CHAPTER 03
THEORY

↑ 035 - Concepts of Theory

3.1// INTRODUCTION

Chapter 3 will discuss the various theoretical influences on the design of the Game of Diminishing returns as well as physical influencing factors. Chapter 3 will form the theoretical argument for the Game of Diminishing return's design and will provide evidence for the potential effectiveness of the proposed program as a rehabilitation agent of Man and Nature.

"God is in the detail(s)."

Ludwig Mies van der Rohe 1886–1969 / Aby Warburg 1866–1929 / Gustave Flaubert 1821–1880

"The devil is in the details."

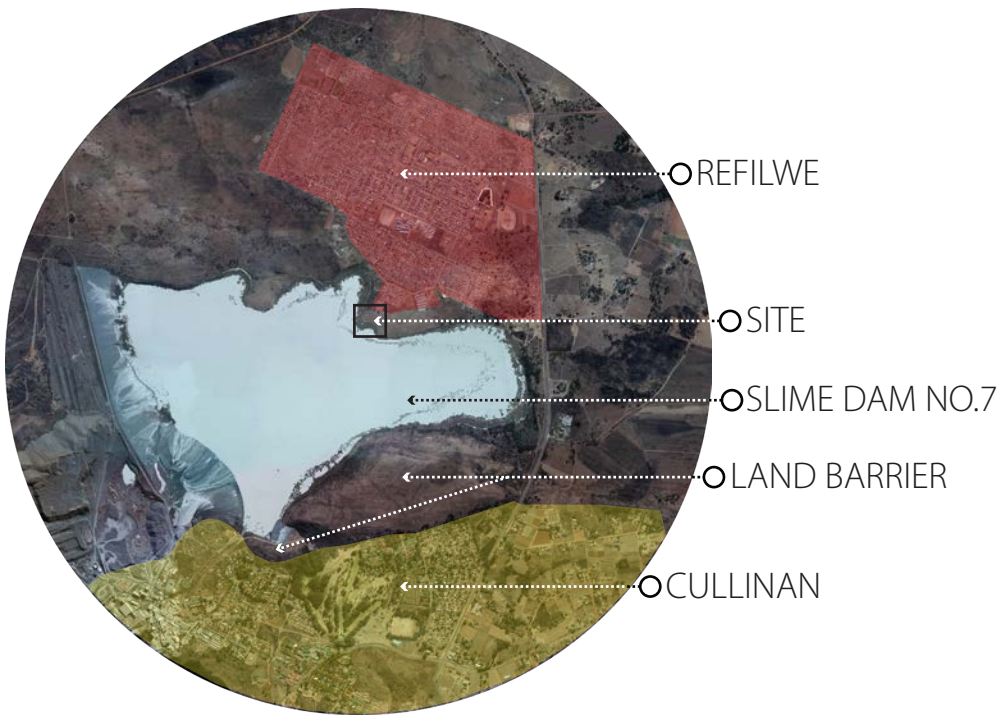
3.2 // TECHNICAL THEORY SEGMENT

3.2.1// A LOOK INTO THE EFFECTS OF MINING POLLUTION

The term "Mining" can be incredibly vague, especially, when referring to a site specific project such as The Game of Diminishing returns, located alongside Cullinan's no.7 slime dam and the Refilwe Community. Not only are there innumerable forms of mining techniques and mined materials, but each site-specific case has its own methods and associated health risks. Mining methods vary for many reasons including government regulations, site specific requirements and the product being mined. This paper will delimit its research to the impact of block cave diamond mining; the technique used for mining the diamond rich kimberlite pipe located in Cullinan. This does not, however, restrict this thesis's potential as a starting point for many other forms of mining and associated types of pollution.

Refilwe is a working class town located alongside the Cullinan Diamond mine's slime dam no.7 . Cullinan has a significant physical barrier, made up of mined soil and rock, which protects it from the majority of mine related pollution, whereas the Refilwe community is located as close as 40m from the water's edge of slime dam no.7 . This proximity to a source of pollution, creates great concern over short-term and long-term community health effects.

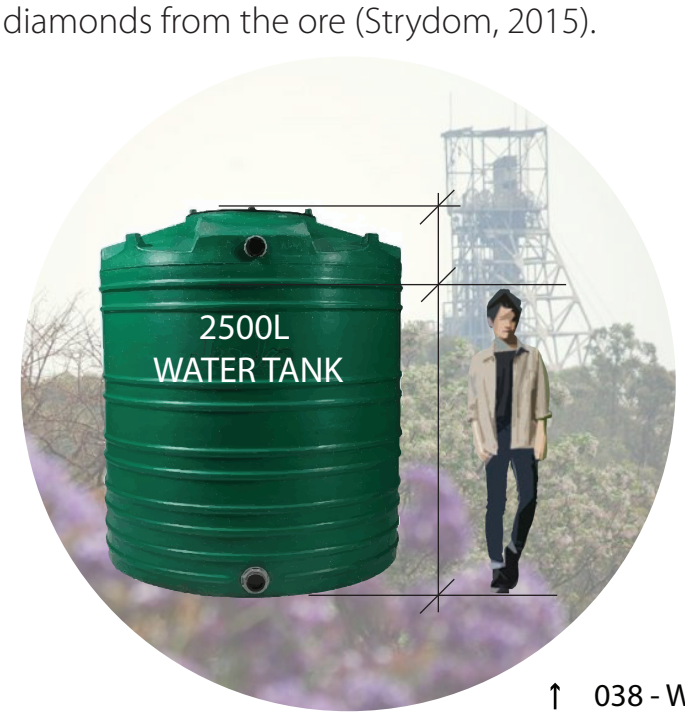
↓ 036 - A Diamond in the Rough. (Diamondland.be, n.d.)

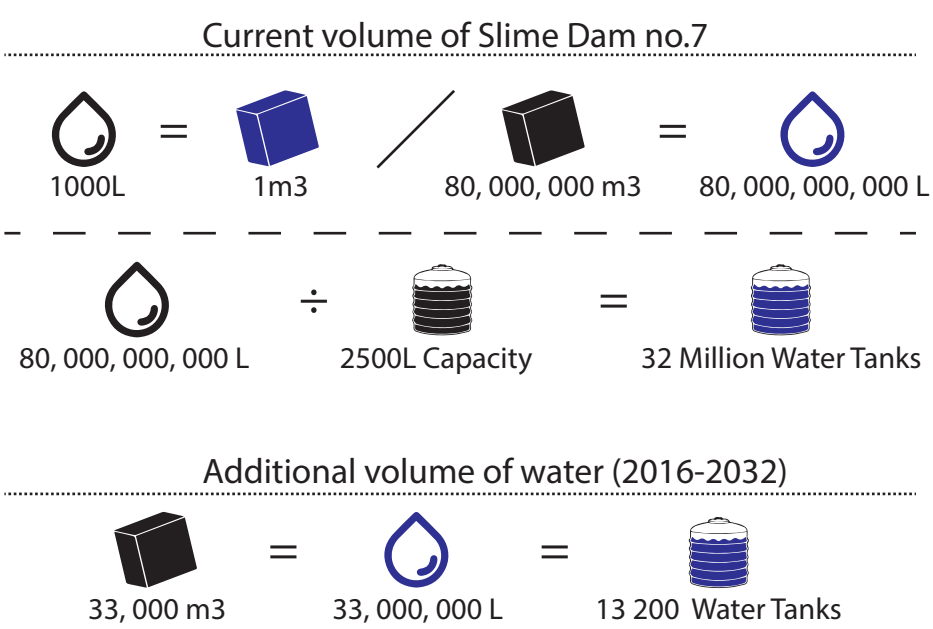


↑ 037 - Site Location Vs Land Barrier

The Cullinan Diamond mine, also called the Petra Diamond Mine, mines a diamond-bearing kimberlite pipe. This kimberlite pipe is the largest of its kind in the region and has been mined from as early as 1902. The Petra Diamond mine currently has a 16 year mining plan in place, but there is a possibility for extended mining of up to 50 years, depending on future mining projections (Mining Technology, 2017). This creates the distinct possibility that the mine will continue to pollute the surrounding area for up to 50 years. Slime dam no.7 has an approximate current volume of 80, 000, 000m3 and will be required to support an additional 33, 000m3 of water for the current 16 year mining plan, this estimate does not include additional water from rainfall. (Strydom, 2015).

It is estimated that only 17% of slime dam no.7's water, only 5m below the surface, can be reused in future mining processes. This leaves a majority proportion of the dam unusable by the mine and unusable as it stands by the Refilwe community (Strydom, 2015). The aforementioned information and the figure 038 exemplifies the scale of the problem. The reasons for not being able to use such a large majority of the water, forms part of the various forms of pollution which also makes the water unsafe for agriculture or use by the Refilwe community. The three main constituents which make slime dam no.7's water unusable are dissolved salts, its high density and extreme turbidity* and excessively high pH level and high alkalinity as discussed in Strydom (2015). These pollution elements result from accelerated weathering of kimberlite ore, due to the crushing process involved with the extraction of diamonds from the ore (Strydom, 2015).



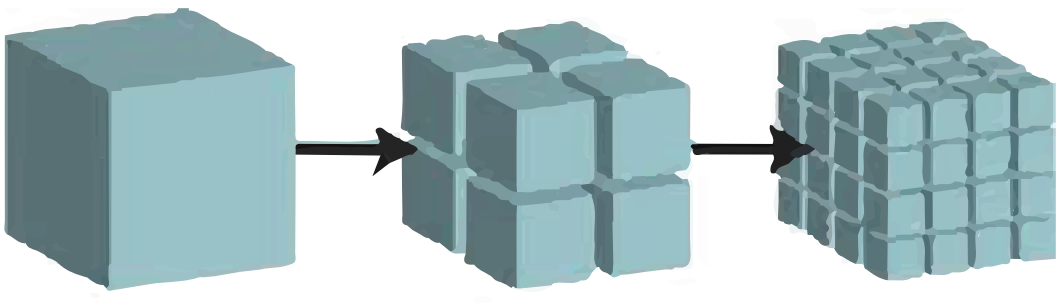


↑ 038 - Water Calculations

Turbidity is a measurement for how densely a water source is contaminated with particulates. Turbidity tests look at the optical clarity of a water source, measuring how much light is deflected by the contaminated particles (Perlman, 2016).

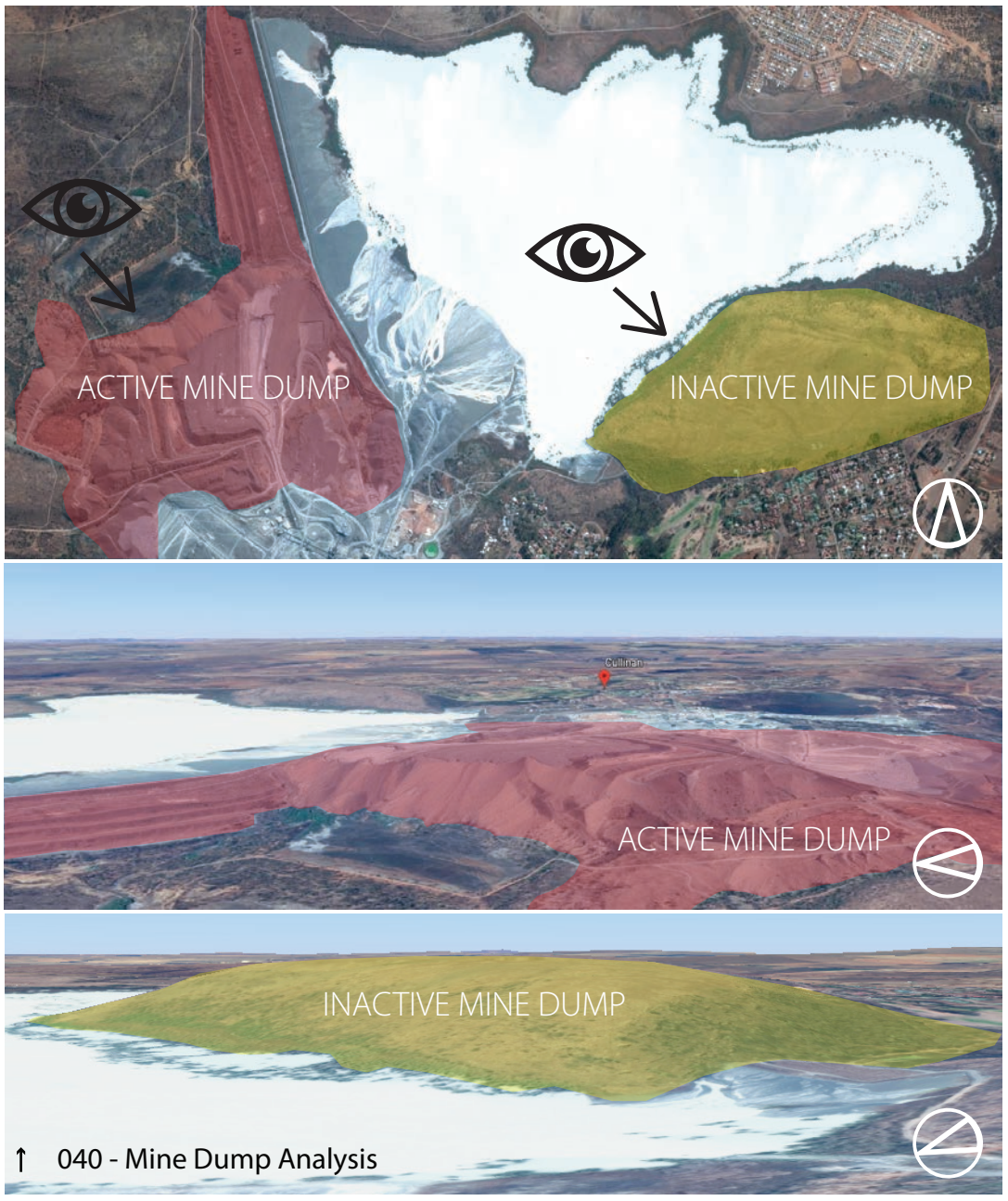
The turbidity in slime dam no.7 is a result of, "the dispersion of colloidal chlorite, saponite and nontronite clays." The non-settling nature of the clays is due to "the chemistry of the solution and their colloidal shape." The main source of these suspended clay particles comes from the process of crushing rock to extract diamonds from the kimberlite pipe. Additionally, natural weathering of exposed kimberlite rock deposited on mine dumps, adds to the mineral content of slime dam no.7 . This is in part due to the accelerated rate of decay of these rock deposits, because of the unusually high surface area of mechanically crushed rock.

↓ 039 - Surface Area Illustration



As rock is broken into smaller pieces, overall surface area increases exponentially.

Kimberlite, the rock from which diamonds are mined, in the Cullinan area, is referred to as an ingenious rock, which is to say that it is formed when magma is forced into older rocks at the depths of the Earth's crust. It is usually only exposed to the elements when kimberlite-rich areas are subjected to erosion (Encyclopedia Britannica, 2017). In the Cullinan mine, once the kimberlite rock is crushed and checked for diamonds it is discarded on a mine dump, artificially exposing it to the elements. One of the main constituents which makes up kimberlite rock is a mineral called olivine. Olivine is rapidly altered by weathering, resulting in the accelerated decay of kimberlite rock. Olivine's chemical composition is mainly made up of Magnesium, Iron, Calcium, Manganese and trace amounts of Nickel (King, 2017). One can thus conclude that the rapid deterioration of kimberlite rock, due to weathering, results in the release of these elements into the surrounding environment. If one considers that in nature, kimberlite rock weathers in small quantities; relative to the large quantities in mining; then the effects on the environment, of natural weathering, is much less pronounced. Due to the proximity of the Cullinan mine dump, to slime dam no.7 , the weathering of the dumps contents flows directly into the slime dam. This accelerated weathering and restricted collection area results in high levels of the aforementioned chemicals in slime dam no.7 . This information is important for two reasons: In considering methods of remediating slime dam no.7 and in the use of rock from the Cullinan mine's dump to decrease the rate of chemical dissolution in the slime dam no.7's water body.



↑ 040 - Mine Dump Analysis

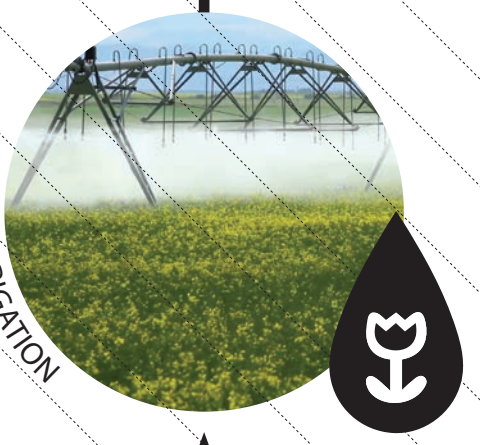
The dissolution of kimberlite, and in turn the olivine making up the majority of its physical mass, has been extensively researched as a possible method of carbon sequestration, which is the storage of converted carbon dioxide in a physical form. "Weathering is the neutralization of an acid (usually carbonic acid) by rocks, turning CO2 into the innocuous bicarbonate ion in solution." (Schuiling, 2017) Olivine weathering results in the conversation of gaseous CO2 into various solid constituents, made up of: Bicarbonate, Silicic acid and Magnesium (Schuiling, 2017). Furthermore the secondary reaction of Bicarbonate and Silicic acid suspended in water, results in the formation of different forms of limestones and dolomites. The end results, in simplified terms, occurring due to the weathering of kimberlite rock, can result in the absorption of CO2 gas. The weathering of kimberlite, as mentioned, also results in the release of Magnesium, Iron, Calcium and Manganese. These chemical are important in the successful growth of most vegetation, especially nutrient hungry plants such as edible crops.

One of the aims of The Game of Diminishing Returns is to utilize the Cullinan mine's various dumps' material contents, to serve as a construction material and to aid in the bioremediation of slime dam no.7 and the surrounding agricultural landscape. As will be discussed in more detail in subsequent chapters, the ability for kimberlite rock used as a construction material, to eventually disintegrate, is of great importance to the conceptual drivers informing the Game of Diminishing Returns architecture.

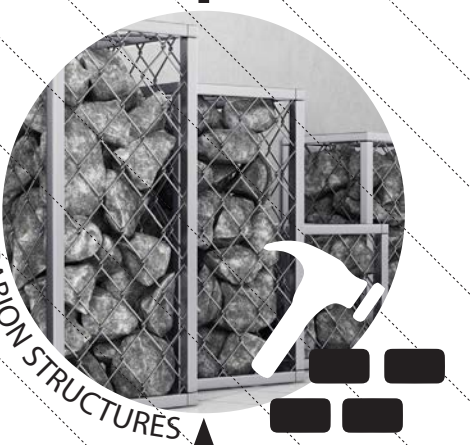
↓ 041 - Early Programme Development & Materials

ROCK EXCAVATION

ROCK CRUSHING



IRRIGATION

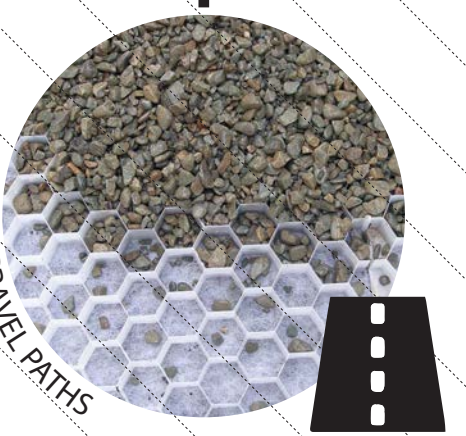


GABION STRUCTURES

ROCK PROCESSING

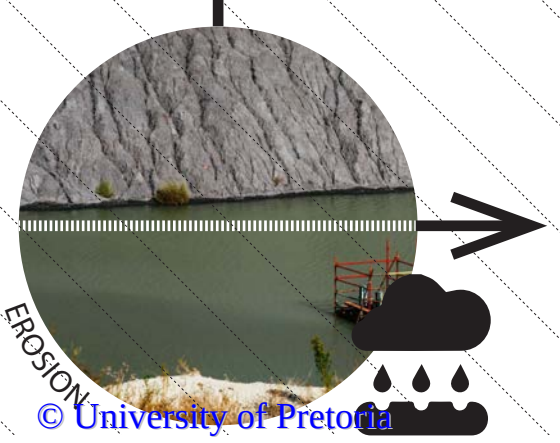
DIAMOND EXTRACTION

WATER SOURCE



GRAVEL PATHS

PROCESSED ROCK

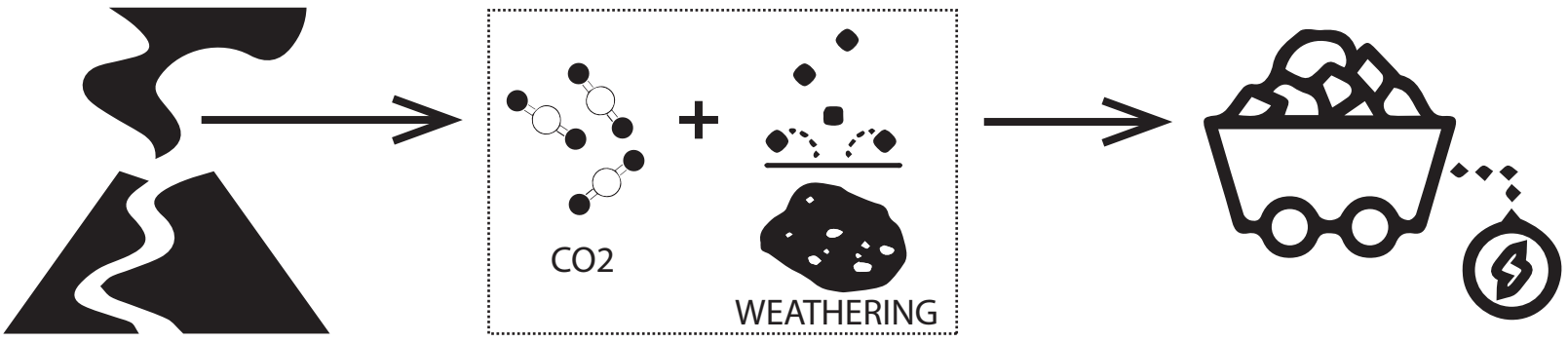


EROSION

Today's climate control proposals are exactly that ost common response to carbon emission reduction, is a reduction in the rate at which fossil fuels are burnt. Unfortunately, even with internationally agreed plans to reduce the rate at which fossil fuels are burnt, and in turn the rate at which carbon emissions are produced, the fossil fuel divestment strategy has been largely unsuccessful (IPCC, 2007; Prins and Rayner, 2007). It is paramount to the global environment to reduce the use of fossil fuels, but the rate at which this reduction is occurring is far too slow. Prevention is better than a cure; a quote by 1466 Dutch Philospher; Desiderius Erasmus, is often used with regards to carbon emissions. Although this sentiment rings true, a plan must be set in action for the reduction of carbon emissions, which have already been produced and that which will still be produced, while reliable alternative energy strategies are implemented (Schuiling, 2017). This sentiment rings true in many institutions internationally; including The Royal Society:

"The safest and most predictable method of moderating climate change is to take early and effective action to reduce emissions of greenhouse gases. No geoengineering method can provide an easy or readily acceptable alternative solution to the problem of climate change. Geoengineering methods could however potentially be useful in future to augment continuing efforts to mitigate climate change by reducing emissions, and so should be subject to more detailed research and analysis." (Shepherd, 2012)

There are unmentionably many sources to quote when it comes to the ability of Olivine in reducing global CO2 levels, yet it widely regarded by the scientific community as one of the most viable options investigated. The process of CO2 absorption through rock weathering is as old as Earth itself. The weathering of rock has been shown to be the main natural process on earth for removing CO2. The existence of fossil fuels is widely regarded to be the direct result of the natural process of carbon dioxide sequestration through rock weathering. Early Earth was significantly more volcanically active, creating an environment which was much richer in greenhouse gasses. The conversion of these greenhouse gasses into solid forms, with unmentionably large amounts of pressure, formed fossil fuels over aeons.



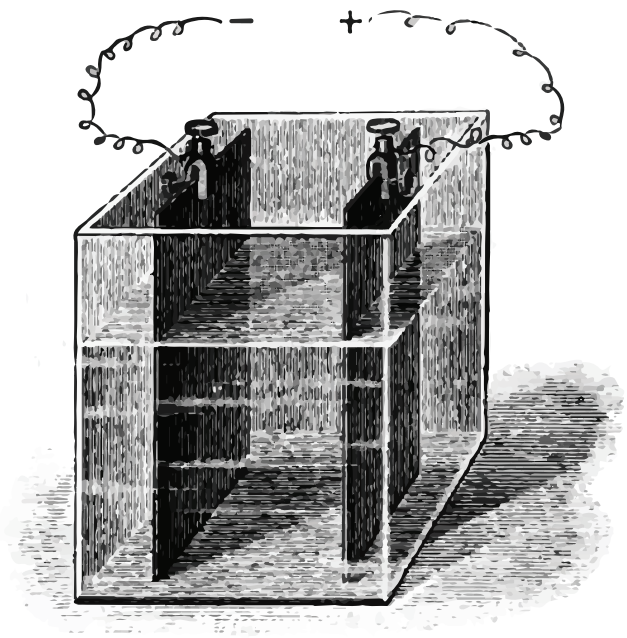
↑ 042 - CO2 Absorption through Weathering

Sites such as Cullinan's Slime Dam no.7 which are primarily affected by high pH levels, water turbidity and high salt concentrations have a higher success rate when it comes to rehabilitation methods, unlike sites which are polluted by heavy metals or radioactive elements.

One can argue that the location of Refilwe is serendipitous in that it is not located in the vicinity of a gold mine, a site which would be far too toxic to envision a purely bioremedial or architectural means of rehabilitation. The process of extracting gold results in large amount of waste, up to 99% of the material extracted. This extracted material, referred to as tailings, contains very high amounts of heavy metals. Due to the open manner in which these tailings are dumped into mounds, exposed to the elements, they can leach out these heavy metals in an environmentally damaging manner. As stated in Fashola, Ngole-Jeme and Babalola (2016) concentrated Heavy Metals in the environment is a serious worldwide health issue, due to the non-degradative nature. Heavy metals, are extremely difficult to extract form polluted environments and can have extremely long-term negative effects on any ecosystem (Fashola, Ngole-Jeme & Babalola, 2016).

The main pollution type directly associated with the process of diamond mining, with cause for health concerns, include the aforementioned high levels of nitrates and other dissolved salts. Bosman (2009) writes about the health concerns associated with high levels of nitrates and general oversight of the mining industry on these chemical's possible effect on communities and the environment. High levels of nitrate in water sources has been noted to lead to methemoglobinemia in infants, resulting from chemical poisoning of the blood, which when sever enough can cause brain damage or even death (McCasland et al., 2012). High pH levels are of very little direct concern to a community's health, as the human stomach can process high or low levels of pH with virtually no health effects (Healthy Drinking Waters, 2017). It must be noted that in severe cases pH levels can become so severe, due to mining, that the polluted water can indirectly have adverse effects on a community's health. The main danger associated with high pH levels, such as those found in slime dam no.7 , is the corrosive abilities on rocks and soils, which could lead to erosion and sub-earth cavities. Strydom (2015) emphasizes the adverse effects which high levels of salts and high levels of pH can have on plant life. Excess salt causes plants to have difficulty with the natural process of osmosis and high pH levels have been shown to cause deficiencies of chemicals, such as Iron, Manganese, Zink, and Copper, which are required for vigorous plant growth (Strydom, 2015).

3.2.2// REHABILITATION THROUGH ELECTROLYSIS



↑ 043 - Historic Electrolysis

Electrolysis is the process of passing a direct electric current between electrodes in a conductive liquid. The electric current acts as a catalyst and drives an otherwise non-spontaneous chemical reaction to take place. Electrolysis is often used in the refining stages of mining and is used to separate selected elements from natural sources such as ore (Gcsescience.com, 2017).

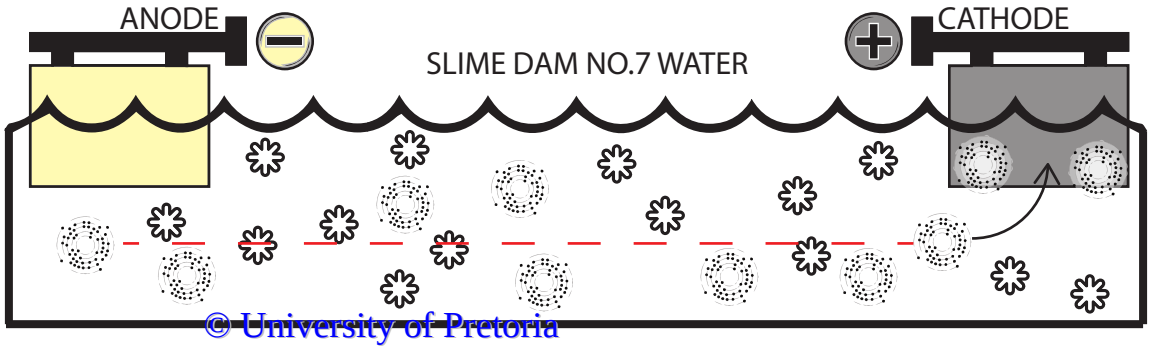
Dating the exact inception of electrolysis is not possible as various sources state various dates of inception, some dating as far back as the ancient Egyptians. Electrochemistry as a scientific field which came about in the early 19th century, with the first electrolysis experiments being conducted by English chemists William Nicholson and Johann Wilhelm Ritter in 1880 (Revankar and Majumdar, 2016).

Electrolysis is used in an extremely wide range of industrial processes, including but not limited to; mining related metal extraction, chemical experimentation, salt extraction, water purification and hydrogen production. Electrolysis has been successfully implemented in various industries, including the production of architectural components and products, but as far as my research can show electrolysis has never been used in any architectural programme or large scale site remediation. This chapter will propose to utilize electrolysis to perform three tasks within an architectural programme. All three of these tasks will aim to remediate Cullinan mine's slime dam no. 7 to such an extent which would allow for the use of the embodied water in agriculture, and possibly even within Refilwe's households. The three tasks mentioned will include: Salt extraction/modification, water purification and metal extraction. These three processes will be discussed individually, in terms of process requirements and implementation into an architectural programme.

Heavy metal extraction is possibly the most important process which electrolysis can perform with regards to remediating mine related slime dams. This is due to the extreme toxicity, not to mention the chemical difficulty of complete elimination of heavy metals which contaminate water used in mining processes. As mentioned in Chapters 2.3 and 3.2.1, the diamond mining produces considerably less heavy metals as compared to gold mining, but not enough chemical studies of Cullinan's slime dam no.7 have been performed to establish the complete absence of heavy metal contamination. Electrolysis can be used to extract metals from electrically conductive liquids. This process is most commonly used in a process called electroplating, where aqueous forms of metal are transferred from a liquid to a cathode, where the cathode is a metallic product which will be evenly coated with the aforementioned aqueous metal. This process is often used to make cheaper metal products more aesthetically pleasing, referred to as a decorative coating, or to protect metallic products from damage; when in use; referred to as functional coatings (Mittal, 2015).

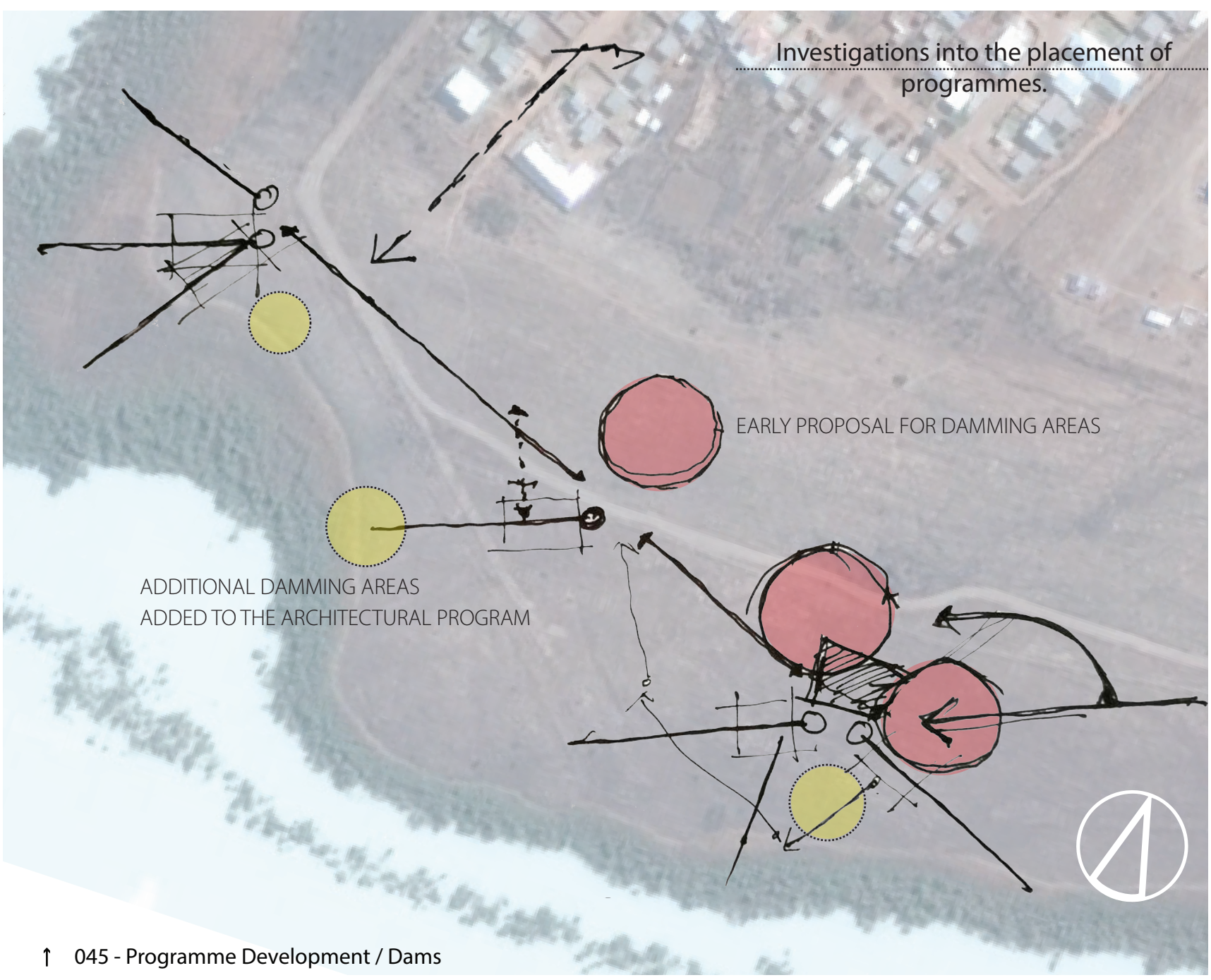
Due to the lack of information available on the possible heavy metal contamination of slime dam no.7 , the proposed process will be experimental and aim to establish which, if any, heavy metals are present. Advantageously, the same process electrolysis based process which could determine the presence of heavy metals, can be used to extract said heavy metals. To make the process more efficient at extracting the determined heavy metal or metals, specific anode and cathode materials can be chosen which react more easily with the aforementioned heavy metals. A recent development by The Massachusetts Institute of Technology (MIT), has successfully utilized an electrochemical process to remove pollutants from water (Chandler, 2017). In short, the dissertation by MIT postdoctoral researchers illustrates the first electrochemical method which can selectively remove organic contaminants from water, even when the contaminants present are in very low concentrations (Su et al., 2017). The term "organic contaminants" refers to contaminants including pesticides, chemical waste products and pharmaceuticals (Ibid., 2017). Su states that, "Current systems for dealing with such dilute contaminants include membrane filtration, which is expensive and has limited effectiveness at low concentrations, and electrodialysis and capacitive deionization, which often require high voltages that tend to produce side reactions," and continues to explain how these processes can also be "hampered by excess background salts" (Ibid., 2017). Due to the high level of background salts in slime dam no.7 , as covered in Chapter 3.2.1, it would be most advantageous to use this new method of electrochemical pollutant extraction to target the elimination of heavy metals. One of the benefits of using the aforementioned system by MIT, is that it would leave behind the salt contaminants present in the slime dam for extraction with a different electrochemical method. This both ensures the removal of the most dangerous pollutants first, and dually allows for more pure forms of salt to be extracted or utilized in chemical processes, with relative safely, by the community.

→ 044 - Electrolysis Process



Once heavy metal pollutants are removed, two will still be present in the slime dam water which must be remediated, for the water to be safe to use within the community. These are: water turbidity and nitrate pollution, as discussed in Chapter 3.2.1. To enable salt extraction or chemical utilisation, the turbidity of the dam's water must first be remediated. The most efficient way of settling the particulates in the water causing the turbidity, is to use a powderous form of gypsum (Strydom, 2015). Once the particulates in the water are settled out, the saline water can be further processed. The water remains very saline due to the powderous gypsum not binding to nitrate atoms which are present. Once the heavy metal and turbidity pollutives are eliminated, multiple further processes exist to both extract the nitrates and/or chemically convert them to produce other products. The same electrolysis based systems used to eliminate heavy metals can be used again; to either accumulate the salt, speeding up the natural evaporative process, or electrolytically convert the nitrates into other usable products. The most common products produced when electrolysis is used on nitrate rich solutions are: Sodium Chlorite – the main constituent of bleach; and hydrogen gas – a gas which is gaining momentum as a substitute for fossil fuels. First, the gypsum based settling method must be more thoroughly explained.

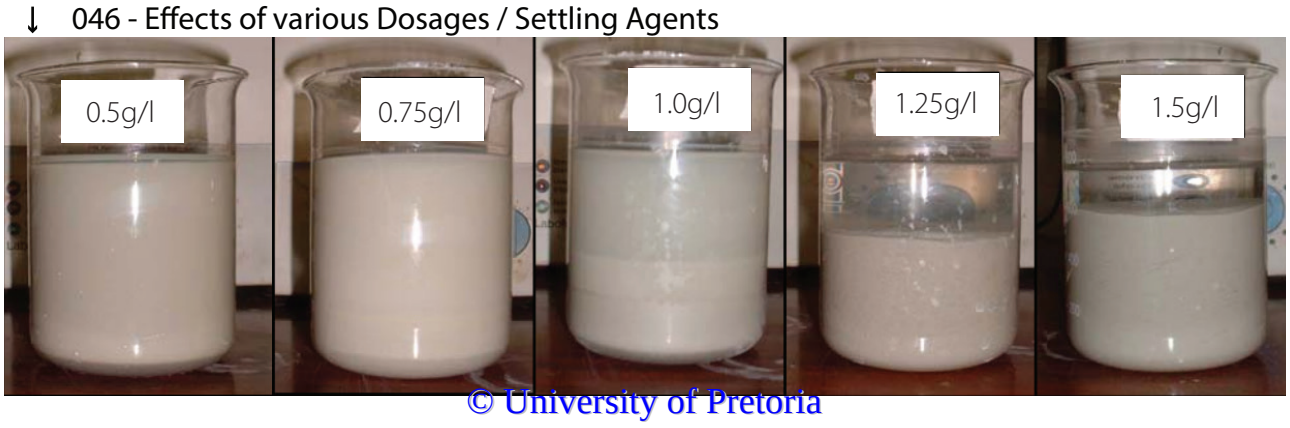
The most important factor in gypsum settling, to understand, is that even though the process has been widely researched and tested it is not a complete solution. Onsite tests by Potgieter & Green (2006) both showed the affectivity of gypsum, as a settling agent, and the increased settling affectivity if an additional dose of gypsum is added shortly after the primary dose. However the addition of the secondary dose caused excessive growth of algae. To prevent such reactions on a large scale, settling will be primarily performed in architecturally planned damming areas. This will allow for both controlled testing and introduction of electrolytic systems which form part of an architectural programme. Gypsum is often combined with other flocculants to increase the affectivity of settling.



↑ 045 - Programme Development / Dams

Flocculants, or chemical settling agents, have been tested and proven to increase the affectivity of gypsum as a settling agent. Scientific analyzes, on water extracted from a specified site, must be performed to analyze which additive/s will work most effectively. The image below was extracted from the paper: A novel application of phosphogypsum: Treatment of a diamond mine's slimes tailings, by Potgieter and Green (2007) and shows how various concentrations of powderous gypsum affect the effectiveness of particle settling.

↓ 046 - Effects of various Dosages / Settling Agents



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

NaCl

ADDITIONAL USES

PHARMACEUTICAL

FOOD INDUSTRY

WATER TREATMENT

CHEMICAL INDUSTRY

SODA ASH

CAUSTIC SODA

CHLORINE

= 1000+ USES + PVC RECYCLING + DISINFECTANT

= GLASSWARE + PAPER PULP + POOL CLEANER

= PAINT + MINERAL OIL + METALS + DYES

② ELECTROLYTIC CLEANING AND SALT EXTRACTION

③

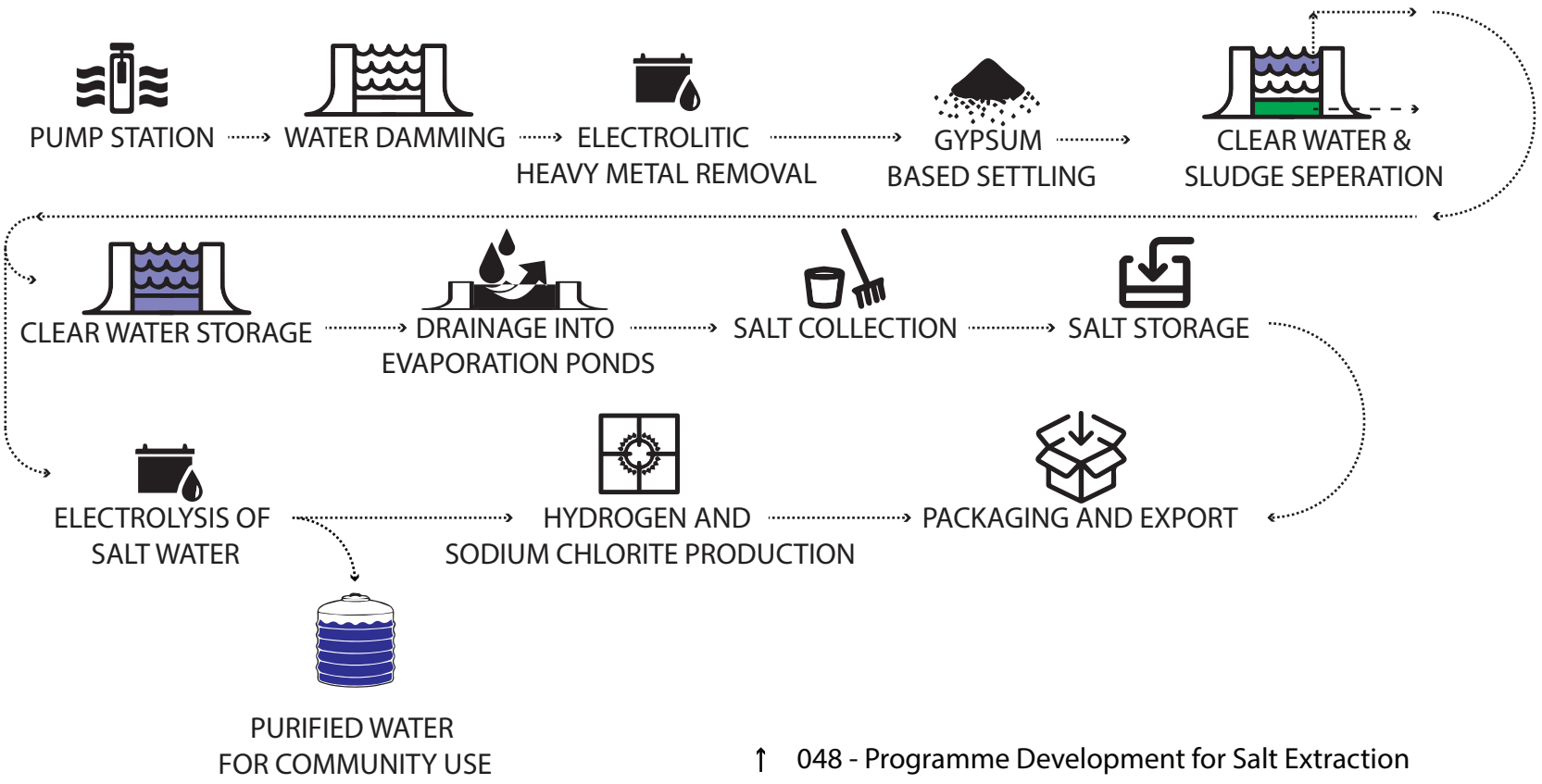
①

WATER EXTRACTION AND DAMMING PROCESS

The process of electrolysis can also be used to pu y microbial contamination. This stage of purification would serve as the final stage before the water can be safely used by the Refilwe community. A research document and prototype produced by MIT showed "that shock ED can enable disinfection of feedwaters, as approximately 99% of viable bacteria in the inflow were killed or removed by our prototype." (Deng et al., 2015). "Shock ED", a system based on electrolysis, showed not only to be extremely effective as a water purification system but also an effective desalination system.

Due to the limit of knowledge expected of an architect on the matter of chemical settling, electrolysis and bioremediation, an architecturally designed laboratory programme will perform the appropriate tests needed to find the best methods of remediating the slime dam. This leaves the architect with the role of designing an architectural programme which can accommodate all the remeditative subjects covered within this document.

PREPOSED SALT EXTRACTION PROCESS - AS A DRIVER FOR ARCHITECTURAL PROGRAMME

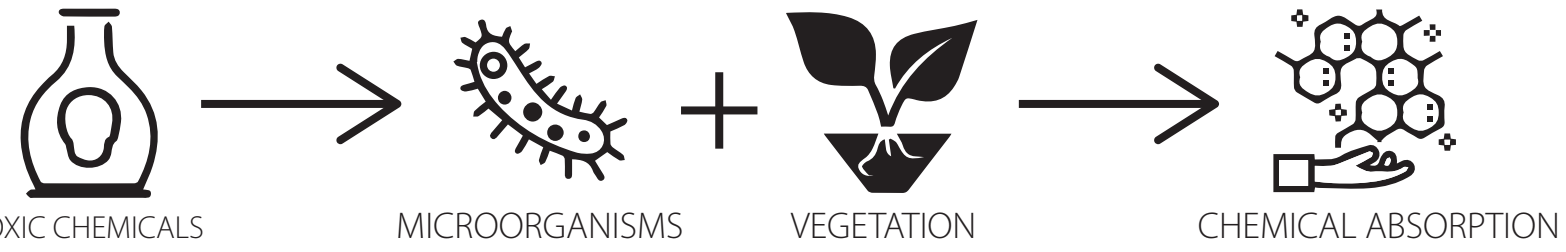


↑ 048 - Programme Development for Salt Extraction

3.2.1// REHABILITATION THROUGH BIOREMEDIATION

Bioremediation is a natural, and therefore passive, environmental rehabilitation method. The use of biological organisms and vegetation allows for contaminated soil or groundwater to be remediated through the natural process of chemical absorption (van Heerden et al., 2017).

In nature, microorganisms and vegetation naturally absorb and process chemicals, as part of nutrient uptake. Bioremediation takes advantage of this system by choosing microorganisms and vegetation that are particularly resilient to damage by polluting chemicals. Suitable biological agents must be chosen as not all microorganisms and species of vegetation are resilient enough to survive severely contaminated soils or water sources. In this document focus will be placed on a bioremediation method called Phytoremediation which utilizes various species of vegetation and not the many microbiological methods of rehabilitation.

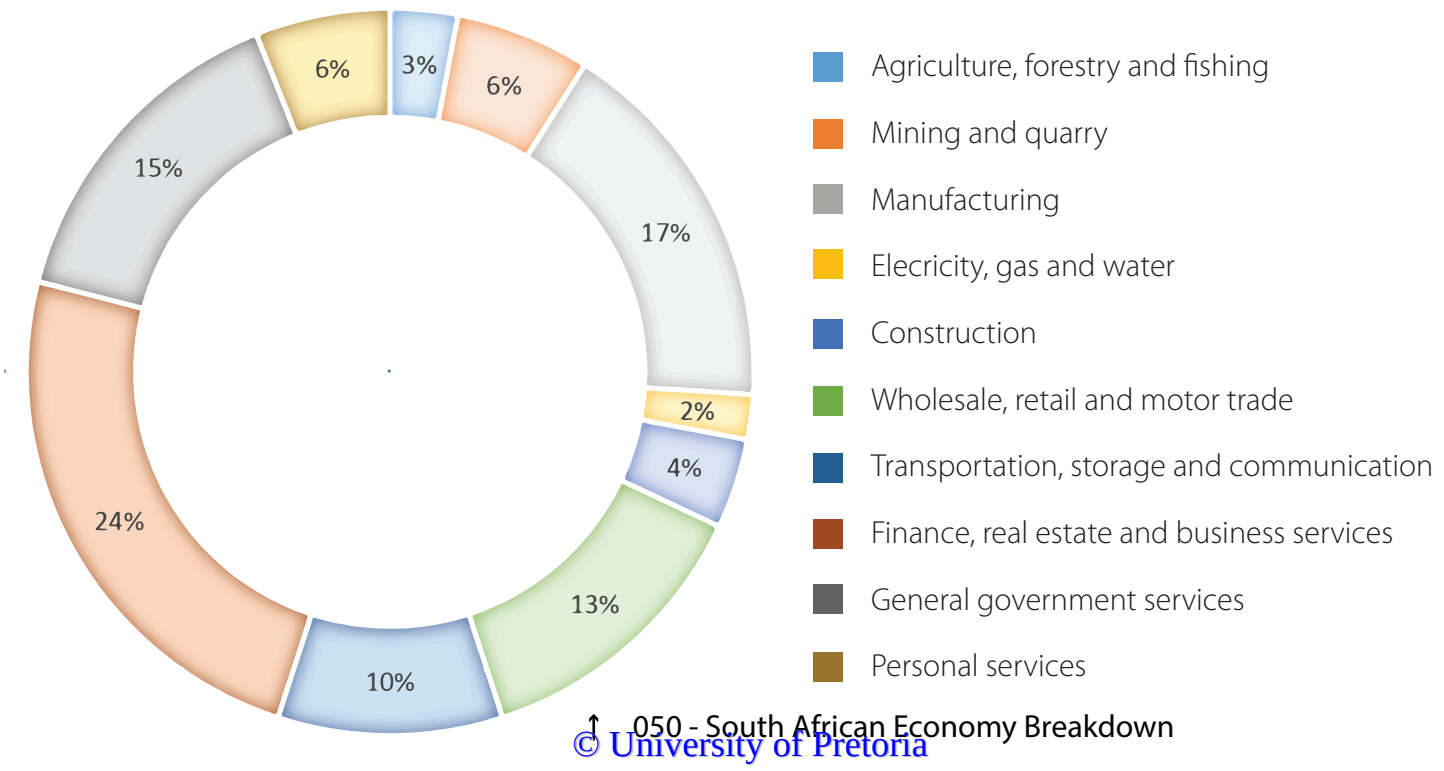


↑ 049 - Bioremediation Principles

Architecture sites are too often sites of addition without mutualism. In the case of sites located on, or adjacent to, industrial programmes, such as mining, structures are too often used to cover damaged land instead of rehabilitate it. This document aims to provide an architectural approach to rehabilitating both man and nature . In South Africa the primary method of remediation is one which consists of physical and industrial chemical processes (van Heerden et al., 2017). These technologies have been proven effective over decades of testing and implementation but require hugely expensive facilities with singular programmes. Physical remediation facilities are not only costly, but they require operation by employees with a high level of education that involves possible exposure to toxic chemicals. This method of chemical "clean-up" may regenerate the site aided by such an industrial programme, but can put other areas at risk due to the large volume of waste produced (Ibid., 2017). This makes bioremediation not only more cost effective bust also more environmentally sustainable. Bioremediation adds the additional opportunity for job creation, as the number of people currently employed in, biological, remediation strategies in South Africa is very limited.

Bioremediation techniques allow for onsite treatment of polluted lands or water bodies, reducing risks and costs associated with transportation of chemical waste materials. Bioremediation produces greatly reduced volumes of waste product, and the waste which the process does create, can be either utilized for other purposes, such as fertilizers, or disposed of with very little environmental risk. Public support of bioremediation is often much greater than industrial methods due to the inherent green nature of the process, as well as the reduced technical knowledge required to understand the methods used (van Heerden et al., 2017).

Phytoremediation as a means of regeneration has much architectural theory supporting its benefits, but as a practical architectural implementation, one would be hard fetched to find a precedent which shows success. This statement must be clarified somewhat; due to the wide range of uses of Bioremediation. Many architectural projects include biological remediation elements, but they are mostly used to clean water from less polluted sources, than that of industrial zones, and are more often used as mere storm water control mechanisms. With more implementation into zones of industry, bioremediation can not only serve as a rehabilitation agent, but the more often biological remediation methods are used, the more data there will be to study its effectiveness treating various level and types of toxic elements. The inclusion of architects and architectural approaches, such as bioremediation, into industry should be considered to be of the utmost importance. This rings particularly true in countries, such as South Africa, which have a large proportion of its economy based on various levels of industry (Laing, 2013).

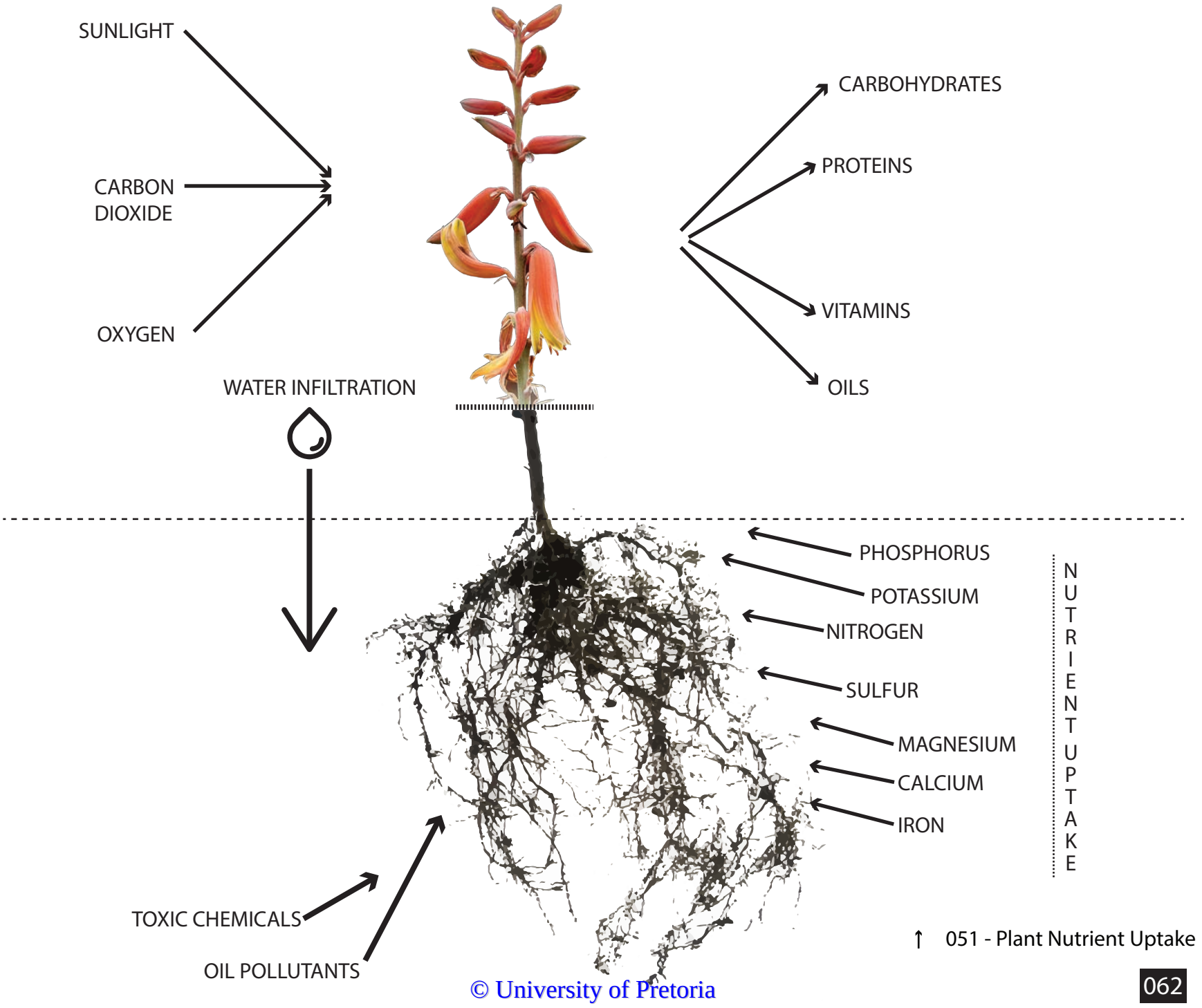


↑ 050 - South African Economy Breakdown

Various plant species have been tested and proven to be resilient candidates for Phytoremediation. Three main categories influencing vegetation species choice will be considered. The first and primary consideration would be one of effectiveness in toxin absorption. This is of importance as toxin absorption abilities varies greatly between species and even subspecies. It is important to consider the type of pollution and their connected toxins, as plants survival and absorption abilities differs between types of pollutants and their toxins (Galon et al., 2017). Where one species of vegetation may survive, another my struggle to propagate or very possibly not propagate at all.

The second set of considerations deals with a subset of species choice; which considers whether to introduce indigenous species or use species isolated from other areas, possibly international, that have shown a high level of effectiveness in Phytoremediation strategies. As described in a publication by University of the Free State, if non-indigenous species are introduced, the process is referred to as bio-augmentation, whereas the introduction of indigenous species which are "encouraged to proliferate by the addition of extraneous electron donors or electron acceptors," the process is referred to as Biostimulation (van Heerden et al., 2017). The publication elaborates on the beneficial nature of using indigenous species, due to their already stabilized adaptation to the environment, and ultimately lower costs involved due to elimination of various cost factors such as importation, transportation and still possible adaptation failure. Various other concerns are associated with the introduction of alien species, which will not be discussed in detail but must be mentioned. These concerns include, "serious ecological, economic and social consequences result from the invasion of natural ecosystems by foreign biological organisms," (Musil et al., 2007).

The third criteria which must be considered is potential interaction of a community with the chosen vegetation. This is possibly the most important consideration, even with bioremediation effectiveness as a criteria, due to the possible use of the vegetation by any individual or community. This is of particular importance when the vegetation of choice is a recognizable crop species. Many studies have been performed on the effectiveness of harvestable crop species and many of these species have been isolated as particularly effective for use in Phytoremediation. The major concerns associated with the implementation of harvestable crops is the possible residual toxic chemicals which may exist in the plant after remediation of polluted areas. One cannot simply plant an edible species of vegetation, such as corn, as a Phytoremediation species. The vegetation in question must have undergone laboratory tests; which were grown in samples of the said-contaminated water or soil, and proven to be safe to consume. If the laboratory tests results determine the crops as inedible, after utilisation as a Phytoremediation species, the tested crop must not be implemented as the risk of individuals accidentally consuming the crop is too high. This is of particular importance to architectural projects which are accessible by the public, but not limited to them. Corporate employees may not always have the same level of awareness with regards to information provided by a particular employer.



↑ 051 - Plant Nutrient Uptake

FORBS TRADITIONAL USES

ACALYPHA INDICA
Emitic (Induce Vomiting), Purgative (Laxitive), Vermifuge (Kills parasitic worms) and Scabicide (Kill scabies mites).

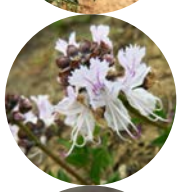
ACHYRANTHES ASPERA
Kidney Disease, Cholera, Heavy Menstration, Piles, Spleen Enlargement.

ADENIA DIGITATA Extremely Toxic
Reduce swelling, Treat various skin ailments and Treat ulcers.

ALOE DAVYANA
Treatment for: Arthritis, Skin Cancer, Burns, Eczema, Digestive problems, High blood pressure and Diabetes.

ALOE PRETORIENSIS
Rare in Gauteng Area.
No known medical use.

ANTHOSPERMUM HISPIDULUM
Threatened Species.
No known medical use.



BECIUM OBOVATUM
Streatment for: Stomach complaints in children, Enemas, and generally as a hair-restorer.

BERKHEYA SEMINIVEA
No known medical use.

BIDENS PILOSA
Shoots and Leaves: Sauces and Teas Inflammation, Immunological disorders, Digestive disorders, Infectious diseases

BOOPHONE DISTICHA Extremely Toxic Roots
Treatment for Babesiosis is a malaria-like parasitic disease.

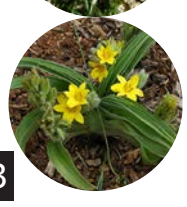
CHEILANTHES HIRTA
Treatment for: Colds, Sore throats and Asthma, whilst the powdered rhizome is used as an anthelmintic for tapeworms.

CHENOPODIUM ALBUM
Treatment for: Bug bites, Sunstroke, Urinary problems, and Skin problems.

CLEOME MACULATA
Leaves - cooked and eaten as a vegetable.

CRABBEA ANGUSTIFOLIA
Treatment for: boils.

HELICHRYSUM RUGULOSUM
Treatment for: Coughs, Colds, Fevers, Infections, Headaches and Menstrual pain.



HYPOXIS HEMEROCALLIDEA
Treatment for: Urinary tract infections, Heart disease, Infertility and Anxiety.

GRASSES TRADITIONAL USES

ARISTIDA TRANSVAALENSIS
Used in the making of brooms.

CYMBOPOGON VALIDUS
Oils used as a natural perfumery in a wide range of compositions, therapeutic qualities and Anti-Inflammatory.

DIGITARIA ERIANTHA
Used for Hay production and can withstand very heavy grazing.

DIHETEROPOGON AMPLECTENS
Used for Weaving and Thatching.

ERAGROSTIS CURVULA
Used for Hay production and is recognized as one of the best erosion control grasses.

ERAGROSTIS LEHMANNIANA
Used as a lesser forage grass.

ERAGROSTIS CURVULA
Used for Hay production and is recognized as one of the best erosion control grasses.

ERAGROSTIS RACEMOSA
Used as groundcover for over grazed areas and helps in prevention of soil erosion.

HARPOCHLOA FALX
Used Aesthetically in Flower Arraignments.

HETEROPOGON CONTORTUS
Planted for erosion control and revegetation of degraded habitats. Serves as Treatment for burns and wounds.

HYPARRHENIA HIRTA
One of the most popular thatching grass, also used for weaving mats and baskets.

IMPERATA CYLINDRICA
Flowers and the Roots are used as an antibacterial, diuretic, and restorative tonic.

LOUDETIA-SIMPLEX
Used domestically as thatching and for broom production.

MELINIS REPENS
Used as pasture grass and ornamental plant.

SETARIA SPACHELATA
Used as a forage grass and is used heavily grazed areas.

THEMEDA TRIANDRA
Known as a very important and well-known grazing grass.

INTERNATIONAL SPECIES

The Game of Diminishing Returns will investigate both the bioremedial potential of local plant life and international plants. Extensive research has been produced on the effectivity of the International species listed, whereas the effectivity of local flora as a bioremedial agent has not. The Agricultural Laboratory will endeavor to establish the local flora's potential for bioremediation.


PTERIS VITTATA - CHINESE BRAKE


HELIANTHUS - SUNFLOWER


AGROSTIS CASTELLANA - HIGHLAND BENT GRASS

ARSENIC

CHROMIUM


THLASPI CAERULESCENS - ALPINE PEN-


SPIRODELA POLYRHIZA - GIANT DUCKWEED


SHEEP FESCUE - FESTUCA OVINA


BRASSICA JUNCEA - CHINESE MUSTARD


COMMON WHEAT - TRITICUM AESTIVUM


BRASSICA OLERACEA - WILD CABBAGE

LEAD

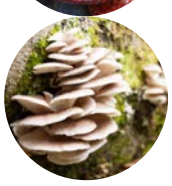
MERCURY


ARMERIA MARITIMA - SEA THRIFT


RAPESEED - BRASSICA NAPUS


SALIX - WILLOW


GANODERMA LUCIDUM - RED REISHI


PLEUROTUS OSTREATUS - OYSTER MUSHROOM

HYDROCARBONS

PETROLEUM

COPPER
IRON
ZINC
CADMIUM
NICKEL
BORON


NICOTIANA GLAUCA - WILD TOBACCO

Particular ability to absorb explosive related chemicals


EICHHORNIA CRASSIPES - WATER HYACINTH

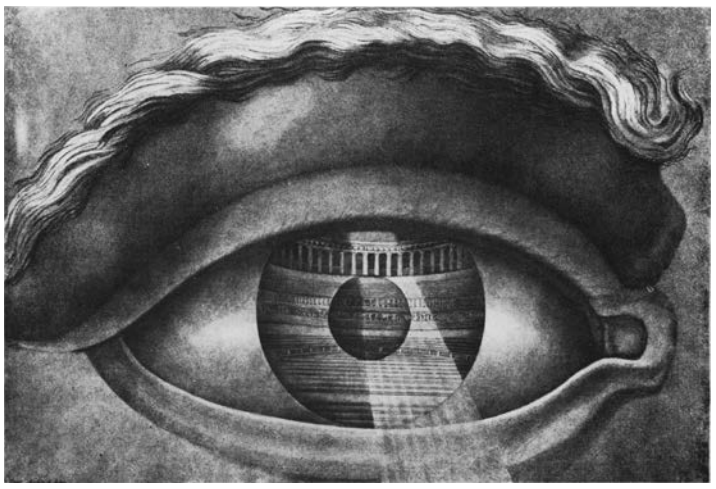

GLYCYRRHIZA LEPIDOTA - AMERICAN LICORICE

SODIUM

SODIC SOILS

↑ 053 - Bioremediation Plants / International Precedents

3.3 // ARCHITECTURAL THEORY SEGMENT



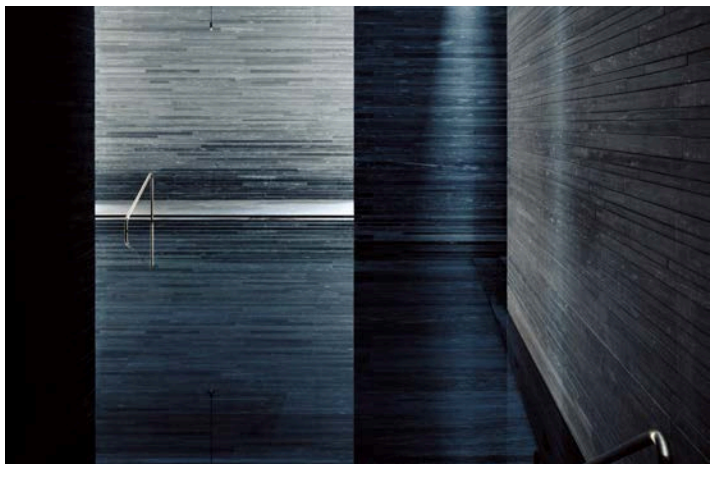
↑ 054 - Eye Reflecting the Interior of the Theatre of Besancon. (Pallasmaa, 2012)

"The flatness of today's standard construction is strengthened by a weakened sense of materiality." (Pallasmaa, 2012)

↑ 055 - Lonely Metropolitan. (Pallasmaa, 2012)

The epidermis: the largest organ of the human body. Juhani Pallasmaa beautifully articulates the role of touch in his publication The Eyes of the Skin, *"touch is the sensory mode that integrates our experience of the world with that of ourselves. Even visual perceptions are fused and integrated into the haptic continuum of the self; my body remembers who I am and where I am located in the world"* (Pallasmaa, 2012)

An architecture of formal restraint with a rare sensuous richness addressing all the senses simultaneously.

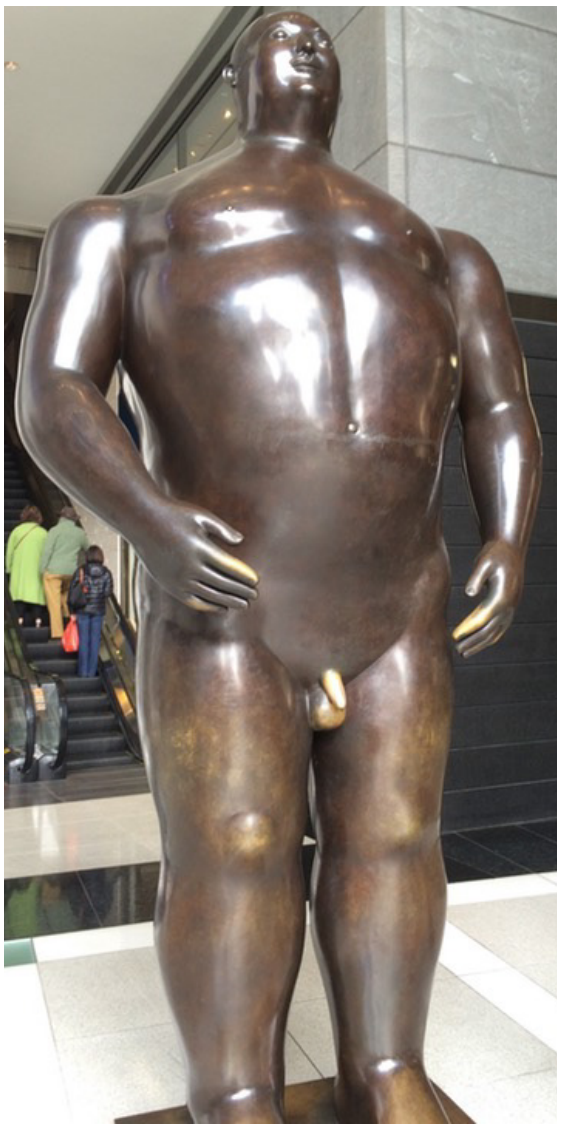


↑ 056 - Peter Zumthor -Thermal Baths. (Kohli and Alsane, 2016)

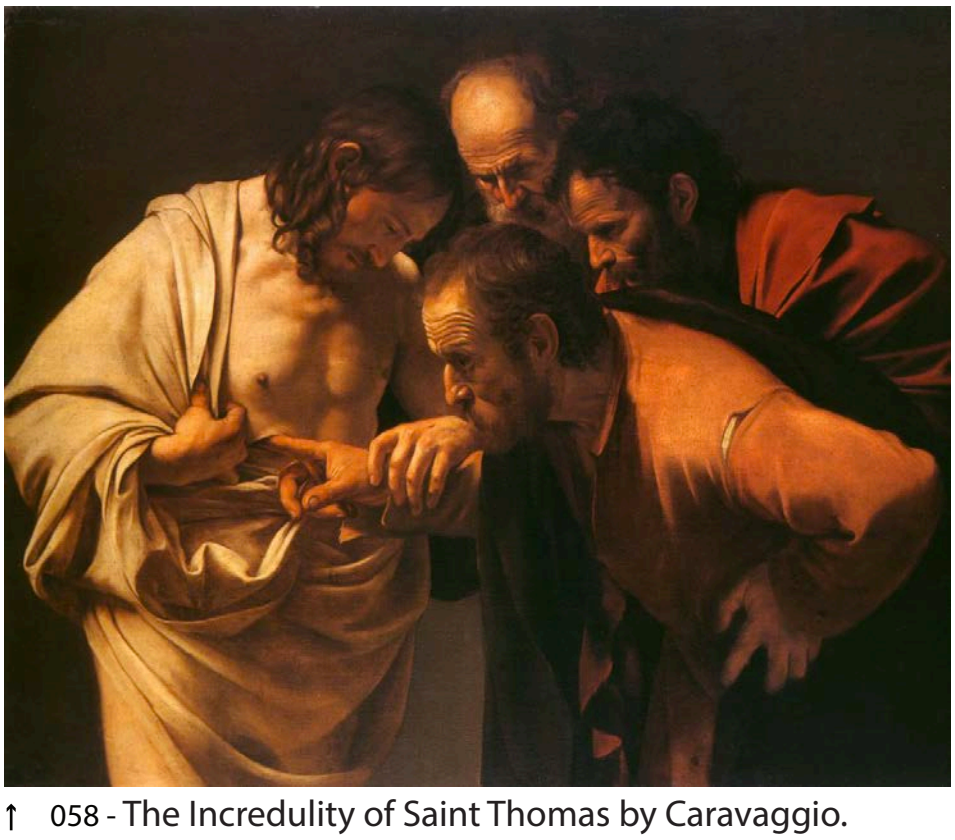
Pallasmaa suggests that, *"natural materials"* like *"stone brick and wood", "allows our vision to penetrate their surfaces and enable us to become convinced of the veracity of matter."* (Pallasmaa, 2012)

Pallasmaa illustrates the importance of multisensory experiences with regards to the built environment and as a defense of his argument, Pallasmaa cites an excerpt from a poem by German poet and writer Johann Wolfgang von Goethe, which reads: *"the hands want to see, the eyes want to caress"*, (Goethe, 1870) translated from: Römische Elegien und Venetianische Epigramme. Shamim argues that this detachment from the other senses results in the being no emotional dialogue with architecture. (Shamim, 2016) Pallasmaa refers to the eye as, *"nihilistic or narcistic"*. (Pallasmaa, 2012)

Without materials which can amuse our senses, the user of a structure becomes deprived of sensory stimuli. Pallasmaa continues to argue that natural materials are excellent at expressing their age, their origins and their history of human use. Additionally the continual contact with users adds a patina of wear, which adds to the possibility of enriching user experiences.



↓ 057 - Adam and Eve by
← Fernando Botero. (Crawford, 2009)



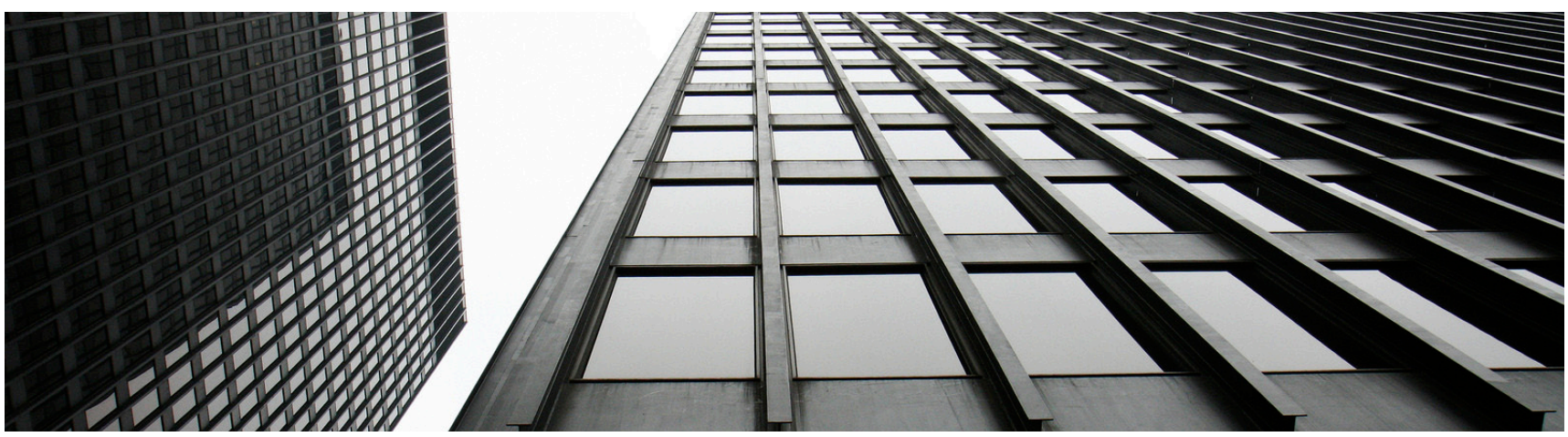
↑ 058 - The Incredulity of Saint Thomas by Caravaggio. (Pallasmaa, 2012)

The author continues to argue that the sensory deprivation caused by Ocularcentrism has left our *"memories, imaginations, dreams homeless."* (Pallasmaa, 2012)

Pallasmaa argues that architecture has become c ming only a visual stimuli and nothing more.

↑ 059 - Corning Museum of Glass Contemporary Art + Design Wing - Thomas Phifer and Partners. (Wood, 2017)

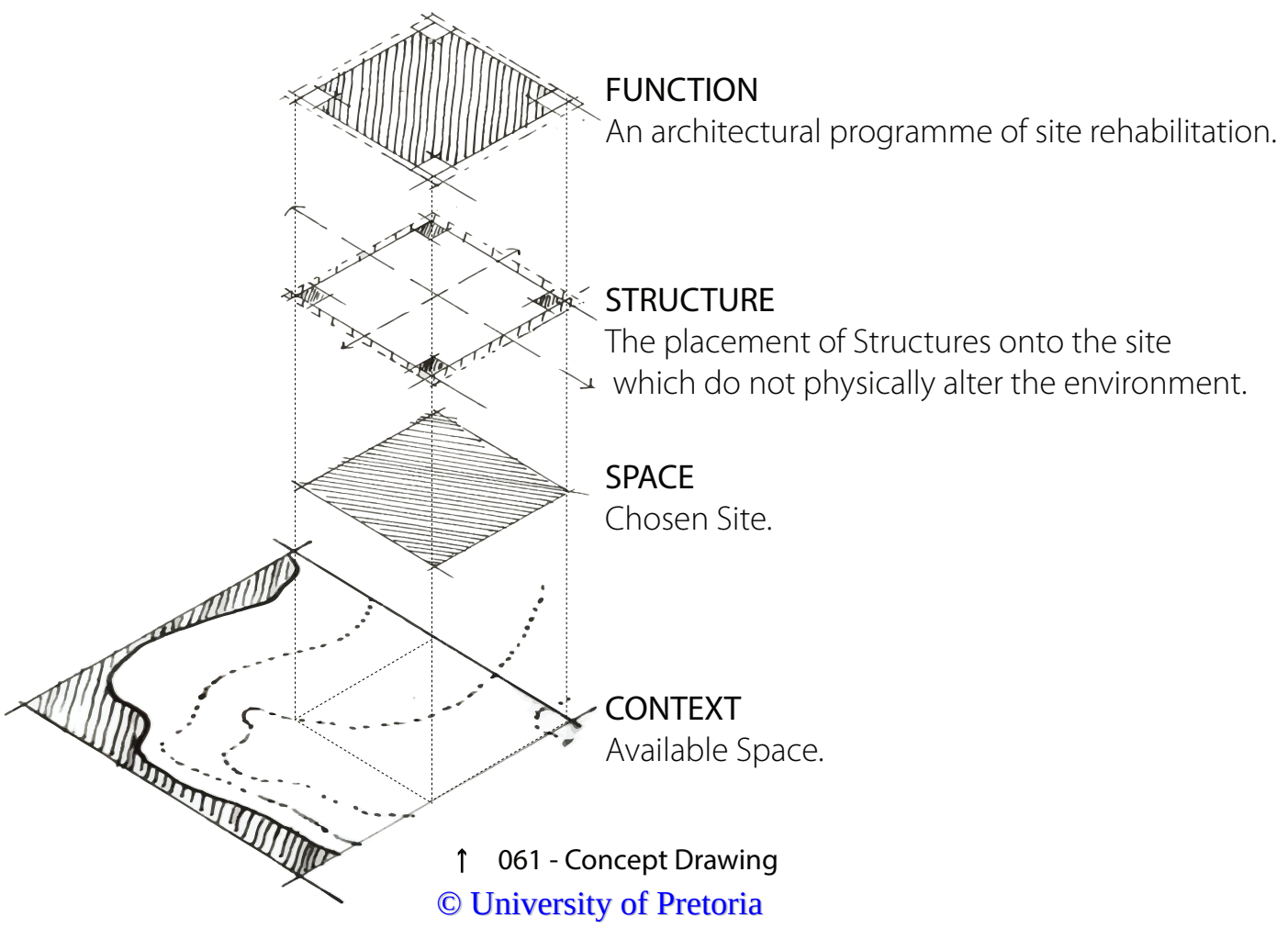
Machine made materials, such as *"scaleless sheets of glass, enamelled metals and synthetic plastics"* lend no hand to the sensory connection of users of a space and conform to our design eras deliberate aim in achieving ageless perfection. Pallasmaa defines this need for material perfection as a coping mechanism, relating to wear and aging of materials, with regards to our fear of death.



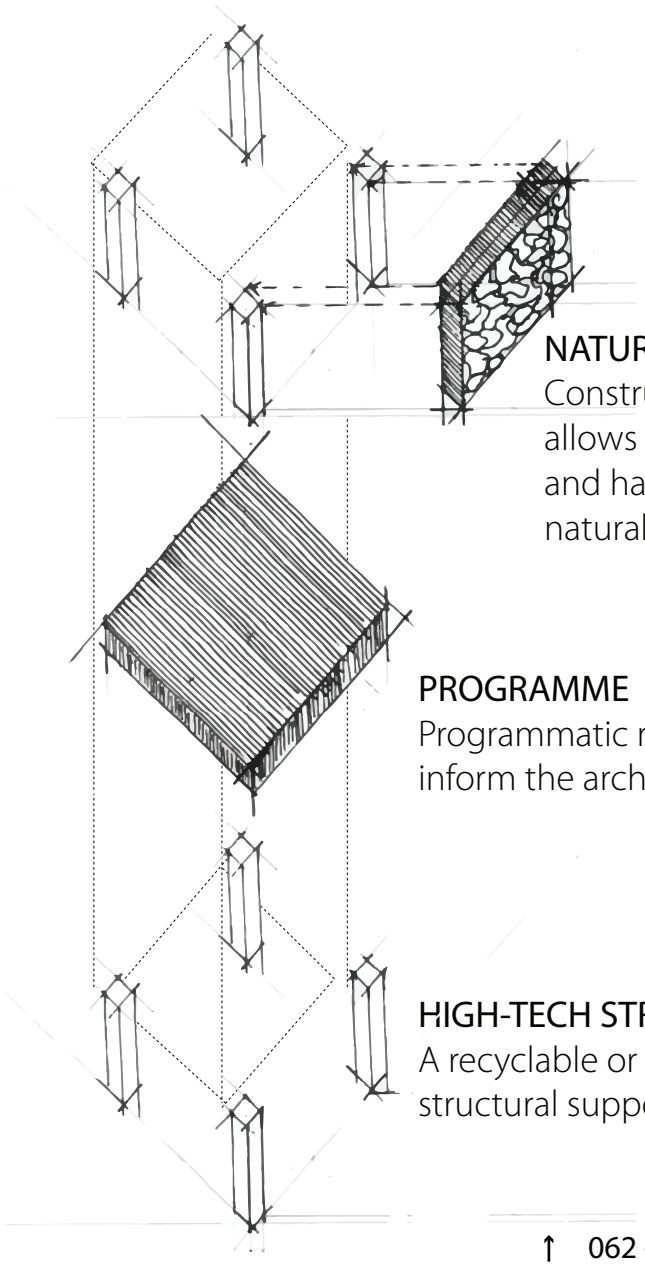
↑ 060 - Chicago Federal Center - Mies van der Rohe. (Monchaux, 2017)

The importance of sensory connection within an architectural environment and the use of materials which enable it, is an extremely important consideration in the design of The Game of Diminishing returns. Modern materials, which have only come about in recent times, due to advancements in material research and production, are often the choice materials when designing architecture. This is due to their enhanced properties and material longevity. The use of these advantageous new materials creates the distinct possibility that the system my fall into the aforementioned problem of ageless perfection. It will be a significant design challenge to integrate such materials, and the systems they form part of, into a structure which can create a sensory connection which does not disconnect the user from nature entirely.

The Game of Diminishing return's design is based on an architecture of impermanence. The programs which form part of the Game of Diminishing returns aim to rehabilitate slime dam no.7 and its surrounding environment; without permanent structures imposing themselves on the landscape long after the program is no longer required. Thus the choice of materials and structural design will be one which allows for recycling of the structures materials. Where material recycling is not possible, the chosen materiality will be one which can disintegrate into the environment with no polluting effects.



↑ 061 - Concept Drawing



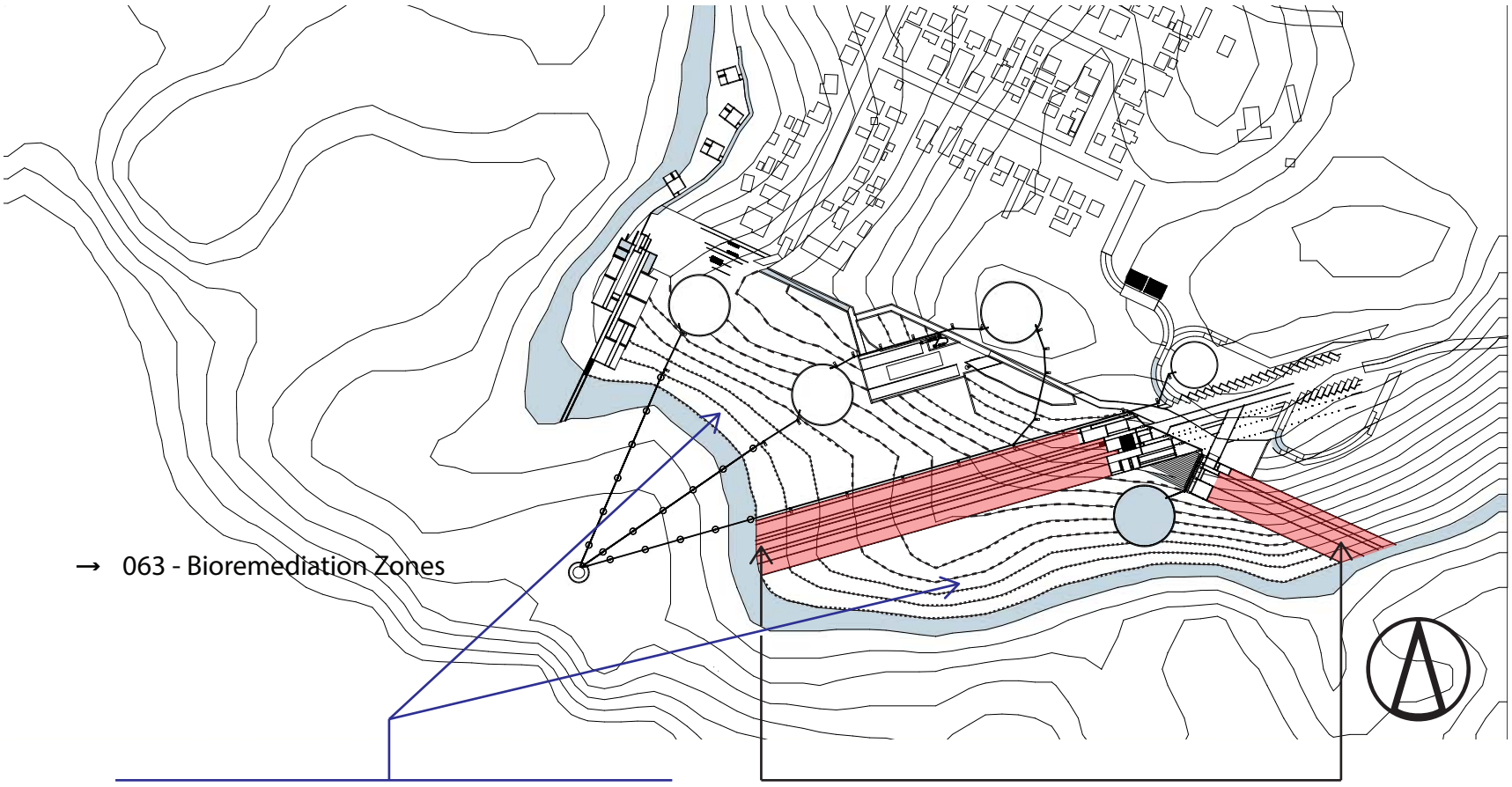
↑ 062 - Concept Drawing 2

The architecture of the Game of Diminishing returns may be designed to eventually disintegrate or be recycled, but it must remain material sound until its programmatic requirement have been met. Thus a delicate balance must be struck between permanence and impermanence.

3.3.2// SPACE VS. PROGRAMME

Material quantities are important factors in considering the impact of an architectural intervention. Superfluous material usage leads to an architecture of excess. The smaller the physical scale of an architectural intervention the less materials are required for the structure. The Game of Diminishing Returns, as previously mentioned, aims to utilize materials found onsite, to reduce the costs and carbon footprint involved in the transportation of goods. Additionally the Game of Diminishing Returns has been designed to accommodate its programme in as small a physical area as possible. Compact arrangement of programme allows for a significant reduction in material usage.

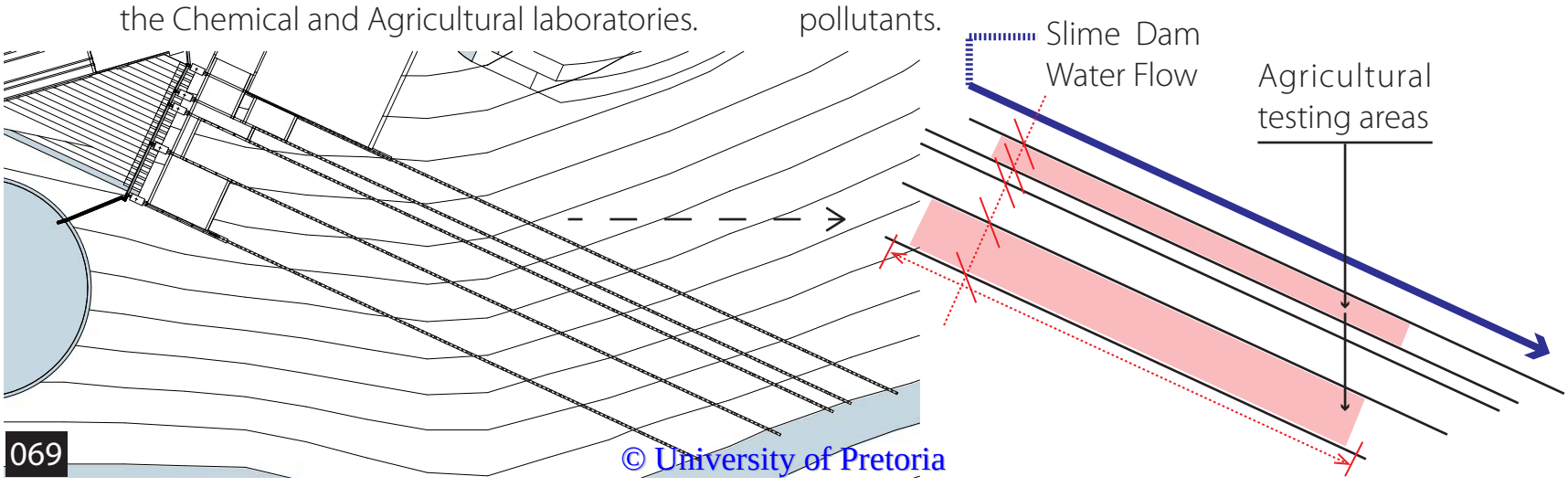
The largest proponent of the architectural programme, consisting of the three research laboratories, is the bioremediation testing areas. The zones of bioremedial testing form part of the sites landscape, using the sites natural contours as boundaries. In addition to the use of natural site elements, the introduction of physical ribs into the landscape, will serve as a scientifically testable area of the bioremedial effectiveness of certain species.



→ 063 - Bioremediation Zones

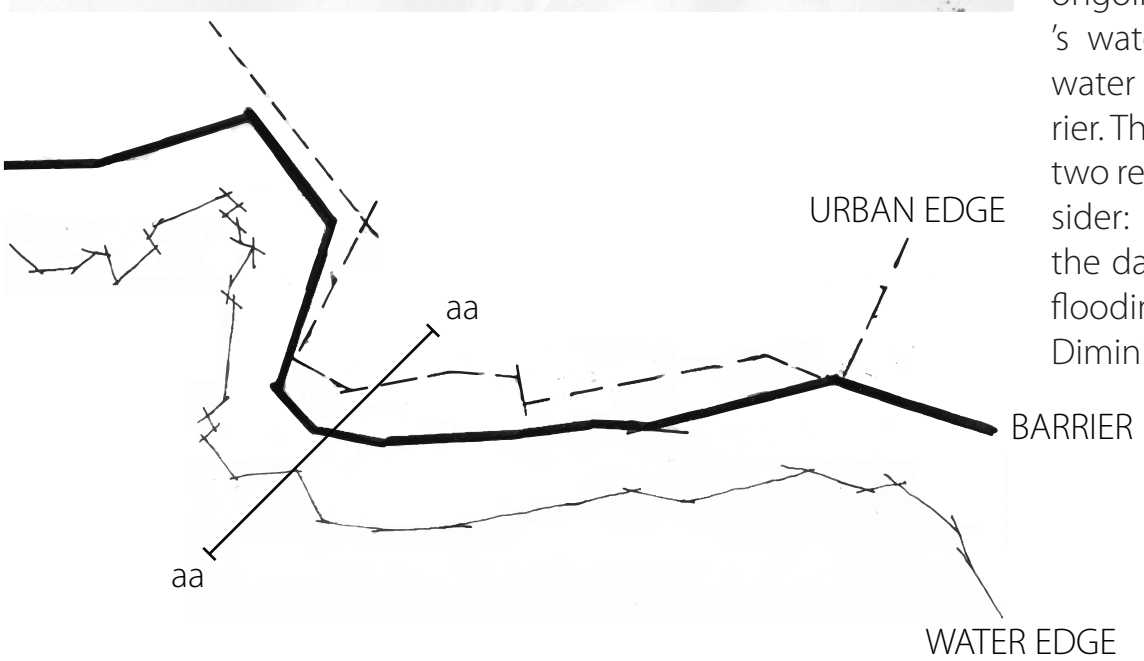
Agricultural zones of Bioremedial testing.
Various bioremedial species are planted following natural contours. Crops and plant species are to be harvested and tested by the Chemical and Agricultural laboratories.

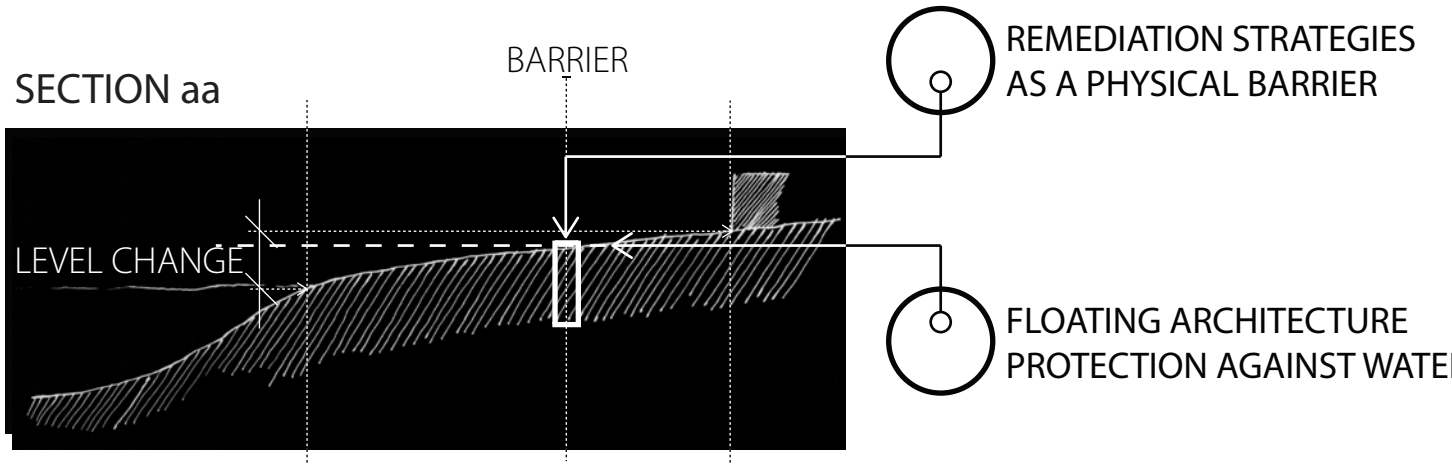
Scientific zones of Bioremedial testing.
Varying lengths and widths between ribs allow for testing the affectivity of various plant species' ability to absorb chemical pollutants.



3.3.3// ARCHITECTURE AS A BARRIER

The word "barrier" refers to various elements which form part of the Game of Diminishing returns; of both of a natural and architectural nature. The first barrier comes in the form of level change (Natural), which limits waters ability to infiltrate soil due to downwards gravitational pull on the water molecules. The second is an architectural barrier, which in itself can be broken up into two parts: Physical (Bioremediation) and Research based (Laboratory Programme). Due to the ongoing nature of the mine, slime dam no. 7 's water level will rise. This may push the water level past the current level change barrier. This future change in water level outlines two requirements for the architecture to consider: a new protective boundary between the dam and Refilwe, and the prevention of flooding into the structures of the Game of Diminishing returns.



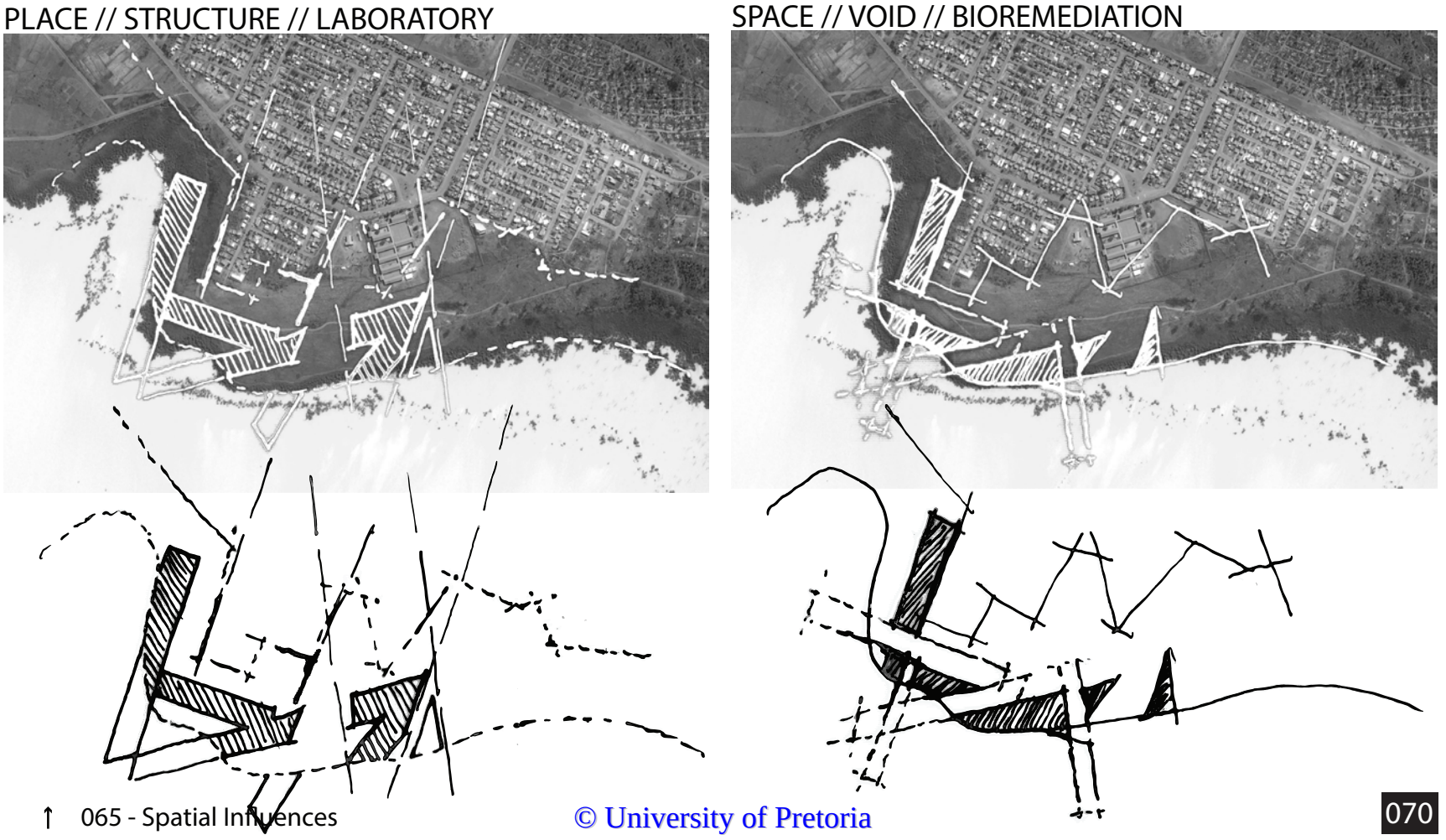


↑ 064 - Concept Drivers

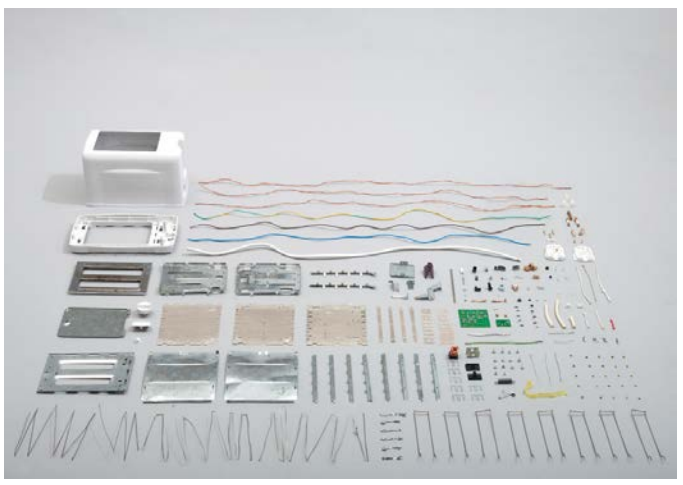
3.3.4// PLACE VS SPACE

PLACE // STRUCTURE // LABORATORY

SPACE // VOID // BIOREMEDIATION

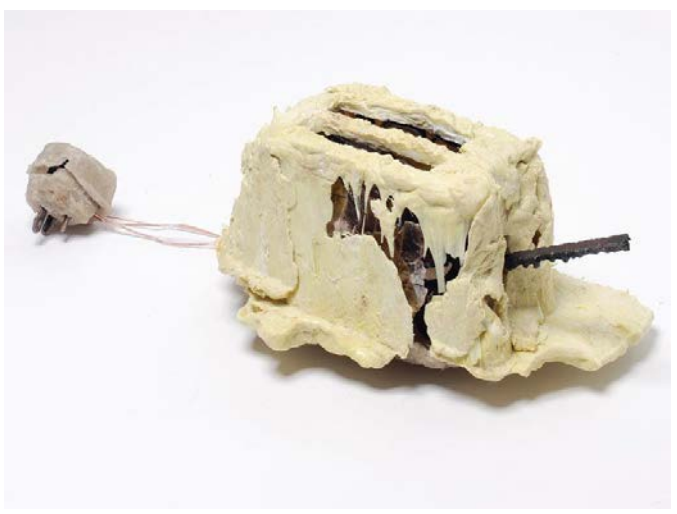


↑ 065 - Spatial Influences



↑ 066 - A deconstructed toaster. All the parts that make a whole. (Thwaites, 2011)

"Yes, I'm going to make a steel spring to pop the toast up," and "Yep, I'm going to make all the electronics from scratch too...refining crude oil to make plastic? No problem, I'll just use a cooking pot." (Thwaites, 2011)



↑ 067 - My Toaster. (Thwaites, 2011)

"My attempt at making a toaster myself, from scratch, has been wildly, absurdly, outrageously 'inefficient'." "My toaster cost 250 times more than the ones from Argos..." "And the carbon footprint must be huge, at least a size 14 (European size 48)." (Thwaites, 2011)

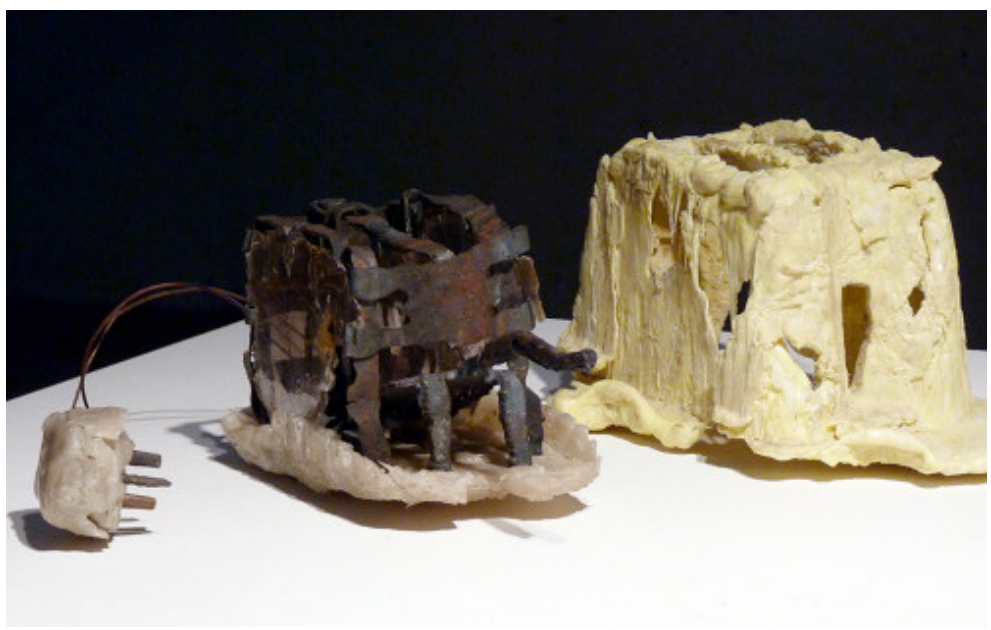
↑ 068 - Picasso Quote by Banksy. (Jencks, 1971)

"I don't believe in God, but I don't believe in man either. Humanism has failed. It didn't prevent the monstrous acts of our generation. It has lent itself to excusing and justifying all kinds of horrors. It has misunderstood man. It has tried to cut him off from all other manifestations of nature." (Jencks, 1971)

ect: or a heroic attempt to build a simple electric appliance from scratch, a thesis and book - **Thomas Thwaites**

The integration of passive and active systems into architecture, in a manner that can create a symbiotic relationship, with construction and the user, is of great importance. Yet before the aforementioned criteria can be met, one must consider the greater implications associated with the manufacturing of a buildings components. The designer must consider the source of materials, used to create a structure, as well as the method of material production to ensure a structure will be beneficial to the natural environment and not just the user environment.

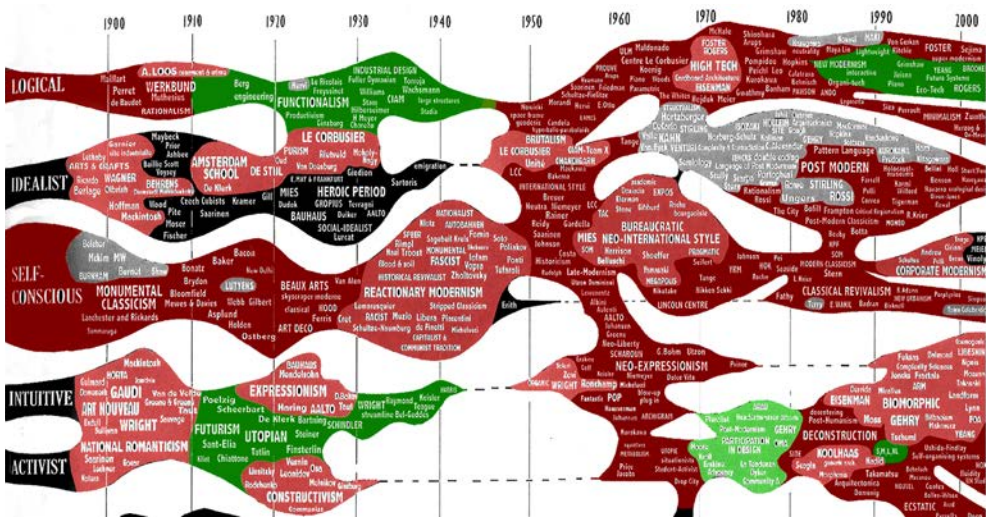
Thwaites Thesis explores the material origins of every component that a toaster consists of, to fully understand the material essence of such an everyday object and to furthermore discover the processes that these materials undergo to form part of a working whole. (Thwaites, 2011)



↑ 069 - My Toaster - Image 2. (Thwaites, 2011)

Architecture 2000: *Predictions and Methods* - **Charles Jencks**

There is an immediate and problematic consideration which must be outlined to ensure the affectivity of technology to form a symbiotic relationship with architecture. This is the problem of integrating components from other fields, which are blindly applied, to architecture to bring about a sense of transformation and progress. This problem is discussed in Architecture 2000 – Predictions and Methods by Charles Jencks, and the author states: *"The intuitive tradition, like the activist, is always looking outside architecture into other fields, hoping to find something it can borrow and re-use to transform the present. This continual ransacking of the cultural cupboard for anything pertinent obviously makes for eclecticism and a certain superficiality."* (Jencks, 1971)



↑ 070 - Charles Jencks, Evolutionary tree to the year 2000. (Jencks, 1971)

The method for determining the six major traditions is based on a structural analysis as outlined by Claude Levi-Strauss, without the claim to completeness which he makes. Some of the relations are obscured because the diagram is only two dimensional, but generally speaking the pulsations represent reversible time while the inventions and movements are irreversible.

3.4 // A CASE FOR MATERIALITY

MATERIAL & COMMUNITY INVOLVEMENT PRECEDENTS

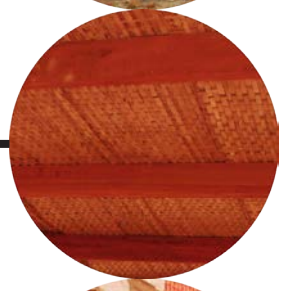
SRA POU VOCATIONAL SCHOOL
RUDANKO + KANKKUNEN ARCHITECTS

Sra Pou is a vocational training school and community Centre Located in Sra Pou village, Cambodia. The structure and associated program was designed by architects Rudanko + Kankkunen based in Finland. The structure was completed in 2011. The programmatic aim for the Sra Pou structure is to provide professional training that helps community members start successful businesses, while simultaneously providing space for public gatherings. (Frearson, 2017)

Due to the location of the Sra Pou village and structure, Rudanko + Kankkunen designed a structure which could be built from materials sourced within the surrounding area. The additional prerogative of the architects was to provide an educational training opportunity for community members, showing them how they can apply the same materials and construction techniques on future projects. (Frearson, 2017)

Soil blocks made up of onsite earth, compacted much in the same fashion as rammed earth would be produced. Ventilation is accommodated through the staggering of bricks.

Locally sourced materials not only form the structure but are also utilized to create tools to aid construction.



Various skills, including existing community skills or skills taught to the community are applied to the construction of elements such as woven ceilings.

Traditional construction methods are used with untraditional materials. Wall plates or cementious materials are omitted for a simplified mud mortar.

Floors are coated in a slurry of mud to create an evenly textured surface.

Stairs are created through extremely basic layering of the aforementioned bricks and layers of timber as treads.

↑ 071 - Photos of Project by Rudanko + Kankkunen. (Frearson, 2017)

↓ 072 - Analysis of Passive systems

Passive ventilation strategies are employed for internal cooling whilst simultaneously providing for water collection to take place. Collected water is used in agricultural areas around the structure during times of limited water.

THE THREAD CULTURAL CENTRE
TOSHIKO MORI ARCHITECTS

Tosjiko Mori architects designed the Thread, a Cultural centre for the residents of the remote village of Sinthian, Senegal. The structure is built exclusively from locally sourced materials. The structure houses various programmes, including; gathering spaces, a performance centre and residency space for visiting artists. The location of the Thread required integration with existing infrastructure, including: a clinic, a kindergarten and an agricultural school. (Griffiths, 2017)

Walls made from rammed earth and earthen blocks from boundaries for programmatic zones. The undulating thatch roof serves dually as cover (calculated to provide shade at the hottest times of day) for programmatic areas and as a water collection system. Collected water is stored in large reservoirs for use during the dry season, to sustain the agricultural training centre. (Griffiths, 2017)

Bamboo is utilized as a battening system for the roof. Acting as a support for thatch roofing.

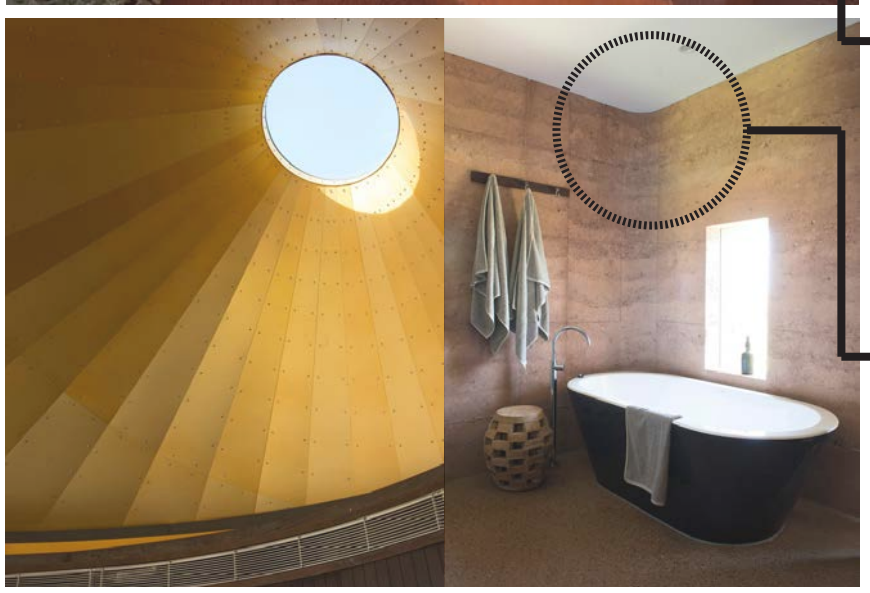
Broken floor tiles, from adjacent infrastructure, is utilized in a mosaic fashion to cover the floors.

Traditional thatch construction with added linear thatch elements to guide the collection of water.

Alternating brickwork allows for passive ventilation of programmatic areas.

↑ 073 - Photos of Project by Iwan Baan. (Griffiths, 2017)

↓ 074 - Drawing by Architects. (Griffiths, 2017)



Sydney firm Luigi Rosselli Architects were commisioned to design housing from seasonal employees on a Australian cattle station. The design of the twelve subterranean rooms are enclosed by a 230 meter-long wavy facade made of rammed earth. The layers of compressed earth, used in the construction of the rammed earth walls, is visiable both externally and internally. (Mairs, 2017)

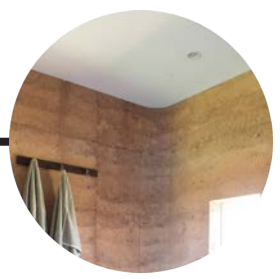
All materials for the rammed earth walls are sourced onsite, including grave from an adjactent river bed. The angular nature of the facade wall adds to the privacy of each residence. The use of untreated bronzed metal, adds to the natural palate used by the architects. (Mairs, 2017)

A small oval pavilion adds aditional programmes to the project, including; a meeting space for ranch hands and small chapel services. The structure is designed with thick rammed earth walls and a Corten steel roof to protect the strucutre from dust storms. (Mairs, 2017)

The utilization of various materials which share a common visual essence.

Seamless connection of Rammed Earth and Natural ground level.

Stairs acting as retaining elements to prevent erosion.

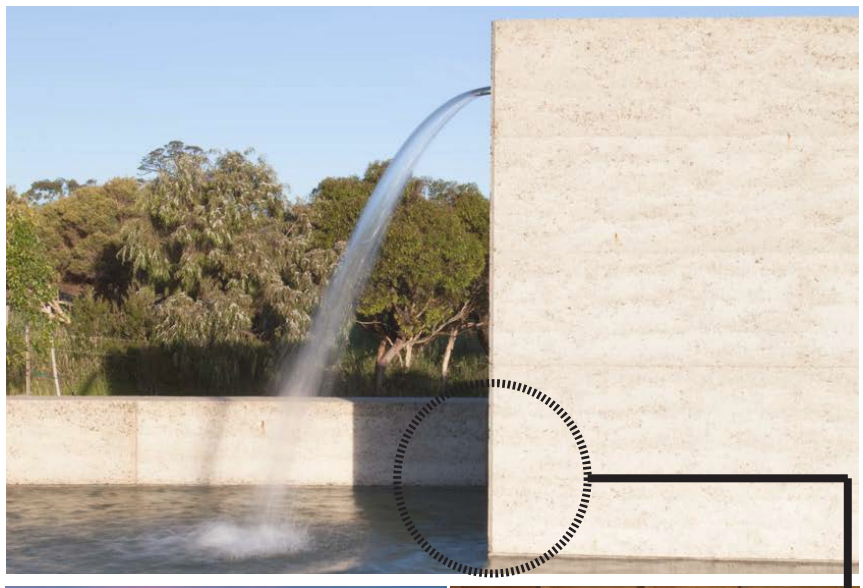


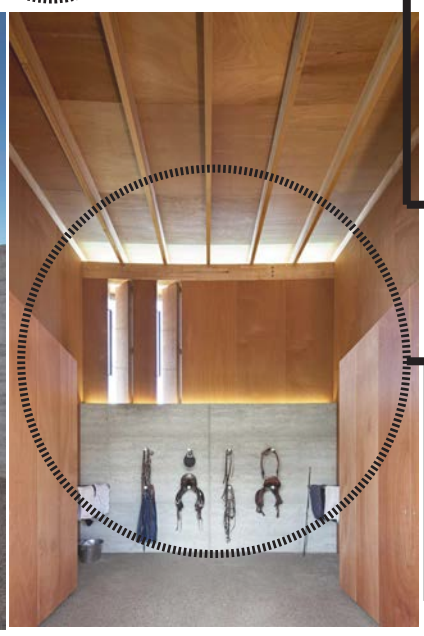
High level of detail resolution seemlessly blending raw material elements with highly finished elements.

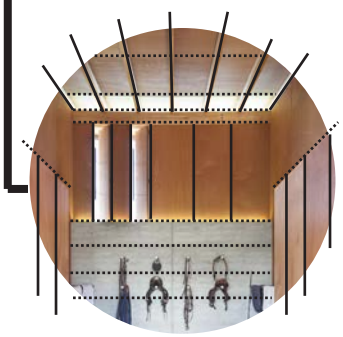
↑
↓ 075 - Photos of Project by Edward Birch. (Mairs, 2017)

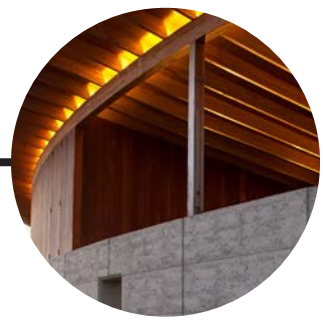
EQUESTRIAN CENTRE

SETH STEIN ARCHITECTS & WATSON ARCHITECTURE + DESIGN









Seth Stein Architects a London based firm and Watson Architecture + Design a Australian firm from Melbourne collaborated to design a rammed earth based equestrian centre. The equestrian centre is located on the Mornington Peninsula just south of Melbourne. (Frearson, 2017)

The rammed earth utilized, is reinforced to provide rigidity and improve longevity. Studio founders Seth Stein and Robert Watson, when interview said: "We are interested in working with ecological materials that will harmonise with the surrounding context and provide very little maintenance...", "Reinforced rammed earth – a low-moisture mix of natural soil and cement compacted around reinforcing bars – is used quite extensively in Australia and in particular in regional Victoria...", "It's more cost-effective than off-form concrete and, once a 600-millimetre tier of wall is compacted, the wall is structurally stable and able to take load, as opposed to a wet-formed concrete wall that typically requires 28 days to reach its design strength.". (Frearson, 2017)

The design utilized primarily timber framework construction where rammed earth was not used. Timber partition walls, inside the structure, offer a warm but stark contrast to the rammed earth. (Frearson, 2017)

Cement is added to reinforce the rammed earth and protect it from water damage. It is not visible in any project photos or drawing but an additional waterproofing must be present.

Crisscross patterning of materials adds to the visual proportions of the structure. Storage additions to the rammed earth shows a high level of detail resolution.

Connection of various materials is highlighted with material variations, visual proportions and level of detail resolution.

↑
↓ 076 - Photos of Project by Lisbeth Grosmann. (Frearson, 2017)