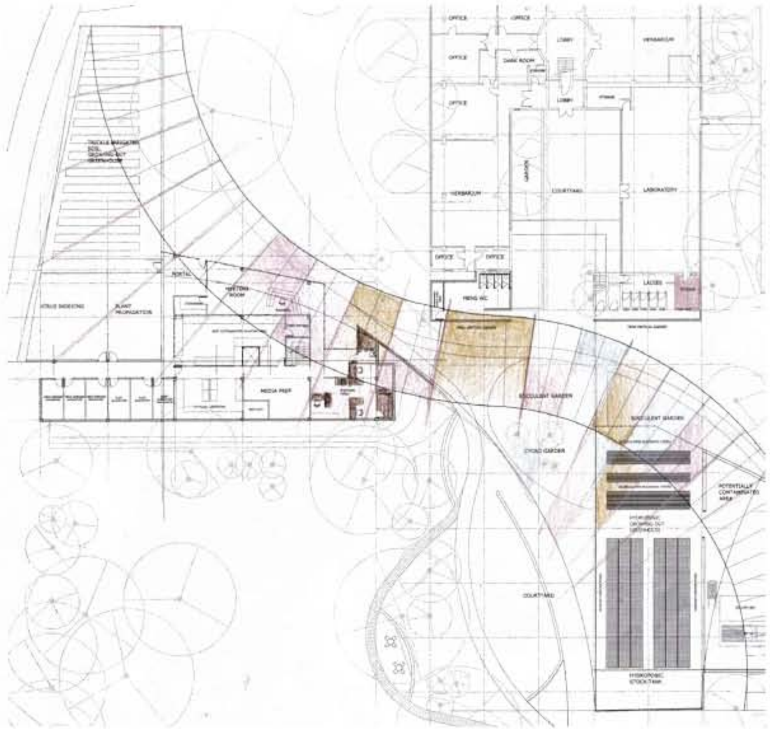
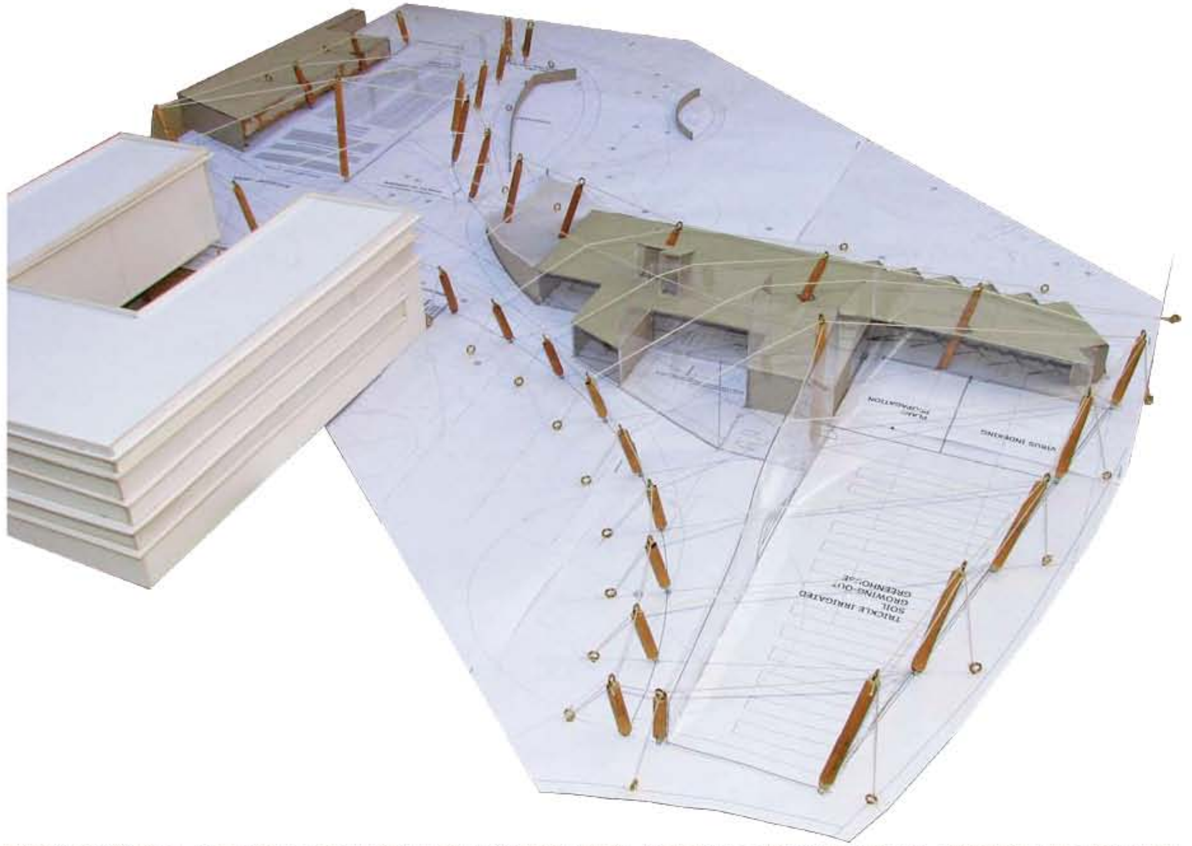


FIG 6.37-38 Deriving a structural logic. Trapezium shapes for main supporting structure proved to be successful at creating the desired shape on plan between the two glasshouse facilities. September 2008



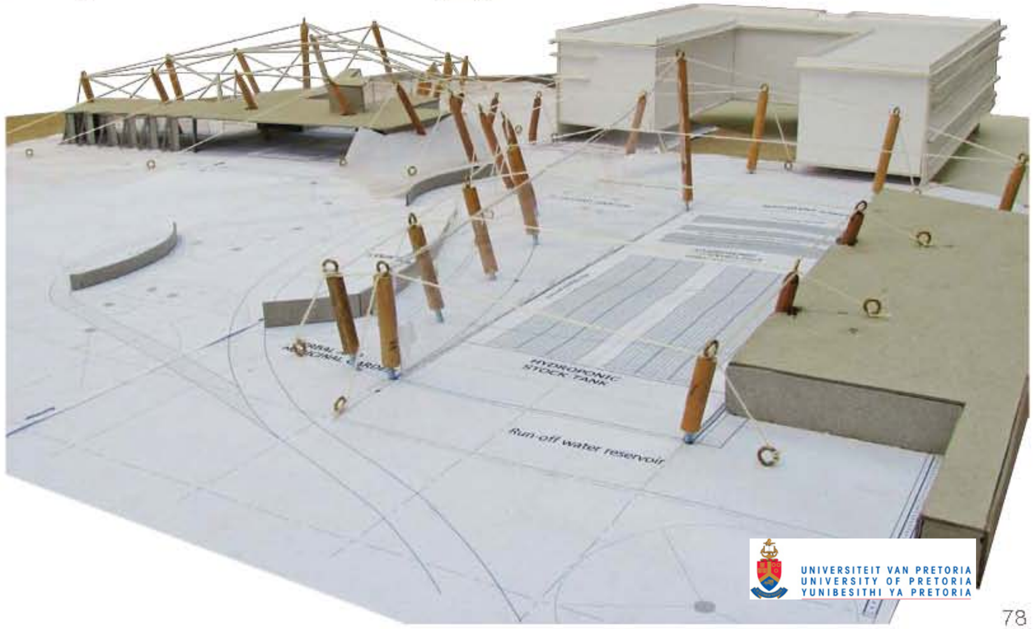


FIG 6.39-40 Final concept model using rope to imitate tensile members. This was used to determine the structural integrity of the assembly and the cohesion of the form language created with the site. September 2008

FIG 6.41

Final intervention proposal

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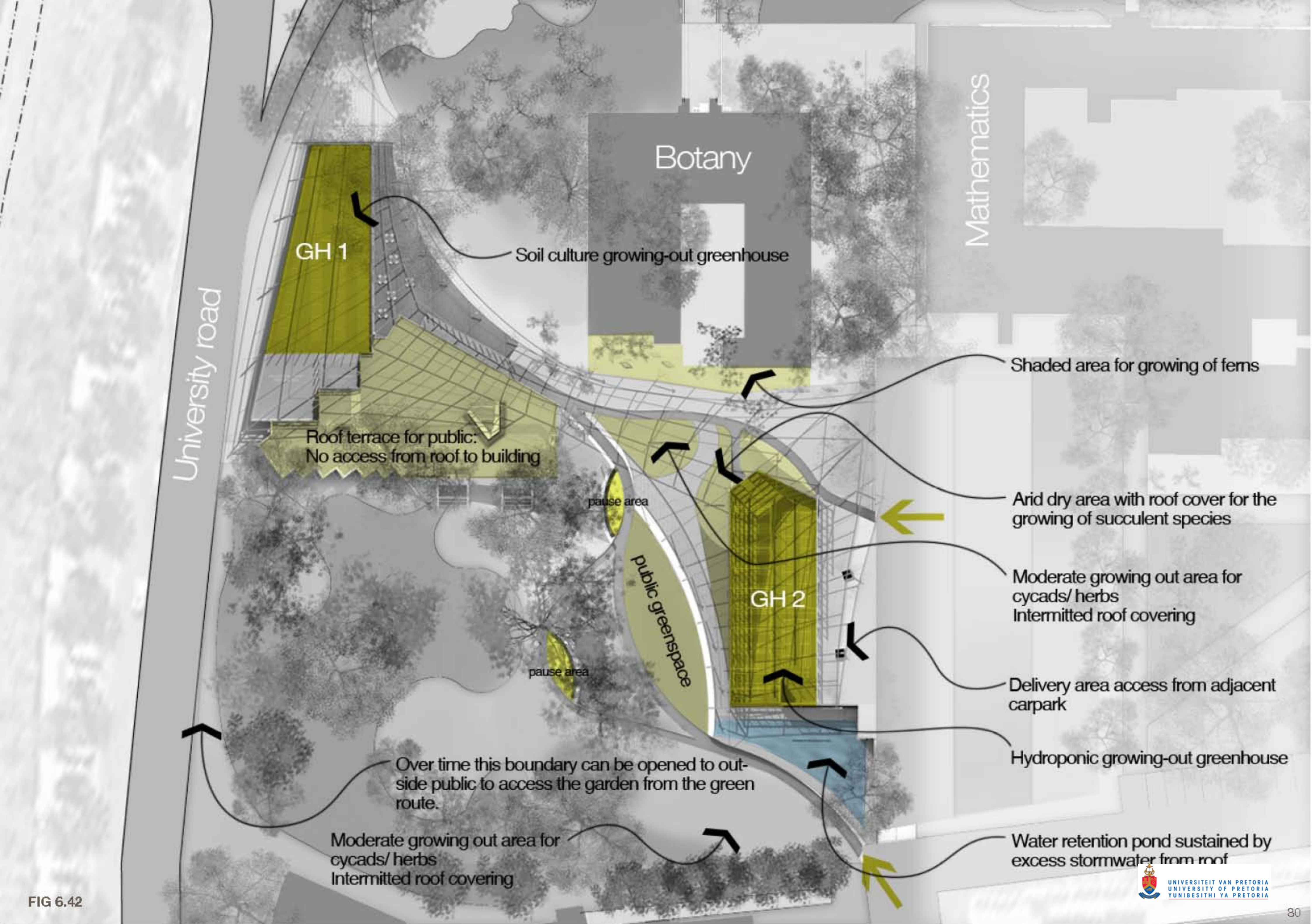
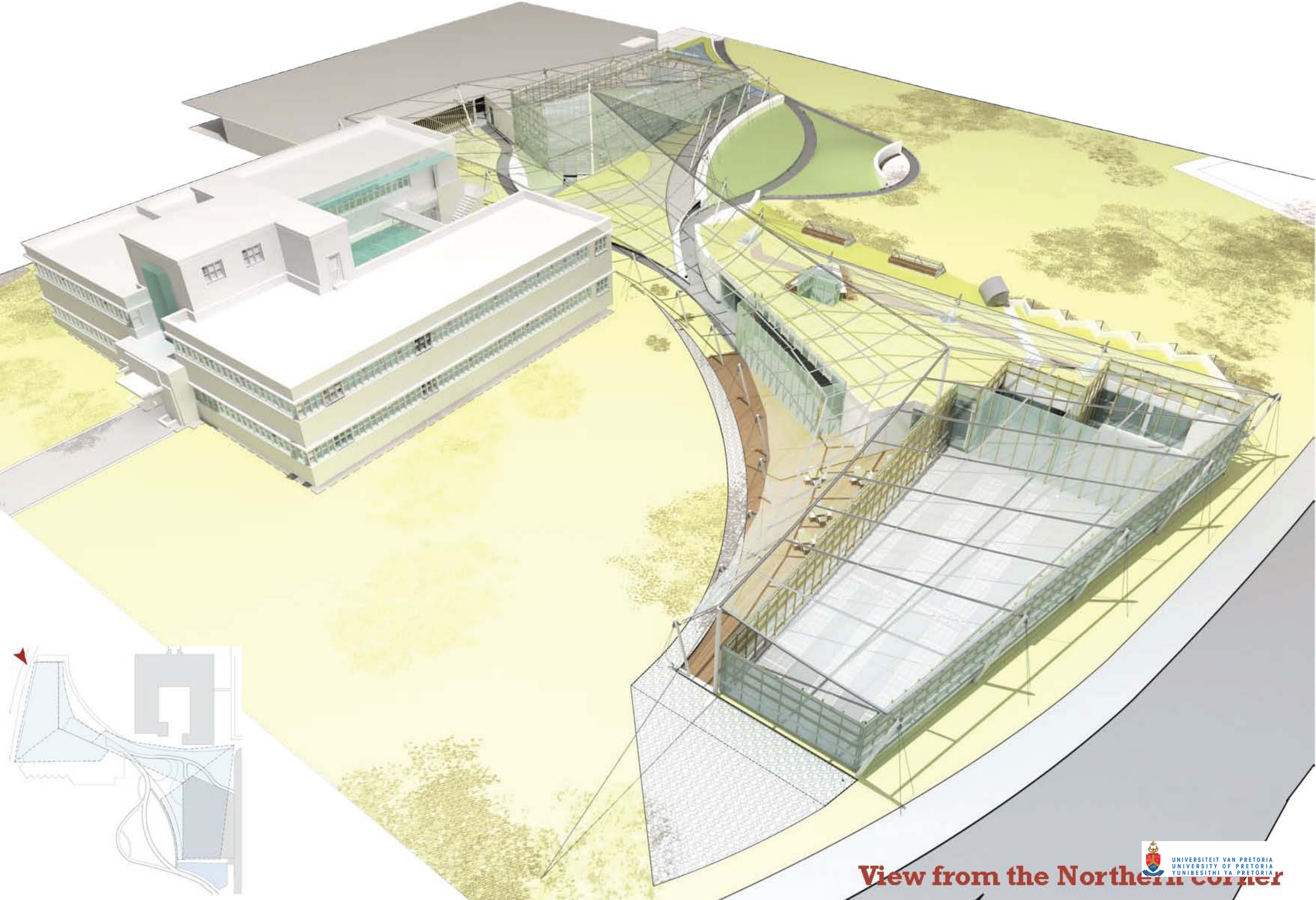

Botany
Mathematics
University road
GH 1
GH 2
Soil culture growing-out greenhouse
Shaded area for growing of ferns
Roof terrace for public:
No access from roof to building
pause area
pause area
public greenspace
Arid dry area with roof cover for the growing of succulent species
Moderate growing out area for cycads/ herbs
Intermitted roof covering
Delivery area access from adjacent carpark
Hydroponic growing-out greenhouse
Over time this boundary can be opened to out-side public to access the garden from the green route.
Moderate growing out area for cycads/ herbs
Intermitted roof covering
Water retention pond sustained by excess stormwater from roof

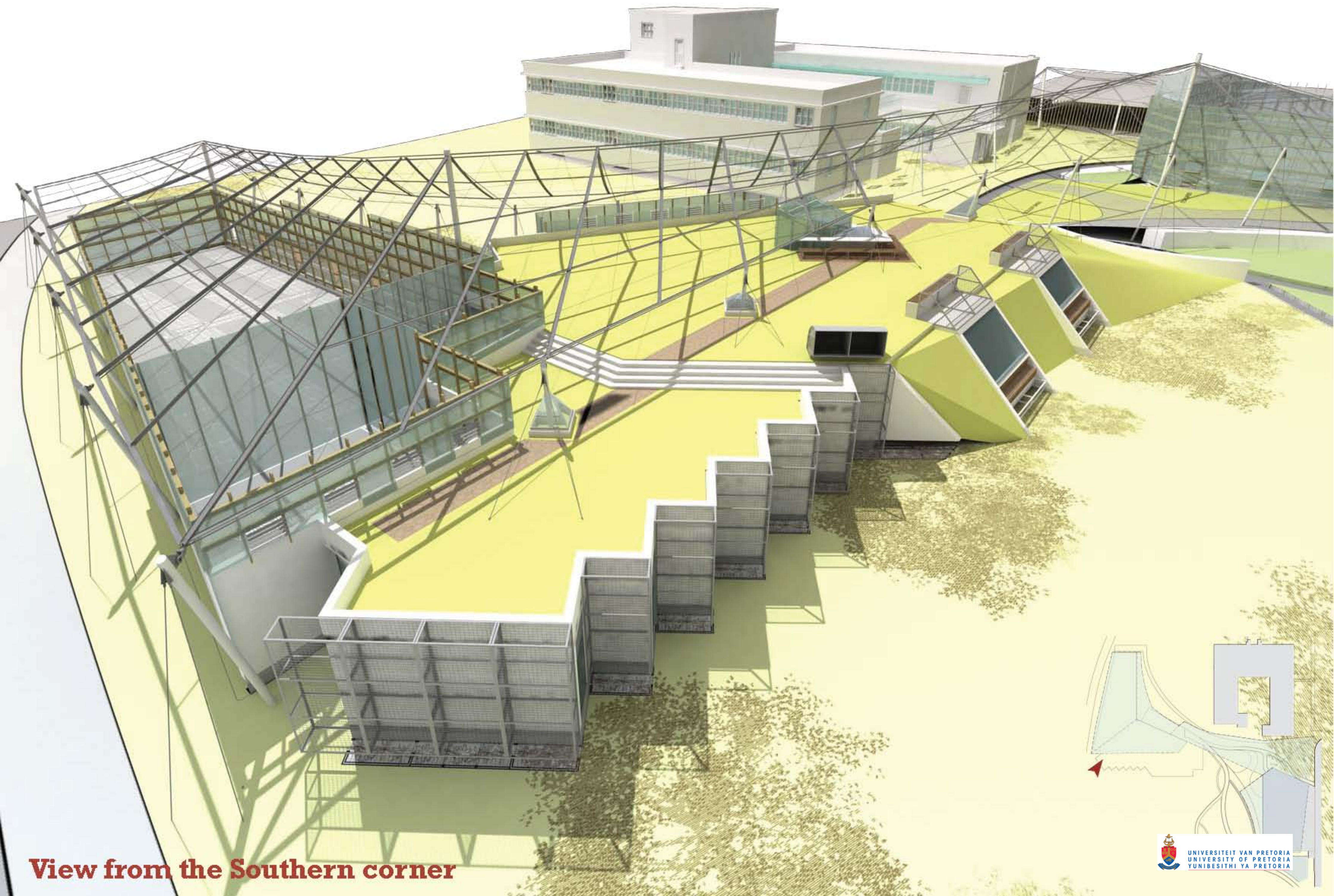
FIG 6.42

FIG 6.43



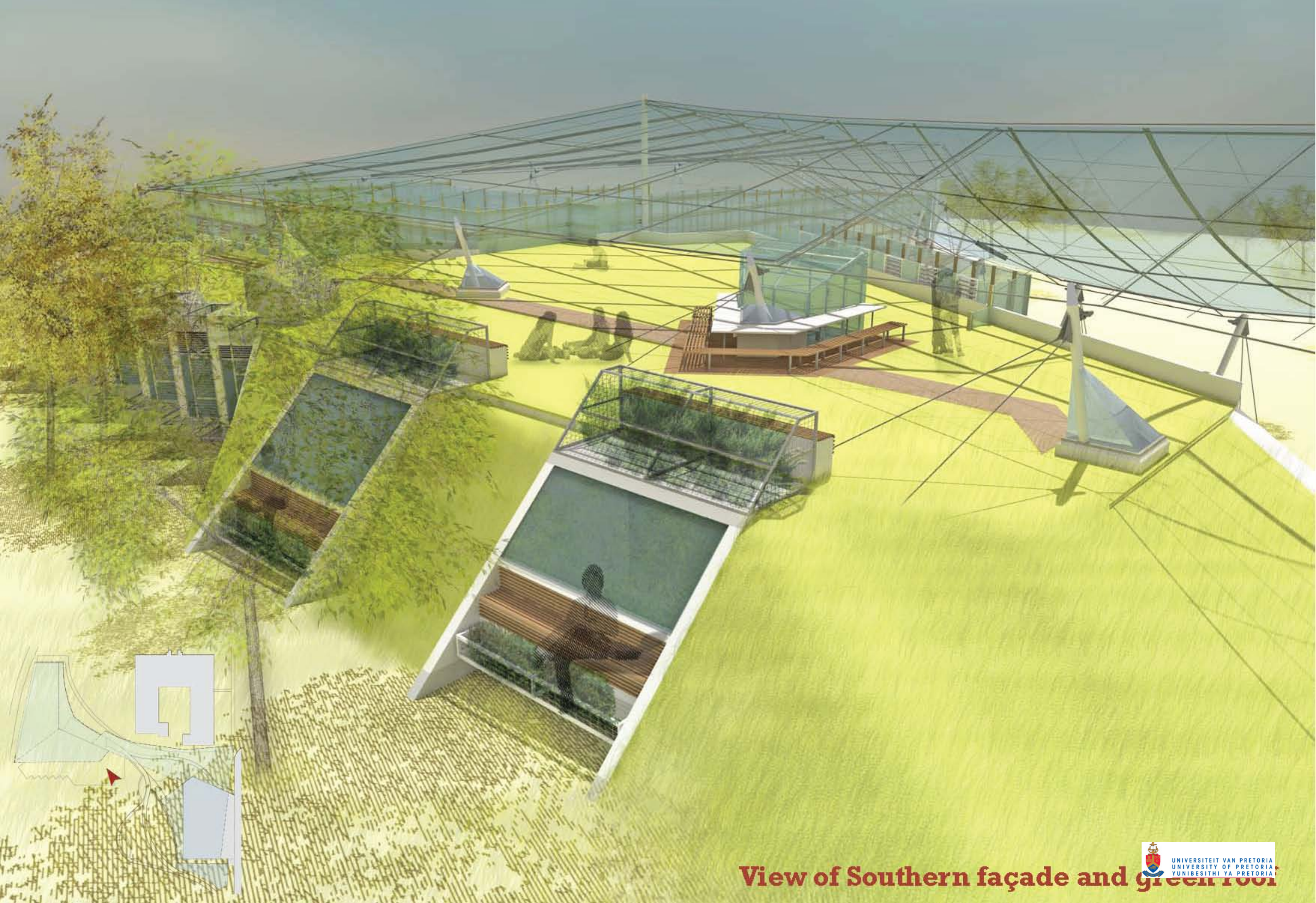
View from the Northern corner

FIG 6.44



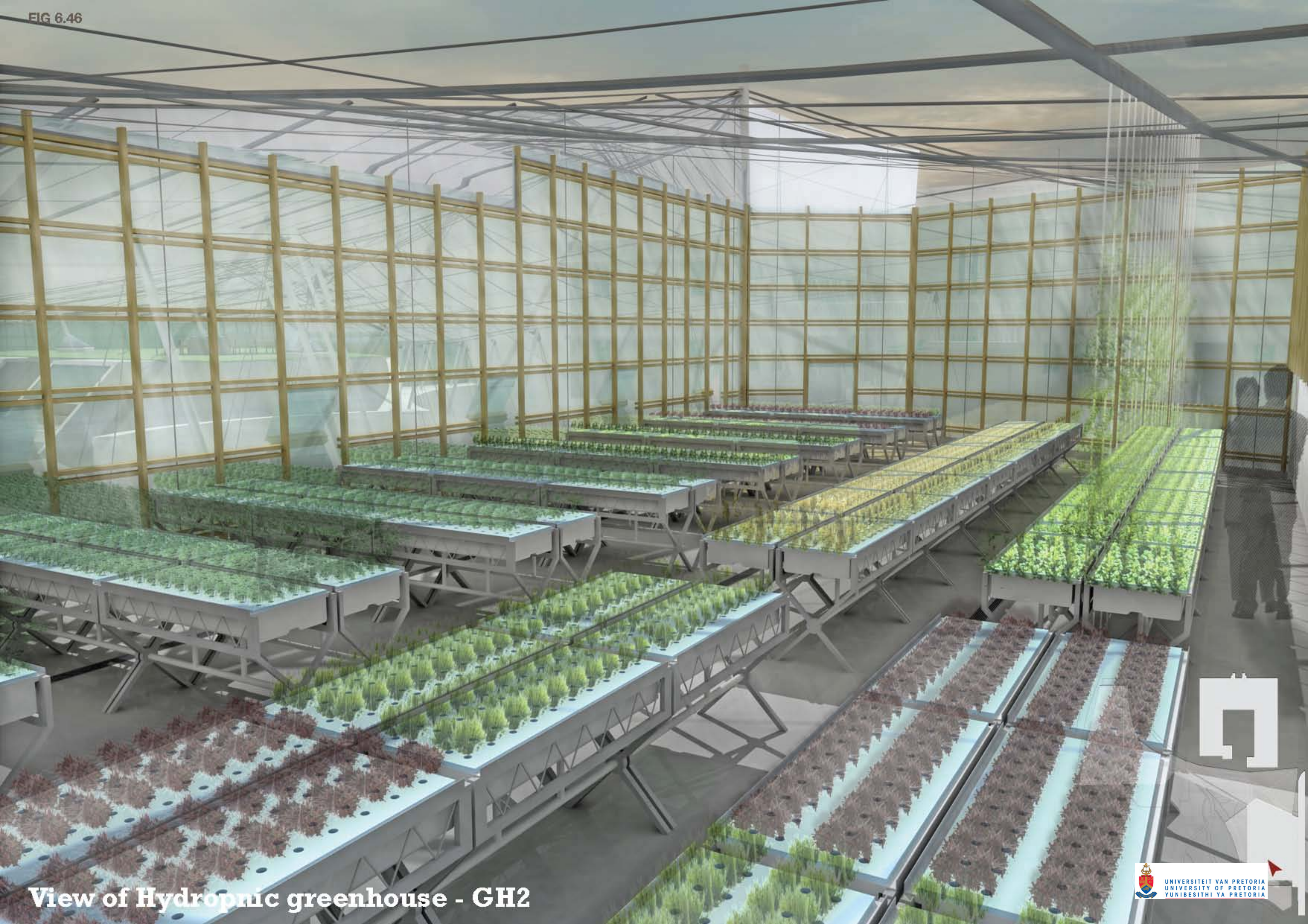
View from the Southern corner

FIG 6.45



View of Southern façade and green roof

FIG 6.46



View of Hydroponic greenhouse - GH2

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Main building - Roof structure

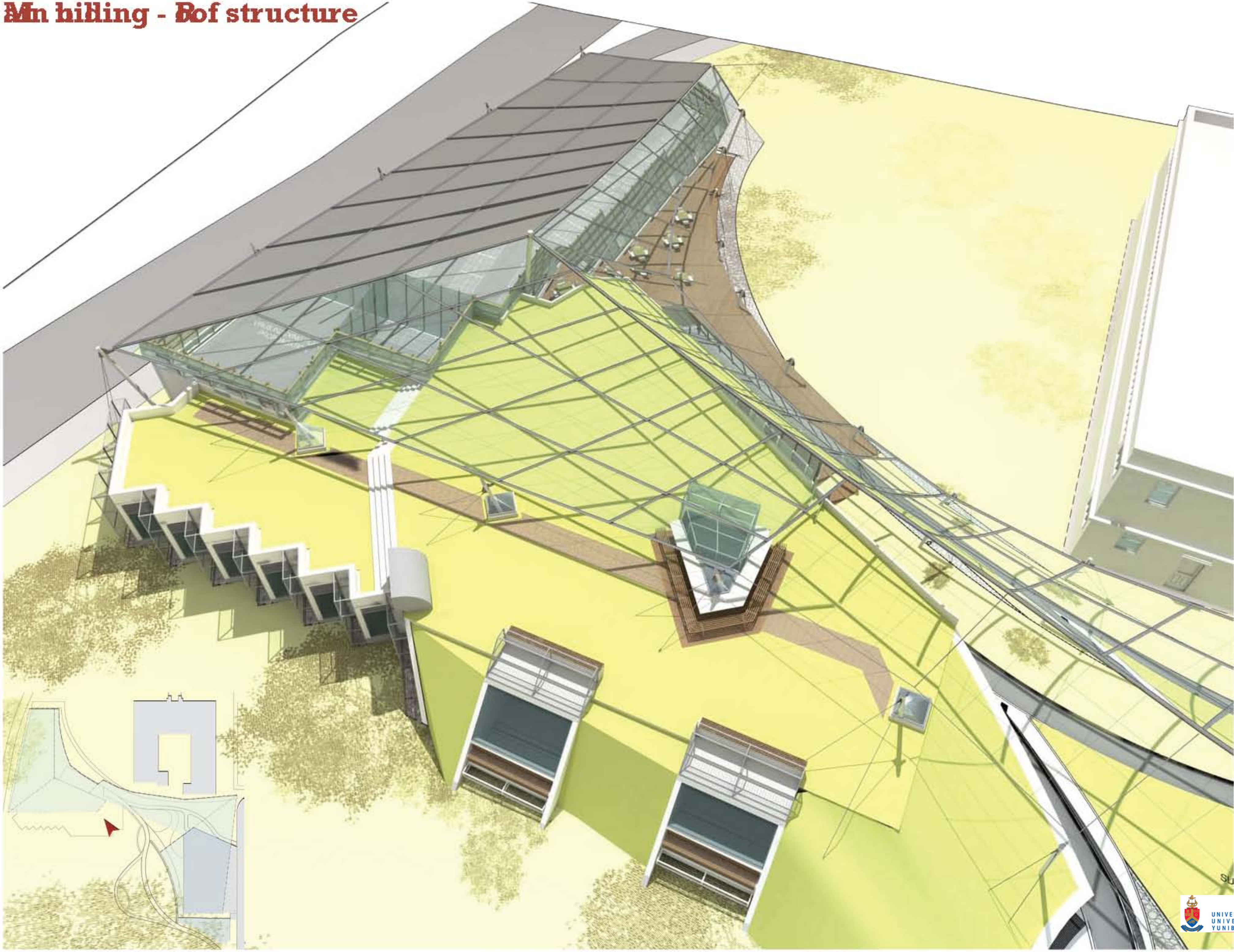

FIG 6.47

Main building - Roof garden

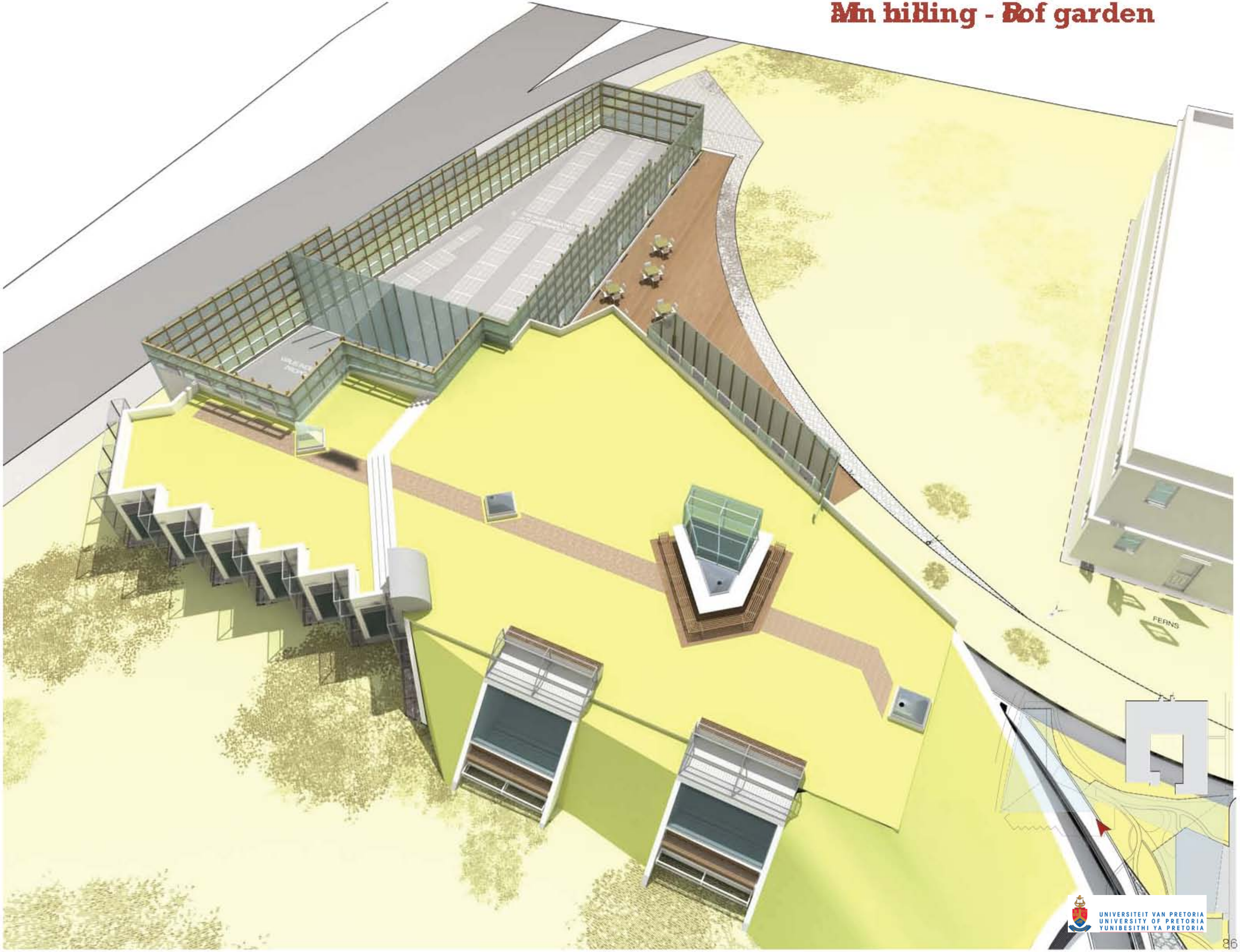

FIG 6.48

Mn hiling - Ground fbor and hsement

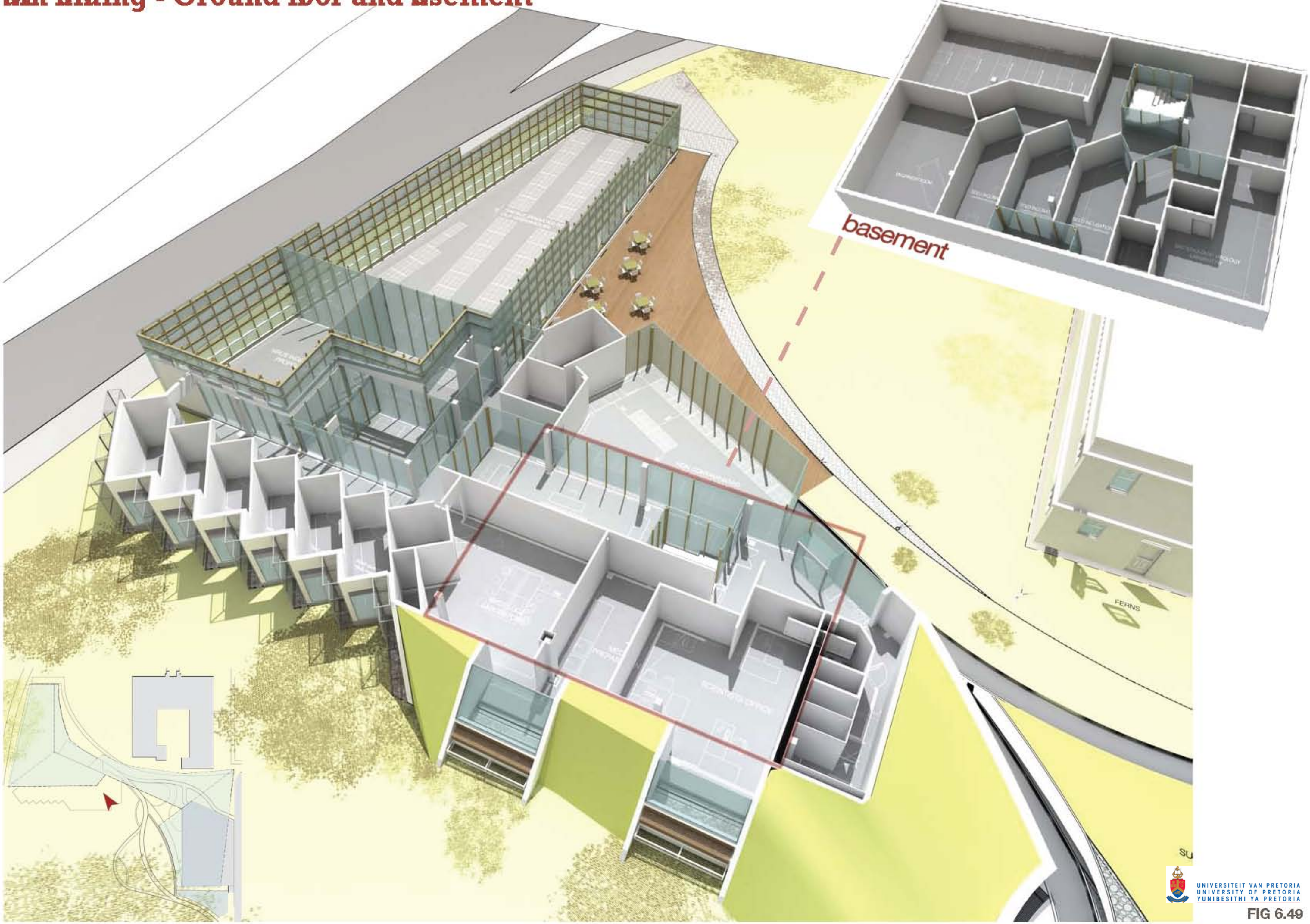

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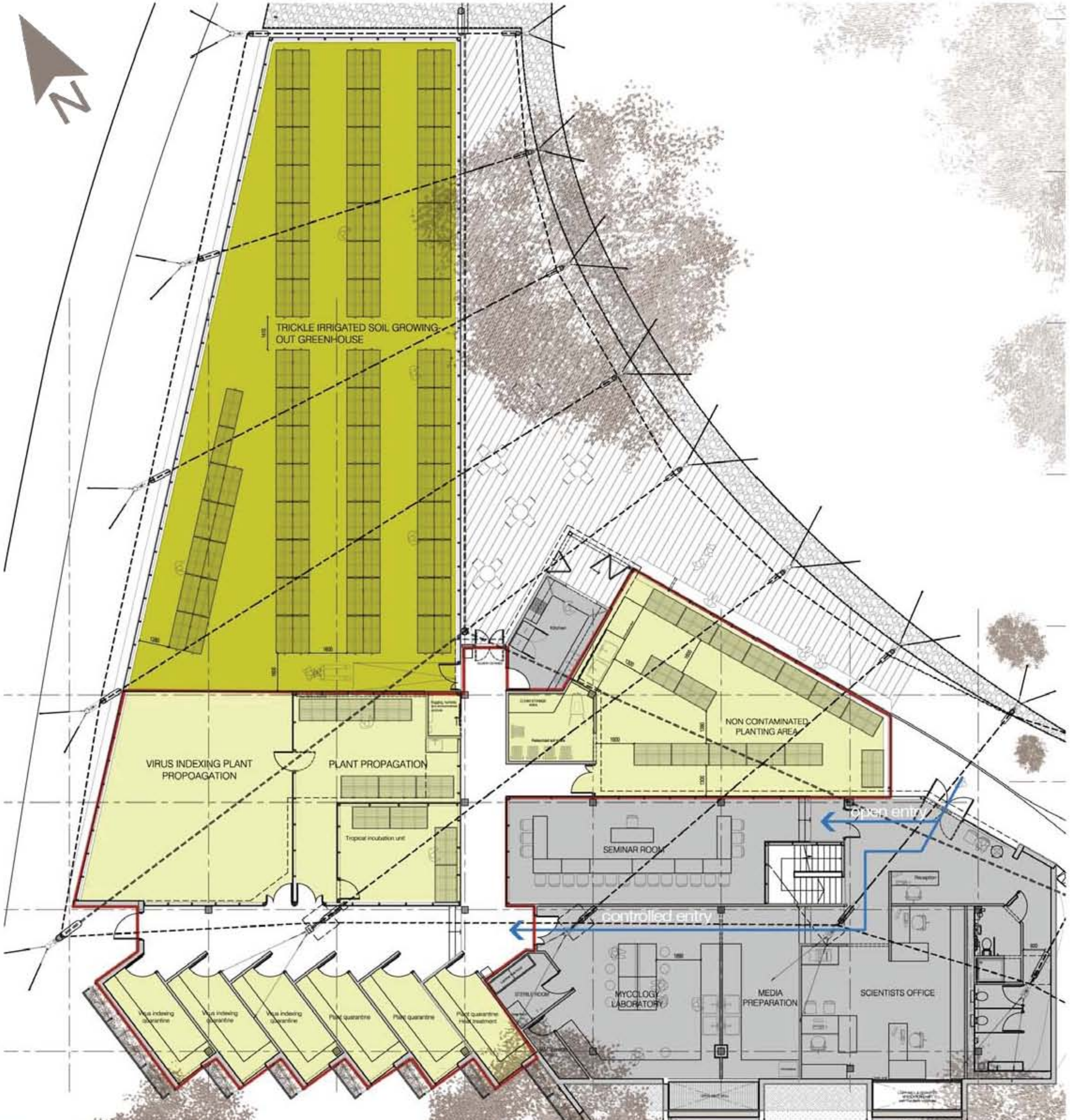
FIG 6.49



PLEASE REFER TO FIG. 6.2 FOR A DETAILED DESCRIPTION ON EACH PHASE

PHASE 1

PHASE 2

PHASE 3

CONTAINMENT FACILITY (PC2 RATED)

ACCESS

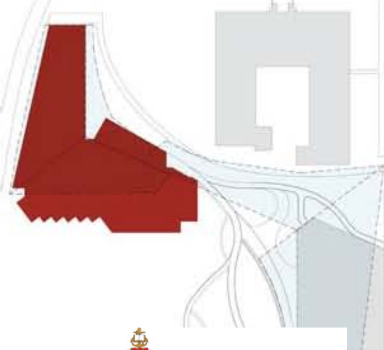


FIG 6.50

Hydroponic greenhouse - GH2

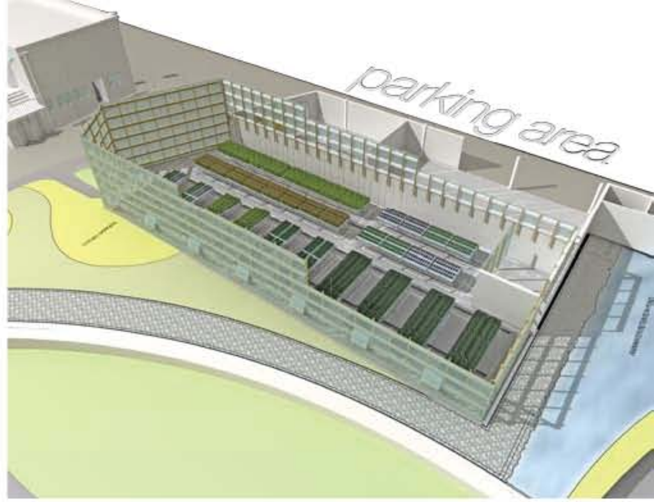


FIG 6.52

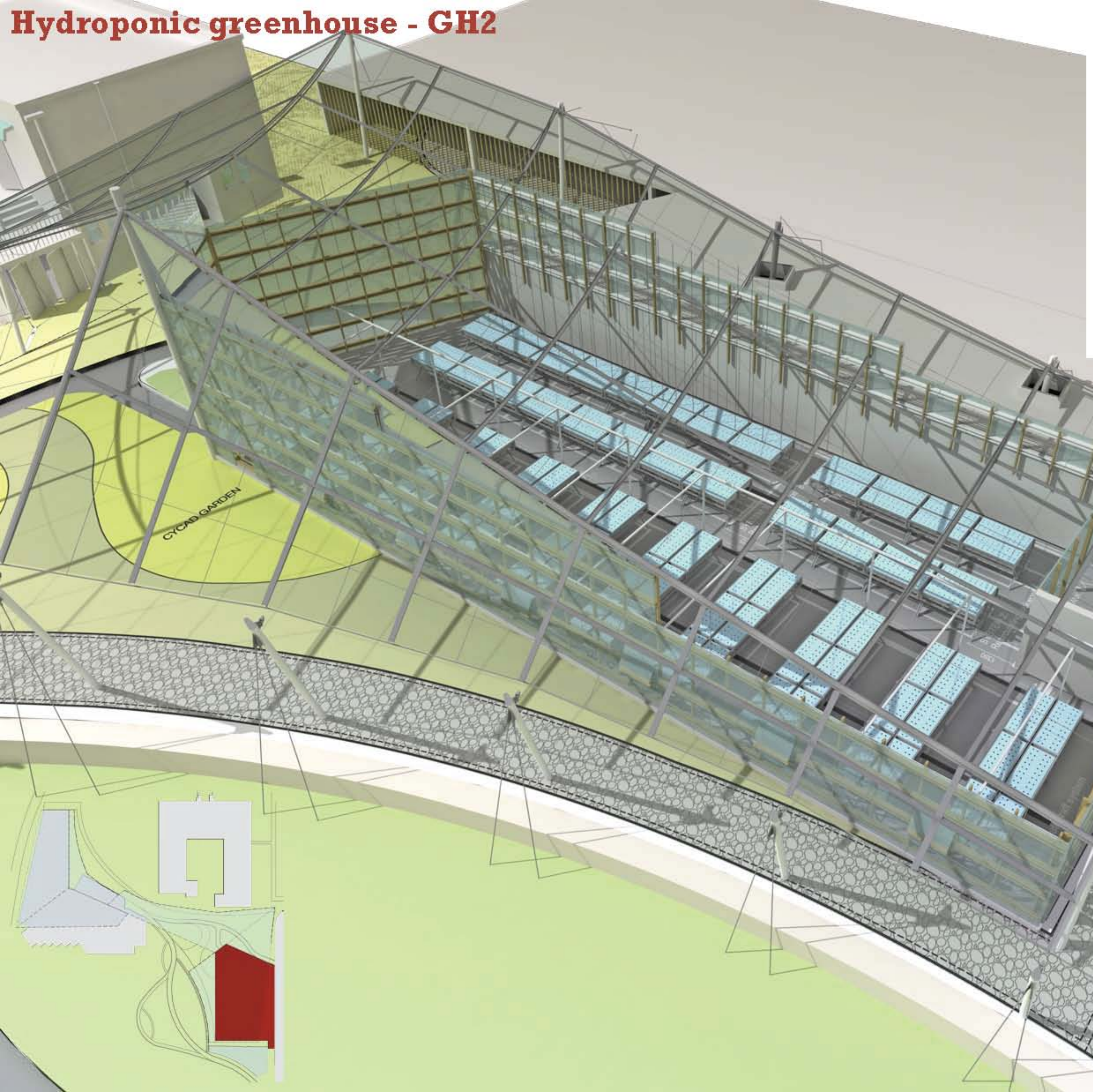
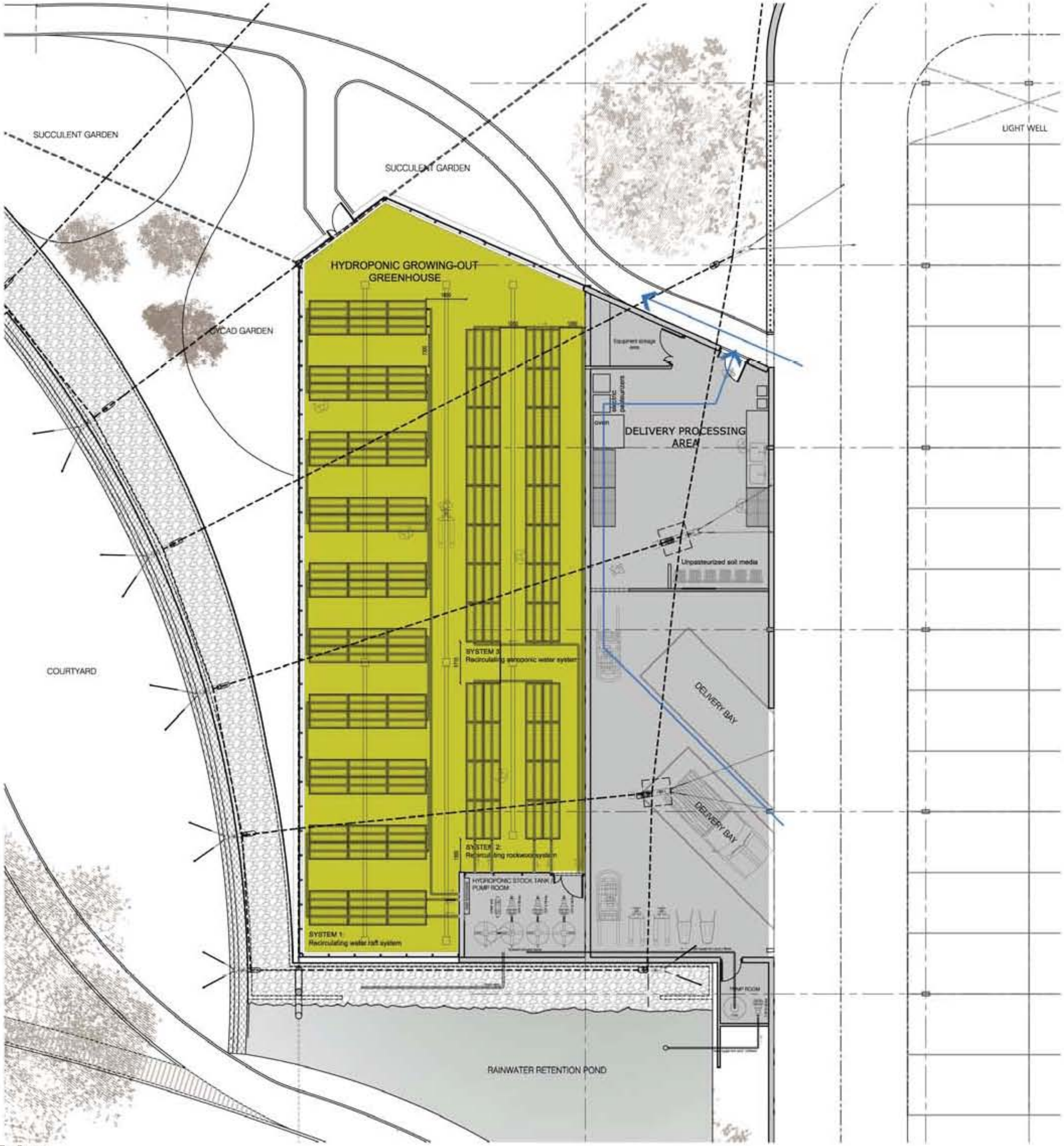


FIG 6.51

PLEASE REFER TO FIG. 6.2 FOR A DETAILED DESCRIPTION ON EACH PHASE



PHASE 1

PHASE 3

ACCESS

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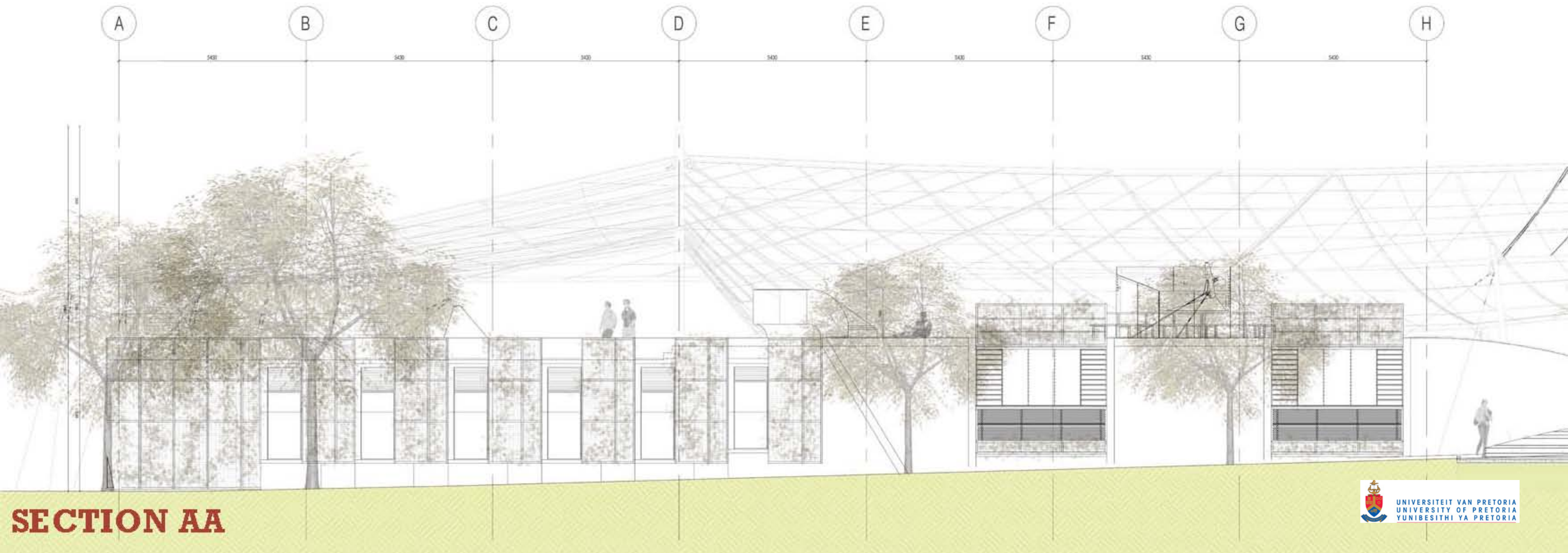
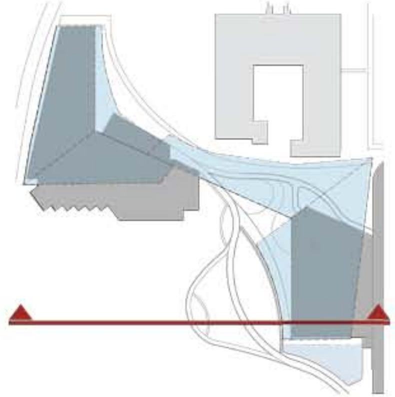
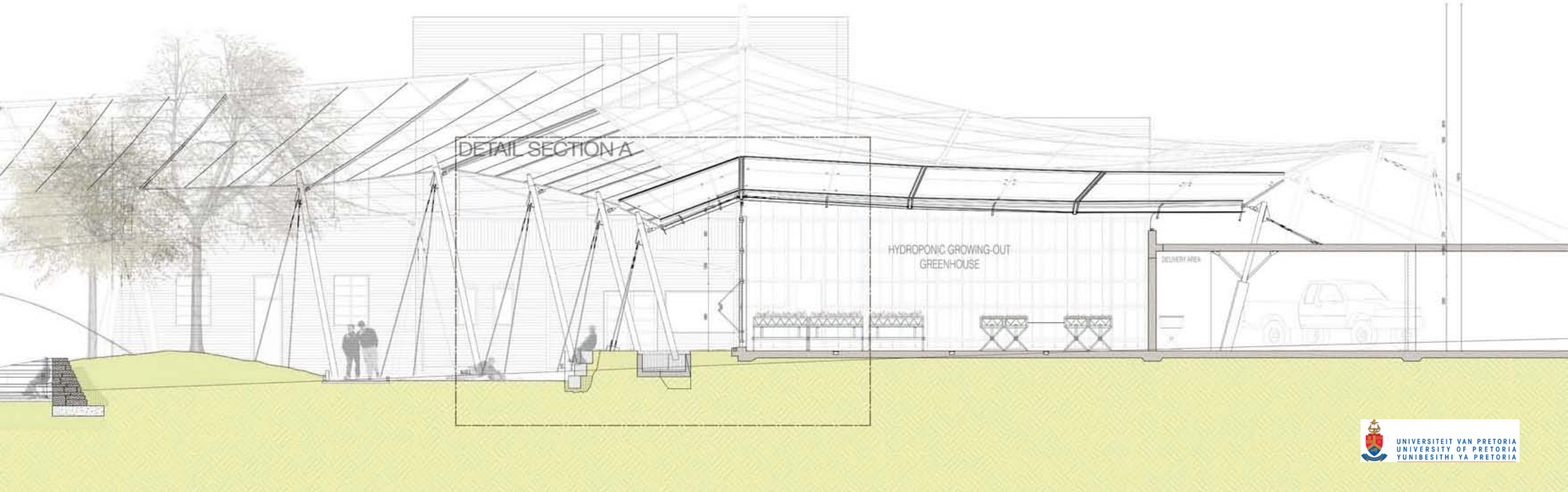
FIG 6.53



SECTION AA





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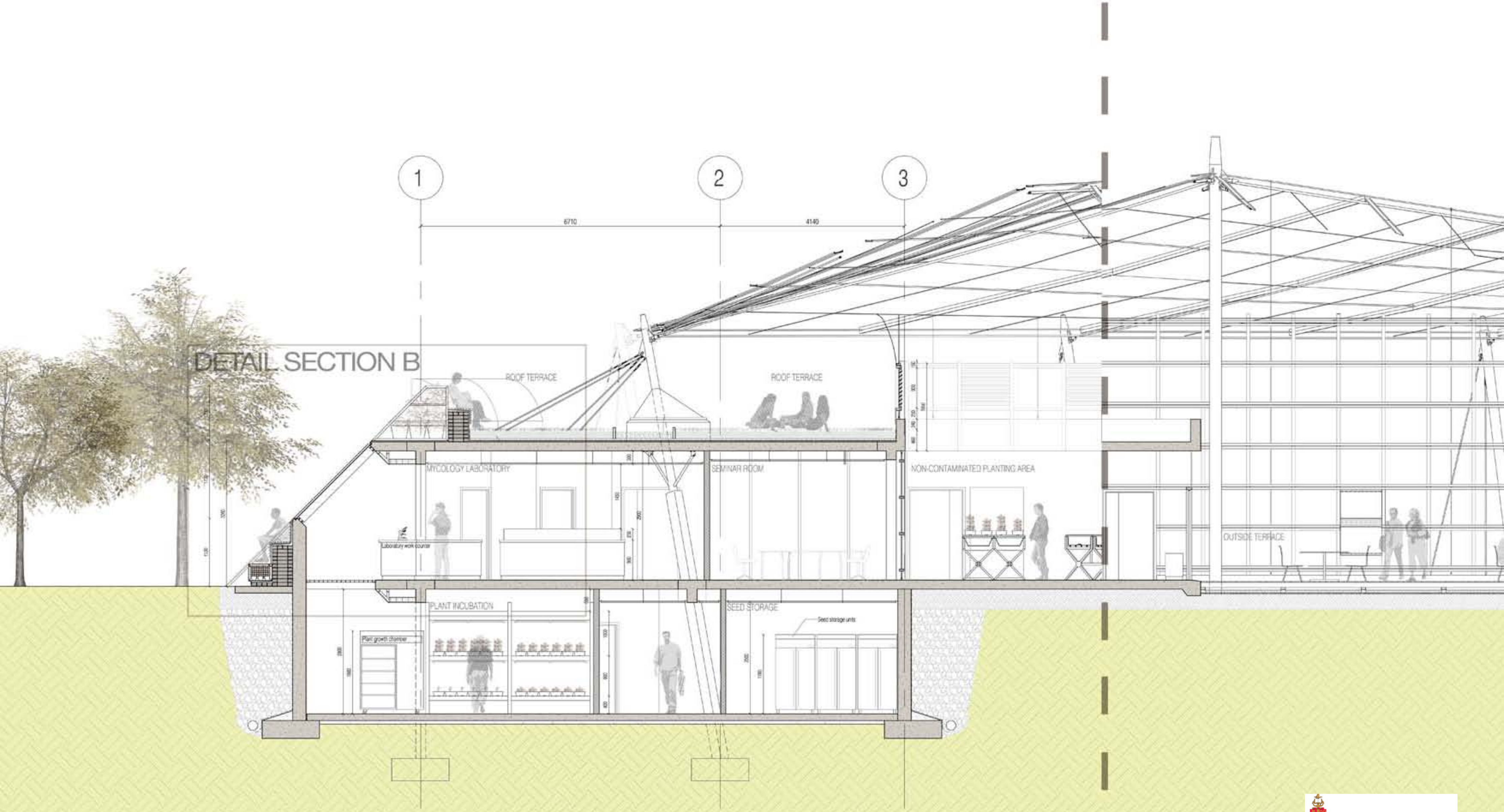
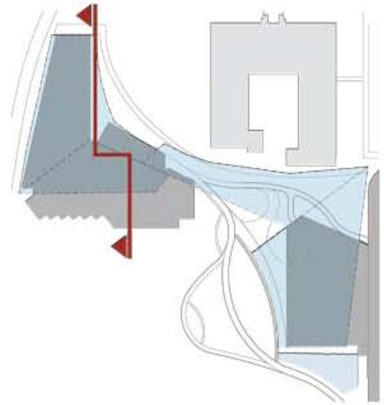
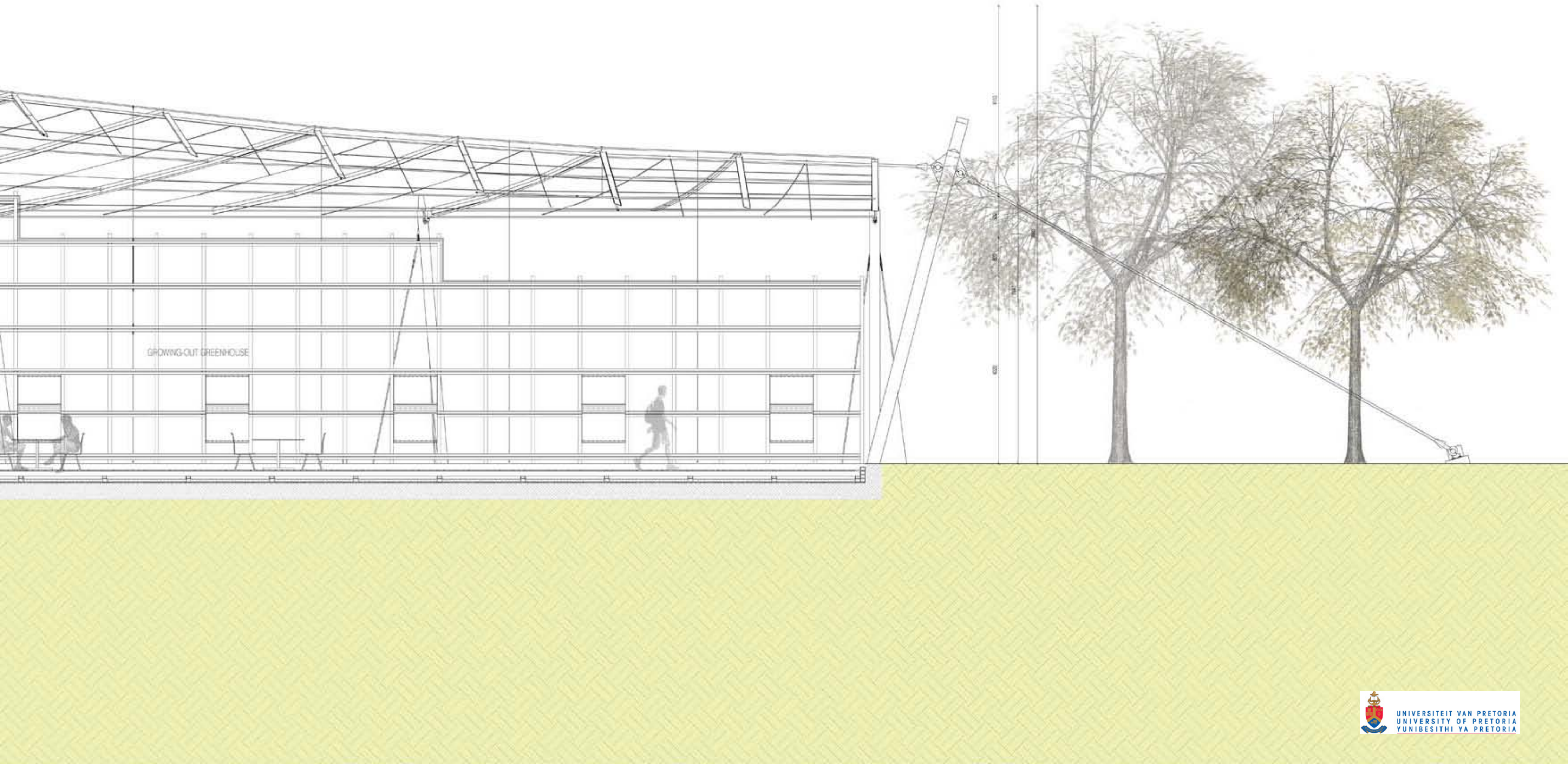

1
2
3
6710
4140
DETAIL SECTION B
ROOF TERRACE
ROOF TERRACE
MYCOLOGY LABORATORY
Laboratory work counter
SEMINAR ROOM
NON-CONTAMINATED PLANTING AREA
OUTSIDE TERRACE
PLANT INCUBATION
Plant growth chamber
SEED STORAGE
Seed storage units

SECTION BB




GROWING-OUT GREENHOUSE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technical investigation

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Roof and façades

7.1 Addressing the problem:

In order for a facility of this kind to be successful, it is preferable to have growing-out greenhouses with large clear spans to allow optimum use and flexibility of space. Specific climatic zones and degrees of sun exposure are required for various plant types to allow for the proper germination of species and their propagation. After consideration of all these requirements, a tensile cable structure (Figures 7.1 & 7.2) proved to be the optimum choice that allows for the following:

- Considerable free span areas beneath the structure.
- A construction process with a more sensitized impact on the existing site and garden.
- Transparent roof panes that can easily be replaced by opaque ones, or be left open depending on the program of the spaces below.
- Cable net structures that allow extraordinary structural transparency that can be very dramatic with regards to the architectural experience, apart from being a lucid solution resulting in a lightweight structure to ultimately keep the elements out.

7.2 Design considerations:

Technologies for building cable net structures are not regularly used in South Africa, although a variety of different tensile structures using textile membranes have been constructed locally.

Loads:

One of the key characteristics that distinguish cable net structures from standard membrane tensile construction is the coordination of the cladding material with the architectural interface such as the fixtures and cables. Loads are much more excessive and must be provided for. Subsequently the choice of cladding material has a great influence on the bearing capacity of the cables. Today, a great variety of transparent polymer cladding materials other than glass exist, but these will be discussed later in the chapter.

Deflection:

Cable structures are more susceptible to deflection under wind loads, and to fluctuations in temperature, than standard concrete or steel structures. Therefore provision should be made for movement between roof cladding components and areas where the tensile structure meets rigid construction components like curtain walls or other façade components.

Water runoff:

Most of the materials used to cover cable net structures are impermeable to water and can therefore result in vast volumes of water run-off during the short, intense rainstorms which are frequently experienced in Pretoria. It is therefore important to deliberately incorporate designated run-off points on the roof and to direct the pitch of the roof in such a manner so as to ensure that run-off is directed away across the entire roof area in a uniform manner. The water can be accounted for where it leaves the roof by means of appropriate gutter systems, groundwater recharge trenches, bio-retention ponds etc, on ground level.

For the 1972 Olympic Stadium in Munich, Frei Otto designed a bespoke system of 140mm wide neoprene gutters that are tightly fitted between glass panels to direct water run-off (black lines visible in Fig. 6.1). Today, commercial products by large polymer corporations such as BASF still use the logic behind Mr. Otto's design, but these will be discussed later in the chapter.

FIG 7.1 Frei Otto institute museum building (http://kubuildingtech.org/cooltour/gallery/ILEK/source/30.html)

FIG 7.2 Frei Otto institute museum building (http://kubuildingtech.org/cooltour/gallery/ILEK/source/22.html)

FIG 7.3 Munich olympic stadium roof (Nerdinger 2005:266)

FIG 7.24 Evaporative cooling units and heat exchangers

FIG 7.25 Evaporative cooling units cold air release ducts

FIG 7.26 Solar curtains

Green roof, laboratories and quarantine rooms

PLEASE REFER TO **DETAILED SECTION BB**

Climate control

PLEASE REFER TO **DRAWINGS ON THE ADJACENT PAGE**

South African greenhouses are different to their European counterparts. European incident solar radiation is considerably less that in South Africa, which means that solar greenhouses in South Africa tend to overheat. Greenhouses in South Africa need ample ventilation and cooling apparatus.

Artificial lighting is controlled by time switches. Greenhouse climates are continuously monitored and air conditioning systems are automatically started when the greenhouse starts to overheat.

There are three main growing environments within the greenhouse complex with specific light and ventilation requirements.

❶ **Plant growth rooms** (solar)
- Lighting intensity of 250-700 micromoles m^2/second
- For the propagation of example tobacco, tomato etc. plants.
- With reference to the glasshouses at Murdoch University in Perth, Western Australia, we can fairly accurately make assumptions on how a facility of this kind will react in the South African solar climate since it is fairly similar to those experienced in Australia whereby solar control is achieved by means of solar curtains (Fig7.27) that is automatically controlled by a central computer system.
- A method that has proved sufficient at Murdoch University is the use of evaporative cooling heat exchanges. These draw in air from the outside, blow it over dry ice reservoirs and expels the cold air onto the plants from a plastic tube in the roof space (Fig 7.26).

❷ **Interior plant growth rooms** (artificial lighting)
- Lighting intensity of 150 micromoles m^2/second
- Biolux fluorescent bulbs E.g. Osram L58W/72 technical lamps with aluminum reflectors
- Suitable for Arabidopsis (small flowering plants for the study of plant genome biology)

❸ **Plant Tissue culture growth rooms** (artificial lighting)
- Standard fluorescent tubes with aluminum reflectors
- High requirement for air quality to remain pure, therefore the air in such a facility needs filtering. This is achieved by making use of PAD (Fig. 7.28) screens or HEPA filters (Fig. 7.29). This prevents the unwanted ingress of pathogens and the spread of pollen and other biological material to the rest of the facility.

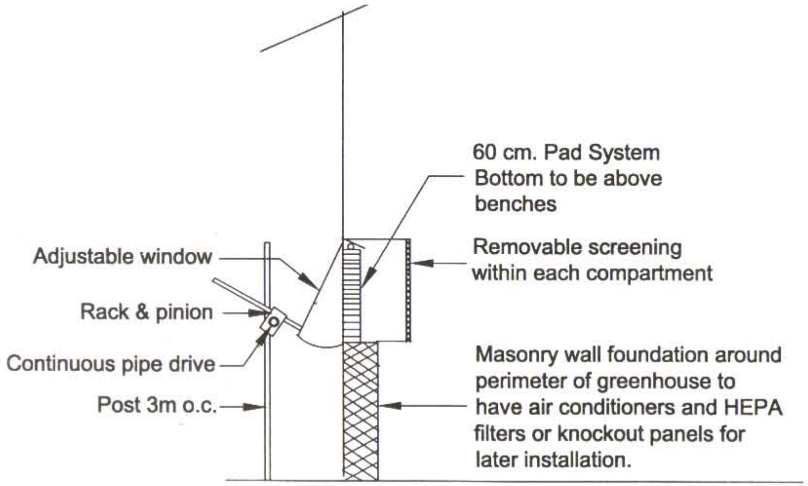


FIG 7.27 PAD screens and filters (Kahn 1999:82)

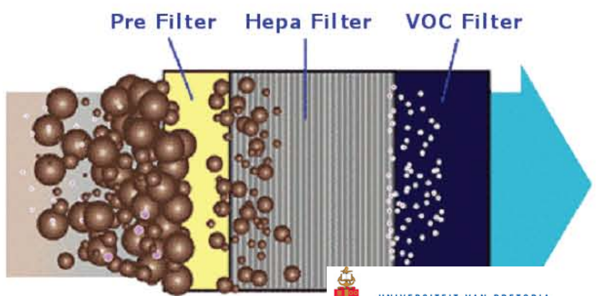


FIG 7.28 HEPA filter (http://www.americansafeair.com)

7.3.1 Roof Structure:

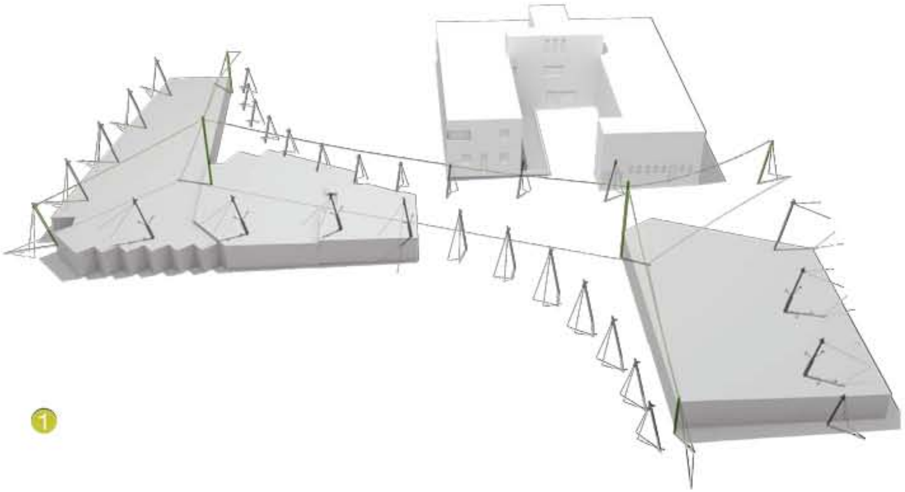
Regarding the aforementioned design considerations, it is necessary first of all to ensure structural stability by reducing deflection to a minimum. Therefore it is essential to ensure axial stiffness in the main supporting cables.

1 Primary Cables: Six main support columns (273x6mm Ø) form the backbone of the structure, keeping 50.8mm Ø, 126 ton nominal strength wire steel rope in place. Four of the columns function in line with each other, whilst two other columns work in at oblique angles to counter bending moments that are induced at the two tallest points.

2 Secondary cables: A network of 31.75mm Ø, 58.1 ton nominal strength wire steel ropes are fixed to 29 support columns (152.44mm Ø or 252mm Ø depending on cable span) at oblique angles to the primary cable. This infill structure transfers dead and live loads evenly from the roof cladding to the foundations.

3 Cable net: An intersecting network of 11.1mmØ, 8.1 ton nominal strength wire steel rope forms a platform for single-point glass fixings to be attached to the cables. These allow roof cladding panels that differ in size to be attached to the structure.

4 Roof cladding and gutters: Irregularly shaped 10mm deep translucent acrylic panels with a 140mm neoprene strip seal gutter at joining edges are fixed to the cable net structure. Material selection for the cladding panels and type of gutter seals will be discussed in Details 1 and 2.



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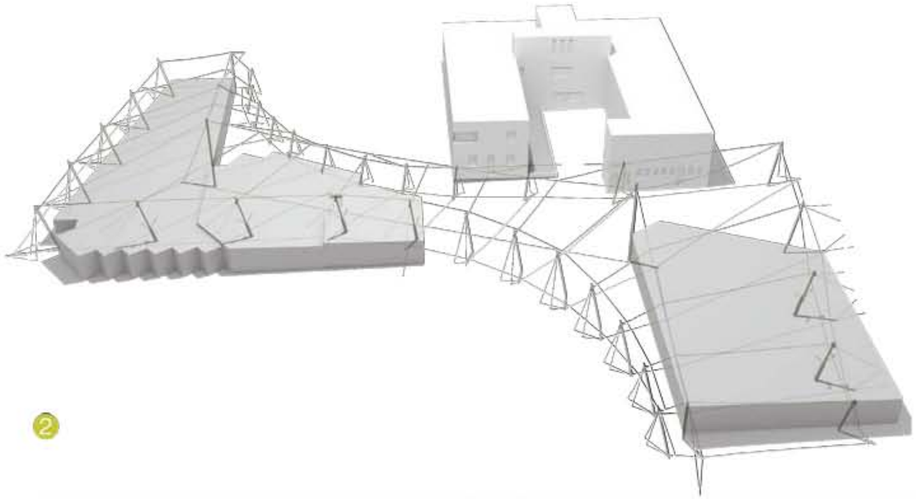

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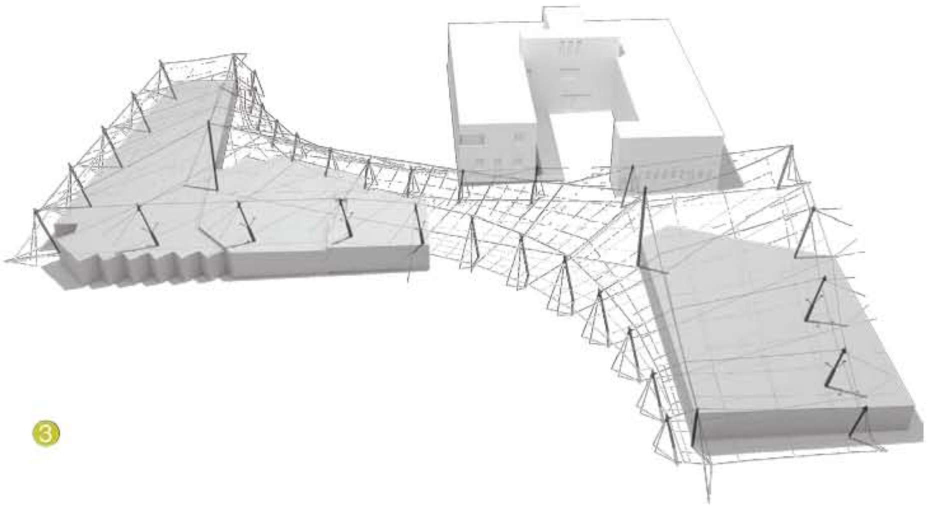

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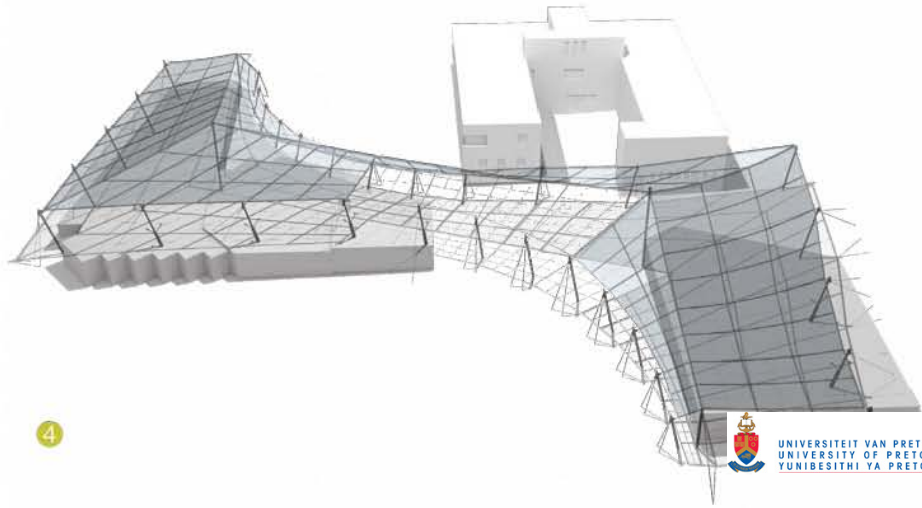

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7.3.2 Roof Structure assembly possibilities:

In order to make tensile structures economically more feasible, a wide variety of standard components are available on the market. Most of these fixtures are used for heavy lifting equipment in the shipping industry. Fixtures are available in a wide range of finishes. Depending on the manufacturing process, they are either chrome plated, galvanized or made of stainless steel.

The two sketches in Figures 7.4 and 7.5 illustrate in very basic terms the two paradigms of assemblies that can be achieved in tensile construction. Being spoiled for choice over the vast array of available fixtures, the challenge of designing a tensile structure is more like putting together a three dimensional rope puzzle. Fig. 7.2 shows a fixed construction method, where resin impregnated spelter sockets (discussed below) are used to anchor cables. The benefit of this type of assembly is that spelter sockets are available in large sizes and subsequently they can resist substantial loads from cables with large diameters. The liability in using such a construction methodology is that cables have to be cut to size very accurately before installation, because post-tensioning is not possible when resin anchors are used.

Alternatively, as in Fig. 7.3, a clevis-threaded rod assembly can be used. This allows for a more dynamic type of system where post tensioning is possible if turnbuckles are included. Threaded rods are less flexible than wire steel ropes (cables) and therefore a combination of anchoring assemblies are preferable as they allow for more flexibility of use. An example of such a combined installation is the Urban-Loritz Platz Straßenbahn by Tillner Architects in Vienna, Austria (Fig. 7.6). The roof canopy consists of a combination of PVC membrane sheets and glass panels. More interesting though is the way in which the architect combined the use of spelter socket anchors at the column supports, creating fixed points to provide a stronger reaction to tensile forces. Adjustable clevises are used inside the structure closer to the roof covering materials, where loads are more evenly distributed.

A method called swaging can also be used, but this is meant for net structures with lower tensile forces, such as cable net walling systems. With swaging a fitting is mechanically pressed into the cable end.

Where cables intersect they are held together with cable clamps. In most cases a single-point fixing will be used in combination with a cable clamp to attach the cladding material. This process will be discussed in greater depth in Detail 2.

7.3.3 Structure anchors and fixers:

1 **Clevis:** Mechanical connection for fixing threaded rods to the structure, mainly available in stainless or galvanized steel. The connection is secured to the structure with a pin-head and cotter pin.

2 **Pin-head and cotter pin:** Manufactured from stainless steel, the pin head diameter should be selected to be 125% of the size of the clevis thread-to-rod connection. This is to ensure that the pin-head does not fail due to high tensile forces

3 **Spelter socket:** Manufactured from either chrome plated or galvanized high-carbon steel, the socket has a cone shaped termination where the splayed wires of the cable termination is inserted and bound by melted zinc alloy or a resin wedge.

4 **Turnbuckle:** Available in a variety of finishes, turnbuckles are mechanical connections used to connect two threaded rods. These are used to allow post tensioning of the structure.

5 **Swivel socket:** Painted high-grade steel with cable end swaged into socket.

6 **Threaded rod** & 7 **Rod-end:** These rods form part of the lateral structure and can be custom ordered in various lengths. The diameter of the threaded rods should match those of the clevis and turnbuckle anchors. Rod-ends are used to allow connections to spelter socket or clevis pin heads.

8 **Hook assembly:** Probably the most basic component of any cable structure, but this type of assembly is versatile, adjustable, and can withstand high tensile forces.


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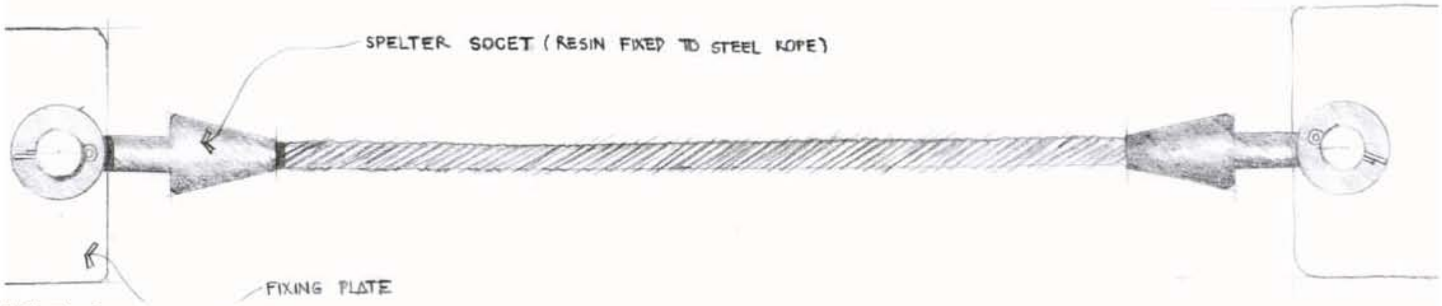


FIG 7.4 Spelter socket assembly

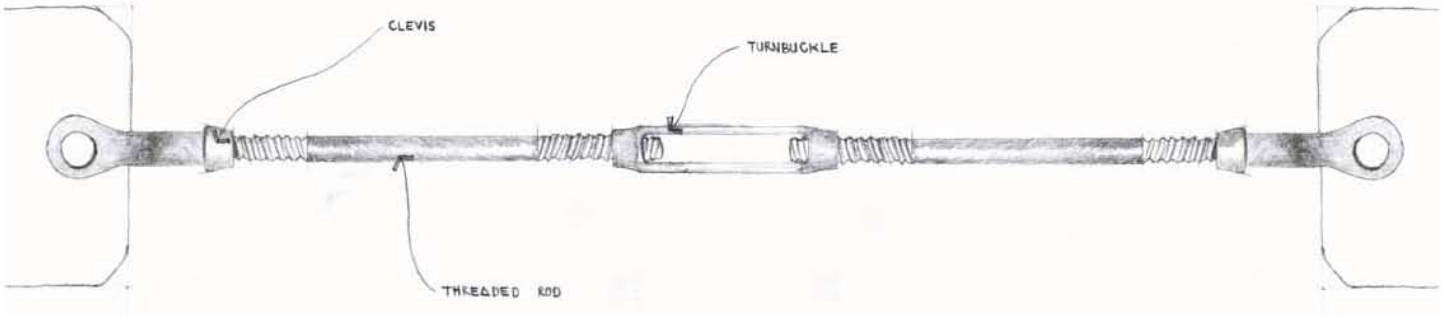


FIG 7.5 Clevis- rod assembly with turnbuckles

FIG 7.6 Urban-Loritz Platz Straßenbahn by Tillner architects in Vienna, Austria clevis-rod assembly

7.3.4 Structure façade assembly:

PLEASE REFER TO **DETAILED SECTION AA**

❶ Run-off water trench:

To adhere to the prescribed guidelines in SABS 0400 Part RR2, a water run-off trench, placed along the periphery of the roofline on ground level, directs stormwater run-off towards the rainwater retention pond for future re-use (Fig. 7.7). Its construction is similar to that of a recharge trench with a coarse aggregate surface layer and a finer aggregate sub-base. In the case of recharge trenches where a porous fabric-separating layer is used to separate aggregate and surrounding groundfill, an impermeable concrete gutter, in adherence to SABS 0400 Part JJ.2 (b), is poured with a minimum fall of 1:70 and slopes towards the retention pond.

The aggregate fill for the trench enables a primary filtering process for rainwater collected from the roof. Water is then directed towards the recharge pond, where it is pumped and filtered for use in the appropriate growing-out green houses. In the case of the hydroponic greenhouses, the water is pumped into storage tanks in the greenhouse control room after it has been filtered. The water is then treated with a pre-calculated nutrient solution and used in the greenhouse. Wastewater from the greenhouses and retention pond are directed to the stormwater sewer as prescribed in SABS 0400 Part RR5. For more information regarding the different hydroponic systems used in the greenhouse, please refer to discussion point number 4: Growing-out greenhouse – Hydroponic systems.

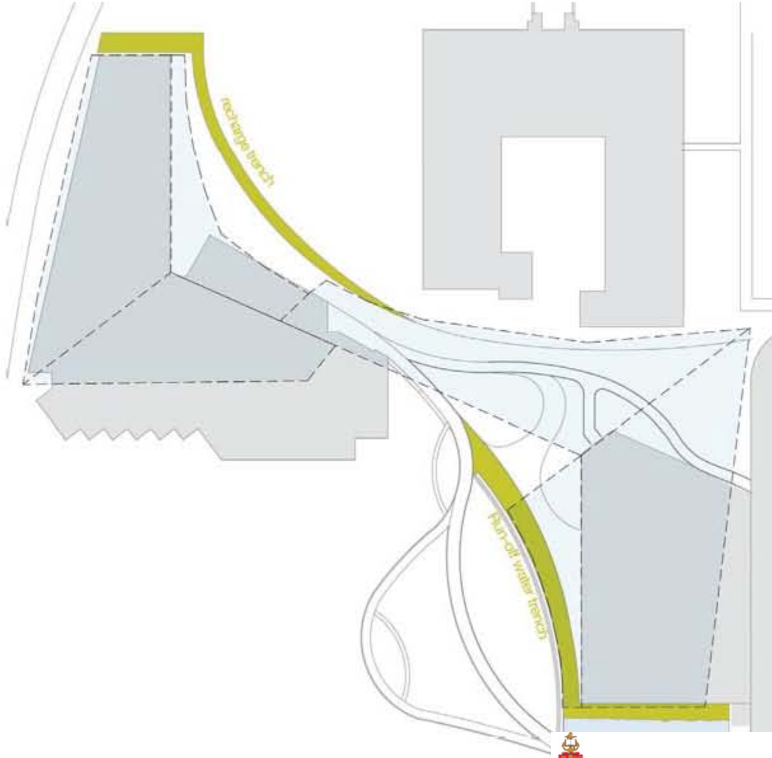


FIG 7.7 Rainwater falloff trenches and retention pond

❷ Façade – Assembly and material selection:

Growing-out greenhouses represent the lowest order of the containment hierarchy at a research facility (Kahn & Mathur, 1999:82) and therefore allow more design freedom. Plants reach this stage after seeds have been incubated under strictly controlled environmental conditions and have been cleared of bacteria and viruses that may pose threats to local plant species. Plants propagated in the growing-out greenhouses primarily need to be protected from pests, insects and harsh fluctuations in ambient air temperature. Due to the moderate and sub-tropical climatic conditions of Pretoria, where short spells of frost are only experienced irregularly during very cold winter nights, the possibility of having natural ventilation for the greenhouses during the daytime is unarguable.

The façade of the proposed building consists of a basic rigid timber skeleton built up of PAR 144X50 wrought and varnished timber studs intersected by PAR 44x94 wrought and varnished timber joists in accordance with SABS 1783. The skeleton timber studs are fixed to the concrete floor upstand (eliminating ingress of water onto timber) with stainless steel L-shaped brackets, and suspended with 11.1mmØ, 8.1 ton nominal strength wire steel rope from the primary cable of the roof structure, utilizing clevis, turnbuckle and swivel socket assemblies.

The timber skeleton is clad with 20mm wide, 1.45 W/m²K polycarbonate panels similar to the system used in Fig. 6.8. Polycarbonate panels are milled during manufacturing to give the façade an irregular profile, as illustrated in Figures 7.9 and 7.10. Every third panel of polycarbonate is operable for natural ventilation (see drawing of detailed section) and follows the same design integrity shown in Fig. 7.10, which depicts a similar mechanical window opening system used for a restaurant in Vienna.

The material selection for the timber skeleton and polycarbonate sheeting was primarily made on the basis of structural dead weight and inherent embodied energy. The aim was to create a lightweight façade that can be suspended from the tensile roof structure. The alternative to timber was aluminium, but it was decided in this case that the two main liabilities of aluminium (high cost and high embodied energy) would not prove feasible for this project. Timber was considered a wise choice due to the fact that it would be protected from moisture by the polycarbonate cladding and the roof overhang. Relatively high humidity levels in the greenhouse would also prevent the timber from drying out.

❸ Flexible membrane infill:

A tensile roof structure system that deflects easily under wind pressures, and that is at the same time connected to a fairly rigid façade system, calls for an intermediate connection that allows both interfaces to behave independently. Due to the façade skeleton's fixed height and the roof structure's changing levels, a flexible material is needed that could easily cover any shape of opening and could be fixed to both assemblies without too much difficulty.
ETFE (ethylene tetrafluoroethylene) has been used since the seventies as a means of covering organic-shaped structures. In recent years, ETFE has developed into a versatile transparent material with exceptional chemical properties. Texlon, its current trade name, is composed of three layers of custom-shaped ETFE sheets fused together to form part of a pneumatic system restrained by aluminium extrusions. The cushions formed in this way are inflated with low-pressure air. See Figures 7.12-7.14.

This flexible, transparent material is visually and physically light. It is able to follow the contours of the roof and can serve as a seal between the roof and the façade.

FIG 7.8 ▲

FIG 7.11 ▶

FIG 7.10 ▼

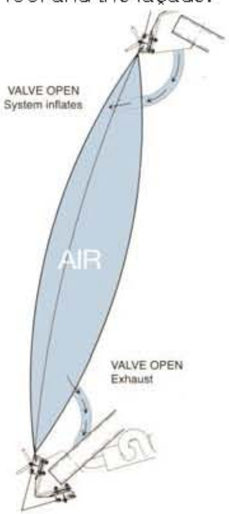


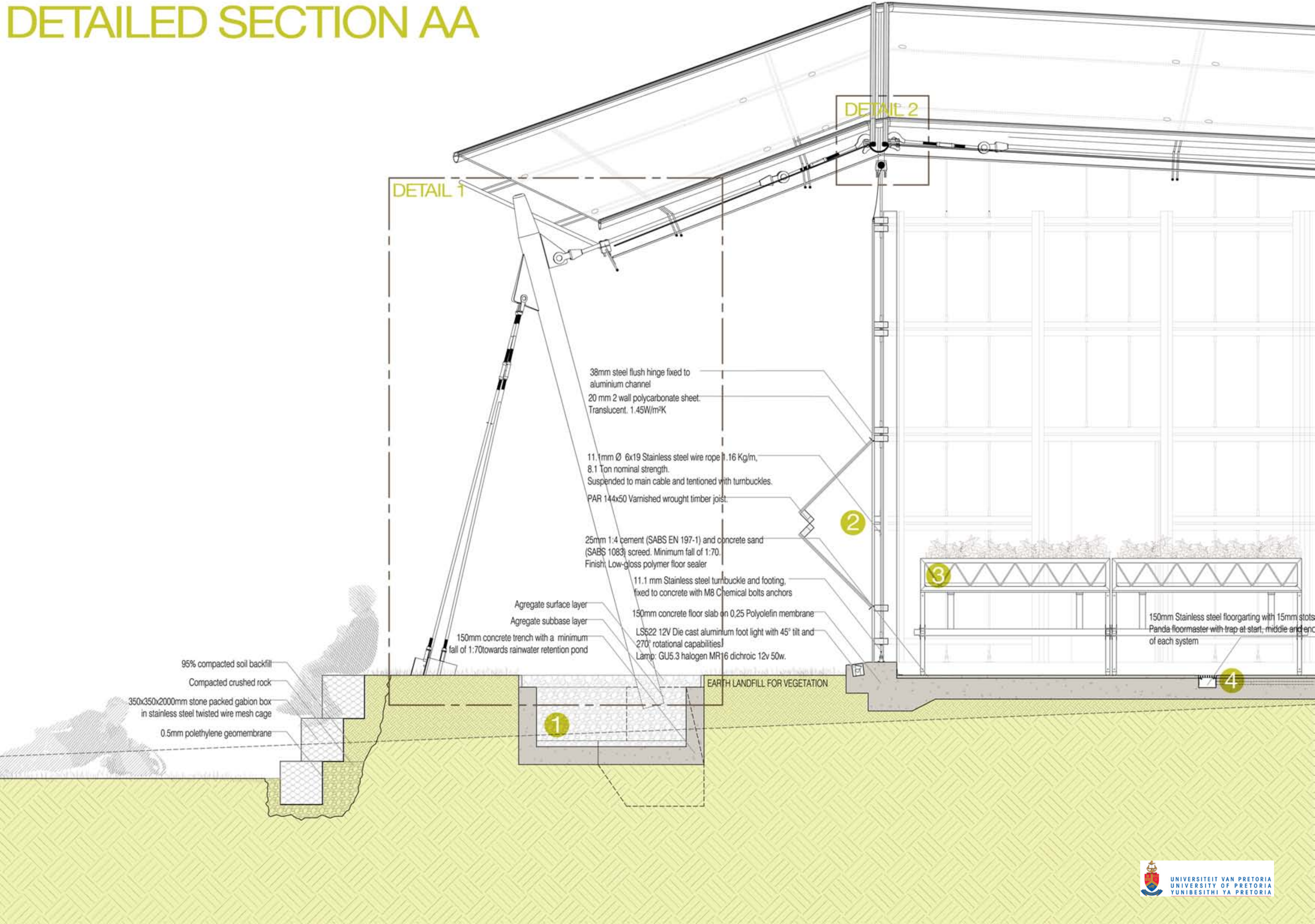
FIG 7.12 ▲

◀ FIG 7.13

FIG 7.14 ▶

FIG 7.9

DETAILED SECTION AA



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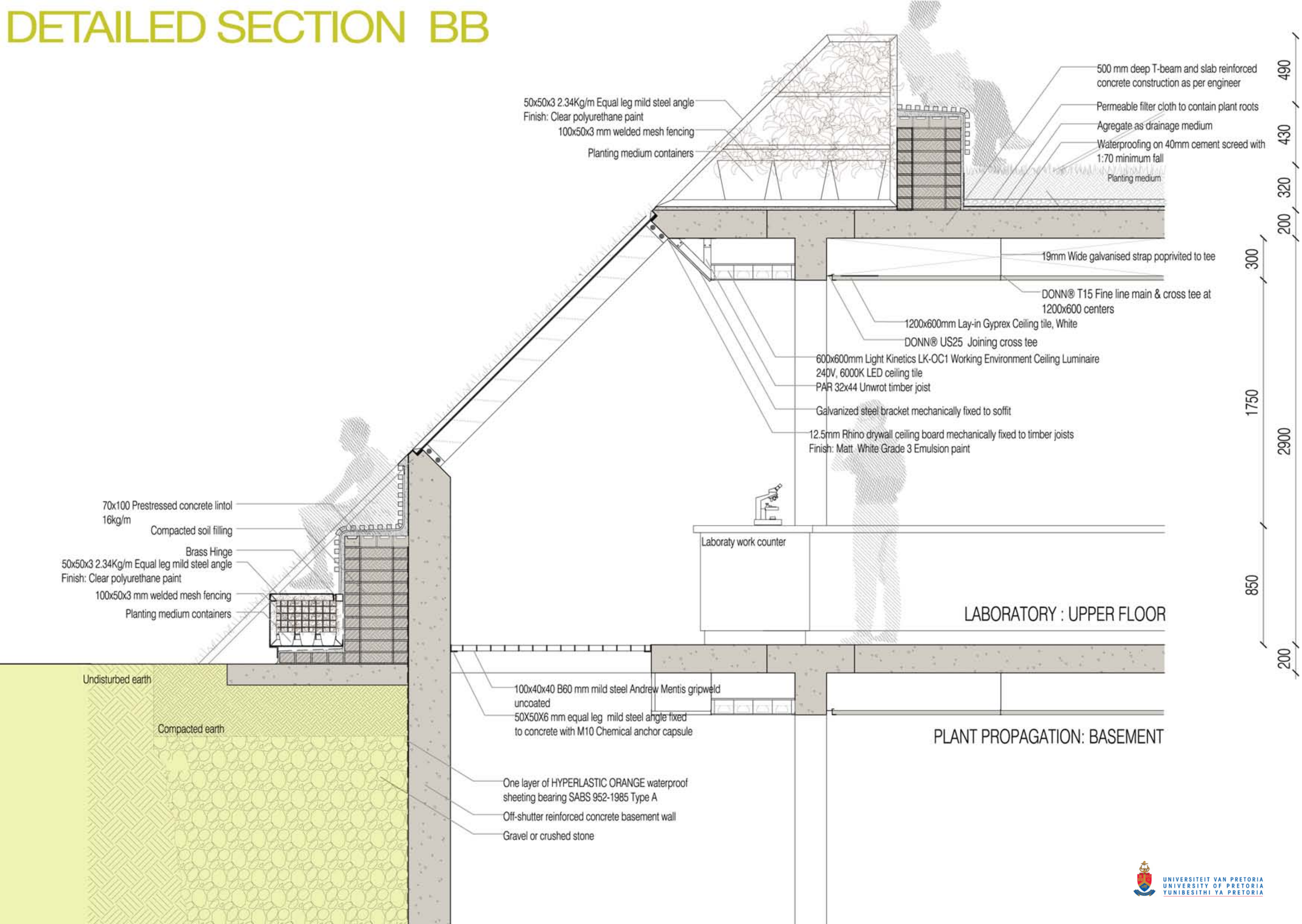


❹ Growing out greenhouse – Hydroponic systems:

Hydroponics is the commercial practice of growing plants without soil and by only immersing their roots in aerated nutrient solutions. It usually uses some type of substrate (gravel, rockwool, foam etc.) to support the plant, but the roots are always saturated by a recalculating nutrient solution (Resh, 1993:9). Hydroponics are successfully used commercially these days to propagate fruits, vegetables, herbs and flowers.

Different hydroponic systems are more suitable for cultivating certain plant species than others. For the research purposes of the proposed facility, the following three methods of hydroponic plant propagation were selected to ensure that a vast array of plant species can be cultivated.

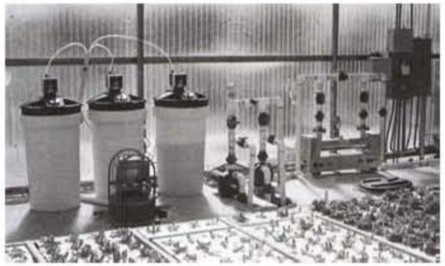
PLEASE REFER TO THE **GROUND FLOOR LAYOUT PLAN: HYDROPONIC GROWING OUT GREENHOUSE**

System 1: **Water raft**

A water raft system is a typical water-culture bed system where plant roots are entirely immersed in a re-circulating nutrient water solution. The system is fairly static with a circulation of approximately 2-3 liters per minute. The solution runs through a nutrient tank where it is aerated by an air pump, chilled in a refrigeration unit and pumped back (Fig. 7.15). On the nutrient solution's return to the beds, it is passed through an ultraviolet sterilizer. Plants are kept in position with Styrofoam sheets (Fig. 7.16).

FIG 7.16 Hydroponic raft system (Resh 2002:138)

FIG 7.15 Hydroponic nutrient tanks (Resh 2002:133)



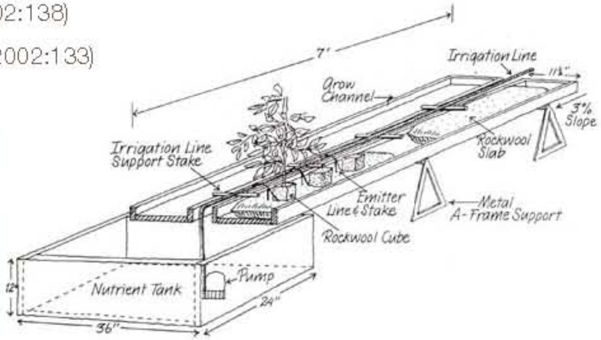


FIG 7.18 **FIG 7.17**

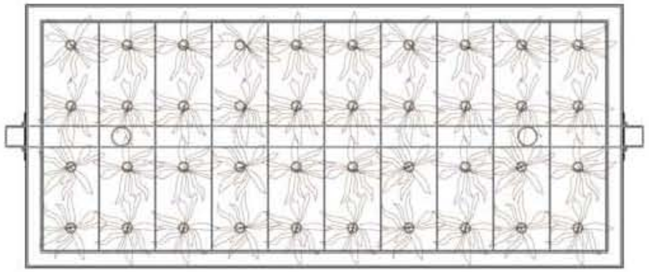
System 2: **Rockwool culture**

Rockwool culture is arguably the most common method of hydroponic plant propagation. Rockwool is an inert, fibrous material manufactured by heating a mixture of limestone, volcanic rock and coke (See Fig. 7.17 depicting rockwool cubes). It is 95% porous, but has a high water retention capability and drains well. This allows for effective air exchange with plant roots (Resh 1993:73). Figure 7.18 illustrates a basic rockwool culture system that is used in many greenhouses.

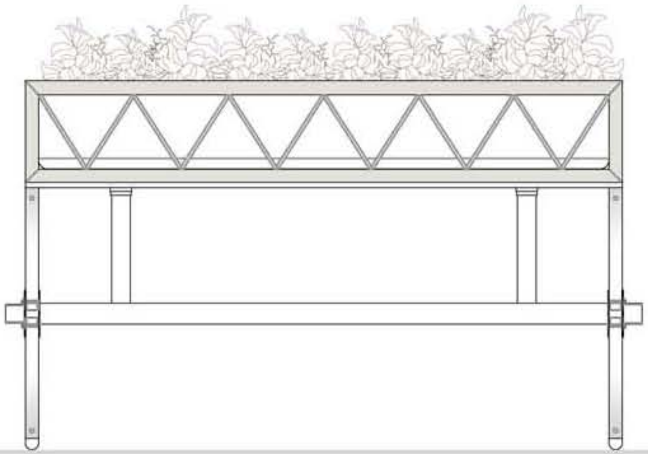
Rockwool culture generally entails an open, non-recycling hydroponic system in which nutrients are fed to the root of the plant via an emitter and drip line.

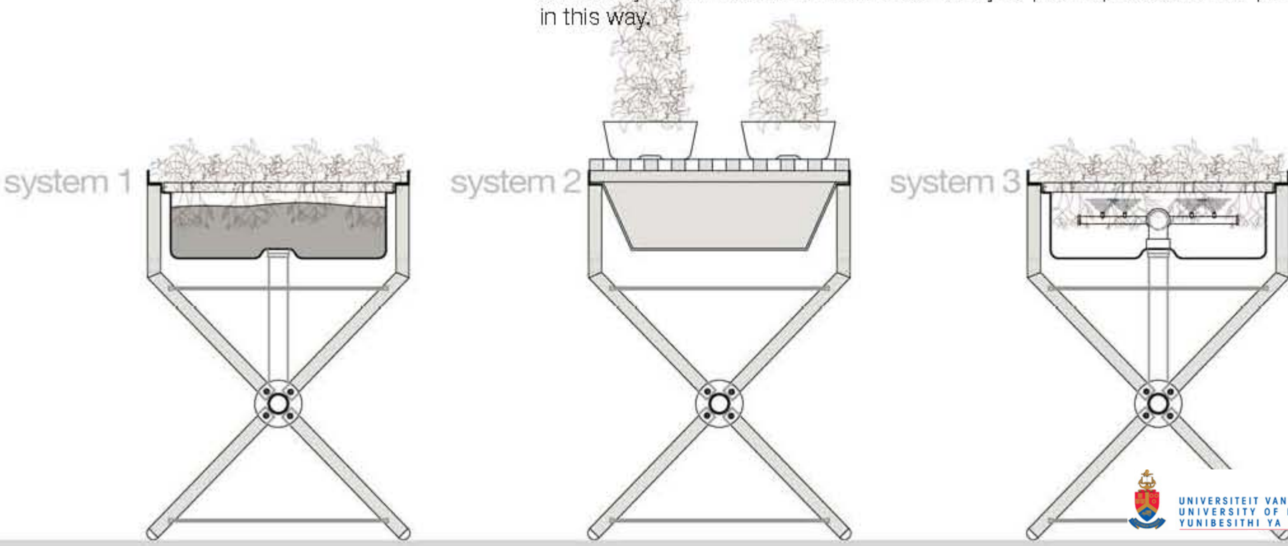
System 3: **Aeroponics**

Aeroponics is argued by experts to be the truest hydroponic system. Plant roots are suspended in mid air inside a planting tray and kept at 100% humidity. The nutrient solution is sprayed directly onto the plant roots with a fine spray. The two biggest benefits of the system is the fact that when the plant roots are suspended in mid-air they absorb much needed oxygen. This speeds up the metabolism of the plants so that they can grow up to 10 times faster than in regular soil. The second benefit of using such a system is that the water temperature can be controlled very accurately and therefore a much wider array of plant species can be propagated in this way.



❺ Interior floor drains wit trap at both ends

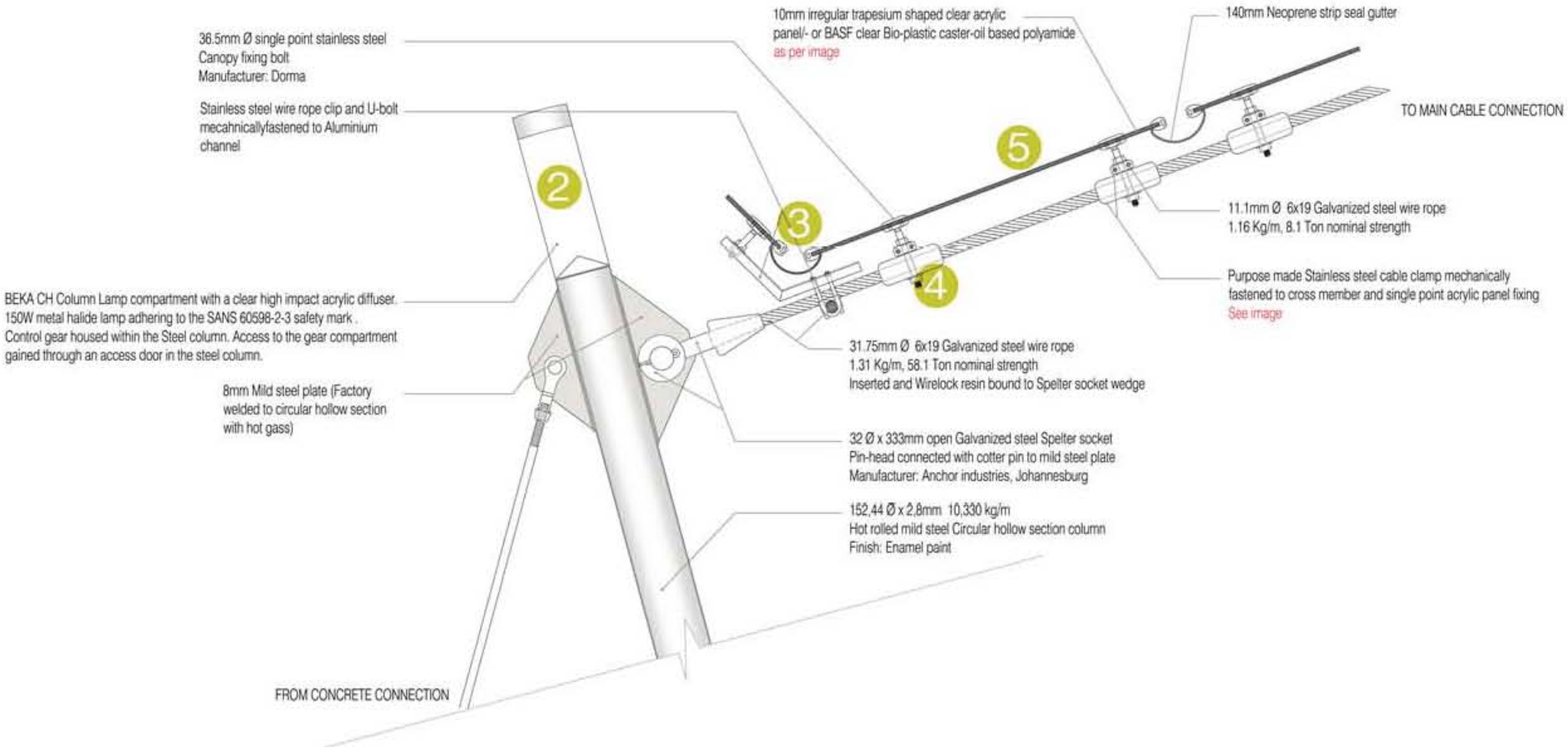


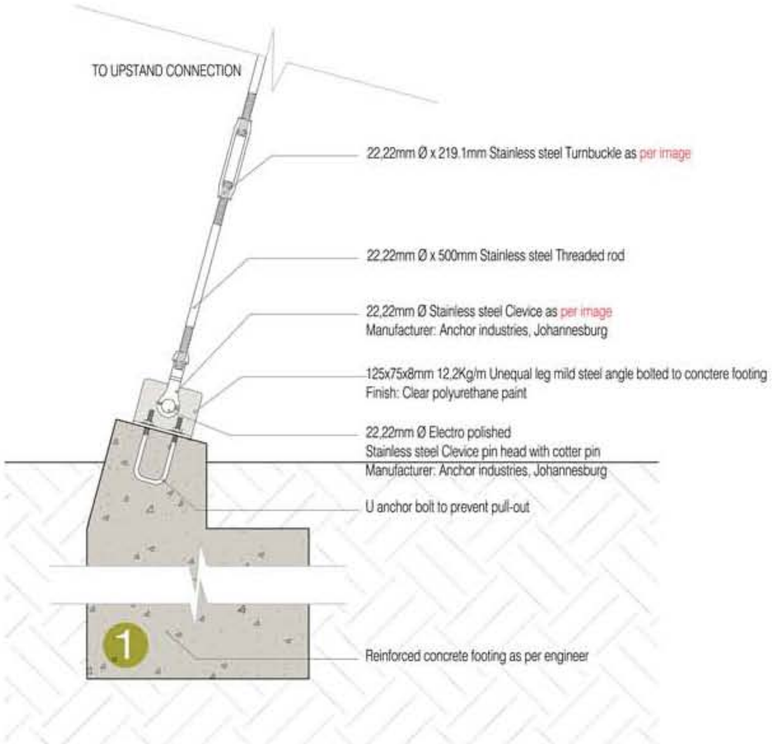


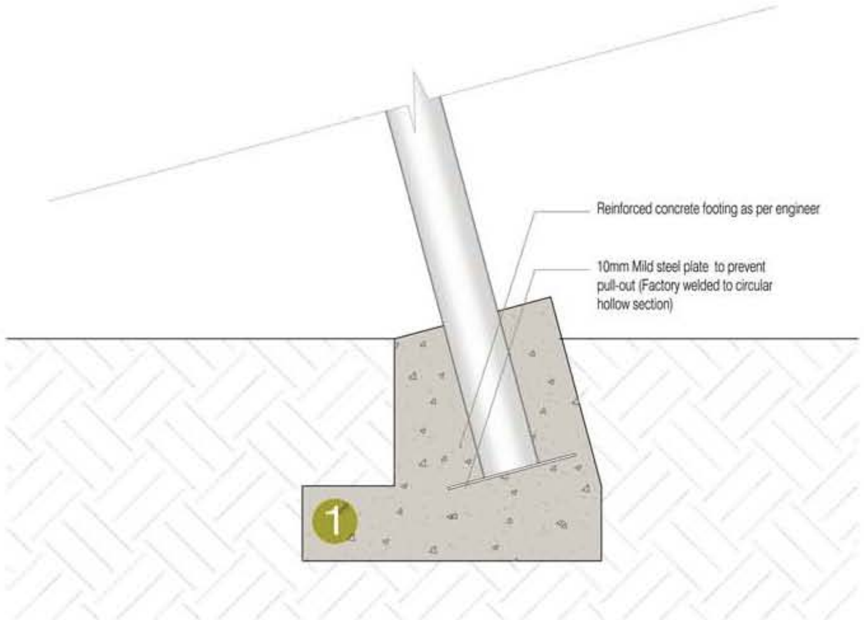
7.4 Critical connections:

7.4.1 Detail1

STRUCTURAL SUPPORTS 1:20







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❶ Column foundations:

The column foundations of the tensile structure must be designed in accordance with SABS 0161. The foundation depth may vary depending on the tensile forces that the support must resist. The foundation shape as illustrated by the sections allows for the weight of the soil to exert a pressure that will help anchor the support more effectively.

❷ Ambient column lighting fixtures:

The luminaire fitting at the top of each structural support of the roof is a modified system from the BEKA CH lighting column range. The off-the-shelf system makes use of a GRP (glass reinforced plastic) column that is bolted to a foundation. The standard system has control gear housed within the GRP. The same system is applied in the case of the proposed facility, apart from the fact that the GRP column is replaced with the structural mild steel columns of the building structure. For reference purposes please see Fig. 7.19. The following specifications apply to the luminaire fitting as provided by BEKA:

- The lighting sculpture consists of a separate lamp compartment with a clear diffuser for use with a 150W metal halide lamp.
- The control gear is mounted on a removable gear tray and is suitable for operation with the specified rating of the lamp on a 230V +3%/-10% 50 Hz single-phase system.
- All internal wiring is coated with Teflon® protective sleeves to prevent damage due to possible abrasion.
- HQI 150W lamp, 12000 lumen
- The luminaire bears the SANS 60598-2-3 safety mark.

FIG 7.19 BEKA CH Lighting column (Product catalogue)

❸ Roof gutters:

a) Run-off water calculations:

ROOF PORTION	AREA (m²)	RELATIVE PITCH (%)	FURHEST RUNOFF LENGTH (m)
1	400	8	21.74
2	145	9	12.22
3	265	14	21.74
4	410	23	24.7
5	125	10	11.21
6	585	6	34.13

RUNOFF COOFICCIENT C

Impermeable hard surfaces:

Concrete	0.8-0.95
Asphalt	0.7-0.95

Permeable surfaces:

Llawns, well drained (sandy soil)	0.10-0.15

A relative cooficient of **0.90** was taken for the Acrylic roof sheets

RETARDANCE COEFICCIENT (C_r)

Smooth asphalt	0.007
concrete pavement	0.012

A relative retardance cooficient of **0.055** was taken for the Acrylic roof sheet panels

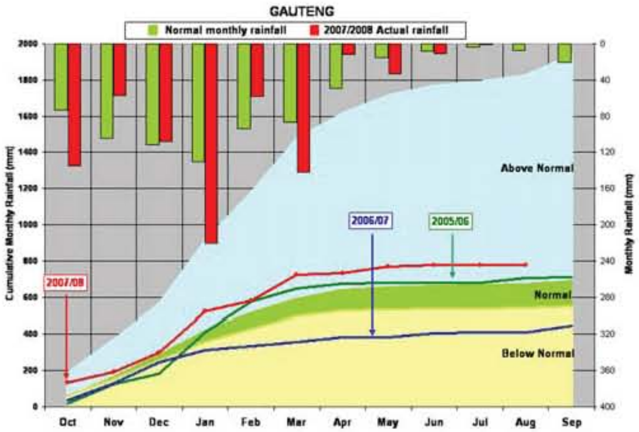


TABLE 1 Summary of monitored storm rainfall and runoff	Rainfall depth (mm)	Rainfall dura-tion (min)	Rainfall max rate (mm/h)	Runoff volume (m³)	Run-off peak (m³/s)
Minimum	0.40	20	2.40	264.00	0.10
Maximum	21.03	120	64.80	12 601.00	5.15
Median	3.81	64.17	12.00	2 409.00	1.63
Mean	7.12	71.03	23.60	4 543.15	1.77
St. dev.	6.84	27.37	23.87	4 013.65	1.48

Maiximum rainfall intensity for Gauteng = **64.80 mm/h**

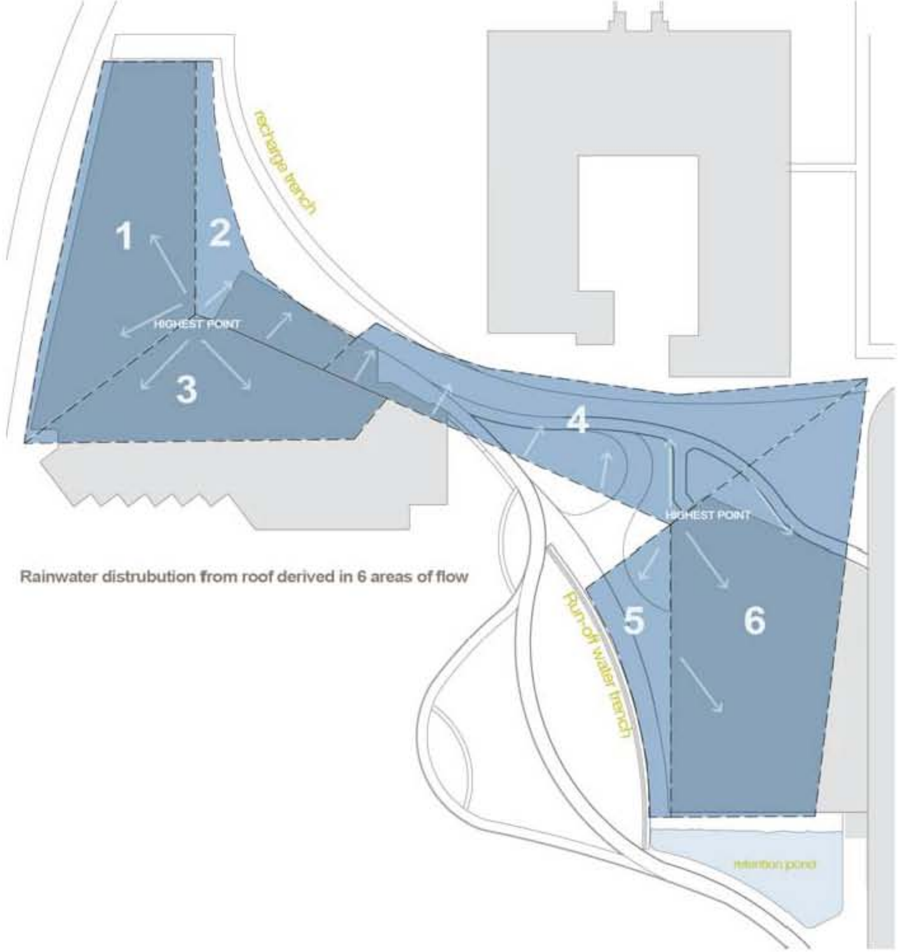
RUNOFF DISCHARGE (Q=V.a, Velocity x Area of flow)

ROOF PORTION	FLOW TIME (s)	DISCHARGE (m_3/s)
1	7.9	0.006
2	5.7	0.002
3	6.6	0.004
4	6	0.006
5	5.3	0.002
6	11	0.009

REQUIRED SIZE OF GUTTER CHANNELS:

Using the n-value of Brass and Glass for the carylic panels as = **0.013**

ROOF PORTION	MINIMUM FULL GUTTER SIZE (mmØ)	MINIMUM HALF GUTTER SIZE (mmØ)
1	30.7	40.1
2	19.3	25.4
3	23.1	30.2
4	24.6	32
5	19.1	24.6
6	36.8	48



Rainwater distrubution from roof derived in 6 areas of flow

FIG 7.20 Neoprene roof gutter system Munich Olympic stadium, Germany (Nerdinger 2005:268)

FIG 7.21 BASF Wabo® gutter flex channels (Product catalogue)

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b) Gutters:

- Acrylic bracket upstands:
  As shown in Fig. 7.20 and Detail 1, acrylic panels are fixed at oblique angles on the periphery of the roof. This is to direct water to dedicated discharge points when no rainwater collection trench is provided below.

- Neoprene channels: Where the acrylic roof cladding panels meet, neoprene BASF Wabo® gutter flex channels form a flexible joint between the panels and also serve to drain away excess rainwater (Fig. 7.21). The gutters have almost 100% flexibility and are fixed with an adhesive tape to the underside of the acrylic panels. Optional small drainpipes can be installed at 7,5m centre to centre intervals to handle excess water over short periods of time.

❹ Cable clamps and point fixings:

Cable nets are made up of cables connected at their intersections and held together by cable clamps. As cable net curtain walls are used more frequently these days, there are already numerous manufacturers that supply these combined joints. See Figures 7.22 and 7.23.

❺ Roof cladding – material selection:

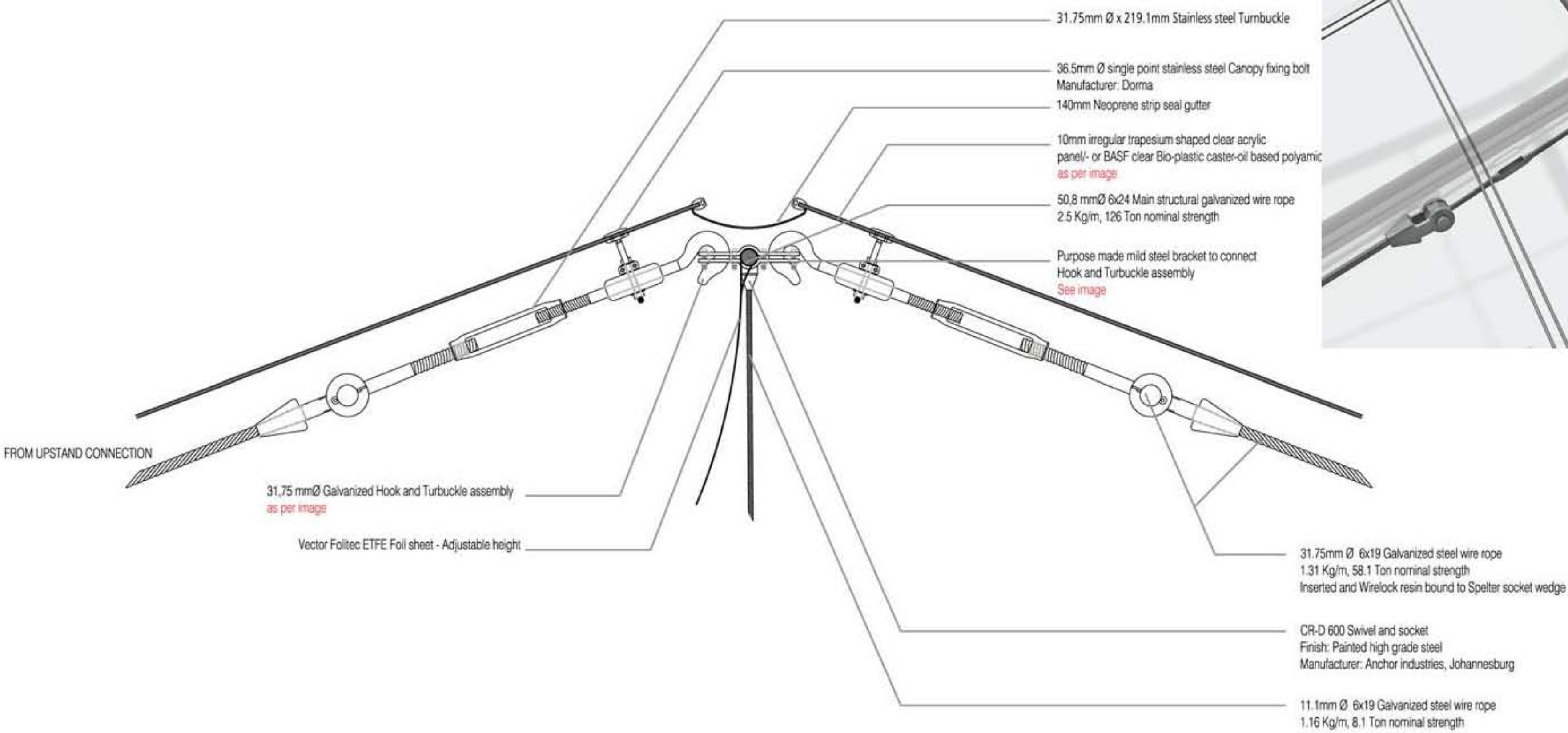
	Acrylic (Polymethylmethacrylate)	Polycarbonate	Bio-plastic caster-oil polyamide
Corrosion resistant	✖	✔	✖
Impact resistant	✖	✔	✖
Stiff	✔	✔	✔
Strong	✔	✔	✔
Tough	✖	✔	✖
UV resistant	✔	✔	✔
Wear resistant	✖	✔	✔
Flame retardant	✖	✔	✔
Opacity	High	High	60%
Recycle potential	High	High	High
Price	Low	High	High

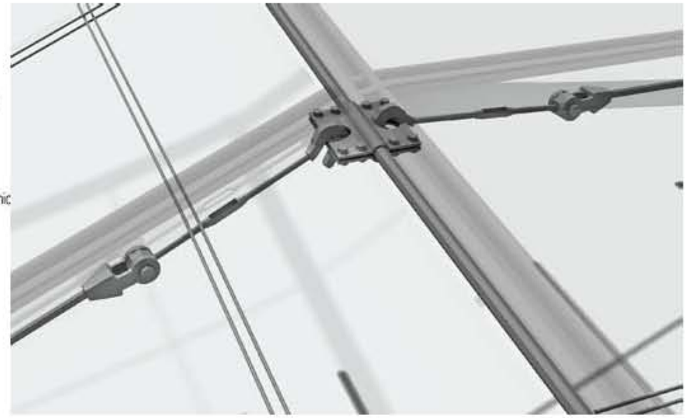
FIG 7.22 ▲

FIG 7.23 ▼

7.4.2 Detail 2

MAIN CABLE TO SECONDARY CABLE CONNECTION 1:20





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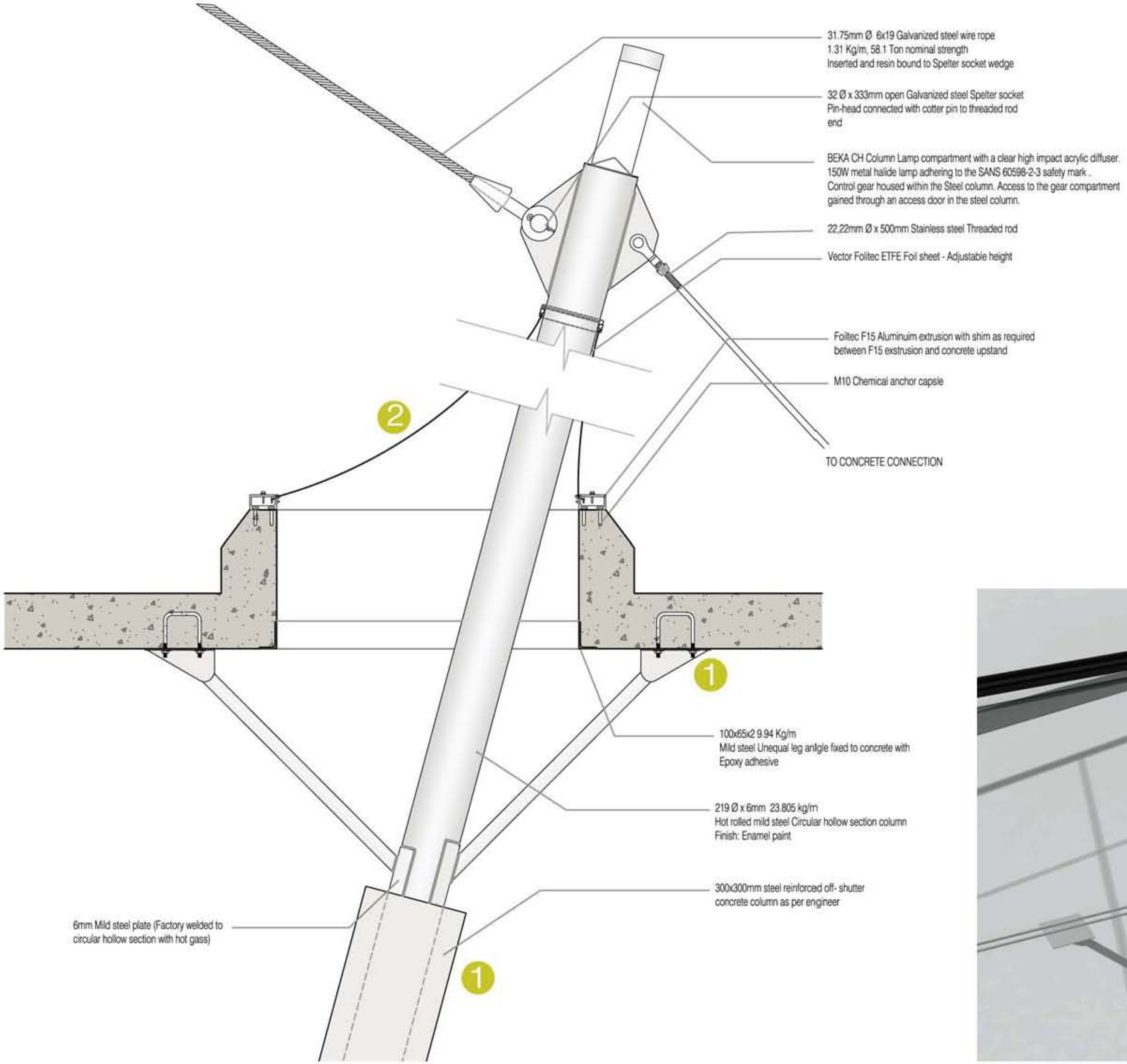
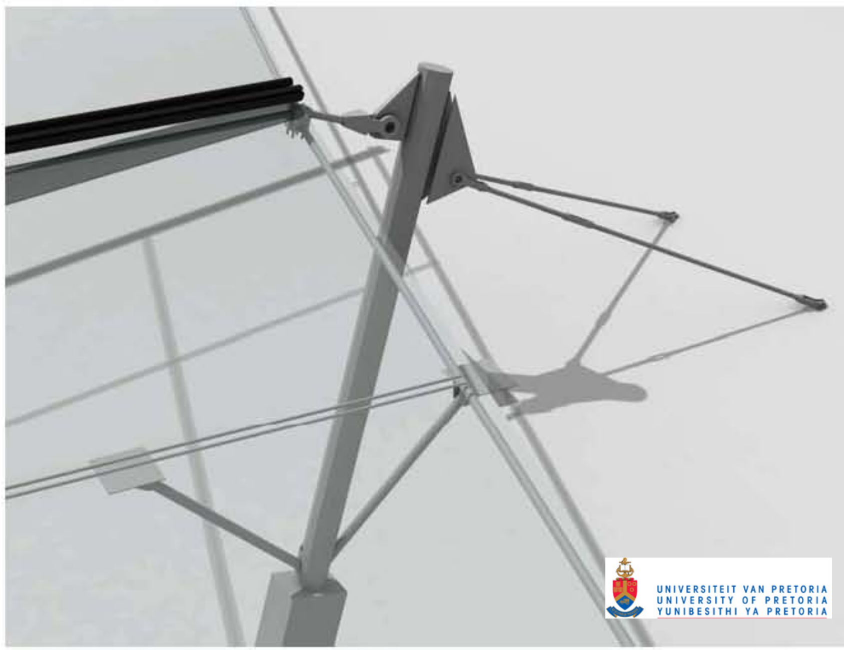
7.4.3 Detail 3
CABLE STRUCTURE TO FIXED STRUCTURE CONNECTION 1:20



❶ **Live loads and structure deflection:**

❷ **Membrane infill - tent**



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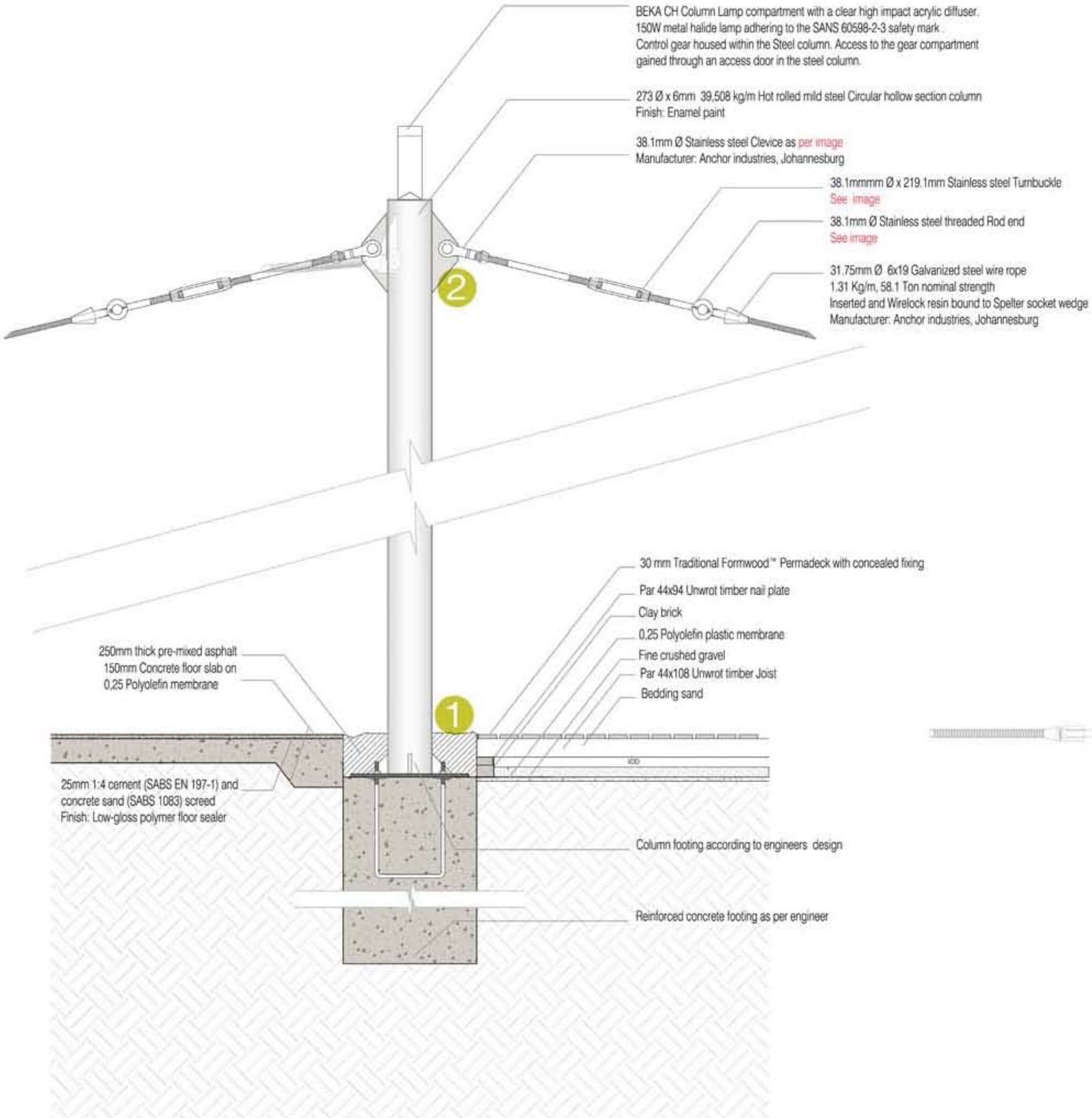
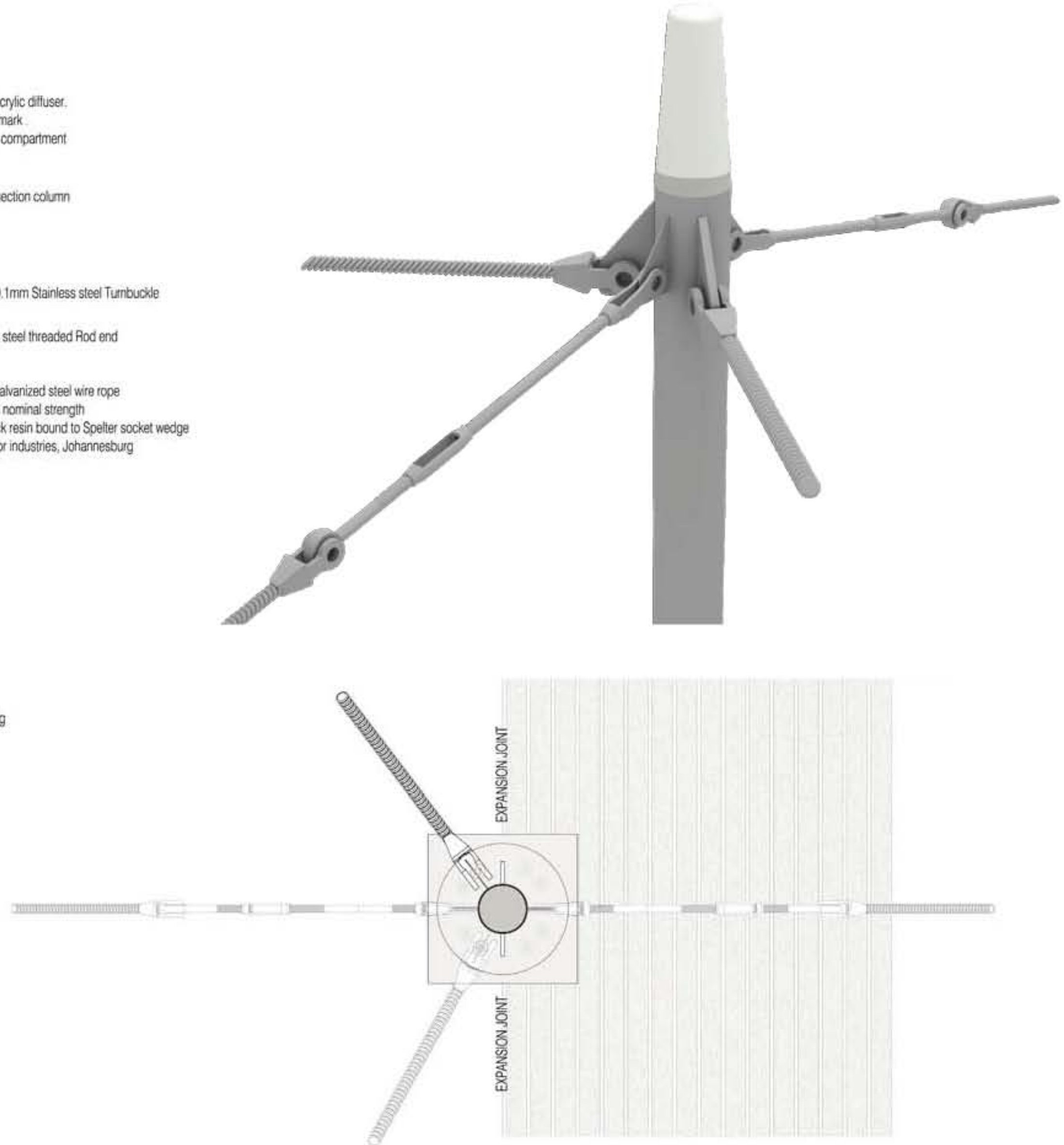
7.4.4 Detail 4

MAIN SUPPORT COLUMN 1:40



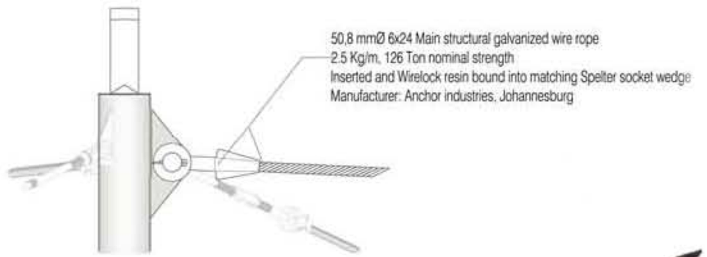


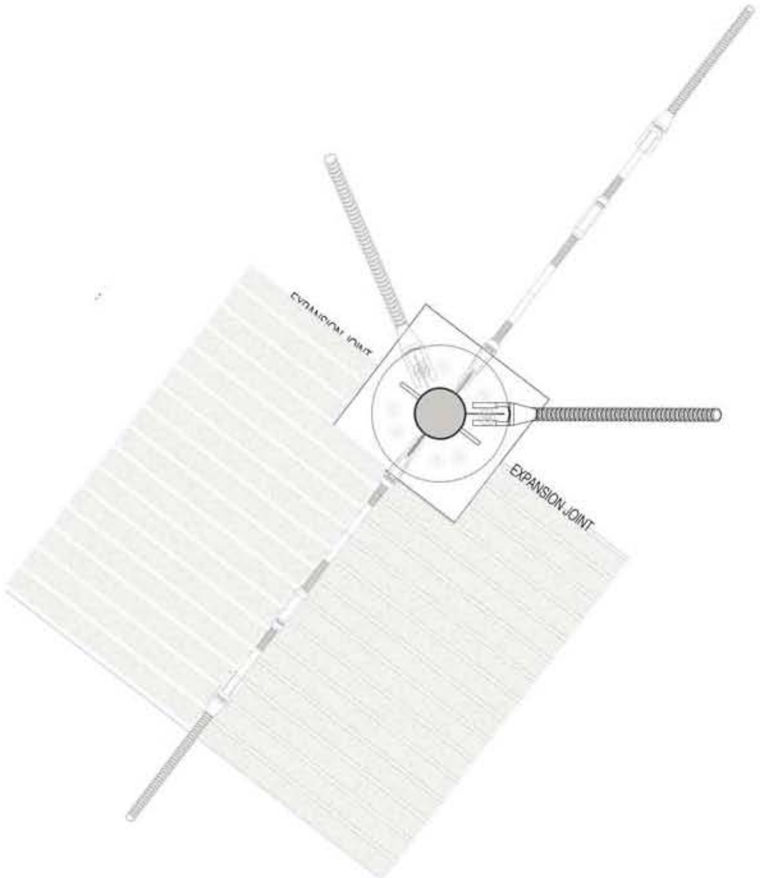
DETAIL 5: Primary support column

❶ Concealed column footing

❷ Force distribution and required connections for stability:

Figure 6.24 illustrates the hierarchy of forces that are dealt with at a critical node. From the main support the primary cable keeps the column stable by directing the forces into three appropriate directions, whilst the secondary cables and cable net evenly disperse forces caused by loads induced by the roof cladding across the area of the structure.





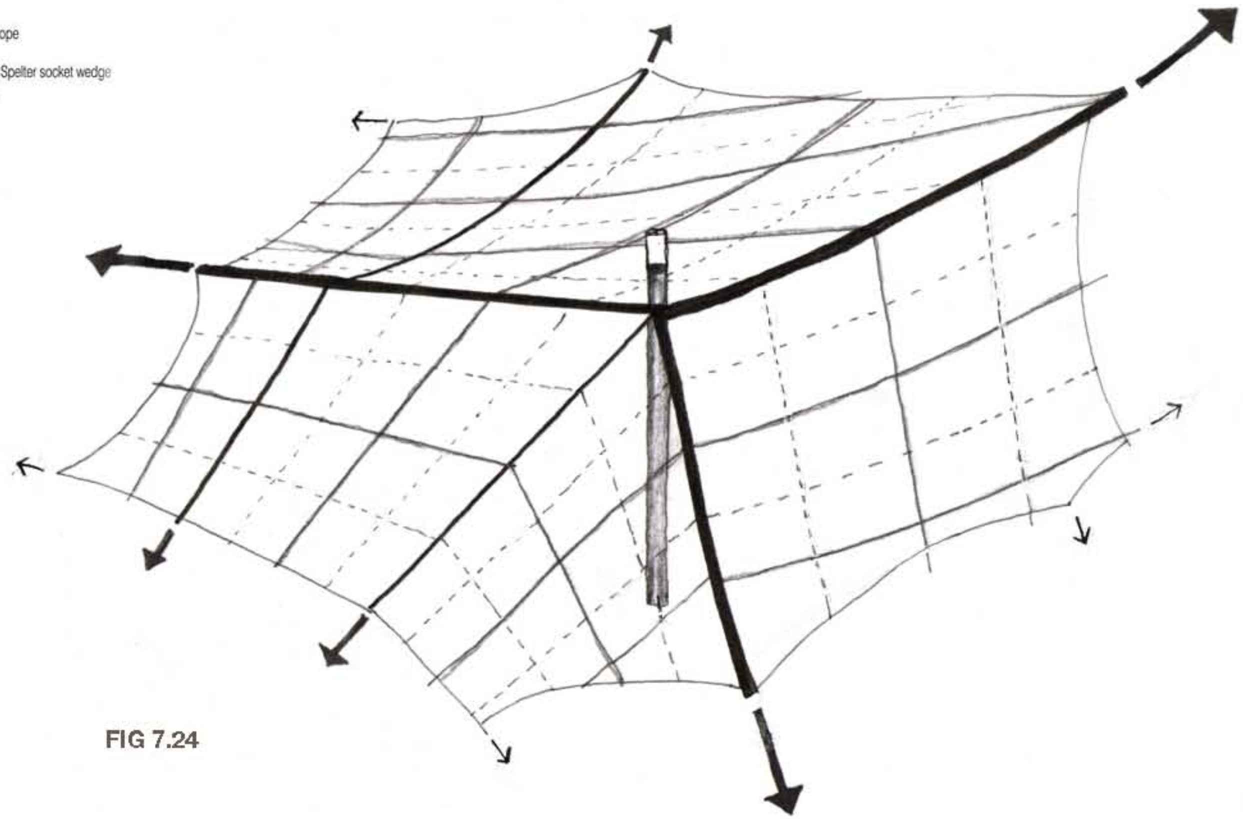


FIG 7.24

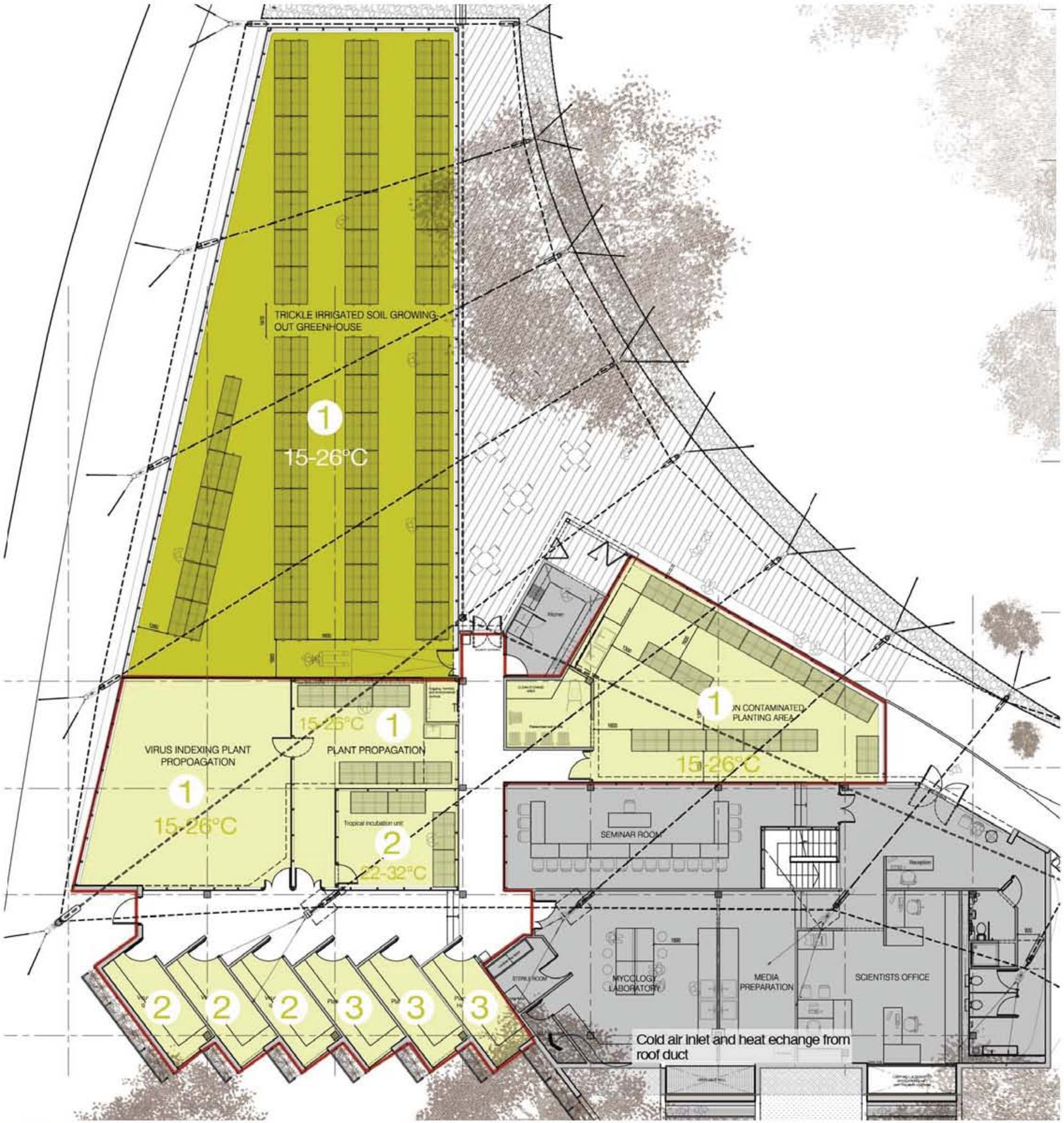
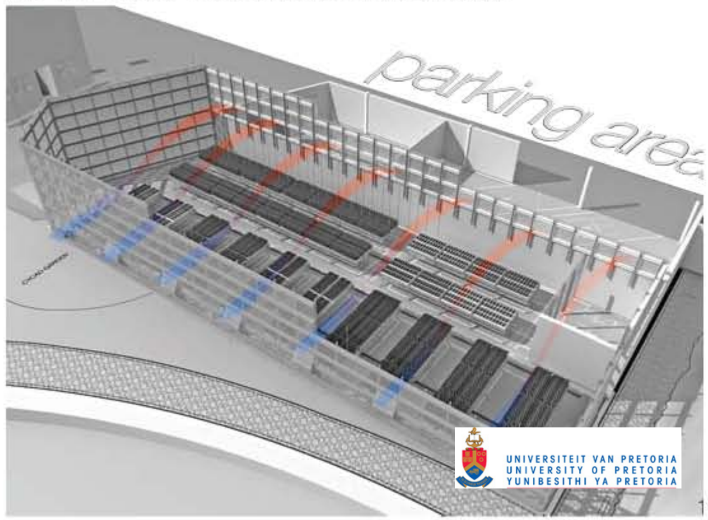


FIG 7.29 Ground floor growth rooms

FIG 7.30 Basement growth rooms

FIG 7.31 Natural cross ventilation in greenhouses



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bibliography/terminology

ACRONYMS AND NON-STANDARD ABBREVIATIONS:
BP: British Petroleum
CSR: Corporate Social Responsibility
ESKOM: Electricity Supply Commission
IDP: Integrated Development Plan
IRIN: Integrated Regional Information Networks
ISDF: Integrated Spatial Development Framework
LDC: Lynedoch Development Company
LHOA: Lynedoch Home Owners Association
MSDF: Metropolitan Spatial Development Framework
NDA: National Department of Agriculture
NPPOSA: National Plant Protection Organization of South Africa
SHTL: Seed Heath Testing Laboratory
SANBI: South African National Biodiversity Institute
TOD: Transit Orientated Development
UN: United Nations

TERMONOLOGY:
Adobe bricks: 300 mm wide clay and straw sun dried bricks (Annecke & Swilling (2006:11)
Kikuyu grass: Warm seasonal grass type commonly found in South Africa.
Metaphysical: Beyond the physical nature. Thoughts, feelings memories etc.
Mycology: Scientific study of fungi.
Pathogen: Disease causing bacterium, viruses and other microorganisms.
Phytotron: Controlled environment plant growth room.
Seed incubation room: Samples incubated for fungal growth under controlled light and temperature.
Sterile room: Media and glassware sterilization.
Virus indexing: Virus detection and isolation.

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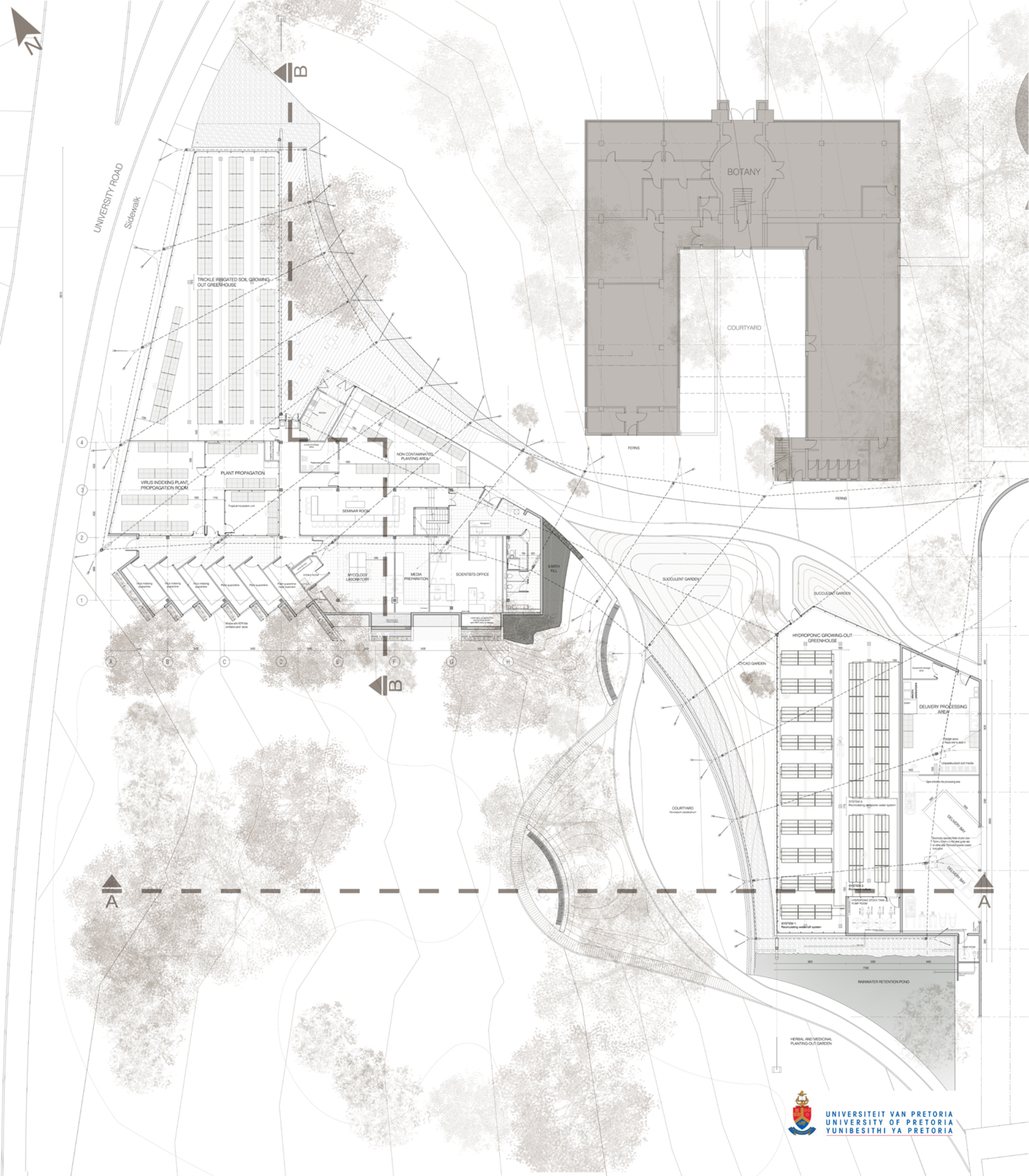
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BOTANY
COURTYARD
FERNS
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PLANT PROPAGATION
NON CONTAMINATED PLANTING AREA
SEMINAR ROOM
MYCOLOGY LABORATORY
MEDIA PREPARATION
SCIENTISTS OFFICE
EARTH FILL
SUCCULENT GARDEN
SUCCULENT GARDEN
CYCAD GARDEN
HYDROPONIC GROWING-OUT GREENHOUSE
DELIVERY PROCESSING AREA
DELIVERY BAY
DELIVERY BAY
COURTYARD
RAINWATER RETENTION POND
HERBAL AND MEDICINAL PLANTING-OUT GARDEN
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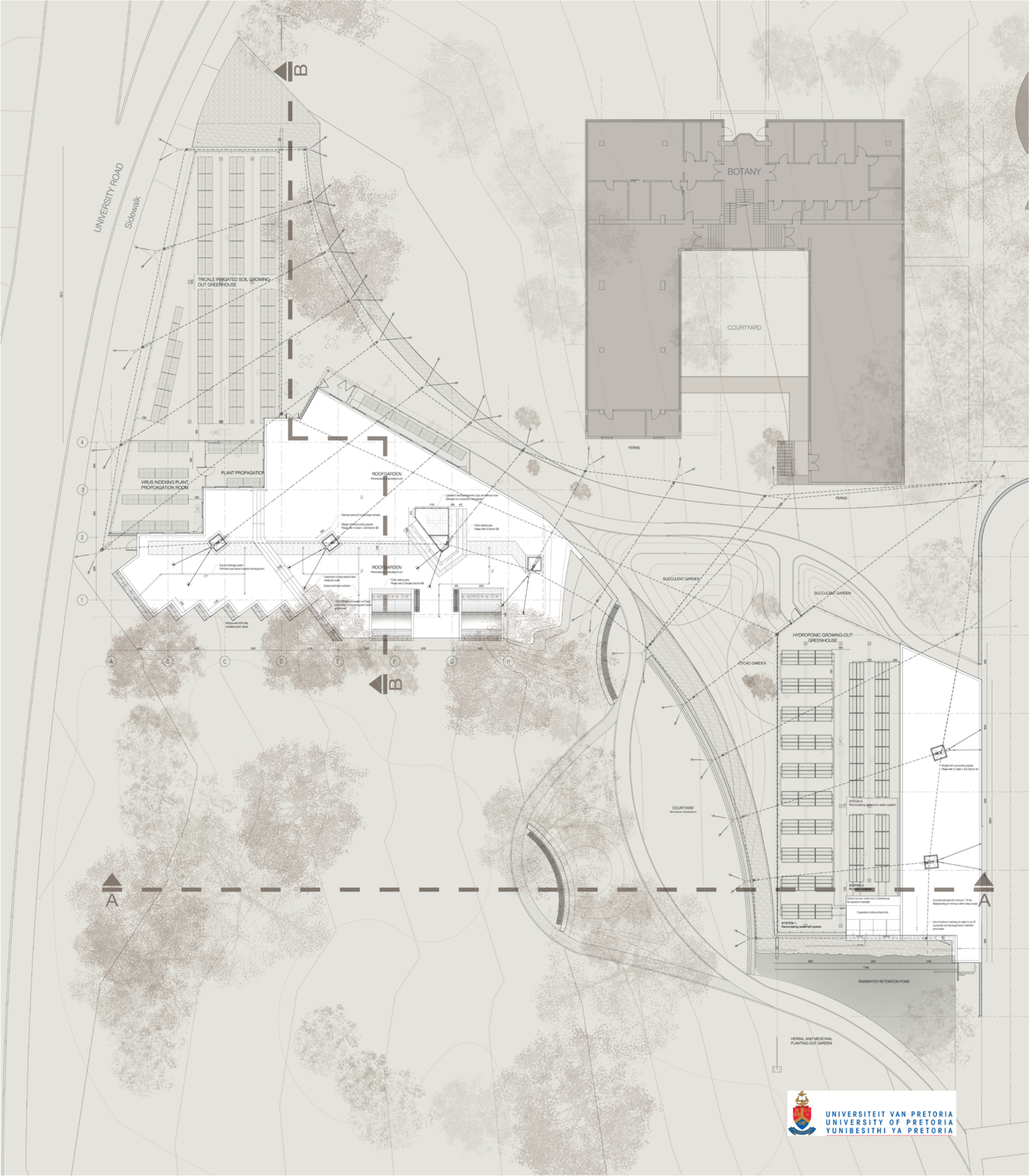

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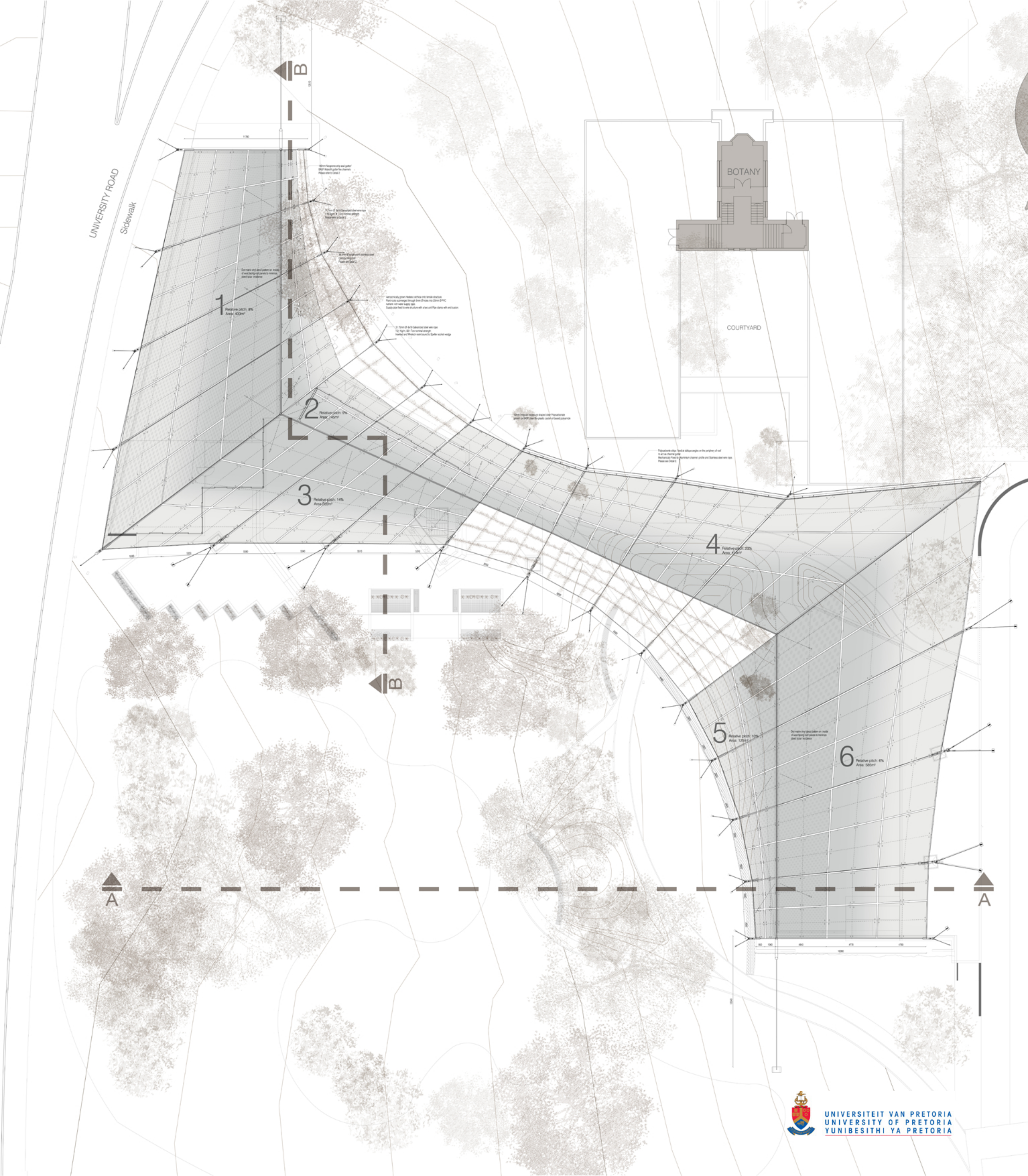

UNIVERSITY ROAD
Sidewalk
BOTANY
COURTYARD
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Relative pitch: 8%
Area: 400m²
2
Relative pitch: 8%
Area: 140m²
3
Relative pitch: 14%
Area: 590m²
4
Relative pitch: 22%
Area: 410m²
5
Relative pitch: 10%
Area: 125m²
6
Relative pitch: 6%
Area: 585m²
A
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