# Pretoria Works' latent potential 3

## 3.1 Introduction

The treated industrial waste water of Pretoria Works requires tertiary treatment before it can be used for agriculture, aquaponics and/or human recreational activities (see figure 3.2). The tertiary treatment that Pretoria Works currently uses is called RO, which is sufficient for recycling the water for industrial purposes, states Project Manager Johan van Rensburg, Pretoria Works (Personal communication, 12 February 2018). This treatment requires high energy consumption that is expensive (Rai 2009:704). This single and costly treatment approach has opened up an opportunity in the marketplace to investigate innovative technologies that are more cost-effective, such as those technologies that make use of living organisms to remove heavy metals. Phytoremediation is an example of such innovative technologies (Rai 2009:704-706).

## 3.2 Phytoremediation as a biological process

Phytoremediation is a relatively new approach to cost-effective treatment of waste water, ground water and soils contaminated by heavy metals. This approach uses plants to remove pollutants found in the environment (Rai 2009:705). Phytoremediation also uses aquatic vascular plants for treating heavy metals found in industrial effluents before the water is discharged into aquatic ecosystems (Rai 2009:711). The use of plants for remediation of metals offers an attractive alternative because it makes use of sunlight for growth and can be carried out in situ, thereby minimising costs and human exposure to tainted water.

However, phytoremediation through aquatic plants requires waste water treatment before the water can be tertiary-treated for future use (SALGA 2016:15)

Phytoremediation technology is comprised of:

- phytoextraction, in which metal-accumulating plants are used to transport and concentrate metals into the harvestable parts of roots and aboveground shoots;
- rhizofiltration, in which plant roots absorb, precipitate, and concentrate toxic metals from polluted effluents; and
- phytostablisation, in which mobility of heavy metals is reduced through the use of tolerant plants (Rai 2009:705-707).

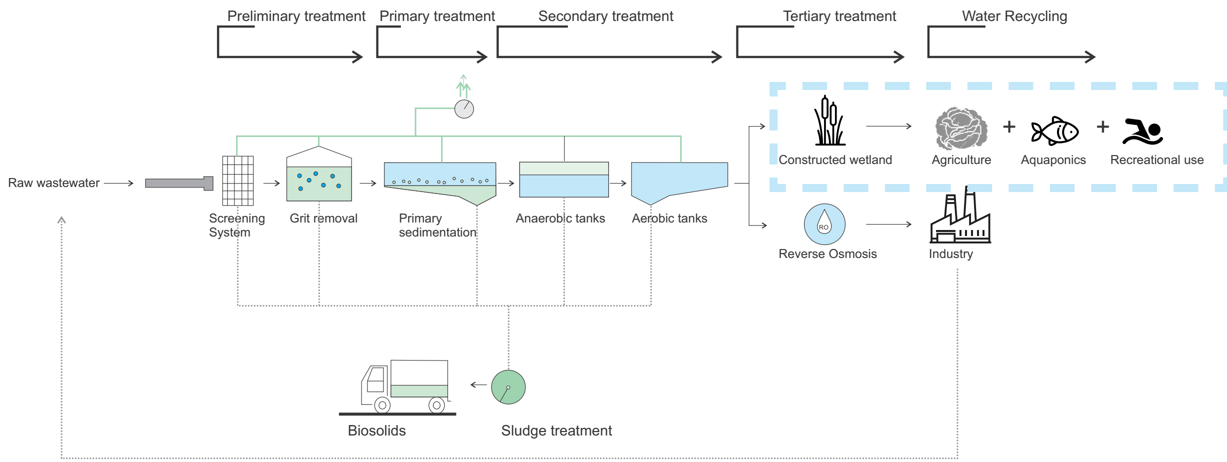


Fig 3.2 Tertiary (WWT) through constructed wetlands (Author 2018)

### 3.2.1 Phytoremediation in constructed wetlands attracting wildlife and people

Using waste water for additional use is not a new concept. The international firm, Integral Climate Change Solutions (ICCS 2018), which also operates in South Africa, suggests that designed landscapes can act as regenerative solutions within cities that can attract people back to recreational nodes. Their vision is a Climatic Park using wetlands through phytoremediation as polishing agents that cleanse waste water for future use (see figure 3.3).

The Climatic Park could result in a system that integrates aquaculture and agricultural functions, which, in turn, could provide job security. This system focusses on re-using the waste in the system that could help to promote a healthy environment for the local community (ICCS 2018). By so doing, the landscape may also work to make the community more resilient. Additional wildlife, tourism and investments could also help to further promote and sustain the newly created wetlands established in this Park (ICCS 2018).

The proposed intervention in this dissertation includes a similar wetlands-based approach. Wetlands are described as areas which are saturated, predominantly, with surface or ground water, and that support vegetation typically adapted for growing in saturated soil conditions (Arceivala & Asolekar 2007).

South Africa's wetlands could perhaps be its most valuable ecological infrastructure (van Vuuren 2014:22). These special ecosystems support water resources by purifying water and regulating flows; also acting as sponges that store water and release it slowly, thereby filtering pollutants and reducing the negative impact of droughts and floods in the process. Wetlands help to sustain a rich diversity of faunal and floral species, and support the economic activities of many rural communities through the provision of food and fuel (van Vuuren 2014:22).

The industrial waste water at Pretoria Works has the latent potential to be tertiary-treated through phytoremediation for future use. A regenerative system is, therefore, proposed for Pretoria Works that makes use of the treated water (see figure 3.2). The system functions as a landscape which encourages long-term sustainability that makes use of land-form, soil, water, plants and biological processes to achieve a productive landscape.

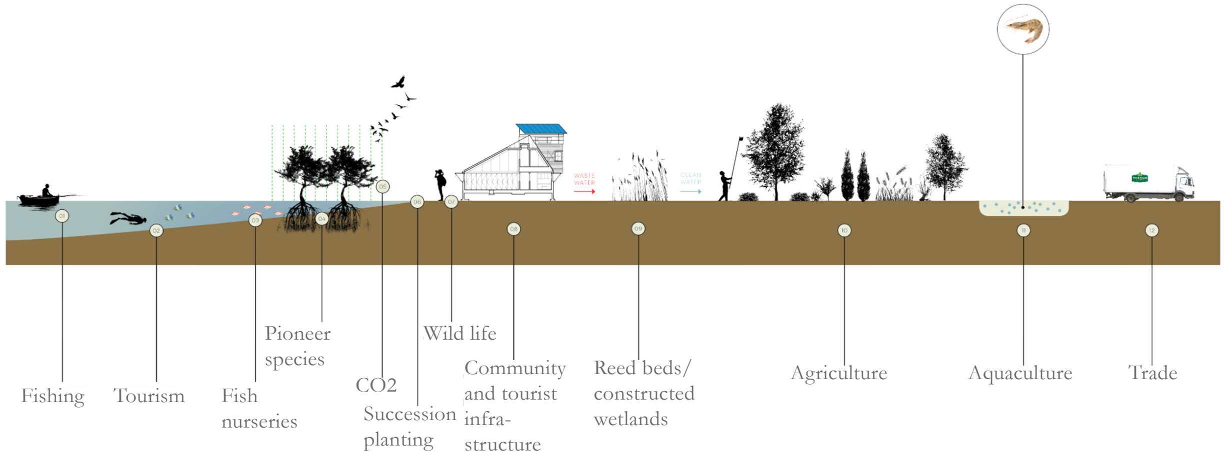


Fig 3.3 The Climatic Park (ICCS 2018)

## 3.3 Regenerative landscape

### 3.3.1 Agriculture through permaculture

Permaculture can be defined as: "consciously designed landscapes which mimic the patterns and relationships found in nature, while yielding an abundance of food, fibre and energy for provision of local needs" (Ferguson & Lovell 2014:252).

Critical considerations for a permaculture garden are related to the management of spatial and topographic relationships with each other, the use of windbreaks, the increase of storm water run-off filtration, contour cultivation, soil and water conservation and the planting of diverse 'nitrogen fixing plants'. Planting these plants (i.e. legumes, such as peas and beans) can improve soil management and conservation by enhancing the nitrogen level in the soil, and making use of crop rotation and planting companion crops that improve resistance to pests (Ferguson & Lovell 2014:264). Aquaculture through aquaponics requires water, not soil, and is discussed as a regenerative landscape in the next subsection.

### 3.3.2 Aquaculture through aquaponics

Aquaponics is an ecosystem that contains fish, plants, bacteria, as well as (sometimes) worms and other organisms growing together symbiotically (Thorarinsdottir 2015:9). The bacteria in the ecosystem convert the waste water produced by the fish into plant food, which means that the waste water is filtered before it returns back to the fish, thereby providing nutrients for plant growth (Thorarinsdottir 2015:9). The demand for aquaponics is significantly high because of its capability of producing fish and plants (e.g. vegetables, herbs, medical plants and fruits) in an environmentally-friendly system that can ensure high levels of water reuse and nutrient recycling (Goddek, Espinal, Delaide & Jijakali 2016:2).

Aquaponics systems can be described as:

…the cultivation of fish and plants together in a constructed, recirculating ecosystem utilizing natural bacterial cycles to convert fish waste to plant nutrition. This is an environmentally friendly, natural food-growing method that harnesses the best attributes of aquaculture and hydroponics without the need to discard any water or filtrate or add chemical fertilizers (Thorarinsdottir 2015:9).

### 3.3.3 Aquaponics requirements

Water is the most essential component of an aquaponics system as plants, fish and bacteria depend on quality water for their survival (ter Morshuizen 2018:31). Significant water quality variables are essential and necessitate proper management thereof. Maintaining high-quality water within an aquaponics system is fundamental to the well-being, sustainability and success of the system (ter Morshuizen 2018:31). The five key water quality parameters for aquaponics are: water temperature (above 12°C); dissolved oxygen (DO: > 5 mg/l); water acidity (pH: alkaline); nitrogen compounds (ammonia< <0.1 mg/l, nitrite <0.1 mg/l, nitrate 50 mg/l); and the electrical conductivity (EC: 400 µS) of the water. All these parameters require frequent monitoring. Each organism in the system (i.e. plants, fish and bacteria) has an ideal parameter range and requires specific management for its optimal growth. Additional water parameters, such as phosphorus and other macro- and micro-nutrients, carbon dioxide and total dissolved solids are essential, but can be measured once a week (Thorarinsdottir 2015:33).

The site selection for an aquaponics process is dependent on the location of the local market, as this location could influence marketing, transportation costs and the types of fish and vegetable species available for use (ter Morshuizen 2018:15). Other requirements for an efficient aquaponics system have to do with qualitative and quantitative water demands for fish, bacteria and vegetables growth. Temperatures within the region are also important, and can influence the selection and survival of the fish and plant species (ter Morshuizen 2018:31).

### 3.3.4 Aquaponics types

*Aggregate Bed Technique (ABT)*

The ABT is the most common aquaponics technique, whereby water is circulated from the fish tanks to the grow beds and back to the fish tanks (ter Morshuizen 2018:15). The water is not static within the grow bed because it rises and falls to ensure that oxygen penetrates throughout the media bed, keeping the system healthy (ter Morshuizen 2018:12). The media bed is filled with gravel or sand which works as a solid removal, bio-filtration and hydroponics all within one unit (Rakocy, Masser & Losordo 2006). The grow bed is attractive because it hosts a variety of crops (e.g. herbs, lettuce, tomato, pepper, cucumber and flowering plants). The weight of the aggregate counterbalances the plants so that they do not fall, while also supporting root growth (ter Morshuizen 2018:12).

*Deep Water Culture (DWC)*

The DWC system requires mechanical and biological filters for removing fish solids, but instead of using plastic pipes, the water flows through 20 centimetre-deep tanks (ter Morshuizen 2018:11).. The plants are suspended through polystyrene rafts that float on the water as the roots hang into the water. Only certain leafy crops, such as lettuce and herbs, can be accommodated in this system, as no weight around the roots is present for support. The system is the least expensive and the most commonly used at commercial aquaponics farms (ter Morshuizen 2018:11).

*Fish as an essential part of aquaponics*

The proposed fish for the aquaponics is the red breast tilapia (*Tilapia rendalli*) and the Mozambique tilapia (*Orecohcromis mossambicus*). The tilapia is regarded as a very popular fish species due to its market demand, with the market price at roughly R35/kilogram. Another reason for choosing tilapia is that the ideal water temperature for growing this fish type is similar to the ideal water temperature required for the plant species used for cleaning fish waste (ter Morshuizen 2018:29). As such, tilapia can be stocked at high densities that produce plenty nutrients for plants, while the plants function as effective mechanisms for cleaning the fish waste (ter Morshuizen 2018:29).

*Fish feed*

The Farmers Weekly article, *Tilapia Feeds & Feeding: Get It Right*, by James (2013) notes that the cost to feed tilapia commercially, by means of pellets, is the largest single expense and accounts for approximately 40% of the fish's sale price. Commercial tilapia feeds are formulated, cooked, extruded and pelletised diets which typically contain 32%-40% protein. This protein can consist of fish meal or soya-based protein, with the former being the most popular form because of it being more palatable to the fish.

It is also important to consider supplementing pellets with alternative fish food in order to decrease costs but, simultaneously, increase fish health. Fish food, such as earthworms, are an excellent supplemental fish food because they grow easily. Lucerne is also an excellent alternative, as tilapia, unlike terrestrial animals, can digest freshly cut green Lucerne without suffering from bloat. This excellent crop, which is high in protein, vitamins and minerals, is also economical as it can be cut repeatedly.

3.4

Pretoria Works is adjacent to the Atteridgeville Prison where Lucerne grows abundantly amongst their crops. Thus, an opportunity arises to harvest freshly cut Lucerne from the prison, which is currently not being sold to the public (see figure 3.4)

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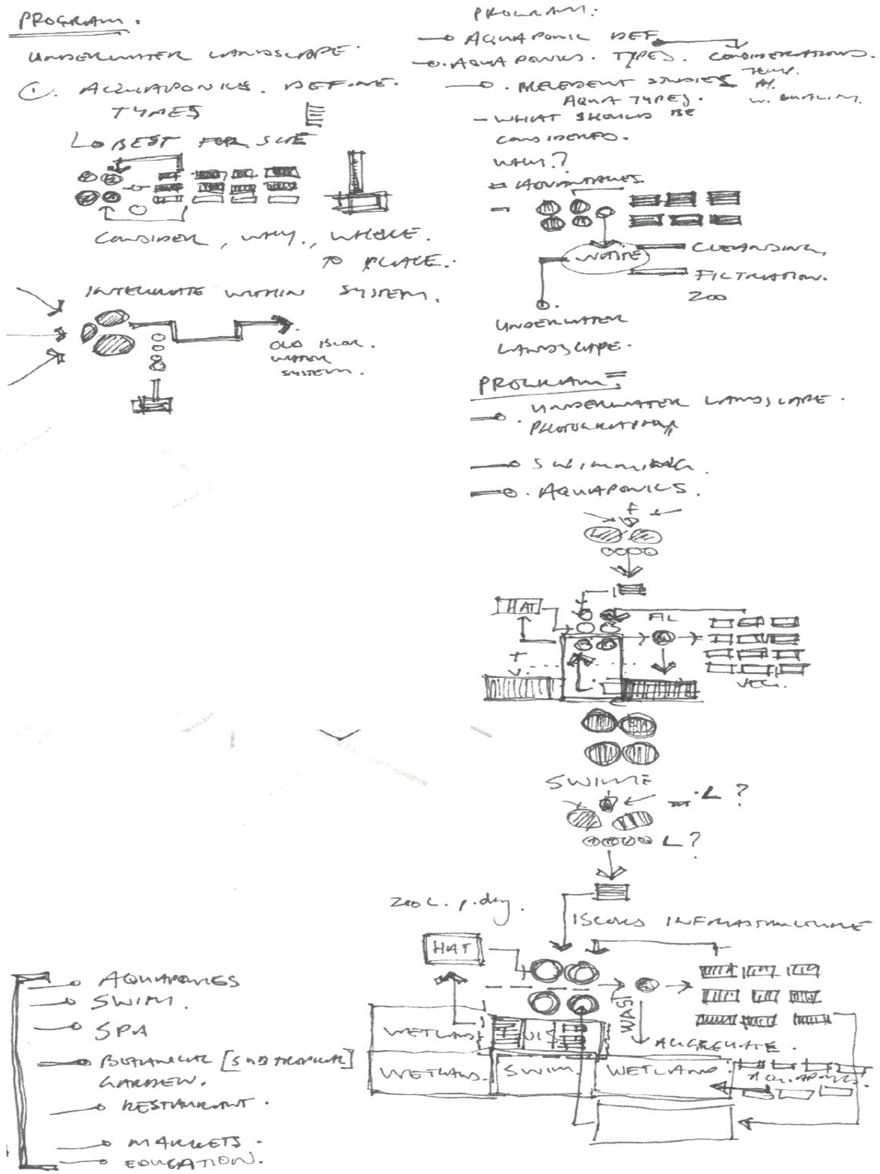



Fig 3.4 Lucerne grows abundantly at Attredgeville Prison (Author 2018)
Fig 3.5 Aquaponics system (Author 2018)

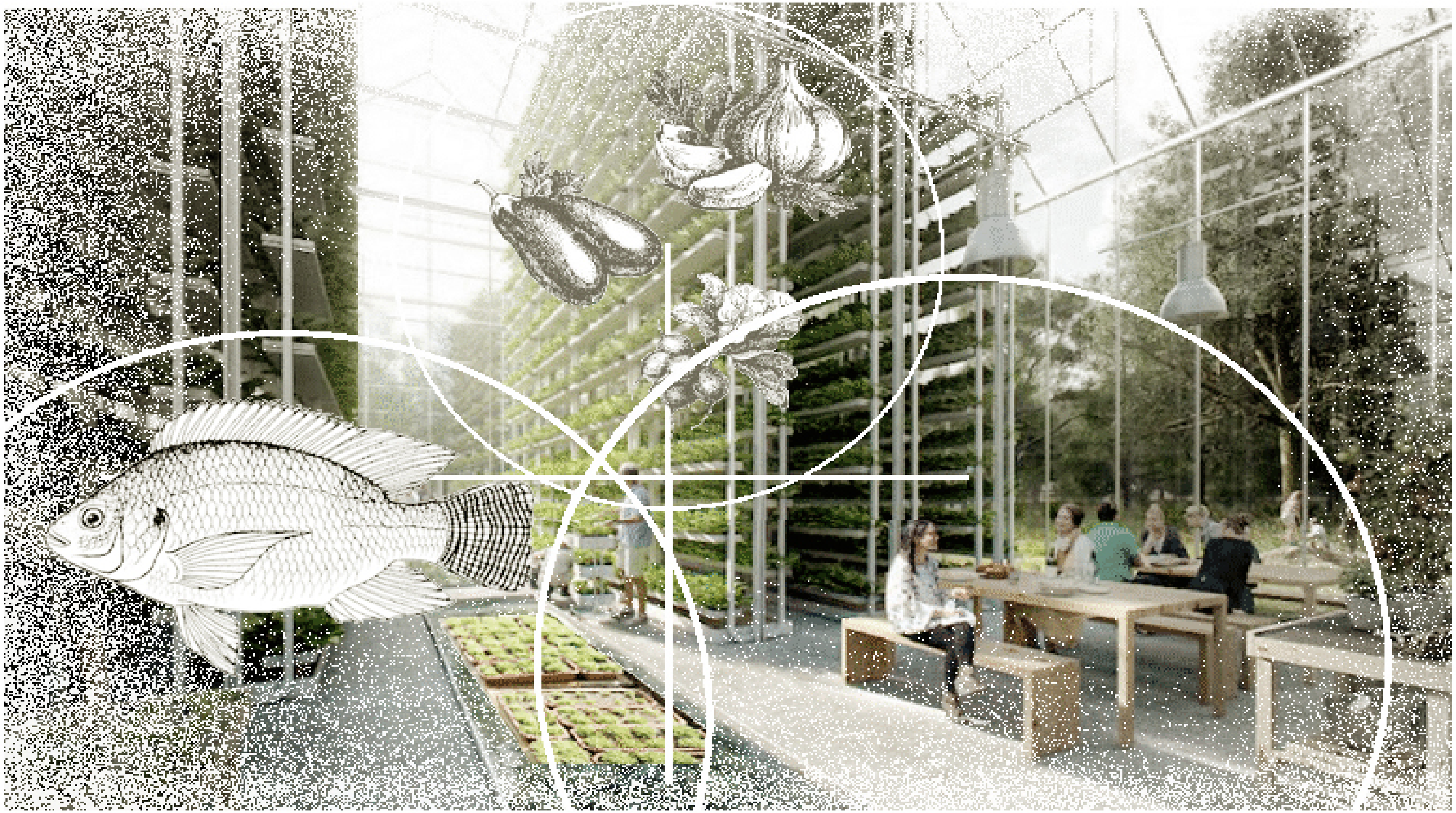
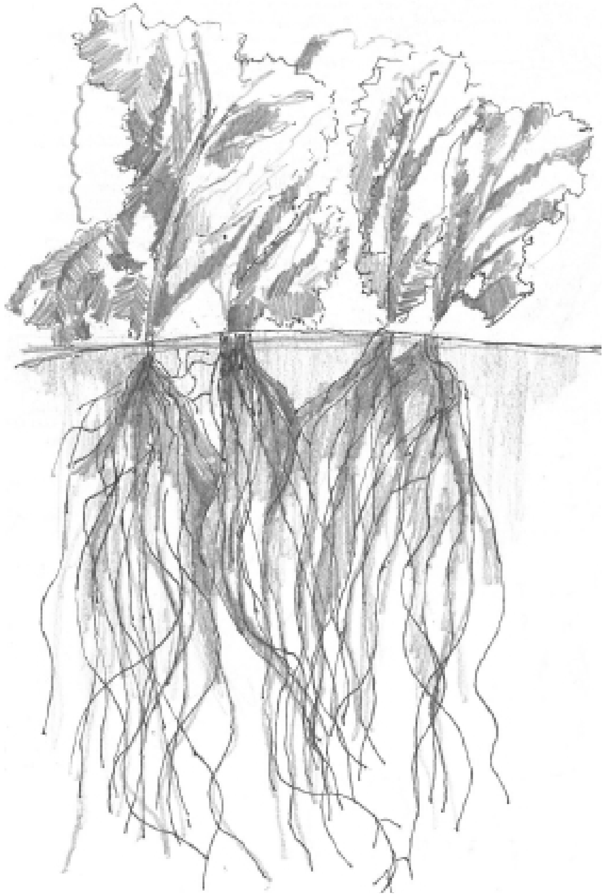


Fig 3.6 The aquaponics vision for Pretoria Works (Lewis. 2016, adapted by Author 2018)



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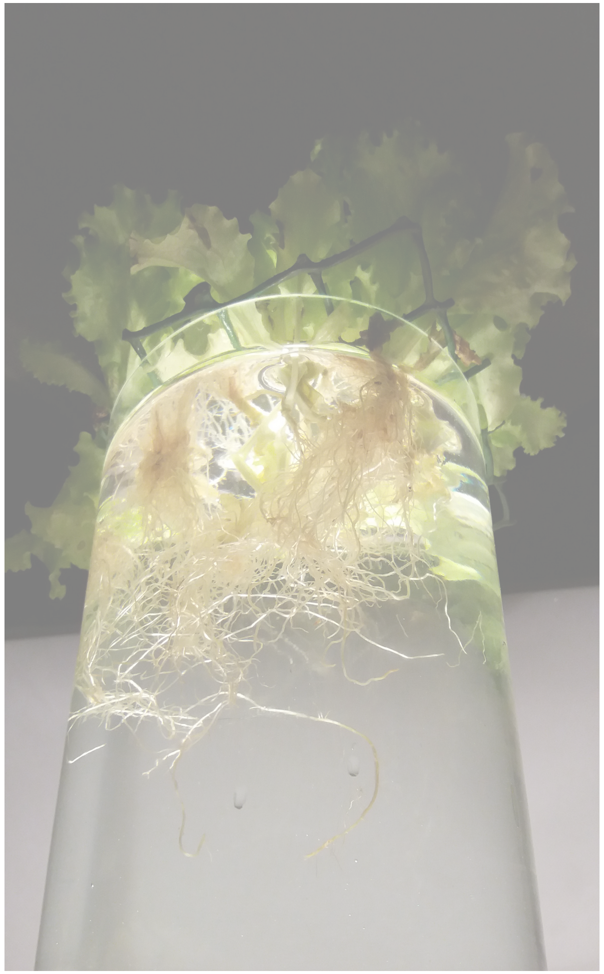

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Fig 3.7-Fig 3.10 Conceptual exploration with an aquaponics system (Author 2018)

## 3.4 Leisure activities

### 3.4.1 Natural swimming pools

Natural swimming pools can be described as constructed pools that imitate mountain pools or lakes found in nature (Pavlis 2017:137). In these pools, also known as aquatic gardens, water is cleaned by continuous circulation through an ecosystem of aquatic plants, where the plants remove nutrients by absorbing them from the water through their roots (Pavlis 2017:137). Through this process, the plants can prevent algae from growing (Pavlis 2017:139). The result is perfectly clear water that does not require chemicals, salt, or sterilisation equipment for treatment (Pavlis 2017:139). The aquatic garden also acts as a natural solar heater that extends the swimming season. These pools are not only used for swimming purposes, because they act as a landscaping feature that invites aquatic life and birdlife (Pavlis 2017:140).

The natural swimming pool needs to maintain plant material by cutting away dead plants and emptying the leaf collector, which can be used for compost. Natural swimming pool companies like Aqua Design advised for the system to undergo a biological service twice a year, whereby the ecosystem is analysed to determine whether there are any issues with the system (Aqua Design 2018).

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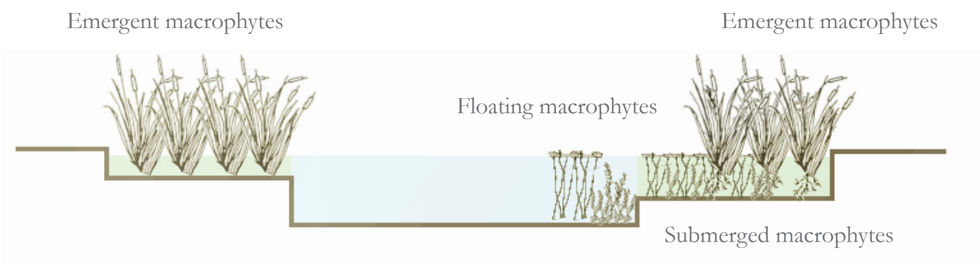


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Fig 3.11 Natural Swimming Pool (Author 2018)

Fig 3.12 Natural pool aquatic vegetation zones (Author 2018)

### 3.4.2 Natural pool aquatic vegetation zones

Aquatic vegetation grow at various depths, and are known as aquatic macrophytes (see figures 3.11-3.12). These macrophytes are any vegetation that emerge near water, or are submerged and/or floating in water. Emerged macrophytes, submerged macrophytes, floating leaved macrophytes and free-floating macrophytes can be further described as follows:

- Emergent macrophytes occur within submerged soils where the water table is about 0.5 metres below the soil;
- Submerged macrophytes refer to vegetation growing completely underwater at the bottom of a wetland;
- Floating leaved macrophytes grow on submerged sediments at water depths of about 0.5-3 metres; and
- Free-floating macrophytes are typically non-rooted and live unattached in water. Diverse in form and habitat, they range from long plants with rosettes of aerial and floating leaves and well-developed submerged roots, to minute surface floating or submerged plants with few or no roots. Reproductive organs are floating and aerial but rarely submerged (Rai 2009:709-710).

Fig 3.13 Natural pool: viewing floating macrophytes underwater (Author 2018)

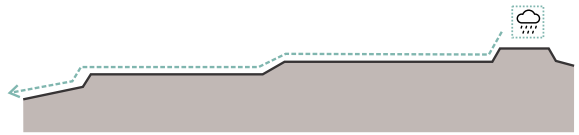
## 3.5 Design vision

From the theory of regenerative design, three main themes have been identified:

- Enhancing ecology through green ways between the terrain of Pretoria Works and the adjacent ridge;
- Creating economic opportunities through the use of treating industrial waste water via constructed wetlands for an aquaponics system; and
- Developing social spaces by means of the development of a natural swimming pool to attract general public and tourists.

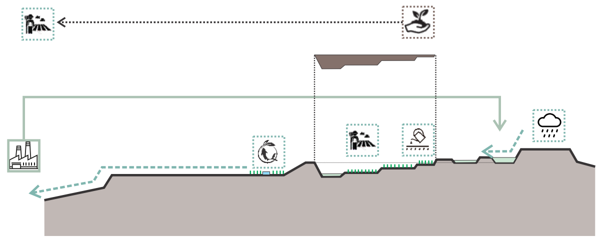
Pretoria Works' sedimentation dams have been chosen for the detail design. These dams have been unattended for the past 20 years. They were filled with topsoil by ArcelorMittal approximately 10 years ago as a means of improving the site's security.

The design is envisaged with three short-term phases, where these phases enable a manageable design vision (see figure 3.14). These phases are presented in the following subsections.



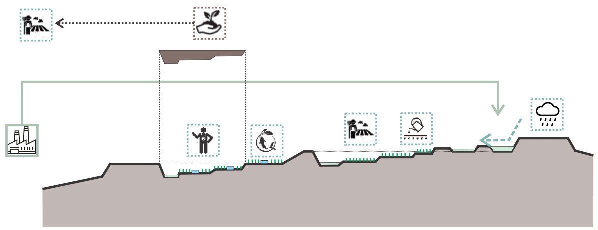
### Existing sedimentation dams

The old sedimentation dams (unattended for the past 20 years) were filled with topsoil approximately 10 years ago.



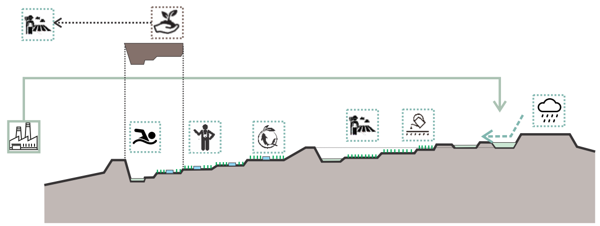
### Phase 1: Earth works

Excavating the filled sedimentation dams for rainwater harvesting and treating industrial water through constructed wetlands for agriculture and aquaponics.



### Phase 2: Tourism attraction

The site will by now be financially stable and can sell to the surrounding community. The site can also attract tourists with food production tours



### Phase 3: Natural swimming pool

The site will by now be financially stable and harvest enough water for the food production. It is proposed that surplus water can attract additional tourists with a natural public swimming pool.

Fig 3.14 Pretoria Works design vision (Author 2018)

### 3.5.1 Phase 1 (1-5 years)

The strategy for this phase is to excavate the filled sedimentation dams by using the construction machinery and vehicles (i.e. the excavator, articulated dump trucks and bulldozers) available from the aforementioned adjacent quarry managed by Vibro Eco Aggregates. The topsoil excavated from the dams should be placed in areas where the slope is suitable for agriculture. The nutrient value of the soil, if required, can be improved by means of permaculture techniques, such as incorporating 'nitrogen fixing plants' (e.g. legumes, such as peas and beans), crop rotation and planting companion crops. The process of excavating the sedimentation dams creates opportunities, firstly, to treat industrial waste water through constructed wetlands and, secondly, to store water for irrigation and aquaponics (see figure 3.15).

Appendix D contains a calculation of the surplus soil excavated from the sedimentation dams, the soil of which is proposed where the slope is suitable for agriculture.

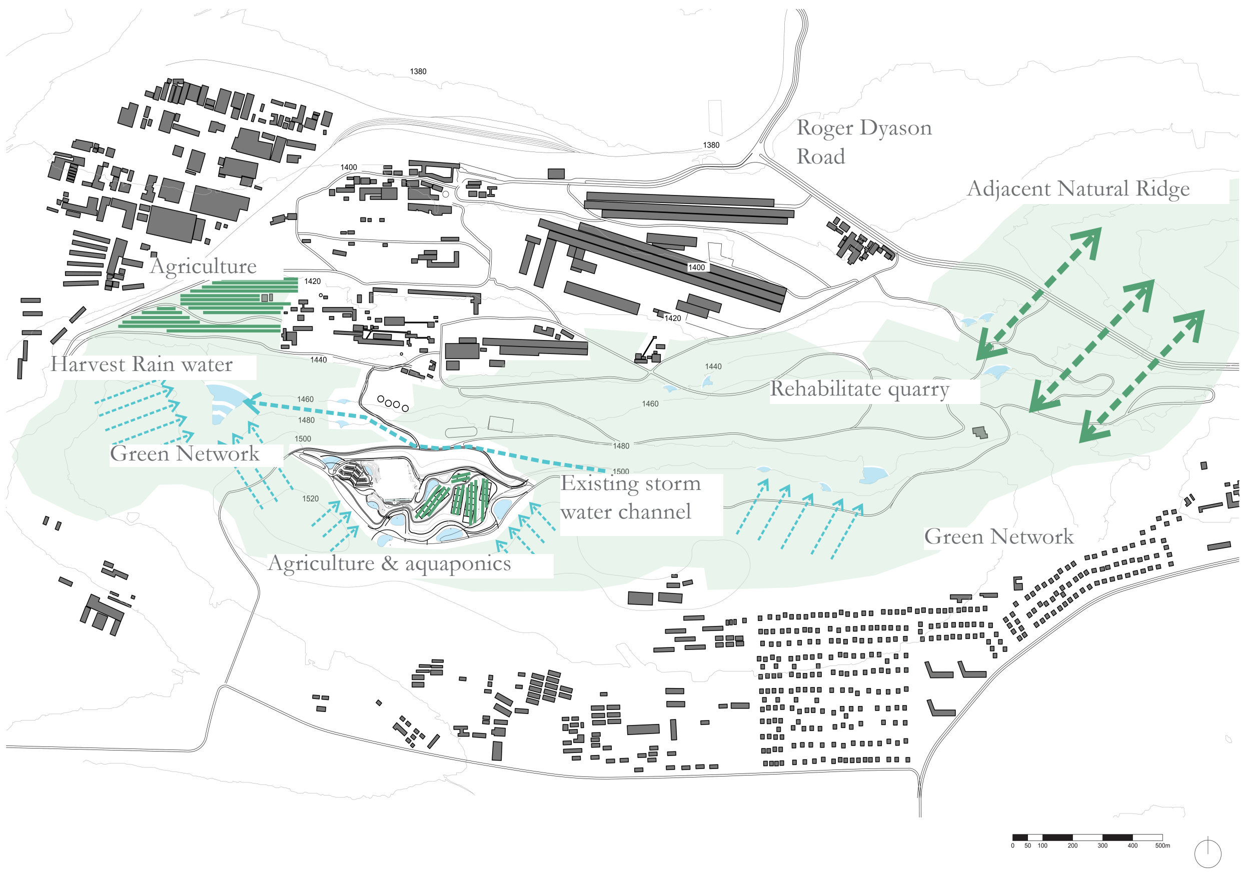



Fig 3.15 Pretoria Works design vision: phase one (Author 2018)

### 3.5.2 Phase 2 (5-10 years)

The productive landscape (agriculture) will, by this time, be established, and profit could be made by selling produce to the surrounding community. The money earned can finance the aquaponics system, which could attract additional tourism from people who are interested in its workings (see figure 3.16). Additional wildlife could also be attracted to the area through the constructed wetlands created by treating industrial waste water and storing rain water. Increased wildlife may further promote eco-tourism opportunities.

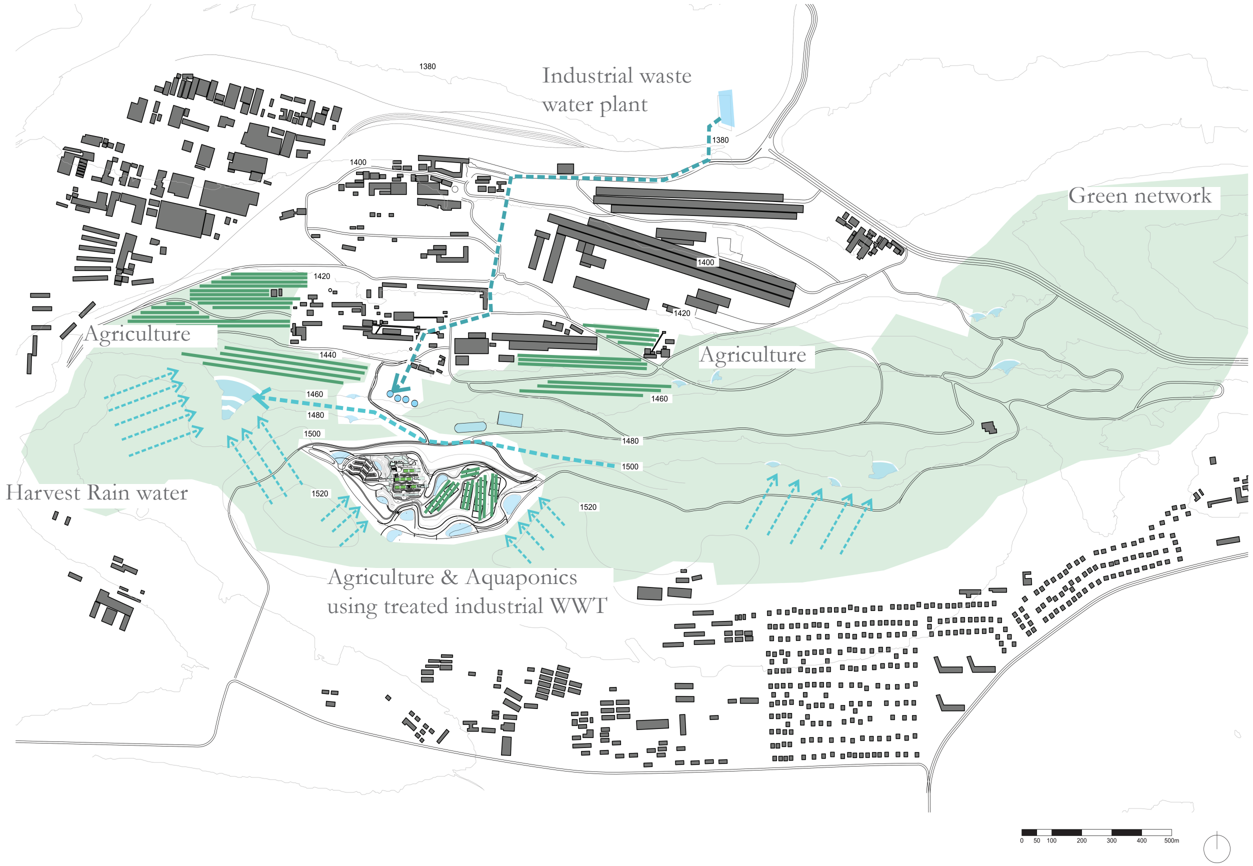



Fig 3.16 Pretoria Works design vision: phase two (Author 2018)

### 3.5.3 Phase 3 (15 years)

The adjacent quarry, which has been rehabilitated by Vibro Eco Aggregates, will most likely achieve the overall soil rehabilitation objective, which could, in turn, result in exposing the virgin soil to environmental elements such as water, wind and natural vegetation. These elements could enhance ecological succession (i.e. the gradual change in species composition in an area) (Miller & Spoolman 2012:117). There is a difference between primary and secondary ecological succession. Primary ecological succession involves the gradual establishment of biotic communities in lifeless areas existing of bare rock and which requires the building up of necessary nutrients to establish plant communities (Miller & Spoolman 2012:117). Secondary ecological succession initiates in an area where an ecosystem has been disturbed, removed or destroyed, but some soil or bottom sediment is still present (Miller & Spoolman 2012:118). Herein, new vegetation can begin to germinate within a few weeks through seeds present in the soil and/or via imported seeds gained through wind, bird droppings and/or animals (Miller & Spoolman 2012:118).

Pretoria Works' rehabilitation quarry is a terrain that could be restored through secondary ecological succession. The succession process can be enhanced

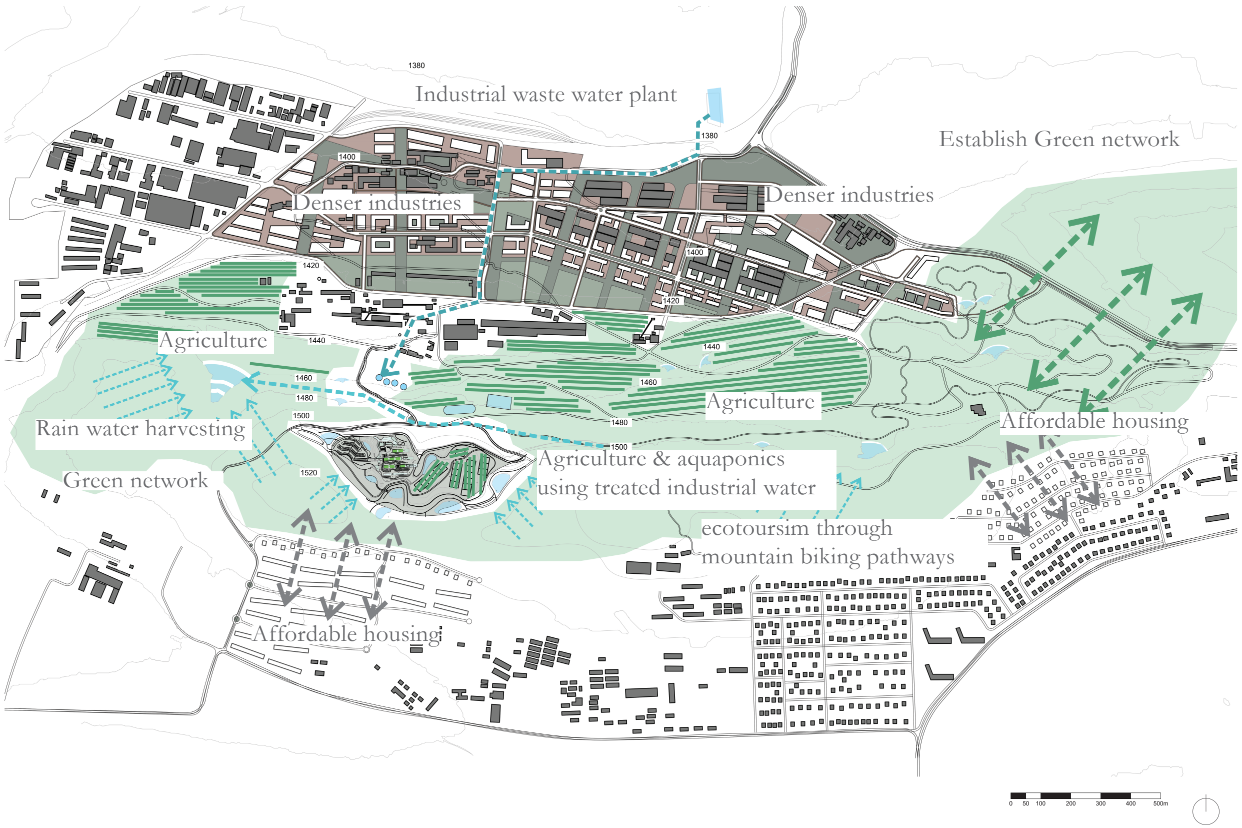
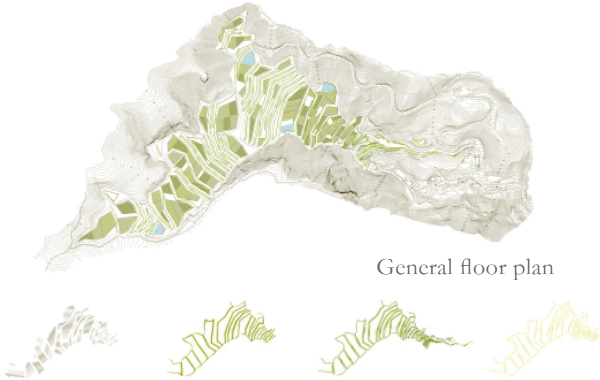



Fig 3.17 Pretoria Works design vision: phase three (Author 2018)

and managed with permaculture techniques that can contribute towards establishing a green network with the adjacent ridge opposite Roger Dyason Road. The green network can lead to additional tourist attractions through the creation of hiking, trail running and mountain biking pathways throughout the extended site. In this way, Pretoria Works could be holistically restored, and the increased availability of water may attract birdlife. The productive landscape (agriculture) and aquaponics system could also attract both locals and tourists who are interested in observing the system and buying fresh fish and vegetables. The money gained from these endeavours could then be used to attract even more locals and tourists by opening avenues for using surplus harvested water to create a public natural swimming pool for recreational activities. The ecological improvement, creation of economic opportunities and attraction of social spaces for tourists and locals could also begin to finance affordable housing (along Hendrik Potgieter Road) for the permanent staff working on the site. Such improvements could also attract financial investors to densify the industrial part of Pretoria Works with offices and additional industrial activities (see figure 3.17)

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### 3.5.4 Precedent study

The Vall d'en Joan Landfill site in Spain (originally opened in 1974) is located in a valley near a limestone ridge named El Garraf in the Barcelona Natural Park (see figures 3.18 and 3.19). The purpose of this landfill project, which started in 2010, was to restore the site by introducing native plant species and opportunities for productive landscapes. Due to the quality of the subsoil, excavation was not recommended in this process (Biennal 2014). The necessity to contain the waste resulted in the construction of terraces made from imported soil. Since the landfill is in a valley, water naturally drains there. The final layout, therefore, created systems for water to accumulate for irrigating the productive landscapes and native plant species (Biennal 2014). The layout also includes a series of perimeter trenches that were constructed to collect and divert rain water that falls outside the landfill boundaries (Kerrigan 2011:52). This landfill project has influenced the proposed design for Pretoria Works in two ways. Firstly, the project presents the idea of creating terraces to be covered by native plant species, as well as opportunities for productive landscapes. Secondly, the project shows the creation of trenches in order to collect and divert rain water, which can be applied in the proposed design.

Fig 3.18 and Fig 3.19 The Vall d'en Joan Landfill site (Biennal 2014)

## 3.6 Conclusion

Pretoria Works uses RO for its tertiary water treatment, which is sufficient for recycling water for industrial purposes. However, surplus water (explained in Chapter 1) which flows into the Apies River should rather be put to better use. As a result of RO's high-energy consumption that is expensive, an alternative more cost-effective technology, such as phytoremediation, has been chosen for treating the waste water that ends up in the Apies River. This technology is considered to replace the existing industrial waste water treatment of Pretoria Works (preliminary to tertiary treatment). However, secondary research has revealed that the industrial waste water treatment cannot be replaced by phytoremediation, and phytoremediation could only be a tertiary treatment to industrial waste water.

This technology makes use of living organisms to remove heavy metals, as well as aquatic vascular plants for treating heavy metals found in industrial effluents before the water is discharged into aquatic ecosystems. The use of plants for remediation of metals offers an attractive alternative because it is solar-driven and is likely to attract wildlife and people.

Therefore, two regenerative landscapes, namely agriculture through permaculture, as well as aquaculture through aquaponics, have been identified as functions for the site. It is the latter regenerative landscape that has drawn the most attention for this project, as it replicates an envisaged ecosystem that contains fish, plants, bacteria and (sometimes) worms and other organisms growing together symbiotically. The bacteria in the ecosystem convert the waste water produced by the fish into plant food, which means that the waste water is filtered before it returns back to the fish, with the result that nutrients are provided for plant growth. Fish, in particular tilapia, have been chosen for various reasons as part of the aquaponics system. The proposed natural public swimming pool bodes to be popular because it will provide for leisure activities. Simultaneously, it could also enable education because the water will be cleaned by continuous circulation through an ecosystem of aquatic plants, where the plants remove nutrients by absorbing them from the water through their roots.

The design is envisaged with three short-term phases. The first phase is to excavate the filled sedimentation dams by using the available construction machinery and vehicles; followed by the productive landscape (agriculture) that will be established and which will be utilised for selling vegetables at a profit. The third phase will be characterised by the adjacent quarry that will most likely achieve the overall soil rehabilitation objective, which could result in exposing the virgin soil to the environmental elements and establish a green network with the adjacent ridge.

It is crucial that the water to be used for the aquaponics system meets certain criteria. The criteria and an appreciation of the value of water as a resource is discussed in Chapter 4.

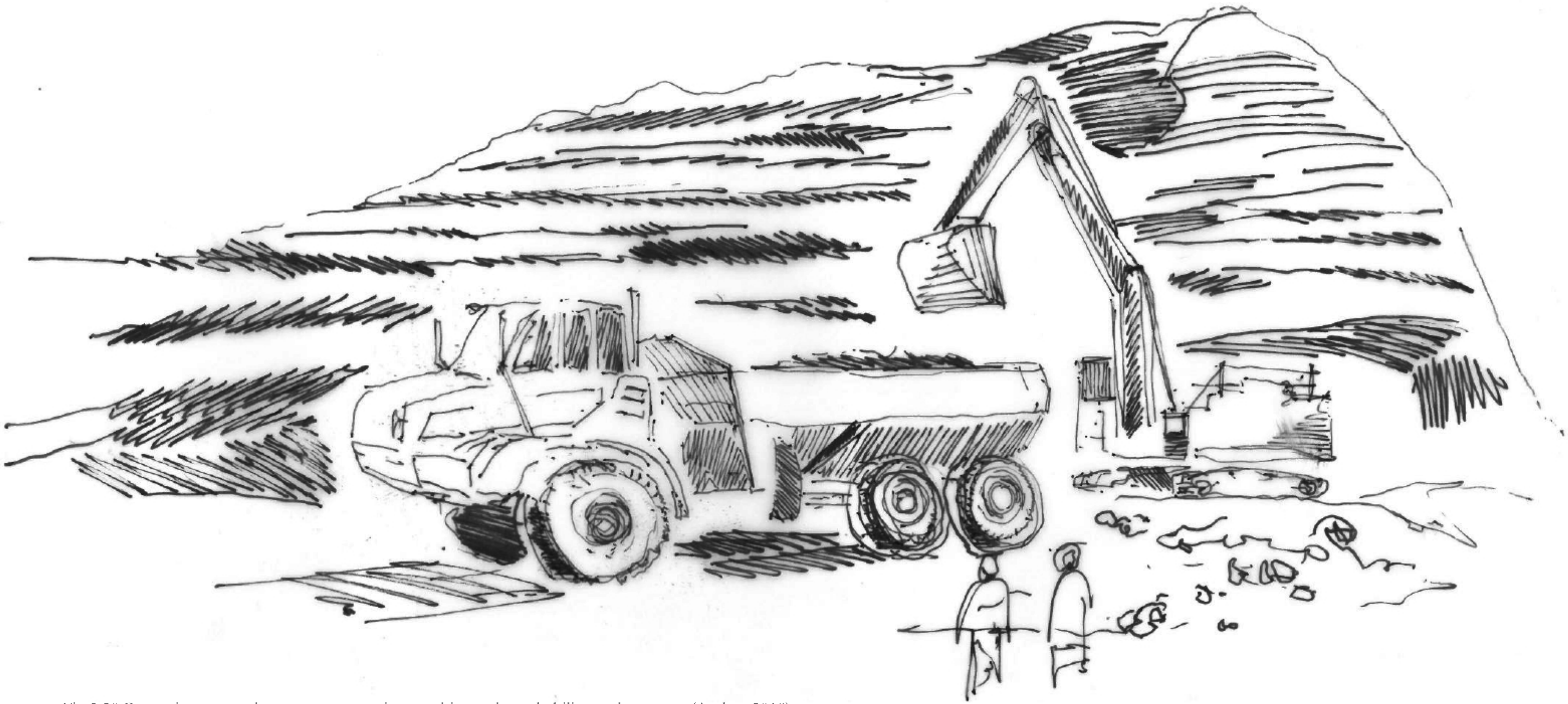

Fig 3.20 Proposing to use the same construction machinery that rehabilitates the quarry (Author 2018)

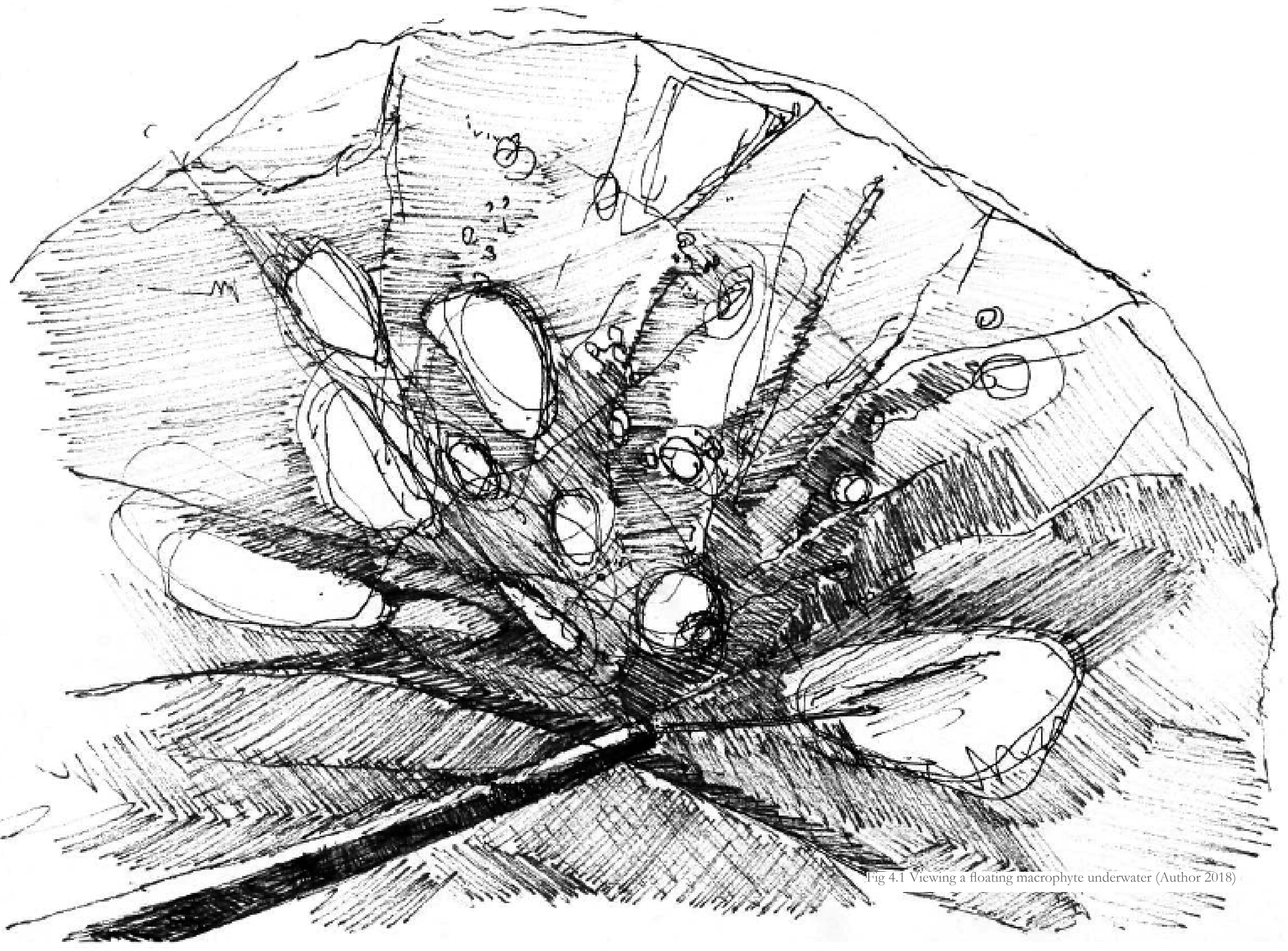

Fig 4.1 Viewing a floating macrophyte underwater (Author 2018)