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references can be found after each chapter

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## *Abstract*

More than one century of gold mining activities and decades of segregative urban policies have created the West Rand's devastated landscape. The cycles of soil and water have been disturbed and the urban tissues speak of severe social inequalities. The surface of the region is littered with golden tailings dams and dusty sand dumps, its soil is polluted and the area is undermined by a network of shafts and tunnels. Years of pumping have altered the water cycle and both underground aquifers and surface river and wetland systems have been polluted by toxic acid mine drainage. The black townships to the south of the mining belt stand in sharp contrast with the more affluent and formerly white neighbourhoods on the ridges in the north.

Gold mining is now coming to an end, but it will leave behind a social and environmental legacy for generations to come. This thesis shows how the rehabilitation of the mined landscape could become the driver of a future vision, which re-imagines the post-mining landscape as a common space that generates alternative economies and spatial transformation.

An integrated vision, structured by the restoration of the soil and water cycles, forms the base for a joint project between mining companies, local communities, experts and authorities. By altering the current reprocessing activities of mining companies, the topography of the Wonderfontein and Tweeloopies Spruit valleys can be reshaped. The required water treatment can be transformed into a decentralised system and integrated in the landscape. This resource of clean water will form an added value in this region with a semi-arid climate, and become the trigger of a new agricultural economy based on medium-scale cooperations. Running through the repetitive, monofunctional and low-density townships in the south, this new water system can catalyse a transformation of the urban tissue as well. The apartheid planning of townships like Kagiso, can be re-thought in terms of densification, hybridisation and productivity.

Throughout this thesis, the main principles of this ambitious vision are outlined and explained in more detailed chapters that deal with specific social, historical, institutional and environmental aspects. An approach to phasing and implementation shows how the mined landscape, which has always been in constant flux, can gradually transform into a sustainable common space. Four focussed designs test and show how the vision's strategies can be applied and adapted in different social and environmental contexts. They represent the potential of strategic projects and a coherent vision to trigger the capacity of inhabitants to re-shape their environment. To conclude, the relevance of this vision for the Witwatersrand region and for post-mining territories in general is explored.



## *Acknowledgements*

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our family and friends for reminding us about life outside of the mining belt, and especially the friends we met in the urbanism programmes in Leuven, for sharing this amazing obsession with us: we will remember many long nights together, be it with beers or for work.



*Kagiso*



*Kagiso*



*view south from railway*



*platforms in Lanwer*



*Krugersdorp Monument*



*Soul City informal settlement*



*Kagiso*





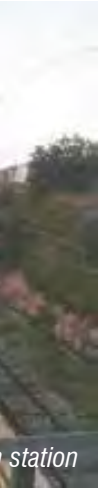
*Kagiso*



*Lewisham*



*Luipaardsvlei*



*station*



*Krugersdorp main station*



*Luipaardsvlei station*



*view from IL 8 towards Kagiso*



*Krugersdorp view to North Sands*



*Kagiso*



*Krugersdorp*



*Luipaardsvlei*





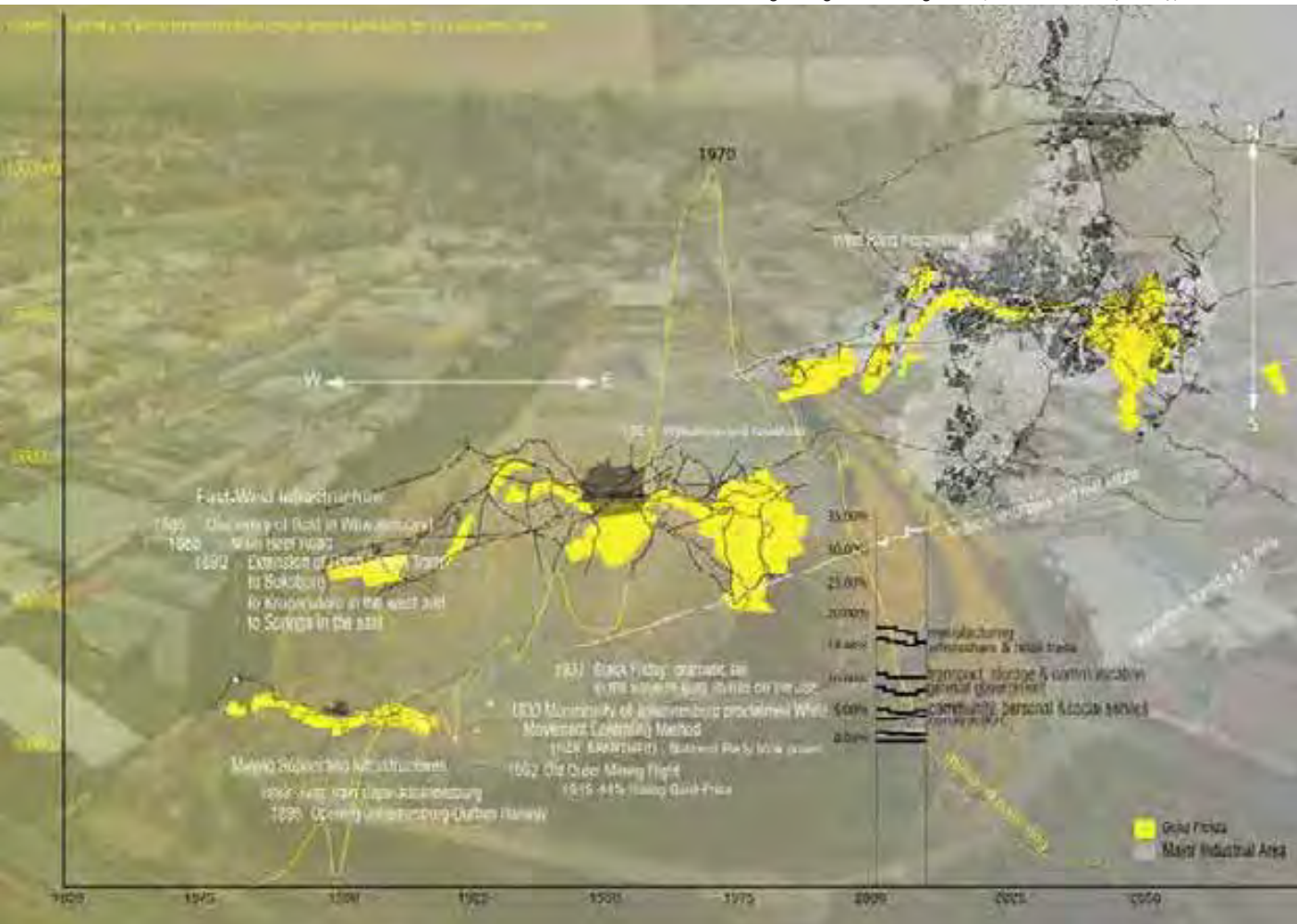
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## Pioneering post-extractive urbanism

Exploring the majestic and devastated landscape of Johannesburg's West Rand, was characterised by a sense of overwhelming complexity and paralysing uncertainty. It induced a feeling of strong dependence, but at the same time extreme imbalance, between the fragility of local ecosystems and the impact of more than a century of urban growth based on the extraction of gold. Witnessing and studying the issues and possible futures for the post-mining territory of the West Rand often felt like pioneering a type of urbanism that has yet to be defined. While many experts have studied the mining belt of the Witwatersrand, up until recently it had rarely attracted the interest of architects and urbanists.

However, from any aerial photo, the potential and strategic importance of the space of the mining belt, as a third space in between the more affluent north of Johannesburg and the mainly non-white, poorer southern townships, becomes evident. But any successful future scenario for this territory has to deal with the toxicity of the waste left behind by decades of gold mining, found in the form of tailings dams and mine dumps, and as acid mine water polluting underground basins and surface water systems. (TOFFA, 2013)

*urban evolution of the Witwatersrand along the gold mining belt (adapted from Vidya Spay)*



## SOCIAL INFRASTRUCTURE - LANDSCAPE

Proposed Social Infrastructure:



### Population



**Krugersdorp:**

People: 140643

Area: 2472 sqkm

Density per sqkm: 568



**Kagiso:**

People: 115802

Area: 14.17 sqkm

Density per sqkm: 8200

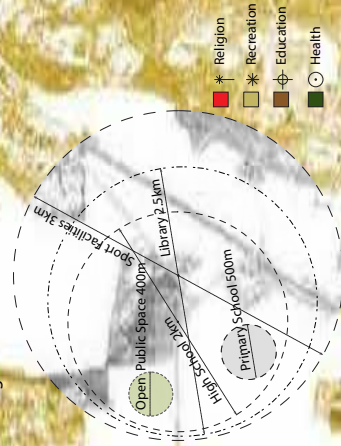
### Access standards

Type of social infrastructure Waitakere City Council, UK example

Primary school	1km to 1.5km
Club/space	800-800m
Open space	400-800m
Sports field	2-3 km
Green corridor	1-2km
Community centre/library	2-3 km
Multifuse community space	2-3km
	500m
	800m
	800m
	2km
	1.5km

The above accessibility indicators were identified in Waitakere City Council's Social Infrastructure Planning Framework (2007) p.44.

Existing Social Infrastructure:



- Religion
- Recreation
- Education
- Health



The apparent complexity of these interlocking cycles of soil and water pollution has been left for environmental scientists and other experts to be studied as fragments of difficult knowledge. Urban designers and developers have looked at the mining belt as a potential space for development and several projects have started to claim it for industrial developments or for the construction of large programmes such as a stadium for the World Cup in 2010. Also informal settlements are appearing in the mining territory, and their inhabitants are facing the health risks of dumps and polluted water.

Dorothy Tang and Andrew Watkins (TANG and WATKINS, 2012) were the first urbanists that tried to unravel the relations between mining logics, environment and urban systems. They developed the first concepts and graphical tools to clearly represent many of the issues at hand. The thesis work of Tahira Toffa (TOFFA, 2013) took their analysis a big step further. After a lucid analysis of the conditions that shape(d) the Witwatersrand mining belt, she proposed a systematic approach to deal with the remediation of water- and soil pollution and catalyse the re-interpretation of the mining belt as a common space between north and south.

This research has been taken further in 2014 by a joint and parallel urban design studio in Johannesburg (School of Architecture and Planning at WITS University) and Leuven (OSA at KULeuven), and through this master thesis. This multiplication of research-by-design projects dealing with the post-mining territory of the Witwatersrand has the potential to become the start of a joint effort between academic work, policy-making and actors on the terrain towards a more comprehensive and long-term approach to the future of the region.

Our work is building on that of Tang and Watkins and Tahira Toffa, while zooming in to the specific conditions in the western mining basin of the Witwatersrand, taking a closer look and evolving towards a smaller scale of spatial design. As urbanists, we used spatial logics to conceptualise and integrate the social, ecological, economic, cultural and political issues around the re-claiming of the mining belt. This implied a confrontation with the communities, companies and institutions of the West Rand, and bringing different, often conflicting, insights together.

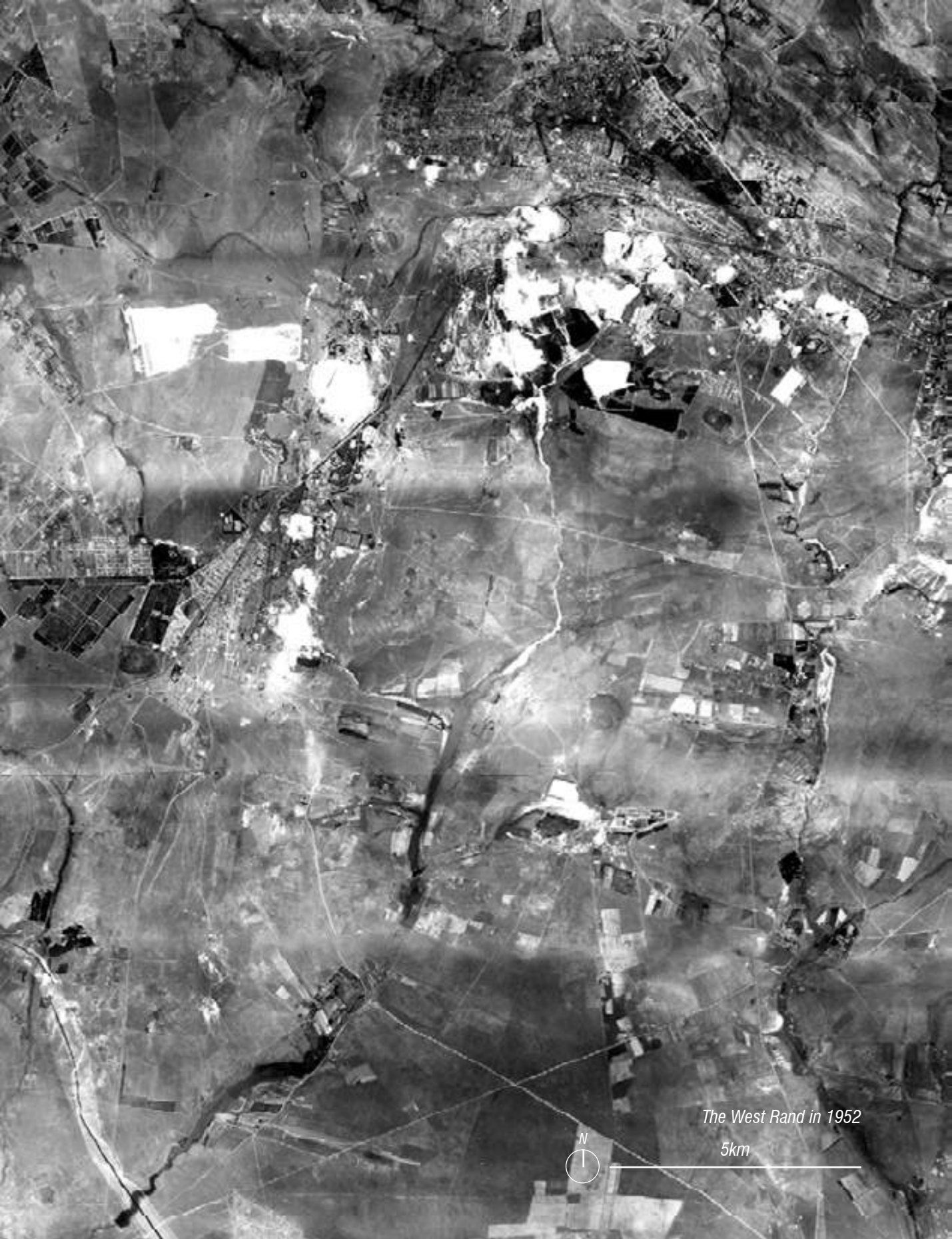
The lack of a synthetic approach to the post-mining territory and a coherent understanding of the interlocking dynamics of water, soil and urbanism proved to be a serious limit to the development of a future vision for the area. Neither the local municipal authorities or the mining companies have the capacity to produce such a comprehensive vision or attract the necessary support from local communities and other actors involved. The need is clear for spatial professionals to assume the role of integrator between different knowledges and interests, creating a forum and base for a common project for the post-mining territory.

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### *The West Rand as a space of friction (adapted from Javier Tamayo)*





*The West Rand in 1952*

5km



### *Research-by-design, a flexible process to deal with uncertainty*

This document is the result of 6 months of work, carried out first in Johannesburg at WITS University and later at KU Leuven in Belgium. Starting off with a period of literature study and explorative field trips, it was then kicked off seriously by two weeks of intensive fieldwork.

This involved meetings and lectures with local specialists concerning the history, ecology and social issues of the Johannesburg mining belt. It also included fieldwork by train and mini-bus, and on foot, to understand the spatial qualities of the area and conduct interviews with its inhabitants. Moreover, there were encounters with several key stakeholders of the area, including a local action committee in Kagiso that is concerned about the impacts of active mining operations on some houses in the neighbourhood, the inhabitants of an informal settlement called Soul City, a tour of the West Rand with Mariette Liefferinck, an activist that wants to bring the ecological issues to the attention of the media and government institutions, and a visit to the Mintails mining area and its active operations with Anthony Turton.

These first impressions formed the basis ingredients for a research-by-design approach whereby the area of the West Rand was analysed and conceptualised through the exploration of possible design strategies for its future. These were first explored through a focused design in the Global City Studio at the WITS School of Architecture and Planning, with Diaan Van Der Westhuizen and guided by Tahira Toffa. Meanwhile, we had the opportunity to deepen our understanding of how mining activities impact the environment, through the course of Mining and the Environment at the CSMI (Centre for Sustainability in Mining and Industry). We also followed a course in Phyto-technologies with Isabel Weiersbye, a specialist in the remediation of mine dumps in the Witwatersrand gold fields, and got to know the potential and limits of a plant-based approach to landscape rehabilitation.

More visits to Kagiso, Krugersdorp, Witpoortjie and West Village gave us a better understanding of the specific spatial characteristics of each area and their socio-economic context, and allowed us to do more interviews with local inhabitants.

An intermediate presentation of our design strategies at Mintails provided us with more feedback and a better understanding of the relevance of our project in a context of uncertainty and lack of a post-closure vision for the mining territory.

Back in Leuven these insights and first design explorations served as starting point for the development of a larger-scale vision for the Wonderfontein Spruit catchment area and its surrounding communities. Working in parallel with an urban design studio guided by Bruno De Meulder and Wim Wambecq, also focussing on the West Rand, allowed to reflect and discuss with other students about issues and solutions. The resulting vision has many elements in common with the results of the studio work and the research collages created by other students have been used in our thesis as graphical representations of our analysis and strategies.

The proposed vision is built around the soil and water cycles that have been so severely disrupted in the West Rand, and looks at the process of landscape rehabilitation as an opportunity to re-think and re-structure the urban tissues around. It is grounded in the expert knowledge and fieldwork obtained during the two months in Johannesburg, but uses this research through the formulation of new concepts and strategies to deal with this urban landscape. The vision was refined and tested in more focused, small-scale design strategies for four strips that each run from hill to valley and show how the vision might play out in different contexts.

Different representation methods (schemes, hand drawings, a model and a stop-motion video) were used to show the vision and more detailed designs during the World Urbanisms Seminar at KULeuven on the 26th of June 2014. The discussions and feedback from this seminar served as a reflection about the layered socio-cultural meaning of the design, its technical foundation, its applicability on the scale of the total mining belt of the Witwatersrand and its relevance in a context of (post-)mining towns scattered around Africa and the globe.

An important challenge in dealing with the mining territory is related with the amount of (technical) information available. The body of knowledge about mining operations, environmental impact and remediation options is extremely wide but also rather fragmented. Using a research-by-design method proved to be an effective way to focus on relevant issues and select essential pieces of information that would be of use in conceptualising and re-thinking this territory. Interviews with experts were extremely helpful to deepen our understanding of the soil and water cycles, and to verify the feasibility or early design strategies.

On the other hand, information about the history of the West Rand and specific social and cultural issues was more scarce and even more fragmented. Nevertheless, some original documents and pioneering works (such as the doctorate of Janetta Du Plooy recounting the history of Krugersdorp) found in the archive of the Krugersdorp museum and in the archives of the local mining companies were extremely informative. More fieldwork and interviews with local communities and organisations could have further enriched our research and design.

A specific issue is that different pieces of information often contradict each other or highlight different issues as being important or urgent. Information is also distributed through popular media and then often extremely popularised or at least simplified. Many experts and actors have





*The West Rand in 1991*



5km



conducted research – in a governmental, academic, activist or mining company’s context - and developed an understanding of particular aspects related with local communities, the environment and ecosystems, mining operations, etc. These are published as scientific articles, policy documents, mining company reports, pamphlets, opinion pieces and newspaper articles, each interpreting knowledge for a different audience and in an adapted language.

The fact that these different pieces of the puzzle often contradict each other, can be related to evolutions in science and changing understandings of the complex dynamics involved. But more often than not, knowledge about the mining belt is tied to a specific interest or point of view and therefore had to be interpreted extremely carefully before being included in our analysis and design.

### *A vision with sidestories*

This thesis is composed of two booklets. The first document contains the main storyline and explains a strategic vision for the West Rand’s post-mining future. The second document contains background stories that elaborate specific aspects of the vision. This structure is explained schematically on the next page.



This first booklet is built around two main chapters that propose a possible vision for the territory of the West Rand, focussing first on the cycle of soil and topography, and second on the water-cycle.

Possible strategies for the implementation of this vision, with phasing and important agencies, are discussed in chapter 3. In chapter 4, four more detailed zooms each focus on a strip of land that runs from hill to valley and show how the vision is played out differently in each specific context.

A reflection at the end in chapter 5 specifies how the vision could be applied to the whole mining belt of the Witwatersrand and starts to define an emergent discipline dealing with post-extraction urbanism.



The second booklet contains side-stories for both the soil- and water-cycles. These explain a specific technical, institutional, historical or urbanistic aspect of this cycle. Focussing on one particular issue, the side-stories provide valuable background information and in-depth analysis. They support the main vision but can be read as separate stories as well.



*The West Rand in 2014*

5km



1.1 The boom-bust cycle  
in an Afrikaner mining town

1.2 The mined landscape: heaps of waste,  
underground voids and contaminated soil

1.3 Broadening the concept of closure mining

1.4 Rehabilitating the mined landscape

2.1 Acid mine drainage:  
the eternal legacy of gold mining

2.2 Constructed wetlands: the potential of  
engineered natural systems to clean AMD

2.3 Water urbanism as an approach for the  
re-conceptualisation of the urban tissue

2.4 The productive landscape as an  
alternative poverty alleviation strategy

0. Where, what and why: the West Rand

1. SCULPTING THE HILL  
re-thinking the soil cycle

2. CULTIVATING THE VALLEY  
restoring the water cycle

3. VISION IMPLEMENTATION  
realising the transformation of a landscape in constant flux

4. ZOOMS

ZOOM I / Azaadville

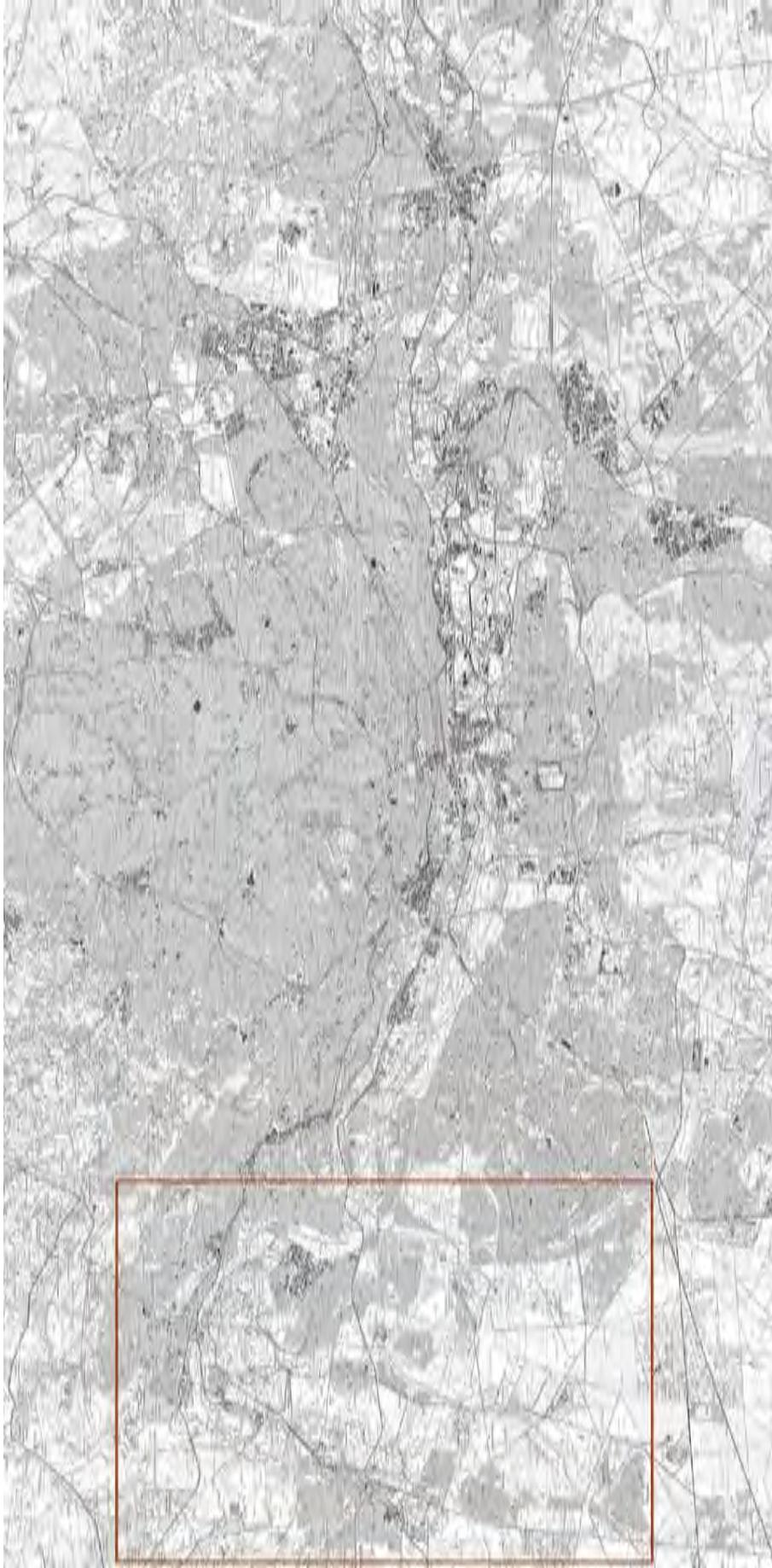
ZOOM II / Kagiso

ZOOM III / Kagiso-Chamdor

ZOOM IV / West Village

5. ZOOMING OUT  
the relevance of post-extraction urbanism  
for the Witwatersrand and the world

*Location of the West Rand in the Witwatersrand*



### *Where, what and why: the West Rand*

The western part of the Witwatersrand mining belt is a large stretch of land that lies in-between the communities of Krugersdorp, Kagiso and Randfontein. On the larger scale, it is also located on the meeting point between different regional systems, being the metropolitan area of Johannesburg and Soweto to the east, the more tourism-oriented Krugersdorp Game Reserve and the Cradle of Humankind to the North, and the agricultural landscape around Magaliesburg to the north-west. The characteristics of these surrounding landscapes, either heavily urban, cultivated rural, or wild natural, can all contribute to a re-definition of the mining-landscape of the West Rand.

The boundaries of the West Rand District go beyond the area of study, and include Westonaria, Merafong City, Randfontein and Mogale City Local Municipality. Mogale City contributes more than half of the district's population, counting 362 442 inhabitants, and contains its main urban centre, Krugersdorp. It also comprises Munsieville, Magaliesburg, Kagiso, Rietvallei and Azaadville (MOGALE CITY, 2009).

The western part of the gold fields is one of the four separate basins (far western, western, central and eastern basin) that compose the mining belt which runs east-west through the Johannesburg metropolitan area. (VILJOEN, 2009) This territory of gold-extraction separates the Victorian grid of Krugersdorp in the north, from the repetitive tissue of the southern townships Kagiso and Rietvallei, the Indian area of Azaadville, and the different neighbourhoods and townships of Randfontein in the south-west. It exemplifies how the mining belt has developed as a third space in-between the northern, more affluent and white mining towns, and the southern, mainly non-white townships in the south. Having been called the ultimate apartheid buffer, it can now be seen as a huge opportunity to re-think the north-south divide in the Johannesburg region, by re-claiming it as a common space (TOFFA, 2013).

However, while the Apartheid regime has already ended 20 years ago, the democratic housing policies (and more specifically the provision of RDP-housing) have reproduced segregative settling patterns by locating poor populations on the outskirts of the metropolitan area, far from places of employment and in low-density settlements (DU PLOOY, 1999). While the space of mining has been claimed elsewhere for industrial developments, informal settlements and large urban projects such as the FNB World Cup Stadium, it is relatively vacant in the West Rand. Its readability as a third space, with qualities and a scale that differ from the urban areas around, make it a great testing ground to develop a post-mining vision for the gold fields of the whole Witwatersrand.



Tweelofriviers Spruit

Mossburn dam

Watershed divide

Lancaster dam

Tutor dam

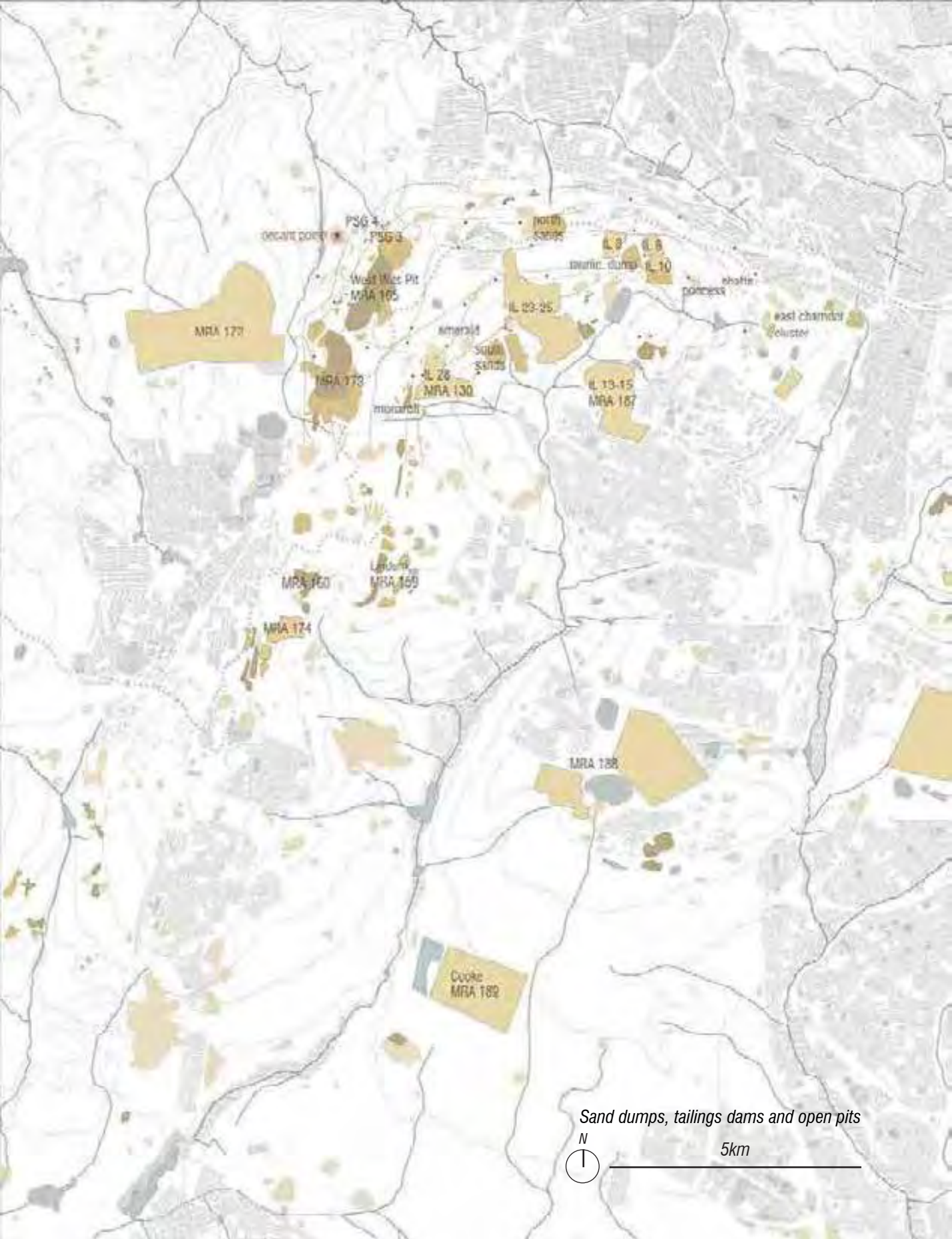
Worcesterdam valley

Worcesterfronten Spruit

Water systems



5km



PSG 4  
PSG 3

West Mies Pit  
MRA 165

north sands

L 9  
L 8  
L 10

shafts  
potass

east chimney cluster

MRA 177

L 23-25

Emerald

MRA 173

L 26

MRA 130

Small Sands

L 13-15

MRA 187

morandi

MRA 160

L 20

MRA 159

MRA 174

MRA 188

Cooke  
MRA 182

*Sand dumps, tailings dams and open pits*



5km



Currently, two main mining companies (Mintails and Sibanye gold) are still operating in the area, doing underground mining (taking out the remaining gold in shafts and stability pillars), opencast mining (on-surface drilling and blasting), and reprocessing left-over mine dumps and tailings dams from previous mining phases. These operations are considered the last phase in over a century of gold extraction in the West Rand, that has left the territory in a state of disruption and pollution. Mine waste in the form of dumps, tailings and pits contains high concentrations of pyrite, metals and uranium that pollute soil and plants. They also contribute to the problem of acid mine drainage (AMD), because exposure to sun and rain creates acidic water that runs off into rivers and wetland systems. It also infiltrates in groundwater basins and underground mining shafts that have slowly filled up and are now decanting unless the water is pumped up (OELOFSE et al., n.d.).

When the water started to decant for the first time in 2002 in the West Rand, polluting the Tweeloopies Spruit and a nature reserve downstream, this ecological disaster was extremely dramatised in the media. The strategic location of the West Rand, straddling the watershed divide between the Orange and Limpopo river systems, only increases the impact of pollution in local water systems, and the importance of finding a solution. A short-term fix was put in place, whereby the water is partially cleaned in treatment plants, and then discharged into the Vaal and Orange river system. But decant still happens in times of heavy rainfall, and shows the urgency of the issues at hand, labelling the West Rand as the most critical mining basin to intervene and develop a more long-term solution to restore the disrupted water cycle (COETZEE et al., 2006).

<b>362 442</b>	<b>26,5%</b>
inhabitants in Mogale City	informal dwellings
<b>24,6%</b>	population in 2020
unemployment	<b>450 000</b>
<b>30 000</b>	<b>2,04%</b>
municipality housing backlog	population growth rate

(source: Statistics South Africa, census 2011)

Moreover, the decline of the gold mining industry since the 70s has left the economy of the West Rand devastated, and created a surplus of low-skilled labour that finds no alternative employment in the current shift to a service economy. While this evolution has impacted the whole Witwatersrand, socio-economic problems are more evident in the West Rand and have created a condition of uncertainty and social unrest. The decrease in economic activity leaves the Randfontein and Mogale City municipalities without sufficient financial means to invest in infrastructure, services and housing. Currently, 73,5% of Mogale City's households live in formal

dwellings, as opposed to those inhabiting backyard shacks or informal settlements. The current housing backlog of the municipality will only worsen in the future as the growth of the population comprises 82% of poor households. Since 2001, the proportion of people earning less than 3500 R/month is growing at a rate of 8.5%. Although the population growth rate is declining, the number of inhabitants is expected to grow up to around 450 000 by 2020. (MOGALE CITY LOCAL MUNICIPALITY, 2009; STATISTICS SOUTH AFRICA, 2011)

A sense of helplessness and lack of information lives among informal dwellers and township residents, having no personal relation anymore with the mining companies in the area, but living daily with the impact of their activities. Activists and action groups often blame mining companies for the ecological and social legacy of more than a century of gold mining (LIEFFERINCK, n.d.), while those could also be important actors that have the technical (and financial) capacity to help implement the large-scale rehabilitation programs that are needed to re-claim this territory. The relative simplicity of ownership and mining rights in the West Rand Basin, with two main companies operating, could allow for the establishment of a partnership for landscape remediation whereby these companies play a crucial role.

These frictions and the lack of a synthetic and long-term approach to the future of the West Rand's mining area prevent the creation of a common vision that is capable to structure the post-mining development and rehabilitation of this territory and inhibits any joint action that would be necessary to realise this vision.

While mining has severely disrupted the soil- and water-cycle, these interlocking landscape processes are also the basis for the spatial qualities of the West Rand's landscape and urban tissues. Therefore, any future vision for the area needs to be built around the restoration of these cycles and take advantage of the landscape possibilities generated by the cleaning of soil and water. This process of landscape rehabilitation can catalyse a re-structuring of existing urban areas and redefine their relationship with each other. Moreover, it can support alternative economies and help to empower local inhabitants to become a part of the socio-economic revival of the West Rand. Looking at the (urban) landscape as a process implies a long-term approach in which many small contributions will, over time, generate a new image for the region.

Large-scale mining operations and apartheid planning policies have been crucial forces that shaped the territory of the West Rand in the past. However, they are also contradicted by countercurrents of informal appropriation, creative recycling and natural colonisation. The future of this landscape lies in a piece-by-piece transformation that can shape the territory of extraction and separation into a productive and common landscape. This document therefore doesn't pretend to formulate a ready-to-go solution, but rather proposes new lines of thinking as a base for debate about a common vision for the West Rand's post-mining landscape.



Waterval

Dullands

Krugersdorp-west

Krugersdorp-noord

Mancoment

**KRUGERSDORP**

Botloana

east-west railway

Main Road

Lefuruvlei

Factoria

West Village

Lewisham

Soul City

Wilpoortje

**KAGISO**

Genedhils

Azadivle

**RANDFONTEIN**

Tshapsonq

Rucvane

Voekomsrus

Moshakong

*Urban areas and infrastructures*



5km

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1 | SCULPTING THE HILL  
*RE-THINKING THE SOIL CYCLE*



5km

## *SCULPTING THE HILL - RE-THINKING THE SOIL CYCLE*

The landscape of the West Rand is littered with mounds of yellow tailings and heaps of sandy dust. These remnants of its gold mining industry are an obvious indication of how the topography and geology of this region have been disturbed. Decades of extracting gold-bearing ore have resulted in a damaged landscape both underground and on the surface. The visible tailings dams and mine dumps, are mirrored by an underground network of shafts and tunnels, and complemented by open cast mining pits and areas of polluted soil.

### *How mining alters topography*

And still, rock is being blasted and strips of land are laid open to find gold on the outcrops of the reef. These open-cast operations leave behind large pits, piles of valuable top soil and heaps of waste rock that can contain metals and even uranium.

Underground workings are being re-opened to extract what was left behind before. The gold mining shafts can go down to 3000 m below surface. They are part of an invisible mining void that is filling up with acid water and has many openings to the surface. It literally undermines the geotechnical stability of the area.

Sand dumps and tailings dams contain the waste material of these extractive activities. The production of one gram of gold leaves behind a tonne of crushed rock, which is deposited on the landscape in older heaps of sand, or more modern engineered slimes dams. Both contain high amounts of heavy metals, and form sources for water and soil pollution in a large area around.

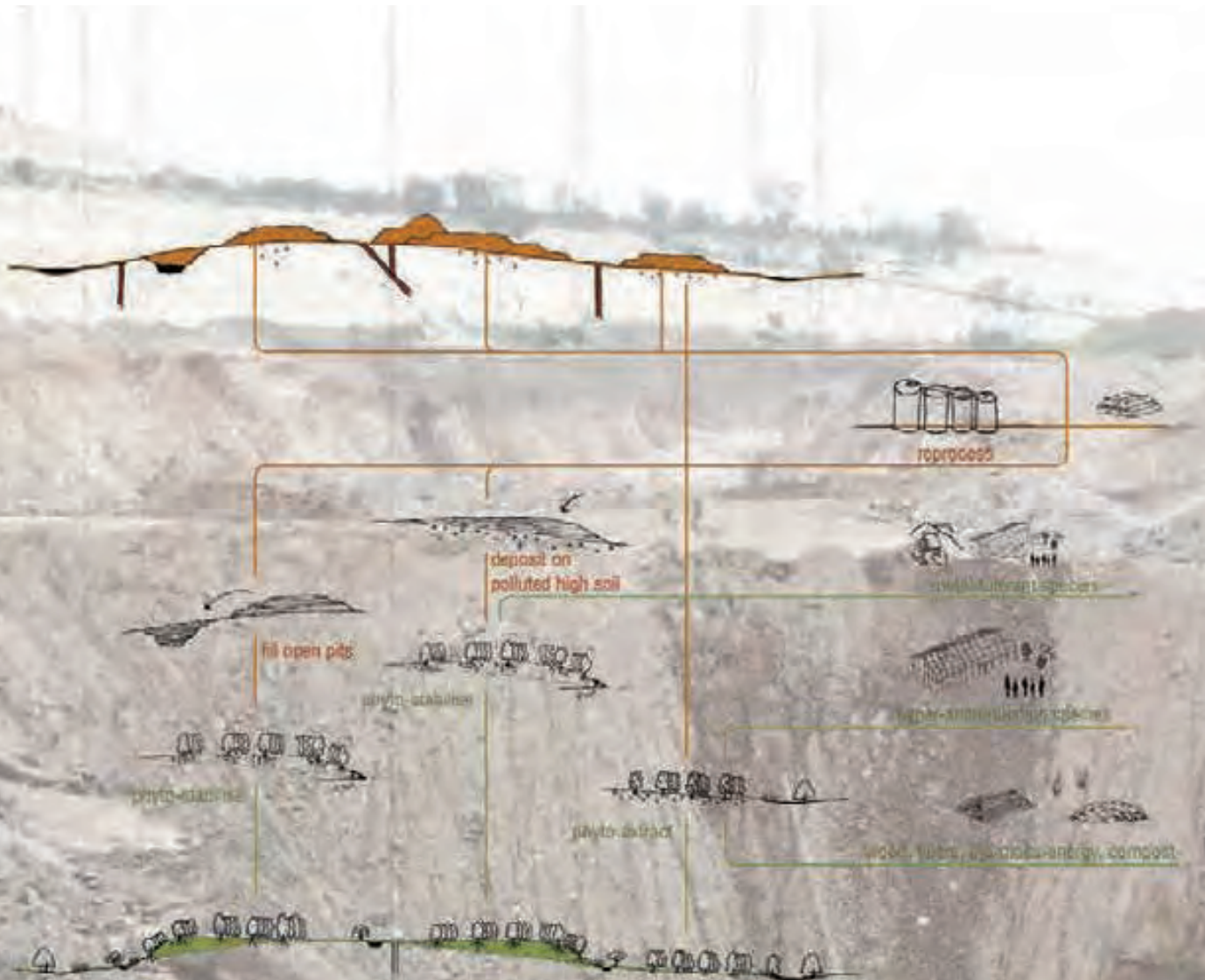
Since the 80s, many of the tailings dams are being re-mined because with current technology the remaining gold can be extracted at a profit. Tonnes of tailings are transported as a slurry to the processing plant, and then dumped at the edges of the city after being re-processed. This removes potential hazards from the West Rand area, but at the same time pollutes pristine lands further away. The 'super-dumps' used to deposit re-processed tailings are a burden for future generations as they require permanent monitoring and maintenance.

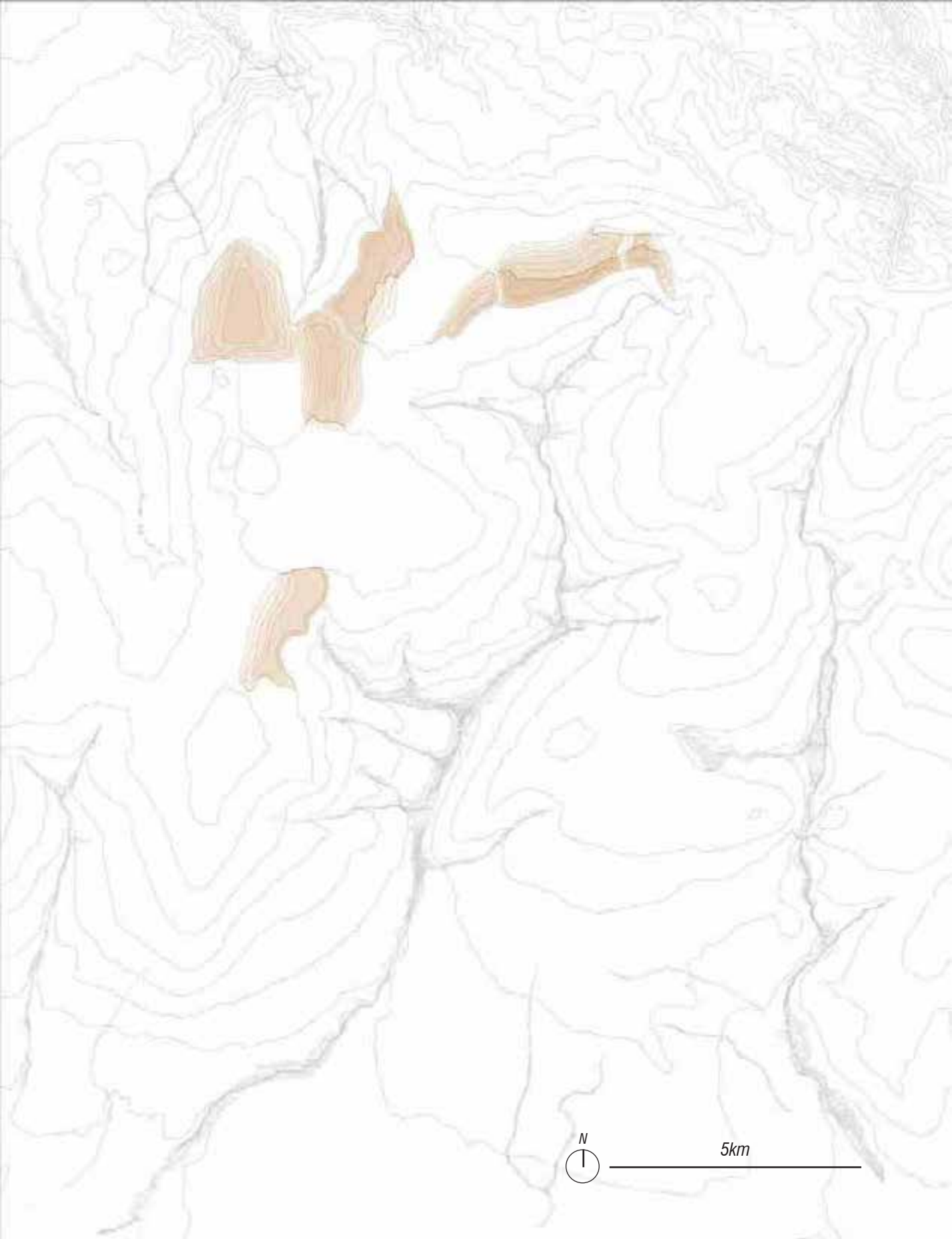


## *'Moving dirt' as a way to re-shape the landscape*

This vision looks at these mine tailings as a building material to reshape the landscape. It wants to operationalise the huge potential of mining companies to alter topography and move dirt. That way, the cycle of extracting and dumping soil and barren tailings can be re-thought in a way that creates a stable and qualitative post-mining landscape surface.

The existing practice of creating huge and purely utilitarian 'facilities' that need to be maintained mechanically, such as tailings dams and super-dumps, could be re-considered radically. The crushed and milled rock, made into a slurry after the gold extraction process, can be deposited on already-polluted areas in the landscape, in a way that accentuates its natural shape. Over time, these depositions could be stabilised by vegetation and form a wild post-mining landscape that can accommodate natural and human appropriation.





5km

## *New soil cycles*

The existing dumps and dams will be re-processed in phases, and can then partly be used to fill existing pits. However, because the mined rock has been milled into fine particles to extract gold, it has double the volume it had underground.

Therefore, the substantial volume of remaining waste material will be deposited on contaminated mine residue areas in the landscape, such as footprints of re-processed dams and dumps and their surrounding, contaminated soil. The contaminated tailings are then concentrated in safe and delineated spaces that can be secured, and play a role in re-defining the topography of the West Rand's post-mining landscape.

This vision proposes to choose higher parts of the landscape, to extend and accentuate the existing hill structure of the watershed divide between the Limpopo and Orange river basins. The tailings will be deposited along the existing hill, with a very gentle, almost invisible slope towards the highest point, and a steeper one towards the valley. Using soft slopes of maximum 16 degrees ensures that the surface can be colonised by plants that will help to physically stabilise it. This will, over time, eliminate the need for mechanical maintenance of the shape of the landscape.

By depositing the material in that way, plateaus will be created that form part of the hill structure and give views over the valley. This new topography will re-shape the horizon and delineate the catchment area of the Wonderfontein and Tweeloopies Spruit rivers.

### *Stabilised by woodlands on the hill, and remediated in the valley*

The contaminated deposits can be stabilised with metal-tolerant vegetation. The woodlands on the tailings deposits will become part of one green structure that follows the hill along the watershed division line. This vegetative range of forests, grassland and woodlands will further frame the space of the valley and strengthen its edge. At the same time, this vegetation can control pollution by binding the metals in the ground to its roots in a chemically more stable form. By evaporating water, the plants will also limit the run-off of polluted water into wetlands and river systems and prevent the infiltration of acid water to the groundwater reserves underneath.

The tailings dams and mine dumps closer to the Wonderfontein Spruit river system will be removed step by step during the process of re-mining. Their polluted footprints and the soil around can then be remediated with metal-accumulating plants. These will extract metals and sulphates by absorbing them into their stem and leaves. On the long term, the soil will become clean if these plants are regularly harvested and the microbiological processes in the soil can revive. In the meantime, these remediation technologies can already become productive in many ways. Plants like rape seed, hemp, flax and bamboo have many applications for their biomass and fibers and can kick-start an alternative economy based on the rehabilitation of polluted land. Nurseries, pilot-projects, maintenance and harvesting can include local businesses and communities to become part of the remediation of the landscape that surrounds and sustains them.

The woodlands on the hill will form a more extensive and wild landscape that can be appropriated in different ways. Areas where the vegetation grows on unpolluted soil can serve as large habitats for wild animals that might attract touristic activity, or generous grazing areas for cattle-farming. Places where, especially in the first decades, vegetation could be contaminated, should remain wild so that a new ecosystem can develop. Nevertheless, they can become accessible for human use and wildlife on the long term. These woodlands can provide close to the city what wilderness has to offer, in the form of harvesting for traditional medicines or household objects, fire and construction wood, as well as a territory for spirituality and traditional rituals.

The sculpting of the landscape is on the one hand based on the creative engineering of the re-processed tailings. On the other hand it re-thinks the landscape of the Wonderfontein Spruit and Tweeloopies Spruit rivers as a large-scale wild and productive landscape that complements the urban areas around it. The hill structure frames the valley and then transitions into the southern townships of Mohlakeng, Toekomsrus and Kagiso. Lying in-between the different parts of the urban agglomeration, it provides a common territory of productivity, landscape rehabilitation and (informal) human appropriation.



## 2 | CULTIVATING THE VALLEY *RESTORING THE WATER CYCLE*



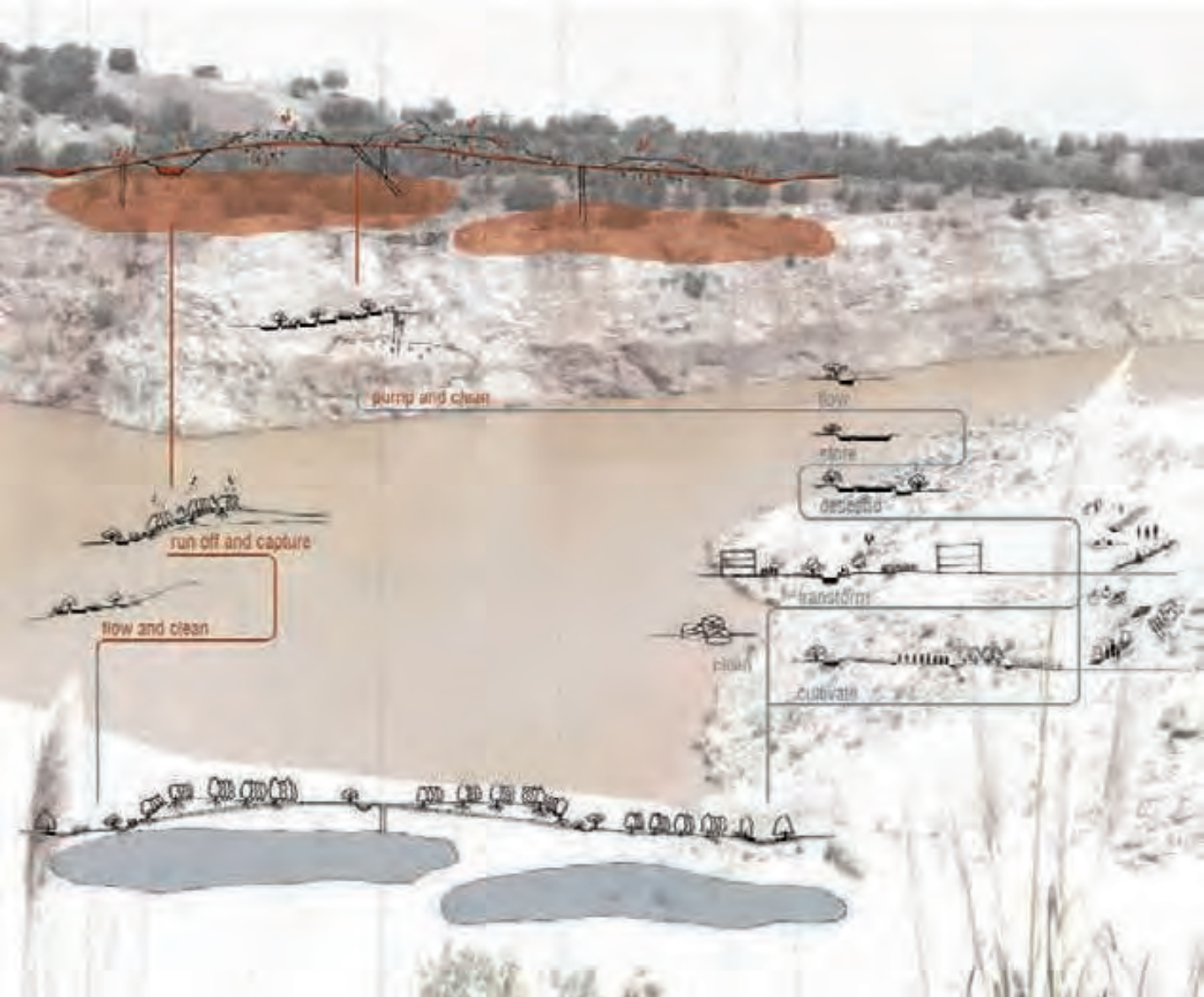
5km

## *Introduction*

The economies of the West Rand have always been based on its water and soil. The well-karstified dolomite formed a rich groundwater reserve for an agriculturally based economy, which has later been taken over by the exploitation of the valuable ore layers (WINDE and STOCH, 2013). Regardless of the value of water in this semi-arid region, the availability of water has been disturbed and its quality is being compromised by the gold mining operations. Water was pumped to allow for deep mineshafts, with a direct impact on the aquifers, the farmers depending on them and the stability of the ground, with large sinkholes as a result (WINDE and STOCH, 2013). Springs of both the Wonderfontein Spruit in the south as the Tweeloopies Spruit in the north have dried up, whereby the flow rate of these rivers has been reduced. Moreover, surface water is being held upstream with multiple dam constructions, since it is used to move the crushed ore from the mines to the processing plant and acts as an energy medium for underground drilling operations. The reduced water volume of the river has affected ecosystems and people living downstream who depend on it for domestic use (ABIYE and BAMUZAAND, 2012). In this semi-arid region, industries and urban agglomerations have a large impact on water scarcity, which forms the main constraint for economic development (TURTON, 2009). Other than reducing the availability of water, mining operations have had a large impact on the quality of the available water as well. The runoff water and seepage from the tailings facilities and the groundwater coming out of the mine shafts is very acid and contains high concentrations of sulphates and heavy metals (ABIYE and BAMUZAAND, 2012).

These conditions are a severe threat for both ecosystems and agriculture. Especially after pumping operations in the West Rand Basin -a system of interlinked voids- ceased in 1998 the threat of rising acidic water has become more and more visible (VAN WYK, MOKGATLE and DE MEILLON, 2013). The acid mine drainage (AMD) started decanting in 2002 (TURTON, 2013) and thereby polluted the Tweeloopies Spruit which flows through the Krugersdorp Game Reserve and the Cradle of Human Kind. Shocking images in local media made people realise the severity of the problem and forced mining companies to undertake emergency measures. Currently mining companies are pumping again, even with some renewed ambitions for underground mining (TURTON, 2014, spoken conversation). Considerations to use the decant water for platinum mines had been turned away and the responsible mine was directed to capture and clean the water (WINDE and STOCH, 2013). Up until today however, this active neutralisation treatment mainly focuses on raising the pH and the precipitation of metals, without a considerable reduction of sulphates (HOBBS and COBBING, 2007). Moreover, a very toxic sludge is being produced, which needs to be disposed of as well. Since the watershed divide between the Limpopo and Orange river system curves down through the mine impacted areas in the West Rand, both river systems are being threatened by the ongoing pollution. This makes the re-conceptualisation of the water cycles in the West Rand of crucial value.





### *New cycles of water*

Complementary to the proposed soil movements, the vision proposes a new water system that converts the interrupted water cycles into an asset for the urban region. The concept is based on a system of canals, fed by either runoff- or groundwater pumped up from the mining void. After a cleaning process, the water is redistributed as a trigger for alternative development. Throughout the process, different systems are implemented to capture polluted runoff water before it reaches the natural river system. As an emergency measure, temporary paddocks are constructed around existing dumps to collect the runoff water before and during the reprocessing activities. Plantations of resistant trees will form an additional buffer to prevent pollution plumes to reach the river. The aim of these measures is to allow the natural river system to revive by taking out the main sources of pollution for the Wonderfontein Spruit and the Tweeloopies Spruit as soon as possible.



Secondly, **three new canals** are constructed that underline the newly created topography, which is formed by the **reprocessed tailings dams** of the area. These canals will not only capture the water, but will also distribute it to **wetland systems** that will clean it to irrigate productive remediation in the valley. Rather than to consider the cleaning of water as a burden, the aim is to convert the need to capture the water during wet seasons or periods of heavy rainfall into an asset that can improve the productivity of remediation when the availability of water is limited. The buffer- and redistribution capacity of these runoff canals, before water flows through the wetland systems, will allow for a constant flow rate to be cleaned in optimal conditions throughout the whole year. Similarly, buffers downstream of the wetlands provide storage of water, to respond to the specific demands during the year. Nevertheless, these canals can be considered as temporary stabilisation systems, since the run-off from the hills will decline as soon as the trees of the stabilisation woodland on the hill have grown and their hydrologic impact is improved. The compost produced by these trees will generate an additional layer on the dumps, which results in reduced acidity of the remaining runoff water.

The clean water supply for the cultivation of the valley will be complemented by a **second, higher canal system**. This canal system is fed by the polluted groundwater which decants currently at an average of 27Ml/day. As soon as the mine impacted areas will be remediated however, this average amount of decant will probably reduce (DIGBY Wells & Associates, 2012). To maximise the potential use of this large volume of water, it will be pumped at the highest points of the area, by reusing **old mineshafts**.

Although the recharge of groundwater differs throughout the year, the water can be pumped at a constant rate. As long as the highest point of the groundwater table remains below the environmental critical level (ECL), there is no threat for uncontrolled pollution plumes, since subsurface flows are not possible below this level (SOUTH AFRICA. COUNCIL FOR GEOSCIENCE, 2010). As a result of the constant flow rate of pumping, the excess of recharge water during wet season is being stored underground and compensates for the lower recharge during dry season. This underground storage is not subjected to evaporation, prevents the construction of large buffer facilities of polluted water above ground and follows the natural fluctuations of the groundwater table (WINDE and STOCH, 2013). As soon as the water is pumped, it is treated by local passive treatment systems -**constructed wetlands**- that are able to work in optimal conditions, due to the constant rate of pumping.

### *Apartheid planning reconsidered*

After being cleaned, the water is redistributed by a canal that follows the highest edge of the landscape and partially runs along the railway. Thereby it is brought through the industrial area of Chamdor, the townships Kagiso, Rietvallei, Azaadvilleville, Mohlakeng and Toekomsrus and the old mining town called West Village. This brings a radical re-conceptualisation of these urban areas, since under the apartheid planning they have been built in-between river valleys. Together with the mining belt, these valleys work as buffers to separate them from each other and the formerly white areas. Therefore they don't have the same spatial quality as for example Krugersdorp, that is built around, and structured by a river valley along which it has open spaces, areas for recreation, a lake, etc. So the idea of bringing a canal into the monotonous, low-density townships, is to profoundly change their character and spatial qualities.

This availability of water at the highest points of the area becomes the backbone of a *new water structure* that can be built by the inhabitants themselves. The resulting network is flexible and can be built incrementally. Its structure is based on the topography and the numerous redundant streets that can be appropriated. Canals that run downhill are smaller and have a constant flow, while those parallel with the topography can take more space to collect and buffer water. The aim of this structure is to generate a piece-by-piece transformation of the urban tissue in order to break the mono-functional and repetitive characteristics of the existing township.

Water-based economies can be inscribed into the urban tissue, recreational spaces can be upgraded and the network for pedestrians can be improved. The creation of open spaces can be encouraged by allowing higher buildings on smaller footprints, which will also diversify the typologies throughout the urban areas. Such open spaces can be appropriated for productive uses such as grazing and urban agriculture, or recreational use, informal meetings, etc. These uses will also define the shape of the canal, from wadi or furrow to large water bodies in correlation with the topography. To counter the history of top-down planning however, the aim is to provide the structure and a set of principles and thereby empower the people to collaborate bottom-up in changing their living environment.



5km





### *Alternative economies*

The availability of water through the canal system can also generate a new kind of agriculture by irrigating the slopes of the Wonderfontein valley. Given the need for a new economic driver in the West Rand, this alternative agriculture can benefit from the large availability of workers and the optimal infrastructural connection to the fresh goods markets in Johannesburg. The access to water makes it possible to grow crops and trees that need supplementary irrigation throughout the year, as long as a delicate balance between consumption and availability of water is preserved.

The availability of cleaned runoff water can also trigger the productivity of areas that need remediation. So again, the aim is to convert the necessity to treat the polluted water into an asset to trigger new economies. Since the timeframe of remediation will outlast the remaining lifespan of mining companies (COETZEE et al., 2003), there is a need for other actors to pay for the pumping and treatment operations. Rather than to count on the government -and therefore the taxpayer- to take on these responsibilities, the potential availability of water -which is a valuable product in the area- can pay for itself.

***“Harness the energy of where you are in a cycle.”*** (Caroline Digby, 2014)

Finally, the river system that is now severely polluted by acid water and has also accumulated uranium in its sediments, can slowly revive. It can resume important ecoprocesses in its wetlands, and its characteristic vegetation can flourish again. Moreover, the cleaning of this important ecosystem will benefit the surrounding villages as well as the communities living downstream.

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## 3 | VISION IMPLEMENTATION

*REALISING THE TRANSFORMATION  
OF A LANDSCAPE IN CONSTANT FLUX*



5km



MRA 172

WWP

north sands

IL8

IL23-25

East Chandor  
cluster

IL28

IL13-15

MRA 159

MRA 160

MRA 174

## *Introduction*

The previous chapters have introduced an ambitious and large-scale vision that starts by re-thinking the water- and soil cycles. However, it is based on existing capacities and potentials of transformation by a multitude of actors. Therefore, while this seems to require huge investments at first sight, this chapter shows how the landscape of the West Rand can be transformed in small steps that do not all require large amounts of financial capital but rely on the engagement and ambitions of many local businesses, public actors and communities.

In this regard, we start from the current reprocessing operations of mining companies and their knowledge about altering water flows, the interest of private investors to develop the area and the creativity of inhabitants to transform their environment and to look for alternative ways of income generation. In contrast with current projects, where the government is the main investor, the aim is to use governmental investment in a strategic way.

Basically, the transformation of the West Rand is already happening, with the reprocessing activities of Mintails and Sibanye Gold. By simply altering the final destinations of these reprocessed tailings to the areas along the watershed defined in the vision, the implementation can already start today. The following chapter shows the different agencies that should be involved and the how the project can be implemented step by step by transforming the landscape.

***“how do you eat an elephant? Piece by piece”.*** (Hannah Le Roux, 2014)

*A stopmotion video visualising the phasing of the vision,  
is available from: [https://www.youtube.com/watch?v=ihLg\\_v8sjwQ&feature=youtu.be](https://www.youtube.com/watch?v=ihLg_v8sjwQ&feature=youtu.be)*

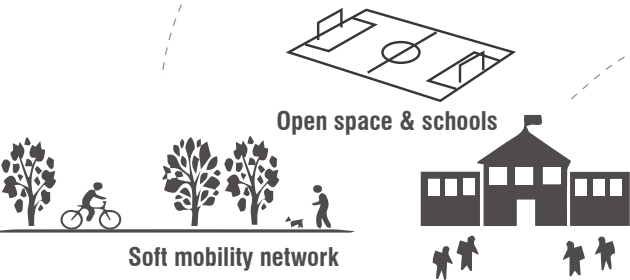
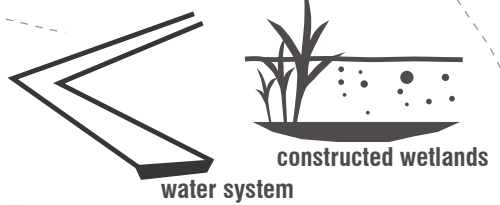
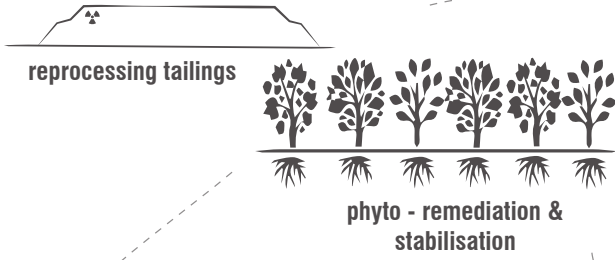
## *Agencies*

When proposing such an ambitious vision, it is important to think about actors that can execute sub-projects. Depending on the agency, different kinds of ambitions, engagement and investment can be expected. To get an idea of potential agencies and collaborations to realise the vision, the following part discusses different types of actors and their interests and capacities. Yet the examples must be seen as suggestions of potential contributors without the aim of excluding others or claiming certain obligations.

Central actors in this regard are the national and regional governmental bodies. They operate with assigned budgets and their interest depends on the next elections. They can start initiatives, grant subsidies or guide private investments based on legislation. Given the history of the country, the national ambitions of the government focus mainly on socio-economic inequalities. Governmental subsidies are invested in programs such as settlement upgrading, financial support for small businesses, a micro and retail agricultural finance scheme for financially active poor people, housing provision programmes etc (SOUTH AFRICA GOVERNMENT ONLINE, 2014).

Parallel or in cooperation with the government, national and international NGO's and foundations invest in charitable projects. Their motives are more directly focused on improving living environments, stimulating economic opportunities or supporting cultural initiatives, since they are not guided by economic or political interests. The 'Ekurhuleni Fruit Trees for Homes project' is an example of a project that was set up as a cooperation between governmental departments (Ekurhuleni's departments of tourism, parks and environment, Gauteng Department of Environment, Agriculture and Conservation) and an NGO (Food and Trees for Africa) (FRUIT AND TREES FOR AFRICA, 2007).

Mining companies have also come to the fore as important investors of charity. Yet their motives reside in the need to maintain their 'social license to operate', given the ecological and social legacy they've accumulated and the growing media attention and stricter legislative requirements they face. Therefore these investments from mining companies must be seen as part of their business strategy, where the ultimate goal of making profit cannot be neglected. They are a valuable partner, since they have the technical capacities to actually convert the legacies of mining. Yet one must realise that the last mining companies standing cannot be held reliable for the accumulated impacts of more than a century of mining. Open communication, sharing of knowledge and local collaborations are important to change the negative attitude towards mining companies, which are often held responsible by protest groups. Projects like the 'Anglo Gold woodland project', whereby the mining company cooperates with phytoremediation-expert Isabel Weiersbye, with WITS for research and with local communities for the implementation show the potential of such new collaborations (WEIERSBYE, 2014). In such partnerships it is also important to understand how the mining company can achieve benefits as well. Land value



Potentially involved agencies

and real estate investments appear to be an important asset in this respect that could attract the interest of mining companies, The foundation of iProp by Rand Mines proves the viability of such a broader frame of investment. Mintails and Sibanye Gold are crucial agencies in this regard for the context of the West Rand. Moreover, shifting from mining to productive rehabilitation activities, mining companies can transform their business model to include and profit from remediation projects.

Knowledge and communication are extremely important to achieve actual collaborations. Relations between the academic and the industrial world are important for ongoing research programs. Institutions such as universities and governmental research centres can improve their research capacity if mining companies work with them. The other way around, mining companies can benefit from the knowledge gained through their research. Good communication is necessary to understand the goals and issues of the different interest groups. Action committees have proven their efficiency to raise awareness locally and elsewhere and to protest against injustices. Stronger communication strategies and a common vision for the future could transform the often negative attitude of such action groups into constructive voices that represent the needs of the community.

The potential of collaboration with local communities however goes beyond communication. Participation should be encouraged by involving local NGO's, but also social organisations and engaged individuals. Such local community organisations are crucial to bring people together, improve the living environment and empower the inhabitants. Whether it is to reduce poverty, create new job opportunities, shape new open spaces or provide recreational activities, they have the capacity to engage locals. Since access and sharing of knowledge are important to stimulate a transformation of the economy, schools and training institutes are crucial. By developing skills and local knowledge among younger sections of the population, a change in mindset and capacity can take place that can support and stimulate the transition to a post-mining economy and society. The Seriti Institute in Randfontein is an example of such a local organisation that empowers and trains local organisations. They organise workshops and internships for youth to create leadership capacity and other skills and set up local projects, like the food garden in Solani Primary school to support children's families to pay for their school fees, organise (SERITI INSTITUTE, 2011). The local government level is an important mediator agency between top-down projects and bottom-up potential. However, the lack of institutional capacity and an insufficient economic base are important weaknesses for the local municipalities of Randfontein and Mogale City.

Since the issues and interests of the reclamation of the mining belt in the West Rand are so complex, strong agencies, which can represent the different actors involved, should lead the planning process. The Chamber of Mines (CM) can represent the interest of mining companies, an agriculturally based economy could be stimulated by the Department of Agriculture and Rural Development (G-DARD) and communities could be legally represented by an institute such as the



Socio Economic Rights Institute of South Africa (SERI). Developing a spatial framework, as is suggested in this thesis, becomes difficult but extremely important, to bring all different interests together into one vision which can be decomposed into guidelines, regulations and projects of different scale that can involve various collaborations between stakeholders. The following part can be seen as a first step to decompose such a broad vision into smaller phases.

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## *Stabilising risks*

The first phases, are about stabilising the biggest immediate risks of the impaired landscape. The closure of open pits is an important aspect, since they are currently responsible for a significant amount of polluted ground water recharge. As soon as they are closed, direct seepage of water into the ground will be replaced by run-off water and evaporation. To minimise ongoing pollution of the natural river systems, the planned runoff canals for the new topography can be constructed already where possible, together with some smaller wetlands which can work as pilot projects for the new type of water treatment. In places where no runoff canal is planned, paddocks can be installed to catch the processing water. These measures can be complemented by riparian vegetation structures that work as a secondary buffer. Most of these interventions are already part of the mining operations today, or can be seen as more permanent alternatives that don't require major additional costs, especially when considering the reduced environmental impacts in the long run. Agreements between local communities and mining companies, based on landswapping arrangements, can be initiated to include the reprocessing of ownerless dumps in close proximity to urban areas.



### **Reprocessing**

*IL8 - Mintails*

*MRA 159 - Sibanye Gold*

*dumps East Chamdor cluster - Mintails*

### **Filling**

*West Wits pit (WWP)- Mintails*

### **Run-off Canals**

*Paddocks IL23-25 - Mintails*

*Paddocks MRA 172 - Sibanye Gold*

*Runoff canal WWP - Mintails*

*Runoff canal MRA 174 - Sibanye Gold*

### *Strategic investment*

Along the watershed, the first pump for AMD and a large wetland system can already be installed and the first part of the main canal can be constructed. Parallel with the construction of the canal, the vegetation structure of the non-polluted hill can be implemented. Since these investments are part of the urban strategy for the West Rand, investments in this regard can be subsidised by the government, although mining companies can execute the works. For the government it should be considered as a catalysing investment for the future, since as soon as the area starts to attract new investors, tax incomes will increase. For the mining company on the other hand, it can be considered as a transition towards a new core business after mining operations have ceased completely.



#### **Reprocessing**

*IL8 - Mintails*

*MRA 159 - Sibanye Gold*

#### **Filling**

*WWP- Mintails*

#### **Run-off Canals**

*Paddocks IL13-15 - Mintails*

*Paddocks IL28 - Mintails*

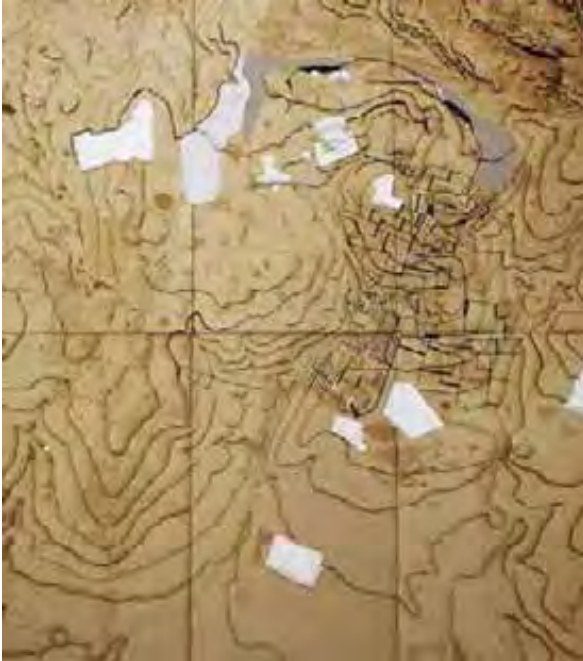
#### **River on the hill**

*Wetland Soul city - Mintails | Mogale City*

*main canal - NGO | local community*

### *Sculpting the hill*

As soon as the pits are filled, the reshaping of the landscape can continue by the construction of the hills along the watershed divide, using the reprocessed tailings. Since the area of West Wits pit doesn't have any tailing dams, this can be the first part of the hill to be constructed. This process is very similar to current practices. Yet in stead of bringing the processed tailings to desolate superdumps, they are deposited within the West Rand mining area to reshape the topography.



#### **Reprocessing**

*1L23-25 & 1L13-15 - Mintails  
MRA 172-174 - Sibanye Gold*

#### **Sculpting the hill**

*area WWP - Mintails*

#### **Runoff canal**

*Spring Wonderfontein Spruit (WFS)-  
Mintails*

#### **River on the hill**

*Wetland West Village -  
Mintails | Mogale city  
main canal - NGO | Mogale City  
urban canals - local community | iProp*

## *Incremental water structure*

After the first wetland along the watershed is completed, pumping can start and the first part of the water system can be filled. The filling of the large water bodies of the buffers will initially compensate the lack of users while the lateral branches are still under construction. This attached canal network can be built incrementally by the inhabitants themselves and by investors of new urban development projects. The government has a organisational role in this respect, since it needs to combine the different cooperation projects into one network. Although the setting is very flexible, a coherent system is necessary to make sure that water flows continue down into the valley to prevent flooding within the urban area. The same organisational role goes for new projects where higher building heights can be allowed if compensated by open space. Yet the municipality can become an investor itself as well, with projects related to schools or recreational areas. Especially in this phase, such investments are crucial, to show the potentials of the new water structure and to convince other actors.



### **Reprocessing**

*1L23-25 & 1L13-15 - Mintails  
MRA 172 - Sibanye Gold*

### **Sculpting the hill**

*MRA 174- Sibanye Gold*

### **Runoff canal**

*Spring WFS - Mintails*

### **River on the hill**

*Wetland Randfontein - Sibanye Gold  
main canal - NGO | Mogale City  
urban canals - local community | iProp*

### *Economies of remediation*

While the reprocessing of dumps and parallel the construction of the sculpted hill continues, the reconstructed landscape needs to be stabilised as well to prevent ongoing pollution. Although the runoff canals capture the majority of the acid water for treatment, vegetation is necessary to stabilise the contaminants and the tailings and to hold as much of the water as possible. Based on experiments and pilot projects, tolerant species can be selected and grown in nurseries before being planted on the new topography. The required investment can come from the mining companies themselves, given the savings on transportation to the super-dumps, and their management in the long term.

The plants used for stabilisation need to be harvested regularly to control their hydraulic impact, which results in biomass that can be used for e.g. biofuels. Although this sculpted hill will never acquire the status of being clean, it will become a stable entity in terms of pollution, that can have a relatively cost-efficient management, given the biomass that is generated. As soon as the tailings facilities within the valley are removed, their polluted footprints can be remediated as well. The aim is to remove pollutants in this area and to allow the micro-organisms within the soil to slowly revive. Therefore species that accumulate pollutants are planted and regularly harvested to extract remaining metals and salts. Yet the aim is to make this remediation process economically



#### **Reprocessing**

*1L23-25 & 1L28 - Mintails  
MRA 172- Sibanye Gold*

#### **Sculpting the hill**

*Spring WFS- Mintails*

#### **Productive remediation**

*Spring WFS - Mintails*

#### **River on the hill**

*main canal - NGO | Mogale City*

viable by using the polluted parts of the valley to grow metal-accumulating productive species as well. Hemp, flax and bamboo are examples of species that are tolerant to the pollutants and with economic value as well. Planting, harvesting, transporting and processing activities for remediation and stabilisation can become the driver of a new economy, that ensures its continuation in the future.

### *Cultivating the valley*

The vegetation structure, that interlinks the newly sculpted hills to form one spatial gesture, will be continued along with the construction of the canal, wetlands and pump-points along the watershed divide. The current pumping and treatment activities of the mining company itself should continue for a while to allow the water table to drop below the environmental critical level. The large amount of available water is much more than necessary to transform the urban areas, and has economic potential as well, which can account for the financing of ongoing pumping and maintenance costs of the wetlands. The water can irrigate the valley of the Wonderfontein Spruit to trigger a new economy of agriculture. These new economies entail a large potential for job creation in the area, which will be reflected in the built tissue as well. Together with the new projects and transformed open space framework, the area of the West Rand can attract a more diverse mix of people of different income groups.



#### **Reprocessing**

*MRA 172- Sibanye Gold*

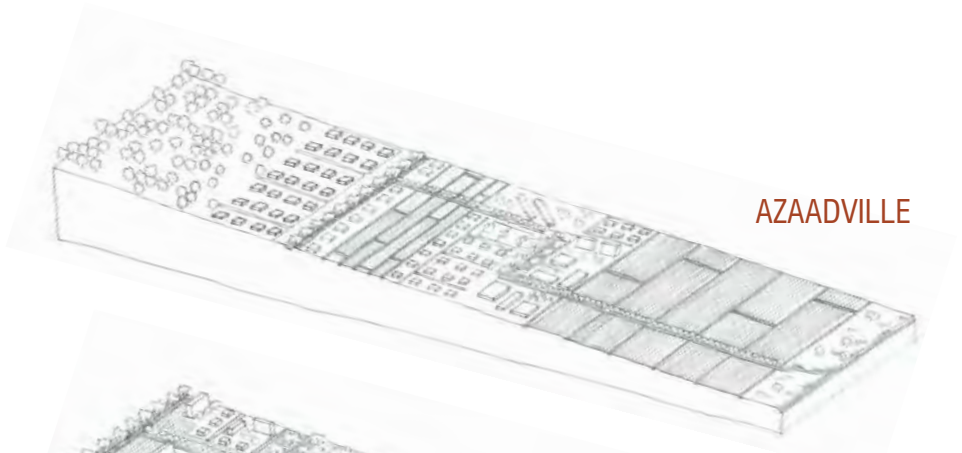
#### **Sculpting the hill**

*extension area WWP- Sibanye Gold*

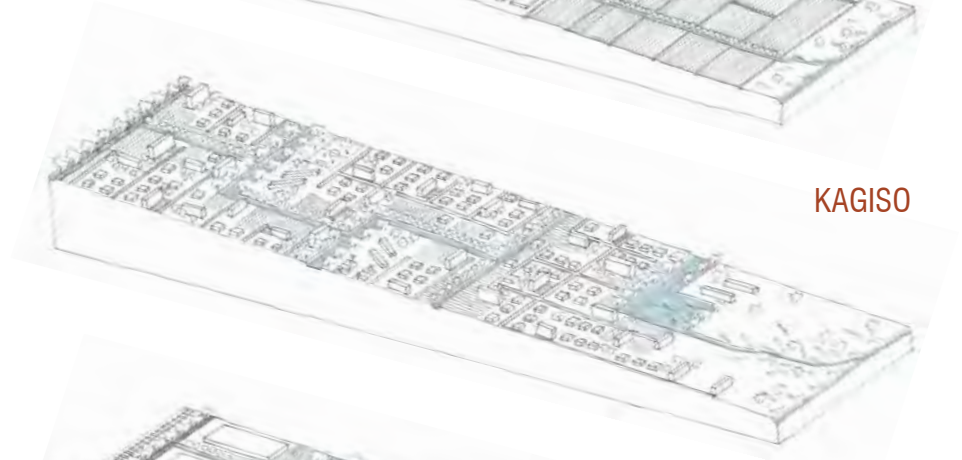
#### **River on the hill**

*main canal - NGO | Mogale City*

*Irrigation - NGO | farmer cooperations*



AZAADVILLE



KAGISO



KAGISO - CHAMDOR



WEST VILLAGE





WEST-VILLAGE

KAGISO-CHAMDOR

KAGISO

AZAADVILLE

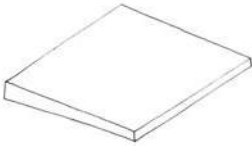


5km

In the following chapter, a more detailed design for 4 specific areas will be explained. These examples test and show how the vision could be translated into different residential, socio-economic and landscape contexts. Main design principles are outlined on the following pages and possible actors that are important for their implementation, are suggested. The strategies represented in the vision and the key design approaches will be adapted according to the specificities of each place represented in the zooms. Both the water system and the landscape of remediation and production take different forms and offer varying opportunities and qualities depending on the inhabitants and spatial characteristics of each area. Also actors can vary according to the type, scale and location of strategic design projects and actions.

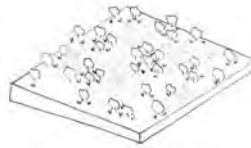
## LANDSCAPE TRANSFORMATION

*existing*

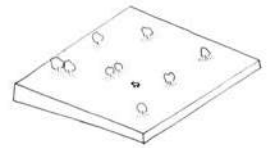


slightly sloping  
unpolluted area

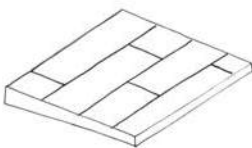
*design principle*



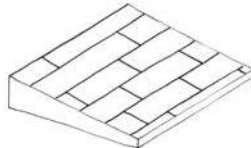
woodland



grazing area



slightly sloping, irrigated  
unpolluted area

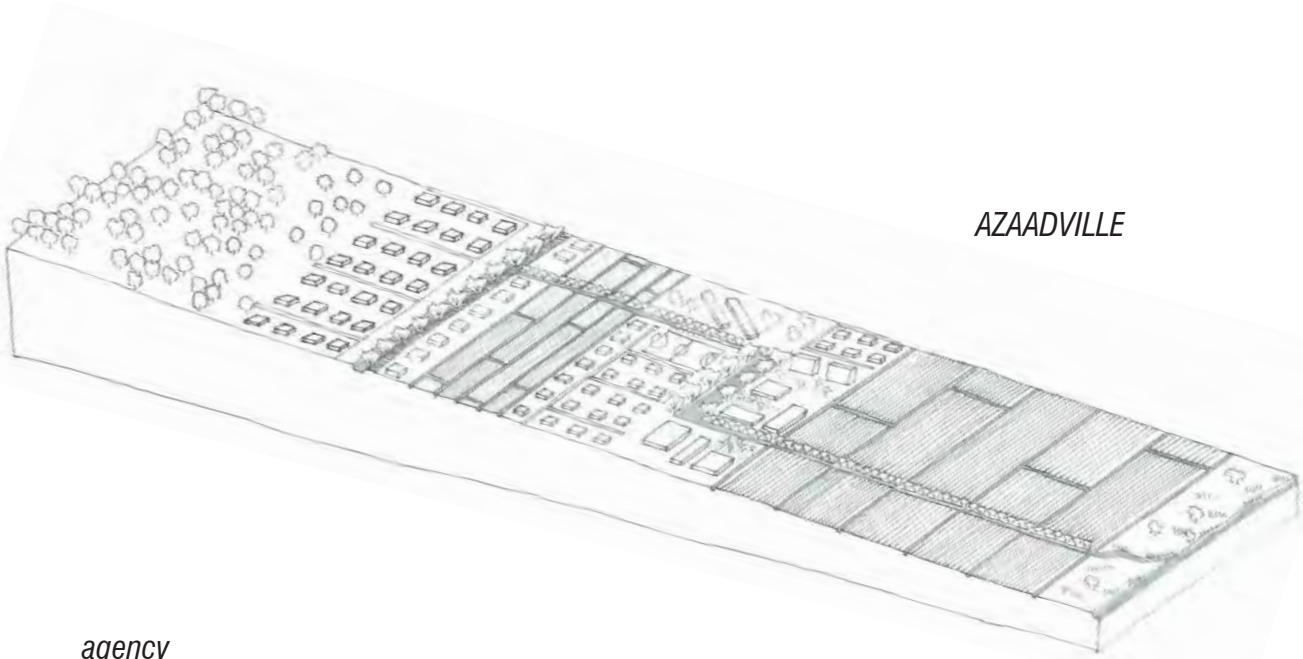


sloping, irrigated  
unpolluted area



irrigated  
agriculture



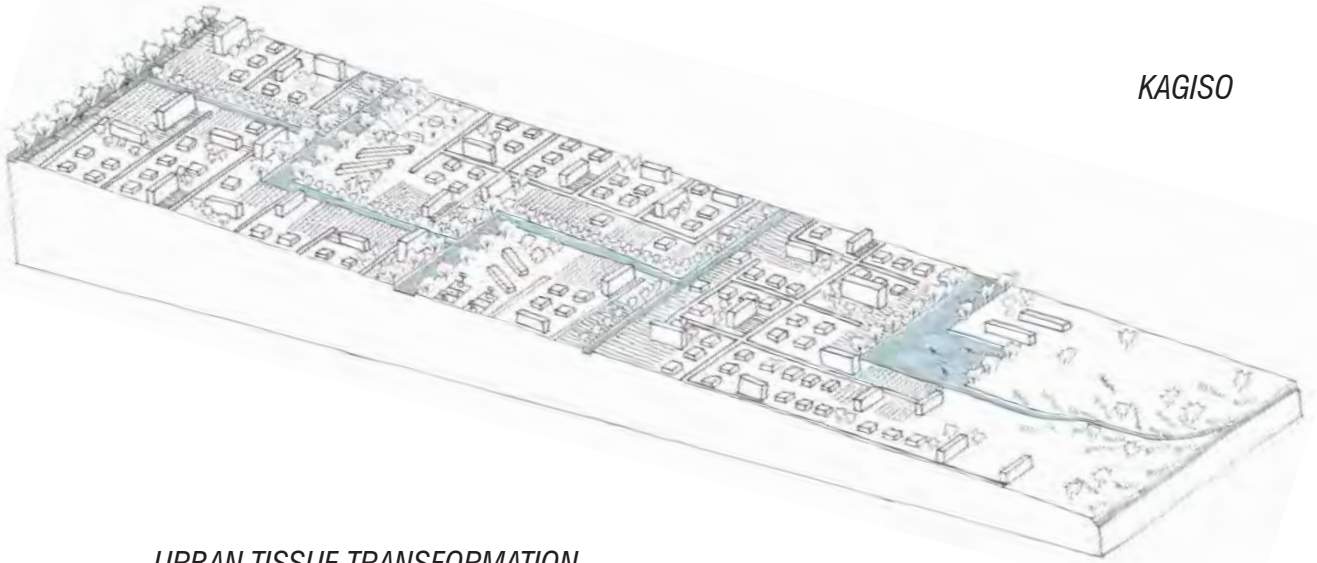


AZAADVILLE

*agency*

local community  
environmental organisation  
agricultural | forestry entrepreneurs

local community  
agricultural entrepreneurs



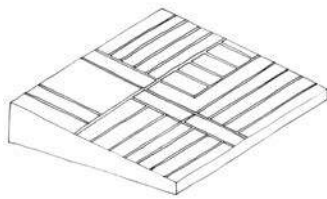
*URBAN TISSUE TRANSFORMATION*

*public space*

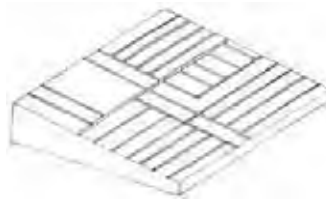
*existing*

*design principle*

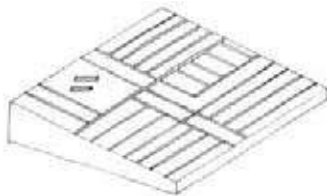
*agency*



lateral street



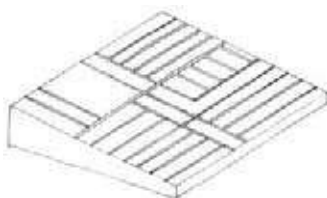
municipality  
community  
organisation / ngo  
inhabitants



transversal street



municipality  
local school  
ngo  
engaged inhabitants

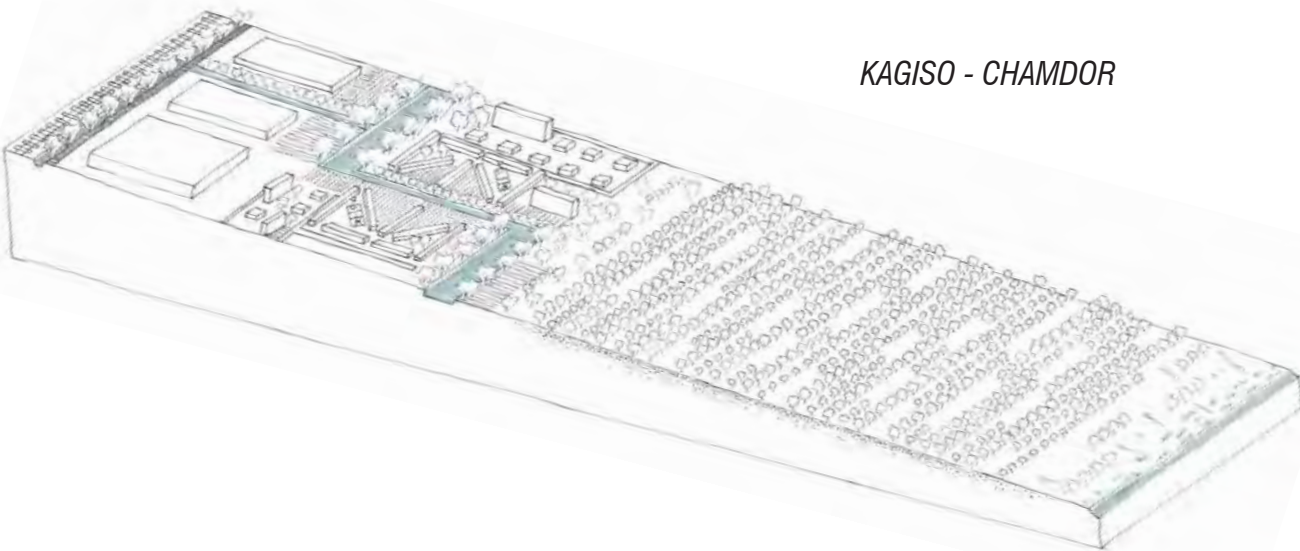


transversal streets



municipality  
community  
organisation  
ngo  
local inhabitants

KAGISO - CHAMDOR



private space

existing

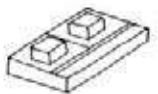
design principle

agency

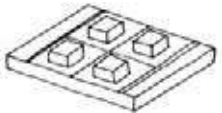
2 plots across



2 adjacent plots

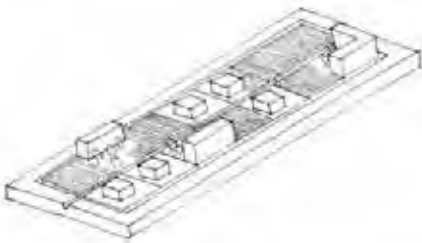
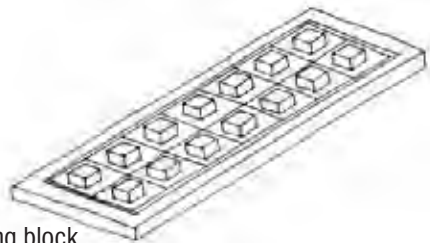


4 plots



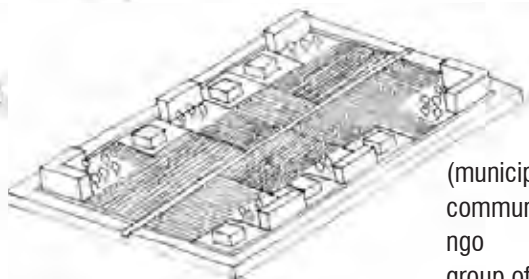
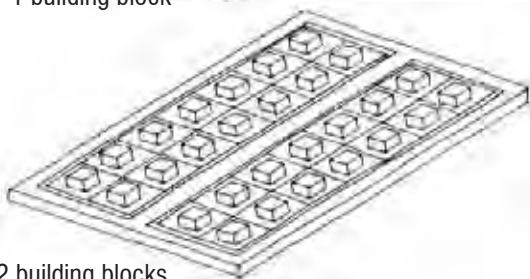
(municipality)  
(community organisation / ngo)  
several neighbours

1 building block



(municipality)  
community organisation / ngo  
group of inhabitants

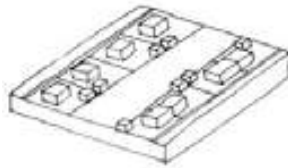
2 building blocks



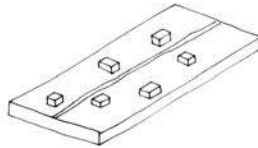
(municipality)  
community organisation / ngo  
group of inhabitants

### URBAN TISSUE TRANSFORMATION

*existing*

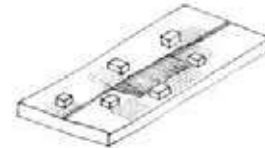
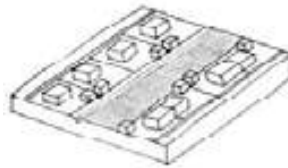


backside alley

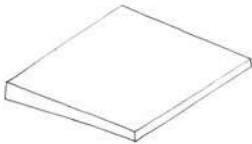


cluster of informal houses

*design principle*



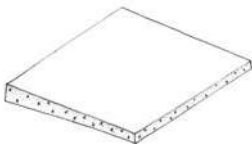
### LANDSCAPE TRANSFORMATION



slightly sloping unpolluted area



woodland, grazing area



slightly sloping polluted area



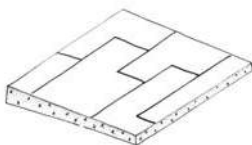
sloping polluted area



pollution stabilisation



pollution extraction



slightly sloping, irrigated, polluted area

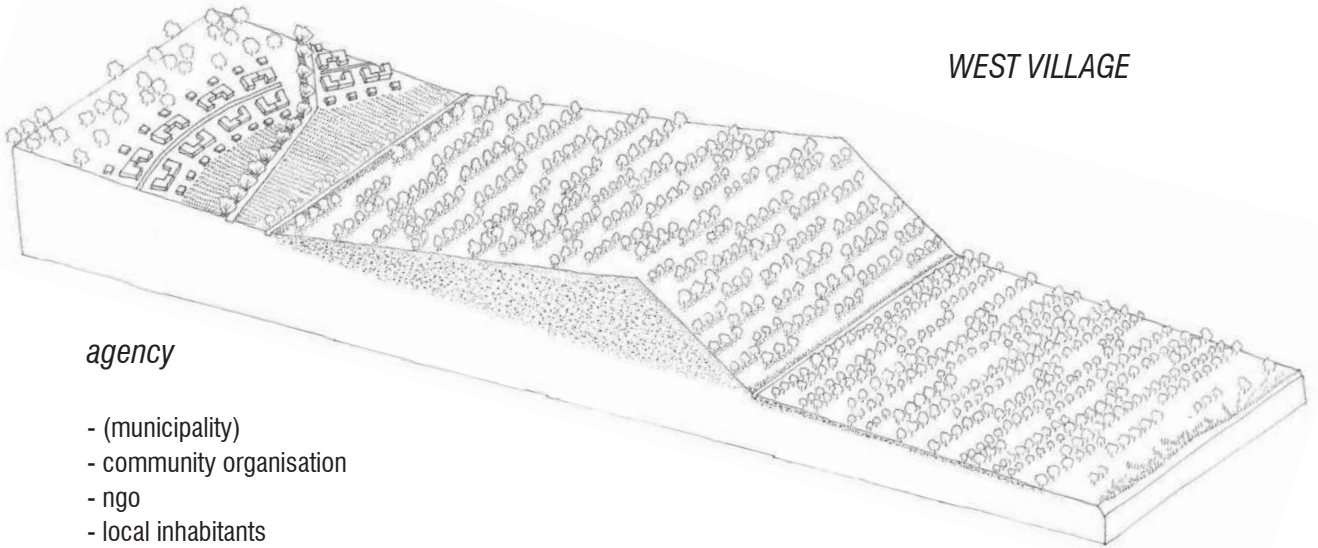


sloping, irrigated, polluted area



productive remediation

## WEST VILLAGE



### agency

- (municipality)
- community organisation
- ngo
- local inhabitants

- ngo
- informal dwellers

- local community
- environmental organisation
- agricultural | forestry entrepreneurs

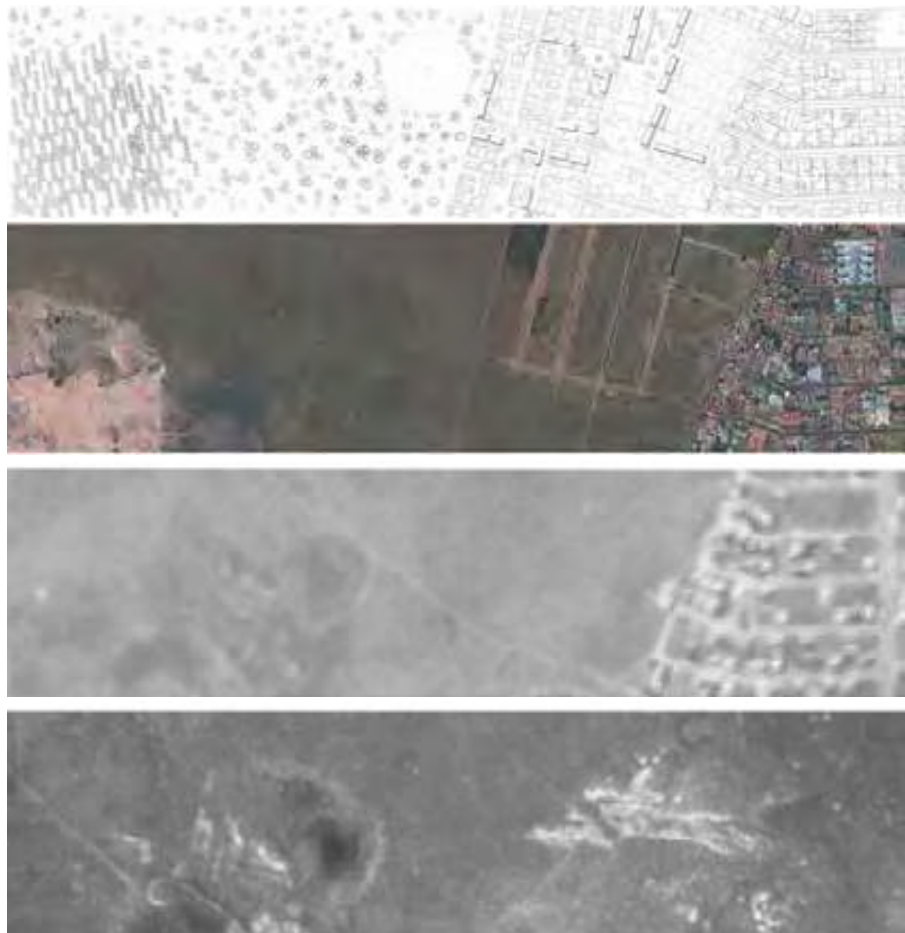
- mining company
- local community
- environmental organisation
- phyto-technology experts / researchers

- mining company
- local community
- innovative businesses
- environmental organisation
- phyto-technology experts / researchers

- mining company
- local community
- innovative businesses
- phyto-technology experts / researchers

## *Azaadville*

Azaadville was proclaimed as a group area for the Indian population of the West Rand in 1963 and was developed by private companies by order of the city council. A first Indian settlement had already existed near Burgershoop since 1897. The Indian trader community found its preferred clientele of low-income buyers in the black and poor white populations nearby. When their trading rights were restricted in 1948, they struggled to remain present in Krugersdorp's centre, but still managed to establish an Indian trading centre just north of Market Square. With the establishment of Azaadville the community had to move to the south of the mining belt, despite protests and alternative suggestions.





By 1993, this Indian neighbourhood had evolved into a rather middle class area. (DU PLOOY, 1999). It mainly consists of rather large plots with single villas, of different sizes, and limited amounts of open space. Services, such as hospitals, religious buildings and especially schools on larger plots interrupt this urban tissue, yet their available open space is often fenced off or used for parking. A small commercial centre which is defined by large boxes and an overload of parking space is located at the outskirts of the urban area. A strip of land in the middle of the neighbourhood has been left vacant because of a large power line running through.

Inserting the water system in this area doesn't aim at transforming the built tissue itself, but to re-think the open spaces within and the large landscape around the settlement.

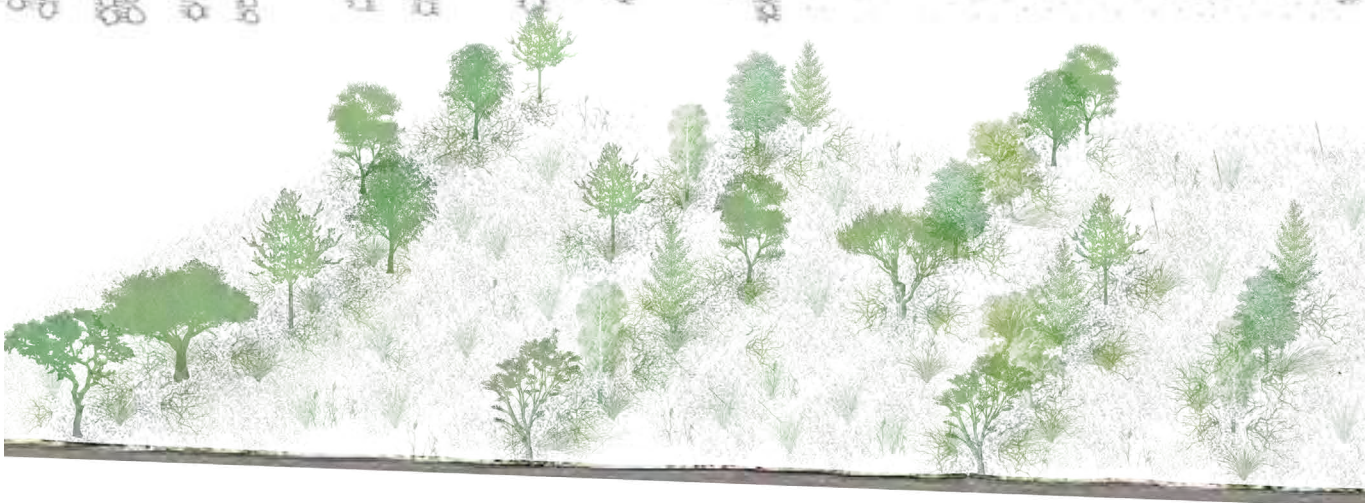
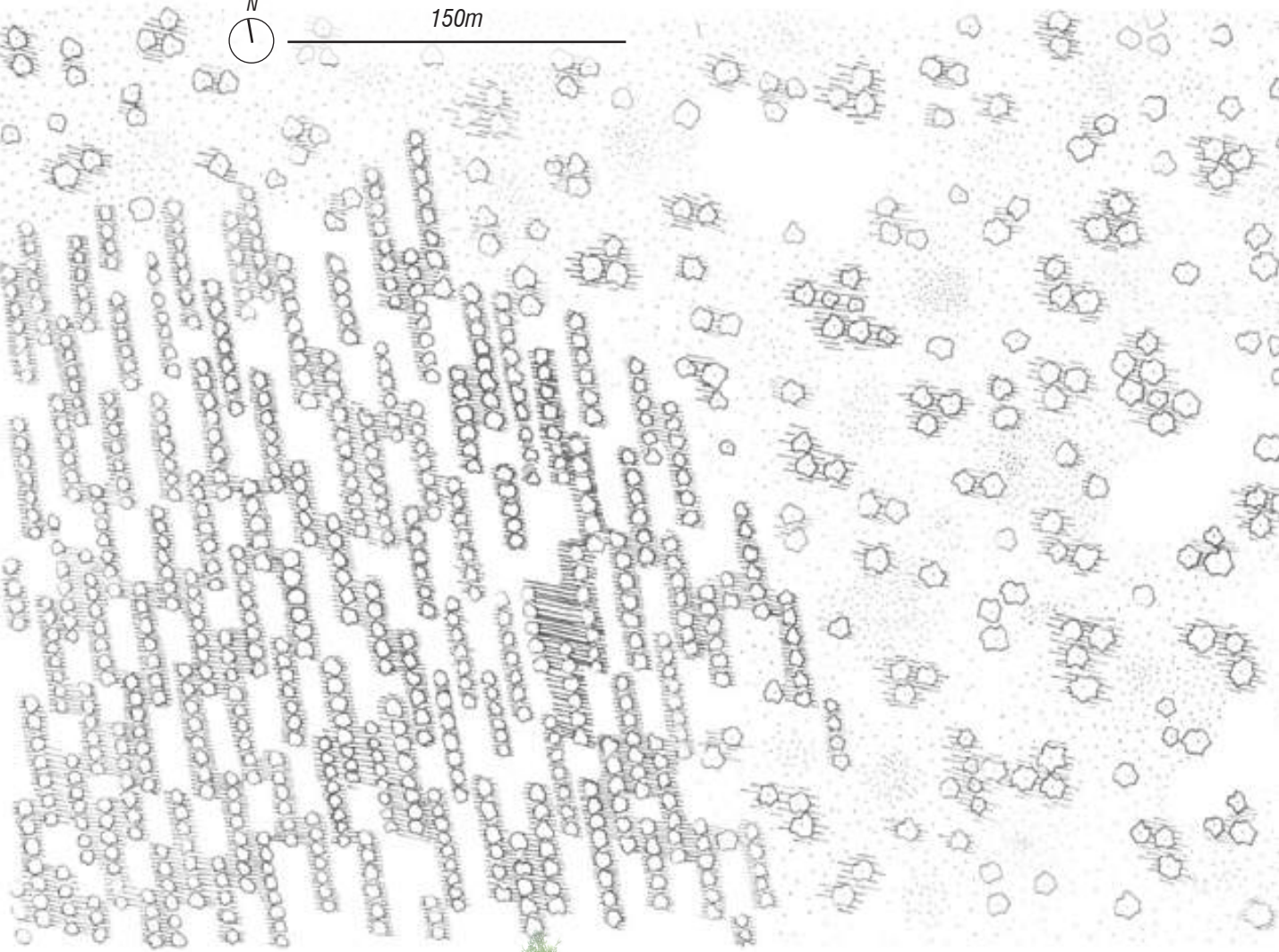
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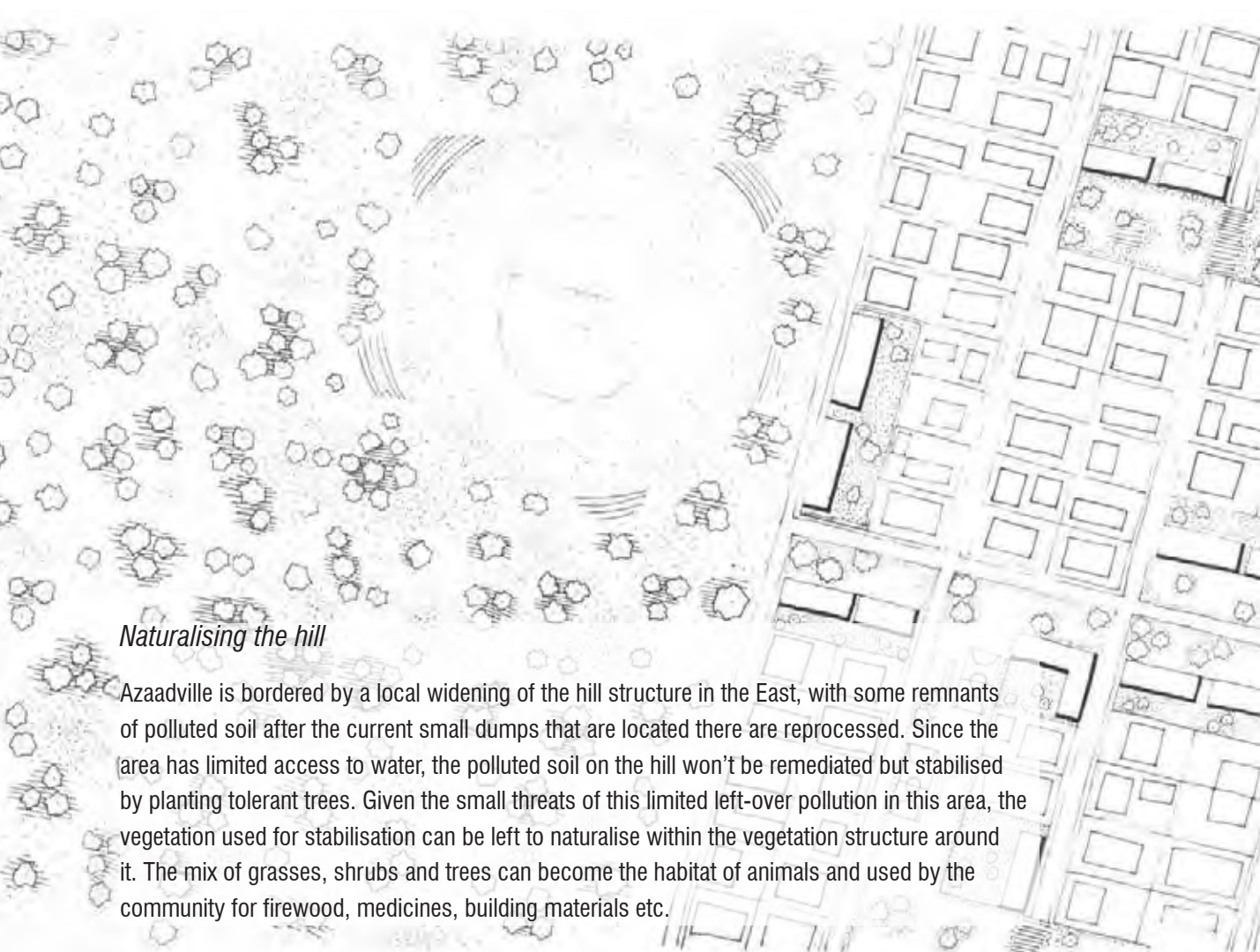
DU PLOOY, J. (1999), *Die sosio-kulturele ontwikkeling van Krugersdorp onder munisipale bestuur tot 1993*, Doctorate Thesis in History, Potchefstroom: University of Potchefstroom.





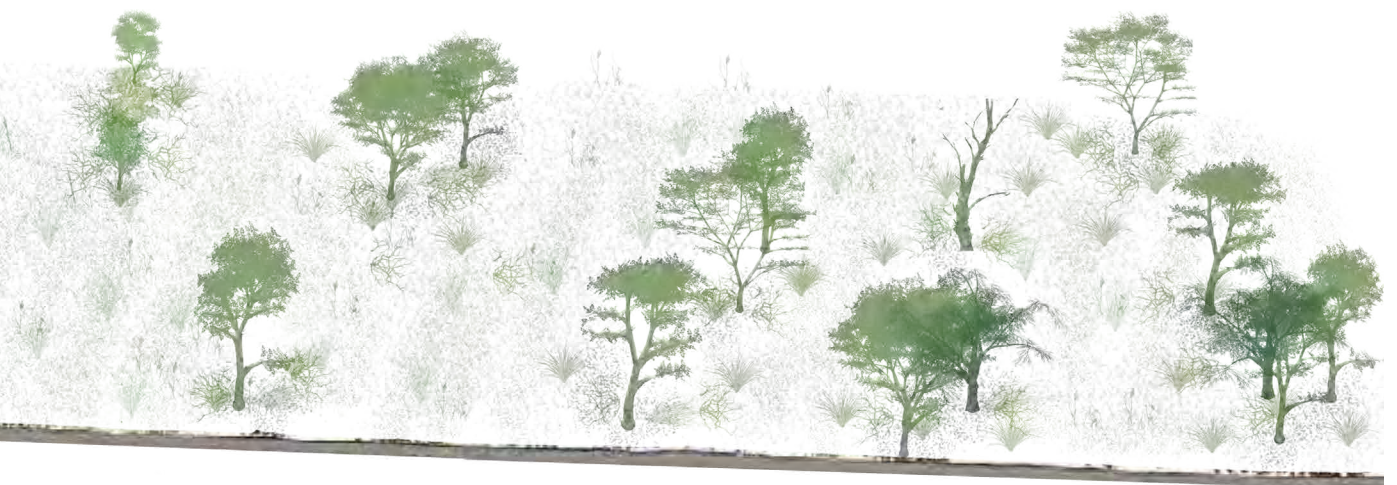
150m

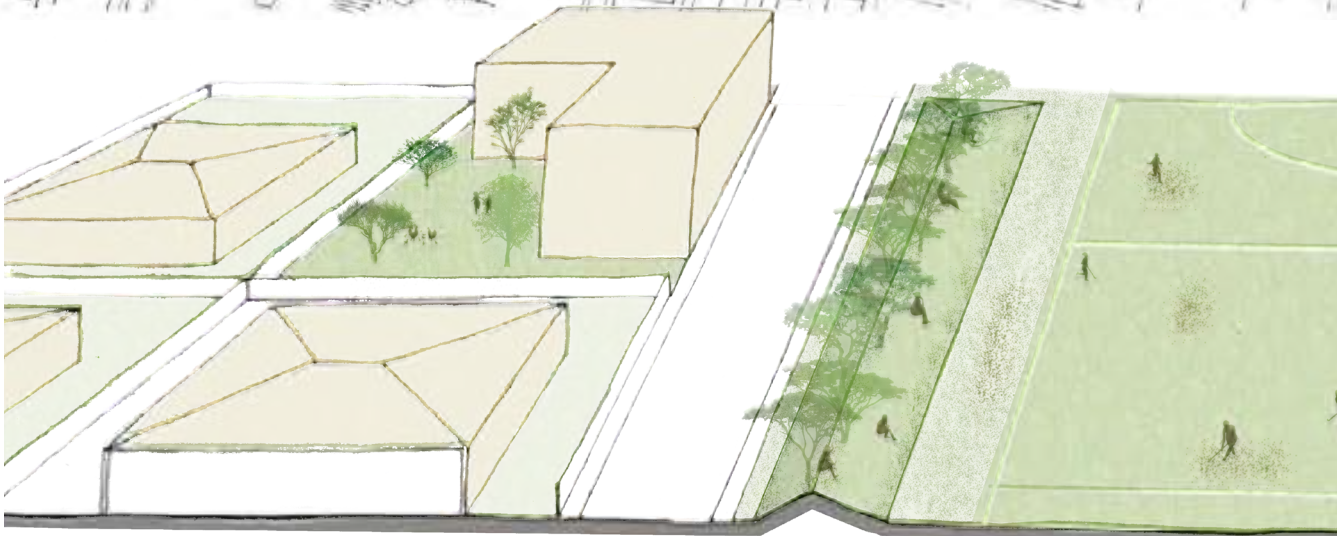
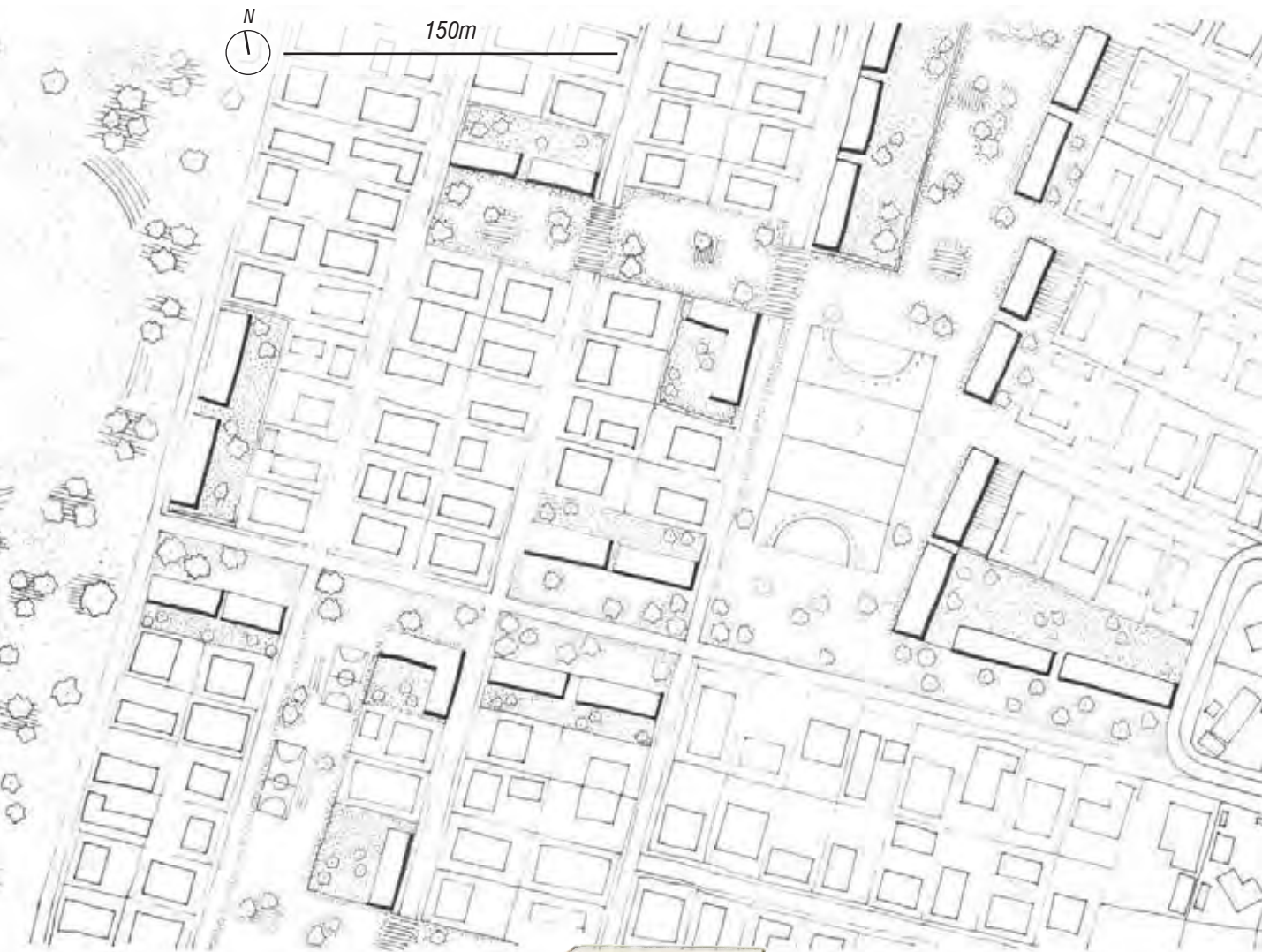




### *Naturalising the hill*

Azaadville is bordered by a local widening of the hill structure in the East, with some remnants of polluted soil after the current small dumps that are located there are reprocessed. Since the area has limited access to water, the polluted soil on the hill won't be remediated but stabilised by planting tolerant trees. Given the small threats of this limited left-over pollution in this area, the vegetation used for stabilisation can be left to naturalise within the vegetation structure around it. The mix of grasses, shrubs and trees can become the habitat of animals and used by the community for firewood, medicines, building materials etc.





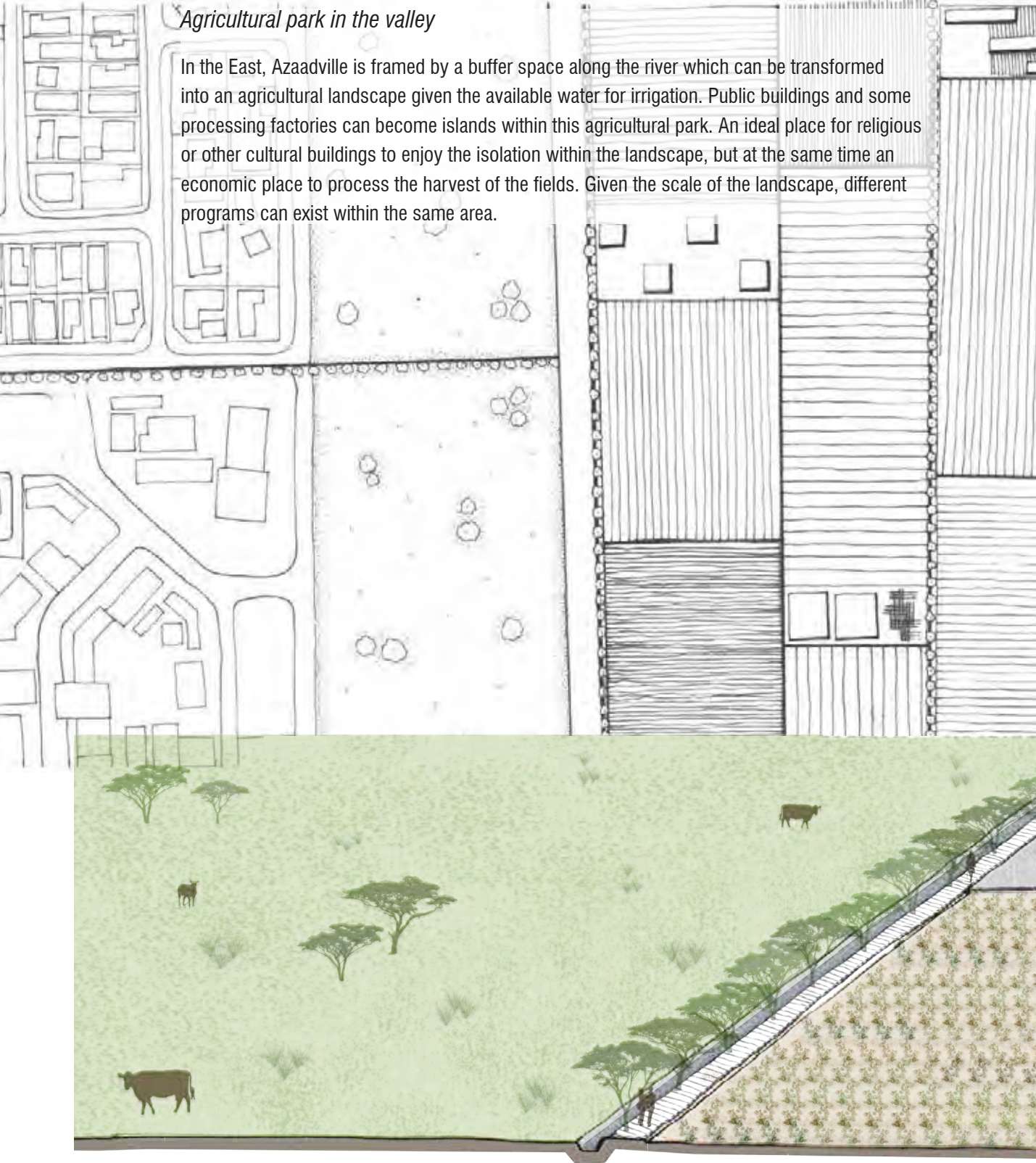
*Planned extension, penetrated by green structure*

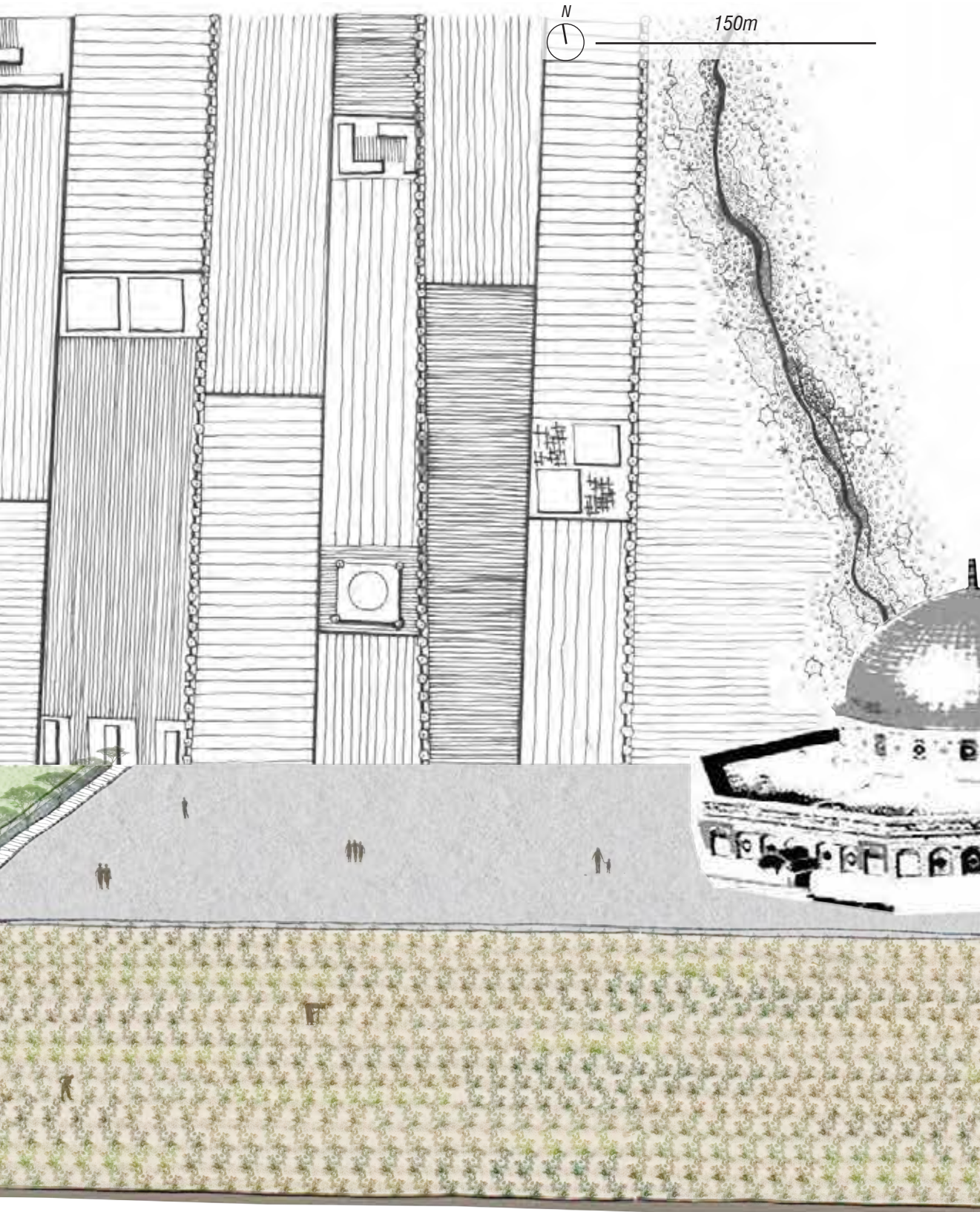
In this area, it wasn't the construction of shacks, but rather the ongoing expansion of large villas that resulted in the congestion of the area. Given this consolidated tissue, the aim is not to insert the additional water layer to generate transformations within it, but to insert a larger scale of landscape that frames the existing settlement. An extension for the area is planned, and the street layout is already under construction. Our design however proposes to break the monotonous iteration of villas by allowing the green structure to infiltrate, with space for recreational activities and framed by multi-storey typologies.



### *Agricultural park in the valley*

In the East, Azaadville is framed by a buffer space along the river which can be transformed into an agricultural landscape given the available water for irrigation. Public buildings and some processing factories can become islands within this agricultural park. An ideal place for religious or other cultural buildings to enjoy the isolation within the landscape, but at the same time an economic place to process the harvest of the fields. Given the scale of the landscape, different programs can exist within the same area.





## *Kagiso*

This strip zooms into part of Kagiso, that was built as a township in 1956. As mentioned before, it is characterised by the monotony of apartheid planning, lacks diversity in typologies, functions, open spaces, etc. The houses in this township were first constructed by the municipality, and counted 2-4 rooms. They were rented out at low prices. Subsequently, plots for private construction were also made available with a subsidy of 250 pounds. When black inhabitants got ownership rights in 1976, parts of Kagiso and Munsieville were developed by the private sector (DU PLOOY, 1999). The growing population number has resulted in the presence of many backyard shacks and a continuous growth of mainly low-income families is expected (SOUTH AFRICA. THE DEVELOPMENT PARTNERSHIP, 2009).





Bringing in the water system could give people a sense of empowerment, to become part of the urban transformation in different ways. Higher densities can be allowed on smaller footprints to break the monotony of the township and to insert a layer of qualitative open space. In this regard, the logics of the water can structure such a transformation based on different levels of cooperation.

*References:*

DU PLOOY, J. (1999), *Die sosio-kulturele ontwikkeling van Krugersdorp onder munisipale bestuur tot 1993*, Doctorate Thesis in History, Potchefstroom: University of Potchefstroom.

SOUTH AFRICA.THE DEVELOPMENT PARTNERSHIP (2009), *Mogale City Spatial Development Framework 2009*, Mogale city Local Municipality.



2014



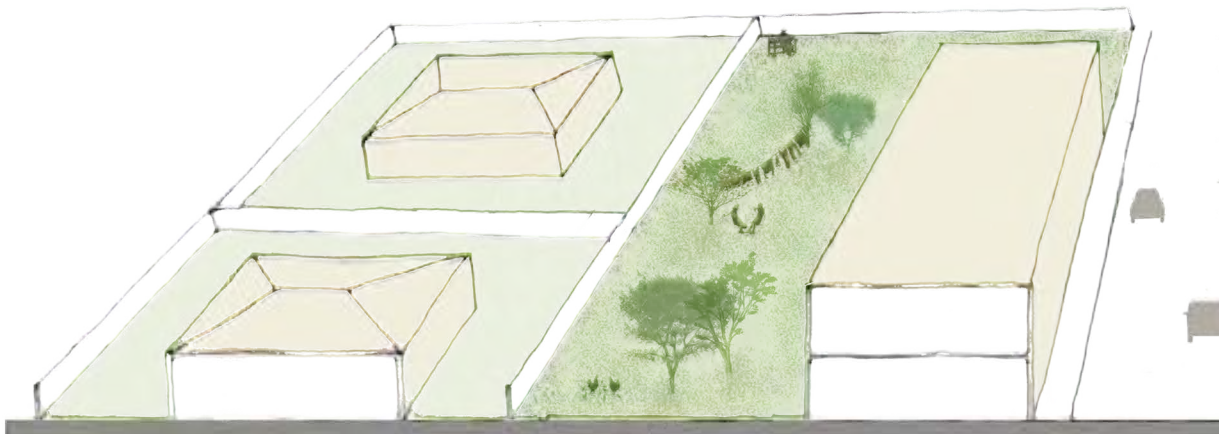
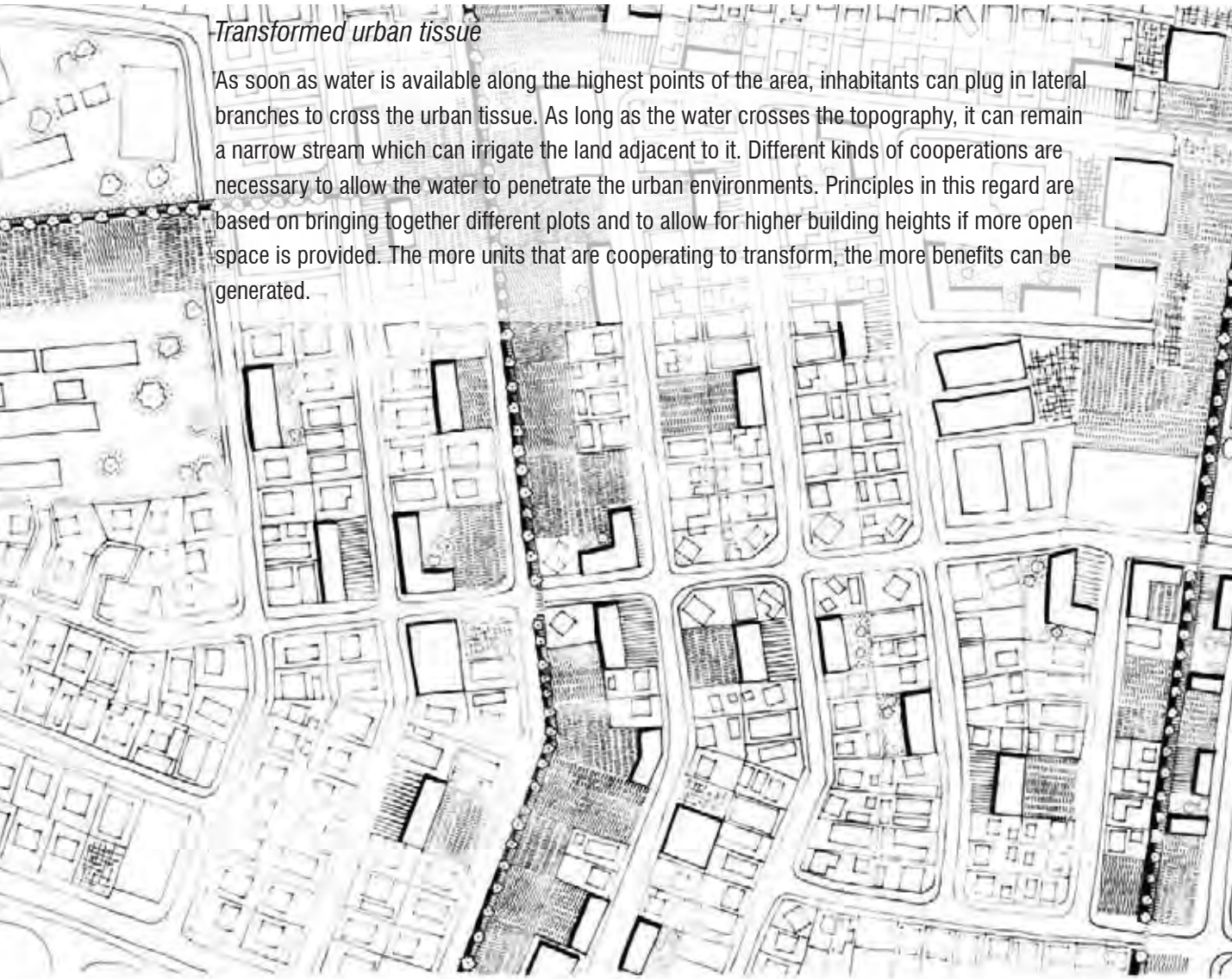
1991

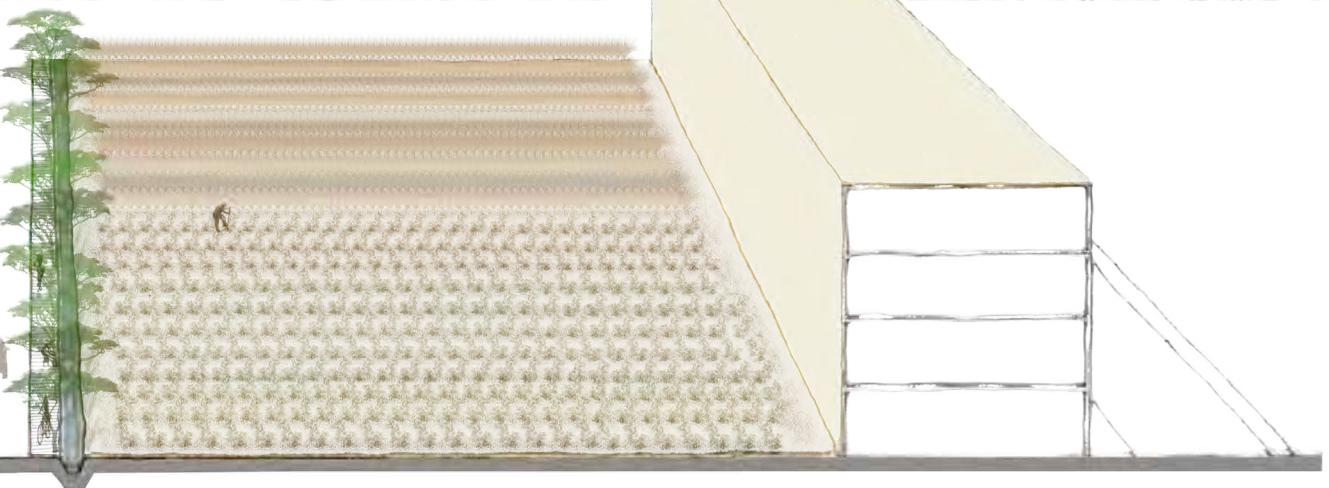


1952

### *Transformed urban tissue*

As soon as water is available along the highest points of the area, inhabitants can plug in lateral branches to cross the urban tissue. As long as the water crosses the topography, it can remain a narrow stream which can irrigate the land adjacent to it. Different kinds of cooperations are necessary to allow the water to penetrate the urban environments. Principles in this regard are based on bringing together different plots and to allow for higher building heights if more open space is provided. The more units that are cooperating to transform, the more benefits can be generated.



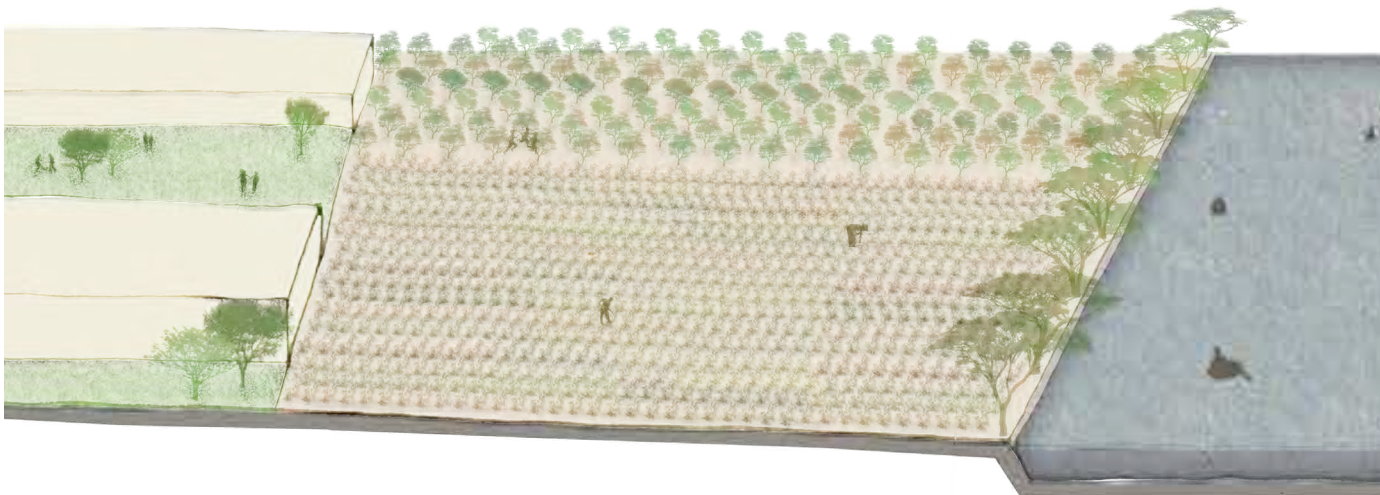
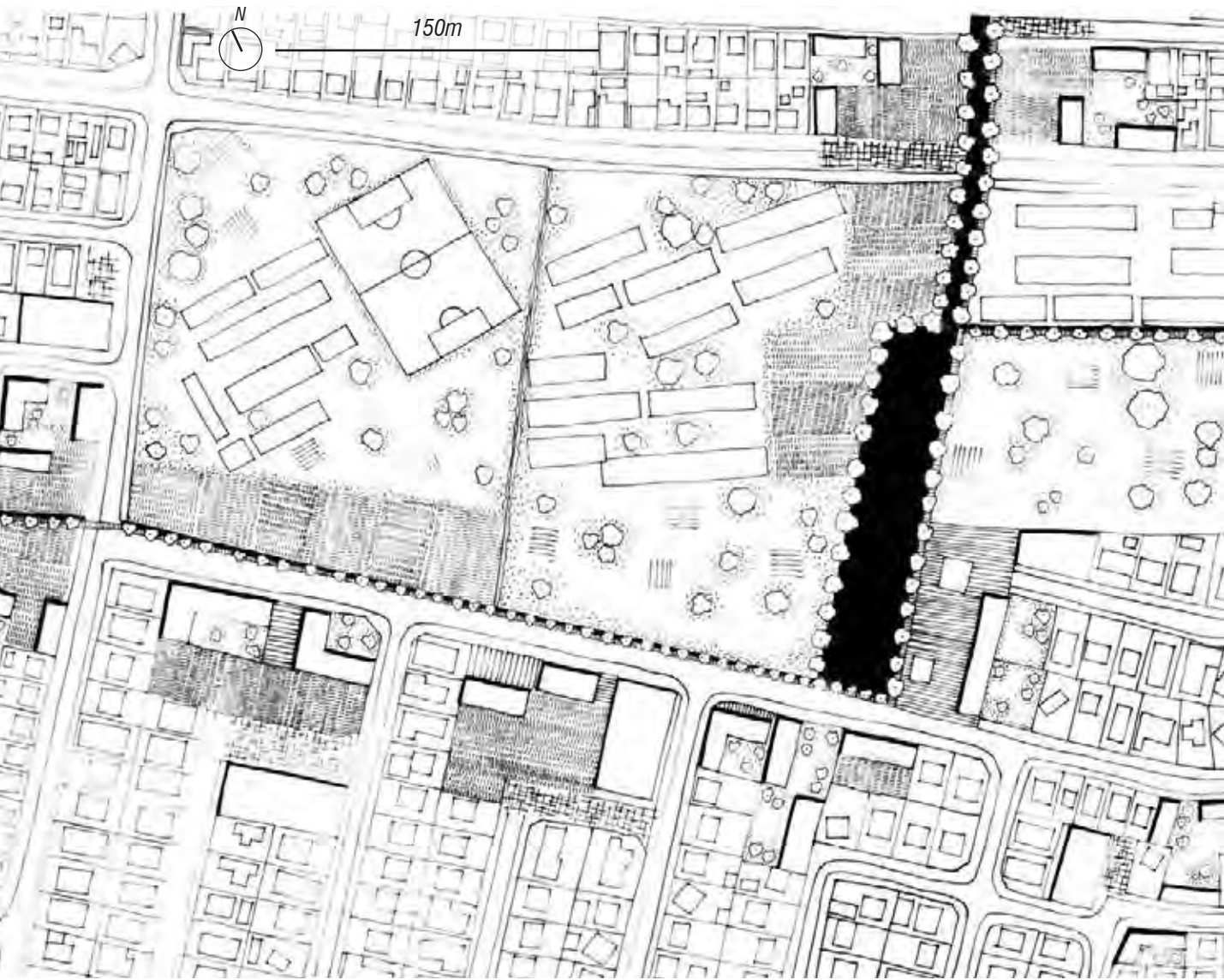




## *Upscaling urban agriculture*

Since the combination of plots already results in larger open spaces, it allows for more efficient urban agriculture as well. Especially when the water system is deflected along topography lines, more space should be given to allow for the water to turn and to build in some buffer spaces to slow down speed and to hold the water during high rainfall periods. This constant availability of water is an opportunity for upscaled high value urban agriculture which could become a new income generator. The transformation in this regard goes beyond the agricultural fields themselves. Side streets can be re-used as either spaces for the canal, or productive spaces where food is processed, dried, packaged, sorted, etc. Spin-off activities can bring diversity in the tissue: shops, small factories for packaging and processing, etc.





## *Qualified public | open space*

Also for public open spaces, the inserted water network can create new qualitative environments. A widened buffer space can become a public swimming facility and dried out open fields can be greened. A network for soft mobility adjacent to the water network can enjoy the cooling by the water and the shadow of the trees. Especially for the multiple schools this entails many opportunities. Safer walkways can be created for children to walk to school, the playground can be transformed from dusty fields to green playgrounds and agricultural fields near schools can become part of a training system so that young people can learn about remediation and innovation in agriculture. ...



## *Kagiso-Chamdor*

In the northern part of Kagiso, different spatial logics come together. The repetitive pattern of the township meets up with the industrial tissue of the industrial area of Chamdor, and a municipal hostel forms a strong exception to its surroundings.

The Chamdor industrial area was originally developed on private initiative by the Champ D'Or Gold Mine, on a plateau in-between the valleys of the Wonderfontein Spruit and the Witpoortjie fault. Soon it was bought by the Municipal Council and completed in 1963 as an investment that could compensate for the decline of the mining industry as an economic driver for the area. It was meant for bigger industries such as steel companies and chemical factories. The extension of Kagiso in the same period provided a pool of black workforce for the industries. (DU PLOOY, 1999) Currently, the main activities in the area are a mix of companies producing mining equipment, abattoirs and food processing companies, security businesses, SA Breweries, recycling activities and logistics companies. A railway weaves through the backsides of the industrial tissue but is now no longer in





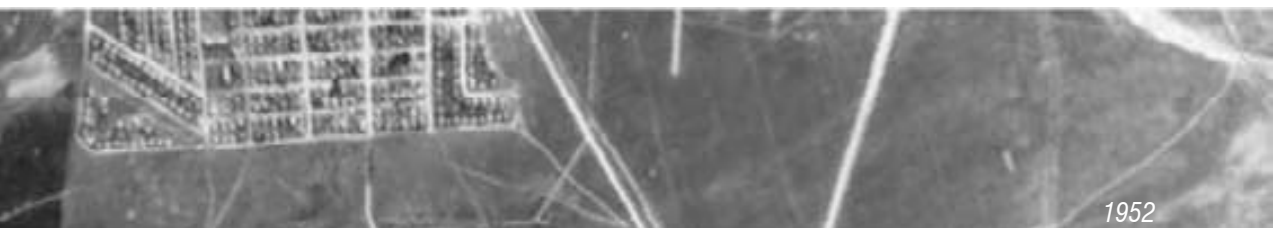
use. It connected the area with the Lanwen railway station on the east-west railway line that links up with Krugersdorp and Johannesburg. The street layout of the industrial area is very introvert and therefore effective in making a buffer between Kagiso and the north. There are almost no connections across the area, or to Chamdor Road, the regional road on the east of the industries.

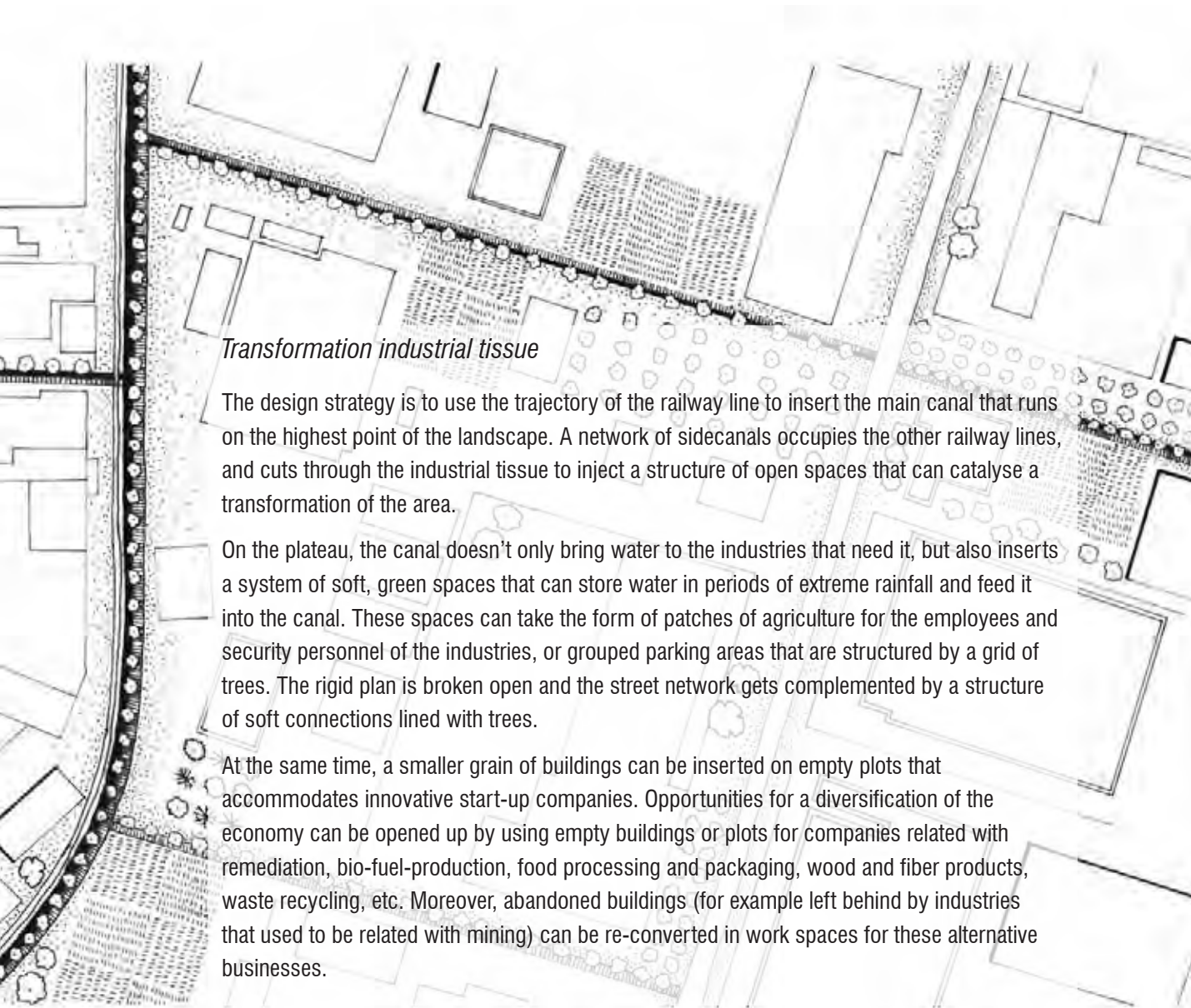
In-between the residential and industrial area, a strip of empty land forms a buffer-space that epitomises the disconnected logics of Apartheid planning. It also runs along an open space that is only partly occupied by a local school.

The municipal hostel to the north of Kagiso has a very strong, closed structure and community. Its inside spaces are filled up with barracks and lack spatial quality and green. The municipal policy is to reconvert the originally single-sex hostel into a complex of family units.

*Reference:*

DU PLOOY, J. (1999), *Die sosio-kulturele ontwikkeling van Krugersdorp onder munisipale bestuur tot 1993*, Doctorate Thesis in History, Potchefstroom: University of Potchefstroom.



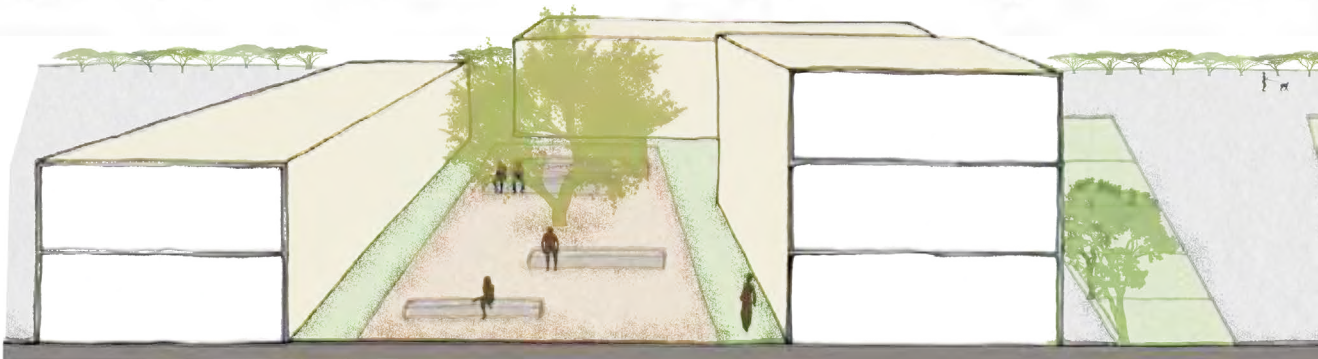


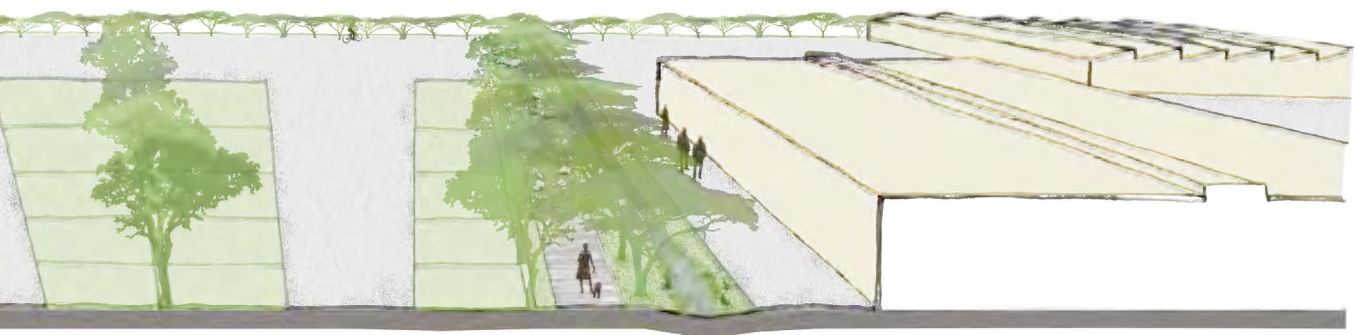
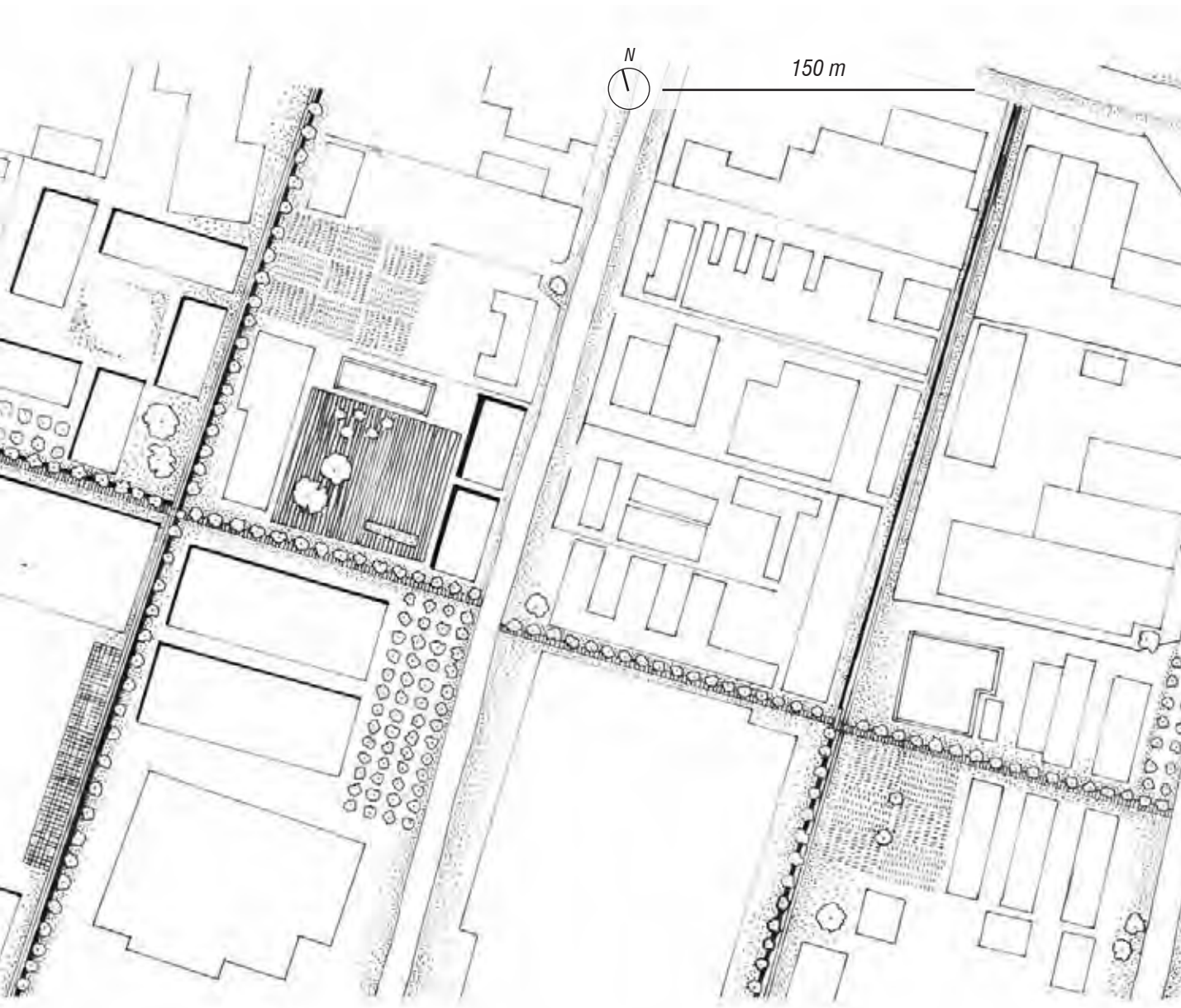
### *Transformation industrial tissue*

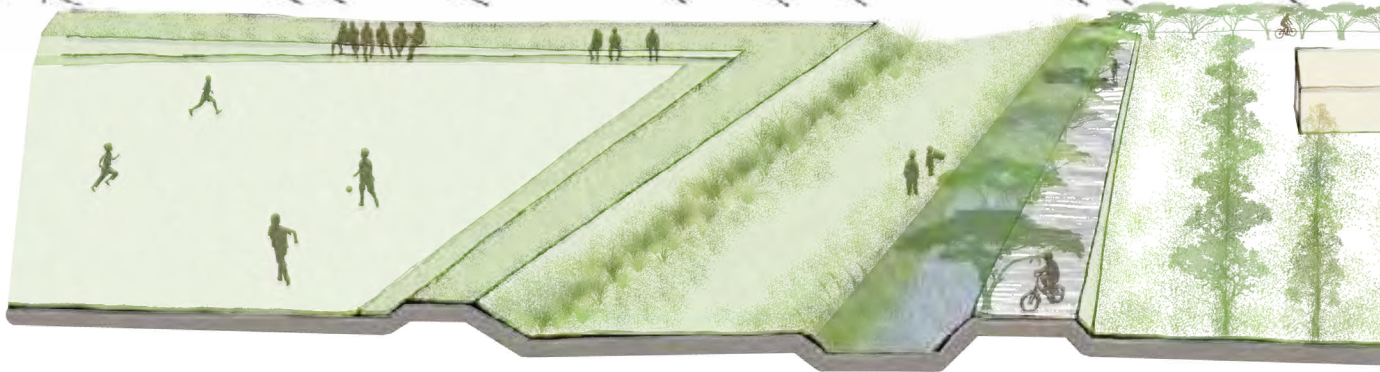
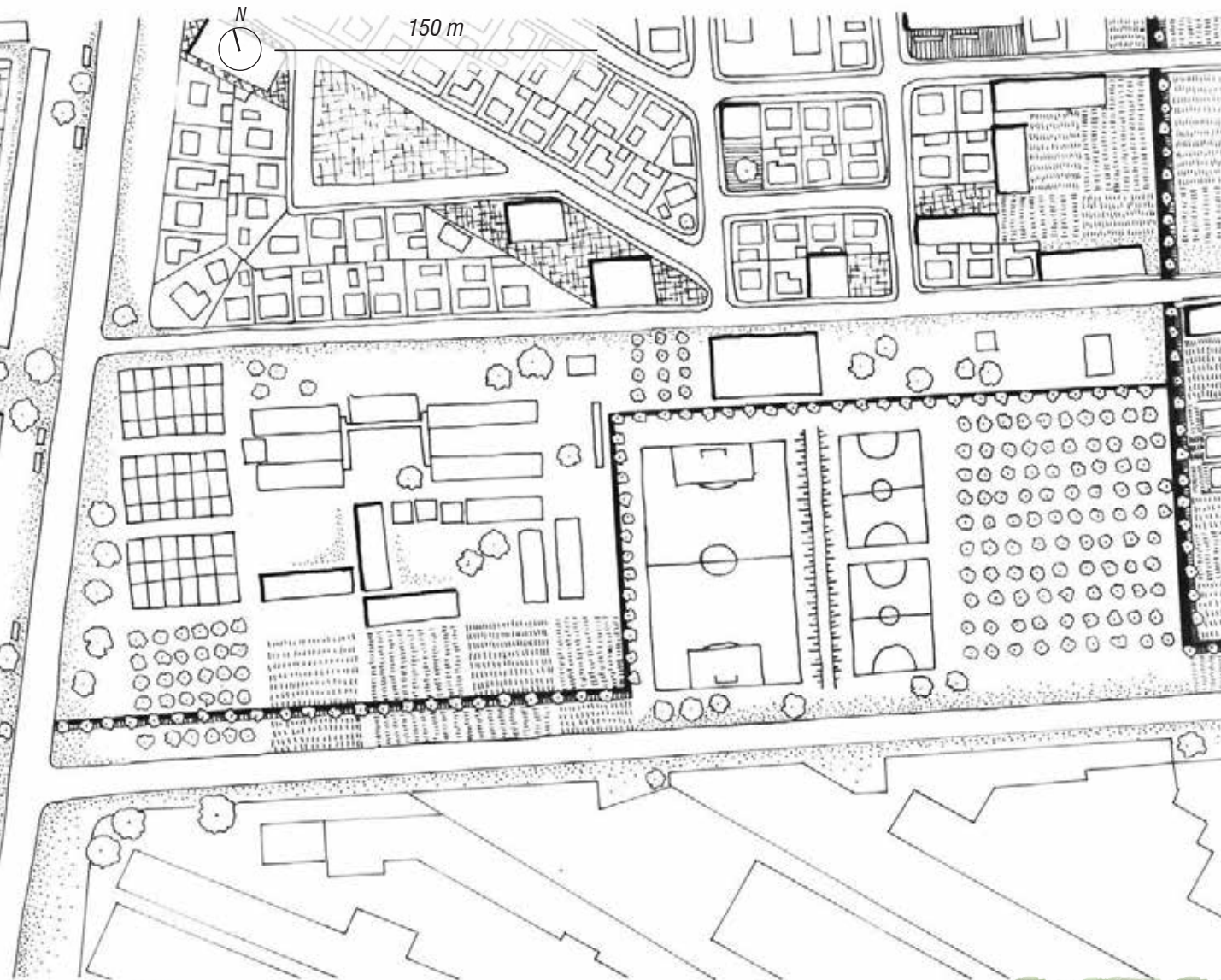
The design strategy is to use the trajectory of the railway line to insert the main canal that runs on the highest point of the landscape. A network of side canals occupies the other railway lines, and cuts through the industrial tissue to inject a structure of open spaces that can catalyse a transformation of the area.

On the plateau, the canal doesn't only bring water to the industries that need it, but also inserts a system of soft, green spaces that can store water in periods of extreme rainfall and feed it into the canal. These spaces can take the form of patches of agriculture for the employees and security personnel of the industries, or grouped parking areas that are structured by a grid of trees. The rigid plan is broken open and the street network gets complemented by a structure of soft connections lined with trees.

At the same time, a smaller grain of buildings can be inserted on empty plots that accommodates innovative start-up companies. Opportunities for a diversification of the economy can be opened up by using empty buildings or plots for companies related with remediation, bio-fuel-production, food processing and packaging, wood and fiber products, waste recycling, etc. Moreover, abandoned buildings (for example left behind by industries that used to be related with mining) can be re-converted in work spaces for these alternative businesses.





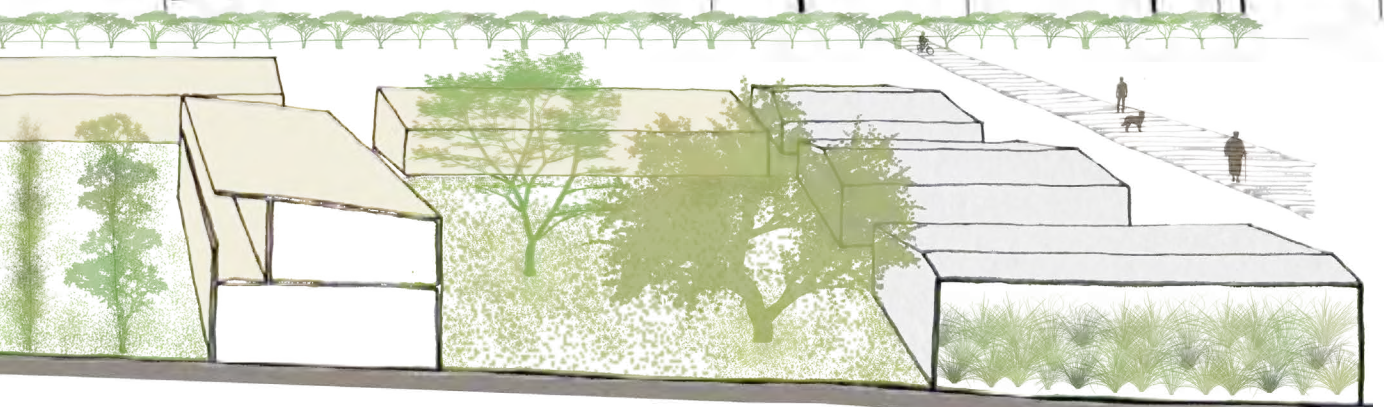




### *Teaching agriculture and landscape remediation*

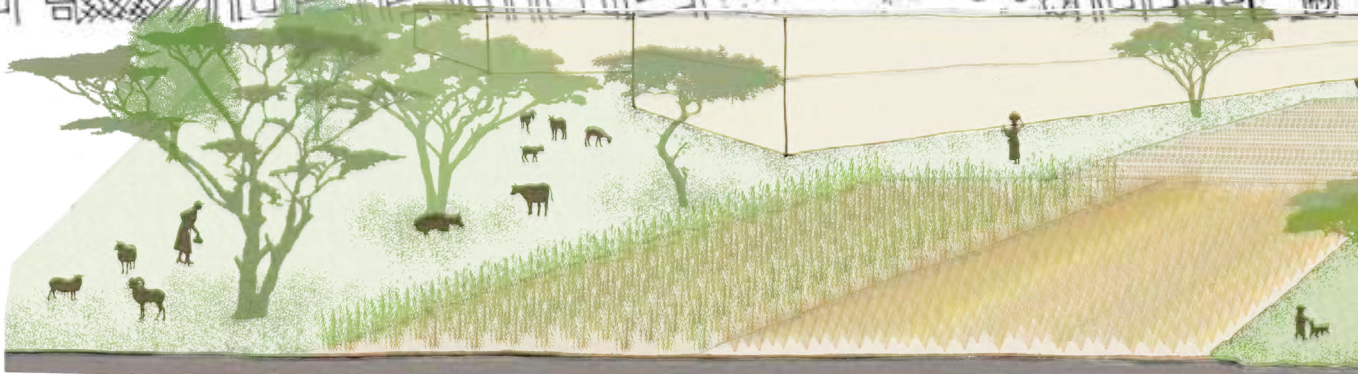
The terrain of the school is incorporated within the open-space system along the canal. Inserting water in this public space opens it up for a broader public to enjoy recreation by the waterside. Moreover, it allows for an extension of the school where technical skills related with agriculture and remediation can be taught. Test fields, greenhouses and an orchard can be used to start a learning process for the youngest part of Kagiso's population. Developing this field of knowledge can also increase their job opportunities in the alternative industries nearby.

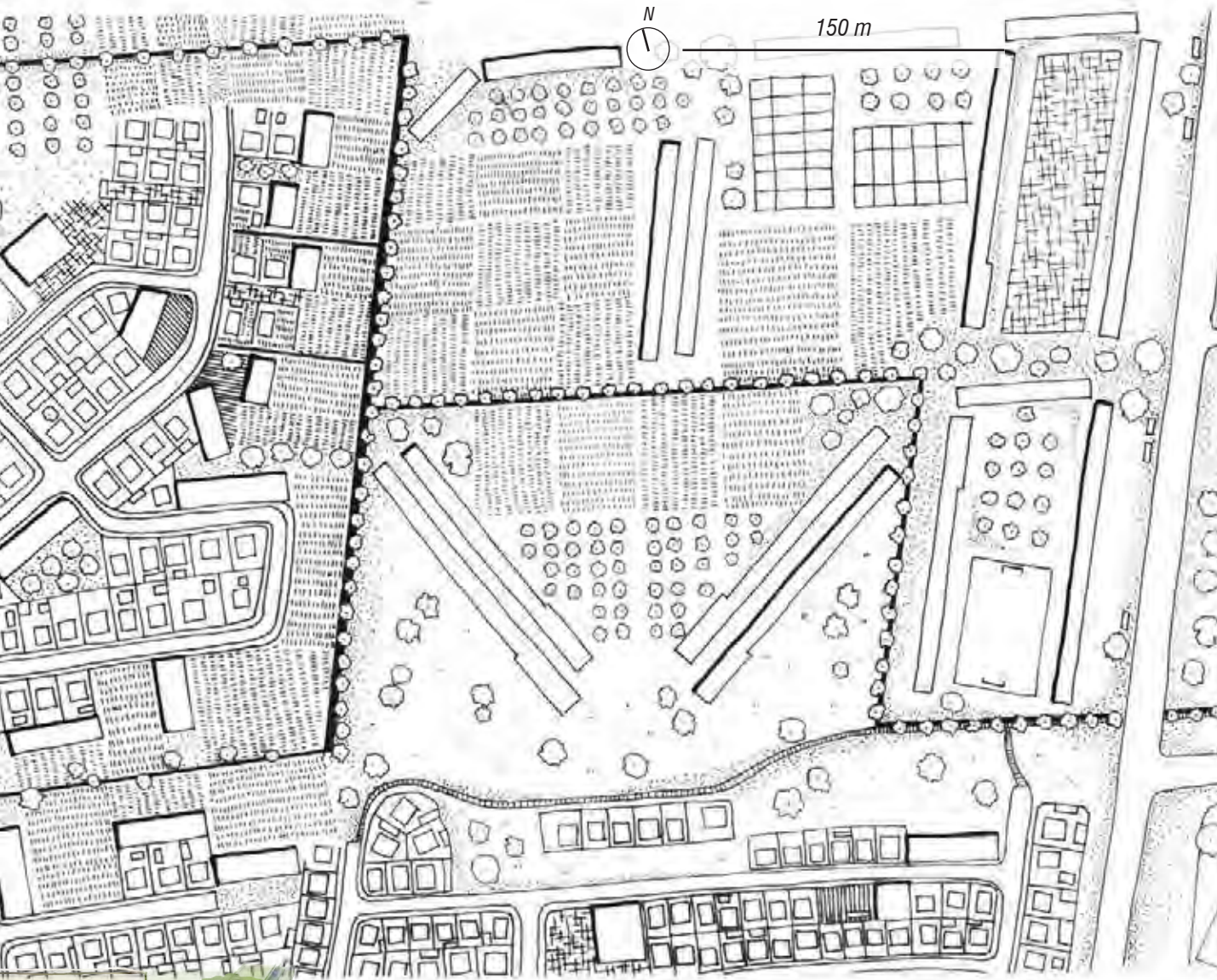
Also within the tissue, a different grain of buildings can provide space for commerce and small industries related with the productive landscape, such as shops for fertiliser, compost and seeds, produce packaging and processing, etc. Products can also be sold on small stands near the road or along the soft network that follows the canal. The strip of empty land in-between industrial and residential area can become common ground for grazing and agriculture, but remain recognisable as an open space system that complements the built urban tissue.



## *Mining hostel transformation*

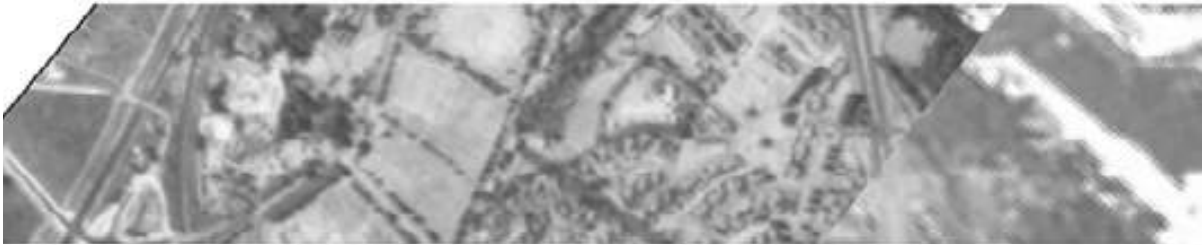
The enclosed, utilitarian and unimaginative structure of the mining hostel will be opened up by removing some of its buildings so that interior open spaces are linked with the open-space network along the canal. Weaving the canal through the hostel's courtyards gives them new purpose and spatial quality. It allows the hostel's community to engage in productive activities related with the process of landscape remediation, for example by running a nursery where specific species are cultivated and tested. Moreover, by removing the buildings in the worst state, and increasing the height of others as compensation, space is opened up for crop farming, small grazing areas and orchards.





## *West Village*

West Village was built by West Rand Consolidated Mines as accommodation for its workforce. The structure of this mining village clearly represented the hierarchy within the mining company. The non-white employees were housed in a hostel. For recreation, they used to be limited to dance competitions and soccer games, although in later stages the company also provided facilities for tennis, cycling and athletics. Nowadays, the mining hostel is used as an institution for youth delinquents. White workers lived in a 'modern' residential area with 400 furnished houses, as well as single sex quarters. There were also sports facilities, a library, a club house, dance hall and a mining hospital (DU PLOOY, 1999). The members of the company's management level lived in even larger villas in the most eastern part of the village. The three different socio-economic classes were separated by the rail tracks that used to carry the ore. These are now recognisable in the landscape as empty ditches in-between the different parts of West Village. Nowadays West Village is running empty, mainly because of tensions with a Zama Zama community that lives in a nearby informal settlement. Allegedly, these immigrant artisanal miners





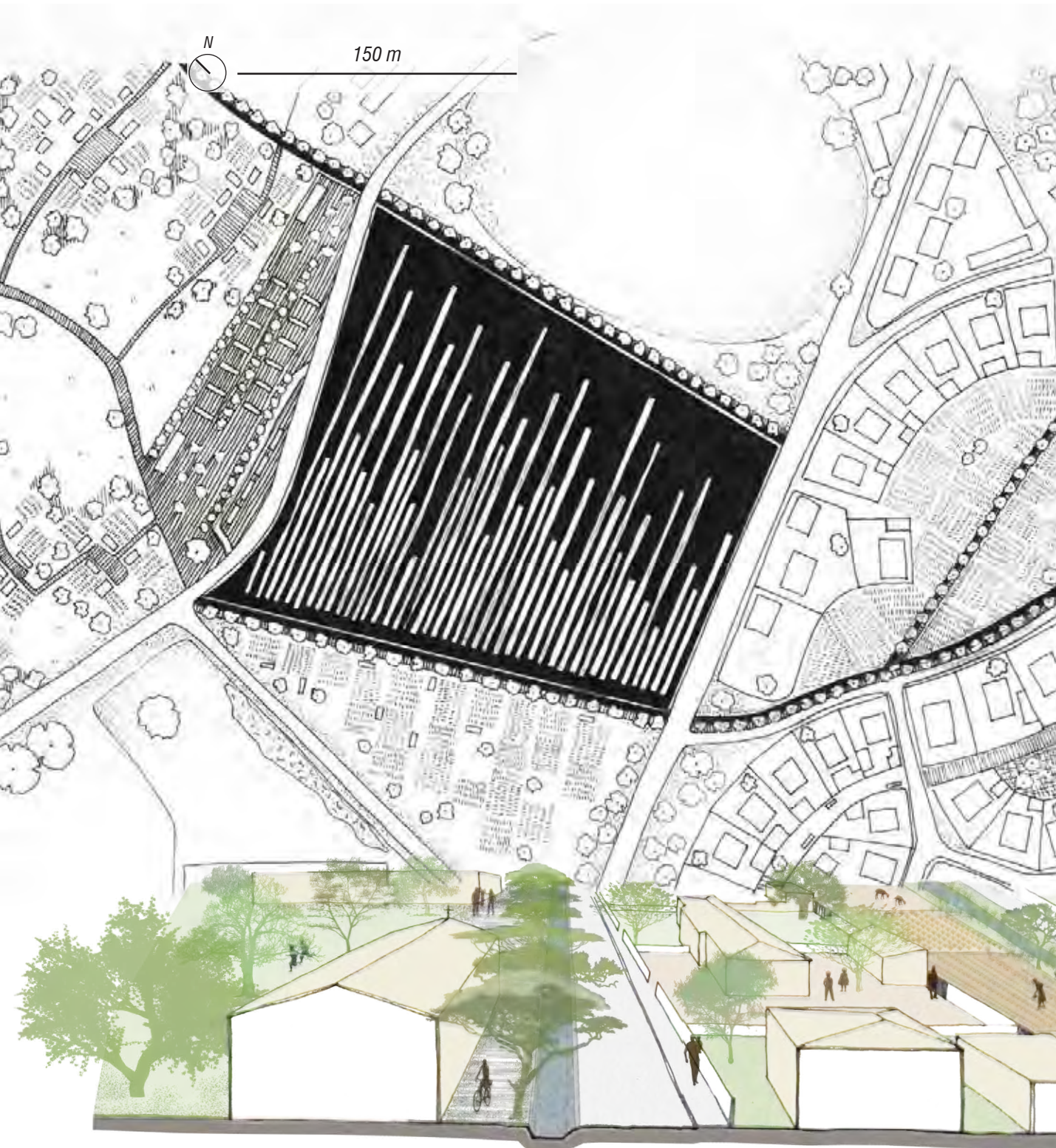
are driving the inhabitants of West Village away by poisoning their dogs and cutting electricity wires. (VANDEMOORTELE, spoken conversation) Moreover, although the town is located on Main Reef Road, this community is rather isolated from other parts of Krugersdorp and doesn't offer many economic opportunities.

The tissue in the zoom shows the part of West Village that used to be inhabited by white employees of the mining company. The tissue consists of a mix of detached and semi-detached typologies that usually have a shed in the back of the plot for the domestic help. Regular streets serve the front of the houses, while service alleys run along the back of the plots. The recreational spaces and the open spaces within the tissue, for example around the church, have been neglected and are in a run-down state. Nevertheless, some of them are used by a mix of white and non-white village inhabitants.

*Reference:*

DU PLOOY, J. (1999), *Die sosio-kulturele ontwikkeling van Krugersdorp onder munisipale bestuur tot 1993*, Doctorate Thesis in History, Potchefstroom: University of Potchefstroom.





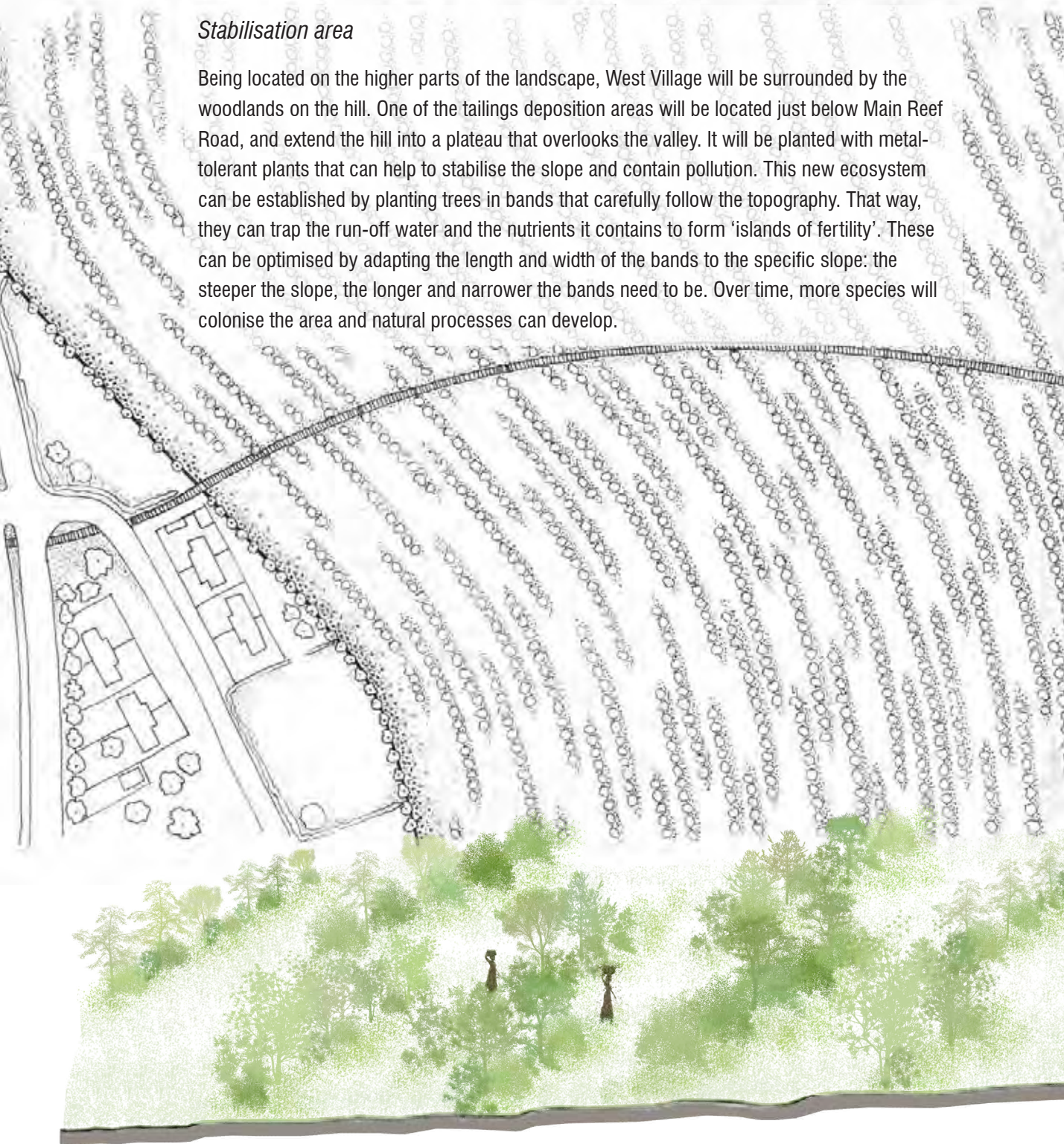
## *Open space transformation within the tissue*

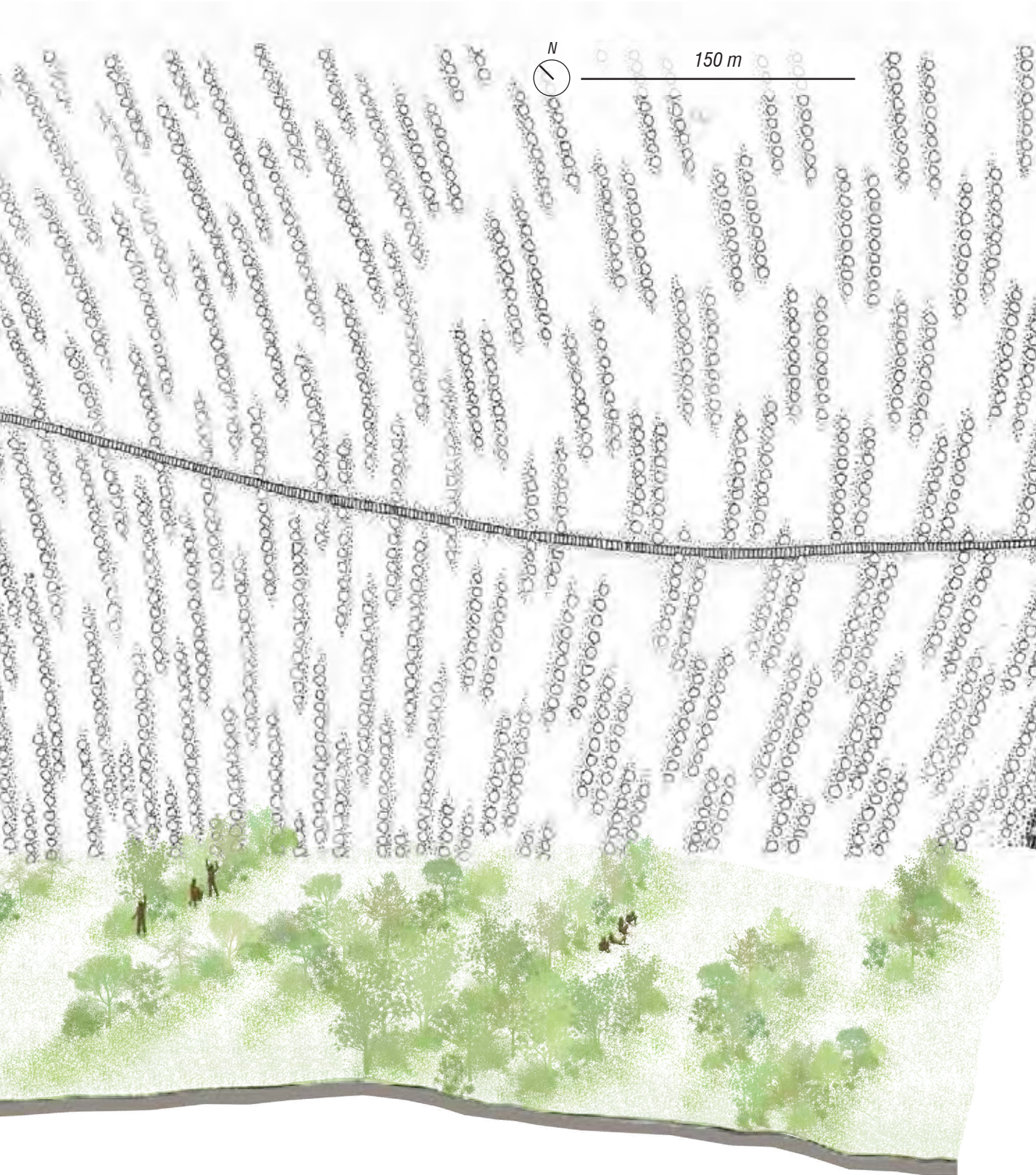
The design proposes to weave the main canal, that runs along the hill tops, through the tissue of West-Village. Before it enters the residential area, the canal needs to be lowered according to the natural topography. This condition is taken as an opportunity to install a large clean-water buffer on part of the old recreational areas. A side-canal of this main structure re-uses the old railway ditches on either side of this part of West Village, and also weaves through the undefined open spaces on the back of the housing plots. By inserting this water structure, the ample open spaces within the tissue of West Village are redefined and can get a new purpose by being appropriated for recreation or urban agriculture. A pathway runs along the canal and links this open space structure also the railway station on top of the hill.

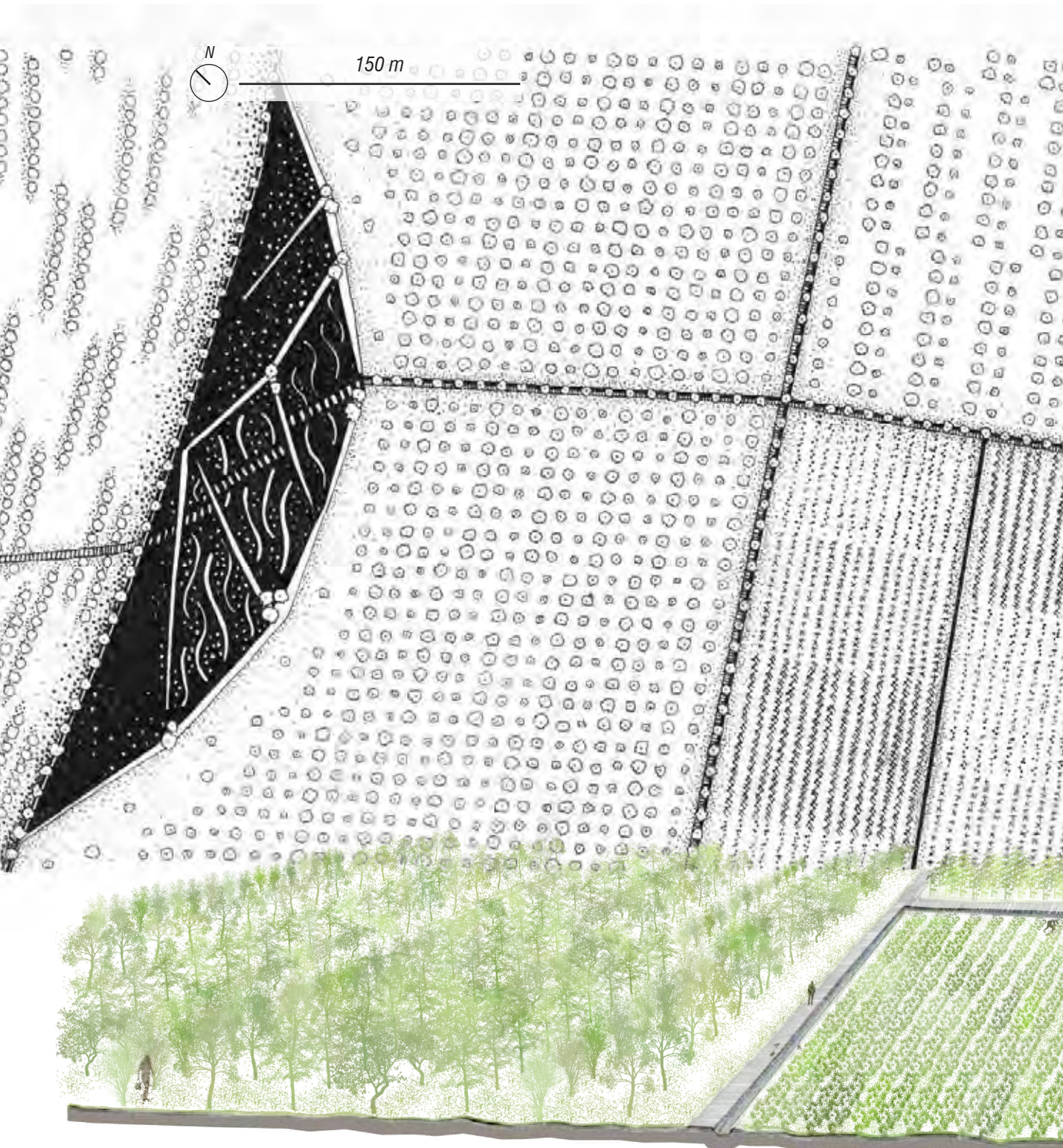


### *Stabilisation area*

Being located on the higher parts of the landscape, West Village will be surrounded by the woodlands on the hill. One of the tailings deposition areas will be located just below Main Reef Road, and extend the hill into a plateau that overlooks the valley. It will be planted with metal-tolerant plants that can help to stabilise the slope and contain pollution. This new ecosystem can be established by planting trees in bands that carefully follow the topography. That way, they can trap the run-off water and the nutrients it contains to form 'islands of fertility'. These can be optimised by adapting the length and width of the bands to the specific slope: the steeper the slope, the longer and narrower the bands need to be. Over time, more species will colonise the area and natural processes can develop.

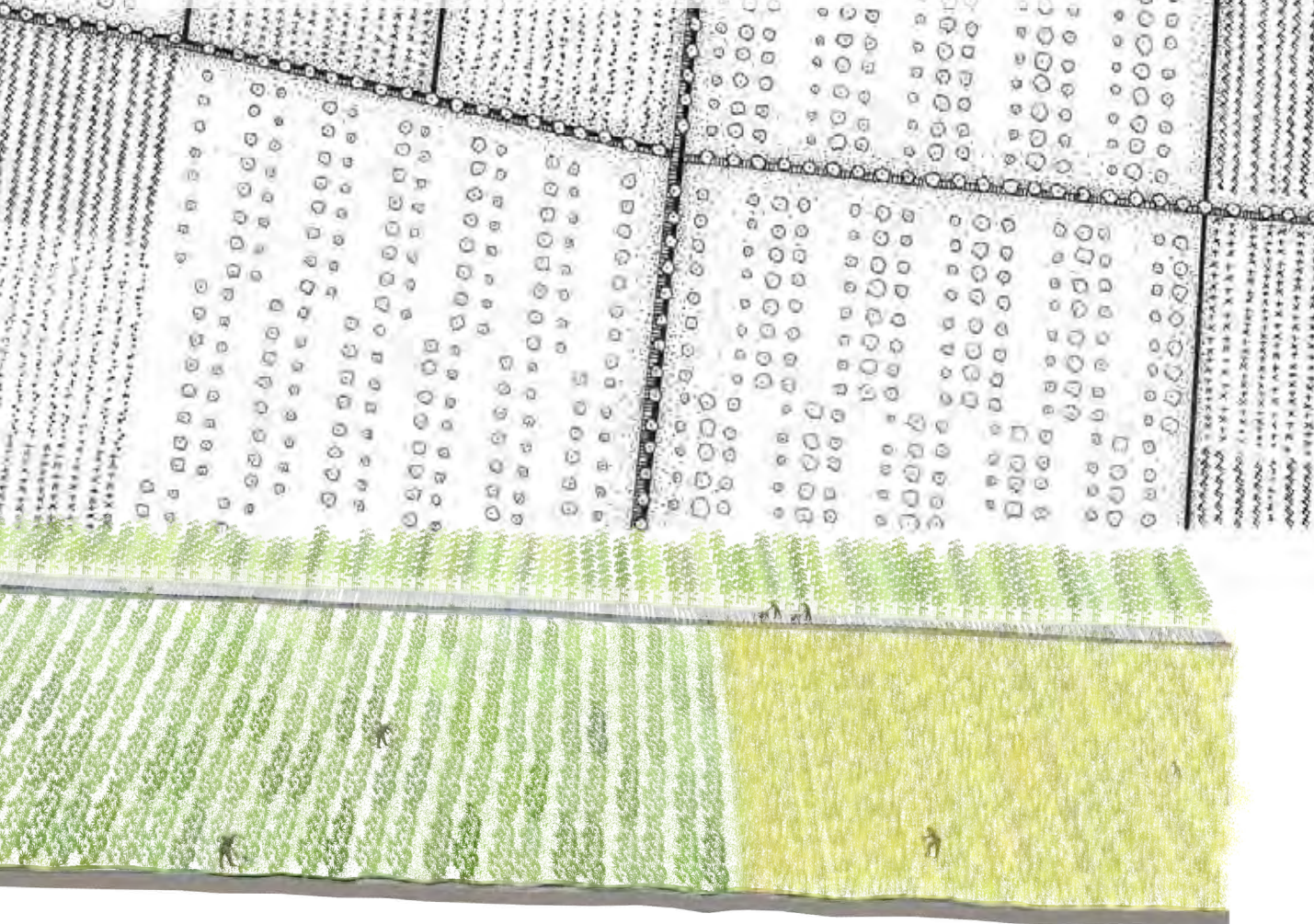






### *Intensive remediation area*

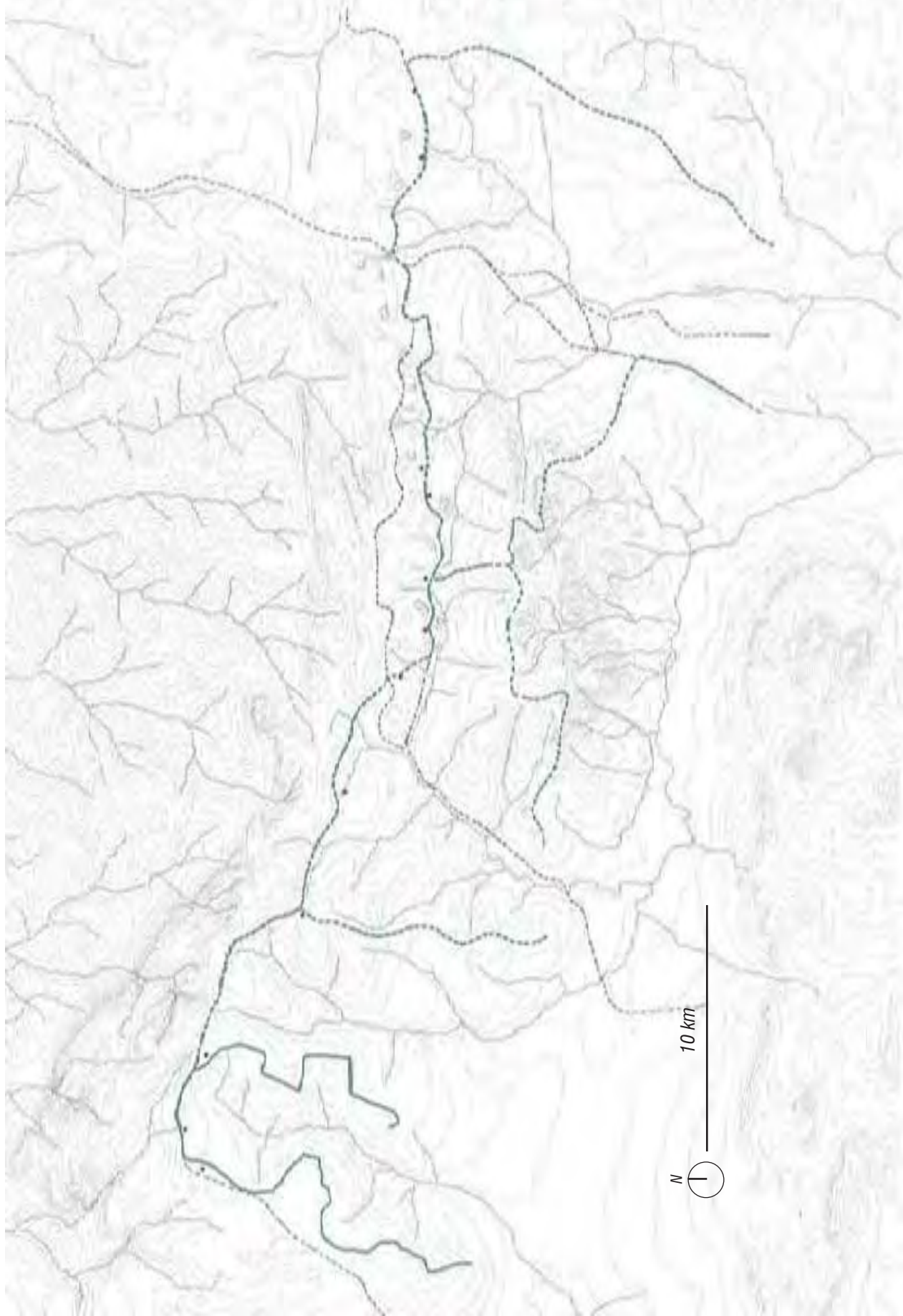
The run-off from the area of tailings deposits is captured in a canal that underlines the hill structure, and then cleaned in a system of wetlands. Below, the soil is remediated more intensively by planting species that (hyper-)accumulate metals. After they have accumulated metals in their biomass, these plants are harvested regularly so that on the long term, the metals will be removed from the soil. By using plants and trees that have productive applications, the process of rehabilitation can become economically sustainable. Plants such as hemp, bamboo and rape seed can be processed in the industrial areas of the West Rand and made into fibers, biofuels, construction wood, etc. Inhabitants of the communities in the Wonderfontein Spruit catchment can be involved in planting, maintenance, harvesting and processing, thereby generating an income for their families and becoming an active contributor to the landscape's remediation.



## 5 | ZOOMING OUT

# THE RELEVANCE OF POST-EXTRACTION URBANISM FOR THE WITWATERSRAND AND THE WORLD

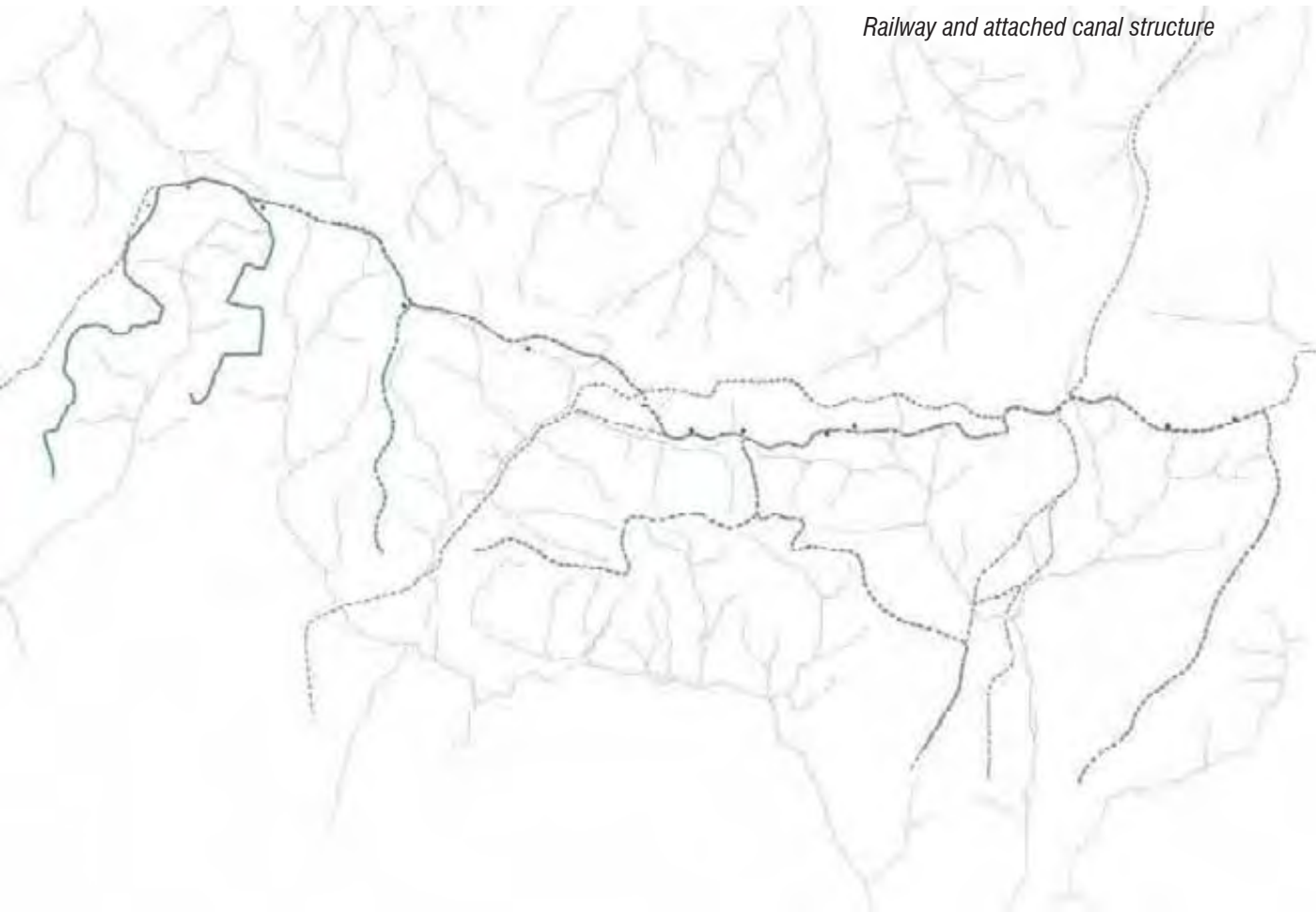




### *Up-scaling the West Rand vision for the whole Witwatersrand*

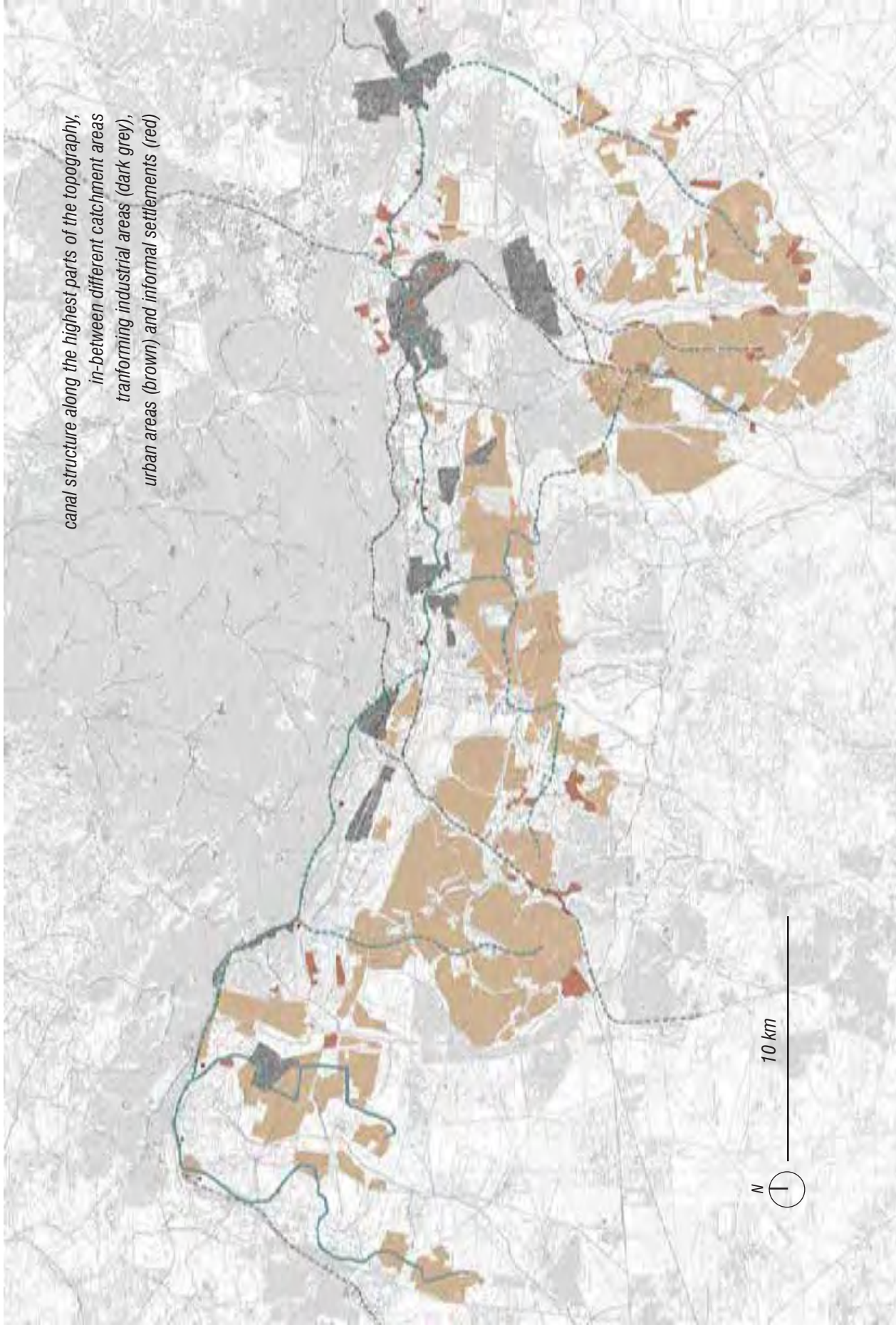
As explained in the introduction, this vision has been developed for the West Rand and specifically the Tweeloopies Spruit and Wonderfontein Spruit catchment areas. However, its main principles can also be applied across the other basins of the Witwatersrand mining belt. The infrastructure of the railway line runs east-west along the gold fields. It is situated just south of the watershed divide and is therefore located on the highest points of the valleys that drain to the south. A canal system could be attached to the railway and extended along the highest points of the landscape. Many of the old shafts on higher points could be used to pump acid mine water into wetlands that feed into the canal. This decentralised natural purification system would ensure that clean water can be distributed towards the townships in the south of the Witwatersrand.

Starting from these main canals on the hills, a rhizomatic system of small-scale furrows and canals can be developed. It can be self-built by local communities incrementally and form the catalyst for urban transformations that re-think apartheid townships in terms of hybridisation, densification and (agricultural) productivity. Informal settlements can be upgraded using a water system as spatial structure and generator of community empowerment and common space. Also industrial areas along the canal structure can be re-thought in terms of water supply and storm water management.



*Railway and attached canal structure*

canal structure along the highest parts of the topography,  
in-between different catchment areas  
transforming industrial areas (dark grey),  
urban areas (brown) and informal settlements (red)



### *Global importance of a spatial approach to post-mining landscapes*

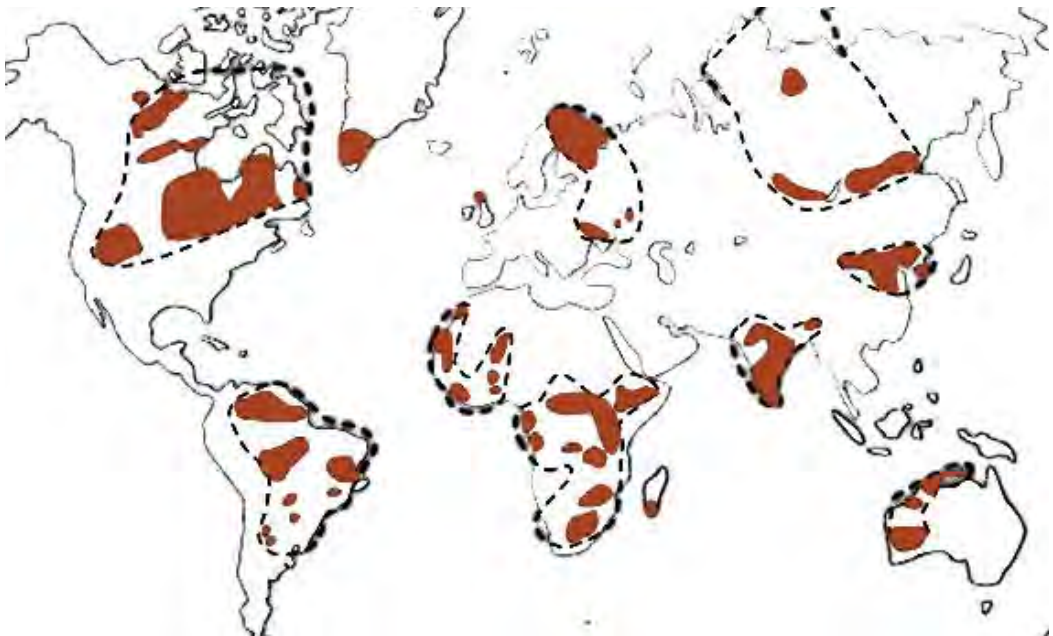
Developing strategies to deal with this post-mining territory, can also be relevant for other areas of South Africa and the world. While the gold mining industry in the Witwatersrand might almost be at the end of its lifespan, the extractive industries continue to have a huge impact on environments and communities in this country and elsewhere in the world. The mining and urban development in Gauteng along the east-west mining belt, has now shifted north-south with the growth of the platinum mining industry around Rustenburg in the North-West province. The country is the biggest producer of platinum globally, and its coal fields make it the fifth largest producer of coal. It is in the global top five of countries owning large reserves of mineral resources, together with Russia, Australia, Ukraine and Guinea.

In this global context of mining, governments and civil society call upon companies to develop responsible mining practices, and include social and environmental plans into their operations. Nevertheless, there is a huge lack of consideration about the relation between mining industries and urban development, between extractive activities and socio-ecological landscapes. Ideally the impact of mining activities on spatial structures is studied as part of the planning of the mine, organising operations according to a sustainable closure vision. But often, this thought process only starts during the end of mining operations or after the mine has been closed down and abandoned.

In both cases, the role of a spatial designer to integrate ecological and socio-economic issues into a long-term spatial vision for a (post-)mining region, is essential.

*prospective mineral regions in the world*

*(source: Risto Pietilä , Nordic Centre for Spatial Development,)*



### *Emergence of post-extraction urbanism*

The impact of mining and abandoned mines on the environment, local communities and regional economies, has been studied by environmentalists, social scientists, etc. Governments and private sectors are struggling with the risks, and realising the opportunities of abandoned mining sites. Society's expectations for sustainable and economically viable post-mining land uses are growing. However, the reflection about the reclamation of post-mining landscapes has so far mainly taken place within the field of mining itself. Also in Johannesburg, projects reclaiming parts of the Central mining basin have mainly followed strategies of mining companies. Since 2005, yearly Mine Closure conferences have been organised in different places of the world, to develop and share the industry's best practice in terms of post-closure landscape rehabilitation and land use projects. Moreover, with '101 things to do with a hole in the ground', a book about creative re-cycling of mining sites has been published in 2009 on initiative of the Eden Project in Cornwall. The book highlights a range of projects that successfully transformed previous mining locations into spaces of culture, heritage, entertainment, leisure, or nature.

Also the discipline of landscape architecture has been involved with the reclamation of mining landscapes, as particular and often even more large-scale versions of post-industrial sites. Several theses have been published on the advantages of including landscape design in the planning of mining operations, and on the value of landscape architecture in the reclamation of mining sites. However, the approach of landscape architecture projects often remains limited to the design of the site itself. Rarely, the debate about post-mining landscapes includes urban or regional spatial thinking and design. But some experiences and research projects have started to develop this particular type of post-industrial urbanism.

In East-Germany, the Internationale Bauausstellung (IBA Fürst-Pückler land) has developed a broad experience with the creative re-thinking of its former lignite-mining landscapes in the Lusatia region. Conceived as a project-oriented planning method, it developed 30 projects that sparked innovative design approaches, as well as new stakeholder coalitions that formed the basis for a transformation of this post-mining territory. The main topics of this IBA process were developed around the following themes: Industrial heritage, Waterscapes, Energy Landscapes, New Land, Border Landscapes, Cityscapes, and Transition Landscapes. Not only the ecological revival of the landscape, but also the socio-economic identity and the future perspectives for the shrinking region's urban development were part of the debate.

In the Ruhr area, a former industrial and coal mining region, the Emscher Landschaftspark is a strategy for regional revival. Using landscape design and heritage re-use, it integrates ecological and economical goals and has been very powerful in generating a new image for the region.

Kate Orff and Richard Misrach have developed an in-depth research project about the environmental consequences of the petrochemical industry along the Mississippi river. This exploration uses the tools of spatial professionals to conceptualise and graphically represent the toxicity of this landscape and the spatial logics of the river system's long-term ecological degradation.

The research and design project 'Petropolis of tomorrow' of Neeraj Bhatia and Mary Casper somehow looks at a reverse type of process. It focuses on the development of a series of cities along the coast of Brazil following the discovery of petroleum within the country's territorial waters. It investigates the relationship between urbanisation and resource extraction and develops templates for sustainable urbanism in this context.

In the South-African context, the work of Dorothy Tang and Andrew Watkins in conceptualising and spatially analysing the gold mining belt was a pioneering work. It was followed by the thesis of Tahira Toffa, which further developed an understanding of the strategic importance of the mining territory on a regional scale, and proposed design strategies to deal with its environmental and socio-economic issues.

This line of research and design can draw from concepts related with the broad fields of post-industrial and landscape urbanism. The notion of *terrain vague* was developed around 1995 by de Sola-Morales and describes undetermined, abandoned urban spaces that are internal to the city but external to its daily life. The concept of 'Drosscape' of Alan Berger (2006-2007), drew attention to the characteristics and values of waste landscapes and offered a vocabulary for the adaptive re-use of these spaces. Some internationally renowned projects have prepared the field of dealing with landscapes of waste, such as the Fresh Kills project of in New York by James Corner, and the Duisburg Landschaftspark by Latz + partner in Germany. The approach of landscape urbanism, whereby natural systems are understood and designed as structuring systems for urban spaces, is also extremely useful in conceptualising and envisioning post-mining landscapes.

*IBA Fürst-Pückler land*



*IBA Fürst-Pückler land*



*Petr*



But the projects dealing with post-extractive landscapes are confronted with territories of an incredible scale and with far-going social and environmental impacts. They deal with landscapes that are the result of essentially temporary activities of extraction that nevertheless attract rapid urbanisation, cause profound ecological degradation and leave behind complex socio-economic issues. They are laying the foundation for a particular type of post-industrial urbanism that is becoming ever more relevant as globally mining activities remain either triggers for urban development, or leave behind devastated regions after closing down.

### *Importance of post-extractive landscape urbanism - in the West Rand and the world*

The examples above already show how urbanism and landscape design can unlock the strategic potential of post-mining landscapes in relation with urban development, ecological rehabilitation and socio-cultural revival. They have in common that the landscape and its remediation process is understood as a structuring element of future perspectives for such regions. The extent of ecological damage, and the complexity of interlocking cycles of pollution and socio-economic legacies, makes post-extraction urbanism stand apart as a specialised form of urbanism. It requires profound technical knowledge (touching upon disciplines ranging from chemistry to geology and phyto-technology) as well as a visionary approach that includes vulnerable communities as well as policy makers and economically powerful extractive industries.

The vision developed in this document, and more importantly the research it is based on, contributes to the development of this exciting field of knowledge. More than formulating a take-or-leave proposal, it wants to generate a dialogue between academics, mining companies, policy makers and local communities that could become the start for the creation of a common vision for the West Rand's post-mining future. Moreover, it wants to inspire this vision by bringing together a thorough analysis of the issues at stake, and innovative strategies to remediate and transform the regional landscape.

*tochemical America*  
Kate Orff



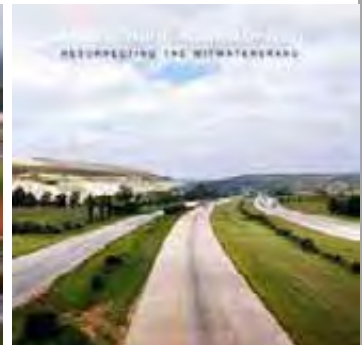
*Petropolis of Tomorrow*



*Ecologies of Gold*  
Dorothy Tang and Andrew Watkins



*Mines of Gold, Mounds of Dust*  
Tahira Toffa



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maps printed by the Chief Directorate of National Geo-spatial  
Information, 2010, and on aerial photographs of Google Maps (Landsat  
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5. ZOOMING OUT  
the relevance of post-extraction urbanism  
for the Witwatersrand and the world

## *Sidestories to the vision*

This thesis is composed of two booklets. The first document contains the main storyline and explains a strategic vision for the West Rand's post-mining future. This document is the second booklet and contains background stories that elaborate specific aspects of the vision. The scheme on the left shows how the two books relate.

The stories in this document can be read separately and focus on aspects of a specific issue related with the soil- or water cycle. Supporting the vision document, each sidestory explains a technical, institutional, historical or urbanistic aspect of one of the cycles. The knowledge gathered in these stories formed the base for the development of the vision and design strategies. By focussing on a particular issue, these sidestories provide valuable background information and an in-depth analysis of their topic for whoever wants to learn more.



Sculpting the hill | cultivating the valley  
Re-claiming the West Rand's post-mining landscape



Sculpting the hill | cultivating the valley  
The West Rand's post-mining landscape unveiled

1 | SCULPTING THE HILL  
*RE-THINKING THE SOIL CYCLE*





5km



*Krugersdorp in 1939*

*(source: Krugersdorp Museum Archive)*

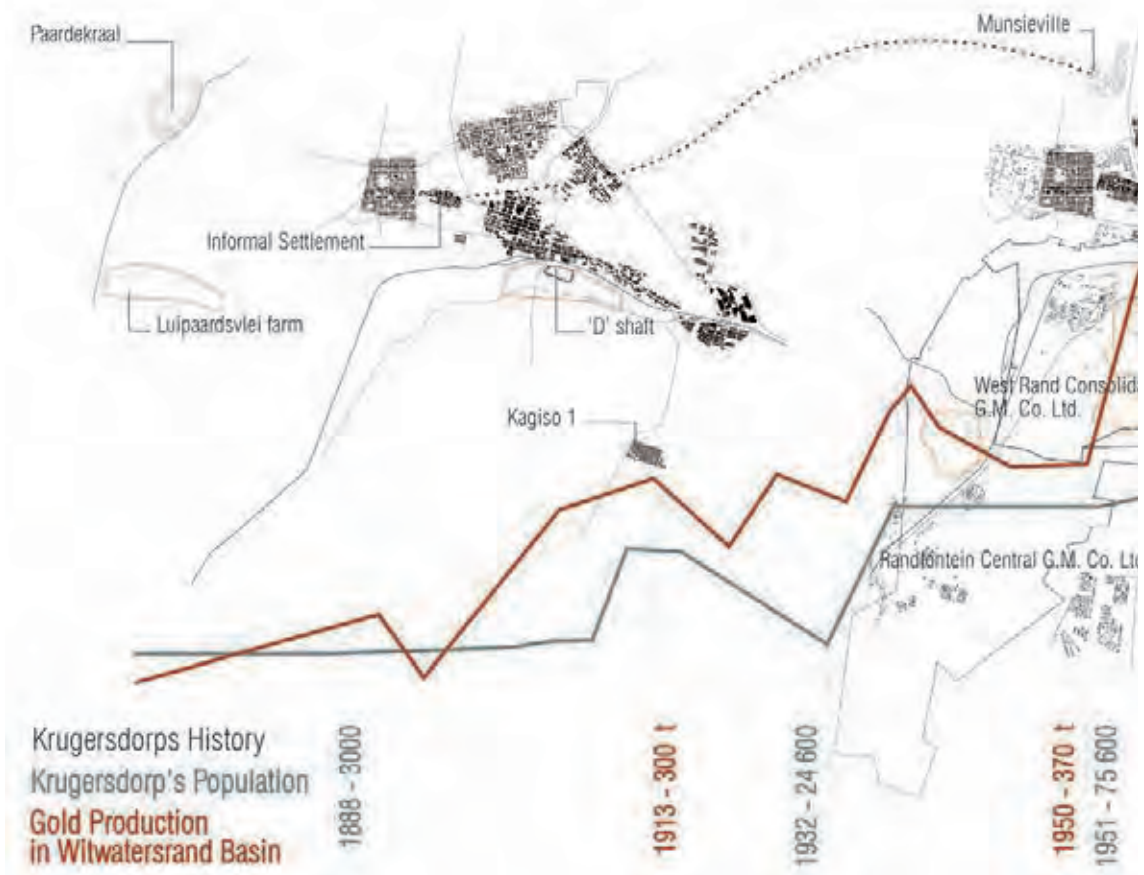
## SOIL SIDESTORY 1

### *THE BOOM-BUST CYCLE IN AN AFRIKANER MINING TOWN*

## Introduction

Krugersdorp owes its existence to the discovery and exploitation of gold. Starting with only 200 plots in 1887, fifty years later Krugersdorp had become a booming town. (DU PLOOY, 1999). Although agriculture remained an important economic activity for the areas west of Krugersdorp, with the proclamation of the first gold digging claims, the town had tied its faith to the boom-bust cycles of mining. Its development was therefore always linked to the ups and downs of the mining industry and the volatility of the gold price. While mining has always been considered an essentially temporary activity, it has lasted for over a century in the case of the West Rand, always extending its lifecycle by adopting new technologies. From dry Highveld with farms here and there, Krugersdorp transformed incredibly into a booming mining town, and then declined into a place of faded glory and devastated landscapes.

At the end of the 20th century the gold fields finally seem to be drying up, and the region finds itself in a phase of transformation, that will determine whether it survives the decline of the gold mining industry and find a new, perhaps more rural, direction for the future. This crucial period is not only about dealing with the ecological and socio-economic legacy of a vanishing mining industry. It is also about transforming the



remnants of the apartheid political ideology and persistent settlement patterns that it created. Not only the sand dumps and the tailings dams, but also the unemployment and housing inequality, the mine hostels and informal settlements, are part of the area's gold mining legacy.

Several phases can be recognised in the lifecycle of gold mining in the West Rand, based on specific extraction technologies, socio-economic conditions and ideological frameworks. After a first phase (1887-1930) of rapid and speculative boom, a second cycle (1930-1952) followed in which urban development and mining industries developed around principles of extraction and separation. These reached their culmination when the apartheid regime (sustained by an economy built around the gold mining and manufacturing industries) strongly influenced the structure of further urban development, using the mining belt as the ultimate buffer space between north and south. Finally the end of Apartheid, but also that of the gold mining age came in sight with a steady decline of production and increasing ecological and socio-economic issues becoming serious limits for the industry and for urban development alike.

*historical evolution of the West Rand's urban areas and mining industry (adapted from Mihalis Mina)*



### Phase 1: gold discovery, speculation and urban boom (1887-1930)

Krugersdorp's history really starts when the discovery of gold on Cecil John Rhodes' farm Paardekraal was confirmed in 1887. Soon public diggings were proclaimed on several farms and small claims were made by individual prospectors (VILJOEN, 2009). Krugersdorp as a settlement was first established when 200 plots were auctioned in 1887 under a 99-year leasehold. There were no provisions for people of colour and black mine workers were typically housed in mine compounds. Their families and other black migrants built informal settlements on the edges of town (DU PLOOY, 2004).

Back then, the gold-bearing reef could be found in outcrops on the surface that were relatively easy to mine and had a high ore grade (HARTNADY and TURTON, 2011). A stock market originated with a dynamic trade in claims and shares. Later, it became clear that the reef extends over a greater length downwards at an angle of around 22°. Mining these underground reefs requires more expensive technology, and soon, small claims were taken over by a few Randlords that could invest international capital or had made their fortune on the diamond fields in Kimberley (HARRISON and ZACK, 2012).

There was a large market for gold because many European currencies were tied to the gold standard, so their economies depended on the availability of the precious metal. However, the gold price was fixed and didn't depend on cost or supply, which meant that the profitability of mining was always tied to a delicate balance between cost and revenue (HARRISON and ZACK, 2012).



One of the companies that determined the faith of Krugersdorp in its early years, was the Luipaardsvlei Estate and Gold Mining Co. Ltd., founded by Cecil John Rhodes in 1888. Despite its tumultuous early years it survived the uncertain conditions of the early gold mining era (DU PLOOY, 1999).

When the mining companies struck pyritic ore in 1889, this seemed to signify the premature end of Krugersdorp's existence because they didn't have the technical means to extract the gold. However, a method using cyanide was discovered by Mac Arthur-Forrest in 1891 and led to a new wave of property development, until the Boer War broke out in 1899 and put an end to all mining activity (HARRISON and ZACK, 2012; VILJOEN, 2009).

This violent struggle didn't only mark a crucial and tough period in the history of Krugersdorp but was in essence about the control over gold. The British fought the two Boer republics (Transvaal and Orange Free State) to bring the Witwatersrand gold fields under their political and economic power (HARRISON and ZACK, 2012).

When the war ended in 1902, mining activities were resumed enthusiastically. This was also the start of engineering of deep mining operations, when first incline and later vertical shafts were developed to reach the underground reefs. However, mining activity soon declined again because of a labour shortage (HARRISON and ZACK, 2012).

In 1903, the second company that strongly influenced Krugersdorp, was established under the name of West Rand Consolidated Mines. This name refers to a common evolution whereby several enterprises were grouped together into more profitable and larger mining companies. (DU PLOOY, 1999). This company created one of Krugersdorp's main landmarks: North Sands is a sand dump that can be spotted from nearly every place in the centre of the town.



gold digging at Witpoortjie Fault  
(source: Krugersdorp Museum archive)

1899  
second Boer War  
breaks out



1900 - mine worker's house  
(source: Krugersdorp Museum archive)



extension of Main Reef Road towards the West Rand

(source: Barloworld Archive)

Mining concessions in 1909,  
land structure based on existing farm boundaries

(source: BROOMHEAD, 1909)

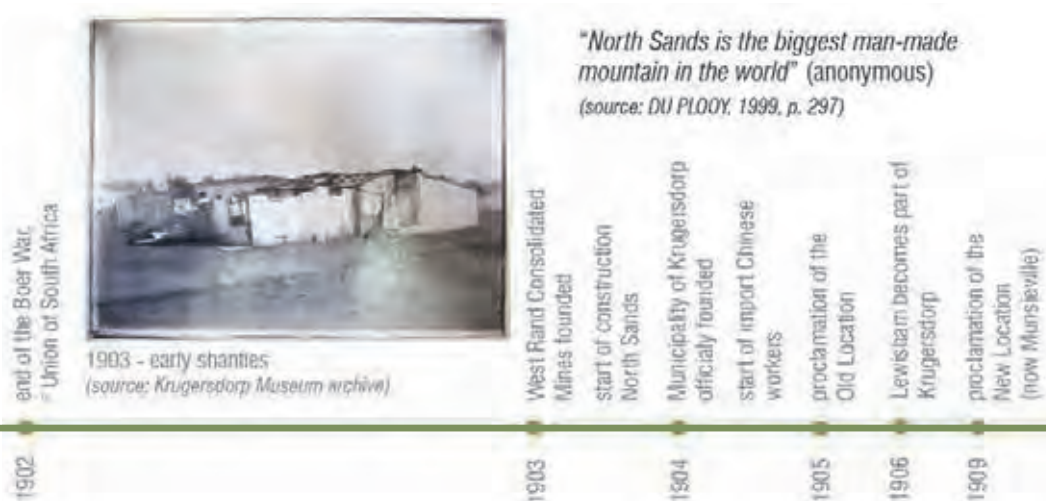




The Municipality of Krugersdorp was officially founded in 1904 and counted 13 000 inhabitants at the time, living in four distinct neighbourhoods. The area where black inhabitants were squatting was proclaimed as a 'Location' in 1905 but little consideration was given to the poor quality of their living conditions. Indians arrived in Krugersdorp in 1897 and settled in-between the black Location and Burgershoop (a neighbourhood with poor white inhabitants) where they found their typical clientele of lower-income customers nearby (DU PLOOY, 2004).

During this period, Krugersdorp didn't only expand, but its existing tissue became consolidated and old houses were replaced with more permanent structures now that the gold mines were trusted to stay. There were still several agricultural farms (Oatlands and Waterval) and village grounds to the north of Distriksdorp, that were considered as potential areas to be developed. The presence of the mining belt in the south, and the dominant north-west wind direction explain the growth of the town towards the north and east where the dust from the mines caused no nuisance (DU PLOOY, 1999).

Since 1912, the idea arose to create agricultural farms in the periphery of the town where people could live self-sustainingly. Both Waterval and Oatlands Limited were developed into small farms with mixed produce. Moreover, fields near Coronation park and Burgershoop were also used for agriculture that could profit from a fertile soil, water availability in the dolomitic underground. Yards in town and in Munsieville were used to keep poultry and cattle, and grow crops. The produce was sold on the municipal market of Krugersdorp until it closed down in 1970, and in Johannesburg. (DU PLOOY, 1999).



The rapid transformation of this territory from an agricultural economy to a mining and industry-related economy, brought with it a radical demographic transition and reconfiguration of the population. The large black population in the Witwatersrand is therefore a direct consequence of its mining origins. Moreover, the socio-economic logics of mining depended on a specific spatial organisation. Mines attracted migrant workers, often from Botswana and Lesotho, that were housed in low-cost accommodation, typically single-sex compounds, for the duration of their contract, and then returned to their family in rural places. This system was supported by the state and allowed for the externalisation of social costs that was necessary to make mining profitable. Without the exploitation of many unskilled and low-wage migrant workers, the deep level gold mining industry in South Africa wouldn't have developed (DU PLOOY, 1999, HARRISON and ZACK, 2012).

The urbanisation of this black, mainly male, population, dissociated them from their previously rural culture and this became the foundation of many socio-cultural issues. Slowly, however, women started to join their husbands in urban areas and found work as labourers or domestic servants (DU PLOOY, 1999). Nevertheless, the demographics of the Witwatersrand were skewed and males far outnumbered female inhabitants, especially among the black population. (HARRISON and ZACK, 2012). The attraction of black migrants led to the genesis of several informal settlements, such as Pangoville near Munsieville, Swanieville south of Kagiso and Lusaka I and II. A lack of (adequate) housing remained a problem throughout the century, especially for non-white inhabitants (DU PLOOY, 1999).

The hierarchy within the mining companies was also reflected in the built tissue of residential accommodation, as can be seen in the layout and typologies of West Village. In this mining village, built by West Rand Cons., the non-white employees were housed in a mining hostel, while white workers lived in a 'modern' residential area and enjoyed far more facilities for recreation.



1911 - tents for black workers on the diggings  
(source: Krugersdorp Museum archive)



1914 - one of the oldest houses in Krugersdorp  
(source: Krugersdorp Museum archive)

expansion of the town with  
Krugersdorp East  
neighbourhood

1911

Members of the company's management inhabited even better villas in the most eastern part of the scheme. These three classes were clearly separated from one another by the railway tracks that transported the ore (DU PLOOY, 1999).

Before the South African war, there were no specific areas declared for black migrants, and these lived in squatter settlements, like many of the white inhabitants did at that time as well, especially poor Afrikaans families that had been attracted to the mining region after the Anglo-Boer war. Most of the residential areas were developed on private initiative and therefore in practice reserved for the white population. Already in 1909, the need arose for a new black settlement (New Location, now known as Munsieville). It was planned out further to the north-west according to a strict municipal plan (DU PLOOY, 1999, referencing the Mayor's Minute for the year 1910, library of Krugersdorp). This laid the basis for later, repetitive and uniform urban layouts such as in the older parts of Kagiso. An extension to this new Location remained partly unoccupied because another Location was built in Randfontein to sustain that town's labour needs, and located closer to the railway (DU PLOOY, 1999).

This early period already shows how the society that emerged around mining was strongly shaped by the logics of that industry. Gold mining shaped the migrant labour system and determined the social and economic relations in the country and the West Rand. (HARRISON, and ZACK, 2012) Class differentiation became ever stronger, whereby the hierarchy of jobs in the mining industry was determined by race: supervising jobs were reserved for white employees while black workers more often got heavy tasks (DU PLOOY, 1999). These hierarchies in employment in turn shaped someone's socio-economic status and dwelling conditions.

1917  
Waterlief and Oatlands  
Limited developed into small  
farms



plowing land with oxes  
(source: Krugersdorp Museum archive)



tobacco field in Magaliesburg  
(source: Krugersdorp Museum archive)

Moreover, the mining belt itself became the ultimate dividing space between white and non-white groups of society and strongly shaped the distorted settlement geographies of the region. During its first years, Krugersdorp developed into a multi-cultural town, counting 7000 whites, but also 5250 black inhabitants, 520 coloureds and 300 Asian inhabitants by 1904 (DU PLOOY, 1999). But soon a spatial division between the different groups became evident. Even though the most extreme forms of segregation are mostly associated with the Apartheid regime, already before 1948, the mining industry was a key driver in the development of urban segregation (HARRISON and ZACK, 2012).

After the Boer War, the poor dwelling and hard labour conditions, and the minimum wage in the mines wasn't supported anymore by the black workforce. Therefore, in 1904, the Chamber of Mines decided to import Chinese labourers under strict contracts that lasted only 3 years. They lived under controlled and poor conditions and had limited ownership and trading rights. When the gold production had increased by 1910, these Chinese workers were returned to China. An economic recession slowed down the increase in black population between 1911 and 1921, but it rose again in the 20s and 30s because of droughts in South Africa (DU PLOOY, 1999).

When the gold price dropped in 1921, the Chamber of mines wanted to replace expensive white labour with black African workers, which provoked a bloody protest. During this Rand Rebellion, white workers carried banners reading '*Workers of the world unite for a White South Africa*'. The state supported the reproduction of low labour costs so that gold mining could survive to sustain the national economy (HARRISON and ZACK, 2012, quoting INNES, 1984). These strikes spread from the East Rand to the West and also caused unrest in Krugersdorp. They motivated West Rand Consolidated Mines to search for a better profitability. In 1928, new crushing technology was taken in use, and a new era for the mine began (DU PLOOY, 1999).



Despite the growth of the mining industry, many houses in Krugersdorp were abandoned during the 30s, with a large part of the white population living in slum conditions. Not only the strikes in 1922, but also the economic crisis of 1907, the first World War and the economic depression and droughts in the beginning of the 30s caused this situation. However, soon confidence about the growth of the city revived and stimulated a building boom in the white centre. Nevertheless, black settlement in the city remained repressed, especially after the Natives Urban Areas Act of 1923. This required all black urban dwellers to live in a 'Location', dedicated 'black' area or hostel for black workers. These restrictions were later repeated in the Natives Consolidation Act of 1945. The local municipality was obliged to provide housing or allow black inhabitants to construct it themselves, although they could not get ownership rights and often depended on a 99-year lease system (DU PLOOY, 1999).



1925 - Distriksdorp  
(source: Krugersdorp Museum archive)

1926  
proclamation of Kagiso I  
(previously Luipaardsvlei  
Location)



1926 - overview of Randfontein mining company  
(source: Gold One archive)



1925 - gold fields of the West Rand

1925 - gold fields of the Witwatersrand  
(source: Barloworld Archive)



## Phase 2: consolidation of mining and of the urban tissue (1911-1952)

In 1930, the collapse of gold mining was predicted to happen by the '50s. However, when South Africa and other countries, such as Great Britain, abandoned the gold standard 2 years later, this had extreme results. The gold price doubled overnight, and continued to rise, generating massive private profit for the industry. It motivated more prospecting and exploration which then led to a next wave of gold mining development in the 40s (HARRISON and ZACK, 2012, quoting SILVERS, 1948 and JSE 1948).

By then, Krugersdorp had developed into an economical centre dominated by gold mining activities and had almost forgotten its rural past. It was considered equal to Johannesburg and the other towns along the Witwatersrand (DU PLOOY, 1999). Its growth was clearly directed north-east, and today links up with Roodepoort and Randburg. The urban tissue was of a high quality, with many facilities and services. At the end of the 30s, a fire department, post office, hospital and railway station were constructed. The development of well-off white neighbourhoods was not clearly coordinated, and left many open spaces in-between that make the different residential areas easy to distinguish: Central Krugersdorp and Luipaardsvlei, Krugersdorp West and Burgershoop (an area for poor families), Distriksdorp and Monument, and Lewisham (DU PLOOY, 1999).

While Appelpark was built in the '40s to provide affordable housing to poor white inhabitants, attention for the poor living conditions in black areas was much lower. When the municipality wanted to develop a white area west of Distriksdorp, this required the removal of the Old Location. Many of the buildings there, were dilapidated and built without foundations. The inhabitants were simply moved to the New Location, from then on called Munsieville (DU PLOOY, 1999, referencing the Africana collection, library of Krugersdorp).

1929  
closure of West Rand  
Consolidated's 'D Street'  
Randfontein becomes  
Independent municipality



1929 - West Rand Consolidated cyanide plant  
(source: Mintails archive)



1929 - residue sand dump; North Sands  
(source: Mintails archive)



*growth of Krugersdorp: 1904 (yellow) and 1939 (grey)  
(source: DU PLOOY, 1999)*



*1929 - West Rand Cons.: natives hospital  
(source: Mintails archive)*



*1929 - West Rand Cons.: bowling green & club house  
(source: Mintails archive)*



*overview  
(source: Gold One archive)*



By the mid '30s, the gold mining surface rights had been consolidated into underground operations that went up till 1000 m below surface. They were more mechanised and capital-intensive. Nevertheless, the average ore grade declined between 1930 and 1950, and the total milled ore tonnage peaked in 1940. This reflected the depletion of the original discovery areas and the increasing difficulty to mine there. While production costs continued to rise, the gold price remained relatively low (HARTNADY and TURTON, 2011).

Because of the expectation that mining would come to an end, the attention of the municipal council shifted towards industrial development to support the economy of Krugersdorp after mining would be gone. While mining was based on migrant labour, industries would work with the local population. This stimulated the urbanisation of the South African black population, that often came to cities to work there temporarily but in practice remained permanently (DU PLOOY, 1999).

The first industries were often related with mining, but the growing town soon also attracted other commercial activities and manufacturing industries that found a ready market in the urban agglomerations along the Witwatersrand. It was no exception that mining companies owned or founded other industries, but the Johannesburg Stock Exchange and many financial institutions that found their origins in a strong relation with the gold mining companies, were mainly based in Johannesburg's centre.

Several industrial areas were installed between the '30s and the '50s by the Krugersdorp municipality, according to a zoning logic. Factoria mainly housed lighter industries and was established near Luipaardsvlei station in 1938. Boltonia was built in 1953, close to the Krugersdorp station and meant for scrapyards, furniture factories and warehouses for wholesale. Industries that could cause nuisance such as tanneries and fertiliser producing companies were located in Delporton, quite far from white residential areas. And finally Chamdor was established in 1963 on a plateau south of Luipaardsvlei (DU PLOOY, 1999).



1935 - south compound, 5631 Natives  
(source: Gold One archive)



1935 - pump house and cooling water dam  
(source: Gold One archive)

1946 - gold fields of the West Rand



1946 - gold fields of the Witwatersrand  
(source: JEPPE, 1946)



1935 - South vertical shaft  
(source: Gold One archive)



1935 - waste rock dump  
(source: Gold One archive)

1935  
New neighbourhoods of  
Monument, Kainmare and  
Wentworth Park

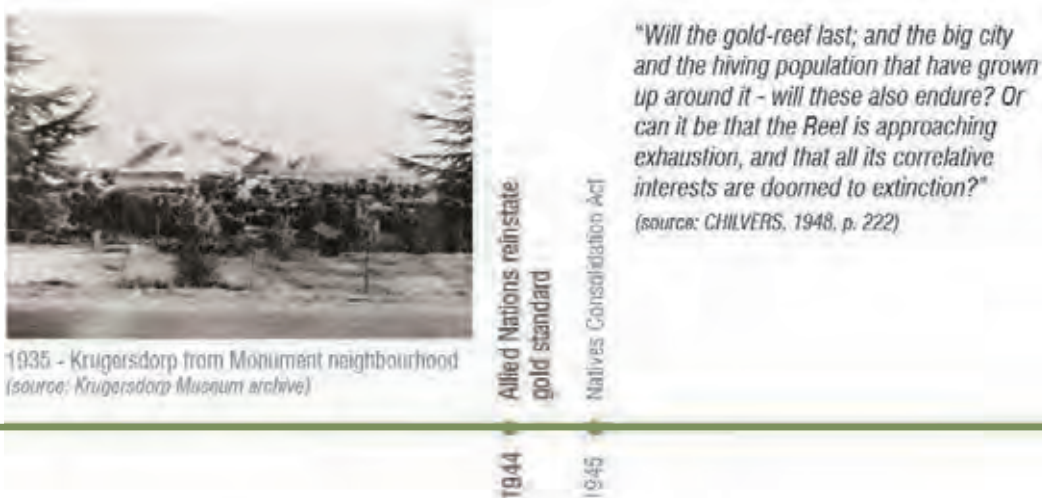
1936  
establishment of Factoria  
industrial area

### Phase 3: Apartheid and the end of mining? (1952-1980)

The gold standard was reinstated by the Allied Nations in 1944, which gave South Africa a steady market for its gold mining industry, but also subjected it to a fixed price. Combined with rising extraction costs this put growing pressure on the industry (HARRISON and ZACK, 2012).

The companies in the West Rand could remain profitable by starting to process the uranium that was present in the ore bodies of the region, in quantities ten times higher than gold. This metal had become in demand during the Second World War for nuclear technology, and South Africa became the most important supplier world-wide. Both for West Rand Cons. and for Luipaardsvlei Estates G. M. Co. Ltd., contracts to produce uranium extended the lifetime of the mining company with around 20 years. However, when the gold price went up again in the '70s, uranium production slowed down (DU PLOOY, 1999).

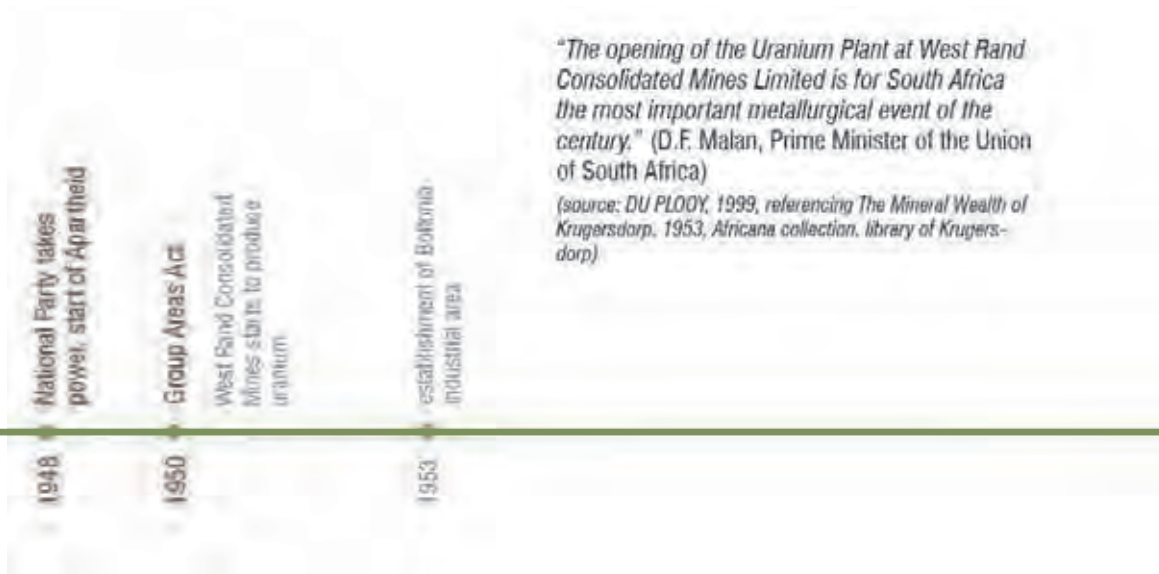
When the National Party had taken power in South Africa in 1948, Apartheid was officially introduced and strongly shaped the urban development of Krugersdorp in the decades to come. Because settlement patterns before had been mainly guided by restricting or allowing rights of ownership and trading, they had already strongly benefitted the white population. The introduction of the Group Areas Act (1950, re-enacted in 1957 and 1966 and amended countless times) strengthened the unequal division of economic development and the segregation of settlement patterns even further. (DU PLOOY, 1999) The Indian population of the West Rand got allocated Azaadville, the coloured population was moved to Toekomsrus in Randfontein, and black people had to live in Kagiso, Rietvallei and Lusaka. A strong north-south divide was the result, conveniently using the mining belt as a buffer space in-between white and non-white areas. Not only the residential neighbourhoods that followed were a typical product of Apartheid planning, whereby even within neighbourhoods ethnical groups were separated. Also industries were strictly grouped, as well as schools, churches and recreation areas.

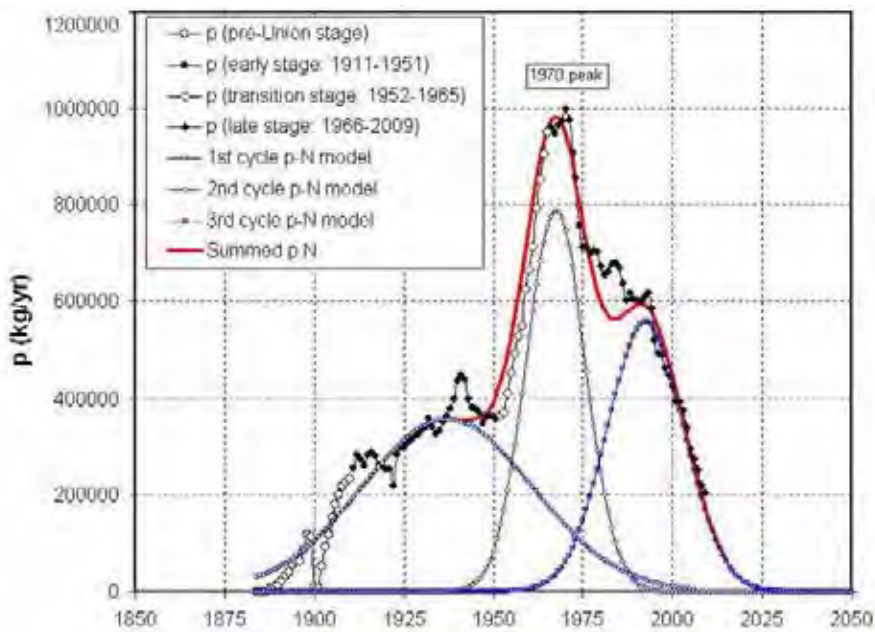


In 1956, Kagiso was founded with the idea to move the residents of Munsieville to this new township over time. When Krugersdorp's white population launched a petition to remove Munsieville completely in the 80s, resistance by the inhabitants of Munsieville prevented that their neighbourhood was completely erased. It remained the only exception to the north-south divided pattern, and was even upgraded in the prospect of black self-rule at the end of the 80s. (DU PLOOY, 1999)

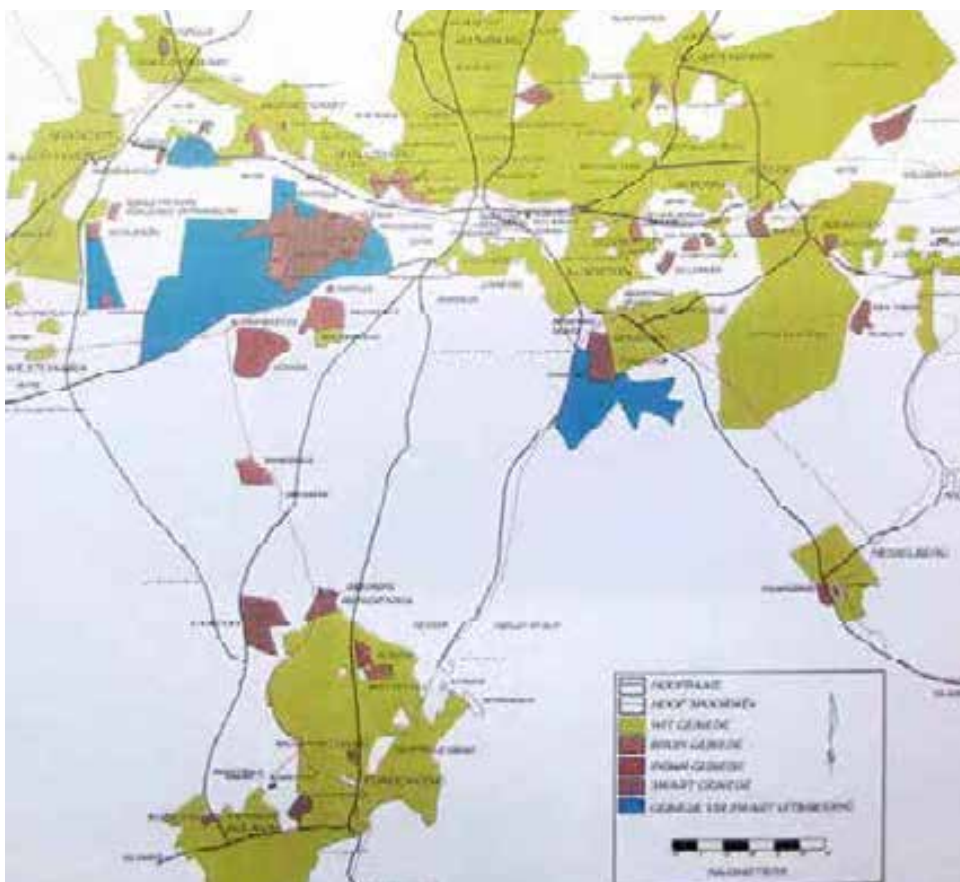
Meanwhile, Kagiso still became the largest black area of Krugersdorp, located south of the mining territory. When the industrial area of Chamdor was built, the township was extended as a pool of black workers for the industries. Moreover, the layout of the industrial platform made it a very effective buffer between Kagiso and the north (DU PLOOY, 1999).

The low-density and often low-income townships of Kagiso, Rietvalley and Lusaka were generally located far away from work opportunities and commercial centres. Black people could not even determine the spatial and cultural characteristics of their own residential environment. Prohibiting them from constructing or owning houses in white areas, was meant not to confirm 'permanence' so that insistence on political rights wouldn't be encouraged. It was also one of main causes of the housing shortage that became ever more pressing towards the end of the century (DU PLOOY, 1999). In the beginning, townships like Kagiso were quite socially homogeneous and different classes were forced to live in close proximity in quasi-identical houses. Over time, social inequalities started to emerge and were represented in space because some inhabitants could extend and transform their house while others still lived in basic township-housing. White-collar workers were increasingly in demand and generally inhabited larger houses that were furnished in more sophisticated ways.





*Cycles of gold extraction*  
 (source: HARTNADY and TURTON, 2011)

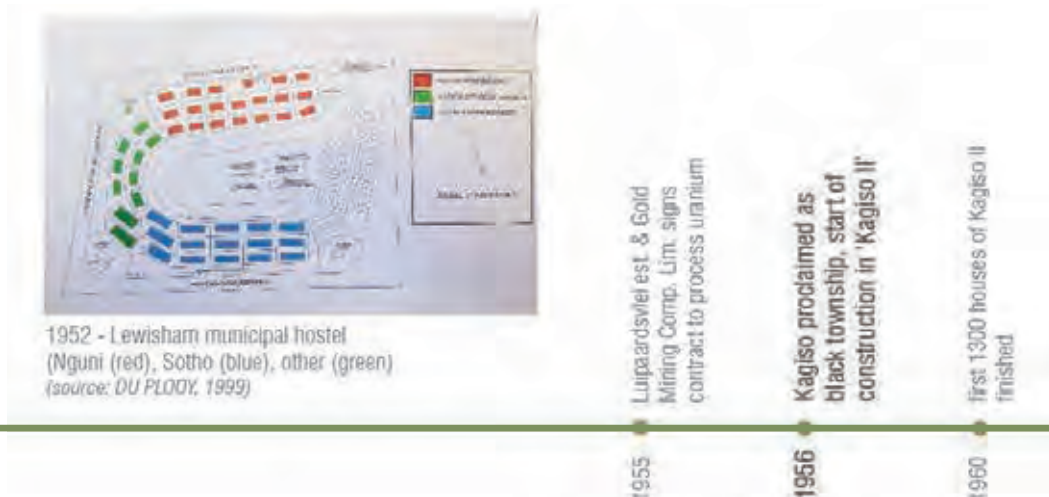


*Group Areas in the Witwatersrand*  
 (source: DU PLOOY, 1999)

In 1970, the peak of gold production was reached, with an output of 1000 tonnes of the precious material (VILJOEN, 2009). After this, a rapid decline in average ore grade (reaching 5 g/t in 1990) was set in. It was compensated by a sharp increase in the rate of ore tonnage milled. When the US left the gold standard in 1971, this also brought new prosperity to South Africa.

In the '80s, the metallurgical process was improved by taking in use the 'carbon-in-pulp' or 'carbon-in-leach' cyanidation process (TURTON, 2014). Furthermore, it was realised that there was still considerable amount of gold in old mine-residues from the era of lower efficiency, which were then reprocessed (HARTNADY and TURTON, 2011, VILJOEN, 2009). This was profitable because of the gold price and improved extraction technology, and extended the lifespan of mining, while at the same time removing an important environmental hazard. Also the landmark of North Sands partially disappeared because of an attempt to reprocess the infamous sand dump. (DU PLOOY, 1999) However, yearly profit continued to decrease in the 80s because of the low gold price, rising labour costs and increasingly deep-level mining. There was little new investment and many mines closed down even though there was still considerable deep resource and relatively low grade shallow resource in place (HARRISON and ZACK, 2012).

Meanwhile, industry, commerce and services began to play a bigger role in the last decades of the 20th century. Trade had always existed in Krugersdorp and was done mainly by British and Jewish inhabitants that often had an important function in the Municipal Council. The local Chamber of Commerce was mainly concerned about the competition with Indian and Chinese traders that had specialised in providing for the specific needs of poorer parts of the population (DU PLOOY, 1999).



In the townships trading by African residents was legally restricted although some informal activity did take place. It was extremely difficult to get loans and permits to establish a regular business. At bus stops and community spaces, local traders (often women) sold bread, fruits, sweets, and other local foods. But generally, black inhabitants had to shop in Krugersdorp centre. Illegal shebeens (taverns) were popular leisure spaces and also gambling was seen as an interesting source of extra income. In the 70s a pirate taxi industry was installed and is still active with an extensive network of minibus routes.

Parallel with the establishment of industrial areas, the CBD had been upgraded in 1967 and developed into a centre of trade. But the loss of jobs and economic activity caused by the decline of the gold mining industry couldn't be compensated completely. The mines had remained the most important employer in the West Rand until West Rand Consolidated finally closed down in 1989. (DU PLOOY, 1999) For the first time in gold mining history, the '80s knew a surplus of labour because of the stagnation of the manufacturing industry, and the worsening conditions in the homelands that generated a steady inflow of South African workers. (HARRISON and ZACK, 2012)



#### *Phase 4: The decline of gold mining and the end of Apartheid (1980-2000)*

While Krugersdorp was still described in 1978 as one of the richest towns in the Witwatersrand, by 1996 57% of its population was unemployed. By that time, only 6.7 % of the local population in the West Rand was still involved with the gold mining industry (DU PLOOY, 1999).

In 1986, the influx control of black people had been lifted and the Pass Laws abolished, which led to a huge increase in rural migrants hoping to find employment near the urban centre. The tenancy system was reformed in the same year and now allowed ownership for black and coloured inhabitants. At the end of Apartheid in 1993, the Local Transition Council was confronted with a huge housing deficit of around 17000 units. Squatter settlements in approved areas were tolerated because the municipality couldn't contain the increase of the black and coloured population (DU PLOOY, 1999).

Municipal and mining hostels are still confronted with socio-spatial issues, because while they were meant for male workers they are over-crowded today since families have moved in over time. Black townships also have to deal with overpopulation of the existing housing stock and the increasing pressure on services by persistent backyard squatting (DU PLOOY, 1999).

In parallel, the economy of the region was declining since the political changes of 1993, which increased the unemployment numbers even more. One fifth of these officially unemployed finds a partial income from informal activities, while many depend on working family members (DU PLOOY, 1999). Between 2001 and 2011, 180 000 jobs were lost in the mining sector over the whole of the country (HARRISON and ZACK, 2012), strongly impacting the economy of the Witwatersrand in general and the West Rand in particular. 2006 was the last year that South Africa was the world's largest gold producer with a production of only 275 tonnes (VILJOEN, 2009).



1980 - Market Street, view towards North Sands  
(source: Krugersdorp Museum archive)

1983 gold price drops



But while Johannesburg had developed into the economic capital of the nation, Krugersdorp and Randfontein remain more peripheral towns that lack the diversified, strong economy of the metropolis nearby. According to the SA Institute of Race Relations, unemployment has replaced race as the main factor in social inequality (DU PLOOY, 1999). This is reflected in the existence of a rare white squatter camp in Krugersdorp's central Coronation Park.

The mining industry has been reduced and is now focussing on the mining of deep resource and relatively low grade shallow resource, as well as the reprocessing of old tailings disposal facilities that form a secure source of income notwithstanding their low gold grade (VILJOEN, 2009). Nevertheless, declining gold reserves, rising energy costs, social unrest and increasing liabilities seem to finally put an end to the era of extraction that produced more than 50 000 tonnes of gold (HARTNADY and TURTON, 2011).

Commerce and services have increased since 1993 and have been supported by making the CBD more accessible for low-income groups of the population. While the Consumer's boycott at the end of the '80s had stimulated a bit of black trade in Kagiso, the township still lacks local entrepreneurship and economic opportunities, and suffers from stigmatisation. Large commercial centra outside of Kagiso and Krugersdorp form strong competition (DU PLOOY, 1999). Agriculture is still present in the western areas of the West Rand region, but the original character of the landscape has changed due to the location of secondary and tertiary businesses. Informal settlements are an important issue in this region as well, and ongoing urbanisation has been a major factor in its transformation. (DU PLOOY, 1999)



1985 - a modern self-built house in Kagiso  
(source: Krugersdorp Museum archive)





*Krugersdorp in 2014*

The post-apartheid era has brought a series of transformations, that have led to both change and continuity. An emerging black middle class has moved to previously white suburbs, while the poorer population is still trapped on the edge of the city in new 'ghettoes of poverty' (HARRISON and ZACK, 2012). Free and affordable housing constructed under the Reconstruction and Development Programme (now Breaking New Ground) only confirms these existing patterns.

Mining policy still reflects a historic legacy whereby the interests of mining companies were protected by the political elite that facilitated rather than regulated the industry that sustained the national economy for so long (TURTON, *South African water and mining policy*). This means that a coherent policy and vision on how to deal with the spatial, environmental and social legacy of more than a century of mining has so far not been developed.

Krugersdorp has become a sleepy town where the inhabitants have forgotten their cultural engagement and the buildings are ageing visibly. Not really a mining town any longer, the spatial structure and its ills and virtues are deeply related with the gold mines that defined its origins and boom. The way this region will deal with the socio-economic and ecological legacy of its mining past will no doubt determine its future development for a long time to come.



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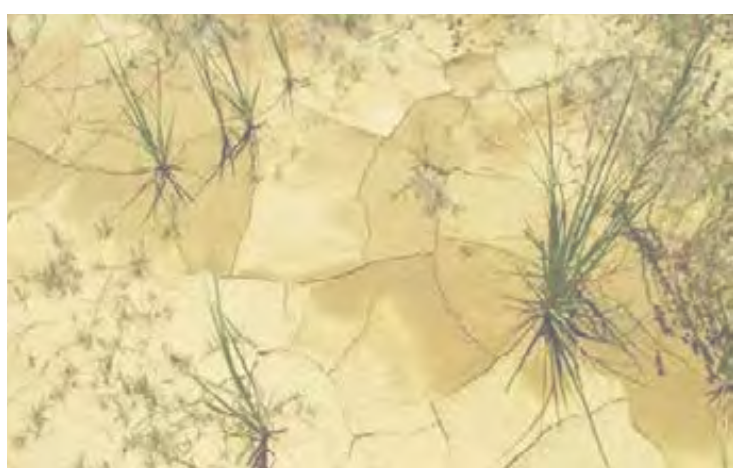
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## SOIL SIDESTORY 2

*THE MINED LANDSCAPE:  
HEAPS OF WASTE,  
UNDERGROUND VOIDS  
AND CONTAMINATED SOIL*

## *Introduction*

More than a century of mining has left the territory of the West Rand with a disturbed topography and a devastated ecology. It has created an impressive and unique landscape with the residue of gold mines scattered around in the form of yellow-golden waste heaps. These large-scale, man-made geometric shapes are scarcely colonised by vegetation. Their red and ochre colours are the result of their sulphur and metal content and returns in the poisonous red of the acid water that has filled up the underground network of mine shafts and tunnels. The risks linked to the invisible presence of uranium in high concentrations should be taken extremely seriously. The ecosystem dynamics of the Wonderfontein Spruit and its wetlands have been changed forever.

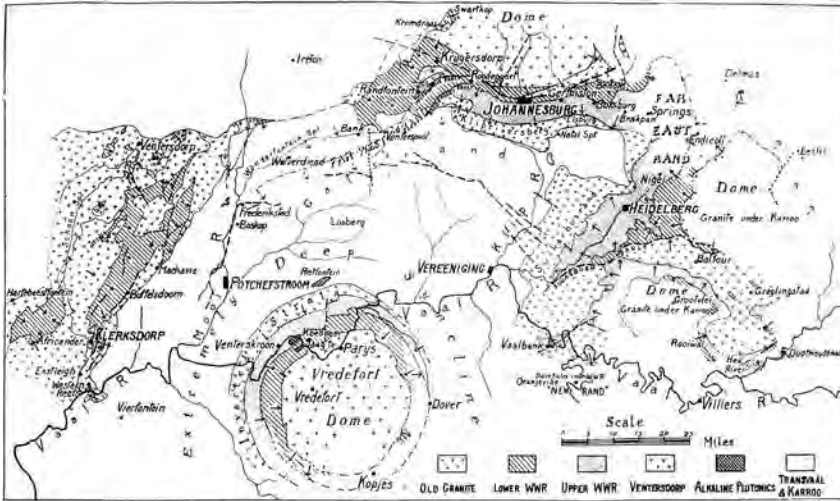
Nevertheless, this landscape is inhabited by plants, animals and people unaware of the risks it poses. Once again the most vulnerable are the poor inhabitants living near mine residue areas, polluted streams and on contaminated soil. While the right to “*an environment that is not harmful to someone’s health or well-being*” is inscribed in the South African constitution, this is definitely not ensured in the landscape of the Wonderfontein and Tweeloopies Spruit valleys. In the media, the issues are often misunderstood and dramatised, the general public is becoming de-sensitised and everyone is overwhelmed by the apparent complexity of the issues to be faced.

## *The geology of the gold fields*

The West Rand is part of the Witwatersrand gold fields that stretch from Springs in the east, to Carletonville in the far west. Due to a meteorite strike in Vredefort, 2000 million years ago, several layers of gold-bearing reef strike the surface under an angle of around 22°. These conglomerate reefs are pebble layers of around 1 m thick, in which gold can be found. Several of these layers appear together, being the Main Reef, Main Reef Leader (which is only 40 cm thin but sometimes contains grades of 50 g/t), South Reef, Bird Reef and Kimberley Reef. They are oriented slightly differently in the West Rand compared to the Central Basin because of a geological fault at Witpoortjie. This shift in geology forms the southern and eastern boundary of the western basin, which is further bounded by the Rietfontein Fault in the north and the West Rand fault in the west (VILJOEN, 2009).

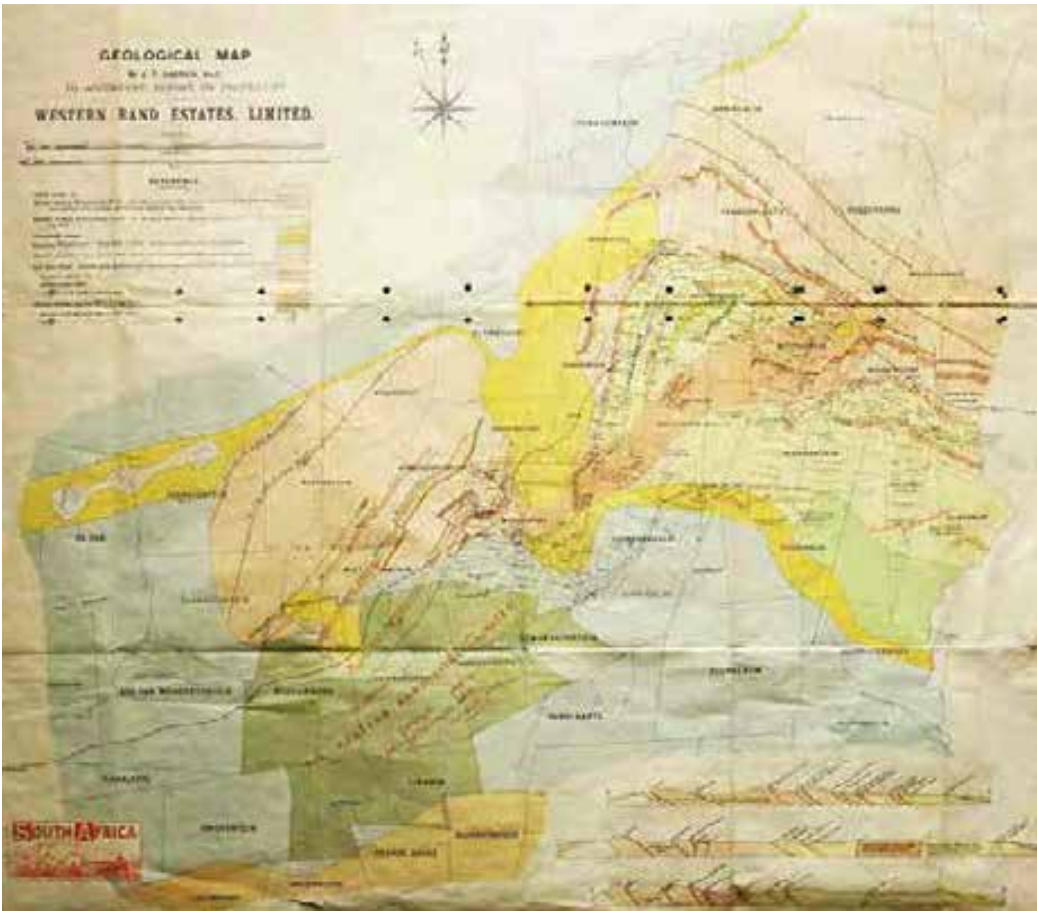
*open landscape south of Luijaardsvlei, Soweto cluster in background*





geological origins of the Witwatersrand gold fields: meteorite impact in Vredefort (source: DU TOIT, s.d.)

1902 - geological map of the West Rand  
(source: Barloworld Archive)



### *The ubiquitous remnants of mining operations*

The extraction of gold first happened at the outcrops on surface through open-cast mining. Even today, open cast mining activities are an important part of active operations. They have an extensive impact on the environment by stripping top soil and leaving behind pits that are up to 30 m deep.

Later, incline shafts were constructed every 100 m, to mine the reefs underground, following the angle of the gold-bearing layers. Horizontal shafts allowed movement sideways to access bigger portions of the gold ore. To extract gold further down, vertical shafts were drilled south of the gold outcrop area, extending up to 3000 m below surface. Together, these shafts and tunnels form an extensive network that is often referred to as the ‘underground mining void’.

This condition implies that a lot of the spaces in the West Rand are, undermined, which poses a risk in terms of geotechnical stability and land subsidence. There are no comprehensive maps with the location of the underground network which forms a major factor of uncertainty. It also limits the possibilities for insurance and sale of houses constructed on undermined land (VILJOEN, 2009; TURTON, 2014).

Moreover, uncoordinated mine closure has left behind thousands of unsealed openings into the underground workings, in the forms of old shafts, ventilation openings, etc. These form a major safety concern, especially because they are used by Zama Zamas or illegal miners that use artisanal methods to extract gold that was left behind by the large companies. The sector is technologically not very developed and lacks economic and environmental knowledge. The mercury that Zama Zamas use to extract and concentrate the gold particles is extremely bad for their health and forms an added source of environmental pollution (DIDIER, 2014; COOKE and JOHNSON, 2002). Not only do the Zama Zamas themselves run enormous risks because of underground instability and lack of monitoring of stress on underground walls, they also further undermine the territory, including residential areas, important roads and railways. Moreover, different gangs fight violent turf wars and migrant Zama Zama communities cause tension with local inhabitants (TURTON, 2014).

On the surface, many infrastructures of the extraction business can be found, such as mining hostels, processing plants, water cleaning plants, and the network of pipes that transport sludge to and from the processing plant.

*open cast mining: Mill Site pit*



*underground mining: re-opening D-shaft*





But the largest remnants of the mining industry can be found in the form of Tailings Disposal Facilities (or TDF's). These are either mechanically placed dumps, or hydraulically placed dams. The dumps are typically from an earlier phase of mining and contain higher grades of residual gold (0,6 g/t), while tailings dams are residues of mining since the late 60s and contain finer particles with a lower gold grade (0,4 g/t) (HARTNADY and TURTON, 2011). Also waste rock dumps and top soil stock piles can be found. These last ones store top soil so that it can be used afterwards for remediation, but are often not maintained carefully and many of the soil qualities get lost over time by compaction and lack of biological processes (PIENAAR, 2014).

### *Sand dumps*

The older sand dumps are made of relatively coarse, crushed rock material. They have a high acidity because of the cyanide that was used for processing. This makes it very difficult for vegetation to colonise these dumps, which leaves their surface open to erosion by wind and water. With the slightest breeze, the particles can be transported in the form of dust (WEIERSBYE, 2014).



*sand dump: North Sands*

*historical headgear of mine shaft, Central Rand*



*processing plant*



*waste rock dump*



## Tailings dams

Tailings dams are made of finer particles of crushed rock that are pumped onto the dam in the form of a slurry. This means that the dams have to dry out to become more stable, and can be imagined as a jelly pudding where only the outer layer is completely dry (WEIERSBYE, 2014). Tailings dams need mechanical maintenance to control their shape. When this is neglected or mining companies become insolvent, spillages and uncontrolled erosion can pollute the soil around the dam, as well as rivers and wetland systems downstream. Over time, 64% of slimes dams have failed at some point. (WEIERSBYE et al., 2006) Careful monitoring and management is therefore crucial, but also signage should warn inhabitants of (informal) settlements nearby about possible risks. (LIEFFERINCK, 2014, DU PLOOY, 1999)

When tailings are deposited, they have a high pH ( $> 10$ ) because of the high alkalinity that is necessary for the metallurgical extraction process. They consist of particles that can be understood as smarties (M&M's): a central quartzite particle is coated with hydroxide. In the outer layer of the tailings dam, this coating can get cracked by the sun and come into contact with rainfall. The combination of oxygen and (already acidic) water then makes the quartzite core oxidise. That is why the pH on the surface of the dump decreases and can generate acid mine drainage (TURTON, 2014). This outer layer affected by oxidation is typically around 2m thick in tailings dams, while it can be thicker in sand dumps because of their greater permeability. (OELOFSE et al., s.d., *The pollution and destruction of gold mining waste on the Witwatersrand*) Dumps and tailings are furthermore characterised by a high content of salts (chlorides, sulphates), cyanide, pyrite and heavy metals that can get mobilised in wind and water, especially in conditions of high acidity. This means that also the soil in a large area around mining activities can contain these contaminants. The fine particle dust that blows from mine dumps and tailings also diffuses heavy metals into the environment, thereby not just causing nuisance to surrounding inhabitants but increasing the risk of respiratory diseases and damage to the lungs (WATSON, 2014).

To prevent polluted water from infiltrating in the ground (and groundwater) underneath, they should be lined with a layer underneath, but this is mostly not the case. Moreover, many dumps have been built in extremely sensitive areas, near rivers or in wetlands and pans. 15% of the dumps and

*re-processing tailings dam IL8*





*tailings dam: IL 23-25*

tailings are located on top of dolomitic layers that were believed to improve the drainage of tailings dams, but have instead been exposed to high risk of groundwater pollution. (OELOFSE et al., s.d.; WEIERSBYE, et al. 2006)

Many of the older tailings disposal facilities have been re-mined since the mid-'70s because processing technologies had improved sufficiently to extract remaining gold at a profit. This re-processing is still a crucial part of the gold mining operations today. It is typically done by using high pressure water jets that make the tailings material into a sludge, which is then transported to the processing plant through a network of pipes. The remaining waste material is then dumped either in open pits (such as West Wits pit in the case of Mintails), or on so-called super-dumps on the edge of the city. These super-dumps make sense from an engineering perspective by still pose a lot of environmental problems. They have a much larger volume than regular tailings dams but a smaller surface in proportion, which slows down the evaporation process of the tailings slurry and increases leaching into the groundwater layers underneath. Moreover, while they are built according to the latest engineering standards, they require continuous monitoring and maintenance. It is impossible to stabilise them with trees because “*nothing can survive on the surface of a super-dump*”. (WEIERSBYE, 2014)

While re-processing removes important hazards from often sensitive original locations, it also exposes previously anaerobic tailings to oxygen and water, and reactivates the water and dust problems. (VILJOEN, 2009)

*reprocessing IL8*



*re-processing sand dump 20*



*sludge transport in pipes*



### *Mine Residue Areas*

Mine Residue Area (MRA) is the collective term that can refer to tailings dams, mine dumps, waste rock dumps, open excavations and quarries, but also water storage facilities and return dams, tailings spillage sites (usually near TDF dams), footprints left after the re-mining of TDF's, or a mix of mine waste, urban waste, spillage, industrial waste within the boundaries of former mine properties. In the whole of Gauteng, there are around 380 MRA's, mostly residues from gold mining. (GDARD, 2011)

The risks posed by specific MRA's depends on their exact composition, age, maintenance and location. Some of the dumps in the West Rand are considered extremely hazardous, especially MRA's 172 and 189. Over time, these tailings dams will be reprocessed depending on their gold content and the evolution of the gold price. The tailings dam 1L8 is currently being re-mined and depending on whether the powerline that runs across its surface can be removed, will take 3 months to a year to be removed. Tailings dam 1L 23-25 is built in a wetland but has huge paddocks around to contain pollution as much as possible. It will take 10 years to reprocess. 1L 25-28 is smaller, but contains potentially high amounts of uranium and is less viable for reprocessing because of its smaller size. Next to it, an alloys company has caused additional pollution with chrome and manganese (TURTON, 2014, spoken conversation).

*Emerald open cast operation*



The majority of the gold MRA's are radioactive, because the gold-bearing ores in the Witwatersrand, and specifically in the West Rand, contain up to ten times more uranium than gold. Because of mining, these NORM's (naturally occurring radioactive materials) are exposed to the oxygen and hydrogen of the environment. While the typical background concentration of uranium is 2-4 g/t, in the West Rand it ranges from 51-383 g/t. (GDARD, 2011, quoting COETZEE et al., 2006) Because the uranium level in its gold mines is higher than elsewhere in the Witwatersrand, Krugersdorp has even been called Uranium City (TURTON, 2014).

Before the '50s, this uranium was considered a waste material, and therefore not extracted, which means it is still present in many of the dumps and tailings found in the landscape of the West Rand. The 1L 13-15 dump located near Kagiso, for example, contains around 818 tonnes of uranium. The mobilisation of uranium is very sensitive and depends on acidity and redox conditions, which means it can become mobile under a range of pH-levels in different chemical complexes (COETZEE et al., 2006). Because of the low pH on the surface of dumps and tailings, it gets concentrated in their crust, and can then be transported with the slightest wind in the form of uraniferous dust (TURTON, 2014). Transported by water, it has become accumulated in the wetlands and river sediments of the Wonderfontein Spruit and could be remobilised by natural environmental processes (COETZEE et al., 2006). Moreover, as the material of tailings dams has been used historically for road construction and other building projects (DU PLOOY, 1999), not only mine dumps but also these infrastructures light up on airborne radiometric surveys of the West Rand. According to Mariette Liefferinck, an activist specialised in the Wonderfontein Spruit area, the brick manufacturing plant next to Lancaster Dam (built on top of the footprint of a historic tailings dam) uses uraniferous tailings for 20% of its brick production (LIEFFERINCK, 2014).

*view from IL 8, towards IL 9, IL 10, municipal waste dump*



### Mining Resources

Older dumps - more inert mining storage

**SAND DUMP** - SLIMES DAM

Processing of sand dumps and slimes dam

Secondary separation

hydraulic separation

21 years

**OPPCALIST** - UNDERGROUND SHAFT

Primary extraction

mechanical separation

5 years

Soil treatment or reprocessing - 1 open-pit result → 1 new rock dump or accumulation in a IIR  
Soil treatment or reprocessing - 1 open-pit result → 1 topsoil → 1 construction

[50] Shaping engineering

[90] Shaping Resources



Risk profile of mine-sterile areas

(USFA)

4.1 Very High

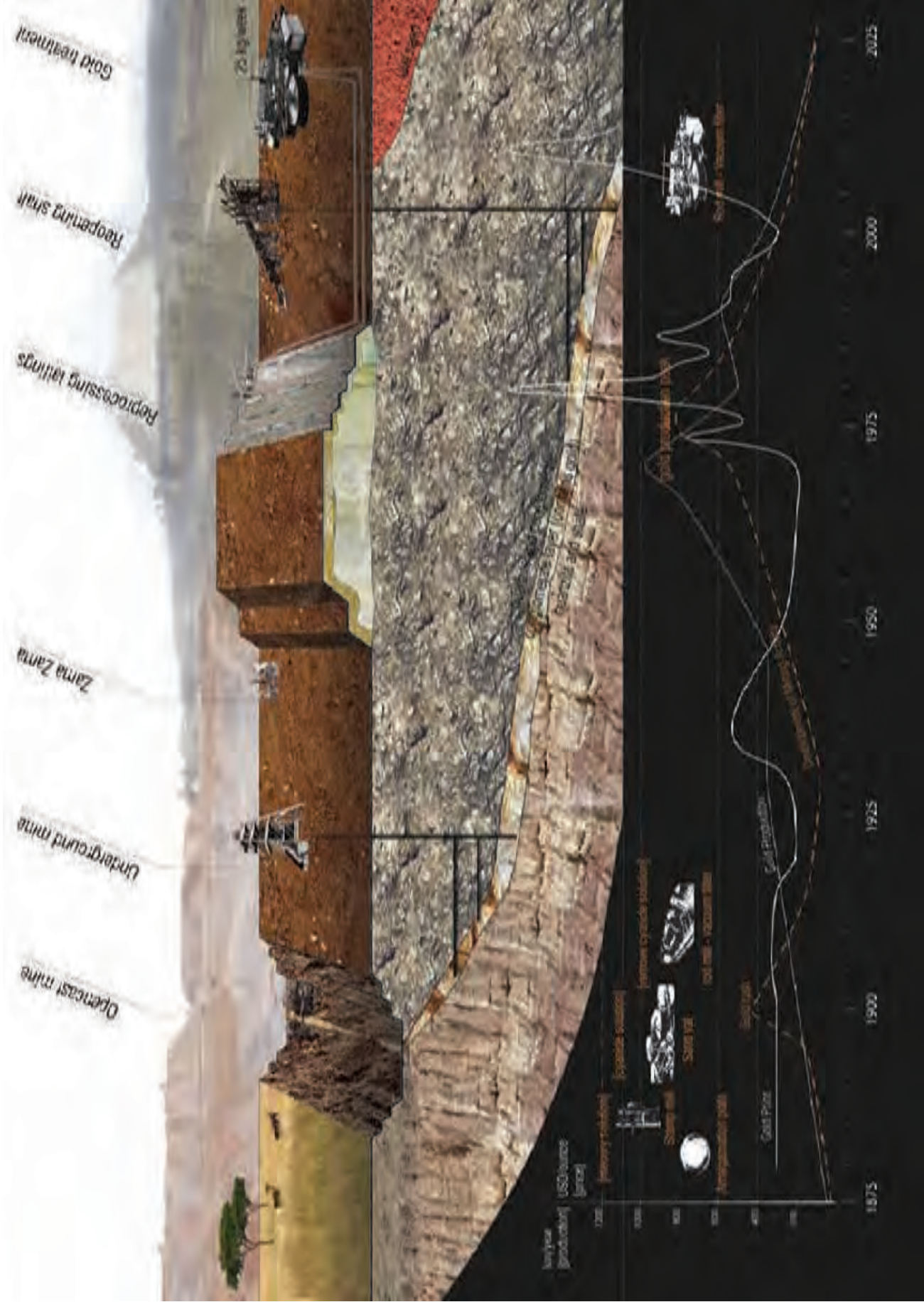
3.5-4.2 High

3.4 Moderate

RECONSTRUCTION CRUISERS → 400 resultant of tailings  
100 000 kg of arsenic for 1 kg of Gold

characteristics of dumps and tailings in the West Rand (adapted from Marine Declève)

layers of soil and rock (adapted from Le Nam Hoang)



### *Environmental, social and health impacts of gold mining waste*

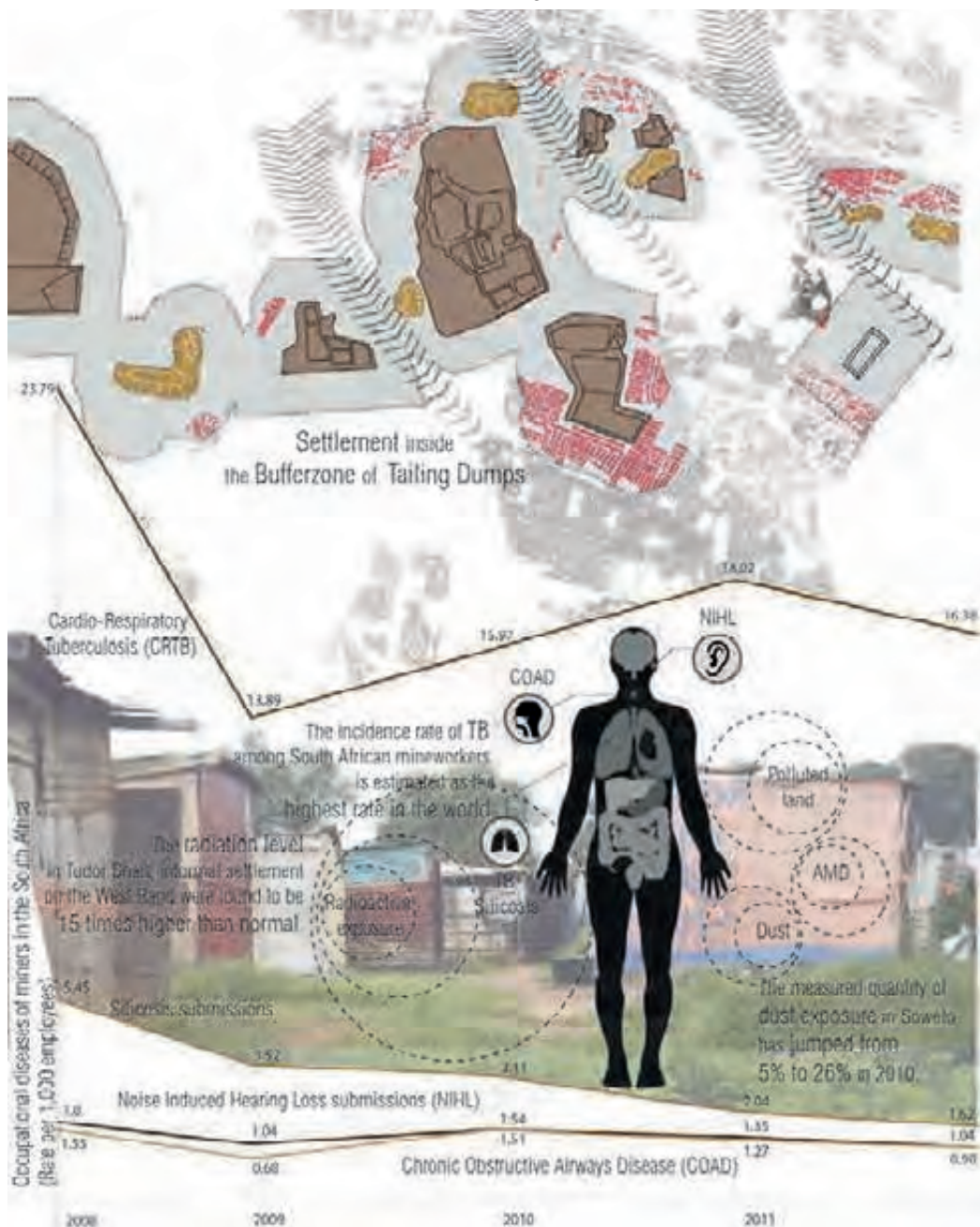
Because of the health risks linked to MRA's, the South African Chamber of Mines uses a guideline which states that each tailings deposit facility should be surrounded by a 500m buffer zone where no human settlement is allowed. (LIEFFERINCK, 2014, referencing COETZEE, Mine Closure 2008: *radiometric surveying in the vicinity of Witwatersrand gold mines*) However, 81% of tailings and dumps lies within 500 m of residential areas and informal settlements, as well as regular urban tissue, have encroached upon hazardous land. (WEIERSBYE et al., 2006) In the whole Witwatersrand, 1.6 million people were living in informal settlements close to mine residue areas in 2011, and the number is steadily growing since mined land is often weakly controlled and thus available for informal settlements. (TURTON, 2014; TANG and WATKINS, 2012) Also in a part of Kagiso, people are living in close proximity to the 1L 13-15 tailings dam, not aware of the health risks it poses, especially to children. Current open cast mining operations have provoked serious anti-mining riots in that area in December 2013 and January 2014. The apparent reason for these was damage caused to several houses which was attributed to blasting activities, although a hail storm and seismological event happening in the same period could also be the cause of the cracks found in the walls of different houses in that neighbourhood (TURTON, 2014). However, being located close to an MRA makes houses un-bankable, un-insurable and thus un-sellable on the market, a situation which is likely to cause more unrest in the future. The solution will be either to move the hazard from the people, or the people from the hazard.

*House in Kagiso right next to IL 13-15*





impacts of mining on human health (adapted from Fitri Maharani Indra)



People living close to hazardous are often ill informed about the related risks. The Soul City informal settlement north of Kagiso was built on uraniumiferous tailings and nearby open shafts. When Geiger counter readings confirmed a high radioactivity level in the area, the National Nuclear Regulator ordered some of the shacks and most of the tailings to be removed (LIEFFERINCK, 2014). However, the remaining tailings material, still high in metal content, remains to be used to grow crops. As a part of traditional medicine, it is even used as a face mask, and the practice of geophagy - eating soil - also occurs as it is common in sub-saharan Africa and seen as a source of minerals (WINDE, 2013; OELOFSE et al., quoting WILEY and KATZ, 1998).

This poses specific risks because when some metals are consumed in excess, this can cause skin irritation, affect organs and the central nervous system, and could lead to behavioural changes and decreased cognitive function. Metal particles can be either inhaled by breathing in the fine particles of mine dust, or absorbed into the body in contaminated water or by the consumption of plants that have accumulated these metals while growing in polluted soil. (ABIYE, 2014)

There is much uncertainty about the specific risks of the presence of (long-term) exposure to uranium in the dumps and tailings in the West Rand for human health and ecology. Radon is a radioactive, natural decay product of uranium but has a relatively short half-life of a few days. It is specifically dangerous if it accumulates in closed, unventilated spaces where people live. Uranium itself has a very long half-life and remains therefore weakly radioactive. Because uranium salts from tailings dams have entered the water cycle of the Wonderfontein spruit catchment, they can contaminate food eaten by people in this unregulated area. The most vulnerable group is poorer people living in the informal settlement near the source of the Wonderfontein Spruit in Soul City, and poor inhabitants of Kagiso living near the polluted river, and using it for recreation and irrigation (WINDE, 2013). Often subsistence farming is the last resort for poor families, even if they only have polluted soil to cultivate (OELOFSE et al.).

Also the inhalation of uraniumiferous particles poses health risks. It can increase the risk of cancer, be toxic to the kidneys and brains and if it enters the bloodstream it tends to bio-accumulate. Studies show that it can damage the DNA and compromises the immune system. (COETZEE, 2012, WINDE, 2013)

*Soul City, leftover tailings in background*

*soil as face mask*



***“Radiation is like beer:  
you don’t feel the first one but after the tenth you start falling down”***  
(Tamiru Abiye, 2014)

In a context of high prevalence of HIV infections, health risks can be more severe, linger and have more long-term impacts. This high occurrence of HIV has also been linked to the destructive effect of labour dynamics in the mining industry that causes loss of family ties and social networks, and often attract sex trade towards mining communities (LIEFFERINCK et al., *Case study on the extractive industries*). While underground gold miners are the main health victims of this industry (with decreased life expectancy, increased frequency of pulmonary tuberculosis (PTB), cancer of the trachea, lung, stomach and liver, insect-borne diseases such as malaria, etc. (DIDIER, 2014; LIEFFERINCK et al. *Case study on the extractive industries*), also people living nearby residue areas or active workings are exposed to health risks caused by dust, soil and water pollution.

For plants and animals as well, the landscape of the West Rand mining belt provides harsh living conditions. The clearing of vegetation for mining operations has led to habitat loss and fragmentation, and a decrease in biodiversity. It has also reduced the capacity for carbon storage, soil formation processes and soil stability. The high salt and metal content of the tailings and polluted soil around, forms a very difficult medium for plants to grow on and is only rarely colonised by specific species that can survive in these toxic circumstances. The dust from mining dumps and tailings inhibits photosynthesis and evapotranspiration processes of plants when it settles on the leaves. Metal accumulated in grasses and shrubs ends up in the food chain and can slowly intoxicate animals that eat them. These conditions strongly determines the character of this landscape as a patchwork of barren tailings, areas of specialised vegetation and colonisation by alien species, and visibly deteriorating wetlands and riparian systems (PIENAAR, 2014; WEIERSBYE, 2014).

*Soul City, North Sands in background*



*sign near Tudor Dam*



*Soul City, old underground workings*



### *A fragmented institutional framework*

The institutional framework that has to deal with the spaces and environmental consequences of mining, is extremely complex. For MRA's alone, many national and local government departments have some level of responsibility. These range from the *Department of Environmental Affairs and Tourism* (DEAT), to that of *Mineral Resources* (DMR), the *National Nuclear Regulator* (NNR), the *Gauteng Department of Health and Social Development*, the *Gauteng City-Region Observatory* (GCRO), and many more (GDARD, 2011). The delegation of powers between different levels and departments of government is very fragmented, and responsibilities are vaguely defined. Moreover, while local authorities are most directly impacted by MRA-related issues, they are the least equipped to deal with them (GDARD, 2011).

Also in terms of legislation, different Acts are related with mining operations, the most important ones being the *Mineral and Petroleum Resources Development Act*, amended 2002 (MPRDA), the *Mine Health and Safety Act 1996* (MHSA), the *National Environment Act 1998* (NEMA), the *Conservation of Agricultural Resources Act 1983* (CARA) and the *National Nuclear Regulator Act 1999* (NNRA). Water is strictly protected by the *National Water Act* (NWA), that proposes an integrated management of this scarce resource. But soil is protected quite weakly by the CARA that is only based on the productive capacity of land. The Chamber of Mines's soil classification uses an extremely limited categorisation that excludes a lot of practically arable land from protection against prospecting or mining activities (PIENAAR, 2014).

National resources are under custodianship of the state, but can be mined by private companies under the provisions of the MPRDA that allows the state to grant prospecting and mining rights. These require an Environmental Management Plan and financial provision for the remediation of negative environmental impacts of the mining activities (HUMBY, 2014). In the West Rand, the two main companies with mining rights (and property) are Mintails and Sibanye Gold, although not all dumps in this territory belong completely to their concessions. A part of the 1L 13-15 tailings dam near Kagiso, for example, partly falls outside the Mintails mining right, although the

*tailings dam in Central Rand (MRA 192, Nasrec)*



company has implied that it would re-process the dump (and thereby remove the hazard from the inhabitants nearby) if the community would agree. (TURTON, 2014 spoken conversation)

The MPRDA exempts residue stockpiles from waste management practices that are considered normal for other industries, because they are considered a potential future source of minerals (in this case gold) and therefore not considered as ‘waste’ in the legislation (HUMBY, 2014; TURTON, *South African water and mine policy*). This implies the assumption that coming generations will be able to develop better technology to extract more gold, and as a consequence will have to be able to deal with the mining residue. That line of thinking raises serious questions of intergenerational justice as a polluted environment is left behind for future generations (HUMBY, 2014).

Moreover, since many mines have been abandoned in the 70s and 80s, countless derelict and ownerless mined lands have been left behind that are now the responsibility of the state. However, the authorities don’t have the capacity nor the financial means to rehabilitate these areas. (Dealing with the 8000 derelict and ownerless mines all around South Africa would costs 100 billion ZAR and 800 years) (GDARD, 2011). This explains why since 1998 no closure licenses have been issued for gold mining companies. Such license requires that effective pollution control and rehabilitation measures on tailings storage facilities and impacted sites can be demonstrated (WEIERSBYE et al., 2009).

### *Conclusion*

Clearly the environmental legacy of mining has important social and economic impacts that reveal the true cost of over one century of gold mining. The mining companies face serious constraints to their activities in the form of non-compliance fines, legal costs in case of class action, loss of the social license to operate, rehabilitation costs, etc. But society as a whole now has to deal with the long-term consequences of the extraction of a limited mineral resource, such as loss of human health, decline of agricultural value and food security, decreasing biodiversity and the destruction of valuable ecosystem processes.

*Millsite pit open cast operations*



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South African  
Chamber of Mines



Johan  
mine safety manager,  
lives in Greenhills, Randfontein



Jabulani and Semphiwa,  
mine workers

**SibanyeGOLD**



Lorraine,  
working mother,  
lives in Lewisham



**Council for Geoscience**



Gauteng City-Region Observatory



Anthony Turton,  
water resource scientist  
and advisor to MinTails



Mo,  
inhabitant of Kagiso, wants  
to open a mine in Lesotho

Kagiso Action Committee  
and inhabitants



**GAUTENG PROVINCE**  
ADMINISTRATIVE AND BUREAU GOVERNMENT  
REPUBLIC OF SOUTH AFRICA



**mineral resources**

Department  
Mineral Resources  
REPUBLIC OF SOUTH AFRICA



**Mogale City**

**Local Municipality**



Mariette Liefferinck  
environmental activist  
and whistle-blower



Sylvia  
former inhabitant of Soul City,  
works for Federation for a Sustained Environment

Patience and Jackson,  
butcher, live in Soul City



Peter,  
painter, lives in Soul City



## SOIL SIDESTORY 3

*BROADENING THE CONCEPT  
OF CLOSURE MINING:  
HOW THE WEST RAND CAN  
TRANSCEND THE BOOM-BUST CYCLE*

## *Introduction*

Although mining has long-lasting social and environmental consequences, it is essentially a temporary activity. Usually the cycle of a mining company runs through the phases of prospecting and exploration, evaluation and planning, construction, operation, and finally mine closure. (WATSON, 2014) While mining activities bring urban and economic development, the question should be asked whether local communities are better off because of the industry having been there. What about the long-term impacts on the environment and the loss of jobs at the end of a mining cycle? Can you ever really close a mine? Is it really over when the gold is gone?

The case of the West Rand (and the Witwatersrand in general) shows how, when mining is dealt with in a temporary mindset for too long, the true cost for society starts to appear only in the long run. Mining has brought urban and economic development, but the legacy of acid mine water, polluted soil, radioactive mine dumps, high unemployment levels and disrupted settlement patterns will remain a burden for generations to come. The costs of remediating the West Rand's landscape appear at a stage in the mining cycle that the cash flow is at its lowest and most of the profits have long left the country. Only around 10 years of regular mining is left, although illegal mining could remain profitable for another 500 years.

***“Still nobody really knows how to close a mine...”***

*(Caroline Digby, CSMI, 2014)*

## *Going beyond closure mining*

In this context, it is too late to 'start mining with closure in mind', as best practice in the industry prescribes. More than one hundred years of gold mining have already created a disturbed landscape, a devastated economy and a society characterised by huge inequalities. Not only the mining companies, but also the authorities (local, regional and national) and civil society are affected by this legacy and will have to deal with it together. The 'pollutor pays' principle (which is included in the Environmental Legislation NEMA), is difficult to apply in this context. It's not realistic, nor fair, to blame the few mining companies that are still active, for environmental degradation that has been caused a long time ago. Basically, in the case of the West Rand there is more than 100 years of bad practice to deal with, an effort that cannot be resolved in a few years. However, the current mining companies, in this case mainly Mintails and Sibanye Gold, are crucial actors because they are the only ones with the knowledge and capacity to intervene positively in the mined landscape. However, the liabilities that they could be facing because of the historical externalities of mining, now put serious constraints on the future development of these mining companies (TURTON, 2014). Even in a context of extreme uncertainty about the best way to deal with this territory, it is clear that the risk of doing nothing, or closing down active companies, is bigger than any attempt to re-think or even just improve current practice.

***“The costs of remedying pollution, environmental degradation and consequent health effects and of preventing, controlling or minimising further pollution, environmental damage or adverse health effects must be paid for by those responsible for harming the environment.”***

*(NEMA polluter pays principle)*

The concept of Closure Mining has been put forward as a way of re-thinking the last phase of the mining cycle. Anthony Turton (consultant to Mintails) defines it as follows: *“Closure Mining can be defined as the deliberate long-term planning to optimise all mining-related processes and operations with a view to aligning the final outcome with the broader interests of society, in collaboration with all key stakeholders in a post-mining future, guided by the triple bottom line associated with sustainability reporting.”* (TURTON, 2014)

Closure mining is about shifting the core business of the mining company to include environmental remediation as a crucial aspect next to gold extraction. However, the idea of closure mining can and should be broadened much more, to include not only the natural environment, but also the urban context and its inherent socio-economic groups and relations, into a common vision for a post-mining future. When Turton states that *“There is an unresolved question as to whether mine closure is about mining, water resource management, human health, economic development, legal liability or simply ecological rehabilitation”* the answer is probably: “all of those, and more”. A closure vision can also include urban development and transformation, new stakeholder coalitions, reshaping the post-mining landscape, productive remediation, community empowerment, etc. (TURTON, *South African water and mining policy*)

***“People count too much on the government to help them but they could also look for opportunities themselves”***

*(Mo, inhabitant of Kagiso)*

Historically, the environmental and social costs of mining have never been on the balance sheet of gold mining companies, but were externalised and left for society to deal with (HARTNADY and TURTON, 2011). Ignoring ecological values and exploiting workers was the only way mining could be profitable for a lucky few (LIEFFERINCK, 2014, spoken conversation). Closure mining is about rethinking that approach and finding ways to make gold mining and environmental rehabilitation beneficial, or at least less harmful for society as a whole. It means that costs and profits have to be redistributed, and the logics of the mining industry as it developed since 1887, have to be re-thought.

**“No gold mining company will survive 10 years from now if they don’t do things differently”**

(Anthony Turton, 24 February 2014)

This means that closure mining is about going beyond narrow interpretations of ‘corporate social responsibility’. It is about broadening the application and meaning of the best practices for the mining industry as they are described by national and international institutions and guidelines such as the *South African Chamber of Mines*, the *International Cooperation of Mining and Minerals (ICMM)*, the *Equator Principles*, the *International Finance Corporation (IFC) guidelines*, the *UN Global Compact guidelines*, etc. These are often used as a mere marketing trick in annual reports of mining companies. However, flagship projects about rehabilitation and participation are not the way to fundamentally change the inherent logics of this extractive industry. Legal requirements (such as financial provision for rehabilitation, a *Social Labour Plan*, an *Environmental Management Plan* or an *Environmental Impact Assessment*) can only work if they become part of the core business and daily operations of mining companies. These documents have to be taken seriously and translated into a ‘way of life’ instead of looked at as another list of boxes to tick by an external consultant. Especially the Department of Mineral Resources has to step it up, not only to ensure that economic development is stimulated, but also that environmental and societal values are protected. The amount of money that has to be put aside by mining companies as provision for rehabilitation and closure, to obtain a mining right, has proven to be insufficient in 9 out of 10 cases (DIGBY, 2014). Strict enforcement of the environmental (NEMA) and mineral resources (MPRDA) legislation is in this respect crucial. That would mean a turning point in a tradition whereby government was a facilitator of the mining industry instead of a regulator, because its financial interests coincided with the interests of the political elite (TURTON, 2014).

### *The need for a common spatial vision*

The extraction of a finite resource can never be truly sustainable, and ‘green gold’ does not exist. Sustainable mine closure is therefore probably a contradiction in terms (BOTHAS, 2014). But the remediation of the impacts of the gold mining industry can be dealt with in a way that rehabilitates the contaminated environment while at the same time generating alternative economies and transforming urban development for the better. This requires the creation of a broad, open and long-term vision that is supported and carried out by all affected parties.

To make the creation of such a sustainable vision possible, there is a need for a platform or institutional structure in which all relevant stakeholders are represented. These include active mining companies such as Mintails and Sibanye, but also the local government (*Mogale City municipality*), and civil society (local action groups and ngo’s such as the *Wonderfontein Action Group WAG*, the *Randfontein Environmental Action Group REAG*, the *Federation for a Sustained Environment FES* of Mariette Liefferinck, and representation of local communities), local

businesses and farmers' associations, etc. At second level the regional and national authorities (*Department of Mineral Resources, Department of Environmental Affairs and Tourism, Gauteng Department of Agriculture and Rural Development, Gauteng Department of Health and Social Development, and the Gauteng City-Region Observatory GCRO*), the Chamber of Mines, research institutes (such as the *Council for Geosciences CGS, the Council for Scientific and Industrial Research CSIR, North-West University, the Centre for Sustainability in Mining and Industry CSMI*, etc.), public institutions such as the *Water Research Commission*, etc. should be included as well. (GDARD, 2011)

Taking the landscape of the West Rand, the rehabilitation of its ecosystems and the wellbeing of its inhabitants should be the common object of interest. Finding a common understanding of this territory, that has different meanings depending on the relation that different actors have with it, will not be an easy task. Negotiating a possible post-mining future for this space can form the base to reconcile the conflicting interests of all these parties. A spatial design-approach, with the help of a multi-disciplinary team of experts as neutral facilitator, would enable a constructive discussion that manages to integrate the complex issues at stake in this area, through their spatial logics.

*graphical representation of a possible integrated spatial vision for the post-mining landscape, combining urban transformation, productive landscape rehabilitation, and the sustainable restoration of the water cycle. (adapted from Phan Vu Hai Au)*



### *The future role of mining companies*

The contribution of the active mining companies to the realisation of this vision is crucial. Like mining companies in the early decades of gold mining also supported manufacturing industries, nowadays they can play a leading role in remediation activities by becoming or supporting rehabilitation companies. The re-processing of remaining mine dumps is still technically and financially feasible and can generate the economic means to fund rehabilitation, while at the same time reducing the hazards related with dumps and tailings (TURTON, 2014). Moreover, if the uranium that is still present in these residue areas, is also extracted, that would take away a huge risk for surrounding communities and reduce future liabilities for the companies as well as the local government. The founding of Rand Uranium in November 2008 - when Harmony Gold sold the Cooke sections of Randfontein Estates Gold Mine, (GDARD, 2011) - can be crucial in this respect since it can treat uranium-containing ores in a new uranium plant, now owned by Sibanye Gold. Not only the direct environment of these mining activities, but also the complete downstream valley of the Wonderfontein and Tweeloopies Spruit would benefit from the rehabilitation of this area and that would be an enormous added value for the project.

Rehabilitating land in the mining belt no doubt can be a profitable business, as it is strategically located near a growing metropolis. This was understood by Rand Mines, when this company founded a development company (iProp) that gradually reclaims and develops land in the Central Basin of the mining belt for different purposes (HARRISON and ZACK, 2012). However, to be truly strategic and maximise the benefit for local communities and ecosystems, post-mining land uses and remediation strategies should be part of a comprehensive common vision. Instead of filling up the space of mining with different projects that stand by themselves, it should be read and envisioned as a third, common space in-between north and south.

***“I think you own an environmental rehabilitation company”***

*(Anthony Turton, to the management of Mintails mining company)*

Through a land-swap policy, abandoned mining residue areas could also be re-processed and rehabilitated by still-active mining companies. This would take away liabilities from a government that doesn't have the financial means, nor the capacity to deal with them, potentially in return for subsidies. The know-how of these companies can also be applied for the implementation of future water-management strategies in the region (treatment plants in the short term, and a sustainable passive cleaning system in the long term) that can be integrated within the Rand Water system. Short-term incentives and profits for the mining companies, can help to protect society's long-term interest, but require that public authorities have a long-term perspective. This can become crucial as the environmental impacts and social costs of gold mining begin to manifest, and the public support for innovative and more sustainable solutions will grow, while the license to operate for polluting companies will decrease.

Initial investment in soil and water rehabilitation programmes (such as pilot projects and nurseries for vegetation, construction of wetlands, construction of water infrastructure, afforestation programmes) can come from mining profits, and potentially from the public sector. However, they can be productive and in the end self-sustaining, especially if local businesses, communities and ngo's are involved in their organisation and operation.

### *Capacity building and community empowerment*

The realisation of this closure vision will have to be supported by capacity building on different levels. Firstly, local authorities are crucial stakeholders but at present do not have the capacity to develop a coherent spatial future vision that integrates economic, social and environmental issues. Asked about a plan for the future of the mining belt, the *Department of Planning* refers to the *Department of Integrated Environmental Management*, while this Department in turn leaves it up to the *National Department of Mineral Resources* as the mandated authority regarding all issues related with the mining belt. However, as a possible link between different stakeholders, this local level of government could play a key role in formulating a future vision for its territory. As pointed out by Nancy Coulson it is important to identify key individuals at this local level that can and want to make a difference (COULSON, 2014).

#### ***“Yes, what to do after mining?”***

*(Employee of the Planning Department of Mogale City)*

In a context of uncertainty about the exact impact of complex and interlocking cycles of environmental pollution, the contribution of academic (but down-to-earth) research is invaluable. Currently there is a lack of data and an integrated monitoring system, despite the efforts of institutions such as the GCRO, the Council for Geoscience, and several universities. Hereby it is crucial not to measure and study everything, but to research and “*monitor what matters*” (WATSON, 2014).

***“We used to call them soft issues, people’s issues - but soft is the new hard.”***

*(someone at De Beer’s Group, quoted by Caroline Digby, 2014)*

Local communities are the most affected by the impacts of mining, both because of the degradation of their living environment, as well as by job loss related with the decline of the industry. Including them in a future vision is therefore crucial, and this requires a broadening of the term participation as it is now understood by mining companies and (local) government. True engagement can only be the result of a co-produced vision. One-way communication (if any) will not be enough to reduce the existing frictions between the mining companies and local communities. If Mintails and Sibanye want to keep their ‘social license to operate’, the first step is

to improve communication and build strong relations with local action committees, businesses, schools, community-based organisations, etc. Managing the perceptions of people, informing them clearly and correctly, will be crucial to build the trust necessary to coproduce a sustainable vision for the future. “*Don’t bullshit them*”, as Rudolph Botha, closure mining expert at Anglo Gold would say. On the contrary, empowering local communities can make them valuable partners for the maintenance and operation of remediation projects. Moreover, a collective learning process can help developing technical skills and become a part of education programmes. Together with the new economic activities generated by the remediation of mining land, these can create new work opportunities and help the establishment of an alternative, post-mining economy.

***“Dialogue can be used as a design strategy”***

*(Hannah Le Roux, 2014)*

***“Facts never get in the way of an opinion”***

*(Anthony Turton, 22 April 2014)*

### *Ambition in a context of uncertainty*

A crucial part of the challenge called ‘closure mining’, is that there is no clear scenario or consensus about the rehabilitation of the mined environment. One of the questions is to what standard the landscape should be remediated? Turton formulates it as follows: “*The outcome of Closure Mining is a rehabilitated landscape and functional ecosystem capable of supporting humans and other species while mitigating all Legacy Issues to the extent that they no longer act as constraints on future socio-economic development*” (TURTON, 2014). Possibly (and as intended by the vision presented in this document) the remediated landscape can even generate future socio-economic development. It could even structure and stimulate the transformation of surrounding neighbourhoods into more dense, hybrid, productive and inclusive living environments. Therefore, while the vision that was worked out for the purpose of this thesis might not be based on true co-production, it should first and foremost be interpreted as an argument for ambition and innovation in the face of extreme complexity and uncertainty. Doing nothing is not an option.



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*AnGoGold Woodland rehabilitation project*

## SOIL SIDESTORY 4

*REHABILITATING THE MINED LANDSCAPE:  
HOW PHYTO-TECHNOLOGIES WORK*

## *Introduction*

The environmental impact of more than 100 years of gold mining in the West Rand requires the rehabilitation of large areas of polluted soil, tailings footprints, disposal facilities, polluted groundwater and surface water systems. The mine dumps might have been temporary elements in the landscape, their reclaimed footprints will be there indefinitely (COOKE and JOHNSON, 2002).

In the last decades, phyto-remediation has gained support as a non-intrusive and relatively low-cost method for remediating soil pollution. It means that plants and their associated micro-organisms are used to remove, degrade or stabilise contaminants. Compared to other remediation technologies (dumping in a landfill elsewhere, mechanised cleaning of soil, ...), phyto-technologies are more economically and ecologically sustainable, and can provide more ecosystem services than dealing with contamination alone (WEIERSBYE, 2014).

Landscape rehabilitation can in this case restore certain ecosystem processes and improve soil-, air- and water-quality. However, some degradation is irreversible, and the environment of the West Rand particularly, has been impacted profoundly for a very long time. The rehabilitation of this landscape will take not less time, and could demand between 50 and 100 years. (WEIERSBYE, 2014) The process of rehabilitation should be interpreted as a long-term experiment with an unpredictable outcome, as a moving target (COOKE and JOHNSON, 2002). Complete restoration to the landscape's original state of extremely diverse Highveld grassland, is impossible. Therefore the aim of the remediation of this post-mining area is to at least stabilise water- and soil contamination, and to restore and enhance the landscape's productivity. As the dependence of people on fragile ecosystem processes and services becomes more clear, vice versa the landscape of the West Rand now needs ambitious human intervention to be able to revive.

## *Rehabilitation in the past: missed opportunities*

In the past, rehabilitation has not often been an important concern of mining companies. In the first decades, the main effort was directed at controlling the dust problem in several ad hoc attempts. Only from the '50s onwards, the first systematic and sustained approach to rehabilitation took shape with the establishment of the Vegetation Unit, as a department of the Chamber of Mines. It proposed to deal with the dust pollution by planting a grass cover on mine tailings (VILJOEN, 2009, REICHARDT, 2013). Although this methodology had not yet matured, from the early '60s it was applied on a large scale. This focus on application and the lack of experts outside of the engineering field, hindered the capacity of the Vegetation Unit to refine and advance their knowledge scientifically. The grassing programmes didn't show the expected results and often required constant aftercare because they made use of non-indigenous species. The concentration of all rehabilitation efforts in one single entity prevented real progress until the '70s. By then it was realised that pollution went much further than dust nuisance and also included water contamination.

Moreover, the work of the Vegetation Unit needed improvement by sound scientific research. However, from then on, the industry was more focussed on the re-processing of mine dumps instead of developing rehabilitation methods (REICHARDT, 2013).

In the '80s, there was a growing concern, about the environmental impact of mining, both in South Africa and globally. The industry wanted to find a 'walk-away' solution, not only for the dust problems but in terms of general pollution prevention. The university of Potchefstroom took the opportunity to develop research and enter the commercial field of rehabilitation. The Vegetation Unit had been reduced to grassing mine dumps for the Department of Minerals and Energy Affairs, but then regained prominence by developing industry guidelines for rehabilitation (REICHARDT, 2013).

With the Minerals Act of 1991, rehabilitation and environmentally responsible mine closure in general became obligatory by law for the first time. Moreover, in that period the country and the development of rehabilitation technology opened up to commercial competition. More ecologically based solutions for environmental remediation, such as using flatter slopes and relying on indigenous species, were developed. However, this increasing knowledge has also become protected as corporate technologies that are not often open to researchers or the general public (REICHARDT, 2013).

***“2.5 cm of good topsoil takes 500 years to form through soil formation processes”***

*(Marine Pienaar, expert in soil contamination by mining activities, 6 March 2014)*

### *The sensitivity of rehabilitation ecology: tailings are not soil*

For phyto-remediation to be succesful, it should be considered as part of a landscape process. Not only types of species or physical landscape structures as such, but the way they interact, determines whether ecosystem processes and cycles can actually be restored. Specifically, nutrient cycling between micro-organisms and different plant and animal species is crucial to establish a sustainable new ecosystem.

Apart from the required end state of landscape rehabilitation, the methodology depends on the exact characteristics of the polluted medium. In this case, there are deposited mine tailings, as well as footprints left behind by re-processed dumps, and soil in surrounding areas that has been polluted by dust, spillages and polluted water run-off. While similar contaminating elements will be present in all of these cases, they do provide different growth media to plants and micro-organisms.

Soil is the upper layer of the earth's crust. It is in itself a very complex medium that contains both organic and non-organic material. It sustains nutrient-cycling organisms, contains a specific seed bank, and a certain composition of nutrients, minerals, boron, copper, zinc, oxygen and nitrogen, etc. It has a certain acidity (pH), water storage capacity, infiltration rate, cation exchange capacity, salinity, sodicity, depth and texture (PIENAAR, 2014; WEIERSBYE, 2014).

Soil does not only sustain above-ground ecosystems by providing a fertile environment for plant and animal growth. It also contains a microscopic soil biological community that contributes to essential ecosystem processes. These include the storing and recycling of nutrients (such as phosphorus, nitrogen and sulphur), waste treatment by decomposing organic matter and metals, climate regulation, gas regulation (around 10% of carbon storage happens in soil), water regulation, water supply and filtering, etc. (DE GROOT et al., 2002; PIENAAR, 2014).

All these processes are crucial in sustaining the growth of plants and animals but can be inhibited when the soil gets contaminated. In the West Rand, contamination typically consists of a higher concentration of heavy metals, including uranium, as well as a decreased pH level, increasing amounts of sulphates and chlorides, and the possible presence of cyanide, mercury and nitrates. To start mining, good top soil is mostly stripped and stored in storage piles. These are a crucial resource for remediation activities if they are carefully maintained, ideally with plant growth to keep the soil aerated and microbiological processes intact (PIENAAR, 2014; COOKE and JOHNSON, 2002).

A clear difference must be made between soil and gold mining tailings. Tailings material doesn't contain organic matter (let alone micro-organisms that can perform nutrient cycling) when it is deposited, and merely consists of crushed rock. It is low on macronutrients that plants need, such as nitrogen (N), phosphorus (P) and potassium (K) (COOKE and JOHNSON, 2002). It contains metals and pyrite, has high salinity and high acidity in its outer layer. Tailings have been compared to Mars in that they provide an extremely hostile environment for plants to grow on (WEIERSBYE, 2014). Not only do plants need to be tolerant to the elements that compose the tailings material, but they are also exposed to more light, and to erosion by wind and water, especially on the slopes of the tailings deposit. Important to keep in mind is that conditions can differ within one area of tailings deposition. Because of the way the sludge is sprayed, finer particles assemble in the middle of the dumping area, while coarser material is found near the edges. In the areas with higher water run-off, the tailings material will be more acidic. These variations in density and acidity influence plant growth and can explain why a certain species thrives in one area but not in another (WEIERSBYE, 2014).

The conditions on deposited tailings can be ameliorated by increasing the tailings pH-level and providing organic material. Liming is a typical first step to prepare tailings material for plant growth, but also compost from garden waste, sewer sludge, paper mill sludge, or fly ash from coal power stations can be used to improve growth conditions. Using these materials that are considered waste by other actors is a relatively cheap solution, compared to putting a soil cap (a layer of top soil) on top of the tailings material. It also has the advantage to include other actors in the remediation process as well as recycling waste for the rehabilitation of a polluted landscape. However, 'soil' can also be created in-situ in an even less-intensive way by planting without preparing the surface, although it might take up to 10 years to establish nutrient cycling (WEIERSBYE, 2014).

Moreover, the shape of the tailings deposit is crucial, and an ideal slope for plant growth is lower than 16°. (WEIERSBYE, 2014) Instead of the accepted, engineered shape of mine dumps, a more gentle landform can help to create a larger variety of slopes and safe sites where plants are more protected from wind.

***“A plant is like a solar-powered pump”***

*(Isabel Weiersbye, 2014)*

### *The incredible ecosystem services offered by plants*

The advantage of using phyto-technologies is that plants can provide many functions at once and can be used to solve different problems at the same time if these processes are well-understood. They only need sufficient nutrients, water and sunlight to be able to perform photosynthesis.

A plant consumes, evaporates and stores water and therefore works as a pump that can help to control the water cycle. Its roots pump up (mainly shallow) groundwater and many plants together can lower the groundwater table locally. Although few plants root directly into the groundwater, their roots can be located in the capillary edge and filter contaminants from the groundwater. This means that they can reduce infiltration of polluted water in the groundwater aquifers, as well as controlling the groundwater pollution plume. (WEIERSBYE, 2014)

Considering the semi-arid climate of the West rand region, it is crucial to plant trees and shrubs in strategic locations. The annual rainfall alone (500-750 mm) cannot sustain dense afforestation in the whole area. (WEIERSBYE, 2014) Its original landscape was a grassveld-savannah, which didn't have an abundance of trees before mining began, and for good reason. Winters are dry and have average temperatures between 2 and 12° C, while most of the rainfall happens in summer, which has average temperatures between 14° and 30 ° C. In dry periods, wildfires are not uncommon, which has to be taken into account when selecting species for rehabilitation projects. To understand the water balance in a more complete way, extensive measuring and modelling can be done, using data about transpiration, relative humidity, solar radiation, water reserves underground, water uptake by specific species, etc. While certain species need a lot of water and therefore have a large impact on the water cycle (e.g. cearsia lancea has an uptake of 1000-1200 mm, acacia karoo less than 900 mm, reed beds need 1200-1800 mm), other types of landscapes can do with much less (e.g. grassland needs only 300-500 mm)

Apart from playing a controlling role in the water-cycle, trees also act as windbreaks against dust, and have a cooling effect. Moreover, woodlands act as carbon sinks which is essential in terms of dealing with climate change. Plants (and especially woody species) are essential to kick-start nitrogen and phosphate cycles and recreate nutrient exchange as the basis for a new ecosystem (WEIERSBYE, 2014).

In terms of dealing with pollution, plants can either stabilise or extract contaminants from the soil. A first requirement is that they are tolerant to the elements present in their growth medium, which in this case means that they can continue to grow and reproduce without showing signs of metal toxicity. Apart from being metallophytes, these plants also need to be resilient to conditions of high acidity and salinity (sulphates). Moreover, they can use and degrade the potassium/calcium cyanide that is used for gold extraction because it works as a fertiliser, while it is highly toxic to animals and humans.

The tolerance of plants to certain conditions can be genetic, constitutive or induced by exposing plants to stress. The relatively large variety of plants that naturally colonise tailings dumps have adapted to these circumstances by natural specialisation. This process of natural selection makes new flora emerge that is adapted to the conditions on mine dumps and on the long term leads to increased biodiversity (WEIERSBYE, 2014, COOKE, and JOHNSON, 2002). That is why it is crucial to collect and harvest species (and the micro-organisms on their roots) in places with conditions similar to the site to be remediated. A lot of work has already been done by Isabel Weiersbye and her team, who did large-scale fieldwork on mine residue areas in the Witwatersrand, to collect naturally colonising species. They found a wide variety of plants, of which 88% were perennial, and 76 % were woody species. They investigated the seed fate and germination methods for 46 perennial species, and found that most trees, shrubs and forbs were able to produce almost 100% viable seeds (WEIERSBYE and WITKOWSKI, 2002). Many of these species can now be further researched and cultivated in nurseries, and have a good chance at being successful in rehabilitation programmes (WEIERSBYE, 2014).

In general, indigenous species will have a higher survival rate, while invasive species would disturb the balance in the ecosystem and alien plants, like Eucalyptus, tend to consume more water. Moreover, alien species have been forbidden by the Conservation of Agricultural Resources Act (CARA) and the Biodiversity Act (WEIERSBYE and ROSSOUW, 2009).

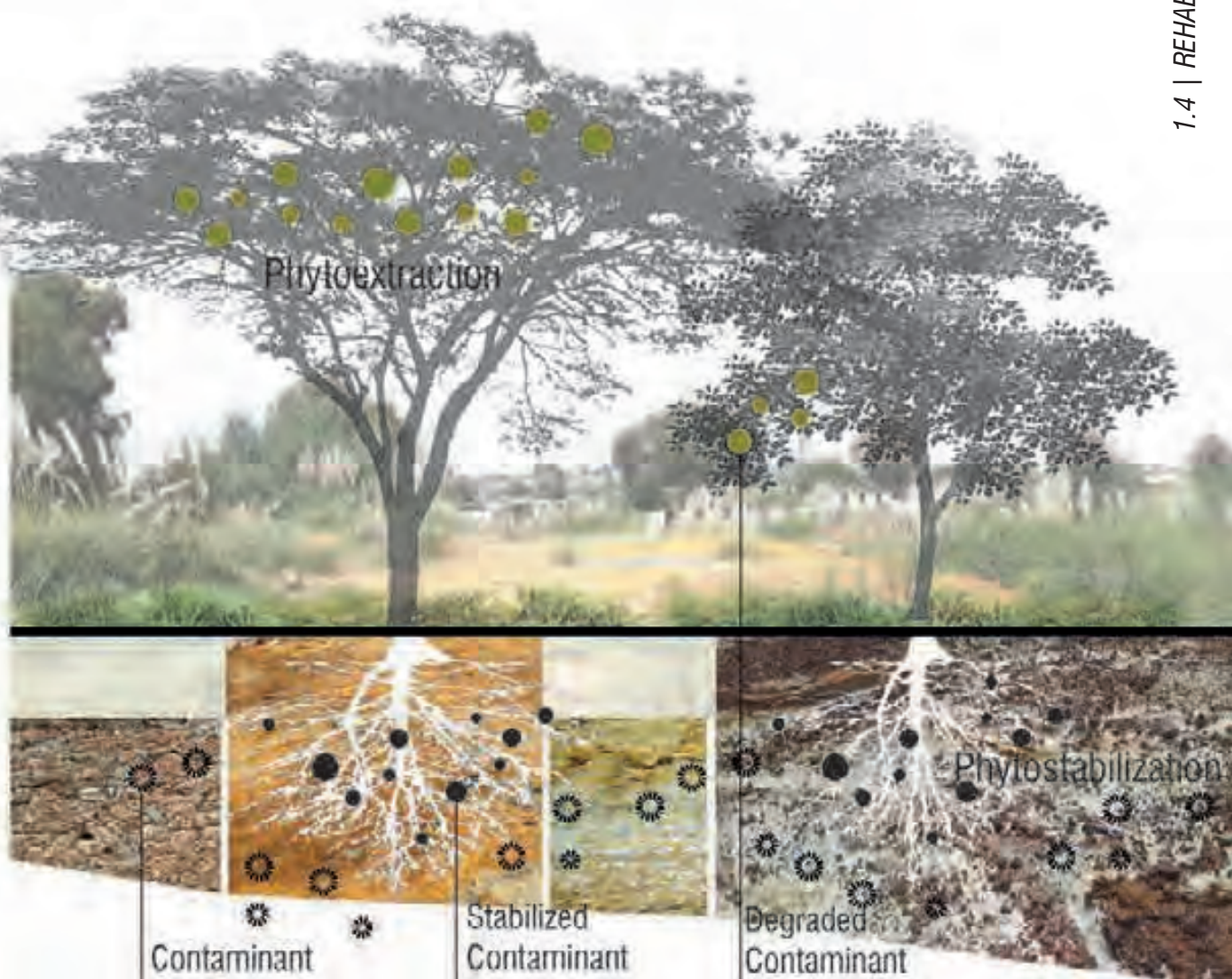
Some plants are not only tolerant to metals, but also accumulate, or even hyper-accumulate them in their biomass. That means they extract the metal from the soil and absorb it into their stem and leaves. This process of hyper-accumulation requires a lot of energy, which typically makes these plants smaller, especially because they also grow in stressful conditions. *Ocimum Centraliafricanum* is such a plant, that accumulates copper, which explains its popular name of Copper Plant. Some species, like sunflowers (*Helianthus Annuus*), are tolerant until a certain level of metal-uptake is reached, and then accumulate most of the metal (in this case uranium) in their dying stage. These (hyper)-accumulating plants can be used for phyto-extraction: after having accumulated metals and metalloids in their above-ground biomass, they can be harvested to remove the metals from site. However, the smaller the plants are, the smaller the rate of metal extraction from the soil. Most of these species don't accumulate all metals, but only one or two of them, although they might be tolerant to several metals at once. This means that zinc,



cadmium, copper, manganese and uranium cannot all be extracted by one plant species alone. It is therefore crucial to know the exact composition of the soil in a certain site before selecting the required species to remediate it (WEIERSBYE, 2014). Generally, woody plants and shrubs are more resilient, have deeper root systems, and are better to deal with nitrates. Grasses need more fertiliser and irrigation (which might increase infiltration of contaminants), but can help in stabilising the top layer of soil or tailings, and can accumulate uranium (WEIERSBYE, 2014).

Metal-accumulating plants (although not all native to South Africa) include the following, *Bambusa Balcooa* (bamboo), *Brassica Juncea* (Indian mustard), *Brassica Napus* (rape seed), *Ocimum Centrafricanum* (copper plant) and *Salix* (willow). Many other metal-accumulating species exist, among which *Amaranthus*, *Brassica Chinensis* and *Brassica Narinosa*, *Berkheya Coddii*, *Picea Mariana*, *Quercus*, *Salix Viminalis*, (that accumulate uranium), several fern species (*Pteris Cretica*,

*phyto-extraction vs. phyto-stabilisation* (adapted from Fitri Maharani Indra)



*P. Multifida*, *P. Oshimensis*, *P. Vittata*) that accumulate arsenic, grass species (*Agrostis Capillaris*, *A. Castellana*, *A. Tenerrima*) that accumulate arsenic and other metals, *Helianthus Annuus* or sunflower, that accumulates uranium, chrome, manganese, copper and zinc, etc. (WEIERSBYE, 2014; VAN GINNEKEN, 2007)

Certain other plants are tolerant to metals, but don't accumulate them in above-ground biomass. They do have micro-organisms around their roots that complex the metals from the soil into organic compounds, or even degrade them. This process of phyto-sequestration means that the metals are bound on the roots of the plant in a chemically more stable form, but not extracted from the ground. Although they might be released on the very long term (in 100 years), these plants will help to stabilise pollution and reduce the bio-availability of metals to the environment (WEIERSBYE, 2014; COOKE, and JOHNSON, 2002).

The following species are found on tailings dams and polluted soil in the Witwatersrand and can therefore be considered tolerant to these conditions and possibly viable for phyto-stabilisation. Trees include: *Acacia Erioloba*, *A. Hebeclada*, *A. Hereroensis*, *A. Karroo*, *A. Robusta*, *Combretum Erythrophyllum*, *Cearsia Leptodictya*, *C. Pendulina*, *C. Succedanea*, *C. Lancea*, *C. Pyroides*, *Diospyros Whyteana*, *Mundulea Sericea*, *Tamarix Urneoides*, *Ziziphus Mucronata*, smaller shrubs are: *Asclepias Fruticosa*, *Asparagus Laricinus*, *Cannabis Sativa*, *Carpobrotus Edulis*, *Clematis Brachiata*, *Clusia Monticola*, *Coccinia Sessilifolia*, *Combretum Caffrum*, *Diospyros Lycioides*, *Elephantorrhiza Elephantina*, *Grewia Flava*, *Gymnosporia Polyacantha*, *Leonotis Leonuris*, *Lessertia*, *Stoebe Vulgaris*, *Sutherlandia Frutescens*, *Triumfetta Sonderi*, and herbs and grasses are: *Aster Harveyanus*, *Berkheya Setifera*, *Delosperma Herbeum*, *Eragrostis*, *Helichrysum Nudifolium*, *Helichrysum Rugulosum*, *Indigofera Adenoides*, *Lippia Scaberimma*, *Monsonia Burkeana*, *Nolletia Rarifolia*, *Pollichia Campestris*, *Salvia Verbenacea*, *Senecio Scitus*, *Solanum Incanum*, and *Ziziphus Zeyheriana* (WITKOWSKI and WEIERSBYE, 2002).

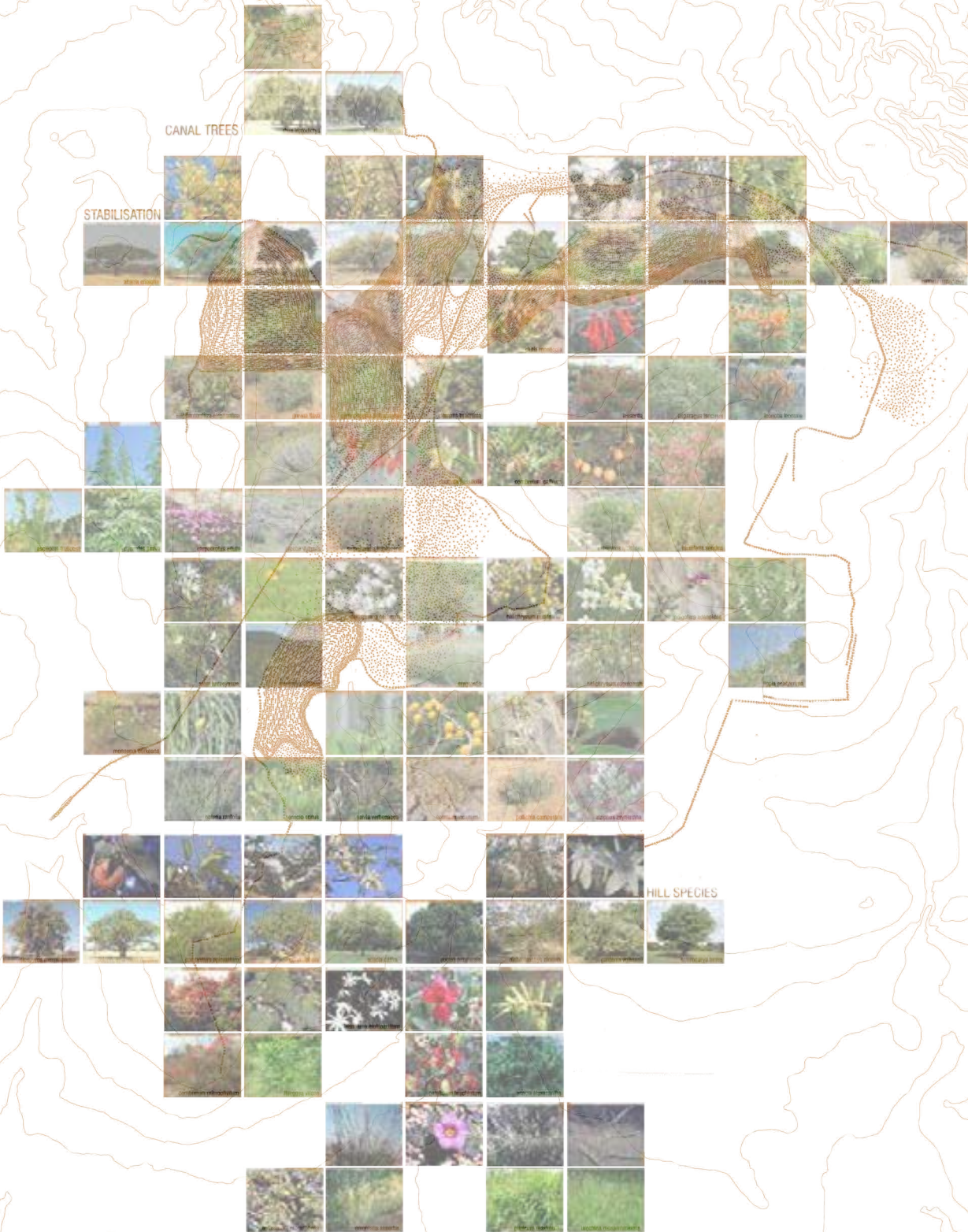
Depending on the type of landscape remediation that a certain area needs, a choice has to be made in terms of the functions plants need to perform. On tailings deposits, it is crucial that plants stabilise pollution and immobilise metals in their organic rooting zone, so that these can't be released into the groundwater or run off into surface water streams. At the same time, these plants can capture CO<sub>2</sub>, evaporate water from the tailings to help them stabilise, and consume cyanide. On slopes, it is especially important that the plant roots help stabilising the slope and prevent erosion. Regular harvesting helps to maintain the capacity of the plants to control water flow as they consume most water in younger stages.

On areas with polluted soil or remaining footprints of re-processed tailings dams, plants can extract sulphates and certain metals, help control seepage, and store carbon. If the purposes is to completely clean the soil, they should be harvested regularly (typically after 18 months-2 years) because they accumulate most metals in their growing stages.

CANAL TREES

STABILISATION

HILL SPECIES



*Vegetation on the hill*

### *How to plant: spatial arrangements, nurseries and pilot projects*

The survival of plants will depend on their spatial arrangement, interaction with their environment and with other plants and animals. It is therefore crucial to understand the landscape processes, and how remediation plants can shape and benefit from them. Specifically, the scarcity of nutrients in this mined landscape is a limit to survival. However, nutrients can be kept in the landscape, by holding water there as much as possible. This can be influenced by the spatial pattern of shrubs and trees. By planting them in bands, 'islands of fertility' can be created where water and valuable nutrients are trapped, to make it easier for plants to survive. Even laying out brush packs, or bands of garden refuse, has proved in experiments to capture mobile resources and micro-organisms, increase the water infiltration and soil respiration rate, and lead to successful plant growth and nutrient cycling after 10 years of doing basically nothing (WEIERSBYE, 2014).

Planting in bands also makes sense from the perspective of water availability in this semi-arid landscape. It makes more sense to plant strategically, rather than creating a complete vegetation cover. That way, trees will only use and control shallow groundwater instead of depleting the groundwater reserves.

The optimal pattern of planting depends on the type of slope. While longer bands work better on steeper slopes, a more patchy pattern helps plant growth and colonisation on lesser slopes. Colonisation then further depends on wind and birds to transport seeds and help establish the ecosystem.

For this ecosystem to be sustainable, it is important to use a variety of species, ranging from trees to grasses. That way, the system is more resilient (e.g. when a disease hits one species, the others can still survive) and nutrient cycles can be sustained. Not only a range of plants, but also micro-organisms and insects are essential elements of these ecosystem dynamics, as well as birds and other animals to complete the food chain.

*Anglogold Woodland project  
preparing the area for planting*



*young shoot waiting to be planted*



Plants are best brought into their new environment while they are still very young, so they can adapt to the stressful conditions on site. Even in the nursery they can be hardened to make them more resilient and develop genes that can deal with heat and high levels of salt and acidity. It is crucial that the plant has micro-organisms (specifically nitrogen-fixing bacteria and mycorrhizal fungi) in its root structure that are also resilient to the conditions of their surroundings. These micro-organisms can be collected from similarly polluted areas and cultivated in top soil in a lab or nursery. A small amount of starter fertiliser a bit below the rooting depth of the plant can help to encourage roots to grow out into their surroundings (WEIERSBYE, 2014). Existing plants could be removed to limit competition for the scarce nutrients in these harsh growing circumstances, but otherwise, the seedlings should be able to survive on their own. In 2-3 years, shrubs and trees can establish 'islands of fertility', and after 6 years on the tailings material, something is formed that *"looks like soil, smells like soil, but isn't really soil"* (WEIERSBYE, 2014).

Before undertaking large-scale remediation projects, it is essential to do careful site research, and develop knowledge and experience in pilot projects and experiments, that can then be up-scaled into larger programmes (WEIERSBYE, 2014). The Anglo-Gold Ashanti Woodland project, run by Isabel Weiersbye, has tested many species specific to the West Rand gold fields – with a focus on *Tamarix* and *Cearsia Lancea* - and studied many aspects of how these can help in landscape rehabilitation and mine dump stabilisation. Over 400 ha have been planted with trees so far, and 900 more will be vegetated in the coming years (spoken explanation during site visit). Moreover, nurseries should be established to cultivate the right species of plants and micro-organisms. Compost can be collected from communities, paper factories, farms, etc. For all these aspects that contribute to the larger rehabilitation project, communities and local businesses can be included in the process. That way, capacity can be built, both in terms of knowledge and technical skills, to sustain the landscape of remediation on the long term, while generating spin-off businesses and employment opportunities.

*trees planted in rows*



*young trees*



*Tamarix trees after several years*



### *The remediated landscape – productive uses*

There is a demand from society in general and mining companies in particular to use land after mine-closure in an economically profitable way. The legislation around post-mining land use is however, rather vague. Clearly certain uses are not suitable for land contaminated by mining and possibly radioactive. Human settlement and certain forms of recreation, growing food crops and home vegetable gardens, livestock grazing and informal re-mining are not advisable (SUTTON and WEIERSBYE, 2007).

However, there are many 'soft' end land uses that can have an economic value as well. Sutton and Weiersbye suggest industrial sites, lined landfills, graveyards, sewage sludge disposal, carbon sinks and high root-biomass crops such as fibres, pharmaceutical and biofuel species as suitable for mined land in the climate of South Africa (SUTTON and WEIERSBYE, 2007). The Gauteng Department of Agriculture and Rural Development takes a more strategic approach and suggests that "*Because the West Rand MRA's straddle a key segment of the continental water divide, the most appropriate strategic objective is to restore as much of this area to this original wilderness state, perhaps as a provincial nature reserve or conservancy area, for the optimal rehabilitation of ecosystem services and for water conservation purposes, but also with the significant potential for mining heritage and historic-cultural tourism.*" (GDARD, 2011) Constructing a vegetated landscape with species adapted to either extract or stabilise pollution, can greatly contribute to this kind of idea. At the same time, this range of forest, woodlands, grasslands and more intensive areas of cultivation can perform cultural and productive functions that increase its value and give it an economic purpose. It can accommodate traditional uses such as harvesting certain plants for medicinal or spiritual purposes, as firewood, or for weaving and constructing furniture or housing. It can also provide habitats for wildlife, and be cultivated to produce biofuel crops, wood and fibres. These added layers of meaning, beyond rehabilitation, can re-create a sustainable relation between the landscape and communities that live in and around it.

A survey by Isabel Weiersbye and Jenny Botha has shown that many plants that occur in mining-impacted sites are currently already harvested, particularly by people from poorer communities, for different purposes. Many are used as firewood or construction material (several *Acacia* species (*A. Caffra*, *A. Erioloba*, *A. Karroo*, *A. Robusta*, ..), *Combretum Erythrophyllum*, *Dichrostachys Cinera*, *Diospyros Lycioides*, *Diospyros Whyteana*, *Gardenia Volkensii*, etc.), others for weaving (*Phragmites species*, *Panicum Deustrum*, ...), and thatching grasses form an important source of income for some inhabitants. Some plants are even harvested as food (*Helichrysum Nudifolium*, *Ziziphus Mucronata*, *Elephantorrhiza Elephantina*, *Searsia Lancea*, and *Searsia Leptodictya*, etc.), although that might pose health risks if the metal content is too high and the plant is consumed in large quantities. Many plants and herbs are collected for their medicinal value (such as many *Aster species*, *Helichrysum Nudifolium*, *Asparagus Laricinus*, *Asclepias Fruticosa*, etc.). Others are considered palatable to livestock, among which many

Acacia species, *Combretum Erythrophyllum*, *Gardenia Volkensii*, *Searsia Lancea*, *Searsia Leptodictya*, *Ziziphus Mucronata*, etc.). The key will be to understand these popular ethnobotanic uses and select species accordingly so that a balance is achieved between remediation efforts and human uses of plants in the rehabilitated landscape (WEIERSBYE and BOTHA, 2010).

Especially in the first years and decades, areas where tailings have been deposited should not be used for grazing as it would further increase the stressful conditions in which the plants have to survive, and animals would run the risk of metal contamination. Also many human uses, especially food production or recreation that exposes children to hand-to-mouth activity with contaminated soil, are not advisable (WEIERSBYE, 2014). The choice of species to be used in those circumstances, can be adapted to include thorny plants that animals and people rather want to avoid, and to exclude plants that have interesting features or applications that would attract people or animals. After the stabilisation woodlands have developed to a stage where the risk of contamination has decreased, these wild forested areas can be entered and appropriated for occasional human use and become natural habitats for animals to enjoy.

By shaping the topography in a creative way, areas can be delineated where wild animals can live safely and possibly generate tourism in the West Rand. In places where the soil is not contaminated, game farms for meat production can become a lucrative business as well.

A succession of phyto-extracting, and then phyto-stabilising plants can be an intermediate solution. In a first period, hyper-accumulating species can extract most of the metals, while they can be succeeded by plants that leave the metals in and around their roots. Their above-ground biomass can then safely be used without fear of contamination.

In areas closer to the river, where tailings dams have been removed, the soil can be cleaned by using metal-accumulating species. To make this phyto-extraction economically feasible, crops that have other productive applications can be used. Certain bamboo species (*Bambusa Balcooa*) can produce wood and biomass, flax (*Linum Usitatissimum*) is used to make linen, (and hemp (*Cannabis Sativa*) also has many applications. Its seeds and fibres can be used for a whole range of products ranging from insulation, paper and clothing, to building materials, oil and pharmaceuticals (CANADA, Ministry of Agriculture and Food, *Hemp fact sheet*, 1999).

While afforestation often degrades and exhausts pristine landscapes, in this case contaminated land can be used to produce wood and biomass. Especially the production of biomass that can be used as source of renewable energy is extremely promising in this respect. Growing crops for biofuels could threaten food security and consume land suitable for agriculture, but in this case it can use areas that would otherwise be useless and remediate them at the same time (GOMES, 2012). Moreover, producing energy through renewable remediation landscapes would reduce the use of fossil fuels, which is crucial in the coal-based economy of South Africa. It could help relieve the pressure on the system of energy production, and eliminate power shortages and the

need for load shedding. This kind of productive landscape would also generate spin-off industries and provide jobs for the communities of the West Rand.

Plants that have been suggested for the production of biofuels, are hemp, flax and peanut (*Arachis Hypogaea*), as well as Short Rotation Coppice (SRC): typically high yield poplar and willow species that are regularly harvested so that they can resprout, thereby keeping a young and active biomass and extracting more metals - and several oil-producing species such as Indian mustard (*Brassica Juncea*), field mustard (*Brassica Rapa*) and rape (*Brassica Napus*) (VAN GINNEKEN, et al., 2007).

These last three are accumulating species, that have the advantage that they grow relatively fast compared to other hyper-accumulating plants, and have high biomass. Moreover, there is more agronomic experience available in growing them as a productive plant (VAN GINNEKEN et al., 2007). While it could take years to decades to remove all the metals by repeatedly harvesting the plants, this process is feasible because these plants can be used to produce biofuel. Moreover, the metal-uptake of the plants can be optimised by selecting those with the highest metal uptake, tolerance, growth rate and yield, by improving the rhizosphere environment of the roots by inoculating it with nitro-fixing bacteria and mycorrhizal fungi, and by increasing the bio-availability of metals.

After the plants have been harvested, there are several ways to recover the energy (gasification, anaerobic digestion, pure plant oil production, and incineration (GOMES, 2012)), but one aspect remains to be the topic of research: what happens with the metals that have been accumulated in the biomass? Technologies to extract the pollutants are being developed and will definitely be optimised in the future. One of those is based on electrokinetics, and uses an electric current that transfers pollutants to an electrolyte solution, where they are then concentrated and treated (GOMES, 2012). The plants can also be incinerated with heat recovery, which would leave behind an ash that still contains some of the pollutants, but in chemically more stable and concentrated form so that they can be controlled or some of the valuable metals even recovered (GOMES, 2012).



## *Conclusion*

Ecosystems have very complex dynamics and depend on many different factors to function well. In the case of the West Rand these have been disturbed profoundly, and the way to their recovery is not clear, not easy or fast. But using technologies based on biological processes in a productive and socially advantageous way, is the only method that can be ecologically and economically sustainable. The first step is a clear understanding of the interlocking complexities that have shaped this landscape and that make successful remediation work. The next aspect, is to involve stakeholders that can bring expertise, funding and engagement to fulfil this overwhelming task and maintain the rehabilitated landscape for the decades to come.

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## 2 | CULTIVATING THE VALLEY *RESTORING THE WATER CYCLE*



5km



*(Hoang Le Nam)*

WATER SIDESTORY 1

*ACID MINE DRAINAGE:  
THE ETERNAL LEGACY  
OF GOLD MINING*

## Introduction

Gold mining operations on the Witwatersrand have had a serious impact on the quality of water in the adjacent river basins. In the West Rand, both pollution by run-off and by decant are causing serious threats to different river systems. The majority of the tailings facilities are constructed within the catchment of the Wonderfontein Spruit, whereby the Orange river basin is polluted, as happens in the rest of the mining belt as well. Due to a deflection of the watershed in relation to the mining belt however, some of the tailings facilities and the decant point of the Western basin lie within the catchment of the Tweeloopies Spruit, whereby the Limpopo river basin suffers pollution as well. The origin of the so called acid mine drainage (AMD) is very complex, yet the outcome is very tangible. Shocking images -like the often cited image of hippos in the Krugersdorp Game Reserve, swimming in water that coloured red due to the precipitation of metals (COETZEE et al., 2003)- are often part of a campaign against mining companies to force them to take responsibility. Unfortunately, the debate therefore shifted to a 'who to blame' discussion, rather than searching for potential solutions for which certain actors can take responsibilities (LIEFFERINCK, 2014). Therefore, the aim of this chapter is to understand where the phenomenon of AMD comes from and how it can be tackled.

*Hippos swimming in AMD water in the Krugersdorp Game Reserve*

*(source: DU TOIT, 2011 from <http://www.earthmagazine.org>)*





## *Chemical background*

The cause for the formation of AMD is the accelerated oxidation of iron pyrite. This basically means that when pyrite (also called fools gold) is being exposed to both water and oxygen, an acidic solution of ferrous iron and sulphate is being formed through a multistep chemical process (JOHNSON and HALLBERG, 2005). Although this process occurs naturally, mining activities can lead to increased exposure of iron-pyrite, with a highly concentrated pollution as a result (OELOFSE et al., 2007). The acid water generated by this reaction, is characterised by a low pH and a high concentration of dissolved salts (sulphates) and metals (iron) (TURTON, 2013).

Since the gold-bearing reef in the Witwatersrand also contains uranium, the mobilisation of this radioactive material forms another threat. Estimations point out that for every kilogram of gold that was mined in the Witwatersrand, approximately 2-40kg of uranium was exposed as well (WINDE, 2013). Depending on the redox and acidity conditions, the uranium can be mobilised and make AMD radioactive (WINDE, 2013).

The release of this acid mine drainage in the environment has many ecological impacts, because it pollutes major river systems and groundwater reserves on a regional scale and leads to localised flooding in low-lying areas (SOUTH AFRICA. COUNCIL FOR GEOSCIENCE, 2010). The metals and uranium which are mobilised in the water, are toxic for both human beings and the environment. (SOUTH AFRICA. COUNCIL FOR GEOSCIENCE, 2010). The low pH or acidity makes the water unfit for domestic use and the high concentrations of salts -even after acidity is neutralised- makes the water unsuitable for agricultural activities as well. The combination of these characteristics, makes AMD an ecological disaster.

## *Physical origin*

Although many people think AMD is formed in the underground mineshafts, the reality is more complex and starts already on the surface. One of the most important sources for the generation of AMD is the outer layer of tailings facilities, that is in direct contact to oxygen and water (OELOFSE et al., 2007). After construction, the outer layer of the tailings dams are high in pH, due to the process of gold extraction (TURTON, 2014a). They consist of quartzite particles and residual pyrite, which is covered by a layer of hydroxide. Due to the sun and acid rain however, the hydroxide coating is damaged and the pyrite particles are exposed to both water and oxygen. This lowers the pH and mobilises uranium (TURTON, 2014a). Polluted water leaches out of the tailings facilities, and finds its way to natural river systems, mine voids and groundwater bodies.

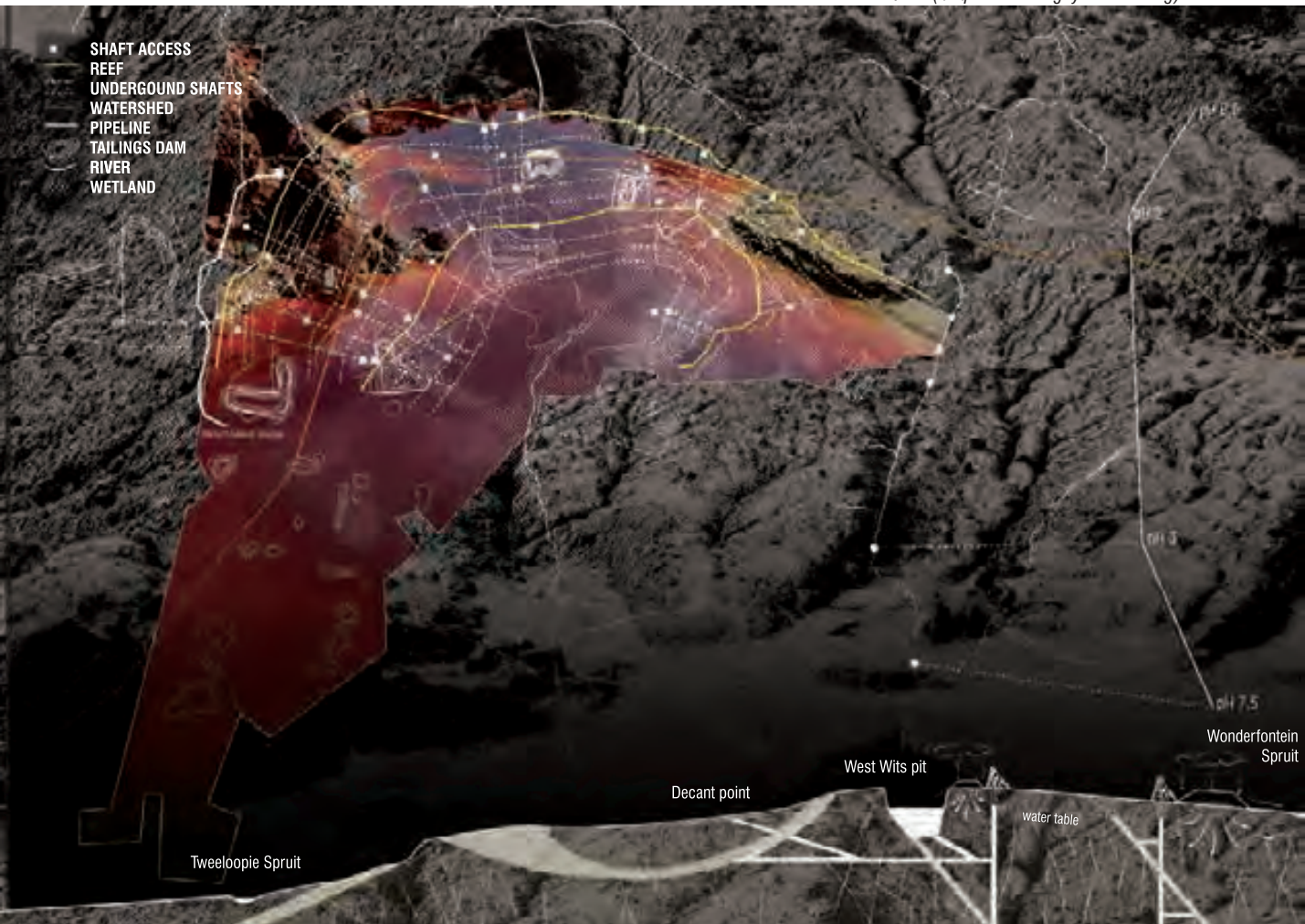
The exposed pyrite in the underground workings on the other hand is less of a problem as long as the water table is kept low to allow for deep-level mining (JOHNSON and HALLBERG, 2005). As soon as the pumps are switched off however and the water table rises, the decanting water becomes a new threat. The water dissolves the built up acid salts on the walls of the mineshafts,

resulting in a peak of pollution during the first years of decant (JOHNSON and HALLBERG, 2005). The emphasis of pollution control is often on tackling the decant problem because it is more visible for outsiders. Yet the pollution of the decanting water is for a large part the result of polluted run-off and seepage from the tailings facilities.

### *AMD in the West Rand*

Based on a risk assessment conducted in 2002, commissioned by the water research commission of Pretoria, the hazard of all the tailings dams in de mining belt of Johannesburg was determined based on multiple factors, such as age, size, geology, precipitation and distance from wetlands. According to this research, the most hazardous dumps are located in the West Rand, causing a threat for the Tweeloopies Spruit and especially the Wonderfontein Spruit (TURTON, 2013). The catchment area of the latter is located on dolomitic layers of the Malmani subgroup, which have neutralised most of the acid water throughout the years (COETZEE, WADE and WINDE, 2006). Metals and uranium have precipitated out in the sediments of the river – especially in the wetlands- which causes a danger of remobilisation when the chemical composition of the

*AMD in the Western basin (adapted from Nguyen Duc Long)*





*Treated water flowing in Robinson lake*



*Decant of AMD in the Western Basin*

*(source: S.A. COUNCIL FOR GEOSCIENCE, 2010)*

river would change (COETZEE, WADE and WINDE, 2006). Due to the close relation of mining and water sources, most of the tailings facilities are located close to or even in water courses, wetlands or dams. Lancaster and Tudor dam, at the upper Wonderfontein Spruit, which are return dams for recycling slurry water, are even located in the water course. This close distance between pollutants and receiving water courses makes it difficult to avoid water pollution (WINDE, 2013).

The Tweeloopies Spruit is not only threatened by polluted run-off but also by decanting water. The interconnected mine voids of the West Rand started to decant in 2002 -after pumping operations ceased in 1998- from a borehole and later from an abandoned shaft upstream of the Tweeloopies Spruit (COETZEE, 2004). Other than threatening the ecosystem of the Krugersdorp Game Reserve, the pollution of the Tweeloopies Spruit also affects the karst ecosystems and fossil sites of the Cradle of Human Kind World Heritage site. Further downstream the groundwater that is used by farmers also suffers AMD pollution. Measurements showed the pH of the water entering the river had a pH value of 3 and an electrical conductivity of 550 mS/m compared to respectively 8 and < 30 for the karst groundwater (HOBBS and COBBING, 2007).

The mining company which was operational at the time (Harmony) initiated a monitoring program (VAN WYK, MOKGATLE and DE MEILLON, 2013) and started by collecting the AMD water in holding facilities, before pumping it for neutralisation and iron removal at a flow rate of 15MI/day –compared to the decant of 18-36MI/day (HOBBS and COBBING, 2007). From the treated water, 10 MI was reused in mining operations, while 5 MI was released back into the Tweeloopies Spruit (HOBBS and COBBING, 2007). The current treatment plant of Mintails however, treats 20-25MI/day (TURTON, 2014b), by using the patented Tailings Water Treatment with water directly pumped from the void (TURTON, 2014b). The company managed to get the water level down again, although it remains a constant struggle depending on the recharge by rain -which resulted in new decant in March 2014 (TURTON, 2014b). Moreover, the water that is being released into the Tweeloopies Spruit still contains high levels of salt, which makes it unsuitable for agriculture.



*West Wits Pit (2014)*

This ongoing struggle against the rising water is extremely important, since the high level of the water table also enables subsurface flows of the pollution plume, making it difficult to control contamination (TURTON, 2013). The critical level in this regard is called the environmental critical level (ECL), and lies around 1500m above sea level in the West Rand (SOUTH AFRICA. COUNCIL FOR GEOSCIENCE, 2010). To acquire this level, pumping operations are necessary with an average of 53MI/day within the first two years and afterwards 27 MI/day and less as soon as the area is remediated and groundwater recharge is therefore reduced (DIGBY WELLS & ASSOCIATES, 2012). Since the pumping and treatment of these volumes is not achieved up until today, Mintails is depositing barren tailings into West Wits pit at high pH (>8) since 2010 (on behalf of the Department of Water Affairs) as an emergency measure, which resulted in the neutralisation of the AMD in the void up to a pH of around 5 (TURTON, 2014b). Nevertheless this remains a temporary solution to prevent the mobilisation of uranium and to reduce the impacts of the water's acidity. Since the consequences of AMD will last longer than the lifespan of any mining company, there is a need for a future vision which can tackle the problem in the long run.

### *Prevention of AMD*

Since the origin of AMD is known, the first measure that should be considered other than cleaning processes is the minimisation of ongoing pollution. Given the necessity of both oxygen and water to initiate the process, the elimination of either of them would prevent the formation of AMD. Depending on whether the AMD-process is initiated below or above surface, different actions can be considered. Underground mineshafts could be sealed and flooded to keep oxygen away from the exposed pyrite (JOHNSON and HALLBERG, 2005). Yet this requires extensive knowledge of the hydraulic system and a complete sealing. In the West Rand this is a difficult task, given the multitude of shafts and the hydraulic head of the water which already reopened previously sealed shafts (TURTON, 2013). Nevertheless attempts to reduce the exposed pyrite surface are being planned by Mintails by refilling the voids with tailings mixed with cement to disable water penetration (TURTON, 2014b). Although this is a valuable measure which can be executed piece by piece -in contradiction with the complete sealing of the void- it can only be implemented as deep as the water is pumped at that time.

Options related to deposits above surface are similarly based on sealing the tailings facilities from either oxygen or water. Underwater storage is the most drastic option (JOHNSON and HALLBERG, 2005), but less feasible in the West Rand, given the amount of tailings dams and the arid climate. Other options focus rather on the exclusion of water, by implementing dry sealing layers based on clay and organic material which can cover and underlay the tailing facilities (JOHNSON and HALLBERG, 2005). Yet the effectiveness of a clay layer in the Witwatersrand may be low, given the alternation of wet and dry seasons, which will cause cracks. A layer of organic material on the other hand, will remove the majority of oxygen from water seeping through and AMD formation will be minimal. Given the practical limitations of most these preventive measurements however, cleaning operations remain inevitable.

### *Value of natural systems*

When considering potential solutions for the long term, an opportunity which is worthwhile to explore is the capacity of natural systems to deal with highly polluted water. Extensive sampling along the Wonderfontein Spruit has demonstrated that the level of radioactivity reduces downstream from the mining area (COETZEE, WADE and WINDE, 2006). This suggests processes within the ecosystem of the river that precipitate uranium. Radiometric images of the area show elevated radioactivity levels in natural wetlands, indicating their influence in the decrease of radioactivity of the water (COETZEE, 2004). Similar phenomena have been noticed for dolomitic layers that seem to neutralise the acid decant water. Based on analysis of the pathways of both the treated decant water and the water that flows into the Tweeloopies Spruit and enters the dolomitic aquifer, a comparison of the change in water quality can be made. The natural pathway appears to result in more extensive quality improvements than the treated water (COETZEE et al., 2003). Research in the UK and elsewhere has also indicated the value of certain bacteria to remove sulphates (COETZEE et al., 2003). Nevertheless, the amount of polluted water drastically



*Metal precipitation near Robinson Lake*



*Salt crusts precipitating on vegetation downstream of the decant from the Western Basin*

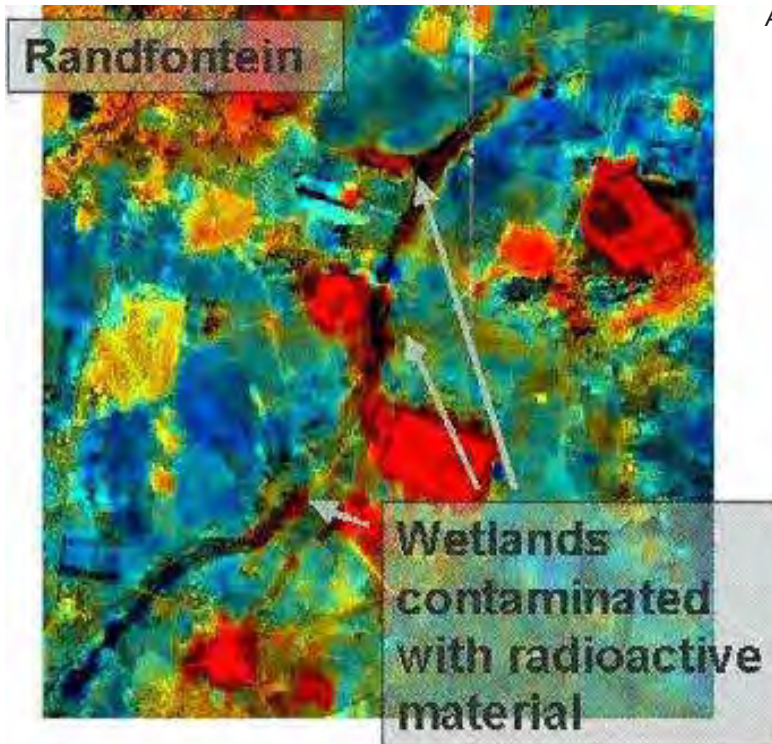
*(source: S.A. COUNCIL FOR GEOSCIENCE, 2010)*

exceeds the capacity of existing natural systems and the limitations and potential dangers need to be considered as well. The wetlands become sinks of toxic material, with the danger of being flushed out and also in dolomite the precipitated metals might be remobilised under changing conditions (COETZEE, WADE and WINDE, 2006). Nevertheless these natural processes are important assets, although they require a controlled environment to maximise their efficiency and to prevent new sources of pollution on the long run.

*Pollution: More than fighting the source*

Given the extensive alterations mining operations have made within the water system of the Witwatersrand, the challenge of reviving the water cycle goes way beyond stabilising the mine impacted areas. Studies have estimated that the sediments in the Wonderfontein Spruit contain over 2200 tonnes of uranium, that have been built up during the past 120 years (WINDE, 2013). If the flow rate of the river would change drastically, there is a risk of high concentrations of uranium being flushed (COETZEE, 2004). Therefore it is important to look for a new balance of water ingress to the river to ensure a gradual removal of uranium over time. Consequently the high amount of decant water shouldn't just be cleaned to be released directly into the natural river systems.

***“Dilution is (NOT) the solution to pollution”*** (Ingrid Watson, 2014)



*Airborne radiometric survey  
Wonderfontein Spruit  
(Source: Coetzee, 2004)*

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## WATER SIDESTORY 2

### *CONSTRUCTED WETLANDS: THE POTENTIAL OF ENGINEERED NATURAL SYSTEMS TO CLEAN AMD*

## Introduction

Multiple studies in the area of the West Rand have showed the potential of existing natural wetlands to tackle AMD pollution. Nevertheless these processes have their saturation points, and contain certain risks due to the accumulation of pollution in uncontrolled conditions (COETZEE, WADE and WINDE, 2002). Currently, the acid mine drainage which is decanting is being treated by active treatment plants (TURTON, 2014). These systems are based on raising the pH by adding lime or tailings, and aeration techniques, basically by stirring the water to stimulate the metals to precipitate out and reduce the level of dissolved metals (SKOUSEN et al., 1998; TURTON, 2014, spoken conversation). If the precipitated metals aren't removed, the water is coloured red. The water is being released again into the natural environment while still containing elevated levels of salts. The most common active treatment option to remove the salts (reverse osmosis) requires a lot of space, is very expensive and produces a lot of waste (COETZEE, 2014, spoken conversation). Such active treatment systems can be initiated relatively fast at high flow rates, but tend to have high operational and maintenance costs (WHITE, n.d.). Moreover, they also require a high degree of supervision, extensive presence of operators, and they rely on external power supply (PULLES and HEATH, 2009). In the context of South Africa, the high risk of theft of valuable materials will increase security costs or can shut down the whole process (PULLES and HEATH, 2009).

Given the emergency of the situation when the AMD water started decanting, the choice for these active treatment systems seemed reasonable at the time. Yet if the West Rand ever wants to overcome its mining legacy, more sustainable options for the future need to be explored. In this

*Water treatment plant Mintails (2014)*



discussion, passive wetland systems come to the fore as a good alternative. Nevertheless experts in the mining field also question the feasibility of such systems due to the large amount of space necessary (TURTON, 2014, spoken conversation). Also the variable amount of water throughout the different seasons are reason for doubt since it could decrease the efficiency of the wetland's functioning and make them a risk for pollution (WEIERSBYE, 2014). While taking these and other constraints into account, this chapter explores the potential of passive treatment options for the West Rand. The aim is not to become experts, but rather to understand the principles, constraints, limitations and values of such passive systems in order to make informed design decisions.

Estimations on the amount of decant water in the West Rand, vary depending on the source. After an initial period of high pumping requirements to reach the environmental critical level, a stable situation of pumping flow rates of 27 MI/day is expected to be enough to maintain this level (DIGBY WELLS & ASSOCIATES, 2012). However, if a decreased recharge is incorporated due to the closing and rehabilitation of the pits and because of planting trees, more conservative estimations expect decant flow rates of about 16 MI/day (DIGBY WELLS & ASSOCIATES, 2012). To compromise between underestimations of necessary pumping requirements and overestimations of the availability of water, the assumption is made for this vision that the pumping flow rates after remediation will be around 20 MI/day.

### *Passive technologies*

The concept '*constructed wetland systems*' points at more than one process, and should be considered as an umbrella term for multiple passive treatment methods that each have their own structure and functionalities. These can be combined to form a multistep process to clean polluted water (SKOUSEN et al., 1998). The main goals in treating AMD are to reduce the acidity and extract the heavy metals and sulphates. One of the most common passive systems that can be of use in treating AMD water, are aerobic wetlands (JOHNSON and HALLBERG; 2005). These are mainly used for iron contamination (WHITE, n.d.) and require alkaline water ( $\text{pH} > 7$ ) to allow iron to precipitate. The system is based on shallow water flowing across organic matter containing vegetation that enhances the aeration of the water to speed up the precipitation process (WHITE, n.d.). Since the accumulation of precipitates will reduce the performance of the wetland, frequent removal by flushing or dredging is necessary (WHITE, n.d., referencing COSTELLO, 2003).

Other systems focus on raising the pH, such as anoxic lime drains (ALD), which are a passive alternative for lime additions in active systems (SKOUSEN et al., 1998). The polluted water is directed through limestone gravel which is contained within a drain, impermeable for oxygen and water. Yet when the concentration of (ferric) iron is too high, precipitations on the limestone may lower the effectiveness of the system on the long term (JOHNSON and HALLBERG; 2005). To reduce this effect, the oxygen in the water should be reduced before entering the drain.

Oxygen-reduction can be achieved by vertical flow ponds, in which the water seeps through a layer of compost to extract oxygen (SKOUSEN et al., 1998). Such vertical flow ponds, also called anaerobic wetlands or compost bioreactors, raise the pH and produce biogenic sulphide -which means the concentration of sulphates (salts) is reduced (JOHNSON and HALLBERG; 2005). The compost can be a mix of locally available organic matter, such as cow manure or compost from locally produced fruits or vegetables, and materials that are characterised by a slower degradation such as straw or peat (JOHNSON and HALLBERG; 2005). This procedure however is still being researched quite intensively, since the efficiency of these systems with regard to sulphate reductions is difficult to predict and often below expectations. Research on this topic has indicated the need for an additional step of sulphide removal, to prevent re-oxidisation to sulphates (PULLES and HEATH, 2009).

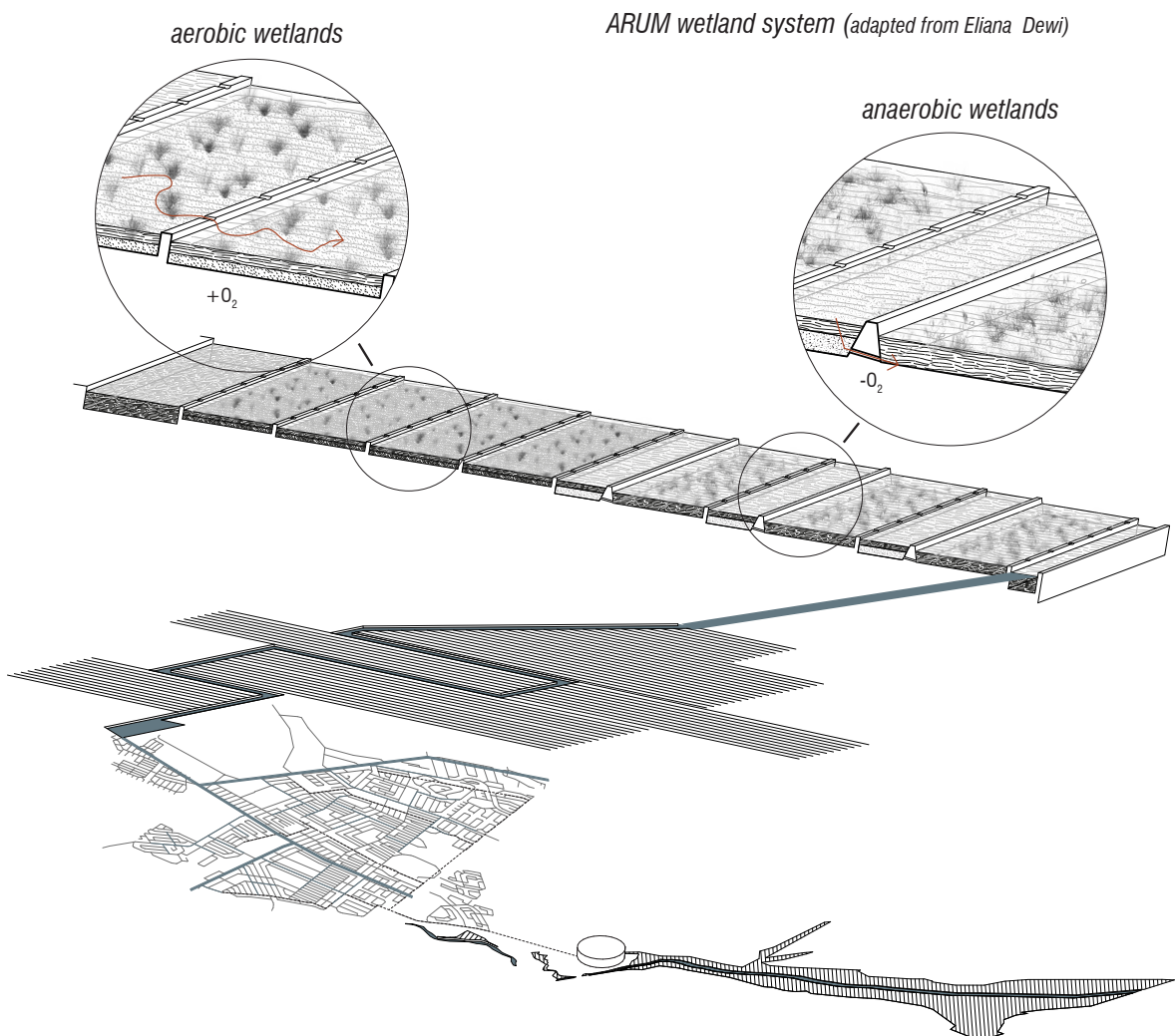
Given the complexity of the pollution pattern of acid mine drainage, a treatment system to attain a level of quality which allows for agricultural and recreational use will require different steps. Many systems exist, based on a combination of the previously described principles. An important system in this regard is the '*Successive alkalinity producing system*' (SAPS), that is based on a combination of a compost layer or anaerobic wetland (to remove dissolved oxygen and reduce sulphates) and iron and a limestone gravel bed (to raise the pH). A sedimentation pond or aerobic wetland can be added to make sure iron precipitates remain inside the wetland system (JOHNSON and HALLBERG; 2005).

Different case studies in Pennsylvania -described by Demschak, Morrow and Skousen (2001)- in which this system has been used, have shown various levels of efficiency in the removal of iron and the increase of pH. These fluctuations can be linked to the difference in inflow parameters, flow rate and the exact set-up of the wetland (depth of water, organic matter, etc). The levels of sulphates however weren't considerably changed throughout the process (DEMSCHAK, MORROW and SKOUSEN, 2001). The construction costs were about the same as 7 years of active chemical treatments, which makes them cost-effective from then on. The flow per area varied from 0.09 l/min/m<sup>2</sup> to 0.52 l/min/m<sup>2</sup> (DEMSCHAK, MORROW and SKOUSEN, 2001), if recalculated, the surface necessary to clean 1 Ml a day varies from 1335 m<sup>2</sup> to 7716 m<sup>2</sup>. If related to the amount of decant in the West Rand that can be expected on the long run (20Ml/day), a comparable system would require an area of 2,7 to 15,4 ha, depending on the set up of the system. Compared to Lancaster dam, built to control pollution, that has made about 16ha of land unavailable, this seems a reasonable amount of space in the context of the West Rand.

Another important passive bioremediation system that makes use of the previously discussed principles is the '*Acid reduction using microbiology system*' (ARUM). It is based on a combination of oxidation cells (aerobic wetlands) to precipitate iron and ARUM-cells (anaerobic wetlands) to reduce sulphates and increase pH (KALIN and CHAVES, 2001). A case study of such an ARUM system in the gold mining district of Nova Lima in Brazil shows slightly better results for the

removal of sulphates, compared to the previously discussed SAPS-systems, yet it is still not as efficient for the reduction of iron. As mentioned before, this is probably due to the need for an additional step of sulphide removal (PULLES and HEATH, 2009). In this case, a total volume of 804 m<sup>3</sup> -through a sequence of 7 ponds- was necessary to clean 0.59 l/s (KALIN and CHAVES, 2001). Recalculations point out that a volume of 15772 m<sup>3</sup> or an area of 3,15 ha -if the average depth of the ponds is considered to be 0,5 m- is required to treat 1Ml/day based on this system. For the West Rand, this would mean a total of 63 ha if 20 Ml is to be treated every day. The larger surface area is due to the assumed low depth and fact that the system consists of multiple ponds. These conservative values can be considered as a good base to consider the feasibility of the necessary surface. Given the large amount of mine impacted land in the West Rand –around 2000 ha (data courtesy of GCRO – Gauteng City Region Observatory)- this is definitely a feasible option.

***“They have nothing else than space!”*** (Bruno De Meulder, 2014)



### *Engineered nature/shaping the landscape*

These constructed wetlands are based on improving the efficiency of the natural systems within a controlled environment to ensure the quality of the outflowing water. As said before, a constant flow rate of the polluted water is extremely important to actually use this natural system as an engineered treatment. To mediate the effects of the alternation of dry and wet seasons, measures need to be taken, depending on the source of polluted water. To ensure a constant flow rate for wetlands treating runoff water, collecting ponds are necessary to buffer the water and to average out the flow rate entering the wetland throughout the year. To mimic the natural filter system of riparian buffers (WEIERBYE, 2014), reed beds can be implemented to take out the majority of sediments to prevent congestions in the wetland systems.

For decanting water, the effectiveness of wetlands can be optimised by pumping at a constant rate, whereby the excess recharge water during wet season will compensate for the lower recharge during dry season. This means water is stored underground, to prevent large storage facilities to buffer polluted water and to minimise loss by evaporation. In the case of the West Rand, a constant pumping rate can only be achieved as soon as the groundwater level is decreased to the environmental critical level. Therefore the initial higher pumping requirements and consequent flow rates of polluted water can be treated by the active treatment processes that are already in place. Since sulphates are not removed by such treatments, alternative uses – for example by industries or mining companies - can prevent elevated levels in the natural cycles. After cleaning, direct recharge of the groundwater table by the treated water should be prevented. This would mix cleaned water with polluted water and will create a vicious circle, whereby the efficiency of treatment is reduced as well. Alternative uses of the large volume of clean water are therefore necessary, which shouldn't be a problem given the shortage of water in the context of the West Rand.

*Natural river system (Lucile Ado)*





*Community involvement*

(Source: LEVY, n.d.)



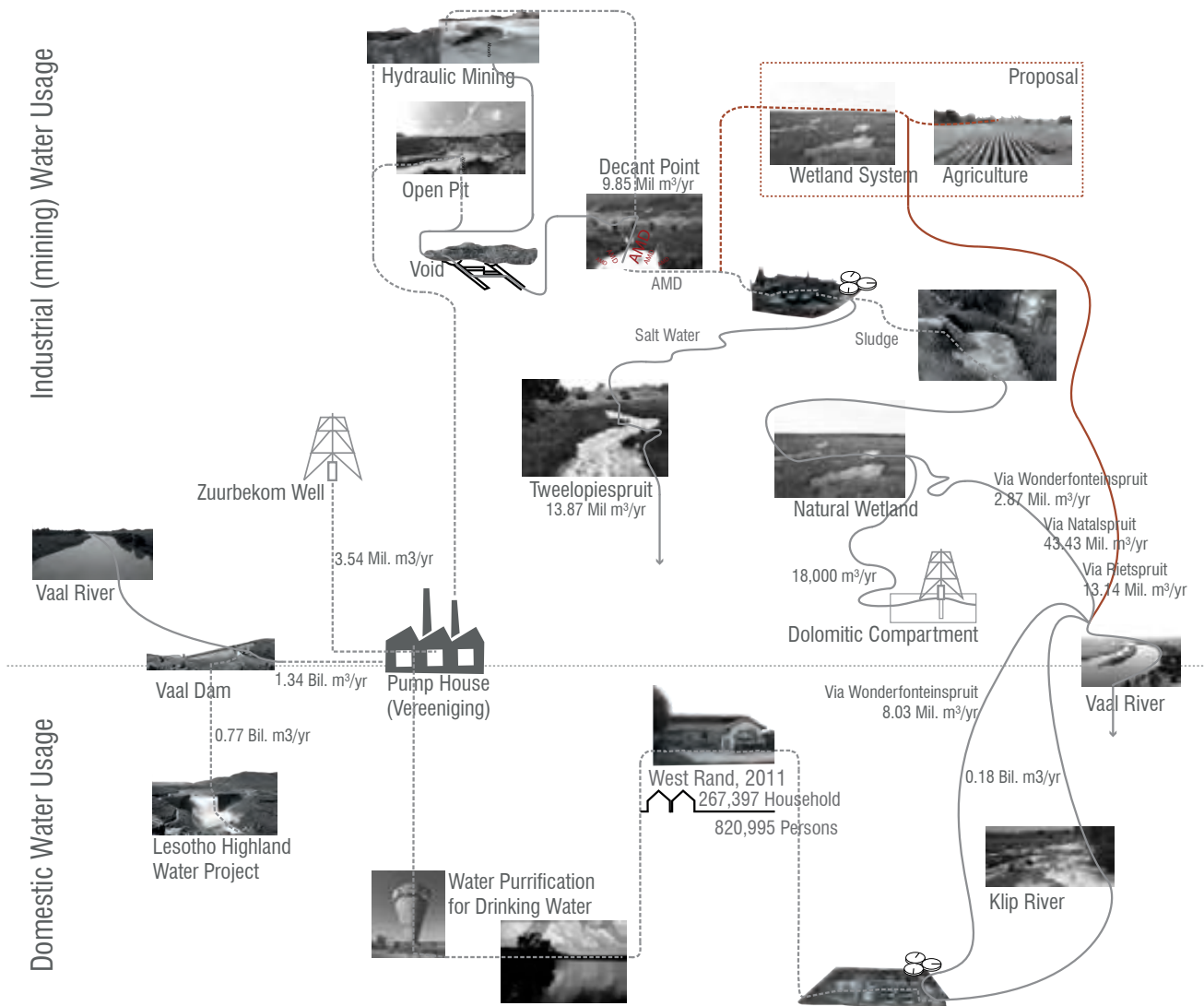
*Adjusted colours of vegetation*

(Source: LEVY, n.d.)

Although constructed wetlands are built according to the system logics of an engineered system, their spatial qualities can't be compared to each other. Whereas active treatment systems that are operational today are alien structures in the devastated landscape, constructed wetlands can become part of the landscape of remediation. In that regard, their size becomes less of an issue, since they are not just claiming a certain area which will be inaccessible for other purposes but rather initiates new kinds of valuable nature that cannot be swallowed by the growing spatial needs of urban development.

Examples such as the Art & AMD project in Pennsylvania, which was initiated as a collaboration between landscape architects, artists, scientists and historians show the potential of the integration of constructed wetlands in the public domain (LEVY, n.d.). The area works as an educational park, in which the system of wetlands is being explained. Aside from cleaning the water, the process of cleaning is shown, by adjusting the colours of surrounding vegetation to the colour of the water from orange to green. Popular walking and cycling trails have also converted the identity of the area from a polluted waste land into a destination for leisure. The community has been involved in both the design and the implementation with local scouting boys helping with the planting of trees or neighbourhood meetings and field days organised by the design team. The need for an alternative identity and involvement of the community also applies to the context of the West Rand. Mining as the identity and generator of economy was never replaced by an alternative, but the mining legacy is nowhere as present. Water and its consequent economies and landscapes could create a different mindset to re-conceptualise the area. The potential to empower communities by involving them in the process of transformation, is crucial in this post-apartheid context.

***Cornish men are fishermen, cornish men are miners too. When all the fish and tin are gone, what are Cornish men to do?*** (graffiti on a mine's wall in Cornwall, UK)



*Cycles of water use (adapted from Aurora Dias Lokita)*

### *Liquid gold: the political value of water*

As mentioned before, the struggle against AMD in the Witwatersrand is more than an ecological struggle for clean water. Given the history and the climate of Johannesburg, water is both a political, social and economical asset. Due to the arid climate, water has always been a limitation for economic development, especially since Johannesburg is globally the only city of this size that hasn't been built on a river, lake or seafront (TURTON et al., 2006). Initially water for the mining villages was supplied by springs located along the Witwatersrand and by pumping water from dolomitic layers. Given the huge demands of the growing city and its mining activities, the water supply for the region had to address sources further and further away from the city. Until the '80s the Vaal river system was sufficient for the water requirements of Johannesburg, the Sterkfontein dam managed to answer the growing demands until the end of the century and today the Lesotho highlands are providing water to Johannesburg as well (TURTON et al., 2006). This constant



struggle for the availability of water is for South Africa and its surrounding countries -Botswana, Zimbabwe and Namibia- the critical threshold for ongoing economic development (TURTON et al. 2006). The pollution of the mining area also threatens the vital water supply of the city because it partially ends up in the Vaal dam, or the dolomitic water reserves. Given its importance for many aspects of the city's urban quality, water appears to be the trigger that can actually become a turning point. The rising pressure on food production, especially in large cities such as Johannesburg, has turned water into the new gold. When fighting the problem of AMD, especially when facing large investments, it is therefore necessary to consider its huge potentials. Since the water resources need to be found further and further away from the city, it becomes worthwhile to look at how this huge resource of polluted water can be used within the city.



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## WATER SIDESTORY 3

*WATER URBANISM AS  
AN APPROACH FOR THE  
RECONCEPTUALISATION  
OF URBAN TISSUE*

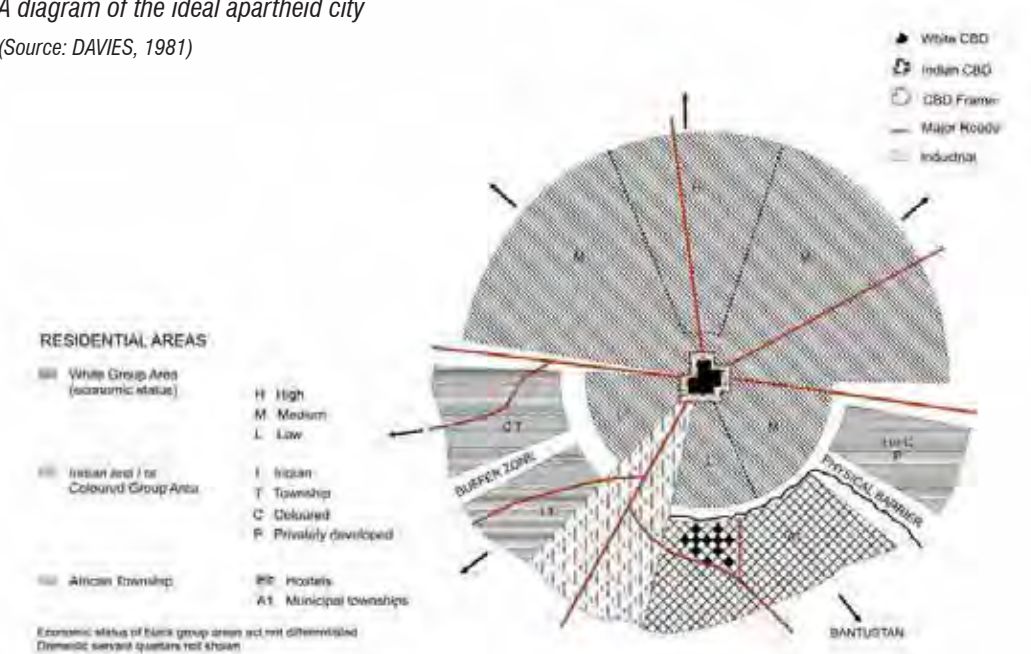
## Landscaped apartheid

The geographies of segregation that exist in Johannesburg up until today are the result of an extensive history of mining and apartheid ideologies. The spatial relations of residential neighbourhoods to the mining belt, topography and river systems have been of great influence in this regard. While the so called 'white elite' started to inhabit the ridges north of the mining belt, to avoid the dust and noise of mining operations, black settlements were systematically planned in the south (TOFFA, 2011, referencing HARRISON AND ZACK, 2012). These early spatial preferences for the northern ridges defined the framework for the development of the city. While the urban setting in the north was structured around the water network and its strong topography with extraordinary views, the southern planning logics approached the river system rather as a delineator.

The northern suburbs of the city were based on the European garden city model and followed the lines of topography (FOSTER, 2009). The aligned grid focuses the view of the majority of the dwellings on the landscape. Trees were added to mediate dust and to create a new sense of place, related to the homelands of the white settlers, since forest in European context were associated with the origin of nations (FOSTER, 2009). This planning structure allowed the landscape to penetrate the city as its counterpart.

### A diagram of the ideal apartheid city

(Source: DAVIES, 1981)



The townships in the south were built on land with limited topography, that had no mining value. The grid structure was based on the boundaries of old farms, but since different townships were often built independently from each other, limited connections exist between them (FOSTER, 2009). While the river systems in the north allow the landscape to penetrate into the tissue, those in the south -which were already polluted by the run-off of the dumps by the time the townships were built- were ignored as backsides to create buffer spaces in between different townships. These contrasting approaches to landscape are represented in the vegetation patterns of the city until today.

When comparing the layout of Johannesburg to the diagram of the typical apartheid city (DAVIES, 1981), it becomes clear how the landscape framework of the city appeared to be the perfect foundation for the segregationist city. The mining belt as an extensive ‘terrain vague’ crosses through the geographical centre of the city (FOSTER, 2009) and separates the formerly white north and black south. This large spatial figure became a strong translation of the buffer space as represented in the diagram. Industrial areas such as Chamdor in the West Rand are located close to the mining belt and work as a secondary buffer space –which differs from the industrial element in the diagram. In the south, the space along the rivers and roads—as for example the buffer along the Wonderfontein Spruit, and the valley of the Witpoortjie - functioned as a buffer to separate people from different origin. They also form some kind of no man’s land in between, reminiscent to the conceptualisation of the original ‘veld’ as a hinterland which defined the landscape of Johannesburg before the city took over.

*Afforested North (view from Munroe Drive, 2014)*

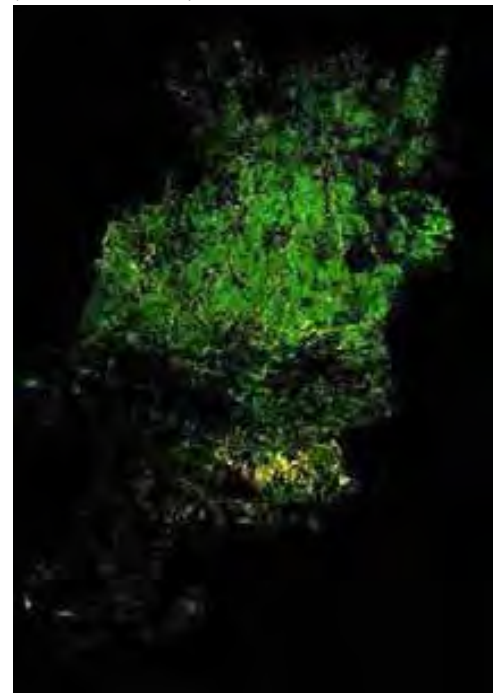


*Sprawled trees in the South (Soweto, 2014)*



*Area of Johannesburg covered by trees.*

(Source: GCRO, 2009)



### *Post-apartheid landscape*

Today these in-between terrain-vagues are an important focus in municipal post-apartheid strategies, where trees are being planted in the south and former buffers are converted into parks (SCHAFFLER and SWILLING, 2012). The mining belt on the other hand is being claimed for development purpose, especially near the city centre where the pressure on land value is high (BARKER,2014). Given the pollution however, the most profitable kind of development in this context is industry-related. Although the development of the mining belt is claimed to be one of the so called “Corridors of Freedom” (CITY OF JOHANNESBURG, 2013), these developments don’t succeed in overcoming the legacy of apartheid. The spatial character of the mining belt as a buffer space is even reinforced by this fragmented “corridor”.

The approach of reverse engineering by converting spaces of control into spaces of connection is a strong conceptualisation to re-imagine the city, current interventions miss a cohesive spatial structure. Other than being used as buffering spaces by the planning of apartheid, the mining belt and the river structure have also kept space for landscape within the city. The mining belt largely follows the watershed divide and drains to the south, with a deflection in the West Rand which makes issues of pollution more complex in this area. The river systems and topography have shaped the urban, be it in different ways north and south of the watershed divide. Since landscape

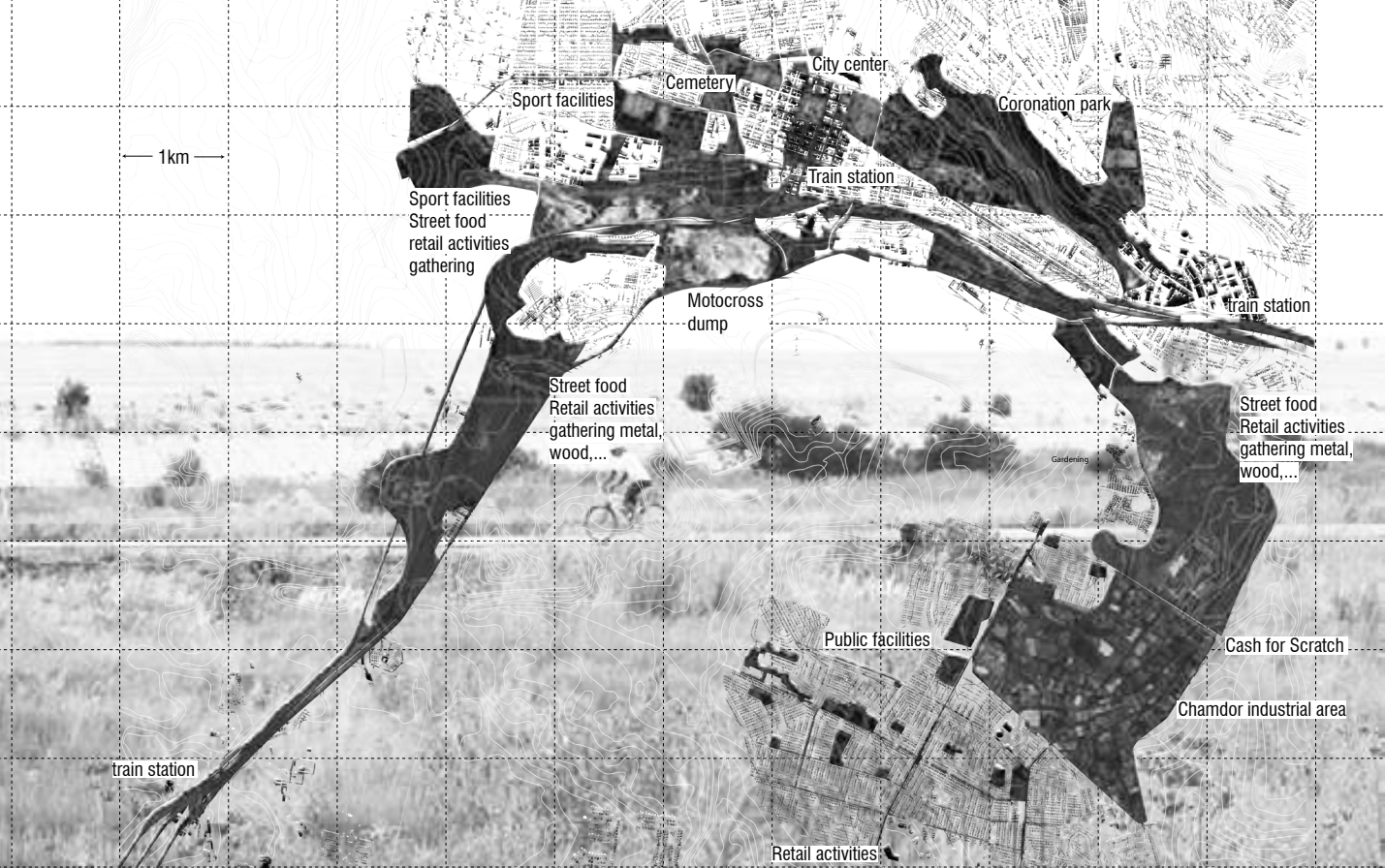
*Football team using an informal path through the MRA's in the West Rand as a shortcut*



*Livestock farmer along the road in Kagiso*







*Places of mixity (adapted from Lucile Adu)*

has always been an important tool in structuring the city during the apartheid-era, it appears to be a valuable starting point to reframe spatially embedded inequalities. This approach literally turns the traditional planning approach inside-out, since it doesn't start from the built form, but from natural systems and open space to (re)structure the urban (DE MEULDER and SHANNON, 2010).

In the West Rand, the pressure on available land is nothing compared to that in the city centre of Johannesburg. Mining operations are still active, wherefore the mining belt as a vast amount of open space hasn't been claimed for other industrial purposes yet. Both the mining belt and the buffer spaces along roads and streams have become spaces of informal soft connections, as the multitude of pathways and small bridges across the streams suggest. People even transform these spaces into productive land, by letting their cows graze in an abandoned part of the mining belt or by taking out their goats along the buffer spaces next to the roads. For informal settlements, the streams themselves are also an important water supply, although it is often heavily polluted (COETZEE, 2004). These appropriations of the different kind of no man's lands of the city, show the potential of such a landscape structure as a trigger for new uses and movements. The potential to re-imagine the Western part of the city doesn't depend on real estate developments to boost new economies, but rather in the re-conceptualisation of the landscape itself. This interest in landscape isn't just a way to deal with ecological issues, but also has the capacity to theorise and structure the urban (DE MEULDER and SHANNON, 2010).

### *Altered water systems*

Given the large amount of decant that needs to be treated, and the problems related to scarcity of water, such a landscape based approach should incorporate the availability of water as an asset. This can be done by creating a new open space structure, by guiding a system of furrows and canals through the urban and natural landscape along the Wonderfontein Spruit. The historical engineered system of the leivoor to guide water from the rivers through the city proofs to be of added value for inhabitants of South African cities up until today.

The system is based on a network of canals, which redirect the water of a river along the streets (JUUTI and MAKI, 2008). At certain times of the day, these canals are filled with water which can be used for domestic or productive purposes. Johannesburg itself also has a history of altering water systems, which started mainly as a functional approach to hold the water of rivers as close as possible to mining operations and urban areas by building dams in the upper area of river catchments. In the north however, the majority of dams have been transformed into areas of recreation. This never happened in the south, due to the lack of interest to provide recreational areas in the southern part of the city by apartheid planners and the high levels of pollution.

#### *Leivoor in Stellenbosch*

(Source: WALLACE, 2007) from [www.flickr.com](http://www.flickr.com)



#### *Children playing in Nieu Bethesda's water furrows (Karoo)*

(Source: MARAIS, n.d.) from <http://www.southafrica.net>



#### *Recreation at Coronation park (Krugersdorp)*



#### *Canoeing at Victoria lake Germiston (East Rand)*



Given this historical embeddedness of altered water systems in urban environments, the insertion of a new water structure can once again become the base to reframe townships in the south. The current decant problem in the West Rand has not only raised the issue of water cleaning, but also the need for new users. This is not only necessary to prevent a vicious cycle of water cleaning due to constant recharge of the underground void, but also to create a market based on this resource of water which can subsidise water cleaning after mining companies are gone. The insertion of such a new water structure in the urban environments could become part of the necessary consumption market to pay for the ongoing water treatment.

Based on the population numbers of different townships, estimations about the necessary volume of water can be made. Because the amount of water depends a lot on what it is used for, these estimations should be considered as an order of magnitude to be able to compare it to the available water. To provide 5 l per inhabitant every day, an amount of 2 Ml is necessary to answer the needs of the townships Kagiso, Rietvallei, Azaadville, Mohlakeng and Toekomsrus and the old mining town called West Village. Compared to the assumed amount for treatment (20 Ml/day), this leaves more than enough water available for industrial and large scale agricultural uses as well.

### *River on the hill*

Basically, the logics of Apartheid planning can be turned inside out, by putting the 'river' on the highest points – as proposed in the vision- and thereby cross the urban areas rather than to border them. The insertion of such a system at the highest points of the area, would generate a flexible backbone which can trigger an incremental change of the townships. New cooperation systems could allow for higher densities on smaller footprints, compensated by open space. A network of water can be created by inhabitants themselves by plugging in to the main canal at the highest point. This water system will form the framework for a transformation of the tissue.

The parallel densification process can be structured by the advantages created by water within a new open space structure. Elaborating on the system of informal paths in the landscape structure that already exists today (buffer spaces along roads and rivers), the inserted network could become a system of preferred pedestrian routes in the otherwise car-dominated townships. Schools and open spaces can get access to water and at the same time get connected to this alternative system of pathways. Other modes of transport, such as bicycles, can get promoted given the minimum slope of the main canal structure at the highest points of the area. Moreover, the micro-climate along the water will be more pleasant, especially if trees are planted along it to provide shade and minimise evaporation. The network through townships to train stations and taxi routes, could provide a complementary system to the large scale East West connections, linking the West Rand more efficiently with the centre of Johannesburg.

A concentration of open spaces along the water structure would make the framework more than a network of water or alternative mobility. The availability of water provides opportunities to use open space in a productive way, such as for different scales of urban agriculture varying from vegetable gardens for one family to cooperations for larger agricultural projects which can generate income as well. Grasslands could provide a structure of common lands, that can be maintained by grazing and used for larger gatherings and festivities. Larger water bodies to buffer the water can become points of recreation as a counterpart for the dams in the northern formerly white areas. At the same time they can ensure the water level of the rest of the system by balancing out the difference in water consumption throughout the year. This will result in a dynamic landscape of releasing and collecting water, creating a different sense of place throughout the year.

Moreover the introduction of multi-storey typologies will result in a densification of Kagiso that can answer the growing demand for dwellings without compromising in terms of open space. The introduction of new economies within the tissue will trigger the hybridisation of the area, with new functions such as small processing factories or shops. This mix of grain goes against the traditional principles of zoning with the aim of interrupting the monotonous living environment.

### *Landscaping the West Rand*

Whether this reinvented landscape framework can actually guide Johannesburg, and more specifically the West Rand, to overcome the deeply embedded apartheid legacies is a complex question to answer. James Corner coined the term '*landscaping*' as an approach for post-industrial landscape design that literally need to be scaped clean to allow for re-use (LISTER, 2010). The landscape of Johannesburg however needs to be scaped both in a physical and in a social sense. The proposed approach is based on the creation of equal opportunities and living qualities and this not necessarily by the creation of 'mixed' areas or the improvement of the transport systems to improve spatial accessibility as is aimed for by current planning strategies. Rather the strategy builds on transforming the spatial and social legacy of apartheid by the inserted landscape figure. It improves the living environment and interrupts the repetitive character of the townships. The availability of water at a low threshold can generate potentials for small-scale businesses which can grow incrementally. Also the identity of the West Rand can change from an area of faded mining glory at the outskirts of Johannesburg to the agricultural hub of the city. So rather than to bring different races and income levels spatially together, the aim of this approach is to reduce the differences between them, which might in the long run result in a new spatial mixture as well.

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## WATER SIDESTORY 4

*THE PRODUCTIVE LANDSCAPE  
AS AN ALTERNATIVE POVERTY  
ALLEVIATION STRATEGY*

## *Introduction*

Food insecurity is a growing concern throughout the world, and it is especially the case in a country as South Africa, given the high level of inequality. Even though agriculture used to be an important part of the South African economy, it has shifted in such a way that South Africa even depends on import nowadays (SATGAR, 2011), which results in increased prices especially when the Rand is weak. Due to the growing differences between rich and poor and the rising food prices, many people suffer food shortages. Mining operations have had a huge influence in this regard, since they often confiscate qualitative soil and consume massive amounts of water that could otherwise be used for agriculture (PIENAAR, 2014). In Mpumalanga this dilemma is very present, since coal mining operations are sought after to boost the local economies and to create new jobs. In 2012, Mpumalanga was the leading producer of soy beans (51%), maize (24%) and dry beans (23%) in South Africa (CITYPRESS, 2012). Yet if all pending prospecting rights and mining permits would be granted, this would mean a loss of 80% of land and the contamination of valuable water resources (CITYPRESS, 2012). The problem of AMD in the West Rand has already contaminated rivers and ground water, with consequences for the agriculture depending on these resources. High unemployment rates and the lack of alternative economies after mining make the issues of poverty and food security very relevant in this context. The availability of decant water however, could become the trigger of a new kind of agricultural development that can generate new economies and tackle food scarcity and unemployment.

## *Strategies to alleviate poverty*

Africa has a history of stimulating agriculture as a way to deal with poverty (MACHETE, 2004). The focus in such projects is on 'smallholder agriculture', since the support for large-scale farmers mostly doesn't benefit those who need it the most (MACHETE, 2004). Such promotion of agricultural activities doesn't only reduce the problem of personal food security, but if the scale is sufficient, it will also reduce food prices, create employment and increase wages (MACHETE, 2004). Current poverty policies in South Africa however, remain focused on providing people with housing. By the development of large quarters of so called RDP housing (Reconstruction and Development Program, now called Breaking New Ground - BNG), new ghettos of poverty are being created. These neighbourhoods are often located at the outskirts of the city with little job opportunities or development of experience and technical skills to overcome the poverty people live in. By shifting this focus from housing to agriculture, the aim is to tackle issues of food security and poverty, while empowering people to obtain their own house and to become self-providing. Nevertheless it's a difficult change of mind, since people expect to get a house, especially after waiting for several years. Lufhereng, a recent RDP project west of Soweto, however, tries to combine this expectation with the potential of agriculture as a new source of income. 25000 units were planned to be built with extensive school and day-care facilities, health



infrastructures and recreational spaces included in the project. The 480 ha of agricultural lots are supposed to provide 10000 direct and indirect jobs based on high-yield production activities (26'10 SOUTH ARCHITECTS, 2013). Although the project aims to step away from the historical focus on housing in South Africa, it can't overcome its limited relations with the city and the landscape. Questions can also be raised about the prospects of the integrated agri-business initiative and its related employment on the limited amount of space and the water requirements of such intensive cultivation. Nevertheless these kind of projects are extremely important to change the mindset of people away from the focus on housing as a way to tackle poverty.

### *Urban agriculture in the West Rand*

To be able to use agriculture as a way to empower people, a certain degree of commercialisation is necessary to actually make profit through small scale agriculture (MACHETE, 2004). Especially within an urban context, the difficulty to attain a sufficiently large scale, makes it difficult to actually make a difference through the concept of 'urban agriculture' (WEBB, 2011). Yet the urban context has other advantages such as the availability of infrastructures and the closeness of consumption markets. The territory of the West Rand seems to have the best of both in this regard. Due to the mining history, the area is extremely well equipped with services and infrastructures and the end of mining operations creates opportunities to convert mining-related industries into food processing firms. Next to the advantages of the urban context of the West Rand, it has a large availability of lands, since it is located at the outskirts of the city, which makes the upscaling of urban agriculture a feasible option.

The benefits of the nearby consumption market of Johannesburg and the availability of infrastructures is already used by the large scale agricultural developments in Magaliesburg. The massive circular irrigation systems have defined the landscape and immediately give a sense of its large scale. Nevertheless the profits of these large companies go to a small group of owners and has led to the formation of many informal settlements for its work force.

***“Magaliesburg has large agricultural areas. The owners are rich, but the workers are poor”***

*(Jerry, taxi driver living in Magaliesburg, 2014)*

*Agriculture Magaliesburg (Source: GOOGLE EARTH, 2014)*





REMEDIATION

PRODUCTIVE VALLEY

NATURAL VALLEY

*The productive valley*



*Hydroponics* (Source:<http://www.farmspeak.com>,  
<http://globerove.com>)



*Cows in MRA near Luipaardsvlei*

The large scale circular irrigation systems of Magaliesburg require large investments that are impossible for small farmers. The boreholes downstream the Wonderfontein Spruit have been a valuable irrigation source for small scale farms, but suffer contamination by acid mine drainage. Current productive uses on the badlands of the West Rand are related to large scale hydroponics and small scale livestock farming. Since hydroponics are only based on the availability of water, the quality of the soil isn't relevant, which makes it cheaper to build the glass houses on polluted land. Livestock on the other hand is less vulnerable for the polluted soil than crops, although contamination of the meat might be possible. Both examples show the potential of consuming the mining belt in a productive way, yet they remain ad hoc appropriations and lack a contextualised approach.

To overcome such fragmented uses of the huge available open space, a new structure is necessary, which can be small scale enough to empower people themselves, yet large enough to deal with the competition of large scale companies. Other than the competition of such large companies, small scale farms are also more vulnerable to extreme droughts, floods, fires, price changes etc. Large farmers use irrigation systems, that allow them to have two harvests a year – e.g. rainfed soy bean or maize in summer and irrigated wheat in winter. A variation of crops and a significant livestock also limit potential losses (WILK, ANDERSSON and WARBURTON, 2012). For small scale farmers that only own about 1 ha of land, such investments are impossible. In the West Rand however, the available decant water could become a source of irrigation, that can be used collectively and become the spatial structure of the area. As proposed in the vision, decant water is pumped, treated and redistributed along the highest points of the Wonderfontein Spruit valley. Attached irrigation systems can make use of this resource to irrigate the valley for productive purposes. Such a framework could be built collectively by farmer cooperations while

the irrigated landscape can be subdivided into individual plots, of variable size. Buffers at the higher points could be filled to prevent crop failures in periods of droughts. In such a system, farmers can maintain their independence, while maximising their profitability and minimising their vulnerability. This can be seen as an alternative approach of existing farming systems in the direct environment, adapted to a bottom-up approach and constraints of pollution.

### *Scales of water, the potential of irrigation*

Since the water resources are not inexhaustible, a balancing exercise needs to be made to use the available land as efficiently as possible. If part of the treated decant water is reserved for the urban areas and small-scale industrial uses, about 17 Ml/day remains for agricultural. To prevent water shortages for certain consumers due to uneven distribution of water, thoughtful canal sections need to prevent overconsumption. An area of 2500 ha can be irrigated, which means 250 mm (l/m<sup>2</sup>) is available throughout the year, on top of the 700 mm by rainfall (ABIYE and BAMUZAAND, 2012). In South Africa, only 14% of the arable land receives enough rainfall for crop production, yet only 10% of the arable land in the country is being irrigated (FAO, 2005). Although Gauteng and especially the metropolitan area of Johannesburg and the West Rand have more rainfall due to the location along the Watershed, most agricultural activities around the West Rand are related to grain, cattle and vegetables (FAO, 2005). A new agricultural hub, based on an irrigation system could improve the yield and allow a wider range of crops. When considering fruit and other orchard trees, the most convenient species for the West Rand are the deciduous plants, since they are more resistant to cold and need less water when they are dormant (TAYLOR and GUSH, 2007). Species in this category vary from pome fruits – apples and pears- to stone fruits – peaches, nectarines, prunes, etc-, berries, vines or nuts (TAYLOR and GUSH, 2007). Such orchards can make use of the natural precipitation, supplemented with irrigation to get to average requirements of 51600 l/ha during a hot summer day for a mix of fruit trees (calculations based on DAY,2002; BLACK et al., 2008; VOSSEN, n.d.).

To get an idea of the difference in water and land requirements for income generation of different crops, some calculations based on different sources have been combined to allow for comparison. Being aware of contextual and time-bound influences on both the products and their market value, these numbers are only used to estimate orders of magnitude, with the aim of making informed design decisions without any claims to be exact.

The production value of orchards appears to be extremely high as compared to cereal crops, with averages of about 150 000 R/ha for apples compared to 6000 R/ha for maize (SOUTH AFRICA. DEPARTMENT OF AGRICULTURE, FORESTRY AND FISHERIES, 2012). The yield of vegetable crops is somewhere in between, with about 45000 R/ha for tomatoes (MOKGONGOA AGRICULTURAL CONSULTING, 2008). Nevertheless these higher revenues also require higher costs for installation and maintenance. One hectare of apples costs about 192060 Rand (SIPHUGY, 2012), but can provide high value harvests at reduced costs for several



*Agricultural potential of the West Rand (adapted from Hao Feng)*

years. One hectare of tomatoes on the other hand costs about 15000 Rand (MOKGONGO AGRICULTURAL CONSULTING, 2008), but needs to be reinvested for every harvest. The water available for irrigation, if supplemented with an average amount of rain, could maintain a mix of fruit trees of 365 ha. Vegetables require smaller amounts water (FAO, 2013), so that irrigation could be used as a tool for optimization and to overcome long periods of drought. Given the combination of water and land availability, high value crops with moderate water needs seem the most appropriate for the West Rand. Vegetables are the most suitable product in this regard, supplemented with a mix of fruit trees. To reduce the vulnerability of farmers for unforeseen weather conditions, it is advisable to preserve some land for grazing as well, which also requires less water. Depending on actual rainfall and evaporation rates, a safe balance needs to be found between profitability and risk of water shortage.

To make a rough estimation about the amount of households this area could maintain, the previous numbers can be compared to the income distribution of Mogale city, which consists of Krugersdorp, Kagiso, Azaadville, Rietvallei and the rural settlements Tarlton, Magaliesburg and Hekpoort. From the 123 937 households (2011) living in Mogale city, more than 100.000 earn less than 3500 Rand a month (SOUTH AFRICA. THE DEVELOPMENT PARTNERSHIP, 2009). To

provide an income of 3500 Rand a month, about 0.5 ha is necessary (depending on the mix of vegetables, fruits and livestock). The cultivated area in the West Rand would therefore create a direct income for about 5000 households. Secondary jobs related to water supply, fertilisers, seeds, food processing, transport, merchandising, etc will be created as well. In combination with the extensive urban agriculture within the urban tissue, food insecurity in the West Rand can be reduced and entrepreneurship can be promoted. Although this boost of new economies will not solve all poverty issues of the area, it will result in a renewed identity and a change of mindset. New companies, but also new inhabitants might be attracted to move to the West Rand, given it's lower land values, opportunities for alternative economies, and close relation to the city.

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