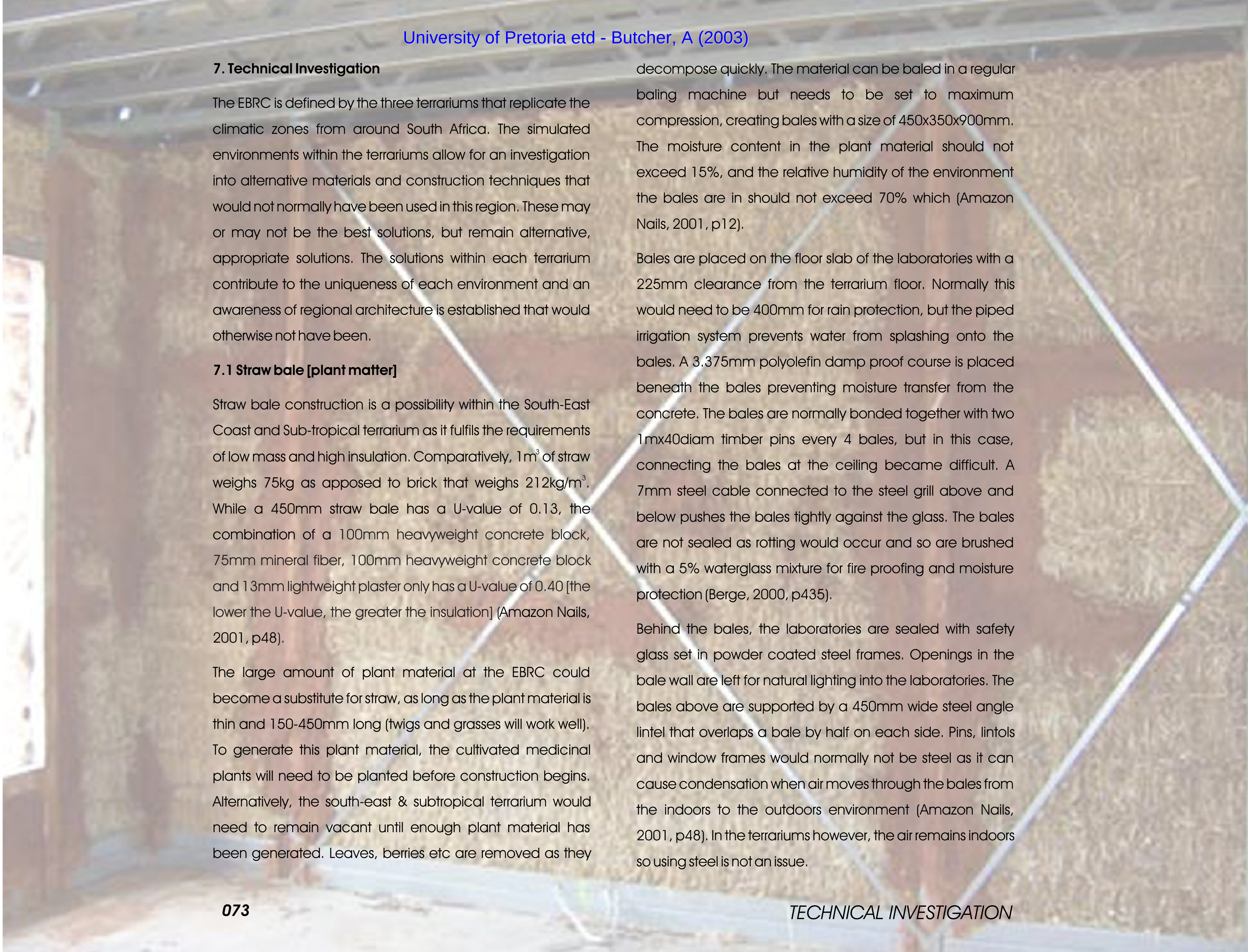


7. Technical Investigation

The EBRC is defined by the three terrariums that replicate the climatic zones from around South Africa. The simulated environments within the terrariums allow for an investigation into alternative materials and construction techniques that would not normally have been used in this region. These may or may not be the best solutions, but remain alternative, appropriate solutions. The solutions within each terrarium contribute to the uniqueness of each environment and an awareness of regional architecture is established that would otherwise not have been.

7.1 Straw bale [plant matter]

Straw bale construction is a possibility within the South-East Coast and Sub-tropical terrarium as it fulfils the requirements of low mass and high insulation. Comparatively, $1m^3$ of straw weighs 75kg as apposed to brick that weighs $212kg/m^3$. While a 450mm straw bale has a U-value of 0.13, the combination of a 100mm heavyweight concrete block, 75mm mineral fiber, 100mm heavyweight concrete block and 13mm lightweight plaster only has a U-value of 0.40 [the lower the U-value, the greater the insulation] (Amazon Nails, 2001, p48).

The large amount of plant material at the EBRC could become a substitute for straw, as long as the plant material is thin and 150-450mm long (twigs and grasses will work well). To generate this plant material, the cultivated medicinal plants will need to be planted before construction begins. Alternatively, the south-east & subtropical terrarium would need to remain vacant until enough plant material has been generated. Leaves, berries etc are removed as they decompose quickly. The material can be baled in a regular baling machine but needs to be set to maximum compression, creating bales with a size of 450x350x900mm. The moisture content in the plant material should not exceed 15%, and the relative humidity of the environment the bales are in should not exceed 70% which (Amazon Nails, 2001, p12).

Bales are placed on the floor slab of the laboratories with a 225mm clearance from the terrarium floor. Normally this would need to be 400mm for rain protection, but the piped irrigation system prevents water from splashing onto the bales. A 3.375mm polyolefin damp proof course is placed beneath the bales preventing moisture transfer from the concrete. The bales are normally bonded together with two 1mx40diam timber pins every 4 bales, but in this case, connecting the bales at the ceiling became difficult. A 7mm steel cable connected to the steel grill above and below pushes the bales tightly against the glass. The bales are not sealed as rotting would occur and so are brushed with a 5% waterglass mixture for fire proofing and moisture protection (Berge, 2000, p435).

Behind the bales, the laboratories are sealed with safety glass set in powder coated steel frames. Openings in the bale wall are left for natural lighting into the laboratories. The bales above are supported by a 450mm wide steel angle lintel that overlaps a bale by half on each side. Pins, lintols and window frames would normally not be steel as it can cause condensation when air moves through the bales from the indoors to the outdoors environment (Amazon Nails, 2001, p48). In the terrariums however, the air remains indoors so using steel is not an issue.

These bales are a completely renewable resource, can easily be removed or replaced and can be composted at the end of their life cycle.

7.2 Rammed earth

As with the South-East Coast and Sub-tropical terrarium, the Semi-Arid and Desert Steppe terrarium, with its low moisture content and need for high mass construction offers the opportunity for rammed earth construction. As with the plant bales, rammed earth can easily be removed or replaced and all the resources needed for rammed earth construction can be found on site at no cost.

The two types of rammed earth construction considered were Pise' and Adobe blocks. Pise' is a process of constructing one solid structure by ramming 150mm layers of earth at a time between shuttering. Adobe blocks are individual blocks of rammed earth and are placed in a similar method to brickwork. Adobe blocks are the choice method in the EBRC as Pise' is not as flexible and because the walls are infill, ramming would be a problem as there would be no room for ramming equipment with the beams above.

The type of earth required for adobe blocks needs a binding capacity of no less than 0.050kp/cm^2, which can be acquired by having a 30% clay content in the earth (Berge, 2000, p124). There is an abundance of earth within the berms on the site and does have a relatively high clay content (see appendix C); however this will need to be tested before being used in construction.

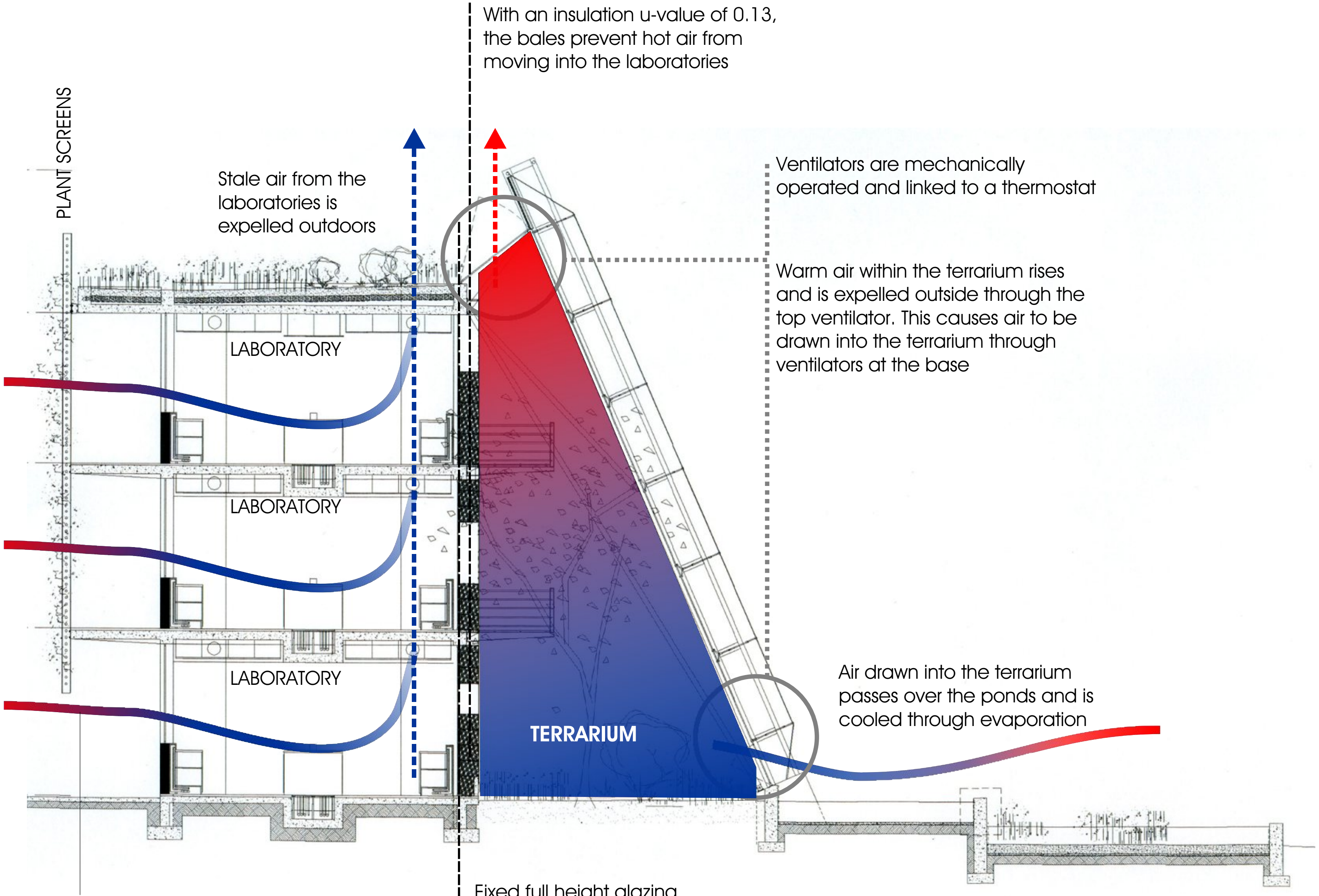
The earth used should not contain any humus, so 20-30mm of topsoil will need to removed; this can be utilised within the terrariums or on the roof gardens. The earth below must be sieved through mesh with a hole size of 10mm. If the soil has a moisture content of between 9.5 and 23%, it can be used immediately, otherwise water will need to be added or the soil will need to be dried (Berge, 2000, p126).

The earth is rammed into timber moulds of 110x320x50mm with either a manual rammer of 6-7kg or a ramming machine that has a compression power of 5hp/hammer. After 2 hours the moulds are removed from the blocks and after 3 days they are stacked for air circulation. After 2 weeks the blocks can be used for construction. Blocks are dipped in a 5% waterglass solution and laid in stretcher bond with a mortar joint of the same earth as the blocks, with wire reinforcement placed on every third course (ibid, p128). The block work sits 150mm above the terrarium floor, and as with the bales, a 0.375mm polyolefin damp proof course is placed between the blocks and the concrete.

On the terrarium side of the wall, the blocks are left only with the waterglass finish. On the laboratory side, the blocks are brushed with clear epoxy to seal the wall but exposing the material.

7.3 Terrarium

The higher the light transmission into a terrarium, the better the plant growth. Terrariums orientated to the north receive very high solar transmittance levels of up to 70% by having roof pitches of 25° and 65° (Von Zabeltitz, 1999, p30), so to maximize the solar transmittance, the entire wall of the terrariums is inclined at 65°. Glass cladding is preferred to plastic alternatives, not only for environmental reasons. On



With an insulation u-value of 0.13, the bales prevent hot air from moving into the laboratories

Stale air from the laboratories is expelled outdoors

Ventilators are mechanically operated and linked to a thermostat

Warm air within the terrarium rises and is expelled outside through the top ventilator. This causes air to be drawn into the terrarium through ventilators at the base

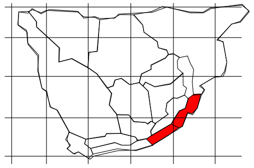
Air drawn into the terrarium passes over the ponds and is cooled through evaporation

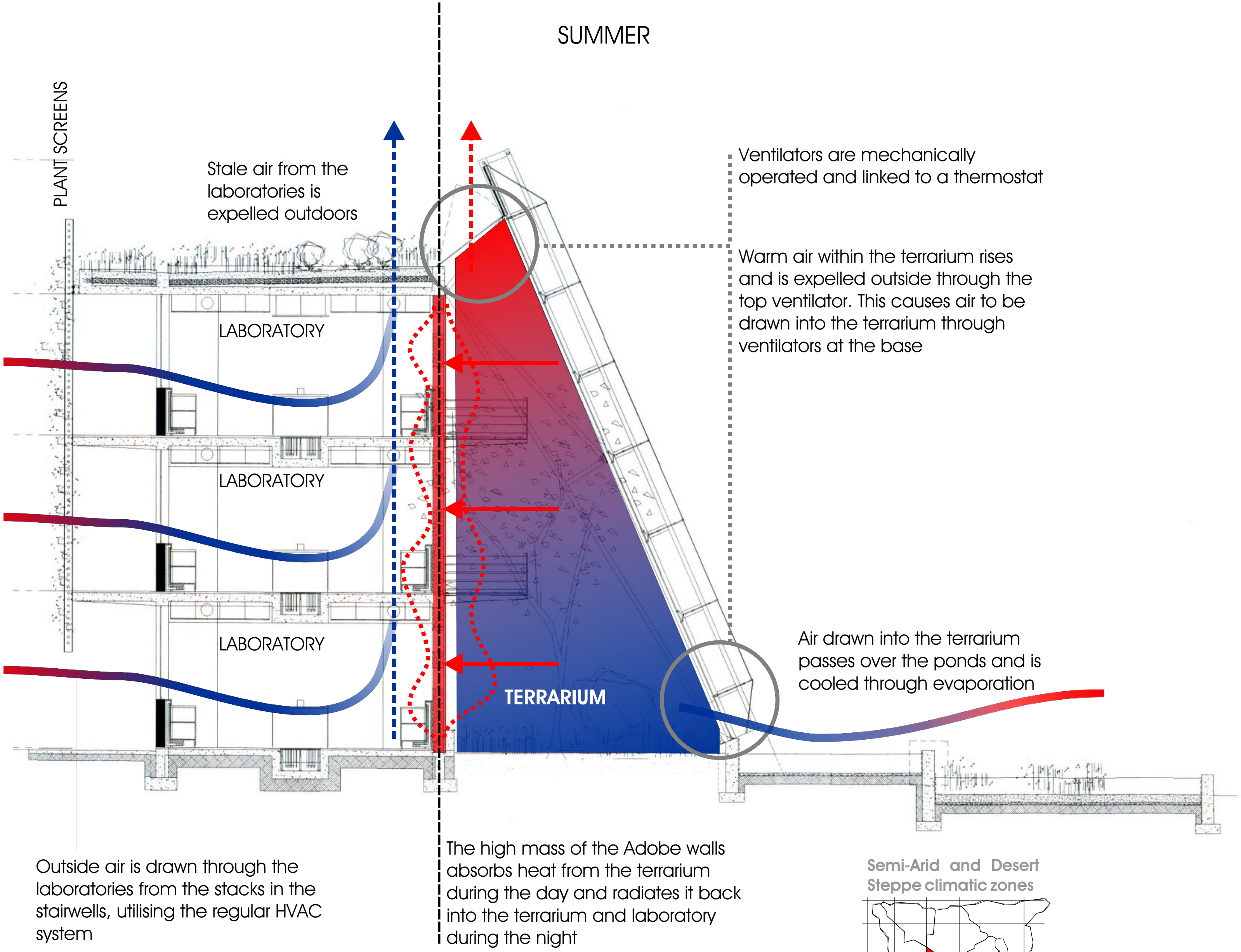
Outside air is drawn through the laboratories from the stacks in the stairwells, utilising the regular HVAC system

Fixed full height glazing allows random window placement for natural lighting but prevents air passing from the terrariums into the laboratories

7.1 Ventilation in SE coast / subtropical terrarium

South-East Coast and Sub-Tropical climatic zone





Stale air from the laboratories is expelled outdoors

Ventilators are mechanically operated and linked to a thermostat

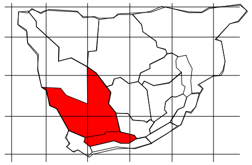
Warm air within the terrarium rises and is expelled outside through the top ventilator. This causes air to be drawn into the terrarium through ventilators at the base

Air drawn into the terrarium passes over the ponds and is cooled through evaporation

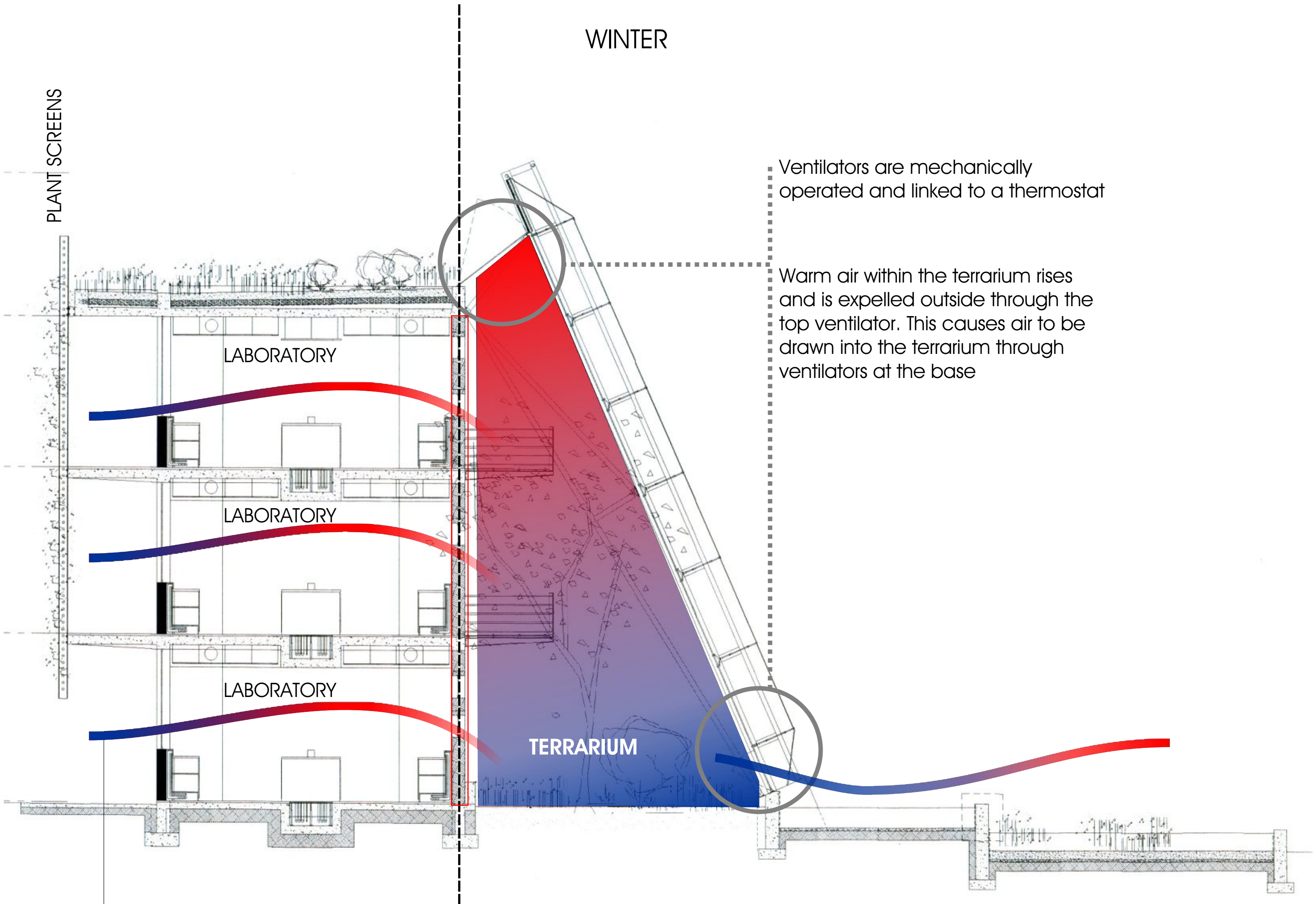
Outside air is drawn through the laboratories from the stacks in the stairwells, utilising the regular HVAC system

The high mass of the Adobe walls absorbs heat from the terrarium during the day and radiates it back into the terrarium and laboratory during the night

Semi-Arid and Desert Steppe climatic zones



7.2 Ventilation in Semi-arid / desert steppe terrarium in summer



Ventilators are mechanically operated and linked to a thermostat

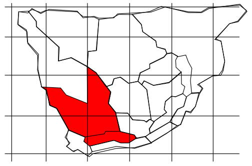
Warm air within the terrarium rises and is expelled outside through the top ventilator. This causes air to be drawn into the terrarium through ventilators at the base

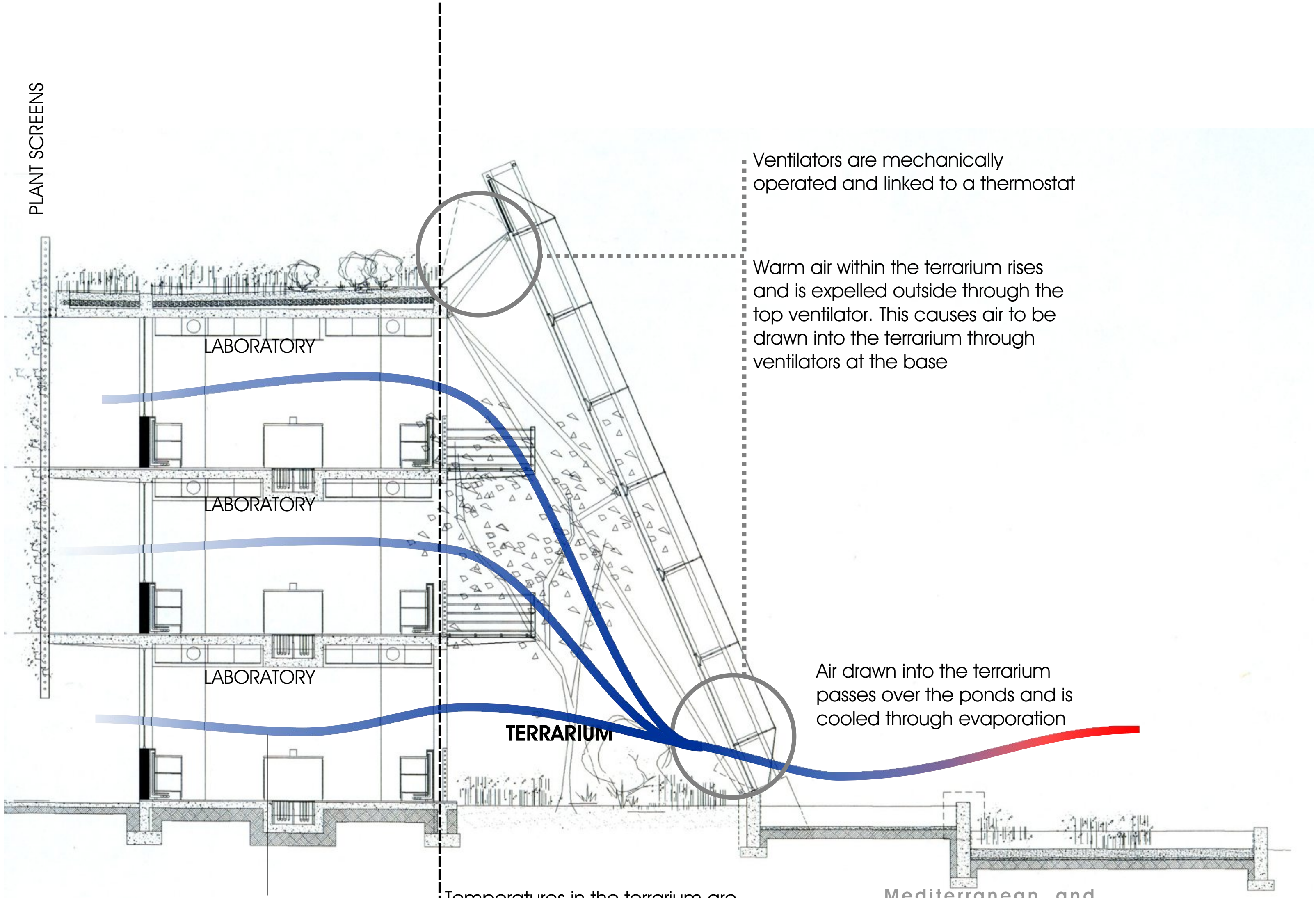
The laboratories are now ventilated independent of the regular HVAC system with the warmer air pushing the cooler air outdoors

Opening windows allows warm air from the terrariums to pass into the laboratories

7.3 Ventilation in Semi-arid / desert steppe terrarium in winter

Semi-Arid and Desert Steppe climatic zones





Ventilators are mechanically operated and linked to a thermostat

Warm air within the terrarium rises and is expelled outside through the top ventilator. This causes air to be drawn into the terrarium through ventilators at the base

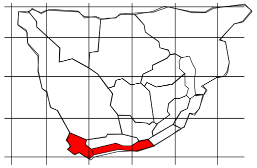
Air drawn into the terrarium passes over the ponds and is cooled through evaporation

Air moves through the laboratories and terrarium as though they are one space

Temperatures in the terrarium are controlled to remain within the comfort zone, resulting in no need for a separating layer between the terrarium and laboratory

7.4 Ventilation in Mediterranean / garden route terrarium

Mediterranean and Garden Route climatic zones



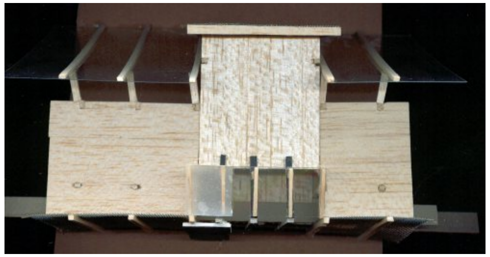
untreated plastics condensation forms and drops onto the plants and can cause fungal growth, while treated plastics have an even higher embodied energy (Von Zabeltitz, 1999, p31). The terrarium facades are 2000x1500x12mm tempered / laminated glass panes, suspended in a high-tension cable system. The glass needs to be tempered to resist breaking where the 'spider' clamps hold it. If the glass did happen to break, because of the angled façade there would be the possibility of the glass falling on people below. For this reason the glass needs to be both tempered and laminated.

Initially the façade consisted of a tensioned cable / mast system with 150mm steel tube masts spanning horizontally across the terrarium façade. This system however cast 23m^2 of shade into the terrariums. This was replaced with a parallel truss system that relies entirely on the tensioned cables to support the glass, maximizing light transmittance. The flat truss is made of a 200mm steel square section and a 100x200mm steel I-section that 'leans' on the main building structure with a 120mm steel tube truss. This system is needed as the steel members in a regular gravity frame system would need to be very large to support the angled glass, which would interfere with the amount of solar transmittance. As the terrariums are windward facing (see Fig.2.21), the system allows the large panes of glass to shift in times of strong winds.

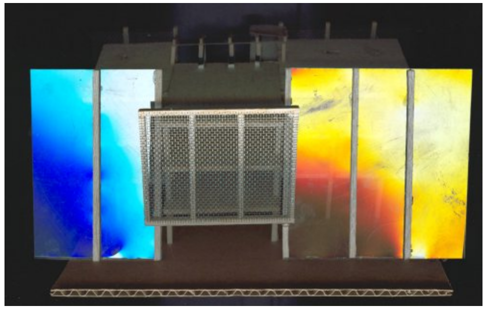
For sufficient ventilation, openings should be 15-25% of the floor area and continuous roof vents are the most efficient (Von Zabeltitz, 1999, p48). The panes at the bottom and the top of the terrarium are openable for ventilation. By extending the glass façade to house a series of solar panels, advantage is taken of the orientation for maximum solar

7.5 Terrarium and library [concept model 04]

7.6 Roof plan of office set 02 [concept model 04]



7.7 Northen facade of office set 02 [concept model 04]



transmittance.

Within the terrariums, steel walkways protrude from the laboratories to form transitional elements, which create places for observation on three levels. These are staggered, allowing trees to grow between them and the platforms are glass plates for maximum observation.

During the night, especially in winter the temperatures within the terrariums can drop below the desired temperature for some of the environments. Thermal screens inside the terrariums are drawn closed at night to prevent heat loss. The screens have a low transmissivity, and long-wave (infa-red) radiation can still enter into and thus heat the terrarium (Von Zabeltitz, 1999, p53). Polyester, felted material is one of the better options for the thermal screens. In terms of heat retention, it does not have the highest energy conservation rating but is sufficient for its purpose; however its energy consumption rating (22MJ/kg) during manufacturing is lower than both polyethylene (67MJ/kg) and acrylic (56MJ/kg) alternatives (Berge, 2000, p143).

Enrichment of terrarium air with CO_2 leads to better plant growth and higher quality plants (Von Zabeltitz, 1999, p59). In the EBRC this is achieved by enclosing the composting area in an airtight container and the CO_2 released by the decaying organic waste is fed through a pipe system into the terrariums, raising the CO_2 levels.

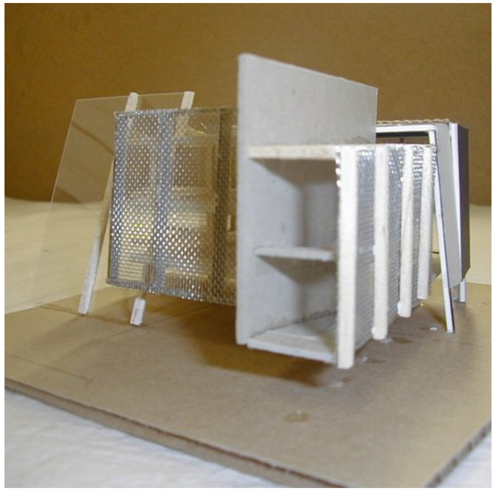
7.8 Roof plan of office set 03 [concept model 04]

7.9 Southern facade of entrance [concept model 04]

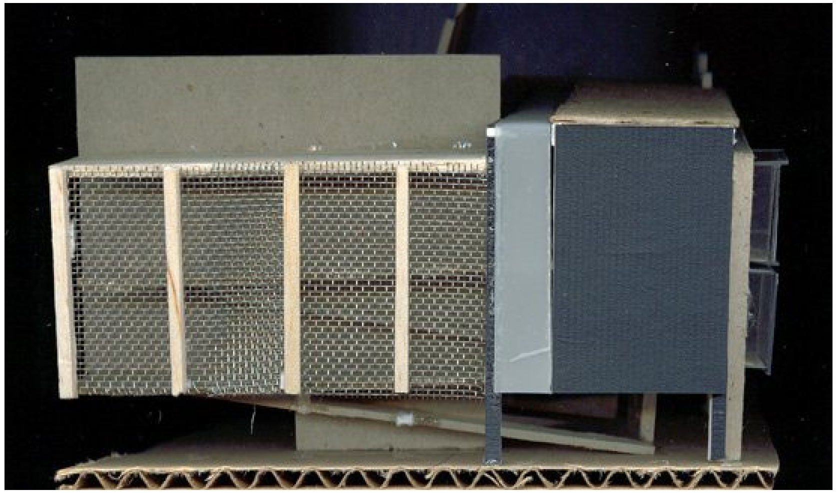
7.4 Laboratories

There are three main laboratory sets, each connected to a terrarium. The function of the laboratories is not likely to change; however the performance within each lab could often change. For adaptability the labs are therefore repetitive modules made up of a 5mx7m column grid, with each lab being 7mx10m. This grid is made up of 300x400mm columns elongated towards the north/south direction to resist in-plane forces from the terrariums. The columns support a system of 300mm beams and 200mm floor slabs. The labs are separated with glass infill panels to allow for flexible, sealed environments. The labs require large service spaces on the floor as well as on the ceiling. Initially a service floor was placed between each level; this however led to wasted spaces and materials. The service floor was replaced with a U-shaped floor slab that drops below the beams. This left a 200mm channel on the floor for gas, water, oxygen, compressed air and electricity conduits to the workbenches above, while a 500mm gap at ceiling level was left for HVAC systems. These U-slabs run the length of each block and are linked by 4 vertical ducts that supply services to the workbenches that flank the exterior walls. These ducts are 200mm concrete and help resist forces from the terrarium façade. The floors are finished with a clear epoxy over a pigmented screed. Parts of the channel that are not covered by workbenches are closed with a corrosion resistant screw-down floor system supported by an adjustable steel pedestal system. This allows for moveable machinery to be placed anywhere along the channel where power points are located. The south facing facades of the laboratories receive no direct sunlight so maximum glazing is used for natural ambient lighting. The glazing is

7.10 Perspective of ramps [concept model 04]



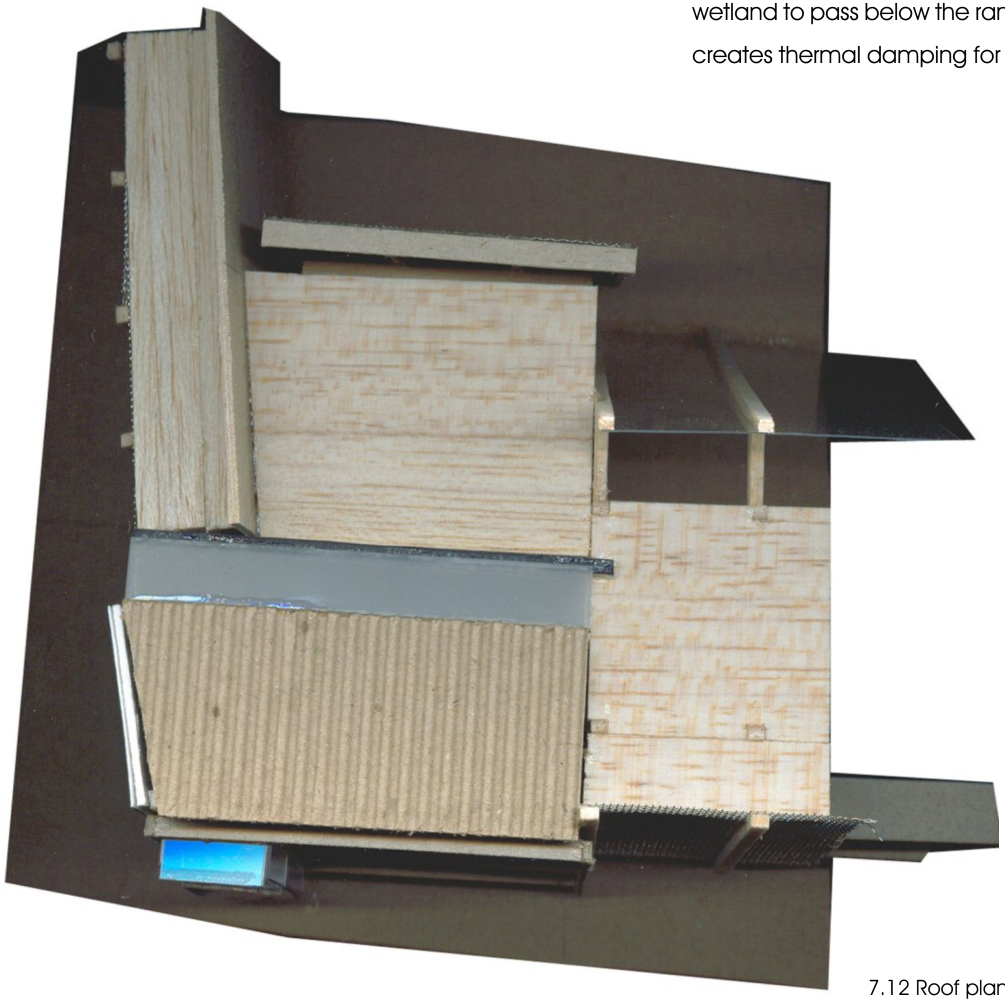
7.11 Ramps on the west entrance [concept model 04]



placed above 1 150m concrete walls, along which workbenches and machinery stand. These walls are finished with a clear epoxy.

7.5 Entrance

Approach to the entrance is both from the south and the west. The west facing side is emphasized by placing the ramps for vertical circulation here, perpendicular to the rest of the building. The ramps are 200mm in-situ concrete that are supported by a series of 200mm square reinforced concrete columns and a 300mm off-shutter / reinforced concrete wall. This wall is stabilized with 2 fins that tie back to the main column and beam structure. The wall follows the angle of the ramps, elevating from the ground towards the northern end with the opening formed allowing for the wetland to pass below the ramps, while the mass of the wall creates thermal damping for the offices behind. The ramps



7.12 Roof plan of entrance [concept model 04] break the rhythm of the 5m-column grid by rotating 7degrees to follow the form of the wetland. GKD 'Luna' stainless steel metal fabric suspended on 75x50mm steel channels serve as weather screens, enclosing the ramps and allowing plants from the roof above to climb down.

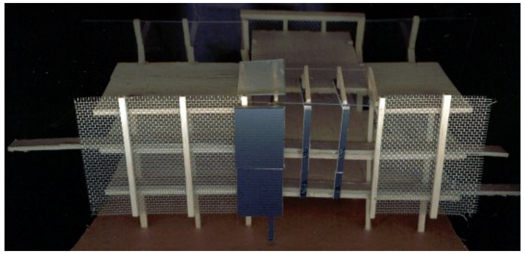
On the southern side, the entrance is defined with a concrete portal structure. A series of glass boxes punch through this structure serving as plant growth chambers and are constructed of 10mm toughened safety glass. The roof is a steel truss structure as apposed to a concrete (roof garden) structure that is used in the rest of the building. This structure tilts-up 5° to the north allowing direct natural light into the entrance foyer, while the growth chambers allow for ambient southern light to enter.

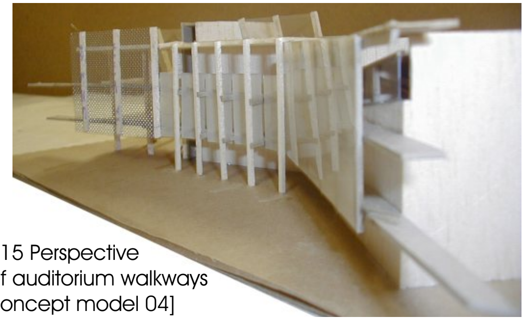
The building is separated into two parts that form two distinct lines that pass past each other connecting the building. These 2 lines make-up the auditorium and are 300mm off-shutter concrete walls with timber acoustic panels mounted internally on 100x50x2mm lipped z-sections. The gap between the panels and the walls are service spaces housing electricity conduits that run into the roof where all lighting and projectors are mounted. The roof is the same steel truss construction as in the entrance foyer. The northern wall of the auditorium extends past the roof while on the southern side; the truss sits on the wall creating a clerestory window that lets daylight into the space. The auditorium faces slightly west, so a series of opaque 12mm laminated safety glass panes, enclose the adjoining walkway, permitting diffuse light and preventing afternoon heat gains.

These panes follow the walkway, which steps back from the five 254x254x14mm steel H-section columns that support

7.13 Perspective of entrance [concept model 04]

7.14 Southern facade of office set 02 [concept model 04]

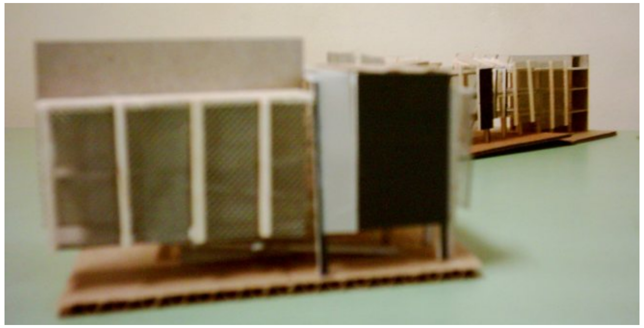




7.15 Perspective of auditorium walkways [concept model 04] the roof of the library and carry the supporting 178x102x8mm steel I-beams of the concrete walkway.

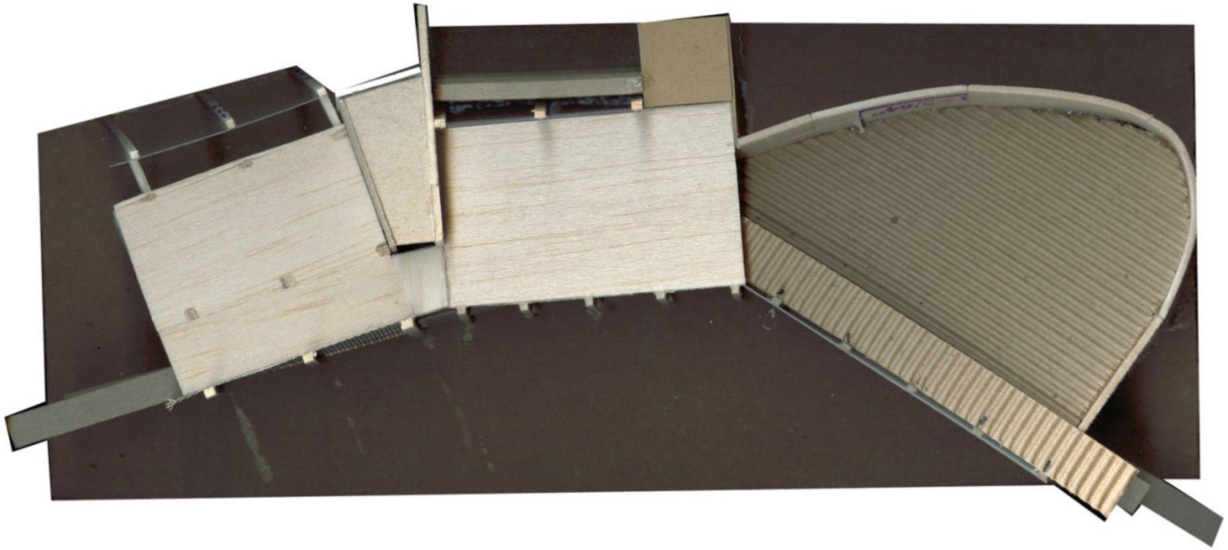
All the remaining walkways are enclosed by steel screens constructed of 100x50mm steel I-sections bolted to the butt of the beams that carry the walkway. 50mm steel tubes are threaded through these I-sections serving a sub-functional role as a balustrade. The functional role is to act as a climbing lattice for the plants from the roof garden above. This serves as a shading device, plant propagation and microclimate control. These screens extend above the roof gardens by1200mm to act as balustrading and below the first floor slab by 1200mm. This defines the edge of the building but blurs the boundary between the interior and exterior environment, allowing people to subconsciously move in and outdoors.

The roof gardens provide protected areas for propagation of medicinal plants. They grow in 70-250mm of soil on 120mm of drainage gravel. Beneath this is a felted protection membrane on asphalt waterproofing. This is laid on the roof slab on top of a layer of screed (minimum of 40mm at its lowest point) that slopes at1:60 to the fulbore rainwater outlets. An expanded metal cage to prevent clogging surrounds these.



7.17 West elevation [concept model 05]

7.16 Roof plan of auditorium and library [concept model 04]



7.5 Library

The northern façade of the library mimics the 65° incline of the terrariums. The smaller glass panes sit in steel frames with tip-up window openings preventing water penetration in times of rain. Two steel sunscreens prevent direct sunlight in summer without inhibiting views onto the river. The lower screen extends over the café that exists on the ground floor providing shaded outdoor seating.

7.6 Ventilation

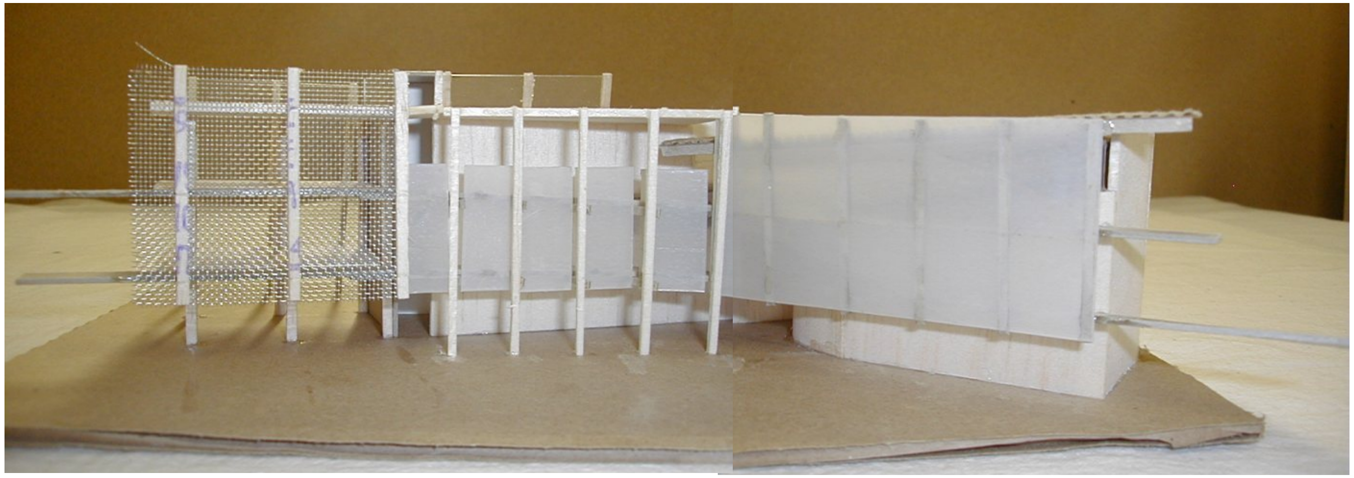
By ventilating the offices through cross ventilation, doors and windows will remain open for long durations. On the southern side of the EBRC, recessing the offices by 4500mm protects openings from driving rain. On the northern side of the EBRC, direct sunlight, driving rain and wind could force openings to be closed. Placing adjustable, tip-up mesh screens on the northern façade prevents this. The frames are constructed of 100x50mm steel I-sections with nylon mesh, keeping the structure as light as possible.

The laboratories are sealed to the north by the terrariums, so cross-ventilation is not an option. By creating a stack-effect in a series of ducts that back the staircases, passive ventilation is achieved. This stack-effect draws air through the laboratories in the same system that the mechanical HVAC system works on. If the air-change rate is not achieved passively, the mechanical system is activated.

7.7 Water

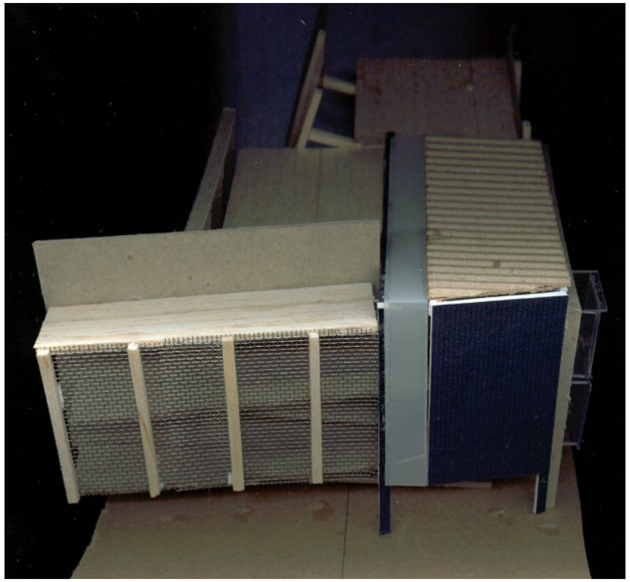
Within the site lie large areas of cultivated plants for community harvesting and research. Rainwater, which is collected from the entire site at 3 locations: A, B and C (see Fig.7.15), is used to irrigate these areas by being periodically

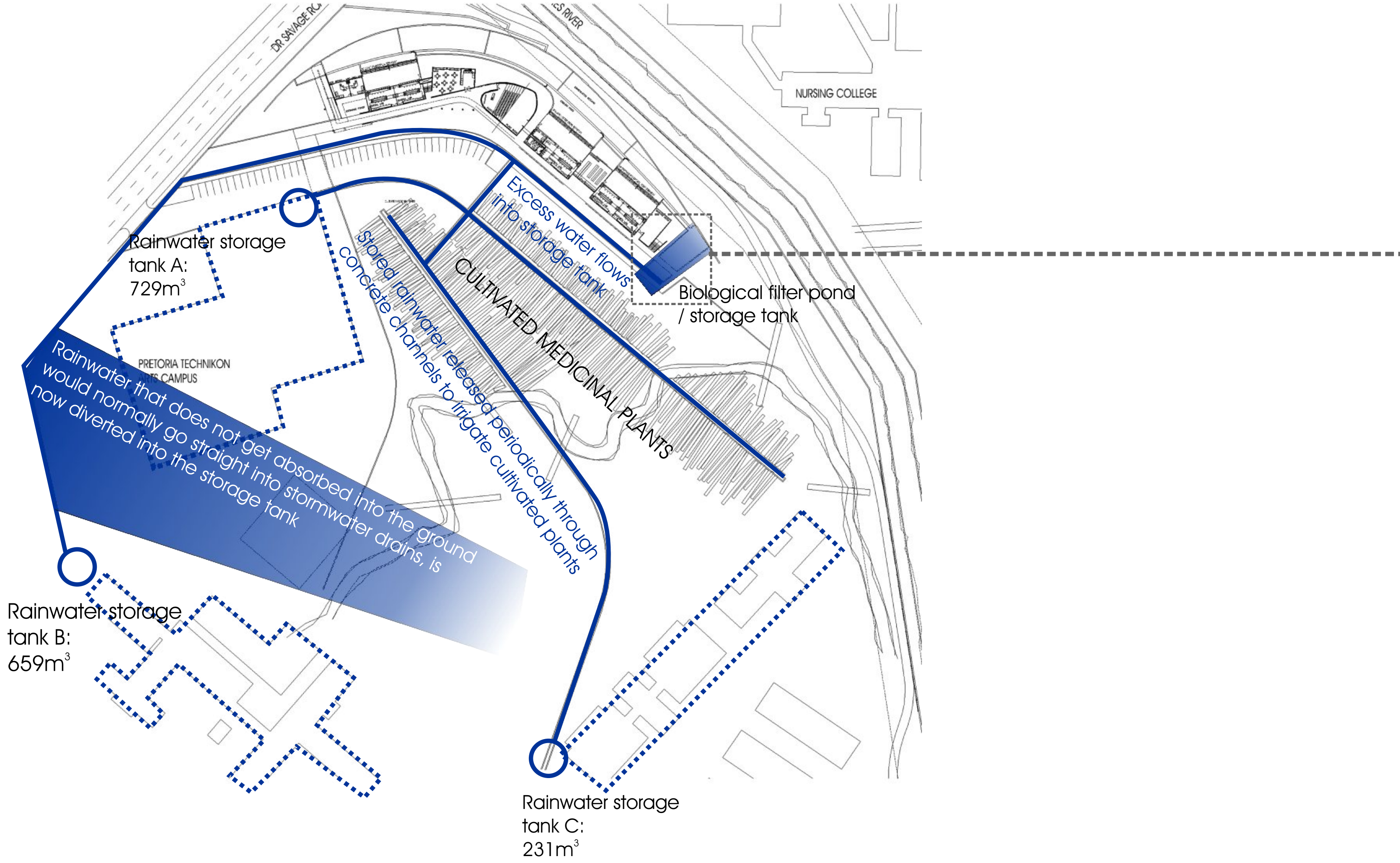
7.18 South elevation of library [concept model 04]



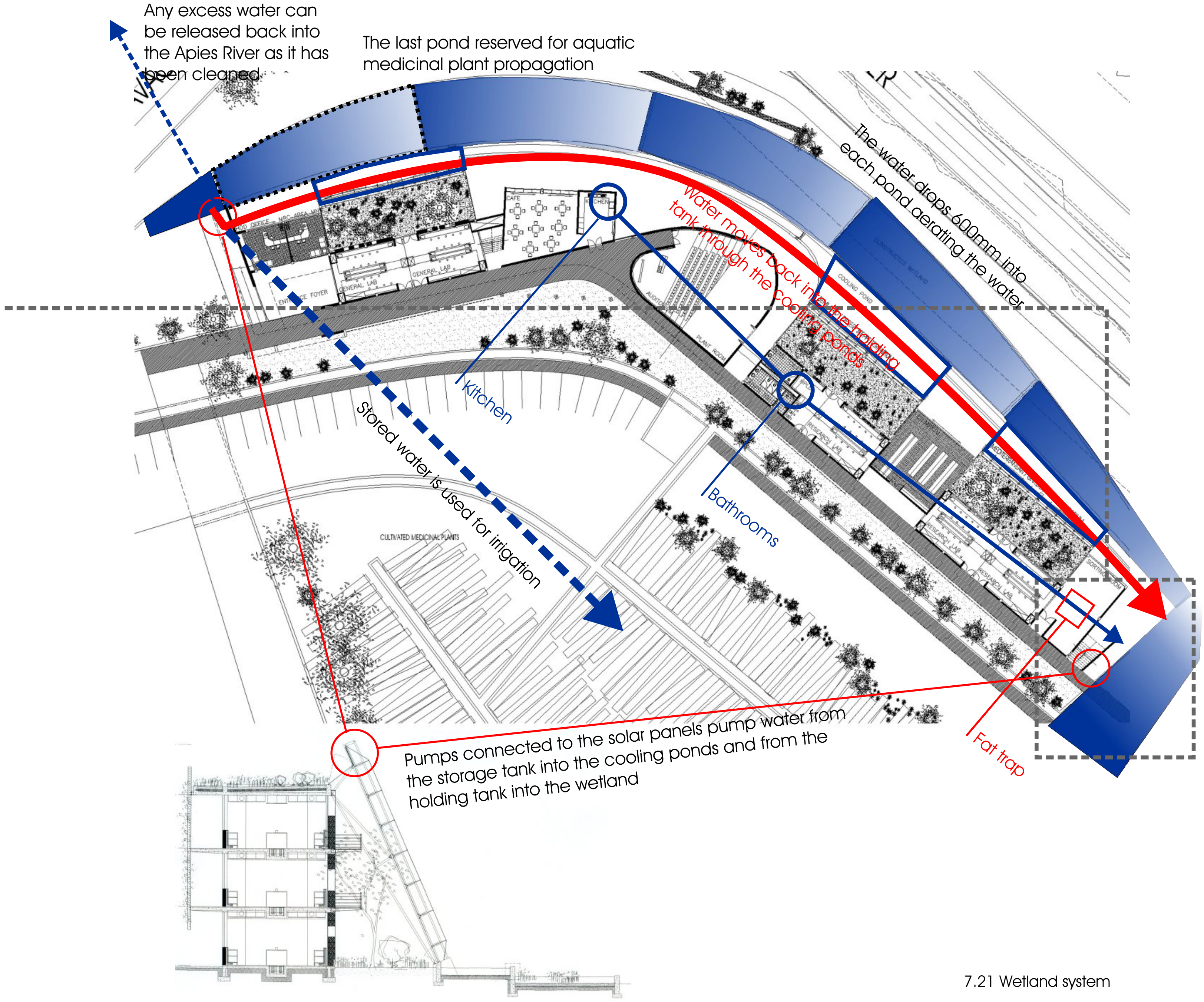
released through a series of concrete channels that permeate within the cultivated plants. Any excess water that is released, ends up in a holding tank at the east end of the building. This tank serves as a biological filtering pond. Grey water from the bathroom and kitchen is placed in this tank after passing through an oil and grease trap, while excess water from the terrariums is released directly into it. Water is released from the grease trap 100mm lower than the level of augmentation, into the holding tank at a 1:60 fall. The water level in the holding tank needs to be a further 100mm lower than the water inlet. Any soaps and oils that may remain float to the surface, so water is pumped from a sump at the bottom of the tank through a solar pump into the first pond of the constructed wetland. Each pond drops 600mm to aerate the water with an overflow depth of 20mm. The constructed wetland is enclosed with 200mm concrete walls. The average water depth is 400mm where the soil depth is 200mm, but does vary as levels of both are adjusted for specific plant preferences. The soil sits on a layer of Bentofix geosynthetic clay liner. Beneath that is a 50mm protective layer of river sand on 200mm of compacted earth. At the end of the wetland, water is kept in a storage tank from which the water is used to irrigate the site. Water is also pumped from here through a solar pump into the series of cooling ponds in front of the terrariums. This water falls back towards the holding tank to keep the water moving in the cooling ponds. This water is disrupted with fountains so that evaporative cooling can take place by air being drawn over the cooling ponds into the terrariums. The ponds can be separated from each other with a closing separating flap and each pond has an outlet onto the wetland. If one of the terrariums needs to be cooled but its humidity level is not to be increased, then the water from the pond is released into the wetland and the terrarium is cooled through stack effect. By closing the flaps that link the ponds, the other terrariums can be cooled by means of evaporative cooling (see Fig.7.17). These separating flaps, outlets and terrarium vents are operated mechanically by being interlinked with a thermostat and humidity detector.

7.19 West perspective of entrance [concept model 04]





7.20 Water irrigation system



Any excess water can be released back into the Apies River as it has been cleaned

The last pond reserved for aquatic medicinal plant propagation

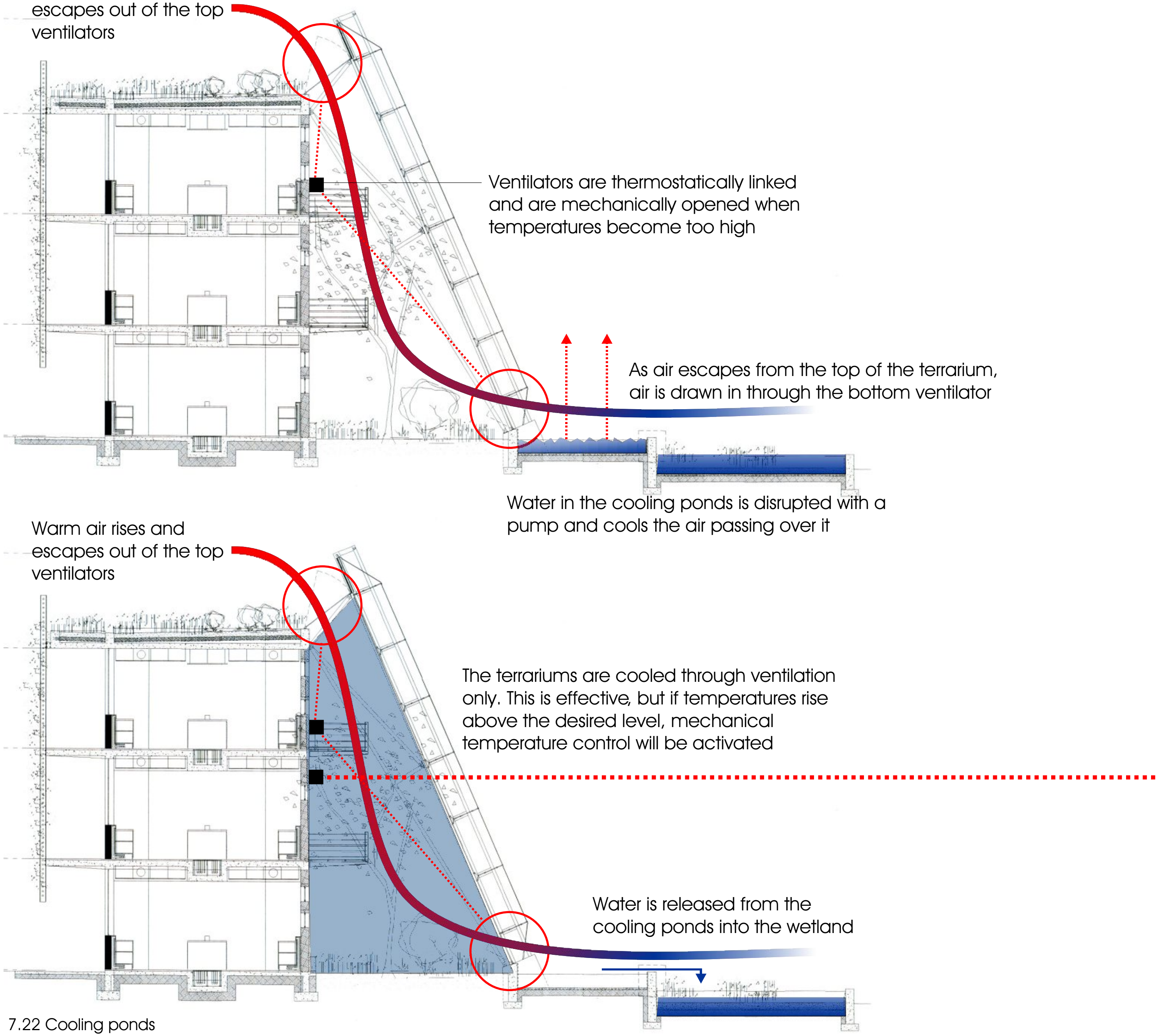
The water drops 600mm into each pond aerating the water

Water moves back into the holding tank through the cooling ponds

Stored water is used for irrigation

Pumps connected to the solar panels pump water from the storage tank into the cooling ponds and from the holding tank into the wetland

7.21 Wetland system



Warm air rises and escapes out of the top ventilators

Ventilators are thermostatically linked and are mechanically opened when temperatures become too high

As air escapes from the top of the terrarium, air is drawn in through the bottom ventilator

Water in the cooling ponds is disrupted with a pump and cools the air passing over it

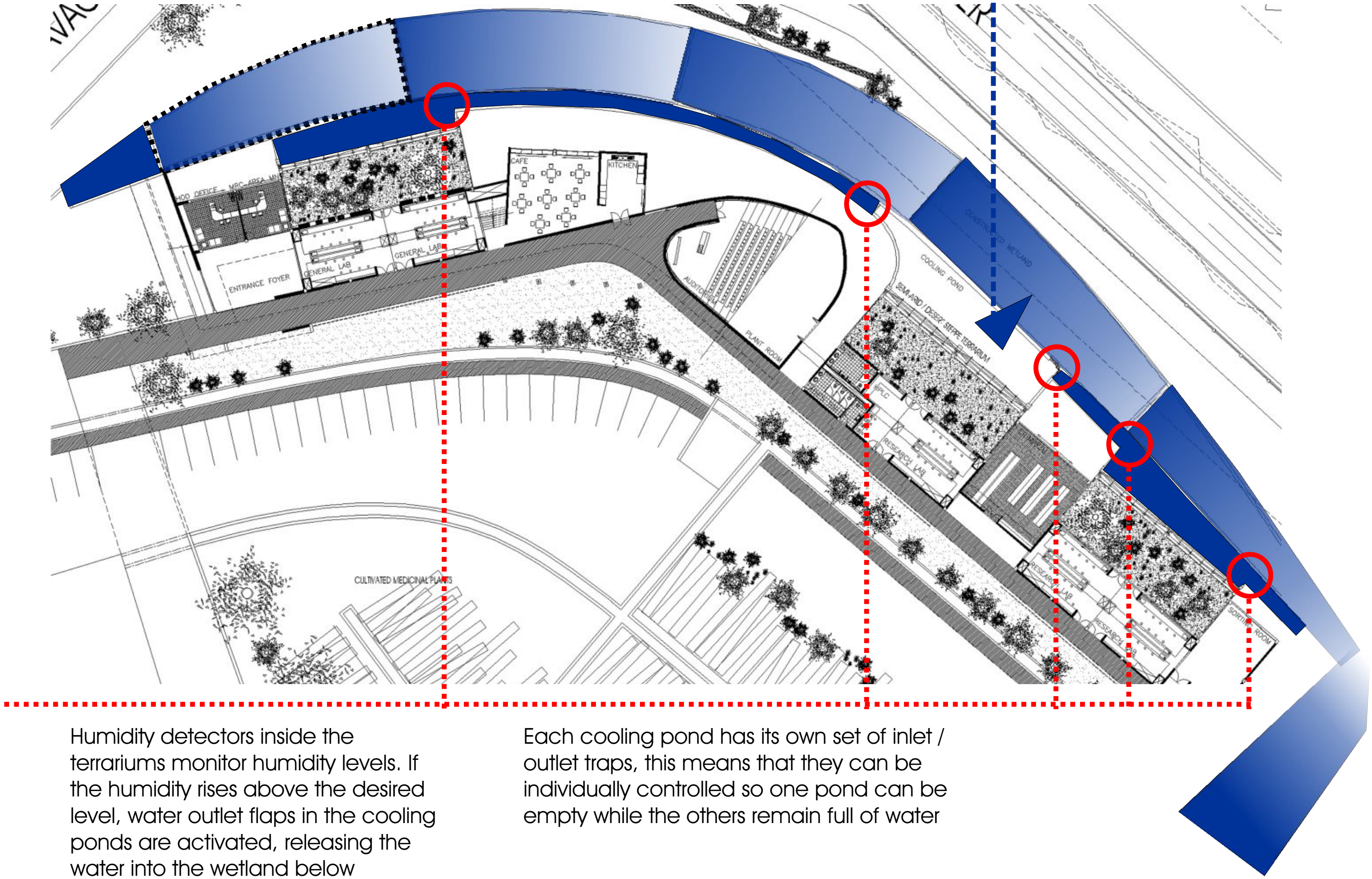
Warm air rises and escapes out of the top ventilators

The terrariums are cooled through ventilation only. This is effective, but if temperatures rise above the desired level, mechanical temperature control will be activated

Water is released from the cooling ponds into the wetland

7.22 Cooling ponds

The released water has already passed
through the wetland, so it is clean enough to
go directly back into the wetland



Humidity detectors inside the
terrariums monitor humidity levels. If
the humidity rises above the desired
level, water outlet flaps in the cooling
ponds are activated, releasing the
water into the wetland below

Each cooling pond has its own set of inlet /
outlet traps, this means that they can be
individually controlled so one pond can be
empty while the others remain full of water

With the water from the cooling
ponds being put back into the
holding tank, the problem of the
wetland drying-out is eliminated

7.23 Cooling ponds