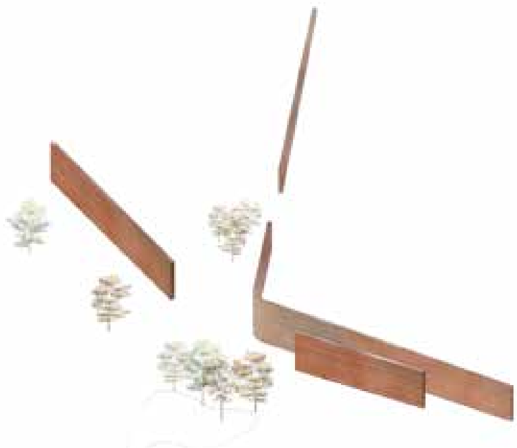
# TECHNICAL INVESTIGATION



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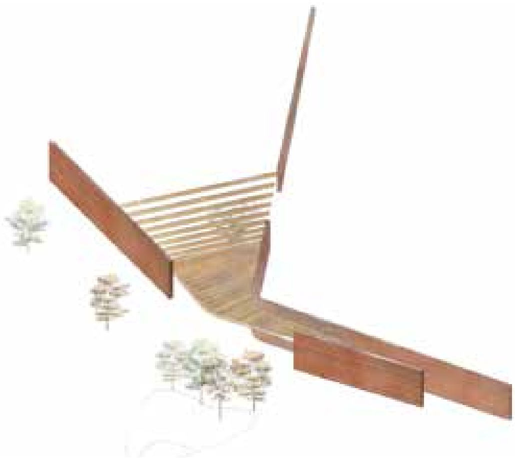

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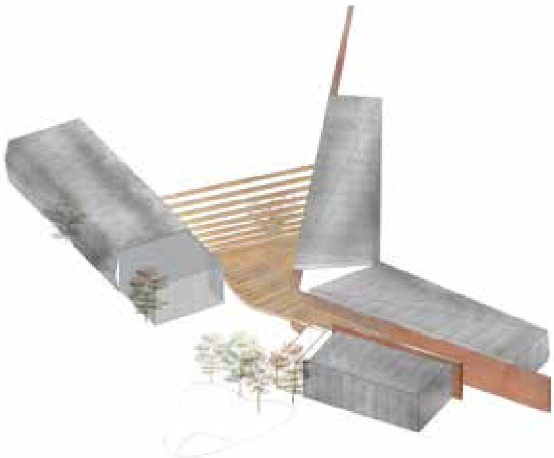


ACCOMMODATING

-8-

# TECHNICAL

INVESTIGATION

◀
FIGURE 8.1
TECTONIC CONCEPT
(Author , 2016)

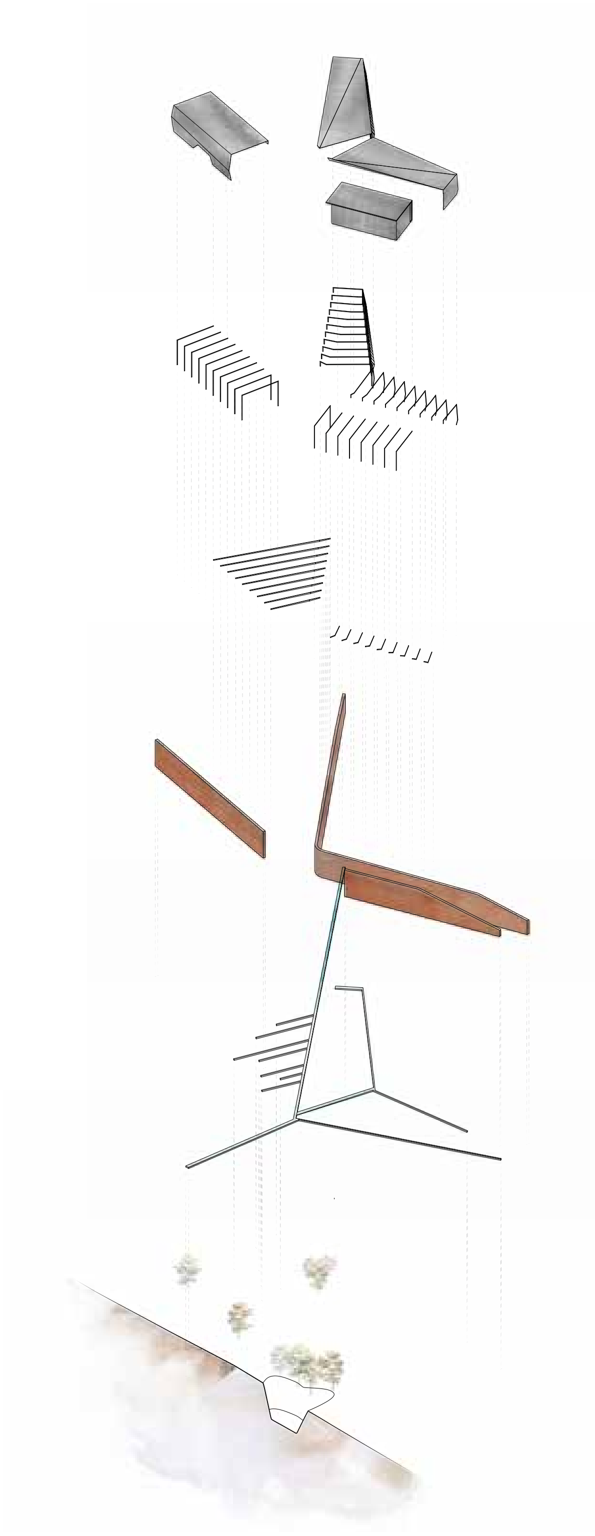
## 8.1 TECTONIC CONCEPT & STRUCTURE

The technical investigation explores two structural concepts developed as a response to the geology of the landscape. The technical premise of the dissertation brings the hidden and forgotten layers of the landscape of the Cradle of Humankind to the forefront. The investigation considers the way in which the layers of a building are exhibited, revealing the layers the building is made up of through both programme and structure.

The second structural concept is a response to the karst system found within the landscape of the Cradle. All structures placed on site intend to protect the landscape, to create habitat, and to accommodate the functions sprouting from the artificial habitats.

The primary intention of the placement of structures in the landscape is to mitigate the current threats and past destruction of the landscape. The proposed channels and furrows are submerged in the landscape, allowing surface water to move through the landscape.

The structures then serve to accommodate habitat, with each habitat favouring the dominant user, while allowing for co-evolution. The various walls forming the habitats are constructed from materials inherent to the site, including stone and earth. Together with the furrows and channels, these solid structures belong to geology of the landscape. The composition of the



structures relate to Kenneth Frampton's theories of architectural composition, where structures are divided into the stereotomic and tectonic. The solidity and mass of the stereotomic is seen to be of the "earth", with the dematerialisation of the tectonic compared to the sky (Van Eeden, 2013:98).

The tectonic structures accommodate the programmes connecting to the habitats, as seen through the tourism and research facilities. Unlike the water channels on site and the walls forming the habitats, these spaces do not add to the current and future functioning of the landscape, and so do not alter the landscape. The tectonic structure sits above the landscape, and is constructed as a laminated timber frame, clad in rheinzink.

## 8.2 BUILDING ASSEMBLY

The building construction relies on a hands-on approach, this allows for the method and craft of the assembly process being visible in the completed buildings. This is true for both low-and high-tech materials, including the construction of the stabilised earth walls and the rheinzink external cladding.

The Vivarium building is assembled by firstly erecting the laminated timber portal frames. The bearer beams on which the floors rest and the beams above the Chiroptera habitat are fixed to either side of the portal frames, allowing for thinner members. The dry packed stone walls, mortared stone walls, and stabilised earth walls are constructed simultaneously between the timber portal frames as infill, extending past the timber frames to the exterior of the building. The exposed timber portal frames are then clad in rheinzink, revealing the internal skin of glazing at points in the building.

◀
FIGURE 8.2
STRUCTURE
(Author , 2016)

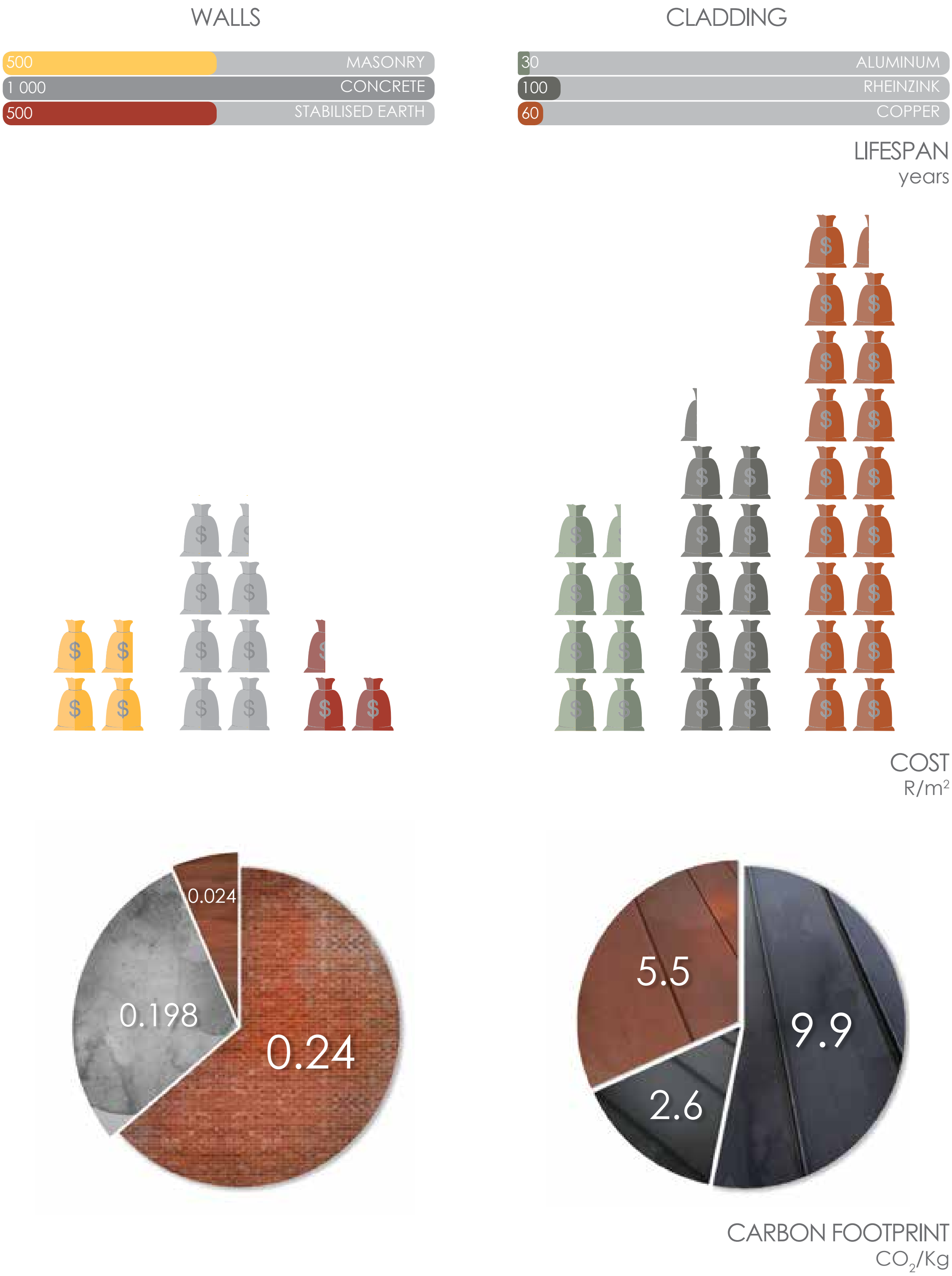



FIGURE 8.3
COMPARISON OF WALL & CLADDING MATERIALS
(Author , 2016)

## 8.3 MATERIALITY

All materials selected for the construction of the proposed buildings fall into one of two categories; materials from the landscape, and new materials to the landscape. In either case, a series of material options where compared with each other, in terms of lifespan, cost, and the carbon footprint of manufacturing the materials, in order to establish the most suitable material to be used in the context of Bolt's Farm and the Cradle.

For the construction of the walls protecting and creating habitats, the following materials where compared; masonry bricks, concrete, and stabilised earth. The study found stabilised earth to be most suitable, as it has the same expected lifespan as masonry bricks, while being lower in cost and carbon footprint (Fig. 8.3).

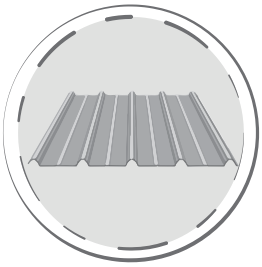
For the external cladding of the Vivarium, rheinzink, aluminum, and copper cladding where compared. Although rheinzink has a greater initial cost, the lifespan of the material outweighed both aluminum and copper cladding, has a lower carbon footprint, and is far less of a liability in terms of theft, when compared to copper cladding.

MATERIALS OF
THE LANDSCAPE

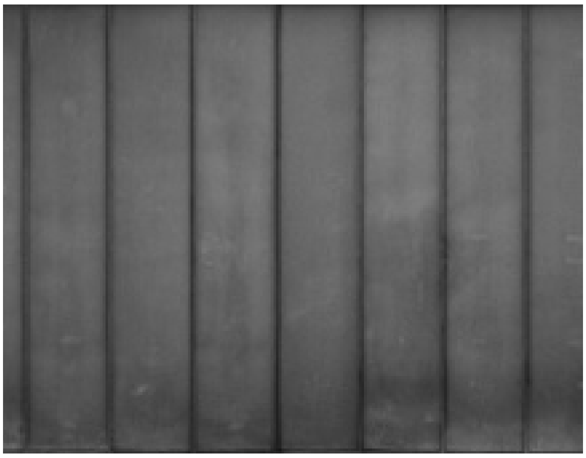
RECLAIMED BRICK SCREEN

WIRE MESH WITH STONE INFILL

NEW MATERIALS
TO THE LANDSCAPE



EXPANDED MESH

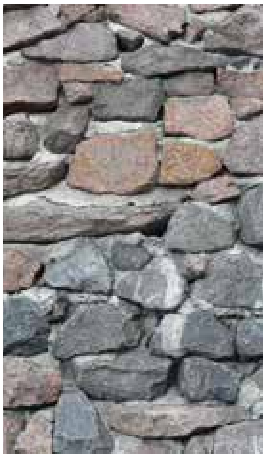


GRAPHITE GREY RHEINZINK

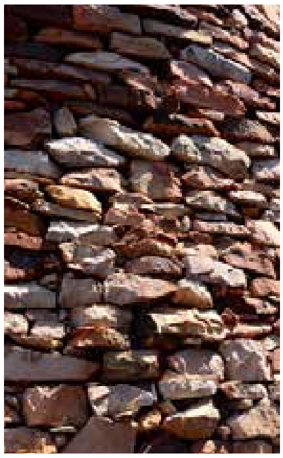
VIEWING THE
LANDSCAPE

DOUBLE GLAZING

LIME STABILISED EARTH



MASONRY STONE



DRY PACKED STONE

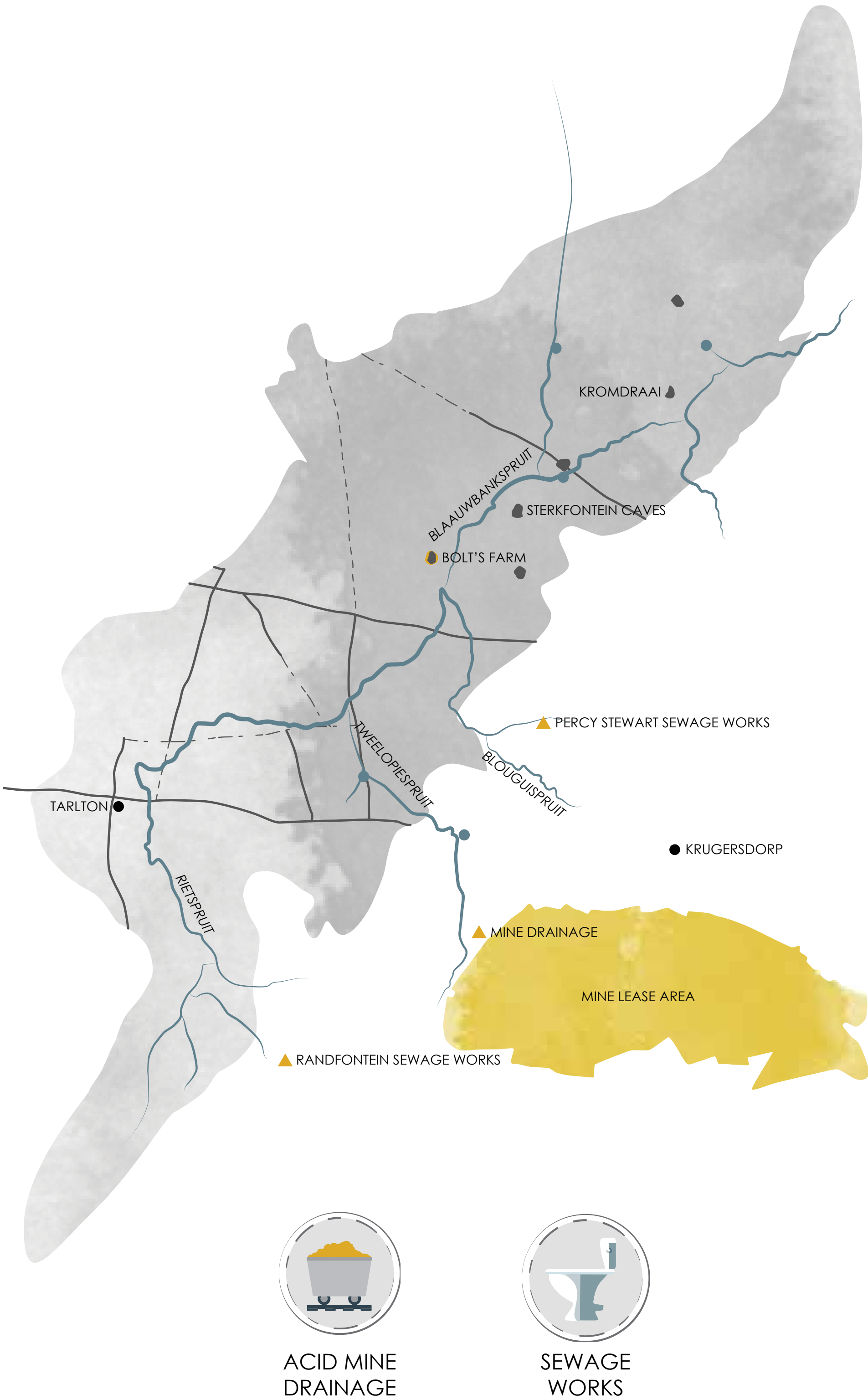
RED GRANDIS LAMINATED TIMBER

EXTRUDED TERRACOTTA CLAY BRICKS

DANPALON POLYCARBONATE

TINTED GLAZING

▲
FIGURE 8.4
MATERIAL PALETTE
(Author , 2016)


KROMDRAAI
BLAAUWBANKSPRUIT
STERKFONTEIN CAVES
BOLT'S FARM
PERCY STEWART SEWAGE WORKS
TWEELOPIESPRUIT
BLOUGUISPRUIT
TARLTON
KRUGERSDORP
RIETSPRUIT
MINE DRAINAGE
MINE LEASE AREA
RANDFONTEIN SEWAGE WORKS
ACID MINE DRAINAGE
SEWAGE WORKS

## 8.4
## TECHNOLOGY & ENVIRONMENTAL STRATEGY

The current state of the landscape is seen as a fragile, fragmented landscape, thus each structure placed in the landscape not only has to sustain itself, but also serves to remediate the landscape. The approach to servicing the habitats and secondary structures is thus to implement active and passive systems within it, with low maintenance and running energy requirements.

### 8.4.1
### WATER
#### 8.4.1.1
#### THREATS TO THE KARST SYSTEM

The structural and ecological stability of the karst system of the Cradle of Humankind relies on ground water of a high quality, as well a constant water level in the subterranean layers of the system (Witthüser 2016). Activities which influence these two factors, the water quality and quantity, are threats to the underground water system, and can be either diffused threats, such as poor farming practices, or point sources, such as the mining affluent and sewage running into the river system (Fig. 8.x).

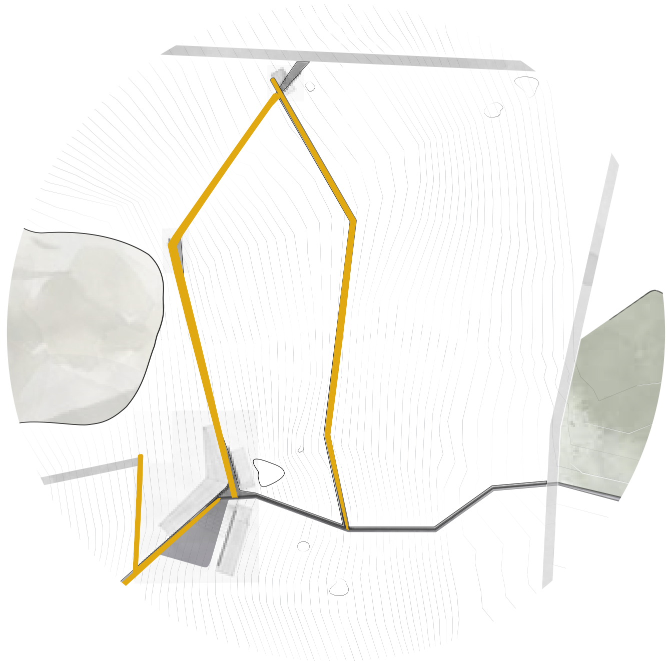
◄
FIGURE 8.5
THREATS TO THE KARST SYSTEM
(Author , 2016)

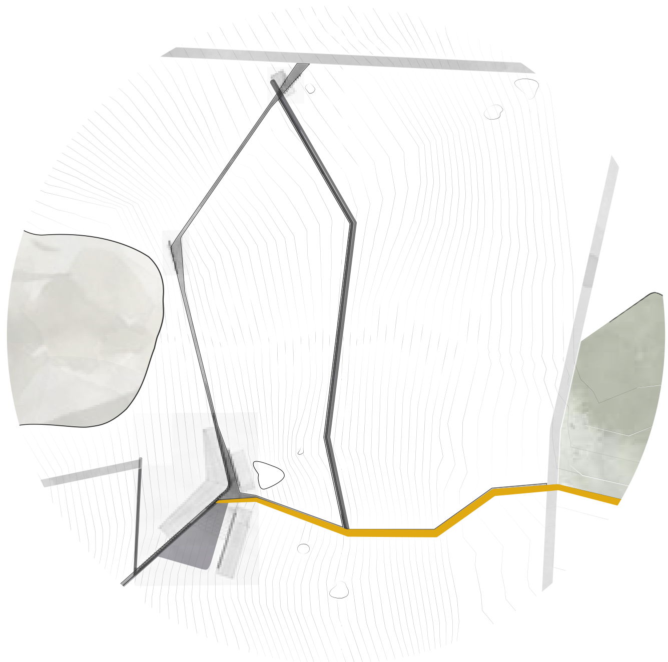
### 8.4.1.2
### WATER STRATEGY
#### 8.4.1.2.1
#### SITE

The water strategy of the larger site focuses on stabilising the water quality and quantity infiltrating the sections of the karst system, which can be controlled. Channels are constructed above the major openings and caves, running along the contours, to reduce the direct water flow into the karst system. The surface water is then channelled down the slope to a water retention pond, located above the Riet Spruit. The retention pond is placed in an area where the karst system is less sensitive, as previously indicated (Witthüser 2016), allowing the surface water to infiltrate the karst system at a slower rate, as well as filtering the surface water as it seeps through.

▶
FIGURE 8.6 a
SURFACE WATER COLLECTION
(Author , 2016)

▶
FIGURE 8.6 b
SURFACE WATER DIVERSION
(Author , 2016)





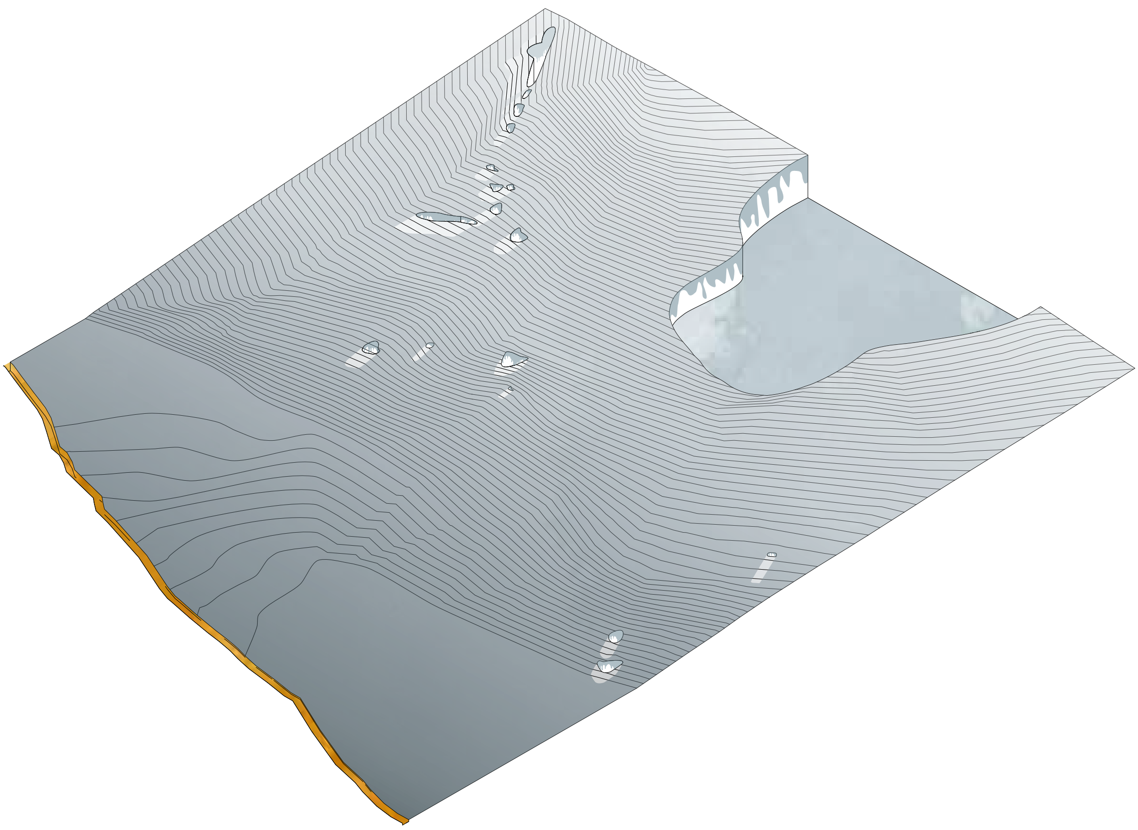


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FIGURE 8.7 a
SURFACE WATER
BEFORE INTERVENTION
(Author , 2016)

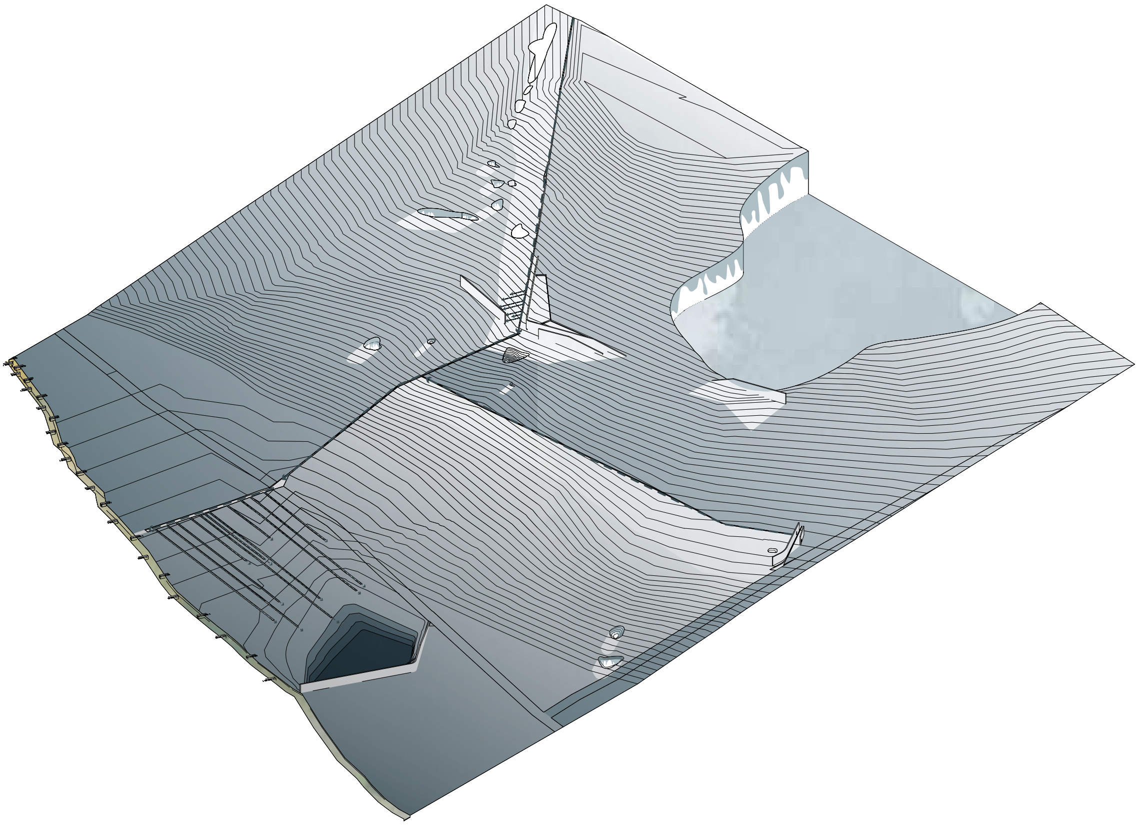

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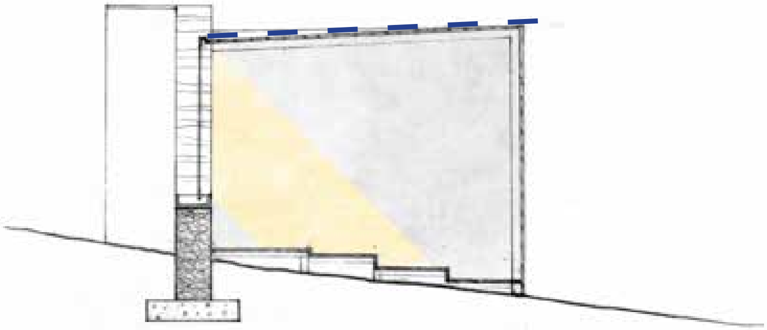
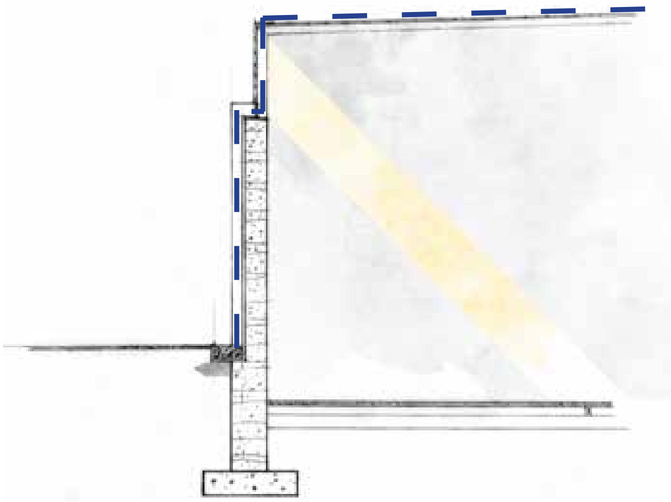
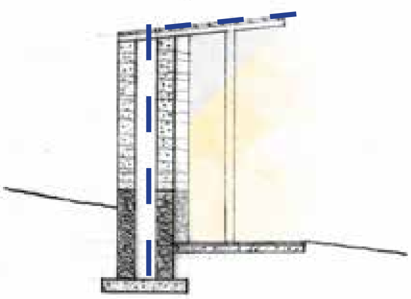
FIGURE 8.7 b
SURFACE WATER
AFTER INTERVENTION
(Author , 2016)







◀
FIGURE 8.8 a
CONCEPTUAL WATER CATCHMENT DIAGRAM OF QUARRY PAVILION
-JUNE-
(Author , 2016)

◀
FIGURE 8.8 b
CONCEPTUAL WATER CATCHMENT DIAGRAM OF VIVARIUM
-JUNE-
(Author , 2016)

◀
FIGURE 8.8 c
CONCEPTUAL WATER CATCHMENT DIAGRAM OF FIELDWORK STATION
-JUNE-
(Author , 2016)

### 8.4.1.2.2 BUILDING

As water is a scarce resource, and no existing municipal waterlines are connected to Bolt's Farm, an alternative water strategy is required. The majority of the surrounding farming community makes use of boreholes, tapping into the karst system (The South African Karst Working Group 2010:25). The Vivarium is, however, a public building, with a much higher water budget that the average farmhouse, thus the use of a borehole would alter the water quantity of the karst system to the extent that the structure might become unstable (Witthüser 2016).

The proposed individual buildings harvest rainwater from the roof-runoff as required by each building. The Vivarium requires the highest amount of water, as it accommodates ablutions, a restaurant, and laboratory spaces. The roofs of each building is sloped in two directions, allowing the water to run to a specific point, where the water is then collected and used or stored for the building specific needs.

The collected water is used in the following ways:

- the roof-runoff from Ticket Office is used for the use of the staff as well as watering the plants in the greenhouse;
- the water collected by the Quarry Pavilion is filtered through a slow-sand filter and is used by the visitors and researchers as a drinking point;
- the Vivarium roofs channel the water to a central water storage point to be stored and used throughout the buildings as needed; and
- the roof of the Fieldwork Station is sloped towards the cavity of the stone wall, to be collected and allowed to drip down the wall, making use of evaporate cooling principles to serve as a cold room for the use of the archaeologists.

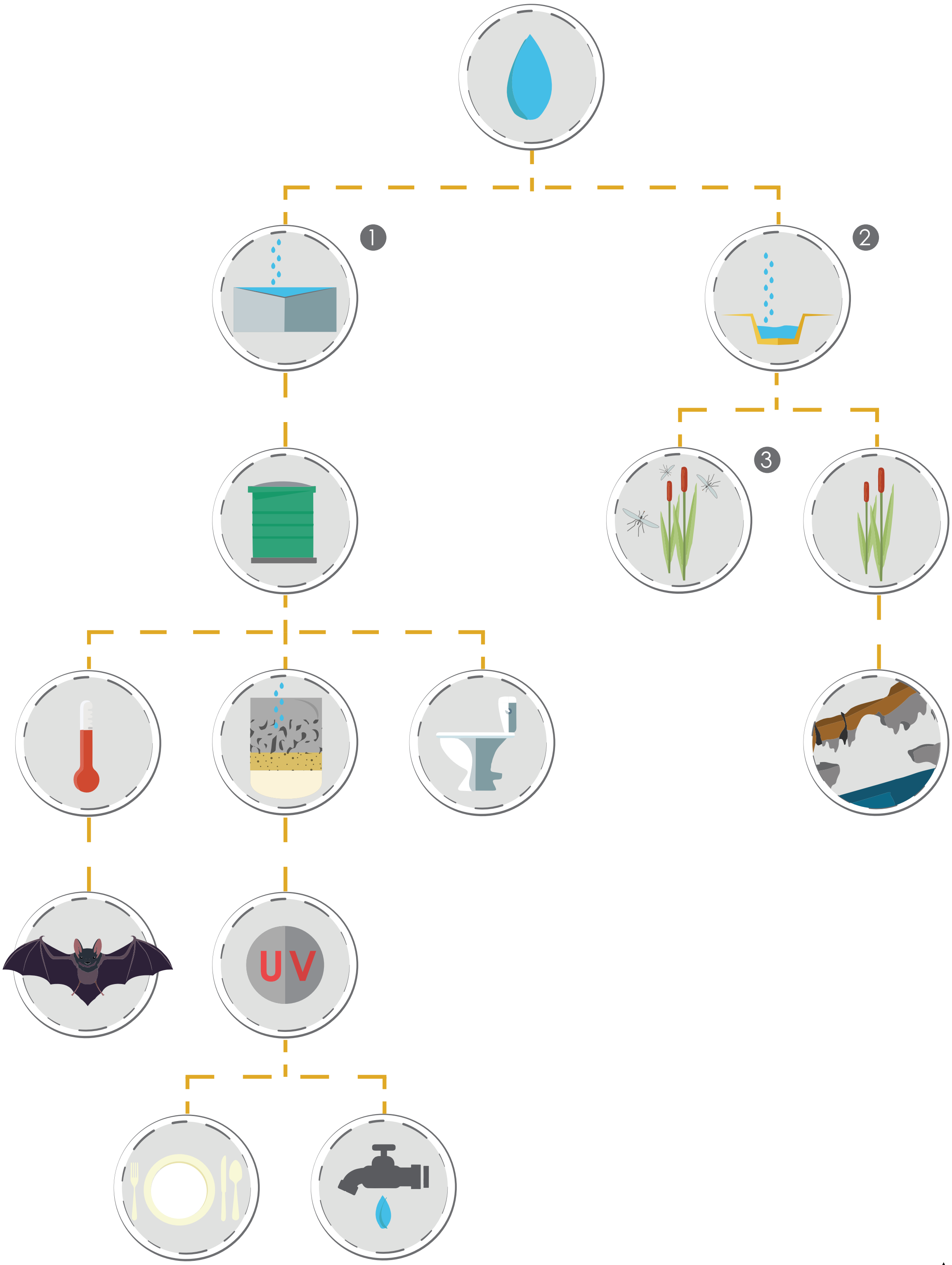



FIGURE 8.9
VIVARIUM ROOF & DRAINAGE DIAGRAM
(Author , 2016)

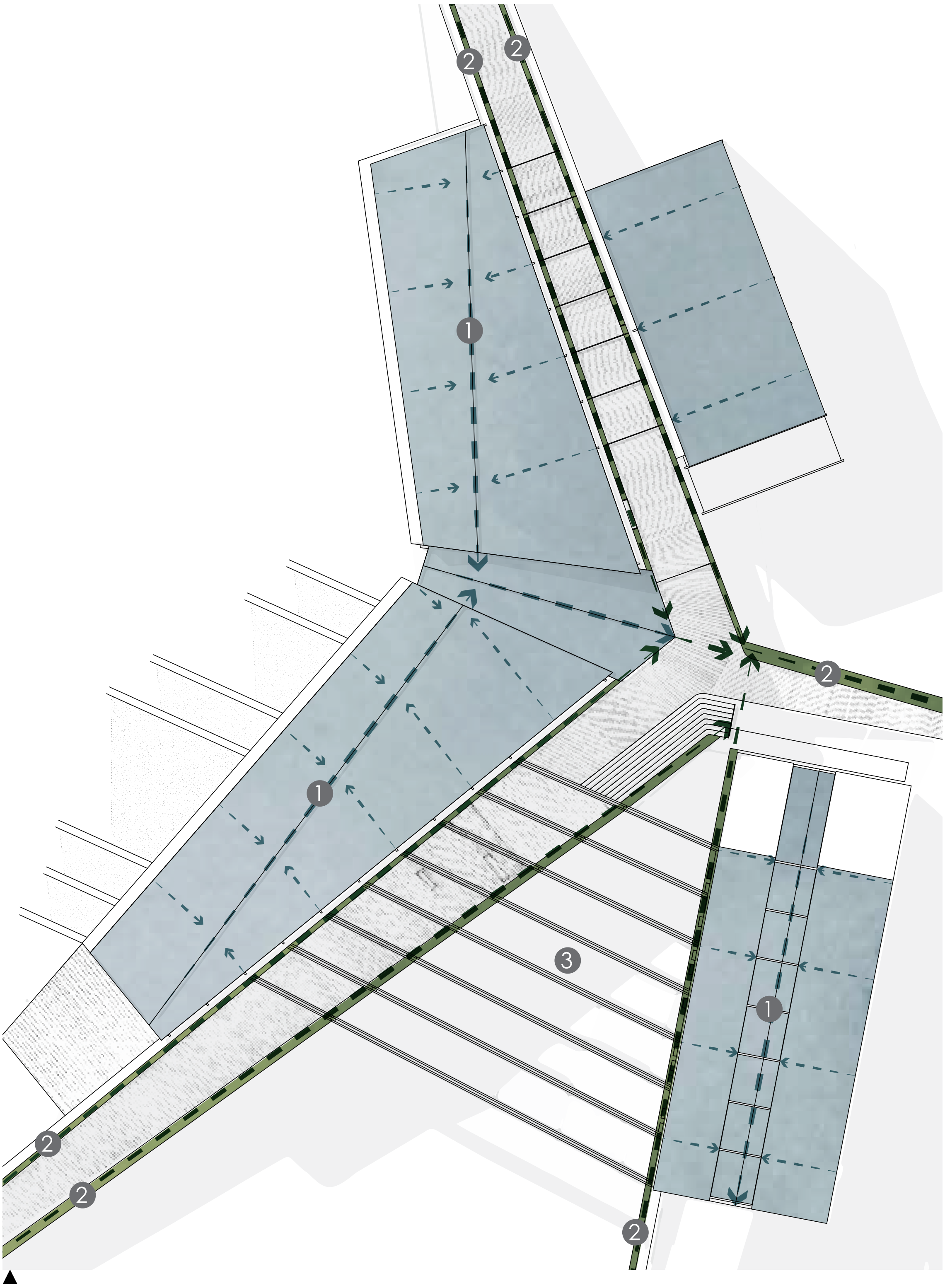



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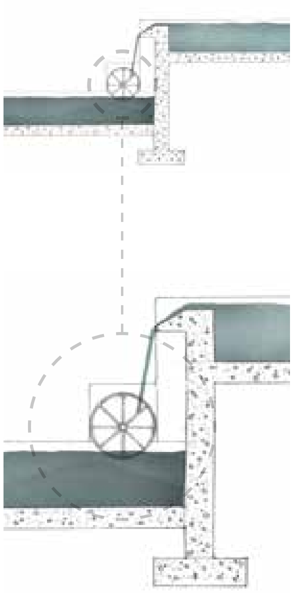
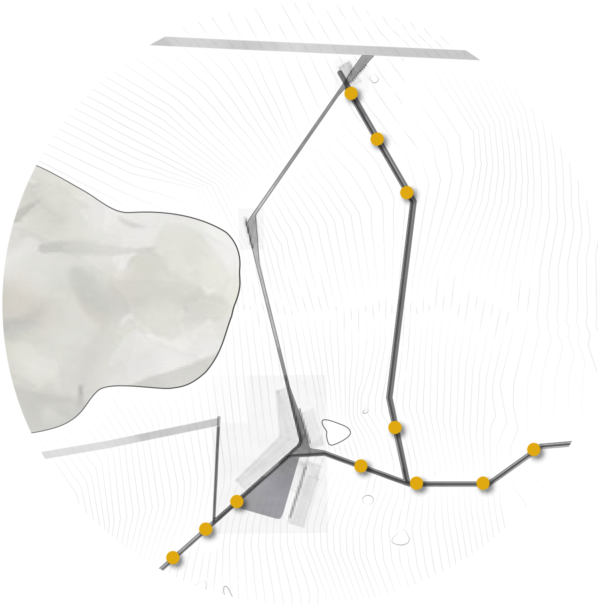
FIGURE 8.10
VIVARIUM ROOF &
DRAINAGE PLAN
(Author , 2016)





◀
FIGURE 8.11 & 8.12
MICRO HYDRO TURBINE IN CHANNEL & PLACEMENT OF MICRO HYDRO TURBINES
(Author , 2015)

## 8.4.2
## ENERGY & WASTE
### 8.4.2.1
### MICRO HYDRO TURBINE

The water flowing along the water collection and diversion tunnels are used to generate hydro-electrical energy. As the water flows from the highest point of the site down to the retention dam, located at the lowest point of the site, the water rotates the series of micro-hydro turbines, connected to individual dynamos. The dynamos convert the kinetic energy of the rotating turbines to electrical energy (Natural Resources Canada 2004).

### 8.4.2.2
### BIOGAS DIGESTER

Organic waste, including food scraps, sewage, and bat guano, is directed to a central biogas digester. The digester makes use of anaerobic bacterial processes to generate methane gas as well as a nutrient compost to be used for all non-edible plant species. The methane gas produced through the digester is used in the restaurant kitchen, with excess gas being converted to electrical energy through a controlled combustion system through a heat engine. The mechanical energy then activated a generator which in turn produces electrical energy (Gensch et al. 2010).

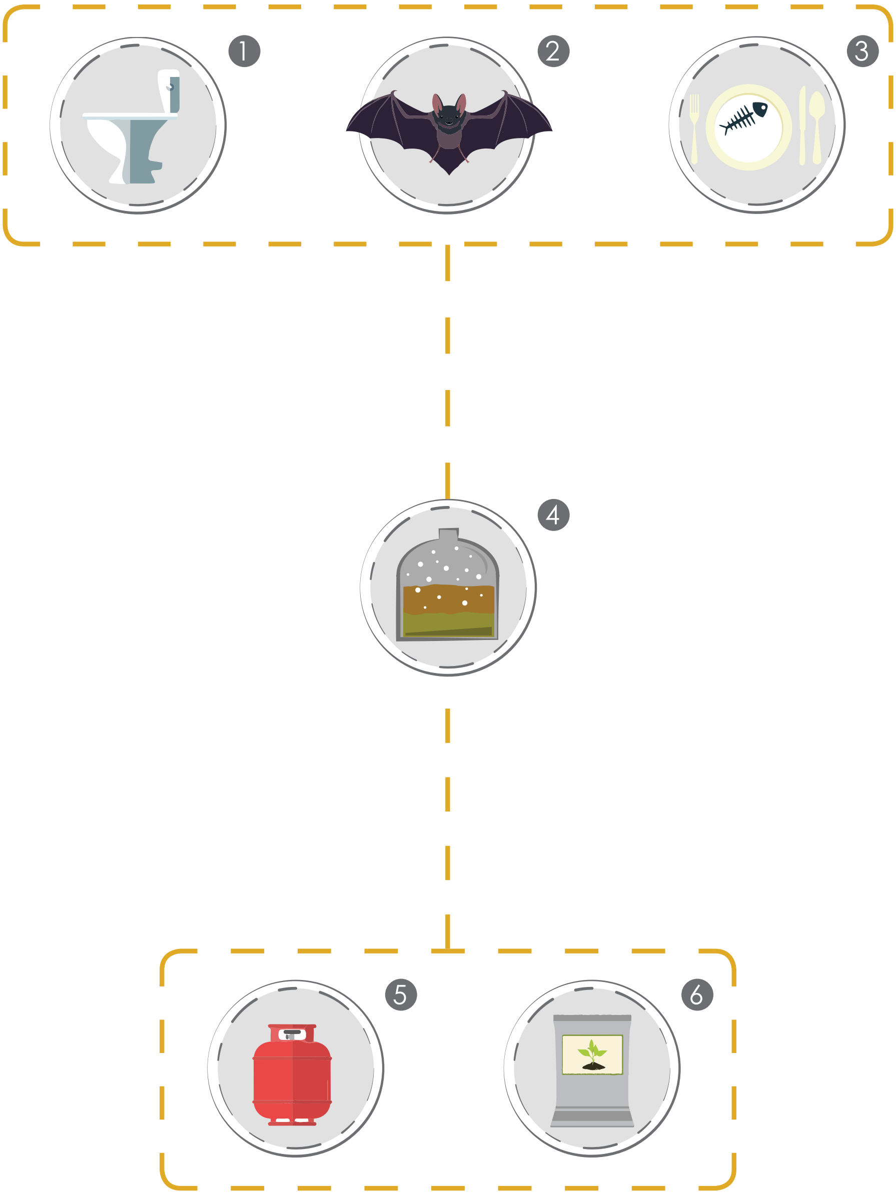



FIGURE 8.13
BIOGAS DIGESTER DIAGRAM
(Author , 2016)

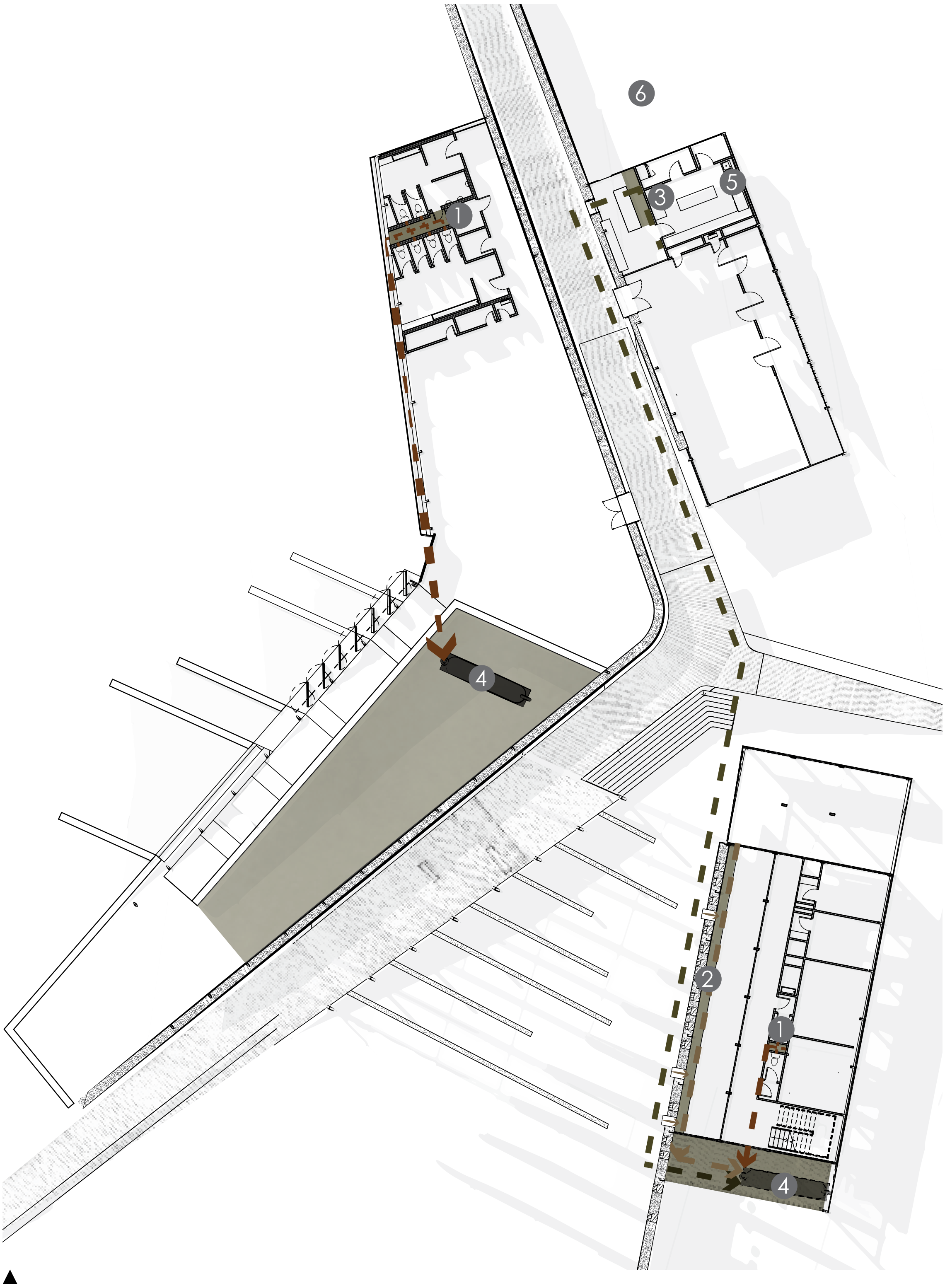



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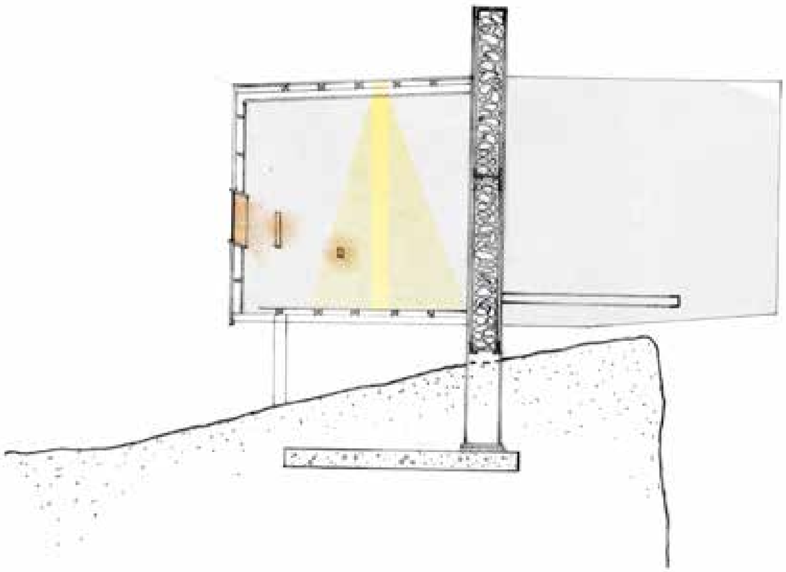
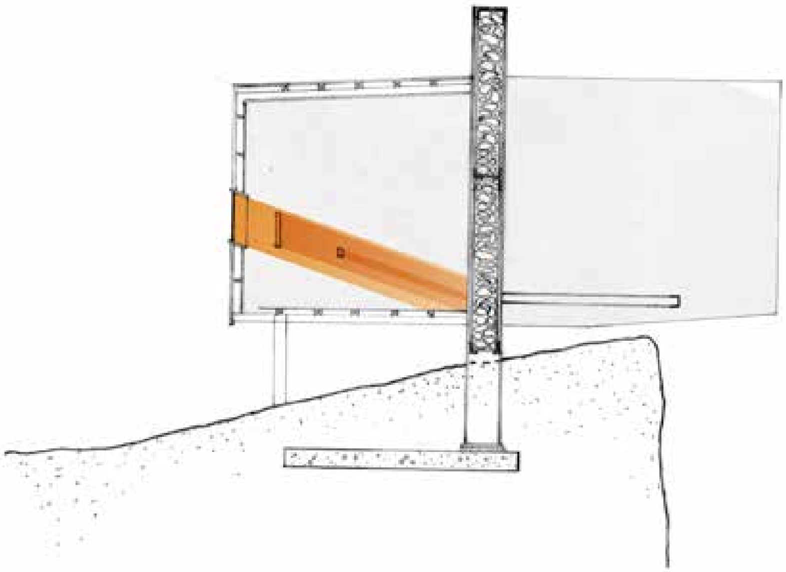
FIGURE 8.14
WASTE & BIOGAS DIGESTER PLAN
(Author , 2016)





### 8.4.4
### DAYLIGHTING

Daylighting principles are applied to the various buildings situated on the route, making use natural lighting as an experiential device, or to illuminate interior spaces.

#### 8.4.4.1
#### QUARRY PAVILION

◄
FIGURE 8.15 a
QUARRY PAVILION
SUMMER MIDDAY
(Author , 2016)

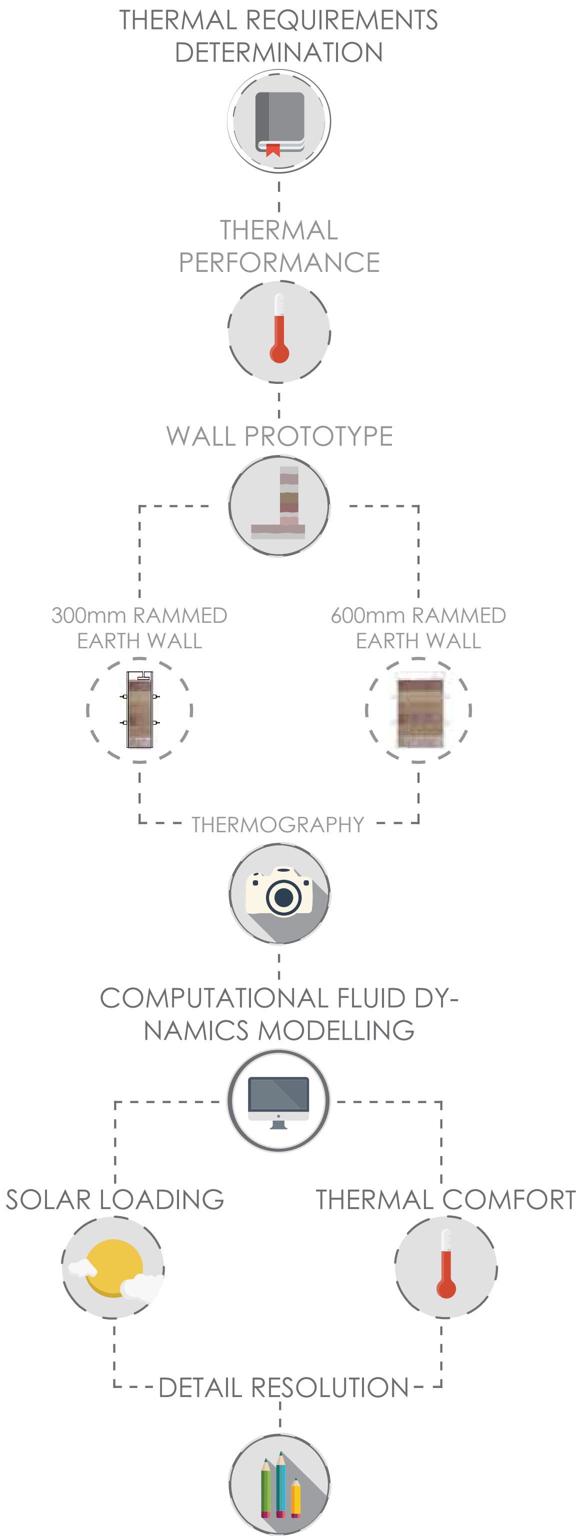
The Quarry Pavilion makes use of daylighting throughout various times of the day, taking into account the lighting quality produced during dawn and dusk. Three orange glazed openings are found on the Eastern façade, allowing early morning sunlight to filter into the pavilion. A narrow opening in the roof of the pavilion tapers in with the pathway through the pavilion, leading the visitor to the edge of the quarry. The lookout point, placed at the edge of the quarry allows visitors a view of the quarry as the sun sets in the west.

#### 8.4.4.2
#### VIVARIUM OFFICE SPACE

Unlike the laboratory and exhibition spaces of the Vivarium, the office space situated to the south-west of the building requires natural daylighting. The building is planned on a north-south axis, due to the direction of the fall of the contours and the route running through all of the structures placed on site.

◄
FIGURE 8.15 b
QUARRY PAVILION
WINTER MORNING
(Author , 2016)

To reduce glare and heat-gain from afternoon Western sun, the Western façade is made up of a series of screens. The mechanically operated screens open to the north, blocking western sun, while allowing for the northern light to illuminate the interior of the office space.


THERMAL REQUIREMENTS DETERMINATION
THERMAL PERFORMANCE
WALL PROTOTYPE
300mm RAMMED EARTH WALL
600mm RAMMED EARTH WALL
THERMOGRAPHY
COMPUTATIONAL FLUID DY-NAMICS MODELLING
SOLAR LOADING
THERMAL COMFORT
DETAIL RESOLUTION

◄
FIGURE 8.16
THERMAL ANALYSIS
RESEARCH DIAGRAM
(Author , 2016)

## 8.5 CHIROPTERA HABITAT

In order to create a favourable environment to attract the Schreiber's long-fingered bat, the thermal comfort of the internal spaces of the Chiroptera roosts becomes the most important environmental requirement (Bat Conservation Trust n.d.). Bats generally roost at temperatures between 30-40°C, this takes into consideration the heat generated by the body mass of the bats increases the internal temperature.

The dissertation aims to propose a design for Chiroptera roosts which relies on as little as possible mechanical heating and cooling strategies, creating the optimal internal thermal comfort with the use of passive heating and cooling strategies, including the use of thermal mass and shading devices where needed.

To determine the thermal properties of the proposed construction materials as well as the influence of these materials on the internal temperature and humidity of the Chiroptera Roosts, Infrared Thermography and Computational Fluid Dynamics (CFD) modelling was used.








◀
FIGURE 8.17
PROTOTYPE CONSTRUCTION PROCESS PHOTOGRAPHS
(Author , 2015)

## 8.5.1 INFRARED THERMOGRAPHY

The study is based on the principle of thermal mass; a material's ability to gain and store thermal energy. A material with a high thermal mass absorbs and retains heat, re-radiating the heat as the surrounding area cools down.

Infrared thermography was used to study the effect of solar heat gain and loss on a series of three wall prototypes, differing in either construction material or in wall thickness, e.g. thermal mass.

Infrared thermography is a process in which an infrared imaging system (an infrared camera) converts the spatial variations in infrared radiance from a surface into a two-dimensional image, in which variations in radiance are displayed as a range of colours or tones. As a general rule, objects that are lighter in colour are warmer, and darker objects are cooler.

A diurnal & nocturnal thermal imagery study of the three prototypes allowed for the analysis of surface radiance and absorption over a period of 24 hours. The three prototypes analysed included the following:
- 300mm stabilised earth wall,
- 230mm clay brick wall,
- 600mm stabilised earth wall,

The 600mm stabilised earth wall was selected as the most suitable material and material thickness for the construction of the wall hosting the Chiroptera roosts. The 600mm stabilised earth wall was selected because of its high thermal mass, allowing for less fluctuation of the internal temperature of the Chiroptera roosts.

a] clean a mason jar
b] fill the jar halfway with soil
c] fill the rest with water
d] tighten the lid and shake
e] let it rest 4-5 hours

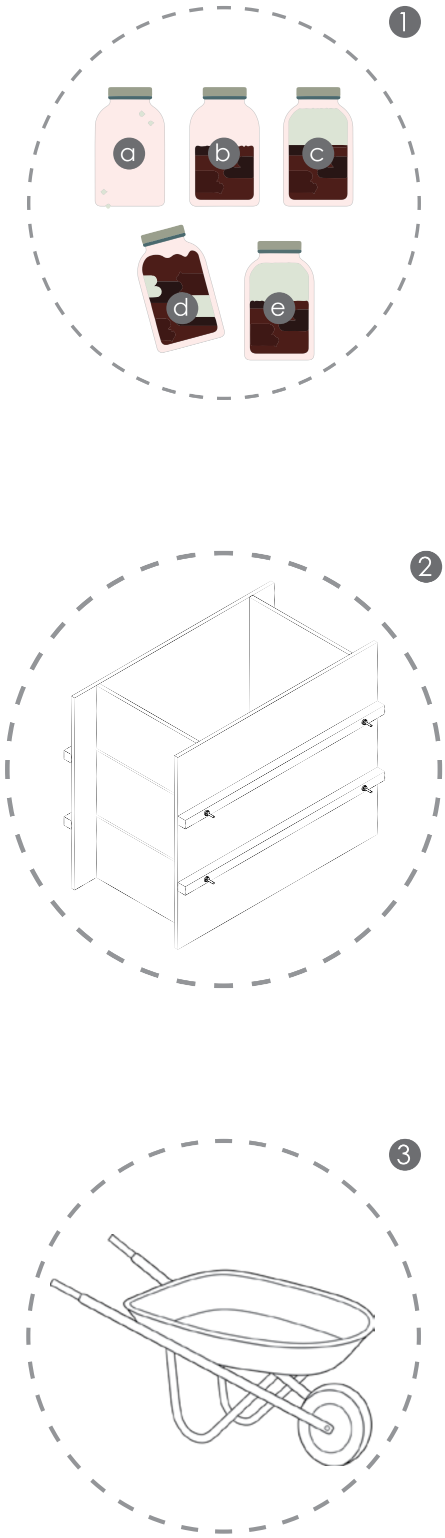
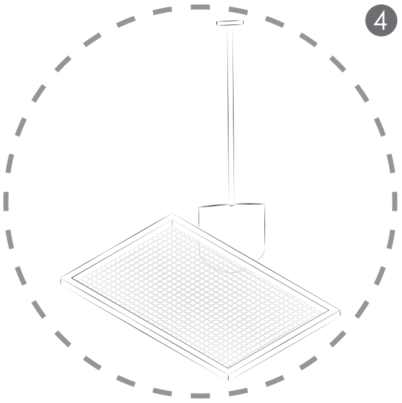
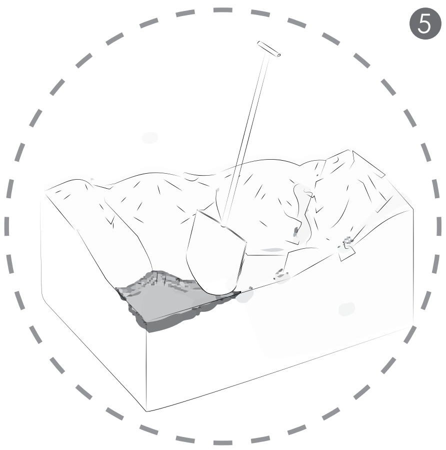
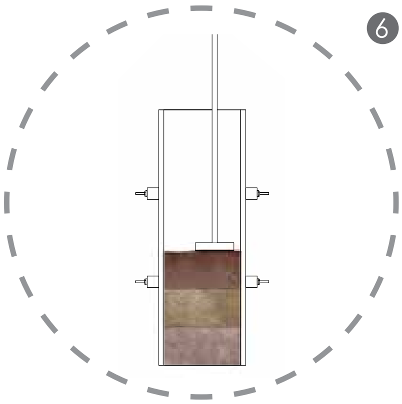



FIGURE 8.18
PROTOTYPE CONSTRUCTION PROCESS DIAGRAM
(Author , 2015)







SEDIMENTATION TEST 1

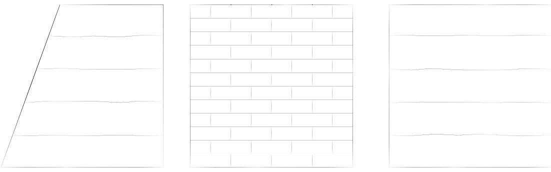
FORMWORK 2

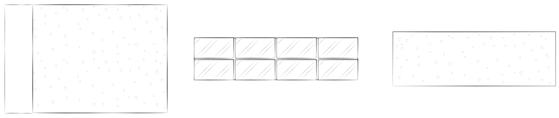
COLLECTING SOIL 3

SIEVING SOIL 4

MIXING SOIL 5

RAMMING SOIL IN FORMWORK 6

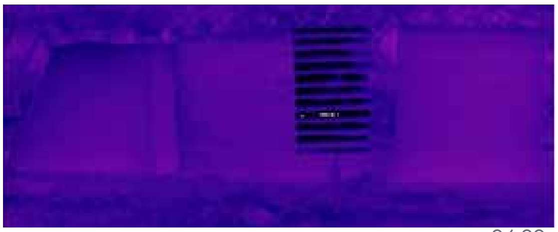




900 x 900 x 600
STABILISED
EARTH WALL

910 x 935 x 230
MASONRY
WALL

900 x 900 x 300
STABILISED
EARTH WALL



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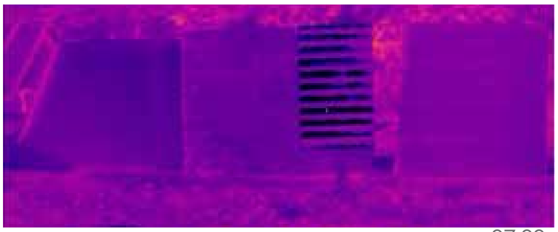

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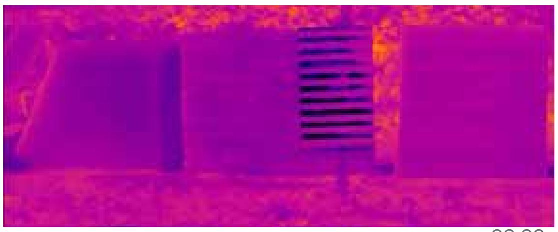

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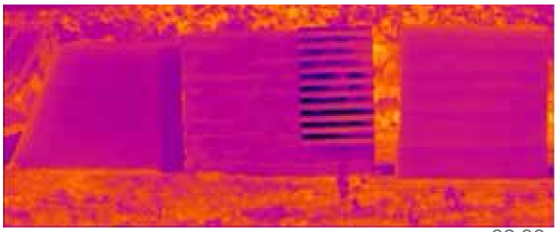

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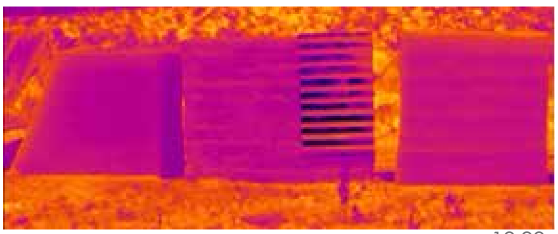

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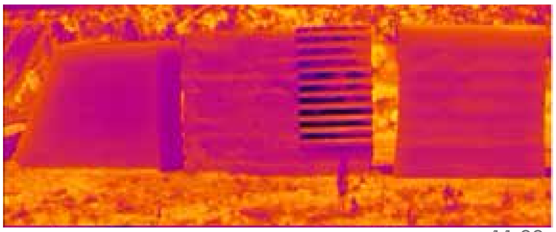

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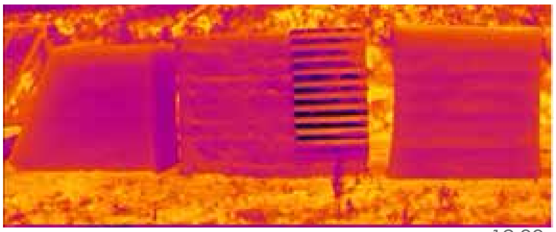
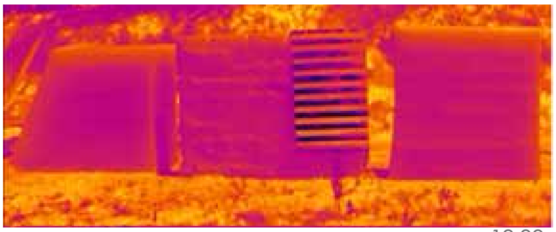


12:00



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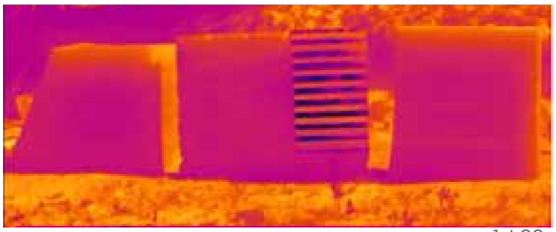

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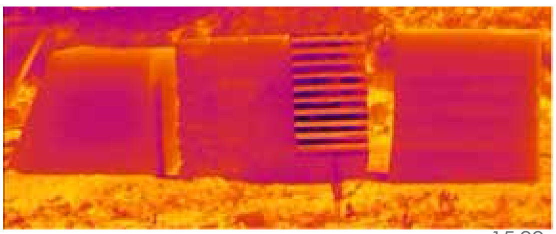
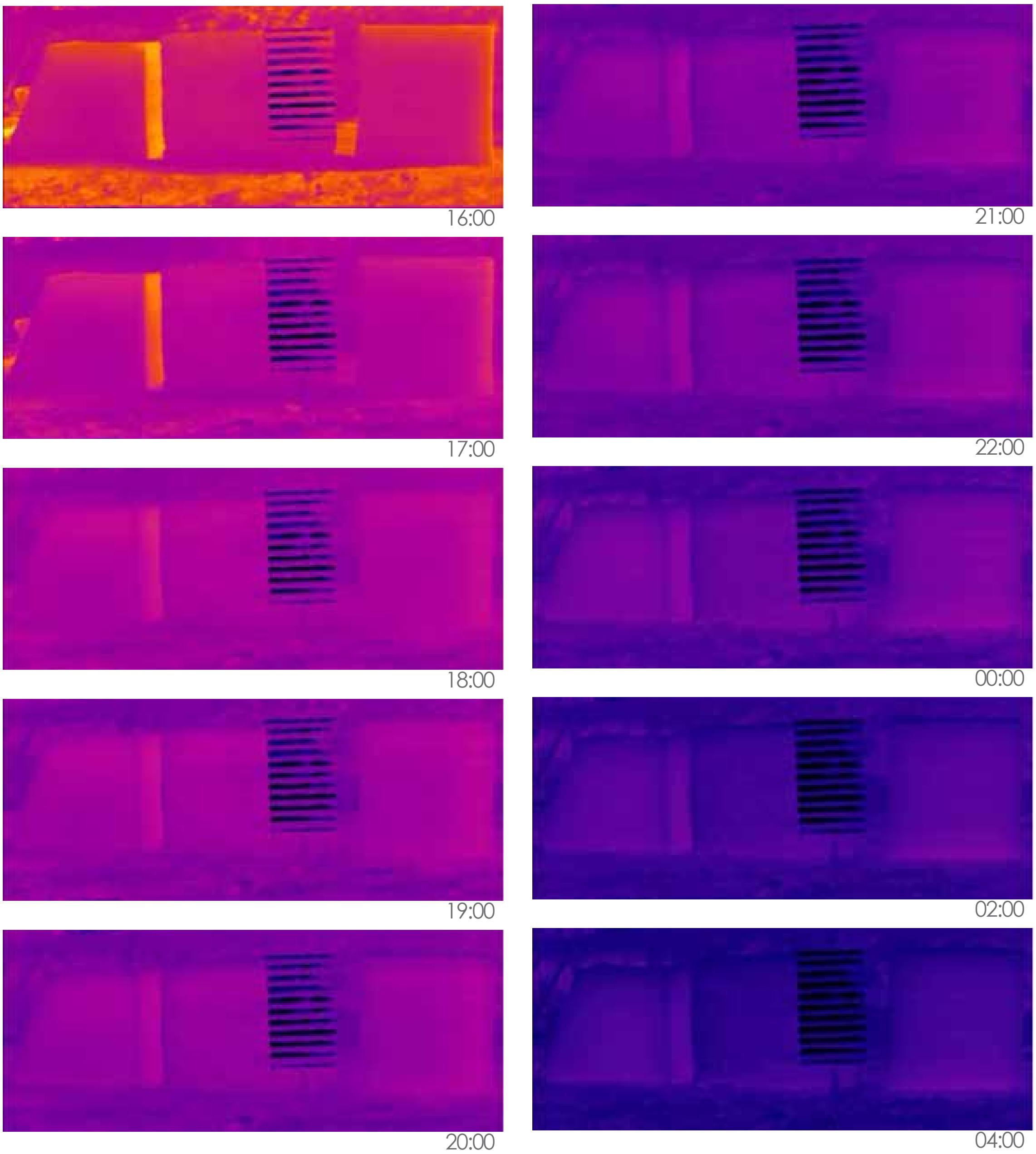


15:00

FIGURE 8.19
INFRARED THERMOGRAPHY
RESULTS
(Author , 2015)
▼



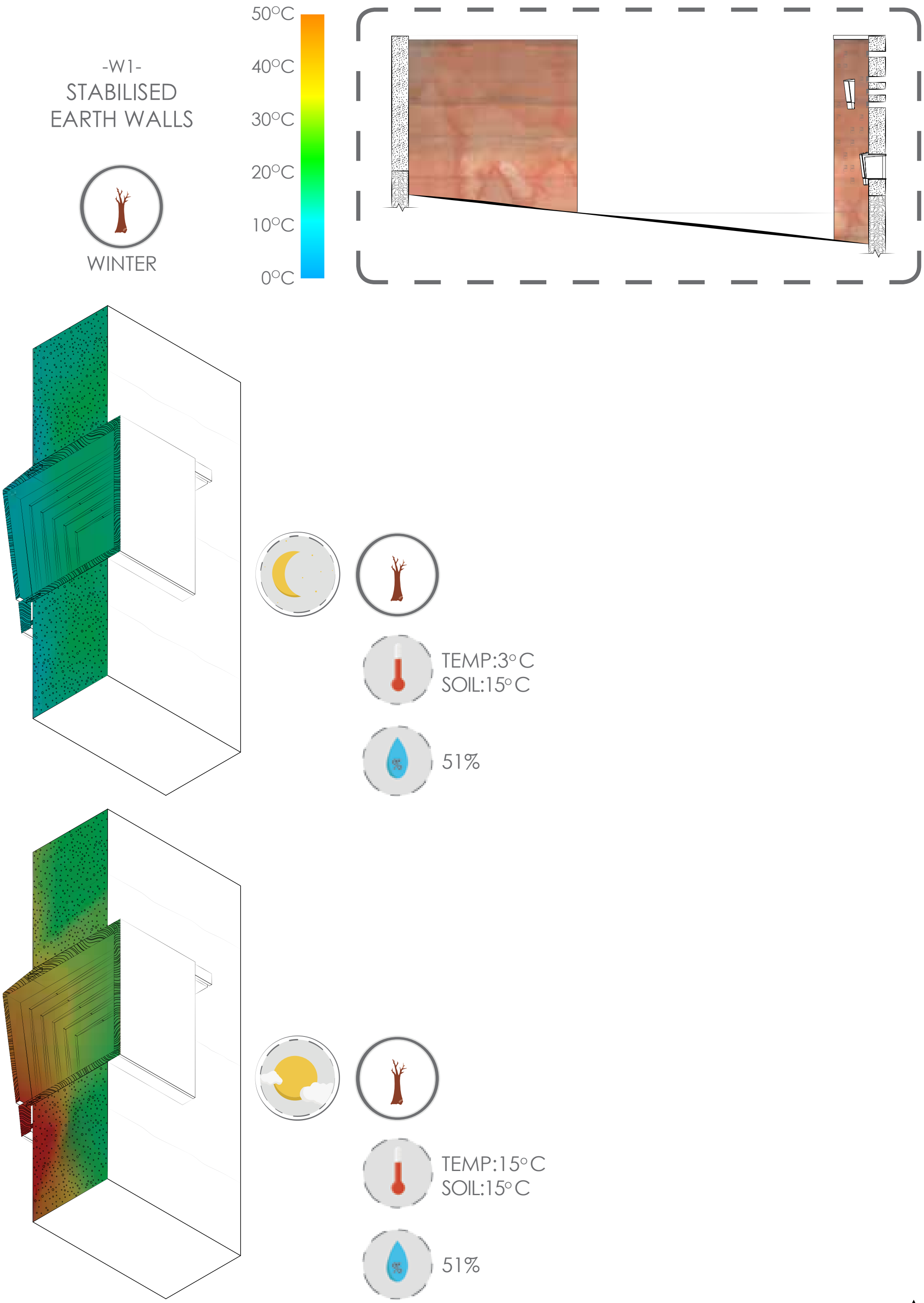



FIGURE 8.20
WINTER CFD ANALYSIS OF
STABILISED EARTH WALLS
(Author , 2015)

## 8.5.2 COMPUTATIONAL FLUID DYNAMICS (CFD) MODELLING

CFD is a computer-based mathematical modelling tool capable of dealing with fluid flow problems and predicting heat transfer, and physical fluid flows, including air. CFD modelling is used as a tool to evaluate the indoor environment of a building and its interaction with the building envelope. In the case of the Vivarium, CFD modelling is used to evaluate the internal temperature and humidity of the Chiroptera roost.

CFD works by dividing a space into a grid containing a large number of 'cells'. The grid of cells is surrounded by boundaries that simulate the surfaces and openings that enclose the space. The software simulates the flow of air from each cell to the cells surrounding it, and the exchange of heat between the boundary surfaces and the cells adjacent to them. After a series of iterations, the model reaches a steady state that represents the distribution of temperature expected to be found within the space (Cao & Chitty 2014).

The study simulates the average summer and winter conditions of the region in which the project is situated, including air temperature, humidity, and soil temperature. Through a series of design iterations, the study aims to simulate the ideal conditions of the Chiroptera roosts.

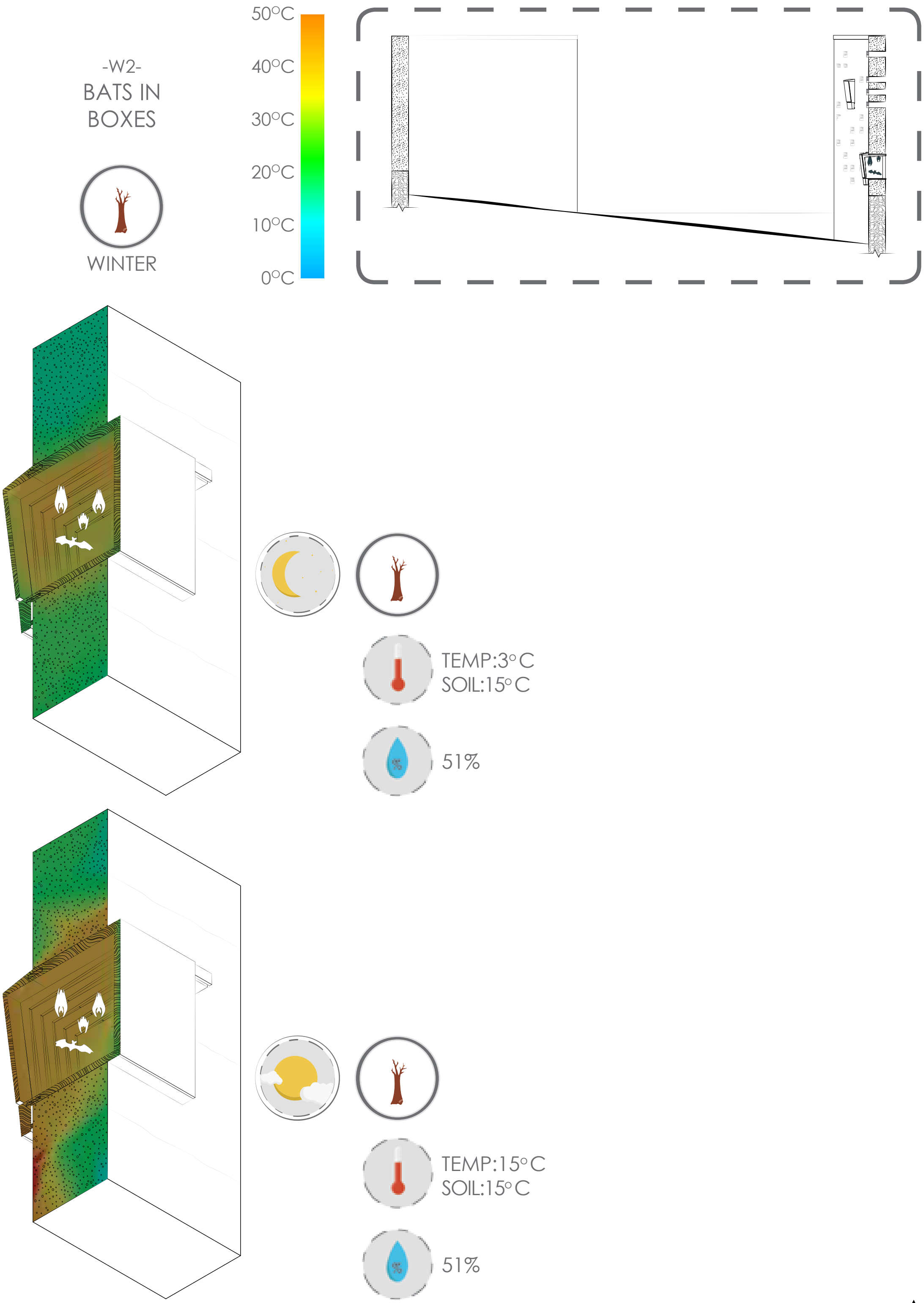



FIGURE 8.21
WINTER CFD ANALYSIS OF HEAT
GENERATED BY BAT BODY MASS
(Author , 2015)

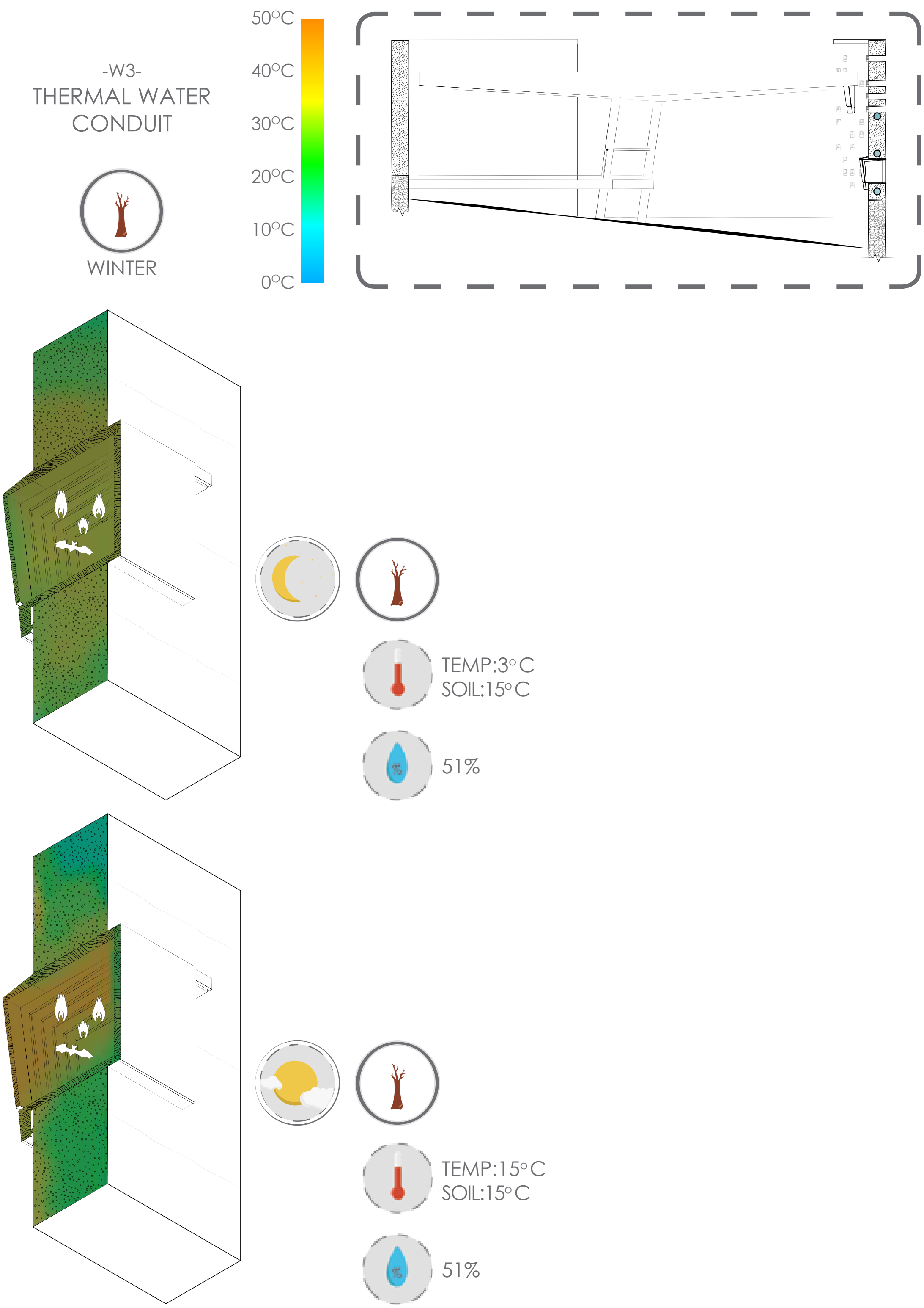



FIGURE 8.22
WINTER CFD ANALYSIS OF THERMAL WATER CONDUIT
(Author , 2015)

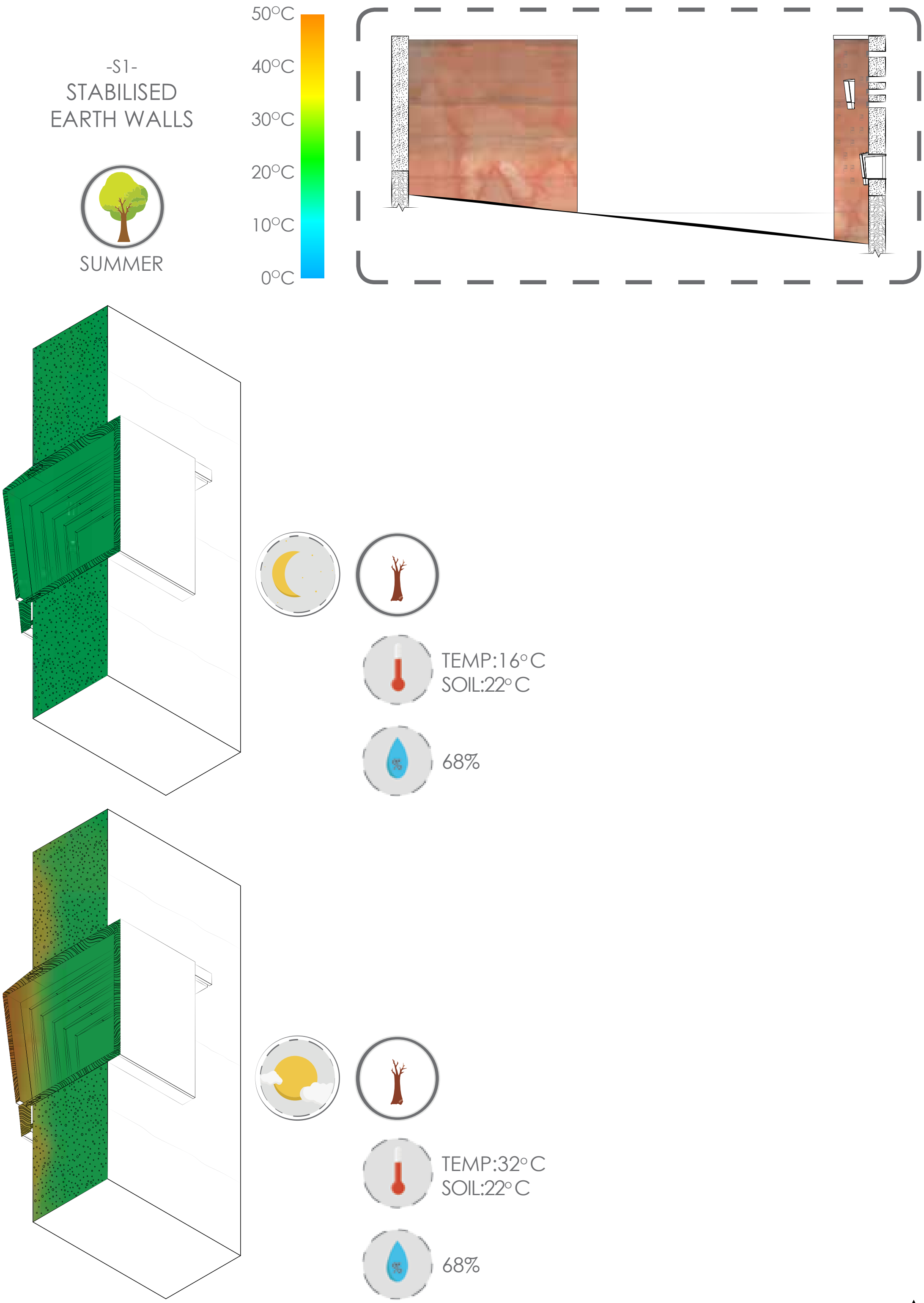
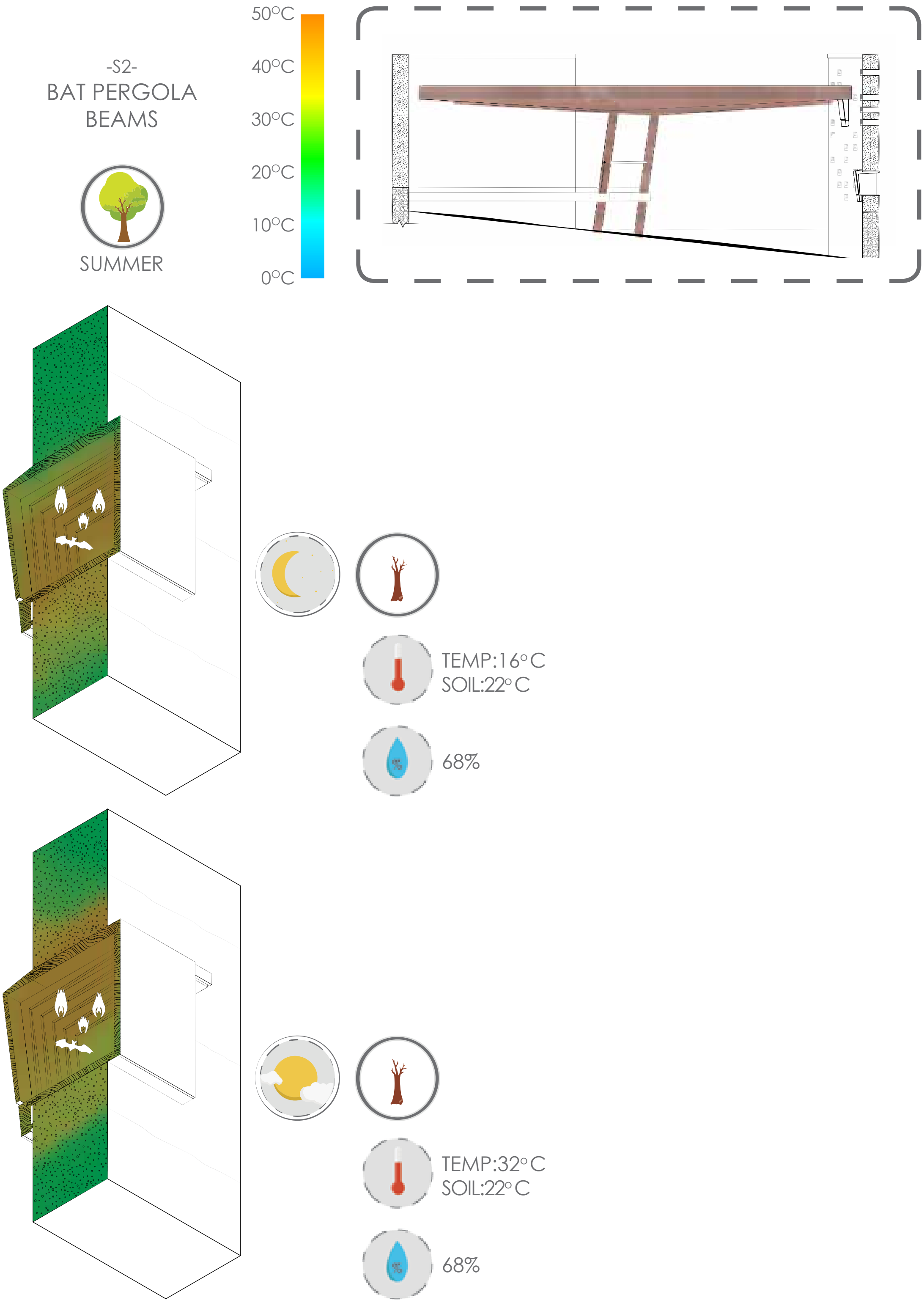



FIGURE 8.23
SUMMER CFD ANALYSIS OF
STABILISED EARTH WALLS
(Author , 2015)




▲
FIGURE 8.24
SUMMER CFD ANALYSIS OF SHADING PERGOLA BEAMS
(Author , 2015)

1 UNTREATED


2 BOILED ALOE VERA

3 UNBOILED ALOE VERA

4 LINSEED OIL

5 SURFACTANT: SURFACE COATED

6 SURFACTANT: MIXED THROUGH

◀
FIGURE 8.25
STABILISED EARTH
TEST BLOCKS
(Author , 2015)

### 8.5.3 STABILISED EARTH SURFACE TREATMENT TEST CUBES

With the selection of rammed earth as the most suitable material for the construction on the Chiroptera Roost, five stabilised test blocks where treated with a series of sealants, including both boiled and fresh Aloe Vera coating, linseed oil, and a surfactant. Through a series of weathering tests the surfactant used as a surface treatment was selected as the most suitable sealant.