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GAUTENG PROVINCE
AGRICULTURE AND RURAL DEVELOPMENT
REPUBLIC OF SOUTH AFRICA

Growing Gauteng Together

COLOPHON

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And: NM & Associates (Pty) Ltd, GreenVision Consulting

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AGRICULTURE AND RURAL DEVELOPMENT
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Gauteng Department of Agriculture and Rural Development

CLIENT CONTACT PERSONS:

Ndivhudza Nengovhela (Project Manager), Rina Taviv (Project Leader), Neggie Bakwunye, Dakalo Phaswa (further members Project Management Committee)

AUTHOR:

Stuart Dunsmore

Reviewed by Douglas Macfarlane and Marieke de Groen

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ACRONYM LIST

CBD	Central Business District
CoJ	City of Johannesburg
EIA	Environmental Impact Assessment
GDARD	Gauteng Department of Agriculture and Rural Development
PMC	Project Management Committee
SuDS	Sustainable Drainage Systems, previously used for Sustainable Urban Drainage Systems
TAHMO	Trans-African Hydro-Meteorological Observatory
ToR	Terms of Reference

1 INTRODUCTION

As part of the project Research on the Use of Sustainable (Urban) Drainage Systems (SuDS) of GDARD, the Terms of Reference identify this report as 'Data Collection on SuDS Installations in Gauteng'. The total list of deliverables is as follows:

1. Inception report and skills transfer plan (not public)
2. Literature review on SuDS: definitions, science, data and policy and legal context in South Africa
3. **Selection of three specific study areas** (this report)
4. Data collection on SuDS installations in Gauteng
5. Analysis of study areas with recommendations
6. Decision Support Tools
7. Best Management Practices
8. Implementation Manual

The Terms of Reference (ToR) identify the task of selecting three case study areas after an analysis of vulnerability hotspots. A site from each of the following locations is to be identified:

- A precinct in the Central Business District (CBD) of the City of Johannesburg that includes a high number of government buildings,
- A suburban area of the City of Ekurhuleni, and
- A township area in the West Rand Municipality.

The last two sites should include "some green areas and/or a stream or wetland". At the Kick-off meeting (28 September 2018), additional clarification was provided:

- The Consultant's team is not limited to strategic (in the sense of large spatial) interventions but also site interventions, although the execution and decision making on those is normally not in the hands of the Gauteng Province, other than indirectly via environmental impact assessment (EIA) approvals;
- The choice of the study areas should not necessarily be based on a vulnerability analysis as such, but can draw on the collective knowledge of the project team and PMC to identify sites with potential for actual project implementation;
- That each of the study sites may have different focus, such as; CBD area would have more of a heat island focus (less attention to drainage and water management), the Westrand township sufficient space for measures such as constructed wetlands, and the Ekurhuleni suburb may have more of an ecological focus.

As identified in the Inception Report, it is understood that the Province sees SuDS as a major climate change adaptation strategy that not only addresses stormwater management in a sustainable manner, but is also a strategic intervention for heat stress impacts and biodiversity enhancement within the city environment. However, planning and design of green systems to address heat stress and ecological enhancement is more about Green Infrastructure than SuDS.

2 PLANNING AND DESIGN FOR SUDS

2.1 Sustainable Stormwater Management

The application of SuDS is centred on the requirement to manage stormwater runoff quantity and quality from a site, or in a developed catchment. The intent is to try to mimic a natural hydrological response with emphasis on retention rather than attenuation (Figure 1). Best practical methods to achieve retention are through infiltration and re-use of stormwater, typically through a series of SuDS measures, collectively called a Treatment Train.

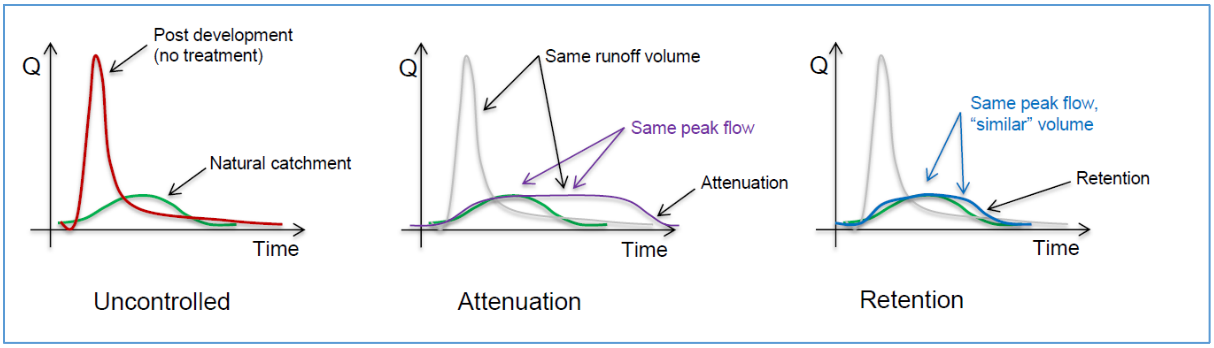

Figure 1: Demonstrating the principles of attenuation and retention (after Dunsmore, 2017).

Source Control	**Local Control**	**Regional control**
Green roofs†	Filter strips†	Detention (attenuation) ponds
Rainwater harvesting	Swales†	Retention Ponds†
Soakaways	Infiltration trenches	Constructed wetlands†
Permeable pavements	Bio-retention areas†	
	Sand filters	
† SuDS facilities that typically support vegetated and ecological systems		

Figure 2: Typical SuDS measures (from Armitage, et al, 2013)

For this study, it is important that the three study areas together include the possibility to cover a full range of typical SuDS measures.

2.2 SuDS Treatment Trains

A treatment train (e.g. Figure 3) is sequence of SuDS facilities that, together, seek to mimic a natural hydrological response to a storm event. Hence the hydrological performance of each component of the treatment train is an important part of the design. The kinds of facilities that can be employed in a SuDS treatment train have been set out by Armitage, et al (2017) as part of a Water Research

Commission study for SuDS in South African applications. Figure 2 presents a summary of the facilities and highlights those that typically support vegetated and ecological systems. SuDS is based on the principle that runoff control begins where the rain falls (source control) and continues at the same site/neighbourhood (local control) into the catchment area (regional control). The interventions make the flows mimic natural hydrological processes, but importantly, applying SuDS at different scales also reflects the difficulty in addressing runoff from paved urban areas; the volumes are so high that adequate retention is unlikely to be achieved by a single SuDS facility on its own. Hence the need for treatment trains. It also highlights why the application of individual attenuation facilities will, in most cases, not achieve the objectives of sustainable drainage, even though attenuation facilities will remain an important part of stormwater management.

Including treatment trains in the systems design, has an impact on the processes to be followed. This is indicated in the approach currently being adopted by the City of Johannesburg. If a developer presents a stormwater plan that includes each of the features in Figure 3, then the performance of each component, and the combined performance of the system as a whole, needs to be demonstrated. If the performance of any part of the treatment train is uncertain, that component is left out of the stormwater management plan.

This approach demonstrates benefit on a larger scale where treatment trains are integrated as part of a wider network. If the performances of individual treatment trains are assured (Figure 4), it reduces the performance requirements of the downstream systems, creating more opportunity for the creation and enhancement of co-benefits such as public amenity and ecological services.

For this study areas selection, not all three sites will need to include a treatment train, but at least one would do. This has not been a decisive criterion, as for all sites considered this is still possible to develop during the period of studying the areas.

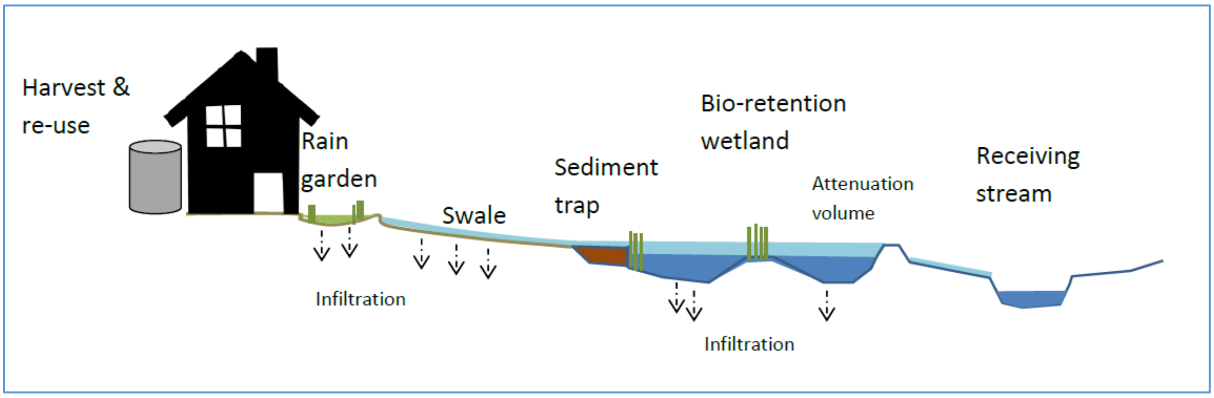

Figure 3: Example of a treatment train.

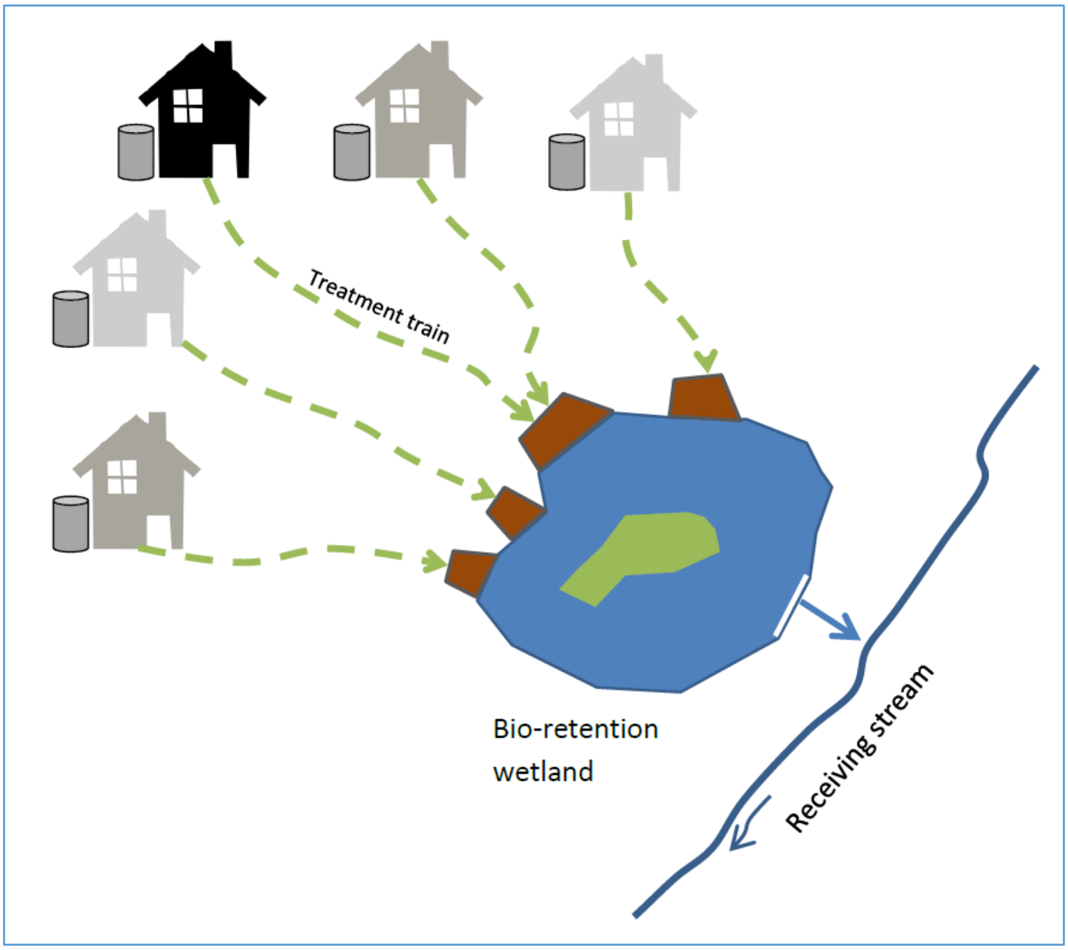

Figure 4: Integrating SuDS on a local and regional scale.

2.3 Designing SuDS for Ecological Enhancement

A SuDS design hierarchy has been proposed by Armitage, et al. (2013) and is presented in Figure 5. They state that "Simply put, there is no point focussing on biodiversity if life and property have not been protected". The City of Johannesburg has adopted the principle that if the water resource is protected, most of the co-benefits of sustainable drainage will follow. The City of Johannesburg promotes the management of stormwater from urban catchments as a resource (CoJ, 2018).

Hence, the approach to planning and designing sustainable drainage systems is meant to focus on the hydrological processes as a priority, and in many of the urban catchments in Gauteng this should be the case. Flash flooding and very poor water quality conditions, even if not a direct threat to communities and human safety, are generally such that opportunities for improving biodiversity conditions are severely constrained. Therefore, without improving the quantity and quality of stormwater, there may not be much that can be done about improving habitat, or even public amenity.

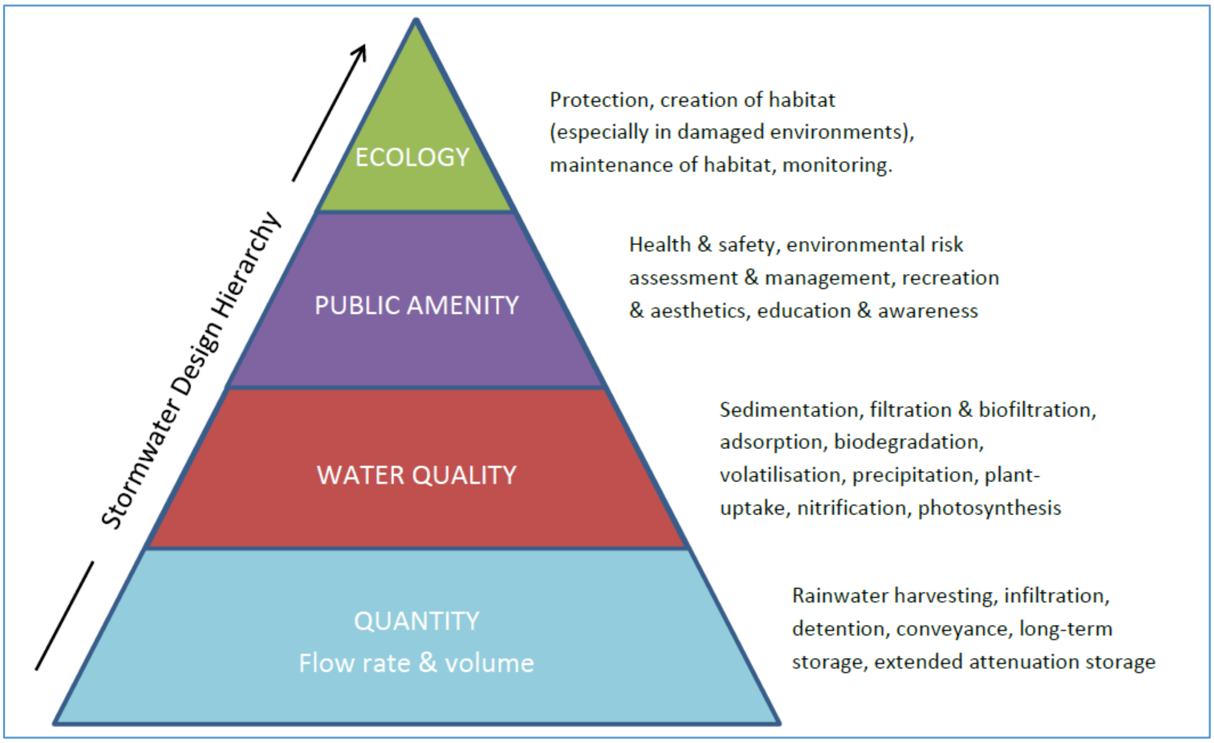

Figure 5: The SuDS Stormwater Design Hierarchy (after Armitage, et al., 2013)

However, this should not mean that healthy wetlands and river systems should not be included in SuDS planning. Nor should it exclude the planning of new or "recovered" biodiversity zones and public amenity areas. These areas would be integrated within the wider sustainable stormwater management system and ideally be protected by upstream SuDS treatment trains. Their design would give priority to ecological (or amenity) functions, and hydrological performance would then become a co-benefit. This would then imply that any hydrological performance of these biodiversity areas may not form part of the integrated stormwater network, especially if hydrological performance will vary with time as the ecological systems develop naturally.

Ideally the upstream, and any downstream, SuDS facilities should consider the nature of the ecological systems they are protecting and be designed accordingly. As much as possible, hydrological responses from the SuDS facilities may be tailored to suit the requirements of the biodiversity zone(s). Similarly, any habitat offered by the SuDS facilities could be aligned with the biodiversity zones.

This approach to planning and designing areas of important biodiversity within a catchment is more aligned with Green Infrastructure planning, where multiple services are supported by the same corridor.

For this study areas selection, ecological enhancement is probably least relevant in the CBD. As mentioned in the introduction, we consider the Ekurhuleni site to go to the level of ecological enhancement. It was discussed with the Client that the WestRand site would need to be a site with a natural wetland in it, although our project would focus on protecting that wetland with upstream measures. This was partly for the practical reason that a parallel GIZ project would be developing a project proposal for rehabilitation of a wetland and therefore it would be good to use the same site location. The joint effort of the two projects might make it more likely that a project idea would be executed in the end.

2.4 Retrofitting SuDS

The applications of new drainage methods such as SuDS typically start with new-build or re-build sites. This results in an incremental roll-out with greenfield sites in peri-urban areas being the primary beneficiaries in the short-term. However, Gauteng is located in the headwaters of a number of major catchments, and much of the urban development has already severely impacted on the river systems (Figure 6). Stabilisation and recovery of these rivers requires an extremely long-term vision if implementation of SuDS in established urban areas relies on re-development projects. A retro-fit programme of SuDS needs to be part of the roll-out of SuDS and Green Infrastructure. This may initially focus on “regional” facilities (e.g. regional attenuation or constructed wetland) at strategic locations within catchments.

Strategic interventions have not yet become mainstream practice in Gauteng, and therefore the sites selected for this study did not use this as a criterion. However, the strategic values of the selected sites in terms of retrofitting will be considered in their evaluation.

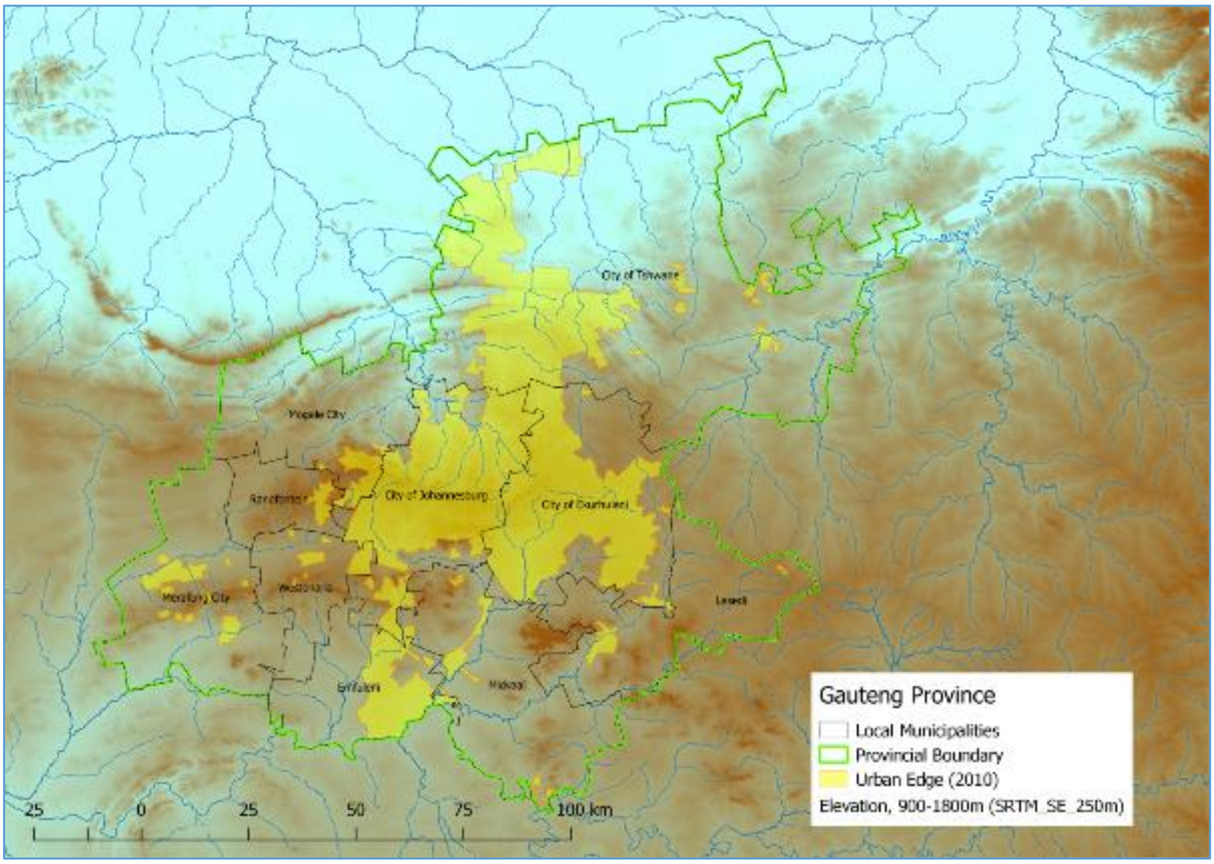

Figure 6: Gauteng topography and the urban edge (2010)

2.5 Designing SuDS for Heat Stress management

In this study, the requirement in the ToR to include a CBD study site was primarily based on the need for heat stress mitigation, and the thought that SuDS could play a role in this, with some SuDS measures having heat stress reduction as a co-benefit or heat stress measures having stormwater management benefits.

For the site selection within the CBD, we did not consider the potential for heat stress reduction as a decisive criterion to choose the site within the CBD, other than that government buildings can be more directly influenced through the outcomes of the study, and accessed for the purpose of the data collection.

3 STUDY AREAS IDENTIFICATION

Sustainable drainage applications are designed to fit the individual requirements of each site. There is not a “one size fits all”. Hence there are a wide range of potential study sites that fit the general requirements of the study objectives, and most would benefit the study. Hence it was agreed that to shorten the selection process, the project team would draw on their experience to identify suitable sites, typically in consultation with representatives from each of the municipalities.

The preliminary selection was narrowed to the six sites in Figure 7, and each is discussed in the sections below.

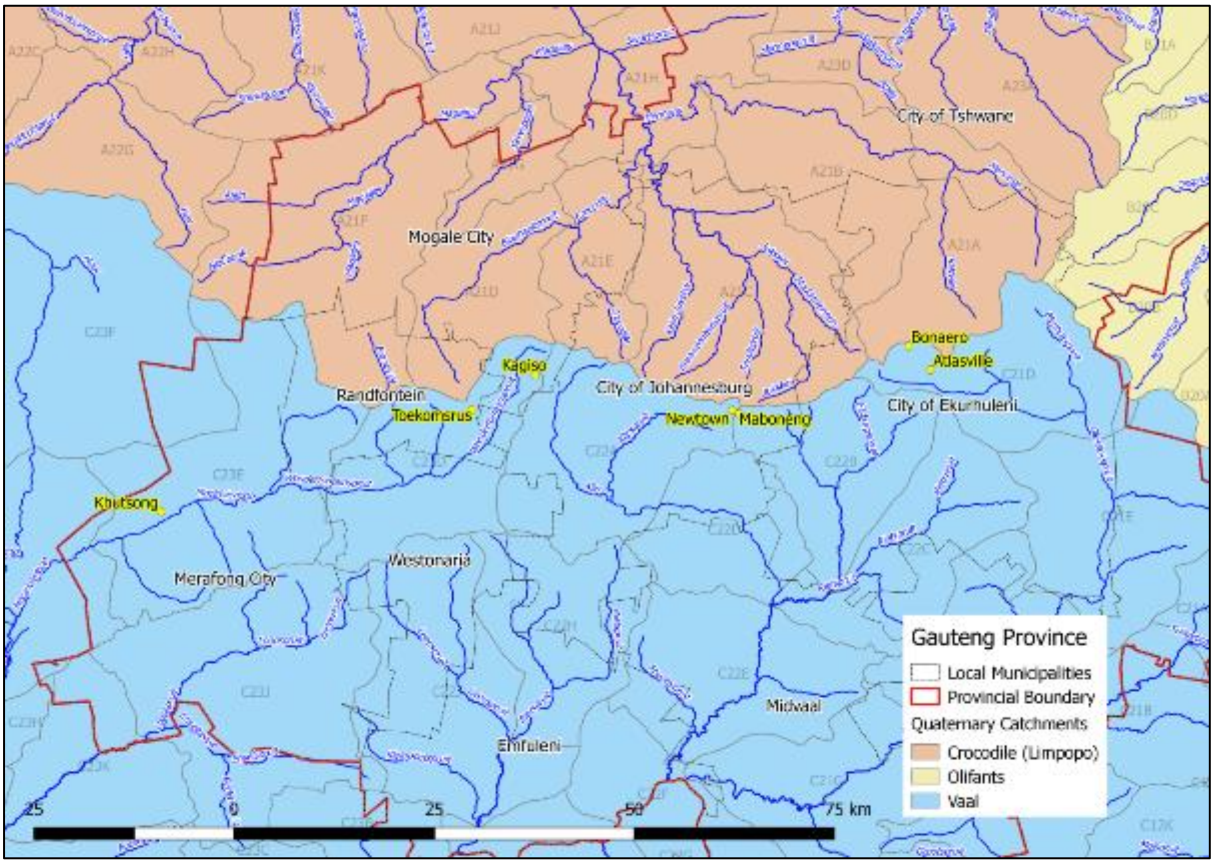

Figure 7: Short-listed SuDS study sites.

3.1 Central Business District area, City of Johannesburg

The Johannesburg CBD area straddles the Crocodile-Limpopo and Vaal-Orange primary catchment systems, though much of the CBD itself lies in the Vaal-Orange catchment. The main receiving local watercourses are the Natalspruit and Klipspruit, both tributaries of the Klip River. The river system is highly polluted due to a long history of gold mining (acidic conditions) and a rapid increase in inner city population that exceeds the original sewer network capacity. The Klip River system is one of the reasons for the very poor conditions in the Vaal River and the need to flush the river from time to time to relieve water quality threats to the Lower Vaal system. This is a significant water security matter.

Figure 8: Johannesburg CBD (*source: Google Earth*)

The Department's view is that the focus of the CBD investigations should be on inclusion of mitigating heat island effects through a greening of the city areas. This places less emphasis on SuDS and more on Green Infrastructure. Potential open space areas for this include:

- Roof space,
- Vertical wall space (vertical gardens), and
- Converting select roads for conversion to pedestrian mall routes and an associated greening plan.

If the assessment is to be based on SuDS, and therefore drainage design, then catchment boundaries will influence the selection of the study sites. The two primary sites are seen to be (Figure 9):

- The Maboneng District area, draining to the Natalspruit catchment (Quaternary C22B), and
- The Newtown-Selby area, draining to the Klipspruit catchment (Quaternary C22A).

Both catchments would benefit from an assessment of potential SuDS interventions. The Department has requested that the study area should include as many of the Gauteng Provincial Government (GPG) buildings as possible, with a view to developing implementable projects in the near future. Applying data supplied by the Department it is apparent that the Newtown area includes the larger portion of the GPG buildings (Figure 9).

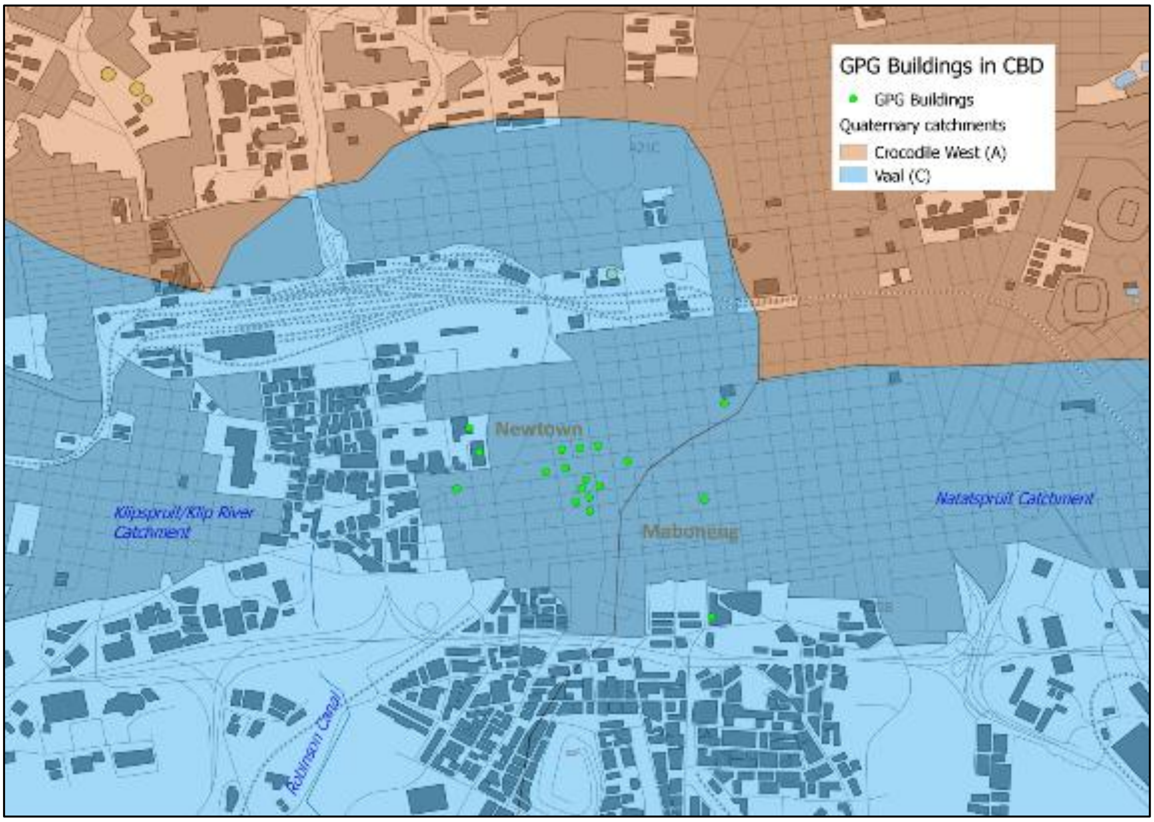

Figure 9: Location of GPG buildings in the Johannesburg City CBD.

The specific study area is shown in Figure 10 with the blue line, indicating a main area with GPG buildings, for which a rejuvenation is planned under the name Kopanong Precinct Project. The rectangular area is 40ha, bounded by Ntemi Piliso, Jeppe, Rissik and Main Streets. The red line is the quaternary catchment boundary. The exact boundaries of the study site will be refined on during the study itself, when the different specialists might have considerations that need to be taken into account in this regard, but will remain in the quaternary catchment boundary.

Figure 9: Proposed CBD study area, hosting the largest collection of GPG buildings (blue line study area, red line catchment boundary).

The TAHMO automatic weather station data, operational in Braamfontein (Juta Street) since July 2017 with 5 minute-data and run by AquaLinks, can support the study in this area.

At the scale of the quaternary catchment area, more is known at this stage than at the specific study area scale. The quaternary catchment area surrounding the study area is quite varied in terms of open spaces and trees, with some recent changes in road construction, and trees having been planted. Therefore, the local heat stress will probably vary within the study area. The quaternary catchment area also has mixed use developments realised and coming up, which adds the aspect of indoor heat stress as an interesting topic in this area. Additionally, some buildings are known to pump groundwater into the stormwater system, to keep the basements dry (e.g. JRA at workshop 5 February 2019).

The quality of life survey of GCRO (GCRO, 2016) indicates that at ward level (larger than the study area) the quality of life index is 5.87-6.33 which is the middle category. According to the Vulnerability Map of GCRO, the CBD is a mix of people who have an 'average' vulnerability (3.0-3.9) and spots with the 5% most vulnerable people (Culwick et al., 2019). According to persons in the project workshop on 5 February, who knowing the area, the study area has many vulnerable residents including vagrants. Some of them are so desperate that sewage systems are blocked to source valuables, which causes resulting water quality problems in the stormwater system (Workshop 5 February 2019).

3.2 Suburban area, City of Ekurhuleni

The suburban study site in the City of Ekurhuleni was identified at an early stage, during the inception meeting. After a site visit, consultation with the City of Ekurhuleni, and GDARD, it was decided that it provided suitable conditions to be included in the study as the selected site.

3.2.1 Bonaero-Atlasville

This site is identified based on knowledge of some of the problems in the catchment and the location of natural wetlands and pans that provide both important habitat and stormwater quantity and quality control.

The wider catchment is approximately 25km^2 (Figure 11) in Quaternary catchment C21D and includes a variety of land uses from residential and housing estates, industrial (Atlas Industries and Denel), and the OR Tambo International Airport. Much of the area east of the airport began to develop in the late 1970's, early 1980's with the growth of Atlas Industries. Farmland was converted to suburban residential, including the area of Atlasville, part of which was built on a wetland.

In 2006 the first of many flood events hit the residents of Atlasville. Analysis of the catchment and hydraulic analysis of the Atlaspruit showed a combination of rapid catchment development combined with a deterioration of the river channel flood capacity to be part of the cause. This resulted in a flood relief scheme downstream of the selected study area, designed along Green Infrastructure principles that has since alleviated the flooding problem.

Figure 11: Bonaero Park-Atlasville. *(source: Google Earth)*

However, earlier studies (Fourth Element, 2011) highlighted the hydrological significance of the combined wetland and pan system upstream of Atlasville. In addition, these were seen to be ecologically sensitive. Yet these sites do not seem to be protected for their hydrological or ecological value, and development draining onto the wetland and pan system continues to threaten their sustainability and function. In extreme cases this includes large volume fuel spillages in the operational areas of OR Tambo International Airport that severely contaminate Blaauwpan.

The proposed site includes the three pans and adjacent wetland in the upper areas of the catchment (Figure 12), a total area of approximately 250 ha. The pans are natural systems and have different development pressures on them and provide key attenuation and treatment functions. The wetland is another natural system that has become part of the treatment train. The site is offered as a potentially good case study looking at development pressures on relatively healthy ecological and hydrological systems (NSS, 2010), and the need to secure and stabilise the key features (wetland and pans) of the catchment for the future.

An existing stormwater model (PCSWMM) is available for this study (Fourth Element, 2011).

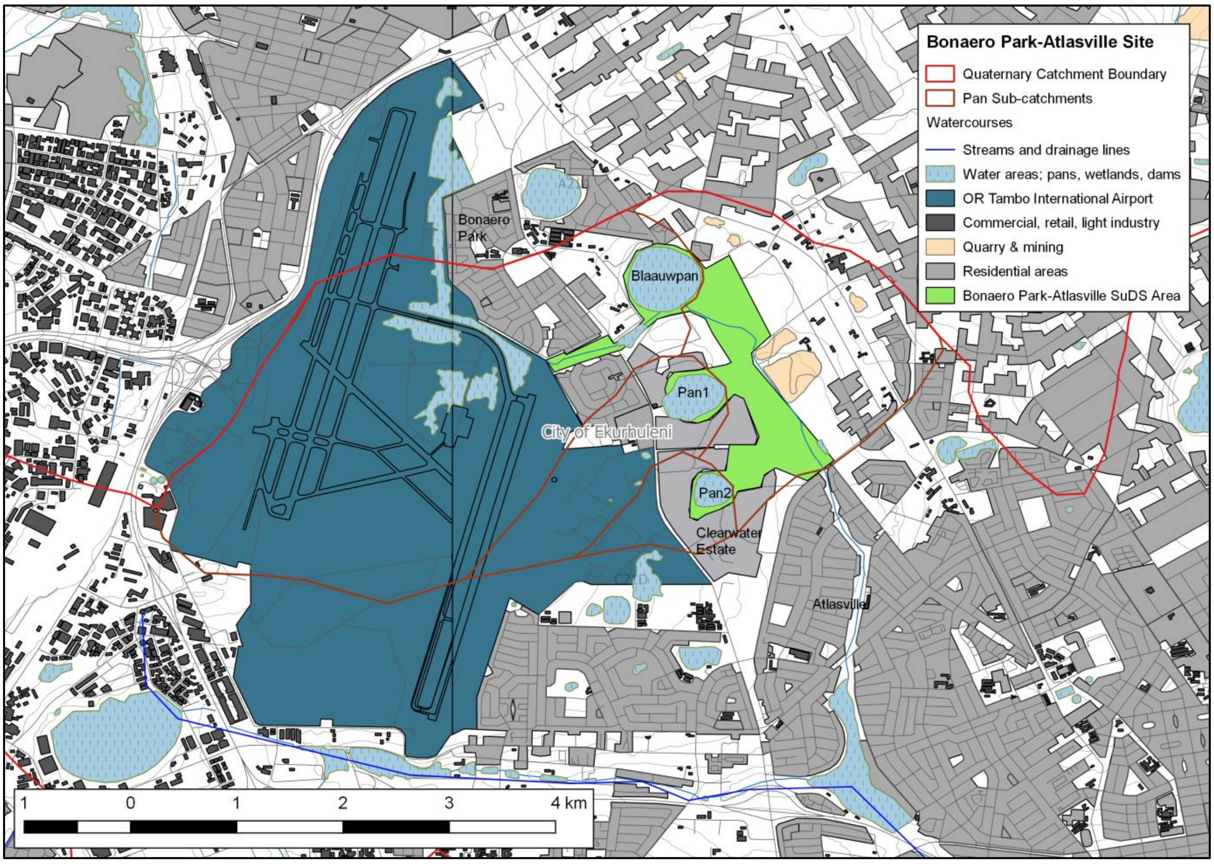

Figure 12: Proposed SuDS study site in the Bonaero Park-Atlasville area, City of Ekurhuleni.

3.3 Township environment, West Rand District Municipality

Early screening led to the identification of three possible sites:

- Kagiso in Mogale City Municipality,
- Toekomsrus in Randfontein Municipality, and
- Khutsong in Merafong City Municipality.

The Consultant's team together with GDARD visited the Khutsong site on 27 November 2018 which originally appeared to have preference based on readily available information. When this site did not seem to cover all criteria in the field, the Kagiso area was selected as an alternative option. After a site visit to Kagiso with the GDARD team and the municipal environmental specialist, Mr Stephan du Toit on 3 December 2019, Kagiso was confirmed to be suitable.

The selected study site for the township environment in West Rand is therefore a site in Kagiso, see description below. The other two sites are described briefly to capture the original arguments discussed around these sites.

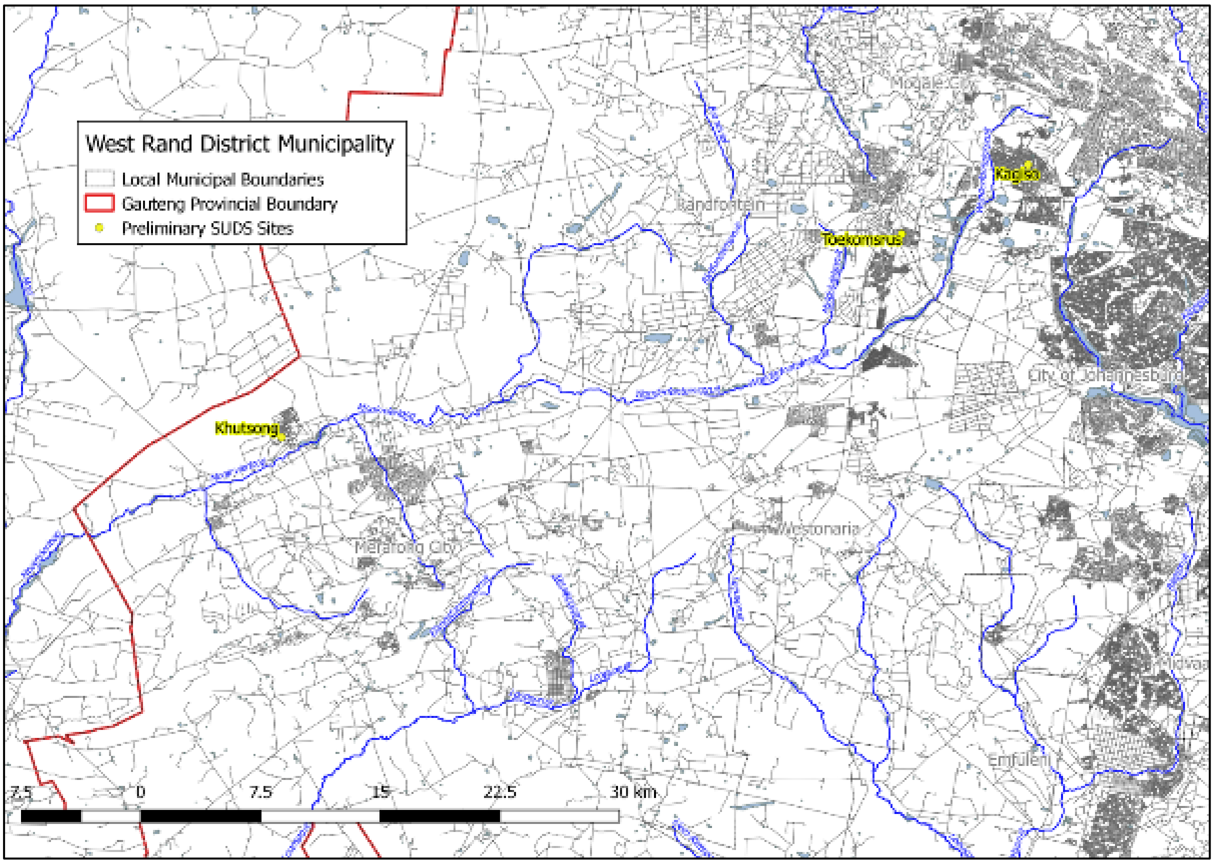

Figure 13: Location of preliminary West Rand SuDS Sites.

3.3.1 Kagiso Area

The initial selection of Kagiso was based on its location in the upper areas of the Wonderfonteinspruit catchment. The Wonderfonteinspruit is highly impacted by mining and industrial development, as well as urban residential development (both formal and informal). AMD with associated low pH, high salt loads and other toxic and potentially radioactive pollutants, other mining diffuse sources as well as sewage are a problem in the system. So the potential for a regional SuDS facility is considered to be very good. Recent research work proposed a constructed wetland system for treating AMD and salt loading (Opperman, 2008). However, concerns were raised about potential misalignment with the objectives of the Department of Mineral Resources (DMR) that may overshadow the aims of the SuDS evaluation, and this option was discarded in the preliminary selection of the sites to visit.

However, after the first site visit which found that Khutsong site was not suitable, attention turned to stormwater drainage from the upstream section of Kagiso developed area, and the site shown in Figures 14 and 15 was identified. It has an existing stormwater drain in an open area between two main roads. The lower portions of the area exhibit wetland features, and the upper areas are a combination of wetland and open drain with some informal agriculture and a waste recycling facility. At least three road crossings provide opportunity for retention (attenuation), though no high water marks were observed that would have indicated the road culverts already promote some degree of attenuation. The footprint of the site is just under 50 ha, but not all of this will be available for stormwater management. The catchment area is approximately 500 ha of dense, serviced, residential development (stand sizes typically between 200 m^2 to 300 m^2). The catchment area is already recently developed, therefore retro-fitting does not seem a feasible option, but for the sake of the study the study team might reflect on missed opportunities when visiting the site. It seems that some residential development already encroached into the floodplain and this may need to be considered.

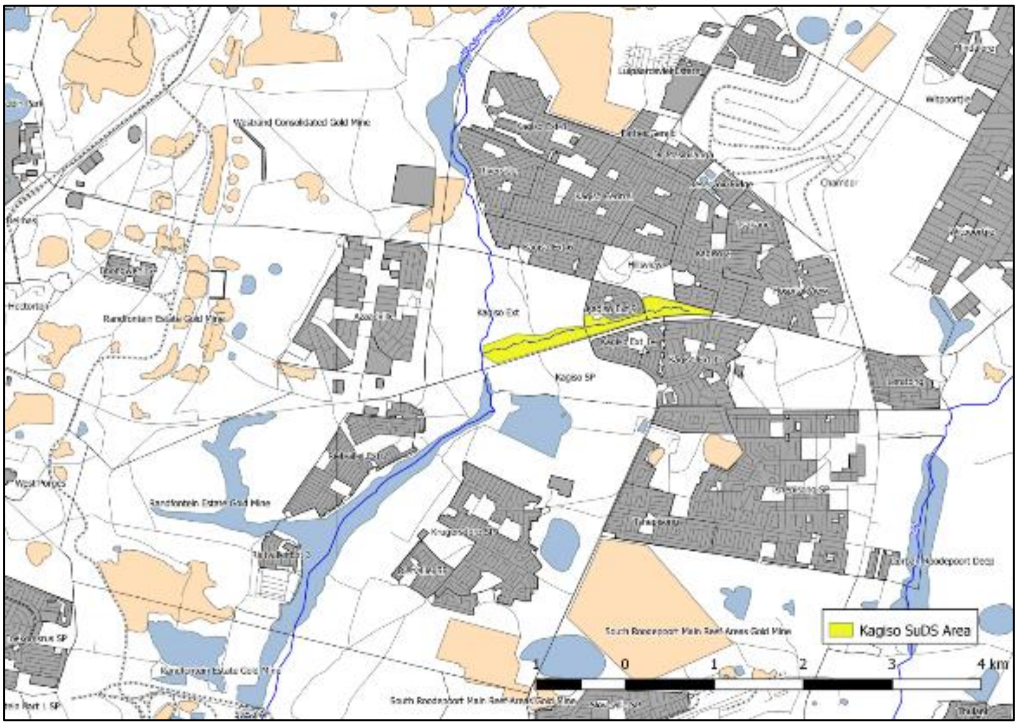

Figure 14: Proposed Kagiso SuDS study site.

Figure 15: Aerial view of the proposed Kagiso SuDS study site. *(Source: Google Earth)*

Consultation with the municipal environmental specialist, Mr Stephan du Toit, indicated the importance of controlled, clean stormwater discharges into the Wonderfonteinspruit. These provide both dilution of the polluted river flow, as well as assist in managing flood conditions in the river system. The latter is particularly sensitive due to flow control requirements in the downstream sections of the Wonderfonteinspruit for water quality management.

This site presents a diversity of issues that a SuDS system will need to consider. Standard stormwater management functions will need to be adapted to address critical downstream flood and quality conditions. On the site there is potential for ecological and public amenity enhancement, support for socio-economic initiatives, reuse and food security (irrigation) in addition to the attenuation and treatment functions. Some food gardens on the site have already been noted, but detailed analysis will be required to see how many of these initiatives are feasible and can be implemented in a cost beneficial manner.

3.3.2 Khutsong Area

Khutsong is a residential area on the north bank of the Mooirivierloop in Merafong City Municipality. The Wonderfonteinspruit is a tributary of the Mooirivierloop. Khutsong is bounded on three sides by the Abe Bailey Provincial Nature Reserve which may imply that urban expansion will be limited. The aerial imagery since 2004 also suggests that current expansion is very slow, if there is any at all. The environmental experts from the Merafong municipality Mr. Itani Mashamba and Itani Mavhutha accompanying the GDARD officials to the site explained that urban expansion or intensification is also not allowed because of the sinkhole risk in this area.

Although there is a formal township layout (i.e. a formal road and stand layout), parts of the area look to be low cost development (possibly temporary or informal dwellings) and it is not clear whether these areas are provided with stormwater and sanitation. On the lower slopes (southern areas) the stands appear to be more formally laid out (and fenced), perhaps suggesting there is formal sanitation and stormwater drainage.

Figure 16: Preliminary identification of potential SuDS sites at Khutsong. *(Source: Google Earth)*

Six initial SuDS sites were identified (Figure 16) in this study area. These include surface drains and parts of the former sewage treatment system along the right (northern) bank of the Mooirivierloop. During an inspection of the site, it was evident that most of the surface drains were lined (concrete) and stable, although the flows were highly polluted with sewage. The site visit was undertaken in dry weather conditions, after limited rain if at all, and the flow in the drains indicated the sewer services were faulty, and sewage was entering the stormwater systems, perhaps mixed with some shallow groundwater ingress.

The conclusion drawn on site was that the failure of the sewer system is a high priority, but that the stormwater facilities were at stable and that stormwater management was not a particular problem on its own. The ecological benefits of converting the concrete drains to be more habitat friendly is unlikely to be cost-beneficial at this stage and could also create additional problems if not properly maintained. If the source(s) of the sewer failure is not easily resolved, then a constructed wetland facility could be established to reduce the pollution load entering the river, but this would need a separate investigation to justify this.

3.3.3 Toekomsrus Area

The Toekomsrus area was originally considered, and then discarded, for the same reasons as the Kagiso site; that a strategic facility (on the Wonderfonteinspruit) would offer the greater benefit but that will have to be aligned with Department of Mineral Resources objectives. Toekomsrus discharges into the Cooke Attenuation Dam which is part of the water treatment system on the Wonderfonteinspruit to address pollution from mining operations. Attention was also given to potential sites within the local urban drainage network, and some provisional sites were identified (Figure 17). At least two of the sites offer interesting potential; the drainage line along the southern boundary of the development, and drainage to the natural pan on the south-western edge of Toekomsrus.

Figure 17: Toekomsrus area on the west bank of the Wonderfonteinspruit. *(Source: Google Earth)*

Toekomsrus was not assessed much further after the proposed site at Kagiso was investigated in more detail and was seen to offer a greater diversity of issues and was seen to fit the requirements of the terms of reference very well.

4 SUMMARY

The approach to site selection was carried out at a relatively high level as it was concluded early on that:

- Few sites will be the same in terms of SuDS design, and
- Lessons would be learnt from most of the sites that may be identified in a study of this nature.

Hence, as long as the basic requirements are met and that there is sufficient diversity of issues that would be experienced more widely in Gauteng, then the identified site was adopted for the study. Therefore, the recommended sites are:

Location	Recommended site	Motivation
Johannesburg CBD	Newtown area	• Central CBD location • High number of GPG buildings • Drains to the highly disturbed Klipspruit and Klip River systems. • A key retrofit site. • Both stormwater and heat island assessment.
City of Ekurhuleni residential suburb	Pan system and wetland at Bonaero Park/ Atlasville.	• Incorporation of natural features with some healthy habitat. • Important flood and water quality treatment functions. • Stormwater assessment, and existing hydrological model available. • Minimum retrofit requirements expected, but strong management and monitoring needed.
West Rand District Municipality township.	Kagiso township, southern drainage line.	• Wide diversity of urban issues in addition to stormwater management; ecological, social, socio-economic. • Water security support (supporting water treatment and flood management in Wonderfonteinspruit). • Retrofit requirements, but large land area available.

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